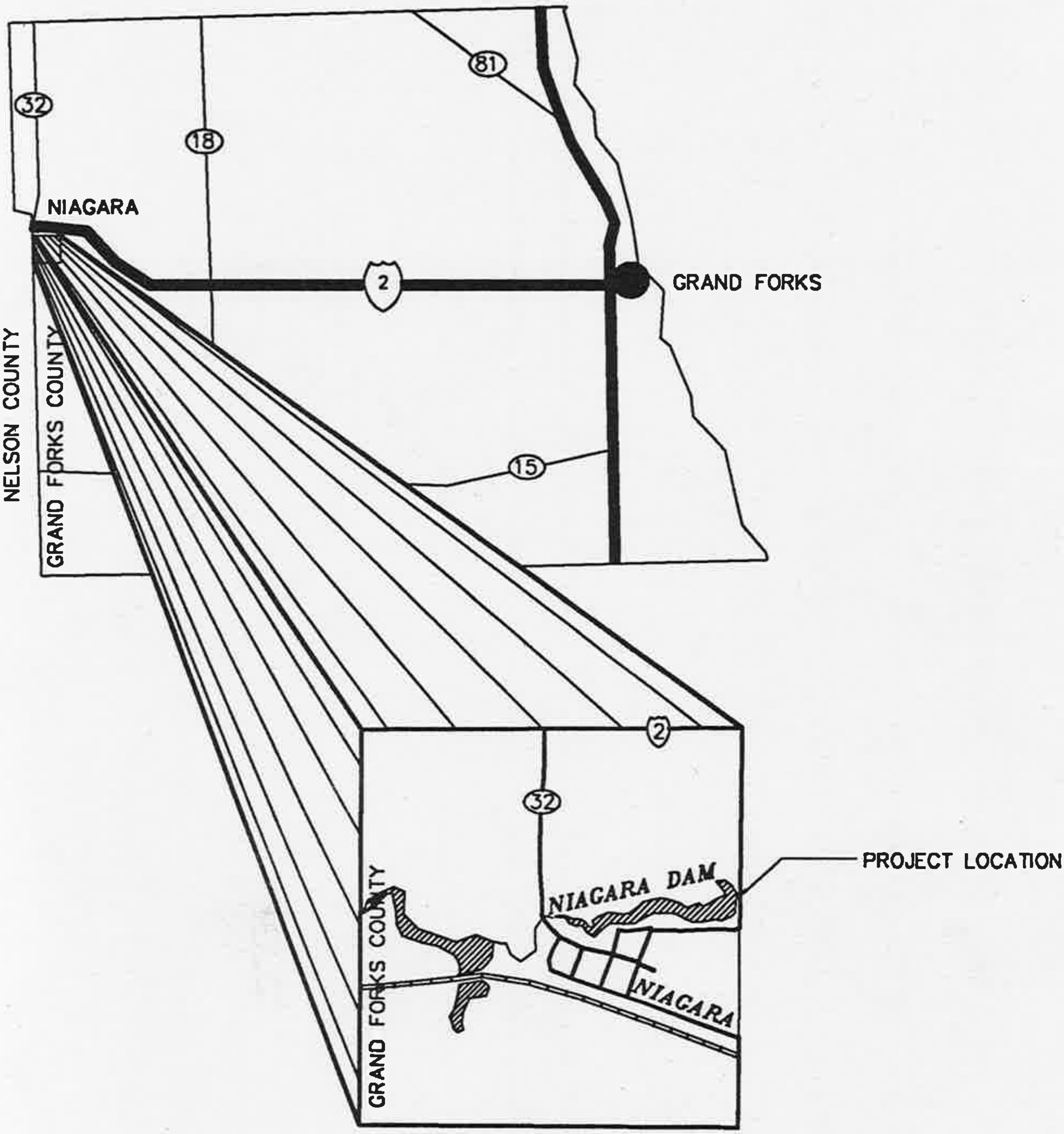
PRELIMINARY ENGINEERING REPORT
NIAGARA DAM
SWC # 464
GRAND FORKS COUNTY



NORTH DAKOTA
STATE WATER COMMISSION

JULY 1991

PRELIMINARY ENGINEERING REPORT

Niagara Dam
SWC Project #464

July 1991

North Dakota State Water Commission
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I. INTRODUCTION

Study Objectives:

In January, 1991, the North Dakota State Water Commission entered into an agreement with the North Dakota State Game and Fish Department and the Grand Forks County Water Resource District. The purpose of the agreement was to investigate the feasibility of repairing and upgrading the downstream Niagara Dam, located northeast of the city of Niagara, North Dakota. The agreement called for the State Water Commission to conduct a field survey of the upstream and downstream embankment and reservoir including topographic data, area-capacity data, and bridge and channel geometry; conduct a geotechnical investigation of the embankment to determine the subsurface conditions at the existing spillway system; conduct a study of the hydrology of the watershed upstream of the dam; design the outlet works necessary to pass the design flood through the dam, giving consideration to the possibility of raising the permanent water surface elevation; perform a preliminary review of the effects of the reservoir on area groundwater; prepare a preliminary cost estimate for the repair and upgrade; and prepare a preliminary engineering report presenting the results of the investigation. A copy of the agreement is contained in Appendix A. Figure 1 shows the location of Niagara Dam within the state.

This report contains information on the geology and climate of the site; results of a geotechnical survey conducted on the embankment; results of a groundwater analysis conducted near the

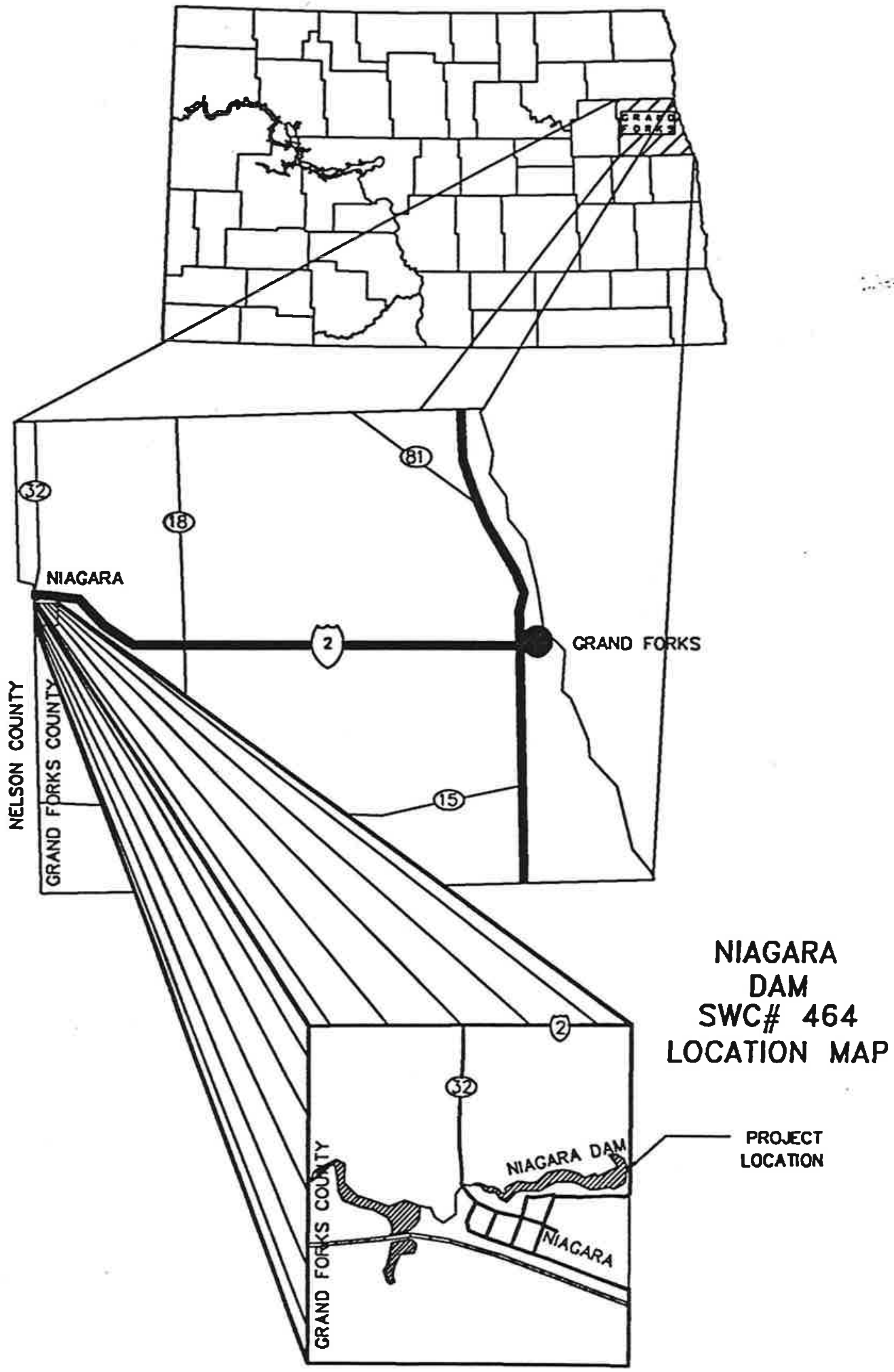


Figure 1 - Location of Niagara Dam

reservoir; results of a hydrologic and hydraulic analysis of the drainage basin; a summary of the preliminary design of the project; a cost estimate based on the preliminary design; and a statement of conclusions and recommendations regarding the project.

Basin Location and Description:

Niagara Dam is located on an unnamed tributary to the North Branch of the Turtle River, northeast of the city of Niagara, North Dakota, between Sections 7 and 8, Township 152 North, Range 56 West. The dam was built for the purpose of swimming, boating, angling, migratory waterfowl refuge, and ice harvesting. The topography of the area consists of a linear belt of knobby hills that have moderate relief. The drainage area for the dam is located to the west and is divided by a water supply dam for the Great Northern Railroad, located approximately 1/2-mile upstream. The drainage basin extends from eastern Nelson County to western Grand Forks County. The drainage area upstream of the railroad dam is 4.1 square miles. An additional 0.2 square miles of drainage area is located between the railroad dam and downstream Niagara Dam. The total drainage area for downstream Niagara Dam is 4.3 square miles. The majority of the inflow into the downstream dam is supplied by outflow from the spillway for the railroad dam. Land use in the basin is primarily agricultural. The upstream railroad dam acts as a sediment trap for the downstream dam.

The embankment is an earthfill structure. The embankment is 500 feet long, 23 feet high at the maximum section, and approximately 25 feet wide at the crest. The crest of the embankment is at an elevation of approximately 1422 msl, and has a north to south alignment with the right abutment on the south side. The embankment also serves as a county road running between the city of Niagara and U.S. Highway 2.

The reservoir is controlled at an elevation of 1416.4 msl by two 60-inch diameter corrugated metal pipe (CMP) culverts and one 30-inch diameter CMP culvert which pass through the embankment. These pipes act as both a principal and an emergency spillway.

Historical Background:

Niagara Dam was constructed in 1935 by the Works Progress Administration (WPA). The original spillway consisted of a rubble-masonry weir structure. The county road passed through the spillway. During the spring flood of 1948, the dam was damaged and repairs ensued. In the summer of 1948, the spillway was replaced by two 30-inch diameter CMP in rubble masonry head walls with an apron. The spillway washed out on several occasions after that and was repaired. It is estimated that the existing spillway, consisting of two 60-inch diameter CMP and one 30-inch diameter CMP, was installed during the mid-1960s.

In 1982, it was brought to the State Water Commission's attention that the spillway had become severely undermined and their assistance in making repairs was requested.

In the fall of 1983, the spillway was repaired by the State Water Commission for a cost of $16,788. Repairs consisted of excavation beneath the pipes, driving a sheet piling cutoff wall, relaying the culverts, guniting of the upstream face of the culverts, and construction of a downstream concrete apron.

In the spring of 1987, a backhoe passing over the road fell through the section of roadway between the two pipes. It was noted that a large cavity had developed between the pipes due to piping that had started around the south culvert. Prior to the accident, water was seen flowing on the outside of the pipe. The Grand Forks County Highway Department repaired the hole, but the south pipe was not relayed.

In the spring of 1988, four alternatives for the repair of Niagara Dam were evaluated. These alternatives ranged from repair of the existing spillway by the installation of a concrete headwall, to the removal of the existing spillway and the installation of a reinforced concrete pipe riser, plus a 48-inch diameter conduit along with an emergency spillway. None of these alternatives were pursued.

In the fall of 1990, a meeting was held in Niagara to discuss possible methods to repair the dam. Deficiencies in the dam were pointed out. These deficiencies included seepage around and under the pipes, corrosion of the spillway pipes, and problems with the embankment fill. After much discussion, it was decided that an investigation would be needed, including a soils study and detailed survey, to determine the best method of repair.

II. GEOLOGY AND CLIMATE

Niagara Dam is located in the Drift Plains, the largest physiographic district in North Dakota. Characteristically, the Drift Plains is a lowland prairie situated upon a gently rolling ground moraine area interrupted by ridged end moraines and flat outwash plains.

The Drift Plains district in Grand Forks County is characterized by ground moraine on Cretaceous bedrock. Its eastern boundary is placed at the western-most extent of glacial Lake Agassiz deposits. This boundary occurs at an elevation ranging from 1160 to 1170 feet above sea level. The Drift Plains reach an elevation of 1500 feet above sea level along the western county boundary. This rise of the land surface is a southern extension of the more conspicuous Pembina escarpment of Cavalier, Pembina, and Walsh Counties. The underlying bedrock escarpment ranges in elevation from about 800 to 1400 feet above sea level and the bedrock outcrops in the valley walls of the deeper drainage.

The climate of the basin is a dry, subhumid climate that is characterized by a wide temperature range, variable precipitation, and rigorous winters. The growing season averages 132 days. Annual precipitation is 18 inches, of which over three-fourths falls during May through September. The prevailing wind direction is from the northwest.

III. COMPUTER MODELS

A hydrologic analysis of the watershed was performed using the HEC-1 computer model, developed by the U.S. Army Corps of Engineers, and the SWAMP computer model, developed by the Soil Conservation Service.

The HEC-1 computer model was used to simulate the rainfall vs runoff response for the basin, and to develop inflow hydrographs for input into the SWAMP computer model. HEC-1 formulates a mathematical hydrologic model of the watershed based on the following data: the amount of rainfall, the rainfall distribution, soil type, land use, and the hydraulic characteristics of the channels and drainage areas. The HEC-1 model is designed to calculate the surface runoff of the watershed, in relation to precipitation, by representing the basin as an interconnected system of hydrologic and hydraulic components. Each component of the model represents an aspect of the precipitation-runoff process within a portion of the subbasin. These components were put into the model to determine the magnitude and duration of runoff from hydrologic events with a range of frequencies.

The SWAMP computer model was used to route the flows through the Railroad Dam, the roadway between the dams, and downstream Niagara Dam. SWAMP is designed to route flows through structures in series, where the upper structure is subject to variable tailwater caused by the fluctuating pool elevation of the lower structure. It is a routing procedure only; it does not develop inflow hydrographs or discharge rating tables. The routing solution used by SWAMP is a "bookkeeping" procedure, where inflow and discharge rates are assumed to remain constant throughout a routing time interval. Storage and elevations are computed at the end of the interval and new flow rates are determined for the next interval. If the routing interval is kept short enough, the routing is accurate. The flow rate from one sub-area to another, in either direction, is determined by interpolating between a family of discharge rating curves supplied by the user. Each of these transfer rating curves has a constant headwater elevation and gives the discharges at various tailwater elevations.

The models were developed to determine the hydrologic response of the Niagara Dam watershed. The results gained from the models included: 1) inflow hydrographs, 2) reservoir stage hydrographs, and 3) outflow hydrographs.

IV. GEOTECHNICAL

Introduction:

A geotechnical exploration on downstream Niagara Dam was initiated by the State Water Commission. The purpose of the exploration was to assist in evaluating the subsurface condition of the embankment. The information gained from the exploration was used to aid in determining the cause of the undermining of the spillway pipes and to determine if the embankment is suitable for repair.

This section of the report describes the exploration and testing performed and summarizes the subsurface soil conditions.

Exploration and Testing:

The drilling and testing was performed by Midwest Testing Laboratory, Inc. The location and elevation of all test borings was surveyed by the State Water Commission (Refer to Figure 2).

The drilling consisted of three standard penetration test borings which were performed on April 29, 1991. Split barrel and thin-walled samples were collected at intervals selected by State Water Commission field personnel. The soils encountered were visually and manually classified and boring logs were prepared. Water level measurements were also collected upon completion of the borings and are contained on the boring logs. Logs of the test borings are contained in Appendix B.

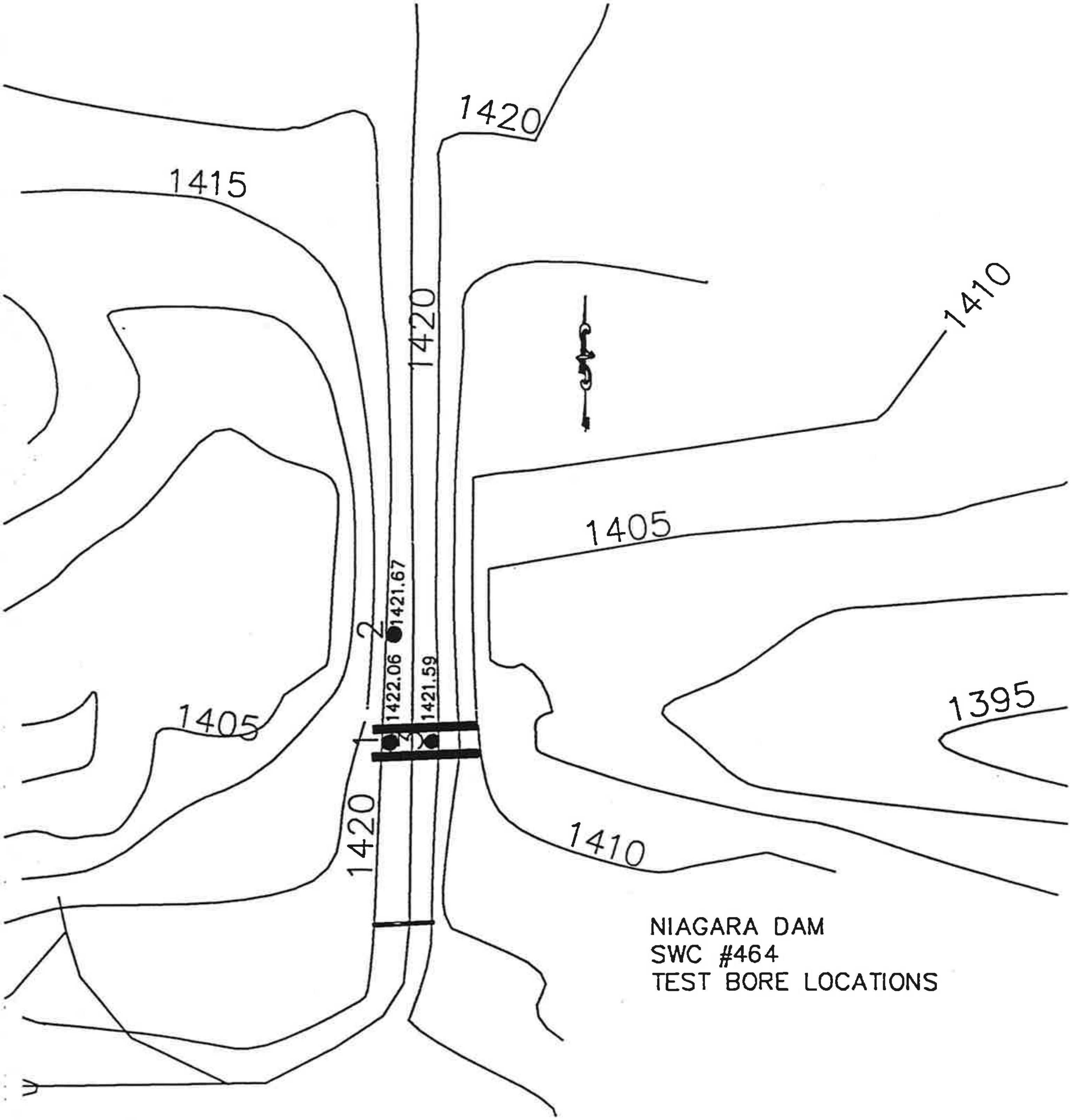


Figure 2

Location of Test Borings

Laboratory tests were conducted on three thin-walled samples collected at the site, as requested by the State Water Commission. The test results are contained in Appendix B.

Subsurface Soil Conditions:

The subsurface condition of Niagara Dam is indicated by the logs of the test borings which are included in Appendix B. The logs indicate the depth and identification of various soil strata, the penetration resistances, and water level information.

The borings indicate that the original embankment was constructed of fill material consisting of sandy lean clay. Test boring number 2 was taken north of the existing spillway where the embankment has been unmodified. This boring shows approximately 24 feet of sandy lean clay fill on top of a layer of organic clay with sand. This indicates that the embankment was constructed on the existing ground without any subsurface preparation. The penetration resistances, "N" indicated on the soil logs indicate that the embankment was constructed of relatively soft material. The water level data indicates that the embankment is relatively water tight.

Test borings number 1 and 3 were taken near the upstream and downstream ends of the existing spillway, respectively. These borings also show soft material in the embankment. This soft material could explain the undermining that has occurred. In all likelihood, the strength of the original fill was insufficient to support the spillway, which resulted in slight movement of the pipes when vehicles passed over the county road over the embankment. This slight movement provided a seam for water passage around the pipes during higher water levels, causing the pipes to undermine. The test borings at the existing spillway indicate that when the spillway was repaired, it was backfilled with firmer material laid on the original fill. Even though the spillway was backfilled with firmer material, it appears that the underlying material still allows movement of the pipes. This movement has resulted in the continued undermining of the pipes.

The proposed method to alleviate the undermining problem is to excavate the soft fill material at the desired spillway location. The original ground surface beneath the dam consists of stiff sandy lean clay with shale fragments. This material should provide a sufficient base for a new spillway. After excavation to the original ground surface, the area should be backfilled with suitable fill material and the new spillway installed. It appears that the most suitable location for the new spillway is at the location of the existing spillway. The depth of excavation required at this location would be approximately 26 feet, while if the spillway were located farther to the north, excavation in excess of 30 feet would be required.

V. GROUNDWATER

Introduction:

The domestic water supply for the city of Niagara is from individual well systems at each of the residences and businesses. The wells are completed low-transmissive sediments in a ground morainal deposit. Most of the wells observed in town are older, large-diameter (36-inch) wells which are open to the formation at the bottom. Local residents in Niagara feel that the reservoirs have a significant impact on the groundwater in the city. They feel that if the downstream reservoir is drained, many of the wells in the city will go dry. The following sections describe the analysis performed to determine the relationship between the water level in the reservoir and the groundwater level.

Analysis:

As part of the analysis, water level elevations were measured at five residential wells in Niagara, as well as in the downstream reservoir. Figure 3 shows the location of the wells that were measured. Table 1 gives the water surface elevations for the wells and reservoir that were measured.

Table 1 - Water Surface Elevations in Wells and Reservoirs

Location	Water Surface Elevation (msl)
Downstream Niagara Dam	1413.6
Well #1	1405.8
Well #2	1425.3
Well #3	1425.6
Well #4	1427.7
Well #5	1426.1

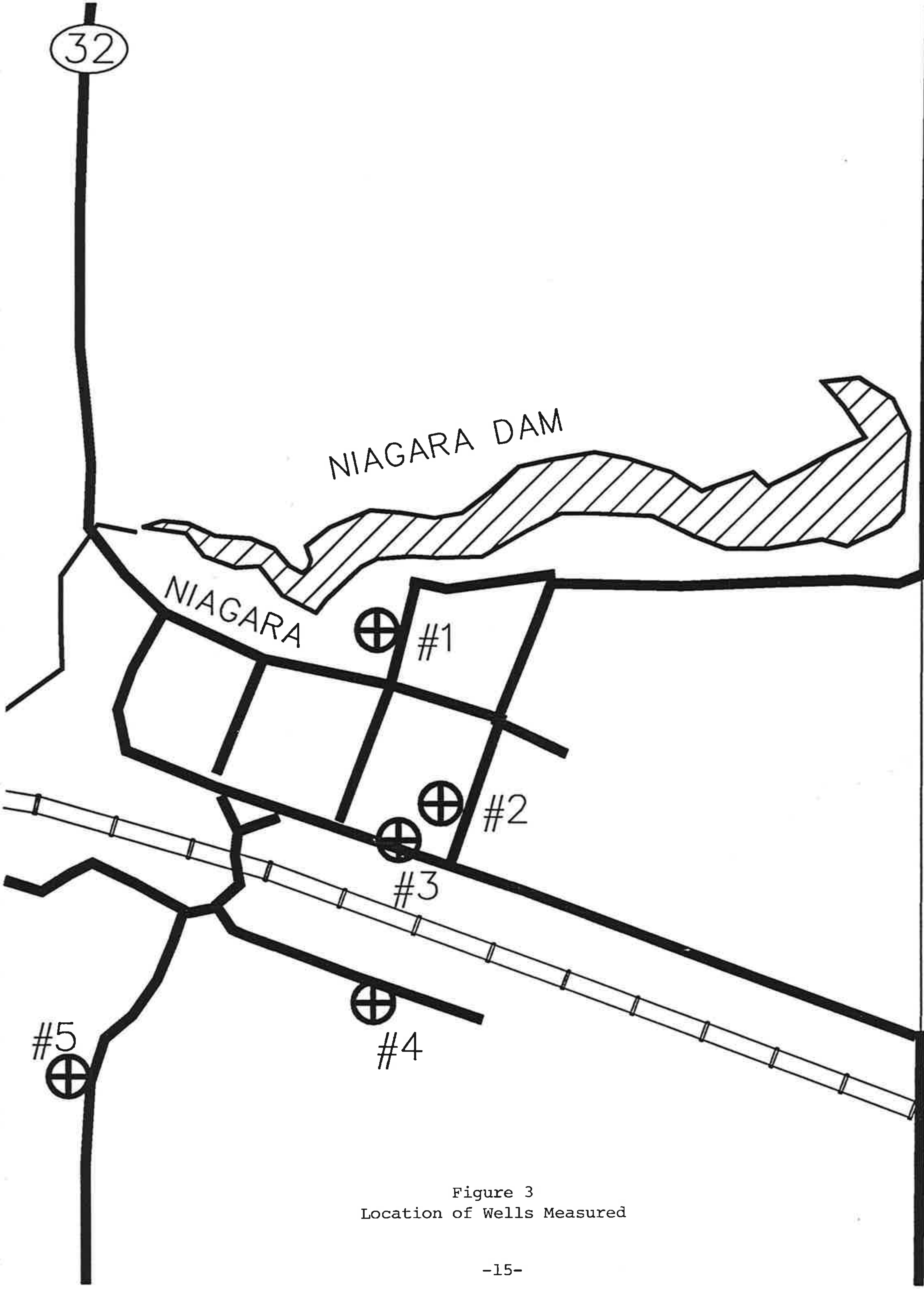


Figure 3
Location of Wells Measured

The water level elevations indicate that the groundwater is poorly connected to the surface water reservoir bordering the town on the north (downstream Niagara Dam). The water level in well #1, located a short distance from the reservoir, is 7.8 feet lower than the water level in the reservoir. The water level in wells 2 through 5, which are farther away from the reservoir, are 11.7 to 14.1 feet higher than in the downstream reservoir. The large difference in water level elevation indicates that there is not a significant amount of water moving from the groundwater into the reservoirs or vise versa.

The perception that the water levels in the wells are controlled by the levels of the two adjacent reservoirs probably stems from the fact that both the surface and the groundwater systems are dependent on precipitation and snowmelt to maintain their levels. In dry cycles, such as the one we have been experiencing for the past three years, the reservoir level has declined because of lack of runoff and the groundwater levels have declined because of lack of direct infiltration of precipitation and snowmelt.

<u>Conclusions</u>:

Based on the analysis, it appears that a change in the water surface elevation of the downstream reservoir will not significantly effect the water level in the wells in Niagara. The scope of this analysis is preliminary in nature. To determine the exact relationship between the reservoir level and area groundwater, a more detailed study, involving the drilling and monitoring of test wells, will be needed. It is estimated that such a study would cost in excess of $10,000. If the decision is made to drain the downstream reservoir, this type of study may be necessary.

VI. PRELIMINARY DESIGN

Dam Classification:

The first step in the investigation of Niagara Dam was to determine the dam classification. Design criteria are based on hazard classification and the height of the dam. Hazards are potential loss of life or damage to property downstream of the dam due to releases through the spillway or complete or partial failure of the structure. Hazard classifications listed in the "North Dakota Dam Design Handbook" are as follows:

Low - dams located in rural or agricultural areas where there is little possibility of future development. Failure of low-hazard dams may result in damage to agricultural land, township and county roads, and farm buildings other than residences. No loss of life is expected if the dam fails.

Medium - dams located in predominantly rural or agricultural areas where failure may damage isolated homes, main highways, railroads, or cause interruption of minor public utilities. The potential for the loss of a few lives may be expected if the dam fails.

High - dams located upstream of developed and urban areas where failure may cause serious damage to homes, industrial and commercial buildings, and major public utilities. There is a potential for the loss of more than a few lives if the dam fails.

Considering that it is located in a rural area, and that no loss of life is expected if the dam fails, Niagara Dam is classified as a low-hazard dam.

After a dam has been given a hazard category, it can be classified according to its height. The following table was listed in the "North Dakota Dam Design Handbook":

Table 2 - Dam Design Classification

Dam Height (feet)	Hazard Categories		
	Low	Medium	High
Less than 10	I	II	IV
10 to 24	II	III	IV
25 to 39	III	III	IV
40 to 55	III	IV	V
Over 55	III	IV	V

Niagara Dam has a low-hazard classification and falls in the 10- to 24-foot height range. Based on this, it is given a class II classification for design purposes.

For a Class II dam, the emergency spillway must pass the flow due to a 50-year precipitation event without overtopping the dam, and pass the flow due to a 25-year precipitation event within an acceptable velocity. Since Niagara Dam does not have a separate emergency spillway, the principal spillway must pass these flows without overtopping the dam.

Hydrology:

The watershed above Niagara Dam was defined using USGS 7.5 minute quadrangle maps of the area. The drainage area for the upstream railroad dam was calculated to be 4.1 square miles. An additional 0.2 square miles of drainage area is located between the railroad dam and downstream Niagara Dam. The total drainage area for downstream Niagara Dam is 4.3 square miles. Figure 4 shows the drainage area above both dams.

Precipitation Design:

Once the dam was classified, precipitation design amounts were determined. Outlet works of a dam are required to have flow capacities capable of passing runoff from precipitation events as suggested by its classification.

The event that provides the maximum reservoir level should be used as the design event (i.e., 24-hour rainfall, 10-day rainfall, or 10-day snowmelt). For Niagara Dam, the design event is the 24-hour rainfall. Table 3 shows the resulting peak inflows to downstream Niagara Dam for these events.

Table 3 - Peak Inflows for Design Frequency

Event	Intensity (in/interval)	Peak Inflow (cfs)
50-year 24-hour rainfall	4.40	540
50-year 10-day rainfall	7.80	533
50-year 10-day snowmelt	3.91	410

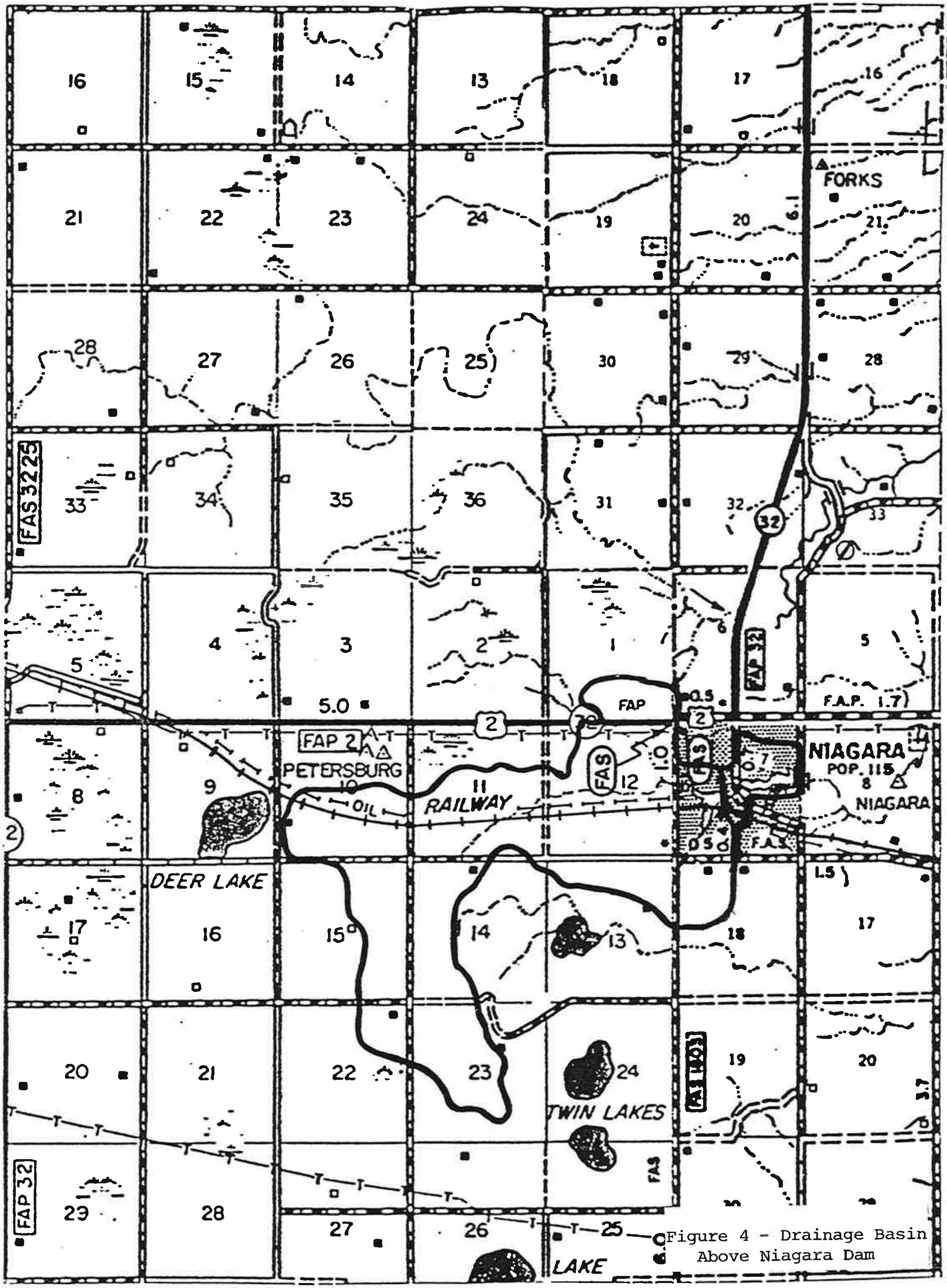


Figure 4 - Drainage Basin
Above Niagara Dam

Hydraulic Design:

The HEC-1 computer model was used to simulate the precipitation vs runoff response for the Niagara Dam basin. The SWAMP computer model was used to route the flows through the upstream railroad dam, through the culvert in the roadway between the two dams, and through downstream Niagara Dam. The area-capacity curves for the reservoirs and the spillway rating curves were needed in order to use these models. Area capacity curves for both reservoirs were developed using topographical maps obtained from survey data. Figure 5 shows the area capacity curve for downstream Niagara Dam. The rating curve for the spillway on downstream Niagara Dam was developed using a Bureau of Public Roads nomograph based on inlet control. Table 4 shows the rating curve for the existing spillway system.

Table 4 - Rating Curve for Existing Spillway

Elevation	Spillway Discharge (cfs)
1416.4	0.0
1418.9	94.0
1419.4	126.0
1419.9	160.0
1420.4	194.0
1420.9	227.0
1421.4	264.0
1421.9	297.0
1422.4	330.0

The rating curve for the principal spillway on the upstream railroad dam, which consists of a 36-inch diameter CMP drop inlet and a 30-inch diameter CMP pipe, was developed using the

NIAGARA DAM

AREA-CAPACITY CURVE

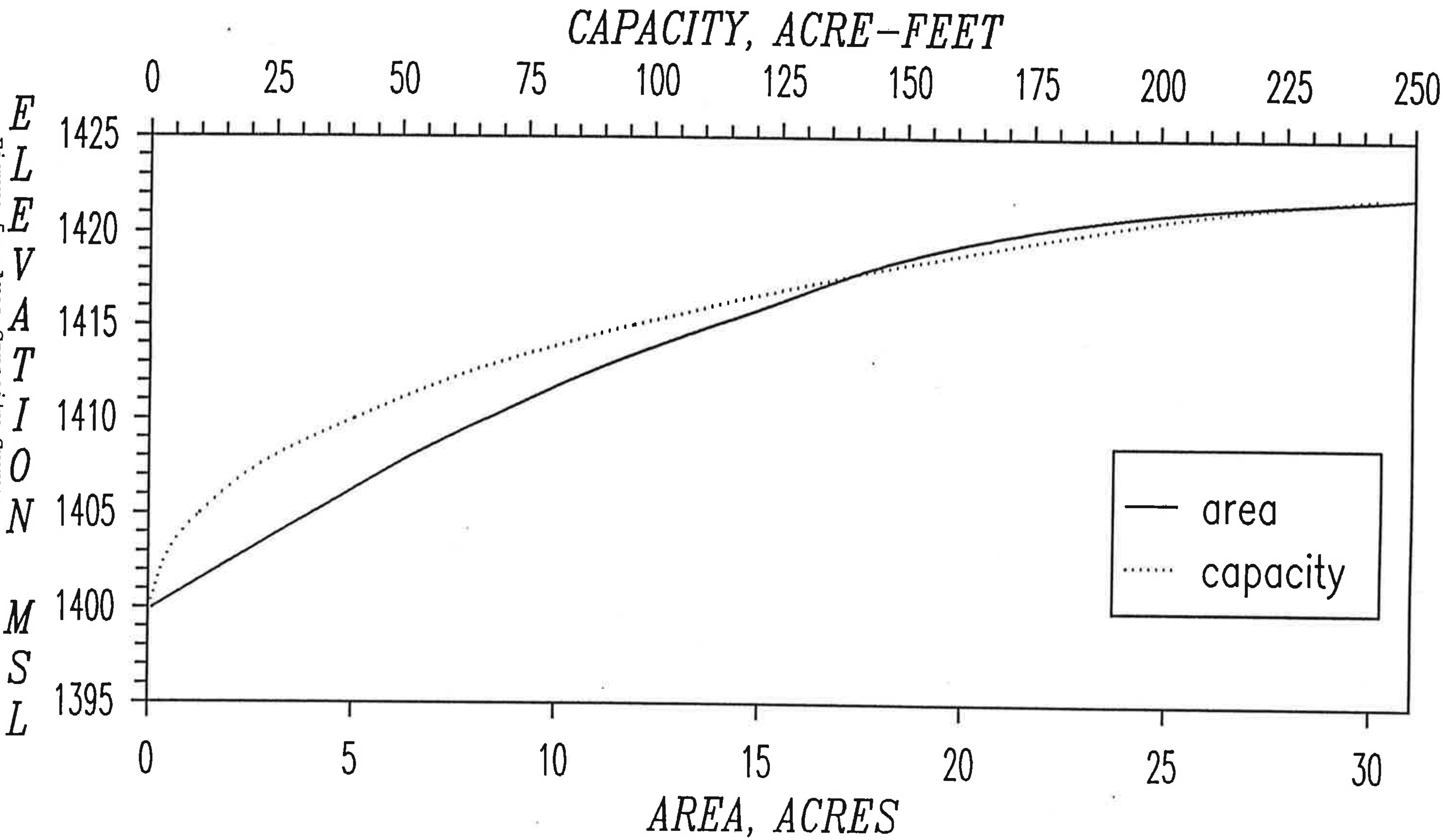


Figure 5 - Area-Capacity Curve for Downstream Niagara Dam

equations for pipe flow. The rating curve for the emergency spillway on the upstream railroad dam, which consists of a 50-foot wide channel with 3:1 side slopes, was developed using the Rater computer program, developed by the North Dakota State Water Commission. The rating curve for the 60-inch diameter reinforced concrete pipe (RCP) culvert under the roadway between the dams was developed using the equations for pipe flow.

<u>Spillway Works</u>:

The present spillway for Niagara Dam consists of two 60-inch diameter CMP culverts and one 30-inch diameter CMP culvert which pass through the embankment. Presently, the two 60-inch diameter pipes are corroded and undermined. The condition of the pipes poses a potential hazard to the integrity of the dam, and during high flows, the dam may fail. In addition to the associated hazard, the existing spillway is inefficient. The low amount of head that is obtainable on the pipes prevents them from achieving full pipe flow, thereby not utilizing the full hydraulic capabilities of the pipes. Another problem with the existing spillway is that it is not capable of handling the design flow required for a Class II dam. Table 5 shows the inflow, outflow, and stage for the different precipitation events for the existing conditions generated by the HEC-1 and SWAMP models. This data shows that the water surface elevation exceeds the elevation of the top of the dam for the 50-year 24-hour rainfall, as well as the 50-year 10-day rainfall.

Table 5 - Results of Hydrologic Study on Existing Conditions

Event	Inflow (cfs)	Outflow (cfs)	Stage (msl)
50-year 24-hour rainfall	540	327	1422.4
50-year 10-day rainfall	533	328	1422.4
50-year 10-day snowmelt	410	305	1422.0

The results of the preliminary investigation show that a single 60-inch diameter CMP with an 84-inch diameter CMP drop inlet will safely handle the design flow. The use of a drop inlet increases the amount of head that is obtainable on the pipe, allowing increased flow through it. The rating curve for this spillway system was developed using the equations for pipe flow. Table 6 shows the rating curve for the proposed spillway system.

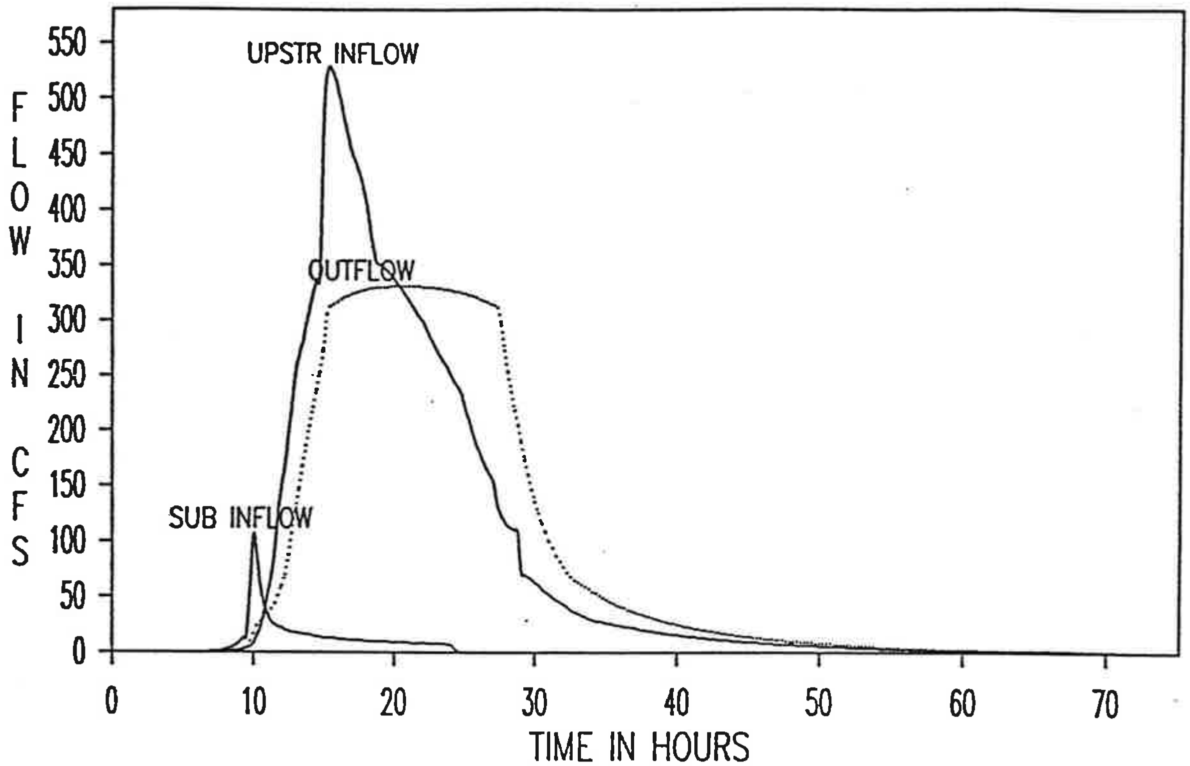
Table 6 - Rating Curve for Proposed Spillway

Elevation	Spillway Discharge (cfs)
1417	0.0
1418	68.2
1419	192.8
1420	311.6
1421	324.8
1422	337.6
1423	349.9
1424	361.7

Table 7 shows the inflow, outflow, and stage for the proposed spillway as generated by the HEC-1 and SWAMP computer models. Figures 6 and 7 show the various inflow-outflow

NIAGARA DAM HYDROGRAPH

50 YEAR 24-HOUR RAINFALL



50 YEAR 10-DAY RAINFALL

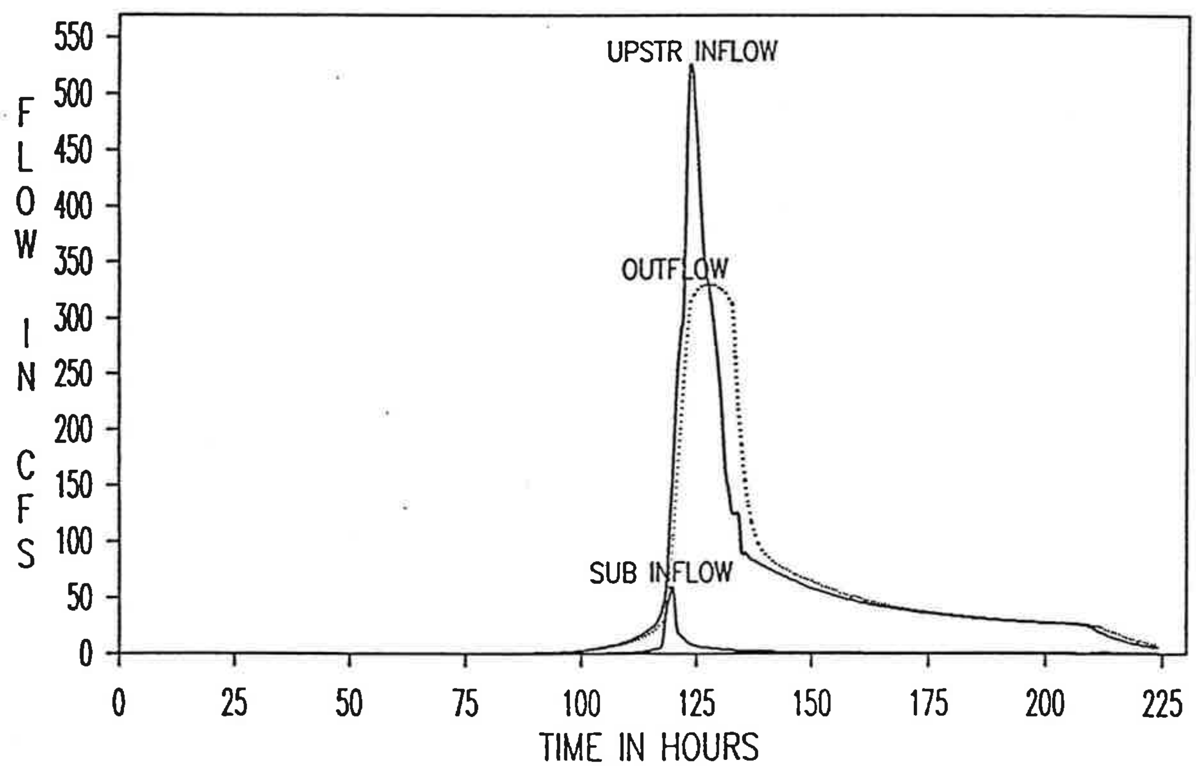


Figure 6 - Niagara Dam Hydrograph

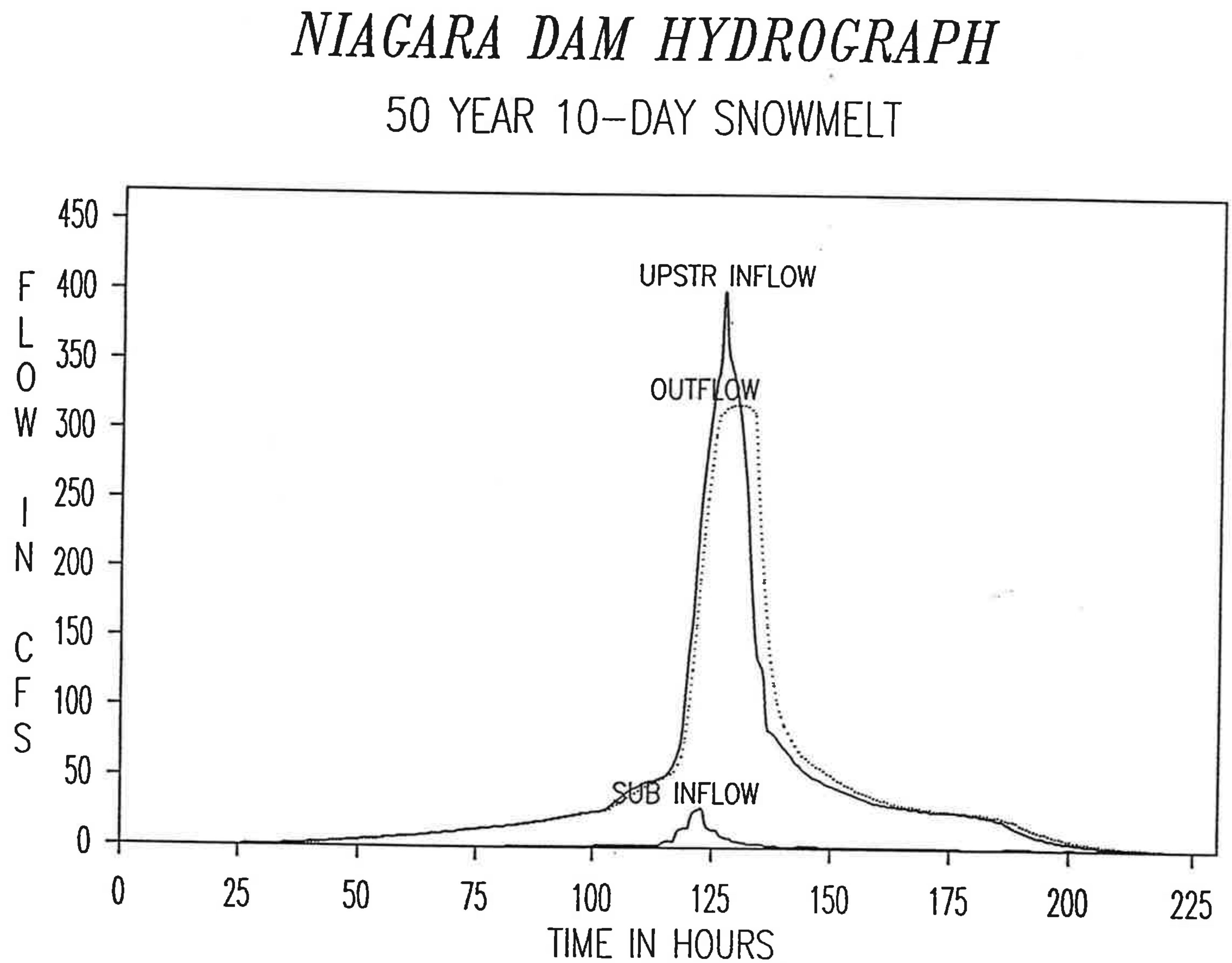


Figure 7
Niagara Dam Hydrograph

hydrographs for the proposed spillway. The inflow shown on the hydrographs is due to outflow from the upstream railroad dam routed through the culvert in the roadway between the dams and runoff from the drainage area between the two dams.

Table 7 - Results of Hydrologic Study on Proposed Spillway

Event	Inflow (cfs)	Outflow (cfs)	Stage (msl)
50-year 24-hour rainfall	540	331	1421.5
50-year 10-day rainfall	533	330	1421.4
50-year 10-day snowmelt	410	320	1420.6

The proposed 84-inch diameter CMP drop inlet will be set at a control elevation of 1417 msl. The entrance invert of the proposed 60-inch diameter CMP spillway pipe will be set at an elevation of 1407 msl. The pipe will be approximately 115 feet long with the outlet set at an elevation of 1406 msl. The spillway pipe will be epoxy coated to help reduce corrosion. Figure 8 shows a transverse section of the dam at the principal spillway. The control elevation of the proposed spillway will be 0.6 feet above the elevation of the existing spillway. Increasing the control elevation higher than 1417 msl will not be possible unless the embankment is raised.

A cantilever outlet and plunge pool will be sufficient to dissipate the energy of the water going through the spillway. The outlet of the pipe is designed so that the invert of the

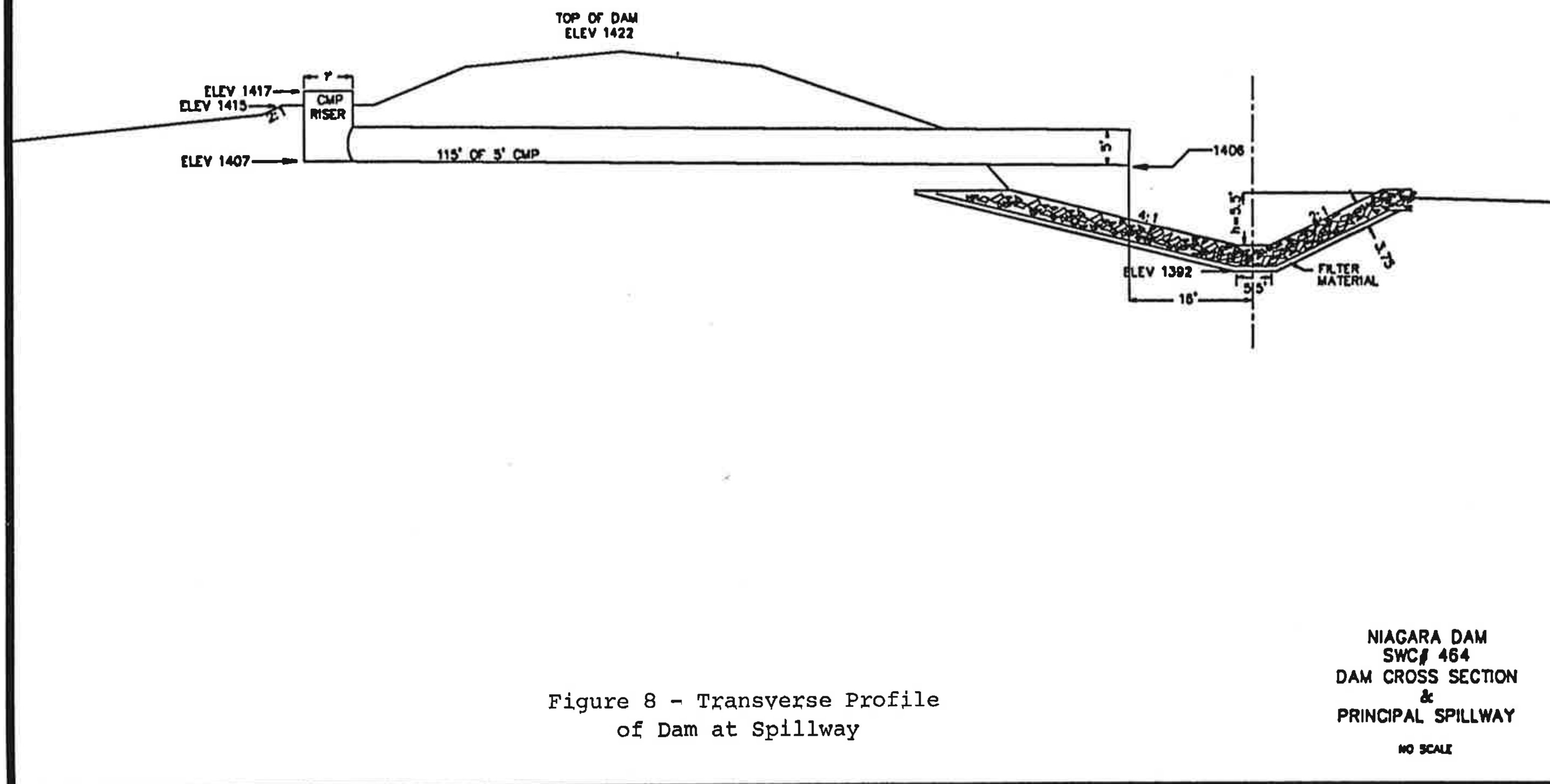


Figure 8 - Transverse Profile
of Dam at Spillway

cantilever outlet is at least one-foot above the tailwater elevation at maximum discharge.

It appears that the best location for the proposed spillway is at the same location as the existing spillway. Following the removal of the existing spillway, the embankment should be excavated to a depth of approximately 26 feet, as discussed in the Geotechnical Section. This depth will be sufficient to reach the original ground surface. Following the excavation, the area should be backfilled with suitable fill material and the new spillway installed.

Low-Level Outlet:

The proposed modifications to Niagara Dam include the installation of a low-level drawdown structure. The low-level drawdown structure, also known as a cold water return or hypolimnetic discharge structure, is designed to counteract accelerated aging in reservoirs. The low-level drawdown structure removes nutrient-rich water from the bottom of a thermally stratified reservoir, leaving the better quality water behind, and thus increasing the usefulness and life span of the reservoir. Improved water quality conditions result in a positive benefit to the fishery and to all other recreational uses.

A rule of thumb used in the design of low-level drawdown structures is that they should pass 10 percent of the reservoir volume in a 14-day time period. For Niagara Dam, a 4-inch PVC pipe is sufficient to act as a low-level drawdown. The pipe will extend into the reservoir for a distance of approximately 200 feet.

<u>Water Control</u>:

Two methods of water control have been analyzed. The first method is to drain the reservoir. This is the simplest method because once the reservoir has been drained, the embankment can be easily accessed. Problems associated with this method are the loss of the fishery established in the reservoir and the time required for the reservoir to refill, especially during dry periods. Local residents of Niagara also feel that the reservoir has a significant impact on the groundwater in the city. Most of the residents draw their water supply from groundwater and feel that if the embankment is drained, their wells will go dry. Comparison of water levels in the wells to the reservoir level indicates that it is unlikely that the reservoir has a significant impact on groundwater levels. To determine an exact relationship between the reservoir level and area groundwater, additional information will be necessary, including a detailed groundwater study. This type of study involves considerable cost and may be necessary prior to draining the reservoir.

The other method of water control is to construct an earthen cofferdam around the area to be excavated. The cofferdam will retain the water in the reservoir, allowing work on the embankment to be performed. The construction of the cofferdam will increase the cost of the project by $12,000. Benefits of this method are that the fishery and reservoir are retained. Preliminary cost estimates have been prepared for both methods and are contained in the preliminary cost estimate section.

VII. LAND AND WATER RIGHTS

Niagara Dam was built in 1935 by the Works Progress Administration (WPA). The owner of the embankment is Niagara Township. Land acquisition was obtained by easements signed in the Fall of 1934. Individuals signing the original easements include W.F. Krueger, Even and Oscar Ellertson, Inga Olson, and James Cummins.

Presently, Niagara Dam does not have a water use permit or a dam permit. Prior to commencement of any work on the dam, these permits will need to be obtained from the North Dakota State Water Commission.

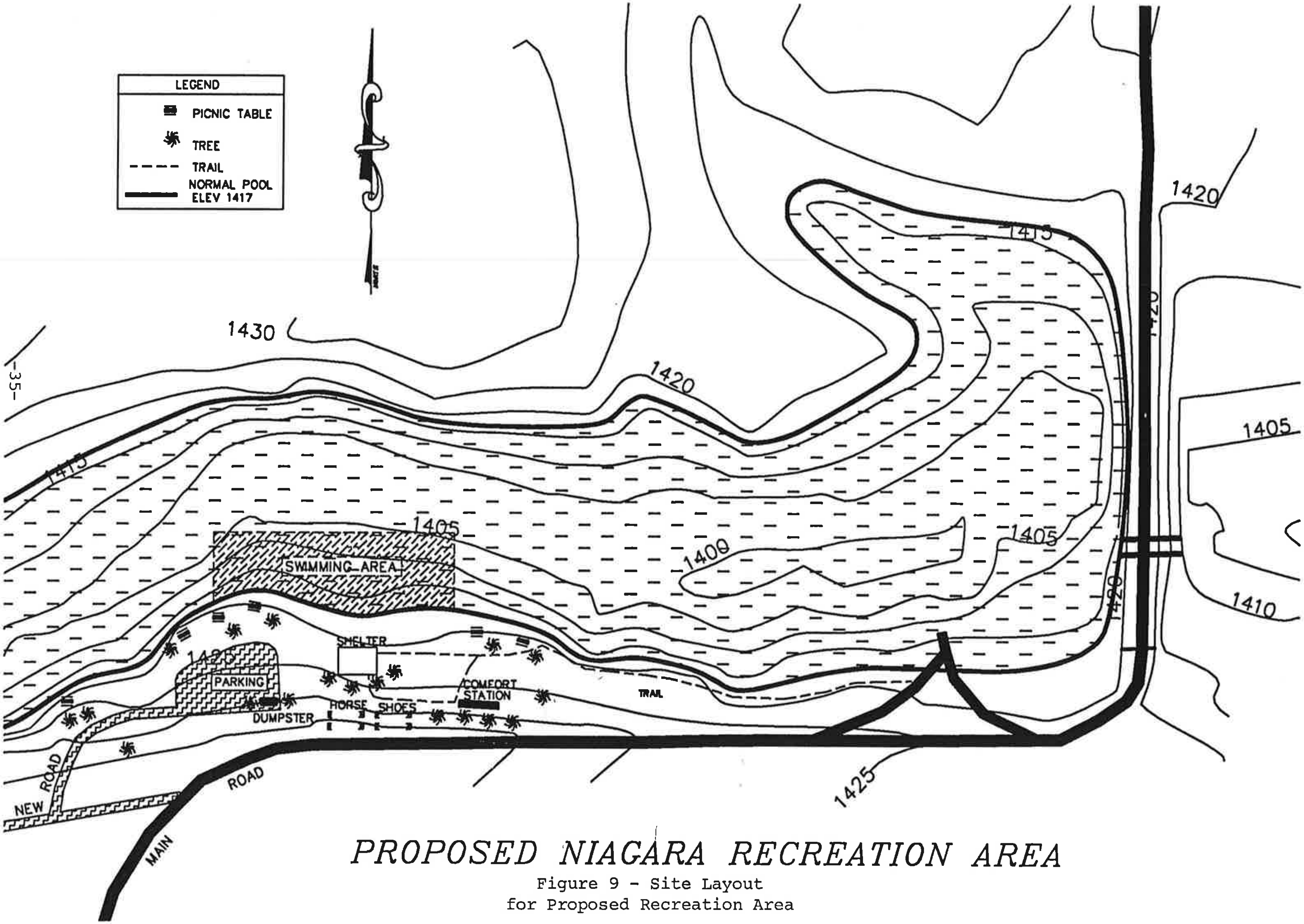
VIII. RECREATION DEVELOPMENT

A recreation area is proposed for the south side of the reservoir. The recreation area consists of day-use facilities; mainly picnic sites, a comfort station, a parking area, and a beach area. Figure 9 shows a site layout for the proposed recreation area.

The North Dakota Parks and Tourism Department designed the proposed facilities and prepared cost estimates for two options. Option A would entail hiring a contractor to construct the facilities, while Option B would concentrate on volunteer labor and materials. Both options allow for revisions to the proposed facilities by local entities. Land acquisition is not included in either cost estimate. Table 8 gives a cost breakdown for Option A.

Table 8 - Cost Estimate for Recreation Development Option A

Item	Cost
Heavy Duty Picnic Table (6 @ $125 ea)	$ 750.00
20'x30' Group Shelter (concrete floor)	6,000.00
Double Vault Toilet	3,500.00
Grading (parking)	2,500.00
Beach - Dredge/Sandfill	4,000.00
Nursery Tree Planting	500.00
Dumpster (purchase)	500.00
Horsehoe Pits	150.00
Buoy System	2,000.00
Signs (Swim in Designated Area Only)	100.00
Total	$20,000.00



PROPOSED NIAGARA RECREATION AREA

Figure 9 - Site Layout
for Proposed Recreation Area

Table 9 gives a cost breakdown for Option B.

Table 9 - Cost Estimate for Recreation Development Option B

Item	Cost
Picnic Tables (6 donated)	$ 0.00
Group Shelter (no concrete floor)	1,000.00
Single Vault Toilet	2,500.00
Park on Grass	0.00
Beach - Dredge/Sandfill (volunteer labor)	0.00
Native Tree Planting (volunteer labor)	0.00
Dumpster Per Month Fee	
Horshoe Pits	50.00
Buoy System (Markers)	1,000.00
Signs (Swim in Designated Area Only)	100.00
Total	$4,650.00

IX. PRELIMINARY COST ESTIMATE

As proposed, the cost to repair Niagara Dam is estimated to be $91,000. This cost estimate is for the method of water control involving the construction of an earth cofferdam. Table 10 shows the breakdown of costs for the modifications.

Table 10 - Earth Cofferdam and Repair Cost Estimate

Item	Quantity	Unit	Cost	Total
Mobilization	1	LS	$ 5,000.00	$ 5,000
Water Control	1	LS	10,000.00	10,000
Stripping and Spreading Topsoil	1,900	SY	0.25	475
Clearing and Grubbing Downstream Apron	1	LS	2,000.00	2,000
Remove Existing Spillway	1	LS	2,000.00	2,000
Trench Excavation	6,300	CY	2.20	13,860
Trench Fill	7,500	CY	1.10	8,250
Rock Riprap	100	CY	25.00	2,500
Plunge Pool				
(a) Riprap	200	CY	25.00	5,000
(b) Filter Material	70	CY	15.00	1,050
(c) Excavation	330	CY	1.50	500
Spillway				
(a) 84" CMP Riser	10	LF	165.00	1,650
(b) 60" Riser Stub	1	LS	900.00	900
(c) 60" CMP Spillway	115	LF	100.00	11,500
(d) Concrete Riser Base	3	CY	250.00	750
(e) Reinforcing Steel	400	Lbs	0.50	200
(f) Trash Rack	1	LS	500.00	500
Low-Level Drawdown	1	LS	2,500.00	2,500
Seeding	1	Ac.	300.00	300
Regrading Roadway	1	LS	1,000.00	1,000
Subtotal				$69,935
Contingencies (+/- 10%)				7,022
Contract Administration (+/- 10%)				7,022
Engineering (+/- 10%)				7,021
Total				$91,000

If the reservoir is drained as a means of water control, the cost to perform the proposed modifications is estimated to be

$79,000. The reason for the reduction in cost for this method is that the excavation for the installation of the new spillway can be done in conjunction with draining the reservoir. Table 11 shows the breakdown of costs for this method of water control.

Table 11 - Breach and Repair
Cost Estimate

Item	Quantity	Unit	Cost	Total
Mobilization	1	LS	$ 5,000.00	$ 5,000
Water Control	1	LS	1,000.00	1,000
Stripping and Spreading				
Topsoil	1,900	SY	0.25	475
Clearing and Grubbing				
Downstream Apron	1	LS	2,000.00	2,000
Remove Existing Spillway	1	LS	2,000.00	2,000
Trench Excavation	6,300	CY	2.20	13,860
Trench Fill	7,500	CY	1.10	8,250
Rock Riprap	100	CY	25.00	2,500
Plunge Pool				
(a) Riprap	200	CY	25.00	5,000
(b) Filter Material	70	CY	15.00	1,050
(c) Excavation	330	CY	1.50	500
Spillway				
(a) 84" CMP Riser	10	LF	165.00	1,650
(b) 60" Riser Stub	1	LS	900.00	900
(c) 60" CMP Spillway	115	LF	100.00	11,500
(d) Concrete Riser Base	3	CY	250.00	750
(e) Reinforcing Steel	400	Lbs	0.50	200
(f) Trash Rack	1	LS	500.00	500
Low-Level Drawdown	1	LS	2,500.00	2,500
Seeding	1	Ac.	300.00	300
Regrading Roadway	1	LS	1,000.00	1,000
Subtotal				$60,935
Contingencies (+/- 10%)				6,022
Contract Administration (+/- 10%)				6,022
Engineering (+/- 10%)				6,021
Total				$79,000

The condition of the existing spillway for Niagara Dam warrants that something be done to protect the integrity of the dam. If a new spillway is not installed, the embankment should be permanently drained and the roadway reconstructed. A 36-inch diameter CMP culvert should be installed at the channel bottom to pass outflow from the railroad dam and local runoff. This culvert will pass flows due to a 25-year precipitation event without overtopping the road. The cost to permanently drain the reservoir and reconstruct the roadway is estimated to be $32,000. Table 12 shows the breakdown of costs for this alternative.

Table 12 - Cost Estimate to Permanently Drain Niagara Dam and Reconstruct the Roadway

Item	Quantity	Unit	Cost	Total
Mobilization	1	LS	$ 5,000.00	$ 5,000
Water Control	1	LS	1,000.00	1,000
Remove Existing Spillway	1	LS	2,000.00	2,000
Excavation	2,700	CY	2.20	5,940
Fill	4,000	CY	1.10	4,400
Culvert				
(a) 36" CMP Culvert	130	LF	42.00	5,460
(b) Flared End Section	2	Ea.	200.00	400
(c) Water Tight Band	4	Ea.	130.00	520
Subtotal				$24,720
Contingencies (+/- 10%)				2,426
Contract Administration (+/- 10%)				2,427
Engineering (+/- 10%)				2,427
Total				$32,000

X. SUMMARY

The feasibility of repairing and upgrading the downstream Niagara Dam has been examined. The dam site is located on an unnamed tributary to the North Branch of the Turtle River. The dam is a combination county road/embankment located northeast of the city of Niagara between Sections 7 and 8, Township 152 North, Range 56 West. The dam was built for the purpose of swimming, boating, angling, migratory waterfowl refuge, and ice harvesting.

Niagara Dam is located in a rural area and no loss of life is expected if it fails. Therefore, it is given a low hazard classification. Based on a 10- to 24-foot embankment height and a low hazard classification, Niagara Dam is classified as a class II dam for design purposes.

Design events for the hydraulic structures are as follows: 1) the emergency spillway must pass the flows due to a 50-year precipitation event without overtopping the dam; and 2) the emergency spillway must pass the flows due to a 25-year precipitation event within an acceptable velocity. Since Niagara Dam does not have a separate emergency spillway, the principal spillway must pass the flows due to a 50-year precipitation event without overtopping the dam.

The Niagara Dam basin was analyzed using the HEC-1 and SWAMP computer models. Analysis indicates that the existing spillway is insufficient to pass runoff from precipitation events as required by the dam's classification. This, in conjunction with the poor condition of the existing spillway, indicates that a new spillway should be installed or the reservoir should be permanently drained and the roadway reconstructed.

The proposed new spillway consists of an 84-inch diameter CMP drop inlet that will control the reservoir elevation at 1417 msl. A 60-inch diameter CMP spillway will extend through the embankment to convey flows. The length of the spillway is approximately 115 feet and extends into a cantilever outlet with a plunge pool to dissipate the energy of the water. The spillway pipe will be epoxy coated to help reduce the potential for corrosion. The spillway pipe will be epoxy coated to help reduce corrosion. A low-level drawdown structure has also been designed to allow for the removal of stagnant water from the bottom of the reservoir.

If the reservoir is permanently drained, the existing spillway should be removed and a culvert installed through the embankment at the channel bottom. This culvert will convey outflows from the Railroad Dam as well as local runoff. A 36-inch diameter CMP will be sufficient to pass flows due to a 25-year precipitation event without overtopping the road. A detailed groundwater study may also be required if the reservoir is permanently drained. This study will determine the relationship between the reservoir level and area groundwater.

The cost to replace the spillway while maintaining the reservoir pool is estimated to be $91,000. The cost to replace the spillway after draining the reservoir is estimated to be $79,000. The cost to permanently drain the reservoir and reconstruct the roadway is estimated to be $32,000.

XI. RECOMMENDATIONS

It is recommended that measures be taken to repair Niagara Dam. The condition of the existing spillway poses a hazard to the integrity of the dam. The existing spillway is corroded, undermined, and undersized which indicate that repair of it is not feasible. Therefore, a new spillway should be installed or the reservoir should be permanently drained and the roadway reconstructed. Cost estimates have been prepared for several alternatives including: installing a new spillway while maintaining the reservoir pool; installing a new spillway after draining the reservoir pool; and permanently draining the reservoir and reconstructing the roadway. Analysis of costs indicates that permanently draining Niagara Dam and reconstructing the roadway represents a significant cost with little benefits being gained. Considering the poor condition of the existing spillway and the significant cost to permanently drain the reservoir, it is recommended that a new spillway be installed with the method of water control selected by local entities. The decision to proceed with this project is the responsibility of the Grand Forks County Water Resource District.

APPENDIX A - COPY OF AGREEMENT

SWC Project #464
January 4, 1991

AGREEMENT

Investigation of Repairing and Upgrading Downstream Niagara Dam Near Niagara, North Dakota

I. PARTIES

THIS AGREEMENT is between the North Dakota State Water Commission, hereinafter Commission, through its Secretary, David Sprynczynatyk; the North Dakota State Game and Fish Department, hereinafter Department, through its Commissioner, Lloyd Jones; and the Grand Forks County Water Resource District, hereinafter District, through its Chairman, C. W. Ekness.

II. PROJECT, PURPOSE, AND LOCATION

The District and the Department have requested the Commission to investigate the feasibility of repairing and upgrading the downstream Niagara Dam. The dam is located in the E1/2 Section 7, Township 152 North, Range 56 West, near Niagara, North Dakota. The dam is currently a popular perch fishing spot and therefore an important area for the District and the Department.

III. PRELIMINARY INVESTIGATION

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

1. A field survey of the upstream and downstream embankment and reservoir including topographic data, area-capacity data, and bridge and channel geometry;

2. A geotechnical investigation of the embankment to determine the subsurface conditions at the existing spillway system;

3. A study of the hydrology of the watershed upstream of the dam;

4. A preliminary design of the outlet works necessary to pass the design flood through the dam, giving consideration to the possibility of raising the permanent water surface elevation;

5. A preliminary review of the effects of the reservoir on area groundwater;

6. A preliminary cost estimate for the repair and upgrade; and

7. Prepare a preliminary engineering report presenting the results of the investigation.

IV. COSTS

The District and Department shall each deposit $1,625 with the Commission prior to investigation commencement to help defray the Commission's costs associated with this investigation.

V. RIGHTS-OF-ENTRY

The District agrees to obtain written permission from any affected landowners for any field investigations by the Commission, which are required for the preliminary investigation.

VI. INDEMNIFICATION

The District hereby accepts responsibility for and holds the Commission, the Department, their employees, their agents, the State Engineer, and the Commissioner free from all claims and damages to public or private property, rights, or persons arising out of this investigation. In the event a suit is initiated or judgment rendered against the Commission, the Department, their employees, or agents, the District shall indemnify them for any judgment arrived at or judgement satisfied.

VII. CHANGES TO THE AGREEMENT

Changes to any contractual provisions herein will not be effective or binding unless such changes are made in writing, signed by all parties and attached hereto.

NORTH DAKOTA STATE WATER COMMISSION
By: David A. Sprynczynatyk
DAVID A. SPRYNCZYNATYK
Secretary

DATE: 7 Jan 91

WITNESS: Dale L Frink

NORTH DAKOTA GAME AND FISH DEPARTMENT
By: Lloyd Jones
LLOYD JONES
Commissioner

DATE:

WITNESS:

GRAND FORKS COUNTY WATER RESOURCE DISTRICT
By: Helmer J. Lien
HELMER J. LIEN
Chairman

DATE: 1/16/91

WITNESS: Pam Aaker

APPENDIX B - LOG OF TEST BORINGS

MIDWEST TESTING LABORATORY

JOB NO. G224 LOG OR TEST BORING NO. 1 VERTICAL SCALE 1"=5'

PROJECT Niagara Dam, Grand Forks County, North Dakota

DEPTH IN FEET	SOIL DESCRIPTION SURFACE ELEV. 1422.06	SAMPLE NO.	SAMPLE TYPE	N VALUE	MOISTURE	DENSITY	LL/PL	Qu
	FILL, SANDY LEAN CLAY-brown, a little gravel	1	SS	13				
		2	SS	20				
		3	SS	53				
		4	SS	8				
11		5	SS	4				
	SILTY SAND-gray & dark gray, dense, waterbearing, with layers of coarse grained sand with gravel *							
14	SANDY LEAN CLAY-gray & dark gray, medium, trace of gravel (CL)	6	SS	20				
		7	SS	6				
20	SANDY LEAN CLAY-grayish brown, very stiff, with a little gravel, some shale fragments (CL)	8	SS	43				
		9	SS	51				
27	FAT CLAY-grayish brown, very stiff (CH)	10	SS	89				
28½	END OF BORING							
	*(SM)							

WATER LEVEL DATA

DATE	TIME	CAVE IN DEPTH	WATER LEVEL
4-29-91	12:09	HSA 27½'	14.0'
4-29-91	12:28	26.4'	21.1'
4-29-91	13:17	26.4'	13.7'

BORING DATA

STARTED 4-29-91 COMPLETED 4-29-91 @ 12:09

METHOD USED: 3-3/8" HSA 0-27½'

CREW CHIEF D. Wysuph

MIDWEST TESTING LABORATORY

JOB NO. G224 LOG OR TEST BORING NO. 2 VERTICAL SCALE 1"=5'

PROJECT Niagara Dam, Grand Forks County, North Dakota

DEPTH IN FEET	SOIL DESCRIPTION SURFACE ELEV. 1421.59	SAMPLE NO.	SAMPLE TYPE	N VALUE	LABORATORY TESTS MOISTURE	DENSITY	LL/PL	Qu
	FILL, SANDY LEAN CLAY-brownish gray, a layer of black organic clay @15', trace of gravel							
		1	SS	18				
		2	3TW		(See attached summary sheet)			450
		3	SS	5				
15	FILL, SANDY LEAN CLAY-grayish brown, a little gravel	4	SS	17				
		5	SS	6				
24	ORGANIC CLAY WITH SAND-black, rather stiff, a little gravel, some small roots (OL)	6	SS	10				
28	LEAN CLAY WITH SAND-gray, very stiff, trace of gravel (CL)	7	SS	35*				
31	END OF BORING							
	*N value may have been influenced by obstruction, soil is relatively soft and wet							

WATER LEVEL DATA

DATE	TIME	CAVE IN DEPTH	WATER LEVEL
4-29-91	14:00	HSA 29½'	None
4-29-91	14:20	27.6'	27.0'
4-29-91	15:50	27.6'	21.8'

BORING DATA

STARTED 4-29-91 COMPLETED 4-29-91 @ 14:00

METHOD USED: 3-3/8" HSA 0-29½'

CREW CHIEF D. Wysuph

MIDWEST TESTING LABORATORY

JOB NO. G224 LOG OR TEST BORING NO. 3 VERTICAL SCALE 1"=5'

PROJECT Niagara Dam, Grand Forks County, North Dakota

DEPTH IN FEET	SOIL DESCRIPTION SURFACE ELEV. 1421.67	SAMPLE NO.	SAMPLE TYPE	N VALUE	MOISTURE	DENSITY	LL/PL	Qu
	FILL, SANDY LEAN CLAY-brown, a little gravel	1	SS	57				
8	FILL, SILTY, CLAYEY SAND-grayish brown, a little gravel	2	3TW		(See Attached Summary Sheet)			2200
12	FILL, SANDY LEAN CLAY-brown, trace of gravel & organics	3	3TW		(See Attached Summary Sheet)			2100
14	ORGANIC CLAY WITH SAND-black, rather stiff (OL)	4	SS	11				
16	SANDY LEAN CLAY-brown, medium, a little gravel (CL)	5	SS	7				
24	SANDY LEAN CLAY-brownish gray, very stiff, a little gravel, numerous shale fragments (CL)	6	SS	43				
		7	SS	100				
31	END OF BORING							

WATER LEVEL DATA

DATE	TIME	CAVE IN DEPTH	WATER LEVEL
4-29-91	15:20	HSA 29½'	27.5'
4-29-91	15:40	28.0'	22.8'
4-29-91	15:50	28.0'	20.2'

BORING DATA

STARTED 4-29-91 COMPLETED 4-29-91 @ 15:20

METHOD USED: 3-3/8" HSA 0-29½'

CREW CHIEF D. Wysuph

NOR)AKC STA ATE I ON S L RATC

CLASSIFICATION OF SOILS FOR ENGINEERING PURPOSES
ASTM Designation: D 2487

REPORT OF TESTS OF SOIL SAMPLES

ASTM Designation D 421
ASTM Designation D 422

Project Name Niagara Dam | Test Boring No. 2

Project No. 464 | County Grand Forks

Sample No.	2-2				
Depth, Feet	9.5-11.5				
(1) Gravel, Pass 3" & Retained on #4					
(a) % Coarse Gravel (-3" + 3/4")	0				
(b) % Fine Gravel (-3/4" + #4)	5				
(2) Sand, Pass #4 & Retained on #200					
(a) % Coarse Sand (-#4 + #10)	5				
(b) % Medium Sand (-#10 + #40)	13				
(c) % Fine Sand (-#40 + #200)	25				
(3) % Silt Size (0.074-0.005 mm)	29				
(4) % Clay Size (Smaller than 0.005 mm)	23				
(5) % Shale & Soft Rock	15.4%				
Moisture Content %	27.2				
Liquid Limit %	35				
Plasticity Index	16				
~~Shrinkage Limit %~~					
~~Shrinkage Ratio~~					
Specific Gravity	2.35				
Color	brownish gray				
Typical Name	sandy lean clay				
Soil Group (U.S.C.S.)	CL				

SWC Form #179A (200/11-76)

NORTH DAKOTA STATE WATER COM. ,SION SOILS LABORATORY

CLASSIFICATION OF SOILS FOR ENGINEERING PURPOSES
ASTM Designation: D 2487

REPORT OF TESTS OF SOIL SAMPLES

ASTM Designation D 421
ASTM Designation D 422

Project Name Niagara Dam

Test Boring No. 3

Project No. 464

County Grand Forks

Sample No.	3-2	3-3			
Depth, Feet	9.5-11.5	12.0-14.0			
(1) Gravel, Pass 3" & Retained on #4					
(a) % Coarse Gravel (-3" + 3/4")	5	0			
(b) % Fine Gravel (-3/4" + #4)	4	5			
(2) Sand, Pass #4 & Retained on #200					
(a) % Coarse Sand (-#4 + #10)	7	4			
(b) % Medium Sand (-#10 + #40)	23	13			
(c) % Fine Sand (-#40 + #200)	17	22			
(3) % Silt Size (0.074-0.005 mm)	31	28			
(4) % Clay Size (Smaller than 0.005 mm)	13	28			
(5) % Shale & Soft Rock	25.5	30.0			
Moisture Content %	15.8	25.1			
Liquid Limit %	28	40			
Plasticity Index	6	19			
~~Shrinkage Limit %~~					
~~Shrinkage Ratio~~					
Specific Gravity	2.20	2.40			
Color	grayish brown	brown			
Typical Name	silty, clayey sand	sandy lean clay			
Soil Group (U.S.C.S.)	SC-SM	CL			

SWC Form #179A

(200/11-76)

MIDWEST TESTING LABORATORY

Project No. G224

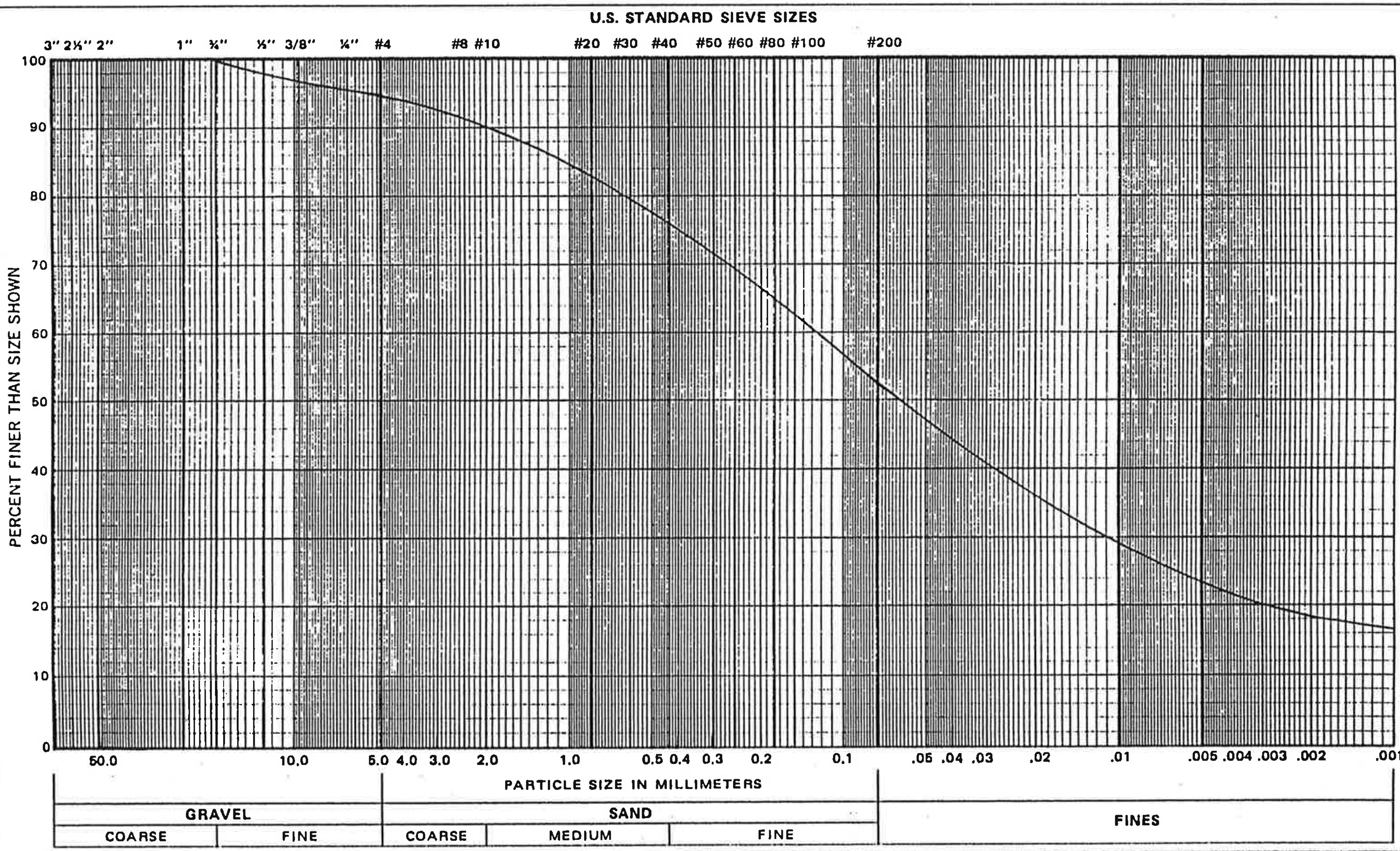
Project: Niagara Dam, Grand Forks County, ND

Sample Source Boring 2 @ 9½'-11½'

Classification SANDY LEAN CLAY-brown, with a trace of gravel (CL)

Reported To: ND State Water Commission

GRAIN SIZE DISTRIBUTION CURVE



MIDWEST TESTING LABORATORY

Project No. G224

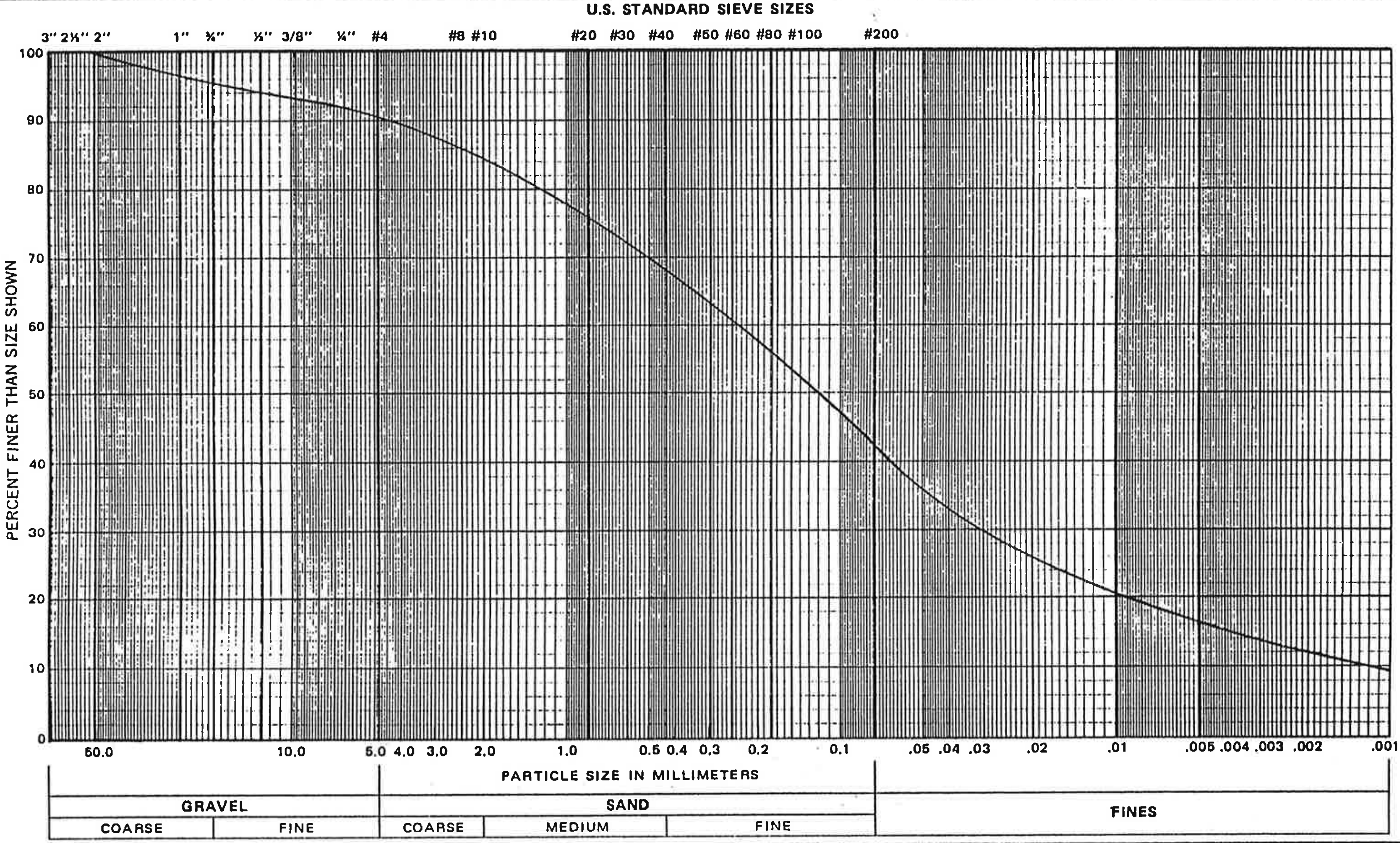
Sample Source Boring 3 @ 9½'-11½'

Classification SILTY, CLAYEY SAND-grayish brown (SC-SM)

Project: Niagara Dam,
Grand Forks County, ND

Reported To: ND State Water Commission

GRAIN SIZE DISTRIBUTION CURVE



MIDWEST TESTING LABORATORY

Project No. G224

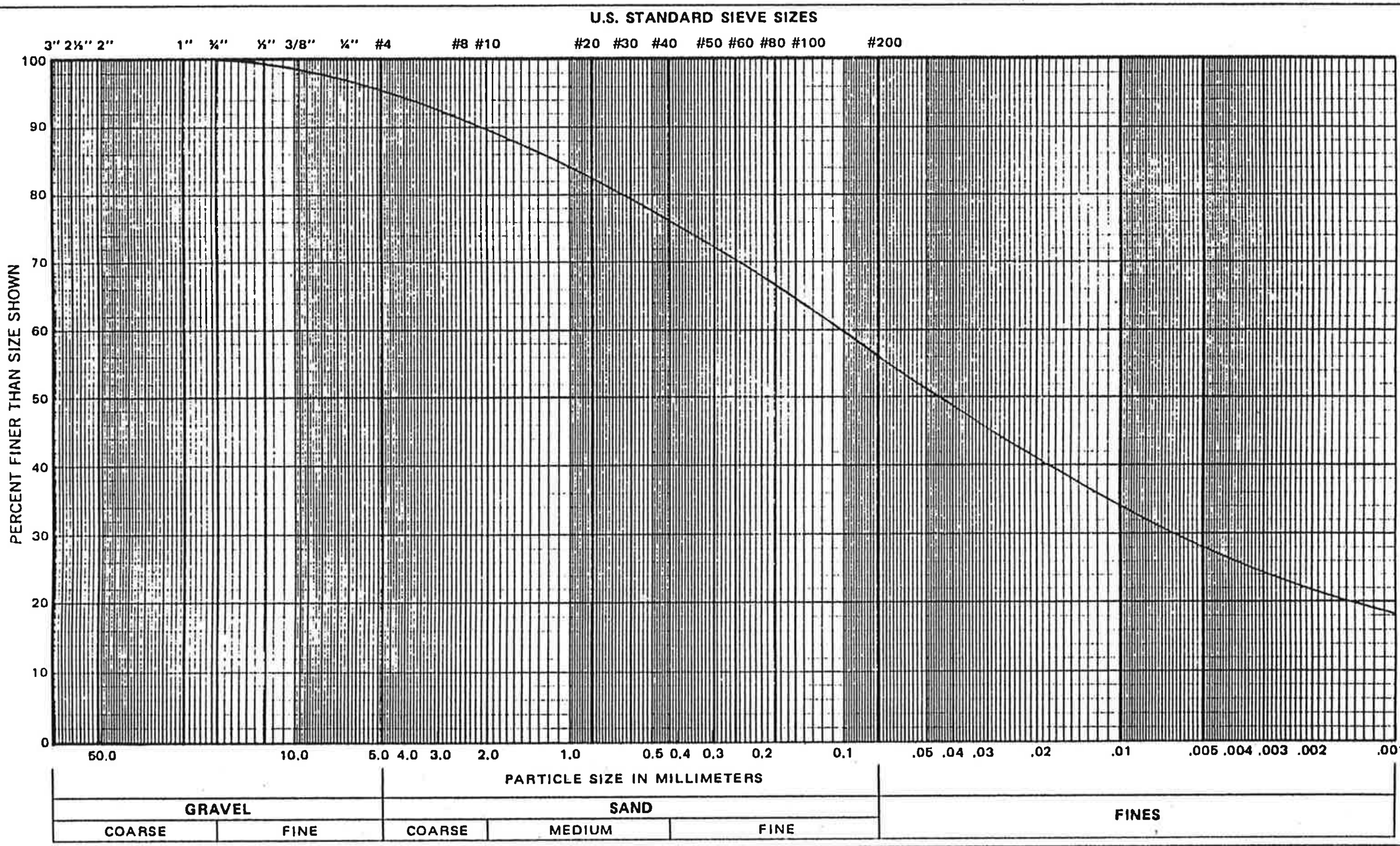
Sample Source Boring 3 @ 12'-14'

Classification SANDY LEAN CLAY-brown, with trace of gravel (CL)

Project: Niagara Dam, Grand Forks County, ND

Reported To: ND State Water Commission

GRAIN SIZE DISTRIBUTION CURVE



DESCRIPTIVE TERMINOLOGY

RELATIVE DENSITY OF COHESIONLESS SOILS

Term	"N" Value
Very Loose	0-4
Loose	5-8
Medium Dense	9-15
Dense	16-30
Very Dense	Over 30

THICKNESS OF SOIL INTRUSIONS

Term	Range
Lense/Lamination	0-1/8"
Seam	1/8"-1"
Layer	1"-12"

CONSISTENCY OF COHESIVE SOILS

Term	"N" Value
Soft	0-4
Medium	5-8
Rather Stiff	9-15
Stiff	16-30
Very Stiff	Over 30

PARTICLE SIZES

Term	Range
Boulders	Over 8"
Cobbles	3"-8"
Gravel	
Coarse	3/4"-3"
Fine	#4-3/4"
Sand	
Coarse	#4-#10
Medium	#10-#40
Fine	#40-#200
Silt and Clay	Determined by Plasticity Characteristics

NOTE: Sieve sizes shown are U.S. Standard

RELATIVE PROPORTIONS

Term	Range
Trace	0-5%
A Little	5-15%
Some	15-30%
With	30-50%

DRILLING & SAMPLING SYMBOLS

Symbol	Definition
FA	Flight Auger
SS	Split Spoon
TW	Thin-Walled Tube
HSA	Hollow Stem Auger
N	Penetration Resistance: blows required to drive a two-inch OD split spoon sampler one foot by means of a 140-pound hammer falling 30 inches.

LABORATORY TEST SYMBOLS

Symbol	Definition
LL	Liquid Limit, %
PL	Plastic Limit, %
Q_u	Unconfined Compressive Strength, psf

Additional insertions in Q_u column

Symbol	Definition
G	Specific Gravity
SL	Shrinkage Limit, %
pH	Hydrogen Ion Content - Meter Method
O	Organic Content, % - Combustion Method
M.A.	Grain Size Analysis - Mechanical Method
Hyd.	Grain Size Analysis - Hydrometer Method
C	One-Dimensional Consolidation
Q_c	Triaxial Compression

WATER LEVEL INFORMATION

Water levels shown on the boring logs are levels measured in the borings at the time and under the conditions noted. In sand, the indicated levels can be considered reliable. In clay soil, it is not possible to determine the ground water level within the normal scope of a test boring investigation, except where lenses or layers of more previous water-bearing soil are present. Even then, a long period of time may be necessary to reach equilibrium. Therefore, the position of the water level noted on the boring logs for cohesive or mixed-texture soils may not indicate the true level of the ground water table.

Classification of Soils For Engineering Purposes

ASTM:D 2487-85

Criteria for Assigning Group Symbols and Group Names Using Laboratory Tests[A]				Soil Classification: Group Symbol	Soil Classification: Group Name[B]
Coarse-Grained Soils More than 50% retained on No. 200 sieve	Gravels More than 50% coarse fraction retained on No. 4 sieve	Clean Gravels Less than 5% fines[C]	$Cu \geq 4$ and $1 \leq Cc \leq 3$[E]	GW	Well graded gravel[F]
			$Cu < 4$ and/or $1 > Cc > 3$[E]	GP	Poorly graded gravel[F]
		Gravels with Fines More than 12% fines[C]	Fines classify as ML or MH	GM	Silty gravel[F,G,H]
			Fines classify as CL or CH	GC	Clayey gravel[F,G,H]
	Sands 50% or more of coarse fraction passes No. 4 sieve	Clean Sands Less than 5% fines[D]	$Cu \geq 6$ and $1 \leq Cc \leq 3$[E]	SW	Well-graded sand[I]
			$Cu < 6$ and/or $1 > Cc > 3$[E]	SP	Poorly graded sand[I]
		Sands with Fines More than 12% fines[D]	Fines classify as ML or MH	SM	Silty sand[G,H,I]
			Fines classify as CL or CH	SC	Clayey sand[G,H,I]
Fine-Grained Soils 50% or more passes the No. 200 sieve	Silts and Clays Liquid limit less than 50	inorganic	PI>7 and plots on or above "A" line[J]	CL	Lean clay[K,L,M]
			PI<4 or plots below "A" line[J]	ML	Silt[K,L,M]
		organic	$\frac{\text{Liquid limit - oven dried}}{\text{Liquid limit - not dried}} < 0.75$	OL	Organic clay[K,L,M,N] Organic silt[K,L,M,O]
	Silts and Clays Liquid limit 50 or more	inorganic	PI plots on or above "A" line	CH	Fat clay[K,L,M]
			PI plots below "A" line	MH	Elastic silt[K,L,M]
		organic	$\frac{\text{Liquid limit - oven dried}}{\text{Liquid limit - not dried}} < 0.75$	OH	Organic clay[K,L,M,P]
					Organic silt[K,L,M,O]
Highly organic soils	Primarily organic matter, dark in color, and organic odor			PT	Peat
Fibric Peat >67% Fibers	Hemic Peat 33%-67% Fibers			Sapric Peat <33% Fibers	

[A]Based on the material passing the 3-in. (75-mm) sieve.

[B]If field sample contained cobbles or boulders, or both, add "with cobbles or boulders, or both" to group name.

[C]Gravels with 5 to 12% fines require dual symbols:
- GW-GM well-graded gravel with silt
- GW-GC well-graded gravel with clay
- GP-GM poorly graded gravel with silt
- GP-GC poorly graded gravel with clay

[D]Sands with 5 to 12% fines require dual symbols:
- SW-SM well-graded sand with silt
- SW-SC well-graded sand with clay
- SP-SM poorly graded sand with silt
- SP-SC poorly graded sand with clay

[E]$Cu = D_{60}/D_{10}$ $\quad Cc = \frac{(D_{30})^2}{D_{10} \times D_{60}}$

[F]If soil contains ≥15% sand, add "with sand" to group name.

[G]If fines classify as CL-ML, use dual symbol GC-GM, or SC-SM.

[H]If fines are organic, add "with organic fines" to group name.

[I]If soil contains ≥15% gravel, add "with gravel" to group name.

[J]If Atterberg limits plot in hatched area, soil is a CL-ML, silty clay.

[K]If soil contains 15 to 29% plus No. 200, add "with sand" or "with gravel," whichever is predominant.

[L]If soil contains ≥30% plus no. 200, predominantly sand, add "sandy" to group name.

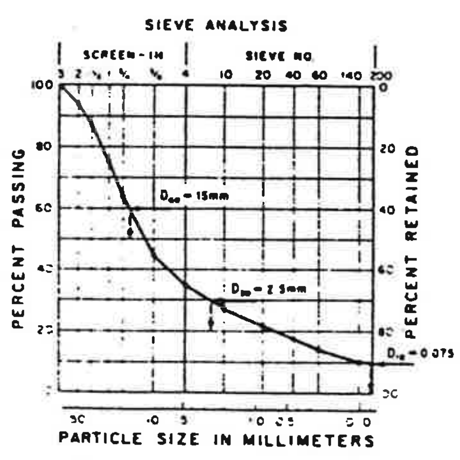
[M]If soil contains ≥30% plus No. 200, predominantly gravel, add "gravelly" to group name.

[N]PI≥4 and plots on or above "A" line.

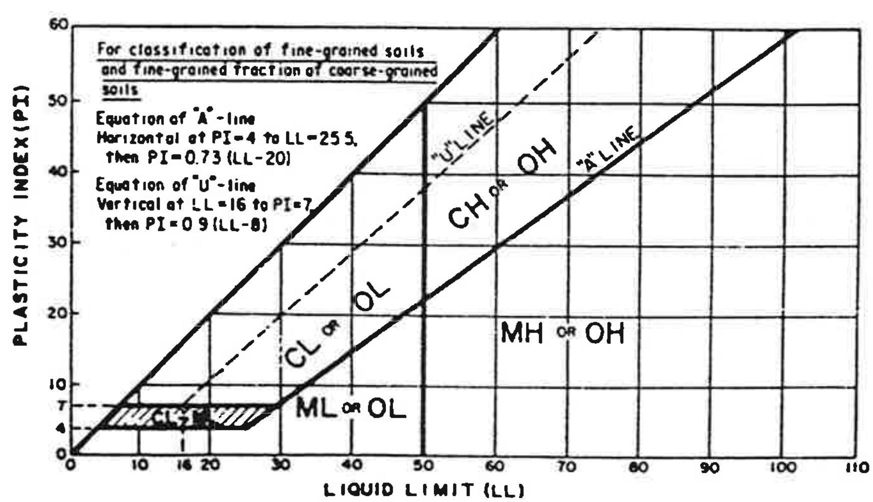
[O]PI<4 or plots below "A" line.

[P]PI plots on or above "A" line.

[Q]PI plots below "A" line.



$C_u = \frac{D_{60}}{D_{10}} = \frac{15}{0.075} = 200 \qquad C_c = \frac{(D_{30})^2}{D_{10} \times D_{60}} = \frac{(2.5)^2}{0.075 \times 15} = 5.6$



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