GREENWATER LAKE SCIENTIFIC AND NATURAL AREA

RESOURCE INVENTORY

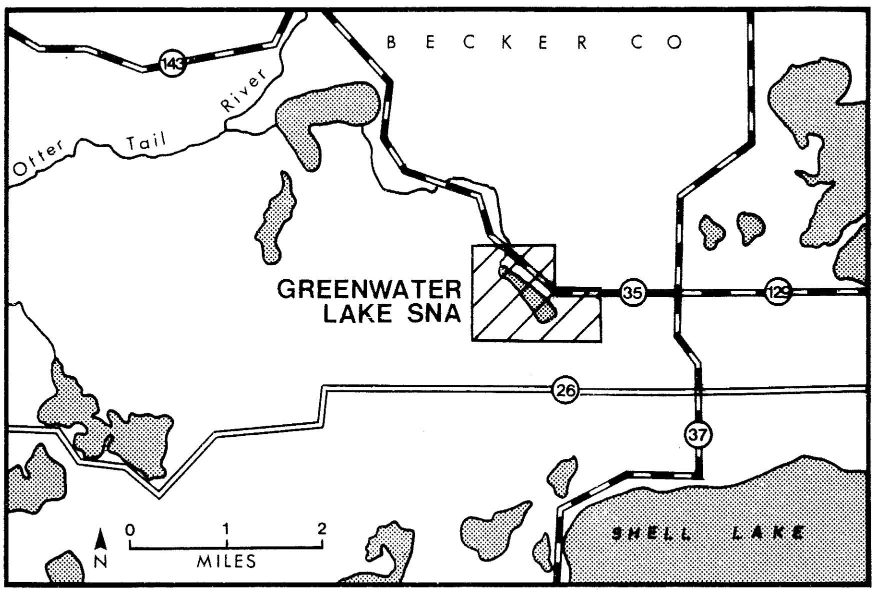
0772B-SL&PC

The 1980 Resource Inventory
for the
Green Water Lake Natural Area

The El/2 SE1/4 SW1/4 SW1/4
of Section 28,
All of Section 33 and
the SW1/4 of Section 34,
Township 141 North, Range 38 West
Height of Land Lake and Ponsford Quadrangles
Becker County
Minnesota

Prepared by
The Scientific and Natural Areas Section
Division of Parks and Recreation
Minnesota Department of Natural Resources

May, 1981


BECKER CO
143
Otter Tail River
GREENWATER
LAKE SNA
35
129
26
37
SHELL LAKE
N
0 1 2
MILES

PREFACE

This report documents the information collected during a 1980 inventory of the Green Water Lake Natural Area. The inventory was designed to collect information on the physical and biological resources of the site, including its geology, soils, climate, water resources, flora and fauna. The land use history of the site was also investigated in an attempt to understand how such practices may have altered the resources of the natural area. Data supplied by this report will be used by evaluators to assess whether the site merits designation as a Scientific and Natural Area (SNA) in accordance with the objectives and criteria established by the program's Long Range Plan (Minn. Dept. of Nat. Res., Div. of Parks and Rec., SNA, 1980a). The report will also be a valuable aid for individuals responsible for future management decisions as well as for scientists, educators and others interested in the area.

The inventory of the Green Water Lake Natural Area was part of a larger effort in which eleven natural areas in northwest, northeast and east-central Minnesota were surveyed. Inventory team members were: Lee Pfannmuller, SNA Planning Coordinator; Carmen Converse, Jane Cross-Cella, Sue Cutler, Ted Petron, Vicki Phelps and Marianne Severson, botanists; Tony Busche, Joel Jokela, Jim Lynch, Jim Pertz, Dan Schneider and Jim Ziegler, zoologists; Larry Killien and Dianne Wade, land use history researchers; and Jim Strudell, geologist. Gerald Jensen, Supervisor, Scientific and Natural Areas Section, and Barbara Coffin, George-Ann Maxson, Welby Smith, Doug Wells and Henry Woolsey, Minnesota Natural Heritage Program, served as inventory advisors. Several individuals and supporting institutions have given freely of both their resources and time, including the following: the Biology Department at Moorhead State University, in particular Dr. R. Pemble and Dr. T. Collins; Dr. E. Birney, Bell Museum of Natural History; Ron Huber, Science Museum of Minnesota; and Gerald Wheeler, University of Minnesota. We are particularly indebted to Dr. G. Ownbey, University of Minnesota, who spent many long hours verifying literally thousands of plant specimens collected during the course of the summer inventory.

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DESCRIPTION OF STUDY AREA

The Green Water Lake Natural Area is a 326-hectare (805-acre) unit in central Becker County, approximately 34 km (21 miles) northeast of Detroit Lakes, Minnesota. The tract is an inholding within the White Earth Indian Reservation, located immediately north of the reservation's southern boundary. Numerous glacial advances over this region of Minnesota thousands of years ago left a hilly topography scattered with bogs and lakes. Referred to as the Pine Moraine Landscape Region (Fig. 1), the area is predominantly a second-growth mixed hardwood and coniferous forest. Small farms are frequent throughout the region.

Interest in the study area centers primarily on Green Water Lake, a noticeably clear 31-hectare (77-acre) body of water with an undeveloped shoreline. The lake occupies a narrow, deep trough that probably formed as a drainageway for glacial meltwater. Most of the nearshore area is underlain by calcium carbonate deposits; peat accumulations above these deposits support a sedge mat which is most extensive at the lake's northwestern end. The presence of the calcium carbonate plays a major role in the water chemistry of Green Water Lake, and helps to maintain a relatively low level of organic productivity in the water.

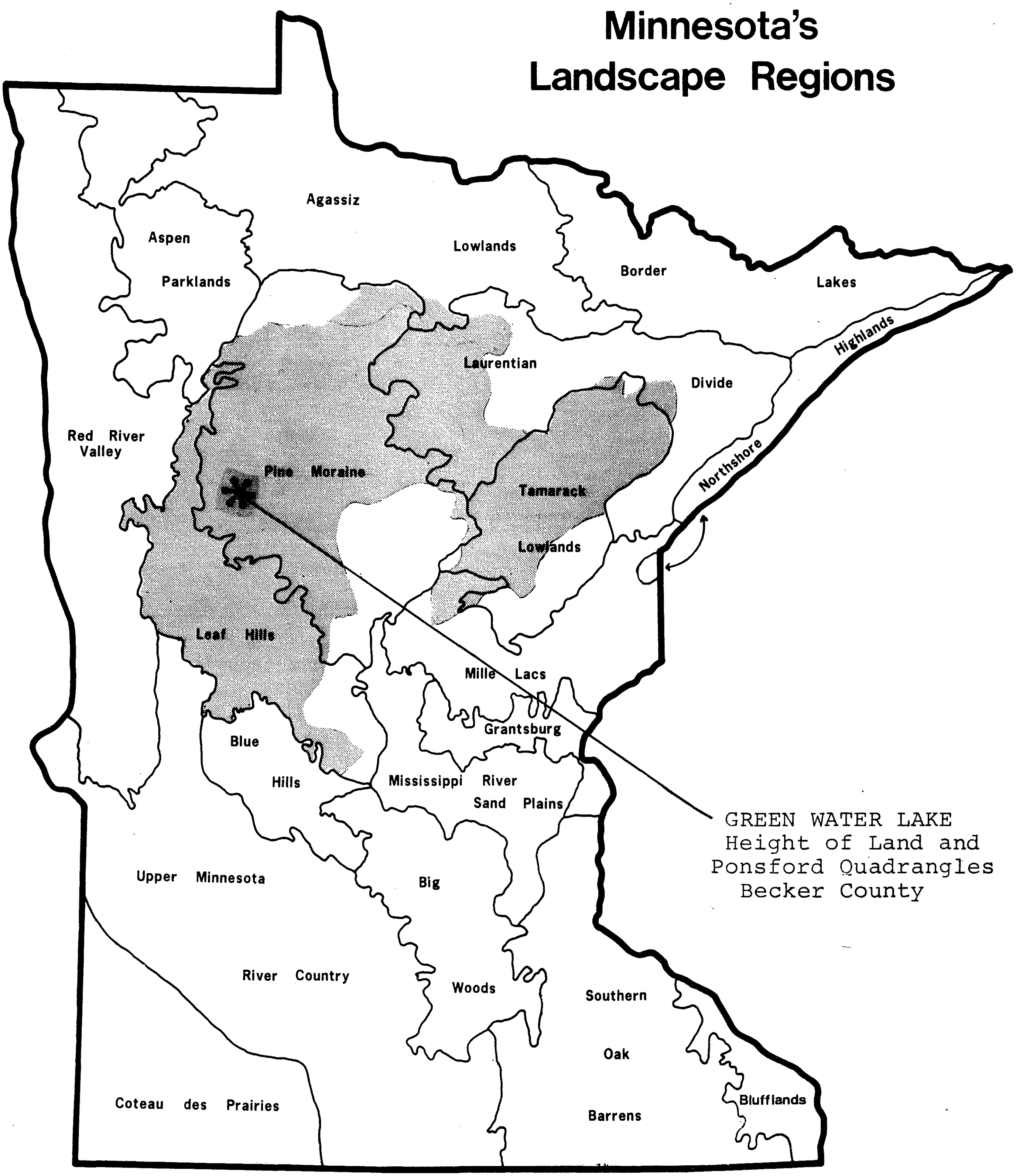


Figure 1. Green Water Lake in relation to Minnesota's landscape region. Adapted from T. Kratz and G.L. Jensen, an ecological geographic division of Minnesota (unpublished, 1977). Also illustrating the forested region of western Minnesota with lakes formed in grey, calcareous glacial deposits.

The woodlands that cover the hills around Green Water Lake are a mixed forest dominated by aspen, birch and oak. Maple and basswood are also common, as is jack pine, which dominates a small sandy hill just west of the lake. Scattered throughout these woodlands are small poorly drained areas characterized by sedge meadows and alder thickets. The flora and fauna of the site are typical of northern Minnesota forests. Species observed on the tract include 253 vascular plants, 34 butterflies, 1 amphibian, 3 reptiles, 58 birds and 23 mammals. The only uncommon species reported were the butterflies *Lethe appalachia leeuwi*, *Pieris napi oleracea* and *Callophrys niphon clarki*.

HISTORY OF PRESERVATION EFFORT

Interest in preserving the Green Water Lake Natural Area was first initiated by a former landowner, Dr. James R. Fox. Relatively little development had taken place on the tract before he purchased the property in the early 1960's. Much of the area had been logged between 1900 and 1940, a road through the tract had been upgraded, gravelled and paved, and several people had established temporary residence on the property. Despite these activities the pristine character of the lake remained relatively unaffected. After his acquisition of the property, Dr. Fox became interested in the quality of the lake and wanted to ensure that the area be kept in its natural condition. In the mid-1970's he contacted the Freshwater Biological Research Foundation, an organization dedicated to the study of Minnesota lakes. The Foundation conducted tests in the spring of 1976 and concluded that the lake was indeed worthy of preservation. In April 1977, Dr. Joseph P. Rossillion, Director of the Foundation, nominated the Green Water Lake site for SNA status. The Commissioner's Advisory Committee recommended in August of the same year that the property be established as an SNA. Further action on this recommendation has been delayed until the results of the 1980 inventory are evaluated.

In the meantime, the two state legislators who represent the district where Green Water Lake is located, Senator Colin Peterson and Representative James Evans, became interested in preserving the tract. Through their efforts in the state legislature money was appropriated for the purchase of approximately half of the site. The remaining parcels were donated to the state by Dr. Fox. As a result of these transactions, the Department of Natural Resources obtained full title to the property in May 1980.

LAND USE HISTORY

The turn of the century marks the beginning of ownership history for the Green Water Lake Natural Area. Beginning in 1902 many of the federal lands in this region were given to individuals of the Ojibway Indian Tribe. The present boundaries of the tract originally encompassed twelve different parcels, nine of which were owned by Ojibways. Each of the parcels were to change ownership on numerous occasions (Appendix I) until in 1963 and 1964 the property became consolidated by Dr. James R. Fox, a medical doctor living and practicing in Minneapolis. In keeping with Dr. Fox's wishes, the Department of Natural Resources was able to acquire the tract in 1980 to insure its continued preservation.

Signs of many of the activities of the past landowners of the Green Water Lake Natural Area are still visible on the tract today. By investigating these features in the field the 1980 inventory staff was able to reconstruct many aspects of the tract's land use history. Field work was supplemented by a thorough search of records in county and state offices, as well as by interviewing local citizens. Landscape features that relate to the site's land use history are illustrated in Figure 2.

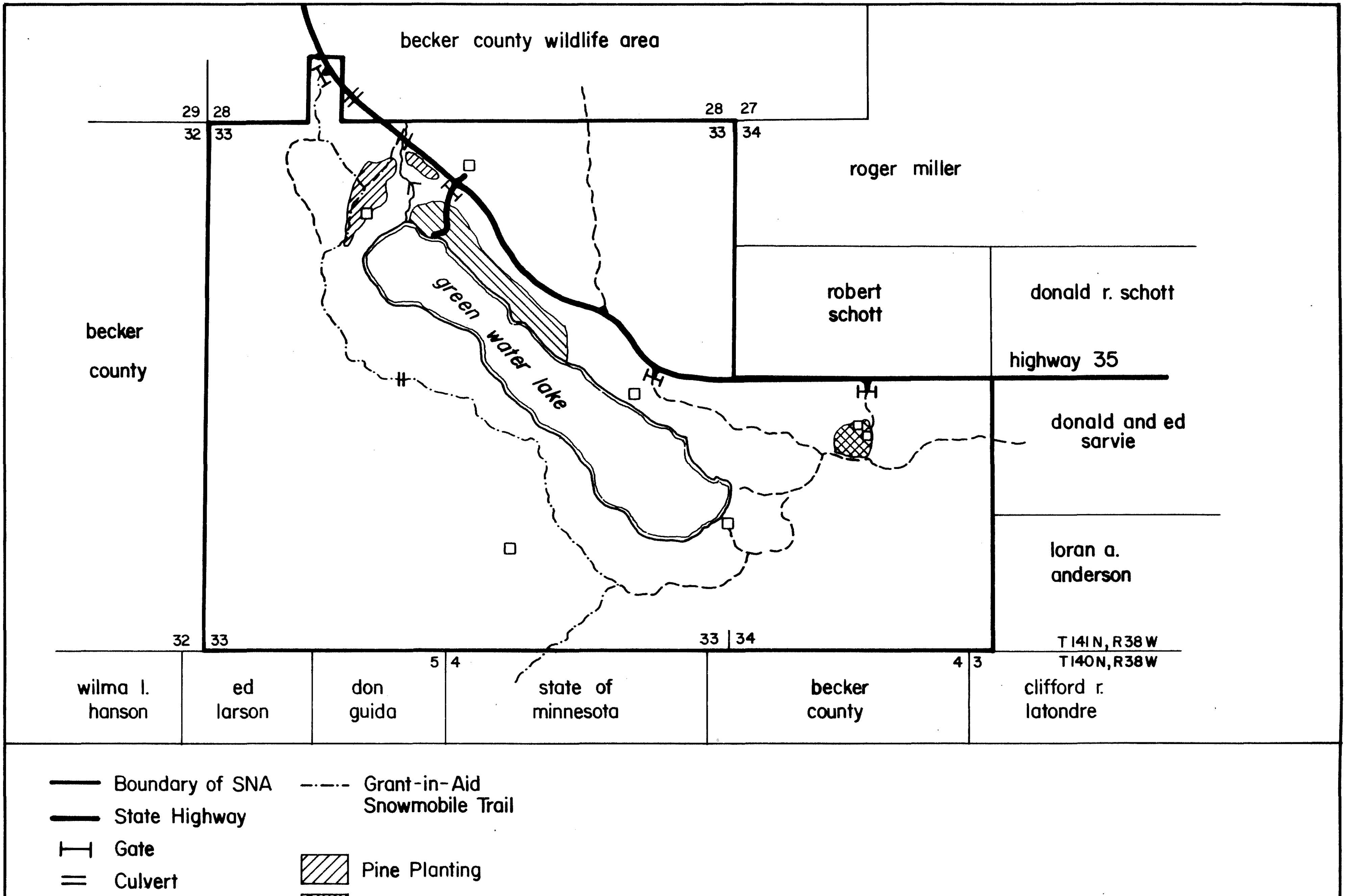


Figure 2 Land Use History and Adjcent Land Ownership

The most obvious indication of man's presence in and around the natural area are the road and trails. Becker County Highway #35 passes through the property, north of the lake (Fig. 2). Initially built by the government in 1868, it was the first wagon road in the Ponsford region. Referred to as the White Earth Road or the Government Indian Trail, it connected the towns of White Earth and Leech Lake. According to the Ponsfordian, a collection of historical data dealing with the pioneer days of Ponsford: "Its construction consisted merely of hewing down the bare width of an ox-cart any obstructing trees and in a 'zig-zag' beeline along the line of least resistance." Improvements to the trail took place in 1961 when the surface was upgraded and graveled, and in 1970 when it was black-topped. As with most roads in northern Minnesota, winter use involves the occasional application of a salt-sand mixture to ice on the curves, hills, and intersections. This activity may be of some consequence to the chemistry of Green Water Lake (see Physical Resources).

Several wide trails also meander through the preserve (Fig. 2). Some of the trails began as hunting and fishing paths that were used by the Indians during the early 1900's while other trails began as logging roads. Portions of this trail network are currently included as part of the Winter Wonderland Snowmobile Trail (Fig. 2). This grant-in-aid trail was established through the property in 1975. Jurisdiction and maintenance of the twelve foot wide path is the responsibility of Becker County, with financial assistance provided by the Department of Natural Resources.

The numerous roads and trails within the natural area make it difficult to control access to the property. Two previous attempts were made. In 1967 Dr. Fox installed four gates along several trails that headed south from Hwy #35. Within a short time, however, all four were torn down by vandals. Several years later, Becker County installed a new gate at the northernmost access in order to control snowmobile traffic. The gate was again vandalized and only the gate posts remain.

The remains of seven buildings are another sign of man's presence on the natural area (Fig. 2). Three of the structures can be traced to Art Alexander, a tenant on the property for several years during the 1930's. Mr. Alexander initially resided in a cabin at the northwest end of the lake. After deserting it a few years later the cabin rotted away, leaving only the root cellar and a few scattered boards. His second residence was a small log house located east of the clearing in Section 34. A barn was also reported near the house, but again, both structures have rotted away. Finally, on the southeast end of the lake, are the remains of a small shack from which Mr. Alexander operated a small boat rental business.

The other three buildings on the tract appear to have been the property of three different owners. The first was a cabin located on a hill just west of the lake, in the southern half of the site. The building reportedly fell down before 1938; its owner and the date of construction are unknown. In 1938 Carl and Clarence Smith, owners of portions of the north half of the tract, placed a house immediately north of Hwy #35. They lived there for 18 years before moving the house to Ponsford in 1956. Planted lilac bushes and a root cellar mark the former location of the house. The third building, a hunting shack, was situated at the south end of the lake. Built before 1936, the cabin was used regularly up until 1978 when it fell down, leaving behind a large pile of debris.

Perhaps the most visible alteration to the Green Water Lake tract during the past 80 years has been the harvest and planting of trees. In the early 1900's the entire region around the preserve was logged. Between 1907 and 1918 timber deeds and contracts were given to the Nichols-Chisholm Lumber Company for all parcels on the natural area except for the N1/2 NE1/4 and the E1/2 SE1/4 of Section 33 and the E1/2 SW1/4 of Section 34 (Fig. 2). Pines were the primary trees harvested. Following this major logging operation further activity appears to have been limited. Prior to Dr. Fox's acquisition of the property the only harvesting that could be documented occurred during the 1930's and 1940's when small areas of aspen and pine in the north half of the tract were logged out by Carl and Clarence Smith.

During the 1960's, Dr. Fox devoted considerable attention to timber management of the property. The planting and harvesting activities that took place were done largely on the advice of Norman O. Zauche, then the District Forester at the Smokey Hills Ranger Station in Osage.[1] Dr. Fox also sought some assistance from the American Forestry Institute, a private timber industry organization. In 1964, 200 hectares were certified by the Institute for inclusion in the American Tree Farm System. This meant that Dr. Fox could receive free technical assistance from the Institute for that portion of the acreage.

1 A copy of the forest management plan compiled by Mr. Zauche is on file with the Scientific and Natural Areas Program.

In accordance with the management plan developed by Mr. Zauche in 1963, the tract was selectively logged and planted over a period of approximately four years. The first planting was done in the spring of 1964, when 4000 red pine and 3000 white pine seedlings were planted at the northwest end of the lake. The two hectares planted are delineated in Figure 2. Most of the planting was done by machine, which accounts for the large furrows that are still visible in this area.

In the fall of 1964, a small area of jack pine near the northwest end of the lake was clearcut. The cutting took place because the site appeared to be losing more timber to porcupine and wind damage than it was gaining through annual growth. Approximately sixty cords of pulpwood were subsequently sold. The following spring, various pines that were considered overmature were selectively logged from throughout the area.

A second major planting took place in 1965, when 3000 red pine and 1000 black spruce seedlings were hand-planted in different parts of the property. It is unclear whether or not the 1965 planting was the most recent one to take place on the tract. Plans were made for the spot-planting of 1000 red pine and 1000 white spruce seedlings in 1968, but the plans may never have been implemented.

Agricultural activities on the Green Water Lake preserve have been limited, confined primarily to the eighteen year period between 1938 and 1956 when Carl and Clarence Smith resided on the property. The Smiths grazed approximately 200 sheep and several horses and cows near the northwest end of the lake. Although the remains are no longer visible, a wire fence was erected to enclose about 160 acres for the grazing animals. It enclosed the clearing by the lake as well as much of the surrounding woods. During the dry years of the late 1930's and early 1940's, several of the sloughs on the tract were hayed to provide additional feed for the livestock. Two small areas near the Smith's house were also cultivated and used as private gardens. The origin of the two clearings on the tract, the one at the northwest end of the lake and the one directly east of the lake, is unknown but likely dates back to the early thirties when Mr. Alexander was a tenant on the property.

Human activity has altered the drainage pattern of the Green Water Lake tract in several ways. First, in 1946, the Smiths altered the course of the creek slightly. This was done to enlarge the field space at the northwest end of the lake. Second, the improvement and raising of the roadbed in 1961 created ditches that parallel both sides of the road. This action resulted in a significant alteration to the drainage basin of Green Water Lake (see Physical Resources). At the same time, a metal culvert was installed in the road to allow the creek to pass through. Finally, in 1965, a small culvert was placed in the trail near the northwest side of the lake to allow easier travel across a low area of the trail during a timber project.

Fire is usually an important aspect of any tract's history. It has been difficult, however, to document the occurrence of fires on the preserve. The only fire that any of the local residents could recall was in 1966 or 1967 when a small fire was started by a camper on the northeast side of the lake (Fig. 2.). The fire was confined to the ground and minimal damage occurred. Small areas of burned trees that are scattered throughout the tract suggest that small isolated fires also have occurred around the lake over the past years, perhaps the result of lightning strikes.

Several other land use activities have occurred on the natural area. Commercial activities have included maple sugar harvesting in an area south of the lake, animal trapping, primarily for beaver, and the installation of an undergound telephone line in the ditch along the north side of the highway. Recreational activities have included boating, swimming, fishing, hiking, camping, snowmobiling, as well as grouse, bear, and deer hunting. These activities have had little influence on the physical aspects of the Green Water Lake natural area. Nevertheless, many of the other activities discussed above, including logging, road and trail construction and timber planting, have had an impact on the site. The nature and extent of these impacts to the soils, water resources and vegetation of the preserve will be discussed in the following sections.

PHYSICAL RESOURCES

OVERVIEW

The physical resources of the study area have been broken down into separate sections on geology, soils, climate and water resources. Geology, generally referring to the study of the earth, forms the first section. It has been further subdivided into separate parts on stratigraphy and geomorphology. The former discusses the various geologic units underlying the tract, while the latter explains the topographic features of the area. The second major part of the report is devoted to soils. Simply defined, soil is the weathered surface of the earth and essentially represents a transition from the geological to the biological realms of any area. Climate, the third main subdivision, relates to the long-term atmospheric characteristics of an area: principally temperature, precipitation and evapotranspiration. The final section, on water resources, discusses soil moisture, groundwater and surface water features, as well as seasonal variations in the water budget of the tract. In the discussion of these physical resources, particularly of geology, attention is given to historical as well as to purely descriptive aspects. A historial view not only aids understanding of the area, but also helps to identify unique physical features.

GEOLOGY

INTRODUCTION

The Green Water Lake property occupies an area of glacial deposits and has an undulating to very steep topography. This landscape is characterized by small peat-filled depressions, many of which are scattered throughout the site. Green Water Lake itself covers the central portion of the property. The lake occupies a deep and narrow valley that once carried a large flow of glacial meltwater. Calcium carbonate deposits have accumulated around much of the shoreline. These deposits are apparently related to the characteristics of the lake water (see Lake Resources Section).

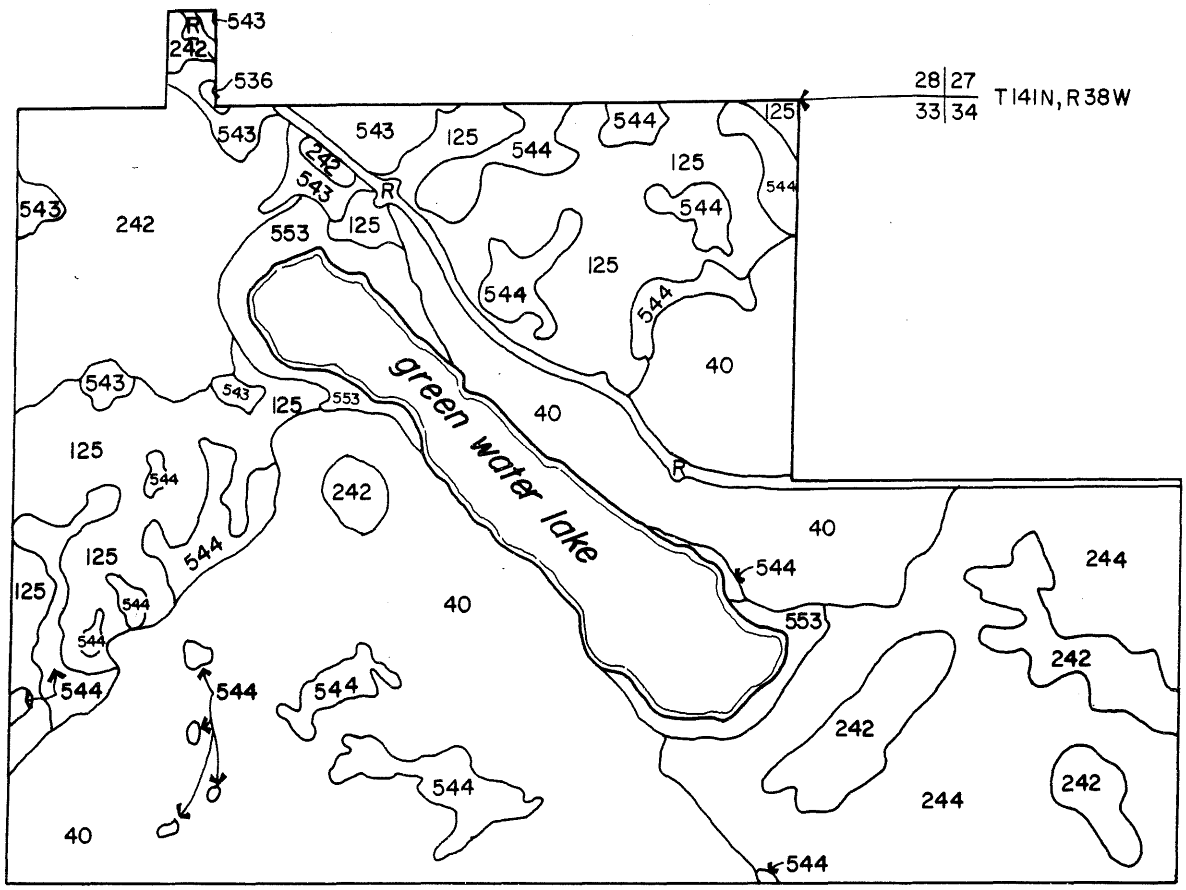
STRATIGRAPHY

Bedrock is encountered beneath the land surface of the Green Water Lake tract at a depth of 90 to 120 meters. Composed of igneous and metamorphic rocks over 600 million years old, the bedrock has very little influence on what is visible aboveground (Winter et. al., 1969). Surface features are, instead, largely the result of the numerous glacial advances that have crossed the area during the past 60,000 years. These glaciers left a series of alternating layers of till (laid down directly by glacial ice), glacial meltwater deposits and lake sediments. The most recent ice advance took place about 20,000 years ago when the St. Croix Phase of the Wadena Lobe of the Laurentian Ice Sheet entered the area from the northwest (Wright, 1972). This ice front appears to have stood over the Green Water Lake property for an extended period of time.

Light grey-brown till deposits left by the Wadena Lobe are found over approximately half of the land surface of the tract (Fig. 3). The composition of the till is largely silt and sand with a coarse fragment content of two to twenty percent. The source material for the deposits was the predominantely carbonate rock of northwestern Minnesota; this origin is reflected by the calcareous nature of the till (Wright, 1972).

Glacial meltwater deposits are found as the uppermost geologic unit on much of the remaining property on the tract (Fig. 3). Waters of the melting Wadena Lobe picked up large amounts of sediment in the area. These sediments were then redeposited by the glacial streams. The glacial meltwater deposits are composed of sand and some silt, and contain up to ninety percent coarse fragments, mostly cobbles. They are principally brown in color, and form thin, stratified layers over the underlying till (U.S. Dept. of Agriculture, Soil Conservation Service, 1976).

Moderately decomposed organic matter has accumulated both around Green Water Lake and in shallow depressions on the glacial deposits (Fig. 3). This mucky peat is seldom more than a meter deep over marl, sand, silt or clay. The organic accumulations around the lake, overlying the marl, have important implications for the future of the lake (see Lake Resources Section). Another type of peat accumulation, primarily little-decomposed *Sphagnum* moss, is found in a small area in the northwestern part of the site (Fig. 3).



LEGEND

TILL

40	Well Drained
125	Moderately Well Drained

GLACIAL MELTWATER DEPOSITS

242	High Sand Content/Somewhat Excessively Drained
244	Moderate Sand Content/ Excessively Drained

SHALLOW PEAT

536	<u>Sphagnum</u> Underlain by Sand/ Very Poorly Drained
543	Mucky Peat Underlain by Sand/ Very Poorly Drained
544	Mucky Peat Underlain by Silt and Clay/ Very Poorly Drained
553	Mucky Peat Underlain by Marl/ Very Poorly Drained

GRAVEL ROADFILL

R	Variably Drained

north

feet: 0, 1000, 2000

meters: 0, 500

note: see appendix I for soil series classifications

Figure 3

Surficial Geology and Soils of the Green Water Lake Natural Area

The remains of aquatic organisms contribute to the significant organic content of the deep water lake sediments, as well as to the sediments along the lakeshore. Inorganic detrital sediments, especially clay, also fill much of the lake basin (Fig. 4). These sediments have filled in the shallow areas on Green Water Lake's northwestern and southeastern ends that were once open water (Fig. 3). The depth of accumulated lake sediments has not been measured, but may extend ten meters or more beneath the floor of the lake. Among the deposits are silica-impregnated cell walls of diatom algae, which have been sampled and identified from one site on the lake bottom (see Appendix III).

Chemical reactions in the lake water have caused calcium carbonate to precipitate over much of the detrital lake sediments (see Lake Resources Section). These deposits, known as marl, are limited to the shallow water zones and adjacent lakeshore. Although primarily composed of calcium carbonate, marl also contains some magnesium carbonate, clay sediments and organic matter. A composite sample taken at Green Water Lake contained 46.60 percent calcium carbonate (Thiel, 1933). Grey in color and up to two meters thick, the marl deposits are most extensive on the northwestern and southwestern ends of the lake. Their areal extent has been roughly estimated on Figures 3 and 4. The presence of marl on the Green Water Lake tract is significant, but is not unique from either a statewide or a county-wide perspective. At least 300 other sites in the state and twelve other sites in the county have reported such deposits (Thiel, 1933).

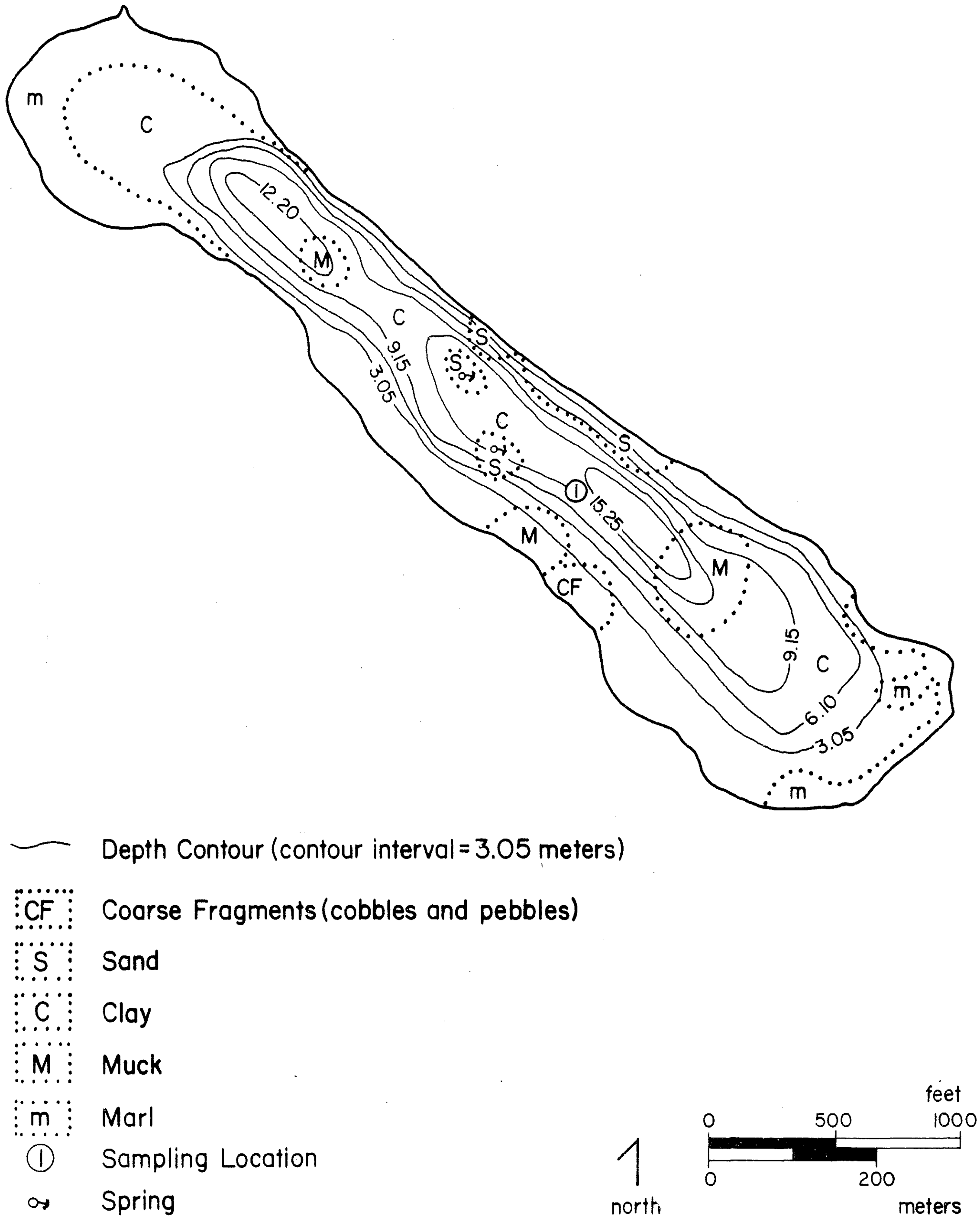


Figure 4

Sediment and Depth Contours of Green Water Lake (modified from Minnesota Department of Natural Resources, Division of Game and Fish, Bur. of Fisheries Research, 1967, with information from Hogan, 1980)

GEOMORPHOLOGY

The total relief of the Green Water Lake property is approximately 27 meters. The lowest point on the tract is found where a small stream exits the north boundary of the site; the highest elevation is found on a hilltop near the southwestern corner of the property (Fig. 5). Green Water Lake, 31.2 hectares in area, is located in a long and narrow depression in the center of the tract. This depression cuts across a high ridge of till, and seems to have been formed by meltwaters flowing beneath the ice sheet. Four somewhat distinct landforms surround the lake. The most obvious of these is the till ridge, which runs in a northeast/southwest direction across the center of the property and which is abruptly interrupted by the lake. A rather subdued topography east of the lake indicates the second landform, a transition zone between the till ridge and the Park Rapids Outwash Plain. The third landform is the hill of sandy meltwater deposits located just west of the lake, and the fourth landform is a rolling area dominated by bogs located between the sandy hill and the till ridge north of the lake. Minor human alterations of these glacial features occurred when road construction, tree planting, and building excavation took place on the tract. Post-glacial stream erosion, however, has not acted long enough to extensively alter the glacial landforms. As a result, the drainage pattern of the site is poorly developed. Drainage out of the lake passes through a small stream that has been affected by both human alteration and recently built beaver dams. The drainage basin of Green Water Lake borders on the continental divide; it was changed significantly by the construction of County Highway #35. All these geomorphologic features are discussed in more detail in the following paragraphs.

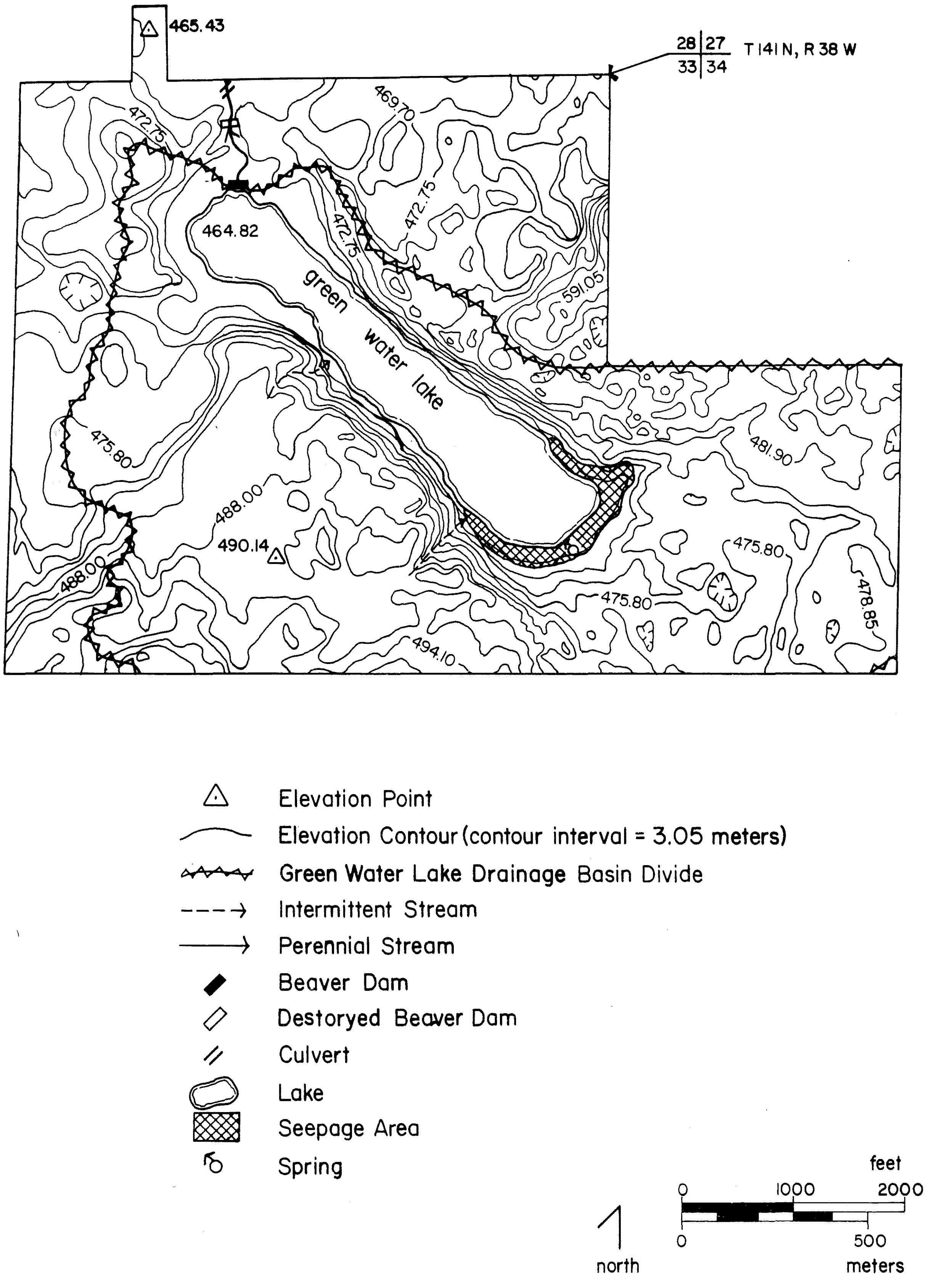


Figure 5

Geomorphology of the Green Water Lake Natural Area

The most prominent of the four major landforms on the propery, the till ridge, is associated with a regional feature known as the Itasca Moraine Complex. The Green Water Lake property is located near the western end of the moraine complex, which extends about 75 km eastward to near Walker, Minnesota. The Itasca Moraine marks the southern limit of advance for the St. Croix Phase of the Wadena Ice Lobe (Wright, 1972). In the immediate area of Green Water Lake, the ice sheet entered from the northwest and stopped near the eastern edge of the lake. The till ridge that is formed is called a terminal moraine, and crosses the middle of the site from the northeast to the southwest. This ridge, which contains scattered peat bogs, is generally represented by the well-drained till deposits shown in Figure 3. The terminal moraine ranges from 480 to 500 meters elevation above sea level, and contains the highest parts of the tract (Fig. 5).

Green Water Lake occupies a deep trough that cuts across the terminal moraine. Very steep bluffs drop down twenty meters on both the northeastern and southwestern shores of the lake (Fig. 5). They continue down steeply to the deepest part of the trough, at the center of the lake. Here, Green Water Lake has a maximum depth of over fifteen meters (Fig. 4). This trough is one of many glacial meltwater channels that cross the Itasca Moraine and may qualify as a tunnel valley (Wright, 1972). Tunnel valleys were eroded by streams of meltwater flowing beneath sheets of glacial ice. On the Green Water Lake property, the present-day lake trough once carried meltwaters from the northwest, perhaps beneath an ice mass that was positioned along the terminal moraine. After most of the ice in the area had melted, one or more large ice blocks may have been left stranded in the valley, possibly preventing meltwater sediments from completely filling it in (Leverett, 1932).

Several kilometers east of both Green Water Lake and the terminal moraine is the Park Rapids Outwash Plain, a broad and relatively level area formed by coalescing streams of glacial meltwater. The second major landform on the tract, located east of the lake, seems to represent a transition between the steep terminal moraine discussed above and the level outwash plain. The glacial stream which once drained eastward through the above-mentioned trough may have left blocks of ice stranded in this area of transition to the outwash plain. The iceblocks melted and left several shallow depressions in the easternmost part of the site (Fig. 5).

Near the northwestern end of Green Water Lake the glacial meltwaters formed a 125-meter high hill of sandy and pebbly sediments (Fig. 4), the third principal landform of the study area. This feature is probably a kame, which was deposited by meltwater in contact with either the ice sheet or a spearate, large block of ice. It is unclear exactly why the kame is located at the upper end of the glacial tunnel valley.

Finally, between the kame and the terminal moraine north of the lake, is an area of ground moraine that is characterized by a gently rolling topography (Fig. 5). Ground moraine indicates an area of till that has no prominent ridges, as opposed to a terminal or other type of marginal moraine. The topography of this ground moraine area is irregular, and is marked by shallow depressions known as kettles. The ground moraine together with the above-mentioned kame represent what is known as kame-and-kettle topography.

Several human activities have brought minor modifications to these glacial landforms. Such activities have included building excavation, tree-planting, and road construction (see Land Use History Section). Building construction in the 1950's east of the lake left both a large and a small excavation pit in what is now a cleared field. Tree-planting, which took place near the north-western end of the lake in 1964 involved the digging of several long and .5-meter furrows in that area. The grading of County Highway #35 in 1961, represents another significant human impact. This gravel-filled roadway, which crosses the tract just north of the lake, was later black-topped in 1970. It is about thirty meters wide, with one-meter deep ditches on each side of the road.

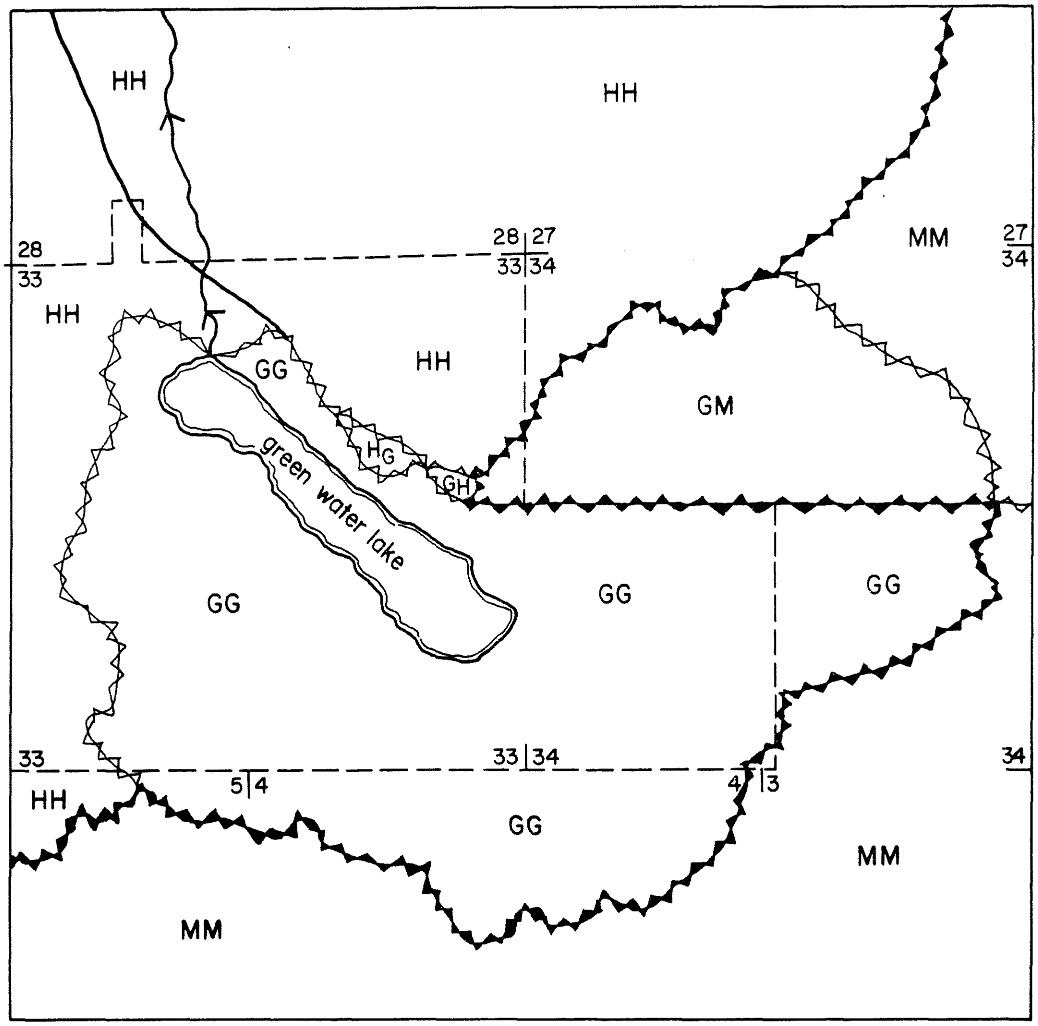
Due to the recent glacial history of the area, a well formed drainage pattern has not yet emerged. There are only four notable drainageways on the land included in the drainage basin of the lake. Two are intermittent streams found on the bluff on the southwestern side of the lake. Another intermittent stream enters the easternmost end of the lake. The fourth drainageway is the south roadside ditch of the highway (Fig. 5).

The only perennial stream on the site is the small creek that drains out of the northwestern end of the lake. This creek is about one meter wide and .2 meters deep at baseflow. Its bed material is largely of fine sediments. Although a short portion of the stream was channelized (see Land Use History Section), it does not flow very rapidly. The creek passes through a one-meter diameter metal culvert beneath the highway. Beavers have been quite active along this stream and two relataively recent dams have been built on it. The first of the dams, destroyed by a road crew in 1973, was near Highway #35

(Fig. 5). It stood at least 1.5 meters high, and created a small, shallow pond between the highway and Green Water Lake. After this dam was destroyed a smaller dam, one-meter high, was built at the point where the creek leaves the lake (Fig. 5). This newer dam caused the lake level to rise between .5 and .75 meters, killing a small ring of trees along the shoreline.

The creek that drains the lake is in drainage basin 56097 (Minn. Dept. of Nat. Res, Div. of Waters, Watershed Mapping Project, 1980), which flows to Ice Cracking Lake, thence to the Otter Tail River and evenutally to Hudson Bay. The east and south boundaries of this drainage basin are represented by the continental divide (Fig. 6). Waters on the other side of the divide flow in drainage basin 12063 to Shell Lake, thence to the Shell River and eventually to the Gulf of Mexico.

The drainage basin history of Green Water Lake is somewhat complicated, as illustrated in Figure 6. Prior to 1961, an eighty-hectare piece of land (labelled GM) north of County Highway #35 drained southward and then westward into the lake. In 1961, the grading of the road significantly altered the drainage basin. The north roadside ditch diverted surface runoff from the eighty-hectare section east, away from the lake; on the other side of the continental divide it cut off a much smaller, 1.0-hectare, section of land (labelled GH) from the lake's drainage basin. The south roadside ditch at the same time captured surface runoff from another, 2.6-hectare, parcel of land (labelled HG) that used to drain away from the lake. This parcel now is within the drainage basin of Green Water Lake. The net result of the road construction was a reduction by 28 percent in the size of the drainage basin and a westward shift of part of the continental divide. At present, 68.2 percent of the 287-hectare drainage basin of the lake lies within the tract.



LEGEND

- Boundary of Green Water Lake Tract
- Drainage Divide
- Present Continental Divide
- County Highway 35, originally graded in 1961
- Lake
- Creek to Ice Cracking Lake

GG	To Hudson Bay via Green Water Lake, before and after 1961
GH	To Hudson Bay via Green Water Lake, before 1961; to Hudson Bay not via Green Water Lake, after 1961
HG	To Hudson Bay not via Green Water Lake, before 1961; to Hudson Bay via Green Water Lake, after 1961
HH	To Hudson Bay not via Green Water Lake, before and after 1961
GM	To Hudson Bay via Green Water Lake, before 1961; to the Gulf of Mexico, after 1961
MM	To the Gulf of Mexico, before and after 1961

north

feet: 0 1000 2000 3000

meters: 0 500 1000

Figure 6

Drainage Basin Divides in the Area of Green Water Lake. Parts of T 140 N, R 38 W and T 141 N, R 38 W

SOILS

The soils of the Green Water Lake tract are not highly developed. Due to the cold climate and the tundra environment near the glaciers, soil development was very slow until the final retreat of the ice about 11,500 years ago. The tundra was first followed by a spruce forest, then later by pines and northern hardwoods (Wright, 1972). In the post-tundra environment soil development has accelerated, but the role of parent material in determining soil type is still predominant. The soils of the site are best described in terms of till-, meltwater sediment-, and peat-derived soils, which correspond to the surficial geology (Fig. 3).

The soils derived from till and glacial meltwater deposits (Fig. 3) are medium to slightly acidic in their upper horizons and become alkaline at depth. The greater alkalinity with depth indicates the downward movement of carbonates in the soil. Other soluble ions, such as calcium, magnesium, sodium, potassium, sulfate and chloride, are also extensively leached.

The solum, or principal zone of active soil-forming processes, is from .5 to 1 meter deep in the soils developed from glacial deposits. The solum is divided into an upper horizon that has been leached and a lower horizon where some of the leached materials have been redeposited. Clay particles and some iron, in addition to soluble salts, are among those materials leached from the upper layer. Much of the leached clay and iron has been redeposited in the lower part of the solum. Below the solum the weathering processes have been largely non-biological (DeMartelaere, 1975).

Texture and color vary somewhat between the till- and glacial meltwater-derived soils. In the till-derived soils (Fig. 3), the texture in the upper solum is that of a sandy loam. The lower solum, due to clay accumulation, is a sandy clay loam. Below the solum the texture is loamy. The upper solum is very dark grey because of the incorporation of organic matter. Colors change to brown in the lower soil horizons and then to light grey-brown in the underlying parent material (DeMartelaere, 1975).

The meltwater-derived soils have a similar sandy loam to loamy sand texture in the upper solum, but become coarser with depth than do the till-derived soils. The former type of soils can be divided into those with high versus those with moderate sand contents (Fig. 3), and can be further distinguished by loamy sand versus coarse sand textures at depth. All glacial meltwater-derived soils on the property have a low to moderate fraction of gravel. Their color is dark grey-brown in the upper solum, shifting to dark yellowish-brown and then brown with increasing depth (DeMartelaere, 1975).

The peat-derived soils on the property (Fig. 3) consist of shallow layers of mostly highly decomposed organic matter. This peat overlies marl and inorganic sediments ranging from gravelly coarse sand to silty clay loam in texture. Most of the peat has a neutral soil reaction, which shifts to mildly alkaline in the underlying inorganic layers. The peat is black, although the color changes to dark grey with an increasing content of inorganic sand, silt and clay (De Martelaere, 1975).

Ash from forest fires is not evident in most of the soils of the tract. A thin layer of ash may be found between Green Water Lake and Highway #35, since a small fire occurred in this area in the late 1960's.

Several human disturbances have affected the soils of the Green Water Lake tract. Most significant was the grading of the highway, whose roadsides ditches have practically no soil development (Fig. 3). On the north and northwestern ends of the lake, the construction of two houses and the digging of trenches for tree-planting have disturbed the soil. Soils also have been affected by clearing and building construction in the field east of the lake (see Land Use History Section).

CLIMATE

The Green Water Lake site has a typical moist continental climate with wide seasonal temperature extremes. Average daily maximum and minimum temperatures in January are -9^{o}C. and -22^{o} C., respectively; in July they are 27^{o} C. and 14^{o} C. The average date of the last spring frost is 26 May, and the average earliest fall frost is 19 September (Univ. of Minn., Agricultural Experiment Station, 1969).

The average annual precipitation on the area is 640 mm. About fifteen to twenty percent of this amount comes as snowfall from November through March. Precipitation, in the form of rainfall, usually increases in the spring to peak in June. Much of the summer rainfall results from heavy thunderstorms. Precipitation commonly decreases in the fall (Winter _et_. _al_., 1969).

The average annual evapotranspiration in the area is estimated at 587 mm. Evapotranspiration rates increase rapidly in the spring from a winter level near zero, and normally peak in July. Like precipitation, evapotranspiration diminishes in the fall (Winter _et_. _al_., 1969).

WATER RESOURCES

NON-LAKE RESOURCES

Rainfall and snowmelt infiltrate and percolate through the various soils of the Green Water Lake property at different rates. The soils derived from glacial meltwater deposits have high infiltration rates, rapid permeability and are somewhat excessively to excessively drained (Fig. 3). The till-derived soils allow water to infiltrate at moderate to slow rates, have moderate to moderately slow permeability and are moderately well to well drained (Fig. 3). On the glacial deposits, water commonly percolates down to a depth of over three meters, below which is located the average annual high water table (DeMartelaere, 1975).

The mucky peat of the shallow kettles and the lakeshore has moderate to moderately slow permeability. Nevertheless, these areas have very slow infiltration rates and are very poorly drained (Fig. 3). The average annual high water table is frequently at the ground surface (DeMartelaere, 1975).

Groundwater in most of the tract moves toward Green Water Lake. The recharge area of groundwater moving toward the lake is substantially larger than the area of the lake's surface drainage basin. A very rough estimate on the size of the former is 700 hectares, compared to a surface drainage area of 287 hectares. The groundwater recharge area is oblong in shape, and extends from the lake about 3.5 km to the northeast, .25 km to the northwest, 2.0 km to the southwest and .5 km to the southeast. The water quality of the lake must be considered in terms of any pollutants that might contaminate groundwater in this 700 hectare area. No significant source of groundwater contamination is presently known.

The water table gradient on the bluffs bordering the lake is steep (Fig. 7), largely due to the moderately permeable till (Winter et al., 1969). Groundwater enters Green Water Lake in a zone that completely encircles the lake. This seepage is most obvious on the southeastern shore of the lake, where a small spring is also located (Fig. 5). Water also seeps into deep zones of the lake (Fig. 7), where two or more springs are believed to exist (Fig. 4). The groundwater discharge maintains the lake at a rather stable level, which in turn sustains the outlet creek at a relatively constant flow.

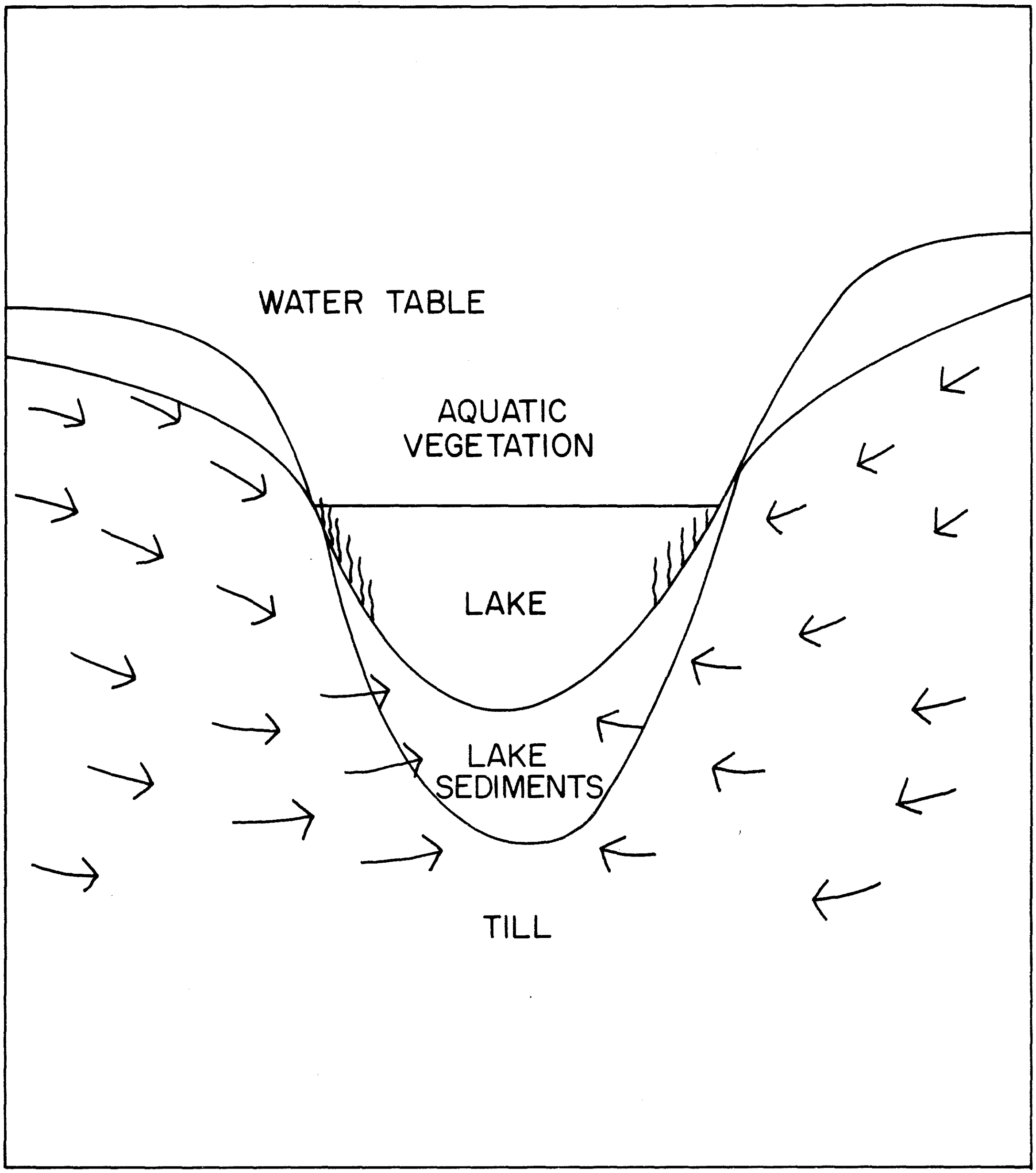


Figure 7

Cross-Section of Typical Lake on Hilly Glacial Moraine, illustrating ground-water flow (modified from Winter et al., 1969).

The annual water budget shows a period of moisture accumulation from October to April. Most of this water is stored aboveground as snow and ice; an average of sixty days annually have more than .15 meters of snow cover. From late November until mid-April the soil is typically frozen, preventing groundwater recharge and leading to a slight decline in the water table during late winter. Snowmelt, thawing, and substantial rainfall in April and May recharge soil moisture and groundwater, and increase surface runoff. In the spring, water usually accumulates in the very poorly drained areas and drainageways (Figs. 3 and 5). Except when rainfalls are excessive, water levels gradually recede through the summer. Reduced evapotranspiration rates in the fall eliminate the moisture deficit of late summer. Water levels increase at this time, but not to the extent observed in the spring (Winter et. all, 1969).

LAKE RESOURCES

Green Water Lake (numbered 3-134 in the DNR Division of Waters classification system) is the principal hydrological feature on the natural area. Because several studies were conducted on the lake during the summers of 1976 and 1980, sufficient data are available upon which some conclusions can be drawn about the lake's characteristics. The 1976 tests were performed by Dr. Robert O. Megard of the University of Minnesota and several staff members of the Freshwater Biological Research Foundation. During the first study, in May 1976, the Foundation took total phosphorus, chlorophyll-a and bacterial count readings (Freshwater Biological Research Foundation, 1976). In August of the same year, pH, chlorophyll-a and oxygen concentrations were measured (Megard, Crawford and Taylor, 1976). Four years later, as part of the SNA inventory, several more tests were carried out. These comprised two sets of chemical analyses (Collins, 1980a and Minn. Poll. Control Agency, Div. of Water Quality, 1980a), a study of surface mud diatoms (Patterson, 1980), readings on the reflection and transmission of incident surface light (Collins, 1980a) and a series of Secchi disc readings. The site of the 1980 sampling is shown in Figure 4. All of these studies are cited throughout this section of the report.

Before discussing some of the various analytical results, it is convenient to give an overview of the nature of Green Water Lake. The groundwater that supplies the lake is the source for the calcium carbonate precipitated in its shallow water zone. This process has helped to create a hardwater marl lake, where the term hardwater refers to the rather high concentrations of calcium and magnesium salts. Most of these salts are probably in the form of calcium carbonate and calcium bicarbonate. Such lakes, according to Wetzel (1975), represent a condition of low photosyntehtic productivity "in which calcareous inputs are sustained over long periods of time. In these waters, reduced productivity is maintained by decreased nutrient availability" (p. 645). A restricted availability of phosphorus may be principally responsible for reduced productivity, although other minor nutrients could also be involved. The level of organic (i.e., photosynthetic) productivity in Green Water Lake would probably qualify it as "mesotrophic," a term that is intermediate between the highly productive "eutrophic" and the less productive "oligotrophic" (Affeldt, 1981 and Megard, 1980).

Green Water Lake is supplied with water from both surface runoff and groundwater discharge. Surface runoff as a source of inflow is significant only during spring snowmelt and heavy rainfalls. Most of the lake water is received from seepage and springs around and beneath the lake (see Non-Lake Resources Section). As mentioned above, this source of inflow is fairly constant throughout the year.

The groundwater that enters the lake generally has a rather high concentration of calcium bicarbonate. This content primarily results from two chemical reactions in the soil moisture and groundwater zones. In the first of these reactions, groundwater percolating through the soil reacts with carbon dioxide in a process known as carbonation. The carbonic acid thus formed then reacts with some of the calcium carbonate of the glacial deposits to make calcium bicarbonate (Thiel, 1933).

When the groundwater enters the shallow water zone of Green Water Lake, another reaction occurs by which some of the calcium bicarbonate is converted to calcium carbonate, carbon dioxide and water. The calcium carbonate precipitates out as marl (Thiel, 1933). In discussing the formation of marl, Wetzel (1975) notes, "While precipitation of calcium carbonate can be induced by many physical and biotic agents (increasing temperature, bacterial metabolism), photosynthetic utilization of carbon dioxide by algae and submerged macrophytes is by far the dominant mechanism" (p. 176). Since photosynthesis principally occurs in the summer, that is the season in which most of the marl in Green Water Lake is formed. Although many of the aquatic plants of the lake are involved in the process of marl precipitation, one type of macroalgae, the Characeae, seems to be very important (Thiel, 1933). Chara are found "all along the shoreline" of the lake, and most are encrusted with calcium carbonate deposits (Hogan, 1980).

Like many other undisturbed hardwater marl lakes in the region, Green Water Lake has low levels of photosynthetic productivity. A water sample from August 1976 revealed concentrations of chlorophyll-a ranging from 1.07 micrograms per liter at the surface to 2.13 micrograms per liter at nine meters depth (Megard et al., 1976). These readings of chlorophyll-a, which is indicative of the population density of algae, are "very low" (Megard, 1980). A low count of bacteria (1500 per milliliter) taken at the lake in May 1976 indicates low organic productivity in general (Freshwater Biological Research Foundation, 1976). Additional evidence of the productive level of the lake is its rather high dissolved oxygen content (Table 1).

The reflection and transmission of light (Table 2) and transparency (Table 3) of the lake water also indicate low productivity. The percentage of light reflected from a particular depth in Green Water Lake is less than the percentage of light reflected from the same depth in most other lakes. This comparison points to a rather low concentration of suspended particulate matter in Green Water Lake. The final three columns of Table 2 compare percentage transmission of surface light with depth for Green Water Lake and two lakes of southwestern Michigan--unproductive Lawrence Lake and highly productive Wintergreen Lake. While Green Water Lake does not transmit quite as much light as less productive Lawrence Lake, its values are similar. The light attenuation coefficient, which expresses the rate at which light intensity decreases with depth, has been calculated at .272 per meter for the uppermost eight meters of Green Water Lake (Megard *et al*., 1976). According to Megard (1980), this value is low and indicates that the lake is "very transparent." A decrease in light intensity with depth is largely due to absorption and scattering by algae and bacteria (Wetzel, 1975); high transmission values such as those at Green Water Lake thus point to low algal and bacterial populations.

Table 1. Chemical Analyses (data not in parentheses adapted from Megard et al. (1976) on 7 August 1976; data in parentheses adapted from Collins (1980a) in July 1980.

Depth (Meters)	0	2	3	4	5	6	7	8	9	10	12	14	16
O_2(mg/l)	7.60	(9.5)	8.35	(9.5)	8.37	(8.5)	7.90	5.30 (5.4)	4.20	.22 (2.8)	.05 (1.9)	0 (0)	(0)
CO_2(mg/l)	-	(0)	-	(0)	-	(0)	-	(15.3)	-	(20.6)	-	(26.0)	-
HCO_3(mg/l)	-	(212.0)	-	(210.0)	-	(215.0)	-	(237.0)	-	(271.0)	-	(285.0)	-
CO_3^{--}(mg/l)	-	(7.0)	-	(6.0)	-	(0)	-	(0)	-	(0)	-	(0)	-
NO_3^{--}(mg/l)	-	(0)	-	(0)	-	(2)	-	(0)	-	(0)	-	(2)	-
NO_2^{-}(mg/l)	-	(0)	-	(.001)	-	(.01)	-	(0)	-	(.002)	-	(.015)	-
NH_3(mg/l)	-	(0)	-	(0)	-	(0)	-	(0)	-	(0)	-	(0)	-
H_2S(mg/l)	-	(0)	-	(0)	-	(0)	-	(0)	-	(0)	-	(0)	-
SO_4(mg/l)	-	(0)	-	(0)	-	(0)	-	(0)	-	(0)	-	(0)	-
PO_4(mg/l)	-	(0)	-	(.25)	-	(.11)	-	(.23)	-	(.21)	-	(1)	-
Fe(mg/l)	-	(0)	-	(0)	-	(0)	-	(0)	-	(0)	-	(0)	-
Salinity(mg/l)	-	(210)	-	(210)	-	(210)	-	(210)	-	(200)	-	(220)	-
Turbidity(mg/l)	-	(0)	-	(0)	-	(0)	-	(0)	-	(0)	-	(2)	-
pH	7.8 (7.1	7.9	(7.2)	8.0	(7.1)	8.1	(7.5)	8.1	(7.5)	8.1	(7.4)	(7.6)	(7.15

Table 2. PCA Chemical Analyses (data from Minn. Pollution Control Agency, Division of Water Quality, 1980a).

Date	Color (Pt-color units)	Total P (mg/1)	Total Kjeldahl N (mg/1)
30 July 1080	5	.018	.63
13 August 1980	5	.020	.52
2 September 1980	5	.024	.54

Table 3. Percentage Reflection and Transmission of Incident Surface Light at Increasing Depth for three lakes (data for Green Water Lake adapted from Collins (1980a) on 30 July 1980; data on Lawrence and Wintergreen Lakes from Wetzel (1975) on 30 July 1968).

Depth (meters)	Green Water Lake Reflection (%)	Green Water Lake Transmission, unfiltered (%)	Lawrence Lake Transmission, unfiltered (%)	Wintergreen Lake Transmission, unfiltered (%)
0	2.4	100	100	100
1	1.8	57	48	10
2	1.4	35	35	4.0
3	.94	20	27	2.3
4	.60	12	14	1.1
5	.36	8	8	.20
6	.20	4.3	5	-
7	.067	2.0	3	-
8	.034	1.2	1.3	-
9	.025	.76	.9	-
10	.019	.34	.5	-
11	.016	.11	.35	-
12	.014	.02	.07	-
13	.014	.015	-	-
14	.014	.015	-	-
15	0	.015	-	-

Table 4. Seechi Disk Transparency.

Date	Time	Weather Conditions	Secchi Disk Transparency (meters)
18 June 1980	1015	Sunny, calm	4.11
3 July 1980	1000	Partly cloudy, breezy	3.81
30 July 1980	1400	Partly cloudy, nw winds 15-20 mph	3.00
13 August 1980	1700	Cloudy, windy, small waves	5.33
2 September 1980	1200	Partly cloudy, slight wind	6.48
16 September 1980	1300	Cloudy, windy, small waves	6.32
7 October 1980	1400	Sunny, breezy, small ripples	7.19
1980 July-August Average			4.05

Secchi disk transparency has a generally inverse relationship with both dissolved organic matter content and particulate matter content (Wetzel, 1975). The Secchi disk readings for Green Water Lake (Table 4) are high, and are further evidence of low organic productivity. The average July-August transparency for Green Water Lake (under less than ideal observation conditions) was 4.05 meters, compared to an average of 2.74 meters for 85 lakes from a surrounding nine-county region. These nine counties-Becker, Beltrami, Clearwater, Douglas, Hubbard, Itasca, Mahnomen, Ottertail and Wadena-roughly approximate the forested region of northern Minnesota that has lakes formed in grey, calcareous glacial deposits (Fig. 1). The data on these other 85 lakes may be misleading, however, since most are larger lakes with often extensive shoreline development. The summer measurements for Green Water Lake actually fall far below those of two well-known oligotrophic lakes in Becker County. These are Big Sugar Lake, with a 6.71-meter average July-August Secchi reading, and Bad Medicine Lake, with a 7.29-meter July-August average. In October, Secchi disk transparency typically rises, and Green Water Lake's October increase is no exception. Yet the fact that this last Secchi reading is more than seven meters is significant because it is unusually high for lakes in the region (Minn. Pollution Control Agency, Div. of Water Quality, 1980b).

The chlorophyll-a count, bacterial count, dissolved oxygen concentration, light reflection and transmission, and water transparency all indicate generally low organic productivity. These measurements were taken in the central part of the lake (Fig. 4), and do not necessarily reflect the extensive plant growth along the edge of the lake (see Vegetation Section).

According to Collins (1980b), the sedge mat and accumulation of organic matter that encircle the lake are unusual in relation to its low organic productivity. He stated that the conditions at Green Water Lake "are intriguing because there is so much bog development, yet the quality and clarity of the water is still high."

As already mentioned, the low organic productivity of most hardwater marl lakes is due to decreased nutrient availability. The limiting nutrient in hardwater marl lakes is commonly phosphorus. The total phosphorus data for Green Water Lake appears to be conflicting, partly due to the difficulty in obtaining good measurements. The available figures are .38 mg per liter (Freshwater Biological Research Foundation, 1976), .11 to 1.0 mg per liter (Collins, 1980a) and .018 to .024 mg per liter (Minn. Poll. Control Agency, Div. of Water Quality, 1980a). The last set of data seems most reliable, while the phosphorus supply is indeed limited, and thus may play a substantial role in maintaining the organic growth at a low level.

[2] For lakes sampled throughout Minnesota in 1978 and 1979, the median total phosphorus figure was .04 mg per liter (Affeldt, 1981).

Another possibility is that some micronutrient needed for enzymatic systems - perhaps molybdenum, copper or vanadium - might be restricted by total alkalinity levels (Hogan, 1980). Essential nutrients also "may be tied up in the sedge mat" surrounding the lake (Collins, 1980b). A third possibility is that the precipitation of marl may be removing critical nutrients from the lake water (Hogan, 1980). The precipitation of calcium carbonate commonly absorbs inorganic nuturients (Wetzel, 1975). In addition, "particulate calcium carbonate effectively adsorbs and complexes certain dissolved organic compounds. It thus reduces the direct metabolic ultilization of dissolved organics, complexing of physiologically unavailable metallic nutrients, especially iron, and suppresses microbial processes of nutrient regeneration" (Wetzel, 1970, p. 502). The observed absence of iron in Green Water Lake (Table 1) helps to implicate this process of nutrient removal.

Low levels of sodium and potassium are common in hardwater marl lakes, and may be a key factor in reduced algal growth (Wetzel, 1975). The concentrations of these ions in Green Water Lake, however, are not known. In discussing the future development of the lake, it is important to consider sodium inputs from the salting of Highway #35 (see Land Use History Section). The sedge mat around the lake provides a certain filtering effect against sodium and other possible contaminants related to use of the highway (Collins, 1980b); nevertheless, continued inputs of sodium would eventually destroy the marl balance of the lake. The principal effect of additional sodium would be to maintain more carbonate and bicarbonate ions in the lake system, which would then lead to shifts in various chemical and biological equilibria (Hogan, 1980).

Even if one ignores the possiblity of contamination from Highway #35 or from other human activity in the area (see Land Use History Section), Green Water Lake is not likely to remain a hardwater marl lake. Wetzel (1975) states, "It is apparent that numerous marl lakes have shifted relatively rapidly, in the range of a millenium, from highly calcareous, alkaline conditions to a state of very acidic, organic rich conditions, which exhibit a marked paucity of divalent cations and bicarbonate" (p. 647). The neutral to moderately alkaline lakeshore and the presence of a shoreline sedge mat may be prime indicators that Green Water Lake is gradually becoming a bog lake.

Most lakes in Minnesota, including bog lakes and marl lakes, experience a spring and a fall turnover of their water columns. These lakes are typically stratified in temperature zones during the winter and summer. Green Water Lake seems to fit this model. Its summer stratification pattern is illustrated in Figure 8. The thermocline, which is the depth at which temperature change is most rapid, is indicated for both dates of measurement.

It is possible that the deepest waters of Green Water Lake do not always undergo the spring and fall turnovers. Such a condition is known as meromixis. Both the presence of lake bottom springs and the shape of the lakebed suggest meromixis; the chemical analyses, however, provide little supporting data. Meromictic tendencies in the lake would be caused by the presence of a higher density, more saline water layer in the deepest zone. Such an increase in salinity, though minimal, is evident at the lake bottom

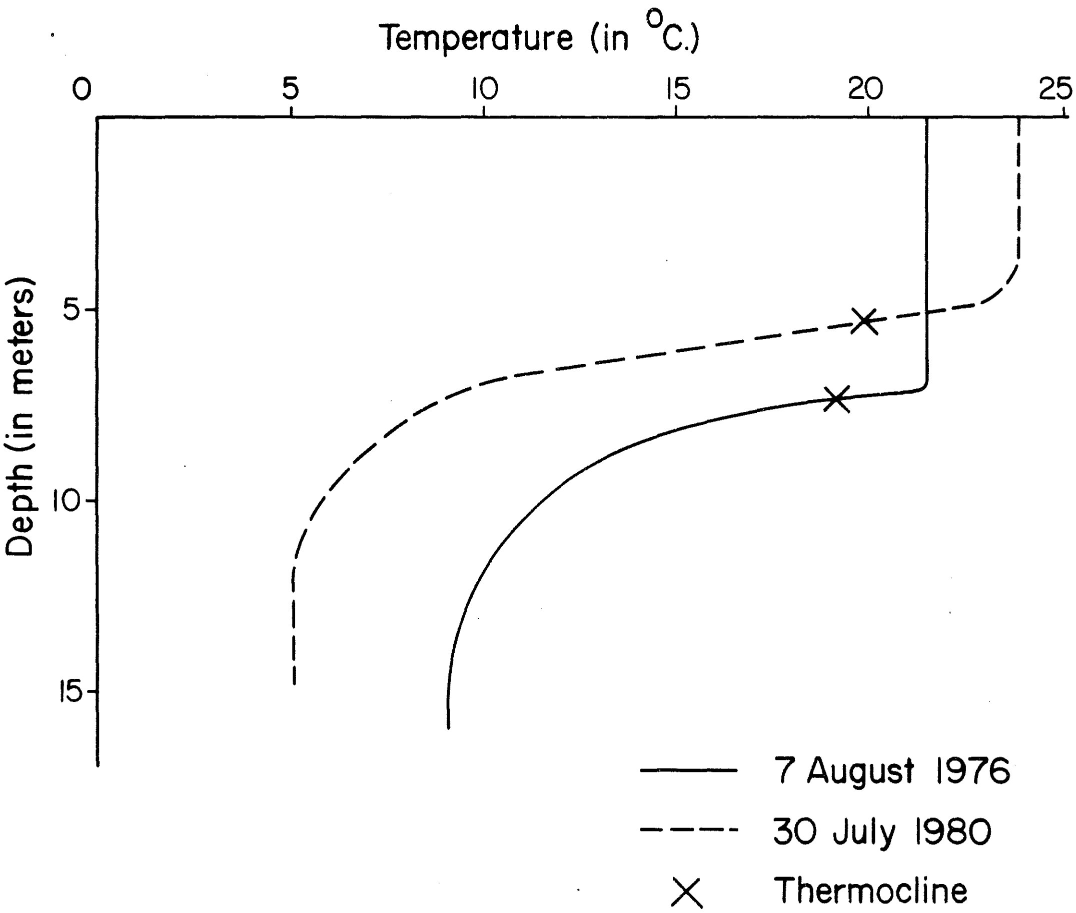


Figure 8

Water Temperature of Green Water Lake (adapted from Megard et al. (1976) and Collins (1980a)

(Table 1). An obvious source for such saline water is the hardwater springs on the lake bottom. Meromixis caused by such a process is known as crenogenic meromixis (Wetzel, 1975). The shape of the lakebed, deep and narrow, would tend to discourage water movements in this lower zone. Although these characteristics of the lake suggest meromixis, the oxygen levels in the deepest water are nevertheless "high enough to indicate a relatively good turnover" (Collins, 1980b). Also, if meromixis occurred, there should be high concentrations of iron and hydrogen sulfide, both of which are absent (Table 1).

Meromixis has been offered as one possible explanation for the results of an analysis performed on the surface mud of the lake bottom. A study of the silicified remains of diatom algae (Appendix III) revealed a very high concentration of the species *Synedra filiformis*. This species was found at a higher relative abundance in Green Water Lake than in 150 other Minnesota lakes that were also sampled for diatoms. Only eight other Minnesota lakes (two in Dakota, three in Hubbard, one in Mahnomen and two in Washington Counties) have reported a relative abundance of *S. filiformis* of more than five percent. The occurrence of *S. filiformis* has not been conclusively linked to any particular environmental conditions. Meromixis, although not well supported by other evidence, could account for the unusual diatom count (see Appendix III). Disturbance of the lake water due to human activity has also been proposed as an explanation; knowledge of the local land use history, however, seems to contradict this theory. Another possibility is that *S. filiformis* happened to be experiencing a bloom, or large population increase at the time the sample was taken (Patterson, 1980a).

It is evident that something atypical about the water chemistry and limnological properties of the lake is at lease partially responsible for the unusual results of the diatom analysis. Without the diatom evidence, Green Water Lake appears to be "rather typical" of the region's marl lakes that have been little disturbed by human development (Megard, 1980). Data on chlorophyll-a, bacterial populations, dissolved oxygen, light reflection and transmission, and water transparency all seem to indicate a low level of organic productivity that is noteworthy for the region. Most indications point to marl formation in the shallow water zone as an indirect control on organic production in the lake. One of the most important questions in assessing the significance of Green Water Lake is knowing how many other hardwater marl lakes in the region (as mapped on Fig. 1) have similarly undeveloped shorelines. Such information, however, is limited.

BIOLOGICAL RESOURCES

OVERVIEW

The description of the natural area's biological resources has been broken into two separate sections. The first section is devoted to vegetation, a major component of the site's ecosystem. Reflecting the combined influences of all the physical factors discussed earlier, the vegetation of the Green Water Lake tract provides the primary energy source for all other living organisms. The primary purpose of this portion of the report is to delineate and describe all the plant communities on the natural area as well as to identify and describe any rare or sensitive plant species. The section begins with a brief overview of the present vegetation, followed by a small discussion of the presettlement vegetation. Next, the vegetative and physical characteristics are thoroughly described for each cover type. Finally, a note is made of rare species that may occur on the natural area but which were not documented during the 1980 inventory. These species should be searched for during future field work.

The second section of the report characterizing the biological resources of the natural area describes many of the zoological components of the tract. Five groups of animals - butterflies, amphibians, reptiles, birds, and mammals - were surveyed during the 1980 inventory. Clearly, such a survey does not represent a complete inventory of all the animal species of the site. Several factors are responsible for the selectivity of the zoological studies. First, restraints of time, manpower and equipment simply precluded a study of all the animals present on the tract. Second, those animals chosen for study are those for which the most information regarding biology and distribution is available. Finally, the animals chosen include most of the more visible species. As such, these species are more easily inventoried and can serve as valuable indicator species for those organisms not studied. Following a brief introduction, the animals that were surveyed are discussed in four sections (butterflies, reptiles and amphibians, birds, and mammals). Each section describes the inventory methodology and then presents the survey results. Special attention is given to any rare or unusual species occurring on the tract.

VEGETATION

INTRODUCTION

The vegetation of the Green Water Lake Natural Area represents a wide variety of moisture conditions, ranging from the wet meadows of the shallow depressions and lakeshore, through the mesic hardwoods and xeric pine stands of the uplands. The tract also contains some small disturbed areas where the vegetation is now distinctly different from the remainder of the tract. Despite this wide range of diversity, the natural vegetation of the tract can be placed into four major cover-type categories: the Aspen - Oak - Birch communities, the Wetland communities, the Mesic Hardwood communities and the Pine communities.

The Aspen - Oak - Birch cover-type includes Trembling Aspen - Paper Birch, Trembling Aspen - Large-toothed Aspen, Paper Birch, Trembling Aspen - Bur Oak and Bur Oak communities. All five of these upland communities are considered to represent successional stages preceeding other mature forest types. Together they cover over 50% of the Green Water Lake Natural Area. The second cateogry, the Wetland cover-type, includes the following: two shrub communities, the first co-dominated by _Alnus rugosa_, _Cornus stolonifera_ and _Salix discolor_ and the second dominated by _Salix gracilis_; wet meadows dominated by sedges; and a Black Ash stand. These wetlands are confined either to the shallow depressions, scattered throughout the tract, or to the lakeshore. The third cover-type category, Mesic Hardwoods, represents the most dense and uniform forest on the Green Water tract. It consists of one well-defined Sugar Maple - Basswood - Paper Birch community located south of the lake. The final category comprises a variety of upland communities characterized by the dominance of coniferous trees. The group is represented by Jack Pine, Jack Pine - Red Pine - Paper Birch - Trembling Aspen, and Balsam Fir communities.

All the communities mentioned above are in relatively natural condition. They represent sites which, with few exceptions, have not been greatly modified by man. Two communities on the tract, however, have been disturbed and differ in many ways from these natural communities. These communities form a fifth category which will be referred to as the Disturbed Sites.

Following a brief discussion of the presettlement vegetation of the tract, as well as a review of the field methods used during the 1980 inventory, each of the communities mentioned above will be described in detail.

ORIGINAL VEGETATION

The present vegetation of the Green Water Lake Natural Area is, in part, a reflection of the human and natural modifications that have taken place since the area was originally settled. In an attempt to understand what the magnitude of these modifications may have been it is important to know how the vegetation appeared prior to settlement. Tools for reconstructing the past vegetation are available in the records of the General Land Survey office. These records, which constitute the field notes of the men who originally surveyed Minnesota during the late 1800's, provide detailed information regarding the presettlement vegetation.

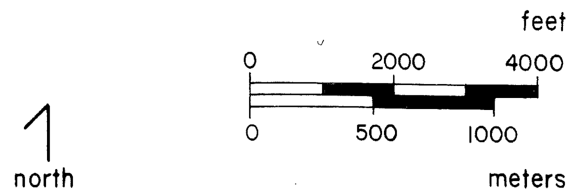
As the men surveyed each township they walked along the section lines, marking the mile and half mile intervals by recording tree species, diameter at breast height (dbh), bearing, and distance from the survey corner to the nearest tree. Theoretically, the only criteria for selecting these bearing trees was that they had to have a minimum dbh of five inches (Fedkenheurer, 1975). As the surveyors travelled through the townships they also recorded the locations of uplands, swamps, streams, roads and lakes. Although there are several problems in the use of survey notes for determining past vegetation, including fraud, bias, and species name duplication, the records remain a valuable source of information regarding the nature of the vegetation prior to settlement by European man (Fedkenheurer, 1975). The origninal survey notes for the general vicinity of the Green Water Lake tract have therefore been transcribed and plotted in Figure 9.

The transcription of the survey notes has been carried one step further by Francis J. Marschner (1930) and James Trygg (1967). Both men have used the records to develop comprehensive maps of the state's original vegetation. By examining Figure 9, as well as the maps prepared by Marschner and Trygg, a general description of the original vegetation of the Green Water Lake tract can be compiled.

Sixteen different tree species were recorded as bearing trees by the surveyors in the Green Water Lake area. Over one third of the 123 trees marked in the area encompassed by Figure 9 were pine species. White pine dominated (27%), followed by jack pine (6%) and norway pine (3%). The dominance of pine prompted Trygg to identify the entire area as the "Original Pine Lands". Although the statistics suggest that white pine was considerably more abundant than either jack or norway pine, the surveyors often tended to evaluate local timber value. This led to a bias in selecting white pines as bearing trees rather than other equally prevalent species.

Marschner's map, on the other hand, delineates four cover types in the vicinity around Green Water Lake. An area of white pine and red pine was outlined south and southwest of the lake; north and northeast of the lake aspen and birch were dominant; conifer bogs and swamps were prevalent in the tract's northwest corner, while jack pine barrens and openings characterized the northwest and southeast ends of the lake. Marschner's interpretation corresponds fairly well to the raw data in Figure 9, although pine appears to have been more numerous north and northeast of the lake than he indicated.

This brief description of the presettlement vegetation helps to provide a setting for the discussion of the present vegetation in the following pages. Clearly, though, the major change that has taken place over the years has been the virtual elimination of white pine. The once extensive stands of white pine have now been replaced by stands of aspen, birch and oak.



LEGEND

- Road
- Creek
- Lake
- Swamp
- Marsh
- Upland
- Tamarack Swamp

4	Section Numbers
a_6	Aspen 6" diameter breast height
a	Aspen
ba	Black Ash
bo	Bur Oak (*Quescus macrocarpa*)
bp	Black Pine (*Pinus banksiana*)
e	Elm (*Ulmus americana*)
f	Fir
i	Ironwood (*Ostrya virginiana*)
jp	Jack Pine
l	Linden (*Tilia americana*)
np	Norway Pine (*Pinus resinosa*)
s	Spruce
sm	Sugar Maple
t	Tamarack (*Larix laricina*)
wb	White Birch
wo	White Oak (*Quercus alba*)
wp	White Pine (*Pinus strobus*)

Figure 9

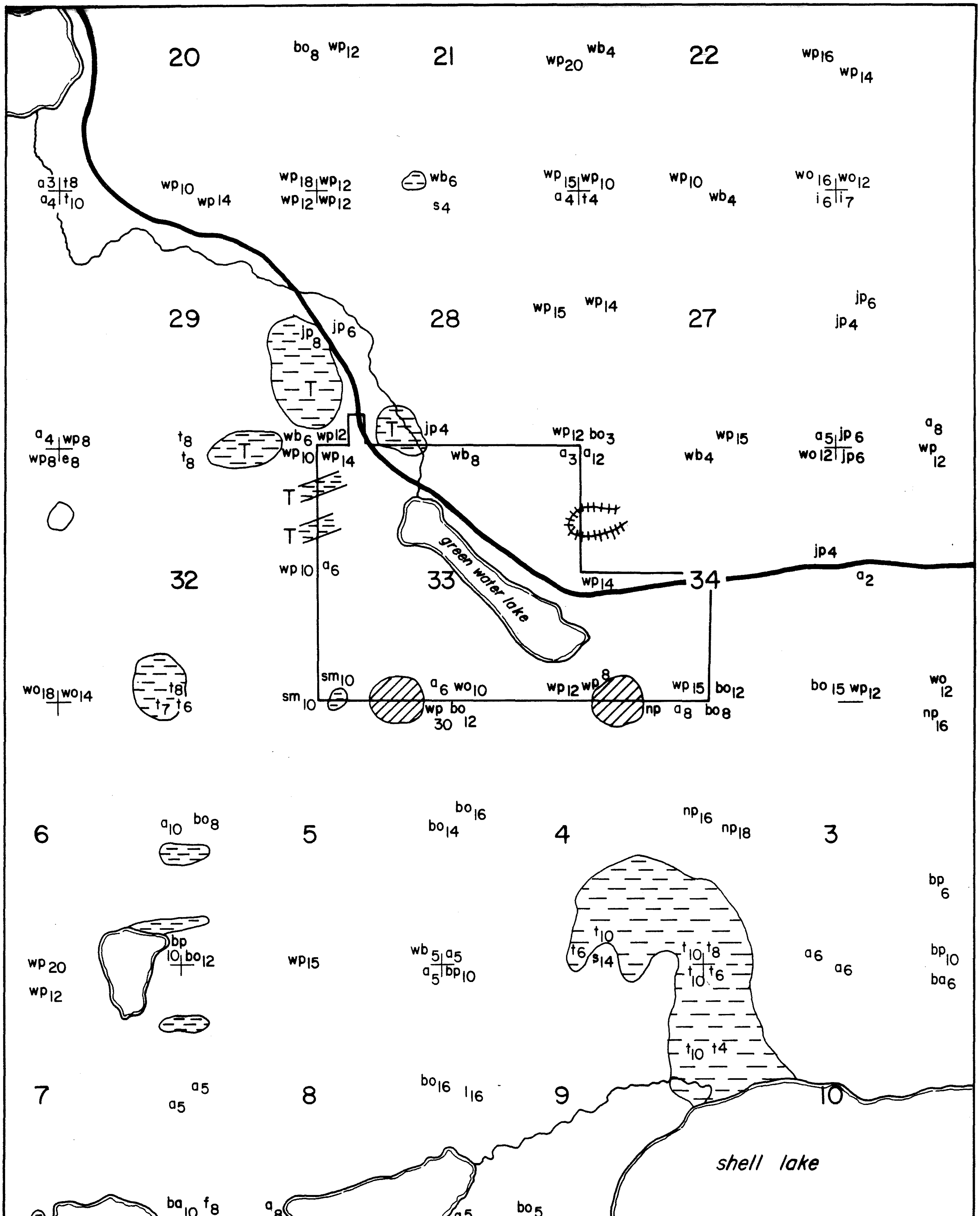


Figure 9

Original Vegetation of the Green Water Lake Area. (Adapted from U.S General Land Office Survey Notes, 1873). Parts of T140N, R38W and T 141N, R38W

METHODS

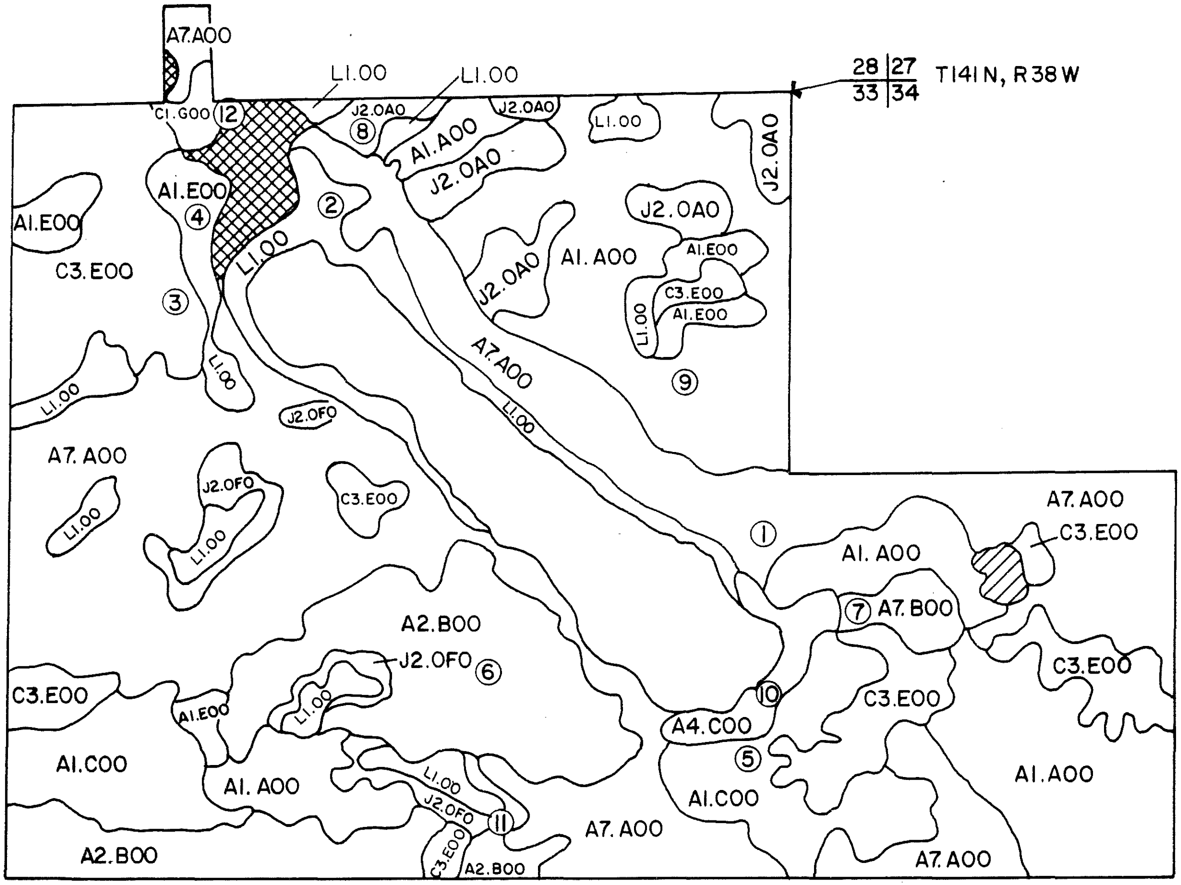
An intensive effort to describe the present vegetation of the Green Water Lake natural area was undertaken during the course of the 1980 inventory. The work proceeded in two directions. The first was an attempt to document the variety of vascular plants growing within the natural area. Work began in June and proceeded through early October. Throughout this period the tract was visited at weekly intervals. During each visit the site was searched systematially so that each cover type was adequately covered. Flowering and fruiting plants were collected and pressed. Pertinent data regarding the habitat, location, associated species and relative abundance for each specimen were recorded. The 253 vascular plants collected during the field survey are presented in Appendix IV. Voucher specimens have been deposited at the University of Minnesota herbarium, St. Paul campus.

The second direction in which the vegetation field work proceeded during the inventory was to collect data that would enable the researchers to identify and describe the plant communities of each natural area. Communities were initially identifed by preparing a cover type map with the use of aerial photos, color-infrared photos and soil maps. The map was then ground-truthed in order to accurately refine and revise the mapping units. Within each community a permanent 20 x 20 meter study area, or releve plot, was established. Species composition and homogeneity, along with soil type and topography, were the major criteria for selecting each plot.

After the plot was chosen, the releve method of vegetation analysis (Heitlinger, 1979) was used to gather supporting data for describing major cover types. Supporting data included sociability, cover abundance, and height classifications for each species identified.

Dbh (diameter breast height) measurements for all trees within the plot were recorded as well as the total number of saplings. These field measurements were used to calculate the relative density and relative basal area for each tree species. These, in turn, were combined to obtain an Importance Value (IV) to be weighed against a maximum value of 200 (Curtis, 1959). Physical features of the releve site, such as soil characteristics, site moisture, topographic position, and evidence of disturbance, were also recorded in order to give a complete description of each community. Importance values and releve data are presented in Appendices V and VI. The information derived from this data was used to classify the different vegetation types on the Green Water Lake tract. A classification scheme developed by the Minnesota Natural Heritage Program (1980a) provided guidelines for designating cover and community types.

The result of the field methods outlined above was the preparation of a vegetation cover type map for the natural area (Fig. 10). Each of the communities delineated on the map will be described in detail in the following pages.



ASPEN / OAK / BIRCH COVER TYPES

Populus Tremuloides/Betula Papyrifera
Populus Tremuloides / Populus Grandidentata
Betula Papyrifera
Populus Tremuloides/Quercus Macrocarpa
Quercus Macrocarpa/Quercus Borealis

DISTURBED SITES

Pinus Resinosa

Old Field

① Releve Sites

WETLAND COVER TYPES

Alnus Rugosa/Cornus Stolonifera/Salix Discolor
Salix Gracilis
Carex
Fraxinus Nigra

MESIC HARDWOOD COVER TYPES

Acer Saccharum / Tilia Americana/Betula Papyrifera

CONIFEROUS COVER TYPES

Pinus Banksiana
Abies Balsamea

Figure 10

Plant Communities of the Green Water Lake Natural Area

COMMUNITY DESCRIPTIONS

ASPEN - OAK - BIRCH COMMUNITIES

Covering nearly 52% of the natural area, the Aspen - Oak - Birch communities compise the largest of the four major cover types on the Green Water Lake tract. The cover type is represented by five distinct communities, each dominated by varying proportions of populars, oaks and paper birch. Much of the area now covered by these communities was, prior to settlement, dominated by large bur oaks and aspens, species which are also prevalent today. However, the southeast quarter of the tract, now aspen - birch, was apparently covered by an extensive stand of virgin white pine. Logged many years ago, the white pine is now represented only by a few remnant trees.

Trembling Aspen - Paper Birch: 58.3 hectares, 18.0% of the study area

The Trembling Aspen - Paper Birch community is represented by three stands on the natural area (Fig. 10). The largest stand, located in the northeast corner of the tract, was chosen for placement of the releve plot (releve 9). The second stand, located southeast of the first, consists of two fragments separated from one another by a small oak woods. The third and smallest stand is located near the southwest corner of the tract. Although all three stands vary in soil moisture and shrub density, their canopies are quite similar in age and composition.

The stand chosen for the releve plot is codominated by trembling aspen and paper birch in approximately a three to one ratio. Two other canopy species, red oak and bur oak, are also present but are rarely important. Total canopy coverage is relativey low, rarely exceeding sixty per cent.

The stand is distinct from the other small stands both in size and overall heterogeneity. Depressions, usually containing wet, peaty soil, are common. Six of the depressions contain alder thickets with green ash, American elm, and tamarack scattered throughout. These species also occasionally invade the fringes of the Aspen - Birch community. Sedge meadows dominate four other depressions. In addition to the wet depressions the stand also contains two small pockets of pure paper birch.

Within the releve plot trembling aspen (IV=130) is the major dominant with an average dbh of 28.4 cm. The low importance value for the codominant, paper birch (IV=38), reflects both a lower tree density and a smaller average dbh (17.2 cm). The oaks, red oak (IV=23) and bur oak (IV=5), are limited primarily to the understory or to openings in the aspen canopy. American elm, red maple and green ash are also encountered outside the releve plot in the northern half of the stand.

The spaling species in the releve plot illustrate the diversity of the understory. They include paper birch, bur oak, red oak, green ask, red maple and sugar maple. Together with American elm, the species are present in varying proportions throughout the stand, with the wetter species, green ash and American elm, more prevalent in the north. Among all aspen communities studied on the natural area this is the only stand where the canopy has begun to open up to any significant degree.

Shrub coverage in the releve plot is relatively low, averaging only twenty percent. Although it is generally low throughout the stand, in areas near the alder thickets coverage is much higher. Two major shrub species, Cornus rugosa and Cornus americana, account for most of the cover in the releve plot. Other species include Amelanchier humilus, Prunus virginiana, Betula pumila and Lonicera canadensis. The presence of Betula pumila is probably due to the proximity of the releve to a wet depression. Outside the releve plot Alnus rugosa is also an important species.

The most prevalent herbaceous genus in the releve plot is Carex, covering between twenty-five and fifty per cent of the forest floor. Other major herbaceous species are perhaps more characteristic of an aspen - birch stand. They include Anemone quinquefolia, Aster macrophyllus, Aralia nudicaulis, Clintonia borealis, Cornus canadensis, Hepatica americana, Maianthemum canadense,Pyrola asarifolia, Sanicula marilandica and Thalictrum dioicum.

The Trembling Aspen - Paper Birch stand in the southeast corner of the tract differs somewhat from the northeastern stand described in releve 9. In general it is drier and more similar to the aspen - oak stand which it borders. Red oak and bur oak tend to be larger and more abundant. Some large remnant jack pines and red pines are also present, especially in the southern portion of the stand, as well as red maple.

The most distinquishing characteristic of this stand, however, is the dense shrub layer, dominated primarily by Corylus americana. Other species contributing to the dense growth include Alnus rugosa, Cornus rugosa, Cornus stolonifera, and Viburnum rafinesquianum. Habaceous species are similar to those found in the nearby aspen - oak community

The third Trembling Aspen - Paper Birch stand is located near the southwest corner of the tract. This stand is both smaller and less uniform than the preceeding stands. Although trembling aspen and paper birch are still the primary dominants, large-toothed aspen also gains importance, as well as sugar maple and red oak.

It does not appear that these three stands will maintain themselves beyond this generation. New, shade tolerant species are becoming established beneath the canopy and neither the aspen or the birch appear to be regenerating.

Trembling Aspen - Large-toothed Aspen: 21.5 hectares, 6.3% of the study area.

The Trembling Aspen - Large-toothed Aspen community is considerably smaller than the Aspen - Birch community described in the preceeding pages. It is confined to two stands in the southern half of the tract. The well or excessively drained soils of the area consist of glacial till and sandy meltwater deposits.

The southeastern stand, where releve 5 was established, has two dominants, large-toothed aspen and trembling aspen. Large-toothed aspen is slightly more abundant. Paper birch is present in the small pockets while scattered throughout the stand are large remnant jack pines.

Releve 5 is located near the lake, on a slight north-facing slope. The major dominants include large-toothed aspen (IV=74), trembling aspen (IV=59), and paper birch (IV=51). The relatively high importance value for paper birch reflects the presence of a portion of one small paper birch pocket. Remnant jack pines (IV=15) were also found in the releve plot and are present throughout the upper slope of the stand. Other canopy species encountered outside of the releve include sugar maple, bur oak and red oak.

Shrub coverage within the releve is low, from three to five percent, and rarely exceeds twenty per cent throughout the entire stand. Shrub species within the releve plot include Betula pumila, Cornus rugosa, Cornus stolonifera, Corylus americana, Lonicera hirsuta, Lonicera canadensis, Lonicera tartarica, Rosa acicularis and Vaccinium angustifolium. Saplings are also infrequent throughout the stand. Within the releve plot only a small red oak and sugar maple were encountered.

In the herbaceous layer cover is quite high, approximately ninety percent. predominant herbaceous species include Anemone quinquefolia, Aralia nudicaulis, Aster macrophyllus, Cornus canadensis, Fragaria virginiana, Galium boreale, Galium triflorum, Maianthemum canadense, and Sanicula marilandica. Seedings of sugar maple, bur oak, red oak, black cherry, and white pine are also present as is a rather high amount of deadfall (approximately 10%), comprised primarily of dead paper birch.

The southwestern stand of Trembling Aspen - Large-toothed Aspen differs in some respects from the southeatern stand near the lake. Larger and older aspens dominate. Paper birch and other hardwood species are almost entirely absent. Pockets of dense aspen saplings are also common beneath infrequent openings in the canopy, a phenomenon not present in the southeastern stand. The density of the shrub layer is also somewhat lower.

Paper Birch: 9.7 hectares, 3.3% of the study area

The Paper Birch community is represented by five small, well-defined stands (Fig. 10). Four of the stands are located in the north half of the tract surrounded either by jack pine or aspen-birch, while the fifth stand is located in the southwest corner of the tract among mixed hardwood communities. Smaller pockets of paper birch, to small to be delineated in Figure 10, are also found scattered throughout the site.

Releve 4, located in one of the larger paper birch stands in the northwest corner of the tract, was chosen to represent the typical vegetation of this community. The releve site is dominated almost exclusively by paper birch (IV=178) with an average dbh of 17.5 cm. Other relatively infrequent canopy species include red oak (IV=13) and red maple (IV=9). Canopy coverage is fairly high, averaging approximately sixty to seventy percent.

In contrast to the lack of diversity in the canopy layer, saplings in the understory represent a wider array of species, including paper birch, red maple, red oak and red pine. Shrubs are relatively sparse but include the following species: Vaccinium angustifolium, Rubus strigosus, Corylus americana, and Alnus rugosa.

The herbaceous layer is relatively similar to the herbaceous layer in the nearby jack pine and aspen-oak forests. Prevalent species include Maianthemum canadense, Fragaria virginiana, Galium triflorum, Thalictrum dioicum, Arisaema triphyllum, Aster macrophyllus and Smilacina stellata.

The small pockets of paper birch tend to be less homogeneous than the five larger stands. The paper birch also tends to be younger while the shrub understory, composed primarily of Alnus and Corylus, tends to be denser. Most of these small pockets, as well as the other stands of paper birch on the tract, arise beneath temporary openings in the canopy created by such disturbances as windfalls, small fires and cutting. Evidence of past logging activities for example, is present near releve 4. These stands will no doubt be gradually replaced by mixed hardwood communities.

Trembling Aspen - Bur Oak: 75.7 hectares, 23.3% of study area

The Trembling Aspen - Bur Oak community is the largest community on the Green Water Lake tract. The community is represented by two stands, one bordering the northeast side of the lake and one bordering the southwest side of the lake. Although they differ slightly, both stands are dry-mesic oak forests situated on well-drained glacial till deposits.

Releve 1, located in the northeast stand, was chosen to describe the community. The plot is situated on a fairly steep southwest-facing slope. Bur oak (IV=53) and trembling aspen(IV=41) are the major dominants with paper birch (IV=39) and red oak (IV=16) appearing as associate species. Other tree species include sugar maple, red maple and green ash. American elm is also encountered outside of the releve plot as are some remnant red pines and jack pines. Canopy coverage within the plot is less than 60%, while it tends to be somewhat higher, 60-80%, outside of the plot.

All of the canopy species are also represented as saplings in the understory, as well as two additional species, white spruce (Picea glauca) and ironwood. Ironwood often reaches the ten to twenty meter height class within the releve, as well as throughout the stand, thus contributing somewhat to the canopy layer. Unlike the canopy, however, sugar maple is the most numerous species in the understory. There is little replacement of the dominant canopy species, aspen and bur oak.

The shrub layer within the releve is fairly dense, with total coverage ranging from about 50-60%. In addition to the saplings listed above other shrub species in the plot include Corylus americana, Cornus rugosa, Cornus stolonifera and Viburnum rafinesquianum. Outside of the releve, notably in the southeast portion of the stand, the shrub layer is dominated almost exclusively by Corylus americana.

Ground coverage in the herbaceous layer is approximately 80-90% in the releve plot. Prevalent species include Aster macrophyllus, Sanicula marilandica, Thalictrum dioicum, Galium triflorum, Smilacina stellata, Maianthemum canadense, Anemone quinquefolia and Aralia nudicaulis. The litter layer is relatively thick throughout the stand. A few fire scarred trees and stumps left from past logging activities are also conspicuous although the damage does not appear to be either recent or extensive.

In the second Trembling Aspen - Bur Oak stand, located west of the lake, the oaks tend to be larger and more abundant than the oaks in the eastern stand. The aspen, on the other hand, tends to be smaller and less abundant. Paper birch is also less prevalent and never attains the importance that it does in sections of the eastern stand. Small pockets of relatively pure jack pine are also present. In the understory ironwood is less prevalent while Alnus rugosa appears to be the primary shrub.

Red Oak - Bur Oak: 3.2 hectares, 1.0% of the study area

In addition to the large area covered by the Trembling Aspen - Bur Oak community there is one relatively pure oak stand near the southeastern tip of the lake. The stand is situated on top of a hill in an area which slopes gently westward. Releve 7 was selected to describe the typical vegetation of the community.

Bur oak dominates the canopy layer throughout most of the stand although in some areas red oak may augment or replace bur oak as the major dominant. The site of releve 7 is atypical of the stand in that bur oak is the sole dominant (IV=179); red oak (IV=3), on the other hand, is represented by a single tree. American elm (IV=18) is the only other canopy species within the releve while outside of the plot paper birch is occasionally present. Canopy coverage is relatively dense throughout the stand, generally exceeding 75%.

The understory in the releve plot is varied but sparse, the coverage averaging approximately 20%. Betula pumila, Alnus rugosa, Cornus stolonifera and Corylus americana are the major species. Saplings are quite infrequent, represented only by a few individuals of green ash, ironwood, American elm and sugar maple. Red oak and bur oak are not present at all below 5 meters.

Ground coverage by herbaceous species in the releve plot is high, averaging about 85%. The herbaceous species reflect the dry nature of the stand. Grasses provide the major ground cover. Other herbaceous species that are present include Aralia nudicaulis, Aster macrophyllus, Anemone quinquefolia, Geranium maculatum and Thalictrum dioicum.

WETLAND COMMUNITIES

Wetland communities cover nearly 15% of the Green Water Lake natural area. As is typical of the entire Pine Moraine Landscape Region, the wetlands on the Green Water tract do not cover extensive, contiguous areas but are found in small, isolated depressions scattered throughout the site. The major environmental factor that distinquishes these areas is the presence of a highly organic soil. All the other cover types on the tract are underlain by mineral soils.

There are three major types of wetland communities on the natural area: lowland shrubs, sedge meadow and forested wetlands. The lowland shrubs are either codominated by Alnus rugosa, Cornus stolonifera and Salix discolor or are dominated solely by Salix gracilis. Sedge meadows may differ depending on their location on the tract. The meadows that dominate some of the small scattered depressions throughout the area are quite similar to one another but differ in a few respects from the sedge mat that borders the lakeshore. The third wetland community, the forested wetland, is represented by a small black ash stand bordering the southeastern tip of the lake.

Alnus rugosa - Cornus stolonifera - Salix discolor: 12.6 hectares, 3.9% of the study area

This lowland shrub community is found in scattered pockets throughout the large Aspen - Birch stand in the northeastern portion of the tract. Despite tree invasion around the periphery of the pockets the shrubs are the major dominants. The shrubs stand from one to three meters high and cover from 60-80% of each stand.

Releve 8, located near the northern boundary of the tract, was selected to characterize the community. The two most important shrub species within the releve plot are Alnus rugosa and Cornus stolonifera, comprising nearly 80% of the shrub layer. Outside of the releve willows are also important and are represented by Salix discolor, Salix bebbiana and Salix gracilis. Another less prevalent shrub species is Ribes americanum. Woody vines, such as Parthenocissus vitaceae, are also common.

Scattered trees are also present in the shrub pockets. Although the species vary, tamaracks appear to be the most numerous. Within the releve plot the tamaracks are relatively large, with an average dbh of 28.7 cm. This, combined with the absence of tamarack saplings and the presence of numerous dead tamaracks, indicates that these trees may be remnants of a past community. Other tree species that are occasionally present in these pockets, American elm, trembling aspen, black ash and paper birch, are usually smaller than the tamarack. Saplings of these species are also present and are frequently encountered encroaching along the periphery.

The herbaceous species of these pockets are quite variable. Although sedges are predominant a variety of other species are present, including Clintonia borealis, Cornus canadensis, Anemone quinquefolia, Thalictrum diocum and Aralia nudicaulis.

Salix gracilis: 6.9 hectares, 2.1% of the study area

Unlike the Alnus rugosa - Cornus stolonifera - Salix discolor community discussed above, the Salix gracilis shrub community is commonly found encircling small sedge meadows. Under such conditions it is present only as a narrow band ranging from 20 to 30 meters wide.

A small stand, located in the soutwest corner of the tract, was selected for establishing releve 11. Within the plot, Salix gracilis is the dominant species while Alnus rugosa is an important associate. Salix bebbiana and Salix discolor are also encountered outside of the plot, as is Cornus stolonifera and Betula pumila. Collectively, however, the willows are the most prevalent species in all the stands, contributing between 40-80% of the cover in the shrub layer.

Like the other lowland shrub community the Salix gracilis community shows some signs of tree invasion around the periphery. In the area where the releve was established a few trembling aspen saplings were present. Overall, however, trees appear to be less important than in the shrub community co-dominated by alders, willows and dogwoods.

Beneath the shrub layer the dominant herbaceous species in the releve are Carex atherodes and Phalaris arundinacea. Other assoicates include Lycopus americanus, Polygonum coccineum, Mentha arvensis and Caltha palustris.

Sedge Meadows: 23.5 hectares, 3.8% of the study area

Sedge meadows can be found bordering much of the lakeshore of Green Water Lake as well as in shallow depressions scattered throughout the tract. The water-saturated soils of the depressions are composed of peat deposits while the lakeshore community is underlain by a mucky peat, seldom more than one meter deep. Releve 2, located at the northwest end of the lake, was chosen to describe this community.

The lakeshore sedge community borders nearly three-quarters of Green Water Lake. It is limited primarily to those areas where the surrounding landscape slopes gradually down to the lake rather than abruptly. In the area where releve 2 was established the dominant species appear to be Carex atherodes and Carex stricta. Because of the late sampling date, 10 September, some difficulty was encountered in identifying many of the Carex species. However, throughout the course of the summer, several sedges had been collected from the lakeshore, including C. bebbi, C. gracilima, C. lasiocarpa and C. pseudo-cyperus. Other important species within the releve include Spartina pectinata and Phalaris arundinacea. Outside of the plot Calamagrostis canadensis, Polygonum natans, Lycopus americanus and Cicuta maculata are also important.

North of the releve plot shrubs become increasingly prevalent as the above-ground moisture decreases. The species encountered most often are Salix gracilis, S. bebbiana, S. discolor and S. humilis. Dogwoods and alders become more frequent near the borders with the upland communities.

In the small sedge openings one _Carex_, usually _C. stricta_, predomiates, although several others, including _C. atherodes_, _C. interior_ and _C. pseudo-cyperus_, are also present. Like the lakeshore community the prominent grasses include _Calamagrostis canadensis_, _Phalaris arundinacea_ and _Spartina pectinata_.

Black Ash: 4.0 hectares, 1.2% of the study area

The only forested wetland on the natural area is a small stand of black ash along the southeast tip of the lake. The spongy peaty soil of this area is scattered with small depressions that accumulate water and organic sediments. Seepage, which feeds directly into the lake, helps to keep the ground surface saturated with water.

Releve 10 was established in the center of the stand, near the lakeshore. Within the releve plot, and throughout the entire stand, black ash is the dominant species (IV=135). Tamarack (IV=43) is the only other species present in the canopy. Although the tamarcks appear to be a bit more vigorous and abundant in the wetter, open areas near the lakeshore, dead standing trees are common elsewhere in the stand.

Beneath the canopy, the understory is fairly open. Coverage in the shrub layer averages approximately 25% and is dominated primarily by _Alnus rugosa_ with some _Salix sp_. Saplings are also infrequent, particularly in the releve plot.

Sedges are the most prevalent species in the ground layer. Carex stricta appears to be the most abundant species, although difficulties were encountered because of the late sampling date. Other sedges that were collected in the stand earlier in the summer included Carex pseudo-cyperus, Carex stipata, and Carex bebbii. Some of the prevalent forbs in the plot include Caltha palustris, Lycopus americanus, Mitella nuda and Smilacina stellata. Cypripedium reginae, the showy lady-slipper, is present in conspicuous colonies, each containing 40 to 200 blooming plants. Most of these colonies are located away from the lakeshore.

Outside of the releve and close to the lakeshore emergent species become more prevalent, as do small pools of standing water, often totally covered with Lemna minor. Sedges become less dominant and are replaced by other species, including Scirpus acutus, Scirpus cyperinus, Scirpus atrovirens, Sagittaria latifolia, Juncus dudleyi and Juncus tenuis. As the water becomes deeper fewer species are encountered. Scirpus acutus and Sagittaria latifolia are the most common species at moderate depths.

MESIC HARDWOOD COMMUNITIES

The mesic hardwood communities are represented by one large maple-basswood stand in the south central portion of the tract. The stand is located atop a relatively level ridge of well-drained glacial till. In contrast to the other forest communities on the natural area the maple-basswood stand is extremely uniform and homogeneous. Releve 6, located in the center of the stand, was selected to describe the typical vegetation.

Sugar Maple - Basswood - Paper Birch: 36.9 hectares, 11.3% of the study area

The structure and composition of the vegetation within releve 6 is typical of the entire stand. Sugar maple, the dominant canopy species (IV=113), is fairly uniform in size and distribution throughout the stand. Most of the maples stand from 20 to 35 meters in height and average 23.9 cm dbh. Strips of metal wrapped around many of the trees suggest they have been tapped in the past for making maple syrup. Basswood (IV=45) is also an important associate in the canopy, the trees standing somewhat taller, about 50 meters or higher, than the maples. Red oak (IV=16) and bur oak (IV=8) are also present. Paper birch, although not found in the releve plot, often achieves levels of importance elsewhere in the stand, either equaling or exceeding that of the oaks. Canopy coverage is very high throughout the stand, ranging from 90-100%.

The shrub layer contributes little to the overall structure of the stand. Coverage averages only between 10% and 15%. Although ironwood is the most prevalent species, other species include _Cornus rugosa_, _Cornus Stolonifera_, _Corylus americana_, _Prunus serotina_, _Prunus virginiana_ and _Viburnum rafinesquianum_. Sugar maple and basswood saplings are also present.

The composition of the herbaceous layer is largely determined by the heavy canopy cover. Because very little direct sunlight penetrates the canopy during the summer the groundlayer is dominated by spring ephemerals. Prominent spring blooming species include *Hepatica americana*, *Arisaema triphyllum*, *Asarum canadense* and *Trillium cernuum*. Saprophytes such as *Corallorhiza trifida* are also adapted to the heavy canopy cover. The most abundant plants in the herbaceous layer, however, are the seedlings of the shade tolerant sugar maple, thus indicating that the maples in the canopy will maintain their dominance for many years to come.

CONIFEROUS COMMUNITIES

Unlike the presettlement era, when large white pines and red pines covered much of the Green Water Lake tract, coniferous communities today comprise only a little over 10% of the natural vegetation. Jack pine is now the predominant species, occurring in natural as well as planted stands. Red pine and white pine, on the other hand, are represented primarily by large old relics that are scattered throughout the jack pine, aspen-oak, and aspen-birch communities. Balsam fir, a rather uncommon species on the natural area, dominates a small stand in the far northwest corner of the tract.

Jack Pine: 34.5 hectares, 10.5% of the study area

The jack pine community is found in several locations on the Green Water Lake natural area (Fig. 10). Nearly all of the sites are characterized by excessively drained, sandy soils derived from glacial meltwater deposits. The largest and most uniform stand, located in the northwest corner of the tract, was selected for establishing releve 3.

Jack pine dominates the canopy of releve 3, with an importance value of 185. The extreme uniformity in the size (avg dbh=21.6 cm) and density of the trees indicates that the stand was either planted or began after some major disturbance nearly 30-50 years ago. The land use history of the tract suggests that the stand originated after the area was clearcut. Fire scars that may have been caused by a small ground fire were present on some of the trees within the releve. A few stumps from recent cuttings are also scattered throughout the stand. The close proximity of County Highway #35 may encourage the occasional cutting and removal of trees.

The jack pine trees in releve 3 are considerably smaller than the large relic red pines (avg dbh 45.2 cm) that are sparsely scattered throughout the canopy (IV=15). The red pines located in the center of the stand are quite large, standing 20-40 meters high. Elsewhere they are more numerous but smaller, about 10-30 meters tall. A third canopy species, paper birch, sometimes appears as an incidental species, largely in areas where there is an opening in the canopy. Overall, coverage in the canopy is high, approximately 80%.

Saplings contribute little to the understory of the stand. The sapling species in releve 3 consist of bur oak, red oak, paper birch and red maple. They are not numerous and few are above 5 meters in height. Shrub coverage is also fairly low, approxiamtely 30%. Shrub species include _Vaccinium angustifolium_, _Lonicera canadensis_ and _Corylus americana_. Typical of most pine stands in northern Minnesota, the herbaceous layer includes such species as _Maianthemum canadense_, _Aster macrophyllus_, _Galium triflorum_, _Linnaea borealis_, _Epigaea repens_ and _Chimaphilia umbellata_.

The other jack pine stands on the Green Water Lake tract are quite similar to that described by releve 3. However, the two stands in the southwest corner of the tract have a more heterogeneous canopy layer. Like releve 3, jack pine is the predominant species, represented by relatively young trees. Yet, in addition to the red pine relics, large, old white pine trees, over 35 meters tall, are also scattered throughout the area. Trembling aspen and paper birch are also more abundant. They are represented primarily by saplings and small trees that fill in small openings beneath the canopy.

Balsam Fir: 2 hectares, .6% of the study area

The balsam fir community is represented by one small stand in the northwest corner of the tract. The stand is surrounded by a dense alder thicket with tamarack, American elm and birch trees scattered throughout. None of these species, however, are important in the balsam fir stand.

The data for releve plot 12 provide a dramatic illustration of the almost complete uniformity of the stand. Balsam fir has an importance value of 197. This high value reflects the extremely dense canopy of relatively small trees. Within the 20m x 20m plot a total of 96 trees were counted, with an average dbh of 15.7 cm. The only other canopy species present within the plot is a single paper birch tree.

The shrub layer is comprised primarily of Alnus rugosa and Cornus stolonifera. Diervilla lonicera, Lonicera canadensis and Ledum groenlandicum are also present. The shrub layer is very sparse, the coverage ranging from 5% to 25%. Near the periphery of the stand, where the invading alder is more prevalent, shrub coverage may reach 40%.

Nearly 40-60% of the rocky ground layer is covered by a soft and spongy carpet of mosses. Herbaceous species are relatively sparse but include *Pyrola asarifolia*, *Moneses uniflora*, *Viola conspera*, *Cornus canadensis*, *Clintonia borealis*, *Galium triflorum* and *Mitella nuda*. Deadfall is also common.

DISTURBED SITES

Although virtually all of the communities on the Green Water Lake tract have been disturbed during the past century there are two relatively large sites where the disturbance is particularly obvious and, in one case, fairly recent. The largest site is the area of planted red pine located on the northwest end of the lake. The second, and smaller, site is an old homestead clearing in the eastern half of the tract.

Red Pine - Planted: 4.7 hectares, 1.5% of the study area

As was discussed earlier (see Land Use History Section), Dr. Fox initiated a tree planting program on the property in the spring of 1964, under the direction of District Forester, Mr. Norman Zauche. The most obvious result of their efforts is the large stand of planted pines on the northwest end of Green Water Lake. This particular area was planted primarily with red pines although there are also some scattered white pines. The large furrows created by the machine used to plant the seedlings are still evident.

Around the periphery of the stand a few oak, aspen, elm and balsam fir saplings have begun to invade from nearby communities. There is also some invasion by shrub species on the western border of the stand, primarily *Alnus rugosa* and *Cornus stolonifera*.

Cleared Homestead: 3 hectares, 1% of the study area

The origin of this cleared area is somewhat uncertain. It was mentioned earlier that a former tenant on the property, Mr. Alexander, took up residence in a small log cabin on the east edge of the clearing during the late 1930's. It is not known, however, whether the forest opening was cleared prior to or during Mr. Alexander's residence in the area. The manner in which the area may have been used over the past 50-60 years is also vague.

Today the clearing remains devoid of trees, with the exception of a few large oaks standing in the center. Shrub cover is also low and consists of two thickets of Corylus americana near the edges and some scattered Rhus glabra. The herbaceous layer is dominated by such grasses as Andropogon gerardi, Panicum capillare, Phleum pratense and Poa compressa. Some of the forbs that are present include Lepidium densiflorum, Thalaspi arvense, Medicago lupulina, Taraxacum vulgare, Tragopogon dubis, Tanacetum vulgare, Ambrosia artemisiifolia, Artemisia caudata, Aster ericoides, Erigeron strigosus and Oenothera biennis.

RARE PLANTS[3]

During the course of the 1980 inventory no rare plant species were documented to occur on the Green Water Lake Natural Area. There are, however, several rare species that are known to occur in the general vicinity, some of which may also occur on the tract. Submerged aquatic species which may be present include: Potamogeton lateralis, Potamogeton vaseyi, Majas gracillima and Myriophyllum tenellum. Rare species of emergent flora that may be present include: Sagittaria brevirostra, Eleocharis olivacea, Eleocharis pauciflora var. fernaldii, Scirpus georgianus, Triglochin palustris, Xyris montana and Glyceria pallida. Because there was not an intensive effort to study the lakeshore and lake vegetation during the 1980 inventory it is recommended that such a study be a priority effort during future field studies.

Several rare woodland species may also be present on the tract and should be searched for during future work. They include: Ophioglossum vulgatum var. pseudopodium, Botrychium matricariaefolia and Carex capillaris var. major.

[3] Information provided by Welby Smith, Minnesota Natural Heritage Program.

ANIMALS

INTRODUCTION

A total of 118 animal species were recorded on the Green Water Lake Natural Area during the 1980 inventory. Nearly half of these species were birds (58) followed by butterflies (34) and mammals (23). Reptiles (3) and amphibians (1) contributed little to the overall diversity. With few exceptions the animals obserbed on the natural area are typical of the forest communities of northwestern Minnesota. The only three uncommon species reported were the butterflies *Lethe appalachia leeuwi*, *Callophrys niphon clarki* and *Pieris napi oleracea*.

BUTTERFLIES

METHODS

An inventory of butterflies[4] was conducted on the Green Water Lake Natural Area during the 1980 inventory to document species composition. From early June through September a group of three zoologists visited the site weekly, between the hours of 8am and 3pm. The objective on each visit was to cover all habitat types, placing special emphasis on those areas where flowering plants were in bloom.

[4] The term butterfly, in this document, refers both to the true k-butterflies (Papilionoidea) and to the skippers (Hesperioidea).

A standard twelve-inch butterfly net was used to capture the insects. Careful notes were taken on the activity of the specimen, the technical location from which it was collected, its habitat, the plant species it was visiting, and the relative abundance of the butterfly on the preseve that day. Specimens were released, except when identification required a prepared specimen or when a voucher specimen was desired.

Identification of butterflies was accomplished by use of the following references: Ehrlich and Ehrlich (1962), Howe (1975), Klots (1951) and McCabe and Post (1977). Specimens were verified by Ron Huber (Zoology Assistant, Science Museum of Minnesota) and vouchers were deposited at the Science Museum of Minnesota.

DISCUSSION

Thirty-four butterfly species representing seven families were identified at the Green Water Lake Natural Area during the 1980 inventory. Table 5 lists all the species, recorded in phylogenetic order. Habitat types, butterfly activity, observed flight dates and a rough estimate of frequency were also recorded and this information is available in the files of the Scientific and Natural Areas Program. The butterfly species sighted at Green Water Lake are largely open forest and forest edge species. With the exception of Callophrys niphon clarki, Pieris napi oleracea and Lethe appalachia leeuwi, all of these species are thought to be common to abundant in northwestern Minnesota.

Callophrys niphon clarki and Lethe appalachia leeuwi are both uncommon species of Minnesota's northern woods (Huber, 1979). C. n. clarki is generally found near the borders of young, open pine stands where the larvae feed on pine needles. The one individual that was collected on the Green Water Lake tract in early June was found in a mixed coniferous - deciduous upland. This record from the natural area is the western most station for the species. The second species, Lethe appalachia leeuwi, is usually found in wooded swamps and in the shrubby, shaded perimeter of bogs. Sedges of the genus Carex are the larval food plant. The record from the Green Water Lake tract is the first record for Becker County.

Pieris napi oleracea, also an uncommon inhabitant of Minnesota's northern woods, is believed to have been more abundant in the past. However, its inability to successfully compete with the introduced species, Pieris rapae, has reduced its range significantly. Found in cool, moist deciduous or mixed coniferous woods, the larvae of P. n. oleracea feed on plants of the Cruciferae family.

Table 5. Butterflies of the Green Water Lake Natural Area

Species			Monthly Abundance [1]		
Family	Scientific Name	Common Name	June	July	August
Hesperiidae	Poanes hobomok Harris.	Hobomok Skipper	A	F	
	Polites themistocles Latreille.	Tawny-edged Skipper	C		
	Polites mystic Scudder.	Long Dash	F		
	Ancyloxpha numitor Fabricius.	Least Skipper	C		
	Carterocephalus palaemon Pallas.	Arctic Skipper	C		
	Erynnis icelus Scudder and Burgess.	Dreamy Dusky Wing	C		
	Thorybes pylades Scudder.	Northern Cloudy Wing	C	F	
	Epargyreus clarus Cramer.	Silver-spotted Skipper	C	F	
Papilionidae	Papilio glaucus canadensis Linnaeus.	Tiger Swallowtail	C	C	
Pieridae	Pieris napi oleracea Harris.	Mustard White	F		
	Pieris rapae Linnaeus.	Cabbage Butterfly	C	C	C
	Colias eurytheme Boisduval.	Alfalfa Butterfly	C	C	C
	Colias philodice Godart.	Common Sulphur	C	C	C

Table 5. Butterflies of the Green Water Lake Natural Area (continued)

Species			Monthly Abundance [1]		
Family	Scientific Name	Common Name	June	July	August
Lycaenidae	Callophrys niphon clarki Freeman.	Pine Elfin	1		
	Celastrina argiolus Linnaeus.	Spring Azure	F	2	
Nymphalidae	Limenitis arthemis Drury.	White Admiral	F	A	
	Limenitis archippus Cramer.	Ciceroy	1		1
	Vanessa atalanta Linnaeus.	Red Admiral	F	2	
	Nymphalis vau-album j-album Boisduval and LeConte.	Compton's Tortoise Shell	1		
	Nymphalis milberti Godart.	Milbert's Tortoise Shell	F	F	1
	Nymphalis antiopa Linnaeus.	Mourning Cloak	3	2	2
	Polygonia comma Harris.	Hop Merchant	F	1	
	Polygonia progne Cramer.	Gray Comma	F		
	Phyciodes tharos Drury.	Pearl Crescent	C	F	
	Chlosyne nycteis Doubleday.	Silvery Checkerspot	C		
	Boloria selene Denis and Schiffermuller.	Silver-bordered Fritillary	C	F	
	Speyeria atlantis Edwards.	Atlantis Fritillary	F	F	
Danaidae	Danaus plexippus Linnaeus.	Monarch	C	C	C

Table 5. Butterflies of the Green Water Lake Natural Area (continued)

Species			Monthly Abundance [1]		
Family	Scientific Name	Common Name	June	July	August
Danaidae	Danaus plexippus Linnaeus.	Monarch	C	C	C
Satyridae	Lethe anthedon Clark.	Pearly Eye	C	A	
	Lethe eurydice Johansson.	Eyed Brown	C	C	
	Lethe appalachia leeuwi Gatrelle and Arbogast.	Appalachian Brown	C		
	Euptychia cymela Cramer.	Little Wood Satyr	F	F	
	Coenonympha tullia inornata Edwards.	Edwards Inornate Ringlet	1		
	Cercyonia pegala nephele Kirby.	Wood Nymph	C	A	C

1 Abundance estimates are derived from signtings during the time spent in the field and are only a relative index of the actual populations. Symbils used to indicate abundance as as follows:

1-5 Actual number sighted
F Few (5-20)
C Common (20-50)
A Abundant (50)

REPTILES AND AMPHIBIANS

METHODS

A survey of reptiles and amphibians was also conducted on the Green Water Lake Natural Area in an attempt to document species composition. Drift fences were the primary collection technique utilized. Animals were also hand captured whenever they were encountered on the area.

Two drift fences, each approximately 12 meters in length, were established in lowland areas on the Green Water Lake tract.[5] One fence was set up in a hardwood stand along the lakeshore while the second was located in a sedge marsh beside the creek. The fences were constructed of .5-m high galvanized flashing which was sunk about 10 cm into the ground. Buckets that served as drop receptacles were placed at various intervals along the fence as well as at each end. Presumably, animals moving through the area would be diverted along the fence and into one of the containers. The fences were in operation from 9 July until 30 September and were checked at least once a week throughout this period.

Reptiles and amphibians collected during the inventory were retained as voucher specimens. The animals were identified in the lab using Conant (1975). Information recorded for each specimen included the date, location, collector, method of capture and habitat collected in. Voucher specimens were tagged and preserved in a 10% Formalin solution.

[5] The locations of the drift fences have been mapped and are available in the SNA files.

DISCUSSION

Only three reptiles and one amphibian were collected and recorded on the Green Water Lake tract during the summer inventory (Table 6). A red-sided garter snake (*Thamnophis sirtalis parietalis*) was captured on 21 May 1980 in a dry, sparsely vegetated area. The snake occurs throughout western Minnesota and is thought to be a common species on the area. A northern prairie skink (*Eumeces septentrionalis septentrionalis*) was also collected on 21 May 1980 in the same locality. On the lake itself western painted turtles (*Chrysemys picta belli*) were seen on numerous occasions. One turtle was hand caught on 14 August 1980 along the shores of the lake and retained as a voucher specimen.

The wood frog (*Rana sylvatica*) was the only amphibian recorded on the tract. More than 60 wood frogs were collected in the two drift fences and many more were seen in moist lowland habitats on the area. The abundance of wood frogs was extremely high on the tract, despite the unusually dry spring and early summer in this region of Minnesota.

The relatively low number of reptiles and amphibians collected during the inventory may be attributed to the timing of the field season. To effectively sample reptiles and amphibians efforts should be concentrated during the spring breeding season when animals are generally more active and vocal. The June starting date likely contributed to the poor results.

Table 6. Reptiles and Amphibians of the Green Water Lake Natural Area.

Scientific Name	Common Name
Thamnophis sirtalis parietalis	Red-sided Garter Snake
Eumeces septentrionalis septentrionalis	Northern Prairie Skink
Chrysemys picta belli	Western painted Turtle
Rana sylvatica	Wood Frog

BIRDS

METHODS

An inventory of birds was conducted at Green Water Lake to document species composition and to provide an index of abundance for each species on the area. The IPA (Indices Ponctuels d'Abondance) or Point Count Method (Robbins, 1979) was used to census bird populations during the summer breeding season. The Point Count Method provides information on species composition and abundance for large, diverse tracts of land, such as the Green Water Lake Area (326 hectares) and the results are comparable to censuses in different habitats or different locations.

The Point Count Method is dependent on the establishment of a series of sampling points throughout the area. While keeping time and manpower constraints in mind, an attempt is made to sample all major habitat types. Nine circular bird stations, each with a 50 meter radius, were dispersed throughout the various habitat types on the Green Water Lake tract.[6] When selecting the stations care was taken so that the sampling area of stations adjacent to one another did not overlap.

During the census a trained observer stood at each designated station for ten minutes and recorded on a map all birds heard or seen within the 50 meter radius. Symbols were used to denote the means of identification (sight, song or call) and the sex of the species. While traveling between stations, time was used to search out questionable species and to record any incidental bird observations. Each bird point was censused six times for a total of 60 minutes at each point during the month of June and the first week of July.

[6]Maps showing the location of sampling points are available in the SNA files.

The six census dates for Green Water Lake were: 5 June, 11 June, 19 June, 25 June, 30 June and 1 July, 1980. To reduce the chance of personal biases, each bird point was visited only two times by the same observer. In addition, the starting point was rotated for each visit so that each bird station would be sampled at different times. The censuses were conducted in the early morning during peak bird activity and only when weather conditions were favorable.

To supplement the bird counts, incidental bird sightings were recorded whenever the researchers were on the area. Many additional hours were spent on the Green Water Lake tract and this increased the chances of encountering uncommon bird species that may not have been recorded during the breeding census.

Census data were analyzed to give an index of abundance for each species. Each singing male, occupied nest or family of birds out of the nest counted as one pair, while a bird seen or heard calling counted as one half of a pair (Robbins, 1979). The highest of the six counts for each species at a particular station was used as a population index. An index of abundance was then calculated for each species by dividing the combined count at all stations by the number of sampling points.

Species were listed taxonomically and assigned to one of four abundance categories based on their index value. The four categories are as follows:

Category	Index Value (Average # pairs/station)
Abundant	1.0
Common	0.5 x 1.0
Uncommon	0.1 x 0.5
Very uncommon	0.1

Species only recorded once during the breeding census were not placed in an abundance category, but were listed along with the other species and with the date of their observation. All birds recorded as incidentals were treated in a similar manner. When positive evidence of nesting was observed (e.g., observations of nests or young) those details are also included in the table.

DISCUSSION

A taxonomic list of the 58 bird species observed on the Green Water Lake tract is presented in Table 7. The wide variety of species reported, ranging from ducks to wood warblers, reflects the diversity of habitats available on the tract. Overall, however, the predominance of the upland Aspen - Oak - Birch communities is reflected by the relative abundance of several species. The red-eyed vireo (*Vireo olivaceus*) ovenbird (*Seiurus aurocapillus*) and chestnut-sided warbler (*Dendroica pennsylvanica*), three of the four species reported as "Abundant" on the tract, are the most typical and abundant species of mixed upland forests throughout northern Minnesota.

Although a large number of species associated with open water were observed at one time or another on the natural area, many of the birds were only passing over the area. The low productivity of the lake, as well as the relatively small amount of marsh-like vegetation along the shoreline, may deter many species from utilizing the area. A few species, however, such as the mallard, wood duck and spotted sandpiper, were actually found feeding or resting on the area.

Despite the large number and diversity of birds observed on the Green Water Lake tract none of the species are considered rare or endangered on a statewide basis (MNHP, 1980b). Yet two species, the western grebe (Aechmophorus occidentalis) and the great blue heron (Ardea herodias) have been recognized as meriting special concern, primarily because of their colonial nesting habits. Although both species were observed while working on the natural area neither utilize the Green Water Lake tract for nesting habitat. A small group of western grebes were observed on the lake twice during the fall; once in mid-September and once in early October. The lake thus served as a stopover point during the birds migration south. Great blue herons, on the other hand, were observed flying over the natural area on four occasions. The birds were probably flying to and from their nesting colony and feeding areas. Cotton Lake, approximately 12 miles southwest of Green Water Lake, is the nearest known active colony. However, the frequent observations may also indicate the presence of an unknown colony close by.

Table 7. Bird Species of the Green Water Lake Natural Area

SCIENTIFIC NAME	COMMON NAME	ABUNDANCE[1]	REMARKS
Gavia immer	Common Loon	Uncommon	
Aechmophorus occidentalis	Western Grebe	*	Species observed as an incidental twice on Green Water Lake: 16 September and 6 October 1980.
Ardea herodias	Great Blue Heron	Uncommon	
Branta canadensis	Canada Goose	*	Species observed flying overhead twice: a flock of 16 on 14 August and a flock of 38 on 16 September 1980.
Anas platyrhynchos	Mallard	*	Two females and one male were observed on the creek flowing out of Green Water Lake on 16 June 1980.
Anas discors	Blue-winged Teal	*	Species observed once during census, flying over lake on 5 June 1980.

Table 7. Bird Species of the Green Water Lake Natural Area (continued)

SCIENTIFIC NAME	COMMON NAME	ABUNDANCE[1]	REMARKS
Aix sponsa	Wood Duck	*	Species observed once during census, on lakeshore on 11 June 1980.
Buteo platypterus	Broad-winged Hawk	*	Nest with 3 young; SW1/4 SW1/4 of Section 34, T141N, R38W.
Pandion haliaetus	Osprey	*	Species observed flying over the lake on two occasions: 11 June and 8 October 1980.
Bonasa umbellus	Ruffed Grouse	*	An adult female with brood was observed on two occasions: 5 June and 11 June 1980.
Charadrius vociferus	Killdeer	*	Adult feigning injury observed once, 16 June 1980.
Philohela minor	American Woodcock	*	Species only observed once during census, 12 August 1980.
Actitis macularia	Spotted Sandpiper	*	Species only observed once during census, 16 June 1980.

Table 7. Bird Species of the Green Water Lake Natural Area (continued)

SCIENTIFIC NAME	COMMON NAME	ABUNDANCE[1]	REMARKS
Coccyzus americanus	Yellow-billed Cuckoo	Uncommon	
Coccyzus erythropthalmus	Black-billed Cuckoo	Uncommon	
Strix varia	Barred Owl		Species only observed once during census, 3 July 1980.
Chordeiles minor	Common Nighthawk	*	Species only observed once. Recorded as an incidental, 12 August 1980. Four birds seen flying overhead.
Archilochus colubris	Ruby-throated Hummingbird	*	Species only observed once during census, 19 June 1980.
Colaptes auratus	Common Flicker	*	Species only observed once during census, 5 June 1980.
Sphyrapicus varius	Yellow-bellied Sapsucker	Very Uncommon	

Table 7. Bird Species of the Green Water Lake Natural Area (continued)

SCIENTIFIC NAME	COMMON NAME	ABUNDANCE	REMARKS
Dendrocopos villosus	Hairy Woodpecker	Uncommon	
Tyrannus tyrannus	Eastern Kingbird	Uncommon	
Myiarchus crinitus	Great Crested Flycatcher	Common	
Empidonax minimus	Least Flycatcher	Common	
Contopus virens	Eastern Wood Pewee	Uncommon	
Iridoprocne bicolor	Tree Swallow	*	Species only seen once during census, 25 June 1980.
Progne subis	Purple Martin	Uncommon	
Cyanocitta cristata	Blue Jay	Uncommon	
Corvus brachyrhynchos	Common Crow	Uncommon	
Parus atricapillus	Black-capped Chickadee	Abundant	

Table 7. Bird Species of the Green Water Lake Natural Area (continued)

SCIENTIFIC NAME	COMMON NAME	ABUNDANCE[1]	REMARKS
Sitta carolinensis	White-breasted Nuthatch	Uncommon	
Certhia familiaris	Brown Creeper	*	Species only heard and seen once during census, 30 June 1980.
Cistothorus platensis	Sedge Wren	*	Species only heard once during census, 3 July 1980.
Dumetella carolinensis	Gray Catbird	Uncommon	
Turdus migratorius	American Robin	Common	
Catharus minimus	Veery	Common	
Mniotilta varia	Black-and-White Warbler	*	Species only heard once during census, 3 July 1980.
Vermivora peregrina	Tennessee Warbler	*	Species only heard only curing census, !! June 1980. Most likely a migrant.
Vermivora ruficapilla	Nashville Warbler	*	Species only seen once. Recorded as an incidental on 3 July 1980.

Table 7. Bird Species of the Green Water Lake Natural Area (continued)

SCIENTIFIC NAME	COMMON NAME	ABUNDANCE[1]	REMARKS
Dendroica virens	Black-throated Green Warbler	Uncommon	
Dendroica fusca	Blackburnian Warbler	Uncommon	
Dendroica pensylvanica	Chestnut-sided Warbler	Abundant	
Dendroica striata	Blackpoll Warbler	*	Species only seen once. Recorded as an incidental on 11 June 1980. A total of 4 birds were observed. Most likely migrants.
Dendroica pinus	Pine Warbler	Uncommon	
Seiurus aurocapillus	Overbird	Abundant	
Geothlypis trichas	Common Yellowthroat	Common	
Setophaga ruticilla	American Redstart	*	Species observed twice. Recorded as an incidental on 25 June and 3 July 1980.

Table 7. Bird Species of the Green Water Lake Natural Area (continued)

SCIENTIFIC NAME	COMMON NAME	ABUNDANCE	REMARKS
Agelaius phoeniceus	Red-winged Blackbird	Uncommon	
Molothrus ater	Brown-headed Cowbird	*	Species only heard once during census, 25 June 1980.
Bombycilla cedrorum	Cedar Waxwing	Uncommon	
Piranaga olivacea	Scarlet Tanager	Uncommon	
Passerina cyanea	Indigo Bunting	Uncommon	
Spinus tristis	American Goldfinch	Uncommon	
Melospiza georgiana	Swamp Sparrow	Uncommon	
Melospiza melodia	Song Sparrow	Uncommon	
Vireo solitarius	Solitary Vireo	Uncommon	
Vireo olivaceus	Red-eyed Vireo	Abundant	

[1]Calculation of the Abundance categories is decribed in the preceeding text.

MAMMALS

METHODS

An inventory of large and small mammals was also conducted to document species composition on the Green Water Lake Natural Area. Small mammal populations were sampled during a summer trapping session, while large mammals were recorded by visual observations only. A three night trapping session (total trap nights = no. traps x no. nights trapped = 315) was carried out from 11 August to 14 August 1980. An attempt was made to sample all major habitat types on the Green Water Lake tract while keeping time and manpower constraints in mind.

Nine traplines were set consisting of museum special snap traps and Sherman and Hav-a-Hart live traps. The ratio of snap traps to live traps was approximately two to one. Six lines of 10 traps each and three lines of 15 traps each (total no. of traps = 105) were distributed on the Green Water tract.[7] The traps were laid down in an alternating pattern of one museum special followed by one live trap. Additional snap traps were placed at the beginning and/or end of each line. The distance between consecutive traps was 8-10 meters and the approximate length of each line was 90 meters or 140 meters, depending on the number of traps. Traps were baited with a mixture of peanut butter, oatmeal, bacon fat and crushed sunflower seeds. In addition to the traplines, two Victor gopher traps were set in an attempt to capture pocket gophers that were burrowing on the tract.

[7] Maps showing locations on traplines and descriptions of vegetation types traversed are available in the SNA files.

All traps were checked and rebaited each morning of the three night session. Dead captures were assigned a number corresponding to the trap number and retained. Specimens badly damaged by scavengers were disposed of. Information on species and sex was obtained, if possible, and in some cases measurements were taken prior to disposal of the specimen. Live captures were identifed by species and sex and retained only if the animal was in poor condition or if the species was not well documented on the area. An attempt was made to save skins and/or skulls from all members of the family Soricidae so that positive species identification could be made.

In the lab, collected specimens were identified to species (if possible), and measured. Measurements included weight (grams), total body, tail, ear and hind foot length (millimeters). Other information recorded included the date and location of the capture, type of trap and the sex and age (immature or adult) of the specimen.

Whenever possible, two specimens of each species caught were prepared as voucher specimens and deposited in the collection at the Bell Museum of Natural History, University of Minnesota. Skulls were kept to provide a means of positive identification. A catalogue of species and a trapping journal also accompained the vouchers to the museum. Copies of the catalogue and journal have been retained for the SNA files. Reproductive information, including measurements of testes and embryos, was obtained for voucher specimens and recorded in the catalogue. Mammals not prepared as vouchers were kept frozen and donated to supporting institutions.

In addition to trapping, drift fences were used to simultaneously collect herps and small mammals. As described earlier, two fences were established on 9 July and checked at least once a week until they were dismantled on 30 September 1980.

To supplement the trapping data, incidental mammal sightings were recorded whenever possible. Many additional hours were spent on the natural area and this increased the chances of encountering uncommon species or larger mammals that could not be trapped effectively. Mammal signs or tracks were also recorded as evidence of an animal's presence on the area. Incidental mammal sightings were recorded with the date, location and details of the observation. These incidentals were added to the existing list of species for the natural area. Copies of this information are available in the SNA files.

DISCUSSION

The results of the 1980 mammal inventory are presented in Table 8. The table indicates the method of identification (trapping, drift fence or sighted/ sign) and the number recorded with each method. Overall, a total of 23 species were observed on the Green Water Lake tract.

Results of the small mammal trapping are given as total numbers of each species caught. One hundred and sixteen animals were captured during the three nights trapping session (315 trap nights). This represents a trapping success of 37%. Nine species were positively identified by skins and skulls deposited at the Bell Museum. For those specimens of Permoyscus, Microtus and Sorex not deposited at the museum, identification is only certain to the generic level. These genera are likely to contain only those species that were already documented on the area. Despite the attempt to save skins and skulls, some specimens were too badly damaged to be retained for identification purposes.

Two members of the family Cricetidae (Peromyscus and Clethrionomys) accounted for 81% of the total number of specimens caught. These two genera were found consistently throughout most of the major habitat types sampled.

Other species found on the area include *Microtus pennsylvanicus*, *Zapus hudsonius*, *Sorex cinereus*, *Sorex arcticus* and *Blarina brevicauda*. The single *S. arcticus* was trapped in its preferred lowland habitat while *S. cinereus* and *B. brevicauda* were not restricted to any particular type. *Microtus pennsylvanicus* was found exclusively in lowland meadows. Two specimens of *Geomys bursarius* were also successfully trapped from burrows in an upland grassy meadow.

Thirteen additional species were recorded as incidentals on the Green Water Lake tract (Table 8). Among the more common species were the eastern chipmunk, eastern gray squirrel, red squirrel and whitetail deer. Although raccoons were observed only on one occasion, tracks were frequently seen along the lakeshore. The one time they were observed, on 26 August 1980, a family of raccoons consisting of one adult and three young were seen crossing County Road #35 in the SE1/4 of Section 33. Raccoons feed along the shores of Green Water Lake and it is likely that they are denning on the area. Other large mammals observed on the tract include beaver, bear, river otters and bobcat. Details of their observations are presented below.

Beaver have a history of activity on the natural area and are still active on the tract despite previous trapping by man (see Land Use History Section). The creek that flows out from the northwest corner of the lake has been the prime recipient of the beaver's work. Recently, a stick dam was constructed at the outlet of the creek in the NE1/4 of Section 33. In 1973, a dam further downstream was destroyed by the highway department when County Road #35 was to be paved. More dams, probably built by the same family of beavers, are known to exist even further downstream on adjacent property. Recent cuttings in the area indicate that the beaver are utilizing aspen from a stand along the northeast shore of the lake.

Despite the failure to see black bear on the natural area there is evidence of their presence. Tracks were found on 6 October 1980 in a mixed hardwood forest on the SW1/4 of Section 34. Area residents were also attracting bear(s) to bait stations set up prior to the 1980 hunting season. Bear hunting has probably been an activity on the area for many years.

The third uncommon large mammal, the river otter, was observed swimming in Green Water Lake on two dates, 12 August and 6 October 1980. On both occasions a group of five otters were seen close to the shoreline in the SE1/4 of Section 33. The clarity of the water probably makes Green Water Lake an attractive feeding location for the otter. Because the otter is a social animal the five observed on the natural area may represent more than a single family group.

Finally, evidence indicating that bobcat utilize the tract was found on one occasion. A single set of tracks was found on 14 August 1980 along a muddy trail in the SW1/4 SE1/4 of Section 33.

Mammals obtained in the two drift fences are also listed in Table 8. Sorex was the predominant genus collected, being found in both hardwoods and sedge marsh habitat. Peromyscus and Clethrionomys were found only in hardwoods while the one Microtus was captured in the sedge marsh. The drift fence established in the hardwood stand in the NE1/4 SE1/4 of Section 33 was successful in capturing a star-nose mole (Condylura cristata) on 26 August 1980. The specimen was in poor condition and only the skull was retained and deposited as a voucher in the Bell Museum collection.

Table 8. Mammals of the Green Water Lake Natural Area

Species		Method		
Scientific Name	Common Name	Trapping	Drift Fence	Sighted/Sign
Sorex cinereus	Masked Shrew	2		
Sorex arcticus	Arctic Shrew	1		
*Sorex sp.	-	1	19	
Blarina brevicauda	Shorttail Shrew	6		
Condylura cristata	Starnose Mole		1	
Sylvilagus floridanus	Eastern Cottontail			1
Marmota monax	Woodchuck			1
Tamias striatus	Eastern Chipmunk			Many
Sciurus carolinensis	Eastern Gray Squirrel			Many
Tamiasciurus hudsonicus	Red Squirrel			Many
Geomys bursarius	Plains Pocket Gopher	2		
Castor canadensis	Beaver			1 sighted; dam, lodge and cuttings observed.
Peromyscus maniculatus	Deer Mouse	3		
Peromyscus leucopus	White-footed Mouse	3		
Peromyscus sp.	-			
Clethrionomys gapperi	Boreal Redback Vole	28	2	
Microtus pennsylvanicus	Meadow Vole	3		

Table 8. Mammals of the Green Water Lake Natural Area

Species		Method		
Scientific Name	Common Name	Trapping	Drift Fence	Sighted/Sign
**Microtus sp.*	-	5	1	
Ondatra zibethica	Muskrat	1		
Zapus hudsonius	Meadow Jumping Mouse	3		
Erethizon dorsatum	Porcupine			1
Ursus americanus	Black Bear			1 sighted; bear-baiting observed.
Procyon lotor	Raccoon			4 sighted plus many signs.
Lutra canadensis	River Otter			5
Lynx rufus	Bobcat			Tracks
Odocoileus virginianus	Whitetail Deer			Many

*Specimens were too badly damaged to be retained for species identification.

MANAGEMENT RECOMMENDATIONS

If the Green Water Lake tract is designated a Scientific and Natural Area it will present a number of difficult management problems. Most of these concerns are related to the easy access to the property provided by County Highway #35 (Fig. 2). In view of this easy access, many of the following managment problems are likely to persist.

Of primary concern to the maintenance of the tract as an SNA is the preservation of the lake in an undisturbed condition. Disruption of the lake ecosystem can occur by both surface and groundwater pollution (see Lake Resources Section). Contamination from surface runoff is a more immediate concern because of the rapid movement of surface flow and the potentially sudden pollution effects. Groundwater contamination, on the other hand, usually occurs more gradually and could have more long-term effects on the quality of the lake.

Any type of human activity in, around, or on the lake can lead to a contamination problem. Most activities that currently take place in the area present no direct threat to the lake ecology. Hunting, snowmobiling and selective logging for firewood all take place on the Green Water Lake property (see Land Use History Section). While these three activities would not be permitted on an SNA, they do not in themselves endanger the lake. Prohibitions of firewood cutting and hunting would be particularly difficult to enforce; snowmobiling, however, may be effectively controlled by closing and placing barriers on the trails that cross the tract (Fig. 2).

Boating and fishing are probably more disruptive than the three above-mentioned activities to the water quality of the lake. This is because inadvertent spills and, at times, deliberate disposal of refuse would enter the lake directly. Due to the abundance of other lakes in the vicinity, however, Green Water Lake is little used for boating and fishing. While such activities could not be effectively eliminated from the lake, they could be curtailed by blocking the two access roads to the lake. One means of blocking access on both these roads and the various snowmobile trails would be to plant trees.

Trash piles are found at several locations on the Green Water Lake property. They should be removed, not only for aesthetic purposes, but also to eliminate possible pollution sources. It is doubtful that any of the debris now found on the tract would cause pollution problems; nevertheless, the presence of this trash might attract further dumping, which could include potentially harmful pollutants. The sites from which trash and deterioated building structures should be removed include each of the building sites marked on Figure 2. Some trash and litter may also have accumulated along Highway #35 and on the two access roads to the lake.

Salting of the highway in the winter could also lead to contamination of Green Water Lake (see Lake Resources Section). This question should be discussed with the Becker County Highway Department to see how the effects of road salt on the lake could be best minimized.

Finally, many of the boundaries of the tract need to be clearly marked. While it is not necessary to place markers along Highway #35, the boundaries that run through the forest (Fig.2) should be better labelled.