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LAKE HERMAN MODEL IMPLEMENTATION PROGRAM AND 314 CLEAN LAKES PROJECT FINAL REPORT

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Richard A. Hanson, Forrest E. Payne and
Timothy M. Bjork

Grant No. S806193010

Project Officer

Thomas Braidech
Water Division, Region VIII
U.S. Environmental Protection Agency
Denver, Colorado 80295

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in cooperation with
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South Dakota Department of Water and Natural Resources
Soil Conservation Service, USDA
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DISCLAIMER

PREFACE

The work at Lake Herman and its watershed was comprehensive in nature and involved separate programs. The Model Implementation Program (MIP) was a cooperative effort by the USDA, USEPA, and various State and local organizations to control nonpoint source pollution through the application of Best Management Practices and other watershed management techniques. The MIP utilized existing programs of the USEPA and USDA to accomplish its goals.

Two USEPA programs were used; the 314 Clean Lakes Program and the 208 Statewide Water Quality Management Program. These programs made possible among other things, the construction of sediment control structures, water quality monitoring, and water sample analyses.

Two USDA programs were also used. The Technical Assistance Program of the Soil Conservation Service and the Agricultural Conservation Program of the Agricultural Stabilization and Conservation Service provided invaluable assistance and funding for the implementation of Best Management Practices.

The work done under these programs perhaps merit separate reports but the information obtained from each is much more meaningful when combined into one comprehensive report. This document combines the results obtained from these programs and is collectively called the Lake Herman Model Implementation Program.

ABSTRACT

The Lake Herman Model Implementation Program (MIP) was initiated in 1978 as a demonstration of interagency cooperation and interaction. The MIP was a joint effort by the U.S. Environmental Protection Agency, the U.S. Department of Agriculture, and various State and local organizations to control nonpoint sources of pollution. A number of land treatment measures were implemented and included Best Management Practices (BMPs), sediment control structures, and lake shoreline stabilization. These measures were intended to decrease erosion and consequently improve lake water quality.

This report describes the project objectives and the major aspects which were considered necessary for successful implementation of land treatment measures. An organizational structure and the basic duties of each organization are presented. Techniques to inform and educate the public are given and their effectiveness is discussed. Land treatment measures are described and the basic activities needed to implement each one are outlined. A water quality sampling program is presented and assessments of nonpoint source pollution control measures, in terms of water quality, are performed. The water quality of Lake Herman is described and quantified with limnological criteria, trophic state indices, nutrient loading models, and South Dakota Water Quality Standards.

This report was submitted in fulfillment of Grant No. S806193010 by the South Dakota Department of Water and Natural Resources under the partial sponsorship of the U.S. Environmental Protection Agency. This report covers a period from January, 1978 to December, 1983.

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ACKNOWLEDGMENTS

The authors are grateful for the efforts of the Lake Herman Development Association and the Lake County Conservation District Board of Supervisors, especially Mr. Vern Spartz, the former Board Chairman. Their enthusiasm and determination were instrumental in making the MIP possible. The administrative assistance of Mrs. Lucille Miller helped keep the project on schedule. The U.S. Soil Conservation Service was a major participant in the project and special thanks are given to Mr. Oakley Hoy, District Conservationist, who directed much of the watershed work and Mr. Ron Adamson, SCS Technician, who provided technical assistance. Mr. James Seyfer, South Dakota Department of Water and Natural Resources, gave valuable expertise in the development and management of the project. The authors also wish to acknowledge all organizations and individuals who provided technical and financial assistance. Finally, we thank the landowners and operators in the Lake Herman watershed. Without their enthusiasm and cooperation this project could not have been possible.

SECTION 1

INTRODUCTION

In September, 1977, the U.S. Department of Agriculture (USDA) and the U.S. Environmental Protection Agency (EPA) agreed to initiate a joint water quality/land management effort, the Model Implementation Program (MIP). These agencies were authorized to formulate an agreement to assist each other in cleaning up our Nation's inland waters under P.L. 92-500, otherwise known as the Federal Water Pollution Control Act of 1972. The MIP was designed to demonstrate the effectiveness of concentrating and coordinating the various soil conservation programs and water quality management programs of the USDA and the EPA. The agreement was to select areas on which land treatment measures to control nonpoint sources of pollution could be applied and to determine their effectiveness in improving water quality. Following an intensive screening process, seven areas were selected for the MIP. Lake Herman and its watershed were selected on January 13, 1978.

Prior to the selection of Lake Herman as a MIP, various local organizations and individuals met to discuss the possibility of generating sufficient support for a project to restore the lake. The amount of support evident at these early meetings was one of the primary reasons why Lake Herman received the MIP designation.

In addition, the lake has a well documented history of water quality problems. Brashier, et al. (1971) reported a fish kill during the winter of 1968-1969 and the South Dakota Department of Game, Fish and Parks (GF&P) recorded fish kills every three or four years. Churchill, et al. (1975) noted regular occurrences of blue-green algae blooms and relatively high siltation levels. The U.S. EPA National Eutrophication Survey (1976) ranked the lake 25th in overall trophic quality out of 31 South Dakota lakes (31 being the worst in trophic quality). The South Dakota Department of Water and Natural Resources[1] (DWNR), through a Section 208 Water Quality Management Planning Grant, found hypereutrophic levels of total phosphorus in the lake and excessive nutrient (nitrogen and phosphorus) loadings from the inflowing streams. These findings indicated a high level of eutrophication and substantiated the need for lake rehabilitation. The excessive nutrient loadings and siltation are due to nonpoint pollution sources and possibly untreated feedlots.

The Lake Herman MIP was a multidisciplinary, interactive, and cooperative effort which allowed for the participation of many organizations. With such a project, proper organization and planning was paramount to success.

By early summer of 1978, a work plan was developed which detailed project objectives and goals, and designated each organization's responsibilities. It

[1] Originally the South Dakota Department of Environmental Protection (DEP) began work on the project. Through an act of the legislature, DEP was merged with the Department of Natural Resources Development to form the Department of Water and Natural Resources.

was determined that the most effective methods for controlling nonpoint source pollution in the watershed were the construction of sediment control structures and the application of Best Managment Practices (BMPs). These methods required landowner acceptance and participation. Thus, informing and educating the public was a necessary project component. A water quality monitoring program was established to assess the the effects of the MIP on the water quality of Lake Herman and its tributaries. Various aspects of implementation have continued to the present. In 1985, a 5-year dredging project was begun to remove accumulated sediment from selected portions of the lake.

The MIP was not an inexpensive endeavor and funding was sought from numerous agencies. The USDA's Agricultural Stabilization and Conservation Service (ASCS) agreed to allocate special project funds and 90% cost sharing for applying BMPs in the watershed. Additional funding came from an EPA 314 grant and various state and local agencies contributed to the required 50% matching share (Table 1).

TABLE 1. FUNDING SOURCES AND CONTRIBUTIONS FOR THE LAKE HERMAN MIP

Source		Contribution
U.S. EPA		407,575.00
USDA - ASCS		150,000.00
SD DWNR		170,087.00
Old West Regional Commission		100,000.00
Lake County Commission		90,000.00
East Dakota Conservancy Sub-District		15,000.00
Madison City Commission		10,000.00
SD GF&P	Technical serivces +	3,500.00
USDA-SCS		Technical services
Lake County Conservation District		In-kind services
Lake Herman Development Association		In-kind services

SECTION 2

CONCLUSIONS, RECOMMENDATIONS AND INSIGHTS

The Lake Herman Model Implementation Program was a successful demonstration of interagency cooperation and interaction. The major factors which led to its success included:

1. A strong organizational structure and project coordinator which allowed for efficient information transfer between cooperating agencies.

   Information transfer was facilitated by a detailed directory which was sent to each participating agency. This directory contained the agencies involved, names of appropriate personnel, telephone numbers and addresses of the participants. The MIP coordinator was a major contact, especially between local agencies and the other state and federal participants. It is recommended that similar projects have such a person. The MIP coordinator not only acted as a liason between agencies but he also performed technical and administrative duties.

2. A functional workplan that contained specific objectives and duties of each agency.

   The importance of a workplan cannot be over stressed. The workplan, however, must be flexible enough to be adapted to changing conditions. Changes in funding, available personnel, and weather conditions could wreak havoc on a project based on very rigid workplan. All three of these changes occurred during the MIP and without flexibility the project could have stagnated.

3. Sufficient funding for project implementation.

   Funding from federal agencies for implementation was adequate but certain problems may have been indirectly due to a lack of funding for the planning phase. For example, five sediment control structures were originally planned but due to unsuitable topography, uncooperative landowners, and lack of matching funds only three were constructed. A relatively detailed reconnaissance that explored these factors could have provided for more realistic planning and consequently more efficient usage of funds. It is suggested that monies be made available prior to project implementation so that a detailed workplan reflects realistic and obtainable goals.

4. An informational and educational program that introduced the project to the public, kept them cognizant of project developments, and provided knowledge necessary for acceptance and application of BMPs.

   Numerous techniques were used to inform and educate the public. These included: radio announcements, newspaper articles, informal visits, brochures and pamphlets, watershed tours, meetings and educational programs. Some techniques, however, were more effective than others and each technique must be keyed to a particular recipient. For example, personal visits to landowners were the best means of communicating project goals and needs to them but such a technique is obviously not an efficient means of informing the general public. Likewise, newspaper articles and radio announcements, though informative to the general public, are inadequate for conveying specific information about BMPs to the landowners.

5. Sufficient landowner cooperation so that most of the watershed has some form of nonpoint source pollution control.

   This is essential to any project based on watershed management. If the majority of landowners are not in favor or are complacent about such a project, it will not be successful. Sustained positive support from the landowners is needed and the Lake Herman project had that support. Other projects, however, may require strong local soil erosion ordinances and vigorous enforcement of them to insure nonpoint source pollution control in areas where erosion is still a major problem, mainly because ot uncooperative landowners.

6. A knowledgeable implementation of nonpoint source pollution control measures based on site-specific assessments of erosion.

   The USDA SCS and ASCS were mostly responsible for successful BMP implementation. Few problems arose but the authors feel that improvements can be made. During the first year of the MIP, 90 farms participated in the Agricultural Conservation Program (ACP). Even though up to 90% cost share was approved for specific practices, the allocated ACP funds for the year were not completely used. This was partially due to the $2,500 spending limitation per farm and the lack of sufficient planning time before receipt of funds. The spending limit was increased to $3,500 the following year and enabled more BMP applications at one time. But even so, a spending limitation does not necessarily reflect the importance of critical erosion areas and cost effectiveness. Efforts to control erosion and nonpoint source pollution should be relatively intensive in critical areas and less so in areas of minor erosion. Landowners of critical areas should, therefore, have the opportunity to apply for more ACP monies, especially if cost effectiveness is important.

These six factors should be major considerations for future projects of this nature. Proper organization and planning, efficient use ot funds, effective informational and promotional techniques, landowner cooperation, and knowledgable implementation of nonpoint source pollution controls can lead to a successful demonstration of interagency cooperation and interaction and nonpoint source pollution control.

The water quality monitoring produced variable results. The major conclusions from these results are listed below.

1. Permanent seeding can reduce nutrient concentrations.

2. Terraces alone are ineffective in reducing nutrient or suspended sediment concentrations if a waterway is left untreated (ungrassed).

3. Sediment control structures can, if operated properly, reduce nutrient and suspended sediment concentrations.

4. Lake Herman does not thermally stratify.

5. Lake Herman is well oxygenated though winter anoxia is a strong possibility.

6. Lake Herman is nitrogen limited.

7. Lake Herman is eutrophic-hypereutrophic.

8. Phosphorus based loading models are presently not appropriate for assessing the water quality of Lake Herman.

9. Given present circumstances, South Dakota Water Quality Standards based on pH, fecal coliforms, and dissolved oxygen are inadequate for assessing BMP effectiveness on improving the water quality of Lake Herman.

SECTION 3

PROJECT AREA DESCRIPTION

Lake Herman is a glacial lake located in Lake County, South Dakota, approximately 65 km (40 miles) northwest of Sioux Falls (Figure 1). The lake and its watershed comprise 17,381 hectares (about 42,948 acres) and are situated in the western edge of the central lowlands province of the Prairie de Coteau region near the City of Madison.

The Prairie de Coteau region is a massive, hilly, lake-dotted highland lying along the State's eastern border and is drained by the Big Sioux River and its tributaries. The geology of this region is complex due to glaciation. The region contains many small boulder-strewn knobs and ridges separated by undrained or poorly drained depressions containing small lakes and sloughs. Deposits of outwash, a component of glacial drift, form shallow underground aquifers (East Dakota Conservancy Sub-District, 1969).

The Lake Herman watershed is nearly level to gently sloping with some moderately well developed drainages. The most common soils are silty and clayey. Four tributaries drain into Lake Herman, one each from the north, west, southwest, and south. The outlet, Silver Creek, is located at the northeast shore of the lake.

The morphometry of Lake Herman is characteristic of lakes in the region. The lake has a surface area of 536 hectares (1,326 acres), a mean depth of 1.7 m (5.6 feet), a maximum depth of 2.4 m (8 feet), a volume of $9.28 \times 10^6 m^3$ (7,525 acre feet), and a mean hydraulic residence time of 3.3 years. The climate of this portion of South Dakota is mid-continental, sub-humid with cold winters and hot summers. The lake freezes over in late fall and opens up in early spring. The mean annual temperature is 7.8°C. Average annual precipitation and lake level evaporation amount to 54 and 84 centimeters, respectively (East Dakota Conservancy Sub-District, 1969).

Approximately 60% of the lake's shoreline is developed. The predominant land use in the watershed is agriculture (75% of the usage is corn and small grain farming in support of livestock operations). The remaining 25% is in hayland, pasture, farmsteads or covered with water. Lake Herman State Park, Camp Lakodia 4-H Camp, Izaak Walton League grounds, Westside Access Area, and a religious affiliated recreation center area are located on the lake shore in addition to 84 private homes, cabins or recreation related businesses.

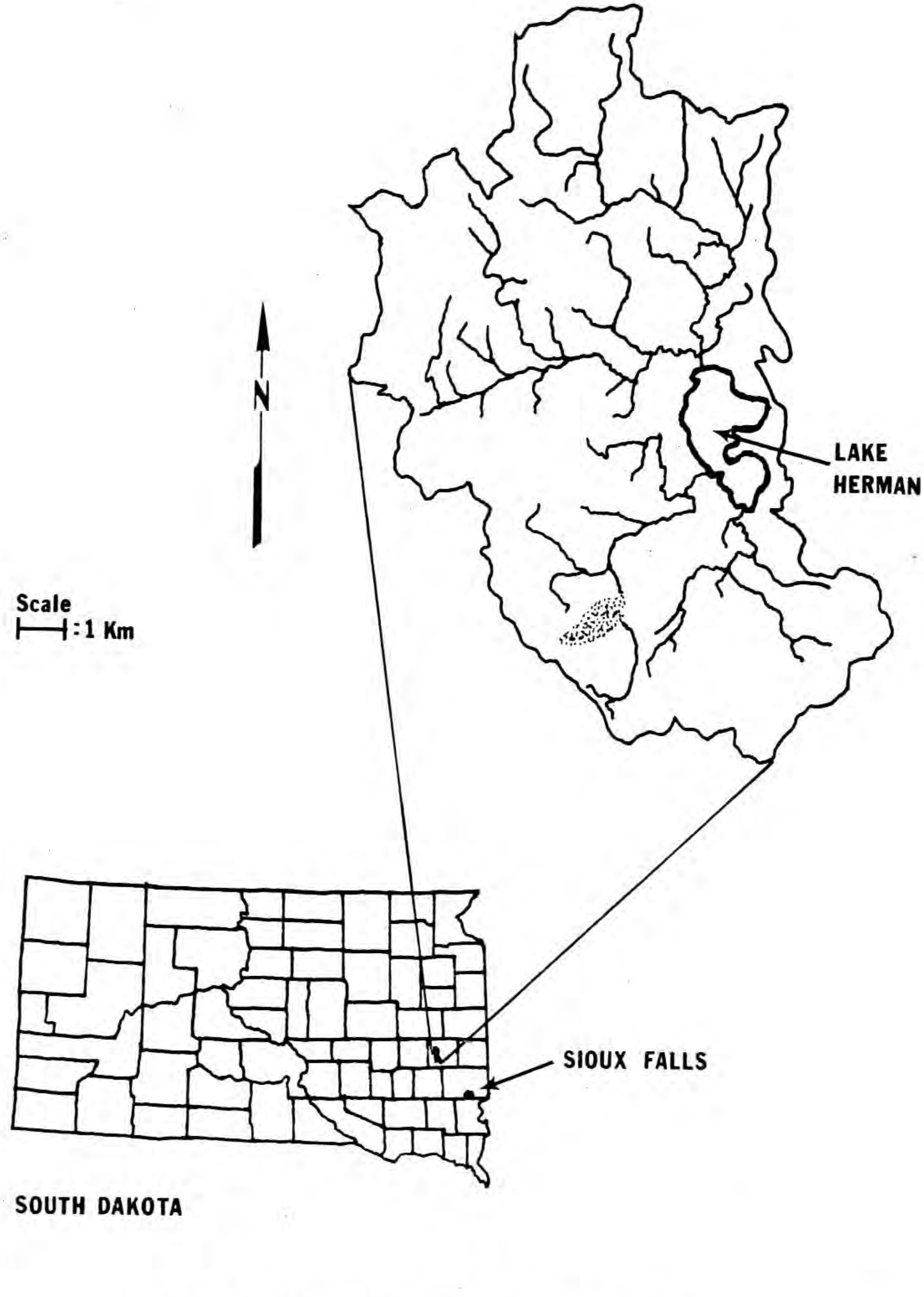

Figure 1. General location of Lake Herman.

SECTION 4

LAKE HERMAN MODEL IMPLEMENTATION PROGRAM OBJECTIVES

At the beginning of the Lake Herman MIP in 1978, the following objectives were developed:

I. Strengthen working arrangements with USDA agencies, Environmental Protection Agency, State DWNR and other State and local agencies who will be assisting in the Lake Herman MIP.

   A. Greater involvement by all agencies in all phases of improving water quality.

   B. Develop lines of communication among staff and personnel of various agencies.

II. Provide planning and technical assistance to land users in the Lake Herman Drainage area to facilitate having as much of the drainage area as possible adequately treated by resource management systems in the next 3 years.

   A. Identify land areas that need additional land treatment.

   B. Provide planning and technical assistance to land users in the Lake Herman area that will help improve water quality through use of practical resource management systems.

III. Complete surveys and designs on five sediment control structures.

   A. Complete design of sediment control structures so sponsors can secure landrights.

   B. Have one structure ready for construction for FY '79.

   C. Have all structures completed in a 3 year period.

IV. Develop with other cooperating agencies an overall Lake Herman MIP plan that will identify tasks to be completed by various agencies.

   A. Prepare plan that will address the objective of improving the water quality of Lake Herman.

   B. Establish baseline data for land use, water quality of Lake Herman and water quality of runoff into Lake Herman so effectiveness of various practices can be evaluated.

V. Assist sponsors and other cooperating agencies in the monitoring operations to determine the effectiveness of various land treatment measures and sediment control structures applied.

A. Establish a system of monitoring water runoff that will provide data for evaluation of the MIP.

B. Develop procedure for determining amount of sediment being trapped behind structures.

VI. Inform landowners and the public of the Model Implementation Program and of the assistance available to apply resource management systems and sediment control structures to improve water quality.

A. Inform public of MIP activities and the effects on water quality.

B. Inform landowners of assistance available to apply conservation practices.

SECTION 5

PROJECT DEVELOPMENT AND IMPLEMENTATION

ORGANIZATIONAL ASPECTS

The combined efforts of many federal, state, and local organizations contributed to the success of the Lake Herman MIP. The project activities were quite varied and as such, a strong but flexible organizational structure was necessary to provide a cohesive network of interacting agencies (Figure 2). Initial interest in restoring Lake Herman began with the Lake Herman Development Association (LHDA), which was instrumental in gaining sufficient support for the project. The LHDA also assisted with project planning and implementation efforts and provided funding with in-kind services.

Local coordination was provided throughout the program by the Lake County Conservation District (LCCD). The LCCD provided administrative services, EPA grant sponsorships, and financial assistance through in-kind services and hiring technical assistants. The LCCD also established the Lake Herman Task Force, a steering committee which helped develop plans and procedures at the local level. At the direction of the Board of Supervisors, many of the LCCD's activities were accomplished by the MIP coordinator, an employee of DWNR who was stationed at the LCCD office in Madison

The DWNR provided the MIP coordinator, water quality data analyses and interpretation, assistance to prepare the "314" Clean Lakes application, a lake dredging plan, and matching funds from the State Lakes Preservation Grant Program. The MIP coordinator's activities were extensive and included: project administration; watershed surveys; water quality sampling; public information and education; solicitation of landowner participation; easement negotiations; and report preparation.

The U.S. EPA furnished "314" Clean Lakes Program matching funds for planning, administration, and portions of the implementation activities. The EPA also provided personnel for technical assistance.

The USDA participated in land treatment activities. The USDA Soil Conservation Service (SCS) through its State, area, and field offices provided the following technical and administrative services:

1. Assisted land operators to develop and apply conservation plans;

2. Provided soil surveys for planning uses;

3. Helped with water quality monitoring program;

4. Prioritized watershed studies for Best Management Practices (BMP's);

5. Conducted engineering surveys and design for sediment control structures;

6. Provided inspectors during construction of structures;

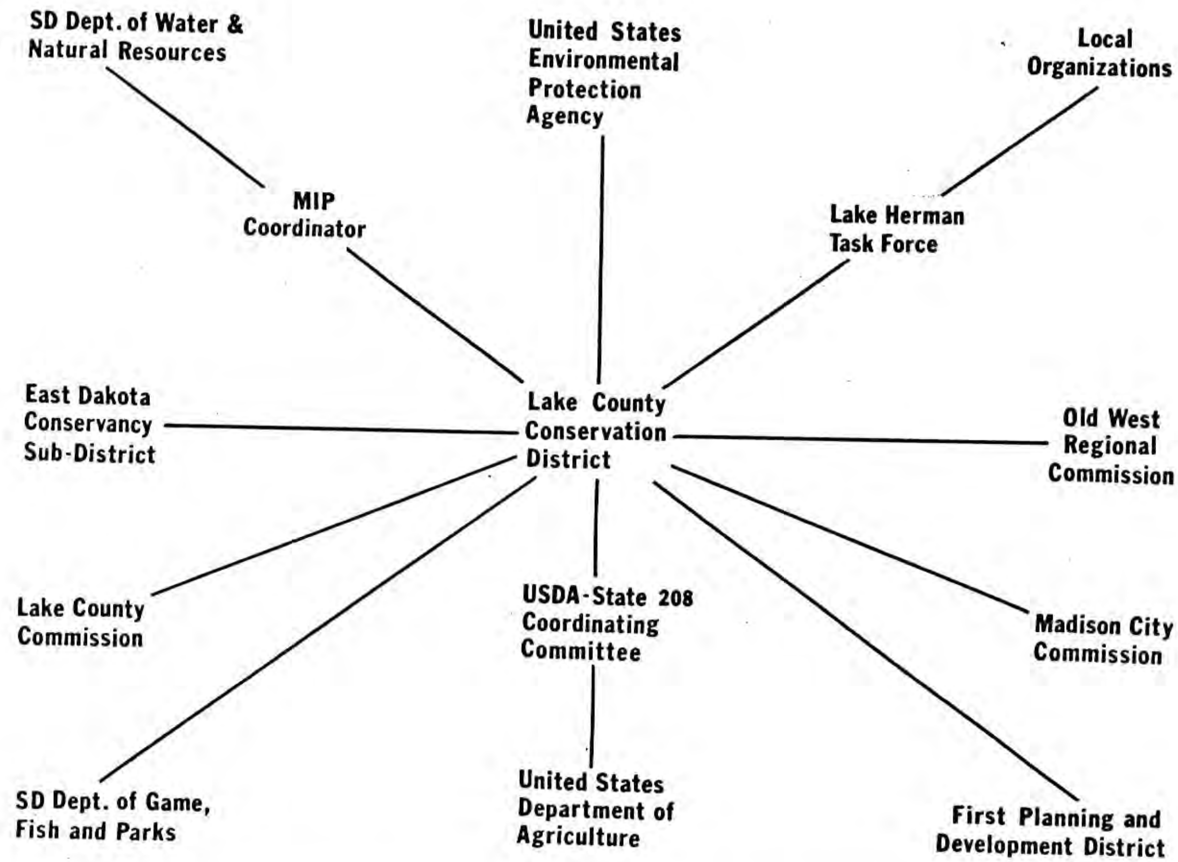

Figure 2. Organizational structure of the Lake Herman MIP.

7. Developed plans and specifications for construction of three sediment dams; and

8. Assisted in the public information program.

The USDA Agricultural Stabilization and Conservation Service (ASCS) provided special funding for cost-sharing conservation measures up to 90%. The ASCS also furnished land use and crop history data and information on previously applied cost-shared conservation measures.

A number of other organizations participated in the MIP. Matching funds were given by the Old West Regional Commission, the East Dakota Conservancy Sub-district, the Lake County Commission, and the Madison City Commission. Further planning, technical assistance and/or implementation was furnished by the First Planning and Development District, the Lake County Commission, the South Dakota Department of Game, Fish and Parks (GF&P), the Remote Sensing Institute (Brookings, South Dakota), the Economics, Statistics and Cooperatives Service (as part of the USDA Section 208 Committee), the Science and Education Administration (USDA), and the Lake County Cooperative Extension Service.

INFORMATION, EDUCATION, AND PUBLIC PARTICIPATION

The public is one of the most important components of any water quality improvement project. The success of a project can be directly related to public support and involvement, especially from owners and managers of lands within the watershed and along the lakeshore.

Local support and enthusiasm for the restoration of Lake Herman began with the Lake Herman Development Association (LHDA) and soon spread to other local organizations by the persuasive efforts of the LHDA and the LCCD. This support and enthusiasm was sustained throughout the duration of the project by various promotional techniques.

Monthly Lake Herman Task Force (LHTF) meetings were held throughout most of the project. Quarterly and annual progress reports were prepared and were made available to the public. Numerous newspaper articles and radio announcements were presented. Brochures and newsletters were made available at local businesses and the local SCS office. One interview with the MIP coordinator was televised by KESD-TV, Brookings, as part of the State 208 Water Quality Management plan documentary along with several news interviews. Various public meetings and informational programs were held. Tours were given to interested local organizations and State and Federal officials. Personal visits were made to landowners affected by the MIP in order to explain the benefits of the project.

Although a wide variety of techniques were used to inform and educate the public, only a few proved to be highly effective. A questionnaire distributed to the public revealed not only overwhelming support for the project but also that newspaper articles and radio programs were considered the most effective means of communication with the general public.

Local civic organizations responded best to slide presentations, meetings, and educational programs. Members of local civic organizations regularly attended the LHTF meetings and presented their concerns and viewpoints. Watershed tours were also well received by local civic organizations and on one tour, the attendance of Congressmen Tom Daschle of South Dakota and James Wright of Texas proved to be effective in increasing news media coverage.

Personal visits were the best means of communicating project goals and needs to landowners. Informational meetings for the landowners were popular and provided assistance useful for active landowners participation through BMP applications. Participation by the landowners was very good and this reflects the excellent efforts of the local SCS office and the MIP coordinator.

On November 21, 1978, the LCCD held a formal public hearing on the Lake Herman MIP (required by SDCL 34:04:11 for the State Lake Restoration Grant Procedures). Although the general public was well represented at the public hearing, citizens not affiliated with a civic organization or who did not own or manage land within the watershed generally did not participate on a regular basis. Being under the auspices of a civic organization apparently improves an individual's participation.

NONPOINT SOURCE POLLUTION CONTROL MEASURES

The DWNR found during its 1977 and 1978 study of Lake Herman that much of the nonpoint sediment and nutrient loadings were due to agricultural activities in the watershed. The State Lakes Preservation Committee (1977) and the South Dakota Statewide 208 Water Quality Management Plan (1978) recommended the restriction of sediment and nutrient inputs to the lake before costly in-lake restoration techniques are used. These recommendations were compatible with the MIP goal to control nonpoint source pollution.

The Agricultural Conservation Program

The Agricultural Stabilization and Conservation Service's (ASCS) Agricultural Conservation Program (ACP) had a major role in the MIP. The ACP uses various soil conservation practices which are also called Best Management Practices (BMPs). Successful BMP applications, however, are dependent on sound, site-specific assessments of erosion, using the best applicable conservation practice(s) per site, effective promotional techniques, and receptive landowners.

The Soil Conservation Service (SCS) was instrumental in making the ACP a success. The SCS interpreted previously collected data to determine areas of high sediment delivery rates or erosion potential and conducted field surveys to corroborate these data. The SCS prioritized critical areas which needed BMPs and contacted landowners to introduce and promote the concept of BMPs. Additional promotional and informational notices were posted in the local, area, and state SCS offices. Subsequent meetings with the landowners (individually or in groups) led to landowner acceptance of BMPs and the SCS began site specific planning and BMP implementation.

The Lake Herman MIP was very successful in applying BMPs. At the beginning of the project, 55% of the watershed had adequate erosion control. By the project's end (1983), nearly 87% of the watershed was covered by some form of erosion control (Figure 3). This was due to the excellent technical and promotional activities of the ASCS, SCS, LCCD, and MIP coordinator. One reason for the high percentage of treatment was the 90% cost sharing that was available on most BMPs during 1978-1980 and part of 1981. Such a monetary incentive led to increased landowners participation.

Twelve (12) conservation practices were used in the ACP (Tables 2-8). The most frequently applied BMPs were terraces, grassed waterways, conservation tillage, and windbreaks.

Few problems arose during the implementation. During the first year (1978), 90 farms participated in the ACP. This was considered a major success, yet the allocated ACP funds for 1978 were not completely used. This was most likely due to the $2,500 spending limitation per farm, lack of planning time prior to receipt of funds, and a late harvest and crop rotation schedule. Another problem was getting farmers to perform (SL-9) conservation tillage operations in a manner which would leave the required minimum percent of ground cover on the land after planting the next crop.

Except for the lack of planning time and weather induced delays in harvesting, these problems were solved. The $2,500 spending limit was increased to $3,500 in early 1979 and this enabled landowners to apply more BMPs at one time. Additional site specific BMP assessments, and more thorough educational meetings and discussions with landowners led to more acceptable SL-9 conservation tillages. Lack of planning time for BMP implementation prior to receipt of ACP funds caused less efficient (and possibly less effective) BMP applications. Sufficient planning time prior to receipt of funds should provide for a more efficient and effective soil conservation program.

Sediment Control Structures

In an effort to minimize sediment and nutrient loadings to Lake Herman, three sediment control structures were constructed in the Lake Herman watershed (Figure 4). Most of the work required for completing the sediment control structures was done by the SCS and funding was provided by EPA 314 Clean Lakes Program funds. The basic activities used in planning and constructing these structures were as follows:

1. Preliminary site selection;
2. Landowner contract;
3. Survey permit acquisition;
4. Site survey/feasibility determination;
5. Topographic survey;

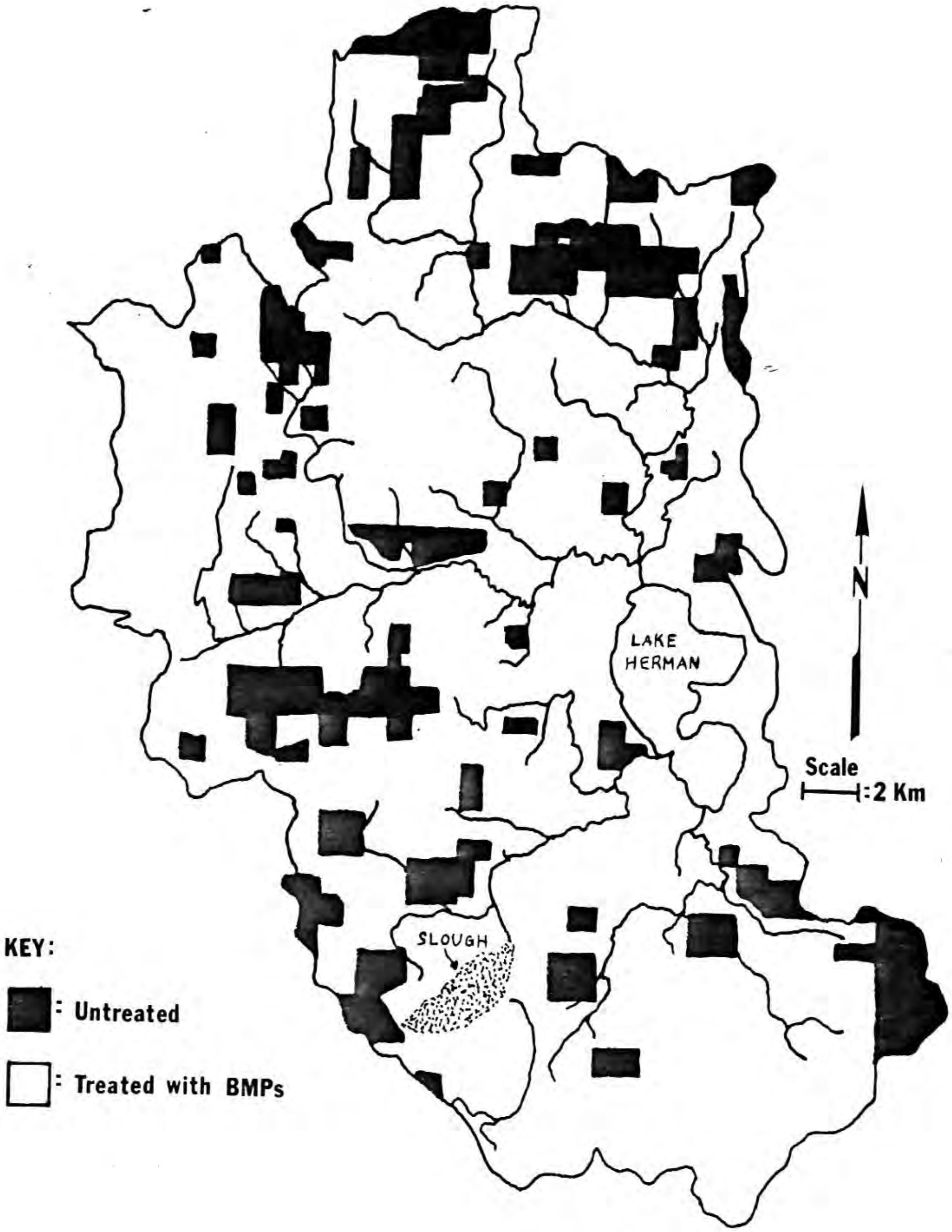

Figure 3. Areas in the Lake Herman watershed that have been treated with BMPs.

TABLE 2. SUMMARY DATA OF THE AGRICULTURAL CONSERVATION PROGRAM (ACP) PRIOR TO THE MIP, 1975-1977

Practice	No. of Practices	Total Cost	Total Cost-Sharing	Units Performed	Hectares Served
RE-1* Permanent Seedings	29	$11,414.25	$ 5,117.40	291.0 Hectares	291.0
RE-5, DC-2 & WE-5 Livestock Watering Facilities	14	8,636.07	4,630.31	14 Structures	198.3
RE-7 & DC-7 Terraces	5	4,103.00	3,165.18	4956.0 Linear Meters	105.2
RE-12 Sod Waterways	2	243.20	129.20	161.5 Linear Meters	8.1
RE-13 Windbreaks and Shelterbelts	18	2,902.60	2,118.39	9.8 Hectares	104.2
DC-5 Improving Established Seedings	2	460.00	317.00	18.3 Hectares	18.3
SG-1 Wildlife Cover Plantings	1	428.00	311.00	16.2 Hectares	16.2
SH-2 Shelterbelt Improvement	1	87.40	65.55	0.8 Hectares	18.2

* The alphanumeric characters in Tables 2-8 are identification codes used by ASCS.

TABLE 3. SUMMARY DATA OF THE ACP DURING 1978

Practice	No. of Practices	Total Cost	Total Cost-Sharing	Units Performed	Hectares Served
SL-1 Permanent Seedings	9	$ 4,123.50	$ 2,198.00	85.4 Hectares	85.4
SL-4 Terraces	15	8,213.35	7,917.00	7757.2 Linear Meters	204.4
SL-6 Livestock Watering Facilities	4	3,068.44	1,535.00	4 Structures	56.7
SL-7 Windbreaks and Shelterbelts	9	1,382.00	1,143.00	4.0 Hectares	42.9
SL-9 Conservation Tillage	59	22,260.50	17,823.00	1801.7 Hectares	1801.7
SP-3 Rotation Seedings	17	7,536.00	3,167.00	150.5 Hectares	152.5
WL-1 Wildlife Cover Plantings	3	606.38	486.00	22.8 Hectares	22.8
WP-2 Wildlife Ponds	1	863.20	432.00	1 Structure	

TABLE 4. SUMMARY DATA FOR THE ACP DURING 1979

Practice	No. of Practices	Total Cost	Total Cost-Sharing	Units Performed	Hectares Served
SL-1 Permanent Seedings	5	$ 2,658.36	$ 1,649.00	59.9 Hectares	59.9
SL-4 Terraces	3	3,400.00	3.060.00	2659.4 Linear Meters	68.8
SL-6 Livestock Watering Facilities	4	3,253.40	1,765.00	4 Structures	46.1
SL-7 Windbreaks and Shelterbelts	12	2,375.69	1,892.00	5.8 Hectares	58.7
SL-9 Conservation Tillage	2	514.50	412.00	41.6 Hectares	41.6
SP-3 Rotation Seedings	1	258.00	108.00	5.2 Hectares	5.2
WL-1 Water Impoundment Reservoirs	4	10,790.60	9,448.00	4 Structures	60.7
WP-3 Sod Waterways	2	210.00	194.00	198.1 Linear Meters	32.4

TABLE 5. SUMMARY DATA FOR THE ACP DURING 1980

Practice	No. of Practices	Total Cost	Total Cost-Sharing	Units Performed	Hectares Served
SL-1 Permanent Seedings	4	$ 1,899.17	$ 945.00	32.3 Hectares	32.3
SL-4 Terraces	21	25,267.05	22,230.00	12056.1 Linear Meters	295.5
SL-6 Livestock Watering Facilities	2	2,208.50	1,325.00	2 Structures	24.3
SL-7 Windbreaks and Shelterbreaks	8	4,135.70	2,581.00	7.6 Hectares	80.6
SL-9 Conservation Tillage	8	1,963.50	1,571.00	158.9 Hectares	158.9
WC-1 Water Impoundment Reservoirs	2	7,816.94	6,717.00	2 Structures	36.4
WL-1 Wildlife Cover Plantings	1	1,427.80	825.00	26.7 Hectares	26.7
WP-3 Sod Waterways	5	1,677.92	1,240.00	1252.7 Linear Meters	80.9
WP-4 Animal Waste Control Facilities	1	7.014.00	3,500.00	1 Structure	1.6

TABLE 6. SUMMARY DATA FOR THE ACP DURING 1981

Practice	No. of Practices	Total Cost	Total Cost-Sharing	Units Performed	Hectares Served
SL-1 Permanent Seedings	+	$ 4,134.16	$ 2,601.00	82.3 Hectares	82.3
SL-2 Improving Permanent Seedings	+	289.50	152.00	4.7 Hectares	4.7
SL-4 Terraces	+	15,959.11	14,043.00	6,996 Meters	161.9
SL-6 Livestock Watering Facilities	26	25,947.71	16,583.00	26 Each	639.4
SL-7 Windbreaks and Shelterbelts	+	3,220.00	2,415.00	6.5 Hectares	74.1
SL-11 Seedings Critical Areas	+	100.00	75.00	1.6 Hectares	1.6
WL-2 Wildlife Ponds Reservoirs	1	1,057.55	500.00	1 Structure	4.0
WP-3 Sod Waterways	2	658.00	647.00	+	24.3

+ Data unavailable at time of writing.

TABLE 7. SUMMARY DATA FOR THE ACP DURING 1982

Practice	No. of Practices	Total Cost	Total Cost-Sharing	Units Performed	Hectares Served
SL-1 Permanent Seedings	1	$ 514.67	$ 386.00	12.7 Hectares	12.7
SL-6 Livestock Watering Facilities	1	1,200.00	600.00	1 Structures	16.2
SL-6 Dugout	3	2,800.00	1,400.00	3 Structures	48.6
SL-7 Windbreaks and Shelterbelts	16	1,525.33	1,144.00	+	48.6

+ Data unavailable at time of writing.

TABLE 8. SUMMARY DATA FOR THE ACP DURING 1983

Practice	No. of Practices	Total Cost	Total Cost-Sharing	Units Performed	Hectares Served
SL-1 Permanent Seedings	3	$ 2,654.67	$ 1,991.00	70.8 Hectares	70.8
SL-7 Windbreaks and Shelterbelts	5	812.00	609.00	+	32.4
SL-14 Reduced Tillage	3	+	1,200.00	+	48.6
WL-1 Wildlife Cover Plantings	1	330.00	165.00	12.1 Hectares	12.1

+ Data unavailable at time of writing.

6. Develop land rights maps/preliminary cost estimates;

7. Conduct archeological survey;

8. Land rights acquisition;

9. Design survey/geologic testing;

10. Structure design;

11. Design review/approval;

12. Contract/cost estimate development;

13. Contract bid letting;

14. Contract award;

15. Construction/land rights payment;

16. Final inspection/payment; and

17. Submit "as built" drawings.

By the end of 1978, the preliminary designs and surveys had been completed for structures #1, #2, and #3. Early in 1979, it was determined that additional soil testing was needed for Site #3, which delayed the construction of structure #3 by approximately one year. The Lake County Conservation District began to secure land rights easements for structures #1 and #2, contract for archeological surveys for all sites, and contract for the Site #3 drilling by the spring of 1979.

The following is a brief synopsis of the construction process on a calendar basis.

<u>1979</u>	May 16	- Drilling began on Site #3. Drilling had been completed for Sites #1 and #2. Archeological surveys for all three sites were completed in May and June at a total cost of $2,478.01.
	June 11	- Final contract documents and designs for structures #1 and #2 were received by the LCCD.
	July 2	- Bid invitations were sent out to prospective bidders for three alternatives: 1) build structure #1; 2) build structure #2; or 3) build both #1 and #2.
	July 16	- Contractor site showing.
	August 1	- Public bid opening.

	August 6	- Special LCCD Board of Supervisors meeting held to select contractor. Vanderpool Construction Company of Harrison, South Dakota, was selected based on their bid of cost estimates of structure #1-$62,012; structure #2-$75,476; and #1 and #2 combined-$133,488.00.
	September 9	- Contract signed, notice to proceed given. The original contract allowed 100 days for construction, with allowances given for suspensions due to weather.
	September 26	- Construction began on Sites #1 and #2.
	November 15	- Seasonal shutdown on Sites #1 and #2 due to adverse weather conditions. SCS estimates showed that the structures were 65% complete, using 55% of the time, and that 14 days would be needed to complete the project.
1980	January	- Many activities--SCS engineers completed design drawings and assembled contract documents for structure #3. It was estimated that it would take 75-100 days to complete. The LCCD began negotiating for easements for Site #3. North watershed plans were reviewed for proposed structure sites, with construction scheduled for the summer of 1981.
	April	- Final designs, cost estimates, and contracts received by the LCCD. Construction resumed on Sites #1 and #2.
	May 19	- Bid invitations for construction of #3 sent out statewide.
	June 13	- Public bid opening.
	June 20	- Structures #1 and #2 were completed.
	July 2	- Final inspection of Sites #1 and #2. Final cost $137,461.42. Construction cost overruns were due to increased excavation and resulting extra seeding and fencing and contract modifications.
	July	- W.D. Priebe Construction Company of Pukwana, South Dakota, was selected as contractor for structure #3. Their bid was $222,568.87. Construction was anticipated to begin in August of 1980 and be completed in 112 days.
	August	- Construction began on structure #3.
	November 18	- Seasonal shutdown due to adverse weather conditions.

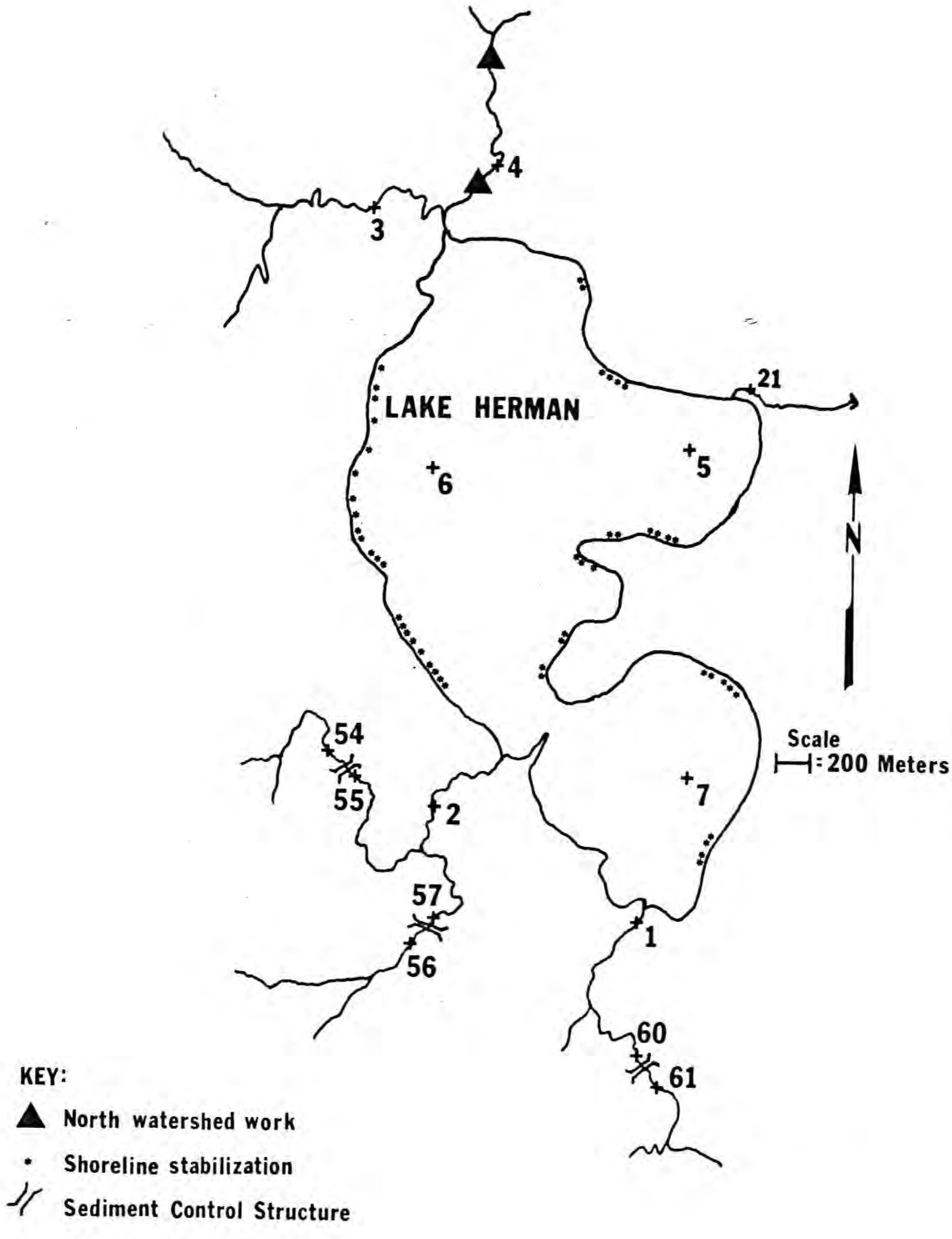

Figure 4. Some sampling sites and areas of interest for the Lake Herman MIP.

Performance time had to be extended due to problems with excavation of boulders and cobbles and a delay in concrete pipe delivery. SCS estimated that the construction was 45% complete, using 78% of the time. Construction was scheduled to resume in the spring of 1981.

<u>1981</u> July 10 - Structure #3 completed.

Additional sediment control structures were planned for the north watershed area but the primary landowners would not grant land easements. Consequently, alternatives to sediment control structures were studied. Control of streambank erosion in this area was considered a viable alternative.

<u>North Watershed Activities</u>

Unsuitable topography and landowner reluctance precluded construction of sediment control structures in the north watershed area. This area had generally been treated with adequate conservation measures but streambank erosion was still a problem. Meetings were held by the LHTF and the LCCD to determine the most feasible alternatives to sediment control structures. It was determined that seeding and fencing areas along the stream were not only feasible streambank stabilization measures but also the most acceptable method to the landowners.

The LCCD conducted a preliminary survey to delineate eroded areas and found the most severely eroded areas within one mile of Lake Herman just north of West Highway 34 (Figure 4). These findings were used during discussions with the landowners about proposed activities. The SCS surveyed the area in more detail after the landowners gave verbal agreements to provide land easements.

Streambank stabilization plans based on the survey included seeding and fencing, rock armorment of some channel slopes, and rock chute construction on one area. Removing one small earthen dam, which had breached many years ago, and contouring and seeding the area were also proposed.

Finalization of the plans, however, was delayed by a South Dakota Department of Transportation (DOT) proposal for reconstruction work on the culvert underneath West Highway 34 north of Lake Herman. Discussions between the SCS and the DOT resulted in a cooperative effort to design the new culvert in a way which would meet DOT requirements and be advantageous to the MIP. The resultant design called for a slightly raised culvert which created some ponding behind the culvert. This effectively reduced water flow and presumably a certain amount of sediment transport to Lake Herman.

Final plans for the north watershed area were subsequently completed and a five year land easement, with an option of renewal for another five years, was obtained. This easement permitted fencing of 4.37 hectares (10.8 acres) to exclude livestock along the stream. Plans for the construction of a rock chute (designed to stop headcut caused by out-of-bank flow) and the removal of the old earthen dam were also finalized.

Bid letters for each of the activities were sent to contractors in Lake County and contracts were later awarded for the rock chute and the dam removal. Bids were not received for the fencing work so a local contractor was hired. The work for these contracts was completed by October, 1983.

Only a few problems were encountered with the north watershed work. Besides weather induced delays in construction, one problem was caused by changes in construction specifications of the culvert. These changes required additional fencing and consequently, more cost. Another problem was caused by the completion date of the culvert. Construction activities on the culvert required removal of some of the fencing until the culvert was finished. This resulted in greater costs for fence removal and replacement. Better coordination and timing of both activities (fencing and culvert work) could have prevented this problem.

Shoreline Stabilization

Nearly 10% of the sediment yield in the Lake Herman watershed is due to erosion of unprotected shoreline banks (SD DWNR and SCS, 1978). In an effort to minimize erosion from as many areas as possible, shoreline stabilization was implemented on severely eroded banks of Lake Herman (Figure 4). Riprapping was designed to provide a means to retard natural erosion processes and decrease the amount of sediments entering the lake. It would also reduce land loss to public and private property owners, an important aspect for convincing landowners to support the program.

Preliminary shoreline surveys led to a qualitative priority scheme which provided decision criteria for site selection. The three categories in this scheme are as follows:

Primary - Serious erosion area, causing a threat to improved facilities such as roads, parks, etc.

Secondary - Serious erosion area, minor or no threat to any improved facilities.

Tertiary - Slight to moderate erosion area, minor or no threat to improved facilities.

The shoreline stabilization project, which took approximately two years to complete, is summarized below.

1. Preliminary shoreline survey.

2. Agreement between LCCD and GF&P for GF&P to obligate funds for engineering services.

3. Engineering firm engaged to complete a more detailed survey, design riprap construction, and assist in bid process.

4. Meeting of LCCD, engineering firm, and GF&P to clarify the contract.

5. Meeting of LCCD, GF&P, engineering firm, and landowners to have survey permits signed.

6. "404" permit application sent to COE by GF&P--permit issued.

7. Survey and riprap design completed.

8. Easements obtained at $1.00 nominal cost.

9. Minor changes made in engineering plans.

10. Pre-bid conference held for riprapping--bids received and awarded to one contractor.

11. Contract signed between LCCD and contractor--notice to proceed given to contractor.

12. Rock sorting, transportation to sites, and placement of rocks.

13. Final assessment of contractors work--minor corrections made--project complete.

Just over 1,280 meters (4,200 feet) of shoreline was riprapped according to two riprap plans; 30" rock over 12" gravel on private land; and 18" rock only on State Park land. One more area, using smaller rock by request of the landowner, was riprapped.

To minimize construction costs and create a more natural looking riprap, local rock was excavated and used for the riprap. Field stones from farm rock piles were donated by local landowners.

The use of local materials was not only a cost saving measure but also a means of increasing local participation. This created a sense of involvement and accomplishment with the local people.

REVIEW OF PROJECT DEVELOPMENT AND IMPLEMENTATION

The Lake Herman MIP had diverse objectives (see Section 4) and with such a project, involvement from many agencies was required. Effective project implementation was dependent on an organizational structure (Figure 2) which reflected the importance of local agencies. These agencies had first hand knowledge of the project's activities and progress and they were able to quickly make assessments and forward information or suggestions to the other agencies. These agencies, in turn, gave services or funds which the local agencies could not provide.

The project was of great interest to people residing within the watershed, especially those who own farms. These landowners were approached by the local agencies (mainly SCS) and asked to participate in the MIP by applying BMPs. Landowner involvement required vigorous promotional and educational techniques. These techniques included: personal visits, newspaper articles, radio announcements, watershed tours, and local meetings.

Successful BMP applications required sound site specific assessments of erosion and using the most appropriate BMP(s) per site. The technical and promotional activities of the SCS, LCCD, and the MIP coordinator contributed to successful BMP applications. This resulted in approximately 87% of the watershed having adequate erosion control. The ASCS provided 90% cost sharing to landowners on many of the BMPs and this was an important monetary incentive for greater landowner involvement.

In addition to BMPs, three sediment control structures were constructed in the watershed to minimize sediment and nutrient loadings to Lake Herman. The basic activities needed to complete these structures included: site selections, gaining landowner acceptance, land right acquisitions, site surveys, designing and planning, cost estimates, contract bidding and awarding, construction, and final inspection and payment. Due to unsuitable topography and landowner reluctance only three out of five structures were completed.

An alternative to a sediment control structure in the north watershed area was seeding and fencing areas for streambank stabilization. Additional work included removing an old breached dam and constructing a rock chute to prevent headcut by out-of-bank flow.

Shoreline stabilization was used to protect eroding banks around Lake Herman. Preliminary surveys led to two riprap designs, one for State park land and the other for private land. A contractor was hired and just over 1,280 meters of shoreline was riprapped with field stones donated by local landowners.

The combination of these various programs and restoration measures at Lake Herman led to a project which was a successful demonstration of interaction and cooperation between various public agencies and private individuals.

SECTION 6

WATER QUALITY

GENERAL PROCEDURES

In 1977, the DWNR began a water quality monitoring program with U.S. EPA "208 Water Quality Management" funds. This program was originally designed to determine if nonpoint source pollution was a problem and to obtain baseline data on the water quality of Lake Herman and streams in the watershed. After Lake Herman was selected as a MIP, the monitoring program was expanded to try to evaluate BMP effectiveness.

Twenty two sampling sites were chosen: one site at the outlet of Lake Herman and each of the four major inflows, seven locations containing sites upstream and downstream from either selected BMPs or potential nonpoint pollution sources and three in-lake sites (Figures 4 and 5). Detailed descriptions of these sites are given in Appendix A.

The three in-lake sites (Sites 5, 6, and 7) at Lake Herman were sampled with a Van Dorn sampler 0.5 meters below the water surface, at middle depth and 0.5 meters above the lake bottom. Sampling occurred monthly and increased to bimonthly during the summers of 1980 and 1981. Middle depth sampling was discontinued in 1980 when statistically significant differences in mean nutrient concentrations with respect to depth were not demonstrated (SD DWNR, 1981).

Composite samples were collected from the major tributaries (Sites 1-4) with ISCO automatic samplers and grab samples were taken during early spring if the ISCO samplers froze up. Sampling occurred daily during spring runoff and at least twice weekly during lower flow periods. The outlet (Site 21) was sampled weekly when water was flowing. Water depth measurements were taken from surveyed culverts at these sites and water flows were calculated with Mannings equation (Linsley and Franzini, 1979). Sampling regimes of the remaining sites are presented in Table 9. Grab samples were taken and water flows were calculated as mentioned above.

Water samples were placed on wet ice and transported to the South Dakota State Health Laboratory in Pierre, South Dakota, for analyses. Seventeen parameters were measured (Table 10). In addition, biological parameters (algae identifications, counts and volume estimates, and chlorophyll a) were analyzed by Dakota State College, Madison, South Dakota, according to U.S. EPA (1973) specifications.

Only data summaries are presented in this report. Original data may be obtained from SD DWNR or the U.S. EPA storage and retrieval (STORET) computer system.

WATER QUALITY ASSOCIATED WITH BMPs AND SEDIMENT CONTROL STRUCTURES

Fourteen sites within the Lake Herman watershed were selected to monitor water quality parameters upstream and downstream from areas with either

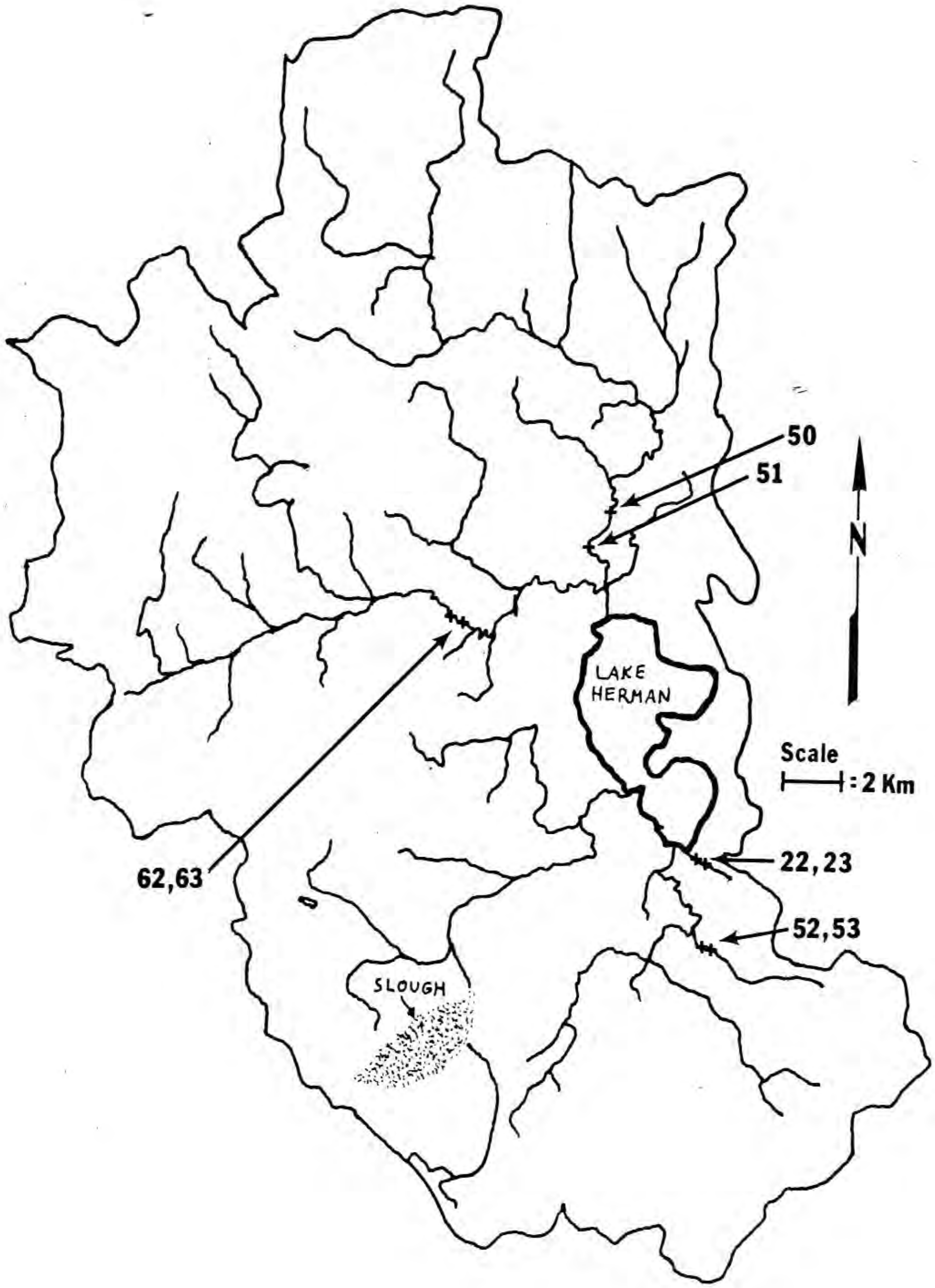

Figure 5. Additional sampling sites for the Lake Herman MIP.

TABLE 9. SAMPLING REGIMES OF PAIRED SITES WITHIN THE LAKE HERMAN WATERSHED*

Site	Site Description	Sampling Frequency
23	Upstream from permanent seeding area	Twice weekly during March-April, 1980; twice weekly during February-March, 1983
22	Downstream from permanent seeding area	Weekly in April, 1980; twice weekly during February-May, 1983
50	Upstream from streambank erosion area	Daily during March-April, 1980; weekly during April-May, 1983
51	Downstream from streambank erosion area	Daily during March-April, 1980; weekly during April-May, 1983
52	Upstream from terraced area	Twice weekly during March-April, 1980
53	Downstream from terraced area	Twice weekly during March-April, 1980
54	Upstream from sediment control structure #1	Weekly during March-April, 1980 and 1983
55	Downstream from sediment control structure #1	Weekly during March-April, 1980 and 1983
56	Upstream from sediment control structure #2	Twice weekly during March-May, 1983
57	Downstream from sediment control structure #2	Twice weekly during March-June, 1983
61	Upstream from sediment control structure #3	Twice weekly during February-May, 1983
60	Downstream from sediment control structure #3	Twice weekly during March-June, 1983
62	Upstream from feedlot area	Twice weekly during March-April, 1980; twice weekly during March-May, 1983
63	Downstream from feedlot area	Twice weekly during March-April, 1980; twice weekly during March-May, 1983

* These regimes were based on spring runoff and additional samples were collected when personnel were available.

TABLE 10. METHODS AND REFERENCES FOR PHYSICAL AND CHEMICAL PARAMETERS

Parameter	Method	Reference
Temperature	Thermometric	APHA (1975)
Secchi disc	Shaded side of boat	Lind (1974)
Dissolved oxygen	Azide modification of Winkler	APHA (1975)
pH	pH probe	APHA (1975)
Total alkalinity	Potentiometric	EPA (1974)
Ammonia-N	Automated phenate	EPA (1974)
Nitrite-N	Automated diazotization	EPA (1974)
Nitrate-N	Automated cadmium reduction	EPA (1974)
Kjeldahl-N	Semi-automated block digester, colorimetric	EPA (1974)
Organic-N	(Kjeldahl-N)-(NH_3-N)	EPA (1974)
Total phosphorus	Persulfate digestion, ascorbic acid reduction	EPA (1974)
Total solids	Gravimetric (103-105°C)	EPA (1974)
Total suspended solids	Gravimetric (103-105°C)	EPA (1974)
Total dissolved solids	Gravimetric (180°C)	EPA (1974)
Fecal coliforms	Membrane filter	EPA (1974)

implemented BMPs or proposed nonpoint source pollution controls (see Figures 3 and 4 and Table 9). Since a paucity of flow data precluded mass loading analyses, parameter mean concentrations upstream and downstream from each area were compared with t-test statistics. Data summary statistics can be found in Appendix B.

Sites 23 and 22 were located upstream and downstream, respectively, an area which had permanent seeding applied as a BMP. Data were collected in 1980 and 1983. The mean total phosphorus concentration upstream from the area (2.06 mg/l) was significantly greater (P<.05) than downstream (0.51 mg/l) in 1980. The mean organic nitrogen concentration upstream from the area (2.75 mg/l) was also significantly greater (P<.10) than downstream (1.78 mg/l). The mean fecal coliform concentration downstream from the area (239/100 ml), however, was significantly greater (P<.10) than upstream (7/100 ml). This was not unexpected because approximately 25-40 stock cows used a pasture that was adjacent to the stream. This pasture contained an intermittent stream which occasionally drained into the study area.

In 1983, the mean inorganic nitrogen (4.15 mg/l), organic nitrogen (1.98 mg/l), and total phosphorus (0.55 mg/l) concentrations were significantly greater (P<.05) upstream from the area. Mean concentrations of these parameters downstream from the area were 0.62 mg/l, 1.13 mg/l, and 0.25 mg/l, respectively. Mean suspended or dissolved solids concentrations were not significantly different.

Between 1980 and 1983 three parameters increased in concentration; fecal coliforms, nitrate nitrogen, and inorganic nitrogen. Although conjecture, one possible reason for this is the difference in runoff. 1983 was a "wetter" water year than 1980 and greater runoff from the manure laden pasture may have caused the increase in fecal coliform and inorganic nitrogen concentrations.

In general, the permanent seeding area was effective in reducing nutrient concentrations but not suspended or dissolved solids. Total phosphorus concentrations were reduced approximately 75% in 1980 and 55% in 1983.

Six other sites were on areas targeted for BMP implementation. These sites were intended to be sampled before and after BMP implementation but lack of personnel relative to sampling time and effort and consolidation of the general sampling program limited sampling to the pre-BMP implementation phase. Additional sampling of these sites has not been planned.

Sites 50 and 51 were located upstream and downstream from, respectively, an exposed streambank which was presumed to be eroded. The only statistically significant difference (P<.05) was between mean total suspended solids concentrations. In 1980, the mean total suspended solids concentration downstream from the area (34 mg/l) was greater than upstream (18 mg/l). Thus, it appears that the initial presumption (i.e., the streambank is an eroded area) was correct. It is also interesting that mean nutrient concentrations did not increase downstream from the area.

It is not known why mean nutrient concentrations did not increase downstream from the eroded area but one possibility is that the nutrients are mainly in a dissolved state. Up to 99 percent of the total solids were comprised of the dissolved fraction and so an increase in suspended solids downstream from the area may not necessarily coincide with increased nutrient levels.

Sites 52 and 53 were located upstream and downstream from, respectively, an area proposed for a terrace and waterway system. Sites 62 and 63 were located upstream and downstream from a feedlot. Statistically significant differences in mean parameter concentrations were not demonstrated for either of these areas.

It was not suprising that differences in parameter concentrations were not demonstrated for the terraced area. Although the terraces were completed, seeding of the waterway (to produce a grassed waterway) had not been done. Thus, erosion adjacent to and within the waterway may have remained the same as before the terracing.

The feedlot was not a nutrient source. This could have been due to a natural ponded area immediately below the feedlot that may have acted as a sink for nutrients and suspended sediments.

The remaining six sites were located upstream and downstream from the three sediment control structures (Table 9). These sites were sampled during and after the construction phase of the sediment control structures. Data summaries are given in Appendix B and results of statistical analyses are presented in Table 11.

Significant differences ($P<.05$) between parameter mean concentrations upstream and downstream from the structures were not found for data collected in 1980. This was not unexpected because structures #1 and #2 were nearly completed but not operational. In addition, the major sampling effort near structure #3 preceeded the construction phase, which began in August, 1980.

In 1982, only structure #3 proved to be effective in decreasing certain parameter mean concentrations. Mean total phosphorus (0.45 mg/l), total solids (850 mg/l), and total dissolved solids (831 mg/l) were significantly greater upstream. Downstream mean concentrations were 0.34 mg/l, 578 mg/l, and 572 mg/l, respectively. Inorganic and organic nitrogen concentrations were not demonstrated to be significantly different.

In 1983, the mean total phosphorus (0.25 mg/l) and total suspended solids (27 mg/l) concentrations upstream from structure #1 were significantly greater than downstream (0.15 mg/l and 9 mg/l, respectively). Mean total solids and total dissolved solids concentrations, however, were significantly greater downstream. Structure #2 did not cause significant differences in parameter mean concentrations during 1983. The mean total phosphorus concentration upstream from structure #3 (0.39 mg/l) was significantly greater than downstream (0.21 mg/l) in 1983. Apparently, nitrogenous compounds were not affected by the sediment control structures.

TABLE 11. THE RESULTS OF TUKEY-KRAMER METHOD FOR MULTIPLE COMPARISONS AMONG PAIRS OF MEANS BASED ON UNEQUAL SAMPLE SIZES

	Sediment Control Structure #1			Sediment Control Structure #2			Sediment Control Structure #3		
Year: Parameter	1980	1982	1983	1980	1982*	1983	1980	1982	1983
Total Phosphorus	NS	NS	U	NS		NS	NS	U	U
Inorganic N	NS	NS	NS	NS		NS	NS	NS	NS
Organic N	NS	NS	NS	NS		NS	NS	NS	NS
Total Solids	NS	NS	D	NS		NS	NS	U	NS
Suspended Solids	NS	NS	U	NS		NS	NS	NS	NS
Dissolved Solids	NS	NS	D	NS		NS	NS	U	NS

* Data not collected because of no flow.
NS No significant difference demonstrated.
U Upstream greater than downstream (P<.05).
D Downstream greater than upstream (P<.05).

The sediment control structures did reduce certain parameter mean concentrations but their effectiveness in reducing suspended solids and associated nutrients was less than expected. This could have been due to improper valve operation of the sediment control structures.

According to the operational procedures, all valves are to remain closed until water stops flowing behind the structure. After flow cessation, material in the water is allowed to settle for 72 hours and then the upper water level valve is opened. Once the water level has dropped below the upper gates, another 72-hour settling period is initiated. A second layer of water is then evacuated. These valves have been discovered open when water was still flowing behind the structures and suspended material may not have had enough time to settle out. This problem, however, has been corrected. The LCCD has taken over valve operations and more attention has been given to operational procedures.

Another possibility is that the 72-hour settling period was insufficient for allowing suspended material to sink to the bottom. This settling period was chosen pragmatically and finer suspended particles may take longer than 72 hours to settle out. Robillard, et al. (1982) reported that sediment which was eroded from cropland contained a higher percentage of finer and lighter particles (i.e., clays and organic residues) than the soil from which it originated. This selective erosion may have occurred in the Lake Herman watershed.

GENERAL LIMNOLOGY OF LAKE HERMAN

Lake Herman is characteristic of lakes in the Prairie de Coteau region of South Dakota. The lake is shallow, well mixed and has excessive nutrient levels. The general limnology of the lake is described by parameters summarized in Appendix C.

Thermal stratification did not occur during the study period (Table 12). Water temperatures reflected seasonal influences with midwinter surface temperatures near 0°C and maximum summer temperatures of 25-28°C.

Dissolved oxygen (D.O.) concentrations indicated a well oxygenated system except during midwinter. D.O. concentrations were generally around 9-10 mg/l and ranged from 0.0 to 20.1 mg/l. Anoxic conditions (D.O. <2 mg/l) occurred during the winters of 1977-1978, 1978-1979, and 1981-1982. An aeration system was purchased with contributions from local businesses and citizens (independantly of the MIP). The system was installed in October, 1979 and operated each winter. This presumably prevented anoxia in subsequent years except during the winter of 1981-1982. It is not known why anoxia occurred but the extremely "dry" water year of 1981 may have been a factor.

Measurements of pH ranged from 5.0 to 9.9 and annual mean values ranged from 7.8 to 8.7. Values less than 7.0 generally coincided with D.O. concentrations less than 2.0 mg/l. Some relatively high values (ph > 9.0) occurred during the summers and these were most likely due to increased photosynthetic activity by algae and aquatic macrophytes.

TABLE 12. TYPICAL SEASONAL TEMPERATURES (°C) AT THE DEEPEST LOCATION IN LAKE HERMAN (SITE 6)

Date	Top*	Bottom
1-17-80	1.1	0.6
2-21-80	0.6	1.7
4-22-80	17.2	17.8
5-8-80	13.3	12.8
5-22-80	16.7	18.3
6-18-80	20.0	21.1
7-1-80	21.1	21.1
7-15-80	26.7	26.7
8-5-80	17.8	20.0
8-21-80	20.0	21.1
9-16-80	15.6	16.1
11-6-80	5.6	5.6

* Top = approximately one foot below water surface; and bottom = approximately one foot above lake bottom; where 1 foot = 30.48 cm.

Total alkalinity ranged from 140 to 381 mg $CaCO_3$/l. Seasonal differences were apparent with higher concentrations (> 200 mg $CaCO_3$/l) during the winter and lower values during the spring and summer. Low values during the spring were probably due to runoff dilution effects.

Secchi transparencies ranged from 12.7 to 198 cm and were greatest during midwinters. Lowest values usually occurred during the spring and summer seasons.

Total phosphorus concentrations ranged from .115 to 1.70 mg/l. Seasonal trends were not well defined though higher concentrations coincided with winter anoxia. Low D.O. concentrations could have caused increased release of phosphorus from the sediments.

Total nitrogen concentrations ranged from 0.29 to 8.05 mg/l and did not exhibit discernible seasonal trends. Inorganic and organic nitrogen concentrations ranged from 0.13 to 3.56 mg/l and 0.31 to 7.01 mg/l respectively. Organic nitrogen normally comprised 80-85% of the total nitrogen. Ammonia nitrogen concentrations ranged from 0.02 to 3.45 mg/l and concentrations greater than 2.0 mg/l were almost always associated with anoxic conditions. Nitrate and nitrite nitrogen concentrations were usually below the analytical detection limits of 0.1 and .01 mg/l respectively.

Total nitrogen: total phosphorus weight ratios ranged from 1.10 to 22.6 and annual mean values ranged from 3.37 to 14.1. These data (Table 40 in Appendix C) indicated nitrogen limitation except during 1977 when the mean ratios indicated either co-limitation or phosphorus limitation. In this study, nutrient co-limitation was defined as ratios between 10 and 17 (see Forsberg, 1980).

Chlorophyll a concentrations were extremely variable and ranged from 14.8 to 1457 mg/l. Most water samples analyzed for chlorophyll a were collected during spring and summer and did not reflect seasonal changes.

Algae groups, based on biomass levels, changed seasonally (Figure 6). Chlorophyta (mainly *Closteriopsis*) were usually most abundant. Cyanophyta (mostly *Microcystis* and *Anabaena*) exhibited late spring/early summer peaks both years although the peak in 1981 was not as great as the previous year. Cyanophyta also peaked during the late summer of 1980 but in 1981, diatoms peaked in late summer rather than the cyanophytes.

It is promising that blue-green algae abundance decreased. Many Cyanophyta, including some species of *Microcystis* and *Anabaena*, are toxic to mammals and produce taste and odor problems (Prescott, 1968) and a decrease in blue-green algae is desirable. The reasons for the decrease of blue-green algae biomass in Lake Herman are not known.

WATER QUALITY ASSESSMENT OF LAKE HERMAN

One objective listed in Section 4 is to establish baseline data on lake water quality so the effectiveness of various BMPs can be evaluated. Lake

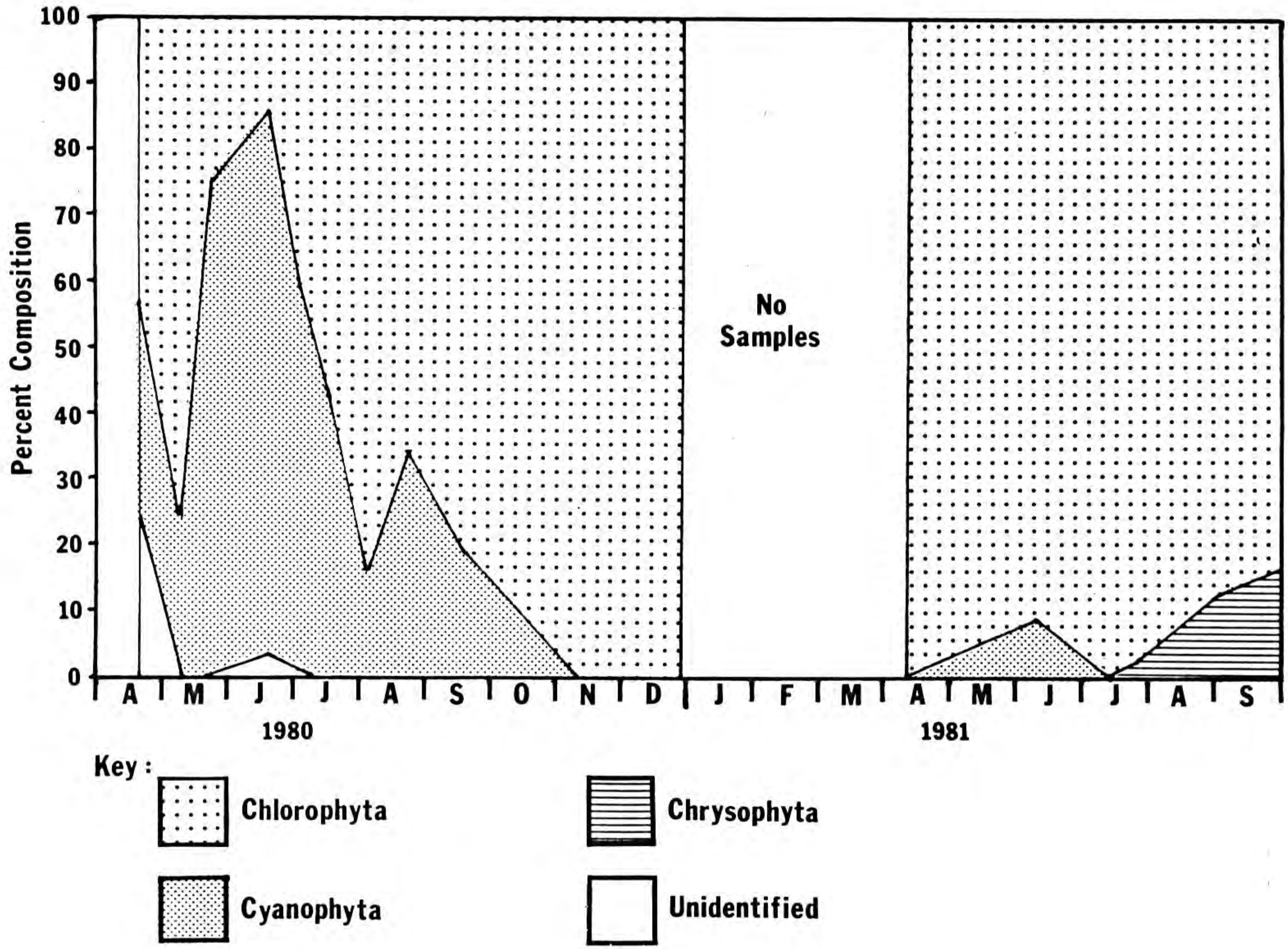

Figure 6. Percent composition of algae types in Lake Herman based on algae biomass.

Herman is the major receiving water body in the watershed and effective nonpoint source pollution control in the watershed may improve Lake Herman's water quality.

Water quality assessments can be made in various ways but any assessment requires decision criteria. The State of South Dakota assigned specific beneficial uses to Lake Herman according to ARSD 74:03:03:42. Each beneficial use has selected parameter values (standards) which should not be exceeded (Table 13) and these may provide decision criteria for assessing lake water quality. Violation of a standard is considered detrimental to its corresponding beneficial use and a decrease in the number of violations is considered an improvement in water quality.

Percent violations of the water quality standards are given in Tables 14 through 16. The standards of three parameters were most frequently violated (fecal coliforms, dissolved oxygen, and pH).

Fecal coliforms can indicate potential human health hazards which may impede immersion or limited contact recreational activities. Tables 14 through 16 show a decrease in the percent violations of fecal coliforms at Sites 6 and 7 during the MIP. Site 5, however, had fecal coliform violations during 1980 and 1981.

Most of the fecal coliform violations occurred during the summer when livestock were present along the tributaries, and sometimes a number of violations occurred during one day. Impacts due to fecal coliforms tend to be short term (days to weeks) and it is possible that the sampling regime was inadequate for assessing water quality. With such short term phenomena, the sampling frequency must approximate the time scale of the parameter's impacts.

Dissolved oxygen is necessary for the maintenance of fish and other aerobic aquatic biota as well as the protection of a lake's aesthetic qualities (U.S. EPA, 1976). In addition, low D.O. concentrations have been shown to facilitate nutrient releases from lake sediments (Mortimer, 1941-1942; Holdren and Armstrong, 1980).

Most of the D.O. violations occurred during the winter months of 1977, 1978, and 1979; and during the winter of 1977-1978 a fish kill was reported. D.O. violations decreased after 1979 (Tables 14 through 16) and this was most likely due to an aeration system which was installed in October, 1979. D.O. violations also occurred at all three sites during 1982 but the reason(s) for this is not known. These data, with the exception of those from 1982, suggest improved water quality but the cause of the improvement is probably due to aeration and not BMPs.

The role of pH in freshwaters is diverse. It has been implicated with nutrient release from lake sediments (Holdren and Armstrong, 1980); it can indicate acidic or alkaline conditions that are injurious to aquatic organisms (U.S. EPA, 1976); and it can influence potential toxicants. For example, a rapid increase in pH may cause un-ionized ammonia concentrations to increase to levels that are toxic to some aquatic organisms.

TABLE 13. BENEFICIAL USES AND WATER QUALITY STANDARDS OF SELECTED PARAMETERS FOR LAKE HERMAN GRAB SAMPLES

	Beneficial Use			
Parameter	Warmwater Marginal Fishlife Propagation	Immersion Recreation	Limited Contact Recreation	Wildlife Propagation and Stock Watering
Total Alkalinity mg $CaCO_3$/l	NA*	NA	NA	~~132.5~~# 1312.5
Fecal Coliforms #/100 ml	NA	400+	2,000+	NA
Nitrate-N mg/l	NA	NA	NA	87.5#
Ammonia-N (unionized) mg/l	.085#	NA	NA	NA
Dissolved Oxygen mg/l	4.0	5.0	5.0	NA
pH standard units	6.0-9.0	6.5-8.3	6.0-9.0	6.0-9.5
Suspended Solids mg/l	262.5#	NA	NA	NA
Dissolved Solids mg/l	NA	NA	NA	4,375#

*NA = Not applicable.

+ = Criterion based on samples collected from May 1 to September 30.

= These values represent 1.75 times the applicable criterion according to a variation allowed to grab samples under ARSD 74:03:02:32 (2).

TABLE 14. PERCENT VIOLATIONS OF SOUTH DAKOTA'S WATER QUALITY STANDARDS FOR SITE 5 IN LAKE HERMAN*

Year: Parameter	1977	1978	1979	1980	1981	1982	1983
Total Alkalinity	0.0	0.0	0.0				
Fecal Coliform	0.0	0.0	0.0	4.2	11.1	0.0	0.0
Nitrate-Nitrogen	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Ammonia-Nitrogen (un-ionized)	0.0	0.0	0.0	0.0	0.0	0.0	22.2
Dissolved Oxygen	12.5	20.0	16.7	0.0	0.0	16.7	0.0
pH (Field)	75.0	40.0	66.7	59.1	60.0	0.0	28.6
Total Suspended Solids	0.0	0.0	0.0	0.0	0.0	0.0	11.1
Total Dissolved Solids	0.0	0.0	0.0	3.9	0.0	0.0	0.0
Temperature	0.0	0.0	0.0	0.0	0.0	0.0	0.0

* Percentages are based on the most stringent criterion if two or more beneficial uses have different criterion values for the same parameter.

TABLE 15. PERCENT VIOLATIONS OF SOUTH DAKOTA'S WATER QUALITY STANDARDS FOR SITE 6 IN LAKE HERMAN*

Year: Parameter	1977	1978	1979	1980	1981	1982	1983
Total Alkalinity	0.0	0.0	0.0				
Fecal Coliform	14.3	11.1	0.0	8.7	0.0	0.0	0.0
Nitrate-Nitrogen	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Ammonia-Nitrogen (un-ionized)	0.0	0.0	0.0	0.0	0.0	25.0	25.0
Dissolved Oxygen	0.0	20.0	8.7	0.0	0.0	16.7	0.0
pH (Field)	83.3	30.0	73.3	59.1	50.0	25.0	25.0
Total Suspended Solids	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Total Dissolved Solids	0.0	0.0	0.0	3.8	0.0	0.0	0.0
Temperature	0.0	0.0	0.0	0.0	0.0	0.0	0.0

* Percentages are based on the most stringent criterion if two or more beneficial uses have different criterion values for the same parameter.

TABLE 16. PERCENT VIOLATIONS OF SOUTH DAKOTA'S WATER QUALITY STANDARDS FOR SITE 7 IN LAKE HERMAN*

Year: Parameter	1977	1978	1979	1980	1981	1982	1983
Total Alkalinity	0.0	0.0	0.0				
Fecal Coliform	12.5	11.5	0.0	0.0	0.0	0.0	0.0
Nitrate-Nitrogen	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Ammonia-Nitrogen (un-ionized)	0.0	0.0	0.0	0.0	0.0	12.5	0.0
Dissolved Oxygen	25.0	20.0	9.5	0.0	0.0	16.7	0.0
pH (Field)	71.4	40.0	81.3	68.2	50.0	0.0	28.6
Total Suspended Solids	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Total Dissolved Solids	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Temperature	0.0	0.0	0.0	0.0	0.0	0.0	0.0

* Percentages are based on the most stringent criterion if two or more beneficial uses have different criterion values for the same parameter.

Violations of the pH standard occurred more frequently than any other parametrical violation (Tables 14 through 16). The percentage of samples violating the standard was often greater than fifty percent and most of the violations were due to pH levels greater than 8.3. Values of pH near 9.0 are relatively common in lakes of the Prairie de Coteau region and have been attributed to photosynthetic processes (State Lakes Preservation Committee, 1977). In addition, the Prairie de Coteau region has naturally alkaline soils (USDA, 1973). Rarely was pH below 6.5 but in the few cases where it was, pH levels below 6.5 coincided with low D.O. concentrations.

An improvement in water quality, relative to pH, was not well defined though the percentages of samples having violations seemed to generally decrease during the MIP. Interestingly, un-ionized ammonia violations only occurred during 1982 and 1983 when pH violations were lowest. These two years, however, had the highest mean ammonia concentrations during the study (see Appendix C).

The South Dakota Water Quality Standards are important parameters, especially because they are related to beneficial uses and can be enforced by the State. Limnologists, however, usually assess water quality with parameters that are related to lake biological productivity rather than beneficial uses. Lakes with high biological productivity and high nutrient levels are called eutrophic and ones with low productivity and nutrient levels are termed oligotrophic. Mesotrophic lakes have moderate levels of biological productivity and nutrients. These three categories describe lake trophic state.

Quantitative criteria for each category have been proposed (Table 17) and many are based on in-lake total phosphorus (TP), total nitrogen (TN), chlorophyll _a_ (CA) concentrations, or Secchi transparency (SD) readings (see review by Reckhow, 1981). Criteria based on nutrient loadings have also been proposed (Vollenweider, 1968; Kirchner and Dillon, 1975; Reckhow et al., 1980; and Bachmann, 1980). Carlson (1977) recognized the difficulty of communicating lake trophic state (in limnological terms) to the public and he developed three trophic state indices based on total phosphorus, chlorophyll _a_, and Secchi transparency. His indices are somewhat analogous to the Richter scale used to describe earthquake magnitude.

To minimize error is assessing the trophic state of Lake Herman, a number of the methods mentioned above were used (Tables 18-20). These data suggest a eutrophic to hypereutrophic system.

Three nutrient loading models were used to predict in-lake phosphorus or nitrogen concentrations. The models of Kirchner and Dillon (1975) and Reckhow et al. (1980) predicted oligotrophic to hypereutrophic levels of TP and the predicted TP concentrations were usually underestimates of the measured values (Table 19).

This is an understandable occurrence when phosphorus based models are applied to a nitrogen limited lake such as Lake Herman. Additionally, the data used in the model of Reckhow et al. (1980) violated the data constraints set by Reckhow et al. The mean total phosphorus concentrations in Lake Herman

TABLE 17. TROPHIC STATE CRITERIA PROPOSED BY VARIOUS AUTHORS

Method and parameter of interest*	Oligotrophic	Mesotrophic	Eutrophic	Reference
Carlson's TSI, Total phosphorus	<40	40-50	>50	Carlson (1977)
Carlson's TSI, Secchi transparency	<40	40-50	>50	Carlson (1977)
Carlson's TSI, chlorophyll _a_	<40	40-50	>50	Carlson (1977)
Total phosphorus (mg/l)	<.010	.010-.020	>.020	U.S. EPA (1974
Chlorophyll _a_ (mg/l)	<.007	.007-.012	>.012	U.S. EPA (1974)
Secchi disc (m)	>3.7	2.0-3.7	<2.0	U.S. EPA (1974)
Total nitrogen (mg/l)	<.140	.140-.180	>.180	Porcella et al. (1980)
Total phosphorus	<.010	.010-.020	.020-.050	Reckhow et al. (1980)

* Carlson's TSIs use a numerical scale from 0-100 and the values presented under each trophic category are subjective interpretations.

TABLE 18. SUMMARY STATISTICS OF VARIABLES USED TO DETERMINE THE TROPHIC STATE OF LAKE HERMAN

		Variable +			
Year	Statistic*	Total phosphorus (mg/l)	Total nitrogen (mg/l)	chlorophyll a (mg/l)	Secchi tranparency (cm)
1977	x	.376	2.93		
	s.d.	.212	0.78		
	m	.323	2.81		
	n	6	7		
1978	x	.456	1.99		
	s.d.	.074	0.93		
	m	.468	1.68		
	n	8	9		
1979	x	.585	1.43		
	s.d.	.074	0.39		
	m	.593	1.48		
	n	13	13		
1980	x	.486	1.74	.115	28.15
	s.d.	.129	0.95	.115	4.83
	m	.448	1.32	.084	25.40
	n	15	15	15	15
1981	x	.327	2.51	.125	17.78
	s.d.	.081	1.22	.102	4.45
	m	.329	1.89	.092	17.15
	n	12	12	9	8
1982	x	.618	3.23	.475	29.75
	s.d.	.632	1.99	.589	8.98
	m	.454	2.62	.229	30.48
	n	5	8	6	7
1983	x	.261	2.82		
	s.d.	.010	0.37		
	m	.261	2.63		
	n	3	3		

+ Variables were measured during the summer (June-August).
* Where x = mean, s.d. = standards deviation, m = median, and n = number of observations.

TABLE 19. MEASURED AND PREDICTED TOTAL PHOSPHORUS AND TOTAL NITROGEN LEVELS FOR LAKE HERMAN

Parameter	Year 1978	1979	1980	1981	1982
Predicted total phosphorus at spring overturn (mg/l)*	.209	.292	.015	-	-
Measured total phosphorus at spring overturn (mg/l)(Apr-May)	.394	.209	.267	.180	.307
Predicted total phosphorus during the growing season (mg/l)+	.091	.170	.012	.002	.012
Measured total phosphorus during the growing season (mg/l) (Apr-Sep)	.438	.504	.419	.338	.395
Predicted total nitrogen (mg/l)#	2166	2468	756		
Measured total nitrogen (mg/l)	2530	2590	1697		

* Based on the model of Kirchner and Dillon (1975).
\+ Based on the model of Reckhow et al. (1980).
\# Based on Bachmann's (1981) model using flushing rates.

TABLE 20. SUMMARY STATISTICS OF CARLSON'S (1977) TROPHIC STATE INDICES FOR LAKE HERMAN*

		Trophic State Index		
Year	Statistic	Total Phosphorus	Chlorophyll *a*	Secchi transparency
1977	x	87.54		
	s.d.	9.48		
	m	86.49		
	n	5		
1978	x	92.30		
	s.d.	2.51		
	m	92.81		
	n	8		
1979	x	95.94		
	s.d.	2.06		
	m	96.28		
	n	13		
1980	x	92.95	75.05	78.25
	s.d.	3.71	5.51	2.29
	m	92.23	74.04	79.07
	n	15	15	15
1981	x	87.29	75.88	85.06
	s.d.	3.61	6.33	3.44
	m	87.61	74.93	84.92
	n	12	9	9
1982	x	91.12	79.83	76.70
	s.d.	14.57	18.83	5.63
	m	92.42	79.50	76.53
	n	5	6	8
1983	x	84.43		71.29
	s.d.	0.56		0
	m	84.43		71.29
	n	3		2

* Values are based on samples collected during the summers (Jun-Aug).

exceeded the maximum concentration (.135 mg/l) set by Reckhow et al. Other violations concerned the areal and phosphorus loads which occasionally failed to meet the minimum values set by Reckhow et al. One other possibility is that there may be significant TP sources not accounted for. The sediments in Lake Herman have been suggested to be a significant nutrient source (State Lakes Preservation Committee, 1977) and this study did not quantify sedimentary nutrient inputs.

Bachmann's (1980) TN loading model underestimated the measured values in two out of three years but the predicted values still implied eutrophy (Table 19). Again, unaccounted nutrient sources such as lake sediments may be significant. In addition, blue-green algae are present in Lake Herman and some cyanophytes are capable of fixing atmospheric nitrogen. Thus, the atmosphere could be a source of nitrogen via blue-green algal nitrogen fixation.

Values derived from Carlson's (1977) Trophic State Indices (TSIs) are presented in Table 20 and these data indicate eutrophy. Theoretically, the TSI values should be similar but the TP TSI values were usually greater than CA or SD based values. The CA and SD derived TSI values, however, were relatively similar except during 1981.

Carlson (1980) examined data collected in the National Eutrophication Survey and noted that TP TSI deviations, such as the one mentioned, largely occurred in nitrogen limited lakes. Lake Herman is obviously nitrogen limited and this may have caused the TP TSI deviation.

The situation in 1981 was different. The mean CA TSI value was lower than the mean TP or SD TSI values and the later two were relatively similar. Carlson (1980) interpreted a similar scenario as being due to abiotic influences on Secchi transparency. The year was an extremely "dry" one and the lowered lake level coupled with wind action may have caused resuspension of lake sediments. Suspended lake sediments could conceivably increase TP concentrations, decrease Secchi transparency (increase the SD TSI values), and decrease CA levels if light became limiting or if the suspended sediments did not provide biologically available nutrients.

Annual mean in-lake TP concentrations were compared with t-test analyses (Table 47 in Appendix C). The results do not indicate a consistent improvement (a decrease) in TP concentration except during 1981. This was an extremely "dry" year and tributary inflows were virtually absent. Statistical analyses were not performed on other variables but the data (Table 18) do not suggest a consistent improvement in water quality. This was not unexpected because the effects of nonpoint source pollution control may not be immediate. Additionally, nutrient sources such as lake sediments may introduce significant amounts of nutrients to the lake. If this is so, then a program integrating both watershed management techniques and in-lake remedial measures (e.g. lake dredging) is necessary to restore the lake.

WATER QUALITY SUMMARY

A sampling program was initiated in 1977 to establish baseline water quality data and assess the effectiveness of BMPs on the water quality of Lake Herman. Data were collected from three sites at Lake Herman and nineteen sites within the watershed.

Statistical analyses of nutrient, total suspended solids, and total dissolved solids concentrations above and below selected areas within the watershed produced variable results. An area with permanent seeding applied as a BMP generally reduced nutrient concentrations but did not effect total suspended or dissolved solids concentrations. Differences between mean concentrations of the these parameters above and below a terraced area were not detected. The three sediment control structures did not consistently reduce total phosphorus, total suspended solids, or total dissolved solids concentrations. Statistically significant differences were not demonstrated during 1980 and 1982 but in 1983 significant differences were found at sediment control structures #1 and #3. Structure #2 was apparently ineffective in 1983.

Three in-lake sites were sampled at Lake Herman and statistical comparisons did not reveal significant differences between mean nutrient concentrations of samples collected near the surface and near the bottom. The lake was well mixed and thermal stratification did not occur during the study period. The lake was usually well oxygenated except during the winter months when dissolved oxygen concentrations occasionally fell below 4.0 mg/l.

Total phosphorus and total nitrogen levels were high (annual mean concentrations ranging from .215 to .721 and 1.48 to 4.02 mg/l respectively) and indicated a eutrophic system. Organic nitrogen usually comprised 80% of the total nitrogen. Ammonia nitrogen levels varied and the highest concentrations (>1.0 mg N/l) coincided with low dissolved oxygen concentrations. Nitrates and nitrites were almost always below the analytical detection limits of 0.10 and 0.01 mg/l respectively. Total nitrogen: total phosphorus weight ratios indicated nitrogen limitation.

Two approaches were used to assess the water quality of Lake Herman; one based on South Dakota Water Quality Standards and beneficial uses, and one based on limnological criteria and trophic state. The standards of three parameters (fecal coliforms, pH, and dissolved oxygen) were most frequently violated. Their adequacy for assessing BMP effectiveness on improving lake water quality, however, was questionable because of complications arising from lake aeration, naturally high pH levels, and the incompatibility of the sampling regime and the time scale of fecal coliform impacts.

Water quality criteria based on nutrient and chlorophyll _a_ concentrations and Secchi transparency depths were compared to summer mean values obtained during the study. These data indicated a eutrophic-hypereutrophic lake and a consistent decrease in mean summer total phosphorus concentration was not demonstrated. The phosphorus loading models of Kirchner and Dillon (1975) and Reckhow et al. (1980) predicted oligotrophic to eutrophic levels of total phosphorus and the predicted values were usually much lower than those acquired during in-lake sampling. The discrepencies were most likely due to violations of the models' data constraints and the use of phosphorus based models on a nitrogen limited lake. Phosphorus inputs from the lake sediments were also considered a possibility. Bachmann's (1980) total nitrogen loading model predicted eutrophic levels of total nitrogen but the predicted values were usually lower than the measured values. Unaccounted nitrogen sources such as lake sediments and the atmosphere (via blue-green algal nitrogen fixation) were considered likely reasons for the discrepencies.

Carlson's (1977) three trophic state indices predicted eutrophic conditions. The TSI values should be similar but differences were noted. Possible reasons for these differences were discussed and they included nitrogen limitation and abiotic influences on Secchi transparency.

POSTSCRIPT

The Lake Herman MIP was a major effort to control erosion within the watershed but for long term effectiveness, efforts must be continuous. Although the MIP has ended, measures to control and assess nonpoint source pollution and restore Lake Herman have continued.

The three sediment control structures constructed during the MIP are presently being monitored for various water quality parameters at sites upstream and downstream from the structures. With the increased attention given to operating procedures by the LCCD, it is expected that these structures will be more effective in reducing suspended solids and possibly nutrient loadings to the lake. A preliminary analysis of current monitoring data has indicated that this is so. The LCCD has also purchased approximately 4.37 hectares of land in the north watershed area. This area had land treatment measures applied during the MIP but the land easements were of short duration. This purchase will establish a degree of permanency and the LCCD plans to manage it as a nature area. In addition, a five year dredging project was begun in 1985 to remove accumulated sediment from selected portions of the lake and a water quality sampling program was established to monitor Lake Herman and the dredging activities under the EPA 314 Clean Lakes Program.

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APPENDIX A

STUDY SITE DESCRIPTION

Table 21. Detailed Description of the Study Sites

Site 1 (46HE01)	This site is located on the south tributary flowing into Lake Herman south of the road culvert. Latitude 43 deg., 58 min., 17 sec., longitude 97 deg., 9 min., 59 sec., township 106N, range 53W, section 23, SW1/4, SE1/4, SW1/4, NW1/4. This tributary carries runoff from approximately 10.84 square miles of the watershed. Data were collected at this site to determine areal phosphorus loading rates to Lake Herman and to monitor water quality.
Site 2 (46HE02)	Site 2 is located on Lake Herman's southwest tributary above Camp Lakodia, south of the road culvert. Latitude 43 deg., 58 min., 43 sec., longitude 97 deg., 11 min., 5 sec., township 106N, range 53W, section 22, NE1/4, NE1/4, NW1/4, NW1/4. This tributary carries runoff from approximately 4.14 square miles of watershed. Water quality data and flow were collected at this site. The flow data and phosphorus data were used to calculate areal phosphorus loading rates to the lake from the southwest.
Site 3 (46HE03)	This site is located on the tributary flowing into north Lake Herman from the west and on the east side of the road culvert. Latitude 44 deg., 0 min., 42 sec., longitude 97 deg., 20 min., 4 sec., township 106N, range 53W, section 3, SW1/4, SW1/4, NW1/4, SW1/4. Approximately 16.5 square miles of watershed are drained by this tributary. Data collected at this site were used to monitor water quality and to calculate areal phosphorus loadings to the lake.
Site 4 (46HE04)	This site is located on the tributary flowing into Lake Herman from the north about 150 meters north of Highway 34. Latitude 44 deg., 0 min., 47 sec., longitude 97 deg., 10 min., 52 sec., township 106N, range 53W, section 3, SW1/4, NE1/4, NE1/4, SW1/4. The tributary drains approximately 19 square miles of watershed. Data collected from this site were used to calculate areal phosphorus loadings into Lake Herman and to monitor water quality.
Site 5 (46HE05)	Site 5 is an in-lake site near the center of the northeast bay. Latitude 97 deg., 59 min., 34 sec., longitude 97 deg., 9 min., 51 sec., township 106N, range 53W, section 11, NW1/4, NW1/4, SE1/4, SW1/4. This site, characterized by moderate water and silt depth, was selected to monitor water quality near the outlet of the lake.

TABLE 21. (continued)

Site 6 (46HE06)	This site is northwest of the lake's center at latitude 43 deg., 59 min., 34 sec., longitude 97 deg., 10 min., 30 sec., township 106N, range 53W, section 10, SE1/4, NE1/4, SW1/4, SW1/4. This site was selected to monitor water quality in an area of low silt content and is the deepest point in the lake.
Site 7 (46HE07)	Site 7 is at the center of the southeast bay area at latitude 43 deg., 58 min., 50 sec., longitude 97 deg., 10 min., 0 sec., township 106N, range 53W, section 14, SE1/4, NW1/4, SW1/4, SW1/4. This site is near the south inlet in the shallowest section of the lake and has been documented as having the greatest amount of silt and silt inflow. Water quality parameters were monitored at this site.
Site 21 (46HE21)	Site 21 is located on Silver Creek, the outlet of Lake Herman on the north side of the road. Latitude 43 deg., 59 min., 58 sec., longitude 97 deg., 9 min., 36 min., township 106N, range 53W, section 11, NE1/4, NE1/4, NE1/4, SW1/4. Data collected from this site were used to calculate the total volume of water and to monitor the concentration of nutrients flowing out of the lake.
Sites 22 and 23 (46HE22) and (46HE23)	Sites 22 and 23 are located on the southeast tributary to Lake Herman. Site 22 is east of the road culvert below the seeding. Latitude 43 deg., 58 min., 7 sec., longitude 97 deg., 9 min., 31 sec., township 106N, range 53W, section 23, NW1/4, SW1/4, NW1/4, SE1/4. Site 23 is above the seeding. Latitude 43 deg., 57 min., 58 sec., longitude 97 deg., 9 min., 7 sec., township 106N, range 53W, section 23, SE1/4, NW1/4, SE1/4, SE1/4. The sites were used to determine the effectiveness of permanent seeding as a method of controlling solids and nutrient runoff.
Sites 50 and 51 (46HE50) and (46HE51)	Sites 50 and 51 are located on the main north tributary. Site 51 is 0.75 miles north of Highway 34, south of the road culvert. Latitude 44 deg., 1 min., 19 sec., longitude 97 deg., 10 min., 48 sec., township 106N, range 53W, section 3, NE1/4, NE1/4, NE1/4, NW1/4. Site 50 is 1.75 miles north of Highway 34, south of the road culvert. Latitude 44 deg., 2 min., 11 sec., longitude 97 deg., 10 min., 21 sec., township 106N, range 53W, section 34, NE1/4, NW1/4, NE1/4, NE1/4. These sites were used to determine the effects of streambank erosion on water quality.

TABLE 21. (continued)

Sites 52 and 53 (46HE52) and (46HE53)	Sites 52 and 53 are located on a tributary to Lake Herman's south tributary. Site 52 is 1.50 miles west of U.S. Highway 81, east of the road. Latitude 43 deg., 57 min., 28 sec., longitude 97 deg., 9 min., 31 sec., township 106N, range 53W, section 26, NW1/4, SW1/4, SW1/4, NE1/4. Site 53 is 1.75 miles west of U.S. Highway 81. Latitude 43 deg., 57 min., 37 sec., longitude 97 deg., 9 min., 43 sec., township 106N, range 53W, section 26, NE1/4, NW1/4, SE1/4, NW1/4. The purpose of these sites was to determine the effectiveness of a terrace on controlling solids and nutrients.
Sites 54 and 55 (46HE54) and (46HE55)	Sites 54 and 55 were located above and below sediment control structure number one. Latitude 43 deg., 59 min., 2 sec., longitude 97 deg., 11 min., 38 sec., township 106N, range 53W, Section 16, SE 1/4. These sites were established to determine the effectiveness of the sediment control structure in reducing nutrients and solids from agricultural land runoff.
Sites 56 and 57 (46HE56) and (46HE57)	Sites 56 and 57 are located above and below sediment control structure number two. Latitude 43 deg., 58 min., 10 sec., longitude 97 deg., 11 min., 38 sec., township 106N, range 53W, section 21, SE1/4. These sites were used to determine the effectiveness of structure number two in reducing solids and nutrient runoff from non-point sources.
Sites 60 and 61 (46HE60) and (46HE61)	Sites 60 and 61 are located above and below sediment control structure number three. Latitude 43 deg., 58 min., 7 sec., longitude 97 deg., 9 min., 59 sec., township 106N, range 53W, section 23, SW 1/4. These sites were established to determine the effectiveness of the sediment control structure in reducing solids and nutrients from agricultural runoff.
Sites 62 and 63 (46HE62) and (46HE63)	Sites 62 and 63 are located on the NNW tributary to Lake Herman. Site 62 is south of the road culvert, upstream of the feedlot. Latitude 44 deg., 0 min., 28 sec., longitude 97 deg., 12 min., 46 sec., township 106N, range 53W, section 8, NE1/4, NW1/4, NE1/4, NE1/4. Site 63 is west of the road culvert, downstream of the feedlot. Latitude 44 deg., 0 min., 19 sec., longitude 97 deg., 12 min., 34 sec., township 106N, range 53W, section 8, NE1/4, SE1/4, NE1/4, NE1/4. These sites were used to determine the nutrient content of runoff from a feedlot containing 50 head of dairy cattle.

APPENDIX B

SUMMARY DATA FOR SITES WITHIN THE LAKE HERMAN WATERSHED

TABLE 22. SUMMARY STATISTICS OF SELECTED PARAMETERS FOR SITES 22 AND 23 (1980)*

Parameter	Site	x	s.d.	n
Fecal Coliform	23	7.25	9.51	8
(#/100 ml)	22	239.00	346.00	4
Ammonia-N	23	0.69	0.68	11
(mg/l)	22	0.10	0.06	6
Nitrate-N	23	0.14	0.12	11
(mg/l)	22	1.02	2.20	6
Inorganic-N	23	0.84	0.74	11
(mg/l)	22	1.15	2.30	6
Organic N	23	2.75	1.27	11
(mg/l)	22	1.78	0.22	6
Total Phosphorus	23	2.06	0.78	11
(mg/l)	22	0.51	0.13	6
Dissolved Solids	23	1,820	2,424	11
(mg/l)	22	423	104	6
Suspended Solids	23	24	31	11
(mg/l)	22	21	28	6

* x=mean, s.d.=standard deviation, n=number of observations.

TABLE 23. SUMMARY STATISTICS OF SELECTED PARAMETERS FOR SITES 22 AND 23 (1983)*

Parameter	Site	x	s.d.	n
Fecal Coliform	23	93.25	111.50	4
(#/100 ml)	22	48.89	86.09	9
Ammonia-N	23	0.49	0.50	6
(mg/l)	22	0.17	0.29	14
Nitrate-N	23	3.52	2.57	6
(mg/l)	22	0.43	0.55	14
Inorganic-N	23	4.15	2.16	6
(mg/l)	22	0.62	0.70	14
Organic N	23	1.98	1.33	6
(mg/l)	22	1.13	0.67	14
Total Phosphorus	23	0.55	0.39	6
(mg/l)	22	0.25	0.22	14
Dissolved Solids	23	660	578	7
(mg/l)	22	614	250	16
Suspended Solids	23	16	20	7
(mg/l)	22	12	11	16

* x=mean, s.d.=standard deviation, n=number of observations.

TABLE 24. SUMMARY STATISTICS OF SELECTED PARAMETERS FOR SITES 50 AND 51*

Parameter	Year	Site	x	s.d.	n
Total Solids (mg/l)	1980	50	1,812	963	38
		51	1,814	937	38
	1983	50	1,314	756	10
		51	811	556	10
Suspended Solids (mg/l)	1980	50	18.4	28.3	38
		51	33.7	46.7	38
	1983	50	13.4	13.0	10
		51	19.9	13.0	10
Dissolved Solids (mg/l)	1980	50	1,796	960	38
		51	1,784	920	38
	1983	50	1,301	758	10
		51	371	527	10

* x=mean, s.d.=standard deviation, n=number of observations.

TABLE 25. SUMMARY STATISTICS OF SELECTED PARAMETERS FOR SITES 52 AND 53*

Parameter	Site	x	s.d.	n
Fecal Coliform	52	4,345	10,339	9
(#/100 ml)	53	10,494	33,042	11
Ammonia-N	52	0.42	0.54	11
(mg/l)	53	0.47	0.62	15
Nitrate-N	52	0.65	0.82	11
(mg/l)	53	0.33	0.36	14
Inorganic-N	52	1.08	1.06	11
(mg/l)	53	0.79	0.68	14
Organic N	52	1.50	0.74	11
(mg/l)	53	1.78	0.37	13
Total Phosphorus	52	0.44	0.18	11
(mg/l)	53	0.38	0.26	14
Dissolved Solids	52	2,255	8,654	11
(mg/l)	53	2,573	849	14
Suspended Solids	52	46	105	11
(mg/l)	53	32	62	14

* x=mean, s.d.=standard deviation, n=number of observations.

TABLE 26. SUMMARY STATISTICS OF SELECTED PARAMETERS FOR SITES 62 AND 63 (1980)*

Parameter	Site	x	s.d.	n
Fecal Coliform	62	16,305	47,153	10
(#/100 ml)	63	324,829	879,451	84
Ammonia-N	62	0.21	0.26	14
(mg/l)	63	0.32	0.34	11
Inorganic-N	62	0.43	0.53	14
(mg/l)	63	0.95	1.33	11
Organic N	62	1.30	0.74	14
(mg/l)	63	2.62	2.67	11
Total Phosphorus	62	0.26	0.17	14
(mg/l)	63	0.51	0.62	11
Total Solids	62	912	352	14
(mg/l)	63	981	456	11
Dissolved Solids	62	893	345	14
(mg/l)	63	958	437	11
Suspended Solids	62	19	20	14
(mg/l)	63	23	29	11

* x=mean, s.d.=standard deviation, n=number of observations.

TABLE 27. SUMMARY STATISTICS OF SELECTED PARAMETERS FOR SITES 62 AND 63 (1983)*

Parameter	Site	x	s.d.	n
Fecal Coliform	62	18.3	11.7	7
(#/100 ml)	63	35.0	20.7	6
Ammonia-N	62	0.17	0.23	10
(mg/l)	63	0.25	0.35	10
Inorganic N	62	0.93	0.77	10
(mg/l)	63	1.15	0.82	10
Organic N	62	0.83	0.32	10
(mg/l)	63	0.92	0.50	10
Total Phosphorus	62	0.29	0.13	10
(mg/l)	63	0.35	0.17	10
Total Solids	62	578	252	10
(mg/l)	63	610	267	11
Dissolved Solids	62	555	273	10
(mg/l)	63	595	276	11
Suspended Solids	62	23	43	10
(mg/l)	63	14	17	10

* x=mean, s.d.=standard deviation, n=number of observations.

TABLE 28. MEAN VALUES OF SELECTED PARAMETERS UPSTREAM (54) AND DOWNSTREAM (55) FROM SEDIMENT CONTROL STRUCTURE #1

Parameter	Year	Site 54	Site 55
Total Phosphorus (mg/l)	1980	0.61	0.46
	1982	0.61	0.23
	1983	0.25	0.15
Inorganic N (mg/l)	1980	0.79	1.09
	1982	0.17	0.16
	1983	1.06	0.59
Organic N (mg/l)	1980	2.65	2.60
	1982	1.15	1.00
	1983	1.02	0.44
Total Solids (mg/l)	1980	1,365	1,488
	1982	591	453
	1983	685	1,088
Suspended Solids (mg/l)	1980	20	19
	1982	5	8
	1983	27	9
Dissolved Solids (mg/l)	1980	1,347	1,469
	1982	587	446
	1983	642	1,082

TABLE 29. MEAN VALUES OF SELECTED PARAMETERS UPSTREAM (56) AND DOWNSTREAM (57) FROM SEDIMENT CONTROL STRUCTURE #2

Parameter	Year	Site 56	Site 57
Total Phosphorus (mg/l)	1980	0.68	0.77
	1982	0.98	0.38
	1983	0.34	0.33
Inorganic N (mg/l)	1980	0.95	1.75
	1982	0.23	1.74
	1983	1.70	1.33
Organic N (mg/l)	1980	3.08	2.00
	1982	2.00	1.85
	1983	1.42	1.28
Suspended Solids (mg/l)	1980	52	169
	1982	12	21
	1983	20	17
Dissolved Solids (mg/l)	1980	1,059	1,879
	1982	139	125
	1983	546	502

TABLE 30. MEAN VALUES OF SELECTED PARAMETERS UPSTREAM (61) AND DOWNSTREAM (60) FROM SEDIMENT CONTROL STRUCTURE #3

		Site	
Parameter	Year	61	60
Total Phosphorus (mg/l)	1982	0.45	0.34
	1983	0.39	0.21
Inorganic N (mg/l)	1982	0.70	1.42
	1983	1.42	1.24
Organic N (mg/l)	1982	1.28	1.36
	1983	1.05	0.82
Total Solids (mg/l)	1982	850	578
	1983	1,093	1,297
Suspended Solids (mg/l)	1982	19	18
	1983	13	21
Dissolved Solids (mg/l)	1982	831	572
	1983	1,080	1,276

APPENDIX C

SUMMARY DATA FOR LAKE HERMAN

TABLE 31. SUMMARY STATISTICS OF DISSOLVED OXYGEN (MG/L) FOR LAKE HERMAN*

Year	Site	x	n	s.d.	min.	max.
1977	5	10.0	8	4.0	1.3	13.0
	6	10.9	7	3.4	6.2	14.9
	7	9.0	8	4.8	1.1	15.0
1978	5	8.5	10	5.1	0.4	19.1
	6	8.7	10	5.6	0.5	19.9
	7	8.7	10	6.1	0.0	20.1
1979	5	7.7	24	2.8	0.5	12.7
	6	8.3	23	2.8	0.5	13.0
	7	8.2	20	2.9	0.7	12.7
1980	5	9.5	24	1.4	7.0	13.0
	6	9.2	24	1.4	7.2	11.4
	7	10.1	24	2.0	7.5	14.5
1981	5	10.2	12	1.6	7.2	12.0
	6	10.6	12	2.4	6.8	15.5
	7	9.8	12	1.4	7.2	11.5
1982	5	9.9	12	4.0	3.0	13.2
	6	10.4	12	4.8	2.2	15.8
	7	9.6	12	5.4	1.5	17.8
1983	5	8.3	9	1.9	6.4	11.5
	6	8.2	10	2.0	5.8	11.5
	7	9.4	9	2.1	6.8	11.9

* x=mean, n=number of observations, s.d.=standard deviation, min.=minimum value observed and max.=maximum value observed.

TABLE 32. SUMMARY STATISTICS OF PH FOR LAKE HERMAN*

Year	Site	x	n	s.d.	min.	max.
1977	5	8.3	9	1.1	5.5	9.0
	6	8.7	7	0.5	7.8	9.5
	7	8.1	7	1.5	5.0	9.5
1978	5	8.0	10	0.8	6.5	9.2
	6	7.8	10	0.9	6.5	9.1
	7	8.1	10	0.8	6.7	9.2
1979	5	8.4	15	0.6	7.2	9.0
	6	8.6	15	0.5	7.1	9.2
	7	8.6	16	0.5	7.3	9.3
1980	5	8.2	22	0.7	6.7	9.3
	6	8.3	22	0.6	7.2	9.5
	7	8.5	22	0.6	7.5	9.3
1981	5	8.2	10	0.7	7.2	8.7
	6	8.0	10	0.7	7.2	8.9
	7	8.0	10	0.7	7.1	8.8
1982	5	7.9	8	0.2	7.6	8.1
	6	8.0	8	0.4	7.5	8.5
	7	8.0	8	0.1	7.8	8.1
1983	5	8.0	7	1.1	7.2	9.9
	6	7.9	8	0.8	7.2	9.3
	7	7.9	7	0.6	7.2	8.7

* x=mean, n=number of observations, s.d.=standard deviation, min.=minimum value observed and max.=maximum value observed.

TABLE 33. SUMMARY STATISTICS OF TOTAL ALKALINITY (MG $CaCO_3$/L) FOR LAKE HERMAN*

Year	Site	x	n	s.d.	min.	max.
1977	5	185	8	23.8	170	239
	6	189	7	27.1	167	245
	7	190	7	35.5	154	261
1978	5	214	10	58.6	141	341
	6	212	10	52.1	140	316
	7	230	10	74.9	140	381
1979	5	184	19	34.5	149	285
	6	186	17	36.1	148	289
	7	190	17	43.6	142	309

* x=mean, n=number of observations, s.d.=standard deviation, min.=minimum value observed and max.=maximum value observed.

Table 34. SUMMARY STATISTICS OF SECCHI TRANSPARENCY (CM) FOR LAKE HERMAN*

Year	Site	x	n	s.d.	min.	max.
1980	5	43.30	11	26.37	24.13	95.25
	6	41.80	12	21.16	22.86	90.17
	7	41.17	12	24.78	24.13	95.25
1981	5	18.20	6	3.74	12.70	22.86
	6	20.32	6	6.01	12.70	27.94
	7	20.96	6	3.83	16.51	27.94
1982	5	38.31	6	14.82	20.32	60.96
	6	26.42	5	6.38	20.32	33.02
	7	27.31	6	7.17	19.05	35.56
1983	5	83.71	4	31.69	45.72	121.92+
	6	147.28	3	53.46	91.44	198.00
	7	60.96	2	21.55	45.72	76.20

* x = mean, n = number of observations, s.d. = standard deviation, min. = minimum value observed, and max. = maximum value observed.

+ = Secchi disc on lake bottom.

TABLE 35. SUMMARY STATISTICS OF TOTAL PHOSPHORUS (MG/L) FOR LAKE HERMAN*

Year	Site	x	n	s.d.	min.	max.
1977	5	.215	9	.089	.120	.345
	6	.270	7	.129	.175	.551
	7	.391	7	.190	.184	.703
1978	5	.429	10	.101	.281	.630
	6	.496	9	.205	.321	1.020
	7	.578	10	.381	.312	1.430
1979	5	.490	25	.176	.197	.105
	6	.491	23	.194	.190	.712
	7	.508	23	.207	.170	.744
1980	5	.452	26	.157	.199	.780
	6	.434	25	.134	.224	.651
	7	.447	26	.142	.236	.777
1981	5	.338	20	.136	.146	.583
	6	.339	20	.134	.180	.527
	7	.363	20	.129	.163	.557
1982	5	.468	15	.361	.144	1.480
	6	.721	10	.578	.203	1.700
	7	.553	12	.480	.115	1.502
1983	5	.373	8	.152	.214	.603
	6	.390	9	.161	.227	.651
	7	.343	8	.133	.200	.576

* x=mean, n=number of observations, s.d.=standard deviation, min.=minimum value observed and max.=maximum value observed.

TABLE 36. SUMMARY STATISTICS OF TOTAL NITROGEN (MG/L) FOR LAKE HERMAN*

Year	Site	x	n	s.d.	min.	max.
1977	5	2.71	9	0.70	1.51	4.07
	6	2.86	7	0.94	1.51	4.45
	7	3.50	8	0.62	2.67	4.61
1978	5	2.44	10	1.61	1.20	6.33
	6	2.30	10	1.34	1.06	5.43
	7	2.84	10	1.76	1.26	6.28
1979	5	1.48	25	0.43	0.73	2.23
	6	1.55	23	0.54	0.78	3.04
	7	1.75	23	0.55	0.90	2.89
1980	5	1.61	26	0.79	0.80	4.98
	6	1.78	26	0.89	0.67	3.87
	7	1.81	26	0.67	0.29	2.66
1981	5	2.25	20	1.03	0.52	4.93
	6	2.18	20	1.02	0.52	4.98
	7	2.20	20	0.88	0.63	4.38
1982	5	3.23	13	1.33	1.43	5.75
	6	4.02	10	2.12	1.66	8.05
	7	3.16	12	1.99	1.54	8.03
1983	5	2.69	9	0.73	1.51	3.47
	6	2.94	10	1.07	1.45	5.21
	7	2.85	10	0.92	1.54	4.14

* x=mean, n=number of observations, s.d.=standard deviation, min.=minimum value observed and max.=maximum value observed.

TABLE 37. SUMMARY STATISTICS OF INORGANIC NITROGEN (MG/L) FOR LAKE HERMAN*

Year	Site	x	n	s.d.	min.	max.
1977	5	0.58	9	0.76	.13	2.11
	6	0.32	7	0.37	.13	1.10
	7	0.77	8	0.92	.13	2.35
1978	5	0.66	9	0.97	.13	2.45
	6	0.62	10	0.88	.13	2.65
	7	0.80	10	1.27	.13	3.56
1979	5	0.28	25	0.23	.13	0.77
	6	0.26	24	0.24	.13	0.79
	7	0.25	23	0.23	.13	0.88
1980	5	0.24	26	0.23	.13	1.25
	6	0.20	25	0.13	.13	0.62
	7	0.21	26	0.15	.13	0.73
1981	5	0.18	20	0.08	.13	0.40
	6	0.15	20	0.02	.13	0.42
	7	0.18	20	0.09	.13	0.45
1982	5	0.94	14	0.58	.13	1.82
	6	0.90	12	0.54	.14	1.90
	7	0.84	14	0.50	.14	1.81
1983	5	1.38	9	0.47	.61	1.90
	6	1.42	10	0.43	.62	1.82
	7	1.36	10	0.41	.70	1.79

* x=mean, n=number of observations, s.d.=standard deviation, min.=minimum value observed and max.=maximum value observed.

TABLE 38. SUMMARY STATISTICS OF ORGANIC NITROGEN (MG/L) FOR LAKE HERMAN*

Year	Site	x	n	s.d.	min.	max.
1977	5	2.07	9	0.55	1.19	2.88
	6	2.52	7	0.90	1.38	4.30
	7	2.74	8	0.97	1.54	4.47
1978	5	1.82	10	0.81	1.06	3.88
	6	1.69	10	0.60	0.93	2.78
	7	2.04	10	0.82	1.13	3.70
1979	5	1.20	25	0.37	0.60	2.10
	6	1.29	24	0.45	0.65	2.35
	7	1.50	23	0.48	0.76	2.42
1980	5	1.37	26	0.60	0.65	3.73
	6	1.58	25	0.87	0.54	3.72
	7	1.56	26	0.60	0.63	2.49
1981	5	2.08	20	1.00	0.39	4.73
	6	2.00	20	1.00	0.39	3.02
	7	2.01	20	0.87	0.43	4.25
1982	5	2.11	14	0.96	0.58	3.93
	6	3.02	10	1.82	1.12	7.01
	7	2.22	12	1.65	0.59	6.22
1983	5	1.10	9	0.45	0.31	1.66
	6	1.53	10	0.74	0.83	1.80
	7	1.49	10	0.60	0.84	2.50

* x=mean, n=number of observations, s.d.=standard deviation, min.=minimum value observed and max.=maximum value observed.

TABLE 39. SUMMARY STATISTICS OF AMMONIA AS N (MG/L) FOR LAKE HERMAN*

Year	Site	x	n	s.d.	min.	max.
1977	5	0.38	9	0.64	.02	1.93
	6	0.20	7	0.39	.02	0.94
	7	0.54	8	0.74	.02	1.96
1978	5	0.50	10	0.93	.02	2.34
	6	0.48	10	0.88	.02	2.54
	7	0.69	10	1.27	.02	3.45
1979	5	0.17	25	0.23	.02	0.66
	6	0.15	24	0.24	.02	0.68
	7	0.14	23	0.23	.02	0.77
1980	5	0.09	26	0.11	.02	0.44
	6	0.09	25	0.13	.02	0.51
	7	0.11	26	0.14	.02	0.60
1981	5	0.07	20	0.08	.02	0.29
	6	0.07	20	0.09	.02	0.31
	7	0.07	20	0.09	.02	0.34
1982	5	0.80	15	0.56	.02	1.71
	6	0.77	12	0.54	.03	1.79
	7	0.73	14	0.50	.03	1.70
1983	5	1.04	9	0.31	.50	1.26
	6	1.02	10	0.27	.51	1.23
	7	0.92	9	0.24	.59	1.28

* x=mean, n=number of observations, s.d.=standard deviation, min.=minimum value observed and max.=maximum value observed.

TABLE 40. SUMMARY STATISTICS OF TOTAL NITROGEN: TOTAL PHOSPHORUS WEIGHT RATIOS FOR LAKE HERMAN SURFACE WATERS*

Year	Site	x	n	s.d.	min.	max.
1977	5	14.09	9	5.96	6.88	22.60
	6	11.11	7	2.48	7.66	14.60
	7	11.02	7	5.25	4.61	20.50
1978	5	5.53	10	2.58	2.77	10.00
	6	4.80	9	1.73	2.69	7.99
	7	5.15	10	1.83	3.01	8.59
1979	5	3.37	10	1.58	1.48	5.85
	6	4.86	9	2.76	2.40	10.00
	7	4.69	9	3.52	1.50	13.10
1980	5	3.98	13	1.80	1.46	7.10
	6	5.04	13	2.66	1.58	10.40
	7	4.15	13	2.15	1.10	7.31
1981	5	6.56	3	3.50	3.56	10.40
	6	5.29	3	1.82	4.15	7.39
	7	8.75	3	4.31	5.81	13.70
1982	5	9.78	2	5.41	5.95	13.60
	6	4.74	1	-	-	-
	7	9.75	2	8.13	4.00	15.50
1983	5	7.83	4	1.78	5.92	10.10
	6	8.12	4	1.62	6.39	10.30
	7	7.84	5	2.62	5.11	12.00

* x=mean, n=number of observations, s.d.=standard deviation, min.=minimum value observed and max.=maximum value observed.

TABLE 41. SUMMARY STATISTICS OF CHLOROPHYLL a (MG/M^2) FOR LAKE HERMAN*

Year	Site	x	n	s.d.	min.	max.
1980	5	108.86	9	157.73	9.14	519.68
	6	59.56	9	35.34	10.40	119.82
	7	79.65	9	44.51	20.31	125.24
1981	5	108.79	8	66.96	30.02	211.68
	6	124.65	8	108.19	47.15	376.23
	7	113.50	8	67.54	31.98	216.72
1982	5	472.06	2	593.31	52.52	891.59
	6	210.00	2	276.05	14.80	405.20
	7	743.00	2	1,009.75	29.00	1,457.00

* x = mean, n = number of observations, s.d. = standard deviation, min. = minimum value observed and max. = maximum value observed.

TABLE 42. THE MAJOR ALGAE OBSERVED IN LAKE HERMAN DURING 1980 AND 1981 FOR ALL SAMPLING SITES

Date	Genera	% of Biomass	Mean (u^3/ml)	Standard deviation	Total Biomass (u^3/ml)
4/22/80	*Microcystis*	32	161,967	127,198	x= 508,278
	Pediastrum	26	134,175	107,698	s= 209,795
	Unknown	24	121,508	188,239	n= 6
	Haematococcus	12	60,597	47,386	
	Cylindrocystis	5	24,335	59,608	
	Euglena	1	5,696	13,952	
5/8/80	*Cylindrocystis*	49	104,667	117,293	x= 214,901
	Microcystis	23	50,284	43,786	s= 131,360
	Pediastrum	21	45,638	35,227	n= 6
	Haematococcus	6	12,808	20,512	
	Anabaena	1	1,500	3,674	
5/22/80	*Anabaena*	59	512,961	170,656	x= 871,908
	Cylindrocystis	19	163,594	237,658	s= 270,925
	Microcystis	16	140,680	49,730	n= 5
	Pediastrum	6	54,675	81,238	
6/18/80	*Microcystis*	59	4,563,727	8,933,690	x= 7,704,094
	Anabaena	24	1,813,655	1,985,755	s=10,207,414
	Closteriopsis	14	1,112,537	971,787	n= 6
	Other	3	214,174	235,861	
7/1/80	*Microcystis*	56	1,796,073	641,946	x= 3,187,741
	Closteriopsis	37	1,178,734	829,196	s= 846,080
	Pediastrum	4	142,453	241,106	n= 6
	Other	1	31,529	77,231	
	Diatoms (Penate)	1	20,605	50,472	
	Trachelomonas	1	18,348	44,941	
7/16/80	*Closteriopsis*	57	2,726,218	1,757,419	x= 4,766,762
	Microcystis	36	1,735,015	834,086	s= 2,712,857
	Anabaena	7	336,364	55,126	n= 6
	Haematococcus	Present	23,431	57,393	
	Other	Present	2,944	7,212	
	Pediastrum	Present	2,663	6,522	
8/5/80	*Closteriopsis*	77	2,780,324	3,421,820	x= 3,632,412
	Microcystis	17	631,242	142,036	s= 3,445,757
	Pediastrum	6	210,876	126,012	n= 6
	Anabaena	Present	9,975	24,434	
8/21/80	*Closteriopsis*	57	896,141	805,570	x= 1,574,453
	Microcystis	34	534,876	238,707	s= 737,522
	Closterium	7	117,786	288,516	n= 6
	Pediastrum	2	25,650	62,829	
9/16/80	*Closteriopsis*	80	3,856,667	4,521,375	x= 4,791,385
	Microcystis	17	821,973	790,150	s= 5,441,527
	Pediastrum	2	97,108	187,554	n= 6
	Haematococcus	Present	12,900	31,598	
	Euglena	Present	2,738	6,707	

TABLE 42. (continued)

Date	Genera	% of Biomass	Mean (u^3/mg)	Standard deviation	Total Biomass (u^3/ml)
11/6/80	*Closteriopsis*	98	11,085,069	3,513,482	x=11,324,071
	Haematococcus	2	236,618	188,465	s= 3,370,699
	Microcystis	Present	2,384	5,840	n= 6
	Cylindrocystis	Present	-	-	
12/30/80	*Closteriopsis*	98	10,040,378	2,660,603	x=10,294,490
	Haematococcus	2	254,112	83,824	s= 2,740,351
	Cylindrocystis	Present	-	-	n= 6
	Trachelomonas	Present	-	-	
4/13/81	*Closteriopsis*	97	3,590,719	1,542,379	x= 3,711,766
	Haematococcus	3	109,634	48,121	s= 1,508,302
	Long Filaments	Present	7,127	17,458	n= 6
	Oocystis	Present	2,562	6,275	
	Pediastrum	Present	7,127	17,458	
	Ulothrix	Present	-	-	
6/9/81	*Closteriopsis*	87	1,165,994	498,398	x= 1,346,662
	Microcystis	8.5	119,455	74,223	s= 579,342
	Haematococcus	4.5	61,214	30,851	n= 6
7/8/81	*Geminella*	53	10,051,734	6,627,701	x=19,061,569
	Closteriopsis	42	8,358,851	2,491,912	s= 8,051,465
	Ulothrix	2	172,672	105,027	n= 6
	Pediastrum	1	241,884	414,223	
	Gloeocystis	Present	90,156	220,836	
	Diatoms	Present	83,996	139,731	
	Anabaena	Present	62,273	152,536	
7/21/81	*Closteriopsis*	95	10,322,537	2,357,189	x=10,895,193
	Diatoms	2	259,383	310,554	s= 2,438,300
	Ulothrix	2	256,525	262,498	n= 6
	Microcystis	Present	40,686	63,522	
	Pediastrum	Present	16,063	39,346	
9/1/81	*Ulothrix*	87	3,214,893	820,628	x= 3,681,984
	Diatoms	13	468,323	202,324	s= 924,299
					n= 6
9/22/81	*Ulothrix*	84	2,806,053	1,341,000	x= 3,322,356
	Diatoms	15	507,537	193,353	s= 1,477,816
					n= 6

TABLE 43. SUMMARY STATISTICS OF FECAL COLIFORMS (count per 100 ml) FOR LAKE HERMAN*

Year	Site	x	n	s.d.	min.	max.
1977	5	10.44	9	10.14	<3	33
	6	119.00	7	183.80	<3	510
	7	4053.00	8	11292.00	<3	32000
1978	5	39.13	8	67.40	<3	200
	6	170.90	9	424.30	<3	1300
	7	489.60	9	1317.80	<3	4000
1979	5	22.47	19	46.33	<3	200
	6	10.64	14	5.83	<3	10
	7	18.21	21	33.51	<3	130
1980	5	47.00	24	145.44	<3	700
	6	134.57	23	436.76	<3	1900
	7	27.63	24	51.70	<3	210
1981	5	233.78	18	665.30	<3	2500
	6	40.72	18	65.05	<3	190
	7	29.39	18	70.81	<3	260
1982	5	37.00	6	63.12	<3	160
	6	8.83	6	6.31	<3	20
	7	8.67	6	10.82	<3	30
1983	5	15.56	9	11.30	<10	40
	6	11.00	10	3.16	<10	20
	7	17.78	9	17.16	<10	60

* x=mean, n=number of observations, s.d.=standard deviation, min.=minimum value observed and max.=maximum value observed.

TABLE 44. SUMMARY STATISTICS OF TOTAL SOLIDS (MG/L) FOR LAKE HERMAN*

Year	Site	x	n	s.d.	min.	max.
1977	5	858.44	9	295.96	85	1092
	6	987.29	7	90.83	907	1132
	7	919.00	8	235.74	374	1180
1978	5	928.00	10	292.11	608	1566
	6	920.10	10	245.19	615	1399
	7	980.00	10	319.95	635	1601
1979	5	844.40	25	109.73	707	1226
	6	850.33	24	177.88	705	1232
	7	867.87	23	131.28	727	1327
1980	5	1178.96	26	824.28	521	5173
	6	1211.00	25	945.28	876	5732
	7	1028.96	26	94.75	894	1279
1981	5	1186.55	20	224.75	303	1333
	6	1202.85	20	198.08	466	1352
	7	1108.00	20	205.80	532	1413
1982	5	1207.07	15	544.97	363	2361
	6	1372.33	13	535.91	942	2380
	7	1282.00	13	544.06	935	2394
1983	5	978.56	9	143.65	790	1252
	6	962.90	10	113.95	781	1109
	7	952.44	9	105.13	824	1114

* x=mean, n=number of observations, s.d.=standard deviation, min.=minimum value observed and max.=maximum value observed.

TABLE 45. SUMMARY STATISTICS OF TOTAL SUSPENDED SOLIDS (MG/L) FOR LAKE HERMAN*

Year	Site	x	n	s.d.	min.	max.
1977	5	42.11	9	21.44	2	68
	6	81.71	7	64.25	10	174
	7	86.63	8	34.45	13	119
1978	5	40.00	9	27.96	7	83
	6	57.30	10	21.93	<1	85
	7	48.70	10	25.94	<1	84
1979	5	22.92	25	19.04	0	62
	6	25.29	24	22.62	<1	76
	7	23.48	23	20.09	0	74
1980	5	44.85	26	36.75	5	130
	6	41.08	25	26.02	5	90
	7	46.92	26	32.08	0	140
1981	5	62.60	20	53.07	8	205
	6	64.15	20	42.04	7	155
	7	59.10	20	27.02	7	100
1982	5	23.53	15	18.76	4	66
	6	24.75	12	17.96	5	60
	7	36.00	14	20.14	12	72
1983	5	50.56	9	113.27	2	352
	6	16.00	10	12.86	3	46
	7	15.89	9	14.72	6	44

* x=mean, n=number of observations, s.d.=standard deviation, min.=minimum value observed and max.=maximum value observed.

TABLE 46. SUMMARY STATISTICS OF TOTAL DISSOLVED SOLIDS (MG/L) FOR LAKE HERMAN*

Year	Site	x	n	s.d.	min.	max.
1977	5	816.33	9	282.25	83	1057
	6	905.57	7	85.51	810	1081
	7	832.38	8	240.48	282	1115
1978	5	892.20	10	284.27	601	1494
	6	862.90	10	241.46	560	1314
	7	931.40	10	330.49	583	1590
1979	5	821.52	25	108.37	698	1221
	6	826.42	24	121.10	682	1228
	7	845.35	24	133.08	693	1322
1980	5	1134.12	26	827.95	493	5144
	6	1159.92	25	942.81	832	5649
	7	982.04	26	104.57	854	1257
1981	5	1129.65	20	216.11	295	1299
	6	1138.70	20	199.27	459	1432
	7	1120.60	20	203.90	525	1397
1982	5	1183.53	15	544.44	359	2342
	6	1347.58	12	544.85	924	2366
	7	1252.77	13	549.57	909	2378
1983	5	928.44	9	98.58	782	1052
	6	946.90	10	108.14	778	1089
	7	936.56	9	106.12	811	1105

* x=mean, n=number of observations, s.d.=standard deviation, min.=minimum value observed and max.=maximum value observed.

TABLE 47. RESULTS OF T-TEST ANALYSES FOR DETECTING TEMPORAL DIFFERENCES IN MEAN IN-LAKE TOTAL PHOSPHORUS (TP) CONCENTRATIONS

SITE 5

	1977	1978	1979	1980	1981	1982
1977						
1978	-5					
1979	-5	0				
1980	-5	0	0			
1981	-10	+5	+5	+5		
1982	-5	0	0	0	-10	

SITE 6

	1977	1978	1979	1980	1981	1982
1977						
1978	-5					
1979	-5	0				
1980	-5	0	+5			
1981	0	+5	+5	+10		
1982	-10	0	0	0	-5	

SITE 7

	1977	1978	1979	1980	1981	1982
1977						
1978	0					
1979	0	0				
1980	0	+10	+5			
1981	0	+10	+10	+10		
1982	0	0	0	0	-10	

Where: 0 = no significant difference demonstrated;
+ = previous year's mean TP > later year's mean TP (an improvement);
- = later year's mean TP > previous year's mean TP (a deterioraion); and
5,10 = percent significance levels.