WATER AND RELATED LAND RESOURCES MANAGEMENT STUDY

for

THE HERON LAKE SYSTEM

Main Report

Consultant's Report prepared for the Natural Resources Department-LRL
recd copies from LCMR 5/82

McCombs - Knutson Associates, Inc.

Pursuant to 1980 Laws, c 614, s 16, (c) ($75,000 of unexpended balance of money appropriated by 1975 Laws, c204, s 55 & 1977 Laws, c 455, s 28 for construction of dams & channel excavation on Heron Lake in Jackson County)

McCOMBS-KNUTSON ASSOCIATES, INC.
CONSULTING ENGINEERS ■ LAND SURVEYORS ■ PLANNERS

Reply To:
12800 Industrial Park Boulevard
Plymouth, Minnesota 55441
(612) 559-3700

March 30, 1982

Mr. J. B. Miranowski, President
Middle Des-Moines Watershed District
and
Mr. Gene Hollenstein, Administrator
Minnesota Department of Natural Resources
Division of Waters

Dear Mr. Miranowski and Mr. Hollenstein:

We respectfully submit this report for the Water and Related Land Resources Management Study for the Heron Lake System. This report is provided to satisfy the requirements set forth in HERON LAKE WATER MANAGEMENT STUDY, LAWS 1980, SECTION 16, and is intended to provide information necessary to understand problems of the Heron Lake System and present a number of potential alternatives to alleviate these problems.

Very truly yours,

McCOMBS-KNUTSON ASSOCIATES, Inc.

Viet Ngo, P.E.
Vice-President

VN:j
Enclosure

Water and Related

Land Resources

MANAGEMENT STUDY

For

THE HERON LAKE SYSTEM

Main Report

March, 1982

I hereby certify that this report was prepared by me or under my direct supervision and that I am a duly Registered Professional Engineer under the laws of the State of Minnesota.

Viet Ngo
Date 3/30/82
Registration No. 14322

Roger Mieden
Date 3/30/82
Registration No. 14167

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Preface

The Heron Lake System, located in Southwestern Minnesota, has been the subject of increasing controversy for the last 70 years over the issues of flooding, lake level control, water quality degradation, fish and wildlife resources and land use management. In the past, numerous studies have been conducted to examine the above problems in varying degrees of details and sophistication. However, up to the initiation of this study program, there was no comprehensive and in-depth evaluation of the existing problems and resources of the area in order to provide directions and alternatives for a responsible and effective solution to these problems.

In January 1980, the Middle Des Moines Watershed District, representing the interest of local residents and local government entities, initiated the first efforts to put together a proposed study program to address the above problems. The Minnesota Department of Natural Resources (DNR) was subsequently involved to assist in the preparation of a scope of work for a Heron Lake Water Management Study Program to be presented to the State of Minnesota for funding. This proposed study represents a break from traditional water resources planning policy in Minnesota in the fact that it was primarily conducted on a local level with maximum local participation, and with assistance from State and Federal Agencies, and not vice-versa.

This program was submitted to the State Legislature in July 1980, and subsequently was approved and funded by the Legislative Commission on Minnesota Resources with matching local contributions.

This report is the result of this study program from March 1981 to March, 1982, prepared by McCombs-Knutson Associates, Inc., consulting engineers to the Middle Des Moines Watershed District, with major input from the

Minnesota Department of Natural Resources and local management groups and private citizens.

I. FUNDING

Funding was provided by the Legislative Commission on Minnesota Resources with local matching contribution.

The total State appropriation amounts to $75,000 reappropriated from the unexpended balance of money reappropriated under Laws 1977, Chapter 455, Section 28. This appropriation covers salary, expenses and fringe benefits for a DNR Unclassified Senior hydrologist and consultant services.

The Middle Des Moines Watershed District initially contributed $50,000 toward this study for consultant services and local administrative costs.

II. PROGRAM DESCRIPTION

This study program is entitled: HERON LAKE WATER MANAGEMENT STUDY, LAWS 1980, ch. 614 SECTION 16. (c)

A. Goals and Objectives:

- To conduct a local-state water management study of Heron Lake to develop alternatives for maintenance of adequate water level and aquatic growth conditions on North Heron Lake for waterfowl management purposes, and water level and water quality conditions on South Heron Lake for improvement for fisheries management purposes.
- To perform a study which will include the collection and analysis of resource information to provide essential technical facts and assessment of the problems of Heron Lake. Heron Lake problems include sedimentation, land use, water quality, lake use, fish

and wildlife values, flooding and low flow and low water level considerations.

B. Study Components:

This study includes the following 7 major components:

- Description and evaluation of land uses and practices, land treatment needs, sedimentation and soils which must be considered in addressing solutions.
- Description and evaluation of climatological data.
- Description of the physical character of the Heron Lake system.
- Description and evaluation of the water quality of Heron Lakes and the streams which provide water to Heron Lakes.
- Description and evaluation of the hydrologic conditions of the Heron Lake system including development of a monitoring system and hydrologic models.
- Description and evaluation of the character, extent, frequency and damages of floods affecting the Heron Lake system.
- Description and evaluation of fish and waterfowl values of Heron Lake.

C. Federal, State and Local Cooperation & Coordination

- Accumulation of data related to land use, treatment needs, sedimentation and soils were accomplished through cooperative efforts by U. S. Soil Conservation Service acting through Soil and Water Conservation Districts for Jackson, Nobles, Murray and Cottonwood counties. These technical assistance services were provided at no cost to the state or local government.
- Climatological data were collected by the engineering consultants with major input from the office of the State Climatologist.
- Physical character such as watershed maps, lake maps, land use maps, stream and lake inventory maps were provided by the DNR with major input from Bureau of Planning.
- Water quality was proposed to be accomplished under a Minnesota Pollution Control Agency (MPCA) and U. S. Environmental Protection Agency (EPA) cooperative program with technical assistance under the Clean Water Act PL 95-217, Sect. 314 subject to priority designation by MPCA and approval by EPA. This MPCA-EPA agreement did not materialize due to shortage of funds. To remedy the situation, the Middle Des Moines Watershed District in agreement with the Minnesota DNR authorized a water quality study by the engineering consultants. This study was much reduced in scope from the original program submitted to MPCA-EPA. The Middle Des Moines Watershed District contributed

an additional $10,000 for this water quality study and DNR contributed the remaining budget for the portion of Unclassified Senior Hydrologist for this study program. This position was vacated on July 28, 1981 and the remaining budget amounted to $19,092.

- Hydrologic data were collected by the consultant employed by the Middle Des Moines Watershed District with cooperation and assistance from the DNR field staff person from March, 1981 to July, 1981.

- Study of floods were proposed to be accomplished under technical assistance program by U.S. Corps of Engineers (USCE), Rock Island District with cooperation from the Middle Des Moines Watershed District consultant subject to U. S. C.E. approvals and work schedules. This technical assistance did not materialize due to shortage of staff and resources from the Rock Island District. The engineering consultants performed these studies to the best of their abilities with existing data and information.

- The fish and waterfowl study was accomplished by DNR and input from Division of Fish and Wildlife Service.

- The overall coordination of the various components was provided by the Middle Des Moines Watershed District acting through its consultants in cooperation with the DNR Division of Waters field person and DNR policy and Planning Section.

Throughout the study efforts, the Middle Des Moines Watershed District and the DNR have cooperated in a local-state effort which included further coordination with the following:

Federal Agencies -	Soil Conservation Service (SCS), the Environmental Protection Agency (EPA), U. S. Fish and Wildlife Service, The Agricultural Stabilization & Conservation Service (ASCS), and the Agricultural Research Service (ARS).
State Agencies -	The Minnesota Pollution Control Agency (MPCA), Soil and Water Conservation Board, Minnesota Water Resources Board.
Regional Agencies -	Region 8, Southwest Regional Development Commission.
Local Agencies -	Soil and Water Conservation Districts by Jackson, Nobles, Murray and Cottonwood counties, County Commissioners of Jackson, Nobles, Murray and Cottonwood counties, Cities of Heron Lake, Okabena, Brewster, Lakefield and Worthington,

Township officials of each township within the study area.

D. Public Participation:

Local citizens and local management groups were fully informed in all aspects of the study effort and plan development through the study period. A local advisory board composed of 20 local citizens was established during the course of the study to provide input and advice to the directions of this study program.

The Middle Des Moines Watershed District held four (4) public meetings and numerous informal meetings between DNR, engineering consultant, advisory board, local management groups and general public throughout the study period. These meetings were conducted in the City of Heron Lake and in DNR headquarters in St. Paul to discuss study status, progress reports, local opinion and aspirations, State and Federal procedures and guidelines, and other technical and management details.

The four (4) public meetings were conducted in Heron Lake, with attendance ranging from 25 to 100, and covered the following topics:

- April 7, 1981: The overall scope and intent of the study was described and public comments were received which expressed concerns regarding fish and wildlife, erosion, flooding and water quality.
- September 30, 1981: Preliminary results of the hydrologic and hydraulic analyses were presented. The scope and nature of the water quality study were presented and potential alternatives were discussed.
- November 28, 1981: Intermediate results of the hydrologic and hydraulic analyses, water quality and erosion studies were presented along with results of DNR fish surveys. Potential alternatives were presented and discussed.

- February 22, 1982: Final results of all phases of the study were presented along with a discussion of potential alternatives. The scope and purpose of the study was again reviewed. The need for local cooperation during the selection and implementation of alternatives was stressed.

E. Study Limitations:

As stated earlier, the original study program called for additional assistance from the Minnesota PCA and the Corps of Engineers, Rock Island District. Due to shortage of Federal and State funds and resources, this assistance did not occur, resulting in a reduction of the scope of the original study program. This report will therefore present the analysis and results by the engineering consultants working to their best abilities with existing funding sources. Efforts were made to maintain the original goals and objectives in order to provide an adequate assessment of the problems and subsequent directions for remedial measures.

The study has the following limitations:

- The water quality study was performed for the period of July 1981 through February 82, therefore may not fully reflect average or typical conditions for the Heron Lake system.
- The erosion and sedimentation study utilized existing information which did not include sediment sampling data on the stream system or quantitative analysis of sediment in the lake system.
- The flooding study was performed using sparse hydrologic and hydraulic data. There are no permanent gaging stations in the Heron Lake Watershed, no permanent and consistent lake elevation reading program, and no known flood damage surveys for the Heron Lake system during past flooding events.
- Detailed analysis of low flow conditions is not possible with available information. An analysis of this type requires channel cross section information of interconnecting channels, consistent records of lake level elevations and other information not available at the time of the study.

- There is no recent hydrographic map (water depths) of the Heron Lake System. The most recent hydrographic survey was done by DNR in 1964 and only covered parts of the lake system. A new hydrographic survey by DNR was planned for the field season of 1981 but was later cancelled due to shortage of field personnel.

- A Normal Ordinary High Water Mark for Heron Lake has never been officially established. The Minnesota DNR is planning to establish this elevation during the coming field season (1982).

The level of funding has provided a report describing and assessing the problems, but it is not adequate to provide for the detailed analysis and selection of the alternative solutions to the problems which may be implemented in future years. Upon local and state agreement on a recommended plan, funds may be required to complete this detailed analysis and selection of alternatives development, and subsequently to implement those portions of the plan where there is a significant state and local interest.

This report thus presents general information, which reviews existing conditions and problems in the study areas, and a general description of potential alternatives for further consideration. A Technical Supplement, published separately, will present a more detailed technical evaluation related to both existing conditions and to the development of potential alternatives.

This report contains the following 3 major sections:

- General overview of the characteristics of the Heron Lake system including location, topography, climate, land use, soils, population, economics and recreation.

- Discussion of major problems involving the Heron Lake System including:

    - Flooding
    - Low flow and low water level considerations
    - Problems with control structures and their tampering
    - Sedimentation & land erosion
    - Land use including apparent encroachments on the lake bed
    - Water quality
    - Lake use
    - Fish & waterfowl values of North Heron Lake and South Heron Lake

- Discussion of potential alternative solutions for the four major problems:

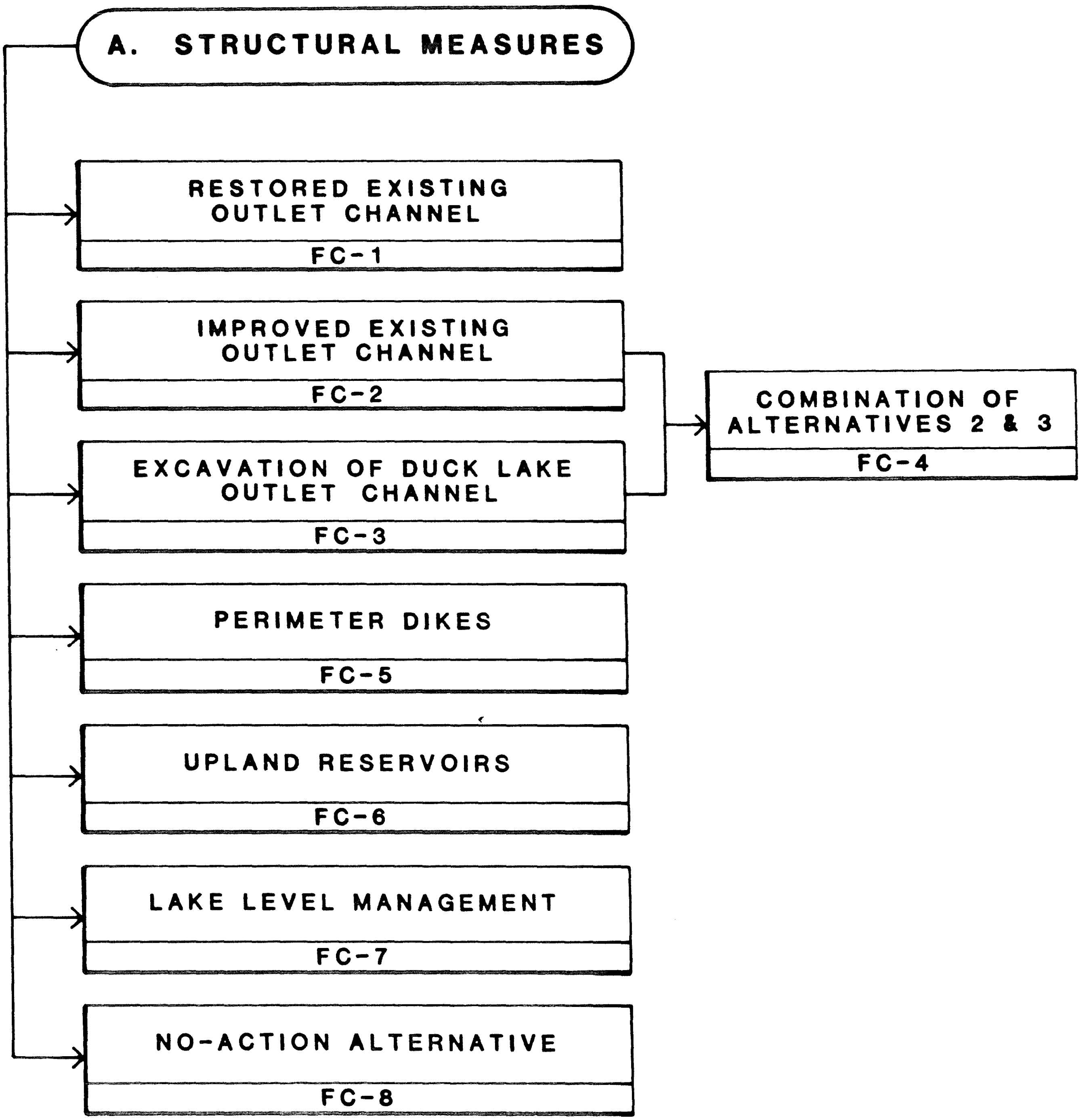
    - Flooding
    - Water Quality & Related Environmental Problems
    - Lake Use
    - Erosion and Sedimentation

Each potential alternative will outline its advantages, disadvantages, limitations and applicability in the Heron Lake system in particular, and in Minnesota in general.

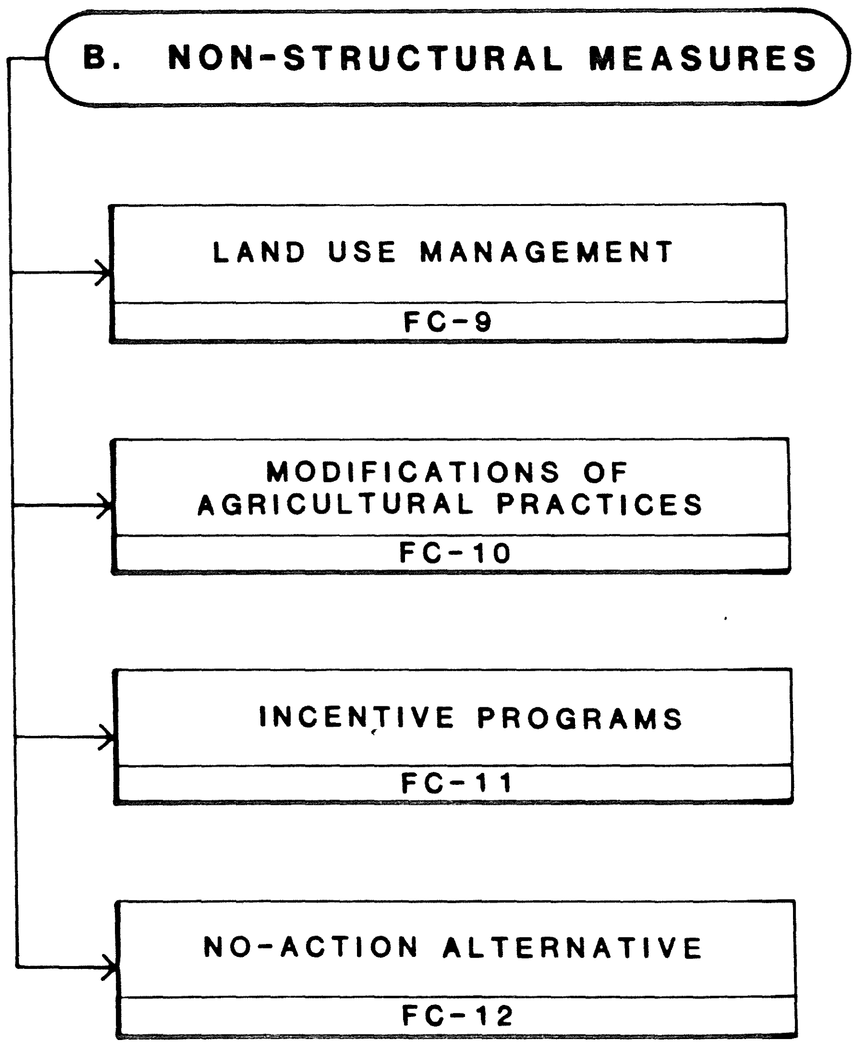
A brief outline of these potential alternatives are shown on the following pages. Detailed description of these alternatives is presented in the last section of this report entitled: "Potential Alternatives".

Summary

HERON LAKE
FLOOD CONTROL ALTERNATIVES

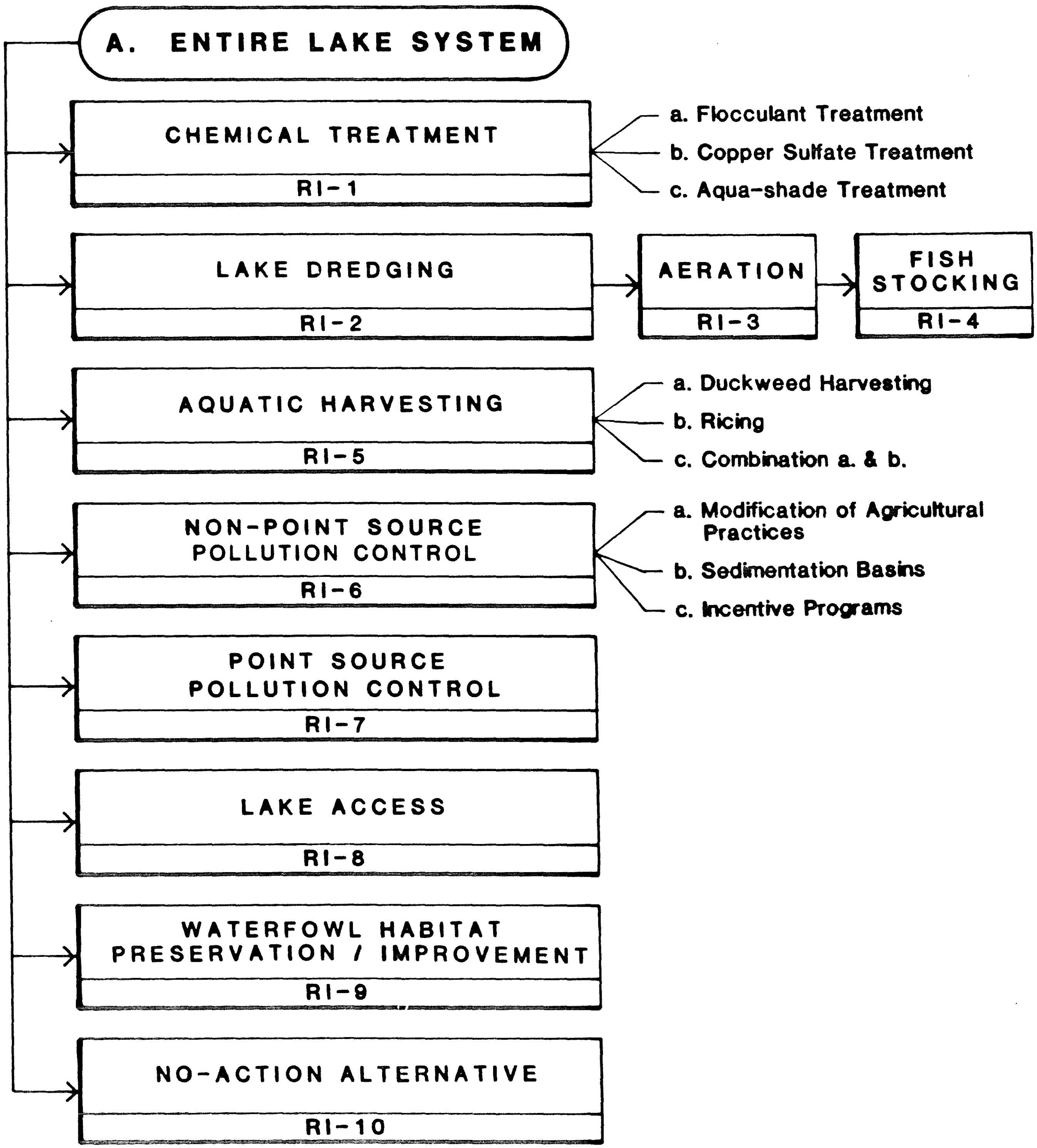


HERON LAKE
FLOOD CONTROL ALTERNATIVES



HERON LAKE
RESOURCES IMPROVEMENT ALTERNATIVES

- WATER QUALITY IMPROVEMENT
- FISHERY DEVELOPMENT
- WATERFOWL PRESERVATION/DEVELOPMENT
- LAKE USE



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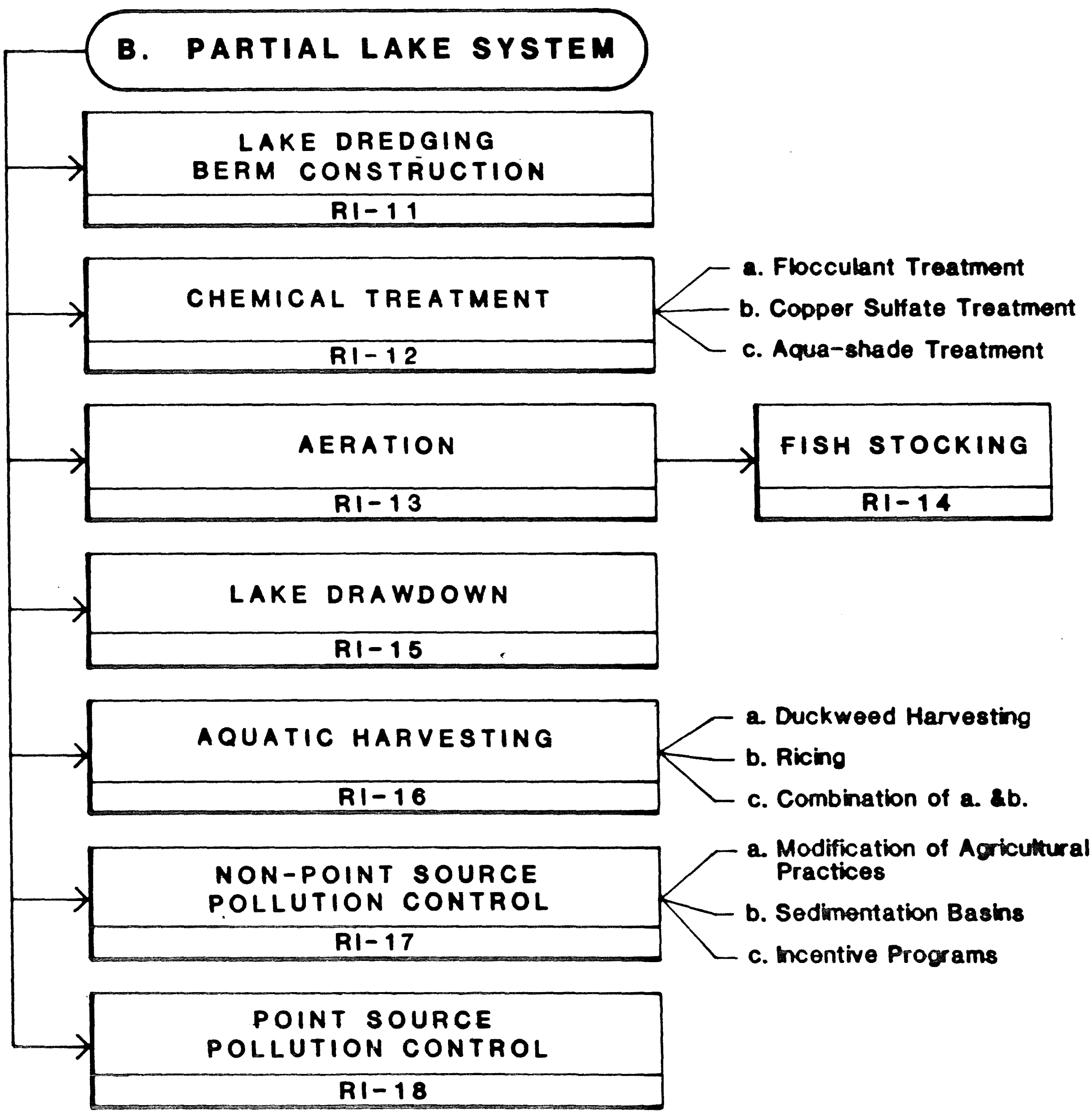


The Heron Lake System

This section of the report outlines the characteristics of the Heron Lake System including:

I. Location

II. Physical characteristics

- A. The Heron Lake System
- B. General topography & Heron Lake System Watershed
- C. Geology
- D. Climate
- E. Soils

III. Socioeconomic characteristics

- A. Land Use
- B. Population
- C. Economy
- D. Recreation

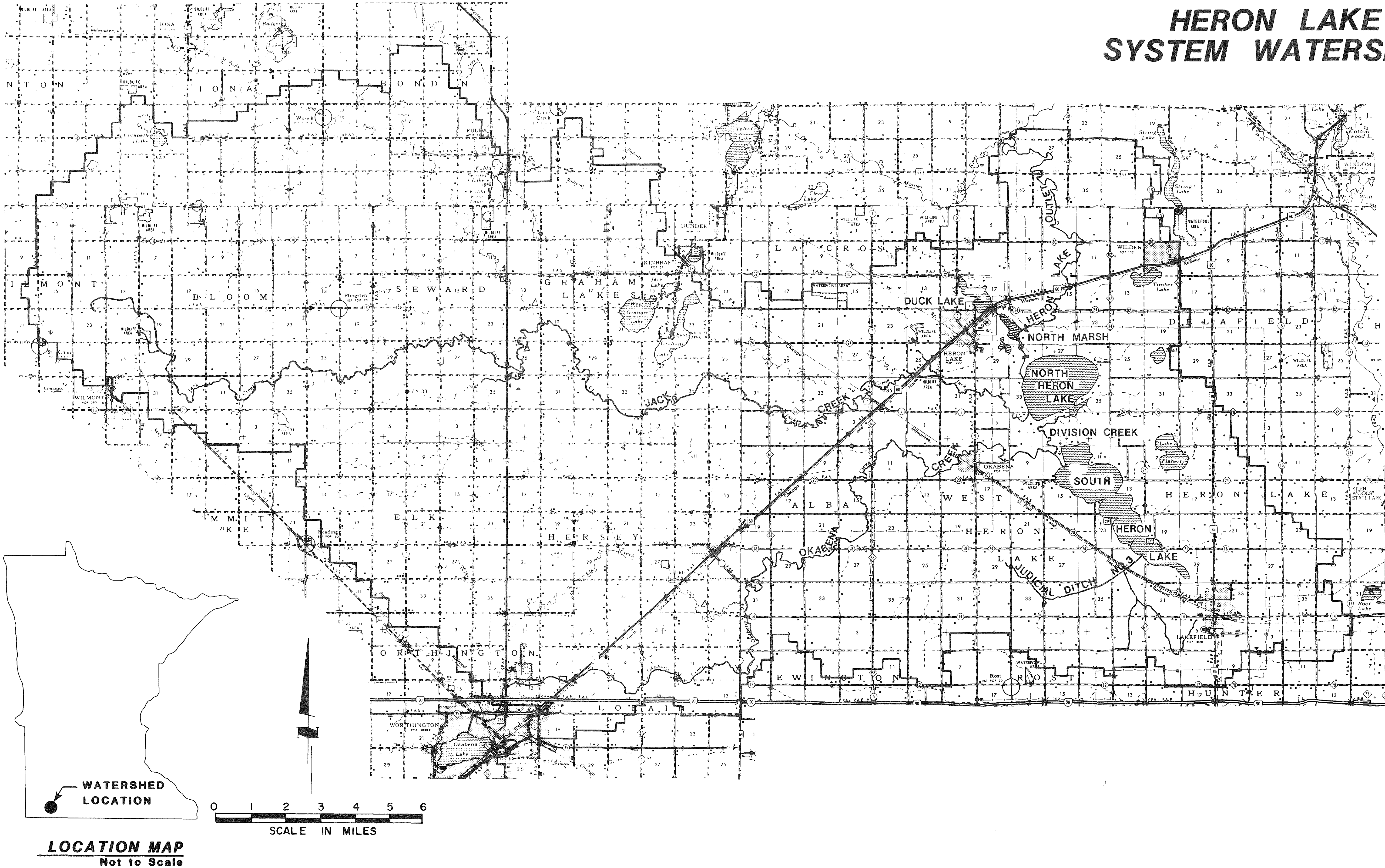
I. LOCATION

The Heron Lake system, an interconnecting group of bodies of water and marshes (North Heron Lake, South Heron Lake, North Marsh and Duck Lake) is located in Jackson County in Southwestern Minnesota, approximately 8 miles Southwest of the City of Windom.

The Heron Lake system has two major tributaries, Jack Creek and Okabena Creek, discharging directly into the lake system with a total drainage area of 453 square miles. This watershed is located in Murray, Nobles, Cottonwood and Jackson Counties. The southern-most portion of the watershed is 8-1/4 miles north of the Minnesota-Iowa border, and the most westerly portion lies 28-1/2 miles east of the Minnesota-South Dakota border.

The Heron Lake System and its drainage area are shown on Map 1.

HERON LAKE SYSTEM WATERSHED



MAP 1

II. PHYSICAL CHARACTERISTICS

A. The Heron Lake System:

The Heron Lake System, as referred to in this report, consists of North and South Heron Lakes, North Marsh and Duck Lake (Map 2).

The Heron Lake System is considered a meandered lake and the area within the meander lines (as established by the United States General Land Office) is 8251 acres (MDNR, Division of Waters, Bulletin 25). This acreage includes open water areas and surrounding marshes and swamps.

Table 1 shows the open water areas, approximate maximum and mean depths, of these bodies of water based on USGS quadrangle maps (U.S.G.S. Wilder, Minnesota, 1970, U.S.G.S. Heron Lake, Minnesota 1970, U.S.G.S. Lakefield, Minnesota, 1970) and field observations.

Table 1

OPEN WATER AREAS IN THE HERON LAKE SYSTEM

	Area (acres)	Maximum Depth (Ft)	Mean Depth (Ft)
North Heron Lake	2067	4	3
South Heron Lake	3359	5	3
North Marsh	339	2.5	1
Duck Lake	293	2.5	1
Total of Heron Lake System	6058		

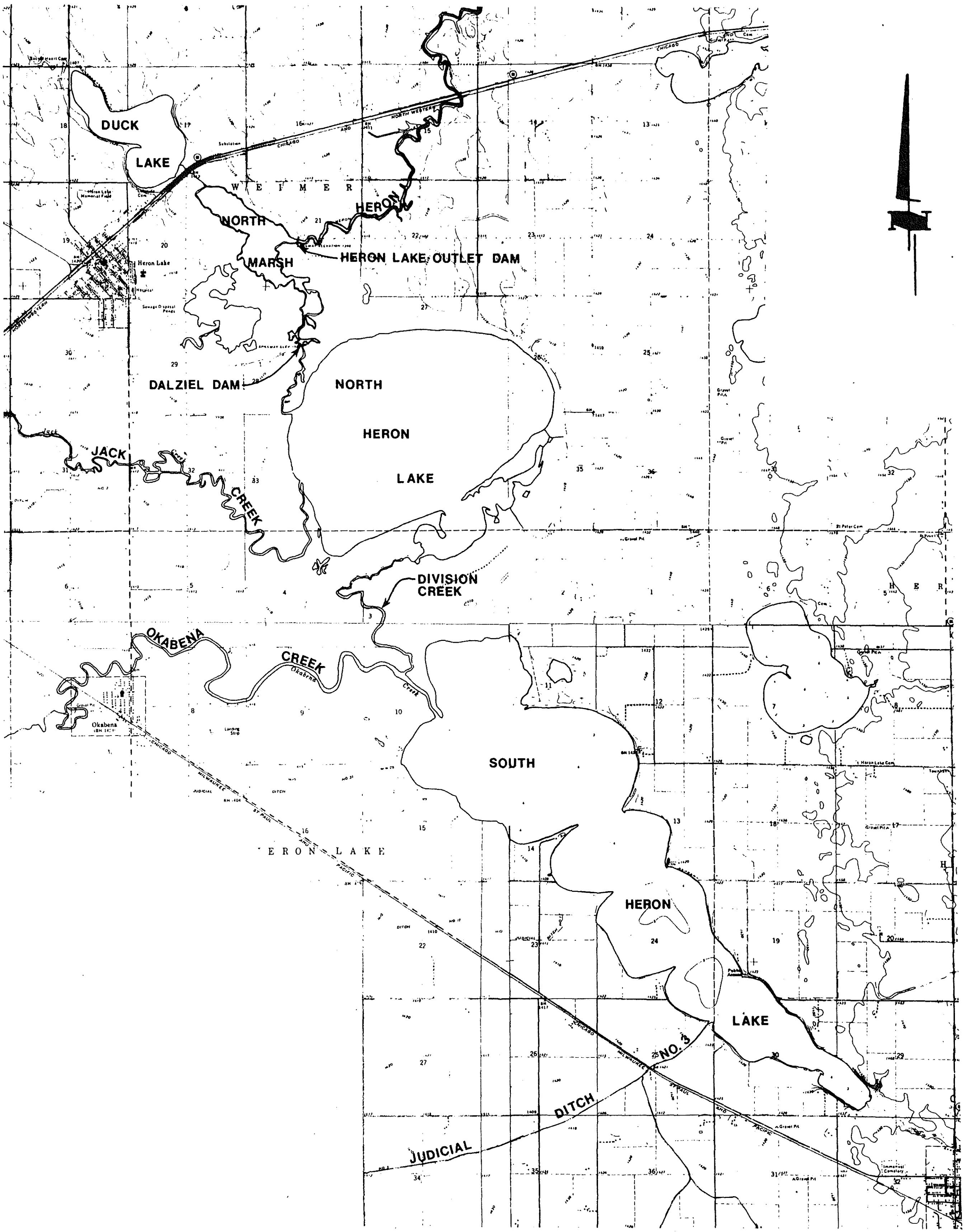
The surface areas shown in Table 1 are based on water surface elevations at the time the aerial photography for the USGS quadrangle sheets was completed (1966). It should be noted that water surface elevations (and surface areas) on the Heron Lake System vary significantly within a given year and from one year to the next. No ordinary high water mark has been established for the lake, and the areas shown in Table 1 should be considered variable.

Each of the individual basins are interconnected by a series of natural waterways. South Heron Lake interacts with North Heron Lake via Division Creek, while North Heron Lake interacts with the North Marsh via a small meandering channel. Duck Lake also interacts with the North Marsh via a small meandering channel. Outflow from the entire system is through a natural channel, the Heron Lake Outlet channel. (Map 2).

Water level on the lake system are affected by a low head dam known as the "Outlet Dam" located at the point that North Marsh discharges into the Heron Lake Outlet Channel. Another dam known as the "Dalziel Dam" is located between North Heron Lake and North Marsh. The location of these 2 structures are shown on Map 2.

During low flow conditions, the channel between Duck Lake and North Marsh frequently dries up, thus eliminating interaction with the remainder of the lake system.

The major tributaries to the Heron Lake System are Jack Creek and Okabena Creek. Jack Creek, with a drainage area of 220.5 square miles, discharges to North Heron Lake, while Okabena Creek, with a drainage area of 146.2 square miles, discharges to Division Creek. Due to the flat gradient of the lake system, Division Creek could at times flow either into North or South Heron Lake depending on the lake elevations.



MAP 2

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THE HERON LAKE SYSTEM

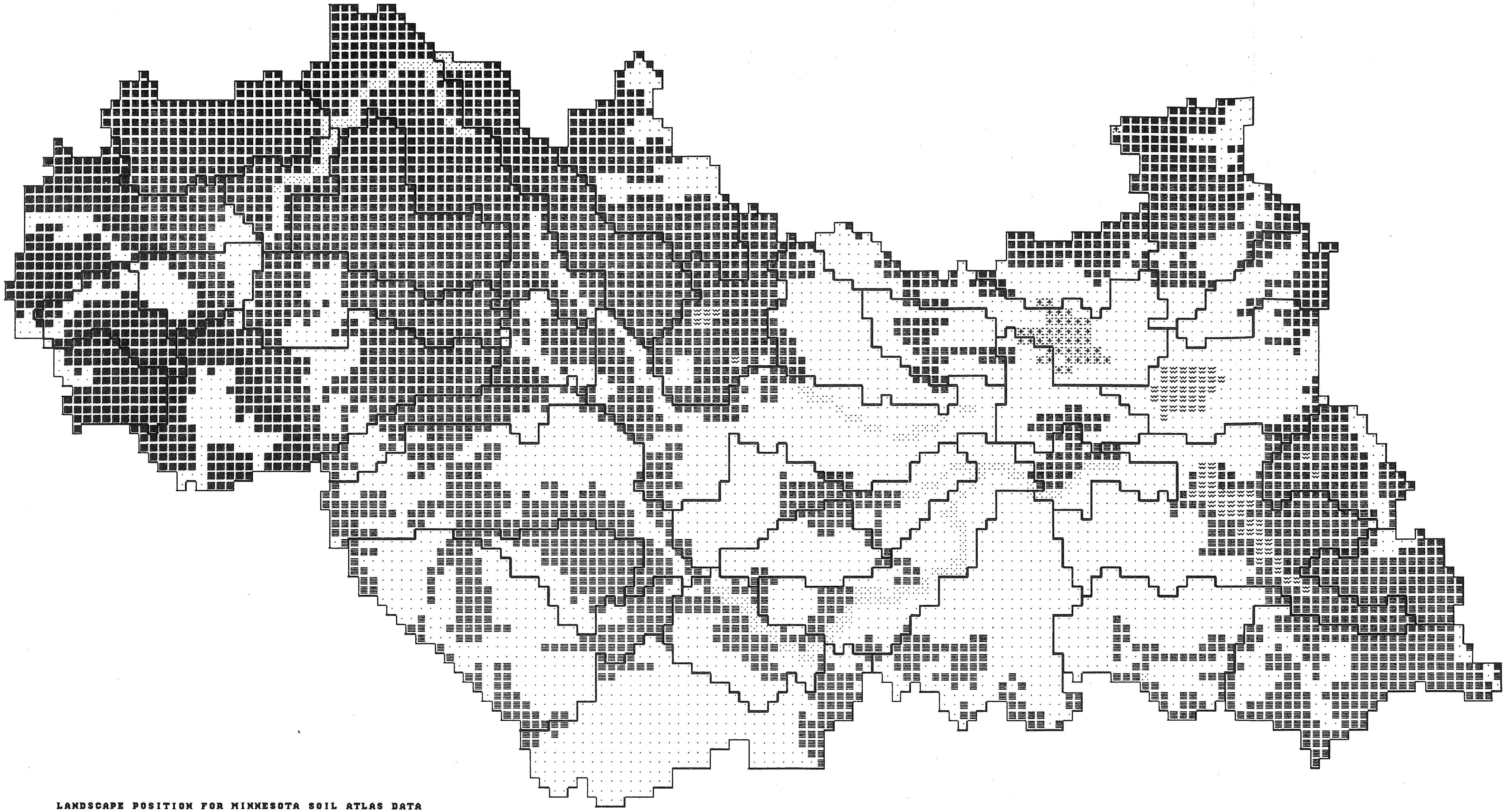
B. Topography of the Heron Lake System Watershed

Elevations within the Heron Lake System watershed range from approximately 1795 feet above Mean Sea Level (MSL) at the western end of the watershed to approximately 1370 at the confluence of the Heron Lake Outlet with the Des Moines River. Land slopes vary widely through the watershed from extremely flat or depressional in the lower portions to over 12 percent in the upland areas of the Jack Creek watershed (Map 3).

Notable differences are present between the Jack Creek and Okabena Creek watersheds (both major tributaries to the Heron Lake system). The Okabena Creek watershed in general is much flatter and has less relief than the Jack Creek watershed. Slopes are also much flatter adjacent to the larger streams.

C. Geology

The watershed of the Heron Lake System is on the Coteau des Prairies, a prominent upland area in southern Minnesota. The western edge of the watershed boundary is very well defined and was formed as a terminal morain of the Wisconsin Glaciation period. This morain serves as the boundary between the Mississippi and Missouri River basins. Surface materials are composed of deep glacial drift deposits which lie over bedrock composed of Cretaceous shales and sandstone or Sioux Quartzite.



LANDSCAPE POSITION FOR MINNESOTA SOIL ATLAS DATA

SYMBOL	COUNT	PERCENT	ACRES	LEGEND
1	119	1.6	4760.0	DEPRESSIONS (0-1 PERCENT)
2	3064	40.2	122560.0	DEPRESSIONAL TO NEARLY LEVEL (0-2 PERCENT)
3	46	0.6	1840.0	DEPRESSIONAL TO LEVEL (0-2 PERCENT)
5	141	1.8	5640.0	NEARLY LEVEL (0-2 PERCENT)
6	41	0.5	1640.0	NEARLY LEVEL TO UNDULATING (1-6 PERCENT)
9	1	0.0	40.0	NEARLY LEVEL TO GENTLY ROLLING (1-6 PERCENT)
12	3676	48.2	147040.0	UNDULATING TO GENTLY ROLLING (2-6 PERCENT)
22	465	6.1	18600.0	ROLLING TO STEEP (12-45 PERCENT)
30	76	1.0	3040.0	WATER

MAP 3

LAND SLOPES

(From Minnesota State Planning Agency, Land Management Information Center)

The depths of the glacial drift as well as the types of underlying bedrock materials may vary significantly from one end of the watershed to the other. Glacial drift thicknesses range from a minimum of 0 to 100 feet near Graham Lakes to over 600 feet in the upstream areas of the Jack Creek watershed.

Cretaceous deposits consisting primarily of shale with some sandstone is present in most of the watershed and overlies Sioux Quartzite or other crystalline rocks. This layer of Cretaceous material is absent in an area from approximately Heron Lake and extending to the northwest beyond the watershed boundaries.

D. Climate

Climatological conditions are relatively uniform throughout the watershed. Long term meteorological records are maintained for Worthington, Windom and Fairmont, Minnesota, all of which are quite close to the Heron Lake System. Average monthly precipitation and temperature from the National Weather Service station at Worthington are shown in Table 2.

TABLE 2

MEAN MONTHLY PRECIPITATION AND TEMPERATURE AT WORTHINGTON, MINNESOTA (1941 - 1970)

	Precipitation In Inches	Temperature In °F
January	0.53	12.6
February	0.81	17.1
March	1.43	27.2
April	2.18	44.1
May	3.44	56.5
June	5.01	66.3
July	3.56	71.6
August	3.28	69.8
September	3.00	59.3
October	1.68	49.0
November	0.99	32.2
December	0.70	18.9

Reference: U.S. Department of Commerce, National Oceanic and Atmospherics Adminstration, Monthly Normals of Temperature Precipitation and Heating and Cooling Degree Days 1941-70, Climatography of the United States No. 81 (Minnesota).

The climate of the Heron Lake System and its watershed can be characterized as continental with warm summers and cold winters. Approximately 90% of the precipitation falls in the period from March through October with snowfall common during the winter months.

Average annual precipitation increases from a minimum of about 25.5 inches in the western part of the watershed to about 27 inches in the eastern part. This slight general increase from west to east is also exhibited in rainfall during individual storms. Mean annual temperatures also increase slightly from west to east.

E. Soils

Soils within the watershed contributing to the Heron Lake System are largely dark, heavy textured soils that are fairly well suited to crop production. Upland areas are typically well drained, loamy soils while areas adjacent to larger tributaries tend to be more poorly drained. In the vicinity of Heron Lake, the soils in general have a heavier clay texture than the loamy texture in the upland areas. The soils in this area tend to be poorly drained.

Marshes are also present, in the vicinity of North Heron Lake. Upland areas may contain small areas of marshy or very poorly drained soil in natural depressions. Soil types common in the watershed include Webster, Nicollet, Clarion, Waldorf, and Collinwood (MDNR file report).

Geomorphic regions are composed of the Blue Earth till plain in the eastern portion, the Ivanhoe-Worthington Coteau in the central portion and the lake Benton-Adrian Coteau in the extreme western portion of the watershed (University of Minnesota, Soil Science Department, Minnesota Soil Atlas, New Ulm Sheet).

III. SOCIOECONOMIC CHARACTERISTICS

A. Land Use

Most of the land within the Watershed of the Heron Lake System was originally a combination of native prairie and natural wetland areas. With increased population, the area was subjected to increased development to the extent that agricultural activities are now the predominant land use.

In conjunction with agricultural development, drainage practices has eliminated most of the natural wetlands in the area. Relatively small areas are also used for farmsteads, roads and urban or residential development. An estimated breakdown of the present land use is shown in Table 3.

TABLE 3

LAND USE IN THE WATERSHED
OF THE
HERON LAKE SYSTEM

(Adapted From MDNR Open File Report 1981)

Category	Percentage
Cropland	86
Pasture/Waterways	5
Lake/Wetlands	2
Farmstead	2
Urban/Roads	5

B. Population

The watershed of the Heron Lake System is located largely in Jackson and Nobles County with portions extending into Murray and Cottonwood Counties. The Cities of Lakefield, Okabena, Heron Lake, Wilder and Brewster are entirely within the watershed. The Cities of Worthington, Kinbrae, Fulda and Wilmont are partially within the watershed.

Exact populations within the boundaries of this watershed were not determined, however there appears to be a slight decline in population in recent years. Table 4 itemizes the populations of the counties and cities in this watershed.

TABLE 4

POPULATIONS OF WATERSHED AREAS

(U.S. Department of Commerce, Bureau of the Census, 1980 Census of Population and Housing, PHC 80-P-25, Minnesota)

Area	Population 1980	Population 1970	% Change
Jackson County*	13,690	14,352	- 4.6
Nobles County*	21,840	23,208	- 5.9
Murray County*	11,507	12,508	- 8.0
Cottonwood County*	14,854	14,887	- 0.2
City of Lakefield	1,845	1,820	1.4
City of Okabena	263	237	11.0
City of Heron Lake	783	777	0.8
City of Wilder	120	132	- 9.1
City of Brewster	559	563	- 0.7
City of Worthington*	10,243	9,916	3.3
City of Kinbrae*	40	37	8.1
City of Fulda*	1,308	1,226	6.7
City of Wilmont*	380	390	- 2.6

* Partially within watershed.

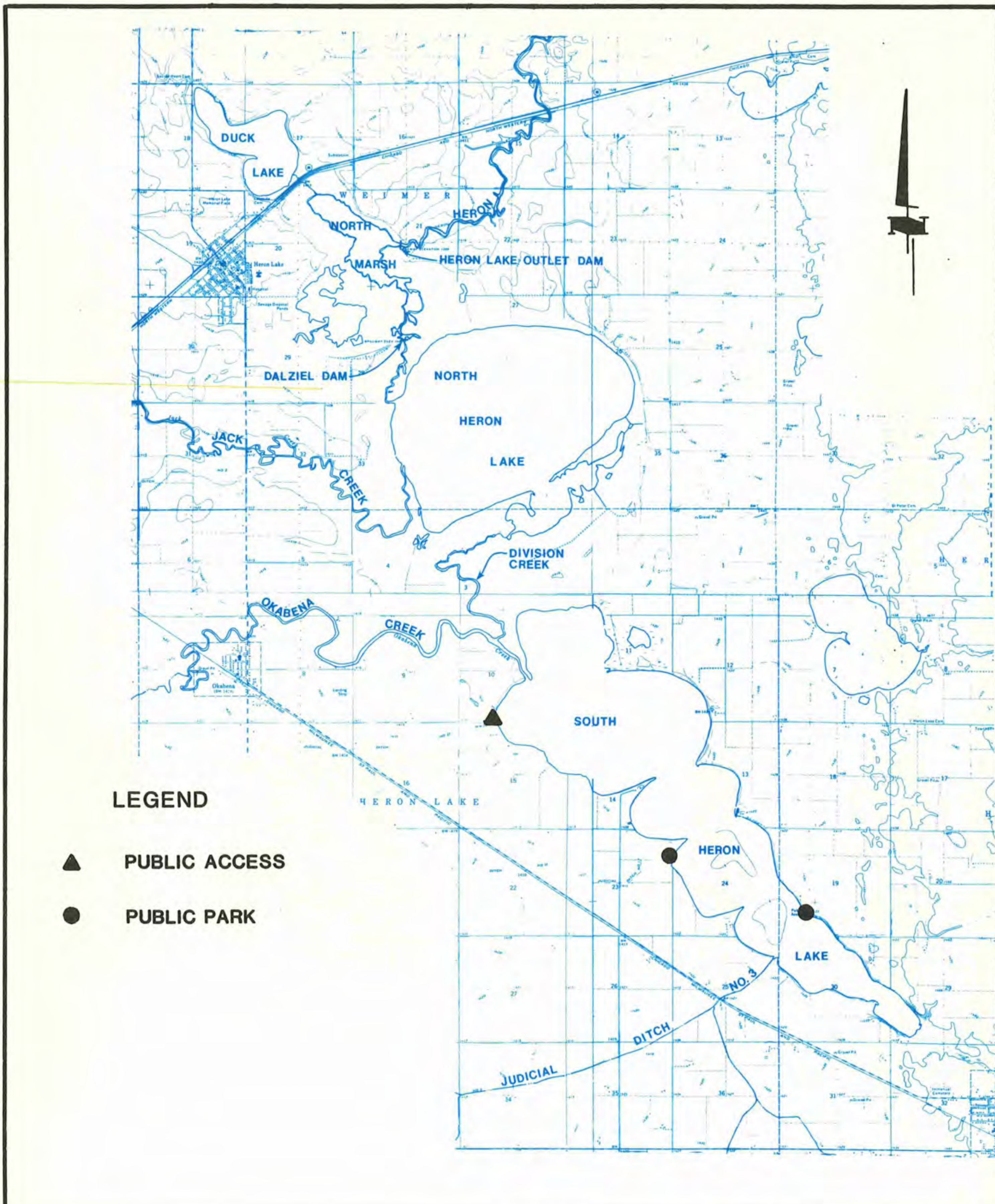
C. Economy

The economy of the Middle Des Moines Watershed District is dominated by agriculture with approximately 90% of its lands devoted to that purpose. Several small towns are present in the watershed which serve the agricultural community.

The primary crops grown are corn, soybeans and to a lesser extent various small grains. Livestock production is composed primarily of beef cattle and hogs.

D. Recreation Around The Heron Lake Area

Recreational opportunities, with the exception of waterfowl hunting, are limited in the area. Duck and goose hunting has been extremely popular around the Heron Lake system for over a century. The Heron Lake system is used for fishing by a limited number of people. Other water based recreation such as swimming or boating is not common in Heron Lake System. Locations of public parks and accesses on the Heron Lake System are shown on Map 4.



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MAP 4
HERON LAKE SYSTEM
PARKS AND PUBLIC ACCESSES

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Land & Water Resource Problems

I. BACKGROUND

Problems in and around the Heron Lake System have been a continuing source of concern and controversy since the turn of the century. Local concerned residents have been repeatedly at odds with each other and with the Minnesota DNR regarding the management of the lake system elevations and land & water resources.

A. History

- 1907 - 1923: The history of the issues behind the Heron Lake System and its tributaries, Jack Creek and Okabena Creek, began with the public expressing concerns about flooding of agricultural lands around Heron Lake and next the areas adjacent to Jack & Okabena Creeks. Other citizens of the watershed expressed concern about fish and waterfowl habitats.

- 1931 - 1937 In 1931 citizens petitioned the Jackson County Board to establish water levels for both North Heron Lake and South Heron Lake. This petition arose from concerns over past flooding and uncertainty about the best lake levels. The Jackson County Board on November 3, 1931 adopted a resolution to investigate water levels on both lakes. On July 12, 1932 Mr. A. E. Wallace recommended that the water level for South Heron Lake be 1400.8 and the water level for North Heron Lake be 1399.6. These elevations reflect the National Geodetic Vertical Datum (NGVD) of 1929. The Jackson County Board adopted a resolution on August 12, 1932, to accept the findings of Mr. Wallace.

  After the adoption of this resolution, temporary dams were built at the outlet of the Heron Lake System and between the north and south lakes. The dam at the outlet of the Heron Lake System was made of loose rock, 175 feet long, with a crest elevation of 1398.8 (NGVD-1929). A temporary dam of wood and sheet piling with a crest of 1401 (NGVD-1929) was constructed in Division Creek between North Heron Lake and South Heron Lake. The Minnesota State Emergency Relief Administration received plans and specifications in January 1935 for permanent dams on both lakes from a consulting hydraulic engineer. The Jackson County Board adopted these resolutions on February 6, 1936: to cooperate fully with the state agencies and federal agencies for constructing the dams, and to operate and maintain the dams in perpetuity. Construction of the existing Heron Lake outlet dam began in January 1937 and it was completed in June, 1937. The proposed South Heron Lake dam was not built at this time due to unfavorable soils at the site.

. 1940 - 1969

During November 1940, Mr. J. Dalziel submitted a permit application and received approval for a dam between North Heron Lake and North Marsh.

During the 1940's, questions arose about the best elevations for the Heron Lake System. Since North Heron Outlet Dam controls the level of the North Marsh, the dam became the center of controversy. Despite the 1936 resolution of the Jackson County Board to maintain the dam in perpetuity, unauthorized tampering of the stoplogs at the dam began. The Division of Waters wedged wooden stoplogs in all nineteen bays of the dam to a crest elevation of 1399.3 (NGVD-1929) during August, 1947. Tampering with the stoplogs at the dam continued. To prevent tampering with the dam, the Division of Waters installed concrete stoplogs in each bay of the dam to a crest elevation of 1399.3 in November, 1956. Because of continued flooding of farm land adjacent to the Heron Lake System and Okabena Creek, farmers appealed to the local leaders of the Soil and Water Conservation Districts for inspection an study. In 1966, local governments supported three applications for Public Law 566, Watershed Protection and Flood Protection Act, for Heron Lake Watershed, Jack Creek Watershed, and Okabena Creek Watershed. During December, 1967 the Division of Waters installed permanent galvanized steel plates in each of the nineteen bays of the dam to a crest elevation of 1399.3. During 1968 and 1969 greater than normal precipitation fell over the Heron Lake Watershed, causing higher lake levels on the Heron Lake System. On March 14, 1969 citizens met with the Division of Waters to disçuss high waters on the lakes and to request removal of the stoplogs in the outlet dam. The Division of Waters stated that the outlet channel, downstream of the dam, controls the high water levels in the lakes. Also, the Division of Waters recommended a need for a comprehensive water management plan.

Neither party agreed to any resolution for the Heron Lake System. On May 14, 1969 the Division of Waters inspected and found the outlet dam in good condition, however on June 5 they found that steel plates had been removed from two bays. A severe rainstorm dropped 11.8 inches at Worthington and 6.09 inches at Windom on June 29, 1969. On July 2 the water elevation at the dam rose to 1406.5. Again, citizens of the watershed and representatives of the Division of Waters toured the watershed and damsite; they made no resolution concerning flooding on the lake system. The stoplogs and piers for bays two through six were destroyed by explosives on September 1, 1969. A local hunting club installed temporary power line poles in the damaged bays on September 11 with the approval of the Division of Waters.

. 1973 - 1981 On October 5, 1973 North and South Heron Lake were declared Waterfowl Lakes by Commissioners Order 1894. Subsequent to this declaration, the Minnesota Department of Natural Rsources Division of Fish and Wildlife developed plans calling for the construction of various channels and structural measures to draw down the water levels of the lakes about 2.5 to 3 feet once every 7 to 10 years.

In order to accomplish the periodic drawdowns, it was proposed to repair and modify the North Marsh outlet dam, to make a 5000' channel with a dam between the North Marsh and North Heron Lake, to make 1350' of channel with a dam between the North and South Lakes and to deepen 4900' of Division Creek between the two lakes.

Because the project makes changes in public waters of the State, it required a permit from the DNR. Such permit was issued in January 1979, but was voided by a request for public hearing filed with the Commissioner of Natural Resources by the Middle Des Moines Watershed District. The overall issue for the hearing was whether the proposal was reasonable, practical, and adequately protected public safety and promoted the public welfare, including whether the project would have material adverse effect on the environment, and if so whether there was a feasible and prudent alternative.

The hearing was held on June 19, 1979 in Heron Lake, Minnesota. A considerable amount of public opposition was raised at the hearing and the proposed project was not implemented. A portion of the funding originally appropriated for construction of the proposed project was reappropriated by Laws 1980, Chapter 614, Section 16(c) for the study which results in this report.

B. Issues

Land & Water Resources Issues for the Heron Lake System affect local farmers, concerned citizens, hunters, local management entities and State

Regulatory Agencies. In general, the problems fall into four (4) categories:

1. Flooding and Lake Levels
2. Water Quality and Other Environmental Concerns
3. Lake Use
4. Erosion and Sedimentation

1. <u>Flooding & Lake Levels</u>:

    a. Outlet Dam
    b. Dalziel Dam
    c. Encroachments on Lake Bed

2. <u>Water Quality and Other Environmental Concerns</u>

    a. Lake Degradation
    b. Stream Degradation
    c. Waterfowl Habitat
    d. Fisheries Resources Development

3. <u>Lake Use</u>:

    a. Access
    b. Public versus Private Rights

4. <u>Erosion and Sedimentation</u>

    a. Lake Sedimentation
    b. Stream Bank Erosion

II. FLOODING PROBLEMS

A. Problem History

Since the turn of the century, flooding and lake levels have been the most controversial issue to the Heron Lake System. Excessive runoff has continuously caused flooding to agricultural land adjacent to the lakes. After the Jackson County Board adopted lake levels in 1932, citizens still questioned the validity of those elevations. Also, numerous people remain uncertain about the effects of both the outlet channel, North Heron Lake Dam and Dalziel Dam on the lake system.

Several severe floods have occurred on the Heron Lake System in recent years as shown below:

TABLE 5

FLOOD ELEVATIONS RECORDED ON HERON LAKE SYSTEM
(MDNR Open File Information)

	North Heron Lake Dam	North Heron Lake	South Heron Lake
July 2, 1969	1406.5	No Data	No Data
April 18, 1975	No Data	1402.84	1403.54
July 10, 1978	No Data	No Data	1404.12
March 30, 1979	No Data	No Data	1405.82
May 8, 1979	No Data	1402.95	1403.64
May 14, 1979	No Data	No Data	1405.12

B. Controlling Structures and Lake Encroachments

The Minnesota DNR conducted a hydraulic study of the Heron Lake Outlet Dam in 1979. The ensueing results showed that the dam does not have any controlling effect on the outflow of Heron Lake at high floods. The control was determined to be in the outlet channel connecting the Heron Lake System to the Middle Des Moines River.

Similarly, the Dalziel Dam does not control the outflow rate of Heron Lake; therefore, both of these structures' main function is to maintain the lake system at the elevation of their crests during low flow periods.

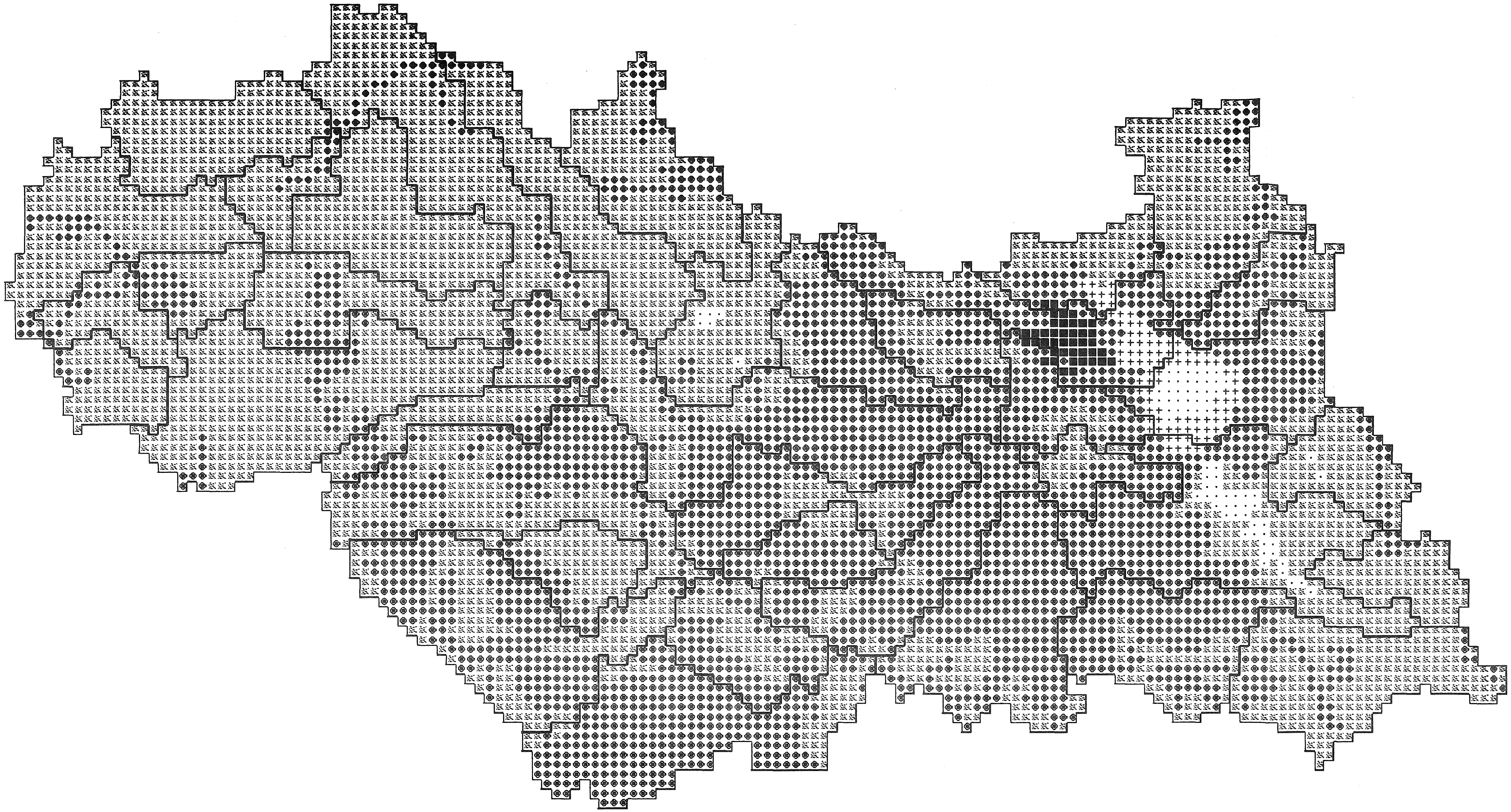
In addition, there have been apparent encroachments into the lake bed over the years; however, the lack of an official Ordinary High Water Mark for the lake system prevents an accurate assessment of this problem.

C. HYDROLOGIC COMPUTER ANALYSIS

An analysis of flood elevations was made with the Corps of Engineers HEC-1 computer program. Based on topography, drainage area characteristics and restrictions such as roads or culverts, the area contributing to the Heron Lake System was divided into subwatersheds. Based on physical conditions of each subwatershed, runoff rates and timing are determined and added together to determine the net inflow to the Heron Lake System.

Drainage areas, channel lengths and slope and other characteristics were determined from USGS quadrangle maps. Soil characteristics were considered with the U.S. Soil Conservation Service Curve Number (CN) method (USDA - SCS NEH 4). This method gives an indication of runoff potential of a given soil and land use. Hydrological soil groups for the Heron Lake System Watershed were determined by the Minnesota State Planning Agency, Land Management Information Center (Map 5).

The hydrologic computer model was calibrated by comparing its results for the June 1969 flood with observed elevations at the North Heron Lake Dam. The peak elevation reported was 1406.5 (NGVD - 1929) while the result of the hydrologic model was 1406.8. It should be noted that this is a summer flood. In a large watershed such as this, severe flooding events are more likely to occur during the spring as a result of a combination of snowmelt and rainfall. There was insufficient information to determine a snowmelt runoff rate and thus the hydrologic model remains uncalibrated for spring floods. Spring floods were analyzed by using the runoff rate curve recommended by the Soil Conservation Service for 10 day runoff events (USDA - SCS NEH 4). This runoff distribution is mainly used for design purposes, and as a result, the



SYMBOL	COUNT	PERCENT	ACRES	LEGEND
1	4230	55.4	169200.0	GROUP B
2	41	0.5	1640.0	GROUP C
3	3192	41.8	127680.0	GROUPS WITH A HIGH WATER TABLE
4	90	1.2	3600.0	NO RATING
5	76	1.0	3040.0	WATER

MAP 5

HYDROLOGIC SOIL GROUP

(From Minnesota State Planning Agency, Land Management Information Center) elevations indicated may be higher than those which would actually occur for a flood of a given frequency. The hydrologic analysis provides the following results for various frequency floods:

TABLE 6

RUNOFF AND PEAK ELEVATION FOR THE HERON LAKE SYSTEM

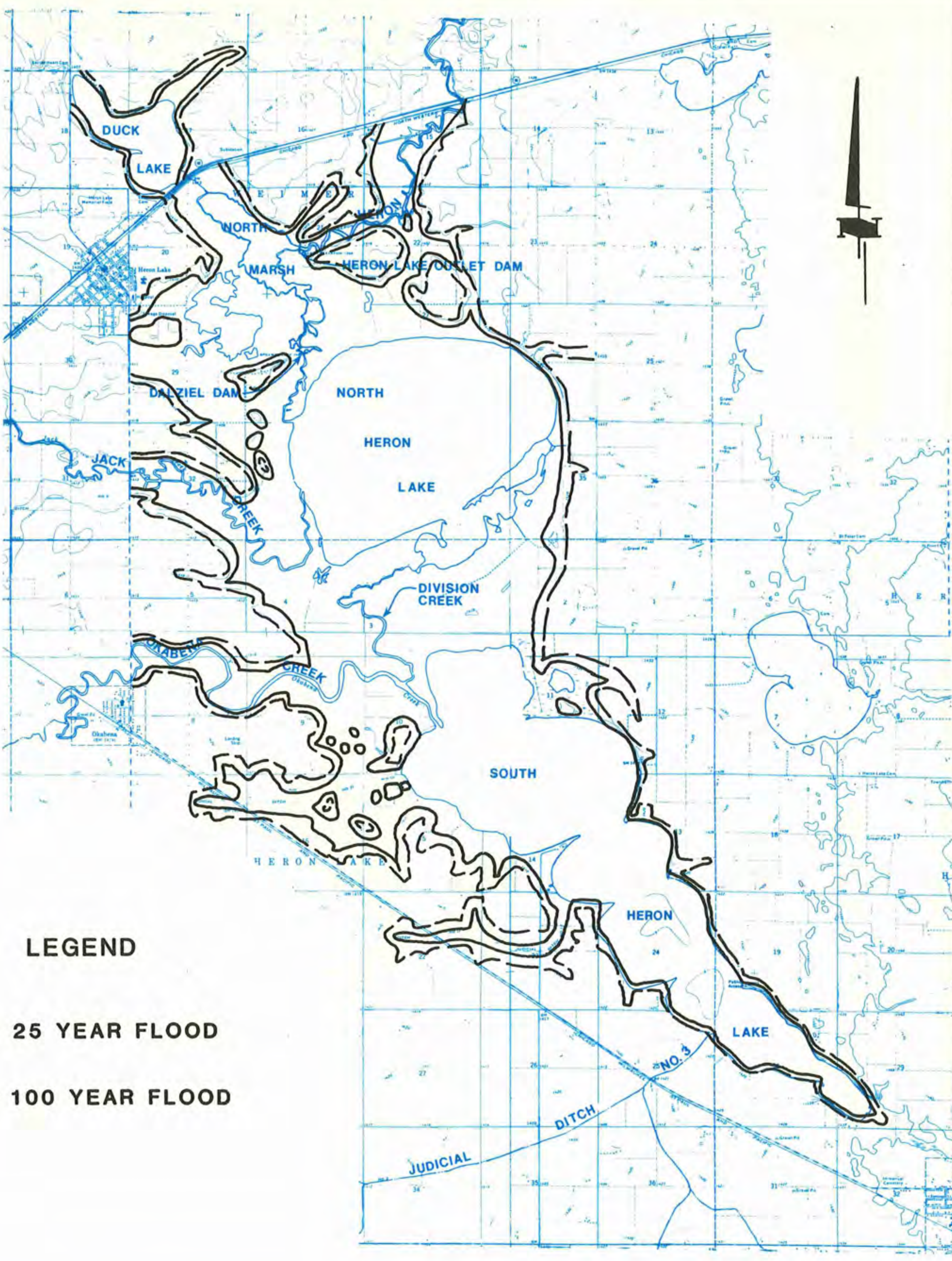
Flood Frequency, Years	Runoff Depth, Inches	Runoff Volume, Acre Feet	Peak Elevation
100	6.0	146,200	1410.6
50	5.4	131,600	1409.7
25	4.8	117,000	1408.9
10	4.1	99,900	1407.9

Results of this hydrologic analysis for the Heron Lake System are shown on Map 5A, (Flood Boundaries for Existing Conditions) and Figure 1, lake elevation versus area flooded.

It should be re-emphasized that the above results are on the conservative side and may be much higher than actual values. In addition, it was assumed in this analysis that the lake elevations in different bodies of water in the lake system were the same at any given time during a flood.

Flooding problems are also prevalent in the lower reaches of Jack Creek and Okabena Creek adjacent to the Heron Lake System. This is due to the large drainage areas of the tributaries and tailwater effects of the Heron Lake System.

The flow distribution of Jack and Okabena Creek on the 100 year, 10 day snowmelt flood is illustrated on Figure 2.



LEGEND

——— 25 YEAR FLOOD

– – – – 100 YEAR FLOOD

MAP 5A

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FLOOD BOUNDARIES FOR EXISTING CONDITIONS

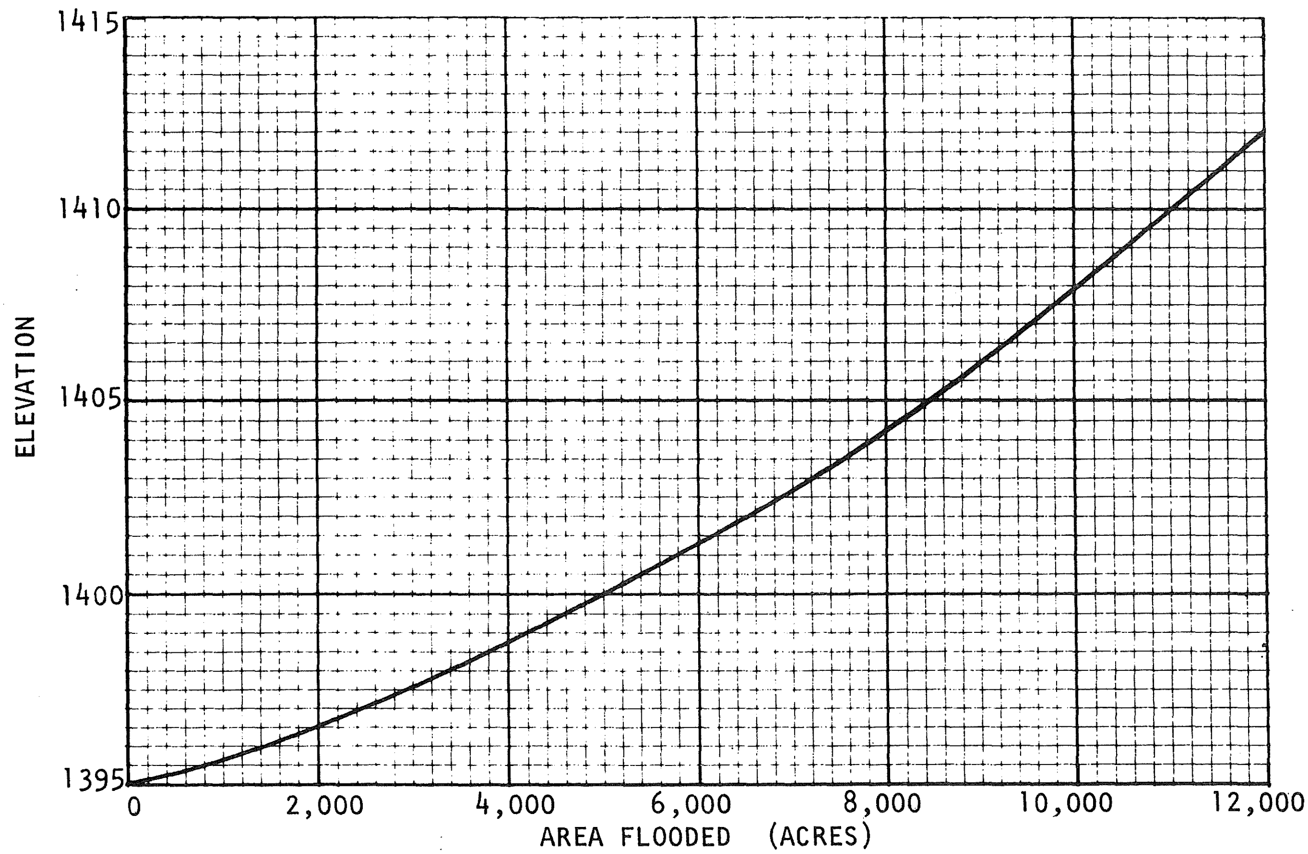

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FIGURE 1
HERON LAKE SYSTEM
ELEVATION-AREA FLOODED

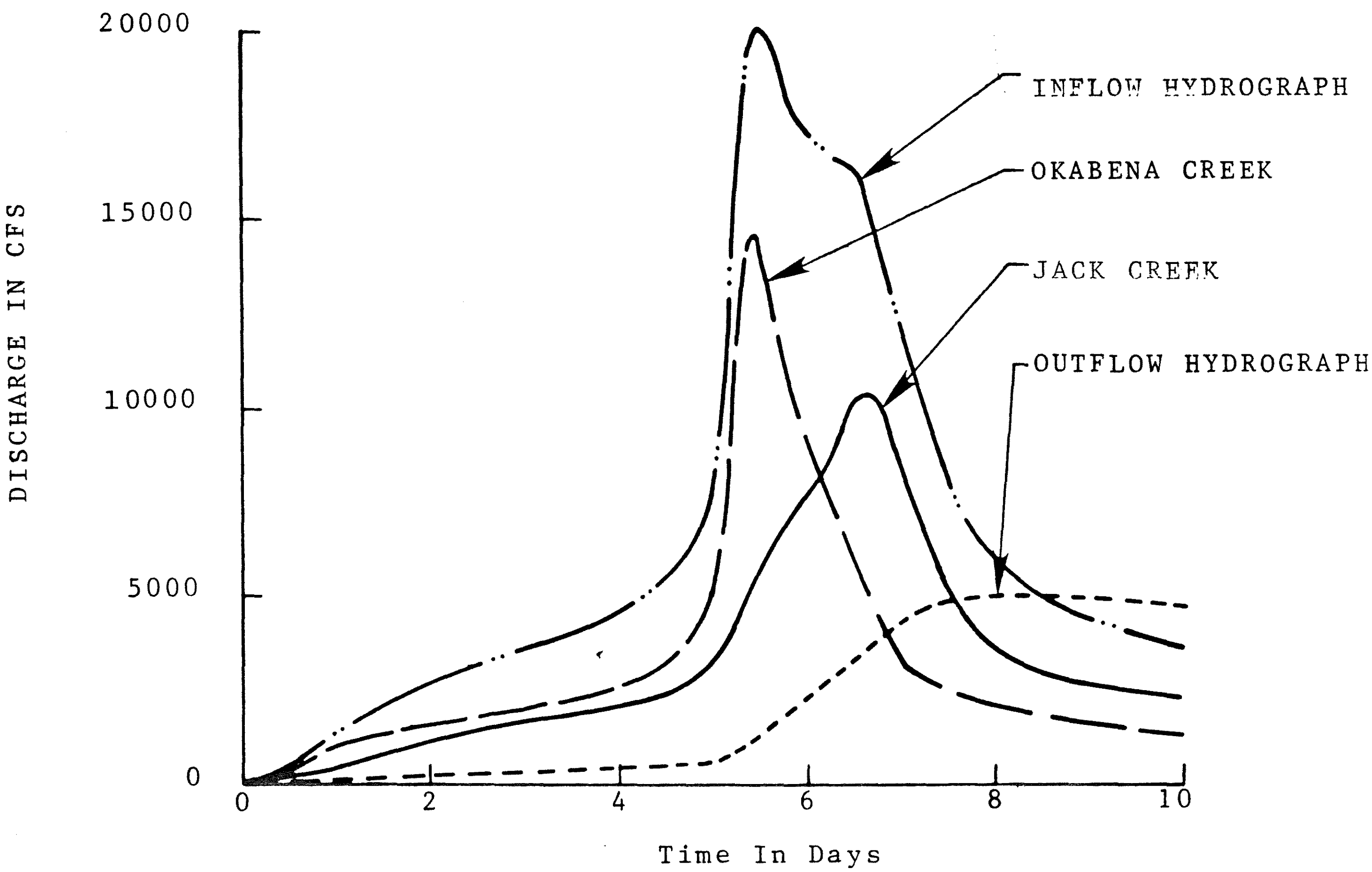

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FIGURE 2
100 YR., 10 DAY SNOWMELT HYDROGRAPH

III. ENVIRONMENTAL CONCERNS

Water quality and related environmental problems are closely intertwined with the other resources and are one of primary considerations in this study. Three main areas of concern were identified and included the following:

A. Water Quality
B. Nutrient Loading
C. Aquatic Biology (Algae & Zooplankton)
D. Fish & Waterfowl

Problems in each of these areas were examined through the use of appropriate testing methods, and analyzed to determine their role in and effect on the Heron Lake System.

A. Water Quality

1. Sampling Regime

    1A. Sample sites
    1B. Sample dates
    1C. Sample type and treatment
    1D. Test parameters

2. Data Presentation and Interpretation

    2A. General presentation notes
    2B. Limitations
    2C. Discussion of water parameters

1. Sampling Regime

1A. Sample Sites: The sampling network for the Heron Lake watershed consisted of nineteen stream sample points and six lake sample points (see Map 6 for location of sample points). The stream sites were selected to determine the contribution of water from all reaches of the watershed on the water quality in the lakes. Lake sites were selected to monitor the conditions in North and South Heron Lake, the North Marsh, and Duck Lake.

1B. Sample Dates: Water samples were taken biweekly, once in July, twice in August, September and October, and once in November of 1981. One winter sample run was performed and sediment samples were taken from the lakes once a month from July through September of 1981.

One sampling period is planned for April 1982 to verify nutrient loading for spring runoff conditions. A 36" core sample was taken on February 4, 1982, the results of which were not available at the time of this report.

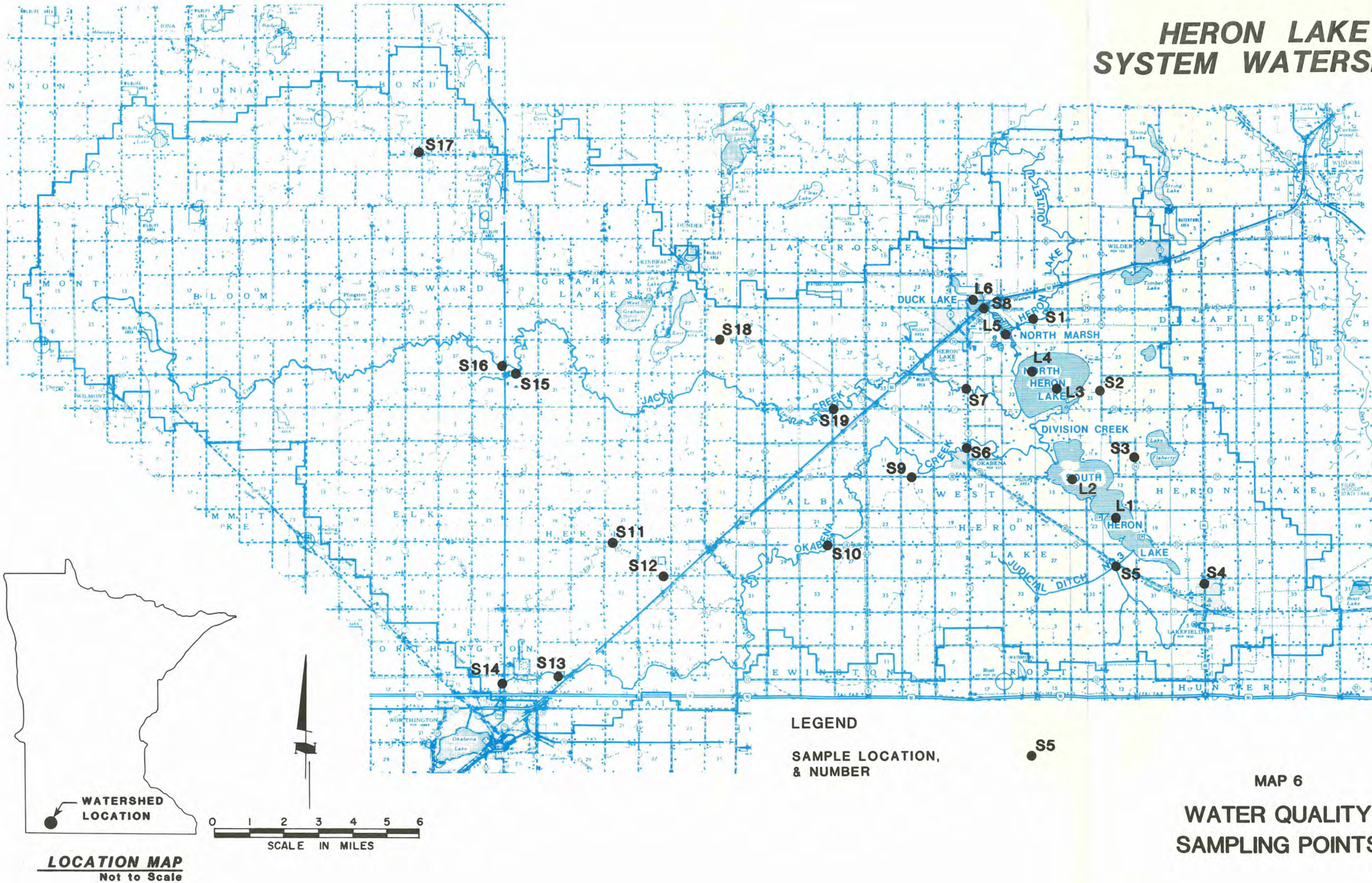
TABLE 7

HERON LAKE WATER QUALITY SAMPLING SCHEDULE

	Sample Type Collected		
Sample Date	Lake Water Samples*	Stream Water Samples*	Lake Sediment Samples*
July 27-28, 1981	X	X	X
August 11-12, 1981	X	X	
August 25-26, 1981	X	X	X
September 15-16, 1981	X	X	
September 29-30, 1981	X	X	X
October 13-14, 1981		X	
October 27-28, 1981	X	X	
November 17-18, 1981	L3 only	X	
February 4-5, 1982	X	S6 & S7 only	

* Lake water samples L1 through L6
Stream water samples S1 through S19
Lake sediment samples L1 through L6

HERON LAKE SYSTEM WATERSHED



MAP 6

WATER QUALITY SAMPLING POINTS

1C. Sample Type and Treatment: Samples taken for this study were exclusively grab samples. The collection of composite and/or integrated samples was unnecessary because of the low flow velocities and the shallowness of the waters tested.

All water samples were stored in two liter polyethylene sample bottles and packed in ice for transport to the Twin Cities. Every effort was made to insure that no more than 48 hours elapsed from the time the sample was collected to the time it was tested.

Sediment samples were stored in 100ml polyethylene sample bottles and refrigerated (0°C) for testing at a later date.

1D. Test Parameters: Both the lakes and streams were tested for a variety of parameters listed on Table 8.

2. Data Presentation and Interpretation

2A. General Data Information: Results obtained from the sample analysis were compiled and reviewed to form a composite representation of the 1981 summer and 1981-82 winter water quality conditions in Heron Lake. In an effort to summarize all the information collected, selected data from the Lake System (North and South Heron, the North Marsh and Duck Lake), Okabena Creek, and Jack Creek was averaged over the testing period. Sample runs yielding data judged to distort the average were omitted. (Omitted data for the Lake System are discussed in the text, as extremes often signal significant changes in lake dynamics).

TABLE 8

HERON LAKE WATER QUALITY STUDY
TEST PARAMETERS

Parameter	Sample Type Collected: Lake Water Sample	Stream Water Sample	Lake Sediment Sample
Dissolved Oxygen (DO)	X	X	
pH	X	X	
Air Temperature	X	X	
Water Temperature	X	X	
Flow (cfs)		X	
Turbidity (Secchi Disc)	X		
Biological Oxygen Demand (BOD)	X	X	
Total Phosphorus (T(PO4)-P)	X	X	X
Ortho-Phosphorus (O(PO4)-P)	X	X	
Nonfilterable Phosphorus (nf(PO-4)-P)	X	X	
Nitrate (NO3-N)	X	X	
Nitrite (NO2-N)	X	X	
Ammonia (NH3-N)	X	X	X
Total Alkalinity (T ALK)	X	X	
Arsenic	X	X	
Total Solids	X	X	
Chlorophyll a	X		
Zooplankton Analysis	X		
Phytoplanton Analysis	X		
Filterable Solids		X	
Chloride		X	X
Sulfate		X	X
% Water			X
Organic Nitrogen			X

Due to the excessive eutrophication present in Heron Lake, test results from July 27 to October 29, 1981 represent similar conditions and are therefore considered as one time period. Indications from data in October, 1981 suggest that true "fall" conditions began in early to middle November. Data collected for this study cannot verify this assumption. Only one sample was taken from the lake in November and a major storm was in progress at that time.

While reviewing the data collected for this report, it is important to note that the early portion of the summer of 1981 was quite dry. The data may reflect worse-than-normal conditions for the Heron Lake System. In summary, sampling period fell in a relatively dry year and may not be representative of long term conditions.

Several references to eutrophication and lake types are made in this report. To aid in the understanding of these terms a brief treatment of each is included here.

Eutrophication is the enrichment of a body of water with nutrients, such as phosphorus and nitrates, that promote biological productivity. As a lake ages, it gradually fills in and the nutrient concentrations of its waters increase. Although this process of eutrophication is a natural one, it can be and often is accelerated by the activities of man.

There are three basic types of lakes to consider; oligotrophic lakes, mesotrophic lakes and eutrophic lakes. Oligotrophic waters have low nutrient concentrations, eutrophic waters are quite high in nutrients and mesotrophic water falls somewhere between these two extremes. The following table lists some features characteristic of oligotrophy and eutrophy.

TABLE 8A

Oligotrophy	Eutrophy
. Deep and steep-banked	. Shallow, broad peripheral plant zone.
. Blue or green water, marked transparency	. Green to yellow or brownish green; limited transparency
. Water poor in plant nutrients	. Plant nutrients abundant
. Oxygen abundant at all levels at all times	. Oxygen depleted in summer lower waters
. Large aquatic plants limited	. Large aquatic plants abundant
. Phytoplankton (algae) quantitatively poor	. Abundant phytoplankton (algae), mass great
. Water blooms of bluegreen algae lacking	. Water blooms common

2B. Limitations: Due to insufficient assistance from federal sources the water quality program for this study was much reduced in scope from the originally proposed by the consultants. As a result the following limitations apply to the interpretation of test data:

- Diurnal fluxes (variations of water quality in a 24-hour period) in the waters tested may account for variations in reported water quality values for this study period.
- Invertebrate populations (i.e. crustaceans and insects) which can be helpful indicators of water quality were not considered in this study.
- Wildlife populations were not considered in this study.

Addition limitations unrelated to funding limitations are as follows:

- Past records of water quality in Heron Lake are limited, making average conditions difficult to predict.

- Absence of past Spring data limits the accuracy of loading estimates and inferences made from these loadings. The upcoming Spring '82* sampling run may therefore modify some portions of this report.

- Jack Creek and Okabena Creek, due to the size of their drainage areas, are complex systems. While sections of these streams affected by major point source pollution can be identified by this study, other smaller sources went undetected. Complete analysis of these stream systems is beyond the scope of this study.

2C. Discussion of Water Parameters:

a. Dissolved Oxygen
b. Biochemical Oxygen Demand
c. pH
d. Phosphorus
e. Nitrogen
f. Total Alkalinity
g. Transparency
h. Chlorophyll a

This portion of the Water Quality Section is devoted to the description, presentation and interpretation of the above test parameters with emphasis on the Heron Lake System:

a. <u>DISSOLVED OXYGEN (DO)</u>

1) Data presentation

2) Data commentary

a. Typical Dissolved Oxygen values
b. Okabena Creek and Jack Creek
c. Lakes

3) Data interpretation

a. General significance of Dissolved Oxygen analysis
b. Lake conditions

* One more sampling session is scheduled for Spring Runoff in 1982, beyond the study period of this report.

1). Data Presentation

Table 9 is a summary graph of the Dissolved Oxygen data collected for this study. As previously mentioned, it is an average of the DO values for each site over the testing period. Dissolved Oxygen is the amount of oxygen present in the water, expressed in milligrams of oxygen per liter of water (mg/l).

2). Data Commentary

a). Typical DO Values: For the average summer temperature, DO readings should range between 9.0 and 9.5 mg/l for a eutrophic lake (100% saturation). A condition known as supersaturation, (i.e. the water contains more than 100% of the oxygen that it is able to dissolve for a given temperature) may exist in the summer for severely eutrophic lakes. Supersaturation usually indicates the presence of air bubbles in the water due to heightened algal acitivity.

It should be noted that during the night and during periods of low sunlight and light wind, dissolved oxygen concentrations can fall to below 50% saturation by sunrise. Similarly, several cloudy days accompanied by light winds may result in reduced algal activity, massive algal kills and greatly reduced oxygen levels in the lake.

Winter DO readings in a typical eutrophic lake have a fairly large range. Winter DO values depend on such factors as ice thickness, snow cover, sediment layer thickness, and several other factors. In general, however, winter DO values may approach zero for lakes such as the Heron Lake System which is quite shallow and very eutrophic.

TABLE 9

AVERAGE* DISSOLVED OXYGEN, 1981-82

	Site #	Site Location	Summer D.O. (mg/l) Average	Summer D.O. (mg/l) Range	Winter D.O. (mg/l) February 4
Lake System	L1	S. South Heron Lake	7.7	5.6-9.8	2.45
	L2	N. South Heron Lake	7.5	6.4-9.4	6.60
	L3	S. North Heron Lake	8.8	5.8-10.4	4.80
	L4	N. North Heron Lake	9.3	7.9-10.0	-
	L5	North Marsh	8.8	6.4-9.4	No Water
	L6	Duck Lake	8.9	8.3-9.6	No Water
Okabena Creek	S14	1 mi. N of Worth	7.0	2.6-13.7	-
	S13	1 mi. NE of Worth	2.9	1.2-4.4	-
	S10	3 mi. E of Brewster	13.6	8.55-19.2	-
	S6	Okabena	11.4	6.7-19.2	-
Jack Creek	S17	1.5 mi. W of Fulda	-	-	-
	S15	10.0 mi. North of Worth	-	-	-
	S16	10.5 mi North of Worth	-	-	-
	S19	3.5 mi. SW of Heron Lake (village)	9.1	8.3-11.4	-
	S7	1.2 mi. S of Heron Lake (village)	9.0	6.85-10.8	-

* Average values = average of sample data July 27 - November 17. When extremes were judged to distort the average they were excluded.

According to the Minnesota Pollution Control Agency Water Standards, Dissolved Oxygen values in Jack Creek are to remain above 5.0 mg/l. Okabena Creek, from Okabena Lake to Brewster, must remain above 1 mg/l and from Brewster to its confluence with Heron Lake, must remain above 4.0 mg/l.

b). Jack Creek and Okabena Creek: These streams registered D.O. values very close to 100% saturation for most of the summer sampling period.

One quite obvious exception to this generalization occurred at site S13 on Okabena Creek. This sample site is located directly downstream from the Worthington Wastewater Treatment Plant. D.O. values dropped sharply here as a result of the oxygen-demanding effluent from the plant. This is a typical condition downstream of wastewater treatment plants (Owen). In addition, water at some of the sample sites was found to be supersaturated.

No winter DO values are available for Jack Creek and Okabena Creek.

c). Lakes: Summer DO values on the Lake System were close to 100% saturation for most sampling periods. Several instances of supersaturation were encountered.

Winter DO values were higher than originally predicted, as anaerobic (zero dissolved oxygen) conditions were anticipated. They are, as is typical, significantly lower than Summer DO readings.

3). Data Interpretation

a). General Significance Of Dissolved Oxygen Analysis: The Dissolved

Oxygen content of bodies of water is an important test parameter for the following reasons. (Cole). Dissolved oxygen concentrations can indicate:

- . the health of fish populations
- . the amount of algal activity
- . the health of other aquatic forms of life
- . point source pollution problems.

b). Lake Conditions: Heron Lake is well aerated during the summer months because of its:

- . morphology, i.e. its shallow depth and wide basin. Winds blow across the lake almost constantly and mix it thoroughly. This mixing allows air to diffuse through the water, keeping it well aerated.

- . high algal populations - algae, in the process of normal growth and reproduction, release oxygen to the surrounding water. Therefore, supersaturation and consistently high D.O. during the summer daylight hours can be expected if a large algal population is present.

Lowered D.O. values in the winter indicate:

- . reduced algal populations
- . increased possibility of winter - kill
- . bullheads of other species tolerant of low oxygen have a competitive advantage over species requiring high concentrations of oxygen.

b. BIOCHEMICAL OXYGEN DEMAND (BOD)

1). Data presentation

2). Data commentary

a. Typical Biochemical Oxygen Demand values
b. Jack Creek and Okabena Creek
c. Lakes

3). Data interpretation

a. General significance of Biochemical Oxygen Demand analysis
b. Lake conditions

1). Data Presentation:

Biochemical Oxygen Demand (BOD) is a measure of the amount of oxygen needed to breakdown the organic load in a body of water and is expressed in milligrams of oxygen per liter of water (mg/l). The organic load is both naturally occurring, dead and decaying plant and animal biomass and man-made, chemicals and chemical by-products. The breakdown of these materials requires oxygen and therefore, oxygen needed to degrade organic consitituents is not available for fish and other aquatic life. Table 10 contains the average BOD values recorded for this study.

2). Data Commentary

a). Typical BOD Values: BOD values for a relatively clean lake generally are 1 mg/l or less (Cole). Throughout most of the year these lakes can decompose organic matter efficiently enough to maintain low to non-existent BOD values. Eutrophic lakes on the other hand, have no specific BOD value associated with their waters. In general, however, values higher than 5 mg/l are uncommon for summer conditions. On the average winter values are considerably lower than summer values.

b). Okabena Creek and Jack Creek: Okabena Creek registered average BOD values between 7.4 and 12.3 for the Summer of 1981. Here, again site S13 is not typical. The higher BOD of 12.3 is a result of the organic load from the treatment plant at Worthington.

The BOD values for Jack Creek were some of the best in the watershed. Site S7 located near the confluence of Jack Creek and Heron Lake, however, was generally quite high. This indicates that as the stream flows toward the lake it picks up additional organic input, probably of a non-point source nature.

TABLE 10

AVERAGE* BIOCHEMICAL OXYGEN DEMAND, 1981-82

	Site #	Site Location	Summer BOD (mg/l) Average	Summer BOD (mg/l) Range	Winter BOD (mg/l) February 4
Lake System	L1	S. South Heron Lake	8.8	6.1-11.4	15.1
	L2	N. South Heron Lake	8.1	6.2-10.3	33.9
	L3	S. North Heron Lake	7.7	4.5-10.7	5.6
	L4	N. North Heron Lake	9.7	8.8-10.4	-
	L5	North Marsh	5.8	3.4-7.5	No Water
	L6	Duck Lake	9.0	4.0-14.2	No Water
Okabena Creek	S14	1 mi. N of Worth.	8.1	1.2-16.2	-
	S13	1 mi. NE of Worth.	12.3	4.3-30.8	-
	S10	3 mi. E of Brewster	7.4	2.2-15.9	-
	S6	Okabena	7.6	3.1-12.8	4.5
Jack Creek	S17	1.5 mi. W of Fulda	-	-	-
	S15	10.0 mi. North of Worth.	-	-	-
	S16	10.5 mi North of Worth.	5.5	4.1-10.8	-
	S19	3.5 mi. SW of Heron Lake (village)	6.4	4.3-10.6	-
	S7	1.2 mi. S of Heron Lake (village)	9.4	6.8-17.0	4.2

* Average values = average of sample data July 27 - November 17. When extremes were judged to distort the average they were excluded.

Winter (for both streams) BOD values were much reduced in comparison with Summer values.

c). Lakes: Average BOD values for the Lake System were close to 9.0 mg/l with L4 being somewhat higher and L5 somewhat lower. On July 27 the BOD values were high all across the Lake System, this is an indication of high amounts of algae present on that date.

Winter values for L1 & L2 seem high and may have been distorted by sampling error.

3). Data Interpretation

a). General Significance of Biochemical Oxygen Demand Analysis: In most eutrophic lakes, the majority of the organic load is dead and decaying algae populations. Therefore, BOD can be a useful parameter to study the dynamics of the algae populations in a given system.

b). Lake Conditions: Even some of the lowest BOD values collected during the sampling period are still quite high. During the summer, BOD values reflect the amount of algae in the free water. The high BOD values in Heron Lake indicate that the lake supports a tremendous algal population.

The average BOD value of 11 mg/l recorded for the Lake System (and omitted from Table 10) on July 27 probably signals the end of the Spring-initiated wave of algae.

c. pH:

1). Data presentation

2). Data commentary

a. Typical pH values
b. Jack & Okabena Creeks
c. Lakes

3). Data interpretation

a. General importance of pH analysis
b. Lake conditions

1). Data Presentation:

pH indicates the concentration of hydrogen ions. It expresses the acidity of the water (Cole). pH values below 7.0 are considered acidic and above 7.0 are considered basic with 7.0 being neutral. Table 11 contains the average pH values for the Lake System, Okabena Creek and Jack Creek.

2). Data Commentary

a). Typical pH values: The pH of natural, eutrophic waters is generally considered to be 8.0 - 8.5 (Cole). The pH of lakes sampled in the winter under ice, maybe slightly more acidic due to the presence of sulfuric acid.

According to the Minnesota Pollution Control Agency Water Standards, pH values are to remain within the range of 6.5 - 9.0 in Jack Creek and Okabena Creek.

TABLE 11

AVERAGE* pH, 1981-82

	Site #	Site Location	Summer pH Average	Summer pH Range	Winter pH February 4
Lake System	L1	S. South Heron Lake	8.4	8.2-8.7	7.77
	L2	N. South Heron Lake	8.6	8.5-8.9	7.98
	L3	S. North Heron Lake	9.0	8.7-9.8	7.60
	L4	N. North Heron Lake	9.2	8.8-9.9	-
	L5	North Marsh	8.5	7.6-9.8	No Water
	L6	Duck Lake	8.8	8.2-9.8	No Water
Okabena Creek	S14	1 mi. N of Worth.	7.7	8.5-7.15	-
	S13	1 mi. NE of Worth.	7.5	7.2-7.85	-
	S10	3 mi. E of Brewster	8.6	8.1-9.15	-
	S6	Okabena	8.3	7.2-9.15	7.61
Jack Creek	S17	1.5 mi. W of Fulda	-	-	-
	S15	10.0 mi. North of Worth.	-	-	-
	S16	10.5 mi North of Worth.	8.0	7.65-8.80	-
	S19	3.5 mi. SW of Heron Lake (village)	8.2	8.0-8.35	-
	S7	1.2 mi. S of Heron Lake (village)	8.1	7.2-8.55	7.61

* Average values = average of sample data July 27 - November 17. When extremes were judged to distort the average they were excluded.

b). Jack & Okabena Creeks: The pH of Okabena Creek at Site S10 averaged a bit higher than normal and at sites S14 and S13 somewhat lower. Site S10 showed slightly higher pH values probably as a result of large populations of algae found at this site. The water at Sites S13 and S14 registered low pH values as a probable result of waste water effluent.

Jack Creek stayed within the accepted limits for most of the Summer. No pH problems are evident in this stream.

Winter pH values for both these streams were more acidic then corresponding Summer values, probably due to the build-up of sulfuric acid in the sediments and the much reduced winter algal populations.

c). Lakes: The high average pH value for the Lake System reflects the high algae activity present. On October 13, 1981, the Lake System registered the highest pH of 10. The following sample run, performed on October 29, 1981 showed pH values of 6.0 across the system.

3). Data Interpretation

a). General Significance of pH Analysis: pH values are an indication of over-all conditions in a body of water and do not reflect the status of any one chemical reaction. During the Summer, however, pH values may be used to follow the dynamics of the algal populations. Generally, the algae absorb CO_2, eliminate bicarbonates, precipitate carbonates, and form hydroxyl ions. (Cole). All these events account for rises in pH values. As the Summer wears on, this process is accelerated as the algae utilize different carbon sources.

In the winter, the greatly reduced algae populations and the build-up of sulfuric acid under the ice generally lower the pH.

b). Lake Conditions: The high average pH values for the Lake System throughout the summer reflect the high algal activity present.

The pH of 10 on October 13, 1981 and 6 on October 29, 1981 indicates that the algal populations peaked for the Summer around October 13, died, and settled out of the free water by October 29.

This suggests that true fall conditions were probably in evidence at the beginning of November.

d. PHOSPHORUS ($T(PO_4)$-P, $O(PO_4)$-P, $nf(PO_4)$-P)

1). Data presentation

2). Data commentary

a). Typical phosphorus values
b). Jack & Okabena Creeks
c). Lakes

3). Data interpretation

a). General importance of phosphorus analysis
b). Conditions indicated by the data

1). Data Presentation:

Phosphorus is necessary to all life; it functions in the storage and transfer of a cell's energy and in genetic systems. (Cole). Phosphorus found in aquatic systems occurs almost solely in the form of various types of phosphates. The phosphates most often assayed for in aquatic systems are Total Phosphates,$T(PO_4)$-P Ortho-phosphate$O(PO_4)$-P (found in agricultural fertilizers) and non-filterable Phosphate$_{nf(PO_4)-P}$. Table 12 contains the values for these milligrams of phosphate per liter of water (mg/l).

2). Data Commentary

a). Typical Phosphorus Values: According to Vollenweider (1968), a lake's internal phosphorus concentration is partially dependent upon areal loading of phosphorus, lake mean depth, and phosphorus residence time. Assuming a 135 day retention time and a 3 foot mean depth, loadings of less than 0.1 grams/m2/year are indicative of an oligotrophic lake, between 0.1 and 0.2 grams/m2/year are indicative of a mesotrophic lake, and loadings above 0.2 grams/m2/year are considered eutrophic lakes. Standing values for $T(PO_4)$-P in a eutrophic lake are generally greater than 0.05 mg/l.

TABLE 12

HERON LAKE STUDY PHOSPHORUS VALUES, 1981-82

	Site No.	Site Location	Total Phosphorous Summer $T(PO_4)$-P (mg/l) Average	Total Phosphorous Range	Total Phosphorous Winter $T(PO_4)$-P (mg/l) Feb. 4	Ortho Phosphorous Summer $O(PO_4)$-P (mg/l) Average	Ortho Phosphorous Range	Ortho Phosphorous Winter $O(PO_4)$-P (mg/l) Feb. 4	Non-Filerable Phosphorous Summer $nf(PO_4)$-P (mg/l) Average	Non-Filerable Phosphorous Range	Non-Filerable Phosphorous Winter $nf(PO_4)$-P (mg/l) Feb. 4
Lake System	L1	S. South Heron Lake	0.8	0.51-1.2	0.760	0.753	0.557-0.860	0.738	0.524	0.225-0.683	0.606
	L2	N. South Heron Lake	0.84	0.54-1.2	0.613	0.719	0.540-0.853	0.431	0.583	0.328-0.795	0.260
	L3	S. North Heron Lake	0.59	0.46-1.1	0.864	0.346	0.143-0.461	0.853	0.276	0.192-0.337	0.704
	L4	N. North Heron Lake	0.48	0.41-0.56	-----	0.173	0.087-0.252	-----	0.115	0.073-0.152	-----
	L5	North Marsh	0.48	0.29-0.81	No Water	0.510	0.365-0.732	No Water	0.396	0.188-0.675	No Water
	L6	Duck Lake	0.47	0.42-0.59	No Water	0.219	0.165-0.321	No Water	0.151	0.103-0.240	No Water
Okabena Creek	S14	1 Mi. N. of Worthington	0.55	0.43-0.67	-----	0.369	0.105-0.649	-----	0.455	0.286-0.647	-----
	S13	1 Mi. NE of Worthington	3.07	1.0-4.72	-----	2.600	1.043-4.402	-----	2.820	0.936-4.396	-----
	S10	3 Mi. E. of Brewster	1.70	0.92-2.62	-----	1.333	0.759-2.153	-----	1.334	0.844-2.209	-----
	S6	Okabena	1.30	0.79-1.89	1.070	0.941	0.050-1.763	1.004	1.005	0.369-1.517	0.952
Jack Creek	S17	1.5 Mi. W. of Fulda	----	---------	-----	-----	-----------	-----	-----	-----------	-----
	S15	10 Mi. N. of Worthington	----	---------	-----	-----	-----------	-----	-----	-----------	-----
	S16	10.5 Mi. N. of Worthington	0.20	0.07-0.35	-----	0.144	0.079-0.196	-----	0.126	0.062-0.191	-----
	S19	3.5 Mi. SW of Heron Lake (village)	0.30	0.1-0.57	-----	0.112	0.037-0.136	-----	0.090	0.042-0.159	-----
	S7	1.2 Mi. S. of Heron Lake (village)	0.38	0.16-0.55	0.191	0.070	0.053-0.194	0.175	0.114	0.023-0.223	0.157

Orthophosphate-phosphorus values are typically one-tenth of the total phosphate values for eutrophic lakes. (Vollenweider).

b). Jack & Okabena Creeks: In general, standing phosphorus values were quite high for Okabena Creek. Again S13 at Worthington was conspicuously high, at 3.07 mg/l $T(PO_4)$-P.

Jack Creek had phosphorus values which were considerably better than those for Okabena Creek, but even these are considered high.

Under reduced flow conditions, like those which existed during the sampling period, these streams have a somewhat longer retention time which intensifies the problems associated with these high concentrations of phosphorus.

c). Lakes: The lake internal concentration of phosphorus was extremely high (Table 12). Phosphorus values appear to drop slightly from South to North.

3. Data Interpretation

a). General Significance of Phosphorus Analysis: The amount of phosphorus in a lake can reflect the standing crop of algae present in its waters. Phosphorus is a limiting nutrient in many systems. If it is present in large concentrations (+0.05 mg/l), then excessive populations of algae would be expected, assuming no other nutrient was limiting. Therefore, phosphorus values can provide insight into algal conditions.

b). Lake Conditions: Assuming a mean depth of 3 feet for the entire Heron Lake System, a low flow summer retention, time of approximately 135 days, and a phosphorus concentration of 0.5 gm/m2/year (0.5 mg/l $T(PO_4)$-P) for the Lake System, phosphorus conditions are considered excessive. (Vollenweider, 1978).

Algae require nitrogen and phosphorus for normal growth in a ratio of approximately 12 to 1 (inorganic nitrogen/ortho phosphorus). Ratios greater than 12 to 1 are generally accepted as indicating potentially nitrogen limited. The N-P ratio for Heron Lake is approximately 2 to 1. Although this may suggest nitrogen limitation, both of these nutrients are present in such high concentrations (see Section on nitrogen) that N - P ratios are useless in predicting algal population numbers. Neither nutrient appeared to be limiting during the Summer sampling time.

As a result of these excessive concentrations of phosphorus in the water, the Lake System supported a very heavy algal population throughout the summer. Since it appears that neither phosphorus nor nitrogen was limiting (as their concentrations were still high at the end of October) the algae may be limited by the availability of sunlight or possible trace metal concentrations.

e. NITROGEN (NO_3-N, No_2-N, NH_3-N)

1). Data presentation
2). Data commentary

a). Typical nitrogen values
b). Jack & Okabena Creeks
c). Lakes

3). Data interpretation

a). General importance of nitrogen analysis
b). Conditions indicated by the data

TABLE 13

HERON LAKE STUDY NITROGEN VALUES, 1

	Site No.	Site Location	Nitrate Summer NO_3-N (mg/l Average	Nitrate Range	Nitrate Winter NO_3-N (mg/l) Feb. 4	Summer NO_2-N (mg/l) Average	
Lake System	L1	S. South Heron Lake	0.453	0.264-0.773	0.70	0.0091	0
	L2	N. South Heron Lake	0.421	0.223-0.563	1.00	0.0057	0
	L3	S. North Heron Lake	0.328	0.261-0.446	0.81	0.0058	0
	L4	N. North Heron Lake	0.322	0.213-0.468	----	0.0057	0
	L5	North Marsh	0.213	0.191-0.327	No Water	0.0101	0
	L6	Duck Lake	0.285	0.249-0.362	No Water	0.0245	0
Okabena Creek	S14	1 Mi. N. of Worthington	1.4	0.91-2.05	-----	0.1414	C
	S13	1 Mi. NE of Worthington	2.45	1.0 -3.78	-----	0.5854	C
	S10	3 Mi. E. of Brewster	2.7	1.2 -4.55	-----	0.2146	C
	S6	Okabena	2.2	0.61-3.64	1.640	0.1034	C
Jack Creek	S17	1.5 Mi. W. of Fulda	----	---------	-----	------	-
	S15	10.0 Mi. N. of Worthington	----	---------	-----	------	-
	S16	10.5 Mi. N. of Worthington	2.0	0.30-3.62	-----	0.567	C
	S19	3.5 Mi.SW. of Heron Lake (village)	1.7	0.51-3.74	-----	0.605	C
	S7	1.2 Mi.S. of Heron Lake (village)	1.42	0.31-3.60	1.102	0.0511	C

* Average values = average of sample data July 27 - November 17th.

When extremes were judged to distort the average, they were excluded.

1). Data Presentation

Nitrogen is necessary for life and is much more abundant than phosphorus. Rainwater contains various forms of nitrogen and is a large contributor to aquatic systems. (Cole). Fertilizer run-off from agricultural lands contributes substantial amounts of nitrogen as well.

Nitrate(NO_3-N), nitrite (NO_2-N) and ammonia (NH_3-N) are all forms of the element nitrogen. Table 13 contains the average values for these forms.

2). Data Commentary

a). Typical Nitrogen Values: Nitrate and nitrite are by products of bacterial decomposition and are normally present in a eutrophic lake, at very low to non-existant concentrations (approximately 0.1 and 0.01 mg/l respectively). This is true because the algae assimilate most if not all of the nitrogen in the lake's photic zone (upper layers).

Ammonia is present at varying concentrations depending on the amount of organic load in the water. Generally ammonia level do not exceed 1 mg/l in eutrophic lakes.

b). Okabena Creek and Jack Creek: Both streams have high nitrogen concentrations in their waters. Concentrations are high enough that nitrogen can not be considered limiting. Again, quite high concentrations of nitrogen were found downstream of Worthington.

Nitrogen values from the winter sample run were significantly higher due to bacterial decomposition taking place under the ice.

c). Lakes: The Lake System also maintained a higher than normal concentration of nitrogen throughout the study period.

3). Data Interpretation

a). General Significance of Nitrogen Analysis: Nitrogen is a very important parameter because although the element is fairly abundant it may be limiting in the photic zone. (Cole). Therefore, N-P ratios can become important to algal populations.

b). Lake Conditions: Data suggests that nitrogen may not be limiting in this system. Even though N-P ratio for the (free water) is approximately 2 to 1, both nutrients are present in excessive amounts rendering such ratios relatively useless.

As mentioned earlier, the high nutrient level allows the lake system to maintain a very large algal population all summer long. Therefore, the algae are probably light limited.

f. TOTAL ALKAKINITY (T-ALK)

1). Data presentation

2). Data commentary

a). Typical T-ALK values
b). Jack & Okabena Creeks
c). Lakes

3). Data interpretation

a). General significance of Total Alkalinity analysis
b). Lake conditions

1). Data Presentation

Alkalinity of a water is its quantitative capacity to neutralize a strong acid to a designated pH. Table 14 contains the Total Alkalinity values for this study. Total alkalinity is expressed in milligram of $CaCO_3$ per liter of water.

2). Data Commentary

a). Typical Total Alkalinity Values: Although sources vary, the following are generally accepted alkalinity values for potable water. (Shuval).

TABLE 14

TOTAL ALKALINITY VALUES

Soft water	50 mg/l $CaCO_3$
Water with low degree of hardness	50-150 mg/l $CaCO_3$
Hard water	150-300 mg/l $CaCO_3$
Very hard water	Over-300 mg/l $CaCO_3$

b). Jack & Okabena Creeks: Summer total alkalinity values fluctuated somewhat about the averages for Okabena Creek and Jack Creek. However, no observable trend was identified. Such fluctuation in stream systems is common.

Winter values were significantly higher as a result of the resoluablization of carbonate. (Cole).

TABLE 14A

AVERAGE* Total Alkalinity, 1981-82

	Site #	Site Location	Summer T-ALK (mg/l) Average	Summer T-ALK (mg/l) Range	Winter T-ALK (mg/l) February 4
Lake System	L1	S. South Heron Lake	205	105-256	415
	L2	N. South Heron Lake	235	182-296	581
	L3	S. North Heron Lake	180	106-196	622
	L4	N. North Heron Lake	142	100-172	-
	L5	North Marsh	189	139-224	No Water
	L6	Duck Lake	170	156-182	No Water
Okabena Creek	S14	1 mi. N of Worth.	244	152-348	-
	S13	1 mi. NE of Worth.	306	105-378	-
	S10	3 mi. E of Brewster	357	301-396	-
	S6	Okabena	312	293-371	378
Jack Creek	S17	1.5 mi. W of Fulda	-	-	-
	S15	10.0 mi. North of Worth	-	-	-
	S16	10.5 mi North of Worth	268	237-310	-
	S19	3.5 mi. SW of Heron Lake (village)	272	243-313	-
	S7	1.2 mi. S of Heron Lake (village)	240	155-317	412

* Average values = average of sample data July 27 - November 17. When extremes were judged to distort the average they were excluded.

c). Lakes: For the summer sampling period the alkalinity of the Heron Lake System was fairly constant, rising somewhat at the end of the summer. Winter alkalinity values were slightly higher.

3). <u>Data Interpretation</u>

a). <u>General Significance of Total Alkalinity Analysis:</u> The alkalinity of many surface waters is primarily a function of carbonate, bicarbonate, and hydroxide content. Therefore this parameter is an indication of significant changes in these forms of carbon.

b). <u>Lake Conditions</u>: Analysis of the data for Total Alkalinity revealed the following:

- The Heron Lake System is a hardwater system.
- During the summer months, algae populations are quite high. The significant jump in the total alkalinity for February indicates that the algae are using bicarbonate to a large extent in the summer.

g. TRANSPARENCY (Secchi Disc)

1). Data presentation

2). Data commentary

a). Typical Secchi disc values
b). Streams
c). Lakes

3). Data interpretation

a). General significance of Secchi disc determinations
b). Lake conditions indicated by the data

1) Data Presentation

Transparency is measured with the aid of a secchi disc. A secchi disc is usually 7 inches in diameter, with alternating quadrants of black and white on its surface. This disc, with the flat surface horizontal, is lowered into the water on a calibrated line. The exact depth at which the disc disappears from view is recorded, then the disc is retrieved and the distance at which it reappears is recorded. The two values are then averaged for the lake's transparency at that point. Secchi disc readings for Heron Lake are presented as follows:

TABLE 15

HERON LAKE SECCHI DISC READINGS (FEET)

	Sampling Site					
	L1	L2	L3	L4	L5	L6
July 27, 1981	0.42	0.50	0.75	0.75	0.83	0.75
August 11-12, 1981	0.40	0.60	0.60	0.80	1.70	0.70
August 25-26, 1981	0.50	0.70	0.60	0.6	1.00	0.40
September 15-16, 1981	0.90	0.90	0.70	0.8	1.30	-
October 28-29, 1981	0.80	0.60	1.20	1.00	1.8+	0.60

2). Data Commentary

a). Typical Secchi Disc Values: In general, eutrophic lakes have much lower secchi disc values than lakes with low nutrient levels. For example ultra clean lakes such as Lake Superior can often register a forty foot secchi disc depth, however, the most eutrophic lakes in the Twin Cities (i.e. Como Lake) will register two feet or less.

Eutrophic lakes, also, typically experience large fluctuations in secchi disc values due to normal algal cycling.

b). Jack & Okabena Creeks: No transparency determinations were recorded for the streams.

c). Lakes: Secchi disc values were generally low all across the Lake System for the Summer sampling period. Some improvement in these values did occur toward the end of the Summer. Relatively little fluctuation occurred over the sampling period. North Marsh, L5 had the highest transparency depths in the Lake System.

3). Data Interpretation

a). General Significance of Transparency Determinations: Waters with high algal populations have low transparencies as a result of the murky, green consistency they impart to water.

In addition, most eutrophic lakes often experience large fluctuations in secchi disc values due to algal cycling. Typical lakes undergo bloom cycles where one species of algal goes through its normal life cycle and is replaced by another species. For the time period between the end of one cycle and the beginning of the next, secchi disc readings increase significantly often by a few feet or more (EPA, 600-4-77-036).

b). Lake Conditions: The low secchi disc values for the lake, are yet another indication of excessive algal populations in the Heron Lake system.

The absence of fluctuation in these values indicates that the Lake System does not undergo bloom cycles but rather maintains a steady algal population all Summer. It also suggests that these algae are not limited by the lack of nutrients. (Refer to previous sections on phosphorus and nitrogen).

h. CHOROPHYLL a (Chloro. a)

1). Data presentation
2). Data commentary

a). Typical chlorophyll a values
b). Jack & Okabena Creeks
c). Lakes

3). Data interpetation

a. General significance of chlorophyll a analysis
b. Lake conditions indicated by the data

1). Data Presentation

Chlorophyll a is a green photosynthetic pigment common to most algae and all photosynthetic plants. The test for this parameter involves the assessment of the amount of chlorophyll a in the water, and is measured in milligrams of chlorophyll a per cubic meter of water. Since this test was run on the Lake

System only, all the data collected has been included for examination in the following Table 16.

TABLE 16

HERON LAKE CHLOROPHYLL a VALUES - 1981-82
mg/M3

Sample Site	July 27	Aug. 11-12	Aug. 25-26	Sept. 15-16	Sept. 29-30	Oct. 13	Oct. 28-29	Nov. 17-18	Feb. 4-5
L1	405	407	312	140	271	-	1050	-	19.9
L2	300	415	298	182	319	-	1045	-	124.4
L3	196	191	254	313	344	-	765	543	21.4
L4	237	156	278	222	276	-	1053	-	-
L5	122	57	153	108	115	-	121	-	No Water
L6	176	109	203	-	-	-	614	-	No Water

2). Data Commentary

a). Typical Chlorophyll a Values: In general chlorophyll a values above 25 mg/m^3 are high and typify eutrophic waters. Winter values are considerably reduced in comparison with Summer values.

b). Jack & Okabena Creeks: Assays of chlorophyll a were not performed for the stream samples.

c). Lakes: Chlorophyll a values were high throughout the Summer. The October 28-29, 1981 sample data showed a large increase in this parameter for all the Heron lake sampling points except North Marsh, L5.

Winter values were considerably reduced although L2, North South Heron still showed a significant amount of Chlorophyll a.

3). Data Interpretation

a). General Significance of Chlorophyll a Analysis: Chlorophyll a determinations are helpful in studying the dynamics of a lake's algal population.

b). Lake Conditions: Analysis of the chlorophyll a data indicates that:

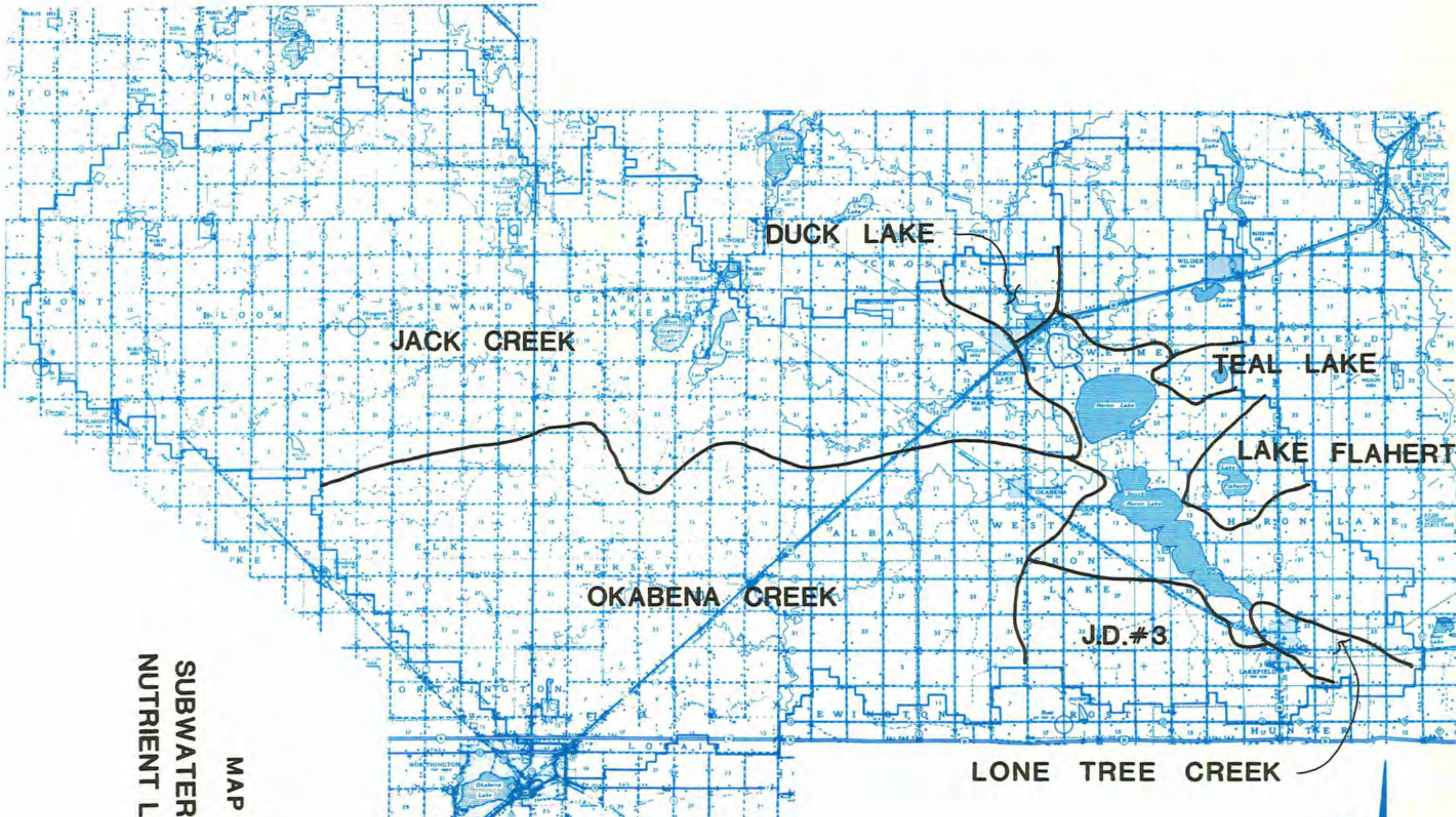
- Heron Lake supports a high algal population during the Summer.
- The algae ended their Summer cycle slightly before the October 28-29, 1981 sample run. This is evidenced in the spike of chlorophyll a values for this date.

B. Nutrient Loading

Nutrients enter the Heron Lake system from a variety of sources including wastewater treatment plants and runoff from agricultural fields, feedlots, or city streets. Precipitation also contributes a significant amount of nutrients. The two primary nutrients necessary for growth of algae or aquatic vegetation are nitrogen and phosphorus and the rate at which these nutrients enter the lake have a large impact on the lake's trophic state or general condition.

Nutrient loading is essentially a determination of the nutrient contribution of a municipal wastewater treatment plant or agricultural runoff contributed by a tributary. This is a function of both the flow rate and the nutrient concentrations in the flow. Nutrient loading was determined based on sampling for seven general area (Map 5). Duck Lake, Jack Creek, Okabena Creek, Judicial Ditch 3, Lone Tree Creek, and the outlets of the Lake Flaherty and Teal Lake.

Periods of high flow are extremely important since they contribute the majority of nutrients attributed to runoff from agricultural lands. For the sampling period utilized in this study, stream flow was extremely low and is not considered typical. In addition, sampling was not conducted during the spring runoff period and no significant flow increases were experienced following summer rainfalls. For these reasons, nutrient loadings were adapted from a previous study (EPA National Eutrophication Survey - Report on Heron Lake, Jackson County, Minnesota) with minor modifications.



MAP 7
SUBWATERSHEDS
NUTRIENT LOADING

NOT TO SCALE

The nutrient loadings is composed of point source and nonpoint source pollution. Point sources are defined as flows originating at an identifiable point and include wastewater treatment plants of the Cities of Worthington, Lakefield, Okabena, Brewster, and Heron Lake. The Worthington Industrial Lagoons are not includled in the nutrient loadings as they are currently scheduled for land application facilities (MPCA permit files). Nonpoint sources include runoff from broad areas such as agricultural land or urban areas. In the Heron Lake System, waterfowl also contribute nutrients, however, there is insufficient information to evaluate this source. Tables 17 and 17A summarize the estimated quantities of nitrogen and phosphorus by known point source and nonpoint sources.

Table 17
Summary of Nutrient Loading

Point Source

City	1980 Population	Lbs. Phosphorous/Year	%	Lbs. Nitrogen/Year	%
Worthington	10,243	14,020	57	81,580	72
Lakefield	1,845	5,540	23	16,790	15
Okabena	263	790	3	2,390	2
Brewster	559	1,680	7	5,090	5
Heron Lake	783	2,350	10	7,130	6
		24,380	100	112,980	100

Non Point Source

Subwatershed	Area (sq. mi.)	Lbs. Phosphorous/Year	%	Lbs. Nitrogen/Year	%
Duck Lake	7.60	1,010	2	13,810	1
Jack Creek	220.50	16,210	30	443,450	39
Okabena Creek	146.25	30,690	56	425,700	37
J.D. #3	21.50	1,790	3	55,000	5
Lakefield Creek	3.60	200	.5	13,050	1
Lake Flaherty	7.50	610	1	16,190	1
Teal Lake	3.80	120	.5	5,960	1
Local Area	42.00	2,890	5	88,760	8
Direct Precipitation	12.70	1,290	2	79,490	7
		54,810	100	1,141,410	100

Based on this information, it is apparent that nonpoint sources (i.e. primary agricultural runoff) provide significantly more nutrients to the lake system than point sources limitations on nutrient loadings analysis.

TABLE 17A

SUMMARY OF NUTRIENT LOADING

City	Lbs. Phosphorous/Year	% of Total	Lbs. Nitrogen/Year	% of Total
Worthington	14,020	17.7	81,580	6.5
Lakefield	5,540	7.0	16,790	1.3
Okabena	790	1.0	2,390	0.2
Brewster	1,680	2.1	5,090	0.4
Heron Lake	2,350	3.0	7,130	0.6
Subwatershed				
Duck Lake	1,010	1.3	13,810	1.1
Jack Creek	16,210	20.5	443,450	35.3
Okabena Creek	30,690	38.7	425,700	33.9
J.D. #3	1,790	2.3	55,000	4.4
Lakefield Creek	200	0.2	13,050	1.0
Lake Flaherty	610	0.7	16,190	1.3
Teal Lake	120	0.1	5,960	0.5
Local Area	2,890	3.6	88,760	7.1
Direct Precipitation	1,290	1.6	79,490	6.3
Total......................	79,190	100.0	1,254,390	100.0

C. AQUATIC BIOLOGY

The systematics of an aquatic system are extremely complex. Two types of organisms which play a very important part in the stability of an aquatic system are the algae, (microscopic plants) and the zooplankton, (microscopic animals) which feed on the algae. These two organisms form the base of the food web. Irregularities in these two populations will affect the entire web.

Typical lakes undergo bloom cycles, wherein one species of algae goes through its normal life cycle and is replaced as the dominant species by another species. In the Spring diatoms are normally the first to appear. They are present until the green algae appears for a short time. The greens are then replaced by the blue-green algae, which are usually dominant much of the summer. Fall conditions, often nutrient poor, bring blooms of blue-green algae. Winter conditions show a gradual change to green algae, brown algae and yellow algae. (Cole).

While this cycle, typical of a eutrophic lake, appeared to take place in Heron Lake during the sampling period, algal populations in Heron lake, as mentioned earlier, were tremendously large. This statement is substantiated by many of the test parameters. For example, chlorophyll a values which are approximate indicators of total algal population numbers, were five to six times those found in most eutrophic lakes, and secchi disc readings were correspondingly low.

Biological analysis of Heron Lake water samples also verified the existence of excessive algal populations. Analysis showed that 99 percent of the algae were blue-green algae and roughly 0.9 percent were green algae. There were nearly 3×10^8 blue-green algal cells per 100 cubic centimeters (cc) of water and ony 7×10^3 green algal cells per 100 cc present during the sampling period. Analysis also identified the dominant alga throughout the summer appeared to be the blue-green alga, Oscillatoria rubescens.

The reason that the blue-green algae are in a bloom condition for the entire summer is intricately related to the high nutrient concentrations in the lake. The blue-green algae appear in large numbers in the late Spring as is expected, but the nutrient concentration is so high that they establish themselves and multiply to the near exclusion of the other algae. Green algae are present during the summer but in much reduced numbers.

This dominance of blue-green algae can cause the following problems:

- Disruption of the food web - no organism other than bacteria feed on the blue-green algae. Their presence in such large numbers also inhibits the growth of the green algae which are an important food source for zooplankton.
- Decrease the aesthetic value of the lake - blue-green are often referred to as nuisance algae because of their pea soup type appearance and noxious odor when in a bloom state. Recreational use of the lakes is greatly reduced as a result of these blooms.

The zooplankton, or microscopic animals, in Heron Lake which are the first organisms to suffer from this shortage of green algae are an important food source for young fish. Biological analysis revealed a fairly good representation of the species of zooplankton expected in a eutrophic lake, but their numbers were disappointingly low. The fact that these animals are even present probably precludes a toxic effect and points to a shortage of suitable food or significant grazing by forage fish to explain their low numbers.

There simply is not enough green algae to support a healthy population of zooplankton in the Lake System.

Winter sampling data revealed greatly reduced algal populations under the ice. In addition, analysis revealed a population shift from a predominantly blue-green algae population to brown algae and yellow algae. Zooplankton numbers remained low, however. The reason for this may be grazing by the fathead minnows in the water, although this is only speculative.

D. FISH AND WATERFOWL

A fourth very important area to consider when considering the environmental concerns of Heron Lake is that of fish and waterfowl. Survey information for Heron Lake presented in this section was provided by the Minnesota Department of Natural Resources (MDNR) and information obtained from MDNR files in St. Paul, Minnesota.

A. Limitations
B. Fish
C. Waterfowl

1. Limitations: According to the original Heron Lake Study work plan the MDNR was to prepare this section of the report. Due to lack of personnel and a rescoping of funding to provide more water quality data, this section was prepared by the consultants, at a much reduced scope.

2. Fish: The MDNR conducted a survey of South Heron Lake to determine the type, frequency, and length of fish present. The survey was done September 8-14 of 1981. The results can be found in Table 18.

This survey concluded that South Heron Lake has a large population of bullheads and carp (rough fish), a fairly large population of small perch and adult northern pike (though no young northerns were taken during the survey), and lesser numbers of black and white crappies, buffalo, and suckers. (MDNR, 1981).

Northern pike brood stock are present in sufficient numbers in many seasons to produce a crop of young-of-the-year. Usually adults and yearlings are also present. This is accountable most likely for two reasons; (1) some fish endure

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MINNESOTA DEPARTMENT OF NATURAL RESOURCES
DIVISION OF FISH AND WILDLIFE
SECTION OF FISHERIES

Lake South Heron

(30) Fish Sizes

TABLE 18

County(ies) Jackson

Date: September 8-14, 1981

Length - Frequency Distributions
Species and Numbers of Fish in Length Groups

Total Length in Inches	Northern Pike	Carp	Fathead minnow	Bigmouth Buffalo	White Sucker	Black Bullhead	Yellow Bullhead	Tadpole madtom	Green sunfish	Orange-spotted sunfish
under 3 inches			3950			7500				
3.0 - 3.4		296						30		66
3.5 - 3.9		237		266				18	10	110
4.0 - 4.4		160						12	20	
4.5 - 4.9		488		60				6		
5.0 - 5.4								2		
5.5 - 5.9						360				
6.0 - 6.4						5000				
6.5 - 6.9						6061	3			
7.0 - 7.4							4			
7.5 - 7.9						120	4			
8.0 - 8.4							8			
8.5 - 8.9							5			
9.0 - 9.4					4		3			
9.5 - 9.9							2			
10.0 - 10.4					5					
10.5 - 10.9		1		25	23					
11.0 - 11.4		2		6	43					
11.5 - 11.9		34		1		2				
12.0 - 12.9		16		2	4	2				
13.0 - 13.9		28			2	3				
14.0 - 14.9		38		2	3					
15.0 - 15.9		3			1					
16.0 - 16.9		3								
17.0 - 17.9		2								
18.0 - 18.9	1	2								
19.0 - 19.9	3	75								
20.0 - 20.9	9	26								
21.0 - 21.9	23	2								
22.0 - 22.9	14									
23.0 - 23.9	24									
24.0 - 24.9	61									
25.0 - 25.9	16	1								
26.0 - 26.9	69	1								
27.0 - 27.9	52	2								
28.0 - 28.9	14	1								
29.0 - 29.9	2	1								
30.0 - 30.9	5									
31.0 - 31.9	2									
32.0 - 32.9										
33.0 - 33.9										
34.0 - 34.9										
35.0 - 35.9										
36.0 - 36.9										
TOTALS	295	1419	3950	362	85	19048	29	68	30	176

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Fish Sizes, Ages, and Growth Rates

TABLE 18 (cont.)

Length-Frequency Distributions

Date: September 8-14, 1981

Species and Numbers of Fish in Length Groups

Total Length in Inches	White Crappie	Black Crappie	Yellow Perch	Walleye					
	1								
3.0 - 3.4			36						
3.5 - 3.9			40						
4.0 - 4.4		18							
4.5 - 4.9									
5.0 - 5.4			8						
5.5 - 5.9		2	256						
6.0 - .6.4		25	88						
6.5 - 6.9			53						
7.0 - 7.4		32	18						
7.5 - 7.9									
8.0 - 8.4		9	2						
8.5 - 8.9		3	11						
9.0 - 9.4			2						
9.5 - 9.9			2						
10.0 - 10.4	1		9	2					
10.5 - 10.9			1						
11.0 - 11.4			2						
11.5 - 11.9			1						
12.0 - 12.9									
13.0 - 13.9									
14.0 - 14.9									
15.0 - 15.9				1					
16.0 - 16.9									
17.0 - 17.9				3					
18.0 - 18.9									
19.0 - 19.9									
20.0 - 20.9									
21.0 - 21.9									
22.0 - 22.9									
23.0 - 23.9									
24.0 - 24.9									
25.0 - 25.9									
26.0 - 26.9									
27.0 - 27.9									
28.0 - 28.9									
29.0 - 29.9									
30.0 - 30.9									
31.0 - 31.9									
32.0 - 32.9									
33.0 - 33.9									
34.0 - 34.9									
35.0 - 35.9									
36.0 - 36.9									
TOTALS	2	89	529	6					

the low oxygen levels of wintertime and (2) some adults migrate into the lakes each spring from the Okabena Creek and the Des Moines River.

The most productive manner of northern pike reproduction depends upon the movement of adult northerns in spring to areas of flooded marsh and upland vegetation. Fisheries techniques to aid natural northern pike reproduction have been based upon this fact-of-life history almost since the origination of pike propagation in Minnesota. The two Heron Lakes have served since 1947 as a source of northern pike to stock other lakes in Jackson County. The Heron Lakes have shallow, marshy areas around their perimeters which are usually newly flooded in spring. Thus they are natural areas for northern pike spawning and rearing.

Numbers of northern pike rescued from the Heron Lakes have been recorded for 33 years. The annual average is 3,886. During some years there were no northern pike taken. The highest number of northern pike rescued was 31,043 in 1964 (DNR, open file). Because of variations which occur in the rescue of northern pike such as weather and manpower, the data provided in Table 19 cannot be effectively analyzed. It can be noted, however, that during the 1970's, a reduction occurred in the number of northern pike removed and the poundage of rough fish removed increased.

Concern has been expressed that the fisheries would be lost if the lake was managed only for waterfowl. This is not always the case. On the Roseau River Wildlife Management Area, which is a product managed primarily for waterfowl, winter northern pike rescue operations are undertaken. Although the Roseau area contains several water impoundments and not lakes, a tremendous population of northerns are produced in most years. From the years 1966 to

TABLE 19

FISH REMOVAL RECORDS FOR
NORTH HERON LAKE, JACKSON COUNTY

MDNR OPEN FILE, 1978

Year	Northern Pike Numbers Rescued	Rough Fish Removal - Pounds			
		Carp	Buffalo	Bullhead	Suckers
1923-43		859,266 - total all species			
1943-46		276,014 - total all species			
1947		32,050	25,500		
1948		253,278	104,492	2,000	
1949		38,151	13,600	180	
1950		7,535	1,600		
1951		350	100		
1952		600			
1953	1,090	165	165	15,200	
1954	2,055	4,500	3,685		
1955	5,615	76,450	3,302	2,450	
1961	6,140				
1962	564				
1963	8,153				
1964	12,692				
1965	9,550				
1966	10,445				
1967	5,984	172,870	10,545		138
1968	296	16,170	95		
1972	14				
1973	76				
	62,673				

Table 19 (continued)

FISH REMOVAL RECORDS FOR
SOUTH HERON LAKE, JACKSON COUNTY

MDNR OPEN FILE, 1978

Year	Northern Pike Numbers Rescued	Rough Fish Removal - Pounds			
		Carp	Buffalo	Bullhead	Suckers
1947	2,651				200
1948	3,077				638
1952	960			400	
1960	10				
1961	547				
1962	884				
1963	12,789				
1964	18,352				
1965	3,506				
1966	522	1,950	6,910	8,775	
1967	1,391	630	260	200	11
1968	37	5,320	3,360		5
1969	3,190				74
1970	108				
1971	5,410				
1972	2,345				
1973	2,997	17,168	13,891	2,151	85
1974	2,712	196,551	99,765	1,733	70
1975	624	2,800	2,010		
1976	2,200	72,400	7,797	3,640	
1979	282				
	64,594				

1975 an average of 25,500 northerns were removed annually compared to an annual removal of 3,500 during the same period for Heron Lake.

Fishing has been at a low level in both of the lakes during the past 15 years according to observations by the Area Fisheries Manager. Fishing pressure is estimated at most to be 300 trips per year or less than 0.1 man-hour per acre per year. This is very low according to Minnesota levels. (MDNR Open File 1978).

There are five basic reasons that Heron Lake supports a large population of rough fish often to the exclusion or detriment of game fish such as the northern pike.

- Winter-kills due to prohibitively low dissolved oxygen in the lake-water and complete freezing of the lake, are common. Such winter-kills, both partial and complete place a great strain on already delicate game fish populations.

- Heavy algal blooms also affect the game fish. Algae reduce the water's transparency, greatly hampering the fish's ability to feed.

- Silt from agricultural run-off, is detrimental in two respects. First, the silt accumulates on the lakebed and destroy's the spawning areas for the fish. Second, a large amount of phosphorus and nitrogen generally accompany the silt into the lake, adding to the already high nutrient load.

- Competition also limits the game fish. Rough fish, such a carp and black bullheads have a competitive advantage in Heron Lake over most of the game fish. As a consequence of this advantage under adverse conditions, the large rough fish populations tend to edge-out the more sensitive game fish.

- The lack of vegetation can effect fish populations in a negative manner as well. Vegetation is needed for both cover and sheltered spawning areas. South Heron lake has vegetation only at its extreme southern and northwestern ends while North Heron is virtually ringed with macrophytes. (MDNR, Survey, 1981).

3. Waterfowl

Although the watershed does support populations of deer, muskrat, mink, beaver and pheasant, waterfowl seems to be the most dominant and important form of wildlife in the area. Heron Lake, has been in the past, and is at present, a prime duck-hunting area in the State of Minnesota.

The Minnesota Department of Natural Resources conducted Game Lake Surveys for North and South Heron Lake during the summer of 1981. The results of their waterfowl count are as follows:

TABLE 20

MDNR WATERFOWL COUNT

Species	Survey Totals	
	North Heron Lake	South Heron Lake
Canada Goose	20	60-70
Mallard	75-100	60-70
Blue-winged teal	15-25	20-30
Pintail	0	1
Wood Duck	10-15	1
Ruddy Duck	0	5
Coot	40-50	10

Table 21 contains the 1980 Log Book totals submitted by Heron Lake hunters, courtesy of the North Heron Lake Game Producers Association (NHLGPA). This table provides additional information on the types of birds present in the fall and their relative numbers. The numbers presented in the table approximate numbers of birds shot in 1980.

TABLE 21

1980 LOG BOOK TOTALS*

Courtesy of the North Heron Lake Game Producers Association

Species	Number	% of Total
Mallard (Wild Origin)	792	35
Mallard (NHLGPA Released)	142	6
Blue Wing Teal	260	11
Green Wing Teal	563	24
Wood Ducks	93	4
Pintail	68	3
Widgeon	72	3
Gadwell	44	2
Shoveler	119	5
Canvasback	32	1
Redhead	64	3
Greater Scaup	27	1
Lesser Scaup	27	1
Bufflehead	17	1
Goldeneye	0	0
Ruddy Duck	16	1
Totals	2336	100
Canada Geese	48	47
Snow & Blue Geese	53	53
Totals	101	100

* Log book totals are records of birds taken by the members of the NHLGPA during the 1980 hunting season and are not typical of year round populations.

Waterfowl habitat, by definition, takes into consideration such factors as nesting cover, brood cover, loafing site abundance and food supply provided by the available aquatic vegetation. Tables 22 contains MDNR information on aquatic plants and their relative waterfowl food values, for North and South Heron Lakes.

North Heron Lake's numerous channels and open-water pockets make it particularly attractive to waterfowl. In general, this lake has a good representation of emergent, floating-leaved, and submergent aquatic plants which provide excellent habitat conditions for waterfowl.

Waterfowl habitat in South Heron Lake was found to be generally quite poor, due to extensive areas of open water and lack of emergent vegetation. The northeastern corner and extreme southeastern tip of the lake are exceptions to this generalization and provide good waterfowl habitat.

Historically the shallow lakes of southern Minnesota have varied in both production and hunting on a periodic or cyclical basis. During extended periods of average or above normal rainfall the lakes, because of high water and turbidity, lose essentially all of their emergent and submergent vegetation. Both are needed for brood cover and for food for waterfowl broods. Emergent vegetation is also needed for overwater nesting species of ducks such as redheads, canvasbacks, coots and ruddy ducks. This type of vegetative cover is of considerable importance as well to other water-oriented wildlife from grebes to marsh wrens. Emergent vegetation is also of value to hunters for blinds during the hunting season. Loss of emergent cover reduces hunting opportunites.

TABLE 22

NORTH HERON LAKE, JACKSON COUNTY
SPECIES OF EMERGENT AQUATIC PLANTS

Observation Date Plants: June 29, June 30, July 1, 1981
About 10% of the present lake water area is covered by standing emergent vegetation.

Common Name	Scientific Name	Relative Abundance	Scattered Along Shore	Food Value To Waterfowl
Narrowleaf cattail	Typha angustifolia	Abundant	Throughout	--
Cane grass	Phragmites communis	Common	Throughout	S-F
Softstem bulrush	Scirpus validus	Scarce	W. & S. sides of lake	S-f
Hardstem bulrush	Scirpus acutus	Scarce	Scattered north half	G
River bulrush	Scirpus fluviatilis	Scarce	Widely scattered	S-F
Arrowhead	Sagittaria rigida	Scarce	West side of lake	--
Smartweed	Polygonum lapathifolium	Scarce	Shoreline	E

Although approximately 65 percent of that portion of the basin covered by this report consisted of standing emergent vegetation, only about 10 percent of the present lake water area was covered by emergent vegetation. These areas were located primarily along the Division Creek inlet and outlet channels.

SPECIES OF FLOATING - LEAVED AND SUBMERGED AQUATIC PLANTS

Total % of occurrence of submerged vegetation - 85.
Greatest depth to which rooted submerged plants grow - 3.5 feet.

Common Name	Scientific Name	% Accurrence N 134	Density	Distribution	Food Value To Waterfowl
Sago pondweed	Potamogeton pectinatus	84	Lush	Throughout	E
Lesser duckweed	Lemna minor	10	Sparse	North Half	F-E
Smartweed	Polygonum spp.	1	Sparse	Near outlet	G-E

S-SLIGHT; SF-SLIGHT FAIR; F-FAIR; FG-FAIR-GOOD; FE-FAIR-EXCELLENT; G-GOOD; GE-GOOD-EXCELLENT; E-EXCELLENT.

Table 22 (continued)

SOUTH HERON LAKE, JACKSON COUNTY
SPECIES OF EMERGENT AQUATIC PLANTS

Observation Date Plants: June 6, June 9, June 14, 1981
About 5% of the present lake water area is covered by standing emergent vegetation.

Common Name	Scientific Name	Relative Abundance	Scattered Along Shore	Food Value To Waterfowl
Narrowleaf cattail	Typha angustifolia	Abundant	Primarily N. & S. Ends	--
Cane grass	Phragmites communis	Common	North end	--
Hardstem bulrush	Scirpus acutus	Occasional	Scattered along shore	G
Softstem bulrush	Scirpus validus	Occasional	Scattered along shore	S-F
River bulrush	Scirpus fluviatilis	Occasional	Scattered along shore	S-F
Smartweed	Polygonum lapathifolium	Common	Scattered along shore	G-E
Curly dock	Rumex crispus	Common	Scattered along shore	--
Arrowhead	Sagittaria rigida	Scarce	Channel - NE side	--

Emergent vegetation (primarily narrowleaf cattail and cane grass) was most abundant around the north portion of the lake and the extreme southeastern tip. A very narrow and sparsely vegetated fringe was present around much of the shoreline.

SPECIES OF FLOATING - LEAVED AND SUBMERGED AQUATIC PLANTS

Total % of occurrence of submerged vegetation - 41.
Greatest depth to which rooted submerged plants grow - 3.9 feet.

Common Name	Scientific Name	% Accurrence N 134	Density	Distribution	Food Value To Waterfowl
Sago pondweed	Potamogeton pectinatus	41	Moderate	North half	E
Lesser duckweed	Lemna minor	1	Sparse	N. & S. ends	F-E

S-SLIGHT; SF-SLIGHT FAIR; F-FAIR; FG-FAIR-GOOD; FE-FAIR-EXCELLENT; G-GOOD; GE-GOOD-EXCELLENT; E-EXCELLENT.

Table 22 (continued)

SOUTH HERON LAKE, JACKSON COUNTY
SPECIES OF EMERGENT AQUATIC PLANTS

SPECIES OF FLOATING - LEAVED AND SUBMERGED AQUATIC PLANTS

Species of submerged aquatic plants observed (channel/wetland area - Northeast Corner of Lake) but not recorded at a sampling station.

Common Name	Scientific Name	% Accurrence N 134	Density	Distribution	Food Value To Waterfowl
Flatstem	Potamogeton zosteriformis	--	Lush	NE corner	F
Water smartweed	Polygonum amphibium	--	Moderate	NE corner	G-E
Star duckweed	Lemna trisulca	--	Scattered	NE corner	F-E
Lesser duckweed	Lemna minor	--	Scattered	NE corner	F-3

S-SLIGHT; SF-SLIGHT FAIR; F-FAIR; FG-FAIR-GOOD; FE-FAIR-EXCELLENT; G-GOOD; GE-GOOD-EXCELLENT; E-EXCELLENT.

The loss of emergent vegetation can adversely affect waterfowl production and hunting. Nature's way of re-establishing emergent and submergent to vegetation is an extended period of drought resulting from sub-normal precipitation. In the absence of adequate rainfall and run-offs the shallow lakes and marshes become dry, or nearly so, and their bottoms assume a mud-flat condition in whole or in part. The parts not still covered with water become firmer, sprouting of the seeds of bullrushes, cattails, etc. is stimulated, and the potential for an increase in waterfowl production and hunting is greatly enhanced. With the return of greater precipitation and water to the shallow lakes and marshes the return of optimum wildlife production and hunting is realized. Man accomplishes the same effect with drawdowns.

Drought periods in southern Minnesota occur consistently every twenty years. Good habitat on the shallow lakes and marshes as a result of a drought lasts only about seven to eight years at best; this means low waterfowl production and hunting between drought periods. For Heron Lake this means that the period of less than optimal conditions is of far longer duration than necessary. Once the planned improvements in the Heron Lake project were operational, the benefits resulting from water drawdowns could be achieved at a greater frequency than the twenty year natural cycle.

The effect of drought type conditions on the restoration of emergent vegetation was demonstrated in 1978 on the north portion of the Heron Lake complex lying between the main outlet dam and the shore of North Lake. This area, known as The Marsh, was dried out when the outlet dam was illegally dynamited. A lush growth of cattails and other marsh type vegetation resulted and in 1978 when water levels were at a high level from heavy run-off in the watershed, the marsh was heavily used for production by waterfowl species such as teal, mallards, shovelers, redheads and pintails. In one hours time an observer noted 23 broods swimming past one point. Also, duck broods were observed by DNR personnel on every occasion in 1978 when water levels were being checked at the outlet dam. (MDNR, Open File 1978).

IV. EROSION PROBLEMS

A. Sediment Sources

Erosion and sedimentation within the Heron Lake Watershed have long been recognized as a significant problem and led in part to the formation of the Middle Des Moines Watershed District. During times of flooding large quantities of sediment are deposited on lands adjacent to streams, disrupting agricultural activities and damaging crops.

Streamback erosion contributes sediment to downstream areas, encroaches onto adjacent farmlands and has potential to endanger roads, buildings, or public utilities.

Sediment delivered to the Heron Lake system causes an increase in turbidity following storms and is eventually trapped to a large extent within the system. The shallow nature of the lakes aggravates this problem due to the fact that bottom sediments are subject to resuspension with the moderate to high winds not uncommon in the area.

Sediment delivered to the lake is also a source of nutrients which contribute to the eutrophication of the lake. Phosphorus and nitrogren compounds from fertilizer and natural sources are absorbed to the surface of the individual sediment particles and transported to the lake system where they are available for the growth of algae and aquatic weeds.

Erosion problems can be characterized as the result of three events:

1. Soil particles must be detached from the surrounding soil mass by a force such as wind, the impact of falling raindrops or flowing water.

2. The detached soil particles must be transported away from the source.

3. The soil particles are ultimately deposited at some other location.

Sheet and rill erosion accounts for sediment which is produced over a broad area from fields, construction sites or natural areas and is often not noticeable at the site. Soil particles are detached by the impact of raindrops or sheet flow on the soil surface, concentrated at rills (small gullies which do not interfer with normal farming operations) and transported to the edge of a field into a stream or other watercourse. Sheet and rill erosion represents a major source of sediment contributed to the Heron Lake System.

Streambank erosion is also a significant problem in the watershed. This form is much more apparent and is evident in the eroded banks of both Jack and Okabena Creeks. Soil detachment and transport with streambank erosion is the result of flowing water and the severity increases as the flow increases.

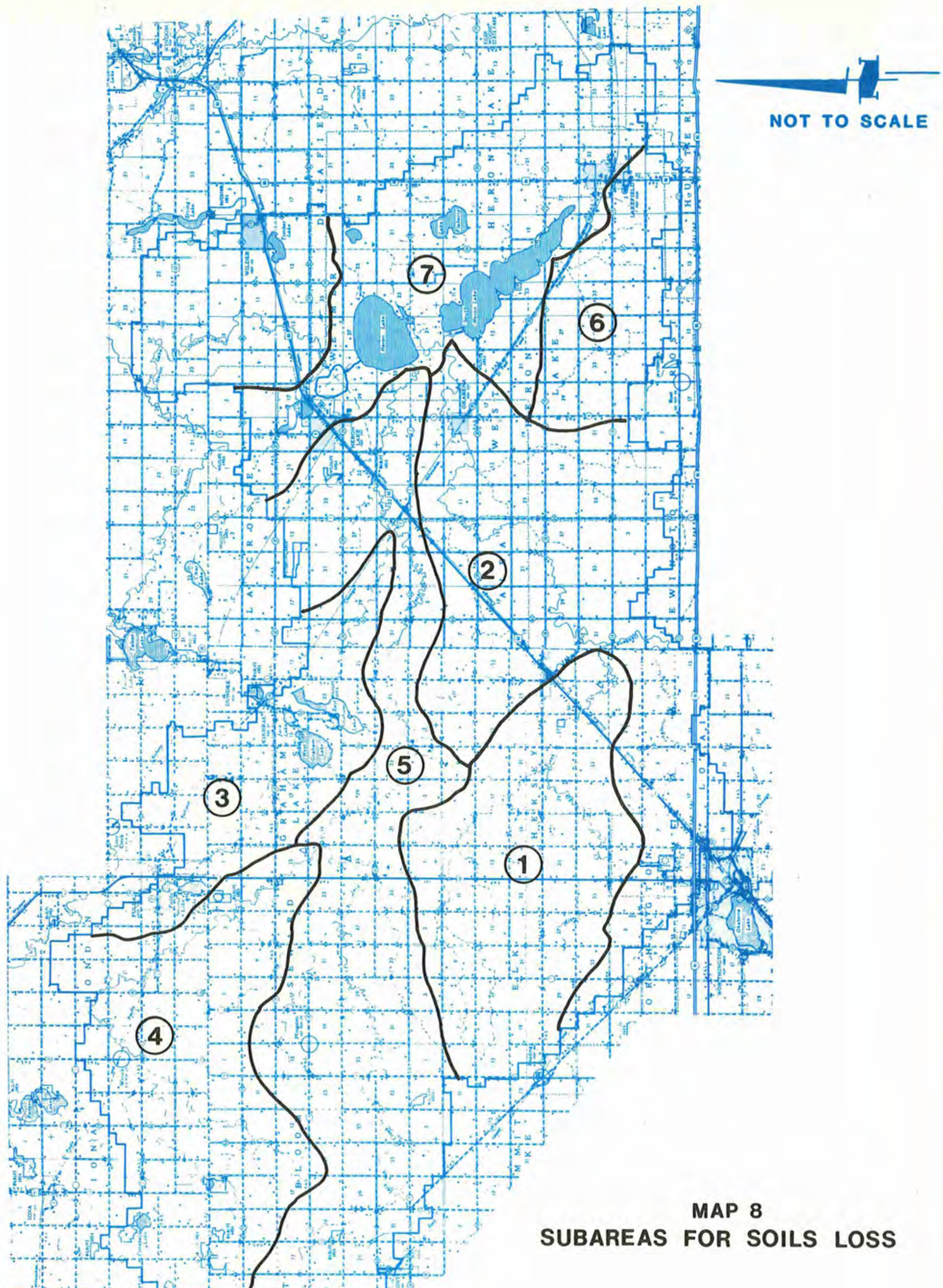
Gully erosion occurs as flows are concentrated and the velocity becomes high enough to erode the underlying materials and create an overfall. Continued runoff causes this overfall or "gully head" to extend further upstream.

Although this form of erosion is present at some locations within the watershed it does not appear to be widespread and does not contribute a large portion of sediment to the Heron Lake System.

B. Sheet and Rill Erosion

Sheet and rill erosion is the result of a combination of factors such as the climate of the area, inherent physical characteristics of the soil, topography and land use. These factors are combined in the Universal Soil Loss Equation (USLE) to arrive at a soil loss in tons per acre. The watershed contributing to the Heron Lake system was subdivided into seven subwatersheds (Map 8) to provide a comparison of general areas. Soil types, topography and land use information were utilized to arrive at an average annaul soil loss for each subwatershed.

Soil losses for cropland range from 2.2 to 3.5 tons/acre in the seven subwatersheds, while averages for the total area (including wetlands, road, etc.) range from 2.0 to 3.1 tons per acre. Table 23 summarizes the soil losses for the seven subwatersheds. A soil loss in excess of 5 tons/acre is ordinarily considered excessive from an agricultural standpoint (USDA 1981 Report and Environmental Impact Statement, Soil and Water Conservation Act) and although some areas exist with losses greater than 5 tons/acre, the averages are below this level. This does not imply that erosion is not a problem within the watershed, as erosion occuring at any level is capable of causing downstream damages or water quality problems for any given condition.



MAP 8
SUBAREAS FOR SOILS LOSS

TABLE 23

SOIL LOSSES BY SUBWATERSHED

	Subwatershed	Soil Loss (Tons/Acre/Year) Cropland Only	Total Area
1.	Elk Creek	2.2	2.0
2.	Okabena Creek	3.3	2.7
3.	Graham Lakes	3.0	2.4
4.	North Branch, Jack Creek	3.0	2.5
5.	Jack Creek	2.7	2.3
6.	Judicial Ditch No. 3	3.4	3.1
7.	Heron Lake (local area)	3.5	3.1

The soil losses estimated from the USLE are higher than what will be delivered to a point downstream since some soil can be trapped in low areas of a field before reaching a watercourse or can be deposited in the channel or on the adjacent floodplain. To determine the sediment delivered to a downstream point a sediment delivery ratio (Renfro, 1975) is applied to the quantities of gross erosion determined by the USLE. The sediment delivery ratio is dependent on the type of sediment produced from an area, the general characteristics of an area and the size of the drainage area. For a small drainage area the sediment delivery ratio is higher than for a large drainage area since there is an easier or shorter path to the downstream area. Table 24 summarizes the estimated quantities of sediment delivered from the subwatersheds to the Heron Lake system in an average year.

TABLE 24

SUMMARY OF SEDIMENT DELIVERY

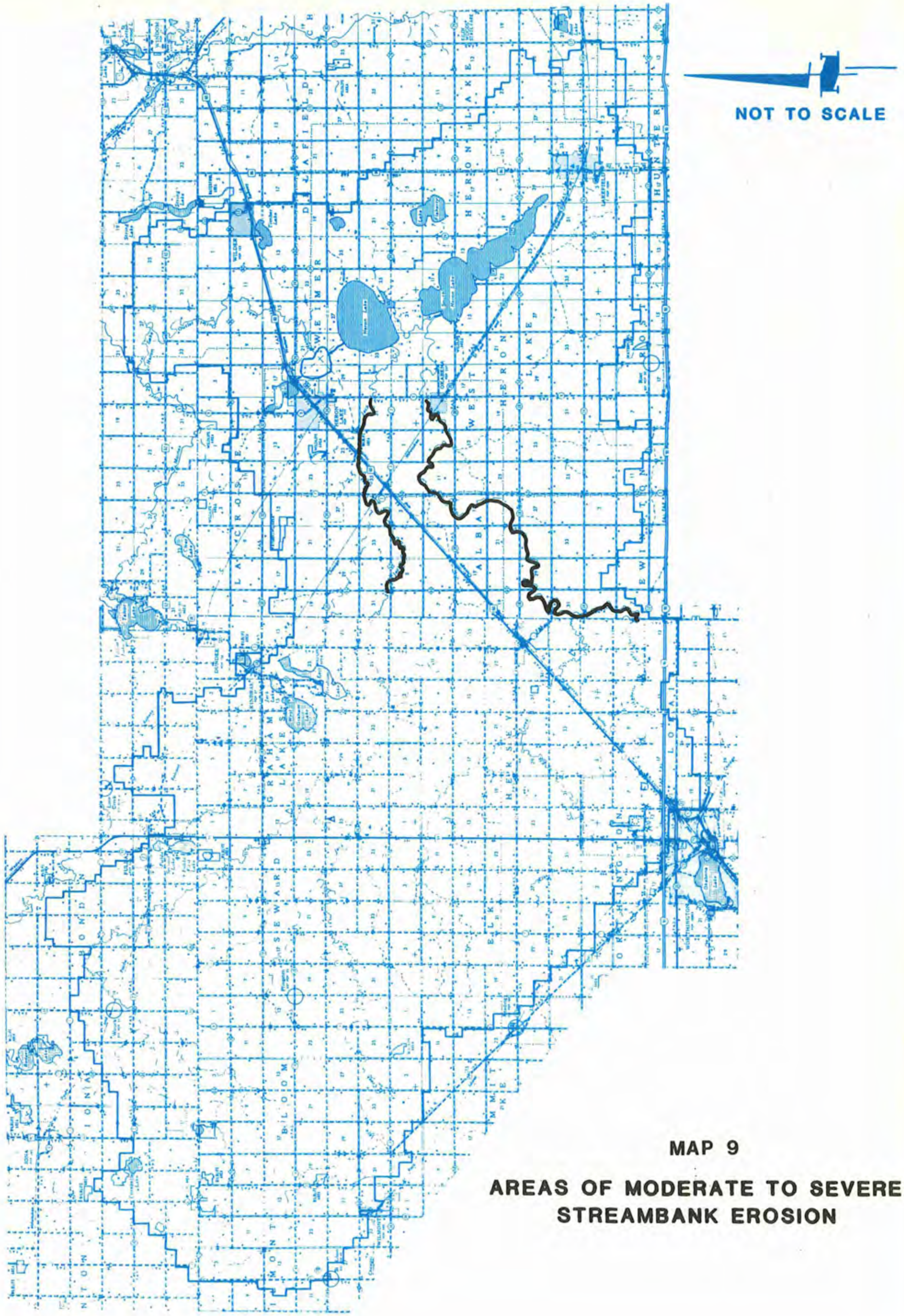
Subwatersheds	D.A. (Sq. Mi.)	100 Tons Sediment/Year	%
Elk Creek & Okabena Creek	146.25	27.3	24
Graham Lakes, North Branch Jack Creek & Jack Creek(1)	220.50	29.5	25
Judicial Ditch No. 3	21.50	10.6	9
Heron Lake (local area)	64.50	48.3	42
	452.75	115.7	100

(1)Sediment production in the Graham Lakes subwatershed is considered to be essentially trapped in the lakes and non-contributing.

In the information presented in Tables 23 and 24, it is apparent that the areas in the vicinity of Heron Lake contribute a much higher amount of sediment per acre than the other areas since they have a higher soil loss and also deliver a higher percentage of the sediment produced.

C. Streambank and Gully Erosion

Determining the quantities of sediment produced by streambank and gully erosion is extremely difficult and beyond the scope of this study. The most severe areas of streambank erosion are in the lower reaches of both Jack and Okabena Creek (Map 9). Although sediment is produced at these locations, a portion of it is also deposited in the channel as the stream meanders. The quantities produced are also dependent on the severity of runoff. While a year with high runoff may produce a high sediment yield from streambank erosion, a normal or low flow year may produce little or no sediment. Frm the standpoint of lake autrophication sediment produced by streambank erosion is less significant than sheet and rill erosion since a greater percentage of soil comes from the less fertile subsoils rather than topsoil. Gully erosion does not appear to be a significant source of sediment to the Heron Lake system. Some small gullies do exist within the watershed notably at some road ditches entering watercourses and in fields bordering watercourses.



MAP 9

AREAS OF MODERATE TO SEVERE STREAMBANK EROSION

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Potential Alternatives

POTENTIAL ALTERNATIVES

INTRODUCTION

The four major problems for the Heron Lake System related to flooding, water quality, lake use, and fish and waterfowl resources are complex and interrelated.

The following section presents an array of potential alternatives broadly divided into two categories:

I. Flood Control Alternatives

   A. Structural
   B. Non-structural

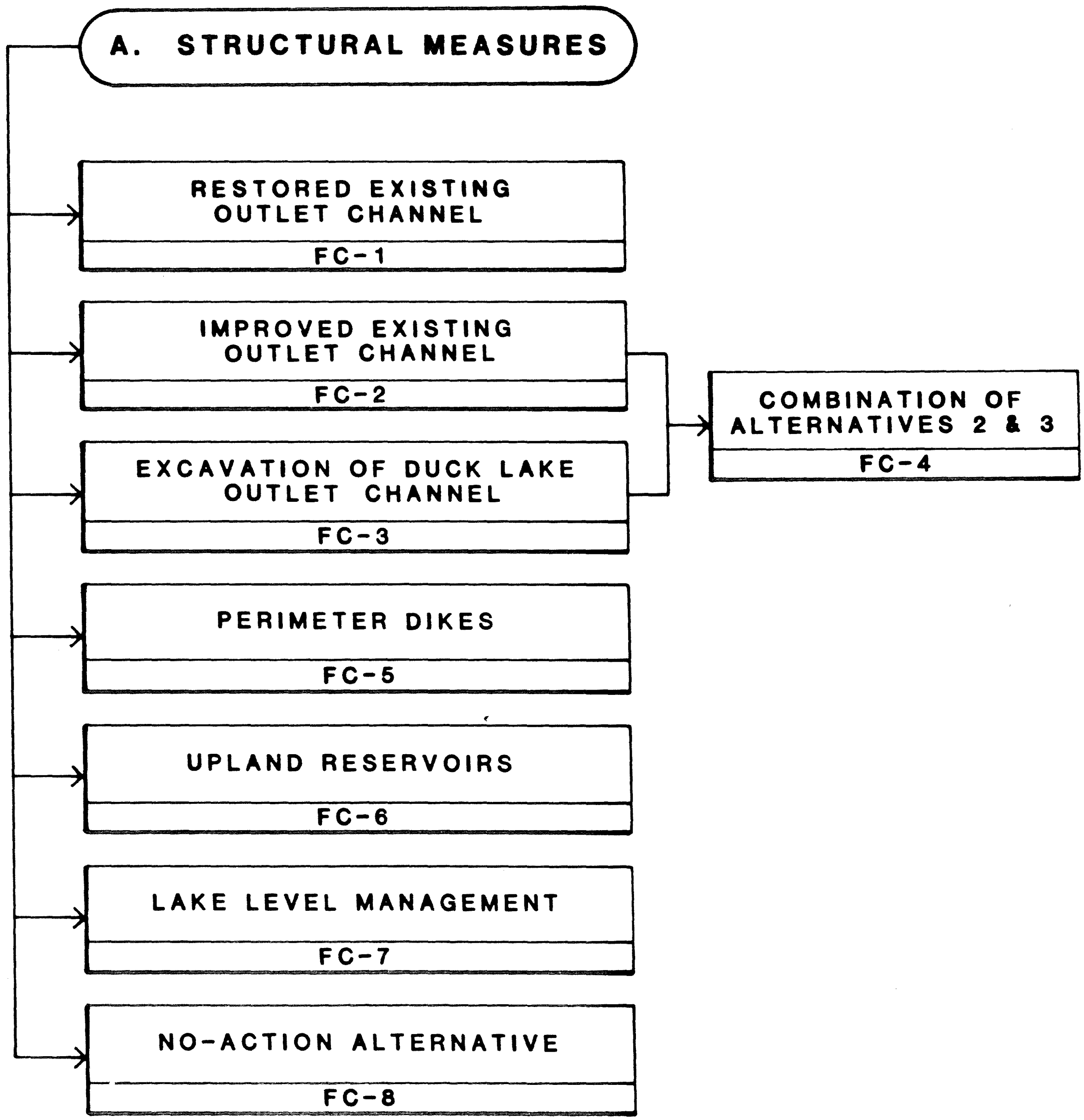
II. Resources Improvement Alternatives (Water Quality, Lake Use, Fish and Waterfowl)

   A. Entire Lake System
   B. Partial Lake System

Each of the categories is composed of several independent or interrelated components. It is not the purpose of this study to recommend and/or develop detailed analysis of any of the following alternatives for implementation.

The alternatives presented herein are therefore conceptual in nature, and their discussion is limited to a brief description, advantages and disadvantages, and applicable location in the Heron Lake System or in its upstream drainage areas.

HERON LAKE
FLOOD CONTROL ALTERNATIVES



RESTORED EXISTING OUTLET CHANNEL

FC-1

As stated earlier in this report, the outflow of the Heron Lake system is not controlled by the existing outlet dam but by the outlet channel from the dam to the junction with the Middle Des Moines River.

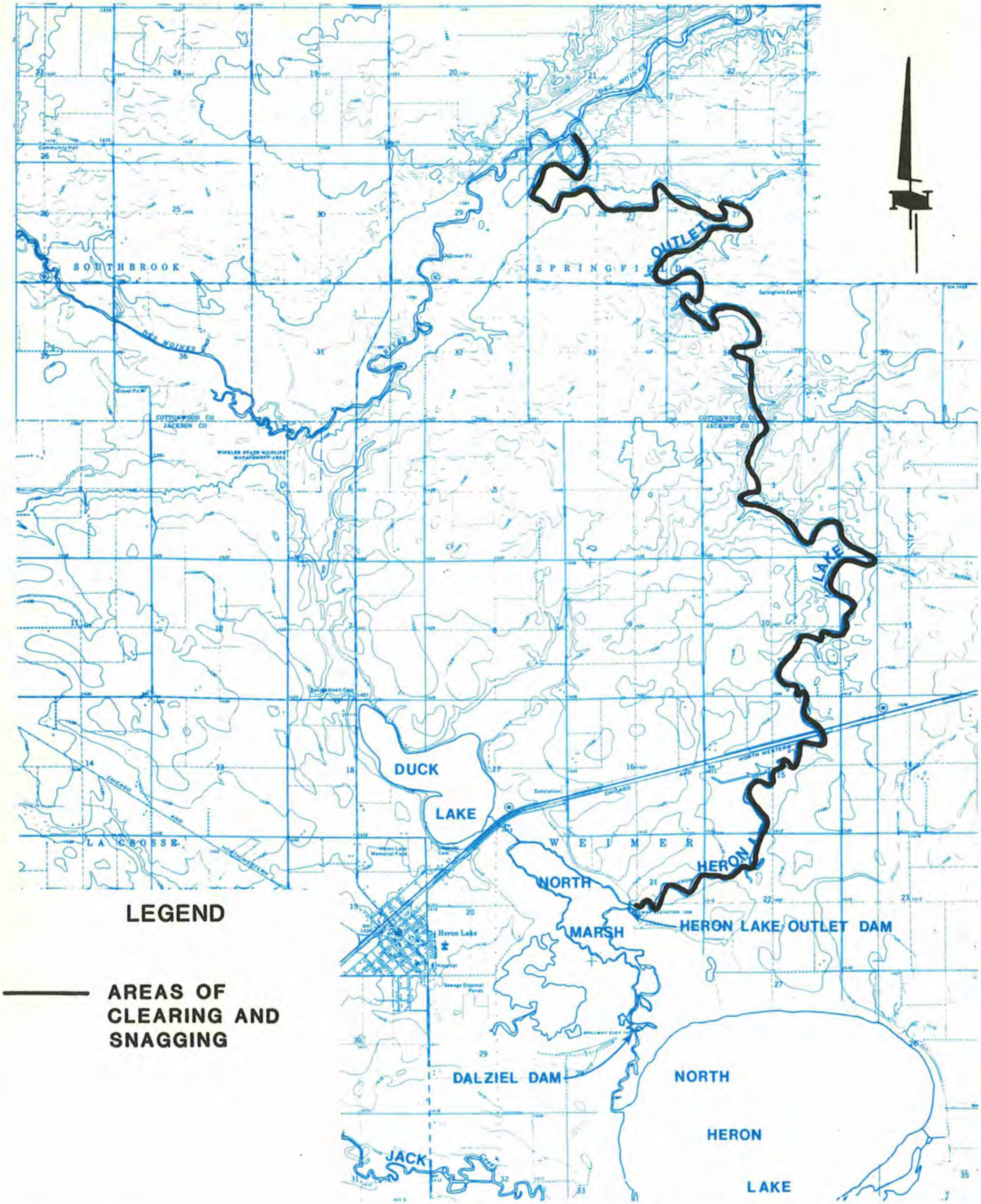
At the present, this channel is partially clogged with debris which significantly reduces its hydraulic capacity to convey flood waters out of the Heron Lake system.

Alternative FC-1 calls for cleaning any vegetation and snagging debris from the channel to restore to its original condition without excavation of materials from the channel. This alternative will result in both a decrease of flood stage and a decrease in the duration of flooding on the lake system.

Our hydrologic analysis provided the following results for spring runoff conditions:

	Present Conditions		FC-1 Conditions		Changes	
Flood Frequency	Lake Elevation (ft.)	Flood Duration(*) (days)	Lake Elevation (ft.)	Flood Duration(*) (days)	Elevation (ft.)	Duration (days)
5-year	1407.1	30	1406.3	10	-0.8	-20
10-year	1407.9	31	1407.2	11	-0.7	-20
25-year	1408.9	32	1408.1	12	-0.8	-20
50-year	1409.7	33	1408.8	13	-0.9	-20
100-year	1410.6	34	1409.7	14	-0.9	-20

(*)Flood duration is defined as time period during which lake elevation is at or above 1402' MSL.



MAP FC-1

McCOMBS-KNUTSON ASSOCIATES, INC. CONSULTING ENGINEERS ■ LAND SURVEYORS ■ SITE PLANNERS MINNEAPOLIS, HUTCHINSON and MARSHALL, MINNESOTA	SCALE BOOK / PAGE FILE NO.	RESTORED EXISTING OUTLET CHANNEL

RESTORED EXISTING OUTLET CHANNEL

FC-1

ADVANTAGES

- Flood Stage Reduction
- Flood Duration Reduction
- Relative Low Cost
- No Bridge Replacement
- No Problem With State Permits
- No Land Easement
- Easy Implementation

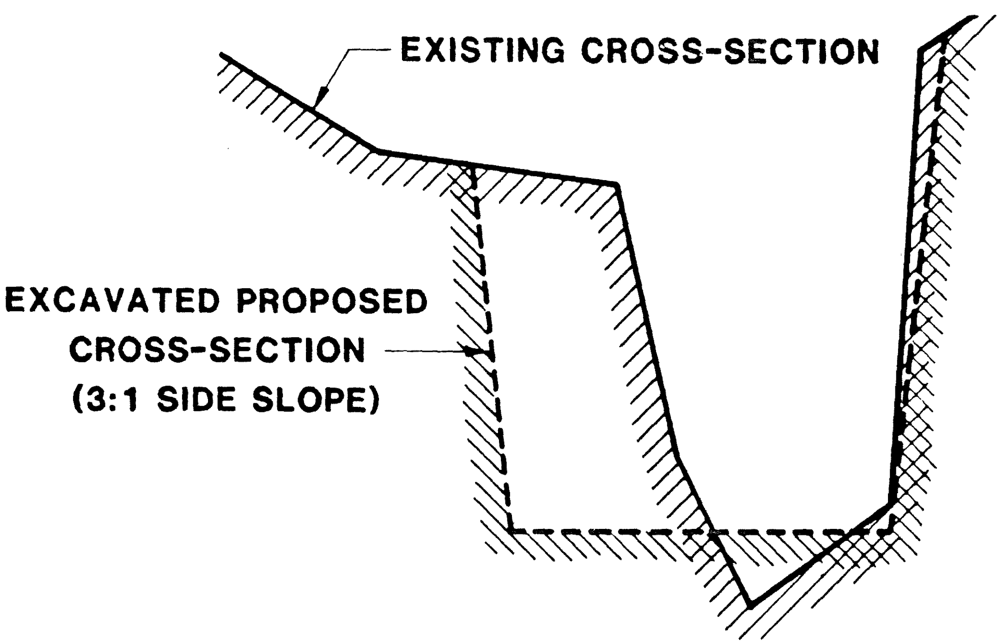
DIS-ADVANTAGES

- Possible negative impact on downstream water quality during the working period

IMPROVED EXISTING OUTLET CHANNEL

FC-2

Alternative FC-2 calls for an enlargement of the existing outlet channel to accomodate higher flows during flooding events. For a 25 year design flood, this excavated channel will have an trapezoidal cross-section with 3:1 side slopes, 100 foot wide bottom, with existing alignment and existing slope.



TYPICAL CROSS-SECTION

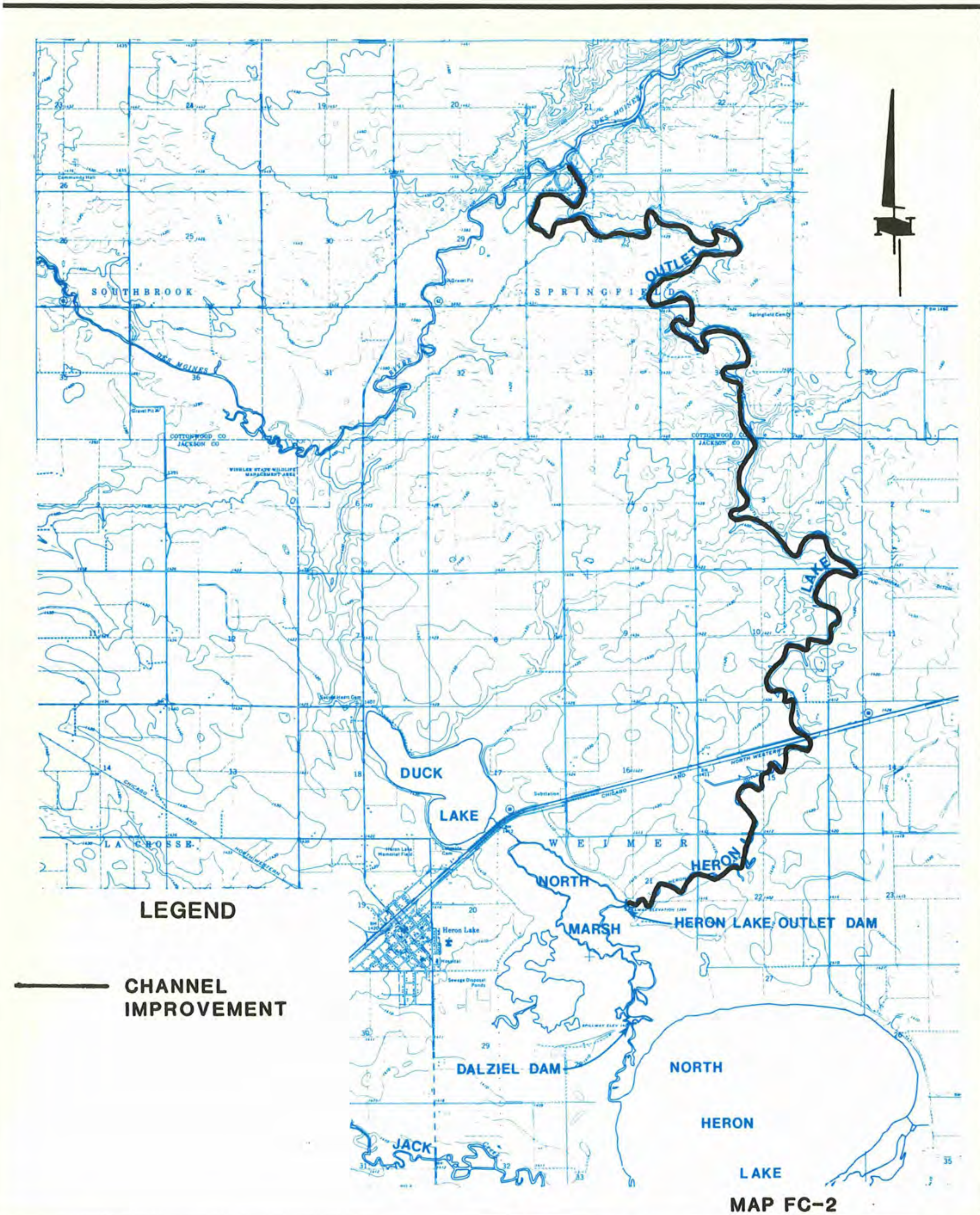
Our hydrologic analysis provided the following results for spring runoff conditions:

Flood Frequency	Present Conditions Lake Elevation (ft.)	Present Conditions Flood Duration* (days)	FC-2 Conditions Lake Elevation (ft.)	FC-2 Conditions Flood Duration* (days)	Changes Elevation (ft.)	Changes Duration (days)
5-year	1407.1	29.7	1404.9	10.5	-2.2	-19.2
10-year	1407.9	32.1	1405.9	11.9	-2.0	-19.1
25-year	1408.9	32.1	1406.9	13.0	-2.0	-19.1
50-year	1409.7	33.1	1407.8	14.0	-1.9	-19.1
100-year	1410.6	33.9	1408.6	14.7	-2.0	-19.2

Alternative FC-2 will require replacement of 2 county bridges and 1 trunk highway bridge (TH 60).

In addition, alternative FC-2 will result in an increase of flooding downstream, particularly in and around the City of Windom located approximately 8 miles northeast of the Heron Lake system on the Middle Des-Moines River. Preliminary analysis indicated that in general, the increase in flooding at Windom is approximately 15% for severe flooding events. A cursory hydrologic analysis of the flooding situation at Windom for the 1969 flood event shows an increase from 8300 cfs to 9600 cfs if FC-2 is adopted. This flooding event has an order of magnitude of between the 50-year and the 100-year flood.

(*)Flood duration is defined as time period during which lake elevation is at or above 1402' MSL.



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IMPROVED EXISTING
OUTLET CHANNEL

IMPROVED EXISTING OUTLET CHANNEL

FC-2

ADVANTAGES

- Flood Stage Reduction
- Flood Duration Reduction
- Relatively Low Cost (compared to other structural alternatives)
- Relatively Short Implementation Time

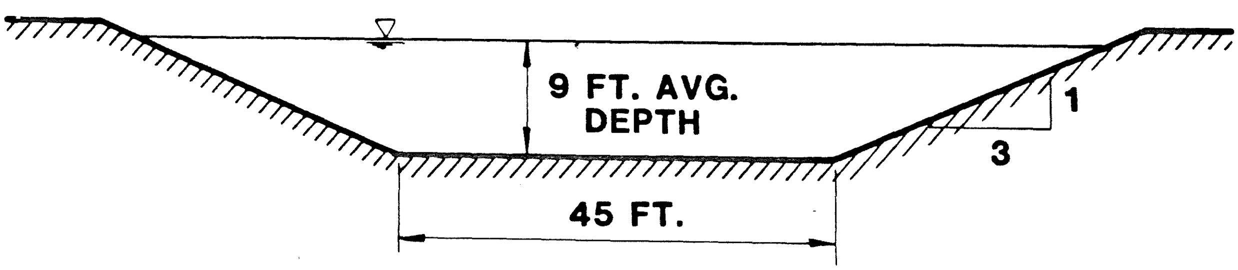
DIS-ADVANTAGES

- High Cost of Bridge Replacement
- Significant Increase of Downstream Flooding
- Problems With Obtaining State Permits
- Land Easements Required

EXCAVATION OF DUCK LAKE OUTLET CHANNEL

FC-3

Alternative FC-3 entails construction of a new outlet channel from Duck Lake to either the Des Moines River (location 2) or the Heron Lake Outlet (location 1). The effects of this alternative are similar to Alternative FC-2 (Improved Existing Outlet Channel) in that flooding conditions on the Heron Lake System are reduced with respect to both peak elevations and flood duration. A preliminary design was not prepared for location 2, however, location 1 would require a trapezoidal channel with 3:1 side slopes, 45 foot wide bottom and a slope of 0.113% (based on a 25 year design flood).



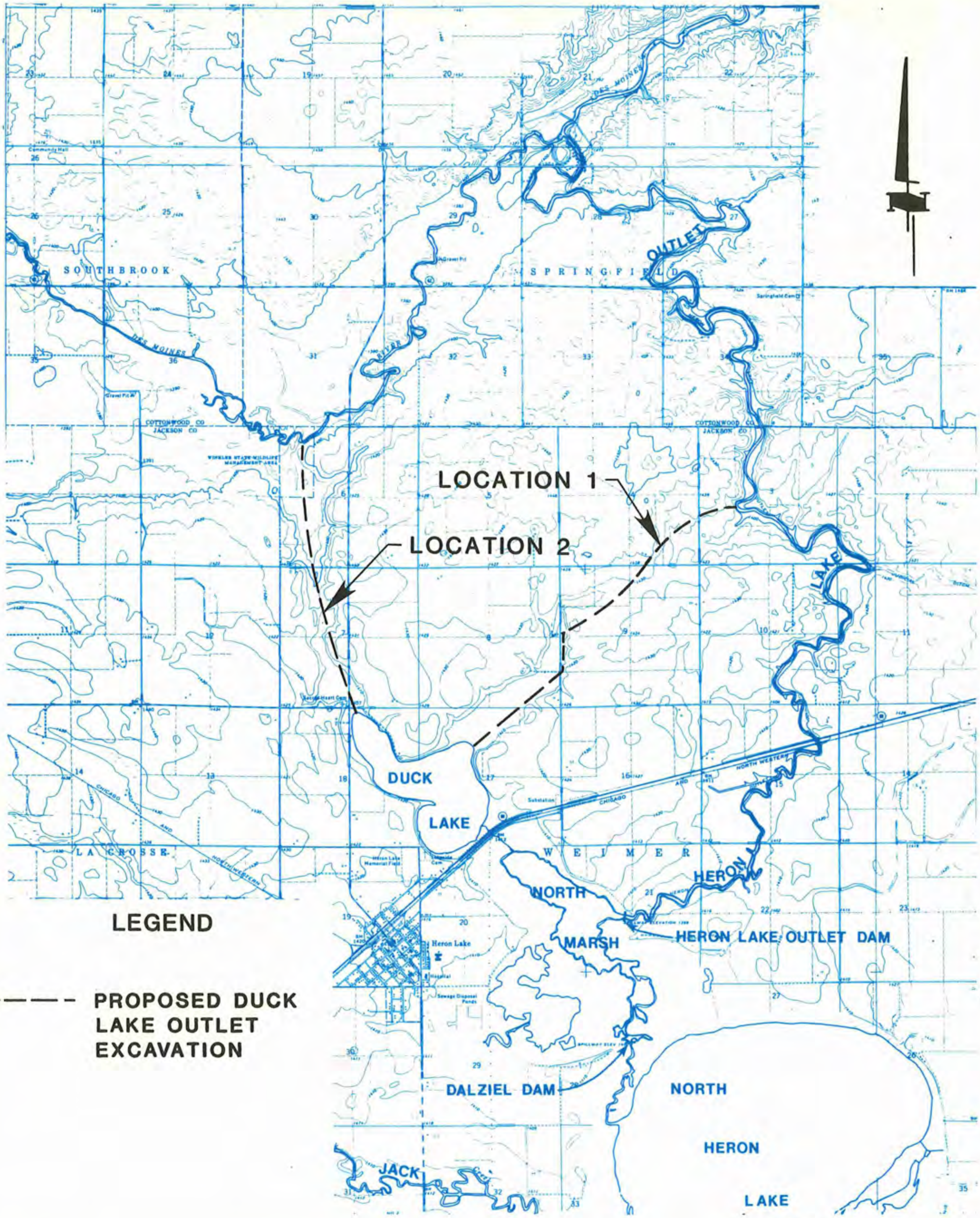
Hydrologic analysis provided the following results for spring runoff conditions:

Flood Frequency	Present Conditions Lake Elevation (ft.)	Present Conditions Flood Duration* (days)	FC-3 Conditions Lake Elevation (ft.)	FC-3 Conditions Flood Duration* (days)	Changes Elevation (ft.)	Changes Duration (days)
5-year	1407.1	30	1406.0	23	-1.1	-7
10-year	1407.9	31	1407.0	24	-0.9	-7
25-year	1408.9	32	1407.9	25	-1.0	-7
50-year	1409.7	33	1408.7	26	-1.0	-7
100-year	1410.6	34	1409.4	26	-1.2	-8

Both locations for Alternative FC-3 require replacement of three county bridges and the Trunk Highway 60 bridge.

Several of the disadvantages associated with Alternative FC-2 also apply to this alternative. Flooding downstream of the Heron Lake System will increase by approximately 15% for severe flooding events. This alternative will also require approximately 30 acres of land for right-of-way.

* Flood duration is defined as time period during which lake elevation is at or above 1402'.



MAP FC-3

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DUCK LAKE OUTLET

EXCAVATION OF DUCK LAKE OUTLET CHANNEL

FC-3

ADVANTAGES

- Flood Stage Reduction
- Flood Duration Reduction

DIS-ADVANTAGES

- High Cost of Bridge Replacement
- Significant Increase In Downstream Flooding (City of Windom)
- Permits Required
- Required Land Acquisition For Right-of-Way

COMBINATION OF ALTERNATIVES 2 & 3

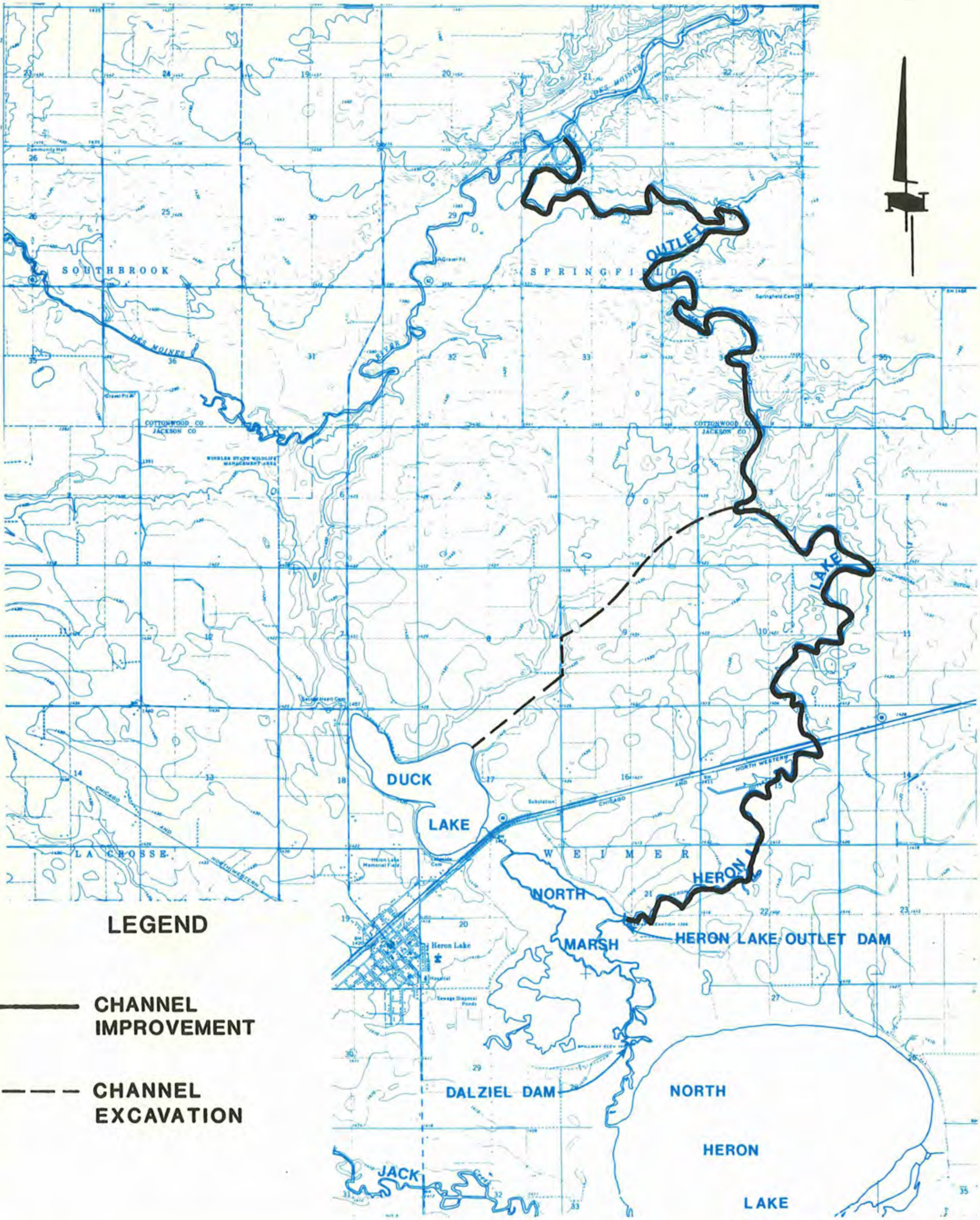
FC-4

Alternative FC-4 is a combination of Alternative FC-2 (Improved Existing Outlet Channel) and Alternative FC-3 (Excavation of Duck Lake Outlet Channel).

A hydrologic analysis indicates the following changes in peak elevation and flood duration for varying frequencies for spring runoff conditions.

	Present Conditions		FC-4 Conditions		Changes	
Flood Frequency	Lake Elevation (ft.)	Flood Duration* (days)	Lake Elevation (ft.)	Flood Duration* (days)	Elevation (ft.)	Flood Duration (days)
5-year	1407.1	30	1404.5	9	-2.6	-21
10-year	1407.9	31	1405.6	10	-2.3	-21
25-year	1408.9	32	1406.4	11	-2.5	-21
50-year	1409.7	33	1407.2	12	-2.5	-21
100-year	1410.6	34	1407.9	13	-2.7	-21

* Flood Duration is defined as time period during which lake elevation is at or above 1402'.



LEGEND

—— CHANNEL IMPROVEMENT

- - - - CHANNEL EXCAVATION

MAP FC-4

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IMPROVED EXISTING OUTLET AND EXCAVATION OF DUCK LAKE OUTLET

COMBINATION OF ALTERNATIVES 2 & 3

FC-4

ADVANTAGES

- More Significant Reduction In Flood Elevation Than Alternative FC-2 or FC-3 alone
- Reduction in Flood Duration

DIS-ADVANTAGES

- High Cost of Bridge Replacement (7 bridges)
- Significant Increase in Downstream Flooding
- Permits Required
- Land Acquisition and/or Easements Required

PERIMETER DIKES

FC-5

As stated earlier in this report, severe flooding problems exist in low lying areas surrounding North and South Heron Lakes. Alternative FC-5 consists of constructing earthen dikes adjacent to the lake to protect these areas. The following table summarizes the reduction in flooded area for various frequency floods for spring runoff conditions:

	Area Flooded		
Flood Frequency	Existing Conditions Area (Acres)	FC-5 Conditions Area (Acres)	Difference Area (Acres)
10 year	9,950	7,100	-2,850
25 year	10,450	7,950	-2,500
50 year	10,800	10,800	0
100 Year	11,300	11,300	0

This information is based on the locations shown on Map FC-5 and assumes that the dikes are designed for a 25 year flood with more severe damages possible at higher frequencies. It also assumes that the dikes are located to protect areas with an elevation greater than 1402 (NGVD-1929)*.

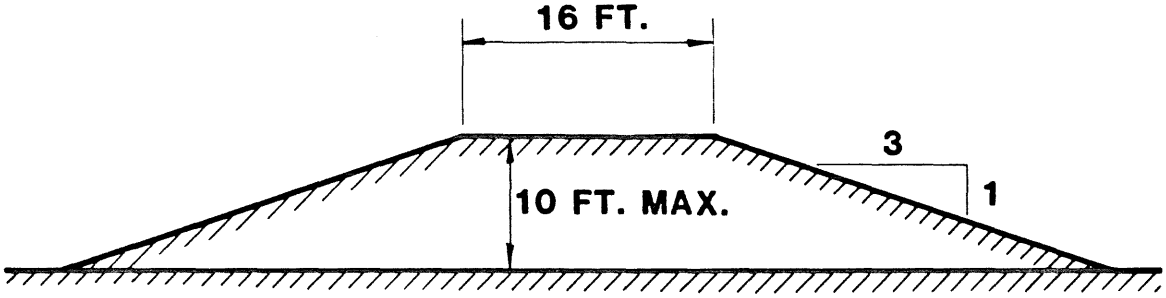
Several potential problems exist with Alternative FC-5. Periodic inspections and maintenance will be necessary to assure the effectiveness and safety of the dikes. In addition, provisions will have to be made for internal drainage (runoff from the areas protected by the dikes). This may require pumping over the dike and would increase operation costs of the system.

Another consequence of alternative FC-5 is that peak elevations on the lakes will increase for a flood of any frequency. This will in turn increase the flow rate from the lake system and increase flooding potential in downstream areas. Hydrologic analysis indicates that the following changes in peak elevation and outflow will occur if Alternative FC-5 is selected.

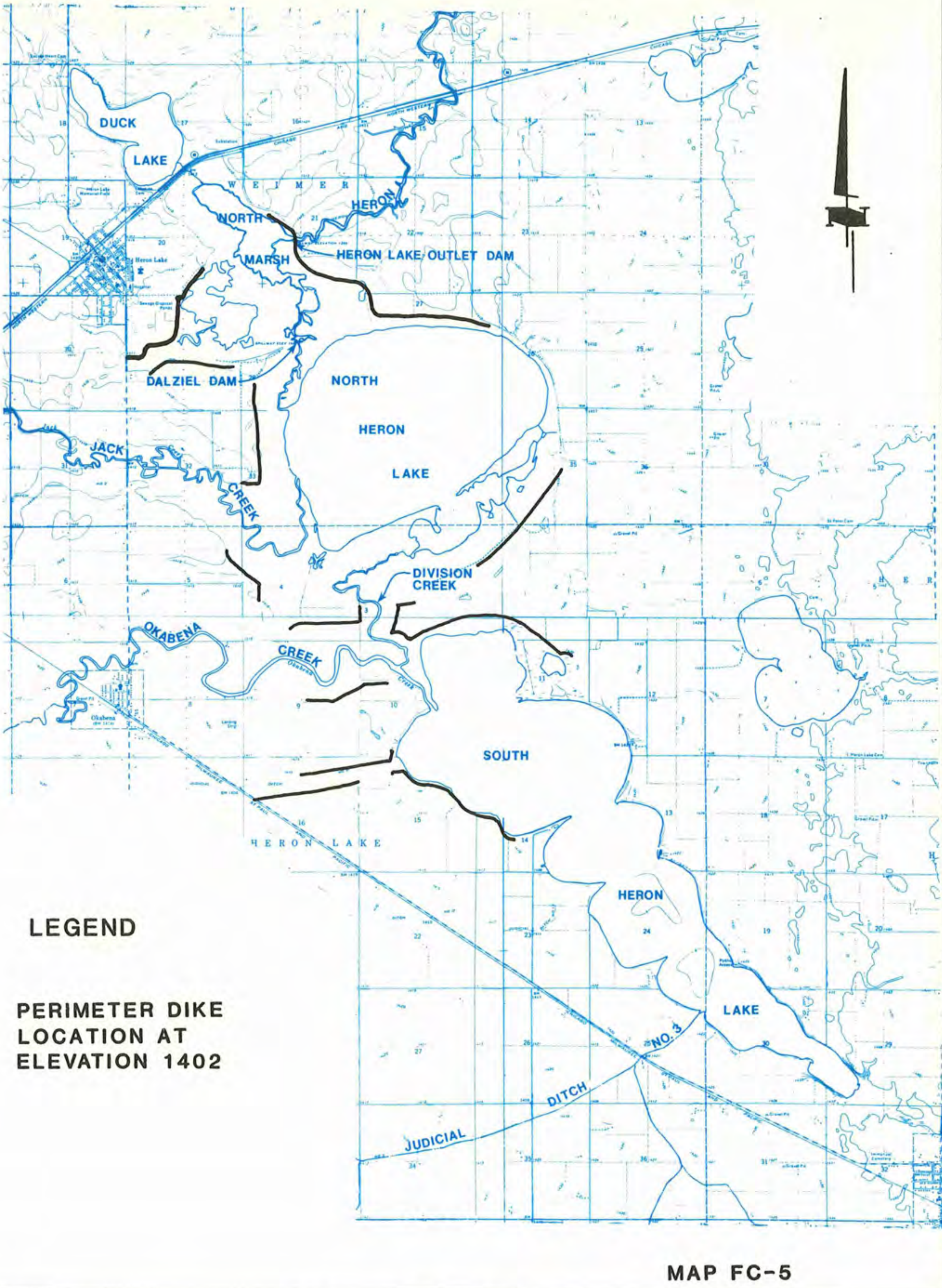
	Existing Conditions		FC-5 Conditions		Difference	
Frequency Years	Elevation Feet Above MSL	Area Flooded Acres	Elevation Feet Above MSL	Area Flooded Acres	Elevation Feet Above MSL	Area Flooded Acres
10	1407.9	9,950	1408.6	7,200	+0.7	-2,850
25	1408.9	10,450	1409.6	7,950	+0.7	-2,500
50	1409.7	10,800	1409.7	10,800	0.0	0
100	1410.6	11,300	1410.6	11,300	0.0	0

A preliminary hydrologic analysis indicates that flooding in Windom, Minnesota will increase by approximately 15% if this alternative is selected.

* Since the Natural Ordinary High Water Mark (NOHWM) has not been established for this lake system it was assumed that 1402' represents a reasonable level at which there is no severe encroachment onto the lake bed.



TYPICAL PERIMETER DIKE CROSS-SECTION



LEGEND

PERIMETER DIKE LOCATION AT ELEVATION 1402

MAP FC-5

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PERIMETER DIKES

PERIMETER DIKES

FC-5

ADVANTAGES

- Flood Protection For Adjacent Areas Around Lake and Jack & Okabena Creeks
- Prevention of Future Encroachment On Lake Bed

DIS-ADVANTAGES

- Increase In Stage on Lake System
- Increase of Peak Discharge From Lake System
- Interior Drainage Problems
- Danger of Dike Breaching At High Floods

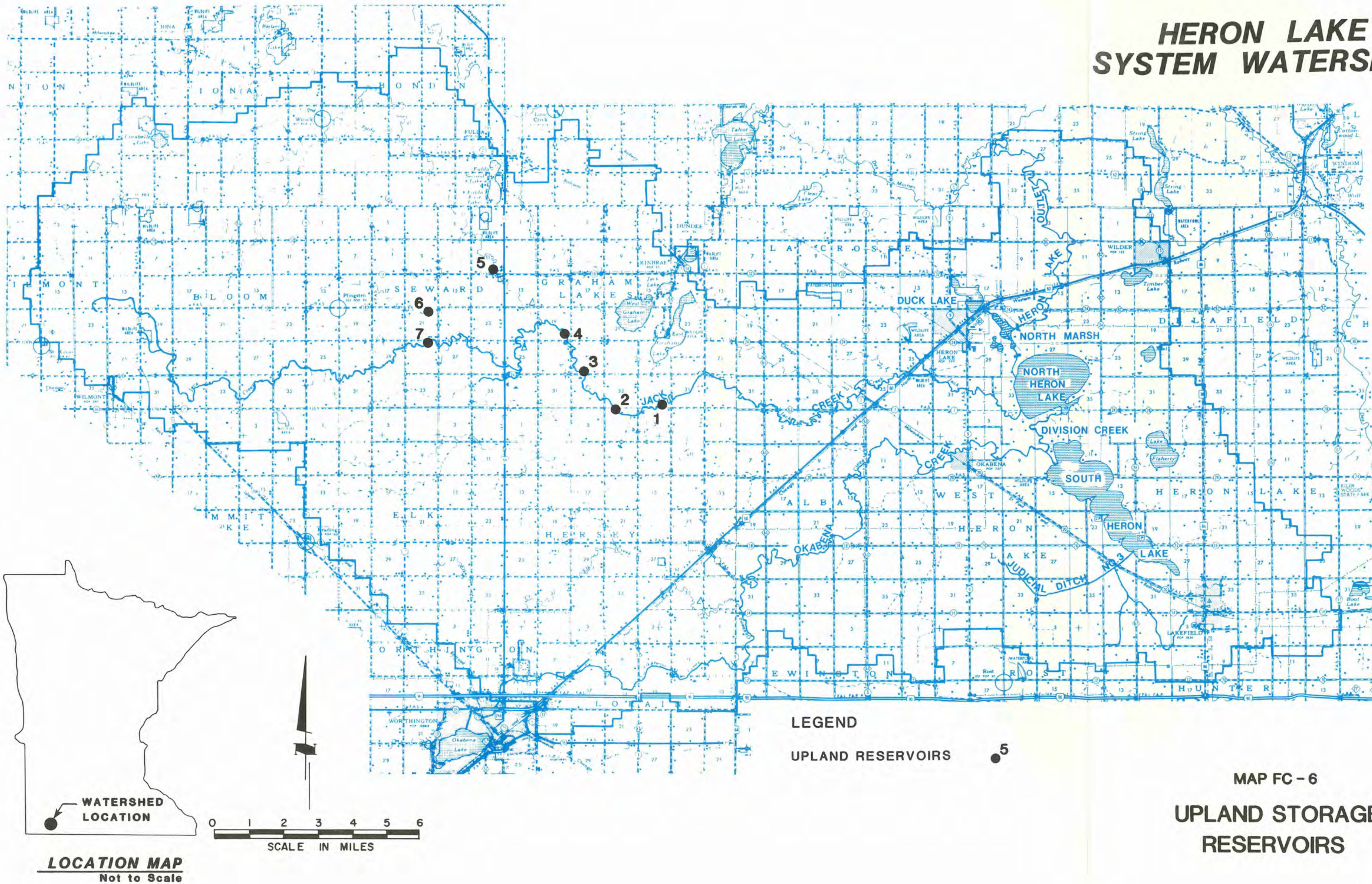
UPLAND RESERVOIRS

FC-6

A major cause of flooding around the Heron Lake System is the flood flows coming from the upstream contributing areas. Upland reservoirs, Alternative FC-6, offer good potential for retaining floodwaters in upland areas before they reach the Heron Lake System and contribute to flooding damages. Seven potential sites for upland storage reservoirs are shown on Map FC-6. These sites are located on Jack Creek or tributaries to Jack Creek. Okabena Creek was also considered, however, suitable sites are not available due to limitations in storage and other factors. The following information summarizes the characteristics of individual sites:

Site	Drainage Area (Sq. Mi.)	Volume (Ac-Ft.)	@ Elevation
1	135	4100	1470
2	131	1560	1480
3	127	3760	1490
4	126	4130	1500
5	54	1770	1510
6	11	1510	1560
7	36	1190	1560

HERON LAKE SYSTEM WATERSHED



MAP FC - 6

UPLAND STORAGE RESERVOIRS

Depending upon the final design and operation of the reservoirs, this alternative has the potential to reduce flood elevations and areas flooded on the Heron Lake System by the following amounts for sites 1, 4, 5, 6 and 7 (Sites 2 and 3 are considered alternatives to sites 1 and 4). This represents the optimum condition for flood reduction benefits downstream:

	Existing Conditions		FC-6 Conditions		Difference	
Frequency Years	Elevation Feet Above MSL	Area Flooded Acres	Elevation Feet Above MSL	Area Flooded Acres	Elevation Feet Above MSL	Area Flooded Acres
10	1407.9	9,950	1406.6	9,220	1.3	730
25	1408.9	10,450	1407.7	9,800	1.2	650
50	1409.7	10,800	1408.4	10,150	1.3	650
100	1410.6	11,300	1409.4	10,700	1.2	600

Several other benefits can also be attributed to Alternative FC-6. As discussed earlier in this report, streambank erosion in the lower reaches of Jack Creek is a recognized problem and in general becomes more severe as streamflows are increased. Implementation of this alternative will decrease and regulate stream flows downstream of the reservoir, and provide control of streambank erosion problems. In addition, a significant portion of sediment generated upstream from the reservoirs will be retained in the reservoir and not be delivered to the Heron Lake System.

Other benefits include the possibility of using the reservoirs for agricultural water supplies, irrigation (to a limited extent) and the possibility of recharge to groundwater supplies.

The primary disadvantage of this alternative is the necessity of acquiring land or easements at the reservoir sites. In addition these reservoirs may constitute a safety hazard and require periodic monitoring and maintenance. Permits will be required for the implementation of this alternative.

UPLAND RESERVOIRS

FC-6

ADVANTAGES

- Flood Reduction In Heron lake
- Flood Reduction In Downstream Reaches of Reservoirs
- Erosion Control In Downstream Reaches
- Water Supply For Surface and Subsurface Demand and Recharge
- Responsible Water and Land Resources Management
- Reduction In Sediment Load To Heron Lake

DIS-ADVANTAGES

- Land Easements Or Acquisition
- Dam Safety Hazard
- Permits Required
- Possible Loss of Arable Land

LAKE LEVEL MANAGEMENT

FC-7

Alternative FC-7, Lake Level Management, will have an effect on the suitability of the lake system for fisheries and wildlife and also affect the maximum elevations attained during a flood. In the past, controversies have centered around the optimum lake levels and the operation of the dam at the outlet of the system. The development of a more effective lake level management plan consists of several elements. A desirable level should be arrived at for management of the fish and wildlife resources and an attempt to maintain this level should be made whenever possible.* In all likelihood, this level will probably not be significantly different than the levels currently maintained on the Heron Lake System.

A second consideration regards the operation of the outlet structure during times of flooding. As discussed previously, damage due to flooding is common around the Heron Lake system and along the lower reaches of both Jack and Okabena Creek. Two approaches can be applied to this problem. The first is the elimination of activities in the flood prone areas which would be subject to damage, and the second is the development of an operational plan for the outlet structure which would minimize flood damages.

---

* It should be noted that this level could vary for different management considerations.

1. The elimination of all uses in flood plain which are subject to damage cannot be considered reasonable.

2. The development of an operational plan for the outlet structure of the Heron Lake system would provide guidelines to the Middle Des Moines Watershed District and the Minnesota Department of Natural Resources for the control of water levels on the lake system on a short and long term basis.

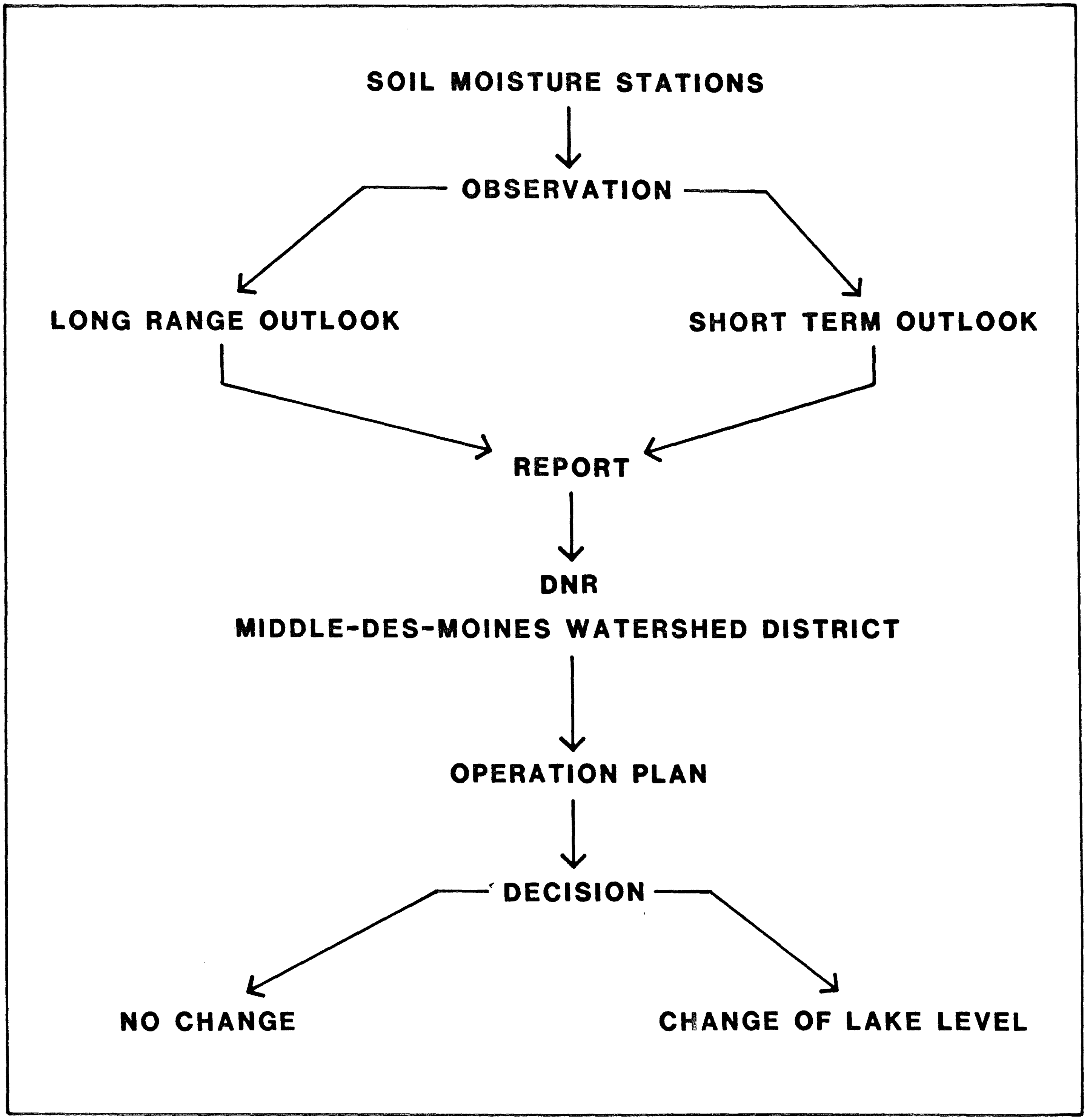
This plan would include monitoring of local climatic and soil moisture conditions and procedures for evaluating the flooding potential of these conditions. Based on this evaluation, elevations of the outlet structure could be manipulated to reduce flooding problems without harming fish and waterfowl habitats.

Hydrologic analysis indicates that if the lake level is lowered 0.5 feet prior to a flood event, Alternative FC-7 will have the following effects on peak elevation and duration of the flood for spring runoff conditions:

	Existing Conditions		FC-7 Conditions		Difference	
Frequency Years	Elevation Feet Above MSL	Flood Duration* (days)	Elevation Feet Above MSL	Flood Duration* (days)	Elevation Feet Above MSL	Flood Duration* (days)
2	1405.5	9.8	1405.4	9.4	-0.1	-0.4
5	1407.2	15.0	1407.1	14.8	-0.1	-0.2
10	1407.9	17.0	1407.9	17.0	-0.0	0.0

This alternative will require considerable effort to establish the technical procedures for developing the lake level management plan, and if implemented, will require a high level of effort to monitor and operate the system. A schematic operation is outlined on the following page.

* Flood duration is defined as time period during which lake elevation is at or above 1402'.



PROPOSED LAKE MANAGEMENT PLAN SCHEMATIC
ALTERNATIVE FC-7

LAKE LEVEL MANAGEMENT

FC-7

ADVANTAGES

- Provision of Additional Flood Storage
- Improved Management of Fish & Wildlife Resources

DIS-ADVANTAGES

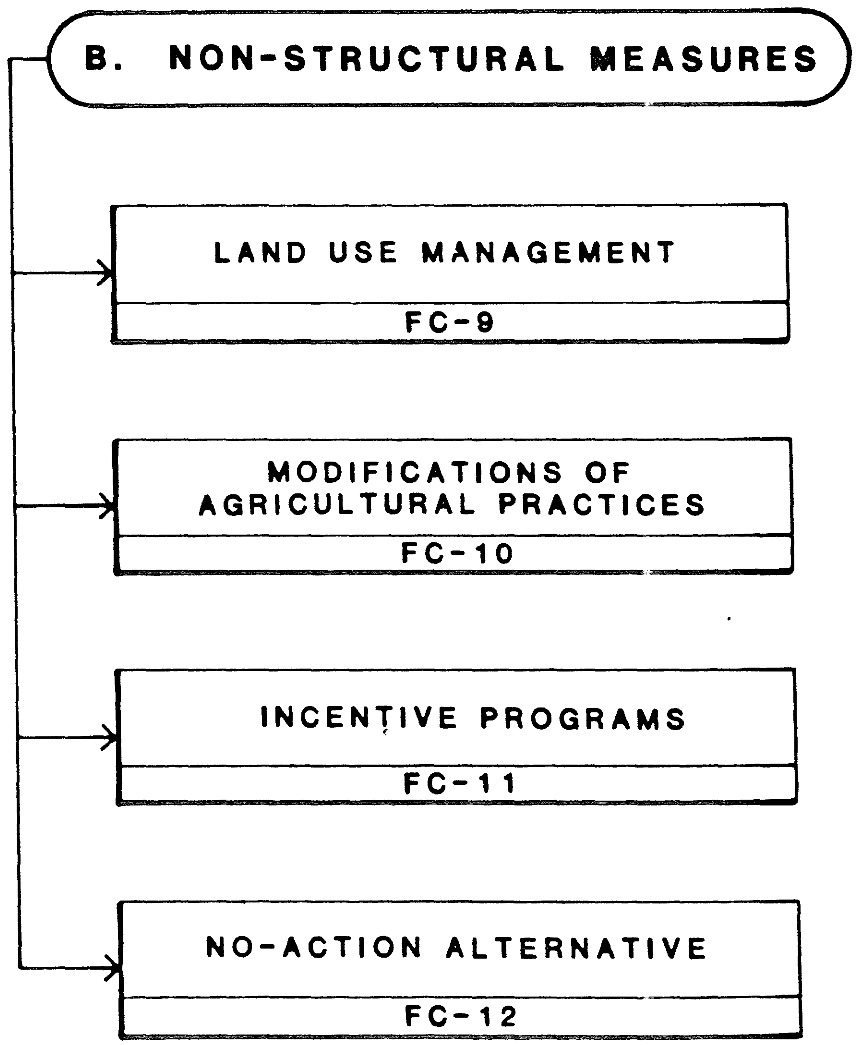
- Limited Additional Benefits In Flooding Reduction
- Continual Monitoring Of Environmental Conditions Necessary
- Potential Problem with Enforcement and Lake Level Tampering

NO-ACTION ALTERNATIVE

FC-8

Alternative FC-8 is a No Action Alternative. While this alternative requires no effort or expenditures, it does not alleviate the flooding problems which are examined in this report.

HERON LAKE
FLOOD CONTROL ALTERNATIVES



LAND USE MANAGEMENT

FC-9

As discussed previously in this report agricultural lands adjacent to the Heron Lake System are frequently subjected to flooding damages. Alternative FC-9, Land Use Management, is essentially an evaluation and alteration of existing land uses in flood prone areas in order to reduce flooding damages. For example, cropland could be converted to pasture or to crops planted later in the Spring.

This alternative requires no structural measures or costs and may be very beneficial depending on the feasibility of alternate land uses. Changes can be brought about on a voluntary basis or possibly by zoning or other land use requirements.

The development of alternative land uses will however require careful consideration of economic aspects as well as requirements of various crops. In the event that zoning or other legal sanctions are utilized, an evaluation will be necessary to determine at which governmental level they can legally be applied.

LAND USE MANAGEMENT

FC-9

ADVANTAGES

- No Cost

DIS-ADVANTAGES

- Possible Adverse Economic Impact
- Some Land Use Alterations May Be Considered Socially Unacceptable
- If Zoning or Other Legal Restrictions are Utilized, Complex Legal Questions May Arise

MODIFICATIONS OF AGRICULTURAL PRACTICES

FC-10

As discussed previously, flooding problems around the Heron Lake System are largely a result of the large drainage area contributing to it (ratio of more than 40 to 1). Alternative FC-10, Modification of Agricultural Practices, provides for implementing soil conservation practices or modifying existing drainage practices so that runoff is reduced or detained.

While the beneficial effects of soil conservation practices on erosion have long been recognized, tneir effects on runoff and flooding characteristics are sometimes overlooked. Structural practices such as terraces reduce the rate of runoff from a field and also allow additional time for infiltration. Nonstructural conservation practices such as conservation tillage increase the ability of soil to retain water.

As discussed previously, U.S. Soil Conservation Service curve number (CN) is an index of hydrologic characteristics of a given soil type. A high curve number indicates high runoff potential while a low curve number indicates more infiltration and less runoff. Past studies (Onstad and Otterby, Rawls and Onstad) have indicated that a reduction of 5 to 10 percent in the CN can occur if crop residues are increased by 2 to 3 metric tons per hectare (1780 to 2680 lbs. per acre). This may be effective in reducing the severity of floods, particularly for relatively frequent summer floods as shown below:

Frequency	Rainfall (1) (in.)	Runoff Existing (2) (in.)	Runoff FC-10 (3) (in.)	Difference (in. & %)	
2 year	2.8	1.10	0.69	-0.41	(37%)
5 year	3.6	1.72	1.19	-0.53	(31%)
10 year	4.3	2.29	1.68	-0.61	(27%)
25 year	4.9	2.81	2.12	-0.69	(25%)
50 year	5.5	3.34	2.59	-0.75	(22%)
100 year	6.0	3.78	2.99	-0.79	(21%)

(1) 24 hour rainfall - (SCS - Hydrology Guide of Minnesota)
(2) Assuming CN 80
(3) Assuming CN 72 (reduction of 10%)

Other benefits of Alternative FC-10 include a reduction in field erosion and sediment delivery to the Heron Lake System.

For implementation of conservation practices to be effective for reducing floods, this alternative will have to be applied extensively throughout the watershed. The reduction in storm runoff shown in the preceding table assumes conservation tillage is applied to the entire watershed which, on a practical level, may be difficult to achieve.

MODIFICATIONS OF AGRICULTURAL PRACTICES

FC-10

ADVANTAGES

- Relatively Easy to Implement
- Significant Reductions in Runoff Volume When Extensively Applied
- Reduced Sediment Production and Delivery to Heron Lake System

DIS-ADVANTAGES

- Must be Extensively Applied To Be Effective
- Limited Benefits For Spring Snowmelt Floods

INCENTIVE PROGRAMS

FC-11

Alternative FC-11, Incentive Programs, is closely related to Alternatives FC-9 (Land Use Management) and FC-10 (Modifications of Agricultural Practices). In essence, desirable conservation practices or land use management changes can be encouraged by the development of cost sharing programs or tax incentives.

Cost sharing programs can logically be developed as a supplement to existing state and federal programs for the implementation of soil conservation practices. Present funding sources include programs of the Minnesota Soil and Water Conservation Board and the U.S. Department of Agriculture. Tax incentives could be developed which would reduce the tax liability for landowners who employ sound land use management practices.

The implementation of this alternative will require:

1. A detailed economic analysis of the tax base to insure the feasibility of the program.
2. A legal determination as to the authority of the various governmental units.
3. Coordination with other funding sources.
4. Coordination between governmental units with taxing authority.

INCENTIVE PROGRAMS

FC-11

ADVANTAGES

- More Effective In Achieving Desired Goals Than If No Incentives Are Offered

DIS-ADVANTAGES

- Program Costs
- Program Administration
- Monitoring To Assure Compliance With Program Guidelines

NO-ACTION ALTERNATIVE

FC-12

The No-Action Alternative, FC-12, entails no expense or effort but does not provide solutions to the problems in this report.

HERON LAKE
RESOURCES IMPROVEMENT ALTERNATIVES

INTRODUCTION

Preservation and Improvement of the Heron Lake System Resources could be done by adopting either of the following two general directions:

1. Focus on the entire lake system.
2. Focus on a portion of lake system followed by expansion to entire lake system.

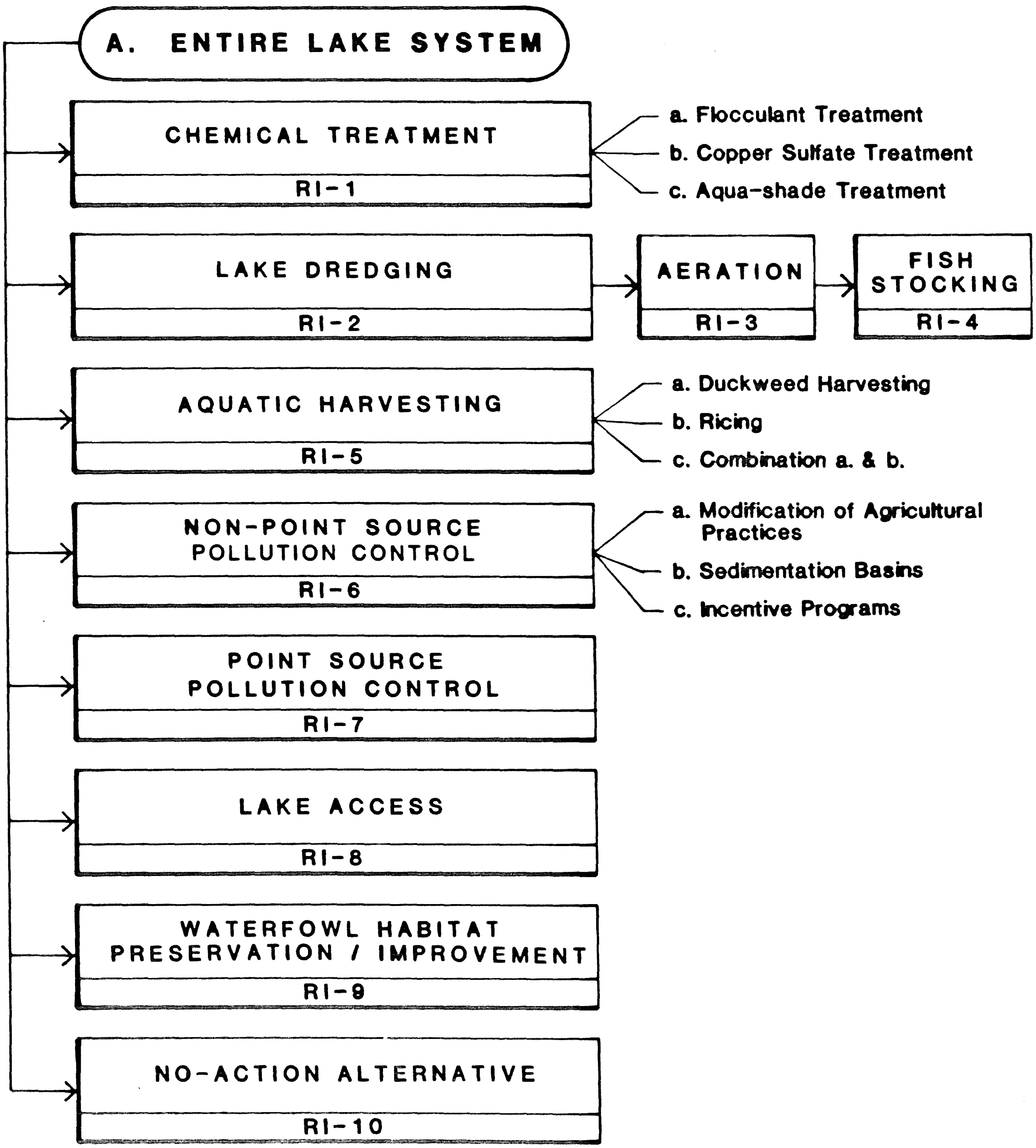
1. The first direction will require an extensive management program not only within the lake system but also in upland contributing areas. This program is time and cost intensive, and will require significant coordination efforts at the local, regional, and state levels.

2. The second direction, a phase approach, will focus on the selection of a small portion of the lake system to be used as a prototype for applications of proposed alternatives described in this section. The results from this phase will allow implementation of successful alternatives to other parts of the lake system, and eventually to the entire lake systems.

The various alternatives for each direction will again be discussed on a conceptual basis with general advantages and disadvantages for each option. Upon state and local agreement on a recommended plan, detailed analysis will be necessary to complete this alternatives development plan for subsequent implementation.

HERON LAKE
RESOURCES IMPROVEMENT ALTERNATIVES

- WATER QUALITY IMPROVEMENT
- FISHERY DEVELOPMENT
- WATERFOWL PRESERVATION/DEVELOPMENT
- LAKE USE



CHEMICAL TREATMENT

RI-1

Results obtained from the study pointed to a need for nutrient reduction and blue-green algae reduction in the Heron Lake System. The use of various chemical treatments, Alternative RI-1, to achieve this objective is quite common in water resource management. Treatment with flocculants, copper sulfate, and Aqua-shade were considered as three possible options for the Heron Lake System. Each of these treatments can be considered as in-lake measures and should be coupled with nutrient inflow reduction for long-term effectiveness.

FLOCCULANT TREATMENT

RI-1A

COPPER SULFATE TREATMENT

RI-1B

AQUA-SHADE TREATMENT

RI-1C

Treatment of the entire lake system by these subalternatives would be quite costly in light of the frequent applications required for full effectiveness.

FLOCCULANT TREATMENT

RI-1A

Flocculants are a class of compounds which readily combine with phosphorus, making it unavailable for use by algae. Flocculants most commonly used in lake management at present are compounds such as ferric chloride, ferric sulfate, and aluminum sulfate (alum).

Alternative RI-la proposes the use of a flocculant to reduce the internal phosphorus load in Heron Lake (Berkherser, Bennett, Gould). The specific flocculant used would be determined if and when this alternative is selected for implementation.

Flocculants generally perform two phosphorus controlling functions in a body of water. First, they combine in the presence of oxygen with the phosphorus making it unavailable to the algae. Secondly, this floc precipitates out of the free water and forms a barrier to the leakage of phosphorus already present in the sediments.

Cost for implementation of this alternative would be high as treatments must be repeated yearly or every other year depending on initial results. In addition, the shallowness and constant wind mixing action in the Heron Lake system could severely limit the effectiveness of this alternative.

FLOCCULANT TREATMENT

RI-1A

ADVANTAGES

- Reduction of Phosphorous Load in the Lake

DIS-ADVANTAGES

- High Cost of Treating the Entire Lake
- Possible Negative Environmental Side Effects
- Experimental in Nature for the Heron Lake System
- Potential Limitations in Effectiveness Due to Lake Shallowness and Wind Mixing Action

COPPER SULFATE TREATMENT

RI-1B

Subalternative RI-lb proposes the use of algacides such as copper sulfate to reduce algal populations. Copper sulfate, and other similar algacides, produce a toxic effect which brings algal populations into check in a relatively short time.

However, Subalternative RI-lb may be unsuitable for use in Heron Lake. The high concentration of chelating agents in the ambient water may essentially defuse the copper's toxic effect (Gachter).

In addition, copper sulfate treatments would be very expensive, and their negative residual chemical effects could pose serious long-range threats to the environment and ecological communities in the area. For some lakes, algacides seem to be the only solution to algal problems, but whenever possible, it has recently been common practice to avoid their use.

COPPER SULFATE TREATMENT

RI-1B

ADVANTAGES

- Reduction of Blue-Green Algae

DIS-ADVANTAGES

- High Cost of Treating The Entire Lake
- Reduced Effectiveness In Heron Lake As A Result of High Concentrations of Chelating Agents.
- Possible Side Effects of copper sulfate
- Experimental in Nature For The Heron Lake System

AQUA-SHADE TREATMENT

RI-1C

Subalternative RI-1c proposes treatment of the lake with Aqua-shade, a blue (aqua-marine blue) low molecular weight dye which absorbs the 630 nm peak in the sun's spectrum. The 630 nm wavelength of light is one of the important wavelengths for the process of photosynthesis. In the absence of this 630nm peak, blue-green algae cannot carry on photosynthesis and soon die out. The green algae, on the other hand, are capable of utilizing other wavelengths of light and become the dominant population in Aqua-shade treated waters. Aqua-shade would be applied in the Spring for two years. Further applications should not be necessary, but would depend on the initial results.

The use of Aqua-shade is still experimental in nature. Aqua-shade was used in Indian Lake in the Twin Cities in 1981 with positive results. The blue-green algae dropped out of the system and the greens then replaced them as the dominant algae. Also zooplankton populations were found to be greatly enhanced as a result of this shift. These same results may occur in Heron Lake.

Treatment of the entire lake for two years would be quite expensive. The feasibility of this Subalternative will very much depend on the success of a small scale experimentation carried out on a small part of the lake.

AQUA-SHADE TREATMENT

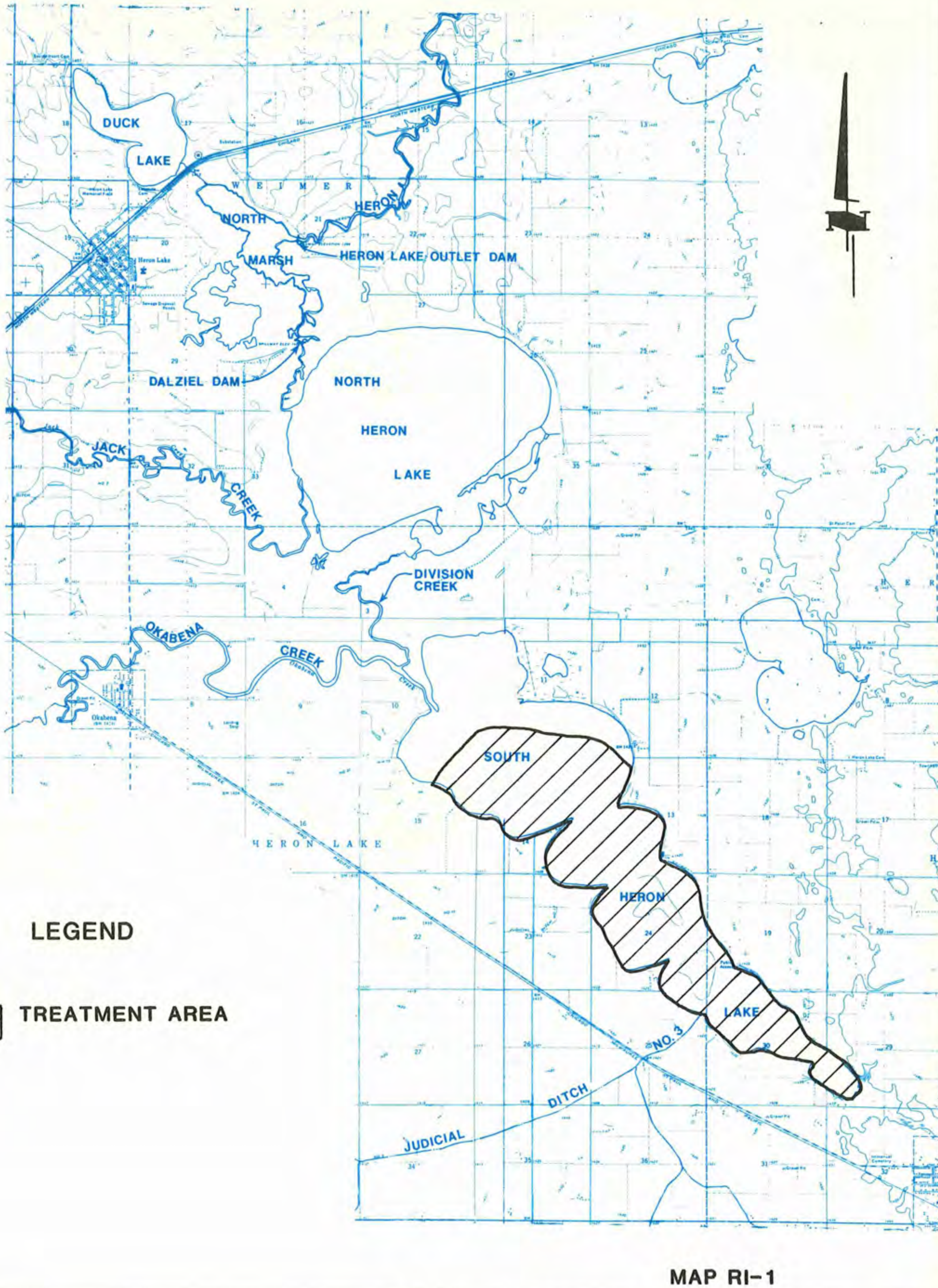
RI-1C

ADVANTAGES

- Facilitation of Shift From Blue-Green Algae To Green Algae
- Enhancement of Zooplankton Populations
- Enhancement of Fish Populations

DIS-ADVANTAGES

- High Cost of Treating The Entire Lake
- Experimental Nature
- Requires experimentation on a small scale prior to lake application
- Aqua-marine Blue Color Imparted To Water



LEGEND

TREATMENT AREA

MAP RI-1

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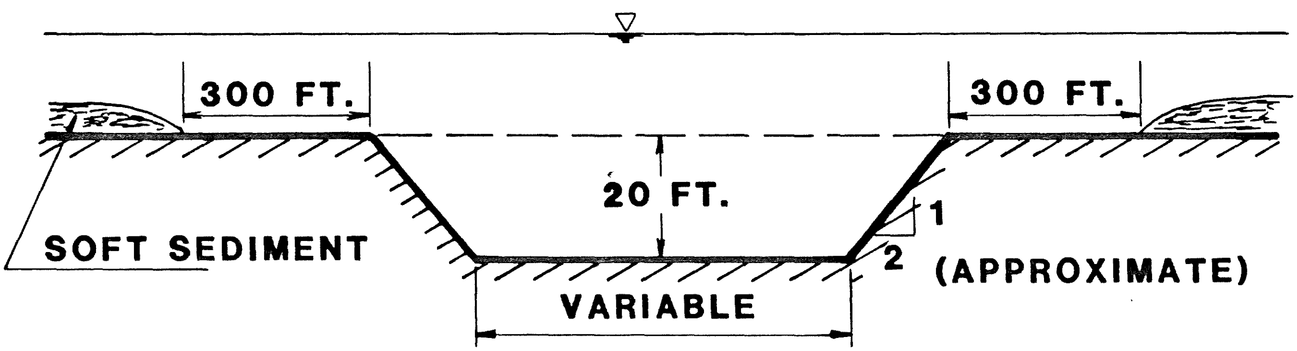
CHEMICAL TREATMENT

LAKE DREDGING

RI-2

As discussed previously, the suitability of the Heron Lake System as fish habitat is severely limited by the shallow depths of the lake which are prone to frequent winter kills. Alternative RI-2, Lake Dredging, would provide additional depth by dredging two large holes in South Heron Lake as shown on Map RI-2. The holes would each have a surface area of approximately 280 acres, side slopes of approximately 2:1 and a depth of 20 feet. The total volume of dredged material would be approximately 9,400,000 cubic yards.



ALTERNATIVE RI-2
TYPICAL CROSS SECTION OF DREDGED AREA

This volume includes approximately 700,000 cubic yards of soft organic sediment extending for approximately 300 feet on each side of the hole. Removal of this sediment is desirable to prevent the dredged hole from filling rapidly and to remove the nutrients associated with the sediment. It would also be very desirable to provide aeration in the dredged areas. This will improve fish habitat by increasing dissolved oxygen concentrations, and will increase the effective life of the dredged areas by oxidizing organic sediment which settles into it.

Dredging could be performed in two ways on the Heron Lake System:

1. Suction Dredging
2. Dragline

1. Suction Dredging - would be performed with the lake system maintained at its normal levels. A suction pipe mounted on a barge removes the material as a slurry from the lake bottom and pumps it to an onland disposal area.

2. Draglines - may be an acceptable method for dredging due to the shallowness of South Heron Lake. With this method, it may be necessary to lower lake levels to some extent to allow easier operations. For the large areas proposed for dredging, disposal of the dredged material will be a significant problem. Disposal in the lake does not appear practical, and transfer to an onshore location would require a barge or additional operations.

The ultimate disposal of the dredged material will depend on the type of sediment and the dredging methods utilized. The organic sediment (approximately the top foot of sediment in the lake) would be suitable for applying to agricultural lands as a nutrient source (W.C. Ku).

Based on chemical analysis of the sediment, 700,000 cubic yards of organic sediment would supply 100% of the nitrogen (as NH_3) requirements, 35% of the phosphorus requirements (as P_2O_5), for 8,000 acres (this assumes annual application of 110 lbs. NH_3, and 78 lbs. P_2O_5, per acre). This application would require spreading to a depth of approximately 1/4 inch on a field.

The disposal of inorganic sediment or other bottom materials is dependent on the dredging method utilized. If a dragline is used, the sediment and underlying clay materials can be expected to remain relatively intact and may be acceptable as fill material for some purposes. If suction dredging is utilized, the construction of an onshore settling basin will be necessary to remove sediment particles from the slurry.

Negative impacts of this alternative include a temporary negative effect on water quality during the dredging period due to increased turbidity. There is also a problem with disposal of the dredged materials such as acquisition of land or easements. Permits are required, and in the case of suction dredging, effluent water quality limitations are imposed on the discharge from on-shore settling basins.

Another consideration is the possible negative effects on groundwater conditions in this lake system. Soil borings and groundwater monitoring wells should be utilized to insure that the dredging areas will not penetrate through the clay seal at the bottom of the lake system.

LAKE DREDGING

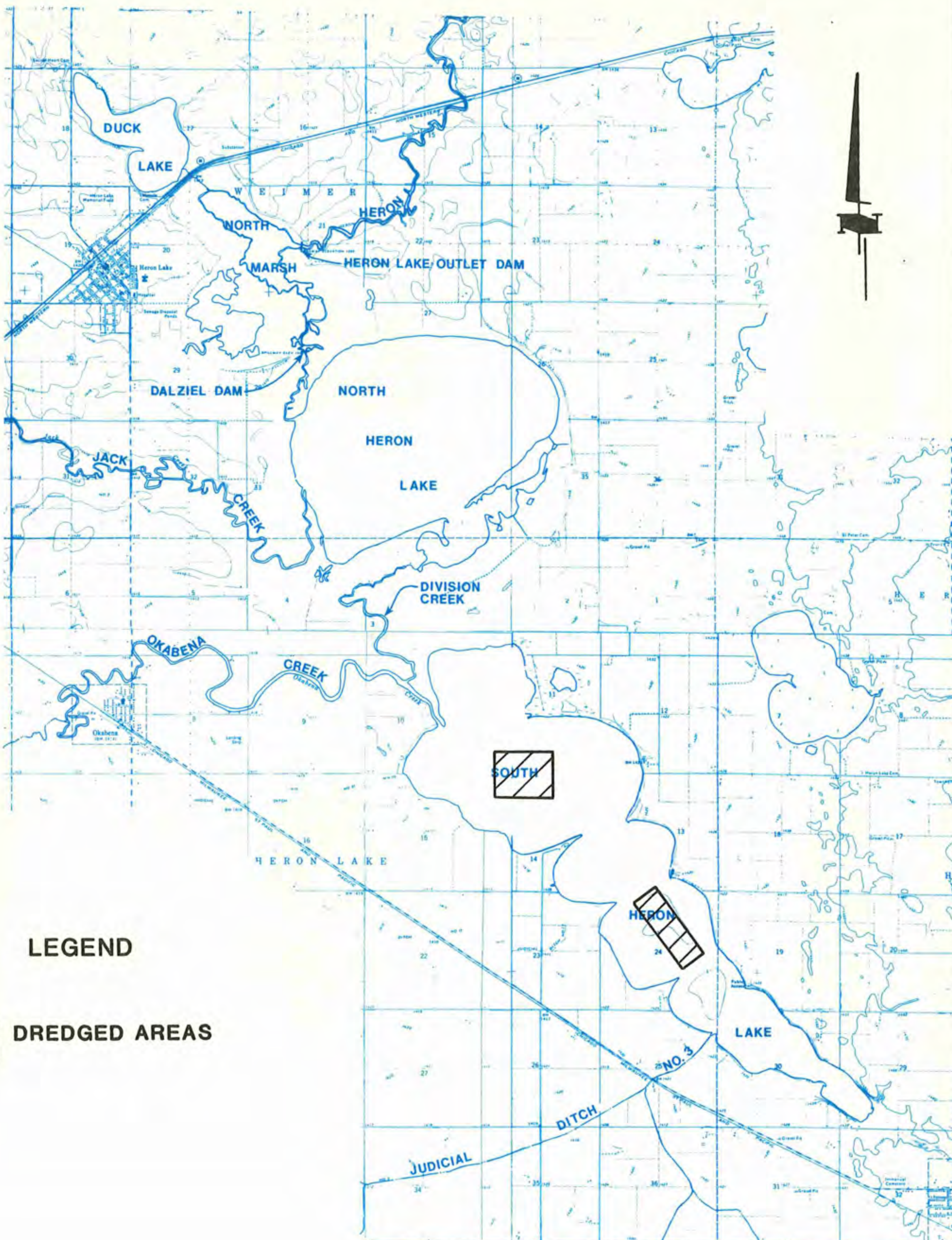
RI-2

ADVANTAGES

- Fish Habitat Improvement

DIS-ADVANTAGES

- Permits related to dredging and water quality
- Disposal Area
- Relatively High Costs
- Potential negative effects on groundwater system



LEGEND

DREDGED AREAS

MAP RI-2

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LAKE DREDGING

AERATION

RI-3

Fisheries development was a primary concern of this study. The study pointed to high blue-green algae populations in the Heron Lake System and frequent winter-kills as the main reasons for high rough fish populations and correspondingly low game fish populations.

Alternative RI-3 calls for the aeration of South Heron Lake to aid in fisheries development. This alternative is recommended in conjunction with Alternative RI-2, Lake Dredging (i.e. aerate only dredged areas), and RI-4, Fish Stocking for maximum effectiveness.

The aeration alternative would be accomplished by injecting air into the lake, via a lakebed network of perforated hose, and allowing it to bubble to the surface. The nearly constant winds in the watershed make a direct-drive, windpowered aeration system a practical and cost effective alternative system to supplement conventional aeration systems for Heron Lake. According to records kept at Sioux Falls, South Dakota, the average windspeed is nearly 11 miles per hour. At this average velocity, wind-driven air pumps could aid in the aeration of the dredged areas. Approximately 3,000 cubic feet per minute (cfm) of air would have to be supplied. This flow rate is based on the amount of air needed to maintain 100% saturation for both oxygen as O_2 and carbon as CO_2 at 15°C (Frey, David G.).

Alternative RI-3
Table 1

National Weather Bureau Records
of
Average Wind Speed for Sioux Falls, South Dakota (miles per hour)

	1981			1980			1979		
Mo.	Avg. Speed	Fastest Wind	Date	Avg. Speed	Fastest Wind	Date	Avg. Speed	Fastest Wind	Date
J	9.9	30	25	13.1	44	06	10.5	28	22
F	13.9	35	22	11.9	30	26	11.0	32	15
M	10.8	36	31	12.3	29	16	14.0	35	13
A	12.9	32	29	11.5	31	09	13.3	35	05
M	12.0	32	02	9.8	35	26	11.1	32	09
J	10.3	37	21	11.0	46	04	10.5	35	19
J	9.0	25	07	9.7	32	15	8.5	29	22
A				12.0	48	03	8.6	25	08
S				11.2	30	03	8.8	30	11
O				12.7	41	16	10.7	35	22
N				10.6	39	28	10.1	29	22
D				10.9	29	25	9.9	32	15

Because of the probability of periods of lesser or no winds the implications of a calm period have to be considered. A way to assess these effects is to look at the oxygen utilization in the system through the five day Biochemical Oxygen Demand (BOD_5).

In mid-summer, assuming a BOD of approximately 20 mg/l, about two days of zero air flow could elapse before the system would be effected. From Weather Bureau records and discussion with local people, calm periods in the Heron Lake area in the summer months are not common. In the winter months, when the aeration becomes more critical, the DO saturation levels are at 13 mg/l and the five day BOD is reduced. During this period (assuming a BOD of approximately 2-4 mg/l), the lake could go for about twelve days without any wind before dangerously low levels of oxygen would result.

Aeration can benefit the lake in many ways. For example, aeration leaves the water ice-free during the winter months, keeping the dissolved oxygen content of the lake water high and eliminating the possibility of a complete freezeout of the lake (Kranenburg). Both of these aspects will enhance fish populations.

In addition, there is published experimental data which shows that increasing the carbon dioxide (CO_2) of the lakewater will select for a population shift from blue-green algae to green algae (Shapiro, Lorenzen). Since air also contains about 0.05% CO_2 (carbon dioxide), Alternative RI-3 will also inject close to 255 liters of CO_2 into one square mile of the lake per hour (Frey, David G., Hogen). The solubility of CO_2 is almost 100% in water, which makes this large induction of CO_2 possible. As a result, a shift from blue green to green algae could be achieved with the help of aeration and, as mentioned earlier in the report, will indirectly contribute to the enhancement of fish populations.

Another added benefit is that Alternative RI-3 will cause a shift to oxygen utilizing bacteria in the sediments (Ku). This shift can result in the breakdown of approximately ninety percent of the detritus load in the sediment. This rapid oxidation of detritus will actually retard the expected fill-in process of the dredged areas, thereby reducing maintenance costs.

Also, aeration will help to reduce the level of soluble phosphorus in the lake. Under enhanced oxygen conditions, the ferrous ion concentrations in the waters of Heron lake will oxidize to ferric ion, complex with the phosphorus, and precipitate out of the free water. By this process the lake can begin to cleanse itself. (Bennett, Bertkerheiser, Gould, McKinney).

One disadvantage associated with Alternative RI-3 is the prohibitively high cost involved in aerating the proposed dredged areas for the entire lake.

Compressors would have to be set up on shore and trunk-line hoses run from that point to the dredged area (Refer to Map RI-3). In all likelihood, a wind-powered system alone would not be capable of maintaining sufficient pressure in an aeration network so far from its power source. Additional power may have to be provided to supplement the wind generators which would be extremely costly for an area as large as the one here proposed.

In addition, once an aeration system is installed, it cannot be removed without serious environmental consequences. (Frey, David G., Hogen).

Footnote: A wind anemometer was installed on February 5, 1982 south of the City of Okabena, one mile west of Heron Lake, to record local wind speeds for the winter of 1982.

AERATION

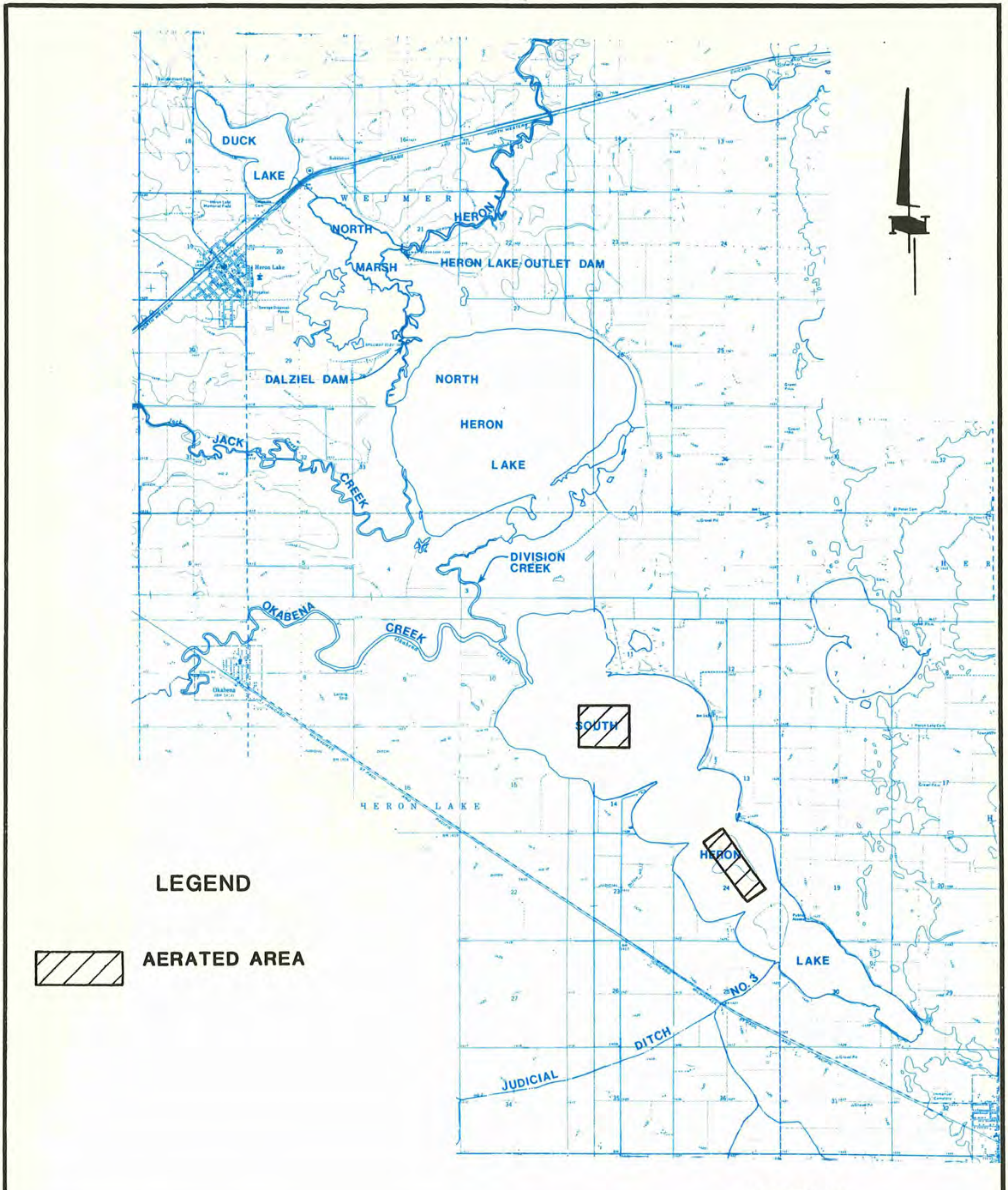
RI-3

ADVANTAGES

- Elimination of Winterkills
- Desirable Dissolved Oxygen Levels Year-around
- Nutrient Reduction
- Increase in CO_2 Levels Resulting In A Shift From Blue-Green Algae To Green Algae
- Enhancement of Green Algae Populations
- Enhancement of Zooplankton Populations
- Enhancement of Fish Populations (Recommended Implementation In Conjunction With RI-4 Fish Stocking)

DIS-ADVANTAGES

- High Cost To Aerate Proposed Dredged Areas
- Potential hazard to snowmobiling and ice fishing in winter due to open water areas
- Wind powered aeration subject to no-wind periods and other winter related problems
- Only Implementable In Dredged Areas (Recommended Implementation In Conjunction With RI-2, Dredging)



MAP RI-3

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AERATION

FISH STOCKING

RI-4

As mentioned earlier in this report, Heron Lake presently supports large populations of rough fish. Results of the MDNR Fish Lake Study were included in precedent sections of this report.

Alternative RI-4 is the initiation of a game fish stocking program in Heron Lake. Implementation of this alternative is recommended in conjunction with Alternatives RI-2, Lake Dredging and RI-3, Lake Aeration. The program would be conducted by the Minnesota DNR, Department of Fisheries, and will follow DNR's established guidelines.

Stocking of Heron Lake would be done annually or as needed. Panfish such as bluegill, crappies and perch would be stocked in the spring of the year. If a substantial number of fish survived the winter, stocking the following spring would not be performed.

This basic stocking program would be modified to accomodate fish populations response to conditions resulting from dredging and aeration. For example, stocking of additional types of fish (northern pikes, walleyes, etc.) or rough fish control may have to be implemented.

FISH STOCKING

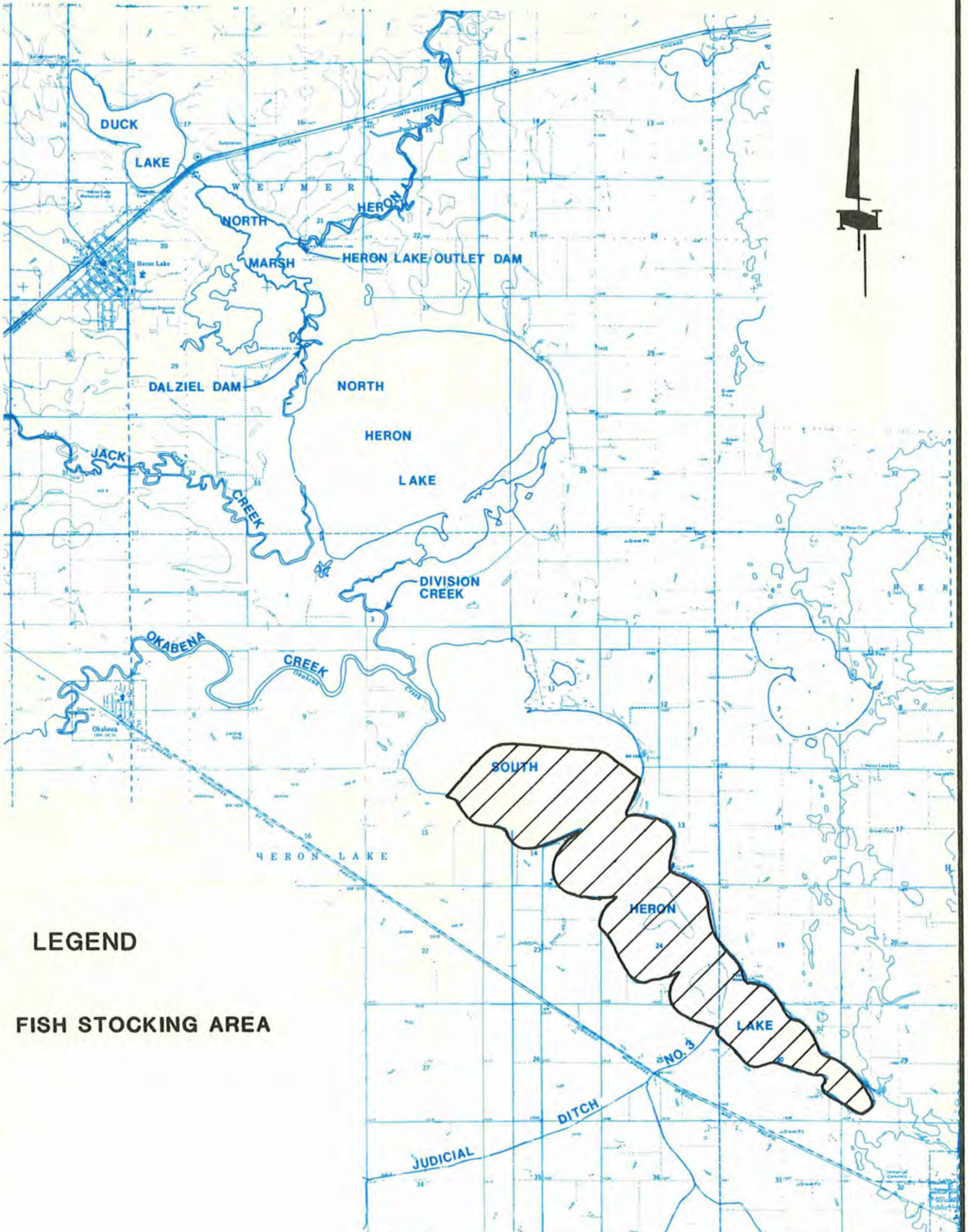
RI-4

ADVANTAGES

- Increased game fish populations
- Control of rough fish populations

DIS-ADVANTAGES

- Must Be Used In Combination With Appropriate Alternatives aimed at Reducing Nutrient Load in the Lake
- Must Be Used In Combination With Alternative RI-2, Lake Dredging
- Step-by-step two year Implementation Plan To See Benefits



LEGEND

FISH STOCKING AREA

MAP RI-4

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FISH STOCKING

AQUATIC HARVESTING

RI-5

A very important part of improving the water quality of Heron Lake is the removal of the existing nutrient load and the management of incoming nutrients. This objective can be achieved largely by implementation of one of the options under Alternative RI-5 Aquatic Harvesting. This alternative would utilize marginal upland areas and non-protected wetlands adjacent to the lake to culture and harvest aquatic biomass. Two potential aquatic plants for use in Heron Lake are duckweed and rice (domestic or wild). Discussion of duckweed harvesting and ricing operations is contained in subalternatives RI-5a, RI-5b, and RI-5c as follows:

DUCKWEED HARVESTING

RI-5A

RICING

RI-5B

COMBINATION OF A. & B.

RI-5C

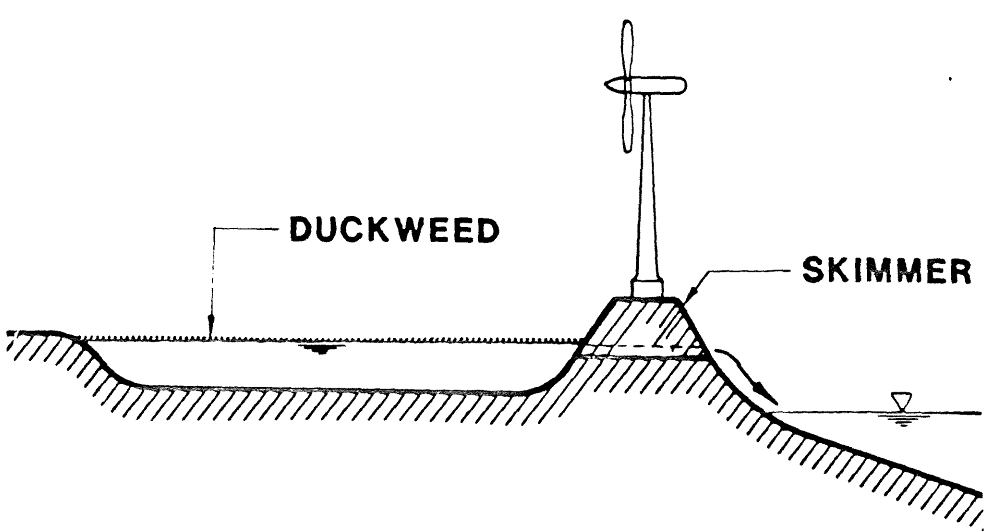
Duckweed has not been grown in Minnesota commercially while rice has. Both would, however, be experimental in Heron Lake. While setup costs for both operation would be high to efficiently recycle nutrients for the whole lake, ricing would incur somewhat higher costs for specialized harvesting equipment and tiling of the paddies. To help defray these expenses, both biomass operations would have wind-powered pumps and harvesting equipment, and, of course, yield a saleable crop.

DUCKWEED HARVESTING

RI-5A

Subalternative RI-5a calls for the set-up and maintenance of duckweed harvesting operations. Duckweed is a small aquatic plant which floats on the surface of calm, nutrient-rich waters. It is very efficient in its utilization of phosphorus and nitrogen, and therefore, could potentially help clean lake waters (Hillman, Burton, O'brien).

To implement Subalternative RI-5a, a diversion channel would be dug to an upland area and water pumped through this channel continuously. For maximum utilization of the available nutrients, there should be a mean retention time of five days in the channel. Because duckweed is a free-floating aquatic plant, it can be harvested by the use of skimmers and dewatered by compression into pellets. The power for harvesting could potentially come from wind-driven systems.



Setup costs for such an operation would be relatively low compared to ricing. The duckweed pellets could be sold as livestock feed for a profit. (Rustoff).

Duckweed, because of its rapid growth, high nutritional value, and ease of harvesting appears to be the best candidate for nutrient management. The yield per acre can be as much as eight times that of alfalfa and contain more than two times the protein of a comparable amount of alfalfa. As a starter feed for domestic birds, tests have shown duckweed to be better than conventional feeds for promoting early rapid weight gains. (Rustoff).

Tests on the growth and use of duckweed species were conducted in Louisiana. (Hillman, Rustoff). The following solar incidence tables (in Langleys/Day) for Minnesota and Louisiana, and related mass doubling times of duckweed allows prediction of growth rates for the plant in Minnesota. The growth period for Minnesota begins in early May and runs to the end of October, therefore, this period of the year was used for comparison.

TABLE OF SOLAR INCIDENCE FOR
MINNESOTA AND LOUISIANNA (LANGLEYS/DAY)

Month	Louisiana La/Day Total	Minnesota La/Day Total	Mass Doubling Time (days)
May	2080	1859	3.9
June	2213	2003	3.6
July	1968	2087	3.5
August	1910	1828	4.0
September	1678	1369	5.3
October	1505	809	9.0

Since the growing season in Louisiana is assumed to be year round and Minnesota is six months, and since there is a difference in the total solar input for the two areas, a growth multiplier of .533 for the two states was calculated. The annual yield for the test site was 7.8 tons (dry weight) per acre per season in Louisiana, resulting in a yield of 4.2 tons per acre per season in Minnesota. The assay for phosphorus in the duckweed gave a yield of 1.48%, and the assay for nitrogen gave yield of 4.78%. The yield of 4.2 tons (dry weight) per acre of plant material would then extract 123 pounds of P/acre/season or 5.57×10^4 grames of P/acre/year, and 398 pounds of N/acre/year or 1.80×10^5 grams of N/acre/year. The Heron Lake Total Phosphorus load is 1.16×10^7 gm of P in 3.26×10^9 gallons of water. For maximum utilization of the available nutrients, there should be a mean retention time of five days in the channel. Since 208 acres would suffice for one day retention, 1041 acres of land would be required for the channeled areas.

The use of duckweed to reduce nutrients in lake systems is still experimental in nature. It has been used successfully in several areas, but not in Heron Lake or any other Minnesota Lake. If successful, this procedure would be a prototype for the State. Before this system was implemented, small-scale experimentation would have to be performed to insure success.

Land easements for 1041 acres of land may also be difficult to obtain. A factor which would ease this difficulty is the increased utilization of marginal land around the lake.

Sale of the duckweed to livestock breeders is at present only speculative. Research into the location and size of such a market would be carried-out if the system was chosen for implementation. It is important to note that duckweed harvesting is still a viable system even without such a market. The duckweed harvested from the growth channels after effectively absorbing nutrients from the lake water could be landfilled or otherwise disposed of.

DUCKWEED HARVESTING

RI-5A

ADVANTAGES

- Saleable Cash Crop
- Potential Market in Livestock and Domestic Fowl Feed
- Nutrient Reduction
- Low Operating Costs (Potential Use of Wind Powered Pumps in Heron Lake)
- Ease of Harvesting
- Profitable Use of Wetlands and/or Marginal Upland Areas
- Relatively Low Set-up Costs

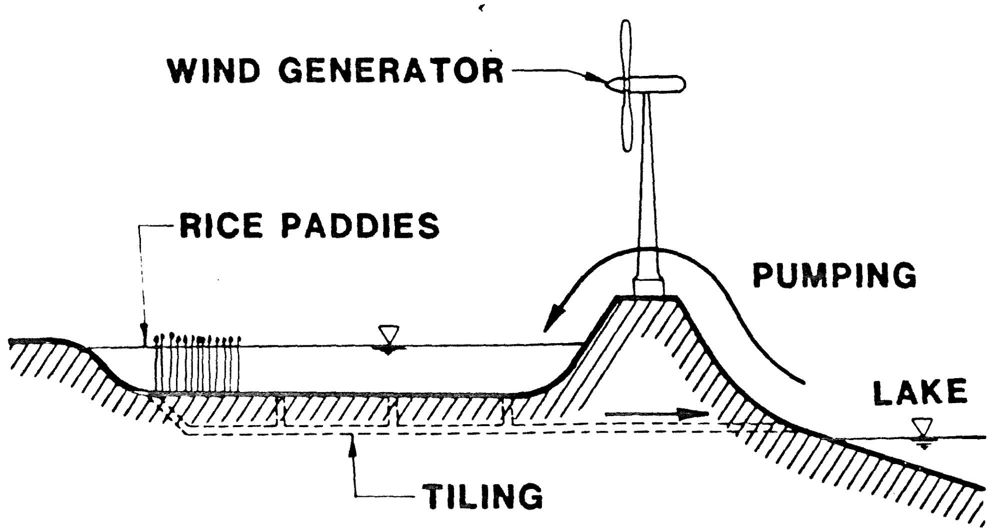
DIS-ADVANTAGES

- Experimental Nature
- Experimentation Required Before Large-Scale Application
- 1040 Acres needed To Reduce Nutrient Load in Entire Lake
- Land Easements
- May disturb natural unprotected wetlands around Heron Lake and may thereby adversely affect wildlife.

RICING
RI-5B

Subalternative RI-5b involves the introduction of commercial ricing operations in the areas immediately adjacent to Heron Lake. Operations would be setup in much the same way as Alternative RI-5a, Duckweed Harvesting.

Water would be pumped into an upland diked paddy on a continuous basis. The bottom of the paddy would be tiled drawing the water down through the root zone of the paddy. Here the high nutrients would be taken up by the plants and utilized in growth. The water collected by the tiles would be returned to lake with a much reduced nutrient concentration. (Staff of Industrial Development News).



As mentioned earlier, setup costs for ricing operations are quite high. However, the return of the initial investment would also be high. Commercial rice growers in Minnesota are producing average yields of 165 lbs/acre of finished rice. In addition, the stalks would bring in a profit if sold.

Accurate nutrient utilization coefficients have not yet been obtained for rice. Consultation with Minnesota rice-growers has reiterated the possibility of growing rice in the areas surrounding Heron Lake, but important data such as nutrient utilization of rice is still being compiled.

However, to gain the full nutrient utilizing advantage of this crop, the remainder of the plant should also be harvested and physically removed to a secure site or utilized in a production process. Two such processes could be the production of paper, utilizing the high silicate content of the plant materials; or the plant would be burned, and the ash then processed for a high grade metal polish.

RICING
RI-5B

ADVANTAGES

- Nutrient Reduction
- Saleable Cash Crop
- Low Power Costs (Potential Wind-Powered Pumps)
- Profitable Use Of Wetlands and/or Marginal Upland Areas

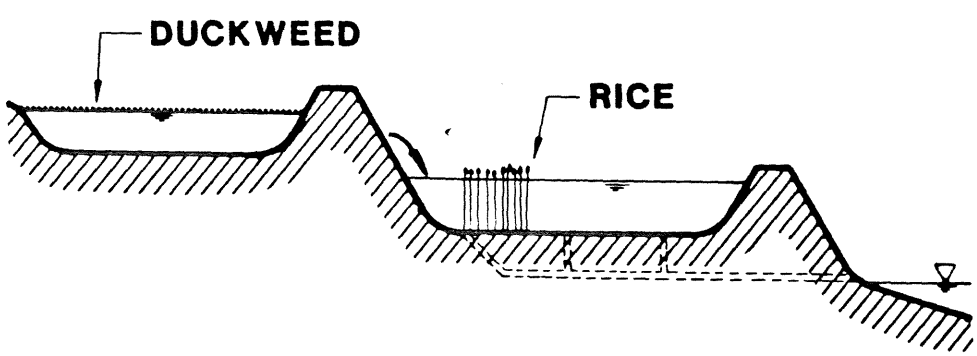
DIS-ADVANTAGES

- May disturb natural unprotected wetlands around Heron Lake and may thereby adversely affect wildlife.
- Rice Stalks Must Be Removed After Harvesting
- Relatively High Set-up Costs
- Experimental Nature
- Special Harvesting Equipment Needed
- Possibility of plant disease
- Approximately 1000 Acres Needed To Reduce Nutrient Load in Entire Lake (based on efficiencies similar to duckweed)
- Land Easements

COMBINATION OF A. & B.

RI-5C

Subalternative RI-5c recommends the use of Subalternative RI-5a, Duckweed Harvesting and Subalternative RI-5a, Ricing in combination. Lakewater would be pumped first through a duckweed growth pond or channel. Water passing through the skimmers at the outlet wier would then trickle through the rice paddy. The lakewater, then greatly reduced in nutrient concentration, would filter through the rice paddy's tiling system and return to the lake.



Details relevant to this alternative are very similar to those present in Subalternatives RI-5a and RI-5b.

COMBINATION OF A. & B.

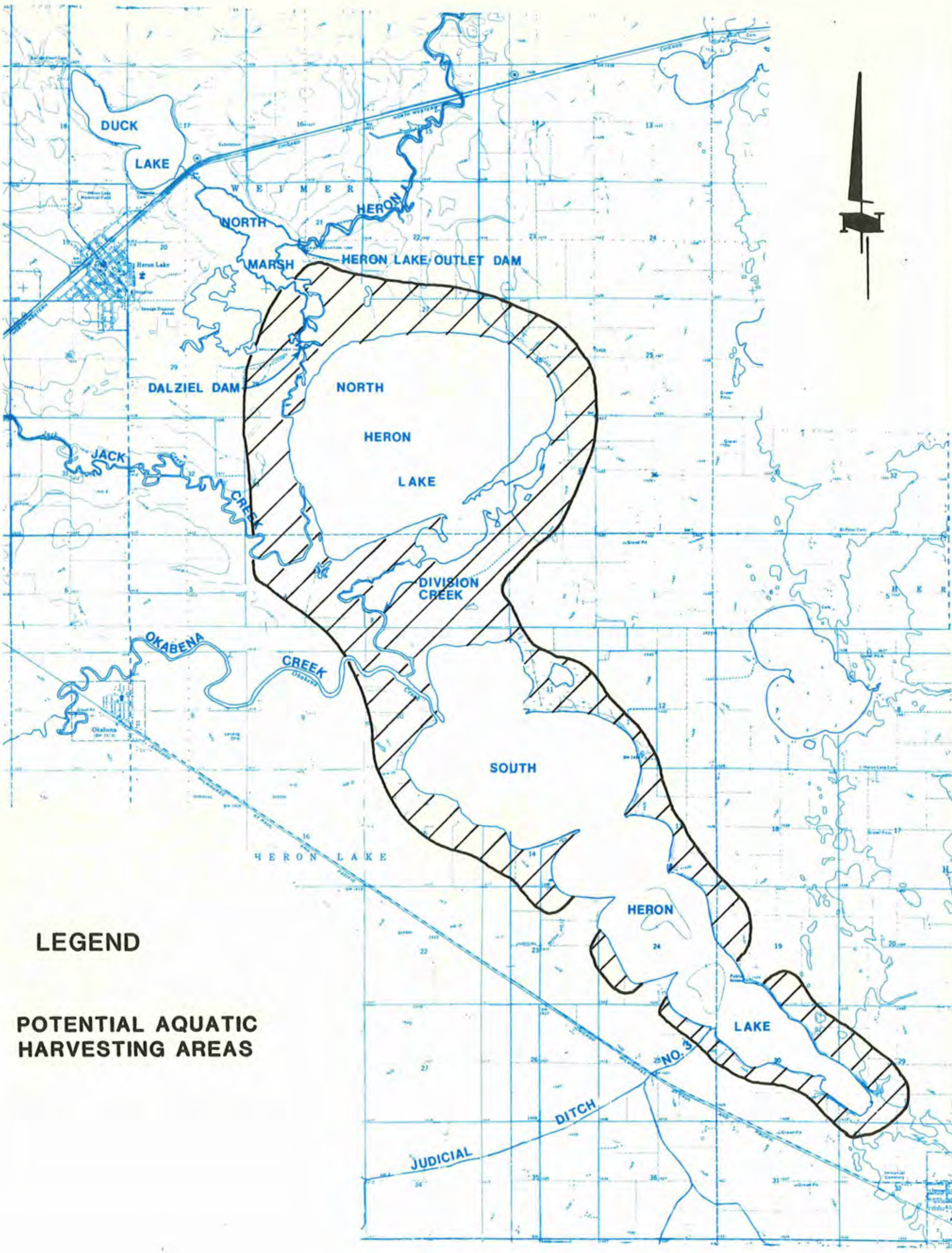
RI-5C

ADVANTAGES

- Advantages Listed For Both RI-5a, Duckweed Harvesting and RI-5b, Ricing Apply Here
- Increased Efficiency of Nutrient Removal as a Result of Combination

DIS-ADVANTAGES

- Disadvantages Listed For RI-5a and RI-5b apply here.



LEGEND

POTENTIAL AQUATIC HARVESTING AREAS

MAP RI-5

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AQUATIC HARVESTING

NON-POINT SOURCE POLLUTION CONTROL
RI-6

As discussed previously in this report, nonpoint sources of pollution contribute approximately 91% of the nitrogen and 69% of the phosphorus to the Heron Lake System in an average year. This is not unexpected due to the agricultural nature of the watershed and the relatively large drainage area.

Nonpoint source pollution from agricultural areas can be controlled by three primary methods:

1. Agricultural Practices Modification
2. Sedimentation Basins
3. Incentive Programs

These three alternatives will be considered as subalternatives and discussed in more details.

MODIFICATION OF AGRICULTURAL PRACTICES
RI-6A

SEDIMENTATION BASINS
RI-6B

INCENTIVE PROGRAMS
RI-6C

MODIFICATION OF AGRICULTURAL PRACTICES

RI-6A

Alternative RI-6a, Agricultural Practices Modification, is composed primarily of conventional soil and water conservation waterways, or other small structures or management practices such as minimum tillage. These measures are recognized as being effective in controlling soil losses and nutrients associated with the soil (EPA-600/3-79-106).

As discussed previously, the amount of sediment delivered to the Heron Lake System is a function of the sediment produced in an area, and the sediment delivery ratio (percentage of sediment produced which actually enters the lakes). Since areas with above average soil losses or areas relatively close to the lake deliver a disproportionate amount of sediment, these areas should receive more consideration than remote areas or areas with relatively low soil losses.

It should also be noted that the traditional conservation practices are concerned primarily with soil erosion and water management, and not specifically with reducing nonpoint source pollution (USEPA, EPA-600/3-A-106). Nonpoint source pollution is composed of both particulate and dissolved nutrients. While most practices will retain nutrients in a particulate form, some practices are more effective than others in reducing total quantities of nutrients leaving a field. This should be considered when deciding which practices to apply. Desirable practices could be implemented on a voluntary basis or by the development of zoning or other legal land use management plans.

In the event that zoning or other practices are used to bring about desired changes, an evaluation will be necessary to determine at which governmental level they can legally be applied.

MODIFICATION OF AGRICULTURAL PRACTICES

RI-6A

ADVANTAGES

- Reduced Nonpoint Source Nutrient Contributions
- Reduced Runoff Contributing To Flooding Problems
- Very Low Cost

DIS-ADVANTAGES

- Must Be Extensively Applied To Be Most Effective

SEDIMENTATION BASINS

RI-6B

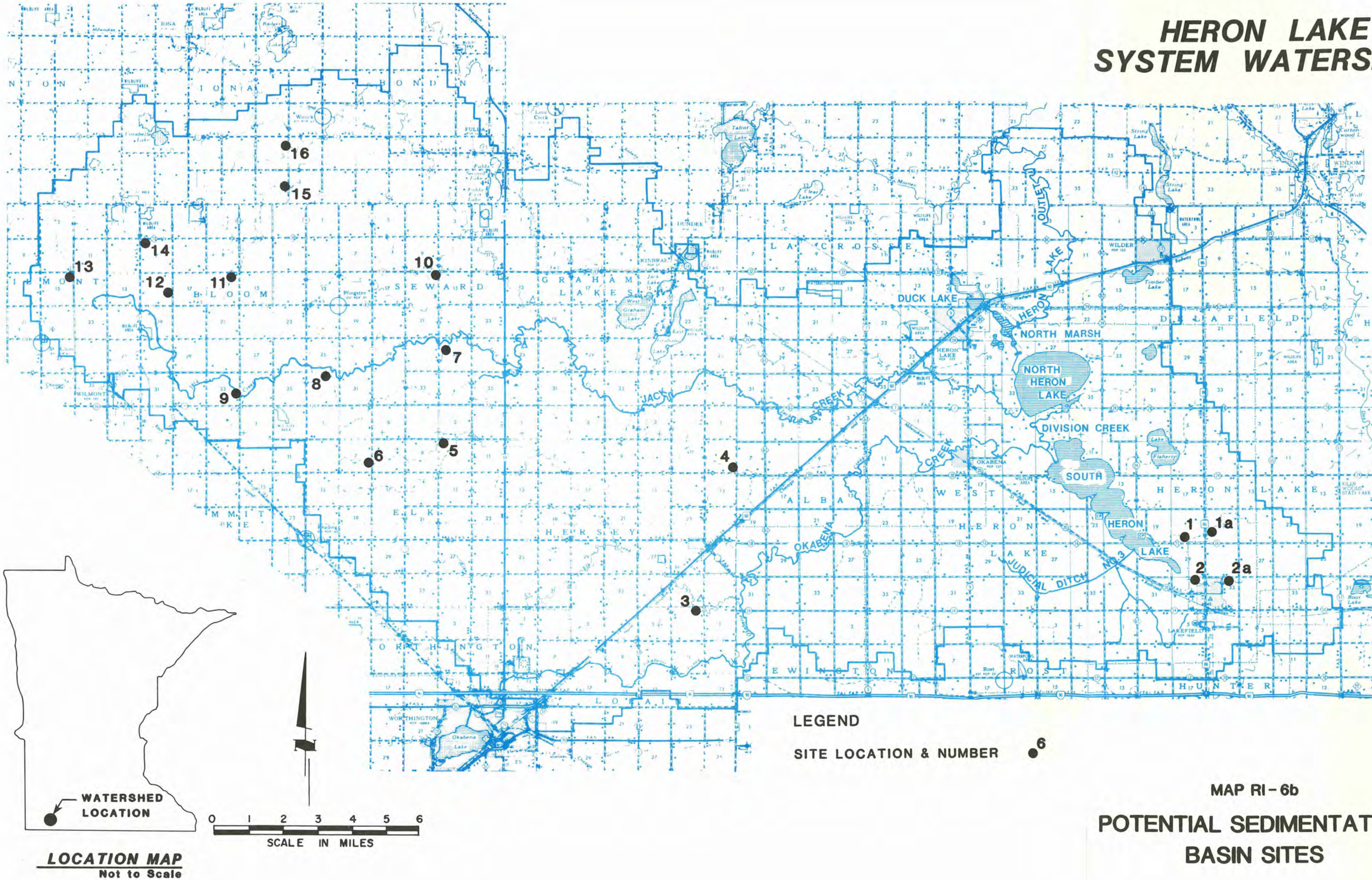
Alternative RI-6b, Sedimentation Basins, would reduce the quantity of sediment delivered to the Heron Lake system. This will, in turn, reduce nonpoint source nutrient contributions to the lake. Based upon review of topographic maps and field inspections, 18 potential sites (Map RI-6b) were located with drainage areas from approximately 1 to 10 square miles. These sites are selected based on site suitability and available storage for sediment and can be expected to trap a significant portion of the sediment produced by the drainage areas.

The effectiveness of individual sites varies and is dependent on the final design selected (Heinemann).

Other benefits of this alternative are a reduction in downstream damage caused by the sediment and some degree of flood reduction in areas immediately downstream.

Disadvantages include the need for acquisition of land or easements and permits. The sedimentation basins are also relatively costly compared to other alternatives.

HERON LAKE SYSTEM WATERSHED



LEGEND

SITE LOCATION & NUMBER ●6

MAP RI-6b

POTENTIAL SEDIMENTATION BASIN SITES

SEDIMENTATION BASINS

RI-6B

ADVANTAGES

- Provides Reduction In Sediment and Nutrient Load To Downstream Areas
- Slight Reduction In Flooding Immediately Downstream
- Provides Control When Nonstructural Alternatives Cannot Be Implemented

DIS-ADVANTAGES

- Relatively High Cost
- Permits Required
- Land Acquisition or Easements Necessary

INCENTIVE PROGRAMS

RI-6C

Alternatives RI-6c, Incentive Programs, is closely related to Alternative RI-6a (Modification of Agricultural Practices). In essence, conservation practices or land use management changes which are thought to be desirable can be encouraged by the development of cost sharing or tax incentives programs.

Cost sharing programs can logically be developed as a supplement to existing state and federal programs for the implementation of soil conservation practices. Present funding sources include programs of the Minnesota Soil and Water Conservation Board and the U.S. Department of Agriculture. Tax incentives could be developed which would reduce the tax liability for landowners who employ sound land use management practices.

The implementation of this alternative will, however, require:

1. A detailed economic analysis of the tax base to insure the feasibility of the program.
2. A legal determination as to the authority of the various governmental units.
3. Coordination with other funding sources.
4. Coordination between governmental units with taxing authority.

INCENTIVE PROGRAMS

RI-6C

ADVANTAGES

- More Effective In Achieving Desired Goals Than If No Incentives Are Offered

DIS-ADVANTAGES

- Program Costs
- Program Administration
- Monitoring To Assure Compliance With Program Guidelines

POINT SOURCE POLLUTION CONTROL

RI-7

With present conditions, point source pollution (primarily from municipal wastewater treatment plants in Worthington, Okabena, Lakefield, Brewster, and Heron Lake) contribute approximately 9% of the total nitrogen and 31% of the total phosphorus to the Heron Lake System in an average year.

Improved treatment processes or land application of wastewater would reduce nutrient input to the Heron Lake System. This would in turn reduce the degree of nonpoint source pollutant reduction necessary to improve the Heron Lake System.

Although control of point source pollution is typically considered much more effective and easier than control of nonpoint source pollution, there is no evidence that control of point source nutrient contributions alone will cause a significant improvement in environmental or aesthetic qualities of the Heron Lake System.

It should be stressed that if other alternatives are implemented as well, point source pollution may become more significant and improvements in treatment processes (such as phosphorus removal) or development of land application systems may be desirable. The effect that this would have depends to a great degree on which other alternatives are selected, the extent of their application and their effectiveness in terms of reducing nonpoint source nutrient contributions.

POINT SOURCE POLLUTION CONTROL

RI-7

ADVANTAGES

- Reduction In Nutrient Loading To Heron Lake System
- Potential Improvements In Riverine Water Quality Downstream of Treatment Plant

DIS-ADVANTAGES

- Moderate To High Initial Costs
- Moderate To High Operation Costs
- Limited effect on Heron Lake System Water Quality Unless Applied With Other Alternatives for Nonpoint Source control

LAKE ACCESS

RI-8

Lake access in the Heron Lake Area has always been a source of controversy. There is at present no readily available public access to North Heron Lake.

It is beyond the scope of this study effort to provide an alternative to this problem. However, it should be pointed out that future inplementation of potential alternatives proposed herein should address this access issue in order to attribute greater benefits to public use of the Heron Lake resources.

WATERFOWL HABITAT PRESERVATION / IMPROVEMENT

RI-9

Waterfowl in the Heron Lake System utilize North Heron, Division Creek, and the north part of South Heron for breeding grounds and migration stop-over areas. Alternative RI-9, calls for the preservation and improvement of those natural waterfowl habitat area via lake drawdown and improved water quality.

Drawdown of the entire north lake would allow the macrophytes to reestablish themselves over much of the lake bed thereby increasing habitat. Partial drawdown could also be considered. If this option were chosen, periodic complete and partial drawdown would have to be included in the overall water level management program (Alternative FC-7, Lake Level Management).

Improvement of the water quality would also benefit waterfowl. Poor water quality and/or lack of sheltered waters appears to be limiting the growth of such preferred waterfowl food as wild celery and wild rice. Therefore, all water quality alternatives previously presented would indirectly be beneficial to waterfowl.

While the benefits of both of these options are substantial, difficulties in implementation should be recognized. For example, the success of a partial or complete drawdown of North Heron Lake would depend largely on the ability to divert or control flows from Jack Creek, Okabena Creek and South Heron Lake. The drawdown would begin in the Spring and be maintained for approximately one year. Summer storm flows and existing summer flows would likely complicate this procedure.

WATERFOWL HABITAT PRESERVATION / IMPROVEMENT

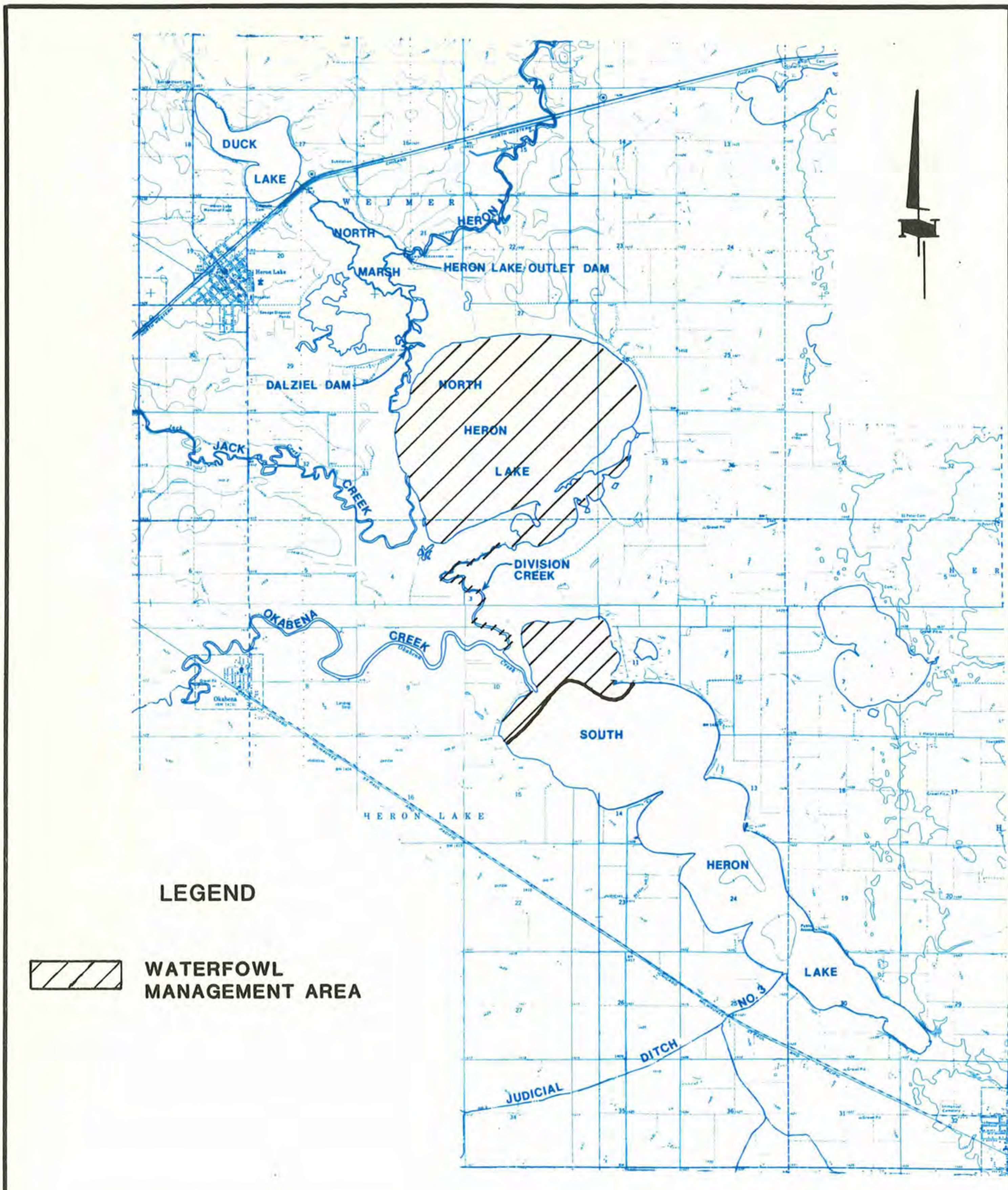
RI-9

ADVANTAGES

- Increased Macrophyte Covered Areas
- Increased Waterfowl Breeding Areas
- Increased Attractiveness As Stop-over Areas For Migrating Waterfowl
- Would Help Improve Water Quality

DIS-ADVANTAGES

- Complete Drawdown Of North Heron Lake Would Be Quite Difficult Due To Diversion Of Jack Creek, Okabena Creek, and South Heron Lake
- Partial Drawdown May Be Difficult
- Difficulty in Improvement of Water Quality for the Entire Heron Lake System



MAP RI-9

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WATERFOWL HABITAT
PRESERVATION/IMPROVEMENT

NO-ACTION ALTERNATIVE

RI-10

The magnitude of the water quality problems in Heron Lake has been discussed at length throughout this report. The importance of taking action to correct these problems cannot be overemphasized if the lake is to be revitalized to restore and enhance its valuable resources.

Adoption of the No Action Alternative, RI-10 will result in the following:

- Further degradation of water quality.
- Continued rough fish populations.
- On-going disputes over utilization of the Lake System due to lack of a detailed management plan.
- Continued high phosphorus and nitrogen loadings due to poor land use techniques.
- Endangered game fish populations due to periodic low dissolved oxygen concentrations and winter freezeouts.
- Continued dominance of blue-green algae, and murky water and unpleasant odor associated with bloom conditions.
- Less than optimum conditions for wildlife.

RESOURCES IMPROVEMENT ALTERNATIVES

(Partial Lake)

INTRODUCTION

This phase-approach management program focuses on the selection of a small and manageable area in this lake system for a Phase I Management Plan. For this phase, a southern portion of South Heron Lake was selected for preliminary analysis. This area is potentially manageable because it does not receive direct inflow from the large upstream areas of Jack and Okabena Creeks.

This partial lake management program will seek to:

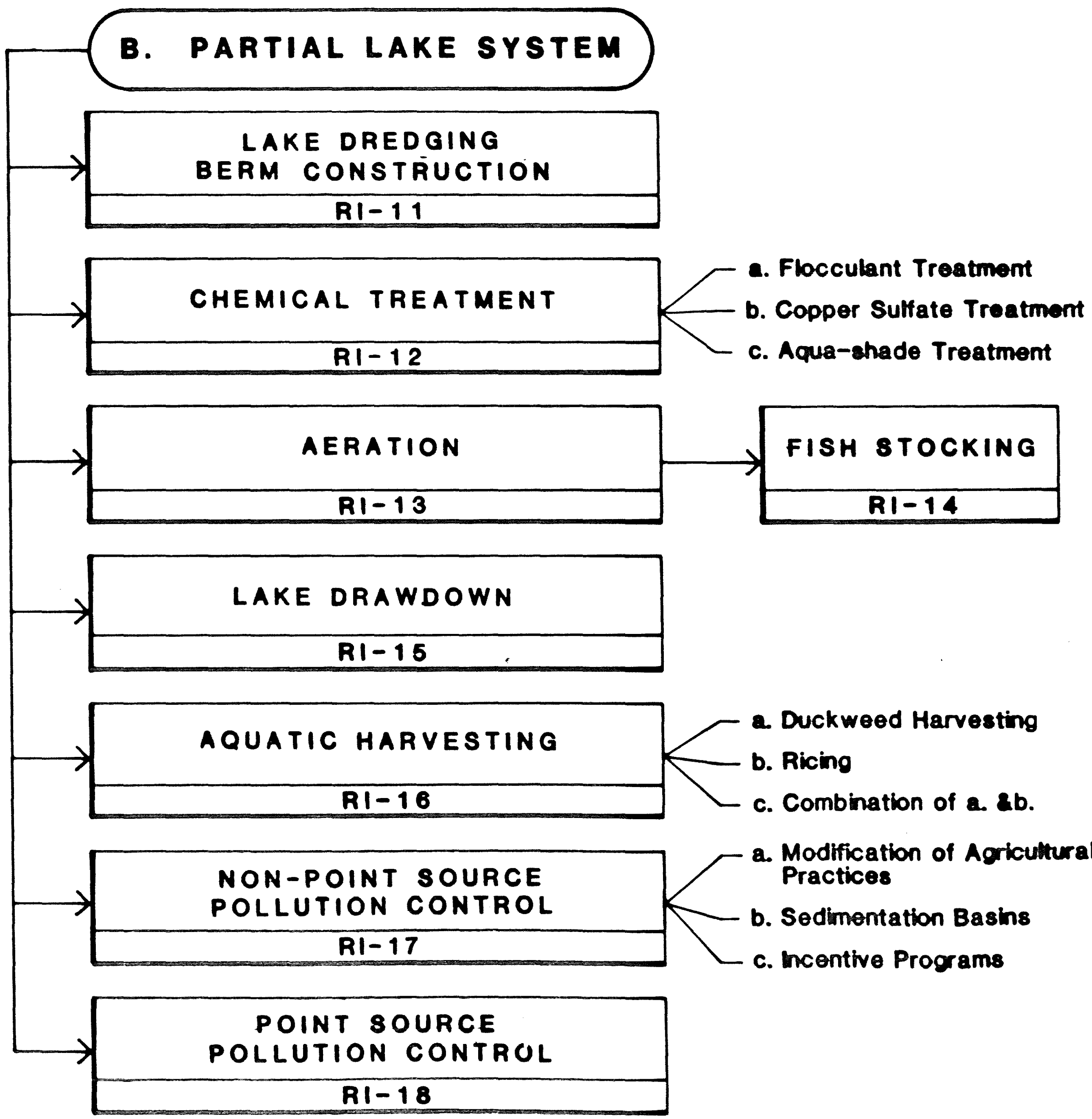
1. Maximize local resouces:
   - Wind Power
   - Nutrient-Rich Waters
   - Available and Potential Fish and Waterfowl Resources
2. Develop economically attractive and environmentally safe management techniques:
   - Aquatic Cash Crops
   - Control of Incoming Nutrient Land Through Land Use Management and Sedimentation Reservoirs
   - Encouragement of Sound and Responsible Point-Source Pollution Control

The several components of this program will require a preliminary small-scale experimentation prior to application to the management area of Phase I. Once Phase I is completed and results show positive effects, expansion of the program (Phase II) will be implemented next to eventually cover the entire Heron Lake System.

It should be reiterated that this program is only another potential management option for further consideration by State and Local Governments. Upon adoption of a definite Management Plan, further analysis and detailed planning will be necessary for the implementation of such a program.

HERON LAKE
RESOURCES IMPROVEMENT ALTERNATIVES

- WATER QUALITY IMPROVEMENT
- FISHERY DEVELOPMENT
- WATERFOWL PRESERVATION/DEVELOPMENT



LAKE DREDGING
BERM CONSTRUCTION
RI-11

Alternatives RI-11, Lake Dreging and Berm Construction, is intended to temporarily separate, for water quality purposes, a portion of South Heron Lake. This will be done by dredging material from the lake bottom and building a berm at one of two locations as shown on Map RI-11. A small channel in the berm will allow access to other parts of the lake, allow fish to move back and forth freely, and water levels to remain the same in both portions of the lake. Technically, this berm therefore does not entirely "separate" one portion from the rest of South Heron Lake. It will, however, serve as a barrier to prevent a high degree of physical mixing between the two portions of the lake. The area of South Heron Lake south of the berm will be much smaller and thus can be managed for water quality improvements much more readily than the entire Heron Lake System can.

Dredging and construction of the berm can occur simultaneously with the dredged material utilized as fill material for the berm. The dredged area is located adjacent to the berm with a maximum depth of 20 feet. Procedures for removal of the top layer sediment on the bottom of the lake, and removal of the clayey sediment for this dredged area are very similar to the procedures outlined in Alternative RI-3, Lake Dredging, except on a much reduced scale.

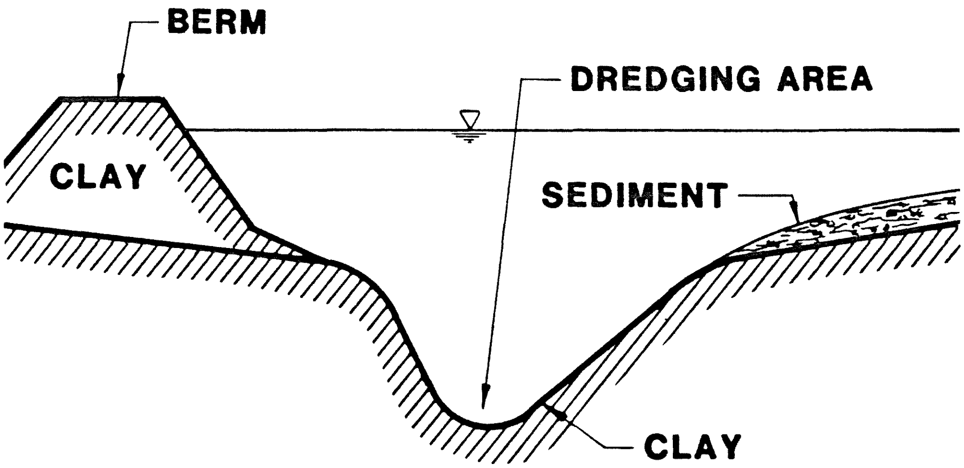
The implementation of Alternative RI-11 will also be effective in that it reduces the size of the contributing drainage area, thus making the control of nonpoint source pollution somewhat easier than it would be for the entire watershed of the Heron Lake System. Based on whether location 1 or location 2 is selected, the management area will have the following characteristics.

	Existing	Location 1	Location 2
Surface Area (Ac.)	6,057	530	950
Drainage Area (Ac.)	289,760	20,800	21,250
Ratio of Drainage Area/ Surface Area	47.8	39.5	22.5
Total Phosphorus (lb/yr.)	79,190	8,070	8,190
Total Nitrogen (lb/yr.)	1,254,390	104,170	109,150

Implementation of this alternative should be considered as a temporary measure which would help verify the applicability of the other Resource Improvement Alternatives to the entire Heron Lake System, notably the practicality of aquatic harvesting. In the event that other alternatives are implemented and proven to be effective, the berm could be eliminated.

Disadvantages of this alternative include a temporary impact on water quality during the construction period. It should be noted that geologic conditions will have to be evaluated more fully to determine the impact of ground water and the suitability of the dredged material as fill for the berm.

Problems with permitting are also anticipated for this alternative since this management technique has never been applied to a major lake in Minnesota.



TYPICAL CROSS SECTION OF DREDGED AREA
ALTERNATIVE RI-11

LAKE DREDGING
BERM CONSTRUCTION

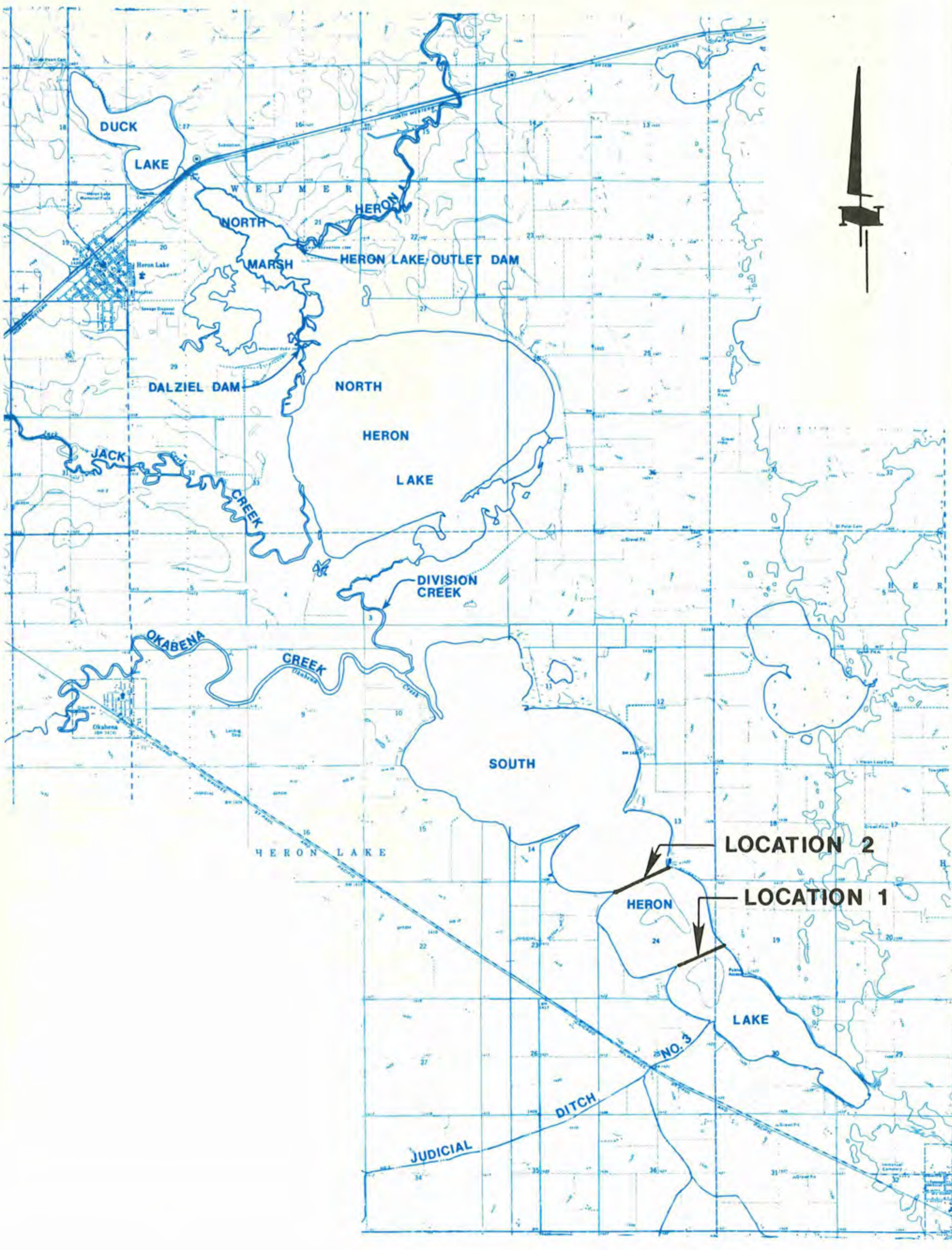
RI-11

ADVANTAGES

- Allows Water Quality Management Alternatives To Be Applied On A Small Scale
- Allows More Effective Management Of Contributing Drainage Area
- No Need for Land Disposal of Dredged Material

DIS-ADVANTAGES

- Permits Required for Berm, Dredging and Water Quality Considerations
- Precedence Setting in Minnesota



MAP RI-11

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PARTIAL LAKE DREDGING AND BERM CONSTRUCTION

CHEMICAL TREATMENT

RI-12

Alternative RI-12 is essentially identical to Alternative RI-1 in theory and justification for use. The difference in these two options lies in the scope of the alternative's application and in the assessment of their various benefits and limitations.

Alternative RI-12 is divided into three subalternatives as follows:

FLOCCULANT TREATMENT

RI-12A

COPPER SULFATE TREATMENT

RI-12B

AQUA-SHADE TREATMENT

RI-12C

FLOCCULANT TREATMENT

RI-12A

Subalternative RI-12 calls for the treatment of a portion of the lake with one of the flocculants ferric chloride, ferric sulfate, or aluminum sulfate as discussed in Subalternative RI-la, Flocculant Treatment for the entire lake.

The flocculant treatment of only a portion of the lake (at location 1 or location 2) offers two important practical advantages in addition to those previously mentioned in RI-la. The volume of water to be treated is reduced from approximately 3260 million gallons to 510 million gallons at location 1 and 920 million gallons at location 2. The savings in treating these areas with flocculants, copper sulfate, or Aqua-shade would be substantial.

In addition, the external loading, of nutrients to these smaller portions of the lake are much reduced and easier to control. Therefore, manipulation of the chemical treatments to eventually "fit" the entire lake would be greatly facilitated.

FLOCCULANT TREATMENT

RI-12A

ADVANTAGES

- Advantages Listed For Subalternative RI-la apply here.
- Relatively Low Cost.
- Facilitation Of Experimentation.

DIS-ADVANTAGES

- The Entire Lake Would Not Benefit Immediately But Would Be Included In Treatment At A Later Date
- Disadvantages Listed For Sub-alternative RI-la Not Related To Cost Apply Here

COPPER SULFATE TREATMENT

RI-12B

Subalternative RI-12b involves the treatment of a portion of the lake with copper sulfate. The discussion of theory and justification for use contained in Subalternate RI-1b applies here. The discussion of partial lake limitations is identical to those contained in RI-12a, Flocculant Treatment.

COPPER SULFATE TREATMENT

RI-12B

ADVANTAGES

- Advantages Listed For Subalternative RI-1b Apply Here.
- Relatively Low Cost.

DIS-ADVANTAGES

- The Entire Lake Would Not Benefit Immediately But Would Be Included In Treatment At A Later Date
- Experimental In Nature
- Disadvantages Listed For Sub-alternative RI-1b No Related To Cost Apply Here

AQUA-SHADE TREATMENT

RI-12C

Subalternative RI-12c calls for the treatment of a portion of the lake with the dye Aqua-shade. This alternative is similar in theory and justification for use to Subalternative RI-1c, Aqua-shade treatment for the entire lake. The discussion of partial lake limitations is identical to those contained in RI-1a, Flocculant Treatment.

Again, a recommended approach would be to conduct a small-scale experimentation prior to application to the entire proposed management area.

AQUA-SHADE TREATMENT

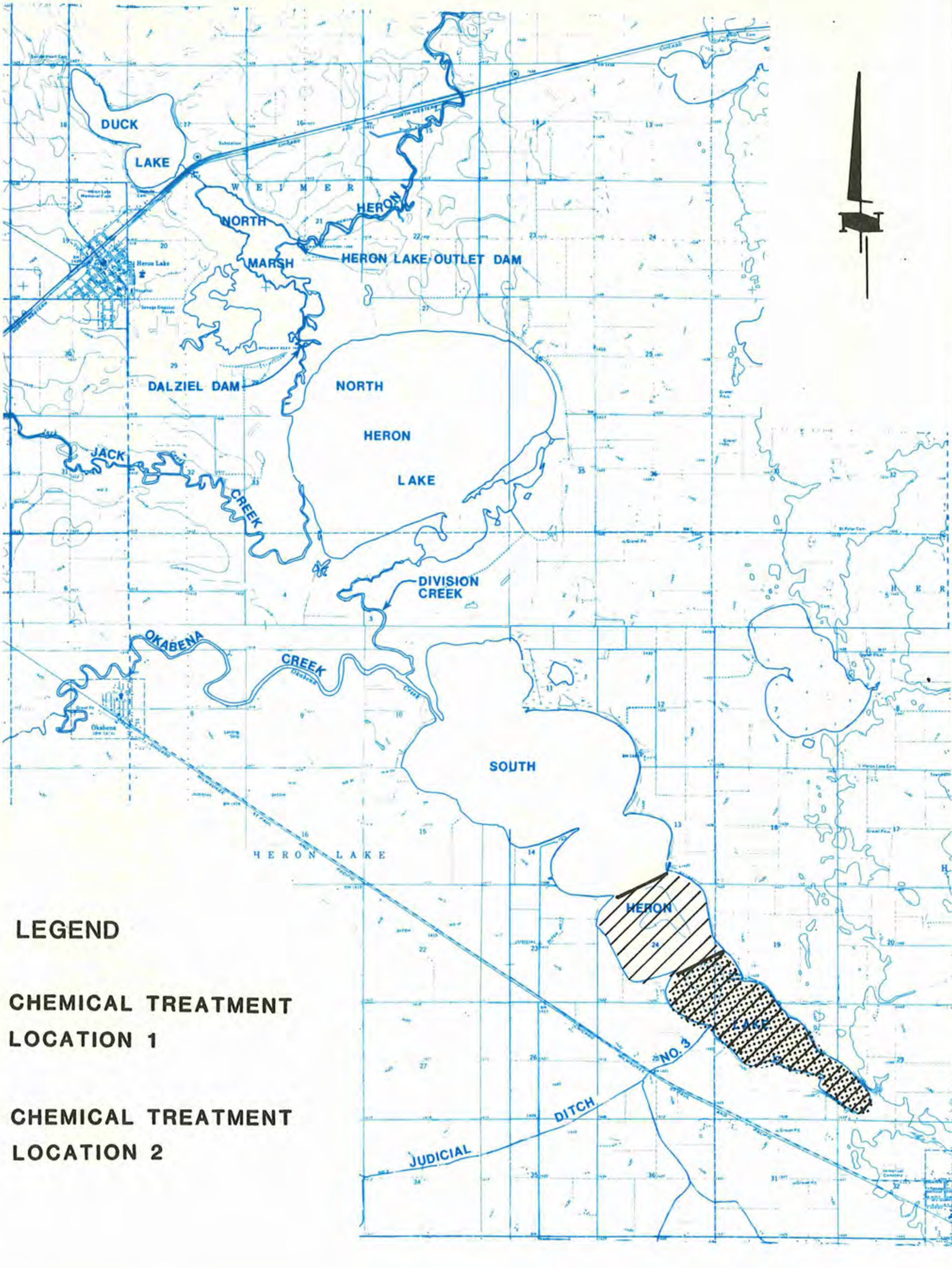
RI-12C

ADVANTAGES

- Advantage Listed For Subalternative RI-lc Apply Here
- Relatively Low Cost

DIS-ADVANTAGES

- The Entire Lake Would Not Benefit Immediately But Would Be Included In Treatment At A Later Date
- Experimental In Nature and Requires Further Investigation
- Disadvantages Listed For Subalternative RI-lc Not Related To Cost Apply Here



LEGEND

CHEMICAL TREATMENT LOCATION 1

CHEMICAL TREATMENT LOCATION 2

MAP RI-12

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CHEMICAL TREATMENT

AERATION

RI-13

Alternative RI-13 calls for the Aeration of a portion of the lake bounded by either Berm Location 1 or Berm Location 2. This alternative is similar to Alternative RI-2, Aeration (entire lake), in theory and justification for use.

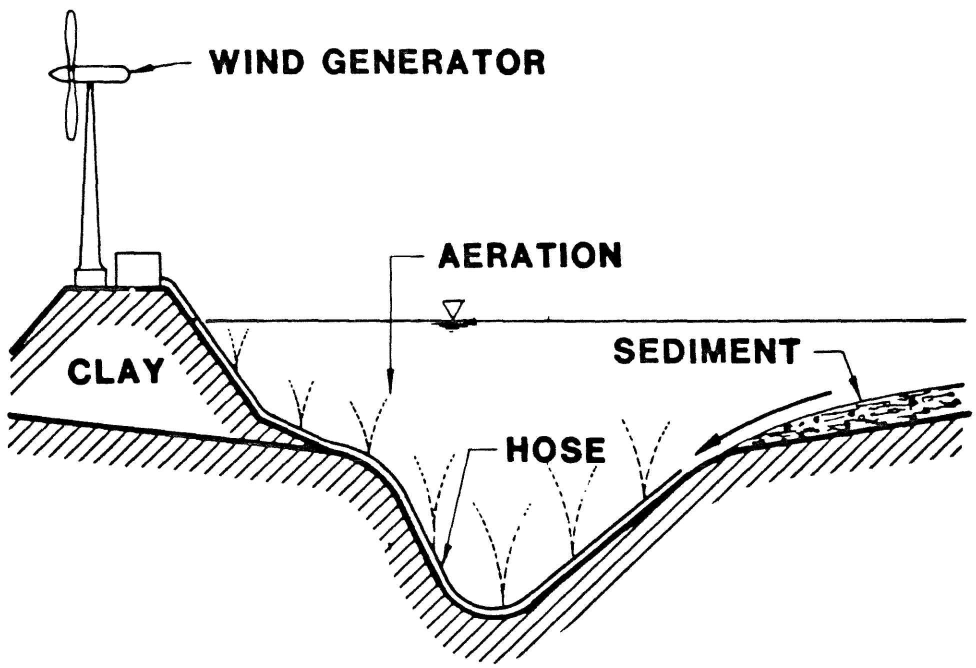
The advantages and disadvantages cited for Alternative RI-2 are applicable to the alternative with one exception, cost. If one of the two proposed portions of the lake was dredged and subsequently aerated, the wind-power system alone could supply sufficient power with back-up power for emergencies only(*). This would result in greatly reduced maintenance costs.

Three wind-driven air pumps at an average wind of 11 mph will provide 300 cfm of air to the lake. This flow rate is based on the amount of air needed to maintain 100% saturation for both oxygen as O_2 and carbon as CO_2 (Frey. David G.). Since the sizes of the dredged areas for Location 1 and Location 2 are comparable, this flow rate would be applicable to both options.

In order to efficiently distribute the air, approximately 900 pressure heads will be arranged on a grid pattern of PVC hose. This will insure that the entire dredged area will be aerated. (Frey, David G., Hogen).

(*)Location 2 is more desirable than Location 1 in this instance because it is closer to an electrical power source for the back-up aeration system and provides one additional public access.

Drawing from Steve



CONCEPTUAL PLAN FOR ALTERNATIVE RI-13

AERATION

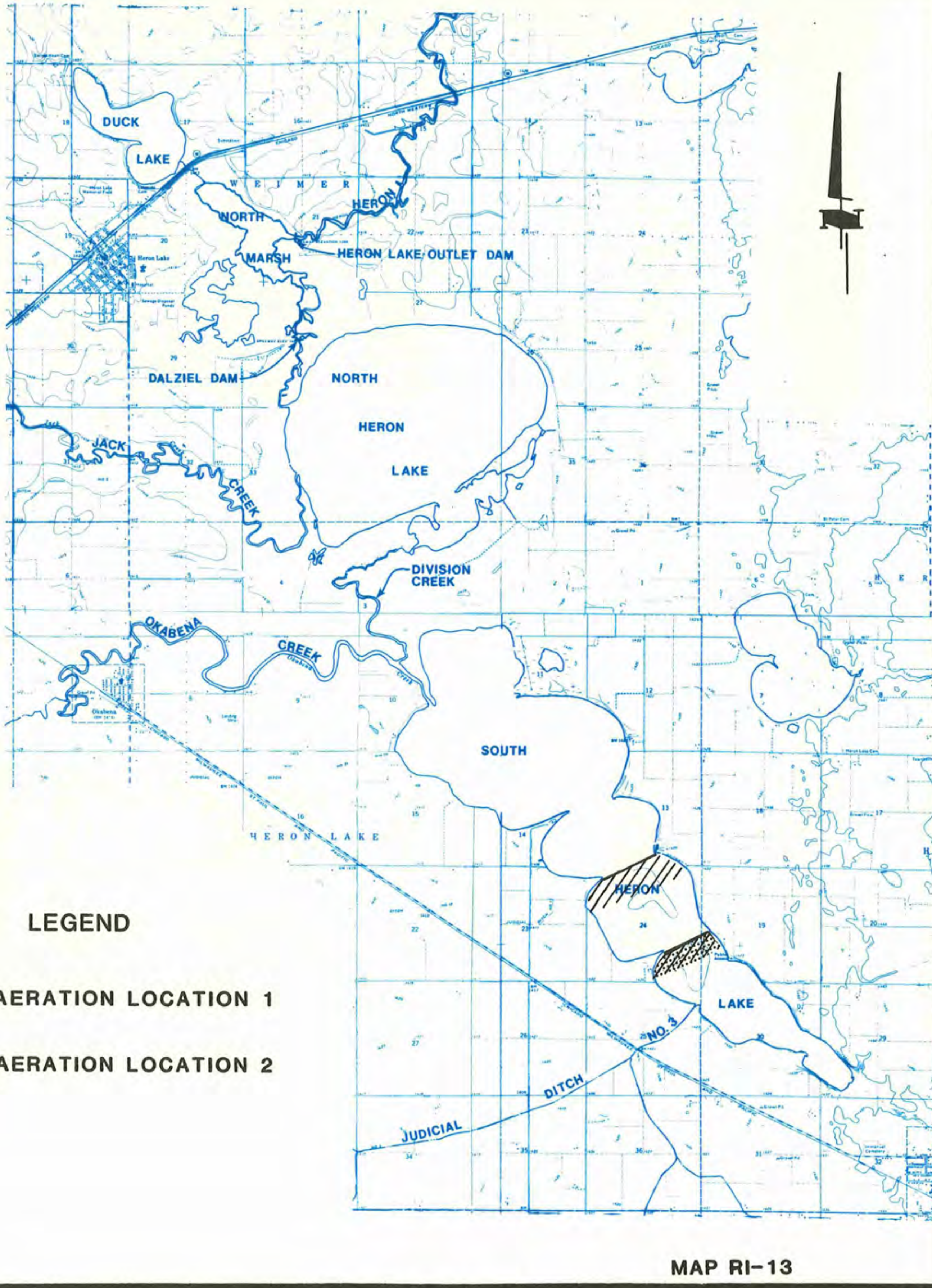
RI-13

ADVANTAGES

- Advantages Listed For Alternative RI-2 Apply Here
- Totally Wind-powered System Would Result In Relatively Low Maintenance Costs

DIS-ADVANTAGES

- Experimental in Nature
- The Entire Lake Would Not Benefit Immediately



LEGEND

AERATION LOCATION 1

AERATION LOCATION 2

MAP RI-13

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AERATION

FISH STOCKING

RI-14

The fish stocking program proposed here would be identical to the one presented in Alternative RI-4, Fish Stocking for the entire lake. It would however be reduced in scope.

This reduction in scope, i.e. treating only a portion of the lake, would both reduce costs involved in implementation of this option and facilitate experimentation to provide a program applicable at a later date to the whole lake.

FISH STOCKING

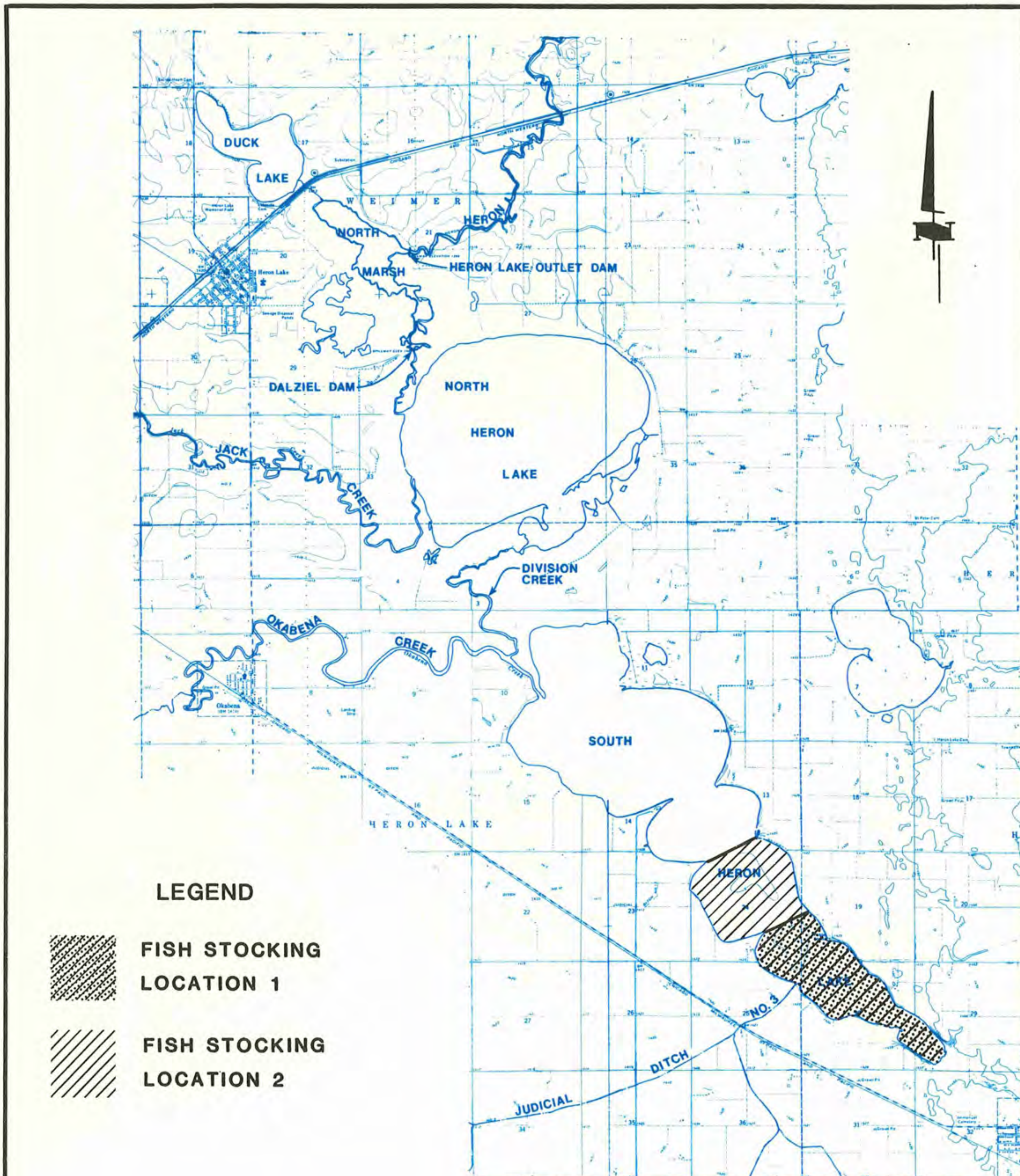
RI-14

ADVANTAGES

- Advantages Listed for Alternative R1-4 Apply Here
- Reduced Costs
- Facilitation of Experimentation

DIS-ADVANTAGES

- Disadvantages Listed for Alternative R1-4 Apply Here
- The Entire Lake Would Not Benefit Immediately But Would Be Included in the Program at a Later Date



MAP RI-14

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FISH STOCKING

LAKE DRAWDOWN

RI-15

Alternative RI-15, is essentially a temporary lowering of water levels to consolidate the bottom sediments which are exposed. This is normally done in spring and allowed to remain over the winter, with the following year's spring runoff filling the lake again. For South Heron Lake, this could be done by lowering the elevation of the North Heron Lake Dam or, if Alternative RI-11 is selected, by pumping from the controlled portion of South Heron Lake.

There are four main benefits to lake drawdown:

1. Bottom sediments are reduced in volume. This is attributed to organic matter drying out, allowing the weight of the sediment to compact it. In the Heron Lake system this would probably not be a significant benefit since the thickness of soft organic sediments appears to be only about 1 foot and thus lake drawdown would not significantly increase the depth.

2. The rough fish population is eliminated or greatly reduced. Small areas which will not drain will subject the fish population to winter freezeout. Game fish can then be stocked when the lake level is restored. Since the Heron Lake system supports predominantly rough fish populations, this would be a significant benefit.

3. The consolidation of bottom sediments greatly reduces the rate at which nutrients can be released from the sediment into the overlying waters.

4. Promotes macrophyte growth favorable to waterfowl.

Lake drawdown is not currently considered a long term solution to water quality problems and may require periodic repeating.

The length of time requried for drawdown is dependent on the size of the area, drawdown methods and the amount of inflow. The area would not be available for recreational use during a period of 6 to 9 months and lake drawdown would have a potentially negative impact on waterfowl during the drawdown period. Due to the high nutrient content of the sediment, a heavy weed growth can be expected.

This growth is acceptable for waterfowl habitat, but for fisheries or recreational use, it may be desirable to remove and dispose of this material prior to refilling.

LAKE DRAWDOWN

RI-15

ADVANTAGES

- Reduces Rough Fish Population
- Promotes Macrophyte Growth Favorable To Waterfowl
- Reduces Nutrient Recycling From Sediment
- Relatively Inexpensive

DIS-ADVANTAGES

- Beneficial Effects on Water Quality Temporary
- Lake Not Available For Recreational Use During Drawdown Period

AQUATIC HARVESTING

RI-16

Alternative RI-16 is identical to Alternative RI-5 in theory and justification for use. Alternative RI-16 is, however, proposed for a smaller portion of the lake, bounded by Berm Location 1 or Berm Location 2. This alternative will be divided into three subalternatives for discussion.

DUCKWEED HARVESTING

RI-16A

RICING

RI-16B

COMBINATION OF A. & B.

RI-16C

DUCKWEED HARVESTING

RI-16A

Subalternative RI-16a calls for the utilization of duckweed harvesting technique to reduce the nutrient load in a portion of the lakes (lcoation 1 or location 2). The discussion of theory and justification for use contained in Subalternative RI-5a is applicable to this alternative.

Two additional advantages result if the area of treatment is reduced to that designated by location 1 or location 2 from the entire lake. One advantage is obvious reduction in cost. Land required for efficient duckweed nutrient utilization would total approximately 125 acres assuming 510 million gallons of water treated at location 1 and 229 acres assuming 920 million gallons of water at location 2 (1040 acres required for the entire lake).

Another advantage is that a portion of the lake would facilitate experimental manipulation and control of the duckweed ponds. In the long run such a reduced scope plan would be modified accordingly and applied to the entire Lake system.

Small-scale experimentation prior to application to the entire management area is recommended.

DUCKWEED HARVESTING

RI-16A

ADVANTAGES

- Advantages Listed For Subalternative RI-5a Apply Here
- Relatively Low Cost
- Facilitation Of Experimentation

DIS-ADVANTAGES

- Disadvantages Listed For Sub-alternative RI-5a Excluding Cost Apply Here
- The Entire Lake Would Not Benefit Immediately But Would Be Included In Treatment At A Later Date

RICING
RI-16B

Subalternative RI-16b involves the utilization of ricing operations to reduce the nutrient load in a portion of the lake (location 1 or location 2). The general discussion of the Ricing alternative contained in RI-5b is applicable here. The partial lake limitations mentioned in RI-16a, Duckweed Havesting are identical to those which result from the implementation of RI-16b.

Small-scale experimentation prior to application to the entire lake management area is recommended.

RICING
RI-16B

ADVANTAGES

- Advantages Listed For Subalternative RI-5b Apply Here
- Relatively Low Cost
- Facilitation Of Experimentation

DIS-ADVANTAGES

- Disadvantages Listed For Sub-alternative RI-5b Excluding Cost Apply Here
- The Entire Lake Would Not Benefit Immediately But Would Be Included In Treatment at a Later Date

COMBINATION OF A. & B.

RI-16C

Subalternative RI-16c calls for the utilization of a combined duckweed harvesting and ricing system to reduce the nutrient load in a portion of the lake (designated by Berm Location 1 or Berm Location 2). Refer to RI-5c, for the entire lake for discussion of theory and implementation pertainant to this subalternative. Refer to RI-16a for a discussion of the partial lake limitations relevant to this subalternative.

COMBINATION OF A. & B.

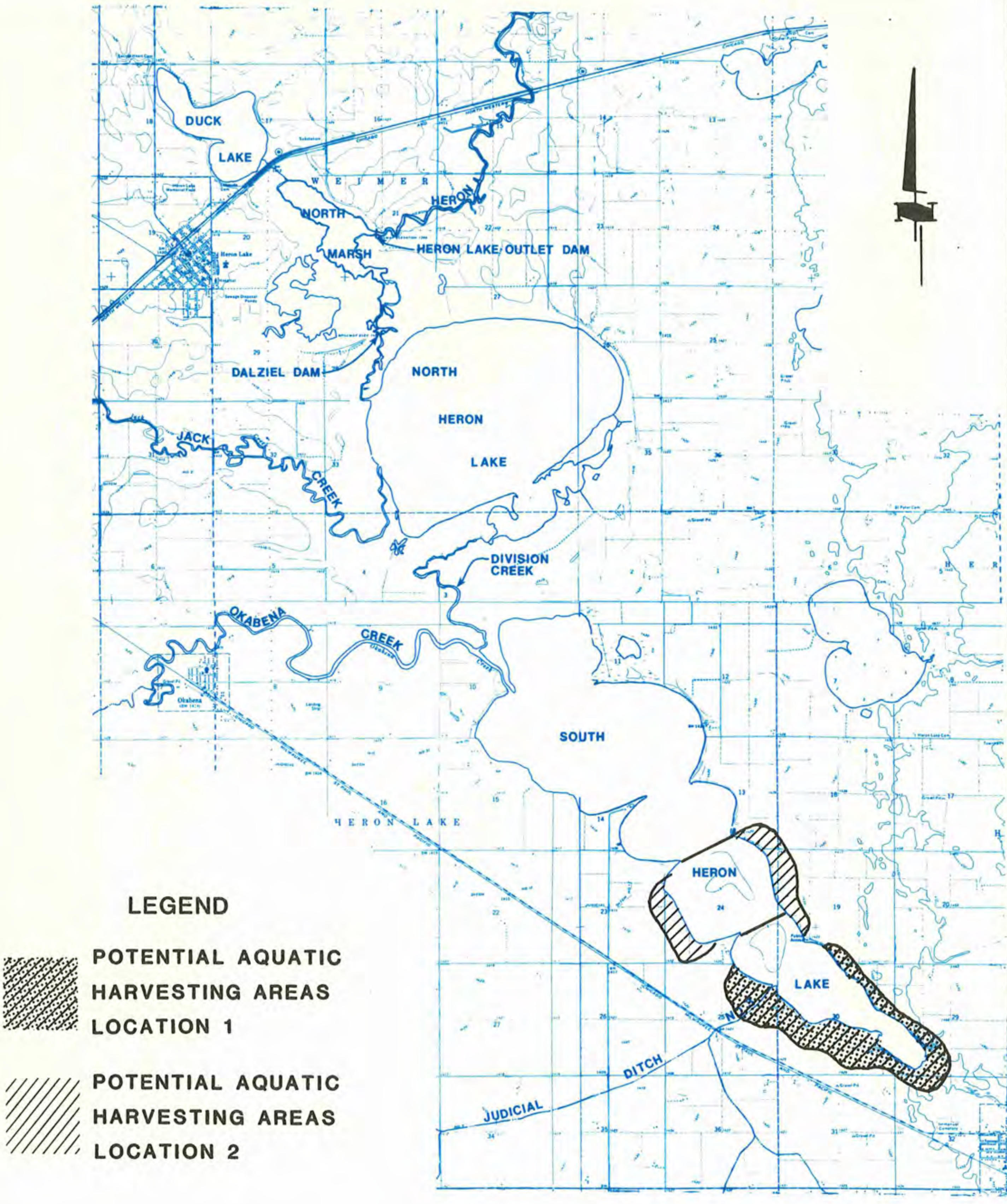
RI-16C

ADVANTAGES

- Advantages Listed For Subalternative RI-5a Apply Here
- Relative Low Cost
- Facilitation Of Experimentation

DIS-ADVANTAGES

- Disadvantages Listed For Subalternative RI-5a Excluding Cost Apply Here
- The Entire Lake Would Not Benefit Immediately But Would Be Included In Treatment At A Later Date



MAP RI-16

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AQUATIC HARVESTING

NON-POINT SOURCE POLLUTION CONTROL

RI-17

The principles and objectives of Alternative RI-17, Nonpoint Source Pollution Control, are identical to those discussed under Alternative RI-6 for the entire Heron Lake System. The difference is that the area in which they should be applied is much smaller and includes only the drainage area contributing to the controlled portion of South Heron Lake.

Benefits of Alternative RI-17 are identical to those for Alternative RI-6 with an additional benefit that drainage areas to controlled portions of the lake lie entirely within Jackson County and thus coordination between governmental units may be simplified to some extent. In addition, overall program costs for cost sharing or tax incentive programs would be less due to the smaller area.

POINT SOURCE POLLUTION CONTROL

RI-18

Alternative RI-18, Point Source Pollution Control, consists of measures to reduce nutrient loading to the controlled portion of South Heron Lake. With present conditions, point-source nutrient contributions are less significant than nonpoint-source nutrient contributions. However, if Alternative RI-11 (Lake Dredging and Berm Construction) is implemented, point-sources (the City of Lakefield) will become significant. A summary of nutrient loading for existing conditions and for Alternative RI-11 conditions is as follows:

Annual Nutrient Loading
(Adapted From EPA-NES Working Paper No. 103)

	Present Conditions	RI-11 Location 1	RI-11 Location 2
Total Nitrogen			
Nonpoint Source - lbs. (%)	1,254,390 (91)	87,380 (84)	92,760 (85)
Point Source - lbs. (%)	112,890 (9)	16,790 (16)	16,790 (15)
Total - lbs.	1,367,280	104,170	109,550
Total Phosphorous			
Nonpoint Source	54,810 (69)	2,530 (31)	2,650 (32)
Point Source	24,330 (31)	5,540 (69)	5,540 (68)
Total	79,190	8,070	8,190

If Alternative RI-11 is selected, point-source pollution control for the City of Lakefield will significantly reduce nutrient loadings to the controlled portion of South Heron Lake. This advantage will become less significant if and when the temporary berm is eliminated.

POINT SOURCE POLLUTION CONTROL

RI-18

ADVANTAGES

- Reduced Nutrient Load to Heron Lake System
- Effective and Responsive Point-Source Effluent Management

DIS-ADVANTAGES

- Moderate to High Initial Cost
- Moderate to High Operation Cost
- May Be Ineffective Unless Implemented With Other Alternatives

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