C. E. Thesis case

COMPARATIVE COSTS OF HYDRO-ELECTRIC PLANTS NO. 3 & 4

of the

NEW ENGLAND POWER COMPANY OF THE DEERFIELD RIVER AT

SHELBURNE FALLS, MASSACHUSETTS

Massachusetts Institute of Technology
Cambridge, Massachusetts

Harry Goodman

Nathan Ginsburg

June, 1924

Cambridge, Mass.
May 29, 1924.

Professor A. L. Merrill,
Secretary of the Faculty,
Massachusetts Institute of Technology,
Cambridge, Mass.

Dear Sir:

This thesis was undertaken with the purpose of fulfilling, in part, the requirements of the Massachusetts Institute of Technology for the degree of Bachelor of Science in Civil Engineering.

The authors wish to express their indebtedness for the assistance and guidance given by Professor H. K. Barrows.

The authors wish, also, to thank the employees of the New England Power Company at Shelburne Falls for the aid given them on their visit to the plants.

Respectfully yours,

Nathan Ginsburg.
Course I_3

Harry Goodman
Course I_3

G/L

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I N T R O D U C T I O N

INTRODUCTION

OBJECT:- The object of this thesis is to compare costs of the hydroelectric plants No. 3 and No. 4 of the New England Power Company, located on the Deerfield River near Shelburne Falls, in order to ascertain the annual cost per kilowatt hour output at the switchboard.

METHOD:- The method of procedure was to determine the quantities of materials used in constructing the plant from blueprints (photostat copies of which are included in Appendix E). The cost figures applied to these quantities were secured from Professor Barrows. The cost of the hydraulic and electrical equipment was obtained by applying a cost of five dollars per horse power for the hydraulic equipment and eighteen dollars fifty cents per kilowatt for the electrical equipment while the cost of the superstructure was found by applying a cost of fifteen cents per cubic foot (inside dimensions).

The annual charges were figured at the switchboard for each plant by applying definite percentages of the total cost.

The output in kilowatt hours for each plant was figured as explained in Appendix G).

R E P O R T

DESCRIPTION OF PLANT NO. 3

LOCATION

This station is located in the village of Shelburne Falls, on the Deerfield River, about three miles above Station No. 2.

DAM

The dam is concrete, of ogee spillway section, built on rock throughout, fifteen feet in maximum height and four hundred seventy-five feet long. One submerged and one surface sluice are provided on the west end of the dam. These are controlled by double-stem timber gates, operated by a single motor-driven hoist of fifty thousand pounds' capacity. The dam diverts water into a reinforced concrete conduit twelve feet six inches high, seventeen feet wide, and six hundred seventy-seven feet long, running underneath buildings of the Lamson & Goodnow Manufacturing Company. The conduit intake is controlled by four double-stem timber gates operated by four motor-driven hoists of fifty thousand pounds' capacity and the conduit discharges into a canal thirty-six feet wide at the bottom, twenty-three feet maximum depth and six hundred sixty-five feet long. The head at this plant varies from sixty to seventy feet and is normally sixty-four feet.

The powerhouse is located on the west bank of the river below the end of the canal, with one-half the building two stories and the other half one story in height. The building is of brick around a steel frame on a concrete substruction. The floors and roof are reinforced concrete, and the inside dimensions are 31' x 97' and 53' high in the two-story section.

POWERHOUSE

On the lower end of the canal, three steel penstocks ten feet in diameter and one hundred fifty-nine feet long connect the waterwheel casings which are thirteen feet in diameter and are located outside the powerhouse. Each penstock is controlled by two double stem timber headgates, one operated by a hoist of fifty thousand pounds' capacity, and the other by one of ten thousand pounds' capacity. Three 3,200 H. P., W. S. Morgan, horizontal, forty-four-inch, double runners, two hundred fifty-seven revolutions per minute, central-discharge turbines are installed at the station. Each unit is controlled by a Lombard Special, horizontal, direct-connected governor of seventeen thousand foot pounds' capacity.

PENSTOCKS

The complete electrical equipment was supplied by the General Electric Company and consists of:

ELECTRICAL EQUIPMENT

3 2000 K. V. A., 2300 V., 3 phase, 60 cycles, 257 r. p. m. horizontal, waterwheel-driven generators.

2 3000 K. V. A., 66000 to 2300 V., 3 phase, 60 cycles, star delta, connected transformers

2 100 K. V. A., 125 V., induction motor-driven exciters

1 switchboard and equipment.

The switchboard is located on the generator-room floor and consists of eleven vertical slate panels with auxiliary slate panels in the rear for the testing switches and recording meters. All oil switches are electrically operated from the switchboard by means of a fifty-five cell, fifteen ampere, U. S. lighting and heating storage battery.

The 2300-Volt oil switches are located in one end of the building on the generator-room floor, in a brick cell structure with duplicate copper busses and selector disconnecting switches mounted overhead and protected by asbestos barriers. All the 2300-Volt wiring for the machines and the control cable from the switchboard is run in conduit embedded in the concrete floor. The high tension oil switches, busses, and transformers are located on the second floor. There are 2K-10, 66,000-Volt oil switches installed to provide control for the two high tension transmission lines leaving the station. Two aluminum cell, 66,000 Volt, three tank lightning arrestors with horn gaps are installed on the roof and provide protection for the lines and transformers. A 2300-Volt, 3-phase, 600 K. W. local feeder is provided in this station to provide two factories in the town of Shelburne Falls.

The auxiliary equipment in this station includes a complete oil treating and storage system, a thirty-ton cyclone high speed hoist with a forty-seven-foot lift, for lowering the transformers from the second floor, and a fifteen-ton Northern Engine hand-operated crane.

DESCRIPTION OF PLANT NO. 4

LOCATION

This station is located about a mile and a quarter north of Shelburne Falls, at a point where the river makes a complete horseshoe bend around a hill.

The dam consists of a concrete ogee spillway section built on rock, two hundred forty feet long between the abutments and forty-four feet in maximum section. A 6' x 8' submerged sluice controlled by a Chapman cast iron sluice gate is built in the left end of the dam. The right-hand abutment of the dam has three surface sluice openings ten feet wide, controlled by double stem timber headgates and motor-operated gate hoists of fifty thousand pounds' capacity. The combined capacity of submerged and sluice is about forty-two hundred cubic feet per second. The head at this plant varies from sixty to seventy feet and is normally about sixty-four feet.

TUNNEL

The dam diverts water through a concrete and brick-lined horseshoe shaped tunnel equivalent to approximately thirteen feet in diameter, fourteen hundred forty-five feet long in rock and one hundred fifty-five feet in earth and has a sectional area of one hundred thirty-four square feet with a normal capacity of fifteen hundred cubic feet per second. The tunnel intake is controlled by means of a steel gate fourteen feet two inches by fourteen feet eight inches, operated by a motor-driven hoist with bevel gears, on two five-inch steel lifting screws. The tunnel discharges into a forebay twelve thousand feet in area and thirty-three feet deep, having an earth embankment.

POWERHOUSE

The powerhouse is located on the west bank of the river below the forebay and is two stories high, built of brick around a steel frame on a concrete substructure. The floors are of reinforced concrete and the inside dimensions of the building are 31' x 97' x 53' high.

PENSTOCKS

The water from the forebay flows through three steel penstocks ten feet in diameter and one hundred fifty-nine feet long, to the waterwheel casings just outside the powerhouse. Each penstock is controlled by two double stem timber headgates, one operated by a hoist of fifty thousand pounds' capacity, the other by one of ten thousand pounds' capacity.

ELECTRICAL EQUIPMENT

Three 3200 H. P., Wellman-Seaver-Morgan horizontal forty-four-inch, double runner, 257 r. p. m., central discharge turbines are installed at this station. Each unit is controlled by a Lombard Special, horizontal, direct-connected generator of 17,000 pounds' capacity.

The complete electrical equipment was supplied by the General Electric Company and consists of:

3 2000 K. V. A., 3-phase, 2300 V., 60 cycles, 257 r. p. m. horizontal, water wheel-driven generators

2 3000 K. V. A., 3-phase, 66000 to 2300 V., 60 cycles, star delta, connected transformers.

2 100 K. W., 125 V., induction motor-driven exciters

1 Switchboard and equipment.

The switchboard is located on the generator-room floor and consists of ten vertical slate panels with auxiliary slate panels in the room for the testing switches and the recording meters. All oil switches are electrically operated from the switchboard by means of a fifty-five-cell, fifteen ampere Exide battery.

The 2300-Volt oil switches are located in one end of the generator floor in a brick cell structure with duplicate copper busses and selector disconnecting switches mounted overhead and protected by asbestos barriers. All the 2300-Volt wiring from the machine and the control cable from the switchboard is run in conduit embedded in the concrete floor. The bus sectionalizing oil switches, the high tension transformer oil switches, busses and transformers are located on the second floor. There were originally six additional high tension oil switches on this floor all remote control type; but these have since been located outdoors, in individual steel asbestos houses, four of which are on the east side of the river, across from the station, on the Vernon Shelburne lines and the two lines connecting the Shelburne Falls plants. A steel cable, suspension foot bridge carrying the oil switch control wire crosses the river from the station to the point. The remaining two high tension oil switches on the Shelburne Falls Station No. 5 are located on the bank next to the forebay on the station side. There are, in all, 9K-10, 66000-Volt oil switches installed, which provide control and interconnection for the six high tension transmission lines leaving the station. Necessary disconnecting switches are located on the roof so that the station can be disconnected from the system and the lines cut through independently.

Two sets of 66,000-V., aluminum cell, 3 tank lightning arrestors with horn gaps are installed on the roof, one set of arrestors being provided for each section of bus. The auxiliary equipment in this station includes a complete oil treating and storage equipment, a fifty-ton cyclone high speed hoist with forty-seven-foot lift for lowering the transformers from the second floor and a fifteen-ton Northern Engineering hand operated crane.

Three one-to-one, 50 K. W., 2300 V., transformers are installed on the bank of the river on the station side for supplying 4000-V. service to the Charlemont Electric Company.

S U M M A R Y

SUMMARY

PLANT NO. 3

Dam and Headworks	$51,684.70
Conduit	34,507.30
Canal	40,198.50
Penstocks	26,015.10
Power House	56,845.80
Electrical Equipment	111,000.00
Hydraulic Equipment	48,000.00

Total	$368,251.40
Engineering and Contingencies 15%	55,300.00
GRAND TOTAL	$423,551.40

ANNUAL CHARGES

Interest on Plant	6%	$25,400.00
Depreciation	$2\frac{1}{4}$%	9,630.00
Sinking Fund	$1\frac{3}{4}$%	7,410.00
Operation and Maintenance	$2\frac{1}{4}$%	9,630.00
TOTAL ANNUAL COST		$52,070.00

Cost per K. W. hour at the switchboard $= \frac{5207000}{20000000} = 0.26$ cents

SUMMARY

PLANT NO. 4

	Dam and Headworks	$133,600	
	Tunnel	140,380	
	Forebay	20,186	
	Penstock	22,204	
	Power House	218,157	
Total			$534,527
	Engineering and Contingencies 15%		80,173
GRAND TOTAL			$614,700

ANNUAL CHARGES

	Interest on Plant	6%	$36,880	
	Depreciation	$2\frac{1}{4}$%	13,800	
	Sinking Fund	$1\frac{3}{4}$%	10,750	
	Operation & Maintenance	$2\frac{1}{4}$%	13,800	
TOTAL ANNUAL COST				$75,230

$$\text{Cost per K. W. hour} = \frac{7523000}{20000000} = 0.376 \text{ cents}$$

DETAILED COST OF PLANT NO. 3

Dam and Headworks					
Preliminary				$3,000.00	
Handling Water				6,000.00	
Ice Fender				2,000.00	
Gates at Dam				2,000.00	
Racks				1,500.00	
Concrete	3,718.7	cu. yds.	@$8.00	29,749.60	
Rock	1,287.9	" "	4.00	5,151.60	
Fill	378.0	" "	0.75	283.50	
Total					$51,684.70
Conduit					
Concrete	3,382.6	cu. yds.	@$8.00	$27,060.80	
Rock	296.0	" "	4.00	1,184.00	
Cut	8,350.0	" "	0.75	6,262.50	
Total					34,507.30
Canal					
Fill	48,118.0	cu. yds.	@$0.75	$36,088.50	
Rip Rap	1,370.0	" "	3.00	4,110.00	
Total					40,198.50
Penstock					
Head Gates				$2,500.00	
Racks				1,500.00	
Concrete	1,040.2	cu. yds.	@$8.00	8,321.60	
Steel Pipe	154,200	lbs.	@$0.05	7,710.00	
Fill	7,978	cu. yds.	@$0.75	5,983.50	
Total					26,015.10
Powerhouse					
Substructure					
Concrete	3,030	cu. yds.	@$10.00	$30,300.00	
Cut	11,308	" "	0.75	8,481.00	
Rip Rap	45	" "	3.00	135.00	
Total					38,916.00
Superstructure	119,527	cu. ft.	@$0.15		17,929.80
Electrical Equipment	6,000	K. W.	@$18.50		111,000.00
Hydraülic Equipment	9,600	H. P.	5.00		48,000.00
Total					$368,251.40
Engineering & Contingencies 15%					55,300.00

GRAND TOTAL $423,551.40

DETAILED COST OF PLANT NO. 4

Dam and Headworks					
Concrete	9,110 cu. yds.	@$8.00	$72,880.00		
Rock	6,039 " "	4.00	24,156.00		
Handling Water			15,000.00		
Clearing and Preliminary			8,000.00		
Earth	10,205 cu. yds.	@$0.75	7,654.00		
Gates			2,500.00		
Racks			2,000.00		
Rip Rap	470 cu. yds.	@$3.00	1,410.00		
Total				$133,600.00	
Tunnel					
Concrete	6,252 cu. yds.	@12.00	$75,024.00		
Rock	10,779 " "	5.00	53,895.00		
Earth	2,812 " "	2.00	5,624.00		
Timber	113,160 Board feet	40.00 M	884.00		
Steel (Rein)	10,670 pounds	0.04	427.00		
Total				140,380.00	
Forebay					
Earth	17,750 cu. yds.	@$0.75	$13,320.00		
Rip Rap	622 " "	3.00	1,866.00		
Head Gates			5,000.00		
Total				20,186.00	
Penstock					
Earth	13,000 cu. yds.	@$0.75	$9,750.00		
Steel	154,200 pounds	@$0.05	7,710.00		
Concrete	593 cu. yds.	@$8.00	2,744.00		
Total				22,204.00	
Powerhouse					
Substructure					
Concrete	3,450 cu. yds.	@10.00	$34,500.00		
Rip Rap	219 " "	3.00	657.00		
Total				35,157.00	
Superstructure	159,000 feet	@$0.15		24,000.00	
Hydraulic Equipment	9600 H. P.	@$5.00		48,000.00	
Electrical Equipment	6000 K. W.	@$18.50		111,000.00	
Total				$534,527.00	
Engineering & Contingencies 15%				80,173.00	
GRAND TOTAL					$614,700.00

A P P E N D I C E S

A P P E N D I X A

PLANT NO. 3

QUANTITIES IN DAM

CONCRETE

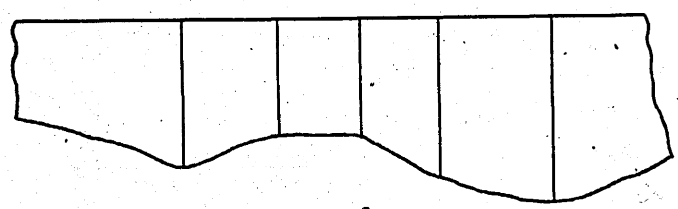
Spillway

Explanation of method of procedure

$$V = \frac{A_1 + A_2}{2} \times \frac{L}{27} \quad \text{where}$$

A_1 = area of first section in square feet
A_2 = area of second section in square feet
L = distance between right section

The sections were taken at the critical points of the spillway section as shown.



PROFILE OF SPILLWAY

Computations

Station		Volume
0 + 00.05 – 0 + 14.4	$\frac{79.5 + 116.6}{2} \times \frac{14.3}{27}$ =	51.9 cu. yds.
0 + 14.4 – 0 + 20.6	$\frac{116.6 + 142.7}{2} \times \frac{6.2}{27}$ =	48.0
0 + 20.6 – 0 + 48.8	$\frac{142.7 + 143.8}{2} \times \frac{28.2}{27}$ =	149.8

QUANTITIES IN DAM (Con.)

Station			Volume
0+ 48.8 0+ 56.9	$\frac{143.8 + 174.6}{2} \times \frac{81}{27}$	=	47.8 cu. yds.
0 + 56.9 1+ 01.6	$\frac{174.6 + 122.2}{2} \times \frac{54.7}{27}$	=	288.5
1 + 01.6 1+ 12.2	$\frac{122.2 + 66.3}{2} \times \frac{10.6}{27}$	=	37.0
1 + 12.2	wedge $\frac{66.3}{27} \times \frac{8.5}{2}$	=	10.4
1+ 19.0	wedge $\frac{73.1}{27} \times \frac{7.7}{2}$	=	10.4
1+ 19.0 1 + 26.3	$\frac{73.1 + 99.6}{2} \times \frac{7.3}{27}$	=	22.4
1+ 26.3 1+ 36.6	$\frac{99.6 + 101.8}{2} \times \frac{10.3}{27}$	=	38.4
1 +36.6 1+ 47.7	$\frac{101.8 + 137.0}{2} \times \frac{11.1}{27}$	=	49.1
1+ 47.7 1+ 56.8	$\frac{137.0 + 141.3}{2} \times \frac{9.1}{27}$	=	44.4
1+ 56.8 1+ 81.1	$\frac{141.3 + 97.1}{2} \times \frac{24.3}{27}$	=	107.2

QUANTITIES IN DAM (Con.)

Station			Volume
1 + 81.1			
	$\frac{97.1 \quad 70.8}{2} \times \frac{7.8}{27}$	=	24.2 cu. yds.
1 + 88.9			
1 + 88.9			
	$\frac{70.8 \quad 102.0}{2} \times \frac{6.8}{27}$	=	21.8
1 + 95.7			
1 + 95.7			
	$\frac{102.0 + 147.3}{2} \times \frac{9.0}{27}$	=	41.5
2 + 04.7			
2 + 04.7			
	$\frac{147.3 + 46.0}{2} \times \frac{12.6}{27}$	=	42.8
2 + 17.3			
2 + 17.3			
	$\frac{46.0 + 103.0}{2} \times \frac{9.6}{27}$	=	26.4
2 + 26.9			
2 + 26.9			
	$\frac{103.0 + 89.4}{2} \times \frac{10.1}{27}$	=	36.0
2 + 37.0			
2 + 37.0			
	$\frac{89.4}{27} \times \frac{4.2}{2}$	=	6.9
2 + 40.4			
2 + 40.4			
	$\frac{89.4 + 62.9}{2} \times \frac{55.5}{27}$	=	156.5
2 + 95.9			

QUANTITIES IN DAM (Con.)

Station			Volume
2 + 95.9			
	$\frac{66.9 + 145.8}{2} \times \frac{17.5}{27}$	=	68.7 cu. yds.
3 + 13.4			
3 + 13.4			
	$\frac{145.8 + 132.6}{2} \times \frac{13.4}{27}$	-	68.2
3 + 26.8			
	$\frac{132.6 + 140.7}{2} \times \frac{8.4}{27}$	=	42.5
3 + 35.2			
3 + 35.2			
	$\frac{140.7 + 168.8}{2} \times \frac{3.5}{27}$	=	20.0
3 + 38.7			
3 + 38.7			
	$\frac{168.8 + 162.0}{2} \times \frac{21.6}{27}$	=	132.3
3 + 60.3			
3 + 60.3			
	$\frac{162.0 + 206.5}{2} \times \frac{23.9}{27}$	=	163.1
3 + 84.2			
	$\frac{206.5 + 146.3}{2} \times \frac{19.3}{27}$	=	126.2
4 + 03.5			
4 + 03.5			
	$\frac{146.3 + 149.0}{2} \times \frac{40.5}{27}$	=	248.5
4 + 49.0			
wedge	$\frac{149}{27} \times \frac{6}{2}$	=	16.6

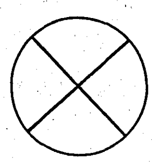
TOTAL CONCRETE IN SPILLWAY — 2146.5 cu. yds

SUBMERGED AND SURFACE SLUICE AND CONDUIT INTAKE

Explanation of method of procedure

The volume had to be figured in pieces, these pieces when put together making the total volume.

Illustration



The summation of areas of the various sectors equals the area of the surface.

Computation	Volume
4.10 x 64 x 3	787 cu. ft.
2.36 x 64 x 4	605
2.88 x 64 x 16	2930
0.37 x 400 x 10	1480
0.55 x 64 x 36	1270
0.30 x 64 x 20	192
0.10 x 64 x 20	128
0.48 x 64 x 2	61
0.48 x 64 x 11	338
0.32 x 64 x 2	41
0.32 x 64 x 2	226
0.22 x 64 x 6	85
0.25 x 64 x 20	320
0.38 x 64 x 1.5	37
10.34 x 64 x 3	1990
10.5 x 7 x 4.25	313
1.33 x 17 x 64	2110
0.50 x 64 x 32	1035
$\frac{1.75 \quad 3}{2} \times 5 \times 9.5$	113
$\frac{1.75 \times 9.5 \quad 0.50 \times 64}{2} \times 5$	121
$\frac{12.5 \times 2 \times 8.5 \quad 14.75}{2}$	291
$\frac{6 \times 1 \times 17.0}{3}$	34
Walls	
3.90 x 64 x 25	6240
1.34 x 64 x 25	2140

Footing

23.

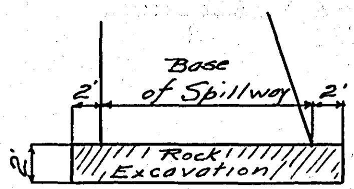
SUBMERGED AND SURFACE SLUICE AND CONDUIT INTAKE
(Continued)

Computations		Volume
Footing		
28.50 x 64 x 2		= 3650 cu. ft.
14.00 x 64 x 2		= 1790
	Total	30,657 " " = 1,136 cu. yds.
Retaining Wall--Left Bank		
$\left(3+\frac{17}{8}\right) \times 17 \times 8$		= 695
$\left(3+\frac{19.5}{8}\right) \times 19 \times 5$		= 517
$\left(3+\frac{21.5}{8}\right) \times 21.5 \times 12.5$		= 1530
$\left(3+\frac{24}{8}\right) \times 24 \times 15.5$		= 3550
$\frac{144+66.5}{2} \times 39$		= 4110
$\frac{66.5+14}{2} \times 31$		= 1250

TOTAL CONCRETE IN SUBMERGED AND SURFACE SLUICE AND CONDUIT INTAKE 11,652 cu. ft.

ROCK EXCAVATION -- SPILLWAY

Station | **Volume**



The rock excavation for the spillway was figured by the average end area method. The allowance for excavation being as shown.

0 + 00.05

$$\frac{36.2 + 38.9}{2} \times \frac{14.3}{27} = 19.9 \text{ cu. yds.}$$

0 + 14.4

0 + 14.4

$$\frac{38.9 + 40.4}{2} \times \frac{6.2}{27} = 9.1$$

0 + 20.6

$$\frac{40.4 + 41.2}{2} \times \frac{28.2}{27} = 42.6$$

0 + 48.8

0 + 48.8

$$\frac{41.2 + 40.4}{2} \times \frac{8.1}{27} = 12.2$$

0 + 56.9

0 + 56.9

$$\frac{40.4 + 36.8}{2} \times \frac{54.7}{27} = 78.4$$

1 + 01.6

$$\frac{36.8 + 32.0}{2} \times \frac{10.6}{27} = 13.5$$

1 + 12.8

$$\frac{32.0}{27} \times \frac{8.5}{2} = 5.0$$

$$\frac{32.2}{27} \times \frac{7.7}{2} = 5.5.0$$

1 + 19.0

$$\frac{32.2 + 33.8}{2} \times \frac{7.3}{27} = 8.9$$

1 + 36.6

1 + 36.6

$$\frac{33.8 + 36.2}{2} \times \frac{10.3}{27} = 13.4$$

1 + 36.6

ROCK EXCAVATION--SPILLWAY
(Continued)

Station		Volume
1+36.6 – 1+47.7	$\frac{36.2+37.7}{2} \times \frac{11.1}{27}$	= 15.2 cu. yds.
1+47.7 – 1+56.8	$\frac{37.7+39.5}{2} \times \frac{9.1}{27}$	= 13.0
1+56.8 – 1+81.1	$\frac{39.5+34.2}{2} \times \frac{24.3}{27}$	= 33.1
1+81.1 – 1+88.9	$\frac{34.2+31.8}{2} \times \frac{7.8}{27}$	= 9.5
1+88.9 – 1+95.7	$\frac{31.8+35.2}{2} \times \frac{6.8}{27}$	= 8.4
1+95.7 – 2+04.7	$\frac{35.2+39.8}{2} \times \frac{9}{27}$	= 12.5
2+04.7 – 2+17.3	$\frac{39.8+29.6}{2} \times \frac{12.6}{27}$	= 16.2
2+17.3 – 2+26.9	$\frac{29.6+35.0}{2} \times \frac{9.6}{27}$	= 11.5
2+26.9 – 2+37.0	$\frac{35.0+37.2}{2} \times \frac{10.1}{27}$	= 13.5

ROCK EXCAVATION--SPILLWAY
(Continued)

Station		Volume
2 + 37.0 to 2 + 40.4	$\frac{37.2}{27} \times \frac{4.2}{2}$	= 3.0
2 + 40.4 to 2 + 75.9	$\frac{37.2 + 31.8}{2} \times \frac{55.5}{27}$	= 70.9
2 + 75.9 to 3 + 13.4	$\frac{31.8 + 42}{2} \times \frac{17.5}{27}$	= 23.9
3 + 13.4 to 3 + 26.8	$\frac{42.0 + 40.4}{2} \times \frac{13.4}{27}$	= 20.4
3 + 26.8 to 3 + 35.2	$\frac{40.4 + 42.2}{2} \times \frac{8.4}{27}$	= 12.9
3 + 35.2 to 3 + 38.7	$\frac{42.2 + 41.4}{2} \times \frac{3.5}{27}$	= 5.4
3 + 38.7 to 3 + 60.3	$\frac{41.4 + 40.6}{2} \times \frac{21.6}{27}$	= 32.8
3 + 60.3 to 3 + 84.2	$\frac{40.6 + 47.2}{2} \times \frac{23.9}{27}$	= 38.8
3 + 84.2 to 4 + 04.5	$\frac{47.2 + 39.2}{2} \times \frac{19.3}{27}$	= 30.9

ROCK EXCAVATION--SPILLWAY
(Continued)

Station		Volume
4 + 04.5		
	$\frac{39.2 + 39.6}{2} \times \frac{45.5}{27}$	= 66.5 cu. yds.
4 + 49.0		
Wedge	$\frac{39.8}{27} \times \frac{6.0}{2}$	= 4.4
	$\frac{36.2 \times 0.1 \times 0.5}{27}$	= 0.1

TOTAL ROCK EXCAVATION FOR DAM 650.9 cu. yds.

SUBMERGED SURFACE SLUICE AND CONDUIT INTAKE--ROCK EXCAVATION

Explanation

The rock excavation figured was taken as the area covered by the works multiplied by thickness of two feet.

Computation

Rock excavation for intake to conduit

$$\frac{3650 + 1790}{27} = 202 \text{ cubic yards}$$ 202 cu. yds.

Before intake to conduit

4	3	2	1
2.3	2.1	0.8	0.0
x4	x3	1.3	6.0
		1.5	2.7
9.2	6.3	3.8	2.4
6.3		[illegible]	4.1
14.8		7.4	
15.2		x2	15.2
45.5		14.8	

$$\text{Volume} = \frac{45.5}{4} \times \frac{400}{27} = 169 \text{ cubic yards}$$ 169 cu. yds.

2	1	
3.8	4.1	31.7
6.5	7.0	2.4
		3.8
10.3	11.1	37.9
x2	20.6	
20.6	31.7	

$$\text{Volume} = \frac{37.9}{4} \times \frac{20 \times 16.5}{27} = 116 \text{ cubic yards}$$ 116 cu. yds.

INTAKE TO CONDUIT
(Continued)

Before Intake to Conduit

Explanation

The volume was figured by prism and triangular pyramid and by the end area method.

By rectangular prism using formula:

$$V \text{ cu. yds.} = \frac{A\,(h_1 + h_2 + h_3 + h_4)}{4 \times 27}$$

where $A =$ Area of right section in square feet
h_1, h_2, h_3, h_4, equal the corner heights of prism in feet

By triangular pyramid

$$V \text{ cu. yds.} = \frac{A}{27} \times \frac{L}{3}$$

where $A =$ Area of base in square feet
and $L =$ Perpendicular distance from base to apex of pyramid in feet

Average end area method has already been explained in Dams.

SUBMERGED SURFACE SLUICE AND CONDUIT INTAKE--ROCK EXCAVATION
(Continued)

Computation	Volume
$\frac{16}{8} \times \frac{57}{3} \times \frac{1}{27}$	= 6 cu. yds.
$\frac{\frac{25}{2} + \frac{36}{2}}{2} \times \frac{45}{27}$	= 25
$\frac{63}{62} \times \frac{6}{27}$	= 7
$20 \times 6 \times \frac{19}{4} \times \frac{1}{27}$	= 21
$16.5 \times 13 \times 5.5 \times \frac{1}{27}$	= 44
$20 \times 8 \quad 12 \times 18 \times \frac{1}{27} \times \frac{13.1}{4}$	= 46
$\frac{24}{2} \times \frac{2.7}{27}$	= 1

TOTAL 435 cu. yds.

Fill

Further Bank

$18 \times 62 \times 6$	6700 cu. ft.	
$\frac{65 \times 15}{2} \times \frac{15}{2}$	3500	
Total	10200 cu. ft. =	378 cu. yds.

QUANTITIES IN CONDUIT

Concrete

Explanation

For the main section, by obtaining the area of the right section of the conduit and multiplying by the length of like section.

For the outlet into the canal by the end area method and triangular pyramids.

Computation	Volume
$\frac{147.3}{27} \times 600$	= 3,280 cu. yds.
$\frac{2 \times 24 \times 2.5 \times 2}{27}$	= 8.9
$\frac{24 \times 7 \times 2.5 \times 2}{27}$	= 31.5
$\frac{24 \times 7 \times 2 \times 2}{27}$	= 24.9
$\frac{30 + 26}{2} \times \frac{1.5 \times 24}{27}$	= 37.3
Total	3,382.6 cu. yds.

Rock Excavation

Explanation

The rock extends over a length of one hundred feet in the conduit, and its average area in this length equals 0.20 x 400.

$$0.20 \times 400 \times \frac{100}{27} \qquad 296 \text{ cu. yds.}$$

QUANTITIES IN CONDUIT
(Continued)

Cut

Explanation

The cut was obtained by finding the area of cut in a right section and multiplying by the length over which it is effective.

Computations	Volume
$0.73 \times 400 \times \frac{100}{27}$	= 1,080 cu. yds.
$0.98 \times 400 \times \frac{242}{27}$	= 3,520
$0.98 \times \frac{258}{27} \times 400$	= 3,750

Total 8,350 cu. yds.

Fill

Explanation

The fill was obtained in a similar manner.

Computations	Volume
$0.24 \times 400 \times \frac{100}{27}$	= 356 cu. yds.
$0.29 \times 400 \times \frac{575}{27}$	= 2,210

Total 2,566 cu. yds.

QUANTITIES IN CANAL

Fill

Right Bank

Explanation

The volumes were obtained by the average end area method, by prisms and by solids of revolution.

By solids of revolution:-

$$V \text{ cu. yds.} = \frac{2 \times 3.14 \times r_o \times A}{27} \times \frac{\theta}{360}$$

where r_o equals the radius in feet from the center of revolution to the center of gravity of the figure.

A equals the area of the right section in square feet and

θ equals the angle in degrees swung through by the right section.

Station	Computations	Volume	Total
0+31.0	.46 x 69 x 7.41	= 235 cu. yds.	
7+00.0	$\frac{0.41 \times 2 \times 3.14 \times 210 \times 19.5 \times 7.41}{360}$	= 217	
8+00.0	$0.38 \times 7.41 \times \frac{15}{360} \times 2 \times 3.14 \times 95$	= 70	
8+47.0	0.35 x 7.41 x 53	= 138	
9+00.0	0.45 x 7.41 x 100	= 334	

QUANTITIES IN CANAL
(Continued)

Station	Computations	Volume	
10 + 00.0			
	0.72 x 7.41 x 100	= 534 cu. yds.	
11 + 00.0			
	0.82 x 7.41 x 100	= 608	
12 + 00.0			
	0.93 x 7.41 x 100	= 690	
13 + 00.0			
	1.18 x 42 x 7.41	= 368	
13 + 29.0			
Total			3,194 cu. yds.

By prisms and solids of revolution

$\frac{3 \times 256 \times 8}{27}$	= 228
$3 \times \frac{256}{27} \times 10$	= 284
$\frac{256}{27} \times 11$	= 105
$\frac{256}{27} \times 14$	= 133
$\frac{256}{27} \times 17$	= 161
$\frac{256}{27} \times 19$	= 180
$\frac{256}{27} \times 20$	= 199
$\frac{16 \times 165}{27} \times 21$	= 2,060
$\frac{0.80 \times 1600}{27} \times 4.5$	= 214
$\frac{1.55 \times 1600}{27} \times 6.5$	= 600

QUANTITIES IN CANAL
(Continued)

Computations	Volume
$\frac{2.50 \times 1600}{27} \times 10.75$	= 1,590 cu. yds.
$\frac{22}{27} \times \frac{43}{2} \times 2 \times 3.14 \times 55 \times 1/4$	= 1,510
$\frac{1.50 \times 1600 \times 9}{27 \times 2}$	= 400
$\frac{0.53 \times 1600 \times 26}{27 \times 4}$	= 240
$\frac{0.82 \times 1600 \times 35}{27 \times 4}$	= 425
$\frac{1.87 \times 1600 \times 42}{27 \times 4}$	= 1,170
$\frac{1.75 \times 1600 \times 44}{27 \times 4}$	= 1,140
$\frac{2.66 \times 1600 \times 23}{27 \times 2}$	= 1,815
$\frac{252 \times 2 \times 3.14 \times 63}{27 \times 4}$	= 925
Total	11,570 cu. yds.

Left-hand side

By average end area method

Station	Computation	Volume
6 + 31.0	$(1.06 + 1.44) \times 7.41 \times 69$	= 1,296 cu. yds.
7 + 00.0	$(1.44 + 1.71) \times 2 \times 3.14 \times 350 \times \frac{19.5}{360} \times 7.41$	= 2,200
8 + 00.0	$(1.71 + 1.71) \times 2 \times 3.14 \times 340 \times \frac{10}{360} \times 7.41$	= 1,500

QUANTITIES IN CANAL
(Continued)

Station	Computations	Volume
8 + 43.0		
	(1.71 + 1.80) x 7.41 x 64	= 1,670 cu. yds.
9 + 00.0		
	(1.80 + 2.02) x 7.41 x 100	= 2,830
10 + 00.0		
	(2.02 + 215) x 7.41 x 100	= 3,090
11 + 00.0		
	(2.15 + 2.45) x 7.41 x 100	= 3,410
12 + 00.0		

By prisms and solids of revolution

Computations	Volume
$\frac{8 \times 256 \times 20}{27}$	= 1,520 cu. yds.
$5 \times 256 \times \frac{19}{27}$	= 900
$6 \times 256 \times \frac{21}{27}$	= 1,200
$3 \times 256 \times \frac{22}{27}$	= 625
$5.83 \times \frac{1600}{27} \times 10$	= 3,460
$2.80 \times \frac{1600}{27} \times 11$	= 1,830
$400 \times \frac{105}{27 \times 4}$	= 390
$13 \times 20 \times \frac{19.5}{27 \times 4}$	= 1,220
$5.70 \times \frac{1600 \times 20}{27 \times 2}$	= 3,380

QUANTITIES IN CANAL
(Continued)

Computations	Volume	
$\frac{306}{27} \times 2 \times 3.14 \times \frac{55}{4}$	= 980 cu. yds.	
Total		31,548 cu. yds.

Fill right-hand side	16,570 cu. yds.	
Fill left-hand side	31,548 " "	
TOTAL		48,118 cu. yds.

Excavation

By average end area method and by prisms

By average end area method

Station	Computation	Volume
6 + 31.0		
	(1.14 + 2.19) x 69 x 7.41	= 2,130 cu. yds.
7 + 00.0		
	(2.19 + 1.69) x 95 x 7.41	= 2,700
8 + 00.0		
	(1.69 + 1.60) x 7.41 x 100	= 2,440
9+00.0	(1.60 + 1.89) x 7.41 x 100	= 2,585
10 + 00.0		
	(1.89 + 1.70) x 7.41 x 100	= 2,660
11 + 00.0		
	(1.70 + 1.63) x 7.41 x 100	= 2,540
12 + 00.0		
	(1.63 + 1.43) x 7.41 x 100	= 2,265
13 + 00.0		
	(1.43 + 1.36) x 7.41 x 30	= 622
13 + 30.0		
	(1.36 + 0.64) x 7.41 x 70	= 1,037
14 + 00.0		

QUANTITIES IN CANAL
(Continued)

By prisms

Computations	Volume
$1.54 \times 1600 \times \frac{7}{27}$	= 640 cu. yds.
$1.76 \times 1600 \times \frac{2}{27}$	= 208
$3.05 \times 1600 \times \frac{5}{27}$	= 905
$3.36 \times 1600 \times \frac{6.75}{27 \times 2}$	= 670
$21 \times 36 \times \frac{13}{27}$	= 364
Total	21,766 cu. yds.

Rip Rap

Explanation

Total area multiplied by a thickness of one foot.

$33,160 \times \frac{1\sqrt{5}}{2}$ cu. ft. = 1,370 cu. yds.

QUANTITIES IN PENSTOCK

CONCRETE

Head Works to Penstock

Explanation

The volume was figured by pieces

Computations	Volume
$0.30 \times 64 \times \frac{54}{27}$	= 38.4 cu. yds.
$0.50 \times 64 \times \frac{15.5 \times 3}{27}$	= 55.1
$1.07 \times 64 \times \frac{27}{27}$	= 68.5
$1.07 \times 64 \times 1$	= 68.5
$2 \times 0.70 \times 64 \times 1$	= 89.6
$\frac{21}{2} \times 30 \times \frac{4.5}{27} \times 2$	= 105
$\frac{2\left(\frac{18+4.5}{2} + 4 \times 10.5 \times \frac{1.875}{2} + \frac{3 \times .75}{2}\right) 30}{6 \times 27}$	=30
$24.5 \times 61 \times \frac{2.5}{27}$	= 138
Total	593.1 cu. yds.

QUANTITIES IN PENSTOCK
(Continued)

Penstock Setting

Explanation

Same as head works to penstock

Computations	Volume
$1.25 \times \frac{61}{27} \times 64$	= 181 cu. yds.
$\frac{10.5}{2} \times 3.0 \times 2 \times 3.14 \times \frac{11.25}{27}$	= 41.2
$2 \times 3.14 \times \frac{11.25}{2} \times 1.5 \times \frac{65.5}{27}$	= 128.8
$2 \times 3.14 \times 7 \times 2 \times \frac{6}{27}$	= 19.5
$6 \times 115 \times \frac{3}{27}$	= 76.6

Total 447.1 cu. yds.

GRAND TOTAL 1,040.2 cu. yds.

STEEL

Outside diameter equals 10 ft. plus $\frac{5}{8 \times 12}$ equals 10.0417 ft.

Inside diameter equals 10.0000 ft.

Cubic feet per linear foot equals $\frac{3.14}{4} \times (\overline{10.0417^2 - 10.00^2}) = 0.656$ cu. ft.

Weight of steel equals 0.656 x 490 x 160 = 154,200 pounds.

QUANTITIES IN PENSTOCK
(Continued)

Excavation:

Explanation

By average end area method, by triangular pyramids and prisms.

Computations	Volume
$\frac{625+1190}{2} \times \frac{19}{27}$	= 638 cu. yds.
$\frac{1190+843}{2} \times \frac{21}{27}$	= 791
$\frac{843+488}{2} \times \frac{20}{27}$	= 495
$\frac{488+344}{2} \times \frac{11}{27}$	= 248
$768 \times \frac{20}{27}$	= 550
$\frac{768+696}{2} \times \frac{20}{27}$	= 541
$696 \times \frac{20}{27}$	= 515
$\frac{625+696}{2} \times \frac{24}{27}$	= 597
$17 \left(\frac{24 \times 61 + 8.5 \times 60}{27}\right)$	= 1,245

Total 5,620 cu. yds.

QUANTITIES IN PENSTOCK
(Continued)

Fill above original ground level

Explanation

By average end area method, by triangular pyramids, and by prisms.

Computations	Volume	
$\frac{1276 \times 65}{27}$	= 3,070 cu. yds.	
$\frac{55 \times 15 \times 5 + 13.5 \times 52 \times 5 + 12.5 \times 52 \times 5}{27}$	= 403	
$\frac{6 \times 10 \times 55}{27}$	= 122	
$2 \times 6 \times \frac{62}{2} \times \frac{52}{3 \times 27}$	= 23	
$\frac{70 \times 3}{2} \times \frac{12}{27}$	= 47	
$2 \times 3 \times \frac{4.5 \times 12}{2 \times 3}$	= 54	
$\left(\frac{223.5 + 146}{2}\right)\frac{25}{27}$	171	3,890 cu. yds.

Deduct volume of pipes

$3.14 \times 25 \times \frac{162}{27} \times 3$	= 1,416	

also a section in which penstock lies wholly in cut

$\left(70 \times \frac{3.5}{2} + 2.6 \times \frac{3.5 \times 2}{2 \times 3}\right)\frac{9.5}{27}$	= 44	
$\left(70 \times \frac{3.5}{2} + 2.6 \times \frac{3.5 \times 2}{2 \times 3}\right)\frac{15.5}{27}$	= 72	1,532

Net fill above ground		2,358 cu. yds.
Amount figured in cost	2,358 5,620	7,978 " "

QUANTITIES IN POWERHOUSE

CONCRETE

Substructure

Below springing line of arch

Explanation

Volume figured by pieces

Computations	Volume
210.2 (3 x 18.5 + 8)	= 13,120 cu. ft.
115.3 (3 x 18.5 + 8)	= 7,210
26 (107)	= 2,780
1098 x 8	= 8,780
12.8 x 18 x 2	= 460
21 x 4 x 6.5	= 545
$\frac{15 \times 6 \times 15 \times 4}{4 \times 2 \times 4}$	= 169
188 x 9.5	= 1,790
$\frac{(204 + 188)}{2}$ 16	= 3,140
204 x 5	= 1,020
8 x 18	= 144
4 x 14.6 x 11	= 640
115.3 x 11	= 1,680
17.2 x 18	= 310
13 x 18	= 234
20.5 x 2 x 9	= 370
3 x 17 x 23	= 1,170
3.75 x 2.5 x 20.25	= 190

QUANTITIES IN POWERHOUSE--CONCRETE (Continued)

Computations	Volume
$\frac{17 \times 17 \times 3}{2 \times 6}$	= 70 cu. ft.
$2.5 \left(\frac{17}{6} + .75\right) 3.75$	= 37
$\left(4.5 + \frac{3.5}{12}\right) 9.0$	= 67
$\left(6.5 + \frac{3.5}{12} \quad \frac{15.5}{12}\right) 9.0$	= 73
$\left(\frac{6.5 + 9.17}{2}\right) 17 \times 23.0$	= 3,650
$8 \times 2.5 \times 35$	= 700
$3.5 \times 2 \times 18.5 - 2$	= 130
$\left(1.5 + \frac{17}{12}\right) 18.5$	= 52
$37.2 \times 17.5 \times 2.5$	= 1,630
$4 \times 17 \times 37.2$	= 2,530
$(6.5 \times 3 - 6.38) 17$	= 220
$11 \times 2.5 \times 17.5$	= 480
92×5	= 460
$\left(\frac{2.25 \times 4.5 + 3.5 \times 7}{4}\right) 18$	= 155
$\left(\frac{3.5 \times 7}{4}\right) 5$	= 31
$\frac{3.5 \times 7 \times 10}{4}$	= 62

Total 54,100, cu. ft.

QUANTITIES IN POWERHOUSE-CONCRETE
(Continued)

Above springing line

Explanation

Same as below springing line

Computations	Volume
2.60 x 64 x 13	= 1,660 cu. ft.
1.19 x 64 x 8	= 610
6.75 x 9.5 x 8	= 515
2.0 x 14.0 x 18.5	= 520
(9 x 20.5 -7 x 4.5) 2.25	= 344
(4 x 9.5) 32	= 1,215
1.19 x 64 x 12	= 915
6.75 x 9.5 x 2	= 130
4.5 x 9.5 x 9	= 385
1.77 x 64 x 12	= 1,360
1.56 x 64 x 24.3	= 2,425
1.19 x 64 x 12	= 915
1.77 x 64 x 12	= 1,360
1.56 x 64 x 24.3	= 2,425
2 x 4.0 x 9.5 x 48.3	= 3,670
1.19 x 64 x 20	= 2,260
6.5 x 9.5 x 48.3	= 2,980
3 x 9.5 x 29	= 825
6.5 x 9.5 x 17.3	= 1,070
4 x 9.5 x 70	= 2,660

QUANTITIES IN POWERHOUSE--CONCRETE (Continued)

Computations	Volume	
2 x 2 x 99	= 396 cu. ft.	
2 x 2 x 33	= 132	
2 x 2 x 20.5	= 82	
2 x 2 x 19.3	= 77	
2 x 2 x 74.5	= 298	
2 x 2 x 48.3	= 193	
Total		29,727 cu. ft.
Deductions		
1 pit 10 x 5 x 2.5	= 125	
3 gen. pits @ (4.33 x 5.42)2.5 plus (5.42 x 6.33) 2.5 " (2 x 5.42)3	= 531	
3 draft tube openings @ 3.14 x 36 x 4	= 1,359	
		2,025
Net total		27,702 cu. ft.

QUANTITIES IN POWERHOUSE--
(Continued)

Superstructure

31 x 97 x 53	= 159,370
-31 x 47.5 x 26.5	= -39,843
Total	119,527 cu. ft.

Excavation

Foundation

Computations	Volume
$\left(13.5 \times 57 + 28 \times 31 + \frac{55}{2} \times 39\right)\frac{100}{27}$	= 10,300 cu. yds.
$\frac{2 \times 62 \times 30 \times 33}{2 \times 3 \times 27}$	= 760
$\frac{2 \times \left(\frac{39 \times 30}{2} + \frac{17.3 \times 23.0}{2}\right) \times 28}{2 \times 27}$	= 813
$\frac{2\left(\frac{17.3 \times 23}{2} + \frac{10 \times 13.5}{2}\right)\frac{57}{27}}{2}$	= 563

Gross 12,435 cu. yds.

Deducting that already figured for penstock

$$\left(\frac{1070 + 344}{2}\right)\frac{43}{27} = 1,128$$

Net 11,308 cu. yds.

Rip Rap $\frac{20 \times 60}{27}$ = 45 cu. yds.

APPENDIX B

PLANT NO. 4

QUANTITIES IN DAM

All prismoidal solids computed by averaging the areas of the two bases and multiplying by the distance between them, i.e.,

$$V \text{ cubic feet} = \frac{A_1 + A_2}{2} \times L \quad \text{where}$$

A_1 = area of first section in square feet
A_2 = area of second section in square feet
L = distance between right section

In all computations:-

V_c = volume of concrete used in structure
V_r = volume of rock excavation
V_e = volume of earth excavation

CONCRETE

Station	Area	Volume		Total	
0+ 00.00	2.18 x 640 = 1396				
		$\frac{1396 + 1158}{2} \times 29.6$	=	37,800	cubic feet
0 + 29.60	1.812 x 640 = 1158				
		$\frac{1158 + 1247}{2} \times 18$	=	21,590	
0 + 65.60	1.948 x 640 = 1247				
		$\frac{1247 + 712}{2} \times 52.5$	=	51,400	
1 + 18.10	1.112 x 640 = 712				
1 + 18.10	1.093 x 640 = 700				
		$\frac{700 + 440}{2} \times 43.6$	=	24,850	
1 + 61.70	0.686 x 640 = 440				
		$\frac{440 + 400}{2} \times 19.0$	=	7,980	
1 + 80.70	0.625 x 640 = 400				
		$\frac{400 + 171.5}{2} \times 21.9$	=	5,975	
2 + 01.60	0.268 x 640 = 171.5				

QUANTITIES IN DAM--CONCRETE
(Continued)

Station	Area	Volume	Total
		$\frac{171.5 + 178.5}{2} \times 34.5$	= 6,040 cubic feet
2 + 36.10	0.279 x 640 = 178.6		
		$\frac{178.6 + 203}{2} \times 7$	= 1,336
2 + 36.10	0.317 x 640 = 203		
	Total concrete		= 156,971 cubic feet

ROCK EXCAVATION

A cut of two feet was made at the base of every section.

Station	Area	Volume	Total
0 + 00.00	47.3 x 2 = 94.67		
		$\frac{94.67 + 89.67}{2} \times 29.6$	= 2,730 cubic feet
0 + 29.60	44.8 x 2 = 89.67		
		$\frac{89.67 + 91.83}{2} \times 18.0$	= 1,632
0 + 65.60	45.9 x 2 = 91.83		
		$\frac{91.83 + 79.16}{2} \times 52.5$	= 4,440
1 + 18.10	39.6 x 2 = 79.16		
1 + 18.10	35.6 x 2 = 71.16		
		$\frac{71.16 + 66}{2} \times 43.6$	= 2,995
1 + 61.70	33 x 2 = 66		
		$\frac{66 + 52.67}{2} \times 19.0$	= 1,129
1 + 80.70	26.3 x 2 = 52.67		
		$\frac{52.67 + 36.33}{2} \times 20.9$	= 930
2 + 01.60	18.16 x 2 = 36.33		

QUANTITIES IN DAM--ROCK EXCAVATION
(Continued)

Station	Area	Volume	Total
		$\frac{36.33 + 37.16}{2} \times 34.5$ =	1,622 cubic feet
2 + 36.10	18.6 x 2 = 37.16		
		$\frac{37.16 + 39.33}{2} \times 7$ =	268
2 + 36.10	19.67 x 2 = 39.33		
		Total rock excavation	15,746 cubic feet

EARTH EXCAVATION

Station	Area	Volume	Total
0 + 00.00	0.852 x 640 = 545		
		$\frac{545 + 260}{2} \times 29.6$ =	12,075 cubic feet
0 + 29.60	0.422 x 640 = 270		
		$\frac{270 + 400}{2} \times 18$ =	5,960
0 + 65.60	0.624 x 640 = 400		
		$\frac{400 + 47.4}{2} \times 52.5$ =	11,710
1 + 18.10	0.074 x 640 = 47.4		
1 + 18.10	0.1005 x 640 = 64.4		
		$\frac{64.4 + 218}{2} \times 43.6$ =	6,160
1 + 61.70	0.340 x 640 = 218		
		$\frac{218 + 163.8}{2} \times 19$ =	3,625
1 + 80.70	0.256 x 640 = 163.8		
		$\frac{163.8}{2} \times 20.9$ =	2,100
2 + 01.60	0		
		$\frac{94.1}{2} \times 34.5$ =	1,268
2 + 36.10	0.147 x 640 = 94.1		
		$\frac{94.1 + 122.8}{2} \times 7$ =	760
2 + 36.10	0.192 x 640 = 122.8		
		Total earth excavation	43,658 cubic feet

DAM-EARTH EMBANKMENT

The volume of a truncated rectangular prism = $A \times \frac{h_1 + h_2 + h_3 + h_4}{4}$

where A = area of cross section

h_1, h_2, h_3, h_4 are corner heights

The volume of a truncated triangular prism = $A \times \frac{h_1 + h_2 + h_3}{3}$

Station	Elevation Ground	Elevation of Embankment	Difference
1	326	348	22
2	328	362	34
3	329	375	46
4	328	375	47
5	331	345	14
6	330	337	7
7	333	348	15
8	333	362	29
9	333	375	42
10	332	375	43
11	334	357	23
12	336	347	11
13	335	338	3
14	338	348	10
15	338	362	24
16	338	375	37
17	340	375	35
18	342	366	24
19	341	353	12
20	340	340	0
21	350	350	0
22	352	362	10
23	350	375	25
24	350	375	25
25	352	367	15
26	365	365	0
27	362	375	13
28	363	375	12
29	360	362	2
30	375	375	0
31	375	375	0
32	350	350	0
33	330	331	1
34	326	341	15
35	327	337	10
36	328	333	5
37	332	332	0
38	339	339	0

DAM-EARTH EMBANKMENT
(Continued)

1 x 22 =	22
2 x 34 =	68
1 x 46 =	46
2 x 15 =	30
4 x 29 =	116
2 x 42 =	84
2 x 10 =	20
4 x 24 =	96
2 x 37 =	74
4 x 10 =	40
2 x 25 =	50
2 x 13 =	26
	672

$V = \frac{672}{4} \times 400 = 67{,}200$ cubic feet

1 x 47 =	47
2 x 14 =	28
2 x 7 =	14
2 x 43 =	86
4 x 23 =	92
4 x 11 =	44
2 x 3 =	6
2 x 35 =	70
4 x 24 =	96
3 x 12 =	36
2 x 25 =	50
3 x 15 =	45
2 x 12 =	24
2 x 2 =	4
	642

$V = \frac{642}{4} \times 400 = 64{,}200$ cubic feet

	64,200
	4,740
	2,040
	300
	1,120
	1,600
	1,600
	600
	400
	12,000
	12,700
	11,000
	2,200
	181,700
Rip Rap	7,000
Total volume of earth embankment	174,700

DAM-RETAINING WALL

Volumes figured by end area method and by pieces.

CONCRETE

0.596 x 640 x 28.2	=	10,750 cubic feet
0.107 x 640 x 12.5	=	855
0.155 x 640 x 11.3	=	1,120
0.240 x 640 x 20	=	3,070
0.368 x 640 x 18.8	=	4,440
0.986 x 640 x 22.5	=	14,200
8.2 x 6.0 x 44.8	=	2,200
5.0 x 2.5 x 35.0	=	440
8.2 x 7.5 x 44.3	=	2,750
8 x 6 x 41	=	1,970
0.393 x 640 x 6.75	=	1,700
0.265 x 640 x 8	=	1,360
0.316 x 640 x 12.5	=	2,530
0.634 x 640 x 10	=	4,060
0.647 x 640 x 15	=	6,210
0.493 x 640 x 10	=	3,160
46 x 8.1	=	372
114 x 8.7	=	1,000
220 x 132	=	2,900
327 x 6	=	1,962
441 x 13	=	5,730
533 x 3	=	1,600
Total concrete		74,379 cubic feet

ROCK EXCAVATION

0.596 x 640 x 2	=	760 cubic feet
0.870 x 640 x 2	=	1,110
0.986 x 640 x 2	=	1,260
0,960 x 400 x 2	=	770
1.98 x 400 x 2	=	1,600
1,680 x 2	=	3,360
Total rock		8.860 cubic feet

DAM-RETAINING WALL
(Continued)

EARTH EXCAVATION

10,750	-	0.409	x	640	x	28.2	=	3,350	cubic feet
855	-	0.014	x	640	x	12.5	=	743	
1,120	-	0.05	x	640	x	11.3	=	760	
3,070	-	0.113	x	640	x	20	=	1,620	
4,440	-	0.208	x	640	x	18.8	=	1,940	
		19.5	x	14	x	22.5	=	6,140	
		0.96	x	400	x	12	=	4,600	
		1.98	x	400	x	7	=	5,600	
372	-	0.008	x	4000	x	8.1	=	100	
1000	-	0.015	x	4000	x	8.7	=	500	
2900	-	0.021	x	4000	x	13.2	=	1,800	
1962	-	0.022	x	4000	x	6	=	1,450	
5730	-	0.029	x	4000	x	13	=	4,220	
1600	-	0.030	x	4000	x	3	=	1,240	
		Total earth						34,063	cubic feet

DAM--SLUICE...

Volume figured by end area method.

CONCRETE

0.690 x 3 x 5.75 x 640 = 7,610 cubic feet

0.344 x 3 x 10.5 x 640 = 6,940

Total Concrete 14,550 cubic feet

EARTH

0.220 x 640 x 23 = 3,250 cubic feet

0.438 x 640 x 28 = 7,850

Total earth 11,100 cubic feet

ROCK

0.368 x 400 x 2 = 2,940 cubic feet

DAM-EXCAVATION

Excavation to Elevation-340

Station	Elevation of Earth	Diff. Elev.
1	367	27
2	360	20
3	355	15
4	353	13
5	350	10
6	365	25
7	359	19
8	355	15
9	353	13
10	349	9
11	342	2
12	364	24
13	358	18
14	348	8
15	341	1
16	360	20
17	355	15
18	340	0
19	355	15
20	348	8
21	343	3
22	340	0
23	350	10
24	346	6
25	342	2
26	340	0
27	350	10
28	346	6
29	342	2
30	340	00
31	347	7
32	345	5
33	341	1
34	340	0
35	343	3
36	340	0
37	340	0

COMPUTATION

$\frac{770}{4} \times 400 = 77{,}000$ cubic feet

7 x 200	=	1,400	
3 x 200	=	600	
16.5 x 120	=	1,980	
19 x 60	=	1,140	
16 x 60	=	1,000	
6.5 x 110	=	710	
8 x 60	=	480	
1.5 x 65	=	100	
Total		84,410	cubic feet

DAM-EXCAVATION
(Continued)

Excavation to Elevation-350

Station	Elev. Earth	Diff. Elev.
1	368	18
2	360	10
3	357	7
4	353	3
5	368	18
6	362	12
7	358	8
8	354	4
9	368	18
10	362	12
11	358	8
12	367	17
13	362	12
14	357	7
15	355	5

COMPUTATION

$\frac{225 \times 400}{4}$ = 22,500 cubic feet
7 x 20 x 12 = 1,680
5 x 90 = 450
15 x 10 x 200 = 3,000
11 x 100 = 1,100
7 x 12 x 5 = 200

Total 28,930 cubic feet

DAM-EXCAVATION
(Continued)

Elev. Earth	Elev. Surface	Diff.	Computation
362	340	22	
364	348	16	$\frac{72}{4}$ x 20 x 6.5 = 2,340 cubic feet
362	348	14	
360	340	20	
		72	
362	346	16	
358	346	12	$\frac{63}{4}$ x 20 x 5 = 1,575
355	340	15	
360	340	20	
		63	
358	346	12	
353	346	7	$\frac{45}{4}$ x 20 x 5 = 1,125
351	340	11	
355	340	15	
		45	
353	345	8	
351	345	6	$\frac{34}{4}$ x 4 x 20 = 680
349	340	9	
351	340	11	
		34	
351	345	6	
347	345	2	
345	340	5	$\frac{22}{4}$ x 20 x 4 = 440
349	340	9	
		22	
368	367	1	
367	358	9	
362	349	13	$\frac{23}{4}$ x 11 x 20 = 1,270
364	364	0	
		23	

4 x 18 x 2.5 =	180
	500
7 x 14 x 20 =	1,960
4 x 8.5 x 20 =	680
4.5 x 6 x 20 =	540
4 x 4 x 23 =	370
Total	11,650 cubic feet

DAM-EXCAVATION
(Continued)

COMPUTATION

4 x 6 x 6 =	175 cubic feet
2.5 x 12 x 3.5 =	105
2 x 3 x 7 =	42
2 x 5 x 7.5 =	75
7 x 5 x 2.5 x 3 =	250
1.5 x 10 x 8 =	120
1.5 x 20 x 6 =	180
1 x 20 x 6 =	120
5.7 x 11 x 21 =	1,320
4.3 x 14 x 29 =	1,760
2 x 29 x 2 =	100
	200
	300
Total	4,577 cubic feet

DAM-EXCAVATION
(Continued)

Sta.	Elev. Earth	Elev. Emb.	Diff.	Computation
1	368	350	18	1 x 18 = 18
2	360	350	16	2 x 10 = 20
3	357	350	7	2 x 7 = 14
4	353	350	3	1 x 3 = 3
5	352	350	2	1 x 27 = 27
6	367	340	27	2 x 20 = 40
7	360	340	20	2 x 15 = 30
8	355	340	15	1 x 13 = 13
9	353	340	13	165
10	352	340	12	
11	350	340	10	1 x 3 = 3
				1 x 13 = 13
				1 x 12 = 12
				1 x 2 = 2
				30
				2
				12
				10
				24

$165 \times \frac{400}{4} = 16{,}500$ cubic feet

$\frac{30}{4} \times 200 = 1{,}500$

$\frac{24}{3} \times 100 = 800$

Total 18,800 cubic feet

TOTAL EXCAVATION AT DAM

4,580 cubic feet
11,650
18,800
84,400
28,930
Total 148,360 cubic feet

DAM-ROCK EXCAVATION

Excavation to Elevation-350

Station	Elevation of Rock	Difference	Computation
1	363	13	2 x 13 = 26
2	358	8	4 x 8 = 32
3	354	4	4 x 4 = 16
4	352	2	4 x 2 = 8
5	351	1	1 x 1 = 1
6	364	14	2 x 14 = 28
7	358	8	4 x 8 = 32
8	356	6	3 x 6 = 18
9	353	3	1 x 3 = 3
10	366	16	1 x 16 = 16
11	361	11	2 x 11 = 22
12	358	8	1 x 8 = 8
13	355	5	210
14	367	17	
15	363	13	
16	358	8	

$$\text{Volume} = \frac{210}{4} \times 400 = 210{,}000 \text{ cubic feet}$$

DAM-ROCK EXCAVATION
(Continued)

Rock Excavation to Elevation-340

Station	Elevation of Rock	Difference	Computation
1	362	22	2 x 22 =44
2	357	17	4 x 17 =68
3	353	13	4 x 13 =52
4	351	11	4 x 11 =44
5	344	4	2 x 4 = 8
6	360	20	2 x 20 =40
7	356	16	4 x 16 =64
8	352	12	4 x 12 =48
9	352	12	4 x 12 =48
10	349	9	3 x 9 =27
11	343	3	1 x 3 = 3
12	358	18	2 x 18 =36
13	354	14	4 x 14 =56
14	348	8	3 x 8 =24
15	340	0	1 x 14 =14
16	340	0	3 x 13 =39
17	340	0	2 x 12 =24
18	354	14	3 x 5 =15
19	353	13	1 x 3 = 3
20	340	0	2 x 10 =20
21	352	12	4 x 7 =28
22	345	5	2 x 2 = 4
23	343	3	3 x 8 =24
24	340	0	2 x 2 = 4
25	350	10	1 x 6 = 6
26	347	7	1 x 6 = 6
27	342	2	749
28	340	0	
29	348	8	
30	348	8	
31	342	2	
32	340	0	
33	348	8	
34	348	8	
35	346	6	
36	346	6	
37	347	7	

$$\text{Volume} = \frac{749}{4} \times 400 = 74{,}900 \text{ cubic feet}$$

DAM-ROCK EXCAVATION
(Continued)

COMPUTATION

6.25	x	12.5	x	20	=	1,560	cubic feet
2	x	9.5	x	10	=	190	
14	x	16.5	x	10.5	=	2,420	
11.5	x	5.5	x	20	=	1,260	
4	x	1 2	x	3	=	140	
15	x	38	x	4	=	2,280	
18	x	20	x	4	=	1,440	
17.5	x	7	x	10	=	1,220	
17.0	x	20	x	6	=	2,040	
16	x	6	x	20	=	1,920	
17	x	3	x	6	=	300	
15	x	19	x	6.5	=	1,850	
12.5	x	20	x	4.5	=	1,125	
10.5	x	20	x	4	=	840	
7.5	x	20	x	4	=	600	
6	x	20	x	7	=	840	
4	x	14.5	x	5	=	172	
15	x	10.5	x	40	=	6,300	
12	x	8.5	x	20	=	2,040	
9	x	20	x	6	=	1,080	
6	x	20	x	3	=	360	
17	x	20	x	3	=	1,020	
13	x	10	x	3	=	390	
10	x	10	x	4	=	400	
7	x	20	x	4.5	=	630	
10	x	23	x	9	-	2,070	
21	x	23	x	5	-	2,420	
27	x	6	x	5	=	810	
28	x	8	x	3	=	672	
28	x	7	x	3	=	590	
27	x	5.5	x	7	=	1,040	
		Total				40,700	

	40,700	cubic feet
	74,900	
	21,000	
Total rock excavation	136,600	cubic feet
[illegible] =	148,360	
Total earth excavation	11,760	cubic feet

TUNNEL

TUNNEL INTAKE

CONCRETE

	Total
Floor	
12.5 x 5 =	60 cubic feet
Walls	
2 (28.75 x 4 x 32 - 0.102 x 64 x 30) =	7,980
Roof	
2 x 0.157 x 10 x 64 x 12 =	2,410
Wing Walls	
0.718 x 10 x 64 x 4.75 =	2,180
0.059 x 10 x 64 x 28.5 =	1,075
0.024 x 10 x 64 x 14.3 =	220
0.011 x 10 x 64 x 14.5 =	100
Total	14,000 cubic feet

TUNNEL OUTLET

EARTH EXCAVATION

	Total
$\frac{377 + 380}{2} \times 5.5 =$	2,080 cubic feet
$\frac{463 + 380}{2} \times 10 =$	4,220
$\frac{463 + 580}{2} \times 10.25 =$	5,350
32.5 x 23.5 x 4.8 =	3,530
$\frac{590 + 470}{2} \times 12.5 =$	6,620
$\frac{280 + 590}{2} \times 10.5 =$	4,570
$\frac{196 + 280}{2} \times 2 =$	470
18.75 x 18 x 9.5 =	3,200
Total	30,000 cubic feet

TUNNEL
(Continued)

TUNNEL OUTLET

CONCRETE

Volumes figured by end area method.

COMPUTATION	Total
$2080 - \frac{165 + 210}{2} \times 5.5 =$	1,050 cubic feet
$4220 - \frac{248 + 210}{2} \times 10 =$	1,930
$5350 - \frac{403 + 248}{2} \times 10.25 =$	2,010
$3530 - \frac{468 + 403}{2} \times 4.75 =$	1,470
$\frac{102 + 67}{2} \times 8.3 \times 2 =$	1,405
$\frac{67.2 + 45}{2} \times 5.5 \times 2 =$	608
$\frac{22 + 6}{2} \times 8.3 \times 2 =$	232
	1,620
Total	10,800 cubic feet

TUNNEL
(Continued)

TUNNEL

Volumes figured by end area method.

Section through Rock

Length of rock excavation = 1,328 feet

$$V_R = \frac{210 \times 1328}{27} = 10,370 \text{ cubic yards}$$

$$V_C = \frac{94.4 \times 1328}{27} = 4,670 \text{ cubic yards}$$

Section through Earth and Rock

Length = 59.3 feet

$$V_E = \frac{96.3 \times 59.3}{27} = 211.5 \text{ cubic yards}$$

$$V_R = \frac{186 \times 59.3}{27} = 409 \text{ cubic yards}$$

$$V_{Brick} = \frac{33.6 \times 54.3}{27} = 73.7 \text{ cubic yards}$$

$$V_C = 2 \times 0.361 \times 10 \times \frac{64 \times 59.3}{9 \times 27} = 113 \text{ cubic yards}$$

$$\text{Timber} = 0.382 \times 2 \times 10 \times \frac{64}{9} \times 59.3 \times 12 = 38,760 \text{ board feet}$$

Section through Earth

Length = 139 feet

$$V_E = 4.075 \times \frac{640}{9} \times \frac{139}{27} = 1,490 \text{ cubic yards}$$

$$V_C = 1.637 \times 10 \times \frac{64}{9} \times \frac{139}{27} = 549 \text{ cubic yards}$$

$$\text{Timber} = 0.367 \times 10 \times \frac{64}{9} \times 139 \times 12 = 74,400 \text{ board feet}$$

TUNNEL
(Continued)

TOTALS IN TUNNELS
(cubic yards)

CONCRETE	EARTH	ROCK	BRICK	TIMBER
4670	212	10370	73.7	38760
113	1490	409		74400
549	1110			
400				
520				
6252	2812	10779	73.7	113160 board feet

TUNNEL
(Continued)

TUNNEL INTAKE-Reinforced Steel

All bars are square.

COMPUTATION

7 - $\frac{3}{4}$" x 35'	=	0.960	cubic feet	
4 - " x 32'	=	0.500		
5 - " x 30'	=	0.585		
11 - $\frac{3}{4}$" x 28'	=	1.200		
5 - " x 26'	=	0.507		
25 - " x 15'	=	1.460		
6 - " x 23'	=	0.538		5.750

TUNNEL OUTLET

Walls

6 - $\frac{3}{4}$" x 23'	=	0.538
6-- " x 22'	=	0.514
66- " x 21'	=	0.490
6 - " x 20'	=	0.468
6 - " x 19'	=	0.444
7 = " x 18'	=	0.490
11 - $\frac{3}{4}$" x 17'	=	0.730
		3.674

For two walls, vol. = 2 x 3.674 = 7.348

2 - $\frac{3}{4}$" x 30'	=	0.234	
2 - " x 28'	=	0.218	
2 - " x 26'	=	0.202	
2 - " x 24'	=	0.187	
2 - " x 22'	=	0.172	
4 - " x 20'	=	0.312	
7 - " x 18'	=	0.491	
9 - " x 30'	=	1.050	
9 - " x 28'	=	0.985	
6 - " x 26'	=	0.609	
6 - " x 24'	=	0.561	
6 - " x 22'	=	0.514	
17 - $\frac{3}{4}$" x 20'	=	1.328	
26 - " x 18'	=	1.822	8.685
		Total	21.783 cubic feet

Total weight equals 21.783 x 490 = 10,670#

PENSTOCKS

Same as for Plant No. 3

(See Pages 34-47)

FOREBAY

FOREBAY

Fill	Total	Cut	Total
305 x 2 x 16 =	9,760 c.f.	20 x 2.5 x 14.3 =	717 cubic feet
36 x 16 x 6 =	3,460	40 x 45 =	1,800
16 x 105 x 13 =	21,850	$\frac{30 + 30 \times 3.75}{2} \times 72 =$	5,150
75 x 8.5 x 16 =	10,200	112.5 x 50 =	5,625
50 x 16.5 x 16 =	13,200	112.5 x 31 =	3,450
0.45 x 10000 x 2 =	99,100	0.72 x 10000 x 15 =	108,000
22 x 5.5 x 9.3 =	1,130	0.57 x 10000 x 9 =	51,300
$\left(\frac{11 \times 11 + 40 \times 10}{2}\right) 115 =$	29,900	0.44 x 10000 x 9 =	39,600
17.5 x 17.5 x 138 =	42,300	0.25 x 10000 x 11.5 =	29,750
$40 \times 9 \times 100 \times 6.28 \times \frac{72}{360} =$	45,200	0.41 x 10000 x 11.5 =	47,100
$50 \times 11 \times 115 \times 6.28 \times \frac{50}{360} =$	55,100		
0.59 x 10000 x 25 =	147,800		
Total	479,000	Total	292,492
		[illegible]	16,780
		Cut	285,712

$$\text{Rip Rap} = (16{,}400 - 23 \times 62)\ \frac{2.25}{2} =$$

SUB-STRUCTURE

CONCRETE

Volumes figured by pieces.

Below springing line

COMPUTATION

193.9 x 45 =	8,620 cubic feet
$\frac{5.625}{2}$ x 8.25 x 50.7 =	1,180
$\frac{6.71}{2}$ x 3.25 x 23.7 =	258
$\frac{5.125}{2}$ x 15.6 x 7.75 =	620
236.4 x 18.5 =	4,380
108.7 x 18.5 =	2,000
119.0 x 51 =	6,060
101.4 x 8 =	8,110
8.1 x 19 x 53 =	7,140
183 x 5 =	92
30.6 x 14 =	430
4.5 x 5.21 x 14 =	328
157.3 x 13 =	2,045
91.3 x 12 =	1,095
2.5 x 8.7 5 x 13 =	260
2.5 x 18.5 x 32 =	1,480
4 x 9.5 x 20 =	760
2.5 x 1 x 10 =	25
6 x 10.5 x 20 =	1,260
2.5 x 8 x 16.75 =	335
568.1 x 5 =	2,840
174 x 11 =	1,925
85.9 x 6 =	515
7.33 x 22 x 13.5 =	2,180
$\frac{161.3 + 199}{2}$ x 11.5 =	2,075
13.6 x 19 =	258
2 x 12.5 x 19 =	475
27 x 29.5 =	797
31.7 x 51 =	1,620
3 x 1.5 x 24.5 =	110
4.5 x 1.5 x 27.5 =	186
4.5 x 1.5 x 20 =	135
7.2 x 1.5 x 12 =	130
30.0 x 1.5 x 19.0 =	855
13 x 1.5 x 2 =	39
11 x 6 x 53 =	3,500

SUB-STRUCTURE
(Continued)

Computation

$\left(\frac{2 \times 9 + 4.5 \times 9 + 8 \times 2 + 4 \times 6}{2}\right)20$	=	985
4.5 x 9.5 x 23	=	985
1 x 4.5 x 9	=	41
5.6 x 8.5 x 9	=	425
3 x 9.5 x 20	=	570
13 x 2 x 5.5	=	143
86 x 14.5	=	1,250
2.5 x 20 x 14.5	=	725
4.5 x 9.5 x 32	=	1,370
3 x 9.5 x 29	=	825
6 x 9.5 x 17.3	=	985
3 x 1.21 x 64x 12	=	2,325
1.78 x 64 x 12	=	4,100
1.52 x 64 x 24.3	=	7,100
2 x 4 x 48.3 x 9.5	=	3,670
6.5 x 9.5 x 48.3	=	2,980
4.0 x 9.5 x 70	=	2,660
2 x 2 x 99 9	=	396
2 x 2 x 33	=	132
2 x 2 x 21	=	84
2 x 2 x 1 5.3	=	61
2 x 2 x 74	=	296
2 x 2 x 48.3	=	193
		95,203
Deduct		2,102
Total		93,100 cubic feet

Rip Rap

40 x 2 x 20	=	1,600
20 x 1 x 20	=	400
40 x 64 x 31	=	795
63 x 64 x49.5	=	2,000
20 x 2 x 28	=	1,120
		5,915 cubic feet

A P P E N D I X   C

HYDROLOGY

PLANT NO. 4

DETAILED DESCRIPTION OF METHOD USED IN OBTAINING KILOWATT HOUR OUTPUT AT PLANTS NO. 3 AND NO. 4

Data:

Drainage area at Charlemont	362 sq. miles
" " " Plant No. 4	403 " "
" " " Plant No. 3	501 " "

Uncontrolled area between Charlemont and

Plant No. 4	41 sq. miles
Plant No. 3	139 " "

From the papers of the United States Geological Survey, the monthly flow at Charlemont and the monthly discharge without storage per square mile were secured. The discharge without storage per square mile above Charlemont was assumed the same as that below Charlemont.

Let "a" equal the discharge without storage per square mile
"b" equal additional uncontrolled flow between Charlemont and Plant No. 4 equals: a x 41
"c" equal the mean observed flow at Charlemont
"d" equal the flow of Plant No. 4 equals "b" plus "c".

A flow duration table was tabulated by the total period basis and the flow duration curve was constructed from this table. A flow duration curve for a wet year and a dry year were also drawn.

The data for the capacity factor was secured from two sources:

1. The Annual Report of the Department of Public Utilities of the Commonwealth of Massachusetts for the year ending November 30, 1920:- Vol. 2-p 462, 469.

2. From a blueprint the photostat of which is in Appendix F

The capacity factor is the ratio of the average load to the total installed rated capacity of the equipment.

From the results obtained, a capacity factor of thirty-eight per cent was used.

The utilization factor is the ratio of the actual output in kilowatt hours per year to the output in kilowatt hours per year if the machinery were working at rated capacity during that year.

The flow required to operate the plant under rated capacity was found. Since the capacity factor was thirty-eight per cent, the actual flow utilized was thirty-eight per cent of the above flow.

The flow that could be utilized if the plant was run at rated capacity was computed by taking the area under the flow duration curve excluding that portion which was above our rated capacity.

The utilization factor was computed from the ratio as given by the definition. This utilization factor was computed for the mean year and applied to the wet and dry year.

The theoretical output in kilowatt hours per year was secured by obtaining the area under the flow duration curve, again excluding that area above the rated capacity, computing the horse power and converting it into kilowatt hours per year.

The actual output was found by multiplying the theoretical output by the utilization factor. This method was applied to the wet and dry years.

Similarly, the actual output for mean, wet and dry years was obtained for Plant No. 3.

HYDROLOGY

FLOW AT PLANT #4.

YEAR	MONTH	a	b	c	d
	Oct.	1.64	67	540	607
	Nov.	3.62	148	1,170	1,318
	Dec.	1.81	74	616	690
	Jan.	1.07	44	363	407
	Feb.	0.86	35	298	333
	Mar.	3.95	162	1,360	1,522
1913-14	Apr.	12.2	500	4,120	4,620
	May	3.84	158	1,230	1,388
	June	0.503	21	279	300
	July	0.691	28	477	505
	Aug.	0.674	28	587	615
	Sept.	0.180	7	190	197
	Oct.	0.282	12	91	103
	Nov.	0.580	24	177	201
	Dec.	0.439	18	133	151
	Jan.	2.36	97	761	858
	Feb.	4.20	172	1,400	1,572
1914-15	Mar.	1.50	62	515	577
	Apr.	4.81	197	1,570	1,767
	May	1.25	51	396	447
	June	0.348	14	224	238
	July	4.70	193	1,610	1,803
	Aug.	3.50	143	1,190	1,333
	Sept.	1.28	53	541	594
	Oct.	1.36	56	600	656
	Nov.	1.92	79	715	794
	Dec.	3.12	128	1,180	1,305
	Jan.	3.81	156	1,290	1,446
	Feb.	3.26	134	1,130	1,264
1915-16	Mar.	2.09	86	728	814
	Apr.	8.51	350	2,860	3,210
	May	4.25	174	1,370	1,544
	June	2.65	109	890	999
	July	1.52	62	569	631
	Aug.	0.511	21	427	448
	Sept.	0.856	35	439	474

HYDROLOGY

FLOW AT PLANT #4

YEAR	MONTH	a	b	c	d
	Oct.	0.823.	34	436	470
	Nov.	2.09	86	747	833
	Dec.	1.77	72	691	763
	Jan.	1.33	54	572	626
	Feb.	1.12	46	590	636
1916-17	Mar.	3.62	148	1,250	1,398
	Apr.	7.24	297	2,410	2,707
	May	4.36	179	1,410	1,589
	June	2.75	112	891	1,003
	July	0.746	31	296	327
	Aug.	0.765	31	299	330
	Sept.	0.387	16	309	325
	Oct.	2.11	87	727	814
	Nov.	1.05	43	443	486
	Dec.	0.671	28	433	461
	Jan.	0.599	25	384	409
	Feb.	2.17	89	808	897
1917-18	Mar.	4.36	179	1,480	1,659
	Apr.	7.57	310	2,500	2,810
	May	2.85	117	885	1,002
	June	1.31	54	407	461
	July	0.312	13	225	238
	Aug.	0.290	12	305	317
	Sept.	1.18	48	426	474
	Oct.	1.60	66	527	593
	Nov.	1.77	73	599	672
	Dec.	2.82	116	969	1,085
	Jan.	1.68	69	583	652
	Feb.	0.50	21	268	289
	Mar.	5.99	246	1,990	2,236
1918-19	Apr.	4.70	193	1,590	1,783
	May	5.97	245	2,030	2,275
	June	0.702	29	344	373
	July	o.412	17	274	291
	Aug.	o.555	23	269	292
	Sept.	2.33	96	819	915

HYDROLOGY

FLOW AT PLANT #4.

YEAR	MONTH	a	b	c	d
	Oct.	2.10	86	699	785
	Nov.	4.25	174	1,450	1,624
	Dec.	2.37	97	877	974
	Jan.	0.384	16	440	456
	Feb.	0.359	15	415	436
1919-20	Mar.	6.30	258	2,190	2,448
	Apr.[1]	9.50	390	3,160	3,550
	May	3.15	139	1,010	1,139
	June	2.62	107	875	982
	July	1.11	46	418	464
	Aug.	0.903	37	389	426
	Sept.	0.980	36	364	400

HYDROLOGY

FLOW DURATION TABLE

PLANT #4

Total Period Basis

	1	2	3	4	5	6	7	8	9	10	11	12
	103	291	333	447	474	607	672	833	1002	1333	1589	2275
	151	292	373	448	474	615	690	858	1003	1388	1624	2448
	197	300	400	456	486	626	763	897	1085	1398	1659	2707
	201	317	407	461	505	631	785	915	1139	1446	1767	2810
	238	325	409	461	577	636	794	974	1264	1552	1783	3210
	238	327	426	464	593	652	814	982	1308	1544	1803	3550
	289	330	430	470	594	656	814	999	1318	1572	2236	4620
Total-	1417	2182	2778	3207	3703	4423	5332	6458	8119	10203	12461	21620
Av.--	202	312	397	458	529	632	762	923	1160	1458	1780	3089

HYDROLOGY

FLOW AT PLANT #4

MEAN	WET YEAR	DRY YEAR
202	400	103
312	426	151
397	430	201
458	456	238
529	464	447
632	785	577
762	974	594
923	982	858
1160	1139	1333
1458	1624	1572
1780	2448	1767
3089	3550	1803

HYDROLOGY

CAPACITY FACTOR

Definition

$$C.F. = \frac{\text{Average Load}}{\text{Total installed rated capacity of equipment}}$$

From Public Utility Report

$$C.F. = \frac{142,033,570}{55,100 \times 0.746 \times 24 \times 365} = 39.5\%$$

From information secured from the New England Power Company

$$C.F. = \frac{142,000,000}{43,000 \times 24 \times 365} = 37.8\%$$

A capacity factor of 38.0% was used

HYDROLOGY

UTILIZATION OF POWER

PLANT #4

Capacity of plant = $\frac{6,000}{0.746}$ = 8,040 H.P.

An overall efficiency of 75% was assumed for the plant

$$Q = \frac{8,040 \times 550}{64 \times 62.5 \times 0.75} = 1,470 \text{ Sec. Ft.}$$

MEAN YEAR

Q = 202
312
397
458
529
632
762
923
1160
1458
1470
1470

Total flow-9773 Sec. Ft. Months

1,470 x 0.38 = 560 Sec. Ft. Months
560 x 12 = 6,720 Sec. F t. Months = Water actually used

Utilization = $\frac{6,720}{9,773}$ = 68.8%

HYDROLOGY

OUTPUT OF PLANT #4

Mean Q = 9,773 Sec. Ft. Months

WET YEAR	DRY YEAR
Q = 400	Q = 103
426	151
430	201
456	238
464	447
785	577
974	594
982	858
1139	1333
1470	1470
1470	1470
1470	1470
Max. Q= 10466 Sec. Ft. Months	Min. Q =8910 Sec. Ft. Months

Theoretical Output

Mean :- $\frac{9,773 \times 62.5 \times 64 \times 0.75}{550} \times 0.746 \times 24 \times 30.4 = 29,100,000$ K.W.H.

Max. :- $\frac{10,466}{9,773} \times 29,100,000 = 31,150,000$ K.W.H.

Min. :- $\frac{8,910}{9,773} \times 29,100,00 = 26,550,000$ K.W.H.

Actual Output

Mean :- $29,100,000 \times 0.688 = 20,000,000$ K.W.H.

Max. :- $31,150,000 \times 0.688 = 21,450,000$ K.W.H.

Min. :- $26,550,000 \times 0.688 = 18,300,000$ K.W.H.

A P P E N D I X D

HYDROLOGY

PLANT NO. 3

HYDROLOGY

FLOW AT PLANT #3.

YEAR	MONTH	b	c	d
	Oct.	228	540	768
	Nov.	504	1,170	1,674
	Dec.	252	616	868
	Jan.	149	363	512
	Feb.	120	298	118
1913-14	Mar.	549	1,360	1,909
	Apr.	1,696	4,120	5,816
	May	534	1,230	1,764
	June	70	279	349
	July	96	477	573
	Aug.	94	587	681
	Sept.	25	190	215
	Oct.	39	91	130
	Nov.	81	177	258
	Dec.	61	133	194
	Jan-	328	761	1,089
	Feb.	584	1,400	1,984
1914-15	Mar.	208	515	723
	Apr.	670	1,570	2,240
	May	174	396	670
	June	48	224	272
	July	654	1,610	2,264
	Aug.	486	1,190	1,676
	Sept.	178	541	719
	Oct.	189	680	789
	Nov.	267	715	982
	Dec.	434	1,180	1,614
	Jan,	530	1,290	1,820
	Feb.	454	1,130	1,584
1915-16	Mar.	290	728	1,018
	Apr.	1,180	2,860	4,040
	May	[illegible],590	1,370	1,960
	June	268	890	1,158
	July	212	569	781
	Aug.	71	427	498
	Sept.	120	439	559

HYDROLOGY

FLOW AT PLANT #3

YEAR	MONTH	b	c	d
	Oct.	114	436	550
	Nov.	291	747	1,038
	Dec.	246	691	937
	Jan.	185	572	757
	Feb.	156	590	746
1916-17	Mar.	504	1,250	1,754
	Apr.	1,000	2,410	3,410
	May	606	1,410	2,016
	June	382	891	1,273
	July	104	296	400
	Aug.	106	299	405
	Sept.	5.40	309	363
	Oct.	294	727	1,021
	Nov.	146	443	589
	Dec.	93	433	526
	Jan.	83	384	467
	Feb.	302	808	1,110
1917-18	Mar.	606	1,480	2,086
	Apr.	1,065	2,500	3,565
	May	396	885	1,281
	June	182	407	589
	July	43	225	268
	Aug.	40	305	345
	Sept.	164	426	590
	Oct.	223	527	750
	Nov.	246	599	845
	Dec.	392	969	1,361
	Jan.	234	583	817
	Feb.	70	268	338
1918 -19	Mar.	834	1,990	2,824
	Apr.	654	1,590	2,244
	May	830	2,030	2,860
	June	97	344	441
	July	57	274	331
	Aug.	77	269	346
	Sept.	324	819	1,143

HYDROLOGY

FLOW AT PLANT #3

YEAR	MONTH	b	c	d
	Oct.	292	699	991
	Nov.	590	1,450	2,040
	Dec.	330	877	1,207
	Jan.	53	440	493
1919-1920	Feb.	50	415	465
	Mar.	875	2,190	3,065
	Apr.	1,320	3,160	4,480
	May	438	1,010	1,448
	June	364	875	1,239
	July	154	418	572
	Aug.	126	389	515
	Sept.	124	364	488

HYDROLOGY

FLOW DURATION TABLE

PLANT #3

Total Period Basis

	1	2	3	4	5	6	7	8	9	10	11	12
	130	338	418	512	573	746	845	1038	1273	1676	2016	2860
	194	345	441	515	589	750	868	1089	1281	1754	2040	3065
	215	346	465	526	589	757	937	1110	1361	1764	2086	3410
	258	349	467	550	590	768	982	1143	1448	1820	2240	3565
	268	363	488	559	681	781	991	1158	1584	1909	2244	4040
	272	400	493	570	719	789	1018	1207	1614	1960	2264	4480
	331	405	498	572	723	817	1021	1239	1674	1984	2824	5816
Total-	1668	2546	3270	3804	4464	5408	6662	7984	10235	12867	15714	27236
Av.--	238	364	467	543	638	773	952	1141	1462	1838	2245	3891

HYDROLOGY

FLOW AT PLANT #3

MEAN	WET YEAR	DRY YEAR
238	465	130
364	488	194
467	493	258
543	515	272
638	572	570
773	991	719
952	1207	723
1141	1239	1089
1462	1448	1676
1838	2040	1984
2245	3065	2240
3891	4480	2264

HYDROLOGY

UTILIZATION OF POWER

PLANT #3

Capacity of plant $= \frac{6,000}{0.746} = 8,040$ H.P.

An overall efficiency of 75 % was assumed for the plant

$$Q = \frac{8,040 \times 550}{66 \times 62.5 \times 0.75} = 1,425 \text{ Sec. Ft.}$$

MEAN YEAR

Q =	238
	364
	467
	543
	638
	773
	952
	1141
	1425
	1425
	1425
	1425
Total flow =	10816

1425 x 0.38 = 542 Sec. Ft. Months

542 x 12 = 6,500 Sec. Ft. Months - Water actually used

utilization $= \frac{6500}{10820} = 60.1\%$

HYDROLOGY

OUTPUT OF PLANT #3

Mean Q = 10,816 Sec. Ft. Months

WET YEAR	DRY YEAR
Q = 465	Q - 130
488	194
493	258
515	272
572	570
991	719
1207	1089
1239	1425
1425	1425
1425	1425
1425	1425
Maximum Q = 11670 Sec. Ft. Months	Min. Q = 9655 Sec. Ft. Months

Theoretical Output

Mean :- $\frac{10,816 \times 62.5 \times 66 \times 0.75 \times 0.746 \times 24 \times 30.4}{550}$ = 33,250,000 K.W.H.

Max. :- $\frac{11,670}{10,816} \times 33,250,000$ = 35,800,000 K.W.H.

Min. :- $\frac{9,655}{10,816} \times 33,250,000$ = 29,650,000 K.W.H.

Actual Output

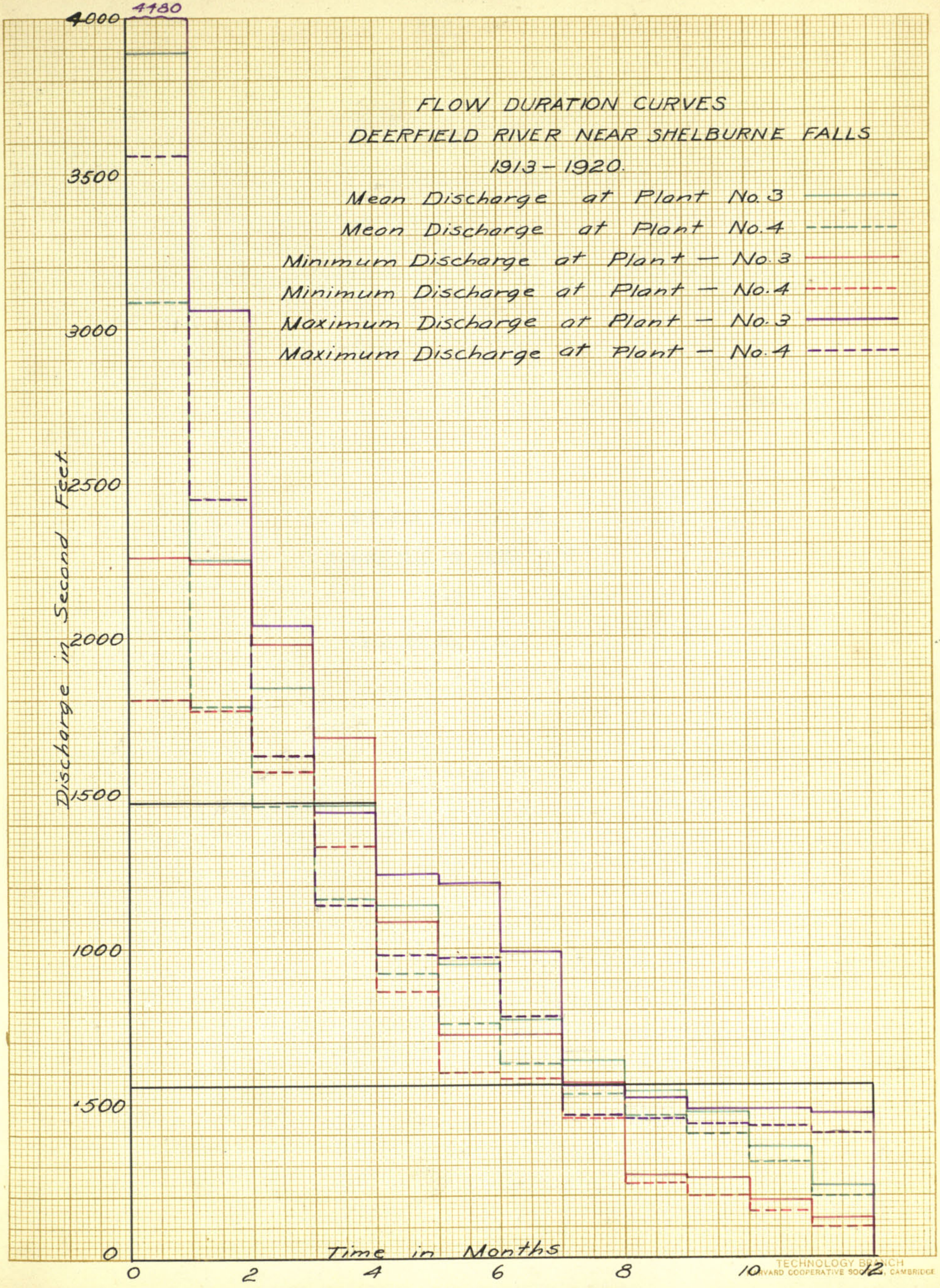
Mean :- 33,250,000 x 0.601 = 20,000,000 K.W.H.

Max. :- 35,800,000 x 0.601 = 21,550,000 K.W.H.

Min. :- 29,650,000 x 0.601 = 17,800,000 K.W.H.

A P P E N D I X E

FLOW DURATION CURVES


FLOW DURATION CURVES
DEERFIELD RIVER NEAR SHELBURNE FALLS
1913 – 1920.
Mean Discharge at Plant No. 3
Mean Discharge at Plant No. 4
Minimum Discharge at Plant – No. 3
Minimum Discharge at Plant – No. 4
Maximum Discharge at Plant – No. 3
Maximum Discharge at Plant – No. 4
4480
4000
3500
3000
2500
2000
1500
1000
500
0
Discharge in Second Feet
Time in Months
0
2
4
6
8
10
12

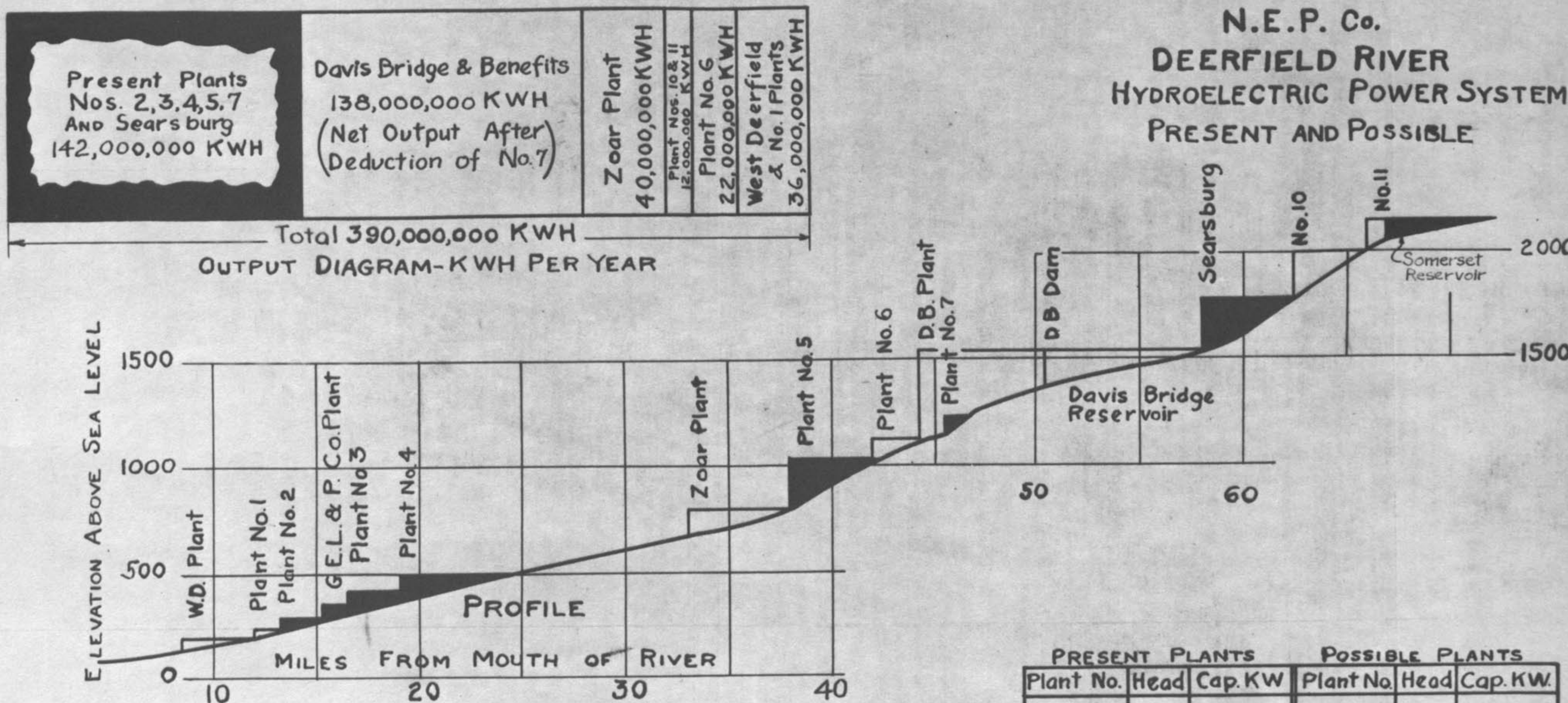
A P P E N D I X   F

PHOTOSTATS OF BLUEPRINTS

of

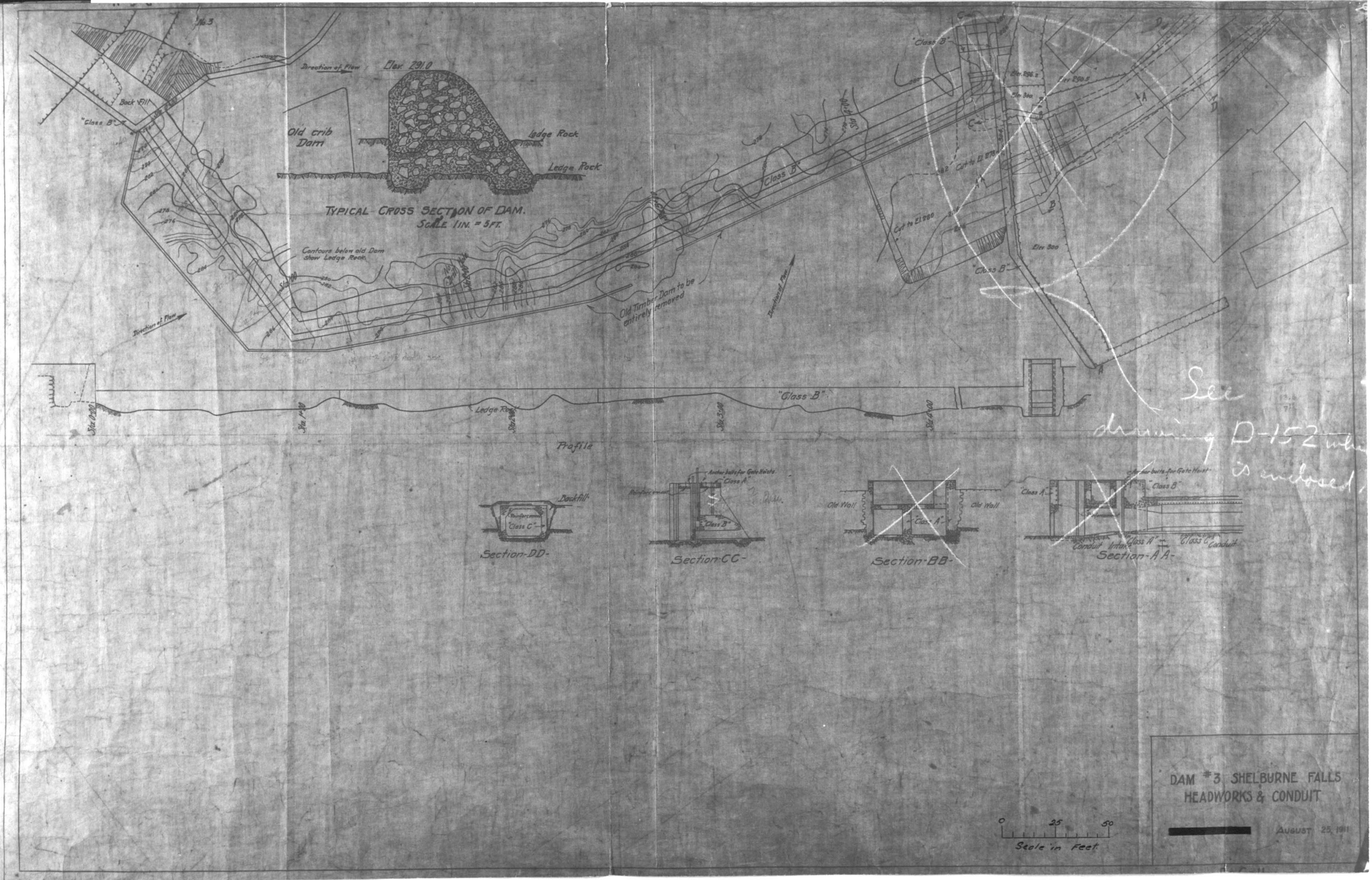
PLANTS NO. 3 & 4

N.E.P. Co.
DEERFIELD RIVER
HYDROELECTRIC POWER SYSTEM
PRESENT AND POSSIBLE

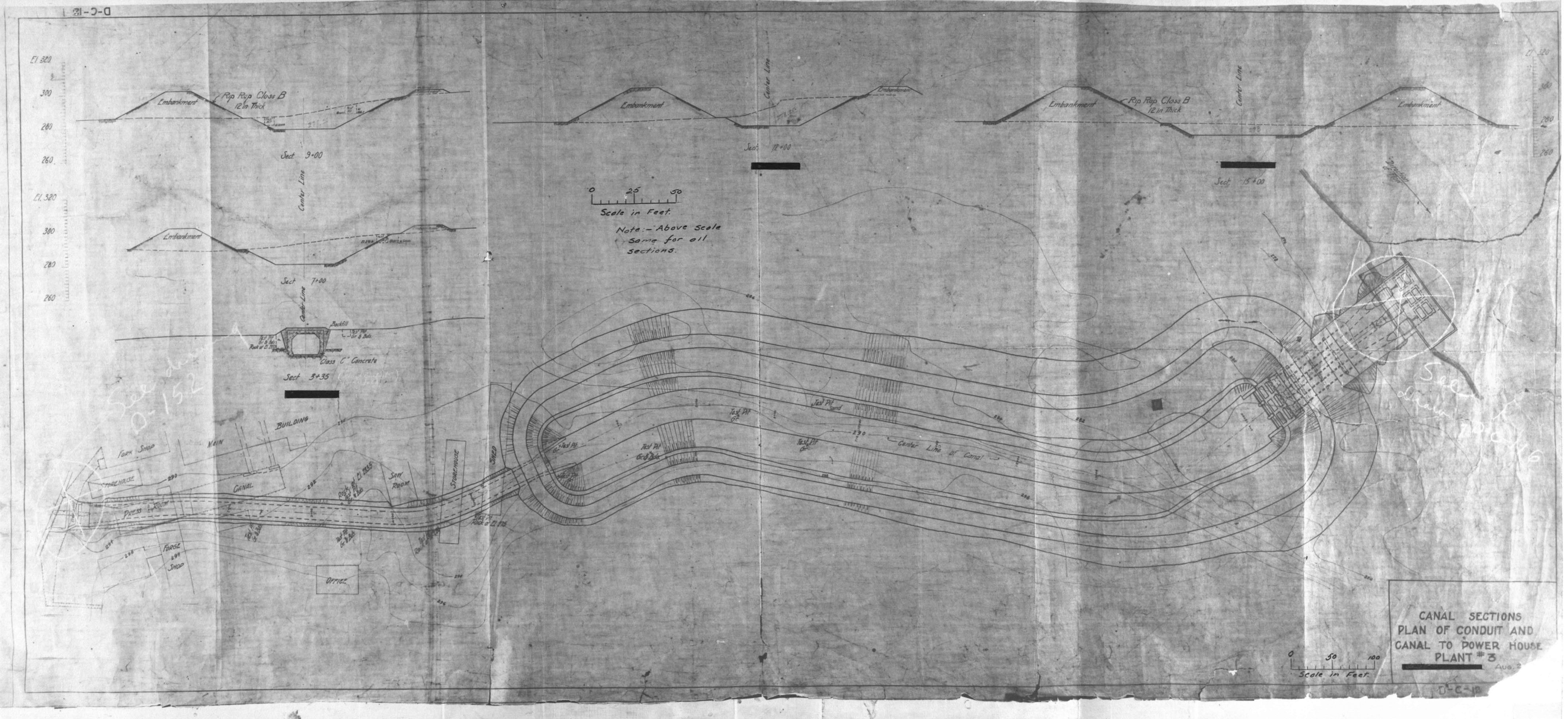


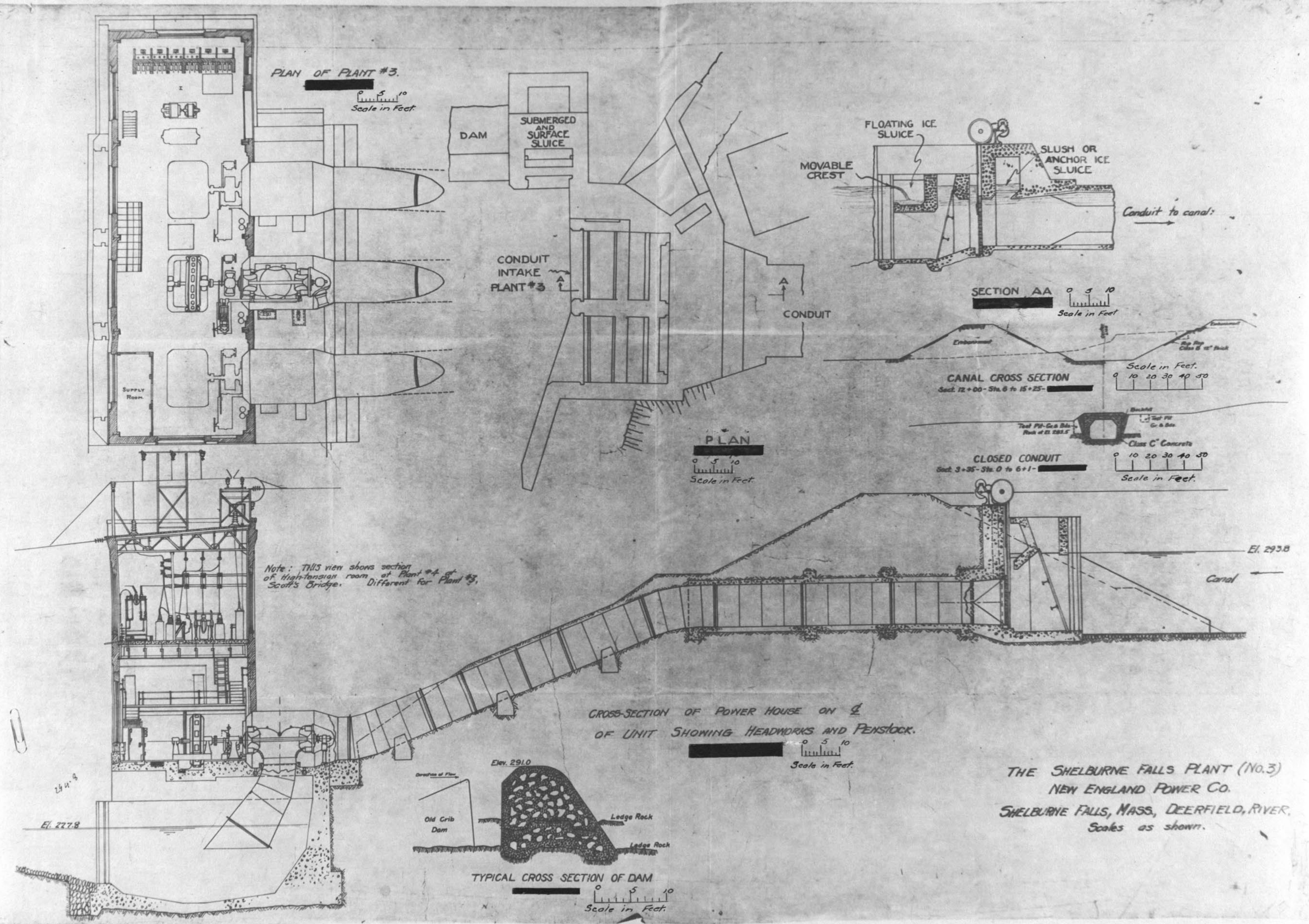
PRESENT PLANTS			POSSIBLE PLANTS		
Plant No.	Head	Cap. KW	Plant No.	Head	Cap. KW.
2	58	6,000	WD	40	4,000
3	66	6,000	1	40	4,000
4	64	6,000	Zoar	150	10,000
5	240	17,000	6	80	5,500
7	72	3,000	Davis Br	360	40,000
Searsburg	230	5,000	10	200	3,000
Som. Res.	—	—	11	100	1,500
Total	730	43,000	Total	970	68,000

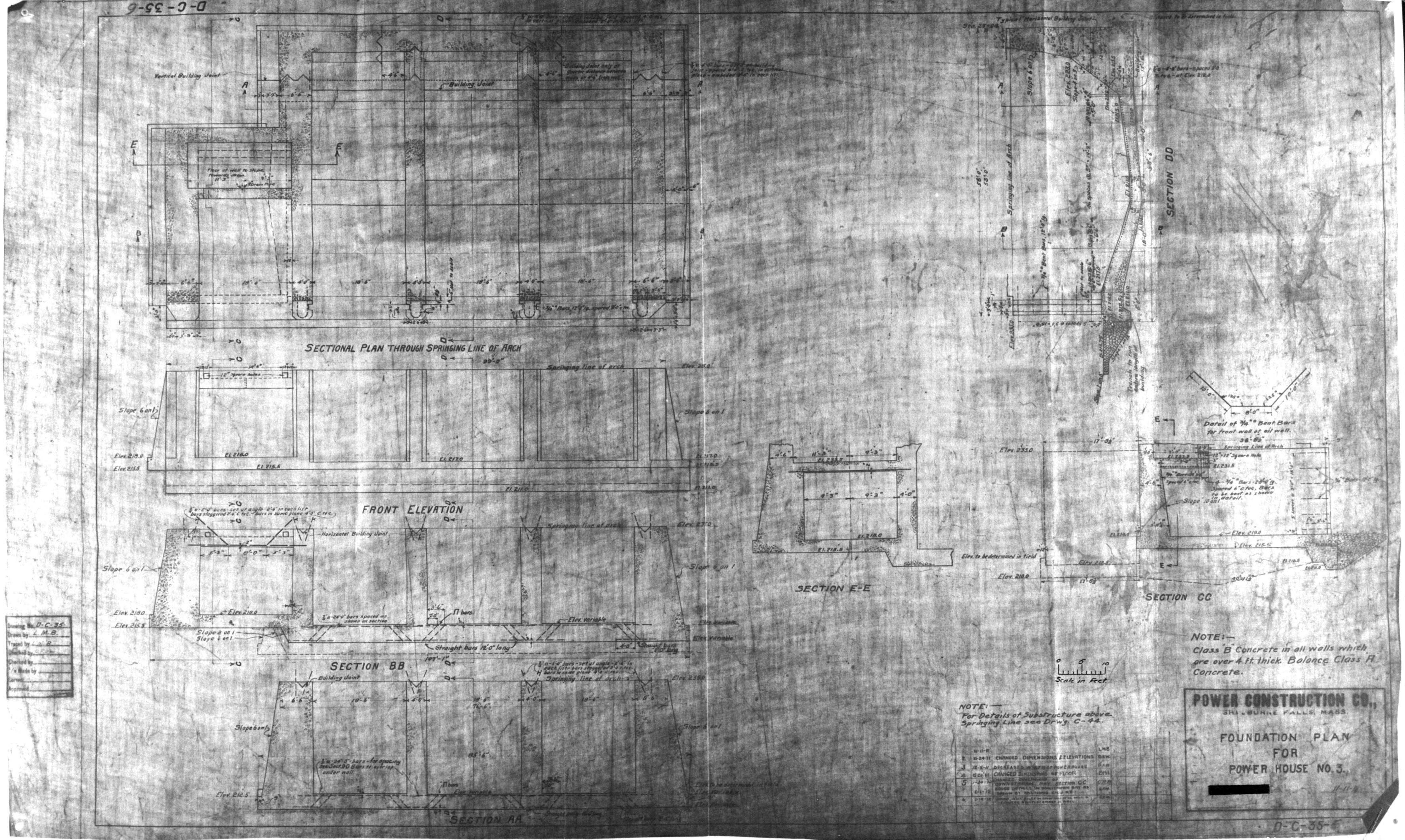
#2

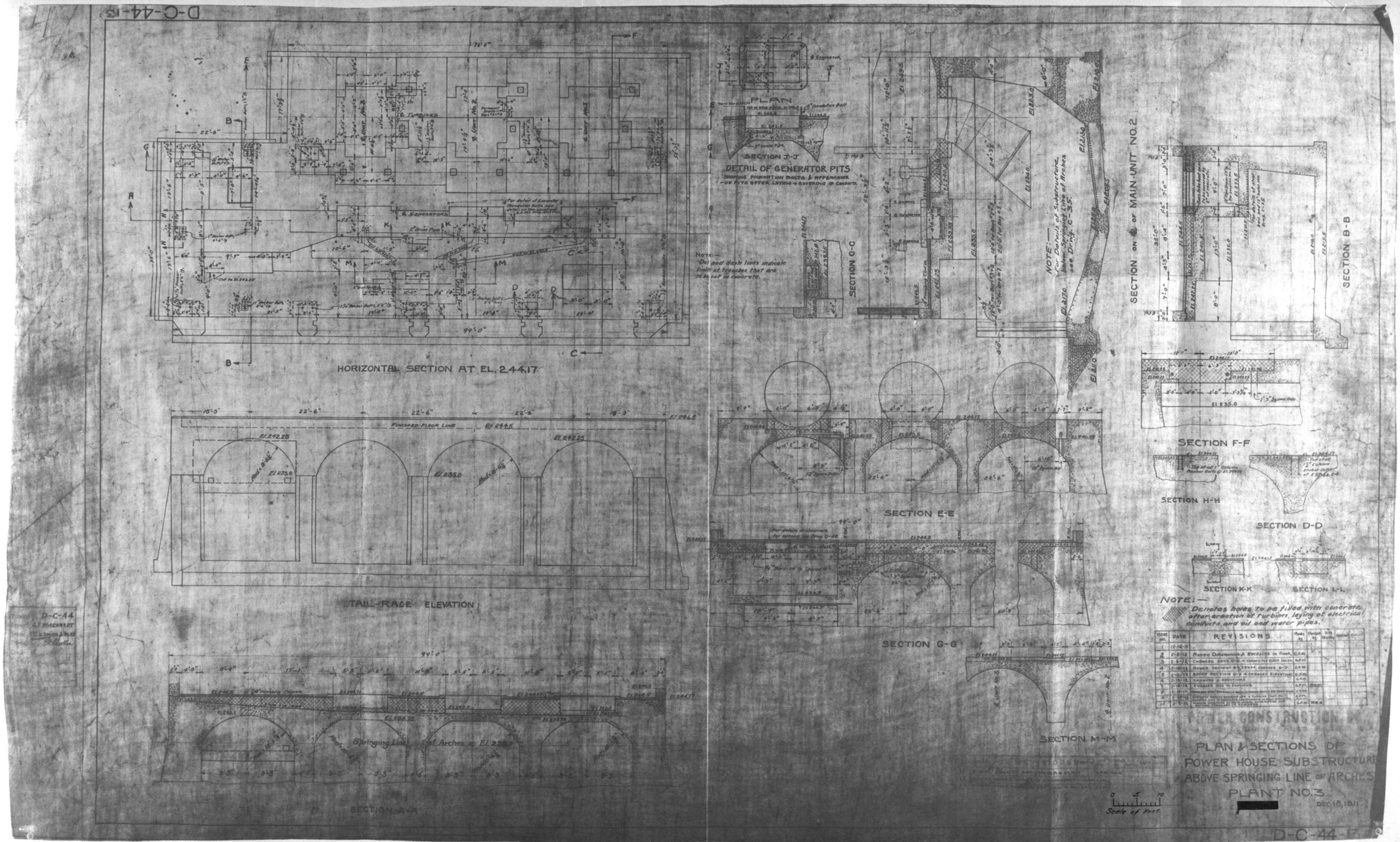


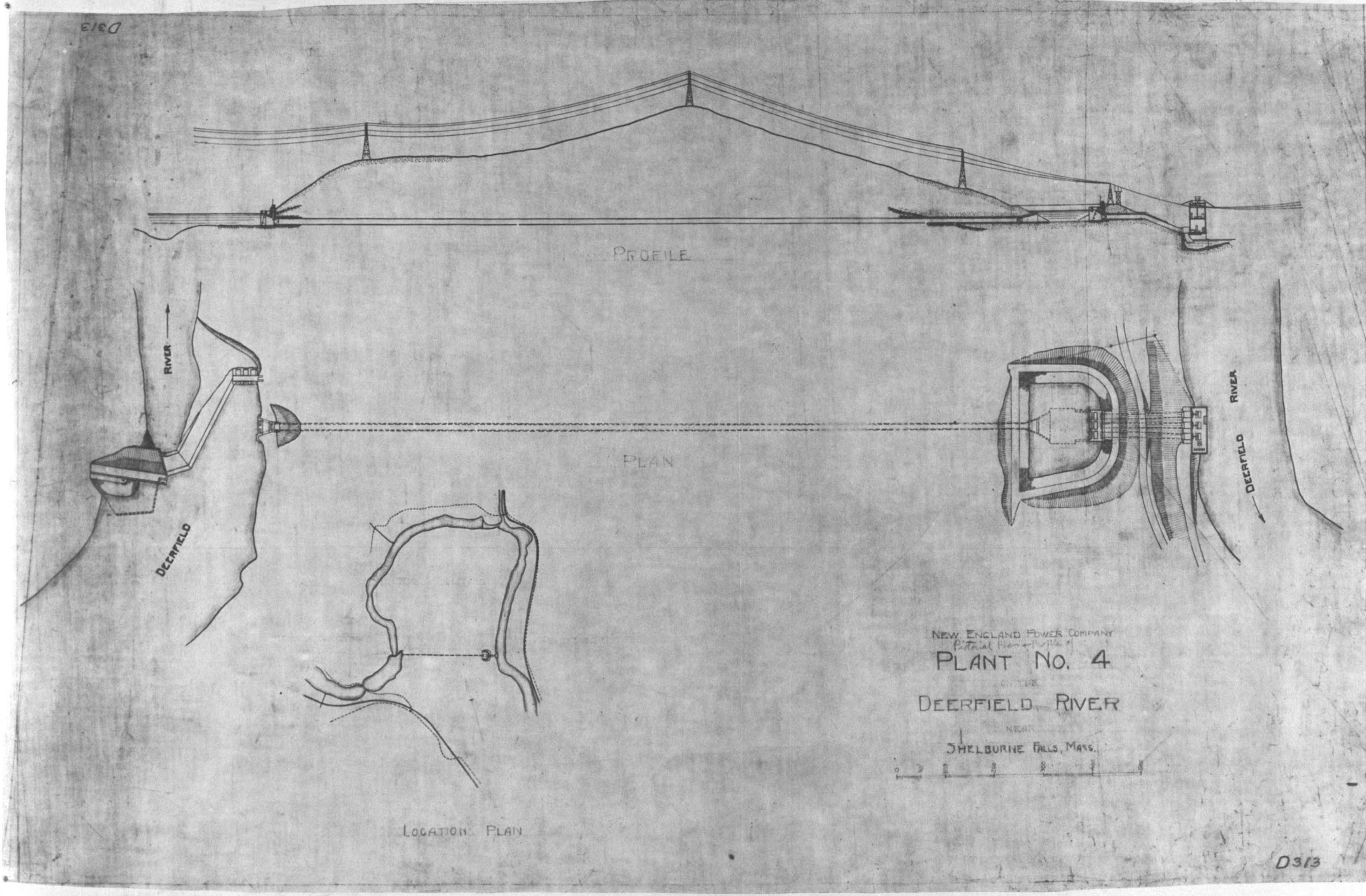
No. 3
Direction of Flow
Elev. 291.0
Back Fill
"Class B"
Old crib Dam
Ledge Rock
Ledge Rock
TYPICAL CROSS SECTION OF DAM.
SCALE 1 IN. = 5 FT.
Contours below old Dam show Ledge Rock.
Direction of Flow
Old Timber Dam to be entirely removed
"Class B"
Cut to El. 280
"Class B"
Elev. 300
"Class B"
"Class B"
Ledge Rock
Sta. 0+00
Sta. 1+00
Sta. 3+00
Sta. 4+00
Profile
Backfill
Reinforcement
"Class C"
Section-DD-
Anchor bolts for Gate Hoists
"Class A"
Reinforcement
"Class B"
Section-CC-
Old Wall
Old Wall
"Class A"
Section-BB-
Anchor bolts for Gate Hoist
"Class A"
"Class B"
Conduit
Intake
"Class A"
"Class C"
Conduit
Section-A-A-
See drawing D-152 which is enclosed.
0
25
50
Scale in Feet
DAM #3 SHELBURNE FALLS
HEADWORKS & CONDUIT
AUGUST 25, 1911


D-C-18
El. 320
300
280
260
Embankment
Rip Rap Class B
12 in Thick
Sect. 9+00
Center Line
Sect. 7+00
Sect. 12+00
Sect. 15+00
Backfill
Class "C" Concrete
Sect. 3+35
0 25 50
Scale in Feet.
Note:- Above Scale
Same for all
sections.
Test Pit
Center Line of Canal
FORK SHOP
MAIN
BUILDING
STOREHOUSE
CANAL
PRESS ROOM
FORGE
SHOP
OFFICE
SAW
ROOM
STOREHOUSE
SHED
See drawing
D-152
CANAL SECTIONS
PLAN OF CONDUIT AND
CANAL TO POWER HOUSE
PLANT # 3
0 50 100
Scale in Feet.

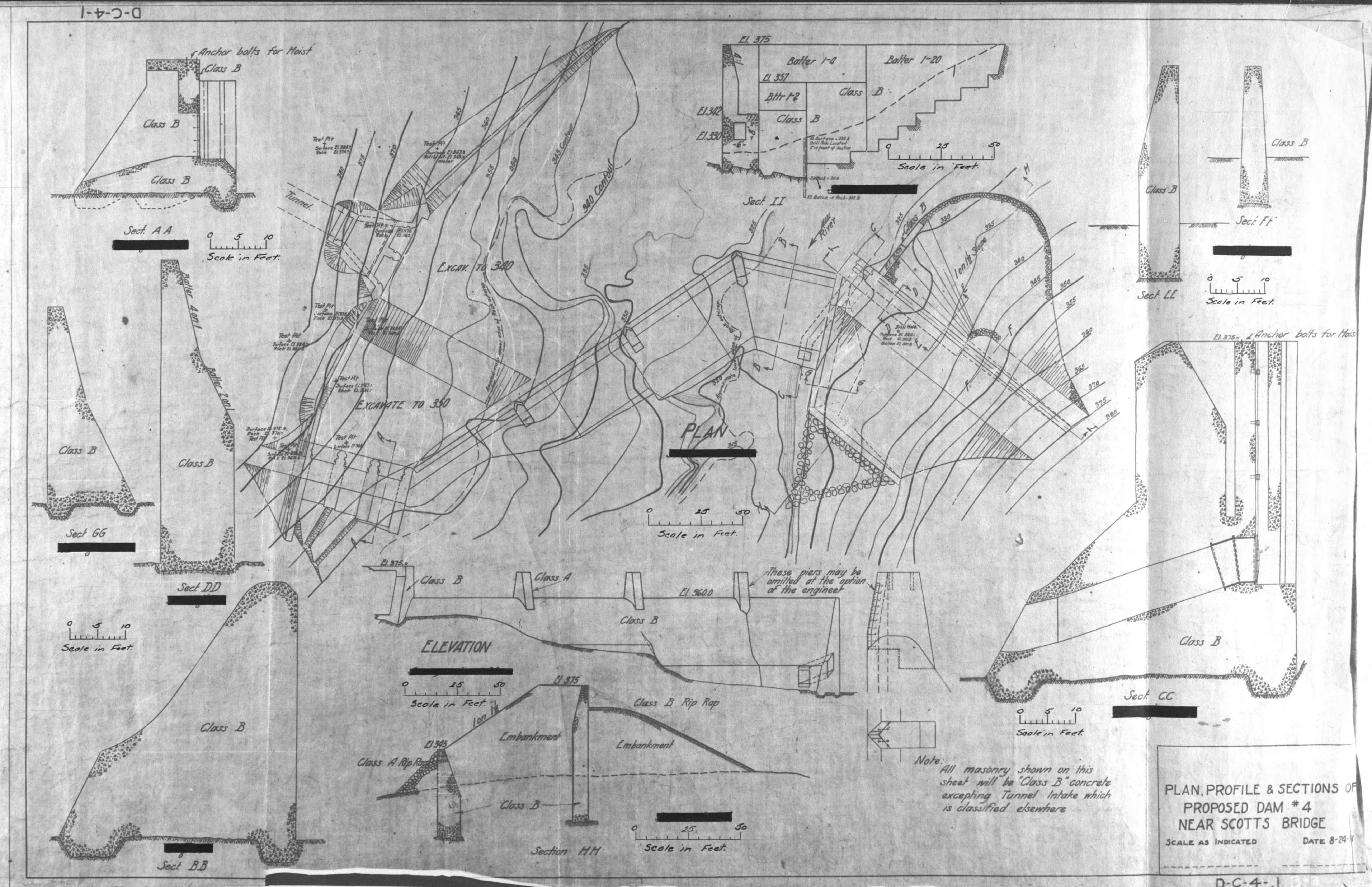

PLAN OF PLANT #3.
[redacted]
0 5 10
Scale in Feet.
SUPPLY ROOM
DAM
SUBMERGED AND SURFACE SLUICE
CONDUIT INTAKE PLANT #3
A
A
CONDUIT
PLAN
[redacted]
0 5 10
Scale in Feet.
FLOATING ICE SLUICE
MOVABLE CREST
SLUSH OR ANCHOR ICE SLUICE
Conduit to canal.
SECTION AA
[redacted]
0 5 10
Scale in Feet
Embankment
Scale in Feet.
0 10 20 30 40 50
CANAL CROSS SECTION
Sect. 12+00 - Sta. 6 to 15+25 - [redacted]
Class C Concrete
CLOSED CONDUIT
Sect. 3+35 - Sta. 0 to 6+1 - [redacted]
0 10 20 30 40 50
Scale in Feet.
Note: This view shows section of high-tension room at Plant #4 at Scott's Bridge. Different for Plant #3.
El. 293.8
Canal
CROSS-SECTION OF POWER HOUSE ON ℄ OF UNIT SHOWING HEADWORKS AND PENSTOCK.
[redacted]
0 5 10
Scale in Feet.
El. 227.8
Elev. 291.0
Direction of Flow
Old Crib Dam
Ledge Rock
Ledge Rock
TYPICAL CROSS SECTION OF DAM
[redacted]
0 5 10
Scale in Feet.
THE SHELBURNE FALLS PLANT (No. 3)
NEW ENGLAND POWER CO.
SHELBURNE FALLS, MASS, DEERFIELD, RIVER.
Scales as shown.

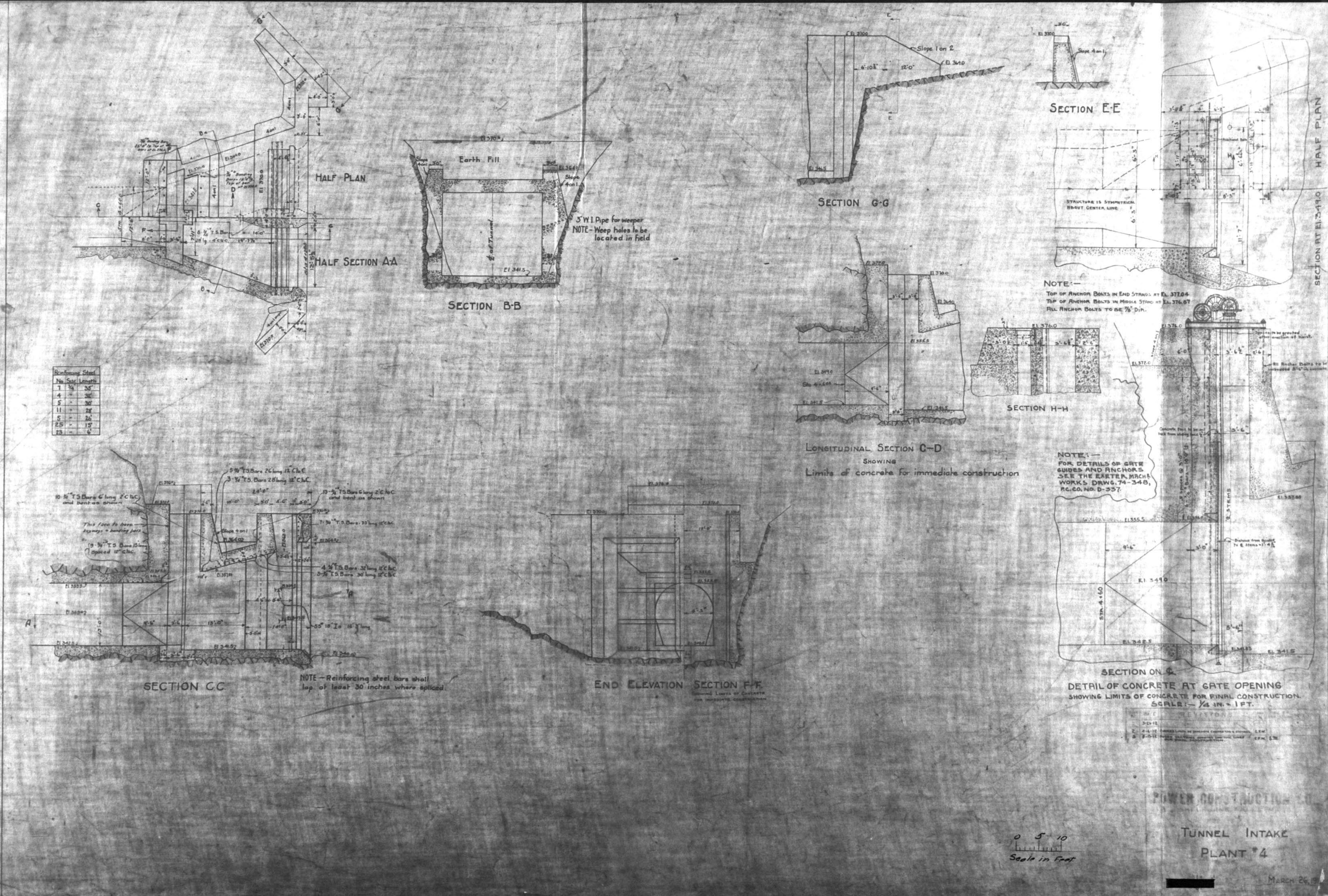

D-C-35-6
SECTIONAL PLAN THROUGH SPRINGING LINE OF ARCH
Vertical Building Joint
Building Joint
FRONT ELEVATION
Springing line of arch
Slope 6 on 1
Horizontal Building Joint
SECTION BB
Slope 2 on 1
Straight bars 12'-0" long
SECTION AA
Building Joint
SECTION DD
Springing line of Arch
Typical Horizontal Building Joint
Detail of 7/8" ⌀ Bent Bars for front wall of oil well.
SECTION E-E
SECTION CC
Elev. to be determined in field
NOTE:—
Class B Concrete in all walls which are over 4 ft. thick. Balance Class A Concrete.
Scale in Feet
NOTE:—
For Details of Substructure above Springing Line see Drwg. C-44.
CHANGED DIMENSIONS & ELEVATIONS
CHANGED DIMENSIONS OF FLOOR
POWER CONSTRUCTION CO.,
SHELBURNE FALLS, MASS.
FOUNDATION PLAN
FOR
POWER HOUSE NO. 3.
[redacted]
Drawing No. D-C-35-
Drawn by L.M.B.
D-C-35-6


D-C-44-13
HORIZONTAL SECTION AT EL. 244.17
TAIL-RACE ELEVATION
Finished Floor Line El. 244.5
Springing Line of Arches El. 235.0
SECTION A-A
PLAN
SECTION J-J
DETAIL OF GENERATOR PITS
SECTION C-C
Note:- Dot and dash lines indicate limit of trenches that are to be cut in concrete.
NOTE:- For Details of Substructure below Springing Line of Arches see Drwg. C-35.
SECTION ON ℄ OF MAIN UNIT NO. 2
SECTION B-B
SECTION F-F
SECTION H-H
SECTION D-D
SECTION E-E
SECTION G-G
SECTION M-M
SECTION K-K
SECTION L-L
NOTE:— Denotes holes to be filled with concrete after erection of turbines, laying of electrical conduits and oil and water pipes.
REVISIONS
Scale of Feet
PLAN & SECTIONS OF POWER HOUSE SUBSTRUCTURE ABOVE SPRINGING LINE OF ARCHES PLANT NO.3
[redacted]
DEC.18,1911.
D-C-44-13



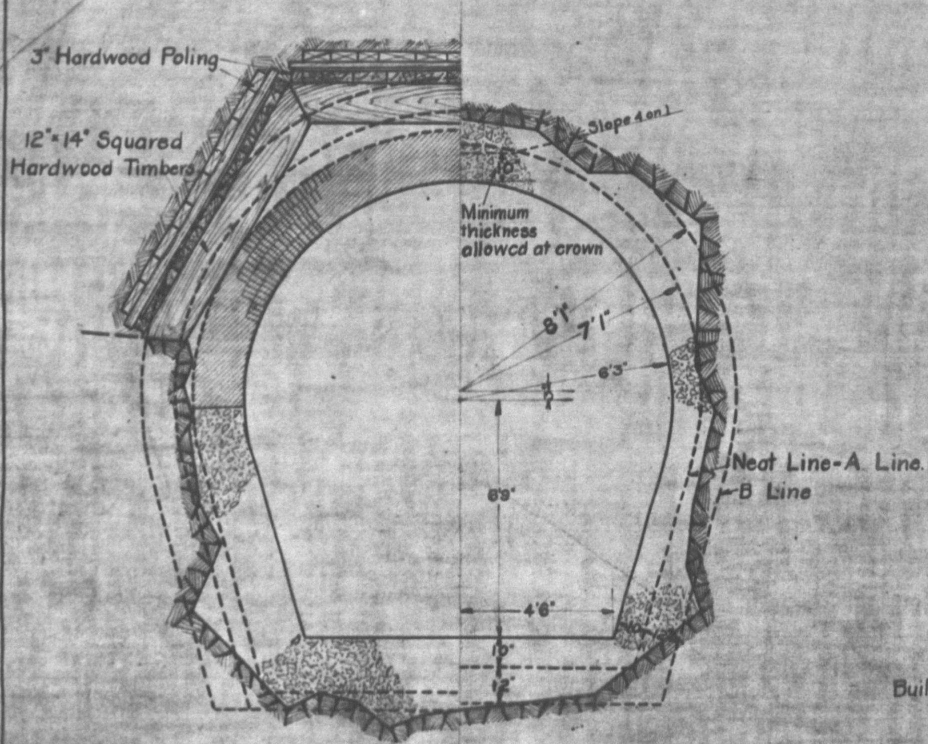
D313
PROFILE
RIVER
DEERFIELD
PLAN
RIVER
DEERFIELD
LOCATION PLAN
NEW ENGLAND POWER COMPANY
Pictorial Plan + Profile of
PLANT NO. 4
ON THE
DEERFIELD RIVER
NEAR
SHELBURNE FALLS, MASS.
D313


D-C-4-1
Anchor bolts for Hoist
Class B
Class B
Class B
Sect. A A
[redacted]
Scale in Feet.
0 5 10
Batter 4 on 1
Batter 2 on 1
Class B
Class B
Sect. GG
[redacted]
Sect. DD
[redacted]
Scale in Feet.
0 5 10
Tunnel
Test Pit
EXCAV. TO 340
EXCAVATE TO 350
345 Contour
340 Contour
PLAN
[redacted]
Scale in Feet.
0 25 50
El. 375
Batter 1-4
Batter 1-20
El. 357
Bttr 1-2
Class B
Class B
El. 342
El. 330
Scale in Feet
0 25 50
[redacted]
Sect. II
River
1 on 1½ Slope
Class B
Class B
Sect. FF
[redacted]
Sect. EE
Scale in Feet.
0 5 10
El. 375
Anchor bolts for Hoist
Class B
Sect. CC
[redacted]
Scale in Feet.
0 5 10
El. 375
Class B
Class A
El. 360.0
Class B
These piers may be omitted at the option of the engineer
ELEVATION
[redacted]
Scale in Feet.
0 25 50
El. 375
1 on 1½
Class B Rip Rap
Embankment
Embankment
El. 345
Class A Rip Rap
Class B
Section HH
[redacted]
Scale in Feet.
0 25 50
Class B
[redacted]
Sect. BB
Note:
All masonry shown on this sheet will be "Class B" concrete excepting Tunnel Intake which is classified elsewhere
PLAN, PROFILE & SECTIONS OF
PROPOSED DAM #4
NEAR SCOTTS BRIDGE
SCALE AS INDICATED
DATE 8-24-
D-C-4-1


HALF PLAN
HALF SECTION A-A
Earth Fill
3" W.I. Pipe for weeper
NOTE - Weep holes to be located in field
SECTION B-B
Slope 1 on 2
SECTION G-G
SECTION E-E
Structure is symmetrical about center line
HALF PLAN
SECTION AT El. 349.0
NOTE: —
Top of Anchor Bolts in End Stems at El. 377.04
Top of Anchor Bolts in Middle Stem at El. 376.87
All Anchor Bolts to be 7/8" Dia.
SECTION H-H
LONGITUDINAL SECTION C-D
SHOWING
Limits of concrete for immediate construction
NOTE: —
For details of gate guides and anchors see the Exeter Mach. Works Drwg. 74-348, P.C. Co. No. D-337.
Reinforcing Steel
SECTION CC
NOTE - Reinforcing steel bars shall lap at least 30 inches where spliced.
END ELEVATION SECTION F-F
SECTION ON ℄
DETAIL OF CONCRETE AT GATE OPENING
SHOWING LIMITS OF CONCRETE FOR FINAL CONSTRUCTION.
SCALE: — 1/4 IN. = 1 FT.
0 5 10
Scale in Feet
POWER CONSTRUCTION CO.
TUNNEL INTAKE
PLANT #4

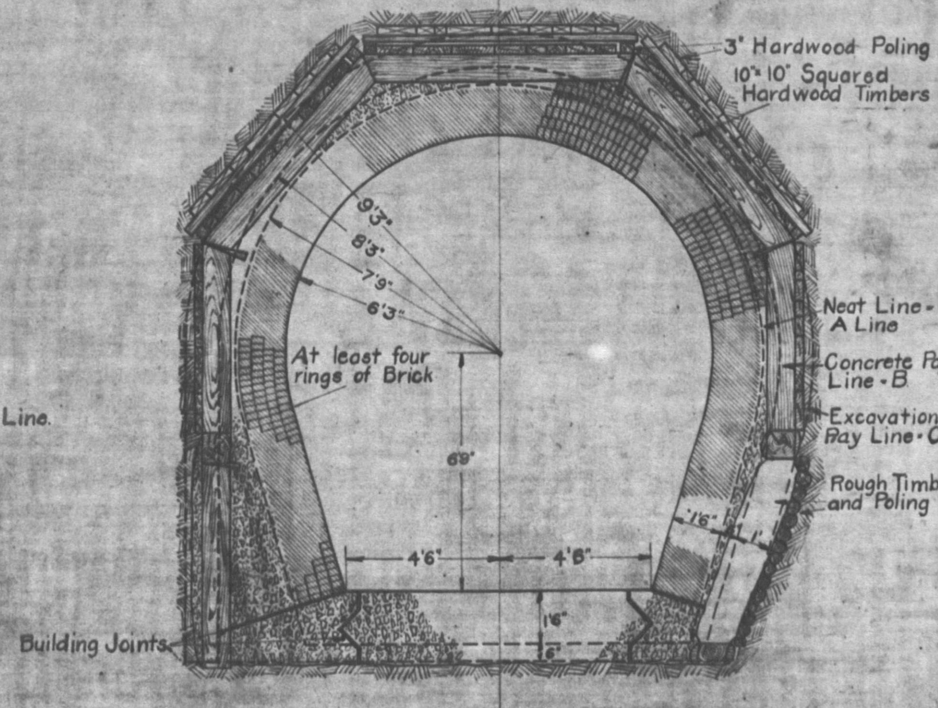
REVISIONS
2. 2/4/13 Corrected Pay Lines in Earth C.R.B.

D-164
C.R. Bliss
C.R. Bliss

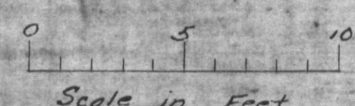


TYPICAL SECTIONS

THRU EARTH AND ROCK — THRU ROCK



TYPICAL SECTION THRU EARTH

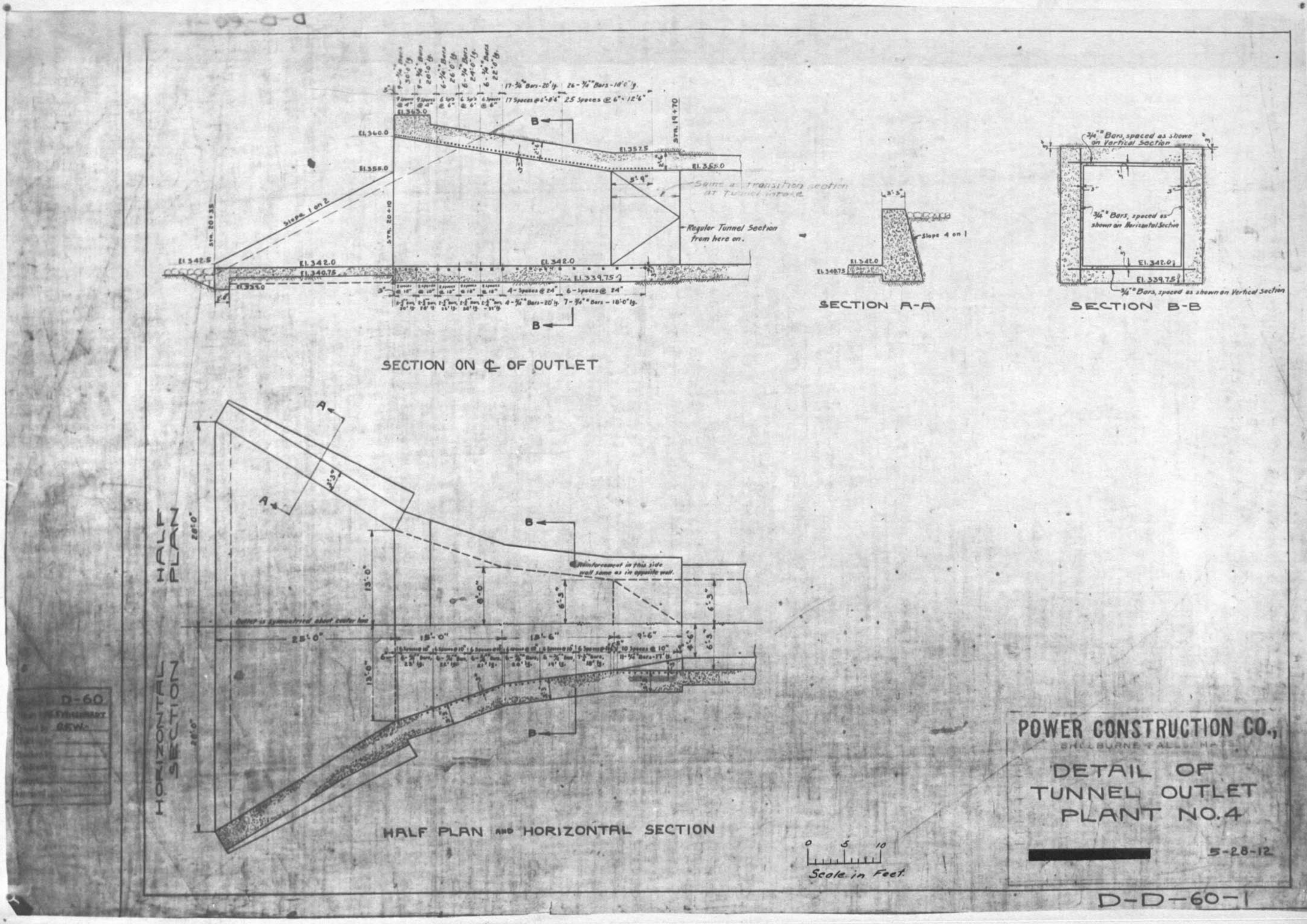


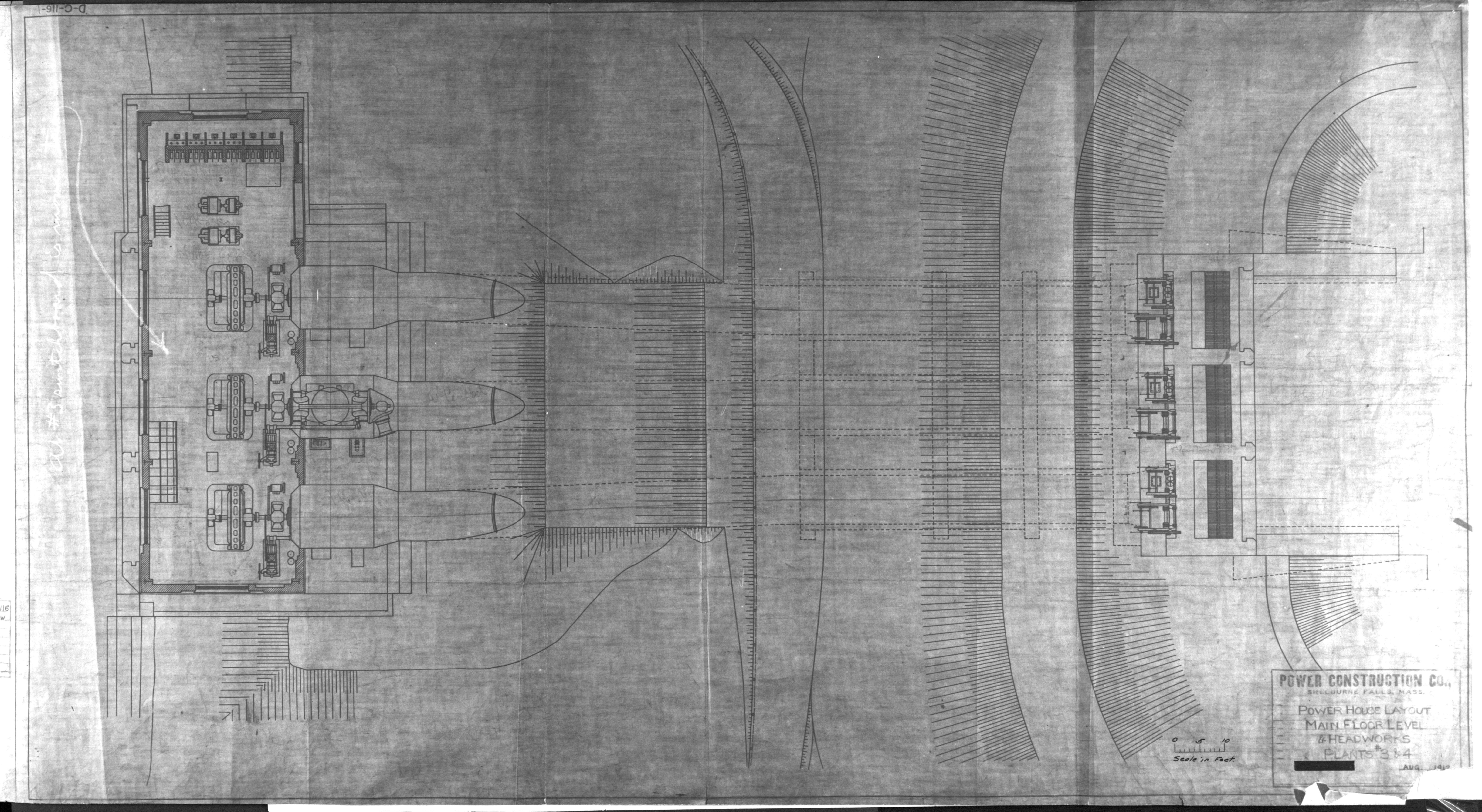
POWER CONSTRUCTION CO.,
SHELBURNE FALLS, MASS.

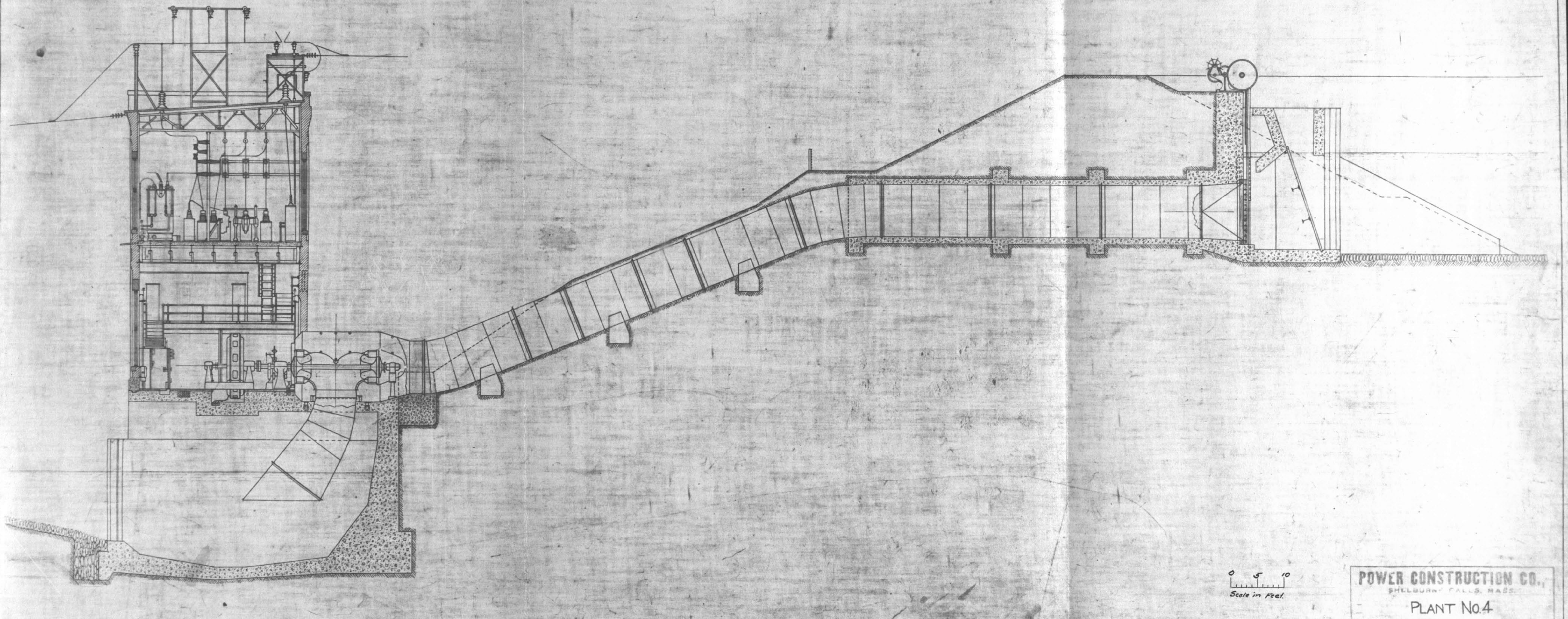
TYPICAL CROSS-SECTIONS OF TUNNEL PLANT NO. 4

[redacted]

FEB. 21, 1913


D-D-60-1
SECTION ON ℄ OF OUTLET
SECTION A-A
SECTION B-B
HALF PLAN
HORIZONTAL SECTION
HALF PLAN AND HORIZONTAL SECTION
Slope 1 on 2
Slope 4 on 1
Regular Tunnel Section from here on.
Same as transition section at Tunnel intake
El. 340.0
El. 342.0
El. 339.75
El. 342.5
El. 340.75
STA. 20+10
STA. 20+35
STA. 19+70
3/4" Bars, spaced as shown on Vertical Section
3/4" Bars, spaced as shown on Horizontal Section
Reinforcement in this side wall same as in opposite wall.
Outlet is symmetrical about center line
4 - Spaces @ 24"
6 - Spaces @ 24"
17 Spaces @ 6" = 8'6"
25 Spaces @ 6" = 12'6"
22'-0"
18'-0"
18'-6"
9'-6"
28'-0"
13'-0"
8'-0"
6'-3"
Scale in Feet
0 5 10
D-60
POWER CONSTRUCTION CO.,
SHELBURNE FALLS, MASS.
DETAIL OF
TUNNEL OUTLET
PLANT NO. 4
[redacted]
5-28-12


D-C-116-1
0 5 10
Scale in Feet.
POWER CONSTRUCTION CO.,
SHELBURNE FALLS, MASS.
POWER HOUSE LAYOUT
MAIN FLOOR LEVEL
& HEADWORKS
PLANTS #3 & 4
[redacted]
AUG. 191



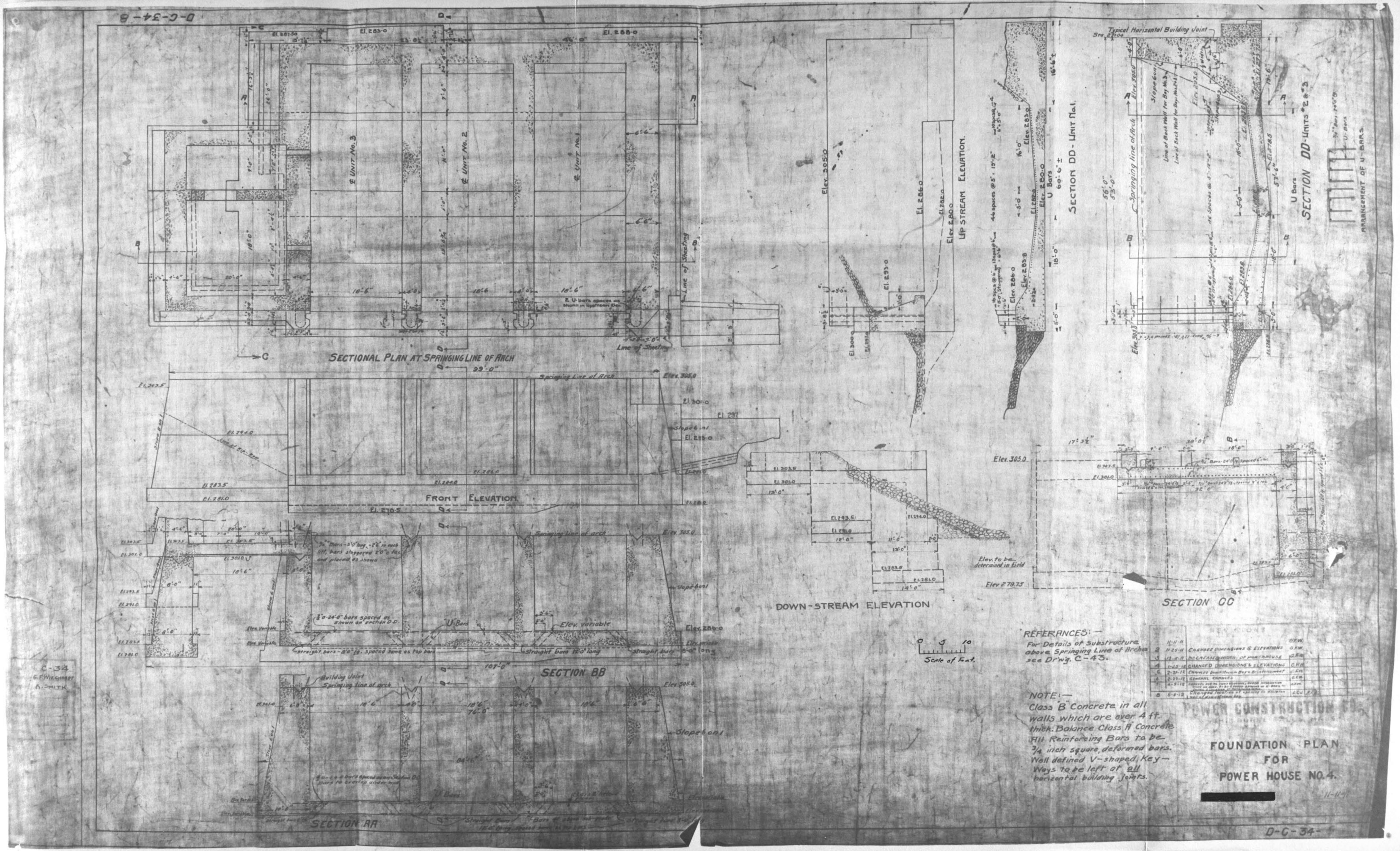
POWER CONSTRUCTION CO.,
SHELBURNE FALLS, MASS.

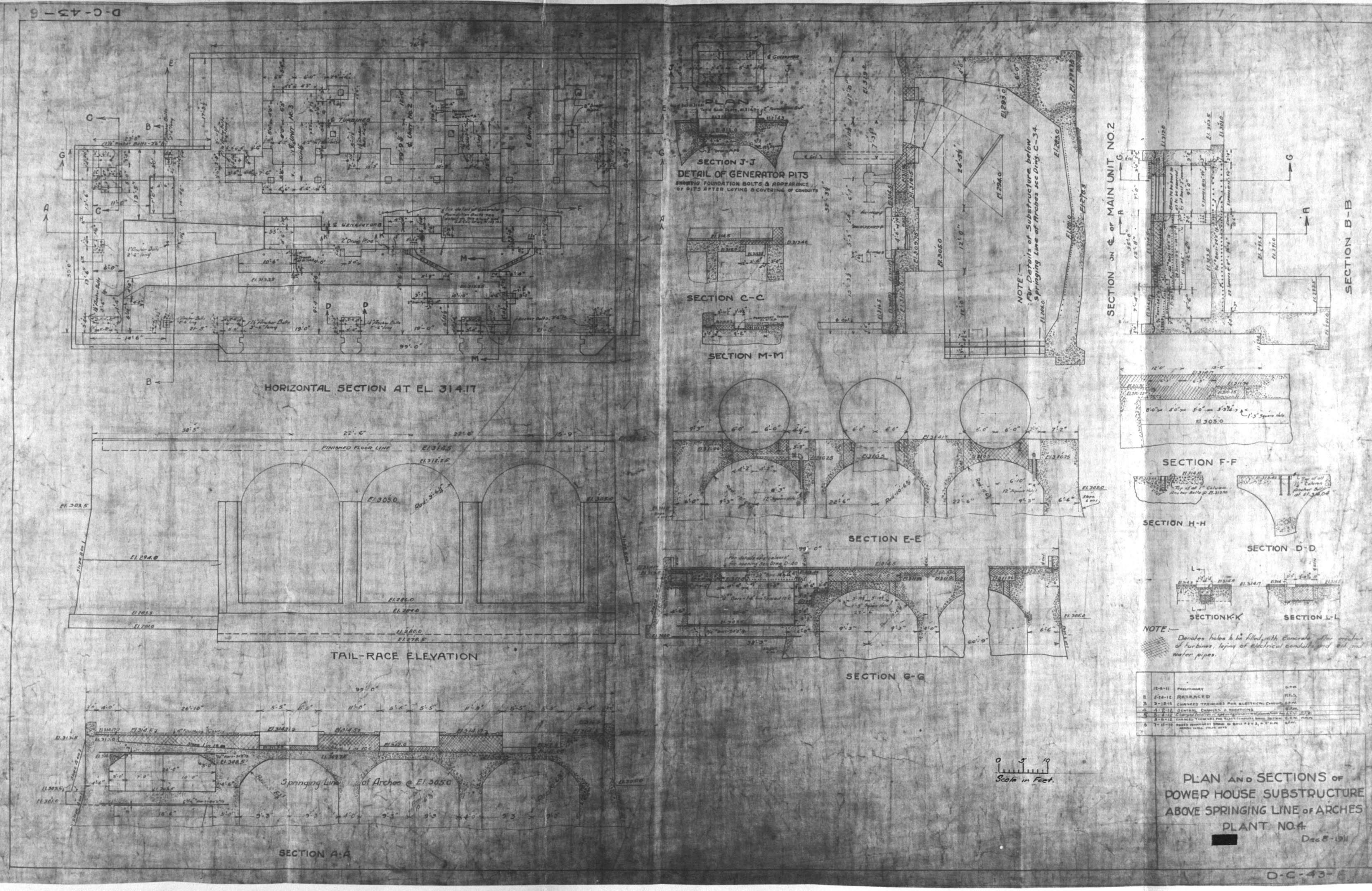
PLANT No.4

CROSS-SECTION OF POWER HOUSE ON CENTER LINE OF UNIT SHOWING HEADWORKS AND PENSTOCK

[redacted]

AUG. 1912


D-C-34-8
SECTIONAL PLAN AT SPRINGING LINE OF ARCH
℄ UNIT No. 3
℄ UNIT No. 2
℄ UNIT No. 1
Line of Sheeting
FRONT ELEVATION
Springing Line of Arch
SECTION BB
SECTION AA
UP STREAM ELEVATION
SECTION DD - UNIT No. 1
SECTION DD - UNITS #2 & 3
ARRANGEMENT OF U-BARS
Typical Horizontal Building Joint
DOWN-STREAM ELEVATION
SECTION CC
Elev. to be determined in field
Scale of Feet
REFERANCES: —
For Details of Substructure above Springing Line of Arches see Dr'w'g. C-43.
NOTE: —
Class "B" Concrete in all walls which are over 4 ft. thick. Balance Class "A" Concrete.
All Reinforcing Bars to be 3/4 inch square, deformed bars.
Well defined V-shaped Key-Ways to be left at all horizontal building joints.
2 11-25-11 CHANGED DIMENSIONS & ELEVATIONS G.F.W.
3 12-6-11 DECREASED WIDTH OF POWER HOUSE G.F.W.
4 1-25-12 CHANGED DIMENSIONS & ELEVATIONS C.R.B.
5 2-21-12 CHANGED Downstream Bay & Reinforcement G.F.W.
6 2-27-12 GENERAL CHANGES G.F.W.
POWER CONSTRUCTION CO.
FOUNDATION PLAN FOR POWER HOUSE NO. 4.
[redacted]
11-11-11
D-C-34-


D-C-43-6
HORIZONTAL SECTION AT EL. 314.17
TAIL-RACE ELEVATION
FINISHED FLOOR LINE
SECTION A-A
Springing Line of Arches @ El. 305.0
SECTION J-J
DETAIL OF GENERATOR PITS
SHOWING FOUNDATION BOLTS & APPEARANCE OF PITS AFTER LAYING & COVERING OF CONDUITS
SECTION C-C
SECTION M-M
NOTE:- For Details of Substructure below Springing Line of Arches see Dwg. C-34.
SECTION ON ℄ OF MAIN UNIT NO. 2
SECTION B-B
SECTION E-E
SECTION G-G
SECTION F-F
SECTION H-H
SECTION D-D
SECTION K-K
SECTION L-L
NOTE:- Denotes holes to be filled with Concrete after erection of turbines, laying of electrical conduits and oil and water pipes.
Scale in Feet.
PLAN AND SECTIONS OF POWER HOUSE SUBSTRUCTURE ABOVE SPRINGING LINE OF ARCHES
PLANT NO. 4
[redacted]
Dec 8 1911
D-C-43-

A P P E N D I X G

TRACINGS

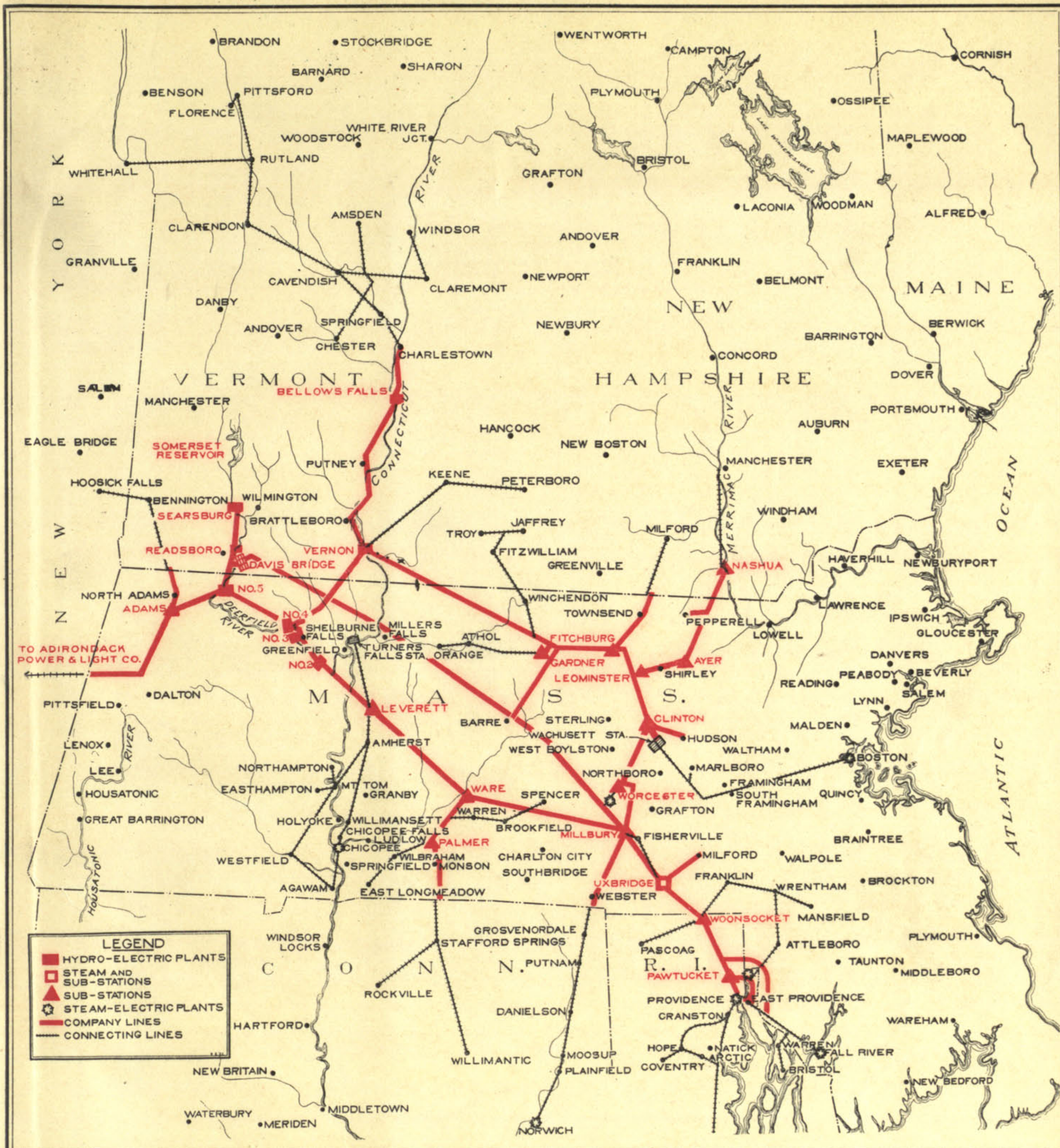
CROSS SECTIONS OF DAM
OF
PLANT NO. 4

SCALE ⅛" = 1'-0"

BY

NATHAN GINSBURG   HARRY GOODMAN

MAY, 1924.

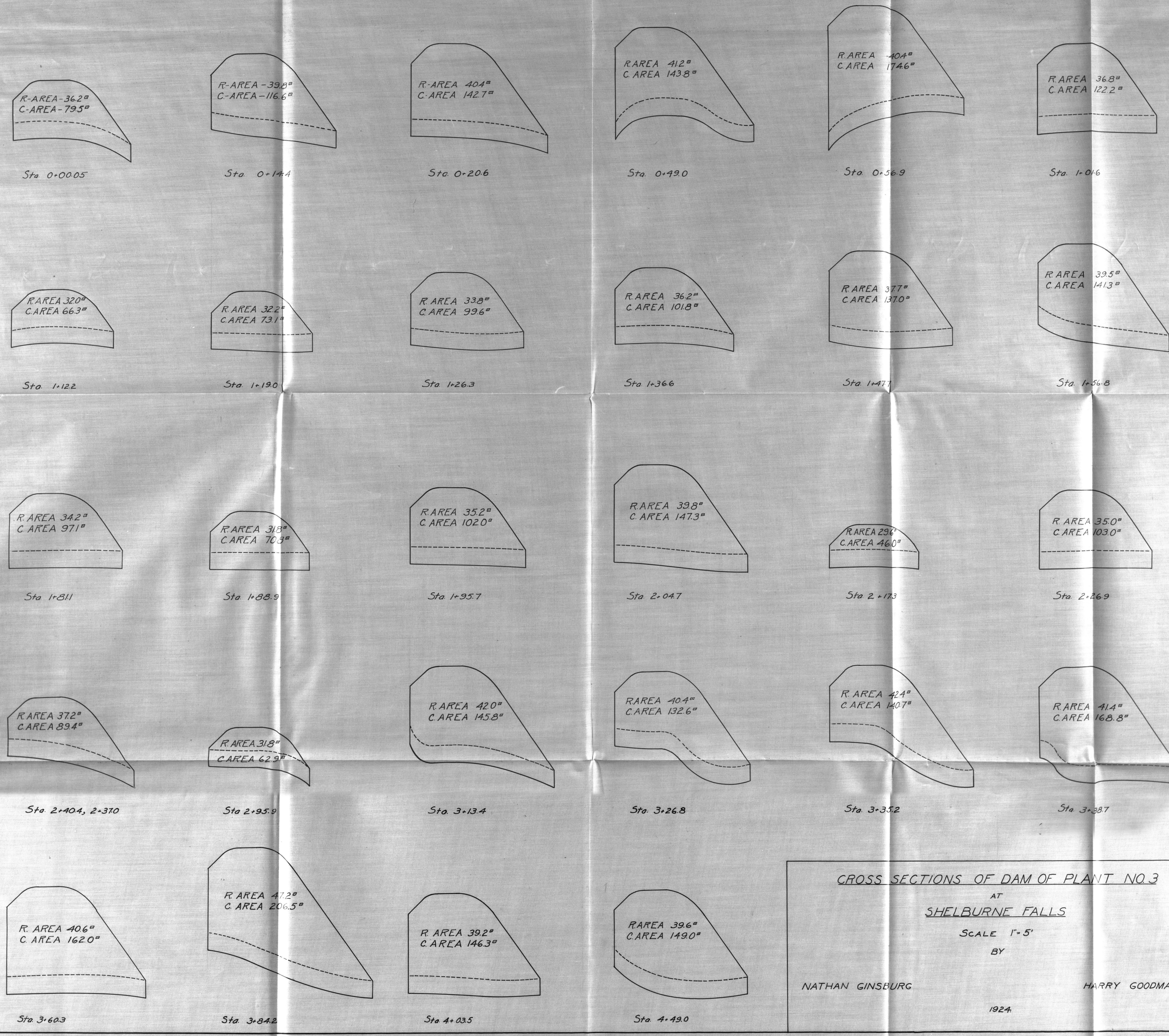


LINES OF THE

NEW ENGLAND POWER SYSTEM

AND CONNECTING LINES

1923



CROSS SECTIONS OF DAM OF PLANT NO. 3

AT

SHELBURNE FALLS

SCALE 1" = 5'

BY

NATHAN GINSBURG HARRY GOODMAN

1924


380 sq. ft.
104 sq. ft.
308 sq. ft.
STA. 6+00.0
420 sq. ft.
100 sq. ft.
776 sq. ft.
STA. 6+31.0
576 sq. ft.
84 sq. ft.
876 sq. ft.
STA. 7+00.0
684 sq. ft.
80 sq. ft.
676 sq. ft.
STA. 8+00.0
720 sq. ft.
68 sq. ft.
640 sq. ft.
STA. 9+00.0
808 sq. ft.
104 sq. ft.
756 sq. ft.
STA. 10+00.0
860 sq. ft.
176 sq. ft.
680 sq. ft.
STA. 11+00.0
980 sq. ft.
152 sq. ft.
652 sq. ft.
STA. 12+00.0
1132 sq. ft.
252 sq. ft.
544 sq. ft.
STA. 13+30.0
1192 sq. ft.
220 sq. ft.
572 sq. ft.
STA. 13+00.0
1356 sq. ft.
396 sq. ft.
276 sq. ft.
STA. 14+00.0
1168 sq. ft.
1200 sq. ft.
672 sq. ft.
STA. 15+00.0
NOTE:
Sta. 13+30.0 is on oblique section.
CROSS SECTIONS OF CANAL AT PLANT NO 3
SHELBURNE FALLS
SCALE 1"=20'
HARRY GOODMAN
NATHAN GINSBURG
MAY, 1924.