FEASIBILITY STUDY

LAKE ISABELLE RESTORATION

MINNESOTA DEPARTMENT OF NATURAL RESOURCES DIVISION OF WATERS

FEBRUARY 1985

KOK AND ASSOCIATES

FEASIBILITY STUDY FOR THE

RESTORATION OF LAKE ISABELLE

PREPARED BY:

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HYDROLOGISTS - ENGINEERS
545 INDIAN MOUND
WAYZATA, MINNESOTA 55391

FEBRUARY 1985

FOR THE

MINNESOTA DEPARTMENT OF NATURAL RESOURCES

DIVISION OF WATERS

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

William D. Weidenbacher — 3/8/85 — 8968
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INTRODUCTION

This report presents the results of a hydrogeologic/hydraulic study that was completed for Lake Isabelle. The study was commissioned by the Minnesota Department of Natural Resources - Division of Waters to develop additional information on a proposed Restoration Project for Lake Isabelle. This study was specifically developed to provide information on:

1. Bedrock geology and groundwater flow patterns in the vicinity of Lake Isabelle.

2. Surface and groundwater flow into Lake Isabelle and its impact on water quality.

3. Soil characteristics in the vicinity of the proposed dike.

4. The feasibility of hydraulically dredging bottom sediments from Lake Isabelle.

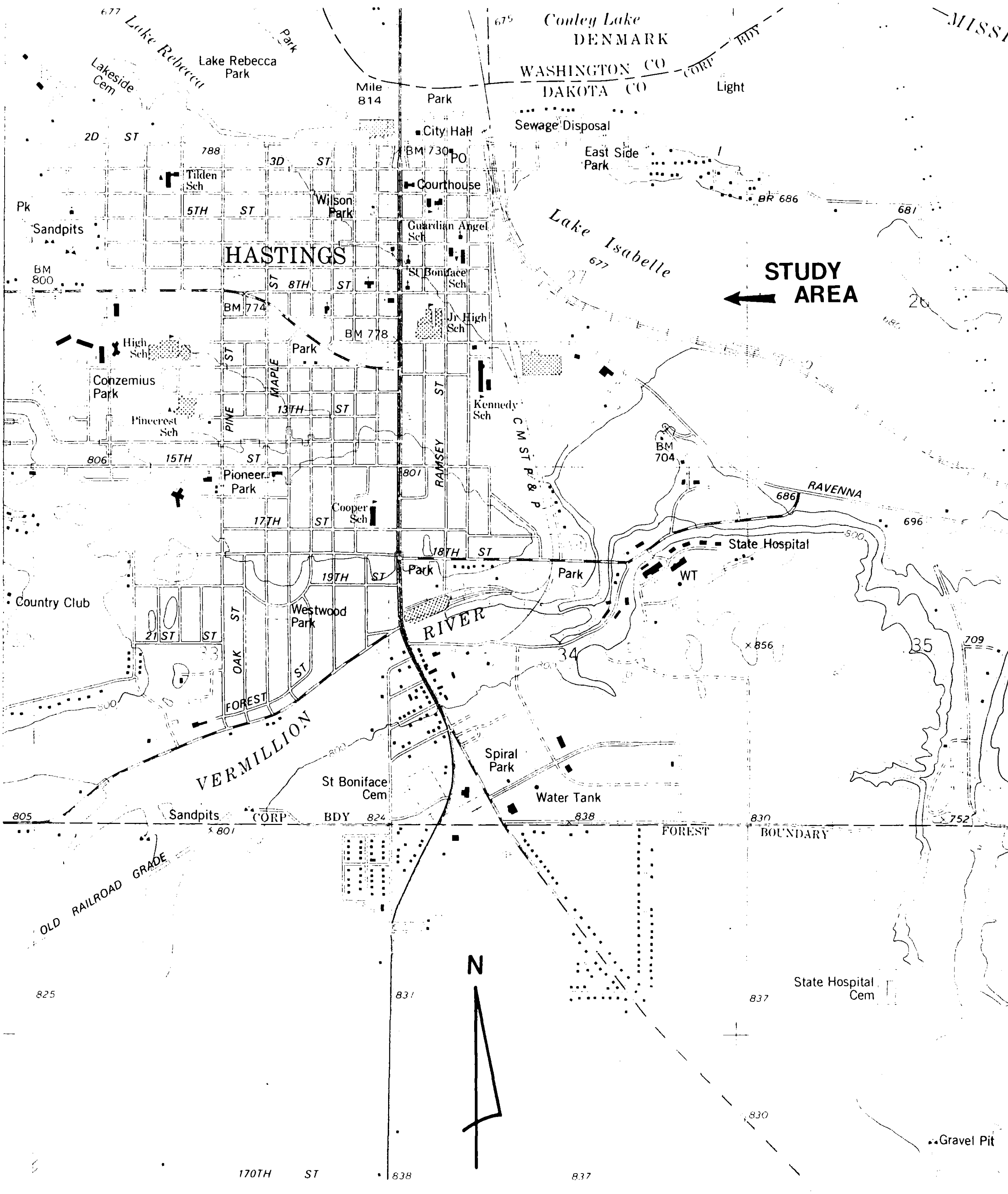
5. Design of the proposed dike and outlet structure.

6. The location and extent of areas that would be impacted should the project be constructed.

BACKGROUND

Lake Isabelle is located within the City of Hastings in Dakota County, Minnesota. (See Figure 1). The lake is in the floodplain of the Mississippi River and discharges into the Vermillion Slough which is a backwater area of the Mississippi River. The lake, as it exists today, has about 80 acres of open water and an average depth of 3 feet.

Studies previously completed by Environmental Research Group, Inc. and Barr Engineering conclude that the water quality of Lake Isabelle is poor, and the lake is in an advanced stage of eutrophication.



LAKE ISABELLE RESTORATION STUDY	E.A. HICKOK & ASSOCIATES HYDROLOGISTS - ENGINEERS MINNEAPOLIS - MINNESOTA	JAN., 1985
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These studies conclude that the lakes poor water quality is caused at least in part by the Mississippi River. During periods of high river stage, water from the Mississippi River will back up into the Vermillion Slough and then into Lake Isabelle. This introduces a heavy nutrient, sediment, and organic load to the lake and significantly impacts water quality. These inundations of Lake Isabelle by water from the Mississippi River and Vermillian Slough occur frequently with the Vermillian Slough having 5, 10 and 20 year flood elevations 8.5, 10.5 and 11.5 feet, respectively, above the normal water elevation of Lake Isabelle.

The lake restoration plan under consideration includes constructing a dike across the outlet of Lake Isabelle to prevent water from the Vermillion Slough from entering Lake Isabelle for all river flood stages up to a 10-year return frequency. The average water depth in the lake would also be increased from 3 feet to 9 feet either increasing the normal lake elevation and/or by hydraulically dredging some of the lake bottom sediments.

CONCLUSIONS AND RECOMMENDATIONS

1. Lake Isabelle is within a basin-like bedrock formation. A broad erosional opening exists at the east side of the lake opening to the Mississippi River valley. Two narrow buried valleys breach the bedrock basin in the southwest portion of the lake. The bedrock contour map provided in Figure 3 describes these erosional features.

2. Groundwater inflow to the lake predominantly occurs along the south shoreline of the lake in the vicinity of the buried bedrock valleys. The groundwater inflow to the lake was determined to be 2 cfs during the study period.

3. Groundwater outflow from the lake is minimal with typical outflow rates calculated to be less than 0.01 cfs.

4. Surface water runoff contributes less than 10 percent of the hydrologic loading to Lake Isabelle, with groundwater sources making up the remainder of the hydraulic inflow. For this reason, the water quality of Lake Isabelle is very dependent on the quality of the groundwater inflow to the lake. An analysis of the nutrient loading to the lake before and after the restoration project is completed indicates the project would reduce the groundwater inflow rate and nutrient loading, and change the lake's trophic status from eutrophic to borderline oligotrophic-mesotrophic.

5. Soils in the vicinity of the proposed dike alignment consist of an upper layer of weak and compressible soils underlain by coarse alluvium. The depth of these materials exceed 60 feet in some locations along the proposed dike alignment. Analyses of these soils indicate that long and short-term settlement for a dike constructed in this vicinity could approach 10 feet over a period of 10 to 20 years. This settlement will present problems in construction; however, the construction of a dike in this vicinity is still feasible provided special construction techniques are followed.

6. Hydraulically dredging bottom sediments of Lake Isabelle to increase depth is feasible. The cost to remove 3 feet of sediment from the bottom of Lake Isabelle is estimated to be $1.5 million.

7. Preliminary design for the Lake Isabelle Outlet Structure includes the construction of a 13-foot high clay dike with a 10-foot wide top and 5:1 side slopes. A structure will be constructed across one section of the dike to provide an outlet for Lake Isabelle when the Mississippi River is not in flood stage. When flood stages are present on the Mississippi River, this outlet can be closed to prevent water from the Mississippi River from

entering Lake Isabelle for flood events less than a 10-year return frequency. If a flood event exceeds the 10-year return frequency, sluice gates must be opened to allow water levels on both sides of the dike to equalize. The engineer's opinion of cost to construct the recommended Lake Isabelle outlet structure is $1,346,000.

GEOLOGICAL INVESTIGATION

The initial analysis of bedrock geology in the vicinity of Lake Isabelle consisted of examining well log data from the Minnesota Geological Survey, soil borings provided by the City of Hastings Engineering Department, and bedrock outcrops around Lake Isabelle. Upon completion of the examination, a geophysical survey was conducted in the vicinity of Lake Isabelle. Primary seismic soundings were taken in the area south and southwest of Lake Isabelle, and supplemental soundings were taken to the north and northeast of the lake. The seismic refraction survey was conducted with a Bison 1570 B seismograph utilizing a 300-foot to 400-foot cable. A total of 14 seismic soundings were made. The profiles at each seismic data location were reversed to more accurately determine bedrock depth and configuration. The Bedrock Data Point Location Map, (Figure 2) shows the location of the seismic survey points. Lake Isabelle seismic information is tabulated and summarized in Table 1.

Additional geologic data was derived from piezometer installations and soil borings. The locations of these installations and borings were determined by the geophysical survey and existing geologic data. All bedrock data used in the geologic investigation is shown in Table 2. The data locations are shown on Figure 2. A total of three piezometer nests consisting of six 2-inch I.D. piezometers were installed in the vicinity at Lake Isabelle. Each nest consisted of a shallow piezometer placed near the top of the water table and a deep piezometer placed at or near the bedrock. The purpose of each nest was to determine both the vertical and horizontal components of groundwater flow in the

TABLE 1

LAKE ISABELLE SEISMIC SOUNDING SUMMARY

Sounding Number	V_1 fps	V_2 fps	V_3 fps	Depth to First Layer (ft)	Depth to Bedrock (ft)	Approximate Surface Elevation (NGVD)(2)	Bedrock Elevation (NGVD)(3)
1	1,200	3,525	7,000	20	65	720	655
2	1,050	1,900	6,500	5	35	710	675
3	975	1,700	5,500	10	30	710	680
4	1,500	12,000	--	15	15	730	715
5	1,075	3,550	6,500	25	90	720	630
6	1,175	3,900	10,000	30	100	720	605
7	1,100	4,000	15,000	30	115	720	605
8	1,100	3,500	7,250	15	75	680	605
9(1)	1,275	11,000	--	20	20	745	725
10(1)	1,500	12,000	--	20	20	750	730
11	1,260	2,050	5,250	10	85	740	655
12(1)	1,450	8,000	--	5	5	695	690
13	1,060	1,425	8,000	20	130	730	600
14	Difficult wave form readings; however, sounding suggests relatively deep unconsolidated material						

(1)Sounding profile not reversed.

(2)Elevation based on USGS 7½ minute quadrangle map.

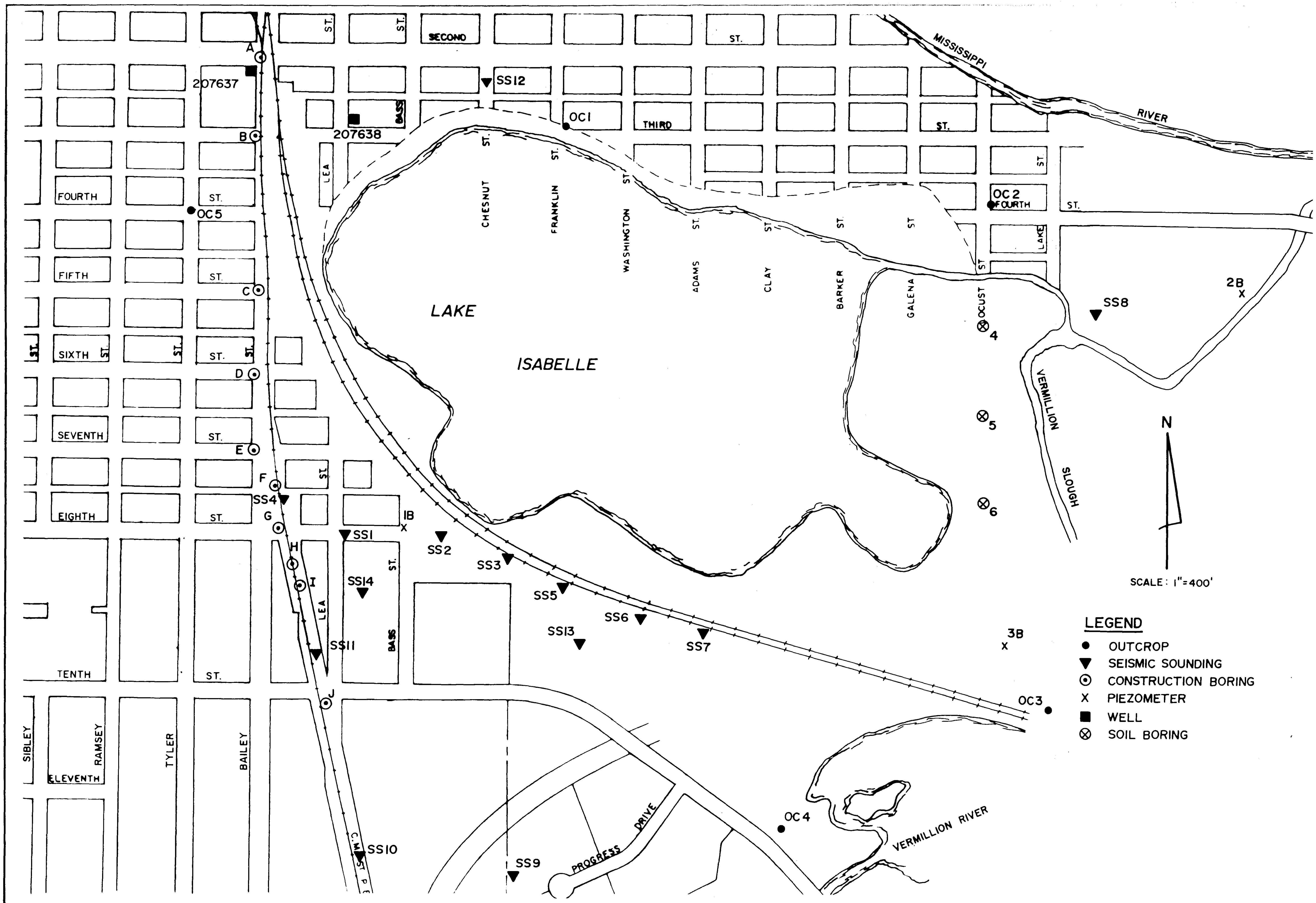
(3)Prairie du Chien formation.

TABLE 2

BEDROCK DATA POINT VALUES(1)

Data Point Identification	Approximate Depth to Bedrock (ft)	Approximate Bedrock Elevation (ft NGVD)	Information Source
SS1	65	655	Sesimic Sounding - EAH
SS2	35	675	Seismic Sounding - EAH
SS3	30	680	Seismic Sounding - EAH
SS4	15	715	Seismic Sounding - EAH
SS5	90	630	Seismic Sounding - EAH
SS6	100	620	Seismic Sounding - EAH
SS7	115	605	Seismic Sounding - EAH
SS8	75	605	Seismic Sounding - EAH
SS9	20	725	Seismic Sounding - EAH
SS10	20	730	Seismic Sounding - EAH
SS11	85	655	Seismic Sounding - EAH
SS12	5	690	Seismic Sounding - EAH
SS13	130	600	Seismic Sounding - EAH
1B	>127	<573	Piezometer Boring Logs - EAH
2B	70	610	Piezometer Boring Logs - EAH
3B	48	640	Piezometer Boring Logs - EAH
4	>31	<650	Soil Boring Log - EAH
5	53	625	Soil Boring Log - EAH
6	>31	<650	Soil Boring Log - EAH
207637	0	710	MN Geological Survey
207638	0	705	MN Geological Survey
OC1	10	690	Observed Outcrops - EAH
OC2	10	690	Observed Outcrops - EAH
OC3	0	700	Observed Outcrops - EAH
OC4	5	690	Observed Outcrops - EAH
OC5	1.5	710	Observed During Utility Excavation in City of Hastings
Boring A	4	700	Hastings City Engineer
Boring B	7	700	Hastings City Engineer
Boring C	5	708	Hastings City Engineer
Boring D	8	714	Hastings City Engineer
Boring E	1	723	Hastings City Engineer
Boring F	7	721	Hastings City Engineer
Boring G	4	729	Hastings City Engineer
Boring H	3	729	Hastings City Engineer
Boring I	>20	<714	Hastings City Engineer
Boring J	18	724	Hastings City Engineer

(1)Prairie du Chien formation.



LAKE ISABELLE RESTORATION STUDY

BEDROCK DATA POINT LOCATION MAP

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vicinity of Lake Isabelle. In addition, geologic data was obtained during the drilling for each of the piezometers installed. Soil boring logs for the installed piezometers are described both in Table 3 and in the soil boring report included in Appendix A. Construction specifications and pertinent elevations of the piezometers are indicated in Table 4. Piezometer construction diagrams are also in the soil boring report.

Each of the piezometers mentioned in the previous section had water levels measured on a weekly basis from November 9 to December 26, 1984.

Along with the piezometer water level measurements, surface water level measurements were made from October 31 to December 26, 1984 at five selected points (S1-S5) as indicated in Figure 6 and with detailed location descriptions shown in Table 5.

The weekly readings at each of the surface water measuring points and each of the piezometers are listed in Tables 6 and 7, respectively. Benchmark data used in the piezometer elevation survey are in Table 8. A graphic description of surface water fluctuations are shown in Figures 7 and 8. Graphic descriptions of groundwater level fluctuations at the piezometers are shown in Figure 9. This graph shows groundwater levels in the vicinity of piezometers 1A and 1B to be near elevation 681.0. This suggests Lake Isabelle could be raised to that elevation if the outlet was obstructed. The hydrogeologic significance of the surface and groundwater level data is further described in the hydrogeologic portion of the text.

Three soil borings (4, 5, and 6) were made along the east side of Lake Isabelle. The purpose of these soil borings was to establish both a depth to bedrock data point and describe the lithology and firmness of the overlying unconsolidated materials. The locations of the soil borings are shown in Figure 2. The soil classifications and penetration resistance (N-values) are in the soil boring report located in Appendix A.

TABLE 3

LAKE ISABELLE PIEZOMETER SOIL BORING LOGS

(GENERAL SOIL DESCRIPTIONS BY EAH PERSONNEL AS OBSERVED ON-SITE WITH GEOTECHNICAL ENGINEERING, INC.)

WELL NEST N1
PIEZOMETER NO. 1B, DRILLED 11/2 AND 11/5/84

Sample Method	Depth (ft)	Description
HSA	0 - 4	Silty sand, with gravel, brown
HSA	4 - 5	Sand and cinders, with gravel, black
HSA	5 - 9	Medium gravel, with sand and silt, black
HSA	9 - 10	Fine sand, trace gravel, reddish-brown
HSA	10 - 12	Fine sand, trace gravel, reddish-brown
HSA	12 - 13	Fine silty sand, brown
HSA	13 - 15	Fine sand, brown
HSA	15 - 20	Fine sand, brown
HSA	20 - 25	Fine sand, with coarse gravel
HSA	25 - 65	Fine-medium sand? -- most samples lost in water-bearing formation
HSA	65 - 75	Coarse sand, some gravel
HSA	75 - 82	Coarse sand, some clay
HSA	82 - 127	Clay, dark gray
	Discontinued Drilling at 127 feet	

WELL NEST N2
PIEZOMETER NO. 2B DRILLED 11/6 AND 11/7/84

HSA	0 - 5	Thick clay, dark brown
HSA	5 - 10	Silty sand, brown
HSA	10 - 20	Fine-medium sand, with silt, brown
HSA	20 - 25	Fine sandy silty clay, gray brown
HSA	25 - 30	Fine sandy silty clay, gray
HSA	30 - 50	Fine-medium, sandy silty clay, dark gray
HSA	50 - 65	Medium sand, with silt
HSA	67 - 70	Medium sand and gravel, with sandstone and limestone chips
HSA	70	Bedrock

TABLE 3 (continued)

LAKE ISABELLE PIEZOMETER SOIL BORING LOGS

(GENERAL SOIL DESCRIPTIONS BY EAH PERSONNEL AS OBSERVED ON-SITE WITH GEOTECHNICAL ENGINEERING, INC.)

WELL NEST N3
PIEZOMETER NO. 3B, DRILLED 11/9/84

Sample Method	Depth (ft)	Description
HSA	0 - 7.5	Fine silty sand, brown
HSA	7.5 - 10	Fine silty sand, with clay, dark brown
HSA	10 - 15	Fine silty sand, brown
HSA	15 - 37	Fine silty sand, brown
HSA	37 - 47.5	Fine-medium sand, trace gravel -- light brown
HSA	47.5	Bedrock -- dolomite

HSA - Hollow Stem Auger

TABLE 4

PIEZOMETER CONSTRUCTION SPECIFICATIONS

Piezometer Number	1A	1B	2A	2B	3A	3B
Top of Protective Casing Elevation (NGVD)	703.67	704.17	685.29	685.34	690.62	690.50
Top of Inner Casing Elevation(1) (NGVD)	703.54	704.05	685.28	685.27	690.59	690.40
Ground Elevation (NGVD)	701.17	701.36	682.37	682.43	687.66	687.49
Casing Type and Inner Diameter	PVC 2"	PVC 2"	PVC 2"	PVC 2"	PVC 2"	PVC 2"
Casing Length (ft from surface)	25	69	10	68	42.5	14.5
Screen Type and Inner Diameter	PVC 2"	PVC 2"	PVC 2"	PVC 2"	PVC 2"	PVC 2"
Screen Slot Size (in)	.080 Wound	.080 Wound	.080 Slotted	.080 Slotted	.080 Slotted	.080 Slotted
Screen Length (ft)	5	5	5	5	5	5
Approximate Borehole Diameter(2) (in)	6.5-HSA	6.5-HSA 3-Rotary	6.5-HSA	6.5-HSA 3-Rotary	6.5-HSA	6.5-HSA 3-Rotary
Type of Screen Backfill	Native Fine-Medium Sands	Native Fine-Medium Sands	Native Fine Sands	Native Medium Gravel	Native Fine-Silty Sand	Native Fine-Medium Sand

TABLE 4 (continued)

PIEZOMETER CONSTRUCTION SPECIFICATIONS

Piezometer Number	1A	1B	2A	2B	3A	3B
Bentonite Plug Interval (ft from surface)	21-23	21-23	None (cement cap)	None (cement cap)	None (cement cap)	9-10
Cement Cap Thickness at Top of Borehole (ft)	3	3	3	3	3	3
Total Piezometer Depth (ft from top of casing)	31.8	76.9	17.7	70.7	22.3	50.1
Approximate Water Level (ft from top of 2" PVC casing)	22.9	22.4	7.3	7.0	11.8	11.6

(1)Reference elvation for subsequent water level measurements.

(2)HSA - Denotes hollow stem auger drilling.

Rotary - Denotes tri-cone bit, mud rotary drilling.

TABLE 5

REFERENCE POINT LOCATION DESCRIPTIONS AND ELEVATIONS
FOR MISSISSIPPI AND VERMILLION RIVERS, AND LAKE ISABELLE WATER LEVELS

Stage Station No.	Location Description	Surveyed Elevation (ft NGVD)
S1	Approximately 550 ft north of the centerline of the intersection of 2nd Street E. and Ramsey Street at the most northwesterly corner of a concrete jetty (with a black iron railing) at the top of the most northwesterly corner of concrete; painted orange. (In Veterans Memorial Park at Mississippi River edge.)	686.17
S1A	S1A is still on concrete jetty as S1; however, due to lower stage at S1, moved stage location to S1A, which is 33.69 feet northeast of S1 at the top of the 20th threaded bolt from S1, upper set of bolts; painted orange. Also, approximate 2 ft southwest of broken corner of concrete jetty.	685.77
S2	Staff gage is located approximately 30 ft upstream of Lake Isabel outlet control structure. Also, approximately 150 feet upstream along Lake Isabel outlet stream from its confluence with the Vermillion River.	676.89
S2A	(Temporary) on west side of five-trunked tree, in stream near top of bank, approximately 30 feet upstream of control structure. Top of painted orange dot. Also, approximately 120 ft northwest of Anoka County Section Mark No. 9748.	681.28
S3	At the approximate center and northeast side of Ravenna Road Bridge No. 19523 over the Vermillion River approximately 80 ft southeast of the northwest corner of concrete railing at top of grout seam of concrete railing sections (painted orange).	697.83
S4	At the approximate center and east side of Vermillion Street Bridge No. 19075 over the Vermillion River. Approximately 75 ft north-northwest of the southeast corner of bridge. Also, the 11th vertical metal railing post north-northwest of the southeast end of railing. At bottom of beveled edge of concrete railing (painted orange). NOTE: This station is approximately 600 ft upstream of Vermillion Falls.	791.10

TABLE 5 (continued)

REFERENCE POINT LOCATION DESCRIPTIONS AND ELEVATIONS FOR MISSISSIPPI AND VERMILLION RIVERS, AND LAKE ISABEL WATER LEVELS

Stage Station No.	Location Description	Surveyed Elevation (ft NGVD)
S5	At the approximte center and south side of Dakota County Road 47, Bridge No. 19503 over the Vermillion River. Approximately 75 ft west-southwest of the southeast corner of bridge. Also, the 10th vertical metal railing west-southwest of the southeast end of railing at bottom of beveled edge of concrete railing (painted orange).	798.24

TABLE 6

MISSISSIPPI, VERMILLION RIVERS, AND LAKE ISABELLE
WATER LEVEL READINGS

(OCT 1984 - DEC 1984)
ALL ELEVATIONS IN FEET (NGVD)

Station Number (Reference Elevation)	10/31	11/7	11/14	11/21	11/28	12/5	12/12	12/19	12/26
S1 (685.77)	679.98	677.52	676.75	675.39	675.12	674.09	675.20	675.50	674.92
S2 (676.89)	679.73	677.30	676.71	676.54	676.65	676.61	676.58	676.62	676.46
S3 (697.83)	679.93	679.63	679.59	679.50	679.52	679.82	679.62	680.55	679.88
S4 (791.10)	775.10	775.15	775.23	775.01	775.30	774.92	774.93	775.40	775.18
S5 (798.24)	783.54	783.24	783.49	783.23	783.17	783.24	783.31	783.84	783.92

TABLE 7

PIEZOMETER WATER LEVEL ELEVATIONS

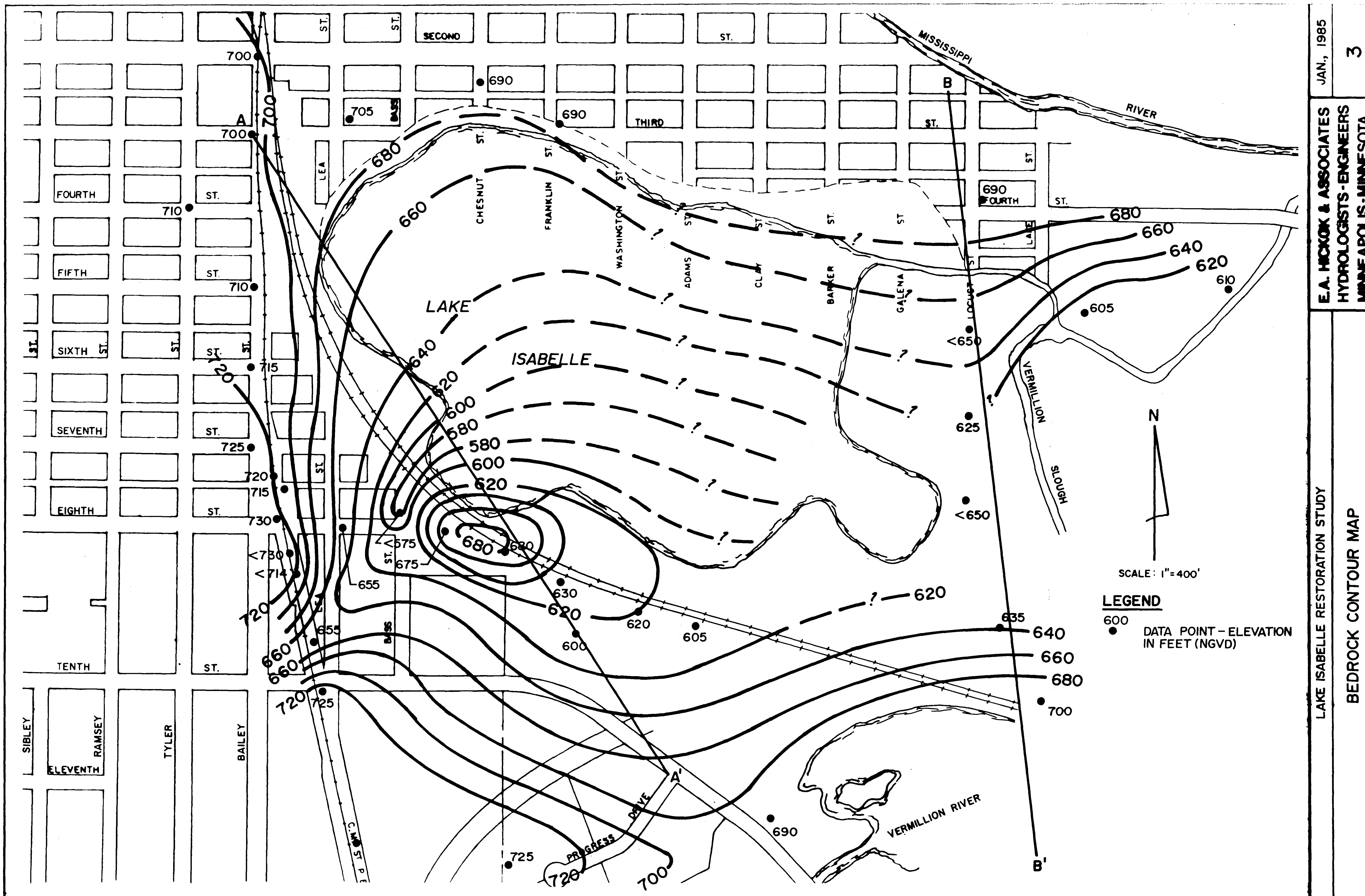
(NOV 1984 - JAN 1985)
ALL ELEVATIONS IN FEET (NGVD)

Piezometer No. (Reference Elevation)	11/9	11/14	11/21	11/28	12/5	12/12	12/19	12/26
1A (703.54)	680.59	680.39	680.10	679.86	679.67	679.52	679.45	679.37
1B (704.05)	681.68	681.50	681.16	680.97	680.80	680.64	680.53	680.42
2A (685.28)	678.00	677.65	676.97	676.70	676.44	676.39	676.90	676.46
2B (685.27)	678.22	677.79	676.94	676.88	676.33	676.34	676.77	676.39
3A (690.59)	Not Installed	678.74	678.32	678.17	678.00	677.91	678.08	677.92
3B (690.40)	Not Installed	678.75	678.35	678.18	677.99	677.92	678.07	677.93

TABLE 8

CITY OF HASTINGS, MINNESOTA BENCH MARKS
(ELEVATIONS BASED ON USGS DISK IN CITY OF HASTINGS)

EAH-Assigned Bench Mark Number	Elevation in feet (NGVD)	Location Description
1	701.30	Top of arrow on fire hydrant, located in alley between 1st Street and 2nd Street on Tyler Street.
2	706.94	Top of ring around top nut of fire hydrant, located in the northeast corner of the intersection of 4th Street and Lake Street.
3	741.50	Top of arrow on fire hydrant, located in the northwest corner of the intersection of 8th Street and Bailly Street.
4	794.93	Top of ring around top nut of fire hydrant, located at the west entrance road to the Dakota County Highway Department garage. Also, approximately 75 feet north of County Road 47 centerline.
5	790.81	Top of arrow on fire hydrant, located in the northwest corner of the 'T' intersection of Minnesota Trunk Highway 61 and Dakota County Road 47.



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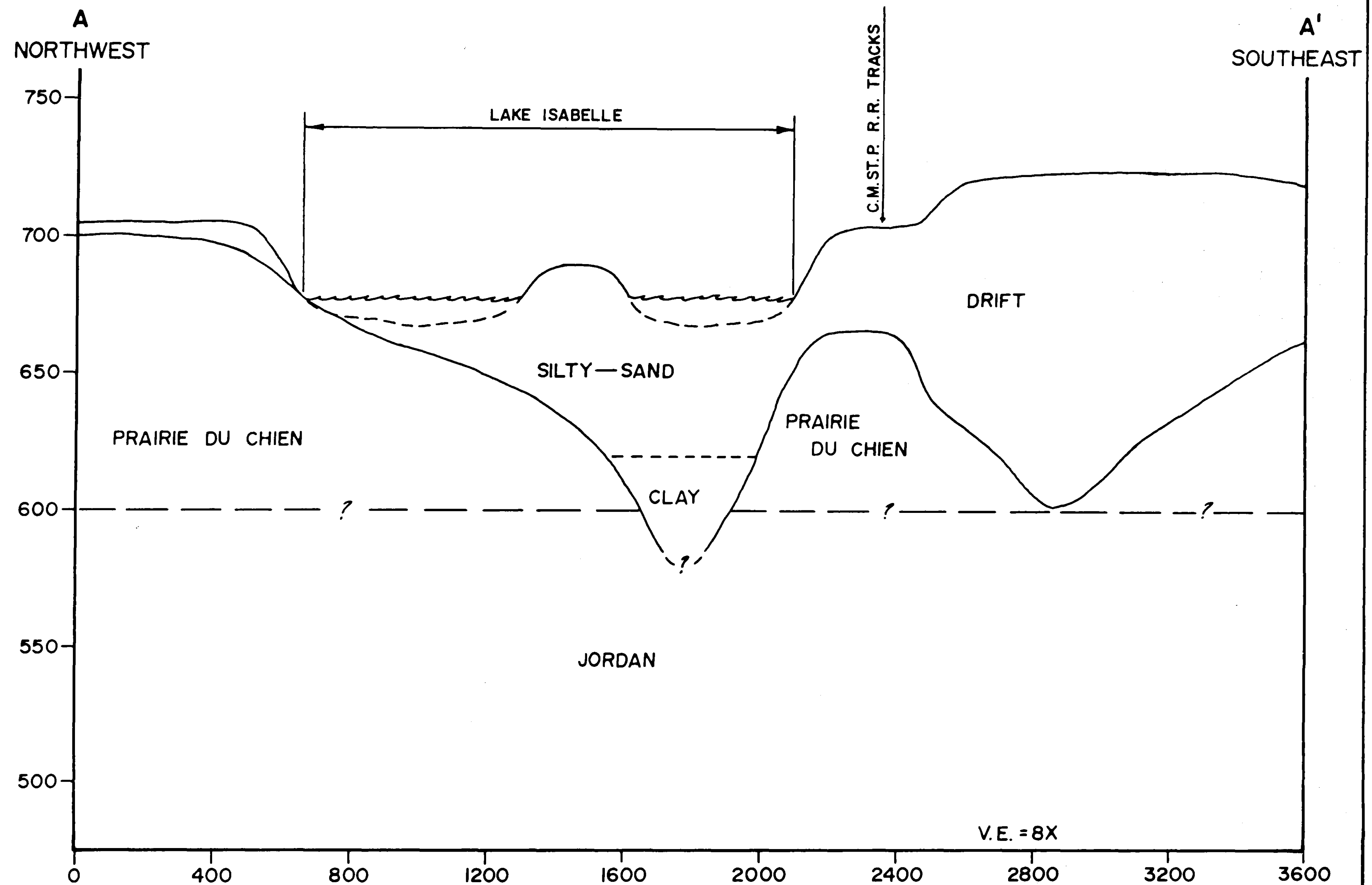
LAKE ISABELLE RESTORATION STUDY
BEDROCK CONTOUR MAP
LEGEND
600
DATA POINT - ELEVATION IN FEET (NGVD)
SCALE: 1"=400'
N
LAKE ISABELLE
MISSISSIPPI RIVER
VERMILLION RIVER
VERMILLION SLOUGH
SECOND ST.
THIRD ST.
FOURTH ST.
FIFTH ST.
SIXTH ST.
SEVENTH ST.
EIGHTH ST.
TENTH ST.
ELEVENTH
SIBLEY
RAMSEY
TYLER
BAILEY
LEA
BASS
CHESNUT ST.
FRANKLIN ST.
WASHINGTON ST.
ADAMS ST.
CLAY ST.
BARKER ST.
GALENA ST.
LOCUST ST.
PROGRESS DRIVE
C.M. ST. P. E.
A
A'
B
B'



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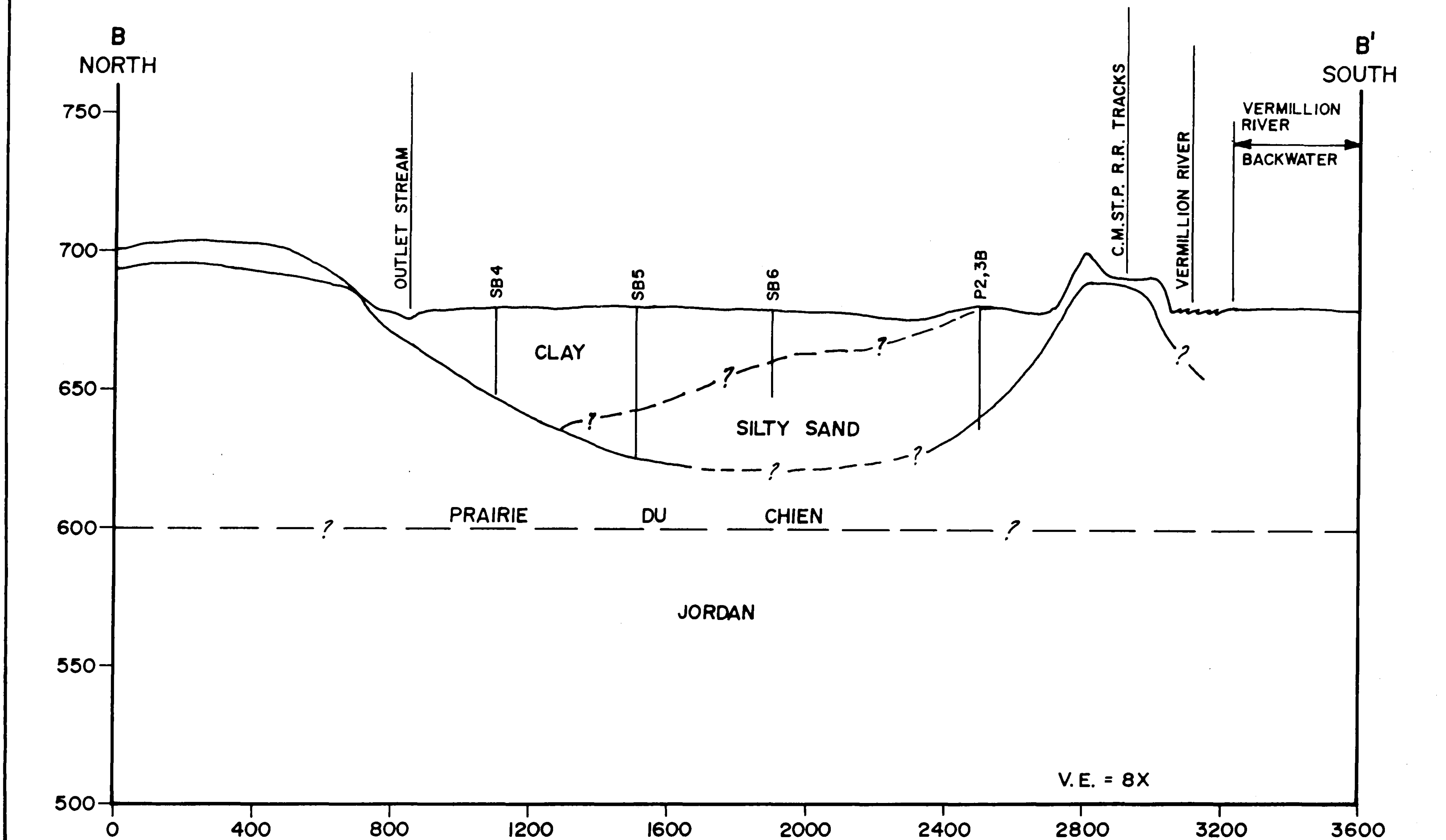

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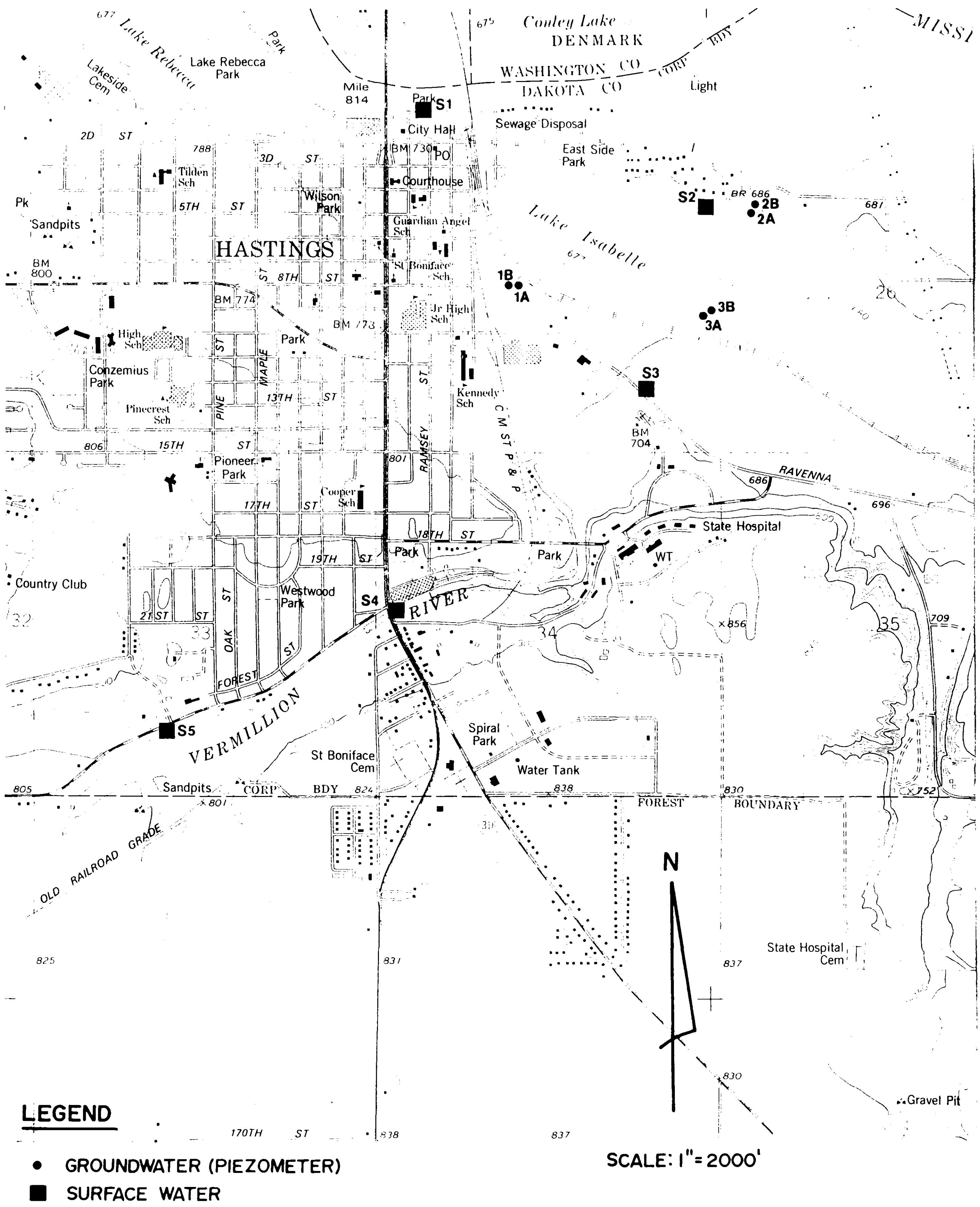
GEOLOGICAL CROSS-SECTION B—B'		5



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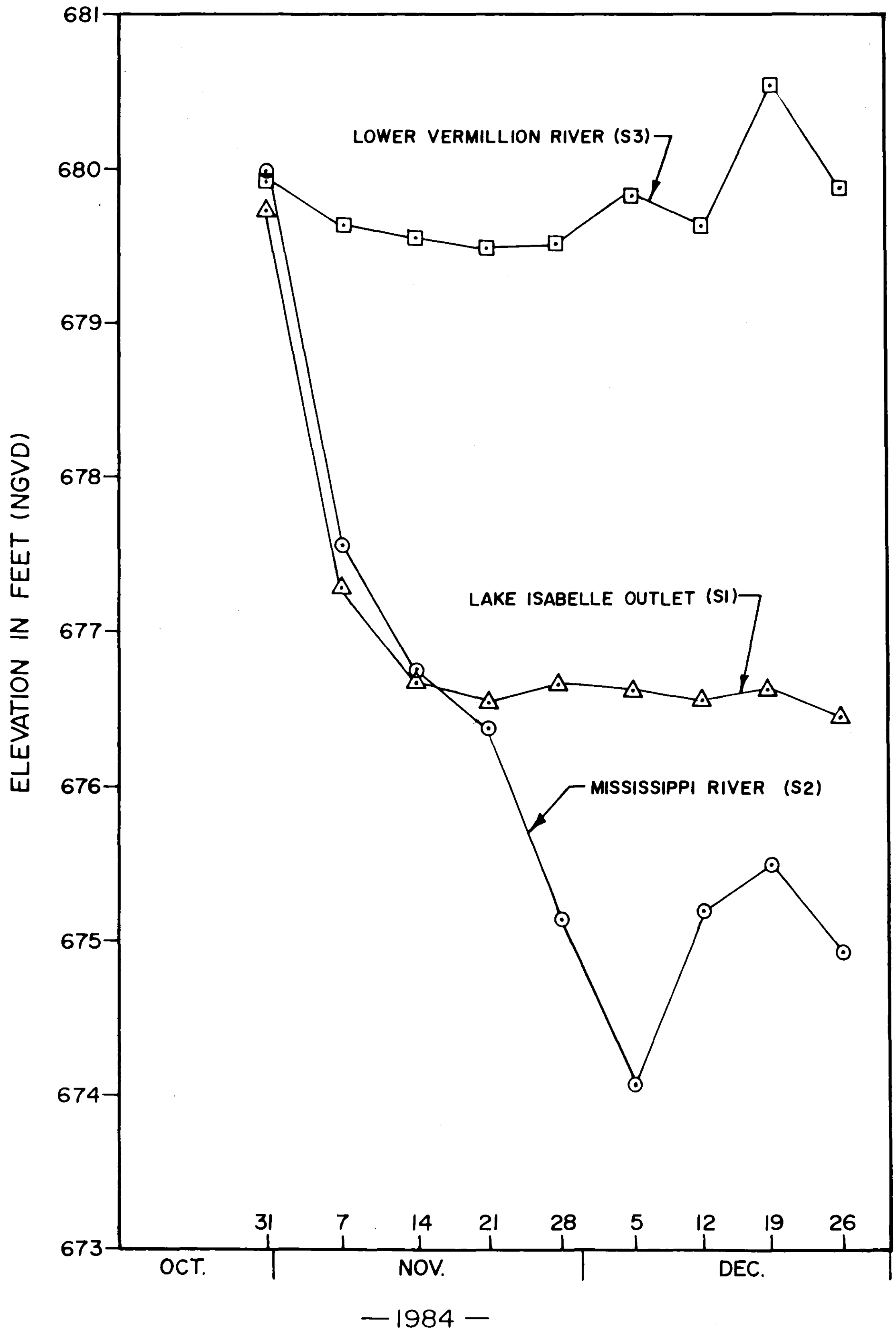

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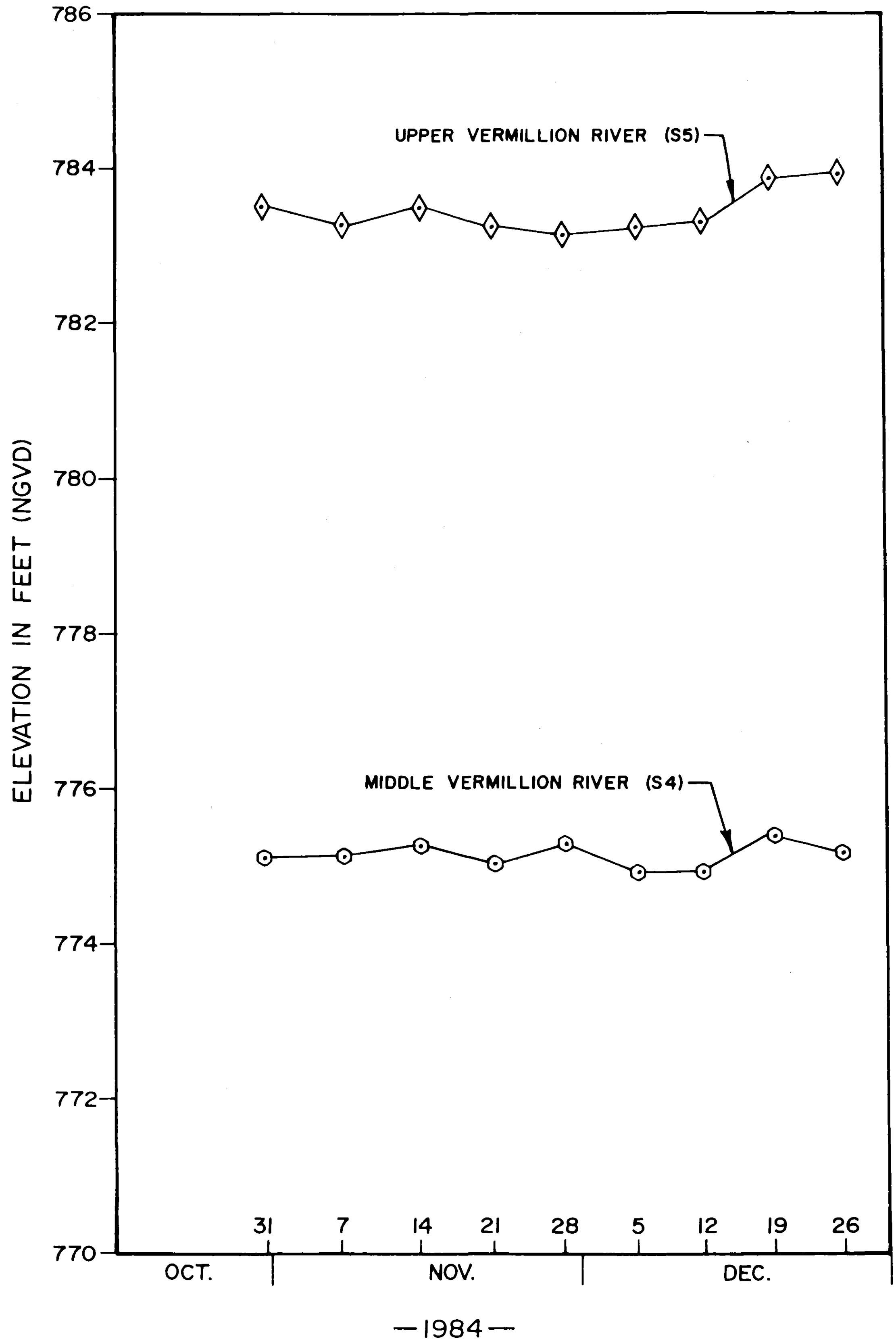

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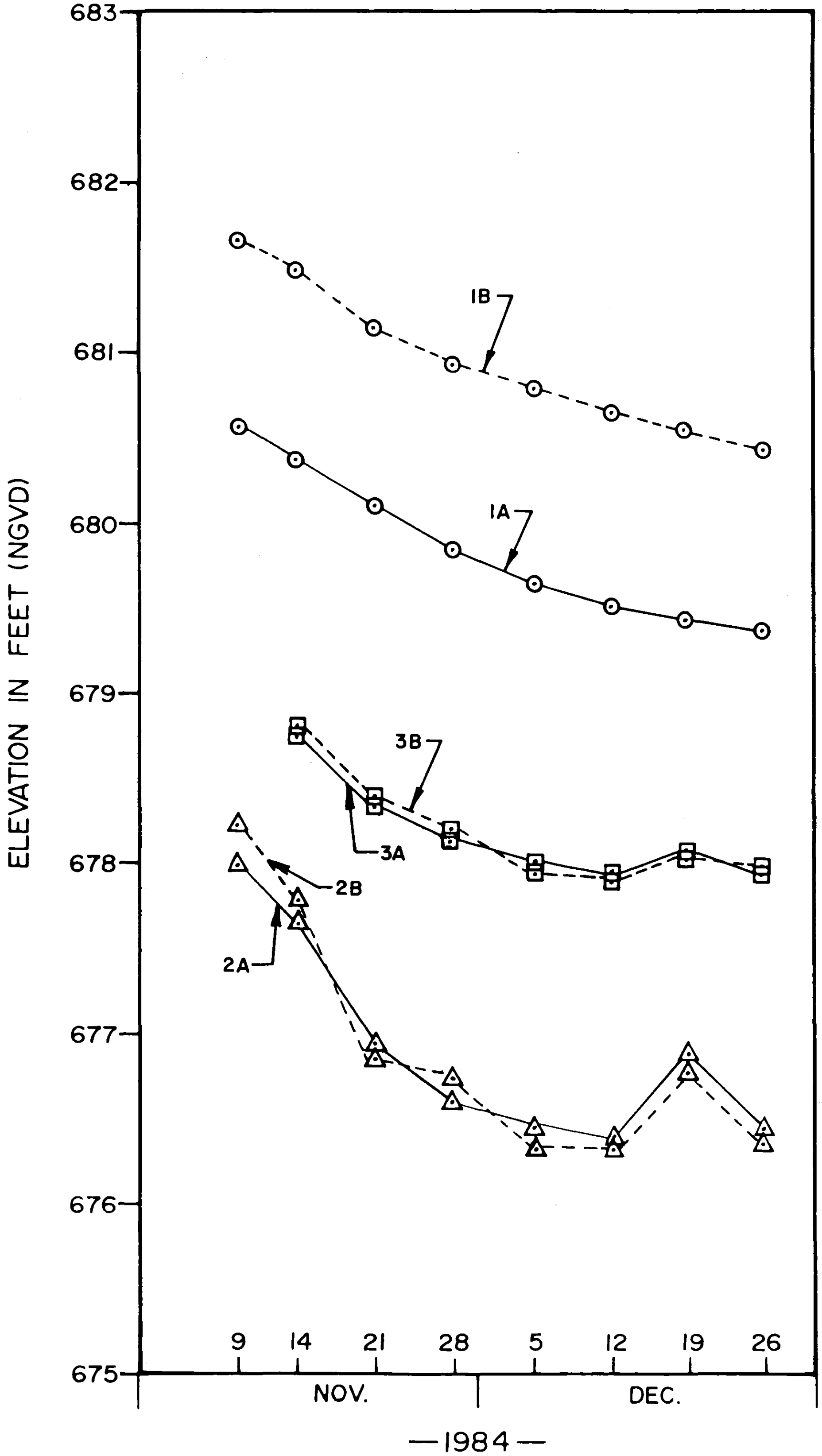

LAKE ISABELLE RESTORATION STUDY	E.A. HICKOK & ASSOCIATES	JAN., 1985
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GEOLOGICAL ANALYSIS

The geologic and hydrogeologic information obtained indicates that Lake Isabelle is within a basin-like bedrock formation. A broad erosional opening exists at the east side of the lake entering the Mississippi River Valley. Two narrow buried valleys breach the bedrock basin in the southwest portion of Lake Isabelle. These erosional features are shown in Figure 3, Bedrock Contour Map. Drilling logs from piezometer installations and soil borings within the narrow and broad buried valleys confirm the existence of both erosional features. Locations for these data points are shown in Figure 2.

Two geologic cross-sections were made describing the bedrock and surficial geology at the southwest and east portions of Lake Isabelle. Locations of the cross-sections are shown on Figure 3.

Geologic cross-section A-A' (Figure 4) describes the buried channels that enter from the southwest towards and under Lake Isabelle. The composition of the material, silty sand and clay, within the more westerly buried bedrock channel are based on soil samples obtained during the installation of piezometer 1B. Based on well log information obtained from the Minnesota Geological Survey, both buried channels are eroded down through the Prairie du Chien to the Jordan sandstone formation.

Geologic cross-section B-B' (Figure 5) describes the more broad erosional opening to the east of Lake Isabelle. Three soil borings and the installation of piezometer 3B provided depth to bedrock and surficial geologic information in this area. As indicated in Figure 5, the unconsolidated material consists of clays and lake deposits that are predominant to the north of the cross-section and silty sands that are predominant to the south of the cross-section. The unconsolidated material has a known depth of 40 to 50 feet below the bottom of

Lake Isabelle at this location. The bedrock rises rapidly toward the land surface to both the north and south with outcrops observed to the south near the C.M.S.P. and P. Railroad tracks and to the north at the intersection of 4th Street and Locust Street.

The depth and configuration of the buried channel(s) directly beneath Lake Isabelle is unknown. However, based on the geologic data presented and the mechanics of fluvial erosional processes, it appears likely that the buried channels described to the southwest (Figure 3) extend eastward through the broad erosional opening described in Figure 5.

HYDROGEOLOGY

The groundwater flow regime of Lake Isabelle has been defined based on the hydrologic and geologic data that was previously presented. A qualitative review of this information indicates the following:

1. Horizontal inflow occurs along the south shoreline of the lake.

2. Verticle inflow is occurring beneath the northerly one-half of the lake bottom.

3. Horizontal outflow is present along the east shoreline of the lake.

4. Very little horizontal inflow or outflow occurs along the north shoreline of Lake Isabelle due to flat groundwater gradients in this area.

The areas of significant inflow and outflow are discussed in greater detail in the following paragraphs.

A. Inflow Along South Shoreline

Significant horizontal inflow occurs along the south shoreline through two buried bedrock valleys. The valleys are cut into the Prairie du Chien-Jordan bedrock and filled with alluvium. The alluvial inflow area consists of three homogeneous anisotropic layers. These three distinctive layers that were found during the installation of piezometer 1B include fine sand, sand and gravel, and clay. Average values for hydraulic conductivity of these layers and the thickness of the bedrock and alluvial deposits are listed in Table 9.

Vertical hydraulic inflow along this south shoreline is anticipated to be minimal due to the presence of a deep clay deposit. (See Figure 4.) This deposit should effectively stop most upward vertical flow along the axis of the bedrock channels and result in the verticle inflow component becoming almost insignificant. Therefore, the discharge into Lake Isabelle along the southern recharge boundary can be determined from the horizontal flow through the fine and coarse sand layers. The horizontal discharge (Q_x) is the product of the equivalent horizontal hydraulic conductivity (K_x), the effective area of flow (A), and the total head loss (h_t) over a horizontal distance (L).

$$Q_x = A \cdot K_x \left(h_t / L \right)$$

The equivalent horizontal hydraulic conductivity is given by:

$$K_x = \sum_{i=1}^{n} \frac{K_i \, d_i}{L}$$

Using the horizontal conductivities listed in Table 9 for the two sand layers, we obtain K_x = 42.3 (ft/day).

TABLE 9

LAKE ISABELLE AVERAGE HYDROLOGIC PARAMETER

Deposit	Average Saturated Thickness d (ft)	Average Horizontal Hydraulic Conductivity K_x (ft/day)	Average Vertical Hydraulic Conductivity K_x (ft/day)
Fine Sand	44.7	1.33 (1)	0.03 (2)
Lake Sediment Fine Silty Sand	19.5	1.06 (1)	0.03 (2)
Coarse Sand Some Gravel Some Clay	17	150 (1)	0.17 (2)
Clay	25	0.0006 (3)	0.000006 (4)
Prairie du Chien Limestone	40	63 (5)	2.8 (5)
Jordan Sandstone	120	63 (5)	2.8 (5)

(1)Freeze, R.A., Allen, J.A., 1979, Groundwater, Chapter 2, Table 2.2, p. 29.

(2)Walton, 1965, Table 7, p. 35.

(3)Todd, D.A., 1968, Groundwater Hydrology, Table 3.1, p. 71.

(4)K_z = 1/100 K_x.

(5)Norvitch et al., USGS, 1973 Water Resources Outlook for the Minneapolis-St. Paul Area, Table 7, p. 115.

The head loss is the difference between the average water level of piezometer 1B and the average lake level. The head loss over this 250-foot horizontal distance is:

$$h_t = (680.97 - 676.72) \text{ ft} = 4.25 \text{ ft}$$

The relationship for Q_x can now be applied over the 3,600-foot southern shoreline with an average saturated thickness of 70 feet.

$$Q_x = 42.3 \text{ (ft/day) } 3{,}600 \text{ (ft) } 70 \text{ (ft)} [4.25 \text{ ft}/250 \text{ ft}]$$

$$Q_x = 181{,}200.4 \text{ (ft}^3\text{/day)}$$

$$Q_x = 2.1 \text{ (cfs)}$$

B. Inflow Along North One-Half of Lake Bed

Vertical groundwater inflow occurs beneath the northern half of the lake by passing through the joints and fractures in the bedrock and alluvial deposits. That area beneath the lake and above the 620-foot bedrock contour as shown in Figure 5 is assumed to be free of the clay deposits. This area consists of lake sediment above fine sand above coarse sand which rests directly on the Prairie du Chien. Three different vertical inflow zones can be defined because the erosional surface of the Prairie du Chien slopes toward the center of the lake.

The vertical discharge into Lake Isabelle will differ for each inflow zone because of the varying thickness and conductivity for each sequence of deposits. The vertical discharge for each inflow zone is the product of the equivalent vertical conductivity (K_{zi}) and the effective area of flow (A_i) and the total head loss (h_{zi}) over a vertical distance (z).

$$Q_{zi} = A_i K_{zi} (\ h_{zi}/ \ z)$$

Where i = (1, 2, 3).

Head loss and vertical distance are constant for each inflow zone. The total head loss is taken to be the difference between the potentiometric surface of the Prairie du Chein over Lake Isabelle and the average lake elevation.

According to the most recent sources (USGS, Potentiometric Surface of the Prairie du Chien-Jordan Aquifer, August 1980) for the Prairie du Chien and the average lake elevations listed in Table 6:

$$h_z = 682 \text{ ft} - 676.72 \text{ ft}$$

$$h_z = 5.28 \text{ (ft)}$$

$$Z = 77 \text{ (ft)}$$

Table 10 provides a summary of the parameters for the three vertical inflow zones.

The total vertical inflow is the sum of the inflows from each zone.

$$Q_z = Q_{z1} + Q_{z2} + Q_{z3}$$

$$Q_z = (325 + 410 + 161) \text{ ft}^3/\text{day}$$

$$Q_z = 896 \text{ (ft}^3/\text{day)}$$

$$Q_z = 0.01 \text{ (cfs)}$$

The total groundwater inflow into Lake Isabelle is the sum of the vertical and horizontal inflows.

$$Q_T = Q_x + Q_z$$

$$Q_T = (8{,}798 + 896) \text{ ft}^3/\text{day}$$

$$Q_T = 182{,}100 \text{ (ft}^3/\text{day)}$$

$$Q_T = 2.1 \text{ (cfs)}$$

TABLE 10

LAKE ISABELLE

VERTICAL INFLOW ZONE PARAMETERS

Elevation Interval	Deposits	Average Thickness (ft)	Vertical Hydraulic Conductivity (ft/day)	Zone Area (ft^2)	Equivalent Vertical Conductivity (ft/day)	Discharge, Q_{zi} (ft/day)
677-660	1. Silty Sand	17	0.03			
	Prairie du Chien	60	2.8	41,600	0.114	325
660-640	2. Silty Sand	25	0.03			
	Fine Sand	10	0.03			
	Prairie du Chien	42	2.8	92,000	0.065	410
640-620	3. Silty Sand	24	0.03			
	Fine Sand	14	0.03			
	Coarse Sand	10	0.17			
	Prairie du Chien	29	2.8	41,280	0.057	161

C. Outflow

Outflow from Lake Isabelle occurs through the alluvial deposits along the eastern shoreline. However, high water levels in the Mississippi River and Vermillion slough could cause this area to become a recharge boundary.

Soil borings taken in a north-south line 500 feet from the east shoreline show clay and silty clay alluvial deposits. Groundwater levels measured in these borings indicate groundwater at 675.8 feet NGVD. The discharge out of the lake through this silty clay is found using:

$$Q_x = A\,K_x\,(\ h_x/\ \ L)$$

$$Q_x = 43{,}200\ (ft^2)\ 0.25\ (ft/day)\ 0.0018\ (ft/ft)$$

$$Q_x = 19.5\ (ft^3/day)$$

The effects of a head increase from dike placement were also investigated and are shown in the table below.

H (ft)	(ft^3/day)	(cfs)
0.92 - present	19.5	.00022
2	63.1	.00073
3	84.7	.00098
4	106.3	.00123
5	127.8	.00147
6	149.5	.00173
7	171.0	.00198
8	192.6	.00223
9	214.3	.00248
10	235.8	.00273

As can be observed from the above table, very little increase in groundwater outflow below the dike will occur as a result of increasing the normal lake level.

D. Supplemental Data Analysis

On March 14 and 15, 1985, two additional borings and one additional piezometer were installed north of Lake Isabelle (see boring logs). Water level information from the new piezometer (4B) indicates that the gradient between the lake and piezometer 1B is continuous at least up to the new piezometer. The table below shows lake level changes are expected to influence groundwater inflow along the southern shoreline. This table is based on a water table elevation at 4B of 689.17 feet a distance of 1,000 feet from the lake.

Lake Level (ft)	Gradient (ft/ft)	Groundwater Inflow (cfs)
676.72	0.017	2.1
678.0	0.011	1.3
680.0	0.009	1.1
682.0	0.007	0.8
684.0	0.005	0.6
686.0	0.003	0.4
688.0	0.001	0.1
689.0	0.0002	0.02

As can be observed from this table, as the lake level increases, the rate of groundwater outflow decreases to almost zero when the lake level reaches elevation 689.0. Taking into consideration losses from additional groundwater outflow at higher lake elevations, the effects of evaporation, and seasonal fluctuations in the groundwater table that are anticipated but were not monitored due to the short study period, it is estimated that the normal elevation of the lake would have to be set at or below elevation 684.0 if a constant lake level is desired.

SURFACE RUNOFF ANALYSIS

A hydrologic analysis of surface water runoff in the Lake Isabelle watershed (see Figure 10) was completed with the assistance of the Soil Conservation Service Hydrologic Model TR-20. The watershed's characteristics for each of

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LAKE ISABELLE WATERSHED

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these were simulated for a 5, 10, and 100-year return frequency, 24-hour duration storm, and a storm that would generate the maximum probable precipitation in this area which has been established to be 23.5 inches in 6 hours. Peak flood levels and discharge rates for Lake Isabelle were determined for each rainfall event assuming the Lake Isabelle outlet dike was constructed in accordance with any of the three alternatives listed in the Preliminary Design section of this report. A groundwater inflow to the lake of 6.7 cfs was also incorporated into the analysis based on the results of the hydrogeologic investigation.

A summary of the surface water runoff analysis results are included in Table 11. A copy of the TR-20 input file and output summary is included in Appendix B. This analysis indicates that the maximum lake level bounce would be 3.8 feet, and would occur during a rainfall event generating the probable maximum precipitation. The lake's water level would reach an elevation of 684.82 if the normal lake level was at elevation 681.0 at the beginning of the rainfall event.

Comparing the surface water runoff analysis information generated for the Lake Isabelle watershed with predicted flood elevation information for the Mississippi River (see Table 12), it is evident that high water on the Mississippi River will inundate areas in the vicinity of Lake Isabelle much more frequently than would rainfall events in the Lake Isabelle watershed. For this reason, the preliminary design for the Lake Isabelle outlet dike and associated structures was based on predicted flood elevations for the Mississippi River.

SOILS ANALYSIS

Split tube penetration borings using a hollow stem auger were taken along the route of the dike construction as shown on Figure 2. The boring logs and an analysis of the boring information by Geotechnical Engineering Corporation is included in Appendix A.

TABLE 11

SUMMARY OF RESULTS FROM SURFACE WATER RUNOFF ANALYSIS

Return Frequency of Rainfall Event	Rainfall Depth (inches)	Rainfall Duration (hours)	Discharge Rate from Lake Isabelle Outlet (cfs)	Lake Level Bounce (feet)	Flood Elevation* (MSL datum)
5 Year	3.6	24.0	5.1	0.45	681.45
10 Year	4.2	24.0	6.7	0.54	681.54
100 Year	6.0	24.0	12.3	0.81	681.81
Probable Maximum Precipitation	23.5	6.0	124.92	3.82	684.82

*Assumes lake outlet constructed as shown on either Alternative A, B, or C and normal lake level established at elevation 681.0.

TABLE 12

PEAK FLOOD ELEVATIONS FOR THE MISSISSIPPI RIVER
IN THE VICINITY OF LAKE ISABELLE (1)

Return Freqency	Flood Elevation (MSL datum)
5 Year	685.5
10 Year	687.5
20 Year	688.5
50 Year	691.4
100 Year	693.1

(1)Taken from "Upper Mississippi River Water Surface Profiles -- River Mile 0.0 to River Mile 847.5." Prepared by the U.S. Army Corps of Engineers, November 1979.

The soil boring logs and subsequent analysis revealed that the typical soil profile in the vicinity of the proposed dike consists of an upper layer of weak and compressible soils underlain by coarse alluvium. The depth of these materials exceeds 60 feet in some locations along the proposed dike alignment. If a 10-foot high dike is constructed on these soils, it is estimated that long and short-term settlement could approach 10 feet over a period of 10 to 20 years. Although this settlement will present problems, construction of the dike is still feasible provided certain precautions and construction techniques are followed. These techniques are further discussed in the Preliminary Design section of the report.

HYDRAULIC DREDGING OF LAKE BOTTOM SEDIMENTS

A study into the feasibility of hydraulically dredging the bottom sediments of Lake Isabelle to increase the lake's depth was completed. The study showed that hydraulically dredging the lake bottom sediments is feasible provided a suitable spoils dewatering/disposal site in close proximity to Lake Isabelle can be acquired.

The size of this site would be dependent on the extent of the dredging to be completed and the settling characteristics of the dredging spoil. The settling characteristics of the dredging spoils were determined by obtaining sediment samples from Lake Isabelle, combining this bottom sediment with lake water in portions that would be similar to that found in the spoil discharge, and then conducting various sediment settling tests on the samples.

The tests indicated that the suspended lake sediments present in the samples would settle out to the bottom four-tenths of the water column within 118 hours or less (five days). At this time, the quality of the supernatant was relatively good, with concentrations of total suspended solids less than 1 mg/l and total phosphorus concentrations averaging 7 mg/l. This is below the 30 mg/l total suspended solids limits the MPCA has set for discharge to the Mississippi River. (No limit has been established for phosphorus.) Therefore, it is recommended the dredging disposal basin be constructed with cells that will be allowed to dewater for this period of time before its supernatant is discharged and additional dredging spoil is introduced into the cell. (See Appendix C for detailed description of procedures and methods used and test results.)

The dredging depth was assumed to be 3 feet. The 3-foot depth was chosen because hydraulically dredging the sediment to a depth significantly less than this generally reduces the solids content of the dredging spoil and increases removal costs per unit volume. If the dredging depth exceeded 3 feet, costs per unit volume would probably decrease slightly over those estimated due to economy of scale.

The removal of 3 feet of sediment from Lake Isabelle under the conditions previously outlined would require a spoils disposal site with a minimum area of 80 acres. Undeveloped property suitable for this activity is located to the south and east of the lake provided an agreement could be reached with the property owner. The disposal basin would need to be designed to accommodate up to 1,170,000 cubic yards of undewatered dredging spoils and provide for permanent disposal of approximately 300,000 cubic yards of dewatered spoils.

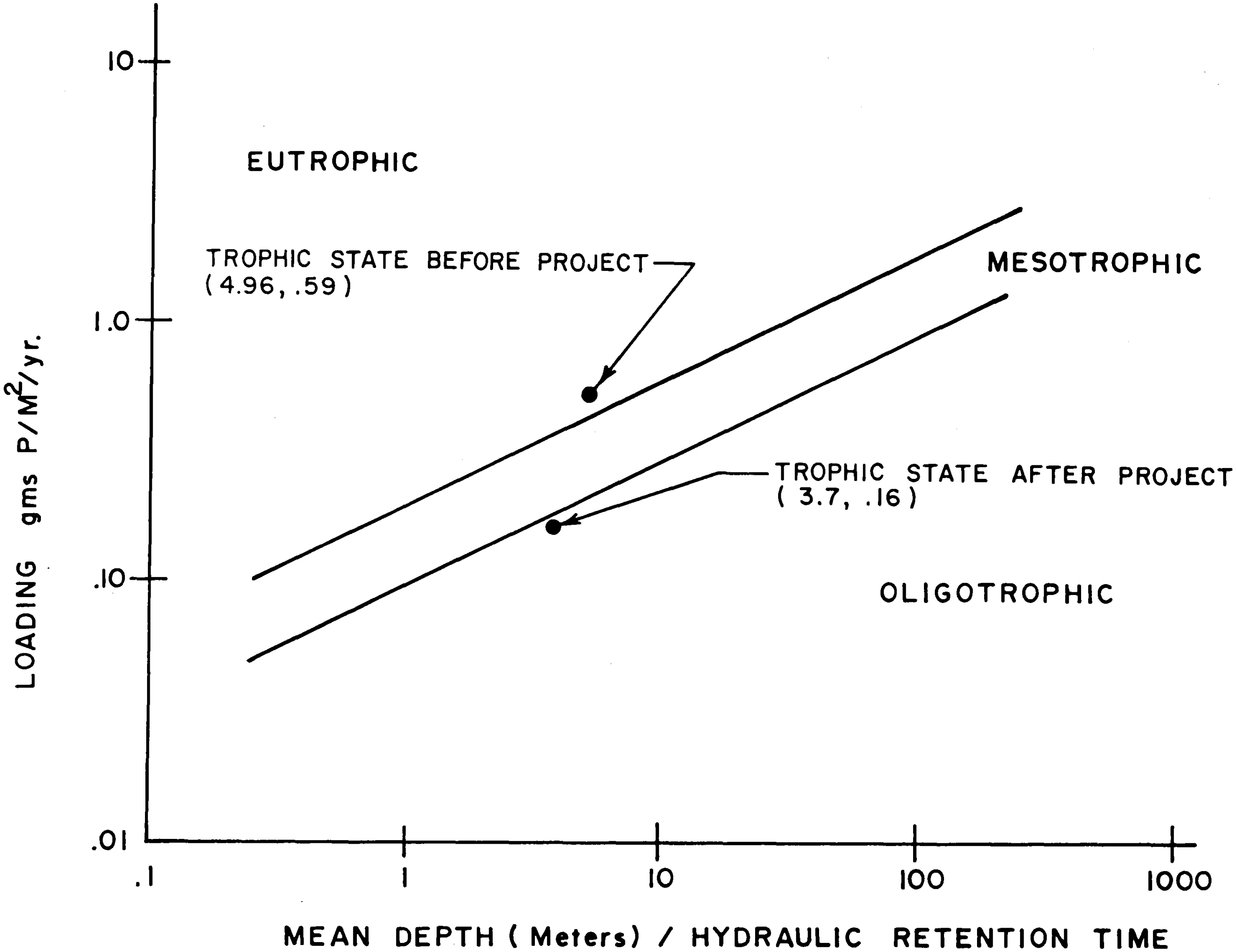
The anticipated cost to complete this dredging activity is outlined below:

1.	Acquire 80 Acre Disposal Site	$ 50,000
2.	Construct Dewatering/Disposal Basin	25,000
3.	Hydraulically Dredge 400,00 Cubic Yards Lake Sediment	1,400,000
4.	Restoration-Spoil Disposal Area	25,000
	Total	$1,500,000

NUTRIENT ANALYSIS

In order to predict the trophic status of Lake Isabelle after the restoration work is completed, hydraulic and nutrient loadings to the lake were analyzed as part of this study. A review of the hydraulic loadings to the lake based on surface and groundwater analyses previous described in this report indicate that approximately 1,500 acre-feet of water entered the lake from groundwater sources annually. Surface water runoff entering the lake from its subwatershed during a year of average rainfall would not be expected to exceed 150 acre-feet. From this comparison, it can be observed that over 90 percent of the lake's hydraulic loading comes from groundwater. For this reason, additional testing was completed on the quality of the groundwater entering the lake in an effort to further define its impact on the lake's water quality.

Analyses of groundwater entering the lake from the bedrock valley along the southwest shoreline shows that the total and ortho-phosphorus concentrations typically range from 0.1 to 0.14 mg/l and 0.08 to 0.10 mg/l, respectively during the study period. These phosphorus concentrations are higher than those typically found in groundwater sources. If it is assumed that the average total phosphorus concentration of the groundwater was at 0.10 mg/l and no inflow from the Mississippi River occurred, the average total phosphorus loading to the lake in its existing and proposed condition would be 190 and 80 kg per year, respectively. If the outlet dike is constructed as outlined in the preliminary plans, and the normal water depth set at elevation 681.0, the lake would have a mean depth of 7.2 feet (2.2 meters), an area of 120 acres, a volume of 840 acre-feet, and a hydraulic retention time of 0.56 years. The lake in its existing condition has a mean depth of 3 feet (0.9 meters), an area of 80 acres, a volume of 280 acre-feet, and a hydraulic retention time of 0.19 years. Using this information in the Vollenweider Phosphorus Loading Model shown on Figure 11, the trophic status of the lake would be moved from the eutrophic range to a borderline area between the mesotrophic and oligotrophic classifications.



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LAKE ISABELLE RESTORATION PROJECT 1977 VOLLENWEIDER PHOSPHORUS LOADING MODEL		11

PRELIMINARY DESIGN

Three alternatives for the Lake Isabelle outlet structure were investigated. The three alternatives are similar in that they all utilize:

1. A 1,900 lineal foot dike that is to be constructed across the westerly lake outlet (see Figures 12 and 13).

2. An outlet channel that will accommodate flow from the lake outlet structure (see Figure 14).

The dike will be constructed across the lake outlet along the alignment of Locust Street extended in a southerly direction. The dike would have an average height of 13 feet, and a top elevation of 690.0. Due to the marginal soils in the area in which this dike is to be constructed, certain precautions and construction techniques must be followed in order to construct a stable dike in a timely manner. Recommended precautions and construction techniques are as follows:

1. Geotextile fabric for stabilization must be placed on the ground surface prior to the placement of any earth fill. The geotextile fabric will allow the weight of the dike to be more uniformly distributed over the weak and compressible soils in the area. The geotextile fabric joints should be sewn together to provide additional strength and the fabric should extend a minimum of 15 feet beyond the base of the dike to accommodate settlement.

2. Fill should be placed on the geotextile fabric in lifts to allow for gradual settlement. The depth of each lift and settlement time should be established during final design.

3. Vertical plastic wick-type drains should be installed along the alignment of the dike to reduce pore pressures and accelerate the rate of consolidation. The exact number of drains and their spacing must be determined during final

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PLAN VIEW - LAKE ISABELLE DIKE

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design. Settlement plates should also be installed to monitor the settlement of the fill.

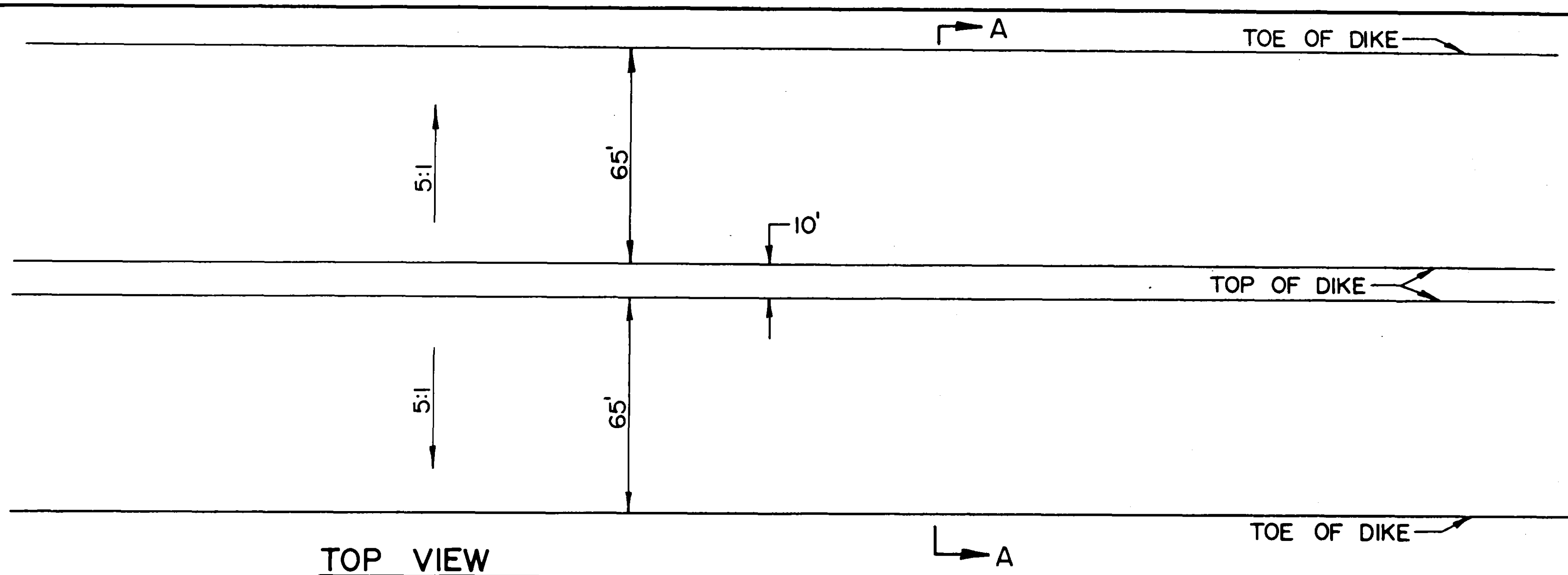
4. Piezometers should be installed along the proposed dike alignment to monitor pore pressures during construction. These piezometers will also assist in determining when the next lift fill can be safely added.

The outlet channel has been designed to accommodate flow from the lake outlet structure. It is recommended that the channel have a 10-foot wide bottom and 3:1 side slopes. Rip-rap bank stabilization should be utilized along the bottom and sides of the channel in the vicinity of the lake outlet structure. It is important that the lake outlet structure be constructed near the northerly end of the dike to take advantage of the more stable soils in this area.

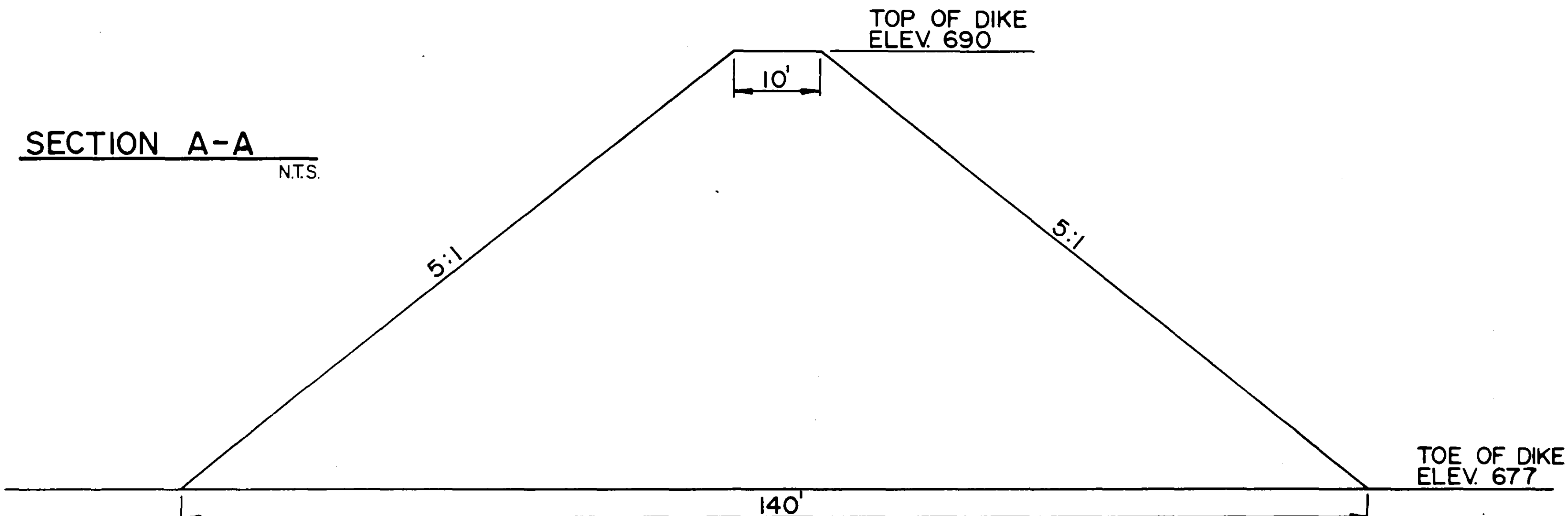
The three alternative designs investigated are shown in Figures 15 through 18. Alternative A (Figure 15), which is the recommended alternative, consists of constructing a concrete or sheet pile weir across the proposed outlet channel. Sluice gates would be incorporated into this structure to allow water from the Mississippi River to enter Lake Isabelle during flood events greater than a 10-year return frequency. During non-flood conditions, one of these sluice gates would be open and serve as the outlet for Lake Isabelle. Access to the dike would need to be obtained from the southerly side of the lake under this alternative.

Alternative B (Figure 16) consists of placing two 60-inch reinforced concrete pipe culverts through the dike to allow a rapid increase in lake level should major flooding conditions exist on the Mississippi River side of the dike. During non-flood conditions, one of the 60-inch reinforced concrete pipe culverts would be used as the normal lake outlet.

Alternative C (Figures 17 and 18) consists of constructing a stabilized spillway channel across 300 lineal feet of the dike's length to allow the water levels on both sides of the dike to equalize during major flood events. It is proposed



TOP VIEW
N.T.S.



SECTION A-A
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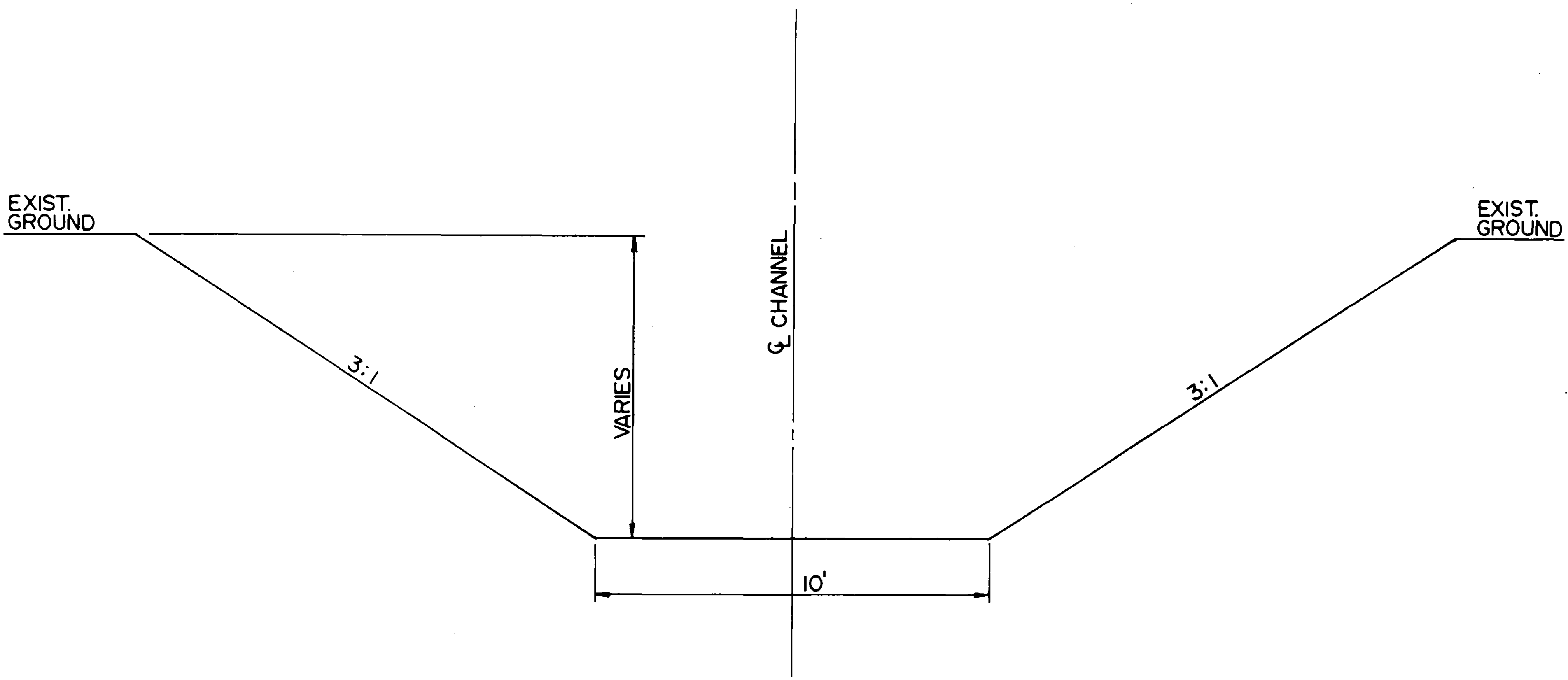
LAKE ISABELLE OUTLET STRUCTURE TYPICAL DIKE SECTION – ALTERNATIVE A, B, OR C		13



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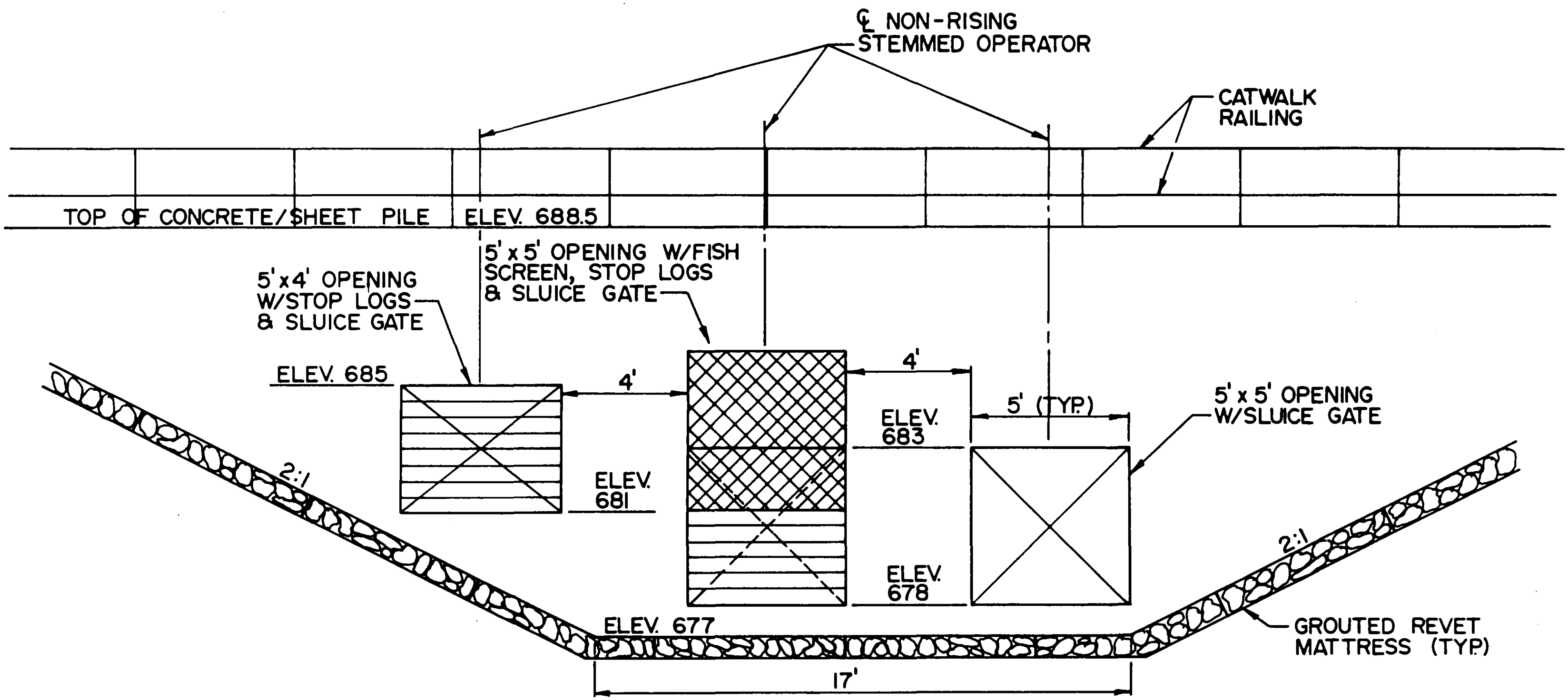
TYPICAL CHANNEL DETAIL	**HYDROLOGISTS - ENGINEERS** **MINNEAPOLIS - MINNESOTA**	14



FRONT VIEW - LAKE ISABELLE SIDE

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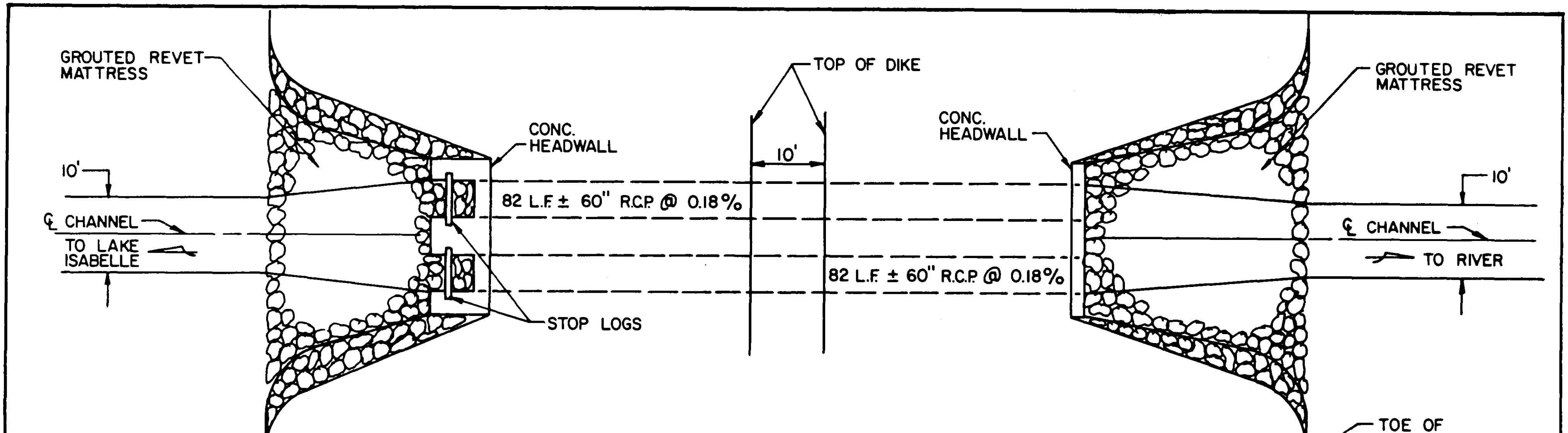
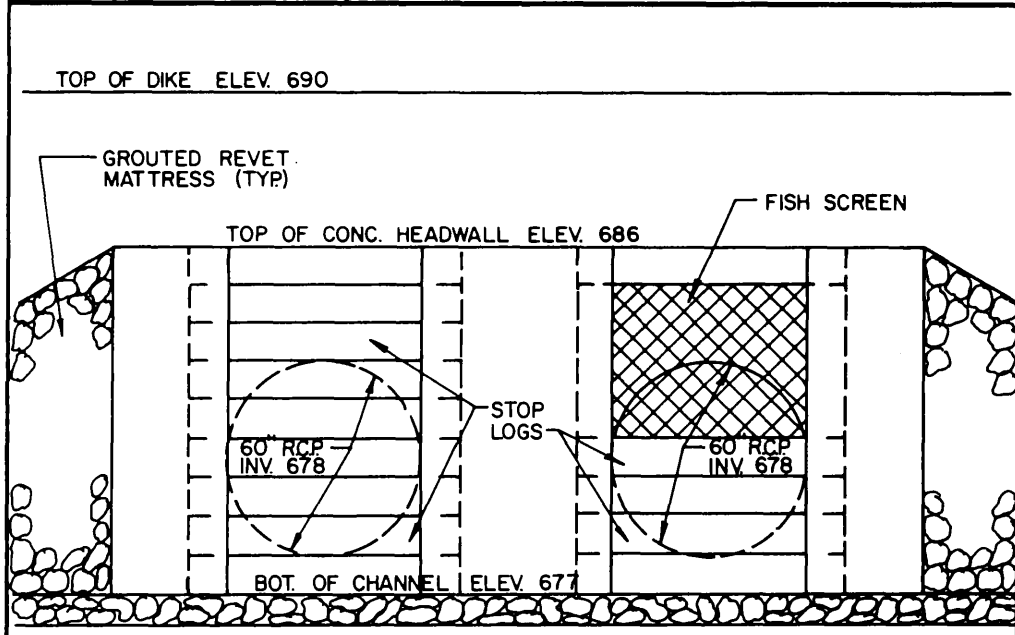
MINNESOTA DEPARTMENT OF NATURAL RESOURCES	**E.A. HICKOK & ASSOCIATES**	FEB., 1985
CONCRETE AND/OR SHEET PILE STRUCTURE DETAIL ALTERNATIVE A	**HYDROLOGISTS-ENGINEERS** **MINNEAPOLIS-MINNESOTA**	15



TOP VIEW
N.T.S.



FRONT VIEW - LAKE ISABELLE SIDE
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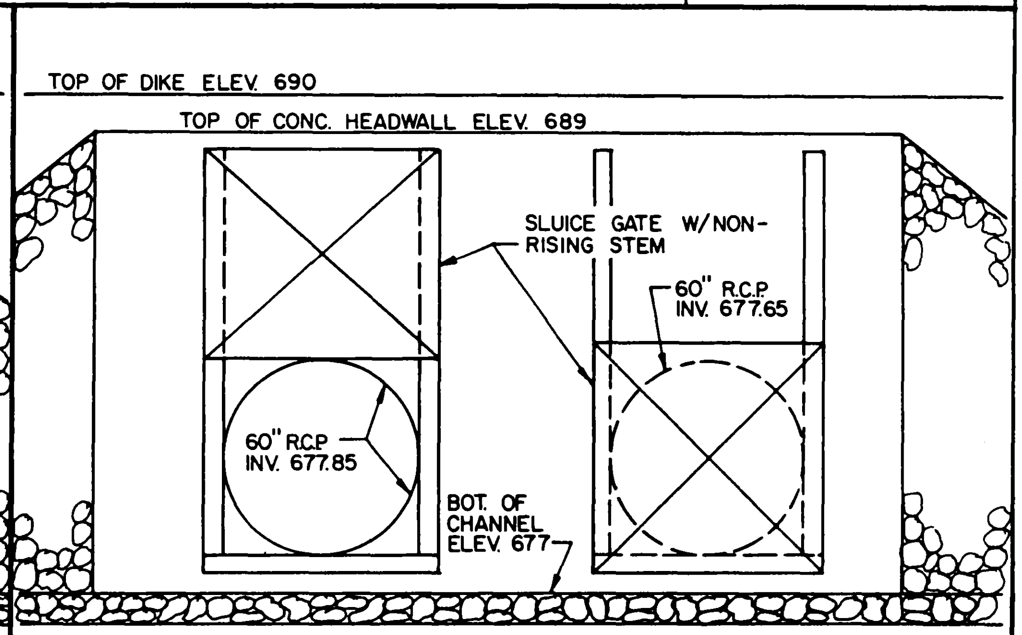

FRONT VIEW - RIVER SIDE
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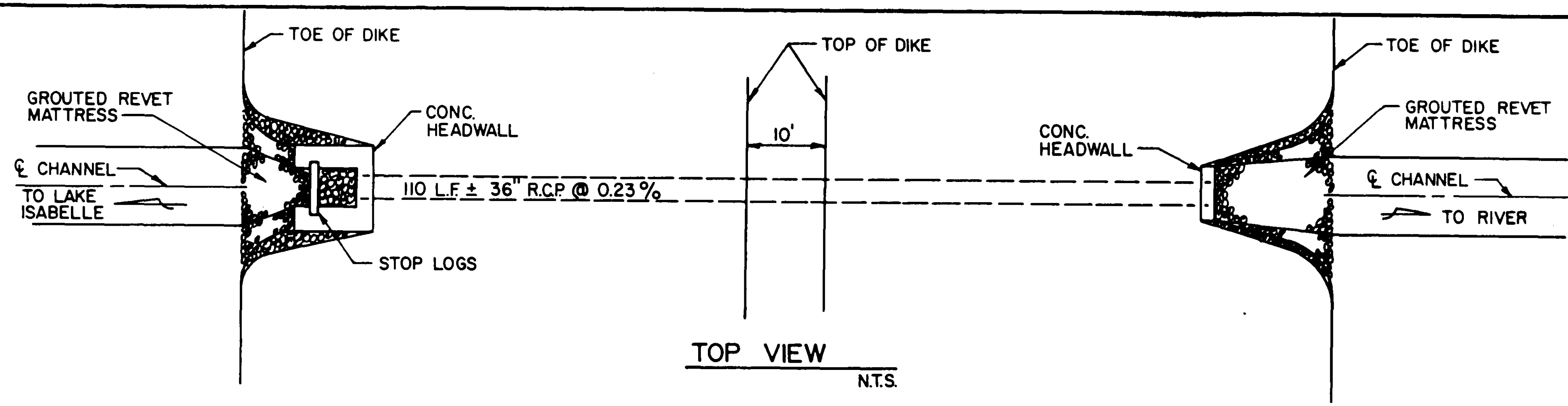
LAKE ISABELLE OUTLET STRUCTURE ALTERNATIVE B	**HYDROLOGISTS-ENGINEERS** **MINNEAPOLIS-MINNESOTA**	16



TOP VIEW
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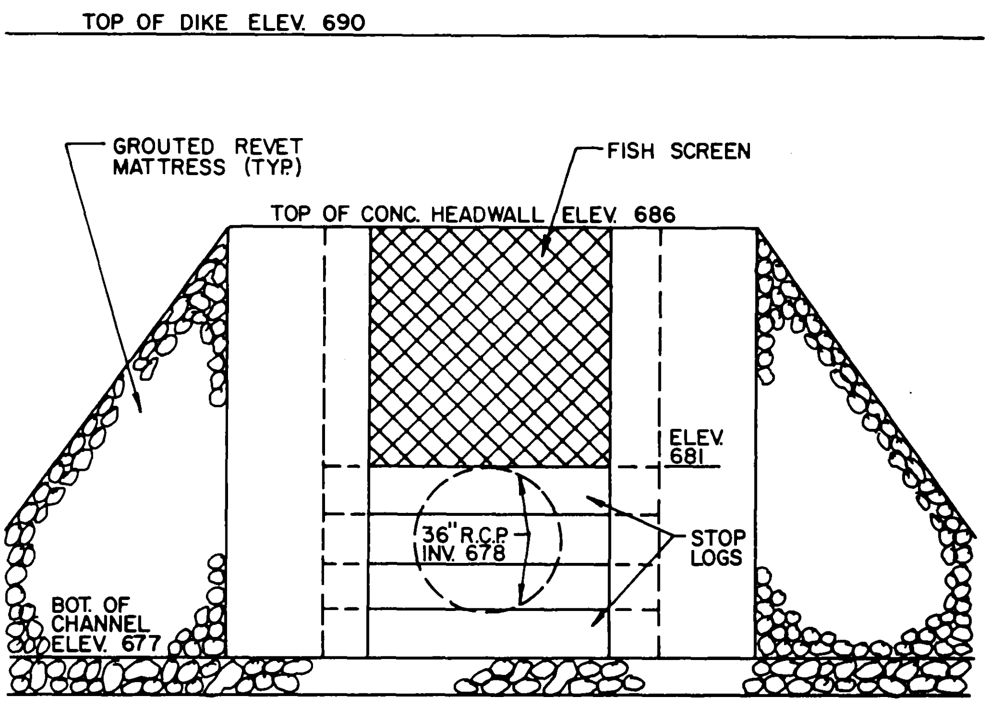

FRONT VIEW – LAKE ISABELLE SIDE
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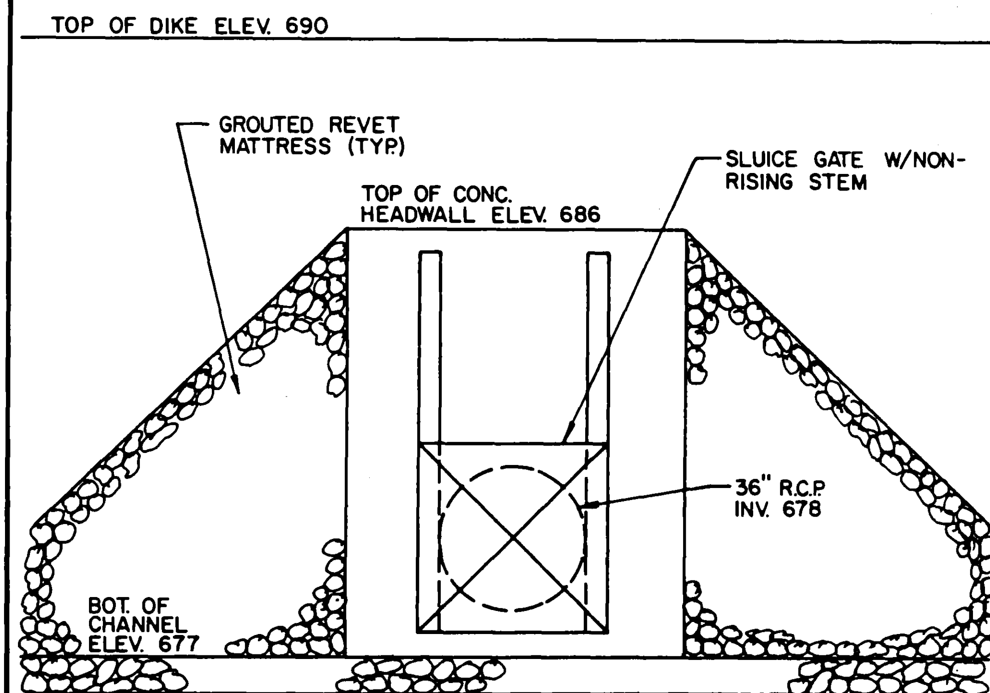

FRONT VIEW – RIVER SIDE
N.T.S.

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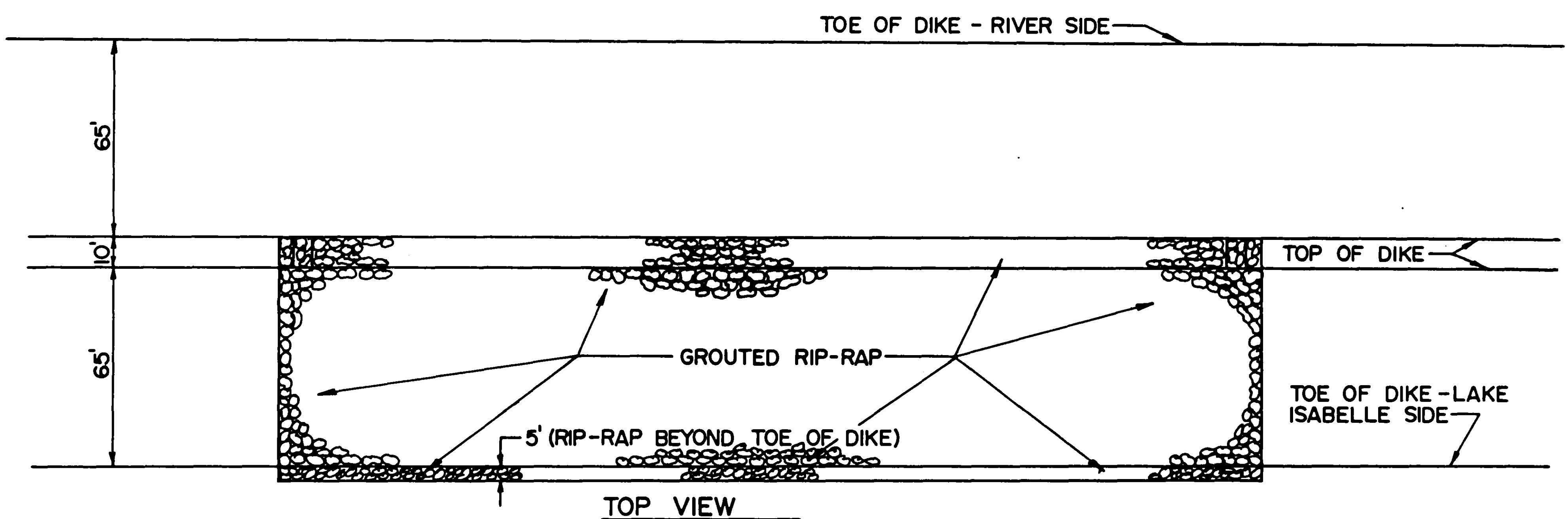
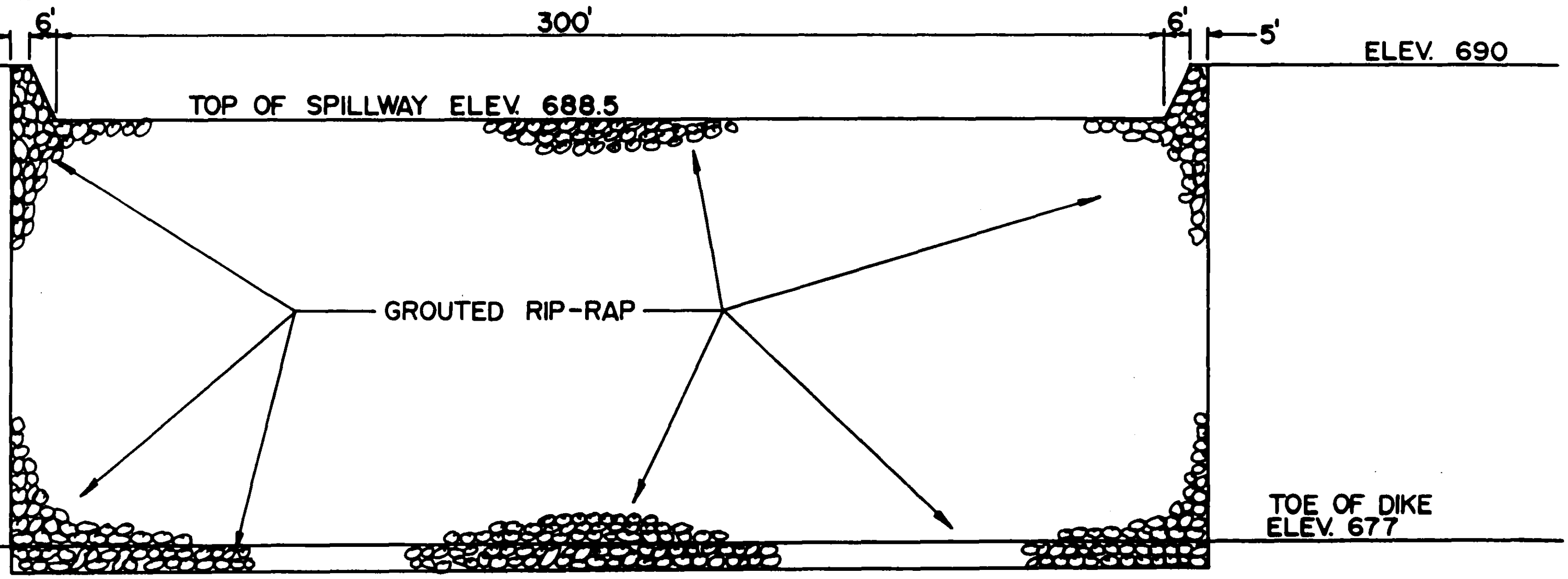
LAKE ISABELLE OUTLET STRUCTURE ALTERNATIVE C		17



TOP VIEW
N.T.S.



FRONT VIEW - LAKE ISABELLE SIDE
N.T.S.

MINNESOTA DEPARTMENT OF NATURAL RESOURCES	E.A. HICKOK & ASSOCIATES	FEB., 1985
LAKE ISABELLE OUTLET STRUCTURE SPILLWAY DETAIL - ALTERNATIVE C	HYDROLOGISTS-ENGINEERS MINNEAPOLIS-MINNESOTA	18

that a 36-inch reinforced concrete pipe be constructed through the dike in addition to the spillway to provide an outlet for water in Lake Isabelle during non-flood conditions.

The Engineer's opinion of cost for Alternatives A, B, and C is shown on Tables 13, 14, and 15, respectively.

FUNDING ALTERNATIVES

The benefits from a Restoration Project such as that proposed for Lake Isabelle are far reaching and could be interpreted to serve the interests of many individuals as well as public agencies. Therefore, the possible funding altenatives for this project include, but may not be limited to:

1. Direct assessment to benefitted properties in the vicinity of Lake Isabelle.

2. Grant from the U. S. Environmental Protection Agency under Section 314 of the Clean Lakes Grant Program.

3. Assistance from the Minnesota Department of Natural Resources for fisheries development.

4. Community Development Block Grant from the U. S. Department of Housing and Urban Development.

5. Direct Appropriation from the Legislative Commission on Minnesota Resources (LCMR).

PROPERTY AFFECTED BY LAKE ISABELLE RESTORATION PROJECT

The Lake Isabelle Restoration Project is anticipated to raise the normal water level of the lake a minimum of 4 feet above that which exists today. As a result, property riparian to Lake Isabelle will be affected. The exact location and extent of the affected property cannot be determined until the normal water level of the lake is established; however, the property will be within the 100-year floodplain of the Mississippi River and includes selected areas within the NE1/4, NW1/4, and SE1/4 of Section 27, T115N, R17W. These areas are further described in Table 16.

CONFORMANCE WITH MINNESOTA DEPARTMENT OF NATURAL RESOURCES DAM SAFETY REGULATIONS

It is anticipated that the Lake Isabelle dike and outlet will be considered a low hazard structure by the Minnesota Department of Natural Resources and will not be included in any of the three dam hazard classifications outlined in 6 MCAR 1.5031.

However, if the structure is included within one of these hazard classifications, this report provides preliminary report information outlined in 6 MCAR 1.5033.

TABLE 13

ENGINEER'S OPINION OF COST - ALTERNATIVE A

Description	Unit	Quantity	Unit Price	Extension
Mobilization	L.S.	1	20,000	20,000
Clearing and Grubbing	Acres	8	6,000	48,000
Tree Removal	Each	50	200	10,000
Vertical Drains	L.F.	30,000	1.50	45,000
Geotechnical Services (Piezometer and Settlement Plate Installation and Monitoring)	L.S.	1	15,000	15,000
Filter Fabric	S.Y.	36,000	3.25	117,000
Clay Borrow	C.Y.	140,000	4.25	595,000
Topsoil	C.Y.	3,000	3.00	9,900
Seed, Mulch and Fertilizer	Acre	7	3,000	21,000
Construct Channel	L.F.	400	15	6,000
Poured In-Place Concrete with Reinforcing Steel	C.Y.	200	300	60,000
Grouted Revet Mattress	S.Y.	1,057	35	37,000
Sluice Gate	L.S.	3	8,000	24,000
Stop Log Structure	L.S.	1	2,000	2,000
Catwalk	L.S.	1	7,000	7,000
			Sub-Total Cost:	$1,016,000
			Engineering, Legal, Administrative Cost (20%):	$ 200,000
			Land Acquisition:	$ 30,000
			Contingencies (10%):	$ 100,000
			Total Cost:	$1,346,000

TABLE 14

ENGINEER'S OPINION OF COST - ALTERNATIVE B

Description	Unit	Quantity	Unit Price	Extension
Mobilization	L.S.	1	20,000	20,000
Clearing and Grubbing	Acres	8	6,000	48,000
Tree Removal	Each	50	200	10,000
Vertical Drains	L.F.	30,000	1.50	45,000
Geotechnical Services (Piezometer and Settlement Plate Installation and Monitoring)	L.S.	1	15,000	15,000
Filter Fabric	S.Y.	36,000	3.25	117,000
Clay Borrow	C.Y.	148,000	4.25	629,000
Topsoil	C.Y.	3,000	3.00	9,000
Seed, Mulch and Fertilizer	Acre	7	3,000	21,000
Construct Channel	L.F.	400	15	6,000
60" RCP	L.F.	180	150	27,000
Concrete Headwall with Stoplogs	L.S.	1	11,000	8,000
Concrete Headwall with Sluice Gates	L.S.	1	23,000	23,000
Grouted Revet Mattress	S.Y.	800	35	7,000
			Sub-Total Cost:	$1,009,000
			Engineering, Legal, Administrative Cost (20%):	$ 200,000
			Land Acquisition:	$ 30,000
			Contingencies (10%):	$ 100,000
			Total Cost:	$1,339,000

TABLE 15

ENGINEER'S OPINION OF COST - ALTERNATIVE C

Description	Unit	Quantity	Unit Price	Extension
Mobilization	L.S.	1	20,000	20,000
Clearing and Grubbing	Acres	8	6,000	48,000
Tree Removal	Each	50	200	10,000
Vertical Drains	L.F.	30,000	1.50	45,000
Geotechnical Services (Piezometer and Settlement Plate Installation and Monitoring)	L.S.	1	15,000	15,000
Filter Fabric	S.Y.	36,000	3.25	117,000
Clay Borrow	C.Y.	148,000	4.25	629,000
Topsoil	C.Y.	3,000	3.00	9,000
Seed, Mulch and Fertilizer	Acre	7	3,000	21,000
Construct Channel	L.F.	400	15	6,000
36" RCP	L.F.	100	60	6,000
Concrete Headwall with Stoplogs	L.S.	1	8,000	8,000
Concrete Headwall with Sluice Gates	L.S.	1	8,000	8,000
Grouted Revet Mattress (Lake Outlet)	S.Y.	200	35	7,000
Grouted Revet Mattress (By Spillway)	S.Y.	2,600	35	91,000
			Sub-Total Cost:	$1,040,000
			Engineering, Legal, Administrative Cost (20%):	$ 200,000
			Land Acquisition:	$ 30,000
			Contingencies (10%):	$ 100,000
			Total Cost:	$1,370,000

TABLE 16

RIPARIAN PROPERTIES AFFECTED BY PROPOSED LAKE ISABELLE RESTORATION PROJECT

NE1/4 of Sec 27, T155, R17

Block 118 - Town of Hastings
Block 119 - Town of Hastings
Block 125 - Town of Hastings
Block 126 - Town of Hastings
Block 127 - Town of Hastings
Block 128 - Town of Hastings

Block 10 - Barkers Addition
Block 11 - Barkers Addition
Block 12 - Barkers Addition
Block 13 - Barkers Addition
Block 14 - Barkers Addition

Parcel No. 010-01 (Part of Government Lot 4 and 5)

NW1/4 of Sec 27, T115, R17

Block 119 - Town of Hastings
Block 120 - Town of Hastings
Block 124 - Town of Hastings
Block 129 - Town of Hastings

Parcel owned by Chicago, Milwaukee, St. Paul and Pacific Railroad right-of-way.

SE1/4 of Sec 27, T115, R17

Parcel No. 010-75 (part of Government Lot 6 north of Chicago, Milwaukee, St. Paul and Pacific Railroad right-of-way).

Parcel owned by Chicago, Milwaukee, St. Paul and Pacific Railroad (Government Lot 7).

APPENDIX A

GEOTECHNICAL ENGINEERING CORPORATION

1925 Oakcrest Avenue • Roseville, Minnesota 55113 • (612) 636-7744
Apple Valley, Minnesota • (612) 431-5266

REPORT

PROJECT:	REPORTED TO:
PROPOSED DIKE LAKE ISABELLE, HASTINGS DAKOTA COUNTY, MINNESOTA	EUGENE A. HICKOK & ASSOCIATES 545 INDIAN MOUND WAYZATA, MINNESOTA 55391
GEC JOB NO: 3843A DATE: JANUARY 15, 1985	ATTN: MR. WILLIAM WEIDENBACHER

INTRODUCTION

This report is a supplement to the report of borings and piezometers dated December 27, 1984.

The purpose of this report is to provide some information regarding design, construction, and settlement of a dike proposed in the area of borings #4, #5 and #6.

GENERAL

The basic soil profile encountered in those borings is an upper layer of weak and compressible soils (fine alluvium and swamp deposits) underlain by sandy coarse alluvium. The low shear strength and high compressibility of the upper soils will present problems in construction.

From a technical standpoint, it should be feasible to construct the embankment. As a worst-case condition, it would be assumed that the upper material is all swamp deposits. Even then, as indicated in attached excerpts from Muskeg Engineering Handbook, it is feasible to construct a dike. Certain precautions should be observed - as outlined on the attached sheets.

Since publication of the Muskeg Engineering Handbook (1969), geotextiles have been used for drainage and structural reinforcement on sites such as this.

SETTLEMENT

The fine alluvium and swamp deposits will consolidate due to the weight of soil on the dike.

The amount and rate of settlement can be (very roughly) predicted by determining the moisture content of the material, and then using empirical relationships between moisture content and consolidation parameters. We ran moisture content tests on samples from boring #4 at depths of 5', 20', and 25', with results of 137%, 38%, and 97% (of dry weight), respectively. In our analyses, we assumed a moisture content of 100%. At that moisture content, estimates of the consolidation parameters would be as follows:

Coefficient of consolidation, C_v	0.02 ft^2/day
Coefficient of seconday compression, C_s	1%/log cycle
Compression index, C_c	1
Initial void ratio, e_o	2

We assumed that a 10' high, infinitely wide (i.e. constant stress with depth) earth embankment, and a thickness of compressible material of 30', with drainage at top and bottom.

With the above parameters and conditions, the predicted settlement is about 10' over a period of 10 - 20 years.

Experience has shown that estimates of this nature generally are conservative, i.e. the actual amount of settlement normally is less, and the rate normally faster than, "predicted."

CLOSURE

To protect the addressee, the public, and ourselves, this report (and all supporting information) is provided for the addressee's own use. No representations are made to parties other than the addressee.

Report Prepared By:

Robert E. Pendergast, P.E.
MN Reg. No. 8450

7 Special Construction Problems

Chapter Co-ordinator*
IVAN C. MACFARLANE

7.1 DAMS AND DYKES

Earth dams and dykes differ from embankments in general in that they are designed to impound water. They must be reasonably watertight, therefore, and for stability the seepage pressures in the body of the fill as well as in the foundations must be controlled, keeping in mind the range in levels over which the impounded water can fluctuate. The immediate and long-term settlement patterns are of importance because of the necessity of adequate freeboard throughout the life of the structure. In addition, excessive differential settlements may crack the dyke embankment and could induce complete failure.

The comparatively high deformation characteristics of peat, even after being highly consolidated, make it hazardous to include it in the body of dam or dyke embankments. Earth dams and dykes can safely be built on peat foundations, however, if proper precautions are taken. The construction of more rigid types of dams or dykes, such as concrete structures, should not be attempted on peat foundations.

While earth dykes are relatively flexible and are capable of accommodating relatively large differential movements, they are much more rigid than peat even after it is highly consolidated. It must be anticipated, therefore, that cracks may develop in such embankments in accordance with their acting as relatively rigid beams resting on a deformable foundation. It is not unusual, of course, for dykes on compressible foundations of inorganic soil to develop cracks. Longitudinal cracks in dyke embankments to heights not exceeding about 20 feet (6.1 m) are not usually objectionable providing the overall stability of the dyke is adequate. Transverse cracks, however, can precipitate failure.

The permeability of peat in its natural state is seldom low enough to keep the seepage loss in the foundation within acceptable limits, or to provide adequate control of seepage pressures. One of the unusual characteristics of peat, however,

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is its extraordinarily large reduction in permeability as consolidation takes place (see Section 4.2(2)). With a reasonable degree of consolidation, the peat foundation can be made sufficiently impermeable for conventional methods of seepage control to be adopted.

A major problem with dykes on peat foundations is the large settlements that must be accommodated as a result of consolidation of the peat and the fact that secondary consolidation (or compression) results in relatively large displacements that are time-dependent. Measurements of pore pressure during and immediately following the application of embankment loads indicate that the pore pressures induced by the load dissipate rapidly. This means that primary consolidation (Wahls 1962) occurs rapidly and therefore an increase in shear strength due to consolidation would also be expected to occur rapidly. Experience in placing fills on peat suggests, however, that a significant increase in the shear strength of the peat occurs after the pore pressures are largely dissipated. This is an anomaly that requires further research attention, but it is of considerable practical importance where stage construction is required to build up sufficient shear strength in the peat to carry the ultimate height of the fill. Failure may be produced in the peat if the rate of loading is based only on the rate of dissipation of pore pressures. Subsequent stages of loading should not be added until the plots of settlement vs. logarithm of time have flattened out virtually to a straight line.

Secondary consolidation (or compression) can be defined as settlement that proceeds with no measurable, or very low, pore pressures existing in the soil. Such settlements generally show a straight line relation between settlement and logarithm of time (see Fig. 4.7). They must be expected to continue, therefore, for the life of the structure but at a gradually decreasing rate. This is true for normal inorganic soils as well as for peat, but some performance records for secondary compression in peat show that the slope of the compression vs. logarithm of time plot increases somewhat with time. Under these circumstances, extrapolation of settlement records to future times would give results that are too low.

The design and construction of dams and dykes require very careful attention to detail if for no other reason than that the release of water following a failure can be catastrophic or result in extraordinarily severe damage. Attention here is confined to the special problems that arise when the foundation material is peat. Within the context of the mechanical properties inherent to peat as noted above, the following factors need to be given special attention in the design and construction of dams and dykes which are intended to be supported on the consolidated peat rather than to displace it.

(1) *Stability of Foundation*

Mathematical analysis of the stability of peat foundations requires estimates of the shear strength characteristics of the peat as discussed in Section 4.4(1). In particular, knowledge of the *in situ* shear strength, angle of internal friction, and K_o values are required. Because of the great difference in the deformation characteristics of the peat as compared with the dam or dyke fill material, stability analyses should assume that the shear resistance of the embankment contributes nothing to the overall stability. The peat itself must be capable of resisting the total shear forces. The effect of reducing K_o value with increasing effective consolidating pressure requires special attention.

These considerations will dictate whether stage construction is necessary, the allowable maximum height of the various stages, and the minimum width of base of the embankment. They will usually dictate the use of berms to widen the base apart from what might be required for the stability of the fill itself. The use of berms is preferable to flattening the slopes of the fill to the overall average slope from the toe to the shoulder of the dyke, because it is desirable to keep the total weight of the applied fill to a minimum. The stability at the end of construction, and with water ponded to full supply level, also requires special attention in view of the seepage pressures that may be induced from the ponded water.

(2) *Settlements*

The question of peat consolidation and settlement is discussed in detail in Section 4.4(5). In the present Section, the theoretical background is presented for the special case of design of dykes on peat foundations. This approach differs slightly from that of Chapter 4, but the discussion that follows represents an application of the present knowledge of peat consolidation characteristics which has resulted in the successful construction of dykes on muskeg.

Settlement in soil types in general is a combination of primary consolidation and secondary compression (Wahls 1962). For peat in contrast to most – but by no means all – inorganic soils, the magnitude of the secondary compression may exceed the primary consolidation within periods of time less than the life of the structure. Moreover, in plots of settlement vs. logarithm of time for either laboratory or field data, the secondary compression may almost completely obliterate the primary consolidation.

In these circumstances, it is impossible at present to separate accurately primary consolidation and secondary compression as is done in conventional design practice with most inorganic soils. Neither is it possible to make meaningful analyses of the rate of consolidation based on primary consolidation theory. The usual practice in attempting to estimate settlements of embankments on peat, however, has been to apply the theory of primary consolidation using the relation

$$S_0 = H_0 \frac{C_c}{1 + e} \log_{10} \frac{p_0 + \Delta p}{p_0}, \qquad (1)$$

where S_0 is the settlement, H_0 is the thickness of the compressible layer, e is the void ratio of the peat, p_0 is the initial load on the peat, Δp is the consolidating load increment, and C_c is the compression index of the peat.

The value of C_c is a soil characteristic that can be determined from standard laboratory consolidation tests on the peat, or from field settlement observations.

It is difficult to secure accurate values for C_c from laboratory tests on peat, but it is known from both laboratory and field test data that it is usually considerably higher than for normal types of inorganic soil. Depending upon the accuracy with which C_c values can be estimated, equation (1) will give realistic estimates of settlement, providing the C_c value used has been derived from settlements taken at times for which the major portion of the settlement under the particular load increment has been completed. A fundamental error in the use of equation (1), however, is the fact that C_c is representative of conditions at a finite time, or a series of finite times, while, in fact, if secondary compression is predominant in the soil, the magnitude of the settlement is predominantly time-dependent. In dealing with peat, estimates of settlement which ignore the time-dependent nature of the movements can lead to serious misconceptions of the ultimate performance of a structure.

An alternative to the use of equation (1) is to base the settlement analysis on the assumption that the settlement has two components: an instantaneous fraction which occurs immediately on application of the load, followed by a second component which proceeds in accordance with a straightline relation between settlement and logarithm of time. The instantaneous fraction can be estimated by using equation (1) with an appropriate adjustment in the C_c value, or alternatively a direct extrapolation can be made from pressure-void ratio curves from laboratory consolidation tests. For the second component the equation for secondary compression can be used, namely

$$S_s = H \frac{C_s}{1 + e} \log_{10} \frac{t}{t_0}, \qquad (2)$$

where S_s is the settlement within the time interval t_0 to t, H is the thickness of the compressible layer, and C_s is the coefficient of secondary compression expressed in terms of change in void ratio over one cycle of the logarithmic scale on a plot of void ratio vs. logarithm of time.

The value of C_s can be determined from laboratory consolidation tests or from field settlement data in the same way as values for C_c, but its determination is subject to the same difficulties noted for the evaluation of C_c.

Field settlement data are usually plotted in terms of settlement vs. logarithm of time. In this case, the settlement over one cycle of the logarithmic scale becomes the term $HC_s/(1 + e)$ in equation (2).

The physical mechanism causing secondary compression is not clearly understood, but there is considerable evidence suggesting that C_s is not a constant soil parameter. A major factor affecting its value appears to be the magnitude of shear stress in the soil. This can readily be shown in laboratory tests in which samples are consolidated in triaxial compression tests under different intensities of shear stress. Under conditions of zero shear stress, C_s is zero, but it increases with increasing shear stress in the soil (Hunter 1967). Results such as these suggest that the standard laboratory consolidation test is not the best method for evaluating C_s, because the shear stresses in the soil specimen are unknown and they may vary with the consolidating pressure.

More sophisticated mathematical analyses have been made (Wahls 1962) by combining equations (1) and (2). The accuracy of the values that are assigned to C_c and C_s, however, is still the major factor governing the precision of the settlement predictions. The best that can be expected, in the light of present knowledge, is that settlement analyses based on values of C_c and C_s from laboratory test results will give only a rather crude estimate of the magnitudes of the settlements to be expected. For more precise estimates of the ultimate settlements, the results of settlement observations made during and immediately following construction on the actual job must be used.

Settlement concepts are also essential in assessing the hazard of transverse cracking in an embankment due to differential movements. Critical sections are to be expected above areas of abrupt changes in foundation soil profiles. These may exist because of large variations in the thickness of peat over short distances along the dyke alignment, or because of an abrupt change in soil type, such as that from peat to an inorganic soil.

With relatively thick peat deposits, attention may need to be given to the horizontal components of the consolidating stresses. These stresses have a tendency to induce a spreading failure in the embankment. The use of berms in the dyke cross-section produces a more favourable stress distribution from the point of view of horizontal consolidating forces.

(3) *Seepage*

The principles of seepage control for dams and dykes are for the most part directly applicable to those on peat foundations. Because of the substantial decrease in the permeability of peat as it is consolidated, the problem of the control of seepage through the foundation soil is less severe than for many more normal soil types.

Standard facilities for seepage control such as upstream impervious blankets, foundation cut-offs, internal drains, and downstream seepage relief wells are all applicable to peat foundation conditions. A major special problem arises where vertical seepage cut-offs, or vertical seepage pressure relief wells are installed in the peat. These facilities are usually much more rigid and considerably less compressible than the surrounding peat. Consolidation of the peat subsequent to the installation of such facilities results in excessive loads being transmitted to them. The facilities themselves may rupture and fail. Alternatively, in the case of vertical cut-offs below the dyke, they may act as a rigid "plug" below the embankment which may result in the embankment being broken. Longitudinal cracks may develop in the dyke on either side of the cut-off. These may or may not be hazardous, but they do result in a reduction in the overall stability of the structure.

The use of vertical cut-offs through peat is a carryover from their use in relatively pervious inorganic soils. They are often used in peat because the substantial decrease in permeability due to consolidation is not recognized. It most cases, therefore, they will be unnecessary. Where they are used, they should not be placed below the centre of the dam or dyke. Rather, their position should be either well upstream or downstream of the centre line, so that, if longitudinal cracks do develop because of differential settlement, they will not affect the main body of the dyke.

(4) *Embankment Materials*

No special problems exist with the selection of materials for the embankment where a dam or dyke is to be built on a peat foundation. There is, however, one consideration. This arises where the differential settlements are expected to be such that transverse cracks may be produced in the embankment. Homogeneous fills of highly impervious clays or silty clays have been successfully used for dykes on muskeg, but these have the poorest self-sealing characteristics. A zoned embankment with properly designed transition sections will provide the maximum self-sealing properties. A zoned embankment includes an impervious core section surrounded on each side by more pervious sections, preferably with granular material being used for the outside zones. The effectiveness of such a cross-section in inducing self-sealing of cracks which may develop in the impervious core depends on the efficiency of the transition zones that should be provided between the adjacent zones of different permeabilities. Records are available (Hardy 1967) showing that dams with zoned cross-sections and properly designed transition sections are self-sealing with transverse cracks that have opened up as much as 3 or 4 inches (7.6 or 10.2 cm). The use of thin impervious zones to control seepage through the dyke should be avoided with dykes on peat foundations.

With homogeneous cross-sections, water should not be permitted to rise against the upstream face if transverse cracks are showing on it, particularly if portions of the fill are frozen. The material in the upstream face should be re-worked to seal off the cracks before the water level is raised against the dyke.

Properly designed internal drains, particularly if they are vertically continuous in the embankment, also provide good self-sealing characteristics. They are unlikely to be as efficient, however, as a properly designed zoned cross-section.

Under some circumstances, horizontal cracks may develop in an embankment. The circumstances most likely to produce such cracks exist where relatively deep frost penetration develops below the surface of the dyke, while at the same time settlements are developing in the peat foundation. Such horizontal cracks could precipitate failure if water is brought up against the crack before the crust has thawed out. The cracks will usually be self-sealing after the frozen crust has thawed.

Longitudinal cracks, either along the upstream or downstream faces, usually are not objectionable. They can be expected to be self-sealing provided they are caused by consolidation in the underlying peat rather than by a partial shear failure in the peat. If the vertical displacement at the crack exceeds a few inches, it is likely that a partial shear failure has occurred. This condition would dictate widening the base of the fill in such areas by using a berm.

(5) *Construction Details*

For dam or dyke construction on peat, the trees and shrubs should be cleared from the area of the base. Contrary to common practice with certain other types of embankments on peat, the trees and shrubs should not be incorporated into the base of the fill as "corduroying," because a seepage failure path may develop through loose soil surrounding the logs or brush. The larger roots should be dug out, but the surface layer of live peat need not be stripped off.

The initial lift of the fill is usually placed by end-dumping to secure a mat on which the earth hauling and compaction equipment can operate. This initial mat should be 2–4 feet (0.61–1.22 m) thick. It is impossible to secure a high degree of compaction in this initial lift. One of the several reasons for the use of berms to widen the base of dams or dykes is to compensate for the poorer quality of fill that will probably form this initial lift. Compaction should be started, however, as soon as possible. For the construction of any sort of dam or dyke it is essential that compaction procedures be used, but the emphasis should be on the securing of a uniform quality of fill rather than on high densities. In the lower portions of the embankment, over-compaction in attempts to secure high densities can result in objectionable disturbance to the underlying peat. Compaction on any lift should be stopped temporarily if the equipment begins to produce appreciable "weaving" due to disturbance of the underlying peat.

Drainage of the muskeg area, for the purpose of lowering the water table at the base of the embankment, can be beneficial in that some consolidation of the peat will be induced prior to placement of the fill, and a thinner initial mat may be required for the fill. It is preferable that the drainage ditches be directed away from the dyke area at right angles to the dyke axis. If drainage ditches must be located on lines more or less parallel to the toes of the dyke, they should be kept as far outside the toes as practicable. Drainage ditches along the toes of the dyke seldom have practical advantages, and they are detrimental to the stability of the peat.

Construction of dams and dykes in winter has several advantages if the operations are properly conducted. While it may be necessary to remove or to compact the snow cover before the peat will freeze, once it is frozen the operations of clearing and stripping can be done more economically than in the summer. Drainage ditches, or seepage cut-off trenches in the peat below the dyke, can also be dug more readily in frozen peat. As a rule a backhoe can cut the frozen peat, and the trench can be dug with vertical sides. This eliminates the difficulties of access and excavation below the water table inherent in summer operations.

Placement of the initial lift of the embankment and backfilling for cut-off trenches can also be done more readily when the peat is frozen. Satisfactory compaction can be secured in these operations if the fill material is excavated in the borrow area in an unfrozen condition and then placed and compacted before it freezes. This can usually be accomplished without too much difficulty at air temperatures down to about 10° F (−12° C), and there are records of it being done at even lower air temperatures (Hardy 1967). With efficient organization of the work and with favourable air temperatures, higher quality of backfilling and of the initial lift in the fill may be achieved than is practically possible under summer conditions.

With embankments constructed on frozen peat, the question arises as to the stability conditions when it thaws. If the peat should thaw instantaneously, or over a very short period, failure of the peat foundation would be expected. Experience has shown, however, that peat thaws very slowly, and that it may, in fact, take several seasons before it completely thaws below the embankment. Under conditions of slow thawing, local consolidation and increase in strength appear to occur in the soil, so that overall instability does not develop. Shortly after thawing is complete, the stability and consolidation conditions are not greatly different than if no freezing had occurred. The settlement pattern during the thawing period will be distorted, however, and the usefulness of field settlement data in extrapolating to future settlements, or in checking laboratory test values for C_c and C_s, may be lost.

Where stage construction procedures have been necessary, experience indicates that there is less chance of failure in the peat when the first stage is built while it is frozen. This suggests that stage construction might not be necessary if the fill is placed on frozen peat. There are insufficient performance data available, however – and a lack of methods for rationally analysing the conditions, as well – to warrant abandoning stage construction procedures where they are dictated by the summer season construction conditions.

(6) *Displacement of Peat*

The practice of displacing the peat by the weight of the fill or by blasting to secure a firm foundation for an embankment has been widely used. Consideration of the techniques used with these procedures is beyond the scope of this discussion. They are dealt with in some detail, however, by Casagrande (1966) and in Section 6.5(3) of this Handbook.

7.2 AIRSTRIPS

Construction of airstrips in areas of organic terrain falls naturally into two main classes which will be considered separately: (1) conventional airstrip or airport runway construction as a part of an existing airport or the development of a new airport; and (2) winter airstrips on muskeg which are built and used only on a seasonal basis.

GEOTECHNICAL ENGINEERING CORPORATION

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Apple Valley, Minnesota • (612) 431-5266

REPORT OF TEST BORINGS AND PIEZOMETERS

PROJECT:

LAKE ISABELLE, HASTINGS
DAKOTA COUNTY, MINNESOTA

GEC JOB NO: 3843
DATE: DECEMBER 27, 1984

REPORTED:

EUGENE A. HICKOK & ASSOCIATES (EAH)
545 INDIAN MOUND
WAYZATA, MINNESOTA 55391

ATTN: MR. WILLIAM WEIDENBACHER

INTRODUCTION

During the period of November 6 to December 21, 1984, we drilled six borings and installed six piezometers for the referenced project. The scope of our work (location, depth, sampling method, etc.) was as directed by EAH.

TEST BORINGS

Samples were obtained using the split-spoon, auger (HSA), and rotary (wash) methods. Auger sampling was done using the "spinning" procedure. Refer to the attached sheets (Drilling, Sampling and Testing; Test Boring and Logging Methods) for additional information regarding test boring and logging methods.

Except for wash samples, the soils were classified in accordance with the ASTM Visual Manual Method (ASTM D 2488). Refer to the attached sheet (Unified Soil Classification System) for a description of the classification method.

Refer to the attached logs for a description of the subsurface conditions encountered in the borings. The logs show: the depths to the boundaries between the soil layers; the description, classification, and geologic identification of the soils; the standard penetration resistance (N values); water level measurements; and other information. Refer to the attached sheets (Drilling, Sampling, and Testing; Test Boring and Logging Methods; Geologic Terminology; Groundwater) for a description of terminology used on the logs.

PIEZOMETERS

Logs of the piezometers are attached.

CLOSURE

Subsurface conditions can vary from that encountered in the borings and piezometers at other locations, depths, and times.

To protect the addressee, the public, and ourselves, this report (and all supporting information) is provided for the addressee's own use. No representations are made to parties other than the addressee.

Report Prepared By:

Robert E. Pendergast

Robert E. Pendergast, P.E.
MN Reg. No. 8450

GEOTECHNICAL ENGINEERING CORPORATION

GEC JOB NO: 3843 VERTICAL SCALE: 1" = 3' LOG OF BORING NO. 1B (P. 1 of 6)

PROJECT: LAKE ISABELLE, HASTINGS, DAKOTA COUNTY, MINNESOTA

DEPTH, IN FEET	SURFACE ELEVATION: DESCRIPTION AND CLASSIFICATION	GEOLOGY	N BPF	WB	SAMPLE TYPE	REC.	MC	DEN	L.L. / P.L.
0–4	SILTY SAND, well graded, with a little gravel, dark brown, (SP-SM)	UNCONTROLLED FILL		N	HSA				
				N	HSA				
4–5	Cinders, black								
5–12	SILTY SAND, fine grained, with a little gravel, dark brown, (nonplastic-SM)			N	HSA				
				N	HSA				
				N	HSA				
12–	SILTY SAND, fine grained, brown, with a trace to a little gravel, (SP-SM)	COARSE ALLUVIUM		N	HSA				
				N	HSA				

DEPTH : DRILLING METHOD	
0-64.5	HSA
64.5 - 127	RD & DM

WATER LEVEL MEASUREMENTS

DATE	TIME	SAMPLED DEPTH	CASING DEPTH	CAVE-IN DEPTH	DRILLING MUD LEVEL	WATER LEVEL
11/2	12:00	25	24.5	21.2		20.3
11/6	11:15	127	-	21.0	wet	

BORING COMPLETED: 11/6/84 11:15

CC: RT Dlr: MH Rig: 55

NOTE: REFER TO THE ATTACHED SHEETS FOR AN EXPLANATION OF TERMINOLOGY ON THIS LOG

GEOTECHNICAL ENGINEERING CORPORATION

GEC JOB NO: 3843 VERTICAL SCALE: 1"=3' LOG OF BORING NO: 1B (P. 2 of 6)

PROJECT: LAKE ISABELLE, HASTINGS, DAKOTA COUNTY, MINNESOTA

DEPTH, in FEET	DESCRIPTION AND CLASSIFICATION	GEOLOGY	N	WB	SAMPLE TYPE	REC.	MC	DEN	L.L./P.L.	
22										
23	---------- SAME AS ABOVE----------			N	HSA					
24										
25										
26										
27										
28	SILTY SAND, fine grained, with a trace of gravel, brown, (nonplastic-SM)	COARSE ALLUVIUM								
29										
30				Y	HSA					
31										
32										
33										
34										
35	Not sampled 35' - 65'.									
36										
37										
38										
39										
40										
41										
42										
43										
44										
45										
46										
47										

GEOTECHNICAL ENGINEERING CORPORATION

GEC JOB NO: 3843 VERTICAL SCALE: 1"=3' LOG OF BORING NO. 1B (P. 3 of 6)

PROJECT: LAKE ISABELLE, HASTINGS, DAKOTA COUNTY, MINNESOTA

DEPTH, In FEET	DESCRIPTION AND CLASSIFICATION	GEOLOGY	N	WB	SAMPLE TYPE	REC.	FIELD & LABORATORY TESTS			
							MC	DEN	L.L./P.L.	
48										
49										
50										
51										
52										
53										
54										
55										
56										
57										
58										
59										
60										
61										
62										
63										
64										
65										
66	SAND and GRAVEL									
67										
68										
69										
70		COARSE ALLUVIUM								
71					wash					
72										
73										

GEOTECHNICAL ENGINEERING CORPORATION

GEC JOB NO: 3843 VERTICAL SCALE: 1"=3' LOG OF BORING NO. 1B (P. 4 of 6)

PROJECT: LAKE ISABELLE, HASTINGS, DAKOTA COUNTY, MINNESOTA

DEPTH, in FEET	DESCRIPTION AND CLASSIFICATION	GEOLOGY	N	WB	SAMPLE TYPE	REC.	FIELD & LABORATORY TESTS: MC	DEN	L.L./P.L.	
74										
75					wash					
76	------------ SAME AS ABOVE ------------									
77										
78										
79										
80					wash					
81										
82										
83	CLAY									
84										
85					wash					
86										
87		FINE ALLUVIUM or LAKE DEPOSITS								
88										
89										
90					wash					
91										
92										
93										
94										
95					wash					
96										
97										
98										
99										

GEC JOB NO: 3843 VERTICAL SCALE: 1"=3' LOG OF BORING NO. 1B (P. 5 of 6)

PROJECT: LAKE ISABELLE, HASTINGS, DAKOTA COUNTY, MINNESOTA

DEPTH, in FEET	DESCRIPTION AND CLASSIFICATION	GEOLOGY	N	WB	SAMPLE TYPE	REC.	FIELD & LABORATORY TESTS MC	DEN	L.L. / P.L.	
100 -										
101 -	------------- SAME AS ABOVE ------------------------------									
102 -					wash					
103 -										
104 -										
105 -										
106 -										
107 -					wash					
108 -										
109 -										
110 -										
111 -										
112 -					wash					
113 -										
114 -										
115 -										
116 -										
117 -					wash					
118 -										
119 -										
120 -										
121 -										
122 -					wash					
123 -										
124 -										
125 -										

GEOTECHNICAL ENGINEERING CORPORATION

GEC JOB NO: 3843 VERTICAL SCALE: 1"=3' LOG OF BORING NO. 1B (P. 6 of 6)

PROJECT: LAKE ISABELLE, HASTINGS, DAKOTA COUNTY, MINNESOTA

DEPTH, In FEET	DESCRIPTION AND CLASSIFICATION	GEOLOGY	N	WB	SAMPLE TYPE	REC.	FIELD & LABORATORY TESTS MC	DEN	L.L. / P.L.
126	--------- SAME AS ABOVE --------------------				wash				
127	END OF BORING								
128	Piezometer installed.								
129									
130									
131									
132									
133									
134									
135									
136									
137									
138									
139									
140									
141									
142									
143									
144									
145									
145									
147									
148									
149									
150									
151									

GEOTECHNICAL ENGINEERING CORPORATION

GEC JOB NO: 3843 VERTICAL SCALE: 1" = 3' LOG OF BORING NO. 2B (P. 1 of 3)

PROJECT: LAKE ISABELLE, HASTINGS, DAKOTA COUNTY, MINNESOTA

DEPTH, IN FEET	SURFACE ELEVATION: DESCRIPTION AND CLASSIFICATION	GEOLOGY	N BPF	WB	SAMPLE TYPE	REC.	FIELD & LABORATORY TESTS MC	DEN	L.L. / P.L.
1									
2									
3	CLAY, dark grayish brown, (CL)	FINE ALLUVIUM							
4				?	HSA				
5									
6	SILTY SAND, fine grained, grayish brown, (nonplastic-SM)	COARSE ALLUVIUM		Y	HSA				
7									
8									
9									
10									
11	Not sampled 9½' - 34'.								
12									
13									
14									
15									
16									
17									
18									
19									
20									
21									

DEPTH	DRILLING METHOD
0-64½	3¼ HSA
64½ - 70	RD & DM

BORING COMPLETED:

CC: RT Dlr: MH Rig: 55

WATER LEVEL MEASUREMENTS

DATE	TIME	SAMPLED DEPTH	CASING DEPTH	CAVE-IN DEPTH	DRILLING MUD LEVEL	WATER LEVEL
11/7	10:00	64.5	64.5	61		wet
11/7	2:30	70	64.5	16.5	wet	

NOTE: REFER TO THE ATTACHED SHEETS FOR AN EXPLANATION OF TERMINOLOGY ON THIS LOG

GEOTECHNICAL ENGINEERING CORPORATION

GEC JOB NO: 3843 VERTICAL SCALE: 1"=3' LOG OF BORING NO: 2B (P. 2 of 3)

PROJECT: LAKE ISABELLE, HASTINGS, DAKOTA COUNTY, MINNESOTA

DEPTH, in FEET	DESCRIPTION AND CLASSIFICATION	GEOLOGY	N	WB	SAMPLE TYPE	REC.	MC	DEN	L.L./P.L.	
22										
23										
24										
25										
26										
27										
28										
29										
30										
31										
32										
33										
34										
35	SANDY CLAY, dark grayish brown, (CL)			Y	HSA					
36		ALLUVIUM								
37										
38										
39	SILTY SAND, medium grained, dark grayish brown, (nonplastic-SM)									
40				Y	HSA					
41										
42		COARSE ALLUVIUM								
43										
44	SILTY SAND, medium grained, grayish brown, (SP-SM)									
45				Y	HSA					
46										
47										

GEOTECHNICAL ENGINEERING CORPORATION

GEC JOB NO: 3843 VERTICAL SCALE: 1"=3' LOG OF BORING NO. 2B (P. 3 of 3)

PROJECT: LAKE ISABELLE, HASTINGS, DAKOTA COUNTY, MINNESOTA

DEPTH, In FEET	DESCRIPTION AND CLASSIFICATION	GEOLOGY	N	WB	SAMPLE TYPE	REC.	FIELD & LABORATORY TESTS MC	DEN	L.L. / P.L.	
48										
49	----------- SAME AS ABOVE ------------------									
50										
51				Y	HSA					
52										
53										
54										
55				Y	HSA					
56										
57										
58										
59										
60				Y	HSA					
61										
62										
63	SILTY SAND, fine to medium grained, (SM)									
64										
65				Y	HSA					
66										
67		COARSE								
68	*SAND grains (rounded) and limestone chips (angular)	ALLUVIUM? *			wash*					
69		TUMBLEROCK?			wash*					
70	———— END OF BORING ————	BEDROCK? *								
71	Rotary drilling - 67-70' *									
72	Hard drilling - 67-69'									
73	Very hard drilling - 69-70'									

GEOTECHNICAL ENGINEERING CORPORATION

GEC JOB NO: 3843 VERTICAL SCALE: 1" = 3' LOG OF BORING NO. 3B (P. 1 of 3)

PROJECT: LAKE ISABELLE, HASTINGS, DAKOTA COUNTY, MINNESOTA

DEPTH, IN FEET	SURFACE ELEVATION: DESCRIPTION AND CLASSIFICATION	GEOLOGY	N BPF	WB	SAMPLE TYPE	REC.	FIELD & LABORATORY TESTS MC	DEN	L.L. / P.L.
1	SILTY SAND, fine grained, dark grayish brown, (nonplastic-SM)								
2				N	HSA				
3									
4									
5				N	HSA				
6									
7				?	HSA				
8									
9									
10				Y	HSA				
11		COARSE ALLUVIUM							
12									
13	SILTY SAND, fine grained, brown, (nonplastic-SM)			Y	HSA				
14									
15									
16									
17				Y	HSA				
18									
19									
20				Y	HSA				
21									

DEPTH	DRILLING METHOD
0-47½	3¼ HSA
47½- 48¼	RD & DM

BORING COMPLETED: 11/9/84 2:15

CC: DO Dlr: SB Rig: 45

WATER LEVEL MEASUREMENTS

DATE	TIME	SAMPLED DEPTH	CASING DEPTH	CAVE-IN DEPTH	DRILLING MUD LEVEL	WATER LEVEL
11/9	12:39		47½	37½	15.0	

NOTE: REFER TO THE ATTACHED SHEETS FOR AN EXPLANATION OF TERMINOLOGY ON THIS LOG

GEOTECHNICAL ENGINEERING CORPORATION

GEC JOB NO: 3843 VERTICAL SCALE: 1"=3' LOG OF BORING NO: 3B (P. 2 of 3)

PROJECT: LAKE-ISABELLE, HASTINGS, DAKOTA COUNTY, MINNESOTA

DEPTH, in FEET	DESCRIPTION AND CLASSIFICATION	GEOLOGY	N	WB	SAMPLE TYPE	REC.	FIELD & LABORATORY TESTS MC	DEN	L.L./P.L.	
22	----------- SAME AS ABOVE ----------------									
23										
24				Y	HSA					
25										
26	SILTY SAND, fine grained, brown, (SP-SM)									
27										
28										
29										
30				Y	HSA					
31										
32										
33										
34										
35				Y	HSA					
36										
37										
38										
39										
40				Y	HSA					
41										
42										
43				Y	HSA					
44										
45										
46				Y	HSA					
47										

GEOTECHNICAL ENGINEERING CORPORATION

GEC JOB NO: 3843 VERTICAL SCALE: 1"=3' LOG OF BORING NO. 3B (P. 3 of 3)

PROJECT: LAKE ISABELLE, HASTINGS, DAKOTA COUNTY, MINNESOTA

DEPTH, in FEET	DESCRIPTION AND CLASSIFICATION	GEOLOGY	N	WB	SAMPLE TYPE	REC.	FIELD & LABORATORY TESTS: MC	DEN	L.L./P.L.	
48	*	*BEDROCK ?			wash*		*SAND grains (rounded) and limestone chips (angular)			
	END OF BORING									
49										
50	HSA obstructed at 47½'.									
51	Piezometer installed.									
52										
53	*Rotary drill with tricone bit.									
54										
55										
56										
57										
58										
59										
60										
61										
62										
63										
64										
65										
66										
67										
68										
69										
70										
71										
72										
73										

GEOTECHNICAL ENGINEERING CORPORATION

GEC JOB NO: 3843 VERTICAL SCALE: 1" = 3' LOG OF BORING NO. 4 (P. 1 of 2)

PROJECT: LAKE ISABELLE, HASTINGS, DAKOTA COUNTY, MINNESOTA

DEPTH, IN FEET	SURFACE ELEVATION: ___ DESCRIPTION AND CLASSIFICATION	GEOLOGY	N BPF	WB	SAMPLE TYPE	REC.	FIELD & LABORATORY TESTS MC	DEN	L.L. / P.L.	
0–3	CLAY, blackish gray, (CL)	FINE ALLUVIUM		N	HSA					
3–17	CLAY, dark gray, (CL)									
5			1	Y	SS	12				
10			2	Y	SS	16				
15			2	?	SS	18				
17–21	Muck, dark grayish brown, (PL) Some small shells	SWAMP DEPOSITS								
20			2	?	SS	18				

DEPTH	DRILLING METHOD
0-24½	3¼ HSA
24½ - 29½	RD/WAT

BORING COMPLETED: 12/20/84 11:33

CC: DO Dlr: MH Rig: 45

WATER LEVEL MEASUREMENTS

DATE	TIME	SAMPLED DEPTH	CASING DEPTH	CAVE-IN DEPTH	DRILLING MUD LEVEL	WATER LEVEL
12/20	11:55			5.0		1.7
12/20	1:12			?		1.3

NOTE: REFER TO THE ATTACHED SHEETS FOR AN EXPLANATION OF TERMINOLOGY ON THIS LOG

GEOTECHNICAL ENGINEERING CORPORATION

GEC JOB NO: 3843 VERTICAL SCALE: 1"=3' LOG OF BORING NO: 4 (P. 2 of 2)

PROJECT: LAKE ISABELLE, HASTINGS, DAKOTA COUNTY, MINNESOTA

DEPTH, in FEET	DESCRIPTION AND CLASSIFICATION	GEOLOGY	N	WB	SAMPLE TYPE	REC.	MC	DEN	L.L./P.L.	
	----------- SAME AS ABOVE -----------									
22										
23	CLAY, dark gray, (CL)									
24										
25		FINE ALLUVIUM	1	?	SS	18				
26										
27										
28	Organic CLAY, dark grayish brown, (OL)									
29										
30			4	?	SS	18				
31	——— END OF BORING ———									
32										
33										
34										
35										
36										
37										
38										
39										
40										
41										
42										
43										
44										
45										
46										
47										

GEOTECHNICAL ENGINEERING CORPORATION

GEC JOB NO: 3843 VERTICAL SCALE: 1" = 3' LOG OF BORING NO. 5 (P. 1 of 3)

PROJECT: LAKE ISABELLE, HASTINGS, DAKOTA COUNTY, MINNESOTA

DEPTH, IN FEET	SURFACE ELEVATION: DESCRIPTION AND CLASSIFICATION	GEOLOGY	N BPF	WB	SAMPLE TYPE	REC.	FIELD & LABORATORY TESTS MC	DEN	L.L. / P.L.
0–2	CLAY, dark grayish brown, (CL)	FINE ALLUVIUM		N	HSA				
2–7½	SILTY CLAY, brown, (ML-CL)		2	?	SS	12			
7½–12½	SILTY CLAY, gray, (ML-CL)								
12½–16	Organic CLAY, dark gray, (OL)		3	Y	SS	18			
16–18	SILTY SAND, medium grained, grayish black, (SP-SM)	COARSE ALLUVIUM							
18–21	Organic CLAY, dark gray, (OL)	FINE ALLUVIUM	3	?	SS	17			

DEPTH	DRILLING METHOD
0-24½	3¼ HSA
24½ - 52½	RD/DM

BORING COMPLETED: 12/10/84 10:20

CC: DO Dlr: MH Rig: 45

WATER LEVEL MEASUREMENTS

DATE	TIME	SAMPLED DEPTH	CASING DEPTH	CAVE-IN DEPTH	DRILLING MUD LEVEL	WATER LEVEL
12/20	1:53	16	14½	14.3		5.8
12/21	10:08		24½	?		4.2
12/21	10:21			9.0	2.0	

NOTE: REFER TO THE ATTACHED SHEETS FOR AN EXPLANATION OF TERMINOLOGY ON THIS LOG

GEOTECHNICAL ENGINEERING CORPORATION

GEC JOB NO: 3843 VERTICAL SCALE: 1"=3' LOG OF BORING NO: 5 (P. 2 of 3)

PROJECT: LAKE ISABELLE, HASTINGS, DAKOTA COUNTY, MINNESOTA

DEPTH, in FEET	DESCRIPTION AND CLASSIFICATION	GEOLOGY	N	WB	SAMPLE TYPE	REC.	FIELD & LABORATORY TESTS: MC	DEN	L.L./P.L.	
22	------------ SAME AS ABOVE -------------------									
23	MUCK, dark brown, (PT)									
24										
25	Some small shells.		3	?	SS	18				
26										
27										
28										
29	Organic CLAY and muck, dark grayish brown, (OL & PT)									
30		SWAMP DEPOSITS	2	?	SS	18				
31										
32										
33										
34										
35										
36										
37										
38	SILTY SAND, fine grained, gray, (nonplastic-SM)	COARSE ALLUVIUM								
39										
40	SILTY & CLAYEY SAND, gray, (SM-SC)	FINE ALLUVIUM	4	Y	SS	14				
41										
42										
43										
44										
45	SILTY SAND, fine grained, brown, (SP-SM)	COARSE ALLUVIUM								
46										
47										

GEOTECHNICAL ENGINEERING CORPORATION

GEC JOB NO: 3843 VERTICAL SCALE: 1"=3' LOG OF BORING NO. 5 (P. 3 of 3)

PROJECT: LAKE ISABELLE, HASTINGS, DAKOTA COUNTY, MINNESOTA

DEPTH, In FEET	DESCRIPTION AND CLASSIFICATION	GEOLOGY	N	WB	SAMPLE TYPE	REC.	MC	DEN	L.L./P.L.	
48										
49	---------- SAME AS ABOVE -----------------									
50			9	Y	SS	12				
51										
52										
53	* END OF BORING	BEDROCK* ?			*wash		*SAND grains and limestone (angular)			(rounded) chips
54										
55										
56										
57	* Rotary drill with tricone bit - solid drilling.									
58										
59										
60										
61										
62										
63										
64										
65										
66										
67										
68										
69										
70										
71										
72										
73										

GEOTECHNICAL ENGINEERING CORPORATION

GEC JOB NO: 3843   VERTICAL SCALE: 1" = 3'   LOG OF BORING NO. 6 (P. 1 of 2)

PROJECT: LAKE ISABELLE, HASTINGS, DAKOTA COUNTY, MINNESOTA

DEPTH, IN FEET	SURFACE ELEVATION: DESCRIPTION AND CLASSIFICATION	GEOLOGY	N BPF	WB	SAMPLE TYPE	REC.	MC	DEN	L.L./P.L.
0–2	Organic SILTY CLAY, dary gray, (OL)	FINE ALLUVIUM		N	HSA				
2–8	CLAY, dark brown, (CL)		2	Y	SS	17			
8–13	SILTY CLAY, dark gray, (ML-CL)		3	Y	SS	16			
13–18	Muck, dark brown, with some small shells, (PL)	SWAMP DEPOSITS	3	?	SS	15			
18–	SILTY SAND, fine to medium grained, gray and brown, (SP-SM)	COARSE ALLUVIUM	1	Y	SS	10			

DEPTH	DRILLING METHOD
0-29½	3¼ HSA

WATER LEVEL MEASUREMENTS

DATE	TIME	SAMPLED DEPTH	CASING DEPTH	CAVE-IN DEPTH	DRILLING MUD LEVEL	WATER LEVEL
12/21	12:41			14.4		1.3

BORING COMPLETED: 12/21/84 12:10

CC: DO Dlr: MH Rig: 45

NOTE: REFER TO THE ATTACHED SHEETS FOR AN EXPLANATION OF TERMINOLOGY ON THIS LOG

GEOTECHNICAL ENGINEERING CORPORATION

GEC JOB NO: 3843 VERTICAL SCALE: 1"=3' LOG OF BORING NO: 6 (P. 2 of 2)

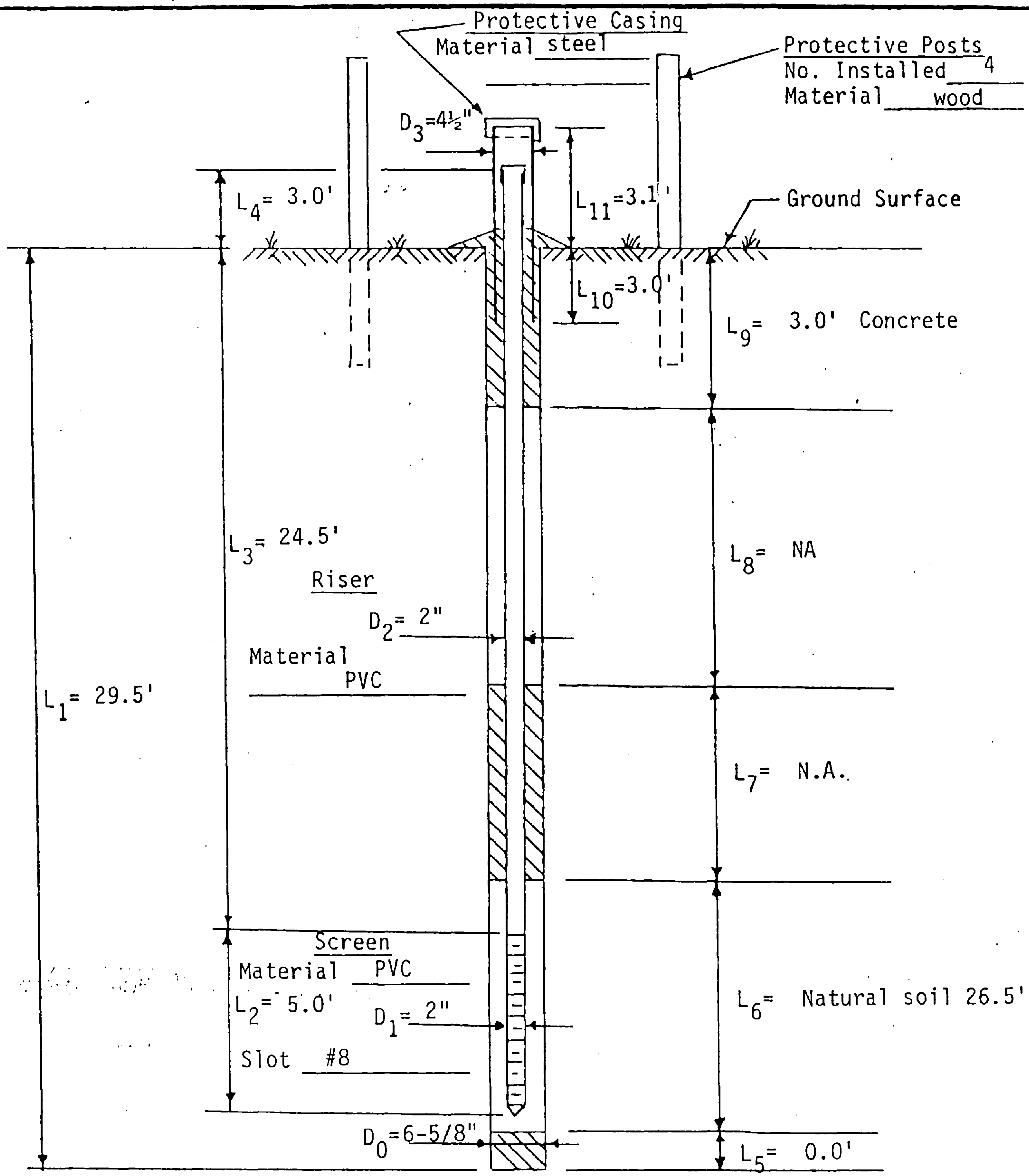
PROJECT: LAKE ISABELLE, HASTINGS, DAKOTA COUNTY, MINNESOTA

DEPTH, in FEET	DESCRIPTION AND CLASSIFICATION	GEOLOGY	N	WB	SAMPLE TYPE	REC.	FIELD & LABORATORY TESTS			
							MC	DEN	L.L./P.L.	
22	--------- SAME AS ABOVE ---------	----------								
23										
24										
25			2	Y	SS	15				
26										
27										
28										
29										
30			8	Y	SS	15				
31	———— END OF BORING ————	————								
32										
33										
34										
35										
36										
37										
38										
39										
40										
41										
42										
43										
44										
45										
46										
47										

MONITORING WELL/PIEZOMETER INFORMATION

JOB NO. 3843 REF. BORING NO. 1A

DATE INSTALLED: 11/6/84 INSTALLATION NO.



NOTES:

1) Refer to boring log for water level measurements.

REMARKS

7/83

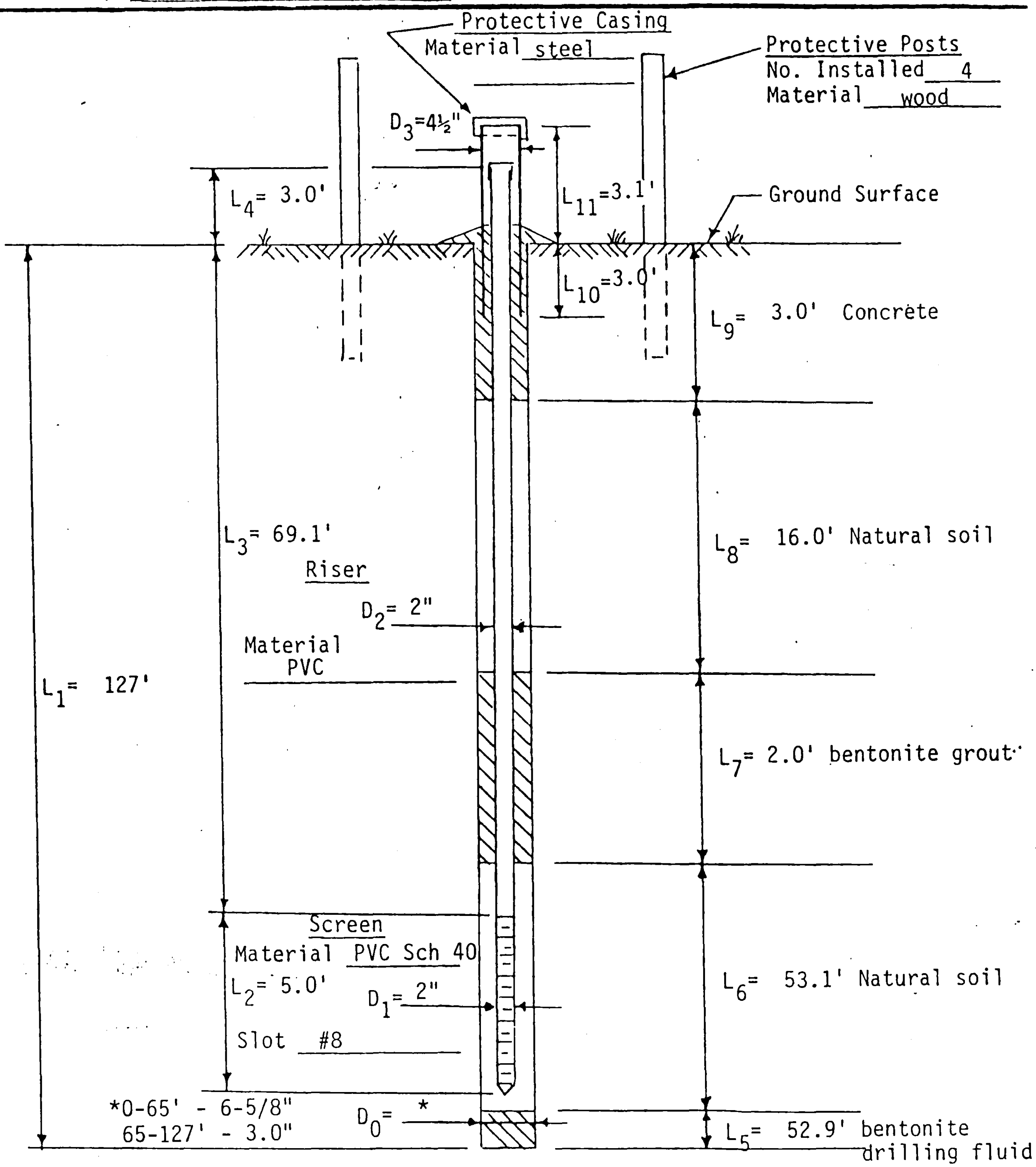
MONITORING WELL/PIEZOMETER INFORMATION

JOB NO. 3843

REF. BORING NO. #1B

DATE INSTALLED: 11/6/84

INSTALLATION NO. ______



NOTES:

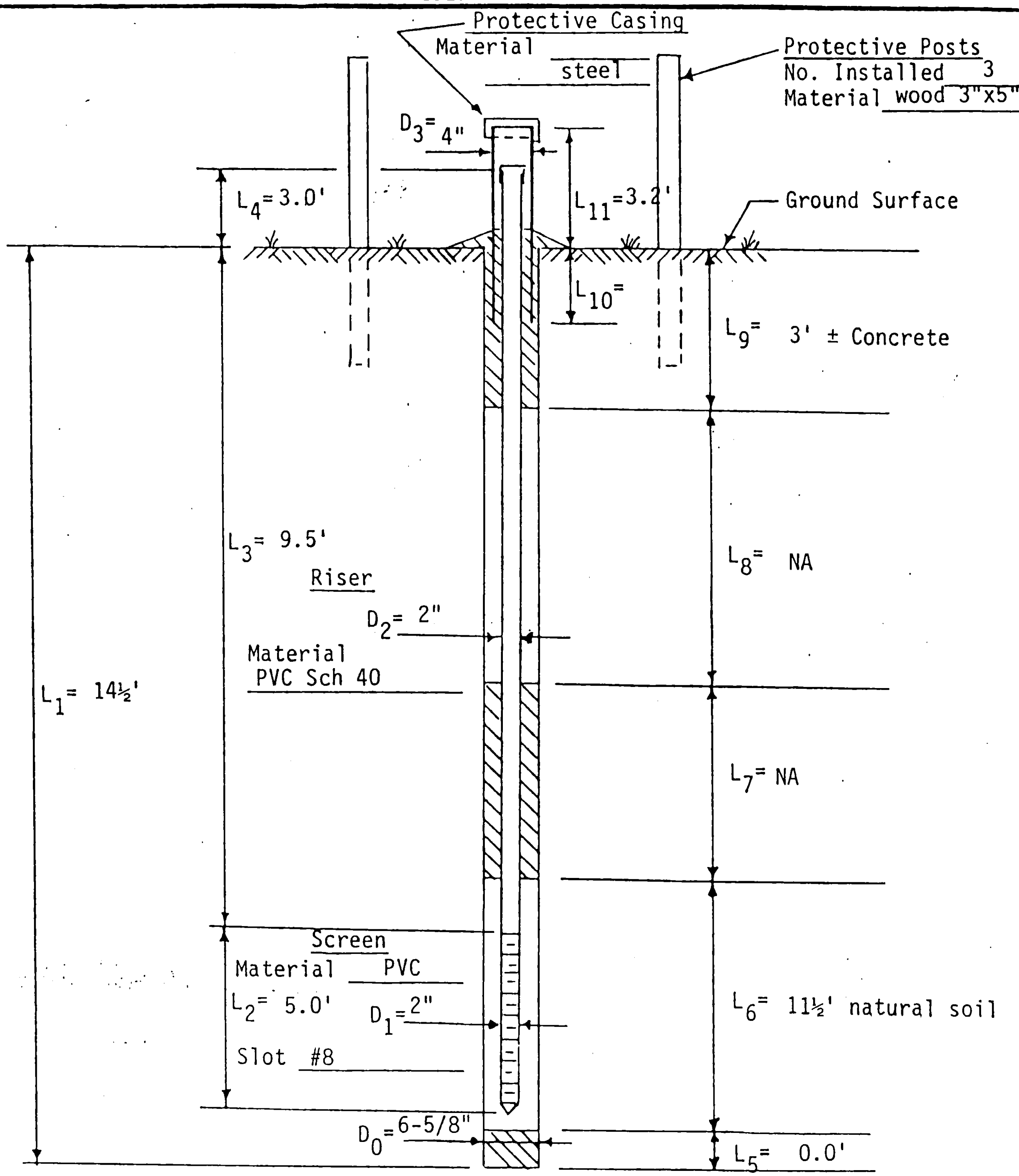
1) Refer to boring log for water level measurements.

REMARKS

MONITORING WELL/PIEZOMETER INFORMATION

JOB NO. 3843 REF. BORING NO. 2A

DATE INSTALLED: 11/7/84 INSTALLATION NO.



NOTES:

1) Refer to boring log for water level measurements.

REMARKS

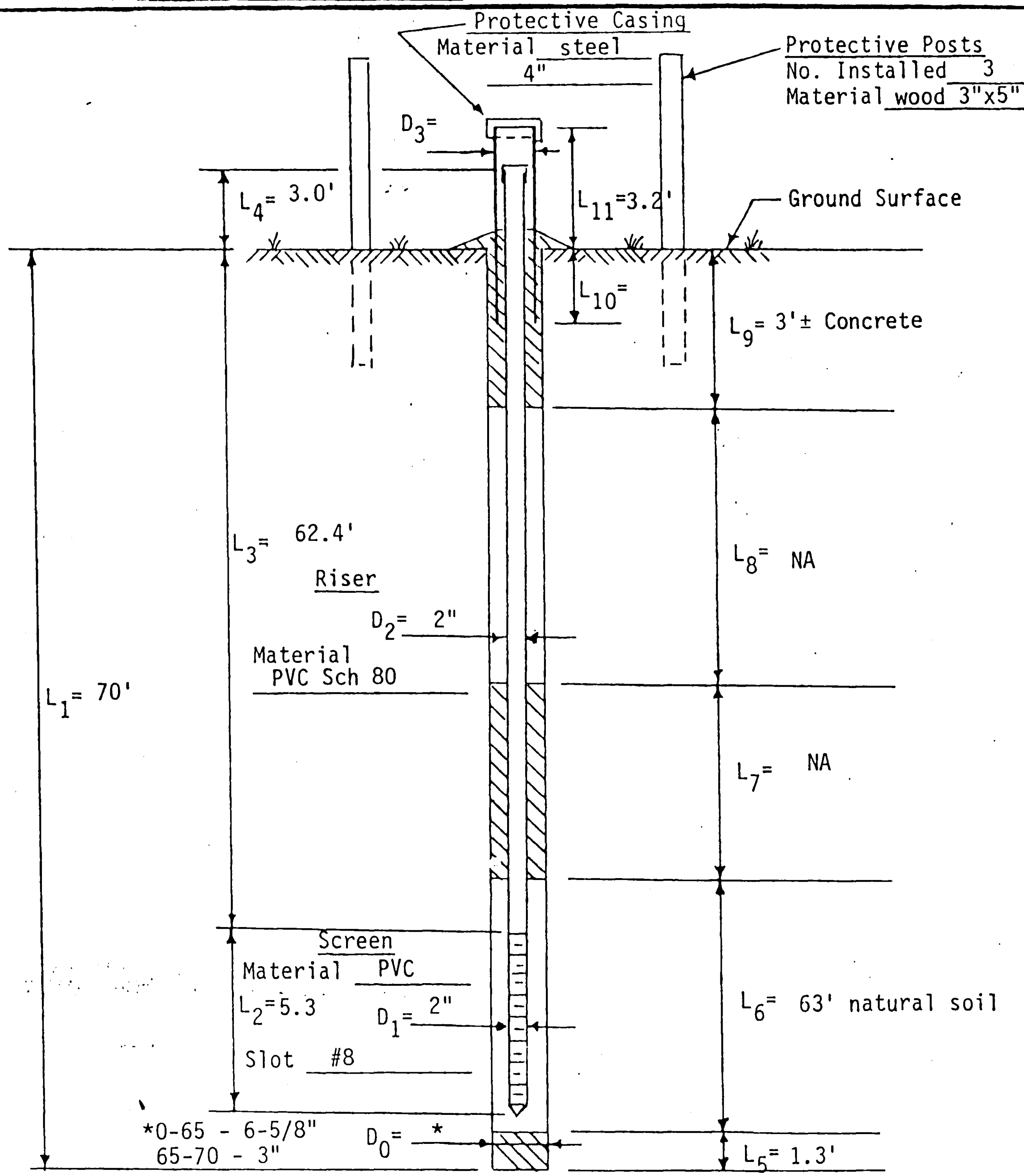
MONITORING WELL/PIEZOMETER INFORMATION

JOB NO. 3843

REF. BORING NO. 2B

DATE INSTALLED: 11/7/84

INSTALLATION NO.



NOTES:

1) Refer to boring log for water level measurements.

REMARKS

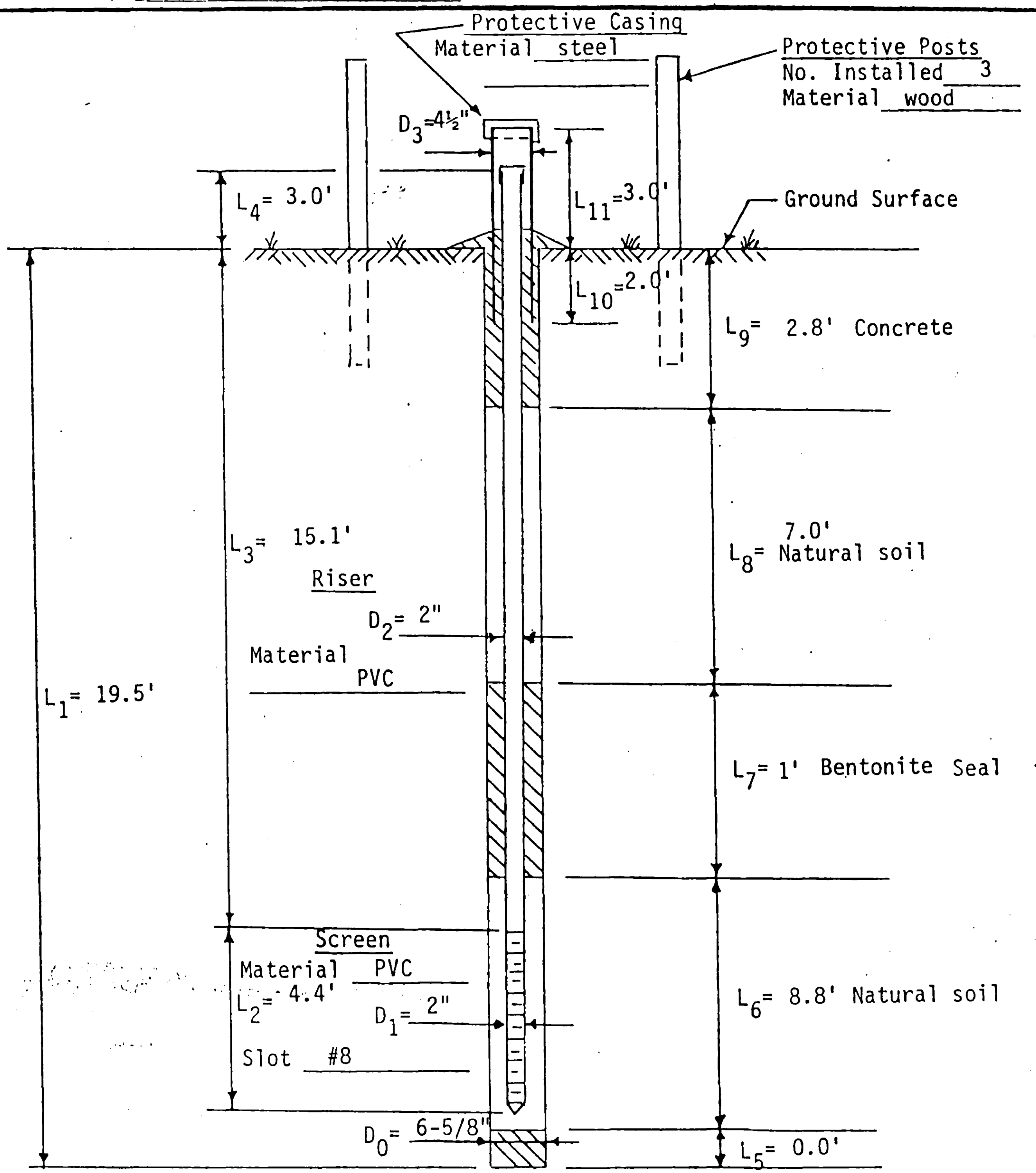
MONITORING WELL/PIEZOMETER INFORMATION

JOB NO. 3843

REF. BORING NO. 3A

DATE INSTALLED: 11/9/84

INSTALLATION NO. 2



NOTES:

1) Refer to boring log for water level measurements.

REMARKS

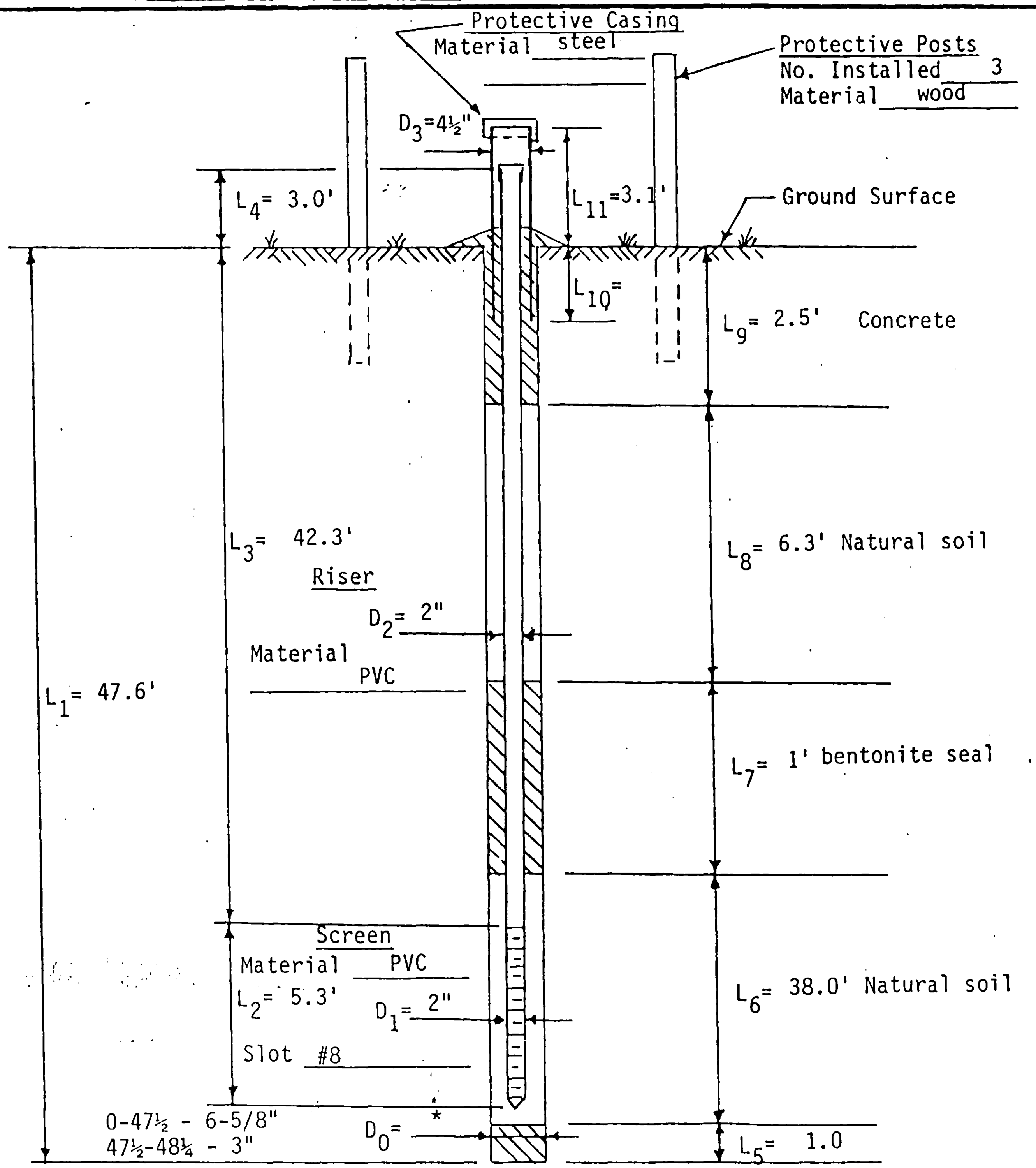
7/83

GEOTECHNICAL ENGINEERING CORPORATION

MONITORING WELL/PIEZOMETER INFORMATION

JOB NO. 3843 REF. BORING NO. 3B

DATE INSTALLED: 11/9/84 INSTALLATION NO. 1



NOTES:

1) Refer to boring log for water level measurements.

REMARKS

TEST BORING AND LOGGING METHODS

STANDARD PENETRATION - SPLIT SPOON TEST

A 1-3/8" ID, 2" OD steel sampling tube is driven into the soil with a 140 pound weight falling 30". The number of hammer blows required to drive the sampler 1', after an initial set of 1/2', is the standard penetration test ("N" value).

The bore hole is advanced between sampling intervals with flite auger, hollow stem auger, casing, or by rotary drilling.

AUGER BORINGS

Auger borings are drilled by hand or with a power-driven auger.

The hand auger method consists of drilling the auger into the soil in increments of approximately 4", then retracting the auger and observing the material recovered. This allows almost continuous observation of the soil profile.

Two procedures are available in drilling power auger borings: "spinning" and "pulling". In the spinning procedure, the auger is drilled into the ground in increments of 5', or less. The auger is then spun rapidly. Soil "rides up" the auger to the ground surface where samples are then taken. In general, this method results in reasonably accurate identification of the soil profile above the groundwater table, but can be very misleading - particularly in sandy and gravelly soils - below the water table. In the pulling procedure, the auger is drilled into the ground and then retracted to above the ground surface. The general soil profile can be observed and samples of materials adhering to the auger are taken. In general, this method is considered to be a little more accurate than the spinning method in soil above the groundwater table, and considerably more accurate than the spinning method in soil below the groundwater table.

THIN WALL TUBE SAMPLES

Comparatively undisturbed samples are taken with thin wall tubes which are pushed into the soil.

STATIC CONE TESTS

The static cone test consists of measuring the force required to push a steel cone penetrometer into soil. Cone diameters are 1-3/4", 2-1/4", and 3". The apex angle is 60^0. The cone is pushed at a rate of approximately 1/2" per second. A hand cone penetrometer also is used. It has a 30^0 apex angle and a projected end area of 0.5 square inches. The static cone bearing pressure, q_c, is the total load divided by the projected end area of the cone.

CORING

Coring is done with a diamond or carbide bit on a double tubed barrel.

TEST BORING & LOGGING METHODS

LOGGING

Both factual data and interpretative information is included on boring logs.

In general, the information on the righthand side and the bottom of a log is considered to be essentially factual data.

In the "Description and Classification" and "Geology" columns, the intent is to portray the soil profile, or stratigraphy, based on interpretation of available data. Since the information shown is interpretive, it is subject to error. The accuracy of the information shown is controlled by the type and amount of data available. In general, there are three basic categories of information shown: 1) the description and classification of material recovered and observed; 2) the depths of the contacts between soil layers; and, 3) the geologic classification of the soils. Comments regarding these items follow: 1) The completeness of the description and classification of soils depends on the description and classification method used and the quality of the samples recovered. 2) Determination of depths to contacts between soil layers is arrived at by taking into consideration the action of the drill tools and the appearance of materials recovered. On a given boring log, contacts shown with solid and dashed lines are used to indicate higher and lower accuracy, respectively. In general, the entire soil profile is not observed or sampled. Consequently, indicated depths of contacts may be incorrect, and some materials or layers may be undetected in a boring and may not be described, identified, or in any way indicated on a boring log. 3) The indicated geology of the soil is interpretive, the accuracy of which is dependent on the judgment of the classifier.

Boulders and other large objects generally are not recovered from test borings. This is due to limitations on the size of particles that can be recovered. Though there may be no specific reference to such materials on boring logs or in a report, they may be present in the ground. This is particularly applicable to deposits such as coarse alluvium, uncontrolled fill, glacial till, outwash, tumblerock, and weathered bedrock.

Typewritten logs are prepared based on field logs. A field log may contain interpretive information - such as notes regarding unusual drilling conditions - which is not indicated on the typewritten log.

TERMINOLOGY ON BORING LOGS:
DRILLING, SAMPLING, AND TESTING NOTATION

(Refer to attached sheets for additional information.)

A,B,N,H:	Size casing or core.
AC:	At completion of boring.
CAS:	Casing.
CONS:	One dimensional consolidation test.
COT:	Clean out tube.
DEN:	Dry density, pounds/cubic foot.
DM:	Drilling mud.
FA:	Flite auger, power driven. P-pull; S-spin.
HA:	Hand auger.
HSA:	Hollow stem auger.
HYD:	Hydrometer analysis.
LL:	Liquid limit.
MC:	Moisture Content, per cent of dry weight.
N:	Standard penetration test, penetration resistance, or N value, blows/foot.
PAP:	Paper plug.
PL:	Plastic limit.
q_p:	Pocket penetrometer strength, tons/square foot.
q_c:	Static cone bearing pressure, tons/square foot.
q_u:	Unconfined compressive strength, tons/square foot.
RD:	Rotary drilling, using drilling fluid and a cone-type roller bit.
REC:	In split spoon and thin wall tube sampling, the length of sample recovered, in inches. In rock coring, the length of core recovered as a percentage of the total core run.
REV:	Revert drilling fluid.
SA:	Sieve analysis.
SS:	Standard split spoon sampler. Steel, 1-3/8" inside diam.; 2" outside diam.
TW:	Thin wall tube sampler.
VANE:	Vane shear strength, tons/square foot. L - Laboratory; F - Field.
WASH:	Sample of coarser-grained material from rotary drilling fluid. Obtained by screening the returning fluid or with a split spoon sampler at the bottom of a bore hole.
WAT:	Water.
WB:	Describes whether the sample appears to be waterbearing.
WH:	Sampler advanced by static weight of drill rod and 140 lb. hammer.
WR:	Sampler advanced by static weight of AW size drill rod.
-200:	Amount of material finer than #200 sieve, per cent.
▼:	Water level symbol.

Note: The size of equipment is indicated by a number preceding the descriptive term. For example, 2-1/2 CAS represents 2-1/2" diameter casing.

MAJOR DIVISIONS			GRAPH SYMBOL	LETTER SYMBOL	TYPICAL DESCRIPTIONS
COARSE GRAINED SOILS	GRAVEL AND GRAVELLY SOILS	CLEAN GRAVELS (LITTLE OR NO FINES)		GW	WELL-GRADED GRAVELS, GRAVEL-SAND MIXTURES, LITTLE OR NO FINES
				GP	POORLY-GRADED GRAVELS, GRAVEL-SAND MIXTURES, LITTLE OR NO FINES
	MORE THAN 50% OF COARSE FRACTION RETAINED ON NO. 4 SIEVE	GRAVELS WITH FINES (APPRECIABLE AMOUNT OF FINES)		GM	SILTY GRAVELS, GRAVEL-SAND-SILT MIXTURES
				GC	CLAYEY GRAVELS, GRAVEL-SAND-CLAY MIXTURES
	SAND AND SANDY SOILS	CLEAN SAND (LITTLE OR NO FINES)		SW	WELL-GRADED SANDS, GRAVELLY SANDS, LITTLE OR NO FINES
MORE THAN 50% OF MATERIAL IS LARGER THAN NO. 200 SIEVE SIZE				SP	POORLY-GRADED SANDS, GRAVELLY SANDS, LITTLE OR NO FINES
	MORE THAN 50% OF COARSE FRACTION PASSING NO. 4 SIEVE	SANDS WITH FINES (APPRECIABLE AMOUNT OF FINES)		SM	SILTY SANDS, SAND-SILT MIXTURES
				SC	CLAYEY SANDS, SAND-CLAY MIXTURES
FINE GRAINED SOILS	SILTS AND CLAYS	LIQUID LIMIT LESS THAN 50		ML	INORGANIC SILTS AND VERY FINE SANDS, ROCK FLOUR, SILTY OR CLAYEY FINE SANDS OR CLAYEY SILTS WITH SLIGHT PLASTICITY
				CL	INORGANIC CLAYS OF LOW TO MEDIUM PLASTICITY, GRAVELLY CLAYS, SANDY CLAYS, SILTY CLAYS, LEAN CLAYS
				OL	ORGANIC SILTS AND ORGANIC SILTY CLAYS OF LOW PLASTICITY
	SILTS AND CLAYS	LIQUID LIMIT GREATER THAN 50		MH	INORGANIC SILTS, MICACEOUS OR DIATOMACEOUS FINE SAND OR SILTY SOILS
MORE THAN 50% OF MATERIAL IS SMALLER THAN NO. 200 SIEVE SIZE				CH	INORGANIC CLAYS OF HIGH PLASTICITY, FAT CLAYS
				OH	ORGANIC CLAYS OF MEDIUM TO HIGH PLASTICITY, ORGANIC SILTS
HIGHLY ORGANIC SOILS				PT	PEAT, HUMUS, SWAMP SOILS WITH HIGH ORGANIC CONTENTS

NOTE: DUAL SYMBOLS ARE USED TO INDICATE BORDERLINE SOIL CLASSIFICATIONS.

SOIL CLASSIFICATION CHART

UNIFIED SOIL CLASSIFICATION SYSTEM

GEOLOGIC TERMINOLOGY

The geologic description indicates the apparent depositional origin or stratigraphic name. Geologic identification is interpretive and subject to error.

General categories of geologic deposits and descriptive information is as follows:

ALLUVIUM	COARSE ALLUVIUM:	Sandy (and gravelly). Stratified. Deposited from fast moving waters in streams, rivers, and deltas.
	FINE ALLUVIUM:	Clayey and/or silty. Stratified. Deposited from slow moving waters in streams, rivers, and lakes.
BEDROCK	Wide range of characteristics, from a hard, dense, consolidated rock to soft, compressible, and unconsolidated soil-like material.	
FILL	CONTROLLED:	Compact, uniform material; inorganic; no debris.
	UNCONTROLLED:	Loose or variable density. Mixture of soil types. Often contains debris and organic material.
GLACIAL TILL	Sandy/silty/clayey. Normally contains a wide range of grain sizes, from clay through boulders. Usually non-stratified. Deposited directly from glaciers.	
LAKE DEPOSIT	Clayey. Laminated. Deposited from very slow moving waters in ponds and lakes.	
LOESS	Silty. Non-stratified. Upper layer. Deposited from wind.	
OUTWASH	Coarse alluvium deposited from glacial meltwaters.	
SLOPEWASH	Organic and/or inorganic material. Washed from slopes and deposited in depressions.	
SWAMP DEPOSIT	Peat, muck, marl. Formed through accumulation of organic material under water.	
TOPSOIL	Contains both inorganic and organic material. Upper, black layer of soil. Formed by weathering of inorganic soil and accumulation of organic material.	
TUMBLEROCK	Dominantly gravel, boulders and rock slabs. Deposited from gravity flow down hills or cliffs.	
WEATHERED BEDROCK	Bedrock which has been substantially weathered through disintegration or decomposition.	
WEATHERED SOIL	Texture and composition is transitional between topsoil and underlying non-weathered soil.	

TERMINOLOGY ON BORING LOGS

GROUNDWATER

Groundwater information is shown in two places on logs: 1) under "Water Level Measurements" and 2) in the "WB" column.

Information under Water Level Measurements includes: 1) The depth to the water level (or drilling fluid, if used) and the depth to the bottom of the hole (cave-in). Water level and cave-in measurements are taken with a weighted measuring tape. If free-standing water is not encountered in the hole, the term wet, or dry, is indicated under water level. This means that the soil adhering to the end of the measuring tape did, or did not, respectively, appear to be saturated. 2) The depth sampled and the depth of casing (or hollow-stem auger) for measurements made during the progress of the boring. 3) Date and time of measurements.

Notation in the WB column describes whether soil samples appear to be water-bearing or saturated. Y means yes, N means no, and ? means questionable or indefinite.

The water level symbol ▼ in the WB column indicates the apparent depth to the groundwater table at the bore hole. Determination of the depth to the groundwater table is an interpretive process. The determination is based on various factors, including: water level measurements, the appearance of samples, overall subsurface conditions, site condictions and weather conditions. The accuracy of the indicated depth to the groundwater table can be quite variable. The water level symbol with an arrow pointed downward (or upward) indicates that the water level is at or below (or above) the level indicated. Absence of the water level symbol does not necessarily mean groundwater was not encountered, or that the water table or piezometric surface was not penetrated.

The presence of groundwater in the soil and the level of the groundwater table can change with time. The information in the WB column is based on observations and measurements made at the time the boring was drilled and water level measurements were taken.

GEOTECHNICAL ENGINEERING CORPORATION

1925 Oakcrest Avenue • Roseville, Minnesota 55113 • (612) 636-7744
Apple Valley, Minnesota • (612) 431-5266

REPORT OF TEST BORINGS AND PIEZOMETER

PROJECT:

LAKE ISABELLE, HASTINGS
DAKOTA COUNTY, MINNESOTA

GEC JOB NO: 3973
DATE: MARCH 21, 1985

REPORTED:

EUGENE A. HICKOK & ASSOCIATES (EAH)
545 INDIAN MOUND
WAYZATA, MINNESOTA 55391

ATTN: MR. WILLIAM WEIDENBACHER

INTRODUCTION

On March 14 and 15, 1985, we drilled two borings and installed a piezometer for the referenced project. The scope of our work (location, depth, sampling method, etc.) was as directed by EAH.

TEST BORINGS

Samples were obtained using the split-spoon and auger (HSA) methods. Auger sampling was done using the "spinning" procedure. Refer to the attached sheets (Drilling, Sampling and Testing; Test Boring and Logging Methods) for additional information regarding test boring and logging methods.

The soils were classified in accordance with the ASTM Visual Manual Method (ASTM D 2488). Refer to the attached sheet (Unified Soil Classification System) for a description of the classification method.

Refer to the attached logs for a description of the subsurface conditions encountered in the borings. The logs show: the depths to the boundaries between the soil layers; the description, classification, and geologic identification of the soils; the standard penetration resistance (N values); water level measurements; and other information. Refer to the attached sheets (Drilling, Sampling, and Testing; Test Boring and Logging Methods; Geologic Terminology; Groundwater) for a description of terminology used on the logs.

PIEZOMETERS

A log of the piezometer is attached.

CLOSURE

Subsurface conditions can vary from that encountered in the borings and piezometer at other locations, depths, and times.

To protect the addressee, the public, and ourselves, this report (and all supporting information) is provided for the addressee's own use. No representations are made to parties other than the addressee.

Report Prepared By:

Robert E. Pendergast

Robert E. Pendergast, P.E.
MN Reg. No. 8450

GEOTECHNICAL ENGINEERING CORPORATION

GEC JOB NO: 3973 VERTICAL SCALE: 1" = 3' LOG OF BORING NO. 4A (P. 1 of 3)

PROJECT: LAKE ISABELLE, HASTINGS; DAKOTA COUNTY, MINNESOTA

DEPTH, IN FEET	SURFACE ELEVATION: DESCRIPTION AND CLASSIFICATION	GEOLOGY	N BPF	WB	SAMPLE TYPE	REC.	FIELD & LABORATORY TESTS MC	DEN	L.L./P.L.
1–4	SILTY SAND, well graded, brown, with a little gravel, (SW-SM)	FILL		N	HSA				
4–9.5	CLAYEY SAND, with a little gravel, grayish brown, (SC)			N	HSA				
9.5–21	SILTY SAND, well graded, dark brown, with a little gravel, (SW-SM)	COARSE ALLUVIUM or FILL		N	HSA				
				N	HSA				
				N	HSA				

Note: Piezometer installed in borehole

See piezometer log.

DEPTH	DRILLING METHOD
0-55	3¼ HSA

BORING COMPLETED: 3/15/85 3:20

CC: JM Dlr: MH Rig: 45

WATER LEVEL MEASUREMENTS

DATE	TIME	SAMPLED DEPTH	CASING DEPTH	CAVE-IN DEPTH	DRILLING MUD LEVEL	WATER LEVEL
3/15	11:00	-	-	54.6		50.6*

*in piezometer

NOTE: REFER TO THE ATTACHED SHEETS FOR AN EXPLANATION OF TERMINOLOGY ON THIS LOG

GEOTECHNICAL ENGINEERING CORPORATION

GEC JOB NO: 3973 VERTICAL SCALE: 1"=3' LOG OF BORING NO: 4A (P. 2 of 3)

PROJECT: LAKE ISABELLE, HASTINGS; DAKOTA COUNTY, MINNESOTA

DEPTH, In FEET	SURFACE ELEVATION: DESCRIPTION AND CLASSIFICATION	GEOLOGY	N	WB	SAMPLE TYPE	REC.	FIELD & LABORATORY TESTS MC	DEN	L.L./P.L.	
22				N	HSA					
23				N	HSA					
24	SILTY SAND, fine grained, light brown, with a trace of gravel, (SP-SM)									
25										
26										
27										
28										
29										
30										
31		COARSE ALLUVIUM		N	HSA					
32										
33										
34										
35										
36				N	HSA					
37										
38										
39	SANDY SILT, light grayish brown, (ML)									
40										
41				N	HSA					
42										
43										
44										
45	SILT, light grayish brown, (plastic-ML)	FINE ALUVIUM		?	HSA					
46										
47										

GEOTECHNICAL ENGINEERING CORPORATION

GEC JOB NO: 3973 VERTICAL SCALE: 1"=3' LOG OF BORING NO. 4A (P. 3 of 3)

PROJECT: LAKE ISABELLE, HASTINGS; DAKOTA COUNTY, MINNESOTA

DEPTH, in FEET	DESCRIPTION AND CLASSIFICATION	GEOLOGY	N	WB	SAMPLE TYPE	REC.	FIELD & LABORATORY TESTS			
							MC	DEN	L.L./P.L.	
48										
49										
50	CLAYEY SILT, light grayish brown, (ML-CL)			Y	HSA					
51										
52		FINE ALLUVIUM								
53										
54										
55	Limestone chips and CLAY, light brown	BEDROCK ?		Y	SS	1				
	END OF BORING									
56										
57										
58	Boring obstructed to HSA and split spoon									
59										
60										
61										
62										
63										
64										
65										
66										
67										
68										
69										
70										
71										
72										
73										

GEOTECHNICAL ENGINEERING CORPORATION

GEC JOB NO: 3973 VERTICAL SCALE: 1" = 3' LOG OF BORING NO. 4B (P. 1 of 2)

PROJECT: LAKE ISABELLE, HASTINGS; DAKOTA COUNTY, MINNESOTA

DEPTH, IN FEET	SURFACE ELEVATION: DESCRIPTION AND CLASSIFICATION	GEOLOGY	N BPF	WB	SAMPLE TYPE	REC.	MC	DEN	L.L./P.L.
1	SILTY SAND, well graded, with a little gravel, dark brown (SW-SM)								
2									
3				N	HSA				
4									
5		COARSE ALLUVIUM or FILL							
6									
7				N	HSA				
8									
9									
10				N	HSA				
11									
12									
13									
14									
15									
16	SILTY SAND, fine grained, brown, with a trace of gravel, (SP-SM)			N	HSA				
17		COARSE ALLUVIUM							
18									
19									
20									
21				N	HSA				

DEPTH	DRILLING METHOD
0-46	$3^1/4$ HSA

BORING COMPLETED:

CC: JM Dlr: MH Rig: 55

WATER LEVEL MEASUREMENTS						
DATE	TIME	SAMPLED DEPTH	CASING DEPTH	CAVE-IN DEPTH	DRILLING MUD LEVEL	WATER LEVEL
3/15	12:39	46	46	45.8		dry
3/15	1:03	46	-	19.3		dry

NOTE: REFER TO THE ATTACHED SHEETS FOR AN EXPLANATION OF TERMINOLOGY ON THIS LOG

GEOTECHNICAL ENGINEERING CORPORATION

GEC JOB NO: 3973 VERTICAL SCALE: 1"=3' LOG OF BORING NO: 4B (P. 2 of 2)

PROJECT: LAKE ISABELLE, HASTINGS; DAKOTA COUNTY, MINNESOTA

DEPTH, In FEET	SURFACE ELEVATION: DESCRIPTION AND CLASSIFICATION	GEOLOGY	N	WB	SAMPLE TYPE	REC.	FIELD & LABORATORY TESTS MC	DEN	L.L. / P.L.	
22	------- SAME AS ABOVE -----------									
23										
24										
25				N	HSA					
26										
27										
28										
29										
30				N	HSA					
31										
32										
33										
34										
35				N	HSA					
36										
37										
38										
39										
40										
41				N	HSA					
42										
43										
44										
45	*Trace of limestone powder on sampler reacted with HCL									
46	END OF BORING		50/1"	?	SS	0*				
47	Boring obstructed to HSA and split spoon									

MONITORING WELL/PIEZOMETER LOG

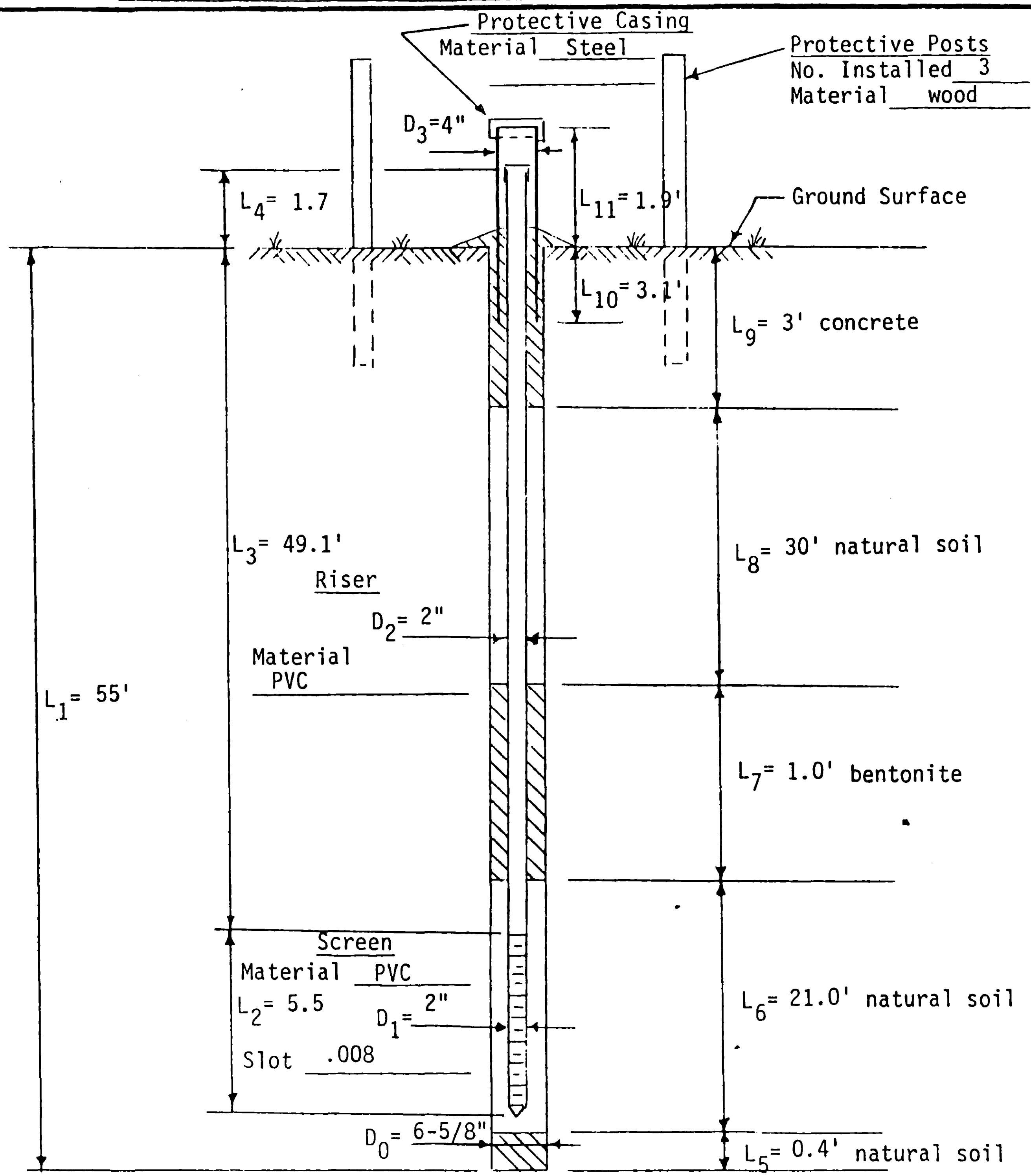
JOB NO: 3973

DATE INSTALLED:

ELEVATION OF

REF. BORING NO. 4A

INSTALLATION NO.



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45:	CME 45 rotary drill rig.
55:	CME 55 rotary drill rig.
▼:	Water level symbol.

Note: The size of equipment is indicated by a number preceding the descriptive term. For example, 2-1/2 CAS represents 2-1/2" diameter casing.

MAJOR DIVISIONS			GRAPH SYMBOL	LETTER SYMBOL	TYPICAL DESCRIPTIONS
COARSE GRAINED SOILS	GRAVEL AND GRAVELLY SOILS	CLEAN GRAVELS (LITTLE OR NO FINES)		GW	WELL-GRADED GRAVELS, GRAVEL-SAND MIXTURES, LITTLE OR NO FINES
				GP	POORLY-GRADED GRAVELS, GRAVEL-SAND MIXTURES, LITTLE OR NO FINES
	MORE THAN 50% OF COARSE FRACTION RETAINED ON NO. 4 SIEVE	GRAVELS WITH FINES (APPRECIABLE AMOUNT OF FINES)		GM	SILTY GRAVELS, GRAVEL-SAND-SILT MIXTURES
				GC	CLAYEY GRAVELS, GRAVEL-SAND-CLAY MIXTURES
	SAND AND SANDY SOILS	CLEAN SAND (LITTLE OR NO FINES)		SW	WELL-GRADED SANDS, GRAVELLY SANDS, LITTLE OR NO FINES
MORE THAN 50% OF MATERIAL IS LARGER THAN NO. 200 SIEVE SIZE				SP	POORLY-GRADED SANDS, GRAVELLY SANDS, LITTLE OR NO FINES
	MORE THAN 50% OF COARSE FRACTION PASSING NO. 4 SIEVE	SANDS WITH FINES (APPRECIABLE AMOUNT OF FINES)		SM	SILTY SANDS, SAND-SILT MIXTURES
				SC	CLAYEY SANDS, SAND-CLAY MIXTURES
FINE GRAINED SOILS	SILTS AND CLAYS	LIQUID LIMIT LESS THAN 50		ML	INORGANIC SILTS AND VERY FINE SANDS, ROCK FLOUR, SILTY OR CLAYEY FINE SANDS OR CLAYEY SILTS WITH SLIGHT PLASTICITY
				CL	INORGANIC CLAYS OF LOW TO MEDIUM PLASTICITY, GRAVELLY CLAYS, SANDY CLAYS, SILTY CLAYS, LEAN CLAYS
				OL	ORGANIC SILTS AND ORGANIC SILTY CLAYS OF LOW PLASTICITY
MORE THAN 50% OF MATERIAL IS SMALLER THAN NO. 200 SIEVE SIZE	SILTS AND CLAYS	LIQUID LIMIT GREATER THAN 50		MH	INORGANIC SILTS, MICACEOUS OR DIATOMACEOUS FINE SAND OR SILTY SOILS
				CH	INORGANIC CLAYS OF HIGH PLASTICITY, FAT CLAYS
				OH	ORGANIC CLAYS OF MEDIUM TO HIGH PLASTICITY, ORGANIC SILTS
HIGHLY ORGANIC SOILS				PT	PEAT, HUMUS, SWAMP SOILS WITH HIGH ORGANIC CONTENTS

NOTE: DUAL SYMBOLS ARE USED TO INDICATE BORDERLINE SOIL CLASSIFICATIONS.

SOIL CLASSIFICATION CHART

UNIFIED SOIL CLASSIFICATION SYSTEM

GEOLOGIC TERMINOLOGY

The geologic description indicates the apparent depositional origin or stratigraphic name. Geologic identification is interpretive and subject to error.

General categories of geologic deposits and descriptive information is as follows:

ALLUVIUM	COARSE ALLUVIUM:	Sandy (and gravelly). Stratified. Deposited from fast moving waters in streams, rivers, and deltas.
	FINE ALLUVIUM:	Clayey and/or silty. Stratified. Deposited from slow moving waters in streams, rivers, and lakes.
BEDROCK	Wide range of characteristics, from a hard, dense, consolidated rock to soft, compressible, and unconsolidated soil-like material.	
FILL	CONTROLLED:	Compact, uniform material; inorganic; no debris.
	UNCONTROLLED:	Loose or variable density. Mixture of soil types. Often contains debris and organic material.
GLACIAL TILL	Sandy/silty/clayey. Normally contains a wide range of grain sizes, from clay through boulders. Usually non-stratified. Deposited directly from glaciers.	
LAKE DEPOSIT	Clayey. Laminated. Deposited from very slow moving waters in ponds and lakes.	
LOESS	Silty. Non-stratified. Upper layer. Deposited from wind.	
OUTWASH	Coarse alluvium deposited from glacial meltwaters.	
SLOPEWASH	Organic and/or inorganic material. Washed from slopes and deposited in depressions.	
SWAMP DEPOSIT	Peat, muck, marl. Formed through accumulation of organic material under water.	
TOPSOIL	Contains both inorganic and organic material. Upper, black layer of soil. Formed by weathering of inorganic soil and accumulation of organic material.	
TUMBLEROCK	Dominantly gravel, boulders and rock slabs. Deposited from gravity flow down hills or cliffs.	
WEATHERED BEDROCK	Bedrock which has been substantially weathered through disintegration or decomposition.	
WEATHERED SOIL	Texture and composition is transitional between topsoil and underlying non-weathered soil.	

TERMINOLOGY ON BORING LOGS
GROUNDWATER

Groundwater information is shown on boring logs: 1) under "Water Level Measurements" and 2) in the "WB" column.

Information under Water Level Measurements includes:

- The depth to the water level (or drilling fluid, if used) and the depth to the bottom of the hole (cave-in). Water level and cave-in measurements are taken with a weighted measuring tape. If free-standing water is not encountered in the hole, the term wet, or dry, is indicated under "Water Level." This means that the soil adhering to the end of the measuring tape did, or did not, respectively, appear to be saturated.

- The depth sampled and the depth of casing (or hollow-stem auger) for measurements made during the progress of the boring.

- Date and time of measurements.

Notation in the WB column describes whether soil samples appear to be water-bearing or saturated. Y means yes, N means no, and ? means questionable or indefinite.

The water level symbol, ▼, in the WB column indicates the apparent depth to the groundwater table at the bore hole. Determination of the depth to the groundwater table is an interpretive process. The determination is based on various factors, including: water level measurements, the appearance of samples, subsurface conditions, site conditions, and weather conditions. The accuracy of the indicated depth to the groundwater table can be quite variable. The water level symbol with an arrow pointed downward (or upward) indicates that the water level is at or below (or above) the level indicated. Absence of the water level symbol does not necessarily mean groundwater was not encountered, or that the water table or piezometric surface was not penetrated.

The presence of groundwater in the soil and the level of the groundwater table can change with time. The information in the WB column is based on observations and measurements made at the time the boring was drilled and the water level measurements were taken.

APPENDIX B

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*******************80-80 LIST OF INPUT DATA FOR TR-20 HYDROLOGY******************

JOB TR-20             ECON        NONPRINT            SUMMARY   NOPLOTS           10
TITLE     LAKE ISABELLE HYDROLOGIC MODEL EXISTING CONDITIONS                      20
TITLE     5,10,100,AND PMP STORM-LAKE OUTLET=5FT WIDE WEIR@681.0                  30
 3 STRUCT      01                                                                260
 8                      681.0       0.          0.                               270
 8                      681.2       1.5         22.                              290
 8                      681.4       4.2         44.                              310
 8                      681.6       7.7         66.                              330
 8                      681.8       11.9        88.
 8                      682.0       16.6        110.
 8                      682.2       21.9        132.
 8                      682.4       27.6        154.
 8                      682.6       33.7        177.
 8                      682.8       40.2        199.
 8                      683.0       47.1        222.
 8                      683.5       65.5        279.
 8                      684.0       86.5        336.
 8                      685.0       133.2       451.
 8                      686.0       166.        568.
 8                      687.0       244.7       685.
 9 ENDTBL                                                                       1380
 6 RUNOFF 1    01     5 .0781       81.         .75          1                  1630
 6 RUNOFF 1    01     6 .0641       86.         .40          1                  1640
 6 ADDHYD 4    01 5 6 7                                      1                  1670
 6 RUNOFF 1    01     6 .0672       70.         .20          1                  2450
 6 ADDHYD 4    01 7 6 5                                      1                  2460
 6 RUNOFF 1    01     6 .1875       100.        .1           1
 6 ADDHYD 4    01 5 6 7                                      1
 6 RESVOR 2    01 7   5  681.0                               1 1 1 1   1
   ENDATA
 7 BASFLO 5              6.7
 7 INCREM 6              0.25                                                   2480
 7 COMPUT 7    01    01  0.0        3.6         1.0          2 2  01  01        2490
   ENDCMP 1                                                                     2500
 7 COMPUT 7    01    01  0.0        4.2         1.0          2 2  01  02
   ENDCMP 1
 7 COMPUT 7    01    01  0.0        6.0         1.0          2 2  01  03
   ENDCMP 1
 7 COMPUT 7    01    01  0.0        23.5        6.0          6 2  01  03
   ENDCMP 1
   ENDJOB 2                                                                     2510

*********************************END OF 80-80 LIST*********************************
```

SUMMARY TABLE 1 - SELECTED RESULTS OF STANDARD AND EXECUTIVE CONTROL INSTRUCTIONS IN THE ORDER PERFORMED
(A STAR(*) AFTER THE PEAK DISCHARGE TIME AND RATE (CFS) VALUES INDICATES A FLAT TOP HYDROGRAPH.)

SECTION/ STRUCTURE ID		STANDARD CONTROL OPERATION	DRAINAGE AREA (SQ MI)	RAIN TABLE #	ANTEC MOIST COND	MAIN TIME INCREM (HR)	PRECIPITATION BEGIN (HR)	PRECIPITATION AMOUNT (IN)	PRECIPITATION DURATION (HR)	RUNOFF AMOUNT (IN)	PEAK DISCHARGE ELEVATION (FT)	PEAK DISCHARGE TIME (HR)	PEAK DISCHARGE RATE (CFS)	PEAK DISCHARGE RATE (CSM)
ALTERNATE 1 STORM 1														
STRUCTURE	1	RUNOFF	0.08	2	2	0.25	0.0	3.60	24.00	1.79	---	12.35	56.38	721.9
STRUCTURE	1	RUNOFF	0.06	2	2	0.25	0.0	3.60	24.00	2.18	---	12.15	72.79	1135.5
STRUCTURE	1	ADDHYD	0.14	2	2	0.25	0.0	3.60	24.00	1.97	684.79	12.23	123.28	867.0
STRUCTURE	1	RUNOFF	0.07	2	2	0.25	0.0	3.60	24.00	1.02	---	12.02	52.34	778.9
STRUCTURE	1	ADDHYD	0.21	2	2	0.25	0.0	3.60	24.00	1.66	685.31	12.13	149.62	714.5
STRUCTURE	1	RUNOFF	0.19	2	2	0.25	0.0	3.60	24.00	3.41	---	11.98	480.45	2562.4
STRUCTURE	1	ADDHYD	0.40	2	2	0.25	0.0	3.60	24.00	2.49	693.41	12.00	621.08	1564.8
STRUCTURE	1	RESVOR	0.40	2	2	0.25	0.0	3.60	24.00	0.99	681.45	24.10	5.14	13.0
ALTERNATE 1 STORM 2														
STRUCTURE	1	RUNOFF	0.08	2	2	0.25	0.0	4.20	24.00	2.29	---	12.35	72.65	930.3
STRUCTURE	1	RUNOFF	0.06	2	2	0.25	0.0	4.20	24.00	2.72	---	12.15	90.33	1409.1
STRUCTURE	1	ADDHYD	0.14	2	2	0.25	0.0	4.20	24.00	2.49	685.42	12.23	155.55	1093.9
STRUCTURE	1	RUNOFF	0.07	2	2	0.25	0.0	4.20	24.00	1.39	---	12.02	73.91	1099.9
STRUCTURE	1	ADDHYD	0.21	2	2	0.25	0.0	4.20	24.00	2.13	686.32	12.11	204.56	976.9
STRUCTURE	1	RUNOFF	0.19	2	2	0.25	0.0	4.20	24.00	3.98	---	11.98	560.53	2989.5
STRUCTURE	1	ADDHYD	0.40	2	2	0.25	0.0	4.20	24.00	3.01	695.57	12.00	747.76	1884.0
STRUCTURE	1	RESVOR	0.40	2	2	0.25	0.0	4.20	24.00	1.27	681.54	24.07	6.71	16.9
ALTERNATE 1 STORM 3														
STRUCTURE	1	RUNOFF	0.08	2	2	0.25	0.0	6.00	24.00	3.89	---	12.34	123.54	1581.8
STRUCTURE	1	RUNOFF	0.06	2	2	0.25	0.0	6.00	24.00	4.40	---	12.13	143.55	2239.5
STRUCTURE	1	ADDHYD	0.14	2	2	0.25	0.0	6.00	24.00	4.12	687.17	12.23	254.86	1792.3
STRUCTURE	1	RUNOFF	0.07	2	2	0.25	0.0	6.00	24.00	2.66	---	12.01	146.10	2174.2
STRUCTURE	1	ADDHYD	0.21	2	2	0.25	0.0	6.00	24.00	3.65	688.95	12.09	359.38	1716.2
STRUCTURE	1	RUNOFF	0.19	2	2	0.25	0.0	6.00	24.00	5.69	---	11.98	800.75	4270.7
STRUCTURE	1	ADDHYD	0.40	2	2	0.25	0.0	6.00	24.00	4.61	702.22	12.00	1138.09	2867.5
STRUCTURE	1	RESVOR	0.40	2	2	0.25	0.0	6.00	24.00	2.22	681.81	23.99	12.25	30.9
STRUCTURE	1	RUNOFF	0.08	6	2	0.25	0.0	23.50	6.00	20.89	---	2.77	607.69	7781.0
STRUCTURE	1	RUNOFF	0.06	6	2	0.25	0.0	23.50	6.00	21.61	---	2.53	642.74	10027.2
STRUCTURE	1	ADDHYD	0.14	6	2	0.25	0.0	23.50	6.00	21.21	702.77	2.62	1170.41	8230.7
STRUCTURE	1	RUNOFF	0.07	6	2	0.25	0.0	23.50	6.00	18.91	---	2.43	692.36	10303.0
STRUCTURE	1	ADDHYD	0.21	6	2	0.25	0.0	23.50	6.00	20.47	713.36	2.53	1792.01	8557.8
STRUCTURE	1	RUNOFF	0.19	6	2	0.25	0.0	23.50	6.00	23.65	---	2.33	2216.15	11819.5

SUMMARY TABLE 1 - SELECTED RESULTS OF STANDARD AND EXECUTIVE CONTROL INSTRUCTIONS IN THE ORDER PERFORMED
(A STAR(*) AFTER THE PEAK DISCHARGE TIME AND RATE (CFS) VALUES INDICATES A FLAT TOP HYDROGRAPH.)

SECTION/ STRUCTURE ID	STANDARD CONTROL OPERATION	DRAINAGE AREA (SQ MI)	RAIN TABLE =	ANTEC MOIST COND	MAIN TIME INCREM (HR)	PRECIPITATION BEGIN (HR)	PRECIPITATION AMOUNT (IN)	PRECIPITATION DURATION (HR)	RUNOFF AMOUNT (IN)	PEAK DISCHARGE ELEVATION (FT)	PEAK DISCHARGE TIME (HR)	PEAK DISCHARGE RATE (CFS)	PEAK DISCHARGE RATE (CSM)
ALTERNATE 1 STORM 3													
STRUCTURE 1	ADDHYD	0.40	6	2	0.25	0.0	23.50	6.00	21.94	746.61	2.41	3743.86	9432.8
STRUCTURE 1	RESVOR	0.40	6	2	0.25	0.0	23.50	6.00	15.92	684.82	6.33	124.92	314.7

APPENDIX C

LAKE SEDIMENT ANALYSIS

Procedures and Methods

Bottom sediments from Lake Isabelle were sampled and analyzed to determine the spoils disposal requirements of the sediments should they be removed by hydraulic dredging.

Five surface sediment samples were collected in five random locations on Lake Isabelle. The sediment samples were then combined one part sediment to three parts lake water to replicate hydraulic dredging spoils in an undewatered condition. These sediment-water mixtures were then thoroughly agitated and used in the following tests:

Test No. 1:

Agitated sediment water mixtures from each of the five sampling sites were deposited into separate 2.5 gallon aquaria. The aquaria were 15 cm deep by 30 cm wide. The depth of the sediment-water mixture was 20 cm. The height of the coarse suspended sediment above the bottom of the aquaria was then observed at regular intervals to determine settling rates. A tabulation of these results are shown on the attached table.

Test No. 2:

An agitated sediment-water sample from site No. 1 was deposited into a 2.25 inch inside diameter graduated cylinder. The depth of the sediment-water mixture in the cylinder was 14.5 inches. The height of the coarse suspended sediment above the bottom of the cylinder was then observed at regular intervals to determine settling rates. A tabulation of those results is shown on the attached table.

Test No. 3:

An agitated sediment-water sample from site No. 1 was deposited into a glass beaker 4.25 inches in diameter. The depth of the sediment-water mixture in the beaker was 5 inches. The height of the coarse suspended sediment above the bottom of the cylinder was recorded at regular intervals to determine settling rates. A tabulation of these results is shown on the attached table.

RESULTS

The coarse suspended sediments that, at the start of the test were fully suspended throughout the water column, settled down to the bottom four-tenths of the water column within 118 hours or less (five days). It is recommended that disposal basins be constructed so that dredging spoils can be deposited in these basins and allowed to remain undisturbed for at least a five day period prior to discharging the supernatant.

LAKE ISABELLE SEDIMENT SETTLING TEST NO. 1

Time (hrs) since Settling Time (hrs)	Height of Coarse Suspended Sediment Above Bottom of 2.5 gallon aquarium* (cm) Site 1	Site 2	Site 3	Site 4	Site 5
0	20	20	20	20	20
.1	10.7	10.8	12.8	13.5	18.1
.2	9.5	9.5	10.6	11.0	17.0
.3	9.1	9.1	10.0	10.6	16.5
.5	8.6	8.7	9.5	10.0	15.5
.8	8.0	8.2	8.7	9.1	14.0
1.3	7.5	7.9	8.0	8.5	12.7
2.3	7.0	7.5	7.5	7.9	11.3
3.3	6.8	7.5	7.3	7.6	10.8
18.3	6.0	7.0	6.5	7.0	8.5
114.0	6.0	7.0	6.5	7.0	8.0
**138	5.9	6.9	6.3	6.9	7.9
186.0	5.8	6.9	6.3	6.9	7.9
330	5.8	6.8	6.2	6.8	7.8
450	5.7	6.8	6.1	6.5	7.5

*Aquarium dimensions 20 cm high < 15 cm deep x 30 cm wide.

**Sample of supernatant collected.

LAKE ISABELLE SEDIMENT SETTLING TEST NO. 2

Settling Time (hrs)	Height of Coarse Suspended Sediment* Above Bottom of Graduated Cylinder** (inches)
0.0	14.5
.1	11.7
.2	9.8
.3	8.4
.4	7.8
.5	7.4
1.0	6.5
1.5	6.1
2.0	5.8
3.0	5.5
4.0	5.4
5.0	5.2
6.0	5.1
7.0	5.0
23.0	4.7
144	4.6
456	4.5

*Sediment obtained from Site No. 1.

**Graduated cylinder volume = 1000 ml,
dimensions = 2.25 inches inside diameter - X 14.5" high.

Depth/Area ratio: 3.63.

LAKE ISABELLE SEDIMENT SETTLING TEST NO. 3

Settling Time (hrs)	Height of Coarse Suspended Sediment* Above Bottom of 1000 ml Glass Beaker**
0	5.0
.1	4.75
.2	4.7
.3	4.6
.8	4.1
1.3	3.7
1.8	3.4
2.3	3.2
3.3	2.95
4.0	2.75
5.3	2.6
6.3	2.5
6.8	2.4
22.8	2.0
46	2.0
70	1.9
118	1.8
237	1.8
357	1.8

*Sediment obtained from Site No. 1

**Glass beaker: 4.25 inches in diameter X 5 inches high.