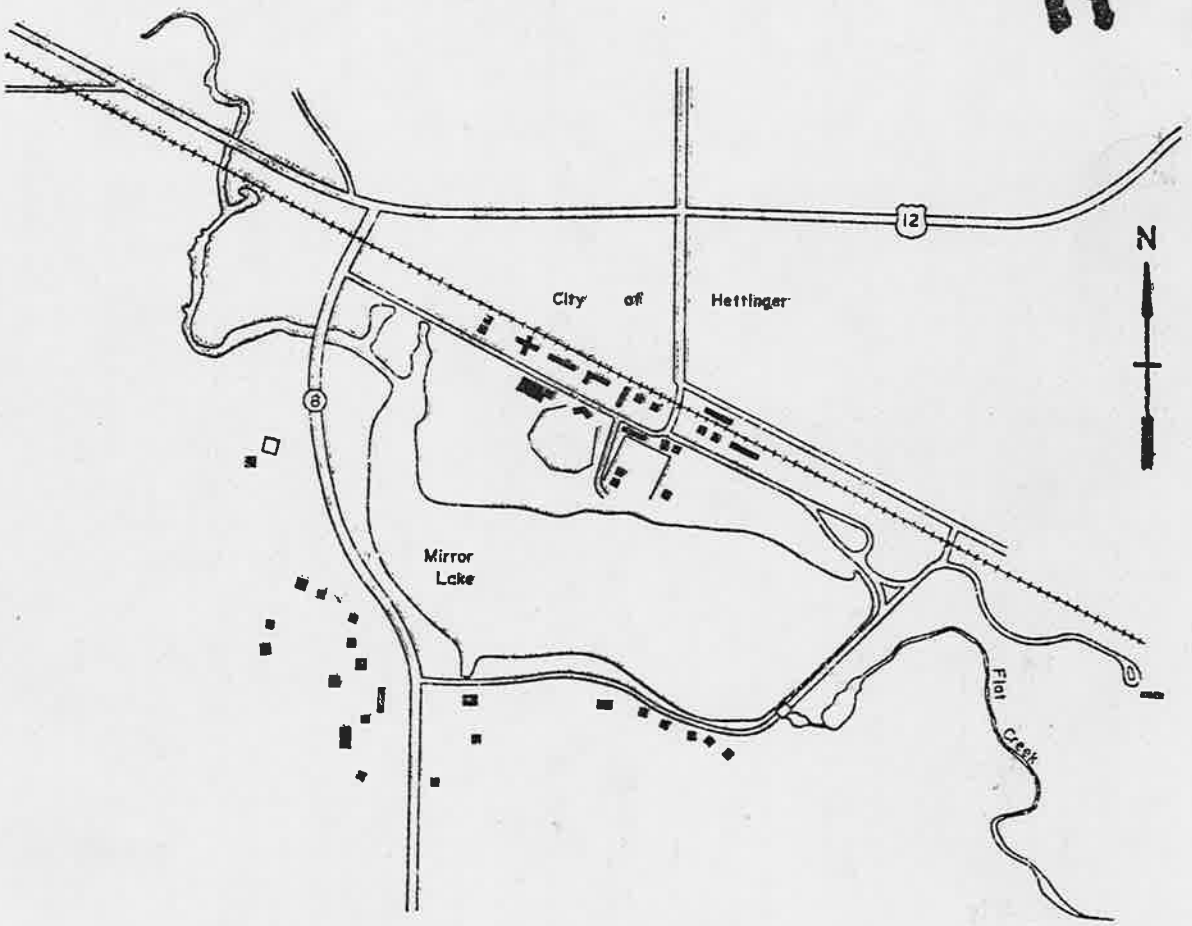
PRELIMINARY ENGINEERING REPORT

FEASIBILITY STUDY
FOR THE
RESTORATION OF MIRROR LAKE



NORTH DAKOTA
STATE WATER COMMISSION
FEBRUARY 1979

FEASIBILITY STUDY

FOR THE

RESTORATION OF MIRROR LAKE

Prepared BY:

DuWayne A. Marthaller
Investigation Engineer

PREPARED FOR:

Hettinger City Park Board

Submitted By:

David A. Sprynczynatyk
Director, Engineering Division

Approved By:

Vernon Fahy
State Engineer

NORTH DAKOTA STATE WATER COMMISSION
STATE OFFICE BUILDING
900 EAST BOULEVARD
BISMARCK, NORTH DAKOTA 58505

SWC Project #420

TABLE OF CONTENTS

LIST OF TABLES

Table No.

LIST OF FIGURES

Figure No.

PAGE

LIST OF APPENDIXES

Appendix

I. Introduction

PURPOSE AND SCOPE

This report on the restoration of Mirror Lake contains the results of a study conducted by the State Water Commission for the Hettinger City Park Board. The study's major objective is to develop alternatives for increasing the depth of Mirror Lake to provide for increased recreational activities. The accumulation of sediment and organic material in the reservoir have essentially eliminated the use of the reservoir as a recreation area. Heavy local interest in renovating the lake prompted the City Park Board to sponsor this engineering study.

The engineering investigation was comprehensive, covering all aspects of the purposed restoration project. The following sections explain in detail the procedures used in the investigation. The first section includes a detailed description of the planning area and a history of activity related to the reservoir. The second section covers the engineering analysis of the present conditions of the lake, the watershed and the dam. An explanation of the alternatives considered in the restoration program is contained in Section III. The next section contains an environmental assessment of the proposed project. A section on possible funding alternatives follows the environmental assessment. The final section contains a summary of the report including conclusions and recommendations. Following the report are the appendices and a glossary of terms and abbreviations.

In the engineering investigation, the best available technology was used to devise alternatives that would solve the problem most effectively. The

design of the alternatives comply with criteria established by the State Water Commission. Data used in this report was obtained by the State Water Commission, the U.S. Soil Conservation Service, L.W. Veigel and Company, the State Health Department, and the Hettinger City Park Board.

DESCRIPTION OF PLANNING AREA

The project study area is located on the south edge of the City of Hettinger in Adams County (see Figure 1). Mirror Lake was formed by a dam constructed on Flat Creek, a tributary of the North Fork of the Grand River. The creek is classified as an influent stream with intermittent flows.

The Mirror Lake watershed is located in the Great Plains physiographic province. More specifically, the area is located within the unglaciated portion of the Missouri Plateau. Surface runoff from the area eventually reaches the Missouri River and ultimately discharges into the Gulf of Mexico. Exposed bedrock of the Tongue River Formation from the Cenozoic Era is characteristic of the watershed. The landscape is largely the result of water and wind erosion. Deep V-shaped valleys and numerous flat-topped steep-sided buttes and hills are common. Most of the larger hills have a very resistant layer of caprock. These resistant beds in the Tongue River Formation contain sandstone and clinker, a reddish brick like material known as scoria.

Flat Creek flows through a broad valley with an average width of about 2 miles and very steep valley walls. Mean Sea Level elevations within the watershed vary from 3050 feet in an area two miles west of Bucyrus (See Figure 2 on page 8) to an elevation of 2550 at the base of the embankment of the dam.

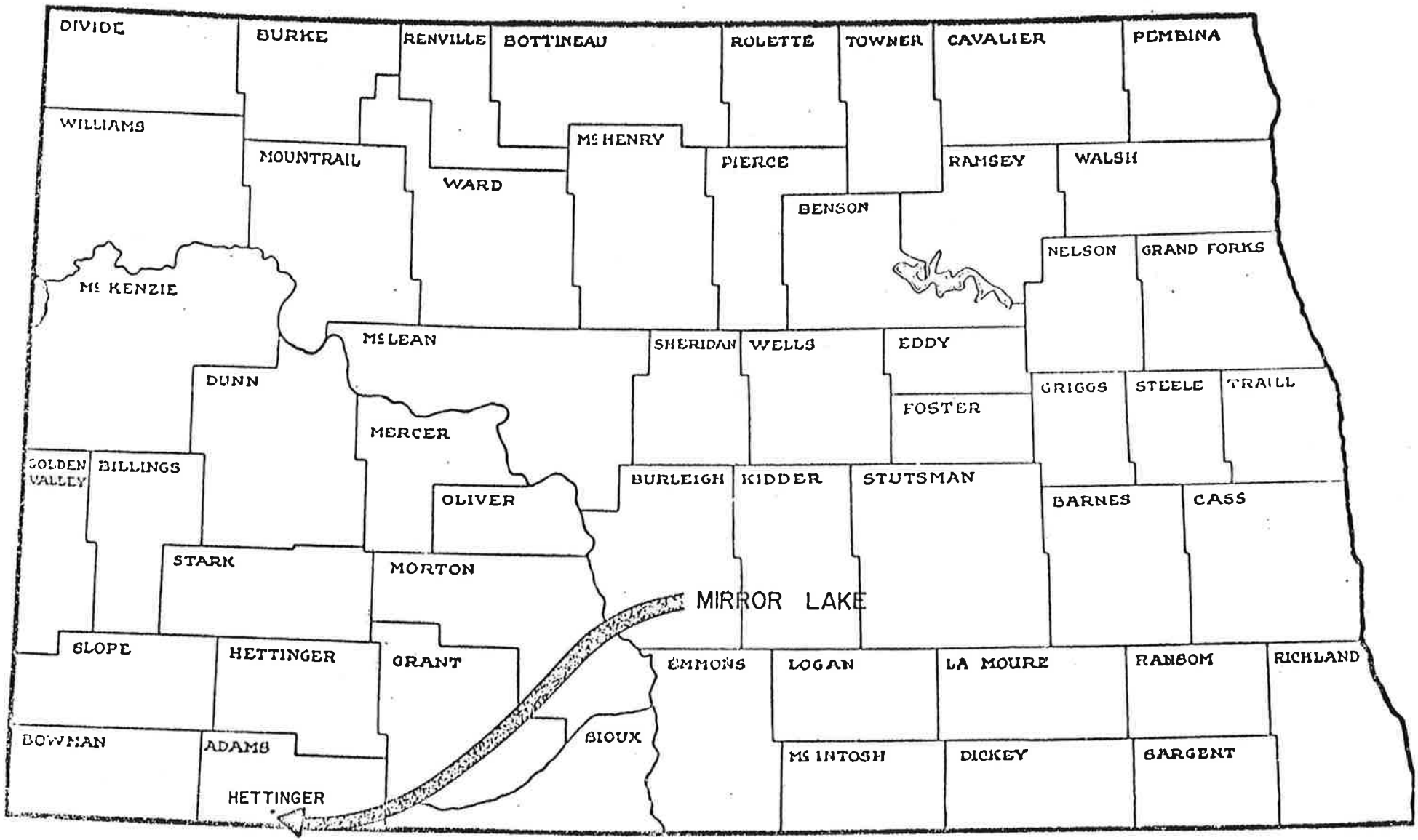


FIGURE 1
MIRROR LAKE
LOCATION MAP

The economy of the area is structured around agriculture. Approximately 50 percent of the land is productive farmland with the remaining portion being used for cattle grazing. The City of Hettinger is the commercial center for the surrounding agricultural community.

According to a 1970 census, Hettinger has a population of 1655. Freight transportation is supplied by the Chicago, Milwaukee, St. Paul and Pacific Railroad and the Barber Truck Transport Company. Daily commercial passenger transportation is provided by a busline to and from Bismarck, North Dakota. The medical facilities at Hettinger serve the surrounding communities within a radius of 40 miles. Surrounding towns include, Bucyrus, Reeder and Haynes in North Dakota and Lodgepole and White Butte in South Dakota.

Precipitation for crop production is adequate during normal years although occasionally the region suffers from periods of drought. The average annual precipitation is 14.5 inches most of which occurs during the growing season with 11.5 inches falling in the period of April through September. The average annual snowfall is 30 inches with 80 days of one inch or more snow on the ground. The annual mean temperature is 43°F.

BACKGROUND

According to the files of the Chicago, Milwaukee, St. Paul and Pacific Railroad Company, Mirror Lake Dam was constructed in 1909. Its purpose was to provide a water supply for the railroad. No additional information concerning the construction of the dam was available from the railroad.

Observations of local residents indicate that during the drought years of the 1930's the lake was nearly dry. Therefore, the lake had no recreational use until 1940 when the Game and Fish Department stocked the lake with Crappies and Bass. In 1946 the city council initiated a program to beautify the site and create a recreation area with picniking, boating and fishing.

In 1956, the City of Hettinger requested the State Water Commission to investigate the feasibility of removing the aquatic vegetation which was causing the lake to become unsuitable for recreational use. The State Water Commission completed a topographic survey and soundings of the lake. This investigation determined that the lake had deposits of sediment that ranged from two to four feet deep, and the cost of removing this sediment would be prohibitive.

No additional work was done on the project until 1959 when there was a renewed local interest in restoring the lake due to the limited number of water-based recreational facilities in the area. The Hettinger City Park Board suggested that the spillway be raised to increase the depth of the lake. The State Water Commission indicated to the Park Board that if the spillway were raised, the park area would be flooded. Dredging of the lake was again discussed but there were no funds available for such a project. Work on the project remained active until 1962, but no feasible alternatives were found.

The project was again reviewed in 1967 by the Hettinger City Park Board and the Adams County Water Management District. The State Water

Commission looked at the project again and determined that the project would be too expensive and that it would be cheaper to find another dam site in the area and develop it for the recreational needs of the area.

In 1970, a citizens committee for the restoration of Mirror Lake was formed. This committee requested the State Water Commission to provide technical assistance to the city in their attempt to obtain assistance from the National Guard to restore the lake. In this proposal, the National Guard would provide the equipment and labor and the cost for the fuel for the equipment would be absorbed by others. A cost estimate for the fuel was made and it was estimated that it would take 100 days to complete the project. No further action was taken on this proposal.

Since 1970, there have been several local interest groups that have attempted to determine a viable way of restoring the lake. In February of 1978 the Hettinger City Park Board requested that the State Water Commission do a comprehensive engineering analysis of the project. A copy of the investigation agreement is contained in Appendix A. This report is the result of this engineering investigation.

II. ANALYSIS OF EXISTING CONDITIONS

PHYSICAL DATA

Mirror Lake has a drainage area of 71.2 square miles, based on U.S. Geological Survey topographic maps. The drainage area boundary is delineated on Figure 2. The watershed has a length of 18 miles and an average width of 4.5 miles.

The embankment of the dam is 800 feet long and has a height of 15 feet. The top of the embankment is at mean sea elevation 2564.8. Figure 3 shows the general layout of the dam and the reservoir. There has been a slope failure on the upstream side of the embankment, approximately 100 feet from the north edge of the spillway. It is an arc-type failure with a width of approximately 20 feet. The failure is located entirely on the upstream side of the embankment and has not affected the crest of the dam. No abnormal seepage is evident in the area of the slide. The remainder of the embankment is in good structural condition.

The spillway consists of an overflow weir constructed of reinforced concrete. It has a length of 140 feet and a crest width of 16 feet. The elevation of the spillway crest is 2559.9. The spillway is in good structural condition. There is an approach section to the concrete weir that is used as a roadway that extends the entire length of the embankment. There is evidence of erosion in this approach section.

In its present condition, the lake has a surface area of 72 acres, an average depth of 4.7 feet and a maximum depth of 12.8 feet. The south side of the lake is bounded by a roadway that is approximately 10 feet above the elevation of the spillway. There are several houses on

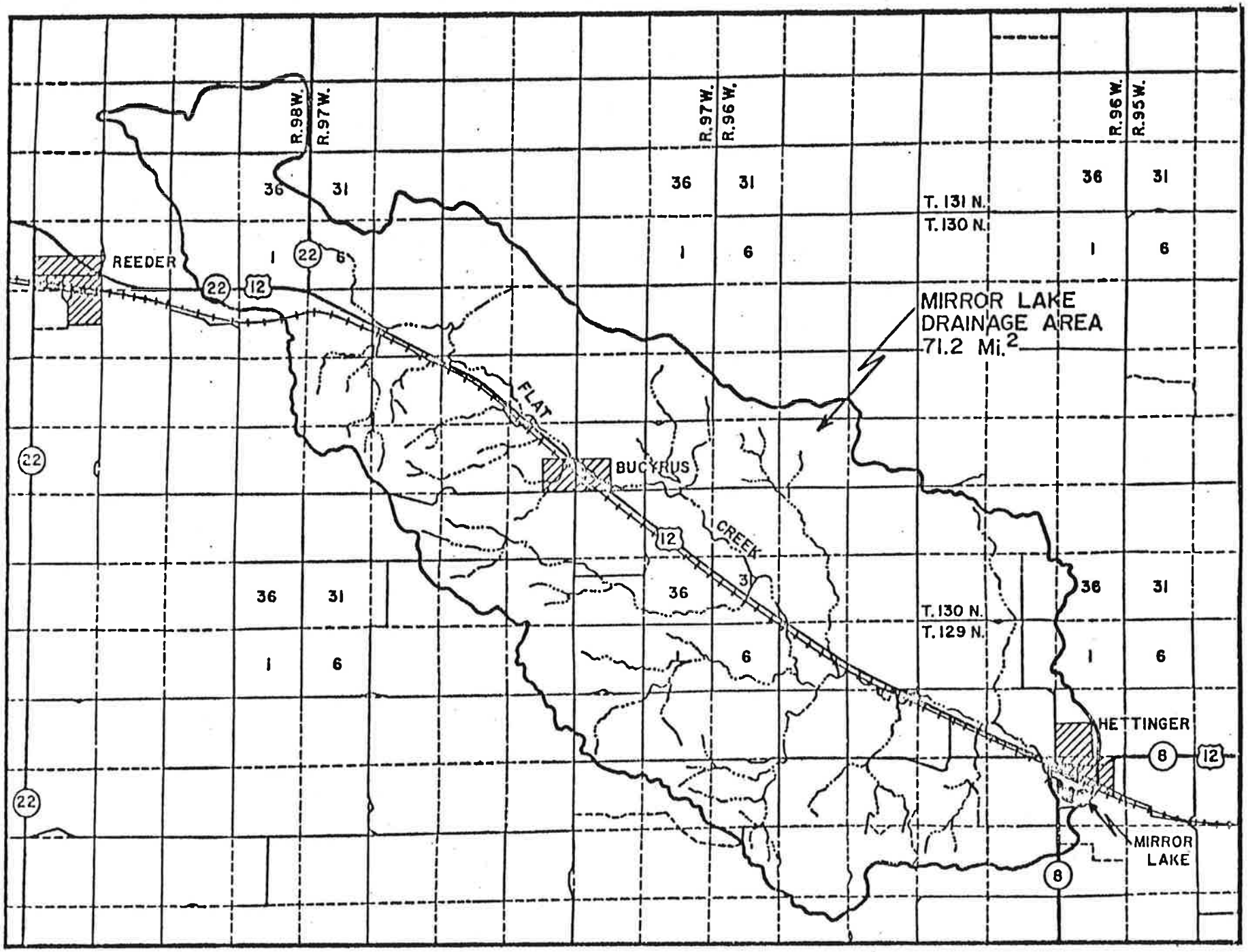


FIGURE 2

MIRROR LAKE WATERSHED

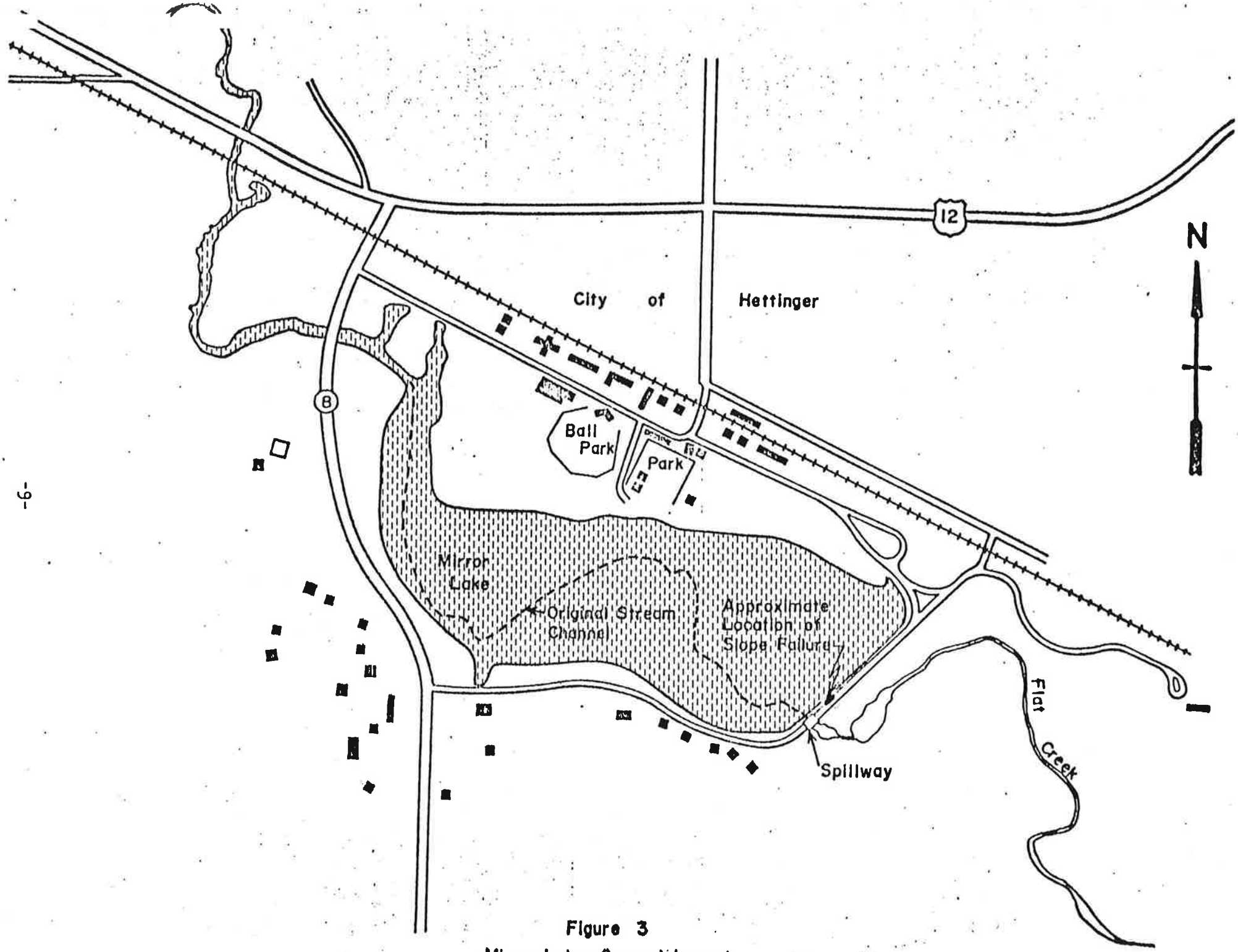


Figure 3
Mirror Lake - General Layout

the south side of this road. The west side of the main body of the lake is bounded by State Highway 8. On the north side of the lake is a park, a museum and a baseball diamond. Overnight camping facilities have recently been installed near the park.

The dam and the lake are owned by the city of Hettinger. Figure 4 contains a map showing a breakdown of the land ownership within the vicinity of the lake. The city is currently negotiating with the railroad to obtain additional land.

SEDIMENTATION

A considerable amount of data has been obtained on the original and present capacity of Mirror Lake. In 1956, the State Water Commission conducted soundings using a grid system with a spacing of 100 feet. This survey extended for a distance of 1,800 feet from the embankment and obtained water depths only. Figure 5 shows the area that was surveyed. L.W. Veigel and Company, consulting engineers from Dickinson, North Dakota, completed a similar survey in 1974. They obtained data on sediment depths as well as water depths. This survey was based on a grid system very similar to the 1956 survey except that it covered the entire main portion of the reservoir. The area surveyed is shown on Figure 6. A topographic survey of the shore line was conducted in August of 1978 by the State Water Commission. This survey extended from the embankment to the area north of U.S. Highway 12, where the backwater terminates (See Figure 7). Permanent range lines were set and a sedimentation survey was conducted in October of 1978. Plates 1, 2, and 3 contained in Appendix B, show the topography of the shoreline and the location of the range lines.

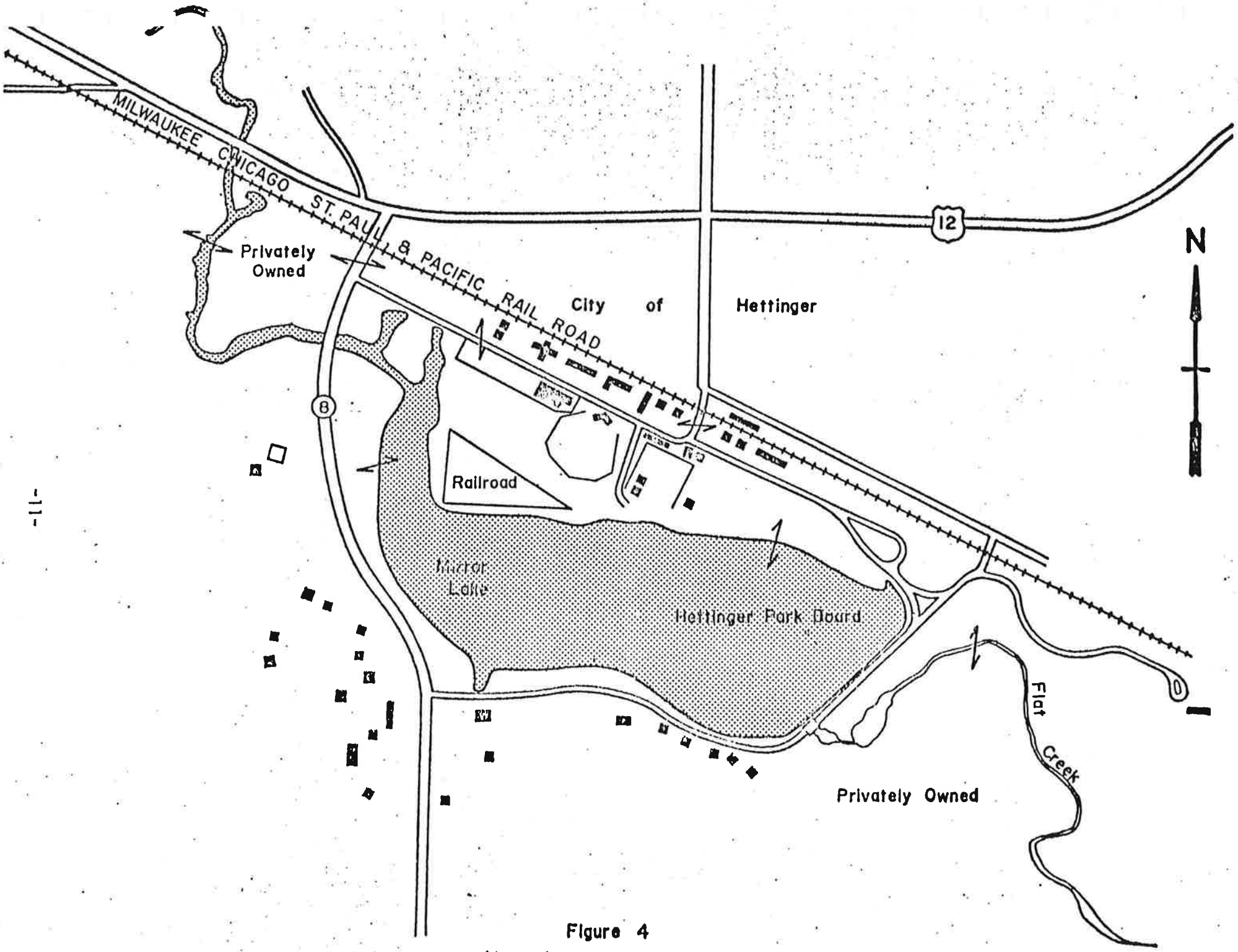


Figure 4
Mirror Lake - Land Ownership

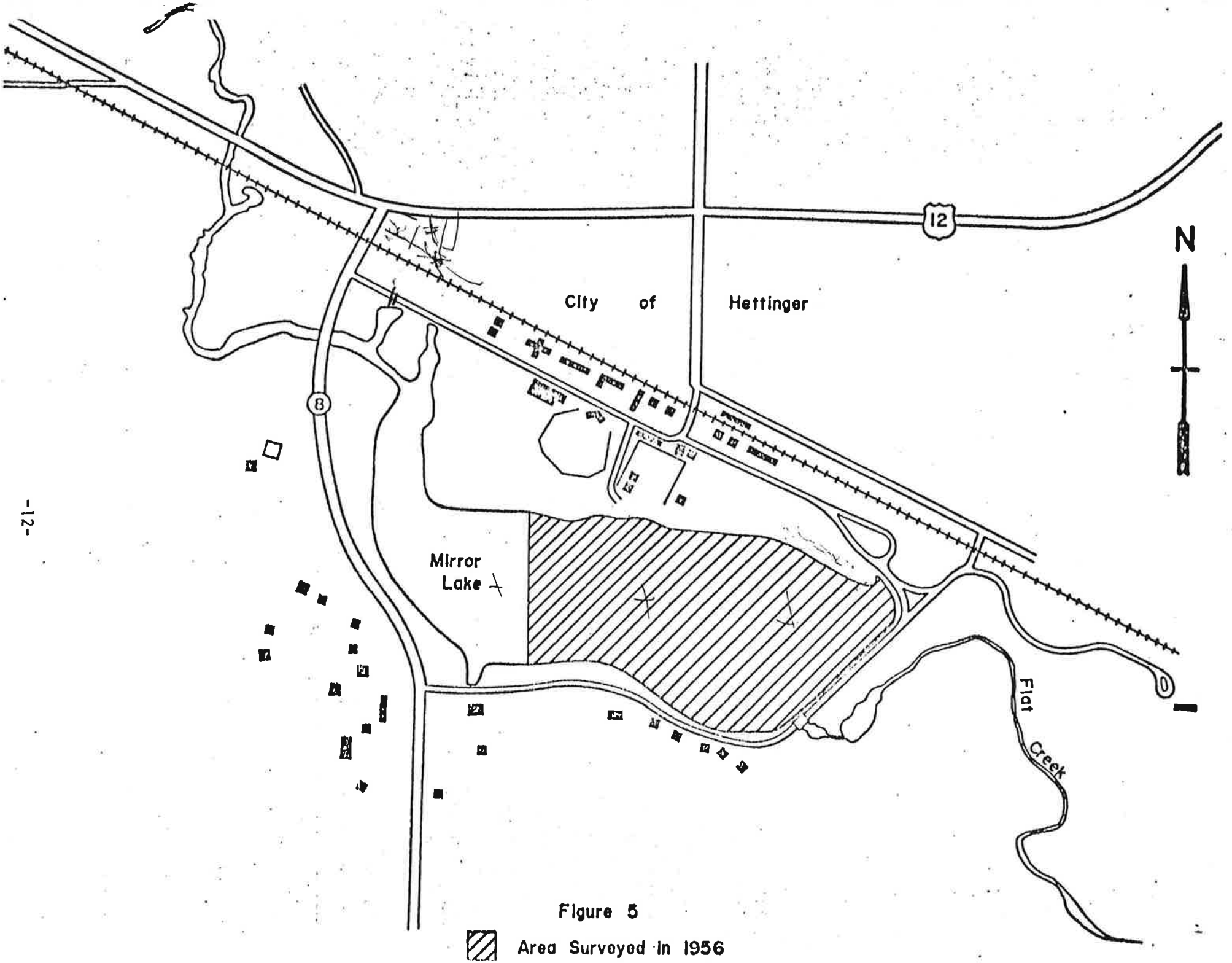


Figure 5

Area Surveyed in 1956

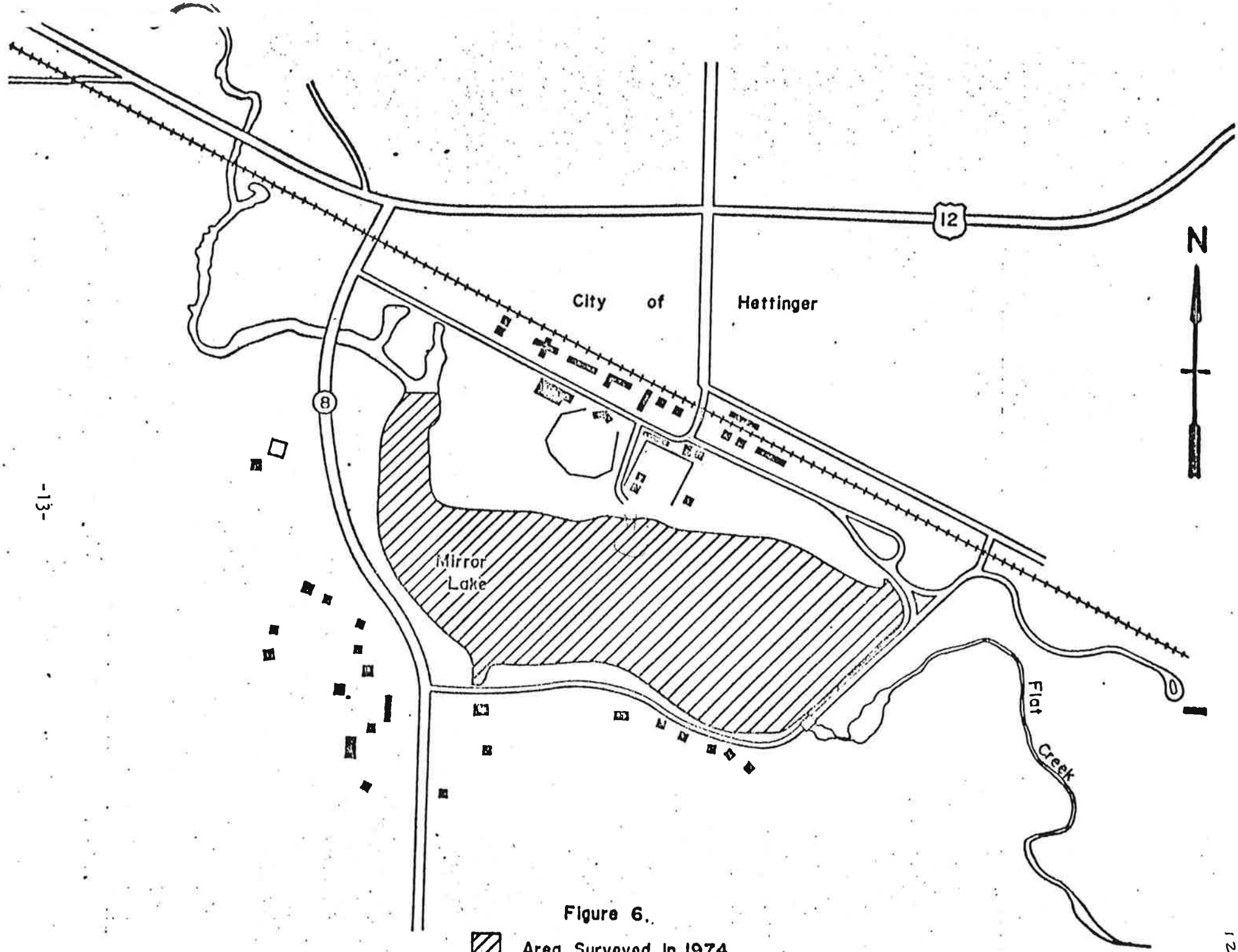


Figure 6.

Area Surveyed in 1974

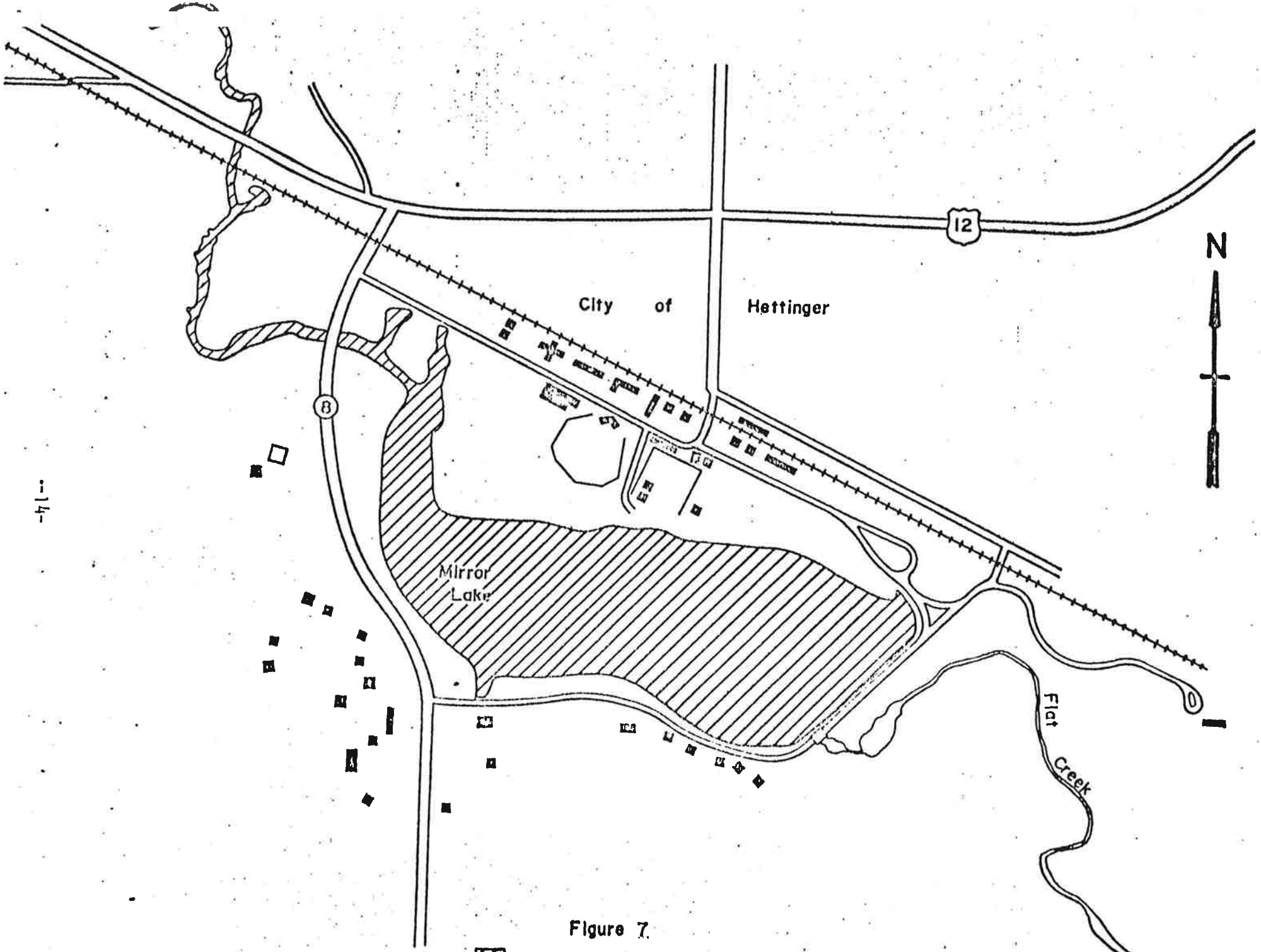


Figure 7.

Area Surveyed In 1978

The aforementioned data was analyzed to determine the amount of sediment in the lake and the history of the sediment accumulation. The capacities based on the 1956 and 1974 surveys were computed using the average-end-area method. The average-end-area formulas are contained in Appendix C. The 1974 survey was done through the ice. It is assumed that a blunt ended object was used to estimate the depth of sediment by the penetration resistance of the sediment. The soundings and sedimentation survey conducted in 1978 was conducted according to guidelines established by the U.S. Soil Conservation Service.

In the method developed by the Soil Conservation Service, primary control is established by a traverse of range lines and an accurate shore-line map. In August, 1978, thirteen range lines were established parallel to the embankment by a permanent system of monuments (See Plates 1, 2 and 3, Appendix B for location of range lines). These range lines may be used for future surveys. Cross-sections were obtained by taking water depth and water plus sediment depth readings every 50 feet along each range line. The original topography of the lake bed was not known so a spud had to be used to obtain the sediment depths. The spud is a case-hardened steel rod with machined grooves at intervals of one-tenth of a foot. Each groove tapers outward from a maximum depth of one-quarter of an inch to zero at the rim of the next tenth above. The spud is attached to a rope and is dropped from the side of the boat. The spud penetrates the sediment and a portion of the underlying lake bed. The spud is then drawn out of the water and the soil retained in the grooves is visually analyzed. An obvious change in consistancy of the soil or remains of original prairie sod will mark the boundary between the sediment deposits and the original lake bed. The spud is

generally used on two or three readings on each rangeline. A blunt ended range pole is used when the amount of force it takes to penetrate the original bottom of the lake bed can be correlated with the readings obtained from the spud. The cross sectional data is then used to compute the sediment volume and storage capacity using the modified end-area method. The formulas used in the modified end-area method are also contained in Appendix C. The average end-area method and the modified end-area method give essentially the same results if the end areas are representative of the area between the cross sections. If there is a significant deviation of the shoreline between the cross sections, the modified end-area method will give the more accurate estimate of the actual volume.

The storage capacities and sediment volumes are summarized in Table I.

TABLE I

STORAGE CAPACITY AND SEDIMENT VOLUME

Data Source	Date	Storage Capacity at Time of Survey Acre-Feet	Sediment Volume, Ac-ft.	Sediment Volume, $Cu. Yd^3$	Original Capacity Acre-Feet
State Water Commission	1956	227	-*	-*	-*
L.W. Veigel & Company	1974	323 (225**)	157	253,300	480
State Water Commission	1978	337	120	193,600	457

* Sediment Data Not Obtained
** Volume in same area surveyed in 1956

Comparison of the 227 acre-feet figure calculated from the 1956 data with the 225 acre-feet volume over the same area using the 1974 data indicates that there has been less than a one percent reduction in capacity in the last 20 years. Therefore, most of the sediment accumulation occurred before 1956. The following theories are proposed as reasons for the decrease in the sediment deposition rate in Mirror Lake in the past 20 years. This decrease could be the result of the shorter residence time caused by the decrease in the lake volume as the sediment accumulates. The residence time is discussed in more detail when the sedimentation rate is analyzed. Another theory is that in its present condition, the aquatic vegetation in the upper part of the reservoir traps the sediment before it can enter the main part of the reservoir where the camparison of sediment volumes was made. The final theory suggests that a considerable amount of wind eroded topsoil was deposited in the lake in the 1930's, and the sediment carried by the surface runoff from the watershed is not significant enough to cause any major accumulation in the lake. Some local residents have stated that a considerable amount of sediment was deposited in the lake during the construction of Highway 8 on the west side of the reservoir. Also contributing to the sediment accumulation is the organic material that is generated within the lake itself.

The State Water Commission survey in 1978 indicates an existing capacity of 337 acre-feet. The 1974 survey indicates a volume of 323 acre-feet over the main portion of the reservoir. These two figures compare very well when considering the proportionate area of the lake covered in these two surveys. The sediment volumes obtained from these two surveys do not correlate. The 1974 survey indicates a sediment

volume of 157 acre-feet or 253,300 cubic yards. The 120 acre-feet or 193,600 cubic yards volume computed from the 1978 data is significantly lower than the 1974 figure and it covers the entire lake. This discrepancy is most likely due to a difference in the procedure used to measure the depth of the sediment. Both figures will be used throughout the report to obtain a range of values for each calculated parameter.

The sediment data collected indicates that there has been a 26-33 percent reduction in the storage capacity of the reservoir. The average depth of the lake has been reduced from 6.3-6.9 feet originally to 4.7 feet in its present condition. The sediment depths in the reservoir range from 1 to 5 feet with an average depth of 1.7 to 2.5 feet depending on which survey data is used. The above data indicates that there has been a significant reduction in the storage capacity of the lake. Therefore, there has been a reduction in the residence time of the water flowing through the reservoir.

Assuming a discharge of 420 cfs, which would be one foot of water going over the spillway, the residence time for the current capacity of the lake would be 9.7 hours. Using the original capacity of the lake, based on the 1978 survey, the residence time is 13.2 hours. According to local residents, the discharge over the spillway seldom exceeds one foot. Suspended particles larger than colloidal size will generally settle out of the upper layer of the reservoir in 2 to 8 hours. Therefore, even at its present capacity the residence time is sufficient to allow for sedimentation of the suspended particles. The reduction of the residence time as a result of sedimentation is not a reason for the reduced rate of sediment deposition in the lake.

Another important factor involved in the sedimentation of lakes is the amount of soil that is eroded from the watershed and transported into the lake. There are several factors that determine the amount of sediment that is carried by the surface runoff. Among them are soil type, amount of runoff, slope of land, land use and conservation practices used.

On June 21, 1978, representatives of the Soil Conservation Service toured the Mirror Lake Watershed. The purpose of this reconnaissance was to examine the watershed and determine what land treatment measures could be incorporated into the future plans to renovate Mirror Lake. A copy of the report on this field examination is contained in Appendix D. The following paragraph will summarize the contents of this report.

The land use breakdown for the watershed is shown as follows:

Table 2

LAND USE

Land Use	Percentage
Cropland	51.7
Pasture & Hayland	18.0
Rangeland	26.7
Other	3.6
	100.0

County records indicate that 50 to 60 percent of the watershed is under cooperative agreements with the Soil Conservation District. Approximately 55 percent of the area is adequately treated. Treatment practices include conservation cropping systems, crop residue use, stuble mulching, strip cropping, grassed waterways, windbreaks and buffers, and several ponds. The report recommends that 20 percent of the existing cropland be converted to grassland. The treatment practices used in the watershed

should be increased and there is a need for improvement in pasture, hayland and range management. The Soil Conservation Service's recommended soil loss tolerance of 5 ton/acre-year is not believed to be exceeded as an overall average in the watershed. These and other observations made during the examination indicate a low sediment delivery from the watershed into Mirror Lake. Flat Creek is bordered almost continuously by grasslands that act as a very effective buffer and filter strip. The report describes the soil conditions of the watershed as follows. On the valley floor are nearly level to gently sloping medium to light textured soils, with minor problems of runoff and/or erosion. On the North and West sides of the watershed are mainly coarse textured gently sloping to very steep soils, which have wind erosion problems, but no special runoff or water erosion problems. The South side, and a fringe area on the West and North sides of the watershed have medium textured soils that are gently to steeply sloping from which erosion could occur. The Soil Conservation Service report concludes that: "Some of the smaller tributaries may deliver sediments directly into Flat Creek, but I believe the majority of sediments from the eroding slope will be deposited before entering Mirror Lake". This report was submitted by Mr. Ed Weimer, Agronomist with the Soil Conservation Service.

Further study was made on the watershed to quantify the actual sediment delivery from the watershed. The Universal Soil Loss Equation (USLE) was used to predict the actual field soil loss from the watershed. The use of the Universal Equation for this purpose is relatively undeveloped. However, the U.S. Department of Agriculture, Agricultural Research Service in Riesel, Texas developed a procedure to apply the USLE to

determine sediment yield from an entire watershed. This procedure is outlined in the December, 1972 Journal of the Hydraulics Division of the American Society of Civil Engineers.

The Universal Soil Loss Equation is: $A = R\ K\ LS\ C\ P$ in which A = the computed soil loss per unit area; R = the rainfall factor; K = the soil-erodibility factor; LS = the slope length and gradient factor; C = the crop management factor; and P = the erosion control practice factor. Figure 8 contains a provisional soils map of the watershed. The values for the above parameters for each type of soil are contained in Table 3. These values were obtained from the Soil Conservation Service.

Table 3

"USLE" PARAMETERS FOR MIRROR LAKE WATERSHED

Soil Assoc. No.	Soil Series	% of Assoc.	K	L	S	LS	C		P	
							Crop	Grass	Downhill Farming	Contour Farming
1	STRAW	50	0.28	500	1	0.20	0.25	0.02	1.0	0.6
	SHAM 30	30	0.28	400	2	0.30	0.30	0.02	1.0	0.6
	PARSHALL	20	0.20	250	4	0.55	0.30	0.04	1.0	0.6
2	VEBAR	64	0.20	200	6	1.00	0.19	0.10	1.0	0.5
	FLASHER	40	0.17	200	10	1.90	0.19	0.15	1.0	0.6
3	CABBA	60	0.32	150	15	3.00	0.40	0.20	1.0	0.8
	SEN	20	0.32	300	6	1.20	0.35	0.04	1.0	0.5
	AMOR	20	0.28	400	4	0.70	0.35	0.04	1.0	0.5
6	SEN	50	0.32	400	4	0.70	0.35	0.10	1.0	0.5
	AMOR	30	0.28	300	5	0.90	0.35	0.10	1.0	0.5
	CABBA	20	0.32	150	15	3.00	0.40	0.20	1.0	0.8
7	REGENT	70	0.32	400	4	0.70	0.35	0.10	1.0	0.5
	SEN	30	0.32	300	6	1.20	0.35	0.04	1.0	0.5
8	RHOADES	50	0.32	400	1	0.20	0.25	0.02	1.0	0.6
	GBAIL	30	0.32	400	1	0.20	0.25	0.02	1.0	0.6
	SEN	20	0.32	300	6	1.20	0.35	0.04	1.0	0.5

The average annual rainfall factor for the Mirror Lake Watershed is 60. The parameters used in the "USLE" are dimensionless and are expressed as a ratio of those for a standard watershed. The total soil loss is

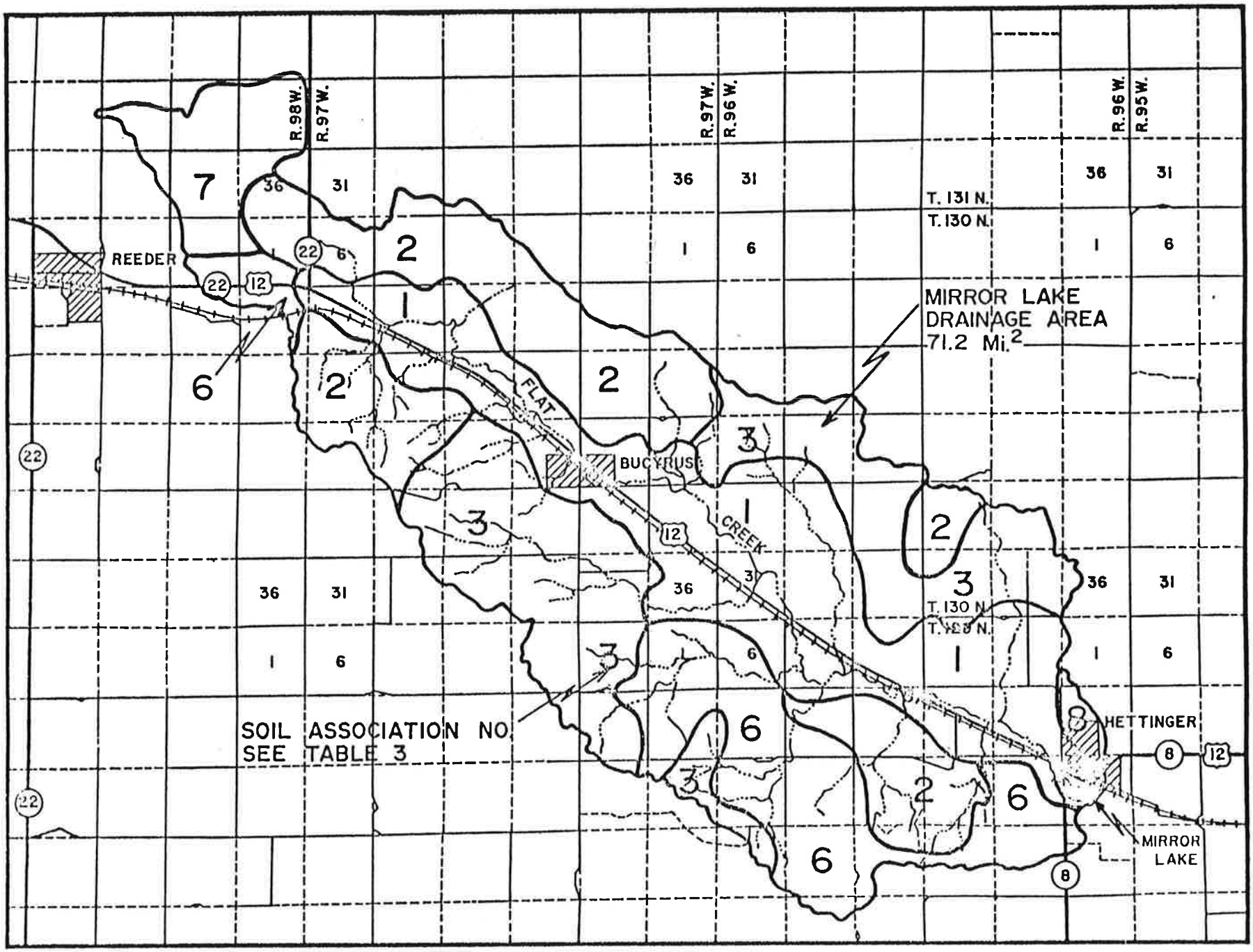


FIGURE 8

MIRROR LAKE WATERSHED

PROVISIONAL GENERAL SOILS MAP

expressed in tons/acre-year. Using this procedure the average annual soil loss from the Mirror Lake Watershed was computed to be 3.6 tons/arce-year. This represents 72% of the soil loss tolerance of 5 tons/acre-year.

The average annual volume of sediment that enters the lake each year is equal to the soil loss times the sediment delivery ratio. Empirical methods for the determination of the sediment delivery ratio have not been fully developed. Therefore, it is not possible to accurately determine the expected volume of sediment delivered into Mirror Lake. However, a sediment delivery ratio can be computed from the actual volume of sediment that has been deposited in Mirror Lake since it was built.

The actual sediment deposited in the lake is equal to the volume of sediment that enters the lake times the trap efficiency. The trap efficiency is based on the ratio of the capacity of the reservoir to the average annual runoff from the watershed. The trap efficiency of Mirror Lake is estimated at 94%. This was obtained from a graph developed from data from 41 reservoirs in the United States. This graph is contained in the book Water Resources Engineering by Linsley and Franzini.

The amount of sediment in the lake was computed from the 1978 survey data and the soil loss was computed from the Universal Soil Loss Equation. Therefore, a sediment delivery ratio can be computed. Assuming a dry unit weight of sediment of 60 lbs./ft.^{3}, a sediment delivery ratio of 0.14 was computed. Assuming a dry unit weight of sediment of 90 lbs./ft.^{3}, a sediment delivery ratio of 0.22 was obtained. The computations are contained in Appendix E. These are moderately low sediment delivery

ratios which substantiates the field observations of the Soil Conservation Service. Therefore, the Mirror Lake watershed does not contribute large volumes of sediment into the Lake. If the land treatment program recommended by the Soil Conservation Service is implemented, the inflow of sediment could be reduced even further. If the existing sediment was removed from the lake and a land treatment program implemented in the watershed, Mirror Lake could possibly become a useful body of water for many years.

SUBSURFACE EXPLORATION

Three soil test borings were made on March 20, 1978. The borings were done by Soil Exploration Company of St. Paul, Minnesota, under the supervision of the State Water Commission. The borings were done through the ice at the approximate locations shown in Figure 9. Two thin wall (Shelly) tube samples were taken on boring No. 2. Standard Penetration Tests were conducted on all borings and disturbed samples for mechanical analysis were obtained from each boring.

Figure 10 shows the boring logs and the results of the penetration tests. The boring logs indicate that the lake bed contains alluvial material consisting primarily of sandy silt with traces of gravel and clay particles. The depth of the bedrock varies from approximately 12 feet from the ice surface in boring #1 to 22 feet in boring #2 and boring #3. This data is useful in determining the most applicable means of excavation.

Four permeability tests were performed on the two thin wall tube samples. These tests were conducted by Soil Exploration Company. A

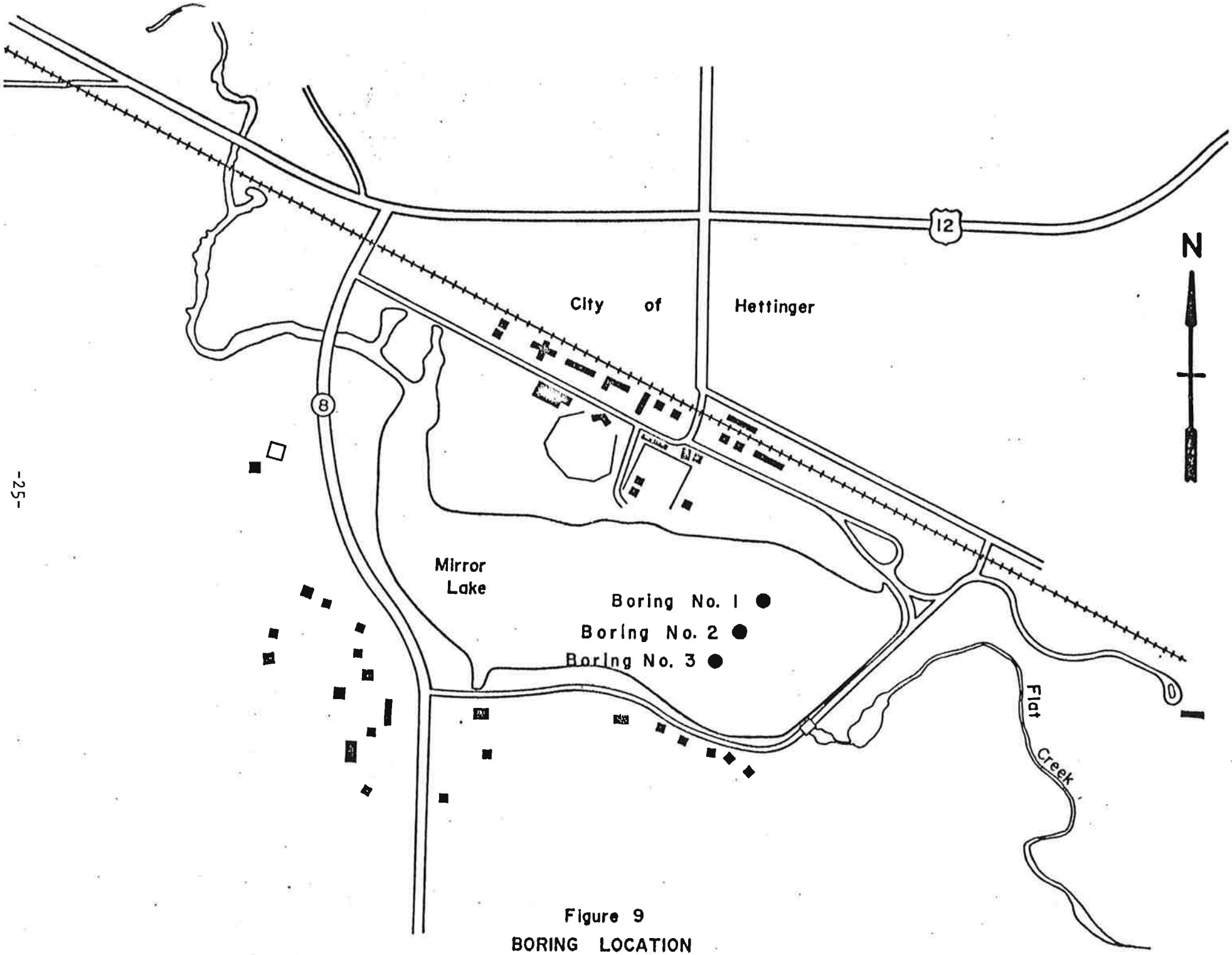


Figure 9
BORING LOCATION

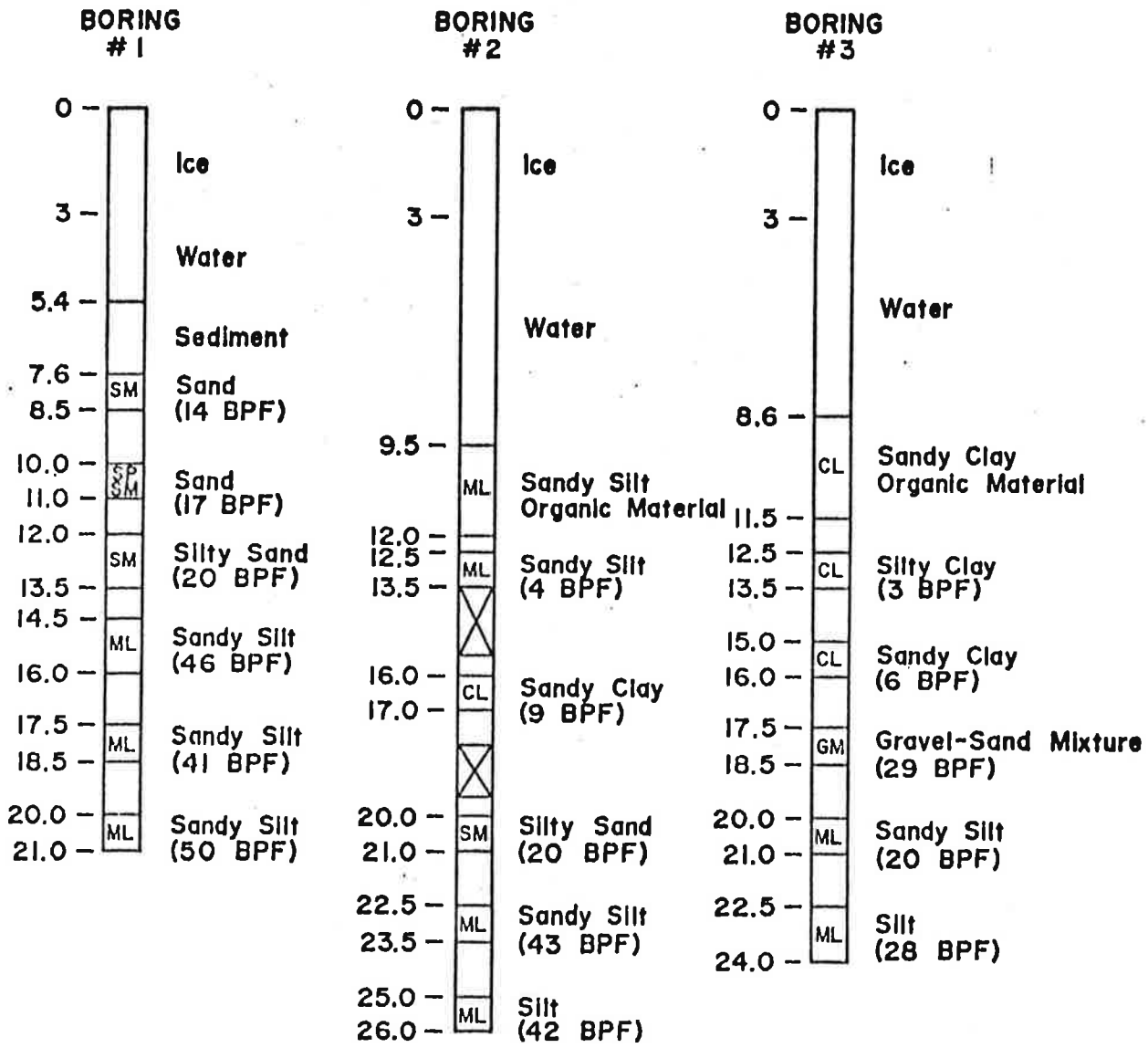


Figure 10
BORING LOGS

copy of their report is contained in Appendix F. The permeabilities vary from 1.6×10^{-5} cm/sec to 2.0×10^{-8} cm/sec. This indicates that the permeability of the underlying deposits vary from poor to practically impervious. These permeabilities give an indication of the ability of the material to drain if the water was removed from the lake. They will also be used in estimating the anticipated additional seepage through and under the embankment if the lake is deepened.

GROUNDWATER CONDITIONS

It is very important to look at the existing groundwater conditions in detail. If there is groundwater inflow to the lake, either directly or from springs discharging into the upstream channel, it will have a significant effect on the degree of dewatering that would be required to allow excavation. There are several characteristics of the area surrounding Mirror Lake that indicate a water table at or near the ground surface both upstream and downstream of the reservoir.

Several isolated potholes exist both upstream and downstream of the lake, along the valley floor. This is a visual indication of a high groundwater table. Several residents on the South side of the lake and within the city of Hettinger have shallow wells that range from 30 to 50 feet deep. Some of the residents indicated they have observed water levels in these wells approximately 5 feet from the ground surface.

Some groundwater and isolated pond elevations were obtained by the State Water Commission on November 8, 1978. Directly upstream of the reservoir, on the North side of U.S. Highway 12, there are several isolated ponds and a dugout that is used for livestock watering. The elevations of these ponds were 0.2 to 1.0 foot higher than the water surface elevation of the reservoir. This indicates a ground-water gradient towards the lake. This gradient would be reversed with a sudden rise in the level of the lake.

A posthole digger was used to dig two shallow holes in the park on the North side of the lake. One hole was dug in an area with a ground surface elevation of 2662.8. Saturated sand and gravel was reached at

a depth of approximately 3.5 feet. A hole dug in a low area near the lake shore indicated a water surface at a depth of 2.0 feet below ground level. These water surfaces were very near the water level of the lake at the time the holes were dug.

An isolated pond was found on the South side of the lake, separated from the lake by a road. The water surface of this pond was found to be 1.1 feet higher than the water surface elevation of the lake. This also indicates a water table gradient towards the lake.

Two holes were dug downstream of the embankment and water levels were found to be within 1 foot of the ground surface. Further downstream several isolated ponds were observed along the valley floor. The water surface elevations of these ponds are at least 10' below the water surface elevation of the lake.

This observation indicates that after the reservoir was drained, the water table would be lowered within the area surrounding the lake. The water table would approach an equilibrium gradient between the natural water tables upstream and downstream of the lake.

WATER QUALITY

Very little water quality data exists for Mirror Lake. The only data available is from three samples taken on December 7, 1977 by the State Health Department. The concentrations of several water quality parameters were determined from these samples and are summarized in Table 4. The exact sampling location is not known.

Table 4

WATER QUALITY DATA

Date	Time	FECAL COLIFORM/100ML	P mg/l	PO_4-P mg/l	Hardness mg/l	Ca mg/l	Mg mg/l	Na mg/l	Na mg/l	Cl^- mg/l	SO_4 mg/l	TDS mg/l
9-7-77	12-1 p.m.	1700 (Surface) 540 (Bottom)	0.259	0.009	549.	55.0	100.	385.	60.3	10.	976.	1820.
9-7-77	12-1 p.m.		0.211	0.008	470.	51.5	83.0	314.	59.1	7.5	838.	1497.
9-7-77	12-1 p.m.		0.291	---	549.	56.0	99.5	376.	59.7	10.	1046.	1802.

No conclusive statements can be made on water quality data from only three samples taken at the same time at an unknown location. However, some general statements can be made about the concentrations of the various parameters. The fecal coliform concentrations of 1700 and 540 MPN/100 ML represent reasonably high concentrations of fecal coliform bacteria. The phospherous concentrations obtained from the samples are low. However, the abundance of aquatic vegetation in the lake indicates that phospherous is available for plant growth. The hardness concentrations indicate that the water in Mirror Lake is very hard. This is also indicated by the high concentrations of calcium and magnesium. The high concentrations of sodium, sulfate and total dissolved solids are typical of groundwater found in Southwestern North Dakota.

The State Health Department has contracted with the U.S. Geological Survey to conduct a water quality sampling program on the lake. The program will consist of obtaining samples three times per year at regular intervals. The first samples will be takin in February, 1979 and the results will be available in early March, 1979. More data will become available as the project progresses.

III. RESTORATION PROGRAM

DISCUSSION OF ALTERNATIVES

The existing condition of the lake prohibits the sustainment of fish life. There are some Sunfish and Bullheads in the lake, but winter kill limits the population. The oxygen demand of the lake sediment depletes the dissolved oxygen in the lower depths of the reservoir. According to the North Dakota Game and Fish Department, the lake would sustain fish life if the organic deposits were removed. However, the preferred alternatives would be to deepen the lake to a maximum depth of 20 feet with an average depth ranging from 10 to 15 feet.

A major consideration in deepening the lake is the adequacy of the existing embankment. The embankment is in good structural condition. The slope from the upstream toe of the embankment to the deepened area of the lake would not be any steeper than 15 horizontal to 1 vertical with any of the alternatives. Therefore, slope stability should not be a problem. The existing slope failure does not appear to be deep seated in the embankment, so it should not cause additional problems. The permeability tests preformed on the soil borings indicate that the underlying alluvial deposits and bedrock have poor permeabilities. Therefore, even though the seepage distance would be decreased if the lake is deepened, there should not be a seepage problem.

There are two basic proposals that will be considered for deepening the lake. One involves the use of a hydraulic dredge. The other would be to drain the reservoir and excavate the material by conventional means. Different construction and implementational altervatives will be given consideration for each proposal. For example, if a hydraulic

dredge is used, the City may choose to purchase a dredge or contract out for the work. They must also decide the amount of material they want to remove from the lake. If the reservoir is drained, all types of excavation techniques must be considered. Aeration was not considered a viable alternative for restoring the lake. The North Dakota Game and Fish Department has been successful in removing organic sediment from a lake in the Turtle Mountains by aeration. However, it has taken 20 years to remove approximately one foot of sediment. Mirror Lake is too far advanced to recover with just aeration in a reasonable period of time. Aeration, combined with one of the other restoration alternatives could restore and retain the lake as a useful recreation area. Which ever method is found to be the most feasible, the problem of disposing of the material will have to be considered.

Construction procedures and cost estimates were developed for each of the proposed alternatives. The following paragraphs will explain each alternative in detail.

DREDGING

Dredging is a method of excavation developed for the removal of material that is under water. The dredge proposed for this project is the hydraulic type that operates from the water surface. More specifically, it is a cutterhead dredge that employs a pump to lift the material from the lake bottom and transport it through a pipeline to the point of disposal.

The portable hydraulic cutterhead dredge was introduced about 30 years ago. This type of dredge is described by the diameter of the

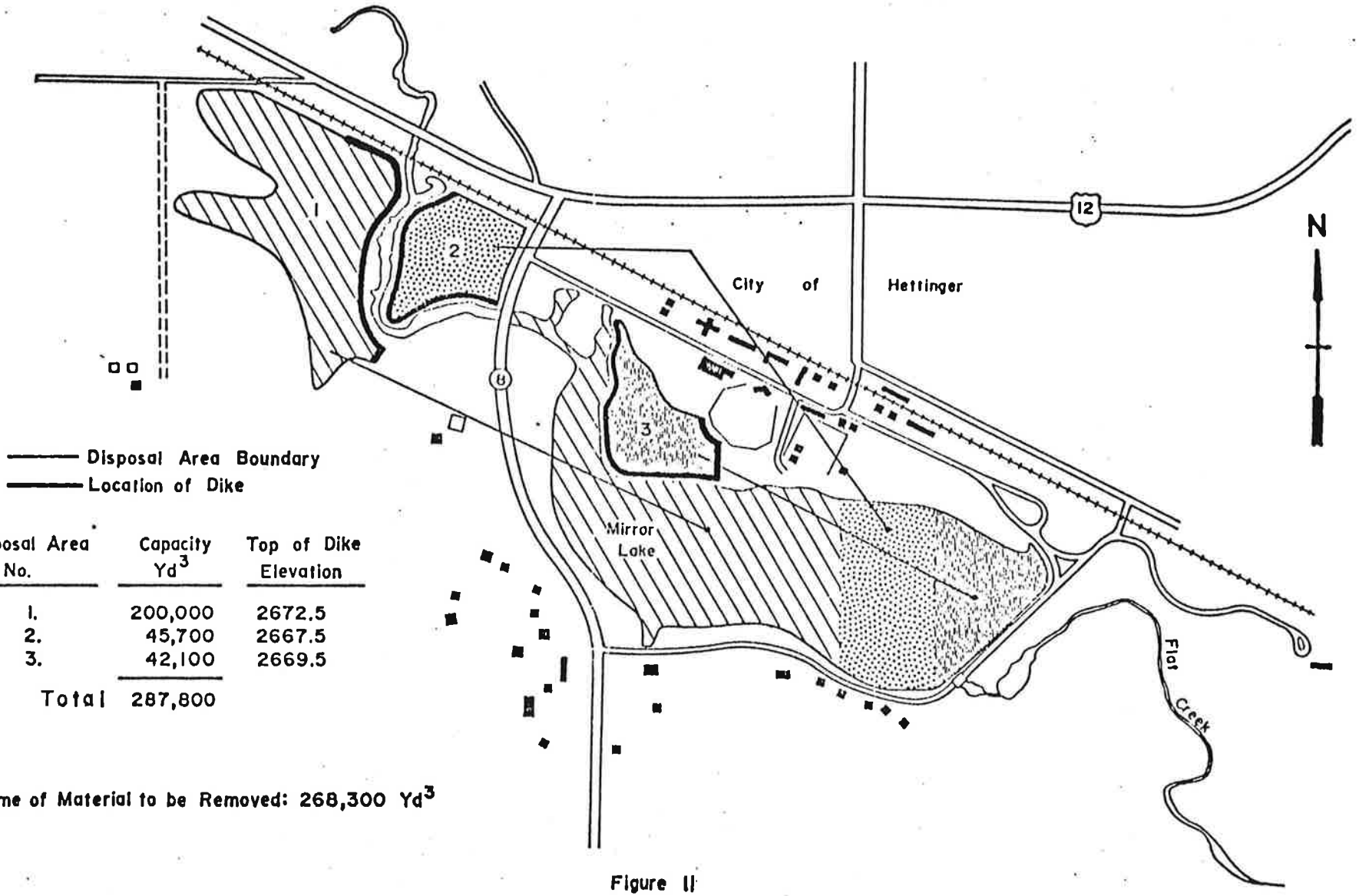
discharge pipe which ranges in size from 6 to 36 inches. Sizes commonly used on inland lakes are 6 inch to 14 inch. Th dredge consists of a steel hull, cutter arm, pump, diesel engine, and a discharge pipeline.

The dredge pumps the material, which is approximately 50-70 percent water, from the lake bottom through the discharge pipe to a disposal area. The disposal site is usually a diked area that acts as a settling pond. A control section in the dike allows the sediment-free water to flow back into the lake. This maintains the water level in the lake and allows for continuous dredging. Upon completion of the dredging project, disposal sites have been used for recreation areas, crop production and excavated and sold for field, lawn, and garden fertilizer. Test on various dredging projects in the United State have indicated that the volume of material when deposited in the disposal area is within 5%, plus or minus, of its original volume in the lake. If the natural ground underneath the disposal area is impervious a subsurface drainage system must be incorporated into the design to alleviate the problem of a perched water table which may result in a "quick" condition.

Three alternatives will be considered for the dredging proposal. Alternative 1 involves the removal of the organic sediment and the original top soil over the entire area of the lake east of Highway 8. The capacity of this portion of the reservoir would be increased from 332 acre-feet to 498 acre-feet. Following the dredging operation, the maximum depth would be 15 feet and the average depth would be 7.0 feet. The total amount of material to be removed is 268,300 cubic yards, according to the survey data obtained by L. W. Veigel and Company in

1974. The 1974 survey data was used because it gives a larger figure for the volume of sediment so it most likely includes the original topsoil of the lake bed. It is desirable to remove the original topsoil because it also includes organic material. The estimated volume of disposal area required is equal to the value of material removed plus 5 percent. Figure 10 shows the location of the proposed disposal sites and the corresponding area of the lake that each disposal site would be used for. Affected landowners have given preliminary approval of the location of the disposal areas. The disposal sites would be constructed by building dikes that tie into the higher ground elevations. The location of the disposal areas is shown on Figure 11. The dikes would have a top width of 8 feet and side slopes of 3 horizontal to 1 vertical. Material for the construction of the dikes would be obtained from the disposal sites. A freeboard of 2.5 feet would be maintained above the invert elevation of the control culverts. A subsurface drainage system is proposed for each disposal area. The drainage system would consist of a 6 inch diameter perforated PVC pipe with a gravel filter. The drain would be placed along the toe of the dike on the upstream side. Non-perforated, 6 inch diameter PVC pipe would be placed through the dike to remove the drainage water from the disposal area. Figure 12 shows a plan view and a cross section of a typical section of dike. Depending on how the solids settle out, a secondary settling pond may be required. If this is the case, a secondary pond would be created by dividing each disposal site into two areas by constructing an additional dike. This may be required at the smaller disposal sites.

NOTE: Shading denotes portion of lake that each disposal site will be used for.

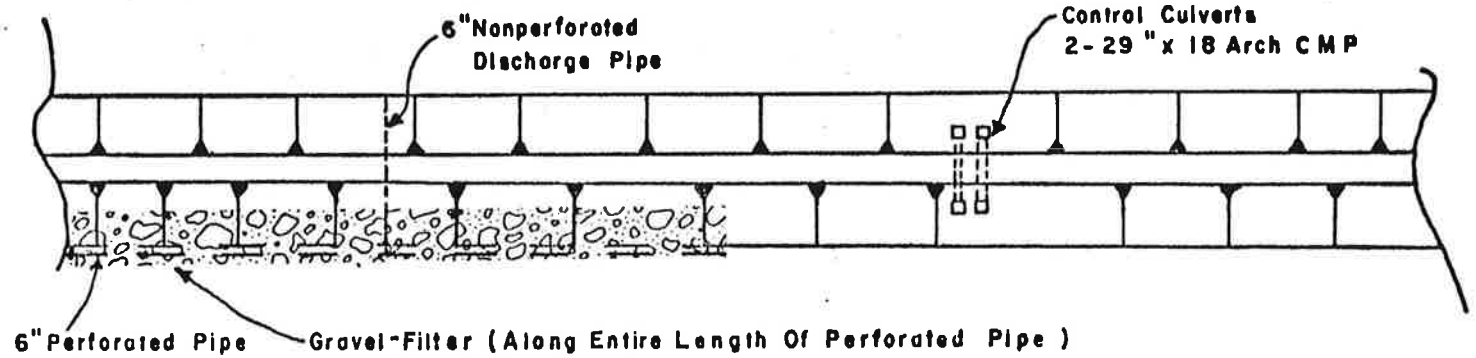


Disposal Area No.	Capacity Yd^3	Top of Dike Elevation
1.	200,000	2672.5
2.	45,700	2667.5
3.	42,100	2669.5
Total	287,800	

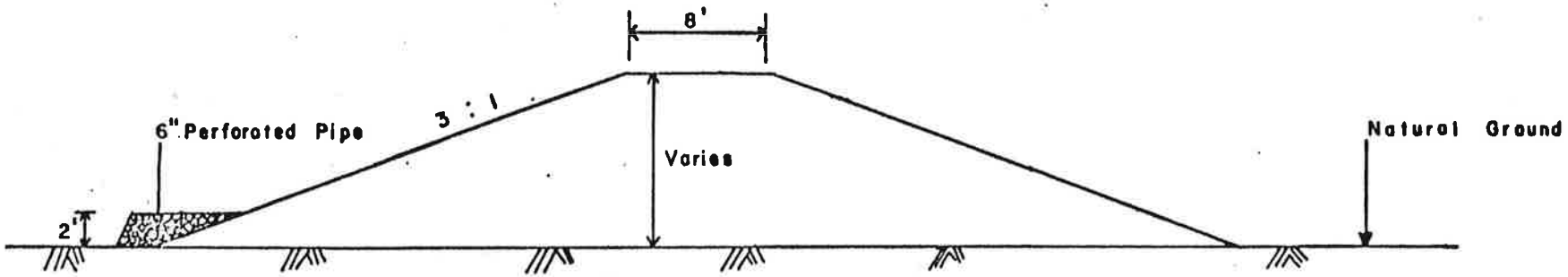
Volume of Material to be Removed: 268,300 Yd^3

Figure 11

DREDGING ALTERNATIVE 1 - REMOVE SEDIMENT ONLY



TYPICAL DIKE PLAN VIEW



TYPICAL DIKE CROSS SECTION
(No Scale)

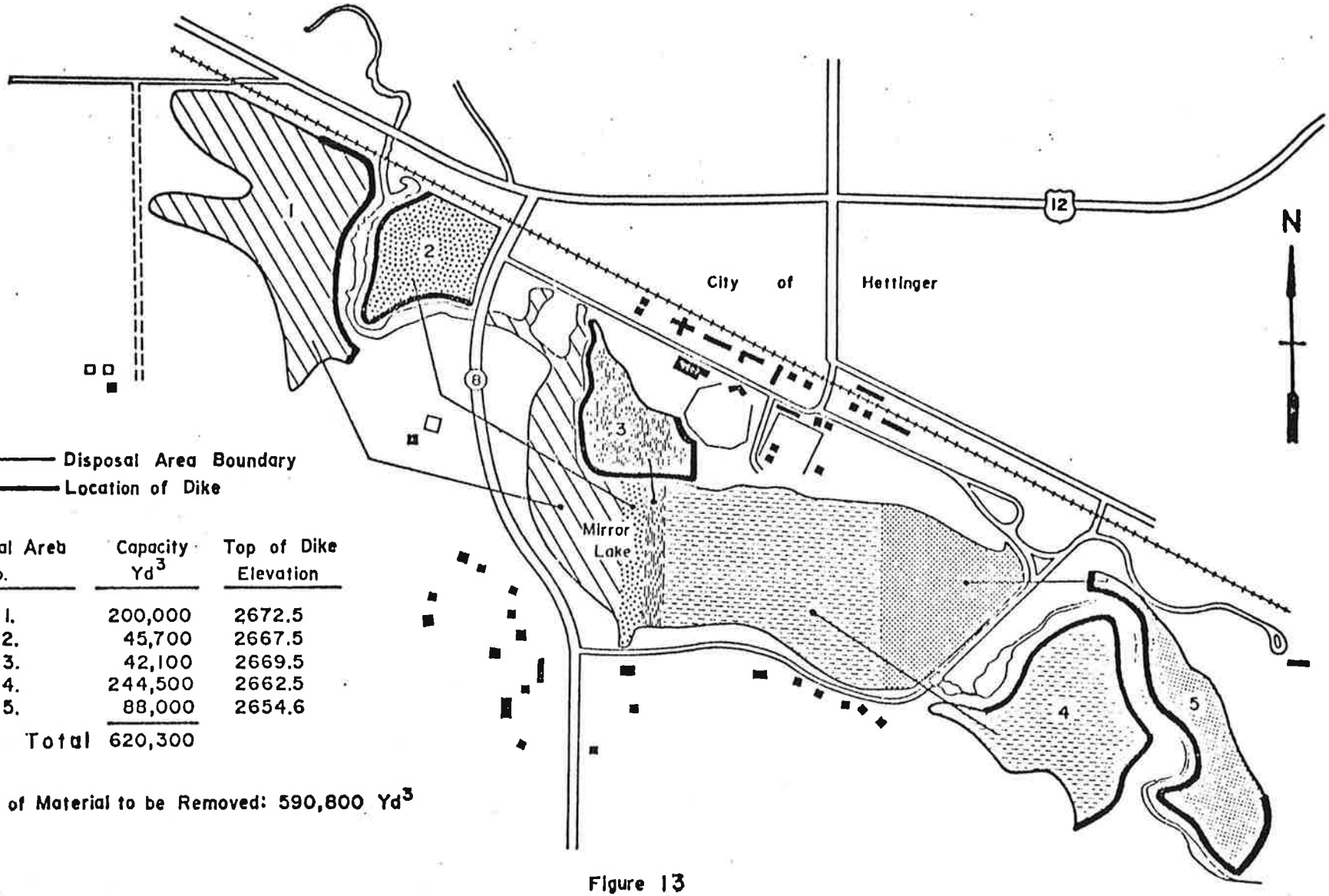
FIGURE 12
DIKE DETAILS

Alternative 2 would be to deepen the lake to a maximum depth of 14 feet. The lake bed would be sloped at 15 horizontal to 1 vertical from the shoreline to a maximum depth of 14 feet. This would involve the removal of 590,800 cubic yards of material and the result would be a lake with an average depth of 10.7 feet. The reservoir capacity east of Highway 8 would be 707 acre-feet. This alternative would meet the suggested criteria of the State Game and Fish Department for recommended average depth. Figure 13 shows the location of the disposal areas and lists the storage capacity for each area.

Alternative 3 would consist of deepening the lake to a maximum depth of 20 feet. This is the maximum depth recommended by the State Game and Fish Department and is the maximum depth capability of a 10 inch dredge. The depth of 20 feet would extend over an area of approximately 13 acres in the main portion of the reservoir. The average depth would be 11.9 feet and the reservoir capacity east of Highway 8 would be 783 acre-feet. A total of 713,600 cubic yards of material would be removed. Figure 14 shows the location of the disposal areas and lists the storage capacity for each area.

There are two methods that the city of Hettinger could use to implement a dredging operation. The first method would be soliciting bids through a normal bid letting procedure. The city could choose to let the contract for the construction of the disposal areas together with the dredging work or treat them as separate projects. Separate contracts may be advantageous to the city because a large dredging contractor would probably subcontract out the work on the disposal sites to a local contractor. The city may save money by dealing directly with the local contractors for the disposal area work.

NOTE: Shading denotes portion of lake that each disposal site will be used for.



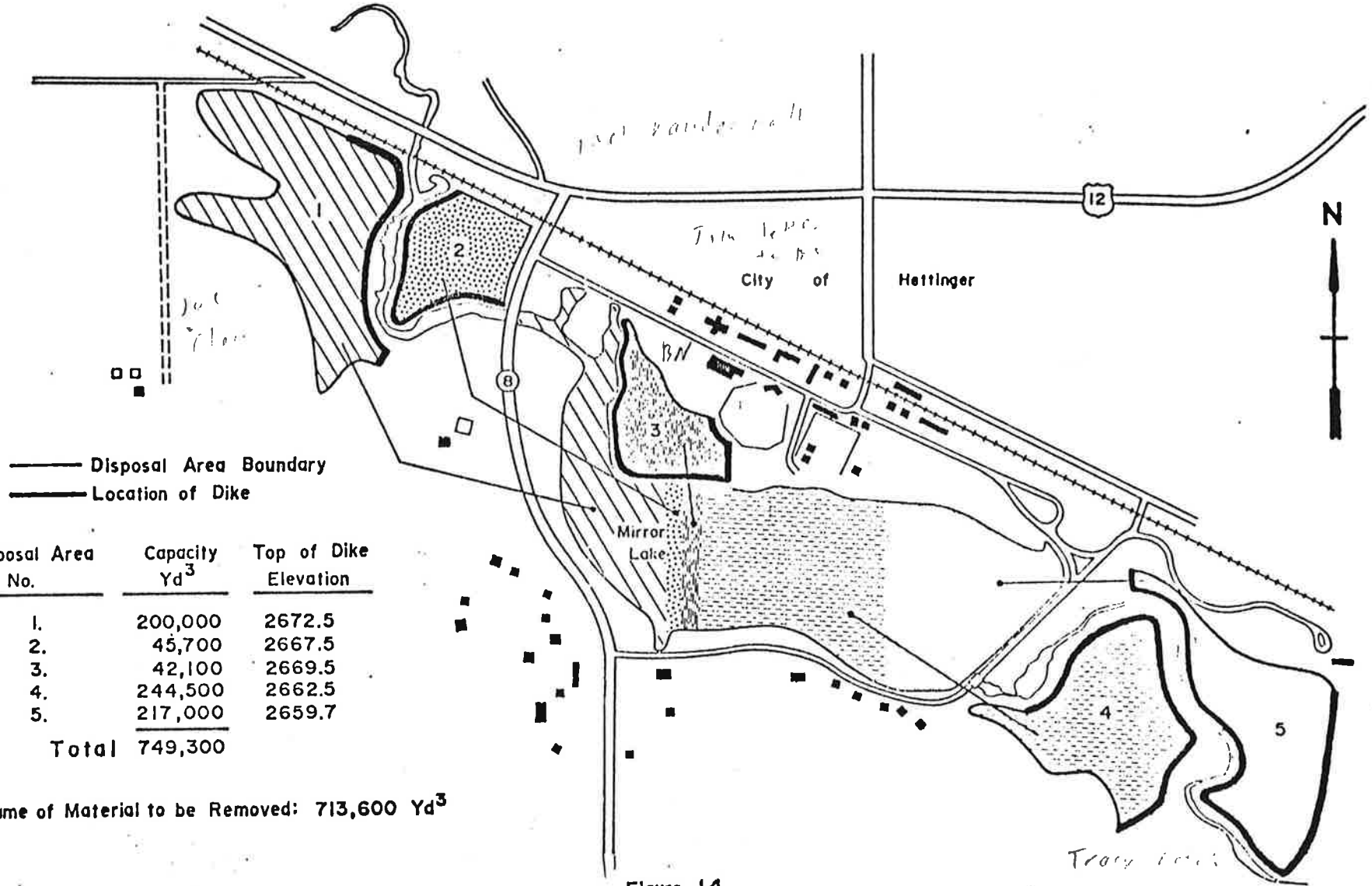
Disposal Area Boundary
Location of Dike

Disposal Area No.	Capacity Yd^3	Top of Dike Elevation
1.	200,000	2672.5
2.	45,700	2667.5
3.	42,100	2669.5
4.	244,500	2662.5
5.	88,000	2654.6
Total	620,300	

Volume of Material to be Removed: 590,800 Yd^3

Figure 13
DREDGING ALTERNATIVE 2 - DEEPEN TO 14'

NOTE: Shading denotes portion of lake that each disposal site will be used for.



Disposal Area Boundary
Location of Dike

Disposal Area No.	Capacity Yd^3	Top of Dike Elevation
1.	200,000	2672.5
2.	45,700	2667.5
3.	42,100	2669.5
4.	244,500	2662.5
5.	217,000	2659.7
Total	749,300	

Volume of Material to be Removed: 713,600 Yd^3

Figure 14
DREDGING ALTERNATIVE 3 - DEEPEN TO 20'

The other implementation plan would be for the city to purchase a dredge and complete the dredging portion of the project themselves. Dredges can be leased, but for larger projects it is not economical. The work on the disposal sites would be contracted out. There may be a cost savings with this procedure, however, the risks are far greater than if a contractor was hired to do the dredging. Under this plan the city would purchase a dredge and the appurtenant equipment and obtain manpower to accomplish the project. If the dredge is operated 24 hours per day, 3 fulltime operators, 3 fulltime laborers and 1 fulltime supervisor would be required. According to data from dredging projects done in this area of the country, the dredge can generally be operated from April 1 through October 31. Assuming the use of a 10 inch dredge, a 6 day work week, a loss of 30 working days due to inclement weather or breakdowns, and a 15 hour per day actual dredging time, alternative one would take 2 years to complete; alternative two would take 3 years to complete and alternative three would take 4 years to complete. Assuming the same factors as above except the use of an 8 inch dredge, alternative one would take 2 years, alternative two would take 4 years and alternative three would take 5 years. Therefore, since both 8 inch and 10 inch dredges are readily available, the 8 inch will be proposed for alternative 1 and the 10 inch will be proposed for alternatives two and three. The time saved by the use of the 10 inch dredge on the larger projects offsets the additional cost of the machine and makes it more economical than the 8 inch dredge.

The following is a listing of the quantity of materials required for each alternative and a detailed cost estimate. These cost estimates are based on current costs and do not include any costs for easements or land aquisition.

DREDGING ALTERNATIVE 1 - REMOVING SEDIMENT

1. Disposal Areas

Area No.	Item	Quantity	Unit Price	Extended Price	Sub-total
1	Earthwork	29,500 yd^3	$ 0.75	$22,125.00	
	28"x20" Arch, CMP	80 ft_3	20.00	1,600.00	
	Rock Riprap	37 yd^3	16.00	592.00	
	Seeding	2.8 Ac_3	100.00	280.00	
	Gravel Filter Material	530 yd^3	12.00	6,360.00	
	6" Ø Perforated PVC Pipe	1200 ft	3.50	4,200.00	
	6" Ø PVC Pipe	250 ft	2.50	625.00	$35,782.00
2	Earthwork	14,900 yd^3	0.75	11,175.00	
	28"x20" Arch, CMP	30 ft_3	20.00	600.00	
	Rock Riprap	22 yd^3	16.00	352.00	
	Seeding	2.2 Ac_3	100.00	220.00	
	Gravel Filter	350 yd^3	12.00	4,200.00	
	6" Ø Perforated PVC Pipe	800 ft	3.50	2,800.00	
	6" Ø PVC Pipe	120 ft	2.50	300.00	19,647.00
3	Earthwork	19,800 yd^3	0.75	14,850.00	
	28'x20' Arch, CMP	25 ft_3	20.00	500.00	
	Rock Riprap	11 yd^3	16.00	176.00	
	Seeding	2.5 Ac_3	100.00	250.00	
	Gravel Filter	350 yd^3	12.00	4,200.00	
	6" Ø Perforated PVC Pipe	800 ft	3.50	2,800.00	
	6" PVC Pipe	140 ft	2.50	350.00	23,126.00
	Total estimated Construction Cost for Disposal Areas				$78,555.00

2. Dredging

A. Dredge Purchase Arrangement

8" Dredge & Appurtenant Eq.	1 ea	$110,000.00	$110,000.00
Booster Pumps	2 ea	20,000.00	40,000.00
Supervisor	14 mo	1,150.00	16,100.00
Operators (3)	42 mo	985.00	41,370.00
Laborers (3)	42 mo	985.00	41,370.00
Operation & Maintenance	2 yr	30,000.00	60,000.00
Vehicle	1 ea	5,000.00	5,000.00
Total Estimated Construction Cost For Dredging			$313,840.00

B. Contract Arrangement

Dredge Material	268,300 yd^3	$ 1.50	$402,450.00
Total Estimated Construction cost for Dredging			$402,450.00

3. Total Costs

	Dredge Purchase Arrangement	Contract Arrangement
Construction of Disposal Areas	$ 78,555.00	$ 78,555.00
Dredging	313,840.00	402,450.00
Total Estimated Construction Cost for Project (Disposal & Dredging)	392,395.00	481,005.00
Contingencies (10%±)	39,205.00	48,095.00
Engineering, Contract Administration & Construction Inspection (15%±)	58,900.00	72,100.00
Total Estimated Project Cost	$490,500.00	$601,200.00

DREDGING ALTERNATIVE 2 - Dredging to 14 Feet

1. Disposal Areas

Area No.	Item	Quantity	Unit Price	Extended Price	Sub-Total
1	Same as Alternative 1				$35,782.00
2	Same as Alternative 1				19,647.00
3	Same as Alternative 1				23,126.00
4	Earthwork	67,500 yd^3	$ 0.75	$50,625.00	
	28"x20" Arch, CMP	120 ft_3	20.00	2,400.00	
	Rock Riprap	37 yd^3	16.00	592.00	
	Seeding	5.7 Ac_3	100.00	570.00	
	Gravel Filter Material	710 yd^3	12.00	8,520.00	
	6" Ø Perforated PVC Pipe	1,600 ft	3.50	5,600.00	
	6" Ø PVC Pipe	400 ft_3	2.50	1,000.00	69,307.00
5	Earthwork	43,900 yd^3	0.75	32,925.00	
	28"x20" Arch, CMP	110 ft_3	20.00	2,200.00	
	Rock Riprap	37 yd^3	16.00	592.00	
	Seeding	4.6 Ac_3	100.00	460.00	
	Gravel Filter Material	356 yd^3	12.00	4,272.00	
	6" Ø Perforated PVC Pipe	800 ft	3.50	2,800.00	
	6" Ø PVC Pipe	180 ft	2.50	450.00	43,699.00
	Total Estimated Construction Cost For Disposal Areas				$191,561.00

2. Dredging

A. Dredge Purchase Arrangement

10" Dredge & Appurtenant Equipment	1 ea	$140,000.00	$140,000.00
Booster Pumps	2 ea	20,000.00	40,000.00
Supervisor	21 mo	1,150.00	24,150.00
Operators (3)	63 mo	985.00	62,055.00
Laborers (3)	63 mo	985.00	62,055.00
Operation & Maintenance	3 yr	40,000.00	120,000.00
Vehicle	1 ea	5,000.00	5,000.00
Total Estimated Construction Cost For Dredging			$453,260.00

B. Contract Arrangement

Dredge Material	590,800 yd^3	1.40	827,120.00	827,120.00
Total Estimated Construction Cost For Dredging				$827,120.00

3. Total Costs

	Dredge Purchase Arrangement	Contract Arrangement
Construction of Disposal Areas	$191,561.00	$ 191,561.00
Dredging	453,260.00	827,120.00
Total Estimated Construction Cost for Project	$644,821.00	$1,018,681.00
Contingencies (10%+)	64,479.00	101,819.00
Engineering, Contract Administration & Construction Inspection (15%+)	96,700.00	152,800.00
Total Estimated Project Cost	$806,000.00	$1,273,300.00

DREDGING ALTERNATIVE 3 - Dredging to 20 Feet

1. Disposal Areas

Area No.	Item	Quantity	Unit Price	Extended Price	Sub-Total
1	Same as Alternative 1				$35,782.00
2	Same as Alternative 1				19,647.00
3	Same as Alternative 1				23,126.00
4	Same as Alternative 2				69,307.00
5	Earthwork	97,400 yd^3	$ 0.75	$73,050.00	
	28"x20" Arch, CMP	170 ft_3	20.00	3,400.00	
	Rock Riprap	37 yd^3	16.00	592.00	
	Seeding	7.3 ac_3	100.00	730.00	
	Gravel Filter Material	356 yd^3	12.00	4,272.00	
	6" Ø Perforated PVC Pipe	800 ft	3.50	2,800.00	
	6" Ø PVC Pipe	230 ft	2.50	575.00	85,419.00
	Total Estimated Construction Cost for Disposal Area				$233,281.00

2. Dredging

A. Dredge Purchase Arrangement

10" Dredge & Appurtanent Equipment	1 ea	$140,000.00	$140,000.00
Booster Pumps	2 ea	20,000.00	40,000.00
Supervisor	28 mo	1,150.00	32,200.00
Operators (3)	84 mo	985.00	82,740.00
Laborer	84 mo	985.00	82,740.00
Operation & Maintenance	4 yr	45,000.00	180,000.00
Vehicle	1 ea	5,000.00	5,000.00
Total Estimated Construction Cost for Dredging			$562,680.00

B. Contract Arrangement

Dredge Material	713,600 yd^3	1.35	963,360.00	963,360.00
Total Estimated Construction Cost for Dredging				$963,360.00

3. Total Costs

	Dredge Purchase Arrangement	Contract Arrangement
Construction & Disposal Areas	$ 233,281.00	$ 233,281.00
Dredging	562,680.00	963,360.00
Total Estimated Construction Cost For Project	795,961.00	1,196,641.00
Contingencies (10%+)	79,593.00	119,659.00
Engineering, Contract Administration & Construction Inspection (15%+)	119,346.00	179,500.00
Total Estimated Project Cost	$ 994,900.00	$1,495,800.00

EXCAVATION

This proposal involves the operation of excavation equipment from the shore or directly on the dewatered lake bottom. The implementation plan for this proposal would be to drain the reservoir following the Spring runoff and allow the lake bed to dry through the Summer months. In the Fall the sediment could be excavated, if it has dried out enough. If it is still in a saturated condition, the sediment would be excavated after it freezes or the lake bed could be allowed to dry out another year. This proposal would take more than one year with the exact time depending on the amount of material that is to be removed. No water would be retained in the reservoir during the period that excavation is taking place.

Three alternatives will be considered under this proposal. Alternative one involves draining the reservoir, allowing the sediment to consolidate for 2 to 3 years and then refilling the reservoir. The sediment could be expected to consolidate approximately 50 percent. With this alternative the depth of water in the lake would be increased 2 to 3 feet. Alternative two involves the removal of the accumulated sediment down to the original lake bed. With this alternative, the amount of material removed would be 268,300 cubic yards. This is the same volume of material as alternative one of the dredging proposal. Excavation alternative three is comparable to Dredging alternative two. The maximum depth would be increased to 14 feet with an average depth of 10.7 feet. The amount of material removed would be 590,800 cubic yards. It is anticipated that excavation below the depth of 14 feet would not be possible without excessive dewatering because it would involve excavation below the bottom of the original streambed. Therefore, a comparable excavation alternative to Dredging alternative three will not be considered.

The lake would be drained by pumping or siphoning until a small coffer dam could be built. The embankment would be breached and a 48 inch diameter culvert installed at the bottom of the embankment. The reason for the initial slow drawdown by pumping and siphoning is to try and prevent a slope failure of the embankment. A high drawdown rate would remove the water from the reservoir faster than the pore water pressures could dissipate in the embankment which may cause a slope failure. These failures generally occur when the rate of drawdown is between 0.3 and 0.5 feet per day and when the water surface is between the maximum water level and mid-height of the dam. The majority of the failures are deep seated. However, it is unlikely that the whole crest would sink and reduce the freeboard. The embankment would be breached near the existing spillway, so the original stream channel could be intercepted. This would be in the vicinity of the existing slope failure which would then be repaired when the embankment is restored following the excavation. After the lake is drained, the 48 inch diameter culvert will be removed and the embankment will remain breached while the lake bed is drying out. Some erosion protection would be required through the breached section of the embankment. Some small sedimentation dams maybe required downstream if erosion is a problem on the lake bed.

The type of excavation equipment employed would depend upon the conditions of the lake bed after it is drained. If excavation is done before freeze-up a dragline or a Sauerman bucket may be used. A large track mounted dragline would operate from the shoreline and would be able to cast its bucket 100 to 125 feet. This restriction would limit the use of the dragline to the area near the shoreline. Another problem

is the difficulty in handling the flocculent organic sediment. The Sauerman bucket is similiar to the dragline in operation. The bucket is hauled across the lake by two cables and a hoist which is mounted on the near shore. The bucket is then pulled across the lake bottom (See Figure 15). There are two drawbacks with this system. The Sauerman bucket cannot be used for loading because it has no bottom and to effectively cover the entire lake bed, it is necessary that both the hoist and anchor system be moved frequently. The saturated condition of the sediment would prohibit the use of scrapers in most areas. In a frozen condition the sediment could be removed by a large backhoe. It is anticipated that pumping would be required with any of the excavation techniques. Because of the high water table surrounding the lake, excavation by any technique is going to be difficult. The disposal areas proposed for the dredging alternatives will also be used for disposal of the excavated material. The proportionate area of the lake that would utilize each disposal site would be the same as the corresponding dredging alternative. This breakdown is shown on Figures 10, 12, and 13. The haul distances are generally less than 3000 feet except for disposal area 1 which involves a haul distance of 5000-6000 feet.

It is anticipated that the draining of the reservoir would be completed prior to the letting of the excavation contract. This would allow the contractors to look at the drained reservoir before they submitted their bids for the excavation. The contract could even be broken down so different prices could be given for materials at different depths because the deeper material would be more difficult to remove. The City would then be able to decide how deep they want the contractor to go.

The following is a cost estimate for the various alternatives under the excavation proposal. The price given per cubic yard includes excavation and hauling.

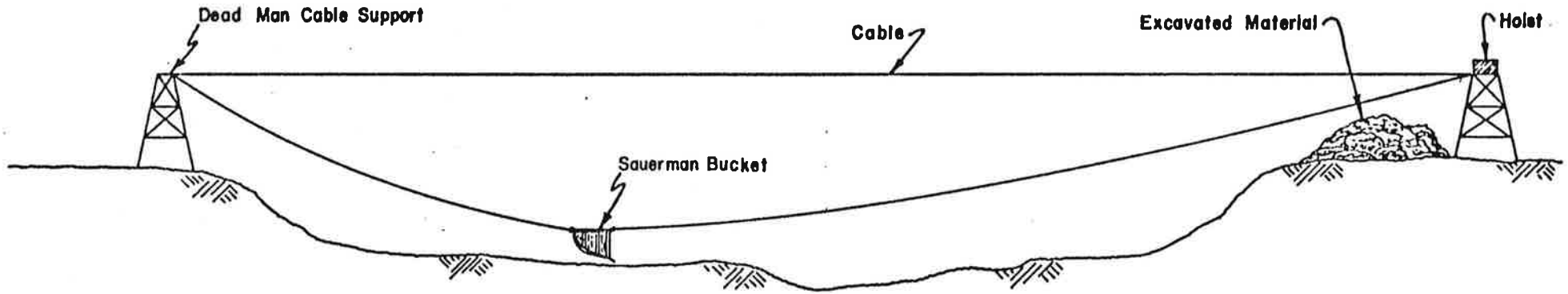


Figure 15

SAUERMAN BUCKET EXCAVATION PROCEDURE

EXCAVATION ALTERNATIVE 1 - Draining the Reservoir

	Item	Quantity	Unit Price	Extended Price	Sub-Total
Draining of Reservoir	Reservoir Drawdown	Lump Sum	$ 2,300.00	$ 2,300.00	
	Site Preparation (Coffer Dam, etc.)	Lump Sum	2,500.00	2,500.00	
	Embankment Excavation	1300 yd^3	1.50	1,950.00	
	Downstream Trench Excavation	650 yd^3	1.00	650.00	
	48" Ø CMP	80 ft	30.00	2,400.00	
	Excavation for Removal of Culvert	1500 yd^3	1.50	2,250.00	
	Rock Riprap	60 yd^3	16.00	960.00	
	Site Restoration	Lump Sum	200.00	200.00	$ 13,210.00
Restoring Embank-ment	Embankment Excavation	1500 yd^3	1.50	2,250.00	
	Downstream Trench Excavation	650 yd^3	1.00	650.00	
	Site Restoration	Lump Sum	2000.00	2,000.00	4,900.00
	Total Estimated Construction Cost				$ 18,110.00
	Contingencies (10%+)				1,800.00
	Engineering, Contract Administration and Construction Inspection (7%+)				2,690.00
	Total Estimated Project Cost				$ 22,600.00

Favored by Locals

EXCAVATION ALTERNATIVE 2 - Removing Sediment

	Draining Reservoir				~~$ 13,210.00~~ Dam
	Restoring Embankment				4,900.00
	Excavation	268,300 yd^3	$ 1.40	$375,620.00	
	Disposal Area Seeding	41 ac	100.00	4,100.00	379,720.00
	Total Estimated Construction Cost				$397,830.00
	Contingencies (10%+)				39,770.00
	Engineering, Contract Administration & Construction Inspection (15%+)				59,700.00
	Total Estimated Project Cost				$497,300.00

EXCAVATION ALTERNATIVE 3 - Excavating to 14 feet

	Draining Reservoir				$ 13,210.00
	Restoring Embankment				4,900.00
	Excavation	590,800 yd^3	$ 1.40	$827,120.00	
	Disposal Area Seeding	78 ac	100.00	7,800.00	834,920.00
	Total Estimated Construction Cost				$853,030.00
	Contingencies (10%+)				85,300.00
	Engineering, Contract Administation & Construction Investigation (15%+)				127,970.00
	Total Estimated Project Cost				$1,066,300.00

IV. ENVIRONMENTAL ASSESSMENT

The purpose of this environmental assessment is to disclose the environmental consequences of the proposed project. Several environmental catagories are identified and explained as to how they relate to this specific project. This assessment is written in accordance with procedures outlined in the Environmental Protection Agency's publication "Guidance for the Preparation of Lake restoration Grant Applications."

LAND USE

The area affected by this project includes the lake and the disposal sites. The watershed would not be directly affected, however, the Soil Conservation Service plans on increasing land treatment measures for sediment and water quality control.

No existing buildings would have to be relocated as a result of this project. No permanent defacement of any existing residential areas would occur. If the reservoir is drained, it would be temporarily displeasing to the residents on the South side of the reservoir. The dredging proposal would not affect these residents.

The established land use patterns of the disposal areas would be changed as a result of this project. None of these lands are prime agricultural land, parkland, or lands of recognized scenic value. Disposal areas 1, 2, 4 and 5 would probably revert to productive farmland. Area 3 would be converted into a recreation area. There would not be any increased residential development near the lake as a result of this project.

All of the disposal sites are located in the flood plain. These areas would be diked and floodwater from the reservoir or the downstream channel would not flow into the disposal areas.

The State Historical Society has been contacted concerning any historical, archaeological or cultural resources that may be affected. The Historical Society recommends that a comprehensive survey report be completed. A copy of a letter stating their concerns is contained in Appendix G.

WATER QUALITY

Water quality is an important aspect of this project. The existing water quality of the lake was previously discussed in this report. The three basic water quality considerations are the quality of water flowing into Mirror Lake, the effects of dredging and the erodibility of floculated sediment if the lake is drained.

The surface runoff flowing into Mirror Lake consists exclusively of direct runoff from the watershed. The city of Hettinger's storm sewer discharges into Flat Creek downstream of Mirror Lake. The treated sewage from the stabilization ponds is also discharged into Flat Creek downstream of the reservoir. The houses on the South side of the lake have septic tanks and drain fields that extend in a southerly direction, away from the lake. There are no large agricultural feed lots within the watershed. One concern is the North Dakota State University Agricultural Experiment Station. It is a pasture type sheep grazing operation, not a feed lot situation. The State Health Department was contacted concerning this and they indicated that this operation is not a major contributor

of nutrients to Mirror Lake. The Section 208 planning program is going to study the effects of this type of operation on the water quality of the surface runoff in this area. This type of problem would also be addressed when the land treatment measures are considered for the watershed. During the project there would not be any in-lake chemical treatment used.

Another major consideration concerning water quality is the effects of dredging. Very little turbulance is caused by the dredge itself. The main concern is the effluent from the disposal sites. Research of the literature on dredging indicates that very little data has been collected on the water quality of the effluent from disposal sites. A dredging operation in progress at Baker, Montana has had no water quality problem with the effluent from their disposal sites. However, it is not known what their detention times are. An entensive water quality study was done on a dredging project on the Maumee River near Toledo, Ohio. The drainage area at this point on the river is 90 percent productive agricultural land. This study concluded that with the exception of nitrate nitrogen, a marked reduction of pollutant concentrations occurs before the effluent water is discharged back into the river. The quality of the effluent water was very similar to that of the river. The organic nitrogen in the slurry goes through the nitrofication process due to the change from anaerobic conditions in the lake bed to aerobic conditions at the disposal site. Therefore, the concentration of the nitrate ion in the effluent water is generally much higher than in the river or lake water. Depending on the permeability of the soils at the disposal site,

there may be a problem with ground water contamination. Most of the contaminates are associated with the solid particles of the sediment, which are usually larger than colloidal size and will generally settle out readily.

The maximum detention times associated with the different disposal sites at Mirror Lake are given in Table 5. As indicated by the figures in the table, there would be sufficient time for the suspended sediment particles to settle out. A water quality monitoring program will be set up when the project is implemented.

TABLE 6

DISPOSAL SITE DETENTION TIMES

Disposal Site No.	Detention Time (hrs.)	Detention Time (days)
1	272	11.0
2	62	2.6
3	57	2.4
4	333	12.3
5	120* & 296**	5* & 12.3**

* Alternative 2
** Alternative 3

If the reservoir is drained the floculated organic sediment will be exposed to surface runoff. The Wisconsin Department of Natural Resources has had experience with this situation and have indicated that there is not an erosion problem with surface runoff on the lake bed if the slopes are not to steep. Mirror Lake has a very flat lake bed so there should not be a problem with erosion and subsequent sediment deposition downstream.

AIR QUALITY AND NOISE LEVELS

There would be no permanent adverse changes to the ambient air quality or noise levels as a result of this project. However, some local changes in air quality and noise levels would be noticed during the construction phase of the project. The excavation proposal would create more problems than any of the dredging alternatives.

POSSIBLE ALTERNATIVES TO THE PROPOSED PROJECT

Besides the alternatives specifically proposed in this report, there were several others that were given consideration. The following is a brief statement for each alternative that was considered but found to be not a viable solution to the problem. If nothing was done to restore the lake, it would continue to deteriorate. The need for a water based recreation facility would not be met. If the lake was completely drained, portions of the lake bed could be used for recreational facilities but the need for a water based recreation area would not be met. If this alternative was chosen, a new dam could possibly be built at a nearby location if an adequate site could be found. This will be addressed further in the Summary, Conclusions and Recommendations section of this report. Since the water flowing into Mirror Lake does not have a high sediment content or poor quality, a nutrient diversion or water dilution proposal would not apply. The nutrients in the lake could be inactivated by chemical treatment or by a watertight covering, but the lake still would not have sufficient depth to sustain fishlife.

Therefore, the only way to restore the lake would be to remove the sediment or drain the lake and allow the sediment to consolidate. This, combined with watershed treatment and possibly aeration, would effectively restore the lake.

EFFECTS ON DOWNSTREAM FLOOD FLOWS

The proposed project would have no effect on the downstream flood flows when it is completed. The spillway would not be altered. If the reservoir is drained under the excavation alternatives, a 48 inch diameter

control culvert would be placed through the embankment to prevent a sudden surcharge of water into the downstream channel.

INTER AGENCY COORDINATION

The State Historical Society has been contacted concerning this project, as indicated earlier in this report. Before the project is implemented it will be reviewed through the A-95 reviewal process. As previously indicated, the North Dakota Game and Fish Department has also been involved in this project. The Army Corps of Engineers and the Fish and Wildlife Service were contacted to determine if any federal permits would be required.

The Corps of Engineers has indicated that no Section 404 permit will be required because no excavation will be placed in a wetland area. However, a permit would be required for any of the dredging alternatives because effluent from the disposal sites will re-enter the lake. A written response from the Corps of Engineers is contained in Appendix G. The Fish and Wildlife Service has indicated that there would be no permit requirement from them. However, they will review the project as it progresses.

WILDLIFE

Mirror Lake presently has very little fish life. The primary purpose of this project is to restore the lake so it can sustain fish life. No data on wildlife populations has been obtained. However, water fowl and other wildlife were observed near the lake during the site surveys. No disposal sites are located in wetland areas. The wildlife habitat will not be decreased as a result of this project.

PUBLIC COMMENT

No formal public meetings have been held concerning this project. Various organizations throughout the area have been in support of the project over the past few years. The first meeting concerning this project will be held with the Hettinger City Park Board. Formal public hearings will follow as the project progresses.

RESOURCE COMMITTMENT

There would be no significant long range energy demand as a result of this project. All materials, labor and energy used in the construction of this project would be irretrievable.

SOCIAL-ECONOMIC EFFECTS

The increased recreational activity, as a result of this project, would have a positive economic affect on the city of Hettinger. No unreasonable labor demands would occur with any of the alternatives.

V. FUNDING ALTERNATIVES

There are basically two funding alternatives that could be pressed for this project. The first alternative is to apply for a lake restoration grant from the Environmental Protection Agency. This program is called the Restoration of Publically Owned Freshwater Lakes as authorized by Section 314 of the Federal Water Pollution Control Act Amendments of 1972 (PL 92-500). The other alternative is to apply for a recreational facility grant from the Bureau of Outdoor Recreation. Other possible contributors to the funding of this project are: North Dakota State Water Commission; North Dakota Game and Fish Department; Adams County Water Management District; North Dakota State Parks and Recreation Department; and the city of Hettinger. In is anticipated that the City would pursue all possible funding alternatives for the project.

VI. SUMMARY, CONCLUSIONS & RECOMMENDATIONS

In its present conditon, Mirror Lake is not a useful water based recreation area. There is a need for this type of recreational facility in this area of the state. The city of Hettinger has invested a considerable amount of money in the adjacent park and baseball field. This includes the recent addition of over-night camping facilities.

The residents of Hettinger have expressed a continuing interest in deepening the lake since the 1950's. This interest has intensified in the past ten years. The City Park Baord requested the State Water Commission to complete a comprehensive study to determine the feasibility of restoring the lake. This report is the result of this investigation.

Mirror Lake has a surface area of 72 acres and a capacity of 337 acre-feet. The maximum depth is 12.8 feet and the average depth is 4.7 feet. The dam was constructed by the Chicago, Milwaukee, St. Paul, and Pacific Railroad in 1909. It is an earthfill structure with a height of 15 feet and a length of 800 feet. The spillway consists of a concrete weir constructed on a depressed section of the embankment. The weir is 140 feet wide and has a drop of 8 feet to the downstream apron.

A significant amount of sediment has accumulated in the reservoir since it was constructed. Most of the sediment was deposited probably before 1956. The depth of sediment in the lake ranges from 2 to 6 feet. The sediment has been deposited by surface runoff from the watershed, wind erosion, nearby construction activities and organic material generation within the reservoir. A reconnaissance of the watershed was made by state and local Soil Conservation Service representatives on June 21, 1978. They concluded that the watershed does not contribute a

significant amount of sediment to the reservoir. However, they did suggest that additional land treatment measures be incorporated into the soil conservation plan for the watershed. An analysis of the watershed using the Universal Soil Loss Equation indicates a sediment production of 3.6 tons/acre-year. This is only 72% of the Soil Conservation Service's tolerance level of 5 tons/acre-year. The derived sediment delivery ratio for the watershed is 0.14 assuming a dry unit weight of sediment of 60 lbs/ft^3. The trap efficiency for the reservoir is 94%.

Two basic proposals were considered for restoring the lake. The first proposal involves the use of a portable hydraulic dredge. The second proposal involves draining the reservoir and removing the material by excavation. Various alternatives are considered for each proposal. Table 6 contains a summary of the proposed alternatives and gives a cost estimate for each.

TABLE 6
SUMMARY OF PROPOSED ALTERNATIVES

Proposal	Alternative	Brief Description of Alternative	Project Cost Estimate	
Dredging	1	Removal of Sediment A.D.≃7D'	$490,500.00	Dredge Purchas Arrangement
			601,200.00	Contract Arrangement
	2	Deepen Lake to 14' with average depth of 10.7'	806,000.00	D.P.A.
			1,273,300.00	C.A.
	3	Deepen Lake to 20' with average depth of 11.9	994,900.00	D.P.A.
			1,495,800.00	C.A.
Excavation	1	Drain Reservoir allow Material to consolidate and then refill reservoir	22,600.00	
	2	Drain reservoir, remove sediment by excavation	497,300.00	
	3	Drain reservoir and deepen Lake to 14' by excavation with an average depth of 10.7'	1,066,300.00	

There are several things to consider when determining the most viable alternative. Several problems could result if the city chose to purchase a dredge. It is a large undertaking for a small city to purchase such a specialized piece of equipment. It would be difficult to organize the project and to find qualified people to manage the operation. State and Federal agencies may find this alternative to be too much of a risk to commit any funds.

To allow a contractor to complete the project appears to be a more favorable alternative. It poses less of a risk to the city of Hettinger and any agencies that may be contributing funds. However, there are also some problems with this alternative. There are not many experienced dredging contractors in North Dakota. The high cost of mobilization for an out-of-state contractor would raise the cost of the project. This effect would be less significant on Alternatives 2 and 3 because of the large volume of material to be removed.

There is less of a risk with the excavation alternatives. The City could drain the reservoir and proceed with the project at their own pace. The high water table surrounding the reservoir may prevent the lake bed from drying out the first year. The City may have to allow the reservoir to remain dry for 2 to 3 years. While the lake bed is drying out, the City could also investigate the feasibility of constructing a new renovation dam at another location in the area. The excavation proposal would enable the contractors to look at the material to be excavated before they submit their bids. If excavation of the material is found to be too expensive or impractical, the reservoir could be refilled. The sediment would have consolidated and the depth increased. The lake may then have to be aerated to sustain fishlife. The aquatic

vegetation could be removed before the reservoir is refilled. The City would also have the option of establishing a channel through the lake bed and converting the lake bed into a recreation area. A small channel dam could be built near the present embankment to maintain water in the channel. The existing dam would be maintained as a roadway.

As a result of this investigation, it has been determined that this project is feasible from an engineering standpoint. It is recommended that the City drain the reservoir and proceed with the project at their own pace. With this procedure, all of the options mentioned in the above paragraph would remain open. While the lake bed is drying out, the City is encouraged to investigate a potential location for a new dam in the area.

Not feasible from economic standpoint.

Indian Creek Dam itself ≈ $400,000

GLOSSARY OF TERMS AND ABBREVIATIONS

Acre-feet	-	A volume equivalent to a depth of one foot over an area of one acre.
Aeration	-	To increase the oxygen content of water by circulation or other means.
cfs	-	Cubic feet per second, a flow rate equivalent to 7.5 gallons per second.
Colloidal Size	-	A particle small enough such that the electrostatic forces on the particle are greater than the force of gravity and prevent the particle from settling out.
Detention Time	-	The average time required for water to flow through an impoundment.
Drainage Area	-	The area contributing surface runoff at a particular point in a basin.
Empirical	-	Derived from experimental data.
Fecal coliform	-	A type of bacteria that gives an indication of microbiological contamination of water.
Flocculent	-	Describes a substance with a loose structural configuration.
Floodplain	-	Relatively level land adjacent to a stream channel that may be submerged by floodwaters.
Freeboard	-	The distance between the water level and the top of the dike or dam.
Perched Water Table	-	An accumulation of sub-surface water above the normal water table created by a layer of impervious material close to the ground surface.
Permeability	-	The ability of a soil to conduct or discharge water under a hydraulic gradientor pressure.
Physiographic Province	-	A natural geographic sub-division.
"Quick" Condition	-	A saturated soil condition where the buoyant force reduce the particle to particle stresses to zero and the soil acts like a fluid.

Rangeline	-	A survey line across a lake and established by permanent monuments.
Residence Time	-	The average time required for water to flow through an impoundment.
Sediment	-	Particles of soil and organic material that has accumulated by settling out in an impoundment or slow moving water.
Sounding	-	The measurement of water depths.
Water Table	-	The static water level in wells that penetrate the saturated zone of sub-surface soils.
Weir	-	A structure used to regulate the waterlevel in an impoundment. Water is released by flowing over it.

APPENDIX A

Exhibit A 27

AGREEMENT

SWC Project #420

Preliminary Investigation
by the
North Dakota State Water Commission

I. PARTIES

THIS AGREEMENT is between the North Dakota State Water Commission, hereinafter referred to as the Commission, acting through the State Engineer, Vern Fahy, and the Hettinger Park Board, hereinafter referred to as the Board, acting through its Chairman, James M. Goplin.

II. PROJECT, LOCATION AND PURPOSE

The Board has requested the Commission to investigate and determine the feasibility of renovation of Mirror Lake, located in Sections 13 and 14, Township 129 North, Range 96 West, in Adams County.

The proposed project is to drain the existing reservoir and excavate the reservoir sediment and underlying deposits to depths which will sustain fish life and promote future recreational development.

III. PRELIMINARY INVESTIGATION

The parties agree that further information is necessary concerning the proposed project. Therefore, the Commission shall conduct preliminary investigations consisting of the following:

1. A minimum of three test borings through the ice this winter. The preliminary boring program would hopefully provide information relative to vertical and horizontal distribution of the underwater sediment deposits and the texture, consolidation and degree of saturation of the underlying deposits.

2. The installation of observation wells to monitor ground water levels adjacent to the reservoir. Installation of the wells shall not be undertaken until the soil samples recovered from the test borings can be tested and the data evaluated. The geological character and tests of the subsurface deposits in their natural state must be found favorable to support excavation of the existing impoundment before the wells are installed.

3. An extensive sedimentation survey will be conducted by the Commission. The major objectives of this survey are twofold: (1) to evaluate the present rate of sediment production from the drainage area of the reservoir and (2) to measure the present and future storage capacity of the reservoir,

based on increased sediment storage capacity and anticipated land treatment measures within the watershed.

4. A preliminary engineering report.

IV. DEPOSIT - REFUND

The Board shall deposit $1500.00 with the Commission. Upon completion of the preliminary investigation, upon receipt of a request from the Board to terminate proceeding further with the preliminary investigation, or upon a breach of this agreement by the Board, the Commission shall provide the Board with a statement of all expenses incurred in the preliminary investigation and shall return any unexpended deposit funds.

V. RIGHTS OF ENTRY

The Board agrees to obtain written permission from any affected landowner for surveys or subsurface investigations by the Commission (or any contractor) which are required for the preliminary investigations.

VI. INDEMNIFICATION

The Board hereby accepts responsibility for, and holds the Commission free from, all claims and damages to public or private properties, rights, or persons arising out of this investigation. In the event a suit is initiated or judgment entered against the Commission, the Board shall indemnify it for any judgment arrived at or judgment satisfied.

HETTINGER PARK BOARD

Chairman

February 13, 1978
Date

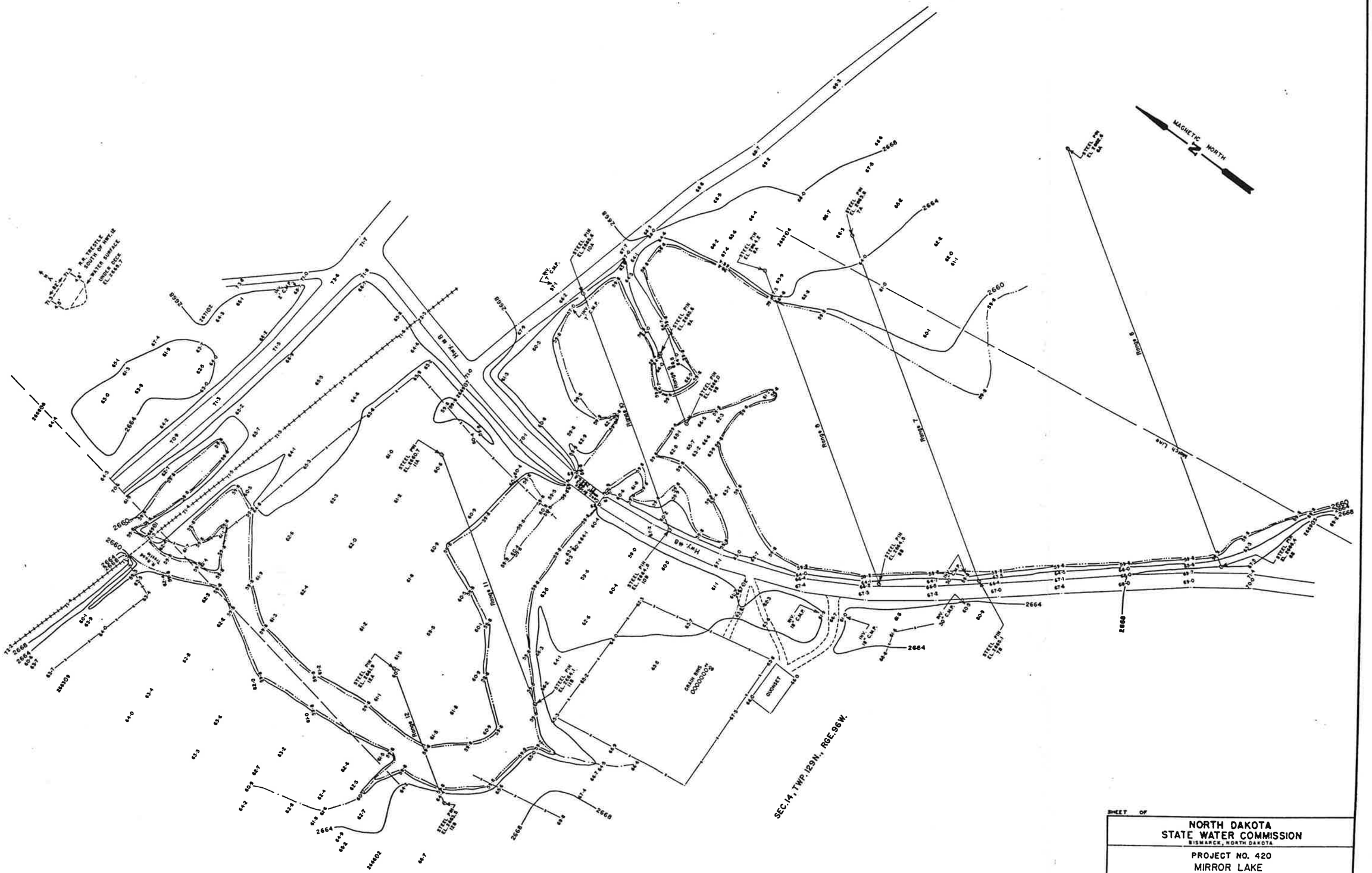
NORTH DAKOTA STATE WATER COMMISSION

Vern Fahy
State Engineer

2/10/78
Date

Distribution:
Board (1)
SWC Project File (1)
SWC Accountant (1)
SWC Investigations Engineer (1)

APPENDIX B



SHEET OF

NORTH DAKOTA STATE WATER COMMISSION

BISMARCK, NORTH DAKOTA

PROJECT NO. 420

MIRROR LAKE

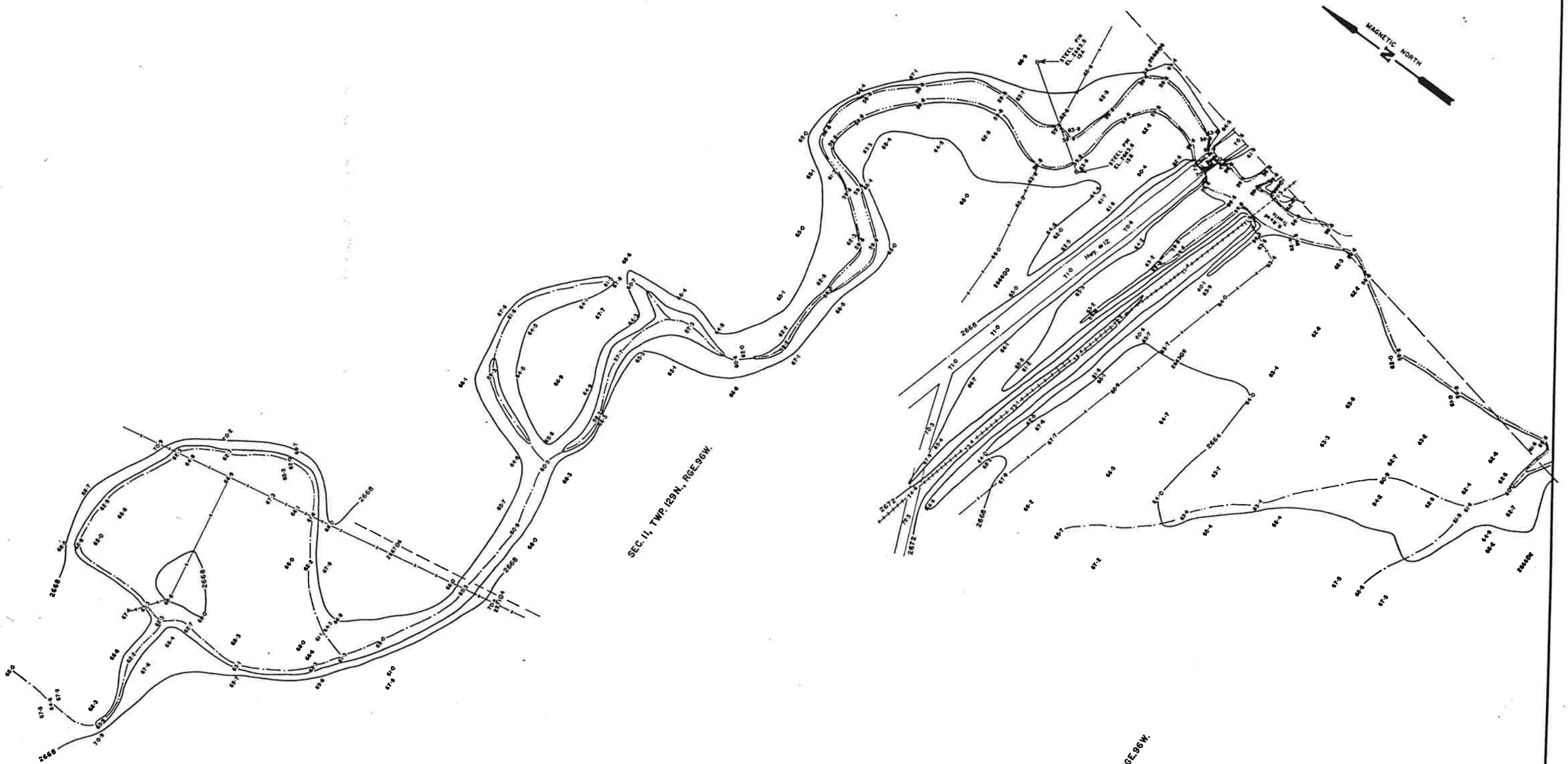
RESERVOIR TOPOGRAPHY

PLATE 2

COUNTY ADAMS DATE 8-3-78

SURVEYED: E.D.S.	CHECKED BY:	SUBMITTED:	
DRAWN: D&D	DESIGNED BY:	APPROVED:	

DRAWING NO. 9108-420-10A SCALE 1"=100'



SHEET OF

NORTH DAKOTA
STATE WATER COMMISSION
BISMARCK, NORTH DAKOTA

PROJECT NO. 420
MIRROR LAKE
RESERVOIR TOPOGRAPHY
PLATE 3

COUNTY ADAMS DATE 8-3-78

SURVEYED: E.D.S.	CHECKED BY:	SUBMITTED:
DRAWN: D.E.D.	DESIGNED BY:	APPROVED:

DRAWING NO. 9109-420-11A SCALE 1"=100'

APPENDIX C

1. Average End-Area Method

$$\text{Vol.} = \frac{(A_1 + A_2)}{2} d$$

Where:

A_1 = Cross Sectional Area of 1st Cross Section

A_2 = Cross Sectional Area of 2nd Cross Section

d = Distance Between Cross Sections

2. Modified End-Area Method

$$\text{Vol.} = \frac{A^1}{3} \cdot \frac{(E_1 + E_2)}{(W_1 + W_2)} + \frac{A}{3} \cdot \left(\frac{(E_1)}{(W_1)} + \frac{(E_2)}{(W_2)} \right) + \frac{h_3 E_3 + h_4 E_4 + .17}{130{,}680}$$

Vol. = The volume in acre-feet

Where:

A^1 = The area in acres of the quadrilateral formed by connecting the points of range intersection with crest contour between the two principal or most nearly parallel ranges.

A = The lake area of the segment in acres.

E = The cross sectional area, in square feet, of original capacity on sediment volume cut by a bounding range.

W = Width (length) of bounding range at crest elevation in feet.

h = The perpendicular distance from the range on a tributary to the junction of the tributary with the main stream, or if this junction is outside the segment, to the point where the thalweg of the tributary intersects the downstream range.

APPENDIX D

Marshall SRC

Appendix D

UNITED STATES DEPARTMENT OF AGRICULTURE

SOIL CONSERVATION SERVICE

Box 1458, Bismarck, North Dakota 58501

SUBJECT: Trip Report - Mirror Lake, Hettinger, Adams County, North Dakota

DATE: September 12, 1978

TO: Russell Nelson
Area Conservationist
Soil Conservation Service
Dickinson, North Dakota

For Your Info.
Draft A Reply
Respond Directly
Comment
Let's Discuss
Return to Sender
File

On June 21, 1978 Larry Luger, Francis Wilhelm, and I toured the watershed above Mirror Lake. The purpose of this field examination was to provide guidance to the district conservationist on land treatment (conservation planning) of this watershed. The land treatment would be incorporated into future plans to rehabilitate Mirror Lake. It is apparent this could only be a cursory review (approximately 40,000 acres in the watershed--about 52 percent cropland). Following are my comments concerning this brief field review of this watershed.

1. Preliminary data shows land use as shown below:

Land Use	Acreage	Percentage
Cropland	19,302	51.7
Pasture and Hayland	6,735	18.0
Rangeland	9,957	26.7
Other	1,343	3.6
Total	37,337	100.0

2. An estimate of 1978 crop distribution is:wheat 40 percent; summer fallow 40 percent; corn silage 8 percent; oats 7 percent; and sunflowers 5 percent.

3. Estimated average yields for crops grown in this watershed are: wheat 25 bu/ac; oats 48 bu/ac; corn silage 4.0 t/ac; and sunflowers 1,000 lbs/ac.

4. Projections from county records indicate 50-60 percent of the area is under cooperative agreements with the SCD. Approximately 55 percent of the watershed area is adequately treated. Practices installed on adequately treated lands include conservation cropping systems, crop residue use, stubbie mulching, strip cropping (both wind and contour), grassed waterways, windbreaks and buffers, and several ponds.

5. An estimated 20 percent (4,000 acres) of the cropland should be converted to grassland (pastureland, hayland, or rangeland).

6. Additional practices needed for land treatment in the watershed include crop residue use and/or stubble mulching, waterways, diversions,

terraces, and contour strip cropping. Further investigation is needed to determine potential sites for detention dams. There is also a need for improvement in pasture, hayland, and range management.

7. Various estimates have been made as relates to the sediment production of this watershed and the resultant deposition into Mirror Lake. (I understand that the North Dakota State Water Commission has made borings to determine depth of lake sediments, but I have not seen this data.) It has been suggested that as much as 10 feet of sediment has been deposited in the lake. My opinion is that this estimate is high---SWC borings should refine these estimates.

   Mirror Lake was constructed in 1911 as a railroad water supply. Surface area of the lake is estimated at 67 acres, and my thoughts are that it was relatively shallow over much of its area.

   Using the above assumptions and estimates, the following calculations are of interest:

   67 ac. lake X 10 ft. depth = 670 ac. ft. of sediment

   670 ac. ft./67 years = 10 ac. ft./yr.

   10 ac. ft./yr. ÷ 37,337 ac. = 0.0003 ac. ft./yr./ac. or 0.0036 ac. in./yr./ac. sediment production from the watershed. This converts to approximately 0.6 ton/ac./yr.

   If the SCS Soil loss tolerance of 5 ton/ac./yr. (which I do not believe is exceeded as an over-all average in the watershed) were applied to this watershed, a soil loss of 12,507,895 tons (approximately 6,300 a. ft.) would have occurred during the 67 year life of the lake. If we accept the 10 ft. sediment figure this indicates a sediment delivery ratio of about 0.1.

8. The above ramifications indicate a low sediment delivery from this watershed into Mirror Lake. I arrived at the same conclusion from my observations on the field trip. The major watercourse in this watershed is Flat Creek. Flat Creek is bordered almost continuously by grasslands. This grassland acts as a very effective buffer and filter strip.

9. A provisional general soils map and legend, furnished by Wilhelm, were used during the field evaluation. The watershed is shaped like an elongated bowl or platter. On the bottom of the bowl are nearly level to gently sloping medium to light textured soils, with minor problems of runoff and/or erosion. On the north and west sides of the bowl are mainly coarse textured gently sloping to very steep soils, which have wind erosion problems, but no special runoff or water erosion problems. The south side, and a fringe area on the

west and north sides, of the bowl have medium textured soils, gently to steeply sloping, from which erosion and runoff can occur. Accelerated land treatment measures, enumerated in Item 6, need to be applied to the latter areas.

Some of the smaller tributaries may deliver sediments directly into Flat Creek, but I believe the majority of sediments from the eroding slopes will be deposited before entering Mirror Lake.

Sorry about the lateness of this report. It continued to get buried by other things of apparently higher priority.

Edward R Weimer

Edward R. Weimer
Agronomist

cc: DuWayne Marthaller, State Water Commission, Bismarck, ND
L. J. Luger, DC, SCS, Hettinger, ND
F. J. Wilhelm, SS, SCS, Hettinger, ND
M. C. Vrem, RC&D Coordinator, SCS, Dickinson, ND
J. C. Carr, SRC, SCS, Bismarck, ND
C. E. Mumma, Asst. STC, SCS, Bismarck, ND

APPENDIX E

Computation For Sediment Delivery Ratio

1. Average Annual Runoff:

   1560 Ac-Ft/Yr (Based on Information Developed by the State Water Commission)

2. Average Capacity over Life of Reservoir:

$$\frac{337 \text{ Ac-ft} + 457 \text{ Ac-Ft}}{2} = 397 \text{ ac-ft}$$

$$\text{Capacity-Inflow Ration} = \frac{397}{1560} = 0.25$$

3. Trap Efficiency: 94% (Based on graph contained in Water-Resources Engineering by Linsley & Franzini)

4. Sediment Eroded:

$$3.7 \text{ tons/acre-yr} \times 71.2 \text{ mi}^2 \times 640 \text{ acres/mi}^2 = 16{,}860 \text{ tons/yr}$$

5. Sediment Delivered:

   Assume Unit Wt. of 60 - 90 lb/ft^3

$$\frac{60 \text{ lb/ft}^3 \times 43{,}560 \text{ ft}^3\text{/ac-ft}}{2000 \text{ lb/ton}} = 1307 \text{ tons/ac-ft}$$

$$\frac{90 \text{ lb/ft}^3 \times 43{,}560 \text{ ft}^3\text{/ac-ft}}{2000 \text{ lb/ton}} = 1960 \text{ tons/ac-ft}$$

   Sediment in Reservoir

$$120 \text{ ac-ft} \times 1307 \text{ tons/ac-ft} = 156{,}840 \text{ Tons}$$

$$120 \text{ ac-ft} \times 1960 \text{ tons/ac-ft} = 235{,}200 \text{ Tons}$$

   Sediment Delivered

$$\frac{156{,}840 \text{ Tons}}{.94} = 166{,}851 \text{ Tons}$$

$$\frac{235{,}200 \text{ Tons}}{.94} = 250{,}213 \text{ Tons}$$

Average Annual Sediment Delivered

$$\frac{166{,}851 \text{ Tons}}{69 \text{ Yrs}} = 2418 \text{ Tons/Yr}$$

$$\frac{250{,}213 \text{ Tons}}{69 \text{ Yrs}} = 3626 \text{ Tons/Yr}$$

6. Sediment Delivery Ratio:

$$\frac{2418 \text{ Tons/Yr}}{16{,}860 \text{ Tons/Yr}} = 0.14$$

$$\frac{3626 \text{ Tons/Yr}}{16{,}860 \text{ Tons/Yr}} = 0.22$$

APPENDIX F

Appendix F

COPY

soil exploration company

662 CROMWELL AVENUE
ST. PAUL, MN. 55114
PHONE 612/645-6446

a sister corporation to TWIN CITY TESTING AND ENGINEERING LABORATORY INC.

April 24, 1978

North Dakota State Water Commission
Bismarck, North Dakota 58501

Attn: Arland Grunseth

Gentlemen

Subj: Subsurface Exploration
Near Mirror Lake
Hettinger, North Dakota
#520-809

On March 20, 1978, we put down three soil test borings. The field exploration was done under your direct supervision. The soil samples were retained by you.

Four permeability tests were performed on two thin wall tube samples shipped to our laboratory. It was initially intended to only perform one series of tests on each tube, this to include permeability and identification tests. Extrusion of these samples showed variable conditions and such that a series was performed on both the top and bottom portions of each tube sample. All of the pertinent test data is given on the attached summary sheet.

The remaining portions of the tube samples will be held at this office for two months at which time they will be discarded, unless we are notified to do otherwise. If you have any questions regarding the test results, or if we can be of any further assistance to you, please do not hesitate to contact us.

Very truly yours

Gordon R Eischens
Manager - Laboratory

Samuel Y Ng, P.E.

GRE/SYN/am
Encs

LABORATORY TEST DATA

PROJECT: SUBSURFACE EXPLORATION NEAR MIRROR LAKE
HETTINGER, NORTH DAKOTA

DATE: April 24, 1978

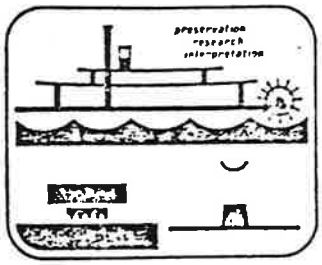
REPORTED TO: North Dakota State Water Commission

JOB NO.: 520-809

BORING NO.	2	2	2	2
SAMPLE NO.				
DEPTH (ft)	13½-15½ (top)	13½-15½ (bottom)	18-19½ (top)	18-19½ (bottom)
SOIL TYPE (ASTM: D 2488)	Sandy Silt (ML-SM)	Silty Clay (CL) with traces of Silty Sand	Sandy Clay (CL)	Medium Fat Clay (CH-CL)
PERMEABILITY TESTS:				
TYPE OF TEST:	Falling Head	Falling Head	Falling Head	Falling Head
SAMPLE DIAMETER (inches)	2.87	2.87	2.85	2.85
SAMPLE HEIGHT (inches)	4.00	3.56	3.53	3.67
WATER TEMPERATURE (°C)	23	23	22	22
CONFINING PRESSURE (Effective-psi)	2.0	2.0	2.0	2.0
HEAD DIFFERENTIAL (H_1 in cm)	153	153	153	153
k @ 20°C (cm/sec)	1.6×10^{-5}	4.5×10^{-5}	1.0×10^{-7}	2.0×10^{-8}
k @ 20°C (ft/min)	3.1×10^{-5}	8.8×10^{-5}	2.0×10^{-7}	4.0×10^{-8}
		Poor permeability	practically impervious	
MOISTURE AND DENSITY				
MOISTURE CONTENT (%)	24.1	23.2	28.9	30.4
DRY DENSITY (pcf)	99.5	98.4	94.7	92.6
ATTERBERG LIMITS				
Liquid Limit (%)	--	31.9	38.2	59.1
Plastic Limit (%)	--	13.5	14.9	21.2
Plasticity Index	NP	18.4	23.3	37.9

APPENDIX G

Appendix G



State Historical Society of north dakota

LIBERTY MEMORIAL BUILDING - BISMARCK, NORTH DAKOTA 58505

December 27, 1978

DuWayne Marthaller
North Dakota State Water Commission
900 East Boulevard
Bismarck, North Dakota 58505

Re: feasibility of restoring Mirror Lake

Dear Mr. Marthaller:

In accordance with Section 106 of the National Historic Preservation Act of 1966 (80 Stat. 915, 16 U.S.C. 470), Executive Order 11593, (36 FR 8921, 16 U.S.C. 270), the Advisory Council on Historic Preservation's "Procedures for the Protection of Historic and Cultural Properties" (36 CFR Part 800), the National Environmental Policy Act of 1969 (83 Stat. 852, 42 U.S.C. 4321), or the Office of Management and Budget's Circular A-95, the North Dakota State Historic Preservation Office has received and reviewed information concerning the project referenced above.

Based on the results of the review, it is our opinion that:

1. - the project's impact area (has not) been adequately surveyed for cultural resources;

2. - a cultural resources survey report (is not) included among our files (and ~~xxx~~) (is not) adequate to determine project related impacts on significant cultural resources;

3. - the project's impact area has had 0 cultural resources reported within its boundaries and that 0 of these resources have been professionally evaluated as significant;

4. - the project impact area has been professionally evaluated as having a ~~(xxx~~ medium ~~xxxx~~) potential to contain additional significant cultural resources;

5. - the project, by its nature, (is ~~xxx~~) likely to have an effect on significant cultural resources, if any exist, in the project area and that effect would probably be ~~(xx/xxxxxxx~~ adverse ~~beneficial~~).

Therefore, the North Dakota State Historic Preservation Officer's opinion is that the project, as currently designed and represented to this agency, will have 6. (an unknown ~~xxxxxxxxxxxxxxxxxxxxxx~~) effect on the cultural character and values of the project area and makes the following recommendations:

Mr. Marthaller
Page 2
December 27, 1978

7. X The (agency ...) should submit a professionally acceptable, comprehensive survey report. ...

8. ___ Approval upon conclusion of a properly completed Cultural Resources Protection Assurance procedure.

9. ___ Approval without further comment.

For further explanation of numbered items, see below or attached. If you have any questions regarding the above referenced project please contact Mr. Walter L. Bailey of our staff at 224-2672.

Sincerely,

James E. Sperry

James E. Sperry
State Historic Preservation Officer
(North Dakota)

JES/je

4) Potential evaluation (medium) - Current in-house knowledge of the project area indicates a medium potential for cultural resources. Site proximity to a streambed and other geographic and topographic features are consistent with factors known to influence the cultural dynamics of that area.

5) Cause of endangerment - Due to the earth disturbing nature of the project, cultural resources may be impacted during project implementation.

6) project effect unknown until a cultural resources survey has been completed to determine the presence or absence of identifiable cultural resources.

7) Survey Report- The requested survey should include all areas of potential earth disturbance including the project location and alternatives, ancillary facilities, haul roads and sources of fill. The survey report should identify the area surveyed (by description and map), features and artifacts identified, description of terrain, results of records search, bibliography and recommendations for future treatment of features found.

LNH

APPENDIX H

Appendix H

DEPARTMENT OF THE ARMY
OMAHA DISTRICT, CORPS OF ENGINEERS
6014 U.S. POST OFFICE AND COURTHOUSE
OMAHA, NEBRASKA 68102

MROOP-N

8 February 1979

North Dakota State Water Commission
Attn: Mr. DuWayne A. Marthaller
900 East Boulevard
Bismarck, North Dakota 58505

Re: Mirror Lake Dam - SWC Project #420

Dear Mr. Marthaller:

Reference is made to your letter dated 5 February 1979 and the recent telephone conversation with Mr. Broers of my staff concerning the restoration of Mirror Lake.

As explained to you by Mr. Broers, a Department of the Army permit would not be required if the sediment from Mirror Lake is excavated and hauled to an upland disposal site (the excavated material not disposed of in a wetland area).

If hydraulic dredging is proposed, a Department of the Army permit will be required if either of the following conditions prevail:

a. The dredged material and/or runoff water is discharged into a wetland area;

b. The runoff water from the dredging operation is allowed to reenter the lake.

In the event that it becomes necessary for you to apply for a Department of the Army permit, inclosed is our pamphlet entitled, "U.S. Army Corps of Engineers Permit Program," an application form, and our environmental data questionnaire.

The form of lettering, conventional signs, etc., shown on the sample drawings need not be followed exactly; but the drawing must be of equal clarity and must be submitted on 8 x 10½ inch paper.

MROOP-N 8 February 1979
North Dakota State Water Commission

Before a permit can be issued, an environmental assessment must be written for each application. A properly completed environmental questionnaire should accompany your application.

It should also be noted that a minimum of 120 days lead time should be allowed for processing dredging permits.

If you have any questions, contact this office or call Mr. Robert Sage at 402-221-4172.

Sincerely yours,

Ralph J. Miller

Inclosures
As stated

RALPH J. MILLER
Chief, Regulatory Functions Branch
Operations Division

MROOP-N

8 February 1979

North Dakota State Water Commission
Attn: Mr. DuWayne A. Marthaller
900 East Boulevard
Bismarck, North Dakota 58505

Re: Mirror Lake Dam - SWC Project #420

Dear Mr. Marthaller:

Reference is made to your letter dated 5 February 1979 and the recent telephone conversation with Mr. Broers of my staff concerning the restoration of Mirror Lake.

As explained to you by Mr. Broers, a Department of the Army permit would not be required if the sediment from Mirror Lake is excavated and hauled to an upland disposal site (the excavated material not disposed of in a wetland area).

If hydraulic dredging is proposed, a Department of the Army permit will be required if either of the following conditions prevail:

a. The dredged material and/or runoff water is discharged into a wetland area;

b. The runoff water from the dredging operation is allowed to reenter the lake.

In the event that it becomes necessary for you to apply for a Department of the Army permit, inclosed is our pamphlet entitled, "U.S. Army Corps of Engineers Permit Program," an application form, and our environmental data questionnaire.

The form of lettering, conventional signs, etc., shown on the sample drawings need not be followed exactly; but the drawing must be of equal clarity and must be submitted on 8 x 10½ inch paper.

MROOP-N 8 February 1979
North Dakota State Water Commission

Before a permit can be issued, an environmental assessment must be written for each application. A properly completed environmental questionnaire should accompany your application.

It should also be noted that a minimum of 120 days lead time should be allowed for processing dredging permits.

If you have any questions, contact this office or call Mr. Robert Sage at 402-221-4172.

Sincerely yours,

Inclosures
As stated

RALPH J. MILLER
Chief, Regulatory Functions Branch
Operations Division