PHASE I
DIAGNOSTIC FEASIBILITY STUDY
FINAL REPORT

LAKE MITCHELL / FIRESTEEL CREEK
DAVISON COUNTY SOUTH DAKOTA

SOUTH DAKOTA WATERSHED PROTECTION PROGRAM
DIVISION OF FINANCIAL AND TECHNICAL ASSISTANCE
SOUTH DAKOTA DEPARTMENT OF
ENVIRONMENT AND NATURAL RESOURCES
NETTIE H. MYERS, SECRETARY

March 1997

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South Dakota Watershed Protection Program
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Nettie H. Myers, Secretary

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South Dakota Department of Environment and Natural Resources

March 1997

EXECUTIVE SUMMARY

Introduction

Lake Mitchell is a man-made reservoir created to serve as a drinking water supply and recreation center for the City of Mitchell and the surrounding south central area of South Dakota. Mitchell currently has a population of approximately 14,000. Lake Mitchell is utilized as the primary drinking water supply for the city, as well as for boating, fishing, and other water contact recreation. The surface area of the lake is 671 acres and the contributing watershed area is 350,960 acres. Firesteel Creek drains the major subwatersheds and flows into the west end of the lake.

During recent years, city officials, lake property owners and recreational users of the lake have expressed concern about the declining water quality of the lake. The primary concerns are the taste and odor problems and excessive algae blooms.

The Firesteel Creek/Lake Mitchell study, which began in 1993, was scheduled to be a two year study. However, due to lack of flow in the tributaries and limited number of samples collected, the project was extended into 1995. The study consisted of inlake and tributary water quality monitoring to determine the causes of the algae blooms and the taste and odor problems. The sampling was also designed to characterize the effects of the watershed inputs on the inlake water quality. In 1995, the Agricultural Nonpoint Source (AGNPS) modeling was initiated to further identify and target problem areas in the watershed. Required agricultural information was incorporated into the computer model. The primary objectives of utilizing a computer model on the Lake Mitchell watershed were to:

1.) Evaluate and quantify Nonpoint Source (NPS) yields from each subwatershed and determine the net loading to Lake Mitchell;
2.) Define critical NPS cells within each subwatershed (elevated sediment, nitrogen, phosphorus).
3.) Prioritize and rank each concentrated feeding area and quantify the nutrient loading from each feeding area.

Results

The results of the water quality samples and the computer model were analyzed and following conclusions were formulated:

1. Watershed Analysis - The overall sediment loading to Lake Mitchell appears to be low. The AGNPS model predicted an annual load of 39,370 tons of sediment to Lake Mitchell. This sediment load would reduce the depth of Lake Mitchell 1 foot every 61 years. Analysis of the 1993 water quality data estimated even less suspended solids entering the lake per year (14,053 tons). When a detailed subwatershed analysis was performed by AGNPS, 7 of the 40 subwatersheds analyzed appeared to have above average sediment deliverability rates. The seven subwatersheds with elevated sediment yields were found to contain 34.3% of the

critical erosion cells and occupy 8.3% of the watershed area. The suspected source of elevated sedimentation is from agricultural croplands that have land slopes of 5% and greater. Water quality samples collected found elevated suspended sediment loads in the same locations as the AGNPS model.

The total nutrient loadings to Lake Mitchell are high. The model estimated the annual loadings to Lake Mitchell at 166 tons of nitrogen and 63.3 tons of phosphorus. Water quality monitoring in 1993 estimated annual loadings of 197 tons of nitrogen and 67.1 tons of phosphorus. It was not possible to pinpoint the sources of the nutrients with the water quality monitoring since the sites were so widely spread throughout the watershed. With the low sedimentation rate to Lake Mitchell, the most likely source of the high nutrients is from animal feeding operations within the watershed. Water quality samples did contain large concentrations of fecal coliform in many of the samples; again pointing to animal waste as a probable source.

2. Inlake - The concentrations of total phosphorus were more than 10 times the amount needed for algae blooms to occur. Secchi disk readings and chlorophyll *a* samples did not always correlate well with the high nutrient concentrations. It appeared that algal growth was hindered by lack of light or possibly the short residence time of phosphorus. The wet period during 1993 reduced the hydrologic residence time to 22 days. According to modeling results from a model developed by Vollenweider and Kerekes, the phosphorus residence time was only 11 days. The short residence time of the phosphorus may not have given the algae time to assimilate the phosphorus. During 1993, the lake actually had a flushing of phosphorus. More phosphorus left the system than entered it. This was probably due to the large amount of relatively low phosphorus groundwater entering the system. Large alluvium and outwash areas are located along Firesteel Creek and the north edge of the lake. The extra phosphorus that left the lake was probably from internal loading (phosphorus released from the sediments).

The phosphorus reduction equation found that a 50% reduction of phosphorus inputs to the lake would reduce the chlorophyll *a* concentrations to the mesotrophic level. The reduction of phosphorus would reduce the intensity and duration of algal blooms and increase water clarity.

3. AGNPS Critical Cells - Lake Mitchell's watershed has 8,774 individual 40 acre cells. The sediment yield analysis revealed 270 (3.1%) had sediment erosion rates greater than 4.0 tons/ acre $_{\text{25 year event}}$. The suspected primary source of elevated sedimentation within the critical cells is from croplands that have land slopes of 5% or overgrazed rangelands that have slopes 8 % or greater.

Results of the AGNPS model indicated 173 (2.0%) of the individual cells had nitrogen yields greater than 2.5 ppm $_{\text{25 year event}}$. The model also indicated 297 (3.4%) of the individual cells had phosphorus yields greater than .40 ppm $_{\text{25 year event}}$. The suspected sources of the elevated nutrients are from animal feeding areas located throughout the watershed.

4. Feeding Area Evaluation - An animal feeding area analysis indicated that animal feeding operations appear to be contributing excessive nutrients. A total of 241 animal feeding areas were evaluated. Of these, 116 animal feeding areas were identified as contributing excessive nutrients to the watershed (AGNPS ranking > 30). Thirty-seven (37) animal feeding areas had an AGNPS ranking greater than 50. A theoretical computer simulation was completed to evaluate the nutrient reductions if feeding areas, with high AGNPS ratings, were eliminated. This analysis found that if the animal feeding areas with an AGNPS non-corrected rating over 50 were eliminated (37 sites), the soluble phosphorus concentrations to Lake Mitchell would be reduced by approximately 37%. This analysis also indicated that if the animal feeding areas with an AGNPS non-corrected ratings between 30-50 were eliminated (an additional 79 sites), the soluble phosphorus concentrations in Lake Mitchell would be reduced by an additional 14%. These two recommendations total a 51% reduction in phosphorus loads to the lake. The phosphorus reduction model predicted a 50% reduction would lower chlorophyll *a* concentrations to mesotrophic level as discussed earlier.

Recommendations

1. - It is recommended that the implementation of appropriate Best Management Practices be targeted to the critical cells and priority animal feeding areas. Feeding areas with an AGNPS non-corrected rating above 30 should be evaluated for an animal waste collection system to minimize future nutrient releases. It is also recommended that all critical cells and feeding areas be field verified prior to the installation of any Best Management Practices. Since the model does not accurately predict the effects of summer long grazing, resource managers should address these concerns on a case by case basis. Improved grazing and riparian management will decrease bank erosion, increase sediment trapping efficiency, and reduce phosphorus in the streams.

2. - The three storm sewers entering the lake should be rerouted to a settling basin away from the lake. The storm sewers present a significant source of nutrient and sediment input, considering the size of the drainage (8% of the nitrogen and 4% of the phosphorus and 8% of the sediment load). Removing the storm sewers would also remove the potential of an urban area spill from entering the lake.

These are the main recommendations from the study. From the data presented, these methods would provide the most long term benefit for the resources invested. Other alternatives are given in the "Restoration Alternatives" section of this report.

ACKNOWLEDGMENTS

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

City of Mitchell
City of Mitchell Public Works Department
City of Mitchell Engineering Department
City of Mitchell Wastewater Plant
Davison County Conservation District and NRCS office
Aurora County Conservation District and NRCS Office
Jerauld County Conservation District and NRCS Office
ENVIROMED, Leonard “Pat” Kuck
SD DENR - Water Rights
SD DENR - Geological Survey
SD DENR Watershed Protection
US Geological Survey

TABLE OF CONTENTS

Page #

LIST OF TABLES

LIST OF FIGURES

Page #

LAKE MITCHELL WATER QUALITY REPORT

INTRODUCTION

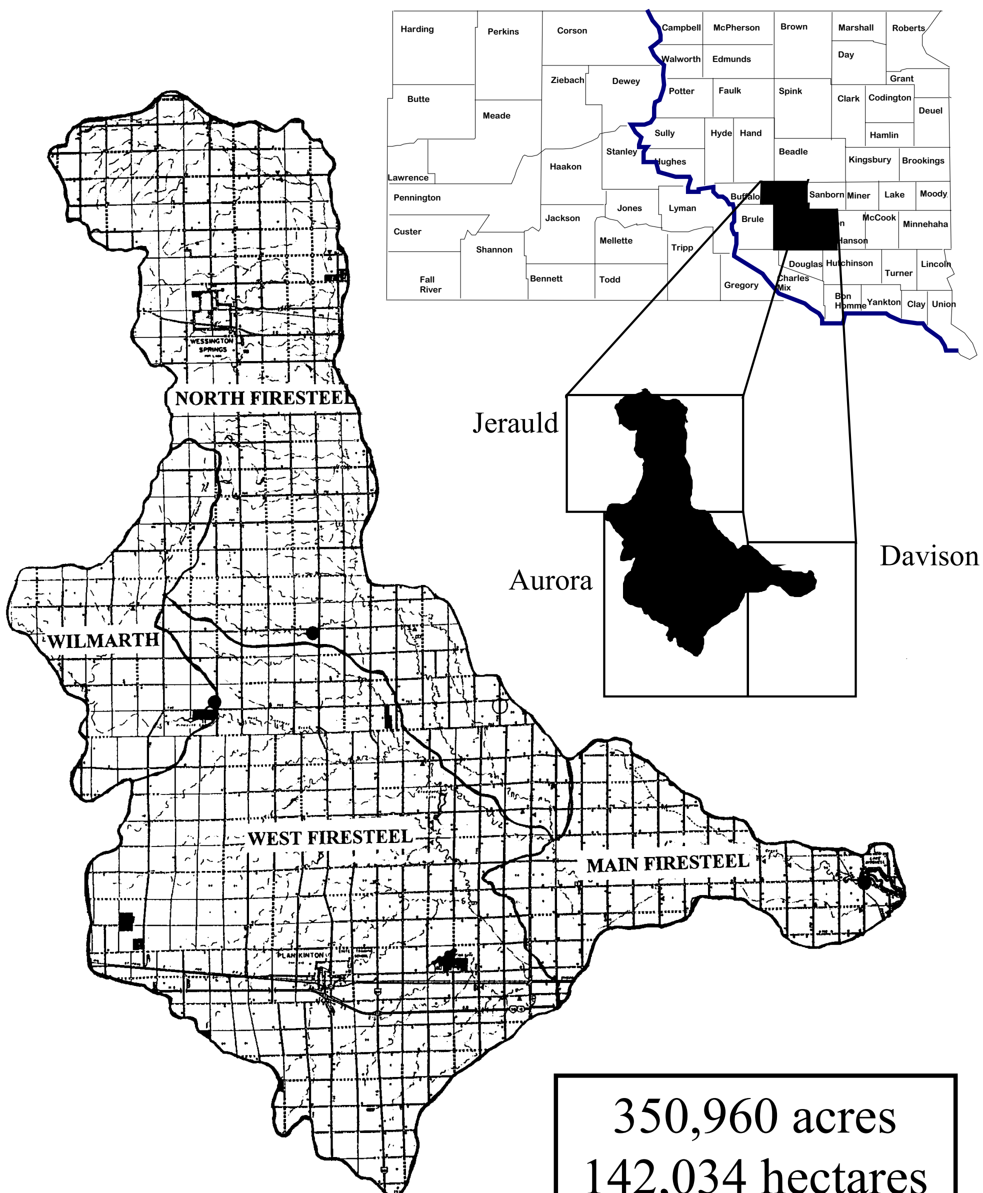
Lake Mitchell, located in south central South Dakota (Figure 1), is a drinking water supply for the city of Mitchell. Periodically Mitchell's drinking water supply experiences taste and odor problems. The city contacted the State of South Dakota for assistance in conducting a study of Lake Mitchell and Firesteel Creek. The purpose of the study was to find the causes of the drinking water taste and odor and the excessive algal blooms. The study would also present alternatives to correct the problem. The city of Mitchell sponsored and funded the study with technical assistance and equipment provided by; 1) State of South Dakota Watershed Protection Program, 2) the Natural Resources Conservation Service (NRCS), and 3) the conservation districts of Davison, Aurora and Jerauld counties. The main components of the assessment consisted of inlake water quality monitoring, algae sampling, tributary monitoring, storm sewer monitoring, and land use assessment. In April, 1995, it was determined that an Agricultural Nonpoint Source (AGNPS) model would be beneficial to the study and was completed along with the other components.

The study was initiated in the spring of 1993, and proceeded until the AGNPS data was collected in the spring of 1996. After the 1993 sampling season, the water quality data showed high nutrient loads and concentrations throughout the watershed. Since it was not cost effective to increase the water quality sampling to cover the entire watershed, it was decided to run the AGNPS model. AGNPS, although a cumbersome model to use on such a large watershed, is the best watershed nutrient and sediment model available. The model helps locate problem or critical sediment and nutrient areas in a watershed. The data collected for the model generates estimates of sediment and nutrients lost from each cell and predicts sediment and nutrient loadings. In this study AGNPS was, and should be used only as a planning tool to compare one 40 acre cell or subwatershed to another.

In July, 1995, the Davison County Conservation District secured a Federal 604b grant. The grant was used to assist in the AGNPS data collection for most of the Firesteel Creek watershed. The city of Mitchell collected the data from the Lake Wilmarth watershed. Additional assistance from a private consultant was used to collect the information needed for the concentrated animal feeding areas in the spring of 1996. The county conservation district offices and the NRCS personnel were important resources throughout the data collection process.

Figure 1.

Firesteel Creek Watershed



BACKGROUND/HISTORY

In 1927, a $350,000 bond issue was approved to begin construction of an artificial lake that would provide a recreation center and a dependable source of water to the city of Mitchell. Land was acquired northwest of Mitchell and horse drawn scrapers began deepening a basin in the Firesteel Creek floodplain. The Lake Mitchell dam was completed in 1928, and by March of 1929, water was going over the spillway (Karolevitz, 1993). Early records state that the lake had depths of up to 40 feet. Waters from Firesteel Creek and Lake Mitchell still serve as regional recreation areas and as the sole source of water for the city of Mitchell. At this time the city has opted out of the Lewis and Clark rural water system and plans to devote resources to the restoration and improvement of Lake Mitchell.

The city has already made many improvements to Lake Mitchell.

Spillway repair	1943	$ 176,402	
Spillway repair	1963	85,660	
Spillway repair	1988	38,329	
Sewer and water around the lake	1974	431,775	
Land, pump station and water line to the James River low water years	1978	744,400	
South Harmon Drive paved	1989	Continuous maintenance	
North Harmon Drive paved	1990	Continuous maintenance	
Earthen dam replacement	1993	240,629	
Shoreline stabilization	1983-1993	848,403	
Dredging project (550,000 yards^3)	1986-1988	443,475	
Additional sewer lines to new development	Up coming	600,000	(approximately)
Rerouting three storm sewers	Up coming	2,000,000	(approximately)

Along with its esthetic beauty, these improvements have made Lake Mitchell an excellent place to live. The lake is well developed with approximately 175 permanent and 20 summer homes in the vicinity. One hundred twenty-six lots are located directly along the shoreline. The average lot value is $114,668, making the total assessed value of the 126 lots' $14,448,168. These lot owners paid a total of $463,680 in local property taxes in 1996.

The Lake Mitchell Development Committee was formed in 1979. It has 19 members and reports directly to the mayor. A lake association was formed in 1993 and to date has 138 members. The shores of Lake Mitchell are also bordered by a municipal golf course, cemetery, and the Mitchell Prehistoric Village, (a National Archaeological Landmark).

FISHERY

Lake Mitchell is a permanent warmwater fishery. The lake has always been know for fine catches of gamefish. The species most sought after are walleye, largemouth bass, northern pike, crappie and bluegill. The Department of Game Fish and Parks (GF&P) completed a comprehensive survey of Lake Mitchell's fishery in the summer of 1996. The complete survey can be found in Appendix C.

In 1996, GF&P collected fish from Lake Mitchell on three separate occasions. For each sample date (June 18, July 15-17, and August 29) different sampling techniques were used to catch fish in different habitats. Samples showed walleyes growing slower than the South Dakota average and little, if any, natural reproduction. Good numbers of largemouth bass were collected by electrofishing in the spring. The samples collected showed excellent size distribution and also good indications of natural reproduction. A large number of black crappies were found in frame nets in 1996. This may be a result of the 12,438 adults stocked in 1995. Bluegill populations were also up in 1996 with most fish ranging in the 13 - 23 cm length (5.1 - 9 inches). The samples also showed indications of natural reproduction.

Other species collected during the survey included northern pike, shorthead redhorse, black bullhead, freshwater drum, carp, white crappie, white sucker, channel catfish, yellow perch, smallmouth bass and saugeye. Data on these species can be found in Appendix C.

Recommendations for the Lake Mitchell fishery were to stock walleye fingerlings in 1997. It appears that natural reproduction is unable to produce sufficient fish to maintain catchable numbers of walleyes in the lake and every other year stocking will be necessary. Also GF&P would like to continue to work with the city of Mitchell and the local sportsman's group to develop a habitat improvement plan for the lake. A tree and snag removal project in 1992 removed many of the small fish habitats.

LAKE SHORE SEPTIC SYSTEMS

The city of Mitchell has provided documentation that all of the homes on the lake are currently on a centralized sewage system. A new development, on the north east corner of the lake, has septic tank set backs of 500 feet for lots less than an acre and 350 feet for lots larger than an acre. The city is planning to run sewer lines to the new development at a later date.

TRIBUTARY MONITORING DISCUSSION

METHODS AND MATERIALS

Hydrologic Data

Eight tributary locations were chosen for collecting hydrologic and nutrient information from Firesteel Creek, Lake Mitchell's watershed. Due to the large size of the Firesteel Creek watershed, tributary site locations were chosen which would best show DENR which sub-watersheds were contributing the largest nutrient and sediment loads. A Steven's Type F paper graph recorder was placed at each of the tributaries sampling locations to record the water height. The recorders were checked weekly when the graph paper needed to be changed. After the chart was changed, the daily average stages were calculated to the nearest 1/100th of a foot. A Marsh-McBirney flow meter was used to take periodic flow measurements at different stage heights. The stage and the flow measurements were used to develop a stage/discharge table for each site. The stage/discharge table was used to calculate an average daily loading for each site. The loadings for each day were totaled for an annual loading.

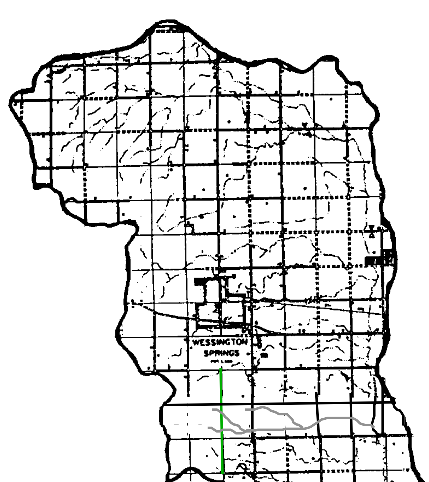
No stage data were available for Site #5 due to bridge construction. To calculate the annual load for Site #5 the following method was used. Site #5 is the last tributary site for the east fork of Firesteel Creek before the east and west fork merge. Site #6 is the last tributary site on the west fork of Firesteel Creek before the east and west fork merge. Site #4 is the first site after the east and west fork merge. Site #6 loadings were subtracted from Site #4 loadings and multiplied by 95% to make up for addition water which may have entered Site #4 from other sources. Please refer to Figure 2 for a diagram of the site locations.

When selecting a site location for the inlet to Lake Mitchell, an effort was made to avoid a backwater situation. If an inlet site is too close to the lake, high water may create unusable stage/discharge tables. Conversely, if the site was to far away, it would not be representative of the water quality entering Lake Mitchell. A site was selected two miles west of the lake inlet. When calculating stage/discharge tables, it was found that upstream Site #4 had a much higher loading than Site #1 (the inlet site). It was obvious Site #1 was still in a backwater situation. To calculate a more accurate Site #1 loading, Site #4 and Site #3 loadings were added together (Figure 2). That total was then multiplied by 105%. The extra 5% was for water added to the system between the upstream sites and Site #1.

Water Quality

Samples collected at each site were taken according to South Dakota's EPA approved *Standard Operating Procedures For Field Samplers*. Water samples were then sent to the State Health Laboratory in Pierre for analysis. Quality Assurance/Quality Control samples were collected in accordance to South Dakota's EPA approved *Clean Lakes*

Figure 2



Firesteel Creek Water Quality Monitoring Sites

Quality Assurance/Quality Control Plan. These documents can be referenced by contacting the South Dakota Department of Environment and Natural Resources at (605) 773 - 4254.

In addition to the tributary water quality monitoring, information was collected to complete a comprehensive watershed model. The AGNPS model was developed by the United States Department of Agriculture (Young et al, 1986) to give comparative values for every 40 acre cell in the watershed. Each 40 acre cell will give an export value for phosphorus, nitrogen and suspended solids. The cells with high export values are field checked to make sure the model is highlighting the correct problem areas in the watershed. The export values of each subwatershed were compared to the water quality data.

The following paragraphs will discuss water quality samples collected during the study period. The discussion of loadings will be confined to the 1993 data because of insufficient sample and stage data in 1994 and 1995.

WATER QUALITY DISCUSSION

Water Quality Standards

Firesteel Creek is broken into two sub-tributaries. The main branch called the east fork of Firesteel Creek begins north of Wessington Springs and travels south until it reaches the confluence of the west fork near Site #4. The west fork of Firesteel Creek begins in the Wessington Springs Hills, runs into Lake Wilmarth, and then travels east until it reaches the confluence with the east fork. Another branch of the west fork begins south of Plankington, South Dakota and runs north east to the confluence of the east fork (Figure 1). Firesteel Creek, from the inlet of the lake to the confluence of Firesteel Creek east and west forks, is assigned the water quality standards for a permanent warm water fishery and limited contact recreation. This area includes Sites #1 and #4 (Figure 3). The east fork of Firesteel Creek, from the confluence of the east and west forks to state highway 34, is given the water quality standards for a semi-permanent fishery and limited contact recreation. Sites #5 and #7 are included in this reach (Figure 3). The west fork of Firesteel Creek from the confluence of the east and west forks to Lake Wilmarth is given the beneficial use of marginal fishery and limited contact recreation. All waters of South Dakota are designated with the beneficial use of wildlife propagation and stock watering and irrigation. When an area has more than one beneficial use, and the uses have standard limits for the same parameter, the most stringent standard is used. Table 1 below shows the most stringent standard limits for the parameters analyzed in this study.

Figure 3. Firesteel Creek Beneficial Use Locations

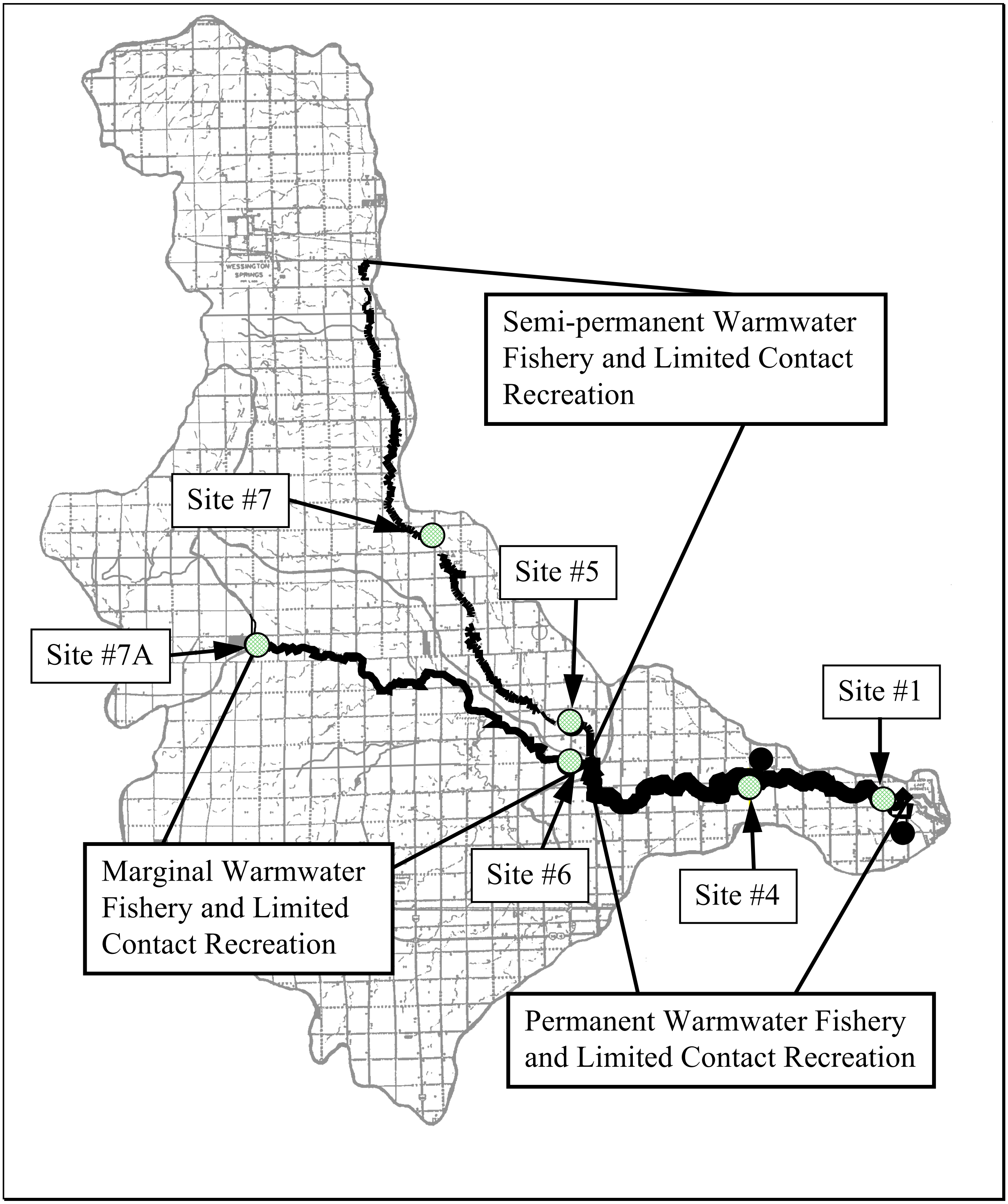


Table 1. South Dakota Water Quality Standards for Specific Stream Segments

Sites Numbers	Parameter	Limits
#1 and #4	Un-ionized ammonia	< 0.04 mg/L
	Dissolved Oxygen	> 5.0
	pH	> 6.5 and < 9.0 su
	Suspended Solids	< 90 mg/L
	Temperature	< 26.67^{o} C
	Fecal Coliform	< 2,000/100 ml (grab sample)
	Alkalinity	< 750 mg/L
	Nitrates	< 50 mg/L
#5 and #7	Un-ionized ammonia	< 0.04 mg/L
	Dissolved Oxygen	> 5.0
	pH	> 6.5 and < 9.0 su
	Suspended Solids	< 90 mg/L
	Temperature	< 32.22^{o} C
	Fecal Coliform	< 2,000/100 ml (grab sample)
	Alkalinity	< 750 mg/L
	Nitrates	< 50 mg/L
#6 and #7a	Un-ionized ammonia	< 0.05 mg/L
	Dissolved Oxygen	> 4.0
	pH	> 6.0 and < 9.0 su
	Suspended Solids	< 150 mg/L
	Temperature	< 32.22^{o} C
	Fecal Coliform	< 2,000/100 ml (grab sample)
	Alkalinity	< 750 mg/L
	Nitrates	< 50 mg/L

Site #1

Water quality standards were exceeded six different times on Site #1. Twice (7/27/96 and 6/13/94) the temperature was 27^{o} C. The standard limit is 26.67 so no severe exceedence occurred considering tolerances for sampler and equipment error. Total suspended sediment concentrations surpassed the standard three times during the sampling season. On 4/19/94 the concentration was 208 mg/L, and on 5/9/95 and 5/10/95 the concentration was 304 mg/L. Fecal coliform concentrations exceeded the water quality standards once during the sampling season. On May 9, 1995, the fecal coliform concentration was 8,100 counts/100 ml.

Site #4

The total suspended solids concentrations exceeded the water quality standards twice for Site #4 during the sampling season. The first sample collected on March 9, 1993, reached 122 mg/L, and again in the summer, June 17, 1993, the sample collected reached 340 mg/L for total suspended solids. On the same day (June 17, 1993) fecal coliform concentrations reached 3,700 counts/100 ml. The fecal coliform standard was again exceeded on April 19, 1995, when the concentration reached 5,000 counts/100 ml.

Site #5

Two parameters exceeded the established water quality standards on May 9, 1995. Total suspended solids reached 120 mg/L and fecal coliform reached 7,300 counts/100 ml.

Site #6

Site #6 also exceeded two water quality standards on May 9, 1995. Total suspended solids reached 380 mg/L and fecal coliform reached 5800 counts/100 ml. Both sites (#5 and #6) have animal feeding areas relatively close to each site location. Spring rainfall events are typically responsible for increased fecal coliform concentrations. Manure may be coming from wintering lots or the cattle may still be in the lots until later in May.

Site #7

Site #7 had only one exceedence of the standards during the sampling season. July 7, 1994, the total suspended solid concentration reached 124 mg/L. Although the fecal coliform concentrations were high (1,500 counts/100 ml), they did not exceed the standard (2,000 counts/ml).

Site #7A

The dissolved oxygen (DO) on August 17, 1993, was 4.4 mg/L, 0.6 mg/L less than the state standard. Site #7A is the outlet to Lake Wilmarth. The low DO is most likely due to decomposition of an algal bloom or other high biological oxygen demand. The phosphorus on the same date was 1.39 mg/L so the lake had an extreme excess of nutrients. The lake water was probably oxygenated immediately as it fell over the spillway and traveled down Firesteel Creek. The fecal coliform standard was exceeded once during the sampling season. On April 19, 1994, a concentration of 2,600 counts/100 ml was collected at the spillway. This high fecal concentration is unusual in a lake because of the length of travel, dilution, and exposure to ultra-violet light. An animal feeding operation adjacent to the lake is a probable source of the high fecal coliform concentrations.

Seasonal Water Quality

Different seasons in the year can yield different water quality in a tributary due to the changes in precipitation and agricultural practices. Firesteel Creek samples were separated into spring (March 10, to May 31, 1993), summer (June 1 to August 31, 1993), and fall (September 1 to November 23, 1993). According to the water quality samples collected in 1993, the largest nutrient and sediment concentrations and loads occurred in the summer (Table 2.). The summer of 1993 was extremely wet. Increased precipitation typically creates an increase in total loadings. Conversely, the flushing effect usually decreases the concentrations of sediments and nutrients. The increased concentrations in

Table 2. Average Chemical Concentrations for All Firesteel Creek Sites by Season*

Parameter	Spring		Summer		Fall	
	Count	Mean	Count	Mean	Count	Mean
Dissolved Oxygen	41	9.84	12	6.51	11	10.93
Field pH	41	7.63	22	7.80	11	8.19
Alkalinity	41	150	22	214	11	305
Total Solids	41	612	22	742	11	1,645
Suspended Solids	41	30	22	55	11	20
Ammonia - N	41	0.12	22	0.02	11	0.02
Nitrate-Nitrite - N	41	0.32	22	0.22	11	0.10
Total Kjeldahl - N	41	2.37	22	1.66	11	1.18
Total Phosphorus	41	0.622	22	0.721	11	0.304
T. Diss. Phosphorus	41	0.438	22	0.532	11	0.194
Fecal Coliform	37	171	15	405	11	45

*The shaded area is the highest seasonal concentration for that parameter.

the summer of 1993 indicate seasonal practices in the watershed are having a negative impact to Firesteel Creek's water quality. The most likely causes of the higher fecal and phosphorus concentrations are; 1) run-off from concentrated feeding areas in the summer, 2) summer long grazing, and 3) summer run-off from concentrated feeding areas used in the winter and abandoned when cattle are put out to pasture. Summer long grazing practices in the watershed could be increasing concentrations of sediment and nutrients during the summer run-off events. Due to the flat slope of the watershed, limited amounts of nutrients and sediments should be coming from the agricultural crop ground.

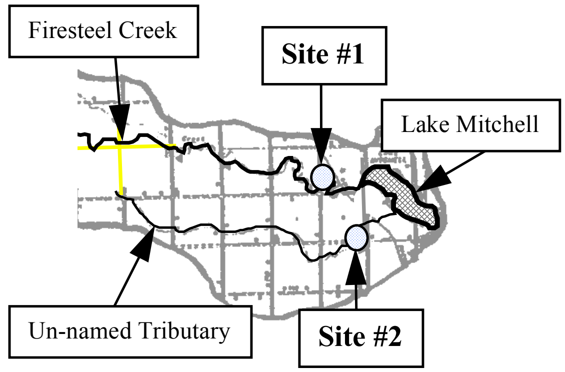
The average nitrogen concentrations are higher in the spring than any other time of year. Applied fertilizer, decaying organic matter and animal waste carried by spring run-off and rain events are the most likely cause of these elevated concentrations. Nitrates are water soluble, meaning it can easily dissolve in water. In the spring the soil may be either frozen or saturated and most of the flow is overland and into surface waters.

Comparing the water quality load of a certain site to the size of the sub-watershed can reveal areas of the watershed which are contributing more nutrients per acre. For the following discussion, the loadings (kg/year) for each site were divided by the number of acres in each watershed to give kg/acre. The numbers were also broken down between spring, summer, and fall. Losses of phosphorus and total suspended solids on a per acre basis reveal the same basic information as the loading discussion above. Per acre losses of phosphorus and suspended sediment in the summer are higher than per acre losses in the spring and fall. In fact, fall nutrient and suspended solids losses are between 10 to 100 times less than the summer losses per acre.

Water Quality of Individual Tributary Sites

Sites #1 and #2

Figure 4. Loaction of Sites #1 and #2



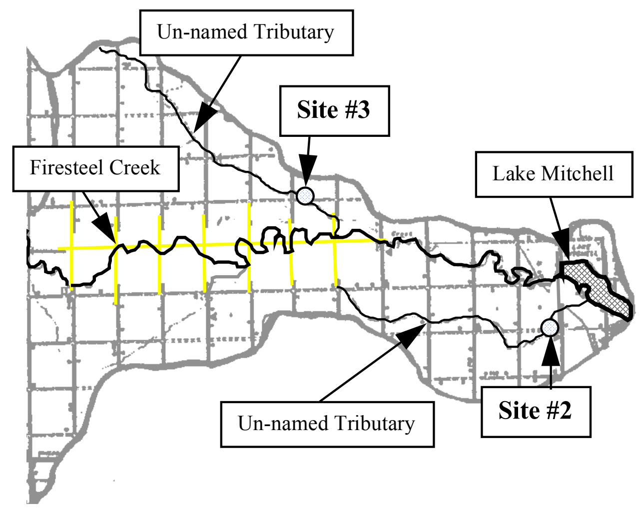
Site #1, the main inlet to Lake Mitchell, will be compared to the other smaller inlet to the lake, Site #2. Site #1 has approximately 345,520 acres in its watershed and Site #2 has approximately a 4,160 acre watershed. The phosphorus and sediment losses per acre for each of these sites are fairly similar except for the phosphorus losses in the spring. In the spring, Site #1 lost 0.051 kg/acre of phosphorus while Site #2 lost only 0.013 kg/acre. In the summer months Site #2 lost 0.134 kg/acre of phosphorus and Site #1 lost 0.124 kg/acre. The increase in phosphorus per acre for Site #2 can probably be attributed to summer grazing practices or seasonal feeding areas. The suspended sediment concentration was fairly low for both sites and the organic nitrogen was slightly higher indicating the phosphorus was not from soil loss but some organic input.

Site #1 sediment and nutrient concentrations are somewhat lower than the concentrations at Site #2. However, the total load to the lake is much higher at Site #1. Approximately 90% of all the nutrients and sediments enter lake Mitchell through Site #1. As mentioned above, the loss of sediments and nutrients per acre are basically the same for both sites. The phosphorus concentrations at Site #1 were unusually high considering the amount of water entering the site. In some cases it appears the nutrients traveling through the upstream sites are definitely increasing the concentrations at Site #1. In other cases the concentrations at Site #1 are higher than Site #4, the next site up stream. Clearly, much of the phosphorus load is traveling the length of the watershed due to the low suspended sediment concentrations and the high dissolved phosphorus. Dissolved phosphorus is unattached, usable phosphorus which will stay dissolved in water until it is used by plants or attached to a substrate. The overall suspended sediment load for Site #1 is low. Less than 1/100th of a foot (1.45 acre-feet) is deposited over the surface area of the lake through Site #1 and less than 1/10000th of a foot (0.007 acre-feet) from Site #2. From the water quality data collected, suspended sediment does not appear to be a problem for Lake Mitchell.

Even though the total loading from Site #2 is much smaller than Site #1, the nutrient sources should not be ignored. All of the nutrients that pass through Site #2 will affect Lake Mitchell's water quality because of its close proximity to the lake. Concentrations of fecal coliform at Site #2 and the presence of livestock feeding operations indicate animal waste as a source of nutrients. Three samples collected in 1994 and 1995 had fecal coliform concentrations of 70,000, 14,000 and 65,000 colonies per 100 ml. Site #2 had the largest concentrations of fecal coliform in the watershed. There was only one fecal coliform sample collected in 1993 at Site #2. Bottles opening in transit, exceeding the 24-hour time limit, and taking the sample too late in the week are the reasons not more fecal samples were analyzed. High phosphorus concentrations coincided with the high fecal concentrations mentioned above, 0.929, 0.784, and 0.853 mg/L respectively. Since Site #2 is a small watershed, the nutrient problem can most likely be addressed by working with one or two landowners.

Site #3

Figure 5. Location of Sites #2 and #3.

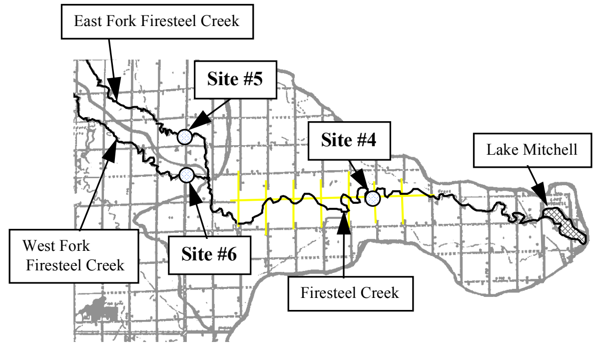


Site #3 a has contributing watershed area of 44,600. According to both the loading and the loss per acre information, it is the cleanest watershed in the Firesteel Creek drainage. Site #3's watershed is approximately 10 times larger than the watershed of Site #2, however, only 20% more water passes through Site #3 water than Site #2. The lack of water may be the result of the level land slopes in the watershed. This may explain the low suspended solid loadings to Firesteel Creek. The suspended solids loss per acre, in the Site #3 watershed, is lower than all of the other sites except the Lake Wilmarth outlet which is 2 kg/year/acre. Riparian areas with good vegetation and slow meandering streams typically are responsible for the low suspended solid concentrations which in turn are most likely responsible for the large percentage of dissolved phosphorus. Eighty percent of the total phosphorus load at Site #3 is dissolved phosphorus. The per acre loss of total phosphorus for 1993 in the watershed was only 0.022 kg/acre. Although the phosphorus loads are relatively low when compared to the other sites in the watershed, the concentrations are still high. The average concentration in 1993 was 0.481 mg/L. Although riparian management may be an issue, overgrazing does not appear as large as a problem as in the rest of the watershed.

Site #4

The contibuting area to Site #4 is approximately 319,200 acres. The water quality at Site #4 is a combination of Sites #5 and #6. Only a relatively small area, 15,640 acres, of Site #4 does not previously run through Site #5 or Site #6. For this reason the increases and decreases of Site #4 largely depend on factors which also effect Site #5 and Site #6. The suspended solid load at Site #4 is the highest of any of the sites. Land managers should assess the 15,640 acres that pass solely through Site #4. Poor crop management leading to soil erosion may be responsible for the increased suspended solids load in the area. The increase suspended solids are adding to the higher total phosphorus concentrations found at Site #4. As expected, the dissolved phosphorus concentrations are lower at Site #4 because dissolved phosphorus can sorb on to the suspended solids and no longer be considered the dissolved fraction of phosphorus. Site #4 experienced a few extremely high concentrations of total phosphorus. On three occasions, during the 1993 sampling season, the total phosphorus concentration exceeded 1.0 mg/L. On March 9, 1993, the phosphorus concentration was 1.16 mg/L. Later in the spring on May 21, and June 17, the concentrations were 1.18 and 1.06 respectively. The concentrations at Site #5 on the three days mentioned above were 0.849 mg/L on March 9, and 0.611 mg/L and 0.737 mg/L on May 21 and June 17. Site #6 had even higher concentrations than Site #5, both most likely effecting the higher concentrations found at Site #4. Site #6 had phosphorus concentrations of 0.904 mg/L on March 9, and 0.923 mg/L on June 17. There was no sample collected on May 21. A Site #6 sample collected on May 18 had a concentration of 0.979 mg/L. Relatively high fecal coliform concentrations coincided with the high phosphorus concentrations at Site #4. On March 9, the fecal coliform concentration was 560 colonies/100mL. On May 21, no sample was collected, however, on June 17 the fecal coliform concentration was 3,700 counts/100mL. The concentrations at Site #4 were higher than those at either Site #5 or Site #6. Since high phosphorus and fecal concentrations were found in more spring samples than summer samples, wintering feedlots or concentrated feeding areas were most likely responsible.

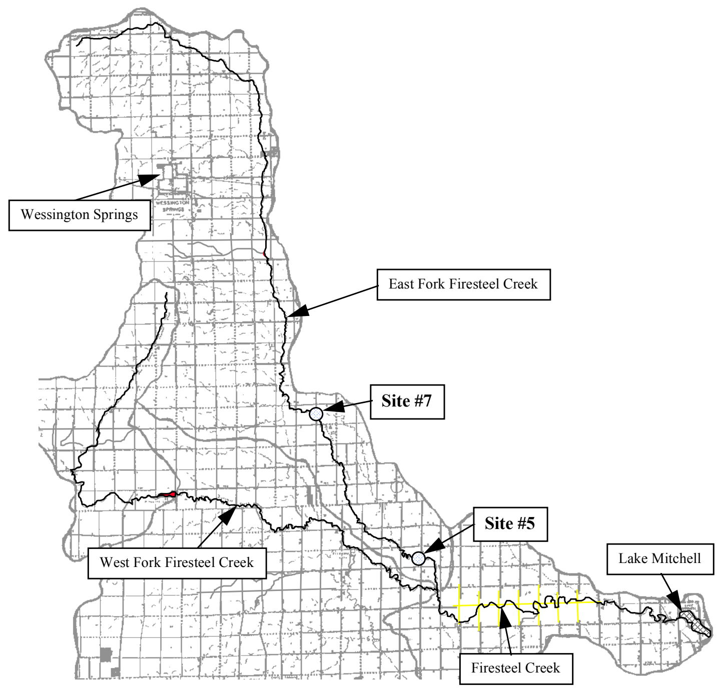
Figure 6. Location of Sites #4, #5, and #6.



Sites #5 and #7

Sites #5 and #7 are located on the east fork of Firesteel Creek that begins north of Wessington Springs, South Dakota. The watershed size draining into Site #7 is 99,600 acres. Site #5 has an additional 20,120 acres for a total of 119,720 acres. The annual suspended sediment loss per acre on the east fork is less than the sediment loss on the west fork. There is little difference in the sediment loss per acre between these two sites. The total suspended solid load is actually higher for Site #7 than Site #5. There may be areas between the sites where the velocity of Firesteel Creek is reduced and the suspended sediment falls out of the water column. The increased concentrations at Site #7 may also be a result of sample collection location. Site #7 is located at a double culvert that increases the water velocity. The solids at this location are well mixed making it is easier to collect a sample from the entire water column. Site #5 is located at a bridge site that is deeper and has a slower velocity. Because the slower flow settles out the solids, the suspended solid concentrations were probably lower. Also the banks of the stream made it difficult to sample Site #5 during the high water. The samples were sometimes collected from the bridge making it difficult for the sampler to sample deeper than the a foot or two from the surface.

Figure 7. Location of Sites #5 and #7



The overall loss of nutrients is lower in the east fork than in the west fork of Firesteel Creek. However, there seems to be a sharp increase in the nutrient loss per acre from Site #7 to Site #5. The total phosphorus loss per acre in the additional 20,120 acres between Site #7 and Site #5 approximately doubles. The water quality sampling information showed that the concentrations at Site #7 were fairly stable throughout the year, while the concentrations at Site #5 increased from the spring (0.463 mg/L) to the summer (0.846 mg/L). This increase in Site #5 occurred with increases in water load. The total 1993 yearly loadings for Site #7 was 8,475 kilograms (18,687 pounds) and 18,004 kilograms (39,700 lb.) for Site #5. The fecal coliform concentrations are not as high at these sites when compared to other Firesteel Creek sites. However, the mere presence of the fecal coliform bacteria is an indicator of animal waste in the stream. Although sediment loss per acre did not increase at these two sites, increases were found in nutrient concentrations. Typically, sediment eroding off agricultural land carries large quantities of phosphorus. If the phosphorus increases and the sediment does not increase, the source of the phosphorus must be something other than sediment from agricultural lands. Due to the grazing and livestock numbers in the area, animal waste appears to be the source of the nutrients.

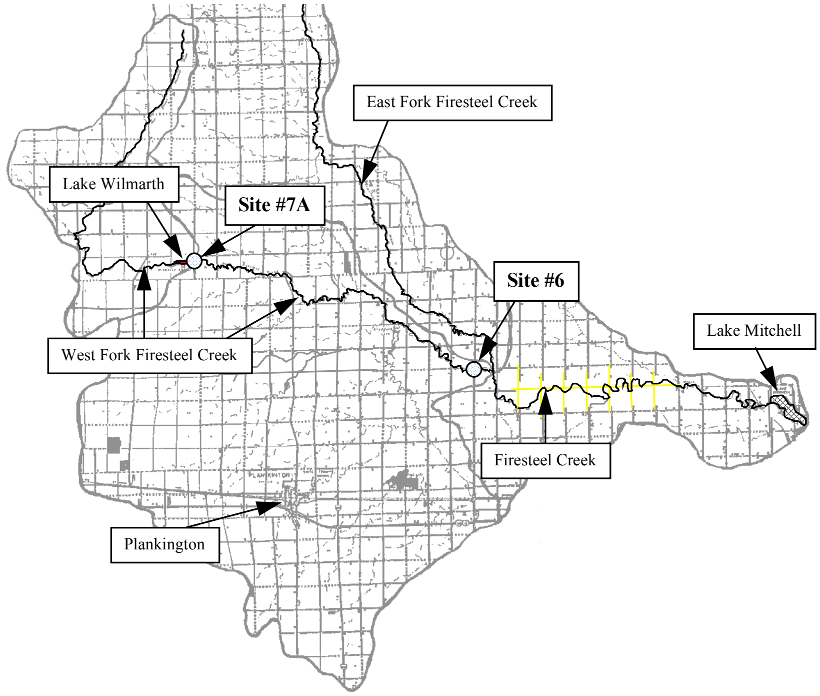
<u>Site #7A and #6</u>

Sites #7A and #6 are located on the west fork of Firesteel Creek. Site #7A is located at the outlet of Lake Wilmarth, which drains approximately 37,320 acres. The watershed draining to Site #6 is 183,840 acres including the 37,720 acres from Lake Wilmarth (Figure 2). Site #6 is the largest single sub-watershed (not including the combined branches of Site #1 and #4).

Samples collected at Lake Wilmarth in 1979 had inlake total phosphorus averages of 0.234 mg/L. From 1993 to 1995 the minimum sample concentration at the outlet was

0.349 mg/L with an average of 0.745 mg/L of total phosphorus. From 1979 to 1993 it appears definite changes took place in Lake Wilmarth. The amount of suspended sediment sampled at Site #6 was quite high and the suspended sediment exiting through #7A was quite low. The average sample concentrations at Sites #6 and #7A were 69.5 and 10.5 mg/L respectively. As stated above, Site #7A is located at the outlet of Lake Wilmarth. The lake acts as a settling basin for any large concentrations of suspended solids. Since no tributary sampling site was placed on the inlet to Lake Wilmarth, the AGNPS model was used to determine sediment and nutrient loads into Lake Wilmarth. Site #6 has an extremely large drainage area, delivering water from south and west of Plankington, South Dakota. Due to the large drainage area it is difficult to pinpoint sources of sediment erosion. Although Site #6 had high suspended solid loads, due to the size of the watershed it did not have any more loss per acre than the other sub-watersheds (Sites #5 and #7). The high suspended sediment loads may be the result of an erosion area close to Site #6.

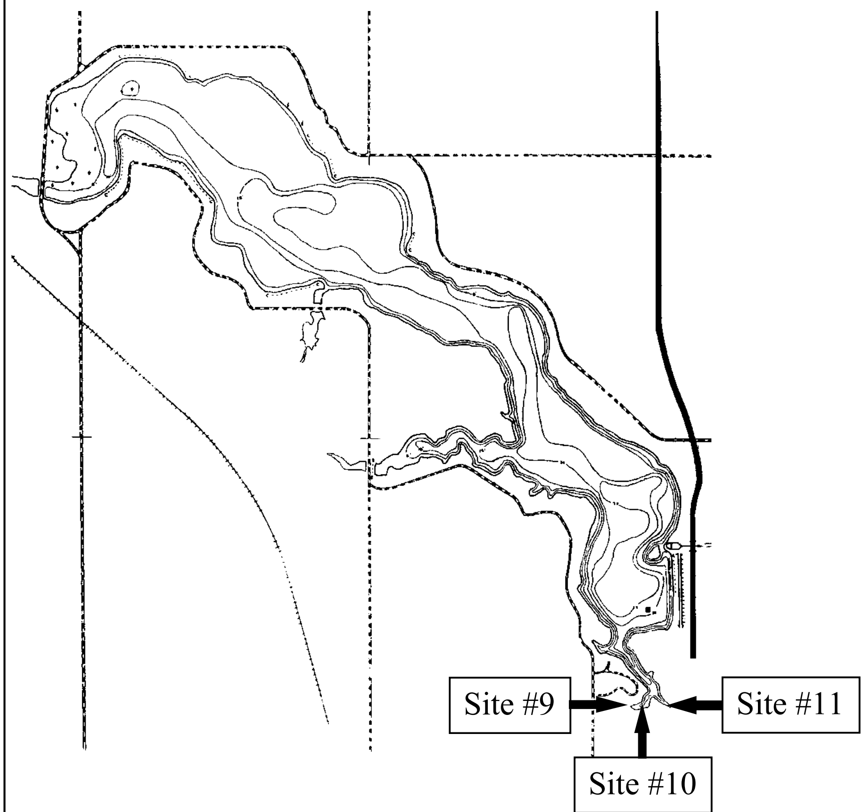
Figure 8. Location of Sites #6 and #7A



Losses per acre of total phosphorus were higher at Site #6 than any other tributary site. In 1993, the total load of phosphorus from Site #6 was 57.61 tons (52,257 kg) and at Site #5, 19.85 tons (18,004 kg). Eighty-four percent of the total load from Site #6 is dissolved phosphorus. The average concentration for total phosphorus was 0.681 mg/L and for dissolved phosphorus 0.527 mg/L. The relatively high dissolved phosphorus concentrations are most likely responsible for the higher concentrations of dissolved phosphorus at Sites #4 and #1. Because the suspended sediment concentrations and the phosphorus concentrations are relatively high at Site #6, both erosion and improper livestock manure management are suspected as the probable causes of the elevated nutrient levels in the sub-watershed.

Storm Sewers

Figure 9. Location of Storm Sewers (bottom of map).



Lake Mitchell receives discharge from three storm sewer drainage areas on the northern edge of the city (Figure 9). Site #11 receives drainage from approximately 136 acres of northeast Mitchell. Site #10 receives drainage from approximately 307 acres just south of the lake and west of US Highway 281. Site #9 receives drainage from a large unknown amount of agricultural land south and east of the lake. The area was tiled and no one has records of where the tiles are located. An area of approximately 2,500 acres was used to estimate the drainage size of Site #9. Since the storm sewers were not gauged, annual discharge was estimated by multiplying the annual rainfall times the surface area of the drainage for each site.

A total of 6 storm sewer samples were collected in 1993 and 2 in 1994. Site #9 was only sampled once during the study so concentrations and loadings should only be considered as estimates. Four samples were collected at Site #10 and 3 samples were collected at Site #11. Due to the range of concentrations, and since discharges were not collected for each sample, the samples for each site were averaged. These average concentrations were multiplied by the total amount of rainfall from each site to acquire an estimated load to the lake. The percentage of the hydrologic load to Lake Mitchell from the storm sewers is estimated at 4%. The storm sewers were also responsible for approximately 8% of the total nitrogen load, 4% of the total phosphorus load, and 8% of the total suspended solids load.

Considering the storm sewer's small drainage area, they transported a relatively large load of nutrients and sediment to the lake. Table 3 shows the average concentration and the standard deviation for each of the sites.

Table 3. Average Concentrations of Storm Sewer Samples

Site Number	9		10		11	
Number of Samples	1		4		3	
Type	Average	Std. Dev.	Average	Std. Dev.	Average	Std. Dev.
Water Temperature	25.0	NA	20.1	12.5	24.3	3.1
Dissolved Oxygen	9.10	NA	10.18	2.28	9.20	1.13
Field pH	7.59	NA	7.97	0.96	7.49	0.23
Total Alkalinity	141	NA	91	40	66	41
Total Solids	604	NA	578	409	371	208
Total Diss. Solids	561	NA	355	153	275	159
Total Susp. Solids	43	NA	224	263	96	53
Ammonia	0.13	NA	0.44	0.28	0.30	0.16
Un-ionized Ammonia	0.0028	NA	0.0491	0.0853	0.0032	0.0043
Nitrate-Nitrite - N	2.00	NA	2.15	1.80	0.77	0.15
Total Kjeldahl -N	1.50	NA	2.22	0.97	1.58	0.06
Total Phosphorus	0.558	NA	0.500	0.305	0.303	0.158
Total Diss. - P	0.093	NA	0.153	0.041	0.097	0.083
Fecal Coliform	100	NA	130,653	252,958	133,370	230,908

Even though Site #9 had only one sample taken, all the concentrations are fairly similar to Sites #10 an #11, except for fecal coliform. On August 18, 1993, sites #10 and #11, recorded fecal coliform concentrations of 510,000 and 400,000 colonies/100 ml respectively. The high fecal coliform concentrations were a result of flooding and the backing up of the city sanitary sewers. The sewage from the sanitary sewers ran into the city storm sewers. Site #10 also had a fecal coliform reading of 12,000 counts/100 ml on June 1, 1993. From the standard deviation values in the above chart, the fecal coliform values were apparently far ranging.

As stated above, the estimated load of suspended sediment to Lake Mitchell from the storm sewers was approximately 8%. The average concentrations for Sites 9, 10, and 11 were 43, 243, and 96 mg/L respectively. For the size of the watershed these concentrations are extremely high. A source of these high solids is from sanding winter roads and dirt and gravel carried on cars from rural roads in the area. Erosion from construction sites can also contibute suspended solids to urban run-off. The concentration of suspended solids are typically high from any urban storm sewer.

By eliminating the storm sewer discharge to Lake Mitchell, the city would eliminate approximately 8% of the suspended solids entering the lake. More importantly however, is the elimination of a potential hazardous materials spill to Mitchell's drinking water supply.

Nutrient and Sediment Budget

<u>Hydrologic Data</u>

The hydrologic load explains how much water entered the lake and how much water left the lake. Monitoring all the possible inputs to a lake is very difficult. In some cases, estimates of the water load to the lake are needed to help balance the equation. The hydrologic inputs to Lake Mitchell come from many different sources; precipitation, tributary run-off, storm sewer run-off, and groundwater.

The sampling and gauging for Lake Mitchell began on March 8, 1993. At that time there was approximately 0.51 feet of water above the spillway. The surface area of the lake was multiplied by the 0.51 feet of water above the dam to reflect extra water which would leave the lake and not be accounted for by any other input.

Precipitation data was taken from the weather station at Mitchell. As discussed in the previous section, three storm sewers run directly into Lake Mitchell and were sampled to assess if there was a possible pollution source to the lake. Since the storm sewers were not gauged, the loadings to the lake were estimated. Two storm sewers drain areas within the city. The areas drained were multiplied by the amount of precipitation received to estimate total loadings. The other storm sewer is linked to an old tile that drains an unknown amount of farmland. A drainage area estimated 3 times larger than the largest city drainage was used.

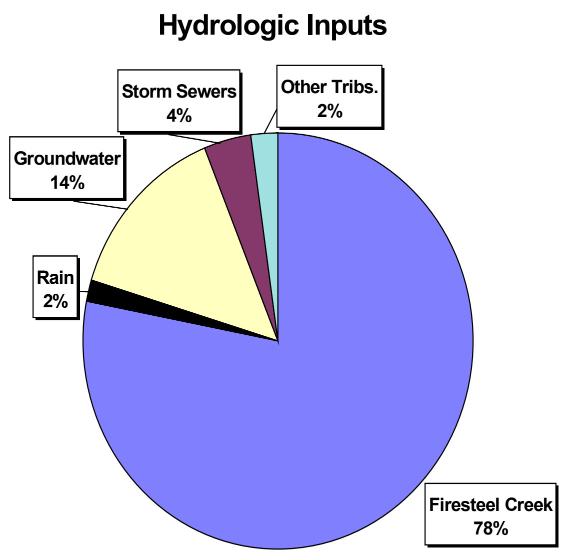
Sites #1 and #2 were the main inlet sites to the lake. The less significant sites from the watershed were not monitored because of lack of flow or inadequate location for a monitoring site. The one other tributary that enters the lake has approximately the same size watershed as Site #2. An estimated loading slightly less than the loading at Site #2 was used.
After all other inputs were added the water budget was short approximately 13,762 acre-feet. The only input source not yet included was groundwater. Inputs from groundwater are generally very difficult to document and the amount of water needed to balance the hydrologic budget seemed quite high. However, there is a documented alluvium following the drainages into Lake Mitchell and a large outwash deposit adjacent to the north side of the lake (Christensen, 1989). Depending on the available storage in these areas and precipitation, alluvium and outwash deposits can either add or remove water

Table 4. Inputs and Outputs to Lake Mitchell

Input Sources		Output Sources	
Source	Load in Acre-Feet	Source	Load in Acre-Feet
Precipitation	1,775.9	Site #8 Outlet	94,477.0
Storm Drain #10	814.1	City pump	1,738.1
Storm Drain #11	361.0	Evaporation	1,395.7
Storm Drain #9	2,500.0		
Un-recorded Trib.	1000.0		
Site #1	75,855.0		
Site #2	1,203.0		
Groundwater	13,761.8		
Water above spillway	340.0		
Totals	97,610.8		97,610.8

from the surface storage. In the fall of 1992, and all of 1993, the high precipitation rates in the area probably saturated these deposits of sand and gravel and added water to the lake system. Table 4 shows the values for the water inputs from March to the end of November 1993. Figure 10 gives the percentages of the same input values.

Figure 10.



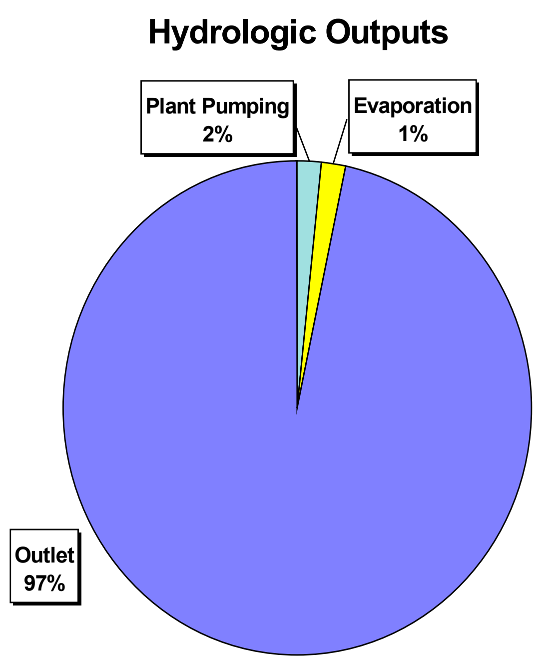
Water releases from Lake Mitchell were easier to document. Evaporation data was supplied by the state climatologist. The city treatment plant pumping records were used to obtain the amount of water taken from the lake for municipal purposes, and the outlet data was collected at the spillway, Site #8.

A Steven's Type F paper graph stage recorder was placed at the outlet to assist in measuring the discharge leaving the lake. Bi-weekly staff readings were taken after it was found that the force of water underneath the stage recorder's stilling basin was creating a suction in the stilling pipe and not recording the proper water levels. Outlet discharges were calculated by using the weir equation:

$$Q = \text{Length} \times \text{Coefficient } (3.0) \times \text{Depth}^{1.5}$$

The discharges were converted from CFS to daily loadings and then annual loadings. The total outlet information is included above in Table 4 and below in Figure 11.

Figure 11.



Suspended Solids Budget

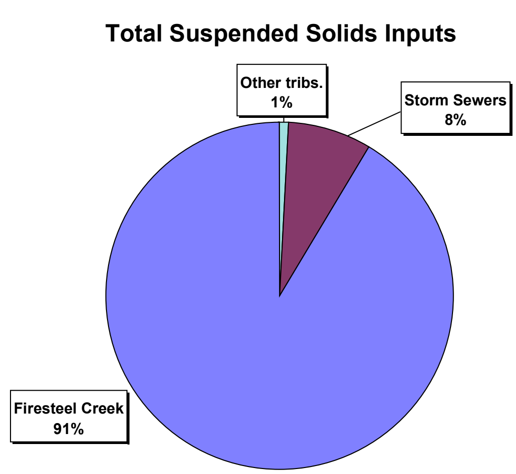
As described in the tributary section of the report, suspended solids did not appear to be a significant impairment. According to the data collected, including all of the inputs in

Table 4, Lake Mitchell shows less than 2 acre feet of suspended solids entering the lake. The load was calculated by dividing the total pounds of sediment entering the lake (11,429,053 pounds) by a factor of 164.5 pounds per cubic feet. The cubic feet were then converted to acre feet. This small loading may be a result of ponding the mile or two before the lake. If the amount of suspended solids entering Lake Mitchell is calculated using the loading from Site #4, before the ponding begins, the total load to Lake Mitchell would still only be 4 acre-feet. There may be more sediment entering Lake Mitchell from bedload. Bedload is the sediment that moves along the sediment water interface of a stream. Even if the bedload doubled the loading to Lake Mitchell, the rate of siltation would still be extremely slow. It is not known how much of the suspended solids are inorganic sediment or organic matter (decaying plants and vegetation). Due to the amount of range land and the lack of slope in the watershed, some of the suspended solids will be organic matter.

In July 1979 the Soil Conservation Service (SCS) conducted a study of the sedimentation in Lake Mitchell. By referencing previous studies, SCS found that from the period 1928 - 1948 the lake averaged 28.43 acre-feet/ year of sedimentation. Due to a period of intensive farming practices, the 10 year period from 1948 - 1958 more than doubled the sedimentation rate to 58.2 acre-feet/year. From 1958 - 1979 the sedimentation rate was dramatically reduced to 6.8 acre-feet/year (SCS, 1979). For this study, no sediment survey was conducted as in the previously mentioned studies, however, the water quality samples were fairly close to the survey's estimation of sedimentation rates to the lake.

Storm sewers contributed 8% percent of the total suspended solids load to the lake (Figure 12) which is high considering the amount of the hydrologic load from the storm sewers. Due to the small size of the watershed, they should be considered a significant source and control measures should be taken.

Figure 12.



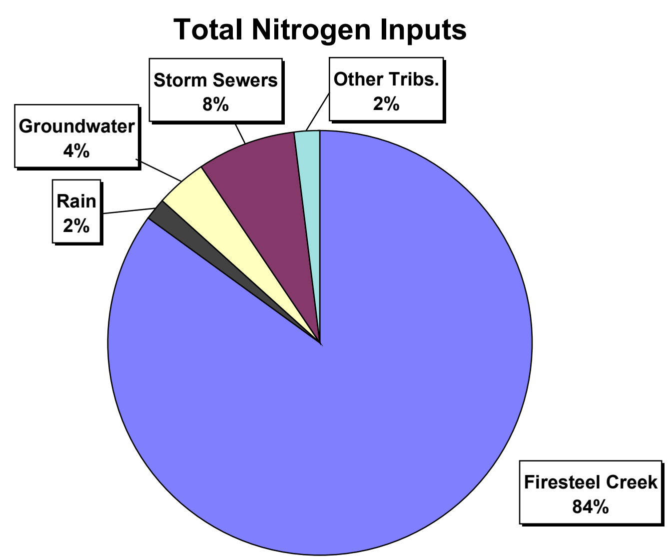
The amount of suspended solids leaving Lake Mitchell in 1993 was approximately 0.3 acre feet. The composition of these solids is mostly algae. A portion of the suspended sediments entering the lake are broken down into nutrients and leave the lake as algae. Many of the algae in the lake do not leave by the outlet or pumping. They settle to the bottom of the lake and are broken down to release nutrients. This process is a form of internal loading.

Nitrogen Budget

Nitrogen is water soluble which makes it very difficult to estimate groundwater contributions. Depending on the time of year and the agricultural practices on the surface of the land, nitrogen concentrations can vary greatly. For the purpose of the study, a total nitrogen concentration of 0.5 mg/L was used for groundwater. This concentration of nitrogen was estimated from groundwater samples collected by the USGS and SDGS (USGS, 1983). Ground water nitrogen does not heavily impact Lake Mitchell since groundwater nitrogen only compromises 4.0% of the total nitrogen budget for the lake. Because it is difficult to remove nitrogen from the system, ground water should not be a concern to the overall budget. The input from precipitation was estimated at 13.1 kg/ha/yr (11.685 pounds/acre/year) (EPA, 1990). A display of the nitrogen inputs is shown in Figure 13.

According to the samples collected, the inlake volume of total nitrogen in Lake Mitchell increased by 38,987 pounds (36,643 kg). Forms of total inorganic nitrogen increased along with the total nitrogen while Lake Mitchell actually lost organic nitrogen (-4,977 pounds or -2,257 kilograms). Since algae is primarily organic nitrogen, the losses of algae through the outlet and the treatment plant intake were responsible for the loss organic nitrogen. However, since blue green algae can convert nitrogen to usable forms, an increase in nitrogen for the whole lake can mean an increase in eutrophy.

Figure 13.



Phosphorus Budget

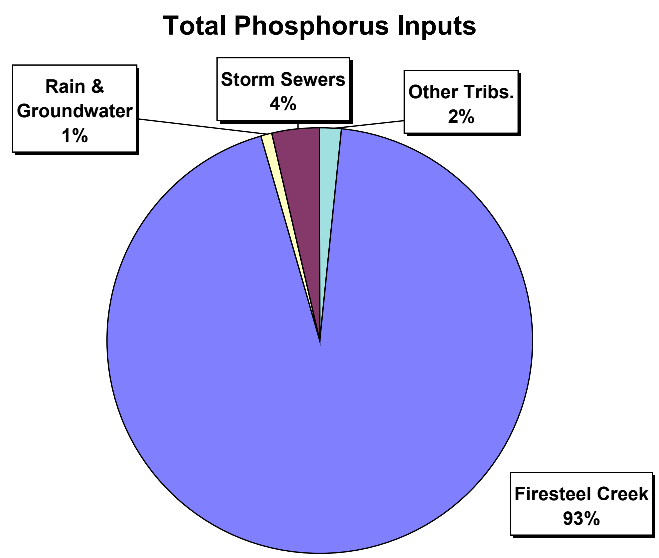
Phosphorus inputs to Lake Mitchell in the 1993 sampling season totaled 141,232 pounds (64,051 kg). Site #1 was responsible for 93% of the total phosphorus to the lake (Figure 14). Although the storm sewers are only estimated at 4% of the load to the lake, the size of the drainage is less than 0.5% of the watershed for Lake Mitchell. For the size of the area the storm sewers present a significant source of phosphorus.

Lake Mitchell actually experienced a loss in total phosphorus during the 1993 sampling season (-79,639 pounds or -36,118 kilograms). More phosphorus left the lake than entered through external sources. Summer rains began in mid-June and continued until late July. June and July are very productive in terms of algal growth. Most likely large summer blooms of floating blue-green algae were flushed out of the lake as the discharge increased through the outlet. The additional phosphorus which was not accounted for in the external sources was most likely from internal loading from the bottom sediments. An explanation of the internal loading process is described later in the report under the dissolved oxygen and phosphorus discussions.

The budget of total dissolved phosphorus further supports the loss of total phosphorus by algae passing through the outlet. The budget for total dissolved phosphorus actually showed a slight increase in Lake Mitchell in the 1993 sampling season (2,023 pounds or 917 kilograms). Since virtually all phosphorus attached to algae would be considered particulate and not dissolved phosphorus, the loss of algae would increase the loss of total phosphorus and not necessarily total dissolved phosphorus.

The total load of phosphorus from groundwater in 1993 was less than 1% of the total inputs (Figure 14). However, groundwater was responsible for approximately 14% of the total hydrologic inputs. The summer rains of 1993 ended a prolonged period of drought which probably left the water levels in the outwashes and alluvium low. The rains increased the water level in the alluvium and outwash which then discharged to the lake. Since groundwater movement is slower than surface water, it is conceivable that the groundwater continued to entered the lake well after the tributaries returned to base flow. The additional water was naturally low in phosphorus, and what entered the lake was the dissolved fraction.

Figure 14.

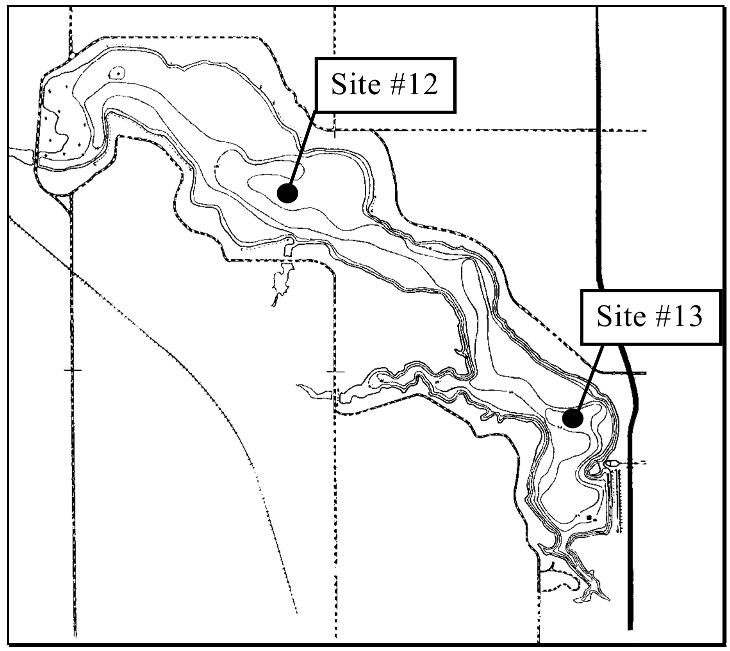


INLAKE DATA

METHODS AND MATERIALS

Two inlake locations were chosen for collecting nutrient information from Lake Mitchell during the study. The locations of the two inlake water quality monitoring sites (Sites #12 and #13) are shown on Figure 15. A sample set consisting of both a surface and bottom sample was to be collected each month. Additional inlake data was collected from 1991 to 1995 for the state sponsored annual lake assessment. These samples were used to analyze water quality trends over time. Samples collected during the assessment are also used to supplement data collected by the local sponsor. The samples collected for the Statewide Lake Assessment were taken by combining three widely separated surface samples for a surface composite and three separate bottom samples for a bottom composite. The samples were analyzed according to *the South Dakota Standard Operating Procedures for Field Samplers* manual.

Figure 15. Location of Inlake Monitoring Sites.



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

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

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

Unionized Ammonia	Organic Nitrogen	Total Nitrogen
Total Dissolved Solids		

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

Water Temperature	Air Temperature	Dissolved Oxygen Profiles
Field pH	Secchi Depth	

The biological parameters are listed below:

Chlorophyll *a* Algal Samples

The chlorophyll *a* samples were used with the phosphorus and secchi disk data to evaluate the eutrophic trend of Lake Mitchell. The hydrologic and nutrient budgets were used to find the lake response to reduced phosphorus inputs. The model, taken from Wetzel 1983, is actually a model derived by Vollenweider and Kerekes, 1980.

Samples collected at the inlake sites were taken according to South Dakota's EPA approved *Standard Operating Procedures For Field Samplers* manual. Water samples were then sent to the State Health Laboratory in Pierre for analysis. Quality Assurance/Quality Control samples were collected in accordance to South Dakota's EPA approved *Clean Lakes Quality Assurance/Quality Control Plan.* These documents can be referenced by contacting the South Dakota Department of Environment and Natural Resources at (605) - 773-4254.

WATER QUALITY DISCUSSION

South Dakota Water Quality Standards

Lake Mitchell is the drinking water supply for the city of Mitchell and is assigned the water quality beneficial uses of:

- Domestic water supply
- Warmwater permanent fish life propagation
- Immersion recreation
- Limited contact recreation
- Wildlife propagation and stock watering

In the case when the above uses have standard limits of the same parameter, the most stringent standard is used. Table 5 shows the most stringent standard limits for Lake Mitchell for the parameters analyzed in this study.

Table 5. Lake Mitchell Beneficial Use Criteria

Parameter	Limits
Un-ionized ammonia	< 0.04 mg/L
Dissolved Oxygen	> 5.0
pH	> 6.5 and < 9.0 su
Suspended Solids	< 90 mg/L
Temperature	< 26.67^{o} C
Fecal Coliform	< 400/100 ml (grab sample)
Alkalinity	< 750 mg/L
Nitrates	< 10 mg/L
Sulfates	< 500 mg/L

Because of its nutrient condition and depth, Lake Mitchell stratifies in the summer months. Dissolved oxygen levels in the lower part of the lake often reach concentrations below 5.0 mg/L, in violation of the standard. The few non-summer samples collected showed a more homogeneous lake with well-mixed oxygen levels. The only other exceedence of the water quality standard occurred on August 13, 1994, in a composite sample collected during the annual lake assessment. The un-ionized ammonia concentration on this date was 0.06 mg/L for the surface composite and 0.07 mg/L for the bottom composite. Unionized ammonia is a fraction of total ammonia which is toxic to fish. It increases with increasing temperature and pH.

Inlake Water Quality

During the study period, 6 inlake sample sets were collected by the local sponsor. Four samples were collected in 1993 and two samples were collected in 1994. An additional 16 statewide water quality assessment samples were taken between 1991 and 1995. Six of the 16 samples were collected between 1993 and 1994, during the study period. Although the statewide water quality samples were a composite of three samples rather than grab samples, they still can be used to assess the water quality of Lake Mitchell.

The following discussion will be based on individual parameters. The discussion will include the importance of the parameter and its effect on the water quality of Lake Mitchell.

<u>Water Temperature</u>

Water temperature is important to the biology of a lake as it effects many chemical processes in the lake. Higher temperatures increase the potential for raising the un-ionized (toxic to fish) fraction of ammonia. Algae have optimal temperature ranges for growth. Blue-green algae are more prevalent in warmer waters. Green algae and diatoms are often found to be more dominate in cooler waters. Fish life and propagation are also dependent on water temperature. Summer temperatures in Lake Mitchell averaged 21.2^{o}C for the bottom samples and 23.9^{o}C for the surface for all samples collected over the years. There is not a permanent themocline in Lake Mitchell. The temperature in the lake usually starts to drop between 10 and 15 feet below the surface. Overall the lake temperature varies little from surface to bottom. Temperature and oxygen profiles are located in Appendix A.

<u>Dissolved Oxygen</u>

Dissolved oxygen changes with the growth and decomposition of living organisms in a lake system. As algae and plants grow, they release oxygen into the lake system. When living organisms decompose, they take oxygen out of the system. Dissolved oxygen can also change at the air-water interface. Wave action and other turbulence can increase the oxygen level of a lake. Dissolved oxygen averaged 8.29 mg/L in the surface samples and dropped to 4.37 mg/L in the bottom samples. The lowest dissolved oxygen level (0.37 mg/L) was recorded in the bottom sample on 7/12/95. Although this concentration is low enough to cause a fish kill, the dissolved oxygen concentration near the surface of the lake on the day was 9.30 mg/L. Fish will typically migrate to the depth of the water which has the coolest temperature and sufficient oxygen. Approximately 11 feet (3.35 meters) from the surface, the temperature was 24^{o}C and the dissolved oxygen was 7.5 mg/L. Fish could easily move to an area with sufficient temperature and oxygen. There have been no reported fish kills in Lake Mitchell.

The majority of the algae present in Lake Mitchell are blue-green algae. These algae can increase the oxygen concentration where they bloom. According to the algal samples collected, there is 30 to 60 times more algae near the surface of the lake than at the bottom. As the algae bloom, it also makes the water more turbid and less light can reach the deeper depths. Aphanizomenon, the dominate summer algae, forms gas cellular vaculoes which allow it to adjust its buoyancy and position in the water column. This bouyancy allows Aphanizomenon to bloom wherever it can find optimal conditions. These blooms can occur at the mid depths or on the surface where they become more obvious. Since algae need light to grow, Aphanizomenon, can prevent other algal cells from developing at deeper depths. The absence of algal growth means no oxygen is being produced at the lower depths. As the algae die, they fall to the bottom where the organic rich sediments begin to decompose and use oxygen. Increased decomposition also leads to lower hypolimnetic oxygen concentrations.

The oxygen level falls, dramatically at times, at depths of 10 - 15 feet (3 - 4.5 meters). Usually the decrease in oxygen coincides with the slight temperature decrease which would indicate some shading by the surface algae effecting the light penetration. Sharp decreases in dissolved oxygen levels have been recorded in late July and in August. These months appear to have the optimal temperature and light conditions for large blue green algal blooms (as discussed in the phytoplankton section of this report). The optimal conditions create the shading effect as stated earlier, and the warmer summer temperatures near the sediments increase the decomposition of organic manner. Both of these incidents result in the decline of oxygen in the hypolimnion (lower part of the lake).

A negative impact of low oxygen near the sediments of a lake is the release of phosphorus from the sediments. As the oxygen levels approach 2 mg/L or less near the sediment water interface, a natural barrier called a microzone is depleted and nutrients are released into the water column. This process, called internal loading, can greatly increase the productivity of a lake (Wetzel, 1983).

pH

pH is the measure of the hydrogen ion (H^+). More free hydrogen ions lower the pH. During decomposition, carbon dioxide (CO_2) is released from the sediments. The carbon dioxide reacts with water to create carbonic acid (H_2CO_3). The carbonic acid creates bicarbonate (HCO_3^-) and hydrogen (H^+). Bicarbonate is converted to carbonate (CO_3) and another hydrogen ion (H^+). These extra hydrogen ions created from decomposition will tend to lower the pH in the hypolimnion. Increases in the different species of carbon (CO_2, HCO_3, and CO_3) come at the expense of oxygen (O_2). Decomposers will use oxygen to break down the material into the carbon species. Also, the lack of light in the hypolimnion prevents plant growth, so no more oxygen can be created. Typically, the higher the decomposition rates, the lower oxygen concentrations in the hypolimnion and lower the pH. An extreme example of low pH due to decomposition is extremely organic-rich bog environments.

Opposite low pH concentrations near the bottom of the lake, plants raise pH near the surface of the water. Plants use carbon dioxide during photosynthesis and release oxygen into the system. The loss of carbon dioxide during photosynthesis typically increases the pH.

Lake Mitchell experienced the typical pH scenario explained above. The pH at the surface of the lake was higher than the pH at the bottom of the lake. The decomposition of the organic matter in the bottom of the lake reduced the pH slightly, the surfaced averaged 8.3 su and the bottom averaged 8.0 su. The pH levels in Lake Mitchell are not extreme at any level. The relatively high alkalinity levels in Lake Mitchell work to buffer dramatic changes. Since increases in decomposition decrease pH, pH can be an indication of increased organic matter in a lake.

Alkalinity

Alkalinity refers to the quantity of different compounds that shift the pH to the alkaline side of neutral (>7). Alkalinity is usually dependent on geology. Ranges in natural environments usually range from 20 to 200 mg/L (Lind, 1985). The average alkalinity in Lake Mitchell was 189 mg/L and the median was 188 mg/L. The alkalinity in Lake Mitchell was relatively stable and the higher concentration probably helped keep the pH from decreasing too much in the bottom samples. Because alkalinity is mostly a result of the natural environment, the concentrations should never change too dramatically.

Solids

Total solids are all the materials, suspended and dissolved, present in water. Dissolved solids include materials which pass through a filtered water sample. Suspended solids are the materials which do not pass through a filtered water sample. Total dissolved solids concentrations were derived by subtracting the suspended solids from the total solids. The dissolved solid concentrations in Lake Mitchell averaged 683 mg/L with a median of 666 mg/L. The dissolved solids are typically made up of the salts and compounds which keep the alkalinity high. There is very little change in total dissolved concentrations from year to year and from surface to bottom samples.

Total suspended solids in the surface samples of Lake Mitchell averaged 8 mg/L. Algae probably made up the majority of the suspended solids in the surface samples. The summer suspended solids concentrations were much higher than the winter concentrations due to reduced algae and reduced tributary inputs.

The bottom samples had higher concentrations of suspended solids than the surface samples. The average concentration of the bottom samples was 18 mg/L and the median was 16 mg/L. Algae, organic matter and fine particles suspended off the bottom increased the concentrations of the bottom samples. Often the sample bottle will be close enough to the bottom to collect the fine particles that float just above the sediments. The suspended sediment concentrations are not particularly high considering the amount of algae and other organic matter present in the lake.

Ammonia (un-ionized ammonia)

Ammonia is the end product of bacteria decomposition of organic matter and is the form of nitrogen most readily available to plants for uptake and growth. High ammonia concentrations can be used to demonstrate organic pollution. The bottom samples averaged 0.27 mg/L (median 0.26 mg/L). This average concentration is twice as high as the ammonia concentration in the surface samples - 0.13 mg/L (median 0.12 mg/L). The decomposition of the organic matter in the bottom sediments of the lake is greater than the decomposition at the surface, and is probably responsible for the increased ammonia concentrations (Cole, 1983). The highest concentrations occurred in the bottom samples in June July and August. The maximum concentration (0.82 mg/L) was sampled on August 13, 1994. As mentioned in the standards discussion, the standard for ammonia is based on the un-ionized fraction of ammonia. Un-ionized ammonia is toxic to fish in concentrations above 0.05 mg/L. On August 13, 1994, the un-ionized fraction of ammonia was 0.07 mg/L. Un-ionized ammonia is calculated from ammonia and dependent on water temperature and pH. Increases in temperature and pH, increase the percentage of un-ionized ammonia. The warm weather of August, coupled with the increases in pH, increased the percentage of the un-ionized fraction of ammonia. By reducing the inputs of nutrients to the lake, the amount of organic matter to be decomposed will also be decreased, thus decreasing the ammonia and un-ionized ammonia in the system.

Nitrate and Nitrite

Nitrate and nitrite are inorganic forms of nitrogen easily assimilated by algae and other macrophytes. Sources of nitrate and nitrite can be agricultural practices and direct input from effluent, septic tanks, or other forms of waste. Nitrate and nitrite can also be converted from ammonia through denitrification by bacteria. The process of denitrification that converts nitrate and nitrite to free nitrogen (N^2) usually takes place in the lower strata of lakes. The process increases with increasing temperature and decreasing pH.

Decomposing bacteria in the sediments and blue green algae in the water column can convert the free nitrogen (N^2) to ammonia. Blue green algae can use the ammonia for growth. Although algae use both nitrate-nitrite and ammonia, highest growth rates are found when ammonia is available (Wetzel, 1983). Since nitrogen is water soluble, and blue green algae can convert its own usable nitrogen, it is very difficult to remove nitrogen from a lake system.

There was very little difference in the surface and bottom sample concentrations for nitrate and nitrite in Lake Mitchell. The surface sample average was 0.16 mg/L and the bottom sample averaged 0.14 mg/L. The median, minimum and maximum concentrations were also very similar for the surface and bottom samples.

Total Kjeldahl Nitrogen / Organic Nitrogen

Total kjeldahl nitrogen is used to calculate both organic nitrogen and total nitrogen. Total kjeldahl nitrogen minus ammonia equals organic nitrogen. Total kjeldahl nitrogen plus nitrate and nitrite are equal to total nitrogen. Organic nitrogen can be released from decaying organic matter or it can enter the lake system by septic systems or agricultural waste. Organic nitrogen is broken down to usable ammonia and other inorganic forms of nitrogen. The organic nitrogen concentration mean and median of the surface samples were 1.14 and 0.98 mg/L, respectively. Mean and median bottom sample concentrations were 0.96 and 0.90, respectively. The highest concentration of organic nitrogen (3.5 mg/L) was sampled at Site #12 near the surface on June 13, 1994. The surface samples usually had higher concentrations than the bottom samples due to the amount of organic matter (algae) near the surface. Near the bottom the organic matter was being decomposed into other forms of nitrogen.

Total Nitrogen

Total nitrogen is the sum of the nitrate-nitrite and the total kjeldahl nitrogen concentrations. Since Lake Mitchell is classified as a drinking water source, there is a more stringent water quality standard for nitrogen compared to most lakes, 10 mg/L. The total nitrogen concentration did not come close to exceeding the water quality standard. The maximum total nitrogen concentration found in Lake Mitchell was 3.81 on June 13, 1994. The surface and bottom samples were fairly similar in total nitrogen concentrations. The mean for the surface and bottom samples were 1.43 mg/L and 1.37 mg/L respectively. The total nitrogen concentrations in Lake Mitchell showed little variation. The concentrations for the surface samples only varied 0.55 mg/L from the mean and the bottom sample only varied 0.31 mg/L from the mean. The overall concentrations of total nitrogen in Lake Mitchell are not inordinate. As stated earlier, nitrogen is water soluble and can enter a lake system through a variety of avenues. Due to the many sources of nitrogen; atmosphere, soil, fertilizer, and fecal matter, nitrogen is difficult to remove from a water system. Also, since blue green algae can convert nitrogen for their own growth, the focus on nutrient reduction should be on phosphorus instead of nitrogen. This report does not advocate ignoring nitrogen. Any measures to reduce excess nitrogen from entering the lake should be explored.

Total Phosphorus

Typically, phosphorus is the single best chemical indicator of the health of a nutrient rich lake. Algae need as little as 0.020 mg/L of phosphorus for blooms to occur. Phosphorus differs from nitrogen in that it is not as water soluble and will sorb on to sediments and other substrates. Once phosphorus sorbs on to any substrate it is not readily available for uptake by algae. Phosphorus sources can be natural in the geology and soil, from decaying organic matter, and waste from septic tanks or agricultural run-off. Once phosphorus enters a lake it may become part of the sediments of the lake. Typically, phosphorus in the sediments will remain there unless released by the loss of oxygen and the reduction of the redox potential of the microzone. The microzone is located at the sediment water interface. As the dissolved oxygen levels are reduced the ability of the microzone to hold phosphorus in the sediments is also reduced. The resuspension of phosphorus into a lake from the sediments is called internal loading and can be a large contributor of the phosphorus available to algae. It is very difficult to accurately estimate internal loadings.

Inlake phosphorus concentrations in Lake Mitchell averaged 0.278 mg/L (median 0.207 mg/L) in the surface samples and 0.320 (median 0.232 mg/L) in the bottom samples. There was quite a large variance from the mean of the phosphorus concentrations. The samples collected reported a standard deviation of 0.184 mg/L for the surface and 0.202 mg/L for the bottom samples. The range of the total phosphorus samples varied from 0.069 mg/L, a surface composite sample taken on July 12, 1995, to 0.770 mg/L which was bottom composite sample collected on August 18, 1993. Most of the higher phosphorus concentrations were taken in late July and August. The highest tributary loads and concentrations also entered the lake at this time. However, the dissolved oxygen levels were also lowest during this period so it is not possible to say whether internal loadings or tributaries were primarily responsible for the increased phosphorus concentrations.

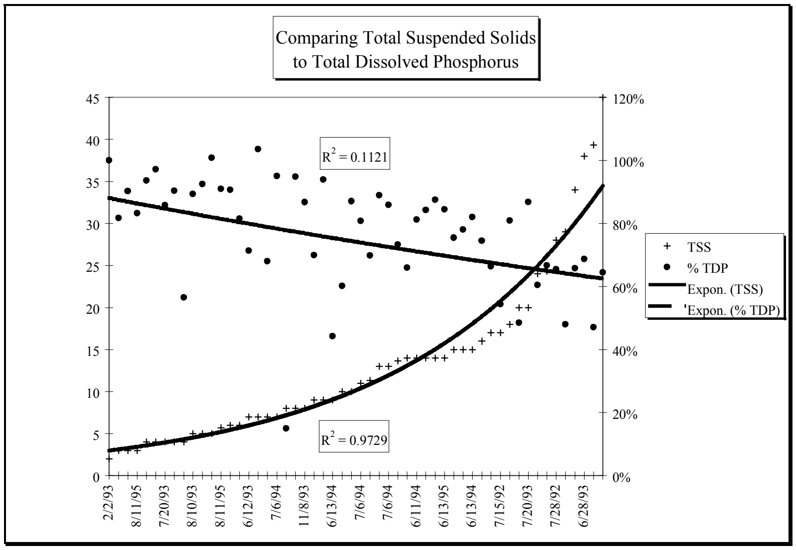
The large algal blooms in Lake Mitchell typically coincide with large phosphorus concentrations. By dramatically reducing the amount of phosphorus entering Lake Mitchell, the duration and intensity of the algal blooms would be reduced.

Total Dissolved Phosphorus

Total dissolved phosphorus is the fraction of total phosphorus that is readily available for use by algae. Dissolved phosphorus will sorb on to suspended materials if they are present in the water column. As found in the tributary samples, there is little suspended sediment in Lake Mitchell so a majority of the phosphorus is dissolved and available to algae (77% in both surface and bottom samples). When total dissolved phosphorus is compared to total suspended solids a slight inverse relationship exists (Figure 16). As the concentration of suspended solids increase, the percentage of the dissolved phosphorus concentration decreases.

The total average concentration of dissolved phosphorus available to algae is 10 times the amount necessary to stimulate algal growth. The maximum dissolved phosphorus reading (0.727 mg/L) was taken at a bottom sample on August 10, 1993. The average concentrations of the bottom samples were slightly higher than that of the surface sample probably due to the release of phosphorus from the sediments. Also the surface samples have more algae present which is using the available dissolved phosphorus, effectively lowering the dissolved phosphorus concentrations.

Figure 16.



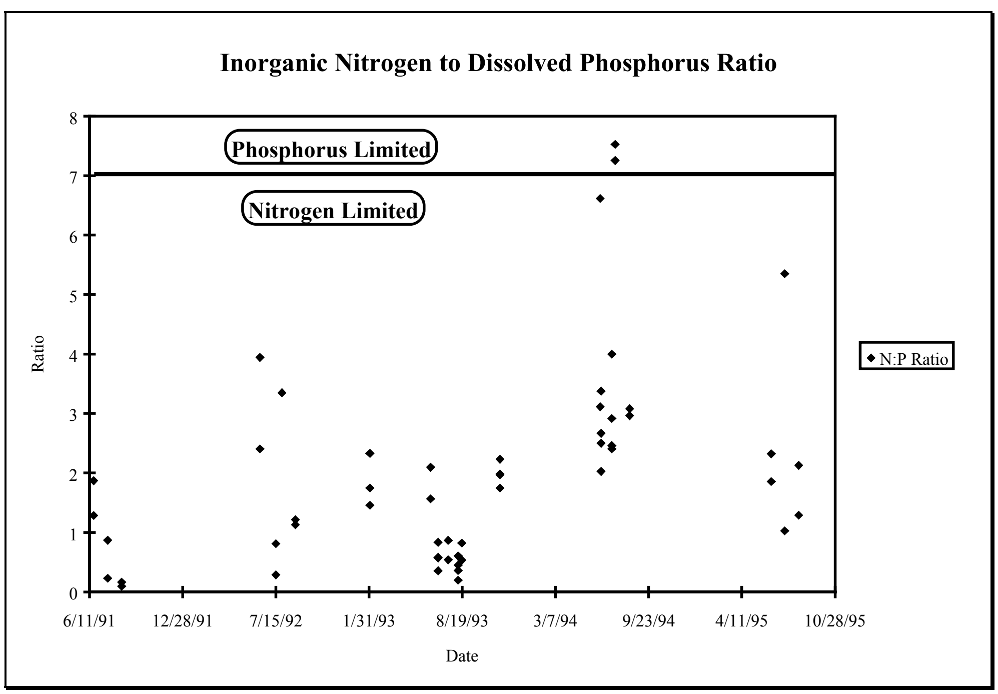
Limiting Nutrient

If an organism (algae) is to survive in a given environment, it must have the necessary nutrients and environment to maintain itself and be able to reproduce. If an essential material approaches a critical minimum, this material will be the limiting factor (Odum, 1959). Phosphorus is often the nutrient that is limiting in aquatic ecosystems. However, a number of highly eutrophic lakes in eastern South Dakota are known to develop nitrogen limitation. If the lake has very abundant phosphorus concentrations, the algal growth is considered to be limited by available nitrogen.

In order to determine which nutrient will tend to be limiting, EPA (1980) has suggested a total nitrogen to total phosphorus ratio of 15:1. They also suggest an inorganic nitrogen to dissolved phosphorus ratio of 7:1 (Figures 17 and 18). EPA (1990) later suggested a 10:1 ratio for total nitrogen to total phosphorus ratio, and no suggestion for the inorganic parameters. Due to the high dissolved phosphorus ratios in Lake Mitchell, the report will refer to the 1980 document. If the ratio of nitrogen divided by phosphorus is greater than either 15:1 or 7:1, the lake is assumed to be phosphorus limited for the respective parameters. A ratio less than any of the above mentioned ratios, assumes the lake is nitrogen limited.

Figure 17.

Figure 18.

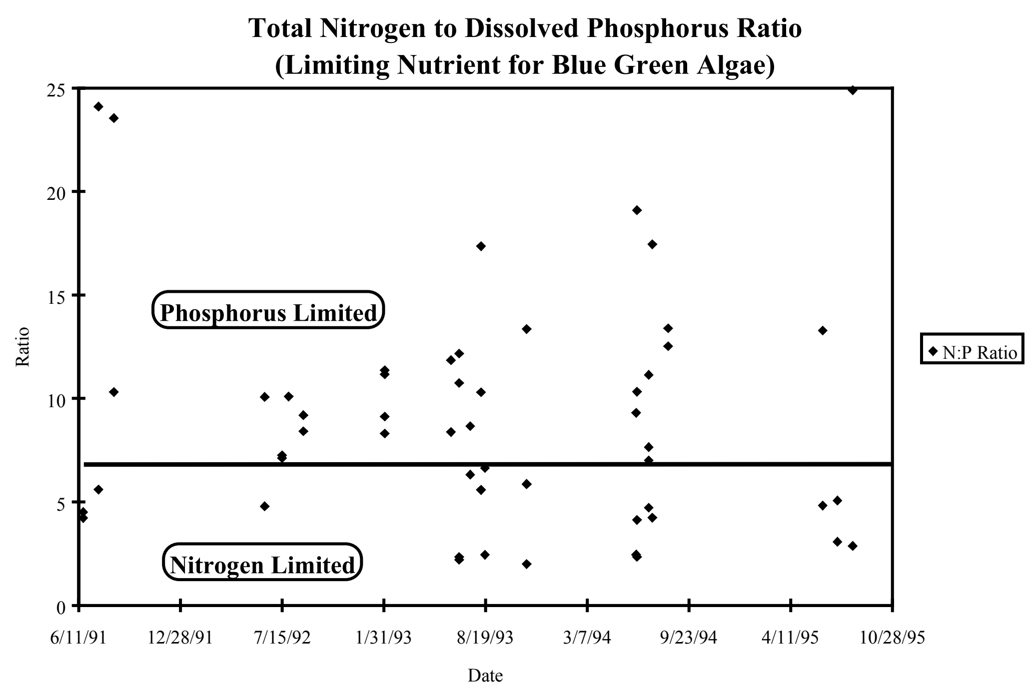


In both cases the ratios indicate a nitrogen limited lake (Figures 17 and 18). For the total nitrogen and total phosphorus, the average ratio was 6.5:1 (phosphorus limit is 15). The inorganic nitrogen and the dissolved phosphorus averaged 1.8:1 (phosphorus limit of 7).

As mentioned earlier in the discussion of nitrogen, blue green algae can assimilate usable nitrogen from the organic fraction of nitrogen. To see if the blue green algae were still limited by nitrogen, assuming they were assimilating their own nitrogen, total nitrogen (organic and inorganic) was divided by dissolved phosphorus. Using the ratio limitation for the inorganic parameters, (7:1 as nitrogen and phosphorus limit split), the blue greens appear to be phosphorus limited (9.23:1 average). Figure 19 clearly shows more ratios appearing in the phosphorus limited section of the graph.

Nutrients, however, are not the only thing that can limit the growth of algae in a lake. Changes in the environment such as temperature and light can also effect algal growth. Due to the large surface algal blooms in Lake Mitchell, the shading effect by the algae may also be considered as a limiting factor.

Figure 19.



Trophic State Index

Carlson's (1977) Trophic State Index (TSI) is an index that can be used to measure the relative eutrophic state of a waterbody. The eutrophic state is how much production occurs in the waterbody. The smaller the nutrient concentrations are in a waterbody, the lower the trophic level and the larger the nutrient concentrations are, more eutrophic the waterbody. Oligotrophic is the term used to describe the least productive lakes and hyper-eutrophic is the term used to describe lake with excessive nutrients and production. Table 6 describes the different numeric limits with the various levels of the Carlson Index.

Table 6. Trophic Index Levels

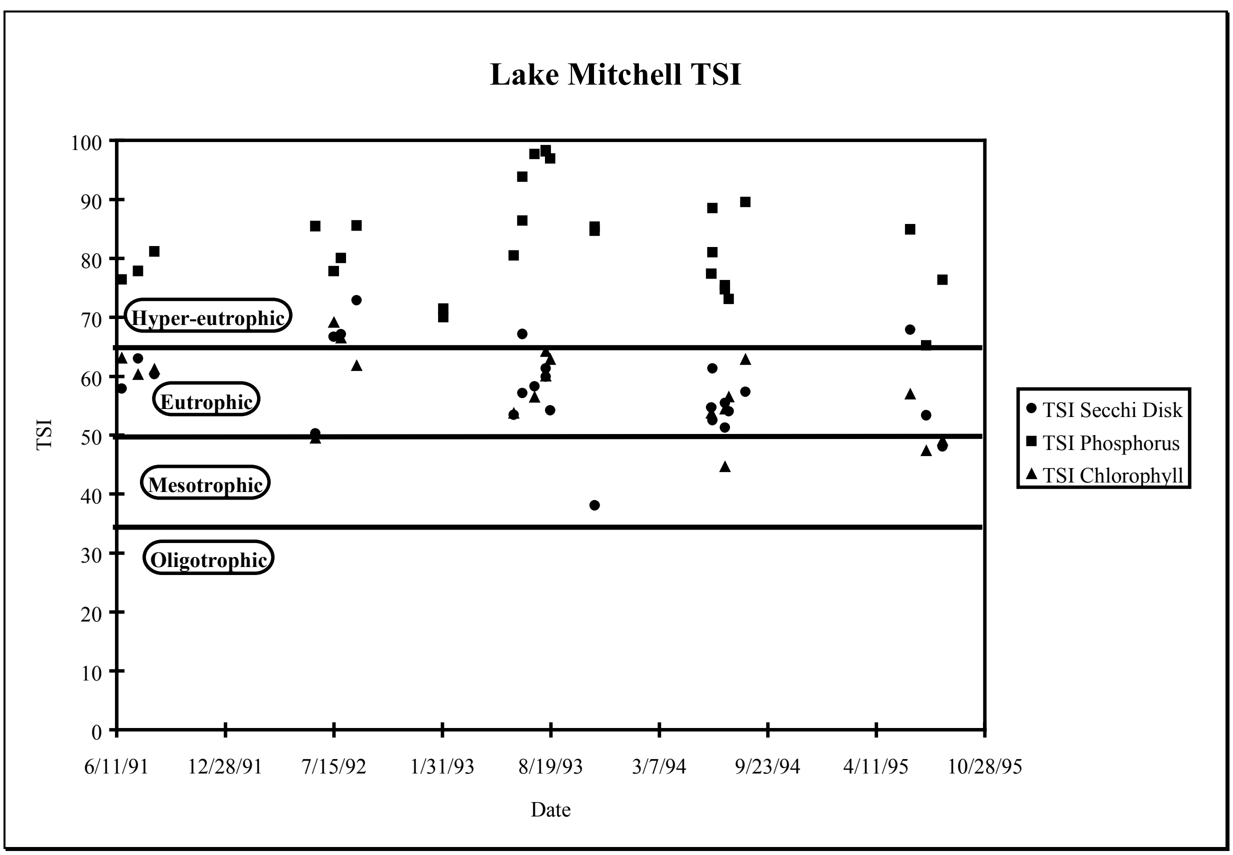
Tropic Level	Numeric Range
Oligotrophic	0 -- 35
Mesotrophic	36 -- 50
Eutrophic	51 -- 64
Hyper-eutrophic	65 -- 100

Three different parameters can be used to compare the TSI level of a lake; 1) total phosphorus, 2) secchi disk, and 3)chlorophyll. The TSI levels are shown on Table 7 and a graph of all the TSI readings is shown on Figure 20.

Table 7. Average Trophic State Index Levels for Lake Mitchell

Parameter [illegible]	Secchi Depth	Chlorophyll *a*	Total Phosphorus
Mean	56.99	57.71	82.63
Median	57.26	58.48	81.08
Standard Deviation	8.27	6.64	8.89

Figure 20.

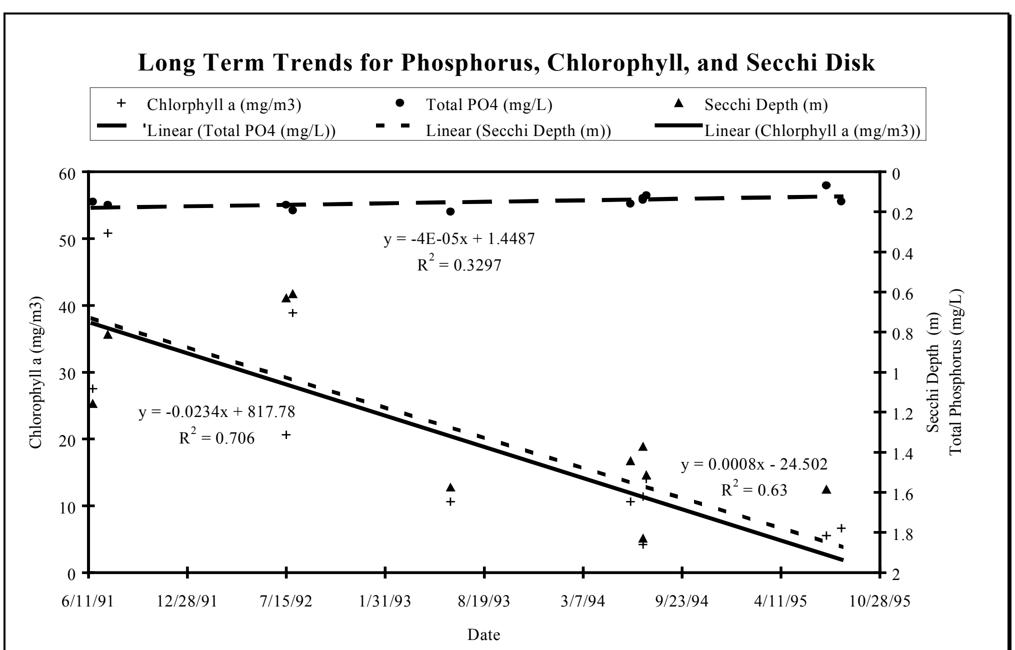

Lake Mitchell TSI
100
90
80
70
60
50
40
30
20
10
0
TSI
Hyper-eutrophic
Eutrophic
Mesotrophic
Oligotrophic
6/11/91
12/28/91
7/15/92
1/31/93
8/19/93
3/7/94
9/23/94
4/11/95
10/28/95
Date
TSI Secchi Disk
TSI Phosphorus
TSI Chlorophyll

The mean and median of the total phosphorus are far into the hyper-eutrophic level of the index. The secchi depth and chlorophyll *a* are in the middle of the eutrophic level. The phosphorus TSI calculations are another indication of the excessive amounts of nutrients in Lake Mitchell. Over the 5 years in which data was collected, the overall trophic status of Lake Mitchell is approximately 67, close to the line between eutrophic and hyper-eutrophic. The samples collected in 1993 seem to have a much higher TSI rating than any other year. The 1993 sampling season was extremely wet, and because of the increased inflow, more suspended solids and nutrients from the watershed were deposited to the lake. The rains of 1993 were also the end of an extended dry period. If a reservoir does not receive sufficient volumes of water to flush phosphorus out of the lake, the internal loading can greatly increase. Since 1993, the overall trend of the TSI levels in Lake Mitchell is decreasing.

Long Term Trends

Because there are a number of summer water quality samples collected over several years, it is possible to make some assumptions about the water quality of Lake Mitchell over time. During the last few years, Lake Mitchell appears to be flushing out many of its nutrients. Figure 21 shows all summer samples that have a complete set of parameters including a phosphorus, chlorophyll and a secchi disk sample. From the graph you can clearly see the drop in chlorophyll concentrations and an increase in secchi depth. Due to the large scale used on the right side of the graph, the drop in phosphorus concentrations does not appear as dramatic, however, there is a slight trend towards less inlake phosphorus. The graph also shows an interesting correlation between the drop in chlorophyll and the increase in secchi depth readings. As stated earlier, in 1993, there was actually a loss of phosphorus from the lake system. If the wet years continue, more of the trapped nutrients may be flushed out of the lake.

Figure 21.



Biological Monitoring

Phytoplankton

Lake Mitchell supports a large variety and concentration of algae over a typical growing season. Algal samples collected in Lake Mitchell on April 20, 1994, indicated the presence of a considerable spring bloom of small-sized (mostly 7-15 micro meter dia.) centric diatoms of the Stephanodiscus hantzschii group. These were present at a density of 20,790 cells/ml and comprised 78% of the total reservoir algal population on the above sampling date. A late April bloom of S. hantzschii of similar magnitude was reported for Lake Poinsett in 1971 (Applegate et al. 1973). The duration of that bloom was slightly more than two weeks. Other algal phyla in Lake Mitchell were relatively sparse on the April sampling date, particularly blue-green algae (Table 8).

Blue-green algae, predominantly Aphanizomenon flos-aquae, had increased sharply by the next sampling date on July 6,1994, particularly at Site #12. Aphanizomenon density recorded at that site was 534 filaments/ml, or approximately 26,700 cells/ml, while the population at Site #13 was 184 fils/ml (9200 cells/ml) or nearly three times smaller (Table 8). In terms of number of cells per milliliter, Aphanizomenon comprised nearly 96% of the algal population at Site #12 and 89% at Site #13. In eastern South Dakota lakes and reservoirs, summer nuisance blue-green blooms often begin to develop in mid or late June. These blooms build up to maximum densities from July through September and decline steeply in October with the seasonal drop in water temperature.

The large spring population of small-sized diatoms had collapsed to less than 50 cells per milliliter by the first week in July. In early summer 1994, flagellated algae of the phylum Cryptophyta (cryptomonads) represented the second most common algal group collected in the reservoir. A small (10-15 micro meter) flagellate, tentatively identified as Chroomonas sp., made up 96% of the cryptomonads with an average density of 600 cells/ml in the surface samples from both sites. Early July reservoir populations of non-motile and motile green algae (Chlorophyta) appeared to be small averaging only 152 cells/ml combined.

Samples collected the previous summer (August 10,1993) disclosed a surface bloom of Aphanizomenon flos-aquae at a density of 345 filaments/ml (or 10350 cells/ml) at Site #13. The density of Aphanizomenon increased nearly three times (1020 fils/ml) at upstream Site #12, a distribution pattern that was again observed in July 1994, as noted above (Table 8). In terms of number of cells per milliliter, Aphanizomenon made up 86% of total algae at Site #12 but only 66% at Site #13 (for surface samples). Melosira granulata represented the dominant diatom species in Lake Mitchell in August and together with Aphanizomenon is considered an indicator of eutrophic conditions in hardwater prairie lakes (Hutchinson 1957).

Table 8. Lake Mitchell Algal Counts

Algae Type	10 August 1993				20 April 1994	6 July 1994	
	Site 12 Surface cells/ml	Site 12 Bottom cells/ml	Site 13 Surface cells/ml	Site 13 Bottom cells/ml	Composite cells/ml	Site 12 Surface cells/ml	Site 13 Surface cells/ml
Blue-Green Algae							
Aphanizomenon flos-aquae	30600 (1020 *fils/ml)	0	10350 (345 fils/ml)	90 (3 fils/ml)	0	26700 (534 fils/ml)	9200 (184 fils/ml)
Chroococcus sp. ?	0	0	0	0	0	285 (19 col/ml)	345 (23 col/ml)
Dactylococcopsis sp.	0	0	0	0	50	0	0
Total Blue-Green Algae	30600	0	10350	90	50	26985	9545
Flagellated Algae							
Cryptomonas spp.	680	6	300	13	4	29	18
Chroomonas spp.	740	4	430	16	20	604	596
Chlamydomonas spp.	560	5	355	22	270	0	0
Pandorina morum	1600 (100 **col/ml)	20 (2 col/ml)	2480 (155 col/ml)	96 (6 col/ml)	15 (1 col/ml)	0	12 (1 col/ml)
Mallomonas sp.	20	0	5	0	0	0	2
Trachelomonas spp.	0	2	25	3	40	5	2
Euglena gracilis	0	12	5	2	0	0	0
Euglena oxyuris	0	3	0	2	0	0	0
Euglena sp.	0	0	0	0	2	1	0
Phacus sp.	0	4	0	2	0	0	0
Strombomonas sp.	0	0	0	1	0	0	0
Pteromonas sp.	0	0	0	0	20	0	0
unidentified small dinoflagellates	20	1	20	0	0	0	0
unidentified flagellates	0	9	0	4	0	0	0
Total Flagellated Algae	3620	66	3620	161	371	639	630
Algae Type	10 August 1993				20 April 1994	6 July 1994	

	Site 12 Surface cells/ml	Site 12 Bottom cells/ml	Site 13 Surface cells/ml	Site 13 Bottom cells/ml	Composite cells/ml	Site 12 Surface cells/ml	Site 13 Surface cells/ml
Diatoms							
Melosira granulata (2 varieties)	900 (90 fils/ml)	410 (41 fils/ml)	1150 (115 fils/ml)	470 (47 fils/ml)	20 (3 fils/ml)	13 (1fil/ml)	0
Melosira varians	0	0	0	0	7 (1 fil/ml)	0	0
Stephanodiscus hantzschii	0	0	0	0	20,790	0	0
Stephanodiscus niagarae	0	0	0	0	41	0	0
Stephanodiscus spp.	0	5	0	0	0	41	0
Nitzschia vermicularis	0	0	0	0	5	0	31
Nitzschia sigma	0	0	0	0	2	0	0
Nitzschia sp.	0	0	0	0	15	0	0
Nitzschia acicularis	0	2	0	0	4	0	0
Synedra sp.	0	2	5	0	0	0	0
unidentified pennate diatoms	0	4	0	0	1	0	0
Navicula sp.	0	0	10	0	1	0	6
Fragilaria capucina	0	0	0	0	60 (1 fil/ml)	0	0
Surirella sp.	0	0	0	0	15	0	0
Surirella sp. #2	0	0	0	0	1	0	0
unid. small centric diatoms	0	0	25	0	0	0	0
Total Diatoms	900	423	1190	470	20,962	55	37

*fils = filaments
**col = colonies

Table 8 continued

Algae Type	10 August 1993				20 April 1994	6 July 1994	
	Site 12 Surface cells/ml	Site 12 Bottom cells/ml	Site 13 Surface cells/ml	Site 13 Bottom cells/ml	Composite cells/ml	Site 12 Surface cells/ml	Site 13 Surface cells/ml
Green Algae							
Schroederia setigera	80	28	90	56	0	10	14
Schroederia judayi	20	1	15	0	0	0	0
Scenedesmus spp.	120 (20 col/ml)	4 (1 col/ml)		28 (5 col/ml)	24 (6 col/ml)	0	0
Crucigenia tetrapedia	40 (10 col/ml)	4 (1 col/ml)	0	0	0	0	0
Crucigenia sp.	0	0	50 (5 col/ml)	0	0	0	0
Characium sp.						130	83
Tetraedron sp.	10	0	0	1	0	0	0
Oocystis sp	40 (10 col/ml)	7	25 (5 col/ml)	11 (3 col/ml)	0	8 (2 col/ml)	0
Ankistrodesmus falcatus	10	0	0	0	200	0	0
Kirchneriella sp.	0	0	0	0	30	27	12
Closteriopsis longissima	0	1	0	0	2	0	0
Pediastrum duplex	0	24 (2 col/ml)	160 (10 col/ml)	48 (3 col/ml)	0	0	0
unidentified small green cells		6 (1 col/ml)	0	0	0	0	0
Micractinium sp.	0	0	90 (10 col/ml)	0	10 (1 col/ml)	0	0
Actinastrum sp.	0	0	0	0	8	0	0
Total Green Algae	320	75	430	144	274	175	109

Table 8 continued

Algae Type	10 August 1993				20 April 1994	6 July 1994	
	Site 12 Surface cells/ml	Site 12 Bottom cells/ml	Site 13 Surface cells/ml	Site 13 Bottom cells/ml	Composite cells/ml	Site 12 Surface cells/ml	Site 13 Surface cells/ml
unidentified single small round cells:							
green/greenish/blue-green cells	0	17	190	35	2590	31	12
brown cells	0	0	0	0	2080	0	0
blue-green cells	0	0	0	0	280	0	0
Grand Total Algae	35,440	581	15,780	900	26,607	27,885	10,333

*fils = filaments
**col = colonies

Melosira granulata frequently attains maximum annual abundance during late summer in eastern state lakes. In Lake Mitchell it was more common at the deeper Site #13 (Table 8). Organic enrichment of the reservoir waters may be indicated by the abundance of green flagellated (motile) algae such as Pandorina, Chlamydomonas, and various euglenoids.

The striking difference in algal density between surface and bottom samples in August 1993 is somewhat unusual for shallow lakes. The mixing action exerted by strong summer winds normally results in at least a roughly similar algal density throughout the water column. The mixing is a partial consequence of the destruction by wind and wave action of any thermocline that may have formed in warm weather. The pronounced differences observed in the vertical distribution of the planktonic algae strongly suggest the absence of any appreciable mixing between the shallow and deeper water strata in Lake Mitchell during late summer.

This temporary or seasonal isolation of shallow and deep water layers is created by unequal warming which results in the formation of a water density gradient known as a summer thermocline in eutrophic lakes. In relatively turbid productive waterbodies, there is not sufficient light remaining in the deeper water strata for the maintenance of algal photosynthesis. Algal numbers decrease sharply unless replenished by water mixing with the well-lit surface layers where most algal production takes place. The evidence in Table 8 suggests that conditions of stratification where there is little or no mixing of the water column, may occur at least intermittently in Lake Mitchell during summer.

Taste and odor problems reported in reservoir drinking water may be caused by the large algal population observed in Lake Mitchell during this study. Large accumulations of organic matter from the sizable reservoir watershed of nearly 350,960 acres may also contribute to taste and odor problems. Living algal cells, if present in sufficient numbers, can impart disagreeable taste and odor to drinking water while decaying algae and organic matter also produce objectionable tastes and odors. This may be the result of the products of decomposition such as hydrogen sulfide, ammonia, and a number of organic compounds. Seasonally abundant algae in Lake Mitchell that have been specifically found to cause undesirable effects in other water supply reservoirs include Stephanodiscus, Aphanizomenon, Chlamydomonas, Pandorina, and Melosira (Palmer 1962). In general, problems in drinking water palatability frequently result when eutrophic reservoirs need to be used as sources of potable water. Taste and odor problems may be due to the large algal populations and considerable amounts of organic matter that typically occur in those productive waterbodies.

A water sample collected on July 6,1994 from the raw water intake pipeline of the Lake Mitchell water treatment facility indicated few larger algal cells were entering the pipe on that date. Counts with a Sedgwick-Rafter chamber at 100x magnification resulted in a tally of 59 cells/ml, 88% of which consisted of the filamentous diatom taxon Melosira granulata. Those, as well as a few other diatoms appeared to be in a moribund state or consisted of only bare shells (frustules). Chlorophyll analysis of the water sample seemed to support those observations. Of the total chlorophyll value of 3.6 milligrams/cubic meter (mg/m^3) obtained, a subsequent procedure showed that 64% was non-viable or ‘dead’ chlorophyll. This large percentage was similar to that obtained on August 1993 for the bottom water sample at Site #13 which is in the general vicinity of the intake of the pipeline. The intake is placed approximately 6 feet above the lake bottom in 25 to 26 feet of water. The same sample at higher magnification contained what appeared to be mostly organic particles with possible bacteria and relatively few very small green and blue-green algal cells.

A sample of facility-treated water collected at the same time as the above raw water sample, contained no recognizable algal cells. This sample did contain a moderate amount of relatively coarse organic and mineral detritus and a small amount of finer (< 10 microns) detritus. Total chlorophyll *a* measured in this sample amounted to only 0.4 mg/m^3. This concentration is very likely below the detection limit of the instrument used for the measurements. No chlorophyll value can therefore be ascribed with any confidence for this sample.

<u>Chlorophyll a</u>

Chlorophyll *a*, a pigment in plants and blue-green algae, may be used to estimate the amount of algae found in a certain sample. Chlorophyll *a* samples were collected on 4 dates in 1993. Three of these samples were collected for the state lake assessment. Typically only surface samples of chlorophyll *a* are analyzed and, as stated above, expressed in units of milligrams/ cubic meter (mg/m^3). Due to light restrictions, chlorophyll *a* concentrations near the bottom of the lake are not representative of the nutrients in the waterbody. For the project however, 2 bottom samples were collected to see if chlorophyll *a* concentrations were high at the intakes of the treatment plant. The bottom samples collected on August 10, 1993, showed concentrations at 5.36 and 8.04 mg/m^3 compared to 30.82 and 20.10 mg/m^3 for the surface samples at the respective sites. The bottom samples are significantly less than the surface samples. There was also a difference in the chlorophyll *a* concentrations of the surface samples collected at the two different inlake sites. Chlorophyll *a* samples collected at Site #12 were higher in concentration than Site #13. On August 8, 1993, Site #12 reported 30.28 mg/m^3 and Site #13 reported 20.10 mg/m^3. July 6, 1994, Lake Mitchell had surface chlorophyll concentrations of 11.39 and 4.19 mg/m^3 for Sites #12 and #13 respectively. Site #12 is only 10 to 12 feet (3 to 3.5 meters) and Site #13 is approximately 26 feet (8 meters) deep. The shallower depth contributes to warmer water temperatures which could increase algal production. The total phosphorus concentrations are also slightly higher at Site #12 on both occasions.

Surface chlorophyll *a* samples were also collected during the summers from 1991 - 1995 for the statewide lake assessment. The chlorophyll *a* samples collected for the assessment were composite samples taken from three different locations on the lake. From 1991 - 1995 the spring and summer calculated Carlson’s TSI values for chlorophyll *a* ranged from 52 in 1995, to nearly 64 in 1992. These annual values place Lake Mitchell in a eutrophic category. Chlorophyll *a* concentrations (averages) corresponding to the above TSIs ranged from 9 mg/m^3 to nearly 30 mg/m^3. The former low reading may have resulted from increased rainfall in the watershed during 1995 which may have flushed and/or diluted reservoir algal populations. However, none of the chlorophyll values reported from 1991 to 1995, seemed particularly high when compared to chlorophyll levels measured in many other eutrophic waterbodies within the state (1995 South Dakota Lakes Assessment Final Report). Usually chlorophyll *a* concentrations increase with increasing eutrophication and nutrients. Increased algal concentrations can become a taste and odor problem for drinking water supplies.

Chlorophyll *a* and total phosphorus have a relationship in regard to increasing concentrations, typically as the total phosphorus increases so does the chlorophyll *a*. However, as shown in Figure 22, there seems to be little relationship between phosphorus and chlorophyll *a* when data from 1991 through 1995 is used (R^{2*} value of 0.0463). The fact that the lake may not always be phosphorus limited, the fixation of nitrogen by blue-green algae, or shading effects from excess algae may be some of the reasons for the lower R^2 value. Since 1993, the lake has been receiving and discharging very large amounts of water, this may have also affected the R^2 value. The retention time of water in the lake is so low that algae do not have time to use the phosphorus before they are flushed out through the spillway.

*The R^2 value gives a number to how close the points are to a line passing through the points. The higher R^2 value means a better the relationship, with a perfect relationship being a R^2=1.0.

Figure 22.

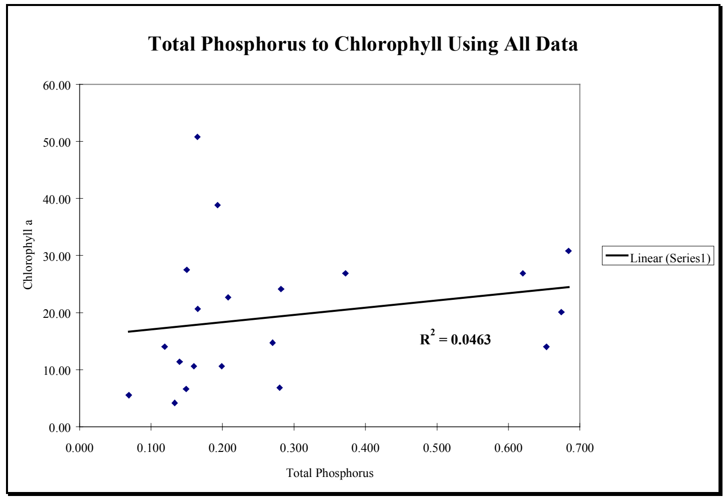


Figure 23.

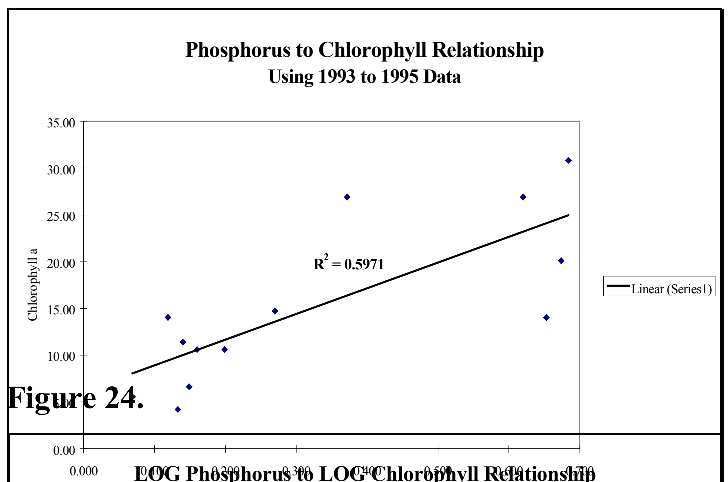
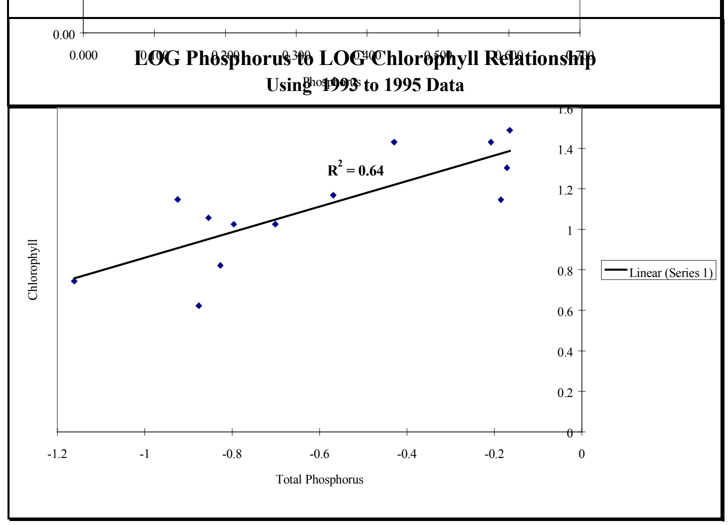


Figure 24.



To see if there was any similarity within wet years only, data previous to 1993 was excluded and the phosphorus to chlorophyll *a* relationship was again analyzed. The R^2 value for chlorophyll *a* and phosphorus from 1993 to 1995 was 0.5971 (Figure 23). Since the relationship was so much higher, the concentrations from the drought years were removed from the data set. To improve the R^2 value further the Log of the total phosphorus concentrations and the Log of the chlorophyll *a* concentrations were analyzed. An R^2 value of 0.64 was the result of the Log comparison (Figure 24).

The relationships between phosphorus and chlorophyll *a* can be used to estimate a reduction in chlorophyll *a* by reducing inlake phosphorus concentrations. The better the relationship the more confident lake managers can be in expected results. The data will be used in the next section for the reduction-response model. The equation for the line in Figure 24 will be used to predict chlorophyll *a* from inlake phosphorus concentrations. The line equation is shown below:

$$\{\text{Equation 1}\}\quad y = 0.6306x + 1.4899$$
$$y = \textit{predicted chlorophyll a concentration}$$
$$x = \textit{phosphorus concentration}$$

Reduction Response Model

Inlake total phosphorus concentrations are a function of the total phosphorus load delivered to the lake by the watershed. Vollenweider and Kerekes (1980) developed a mathematical relationship for inflow of total phosphorus and the inlake total phosphorus concentration. They assumed that if you change the inflow of total phosphorus you change inlake phosphorus concentration a relative but steady amount. The variables used in the relationship are:

1) $[\overline{P}]\lambda$ = Average inlake total phosphorus concentration
2) $[\overline{P}]i$ = Average concentration of total phosphorus which flow into the lake
3) $\overline{T}p$ = Average residence time of inlake total phosphorus
4) $\overline{T}w$ = Average residence time of lake water

Data collected from 1993 to 1995 provided enough information to estimate $[\overline{P}]\lambda$, $[\overline{P}]i$, and $\overline{T}w$. In order to estimate the residence time of total phosphorus ($\overline{T}p$) it was necessary to back calculate Equation 2 below, and solve for $\overline{T}p$ by forming Equation 3 (Wittmuss, 1996):

$$\{\text{Equation 2}\}\quad [\overline{P}]\lambda = \left[\frac{\overline{T}p}{\overline{T}w}\right][\overline{P}]i$$

$$\{\text{Equation 3}\}\quad (\overline{T}p) = \frac{[\overline{P}]\lambda}{[\overline{P}]i}(\overline{T}w)$$

Values for $[\overline{P}]\lambda$, $[\overline{P}]i$, and $\overline{T}w$ were determined in the following manner:

$[\overline{P}]\lambda$ was determined by averaging all of the surface total phosphorus samples from 1993-1995.

$[\overline{P}]i$ was determined by adding all of the input loadings for total phosphorus in milligrams and dividing that number by the total number of liters that entered the lake. The values for both of these numbers came from tributaries, storm sewers, groundwater, and the atmosphere.

$\overline{T}w$ was determined by averaging the total volume of Lake Mitchell (8,212 acre-feet) by the total inputs of water into the lake (97,271 acre-feet/days of discharge measurements).

$$\overline{T}w = {8{,}212 acre/feet} \Big/ {97{,}271 acre/feet/261\, days} = 22\ days = 0.06\ year$$

The final values for $[\overline{P}]\lambda$ and $[\overline{P}]i$ are:

$[\overline{P}]\lambda = 0.278$ mg/L $\qquad [\overline{P}]i = 0.534$

By placing the numbers in the proper places as discussed in Equation 3, $\overline{T}p$ would be:

$$\left(\overline{T}p\right) = \left[\frac{0.278}{0.534}\right](0.06) = 0.03\ years = 11\ days$$

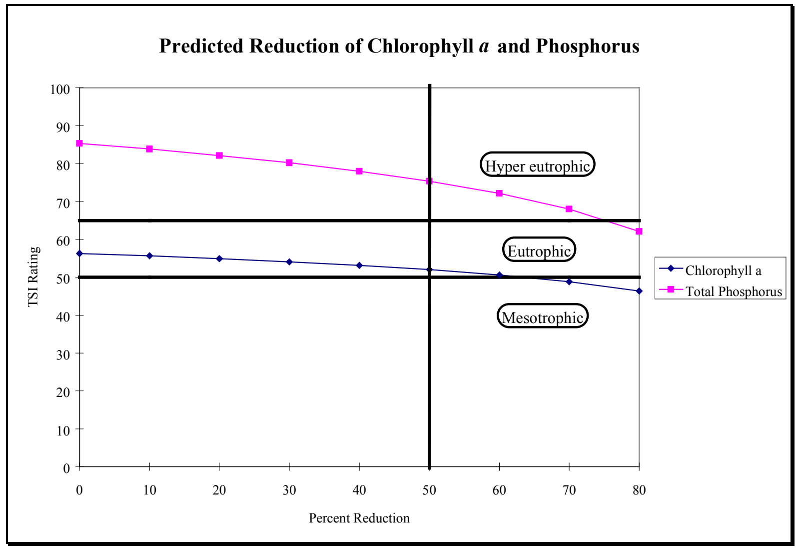
Referring back to Equation 2, reducing the inputs of total phosphorus, the equation would estimate the reduction of inlake total phosphorus. This is assuming constant inputs of water. Theoretically the retention time for total phosphorus should also be reduced. With only one year of sampling, there is no way to estimate the reduction in the retention time of total phosphorus. The $\overline{T}p$ constant (0.03) derived from the data will be used in Equation 2. As can be seen in Table 9, a reduction in phosphorus inputs to Lake Mitchell by 50% will reduce the inlake phosphorus by 50% or to a concentration of 0.139 mg/L (Figure 25).

Table 9. Effects of Reducing Phosphorus Inputs to Lake Mitchell

Reduction of Phosphorus Inputs	Input Concentration Reduction	In-lake Concentration Reduction	Percent Inlake Reduction	Chlorophyll *a* Reduction	Percent Chlorophyll *a* Reduction	Phosphorus TSI Reduction	Chlorophyll TSI Reduction
0	0.534	0.278	0%	13.78	0%	85.34	56.31
10	0.480	0.250	10%	12.90	6%	83.82	55.65
20	0.427	0.222	20%	11.97	13%	82.12	54.92
30	0.374	0.195	30%	11.01	20%	80.19	54.10
40	0.320	0.167	40%	9.99	28%	77.97	53.14
50	0.267	0.139	50%	8.90	35%	75.34	52.02
60	0.214	0.111	60%	7.73	44%	72.12	50.64
70	0.160	0.083	70%	6.45	53%	67.97	48.86
80	0.107	0.056	80%	5.00	64%	62.12	46.35

The 50% reduction would also lower the chlorophyll TSI value close to the mesotrophic line (Figure 25). As stated above, this is considering no reduction in the retention time of total phosphorus. If the retention time was lowered, the lake should experience even lower inlake concentrations and lower chlorophyll *a* concentrations. As the input concentrations of phosphorus are lowered, the lake will see algal blooms that are less intense and of a shorter duration. These tables and graphs are predictive on the data collected during the study. Actual changes can be expected to be different if other climatic changes occur which increase or decrease the volume of water passing through the lake.

Figure 25.



FIRESTEEL CREEK WATERSHED AGNPS ANALYSIS

Due to the lack of water quality data, a computer model was selected to assess the Nonpoint Source (NPS) loadings throughout the Lake Mitchell watershed. The model that was selected was the Agricultural Nonpoint Source Pollution Model (AGNPS) version 5.0. This model was developed by the Agricultural Research Service to analyze the water quality of runoff events from watersheds. The model predicts various parameters from a single storm event for every 40 acre cell in the watershed. These predicted parameters include:

runoff volume	peak rate	sediment erosion
sediment deliverability	nitrogen concentrations	phosphorus concentrations
chemical oxygen demand		

Proceeding from the headwaters to the outlet, the pollutants are routed in a step-wise fashion so the flow at any point may be examined. This model was developed to estimate subwatershed or tributary loadings to a water body. The AGNPS model is intended to be used as a tool to objectively compare different subwatersheds within a watershed and watersheds throughout a basin.

The size of the Firesteel Creek watershed and area modeled was 350,960 acres. This area includes the drainage associated with the Lake Wilmarth watershed. Initially, the watershed was divided into cells, each of which had an area of 40 acres (1,320 feet by 1,320 feet). The fluid flow directions were then determined. Considering the flow directions and drainage patterns, 4 primary subwatersheds were identified (Wilmarth, North Firesteel, West Firesteel, Main Firesteel). Each of the primary subwatersheds was then sub-divided into secondary subwatersheds. The AGNPS analysis and calculation of the Firesteel Creek watershed consisted of NPS pollution yields for individual cells, secondary and primary subwatersheds, and the estimated hydrologic runoff volumes for each storm event modeled. The impact of each animal feeding area was also included along with a relative impact ranking. The amount of sediment and nutrients delivered from each primary subwatershed to Lake Mitchell and the amount deposited and transported out of Lake Mitchell were also calculated. However, the calculated amounts of sediment and nutrients deposited in Lake Mitchell may be in error because the model does not account for retention time and the lake storage capacity.

AGNPS GOALS

The primary objectives of running AGNPS on the Firesteel Creek watershed were:

1.) Evaluate and quantify NPS yields from each primary and secondary subwatershed, and determine the net loading to Lake Mitchell;
2.) Define critical NPS cells within each primary and secondary subwatershed (elevated sediment, nitrogen, phosphorus); and
3.) Rank and prioritize each concentrated feeding area and quantify the nutrient loadings from each feeding area.

OBJECTIVE 1 - EVALUATE AND QUANTIFY SUBWATERSHED NPS LOADINGS

DELINEATION AND LOCATION OF PRIMARY AND SECONDARY SUBWATERSHEDS

Based upon the flow directions and drainage patterns, four (4) primary subwatersheds were delineated. The four primary subwatersheds are;

SUBWATERSHED	DRAINAGE AREA	OUTLET CELL #	DESCRIPTION
1	37,320	796	Lake Wilmarth (Jerauld Co.)
2	121,320	3031	North Firesteel Creek (Jerauld Co.)
3	147,720	1329	West Firesteel Creek (Aurora Co.)
4	44,600	973	Main Firesteel Creek (Davison Co.)
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TOTAL 4	350,960	973	

Each of the primary subwatersheds was then divided into secondary subwatersheds based upon fluid flow and drainage patterns. The secondary subwatersheds for each primary subwatershed are;

1.) LAKE WILMARTH WATERSHED (JERAULD CO.)

SUBWATERSHED	DRAINAGE AREA	OUTLET CELL #	DESCRIPTION
1	7,080	254	Northeast Wilmarth
2	13,440	535	N.E. & North Central Wilmarth
3	7,360	670	Northwest Wilmarth
4	18,320	672	N.E. & N.C. & Central Wilmarth
5	160	775	Direct Drainage North of Lake Wilmarth
6	1,200	776	Small Trib. North of Lake Wilmarth
7	35,680	813	Inlet to Lake Wilmarth
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TOTAL 7	37,320	796	Outlet of Lake Wilmarth (DF Site #7A)

2.) NORTH FIRESTEEL CREEK WATERSHED (JERAULD CO.)

SUBWATERSHED	DRAINAGE AREA	OUTLET CELL #	DESCRIPTION
1	36,200	1020	North Wessington
2	8,160	1049	East Wessington
3	54,560	1464	Wessington Area
4	73,960	1956	North Half of North Firesteel Watershed
5	11,560	2293	Viola Area
6	100,120	2382	North & Central North Firesteel (DF Site #7)
7	7,880	2917	South Storla
8	108,400	2928	North & Central & South Central Firesteel
9	119,720	2984	North & Central & South Central (DF Site #5)
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TOTAL 9	121,320	3031	Outlet of North Firesteel Creek Watershed

3.) WEST FIRESTEEL CREEK WATERSHED (AURORA CO.)

SUBWATERSHED	DRAINAGE AREA	OUTLET CELL #	DESCRIPTION
1	5,680	401	See West Firesteel Subwatershed Map
2	10,280	454	See West Firesteel Subwatershed Map
3	18,200	521	See West Firesteel Subwatershed Map
4	4,400	720	See West Firesteel Subwatershed Map
5	47,440	722	Northwest West Firesteel Watershed
6	95,760	825	Central & South, West Firesteel Watershed
7	21,600	1175	See West Firesteel Subwatershed Map
8	146,120	1257	West Firesteel Creek Watershed (DF Site #6)
9	3,240	1311	See West Firesteel Subwatershed Map
10	1,240	1327	See West Firesteel Subwatershed Map
11	2,120	1597	See West Firesteel Subwatershed Map
12	18,400	1792	See West Firesteel Subwatershed Map
13	11,360	2267	See West Firesteel Subwatershed Map
14	15,840	2335	See West Firesteel Subwatershed Map
15	15,600	2734	See West Fire steel Subwatershed Map
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TOTAL 15	147,720	1329	Outlet of West Firesteel Creek Watershed

4.) MAIN FIRESTEEL CREEK WATERSHED (DAVISON CO.)

SUBWATERSHED	DRAINAGE AREA	OUTLET CELL #	DESCRIPTION
1	10,360	258	North Main Firesteel (DF Site #3)
2	11,280	358	See Main Firesteel Subwatershed Map
3	12,440	390	West Main Firesteel (DF Site #4, GS station)
4	1,640	435	See Main Firesteel Subwatershed Map
5	6,440	561	See Main Firesteel Subwatershed Map
6	1,720	578	See Main Firesteel Subwatershed Map
7	34,880	605	Inlet to Lake Mitchell (DF Site #1)
8	2,240	663	See Main Firesteel Subwatershed Map
9	35,600	730	Inlet to Lake Mitchell (Model)
10	4,160	922	Small S.W. Trib. (DF Site #2)
11	4,960	926	Small S.W. Trib. (Model)
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TOTAL 11	44,600	973	Outlet of Lake Mitchell

The NPS per acre loadings for each of the secondary subwatersheds within the Lake Wilmarth subwatershed for modeled “annual” and 25 year storm events are;

1.) LAKE WILMARTH SUBWATERSHED PER ACRE LOADINGS

SUBWATERSHED	DRAINAGE AREA (ACRES)	SEDIMENT TON/AC/EVT. (1 YR.+ANN.) ♣	SEDIMENT TON/AC/EVT. (25YR. .EVT)	TOTAL NITRO. TON/AC/EVT. (1 YR.+ANN.)	TOTAL NITRO. TON/AC/EVT. (25YR. EVT)	TOTAL PHOS. TON/AC/EVT. (1 YR.+ANN.)	TOTAL PHOS. TON/AC/EVT. (25YR. EVT)
1 (#254)	7080	.107 .026+.042+.039	.21	.0009 .0002+.0003+ .0004	.0009	.00040 .00007+.00015+ .00018	.0003
2 (#535)	13,440	.110 .027+.042+.041	.21	.0009 .0002+.0003+ .0004	.0009	.00040 .00007+.00015+ .00018	.0003
3 (#670)	7360	.114 .027+.042+.045	.21	.0009 .0002+.0003+ .0004	.0008	.00037 .00007+.00012+ .00018	.0003
4 (#672)	18,320	.089 .022+.033+.034	.17	.0009 .0002+.0003+ .0004	.0007	.00030 .00006+.00012+ .00012	.0002
5 (#775)	160	**.418** .099+.156+.163	**.90**	**.0020** .0004+.0008+ .0008	**.0019**	**.00082** .00016+.00030+ .00036	**.0008**
6 (#776)	1200	.104 .030+.042+.032	**.26**	.0009 .0002+.0003+ .0004	.0009	.00031 .00007+.00012+ .00012	.0003
7 (#813) (Inlet to Lake Wilmarth)	35,680	.079 .019+.030+.030	.14	.0009 .0002+.0003+ .0004	.0007	.00027 .00006+.00009+ .00012	.0002
Outflow of Lake Wilmarth (#796) (DF SITE 7A)	37,320	**.179** .037+.069+.073	.13	**.0010** .0002+.0003+ .0005	.0007	**.00047** .00008+.00015+ .00024	.0002
MEAN		.112	.19	.0009	.0008	.00036	.00026
MEDIAN		.107	.21	.0009	.0008	.00037	.00030
♥STDS		.032	.05	.00004	.0001	.00007	.00005
MEAN + 1 STDS (σ)		.144	.24	.00094	.0009	.00043	.00031
♠EXP.CRIT. RANGE		.12 ⇒ .20	.40 ⇒ .89	.002 ⇒ .003	.001 ⇒ .003	.0005 ⇒ .0008	.0004 ⇒ .0012

♣- Annual loadings were estimated by calculating the NPS loadings for the cumulating of rainfall events during an average year.
This includes a 1 year 24 hour event of 2.0" (E.I. = 21.8), 3 four month rainfall events of 1.5" (E.I. = 11.7) and a series of 12 small rainfall events of .8" (E.I. = 3.0) for a total “R” factor of 92.9. Rainfall events of less than .8" were modeled and found to produce insignificant amounts of sediment and nutrient yields.

♥ - In order to have any "statistical significance" the value of the sample standard deviation (STDS) should be at least 50% of the mean value.

♠ -Values for smaller watersheds will be higher than larger watersheds because of the inverse relationship of loadings to the distance of the NPS from the lake. The “critical range” was developed based on estimated NPS loadings utilizing the AGNPS model from seven watersheds found within Eastern South Dakota.

The NPS total loadings for each of the secondary subwatersheds within the Lake Wilmarth subwatershed for modeled "annual" and "25 year storm" events are;

LAKE WILMARTH SUBWATERSHED TOTAL LOADINGS

SUBWATERSHED	DRAINAGE AREA (ACRES)	SEDIMENT TON/YR. (1 YR.+ANN.) ♣	SEDIMENT TON/YR. (25YR. .EVT)	TOTAL NITRO. TON/YR. (1 YR.+ANN.)	TOTAL NITRO. TON/YR. (25YR. EVT)	TOTAL PHOS. TON/YR. (1 YR.+ANN.)	TOTAL PHOS. TON/YR. (25YR. EVT)
1 (#254)	7080	751 (187+288+276)	1503	7.3 (1.5+2.8+3.0)	6.2	2.7 (.50+.96+1.27)	2.3
2 (#535)	13,440	1485 (370+569+546)	2859	14.0 (3.0+5.4+5.6)	11.6	5.1 (.94+.1.8+2.4)	4.2
3 (#670)	7360	846 (200+312+334)	1575	7.2 (1.5+2.6+3.1)	5.8	2.6 (.48+.77+.1.32)	2.0
4 (#672)	18,320	1658 (405+631+622)	3184	16.8 (3.6+6.6+6.6)	13.3	5.1 (1.0+1.9+2.2)	4.4
5 (#775)	160	**67** (16+25+26)	**144**	**.3** (.1+.1+.1)	**.3**	**.13** (.02+.05+.06)	**.1**
6 (#776)	1200	123 (36+49+38)	**315**	1.3 (.3+.5+.5)	1.1	.36 (.08+.14+.14)	.4
7 (#813) (Inlet to Lake Wilmarth)	35,680	2862 (681+1103+1078)	4900	31.0 (6.4+11.8+12.8)	23.7	9.5 (1.96+3.2+4.3)	7.5
Outflow of Lake Wilmarth (#796) (DF SITE 7A)	37,320	**6641** (1373+2562+2706)	4840	**42.7** (8.6+16.2+17.9)	24.3	**17.3** (2.8+5.6+8.9)	7.6

♣- Annual loadings were estimated by calculating the NPS loadings for the cumulating of rainfall events during an average year.
This includes a 1 year 24 hour event of 2.0" (E.I. = 21.8), 3 four month rainfall events of 1.5" (E.I. = 11.7) and a series of 12 small rainfall events of .8" (E.I. = 3.0) for a total "R" factor of 92.9. Rainfall events of less than .8" were modeled and found to produce insignificant amounts of sediment and nutrient yields.

♥ - In order to have any "statistical significance" the value of the sample standard deviation (STDS) should be at least 50% of the mean value.

♠ -Values for smaller watersheds will be higher than larger watersheds because of the inverse relationship of loadings to the distance of the nonpoint source from the lake. The "critical range" was developed based on estimated NPS loadings utilizing the AGNPS model from seven watersheds found within Eastern South Dakota.

The NPS per acre loadings for each of the secondary subwatersheds within the North Firesteel subwatershed for modeled "annual" and "25 year storm" events are;

2.) NORTH FIRESTEEL CREEK SUBWATERSHED PER ACRE LOADINGS

SUBWATERSHED	DRAINAGE AREA (ACRES)	SEDIMENT TON/AC/EVT. (1 YR.+ANN.) ♣	SEDIMENT TON/AC/EVT. (25YR. .EVT)	TOTAL NITRO. TON/AC/EVT. (1 YR.+ANN.)	TOTAL NITRO. TON/AC/EVT. (25YR. EVT)	TOTAL PHOS. TON/AC/EVT. (1 YR.+ANN.)	TOTAL PHOS. TON/AC/E
1 (#1020)	36,200	.188 .047+.077+.064	.27	.0007 .0002+.0003+ .0002	.0006	.00024 .00007+.00011+ .00006	.0002
2 (#1049)	8160	**.211** .055+.086+.070	**.40**	.0007 .0002+.0003+ .0002	**.0009**	**.00033** .00007+.00014+ .00012	.0003
3 (#1464)	54,560	**.216** .052+.089+.075	.29	.0007 .0002+.0003+ .0002	.0006	.00027 .00007+.00014+ .00006	.0003
4 (#1956)	73,960	.178 .045+.076+.057	.26	.0007 .0002+.0003+ .0002	.0006	.00025 .00007+.00012+ .00006	.0003
5 (#2293)	11,560	.126 .034+.052+.040	.23	.0007 .0002+.0003+ .0002	.0007	.00021 .00006+.00009+ .00006	.0003
6 (#2382) (DF SITE #7)	100,120	.160 .040+.067+.053	.24	.0007 .0002+.0003+ .0002	.0006	.00023 .00006+.00011+ .00006	.0002
7 (#2917)	7880	.174 .042+.071+.061	.26	.0008 .0002+.0003+ .0003	.0007	.00023 .00006+.00011+ .00006	.0003
8 (#2928)	108,400	.165 .043+.069+.053	.26	.0005 .0001+.0002+ .0002	.0006	.00021 .00006+.00009+ .00006	.0002
9 (#2984) (DF SITE #5)	119,720	.150 .039+.063+.048	.23	.0005 .0001+.0002+ .0002	.0005	.00021 .00006+.00009+ .00006	.0002
Outflow of North Firesteel Creek (#3031)	121,320	.152 .039+.064+.049	.23	.0005 .0001+.0002+ .0002	.0005	.00021 .00006+.00009+ .00006	.0002
MEAN MEDIAN ♥STDS MEAN + 1 STDS (σ) ♠EXP.CRIT. RANGE		.172 .170 .028 .200 .12 ⇒ .20	.27 .26 .05 .32 .40 ⇒ .89	.0007 .0007 .0001 .0008 .002 ⇒ .003	.0006 .0006 .0001 .0007 .001 ⇒ .003	.00024 .00023 .00004 .00028 .0005 ⇒ .0008	.00025 .00025 .00005 .00030 .0004 ⇒ .0012

♣- Annual loadings were estimated by calculating the NPS loadings for the cumulating of rainfall events during an average year.
This includes a 1 year 24 hour event of 2.0" (E.I. = 21.8), 3 four month rainfall events of 1.5" (E.I. = 11.7) and a series of 12 small rainfall events of .8" (E.I. = 3.0) for a total "R" factor of 92.9. Rainfall events of less than .8" were modeled and found to produce insignificant amounts of sediment and nutrient yields.

♥ - In order to have any "statistical significance" the value of the sample standard deviation (STDS) should be at least 50% of the mean value.

♠ -Values for smaller watersheds will be higher than larger watersheds because of the inverse relationship of the loadings to the distance of the nonpoint source from the lake. The "critical range" was developed based on estimated NPS loadings utilizing the AGNPS model from seven watersheds found within Eastern South Dakota.

The NPS total loadings for each of the secondary subwatersheds within the North Firesteel subwatershed for modeled "annual" and “25 year storm” events are;

NORTH FIRESTEEL CREEK SUBWATERSHED TOTAL LOADINGS

SUBWATERSHED	DRAINAGE AREA (ACRES)	SEDIMENT TON/YR. (1 YR.+ANN.) ♣	SEDIMENT TON/YR. (25YR. .EVT)	TOTAL NITRO. TON/YR. (1 YR.+ANN.)	TOTAL NITRO. TON/YR. (25YR. EVT)	TOTAL PHOS. TON/YR. (1 YR.+ANN.)	TOTAL PHOS. TON/YR. (25YR. EVT)
1 (#1020)	36,200	6800 (1704+2793+2303)	9918	24.1 (5.6+9.8+8.7)	21.9	8.4 (2.4+3.8+2.2)	8.7
2 (#1049)	8160	**1728** (449+705+574)	**3298**	6.2 (1.5+2.7+2.0)	**6.9**	**2.7** (.6+1.1+1.0)	2.8
3 (#1464)	54,560	**11,740** (2818+4851+4071)	16,031	39.6 (9.3+17.2+13.1)	34.9	14.5 (3.8+7.4+3.3)	14.2
4 (#1956)	73,960	13,153 (3361+5595+4197)	19,566	44.8 (11.5+20.0+13.3)	44.4	18.1 (4.8+8.9+4.4)	18.1
5 (#2293)	11,560	1466 (397+606+463)	2602	7.0 (1.8+3.1+2.1)	8.0	2.3 (.63+1.0+.7)	2.8
6 (#2382) (DF SITE #7)	100,120	16,070 (4047+6753+5270)	23,744	57.5 (14.0+25.5+18)	56.1	22.5 (6.0+10.5+6.0)	22.5
7 (#2917)	7880	1369 (330+561+478)	2023	6.2 (1.3+2.5+2.4)	5.5	1.8 (.5+.8+.5)	2.0
8 (#2928)	108,400	18,027 (4689+7545+5793)	27,827	60.1 (14.6+26.0+19.5)	59.6	22.8 (6.5+9.8+6.5)	25.5
9 (#2984) (DF SITE #5)	119,720	17,991 (4670+7536+5785)	28,075	64.0 (15.6+26.9+21.5)	62.8	24.6 (6.6+10.8+7.2)	26.3
Outflow of North Firesteel Creek (#3031)	121,320	18,372 (4729+7749+5894)	28,336	64.9 (15.8+27.3+21.8)	63.1	24.9 (6.7+10.9+7.3)	26.7

♣- Annual loadings were estimated by calculating the NPS loadings for the cumulating of rainfall events during an average year.
This includes a 1 year 24 hour event of 2.0" (E.I. = 21.8), 3 four month rainfall events of 1.5" (E.I. = 11.7) and a series of 12 small rainfall events of .8" (E.I. = 3.0) for a total “R” factor of 92.9. Rainfall events of less than .8" were modeled and found to produce insignificant amounts of sediment and nutrient yields.

♥ - In order to have any "statistical significance" the value of the sample standard deviation (STDS) should be at least 50% of the mean value.

♠ -Values for smaller watersheds will be higher than larger watersheds because of the inverse relationship of the loadings to the distance of the nonpoint source from the lake. The “critical range” was developed based on estimated NPS loadings utilizing the AGNPS model from seven watersheds found within Eastern South Dakota.

The NPS per acre loadings for each of the secondary subwatersheds within the West Firesteel subwatershed for modeled "annual" and "25 year storm" events are;

3.) WEST FIRESTEEL CREEK SUBWATERSHED PER ACRE LOADINGS

SUBWATERSHED	DRAINAGE AREA (ACRES)	SEDIMENT TON/AC/EVT. (1 YR.+ANN.) ♣	SEDIMENT TON/AC/EVT. (25YR. .EVT)	TOTAL NITRO. TON/AC/EVT. (1 YR.+ANN.)	TOTAL NITRO. TON/AC/EVT. (25YR. EVT)	TOTAL PHOS. TON/AC/EVT. (1 YR.+ANN.)	TOTAL PHOS. TON/AC/EVT. (25YR. EVT)
1 (#401)	5680	.111 .030+.049+.032	.19	.0004 .0001+.0002+ .0001	.0005	.00018 .00004+.00008+ .00006	.0002
2 (#454)	10,280	.146 .036+.054+.056	.22	**.0006** .0002+.0002+ .0002	**.0006**	.00021 .00006+.00009+ .00006	.0002
3 (#521)	18,200	.104 .029+.043+.032	.17	.0004 .0001+.0002+ .0001	.0005	.00016 .00004+.00006+ .00006	.0002
4 (#720)	4,400	.130 .031+.048+.051	.24	.0004 .0001+.0002+ .0001	.0006	.00016 .00004+.00006+ .00006	.0002
5 (#722)	47,440	.090 .023+.037+.030	.13	.0004 .0001+.0002+ .0001	.0004	.00016 .00004+.00006+ .00006	.0002
6 (#825)	95,760	.081 .022+.035+.024	.12	.0004 .0001+.0002+ .0001	.0004	.00016 .00004+.00006+ .00006	.0001
7 (#1175)	21,600	.094 .028+.040+.026	.17	.0004 .0001+.0002+ .0001	.0005	.00017 .00005+.00006+ .00006	.0002
8 (#1257) (DF SITE #6)	146,120	.077 .021+.034+.022	.11	.0003 .0001+.0001+ .0001	.0003	.00010 .00004+.00006+ .00000	.0001
9 (#1311)	3240	.170 .041+.064+.065	.29	.0004 .0001+.0002+ .0001	.0006	.00016 .00004+.00006+ .00006	.0002
10 (#1327)	1240	**.200** .052+.077+.071	**.42**	**.0007** .0002+.0003+ .0002	**.0009**	**.00030** .00007+.00011+ .00012	**.0004**
11 (#1597)	2120	**.253** .062+.092+.099	**.49**	**.0007** .0002+.0003+ .0002	**.0009**	**.00029** .00006+.00011+ .00012	**.0004**
12 (#1792)	18,400	.114 .026+.039+.049	.17	.0004 .0001+.0002+ .0001	.0005	.00018 .00004+.00008+ .00006	.0002
13 (#2267)	11,360	.085 .026+.040+.019	.19	.0004 .0001+.0002+ .0001	.0005	.00016 .00004+.00006+ .00006	.0002
14 (#2335)	15,840	.093 .023+.038+.032	.13	.0004 .0001+.0002+ .0001	.0004	.00016 .00004+.00006+ .00006	.0001
15 (#2734)	15,600	.123 .030+.053+.040	.17	.0005 .0001+.0002+ .0002	.0005	.00020 .00005+.00009+ .00006	.0002
Outflow of West Firesteel Creek (#1329)	147,720	.077 .021+.034+.022	.11	.0003 .0001+.0001+ .0001	.0003	.00010 .00004+.00006+ .00000	.0001
MEAN		.122	.21	.0004	.0005	.00018	.00020
MEDIAN		.107	.17	.0004	.0005	.00016	.00020
♥STDS		.049	.11	.0001	.0001	.00005	.00009
MEAN + 1 STDS (σ)		.171	.32	.0005	.0006	.00023	.00029
♠EXP.CRIT. RANGE		.12 ⇒ .20	.40 ⇒ .89	.002 ⇒ .003	.001 ⇒ .003	.0005 ⇒ .0008	.0004 ⇒ .0012

The NPS total loadings for each of the secondary subwatersheds within the West Firesteel subwatershed for modeled "annual" and "25 year storm" events are;

WEST FIRESTEEL CREEK SUBWATERSHED TOTAL LOADINGS

SUBWATERSHED	DRAINAGE AREA (ACRES)	SEDIMENT TON/YR. (1 YR.+ANN.) ♣	SEDIMENT TON/YR. (25YR. .EVT)	TOTAL NITRO. TON/YR. (1 YR.+ANN.)	TOTAL NITRO. TON/YR. (25YR. EVT)	TOTAL PHOS. TON/YR. (1 YR.+ANN.)	TOTAL PHOS. TON/YR. (25YR. EVT)
1 (#401)	5680	637 (172+280+185)	1087	2.0 (.6+1.1+.3)	2.9	.9 (.2+.4+.3)	1.1
2 (#454)	10,280	1503 (373+559+571)	2305	**5.9** (1.5+2.5+1.9)	**6.4**	2.1 (.6+.9+.6)	2.3
3 (#521)	18,200	1874 (520+777+577)	3028	7.5 (2.0+3.3+2.2)	8.4	2.9 (.7+1.1+1.1)	3.1
4 (#720)	4,400	575 (136+212+227)	1065	1.8 (.5+.8+.5)	2.4	.8 (.2+.3+.3)	.9
5 (#722)	47,440	4269 (1099+1739+1431)	6371	18.7 (4.5+8.5+5.7)	19.4	7.5 (1.9+2.8+2.8)	6.9
6 (#825)	95,760	7824 (2147+3348+2329)	11,790	28.7 (8.6+14.4+5.7)	35.4	15.2 (3.8+5.7+5.7)	12.9
7 (#1175)	21,600	2054 (612+870+572)	3732	7.3 (2.4+3.6+1.3)	9.9	3.6 (1.0+1.3+1.3)	3.8
8 (#1257) (DF SITE #6)	146,120	11,282 (3073+4942+3267)	16,324	41.7 (13.2+19.7+8.8)	49.7	13.9 (5.1+8.8+0.0)	18.3
9 (#1311)	3240	552 (133+207+212)	938	1.1 (.4+.5+.2)	2.0	.5 (.1+.2+.2)	.8
10 (#1327)	1240	**249** (65+96+88)	**522**	**.9** (.2+.4+.3)	**1.1**	**.3** (.1+.1+.1)	**.4**
11 (#1597)	2120	**539** (131+197+211)	**1041**	**1.2** (.3+.5+.4)	**1.9**	**.5** (.1+.2+.2)	**.8**
12 (#1792)	18,400	1762 (487+719+556)	3145	7.2 (2.0+3.0+2.2)	8.8	3.2 (.7+1.4+1.1)	3.2
13 (#2267)	11,360	965 (299+455+211)	2136	3.8 (1.1+2.0+.7)	5.6	1.9 (.5+.7+.7)	2.2
14 (#2335)	15,840	1481 (364+609+508)	2024	6.1 (1.6+2.6+1.9)	6.3	2.5 (.6+1.0+.9)	2.2
15 (#2734)	15,600	1918 (473+820+625)	2678	9.4 (2.0+3.7+3.7)	7.7	3.1 (.8+1.4+.9)	2.9
Outflow of West Firesteel Creek (#1329)	147,720	11,319 (3095+4958+3266)	16,657	42.1 (13.3+19.9+8.9)	50.2	14.1 (5.2+8.9+0.0)	19.2

The NPS per acre loadings for each of the secondary subwatersheds within the Main Firesteel subwatershed for modeled "annual" and "25 year storm" events are;

4.) MAIN FIRESTEEL CREEK SUBWATERSHED PER ACRE LOADINGS

SUBWATERSHED	DRAINAGE AREA (ACRES)	SEDIMENT TON/AC/EVT. (1 YR.+ANN.) ♣	SEDIMENT TON/AC/EVT. (25YR. .EVT)	TOTAL NITRO. TON/AC/EVT. (1 YR.+ANN.)	TOTAL NITRO. TON/AC/EVT. (25YR. EVT)	TOTAL PHOS. TON/AC/EVT. (1 YR.+ANN.)	TOTAL PHOS. TON/AC/EVT. (25YR. EVT)
1 (#258) (DF SITE #3)	10,360	.083 .027+.036+.020	.20	.0004 .0001+.0002+ .0001	.0005	.00017 .00005+.00006+ .00006	.0002
2 (#358)	11,280	.104 .033+.045+.026	.23	.0004 .0001+.0002+ .0001	.0006	.00019 .00005+.00008+ .00006	.0002
3 (#390) (DF SITE #4)	12,440	.131 .040+.057+.034	.29	.0004 .0001+.0002+ .0001	.0006	.00019 .00005+.00008+ .00006	.0002
4 (#435)	1640	**.219** .063+.095+.061	**.47**	**.0010** .0002+.0004+ .0004	**.0011** high water soluble	**.00041** .00009+.00014+ .00018	**.0004** high water soluble
5 (#561)	6440	.104 .031+.046+.027	.21	.0004 .0001+.0002+ .0001	.0006	.00019 .00005+.00008+ .00006	.0002
6 (#578)	1720	.092 .028+.040+.024	.23	.0005 .0001+.0002+ .0002	.0006	.00019 .00005+.00008+ .00006	.0002
7 (#605) (DF SITE #1)	34,880	.073 .022+.033+.018	.15	.0004 .0001+.0002+ .0001	.0004	.00018 .00004+.00008+ .00006	.0002
8 (#663)	2240	.090 .027+.039+.024	.21	**.0010** .0002+.0004+ .0004	**.0009** high water soluble	**.00034** .00008+.00014+ .00012	**.0003** high water soluble
9 (#730)	35,600	.027 .010+.014+.003	.07	.0003 .0001+.0001+ .0001	.0003	.00007 .00002+.00005+ .00000	.0001
10 (#922) (DF SITE #2)	4,160	.104 .029+.043+.032	.21	.0006 .0002+.0002+ .0002	.0007	.00020 .00005+.00009+ .00006	.0002
11 (#926)	4,960	.092 .026+.038+.028	.20	.0005 .0001+.0002+ .0002	.0006	.00020 .00005+.00009+ .00006	.0002
Outflow of Lake Mitchell (#973)	44,600	.027 .006+.010+.011	.02	.0003 .0001+.0001+ .0001	.0002	.00004 .00001+.00003+ .00000	.00004
MEAN		.096	.21	.0005	.0006	.00020	.00020
MEDIAN		.092	.21	.0004	.0006	.00019	.00020
♥STDS		.049	.11	.0002	.0002	.00010	.00009
MEAN + 1 STDS (σ)		.145	.32	.0007	.0008	.00030	.00029
♠EXP.CRIT. RANGE		.12 ⇒ .20	.40 ⇒ .89	.002 ⇒ .003	.001 ⇒ .003	.0005 ⇒ .0008	.0004 ⇒ .0012

♣- Annual loadings were estimated by calculating the NPS loadings for the cumulating of rainfall events during an average year.
This includes a 1 year 24 hour event of 2.0" (E.I. = 21.8), 3 four month rainfall events of 1.5" (E.I. = 11.7) and a series of 12 small rainfall events of .8" (E.I. = 3.0) for a total "R" factor of 92.9. Rainfall events of less than .8" were modeled and found to produce insignificant amounts of sediment and nutrient yields.

♥ - In order to have any "statistical significance" the value of the sample standard deviation (STDS) should be at least 50% of the mean value.

♠ -Values for smaller watersheds will be higher than larger watersheds because of the inverse relationship of the loadings to the distance of the nonpoint source from the lake. The "critical range" was developed based on estimated NPS loadings utilizing the AGNPS model from seven watersheds found within Eastern South Dakota.

The NPS total loadings for each of the secondary subwatersheds within the Main Firesteel subwatershed for modeled "annual" and "25 year storm" events are;

MAIN FIRESTEEL CREEK SUBWATERSHED TOTAL LOADINGS

SUBWATERSHED	DRAINAGE AREA (ACRES)	SEDIMENT TON/YR. (1 YR.+ANN.) ♣	SEDIMENT TON/YR. (25YR. .EVT)	TOTAL NITRO. TON/YR. (1 YR.+ANN.)	TOTAL NITRO. TON/YR. (25YR. EVT)	TOTAL PHOS. TON/YR. (1 YR.+ANN.)	TOTAL PHOS. TON/YR. (25YR. EVT)
1 (#258) (DF SITE #3)	10,360	851 (282+369+200)	2035	4.3 (1.2+1.9+1.2)	5.6	1.7 (.5+.6+.6)	2.1
2 (#358)	11,280	1181 (375+512+294)	2593	5.1 (1.5+2.2+1.4)	6.5	2.1 (.6+.8+.7)	2.5
3 (#390) (DF SITE #4)	12,440	1621 (495+708+418)	3596	5.5 (1.6+2.4+1.5)	7.7	2.2 (.6+.9+.7)	3.0
4 (#435)	1640	**359** (103+156+100)	**763**	**1.6** (.4+.6+.6)	**1.8**	**.6** (.1+.2+.3)	**.7**
5 (#561)	6440	671 (197+297+177)	1349	2.9 (.8+1.4+.7)	3.6	1.2 (.3+.5+.4)	1.4
6 (#578)	1720	156 (48+68+40)	399	.9 (.2+.4+.3)	1.1	.3 (.1+.1+.1)	.4
7 (#605) (DF SITE #1)	34,880	2580 (783+1141+656)	5331	13.5 (3.5+5.8+4.2)	15.3	6.1 (1.4+2.6+2.1)	5.8
8 (#663)	2240	202 (61+87+54)	465	**2.3** (.5+.9+.9)	**2.1**	**.8** (.2+.3+.3)	**.7**
9 (#730)	35,600	971 (373+489+109)	2573	8.3 (2.5+3.7+2.1)	10.3	2.3 (.7+1.6+0)	3.2
10 (#922) (DF SITE #2)	4,160	431 (119+178+134)	885	2.6 (.6+1.0+1.0)	2.8	.8 (.2+.4+.2)	1.0
11 (#926)	4,960	458 (128+191+139)	972	3.1 (.7+1.2+1.2)	3.2	.9 (.2+.4+.3)	1.1
Outflow of Lake Mitchell (#973)	44,600	1183 (248+455+480)	868	11.8 (2.5+4.0+5.3)	8.5	1.7 (.4+1.3+0)	1.8

♣- Annual loadings were estimated by calculating the NPS loadings for the cumulating of rainfall events during an average year.
This includes a 1 year 24 hour event of 2.0" (E.I. = 21.8), 3 four month rainfall events of 1.5" (E.I. = 11.7) and a series of 12 small rainfall events of .8" (E.I. = 3.0) for a total "R" factor of 92.9. Rainfall events of less than .8" were modeled and found to produce insignificant amounts of sediment and nutrient yields.

♥ - In order to have any "statistical significance" the value of the sample standard deviation (STDS) should be at least 50% of the mean value.

♠ -Values for smaller watersheds will be higher than larger watersheds because of the inverse relationship of the loadings to the distance of the nonpoint source from the lake. The "critical range" was developed based on estimated NPS loadings utilizing the AGNPS model from seven watersheds found within Eastern South Dakota.

A comparative analysis of "per acre" and "total loadings" for other South Dakota watersheds analyzed utilizing the AGNPS model are;

COMPARATIVE ANALYSIS OF PER ACRE LOADINGS FOR OTHER SOUTH DAKOTA WATERSHEDS

WATERSHED	DRAINAGE AREA (ACRES)	SEDIMENT TON/AC/EVT (1 YR.+ANN.)	SEDIMENT TON/AC/EVT (25YR. .EVT)	TOT. NITRO TON/AC/EVT. (1 YR.+ANN.)	TOT. NITRO. TON/AC/EVT	TOTAL PHOS. TON/AC/EVT. (1 YR.+ANN.)	TOTAL PHOS. TON/AC/EVT. (25YR. EVT)
Lake Faulkton	158,240	.0084	.0217	.00037	.00029	.00010	.00007
Lake Campbell	10,960	.0703	.2739	.00073	.00099	.00021	.00036
Lake Poinsett	16,240 (Dry) 16,160 (Poin.) 34,000(Albert)	.1045 .0985 .1324	.3741 .3883 .4691	.00180 .00132 .00131	.00171 .00153 .00160	.00051 .00038 .00041	.00060 .00056 .00060
Pelican Lake	13,160	.2447	.6309	.0064	.00439	.00161	.00137
Lake Herman	40,440	.1380	--------	.0024	--------	.00062	--------
Richmond Lake	86,680	.0372	.2260	.00025	.00057	.00010	.00023
Lake Mitchell	23,960	.0560	.1093	.00109	.00064	.00030	.00019
Firesteel Creek **(Lake Mitchell Outlet)**	**350,960** **(44,600)**	**.0270**	**.0200**	**.0003**	**.0002**	**.00004**	**.00004**
Wilmarth	**37,320**	**.1790**	**.1300**	**.0010**	**.0007**	**.00047**	**.00020**
North Firesteel	**121,320**	**.1520**	**.2300**	**.0005**	**.0005**	**.00021**	**.00020**
West Firesteel	**147,720**	**.0770**	**.1100**	**.0003**	**.0003**	**.00010**	**.00010**
Main Firesteel **(DF site #1)**	**34,880**	**.0730**	**.1500**	**.0004**	**.0004**	**.00018**	**.00020**
Total to Lake	**346,200**	**.1137**	**.1152**	**.0005**	**.0005**	**.00018**	**.00017**

COMPARATIVE ANALYSIS OF TOTAL LOADINGS FOR OTHER SOUTH DAKOTA WATERSHEDS

WATERSHED	DRAINAGE AREA (ACRES)	SEDIMENT TON/YR. (1 YR.+ANN.)	SEDIMENT TON/YR. (25YR. .EVT)	TOTAL NITRO. TON/YR. (1 YR.+ANN.)	TOTAL NITRO. TON/YR. (25YR. EVT)	TOTAL PHOS. TON/YR. (1 YR.+ANN.)	TOTAL PHOS. TON/YR. (25YR. EVT)
Lake Faulkton	158,240	1331	3429	57.8	45.1	15.8	11.1
Lake Campbell	10,960	771	3002	8.0	10.9	2.3	3.9
Lake Poinsett	16,240 (Dry) 16,160 (Poin.) 34,000(Albert)	1697 1591 4501	6075 6275 15951	29.2 21.3 44.5	27.8 24.7 54.4	8.3 6.1 14.0	9.7 9.0 20.5
Pelican Lake	13,160	3220	8302	84.6	57.8	21.2	18.0
Lake Herman	40,440	5582	--------	96.4	--------	24.9	--------
Richmond Lake	86,680	3226	19593	21.6	49.1	8.2	20.2
Lake Mitchell	23,960	1342	2618	26.2	15.3	7.2	4.6
Firesteel Creek **(Lake Mitchell Outlet)**	**350,960** **(44,600)**	**1183**	**868**	**11.8**	**8.5**	**1.7**	**1.8**
Wilmarth	**37,320**	**6641**	**4840**	**42.7**	**24.3**	**17.3**	**7.6**
North Firesteel	**121,320**	**18,372**	**28,336**	**64.9**	**63.1**	**24.9**	**26.7**
West Firesteel	**147,720**	**11,319**	**16,657**	**42.1**	**50.2**	**14.1**	**19.2**
Main Firesteel **(DF site #1)**	**34,880**	**2580**	**5331**	**13.5**	**15.3**	**6.1**	**5.8**
(Site #11, Cell #926)	**4960**	**458**	**972**	**3.1**	**3.2**	**.9**	**1.1**
Total to Lake	**346,200**	**39,370**	**39,884**	**166.3**	**156.1**	**63.3**	**60.4**

SEDIMENT YIELD RESULTS

The AGNPS data indicates that the Firesteel Creek Watershed has below average sediment deliverability rates. The sediment deliverability rate to Lake Mitchell was found to be 0.11 tons/event/acre during a 25 year 24 hour storm event. The average annual sediment deliverability rate to Lake Mitchell was estimated to be 0.11 tons/ year/ acre. This rate is approximately 50%-75% below the expected critical range of 0.20-0.40 tons/acre/event. However, the sediment deliverability rates from subwatersheds 5 (#775), 6 (#776) located in the Wilmarth watershed, 2 (#1049) located in the North Firesteel watershed, 10 (#1327), 11 (#1597) located in the West Firesteel watershed, and 4(#435) located in the Main Firesteel, watershed are all contributing elevated sediment loads. Below is a comparison of the 25 year event, subwatershed sediment yield to its aerial size:

Subwatersheds Within the Primary Watersheds Producing Excessive Sediment Loads

Subwatershed	% of Total Sediment Loading	% of Watershed Area	# of Critical Cells
5 (#775)	2.7%	0.4%	3
6 (#776)	5.9%	3.2%	1
Totals (Wilmarth)	8.6%	3.6%	4 of 24 (16.7%)

Subwatershed	% of Total Sediment Loading	% of Watershed Area	# of Critical Cells
2 (#1049)	11.6%	6.7%	9
Totals (North Firesteel)	11.6%	6.7%	9 of 148 (6.1%)

Subwatershed	% of Total Sediment Loading	% of Watershed Area	# of Critical Cells
10 (#1327)	3.1%	0.8%	10
11 (#1597)	6.3%	1.4%	24
Totals (West Firesteel)	9.4%	2.2%	34 of 84 (41.0%)

Subwatershed	% of Total Sediment Loading	% of Watershed Area	# of Critical Cells
4 (#435)	12.1%	4.1%	7
Totals (Main Firesteel)	12.1%	4.1%	7 of 14 (50.0%)

SEDIMENT ANALYSIS

Wilmarth Watershed

Subwatersheds #775 and #776 are contributing very high amounts of sediment to Lake Wilmarth. These two subwatersheds contribute 8.6% of the total sediment to Lake Wilmarth, contain 16.7% of the critical erosion cells, and only occupy 3.6% of the watershed area. The high sediment yields can be attributed to the proximity of these two subwatersheds to the lake and to land use. The source of this sediment is primarily from 200 acres of land near the north side of the lake. This area has an average slope of 5% and is currently cropped (C-Factor 0.29). The conversion of these 200 acres to high residue management or rangeland should reduce the volume of sediment delivered to Lake

Wilmarth by 146 tons (25 year event). Additional sediment reductions could be achieved by the incorporation of high residue management practices on approximately 720 acres of cropland located just north of Lake Wilmarth. The impact of sediment erosion derived from wind and its deliverabilty to Lake Wilmarth was not modeled. However, the magnitude of wind erosion is probably at least as great as that of water derived erosion. Therefore, the impact of the conversion of the critical 200 acres of cropland to high residue management operation should reduce sediment delivered to Lake Wilmarth by at least 150 tons/year. Overall, the Lake Wilmarth watershed is contributing a very low rate of sediment (0.130 $_{\text{tons/acre/25 year event}}$). Efforts should be made to target appropriate Best Management Practices (BMP's) to the 24 critical erosion cells identified on page 66.

North Firesteel Watershed

Subwatershed #1049 is contributing moderately high amount of sediment. This subwatershed contributes 11.6% of the total sediment, contains 6.1% of the critical erosion cells, and occupies only 6.7% of the North Firesteel watershed area. Overall, the North Firesteel watershed is contributing a low rate of sediment (0.230 $_{\text{tons/acre/25 year event}}$). However this rate is approximately twice that of the other 3 primary watersheds. This can probably be attributed to the higher average land slopes within the North Firesteel watershed contributing a higher average sediment yield. The elevated sediment erosion rate in subwatershed #1049 can probably be attributed to various land use practices. Of the nine critical cells identified, the land use in eight cells is cropland and one cell is rangeland. The land slopes range from 8% to 20%. It is recommended that the eight cells that are currently in cropland be returned to rangeland or implement a high residue management plan. The one cell (#872) which is currently in rangeland should be placed into CRP. Substantial reductions of sediment from the North Firesteel watershed are probably not possible due to the natural conditions (steep slopes). Therefore, efforts to reduce sediment in this watershed should be limited and targeted to appropriate BMP's for the 148 critical erosion cells identified on pages 68-71.

West Firesteel Watershed

Subwatersheds #1327 and #1597 are contributing high amounts of sediment. These subwatersheds were found to contribute 9.4% of the total sediment load, contain 41.0% of the critical erosion cells, while occupying 2.2% of the West Firesteel watershed area. Overall, the West Firesteel watershed is contributing a very low rate of sediment (0.1100 $_{\text{tons/acre/25 year event}}$). The area contained within these two small subwatersheds (1240 and 2120 acres) is characterized by steep land slopes (2-8%) which are utilized as cropland. It is recommended that the 34 cells that are currently in cropland (5-8% slopes) be returned to rangeland or implement a high residue management plan. Due to the relatively low rate of sediment throughout the West Firesteel watershed, efforts to reduce sediment in this watershed should be limited. The other 50 critical erosion cells, identified on pages 73-74, should be targeted for appropriate BMP's.

Main Firesteel Watershed

Subwatershed #435 is contributing high amounts of sediment. This subwatershed was found to contribute 12.1% of the total sediment load, contain 50.0% of the critical erosion cells (7), while occupying only 4.1% of the Main Firesteel watershed area. The area contained within this small subwatershed (1640 acres) is characterized by moderate land slopes (1-8%) which are utilized as cropland. It is recommended that the seven cells that are currently in cropland (5% slopes) be returned to rangeland or implement a high residue management plan. Overall, the Main Firesteel watershed is contributing a very low rate of sediment (0.1500 $_{\text{tons/acre/25 year event}}$). Due to the relatively low rate of erosion throughout the Main Firesteel watershed, efforts to reduce sediment in this watershed could be limited. The 14 critical erosion cells, identified on page 76, should be targeted for appropriate BMP's.

Entire Firesteel Watershed

Overall, the sediment loadings to Lake Mitchell is very low (0.1137 $_{\text{tons/acre/year}}$). This rate is equivalent to a volume of 39,370 tons of sediment delivered to Lake Mitchell. If it is assumed that 100% of the sediment delivered to Lake Mitchell is captured within the lake, this would be equivalent to a deposition rate of 0.44 inches/year over the 660 acre lake. This is equivalent to a loss of 1 foot of lake depth every 61 years. This depth loss rate is optimistic because it is assumed that 100% of the sediment delivered to the lake is retained in the lake. This deposition rate is very low for a South Dakota lake. Therefore, it is recommended that efforts to reduce sediment be focused within the identified critical subwatersheds and individual critical erosion cells located throughout the watershed.

NUTRIENT YIELD RESULTS

The AGNPS data indicates that the Firesteel Creek watershed has an above average total nitrogen (soluble + sediment bound) deliverability rate of 0.0005 $_{\text{tons/acre/25 year event}}$. Firesteel Creek watershed also has above average total phosphorus (soluble + sediment bound) deliverability rate of 0.00017 $_{\text{tons/acre/25 year event}}$. The estimated deliverability rate for an average large watershed is 0.00025 $_{\text{(soluble + sediment bound)}}$ for nitrogen and 0.00007 $_{\text{tons/acre/25 year event}}$ for phosphorus. Due to the size of the Lake Mitchell watershed (350,960 acres), the total volume of nutrients delivered to Lake Mitchell is high (166 tons/year of nitrogen, 63.3 tons/year of phosphorus). The nutrient deliverability rates from subwatershed 5 located in the Wilmarth watershed, subwatershed 2 located in the North Firesteel watershed, subwatersheds 10 and 11 located in the West Firesteel watershed, and subwatersheds 4 and 8 located in the Main Firesteel watershed appear to be contributing elevated nutrient loadings. There is a correlation between the subwatersheds which have a high sediment yield and those which have a high nutrient yield since some of the nutrients will attach to the sediment. A comparison of the subwatershed total nutrient yield to its aerial size for a 25 year storm event is:

Subwatersheds Within the Primary Watersheds Producing Excessive Nutrient Loads

Subwatershed	% of Total Nutrient Loading	% of Watershed Area	# of Phos. Critical Cells
5 (#775)	1.3%	.4%	0
Totals (Wilmarth)	1.3%	.4%	0 of 36 (0.0%)

Subwatershed	% of Total Nutrient Loading	% of Watershed Area	# of Phos. Critical Cells
2 (#1049)	10.7%	6.7%	9
Totals (North Firesteel)	10.7%	6.7%	9 of 114 (7.9%)

Subwatershed	% of Total Nutrient Loading	% of Watershed Area	# of Phos. Critical Cells
10 (#1327)	2.2%	.8%	0
11 (#1597)	4.0%	1.4%	0
Totals (West Firesteel)	6.2%	2.2%	0 of 116 (0.0%)

Subwatershed	% of Total Nutrient Loading	% of Watershed Area	# of Phos. Critical Cells
4 (#435)	9.9%	4.1%	0
8 (#663)	11.2%	5.5%	5
Totals (Main Firesteel)	21.1%	9.6%	5 of 31 (16.1%)

TOTAL NUTRIENT ANALYSIS

Wilmarth Watershed

One subwatershed within the Lake Wilmarth basin (subwatershed 5 as in the previous table) appears to be contributing a very high amount of total nutrients. This can probably be attributed to nutrients which are associated with the high sediment yields from this subwatershed. This is verified by the fact that there are no critical phosphorus cells or animal feeding areas located within this subwatershed.

The total Wilmarth watershed nutrient losses per acre are significantly higher than the other three primary watersheds of Firesteel Creek. When adjusted for drainage size and deliverability, the Lake Wilmarth watershed nutrient loads are less than the North and West Firesteel watersheds and more than the Main Firesteel watershed. The suspected sources for the elevated nutrients are from animal feeding operations. Animal feeding operations within cells #113, 182, 694 and 810 appear to be contributing significant nutrients to the watershed (AGNPS >50). A detailed evaluation of the feeding areas within the Lake Wilmarth watershed appears on pages 79.

North Firesteel Watershed

One subwatershed, discharging in cell #1049, appears to be contributing very high amounts of total nutrients. This is most likely attributed to nutrients associated with the high sediment yields from this subwatershed and animal feeding areas located within cells #1084 and #1115. This is verified by the fact that eight of the nine critical phosphorus cells are located within and adjacent downstream of these two animal feeding areas.

The total nutrient loads leaving the North Firesteel watershed are high when adjusted for the size of its watershed drainage area and deliverability rate. Typically, the smaller the size of the watershed drainage, the higher the per acre deliverability rates. Conversely, the larger the size of the watershed drainage, the smaller the per acre deliverabilty rates per acre. The total loads of 0.00050 tons/acre/25 year event and 0.00020 tons/acre/25 year event, for nitrogen and phosphorus respectively, are very high when adjusted for its watershed drainage area and stream length.

The primary suspected sources for the elevated total nutrient loads are from animal feeding operations. Animal feeding operations within cells #216, 1067, 1115, 1130, 1155, 1228, 1386(001), 1517, 1618, 1727, 1780, 1958, 2287, 2437, 2482, 2506, 2664, 2792 and 2850 appear to be contributing significant nutrients to the watershed (AGNPS ranking > 50). A detailed evaluation of the feeding areas within the North Firesteel watershed appears on pages 84-89.

West Firesteel Watershed

Two subwatersheds within the West Firesteel watershed (West Firesteel subwatersheds #10 and #11) appear to be contributing very high total nutrients loads. These may be attributed to nutrients associated with the high sediment yields from the subwatersheds. This is verified by the fact that there are no critical phosphorus cells and no animal feeding areas within these subwatersheds.

Overall, the total nutrient loads leaving the West Firesteel watershed are less than that of the North Firesteel watershed when adjusted for the size of its watershed drainage area. The total loads of 0.00030 tons/acre/25 year event and 0.00010 tons/acre/25 year event, for nitrogen and phosphorus respectively, are moderately high when adjusted for their watershed drainage area. The West Firesteel Creek loads are approximately 1/2 (40-50%) of the per acre loads found within the North Firesteel watershed. The difference is most likely due to the flat land slopes and the greater size of the watershed.

The primary suspected sources for the elevated nutrient loads are from animal feeding operations. Animal feeding operations within cells #235, 254, 331, 375, 1108, 1253(002), 1428, 1703, 2218, 2536 and 2757 appear to be contributing significant nutrient loads (AGNPS ranking > 50). Although the model did not highlight the cells as relatively critical, these cells have feeding areas with high ratings. A detailed evaluation of the feeding areas within the West Firesteel watershed appears on pages 93-97.

Main Firesteel Watershed

Two subwatersheds (#4 and #8) within the Main Firesteel watershed appear to be contributing high accumulations of total nutrient loads. Some of the nutrients in subwatershed #4 can be attributed to nutrients which are associated with the high sediment yields from areas in this subwatershed. There are also some critical cells containing animal feeding areas within this watershed. Cell #432 appears to be contributing a high level of nutrients.

Subwatershed #8 within the Main Firesteel watershed also appears to be contributing high nutrient levels. This higher nutrient load may be attributed to nutrients from the animal feeding area in cell #659 (AGNPS ranking 77).

Overall, the nutrient loads entering Lake Mitchell from the Main Firesteel watershed are average (0.00040 tons/acre/25 year event for nitrogen and 0.00020 tons/acre/25 year event for phosphorus). The suspected nutrient sources are mostly from animal feeding operations. Animal feeding operations within cell's #432, 659 and 876 appear to be contributing significant nutrients to the watershed (AGNPS ranking > 50). Although these cells were not highlighted as critical, they may still be releasing elevated nutrient levels. A detailed evaluation of the feeding areas within the Main Firesteel watershed appear on pages 99-100.

Entire Firesteel Watershed

Overall, the nutrient loadings to Lake Mitchell are high (0.00050 tons/acre/25 year event for nitrogen and 0.00017 tons/acre/25 year event for phosphorus). This rate is equivalent to 156.1 tons of nitrogen and 60.4 tons of phosphorus delivered to the lake. Since the sedimentation rate to the lake is low, the most likely source of the high nutrients is from animal feeding operations within the watershed. A total of 37 animal feeding areas with an AGNPS ranking of greater than 50 were identified. Therefore, it is recommended that efforts to reduce nutrients be targeted to the installation of appropriate BMP's in order to minimize the impact of animal feeding areas.

The overall sediment load to the lake is still very small. Considering the subwatershed analysis in the previous section, it appears that another source of nutrients is from the above noted subwatersheds with excessive erosion. These subwatershed were highlighted because they had specific areas contributing relatively high nutrients. These watersheds were highlighted to help planners target areas if erosion controls are being considered.

The elevated nutrient rate from subwatershed #663, appears to be associated with nutrients from the animal feeding operation in cell #659. Even though only one subwatershed, of the larger primary subwatersheds, had animal feeding areas as the main source of nutrients, the nutrients from individual feeding areas are much larger than this analysis may show. This analysis is comparing subwatersheds and not loadings from individual cells.

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

LAKE WILMARTH SUBWATERSHEDS

SUBWATERSHED	DRAINAGE AREA (ACRES)	NUMBER OF CELLS WITH EROSION ⇩ 4.0 TONS/AC.	(%)	NUMBER OF CELLS WITH TOT. NIT. ⇩ 2.5 PPM	(%)	NUMBER OF CELLS WITH TOT. PHOS. ⇩ .40 PPM	(%)	NUMBER OF CELLS WITH ANIMAL FEEDING AREAS
1 (#254)	7080	2	1.1	5	2.8	6	3.4	4
2 (#535)	13,440	4	2.5	5	3.1	6	3.8	1
3 (#670)	7360	6	3.3	5	2.7	8	4.4	2
4 (#672)	18,320	4	3.3	6	4.9	6	4.9	0
5 (#775)	160	3	**75.0**	0	0.0	0	0.0	0
6 (#776)	1200	1	3.3	2	**6.7**	2	**6.7**	0
7 (#813)	35,680	4	1.9	7	3.2	8	3.7	4
TOTAL (Outlet of Lake Wilmarth, DF Site 7A)	37,320	24	2.6	30	3.2	36	3.9	11

Priority Erosion Cells
(erosion >4.0 tons/acre)

103 4.39 tons/acre
115 4.39 "
119 22.63 "
120 29.45 "
338 12.74 "
376 8.47 "
378 6.96 "
410 6.96 "
441 12.74 "
442 6.96 "
443 6.96 "
490 8.34 "
519 6.96 "
541 6.96 "
542 6.96 "
553 6.96 "
589 6.96 "
732 4.09 "
753 4.09 "
773 4.09 "
774 4.09 "
775 4.09 "
920 6.02 "
922 6.96 "

Priority Feeding Areas
(AGNPS ranking >40)

810 (74)
694 (65)
113 (57)
182 (55)
351 (46)
670 (42)
895 (40)

Priority Nitrogen Cells
(Total nit.conc.>2.5 ppm)

79 2.63 ppm
100 2.63 "
113 5.55 "
132 5.06 "
178 2.63 "
198 2.63 "
246 2.63 "
276 2.63 "
284 2.66 "
351 4.79 "
365 2.87 "
379 2.63 "
385 3.51 "
386 2.89 "
508 2.63 "
509 2.63 "
531 2.63 "
532 2.63 "
557 2.53 "
626 3.61 "
668 2.63 "
694 58.16 "
714 2.87 "
754 3.41 "
755 2.73 "
795 2.76 "
796 2.72 "
895 5.86 "
906 2.73 "
917 3.41 "

Priority Phosphorus Cells
(Total phos.conc.>.40 ppm)

79 .46 ppm
100 .46 "
113 1.30 "
132 1.16 "
178 .46 "
198 .46 "
246 .46 "
255 .42 "
284 .71 "
351 1.53 "
365 .53 "
379 .46 "
385 1.05 "
386 .80 "
398 .41 "
411 .42 "
418 .53 "
450 .47 "
508 .46 "
509 .46 "
531 .46 "
532 .46 "
557 .44 "
626 .70 "
668 .46 "
694 16.17 "
706 .43 "
714 .53 "
754 .67 "
755 .50 "
895 2.42 "
896 .62 "

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Priority Erosion Cells (erosion >4.0 tons/acre)	Priority Feeding Areas (AGNPS ranking >40)	Priority Nitrogen Cells (Total nit.conc.>2.5 ppm)	Priority Phosphorus Cells (Total phos.conc.>.40 ppm)
			897 .43 ppm
			906 .50 "
			917 .67 "
			276 .46 "

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

sediment erosion rate ⇩ 4.0 tons/ acre
total nitrogen concentration rate ⇩ 2.5 ppm
total phosphorus concentration rate ⇩ .40 ppm

An analysis of the Lake Wilmarth watershed indicates that there are approximately 24 cells which have greater than 4.0 tons/acre of sediment yield. This is approximately 2.6% of the cells found within the entire Lake Wilmarth watershed. The model also estimated that there are 30 cells (3.2%) that have a total nitrogen yield of greater than 2.5 ppm and 36 cells (3.9%) that have a total phosphorus yield greater than 0.40 ppm. The location and yields for each of these cells are listed on page 66.

The most critical area for deliverable sediment is located just north of Lake Wilmarth (7 cells). One of the most critical sources of deliverable nutrients is from the feeding area located within cell #810. These critical areas of the Lake Wilmarth watershed should be given high priority when installing any future best management practices. It is recommended that any targeted cell should be field verified prior to the installation of any best management practices.

NORTH FIRESTEEL SUBWATERSHEDS

SUBWATERSHED	DRAINAGE AREA (ACRES)	NUMBER OF CELLS WITH EROSION ⇩ 4.0 TONS/AC.	(%)	NUMBER OF CELLS WITH TOT. NIT. ⇩ 2.5 PPM	(%)	NUMBER OF CELLS WITH TOT. PHOS. ⇩ .40 PPM	(%)	NUMBER OF CELLS WITH ANIMAL FEEDING AREAS
1 (#1020)	36,200	51	5.6	17	1.9	30	3.3	24
2 (#1049)	8160	9	4.4	6	2.9	9	4.4	11
3 (#1464)	54,560	16	6.2	2	.8	11	4.3	10
4 (#1956)	73,960	18	3.7	10	2.1	15	3.1	17
5 (#2293)	11,560	10	3.5	12	**4.2**	23	**8.0**	10
6 (#2382) DF Site #7	100,120	9	2.5	7	1.9	9	2.5	9
7 (#2917)	7880	11	5.6	7	**3.6**	9	**4.6**	7
8 (#2928)	108,400	24	**11.6**	3	1.5	7	3.4	8
9 (#2984) DF Site #5	119,720	0	0.0	0	0.0	1	1.2	4
TOTAL Outlet of North Firesteel	121,320	148	4.9	64	2.1	114	3.8	100

Priority Erosion Cells	**Priority Feeding Areas**	**Priority Nitrogen Cells**	**Priority Phosphorus Cells**
(erosion >4.0 tons/acre)	(AGNPS ranking >40)	(Total nit.conc.>2.5 ppm)	(Total phos.conc.>.40 ppm)
5 12.30 tons/acre	2482 (71)	84 2.83 ppm	84 .92 ppm
14 12.30 "	1155 (71)	216 8.28 "	85 .67 "
41 13.03 "	1228 (65)	383 8.09 "	86 .52 "
42 13.03 "	1618 (60)	462 7.40 "	216 2.14 "
43 13.03 "	2506 (60)	463 4.61 "	232 .46 "
44 13.03 "	2850 (59)	464 3.19 "	383 1.51 "
45 13.03 "	1727 (58)	465 2.67 "	411 .55 "
46 13.03 "	2437 (57)	491 3.19 "	412 .51 "
47 13.03 "	216 (56)	497 3.63 "	451 .61 "
48 13.03 "	1067 (56)	498 2.72 "	462 3.75 "
49 13.03 "	1780 (56)	531 3.89 "	463 2.18 "
50 13.03 "	1386-1 (55)	541 8.50 "	464 1.38 "
64 12.30 "	2287 (55)	704 4.38 "	465 1.09 "
70 12.30 "	2792 (54)	705 2.70 "	466 .90 "
105 12.30 "	1130 (53)	777 5.37 "	491 .98 "
111 12.30 "	1517 (53)	778 3.48 "	497 .83 "
115 12.30 "	2664 (53)	779 2.83 "	498 .58 "
146 12.30 "	1115 (52)	1084 10.63 "	531 1.29 "
147 12.30 "	1958 (51)	1087 2.83 "	541 3.38 "
150 12.30 "	2810 (49)	1115 20.62 "	542 .49 "
154 12.30 "	531 (48)	1116 10.59 "	543 .45 "
198 13.03 "	225 (47)	1117 8.05 "	544 .42 "
199 13.03 "	383 (47)	1118 3.21 "	545 .40 "
228 12.30 "	462 (47)	1177 4.09 "	608 .44 "
262 12.30 "	541 (47)	1222 4.03 "	704 1.44 "
263 12.30 "	1559 (46)	1504 4.00 "	705 .73 "
304 12.30 "	2529 (44)	1505 3.13 "	706 .45 "
324 12.30 "	2063 (43)	1506 2.62 "	777 1.90 "
363 12.30 "	1835 (43)	1618 2.85 "	778 1.13 "
364 12.30 "	1386-2 (42)	1646 2.73 "	779 .85 "

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Priority Erosion Cells **Priority Feeding Areas** **Priority Nitrogen Cells** **Priority Phosphorus Cells**

(erosion >4.0 tons/acre)	(AGNPS ranking >40)	(Total nit.conc.>2.5 ppm)	(Total phos.conc.>.40 ppm)
375 12.30 tons/acre	1504 (42)	1647 2.59 ppm	1001 .42 ppm
376 12.30 "	1084 (42)	1780 26.65 "	1026 .43 "
457 22.63 "	2288 (42)	1781 10.04 "	1056 .63 "
461 12.30 "	777 (41)	1835 8.50 "	1084 4.04 "
498 22.63 "	1222 (41)	1864 8.84 "	1087 .85 "
539 22.63 "	1975 (41)	1881 2.62 "	1115 7.77 "
666 12.30 "		1957 4.41 "	1116 3.92 "
734 12.30 "		1958 19.71 "	1117 2.92 "
743 12.30 "		1959 5.04 "	1118 1.00 "
758 12.30 "		1962 3.10 "	1130 2.26 "
759 12.30 "		1984 4.23 "	1131 .56 "
760 12.30 "		1985 3.67 "	1132 .53 "
770 12.30 "		2437 10.39 "	1155 .53 "
778 5.53 "		2438 7.27 "	1156 .49 "
796 12.30 "		2439 5.93 "	1157 .47 "
797 12.30 "		2440 5.03 "	1177 1.28 "
841 22.63 "		2441 4.39 "	1222 .95 "
872 29.45 "		2450 3.71 "	1228 13.81 "
880 12.30 "		2452 3.40 "	1291 .47 "
895 13.03 "		2482 10.28 "	1386 12.34 "
896 13.03 "		2483 9.62 "	1420 .57 "
928 13.03 "		2484 2.64 "	1504 .95 "
933 16.16 "		2485 2.59 "	1505 .70 "
961 13.03 "		2486 2.54 "	1506 .56 "
1007 22.63 "		2506 7.64 "	1559 .71 "
1036 12.30 "		2740 3.24 "	1560 .53 "
1053 22.63 "		2792 3.38 "	1618 .63 "
1071 12.30 "		2804 3.27 "	1646 .60 "
1082 13.03 "		2810 18.66 "	1647 .56 "
1083 13.03 "		2811 7.20 "	1780 10.21 "
1103 12.30 "		2818 2.96 "	1781 3.67 "
1113 22.63 "		2819 5.13 "	1835 3.12 "
1114 13.03 "		2850 42.20 "	1838 .49 "
1122 12.30 "		2882 6.35 "	1864 3.28 "
1147 12.30 "			1880 .40 "
1150 22.63 "			1881 .75 "
1161 12.30 "			1957 1.66 "
1178 12.30 "			1958 5.39 "
1205 12.30 "			1959 1.24 "
1214 12.30 "			1962 .78 "
1222 12.30 "			1963 .47 "
1302 13.30 "			1984 1.01 "
1309 14.06 "			1985 .85 "
1318 12.30 "			2063 .40 "
1349 12.30 "			2230 .68 "
1370 5.53 "			2271 .47 "
1380 15.77 "			2287 .42 "
1397 12.30 "			2288 .55 "
1399 12.30 "			2289 .48 "
1425 12.30 "			2290 .46 "
1454 12.30 "			2291 .45 "

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Priority Erosion Cells	**Priority Feeding Areas**	**Priority Nitrogen Cells**	**Priority Phosphorus Cells**

Priority Erosion Cells	Priority Feeding Areas	Priority Nitrogen Cells	Priority Phosphorus Cells
(erosion >4.0 tons/acre)	(AGNPS ranking >40)	(Total nit.conc.>2.5 ppm)	(Total phos.conc.>.40 ppm)
1460 13.03 tons/acre			2292 .43 ppm
1464 22.63 "			2437 2.76 "
1486 22.63 "			2438 1.87 "
1488 13.03 "			2439 1.49 "
1529 12.30 "			2440 1.24 "
1558 12.30 "			2441 1.06 "
1585 12.30 "			2447 .53 "
1768 12.30 "			2450 1.17 "
1802 12.30 "			2452 1.07 "
1819 12.30 "			2482 2.77 "
1826 5.53 "			2483 2.58 "
1827 5.53 "			2484 .59 "
1851 5.53 "			2485 .58 "
1867 22.63 "			2486 .56 "
1901 12.30 "			2487 .52 "
1978 12.30 "			2502 .40 "
2031 12.30 "			2506 1.70 "
2058 12.30 "			2582 .47 "
2089 22.63 "			2624 .64 "
2110 12.30 "			2625 .51 "
2296 12.74 "			2646 .70 "
2341 6.96 "			2740 .74 "
2342 6.96 "			2792 1.05 "
2377 4.19 "			2804 .46 "
2378 12.74 "			2810 7.25 "
2421 4.19 "			2811 2.62 "
2422 4.19 "			2816 .46 "
2434 6.96 "			2817 .60 "
2448 6.96 "			2818 .89 "
2458 12.74 "			2819 1.74 "
2462 4.19 "			2850 11.69 "
2463 4.19 "			2882 1.20 "
2467 6.96 "			2949 .53 "
2503 4.19 "			
2506 4.19 "			
2534 4.19 "			
2536 4.19 "			
2558 4.19 "			
2560 4.19 "			
2562 4.19 "			
2563 4.19 "			
2621 4.19 "			
2638 6.96 "			
2644 6.96 "			
2654 4.19 "			
2659 4.19 "			
2660 4.19 "			
2664 4.19 "			
2670 4.19 "			
2675 4.19 "			
2700 6.96 "			

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(erosion >4.0 tons/acre) (AGNPS ranking >40) (Total nit.conc.>2.5 ppm) (Total phos.conc.>.40 ppm)

2705 4.19 tons/acre
2746 6.96 "
2747 12.74 "
2764 6.96 "
2765 12.74 "
2789 6.96 "
2799 6.96 "
2800 4.19 "
2830 4.19 "
2846 12.74 "
2865 4.19 "
2866 4.19 "
2867 6.96 "
2883 4.19 "
2884 6.96 "
2886 6.96 "

Considering an evaluation of NPS cell yield data, the following critical cell yield criteria were established:

> sediment erosion rate ⇩ 4.0 tons/ acre
> total nitrogen concentration rate ⇩ 2.5 ppm
> total phosphorus concentration rate ⇩ .40 ppm

An analysis of the North Firesteel watershed indicates that there are approximately 148 cells which have greater than 4.0 tons/ acre of sediment yield. This is approximately 4.9% of the cells found within this entire watershed. The model also estimated that there are 64 cells (2.1%) that have a total nitrogen yield of greater than 2.5 ppm and 114 cells (3.8%) that have a total phosphorus yield greater than 0.40 ppm. The cell number and yields for each of these cells are listed on pages 68-70.

The most critical area for deliverable nutrients is located within subwatershed 8(#2928). The most critical sources of deliverable nutrients are from the feeding areas located within subwatersheds 5 (#2293) and 7 (#2917). These subwatersheds of North Firesteel and all critical cells should be given high priority when installing any future best management practices. It is recommended that any targeted cell should be field verified prior to the installation of any best management practices.

WEST FIRESTEEL SUBWATERSHEDS

SUBWATERSHED	DRAINAGE AREA (ACRES)	NUMBER OF CELLS WITH EROSION > 4.0 TONS/AC.	(%)	NUMBER OF CELLS WITH TOT. NIT. > 2.5 PPM	(%)	NUMBER OF CELLS WITH TOT. PHOS. > .40 PPM	(%)	NUMBER OF CELLS WITH ANIMAL FEEDING AREAS
1 (#401)	5680	0	0	0	0	0	0	1
2 (#454)	10,280	8	3.1	11	**4.3**	17	**6.6**	5
3 (#521)	18,200	3	0.7	1	0.2	4	0.9	4
4 (#720)	4400	3	2.7	0	0.0	1	0.9	1
5 (#722)	47,440	0	0.0	3	1.4	10	4.5	4
6 (#825)	95,760	16	**8.4**	0	0.0	0	0.0	6
7 (#1175)	21,600	3	0.6	15	2.8	29	5.4	9
8 (#1257) DF Site #6	146,120	12	**28.6**	8	**19.0**	10	**23.8**	7
9 (#1311)	3240	0	0.0	0	0.0	3	3.7	1
10 (#1327)	1240	10	**32.3**	0	0.0	0	0.0	0
11 (#1597)	2120	24	**45.3**	0	0.0	0	0.0	0
12 (#1792)	18,400	1	0.2	19	**4.1**	29	**6.3**	15
13 (#2267)	11,360	0	0.0	0	0.0	3	1.1	9
14 (#2335)	15,840	4	1.0	6	1.5	7	1.8	15
15 (#2734)	15,600	0	0.0	1	0.3	3	0.8	10
TOTAL Outlet of West Firesteel	147,720	84	2.3	64	1.7	116	3.1	87

Priority Erosion Cells (erosion >4.0 tons/acre)	**Priority Feeding Areas** (AGNPS ranking >40)	**Priority Nitrogen Cells** (Total nit.conc.>2.5 ppm)	**Priority Phosphorus Cells** (Total phos.conc.>.40 ppm)
10 6.96 tons/acre	254 (78)	232 2.60 ppm	186 .43 ppm
11 6.96 "	1703 (66)	235 2.68 "	204 .46 "
186 6.96 "	375 (60)	236 2.57 "	210 .54 "
242 4.19 "	235 (56)	237 2.50 "	211 .49 "
260 6.96 "	331 (55)	254 6.82 "	232 .58 "
261 12.74 "	1108 (53)	255 3.60 "	233 .54 "
264 6.96 "	1253 (52)	256 3.46 "	234 .52 "
355 4.19 "	1428 (52)	259 2.92 "	235 .60 "
439 4.19 "	2218 (51)	283 3.31 "	236 .57 "
477 4.19 "	2536 (51)	284 3.23 "	237 .55 "
520 6.96 "	2757 (51)	285 3.10 "	254 1.76 "
609 4.19 "	2205 (49)	331 29.11 "	255 .84 "
610 4.19 "	1286 (49)	332 12.56 "	256 .81 "
719 12.74 "	405 (48)	405 5.55 "	259 .66 "
874 4.19 "	1249 (48)	976 2.78 "	270 1.94 "
993 4.19 "	1933 (48)	1027 9.72 "	271 .47 "
995 4.19 "	1576 (47)	1056 3.58 "	283 .76 "
998 4.19 "	1027 (46)	1057 3.17 "	284 .74 "
1058 4.19 "	3366 (46)	1063 2.59 "	285 .71 "
1059 4.19 "	1116 (45)	1108 13.04 "	303 .48 "
1118 4.19 "	1793 (44)	1109 9.35 "	304 .43 "
1179 4.19 "	1567 (43)	1110 7.33 "	331 6.96 "
1181 4.19 "	3226 (41)	1116 7.00 "	332 2.91 "
1185 4.19 "	2442 (40)	1121 2.55 "	333 .45 "
1189 4.19 "	2826 (40)	1124 2.78 "	334 .41 "
1190 4.19 "		1183 8.93 "	405 1.97 "
1224 6.96 "		1249 14.91 "	447 .42 "
1246 4.19 "		1286 9.24 "	747 .54 "
1247 4.19 "		1287 5.00 "	808 .54 "
1248 4.19 "		1567 3.09 "	976 .85 "
1249 4.19 "		1574 3.47 "	977 .52 "
1250 6.96 "		1575 3.33 "	1027 3.74 "
1251 4.19 "		1576 3.79 "	1028 .47 "
1252 4.19 "		1577 3.65 "	1056 .82 "
1294 6.96 "		1578 3.52 "	1057 .70 "
1316 4.19 "		1639 3.74 "	1058 .40 "
1317 4.19 "		1643 3.13 "	1063 .79 "
1318 4.19 "		1644 3.03 "	1108 3.49 "
1319 4.19 "		1645 2.94 "	1109 2.45 "
1320 4.19 "		1703 25.44 "	1110 1.88 "
1321 4.19 "		1704 6.13 "	1116 1.78 "
1534 4.19 "		1705 5.55 "	1121 .54 "
1600 4.19 "		1711 2.60 "	1122 .51 "
1601 4.19 "		1712 2.53 "	1124 .73 "
1794 4.19 "		1791 5.65 "	1183 2.34 "
1795 4.19 "		1933 13.94 "	1249 4.04 "
1797 4.19 "		1934 7.32 "	1271 .40 "
1798 4.19 "		1935 4.62 "	1286 4.33 "
1861 4.19 "		2205 6.21 "	1287 2.17 "
1862 4.19 "		2206 4.14 "	1446 .64 "
1863 4.19 "		2207 3.44 "	1447 .48 "

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Priority Erosion Cells **Priority Feeding Areas** **Priority Nitrogen Cells** **Priority Phosphorus Cells**

Priority Erosion Cells	**Priority Feeding Areas**	**Priority Nitrogen Cells**	**Priority Phosphorus Cells**
(erosion >4.0 tons/acre)	(AGNPS ranking >40)	(Total nit.conc.>2.5 ppm)	(Total phos.conc.>.40 ppm)
1864 4.19 tons/acre		2208 2.98 ppm	1448 .40 ppm
1923 4.19 "		2209 2.64 "	1567 1.37 "
1931 4.19 "		2401 3.86 "	1568 .76 "
1932 4.19 "		2468 4.56 "	1574 .80 "
1992 4.19 "		2536 13.04 "	1575 .76 "
1999 4.19 "		2537 6.85 "	1576 .86 "
2000 4.19 "		2757 7.00 "	1577 .82 "
2064 4.19 "		2758 5.41 "	1578 .78 "
2065 4.19 "		2759 4.41 "	1639 .88 "
2066 6.96 "		2760 3.58 "	1643 .68 "
2130 4.19 "		3434 2.76 "	1644 .65 "
2132 4.19 "		3530 9.95 "	1645 .63 "
2133 4.19 "		3607 3.10 "	1647 .49 "
2135 4.19 "			1648 .48 "
2136 4.19 "			1649 .46 "
2198 4.19 "			1650 .45 "
2202 6.96 "			1703 6.98 "
2203 4.19 "			1704 1.54 "
2204 4.19 "			1705 1.38 "
2269 6.96 "			1711 .54 "
2270 6.96 "			1712 .52 "
2271 6.96 "			1791 2.96 "
2334 4.19 "			1869 .61 "
2335 4.19 "			1870 .53 "
2338 8.34 "			1871 .48 "
2405 6.96 "			1933 4.57 "
2406 6.96 "			1934 2.29 "
2471 4.19 "			1935 1.36 "
2541 4.19 "			1977 .42 "
2542 4.19 "			2205 6.21 "
2671 6.96 "			2206 1.57 "
2716 6.96 "			2207 1.25 "
2840 6.96 "			2208 1.04 "
			2209 .89 "
			2210 .77 "
			2211 .64 "
			2212 .58 "
			2213 .52 "
			2214 .48 "
			2215 .44 "
			2216 .40 "
			2218 .70 "
			2219 .65 "
			2401 .91 "
			2442 .80 "
			2443 .61 "
			2444 .49 "
			2445 .42 "
			2468 1.11 "
			2536 3.51 "
			2537 1.76 "
			2582 .60 "

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(erosion >4.0 tons/acre)	(AGNPS ranking >40)	(Total nit.conc.>2.5 ppm)	(Total phos.conc.>.40 ppm)
			2697 .45 ppm
			2698 .41 "
			2757 1.65 "
			2758 1.24 "
			2759 .99 "
			2760 .77 "
			2941 .42 "
			3083 .95 "
			3214 .42 "
			3434 .90 "
			3530 1.47 "
			3591 .52 "
			3607 1.00 "
			3664 .42 "

Considering an evaluation of NPS cell yield data, the following critical cell yield criteria were established:

sediment erosion rate > 4.0 tons/ acre
total nitrogen concentration rate > 2.5 ppm
total phosphorus concentration rate > 0.40 ppm

An analysis of the West Firesteel watershed indicates that there are approximately 84 cells which have greater than 4.0 tons/ acre of sediment yield. This is approximately 2.3% of the cells found within the entire watershed. The model also estimated that there are 64 cells (1.7%)that have a total nitrogen yield of greater than 2.5 ppm and 116 cells (3.1%) that have a total phosphorus yield greater than 0.40 ppm. The cell number and yields for each of these cells are listed on pages 73-75.

The most critical areas for deliverable sediment are located within subwatersheds 6(#825), 8(#1257), 10(#1327) and 11(#1597). The most critical sources of deliverable nutrients are from the feeding areas located within subwatersheds 2(#454), 8(#1257) and 12(#1792). These subwatersheds of West Firesteel and all critical cells should be given high priority when installing any future best management practices. It is recommended that any targeted cell should be field verified prior to the installation of any best management practices.

MAIN FIRESTEEL SUBWATERSHEDS

SUBWATERSHED	DRAINAGE AREA (ACRES)	NUMBER OF CELLS WITH EROSION > 4.0 TONS/AC.	(%)	NUMBER OF CELLS WITH TOT. NIT. > 2.5 PPM	(%)	NUMBER OF CELLS WITH TOT. PHOS. > .40 PPM	(%)	NUMBER OF CELLS WITH ANIMAL FEEDING AREAS
1 (#258) DF Site #3	10,360	N.A	N.A	N.A.	N.A	N.A.	N.A	N.A.
2 (#358)	11,280	0	0.0	2	0.7	4	1.4	8
3 (#390) DF Site #4 -GS station	12,440	2	1.8	0	0.0	5	4.6	3
4 (#435)	1640	7	**17.1**	0	0.0	0	0.0	2
5 (#561)	6440	4	2.5	0	0.0	4	2.5	6
6 (#578)	1720	0	0.0	0	0.0	0	0.0	3
7 (#605) DF Site #1	34,880	0	0.0	3	1.0	4	1.4	4
8 (#663)	2240	0	0.0	5	**8.9**	5	**8.9**	2
9 (#730)	35,600	N.A.	N.A	N.A.	N.A	N.A.	N.A	N.A.
10 (#922) DF Site #2	4160	N.A.	N.A	N.A.	N.A	N.A.	N.A	N.A.
11 (#926)	4960	1	0.8	2	1.6	4	3.2	7
DIRECT	4040	0	0.0	3	**3.0**	5	**5.0**	2
TOTAL Outlet of Lake Mitchell	44,600	14	1.2	15	1.3	31	2.8	37

Priority Erosion Cells
(erosion >4.0 tons/acre)

426	4.19	tons/acre
430	4.19	"
431	4.19	"
490	4.19	"
553	4.19	"
615	4.19	"
616	4.19	"
627	6.09	"
628	37.96	"
769	6.09	"
791	4.19	"
841	4.19	"
888	4.19	"
1010	4.19	"

Priority Feeding Areas
(AGNPS ranking >40)

659	(77)
876	(71)
432	(61)
326	(49)
481	(44)

Priority Nitrogen Cells
(Total nit.conc.>2.5 ppm)

17	5.30	ppm
23	3.53	"
326	8.18	"
360	5.68	"
420	3.32	"
481	3.32	"
482	2.68	"
483	2.50	"
659	3.02	"
660	2.84	"
661	2.77	"
662	2.56	"
663	2.51	"
876	32.05	"
919	23.55	"

Priority Phosphorus Cells
(Totalphos.conc.>.40 pm)

17	1.51	ppm
23	1.06	"
176	.47	"
195	.91	"
295	.92	"
326	2.13	"
329	.79	"
330	.66	"
360	1.42	"
378	.42	"
420	1.24	"
440	.55	"
478	.64	"
481	1.11	"
482	.84	"
483	.78	"
546	.65	"
608	.58	"
621	.77	"
659	.68	"
660	.63	"
661	.61	"
662	.55	"
663	.54	"
822	.78	"
876	8.89	"
879	.43	"
919	6.49	"
1103	.45	"
1104	.56	"
1109	.82	"

Considering an evaluation of NPS cell yield data, the following critical cell yield criteria were established:

sediment erosion rate > 4.0 tons/ acre
total nitrogen concentration rate > 2.5 ppm
total phosphorus concentration rate > 0.40 ppm

An analysis of the Main Firesteel watershed indicates that there are approximately 14 cells which have greater than 4.0 tons/ acre of sediment yield. This is approximately 1.2% of the cells found within the entire watershed. The model also estimated that there are 15 cells (1.3%) which have a total nitrogen yield greater than 2.5 ppm and 31 cells (2.8%) which have a total phosphorus yield greater than 0.40 ppm. The location and yields for each of these cells are listed on page 76.

The most critical area for sediment erosion and deliverablilty is located in subwatershed 4(#435), and the most critical source of nutrients and deliverability is from the feeding areas located within subwatershed 8(#663). These subwatersheds of Main Firesteel Creek and all critical cells should be given high priority when installing any future best management practices. It is recommended that any targeted cell should be field verified prior to the installation of any best management practices (BMP's).

Entire Firesteel Watershed

Since the primary source of elevated nutrients is from animal feeding operations, the targeting of appropriate measures to reduce nutrients from the critical feeding operations identified on pages 78-100 should be implemented. Even though the sediment loadings to Lake Mitchell are low, subwatersheds 5(#775) Wilmarth, 8(#2928) North Firesteel, 6(#825) West Firesteel, 8(#1257) West Firesteel, 10 (#1327) West Firesteel, 11(#1597) West Firesteel and 4(#435) Main Firesteel contain 34.4% of the critical erosion cells and comprise only 8.3% of the watershed area. The targeting of appropriate BMP's to reduce sediment erosion in these six subwatersheds should be implemented. These practices, combined with the targeting of BMP's to the other critical erosion cells located throughout the watershed, should provide the most cost effective means at reducing sediment erosion throughout the watershed.

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

A total of 241 animal feeding areas were identified as potential NPS sources during the AGNPS data acquisition phase of the project. Below is a listing of the AGNPS analysis of each feeding area:

WILMARTH WATERSHED

FEEDLOT (CELL #)	SUBWATERSHED LOCATION	AGNPS RATING (25 YR. EVT.)	RANKING PRIORITY♣	VARIANCE FROM RANKED MEAN OF 42.1	VARIANCE FROM 1 SSTD (σ = 19.9) FROM MEAN	PRIORITY RANK BASED ON AGNPS RANK AND DISTANCE FACTORS ∗		
						C.FACT	C.RATE	C.RANK
53	#1 (254)	16	5	-26.1	-1.31	.60	10	5
113	#1 (254)	**57**	3	+14.9	+.75	.60	**34**	4
182	#1 (254)	**55**	3	+12.9	+.65	.60	**33**	4
284	#1 (254)	27	4	-15.1	-.76	.60	16	5
351	#3 (670)	**46**	3	+3.9	+.20	.24	11	5
360	#2 (535)	30	4	-12.1	-.61	.36	11	5
670	#3 (670)	**42**	3	-.1	-.01	.60	25	4
694	#7 (813)	**65**	2	+22.9	+1.15	.60	**39**	4
706	#7 (813)	11	5	-31.1	-1.56	.32	4	5
810	#7 (813)	**74**	2	+31.9	+1.6	1.0	**74**	2
895	#7 (813)	40	3	-2.1	-.10	.36	15	5

♣ - PRIORITY RANKING

AGNPS RANK 80-100 = 1 (extremely critical)
AGNPS RANK 60-80 = 2 (very critical)
AGNPS RANK 40-60 = 3 (critical)
AGNPS RANK 20-40 = 4 (possibly critical)
AGNPS RANK 0-20 = 5 (not critical)

∗ - PRIORITY RANK = AGNPS 25 YEAR FEEDLOT RATING X DISTANCE TO STREAM X DISTANCE TO LAKE

DISTANCE TO STREAM FACTORS

Adjacent to stream = 1.0
Within 1 cell (1300 feet) = .8
Within 2 cells (2600 feet) = .6
Within 3 cells (3900 feet) = .4
Within 4 cells (5200 feet) = .2

DISTANCE TO LAKE FACTORS

Adjacent to lake = 1.0
Within 4 cells (5200 feet) = .9
Within 8 cells (10400 feet) = .8
Within 16 cells (15600 feet) = .7
Within 20 cells (20800 feet) = .6

Mean value = 42.1
Median value = 42.0
STDS = 19.9
Mean + 1STDS = 62.0

LAKE WILMARTH WATERSHED FEEDING AREA SELECTION CRITERIA AND STATISTICS (NOT WEIGHTED FOR DISTANCE FACTORS)

1.) Animal feedlot ranking	25 year event
2.) Range of feedlot rankings	11 - 74
3.) Mean	42.1
4.) Sample standard deviation (σ)	19.9

5.) Feedlots with rating ($\geq$ 40) are :

Cell # 113 000	
Nitrogen concentration (ppm)	141.000
Phosphorus concentration (ppm)	38.463
COD concentration (ppm)	2171.250
Nitrogen mass (lbs)	504.164
Phosphorus mass (lbs)	137.528
COD mass (lbs)	7763.591
Animal feedlot rating number	57 (+.75 σ)

Cell # 182 000	
Nitrogen concentration (ppm)	125.082
Phosphorus concentration (ppm)	35.230
COD concentration (ppm)	1858.262
Nitrogen mass (lbs)	433.774
Phosphorus mass (lbs)	122.175
COD mass (lbs)	6444.286
Animal feedlot rating number	55 (+.65 σ)

Cell # 351 000	
Nitrogen concentration (ppm)	59.629
Phosphorus concentration (ppm)	24.680
COD concentration (ppm)	1137.294
Nitrogen mass (lbs)	180.591
Phosphorus mass (lbs)	74.745
COD mass (lbs)	3444.389
Animal feedlot rating number	46 (+.20 σ)

Cell # 670 000	
Nitrogen concentration (ppm)	82.284
Phosphorus concentration (ppm)	23.032
COD concentration (ppm)	1210.097
Nitrogen mass (lbs)	176.960
Phosphorus mass (lbs)	49.532
COD mass (lbs)	2602.443
Animal feedlot rating number	42 (-.01 σ)

Cell # 694 000	
Nitrogen concentration (ppm)	125.118
Phosphorus concentration (ppm)	35.200
COD concentration (ppm)	1832.634
Nitrogen mass (lbs)	796.416
Phosphorus mass (lbs)	224.062
COD mass (lbs)	11665.350
Animal feedlot rating number	65 (+1.15 σ)

Cell # 810 000	
Nitrogen concentration (ppm)	148.788
Phosphorus concentration (ppm)	41.421
COD concentration (ppm)	2168.807
Nitrogen mass (lbs)	1476.638
Phosphorus mass (lbs)	411.086
COD mass (lbs)	21524.270
Animal feedlot rating number	74 (+1.60 σ)

LAKE WILMARTH WATERSHED FEEDING AREA SELECTION CRITERIA AND STATISTICS (WEIGHTED FOR DISTANCE FACTORS)

1.) Animal feedlot ranking	25 year event
2.) Range of feedlot rankings	4 - 74
3.) Mean	24.7
4.) Sample standard deviation (σ)	20.0

5.) Feedlots with rating ($\geq$ 30) are: 113, 182, 694, 810

6.) Additional feeding areas contributing high nutrients ($\geq$ 20) are: 670

Eleven (11) feeding areas within the Lake Wilmarth watershed were evaluated as part of this study. The AGNPS analysis consists of a feeding area numerical rating from 0 to 100. The ratings were then adjusted by factors based upon the distance from major streams and Lake Wilmarth. In general, the farther an animal feeding area is from a stream or lake, the less likely runoff from the facility will reach either. It is generally recommended that feeding areas with an AGNPS rating in excess of 30, or those with a distance corrected rating greater than 20, be targeted for treatment.

Of the eleven (11) evaluated feeding areas, five (5) had an $\text{AGNPS}_{\text{corr. rating}} > 20$. Four feeding areas, located in cells #113, 182, 694 and 810, appear to be contributing significant levels ($\text{AGNPS}_{\text{corr. rating}} > 30$) of nutrients to the watershed. When comparing other watersheds within eastern South Dakota, the numbers of critical feeding areas within the Wilmarth watershed are high (8 with $\text{AGNPS}_{\text{non-corr. rating}} > 30$).

It is recommended that the feeding areas within these eight (8) cells be evaluated for potential operational or structural modifications in order to minimize future nutrient releases. It is also recommended that all other potential feeding areas within the Lake Wilmarth watershed be evaluated. Other possible sources of nutrient loadings not modeled through this study were those from septic systems and from livestock depositing fecal material directly into the lake or adjacent streams. Overall, based upon the accuracy of the watershed information gathered and entered into the model, the total nutrients being deposited from the watershed into Lake Wilmarth appears to be very high.

NORTH FIRESTEEL WATERSHED

FEEDLOT (CELL #)	SUBWATERSHED LOCATION	AGNPS RATING (25 YR. EVT.)	RANKING PRIORITY♣	VARIANCE FROM RANKED MEAN OF 32.5	VARIANCE FROM 1 SSTD (σ = 18.0) FROM MEAN	PRIORITY RANK BASED ON AGNPS RANK AND DISTANCE FACTORS ∗		
						C.FACT	C.RATE	C.RANK
69	#1 (1020)	18	5	-14.5	-.81	.60	11	5
70	#1 (1020)	16	5	-16.5	-.92	.60	10	5
84	#1 (1020)	35	4	+2.5	+.14	.24	9	5
171	#1 (1020)	33	4	+.5	+.03	.60	20	4
216	#1 (1020)	**56**	3	+23.5	+1.31	.60	**34**	4
217	#1 (1020)	38	4	+5.5	+.31	.60	23	4
225	#1 (1020)	**47**	3	+14.5	+.81	.60	28	4
232	#1 (1020)	25	4	-7.5	-.42	.60	15	4
383	#1 (1020)	**47**	3	+14.5	+.81	.60	28	4
392	#1 (1020)	0	5	-32.5	-1.81	.60	0	5
421	#1 (1020)	2	5	-30.5	-1.69	.60	1	5
430	#1 (1020)	8	5	-24.5	-1.36	.48	4	5
432	#1 (1020)	0	5	-32.5	-1.81	.48	0	5
462	#1 (1020)	**47**	3	+14.5	+.81	.36	17	5
474	#1 (1020)	25	4	-7.5	-.42	.60	15	5
497	#1 (1020)	37	4	+4.5	+.25	.60	22	4
531	#1 (1020)	**48**	3	+15.5	+.86	.60	28	4
541	#1 (1020)	**47**	3	+14.5	+.81	.48	23	4
582	#1 (1020)	38	4	+5.5	+.31	.48	18	5
608	#1 (1020)	14	5	-18.5	-1.03	.24	4	5
704	#1 (1020)	27	4	-5.5	-.31	.60	16	5
745	#1 (1020)	18	5	-14.5	-.81	.60	11	5
748	#1 (1020)	0	5	-32.5	-1.81	.24	0	5
777	#1 (1020)	**41**	3	+8.5	+.47	.48	20	4
883	#2 (1049)	20	5	-12.5	-.69	.60	12	5
939	#2 (1049)	31	4	-1.5	-.08	.60	19	5
940	#2 (1049)	26	4	-6.5	-.36	.60	16	5
983	#2 (1049)	34	4	+2.5	+.14	.60	20	4
1001	#2 (1049)	32	4	-.5	-.03	.48	15	5
1010	#2 (1049)	35	4	+2.5	+.14	.60	21	4
1067	#2 (1049)	**56**	3	+23.5	+1.31	.60	**34**	4
1084	#2 (1049)	**42**	3	+9.5	+.53	.60	25	4
1097	#2 (1049)	0	5	-32.5	-1.81	.60	0	5
1115	#2 (1049)	**52**	3	+19.5	+1.08	.60	**31**	4
1129	#2 (1049)	27	4	-5.5	-.31	.60	16	5
1130	#3 (1464)	**53**	3	+20.5	+1.14	.60	**32**	4
1155	#3 (1464)	**71**	2	+38.5	+2.14	.60	**43**	3

NORTH FIRESTEEL WATERSHED

FEEDLOT (CELL #)	SUBWATERSHED LOCATION	AGNPS RATING (25 YR. EVT.)	RANKING PRIORITY♣	VARIANCE FROM RANKED MEAN OF 32.5	VARIANCE FROM 1 SSTD (σ = 18.0) FROM MEAN	PRIORITY RANK BASED ON AGNPS RANK AND DISTANCE FACTORS *		
						C.FACT	C.RATE	C.RANK
1177	#3 (1464)	31	4	-1.5	-.08	.60	19	5
1186	#3 (1464)	0	5	-32.5	-1.81	.60	0	5
1222	#3 (1464)	**41**	3	+8.5	+.47	.60	25	4
1228	#3 (1464)	**65**	2	+32.5	+1.81	.60	**39**	4
1249	#3 (1464)	31	4	-1.5	-.08	.60	19	5
1264	#3 (1464)	12	5	-20.5	-1.14	.60	7	5
1291	#3 (1464)	29	4	-3.5	-.19	.60	17	5
1345	#4 (1956)	28	4	-4.5	-.25	.60	17	5
1386-001	#3 (1464)	**55**	3	+22.5	+1.25	.60	**33**	4
1386-002	#3 (1464)	**42**	3	+9.5	+.53	.60	25	4
1420	#4 (1956)	34	4	+1.5	+.08	.60	20	4
1504	#4 (1956)	**42**	3	+9.5	+.53	.60	25	4
1515	#4 (1956)	24	4	-8.5	-.47	.60	14	5
1517	#4 (1956)	**53**	3	+20.5	+1.14	.60	**32**	4
1537	#4 (1956)	19	5	-13.5	-.75	.60	11	5
1559	#4 (1956)	**46**	3	+13.5	+.75	.60	28	4
1573	#4 (1956)	32	4	-.5	-.03	.60	19	5
1574	#4 (1956)	10	5	-22.5	-1.25	.60	6	5
1618	#4 (1956)	**60**	2	+27.5	+1.53	.60	**36**	4
1724	#4 (1956)	32	4	-.5	-.03	.60	19	5
1727	#4 (1956)	**58**	3	+25.5	+1.42	.60	**35**	4
1760	#4 (1956)	0	5	-32.5	-1.81	.60	0	5
1780	#4 (1956)	**56**	3	+23.5	+1.31	.60	**34**	4
1835	#6 (2382)	**43**	3	+10.5	+.58	.60	26	4
1838	#4 (1956)	31	4	-1.5	-.08	.60	19	5
1864	#6 (2382)	39	4	+6.5	+.36	.60	23	4
1881	#4 (1956)	29	4	-3.5	-.19	.48	14	5
1957	#4 (1956)	34	4	+1.5	+.08	.60	20	4
1958	#6 (2382)	**51**	3	+18.5	+1.03	.12	6	5
1962	#6 (2382)	31	4	-1.5	-.08	.12	4	5
1975	#6 (2382)	**41**	3	+8.5	+.47	.60	25	4
2063	#6 (2382)	**43**	3	+10.5	+.58	.12	5	5
2156	#6 (2382)	39	4	+6.5	+.36	.60	23	4
2207	#6 (2382)	37	4	+4.5	+.25	.48	19	5
2230	#5 (2293)	27	4	-5.5	-.31	.24	7	5
2287	#5 (2293)	**55**	3	+22.5	+1.25	.60	**33**	4
2288	#5 (2293)	**42**	3	+9.5	+.53	.60	25	4

NORTH FIRESTEEL WATERSHED

FEEDLOT (CELL #)	SUBWATERSHED LOCATION	AGNPS RATING (25 YR. EVT.)	RANKING PRIORITY♣	VARIANCE FROM RANKED MEAN OF 32.5	VARIANCE FROM 1 SSTD (σ = 18.0) FROM MEAN	PRIORITY RANK BASED ON AGNPS RANK AND DISTANCE FACTORS ∗		
						C.FACT	C.RATE	C.RANK
2295	#6 (2382)	33	4	+.5	+.03	.60	20	4
2343	#8 (2928)	25	4	-7.5	-.42	.60	15	5
2437	#5 (2293)	**57**	3	+24.5	+1.36	.48	27	4
2442	#5 (2293)	8	5	-24.5	-1.36	.60	5	5
2450	#5 (2293)	29	4	-3.5	-.19	.60	17	5
2452	#5 (2293)	27	4	-5.5	-.31	.60	16	5
2482	#5 (2293)	**71**	2	+38.5	+2.14	.48	**34**	4
2502	#8 (2928)	11	5	-21.5	-1.19	.48	5	5
2506	#8 (2928)	**60**	2	+27.5	+1.53	.60	**36**	4
2529	#5 (2293)	**44**	3	+11.5	+.64	.60	26	4
2582	#5 (2293)	24	4	-8.5	-.47	.60	14	5
2624	#8 (2928)	34	4	+1.5	+.08	.48	16	5
2646	#8 (2928)	30	4	-2.5	-.14	.60	18	5
2660	#8 (2928)	38	4	+5.5	+.31	.60	23	4
2664	#7 (2917)	**53**	3	+20.5	+1.14	.60	**32**	4
2740	#7 (2917)	22	4	-10.5	-.58	.12	3	5
2792	#7 (2917)	**54**	3	+21.5	+1.19	.60	**32**	4
2798	#7 (2917)	4	5	-28.5	-1.58	.12	.5	5
2804	#8 (2928)	0	5	-32.5	-1.81	.60	0	5
2810	#7 (2917)	**49**	3	+16.5	+.92	.60	29	4
2819	#7 (2917)	33	4	+.5	+.03	.12	4	5
2850	#7 (2917)	**59**	3	+26.5	+1.47	.60	**35**	4
2882-001	#8 (2928)	0	5	-32.5	-1.81	.60	0	5
2882-002	#8 (2928)	1	5	-31.5	-1.75	.60	.6	5
2942	#9 (2984)	27	4	-5.5	-.31	.60	16	5
2949	#9 (2984)	19	5	-13.5	-.75	.36	7	5
2972	#9 (2984)	5	5	-27.5	-1.53	.60	3	5
2999	#9 (2984)	10	5	-22.5	-1.25	.60	6	5

♣ - PRIORITY RANKING

AGNPS RANK 80-100 = 1 (extremely critical)
AGNPS RANK 60-80 = 2 (very critical)
AGNPS RANK 40-60 = 3 (critical)
AGNPS RANK 20-40 = 4 (possibly critical)
AGNPS RANK 0-20 = 5 (not critical)

∗ - PRIORITY RANK = AGNPS 25 YEAR FEEDLOT RATING X DISTANCE TO STREAM X DISTANCE TO LAKE

DISTANCE TO STREAM FACTORS
Adjacent to stream = 1.0
Within 1 cell (1300 feet) = .8
Within 2 cells (2600 feet) = .6
Within 3 cells (3900 feet) = .4
Within 4 cells (5200 feet) = .2

DISTANCE TO LAKE FACTORS
Adjacent to lake = 1.0
Within 4 cells (5200 feet) = .9
Within 8 cells (10400 feet) = .8
Within 16 cells (15600 feet) = .7
Within 20 cells (20800 feet) = .6

NORTH FIRESTEEL CREEK WATERSHED FEEDING AREA SELECTION CRITERIA AND STATISTICS (NOT WEIGHTED FOR DISTANCE FACTORS)

1.) Animal feedlot ranking	25 year event
2.) Range of feedlot rankings	0 - 71
3.) Mean	32.5
4.) Sample standard deviation (σ)	18.0

5.) Feedlots with rating (≥ 40) are :

Cell # 216 000

Nitrogen concentration (ppm)	126.261
Phosphorus concentration (ppm)	35.455
COD concentration (ppm)	1866.556
Nitrogen mass (lbs)	475.665
Phosphorus mass (lbs)	133.569
COD mass (lbs)	7031.917
Animal feedlot rating number	56 (+1.31 σ)

Cell # 225 000

Nitrogen concentration (ppm)	94.448
Phosphorus concentration (ppm)	26.429
COD concentration (ppm)	1388.333
Nitrogen mass (lbs)	257.137
Phosphorus mass (lbs)	71.954
COD mass (lbs)	3779.754
Animal feedlot rating number	47 (+.81 σ)

Cell # 383 000

Nitrogen concentration (ppm)	62.605
Phosphorus concentration (ppm)	12.683
COD concentration (ppm)	1096.204
Nitrogen mass (lbs)	204.966
Phosphorus mass (lbs	41.525
COD mass (lbs)	3588.911
Animal feedlot rating number	47 (+.81 σ)

Cell # 462 000

Nitrogen concentration (ppm)	30.005
Phosphorus concentration (ppm)	16.949
COD concentration (ppm)	808.096
Nitrogen mass (lbs)	127.712
Phosphorus mass (lbs)	72.142
COD mass (lbs)	3439.571
Animal feedlot rating number	47 (+.81 σ)

Cell # 531 000

Nitrogen concentration (ppm)	62.709
Phosphorus concentration (ppm)	24.491
COD concentration (ppm)	1118.479
Nitrogen mass (lbs)	216.554
Phosphorus mass (lbs)	84.575
COD mass (lbs)	3862.487
Animal feedlot rating number	48 (+.86 σ)

Cell # 541 000

Nitrogen concentration (ppm)	69.549
Phosphorus concentration (ppm)	30.240
COD concentration (ppm)	1403.704
Nitrogen mass (lbs)	190.883
Phosphorus mass (lbs)	82.996
COD mass (lbs)	3852.598
Animal feedlot rating number	47 (+.81 σ)

Cell # 777 000

Nitrogen concentration (ppm)	46.038
Phosphorus concentration (ppm)	18.792
COD concentration (ppm)	864.485
Nitrogen mass (lbs)	127.288
Phosphorus mass (lbs)	51.957
COD mass (lbs)	2390.181
Animal feedlot rating number	41 (+.47 σ)

Cell # 1067 000

Nitrogen concentration (ppm)	80.218
Phosphorus concentration (ppm)	32.505
COD concentration (ppm)	1493.610
Nitrogen mass (lbs)	358.567
Phosphorus mass (lbs)	145.296
COD mass (lbs)	6676.329
Animal feedlot rating number	56 (+1.31 σ)

Cell # 1084 000

Nitrogen concentration (ppm)	58.300
Phosphorus concentration (ppm)	23.759
COD concentration (ppm)	1093.240
Nitrogen mass (lbs)	137.451
Phosphorus mass (lbs)	56.016
COD mass (lbs)	2577.480
Animal feedlot rating number	42 (+.53 σ)

Cell # 1115 000

Nitrogen concentration (ppm)	69.342
Phosphorus concentration (ppm)	27.078
COD concentration (ppm)	1239.587
Nitrogen mass (lbs)	277.648
Phosphorus mass (lbs)	108.420
COD mass (lbs)	4963.384
Animal feedlot rating number	52 (+1.08 σ)

Cell # 1130 000

Nitrogen concentration (ppm)	240.000
Phosphorus concentration (ppm)	68.000
COD concentration (ppm)	3600.000
Nitrogen mass (lbs)	420.024
Phosphorus mass (lbs)	119.007
COD mass (lbs)	6300.362
Animal feedlot rating number	53 (+1.14 σ)

Cell # 1155 000

Nitrogen concentration (ppm)	187.729
Phosphorus concentration (ppm)	71.747
COD concentration (ppm)	3279.430
Nitrogen mass (lbs)	1067.085
Phosphorus mass (lbs)	407.821
COD mass (lbs)	18640.906
Animal feedlot rating number	71 (+2.14 σ)

Cell # 1222 000

Nitrogen concentration (ppm)	100.000
Phosphorus concentration (ppm)	28.333
COD concentration (ppm)	1500.000
Nitrogen mass (lbs)	169.314
Phosphorus mass (lbs)	47.972
COD mass (lbs)	2539.710
Animal feedlot rating number	41 (+.47 σ)

Cell # 1228 000

Nitrogen concentration (ppm)	281.618

Phosphorus concentration (ppm) 79.703
COD concentration (ppm) 4216.618
Nitrogen mass (lbs) 947.365
Phosphorus mass (lbs) 268.120
COD mass (lbs) 14184.712
Animal feedlot rating number 65 (+1.81 σ)

Cell # 1386 **001**
Nitrogen concentration (ppm) 44.989
Phosphorus concentration (ppm) 17.972
COD concentration (ppm) 826.350
Nitrogen mass (lbs) 310.261
Phosphorus mass (lbs) 123.942
COD mass (lbs) 5698.816
Animal feedlot rating number 55 (+1.25 σ)

Cell # 1386 **002**
Nitrogen concentration (ppm) 12.290
Phosphorus concentration (ppm) 5.956
COD concentration (ppm) 277.661
Nitrogen mass (lbs) 100.309
Phosphorus mass (lbs) 48.612
COD mass (lbs) 2266.247
Animal feedlot rating number 42 (+.53 σ)

Cell # 1504 000
Nitrogen concentration (ppm) 170.000
Phosphorus concentration (ppm) 48.167
COD concentration (ppm) 2550.000
Nitrogen mass (lbs) 196.479
Phosphorus mass (lbs) 55.669
COD mass (lbs) 2947.184
Animal feedlot rating number 42 (+.53 σ)

Cell # 1517 000
Nitrogen concentration (ppm) 33.215
Phosphorus concentration (ppm) 19.615
COD concentration (ppm) 941.492
Nitrogen mass (lbs) 185.857
Phosphorus mass (lbs) 109.754
COD mass (lbs) 5268.118
Animal feedlot rating number 53 (+1.14 σ)

Cell # 1559 000
Nitrogen concentration (ppm) 76.163
Phosphorus concentration (ppm) 30.790
COD concentration (ppm) 1418.376
Nitrogen mass (lbs) 187.007
Phosphorus mass (lbs) 75.601
COD mass (lbs) 3482.598
Animal feedlot rating number 46 (+.75 σ)

Cell # 1618 000
Nitrogen concentration (ppm) 120.842
Phosphorus concentration (ppm) 34.095
COD concentration (ppm) 1800.282
Nitrogen mass (lbs) 609.623
Phosphorus mass (lbs) 171.999
COD mass (lbs) 9082.024
Animal feedlot rating number 60 (+1.53 σ)
Cell # 1727 000
Nitrogen concentration (ppm) 147.918

Phosphorus concentration (ppm)	41.905
COD concentration (ppm)	2086.341
Nitrogen mass (lbs)	556.425
Phosphorus mass (lbs)	157.635
COD mass (lbs)	7848.207
Animal feedlot rating number	58 (+1.42 σ)

Cell # 1780 000	
Nitrogen concentration (ppm)	82.349
Phosphorus concentration (ppm)	32.424
COD concentration (ppm)	1485.461
Nitrogen mass (lbs)	362.259
Phosphorus mass (lbs)	142.636
COD mass (lbs)	6534.615
Animal feedlot rating number	56 (+1.31 σ)

Cell # 1835 000	
Nitrogen concentration (ppm)	40.629
Phosphorus concentration (ppm)	16.270
COD concentration (ppm)	746.466
Nitrogen mass (lbs)	149.283
Phosphorus mass (lbs)	59.781
COD mass (lbs)	2742.751
Animal feedlot rating number	43 (+.58 σ)

Cell # 1958 000	
Nitrogen concentration (ppm)	193.217
Phosphorus concentration (ppm)	54.648
COD concentration (ppm)	2766.638
Nitrogen mass (lbs)	367.826
Phosphorus mass (lbs)	104.034
COD mass (lbs)	5266.836
Animal feedlot rating number	51 (+1.03 σ)

Cell # 1975 000	
Nitrogen concentration (ppm)	63.546
Phosphorus concentration (ppm)	24.179
COD concentration (ppm)	1101.696
Nitrogen mass (lbs)	140.166
Phosphorus mass (lbs)	53.332
COD mass (lbs)	2430.066
Animal feedlot rating number	41 (+.47 σ)

Cell # 2063 000	
Nitrogen concentration (ppm)	28.088
Phosphorus concentration (ppm)	12.228
COD concentration (ppm)	566.245
Nitrogen mass (lbs)	128.632
Phosphorus mass (lbs)	55.999
COD mass (lbs)	2593.152
Animal feedlot rating number	43 (+.58 σ)

Cell # 2287 000	
Nitrogen concentration (ppm)	225.020
Phosphorus concentration (ppm)	63.391
COD concentration (ppm)	3344.059
Nitrogen mass (lbs)	498.952
Phosphorus mass (lbs)	140.562
COD mass (lbs)	7415.005
Animal feedlot rating number	55 (+1.25 σ)

Cell # 2288 000	
Nitrogen concentration (ppm)	83.612
Phosphorus concentration (ppm)	32.304

COD concentration (ppm)	1478.943
Nitrogen mass (lbs)	149.197
Phosphorus mass (lbs)	57.644
COD mass (lbs)	2639.031
Animal feedlot rating number	42 (+.53 σ)

Cell # 2437 000

Nitrogen concentration (ppm)	144.000
Phosphorus concentration (ppm)	40.800
COD concentration (ppm)	2160.000
Nitrogen mass (lbs)	506.753
Phosphorus mass (lbs)	143.580
COD mass (lbs)	7601.293
Animal feedlot rating number	57 (+1.36 σ)

Cell # 2482 000

Nitrogen concentration (ppm)	271.707
Phosphorus concentration (ppm)	78.218
COD concentration (ppm)	4181.438
Nitrogen mass (lbs)	2093.518
Phosphorus mass (lbs)	602.677
COD mass (lbs)	32218.211
Animal feedlot rating number	71 (+2.14 σ)

Cell # 2506 000

Nitrogen concentration (ppm)	183.200
Phosphorus concentration (ppm)	43.293
COD concentration (ppm)	2938.500
Nitrogen mass (lbs)	614.507
Phosphorus mass (lbs)	145.219
COD mass (lbs)	9856.605
Animal feedlot rating number	60 (+1.53 σ)

Cell # 2529 000

Nitrogen concentration (ppm)	90.000
Phosphorus concentration (ppm)	25.500
COD concentration (ppm)	1350.000
Nitrogen mass (lbs)	207.823
Phosphorus mass (lbs)	58.883
COD mass (lbs)	3117.338
Animal feedlot rating number	44 (+.64 σ)

Cell # 2664 000

Nitrogen concentration (ppm)	103.654
Phosphorus concentration (ppm)	42.268
COD concentration (ppm)	1949.334
Nitrogen mass (lbs)	309.348
Phosphorus mass (lbs)	126.146
COD mass (lbs)	5817.635
Animal feedlot rating number	53 (+1.14 σ)

Cell # 2792 000

Nitrogen concentration (ppm)	121.238
Phosphorus concentration (ppm)	47.458
COD concentration (ppm)	2173.912
Nitrogen mass (lbs)	340.295
Phosphorus mass (lbs)	133.206
COD mass (lbs)	6101.812
Animal feedlot rating number	54 (+1.19 σ)

Cell # 2810 000

Nitrogen concentration (ppm)	126.939
Phosphorus concentration (ppm)	51.317

COD concentration (ppm)	2363.959
Nitrogen mass (lbs)	250.123
Phosphorus mass (lbs)	101.117
COD mass (lbs)	4658.004
Animal feedlot rating number	49 (+.92 σ)

Cell # 2850 000	
Nitrogen concentration (ppm)	142.115
Phosphorus concentration (ppm)	40.009
COD concentration (ppm)	2109.667
Nitrogen mass (lbs)	580.524
Phosphorus mass (lbs)	163.430
COD mass (lbs)	8617.733
Animal feedlot rating number	59 (+1.47 σ)

NORTH FIRESTEEL CREEK WATERSHED FEEDING AREA SELECTION CRITERIA AND STATISTICS (WEIGHTED FOR DISTANCE FACTORS)

1.) Animal feedlot ranking 25 year event
2.) Range of feedlot rankings 0 - 43
3.) Mean 17.7
4.) Sample standard deviation (σ) 11.1
5.) Feedlots with rating (≥ 30) are: 216, 1067, 1115, 1130, 1155, 1228, 1386-001, 1517, 1618, 1727, 1780, 2287, 2482, 2506, 2664, 2792, 2850.
6.) Additional feeding areas contributing high nutrients (≥ 20) are: 171, 217, 225, 383, 497, 531, 541, 777, 983, 1010, 1084, 1222, 1386-002, 1420, 1504, 1559, 1835, 1864, 1957, 1975, 2156, 2288, 2295, 2437, 2529, 2660, 2810.

One hundred and two (102) feeding areas within the North Firesteel watershed were evaluated as part of this study. Forty-four of the 102 feeding areas had an AGNPS corrective rating > 20. The feeding areas located in cells #216, 1067, 1115, 1130, 1155, 1228, 1386-001, 1517, 1618, 1727, 1780, 2287, 2482, 2506, 2664, 2792 and 2850 appear to be contributing significant levels ($AGNPS_{corr.\ rank} > 30$) of nutrients to the watershed. North Firesteel Creek has a large number of critical feeding areas, (61 with an $AGNPS_{non\text{-}corr.\ rank} > 30$), when compared to other watersheds in eastern South Dakota.

These 61 feedlots should be evaluated for potential operational or structural modifications in order to minimize future nutrient releases. It is also recommended that all other feeding areas within the North Firesteel watershed be evaluated. Other possible sources of nutrient loadings not modeled through this study were those from septic systems and from livestock depositing fecal material directly into the lake or adjacent streams. Based upon the accuracy of the watershed information gathered and entered in the model, the total nutrients contributed from the North Firesteel watershed are very high.

WEST FIRESTEEL WATERSHED

FEEDLOT (CELL #)	SUBWATERSHED LOCATION	AGNPS RATING (25 YR. EVT.)	RANKING PRIORITY♣	VARIANCE FROM RANKED MEAN OF 28.0	VARIANCE FROM 1 SSTD (σ = 17.9) FROM MEAN	PRIORITY RANK BASED ON AGNPS RANK AND DISTANCE FACTORS ∗		
						C.FACT	C.RATE	C.RANK
8	#2 (454)	0	5	-28	-1.56	.12	0	5
161	#2 (454)	35	4	+7	+.39	.60	21	4
204	#2 (454)	39	4	+11	+.61	.60	23	4
235	#2 (454)	**56**	3	+28	+1.56	.60	**34**	4
254	#2 (454)	**78**	2	+50	+2.79	.60	**47**	3
331	#5 (722)	**55**	3	+27	+1.51	.60	**33**	4
375	#5 (722)	**60**	2	+32	+1.78	.60	**36**	4
405	#5 (722)	**48**	3	+20	+1.12	.60	29	4
447	#5 (722)	25	4	-3	-.17	.36	9	5
514	#3 (521)	30	4	+2	+.11	.60	18	5
747	#3 (521)	28	4	0	0	.60	17	5
808	#4 (720)	27	4	-1	-.06	.48	13	5
925	#7 (1175)	0	5	-28	-1.56	.60	0	5
942	#8 (1257)	29	4	+1	+.06	.60	17	5
947	#1 (401)	36	4	+8	+4.5	.48	17	5
976	#7 (1175)	29	4	+1	+.06	.48	14	5
991	#6 (825)	23	4	-5	-.28	.60	14	5
1001	#8 (1257)	35	4	+7	+.39	.60	21	4
1027	#3 (521)	**46**	3	+18	+1.01	.24	11	5
1054	#6 (825)	0	5	-28	-1.56	.60	0	5
1063	#8 (1257)	18	5	-10	-.56	.60	11	5
1108	#7 (1175)	**53**	3	+25	+1.40	.60	**32**	4
1116	#8 (1257)	45	3	+17	+.95	.48	22	4
1124	#8 (1257)	11	5	-17	-.95	.60	7	5
1249	#8 (1257)	**48**	3	+20	+1.12	.48	23	4
1253-001	#8 (1257)	38	4	+10	+.56	.60	23	4
1253-002	#8 (1257)	**52**	3	+24	+1.34	.60	**31**	4
1271	#3 (521)	26	4	-2	-.11	.12	3	5
1286	#7 (1175)	**49**	3	+21	+1.17	.48	24	4
1428	#7 (1175)	**52**	3	+24	+1.34	.24	12	5
1446	#9 (1311)	36	4	+8	+.45	.12	4	5
1567	#7 (1175)	**43**	3	+15	+.84	.60	26	4
1576	#12 (1792)	**47**	3	+19	+1.06	.60	28	4
1703	#12 (1792)	**66**	2	+38	+2.12	.60	**40**	3
1791	#12 (1792)	39	4	+11	+.61	.60	23	4
1793	#6 (825)	**44**	3	+16	+.89	.60	26	4
1837	#12 (1792)	13	5	-15	-.84	.60	8	5

WEST FIRESTEEL WATERSHED

FEEDLOT (CELL #)	SUBWATERSHED LOCATION	AGNPS RATING (25 YR. EVT.)	RANKING PRIORITY♣	VARIANCE FROM RANKED MEAN OF 28.0	VARIANCE FROM 1 SSTD (σ = 17.9) FROM MEAN	PRIORITY RANK BASED ON AGNPS RANK AND DISTANCE FACTORS *		
						C.FACT	C.RATE	C.RANK
1923	#12 (1792)	0	5	-28	-1.56	.60	0	5
1933	#7 (1175)	**48**	3	+20	+1.12	.12	6	5
1977	#12 (1792)	13	5	-15	-.84	.48	6	5
1995	#6 (825)	9	5	-19	-1.06	.60	5	5
2110	#12 (1792)	28	4	0	0	.60	17	5
2120	#12 (1792)	0	5	-28	-1.56	.60	0	5
2205	#7 (1175)	**49**	3	+21	+1.17	.12	6	5
2218	#7 (1175)	**51**	3	+23	+1.28	.48	25	4
2242	#12 (1792)	22	4	-6	-.34	.60	13	5
2253	#12 (1792)	14	5	-14	-.78	.60	8	5
2299	#12 (1792)	19	5	-9	-.50	.60	11	5
2375	#12 (1792)	0	5	-28	-1.56	.60	0	5
2403	#6 (825)	18	5	-10	-.56	.60	11	5
2442	#12 (1792)	**40**	3	_12	+.67	.48	19	5
2536	#14 (2335)	**51**	3	+23	+1.28	.60	**31**	4
2580	#12 (1792)	20	4	-8	-.45	.60	12	5
2582	#13 (2267)	14	5	-14	-.78	.60	8	5
2596	#14 (2335)	8	5	-20	-1.12	.48	4	5
2737	#6 (825)	19	5	-9	-.50	.60	11	5
2757	#12 (1792)	**51**	3	+23	+1.28	.12	6	5
2769	#13 (2267)	0	5	-28	-1.56	.12	0	5
2786	#14 (2335)	12	5	-16	-.89	.60	7	5
2794	#15 (2734)	22	4	-6	-.34	.60	13	5
2810-001	#13 (2267)	21	4	-7	-.39	.12	3	5
2810-002	#13 (2267)	4	5	-24	-1.34	.12	.5	5
2824	#13 (2267)	0	5	-28	-1.56	.60	0	5
2826	#13 (2267)	**40**	3	+12	+.67	.60	24	4
2941	#14 (2335)	9	5	-19	-1.06	.12	1	5
3043	#14 (2335)	25	4	-3	-.17	.12	3	5
3056	#14 (2335)	19	5	-9	-.50	.60	11	5
3083	#13 (2267)	26	4	-2	-.11	.12	3	5
3133	#13 (2267)	28	4	0	0	.60	17	5
3183	#14 (2335)	18	5	-10	-.56	.24	4	5
3214-001	#13 (2267)	0	5	-28	-1.56	.60	0	5
3214-002	#13 (2267)	30	4	+2	+.11	.60	18	5
3220	#14 (2335)	33	4	+5	+.28	.12	4	5
3226	#14 (2335)	**41**	3	+13	+.73	.60	25	4

WEST FIRESTEEL WATERSHED

FEEDLOT (CELL #)	SUBWATERSHED LOCATION	AGNPS RATING (25 YR. EVT.)	RANKING PRIORITY♣	VARIANCE FROM RANKED MEAN OF 28.0	VARIANCE FROM 1 SSTD (σ = 17.9) FROM MEAN	PRIORITY RANK BASED ON AGNPS RANK AND DISTANCE FACTORS ∗		
						C.FACT	C.RATE	C.RANK
3288	#14 (2335)	35	4	+7	+.39	.60	21	4
3316	#13 (2267)	0	5	-28	-1.56	.60	0	5
3325	#14 (2335)	0	5	-28	-1.56	.60	0	5
3366	#15 (2734)	**46**	3	+18	+1.00	.60	28	4
3381	#14 (2335)	14	5	-14	-.78	.60	8	5
3406	#14 (2335)	8	5	-20	-1.12	.60	5	5
3425	#15 (2734)	10	5	-18	-1.00	.36	4	5
3434	#14 (2335)	21	4	-7	-.39	.60	13	5
3474	#15 (2734)	29	4	+1	+.06	.36	10	5
3516	#15 (2734)	28	4	0	0	.60	17	5
3530	#14 (2335)	39	4	+11	+.61	.60	23	4
3548	#15 (2734)	18	5	-10	-.56	.60	11	5
3594	#15 (2734)	32	4	+4	+.22	.12	4	5
3607	#15 (2734)	25	4	-3	-.17	.12	3	5
3639	#15 (2734)	26	4	-2	-.11	.12	3	5
3664	#15 (2734)	28	4	0	0	.12	4	5

♣ - PRIORITY RANKING

AGNPS RANK 80-100 = 1 (extremely critical)
AGNPS RANK 60-80 = 2 (very critical)
AGNPS RANK 40-60 = 3 (critical)
AGNPS RANK 20-40 = 4 (possibly critical)
AGNPS RANK 0-20 = 5 (not critical)

∗ - PRIORITY RANK = AGNPS 25 YEAR FEEDLOT RATING X DISTANCE TO STREAM X DISTANCE TO LAKE

<u>DISTANCE TO STREAM FACTORS</u>

Adjacent to stream = 1.0
Within 1 cell (1300 feet) = .8
Within 2 cells (2600 feet) = .6
Within 3 cells (3900 feet) = .4
Within 4 cells (5200 feet) = .2

<u>DISTANCE TO LAKE FACTORS</u>

Adjacent to lake = 1.0
Within 4 cells (5200 feet) = .9
Within 8 cells (10400 feet) = .8
Within 16 cells (15600 feet) = .7
Within 20 cells (20800 feet) = .6

Mean value = 28.0
Median value = 28
STDS = 17.9
Mean + 1STDS = 45.9

WEST FIRESTEEL CREEK WATERSHED FEEDING AREA SELECTION CRITERIA AND STATISTICS (NOT WEIGHTED FOR DISTANCE FACTORS)

1.) Animal feedlot ranking	25 year event
2.) Range of feedlot rankings	0 - 78
3.) Mean	28.0
4.) Sample standard deviation (σ)	17.9

5.) Feedlots with rating (≥ 40) are :

Cell # 235 000	
Nitrogen concentration (ppm)	80.000
Phosphorus concentration (ppm)	22.667
COD concentration (ppm)	1200.000
Nitrogen mass (lbs)	435.992
Phosphorus mass (lbs)	123.531
COD mass (lbs)	6539.874
Animal feedlot rating number	56 (+1.56 σ)

Cell # 254 000	
Nitrogen concentration (ppm)	300.000
Phosphorus concentration (ppm)	85.000
COD concentration (ppm)	4500.000
Nitrogen mass (lbs)	2031.272
Phosphorus mass (lbs)	575.527
COD mass (lbs)	30469.088
Animal feedlot rating number	78 (+2.79 σ)

Cell # 331 000	
Nitrogen concentration (ppm)	91.022
Phosphorus concentration (ppm)	22.232
COD concentration (ppm)	1472.302
Nitrogen mass (lbs)	396.871
Phosphorus mass (lbs)	96.935
COD mass (lbs)	6419.511
Animal feedlot rating number	55 (+1.51 σ)

Cell # 375 000	
Nitrogen concentration (ppm)	73.516
Phosphorus concentration (ppm)	29.685
COD concentration (ppm)	1340.167
Nitrogen mass (lbs)	451.825
Phosphorus mass (lbs)	182.444
COD mass (lbs)	8236.609
Animal feedlot rating number	60 (+1.78 σ)

Cell # 405 000	
Nitrogen concentration (ppm)	51.308
Phosphorus concentration (ppm)	20.873
COD concentration (ppm)	960.760
Nitrogen mass (lbs)	204.929
Phosphorus mass (lbs)	83.369
COD mass (lbs)	3837.376
Animal feedlot rating number	48 (+1.12 σ)

Cell # 1027 000

Nitrogen concentration (ppm)	44.669
Phosphorus concentration (ppm)	18.581
COD concentration (ppm)	832.545
Nitrogen mass (lbs)	173.120
Phosphorus mass (lbs)	72.013
COD mass (lbs)	3226.644
Animal feedlot rating number	46 (+1.01 σ)

Cell # 1108 000

Nitrogen concentration (ppm)	161.468
Phosphorus concentration (ppm)	45.462
COD concentration (ppm)	2397.426
Nitrogen mass (lbs)	409.149
Phosphorus mass (lbs)	115.199
COD mass (lbs)	6074.918
Animal feedlot rating number	53 (+1.40 σ)

Cell # 1116 000

Nitrogen concentration (ppm)	132.032
Phosphorus concentration (ppm)	37.009
COD concentration (ppm)	1946.219
Nitrogen mass (lbs)	240.157
Phosphorus mass (lbs)	67.317
COD mass (lbs)	3540.039
Animal feedlot rating number	45 (+.95 σ)

Cell # 1249 000

Nitrogen concentration (ppm)	120.000
Phosphorus concentration (ppm)	34.000
COD concentration (ppm)	1800.000
Nitrogen mass (lbs)	274.176
Phosphorus mass (lbs)	77.683
COD mass (lbs)	4112.634
Animal feedlot rating number	48 (+1.12 σ)

Cell # 1253 **002**

Nitrogen concentration (ppm)	225.000
Phosphorus concentration (ppm)	63.750
COD concentration (ppm)	3375.000
Nitrogen mass (lbs)	395.971
Phosphorus mass (lbs)	112.192
COD mass (lbs)	5939.558
Animal feedlot rating number	52 (+1.34 σ)

Cell # 1286 000

Nitrogen concentration (ppm)	39.256
Phosphorus concentration (ppm)	19.982
COD concentration (ppm)	945.699
Nitrogen mass (lbs)	163.739
Phosphorus mass (lbs)	83.346
COD mass (lbs)	3944.559
Animal feedlot rating number	49 (+1.17 σ)

Cell # 1428 000
Nitrogen concentration (ppm) 128.571
Phosphorus concentration (ppm) 36.429
COD concentration (ppm) 1928.572
Nitrogen mass (lbs) 353.135
Phosphorus mass (lbs) 100.055
COD mass (lbs) 5297.018
Animal feedlot rating number 52 (+1.34 σ)

Cell # 1567 000
Nitrogen concentration (ppm) 21.869
Phosphorus concentration (ppm) 12.053
COD concentration (ppm) 574.898
Nitrogen mass (lbs) 94.271
Phosphorus mass (lbs) 51.955
COD mass (lbs) 2478.228
Animal feedlot rating number 43 (+.84 σ)

Cell # 1576 000
Nitrogen concentration (ppm) 80.048
Phosphorus concentration (ppm) 17.239
COD concentration (ppm) 1340.548
Nitrogen mass (lbs) 218.014
Phosphorus mass (lbs) 46.950
COD mass (lbs) 3651.025
Animal feedlot rating number 47 (+1.06 σ)

Cell # 1703 000
Nitrogen concentration (ppm) 228.668
Phosphorus concentration (ppm) 64.442
COD concentration (ppm) 3400.292
Nitrogen mass (lbs) 958.955
Phosphorus mass (lbs) 270.250
COD mass (lbs) 14259.676
Animal feedlot rating number 66 (+2.12 σ)

Cell # 1793 000
Nitrogen concentration (ppm) 112.500
Phosphorus concentration (ppm) 31.875
COD concentration (ppm) 1687.500
Nitrogen mass (lbs) 210.296
Phosphorus mass (lbs) 59.584
COD mass (lbs) 3154.441
Animal feedlot rating number 44 (+.89 σ)

Cell # 1933 000
Nitrogen concentration (ppm) 38.900
Phosphorus concentration (ppm) 13.417
COD concentration (ppm) 787.556
Nitrogen mass (lbs) 183.948
Phosphorus mass (lbs) 63.447
COD mass (lbs) 3724.190
Animal feedlot rating number 48 (+1.12 σ)

Cell # 2205 000	
Nitrogen concentration (ppm)	38.954
Phosphorus concentration (ppm)	17.747
COD concentration (ppm)	829.787
Nitrogen mass (lbs)	189.895
Phosphorus mass (lbs)	86.514
COD mass (lbs)	4045.067
Animal feedlot rating number	49 (+1.17 σ)

Cell # 2218 000	
Nitrogen concentration (ppm)	35.708
Phosphorus concentration (ppm)	16.268
COD concentration (ppm)	760.638
Nitrogen mass (lbs)	203.457
Phosphorus mass (lbs)	92.693
COD mass (lbs)	4333.960
Animal feedlot rating number	51 (+1.28 σ)

Cell # 2442 000	
Nitrogen concentration (ppm)	23.779
Phosphorus concentration (ppm)	13.514
COD concentration (ppm)	617.704
Nitrogen mass (lbs)	79.078
Phosphorus mass (lbs)	44.940
COD mass (lbs)	2054.182
Animal feedlot rating number	40 (+.67 σ)

Cell # 2536 000	
Nitrogen concentration (ppm)	125.000
Phosphorus concentration (ppm)	35.417
COD concentration (ppm)	1875.000
Nitrogen mass (lbs)	342.616
Phosphorus mass (lbs)	97.075
COD mass (lbs)	5139.244
Animal feedlot rating number	51 (+1.28 σ)

Cell # 2757 000	
Nitrogen concentration (ppm)	115.440
Phosphorus concentration (ppm)	30.056
COD concentration (ppm)	1591.200
Nitrogen mass (lbs)	360.528
Phosphorus mass (lbs)	93.867
COD mass (lbs)	4969.441
Animal feedlot rating number	51 (+1.28 σ)

Cell # 2826 000	
Nitrogen concentration (ppm)	70.000
Phosphorus concentration (ppm)	18.417
COD concentration (ppm)	975.000
Nitrogen mass (lbs)	161.806
Phosphorus mass (lbs)	42.570
COD mass (lbs)	2253.729
Animal feedlot rating number	40 (+.67 σ)

Cell # 3226 000	
Nitrogen concentration (ppm)	33.746
Phosphorus concentration (ppm)	17.651
COD concentration (ppm)	834.667
Nitrogen mass (lbs)	141.155
Phosphorus mass (lbs)	73.831
COD mass (lbs)	3491.313
Animal feedlot rating number	41 (+.73 σ)

Cell # 3366 000	
Nitrogen concentration (ppm)	165.600
Phosphorus concentration (ppm)	46.920
COD concentration (ppm)	2448.000
Nitrogen mass (lbs)	254.423
Phosphorus mass (lbs)	72.087
COD mass (lbs)	3761.038
Animal feedlot rating number	46 (+1.00 σ)

WEST FIRESTEEL CREEK WATERSHED FEEDING AREA SELECTION CRITERIA AND STATISTICS (WEIGHTED FOR DISTANCE FACTORS)

1.) Animal feedlot ranking 25 year event
2.) Range of feedlot rankings 0 - 47
3.) Mean 13.4
4.) Sample standard deviation (σ) 10.9
5.) Feedlots with rating (≥ 30) from mean are: 235, 254, 331, 375, 1108, 1253-002, 1703, 2536
6.) Additional feeding areas contributing high nutrients (≥ 20) are: 161, 204, 405, 1001, 1116, 1249, 1253-001, 1286, 1567, 1576, 1791, 1793, 2218, 2826, 3226, 3288, 3366, 3530.

Ninety (90) feeding areas within the West Firesteel watershed were evaluated as part of this study. Twenty-six of the 90 feeding areas had an AGNPS corrected rating > 20. The feeding areas located in cells #235, 254, 331, 375, 1108, 1253-002, 1703 and 2536 had an AGNPS corrected rating > 30. These corrected feeding areas appear to be contributing significant levels of nutrients to the watershed. There are 59 feedlots in the West Firesteel Creek watershed with AGNPS non-corrected ratings > 30. This is a high number of critical feeding areas when compared to other eastern South Dakota watersheds.

These 59 feeding areas should be evaluated for potential operational or structural modifications in order to minimize future nutrient releases. It is also recommended that all other feeding areas within the North Firesteel watershed be evaluated. Other possible sources of nutrient loadings not modeled through this study were those from septic systems and from livestock depositing fecal material directly into the lake or adjacent streams. In conclusion, based upon the accuracy of the watershed information gathered and entered into the model, the total nutrients contributed from the West Firesteel watershed are very high.

MAIN FIRESTEEL WATERSHED

FEEDLOT (CELL #)	SUBWATERSHED LOCATION	AGNPS RATING (25 YR. EVT.)	RANKING PRIORITY♣	VARIANCE FROM RANKED MEAN OF 21.9	VARIANCE FROM 1 SSTD (σ = 19.2) FROM MEAN	PRIORITY RANK BASED ON AGNPS RANK AND DISTANCE FACTORS *		
						C.FACT	C.RATE	C.RANK
17-001	#2 (358)	25	4	+3.1	+.16	.60	15	5
17-002	#2 (358)	34	4	+12.1	+.63	.60	20	4
23	#2 (358)	26	4	+4.1	+.21	.36	9	5
69	#2 (358)	0	5	-21.9	-1.14	.12	0	5
112	#2 (358)	11	5	-10.9	-.57	.12	1	5
149	#2 (358)	26	4	+4.1	+.21	.36	9	5
176	#2 (358)	17	5	-4.9	-.26	.60	10	5
195	#2 (358)	27	4	+5.1	+.27	.48	13	5
216	#2 (358)	12	5	-9.9	-.52	.24	3	5
276	#7 (605)	5	5	-16.9	-.88	.36	2	5
278	#7 (605)	11	5	-10.9	-.57	.36	4	5
326	#7 (605)	**49**	3	+27.1	+1.41	.48	24	4
372	#4 (435)	24	4	+2.1	+.11	.60	14	5
386	#3 (390)	26	4	+4.1	+.21	.60	16	5
420	#7 (605)	24	4	+2.1	+.11	.64	15	5
432	#4 (435)	**61**	2	+39.1	+2.27	.60	**37**	4
440	#3 (390)	19	5	-2.9	-.15	.60	11	5
481	DIRECT	**44**	3	+22.1	+1.15	.54	24	4
483	DIRECT	14	5	-7.9	-.41	.60	8	5
621	#5 (561)	24	4	+2.1	+.11	.60	14	5
659	#8 (663)	**77**	2	+55.1	+2.87	.80	**62**	2
663	#8 (663)	2	5	-19.9	-1.04	.80	2	5
693	#3 (390)	8	5	-13.9	-.72	.36	3	5
700	#6 (578)	35	4	+13.1	+.68	.60	21	4
759	#6 (578)	10	5	-11.9	-.62	.60	6	5
767	#11 (926)	0	5	-21.9	-1.14	.60	0	5
812	#6 (578)	14	5	-7.9	-.41	.60	8	5
820	#11 (926)	9	5	-12.9	-.67	.70	6	5
822	#11 (926)	19	5	-2.9	-.15	.70	13	5
846	#5 (561)	0	5	-21.9	-1.14	.36	0	5
869	#11 (926)	0	5	-21.9	-1.14	.70	0	5
876	#11 (926)	**71**	2	+49.1	+2.56	.64	**45**	3
879	#11 (926)	16	5	-5.9	-.31	.72	11	5
880	#11 (926)	37	4	+15.1	+.79	.72	27	4
901	#5 (561)	0	5	-21.9	-1.14	.60	0	5
940	#5 (561)	21	4	-.9	-.05	.60	13	5
1098	#5 (561)	0	5	-21.9	-1.14	.36	0	5
1109	#5 (561)	34	4	+12.1	+.63	.12	4	5

♣ - PRIORITY RANKING

AGNPS RANK	80-100	= 1 (extremely critical)
AGNPS RANK	60-80	= 2 (very critical)
AGNPS RANK	40-60	= 3 (critical)
AGNPS RANK	20-40	= 4 (possibly critical)
AGNPS RANK	0-20	= 5 (not critical)

∗ - PRIORITY RANK = AGNPS 25 YEAR FEEDLOT RATING X DISTANCE TO STREAM X DISTANCE TO LAKE

<u>DISTANCE TO STREAM FACTORS</u>

Adjacent to stream	= 1.0
Within 1 cell (1300 feet)	= .8
Within 2 cells (2600 feet)	= .6
Within 3 cells (3900 feet)	= .4
Within 4 cells (5200 feet)	= .2

<u>DISTANCE TO LAKE FACTORS</u>

Adjacent to lake	= 1.0
Within 4 cells (5200 feet)	= .9
Within 8 cells (10400 feet)	= .8
Within 16 cells (15600 feet)	= .7
Within 20 cells (20800 feet)	= .6

Mean value	= 21.9
Median value	= 19
STDS	= 19.2
Mean + 1STDS	= 41.1

<u>MAIN FIRESTEEL CREEK WATERSHED FEEDING AREA SELECTION CRITERIA AND STATISTICS (NOT WEIGHTED FOR DISTANCE FACTORS)</u>

1.) Animal feedlot ranking	25 year event
2.) Range of feedlot rankings	0 - 77
3.) Mean	21.9
4.) Sample standard deviation (σ)	19.2

5.) Feedlots with rating (≥ 40) are :

Cell # 326 000	
Nitrogen concentration (ppm)	120.000
Phosphorus concentration (ppm)	34.000
COD concentration (ppm)	1800.000
Nitrogen mass (lbs)	286.135
Phosphorus mass (lbs)	81.072
COD mass (lbs)	4292.032
Animal feedlot rating number	49 (+1.41 σ)

Cell # 432 000	
Nitrogen concentration (ppm)	200.175
Phosphorus concentration (ppm)	56.545
COD concentration (ppm)	2987.969
Nitrogen mass (lbs)	703.605
Phosphorus mass (lbs)	198.754
COD mass (lbs)	10502.548
Animal feedlot rating number	61 (+2.27 σ)

Cell # 481 000	
Nitrogen concentration (ppm)	45.309
Phosphorus concentration (ppm)	19.415
COD concentration (ppm)	889.352
Nitrogen mass (lbs)	145.413
Phosphorus mass (lbs)	62.310
COD mass (lbs)	2854.289
Animal feedlot rating number	44 (+1.15 σ)

Cell # 659 000	
Nitrogen concentration (ppm)	241.875
Phosphorus concentration (ppm)	68.531
COD concentration (ppm)	3628.125
Nitrogen mass (lbs)	1795.083
Phosphorus mass (lbs)	508.607
COD mass (lbs)	26926.248
Animal feedlot rating number	77 (+2.87 σ)

Cell # 876 000	
Nitrogen concentration (ppm)	154.688
Phosphorus concentration (ppm)	43.828
COD concentration (ppm)	2320.312
Nitrogen mass (lbs)	1216.822
Phosphorus mass (lbs)	344.766
COD mass (lbs)	18252.324
Animal feedlot rating number	71 (+2.56 σ)

MAIN FIRESTEEL CREEK WATERSHED FEEDING AREA SELECTION CRITERIA AND STATISTICS (WEIGHTED FOR DISTANCE FACTORS)

1.) Animal feedlot ranking 25 year event
2.) Range of feedlot rankings 0 - 62
3.) Mean 12.4
4.) Sample standard deviation (σ) 13.3
5.) Feedlots with rating (≥ 30) from mean are : 432, 659, 876.
6.) Additional feeding areas contributing high nutrients (≥ 20) are : 17-002, 326, 481, 700, 880.

Thirty-eight (38) feeding areas within the Main Firesteel watershed were evaluated in this part of the study. Eight (8) of the 38 feeding areas evaluated had an AGNPS corrected rating > 20. Three feeding areas, located in cells #432, 659 and 876, have an AGNPS corrected rating > 30. For this subwatershed, these 3 feeding areas have the greatest potential for releasing nutrients to the lake. When compared to other eastern South Dakota watersheds, the Main Firesteel watershed has a large number of animal feeding areas (9) with non-corrected AGNPS ratings > 30.

It is recommended that the feeding areas within these nine (9) cells be evaluated to minimize future nutrient releases. It is also recommended that all other feeding areas within the Main Firesteel watershed be field verified. Other possible sources of nutrient loadings not modeled through this study were from septic systems and from livestock depositing fecal material directly into the lake or adjacent streams. In conclusion, the total nutrients contributed from the Main Firesteel watershed are very high, based upon the accuracy of the watershed information gathered and entered into the model.

SUMMARY OF FEEDING AREA EVALUATIONS

AGNPS RATING										
	Not Distance Corrected					Distance Corrected				
Range	Wilmarth (# sites)	N. Firesteel (# sites)	W. Firesteel (# sites)	M. Firesteel (# sites)	Totals	Wilmarth (# sites)	N. Firesteel (# sites)	W. Firesteel (# sites)	M. Firesteel (# sites)	Totals
90 -100	0	0	0	0	0	0	0	0	0	0
80 - 90	0	0	0	0	0	0	0	0	0	0
70 - 80	1	2	1	2	6	1	0	0	0	1
60 - 70	1	3	2	1	7	0	0	0	1	1
50 - 60	2	14	8	0	24	0	0	0	0	0
40 - 50	3	17	14	2	36	0	1	2	1	4
30 - 40	1	25	13	4	43	3	16	6	1	26
20 - 30	1	17	21	9	48	1	27	18	5	51
10 - 20	2	10	15	10	37	5	31	25	11	72
0 - 10	0	14	16	10	40	1	27	39	19	86
Totals	11	102	90	38	241	11	102	90	38	241

CONCLUSIONS

Water Quality Samples

Water Quality Standards

All of the tributary sample sites except Site #2 and #3 exceeded the state water quality standards at least once during the 1993 through 1995 tributary sample period. The water quality standard for temperature was exceeded twice at Site #1. The standard for fecal coliform was exceeded twice at Site #4 and once each at Sites #1, #5, #6, and #7A. The total suspended solids standard was exceeded three times at Site #1, twice at site #4 and once each at Sites #5, #6, and #7. The standard for dissolved oxygen was exceeded once at Site #7A. Many times the fecal coliform standard was exceeded at the same time as the suspended solids standard. This indicates agricultural run-off from concentrated feeding areas or livestock pasturing in riparian areas in the watershed.

Seasonal Water Quality

Typically, water quality parameters decrease in concentration as the volume of water increases because of dilution. In Firesteel Creek, intense summer rains not only increased the amount of water passing through the system, but also increased the concentrations. Either concentrated feeding areas or summer long pasturing are the most likely sources of increased nutrient concentrations.

Tributary Sampling

Sites #1 and #2 are the inlets to Lake Mitchell. Site #1 was located in a backwater situation. Due to the location of Site #1, suspended sediment loadings were underestimated by approximately 1/3. However, even using the inflated number, the sediment loadings to Lake Mitchell are extremely low (4 acre-feet/year). The fraction of phosphorus entering Lake Mitchell is largely dissolved (69% for Site #1 and 83% for Site #2). This is due in part to the low concentrations and loadings of suspended sediment. Although the loadings to Site #2 are small, the site is close to Lake Mitchell thus increasing its effect on the lake. Occasionally the site records high fecal coliform and high phosphorus concentrations.

Site #3 is the least impacted site in the watershed. The land slopes in the watershed are extremely flat and the riparian areas are well lined with vegetation. The concentrations are relatively low, and since very little water passes through the site, the loadings are also relatively low.

Site #4 receives water from both the east and west forks of Firesteel Creek. Site #4 is not in a back wash area like Site #1. Loadings from Site #4 were used to estimate the 4 acre-feet/year of suspended sediment stated above. High concentrations of phosphorus and suspended solids coincide with those at Site #6 more so than Site #5. Site #4 had high suspended solid samples which are probably coming from poor cropland management. The high phosphorus loads are most likely coming from the sediment, animal feeding areas, and summer long grazing practices.

Sites #5 and #7 are located on the east branch of Firesteel Creek. Suspended solids concentrations are higher at Site #7 most likely due to the location of the sample site. The site is at a double culvert that increases the velocity of the flow for better mixing of the sample. The velocity also causes bank erosion on the other side of the site which may be affecting the sample concentrations. Site #5 showed a sharp increase in total phosphorus load from Site #7. The total phosphorus load almost doubled in a 20,000 acre area between the sites. The increased loading in the area was most likely due to animal feeding areas along the tributaries.

Sites #6 and #7A are located on the west fork of Firesteel Creek. Site #7A is located at the outlet of Lake Wilmarth, and Site #6 is located just upstream of the confluence of the east and west forks of Firesteel Creek. Since 1979, Lake Wilmarth's total phosphorus concentrations have increased dramatically. Changes in the watershed have more than doubled the average total phosphorus concentration. Suspended sediments at Site #7A were low due to the settling effect of Lake Wilmarth. Suspended sediment concentrations and loadings at Site #6 were quite high, which is noteworthy because of low suspended sediment coming from upstream Site #7A. Site #6 also has a high total phosphorus load which is most likely due to animal waste because fecal coliform was also detected at the site.

Storm Sewers

Drainage from storm sewers makes up approximately 1% of the total drainage of the watershed. The percentages of the total load to Lake Mitchell from the storm sewers were 4% of the phosphorus, 8% of the total nitrogen, and 8% of the total suspended solids. The average samples from the storm sewers are relatively high in nitrogen and phosphorus when compared to tributary samples.

While the loadings from the storm sewers are only a fraction of the Firesteel Creek watershed, they are direct conduits to the lake. As conduits, they present the possibility of a hazardous spill in town reaching the lake. The amount of the nutrients entering the lake from the storm sewers were extremely high when considering the relatively small area of drainage.

Hydrologic and Nutrient Loadings

The amount of rain received in 1993 was 11 inches greater than an average rainfall from March to November. The outwash areas along Firesteel Creek and the north edge of Lake Mitchell most likely filled and discharged to Lake Mitchell during most of the year. During 1993, 14% of the total water load came from groundwater. The lake actually experienced a flushing of phosphorus from the system. More phosphorus (79,639 pounds or 36,118 kilograms) actually left the lake through the spillway than entered through all sources. There was also a loss of total kjeldahl nitrogen which is mostly organic nitrogen (4,977 pounds or 2,257 kilograms). The loss of these two parameters suggests that the algae were assimilating the phosphorus, growing, and flushing out before they had a chance to die and sink to the bottom. The extra phosphorus that left the system had to come from internal loading, that is, the regeneration of phosphorus from the sediments.

Suspended sediment did not seem to be a problem in the watershed, however Sites #6 and #4 did record the highest concentrations and loads. The water quality data collected in 1993 indicated the amount of suspended solids entering the lake was 4 acre-feet/year.

From the water quality and quantity data collected in 1993, Firesteel Creek was responsible for the following percentages of loadings to the lake:

78% of the water	93% of the total phosphorus	84% of the total nitrogen
	91% of the suspended solids	

Storm sewers were second for nutrient and sediment input to the lake.

Inlake

Occasionally, Lake Mitchell stratifies, depleting the oxygen levels in the hypolimnion (lower half of the lake) and also lowering the temperature. When this happens, dissolved phosphorus is released from the sediments and is available for algal uptake and growth. Suspended solids were not extremely high in the lake (8 mg/L average). The majority of the suspended solids near the surface was algae. All nutrient concentrations increased during the summer months. The mean total nitrogen concentration for surface samples was 1.43 mg/L. The mean concentration of phosphorus from surface samples was 0.278 mg/L. Approximately 77% of the total phosphorus concentrations were in the dissolved fraction and available for algal uptake. Since algae need only 0.020 mg/L to begin bloom, Lake Mitchell appears to have over 10 times the amount of phosphorus needed for algae growth.

Limiting Nutrient and Trophic State Index

Lake Mitchell was found to be hyper-eutrophic in terms of total phosphorus and eutrophic in terms of chlorophyll *a* and secchi depth. The excessive phosphorus loading to Lake Mitchell means the lake fluctuates between phosphorus and nitrogen limitation. The lake is most likely phosphorus limited in the summer when blue-green algae are blooming, and nitrogen limited in the spring and fall when green algae and diatoms dominate the algal population. There also seems to be a hindrance to algal growth due to turbidity from shading, stained water, or possibly from the short length of water residence time.

Long Term Trends

Data collected from 1991 to 1995 for the Statewide Water Quality Assessment shows the overall water quality in Lake Mitchell improving. This is mainly due to the wet years from 1993 to the present flushing the system and reducing the high concentrations of inlake phosphorus left from the drought years of 1989 to 1992. Since groundwater is relatively low in phosphorus, the inputs from the outwash areas in wet years help decrease the total phosphorus inputs to the lake. When the wet cycle stops, the trend will probably reverse to increasing eutrophy.

Chlorophyll *a* and Phytoplankton

The dominate species found in the summer blooms of Lake Mitchell is Aphanizomenon flos-aquae. Also found in the samples from Site #13 was Melosira granulata. Melosira granulata is an indicator of eutrophic conditions. Site #12 had algal counts consistently above that of Site #13. The increased algal counts and the dominance of Aphanizomenon at Site #12 appear to make Site #12 more eutrophic than Site #13. The increased algae are probably due to Site #12's shallower depth, warmer water, and more accessible phosphorus from the mixing of sediments by wind and wave action. The bottom samples also showed less chlorophyll *a* than the surface samples. The bottom samples at Site #13 (near the treatment plant intakes) had dramatically fewer colonies than the surface. Lack of light is probably the most plausible reason for the dramatic drop in the chlorophyll *a* concentration of bottom samples. As expected, the chlorophyll *a* samples closely paralleled the results from the algal counts.

A poor relationship was found when chlorophyll *a* was compared to total phosphorus from the samples collected from 1991 - 1995 (R^2=0.1722). When chlorophyll *a* was compared to total phosphorus using samples from 1993 - 1995, a much higher R^2 value was found (R^2=0.64). Drought years from 1989 to 1992 concentrated the nutrients which increased the algal growth, while the wet years of 1993 to 1995 diluted the concentrations. To make the reduction response model more accurate, the data from 1993 to 1995 was used.

Reduction Response Model

A model estimated the effects of reducing phosphorus in the watershed. A 50% reduction of tributary loadings to the lake would result in a minimum of 11% reduction in chlorophyll *a* concentrations. If the reduction could be reached, the TSI ranking for chlorophyll would be reduced to mesotrophic.

Agricultural Nonpoint Source Model

Sediment

When comparing Lake Mitchell to other watersheds in Eastern South Dakota, the overall sediment loadings to Lake Mitchell appears to be low (0.1137 $_{\text{tons/acre/year}}$). This rate is equivalent to a volume of 39,370 tons of sediment delivered to Lake Mitchell. If it is assumed that 100% of the sediment delivered to Lake Mitchell is captured within the lake, this would be equivalent to a deposition rate of 0.44 inches/year. This is equivalent to 1 foot of lake depth lost every 61 years. This depth loss rate is optimistic because it is assumed that 100% of the sediment delivered to the lake is retained in the lake. This deposition rate is very low for a South Dakota lake.

A detailed subwatershed analysis showed 7 of the 40 subwatersheds have high (>2 times the average) number of critical cells. The seven subwatersheds were #5 Wilmarth, #8 N. Firesteel, #6 West Firesteel, #8 West Firesteel, #10 West Firesteel, #11 West Firesteel and #4 Main Firesteel. These seven subwatersheds contained 34.3% of the critical erosion cells in the watershed and occupy only 8.3% of the watershed area. The suspected sedimentation source is from croplands having land slopes of 5% and greater. In order to reduce sedimentation from these seven (7) subwatersheds, it is recommended that the critical cells within the subwatersheds be targeted for conversion to rangeland or a high residue management plan.

An analysis of individual cell sediment yields indicated 270 (3.1%) of 8,774 cells in the Lake Mitchell watershed had sediment erosion yields greater than 4.0 tons/ acre $_{25\ year\ event}$. The suspected source of sedimentation from the critical cells is from cropland with slopes greater than 5% and overgrazed rangeland with land slopes greater than 8%. In order to reduce sedimentation from these 270 critical cells, the appropriate best management practice should be installed.

Therefore, it is recommended that if efforts to reduce sediment loads are made they should be focused within the identified critical subwatersheds and individual critical erosion cells located throughout the watershed. However, due to the overall low rate of sediment erosion throughout the watershed and the low deposition rate within Lake Mitchell, efforts to reduce sediment throughout the watershed should be limited. It is recommended that any targeted cell should be field verified prior to the installation of any best management practice.

Nutrients

Overall, the total nutrient loading to Lake Mitchell is high (0.00050 $_{tons/acre/25\ year\ event}$ for nitrogen and 0.00017 $_{tons/acre/25\ year\ event}$ for phosphorus). This 25-year event loading is equivalent 156.1 tons of nitrogen and 60.4 tons of phosphorus delivered to Lake Mitchell. Since the sedimentation rate to Lake Mitchell is low, the most likely source of the high nutrients is from animal feeding operations within the watershed. A total of 37 animal feeding areas with an AGNPS ranking of greater than 50 were identified. Two computer simulations were completed to evaluate the nutrient reductions if certain feeding areas were eliminated. This analysis found that if the animal feeding areas with an AGNPS non-corrected rating over 50 were eliminated (37 sites), the soluble phosphorus concentrations delivered Lake Mitchell would be reduced by approximately 37%. This analysis also indicated that if the animal feeding areas with an AGNPS non-corrected rating between 30-50 were eliminated (79 sites), the soluble phosphorus concentrations within Lake Mitchell would be reduced by an additional 14%.

A detailed subwatershed analysis concluded 5 of the 40 subwatersheds analyzed appeared to have an elevated (>2 times the average) number of critical cells. The five subwatersheds were; 5(#2293) N. Firesteel, 2(#454) West Firesteel, 8(#1257) West Firesteel, 12(#1792 West Firesteel, and 8(#663) M. Firesteel. The suspected sources of these nutrients are from animal feeding operations.

An analysis of nutrient yields from individual cells indicated that 173 of the 8,774 AGNPS cells had nitrogen yields greater than 2.5 $_{ppm\ 25\ year\ event}$. The analysis also determined that 297 cells had phosphorus yields greater than 0.40 ppm $_{25\ year\ event}$. The suspected sources of the elevated nutrients are from a number of the 241 animal feeding areas located throughout the watershed. Analysis concluded the 241 animal feeding areas were contributing excessive nutrients to the watershed and that all other potential nutrient sources were minimal.

According to the model, the 37 feedlots with rankings over 50 contribute 37% of the total phosphorus load to Lake Mitchell. Correcting this small number of feedlots would appear to have an impact on the phosphorus reduction to Lake Mitchell. If all of the 116 feedlots with feedlot rating > 30 were corrected, the model estimated 51% of the total phosphorus load would be eliminated.

It is recommended that the feeding areas with an AGNPS $_{\text{non-corrected rating}}$ > 30 be field verified, evaluated, and redesigned to minimize future nutrient releases. Additionally, all other potential feeding operations/practices within the Lake Mitchell watershed should be evaluated and efforts made to reduce nutrients by installing appropriate BMP's to minimize the impacts of the animal feeding areas.

The evaluation of appropriate BMP's for identified critical cells and feeding areas should produce the most cost effective treatment plan for reducing sediment and nutrient yields to Lake Mitchell.

Comparison of Water Quality Samples and AGNPS Modeling

The AGNPS model found a very small number of cells contributing excessive sediment. The few areas that exhibited excessive soil loss were typically on rangelands with slopes over 8%, or on cropland designated as highly erosive. These areas are located across the Davison County border on the west branch of Firesteel Creek, and a small area just north of Lake Wilmarth. The sites that had elevated suspended solids loadings were also from these areas (Sites #6 and #4). The AGNP's model estimated 11 acre feet of sediment entering the lake from the watershed. The water quality monitoring estimated approximately 1.5 acre-feet entering the lake through various sources (91% through Firesteel Creek). Since Site #1 is in a backflow situation the velocity of the water has already slowed and dropped suspended solids from the water column. If the suspended solids loading at Site #4, which is not in the back flow area, is substituted for Site #1 the total load from water quality is approximately 4 acre-feet. The water quality monitoring may have been missing the bedload that moves at the sediment-water interface of a stream. Another area that is difficult to estimate is scouring and cutting on the main channel. Material from cuts and scours increase the bedload which was not measured. Overall however, the model and sampling concluded suspend solids were not a major problem in the Lake Mitchell watershed. This fact is again substantiated in the late 1980's when a dredging project found mostly sand at the mouth of the lake. Silt is the major soil component in the watershed. Sand probably came from the alluvium and outwash areas around the lake and Firesteel Creek.

The estimates of total nitrogen and total phosphorus from AGNPS and the water quality sampling were relatively close in annual loading estimations. The AGNPS program estimated 166 tons of total nitrogen entering Lake Mitchell from the watershed. The water quality monitoring estimated 197 tons of total nitrogen from Firesteel Creek and Site #2 (229 tons total from all sources). AGNPS estimated 63.3 tons of total phosphorus from the watershed, while the water quality monitoring estimated 67 tons from Firesteel Creek and Site #2 (70.5 tons from all sources). Not only were the nutrient estimates close when comparing loadings, higher nutrient loading from the water quality sampling coincided with large feedlot operations. Water quality monitoring sites with higher concentrations of phosphorus and fecal coliform were areas also highlighted as critical cells of the AGNPS model.

In conclusion, excessive nutrients appear to be the main cause of eutrophication in Lake Mitchell. Sedimentation does not seem to be a serious problem in the watershed or Lake Mitchell. The main source of the nutrients is from concentrated animal feeding areas and/or intense summer long grazing. Storm sewers that enter the lake are a high source of sediment and nutrients for the size of the drainage area. By reducing the inputs of total phosphorus to the lake by 50%, the chlorophyll *a* concentrations in the lake are estimated to reach a minimum Carlson TSI rating of 52 (close to mesotrophic).

Additional nutrient inputs may be coming from summer long grazing. However, estimation of the sediment and phosphorus inputs from the grazing is difficult. The reduced chlorophyll *a* concentrations will decrease the amount of organic matter which would enter the treatment plant and should reduce the taste and odor problems. The clearer water will also increase light at greater depths and reduce the chance of stratification which can cause the anaerobic hydrogen sulfide smell (rotten egg) in the hypolimnion.

RESTORATION ALTERNATIVES

Because of the soluble nature of nitrogen it is very difficult to remove it from a lake and watershed system. Phosphorus will not pass through groundwater as readily as nitrogen, as it sorbs on to soil and other substrates. Phosphorus is also considered the limiting nutrient when blue-green algae bloom. For these reasons the sponsors should concentrate on the removal of phosphorus from sources entering the lake.

The AGNPS model estimated the top 37 concentrated animal feeding areas (ratings >50) input 37% of the total phosphorus from Firesteel Creek. Building animal waste management systems for these highest rated feedlots would be the most cost effective way to reduce inlake phosphorus concentrations.

There are 79 feeding areas with ratings between 30 and 50. The model suggests animal waste management systems would remove an additional 14% of the total phosphorus from entering the lake. All animal feeding areas should be field verified for animal numbers, animal types and drainage area.

Storm sewers input an additional 4% of total phosphorus. The storm sewers present a direct discharge from a large urban area. Any hazardous spill in the drainage area of the storm sewers would result in damage to the lake. By removing the storm sewers, the nutrients and sediment from urban sources could be eliminated.

Areas which were highlighted in the AGNPS model for high suspended solids loss should be addressed by working with the land owners and applying best management practices.

Grazing management systems and better riparian management in the watershed would reduce bank erosion along riparian areas, improve the trapping efficiency of solids from pasture land, and reduce phosphorus inputs to Lake Mitchell.

A proper aeration system placed in the area close to the intake pipe of city treatment plant would help eliminate stratification, thus eliminating the hydrogen sulfide smell. The circulating water will also keep the bottom sediments from releasing dissolved phosphorus in anoxic conditions. Depending on how long the lake would take to respond to the work in the watershed, the aeration system may be temporary.

More samples are needed to assess the impact the Wessington Springs waste water treatment facility is having on the water quality down stream. One site upstream and one site downstream of the confluence of the drainage from the treatment facility should be selected for sampling. Two samples should be taken in the weeks before the facility discharges, and two to three samples should be taken during discharge. Samples should also be collected at the USGS site (Site #4) to see if the water quality is notably affected farther downstream.

The golf course, along the shore of lake, should consider its management practices of fertilization and irrigation. Although no data was collected on the golf course specifically, in general, golf courses use large amounts of fertilizer and a great deal of water to maintain good course conditions.

The city has a water permit to use James River water when Lake Mitchell water level is low. Since water quality in the James River is generally poor, the city may consider a wetland treatment of the water prior to pumping it into Lake Mitchell. Typically, the city pumps about 2,000 acre-feet of water a year from the lake. A wetland complex of appropriate size could be used to settle out suspended solids and some of the nutrients from the nutrient rich James River. When the artificial wetland is dry, it may be cleaned to ensure capacity is maintained.

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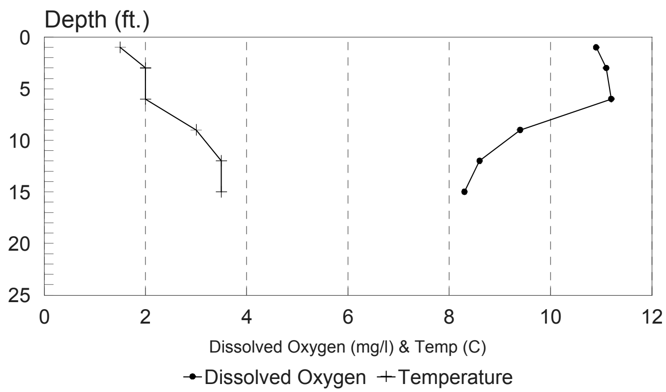
APPENDIX A

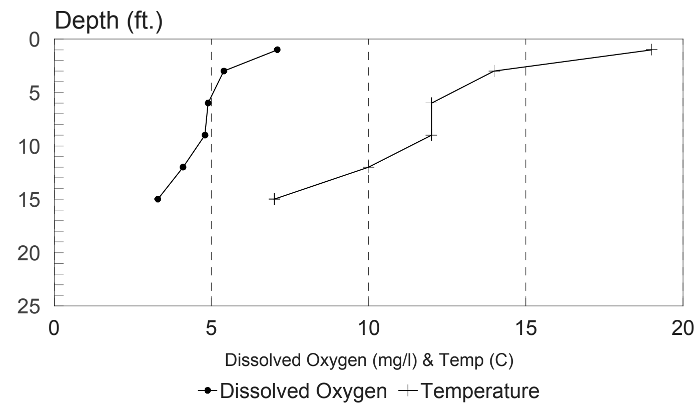
Water Quality Data

Site Specific Dissolved Oxygen Profiles

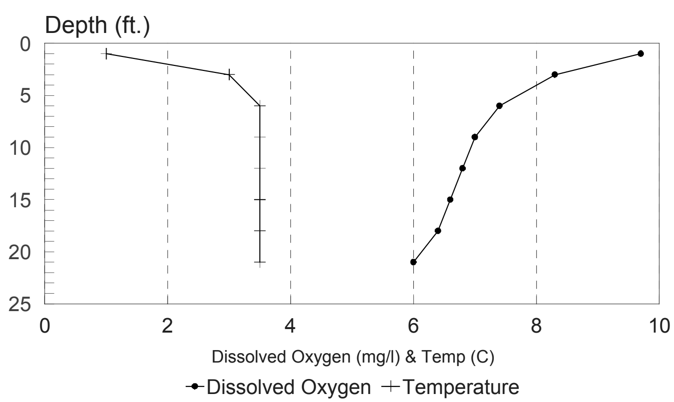
LAKE MITCHELL 2/2/93 Site #12
Dissolved Oxygen & Temperature Profile



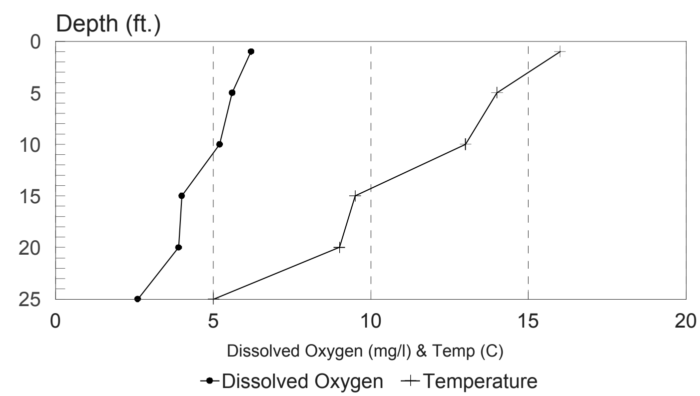
LAKE MITCHELL 6/13/94 Site #12
Dissolved Oxygen & Temperature Profile



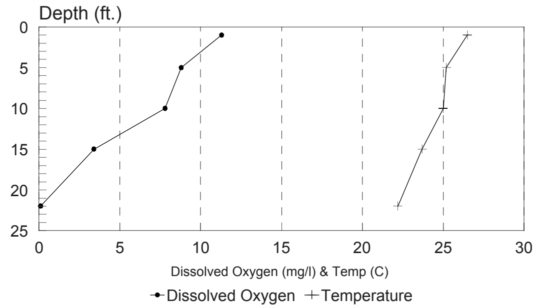
LAKE MITCHELL 2/2/93 Site #13
Dissolved Oxygen & Temperature Profile



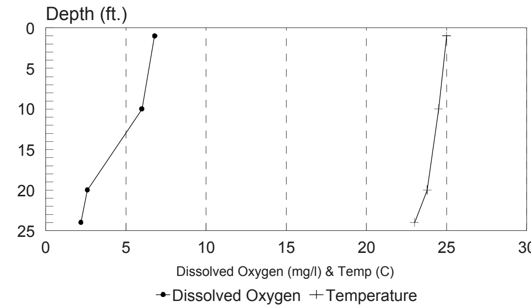
LAKE MITCHELL 6/13/94 Site #13
Dissolved Oxygen & Temperature Profile



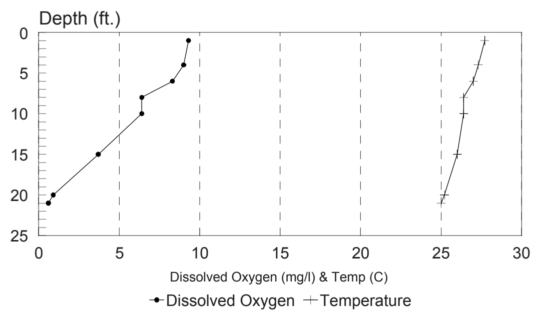
LAKE MITCHELL 5/26/79
Dissolved Oxygen & Temperature Profile



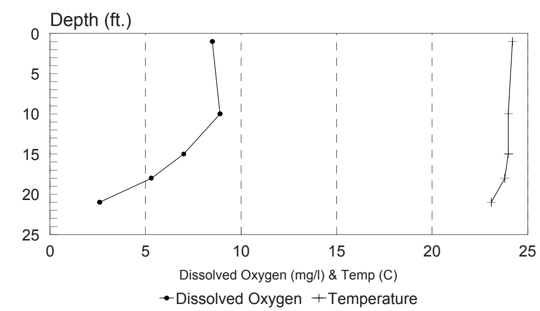
LAKE MITCHELL 6/20/91
Dissolved Oxygen & Temperature Profile



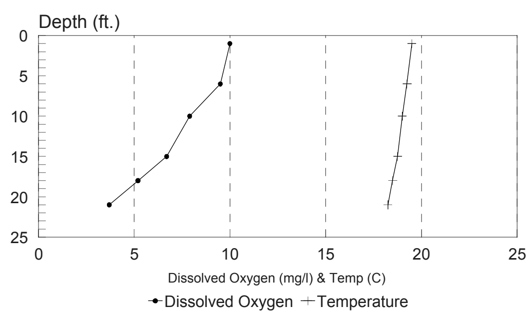
LAKE MITCHELL 7/20/91
Dissolved Oxygen & Temperature Profile



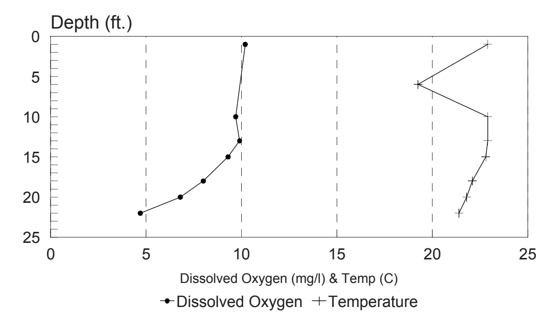
LAKE MITCHELL 8/19/91
Dissolved Oxygen & Temperature Profile



LAKE MITCHELL 6/11/92
Dissolved Oxygen & Temperature Profile

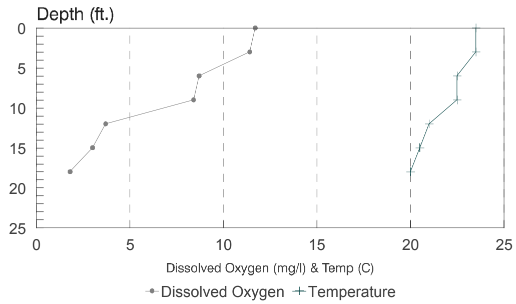


LAKE MITCHELL 7/15/92
Dissolved Oxygen & Temperature Profile



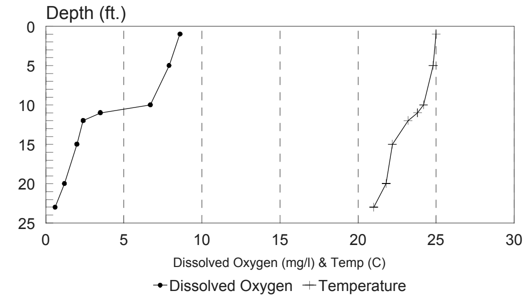
LAKE MITCHELL 7/28/92

Dissolved Oxygen & Temperature Profile



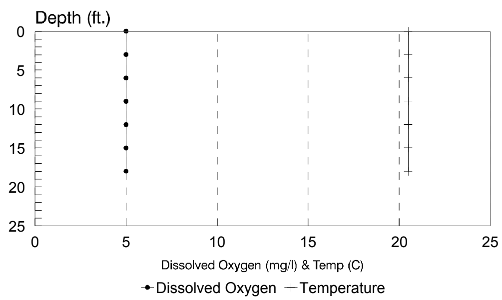
LAKE MITCHELL 8/13/92

Dissolved Oxygen & Temperature Profile



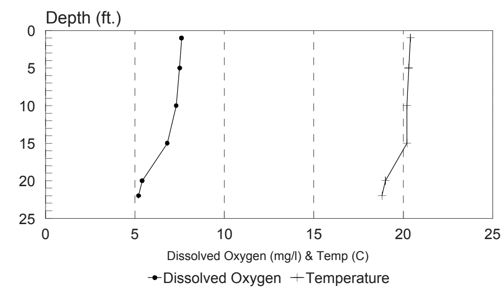
LAKE MITCHELL 8/26/92

Dissolved Oxygen & Temperature Profile



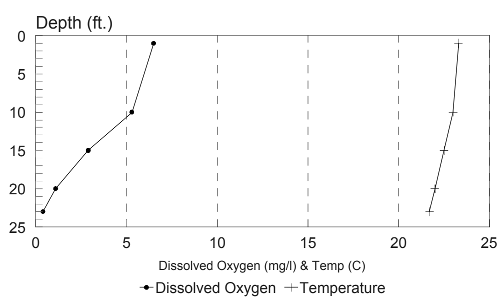
LAKE MITCHELL 6/12/93

Dissolved Oxygen & Temperature Profile



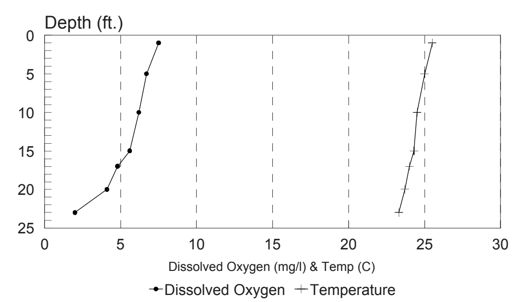
LAKE MITCHELL 7/20/93

Dissolved Oxygen & Temperature Profile

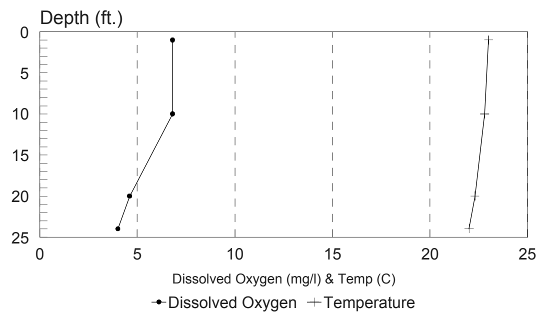


LAKE MITCHELL 8/18/93

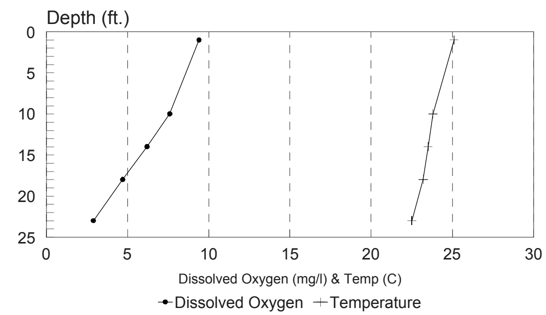
Dissolved Oxygen & Temperature Profile



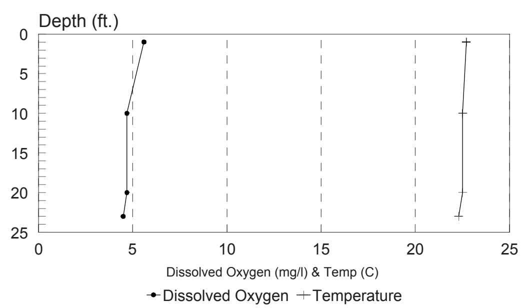
LAKE MITCHELL 6/11/94
Dissolved Oxygen & Temperature Profile



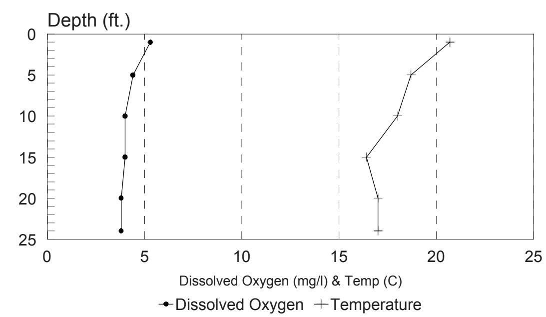
LAKE MITCHELL 7/13/94
Dissolved Oxygen & Temperature Profile



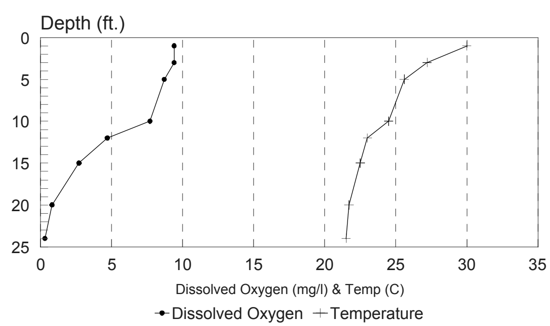
LAKE MITCHELL 8/13/94
Dissolved Oxygen & Temperature Profile



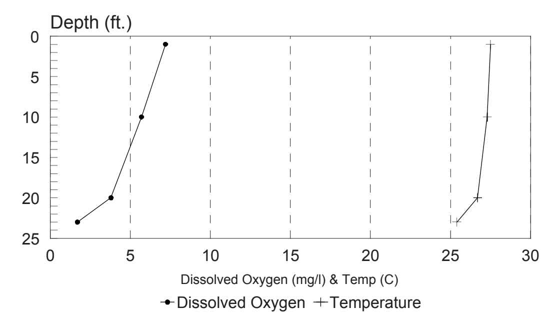
LAKE MITCHELL 6/13/95
Dissolved Oxygen & Temperature Profile



LAKE MITCHELL 7/12/95
Dissolved Oxygen & Temperature Profile



LAKE MITCHELL 8/11/95
Dissolved Oxygen & Temperature Profile



Tributary Sample Data

WATERBODY	SITE	COUNTY	DATE	TIME	SAMPLER	WTEMP	ATEMP	DISOX	FPH	TALKA	TSOL	TDSOL	TSSOL	AMMONIA	UNI-NH4	NITRATE	TKN	TPO4	TDPO4	% DISS. PO4	FECAL
						ºC	ºC	mg/L	su	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	%	Colonies
FIRESTEEL CREEK	1	DAVISON	3/10/93	1530	SCHIEVELBIEN	1.0	8.0	12.4	7.00	98	344	272	72	0.76	0.0007	0.70	4.38	0.870	0.590	68%	170
FIRESTEEL CREEK	1	DAVISON	3/29/93	1530	CAK	10.0	10.0	8.4	7.85	146	632	548	84	0.02	0.0003	0.20	2.91	0.408	0.066	16%	
FIRESTEEL CREEK	1	DAVISON	4/13/93	1400	CAK	7.0	12.0	10.0	8.16	217	980	950	30	0.02	0.0004	0.10	1.51	0.269	0.126	47%	560
FIRESTEEL CREEK	1	DAVISON	5/4/93	1630	CAK	16.0	28.0	8.6	7.86	152	709	657	52	0.02	0.0004	0.40	2.14	0.518	0.349	67%	10
FIRESTEEL CREEK	1	DAVISON	5/18/93	1315	WALLACE	16.5	20.5	6.4	7.54	196	773	746	27	0.07	0.0007	0.10	2.08	1.020	0.764	75%	10
FIRESTEEL CREEK	1	DAVISON	6/18/93	1415	WALLACE	15.0	17.5	5.8	7.56	159	655	587	68	0.02	0.0002	0.50	1.29	0.385	0.203	53%	330
FIRESTEEL CREEK	1	DAVISON	7/27/93	1700	WALLACE	27.0	28.0		7.78	155	431	392	39	0.02	0.0008	0.20	1.20	0.920	0.727	79%	30
FIRESTEEL CREEK	1	DAVISON	8/5/93	1430	WALLACE	24.0	22.0		8.57	253	863	837	26	0.02	0.0033	0.10	2.33	0.452	0.209	46%	360
FIRESTEEL CREEK	1	DAVISON	10/12/93	1345	WALLACE	8.0	30.0	10.6	8.09	274	1,284	1,270	14	0.02	0.0004	0.10	1.20	0.179	0.063	35%	490
FIRESTEEL CREEK	1	DAVISON	11/23/93	1450	WALLACE	2.0	-20.0	13.4	8.05	283	1,512	1,502	10	0.02	0.0002	0.10	1.22	0.169	0.020	12%	10
UNNAMED TRIBUTARY	2	DAVISON	3/9/93	1750	SCHIEVELBIEN	4.0	9.5	10.3	6.80	45	148	134	14	0.14	0.0001	1.60	2.80	0.707	0.578	82%	200
UNNAMED TRIBUTARY	2	DAVISON	5/11/93	1500	CAK	22.0	28.0	5.6	7.60	150	543	534	9	0.02	0.0004	0.30	1.78	0.325	0.292	90%	10
UNNAMED TRIBUTARY	2	DAVISON	6/18/93	1200	WALLACE	14.0	16.0	5.4	7.15	69	222	200	22	0.02	0.0001	0.10	1.12	0.422	0.335	79%	120
UNNAMED TRIBUTARY	2	DAVISON	7/28/93	1145	WALLACE	22.7	27.0		7.76	217	722	713	9	0.02	0.0005	0.10	1.41	0.428	0.372	87%	10
UNNAMED TRIBUTARY	3	DAVISON	3/9/93	800	SCHIEVELBEIN	3.0	9.0	10.4	6.78	48	158	145	13	0.04	0.0000	0.80	2.84	0.413	0.330	80%	220
UNNAMED TRIBUTARY	3	DAVISON	3/29/93	1500	CAK	9.0	12.0	9.2	7.62	94	406	384	22	0.02	0.0001	0.20	2.10	0.322	0.189	59%	40
UNNAMED TRIBUTARY	3	DAVISON	4/20/93	1230	CAK	9.0	10.0	10.3	7.88	142	506	490	16	0.02	0.0003	0.10	1.50	0.249	0.189	76%	10
UNNAMED TRIBUTARY	3	DAVISON	5/4/93	1500	CAK	21.0	26.0	9.2	7.81	11	358	318	40	0.02	0.0005	0.10	2.29	0.525	0.382	73%	1,100
UNNAMED TRIBUTARY	3	DAVISON	5/24/93	1637	WALLACE	16.2	15.0	9.0	7.72	225	682	681	1	0.02	0.0003	0.10	2.29	0.940	0.807	86%	
UNNAMED TRIBUTARY	3	DAVISON	6/18/93	1100	WALLACE	13.0	16.5	5.2	6.91	80	426	302	124	0.02	0.0000	0.60	1.32	0.461	0.242	52%	10
UNNAMED TRIBUTARY	3	DAVISON	7/28/93	1100	WALLACE	23.8	24.0		7.62	135	263	236	27	0.02	0.0004	0.10	1.42	0.604	0.432	72%	10
UNNAMED TRIBUTARY	3	DAVISON	8/5/93	1345	WALLACE	24.7	23.0		7.96	233	713	695	18	0.02	0.0010	0.10	2.88	0.627	0.432	69%	180
UNNAMED TRIBUTARY	3	DAVISON	10/12/93	1220	WALLACE	20.0	13.5	7.6	7.83	368	1,944	1,940	4	0.02	0.0005	0.10	0.75	0.481	0.349	73%	360
UNNAMED TRIBUTARY	3	DAVISON	11/22/93	1525	WALLACE	3.7	-20.0	13.4	7.91	421	1,626	1,622	4	0.02	0.0002	0.10	1.21	0.186	0.100	54%	410
FIRESTEEL CREEK	4	DAVISON	3/9/93	1750	SCHIEVELBIEN	1.0	9.5	11.9	7.35	101	384	262	122	0.80	0.0016	0.70	4.21	1.160	0.678	58%	10
FIRESTEEL CREEK	4	DAVISON	3/11/93	1300	SCHIEVELBIEN	2.0	2.0	11.8	6.51	86	328	288	40	0.38	0.0001	0.70	3.34	0.860	0.621	72%	
FIRESTEEL CREEK	4	DAVISON	4/5/93	1430	CAK			11.8	8.50	183	761	737	24	0.02	0.0005	0.10	2.02	0.302	0.236	78%	430
FIRESTEEL CREEK	4	DAVISON	4/27/93	1230	CAK	13.0	17.0	9.0	8.17	222	1,007	968	39	0.02	0.0007	0.10	1.11	0.266	0.146	55%	10
FIRESTEEL CREEK	4	DAVISON	5/11/93	1300	CAK	18.0	26.0	6.8	7.74	123	465	397	68	0.02	0.0004	0.40	2.03	0.618	0.465	75%	10
FIRESTEEL CREEK	4	DAVISON	5/21/93	1600	WALLACE	22.7	26.0	8.6	7.68	232	939	920	19	0.02	0.0005	0.10	1.84	1.180	0.471	40%	2
FIRESTEEL CREEK	4	DAVISON	6/17/93	1605	WALLACE	16.0	19.5	6.2	7.53	112	840	500	340	0.06	0.0006	1.20	2.56	1.060	0.239	23%	10
FIRESTEEL CREEK	4	DAVISON	7/28/93	1015	WALLACE	24.4	22.0		7.79	177	476	430	46	0.02	0.0007	0.20	1.53	0.860	0.780	91%	620
FIRESTEEL CREEK	4	DAVISON	8/17/93	1410	WALLACE	25.5	27.5	9.4	8.38	321	1,125	1,037	88	0.02	0.0025	0.10	1.84	0.395	0.083	21%	
FIRESTEEL CREEK	4	DAVISON	11/22/93	1422	WALLACE	4.4	-16.0	13.6	8.39	297	1,694	1,677	17	0.02	0.0006	0.10	1.20	0.169	0.046	27%	410
UNNAMED TRIBUTARY	5	AURORA	3/9/93	1550	SCHIEVELBIEN	2.0	10.0	11.8	7.15	64	300	282	18	0.26	0.0004	0.80	3.15	0.849	0.704	83%	10
UNNAMED TRIBUTARY	5	AURORA	3/23/93	1430	SCHIEVELBIEN	6.0	6.0	13.2	8.21	138	571	556	15	0.02	0.0004	0.10	2.32	0.448	0.368	82%	10
UNNAMED TRIBUTARY	5	AURORA	4/27/93	1000	CAK	12.0	14.0	8.4	7.83	220	1,059	1,045	14	0.02	0.0003	0.10	1.37	0.242	0.173	71%	10
UNNAMED TRIBUTARY	5	AURORA	5/11/93	1030	CAK	16.0	25.0	6.2	7.54	130	621	577	44	0.02	0.0002	0.30	2.05	0.428	0.329	77%	30
UNNAMED TRIBUTARY	5	AURORA	5/21/93	1650	WALLACE	22.5	23.0	8.0	7.48	227	965	947	18	0.02	0.0003	0.10	1.74	0.611	0.448	73%	10
UNNAMED TRIBUTARY	5	AURORA	6/17/93	1120	WALLACE	16.5	17.0	6.5	7.53	193	740	708	32	0.02	0.0002	0.10	1.69	0.737	0.564	77%	100
UNNAMED TRIBUTARY	5	AURORA	7/28/93	925	WALLACE	22.9	24.5		7.60	203	609	586	23	0.02	0.0004	0.10	1.64	1.010	0.867	86%	10
UNNAMED TRIBUTARY	5	AURORA	10/12/93	1120	WALLACE	19.0	9.0	7.2	7.99	316	1,752	1,721	31	0.02	0.0007	0.10	1.31	0.378	0.299	79%	20
UNNAMED TRIBUTARY	5	AURORA	11/22/93	1100	WALLACE	5.5	-17.0	12.0	8.33	300	1,901	1,892	9	0.02	0.0005	0.10	0.89	0.163	0.156	96%	250

Tributary Sample Data (continued)

WATERBODY	SITE	COUNTY	DATE	TIME	SAMPLER	WTEMP	ATEMP	DISOX	FPH	TALKA	TSOL	TDSOL	TSSOL	AMMONIA	UNI-NH4	NITRATE	TKN	TPO4	TDPO4		FECAL
						ºC	ºC	mg/L	su	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	%	Colonies
UNNAMED TRIBUTARY	6	AURORA	3/9/93	1515	SCHIEVELBIEN	1.0	11.0	11.9	7.35	93	354	278	76	0.92	0.0018	0.70	4.36	0.904	0.785	87%	3,700
UNNAMED TRIBUTARY	6	AURORA	3/23/93	1515	SCHIEVELBIEN	5.0	8.0	13.4	8.24	131	427	419	8	0.02	0.0004	0.40	2.24	0.588	0.488	83%	170
UNNAMED TRIBUTARY	6	AURORA	4/13/93	1200	CAK	6.5	11.4	11.4	8.28	225	896	878	18	0.02	0.0005	0.10	1.80	0.309	0.229	74%	10
UNNAMED TRIBUTARY	6	AURORA	5/4/93	1230	CAK			7.9	8.60	145	534	494	40	0.02	0.0006	0.20	1.74	0.528	0.418	79%	10
UNNAMED TRIBUTARY	6	AURORA	5/18/93	1145	WALLACE	15.0	16.0	6.0	7.08	208	727	708	19	0.15	0.0005	0.20	1.92	1.180	0.793	67%	650
UNNAMED TRIBUTARY	6	AURORA	6/17/93	1500	WALLACE	16.5	15.5	6.4	8.12	288	1,079	1,029	50	0.02	0.0008	0.50	1.63	0.979	0.843	86%	270
UNNAMED TRIBUTARY	6	AURORA	7/28/93	845	WALLACE	23.8	21.0		7.85	166	444	400	44	0.02	0.0007	0.20	1.54	0.923	0.833	90%	130
UNNAMED TRIBUTARY	6	AURORA	8/18/93	1315	WALLACE	21.0	27.5	7.9	8.38	309	973	903	70	0.02	0.0019	0.10	1.75	0.461	0.216	47%	
UNNAMED TRIBUTARY	6	AURORA	11/22/93	1115	WALLACE	5.3	-15.0	12.8	8.59	299	1,605	1,582	23	0.02	0.0009	0.10	1.37	0.259	0.136	53%	10
DOUBLE CULVERT	7	AURORA	3/9/93	1300	SCHIEVELBIEN	5.7	11.0	11.2	7.02	79	410	366	44	0.14	0.0002	0.80	2.83	0.762	0.788	103%	100
DOUBLE CULVERT	7	AURORA	3/23/93	1300	SCHIEVELBIEN	4.0	9.0	13.5	7.98	119	530	510	20	0.02	0.0002	0.10	2.25	0.458	0.349	76%	180
DOUBLE CULVERT	7	AURORA	4/5/93	1030	CAK	6.7	16.0	11.6	8.41	195	994	958	36	0.02	0.0007	0.10	2.79	1.030	0.193	19%	
DOUBLE CULVERT	7	AURORA	4/27/93	900	CAK	13.0	15.0	7.8	8.05	212	1,087	1,051	36	0.02	0.0005	0.10	2.03	0.266	0.146	55%	300
DOUBLE CULVERT	7	AURORA	5/11/93	900	CAK	15.5	18.0	6.8	7.76	137	671	627	44	0.02	0.0003	0.30	2.03	0.339	0.256	76%	
DOUBLE CULVERT	7	AURORA	5/24/93	1525	WALLACE	21.0	17.0	7.8	8.08	270	1,029	1,014	15	0.02	0.0010	0.10	1.74	0.744	0.455	61%	20
DOUBLE CULVERT	7	AURORA	6/18/93	1605	WALLACE	21.5	16.5	8.0	7.95	333	1,266	1,240	26	0.02	0.0008	0.10	1.31	0.352	0.259	74%	
DOUBLE CULVERT	7	AURORA	7/27/93	1540	WALLACE	24.7	28.0		7.93	228	807	727	80	0.02	0.0009	0.10	1.51	0.750	0.584	78%	
DOUBLE CULVERT	7	AURORA	8/17/93	1200	WALLACE	20.0	25.0	7.4	8.13	427	1,537	1,473	64	0.02	0.0010	0.10	2.14	1.090	0.727	67%	250
DOUBLE CULVERT	7	AURORA	10/13/93	1000	WALLACE	13.5	10.5	5.4	8.17	304	2,133	2,051	82	0.02	0.0007	0.10	1.74	0.478	0.179	37%	
DOUBLE CULVERT	7	AURORA	11/22/93	1030	WALLACE	3.9	-18.0	13.0	8.29	256	1,960	1,944	16	0.02	0.0004	0.10	0.70	0.176	0.133	76%	
WILMARTH SPILLWAY	7A	AURORA	3/9/93	1135	SCHIEVELBIEN	3.0	10.0	10.1	7.40	98	380	364	16	0.34	0.0009	0.60	3.73	0.995	0.875	88%	10
WILMARTH SPILLWAY	7A	AURORA	3/11/93	1015	SCHIEVELBIEN	2.5	3.5	10.4	7.26	76	294	274	20	0.25	0.0005	0.70	3.71	0.953	0.707	74%	180
WILMARTH SPILLWAY	7A	AURORA	3/23/93	1130	SCHIEVELBIEN	3.5	4.0	15.0	8.65	72	251	245	6	0.02	0.0009	0.30	2.42	0.674	0.544	81%	10
WILMARTH SPILLWAY	7A	AURORA	4/5/93	800	CAK			12.2	8.35	199	575	563	12	0.02	0.0004	0.10	2.57	0.594	0.471	79%	180
WILMARTH SPILLWAY	7A	AURORA	4/20/93	1030	CAK	8.0	10.0	10.6	8.35	201	672	662	10	0.02	0.0007	0.10	2.05	0.408	0.471	115%	10
WILMARTH SPILLWAY	7A	AURORA	5/5/93	900	CAK	13.0	15.0	10.8	8.43	206	671	658	13	0.02	0.0012	0.10	1.74	0.349	0.289	83%	10
WILMARTH SPILLWAY	7A	AURORA	5/18/93	1000	WALLACE	21.0	13.0	7.8	2.68	227	945	935	10	0.02	0.0000	0.10	1.44	0.873	0.398	46%	10
WILMARTH SPILLWAY	7A	AURORA	6/17/93	1000	WALLACE	13.5	16.5	5.5	8.06	268	917	914	3	0.02	0.0005	0.10	1.39	0.691	0.624	90%	10
WILMARTH SPILLWAY	7A	AURORA	7/12/93	1000	WALLACE	21.0	16.7		7.34	173	609	605	4	0.03	0.0003	0.10	1.52	0.860	0.784	91%	50
WILMARTH SPILLWAY	7A	AURORA	8/17/93	1000	WALLACE	21.0	25.0	4.4	7.71	218	612	609	3	0.04	0.0009	0.10	1.56	1.390	1.340	96%	10
WILMARTH SPILLWAY	7A	AURORA	11/23/93	945	WALLACE	3.6	-19.0	11.2	8.43	241	685	675	10	0.03	0.0009	0.10	1.44	0.707	0.650	92%	10
MITCHELL SPILLWAY	8	DAVISON	3/10/93	1600	SCHIEVELBIEN	2.0	8.0	9.0	7.42	179	661	658	3	0.13	0.0003	0.20	1.52	0.226	0.116	51%	20
MITCHELL SPILLWAY	8	DAVISON	3/22/93	830	SCHIEVELBIEN	4.0	8.0	10.5	7.61	89	312	298	14	0.20	0.0009	0.60	2.80	0.558	0.398	71%	10
MITCHELL SPILLWAY	8	DAVISON	4/5/93	1430	CAK		12.0	11.0	8.03	151	550	542	8	0.12	0.0011	0.20	1.76	0.213	0.169	79%	10
MITCHELL SPILLWAY	8	DAVISON	4/27/93	1430	CAK	11.0	14.0	11.4	8.66	161	634	613	21	0.02	0.0017	0.10	0.70	0.139	0.046	33%	10
MITCHELL SPILLWAY	8	DAVISON	5/18/93	1415	WALLACE	21.5	18.5	8.0	7.95	152	620	611	9	0.02	0.0008	0.10	1.38	1.320	0.183	14%	10
MITCHELL SPILLWAY	8	DAVISON	7/28/93	1215	WALLACE	26.0	26.5		8.02	150	418	412	6	0.02	0.0012	0.20	1.36	0.657	0.588	89%	
MITCHELL SPILLWAY	8	DAVISON	11/23/93	1410	WALLACE	3.0	-25.0	13.4	8.06	205	667	660	7	0.06	0.0007	0.30	1.26	0.249	0.226	91%	10
MITCHELL SPILLWAY	8	DAVISON	6/13/94	1430	WALLACE	19.0	27.3	7.3	8.01	194	875	870	5	0.20	0.0073	0.10	1.32	0.163	0.130	80%	20
MITCHELL SPILLWAY	8	DAVISON	5/9/95	1445	WALLACE	13.7	11.1		7.35	118	529	512	17	0.16	0.0009	0.20	0.29	0.295	0.213	72%	5

Annual Loadings For Inputs and Outputs

SITE	UNITS	WATER PER YEAR	YEARLY LOAD TALKA	YEARLY LOAD TSOL	YEARLY LOAD TDSOL	YEARLY LOAD TSSOL	YEARLY LOAD AMMONIA	YEARLY LOAD NITRATE	YEARLY LOAD TKN	YEARLY LOAD NITROGEN	YEARLY LOAD TPO4	YEARLY LOAD TDPO4
Site #1	Liters or Kilograms	93,570,055,078	15,322,511	56,944,843	52,202,353	4,742,490	4,780	30,091	153,347	183,438	60,121	41,476
Site #2	Liters or Kilograms	1,483,964,055	203,928	679,700	657,336	22,365	36	254	2,021	2,275	631	526
Unsampled Trib.	Liters or Kilograms	1,233,619,200	169,525	565,035	546,443	18,592	30	211	1,680	1,891	524	437
Groundwater	Liters or Kilograms	16,976,931,732								849	340	255
Rain	Liters or Kilograms	2,190,640,926								3,556	77	39
Storm Sewer #9	Liters or Kilograms	3,084,048,000	434,851	1,862,765	1,730,151	132,614	401	6,168	4,626	10,794	1,721	287
Storm Sewer #10	Liters or Kilograms	1,004,166,029	90,977	580,408	355,977	224,431	442	2,159	2,224	4,383	502	154
Storm Sewer #11	Liters or Kilograms	445,336,531	29,541	165,071	122,319	42,752	132	341	702	1,044	135	43
TOTAL INPUTS		119,988,761,551	16,251,332	60,797,823	55,614,579	5,183,244	5,820	39,224	164,601	208,230	64,050	43,217
Evaporation	Liters or Kilograms	1,721,737,645										
Plant Pumping	Liters or Kilograms	2,144,227,549	405,259	1,464,507	1,447,354	17,154	579	300	2,444	2,745	596	474
Site #8	Liters or Kilograms	116,540,375,862	17,810,613	61,281,506	60,379,418	902,088	4,141	20,338	164,414	184,752	99,572	41,826
TOTAL OUTPUTS		118,684,603,411	18,215,872	62,746,013	61,826,771	919,242	4,720	20,638	166,858	187,496	100,168	42,300
Budget	Liters or Kilograms	(417,579,505)	(1,964,540)	(1,948,190)	(6,212,192)	4,264,002	1,100	18,586	(2,257)	20,734	(36,118)	917
Site #1	Acre/Ft or Pounds	75,855	33,786,136	125,563,379	115,106,189	10,457,190	10,539	66,351	338,130	404,481	132,568	91,456
Site #2	Acre/Ft or Pounds	1,203	449,660	1,498,739	1,449,425	49,314	79	559	4,457	5,016	1,390	1,160
Unsampled Trib.	Acre/Ft or Pounds	1,000	373,803	1,245,902	1,204,907	40,995	66	465	3,705	4,170	1,156	964
Groundwater	Acre/Ft or Pounds	13,762								1,872	750	562
Rain	Acre/Ft or Pounds	1,776								7,841	170	85
Storm Sewer #9	Acre/Ft or Pounds	2500	958,846	4,107,397	3,814,983	292,414	884	13,601	10,200	23,801	3,795	632
Storm Sewer #10	Acre/Ft or Pounds	814	200,605	1,279,800	784,929	494,871	974	4,761	4,904	9,665	1,107	339
Storm Sewer #11	Acre/Ft or Pounds	361	65,137	363,982	269,714	94,269	291	753	1,548	2,301	297	96
TOTAL INPUTS		97,271	35,834,187	134,059,199	122,630,146	11,429,053	12,833	86,489	362,945	459,147	141,232	95,294
Evaporation	Acre/Ft or Pounds	1,396										
Plant Pumping	Acre/Ft or Pounds	1,738	893,596	3,229,239	3,191,415	37,824	1,277	662	5,390	6,052	1,314	1,045
Site #8	Acre/Ft or Pounds	94,477	39,272,402	135,125,720	133,136,616	1,989,104	9,131	44,846	362,532	407,377	219,556	92,226
TOTAL OUTPUTS		96,215	40,165,998	138,354,959	136,328,030	2,026,928	10,408	45,507	367,922	413,429	220,871	93,271
Budget	Acre/Ft or Pounds	(340)	(4,331,811)	(4,295,760)	(13,697,884)	9,402,124	2,425	40,982	(4,977)	45,717	(79,639)	2,023

Inlake Surface Samples 1991 -- 1995

PROJECT TYPE	SITE	DATE	TIME	SAMPLER	TYPE	MAX. SAMPLE DEPTH	WATER TEMP.	AIR TEMP.	SECCHI DEPTH	DO	FPH	TALKA	TSOL	TDSOL	TSSOL	AMMONIA	UNIONIZED AMMONIA	NITRATE NITRITE	TKN	TOTAL N	TPO4	TDPO4	% Diss. PO4	FECAL
							°C	°C	Meters	mg/L	su	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	Colonies
ASSESSMENT		6/20/91	1530	GERMAN	COMPOSITE		25.20	33.33	1.16	7.40					14	0.14		0.01	1.46	1.47	0.150	0.110	73%	
ASSESSMENT		7/20/91	1500	GERMAN	COMPOSITE		27.80	33.89	0.81	9.00	8.74				10	0.02	0.0061	0.00	1.00	1.00	0.165	0.100	60%	
ASSESSMENT		8/19/91	1400	GERMAN	COMPOSITE		24.10	27.22	0.98	8.50	8.43				11	0.01	0.0018	0.00	1.03	1.03	0.208	0.145	70%	
ASSESSMENT		6/11/92	1945	GERMAN	COMPOSITE		20.33	27.22	1.96	10.93	8.77				8	0.06	0.0120	0.04	0.95	0.99	0.280	0.042	15%	
ASSESSMENT		7/15/92	1900	GERMAN	COMPOSITE		23.03	26.67	0.63	10.37	9.09				20	0.01	0.0053	0.01	1.38	1.39	0.165	0.080	48%	
ASSESSMENT		7/28/92	1300		COMPOSITE		23.50	25.50	0.61	12.57	8.61	177	800	792	8	0.02	0.0034	0.10	0.83	0.93	0.193			
ASSESSMENT		8/26/92	920		COMPOSITE		20.50	13.70	0.41	5.40	8.00	138	524	510	14	0.11	0.0044	0.10	0.74	0.84	0.282	0.186	66%	
FIRESTEEL	12	2/2/93	1400	SHIEVELBEIN	GRAB	1.5		4.00		10.90	7.71	196	696	694	2	0.04	0.0002	0.10	0.89	0.99	0.096	0.096	100%	10
FIRESTEEL	13	2/2/93	1540	SHIEVELBEIN	GRAB	1		4.00		9.70	7.48	184	676	672	4	0.14	0.0004	0.10	1.07	1.17	0.106	0.103	97%	10
ASSESSMENT		6/12/93	1643	GERMAN	COMPOSITE	6.40	21.53	25.00	1.57	9.03	8.55				7	0.20	0.0270	0.02	1.17	1.19	0.199	0.142	71%	
FIRESTEEL	13	6/28/93	1345	WALLACE	GRAB		24.70	32.00	1.22	8.00	8.29	161	567	558	9	0.02	0.0020	0.10	1.22	1.32	0.299	0.209	70%	10
FIRESTEEL	12	6/28/93	1540	WALLACE	GRAB		25.00	27.00	0.61	8.00	7.42	149	494	479	15	0.02	0.0003	0.20	1.36	1.56	0.501	0.378	75%	20
ASSESSMENT		7/20/93	1800	GERMAN	COMPOSITE	6.50	23.93	20.00	1.13	7.37	7.72				4	0.15	0.0039	0.16	1.16	1.31	0.653	0.560	86%	
FIRESTEEL	13	8/10/93	1000	WALLACE	GRAB		27.00		0.91		8.35	170	455	449	6	0.02	0.0026	0.10	1.78	1.88	0.674	0.611	91%	10
FIRESTEEL	12	8/10/93	1030	WALLACE	GRAB		27.00	32.00	1.01		8.33	169	456	451	5	0.02	0.0025	0.20	1.30	1.50	0.684	0.611	89%	10
ASSESSMENT		8/18/93	1730	GERMAN	COMPOSITE	6.40	25.67	23.00	1.49	7.77	8.36				4	0.24	0.0285	0.06	1.18	1.24	0.620	0.560	90%	
FIRESTEEL	13	11/8/93	1400	WALLACE	GRAB				4.57			220	660	652	8	0.18	0.0000	0.30	1.12	1.42	0.279	0.242	87%	10
FIRESTEEL	12	11/8/93	1430	WALLACE	GRAB				4.57			216	658	653	5	0.13	0.0000	0.30	1.14	1.44	0.266	0.246	92%	10
ASSESSMENT		6/11/94	1556	GERMAN	COMPOSITE	7.62	22.80	22.50	1.44	6.47	8.22				14	0.36	0.0269	0.50	1.24	1.74	0.160	0.130	81%	
FIRESTEEL	13	6/13/94	2300	WALLACE	GRAB		16.00	27.50	1.68	6.20	7.88	218	889	882	7	0.25	0.0055	0.10	1.76	1.86	0.206	0.140	68%	10
FIRESTEEL	12	6/13/94	2330	WALLACE	GRAB		18.00	29.00	0.91	7.10	8.12	194	925	916	9	0.21	0.0091	0.10	3.71	3.81	0.346	0.153	44%	10
FIRESTEEL	13	7/6/94	1400	WALLACE	GRAB		24.50	29.00	1.83	6.90	8.40	188	967	964	3	0.15	0.0182	0.20	1.09	1.29	0.133	0.120	90%	10
FIRESTEEL	12	7/6/94	1430	WALLACE	GRAB		25.00	32.00	1.37	8.10	8.18	190	870	863	7	0.12	0.0095	0.20	1.17	1.37	0.140	0.133	95%	10
ASSESSMENT		7/13/94	1702	GERMAN	COMPOSITE	7.62	25.30	26.80	1.51	10.37	8.70				6	0.05	0.0113	0.68	1.01	1.69	0.119	0.097	82%	
ASSESSMENT		8/13/94	1528	GERMAN	COMPOSITE	7.32	22.50	20.00	1.20	5.20	8.30				5	0.71	0.0617	0.40	1.41	1.81	0.372	0.375	101%	
ASSESSMENT		6/13/95	1800	GERMAN	COMPOSITE	7.62	21.50	26.30	0.58	6.70	8.48				14	0.23	0.0274	0.19	1.41	1.60	0.270	0.228	84%	
ASSESSMENT		7/12/95	1530	GERMAN	COMPOSITE	7.62	29.90	36.30	1.58	9.30	7.86				4	0.01	0.0003	0.04	0.91	0.94	0.069	0.039	57%	
ASSESSMENT		8/11/95	1541	GERMAN	COMPOSITE	7.32	27.93	33.50	2.29	7.73	8.09				3	0.10	0.0079	0.06	1.08	1.14	0.149	0.124	83%	

Inlake Bottom Samples 1991 -- 1995

PROJECT TYPE	SITE	DATE	TIME	SAMPLER	TYPE	MAX. SAMPLE DEPTH	WATER TEMP.	AIR TEMP.	SECCHI DEPTH	DO	FPH	TALKA	TSOL	TDSOL	TSSOL	AMMONIA	UNIONIZED AMMONIA	NITRATE NITRITE	TKN	TOTAL N	TPO4	TDPO4	% Diss. PO4	FECAL
							°C	°C	Meters	mg/L	su	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	Colonies
ASSESSMENT		6/20/91	1530	GERMAN	COMPOSITE	7.32	24.00	33.33	NA	5.10					24	0.26		0.00	1.16	1.16	0.210	0.140	67%	
ASSESSMENT		7/20/91	1500	GERMAN	COMPOSITE	6.71	25.40	33.89	NA	2.60	8.27				23	0.12	0.01199	0.00	1.03	1.03		0.142		
ASSESSMENT		8/19/91	1400	GERMAN	COMPOSITE	6.71	23.50	27.22	NA	5.40	8.31				17	0.02	0.00161	0.01	0.84	0.84	0.228	0.151	66%	
ASSESSMENT		6/11/92	1945	GERMAN	COMPOSITE	6.71	19.20	27.22	NA	5.43	8.50				16	0.38	0.04035	0.05	1.27	1.32	0.145	0.108	74%	
ASSESSMENT		7/15/92	1900	GERMAN	COMPOSITE	6.71	22.03	26.67	NA	6.30	8.85				17	0.08	0.01868	0.01	1.18	1.19	0.184	0.100	54%	
ASSESSMENT		7/28/92	1300		COMPOSITE	6.25	21.00	25.50	NA	3.20	8.00	182	823	795	28	0.60	0.02459	0.10	0.90	1.00	0.319	0.209	66%	
ASSESSMENT		8/26/92	920		COMPOSITE	5.87	20.00	13.70	NA	5.30	8.02	280	531	507	24	0.11	0.00439	0.10	0.63	0.73	0.286	0.173	60%	
FIRESTEEL	12	2/2/93	1400	SHIEVELBEIN	GRAB	3.50		4.00	NA	8.30	7.40	200	708	704	4	0.08	0.00022	0.10	0.94	1.04	0.110	0.103	94%	10
FIRESTEEL	13	2/2/93	1540	SHIEVELBEIN	GRAB	3.80		4.00	NA	6.00	7.51	189	696	693	3	0.14	0.00051	0.10	1.05	1.15	0.126	0.103	82%	10
ASSESSMENT		6/12/93	1643	GERMAN	COMPOSITE	6.40	20.83	25.00	NA	7.17	8.44				18	0.26	0.02718	0.06	1.27	1.33	0.189	0.153	81%	
FIRESTEEL	13	6/28/93	1345	WALLACE	GRAB		24.40	32.00	NA	3.60	7.14	170	634	596	38	0.24	0.00179	0.10	1.63	1.73	0.594	0.408	69%	10
FIRESTEEL	12	6/28/93	1540	WALLACE	GRAB		24.00	28.00	NA	6.80	7.16	150	523	489	34	0.02	0.00015	0.10	1.50	1.60	0.515	0.339	66%	10
ASSESSMENT		7/20/93	1800	GERMAN	COMPOSITE	6.50	22.47	20.00	NA	2.60	7.62				20	0.34	0.00660	0.16	1.24	1.40	0.661	0.574	87%	
FIRESTEEL	13	8/10/93	1000	WALLACE	GRAB		23.00		NA		7.85	167	451	443	8	0.24	0.00810	0.20	1.89	2.09	0.767	0.727	95%	10
FIRESTEEL	12	8/10/93	1030	WALLACE	GRAB		25.00	21.00	NA	3.60	7.99	170	470	463	7	0.10	0.00527	0.20	1.36	1.56	0.644	0.667	104%	10
ASSESSMENT		8/18/93	1730	GERMAN	COMPOSITE	6.40	23.33	23.00	NA	1.80	7.98				9	0.52	0.02413	0.07	1.37	1.44	0.770	0.723	94%	
FIRESTEEL	13	11/8/93	1400	WALLACE	GRAB				NA			220	654	644	10	0.19	0.00000	0.30	1.09	1.39	0.286	0.249	87%	10
FIRESTEEL	12	11/8/93	1430	WALLACE	GRAB				NA			216	672	659	13	0.14	0.00000	0.40	0.95	1.35	0.272	0.242	89%	10
ASSESSMENT		6/11/94	1556	GERMAN	COMPOSITE	7.62	22.03	25.50	NA	4.50	8.30				15	0.42	0.03534	0.00	1.14	1.14	0.173	0.135	78%	
FIRESTEEL	13	6/13/94	2300	WALLACE	GRAB	5.00	5.00	27.50	NA	2.60	7.72	195	906	877	29	0.44	0.00287	0.10	1.39	1.49	0.333	0.160	48%	10
FIRESTEEL	12	6/13/94	2330	WALLACE	GRAB		7.00	29.00	NA	3.30	7.99	193	927	912	15	0.30	0.00425	0.10	1.45	1.55	0.183	0.150	82%	10
FIRESTEEL	13	7/6/94	1400	WALLACE	GRAB		22.00	29.00	NA	2.20	7.71	194	952	939	13	0.36	0.00829	0.20	1.36	1.56	0.163	0.140	86%	10
FIRESTEEL	12	7/6/94	1430	WALLACE	GRAB		24.00	32.00	NA	6.30	8.08	188	876	865	11	0.11	0.00659	0.20	0.95	1.15	0.156	0.126	81%	10
ASSESSMENT		7/13/94	1702	GERMAN	COMPOSITE	7.62	23.30	26.80	NA	5.13	8.29				14	0.36	0.03178	0.69	1.11	1.80	0.171	0.144	84%	
ASSESSMENT		8/13/94	1528	GERMAN	COMPOSITE	7.32	22.20	20.00	NA	3.73	8.31				14	0.82	0.07150	0.32	1.56	1.88	0.424	0.371	88%	
ASSESSMENT		6/13/95	1800	GERMAN	COMPOSITE	7.62	17.70	26.30	NA	4.90	8.43				45	0.29	0.02434	0.19	1.40	1.59	0.323	0.208	64%	
ASSESSMENT		7/12/95	1530	GERMAN	COMPOSITE	7.62	21.90	36.30	NA	0.37	7.60				39	0.37	0.00651	0.06	1.47	1.53	0.170	0.080	47%	
ASSESSMENT		8/11/95	1541	GERMAN	COMPOSITE	7.32	25.83	33.50	NA	3.07	7.95				6	0.39	0.02001	0.06	1.34	1.40	0.232	0.211	91%	

APPENDIX B

OVERVIEW OF AGNPS DATA INPUTS

OVERVIEW

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

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

PRELIMINARY EXAMINATION

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

1) Detailed topographic map of the watershed (USGS map 1:24,000).

2) Establish the drainage boundaries.

3) Divide watershed up into cells (40 acre, 1320 X 1320). Only those cells with greater than 50% of their area within the watershed boundary should be included.

4) Number the cells consecutively from one to the number of cells (begin at NW corner of watershed and proceed west to east then north to south).

5) Establish the watershed drainage pattern from the cells.

DATA FILE

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

Data input for watershed

a) Area of each cell (acres)
b) Total number of cells in watershed
c) Precipitation for a ___ year, 24 hour rainfall
d) Energy intensity value for storm event previously selected

Data input for each cell

1) **Cell number**

2) **Receiving cell number**

3) **SCS number** runoff curve number, (use antecedent moisture condition II)

4) **Land slope** (topographic maps), average slope if irregular, water or marsh = 0

5) **Slope shape factor** water or marsh = 1 (uniform)

6) **Field slope length** water or marsh = 0, for S.D. assume slope length area 1

7) **Channel slope** (average), topo maps, if no definable channel, channel slope = 1/2 land slope, water or marsh = 0

8) **Channel sideslope**, the average sideslope (%), assume 10% if unknown, water or marsh=0 9)

9) **Manning roughness coefficient for the channel** if no channel exists within the cell, select a roughness coefficient appropriate for the predominant surface condition within the cell

10) **Soil erodibility factor** water or marsh = 0

11) **Cropping factor** assume conditions at storm or worst case condition (fallow or seedbed periods), water or marsh = .00, urban or residential = .01

12) **Practice factor** worst case = 1.0, water or marsh = 0, urban or residential = 1.0

13) **Surface condition constant** a value based on land use at the time of the storm to make adjustments for the time it takes overland runoff to channelize.

14) **Aspect** a single digit indicating the principal direction of drainage from the cell (if no drainage = 0)

15) **Soil texture**, major soil texture and number to indicate each are:

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

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

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

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

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

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

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

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

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

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

DATA OUTPUT AT THE OUTLET OF EACH CELL

Hydrology

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

Sediment Output

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

Chemical Output

Nitrogen

Sediment associated mass
Concentration of soluble material
Mass of soluble material

Phosphorus

Sediment associated mass
Concentration of soluble material
Mass of soluble material

Chemical Oxygen Demand

Concentration
Mass

PARAMETER SENSITIVITY ANALYSIS

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

RAINFALL SPECS FOR THE FIRESTEEL CREEK WATERSHED STUDY

EVENT	RAINFALL	ENERGY INTENSITY
Monthly	.8	3.0
Semi-annual	1.5	11.7
1 year	2.0	21.8
5 year	3.2	60.6
10 year	3.8	88.1
25 year	4.4	121.2
50 year	5.0	160.1
100 year	5.5	197.1

NRCS R_{factor} for the Firesteel Creek watershed = 95

Annual Loadings Calculations

monthly events = 12 events x 3.0 = 36.0

4-6 month event = 3 event x 11.7 = 35.1

1 year event = 1 event x 21.8 = 21.8

========

Modeled Cumm. R_{factor} = 92.9

APPENDIX C

SOUTH DAKOTA STATEWIDE FISHERIES SURVEY
LAKE MITCHELL - 1996

SOUTH DAKOTA STATEWIDE FISHERIES SURVEY

2102-F21-R-29

Name: Lake Mitchell **County (ies)**: Davison
Legal Description: Sec. 4-5, 9, 31-32, Range 60W, T103-104N
Location from nearest town: Northwest side of Mitchell, SD

Dates of present survey: July 15-17, 1996
Date last surveyed: July 10-12, 1995
Most recent lake management plan: F21-R-24 Date: 1990
Management classification: Warmwater Permanent
Contour mapped: Aerial photo date 1970

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

PHYSICAL CHARACTERISTICS

Surface Area: 670 acres **Watershed**: 229,911 acres
Maximum depth: 24 feet **Mean depth**: 12.2 feet
Lake elevation at time of survey (from known benchmark): Full

1. Describe ownership of lake and adjacent lakeshore property:

   Lake Mitchell was constructed and is owned by the city of Mitchell and its fishery is managed by the South Dakota Department of Game, Fish and Parks.

2. Describe watershed condition and percentages of land use:

   The watershed consists of 41% cropland and 59% pastureland.

3. Describe aquatic vegetative condition:

   Scattered beds of submergent coontail and emergent cattail were common in the bays and creek arms of the lake.
4. Describe pollution problems:

No problems were observed during the survey.

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

All structures appeared to be in good condition.

CHEMICAL DATA

1. Describe general water quality characteristics:

The water quality in Lake Mitchell appeared to be quite good with very little algae and a Secchi disk reading of 14 inches.

BIOLOGICAL DATA

Methods:

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

On July 15-17, 1996, Lake Mitchell was sampled with twelve, 3/4 inch, overnight frame net sets and four, 150 foot, overnight gill net sets. On August 29, 1996, seven quarter arc pulls with a 6x100 foot, 1/4 inch mesh bag seine were made. On June 18, 1996, we electrofished for 2 hours using a boat mounted pulsed AC electrofishing unit. Netting and electrofishing results are listed in Tables 1-4, length frequencies in Figure 1 and sampling locations in Figure 2.

Results and Discussion:

Table 1. Total catch of four, 24 hour, 150 foot overnight gill net sets at Lake Mitchell, Davison County, July 15-17, 1996.

Species	Number	Percent	CPUE	80% C.I.	3 Year CPUE Avg.	PSD	Mean Wr
Black Bullhead	30	17.3	7.5	±7.6	7.0	--	--
Black Crappie	29	16.8	7.2	±7.2	2.6	--	126
Walleye	24	13.9	6.0	±3.5	4.3	--	86
Channel Catfish	24	13.9	6.0	±4.4	3.4	59	--
Shorthead Redhorse	23	13.2	5.7	±5.9	2.2	--	--
Freshwater Drum	19	11.0	4.7	±1.4	3.1	--	--
Carp	15	8.7	3.7	±2.7	1.9	--	--
White Crappie	3	1.7	0.7	±0.8	0.3	--	--
White Sucker	3	1.7	0.7	±0.8	0.5	--	--
Yellow Perch	2	1.2	0.5	±0.8	0.2	--	--
Northern Pike	1	0.6	0.25	±0.4	0.08	--	--

Table 2. Total catch of twelve, 24 hour, 3/4 inch mesh overnight frame net sets at Lake Mitchell, Davison County, July 15-17, 1996.

Species	Number	Percent	CPUE	80% C.I.	3 Year CPUE Avg.	PSD	Mean Wr
Bluegill	389	41.5	32.4	+12.2	17.2	88	117
Black Crappie	382	40.8	31.8	+27.7	15.0	53	124
Carp	54	5.7	4.5	+1.8	3.6	--	--
Shorthead Redhorse	25	2.7	2.1	+1.1	1.4	--	--
Walleye	22	2.3	0.2	+1.4	0.3	--	87
Smallmouth Bass	14	1.5	1.2	+0.6	0.8	--	100
Channel Catfish	10	1.1	0.8	+0.4	0.9	--	--
Freshwater Drum	9	1.0	0.7	+0.4	0.4	--	--
White Sucker	9	1.0	0.7	+0.5	0.4	--	--
Yellow Perch	7	0.7	0.6	+0.5	0.3	--	--
Black Bullhead	7	0.8	0.6	+0.5	0.6	--	--
Saugeye	4	0.4	0.3	+0.3	0.2	--	--
Northern Pike	3	0.3	0.2	+0.2	0.2	--	--
Sunfish Hybrid	1	0.1	0.1	+0.1	0.03	--	--
Largemouth Bass	1	0.1	0.1	+0.1	0.03	--	--

Table 3. Total catch of 2 hours of electrofishing at Lake Mitchell, Davison County, June 18, 1996.

Species	Number	Percent	CPUE	80% C.I.	3 Year CPUE Avg.	PSD	Mean Wr
Largemouth Bass	63	80.0	31.5	--	14.1	43	107
Smallmouth Bass	16	20.0	8.0	--	5.0	--	--

Table 4. Total catch from ten quarter-arc seine pulls at Lake Mitchell, Davison County, August 29, 1996.

Species	Number	Percent	CPUE	80% C.I.	3 Year CPUE Avg.
Bluegill	88	75.2	12.6	+15.3	98.5
Largemouth Bass	24	20.5	3.4	+3.6	9.4
Shiners	4	3.4	0.6	+0.8	29.2
Smallmouth Bass	1	0.9	0.1	+0.2	0.4

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

Walleye gill net catch-per-unit-effort (CPUE) was 5.8 in 1994, decreased to 1.0 in 1995, then increased to 6.0 in 1996 (Table 1). Age and growth analysis shows the walleyes in Lake Mitchell are growing slower than the South Dakota average and are reaching 35.6 centimeters (cm.) or 14 inches (in.) between their fourth and fifth year (Table 5). No young-of-the-year (YOY) walleye were sampled by shoreline seining (Table 4).

This was the first year a decent electrofishing sample of largemouth bass was taken from Mitchell. Age and growth analysis shows that the growth rates for bass are nearly normal for South Dakota and there seems to be a good year class from 1992 (Table 6). The length frequency histogram in Figure 1 shows an excellent size distribution and shoreline seining sampled 24 YOY indicating natural reproduction.

Black crappie frame net CPUE was 5.8 in 1994, increased to 7.5 in 1995 and jumped to 31.8 in 1996 (Table 2). In the fall of 1995, 12,438 black crappie adults were stocked that may have contributed to the increase (Table 7). The length frequency histogram shows one group of fish from 11-17 cm. (4.3-6.7 in.) and another from 19-26 cm. (7.5-10.2 in.) in length.

Bluegill frame net CPUE was 9.0 in 1994, increased to 10.1 in 1995 and increased again to 32.4 in 1996. Most of the bluegills ranged in length from 13-23 cm. (5.1-9 in.). Shoreline seining sampled 88 YOY bluegills indicating some natural reproduction.

Other species sampled during the survey included northern pike, shorthead redhorse, black bullhead, freshwater drum, carp, white crappie, white sucker, channel catfish, yellow perch, smallmouth bass and saugeye. Data concerning these species can be found in Tables 1-4.

Table 5. Average back-calculated lengths, in mms., for each age class of walleye in Lake Mitchell, Davison County, 1996.

			Back-calculation Age						
Year Class	Age	N	1	2	3	4	5	6	7
1995	1	6	149.42						
1994	2	10	152.20	184.09					
1993	3	5	163.61	221.67	276.50				
1992	4	7	167.91	212.73	264.62	292.27			
1991	5	2	184.25	272.67	320.39	344.11	381.75		
1990	6	5	173.58	245.55	298.65	349.20	385.20	413.18	
1989	7	8	178.13	241.87	293.40	340.78	396.01	427.65	451.78
All Classes			164.50	220.17	285.78	327.56	390.50	422.08	451.78
SD Average			163	289	389	450	508	547	587

Table 6. Average back-calculated lengths, in mms., for each age class of largemouth bass in Lake Mitchell, Davison County, 1996.

			Back-calculation Age						
Year Class	Age	N	1	2	3	4	5	6	7
1995	1	0	0.00						
1994	2	3	104.02						
1993	3	8	100.92	157.61	205.14				
1992	4	22	110.63	172.69	225.90	256.83			
1991	5	8	112.20	208.65	266.03	296.35	321.99		
1990	6	9	111.61	176.70	247.13	305.60	332.63	353.25	
1989	7	2	78.47	185.22	260.53	301.47	343.62	367.15	386.91
1988	8	2	120.10	241.47	306.29	335.19	365.25	395.83	419.68
All Classes			108.38	179.90	237.19	280.11	332.73	361.94	403.30
SD Average			91	184	251	305	345	400	435

RECOMMENDATIONS

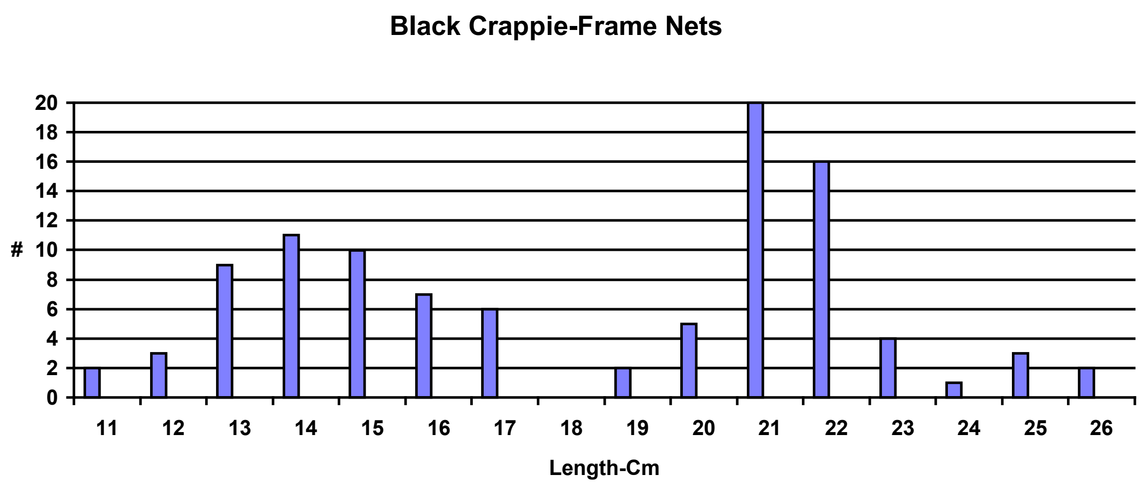
1. Stock 67,000 walleye fingerlings in 1997. It appears that natural reproduction is unable to produce sufficient fish to maintain catchable numbers of walleyes in the lake and every other year stockings will be necessary.

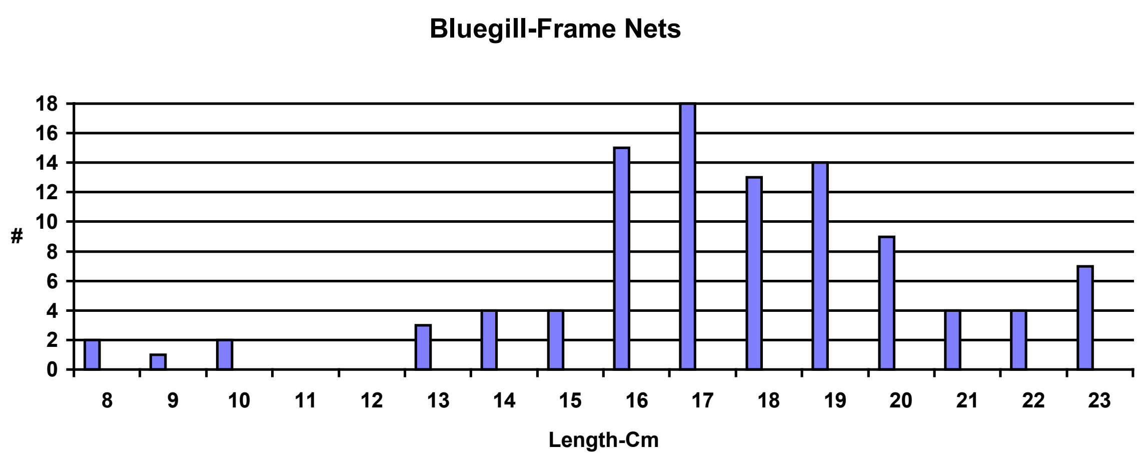
2. Work with the City of Mitchell and local sportsmen to develop a habitat improvement plan for the lake.

Table 7. Stocking record for Lake Mitchell, Davison County, 1986-1996.

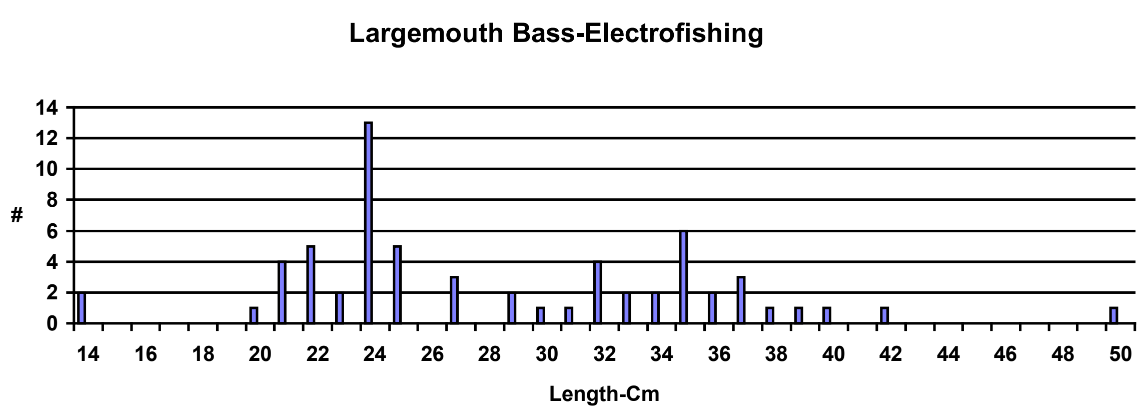
Year	Number	Species	Size
1986	13,815	Muskellunge	Lrg. Fingerling
	50	Muskellunge	Fingerling
1987	8,980	Walleye	Lrg. Fingerling
	9,960	Walleye	Yearling
1988	33,500	Largemouth Bass	Fingerling
1989	33,500	Walleye	Fingerling
1990	33,500	Saugeye	Sml. Fingerling
	2,250	Muskellunge	Fingerling
1991	67,000	Saugeye	Fingerling
1992	35,000	Largemouth Bass	Med. Fingerling
	67,000	Saugeye	Sml. Fingerling
	35,000	Smallmouth Bass	Med. Fingerling
1993	82,900	White Crappie	Fingerling
	70,000	Walleye	Sml. Fingerling
	67,200	Smallmouth Bass	Med. Fingerling
1994	13,125	Channel Catfish	Fingerling
1995	12,438	Black Crappie	Adult
	67,000	Walleye	Fingerling
1996	22,746	Black Crappie	Fingerling
	3,198	Black Crappie	Adult
	42,500	Smallmouth Bass	Fingerling

Figure 1. Length frequency histograms of selected species from Lake Mitchell, Davison County, 1996





Bluegill-Frame Nets
18
16
14
12
10
8
6
4
2
0
#
8
9
10
11
12
13
14
15
16
17
18
19
20
21
22
23
Length-Cm


Largemouth Bass-Electrofishing
#
14
12
10
8
6
4
2
0
14
16
18
20
22
24
26
28
30
32
34
36
38
40
42
44
46
48
50
Length-Cm

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