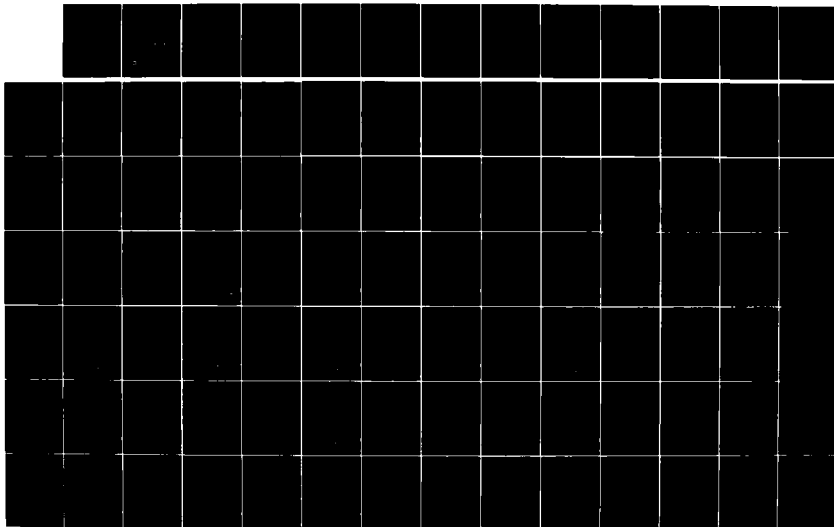


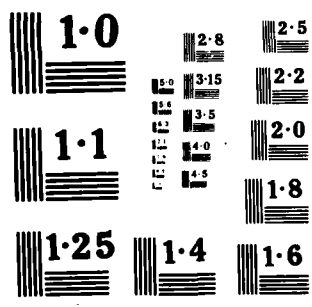
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**GRAND RIVER
BOWMAN-HALEY PROJECT
NORTH DAKOTA**

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**CONSTRUCTION FOUNDATION REPORT
BOWMAN-HALEY DAM
MISSOURI RIVER BASIN, NORTH DAKOTA**

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**CONSTRUCTION FOUNDATION REPORT
BOWMAN-HALEY DAM
MISSOURI RIVER BASIN, NORTH DAKOTA**

CHAPTER 1. - INTRODUCTION

1.1 LOCATION AND GENERAL DESCRIPTION OF PROJECT: The Bowman-Haley Project is located on the north fork of the Grand River in a sparsely settled area in southwestern North Dakota. The north fork basin is bounded by the Little Missouri River on the west and north. Other Grand River tributaries bound the basin to the east and south. The project is about 6 miles upstream (west) of the town of Haley, North Dakota. The geographic location of the project is shown on Plate 1. The project layout is shown on Plate 2.

The following tabulation summarizes pertinent data for the project's structure, the reservoir, and flood design:

Drainage Area

Above Bowman-Haley Damsite - 471 square miles.

Reservoir Area

	<u>El., ft. m.s.l.</u>	<u>Acres</u>
Top of Design Pool	2789.0	8130
Top of Controlled Storage	2781.0	6050
Top of Flood Control Pool	2777.0	5170
Top of 5-year Freq. Flood Control Pool	2758.3	2200
Top of Multi-purpose Pool	2755.0	1750

Storage Capacity

	<u>Acre-Feet</u>
Total @ 2789 m.s.l.	171,838
Gross Controlled Storage @ 2781.00	113,940
Flood Control @ Spillway Crest of 2777.0 m.s.l.	92,980
Multi-purpose	19,780
Sediment reserve	4,280

Elevations

	<u>Feet, m.s.l.</u>
Top of Dam	2794.0
Multi-purpose Pool	2755.0
Maximum Pool	2789.0
Emergency Spillway Crest	2777.0
Top of Fuse Plug	2781.0

Dam

Type	Rolled Earth Fill
Maximum height above River	79.0 feet
Crest Length	5,730 feet
Fill Quantity	1,750,000 Cu. Yds.

Emergency Spillway

Type	Uncontrolled notch
Bottom Width	650 feet
Side Slopes	1 on 3
Crest Elevation	2,777 ft., m.s.l.
Top of Fuse Plug	2,781 ft., m.s.l.

Service Spillway

Type	Uncontrolled morning glory
Throat diameter	9.0 feet
Conduit diameter	10 feet
Conduit length	341 feet
Crest elevation	2,755 ft., m.s.l.
Upstream invert elevation (P.T.)	2,720.51 ft., m.s.l.
Downstream invert elevation	2,712.0 ft., m.s.l.
Capacity, Pool El. 2773	2,555 c.f.s.
Capacity, Pool El. 2781	2,900 c.f.s.

Stilling Basin

Width	25 feet
Length - Drop Section	57 feet
Length - Basin	59 feet
Floor Elevation	2,700 ft., m.s.l.

Outlet Works

Type	Wet well forebay; gate control in dry well; discharge into spillway conduit
Conduit diameter	30 inches
Capacity, Multi-purpose pool	140 c.f.s.
Control	30-inch gate valve
Trashrack Invert Elevation	2,740 ft., m.s.l.

1.2 AUTHORITY: The project was authorized by the Flood Control Act of 1962, H.D. 574/87/2, for the purpose of flood control, municipal water supply, general recreation and fish and wildlife recreation. Full monetary authorization for the project was provided by the act which authorized the project.

1.3 PURPOSE OF REPORT: This report has been prepared in accordance with requirements set forth in Regulation No. 1110-1-1801, Engineering and Design Construction Foundations Reports, Office, Chief of Engineers dated 14 January 1972. The purpose of the report is to compile a record of the foundation conditions encountered for the various structures comprising the Bowman-Haley Project. Included are pertinent data concerning the site geology, explorations, engineering characteristics of overburden and bedrock, excavation methods, foundation treatment, instrumentation and other related subjects. Also included are supplemental drawings, logs, test data and photographs. Detailed information concerning materials testing, stability analysis, and other foundation design data relating to the project are available from the numerous files of the Omaha District Office and are not repeated in this report.

1.4 PROJECT HISTORY: Initial local interest in the project was expressed at public hearings which were held at Lemmon, South Dakota (April, 1945) and Bowman, North Dakota (August, 1956) with regard to flood protection and municipal and irrigation water supply. State and local interests later excluded irrigation water supply as a requirement for the project.

1.4.1 Design Memo No. BH-1, "Hydrology" dated January 1963, was prepared by Omaha District and in February, 1964, a revised General Design Memorandum No. BH-2 was submitted by the District to higher authority. Design Memorandum No. BH-2 specified the extent and location of major features of the project. Final design for structures of the project is covered in Design Memorandum No. BH-5, October, 1964. This report covers the design of the embankment, emergency spillway, outlet works and road/utility relocations and alterations. All Design Memorandums are available in the Omaha District Office.

1.4.2 Initial borings (four) were drilled at the right bank spillway location in the Fall of 1959. In 1963, 29 additional borings were drilled for the embankment centerline, outlet works, right bank spillway and an alternate spillway location on the left bank. Boring locations are shown on Plate 4.

1.4.3 The work for the outlet works service spillway conduit was awarded on 30 June 1964; construction for the conduit started July 1964 and was completed December 1964.

1.4.4 The work for the dam and appurtenant structures (including the spillway intake structure and stilling basin), was awarded in June 1965. Construction was originally scheduled for two construction seasons. The first construction period started in August 1965 and was completed in November 1965. The second construction period began in April 1966 and ended in July 1967. A claim which alleged unanticipated rock excavation (for the spillway) resulted in the project extending into a third construction period.

1.4.5 Closure operations began on 22 August, 1966 and were essentially complete by 19 December 1966.

1.5 **CONTRACTORS:** Brezina Construction Company of Rapid City, South Dakota was the Contractor for the entire project.

1.6 **KEY RESIDENT AND DESIGN STAFF:** Mr. D. J. Nesson was the Resident Engineer at the project site. Mr. C. A. Powell was the Garrison Area Engineer. Mr. S. L. Price was Chief, Construction Div., Omaha District, and Mr. Charles L. Hipp was Chief, Engineering Division, Omaha District. Don Knight was Chief, F&M, Omaha District. Mr. L. J. Stutz, F&M, Omaha District and Mr. A. Koop, F&M, Omaha District were Project Engineer and Geologist, respectively.

CHAPTER 2. - FOUNDATION EXPLORATIONS

2.1 FOUNDATION EXPLORATIONS:

2.1.1 Investigations Prior to Construction - Including Testing: Preconstruction borings consisted of thirty-three drill holes at depths between 18 to 114 feet. Four initial borings were drilled for the right bank spillway location in the fall of 1959. Twenty-nine additional holes were drilled in 1963 along the embankment centerline, in the outlet works area, the alternative spillway location (left bank), and the right bank spillway location. Hole locations are shown on Plate 4. (Note: Holes on Plate 4 without a yearly prefix are holes drilled in 1959). Plates 5 thru 12 show subsurface conditions encountered in the bore holes.

In addition, borings for five piezometers and six lignite water pressure tests were drilled in 1963.

Drill holes 63-13, 63-19, and 63-26 thru 63-28, were drilled with a rotary drill which used a 5-3/8" double tube core barrel or Dennison barrel. The remainder of the borings were drilled by a churn drill with 4" or 6" drive barrels. Borings were drilled at varying depths into the Ludlow formation. Disturbed (jar) and moisture samples were taken from all borings at changes-of-material or 5-foot intervals. Undisturbed samples were taken from holes drilled by the rotary method. Standard penetration tests were not taken. Characteristics of the materials will be discussed under "Engineering Characteristics of Overburden and Bedrock."

2.1.2 Investigations During Construction: In 1966, 10 additional holes were drilled in the emergency spillway as general investigation holes along the centerline and for exploration to determine location of the spillway scour cutoff. Hole locations are indicated on plate 4. Strip logs of the spillway holes are shown on plates 7 and 10.

CHAPTER 3. - GEOLOGY

3.1 REGIONAL GEOLOGY: The Bowman-Haley Project lies within the unglaciated Missouri Plateau section of the Great Plains Physiographic Province. The history of this Province has been of long erosion which has resulted in residual buttes and mesas that rise 400-600 feet above the lower erosion surface. Rocks in the general project area are Paleocene continental deposits of the Ludlow formation. The Tongue River formation overlies the Ludlow at higher elevations on buttes and mesas. The overall regional dip is toward the north into the Williston basin at 10 to 20 feet per mile. The project is northeast of the Black Hills uplift area and directly east of the Cedar Creek Anticline.

3.2 SITE GEOLOGY: Plate 3 shows the geology at the site. Surface geology consists of the Ludlow formation which is thinly covered by residual soil. The Ludlow is approximately 184 feet thick and, at the site, extends from elevation 2836 to elevation 2656.

3.2.1 Physiography: The Project site consists of a rolling prairie with a dendritic drainage system which has developed on the unconsolidated sediments. The North Fork of the Grand River, Spring Creek, and their tributaries, commonly have incised meanders. Flood plains of streams are bordered by low terraces and cutoff meanders.

3.2.2 Description of Overburden: Overburden consists of thin (0-5 feet thick) residual soils which have developed on the Ludlow formation and alluvial valley deposits and consist mainly of fine sands and silty sands, along with minor amounts of lean clay that is underlain by gravelly sand, clayey gravel, and sandy gravel. A gravel terrace deposit (1-3 feet in thickness) was located beneath the left bank embankment. The gravel was removed by stripping operations.

3.2.3 Bedrock Stratigraphy: The Ludlow formation is composed of interbedded, lenticular mixtures of poorly indurated shales (classified as lean clays, sandy clays, fat clays), sandstones (classified as clayey sands, silty sands, calcareous sands), indurated sandstones (soft to hard) and lignites. Five lignites, designated as "A", "B", "C", "D", and "E" are present. The lignites serve as marker beds for correlation and as reference datum. The lignites and other bedrock units at the project are shown by profiles on plates 5 thru 12. The material above lignite "C" on the left bank is mainly stiff to very stiff sandy clay and dense clayey sands interbedded by dense, silty sands. Lignite "C" is 30 to 40 feet lower in the left bank area than the right bank. Material above lignite "C" on the right bank area consists of dense, clayey sand and stiff sandy clay. The material between lignites "C" and "A" is approximately 36 to 41 feet in thickness and consists of stiff to very stiff lean clays, sandy clays, and fat clays. Besides the lignites, the most distinct lithologic unit at the site is a green-gray dense clayey sand horizon which is between the "A" and "B" horizons. A thin (1 to 2 feet in thickness) discontinuous sandstone occurs

midway between the "A" and "B" lignites and, during the exploration phase of the project, served as an additional marker horizon.

3.2.4 Bedrock Structure, Jointing, Discontinuities: No evidence of faulting has been found in the immediate project area nor are there any discontinuities. Overall bedrock structure is best illustrated by the lignites which undulate gently over the project area but, locally, can be relatively level. No distinct bedding is apparent in the Ludlow nor are any joint patterns apparent in bedrock.

3.2.5 Bedrock Weathering: At the site, the Ludlow formation is weathered into colluvial and alluvial deposits consisting of varied mixtures of clays, sands and silts. Weathered bedrock is 5 feet or less in thickness on the abutment slopes and merges with alluvial deposits in the valley.

3.2.6 Leaching and/or Solution Activity: Neither solution nor leaching activity of the bedrock or overburden has been a problem at the project.

3.2.7 Ground Water: Ground water levels were taken in 17 of the 24 exploratory borings. Ground water levels, as encountered in the drill holes, are shown on plates 5 thru 12. Ground water was encountered in pervious floodplain deposits at approximately 5 to 10 feet above bedrock. Overall, the borings in the Ludlow formation indicated ground water levels at one or more horizons, but there did not appear to be any extensive lateral continuity of wet or saturated zones. This is very probably due to lateral changes in lithology within the Ludlow. Water was encountered in amounts which varied from moist to saturated in all lignites, but no single lignite was found to be water-bearing over an extensive area. The "A" lignite layer was water pressure tested but it did not appear that the lignite was sufficiently jointed or fractured to transmit any appreciable amount of water.

Water levels across the valley section were found to be uniform and ranged in elevation from 2713 to 2718 MSL. Water levels in the right abutment area reflect the topographic rise as ground water elevations rose from 2722.5 MSL near the valley floor to 2777.5 in the spillway area. The ground water level in the left abutment area also reflected a topographic rise to the abutment. Top-of-ground water was found to be at elevation 2735 MSL for the left abutment area.

3.3 ENGINEERING CHARACTERISTICS OF OVERBURDEN MATERIALS:

3.3.1 Overburden Materials Classified As: Lean and sandy clay (CL); clayey sand (SC); silty sand (SM); and clayey and sandy silts (ML). Atterberg limits are given in Table 1, below.

TABLE 1
ATTERBERG LIMITS - OVERBURDEN MATERIALS

<u>SOURCE</u>	<u>ATTERBERG LIMITS-RANGE</u>	<u>PREDOMINANT VALUE</u>
Left Abutment Area (includes Borrow Area)	LL 26-96 PI 0-74	33-52 (CL, ML) 4-24
Left Valley Area	LL 25-94 PI 2-70	34-47 (CL) 14-28
Right Valley Area	LL 25-73 PI 1-43	28-41 (CL, ML) 7-22
Right Abutment Area- Embankment	LL 28-70 PI 4-45	39-57 (CL, ML) 19-35
Right Abutment Area- Spillway	LL 21-74 PI 0-39	29-41 (CL, ML) 4-20

3.3.2 Five series of direct shear tests were performed on remolded embankment and undisturbed foundation material. Remolded specimens were compacted to 95 percent of maximum density with water contents 2 percent above optimum. Adopted shear strength values for overburden and embankment materials are given below in Table 2. (Coh. is in T/sq. ft.). Results of direct shear tests are given on Plates 13 thru 15.

TABLE 2
SHEAR STRENGTH VALUES

<u>Material</u>	<u>Unconsolidated Undrained (Q) Strength</u>		<u>Consolidated Undrained (R) Strength</u>		<u>Consolidated Drained (S) Strength</u>	
	<u>Tan ϕ</u>	<u>Coh.</u>	<u>Tan ϕ</u>	<u>Coh.</u>	<u>Tan ϕ</u>	<u>Coh.</u>
Embankment	0.02	0.88	0.23	0.35	0.50	0
Overburden (Lean and Fat Clay)	0.32	0.60	0.20*	0.10*	0.45	0
Clayey Sand Between "A" and "B" Lignite	0.49	1.30	0.47	2.06	0.65	0

*The alluvial clay overburden's low R strength indicated low safety factors for stability. As construction progressed, overburden was removed as indicated in contract plans or as determined in the field.

3.3.3 Triaxial compression tests were performed on remolded embankment material and undisturbed samples of foundation material.

3.3.3.1 Two series of "Q" tests were performed on sandy clay embankment material remolded to 95% of maximum density and at optimum, and 2% above optimum, moisture contents. Shear strengths were: coh. = 1.12 T/sq. ft., and $\tan \phi = 0.05$; coh. = 0.88 T/sq. ft., and $\tan \phi = 0.02$.

3.3.3.2 One series of "R" tests on material remolded to 95% of maximum density at 2% above optimum moisture indicated a shear strength coh. = 0.35 T/sq. ft. and $\tan \phi = 0.23$.

3.4 ENGINEERING CHARACTERISTICS OF BEDROCK:

3.4.1 The Ludlow formation consists of interbedded lenses of lean-clays, sandy clays, fat clays, clayey sands and silty sands and soft-to-hard thin bedded calcareous sandstones, soft shales, lignites and carbonaceous, silty clays. Sands in the Ludlow formation are generally fine grained.

3.4.2 A series of direct shear tests were performed on undisturbed foundation material. Adopted shear strength values that were used for stability computations are given below in Table 3.

TABLE 3

<u>Material</u>	<u>Unconsolidated Undrained (Q) Strength</u>		<u>Consolidated Undrained (R) Strength</u>		<u>Consolidated Drained (S) Strength</u>	
	<u>Tan ϕ</u>	<u>Coh.</u>	<u>Tan ϕ</u>	<u>Coh.</u>	<u>Tan ϕ</u>	<u>Coh.</u>
Lean and Fat Clay (Ludlow)	0.40	1.30	0.38	1.80	0	0
Clayey Sand Between "A" and "B" Lignites (Ludlow)	0.49	1.30	0.47	2.00	0.65	0

Resulting strengths from four series of "Q" tests and four series of "R" tests on bedrock material were:

<u>Type Test</u>	<u>Material</u>	<u>Cohesion T/sq. ft.</u>	<u>Tan ϕ</u>
"Q"	Clayey Sand (Ludlow)	1.3	0.49
"Q"	Lean Clay (Ludlow)	0.7	0.56
"Q"	Lean Clay (Ludlow)	2.9	0.39
"R"	Fat Clay (Ludlow)	1.8	0.38

The result of tests on the Ludlow formation are shown on Plates 13 and 14.

3.4.3 Direct shear tests on clayey sands of the Ludlow formation show no cohesion and have a high friction angle ($\tan \phi = 0.85$). Fat clays have some cohesion (0.15 TSF) and a lower friction angle ($\tan \phi = 0.45$) than the sands. Consolidated, drained, design strengths were taken from these tests.

3.4.3.1 For the unconfined compression tests, the Ludlow sands have an average unconfined strength of 1.56 TSF. The test results are very consistant for the sands. Ludlow sands all failed at approximately 2% axial strain.

3.4.3.2 Two types of lean clay were tested for the "Q" triaxial tests. Tangents of ϕ were 0.56 and 0.39 for the samples and C equaled 0.7 TSF and 2.9 TSF respectively. Foundation design values were a compromise between the two clay test values. "Q" tests on the Ludlow clayey sand gave a $\tan \phi = 0.49$ and $C = 1.3$ TSF. These values were used for foundation designs.

3.4.3.3 "R" test results from Plate 14 indicate that one set was unsuccessful on Ludlow clays. The other set gave peak strength at values of, $\tan \phi = 0.38$. Samples in the second set all failed at 4 to 5% axial strains. Ultimate strengths were: For the clay, $\tan \phi = 0.38$; for the sand, $\tan \phi = 0.47$ and $C = 2.0$ TSF. The ultimate strength values were used for design.

3.5 UNUSUAL OR UNANTICIPATED GEOLOGIC CONDITIONS ENCOUNTERED DURING CONSTRUCTION:

3.5.1 In June 1967, the Contractor, Brezina Construction Company, filed a changed conditions claim related to rock quantities, bedding, and lithology encountered during excavation of the spillway.

3.5.1.1 While excavating the spillway, the Contractor claimed that he encountered extensive areas of unanticipated limestone boulders which extended to depths of 10-12 feet - "like eggs in a nest." The total claim was for \$700,000. The Government's position was that contract drawings accurately portrayed subsurface conditions. The Contractor agreed that he expected to encounter rock; however, he could not anticipate the "massiveness" or position of the rock.

3.5.1.2 The Government allowed the Contractor to utilize the rock boulders encountered in the spillway for rip-rap. The Contractor claimed that excavation of the spillway rock for rip-rap stockpiling caused him delays in embankment closure and excavation of the outlet works. To this contention, the Government maintained that it was the locations at which the Contractor chose to stockpile the spillway rock which caused construction delays-rock was stockpiled in such a manner that it interfered with the movement of equipment and improper equipment was used for excavation.

3.5.1.3 In August 1967, the District Engineer determined that the Contractor had encountered a changed condition, and had a claim.

3.5.1.4 Original exploration for the spillway consisted of four drill holes (DH-1 - DH-4) drilled in 1959 and two drilled in 1963 (DH63-16 and 63-9). Hole locations are shown on Plate 4, and subsurface conditions encountered by the bore holes are shown on Plates 5, 6, 8 and 10. The claim was not related to the extent of sufficiency of exploration, but to "rock" as interpreted by the Contractor from the drill hole logs.

3.5.2 A unique foundation condition for the Bowman-Haley Project exists in the form of lignites which underlay the reservoir and embankment. Bore hole profiles which indicate lignite horizons are shown on Plates 5 thru 12.

3.5.2.1 Seepage under the embankment has occurred along Lignite "A". Seepage surfaces along the sides of the stilling basin and is directly related to reservoir levels. No structures have been damaged by the seepage nor is it presently considered a serious problem for the project structures. Seepage along Lignite "A" will be further discussed later in this report under "Foundation Instrumentation," "Possible Future Problems," and Chapter 4. The relationship of Lignite "A" to the embankment is shown on plates 25, 26 and 27.

CHAPTER 4. - SPECIAL DESIGN CONSIDERATIONS

4.1 EMBANKMENT FOUNDATION CUTOFF TRENCH:

4.1.1 Approximately an 80 foot (width) of low "R" shear strength alluvium clay was removed from the foundation from Station 37+00 to Station 42+50 for foundation stability. Underseepage control is provided in the valley section by a cutoff trench from Station 29+00 to Station 59+00. This portion of the trench is through alluvial sands and gravels and extends to the clayey sand horizon which underlies the "A" lignite (Plates 5, 6, and 9). The clayey sand is considered impervious with 33% to 44% of the material passing the #200 sieve and horizontal and vertical coefficients of permeability of 5.5×10^{-7} and 5.8×10^{-7} cm/sec. respectively. The trench has a 25 foot bottom width in the valley section, 1:1 side slopes (Plate 19), and narrows to 5'-8' widths on abutment slopes. Trench backfill is impervious material that consists of lean clays, clayey silts, sandy clays or silts.

The bottom of flat or gently sloping portions of the excavated trench was scarified to a depth of six inches and one initial lift of impervious material was compacted on the trench bottom with sheeps foot tamping rollers and power and hand tampers. The impervious fill was then brought up in 4"-6" lifts.

4.1.2 A shallower (5 to 15 feet in depth) portion of the cutoff trench extends from Station 59+00 to Station 70+00. This portion of the trench extends through more gravelly and sandy material above the "C" and "E" lignites, but does not penetrate any of the lignites.

4.1.3 From Station 29+00 to Station 25+80, the trench extends upslope at a depth of five feet. The trench intercepts the "C" lignite at Station 27+50. From Station 25+80 to Station 27+50, the trench bottoms in silty sands and sandy clays. From Station 27+50 to Station 29+00, the trench generally bottoms in lean and fat clays.

4.1.3.1 For the portion of the trench between Station 29+00 and Station 25+80, loose material was removed from the existing slope and the trench excavated in notches up and down slope. Fill was placed and rolled to bind with natural material.

A considerable amount of borrow used for the impervious fill was very dry and required watering, discing, and blading with the result that lifts were restricted to 4"-6" in thickness to allow adequate mixing by discs and blades.

4.1.4 Laboratory and field compaction tests for the cutoff trench impervious fill are given below on Table 4.

TABLE 4
BONHAM-BALLET DAM
PERMANENT CUTOFF TRENCH
SUMMARY OF COMPACTION TEST RESULTS

DATE TESTED	TEST NUMBER	STATION	RANGE	ELEVATION	TYPE OF ROLLER	NO. OF PASSES	TYPE OF DENSITY TEST	LAB DATA		FIELD DATA			
								MAX. DENSITY	OPT. M	WET DENSITY	X M	X COMP.	CLASS
Oct 9, 1965	48	38+25	Centerline	2714	Sheeps Foot	6	Balloon	103.4	20.5	98.5	22.2	95.5	CL, Sdy, Si
Oct 13, 1965	57	36+00	Centerline	2709	Sheeps Foot	6	Balloon	103.4	20.5	100.6	22.6	97.3	CL, Sdy, Si
Oct 13, 1965	59	34+75	Centerline	2712	Sheeps Foot	-	Balloon	103.4	20.5	92.0	24.3	94.8	CL, Sdy, Si
Oct 14, 1965	62	34+25	Centerline	2718	Sheeps Foot	6+	Balloon	103.4	20.5	102.3	23.3	98.9	CL, Sdy, Si
Oct 14, 1965	63	32+75	Centerline	2720	Sheeps Foot	6+	Balloon	103.4	20.5	102.3	23.0	98.9	CL, Sdy, Si
Oct 14, 1965	64	40+25	8' Rt. Center	2708	Sheeps Foot	6	Sand	103.4	20.5	98.0	22.9	94.8	CL, Sdy, Si
Oct 14, 1965	65	41+50	Center Line	2707	Sheeps Foot	6	Sand	103.4	20.5	102.1	20.9	98.7	CL, Sdy, Si
Oct 14, 1965	66	39+00	5' Lt. Center	2714	Sheeps Foot	6	Sand	103.4	20.5	98.1	20.7	94.9	CL, Sdy, Si
Oct 15, 1965	67	40+00	Center Line	2713	Sheeps Foot	6	Balloon	103.4	20.5	99.6	18.5	96.3	CL, Sdy, Si
Oct 15, 1965	68	38+10	Centerline	2716	Sheeps Foot	6+	Balloon	103.4	20.5	103.1	18.3	99.7	CL, Sdy, Si
Oct 15, 1965	69	52+50	6' Rt. Center	2712	Sheeps Foot	6	Sand	103.7	12.5	103.4	18.5	99.7	CL, Sdy, Si
Oct 15, 1965	70	56+00	8' Lt. Center	2716	Sheeps Foot	6	Sand	103.7	12.5	101.0	19.0	97.3	CL, Sdy, Si
Oct 16, 1965	71	37+10	15' Lt. Center	2719	Sheeps Foot	6+	Sand	103.4	20.5	103.3	16.5	99.9	CL, Sdy, Si
Oct 16, 1965	72	56+60	5' Lt. Center	2710	Sheeps Foot	6	Sand	104.4	19.8	104.1	20.9	99.7	CL, Sdy, Si
Oct 16, 1965	74	31+40	12' Rt. Center	2721	Sheeps Foot	6	Sand	104.4	19.8	99.2	20.8	95.9	CL, Sdy, Si
Oct 17, 1965	75	49+50	3' Rt. Center	2712	Sheeps Foot	6+	Sand	103.7	12.5	107.6	18.3	103.8	CL, Sdy, Si
Oct 17, 1965	76	56+50	10' Lt. Center	2720	Sheeps Foot	6+	Balloon	103.7	12.5	107.2	18.1	103.5	CL, Sdy, Si
Oct 17, 1965	77	47+80	Centerline	2708	Sheeps Foot	6	Sand	103.7	12.5	104.2	20.0	100.5	CL, Sdy, Si
Oct 18, 1965	80	30+50	Centerline	2727	Sheeps Foot	6	Balloon	103.7	12.5	104.1	12.4	93.9	SM
Oct 18, 1965	81	54+00	Centerline	2713	Sheeps Foot	6+	Balloon	103.7	12.5	104.7	18.9	101.0	CL, Sdy, Si
Oct 18, 1965	84	29+50	15' Lt. Center	2731	Sheeps Foot	6	Balloon	103.4	20.5	102.2	16.9	98.8	CL, Sdy, Si
Oct 18, 1965	85	31+20	15' Lt. Center	2728	Sheeps Foot	6	Sand	103.4	20.5	100.7	17.8	97.4	CL, Sdy, Si
Oct 18, 1965	86	35+00	10' Lt. Center	2727	Sheeps Foot	6	Sand	103.4	20.5	105.9	18.1	102.4	CL, Sdy, Si
Oct 18, 1965	87	33+10	20' Rt. Center	2729	Sheeps Foot	6	Balloon	103.4	20.5	101.2	18.3	97.9	CL, Sdy, Si
Oct 19, 1965	88	30+00	20' Rt. Center	2734	Sheeps Foot	6	Balloon	103.4	20.5	100.8	19.9	97.5	CL, Sdy, Si
Oct 20, 1965	95	29+40	10' Rt. Center	2740	Sheeps Foot	6	Balloon	110.9	16.6	105.3	13.9	95.0	SM
Oct 20, 1965	96	46+00	Centerline	2717	Sheeps Foot	6	Balloon	106.9	19.6	96.4	23.8	90.2	CL
Oct 20, 1965	97	32+50	35' Rt. Center	2725	Sheeps Foot	6	Balloon	103.4	20.5	101.3	15.9	98.0	CL, Sdy, Si

TABLE 4 (Cont'd)
 BOWMAN-SALEY DAM
 IMMEDIATE CUTOFF TRENCH
 SUMMARY OF COMPACTION TEST RESULTS

DATE TESTED	TEST NUMBER	STATION	RANGE	ELEVATION	TYPE OF ROLLER	NO. OF PASSES	TYPE OF DENSITY TEST	LAB DATA		FIELD DATA				CLASS
								MAX. DENSITY	OPT. M	WET DENSITY	γ _m	γ _{comp.}		
Oct 20, 1965	98	47+90	10' Rt. Center	2715	Sheeps Foot	6	Balloon	106.9	19.6	96.6	23.2	90.4		CL
Oct 20, 1965	99	34+10	10' Lt. Center	2718	Sheeps Foot	6	Balloon	103.4	20.5	105.5	17.7	102.0		CL, Sdy, Si
Oct 20, 1965	100	31+20	35' Rt. Center	2735	Sheeps Foot	6	Balloon	103.4	20.5	104.1	14.8	100.7		CL, Sdy, Si
Oct 21, 1965	102	50+00	10' Lt. Center	2719	Sheeps Foot	6	Proctor	103.4	20.5	100.0	25.4	93.5		CL, Sdy, Si
Oct 21, 1965	103	42+45	15' Rt. Center	2713	Sheeps Foot	6	Balloon	103.4	20.5	99.0	12.8	95.7		CL, Sdy, Si
Oct 21, 1965	104	36+75	80' Rt. Center	2727	Sheeps Foot	6	Balloon	103.4	20.5	107.2	14.5	103.7		CL, Sdy, Si
Oct 21, 1965	105	47+85	20' Rt. Center	2719	Sheeps Foot	6	Balloon	106.9	19.6	99.3	23.6	92.9		CL, Sdy, Si
Oct 22, 1965	108	55+83	10' Lt. Center	2721	Sheeps Foot	6	Balloon	106.9	19.6	110.1	16.7	103.0		CL
Oct 23, 1965	112	38+25	25' Lt. Center	2728	Sheeps Foot	6+	Balloon	106.9	19.6	111.0	12.7	107.4		CL, Sdy, Si
Oct 23, 1965	114	41+00	Centerline	2716	Sheeps Foot	6	Balloon	110.9	16.6	108.8	15.4	98.1		SM
Oct 23, 1965	115	39+00	170' Rt. Center	2728	Sheeps Foot	6	Balloon	103.4	20.5	103.3	12.3	99.9		CL, Sdy, Si
Oct 26, 1965	119	42+50	20' Rt. Center	2716	Sheeps Foot	6+	Balloon	103.4	20.5	102.7	19.3	99.3		CL, Sdy, Si
Oct 26, 1965	121	51+60	15' Lt. Center	2734	Sheeps Foot	6	Balloon	106.9	19.6	101.8	22.0	95.2		CL
Oct 26, 1965	122	41+90	5' Rt. Center	2723	Sheeps Foot	6+	Balloon	103.4	20.5	101.0	15.6	97.7		CL, Sdy, Si
Oct 26, 1965	123	58+80	4' Rt. Center	2720	Sheeps Foot	6	Balloon	106.9	19.6	102.9	22.9	96.3		CL
Oct 27, 1965	126	58+25	15' Rt. Center	2728	Sheeps Foot	6	Balloon	106.9	19.6	88.8	25.9	83.3		CL
Oct 28, 1965	128	42+40	15' Lt. Center	2728	Sheeps Foot	6	Balloon	106.9	19.6	100.6	16.7	94.1		CL
Oct 29, 1965	131	58+00	30' Lt. Center	2735	Sheeps Foot	6+	Balloon	103.4	20.5	94.0	24.7	90.1		CL, Sdy, Si
Oct 29, 1965	133A	58+90	25' Lt. Center	2740	Sheeps Foot	6+	Balloon	106.9	19.6	101.8	21.0	95.2		CL
Oct 29, 1965	134A	56+85	20' Rt. Center	2735	Sheeps Foot	6+	Balloon	106.9	19.6	100.5	23.7	94.0		CL
Oct 30, 1965	136	50+00	10' Lt. Center	2722	Sheeps Foot	6	Balloon	106.9	19.6	100.6	21.0	94.1		CL
Nov 1, 1965	137	53+75	25' Lt. Center	2727	Sheeps Foot	6+	Balloon	106.9	19.6	98.3	22.7	92.0		CL
Nov 2, 1965	139	53+00	30' Lt. Center	2727	Sheeps Foot	6	Balloon	106.9	19.6	99.1	25.3	92.7		CL
Nov 2, 1965	140	36+50	35' Lt. Center	2732	Sheeps Foot	6+	Balloon	103.4	20.5	109.7	15.5	106.1		CL, Sdy, Si
Nov 2, 1965	141	48+95	15' Lt. Center	2725	Sheeps Foot	6+	Balloon	103.4	20.5	105.2	14.9	101.7		CL, Sdy, Si
Nov 3, 1965	147	49+70	30' Lt. Center	2726	Sheeps Foot	6+	Balloon	106.9	19.6	104.0	19.3	97.3		CL
Nov 3, 1965	149	36+30	20' Rt. Center	2732	Sheeps Foot	6	Balloon	113.1	15.6	104.8	17.3	92.5		CL, Sdy

TABLE 4 (Cont'd)
 ROMAN-HALTY DAN
 SPRINKLER CUTOFF TRENCH
 SUMMARY OF COMPACTION TEST RESULTS

								LAB DATA		FIELD DATA			
DATE TESTED	TEST NUMBER	STATION	RANGE	ELEVATION	TYPE OF ROLLER	NO. OF PASSES	TYPE OF DENSITY TEST	MAX. DENSITY	OPT. M	WET DENSITY	X M	X COMP.	CLASS
Nov 4, 1965	150	46+75	35' Lt. Center	2728	Sheeps Foot	6	Balloon	113.1	15.6	104.4	18.5	92.3	CL, Sdy
Nov 9, 1965	165	54+50	30' Rt. Center	2734	Sheeps Foot	6+	Balloon	106.9	19.6	105.8	21.5	99.0	CL
Nov 9, 1965	167	54+00	10" Rt. Center	2730	Sheeps Foot	6+	Balloon	102.7	17.5	108.0	16.2	105.2	ML, Sdy
Nov 10, 1965	170	51+75	Centerline	2729	Sheeps Foot	3	Balloon	102.7	17.5	96.0	14.0	93.2	ML, Sdy
Nov 10, 1965	171	46+95	35' Rt. Center	2725	Sheeps Foot	6+	Balloon	103.4	20.5	102.2	21.1	99.0	CL, Sdy, Si
Nov 11, 1965	174	46+50	45' Rt. Center	2729	Sheeps Foot	6+	Balloon	103.4	20.5	102.7	17.6	99.2	CL, Sdy, Si
Nov 11, 1965	175	48+50	Centerline	2730	Sheeps Foot	6+	Balloon	102.7	17.5	116.1	15.8	113.0	ML, Sdy

4.2 PERMEABILITY OF LIGNITES THAT UNDERLIE THE EMBANKMENT:

4.2.1 It was recognized early in the project that lignites represented potential seepage zones. To verify whether or not a seepage problem along the lignites could occur, a representative lignite (the "A" lignite) was pressure tested by water.

4.2.1.1 The "A" lignite was selected for testing because it was considered to be representative of all the lignites and was thick enough (approx. 3 feet) to provide a satisfactory test. In preparation for the water pressure tests, a series of 5 piezometers were installed on the right abutment - two upstream and two downstream - from the proposed embankment centerline and one on the centerline. The holes were drilled to the bottom of Lignite "A". Prior to setting the well points, grout was tremied to the bottom of each hole, forming a plug to seal off the underlying beds. The well points were then installed within the vertical limits of Lignite "A", with a bentonite plug at the top of the lignite to seal off the overlying beds. Upon completion of the piezometer installations, the water levels in Lignite "A", when present, were measured prior to running the pressure tests. Three separate water pressure test holes were drilled, each to the bottom of Lignite "A". In preparing the test holes, grout was tremied to the bottom to seal off the underlying beds. In testing each hole, a single packer assembly was used to seal off the overlying beds. The lignite bed, isolated from the top and bottom, was then subjected to a water pressure gage reading at the surface equal to 1 pound of pressure for each foot of depth in the hole. This water pressure, plus the weight of the column of water in the drill pipe, was the maximum applied to the lignite unit. During the test period, records were kept of the applied pressure and the water take per unit of time, and also water levels in the piezometers, if present, were recorded at regular intervals. Prior to running the series of tests on the right bank, a similar testing program was proposed for the left abutment, but in light of the negligible water take in Lignite "A" on the right bank, the left bank testing program was modified. Piezometers were not installed on the left bank; however, 3 drill holes were pressure tested. The tests on Lignite "A" confirmed the results obtained from the right bank in that Lignite "A" did not take appreciable amounts of water. From the results of the tests it appeared that Lignite "A", at the six locations, was not jointed or fractured sufficiently to pass any appreciable amount of water.

4.2.1.2 Water pressure tests were performed on the "A" lignite vein in each abutment to determine the degree of cracking, apparent permeability, and possible need for grouting. The thickness of the "A" lignite as determined from the six pressure test holes varied from 2.5 to 2.8 feet. The lignite beds were the only layers in the abutments with a water bearing potential as the remaining foundation material below the elevation of the conservation pool was indicated to be impervious. Pressure test hole T-4 was the only hole that showed even a nominal water take 1.28 - gpm with a gage pressure at the ground surface of 24 psi. This pressure, plus the column of water in the hole, would result in a water head at the elevation of the lignite layer of 80 feet. The other five holes had an average water take of 0.25 gpm under an average gage pressure of 35 psi, equal to a water head of over 100 feet. The

piezometers installed in the "A" lignite did not show any change in water level during the water pressure tests. The tests indicated that even under a head of water twice as high as would result with the pool at conservation level, the lignite would not pass an appreciable amount of water, and that grouting of the lignite was not required. The results were consistent with experience elsewhere with thin lignites of the Fort Union group - such as the 2-foot-thick abutment lignites at Garrison Dam where very few holes would accept grout. Table 5 below summarizes Pressure Test results. Test hole and piezometer locations are shown on Plate 4.

TABLE 5
WATER PRESSURE TEST RESULTS
BOWMAN-HALEY DAM
September 1963

(a) "A" Lignite Test, Hole T-1.

<u>Gage Pressure</u>	<u>Time</u>	<u>Take (Total)</u>	<u>Take (gpm)</u>
10 psi	--	---	---
35 psi	30 min.	3.4 gal.	0.11 gpm
40 psi	30 min.	2.9 gal.	0.10 gpm
45 psi	30 min.	5.6 gal.	0.19 gpm
50 psi	30 min.	7.5 gal.	0.25 gpm

Piezometer reactions: Test Hole T-1.
P-1, 500' upstream, 1 foot rise
P-4, 150' downstream, 1 foot rise

(b) "A" Lignite Test, Hole T-2A

<u>Gage Pressure</u>	<u>Time</u>	<u>Take (Total)</u>	<u>Take (gpm)</u>
32	240 min.	24.1 gal.	0.10 gpm

Piezometer reactions: Test Hole, T-2A.
Piezometers 1, 2, 3, 4, 5 - no reactions.

(c) "A" Lignite Test Holes T-3, T-4, T-5.

<u>Gage Pressure</u>	<u>Time</u>	<u>Take (Total)</u>	<u>Take (gpm)</u>
28	120 min.	Hole T-3	
		20.4 gal.	0.16 gpm
24	120 min.	Hole T-4	
		154.3 gal.	1.28 gpm
32	120 min.	Hole T-5	
		2.7 gal.	0.02 gpm

No piezometer reactions for Holes T-3, T-4, T-5 were given in the original field notes.

4.3 SPILLWAY FUSE PLUG FOUNDATION:

4.3.1 A fuse plug was constructed in the spillway. The plug is located at spillway Station 27+50 (Plate 17), and is designed to store 90 percent of the standard project flood before failing under floods of greater magnitude.

4.3.2 Drill Hole #DH-1, as shown on Plates 4 and 16, indicates a predominance of sandy clay material for the fuse plug foundation. Two 12-inch by 72-foot corrugated metal pipes are located at the base of the fuse plug at the flow line elevation of the spillway (Plate 16).

4.3.3 The original surface beneath the fuse plug was cleared and stripped to a depth of 6 inches and a 2-foot layer of compacted impervious fill was placed on the cleared foundation. Pervious fill was then placed on the impervious base of the fuse plug.

4.3.4 The spillway fuse plug is designed to store the standard project flood but to fail whenever overtopped by floods of greater magnitudes. It was felt that seepage under the fuse plug would not present a problem due to the base width of the plug and the relatively low potential head that could be expected against the plug. Plate 16 shows the fuse plug profile.

4.4 **SPILLWAY SCOUR CUTOFF:** As shown on Plate 16 and 17, a soil cement scour trench was constructed near the lower end of the spillway channel. The scour cutoff bottoms between the "C" and "D" lignites in the spillway and relies on the lignites to provide some degree of erosion control if needed. The scour cutoff trench extends approximately 12 feet below the spillway floor at Station 23+00. Plate 16 shows details of the spillway scour cutoff.

4.4.1 Material placed in the scour cutoff consisted of a combination of soil (mineral aggregate), Portland cement, and water. The soil (mineral aggregate) was obtained from local alluvial deposits and met the following gradation requirements:

<u>Sieve Size</u>	<u>% Passing (Weight)</u>
3-inch	100
#4	50-75
#40	25-50
#200	5-15

Blending sands were added when necessary to meet gradation requirements. Mixing of the soil, cement, and water was accomplished by an in-place mixing plant.

4.4.2 The cement content of the soil-cement mix ranged between a minimum of 8% to a maximum of 12%. The amount of water in the mix was restricted on the basis of over dry weight such that, at compaction, the material was at, or no more than 2% above, optimum moisture as specified by AASHTO Standard T 134-57. Haul times were restricted to 45 minutes maximum.

4.4.3 Soil-cement was placed in the trench in 6" layers and initially compacted with tamping rollers. Final compaction was by rubber-tired rollers. Compaction was to 95% of maximum density. Time between placing the 6" layers and complete compaction did not exceed 1-1/2 hours.

Bonding surfaces between the 6" layers were kept moist until the next layer of the mix was placed-either vertically or laterally. If time exceeded 4 hours between bonding layers the bonding surface was cleaned by wire brooms before placing the next layer.

CHAPTER 5. - EXCAVATION PROCEDURES FOR COMPONENT PARTS

5.1 EXCAVATION GRADES: AS-DESIGNED AND AS-BUILT: The original onsite field documentation of excavation cuts are no longer available. It is assumed that grades were excavated to profiles shown on specification drawings. It is realized that the bottom of the embankment cutoff trench probably varies slightly from the outline given on Plates 6 and 9 since the depth of excavation for the trench varied with the elevation of the "A" lignite and the "A" lignite undulates across the embankment area. The cutoff trench's bottom is below the "A" lignite.

5.2 DEWATERING:

5.2.1 As shown by photos 2 and 3 and drill holes 63-12, 63-4, 63-11, 63-3, and 63-10 (Plates 5 and 6), it was necessary to dewater the embankment cutoff trench; also, as shown by water levels for drill hole 63-18, it would have been necessary to dewater portions of the excavation for the outlet works. Details of the dewatering process are no longer available; however, photographs 2 and 3 give an indication of the general method used for the embankment cutoff trench.

5.2.2 It appears as though water levels were lowered by pumping while excavation below the "A" lignite was accomplished by bulldozers which pushed the excavated material into the ponded water. The water-earth mixture was removed by dragline bucket. Impervious fill was then placed and compacted by rollers.

5.3 OVERBURDEN EXCAVATION: Overburden was excavated by traditional bulldozer and scraper methods (photo 27). No special supporting methods were needed. Excavated overburden was used as fill for the project.

5.4 ROCK EXCAVATION: Excavation methods of the bedrock (Ludlow formation) were similar to methods used for the overburden. No drilling and blasting program was used.

5.5 SPILLWAY EXCAVATION: Spillway excavation was by conventional bulldozer and scraper methods. In addition, a power shovel was used to excavate the layer of concretionary rock encountered during spillway excavation (photo 24).

5.6 FOUNDATION PREPARATION (INCLUDES PROTECTION OF WEATHER SENSITIVE MATERIALS): Structure foundations were excavated to neat lines as shown on drawings after all unsuitable material was stripped from the surface. Prior to placing fill on flat or gently sloped areas, the foundation was scarified to a depth of 6 inches. The surface was then compacted. On steeper slopes, the slope was notched through any dried material to allow rollers to bond the fill to the slope material. Prior to placing fill, all foundation surfaces were inspected and approved by the Government. No fill was placed on any surface that was frozen or had standing water or was slushy or slippery. Work completion schedules were such that no critical surfaces were exposed during the winter months.

5.7 **SAFETY:** No special safety requirements were necessary to protect against slides or rock falls.

CHAPTER 6. - TUNNELS, SHAFTS, AND UNDERGROUND STRUCTURES

6.1 INTAKE CONDUIT: The outlet works are located in the left abutment. The excavation for the intake structure and conduit extend through the overburden and a lean clay-clayey sand horizon of the Ludlow formation (Plate 7). The bottom of the intake structure is located below the "A" lignite, and the structures are founded in the clayey sand layer between the "A" and "B" lignite. Details of the outlet works conduit are shown on Plate 22.

6.1.1 The conduit is 10 feet in diameter and consists of 14 cast-in-place monoliths that extend 341 feet between the intake structure and the stilling basin. Concrete collars were placed between all monoliths. The conduit was constructed through two contracts. The first contract involved placing 12 monoliths and the construction was completed by a second contract which placed the two remaining monoliths (those connecting to the intake structure and stilling basin). Photos 21 and 22 show methods used for casting in-place conduit inverts.

6.1.2 Excavation for the conduit was by conventional excavation methods. The conduit was cast in-place, and no unusual or unique foundation conditions were encountered during construction. The conduit foundation is the only underground structure at the project. Dewatering was necessary for construction portions of the conduit (Photo 11). Dewatering methods have been discussed in Chapter 5. Emplacement of the conduit was by the cut-and-cover method.

CHAPTER 7 - CHARACTER OF FOUNDATION

7.1 FOUNDATION SURFACE: The soil and rock units which form the foundation materials of the dam, after excavation of the cutoff trench, are shown on Plates 5 and 6. The plates indicate that generally from Station 25+00 to Station 55+00 foundation materials are mostly classified as SC. From Station 55+00 on the foundation materials are classified as CL.

7.2 Engineering characteristics of foundation soil and rock have previously been discussed under "Engineering Characteristics of overburden Material" and "Engineering Characteristics of Bedrock Material."

7.3 WATER:

7.3.1 Natural water levels at the project are shown on Plates 5 through 12. As indicated, water levels were generally below the base of the intake structure but above the bottom of portions of the cutoff trench. Portions of the cutoff trench were dewatered; however, original records with details of the dewatering program are not available.

7.4 SPECIAL OR UNUSUAL CONDITIONS: The dam is underlain by several lignite seams and seepage does occur along lignite "A." Seepage along the lignite is discussed later in this report under "Foundation Instrumentation." Water pressure tests of the lignite are discussed in paragraph 4.2.1.2.

CHAPTER 8. - FOUNDATION INSTRUMENTATION

8.1 GENERAL: Foundation instrumentation consists of seven (7) open tube piezometers, eleven (11) crest movement markers, thirty (30) conduit markers, six (6) stilling basin markers, and eight (8) intake markers. In addition, four lignite drains are used to monitor a seepage area on the left bank of the outlet channel near the stilling basin. Location of the instruments are shown on Plates 23 and 24.

8.2 PIEZOMETERS: Seven piezometers were installed in the left abutment in 1969 to monitor the piezometric gradient in the left abutment along a line of seepage through lignites. Piezometer observations are shown on Plate 23. Piezometer readings generally respond to pool fluctuations (Plates 25 through 27) and have decreased through time. This could indicate that there has been a buildup of silt along the upstream toe.

8.2.1 Seepage Through Lignites: In August 1968 (Periodic Inspection No. 1), seepage was observed to be emerging adjacent to the stilling basin at approximately elevation 2720. At the time the pool was at elevation 2749. The seepage was in or at the top of the "A" lignite layer. Several other seeps were observed at the same elevation further downstream from the stilling basin (Plate 24). Seepage was limited to the left abutment side of the outlet channel. Seepage water was clear with no evidence of piping. Seepage flow observations are shown on Plate 24A. The plate shows flow observations as indicated by four drains that had been installed earlier to monitor the seepage. In September 1982, the four older drains were replaced.

8.2.2 Overall seepage through the "A" lignite is sufficient to saturate the slope on the side of the stilling basin but is not considered dangerous to the abutment.

8.2.3 Crest Movement Markers: The location and plots of the crest movement markers are shown on Plates 28 and 29. The settlement plots show settlement at a fairly uniform rate except for marker CM-7 which has settled at a slower rate. There is slight nonuniform settlement in the area of the conduit that is not considered critical but is monitored. Maximum settlement has occurred in the closure area at Station 45+00 (CM-5) with 0.223 feet of total settlement. Crest markers indicate only minor horizontal movement and most of this is in the closure area.

8.3 CONDUIT, STILLING BASIN, AND INTAKE MARKERS: Vertical movement surveys for the structures are shown on Plate 30. Survey data indicates that only minor movement has occurred. It should be noted that the 1975 reading at Point C-13 and the 1981 reading at Point SB-5 are survey errors.

8.4 AUTOMATIC PIEZOMETER MONITORING SYSTEM: Due to the project's isolation and the fact that no employees of the Corps are stationed near the dam, a satellite monitoring system is currently being implemented to observe water

levels in six of the seven existing piezometers at the dam. Piezometer locations are shown on Plate 33 and an installation diagram is shown on Plate 34. Bell and Howell pressure transducers are being placed in the piezometers and every 4 hours water level readings will be relayed via the National Environmental Satellite Service to a U.S. Bureau of Reclamation station at Boise, Idaho. The data will be forwarded to the Corps computer in Portland, Oregon, where the information will be stored. Omaha District will receive the water levels daily through a telephone hookup. Specifications for the transducers are shown on Plate 35.

The system is justified by dam safety requirements. On several occasions in the past, the public has called the District Office with what they (the public) thought were safety problems. Although the reports were false, they were difficult to investigate in a timely matter. The satellite system will permit a timely determination as to whether or not a safety problem exists when similar reports are received from the public in the future. It is estimated that the automatic piezometer monitoring system will be operational by the end of 1985.

CHAPTER 9. - POSSIBLE FUTURE PROBLEMS

9.1 CONDUIT LEAKAGE: In June 1981, a slow oozing leak was discovered at the conduit monolith joint 9-10 which is approximately 50 feet upstream from the centerline of the dam. There was a three (3) inch deep layer of soil in the conduit that extended approximately 12 feet downstream from the joint and 5 feet upstream from the joint. Holes were drilled through the conduit to determine the existence of voids between the conduit and embankment material. No voids were found. Fill and water were found immediately behind the conduit in all the holes. Sieve analysis was run on the embankment soils and soil found inside the conduit. Embankment soil was a fat clay with 84 percent passing the No. 200. Soil found inside the conduit was silty with 28-34 percent passing the No. 200 sieve. Since no voids were found behind the conduit, it was concluded that embankment material was not piping through the conduit joint. It is possible that the sand was deposited in the wet area by wind passing through the conduit. Seepage which produces the moist area in the conduit is not presently considered critical but is closely monitored.

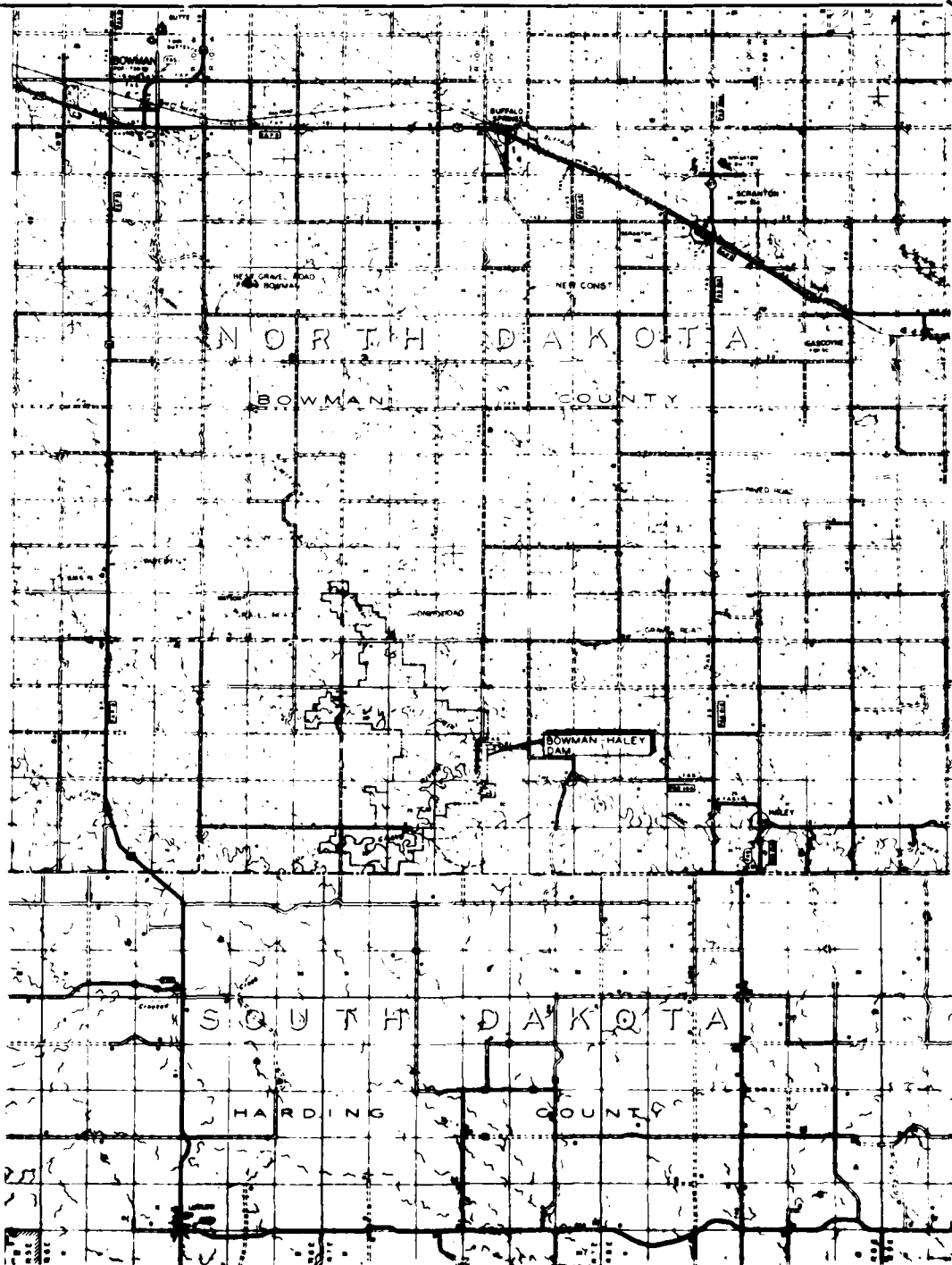
9.2 "A" LIGNITE: Underseepage through the "A" lignite is another potential future problem which is not currently critical but is monitored closely.

DRAWINGS

CORPS OF ENGINEERS

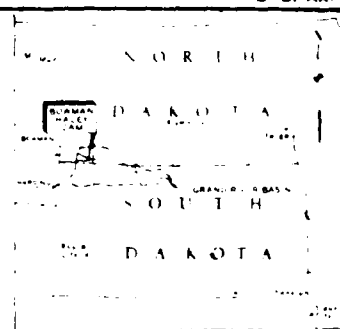
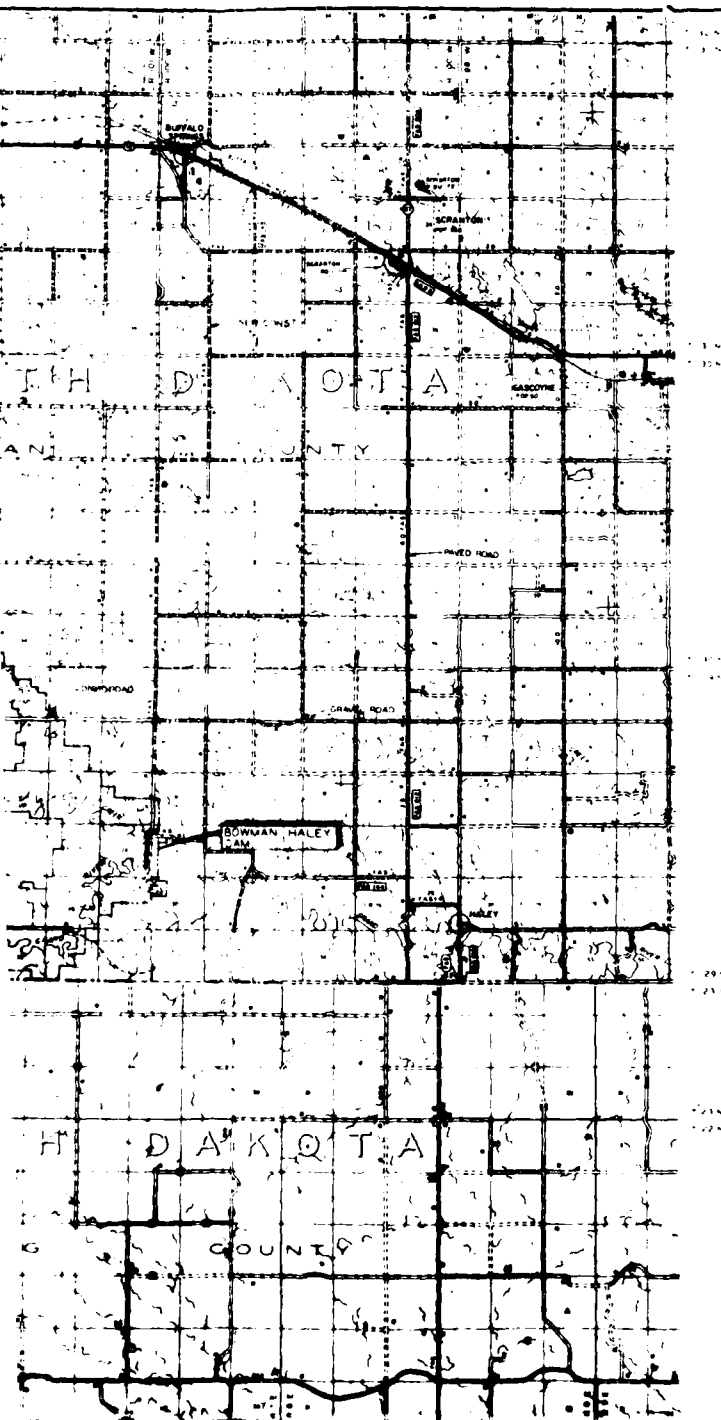


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CONSTRUCTION F

U. S. ARMY



LOCATION MAP
SCALE IN MILES
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LEGEND

- PAVED ROAD
- GRAVEL, SURFACE ROAD
- UNPAVED ROAD

THIS DRAWING HAS BEEN REVISED TO
REFLECT THE ORIGINAL SCALE

OCT 1981 REVISED TO 1:50,000

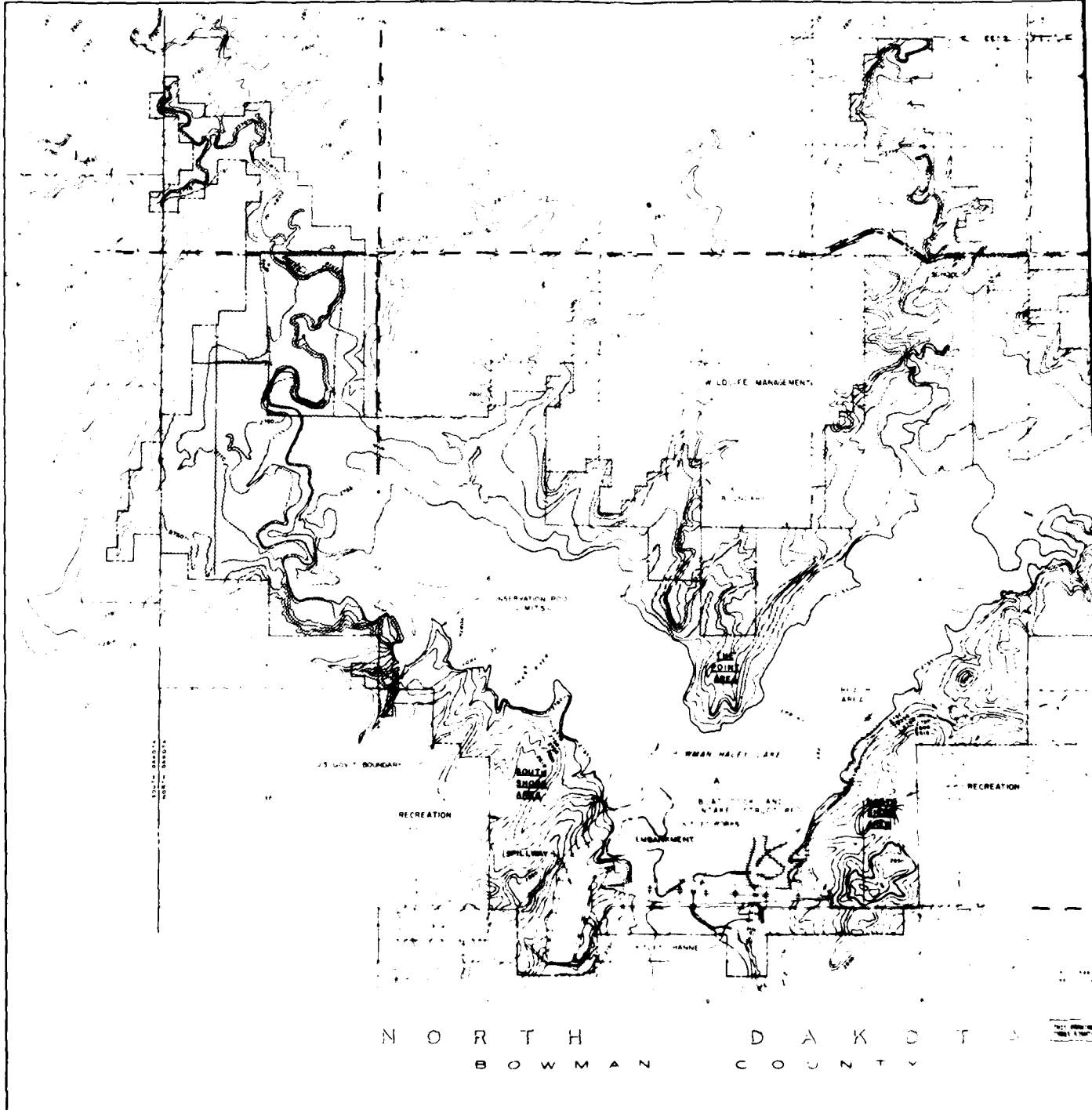
U. S. ARMY ENGINEER DISTRICT, OMAHA
CORPS OF ENGINEERS
OMAHA, NEBRASKA

NORTH FORK OF GRAND RIVER, NORTH DAKOTA
BOWMAN-HALEY DAM & RESERVOIR
OUTLET WORKS CONDUIT
PROJECT LOCATION MAP
AND INDEX

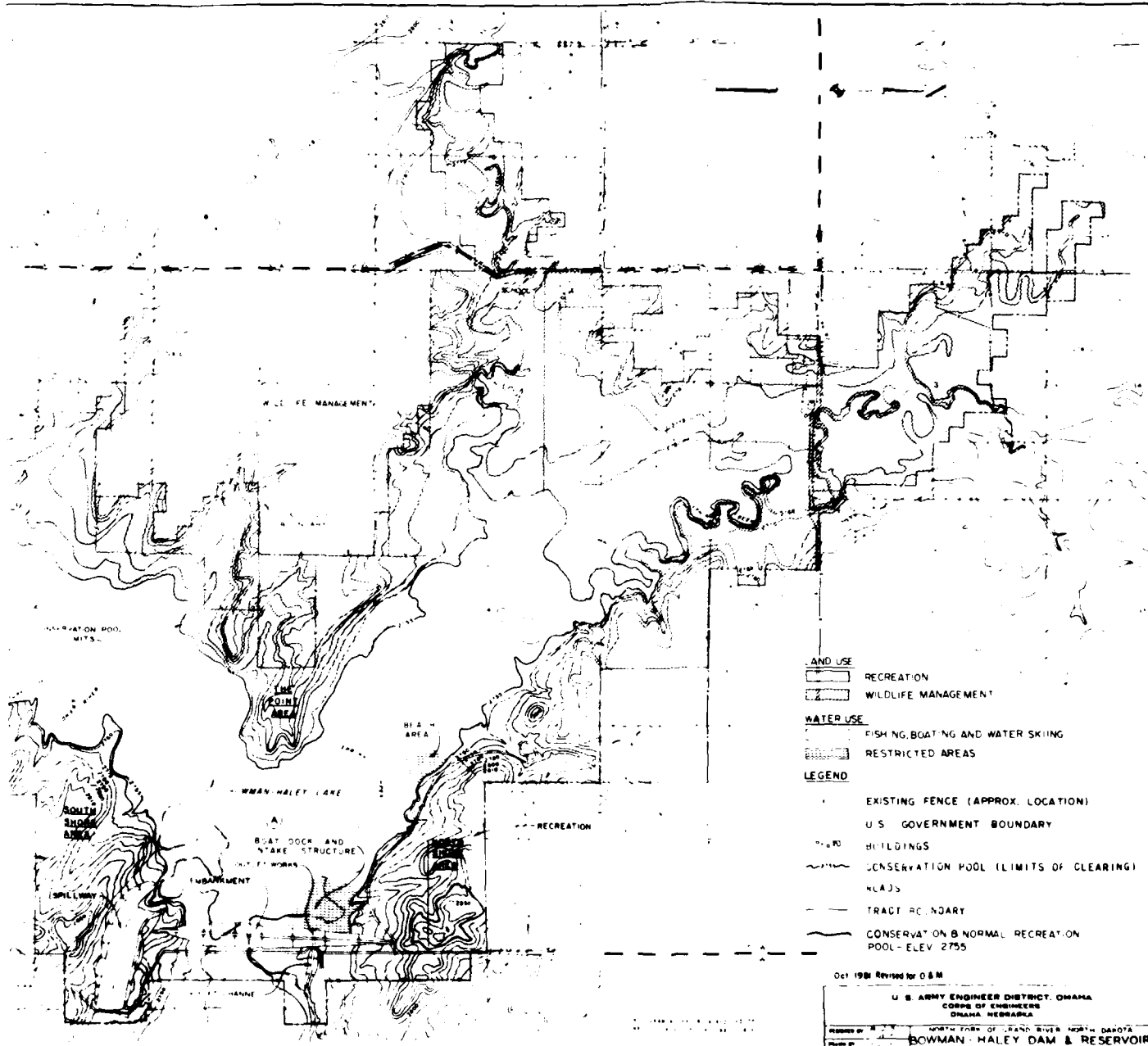
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CORPS OF ENGINEERS



CONSTRUCTI



NORTH DAKOTA
BOWMAN COUNTY

THIS DRAWING HAS BEEN REDUCED TO
ONE EIGHTH THE ORIGINAL SIZE

SCALE 1" = 100 FEET

LAND USE

- RECREATION
- WILDLIFE MANAGEMENT

WATER USE

- FISHING, BOATING AND WATER SKIING
- RESTRICTED AREAS

LEGEND

- EXISTING FENCE (APPROX. LOCATION)
- U.S. GOVERNMENT BOUNDARY
- BUILDINGS
- CONSERVATION POOL (LIMITS OF CLEARING)
- RAJDS
- TRACT RECORDARY
- CONSERVATION NORMAL RECREATION POOL - ELEV. 2755

Oct 1981 Revised for O & M

U.S. ARMY ENGINEER DISTRICT, OMAHA
CORPS OF ENGINEERS
OMAHA, NEBRASKA

DESIGNED BY: [Signature]
DRAWN BY: [Signature]
CHECKED BY: [Signature]
APPROVED BY: [Signature]

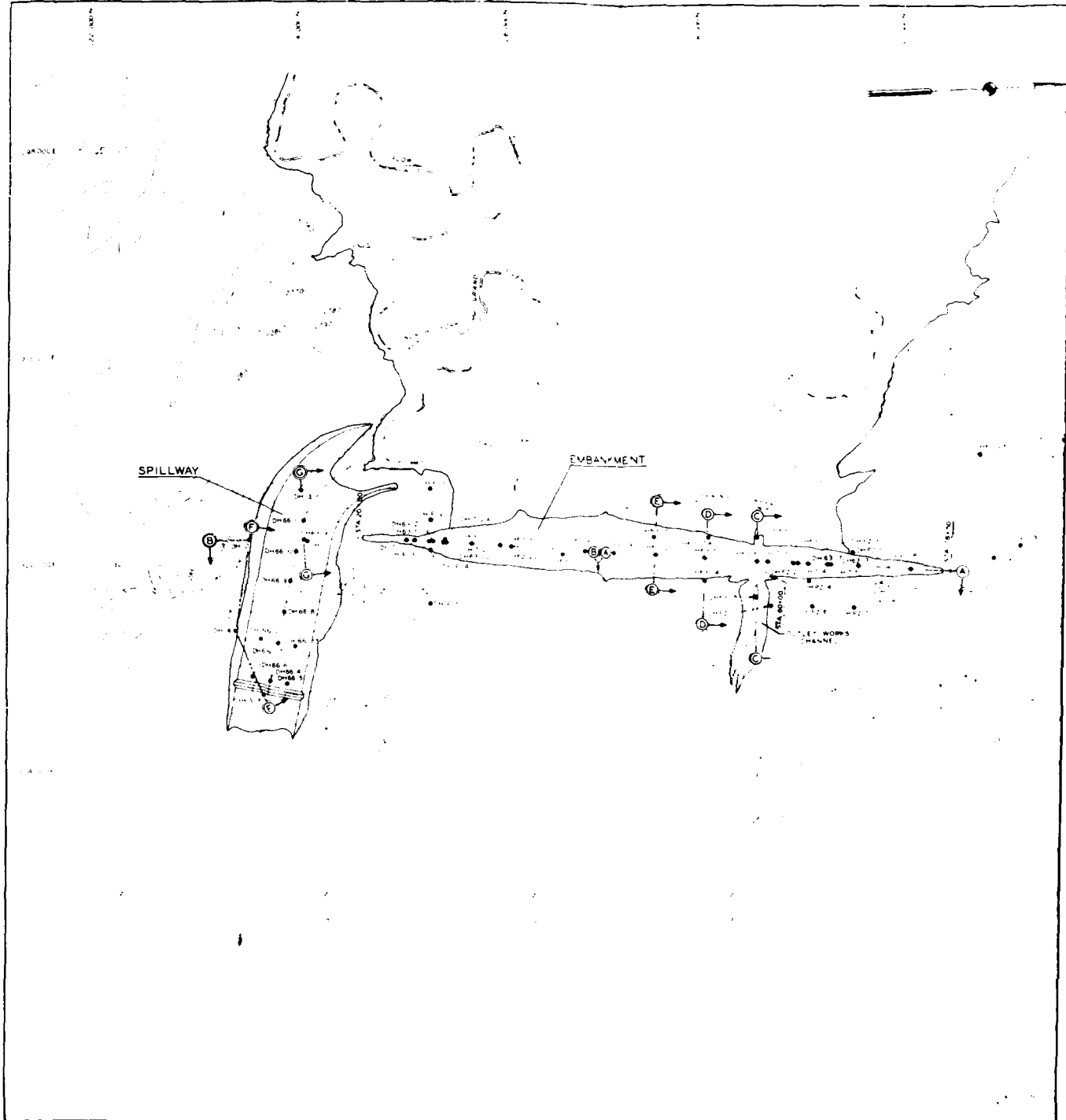
NORTH FENCE OF GRAND RIVER NORTH DAKOTA
BOWMAN-HALEY DAM & RESERVOIR
DAM AND APPURTENANT WORKS
GENERAL PLAN AND AREA USE

DATE: APR 1981
BY: [Signature]
G8H2-SOE 2

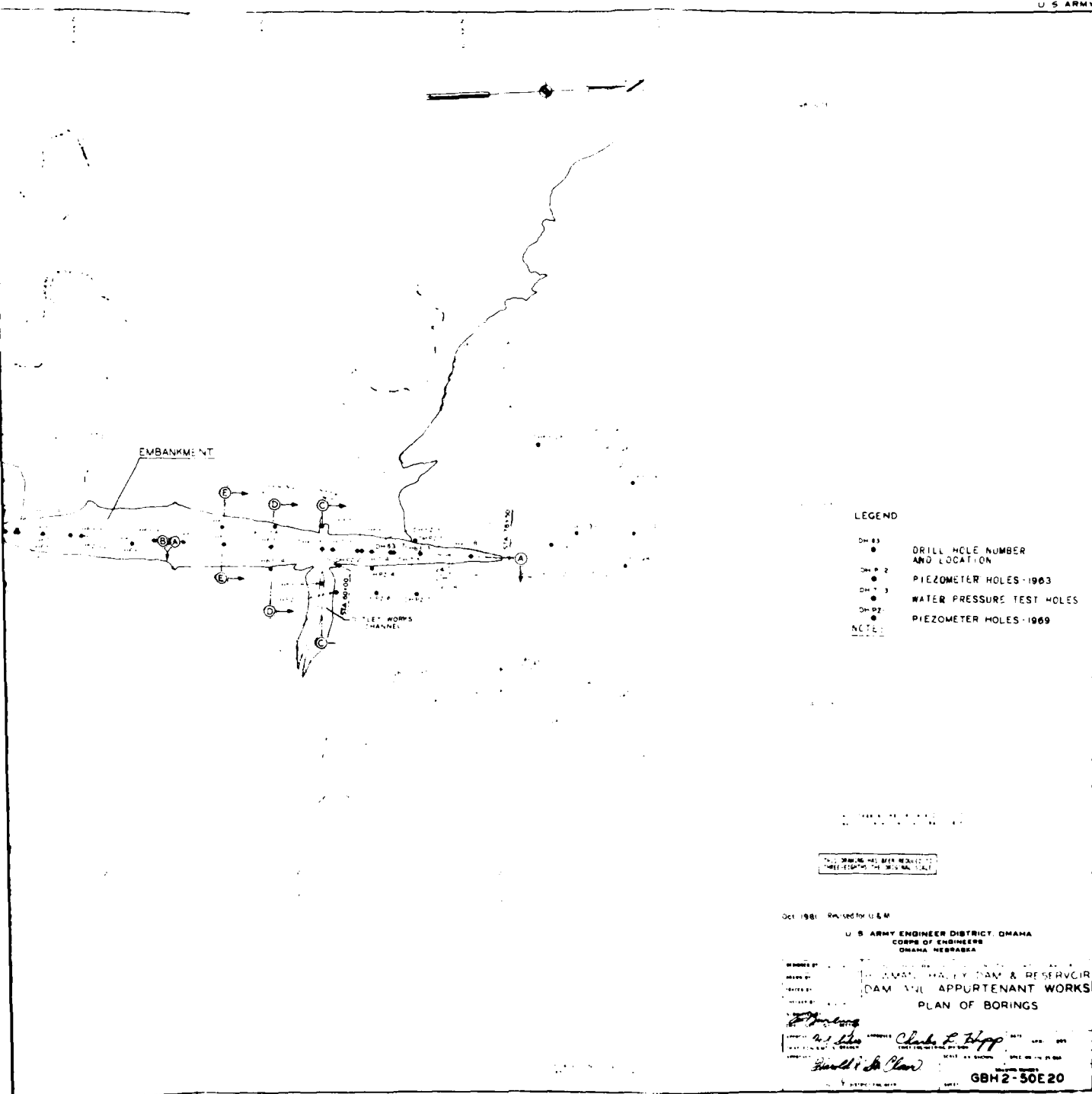
DA

CONSTRUCTION FOUNDATION REPORT (1985) PLATE 3

CORPS OF ENGINEERS



CONSTR



LEGEND

- DRILL HOLE NUMBER AND LOCATION
- PIEZOMETER HOLES-1963
- WATER PRESSURE TEST HOLES
- PIEZOMETER HOLES-1969

NOTE:

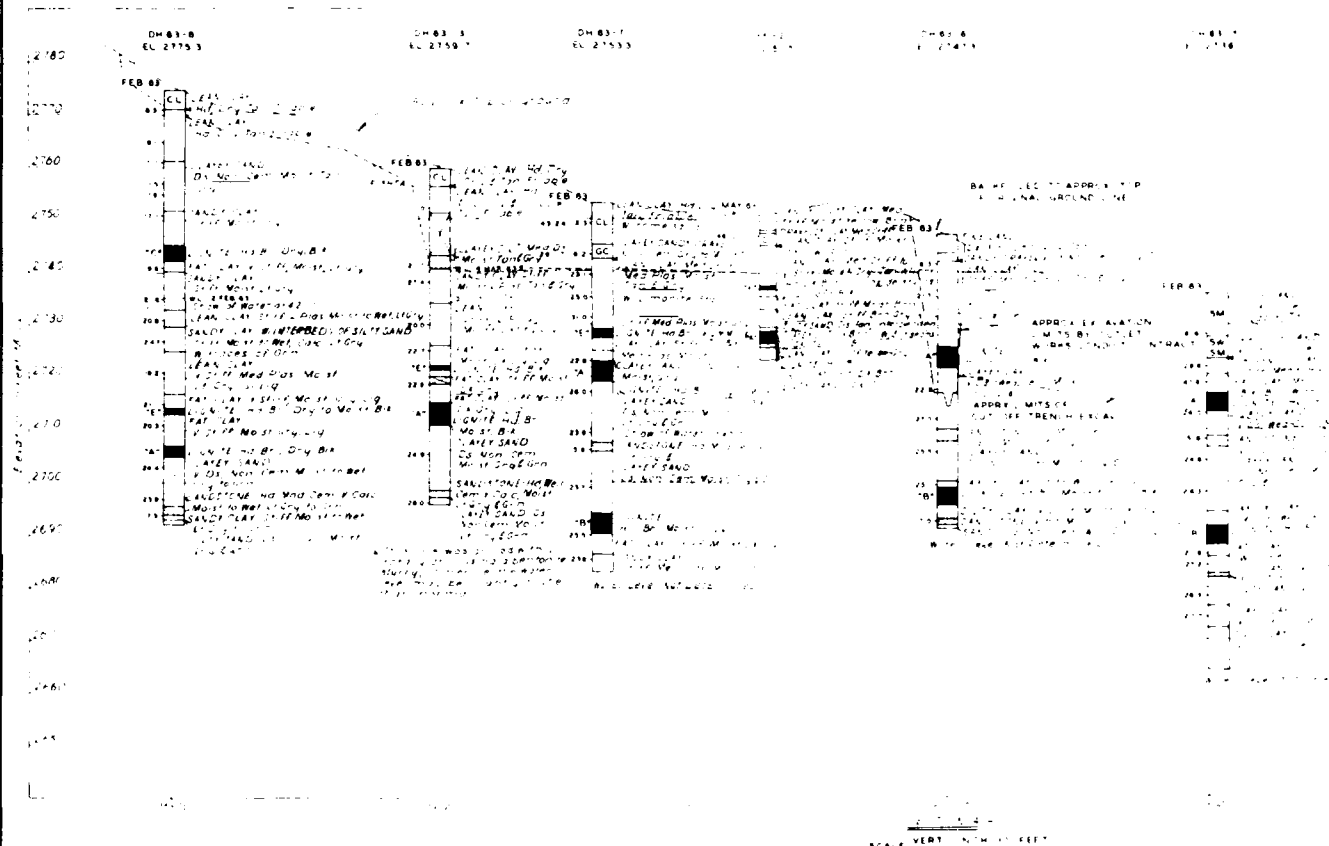
THIS DRAWING HAS BEEN REPRODUCED TO THE BEST OF THE ENGINEER'S KNOWLEDGE

Oct. 1981 Revised for U.S.M.
 U.S. ARMY ENGINEER DISTRICT, OMAHA
 CORPS OF ENGINEERS
 OMAHA, NEBRASKA
 DRAWN BY: [Signature]
 CHECKED BY: [Signature]
 DESIGNED BY: [Signature]
 PROJECT: ADAMS VALLEY DAM & RESERVOIR
 DAM AND APPURTENANT WORKS
 PLAN OF BORINGS
 APPROVED BY: [Signature]
 DATE: [Date]
 SCALE: [Scale]
 SHEET NO. 20 OF 20
 GBH2-50E20

CORPS OF ENGINEERS

A 105 Micron mesh (40 or 45 Paper Reproducible) Record
Copy Now Be Made Before Every Drilling and/or Modification

DATE
TIME
LOCATION
DATE



LEGEND
DH 63-8
EL 2775.3

Drill Hole Number
M.S.L. Elevation
Date of drilling
Percent of moisture at time of drilling
determined by laboratory test.
(L.L.) Liquid Limit
(P.I.) Plasticity Index
Soil Classification based on laboratory
tests, Atterberg limits, mechanical
analysis and visual examination.
Soil Classification based on visual
inspection in the field.
Water Level and date of observation.
Established by measurement in open
holes or piezometers.
Top of Ludlow Formation (both soil and
rock terms used to describe the Ludlow
Formation)
The principal lignites used for
correlation are indicated by the
letters "A", "B" etc.
Core Loss
Proposed excavation limits this contract.
Excavation limits by previous contract.

GENERAL NOTES:

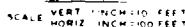
1. The data shown graphically and by symbol for each respective boring represents the actual geologic features observed and logged at the location given on the drawings. While the borings are representative of subsurface conditions at their respective locations and for their respective vertical reaches, local variations characteristic of the subsurface materials of this region are anticipated and, if encountered, such variations will not be considered as differing materially with the purview of Article IV of the contract.
2. The Ludlow Formation consists of soft to very stiff clays, medium dense to very dense, fine-grained sands, soft to hard, thin-bedded sandstones, soft shales and soft to hard lignites.
3. Descriptions of material, based on visual inspection in the field, are shown to the right of the graphic log.
4. Absence of water readings in the Graphic Log of any boring is not necessarily to be construed that ground water will not be encountered in excavation at that location.
5. Information on material has been condensed in the Graphic Logs. Additional information is shown on field logs, which may be inspected at the Omaha District Office.
6. Overburden sampling was accomplished by using a percussion type drill using a 6 inch inside diameter open and drive barrel, although a rotary drill was used at some locations. The Ludlow Formation was drilled with both a percussion type drill with either a 4 or 6 inch inside diameter open and drive barrel and a rotary drill using a 5 3/8 inch diameter double-tube core barrel or Dennison barrel, using haystackite slug bits.

ABBREVIATIONS		
Amount	amt	Lt
Black	blk	Lt
Brittle	brt	Low
Brown	brn	Med
Calcareous	calc	Med
Carbonaceous	carb	CC
Cemented	cm	Fla
Concretions	conc	Sat
Dark	dk	Sil
Dense	ds	ver
Gray	gray	Med
Green	grn	Med
Hard	hd	Med
High	h	Med

CLASSIFICATION OF SOILS:

GW	GRAVEL OR SANDY GRAVEL
GC	CLAYEY GRAVEL OR CLAYEY SAND
SW	SAND OR GRAVELLY SAND
SP	SAND OR GRAVELLY SAND
SM	SILTY SAND OR SILTY GRA
SC	CLAYEY SAND OR CLAYEY C
ML	SILTS, SANDY SILTS, GRA OR CLAYEY SILTS
CL	LEAN CLAYS, SANDY CLAYS OR GRAVELLY CLAYS
CH	FAT CLAYS

CONSTRU



ABBREVIATIONS

- | | | | |
|--------------|------|------------------|---------|
| Amount | Amt | Light | Lt. |
| black | Blk | Lighte, Lignitic | Lig |
| Brittle | Brk | Loe | L |
| Brown | Brn | Medium | Med |
| Calcareous | Calc | Moderately | Mod |
| Carbonaceous | Carb | Occasional | Occ |
| Cemented | Cem | Plasticity | Plas |
| Concretions | Cnc | Saturated | Sat |
| Dark | Dk | Slightly | Sl |
| Dense | Ds | Very | V |
| Gray | Gry | Weakly | Weak |
| Green | Grn | Weathered | Weather |
| Hard | Hrd | With | W |
| High | H | | |

CLASSIFICATION OF SOILS:

GN	GRAVEL OR SANDY GRAVEL, WELL GRADED
GC	CLAYEY GRAVEL OR CLAYEY SANDY GRAVEL
SW	SAND OR GRAVELLY SAND, WELL GRADED
SP	SAND OR GRAVELLY SAND, POORLY GRADED
SC	SILTY SAND OR SILTY GRAVELLY SAND
ML	CLAYEY SAND OR CLAYEY GRAVELLY SAND
CL	SILTS, SANDY SILTS, GRAVELLY SILTS OR CLAYEY SILTS
OL	LEAN CLAYS, SANDY CLAYS, SILTY CLAYS OR GRAVELLY CLAYS
CH	FAT CLAYS

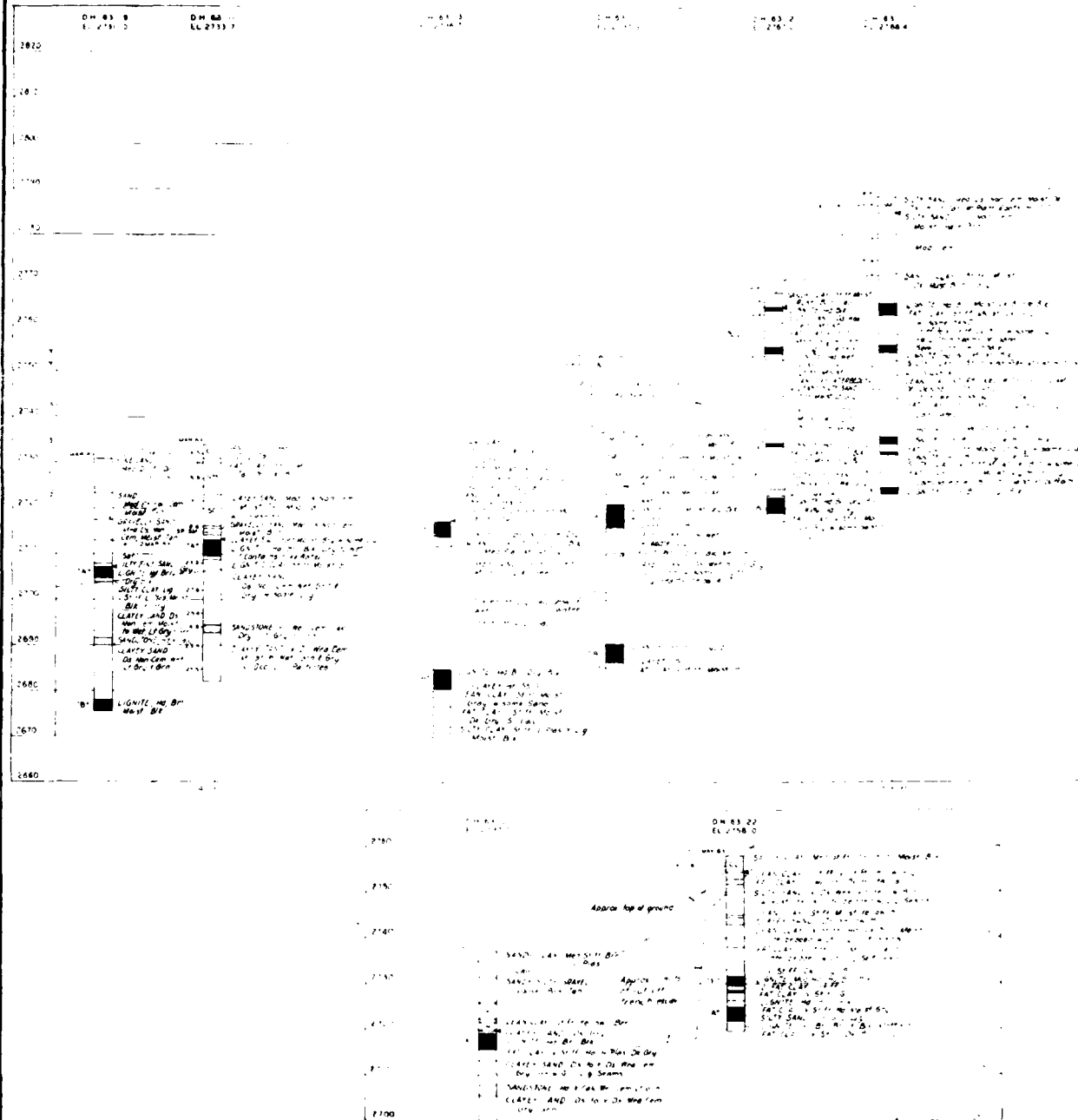
NOTES:

1. All elevations shown refer to feet above M.S.L., 1929 General Adjustment.
2. For Boring Locations, see page 4.

"THIS DRAWING HAS BEEN REDUCED TO
"THREE-FIFTHS THE ORIGINAL SCALE"

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DM 63 9 (2'53)	DM 63 10 (2'53)	DM 63 11 (2'53)	DM 63 12 (2'53)	DM 63 13 (2'53)	DM 63 14 (2'53)	DM 63 15 (2'53)	DM 63 16 (2'53)	DM 63 17 (2'53)	DM 63 18 (2'53)	DM 63 19 (2'53)	DM 63 20 (2'53)	DM 63 21 (2'53)	DM 63 22 (2'53)	DM 63 23 (2'53)	DM 63 24 (2'53)	DM 63 25 (2'53)	DM 63 26 (2'53)	DM 63 27 (2'53)	DM 63 28 (2'53)	DM 63 29 (2'53)	DM 63 30 (2'53)	DM 63 31 (2'53)	DM 63 32 (2'53)	DM 63 33 (2'53)	DM 63 34 (2'53)	DM 63 35 (2'53)	DM 63 36 (2'53)	DM 63 37 (2'53)	DM 63 38 (2'53)	DM 63 39 (2'53)	DM 63 40 (2'53)	DM 63 41 (2'53)	DM 63 42 (2'53)	DM 63 43 (2'53)	DM 63 44 (2'53)	DM 63 45 (2'53)	DM 63 46 (2'53)	DM 63 47 (2'53)	DM 63 48 (2'53)	DM 63 49 (2'53)	DM 63 50 (2'53)	DM 63 51 (2'53)	DM 63 52 (2'53)	DM 63 53 (2'53)	DM 63 54 (2'53)	DM 63 55 (2'53)	DM 63 56 (2'53)	DM 63 57 (2'53)	DM 63 58 (2'53)	DM 63 59 (2'53)	DM 63 60 (2'53)	DM 63 61 (2'53)	DM 63 62 (2'53)	DM 63 63 (2'53)	DM 63 64 (2'53)	DM 63 65 (2'53)	DM 63 66 (2'53)	DM 63 67 (2'53)	DM 63 68 (2'53)	DM 63 69 (2'53)	DM 63 70 (2'53)	DM 63 71 (2'53)	DM 63 72 (2'53)	DM 63 73 (2'53)	DM 63 74 (2'53)	DM 63 75 (2'53)	DM 63 76 (2'53)	DM 63 77 (2'53)	DM 63 78 (2'53)	DM 63 79 (2'53)	DM 63 80 (2'53)	DM 63 81 (2'53)	DM 63 82 (2'53)	DM 63 83 (2'53)	DM 63 84 (2'53)	DM 63 85 (2'53)	DM 63 86 (2'53)	DM 63 87 (2'53)	DM 63 88 (2'53)	DM 63 89 (2'53)	DM 63 90 (2'53)	DM 63 91 (2'53)	DM 63 92 (2'53)	DM 63 93 (2'53)	DM 63 94 (2'53)	DM 63 95 (2'53)	DM 63 96 (2'53)	DM 63 97 (2'53)	DM 63 98 (2'53)	DM 63 99 (2'53)	DM 63 100 (2'53)
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CONSTR



A 16mm Micro-reducer Film or a Paper Reproducible Record
 Must Be Made Before Every Amendment and/or Modification

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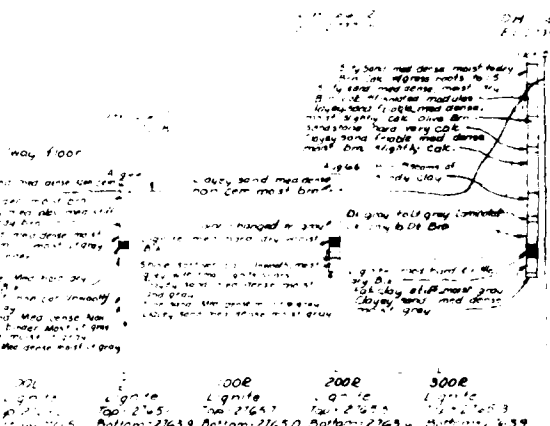
Figure 1

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Bottom 27594 Bottom 27594

CONSTRU

SECTION E-E



SPILLWAY SECTION AT STA. 23+00
Vert. 1"=10', Horiz. 1"=50'

THIS DRAWING HAS BEEN REDUCED TO
THREE-FOURTHS THE ORIGINAL SCALE

U. S. ARMY ENGINEER DISTRICT, OMAHA Bureau of Engineering Omaha, Nebraska	
NORTH FORK OF GRAND RIVER, NEBRASKA BOWMAN-HALEY DAM & RESERVOIR DAM AND APPURTENANT WORKS RECORD OF BORINGS SECTIONS C-C, D-D AND E-E	
DRAWN BY: <i>Charles R. Hopp</i> CHECKED BY: <i>Donald V. & Clair</i> DATE: <i>10/1/50</i>	SHEET NO. <i>50E23</i> OF <i>50E23</i>

CORPS OF ENGINEERS

A 105 Micrometer film or a Paper Reproduction Record
 (CR) Must Be Made Before Every Amendment and/or Modification

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CONSTRUCT

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1. **Introduction**
 2. **Background**
 3. **Methodology**
 4. **Results**
 5. **Discussion**
 6. **Conclusion**
 7. **References**
 8. **Appendix**
 9. **Figure 1**
 10. **Figure 2**
 11. **Figure 3**
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 217. **Figure 209**

Figure 1. The effect of the initial concentration of the monomer (C_0) on the polymerization rate at different temperatures. The reaction conditions were as follows: $[AIBN] = 0.005 \text{ mol/L}$, $[M] = 0.05 \text{ mol/L}$, $[K_2S_2O_8] = 0.005 \text{ mol/L}$, $[NaHCO_3] = 0.005 \text{ mol/L}$, $[NaHSO_3] = 0.005 \text{ mol/L}$, $[Na_2SO_3] = 0.005 \text{ mol/L}$, $[Na_2S_2O_4] = 0.005 \text{ mol/L}$, $[Na_2S_2O_5] = 0.005 \text{ mol/L}$, $[Na_2S_2O_6] = 0.005 \text{ mol/L}$, $[Na_2S_2O_7] = 0.005 \text{ mol/L}$, $[Na_2S_2O_8] = 0.005 \text{ mol/L}$, $[Na_2S_2O_9] = 0.005 \text{ mol/L}$, $[Na_2S_2O_{10}] = 0.005 \text{ mol/L}$, $[Na_2S_2O_{11}] = 0.005 \text{ mol/L}$, $[Na_2S_2O_{12}] = 0.005 \text{ mol/L}$, $[Na_2S_2O_{13}] = 0.005 \text{ mol/L}$, $[Na_2S_2O_{14}] = 0.005 \text{ mol/L}$, $[Na_2S_2O_{15}] = 0.005 \text{ mol/L}$, $[Na_2S_2O_{16}] = 0.005 \text{ mol/L}$, $[Na_2S_2O_{17}] = 0.005 \text{ mol/L}$, $[Na_2S_2O_{18}] = 0.005 \text{ mol/L}$, $[Na_2S_2O_{19}] = 0.005 \text{ mol/L}$, $[Na_2S_2O_{20}] = 0.005 \text{ mol/L}$.

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Oct 98

U S ARMY ENGINEER DISTRICT, OMAHA
CORPS OF ENGINEERS
OMAHA, NEBRASKA

BRADMAN HALEY DAM & RES

RECORD OF BORROWINGS
SECTIONS F-F, G & BORROW ARE A B

Oct 1988

U S ARMY ENGINEER DISTRICT, OMAHA
CORPS OF ENGINEERS
OMAHA, NEBRASKA

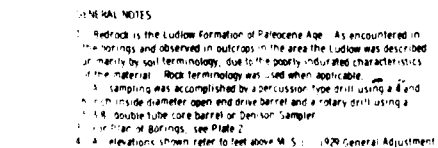
DESIGNED BY: RODMAN HALEY DAM & RESERVOIR
 DRAWN BY: DAM AND APPURTENANT WORKS
 CHECKED BY: RECORD OF BORINGS
 SECTION F-F G.G. & BORROW AREA BORINGS

[Handwritten signatures and stamps are visible over the form fields.]

DATE: 06-17-89
APPROVED: [Signature]
COPIES: 1 - [illegible]
REMARKS: [illegible]
GSM2-SOE 24

GBM2-SOE 24

CONSTRUCTION FOUNDATION REPORT (1985) PLATE 8



ABBREVIATIONS		30-00	
amt	amount	ft	high
blk	black	ht	height
brl	brittle	lq	light, lightning, lightning
brn	brown	L	low
calc	calcareous	med	medium
carb	carbonaceous	mod	moderately
cem	cemented	occ	occasional
conc	concretions	plax	plates
ds	dark	sl	slightly
ds	dense	sl	slightly
gr	gray	st	stiff
grn	green	weak	weakly
hd	hard	weakth	weakness

CLASSIFICATION OF SOILS

CH	FAT CLAY
CL	LEAN CLAY AND SANDY CLAY
CI	CLAYEY CLAY AND CLAYEY SILT
ML	SILT, SANDY SILTS AND CLAYEY SILT
SP	SAND OR GRAVELLY SAND, POORLY GRADED
SW	SAND OR GRAVELLY SAND, WELL GRADED
SM	SILTY SAND OR SILTY GRAVELLY SAND
SC	CLAYEY SAND OR CLAYEY GRAVELLY SAND
GW	GRAVEL OR SANDY GRAVEL, WELL GRADED
GC	GRAVELLY GRAVEL OR GRAVEL SANDY GRAVEL



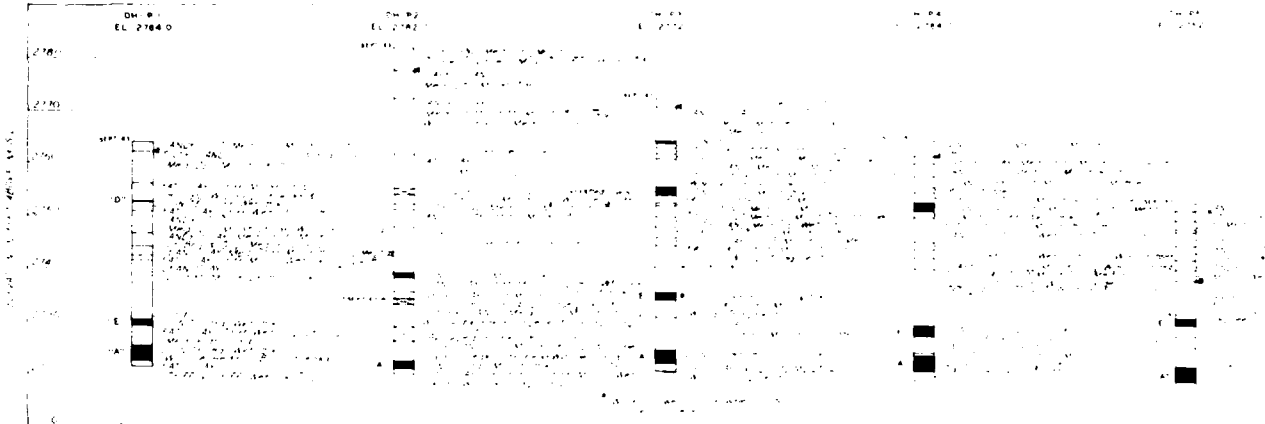
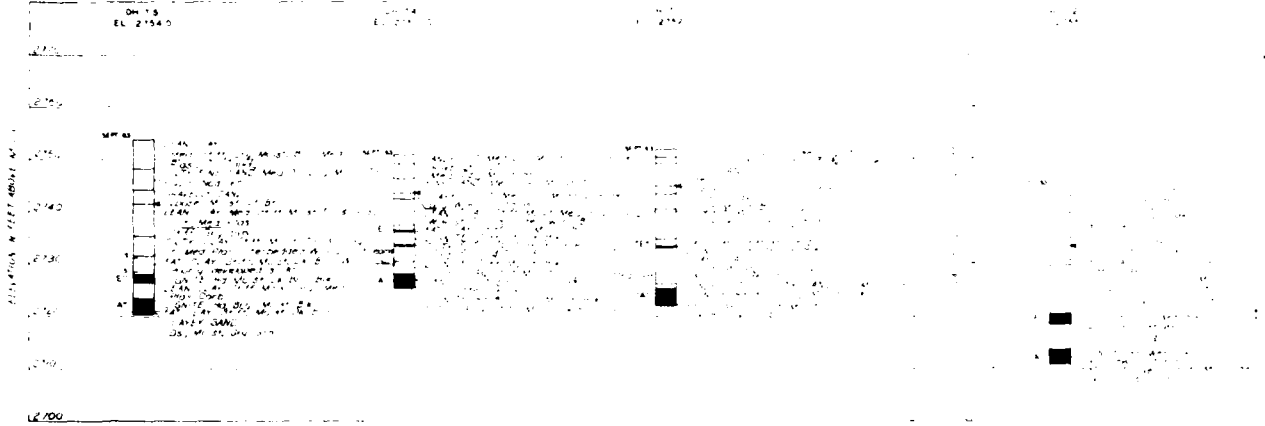
THIS PLAN ACCOMPANIES CONTRACT NO. DA-20-066-
MODIFICATION NO.

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10011 1:00703 701 0016100 30001

DATE		DIVISION		GRADE	OFFICE
U. S. ARMY ENGINEER DISTRICT, OMAHA DEPT. OF ENGINEERS OMAHA, NEBRASKA					
NORTH FORK OF GRAND RIVER, NORTH DAKOTA BOWMAN-HALEY DAM & RESERVOIR SOIL PROFILE EMBANKMENT CENTERLINE					
DESIGNED BY DRAWN BY CHECKED BY APPROVED BY DATE	PROJECT NO. DRAWING NO. SHEET NO. OF SHEETS	PROJECT NAME DRAWING NAME SHEET NAME		DATE BY FOR	DATE BY FOR
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CORPS OF ENGINEERS

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 MODIFICATION _____ DATE _____



Sheet 11
E 2752

Sheet 12
E 2753

Sheet 13
E 2754

Sheet 14
E 2755

Sheet 15
E 2756

Sheet 16
E 2757

THE ENGINEERING DISTRICT OF OMAHA
CORPS OF ENGINEERS
OMAHA, NEBRASKA

OF 98

U. S. ARMY ENGINEER DISTRICT OMAHA
CORPS OF ENGINEERS
OMAHA, NEBRASKA

PROJECT: OMAHA DAM & REMEDIATION
DAM AND APPURTENANT WORKS
REPAIR OF BURST
112 METER AND PRESSURE TEST HOLES

DESIGNED BY: [Signature]
CHECKED BY: [Signature]
APPROVED BY: [Signature]
DATE: 10/1/85

GBH2-50E25



5463
E. C. 409



DATE OF DRILLING
PER CENT OF MOISTURE AT TIME OF DRILLING
DETERMINED BY LABORATORY TEST

(4.4.1) UPPER LIMIT
(4.4.2) LOWER LIMIT
(4.4.3) INDEX

SOIL CLASSIFICATION BASED ON LABORATORY TESTS, ATTERBURG LIMITS, MECHANICAL ANALYSIS AND VISUAL EXAMINATION

SOIL CLASSIFICATION BASED ON VISUAL INSPECTION IN THE FIELD

WATER LEVEL AND DATE OF OBSERVATION
ESTABLISHED BY MEASUREMENT IN OPEN HOLE
TOP OF THE LADLER FORMATION (BOTH SOIL
AND ROCK TYPES USED TO DESCRIBE THE
LADLER FORMATION)

THE PRINCIPAL LIGHTENING USED FOR CORRELATION ARE INDICATED BY THE LETTERS "A", "B", ETC.

PROPOSED EXPLANATION LIMITS

GENERAL NOTES:

- [illegible]

NOTE:

1. ALL ELEVATIONS SHOWN REFER TO FEET ABOVE M.S.L.
1989 GENERAL ADJUSTMENT.

CLASSIFICATION OF SOILS

- SM SAND OR GRAVELLY SAND, WELL GRADED
SP SAND OR GRAVELLY SAND, POORLY GRADED
SM SILTY SAND OR SILTY GRAVELLY SAND
SC CLAYEY SAND OR CLAYEY GRAVELLY SAND
ML SILT, SANDY SILTS, GRAVELLY SILTS OR CLAYEY SILTS
CL CLAY CLAYS, SANDY CLAYS, SILTY CLAYS OR GRAVELLY CLAYS

ABBREVIATIONS

Account	Ant	Light	Li
Black	Blk	Lignite, Lignitic	Lig
Boat	Bo	Low	L
Bygone	By	Medium	Med
Calcareous	Calc	Moderately	Mod
Carbonaceous	Carb	Occasional	Ocr
Commented	Com	Plasticity	Plas
Cure	Cu	Saturated	Sat
Curse	C	Slightly	Sl
Day	Day	Very	V
Green	Grn	Weakly	Wak
Hard	Hrd	Weathered	Weth
Herd	H		

THIS DRAWING HAS BEEN REDUCED TO
THREE-EIGHTHS THE ORIGINAL SIZE.

Oct 1991 Revised for O & M

U. S. ARMY ENGINEER DISTRICT, OMAHA
CORPS OF ENGINEERS
OMAHA, NEBRASKA

NORTH SIDE OF GRAND RIVER NORTH DAKOTA

**BOWMAN-HALEY DAM & RESERVOIR
OUTLET WORKS CONDUIT
RECORD OF BORINGS**

[illegible]

CONSTRUCTION FOUNDATION REPORT (1985)

PLATE 12

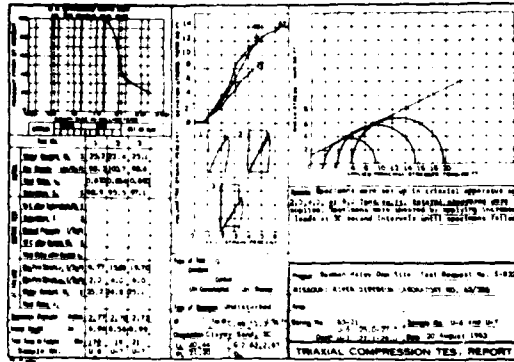


FIGURE 1

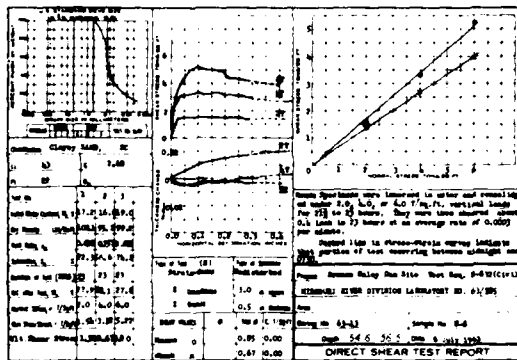


FIGURE 4

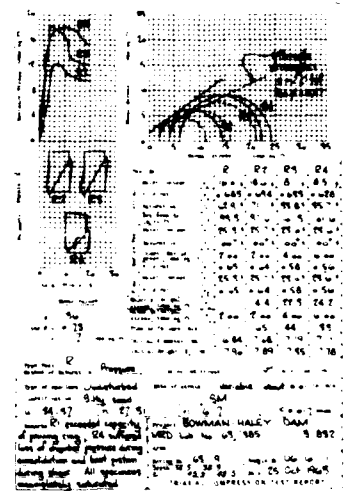


FIGURE 2

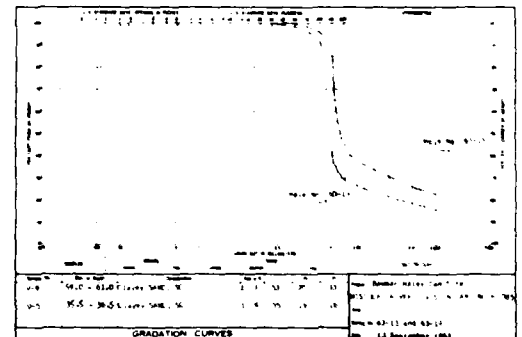


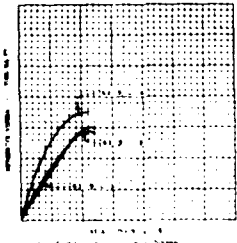
FIGURE 5

U. S. ARMY ENGINEER DIVISION, WASHINGTON, D. C.
CORPS OF ENGINEERS
ENGINEER ASSISTANT
CHIEF, DIVISION

TABLE 2. - UNOBTAINED COMPRESSION AND CLASSIFICATION TEST DATA

TEST REPORT NO. 64-100									
ENGINEER ASSISTANT, CHIEF, DIVISION									
Specimen No.	Sample No.	Depth (ft.)	Dry Density (pcf)	Moisture Content (%)	Initial Void Ratio	Initial Water Content (%)	Final Void Ratio	Final Water Content (%)	Classification
64-10	1-3	20.1-21.3	100.0	25.1	1.00	25.0	1.01	25.0	CLAYEY SAND, S
64-10	1-4	21.3-22.5	100.0	25.0	1.00	25.0	1.00	25.0	CLAYEY SAND, S
64-10	1-5	22.5-23.7	100.0	25.0	1.00	25.0	1.00	25.0	CLAYEY SAND, S

NOTE: 1. 1/2 specimen height to specimen ratio of test specimen.



THIS PLAN
64-100-000-10

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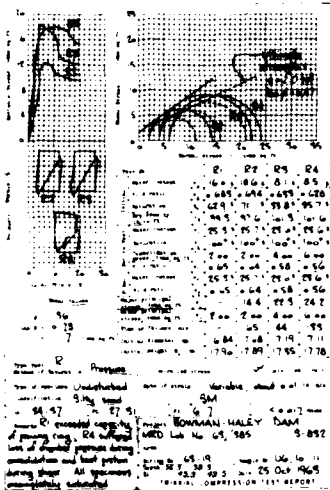


FIGURE 2

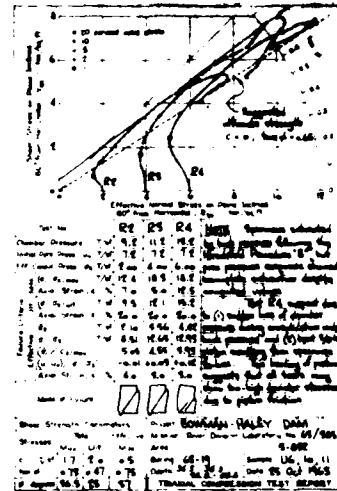


FIGURE 3

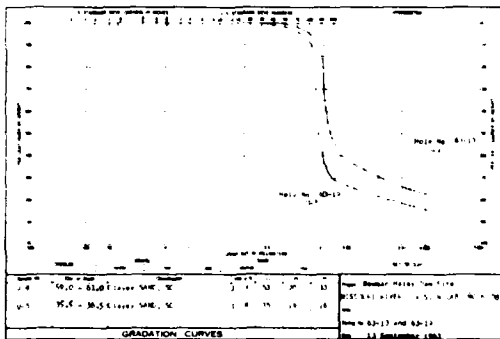


FIGURE 5

No.	Time	Flow	Area	Permeability		Remarks
				cm/sec	ft/day	
1	10	100	100	0.0001	10	CLAYEY SAND
2	10	100	100	0.0001	10	CLAYEY SAND
3	10	100	100	0.0001	10	CLAYEY SAND
4	10	100	100	0.0001	10	CLAYEY SAND
5	10	100	100	0.0001	10	CLAYEY SAND
6	10	100	100	0.0001	10	CLAYEY SAND
7	10	100	100	0.0001	10	CLAYEY SAND
8	10	100	100	0.0001	10	CLAYEY SAND
9	10	100	100	0.0001	10	CLAYEY SAND
10	10	100	100	0.0001	10	CLAYEY SAND
11	10	100	100	0.0001	10	CLAYEY SAND
12	10	100	100	0.0001	10	CLAYEY SAND
13	10	100	100	0.0001	10	CLAYEY SAND
14	10	100	100	0.0001	10	CLAYEY SAND
15	10	100	100	0.0001	10	CLAYEY SAND
16	10	100	100	0.0001	10	CLAYEY SAND
17	10	100	100	0.0001	10	CLAYEY SAND
18	10	100	100	0.0001	10	CLAYEY SAND
19	10	100	100	0.0001	10	CLAYEY SAND
20	10	100	100	0.0001	10	CLAYEY SAND
21	10	100	100	0.0001	10	CLAYEY SAND
22	10	100	100	0.0001	10	CLAYEY SAND
23	10	100	100	0.0001	10	CLAYEY SAND
24	10	100	100	0.0001	10	CLAYEY SAND
25	10	100	100	0.0001	10	CLAYEY SAND
26	10	100	100	0.0001	10	CLAYEY SAND
27	10	100	100	0.0001	10	CLAYEY SAND
28	10	100	100	0.0001	10	CLAYEY SAND
29	10	100	100	0.0001	10	CLAYEY SAND
30	10	100	100	0.0001	10	CLAYEY SAND
31	10	100	100	0.0001	10	CLAYEY SAND
32	10	100	100	0.0001	10	CLAYEY SAND
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34	10	100	100	0.0001	10	CLAYEY SAND
35	10	100	100	0.0001	10	CLAYEY SAND
36	10	100	100	0.0001	10	CLAYEY SAND
37	10	100	100	0.0001	10	CLAYEY SAND
38	10	100	100	0.0001	10	CLAYEY SAND
39	10	100	100	0.0001	10	CLAYEY SAND
40	10	100	100	0.0001	10	CLAYEY SAND
41	10	100	100	0.0001	10	CLAYEY SAND
42	10	100	100	0.0001	10	CLAYEY SAND
43	10	100	100	0.0001	10	CLAYEY SAND
44	10	100	100	0.0001	10	CLAYEY SAND
45	10	100	100	0.0001	10	CLAYEY SAND
46	10	100	100	0.0001	10	CLAYEY SAND
47	10	100	100	0.0001	10	CLAYEY SAND
48	10	100	100	0.0001	10	CLAYEY SAND
49	10	100	100	0.0001	10	CLAYEY SAND
50	10	100	100	0.0001	10	CLAYEY SAND
51	10	100	100	0.0001	10	CLAYEY SAND
52	10	100	100	0.0001	10	CLAYEY SAND
53	10	100	100	0.0001	10	CLAYEY SAND
54	10	100	100	0.0001	10	CLAYEY SAND
55	10	100	100	0.0001	10	CLAYEY SAND
56	10	100	100	0.0001	10	CLAYEY SAND
57	10	100	100	0.0001	10	CLAYEY SAND
58	10	100	100	0.0001	10	CLAYEY SAND
59	10	100	100	0.0001	10	CLAYEY SAND
60	10	100	100	0.0001	10	CLAYEY SAND

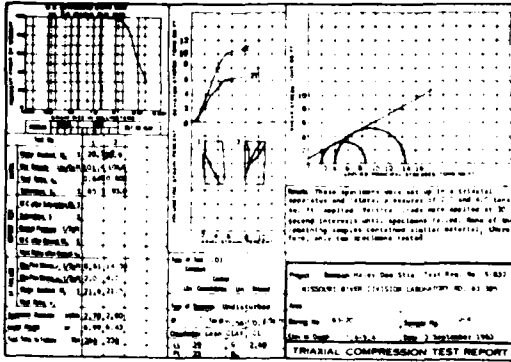


FIGURE 1

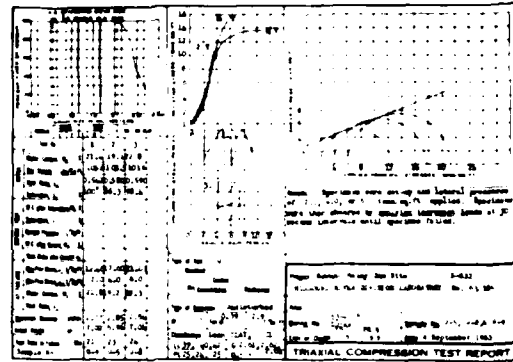


FIGURE 2

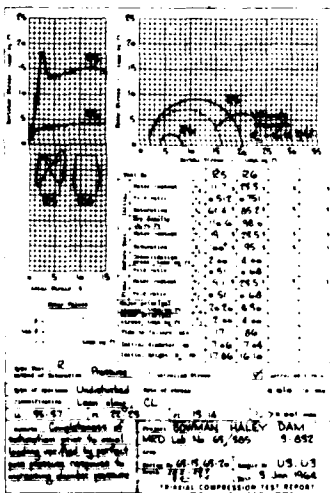


FIGURE 4

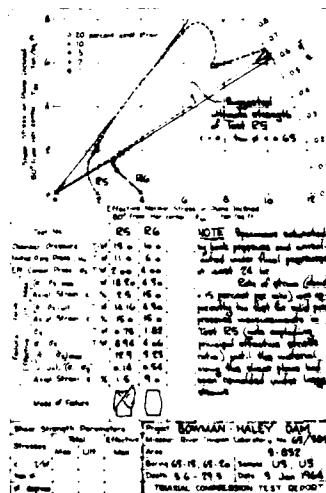


FIGURE 5

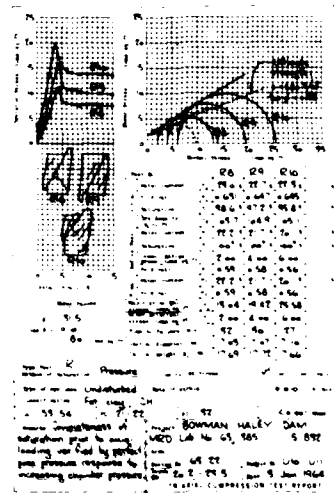
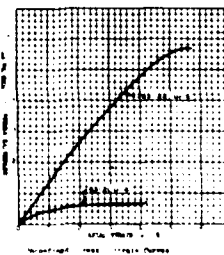


FIGURE 6

TABLE 1. - TRIAXIAL COMPRESSION TEST RESULTS

Test No.	Specimen No.	Depth (ft)	Dry Density (pcf)	Relative Compaction (%)	Peak Stress (kips)	Peak Strain (in/in)	Modulus (kips/in ²)
11-28	84	21.0	112.0	81.1	10.5	0.0015	7,000
11-27	85	20.0	112.0	81.1	9.0	0.0015	6,000

Note: 1. 100 percent length to diameter ratio of test specimen.



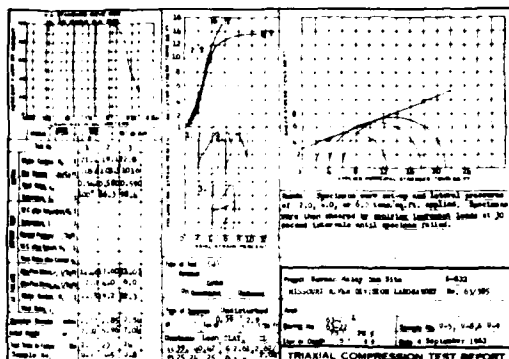


FIGURE 2

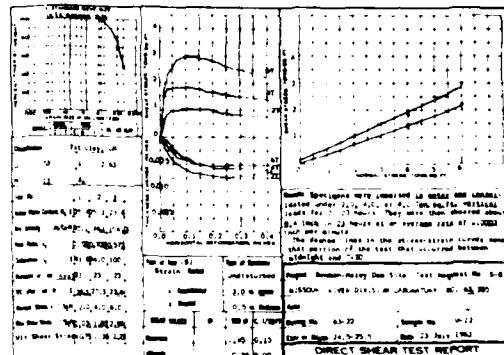


FIGURE 3

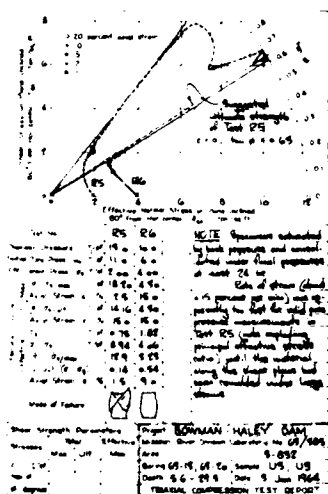


FIGURE 5

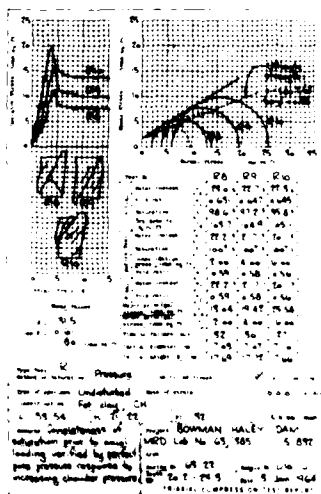


FIGURE 6

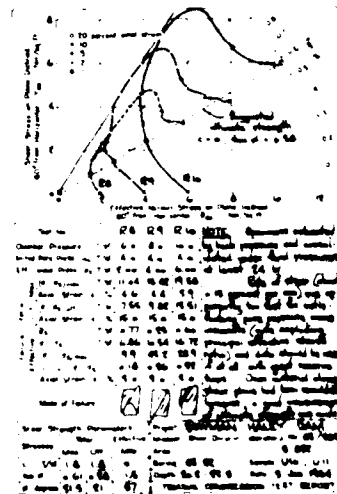


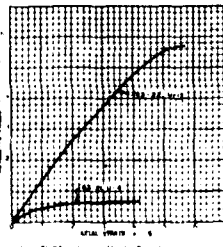
FIGURE 7

AND AT THE TIME OF THE TEST, THE FOLLOWING FACTORS WERE TAKEN INTO CONSIDERATION:

1. The test was conducted in accordance with the provisions of the U.S. Army Corps of Engineers, Manual of Practice, No. 11-1, dated 1954.

2. The test was conducted in accordance with the provisions of the U.S. Army Corps of Engineers, Manual of Practice, No. 11-1, dated 1954.

3. The test was conducted in accordance with the provisions of the U.S. Army Corps of Engineers, Manual of Practice, No. 11-1, dated 1954.



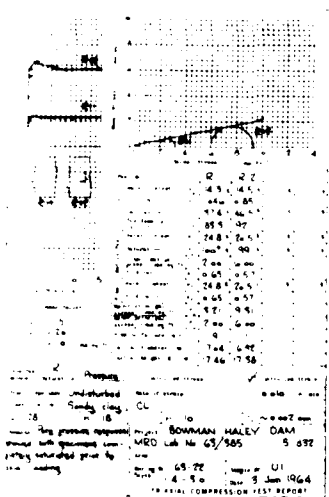


FIGURE 2

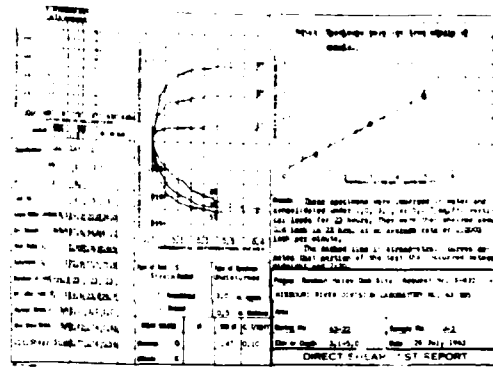


FIGURE 3

UNIT: POUNDS PER SQUARE INCH (PSI)
 SHEAR STRESS (PSI) vs. NORMAL STRESS (PSI)
 20.0 kN/m² (4.5 kips/ft²)
 40.0 kN/m² (9.0 kips/ft²)
 60.0 kN/m² (13.5 kips/ft²)
 80.0 kN/m² (18.0 kips/ft²)
 100.0 kN/m² (22.5 kips/ft²)
 120.0 kN/m² (27.0 kips/ft²)
 140.0 kN/m² (31.5 kips/ft²)
 160.0 kN/m² (36.0 kips/ft²)
 180.0 kN/m² (40.5 kips/ft²)
 200.0 kN/m² (45.0 kips/ft²)
 220.0 kN/m² (49.5 kips/ft²)
 240.0 kN/m² (54.0 kips/ft²)
 260.0 kN/m² (58.5 kips/ft²)
 280.0 kN/m² (63.0 kips/ft²)
 300.0 kN/m² (67.5 kips/ft²)
 320.0 kN/m² (72.0 kips/ft²)
 340.0 kN/m² (76.5 kips/ft²)
 360.0 kN/m² (81.0 kips/ft²)
 380.0 kN/m² (85.5 kips/ft²)
 400.0 kN/m² (90.0 kips/ft²)
 420.0 kN/m² (94.5 kips/ft²)
 440.0 kN/m² (99.0 kips/ft²)
 460.0 kN/m² (103.5 kips/ft²)
 480.0 kN/m² (108.0 kips/ft²)
 500.0 kN/m² (112.5 kips/ft²)
 520.0 kN/m² (117.0 kips/ft²)
 540.0 kN/m² (121.5 kips/ft²)
 560.0 kN/m² (126.0 kips/ft²)
 580.0 kN/m² (130.5 kips/ft²)
 600.0 kN/m² (135.0 kips/ft²)
 620.0 kN/m² (139.5 kips/ft²)
 640.0 kN/m² (144.0 kips/ft²)
 660.0 kN/m² (148.5 kips/ft²)
 680.0 kN/m² (153.0 kips/ft²)
 700.0 kN/m² (157.5 kips/ft²)
 720.0 kN/m² (162.0 kips/ft²)
 740.0 kN/m² (166.5 kips/ft²)
 760.0 kN/m² (171.0 kips/ft²)
 780.0 kN/m² (175.5 kips/ft²)
 800.0 kN/m² (180.0 kips/ft²)
 820.0 kN/m² (184.5 kips/ft²)
 840.0 kN/m² (189.0 kips/ft²)
 860.0 kN/m² (193.5 kips/ft²)
 880.0 kN/m² (198.0 kips/ft²)
 900.0 kN/m² (202.5 kips/ft²)
 920.0 kN/m² (207.0 kips/ft²)
 940.0 kN/m² (211.5 kips/ft²)
 960.0 kN/m² (216.0 kips/ft²)
 980.0 kN/m² (220.5 kips/ft²)
 1000.0 kN/m² (225.0 kips/ft²)
 1020.0 kN/m² (229.5 kips/ft²)
 1040.0 kN/m² (234.0 kips/ft²)
 1060.0 kN/m² (238.5 kips/ft²)
 1080.0 kN/m² (243.0 kips/ft²)
 1100.0 kN/m² (247.5 kips/ft²)
 1120.0 kN/m² (252.0 kips/ft²)
 1140.0 kN/m² (256.5 kips/ft²)
 1160.0 kN/m² (261.0 kips/ft²)
 1180.0 kN/m² (265.5 kips/ft²)
 1200.0 kN/m² (270.0 kips/ft²)
 1220.0 kN/m² (274.5 kips/ft²)
 1240.0 kN/m² (279.0 kips/ft²)
 1260.0 kN/m² (283.5 kips/ft²)
 1280.0 kN/m² (288.0 kips/ft²)
 1300.0 kN/m² (292.5 kips/ft²)
 1320.0 kN/m² (297.0 kips/ft²)
 1340.0 kN/m² (301.5 kips/ft²)
 1360.0 kN/m² (306.0 kips/ft²)
 1380.0 kN/m² (310.5 kips/ft²)
 1400.0 kN/m² (315.0 kips/ft²)
 1420.0 kN/m² (319.5 kips/ft²)
 1440.0 kN/m² (324.0 kips/ft²)
 1460.0 kN/m² (328.5 kips/ft²)
 1480.0 kN/m² (333.0 kips/ft²)
 1500.0 kN/m² (337.5 kips/ft²)
 1520.0 kN/m² (342.0 kips/ft²)
 1540.0 kN/m² (346.5 kips/ft²)
 1560.0 kN/m² (351.0 kips/ft²)
 1580.0 kN/m² (355.5 kips/ft²)
 1600.0 kN/m² (360.0 kips/ft²)
 1620.0 kN/m² (364.5 kips/ft²)
 1640.0 kN/m² (369.0 kips/ft²)
 1660.0 kN/m² (373.5 kips/ft²)
 1680.0 kN/m² (378.0 kips/ft²)
 1700.0 kN/m² (382.5 kips/ft²)
 1720.0 kN/m² (387.0 kips/ft²)
 1740.0 kN/m² (391.5 kips/ft²)
 1760.0 kN/m² (396.0 kips/ft²)
 1780.0 kN/m² (400.5 kips/ft²)
 1800.0 kN/m² (405.0 kips/ft²)
 1820.0 kN/m² (409.5 kips/ft²)
 1840.0 kN/m² (414.0 kips/ft²)
 1860.0 kN/m² (418.5 kips/ft²)
 1880.0 kN/m² (423.0 kips/ft²)
 1900.0 kN/m² (427.5 kips/ft²)
 1920.0 kN/m² (432.0 kips/ft²)
 1940.0 kN/m² (436.5 kips/ft²)
 1960.0 kN/m² (441.0 kips/ft²)
 1980.0 kN/m² (445.5 kips/ft²)
 2000.0 kN/m² (450.0 kips/ft²)
 2020.0 kN/m² (454.5 kips/ft²)
 2040.0 kN/m² (459.0 kips/ft²)
 2060.0 kN/m² (463.5 kips/ft²)
 2080.0 kN/m² (468.0 kips/ft²)
 2100.0 kN/m² (472.5 kips/ft²)
 2120.0 kN/m² (477.0 kips/ft²)
 2140.0 kN/m² (481.5 kips/ft²)
 2160.0 kN/m² (486.0 kips/ft²)
 2180.0 kN/m² (490.5 kips/ft²)
 2200.0 kN/m² (495.0 kips/ft²)
 2220.0 kN/m² (499.5 kips/ft²)
 2240.0 kN/m² (504.0 kips/ft²)
 2260.0 kN/m² (508.5 kips/ft²)
 2280.0 kN/m² (513.0 kips/ft²)
 2300.0 kN/m² (517.5 kips/ft²)
 2320.0 kN/m² (522.0 kips/ft²)
 2340.0 kN/m² (526.5 kips/ft²)
 2360.0 kN/m² (531.0 kips/ft²)
 2380.0 kN/m² (535.5 kips/ft²)
 2400.0 kN/m² (540.0 kips/ft²)
 2420.0 kN/m² (544.5 kips/ft²)
 2440.0 kN/m² (549.0 kips/ft²)
 2460.0 kN/m² (553.5 kips/ft²)
 2480.0 kN/m² (558.0 kips/ft²)
 2500.0 kN/m² (562.5 kips/ft²)
 2520.0 kN/m² (567.0 kips/ft²)
 2540.0 kN/m² (571.5 kips/ft²)
 2560.0 kN/m² (576.0 kips/ft²)
 2580.0 kN/m² (580.5 kips/ft²)
 2600.0 kN/m² (585.0 kips/ft²)
 2620.0 kN/m² (589.5 kips/ft²)
 2640.0 kN/m² (594.0 kips/ft²)
 2660.0 kN/m² (598.5 kips/ft²)
 2680.0 kN/m² (603.0 kips/ft²)
 2700.0 kN/m² (607.5 kips/ft²)
 2720.0 kN/m² (612.0 kips/ft²)
 2740.0 kN/m² (616.5 kips/ft²)
 2760.0 kN/m² (621.0 kips/ft²)
 2780.0 kN/m² (625.5 kips/ft²)
 2800.0 kN/m² (630.0 kips/ft²)
 2820.0 kN/m² (634.5 kips/ft²)
 2840.0 kN/m² (639.0 kips/ft²)
 2860.0 kN/m² (643.5 kips/ft²)
 2880.0 kN/m² (648.0 kips/ft²)
 2900.0 kN/m² (652.5 kips/ft²)
 2920.0 kN/m² (657.0 kips/ft²)
 2940.0 kN/m² (661.5 kips/ft²)
 2960.0 kN/m² (666.0 kips/ft²)
 2980.0 kN/m² (670.5 kips/ft²)
 3000.0 kN/m² (675.0 kips/ft²)
 3020.0 kN/m² (679.5 kips/ft²)
 3040.0 kN/m² (684.0 kips/ft²)
 3060.0 kN/m² (688.5 kips/ft²)
 3080.0 kN/m² (693.0 kips/ft²)
 3100.0 kN/m² (697.5 kips/ft²)
 3120.0 kN/m² (702.0 kips/ft²)
 3140.0 kN/m² (706.5 kips/ft²)
 3160.0 kN/m² (711.0 kips/ft²)
 3180.0 kN/m² (715.5 kips/ft²)
 3200.0 kN/m² (720.0 kips/ft²)
 3220.0 kN/m² (724.5 kips/ft²)
 3240.0 kN/m² (729.0 kips/ft²)
 3260.0 kN/m² (733.5 kips/ft²)
 3280.0 kN/m² (738.0 kips/ft²)
 3300.0 kN/m² (742.5 kips/ft²)
 3320.0 kN/m² (747.0 kips/ft²)
 3340.0 kN/m² (751.5 kips/ft²)
 3360.0 kN/m² (756.0 kips/ft²)
 3380.0 kN/m² (760.5 kips/ft²)
 3400.0 kN/m² (765.0 kips/ft²)
 3420.0 kN/m² (769.5 kips/ft²)
 3440.0 kN/m² (774.0 kips/ft²)
 3460.0 kN/m² (778.5 kips/ft²)
 3480.0 kN/m² (783.0 kips/ft²)
 3500.0 kN/m² (787.5 kips/ft²)
 3520.0 kN/m² (792.0 kips/ft²)
 3540.0 kN/m² (796.5 kips/ft²)
 3560.0 kN/m² (801.0 kips/ft²)
 3580.0 kN/m² (805.5 kips/ft²)
 3600.0 kN/m² (810.0 kips/ft²)
 3620.0 kN/m² (814.5 kips/ft²)
 3640.0 kN/m² (819.0 kips/ft²)
 3660.0 kN/m² (823.5 kips/ft²)
 3680.0 kN/m² (828.0 kips/ft²)
 3700.0 kN/m² (832.5 kips/ft²)
 3720.0 kN/m² (837.0 kips/ft²)
 3740.0 kN/m² (841.5 kips/ft²)
 3760.0 kN/m² (846.0 kips/ft²)
 3780.0 kN/m² (850.5 kips/ft²)
 3800.0 kN/m² (855.0 kips/ft²)
 3820.0 kN/m² (859.5 kips/ft²)
 3840.0 kN/m² (864.0 kips/ft²)
 3860.0 kN/m² (868.5 kips/ft²)
 3880.0 kN/m² (873.0 kips/ft²)
 3900.0 kN/m² (877.5 kips/ft²)
 3920.0 kN/m² (882.0 kips/ft²)
 3940.0 kN/m² (886.5 kips/ft²)
 3960.0 kN/m² (891.0 kips/ft²)
 3980.0 kN/m² (895.5 kips/ft²)
 4000.0 kN/m² (900.0 kips/ft²)
 4020.0 kN/m² (904.5 kips/ft²)
 4040.0 kN/m² (909.0 kips/ft²)
 4060.0 kN/m² (913.5 kips/ft²)
 4080.0 kN/m² (918.0 kips/ft²)
 4100.0 kN/m² (922.5 kips/ft²)
 4120.0 kN/m² (927.0 kips/ft²)
 4140.0 kN/m² (931.5 kips/ft²)
 4160.0 kN/m² (936.0 kips/ft²)
 4180.0 kN/m² (940.5 kips/ft²)
 4200.0 kN/m² (945.0 kips/ft²)
 4220.0 kN/m² (949.5 kips/ft²)
 4240.0 kN/m² (954.0 kips/ft²)
 4260.0 kN/m² (958.5 kips/ft²)
 4280.0 kN/m² (963.0 kips/ft²)
 4300.0 kN/m² (967.5 kips/ft²)
 4320.0 kN/m² (972.0 kips/ft²)
 4340.0 kN/m² (976.5 kips/ft²)
 4360.0 kN/m² (981.0 kips/ft²)
 4380.0 kN/m² (985.5 kips/ft²)
 4400.0 kN/m² (990.0 kips/ft²)
 4420.0 kN/m² (994.5 kips/ft²)
 4440.0 kN/m² (999.0 kips/ft²)
 4460.0 kN/m² (1003.5 kips/ft²)
 4480.0 kN/m² (1008.0 kips/ft²)
 4500.0 kN/m² (1012.5 kips/ft²)
 4520.0 kN/m² (1017.0 kips/ft²)
 4540.0 kN/m² (1021.5 kips/ft²)
 4560.0 kN/m² (1026.0 kips/ft²)
 4580.0 kN/m² (1030.5 kips/ft²)
 4600.0 kN/m² (1035.0 kips/ft²)
 4620.0 kN/m² (1039.5 kips/ft²)
 4640.0 kN/m² (1044.0 kips/ft²)
 4660.0 kN/m² (1048.5 kips/ft²)
 4680.0 kN/m² (1053.0 kips/ft²)
 4700.0 kN/m² (1057.5 kips/ft²)
 4720.0 kN/m² (1062.0 kips/ft²)
 4740.0 kN/m² (1066.5 kips/ft²)
 4760.0 kN/m² (1071.0 kips/ft²)
 4780.0 kN/m² (1075.5 kips/ft²)
 4800.0 kN/m² (1080.0 kips/ft²)
 4820.0 kN/m² (1084.5 kips/ft²)
 4840.0 kN/m² (1089.0 kips/ft²)
 4860.0 kN/m² (1093.5 kips/ft²)
 4880.0 kN/m² (1098.0 kips/ft²)
 4900.0 kN/m² (1102.5 kips/ft²)
 4920.0 kN/m² (1107.0 kips/ft²)
 4940.0 kN/m² (1111.5 kips/ft²)
 4960.0 kN/m² (1116.0 kips/ft²)
 4980.0 kN/m² (1120.5 kips/ft²)
 5000.0 kN/m² (1125.0 kips/ft²)
 5020.0 kN/m² (1129.5 kips/ft²)
 5040.0 kN/m² (1134.0 kips/ft²)
 5060.0 kN/m² (1138.5 kips/ft²)
 5080.0 kN/m² (1143.0 kips/ft²)
 5100.0 kN/m² (1147.5 kips/ft²)
 5120.0 kN/m² (1152.0 kips/ft²)
 5140.0 kN/m² (1156.5 kips/ft²)
 5160.0 kN/m² (1161.0 kips/ft²)
 5180.0 kN/m² (1165.5 kips/ft²)
 5200.0 kN/m² (1170.0 kips/ft²)
 5220.0 kN/m² (1174.5 kips/ft²)
 5240.0 kN/m² (1179.0 kips/ft²)
 5260.0 kN/m² (1183.5 kips/ft²)
 5280.0 kN/m² (1188.0 kips/ft²)
 5300.0 kN/m² (1192.5 kips/ft²)
 5320.0 kN/m² (1197.0 kips/ft²)
 5340.0 kN/m² (1201.5 kips/ft²)
 5360.0 kN/m² (1206.0 kips/ft²)
 5380.0 kN/m² (1210.5 kips/ft²)
 5400.0 kN/m² (1215.0 kips/ft²)
 5420.0 kN/m² (1219.5 kips/ft²)
 5440.0 kN/m² (1224.0 kips/ft²)
 5460.0 kN/m² (1228.5 kips/ft²)
 5480.0 kN/m² (1233.0 kips/ft²)
 5500.0 kN/m² (1237.5 kips/ft²)
 5520.0 kN/m² (1242.0 kips/ft²)
 5540.0 kN/m² (1246.5 kips/ft²)
 5560.0 kN/m² (1251.0 kips/ft²)
 5580.0 kN/m² (1255.5 kips/ft²)
 5600.0 kN/m² (1260.0 kips/ft²)
 5620.0 kN/m² (1264.5 kips/ft²)
 5640.0 kN/m² (1269.0 kips/ft²)
 5660.0 kN/m² (1273.5 kips/ft²)
 5680.0 kN/m² (1278.0 kips/ft²)
 5700.0 kN/m² (1282.5 kips/ft²)
 5720.0 kN/m² (1287.0 kips/ft²)
 5740.0 kN/m² (1291.5 kips/ft²)
 5760.0 kN/m² (1296.0 kips/ft²)
 5780.0 kN/m² (1300.5 kips/ft²)
 5800.0 kN/m² (1305.0 kips/ft²)
 5820.0 kN/m² (1309.5 kips/ft²)
 5840.0 kN/m² (1314.0 kips/ft²)
 5860.0 kN/m² (1318.5 kips/ft²)
 5880.0 kN/m² (1323.0 kips/ft²)
 5900.0 kN/m² (1327.5 kips/ft²)
 5920.0 kN/m² (1332.0 kips/ft²)
 5940.0 kN/m² (1336.5 kips/ft²)
 5960.0 kN/m² (1341.0 kips/ft²)
 5980.0 kN/m² (1345.5 kips/ft²)
 6000.0 kN/m² (1350.0 kips/ft²)
 6020.0 kN/m² (1354.5 kips/ft²)
 6040.0 kN/m² (1359.0 kips/ft²)
 6060.0 kN/m² (1363.5 kips/ft²)
 6080.0 kN/m² (1368.0 kips/ft²)
 6100.0 kN/m² (1372.5 kips/ft²)
 6120.0 kN/m² (1377.0 kips/ft²)
 6140.0 kN/m² (1381.5 kips/ft²)
 6160.0 kN/m² (1386.0 kips/ft²)
 6180.0 kN/m² (1390.5 kips/ft²)
 6200.0 kN/m² (1395.0 kips/ft²)
 6220.0 kN/m² (1399.5 kips/ft²)
 6240.0 kN/m² (1404.0 kips/ft²)
 6260.0 kN/m² (1408.5 kips/ft²)
 6280.0 kN/m² (1413.0 kips/ft²)
 6300.0 kN/m² (1417.5 kips/ft²)
 6320.0 kN/m² (

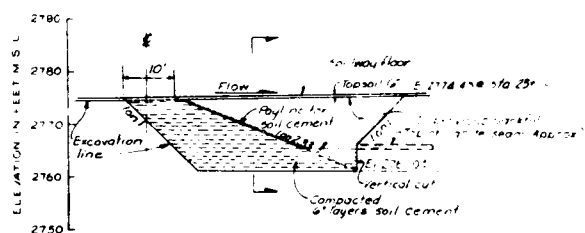
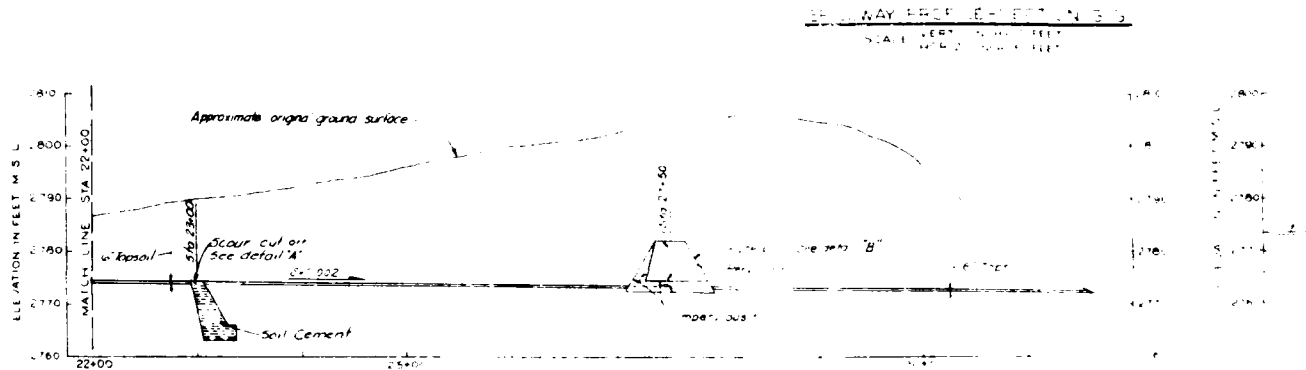
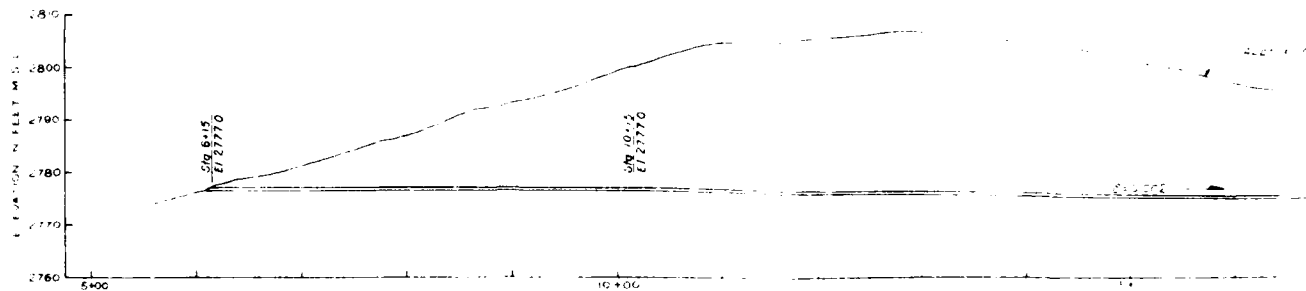
CORPS OF ENGINEERS

A 105 Maximum Plan of a River, Reservoir, or Waterway, and the Mouth, Before Any Amendment and for Application

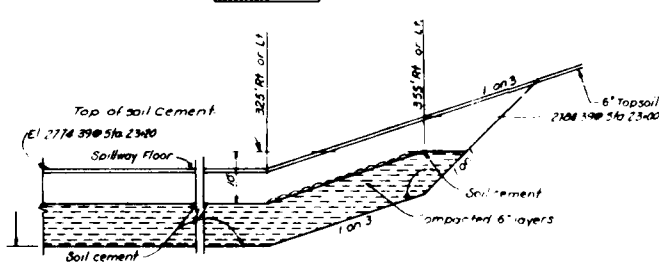
DATE: _____

BY: _____

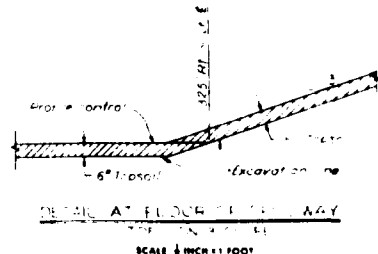
FOR: _____



DETAIL A
SCOUR CUT-OFF CROSS SECTION
SCALE 1 INCH = 10 FEET



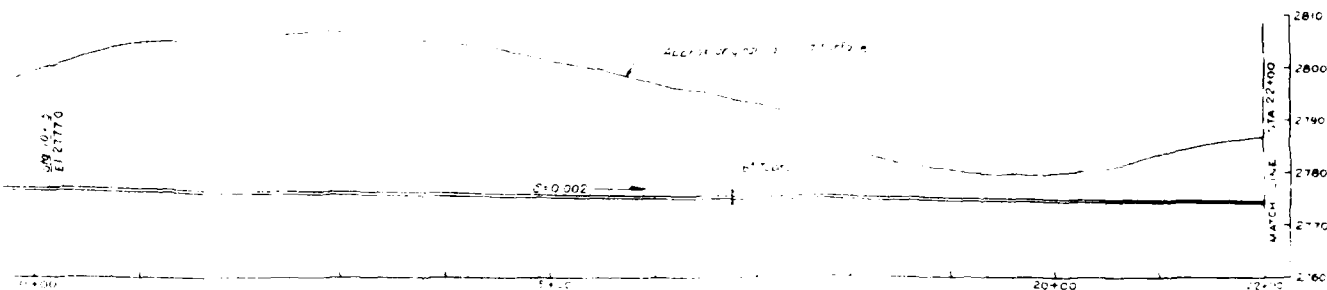
SPILLWAY SIDE SLOPES AT SCOUR
CUT-OFF CENTER LINE
SCALE 1 INCH = 10 FEET



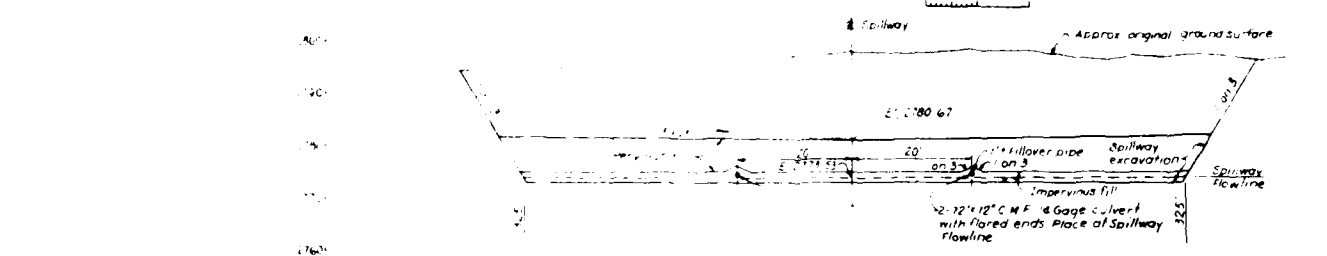
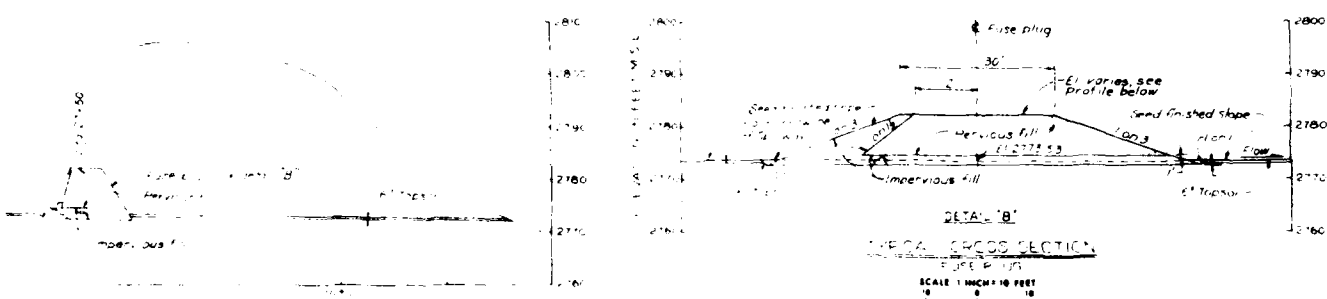
DETAIL AT FLOOR OF SPILLWAY
SCALE 1 INCH = 10 FEET

PIERCING END SECTION
SCALE 1 INCH = 10 FEET

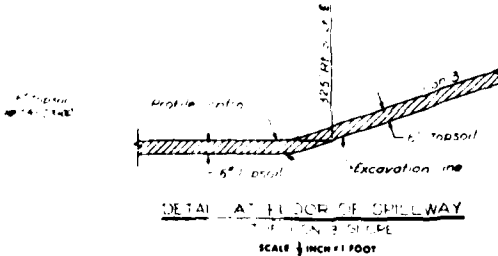
U. S. ARMY



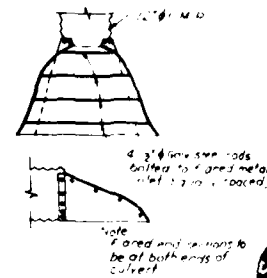
WAY PROFILE-SECTION 3-6
VERT. CURVE 100 FEET
GRADE 0.002



SPILLWAY
APPROX ORIGINAL GROUND SURFACE
ELEVATION 2760
ELEVATION 2770
ELEVATION 2780
ELEVATION 2790
ELEVATION 2800
ELEVATION 2810



DETAIL AT FLOOR OF SPILLWAY
SCALE 1/4" = 1' 0"



FLARED END SECTION AND DETAIL
SCALE 1/4" = 1' 0"

GENERAL NOTES:

- All elevations shown refer to feet above M.S.L. 1929 General Adjustment

THIS DRAWING HAS BEEN REVISIONED TO
SHOW A LARGER SCALE

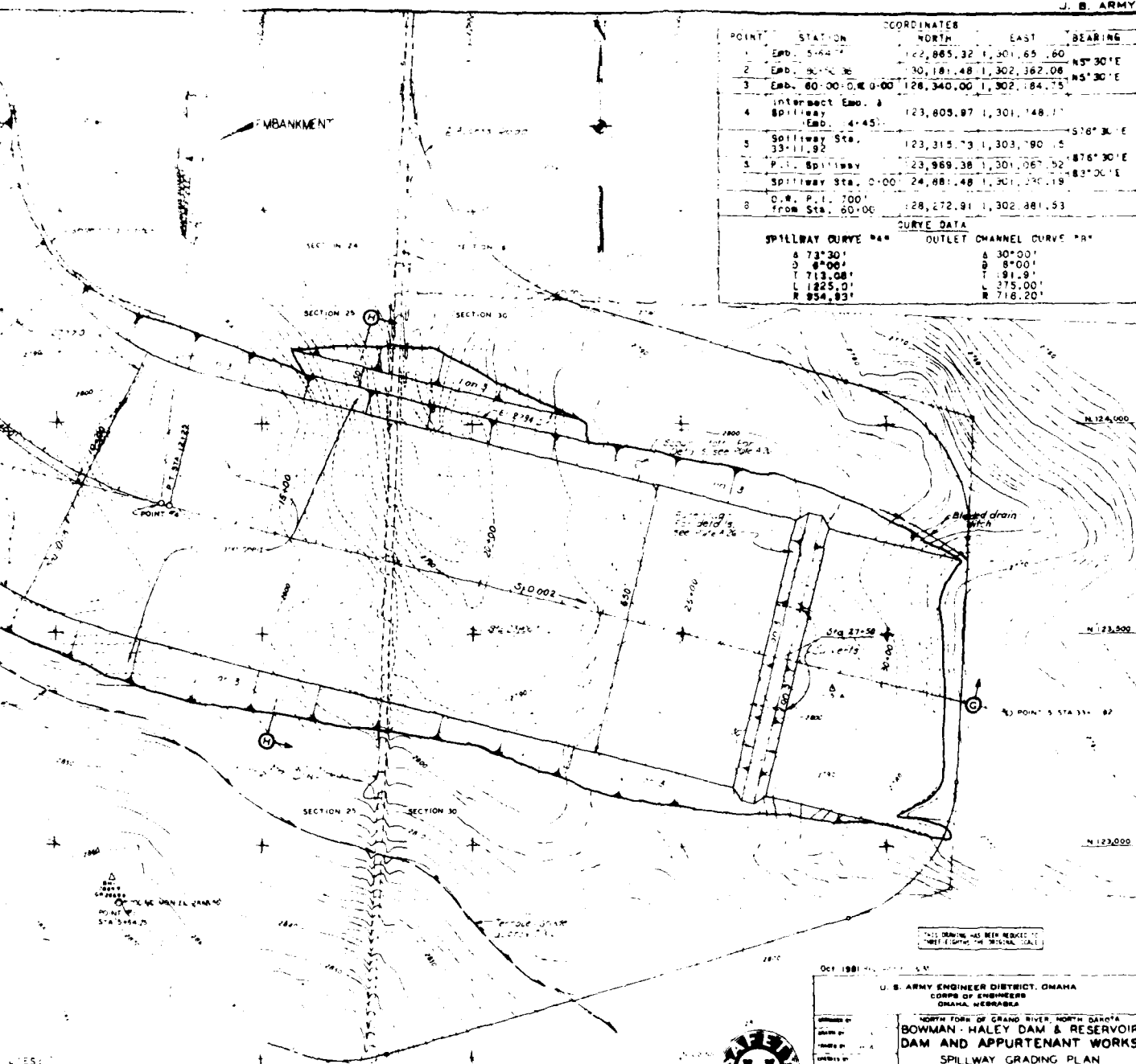
Oct 1981 Revised for O & M

U. S. ARMY ENGINEER DISTRICT, OMAHA GROUP OF ENGINEERS OMAHA, NEBRASKA	
NORTH FORK OF GRAND RIVER, NORTH DAKOTA BOWMAN - HALEY DAM & RESERVOIR DAM AND APPURTENANT WORKS	
SPILLWAY PROFILE SECTIONS AND DETAILS	
DESIGNED BY: J. E. L.	APRIL 1983
CHECKED BY: J. E. L.	DATE: 11-1-83
APPROVED BY: J. E. L.	SCALE: AS SHOWN
6042-50E11	

U. S. ARMY

POINT	STATION	COORDINATES	NORTH	EAST	BEARING
1	Emb. 544.7	122,865.32	1,301.65	60	
2	Emb. 504.36	120,181.48	1,302,162.08		N 5° 30' E
3	Emb. 60.00 + 0.00	126,340.00	1,302,184.75		N 5° 30' E
4	Intersect Emb. A Spillway Sta. 0+00	123,605.97	1,301,948.17		
5	Spillway Sta. 33+11.92	123,315.73	1,303,190.15		S 16° 30' E
6	P.I. Spillway	123,969.38	1,301,067.52		S 76° 30' E
7	Spillway Sta. 0+00	124,681.48	1,301,240.19		S 83° 00' E
8	O.R. P.I. 100' from Sta. 60+00	128,272.91	1,302,881.93		

CURVE DATA	
SPILLWAY CURVE "A"	OUTLET CHANNEL CURVE "B"
A 73° 30'	A 30° 00'
B 8° 00'	B 8° 00'
T 713.08'	T 81.9'
L 225.0'	L 375.00'
R 954.83'	R 716.20'



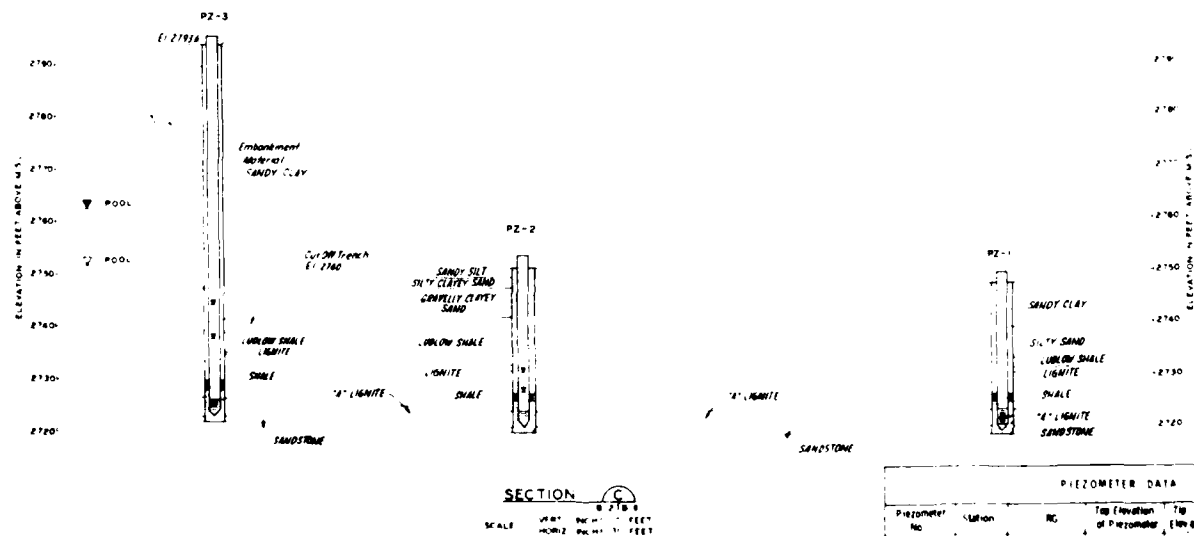
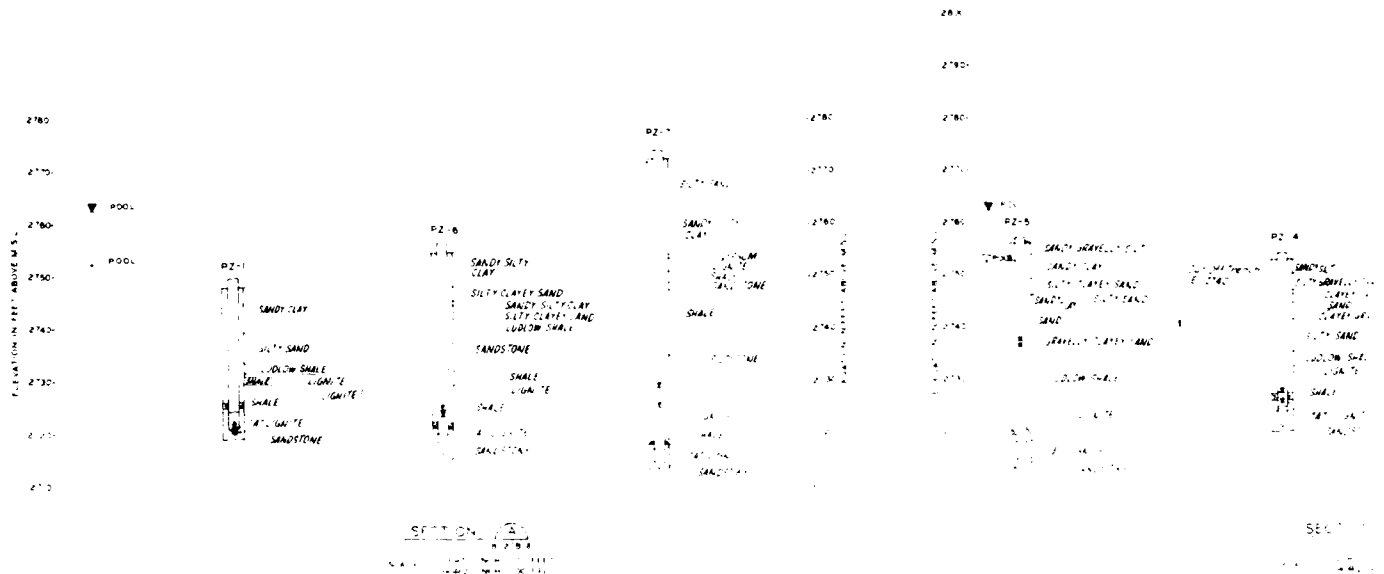
Oct 1981

U. S. ARMY ENGINEER DISTRICT, OMAHA
CORPS OF ENGINEERS
OMAHA, NEBRASKA

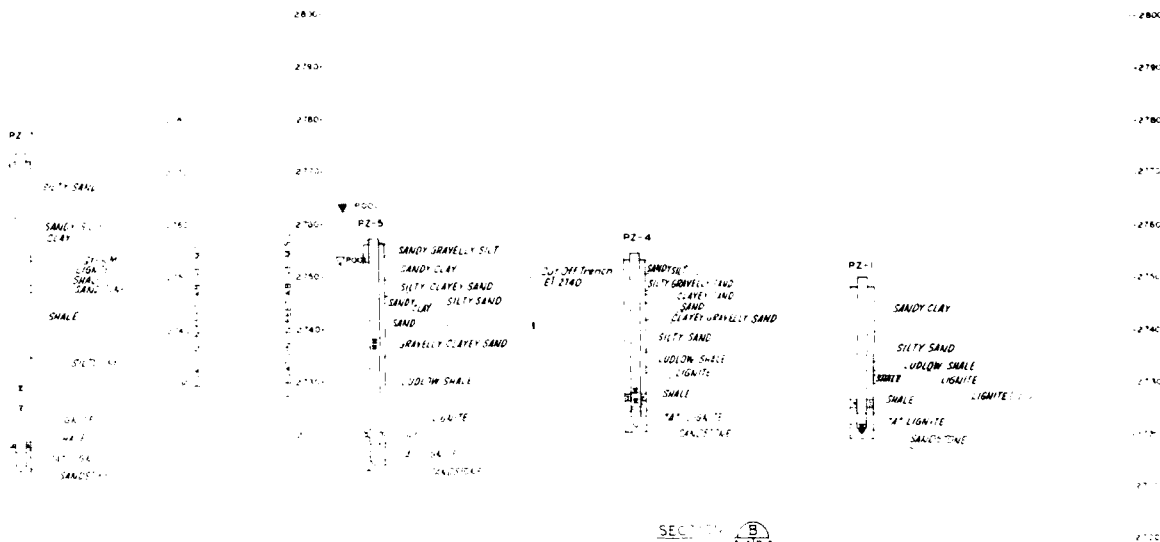
REPORT FORM OF GRAND RIVER, NORTH DAKOTA
BOWMAN-HALEY DAM & RESERVOIR
DAM AND APPURTENANT WORKS
SPILLWAY GRADING PLAN

DESIGNED BY: [Signature]
CHECKED BY: [Signature]
APPROVED BY: [Signature]
DATE: 10/1/81

GBM2-50E6

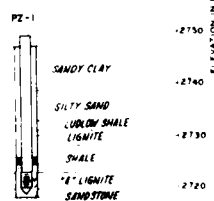


Piezometer No.	Station	RG	Top Elevation of Piezometer	Top Elevation	Sensing Zone Top Elev.	Sensing Zone Bottom Elev.
PZ-1	61+56	410 D/S	2718.1	2718.1	2718.4	2718.2
PZ-2	61+80	190 D/S	2719.0	2719.9	2720.0	2719.0
PZ-3	62+00	12 D/S	2718.1	2722.1	2721.1	2721.6
PZ-4	65+10	140 D/S	2715.1	2720.9	2721.8	2719.8
PZ-5	10+20	130 D/S	2718.8	2714.1	2719.1	2713.1
PZ-6	15+54	400 D/S	2717.1	2718.0	2725.0	2715.1
PZ-7	5+01	190 D/S	2717.8	2713.4	2718.4	2712.1



SECTION B
A 278.6
ELEVATION IN FEET ABOVE M.S.L.

LEGEND
 * March 10 (Record High Pool)
 * June 01 (Record Low Pool)



PIEZOMETER DATA

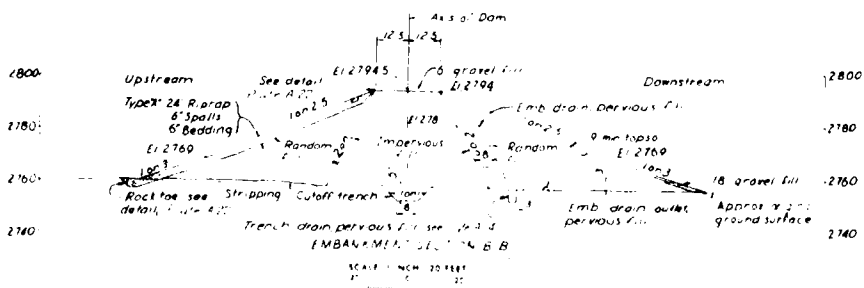
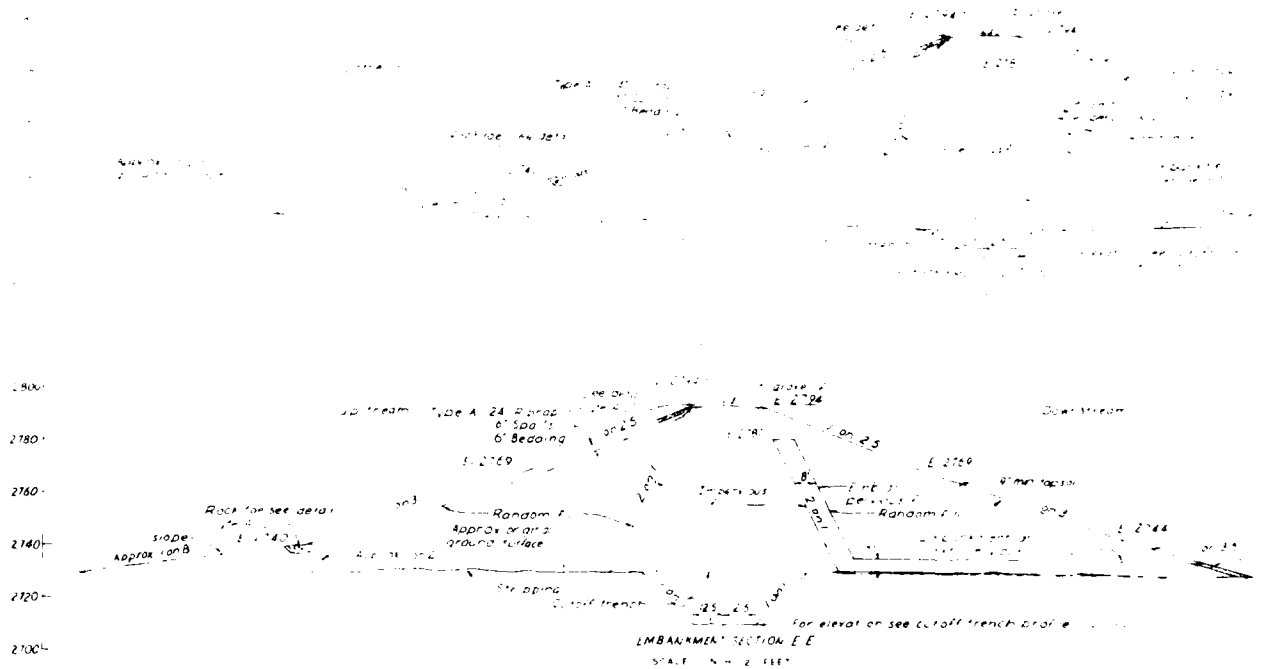
Piezometer No.	Station	R.C.	Top Elevation of Piezometer	Top Elevation	Top Elev.	Bottom Elev.
PZ-1	61+56	410' O/S	2749.7	2719.7	2724.4	2718.1
PZ-2	61+80	150' O/S	2753.0	2719.9	2725.0	2719.0
PZ-3	62+00	12' U/S	2746.1	2722.7	2727.1	2721.6
PZ-4	65+10	140' O/S	2755.3	2720.9	2725.8	2719.8
PZ-5	70+20	130' U/S	2756.8	2714.3	2719.7	2711.3
PZ-6	75+54	400' O/S	2757.1	2718.0	2723.0	2715.3
PZ-7	79+55	390' O/S	2774.4	2713.4	2718.4	2712.1



U. S. ARMY ENGINEER DISTRICT, OMAHA CORPS OF ENGINEERS OMAHA, NEBRASKA	
NORTH FORK OF GRAND RIVER, NORTH DAKOTA BOWMAN-HALEY DAM AND RESERVOIR	
PIEZOMETER SECTIONS 1/4" LIGNITE LAYER	
DATE: _____	BY: _____
CHECKED BY: _____	DATE: _____

CORPS OF ENGINEERS

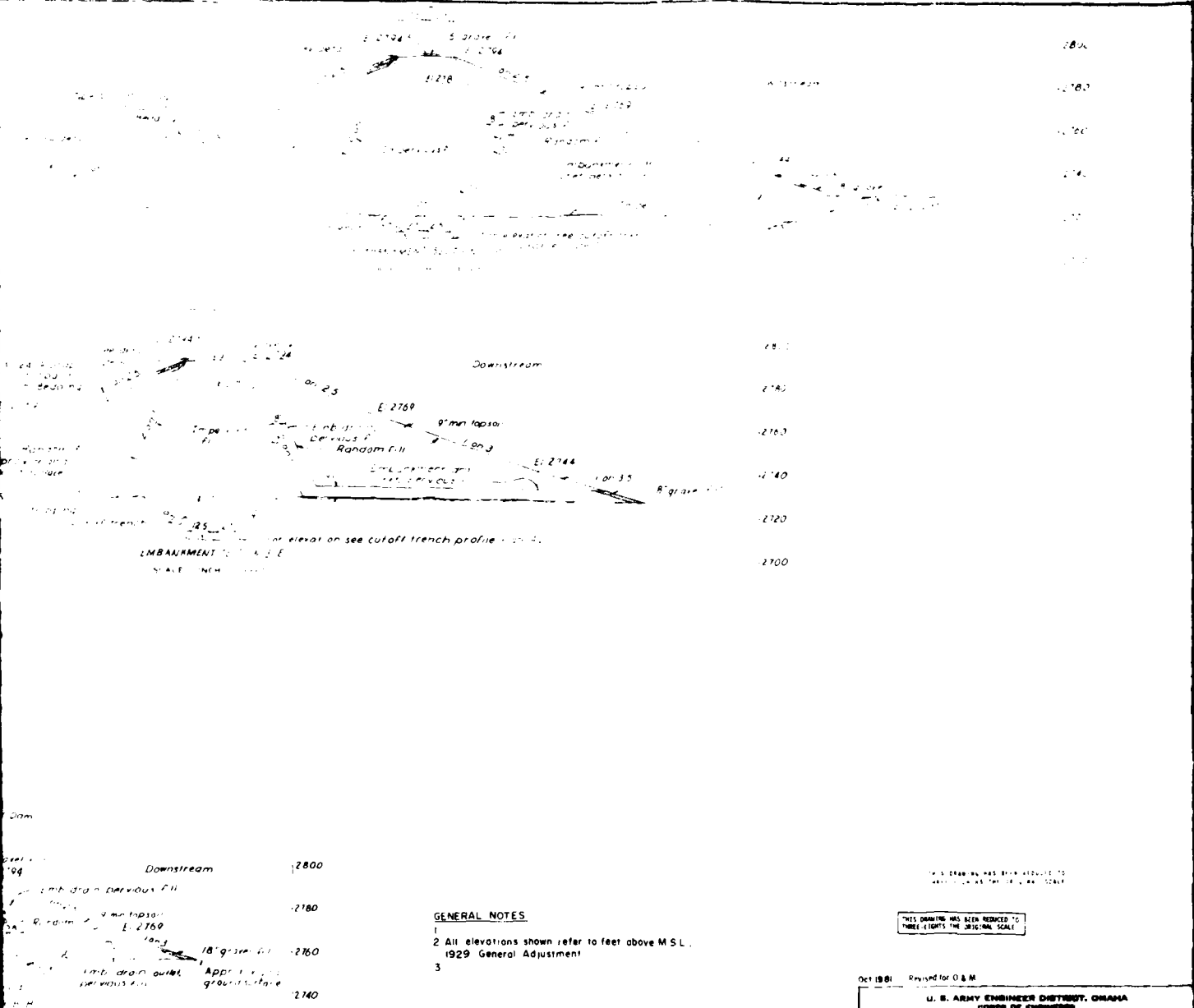
A 105 Measurement Plan of a Paper Reproduced from
 Army Corps of Engineers, Hydrographic Survey, and for
 Navigation
 AMERICAN
 CORPORATION
 DATE



GENERAL NOTES

- 1 All elevations shown refer to feet above 1929 General Adjustment
- 2
- 3

CONSTRUCT



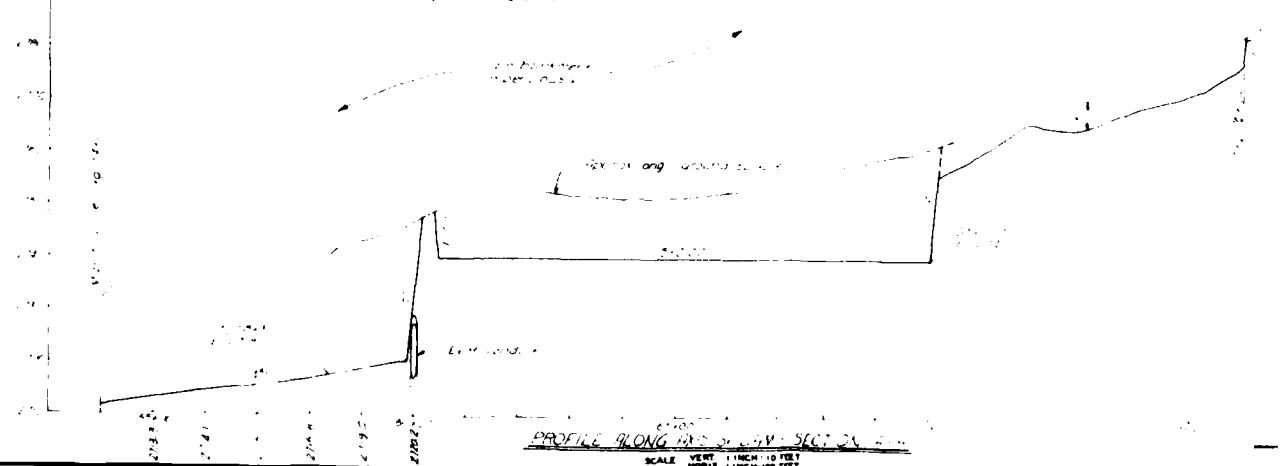
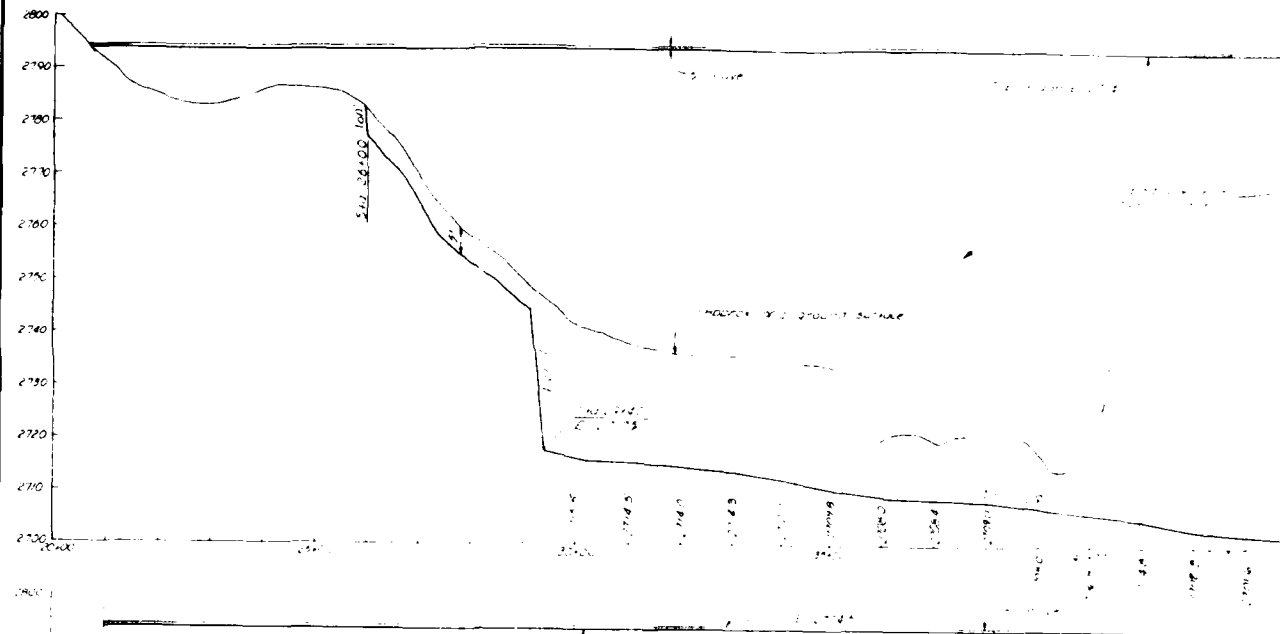
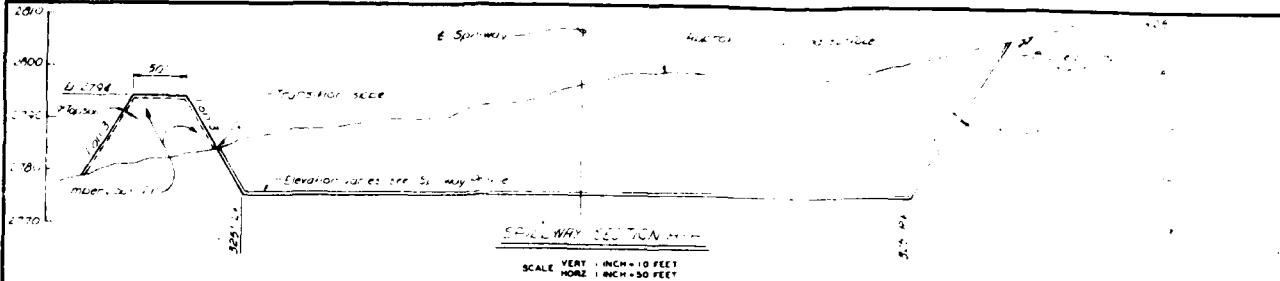
GENERAL NOTES
 1
 2 All elevations shown refer to feet above M.S.L.
 1929 General Adjustment
 3

THIS DRAWING HAS BEEN REDUCED TO
 THREE EIGHTS THE ORIGINAL SCALE

OCT 1961		Revised for O & M	
U. S. ARMY ENGINEER DISTRICT, OMAHA CORPS OF ENGINEERS OMAHA, NEBRASKA			
DESIGNED BY		NORTH FORK OF GRAND RIVER, NORTH DAKOTA	
DRAWN BY		BOWMAN-HALEY DAM & RESERVOIR	
CHECKED BY		DAM AND APPURTENANT WORKS	
APPROVED BY		EMBANKMENT SECTIONS	
DATE		APRIL 1965	
SCALE		AS SHOWN	
PROJECT		GBH2-50E8	

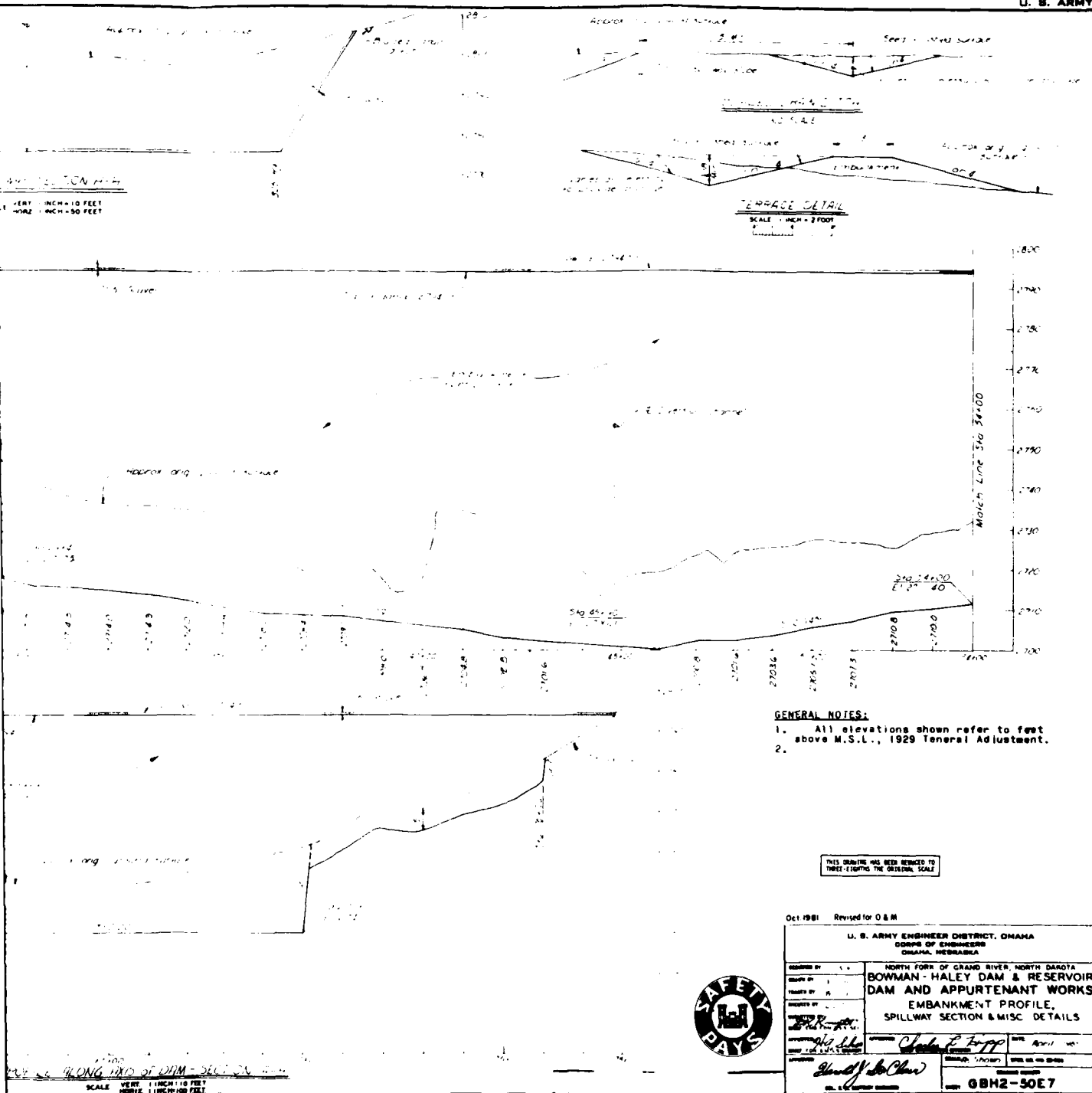


CORPS OF ENGINEERS



CONST

U. S. ARMY

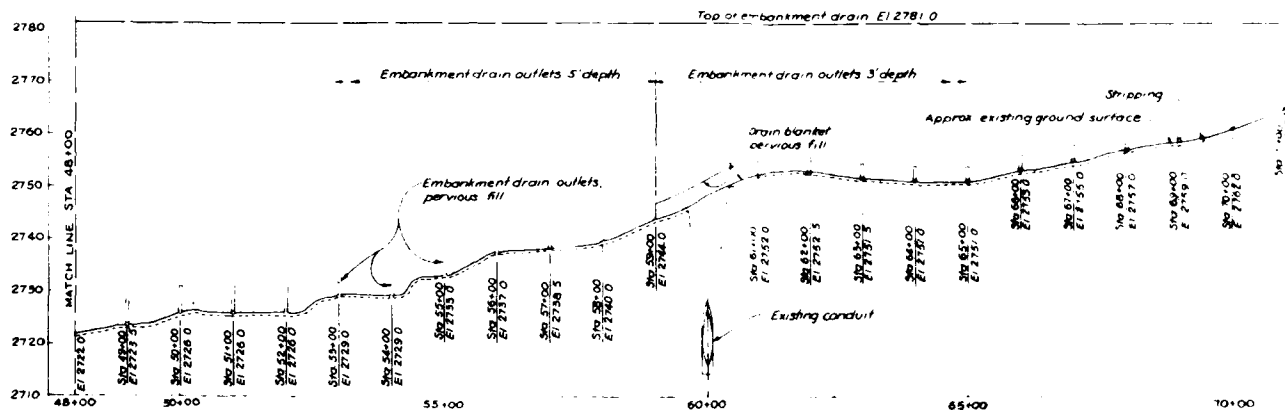


GENERAL NOTES:
1. All elevations shown refer to feet above M.S.L., 1929 Tederal Adjustment.
2.

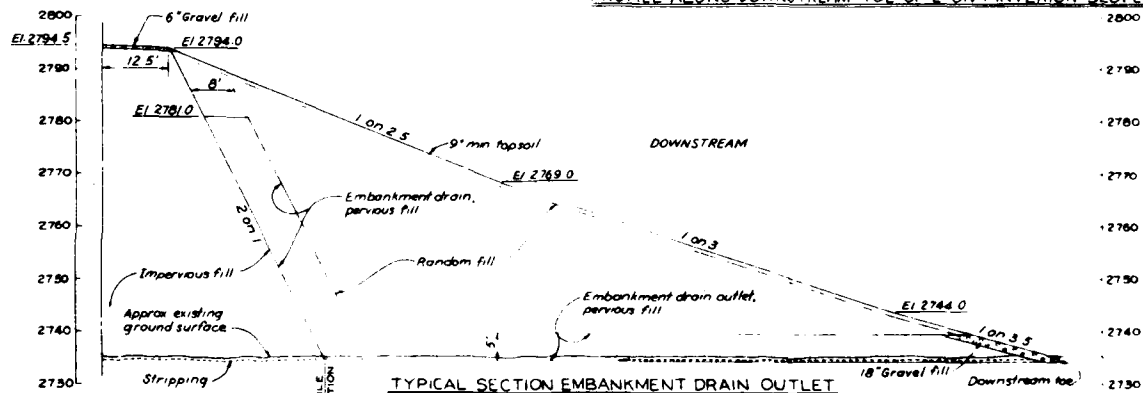
THIS DRAWING HAS BEEN REDUCED TO THREE-EIGHTHS THE ORIGINAL SCALE

Oct 1981		Revised for O & M	
U. S. ARMY ENGINEER DISTRICT, OMAHA CORPS OF ENGINEERS OMAHA, NEBRASKA			
DESIGNED BY	1	NORTH FORK OF GRAND RIVER, NORTH DAKOTA	
DRAWN BY	1	BOWMAN - HALEY DAM & RESERVOIR	
CHECKED BY	1	DAM AND APPURTENANT WORKS	
APPROVED BY	1	EMBANKMENT PROFILE, SPILLWAY SECTION & MISC. DETAILS	
DATE	April 1981	DESIGNED BY	Charles E. Foy
DRAWN BY	1	CHECKED BY	1
CHECKED BY	1	APPROVED BY	1
DATE	April 1981	PROJECT NO.	GBH2-50E7

SCALE HORIZ 1 INCH = 100 FEET
VERT 1 INCH = 10 FEET



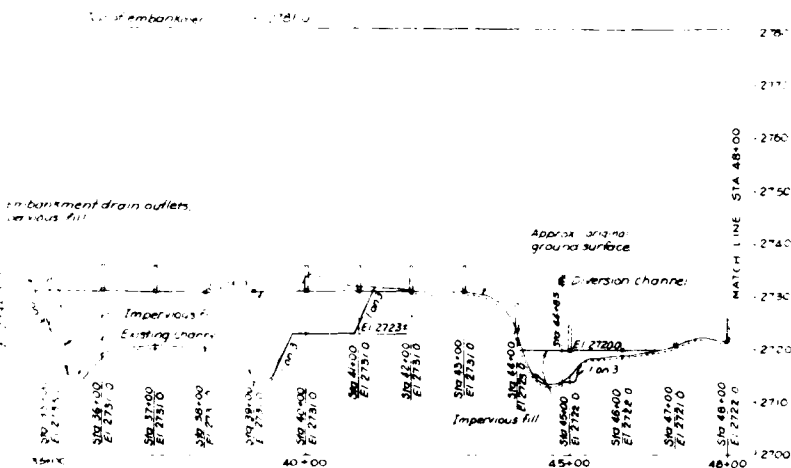
PROFILE ALONG DOWNSTREAM TOE OF 2 ON 1 INTERIOR SLOPE



TYPICAL SECTION EMBANKMENT DRAIN OUTLET

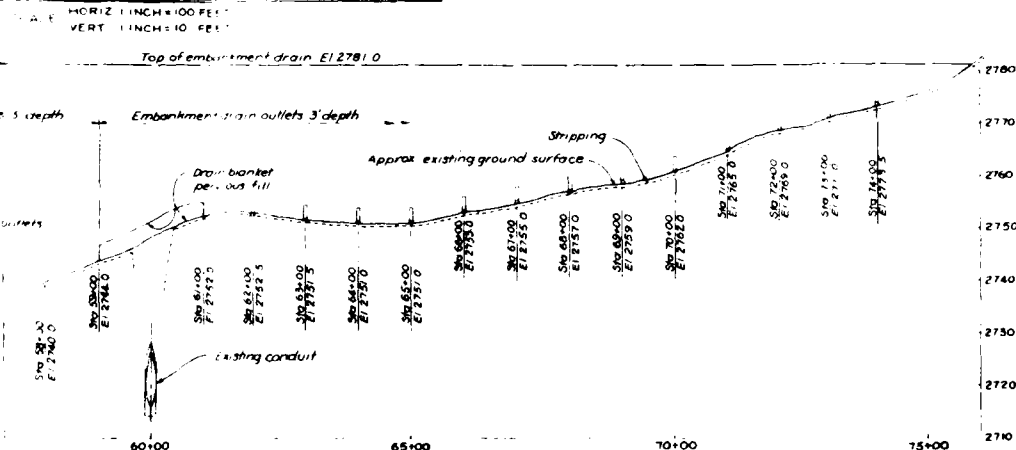
SCALE 1 INCH = 10 FEET

CONSTH



TYPICAL EMBANKMENT DRAIN OUTLET

PROFILE DOWNSTREAM TOE OF 2 ON 1 INTERIOR SLOPE



PROFILE ALONG DOWNSTREAM TOE OF 2 ON 1 INTERIOR SLOPE

GENERAL NOTES:

- All elevation shown refer to feet above M.S.L. 1929 General Adjustment.

THIS DRAWING HAS BEEN REDUCED TO THREE EIGHTS THE ORIGINAL SCALE

THIS DRAWING HAS BEEN REDUCED TO THREE EIGHTS THE ORIGINAL SCALE

DOWNSTREAM

Embankment drain outlet, pervious fill

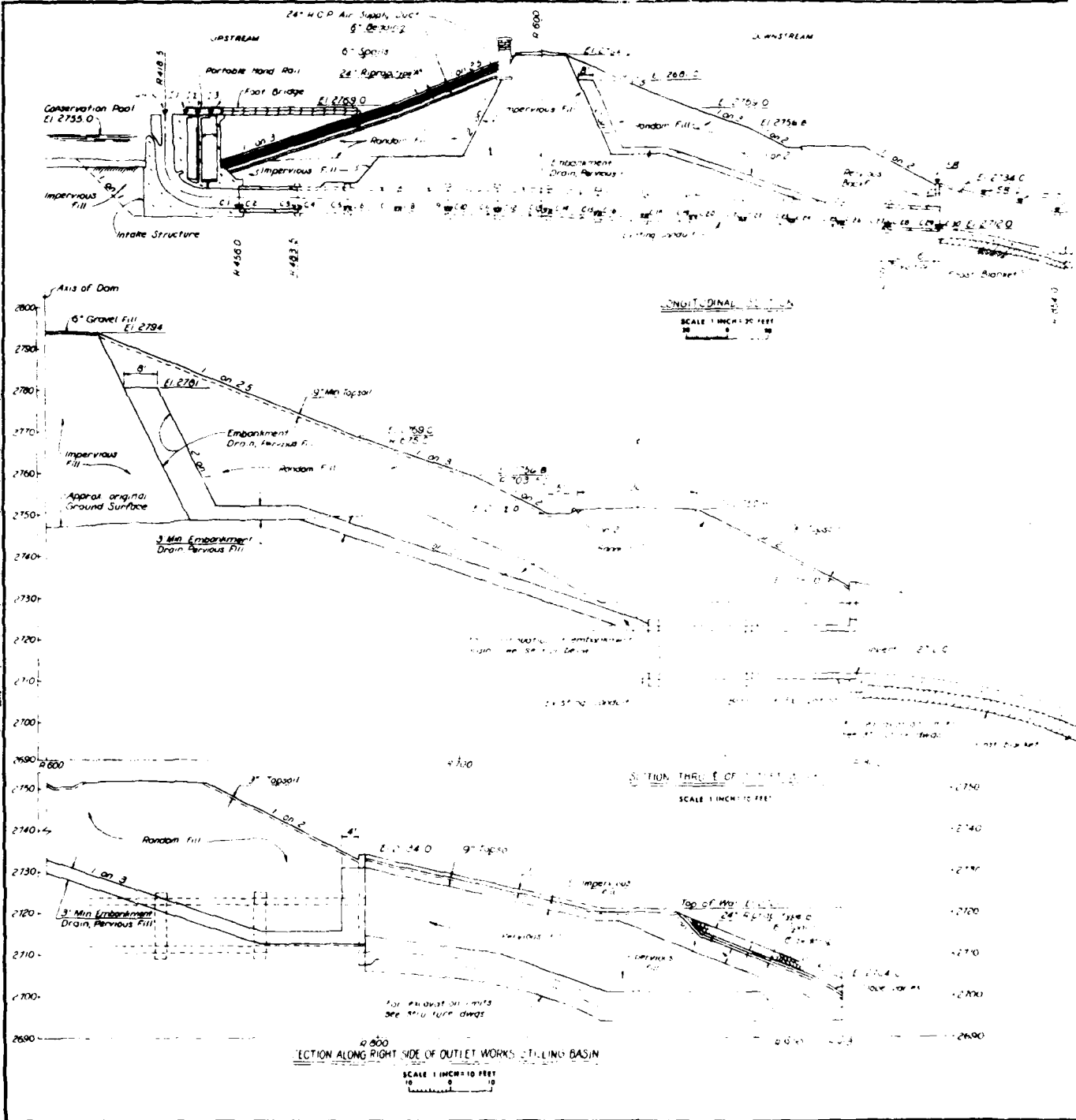
EMBANKMENT DRAIN OUTLET

Scale: 1" = 10 FEET



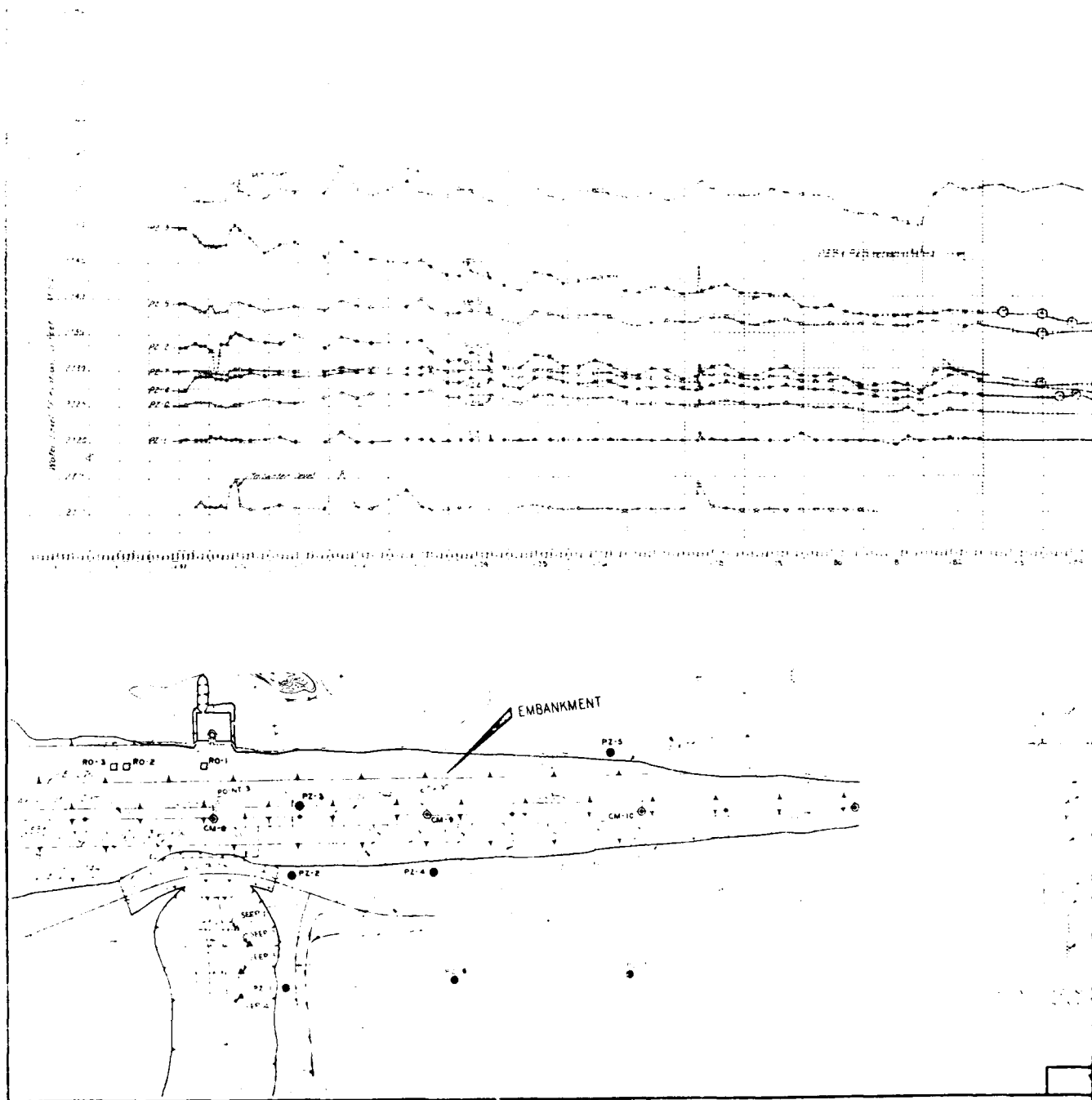
Oct 1981 Revised for O & M	
U. S. ARMY ENGINEER DISTRICT, CHAMPAIGN GROUP OF ENGINEERS CHAMPAIGN, ILLINOIS	
DESIGNED BY: [Signature]	NORTH FORK OF GRAND RIVER, NORTH DAKOTA BOWMAN-HALEY DAM & RESERVOIR DAM AND APPURTENANT WORKS EMBANKMENT DRAIN PROFILE, SECTION AND DETAIL
CHECKED BY: [Signature]	DATE: APRIL 1988
APPROVED BY: [Signature]	DATE: 45 MONTHS
GEM2-80E9	

CORPS OF ENGINEERS

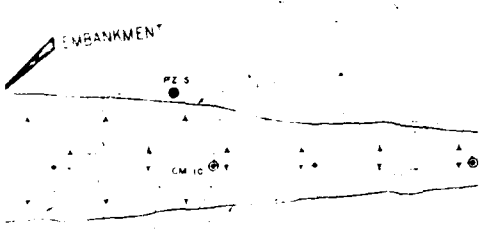
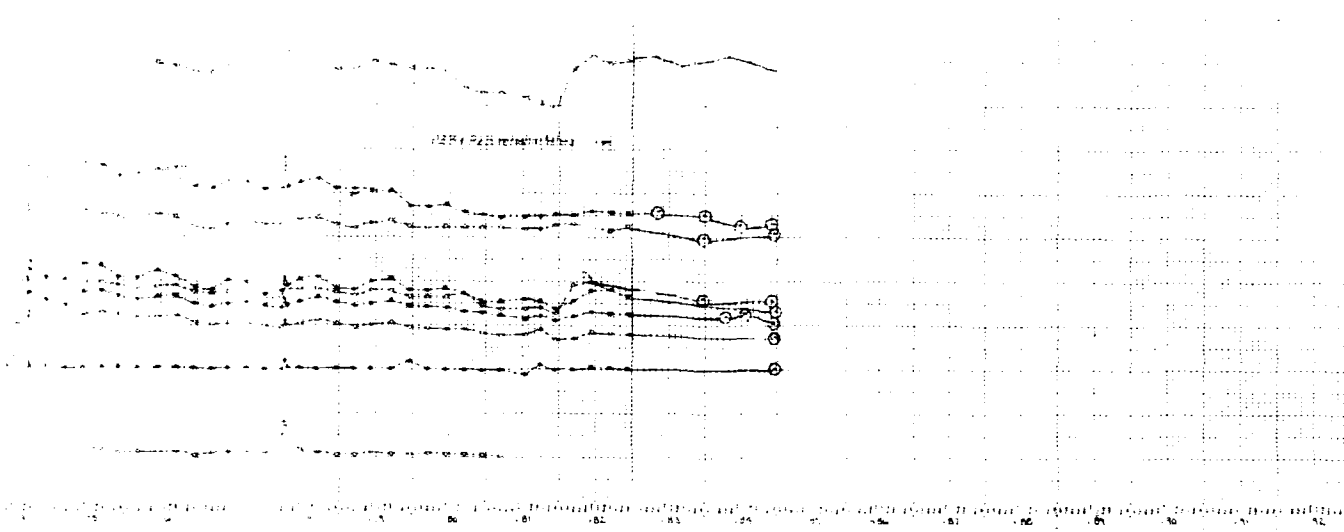


CONSTRUCTI





CONSTR

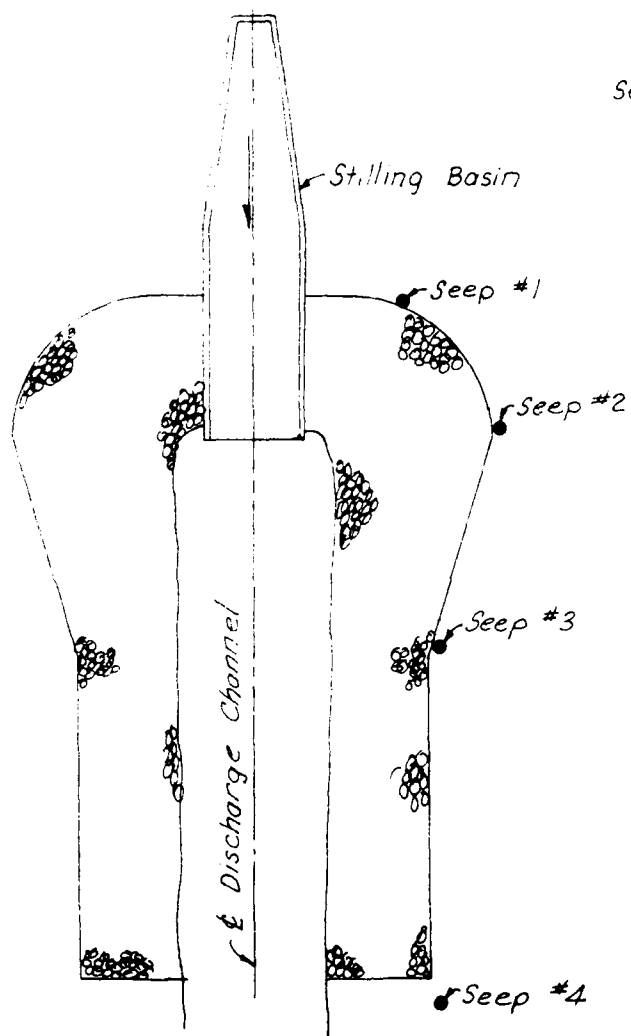


PIEZOMETER DE A. 1



THIS PLAN ACCOMPANIES CONTRACT NO. MODIFICATION NO.

DATE		REVISION		NAME	
U. S. ARMY ENGINEER DISTRICT OMAHA CORPS OF ENGINEERS OMAHA, NEBRASKA					
DESIGNED BY		NORTH FOR. OF GRAND D. DAM NORTH DAM, I.A.			
DRAWN BY		BOWMAN-HALEY DAM AND RESERVOIR			
CHECKED BY		PIEZOMETER OBSERVATIONS			
APPROVED BY		IN LIGNITE LAYER			
SCALE	SECTION	DATE			
APPROVED	SCALE	DATE			



Seepage area
 4" Steel pipe
 Steel support posts
 Dike formed from material in basin

PLAN - SEEPAGE MEASUREMENT STATION

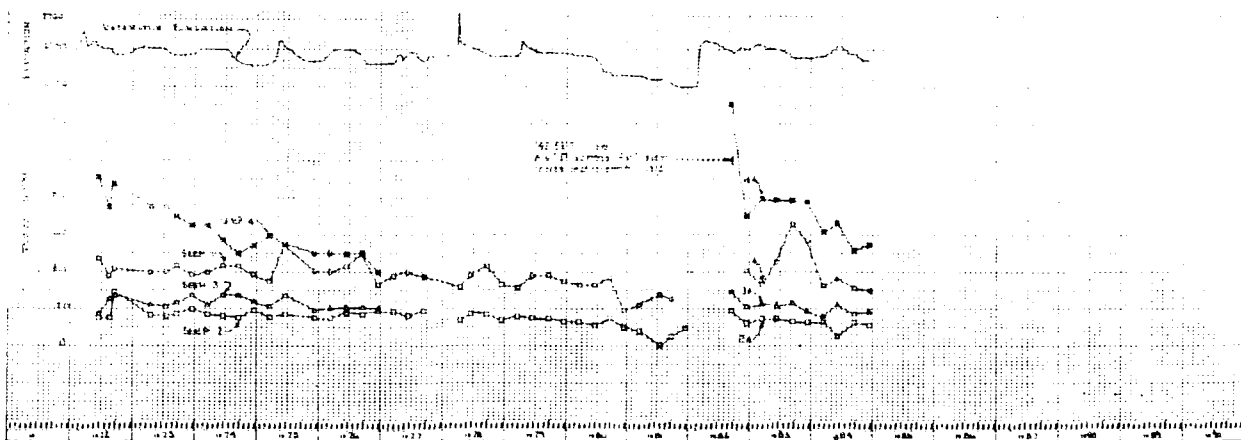
SEEPAGE AREA LOCATION PLAN

are formed from
potential in basin

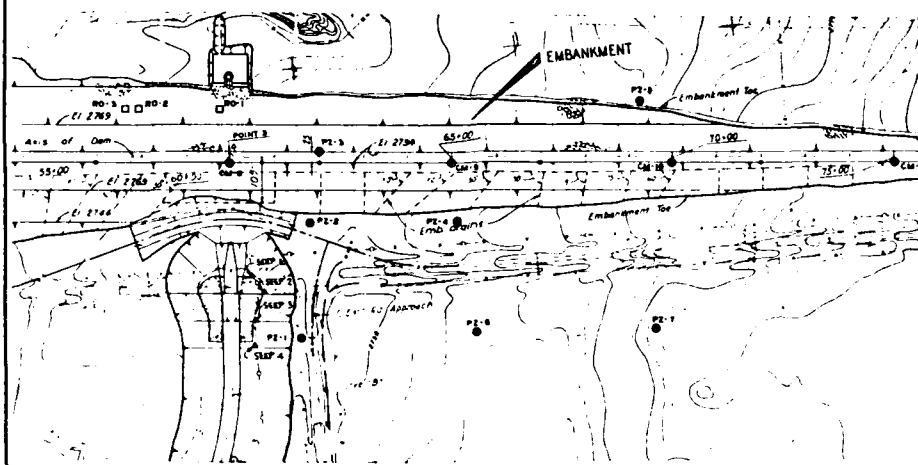
SEEPAGE MEASUREMENT

[illegible]

BOWMAN-HALEY DAM AND LAKE
SEEPAGE ALONG LIGNITE SEEMS
LEFT BANK DISCHARGE CHANNEL

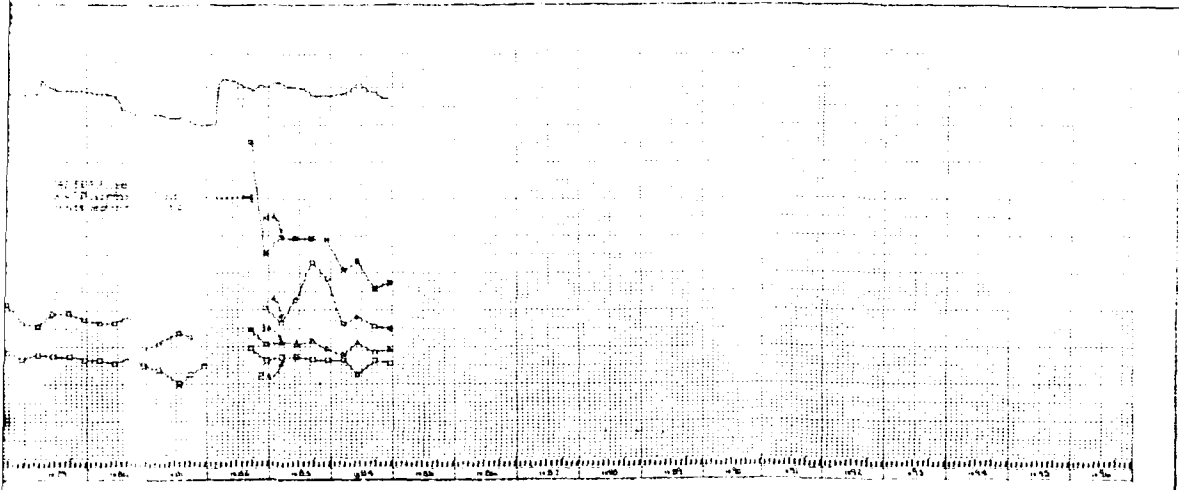


Note: Seals No 384 are missing - 208
last reading Dec 97
2 Seals No 2 - no reading taken between
August 97 and April 98

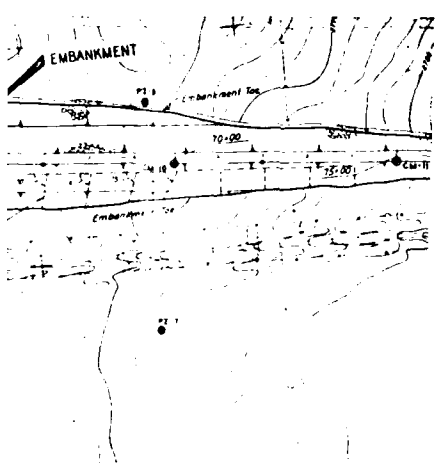


THE PLAN ASSUMES CONTRA

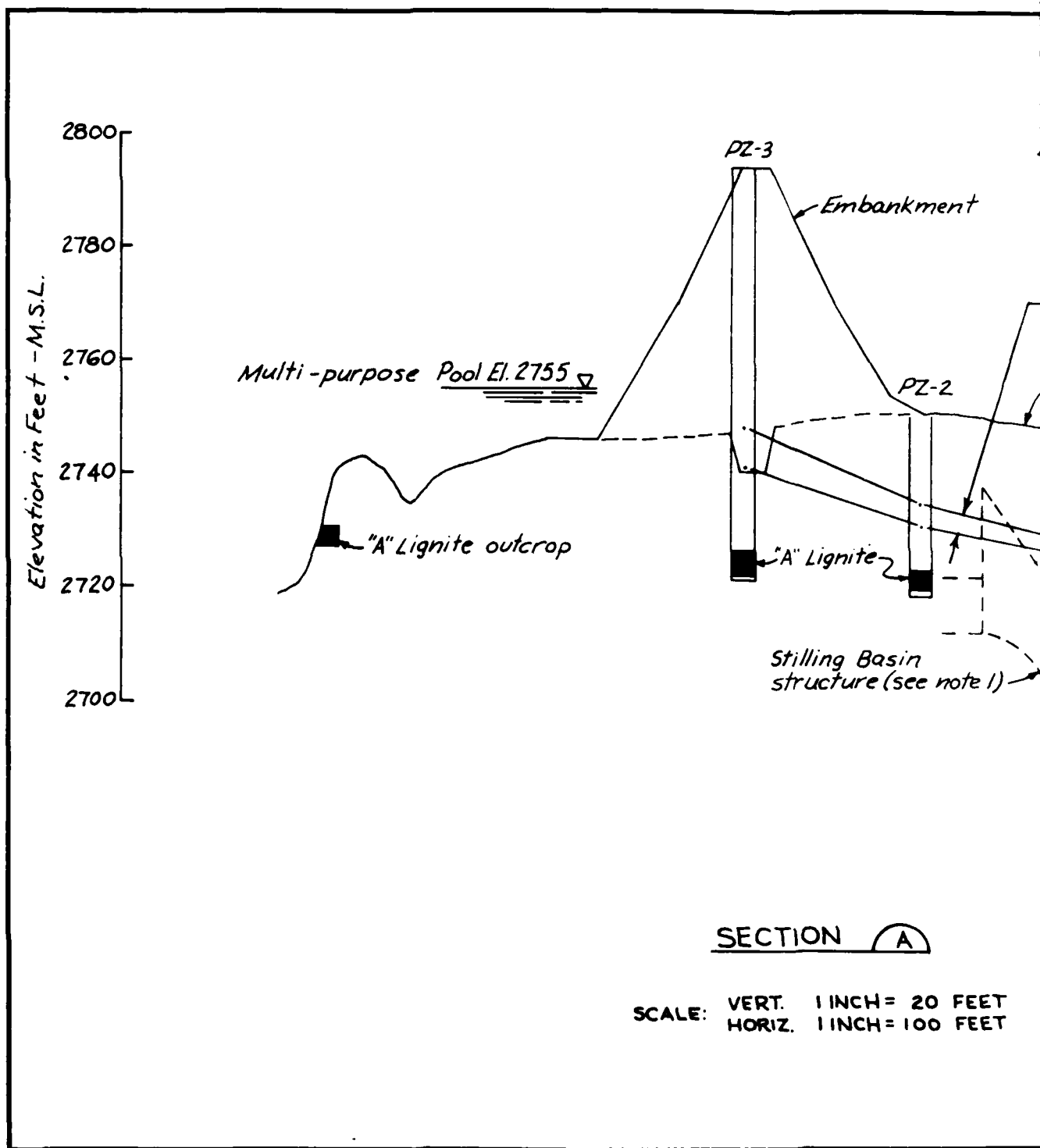
INSTRUCTION FOUNDATION :

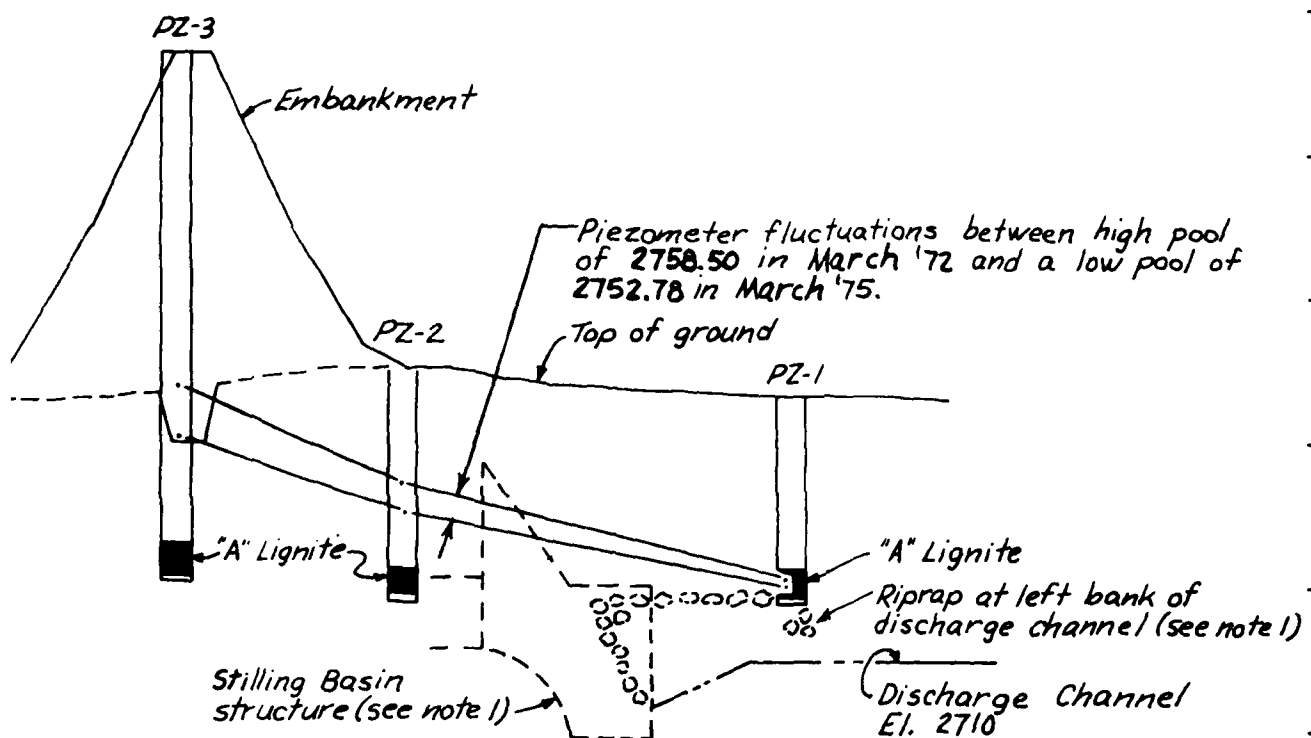


Note: 1 Seep No 314 are in danger of
 lost reading Dec 1976
 2 Seep No 2, no reading from 24 March
 August 1977 and April 1978



DATE		DRAWN BY		CHECKED BY	
U. S. ARMY ENGINEER DISTRICT, OMAHA CORPS OF ENGINEERS OMAHA, NEBRASKA					
NORTH FORK OF GRAND RIVER, NORTH DAKOTA BOWMAN-HALEY DAM AND RESERVOIR					
SEEPAGE ALONG LIGNITE SEAMS LEFT BANK DISCHARGE CHANNEL FLOW OBSERVATIONS					
DESIGNED BY	DATE	SCALE	AS SHOWN	DATE	BY
CHECKED BY	DATE	SCALE	AS SHOWN	DATE	BY





Notes:

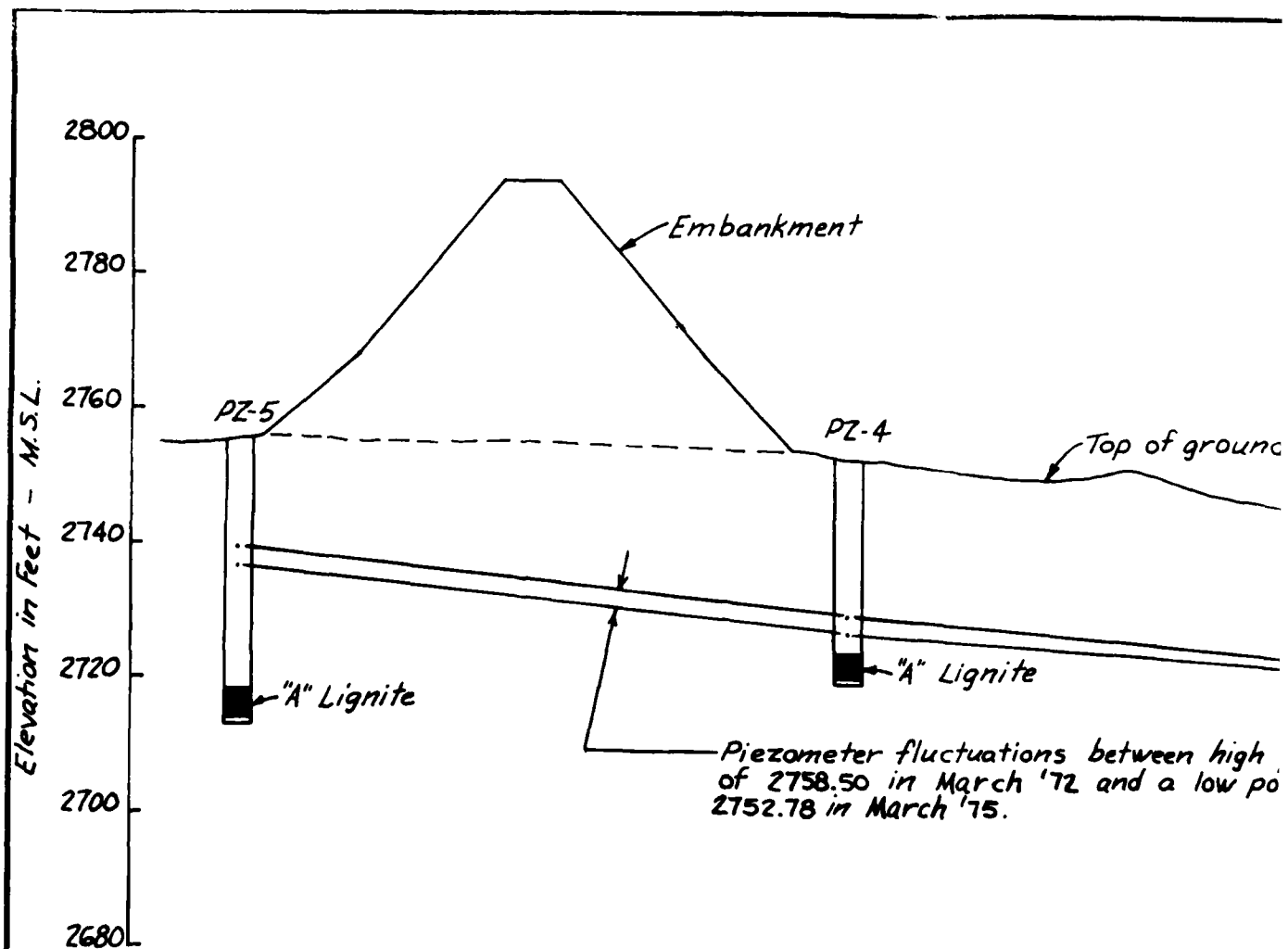
1. The stilling basin structure is located approx. 150' south of Section "A"
2. Seepage is emerging along the upper edge of the riprap, at the exposed "A" Lignite seam.

SECTION A

SCALE: VERT. 1 INCH = 20 FEET
HORIZ. 1 INCH = 100 FEET

BOWMAN-HALEY DAM AND LAKE

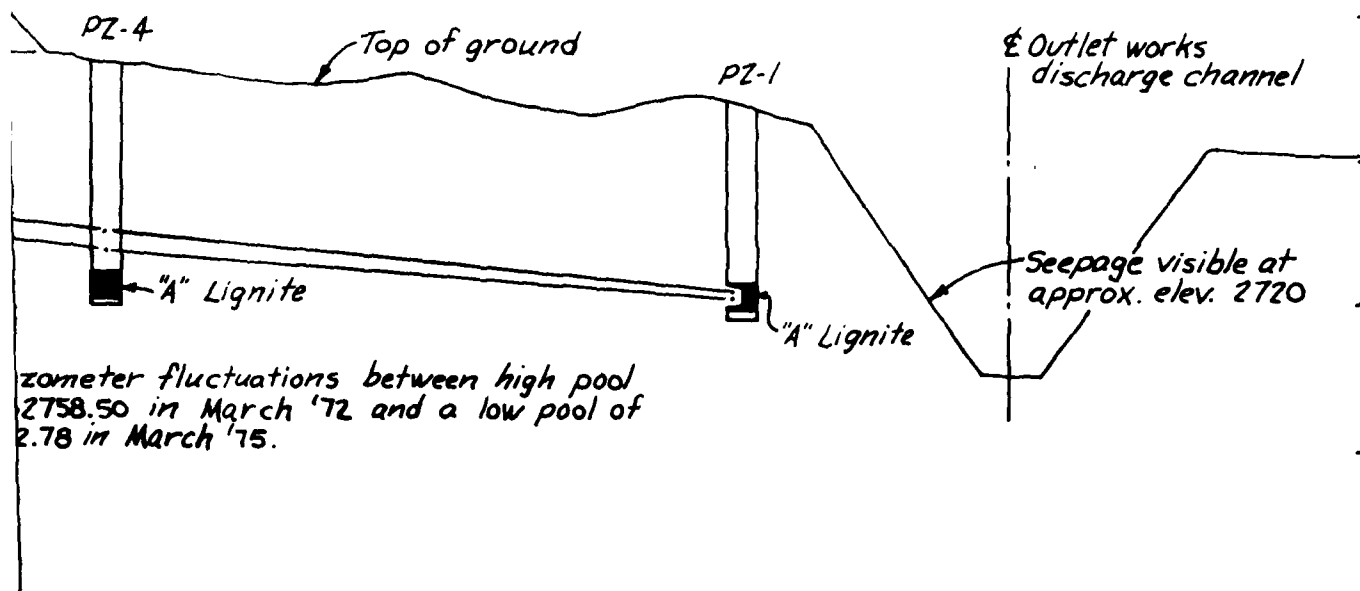
**PIEZOMETERS
SECTION "A"**



SECTION B

SCALE: VERT. 1 INCH = 20 FEET
HORIZ 1 INCH = 100 FEET

nkment

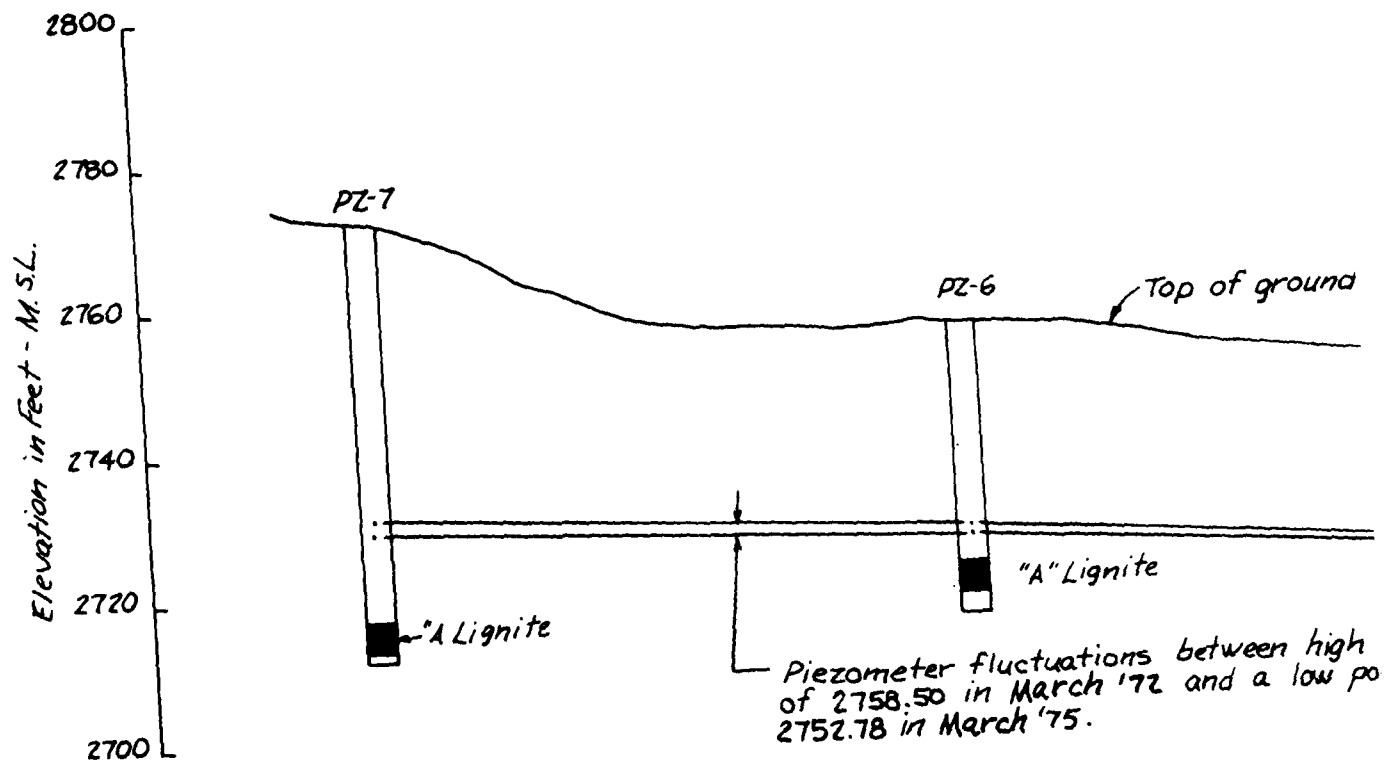


piezometer fluctuations between high pool
2758.50 in March '72 and a low pool of
2718 in March '75.

SECTION B

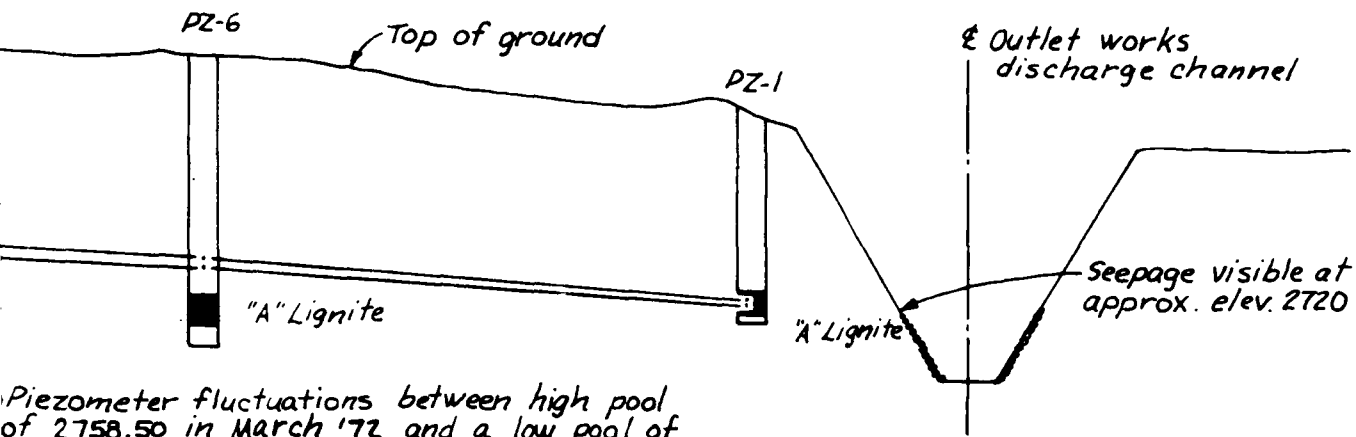
SCALE: VERT. 1 INCH = 20 FEET
HORIZ 1 INCH = 100 FEET

BOWMAN-HALEY DAM AND LAKE
PIEZOMETERS
SECTION "B"



SECTION C

SCALE: VERT. 1 INCH = 20 FEET
HORIZ. 1 INCH = 100 FEET

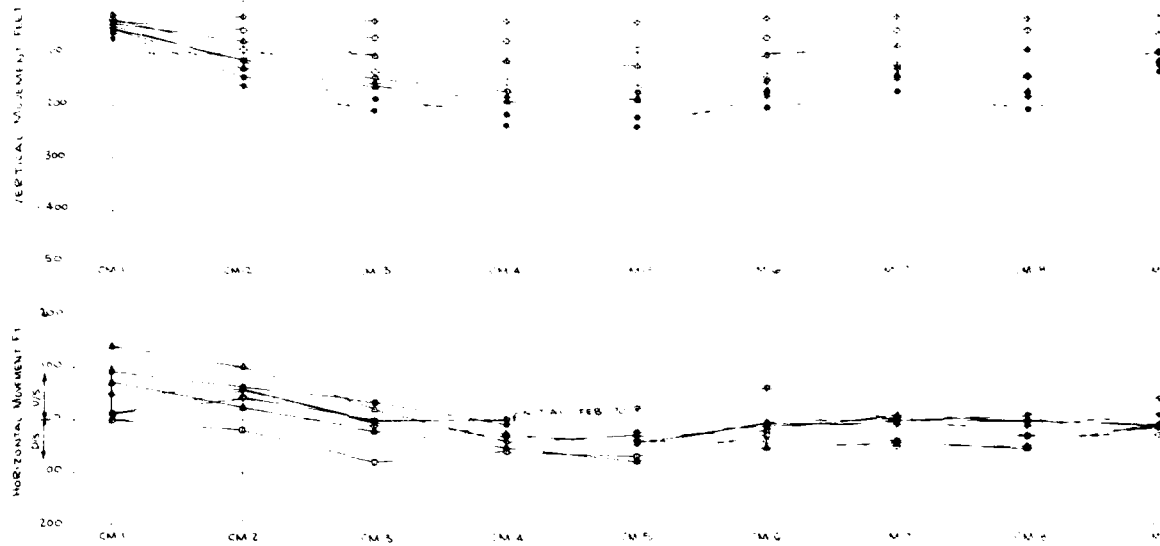


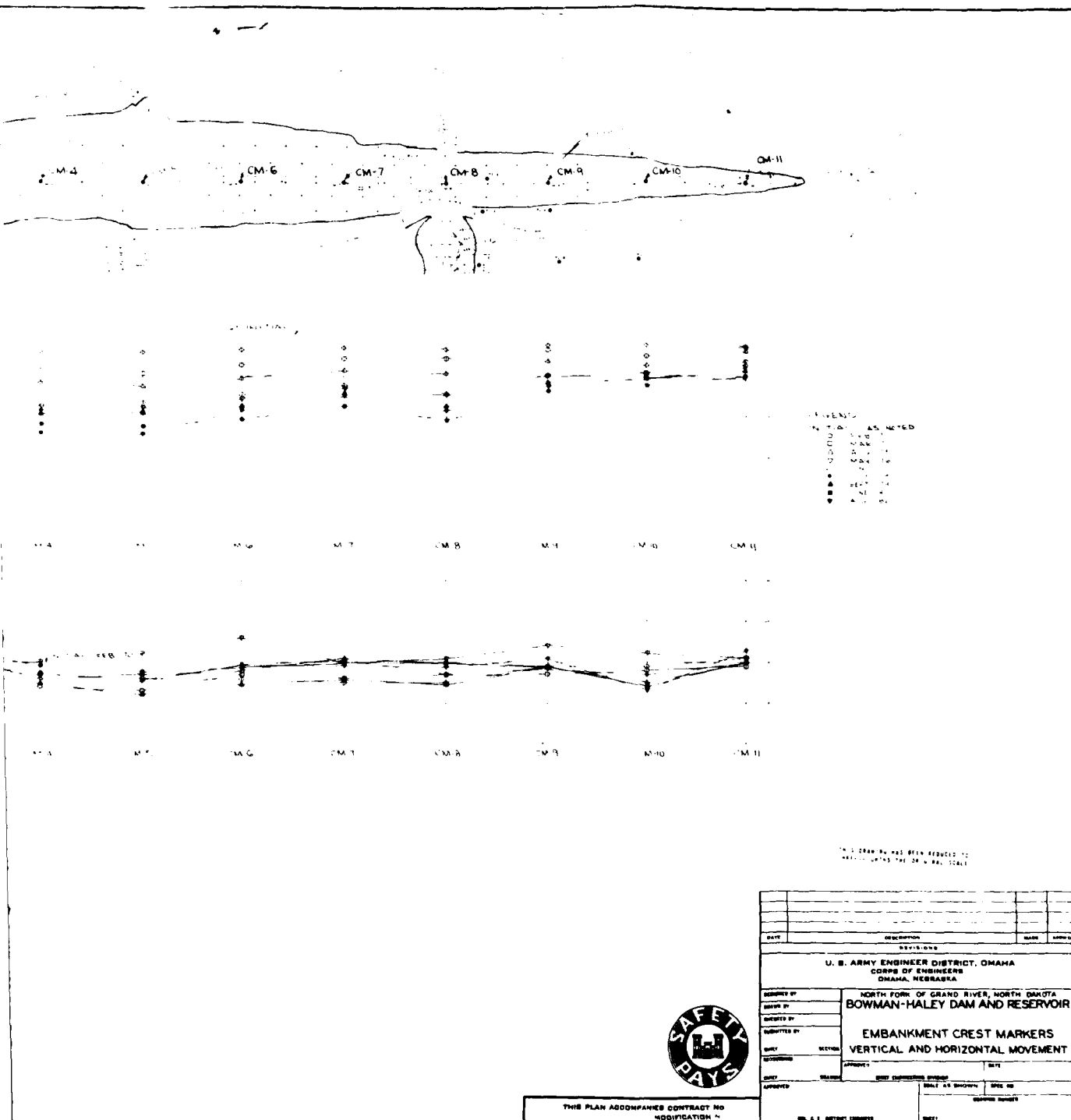
Piezometer fluctuations between high pool of 2758.50 in March '72 and a low pool of 2752.78 in March '75.

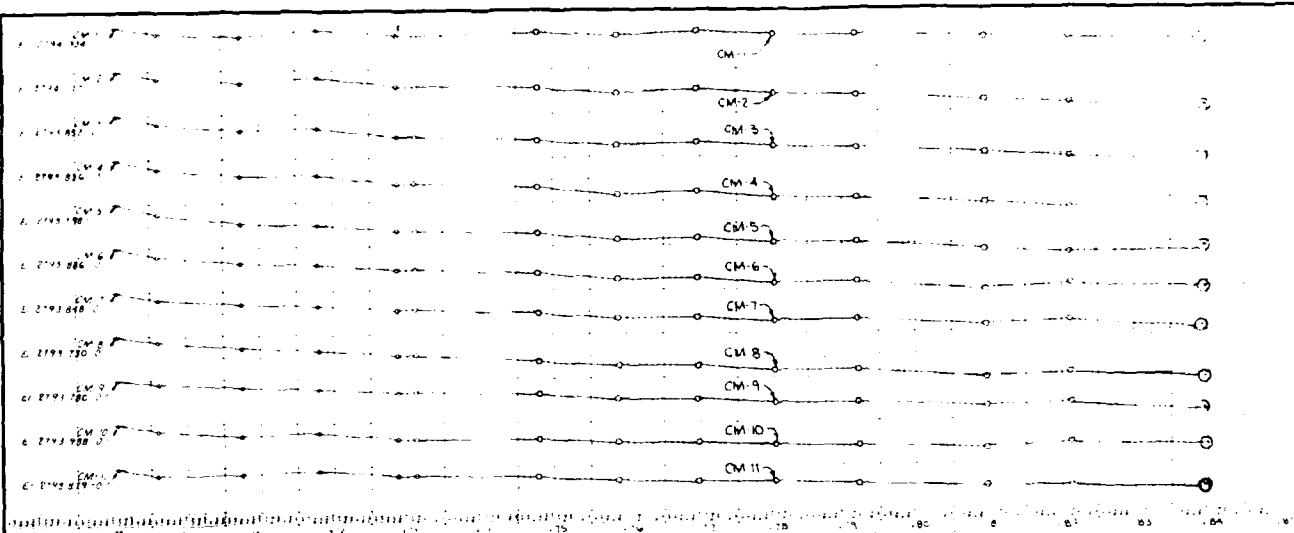
SECTION C

SCALE: VERT. 1 INCH = 20 FEET
HORIZ. 1 INCH = 100 FEET

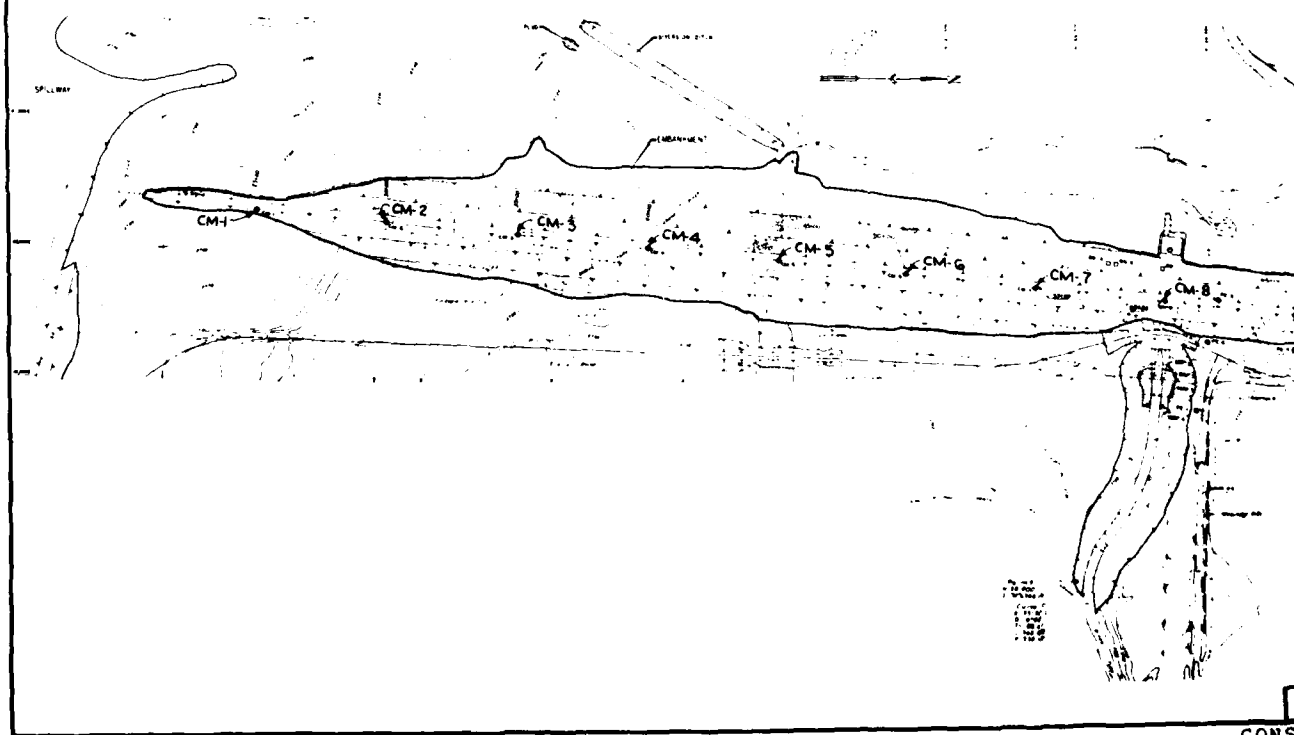
BOWMAN-HALEY DAM AND LAKE PIEZOMETERS SECTION C



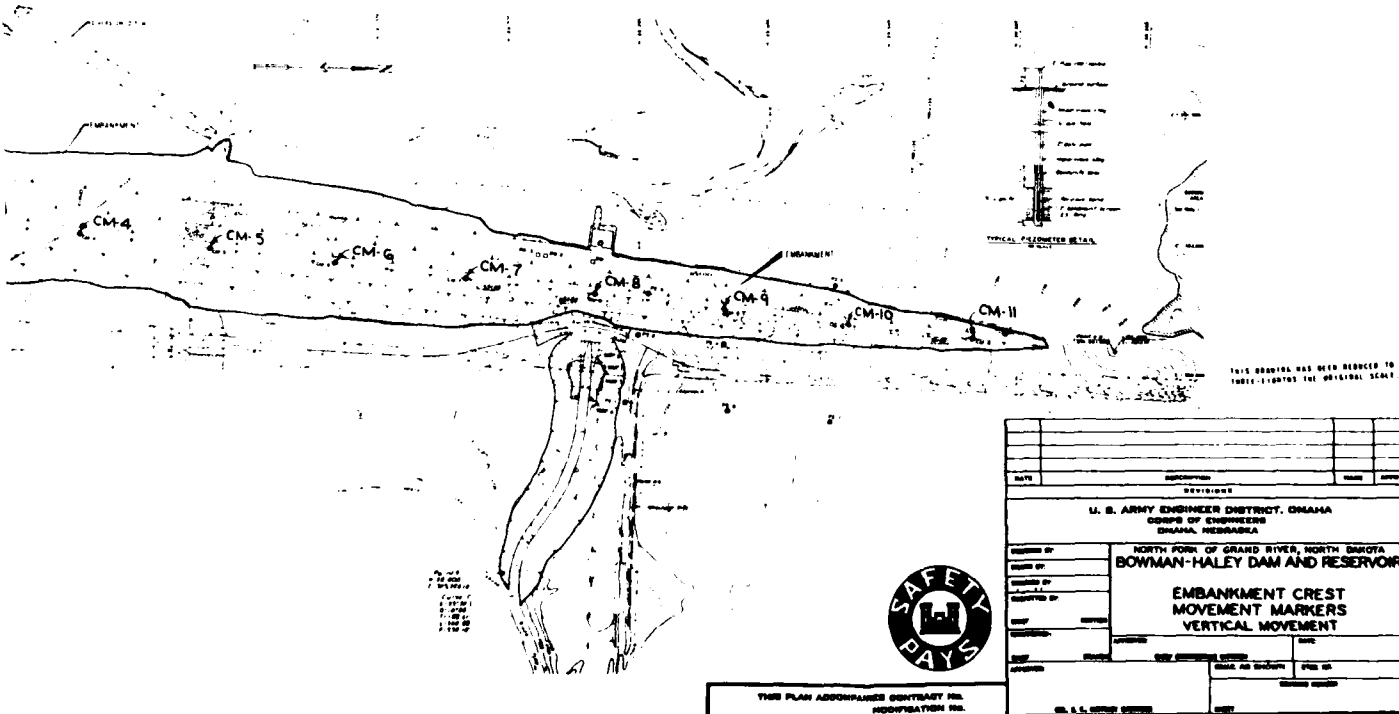
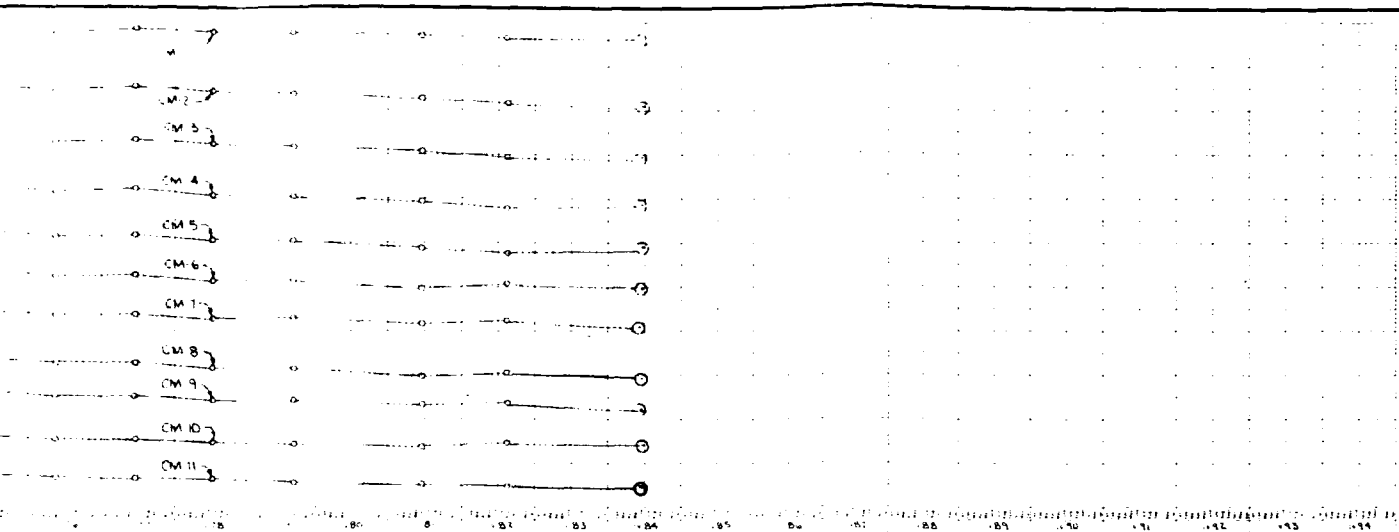


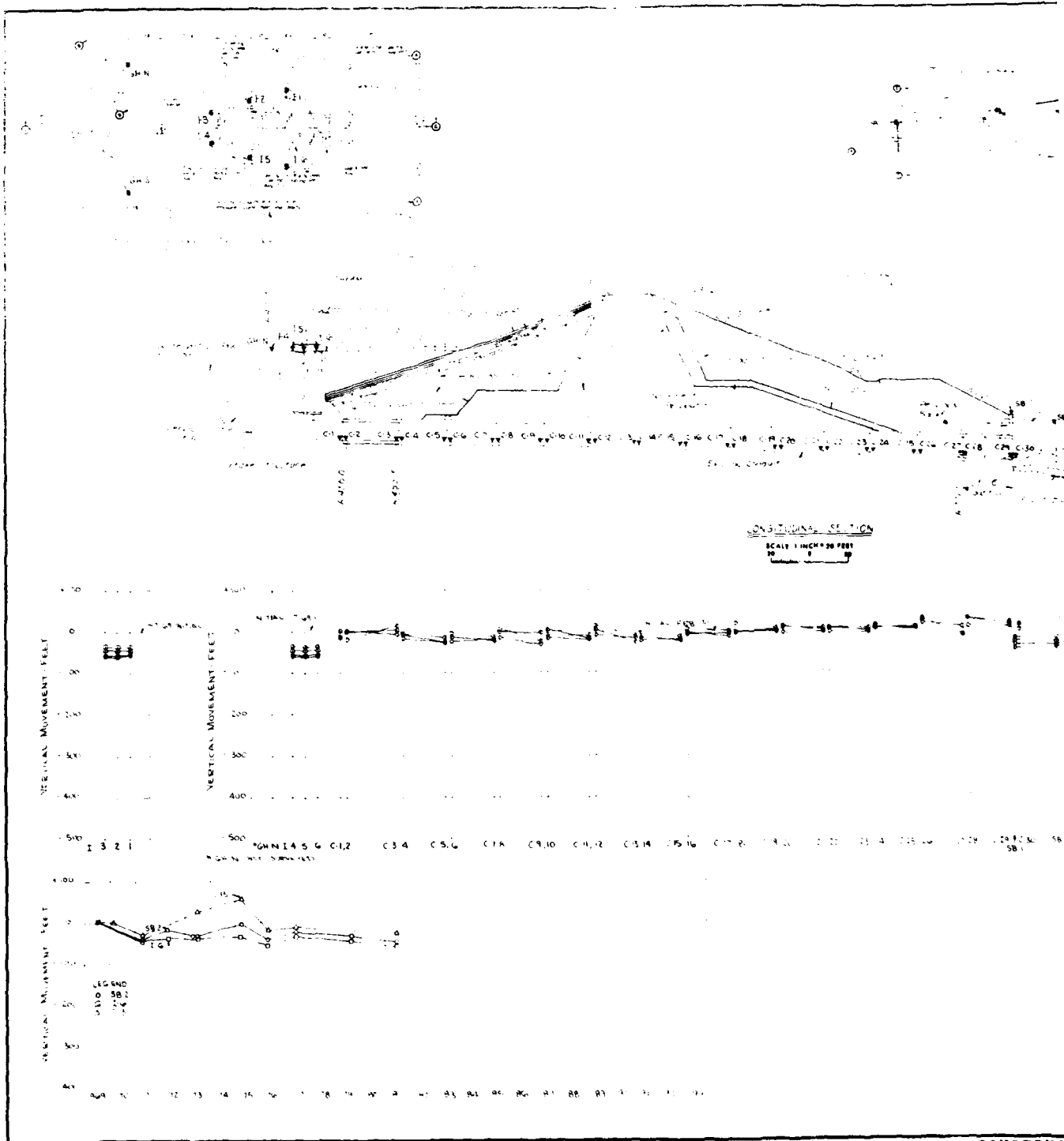


SCALE
1
100
1
NOTE: 1017.01 reading 10
24 July 1969

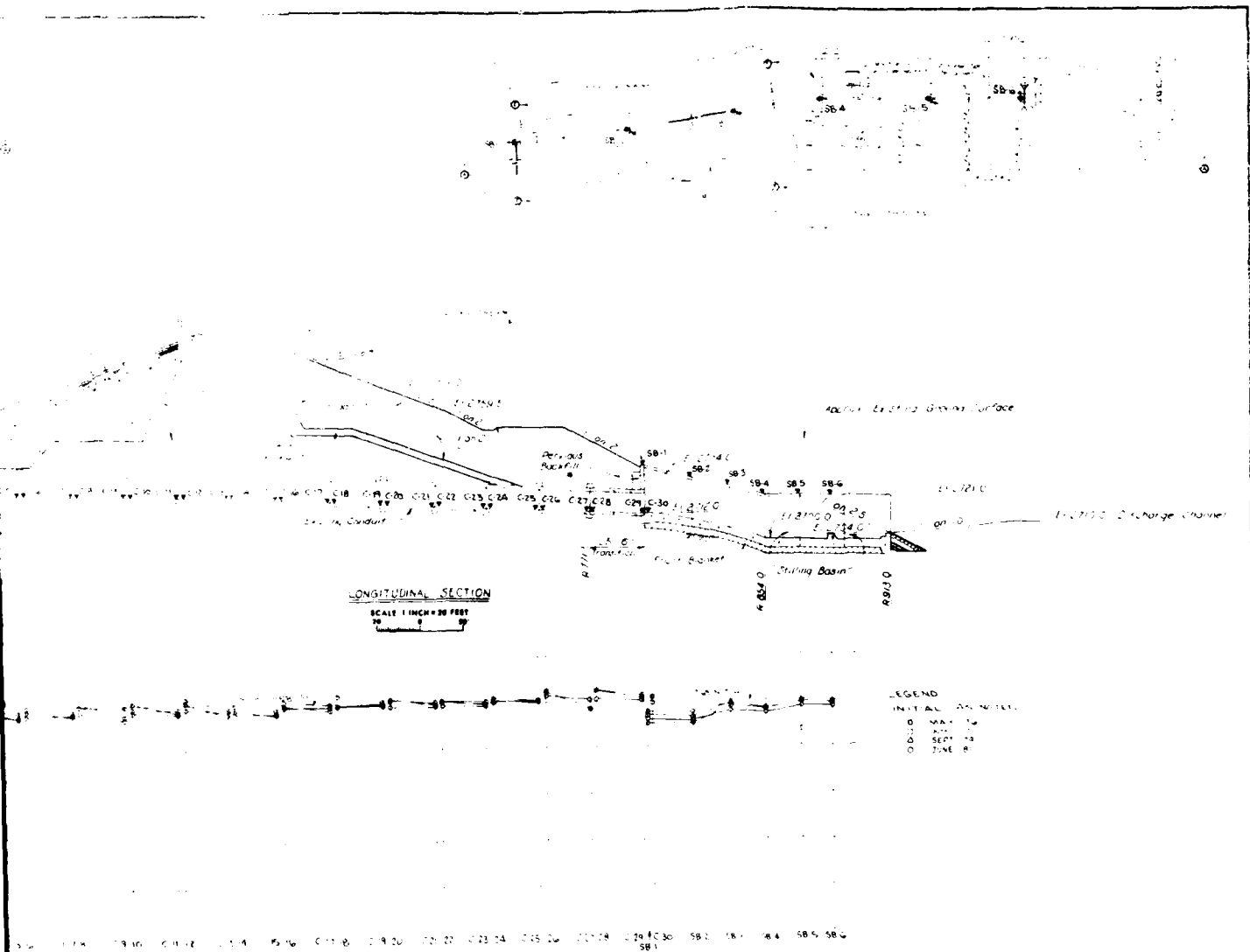


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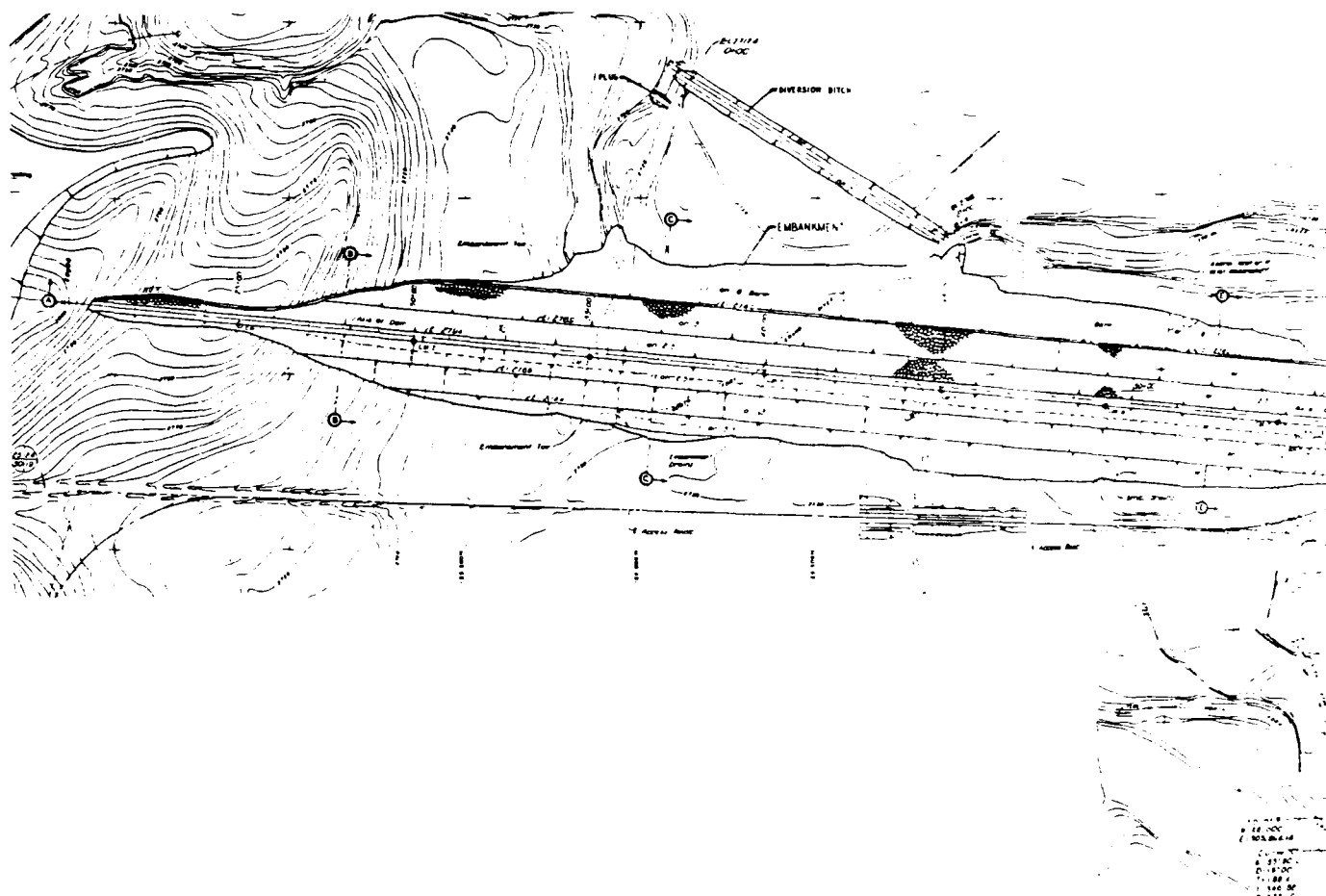




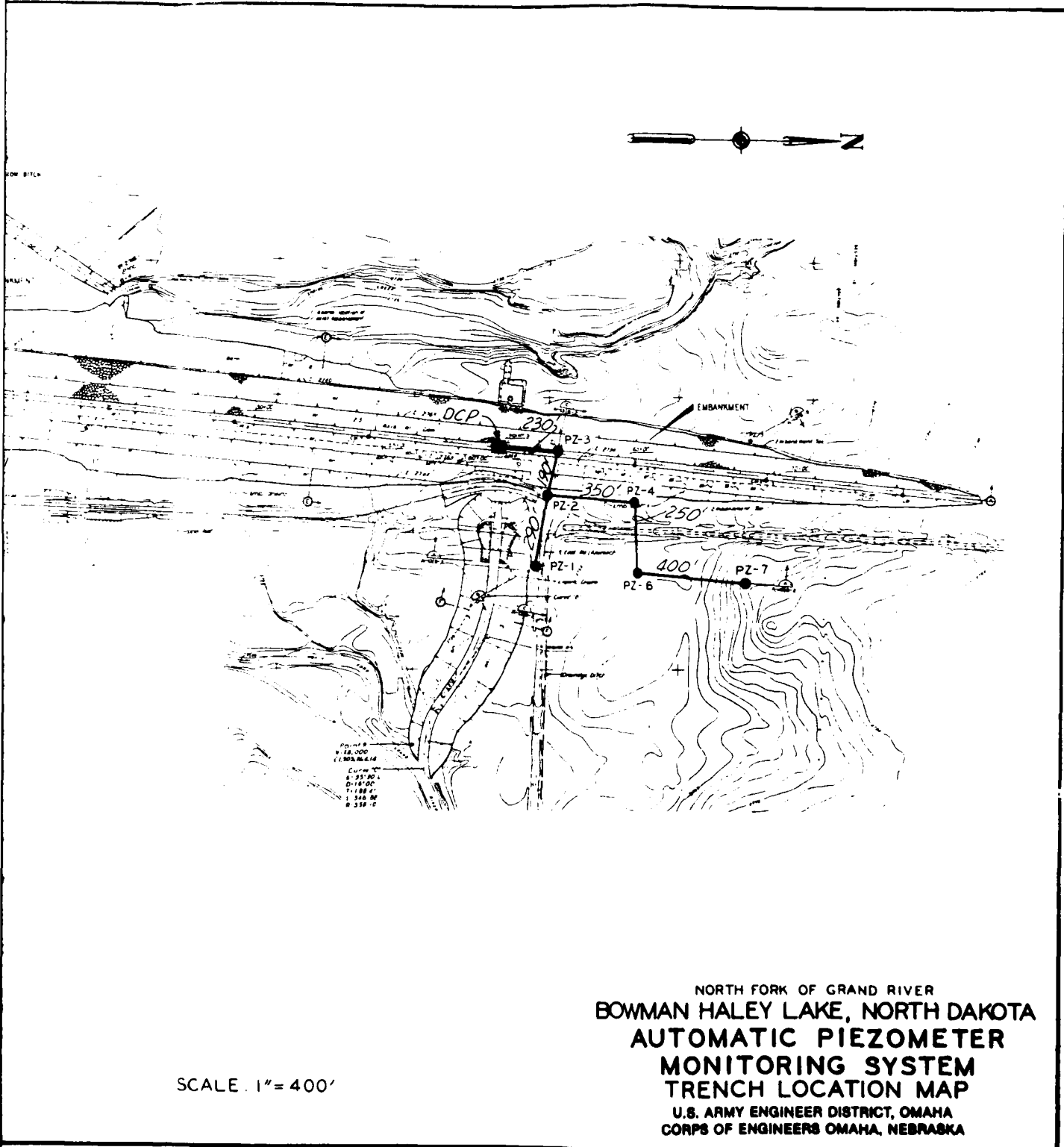
CONSTRUC



PROJECT NO.		NORTH FORK OF GRAND RIVER, NORTH DAKOTA	
DRAWN BY		BOWMAN-HALEY DAM AND RESERVOIR	
CHECKED BY			
SUBMITTED BY			
DATE	SECTION		
REVISIONS	APPROVED		
DATE	REVISION		
APPROVED	DATE		
DR. C. E. DEWITT ENGINEER		DATE	



SCALE 1" = 400'



AD-A183 265

CONSTRUCTION FOUNDATION REPORT GRAND RIVER BORRIAN-HALEY
PROJECT NORTH DAKOTA VOLUME 1 TEXT DRAWINGS PHOTOS(U)
CORPS OF ENGINEERS OMAHA NE MAY 85

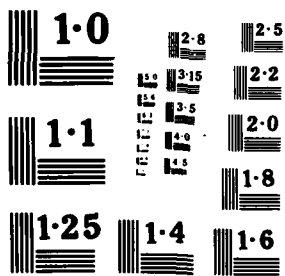
2/2

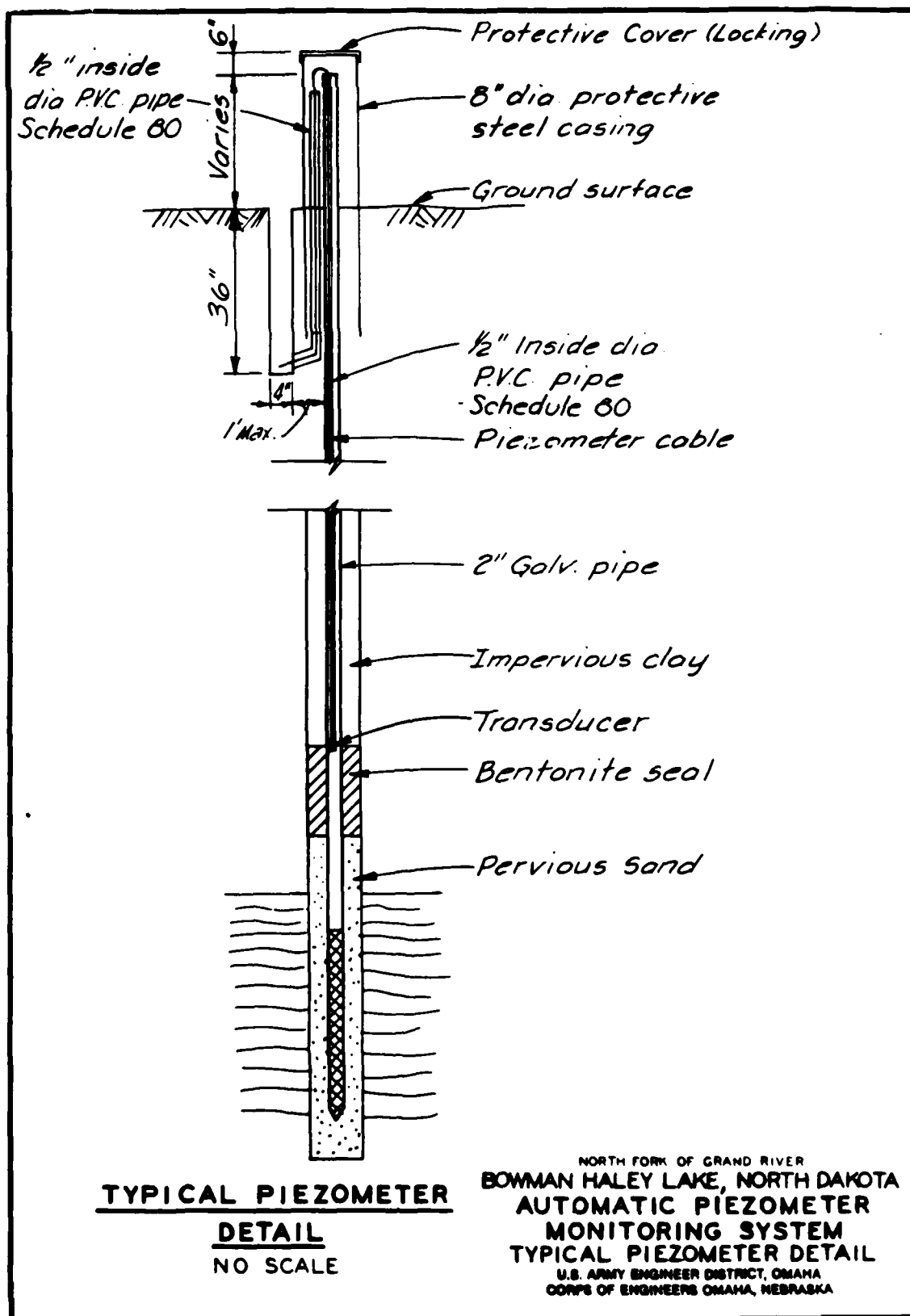
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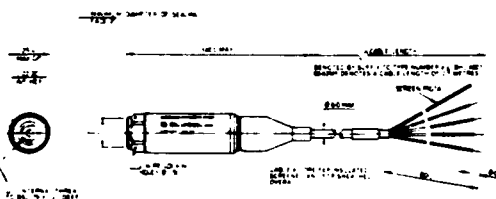


Specifications

Bell & Howell

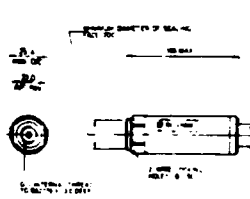
INPUT	
Type Number	BHL 4003 Integral Sealed Cable BHL 4004 On Board Sealed Cable
Pressure Ranges	0.75, 1, 2, 3, 5, 7, 10 bar: Absolute or Vented Gauge Reference 20, 30, 50, 70, 100, 150, 200, 250, 350, 500, 700 bar: Sealed Reference
Pressure Limits	2 x rated pressure or 800 bar whichever is less when supplied for minutes will not cause a zero set exceeding 0.5% FRO
Electrical Configuration	4 wire system. Output not isolated from input (see wiring diagram)
Supply	Rated 10V d.c. Operable 10-30V d.c. continuous 35V d.c. for 5 seconds maximum. Consumption 22 mA maximum
Supply Protection	The transducer is protected against supply polarity reversal
OUTPUT	
Full Range Output (FRO)	5V $\pm$ 1% at +25°C and rated supply (2mA maximum output current)
Residual Unbalance	0V $\pm$ 1% FRO at +25°C and rated supply
Non-Linearity & Hysteresis	Maximum combined effect $\pm$ 0.5% FRO from best straight line
Resolution	Continuous
Output Resistance	50 Ω maximum
Capacitive Loading	Up to 0.1 μ F
Output Noise	5 mV peak to peak maximum
Supply Voltage Sensitivity	Less than 0.25% FRO/V for 10 to 30V d.c. supply
Output Protection	Short circuit of outputs or connections to negative supply line will not cause damage Short circuit of outputs to positive supply line for longer than 5 seconds not permitted
Output Limit	Output will not exceed 6.5V d.c.
ENVIRONMENTAL	
Temperature Range	-10°C to +100°C (compensated), -54°C to +120°C (operating)
Thermal Zero Shift	Maximum $\pm$ 0.018% FRO/°C over compensated temperature range
Thermal Sensitivity Shift	Maximum $\pm$ 0.018% FRO/°C over compensated temperature range
Vibration (35 g peak 5-2000 Hz 12 mm double amplitude maximum)	Response will not exceed 0.08% FRO/g for 0.75 bar range decreasing logarithmically with pressure range to 0.015% FRO/g for 700 bar range
Acceleration (100 g steady)	Response will not exceed 0.05% FRO/g for 0.75 bar range decreasing logarithmically with pressure range to 0.015% FRO/g for 700 bar range
Mechanical Shock	100 g half sine wave pulse for 11 milliseconds will not damage the transducer
External Pressure	External pressure (not applied to pressure port) from 0 to 20 bar A will not affect the transducer (Absolute and Sealed Reference units only)
Humidity	BHL 4004-00: Operable to 95% R.H. at up to 38°C BHL 4003-00: Fully Immersible to 200 m
PHYSICAL	
Pressure Connection	G 1/4 internal thread to BS 2779, 13 mm deep
Electrical Connection	BHL 4003-00: Integral sealed cable assembly in standard lengths of 1 metre terminating in flying leads BHL 4004-00: 6 pin size 10 bayonet lock connector
Isolation	All connections isolated from case. Insulation resistance greater than 500 M Ω at 85V d.c.
Materials in Contact with Pressure Media	17.4 Ph and 15.7 Mo stainless steels for ranges 5 bar and below 17.4 Ph stainless steel for ranges 7 bar and above
Included Accessories	Calibration Record, Dowty Seal L499207 0002
Optional Accessories	BHL 4004-00: only detachable connector to MS 3116F 10-6S Screw in stainless steel pressure fitting adaptors or welded adaptors to special pipe Additional cable on BHL 4003-00: Specify total length required in metres

BHL 4003



Weight 245g including one metre cable

BHL 4004



Weight 185g

FUNCTION	BHL 4003 WIRE COLOUR	BHL 4004 PIN REFERENCE
Positive Excitation	RED	A
Positive Output	YELLOW	B
Negative Output	BLUE	C and F
Negative Excitation	WHITE	D and E

Due to continuous development we reserve the right to amend specifications without notification

United States of America: Bell & Howell Co. Electronics & Instruments Group, 360 North Sierra Madre Villa, Santa Ana, California 91109

Japan: Bell & Howell Australia (Pty) Ltd, 4778 55.65 Murray Street, Sydney, South Wales 2001

England: Bell & Howell Ltd, Lennor Road, Basingstoke, Hampshire RG22 4AW

France: Bell & Howell France S.A., Electronics & Instruments Division, 112 Rue Des Soiers, 91138 94523 Rungrs Cedex

Italy: Bell & Howell Italia SpA, Via Inverigo 6, 20151 Milan

Netherlands: Bell & Howell GmbH, Veldringweg 23, 3044 CJ Rotterdam, Postbox 10054, 3004 AB Rotterdam
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CONSTRUCTION FOUNDATION REPORT (1985)

PLATE 34

PHOTOS



PHOTO 1. July, 1964. View toward South at
Dam Site Prior to Construction



PHOTO 2. September, 1966, Excavation of Cut-Off
Trench-Closure Section, Main Embankment.

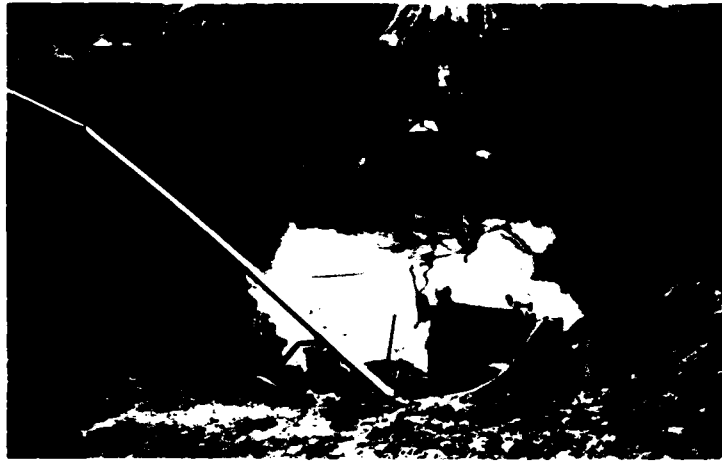


PHOTO 3. September, 1966, Excavation of Cut-Off Trench-Closure Section, Main Embankment.



PHOTO 4. September, 1966, Backfill Operations in Cut-off Trench-Closure Section, Main Embankment.



PHOTO 5. September, 1966, Excavation of Cut-Off Trench-Closure Section, Main Embankment.



PHOTO 6. September, 1966, Excavation of Cut-Off Trench-Closure Section, Main Embankment.



PHOTO 7 September, 1966, Excavation of Cut-Off
Trench-Closure Section, Main Embankment



PHOTO 8. September, 1966, Excavation of Cut-Off
Trench-Closure Section, Main Embankment.



PHOTO 9 September, 1966, Excavation of Cut-Off
Trench-Closure Section, Main Embankment.



PHOTO 9A. September, 1966, Excavation of Cut-Off
Trench-Closure Section, Main Embankment



PHOTO 9B September, 1966, Excavation of Cut-Off
Trench-Closure Section, Main Embankment

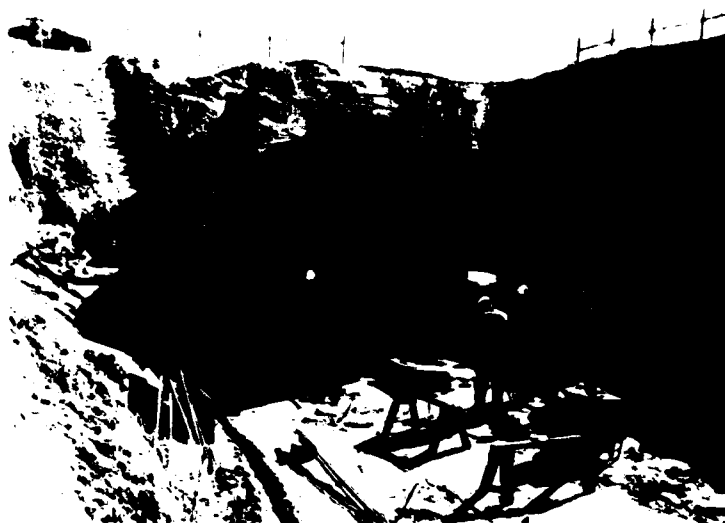


PHOTO 10. Conduit Construction

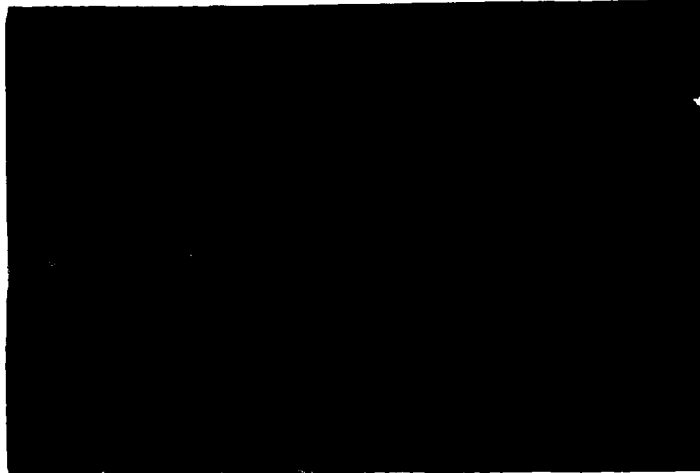


PHOTO 11. September, 1966, Trenching for Outlet Works

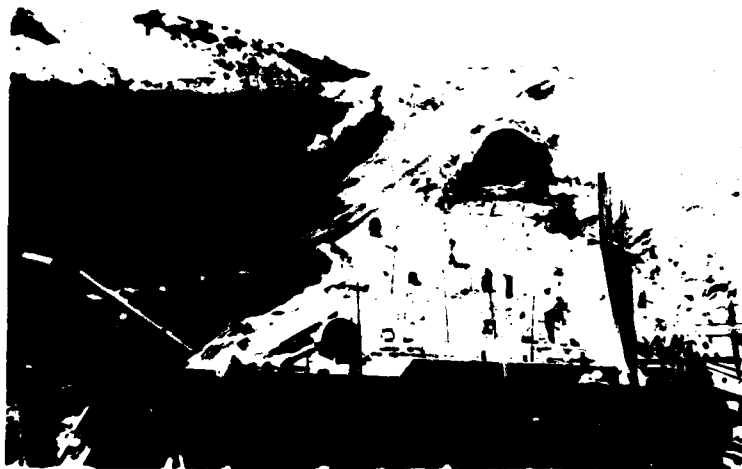


PHOTO 12 Upstream Portion of Stilling Basin
With Fill Placed on Conduit.



PHOTO 13. October, 1966, View East of Stilling Basin After Substantial Backfill Placement.



PHOTO 14. August, 1966, N.E. Corner of Stilling Basin- View Toward S.E.



PHOTO 15. Stilling Basin, Showing Foundation, Slab, and Wall Reinforcing-View is East



PHOTO 16. August, 1966, Stilling Basin Slab Pour-View is N. W.



PHOTO 17. September, 1966, Spillway-Soil Cement
Scour Cut-Off Prior to Watering and Covering.
View is to the South.



PHOTO 18. September, 1966, Beginning to Place
Soil Cement in Spillway Cut-Off Trench. View
is to the South



PHOTO 19. September, 1966, Spillway-Lignite in
Scour Cut-Off Excavation.

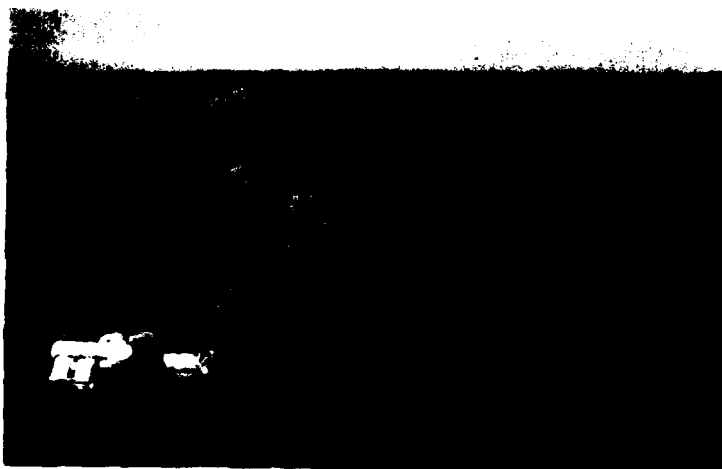


PHOTO 20. September, 1966, Spillway Scour
Cut-Off Excavation



PHOTO 21. September, 1964, Outlet Works-
Conduit Invert Collar Excavation.



PHOTO 22. August, 1964, Outlet Works-
Excavation for Conduit Collar Invert,
17% Completion



PHOTO 23. November, 1964, Outlet Works
Conduit, 90% Backfilled. View is East.



PHOTO 24. April, 1967, Spillway Excavation Showing Concretionary Type Rock Encountered.



PHOTO 25. April, 1967, South Slope of Spillway Showing Concretionary Rock in Place.

END

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