Trip C

SOME ASPECTS OF ENGINEERING GEOLOGY IN THE ST. LAWRENCE VALLEY AND NORTHWEST ADIRONDACK LOWLANDS

by

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ABSTRACT

The purpose of this field trip is to illustrate the interdependence of geology and civil engineering by means of several examples from the St. Lawrence Valley and the Lowlands of the Northwest Adirondacks. We will make seven stops in the vicinity of Norfolk, Massena, Potsdam, and South Colton, New York.

Stop 1 will be at a limestone quarry where the rock is processed for Portland cement and asphalt concrete aggregate. Here we will emphasize the interrelationship between the bedrock type and the physiography. Stops 5 and 7 will be at gravel quarries of very different geologic and physiographic character. The relationship of physiography and bedrock to gravel characteristics will be stressed. Stop 6 will be at concrete gravity dams on the Racquette River, for which much of the crushed stone and concrete aggregate was taken from the gravel pit at stop 5. We will indicate some of the desirable and undesirable properties of this fill for use in this particular dam project. At stop 2 we will visit the site of a landslide in the sensitive Leda Clay. Stops 3 and 4 will be in the Moses-Saunders Power Dam and Eisenhower Lock, respectively. Here the geologic parameters and problems of construction will be stressed.

STOP DESCRIPTIONS

The trip will consist of seven stops.

Stop 1 - <u>Barrett Allied Chemical Pit, Norwood, N.Y.</u> (Figs. 1,2,3 and Table 1)

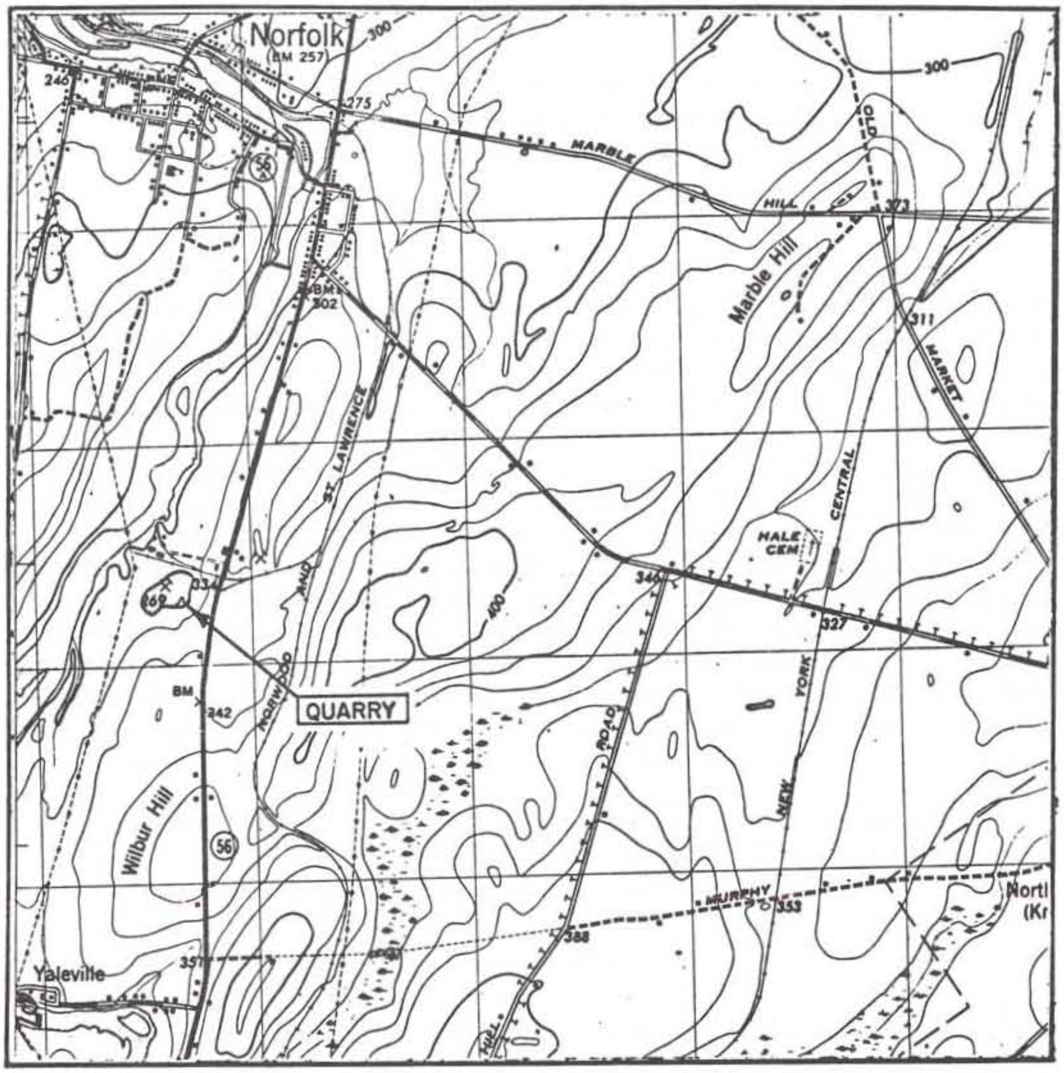
The ten to fifteen feet of glacial cover can be clearly seen at the southern end of the pit, and the fairly clean character of the overlying till is evident, as is the thin soil cover at the grass line near the top.

The rock is drilled, blasted, broken down further by the large steel ball, and trucked to the primary crusher, where it is sized, recrushed and stocked in piles according to size for use as Portland cement aggregates, asphalt concrete aggregates, and general engineering use as fills, drains, etc.

LOCATION MAP

BARRETT DIVISION OF ALLIED CHEMICAL

ST. LAWRENCE COUNTY: TOWN OF NORFOLK



SCALE 1" = 2000'

PHYSIOGRAPHIC PROVINCE: St. Lawrence Lowland

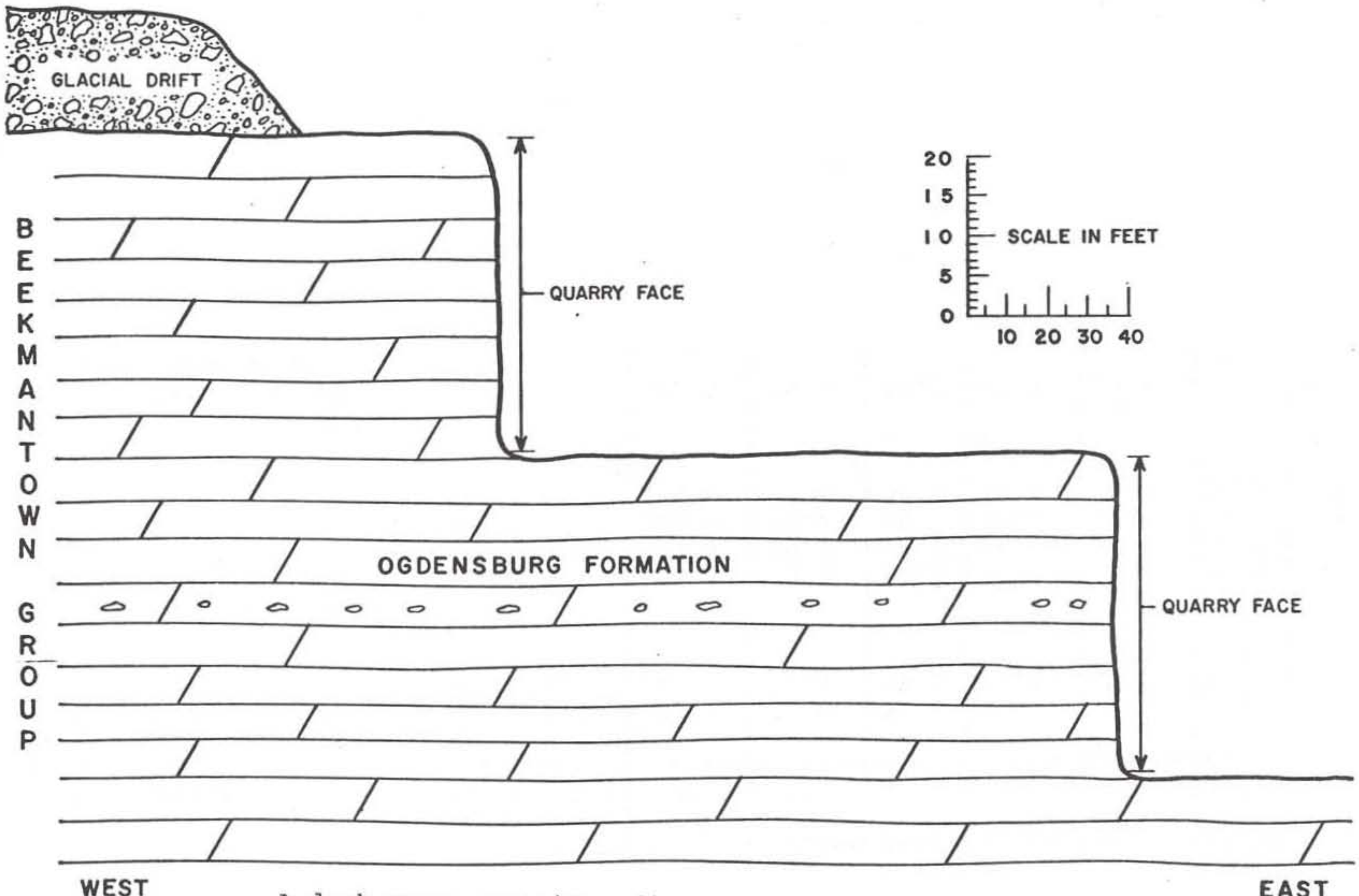
ARTIFICIAL SAND: Dolomite Quarry

MATERIAL ORIGIN: Dolomite

GEOLOGIC FORMATIONS: BEEKMANTOWN (Dol.)

STRUCTURE: HORIZONTAL BEDDING

Fig. 2



A dark gray, massive, fine-to-medium-grained dolomite, which contains small aggregates of white to pinkish dolomite and dolomite cyrstals. A prominent horizon of the dolomite crystals occurs about 15 feet above the quarry floor. Bedding ranges from 3 inches to a foot in thickness.

ELEVATION OF PIT
BARRETT DIVISION, ALLIED CHEMICAL

Fig. 3

ENGINEERING DATA

Commercial Gravel Pits Stops 1, 5, 7

Pit & Location	PI	MG504 Loss 4 cyl	Sieve Analysis (% finer than by wt.) 2"	1"	1/4"	#4	#10	#40	#200	% #200/#40
1. Barrett, Norwood, N.Y. St. Lawrence Lowland	NP	2.4	100.0	89.6	59.6	49.3	30.7	3.5	0.8	22.9
	NP	1.7	100.0	88.4	58.6	54.6	43.7	9.1	1.1	11.6
6. Edson Martin, Colton, N.Y. Adirondack Mountain	NP	4.1	100.0	79.2	60.4	57.2	50.1	31.8	7.5	23.6
	NP	4.6	100.0	80.4	61.2	58.6	50.5	26.8	3.9	14.6
	NP	2.3	100.0	77.0	60.8	57.7	50.8	27.9	3.4	12.2
	NP	4.2	100.0	67.8	52.7	49.2	40.6	26.3	6.5	24.6
7. Bicknell, Potsdam, N.Y. Transition Area - St. Lawrence Lowland and Adirondack	NP	7.4	100.0	74.3	56.7	55.5	53.4	40.2	2.4	5.9

Table 1

The rock which usually is hard and dense, probably extends 100 feet deeper than the present base of the pit.

Its denseness is apparent on the west side of the pit, where minimum pumping operation is required to keep out the water infiltrating from the river just over the hill, and whose elevation is considerably higher than the base of the pit.

Stop 2 - Landslide in Leda Clay on the Massena Springs Road Near the Massena Airport (Racquette Cemetery Site)

The general area of the Racquette cemetery site has been exposed to many earthquakes, the most severe that of September 5, 1944. Many smaller tremors have been recorded prior to and after this shock.

Structures founded on the marine (Leda) clay were most affected by earthquake shock, while those founded on glacial till showed much less response. The epicenter of the 1944 earthquake was located in Massena Springs, approximately one mile north of the cemetery site.

The last glacial ice sheet deposited many very dense glacial till moraines near the St. Lawrence River. Streams with their headwaters in the Adirondacks encountered these moraines, and generally cut through glacial outwash deposits and the clays, these offering the least resistance.

The cemetery site consists of marine clay deposited between two moraines. The moraines existed prior to the formation of Lake Iroquois, which deposited clay in the valley between the moraines. The highest points of these moraines are 250 feet and 230 feet above sea level for the south and north shore respectively.

Soil borings performed at the site on the north shore indicated a clay layer thickness of about 65 feet, where surface elevation was 200 feet. Since till was encountered below the clay, the valley between the moraines was at or below 140 feet. The clay offered very little resistance so that the water was confined between these two moraines.

The clay at the site is rather strong and somewhat preconsolidated in the undisturbed state, but remolding causes a drop in shear strength to a very small value. If one looks closely at the surface topography immediately adjacent to the river as the bus proceeds along the road to this stop, old landslide scars will be evident in the form of small surface scarps.

The landslide located at this stop resulted from the combination of heavy loads on top of the slope (logs from cut elms, sand piles), and erosion of the clay by the river at the foot of the slope. Many graves were lost and the trees near the river were tilted. The small island nearest the cemetery is probably a remnant of an old slide.

Mr. Spencer Thew of Clarkson College has placed observation wells in the slide area, and has taken samples of the undisturbed clay. The failure plane of the slide can be seen in the field, and it is possible that the soil strength parameters existing before the slide occurred can be inferred from the data he will collect. Such studies of field failures may make it possible to prevent future slides and property damage and personal injury. Note how close the next group of houses to the right of the cemetery is to an apparent old slump scarp.

Stop 3 - Moses-Saunders Power Dam; St. Lawrence Seaway, Massena, New York

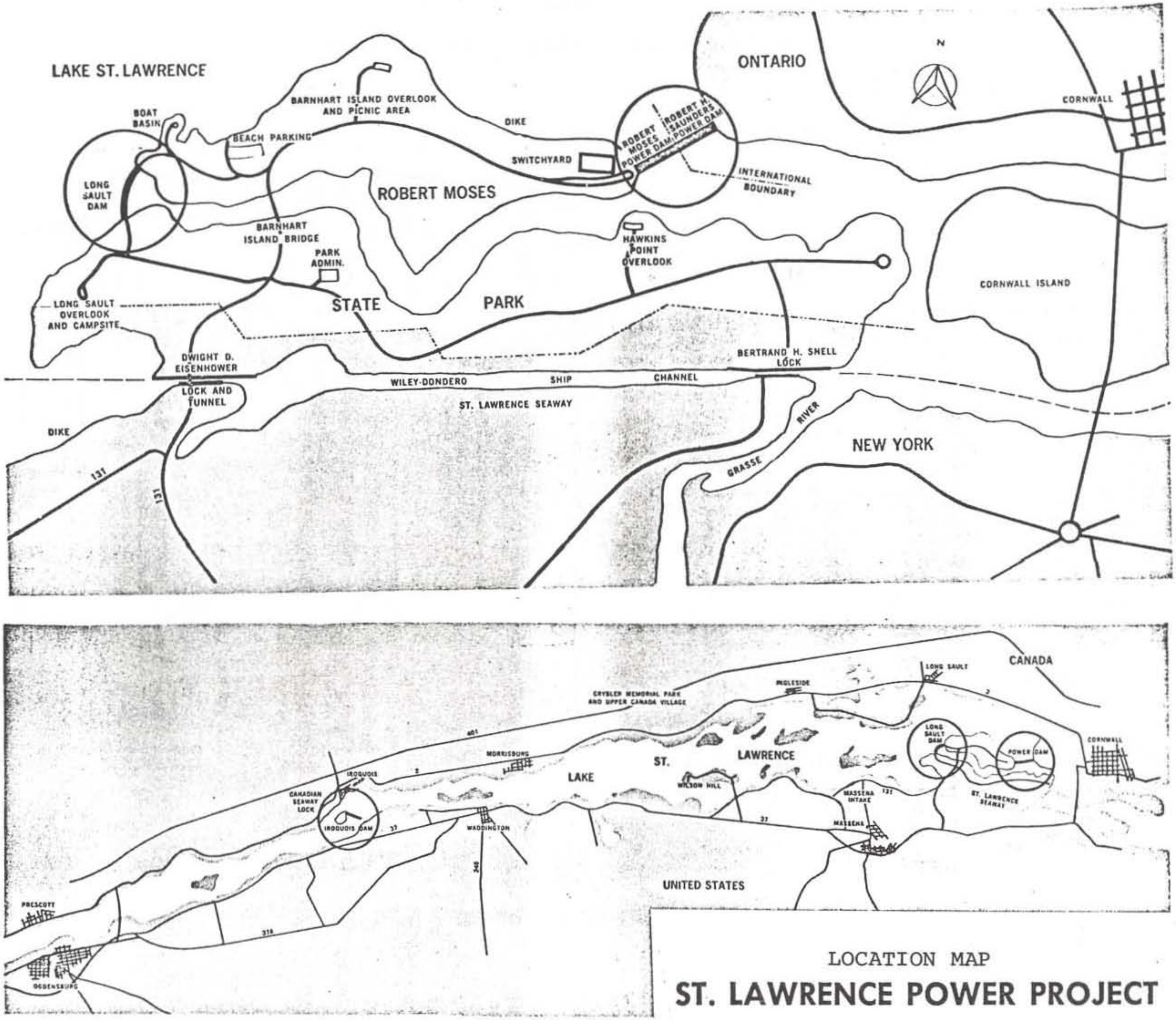
The location map is shown in Fig. 4. This dam provides approximately 912,000 kilowatts of power. The dam has a head of 81 feet, and behind it is Lake St. Lawrence, with its fine marina and Barnhart Island Beach. A section through the Moses Power Dam is shown on Fig. 5, and of the Long Sault Control Dam on Fig. 6.

A thirty minute film will be shown in the auditorium at the dam, which will illustrate the methods and problems of construction.

A tour of the dam will be made, and from the top of the building Lake St. Lawrence can be clearly seen, with some of the zoned and rip-rapped dikes bounding it composed of compacted glacial till with dry densities on the order of 140 pcf (concrete is 150 pcf).

Stop 4 - Eisenhower Lock, St. Lawrence Seaway

This structure enables ships traveling the St. Lawrence River to pass around the Moses Saunders Power Dam and, along with Snell Lock five miles farther east, lowers the ships through a total of 95 feet of elevation. Both locks have dimensions of 860 feet by 80 feet and are of concrete construction. The locks are huge bathtubs in a sense, with openings along the sides into a passageway (about 13' wide by 15' high) on each side which slopes to the upstream end of the lock. When a ship comes down the St. Lawrence River and through the canal to the lock, the lower lock gates are closed, and the water is at the upper canal elevation. The ship moves slowly into the "bathtub", the upstream gates are closed, and then the water is let out of the locks through the openings in their sides, down the passageway on either side and discharged below the lock. A system of

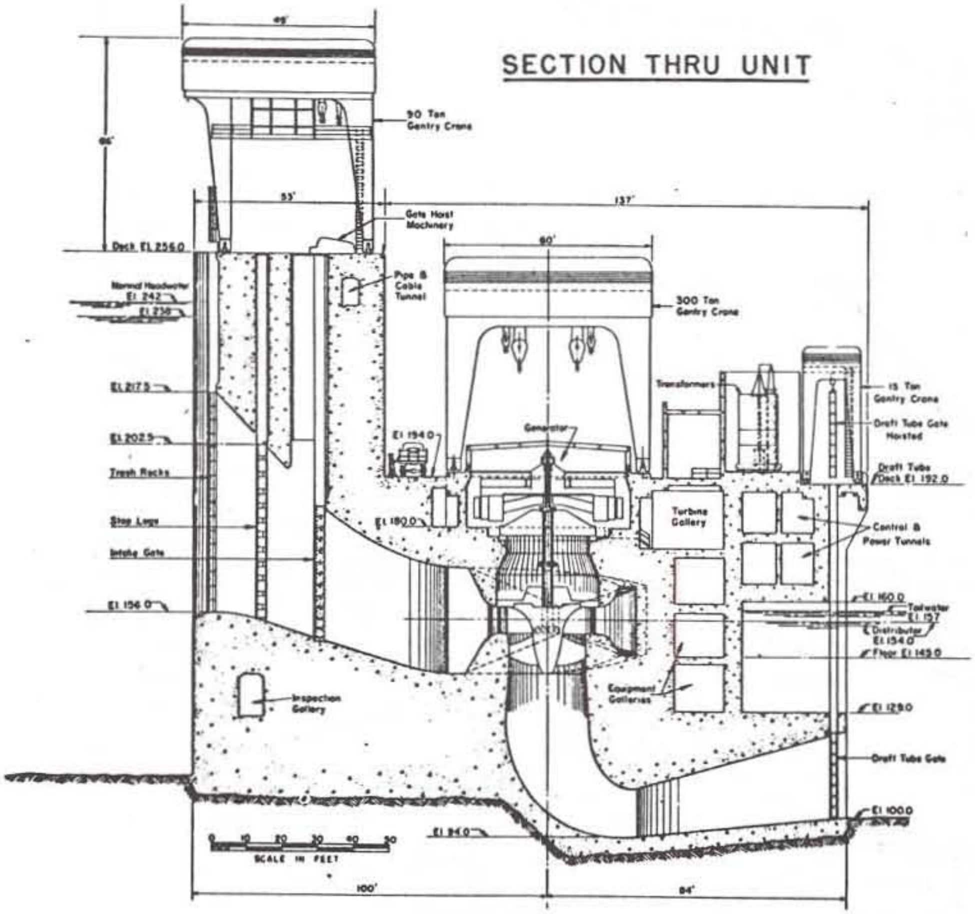


LOCATION MAP

ST. LAWRENCE POWER PROJECT

Fig. 4

ROBERT MOSES POWER DAM



UNITED STATES HALF—ROBERT MOSES POWER DAM

STATISTICS

Length of structure	1,608 feet
Width (face of intake to down-stream face)	184 feet
Height—intake deck	167 feet
Height—observation roof	195.5 feet
Excavation, earth	2,587,000 cubic yards
rock	275,000 cubic yards
borrow	1,031,000 cubic yards
Excavation, total	3,893,000 cubic yards
Embankment and Riprap	1,458,000 cubic yards
Miscellaneous earth fill	450,000 cubic yards
Concrete	985,000 cubic yards
Cement	1,111,000 barrels
Reinforcing steel	49,767,000 pounds
Structural steel	6,793,000 pounds
Towers, gates, crane and guides	18,471,000 pounds

The general contractor for the structure was a joint venture of B. Perini & Sons, Inc., Peter Kiewit Sons' Co., Walsh Construction Co., Morrison-Knudsen Co., Inc., and Utah Construction Co.

Section Thru Robert Moses Power Dam

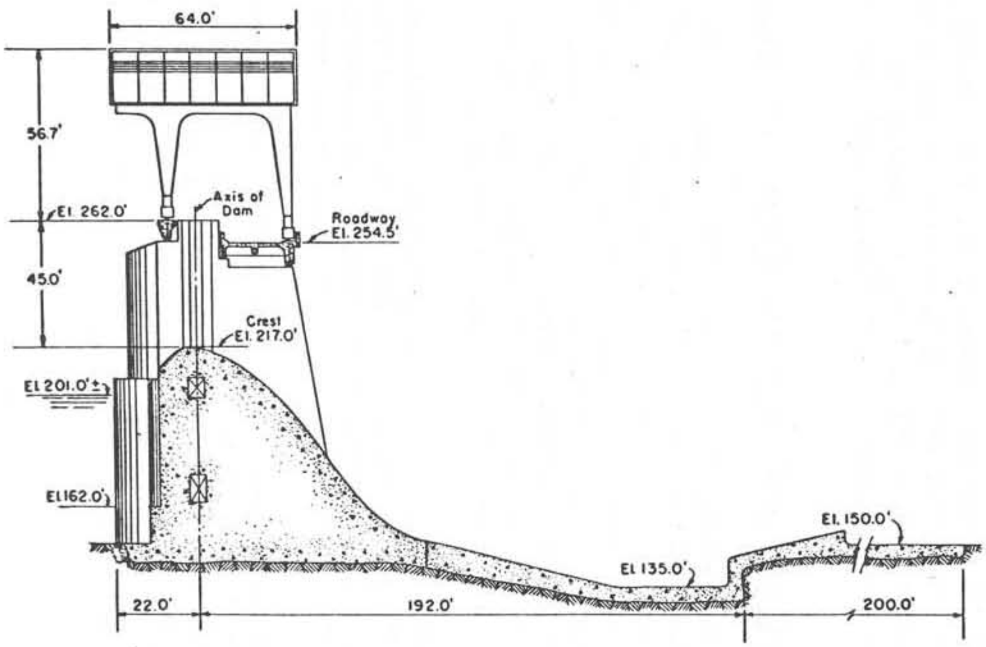
Fig. 5

LONG SAULT DAM

STATISTICS

Height above foundation	132	feet
Length	2,960	feet
Length of spillway	1,800	feet
Width (including apron)	414	feet
Number of spillway sections	30	
Type of spillway gates	vertical	
Size of spillway gates	52′ x 30′	
Gantry cranes (2 each) capacity	275	tons
Excavation:		
Earth	7,522,000	cubic yards
Rock	479,000	cubic yards
Embankment and riprap	627,000	cubic yards
Concrete	675,000	cubic yards
Cement	703,000	barrels
Reinforcing steel	16,142,000	pounds
Structural steel	6,429,000	pounds
Gates, stop logs and hoists	12,459,000	pounds
Two 275-ton gantry cranes	1,672,000	pounds

The general contractor for the structure was a joint venture of Walsh Construction Co., B. Perini & Sons, Inc., Morrison-Knudsen Co., Inc., Peter Kiewit Sons' Co. and Utah Construction. Total Cost: $35,900,000.



LONG SAULT DAM

Section Thru Long Sault Dam

Fig. 6

baffles on the downstream end prevents excessive turbulence.

When a ship comes upstream to the lock, the upper gates are closed and the water level is at the same elevation as the water surface downstream from the lock. The ship moves into the lock, the lower gates are closed, and water is introduced into the side passageways from the upstream end of the locks flowing into the lock through the side openings, thus filling the lock and raising the ship to the elevation of the canal on the upstream side. Then the upper gates are opened and the ship moves out of the lock upstream. Recently, some deterioration of the lock concrete has been observed, and an extensive study has been made by the Corps of Engineers, which is resulting in appropriate remedial measures.

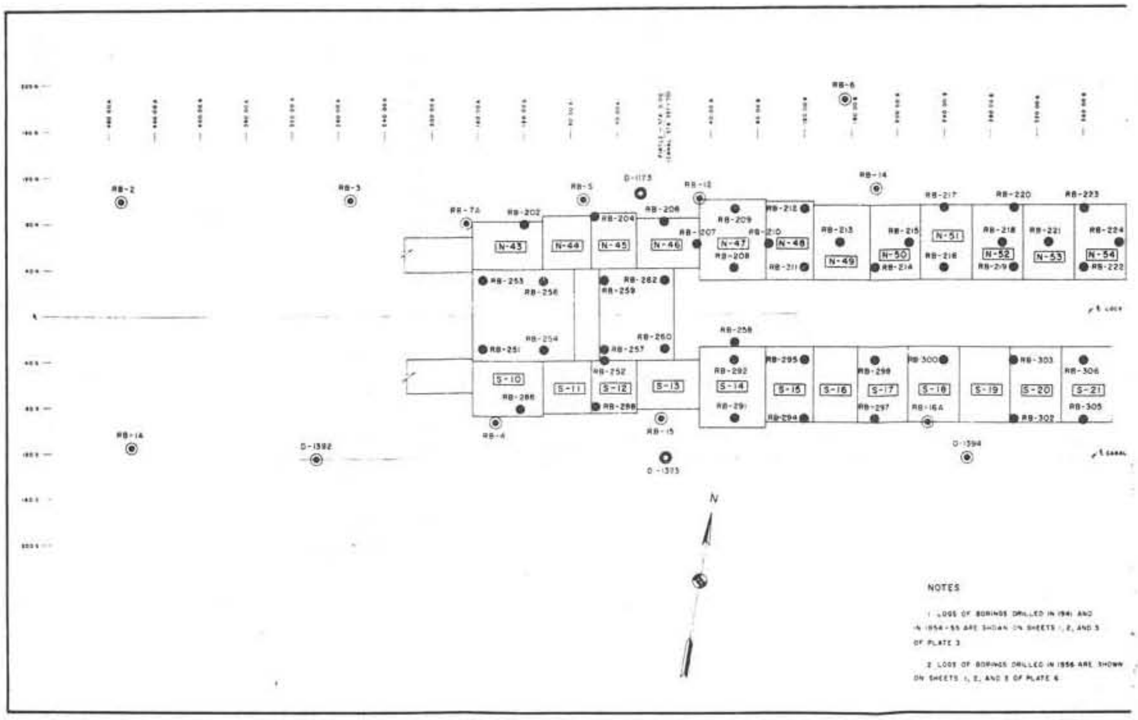
Since the overburden materials and lock location problems at Eisenhower and Snell Lock are very different, Figures 7 through 10 are included to show, for Eisenhower Lock, boring locations, exploratory core borings, some laboratory test data on overburden material and geologic sections. Figures 11, 12, 13a, 13b, 14 and 15 show the same data for Snell Lock. Note the difference in the overburden at the two sites 5 miles apart. Also note in Figure 13b boring D-1302, which shows evidence of a possible fault at the site. This fault area is shown in Figure 12.

Stop 5 - The Martin Gravel Pit, "The Plains", South Colton

This pit is twenty miles from Potsdam on Route 56 towards Tupper Lake in the Adirondack Physiographic Province. The pit is part of a Kame Terrace deposit of very clean and uniform quality, largely composed of reddish brown gneiss. Excellent quality fine and coarse aggregate are produced from this pit. Due to its proximity to the construction site, most of the aggregate used in the construction of the five Niagara Mohawk dams on the Racquette River, completed in 1957, came from this pit.

At the site of the pit the company installed a large crushing, screening and washing plant for producing the aggregates for making concrete. This plant also produced several sizes of unwashed material for use in road and dike construction.

The processing plant was about 400 feet long and 100 feet wide covering about 2 acres. Stock piles of sand and various sizes of processed stone surrounded the plant, some of which were 100 feet in diameter, forty feet high, and contained as much as 8000 tons of product. The plant had a capacity of 200 tons per hour, and 15 men worked full time.



Note: Borings are located with reference to Monoliths (poured concrete lock sections)

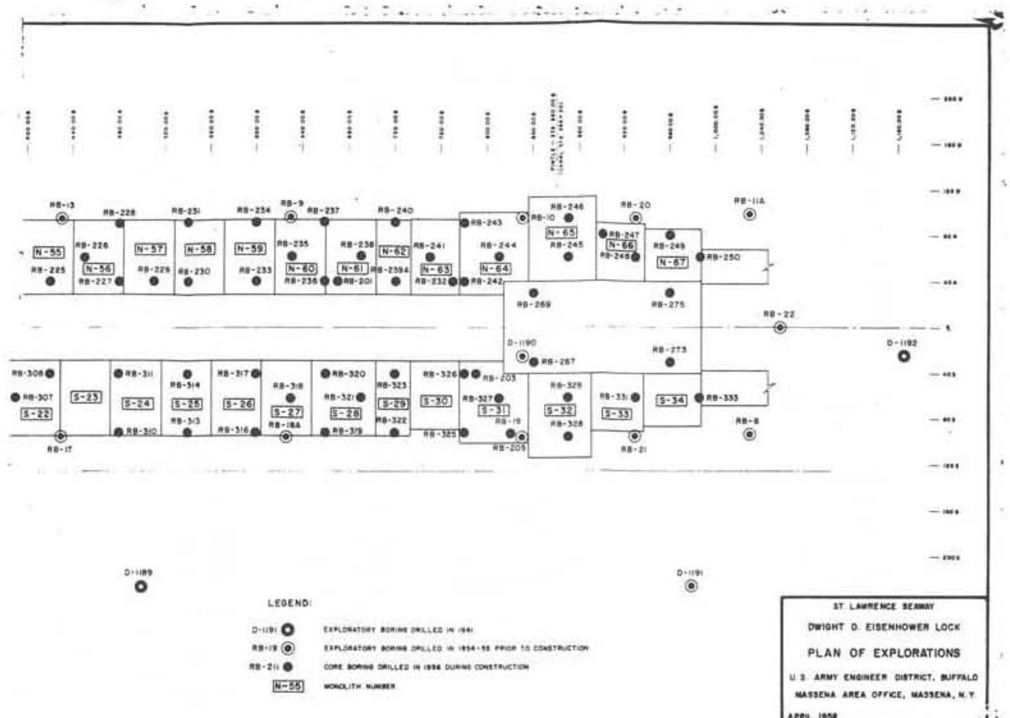


Fig. 7

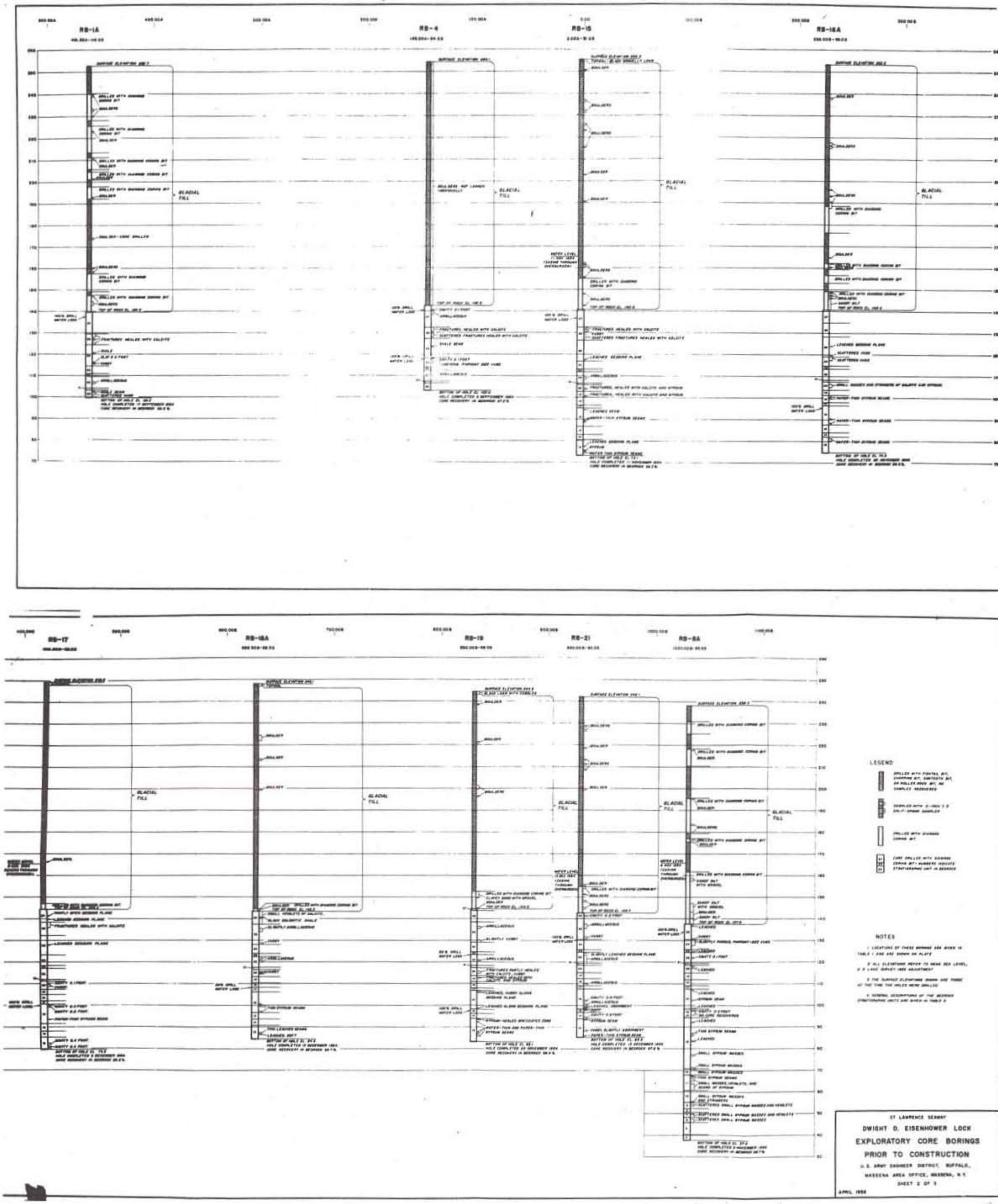

RB-1A
RB-4
RB-15
RB-16A
GLACIAL TILL
RB-17
RB-18A
RB-19
RB-21
RB-8A
LEGEND
NOTES
ST LAWRENCE SEAWAY
DWIGHT D. EISENHOWER LOCK
EXPLORATORY CORE BORINGS
PRIOR TO CONSTRUCTION
U.S. ARMY ENGINEER DISTRICT, BUFFALO,
MASSENA AREA OFFICE, MASSENA, N.Y.
SHEET 2 OF 3
APRIL

Fig. 8

DEPTH OF SAMPLES FT.	ELEVATION OF SAMPLES	MECHANICAL ANALYSIS GRAVEL %	SAND %	FINES %	* CLASSIFICATION	ATTERBERG LIMITS LIQUID LIMITS	PLASTIC LIMITS	MOISTURE CONTENT %	SPECIFIC GRAVITY G	DENSITY (DRY) lbs./cu.ft.	VOID RATIO e	SATURATION %	ANGLE INTERNAL FRICTION ϕ	COHESION (C) Tons/sq.ft.	TRIAXIAL COMPRESSION STRENGTH DATA (UNCONSOLIDATED - UNDRAINED) LATERAL LOAD Tons/sq.ft.	COMPRESSIVE STRENGTH Tons/sq.ft.	SHEAR STRENGTH Tons/sq.ft.	PERCENT STRAIN AT FAILURE
								HOLE RB-2	(DRIVE SAMPLES)									
10.0 - 11.0	241.2 - 240.2	25	37	38	SM - SC	14.8	10.8	9.3	2.81	132.8	0.32	82.5			2.0	2.9	1.45	4.2
15.0 - 16.0	236.2 - 235.2	22	36	42	SM - SC	16.3	11.9	19.2		105.6								
20.0 - 20.8	231.2 - 230.4	6	38	56	ML - CL	15.8	10.8	10.4		131.9								
50.0 - 51.1	201.2 - 200.1	2	44	54	ML	13.2	8.6	7.8		138.9								
60.0 - 61.5	191.2 - 189.7	25	33	42	SM - SC	14.3	9.7	7.6	2.78	140.0	0.23	86.0			0.5	9.2	4.64	5.5
								7.0	2.75	140.4	0.22	88.6			1.0	4.8	2.38	6.0
								6.2	2.74	141.4	0.21	78.7			2.0	10.2	5.10	3.5
65.0 - 66.5	186.2 - 184.7	19	38	53	CL - ML	16.8	9.5	6.8	2.78	142.1	0.21	90.1			1.0	13.2	6.50	4.0
								6.8	2.74	142.4	0.20	81.3			2.0	17.0	8.50	4.6
70.0 - 71.5	181.2 - 179.7	16	32	52	ML - CL	14.8	9.0	8.1	2.78	138.8	0.24	84.0			2.0	5.6	2.80	8.5
85.0 - 86.0	166.2 - 165.2	5	40	55	CL - ML	16.4	8.7	4.9	2.75	142.0	0.21	81.1			2.0	9.8	4.90	12.5
105.0 - 106.0	146.2 - 145.2	15	27	58	CL - ML	18.5	10.2	7.5	2.78	138.8	0.24	90.8			2.0	6.4	3.20	5.6
								HOLE RB - 7A	(NX CORES)									
100.2 - 104.5	156.2 - 151.9	3	32	65	CL - ML	19.2	11.4	8.6	2.75	136.1	0.27	88.9			2.0	13.7	6.85	4.7
		8	29	63	CL - ML	19.4	10.8	8.1	2.74	136.7	0.25	88.5			3.0	13.9	6.95	7.0
		8	29	63	CL - ML	18.3	11.0	9.0	2.73	137.8	0.24	90.2			4.0	12.0	6.00	7.2
104.5 - 110.5	151.9 - 146.0	6	32	62	CL - ML	19.8	11.1	6.9	2.73	131.1	0.30	75.6			2.0	8.7	4.35	5.1
		10	33	57	CL - ML	18.7	10.7	7.4	2.74	133.8	0.28	73.1			3.0	10.7	5.35	2.2
		6	32	62	CL - ML	18.7	10.6	8.6	2.73	125.8	0.37	65.6			4.0	7.5	3.75	2.5
								HOLE RB - 8A	(NX CORES)									
78.4 - 80.7	159.8 - 157.5	7	35	58	CL - ML	17.2	10.2	7.2	2.73	142.1	0.20	97.0			2.0	14.6	7.30	3.5
					CL - ML	18.3	10.5	7.5	2.74	141.2	0.21	97.5			3.0	11.8	5.90	2.5
					CL - ML	16.6	11.0	6.9	2.75	143.0	0.20	96.5			4.0	12.9	6.45	3.0
81.1 - 95.1	157.1 - 143.1	14	31	55	CL - ML	18.4	10.8	6.7	2.74	143.5	0.19	95.8			2.0	22.3	11.15	4.2
		10	35	55	ML - CL	18.2	9.7	7.5	2.74	141.2	0.21	97.5			3.0	13.1	6.55	7.0
		10	35	55	CL - ML	18.9	10.6	7.3	2.73	142.0	0.20	98.1			4.0	17.3	8.65	5.0
97.9 - 100.4	140.3 - 137.8	6	26	68	CL - ML	21.9	10.7	7.8	2.75	141.8	0.21	100.0			2.0	28.0	14.00	4.0
		5	21	74	CL	29.2	12.0	9.2	2.73	138.5	0.25	99.8			3.0	22.3	11.15	4.1
		4	14	82	CL	27.5	13.1	11.0	2.74	131.3	0.30	99.6			4.0	18.3	9.15	8.0
								HOLE RB -12	(DRIVE SAMPLES)									
39.1 - 40.5	222.1 - 221.6	2	88	10	SM - SP			18.8										
61.1 - 71.2	200.1 - 190.0	10	37	53	ML - CL	13.9	8.4	8.2	2.75	140.5	0.22	91.8			2.0	5.2	2.60	14.3
79.0 - 81.1	182.2 - 180.0	15	33	52	ML - CL	14.6	9.4	7.0	2.75	141.5	0.21	90.5			2.0	9.4	4.70	9.3
89.1 - 91.4	172.1 - 170.4	4	22	74	CL	26.3	16.8	10.7	2.75	132.2	0.30	98.0			1.0	2.3	1.12	12.1
100.2 - 101.2	161.0 - 160.0	10	33	57	CL - ML	15.6	9.7	7.5	2.75	140.4	0.22	93.3			1.0	6.8	3.81	12.0
								7.2	2.74	142.1	0.21	94.7			2.0	11.1	5.55	11.0
105.1 - 106.2	156.1 - 155.0	10	33	57	CL	19.0	8.9	7.8	2.74	141.2	0.22	99.8			1.0	8.1	4.05	14.0
								8.2	2.74	139.9	0.23	98.9			2.0	6.9	3.45	15.0

*Unified classification system.

DWIGHT D. EISENHOWER LOCK

LABORATORY TEST DATA

OVERBURDEN MATERIAL

U.S. ARMY ENGINEER DISTRICT, BUFFALO
MASSENA AREA OFFICE, MASSENA, N.Y.
SHEET 1 OF 2
APRIL 1958

Fig. 9

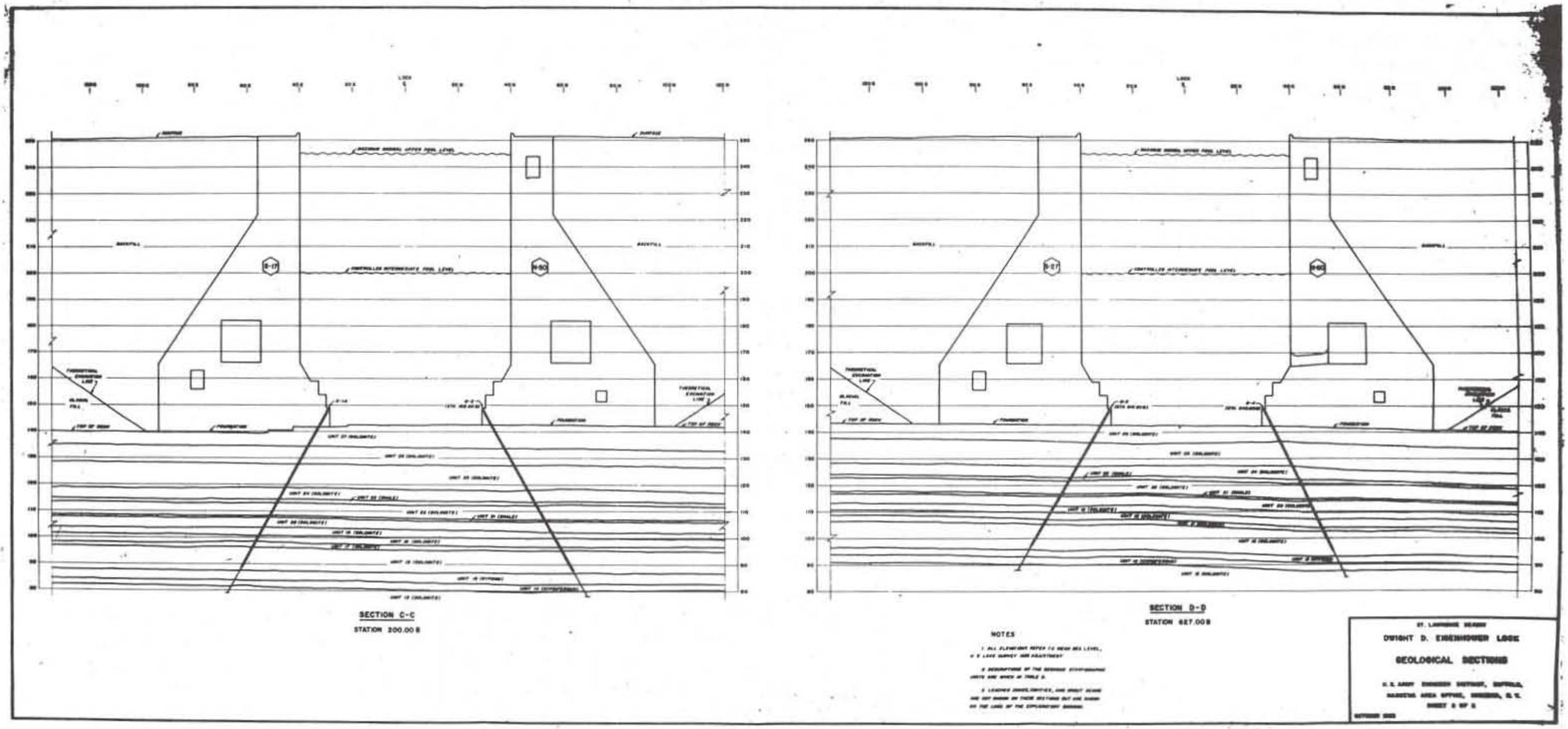
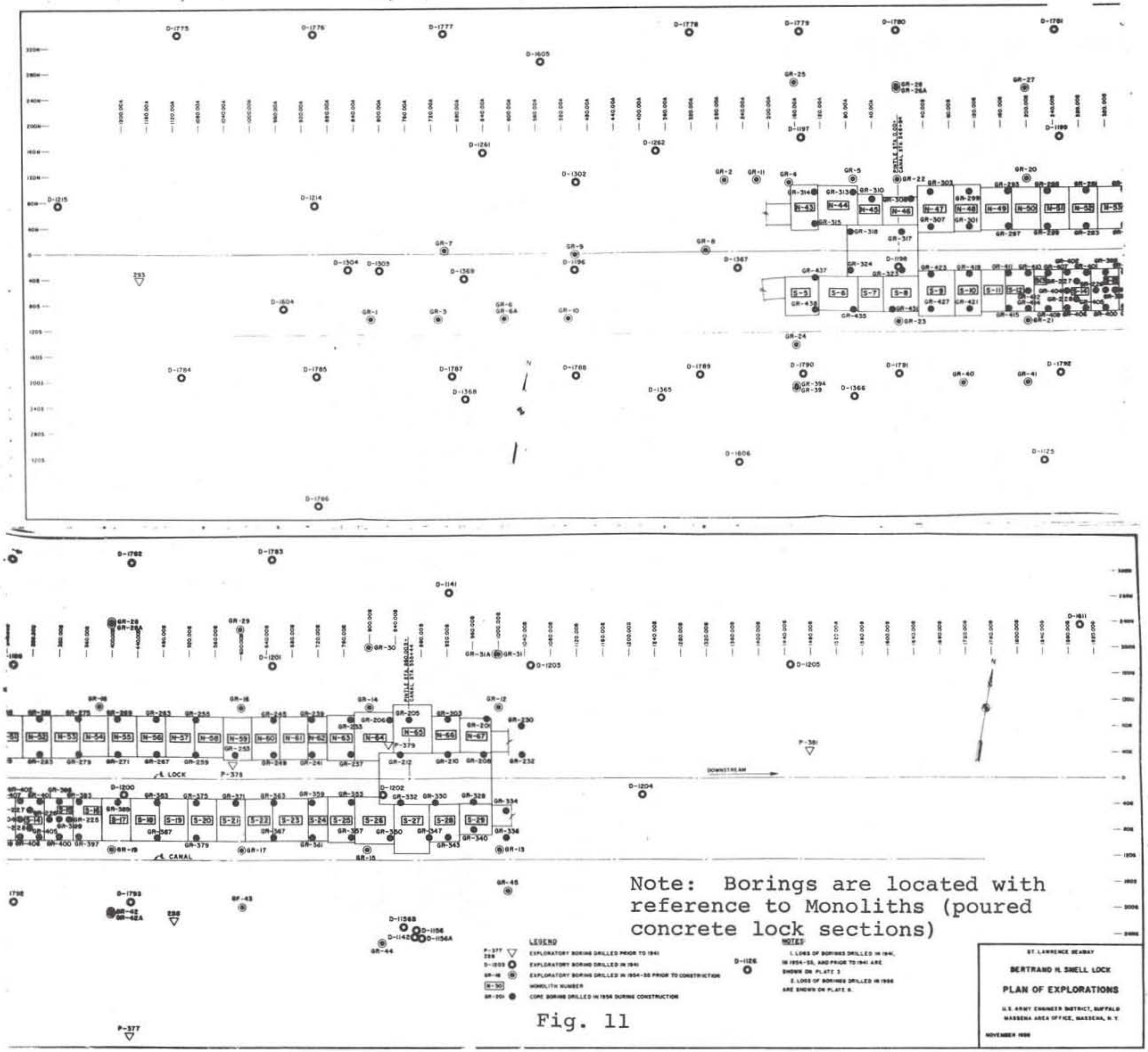
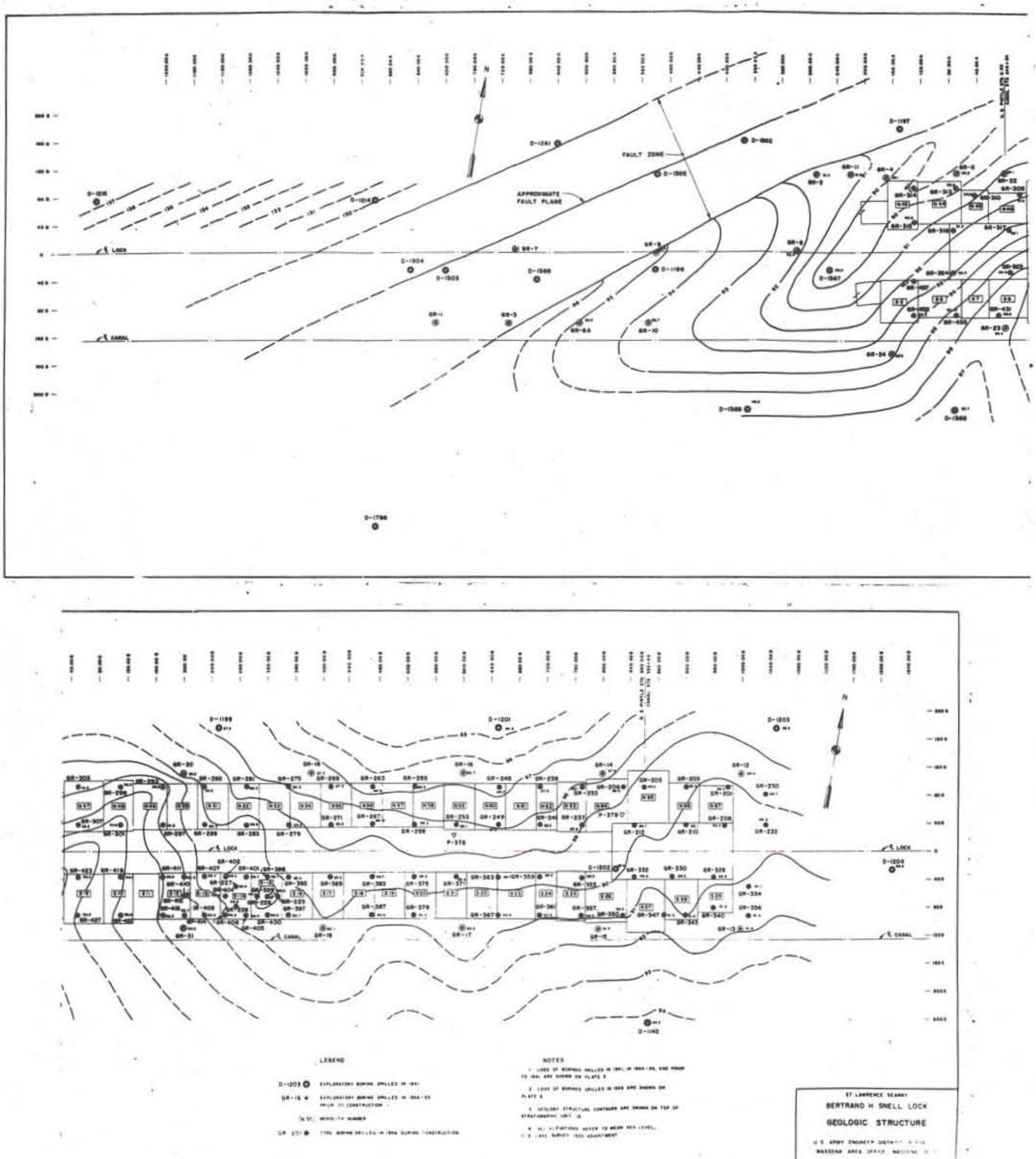

SECTION C-C
STATION 200.00 B
SECTION D-D
STATION 627.00 B
NOTES
DWIGHT D. EISENHOWER LOCK
GEOLOGICAL SECTIONS

Fig. 10



Note: Borings are located with reference to Monoliths (poured concrete lock sections)

Fig. 11



Note: Borings are located with reference to Monoliths (poured concrete lock sections)

Fig. 12

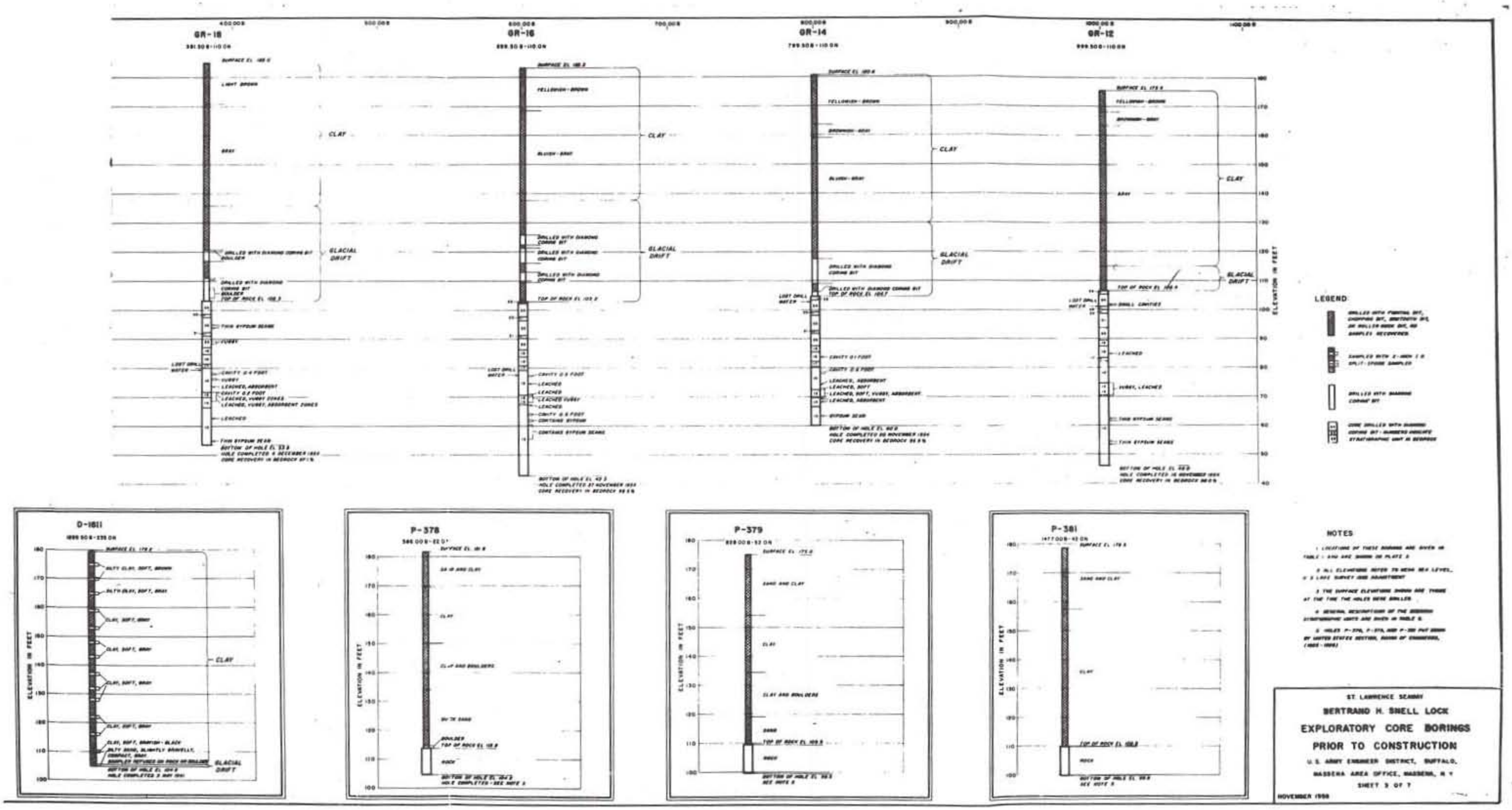

GR-18
GR-16
GR-14
GR-12
CLAY
GLACIAL DRIFT
ELEVATION IN FEET
LEGEND
D-1811
P-378
P-379
P-381
NOTES
ST. LAWRENCE SEAWAY
BERTRAND H. SNELL LOCK
EXPLORATORY CORE BORINGS
PRIOR TO CONSTRUCTION
U.S. ARMY ENGINEER DISTRICT, BUFFALO,
MASSENA AREA OFFICE, MASSENA, N.Y.
SHEET 3 OF 7
NOVEMBER 1958

Fig. 13a

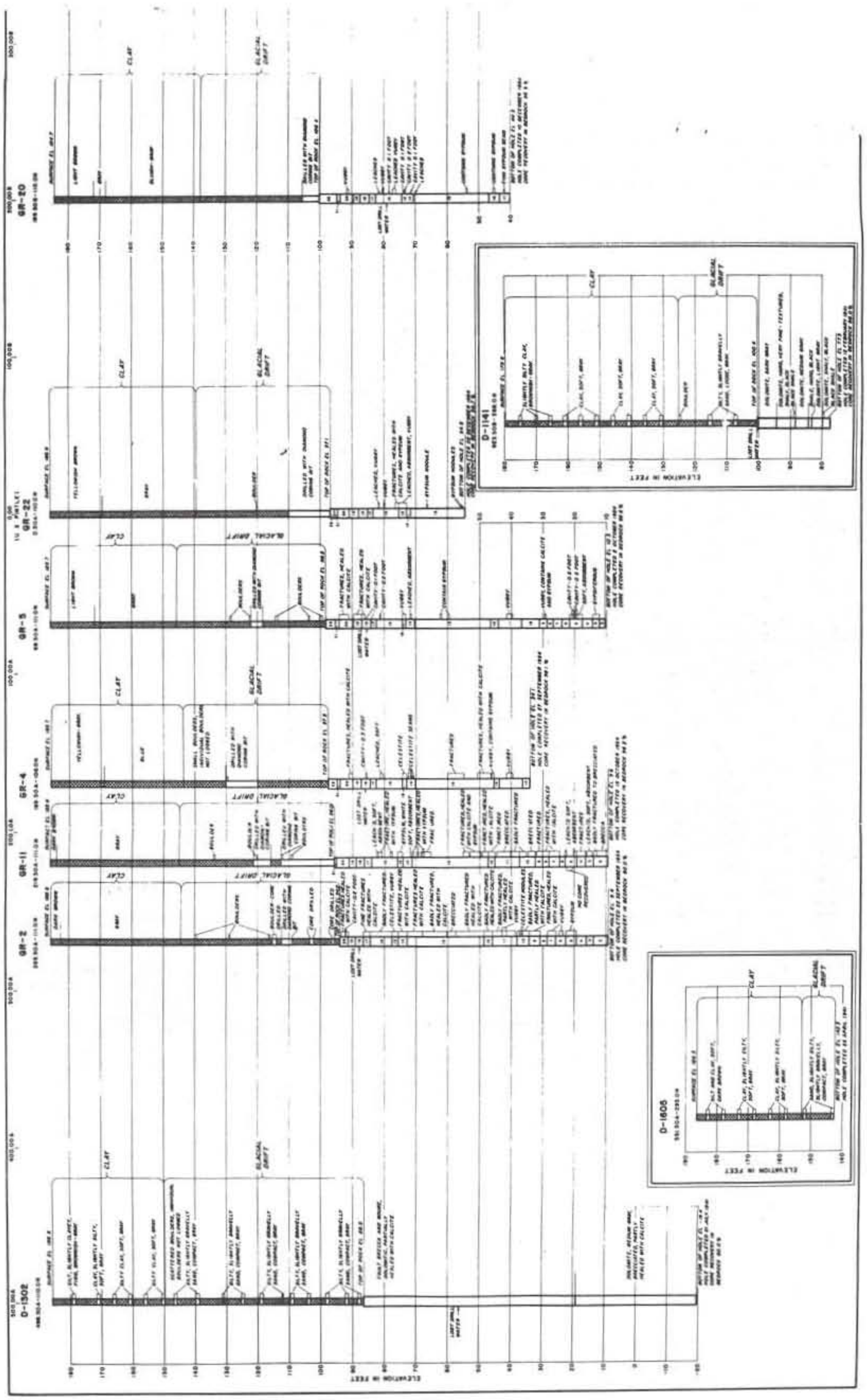


Fig. 13b

DEPTH OF SAMPLES FT.	ELEVATION OF SAMPLES	CLASSI-FICATION	ATTERBERG LIMITS		MOISTURE CONTENT %	DENSITY (DRY) lbs./cu.ft.	VOID RATIO	SATUR-ATION %	TRIAXIAL COMPRESSION STRENGTH DATA (UNCONSOLIDATED - UNDRAINED)			
			LIQUID LIMITS	PLASTIC LIMITS					LATERAL PRESSURE Tons/sq.ft.	COMPRESSIVE STRENGTH Tons/sq.ft.	SHEAR STRENGTH Tons/sq.ft.	PERCENT STRAIN AT FAILURE
					HOLE GR-25							
10.0-12.5	179.8-177.3	CH	52.2	24.2	47.8	72.8	1.40	95.3	0.0	0.47	0.24	2.5
		CL	43.4	21.7	42.4	77.7	1.25	94.9	0.0	0.44	0.22	5.0
10.0-11.5	179.8-175.3	CH	55.2	24.2	47.8	72.8	1.40	95.3	0.0	0.47	0.24	2.5
		CH	55.1	26.1	53.3	68.2	1.56	95.5	1.0	0.71	0.36	6.1
		CH	55.1	26.1	53.0	62.8	1.62	91.7	2.0	0.68	0.34	5.7
		CH	53.3	19.7	44.6	72.4	1.41	88.4	4.0	0.68	0.34	2.3
11.5-12.5	176.3-174.3	CL	43.2	21.7	42.4	77.7	1.25	94.9	0.0	0.44	0.22	4.7
20.0-22.5	166.8-164.3	CH	53.6	25.3	61.2	63.4	1.76	97.6	0.0	0.53	0.26	1.8
		CH	53.0	23.0	59.5	64.8	1.70	98.1	1.0	0.67	0.34	3.2
		CL	48.2	23.2	58.1	64.2	1.72	96.1	2.0	0.74	0.37	2.1
		CH	55.8	24.9	61.0	63.7	[illegible]	98.0	4.0	0.62	0.31	2.5
30.0-32.5	158.8-154.3	CH-MH	66.9	27.7	64.8	61.1	[illegible]	97.5	0.0	0.22	0.11	1.1
		CH	72.1	28.3	70.0	58.6	1.96	99.0	1.0	0.83	0.42	1.8
		CH	71.8	27.7	69.2	58.5	1.96	97.6	2.0	0.73	0.36	3.8
		CH	73.3	27.5	68.5	58.1	1.95	98.0	4.0	0.66	0.33	2.8
					HOLE GR-28							
10.0-12.5	175.7-173.2	CH	51.0	22.2	41.5	77.6	1.25	93.3	0.0	1.04	0.52	1.8
		CH	56.8	24.2	45.5	73.0	1.39	91.4	1.0	0.64	0.32	1.1
		CH	55.9	21.2	42.3	75.9	1.30	90.9	2.0	0.73	0.36	1.4
		CH	59.2	20.6	42.5	76.0	1.24	96.0	4.0	1.10	0.55	1.1
20.0-22.5	165.7-163.2	CH-MH	50.9	26.5	50.6	70.9	1.38	97.2	0.0	0.78	0.39	2.8
		CH-MH	52.9	27.1	52.5	69.8	1.50	97.8	1.0	0.81	0.40	2.1
		CH-MH	53.5	28.2	52.3	69.8	1.50	97.4	2.0	0.93	0.46	3.2
		CH-MH	52.6	26.7	51.5	70.5	1.48	97.5	4.0	0.93	0.46	2.5
30.0-32.5	155.7-153.2	CL	47.7	24.7	46.7	72.9	1.40	97.6	0.0	1.03	0.52	1.4
		CL-ML	48.3	26.0	46.1	73.6	1.37	98.1	1.0	1.25	0.62	2.9
		CL-ML	48.9	26.4	48.9	72.1	1.42	98.2	2.0	1.50	0.75	1.5
		CL	48.2	25.0	46.9	74.0	1.36	96.5	4.0	1.31	0.66	2.8
40.0-42.5	145.7-143.2	CL	44.8	24.4	43.4	77.5	1.25	97.0	0.0	0.58	0.29	2.5
		CL	43.1	21.8	43.1	77.8	1.25	96.8	1.0	0.90	0.45	3.3
		CL	43.1	21.8	42.5	78.1	1.24	96.1	2.0	1.01	0.50	2.8
		CL	42.8	22.8	39.7	81.1	1.16	96.2	4.0	1.47	0.74	2.7
42.5-43.5	143.2-142.2	CL	43.1	23.4	40.0	80.0	1.18	96.8	0.0	1.20	0.60	4.0
					HOLE GR-31							
10.0-12.2	167.6-165.4	CL-ML	40.7	20.4	39.2	82.1	1.13	94.4	0.0	1.16	0.58	2.1
		CH	53.4	24.0	60.6	77.0	1.27	94.4	1.0	1.00	0.50	1.8
		CH	56.5	25.0	57.0	74.3	1.35	98.3	2.0	1.17	0.58	1.8
		CH	58.2	27.6	57.7	72.9	1.40	93.3	4.0	0.71	0.38	1.8
20.0-22.2	157.6-155.4	CL-ML	48.2	26.4	58.2	64.3	1.72	96.5	0.0	0.86	0.43	1.8
		CH	59.1	24.0	60.8	63.8	1.74	97.6	1.0	1.26	0.63	1.4
		CL-ML	48.6	25.9	57.0	65.8	1.65	95.5	2.0	1.32	0.66	1.4
		CL-ML	48.2	27.6	57.7	65.4	1.67	96.6	4.0	0.94	0.47	2.1
30.0-32.2	147.6-145.4	CL-ML	44.7	25.0	58.7	63.8	1.72	96.8	0.0	0.71	0.36	2.9
		CL-ML	43.9	24.8	58.5	65.4	1.67	97.8	1.0	0.93	0.46	1.8
		CL-ML	48.3	26.1	56.7	64.9	1.66	97.1	2.0	0.69	0.34	2.9
		CL-ML	48.8	27.9	57.6	66.4	1.63	97.5	4.0	0.61	0.30	2.9
40.0-42.2	137.6-135.4	CL-ML	42.8	24.0	58.6	64.5	1.71	98.0	0.0	0.71	0.36	3.6
		CL-ML	41.5	22.9	58.5	64.3	1.72	97.0	1.0	0.44	0.22	5.4
		CL-ML	42.8	25.0	58.6	64.5	1.71	97.7	2.0	0.71	0.36	3.6
		CL-ML	42.8	25.3	58.8	65.0	1.69	97.4	4.0	0.69	0.34	2.5
50.0-50.8	128.6-127.8	CL-ML	41.2	25.7	62.2	62.3	1.80	96.6	0.0	0.40	0.20	3.6
		CL-ML	46.2	25.1	62.1	62.5	1.80	96.6	1.0	0.59	0.30	6.3
		CL-ML	48.2	25.1	63.0	61.7	1.83	96.3	2.0	0.59	0.30	5.0
		CL-ML	48.2	25.1	62.8	62.0	1.82	96.6	4.0	0.56	0.28	6.9
51.5-53.5	126.1-124.1	CH-MH	52.6	26.7	63.4	61.8	1.83	97.3	0.0	1.03	0.56	1.4
		CH-MH	59.8	30.8	62.2	63.0	1.77	98.2	1.0	0.56	0.28	2.5
		CL-ML	48.8	26.2	58.3	66.3	1.66	97.4	2.0	0.61	0.28	3.8
		CL-ML	47.0	26.0	61.9	63.3	1.76	99.4	4.0	0.41	0.20	4.7
54.8-56.2	123.6-121.4	CL-ML	48.8	25.5	55.9	67.2	1.60	97.6	0.0	0.68	0.34	1.8
		CL-ML	44.0	25.4	52.0	71.0	1.48	99.7	1.0	0.76	0.38	2.1
		CL-ML	45.9	26.0	46.2	72.7	1.41	98.1	2.0	0.58	0.29	4.3
		CL-ML	39.0	22.8	44.1	77.4	1.28	98.3	4.0	0.58	0.29	4.6

ST. LAWRENCE SEAWAY

BERTRAND H. SNELL LOCK

LABORATORY TEST DATA
CLAY OVERBURDEN MATERIALS

U.S. ARMY ENGINEER DISTRICT, BUFFALO
MASSENA AREA OFFICE, MASSENA, N.Y.
SHEET 1 OF 2
NOVEMBER 1956

Fig. 14

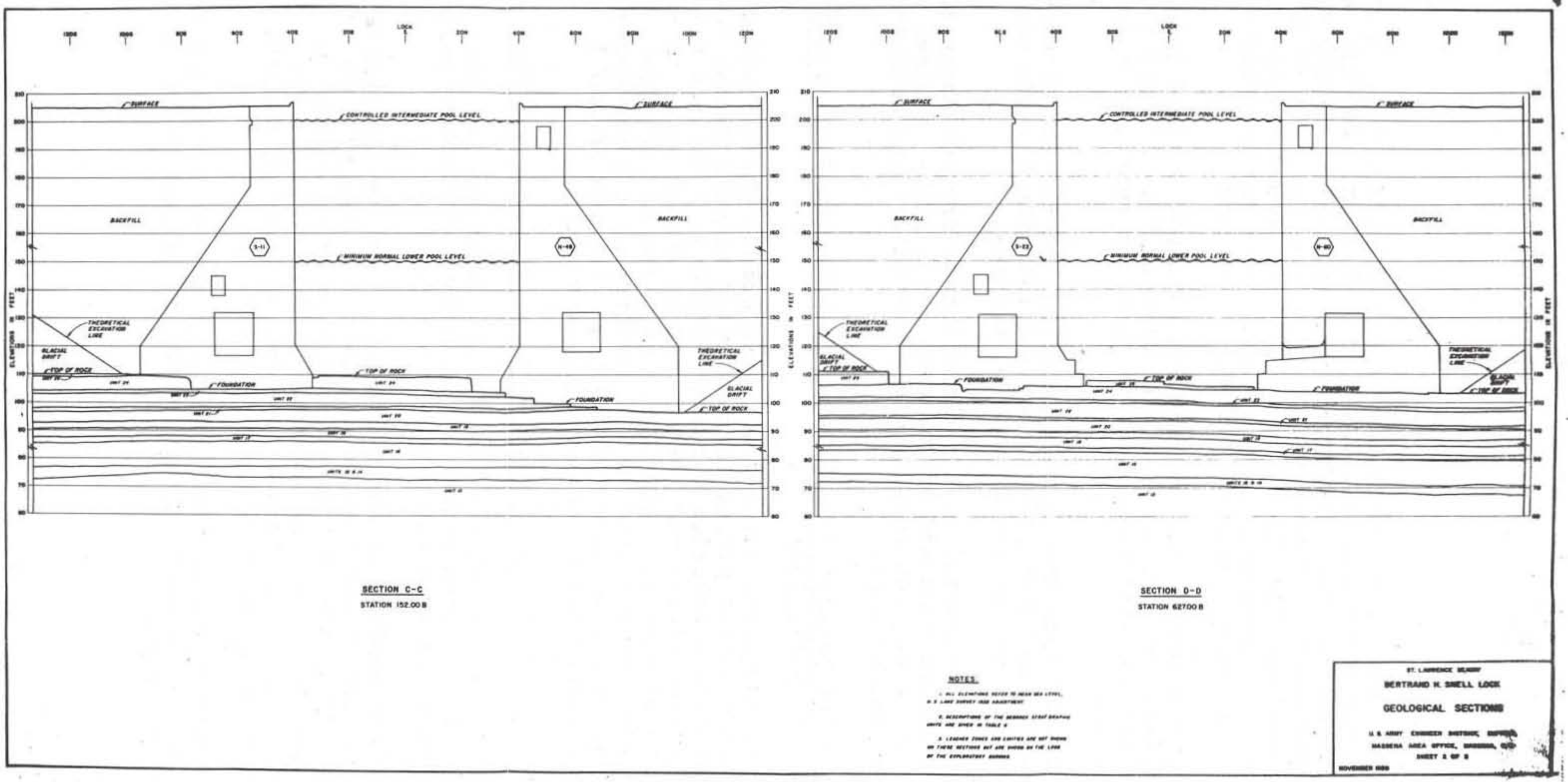

SURFACE
CONTROLLED INTERMEDIATE POOL LEVEL
MINIMUM NORMAL LOWER POOL LEVEL
BACKFILL
THEORETICAL EXCAVATION LINE
GLACIAL DRIFT
TOP OF ROCK
FOUNDATION
ELEVATIONS IN FEET
LOCK
SECTION C-C
STATION 152.00 B
SECTION D-D
STATION 627.00 B
NOTES.
BERTRAND H. SNELL LOCK
GEOLOGICAL SECTIONS

Fig. 15

The operation starts with the "run of the bank" gravel and rocks which are fed into one end of the plant. As this material moves along the plant conveyor belts, the sand is separated and the rocks crushed, screened to size and washed. Waste material is screened out and the balance runs the gamut of vibrating screens, scrubbers and washers until there are a number of neat piles of various sized crushed stone and sand.

The crushed stone for the concrete was divided into 3 stockpiles, one with stone graded from 1/2" to 1"; one from 1" to 2"; and one with sand which varied from near a #200 sieve-size to 1/4".

Trucks took the various materials to the job sites where it was handled in batch plants as its first step towards becoming concrete for one of the project structures.

It is estimated that for the entire project about 400,000 tons of washed sand and gravel were used. This required excavating about 600,000 tons from the gravel pit and crushing about 300,000 tons of rock.

Stop 6 - The Niagara Mohawk Power Corporation Dams, South Colton to Carry Falls

The Racquette River Power Development Project added five new hydro-electric plants which boosted Niagara Mohawk Power Corporation's production capacity to almost 1 billion kilowatt hours of electricity per year. This is enough power to supply the needs of more than 400,000 homes. The project cost $33,000,000 and resulted in the creation of six new lakes and public areas for boating and fishing. Figures 16 and 17 show the plan and statistics of the project (also Table 2).

Stop 7 - Bicknell Gravel Pit, West Parishville, New York

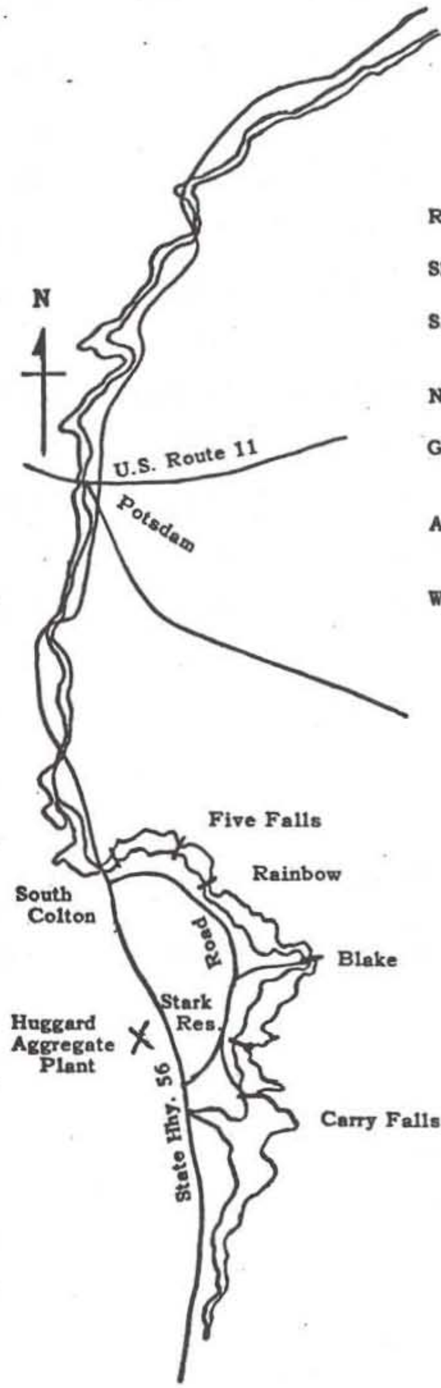
This site is also a Kame Terrace deposit, but the rock utilized for crushed gravel and sand shows different geologic characteristics from the Martin Pit of stop 5.

Cross bedding of sand, boulder pavements (concentrations of large cobbles in one area of the deposit), the effects of water-working and a wide variety of rock types can be seen here, allowing comparison to be made between different physiographic areas visited, the very different types of engineering material types and their relation to the area geology.

Sandstone, quartzite, gneiss, limestone can be observed at this pit, contrasting markedly with the uniform material at the Martin Gravel Pit.

NIAGARA MOHAWK

UPPER RAQUETTE DEVELOPMENT



GENERAL DATA

Raquette River Construction Corp. - General Contractor:

Shellet Electric	- Electric Contractor
S. Morgan Smith	- All turbines, intake and sluice gates.
Newport News	- Tainter Gates
General Electric	- Generators at Five Falls, Rainbow and Stark.
Allis Chalmers	- Generators at South Colton and Blake.
Westinghouse	- All transformers and switchgear.

Est. total yds. of concrete -	286,000
Est. total yds. of embankments -	756,000
Est. total yds. of earth excav. -	1,250,000
Est. total yds. of rock excav. -	170,000

Location Map - Upper Raquette Development

Fig. 16

	CARRY FALLS	STARK	BLAKE	RAINBOW	FIVE FALLS	SOUTH COLTON
Generator	*	22,500 KW	14,400 KW	22,500 KW	22,500 KW	19,350 KW
Turbine		30,600 HP	18,650 HP	30,600 HP	30,600 HP	25,400 HP
Gross Hd.	Varies to 35'	105'	69'	103'	104'	85'
Dam Height	70'	35'	55'	100'	55'	45'
Spillway Dam Length	830' **	340'	600'	760'	500'	600'
Concrete Cu. Yds.	36,000	42,000	44,000	99,000	37,000	28,000
Embankments Cu. Yds.	90,000	143,000	155,000	227,000	104,000	37,000
Resv. Acres	3,300	600	660	710	120	225
Resv. Volume Cu. Ft.	5 Billion	560 Million	550 Million	530 Million	100 Million	130 Million
Normal Res. Elev.	1,385	1,355	1,250	1,181	1,077	973
Length of Reservior	6 Mi. ***	1½ Mi.	3 Mi.	3½ Mi.	1½ Mi.	2
Pipe Diam.		18'	18'	18'	18'	18'
Pipe Length		590'	670'	585'	1,620'	1,300'
Tainter Gates 2		2				
Tainter Gate Size	27' x 15'	27' x 15'				—
Sluice Gates 2		1				
Sluice Gate Size'	10' x 10'	12' x 12'				
Surge Tank Size	None	None	None	None	65' Dia. 85' High	60' Dia. 70' High
Generator Voltage	—	11,500	6,900	11,500	11,500	11,500

NOTE * Intake provided for approximately 3,500 KW Generator in future.

** Five earth dikes or dams around reservoir.

*** About 25 miles perimeter at flow line.

AGGREGATE PLANT

Input - 200 tons per hour.

Output - 180 tons of washed #3, #2, #1 stone and sand.

Also makes filter stone for use on dikes #3, #2, and #1 stone sizes unwashed.

Table 2. Upper Raquette Power Station Data

ST. LAWRENCE COUNTY: TOWN OF PARISHVILLE

SCALE 1"= 1 MILE

PHYSIOGRAPHIC PROVINCE: Adirondack Mts.— St. Lawrence Lowland

DEPOSITIONAL UNIT: Kame-type

PEDOLOGICAL SOIL SERIES: Hinckley

MATERIAL ORIGIN: Crystalline

Location Map for Bicknell Gravel Pit
(formerly Putnam-Hawley Pit)

Fig. 17

APPENDIX

Dwight D. Eisenhower Lock

GEOLOGY

Physiography

Dwight D. Eisenhower lock is constructed diagonally through a northeast-southwest-trending ridge. The ridge is between 1,500 and 2,000 feet wide and is bounded by the valley of Robinson Creek on the southeast and by a small valley or low area on the northwest. Relief is about 70 feet. Top of the ridge varies around elevation 255 with the highest point along the alignment for the lock prior to excavation being about elevation 263. Robinson Creek valley downstream from the lock varies around elevation 195, and Robinson Creek is at about elevation 175. The small valley upstream from the lock is around elevation 215. The location of the lock, except for the guidewalls is within the limits of the ridge.

Overburden

The material composing the ridge at the lock site is principally glacial till of late Pleistocene age. In the excavation and foundation area for the lock it ranged in thickness from 100 feet to 123 feet except at each end where excavation for ramps into the work area extended out onto and beyond the sides of the ridge and the depth was less. The glacial till is gray in color except in the oxidized zone near the surface and consists of a compact, unsorted mixture of clay, silt, sand, gravel, cobbles, and boulders in non-uniform proportions. The predominant constituents are silt and sand, but the till also contains a considerable quantity of gravel; cobbles are abundant, and boulders are common. Pockets and lenses of sorted and stratified materials are contained within the till.

The till is separated into three distinct layers by zones of stratified glacial drift, which contain finely stratified or varved silt and clay. These layers and zones were exposed in the sides of the excavation prior to backfilling, but they were not mapped and only a few measurements were made of them. The lower till layer is about 18 to 30 feet thick in the immediate vicinity of the lock depending on the elevation of top of bedrock. The zone of stratified drift separating it from the middle till layer is about at elevation 165 and is principally a layer of finely stratified silt and clay. The finely stratified silt and clay ranges in thickness from a featheredge to about 10 feet and is cut out in places by lenses of stratified sand and by glacial till. The silt and clay are overlain by 10 feet or more of well-sorted horizontal and cross-bedded sand interstratified with poorly sorted coarse sand and gravel at the northeastern corner of the lock excavation behind the downstream guide wall. The middle layer of till is around 20 to 35 feet thick. The stratified drift zone that separates it from the upper till layer is about at elevation 200 and is about 10 feet or so thick. The upper layer of glacial till is around 50 feet thick.

The lower and middle layers of glacial till in the Eisenhower lock area are correlated by MacClintock (1958) with the Malone till of his classification. This till is considered tentatively by him to belong to the Cary substage of Wisconsin glaciation. The upper till layer is correlated by MacClintock with the Fort Covington till of his classification, which he tentatively considers to belong to the Valders substage of Wisconsin glaciation.

A deposit of fossil-bearing gravel that was formed as a beach in a body of marine water at the close of the Pleistocene Epoch following Wisconsin glaciation overlies the glacial till near the crest of the ridge in the Eisenhower lock area.

Bedrock Stratigraphy

Bedrock in the Eisenhower lock area penetrated by core borings belongs to the upper part of the Beekmantown Formation, or the Oxford Formation of Wilson (1946), and is Ordovician in age. The rock is dolomite for the most part but contains shale and dolomitic shale layers interbedded with it. Two gypsum beds occur at depths around 50 and 100 feet, respectively, below top of the unit. Gypsum also is irregularly distributed through some of the dolomite layers as paper- and wafer-thin seams along partings, as small stringers or veinlets, and as small irregularly-shaped replacement bodies. The core log for bedrock borings is given in Table 1. Stratigraphic units in this log have the same number as correlative units in the core log for the Snell Lock (Table 2).

Table 1. Core Log for bedrock beneath Eisenhower lock.

Stratigraphic Unit	Thickness ft.	Description
27	10.4+	Dolomite, dense to very finely crystalline gray to dark gray. Contains a dolomite conglomerate zone from 0.1 to 1.0 foot thick at or near the base and another from 0.2 to 0.9 foot thick from 1.8 to 3.2 feet above the base in many of the cores. The conglomerate consists of small gray dolo-

Table 1. Core Log for bedrock beneath Eisenhower lock.

Strati-graphic Unit	Thickness ft.	Description
		mite pebbles in a slightly lighter gray dolomite mortar (probably intraformational conglomerate zone). The unit also contains a few thin shaly zones and thin shale seams.
26	4.5-6.4	Dolomite, dense, argillaceous, dark gray. Contains a black shale seam from 0.1 to 0.35 foot thick at bottom that, in many of the cores, has a sandy appearance because of light colored dolomite or quartz impregnated into or disseminated through it. Other thin black shale seams and partings are scattered through the unit. The unit also contains zones and pockets in which are veinlets and irregular masses of white calcite.
25	8.9-10.2	Dolomite, dense to very finely crystalline, gray. Contains argillaceous zones and thin black shale seams and partings. Most of the cores show a dolomite conglomerate zone between 0.1 foot and 1.7 feet thick and a vuggy zone between 0.1 foot and 1.4 feet thick near the bottom. The conglomerate consists of pebble-size dolomite particles or lenses in a slightly lighter gray dolomite matrix. The vugs range in size from pinpoint to about 1.5 inches in diameter.
24	3.4-4.9	Dolomite, very finely crystalline, brownish-gray. Contains a mottled zone 1.5 to 2.0 feet thick about 2 feet below the top of the unit. Tiny vugs or pores about pinpoint size are contained in the mottled zone. The lower 0.4 to 0.8 feet of the unit is dense.
23	1.0-1.4	Shale, black. Dolomitic in some cores.
22	5.1-5.6	Dolomite, dense, gray to dark gray. Argillaceous in some cores and contains argillaceous and black shale seams in others.

Table 1. Core Log for bedrock beneath Eisenhower lock.

Strati-graphic Unit	Thickness ft.	Description
21	0.6-0.9	Shale, dark brownish-gray to black. Logged as dolomitic shale in some cores and as argillaceous dolomite in others. Contains black shale zones at top and at bottom of unit where it appears as argillaceious dolomite.
20	3.1-4.2	Dolomite, dense, gray. A dark gray argillaceous zone about 0.3 foot thick occurs around 0.6 to 0.9 foot below the top of the unit. The unit contains thin vuggy zones in some cores. The vuggy zones are in the lower 2.5 feet of the unit, and the vugs are mostly pinpoint-size to 1/8 inch in diameter.
19	2.4-3.0	Dolomite, dense, very argillaceous, very dark gray to black. Contains a black shale seam at the base from 0.1 to 0.3 foot thick and other thin black shale seams. A zone from 0.2 foot to about 1.0 foot thick containing white calcite in veinlets and in small irregularly shaped masses occur in most of the cores at around 1.5 feet above the base of the unit.
18	2.0-3.6	Dolomite, dense, gray. Lower 1.1 feet in some cores is dark gray, argillaceous or contains thin, dark dray argillaceous zones.
17	1.1-2.1	Dolomite, dense, very argillaceous, very dark gray to black. Contains black shale seams.
16	8.4-9.5	Dolomite, dense, gray. Contains scattered dark gray argillaceous zones in some cores.
15	1.4-3.8	Gypsum, finely to coarsely crystalline, white to dark gray or dark brown.
14	1.9-3.8	Dolomite, dense, argillaceous, gypsiferous, gray. The gypsum occurs as white or very light gray lenses and irregularly shaped

Table 1. Core Log for bedrock beneath Eisenhower lock.

Strati-graphic Unit	Thickness ft.	Description
		masses in the dolomite and in seams paper-thin to 0.3 foot or more thick.
13	21.1-24.4	Dolomite, dense, gray. Contains slightly darker gray argillaceous zones.
12	2.1-2.7	Dolomite, dense, argillaceous, dark brownish-gray. Penetrated only by holes RB-7A and 8A.
11	7.1-10.7	Dolomite, dense, gray. Contains scattered thin black shale seams and partings. Lower part apparently is gypsiferous. Penetrated only by holes RB-7A and 8A.
10	5.6±	Dolomite, dense, argillaceous, dark gray to dark brownish-gray. Contains scattered thin black shale seams and partings. Penetrated only by holes RB-7A and 8A.
9	2.9±	Dolomite, dense, gray. Penetrated only by hole RB-8A.
8	1.7±	Dolomite, dense, argillaceous, dark brownish-gray. Penetrated only by hole RB-8A.
7	2.4±	Dolomite, very finely crystalline, brownish-gray. Contains scattered, wavy, paper-thin shale seams. Penetrated only by hole RB-8A.
6	2.2±	Dolomite, dense to very finely crystalline, gray. Penetrated only by hole RB-8A.
5	5.7±	Gypsum, very finely crystalline, argillaceous, brownish-gray. Penetrated only by hole RB-8A.
4	2.6±	Dolomite, dense to very finely crystalline, gray. Contains scattered thin black shale seams. Penetrated only by hole RB-8A.

Bedrock Structure

The rock strata at Eisenhower Lock are very nearly horizontal but have a slight general dip north-westward and contain small undulations. The dip for the most part is less than 1°43' or 3 feet per 100 feet.

The foundation rock contains three major sets of nearly vertical joints. Those belonging to the most prominent set strike between N 8°W and N 20°W, and the other two sets strike between N 26°E and N 43°E and N 70°E and S 85°E, respectively.

Bedrock Weathering

The rock in the Eisenhower Lock area is virtually unweathered, except for some yellowish-brown or rust-colored staining observed along partings in the upper 5 feet of rock in a few cores. Weathered rock probably was removed by glacial erosion during the Pleistocene, and the bedrock since has been protected by the mantle of glacial till.

Leaching and Solution in Bedrock

Thin zones of leached rock and small solution cavities are widely distributed in certain stratigraphic zones in the foundation rock. They apparently are more common in the downstream portion of the foundation rock than in the upstream portion. Those which are most persistent occur about 3 feet below the top of stratigraphic unit 13, at the top of stratigraphic unit 15, near the bottom and at the top of unit 16, and near the bottom and near the middle of unit 25. For the most part, these are parallel to the bedding. The leached zones range in thickness from 0.1 inch along bedding planes or partings to about 7.8 inches and in degree of leaching from just a slight difference in color to earthy-appearing rock with high absorption. The cavities range in thickness from about 0.1 foot to 0.9 foot.

Ground Water

The ground-water level in drill hole D-1173 (Fig. 7) over the till ridge fluctuated between 11 and 17 feet below the ground surface, or between elevations 245 and 251, during the periods prior to construction when measurements on that hole were made. This one drill hole was the only observation well or piezometer in the overburden prior to construction, and the water levels in it were interpreted as indicating the ground-water level in the overburden across the top of the ridge. Test pits dug on the upstream and downstream sides of the ridge in November and in December 1954 by the Power Authority of the State of New York filled with water to within 4 to 6 feet of the ground surface at the time they were dug. The ground water level adjacent to the lock area was lowered during excavation for the lock by drainage into the excavated area but has risen again since the space between the lock walls and the excavation slope was backfilled.

The water in the bedrock has a lower pressure head than that in the overburden materials. Water levels measured in core holes drilled into bedrock in 1954 and in 1955 prior to construction, for the most part, were between elevations 160 and 170 feet, and thus were about 80 to 90 feet below the ground-water levels that were observed in drill hole D-1173. The piezometric level of the water in the bedrock prior to construction was about 20 to 30 feet above the bedrock surface, and fluctuations in that piezometric level tended to reflect fluctuations in the level of St. Lawrence River. During construction after the overburden had been removed, the piezometric level or pressurehead of the water in the bedrock was lowered to top of rock in the lock area by relief through joints and through core holes that were drilled for foundation exploration and to a level below top of rock in the downstream portion of the lock area by relief into the excavation for the lower sill. The piezometric level in these areas rose again after the core holes were backfilled and concrete placed in the foundation areas. By December 1956, the piezometric level for the water in bedrock in the lock area had recovered to an elevation of 149 feet as indicated by water rising to that elevation in observation holes drilled into bedrock from benches on the chamber side of the lock walls.

No chemical analyses of the ground water at Eisenhower Lock were made. An analysis made in 1955 of a sample of water from a farm well 1,920 feet upstream from the upstream gate location and 135 feet north from the centerline for the lock in connection with the determination of acceptable sources of concrete mixing and curing water is given below:

Iron	0.2	PPM
Sulphates	102	PPM
Chlorides	19	PPM
pH	7.5	

The water in the bedrock has a slight odor of hydrogen sulphide.

Engineering Characteristics of the Glacial Till

The glacial till, except where it has been disturbed by frost action or by other means and except for pockets and lenses of loose stratified materials, is compact and dense, and parts of it are very tough. The characteristics of the undisturbed till at Eisenhower Lock, on an average, are:

Classification . . . . .Sandy silt (ML-CL) with gravel, cobbles and boulders. (Unified classification system)

Mechanical analysis
(not including cobbles and boulders)

gravel. . . . . 13 percent
sand. . . . . 34 percent
fines . . . . 53 percent

Unit weight in place (wet weight). . . .149 pounds/cubic foot
Density (dry weight) . . . . .139 pounds/cubic foot
Specific gravity, G. 2.74

Liquid limit 17.4
Plastic limit. 10.7
Moisture content . . . . 7.5 percent
Void ratio 0.24

*Angle of internal friction, Ø. . . . .35 degrees
*Cohesion, c. . . . . 2.1 tons/square foot
*Coefficient of permeability, K . . . .48 x 10^{-6} centimeters/second

*Averages from tests on only three samples.

These characteristics except for coefficient of permeability were obtained from the test data given on figure 14.

Bertrand H. Snell Lock

GEOLOGY

Physiography

Bertrand H. Snell Lock is constructed above the left bank of Grass River near where that stream empties into St. Lawrence River. It lies in a flat area, a short distance beyond the northeast end of a gentle, northeast-trending ridge. Before construction, a small stream tributary to Grass River flowed along the south side of the lock excavation area between the lock site and the end of the ridge. Topography at the lock site prior to construction was nearly flat, with a relief about 25 to 30 feet. Grass River varies around elevation 157. Top of the bank above Grass River was about elevation 175, and the surface in the lock area, for the most part, was between elevations 180 and 185. The small tributary stream along the south side of the lock area was about elevation 160. The topography at the lock site has been altered somewhat by the construction of dikes north and south from the lock; the placement of backfill behind the lock walls; and the construction of spoil piles north of the lock. The roadway on top of the dikes is about elevation 212; backfill behind the lock walls was placed to elevation 205; and spoil was placed in the spoil areas to about elevation 205. About 3,000 feet southwest from the lock area, the gentle ridge rises to elevation 250.

Overburden

The material overlying bedrock in the area of Snell Lock is glacial drift and soft clay, both of which are of late Pleistocene Age. Before excavation was started it ranged in thickness at the lock site from about 60 feet to about 100 feet, with an average of about 80 feet.

The glacial drift lies directly on bedrock and consists principally of till but includes water-lain sand and gravel. The till is gray and is a more or less tough, compact mixture of clay, silt, sand, gravel, cobbles and boulders. The predominant constituents are silt and sand. Water-lain sand and gravel occur as lenses and layers of loose sandy gravel and gravelly sand within, above, and at the eastern margin of the till. Prior to excavation and construction, the glacial material ranged in thickness from a feather edge to about 6 feet in the downstream lock approach area and was absent in places. It increased in thickness upstream from there to about 55 feet near the upstream limits of the lock walls and to about 72 feet near the upstream limit for the upstream guide wall. The glacial drift surface rose in elevation from downstream to upstream more or less corresponding to the increase in thickness. No mineralogical studies were made on the till at Snell Lock site, but studies at U. S. Army Engineer Waterways Experiment Station, Vicksburg, Mississippi, on five samples taken from the excavation for Wiley-Dondero ship channel show the major constituents of the till to be carbonate rocks and minerals, quartz, feldspar, and clay. These made up 85 percent or more of each of the five samples studied. Most of the gravel-size particles are dense, dark gray limestone and dolomite, but gravels of quartzite and granite also are contained in the till. The average composition of the five samples are:

	Percent
Carbonate rocks and minerals	26
Quartz and feldspar	53
Igneous rocks and gneiss	3
Graywacke	1
Sandstone	trace
Shale, slate	1
Clay	11
Miscellaneous	5

Soft clay overlies the glacial material where the overburden has not been disturbed by construction and lies directly on bedrock where glacial material is absent. It consists of soft silty clay ranging in color from brown in the zone of oxidation to gray to blue-gray below that zone. The clay contains marine shell fossils and small, thin, fine-grained sand lenses. Varves were observed in the lower part of the clay. Prior to excavation, the clay ranged in thickness at the lock site from about 10 or 12 feet near the upstream limits for the upstream approach wall to about 70 feet in the downstream approach area. In general, the thickness of clay was least where the thickness of glacial material was greatest and greatest where the thickness of glacial material was least.

Mineralogical analyses of samples of clay from the Massena area by R. Torrence Martin, Massachusetts Institute of Technology, Cambridge, Massachusetts, indicate the clay to be predominantly hydrous mica and chlorite and to contain appreciable carbonate minerals. Near the surface, the carbonate minerals have been leached. The results of the analyses on two samples from the downstream approach wall area for Snell Lock, one sample from the oxidized brown clay zone and one from the lower gray clay zone, are:

	Percent by Weight	
	Brown Clay Zone (depth 10.0-12.4 feet-Lab Sample 3)	Gray Clay Zone (depth 35.0-37.4 feet-Lab Sample 13)
Illite	30±6	30±3
Montmorillonoid	10±2	-
Chlorite	20±6	15±5
Carbonates (calcite and dolomite)	-	25±3
Quartz	20±2	10±2
Feldspar	20±10	20±10

The soft clay was called "Leda Clay", "Massena" clay, or just "marine" clay prior to construction of the lock and was considered to be a marine deposit formed in an arm of the late Pleistocene Champlain Sea that extended up the St. Lawrence valley after the Wisconsin ice sheet had receded from the mouth of St. Lawrence River. Dr. MacClintock and others, however, have observed varves in the lower part of the clay where it was exposed in excavations in the Massena area and have concluded that the lower part of the clay is a fresh-water deposit. MacClintock (1958) considers the lower clay to have been deposited in a fresh-water lake that was confluent with the Fort Ann stage of Lake Vermont. Fossiliferous marine clay was deposited over the fresh-water clay after the ice barrier had receded from the mouth of St. Lawrence River and the level of marine water had risen to where it could back up into the St. Lawrence Valley.

Bedrock Stratigraphy

Bedrock in the Snell Lock area explored by core borings belongs to the upper part of the Beekmantown formation, or the Oxford formation as classified by Wilson (1946) and is Ordovician in age. The uppermost rock layer at Snell Lock is 70 to 80 feet below the top of the Beekmantown formation. The rock is dolomite for the most part but contains shale and dolomitic shale layers interbedded with it. Two stratigraphic units that were at depths around 35 and 85, respectively, below top of rock before construction, are replaced or partly replaced by gypsum and/or celestite in and near the fault zone upstream from the limits of the lock walls but are unreplaced dolomite under the foundation. The upper one of these two units, at least, is badly leached under the foundation area. Both of these units are replaced by gypsum in the Eisenhower Lock area. The rock penetrated by the borings has been separated into stratigraphic units on the basis of lithology, and brief descriptions of these units are given in table 2 below. The units are numbered from unit 25, the uppermost unit at Snell Lock, in decreasing sequence downward and correlate with same-numbered units at Dwight D. Eisenhower Lock (Robinson

Bay Lock). Unit 2 is the lowermost unit penetrated by exploratory borings in or near the foundation area for Snell Lock, but one boring in the fault zone penetrated below unit 1.

Table 2. Core Log for bedrock beneath Snell Lock.

Strati-graphic Unit	Thickness ft.	Description
25	4.4+	Dolomite, dense to very finely crystalline, gray. Contains a dolomite conglomerate zone from 0.1 to 1.0 foot thick at or near the base. The conglomerate consists of small gray dolomite pebbles in a slightly lighter gray dolomite mortar (probably intraformational conglomerate zone).
24	4.0 - 5.0	Dolomite, very finely crystalline, brownish-gray to dark gray. Contains a mottled zone from 1.5 to 2.0 feet thick about 2 feet below the top of the unit. The mottled zone contains tiny vugs or pore spaces most of which are about pinpoint size. The lower 0.4 to 0.7 foot of the unit is dense.
23	1.0 - 1.4	Shale, black. Dolomitic in some cores.
22	4.7 - 5.6	Dolomite, dense, gray to dark gray. Argillaceous in some cores and contains argillaceous and black shale seams in others.
21	0.7 - 1.4	Dolomite, dense, argillaceous to very argillaceous, dark brownish-black to black. Contains a black shale seam from about 1 to 8 inches thick at the top of the unit. Also contains thin shale or shaly seams at or near the bottom.
20	3.6 - 4.6	Dolomite, dense, gray. A dark gray argillaceous zone about 3.5 to 8.5 inches thick occurs around 1.0 to 1.5 feet below the top. The lower half of the unit contains vuggy zones in some cores. The vugs range in size from pinpoint size to 0.5 inch or larger.
19	2.0 - 3.0	Dolomite, dense, very argillaceous, very dark gray to black. Contains a black shale seam at the base from 0.1 to 0.3 foot thick and other thin black shale seams.

Table 2. Core Log for bedrock beneath Snell Lock.

Strati-graphic Unit	Thickness ft.	Description
18	2.4 - 3.8	Dolomite, dense, gray.
17	1.5 - 2.2	Dolomite, dense, argillaceous to very argillaceous, very dark gray to black. Contains black shale seams. Logged as dolomitic shale in one core.
16	7.6 - 9.2	Dolomite, dense, gray.
15	0.5 - 2.6	Dolomite, dense, argillaceous, gray. Is leached and vuggy in most cores. Replaced by gypsum and/or celestite in some cores in and near the fault zone upstream from the limits of the lock walls.
14	1.3 - 4.5	Dolomite, dense, argillaceous, laminated, dark gray. Some cores show leached zones.
13	22.5 - 24.8	Dolomite, dense, gray. Contains slightly darker gray argillaceous zones and scattered thin black shale seams.
12	1.0 - 3.3	Dolomite, dense, argillaceous, dark brownish-gray.
11	7.3 - 8.1	Dolomite, dense to very finely crystalline, gray.
10	4.9 - 5.9	Dolomite, dense, argillaceous, dark gray to black. Contains scattered thin black shale seams.
9	2.1 - 3.1	Dolomite, dense to very finely crystalline, gray.
8	1.8 - 2.2	Dolomite, dense, argillaceous, dark gray to dark brownish-gray. Contains thin black shale seams.
7	2.3 - 3.4	Dolomite, very finely crystalline, brownish gray.

Table 2. Core Log for bedrock beneath Snell Lock.

Strati-graphic Unit	Thickness ft.	Description
6	1.4 - 3.2	Dolomite, dense to very finely crystalline, gray.
5	3.3 - 5.8	Dolomite, dense, argillaceous, gray to dark brownish-gray. Logged as gypsum in core from hole GR-2 and as gypsiferous in core from hole GR-13.
4	2.8 - 3.3	Dolomite, dense, gray. Contains scattered thin shale seams.
3	2.2 - 3.0	Dolomite, dense, argillaceous, dark gray to very dark brownish-gray. Gypsiferous in hold GR-5.
2	15.0±	Dolomite, dense, gray. Total thickness of unit penetrated only in hole GR-1.
1	1.4±	Dolomite, very finely crystalline, agrilla-ceous brownish-gray. Upper 0.8 foot of unit is slightly vuggy. Penetrated only in hole GR-1.
0	12.3±	Dolomite, very finely crystalline, gray to dark gray. Contains thin argillaceous seams. Penetrated only in hole GR-1.

Bedrock Structure

The rock strata in the upstream one-fourth of the foundation area for Snell Lock are folded in a small plunging anticline, the crest of which crosses the foundation diagonally from the foundation for monolith S-8 to the foundation for monolith N-49 (see figures 11 and 12 for monolith orientation) and plunges northeastward. Downstream from the anticline, the rock strata are only very slightly undulated and have a slight dip northward. The dip at most places, except on the flanks of the small anticline, is less than 2 feet per 100 feet.

The rock is broken by a fault upstream from the limits of the lock walls. The fault crosses the center line for the lock about 760 feet upstream from the upstream lock gate station and strikes about N 56°E. It probably dips very steeply northwestward. The rock at and adjacent to the fault is badly brecciated and fractured in a zone around 300 feet wide. Vertical displacement of beds is about 35 feet with the upthrown side on the northwest.

The foundation rock contains two major sets of joints. Joints belonging to one of these, for the most part, strike between N 37°E and N 56°E, and those belonging to the other, for the most part, strike between N 80°W and N 90°W. A few joints belonging to a third set strike around N 10°W. The joints are nearly vertical or dip at a very steep angle.

Weathering in Bedrock

Bedrock in the Snell Lock area is virtually unweathered, except for some yellowish-brown or rust-colored staining along partings or bedding planes in the upper 10 feet in one or two cores drilled before construction.

Leaching and Solution in Bedrock

Zones of leached rock and small cavities or solution voids are widely distributed in certain stratigraphic zones in the foundation rock. These are mostly parallel to the bedding. The leached zones range in thickness from 0.1 inch to about 3.0 feet and in degree of leaching from a slight change in color to soft, earthy-appearing rock exhibiting honey-combing by solution and high absorption. The solutional cavities range in thickness from about 0.5 inch to about 7 inches. Most of the leached zones and cavities are in stratigraphic units 16, 15, 14, and 13 although they were encountered in nearly all units. Some of the leached zones and cavities are persistent under a fairly large portion of the foundation area. One such persistent zone is about 2 feet below the top of stratigraphic unit 16, characterized in many cores as a leached or a soft absorbent zone, or as a cavity. Unit 15 contains cavities and is composed of or contains zones of soft, absorbent, honeycombed rock under most of the foundation area. Unit 14 also contains persistent zones that are absorbent and that are honeycombed by solution.

Ground Water

No measurements of ground-water levels in the overburden materials were made prior to excavation, but measurements of water levels in piezometers that were installed in the clay portion of the overburden less than 2 months after excavation was commenced, showed a piezometric level from 7 to 9 feet below the ground surface at that time. The piezometric level adjacent to the lock area was lowered during excavation, and has risen again since the space between the lock walls and the excavation slope has been backfilled.

The piezometric level of water in the bedrock is lower than that in the overburden materials. Water levels that were measured in those core holes that were drilled in bedrock in 1954 and in 1955 prior to construction were about elevation 158, or about 26 feet below the ground surface at the time of measurement. This was 46 to 72 feet above the bedrock surface in the lock foundation area and very close to the level of Grass River. Fluctuations in water levels in those holes tended to reflect fluctuations in Grass River. During construction, the piezometric level of the water in the bedrock was lowered to top of bedrock or lower in the lock area by pumping from drain wells in the bedrock and by relief through joints and through core holes and relief into the excavation for the lower sill. The piezometric level in these areas rose again slightly after concrete had been placed in the foundation areas and pumping from the drain wells was stopped. Complete recovery of the piezometric level for the water in bedrock occurred in June 1958 when the lock area was flooded preparatory to opening the lock and canal to navigation. Since the lock has been in operation, the piezometric level of the water in bedrock has fluctuated with the filling and emptying of the lock chamber.

The water in the bedrock has a slight odor of hydrogen sulphide. A chemical analysis of a sample taken from core hole GR-23 on 4 May 1955 in connection with the determination of acceptable sources of concrete mixing and curing water is given below. Approximately 50 gallons of water were bailed from the hole before the sample was taken. The analysis was performed in the U.S. Army Engineer Division Laboratories, Ohio River, Cincinnati, Ohio.

Iron	2.5	PPM
Sulphates	639	PPM
Chlorides	79	PPM
pH	7.3	

Engineering Characteristics of the Overburden Materials

The marine and fresh-water clay is a soft, low-strength, sensitive material. The average characteristics of the undisturbed clay at Snell Lock, based on the laboratory test data contained on Fig. 14, are

Classification.	Clay (CL-CH)
Unit Weight in place (wet weight) . . .	106.6 pounds/cubic foot
Density (dry weight).	69.4 pounds/cubic foot
Specific gravity, G	2.82
Liquid limit.	50.3
Plastic limit	25.1
Moisture content.	53.6 percent
Void ratio.	1.54
Cohesion, c	0.43 tons/square foot

The glacial till, except where it has been disturbed and except for pockets and lenses of loose stratified materials, is compact and dense, and parts of it are very tough. No tests were performed on glacial till samples from the Snell Lock area, but the average characteristics of undisturbed till at Eisenhower Lock are:

Classification.	Sandy silt (ML-CL) with gravel, cobbles and boulders
Unit weight in place (wet weight) . . .	149 pounds/cubic foot
Density (dry weight).	139 pounds/cubic foot
Specific gravity.	2.74
Liquid limit.	17.4
Plastic limit	10.7
Moisture content.	7.5 percent
Void ratio.	0.24
Angle of internal friction.	35 degrees
Cohesion.	2.1 tons/square foot

Effect of Glaciation on Bedrock

Weathered rock probably was removed by glacial erosion during the Pleistocene Epoch, and the bedrock since then has been protected from weathering by the mantle of glacial till and of clay covering it. The movement of the ice across the bedrock, however, caused fracturing or jointing in the rock and left scratches or striations on the rock surface. The lower part of stratigraphic unit 25, which made up the upper layer of rock over the downstream portion of the foundation area was badly jointed or fractured and was removed with a bulldozer in places without blasting. Drag joints also occurred in stratigraphic unit 24 over parts of the foundation area. These were nearly vertical at the top of the stratigraphic unit but curved in the lower part of the unit to nearly horizontal. These joints in unit 24 also were very tightly filled with glacial till material that apparently was forced into the joints by the ice as the joints were formed. Two sets of glacial striae were exposed on the rock surface over approximately the downstream third of the foundation area before bedrock excavation. One set had a strike around S 50°W and the other around S 9°E.

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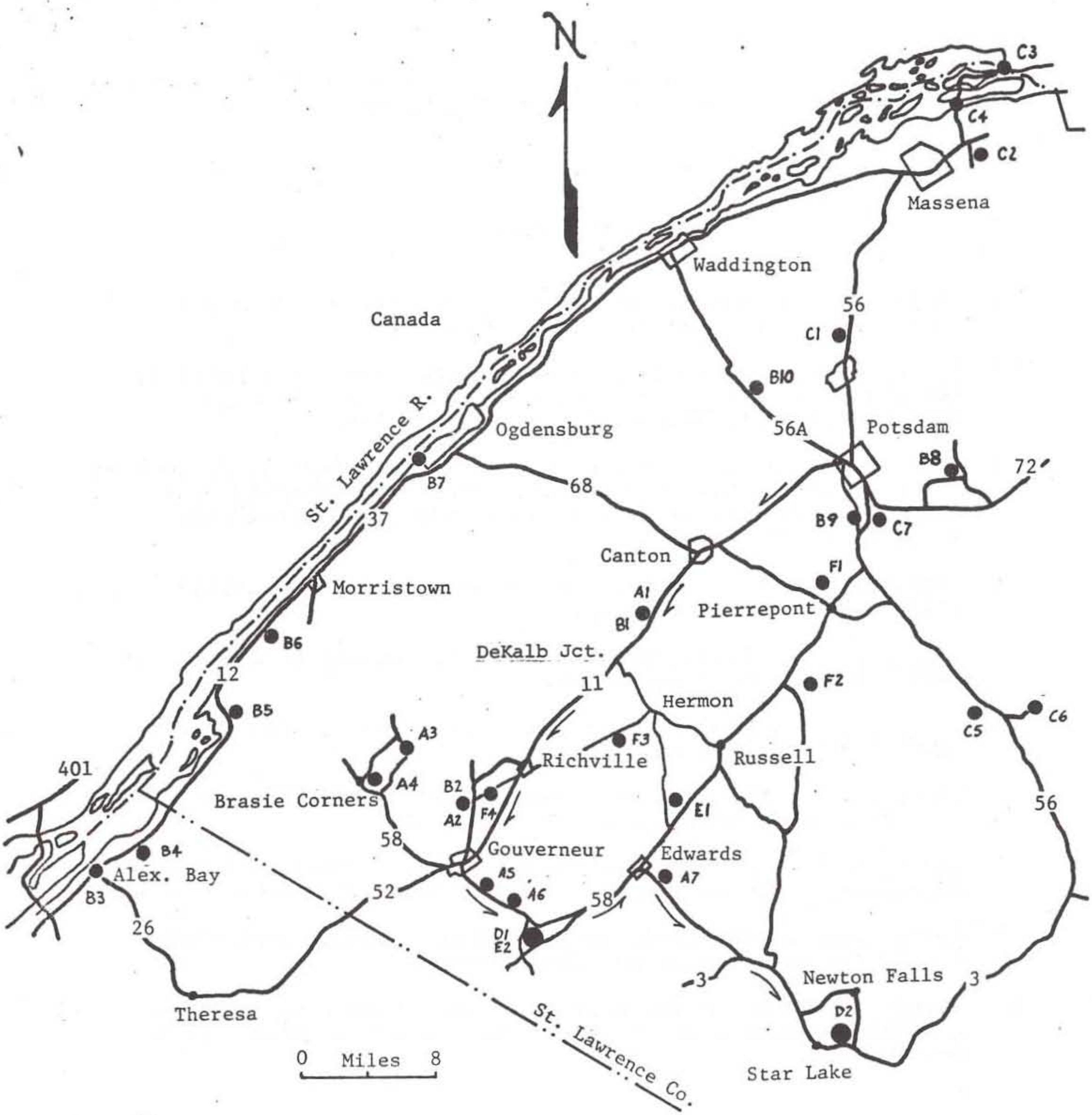

Figure 1. STOP MAP FOR TRIP D

Large dots indicate stops for this trip
and arrows show route.
Stops for other trips in guidebook
are indicated by smaller dots.