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ROCHESTER CONTROL STRUCTURE 46

SIPHON RISER STRUCTURE

MODEL STUDIES

by

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Conducted for

ERDMAN, ANTHONY, ASSOCIATES
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and

HARZA ENGINEERING COMPANY
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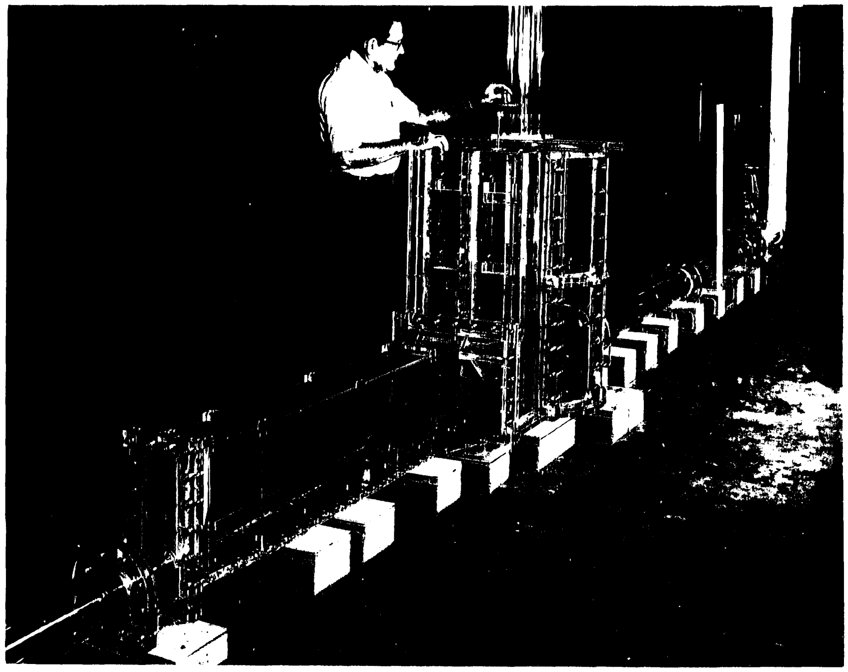

Frontispiece 1 - Type CS46 control structure. The initial low model.

Frontispiece 2 - Type CS46 R10 control structure. The overall model.

PREFACE

In most large metropolitan areas the problems of handling storm water and sanitary sewage have increased severely. The City of Rochester, New York, has developed a solution unique to its particular problems and topographic features called the Combined Sewer Overflow Abatement Program (CSOAP). The CSOAP is a comprehensive project that includes numerous conventional dropshafts, control structures, and several combined surge and dropshaft structures. Previous model studies at the St. Anthony Falls Hydraulic Laboratory for Rochester, New York, were concerned with the development of optimum designs for these various structures. The project also includes some special control structures, each unique in regards to physical geometry, purpose, and operating procedures. One of these is Control Structure 46 (CS46) on the St. Paul Boulevard Tunnel System which is a major sub-system of CSOAP. Erdman, Anthony Associates is the designer of the St. Paul Boulevard system and CS46 which is a multi-purpose structure with four modes of operation: filling, siphoning, drawdown, and flushing. A complex control structure like CS46 has not been model tested previously, although many features developed previously in the Rochester model studies indicated above have been incorporated into the CS46 structure. **Rochester Control Structure 46 Model Studies** were conducted at the St. Anthony Falls Hydraulic Laboratory to develop an optimum design that would satisfy the requirements of the four modes of operation. To study the problems associated with CS46 a 1:12 scale model was constructed at the Laboratory.

The model tests described in this report were conducted for Erdman, Anthony, Associates of Rochester, New York, and Harza Engineering Company of Chicago, Illinois. The model tests were sponsored by the Rochester Pure Waters District, Monroe County, New York, Department of Engineering. During the course of the model studies, several meetings were held at the St. Anthony Falls Hydraulic Laboratory and attended by representatives of the above organizations and the Laboratory. Various aspects of the project were discussed, the model testing program outlined, the model demonstrated extensively, and the results interpreted and reviewed.

Karl Nesbeitt, Senior Hydraulic Engineer of Harza Engineering Company; and Kenneth Avery and Monica Cheng, Hydraulic Engineers of Erdman, Anthony, Associates, were the principal coordinators between the Laboratory and the above organizations. The study was under the immediate direction of Warren Dahlin, Scientist, and tests were conducted by Karen Lindblom, Research Fellow. The sediment scaling problem was analyzed and the program developed by Dr. Gary Parker. A silent-color motion picture summarizing the model studies was prepared by Warren Dahlin and Karl Wikstrom. Various aspects of the project were reviewed by Joseph Wetzel, Assistant Director, of the Laboratory This final report summarizes the model program and the test results.

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I. INTRODUCTION

The City of Rochester, New York, is developing the Combined Sewer Overflow Abatement Program (CSOAP) to handle sanitary sewage and storm water. The system includes many conventional dropshafts which transport the water collected in surface conduits to the storage and conveyance tunnels at a lower elevation beneath the ground surface. At several locations where surge shafts are near conventional dropshafts the two structures are combined. These combined surge and dropshaft structures have a dual purpose of conveying water from the ground level to the underground tunnels and relieving surge pressures in the system. Located throughout the system are control structures to regulate and divert the flow as required. One of these structures is designated as control structure 46 (CS46).

The structure is to be located near the Van Lare treatment plant at the end of the three-mile long siphon tunnel. This is also the downstream terminus of the 22 mile tunnel system. The primary purpose of the structure is to raise flows coming in through the siphon tunnel and direct them to a distribution structure at the head of the Van Lare treatment plant. The configuration of the structure in this siphon mode is intended to maximize the transport of sediment entering through the siphon tunnel, up the siphon riser, and through the bifurcation structure. Since it will be difficult to remove all the sediment in the siphon mode, the structure will be operated in the flushing mode. In this mode, supercritical flows will pass straight through the structure and enter a tunnel to the Cross-Irondequoit pumping station. The effectiveness of the structure in transporting sediment is one of the major concerns in the operation of CS46.

The complex structure is required to operate satisfactorily through four modes of operation. The four modes of operation are:

1. Filling the St. Paul Boulevard siphon tunnel and CS46.

2. Full siphon operation through CS46 to the Frank E. Van Lare Treatment Plant.

3. Transition drawdown of CS46 from siphon operation to Flushing mode.

4. Tunnel flushing to the Cross-Irondequoit pump station with supercritical flow through CS46.

The relationship of these various facilities is shown on Chart 1. A structure like CS46 has not been modeled previously and the complex operating conditions necessitated model studies to optimize the geometry of the structure to satisfy the requirements of the four operating modes.

Because of the complex model and to expedite the model program, the 1:12 model was constructed in two stages. Initially the so-called low model as shown in Frontispiece 1 was fabricated and installed at the model site. While this low model was being tested for the through-flow flushing mode of operation, the components of the surge shaft and upper bifurcation structure were being fabricated in the laboratory shops. These were installed later to complete the model as shown in Frontispiece 2. As it turned out, the low model required extensive revisions to keep the flushing flow supercritical, and these revisions were advantageously completed while the upper structure was being fabricated.

Charts 2, 3, and 4 show details of the structure. The 7-ft circular siphon tunnel conveys the flow to CS46 and the flow enters the 25-ft diameter surge shaft through a transition. With the flushing gate at the bottom and the head breaker gates closed, the surge shaft and siphon riser will fill up. The siphon riser is a vertical 6-ft circular pipe with a bellmouth at the bottom and ending in an elbow at the top. The bellmouth is spaced 2.75 ft up from the invert at elevation 229.0 ft to provide clearance for the flushing flow. When sufficient head is reached, the water will be forced up and over the top elbow of the siphon riser into the bifurcation structure. The bifurcation structure is not shown on Chart 2. The invert of the surge shaft is channelized to improve transport of sediment and the shaft is about 130-ft high.

To divert from the siphon mode to the flushing mode the following procedure is followed. The incoming flow is turned off, and the siphon tunnel and surge shaft drawn down by opening the head breaker gates in succession, that is starting with one at the top and ending up at eight on the bottom as shown on Chart 4. By opening the gates in succession and drawing down the water level to the next gate before opening it, the head on the open gate is kept to an acceptable maximum of about 12 ft. When the water level has reached gate 8 at elevation 241 ft, the flushing gate can be opened under a relatively low head and the flushing mode started. The flow jets through the head breaker gates into two-parallel vertical dropshafts, each having a slotted divider wall between the falling water-air mixture and the air vent which returns the collected air to the surface. The slots provide for pressure relief in the air vent and the re-entrainment of some air to reduce impact pressures on the invert. The flow from the dropshaft passes through a converging section or boot to the 6-ft wide deaeration chamber. The dropshaft and boot invert have low side slopes to contain and channelize the flushing flow. The deaeration chamber contains a false crown with air slots for air removal.

Above the false crown, an air chamber guides the collected air to the vertical air shaft. The effectiveness of the deaeration chamber configuration in removing the entrained air, was demonstrated in the earlier Rochester dropshafts model studies and not repeated in this study. Therefore the false crown was not modeled. In the rare event that the flow would be backed up for some reason in the prototype, the air slots would provide for air collection. At the downstream end of the deaeration chamber a transition from a rectangular section to an arch and a transition from the arch to the 4-ft circular flushing tunnel was provided.

All tests in the CS46 model studies were made with the tailwater uncontrolled; that is, no valve was installed at the downstream end of the model as in previous models to cause resistance to the flow, and hopefully the flow would be supercritical for flushing purposes.

During the course of the model studies on the low model, nine revisions were made to the low model to develop a structure through which the flushing flow would remain supercritical. These revisions are outlined on Charts 5 through 14. Type CS46 R9 (Charts 13 and 14) was the optimum design developed in the low model to sustain supercritical flow. The upper sections of the surge shaft and siphon riser were added to this low model bringing the structure to the full height of about 130 ft. The upper elbow turns the flow rising up the surge shaft 90° into a short-level section of pipe that conveys the flow through the wall of the surge shaft into the bifurcation structure. The purpose of the bifurcation structure is to regulate the outflow to either or both of the two 6 ft outlet conduits to Van Lare. The centerline of the bifurcation structure is at an angle of 68° with the centerline of the lower structure. The geometry of the upper part of the structure is shown on Charts 15 through 17. The complete model shown in Frontispiece 2 was designated as Type CS46 R10 and consists of the CS46 R9 low model with the upper structure added. Type CS46 R11 is the same as R10 with the bellmouth spacing from the invert raised from 2.75 ft (R10) to 3.25 ft (R11).

Photographic documentation included still photos, motion pictures, color slides, and video tapes. These proved to be excellent methods of recording the overall hydraulic characteristics of the structures, the air entrainment and release mechanisms, and the transport and deposition of sediment. On design types that were not hydraulically acceptable, documentation was limited to the visual observations and photography. For hydraulically acceptable designs more detailed documentation was made which included the recording of water surface profiles, static pressures, hydraulic gradelines, fluctuating pressures on the bellmouth, and extensive sediment tests.

In both the prototype and the model, gravity is the predominant motion-producing force. For this type of system the greatest degree of dynamic similarity is obtained when the model-prototype relationships are established by the Froude law. The following expressions were used to convert dimensions and hydraulic quantities from model to prototype or vice versa. The letter L is the length in ft, Q the discharge in cfs, V the velocity in fps, P the pressure head in ft, T the time, and f the frequency. The subscripts m and p refer to model and prototype, respectively, and the subscript r denotes the ratio of model to prototype.

Quantity	Ratio	Scale Relation
Length, L	$L_r = L_m / L_p$	1:12
Discharge, Q	$Q_r = L_r^{5/2}$	1:498.8
Velocity, V	$V_r = L_r^{1/2}$	1:3.464
Pressure, P	$P_r = L_r$	1:12
Time, T	$T_r = L_r^{1/2}$	1:3.464
Frequency, f	$f_r = 1/L_r^{1/2}$	1:0.2887

For example, if the velocity in the model is 1.0 ft/sec, the corresponding velocity in the prototype will be 3.464 ft/sec.

Complete similarity for the air entrainment and air removal processes cannot in general be obtained because the mechanism of entrainment, the size of bubbles, and the relative movement of the bubbles through the water are subject to forces other than gravity and depend more on such forces as surface tension and viscosity. However, the model is believed to be sufficiently large, such that the processes employed in the model experiments are quite similar to those expected in the prototype. It is believed that the observations made in the model regarding the flow characteristics of the aerated mixture will be qualitatively correct.

II. CONCLUSIONS

1. For necessary sediment transport and flushing of control structure 46, the flushing flow must be supercritical. Hydraulic jumps formed resulting in subcritical flow, making the Type CS46 design unacceptable.

2. Although a slightly lower depth of flow occurred through the structure for Type CS46 R1 control structure, the flow was subcritical as hydraulic jumps still formed, making this type unacceptable.

3. The stabilized flow through the Type CS46 R2 control structure was still subcritical and a sediment test showed that the structure would not be flushed out. Therefore, this type is not acceptable.

4. Although some improvement was noted in the hydraulic characteristics due to increased channelization of the invert for the Type CS46 R3 control structure, the flow still went subcritical making this type unacceptable.

5. Considerable improvement in the flow pattern was observed in the Type CS46 R4 control structure. The depth of flow was less in the surge shaft and still subcritical. Through the drop structure and the rest of the structure the flow remained supercritical. In a sweepout test, when an obstruction placed in the exit conduit to cause subcritical flow was removed, the flow characteristics reverted to the original conditions. Two sediment tests were made that indicated fairly good sediment transport. Although considerable improvement was achieved in the Type CS46 R4 design, it was concluded that more should be done in the area of the surge shaft invert and flushing gate.

6. The flow characteristics for the Type CS46 R5 control structure were similar to those for R4, and it was again concluded that improvements could be made.

7. The flow through Type CS46 R6 control structure remained supercritical, and clear of the bellmouth for all flows from 16 cfs to 125 cfs. This design is hydraulically acceptable for flushing flows, but further refinements are necessary so that the structure will satisfy all the necessary requirements through the four modes of operation.

8. The flow through the Type CS46 R7 control structure is quite similar to that for R6. The open channel supercritical flows were observed to be fairly smooth throughout the model, free of any hydraulic jumps, and had only mild surface disturbances in the contoured areas beneath the bellmouth. Sweepout tests were good for all flows from 16 to 100 cfs. At 125 cfs a hydraulic jump formed in the transition upstream of the surge shaft and persisted until the bellmouth was raised 0.3 ft. Sediment tests showed this design to be excellent in sediment transport.

9. The flow through the Type CS46 R8 control structure is similar to that for R7. The revised section of the flushing tunnel had very little effect on the flow pattern through the structure, and it was decided to include this in the overall design geometry.

10. The flow through the Type CS46 R9 control structure is similar to that for R8 and R7. For all flushing discharges from 16 through 125 cfs, the flow was supercritical, free of hydraulic jumps, and only had mild surface disturbances. Sweepout tests were excellent for all discharges up to and including 100 cfs. Sediment transport through the structure was also excellent. Type CS46 R9 is the optimum design developed in the low model to meet the requirements of the flushing mode of operation. The hydraulic performance of this control structure design is excellent.

11. The hydraulic performance of the Type CS46 R10 control structure was excellent through all four modes of operation: filling, siphon, drawdown, and flushing. The flushing mode had been extensively tested before as Type CS46 R9. The performance of the surge shaft, siphon riser, and bifurcation structure was excellent for the proposed initial design and no revisions were necessary. The visual observations, water surface profiles, piezometric pressures, and sediment tests all show the structure to be hydraulically acceptable. Siphon bell loadings do not seem excessive and should be considered in the design of the support of the siphon riser bellmouth. Injection of air into the siphon tunnel for odor and hydrogen sulfide control is not recommended as the air pockets travel upstream and would eventually reach structure 243.

12. Although the Type CS46 R11 shows a slight advantage in the flushing mode with its higher bellmouth clearance as compared to R10, this is negated by the much greater sediment deposition during the siphon mode. Therefore, Type CS46 R11 is not recommended.

13. The Type CS46 R10 control structure was the optimum design developed in the model studies and is recommended as the final design for the structure. It is recommended that during initial operation, the siphon tunnel be flushed every two months for about five hours. This initial frequency and duration can be adjusted as prototype operating experience dictates.

III. SEDIMENTATION

A. Prototype Sediment

Information on sediment types and gradations that will be conveyed through control structure 46 was provided by Erdman, Anthony, Associates (EAA). Sediment movement was to be observed in the model for both the siphon and flushing modes of operation, and is more critical in the siphon mode than the flushing mode. Two different siphon mode flow conditions will occur during normal siphon operation.

Siphon condition 1 consists of the higher storm water overflows from surface sewers and is expected to contain a high percentage of inorganic sediments. These flows are 150 cfs initially and 300 cfs ultimately, and result in average velocities of 3.9 fps and 7.8 fps, respectively, in the 7 ft circular siphon tunnel.

Siphon condition 2 consists of the lower dry-weather combined sanitary flows and is expected to contain a high percentage of organic sediments. The average dry weather flow is estimated to be 16 cfs, producing a siphon flow velocity of 0.4 fps.

A sediment sampling and analysis program was conducted by EAA at existing facilities in the Rochester Pure Waters District to closely approximate the different sediment types that will exist during both siphon flow conditions. The Van Lare Grit Chamber was selected as the sediment sampling location for sediment representation of siphon condition 1 and the Cross-Irondequoit Pump Station as the sediment sampling location for siphon condition 2. The locations are shown on Chart 1.

Five sediment samples were taken at both of these locations on July 8, 1983, and analyzed for grain-size distribution, specific gravities, and organic content. This information is summarized in the table below.

Sieve Size	Cross-Irondequoit (Average) Specific Gravity = 1.71			Van Lare (Average) Specific Gravity = 2.08		
	Percent	Percent Organic	Percent Inorganic	Percent	Percent Organic	Percent Inorganic
> 4	10.5	8.3	2.2	6.4	4.3	2.1
4-10	25.7	19.3	6.4	12.1	8.1	4.0
10-20	22.6	16.1	6.5	17.5	6.3	11.2
20-40	14.4	5.8	8.6	20.9	5.7	15.2
40-60	9.9	0.7	9.2	15.4	1.1	14.3
60-100	6.0	0.4	5.6	15.2	0.6	14.6
100-pan	10.9	1.1	9.8	17.5	0.8	11.7
	100	51.7	48.3	100	26.9	73.1

The Cross-Irondequoit sediment is 52 percent organic by weight, with a mixture specific gravity of 1.71. The Van Lare sediment is 27 percent organic by weight, with a mixture specific gravity of 2.08. Chart 18 shows the average grain-size distribution curves and specific gravities of the sediment samples taken at the Van Lare Grit Chamber and the Cross-Irondequoit Pump Station. Based on the above data provided by EAA, the following analysis of sediment scaling was made by Dr. Gary Parker.[1, 2] Let ρ_I denote the density of the inorganic material, ρ_o denote the density of the organic material, P_I denote the mass fraction of a sample that is inorganic, and P_o denote the mass fraction that is organic. Then where ρ_m is the density of the mixed sample, $\forall_I$ denotes the solid volume of inorganics, and $\forall_o$ denotes the solids volume of organics, the following relations hold

$$P_I = \frac{\rho_I \forall_I}{\rho_I \forall_I + \rho_o \forall_o} ; \quad P_o = 1 - P_I$$

and

$$\rho_m(\forall_I + \forall_o) = \rho_I \forall_I + \rho_o \forall_o$$

Solving for the mixture density

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[1]Parker, Gary, letter to Karl Nesbeitt, Harza Engineering Company, November 28, 1983.

[2]Parker, Gary, letter to Karl Nesbeitt of Harza Engineering Company, September 16, 1983 (some modifications were subsequently made).

$$\rho_m = \frac{1}{\left(\frac{P_I}{\rho_I} + \frac{P_o}{\rho_o} \right)}$$

For the Cross-Irondequoit sediment analysis, $P_I = 0.483$, $P_o = 0.517$, $\rho_I = 2.65$ gr/cm^3 and $\rho_m = 1.71$ gr/cm^3 . Solving for ρ_o ,

$$\rho_o = 1.28 \text{ gr/cm}^3$$

For the Van Lare sediment, $P_I = 0.731$, $P_o = .269$, $\rho_I = 2.65$ gr/cm^3 and $\rho_m = 2.08$ gr/cm^3. Solving for ρ_o ,

$$\rho_o = 1.31 \text{ gr/cm}^3$$

Thus it is considered appropriate to assume an overall organic specific gravity of 1.30. A specific gravity of 2.65 is assumed for the inorganic material. The following values were determined from arithmetic averages of data from Cross-Irondequoit and Van Lare.

Sieve size	Average Organic		Average Inorganic	
	Percent	Percent Finer	Percent	Percent Finer
> 4	16.0	84.0	3.7	96.3
4-10	33.7	50.3	9.4	86.9
10-20	27.3	23.0	14.4	72.5
20-40	16.2	6.8	19.3	53.2
40-60	2.7	4.1	19.3	33.9
60-100	1.5	2.6	15.8	18.1
100-pan	2.6	0	18.1	0
	100		100	

	Average Organic	Average Inorganic
Specific Gravity	1.30	2.65
D_{84}	4.75 mm	1.7 mm
D_{50}	2.0 mm	0.38 mm
D_{16}	0.6 mm	0.14 mm
$D_g = \sqrt{D_{84}\ D_{16}}$	1.69 mm	0.49 mm
$\sigma_g = \sqrt{D_{84}/D_{16}}$	2.81	3.48 mm

B. Sediment Modeling

In the analysis of the sediment to be used in the 1 to 12 scale model, it was assumed that the shear velocity, u_* , scales according to the Froude relationship, i.e., as $\sqrt{L_r}$. Furthermore, the specific gravity of the model inorganic material would be a quartz sand with a specific gravity of 2.65, and walnut shells with a specific gravity of 1.35 would be used for the organic material.

Three alternate modeling criteria were investigated including Shields, fall velocity, and entrainment and these criteria are summarized below:

1. Shields Stress Modeling

In Shields stress modeling it is assumed that the Shields stress, τ^* , is the same in the model and the prototype, i.e.

$$\tau^* = \frac{u_*^2}{Rg\ D_s}$$

and

$$(\tau^*)_r = 1$$

where u_* = shear velocity

$$R = \frac{\rho_s}{\rho} - 1 = \text{submerged specific gravity}$$

ρ_s = solid particle density

ρ = water density

D_s = grain size

Assuming that u_* scales with the Froude relationship,

$$(D_s)_r = \frac{\lambda_L}{R_r}$$

Using a submerged specific gravity, R, of 1.65 for inorganic material in both model and prototype, 0.3 for prototype organics, and 0.35 for model inorganics,

$$(D_s)_r \begin{cases} = 0.083 \text{ for inorganics} \\ = 0.071 \text{ for organics} \end{cases}$$

The resulting grain sizes as a result of Shields modeling are tabulated below:

	Prototype Organic	Model Organic	Prototype Inorganic	Model Inorganic
	(mm)	(mm)	(mm)	(mm)
D_{84}	4.75	0.34	1.7	0.14
D_{50}	2.0	0.14	0.38	0.032
D_{16}	0.60	0.043	0.14	0.012

2. <u>Fall Velocity Modeling</u>

In fall velocity modeling, it is assumed that

$$\left(\frac{u_*}{v_s} \right)_r = 1$$

where v_s = particle fall velocity. Thus, with $u_*{}^2_r = L_r$,

$$(v_s)_r = \sqrt{L_r}$$

For spheres, fall velocity is determined in terms of the plot (Chart 19) of R_f versus Re , where

$$R_f = \frac{v_s}{\sqrt{Rg\ D_s}} \qquad Re = \frac{\sqrt{Rg\ D_s}\ D_s}{\nu}$$

For a prototype size D_s , the particle Reynolds number, Re, is computed assuming the kinematic viscosity, $\nu = 0.01\ cm^2/sec$, and the value of R_f is read from the plot and used to compute v_s . This value is then scaled down to the model, and a trial and error method is used in conjunction with the plot to find the model D_s . The complete set of iterations is shown in the following table.

PROTOTYPE					MODEL				
						Estimated			Check
Material	D_s mm	R_p	R_f	v_s cm/s	v_s cm/s	D_s mm	Re	R_f	v_s cm/s
Org.	4.75	562	1.75	20.7	6.0	1.2	77	1.12	7.2
						1.1	68	1.09	6.7
						1.0	59	1.02	5.97
Org.	2.0	153	1.35	10.4	3.0	.58	26	.68	3.03
Org.	0.60	25.2	.67	2.82	0.81	.23	6.5	.265	.74
						.24	6.9	.215	.79
Inorg.	1.7	282	1.55	25.7	7.4	.50	45.0	.92	8.1
						.48	42.3	.9	7.9
						.45	38.4	.85	7.3
Inorg.	0.38	29.8	.75	5.88	1.7	0.15	7.4	.29	1.4
						0.16	8.1	.33	1.7
Inorg.	0.14	6.7	.27	1.29	.37	0.055	1.6	.1	.30
						0.060	1.9	.11	.34
						0.065	2.1	.12	.39

The grain sizes based on fall velocity modeling are summarized below.

	Prototype Organic (mm)	Model Organic (mm)	Prototype Inorganic (mm)	Model Inorganic (mm)
D_{84}	4.75	1.0	1.7	0.45
D_{50}	2.0	0.58	0.38	0.16
D_{16}	0.60	0.24	0.14	0.065

3. <u>Entrainment modeling</u>

In entrainment modeling it is assumed that the parameter

$$Z = \frac{u_*}{v_s} Re^{0.5}$$

is the same in the model and prototype (see the manuscript by Akiyama and Fukushima).[3] Using the particle entrainment parameter $\zeta = v_s Re^{-0.5}$ it is found that

$$(\zeta)_r = (v_s Re^{-0.5})_r = \sqrt{L_r}$$

[3]Akiyama, J. and Fukushima, Y., "Entrainment of Noncohesive Bed Sediment into Suspension," submitted to ASCE, Hydraulic Division, May, 1984.

Determination of the model grain size is accomplished again by trial and error as shown in the table below.

Mat'l.	PROTOTYPE D_s mm	Re	R_f	v_s cm/s	ζ	MODEL Estimated ζ	D_s mm	Re	R_f	v_s cm/s	Check ζ
Org.	4.75	562	1.75	20.7	0.87	0.25	0.2 0.19	5.24 4.85	.23 .215	.60 .55	0.26 0.25
Org.	2.0	153	1.35	10.4	0.84	0.24	0.16 0.17	3.75 4.10	.185 .20	.43 .48	0.22 0.24
Org.	0.60	25.2	0.67	2.82	0.56	0.16	0.11	2.14	.12	.23	0.16
Inorg.	1.7	282	1.55	25.7	1.53	0.44	0.11 0.12	4.64 5.29	.21 .23	.89 1.01	0.41 0.44
Inorg.	0.38	29.8	0.75	5.88	1.08	0.31	0.07 0.077	2.36 2.71	.13 .145	.44 .51	0.28 0.31
Inorg.	0.14	6.7	0.27	1.29	0.50	0.14	0.042 0.025	1.10 0.50	.078 .049	.20 .099	0.19 0.19

The results of entrainment modeling are thus summarized in mm below.

	Prototype Organic	Model Organic	Prototype Inorganic	Model Inorganic
D_{84}	4.75	0.19	1.7	0.12
D_{50}	2.0	0.17	0.38	0.077
D_{16}	0.60	0.11	0.14	0.025

C. Model Sediment Selection

The results of the sediment scaling are summarized in the table below.

		Prototype	Shields	Model Fall	Entrainment
Inorganic	D_{84}	1.7 mm	0.14	0.45	0.12
	D_{50}	0.38 mm	0.032	0.16	0.077
	D_{16}	0.14 mm	0.012	0.065	0.025
Organic	D_{84}	4.75 mm	0.34	1.0	0.19
	D_{50}	2.0 mm	0.14	0.58	0.17
	D_{16}	0.6 mm	0.043	0.24	0.11

The difference in the model values reflects the classic uncertainty when similarity must be satisfied in several parameters (in this case Froude and Reynolds number).

There is little point in trying to model the entire size distribution for both the organic and inorganic material. The sizes of interest are the coarser ones of each. It is thus appropriate to choose an actual model D_{50} value, so as to correspond to one of the scaled-down D_{84} sizes of the table above. A fairly unbiased estimate is the average of the three scaled-down D_{84} values. (Note that fall velocity scaling provides input, but is not relied upon entirely.) The sediment sizes recommended for the model are thus based on the average D_{84} value from the three methods, which results in 0.51 mm for the organic material and 0.24 mm for the inorganic material.

It was recommended that the inorganic material should be modelled with quartz sand with a specific gravity of 2.65. The organic material should be modeled with walnut shells with a specific gravity near 1.35.

For the inorganic sediment St. Peter sand was selected which has a specific gravity of 2.65 and a D_{50} of about 0.22 mm. For the organic sediment crushed 10/30 walnut shells were selected which have a specific gravity of 1.35 and a D_{50} of about 0.68 mm. The size distribution of these sediments are shown on Chart 21.

Two grades of sediment were recommended. Grade 1 consisted of 50 percent organic material by weight (Cross-Irondequoit) and was used for prototype discharges up to and including 50 cfs. Grade 2 consisted of 25 percent organic material by weight (Van Lare) and was used for all other discharges. During the testing program, for more severe tests, a grade 3 sediment was also used which consisted of 100 percent inorganic sediment.

Prototype concentrations are shown on Chart 20. The mean volumetric sediment concentration is the flow to the Cross-Irondequoit pump station and is 7.8 parts per million (0.011 grams/liter). The corresponding values near the Van Lare sand trap are 4.6 parts per million (0.01 grams liter). These concentrations are too low to be of use in the model. Several days might be required to simulate any sediment buildup. It was therefore recommended that in the model, feed concentration should be increased at least tenfold, to about 0.1 grams/liter. The recommended model feed rates which are 10 times the normal of sediment vary according to the discharge and are listed below.

Prototype Discharge cfs	Model Feed Rate grams/minute
16	6
25	9
50	17
75	25
100	34
125	43
150	51
200	68
250	85
300	102
375	128

These rates are adjusted upwasrd for some tests to reduce the model operating time and better show the pattern of sediment movement and deposition.

The sediment was fed into the model through a vertical pipe with a Syntron vibrating sediment feeder at the upstream end of the siphon tunnel.

IV. TYPE CS46 CONTROL STRUCTURE

A. Description of Model

The initial 1:12 model as discussed earlier was constructed up to elevation 266.18 ft and based on Erdman, Anthony, Associates Drawings SP-TU-7, sheets 1 to 10, and SP-CS-G2 sheet 44. This was designated as the Type CS46 control structure, the details of which are shown on Charts 2 through 4. The model was fabricated mostly from transparent lucite as shown in the Frontispieces and Photos 1 through 6 so that flow characteristics in the structure could be observed and photographed. Some inserts and components with complicated shapes were made from sheet metal and styrofoam to save construction time and facilitate revisions. The model components were fabricated in the Laboratory shops (Photo 1) and assembled at the model site (Photos 2 through 6). The water supply for the model was obtained from the Mississippi River through the Laboratory supply system.

A 6-inch supply line was provided which contained a control valve and a calibrated 4 inch diameter orifice meter for measuring the discharge. Just upstream of the 7 inch diameter (7 ft prototype) clear lucite siphon tunnel another valve was placed. By regulating this valve and varying the density of a mesh baffle downstream of the valve, the depth of flow at the upstream end of the siphon tunnel could be adjusted.

The throughflow flushing flows to be investigated in the model were 16, 25, 50, 75, 100, and 125 cfs with the design flow being 100 cfs. The depths of flow expected at the upstream end of the model were computed by EAA using two friction factors (Manning's n) of 0.013 and 0.020 for each flow rate. The condition of the inside of the tunnel would determine which factor was more appropriate to use. In the model studies it was decided to use the average of the two depths computed for each flow. Through a series of calibration tests an optimum combination of valve openings and mesh densities was achieved so that the approximate computed depth for each flow would occur when that flow was turned on. The depth of flow was measured at the first pressure tap in the siphon tunnel. This depth of flow would vary slightly throughout the model studies depending on several factors.

The regulation valve may be seen at the upstream end of the model shown in Frontispiece 1. The siphon tunnel was made 144 inches long, fabricated from 7 inch lucite tubes (144 ft prototype), and one foot from the upstream end a 4 inch diameter standpipe was placed for the feeding in of sediment. Two feet from the upstream end provisions were made for injecting air into the flowing water. Attached to the downstream end of the siphon tunnel is a transition from 7 ft circular to a 7 ft arch. Next is a short transition which expands the flow in plan and elevation into the surge shaft (see Photo 1).

Photo 1 shows the surge shaft being fabricated to elevation 266.18 ft in the Laboratory shop. Most of the components are fabricated with flanges for convenience in assembling the model and revisions later in the program. The shop personnel are installing a flanged section of the 25 ft circular surge shaft. Clearly shown in Photo 1 is the 4 ft by 8 ft flushing gate in the closed position at the downstream end of the surge shaft.

Separating the surge shaft and drop structure is the head breaker wall containing the eight head breaker gates for drawndown. Each gate opening is 2 ft wide by 3 ft high and gates are spaced 12 ft apart. Only gates 7 and 8 (charts 2 and 4) were built into the model as dropshafts with higher drops than these would present no problems in the operation of the structure. The flows from the head breaker gate openings shoot into two parallel dropshafts each rectangular in shape and 4.5 ft by 7 ft.

Separating the dropshaft and air vent is a divider wall with air slots and projections over the slots (Chart 2) to provide for re-entraining some of the air rising in the air vent and also for pressure relief. Connected to the downstream end of the drop structure is a 14.625 ft long section converging in width from 15 ft to 6 ft, and then the 6 ft wide by 41 ft long deaeration chamber. The deaeration chamber includes a false crown with 5 - 1.5 ft wide air slots and is 9.75 ft above the invert, although the false crown was not modeled. Above the false crown a 2.5 ft chamber is provided for air collection and conveyance back to the air vent.

At the downstream end of the deaeration chamber is a transition from a 4 by 9.75 ft rectangular to a 4 ft arch, and a transition from a 4 ft arch to the 4 ft circular flushing tunnel. The flushing tunnel was made 72 inches long in the model (72 ft prototype) and emptied into a larger rectangular waste channel. No provisions were made for tailwater control as most of the time the flow would be uncontrolled supercritical flow. The invert is channelized to some extent through the surge shaft and drop structure. The invert of the structure is sloping, and the model was carefully adjusted to the values shown on Chart 3. The various components are shown in Photos 1 through 6 and detailed dimensionally on Charts 2 through 4.

For measuring static pressures or hydraulic gradelines a number of pressure taps were drilled into the model at selected locations. These taps were connected by plastic tubes to a bank of piezometer tubes where the hydraulic gradelines were observed and recorded. The upstream tap in the siphon tunnel was used for measuring the headwater depth and the downstream tap in the flushing tunnel for measuring the tailwater depth. No provisions were made for measuring fluctuating pressures on the invert as this information was available from previous model studies.

Water surface elevations were measured with a standard point gage where access was possible from the top and using a tape measure at other closed sections.

B. Model Observations

The model was put in operation and flushing flows (Q_F) of 16, 25, 50, 75, 100, and 125 cfs observed in the model. The initial observations indicated that the inflow depths were lower than the desired computed values and were adjusted to correspond using the regulation valve and mesh baffle described in the introduction. With the inflow properly adjusted, visual observations were made, headwater and tailwater elevations recorded from the piezometer tubes, approximate depths of flow measured in the surge shaft and downstream end of the deaeration chamber, the clearance of the bellmouth above the water surface in the surge shaft noted, and the location of any hydraulic jumps determined. This information is summarized in the table on Chart 22 for all the flushing flows from 16 to 125 cfs. It was readily apparent that the flow would not remain supercritical as necessary for proper flushing of the structure. Hydraulic jumps formed and moved upstream to a certain location, resulting in subcritical flow through the structure. For all flows the hydraulic jump eventually stabilized in the upstream transition or the siphon tunnel. At the design flushing flow (Q_F) of 100 cfs, initially two jumps formed. One formed downstream of the flushing gate and the other at the downstream end of the deaeration chamber. The jump at the downstream end of the deaeration chamber gradually moved upstream and combined with the jump below the gate. This combined jump then traveled upstream through the surge shaft to a stable location in the transition or siphon tunnel as indicated on Chart 22. Photo 7 shows an overall view of the structure with Q_F = 100 cfs, and the resulting subcritical flow. Photo 8 shows the restriction of flow at the downstream end of the deaeration chamber where one jump starts and Photo 9 where the second jump starts below the gate. When the flow has stabilized and the resultant jump is located in the siphon tunnel, the siphon riser bellmouth is submerged about 0.5 ft for Q_F = 100 cfs as shown in Photo 10. Generally for flows up through 50 cfs the bellmouth is clear, touching at 75 cfs, and submerged at 100 and 125 cfs.

The basic requirement in the flushing mode is that the flow be supercritical to accomplish sediment transport and flush out the structure. The flow in the Type CS46 control structure is subcritical; therefore, this design is not acceptable.

V. TYPE CS46 R1 CONTROL STRUCTURE

A. Description of Model

There is definitely some obstruction to the flow at the downstream end of the deaeration chamber in Type CS46 as shown in Photo 8. In Type CS46 R1 the transition from a 4 ft arch to a 4 ft circular has been revised to a 4 ft arch and the 4 ft circular tunnel replaced with a 4 ft wide rectangular channel as shown on Chart 5 and in Photo 11.

B. Model Observations

The flow characteristics for Type CS46 R1 are similar to those for Type CS46 for all flows from 16 to 125 cfs. The flow through the structure is again subcritical. Photo 11 shows the downstream end of the deaeration chamber, the section of 4 ft arch, and the 4 ft rectangular channel with Q_F = 100 cfs and may be compared to Photo 8 showing the same area for Type CS46. The depth of flow through the structure is about 0.5 ft lower at 100 cfs for Type CS46 R1 as compared to Type CS46 (Chart 22). In the surge shaft the depth dropped from 4.4 to 3.9 ft and in the deaeration chamber from 4.3 to 3.8 ft. Although a slightly lower depth of flow occurred, the flow was still subcritical and Type CS46 R1 is not acceptable.

VI. TYPE CS46 R2 CONTROL STRUCTURE

A. Description of Model

The Type CS46 R2 control structure is the same as Type CS46 R1 with the drop structure and boot invert channelized to a height of 4 ft as shown on Chart 6.

B. Model Observations

With a Q_F = 100 cfs through the Type CS46 R2 control structure only one hydraulic jump occurred and that was at the downstream end of the deaeration chamber. In a relatively short time this jump traveled up through the entire structure into the siphon tunnel and the flow became subcritical. A slight improvement in the flow pattern was observed in the channelized section as shown in Photo 12, but the depths of flow in the surge shaft and deaeration chamber had changed little when compared to those for Type CS46 R1 (Chart 22).

C. Sediment Tests

The first sediment test was made on Type CS46 R2 with Q_F = 100 cfs. Sediment grade 3 (100 percent inorganic sediment) was fed into the vertical pipe at the upstream end of the siphon tunnel with the Syntron vibrating sediment feeder as shown in Photo 13. The sediment dropped into the inflow and was carried into the model. The sediment feed rate was adjusted to about 62 grams per minute and the test run for 30 minutes as shown in Photo 14. At this time the flow was turned off and the location of sediment deposits recorded. The sediment was deposited mainly in the transition (Photo 15) and the surge shaft (Photo 16). Some was deposited in the drop structure and deaeration chamber as shown in Photo 14. The model was turned on again with Q_F = 100 cfs and sediment Grade 3 fed in for another 43 minutes. The sediment kept accumulating slowly, and the test was terminated at this time because it was not being flushed out. At this time it was estimated that 66 percent of the sediment fed into the model actually was deposited at various locations in the model. Chart 23 contains a list of sediment tests run, and sediment Test 1 is summarized thereon. A sample of the sediment deposited in the model was taken and a size distribution analysis made. The results along with the size distribution of the sediment fed into the model are plotted in Chart 24. The curve for the material deposited in the model plots to the right of the curve for the material fed in, indicating as one would expect, that more of the finer material was transported through the model.

The flow through the Type CS46 R2 control structure which has increased channelization is subcritical and the sediment test showed that the structure would not be flushed out; therefore, this design is not acceptable.

VII. TYPE CS46 R3 CONTROL STRUCTURE

A. Description of Model

The Type CS46 R3 control structure is the same as R2 with the deaeration chamber channelized to a height of 4 ft and the surge shaft to 3 ft as sketched on Chart 7 and shown in Photos 17 and 18. The invert is now channelized and rectangular in section from the upstream end of the surge shaft through the entire length of the model. The width of the channel varies from 7 ft at the siphon tunnel, to 8 ft at the flushing gate, to 6 ft at the upstream end of the deaeration chamber, and to 4 ft at the arch section.

B. Model Observations

Photos 17 and 18 show the flow pattern through the Type CS46 R3 control structure. The flow pattern is improved somewhat, but the hydraulic jump still occurs for flows of 25 cfs and above. For 16 cfs the flow appears marginally supercritical through the structure. When compared to R2 the depth of flow in the surge shaft dropped from 3.9 to 3.8 ft and in the deaeration chamber from 3.7 to 3.4 ft. Although some improvement is noted, the Type CS46 R3 control structure is still not acceptable.

VIII. TYPE CS46 R4 CONTROL STRUCTURE

A. Description of Model

Observations on all types from CS46 up through CS46 R3 show that a major obstruction to the flow occurs at the downstream end of the deaeration chamber where the transition from the 6 ft chamber to the 4 ft wide tunnel or rectangular channel is located. A revision in geometry was needed at this location. This was approached with reluctance as the 4 ft diameter tunnel was intended to regulate the flow to the Cross-Irondequoit pump station. In deliberating the situation, it was decided to remove the transition and 4 ft wide flushing tunnel and replace them both with a 6 ft wide rectangular channel as shown on Chart 8 and Photo 19. The deaeration chamber and the flushing tunnel are now both 6 ft in width and rectangular in shape. In addition to this the drop structure and pinch area are channelized to a height of 4 ft (Chart 8).

B. Model Observations

The Type CS46 R4 control structure shows some noticeable improvements in the flow patterns. For all flows up through 75 cfs a disturbance occurs near the center of the surge shaft but the bellmouth remains clear of the water. At 100 cfs, a disturbance or weak jump occurs at the upstream end of the surge shaft and the water surface touches the downstream edge of the bellmouth (Photo 20). In comparison with R3 and at 100 cfs, the water depth for R4 dropped from 3.8 to 2.6 in the surge shaft, and from 3.4 to 1.8 ft in the deaeration chamber (Chart 22). This large drop in water surface, particularly at the downstream end of the deaeration chamber shows the effectiveness of the 6 ft wide rectangular channel as shown in Photo 19. At Q_F = 125 cfs a hydraulic jump occurs in the transition, and the bellmouth is submerged.

The flow is supercritical for all flows from the drop structure downstream through the entire model. The surge shaft is mostly subcritical. A sweepout test was recommended and tried. A sweepout test consists of artificially raising the tailwater by placing a plate in the exit conduit to cause a hydraulic jump as shown in Photo 21 for Q_F = 100 cfs. The jump travels upstream through the structure to the upstream end of the siphon tunnel resulting in subcritical flow. The plate in the exit conduit was then removed and the flow characteristics observed. After a relatively short time, the flow reverted to its original state; that is, subcritical in the surge shaft and supercritical in the drop structure and downstream. This occurred for all flushing flows. It is evident that more improvement is still needed in the surge shaft invert.

C. Sediment Tests

Even though the flow through the Type CS46 R4 control structure was not all supercritical, two sediment tests were made. In sediment test 2 with Q_E = 100 cfs, sediment Grade 3 was fed into the model at a rate of about 35 grams per minute for 30 minutes (Chart 23). At the end of that time no sediment accumulated in the surge shaft and only a trace in the deaeration chamber. Although the flow is not ideal, sediment transport is fairly effective. For sediment test 3, a 1-inch layer of sediment Grade 3 was placed in the surge shaft as shown in Photo 22. A flushing flow of 100 cfs was turned on and the sediment transport observed. After 40 minutes model time all the placed sediment was flushed completely out of the model (Chart 23).

Although considerable improvement was achieved in the Type CS46 R4 design, it was concluded that more should be done in the area of the surge shaft invert and flushing gate.

IX. TYPE CS46 R5 CONTROL STRUCTURE

A. Description of Model

The Type CS46 R5 control structure is similar to R4 except that the channel through the pinch, drop structure and flushing gate is at a constant width of 6 ft, as shown on Chart 9 and in Photo 23. From the upstream face of the gate, the channel widens to 10 ft at the centerline of the surge shaft and the walls tie into the original surge shaft invert geometry (Chart 9 and Photo 24).

B. Model Observations

The flow pattern in the deaeration chamber and pinch area is shown in Photo 23 and the surge shaft in Photo 24. The flow characteristics of Type CS46 R5 are quite similar to those for R4. In fact, the depth in the surge shaft for Q_F = 100 cfs actually increased from 2.6 (R4) to 2.9 ft (R5). The rather abrupt change in the surge shaft invert channel from a 10 ft width to 6 ft (Photo 24) appears to cause considerable resistance to the flow. No improvement in the flow pattern for the Type CS46 R5 control structure was observed. The pattern was similar to that for R4, and it was again concluded that flow characteristics could be improved.

X. TYPE CS46 R6 CONTROL STRUCTURE

A. Description of Model

Type CS46 R6 control structure is the same as R5, which has the pinch and drop structure channelized to a constant width of 6 ft (Photo 25), except that a channel was added through the surge shaft (Photo 26). The 2.75 ft high channel provided a gradual transition from 7 ft at the upstream end of the surge shaft to 6 ft at the flushing gate. The geometry is defined on Chart 10.

B. Model Observations

In Type CS46 R6 no hydraulic jump occurred and the flow through the entire model was supercritical for all flows. The flow pattern for Q_F = 100 cfs is shown on Photos 25 and 26. Some disturbance may be seen on the water surface in the surge shaft (Photo 26) but the bellmouth remains clear of the water surface for all flows. At 100 cfs, the water depth in the surge shaft dropped from 2.9 (R5) to 1.6 ft for R6 and from 1.8 to 1.6 ft in the deaeration chamber (Chart 22). The improvement is even more noticeable when the depths in Type CS46 R6 are compared with those in the original Type CS 46 (Chart 22). For example at a flushing flow of 100 cfs, in Type CS46, the depth in the surge shaft was 4.4 ft and in the deaeration chamber 4.3 ft and the corresponding depths in Type CS46 R6 were both 1.6 ft. The flow characteristics through the Type CS46 R6 control structure are hydraulically acceptable for the flushing flows, but further refinements are needed in the geometry to meet all the necessary requirements through all 4 modes of operation.

C. Sediment Tests

Two sediment tests were made on the Type CS46 R6 control structure (Chart 23). Sediment test 4 was made with Q_F = 100 cfs and sediment Grade 3 fed into the model at a rate of about 35 grams per minute for 30 minutes. No deposition occurred in the model during that time and the test was terminated.

For sediment test 5 a 1-inch layer of sediment Grade 3 was placed on the surge shaft invert. A flushing flow of 100 cfs was turned on, and it took only 2.3 minutes model time to flush the sediment completely out of the model. The sediment transport through this type is excellent.

XI. TYPE CS46 R7 CONTROL STRUCTURE

A. Description of Model

In Type CS46 R6, the 2.75 ft high sheet metal walls of the channel through the surge shaft are touching the bellmouth and probably would interfere with the flow entering the siphon riser during the siphon mode (Photo 26). The model was revised to provide clearance for the flow entering the bellmouth. The Type CS46 R7 control structure is the same as R6 with the surge shaft invert revised to conform to Harza Engineering Company drawings dated November 16, 1983. The temporary vertical walls shown in Photo 26 were replaced with the solid benches shown in Photo 27. The channel walls are in the same location and reduced in height from 2.75 to 2.5 ft, and the top of the benches extend horizontally to the surge shaft wall. These side benches are contoured in the bellmouth area as shown on Chart 11 and in Photo 27 to provide the necessary clearance.

B. Model Observations

The flow pattern through Type CS46 R7 is quite similar to the pattern for R6 with the exception of slight disturbances caused by the contoured areas near the bellmouth. The open channel supercritical flows were observed to be fairly smooth throughout the model, free of any hydraulic jumps, and had only mild surface disturbances in the contoured areas beneath the bellmouth as shown in Photo 27. The water depths for Type CS46 R7 are about the same as for R6 (Chart 22).

Sweepout tests were made on Type CS46 R7 also. In these tests the water was blocked off in the deaeration chamber causing a hydraulic jump to form and move upstream through the model; eventually the siphon tunnel filled completely. The block was then removed releasing the water. For all flows from 16 to 100 cfs the water drained out of the model and the flow pattern reverted again to the original supercritical flow clear of the bellmouth. With a flow of 125 cfs, most of the water drained out but resistance to the flow by the bellmouth caused a hydraulic jump to form and persist in the transition upstream of the surge shaft. The flow went through critical somewhere in the drop structure and was supercritical in the deaeration chamber and flushing tunnel. The bellmouth was raised 0.1 ft (prototype) and then to 0.2 ft, but the jump still persisted. When the bellmouth was raised to 0.3 ft, the water surface broke free of the bellmouth, the jump disappeared, and the flow reverted to supercritical.

The Type CS46 R7 revision provides the necessary clearance for the siphon riser bellmouth and does not affect the flow pattern appreciably; therefore, it is recommended that it be included in the design geometry.

C. Sediment Tests

Two sediment tests were made on Type CS46 R7 similar to those made on previous types (Chart 23). Sediment test 6 was run with Q_F = 100 cfs and sediment Grade 3 fed into the model for 30 minutes. No deposition occurred in the model. Sediment test 7 consisted of placing a 1 inch layer of sediment Grade 3 over the surge shaft invert and turning on a Q_F = 100 cfs. The model was flushed clean in 3 minutes, a slightly longer time than for R6, but still quite acceptable.

XII. TYPE CS46 R8 CONTROL STRUCTURE

A. Description of Model

The original flushing tunnel was circular and 4 ft in diameter. It was made this size to limit the discharge to the Cross-Irondequoit pump station. The proposed flushing tunnel in the model is now 6 ft wide and rectangular. To limit the discharge to about the same as the 4 ft tunnel, EAA proposed an alternate flushing tunnel section on a drawing dated October 10, 1983, which retained the 6 ft wide rectangular base with walls 2.02 ft high and added a round crown with a radius of 4.24 ft. The total height of the horseshoe shaped tunnel is 3.26 ft as shown in section H-H on Chart 12. A temporary insert 24 ft long was fabricated of wood and sheet metal and inserted into the existing rectangular channel as shown in Photo 28. With the exception of this tunnel revision, Type CS46 R8 is the same as R7.

B. Model Observations

The flow pattern through Type CS46 R8 is similar to that for R7. The flow through the entire model is supercritical with no hydraulic jumps, and the bellmouth is clear of the water surface for all flows from 16 cfs through 125 cfs. The water depths are the same for R7 and R8 (Chart 22). For flows from 16 through 100 cfs the water surface does not reach the crown of the revised section of flushing tunnel and, therefore, does not affect the flow pattern (Photo 28). At 125 cfs the water surface barely touches the crown at the sidewalls and only slight surface disturbances were observed. Although 125 cfs is the upper design limit, a test was made at 150 cfs to check the sensitivity only. At 150 cfs, entrance choking occurred resulting in a hydraulic jump.

Sweepout tests were also made on Type CS46 R8 with the same results as for R7. The subcritical flow reverted to the original supercritical flow throughout the entire model including the revised section of flushing tunnel for all flows through 100 cfs. At 125 cfs the flow became supercritical through the revised section of tunnel, but the jump still persisted upstream of the surge shaft. Again raising the bellmouth 0.3 ft caused the water surface to break free and the flow reverted to supercritical.

The revised section of the flushing tunnel had very little effect on the flow pattern through the structure, and it was decided to include this in the overall design geometry.

XIII. TYPE CS46 R9 CONTROL STRUCTURE

A. Description of Model

Type CS46 R9 control structure is the optimum design for the flushing mode of operation developed in the low model through the revisions described. Charts 13 and 14 show dimensioned drawings of the structure and may be compared to Charts 3 and 4 which show the original Type CS46. Pictorial views are shown in Photos 29 through 42. Photo 29 shows the overall model with all the final revisions installed. The surge shaft channel geometry was revised according to Harza drawings, sheets 1 and 2 dated November 16, 1983, as shown on Charts 13 and 14 and Photos 30 through 32. The invert was channelized from a 7 ft width at the upstream transition to 6 ft at the flushing gate by installing two benches, one on either side of the surge shaft. Each bench has a 2.5 ft high vertical face to contain the flow and is contoured out beneath the bellmouth (Photos 31 and 32). The top of the bench has a 2 to 1 slope to the surge shaft wall. This includes the bench geometry inside the entrance transition as was done in Type CS46 R7.

The flushing gate was reduced in width from 8 ft to 6 ft, but remains 4 ft high.

The drop structure and pinch were channelized according to EAA drawing, subsheet 2, dated September 20, 1983, as shown in Photo 33. Benches were placed on each side forming a constant 6 ft wide channel. The walls are 2.5 ft high with a short radius at the the top continuing into the bench top which has a 5 to 1 slope as shown in Section F-F on Chart 14.

The exit conduit crown geometry based on EAA drawing dated October 27, 1983, which was tested as Type CS46 R8 was included in CS46 R9. The temporary section was replaced with a clear lucite section 19.33 ft long containing the exact same cross section as shown in Section I-I on Chart 14 and Photo 34. The 6 ft wide section contains 2.02 ft high walls topped with a 4.24 ft radius circular segment. The total height of the horseshoe section is 3.26 ft. This configuration is designed to limit the flow to the Cross Irondequoit Pump Station.

To provide better entrance conditions to the flushing tunnel a bellmouth was installed at the downstream end of the deaeration chamber (Charts 13 and 14, Photo 34). The bellmouth was fabricated with a crown radius of 4.24 ft and bell section radius of 4.33 ft.

B. Model Observations

Observations were made on Type CS46 R9 for flushing flows of 16, 25, 50, 75, 100, and 125 cfs. The flow characteristics are shown in Photos 29 through 34 for the design flow of 100 cfs. Photos 35 and 36 show the flow patterns for Q_F = 50 cfs and Photos 37 through 40 for Q_F = 125 cfs. As may be seen in the photos, the open channel supercritical flows were observed to be fairly smooth throughout the model, free of any hydraulic jumps, and having only mild surface disturbances.

The flow characteristics of Type CS46 R9 are quite similar to those for R8 and R7. The water depths were essentially the same and reported as such on Chart 22. On Chart 22 the headwater depths were adjusted as close as practical to the values calculated by EAA. The tailwater values were read on a piezometer tube and the surge shaft and deaeration chamber depths measured with a tape. Occasionally the headwater and tailwater elevations would vary slightly for the same discharge and geometry from one test to the next, and was reported this way on the data charts and the photos.

Sweepout tests on Type CS46 R9 showed the same results as for R8 and R7. The same test procedure was used, that is, blocking the flow as shown in Photo 41 and releasing it. Sweepout occurred for all flows through 100 cfs and the flow would return to supercritical as shown in Photos 29 through 34. Sweepout did not occur at 125 cfs until the bellmouth was raised up 0.3 ft the same as for R8 and R7.

C. <u>Sediment Tests</u>

Two sediment tests were made on Type CS46 R9 similar to tests on the previous types. Sediment test 8 was made with Q_F = 100 cfs with sediment Grade 3 fed into the model at a feed rate of about 35 grams per minute for 30 minutes. All the sediment was flushed through the model and none deposited.

For sediment test 9, a 1-inch layer of sediment Grade 3 was placed in the surge shaft invert (Photo 42). A Q_F = 100 cfs was turned on and the time required to flush the sediment completely out of the model recorded. The model flushing time was 3 minutes, the same as for Type CS46 R7. The Type CS46 R9 control structure was observed to be very effective in transporting sediment through the structure.

XIV. TYPE CS46 R10 CONTROL STRUCTURE

A. Description of Model

The Type CS46 R10 control structure consists of the optimum design developed in the low model to meet the requirements of the flushing mode of operation (Type CS46 R9) with the surge shaft and siphon riser raised to full height, and the bifurcation structure and outlet tunnels installed as shown in Frontispiece 2 and Photos 43 and 44. Charts 13 and 14 give the details for the lower part of the structure as described in the section for Type CS46 R9, and this lower part is identical for Types CS46 R9 and R10. The 25 ft circular surge shaft was constructed to elevation 356 ft or about 130 ft above the invert as shown on Chart 2. At the 1:12 scale the resulting height of the model is 130 inches, a rather tall model as emphasized by the personnel in Photo 43. The researcher is holding Mr. 1:12. In relationship to the 130 ft high surge shaft he represents a man 6 ft tall. The head breaker wall was raised to elevation 356 ft but only gates 7 and 8 were modeled. The air vent divider wall was raised to elevation 331.5 but only the slots and wedges located opposite headbreaker gates 7 and 8 were installed in the model (Chart 2). The 6 ft circular siphon riser was raised to full height topped off with a 90-degree elbow with the invert at elevation 336.7 ft as shown on Charts 15 and 16 and Photo 44. A short section of level pipe connects the elbow to the bifurcation structure. The upper elbow, inlet pipe, and bifurcation structure are at an angle of 68 degrees with the centerline of the lower structure (Chart 15). The bifurcation structure chamber is 25.5 ft long by 20 ft wide with a 14.58 percent sloping invert and contains side fillets with 5 to 1 slopes (Charts 15 and 16). At the bottom of the slope is a 1.5 ft long level section of floor at elevation 332.2 ft which extends to the two gates. The left gate controls the flow to Van Lare Connection (VLC) No. 1 and the right gate the flow to VLC No. 2 which are both 6 ft diameter exit conduits leading to Van Lare. Various design conditions call for either, or both gates to be open as specified by EAA on Chart 25, design conditions 1, 2, and 4. Design condition 3 specifies both gates closed, in which case the structure fills with water and eventually overflows through two weir slots with crest elevations of 341.2 ft and falls into the right exit tunnel or VLC No. 2 as shown in Section C-C on Chart 17.

The gates are either closed, or open as shown in Photo 44. In the model a butterfly control valve was installed in each exit conduit to control the tailwater elevation. These valves were located at the downstream end of the clear lucite pipes from the bifurcation structure as shown in Photo 44 and being adjusted in Photo 46. Pipes downstream of the valves convey the water into the laboratory discharge system. The completed model was thoroughly tested in all four modes of operation as outlined in a test program developed by Harza Engineering Company.

B. Filling Mode of Operation

Model Observations

The filling mode of operation would be necessary after flushing the deposited sediment out of the structure. The lower flushing gate and all the head breaker gates would be closed. The flow entering from the siphon tunnel would gradually fill the siphon tunnel, surge shaft, and siphon riser as shown in the series of pictures on Photo 45. When the water surface reaches the necessary elevation, flow would start up the siphon riser and spill over the top into the bifurcation structure, thus starting the siphon mode of operation. The filling mode of operation as shown in Photo 45 was uneventful and presented no problems.

C. Siphon Mode of Operation

1. Model Observations

Control structure 46 will operate in the siphon mode most of the time and, therefore, the hydraulic characteristics must be acceptable with little doubt. Photo 46 shows the overall model in operation with a siphon flow (Q_s) of 300 cfs and the tailwater elevations in the two tunnels being adjusted. The siphon mode operating conditions for the bifurcation structure were supplied by EAA and outlined on Chart 25. The structure must perform acceptably for four design conditions, each having a specified range of flows and gates completely open or closed. Design condition 1 has only gate 2 open with siphon flow of 50, 100, and 150 cfs, with 150 cfs being the primary flow. Photo 47 shows the flow pattern through the structure with Q_s = 50 cfs and specified tailwater of 334.5 ft (Chart 25). The flow from the surge shaft and connecting pipe free-falls into the structure impinging on the sloping invert with a hydraulic jump forming about halfway down the slope. With Q_s = 100 cfs the flow pattern is about the same, only slightly deeper. Photo 48 shows the flow pattern through the structure with Q_s = 150 cfs and tailwater of 336.6 ft. The flow pattern is similar to that for the lower flows with the jump occurring near the upstream end of the chamber. Photo 49 is a close-up of the chamber showing the presence of turbulence and air entrainment.

Photos 50 through 53 show the flow patterns through the bifurcation structure for design condition 2 which has both gates open. The lowest Q_s for this condition is 200 cfs shown in Photo 50, the primary Q_s = 300 cfs shown in Photos 51 and 52, and the extreme maximum Q_s = 375 cfs shown in Photo 53. For all discharges, the water from the surge shaft and connecting tunnel falls free into the chamber with a hydraulic jump forming just downstream of the point of impact. Some moderate turbulence and air entrainment occurs, but the pattern appears hydraulically acceptable. The sign in Photo 51 shows the type of structure and the design conditions for the test. The headwater of 118.7 ft is the piezometric head recorded at tap 1 at the upstream end of the siphon tunnel. The tailwaters, TW_1 = 5.1 ft and TW_2 = 4.8 ft are the depths of flow in tunnels 1 and 2, respectively, and recorded at taps 43 and 44 at the upstream end of the twin tunnels. These depths of flow, 5.1 and 4.8 ft, correspond to tailwater elevations of 337.3 and 337.0 ft given in the table on Chart 25 for Q_s = 300 cfs.

For design condition 3, both gates are closed, the chamber fills up (Photos 54 and 55), resulting in weir flow through the two weir slots on the right side of the downstream wall. The flow jet entering the chamber is submerged with some turbulence occurring. The weir flow impinges on the opposite wall and drops vertically into tunnel 2 with considerable turbulence as shown in Photos 54 and 55 for a Q_s = 300 cfs. Observations were made for siphon flows of 200, 250, 300, and 375 cfs, with 300 cfs being the primary flow. Flow patterns for all flows appear similar except for some variations in water depth and turbulence. Photo 56 shows a Q_s = 375 cfs with somewhat more turbulence that Q_s = 300 cfs and the water surface elevation is close to the top of the surge shaft.

Design condition 4 specifies that only gate 1 be open and siphon flow of 16 and 50 cfs be observed. The flow pattern as shown in Photo 57 for Q_s = 50 cfs is slightly turbulent and acceptable. All visual observations and photographic documentation recorded on the Type CS46 R10 control structure indicate at this point, that the structure is hydraulically acceptable. Some turbulence occurs but does not appear significant.

2. Water Surface Profiles

Water surface profiles were recorded for all the siphon mode operating conditions of the bifurcation structure listed on Chart 25. Water surface profiles were measured in the surge shaft, connecting tunnel and bifurcation structure. The profiles were determined by measurements from a reference elevation to the water surface at various selected stations. Water depths in the surge shaft were converted to water surface elevations in feet prototype and plotted versus siphon discharge (Q_s) as shown on Chart 26. A table of the actual values is tabulated on Chart 27. The data points plotted as circles represent data taken with gate operation for design conditions 1, 2, and 4 and for discharges listed on Chart 25. The squares represent data taken for weir flow or design condition 3 for the discharges listed on Chart 25, and in addition, data for other discharges to define the curve better.

The measured water surface profiles are plotted on Charts 28 through 40 and the water depth values tabulated on Charts 41 through 53 for all the design conditions and discharges specified on Chart 25. Three profiles were determined for each flow condition, along the centerline (circles), the right side (squares), and the left side (triangles). The data is plotted on the graphs with the ordinate as elevation in feet and the abscissa as stations in feet. The outline of the structure is superimposed so that the water depths can readily be seen and compared. The circles show the water depth in the surge shaft and profile in the connecting tunnel and along the centerline in the chamber. Some variations in water surface profiles occur laterally across the chamber as shown on Charts 28 through 34 for design conditions with gate operation. The centerline profiles (circles) are generally higher than the profiles along the sides at the upstream end of the chamber, which defines the incoming jet, and at the downstream end, which shows the run-up on the wall. The higher the siphon discharge the more pronounced this effect becomes which may be seen by comparing Chart 28 with 34.

Charts 35 through 38 show the profiles for design condition 3 which has both gates closed and the flow going through the weir slots. For this condition the incoming jet is submerged and the water surface variations laterally across the chamber are minimal. Run-up does occur on the wall opposite the weir slots as shown on the charts.

For design condition 4 which has only gate 1 open, the discharges are lower, and the variations in the water surface are minimal as shown on Charts 39 and 40. The numerical depth values at various stations through the structure for all the design conditions and flows are tabulated on Charts 41 through 53 for use in any necessary design considerations.

3. Piezometric Pressures

A total of 48 pressure taps were installed throughout the model at selected locations. Taps 1 through 29 are located on the invert of the low structure starting at the upstream end of the siphon tunnel, going through the surge shaft, drop structure, deaeration chamber and siphon tunnel. All of these taps were utilized in the flushing mode of operation. In the siphon mode of operation with the flushing gate closed, taps 1 through 13 were utilized as shown on Chart 54. Taps 30 and 31 are located in the bellmouth and tap 32 in the siphon riser (Chart 54). All of the taps shown on Chart 54 were connected to a high manometer board to cover the full range in pressures from the flushing mode to the siphon mode. In the upper structure taps 33 through 48 were installed as shown on Chart 55. Taps 33 through 38 were located along the centerline of the elbow, connecting tunnel, and bifurcation structure. Taps 39, 41, 43, 45, and 47 were located along the centerline of tunnel 1, and taps 40, 42, 44, 46, and 48 along the centerline of tunnel 2 (Chart 55). All of the taps in the upper structure were connected to a short manometer board mounted at ceiling level near the upper structure.

Piezometric pressures were recorded for all the siphon mode operating conditions in the bifurcation structure listed on Chart 25. The pressure values were read on the manometer boards, datum correction applied, and transposed to prototype elevations in feet. These values are plotted on Charts 54 through 79 for all the siphon mode operating conditions. Two charts are presented for each condition. For example, for design condition 1 and Q_s = 50 cfs, Chart 54 shows the piezometric pressures in the siphon tunnel, surge shaft, and siphon riser, and Chart 55 the pressures in the upper bifurcation structure. On Chart 54 the pressures along the centerline (circles) are connected by a line; whereas, the pressures at taps 30, 31, and 32 are plotted as point values. On Chart 55 the pressures along the centerline of the siphon riser are plotted as circles, along the centerline of tunnel 1 as squares, and along the centerline of tunnel 2 as triangles. For design conditions 1 (Charts 54 through 59), 2 (Charts 60 through 67), and 4 (Charts 76 through 79) the piezometric pressures are all positive and plot as expected. Nothing unusual was observed. For the primary flow in each of the design conditions, 150 cfs in condition 1 (Chart 59), 300 cfs in condition 2 (Chart 65), and 16 cfs in condition 4 (Chart 77), the tailwater levels in the open tunnels were also raised 1 ft and 2 ft above the normal levels. The piezometric pressures were recorded for these raised tailwater levels and plotted on the charts indicated above. Nothing unusual was observed that would have any detrimental effect on the structure. For design condition 3 which has weir flow (Charts 68 through 75), all piezometric pressures are positive except at taps 46 and 48 in the exit tunnel as shown on Charts 69, 71, 73, and 75. The lowest pressure observed was a - 5.5 ft at tap 46 with the maximum Q_S = 375 cfs. These negative values do not approach the cavitation pressure of - 34 ft and should not adversely affect the structure. The numerical values of piezometric pressure are tabulated on Charts 80 through 89 for all the tests described above. In addition to the piezometric pressures, the pressures at the various tap in ft are included in the tables.

All investigations made on the siphon mode of operation described in this section of the report including visual, photographic, water surface profiles, and piezometric pressures show that the entire structure (Type CS46 R10) performs quite effectively and is hydraulically acceptable for the siphon mode.

D. Drawdown Mode of Operation

1. Model Observations

The flow entering the surge shaft during the siphon mode of operation carries in a certain amount of sediment. Some sediment will be drawn up through the siphon riser, the rest will be deposited in the siphon tunnel, transition, and invert of the surge shaft. After a period of time this accumulated sediment will be flushed out. The siphon mode of operation will be terminated and the structure drained down. This is accomplished by means of the eight head breaker gates as described earlier. Only gates 7 and 8 near the bottom are modeled. Observations were made at drawdown flows (Q_D) of 16, 25, 50, 75, 100, and 125 cfs and through both gates 7 and 8. The model was operated in a steady state condition; that is, the flow was set to the desired discharge and kept constant, resulting in a constant head on the gate. In the prototype the head on the gate would be continually reducing, and along with that, the discharge, until the next lower gate is opened. The flow from the gate is deflected off the opposite wall, falls vertically downward impinging on the invert, and is deflected 90 degrees into the pinch and deaeration chamber. Photo 58 shows the flow pattern for the lowest Q_D = 16 cfs through upper gate 7 of the model, and Photo 59 the same Q_D through lower gate 8. Photos 60 and 61 show the flow patterns for Q_D = 50 cfs, Photos 62 and 63 for the design Q_D = 100 cfs, and Photos 64 and 65 for Q_D = 125 cfs. The drop structure performs effectively similar to conventional dropshafts tested in previous model studies.

2. Water Surface Profiles

The measured water depths are plotted on Charts 90 through 95 and the numerical values tabulated on Charts 96 through 98. Chart 94 shows the water surface profiles for both gates 7 (circles) and 8 (squares) for the design Q_D = 100 cfs. The measurements were made with only one gate open, this is, either gate 7 or 8. Nothing unusual was observed in the water surface profiles. Considerable turbulence occurs in the dropshaft as shown in the photos; the solid jets from the gate openings are approximated on Charts 90 through 95. The flow is supercritical through the deaeration chamber and flushing tunnel and is the same when either gate is open.

3. Piezometric Pressures

The piezometric pressures were recorded at taps 1 through 29 for drawdown flows of 16, 25, 50, 75, 100 and 125 cfs. The pressures were recorded for each flow when either gate 7 or 8 was open, although the data is combined on the charts. Data taken when only gate 7 was open is plotted as circles, and when only gate 8 was open as squares. The pressures are different in the siphon tunnel and surge shaft due to the different water levels, but essentially the same in the drop structure, deaeration chamber, and flushing tunnel. Charts 99 through 105 show plots of the piezometric pressures, and Charts 106 through 111 show the tabulated values. The pressures at the taps in feet are also tabulated. The pressures are all positive, and the plots show nothing unusual.

E. Flushing Mode of Operation

1. Model Observations

After the structure has been drained down in the drawdown mode, the flushing gate is opened and the flushing flow (Q_F) is turned on as shown in Photo 66. The flow pattern is barely discernable in Photo 66 because the water depth is shallow and supercritical throughout the entire structure. As the lower part of the model is identical for Types CS46 R9 and R10, Photos 29 through 41, which show flow patterns for R9 would also show the flow patterns for R10 in the flushing mode. The patterns were discussed in the section on Type CS46 R9 and will not be repeated here.

2. Water Surface Profiles

Water surface profiles were measured in the Type CS46 R10 control structure. Where possible a standard point gage was used and at enclosed sections measurements were made from a reference elevation with a tape. Profiles were measured for flushing flows (Q_F) of 16, 25, 50, 75, 100, and 125 cfs with the design flow being 100 cfs and are presented on Charts 112 through 117. The ordinate on the graphs is elevation in feet and the abscissa is stations in feet. The numerical depth values measured at various stations are tabulated on Charts 118 and 119. For all discharges the graphs show a shallow-uniform depth of supercritical flow through the entire structure. For example with Q_F = 16 cfs, the depth varies from 0.90 ft at station 359.81 to 0.53 ft at station 659.56 (Chart 118). At the design Q_F = 100 cfs, the flow depths vary from 2.30 to 1.66 ft, and at a Q_F = 125 cfs from 2.50 to 1.99 ft. These shallow-supercritical depths resulting from the revisions and channelization of the invert were one of the major goals of the model studies and provide excellent flushing characteristics.

3. Piezometric Pressures

Piezometric pressures were also recorded for Type CS46 R10 control structure at taps 1 through 29 for flushing flows of 16, 25, 50, 75, 100, and 125 cfs. The pressures are plotted on Charts 120 through 125 and the numerical values tabulated on Charts 126 through 128. The pressures are all positive and uniform and plot similar to the water surface profiles. All the pressures were recorded along the centerline of the structure and plotted as circles, except the pressure on the invert of the right gate slot which is plotted as a square. The pressure in the gate slot was positive and about the same as the centerline pressures. The pressures at the taps are also tabulated on Charts 126 through 128 and are about the same as the water depths reported on Charts 118 and 119. At Q_F = 100 cfs the pressures at the taps vary from 2.2 to 1.6 ft and the depths from 2.30 to 1.66 ft. The piezometric pressures recorded for the flushing mode show nothing unusual or detrimental to the operation of the structure.

F. Determination of Siphon Bell Loadings

To measure fluctuating pressures on the siphon bell lip of Type CS46 R10 which has a spacing of 2.75 ft from the invert, a 1/8 inch I.D. pitot tube was attached to the bellmouth as shown in Photo 67 and on Chart 129. The tube was placed so that it faced upstream along the centerline of the structure. The copper tube went through the surge shaft wall and was connected to a chamber mounted 25 psi CEC transducer outside of the model. The output was transmitted to a Sanborn amplifier and strip chart recorder which utilized a thermo pen to trace the record on heat sensitive paper. The 25 psi CEC transducer has a sensing area of about 0.5 inch diameter. The frequency response of the transducer used was 5-10 kHz in air,the Sanborn amplifier 600 Hz, and the thermo pen 125 Hz for one-half scale deflection. When the transducer was used in water, the frequency response was somewhat lower, but still higher than the response of the amplifier.

Fluctuating pressures on the siphon bell lip were recorded during the siphon, drawdown, and flushing modes. A siphon flow of 375 cfs was established and a 10 minute record of fluctuating pressures recorded. A typical sample of the record is shown on Chart 130. The vertical scale was calibrated to elevation in feet prototype and the horizontal scale is recording time which was selected to be 20 mm per second as indicated in the lower left corner of the chart. The model time was converted to prototype time by multiplying by the T_r = 3.464. The complete record was carefully analyzed and maximum fluctuating pressure was determined to be 8.0 ft and the average frequency about 11.5 Hz (Chart 129).

To record fluctuating pressures during the drawdown mode, the following procedure was used. The flushing gate and all the head break gates were closed and the surge shaft filled. The flow was turned off. The recorder was started and the flushing gate was opened 1-inch in the model in a time of 17 seconds. For initial tests the vertical scale on the chart was set to cover the entire height of the model but the fluctuations were low and not very distinguishable. Consequently, the scale was expanded to the maximum possible as shown on Chart 131 and recordings made when the water level was near the top and then near the bottom as shown on the chart. The records shown are typical of the many runs made. The maximum fluctuating pressures recorded were 7.0 ft near the top and 5.5 ft near the bottom. The average frequency for both was about 13.0 Hz.

In the flushing mode with the flow established a hydraulic jump was induced. Recordings were made as the jump reached the bell and when it had stabilized there. Fluctuating pressures were recorded for flushing flows of 100, 125, and 150 cfs and the maximums determined for each flow were 4.0, 4.5, and 4.5 ft, respectively (Chart 129). The frequency was about 14.4 Hz for all flows. Typical records are presented on Chart 132.

The maximum fluctuating pressure recorded was 8.0 ft during the siphon mode of operation with Q_s = 375 cfs. The fluctuations summarized on Chart 129 may be used to determine siphon bell loadings.

G. Sediment Tests

Extensive sediment tests were conducted on the Type CS46 R10 control structure to determine sediment transport capabilities. For sediment test 10 (Chart 23) the model was operated in the siphon mode with Q_s = 150 cfs. To reduce the time required to reach stability of the sediment fed into the model, the sediment feed rate was increased greatly over the initial rates proposed by Parker. During sediment test 10, 500 grams per minute of sediment grade 2 was fed into the model (Chart 23). Grade 2 sediment contains 25 percent organic sediment and 75 percent inorganic sediment. After 60 minutes the migrating sand dune was only part way down the siphon tunnel. The inorganic sediment was carried through the model. It was decided to feed in Grade 3 sediment which is 100 percent inorganic, to complete the test. The model was run for 60 minutes more for a total time of 120 minutes before the sand dune reached the invert below the bellmouth. At this point most of the sediment is sucked up the siphon riser.

For sediment test 11 the model was operated in the siphon mode with Q_s = 300 cfs. Grade 3 sediment was fed in at the rate of 800 grams per minute for 52 minutes (Chart 23). At this high feed rate, some slight deposition occurred in the siphon tunnel and surge shaft, with most of the sediment sucked up the siphon riser. Little if any sediment was deposited in the bifurcation structure; it was transported through the structure and outlet tunnels.

Sediment test 12 was a combination test as outlined on Chart 23. First, the sediment was fed in during the siphon mode and deposited, and then flushed out in the flushing mode. The model was operated in the siphon mode with Q_s = 150 cfs and sediment Grade 3 fed in at a rate of 500 grams per minute for 120 minutes. To determine the effect of the deposited sediment on the piezometric pressures, readings were taken at taps 1a through 7a at the crown of the tunnel. The pressures were read at the start of the test, and every 30 minutes thereafter. These piezometric pressures are plotted on Chart 133 and tabulated on Chart 134. Some slight changes occurred at taps 1a and 2a as indicated in the table on Chart 134. At 120 minutes the sand dune had stabilized beneath the bellmouth and the test terminated. Siphon flows of 16, 50, and 100 cfs were then each established and the piezometric pressure read as fast as possible so that the deposited material would be disturbed as little as possible. These pressures are plotted on Chart 135 and tabulated on Chart 136. It was estimated that 48 percent of the material fed in was deposited in the siphon tunnel and surge shaft. The model was slowly and carefully drained down and the flushing gate opened. A flushing flow of 100 cfs was established with no sediment fed in. The deposition remaining from the siphon mode was flushed out in 19 minutes.

Sediment test 14 consisted of operating the model through a cycle of siphon flows from 16 to 300 cfs (Chart 23). A Q_s = 16 cfs was first established and sediment grade 1 fed in at a rate of 18 grams per minute for 180 minutes. At this time only a small sand dune had formed just downstream of the feed pipe and testing at this flow was stopped. The deposition was estimated to be 47 percent. A Q_S = 50 cfs was turned on and sediment grade 1 was fed into the model at a rate of 22 grams per minute. The test was stopped after 190 minutes and the deposition estimated to be 79 percent. This is the accumulative percent of deposition; that is, it includes the deposition that occurred during the 16 cfs flow. With the deposition from the previous flows still in the model, a Q_S = 100 cfs was established and sediment grade 3 fed in at a rate of 43 grams per minute for 180 minutes. The flow was turned off and the deposition estimated to be 80 percent, as shown in Photo 68. This is only a 1 percent increase in deposition from the previous Q_S = 50 cfs, showing that most of the material fed in during the 100 cfs flow was transported through the model. A Q_S = 150 cfs was turned on and sediment grade 3 fed in at a rate of 54 grams per minute for 180 minutes. The flow was turned off and the deposition estimated to be 41 percent is shown in Photo 69. This is a 39 percent reduction in the accumulated deposition during this flow test showing that flushing is taking place during the siphon mode at 150 cfs. At this time a sediment sample was taken from the material remaining in the model and a size distribution analysis made. This is plotted on Chart 137 along with the size distribution of the inorganic sediment fed into the model. The shift in the curve towards the coarser sediment sizes indicates that a greater portion of the finer sediments are transported through the model. A siphon flow of 300 cfs was turned on and sediment grade 3 was fed into the model at a rate of 102 grams per minute for 150 minutes, and the test terminated at this time. All the deposition was flushed out of the model and the sediment being fed in was transported through the model with no deposition as shown in Photo 70. This concluded sediment test 14 with the interesting result that during siphon flows of 150 and 300 cfs actual flushing occurred. At 300 cfs the model was completely flushed out. This test is summarized on Chart 23.

During sediment test 14 piezometric pressures were recorded at the start and end of each test discharge. This data is plotted on Chart 138 and tabulated on Chart 139. Some slight variations occur in the pressure readings from the beginning of the test period to the end for the higher siphon flows of 150 and 300 cfs. This may be the result of the flushing taking place during these flow conditions.

Sediment test 15 consisted of operating the model in the flushing mode for discharges of 16, 50, and 100 cfs. With Q_F = 16 cfs, 11 grams per minute of sediment grade 1 was fed into the model for 50 minutes (Chart 23). A trace of sediment was noticed in the surge shaft and deaeration chamber as shown in Photo 71. With Q_F = 50 cfs, 21 grams per minute of sediment grade 1 was fed into the model for 120 minutes. All the sediment was transported through the model and no deposition occurred (Photo 72). The design flushing flow of 100 cfs was established and 57 grams per minute of sediment grade 3 was fed into the model for 120 minutes. Again all the sediment was transported through the model and no deposition took place (Photo 73). This concluded sediment test 15 with the conclusion that the Type CS46 R10 control structure operates very effectively in transporting sediment.

H. Sediment Flushing Time

In accordance with the fundamental physical processes involved in sediment scouring, the flushing time required is a combination of the vertical cut down time which is independent of tunnel length, and the thin layer sweepout time which is dependent on sweepout velocity and tunnel length.

The vertical cut-down time was determined in the model as follows. First the model was operated in the siphon mode until the dune pattern had reached equilibrium in the siphon tunnel down to the siphon bellmouth. The siphon flow was then turned off and the surge shaft slowly drained to leave the undisturbed dune pattern in the invert. The flushing gate was opened and a flushing flow of 100 cfs was turned on. The time from turning on of the flow until the model was completely flushed of sediment was considered as the vertical cut-down time. Two tests were run in this manner and the vertical cut-down time determined to be about 20 minutes model time or 69.3 minutes prototype.

The sweepout time was determined as follows. With the model operating in the flushing mode with a discharge of 100 cfs, sediment grade 3 was fed in until a thin layer of sediment covered the siphon tunnel invert. The sediment feeder was turned off, and the time required to flush the sediment from a measured length of the tunnel recorded. From the length and time the sweepout velocity in fps was computed, observations were made for sediment depths in the model invert of 3, 1, and 0.5 mm. Five runs were made at each depth and the average time used to compute the prototype sweepout velocity. These tests are summarized as sediment test 16 on Chart 23 and the results presented on Chart 140. The prototype sweepout velocity of 2.07 fps obtained from using a sediment depth of 1 mm is recommended for computing the sweepout time for the 16,000 ft tunnel. With a depth of 3 mm the dune movement varied considerable in time depending on location in the tunnel, and with a depth 0.5 mm the sediment was difficult to see in the model and determine when it was all swept out. With a sediment depth of 1 mm the rate of movement was reasonably uniform and the sediment could be seen better. Using a flushing rate of 2.07 fps the sweepout time for the 16,000 ft tunnel was computed to be 128.8 minutes. The total flushing time including the vertical cut-down time and sweepout time is 3.3 hours as shown on Chart 140. In discussions with Parker of SAFHL and Nesbeitt of Harza, it was decided to recommend a flushing time of about 5 hours. The flushing frequency can be approximated on the basis of the measured prototype sediment inflow concentrations and model tests, or on the basis of increase in the hydraulic gradeline elevation at structure 243. The resulting frequency would probably be relatively long and could result in some cohesive cementation. It is therefore recommended on an experience basis that the tunnel be flushed about every 2 months of operation until prototype operating experience shows differently.

I. Air Injection Tests

A major concern of EAA is the generation of hydrogen sulfide under low flow operating conditions in the long tunnel system. It was determined that the most cost effective method for combatting this problem would be to inject air into the siphon tunnel, providing there were no detrimental hydraulic effects. Therefore, air injection tests were conducted on the Type CS46 R10 control structure to observe the effect of the air entering the surge shaft from the siphon tunnel. The prototype air discharge is 85 cfm at water discharges of 16, 50, and 100 cfs as given by an EAA report dated September 26, 1983. This transposes to an air discharge of 4825 ccm in the model and was metered into the model through a Fischer and Porter flowrator meter 138 ft upstream of the surge shaft. With the air discharge maintained at 85 cfm, observations were made at siphon discharges of 16, 50, and 100 cfs. For all flows the air injected into the siphon tunnel was not entrained into the flow. It rose rather quickly to the tunnel crown where it coalesced into large air pockets, which then traveled upstream against the water flow in the tunnel. In the model this air traveled upstream to the sediment feed standpipe where it was released, accompanied by substantial water hammer shock in the tunnel.

The air was then injected into another tap 31.5 ft upstream of the surge shaft at the same rate of 85 cfm. With a siphon flow of 100 cfs, the injected air divided with about half the air traveling upstream as before and the other half moving downstream along the crown into the surge shaft. The air reaching the surge shaft rose vertically along the upstream wall with no air entering the siphon riser.

The air discharge was increased to 317 cfm injected 31.5 ft upstream of the surge shaft. With the siphon flow of 100 cfs the performance was the same as above. It was concluded that these conditions were hydraulically unacceptable and that air should not be injected into the tunnel.

XV. TYPE CS46 R11 CONTROL STRUCTURE

A. Description of Model

In previous tests it was observed that for 125 cfs an induced hydraulic jump would hang up on the bellmouth and not break free. By reducing the discharge or raising the bellmouth 0.3 ft, the jump would break free and the flow would revert to supercritical. The Type CS46 R11 control structure is the same as Type CS46 R10 with the siphon riser bellmouth raised from 2.75 ft to 3.25 ft from the surge shaft invert (Charts 13 and 14), or from elevation 229.0 ft to 229.5 ft. To accomplish this a section of the siphon riser was cut out, so that the upper elbow remained at the same elevation.

B. Model Observations

In the siphon mode of operation with no sediment fed in, no noticeable changes in the flow pattern for all discharges were observed. In the flushing mode of operation for all flows up to 125 cfs, the induced hydraulic jump would now break free and the flow would revert to supercritical through the entire model. This is an improvement in the flow characteristics as compared to Type CS46 R10. Except for this, the flow characteristics for Types R10 and R11 are similar and both hydraulically acceptable.

C. Determination of Siphon Bell Loadings

The siphon bell loadings were determined on Type CS46 R11 the same as for R10. The procedures were outlined in the Type CS46 R10 section and not repeated here. Fluctuating pressures on the siphon bell lip were recorded during the siphon mode with Q_s = 375 cfs (Chart 141), during the drawdown mode (Chart 142), and for flushing flow of 100, 125, and 150 cfs (Chart 143). A summary of the maximum fluctuating pressure recorded for each condition is presented on Chart 129 along with those for Type CS46 R10. The maximum pressure fluctuation observed was 10 ft and occurred during the drawdown mode when the water surface was near the bottom of the surge shaft. This may be compared to 5.5 ft for R10 or an increase of 4.5 ft. In the siphon mode the maximum fluctuations decreased from 8.0 (R10) to 5.2 ft (R11) a reduction of 2.8 ft. During the flushing mode the fluctuations are similar as well as the frequencies estimated for all modes of operation.

D. Sediment Tests

Sediment test 13 was conducted on the Type CS46 R11 control structure and was a combination test similar to test 12 conducted on Type CS46 R10 (Chart 23). First a siphon flow of 150 cfs was established, and then sediment Grade 3 was fed into the model at a rate of 500 grams per minute for 135 minutes. At this time the deposition appeared to be stabilized and the test terminated. The estimated deposition was 92 percent as compared to 48 percent for R10 (Chart 23). The deposition in the siphon tunnel is shown in Photo 74 and that in the surge shaft in Photo 75. Photo 75 was taken through the water and is not too clear, but the sediment fills more than half the siphon tunnel upstream of the bellmouth, with a layer beneath the bellmouth, and is deposited against the flushing gate almost to the top. In Type CS46 R10 very little sediment was deposited under the bellmouth or by the flushing gate. The Type CS46 R11 control structure is definitely not as effective in sediment transport as R10 in the siphon mode.

During the sediment test the piezometric pressures were recorded at taps 1a through 7a at the start of the test, every 30 minutes up to 120 minutes, and then when the test was terminated at 135 minutes. At the end of this time, siphon discharges of 16, 50, and 100 cfs were each established and the piezometric pressures recorded as soon as possible so as not to disturb the deposition. The pressures are plotted on Charts 144 and 145 and tabulated on Charts 146 and 147. Chart 146 shows that as the depth of sediment builds up the pressures also increase. For example, at tap 1a at time = 0, the pressure at the tap is 108.0 ft. This increases gradually to 109.2 ft at a time of 120 minutes, and actually drops to 108.9 ft at a time of 135 minutes. This is probably an overall effect due to the siphon tunnel gradually filling with sediment, and a local effect as influenced by single sand dunes as may be seen in Photo 74. These pressure changes diminish for taps further downstream in the siphon tunnel with tap 7a affected the least. A sediment sample was taken at this time. A size distribution analysis was made and the results plotted on Chart 148 along with the size distribution of the inorganic sediment fed into the model. The curve for the deposited material shows a shift towards the coarser sizes, indicating that a larger proportion of the finer materials are transported through the model.

The model was carefully drained down in the drawdown mode and the flushing gate opened. A flushing flow of 100 cfs was established and after 22 minutes the deposited sediment was flushed completely out of the model (Chart 23). This is a slightly longer time than the 19 minutes for Type CS46 R10, but this was to be expected as considerably more sediment had to be flushed out. The flushing characteristics of Type CS46 R11 during the flushing mode are excellent. The Type CS46 R11 control structure is very effective in sediment transport during the flushing mode, but deposition almost twice that of Type CS46 R10 occurs during the siphon mode. In conclusion, it was judged that the slight advantage of the higher bellmouth clearance above the surge shaft invert was negated by the much greater sediment deposition in the siphon mode. Therefore, the Type CS46 R11 control structure is not recommended.

LIST OF PHOTOGRAPHS

Photo 16 Type CS46 R2 control structure, Q_F = 100 cfs, H.W. = 2.2 ft, T.W. = 2.4 ft. Sediment test 1, the deposition in the surge shaft invert after 30 minutes.

Photo 17 Type CS46 R3 control structure, Q_F = 100 cfs, H.W. = 2.2 ft, T.W. = 2.3 ft. The pinch area and deaeration chamber.

Photo 18 Type CS46 R3 control structure, Q_F = 100 cfs, H.W. = 2.2 ft, T.W. = 2.3 ft. The surge shaft invert.

Photo 19 Type CS46 R4 control structure, Q_F = 100 cfs, H.W. = 2.1 ft, T.W.= 1.5 ft. The deaeration chamber and rectangular flushing tunnel.

Photo 20 Type CS46 R4 control structure, Q_F = 100 cfs, H.W. = 2.1 ft, T.W. = 1.5 ft. The surge shaft invert and siphon riser.

Photo 21 Type CS46 R4 control structure, Q_F = 100 cfs, H.W. = 2.1 ft, T.W. = 1.5 ft. Sweepout test.

Photo 22 Type CS46 R4 control structure. The sediment placed in the surge shaft invert for sediment test 3.

Photo 23 Type CS46 R5 control structure, Q_F = 100 cfs, H.W. = 2.1 ft, T.W. = 1.5 ft. The pinch area.

Photo 24 Type CS46 R5 control structure, Q_F = 100 cfs, H.W. = 2.1 ft, T.W. = 1.5 ft. The surge shaft invert and siphon riser.

Photo 25 Type CS46 R6 control structure, Q_F = 100 cfs, H.W. = 2.1 ft, T.W. = 1.4 ft. The pinch area.

Photo 26 Type CS46 R6 control structure, Q_F = 100 cfs, H.W. = 2.1 ft, T.W. = 1.4 ft. The surge shaft invert and siphon riser.

Photo 27 Type CS46 R7 control structure, Q_F = 100 cfs, H.W.= 2.1 ft, T.W. = 1.4 ft. The surge shaft invert and siphon riser.

Photo 28 Type CS46 R8 control structure, Q_F = 100 cfs, H.W. = 2.1 ft, T.W. = 1.4 ft. The deaeration chamber and flushing tunnel.

Photo 29 Type CS46 R9 control structure, Q_F = 100 cfs, H.W. = 2.1 ft, T.W. = 1.4 ft. The overall model.

Photo 30 Type CS46 R9 control structure, Q_F = 100 cfs, H.W. = 2.1 ft, T.W. = 1.4 ft. The siphon tunnel and surge shaft invert.

Photo 31 Type CS46 R9 control structure, Q_F = 100 cfs, H.W. = 2.1 ft, T.W. = 1.4 ft. The surge shaft invert and siphon riser.

Photo 32 Type CS46 R9 control structure, Q_F = 100 cfs, H.W. = 2.1 ft, T.W. = 1.4 ft. The surge shaft invert and siphon riser.

Photo 33 Type CS46 R9 control structure, Q_F = 100 cfs, H.W. = 2.1 ft, T.W. = 1.4 ft. The pinch area.

Photo 34 Type CS46 R9 control structure, Q_F = 100 cfs, H.W. = 2.1 ft, T.W. = 1.4 ft. The entrance to the flushing tunnel.

Photo 35 Type CS46 R9 control structure, Q_F = 50 cfs, H.W. = 1.4 ft, T.W. = 1.1 ft. The siphon tunnel and surge shaft invert.

Photo 36 Type CS46 R9 control structure, Q_F = 50 cfs, H.W. = 1.4 ft, T.W. = 1.1 ft. The pinch area.

Photo 37 Type CS46 R9 control structure, Q_F = 125 cfs, H.W. = 2.4 ft, T.W. = 1.8 ft. The siphon tunnel and surge shaft invert.

Photo 38 Type CS46 R9 control structure, Q_F = 125 cfs, H.W. = 2.4 ft, T.W. = 1.8 ft. The surge shaft invert and siphon riser bellmouth.

Photo 39 Type CS46 R9 control structure, Q_F = 125 cfs, H.W. = 2.4 ft, T.W. = 1.8 ft. The pinch area.

Photo 40 Type CS46 R9 control structure, Q_F = 125 cfs, H.W. = 2.4 ft, T.W. = 1.8 ft. The entrance to the flushing tunnel.

Photo 41 Type CS46 R9 control structure, Q_F = 100 cfs, H.W. = 2.1 ft, T.W. = 1.4 ft. Sweepout test.

Photo 42 Type CS46 R9 control structure, Q_F = 100 cfs, H.W. = 2.1 ft, T.W. = 1.4 ft. The sediment placed in the surge shaft invert for sediment test 9.

Photo 43 Type CS46 R10 control structure. The overall model, laboratory research personnel, and Mr. 1:12.

Photo 44 Type CS46 R10 control structure. The top of the surge shaft, upper elbow, and bifurcation structure.

Photo 45 Type CS46 R10 control structure. The filling mode of operation.

Photo 46 Type CS46 R10 control structure, Q_s = 300 cfs, H.W. = 118.7 ft, Gates 1 and 2 open, $T.W._1$ = 5.1 ft, $T.W._2$ = 4.8 ft. The overall model, siphon mode of operation.

Photo 47 Type CS46 R10 control structure, Q_s = 50 cfs, H.W. = 112.5 ft, Gate 2 open, $T.W._1$ = 0 ft, $T.W._2$ = 2.3 ft. The bifurcation structure.

Photo 48 Type CS46 R10 control structure, Q_s = 150 cfs, H.W. = 115.0 ft, Gate 2 open, $T.W._1$ = 0 ft, $T.W._2$ = 4.4 ft. The bifurcation structure.

Photo 49 Type CS46 R10 control structure, Q_s = 150 cfs, H.W. = 115.0 ft, Gate 2 open, $T.W._1$ = 0 ft, $T.W._2$ = 4.4 ft. The bifurcation structure.

Photo 50 Type CS46 R10 control structure, Q_s = 200 cfs, H.W. = 116.2 ft, Gates 1 and 2 open, $T.W._1$ = 4.8 ft, $T.W._2$ = 4.2 ft. The bifurcation structure.

Photo 51 Type CS46 R10 control structure, Q_s = 300 cfs, H.W. = 118.7 ft, Gates 1 and 2 open, $T.W._1$ = 5.1 ft, $T.W._2$ = 4.8 ft. The bifurcation structure.

Photo 52 Type CS46 R10 control structure, Q_s = 300 cfs, H.W. = 118.7 ft, Gates 1 and 2 open, $T.W._1$ = 5.1 ft, $T.W._2$ = 4.8 ft. The bifurcation structure.

Photo 53 Type CS46 R10 control structure, Q_s = 375 cfs, H.W. = 119.4 ft, Gates 1 and 2 open, $T.W._1$ = 5.6 ft, $T.W._2$ = 6.0 ft. The bifurcation structure.

Photo 54 Type CS46 R10 control structure, Q_s = 300 cfs, H.W. = 124.0 ft, no gates open, $T.W._1$ = N/A, $T.W._2$ = N/A. The bifurcation structure.

Photo 55 Type CS46 R10 control structure, Q_s = 300 cfs, H.W. = 124.0 ft, no gates open, $T.W._1$ = N/A, $T.W._2$ = N/A. The bifurcation structure.

Photo 56 Type CS46 R10 control structure, Q_s = 375 cfs, H.W. = 127.5 ft, no gates open, $T.W._1$ = N/A, $T.W._2$ = N/A. The bifurcation structure.

Photo 57 Type CS46 R10 control structure, Q_s = 50 cfs, H.W. = 112.3 ft, Gate 1 open, $T.W._1$ = 4.7 ft, $T.W._2$ = 0 ft. The bifurcation structure.

Photo 58 Type CS46 R10 control structure, Q_D = 16 cfs, H.W. = 28.0 ft, T.W. = 0.4 ft, Gate 7 open. Drawdown mode of operation.

Photo 59 Type CS46 R10 control structure, Q_D = 16 cfs, H.W. = 16.2 ft, T.W. = 0.4 ft, Gate 8 open. Drawdown mode of operation.

Photo 60 Type CS46 R10 control structure, Q_D = 50 cfs, H.W. = 30.3 ft, T.W. = 1.0 ft, Gate 7 open. Drawdown mode of operation.

Photo 61 Type CS46 R10 control structure, Q_D = 50 cfs, H.W. = 18.4 ft, T.W. = 1.0 ft, Gate 8 open. Drawdown mode of operation.

Photo 62 Type CS46 R10 control structure, Q_D = 100 cfs, H.W. = 38.3 ft, T.W. = 1.4 ft, Gate 7 open. Drawdown mode of operation.

Photo 63 Type CS46 R10 control structure, Q_D = 100 cfs, H.W. = 26.2 ft, T.W. = 1.5 ft, Gate 8 open. Drawdown mode of operation.

Photo 64 Type CS46 R10 control structure, Q_D = 125 cfs, H.W. = 44.4 ft, T.W. = 1.8 ft, Gate 7 open. Drawdown mode of operation.

Photo 65 Type CS46 R10 control structure, Q_D = 125 cfs, H.W. = 33.0 ft, T.W. = 1.9 ft, Gate 8 open. Drawdown mode of operation.

Photo 66 Type CS46 R10 control structure, Q_F = 100 cfs, H.W. = 2.1 ft, T.W. = 1.4 ft. The flushing mode of operation; the overall model.

Photo 67 Type CS46 R11 control structure. The surge shaft invert and siphon bellmouth with pitot tube attached.

Photo 68 Type CS46 R10 control structure, Q_s = 100 cfs. Sediment test 14, deposition in siphon tunnel after 180 minutes.

Photo 69 Type CS46 R10 control structure, Q_s = 150 cfs. Sediment test 14, deposition in siphon tunnel after 180 minutes.

Photo 70 Type CS46 R10 control structure, Q_s = 300 cfs. Sediment test 14, the accumulated deposition was flushed through the siphon riser and bifurcation structure.

Photo 71 Type CS46 R10 control structure, Q_F = 16 cfs. Sediment test 15, trace of deposition in drop structure and pinch area after 150 minutes.

Photo 72 Type CS46 R10 control structure, Q_F = 50 cfs. Sediment test 15, no deposition in structure after 120 minutes.

Photo 73 Type CS46 R10 control structure, Q_F = 100 cfs. Sediment test 15, no deposition in structure after 120 minutes.

Photo 74 Type CS46 R11 control structure, Q_s = 150 cfs. Sediment test 13, deposition in siphon tunnel after 135 minutes.

Photo 75 Type CS46 R11 control structure, Q_s = 150 cfs. Sediment test 13, deposition in surge shaft invert after 135 minutes.

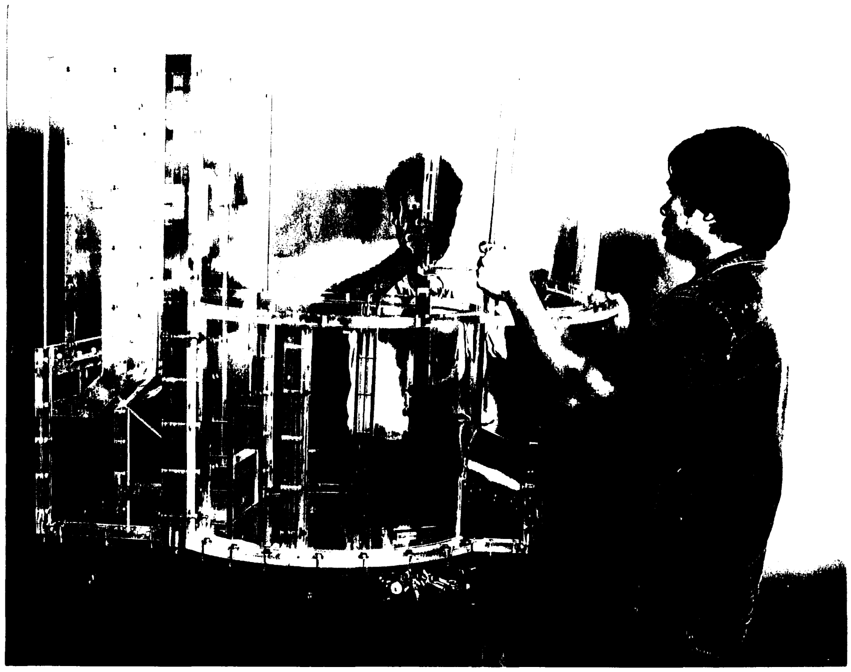


Photo 1 - Type CS46 control structure. The surge shaft and drop structure being fabricated in the laboratory shop.

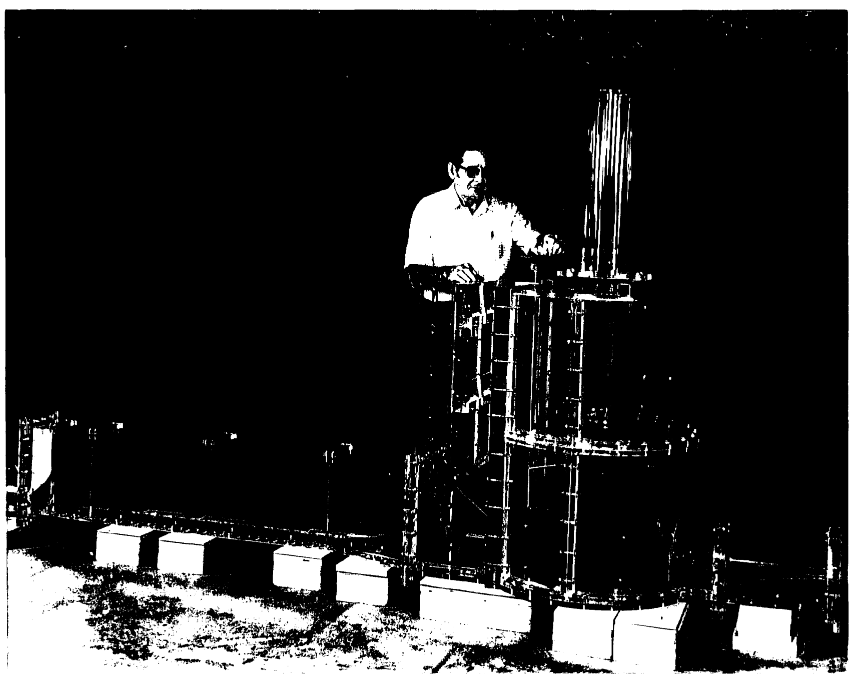


Photo 2 - Type CS46 control structure. The completed low model ready for testing.

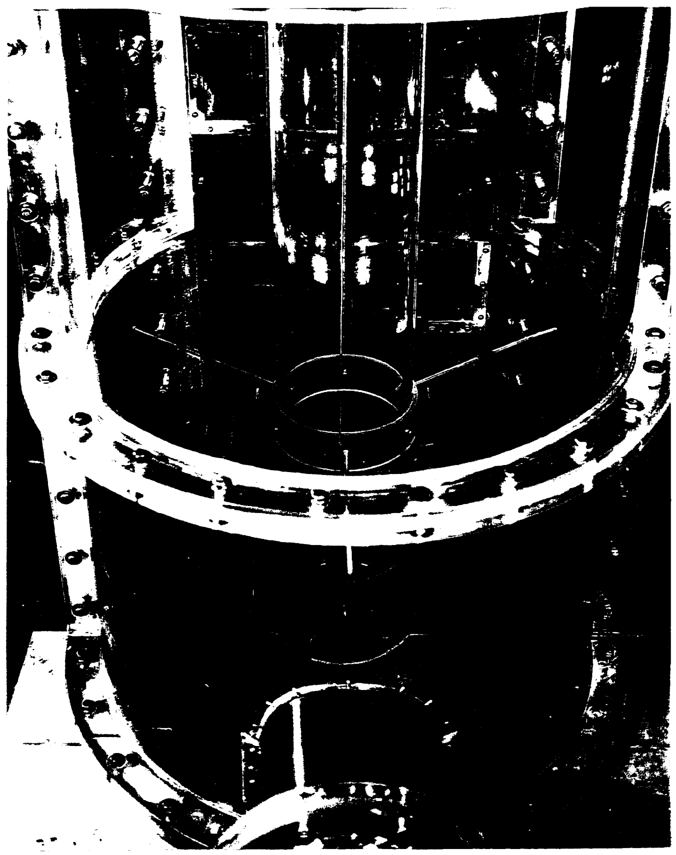


Photo 3 - Type CS46 control structure.
The surge shaft and invert.

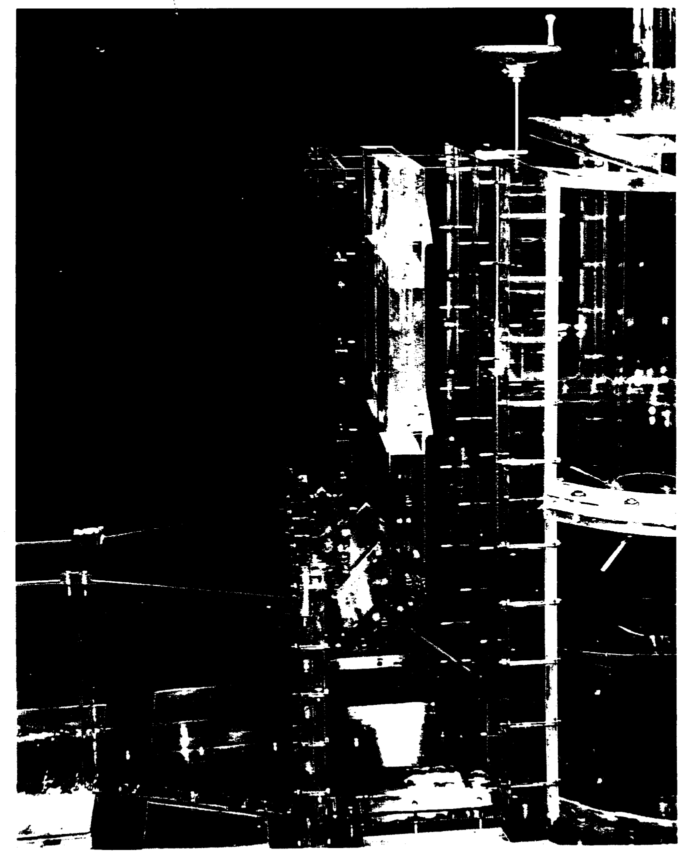


Photo 4 - Type CS46 control structure.
The drop structure.

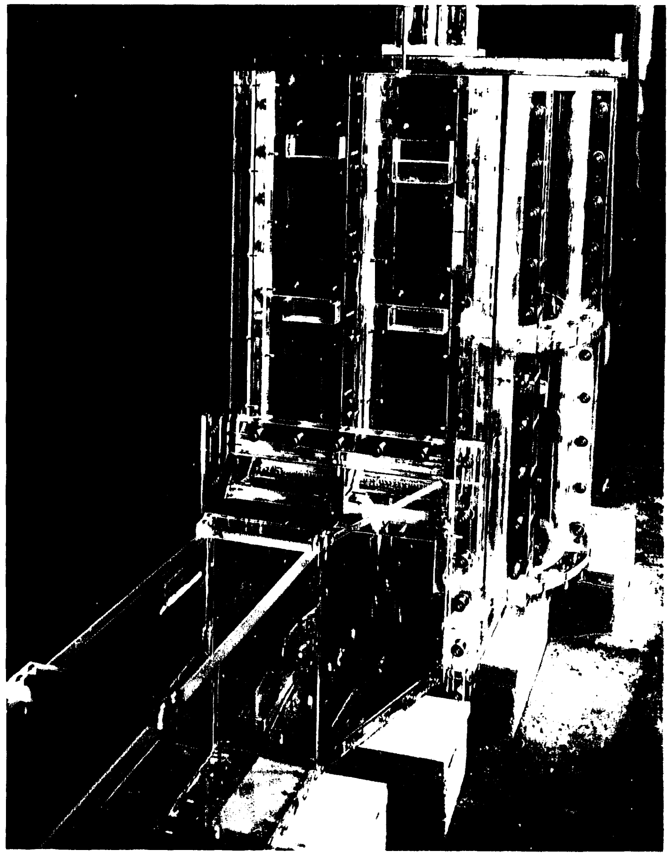


Photo 5 - Type CS46 control structure. The drop structure.

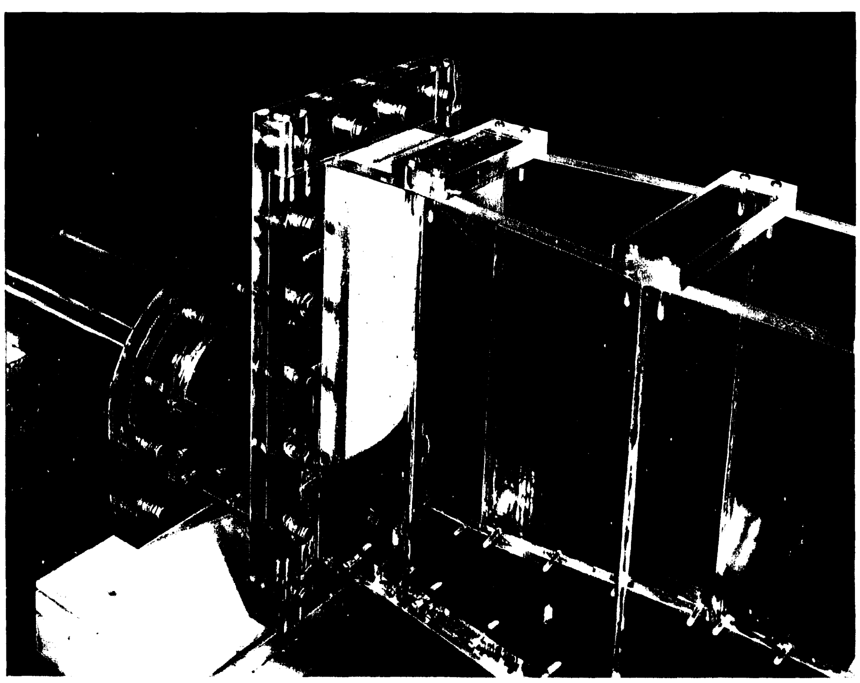


Photo 6 - Type CS46 control structure. The entrance to the flushing tunnel.

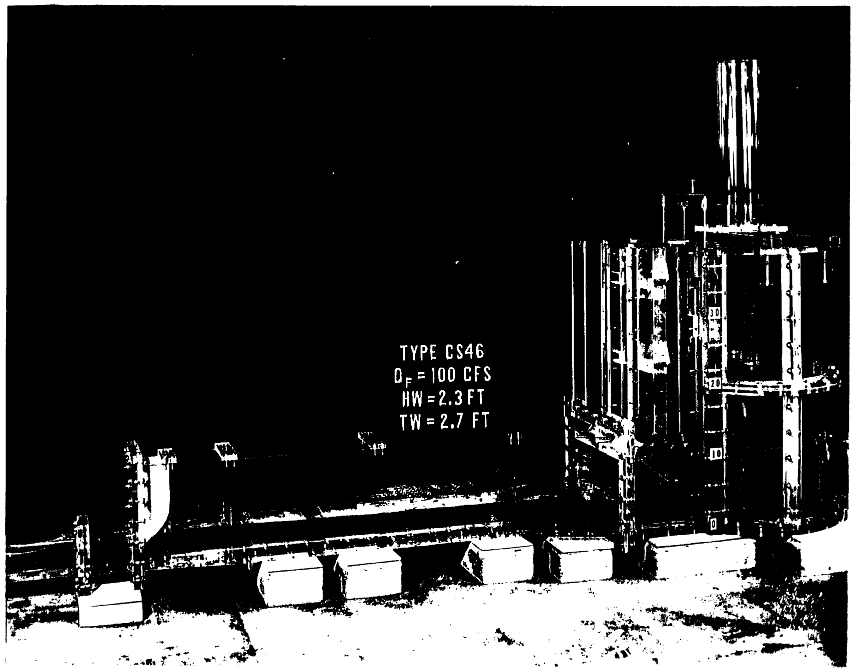


Photo 7 - Type CS46 control structure, Q_F = 100 cfs, H.W. = 2.3 ft, T.W. = 2.7 ft. The overall model.

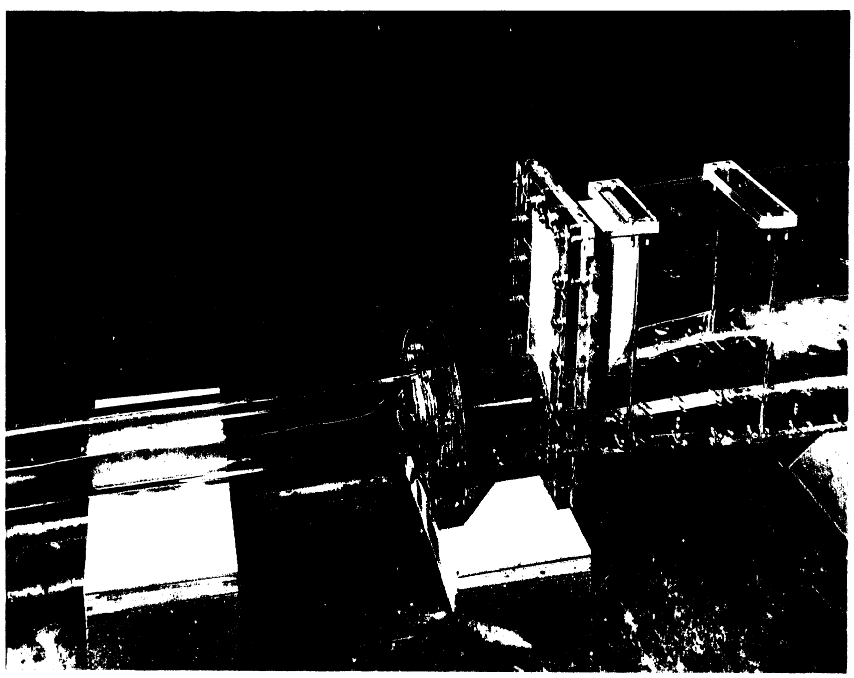


Photo 8 - Type CS46 control structure, Q_F = 100 cfs, H.W. = 2.3 ft, T.W. = 2.7 ft. The entrance to the flushing tunnel.

Photo 9 - Type CS46 control structure, Q_F = 100 cfs, H.W. = 2.3 ft, T.W. = 2.7 ft. The pinch area and deaeration chamber.

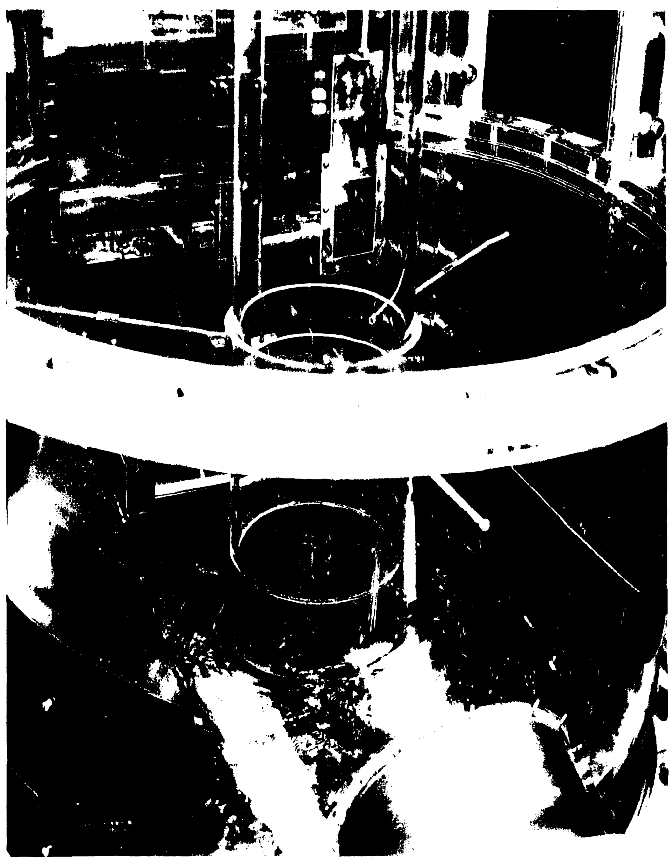


Photo 10 - Type CS46 control structure, Q_F = 100 cfs, H.W. = 2.3 ft, T.W. = 2.7 ft. The surge shaft invert and siphon riser.

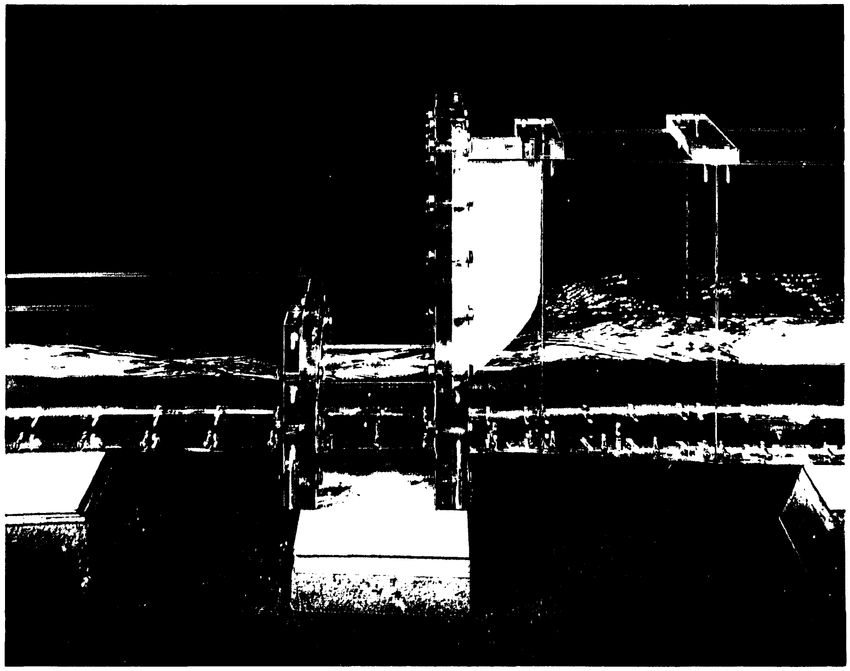


Photo 11 - Type CS46 R1 control structure, Q_F = 100 cfs, H.W. = 2.3 ft, T.W. = 2.5 ft. The entrance to the flushing tunnel.

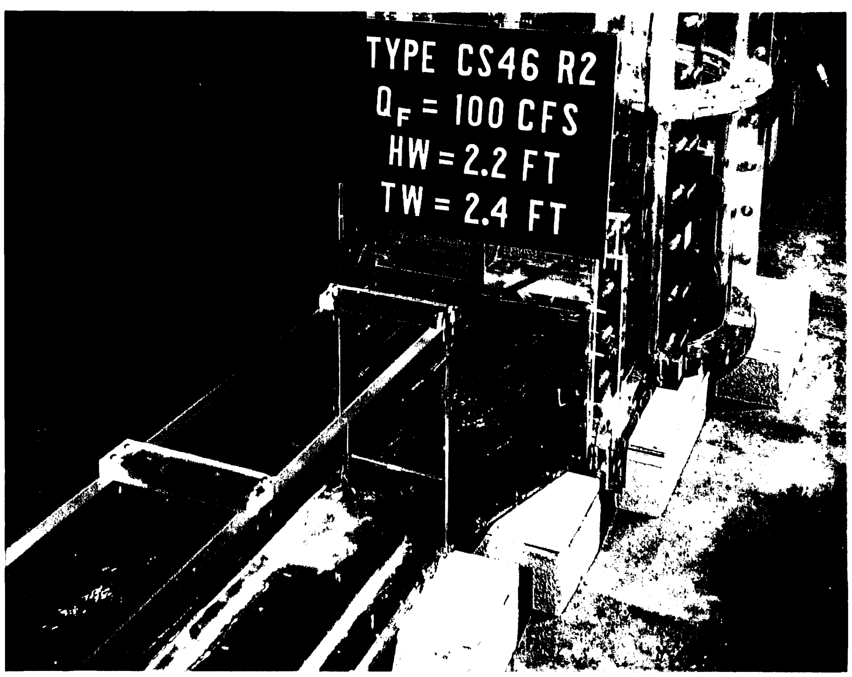


Photo 12 - Type CS46 R2 control structure, Q_F = 100 cfs, H.W. = 2.2 ft, T.W. = 2.4 ft. The pinch area and deaeration chamber.

Photo 13 - Type CS46 R2 control structure. The sediment feeder.

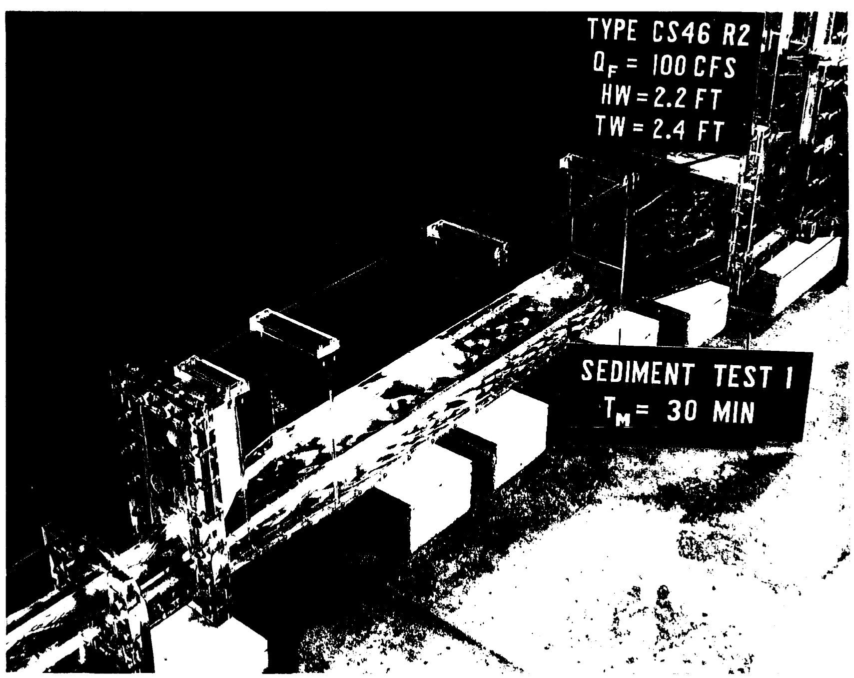


Photo 14 - Type CS46 R2 control structure, Q_F = 100 cfs, H.W. = 2.2 ft, T.W. = 2.4 ft. Sediment test 1 after 30 minutes, the deaeration chamber.

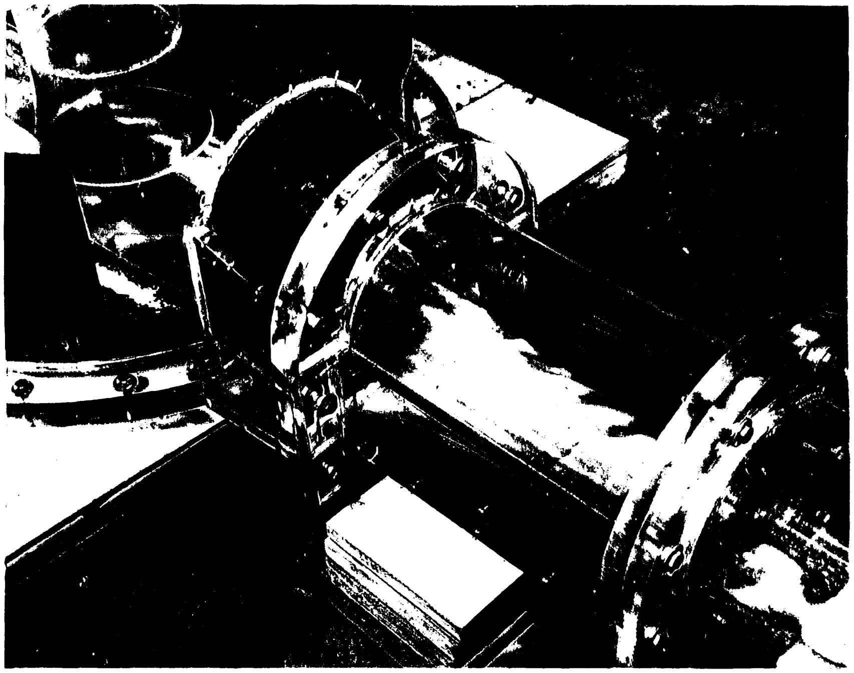


Photo 15 - Type CS46 R2 control structure, Q_F = 100 cfs, H.W. = 2.2 ft, T.W. = 2.4 ft. Sediment Test 1, the deposition in the siphon tunnel after 30 minutes.

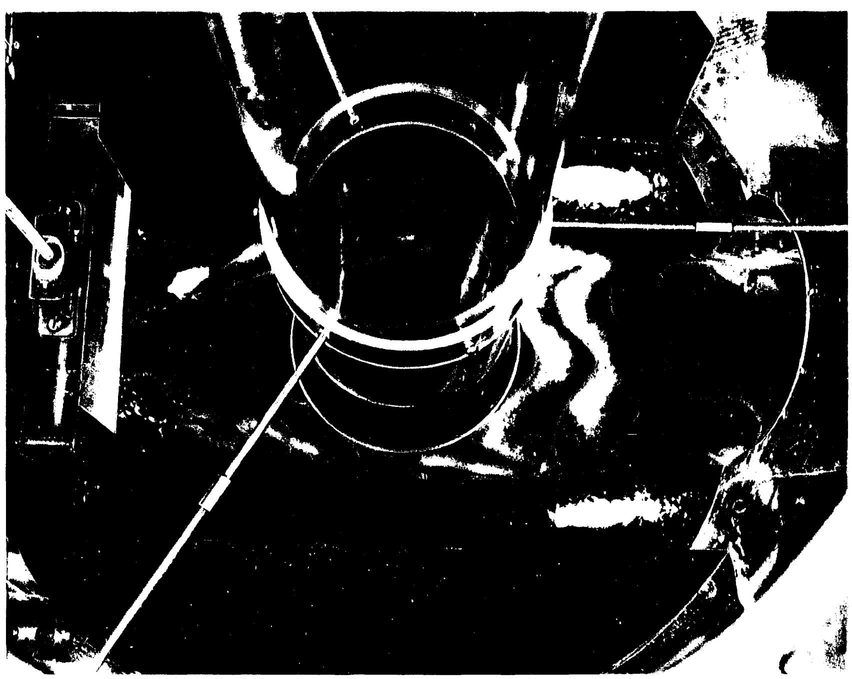


Photo 16 - Type CS46 R2 control structure, Q_F = 100 cfs, H.W. = 2.2 ft, T.W. = 2.4 ft. Sediment test 1, the deposition in the surge shaft invert after 30 minutes.

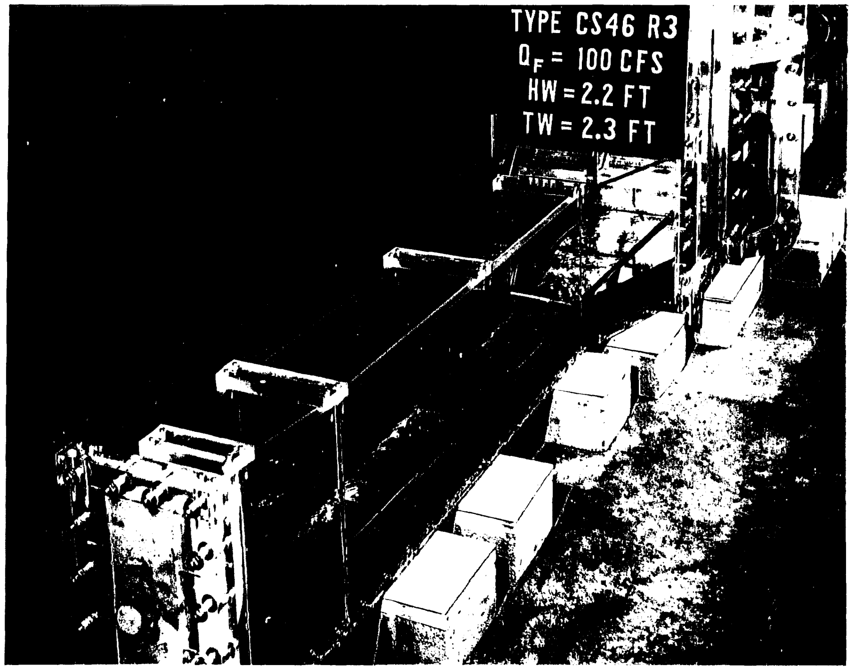


Photo 17 - Type CS46 R3 control structure, Q_F = 100 cfs, H.W. = 2.2 ft, T.W. = 2.3 ft. The pinch area and deaeration chamber.

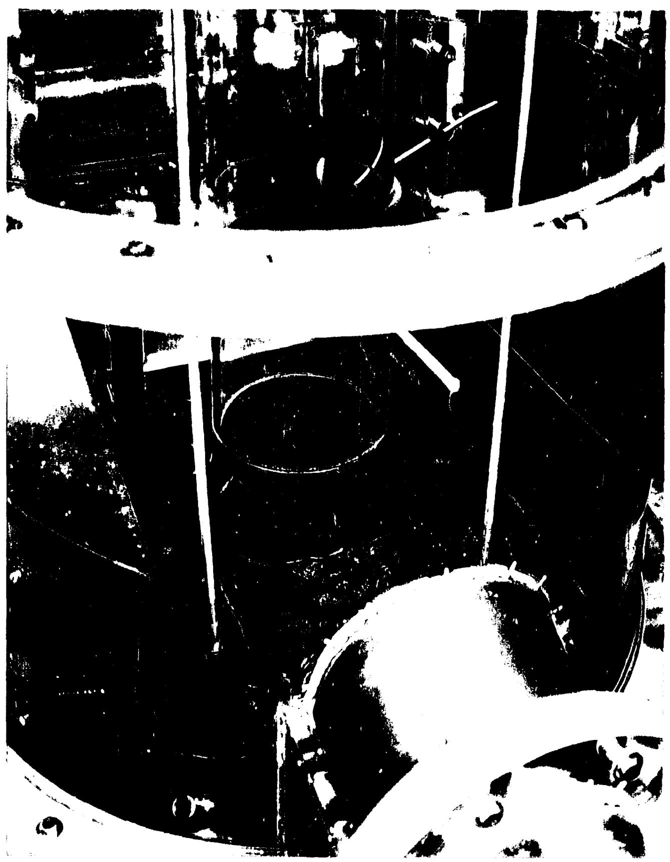


Photo 18 - Type CS46 R3 control structure, Q_F = 100 cfs, H.W. = 2.2 ft, T.W. = 2.3 ft. The surge shaft invert.

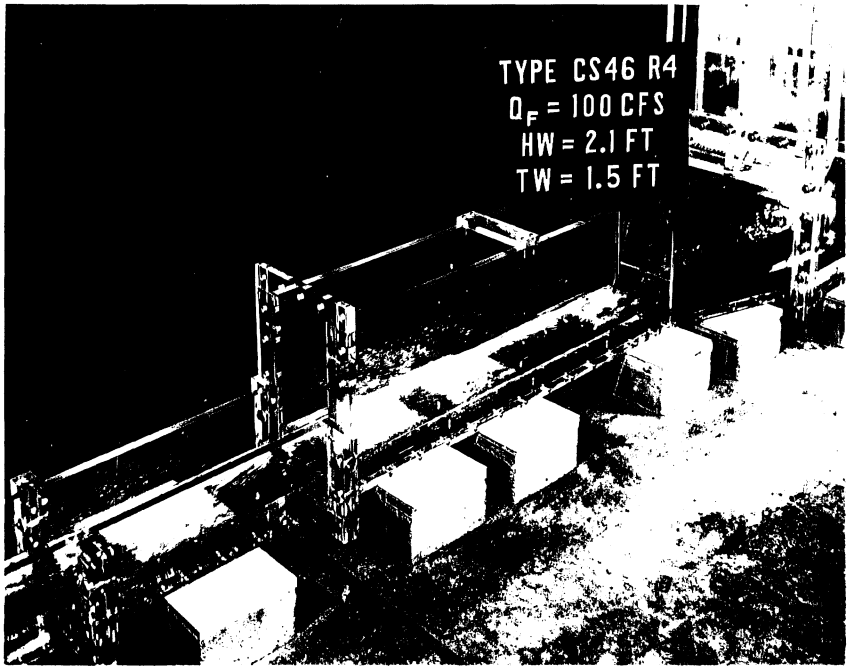


Photo 19 Type CS46 R4 control structure, Q_F = 100 cfs, H.W. = 2.1 ft, T.W.= 1.5 ft. The deaeration chamber and rectangular flushing tunnel.

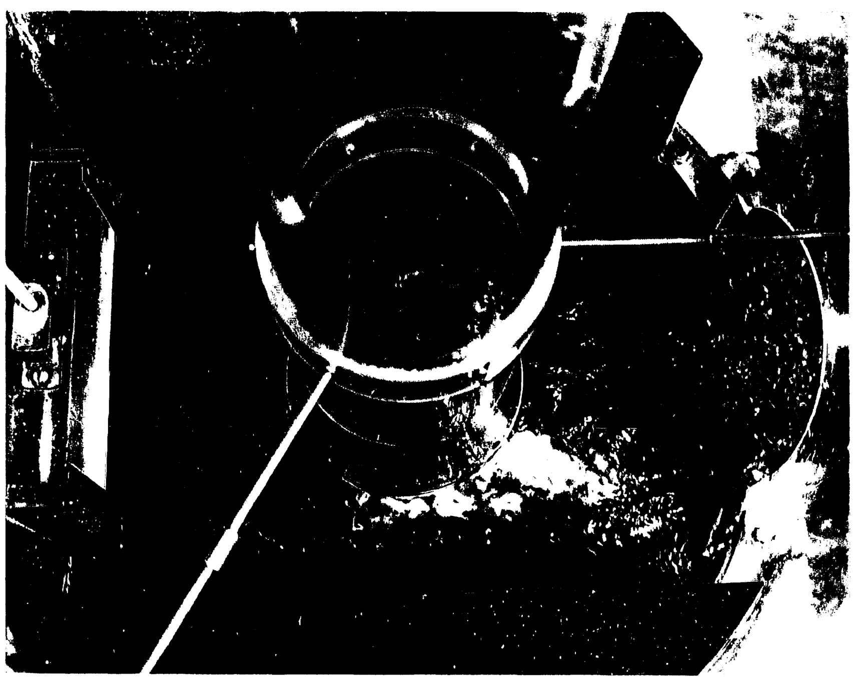


Photo 20 - Type CS46 R4 control structure, Q_F = 100 cfs, H.W. = 2.1 ft, T.W. = 1.5 ft. The surge shaft invert and siphon riser.

Photo 21 - Type CS46 R4 control structure, Q_F = 100 cfs, H.W. = 2.1 ft, T.W. = 1.5 ft. Sweepout test.

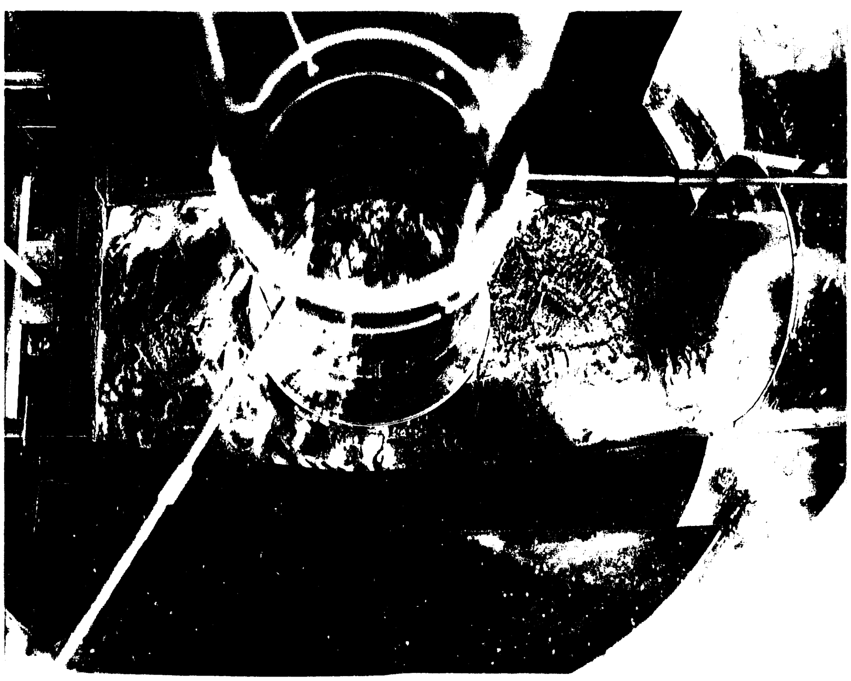


Photo 22 - Type CS46 R4 control structure. The sediment placed in the surge shaft invert for sediment test 3.

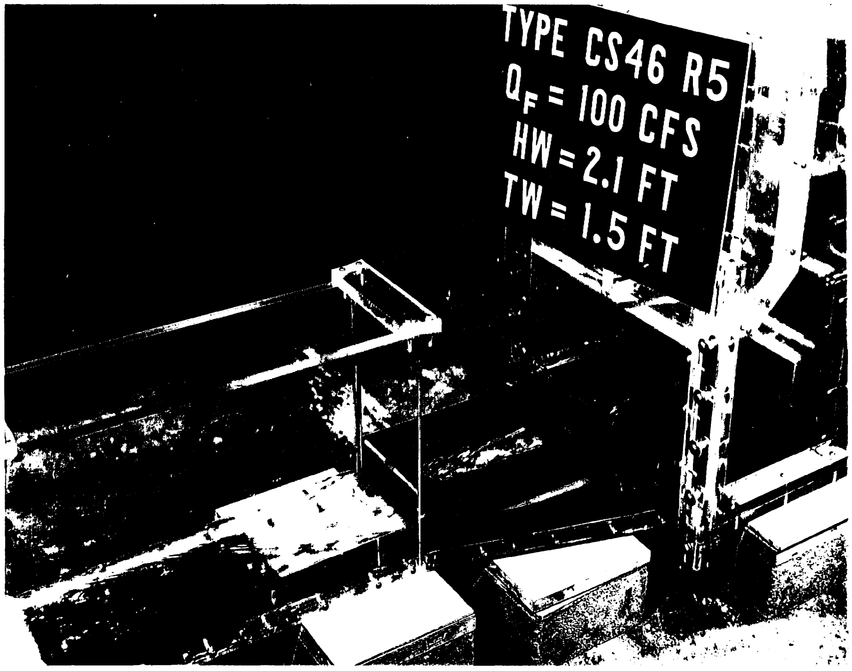


Photo 23 - Type CS46 R5 control structure, Q_F = 100 cfs, H.W. = 2.1 ft, T.W. = 1.5 ft. The pinch area.

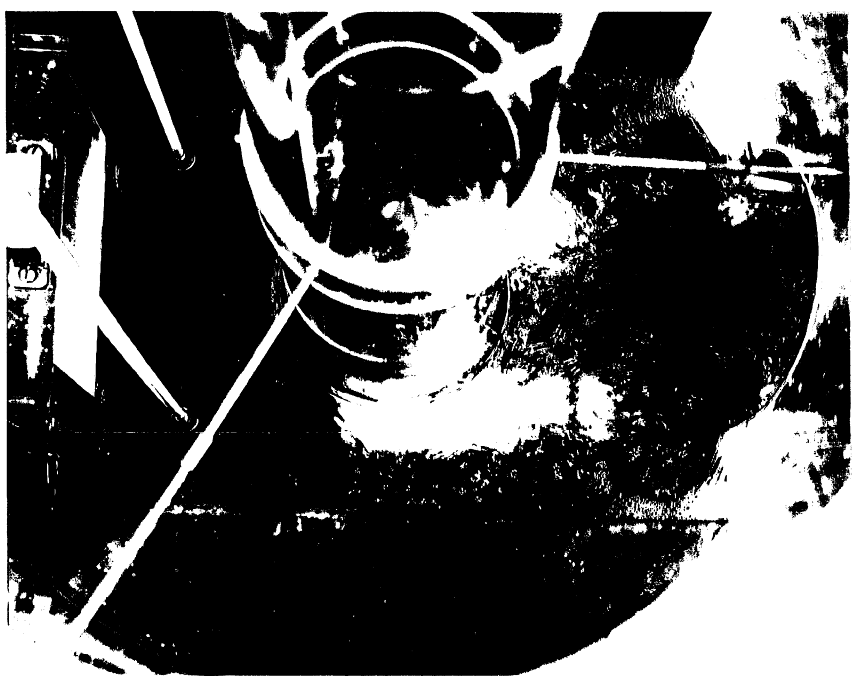


Photo 24 - Type CS46 R5 control structure, Q_F = 100 cfs, H.W. = 2.1 ft, T.W. = 1.5 ft. The surge shaft invert and siphon riser.

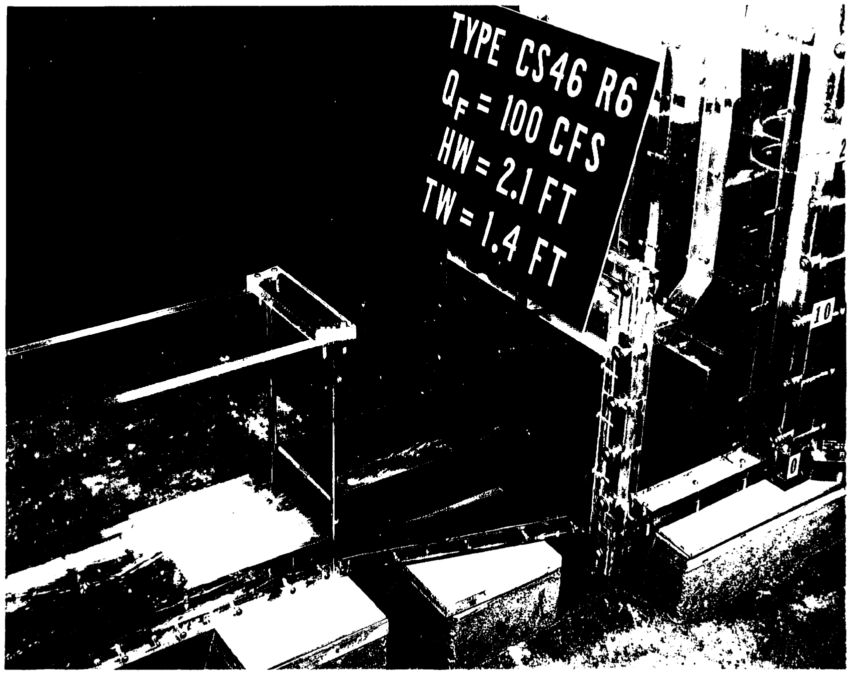


Photo 25 - Type CS46 R6 control structure, Q_F = 100 cfs, H.W. = 2.1 ft, T.W. = 1.4 ft. The pinch area.

Photo 26 Type CS46 R6 control structure, Q_F = 100 cfs, H.W. = 2.1 ft, T.W. = 1.4 ft. The surge shaft invert and siphon riser.

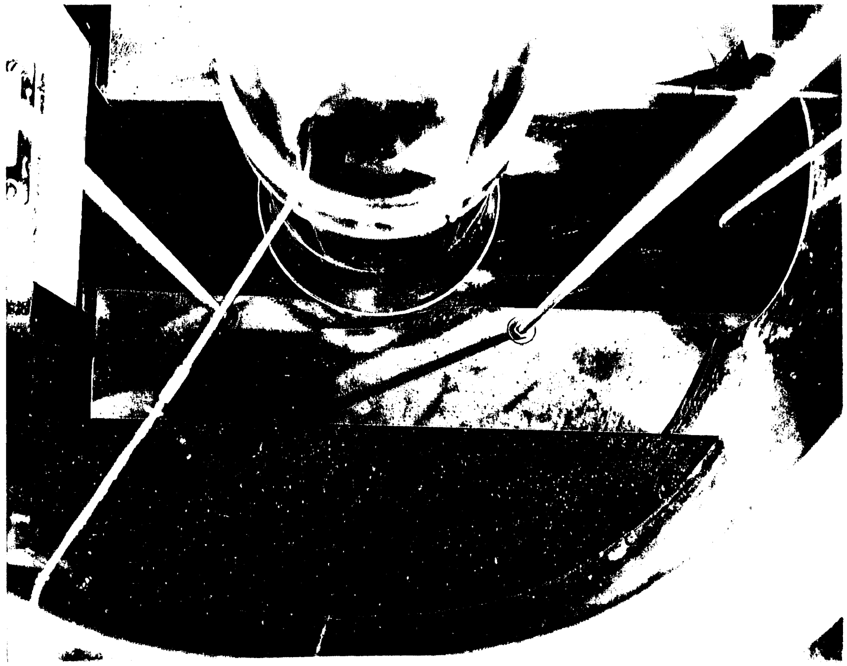


Photo 27 Type CS46 R7 control structure, Q_F = 100 cfs, H.W.= 2.1 ft, T.W. = 1.4 ft. The surge shaft invert and siphon riser.

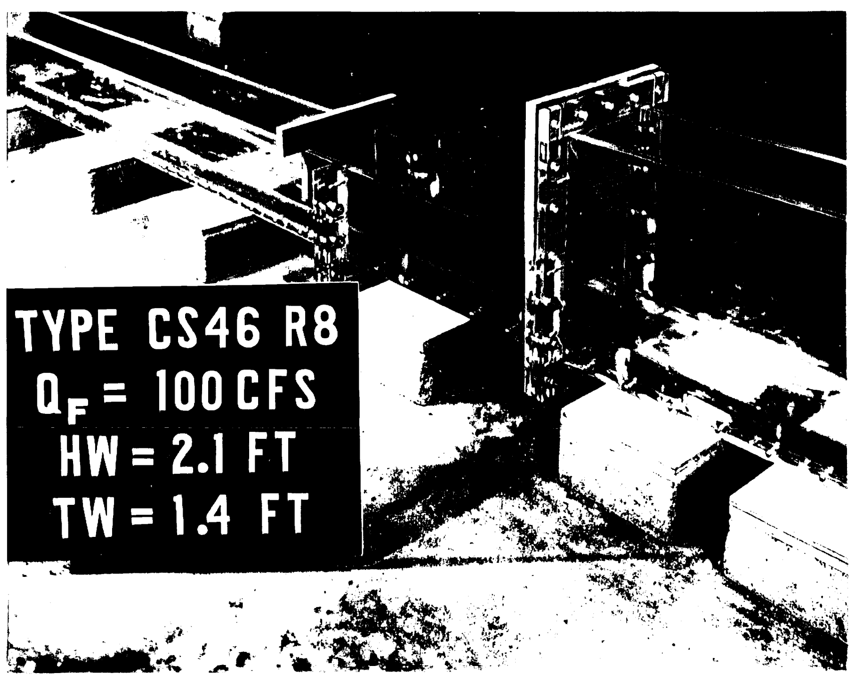


Photo 28 - Type CS46 R8 control structure, Q_F = 100 cfs, H.W. = 2.1 ft, T.W. = 1.4 ft. The deaeration chamber and flushing tunnel.

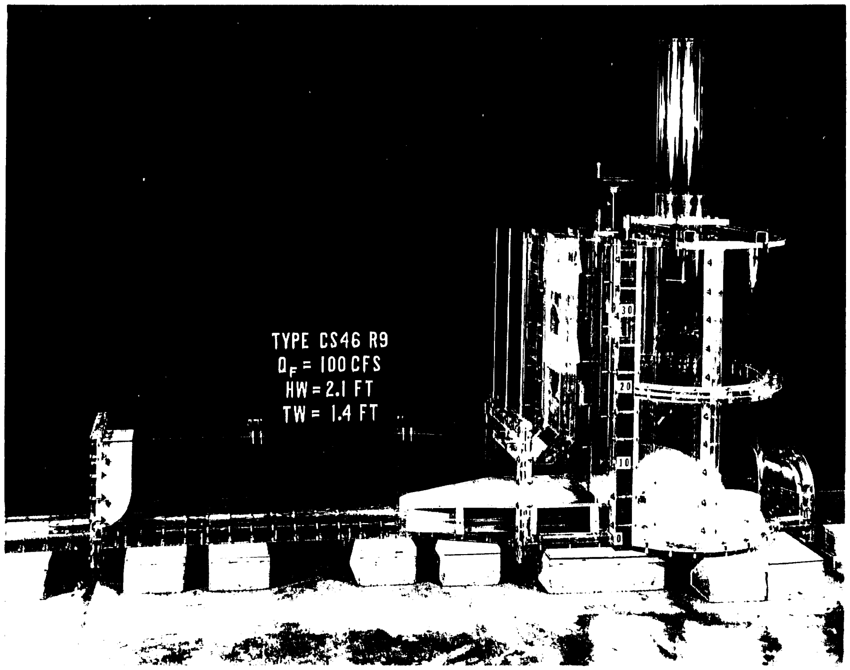


Photo 29 - Type CS46 R9 control structure, Q_F = 100 cfs, H.W. = 2.1 ft, T.W. = 1.4 ft. The overall model.

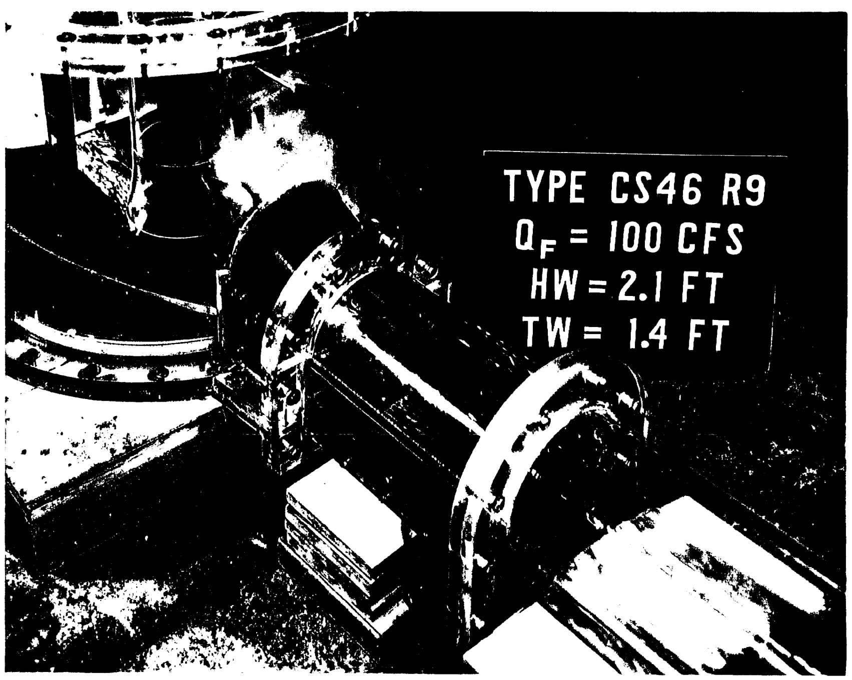


Photo 30 - Type CS46 R9 control structure, Q_F = 100 cfs, H.W. = 2.1 ft, T.W. = 1.4 ft. The siphon tunnel and surge shaft invert.

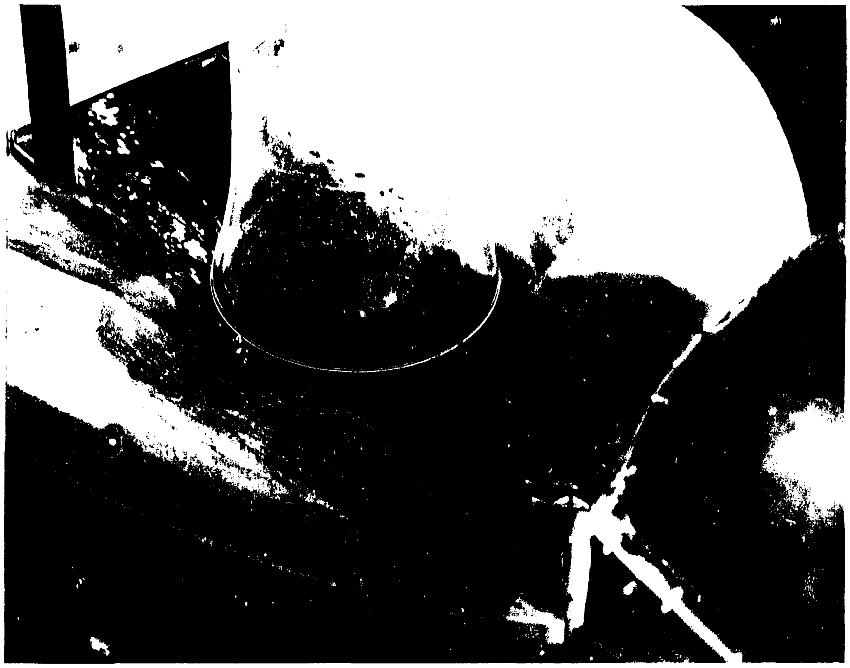


Photo 31 - Type CS46 R9 control structure, Q_F = 100 cfs, H.W. = 2.1 ft, T.W. = 1.4 ft. The surge shaft invert and siphon riser.

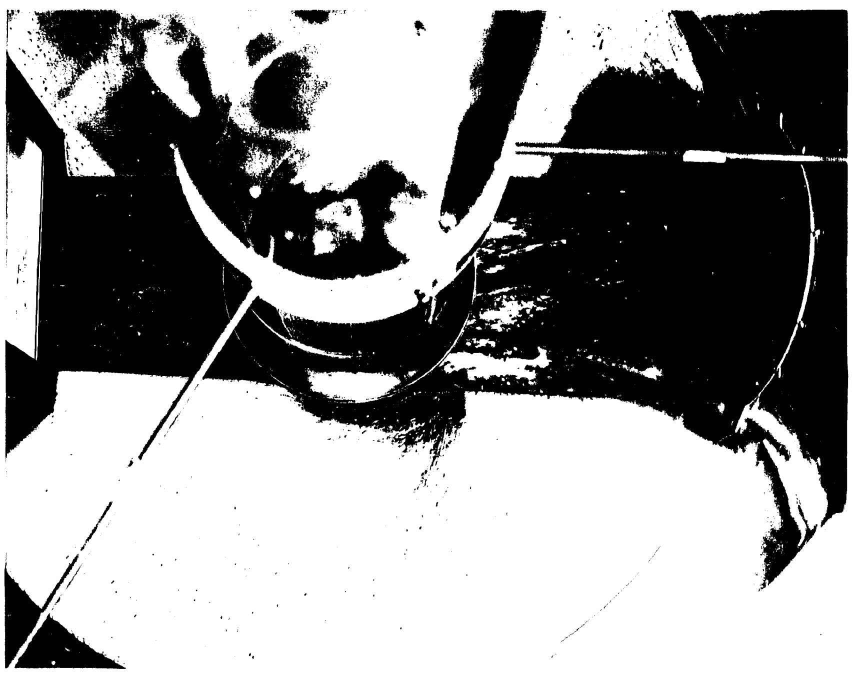


Photo 32 - Type CS46 R9 control structure, Q_F = 100 cfs, H.W. = 2.1 ft, T.W. = 1.4 ft. The surge shaft invert and siphon riser.

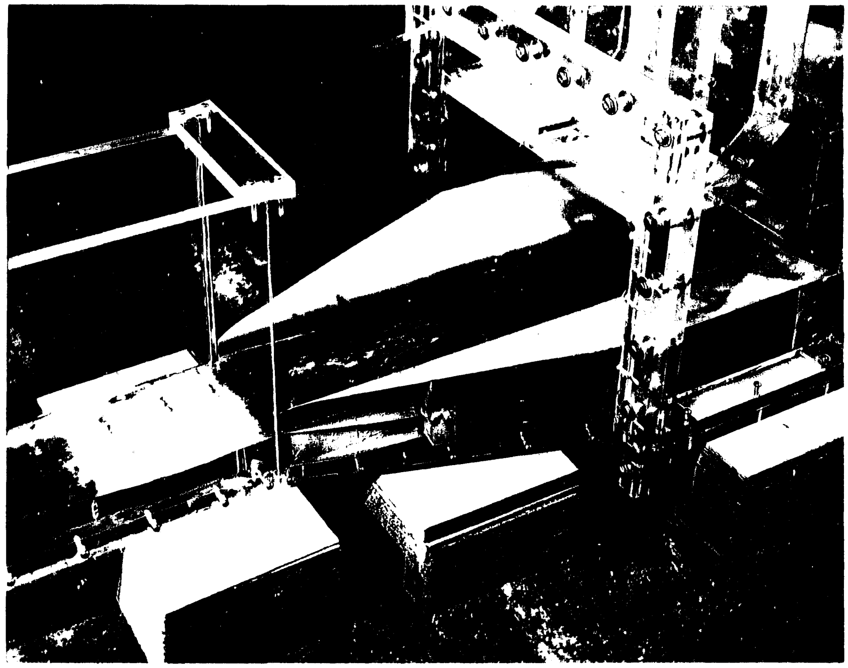


Photo 33 - Type CS46 R9 control structure, Q_F = 100 cfs, H.W. = 2.1 ft, T.W. = 1.4 ft. The pinch area.

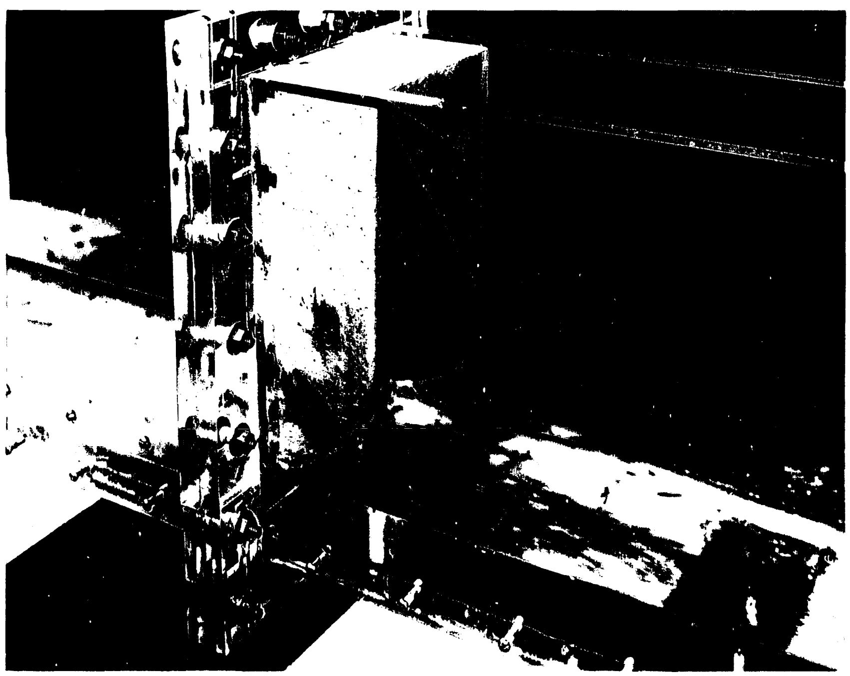


Photo 34 - Type CS46 R9 control structure, Q_F = 100 cfs, H.W. = 2.1 ft, T.W. = 1.4 ft. The entrance to the flushing tunnel.

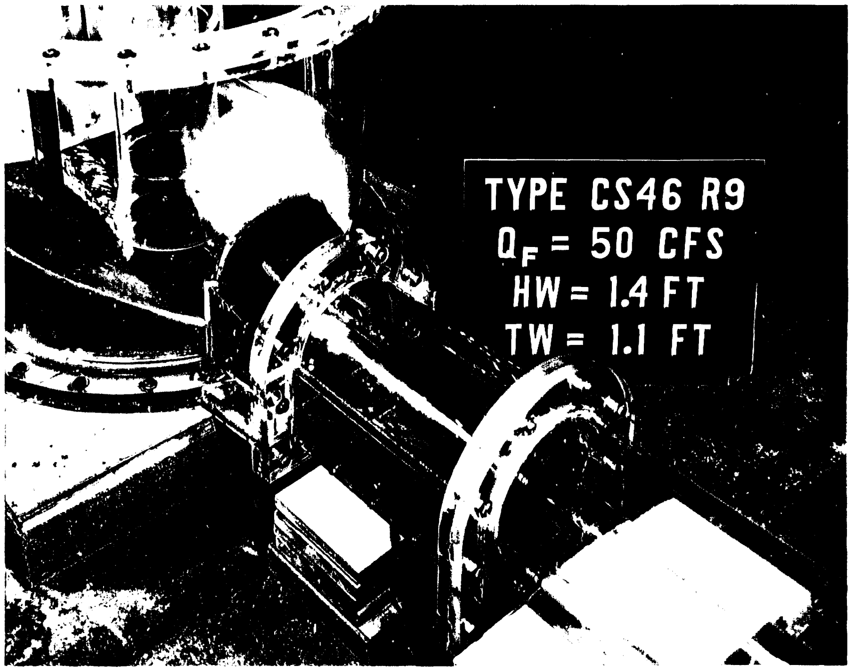


Photo 35 - Type CS46 R9 control structure, Q_F = 50 cfs, H.W. = 1.4 ft, T.W. = 1.1 ft. The siphon tunnel and surge shaft invert.

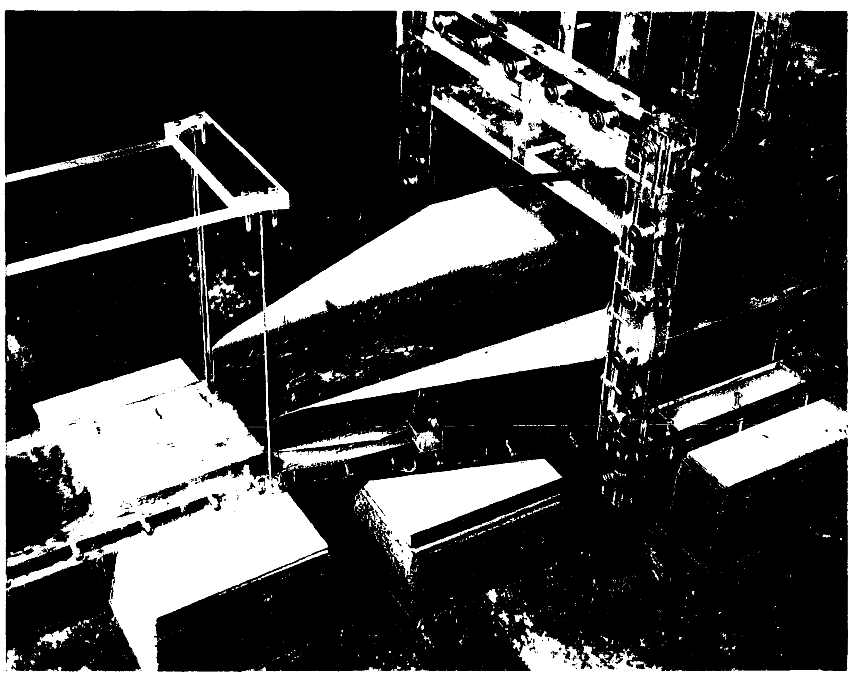


Photo 36 - Type CS46 R9 control structure, Q_F = 50 cfs, H.W. = 1.4 ft, T.W. = 1.1 ft. The pinch area.

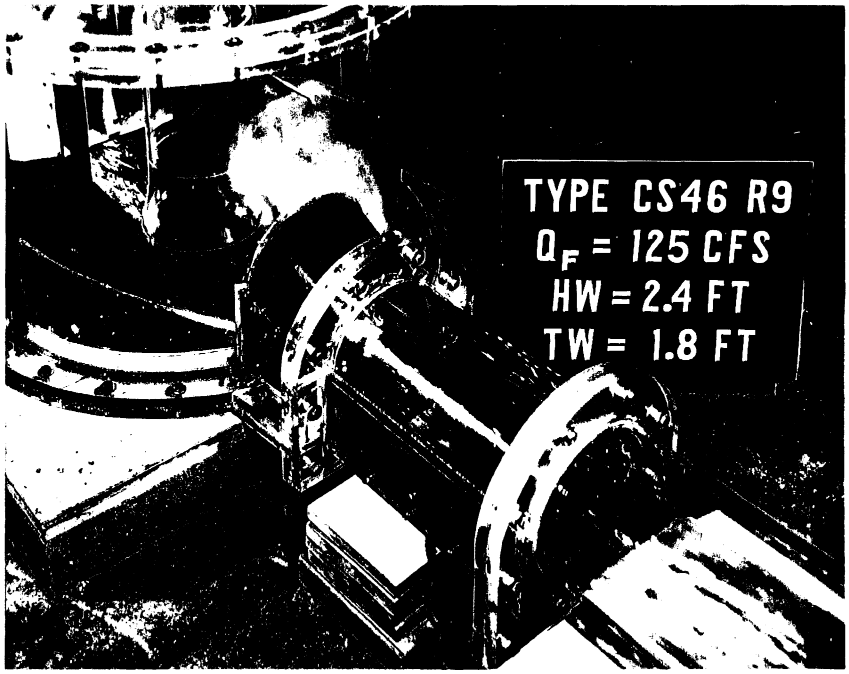


Photo 37 - Type CS46 R9 control structure, Q_F = 125 cfs, H.W. = 2.4 ft, T.W. = 1.8 ft. The siphon tunnel and surge shaft invert.

Photo 38 - Type CS46 R9 control structure, Q_F = 125 cfs, H.W. = 2.4 ft, T.W. = 1.8 ft. The surge shaft invert and siphon riser bellmouth.

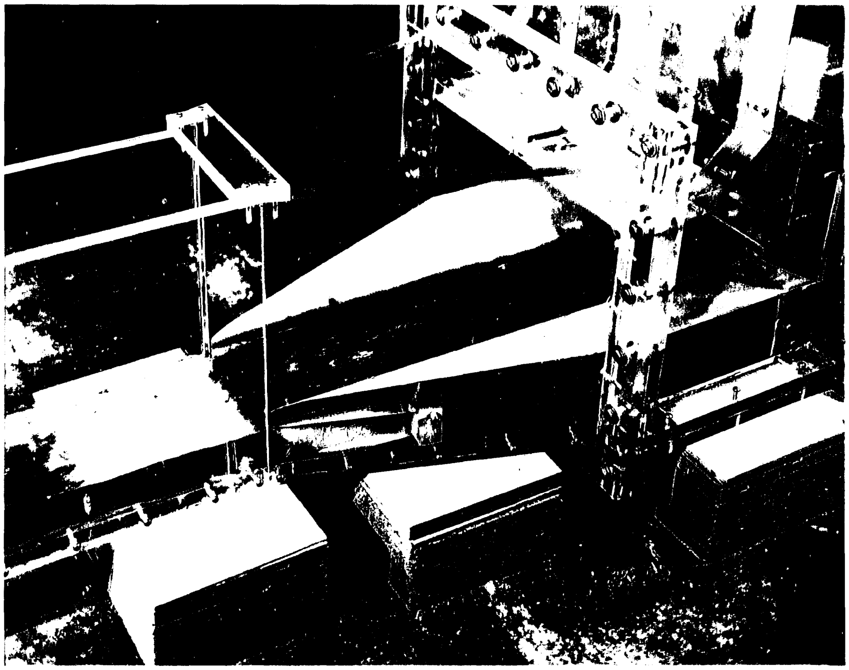


Photo 39 - Type CS46 R9 control structure, Q_F = 125 cfs, H.W. = 2.4 ft, T.W. = 1.8 ft. The pinch area.

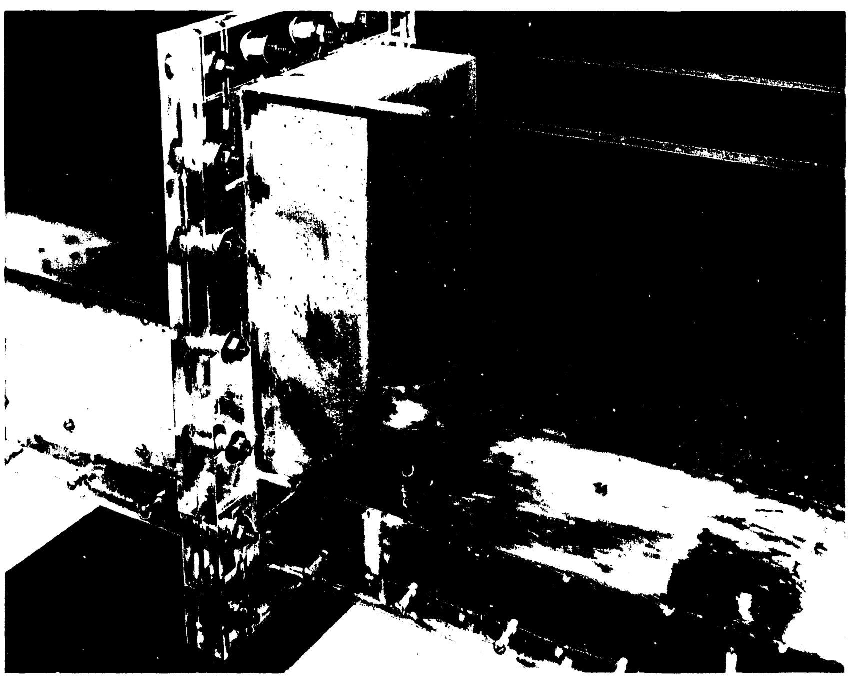


Photo 40 - Type CS46 R9 control structure, Q_F = 125 cfs, H.W. = 2.4 ft, T.W. = 1.8 ft. The entrance to the flushing tunnel.

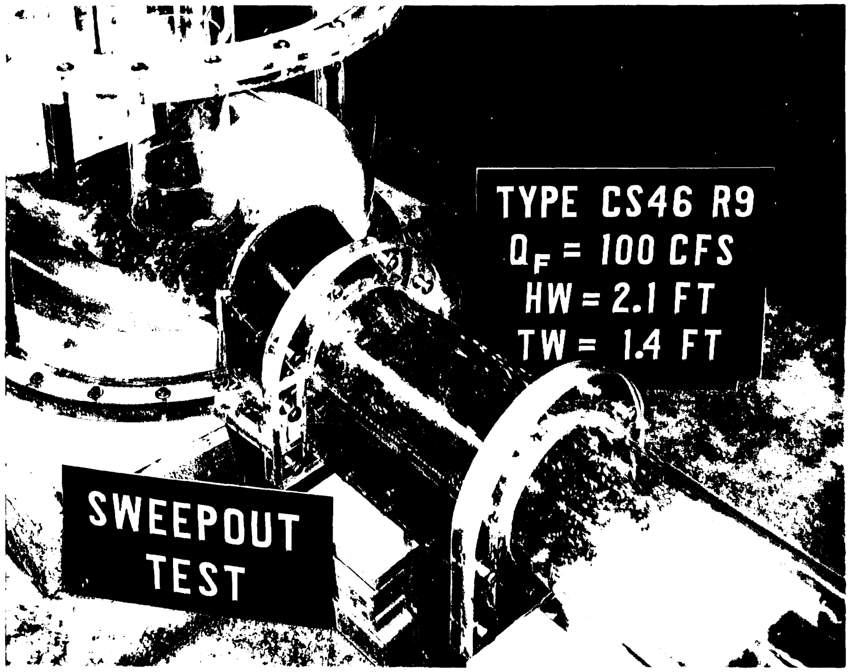


Photo 41 - Type CS46 R9 control structure, Q_F = 100 cfs, H.W. = 2.1 ft, T.W. = 1.4 ft. Sweepout test.

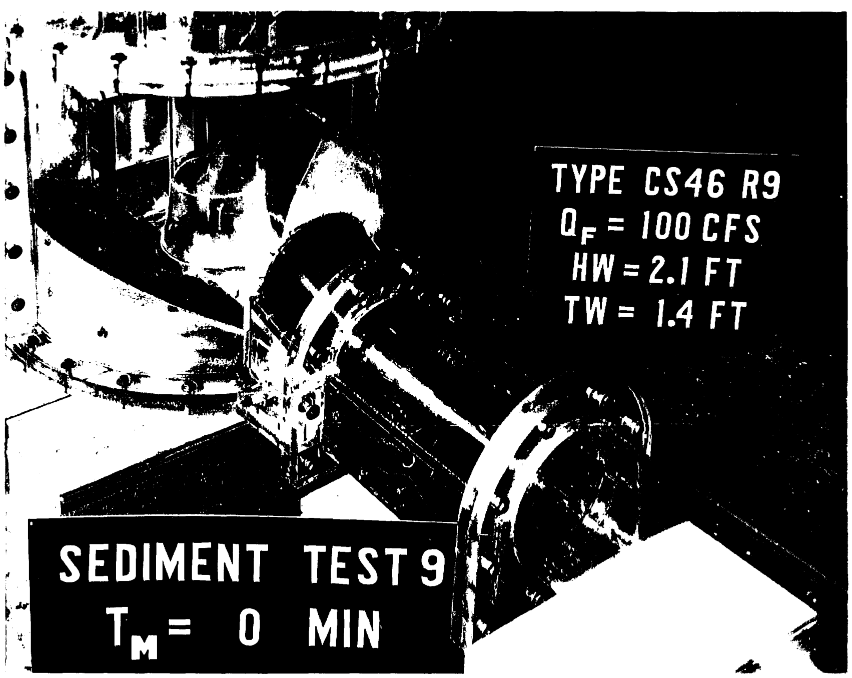


Photo 42 - Type CS46 R9 control structure, Q_F = 100 cfs, H.W. = 2.1 ft, T.W. = 1.4 ft. The sediment placed in the surge shaft invert for sediment test 9.

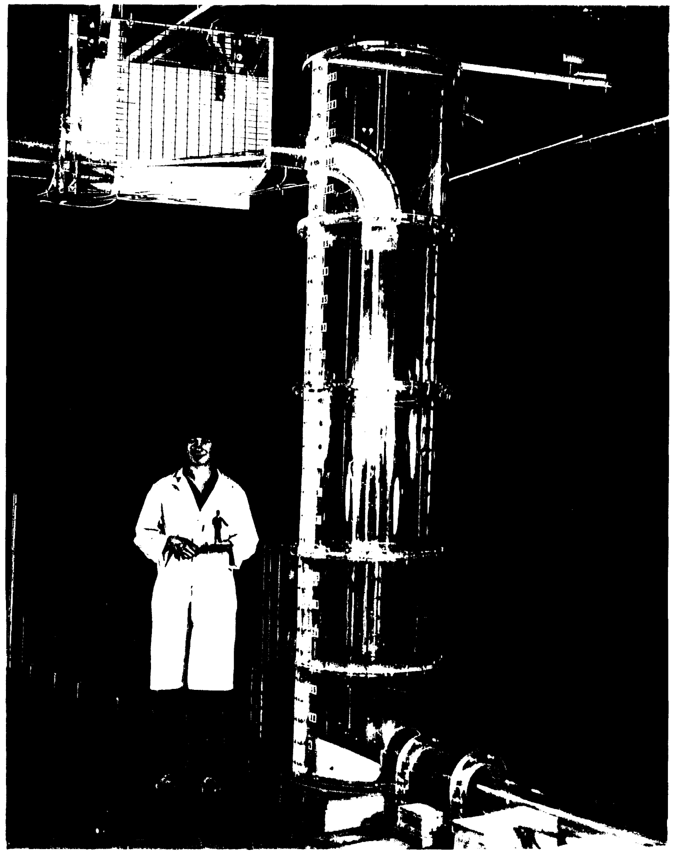


Photo 43 - Type CS46 R10 control structure. The overall model, laboratory research personnel, and Mr. 1:12.

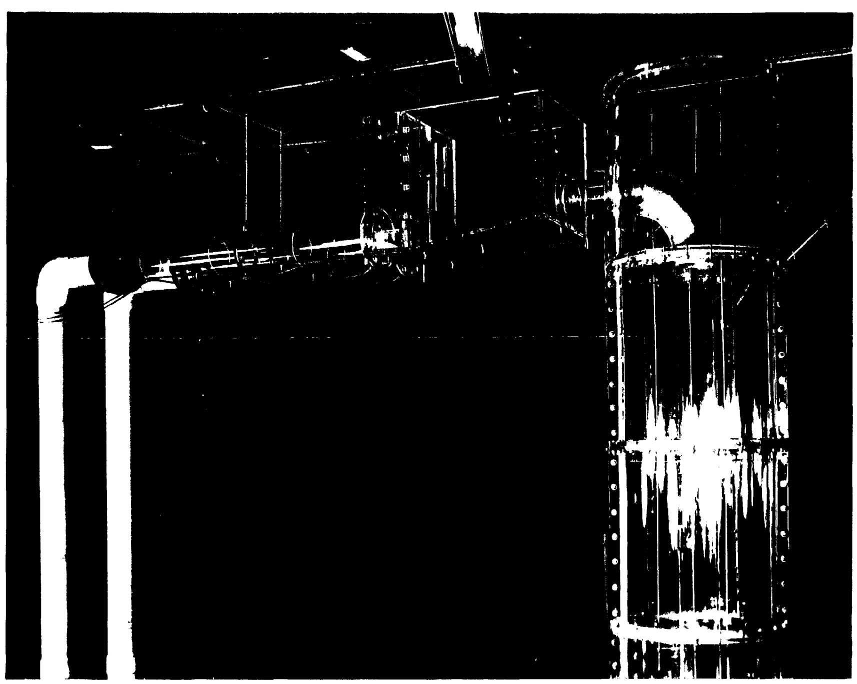


Photo 44 - Type CS46 R10 control structure. The top of the surge shaft, upper elbow, and bifurcation structure.

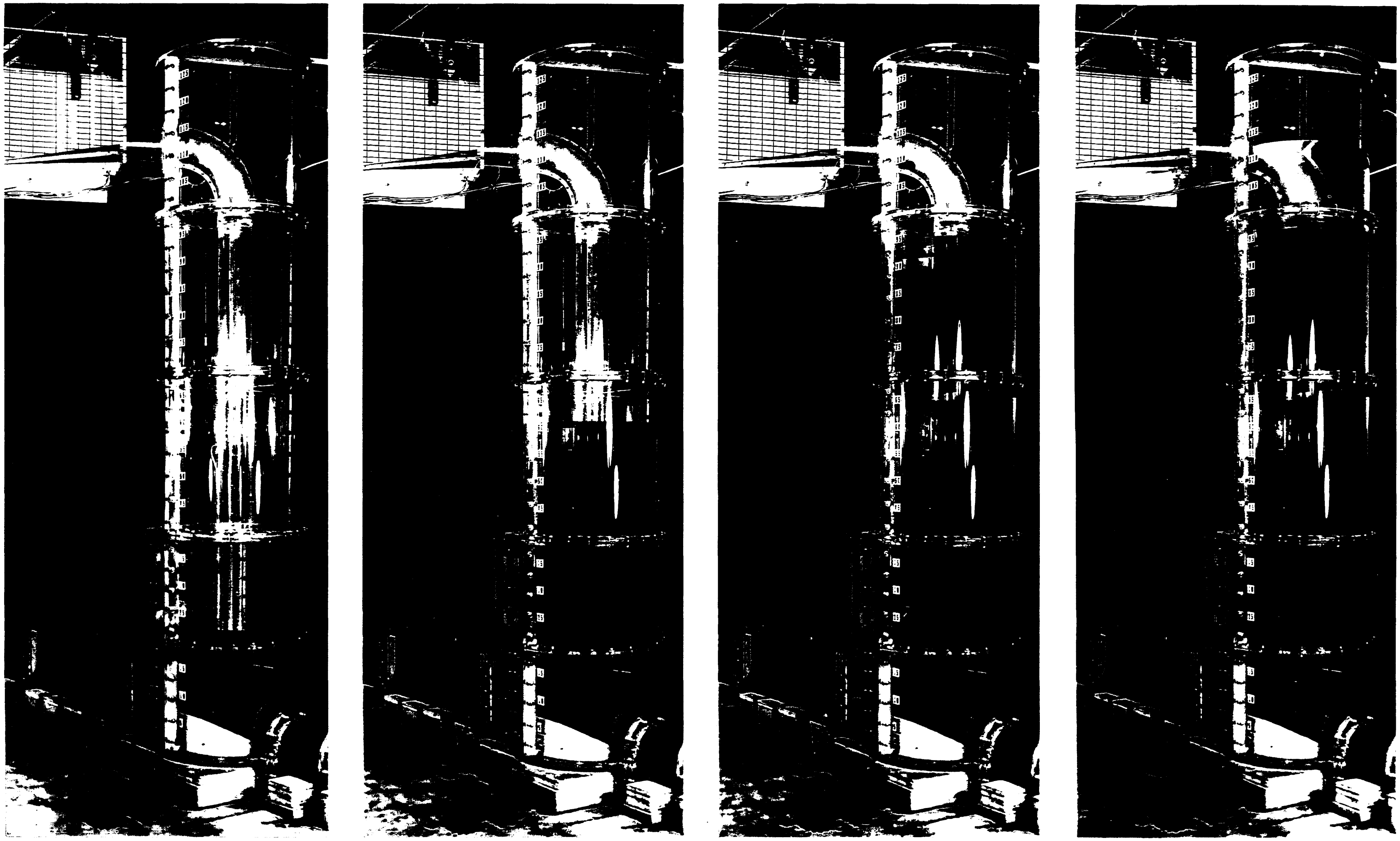


Photo 45 - Type CS46 R10 control structure. The filling mode of operation.

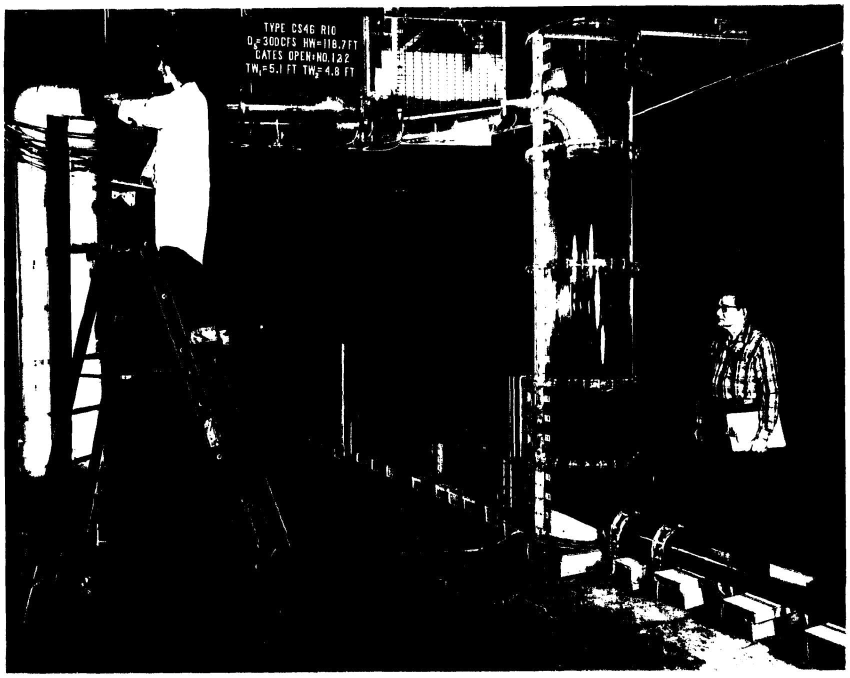


Photo 46 - Type CS46 R10 control structure, Q_s = 300 cfs, H.W. = 118.7 ft, Gates 1 and 2 open, $T.W._1$ = 5.1 ft, $T.W._2$ = 4.8 ft. The overall model, siphon mode of operation.

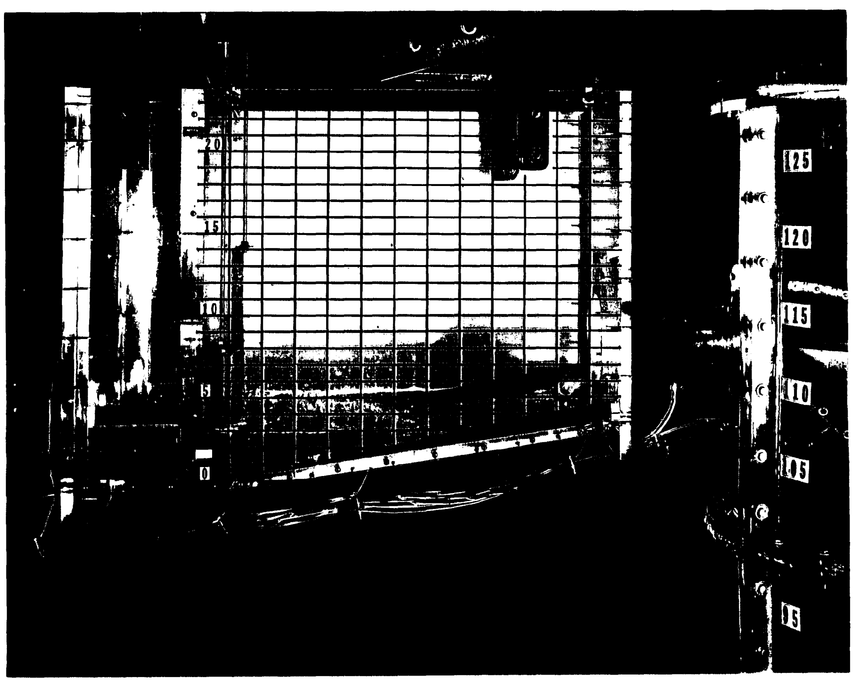


Photo 47 - Type CS46 R10 control structure, Q_s = 50 cfs, H.W. = 112.5 ft, Gate 2 open, $T.W._1$ = 0 ft, $T.W._2$ = 2.3 ft. The bifurcation structure.

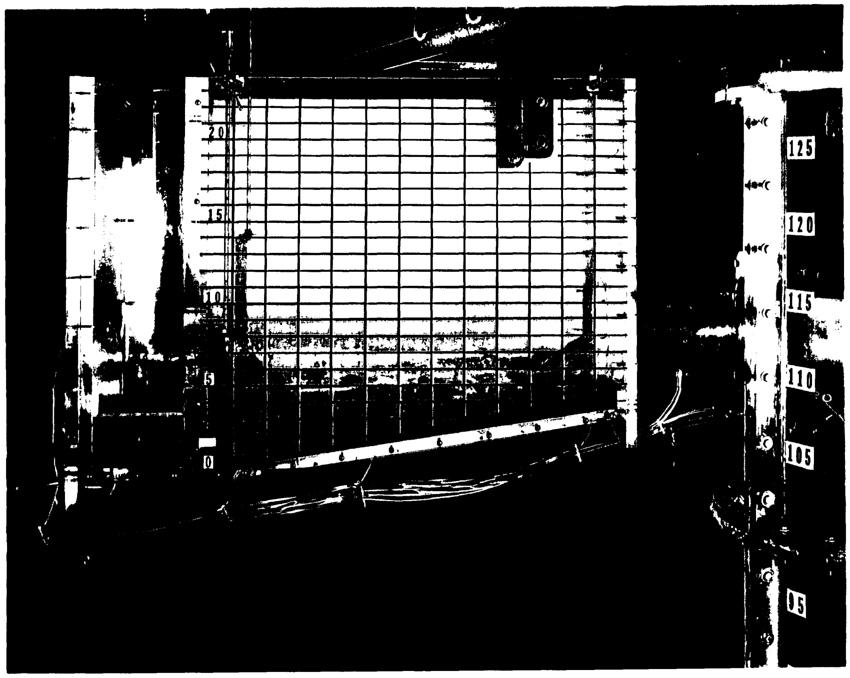


Photo 48 - Type CS46 R10 control structure, Q_s = 150 cfs, H.W. = 115.0 ft, Gate 2 open, $T.W._1$ = 0 ft, $T.W._2$ = 4.4 ft. The bifurcation structure.

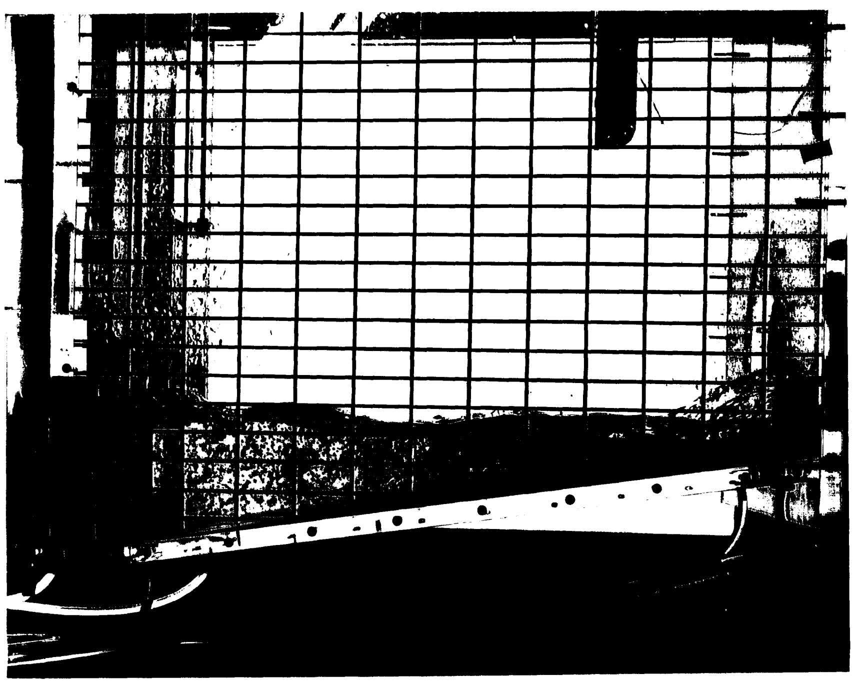


Photo 49 - Type CS46 R10 control structure, Q_s = 150 cfs, H.W. = 115.0 ft, Gate 2 open, $T.W._1$ = 0 ft, $T.W._2$ = 4.4 ft. The bifurcation structure.

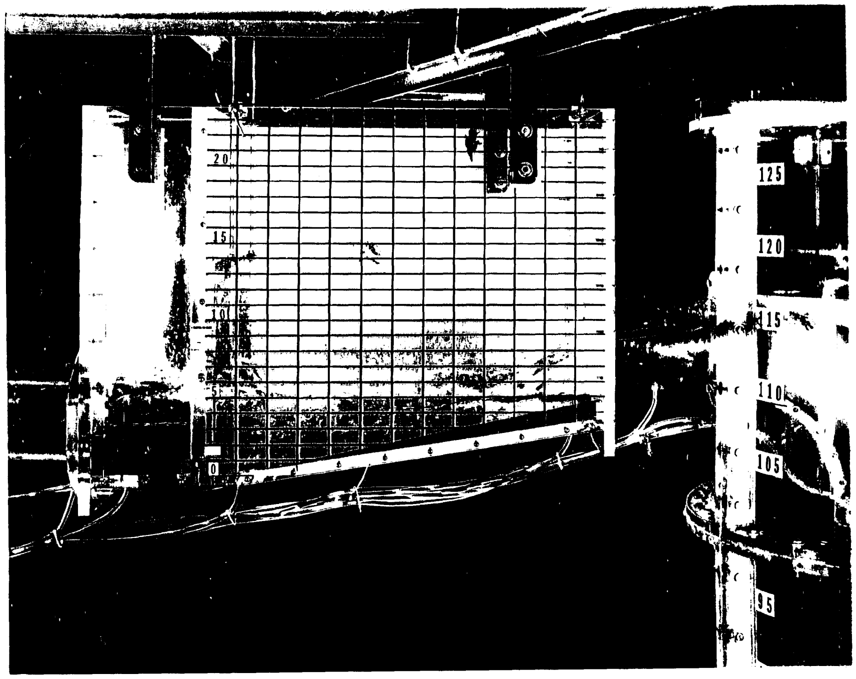


Photo 50 - Type CS46 R10 control structure, Q_s = 200 cfs, H.W. = 116.2 ft, Gates 1 and 2 open, $T.W._1$ = 4.8 ft, $T.W._2$ = 4.2 ft. The bifurcation structure.

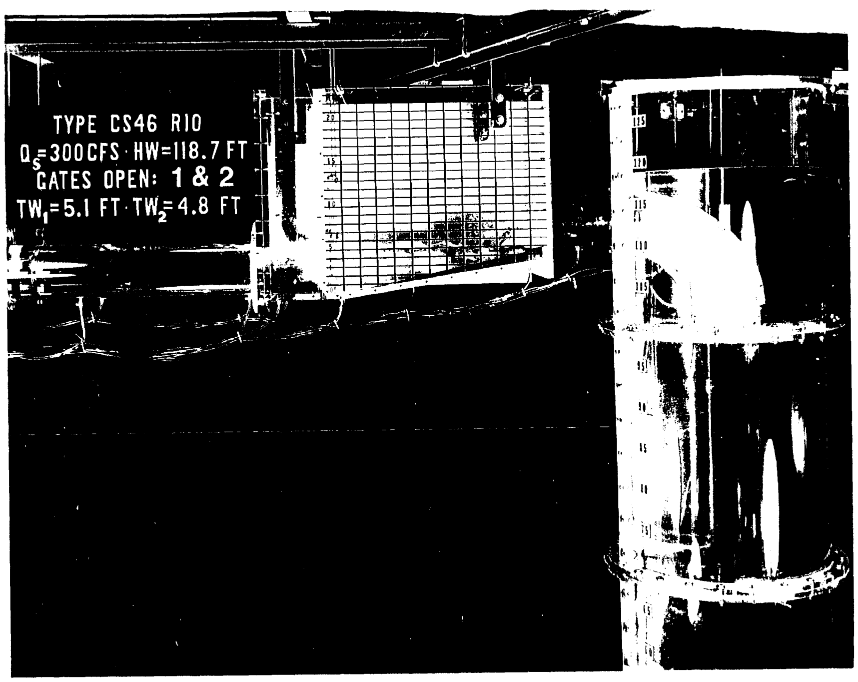


Photo 51 - Type CS46 R10 control structure, Q_s = 300 cfs, H.W. = 118.7 ft, Gates 1 and 2 open, $T.W._1$ = 5.1 ft, $T.W._2$ = 4.8 ft. The bifurcation structure.

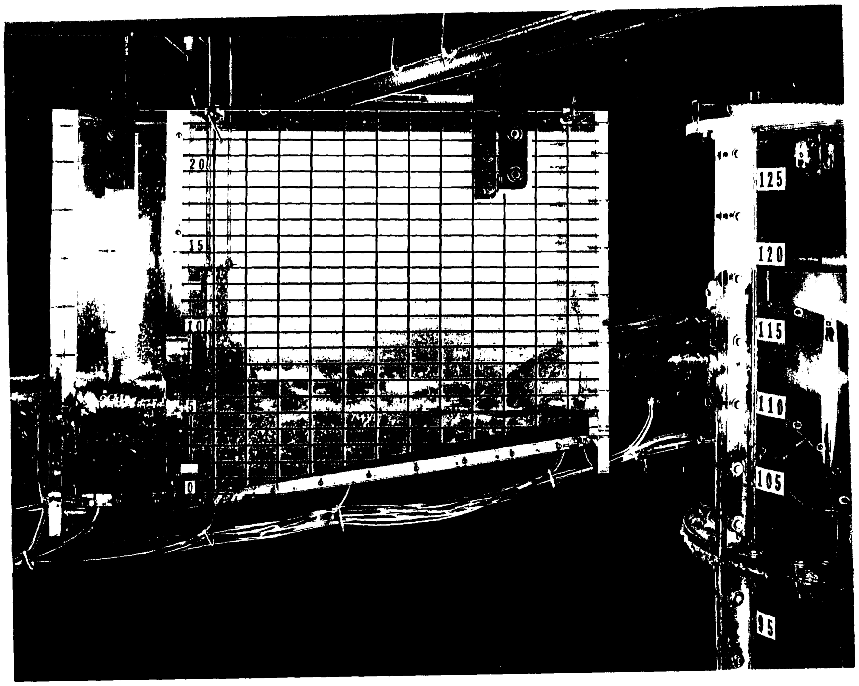


Photo 52 - Type CS46 R10 control structure, Q_s = 300 cfs, H.W. = 118.7 ft, Gates 1 and 2 open, $T.W._1$ = 5.1 ft, $T.W._2$ = 4.8 ft. The bifurcation structure.

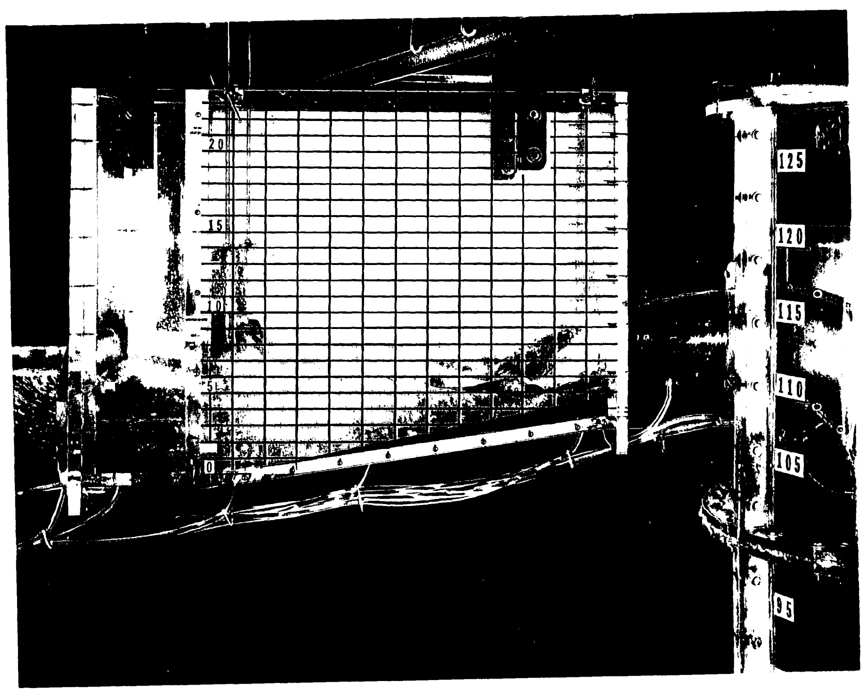


Photo 53 - Type CS46 R10 control structure, Q_s = 375 cfs, H.W. = 119.4 ft, Gates 1 and 2 open, $T.W._1$ = 5.6 ft, $T.W._2$ = 6.0 ft. The bifurcation structure.

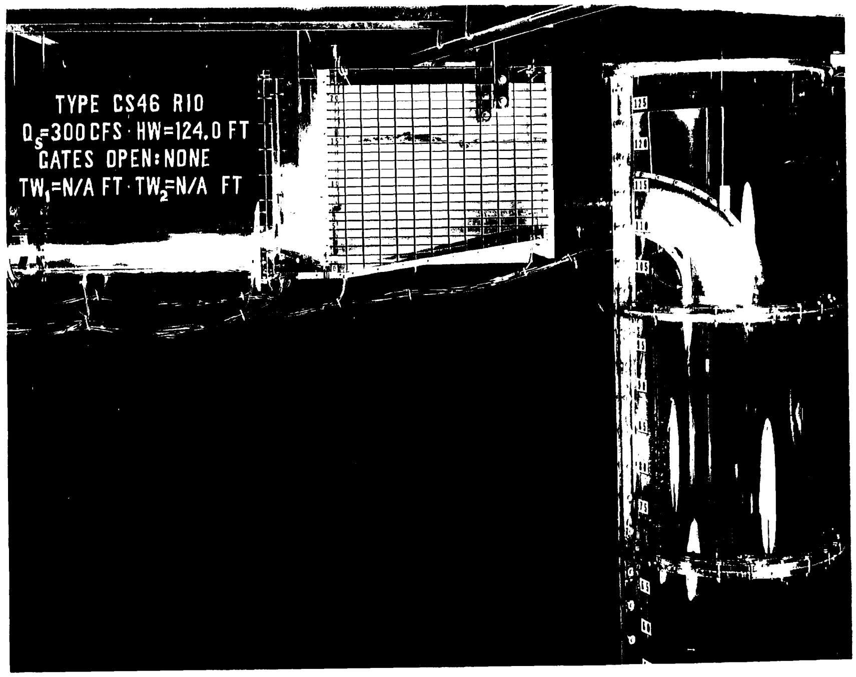


Photo 54 - Type CS46 R10 control structure, Q_s = 300 cfs, H.W. = 124.0 ft, no gates open, T.W.$_1$ = N/A, T.W.$_2$ = N/A. The bifurcation structure.

Photo 55 - Type CS46 R10 control structure, Q_s = 300 cfs, H.W. = 124.0 ft, no gates open, T.W.$_1$ = N/A, T.W.$_2$ = N/A. The bifurcation structure.

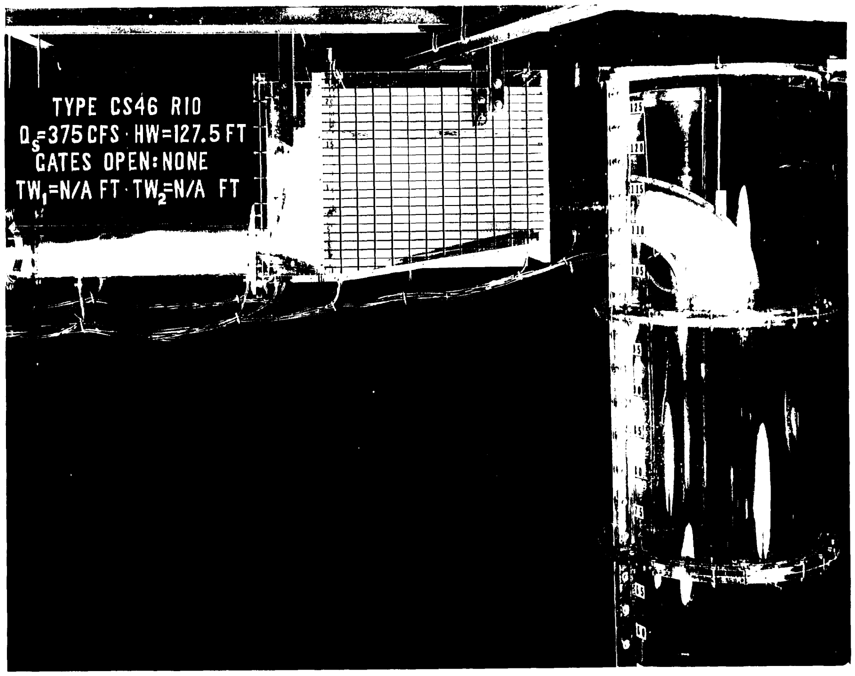


Photo 56 - Type CS46 R10 control structure, Q_s = 375 cfs, H.W. = 127.5 ft, no gates open, $T.W._1$ = N/A, $T.W._2$ = N/A. The bifurcation structure.

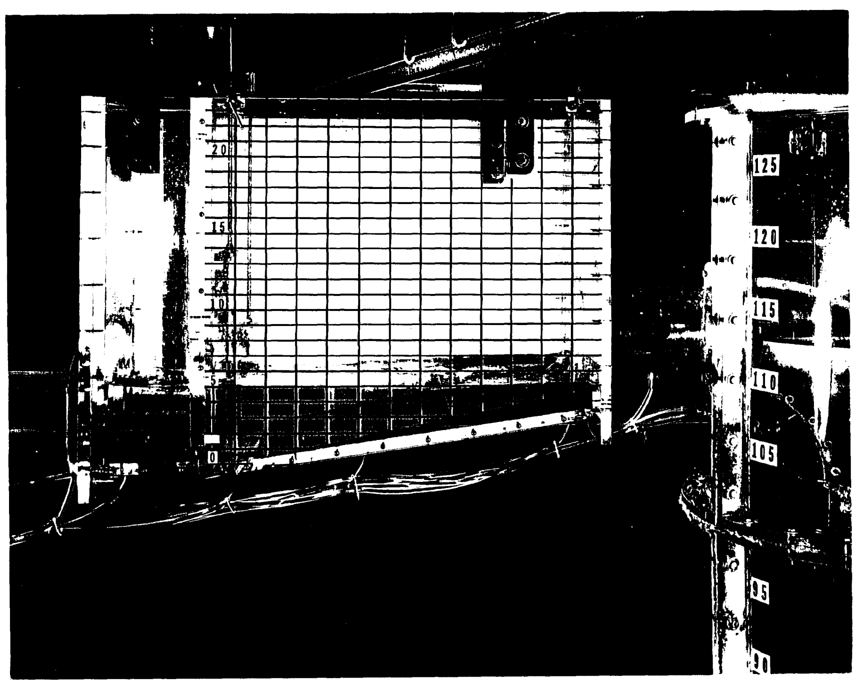


Photo 57 - Type CS46 R10 control structure, Q_s = 50 cfs, H.W. = 112.3 ft, Gate 1 open, $T.W._1$ = 4.7 ft, $T.W._2$ = 0 ft. The bifurcation structure.

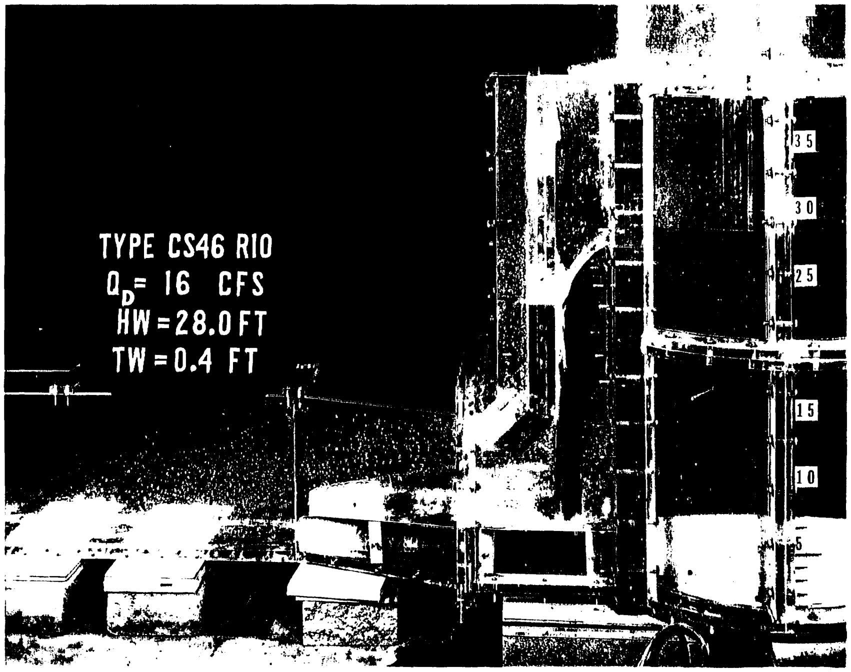


Photo 58 - Type CS46 R10 control structure, Q_D = 16 cfs, H.W. = 28.0 ft, T.W. = 0.4 ft, Gate 7 open. Drawdown mode of operation.

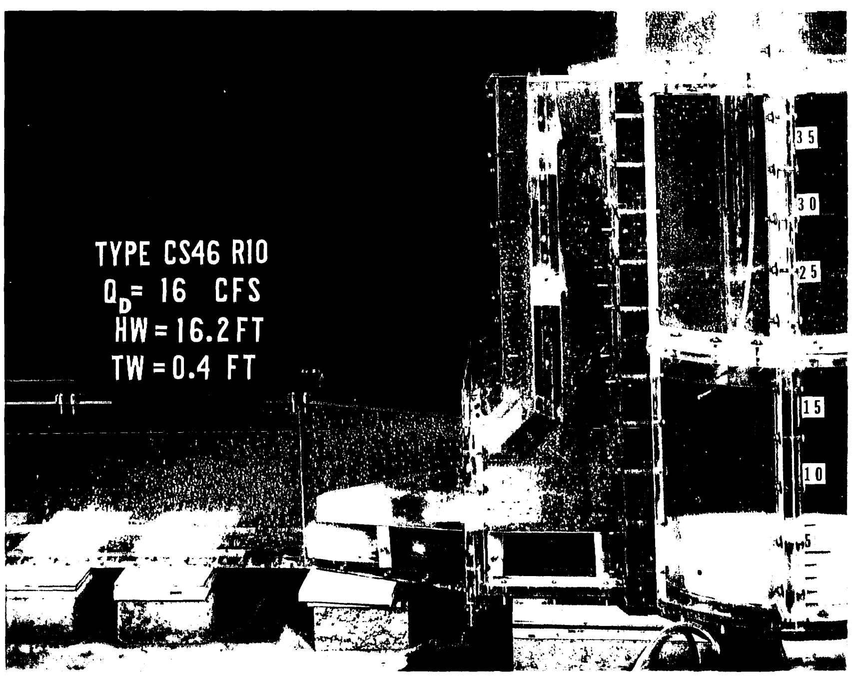


Photo 59 - Type CS46 R10 control structure, Q_D = 16 cfs, H.W. = 16.2 ft, T.W. = 0.4 ft, Gate 8 open. Drawdown mode of operation.

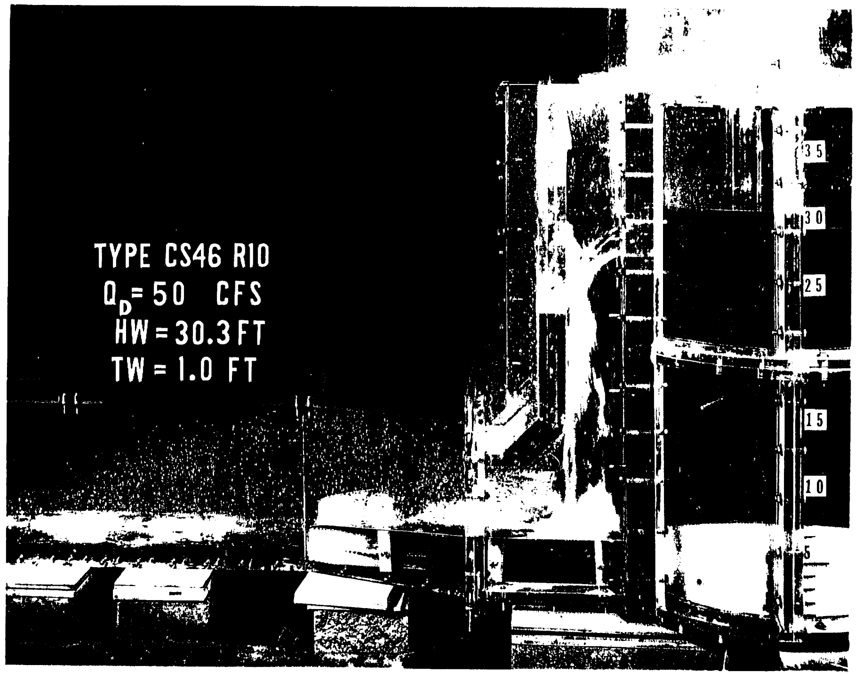


Photo 60 - Type CS46 R10 control structure, Q_D = 50 cfs, H.W. = 30.3 ft, T.W. = 1.0 ft, Gate 7 open. Drawdown mode of operation.

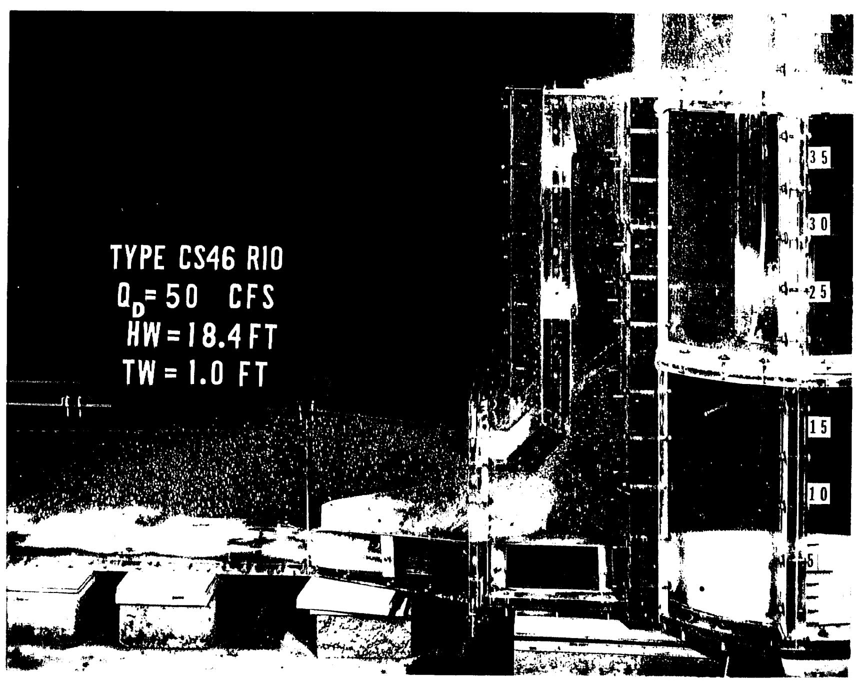


Photo 61 - Type CS46 R10 control structure, Q_D = 50 cfs, H.W. = 18.4 ft, T.W. = 1.0 ft, Gate 8 open. Drawdown mode of operation.

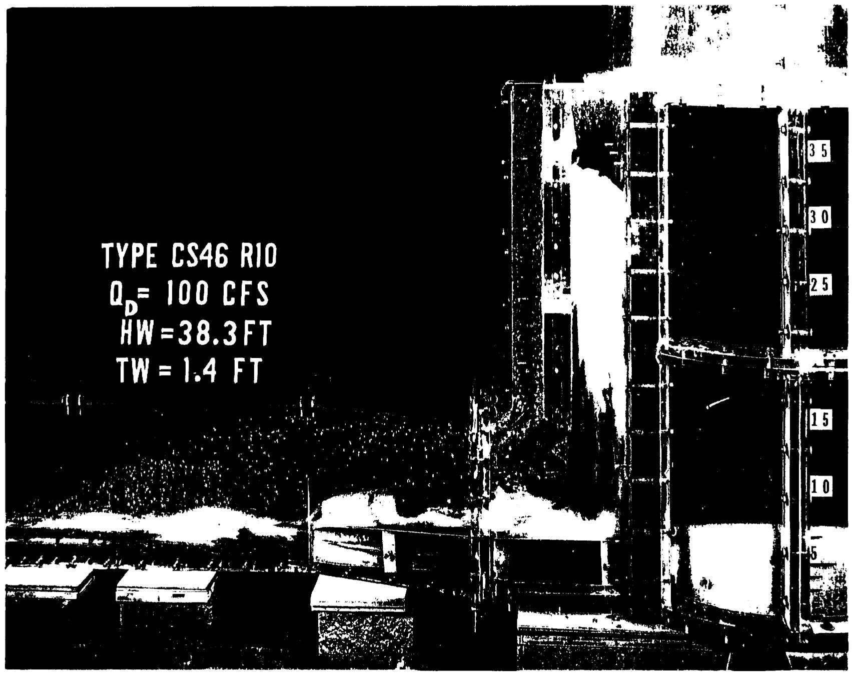


Photo 62 - Type CS46 R10 control structure, Q_D = 100 cfs, H.W. = 38.3 ft, T.W. = 1.4 ft, Gate 7 open. Drawdown mode of operation.

Photo 63 - Type CS46 R10 control structure, Q_D = 100 cfs, H.W. = 26.2 ft, T.W. = 1.5 ft, Gate 8 open. Drawdown mode of operation.

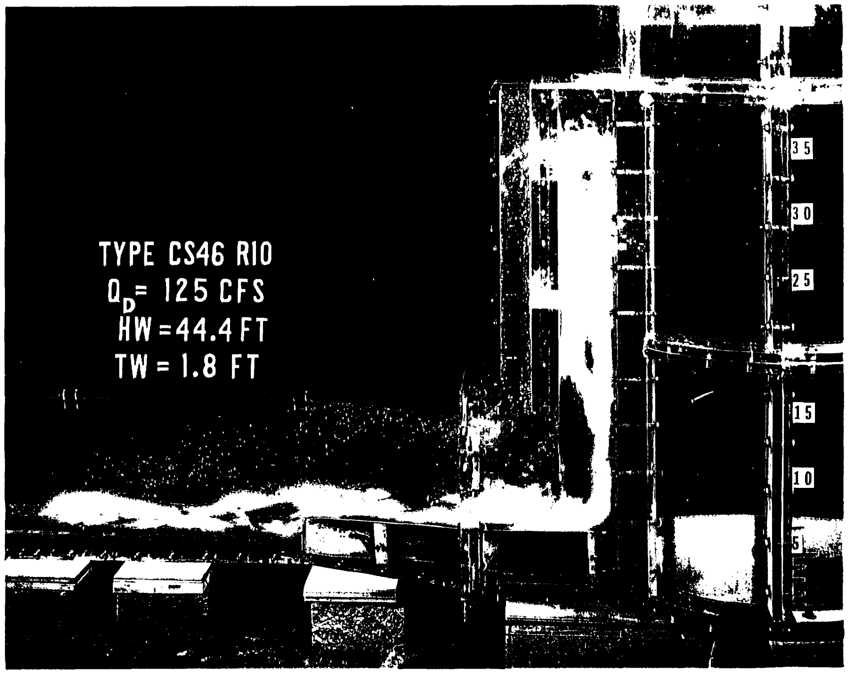


Photo 64 - Type CS46 R10 control structure, Q_D = 125 cfs, H.W. = 44.4 ft, T.W. = 1.8 ft, Gate 7 open. Drawdown mode of operation.

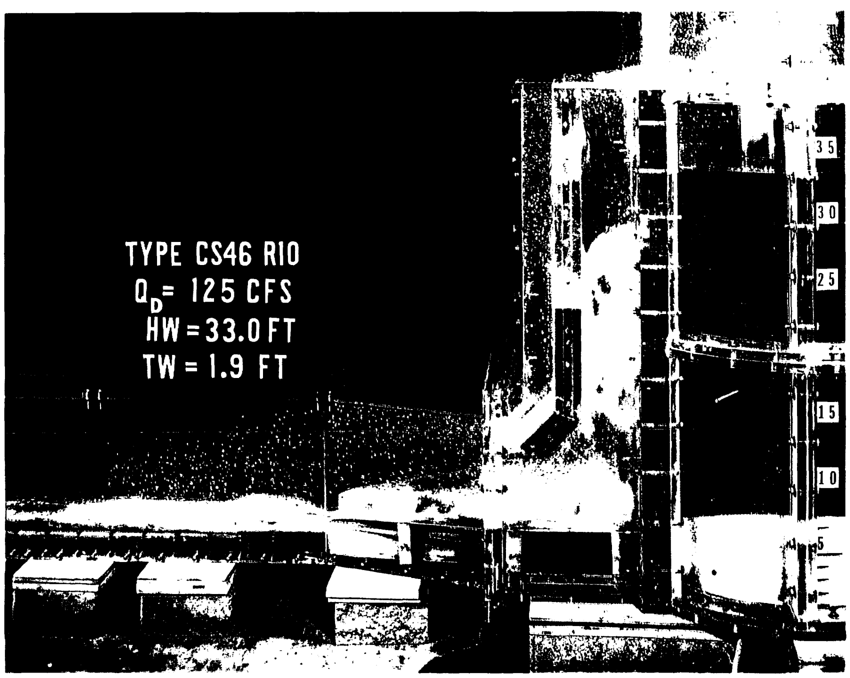


Photo 65 - Type CS46 R10 control structure, Q_D = 125 cfs, H.W. = 33.0 ft, T.W. = 1.9 ft, Gate 8 open. Drawdown mode of operation.

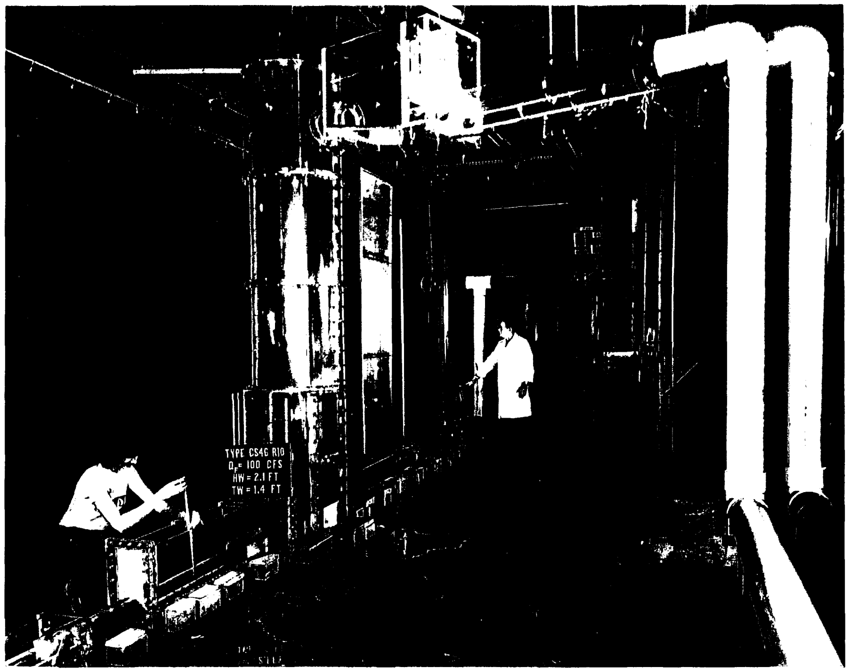


Photo 66 - Type CS46 R10 control structure, Q_F = 100 cfs, H.W. = 2.1 ft, T.W. = 1.4 ft. The flushing mode of operation, the overall model.

Photo 67 - Type CS46 R11 control structure. The surge shaft invert and siphon bellmouth with pitot tube attached.

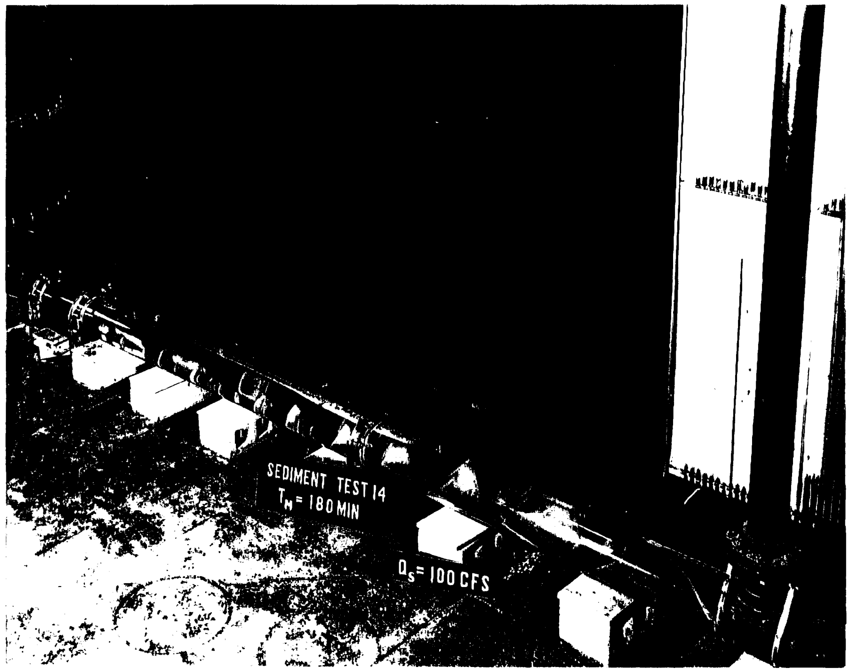


Photo 68 - Type CS46 R10 control structure, Q_s = 100 cfs. Sediment test 14, deposition in siphon tunnel after 180 minutes.

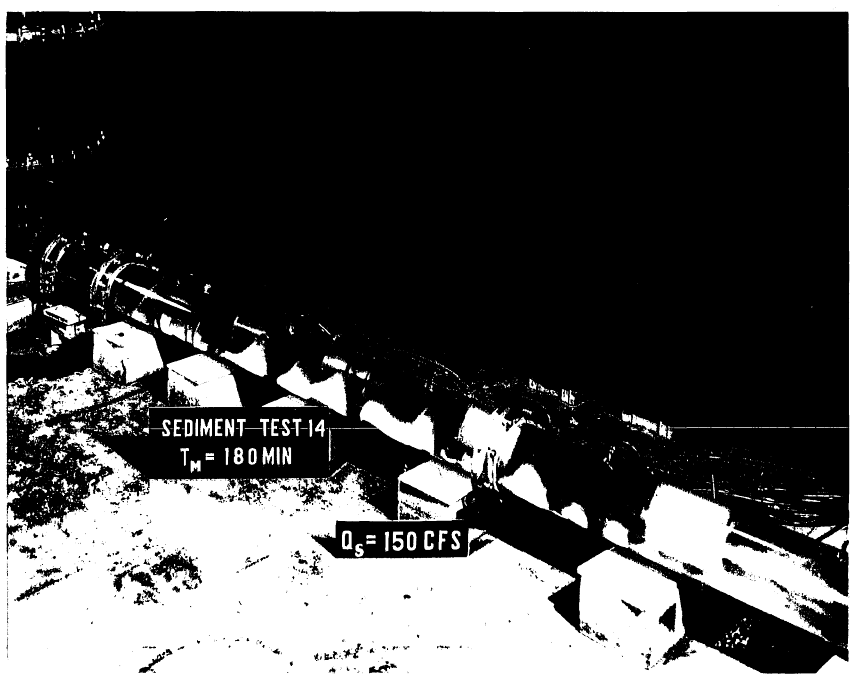


Photo 69 - Type CS46 R10 control structure, Q_s = 150 cfs. Sediment test 14, deposition in siphon tunnel after 180 minutes.

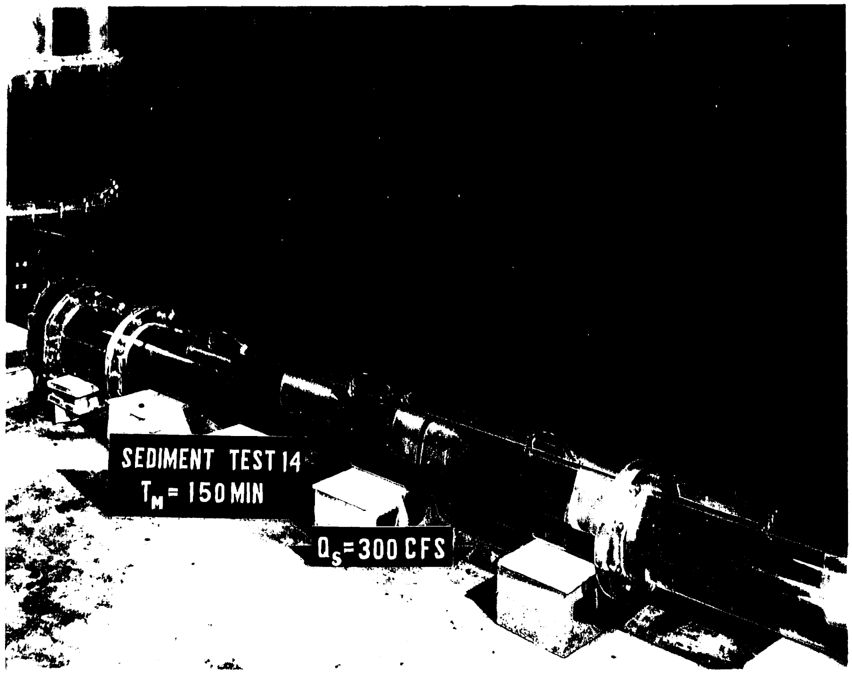


Photo 70 - Type CS46 R10 control structure, Q_S = 300 cfs. Sediment test 14, the accumulated deposition was flushed through the siphon riser and bifurcation structure.

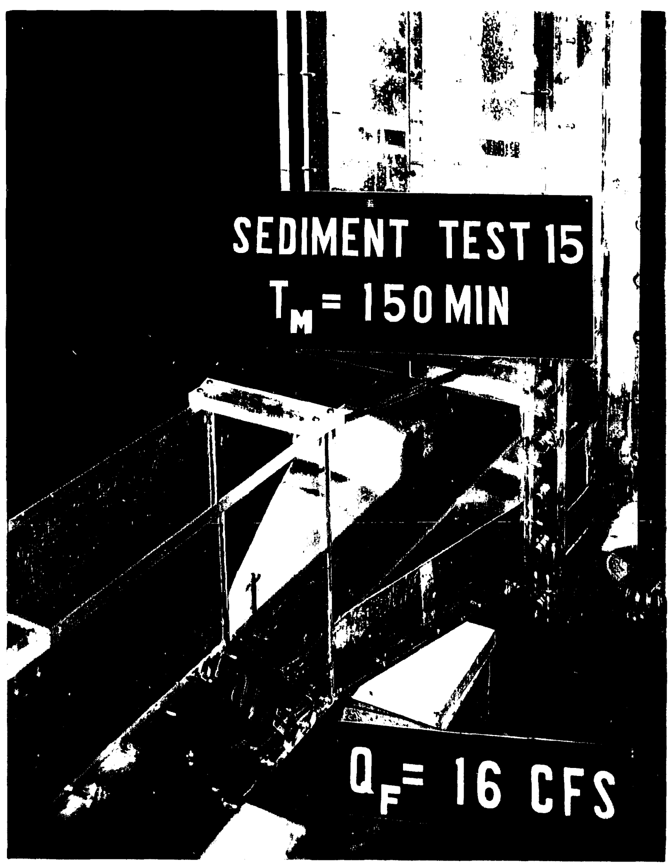


Photo 71 - Type CS46 R10 control structure, Q_F = 16 cfs. Sediment test 15, trace of deposition in drop structure and pinch area after 150 minutes.

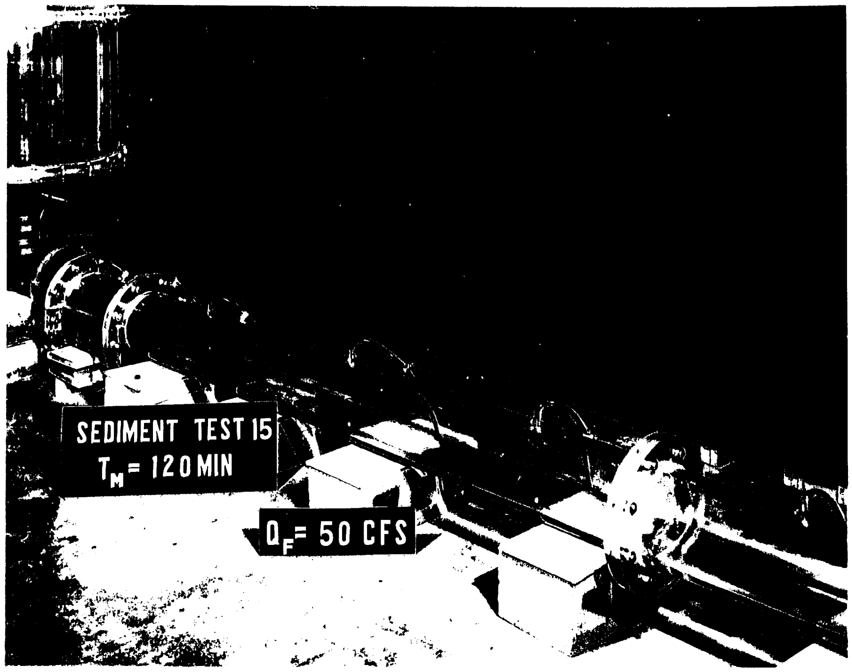


Photo 72 - Type CS46 R10 control structure, Q_F = 50 cfs. Sediment test 15, no deposition in structure after 120 minutes.

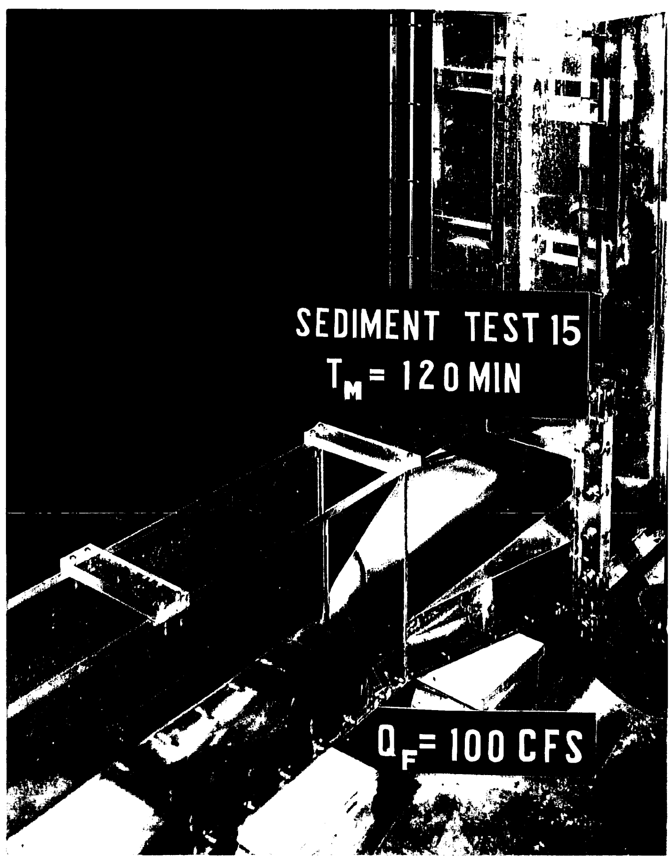


Photo 73 - Type CS46 R10 control structure, Q_F = 100 cfs. Sediment test 15, no deposition in structure after 120 minutes.

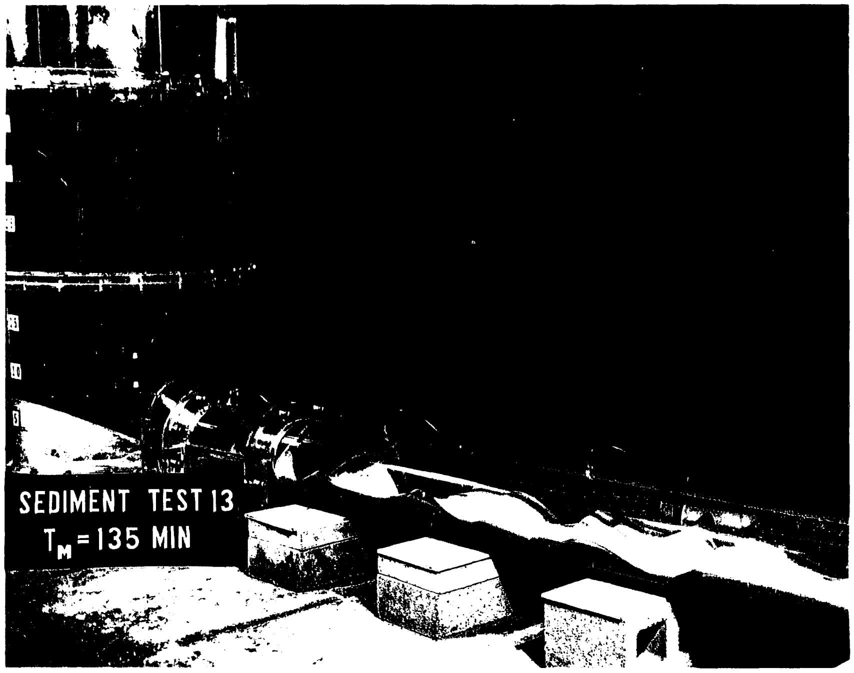


Photo 74 - Type CS46 R11 control structure, Q_s = 150 cfs. Sediment test 13, deposition in siphon tunnel after 135 minutes.

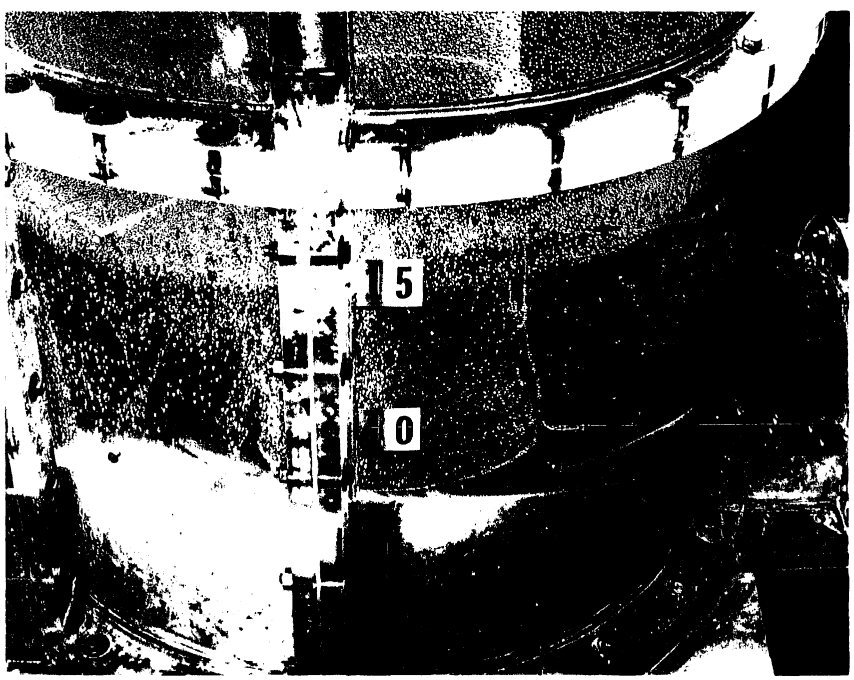


Photo 75 - Type CS46 R11 control structure, Q_s = 150 cfs. Sediment test 13, deposition in surge shaft invert after 135 minutes.

LIST OF CHARTS

CHART 35 (328B514-67) Type CS46 R10 control structure, Q_s = 200 cfs, H.W. = 120.3 ft, no gates open, $T.W._1$ = N/A, $T.W._2$ = N/A. Water surface profiles--siphon mode.

CHART 36 (328B514-68) Type CS46 R10 control structure, Q_s = 250 cfs, H.W. = 122.3 ft, no gates open, $T.W._1$ = N/A, $T.W._2$ = N/A. Water surface profiles--siphon mode.

CHART 37 (328B514-69) Type CS46 R10 control structure, Q_s = 300 cfs, H.W. = 123.9 ft, no gates open, $T.W._1$ = N/A, $T.W._2$ = N/A. Water surface profiles--siphon mode.

CHART 38 (328B514-70) Type CS46 R10 control structure, Q_s = 375 cfs, H.W. = 124.7 ft, no gates open, $T.W._1$ = N/A, $T.W._2$ = N/A. Water surface profiles--siphon mode.

CHART 39 (328B514-71) Type CS46 R10 control structure, Q_s = 16 cfs, H.W. = 111.0 ft, gate 1 open, $T.W._1$ = 4.8 ft, $T.W._2$ = 0 ft. Water surface profiles--siphon mode.

CHART 40 (328B514-72) Type CS46 R10 control structure, Q_s = 50 cfs, H.W. = 112.2 ft, gate 1 open, $T.W._1$ = 4.7 ft, $T.W._2$ = 0 ft. Water surface profiles--siphon mode.

CHART 41 (328A2323-22) Type CS46 R10 control structure, Q_s = 50 cfs, H.W. = 112.4 ft, gate 2 open, $T.W._1$ = 0 ft, $T.W._2$ = 2.3 ft. Water depths--siphon mode. Bifurcation structure.

CHART 42 (328A2323-23) Type CS46 R10 control structure, Q_s = 100 cfs, H.W. = 113.8 ft, gate 2 open, $T.W._1$ = 0 ft, $T.W._2$ = 2.3 ft. Water depths--mode. Bifurcation structure.

CHART 43 (328A2323-24) Type CS46 R10 control structure, Q_s = 150 cfs, H.W. = 114.9 ft, gate 2 open, $T.W._1$ = 0 ft, $T.W._2$ = 4.4 ft. Water depths--mode. Bifurcation structure.

CHART 44 (328A2323-25) Type CS46 R10 control structure, Q_s = 200 cfs, H.W. = 116.1 ft, gates 1 and 2 open, $T.W._1$ = 4.8 ft, $T.W._2$ = 4.2 ft. Water depths--mode. Bifurcation structure.

CHART 45 (328A2323-26) Type CS46 R10 control structure, Q_s = 250 cfs, H.W. = 117.3 ft, gates 1 and 2 open, $T.W._1$ = 4.9 ft, $T.W._2$ = 4.4 ft. Water depths--siphon mode. Bifurcation structure.

CHART 46 (328A2323-27) Type CS46 R10 control structure, Q_s = 300 cfs, H.W. = 118.6 ft, gates 1 and 2 open, $T.W._1$ = 5.1 ft, $T.W._2$ = 4.8 ft. Water depths--siphon mode. Bifurcation structure.

CHART 47 (328A2323-28) Type CS46 R10 control structure, Q_s = 375 cfs, H.W. = 119.3 ft, gates 1 and 2 open, $T.W._1$ = 5.6 ft, $T.W._2$ = 6.2 ft. Water depths--siphon mode. Bifurcation structure.

CHART 48 (328A2323-29) Type CS46 R10 control structure, Q_s = 200 cfs, H.W. = 120.3 ft, no gates open, $T.W._1$ = N/A, $T.W._2$ = N/A. Water depths--siphon mode. Bifurcation structure.

CHART 49 (328A2323-30) Type CS46 R10 control structure, Q_s = 250 cfs, H.W. = 122.3 ft, no gates open, $T.W._1$ = N/A, $T.W._2$ = N/A. Water depths--siphon mode. Bifurcation structure.

CHART 50 (328A2323-31) Type CS46 R10 control structure, Q_s = 300 cfs, H.W. = 123.9 ft, no gates open, $T.W._1$ = 4.9 ft, $T.W._2$ = N/A. Water depths--siphon mode. Bifurcation structure.

CHART 51 (328A2323-32) Type CS46 R10 control structure, Q_s = 375 cfs, H.W. = 127.4 ft, no gates open, $T.W._1$ = N/A, $T.W._2$ = N/A. Water depths--siphon mode. Bifurcation structure.

CHART 52 (328A2323-33) Type CS46 R10 control structure, Q_s = 16 cfs, H.W. = 111.0 ft, gate 1 open, $T.W._1$ = 4.8 ft, $T.W._2$ = 0 ft. Water depths--siphon mode. Bifurcation structure.

CHART 53 (328A2323-34) Type CS46 R10 control structure, Q_s = 50 cfs, H.W. = 112.2 ft, gate 1 open, $T.W._1$ = 4.7 ft, $T.W._2$ = 0 ft. Water depths--siphon mode. Bifurcation structure.

CHART 54 (328B514-34) Type CS46 R10 control structure, Q_s = 50 cfs, H.W. = 112.4 ft, gate 2 open, $T.W._1$ = 0 ft, $T.W._2$ = 2.3 ft. Piezometric pressures--siphon mode.

CHART 55 (328B514-47) Type CS46 R10 control structure, Q_s = 50 cfs, H.W. = 112.4 ft, gate 2 open, $T.W._1$ = 0 ft, $T.W._2$ = 2.3 ft. Piezometric pressures--siphon mode.

CHART 56 (328B514-35) Type CS46 R10 control structure, Q_s = 100 cfs, H.W. = 113.8 ft, gate 2 open, $T.W._1$ = 0 ft, $T.W._2$ = 3.4 ft. Piezometric pressures--siphon mode.

CHART 57 (328B514-48) Type CS46 R10 control structure, Q_s = 100 cfs, H.W. = 113.8 ft, gate 2 open, $T.W._1$ = 0 ft, $T.W._2$ = 3.4 ft. Piezometric pressures--siphon mode.

CHART 58 (328B514-36) Type CS46 R10 control structure, Q_s = 150 cfs, H.W. = 114.9 ft, gate 2 open, $T.W._1$ = 0 ft, $T.W._2$ = 4.4 ft. Piezometric pressures--siphon mode.

CHART 59 (328B514-49) Type CS46 R10 control structure, Q_s = 150 cfs, H.W. = 114.9 ft, gate 2 open, $T.W._1$ = 0 ft, $T.W._2$ varied. Piezometric pressures--siphon mode.

CHART 60 (328B514-37) Type CS46 R10 control structure, Q_s = 200 cfs, H.W. = 116.1 ft, gates 1 and 2 open, $T.W._1$ = 4.8 ft, $T.W._2$ = 4.1 ft. Piezometric pressures--siphon mode.

CHART 61 (328B514-50) Type CS46 R10 control structure, Q_s = 200 cfs, H.W. = 116.1 ft, gates 1 and 2 open, $T.W._1$ = 4.8 ft, $T.W._2$ = 4.1 ft. Piezometric pressures--siphon mode.

CHART 62 (328B514-38) Type CS46 R10 control structure, Q_s = 250 cfs, H.W. = 117.3 ft, gates 1 and 2 open, $T.W._1$ = 4.9 ft, $T.W._2$ = 4.4 ft. Piezometric pressures--siphon mode.

CHART 63 (328B514-51) Type CS46 R10 control structure, Q_s = 250 cfs, H.W. = 117.3 ft, gates 1 and 2 open, $T.W._1$ = 4.9 ft, $T.W._2$ = 4.4 ft. Piezometric pressures--siphon mode.

CHART 64 (328B514-39) Type CS46 R10 control structure, Q_s = 300 cfs, H.W. = 118.6 ft, gates 1 and 2 open, $T.W._1$ = 5.1 ft, $T.W._2$ = 4.8 ft. Piezometric pressures--siphon mode.

CHART 65 (328B514-52) Type CS46 R10 control structure, Q_s = 300 cfs, H.W. = 118.6 ft, gates 1 and 2 open, $T.W._1$ varied, $T.W._2$ varied. Piezometric pressures--siphon mode.

CHART 66 (328B514-40) Type CS46 R10 control structure, Q_s = 375 cfs, H.W. = 119.3 ft, gates 1 and 2 open, $T.W._1$ = 5.6 ft, $T.W._2$ = 6.0 ft. Piezometric pressures--siphon mode.

CHART 67 (328B514-53) Type CS46 R10 control structure, Q_s = 375 cfs, H.W. = 119.3 ft, gates 1 and 2 open, $T.W._1$ = 5.6 ft, $T.W._2$ = 6.0 ft. Piezometric pressures--siphon mode.

CHART 68 (328B514-41) Type CS46 R10 control structure, Q_s = 200 cfs, H.W. = 120.3 ft, no gates open, $T.W._1$ = N/A, $T.W._2$ = N/A. Piezometric pressures--siphon mode.

CHART 69 (328B514-54) Type CS46 R10 control structure, Q_s = 200 cfs, H.W. = 120.3 ft, no gates open, $T.W._1$ = N/A, $T.W._2$ = N/A. Piezometric pressures--siphon mode.

CHART 70 (328B514-42) Type CS46 R10 control structure, Q_s = 250 cfs, H.W. = 122.3 ft, no gates open, $T.W._1$ = N/A, $T.W._2$ = N/A. Piezometric pressures--siphon mode.

CHART 71 (328B514-55) Type CS46 R10 control structure, Q_s = 250 cfs, H.W. = 122.3 ft, no gates open, $T.W._1$ = N/A, $T.W._2$ = N/A. Piezometric pressures--siphon mode.

CHART 72 (328B514-41) Type CS46 R10 control structure, Q_s = 300 cfs, H.W. = 123.9 ft, no gates open, $T.W._1$ = N/A, $T.W._2$ = N/A. Piezometric pressures--siphon mode.

CHART 73 (328B514-56) Type CS46 R10 control structure, Q_s = 300 cfs, H.W. = 123.9 ft, no gates open, $T.W._1$ = N/A, $T.W._2$ = N/A. Piezometric pressures--siphon mode.

CHART 74 (328B514-44) Type CS46 R10 control structure, Q_s = 375 cfs, H.W. = 127.4 ft, no gates open, $T.W._1$ = N/A, $T.W._2$ = N/A. Piezometric pressures--siphon mode.

CHART 75 (328B514-57) Type CS46 R10 control structure, Q_s = 375 cfs, H.W. = 127.4 ft, no gates open, $T.W._1$ = N/A, $T.W._2$ = N/A. Piezometric pressures--siphon mode.

CHART 76 (328B514-45) Type CS46 R10 control structure, Q_s = 16 cfs, H.W. = 111.0 ft, gate 1 open, $T.W._1$ = 4.7 ft, $T.W._2$ = 0 ft. Piezometric pressures--siphon mode.

CHART 77 (328B514-58) Type CS46 R10 control structure, Q_s = 16 cfs, H.W. = 111.0 ft, gate 1 open, $T.W._1$ varied, $T.W._2$ = 0 ft. Piezometric pressures--siphon mode.

CHART 78 (328B514-46) Type CS46 R10 control structure, Q_s = 50 cfs, H.W. 112.2 ft, gate 1 open, $T.W._1$ = 4.7 ft, $T.W._2$ = 0 ft. Piezometric pressures--siphon mode.

CHART 79 (328B514-59) Type CS46 R10 control structure, Q_s = 50 cfs, H.W. 112.2 ft, gate 1 open, $T.W._1$ = 4.7 ft, $T.W._2$ = 0 ft. Piezometric pressures--siphon mode.

CHART 80 (328A2323-15) Type CS46 R10 control structure, flow conditions varied. Pressure readings--siphon mode.

CHART 81 (328A2323-16) Type CS46 R10 control structure, Q_S = 150 cfs, H.W. = 114.9 ft, gate 2 open, $T.W._1$ = 0 ft, $T.W._2$ = 4.4 ft. Pressure readings--siphon mode.

CHART 82 (328A2323-17) Type CS46 R10 control structure, flow conditions varied. Pressure readings--siphon mode.

CHART 83 (328A2323-18) Type CS46 R10 control structure, flow conditions varied. Pressure readings--siphon mode.

CHART 84 (328A2323-19) Type CS46 R10 control structure, flow conditions varied. Pressure readings--siphon mode.

CHART 85 (328A2323-20) Type CS46 R10 control structure. Pressure readings--siphon mode.

CHART 86 (328A2323-21) Type CS46 R10 control structure, flow conditions varied. Pressure readings--siphon mode.

CHART 87 (328A2323-35) Type CS46 R10 control structure, flow conditions varied. Pressure readings--siphon mode.

CHART 88 (328A2323-36) Type CS46 R10 control structure, flow conditions varied. Pressure readings--siphon mode.

CHART 89 (328A2323-37) Type CS46 R10 control structure, flow conditions varied. Pressure readings--siphon mode.

CHART 90 (328B514-28) Type CS46 R10 control structure, Q_D = 16 cfs, other flow conditions varied. Water surface profiles--drawdown mode.

CHART 91 (328B514-29) Type CS46 R10 control structure, Q_D = 25 cfs. other flow conditions varied. Water surface profiles--drawdown mode.

CHART 92 (328B514-30) Type CS46 R10 control structure, Q_D = 50 cfs. other flow conditions varied. Water surface profiles--drawdown mode.

CHART 93 (328B514-31) Type CS46 R10 control structure, Q_D = 75 cfs. other flow conditions varied. Water surface profiles--drawdown mode.

CHART 94 (328B514-32) Type CS46 R10 control structure, Q_D = 100 cfs. other flow conditions varied. Water surface profiles--drawdown mode.

CHART 95 (328B514-33) Type CS46 R10 control structure, Q_D = 125 cfs. other flow conditions varied. Water surface profiles--drawdown mode.

CHART 96 (328A2323-12) Type CS46 R10 control structure, flow conditions varied. Water depths--drawdown mode.

CHART 97 (328A2323-13) Type CS46 R10 control structure, flow conditions varied. Water depths--drawdown mode.

CHART 98 (3282323-14) Type CS46 R10 control structure, flow conditions varied. Water depths--drawdown mode.

CHART 99 (328B514-21) Type CS46 R10 control structure, Q_D = 16 cfs, other flow conditions varied. Piezometric pressures--drawdown mode.

CHART 100 (328B514-22) Type CS46 R10 control structure, Q_D = 25 cfs, other flow conditions varied. Piezometric pressures--drawdown mode.

CHART 101 (328B514-23) Type CS46 R10 control structure, Q_D = 50 cfs, other flow conditions varied. Piezometric pressures--drawdown mode.

CHART 102 (328B514-24) Type CS46 R10 control structure, Q_D = 75 cfs, other flow conditions varied. Piezometric pressures--drawdown mode.

CHART 103 (328B514-25) Type CS46 R10 control structure, Q_D = 100 cfs, other flow conditions varied. Piezometric pressures--drawdown mode.

CHART 104 (328B514-26) Type CS46 R10 control structure, Q_D = 125 cfs, other flow conditions varied. Piezometric pressures--drawdown mode.

CHART 105 (328B514-27) Type CS46 R10 control structure, Q_D = 125 cfs, other flow conditions varied. Piezometric pressures--drawdown mode.

CHART 106 (328A2323-6) Type CS46 R10 control structure, flow conditions varied Pressure readings--drawdown mode.

CHART 107 (328A2323-7) Type CS46 R10 control structure, flow conditions varied Pressure readings--drawdown mode.

CHART 108 (328A2323-8) Type CS46 R10 control structure, flow conditions varied Pressure readings--drawdown mode.

CHART 109 (328A2323-9) Type CS46 R10 control structure, flow conditions varied Pressure readings--drawdown mode.

CHART 110 (328A2323-10) Type CS46 R10 control structure, flow conditions varied Pressure readings--drawdown mode.

CHART 111 (328A2323-6) Type CS46 R10 control structure, flow conditions varied. Pressure readings--drawdown mode.

CHART 112 (328B514-15) Type CS46 R10 control structure, Q_F = 16 cfs, H.W. = 0.8 ft, T.W. = 0.4 ft. Water surface profiles--flushing mode.

CHART 113 (328B514-16) Type CS46 R10 control structure, Q_F = 25 cfs, H.W. = 1.1 ft, T.W. = 0.6 ft. Water surface profiles--flushing mode.

CHART 114 (328B514-17) Type CS46 R10 control structure, Q_F = 50 cfs, H.W. = 1.5 ft, T.W. 1.0 ft. Water surface profiles--flushing mode.

CHART 115 (328B514-18) Type CS46 R10 control structure, Q_F = 75 cfs, H.W. = 1.9 ft, T.W. = 1.3 ft. Water surface profiles--flushing mode.

CHART 116 (328B514-19) Type CS46 R10 control structure, Q_F = 100 cfs, H.W. = 2.2 ft, T.W. = 1.5 ft. Water surface profiles--flushing mode.

CHART 117 (328B514-20) Type CS46 R10 control structure, Q_F = 125 cfs, H.W. = 2.5 ft, T.W. = 1.8 ft. Water surface profiles--flushing mode.

CHART 118 (328A2323-4) Type CS46 R10 control structure, flow conditions varied. Water depths--flushing mode.

CHART 119 (328A2323-5) Type CS46 R10 control structure, flow conditions varied. Water depths--flushing mode.

CHART 120 (328B514-9) Type CS46 R10 control structure, Q_F = 16 cfs, H.W. = 0.8 ft, T.W. = 0.4 ft. Piezometric pressures--flushing mode.

CHART 121 (328B514-10) Type CS46 R10 control structure, Q_F = 25 cfs, H.W. = 1.1 ft, T.W. = 0.6 ft. Piezometric pressures--flushing mode.

CHART 122 (328B514-11) Type CS46 R10 control structure, Q_F = 50 cfs, H.W. = 1.5 ft, T.W. = 1.0 ft. Piezometric pressures--flushing mode.

CHART 123 (328B514-12) Type CS46 R10 control structure, Q_F = 75 cfs, H.W. = 1.9 ft, T.W. = 1.3 ft. Piezometric pressures--flushing mode.

CHART 124 (328B514-13) Type CS46 R10 control structure, Q_F = 100 cfs, H.W. = 2.2 ft, T.W. = 1.5 ft. Piezometric pressures--flushing mode.

CHART 125 (328B514-14) Type CS46 R10 control structure, Q_F = 125 cfs, H.W. = 2.5 ft, T.W. = 1.8 ft. Piezometric pressures--flushing mode.

CHART 126 (328A2323-1) Type CS46 R10 control structure, flow conditions varied. Pressure readings--flushing mode.

CHART 127 (328A2323-2) Type CS46 R10 control structure, flow conditions varied. Pressure readings--flushing mode.

CHART 128 (328A2323-3) Type CS46 R10 control structure, flow conditions varied. Pressure readings--flushing mode.

CHART 129 (328A2323-46) Type CS46 R10 and R11 control structures, flow conditions varied. Fluctuating pressures on siphon bell lip.

CHART 130 (328A2323-47) Type CS46 R10 control structure, Q_s = 375 cfs. Fluctuating pressures on siphon bell lip--siphon mode.

CHART 131 (328A2323-49) Type CS46 R10 control structure. Fluctuating pressures on siphon bell lip--drawdown mode.

CHART 132 (328A2323-51) Type CS46 R10 control structure, flow condition varied. Fluctuating pressures on siphon bell lip--flushing mode.

CHART 133 (328B514-73) Type CS46 R10 control structure, flow condition varied. Piezometric pressures--siphon mode. Sediment test No. 12.

CHART 134 (328A2323-40) Type CS46 R10 control structure, flow condition varied. Pressure readings--siphon mode. Sediment test No. 12.

CHART 135 (328B514-74) Type CS46 R10 control structure, flow condition varied. Piezometric pressure--siphon mode. Sediment test No. 12.

CHART 136 (328A2323-41) Type CS46 R10 control structure, flow condition varied. Pressure readings--siphon mode. Sediment test No. 12.

CHART 137 (328A2323-57) Type CS46 R10 control structure. Size distribution of model sediments. Sediment test No. 14.

CHART 138 (328B514-77) Type CS46 R10 control structure, flow condition varied. Piezometric pressures--siphon mode. Sediment test No. 14.

CHART 139 (328A2323-44, 45) Type CS46 R10 control structure, flow conditions varied. Pressure readings--siphon mode. Sediment test No. 14.

CHART 140 (328A2323-38) Type CS46 R10 control structure, Q_F = 100 cfs, H.W. = 2.2 ft, T.W. = 1.5 ft. Sediment flushing time.

CHART 141 (328A2323-48) Type CS46 R11 control structure, Q_s = 375 cfs. Fluctuating pressures on siphon bell lip--siphon mode.

CHART 142 (328A2323-50) Type CS46 R11 control structure. Fluctuating pressures on siphon bell lip--drawdown mode.

CHART 143 (328A2323-52) Type CS46 R11 control structure, flow conditions varied. Fluctuating pressures on siphon bell lip--flushing mode.

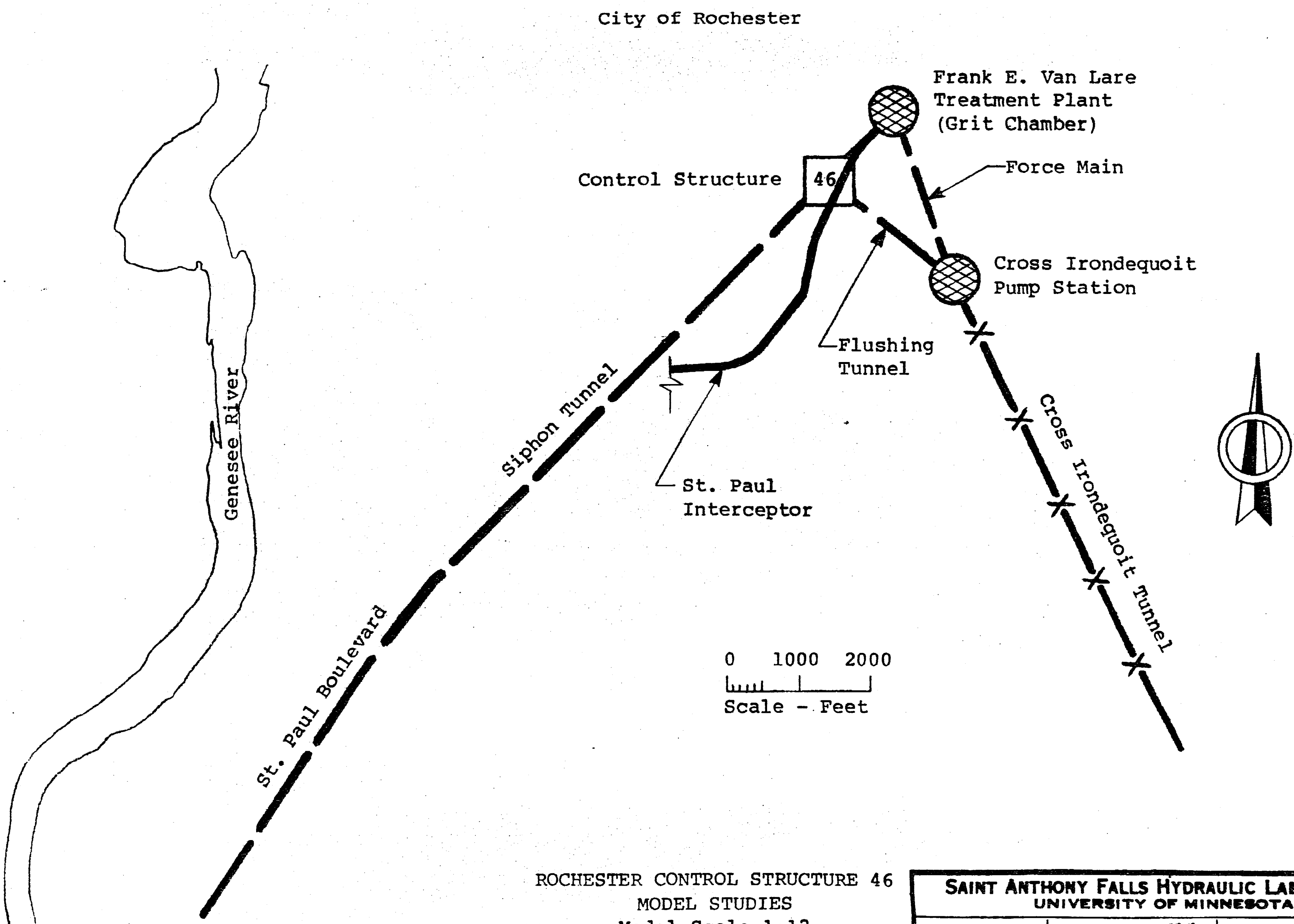
CHART 144 (328B514-75) Type CS46 R11 control structure, flow conditions varied. Piezometric pressure--siphon mode. Sediment test No. 13.

CHART 145 (328B514-76) Type CS46 R11 control structure, flow conditions varied. Piezometric pressure--siphon mode. Sediment test No. 13.

CHART 146 (328A2323-42) Type CS46 R11 control structure, flow conditions varied. Pressure readings--siphon mode. Sediment test No. 13.

CHART 147 (328A2323-43) Type CS46 R11 control structure, flow conditions varied. Pressure readings--siphon mode. Sediment Test No. 13.

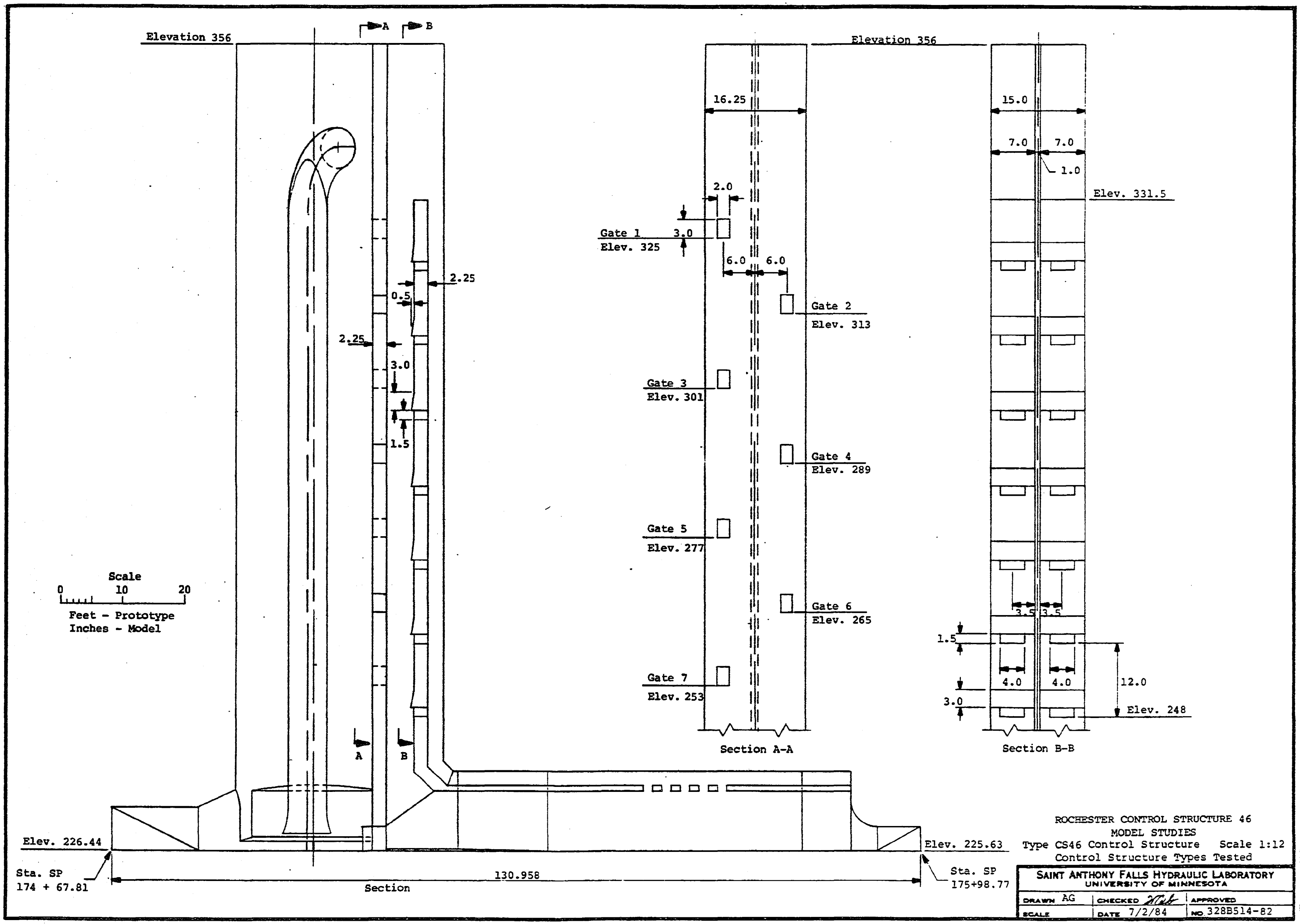
CHART 148 (328A2323-56) Type CS46 R11 control structure. Size distribution of model sediments. Sediment test No. 13.



ROCHESTER CONTROL STRUCTURE 46
MODEL STUDIES
Model Scale 1:12
Location of Facilities

SAINT ANTHONY FALLS HYDRAULIC LABORATORY UNIVERSITY OF MINNESOTA		
DRAWN AG	CHECKED [signature]	APPROVED
SCALE	DATE 7/16/84	NO. 328A2323-59

CHART 1


Elevation 356
A
B
2.25
0.5
2.25
3.0
1.5
Scale
0 10 20
Feet - Prototype
Inches - Model
Elev. 226.44
Sta. SP
174 + 67.81
130.958
Section
Elev. 225.63
Sta. SP
175+98.77
16.25
2.0
Gate 1 3.0
Elev. 325
6.0 6.0
Gate 2
Elev. 313
Gate 3
Elev. 301
Gate 4
Elev. 289
Gate 5
Elev. 277
Gate 6
Elev. 265
Gate 7
Elev. 253
Section A-A
15.0
7.0 7.0
1.0
Elev. 331.5
3.5 3.5
1.5
4.0 4.0
12.0
3.0
Elev. 248
Section B-B
ROCHESTER CONTROL STRUCTURE 46
MODEL STUDIES
Type CS46 Control Structure Scale 1:12
Control Structure Types Tested
SAINT ANTHONY FALLS HYDRAULIC LABORATORY
UNIVERSITY OF MINNESOTA
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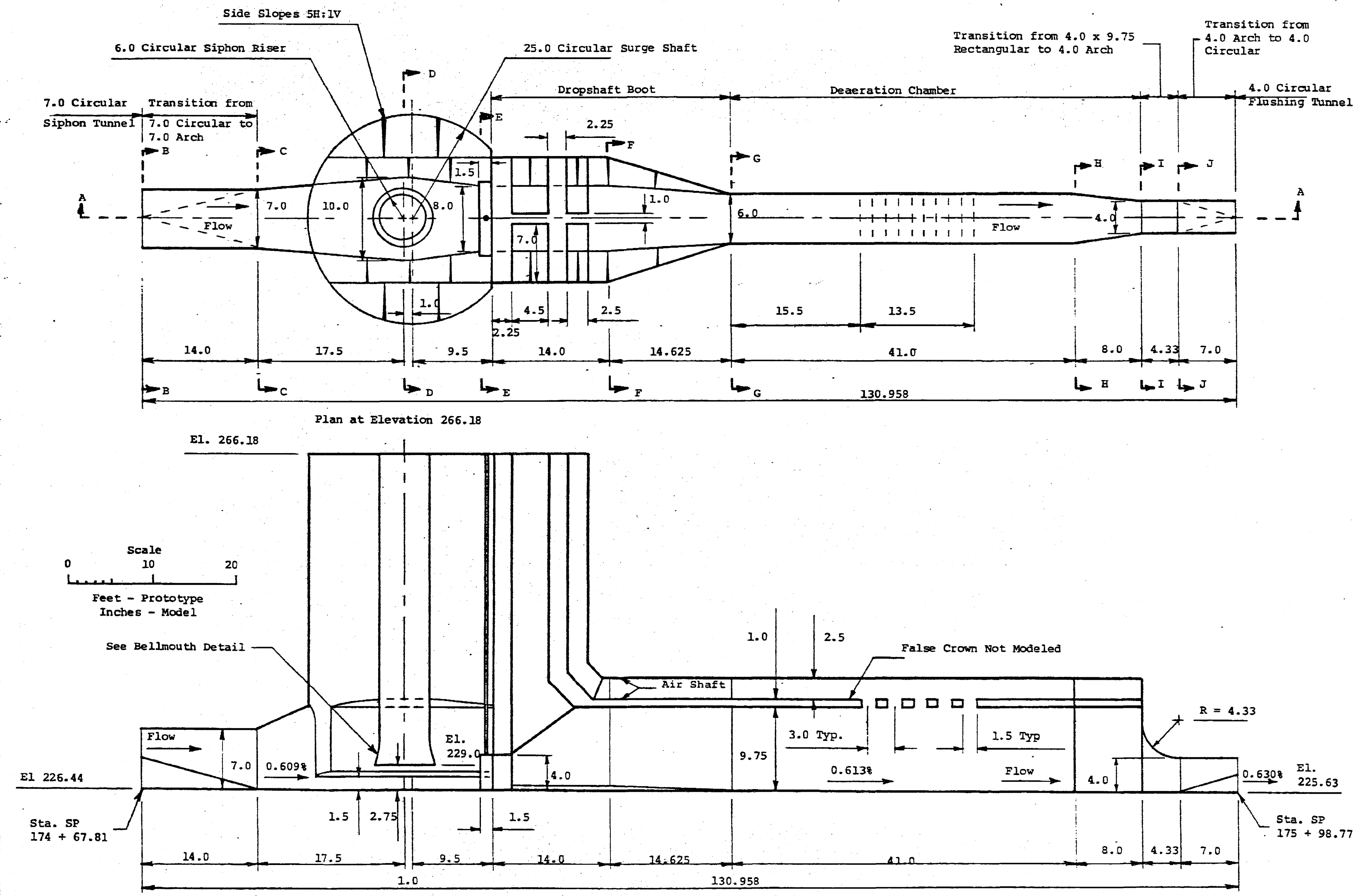
APPROVED
SCALE
DATE 7/2/84
NO. 328B514-82

CHART 2



Model constructed according to Erdman, Anthony, Associates Drawings SP - TU - 7 Sheets 1 to 10 and SP - CS - G2 Sheet 44.

ROCHESTER CONTROL STRUCTURE 46
MODEL STUDIES
Type CS46 Control Structure Scale 1:12
Control Structure Types Tested

SAINT ANTHONY FALLS HYDRAULIC LABORATORY
UNIVERSITY OF MINNESOTA

DRAWN B.B.	CHECKED	APPROVED
SCALE	DATE 12/21/83	NO. 328B514-1

CHART 3

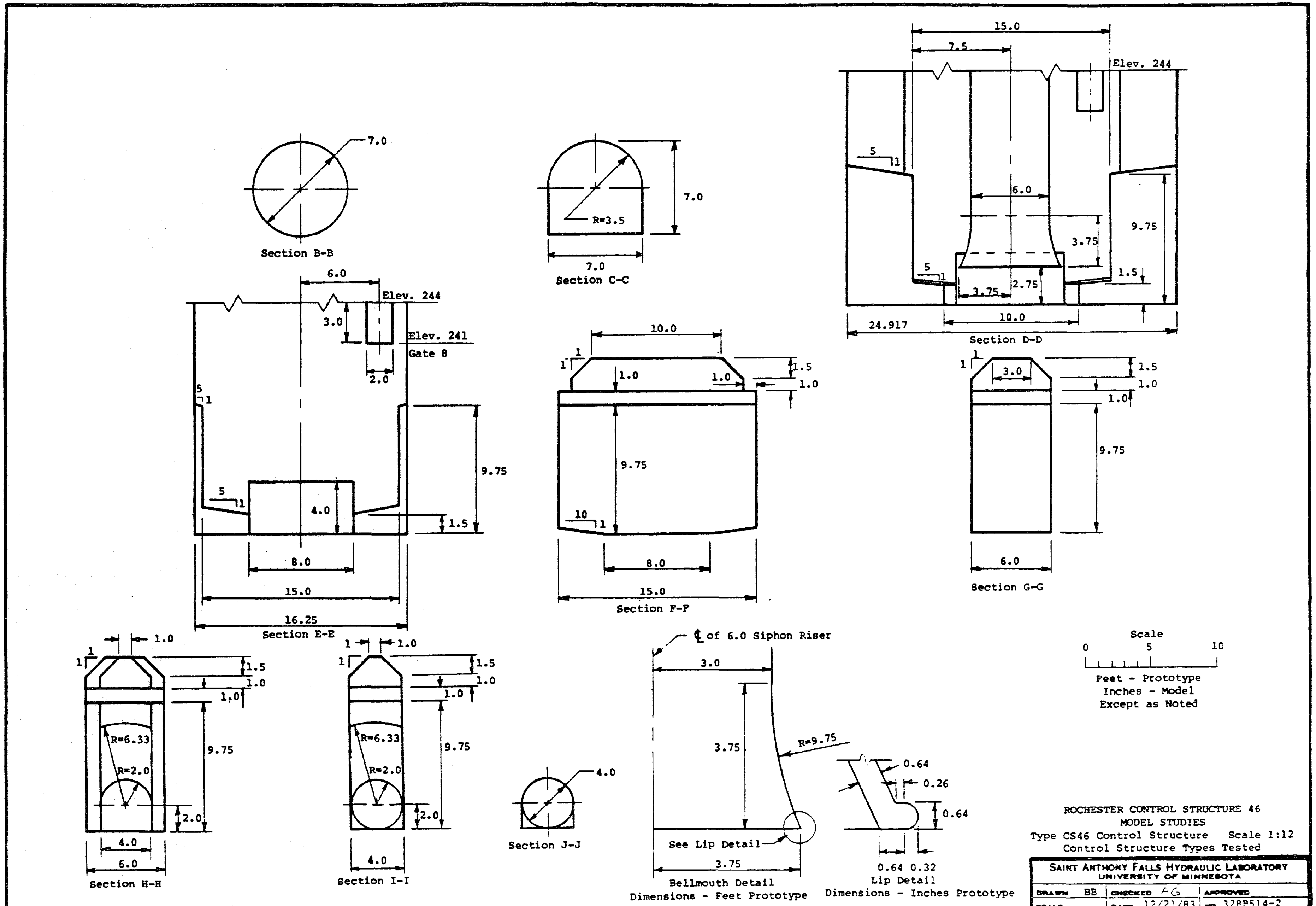
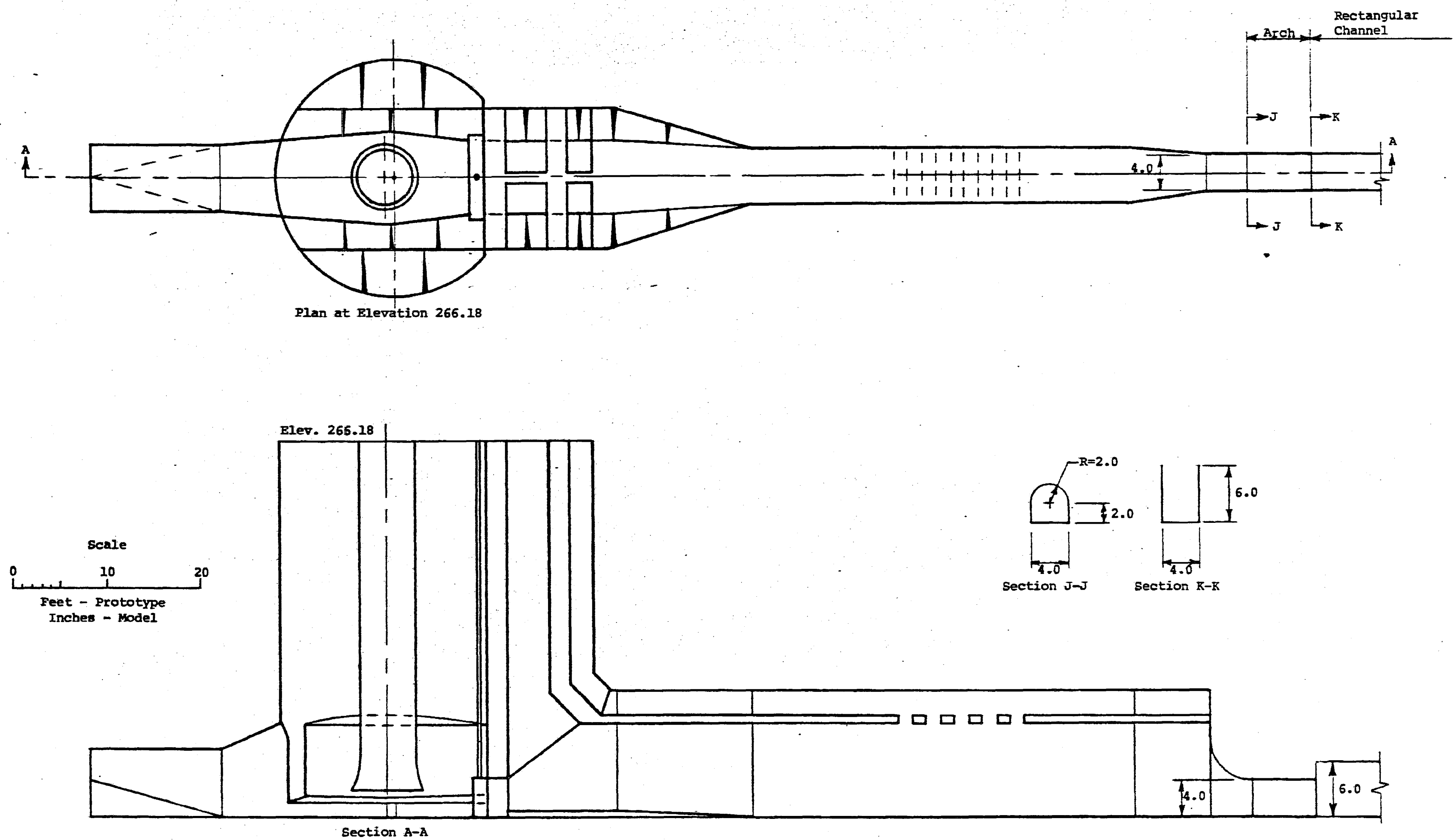

Section B-B
Section C-C
R=3.5
Elev. 244
Elev. 241
Gate 8
Section E-E
Section F-F
Section D-D
Section G-G
Section H-H
Section I-I
Section J-J
R=6.33
R=2.0
℄ of 6.0 Siphon Riser
R=9.75
See Lip Detail
Bellmouth Detail
Dimensions - Feet Prototype
Lip Detail
Dimensions - Inches Prototype
Scale
Feet - Prototype
Inches - Model
Except as Noted
ROCHESTER CONTROL STRUCTURE 46
MODEL STUDIES
Type CS46 Control Structure Scale 1:12
Control Structure Types Tested
SAINT ANTHONY FALLS HYDRAULIC LABORATORY
UNIVERSITY OF MINNESOTA
DRAWN BB
CHECKED FG
APPROVED
SCALE
DATE 12/21/83
NO 328B514-2

CHART 4

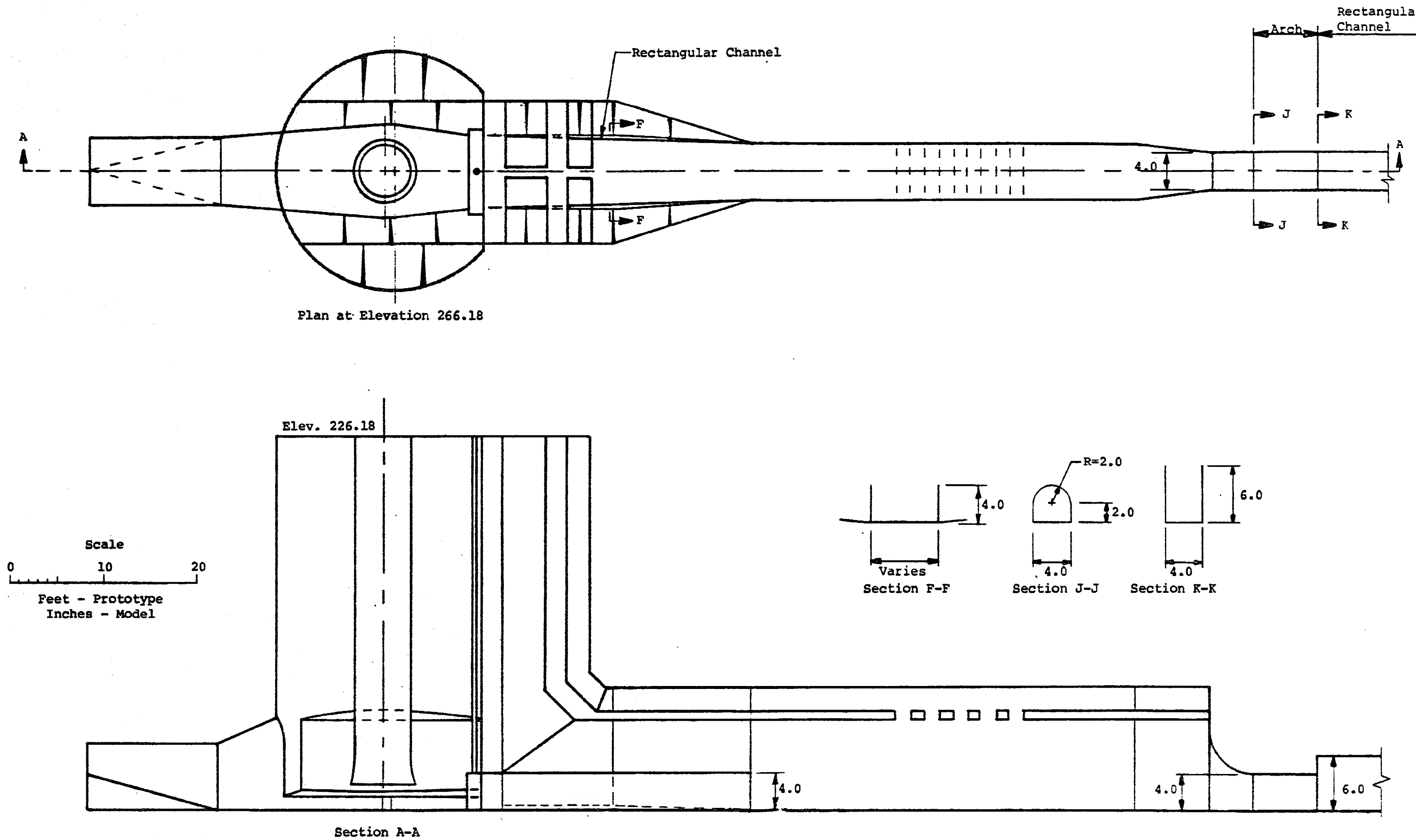


Type CS46 R1 Control Structure is the same as Type CS46 with the changes shown.

ROCHESTER CONTROL STRUCTURE 46
MODEL STUDIES
Type CS46 R1 Control Structure Scale 1:12
Control Structure Types Tested

SAINT ANTHONY FALLS HYDRAULIC LABORATORY UNIVERSITY OF MINNESOTA		
DRAWN B.B.	CHECKED A.G.	APPROVED
SCALE	DATE 2/20/84	NO. 328B514-3

CHART 5



Type CS46 R2 Control Structure is the same as Type CS46 with the changes shown.

ROCHESTER CONTROL STRUCTURE 46
MODEL STUDIES
Type CS46 R2 Control Structure Scale 1:12
Control Structure Types Tested

SAINT ANTHONY FALLS HYDRAULIC LABORATORY UNIVERSITY OF MINNESOTA		
DRAWN B.B.	CHECKED A.S.	APPROVED
SCALE	DATE 2/20/84	NO. 328B514-4

CHART 6

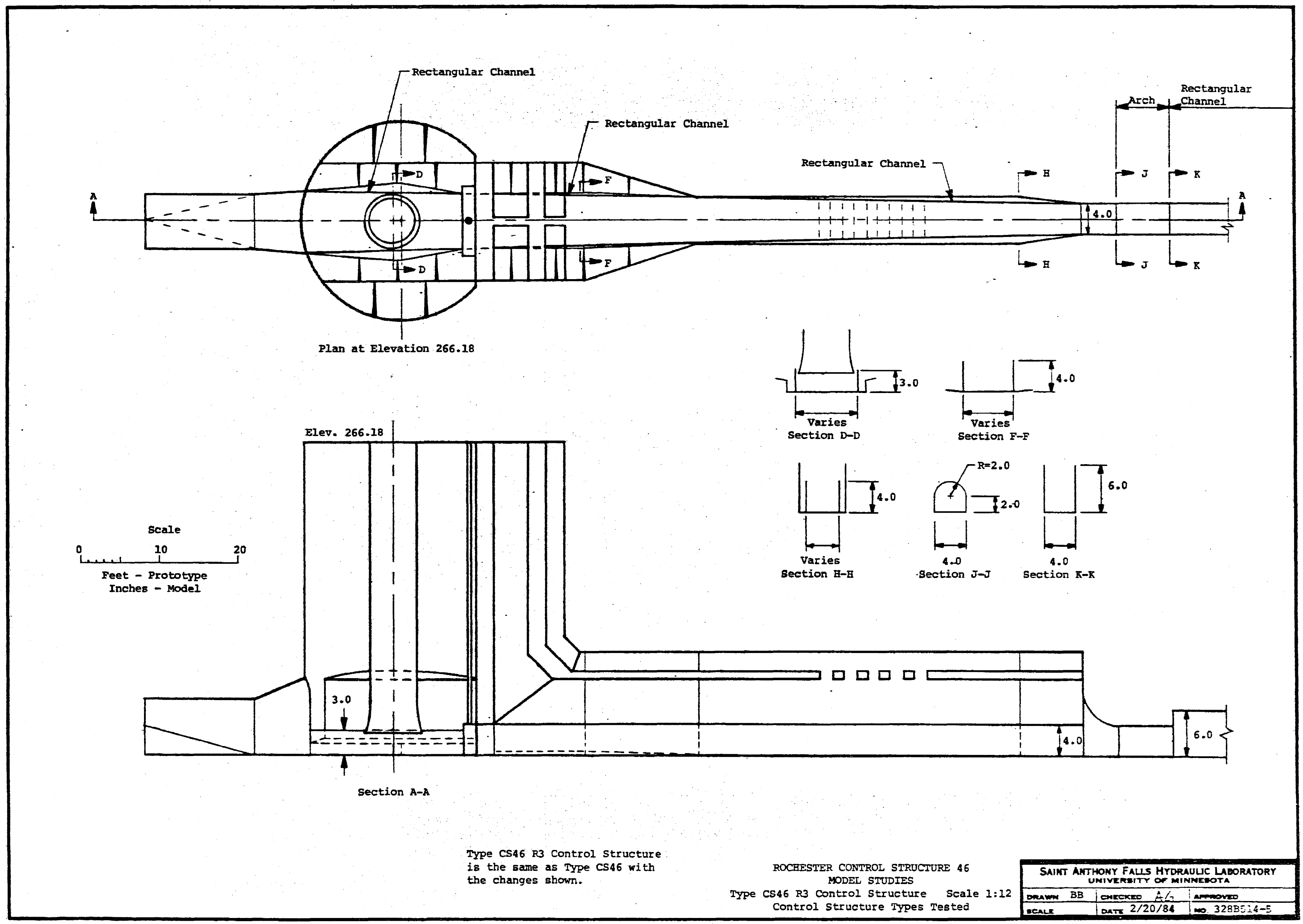
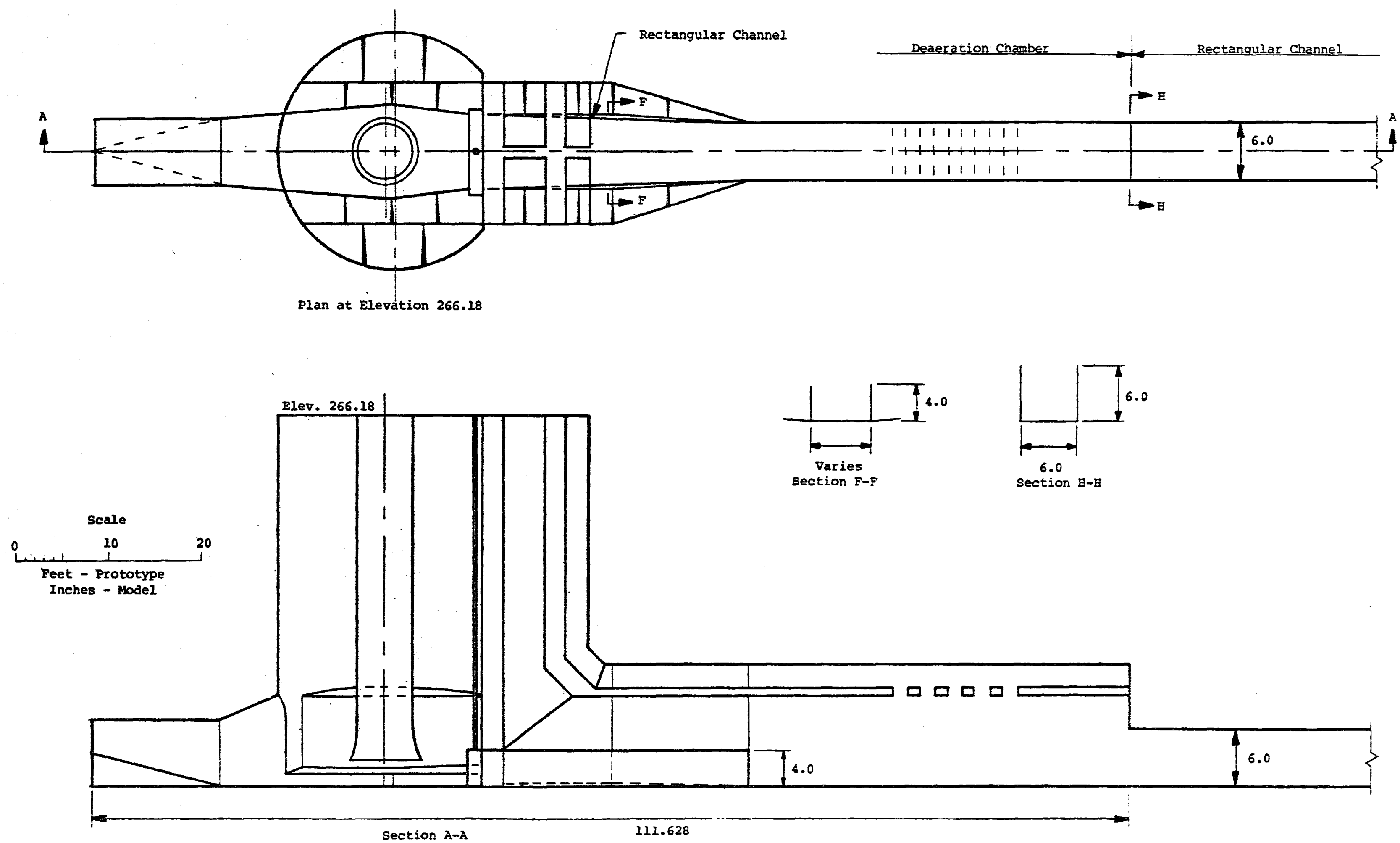

Rectangular Channel
Rectangular Channel
Rectangular Channel
Arch
Rectangular Channel
A
A
D
D
F
F
H
H
J
J
K
K
4.0
Plan at Elevation 266.18
3.0
Varies
Section D-D
4.0
Varies
Section F-F
4.0
Varies
Section H-H
R=2.0
2.0
4.0
Section J-J
6.0
4.0
Section K-K
Elev. 266.18
Scale
0
10
20
Feet - Prototype
Inches - Model
3.0
4.0
6.0
Section A-A
Type CS46 R3 Control Structure
is the same as Type CS46 with
the changes shown.
ROCHESTER CONTROL STRUCTURE 46
MODEL STUDIES
Type CS46 R3 Control Structure Scale 1:12
Control Structure Types Tested
SAINT ANTHONY FALLS HYDRAULIC LABORATORY
UNIVERSITY OF MINNESOTA
DRAWN BB
CHECKED
APPROVED
SCALE
DATE 2/20/84
NO. 328B514-5

CHART 7

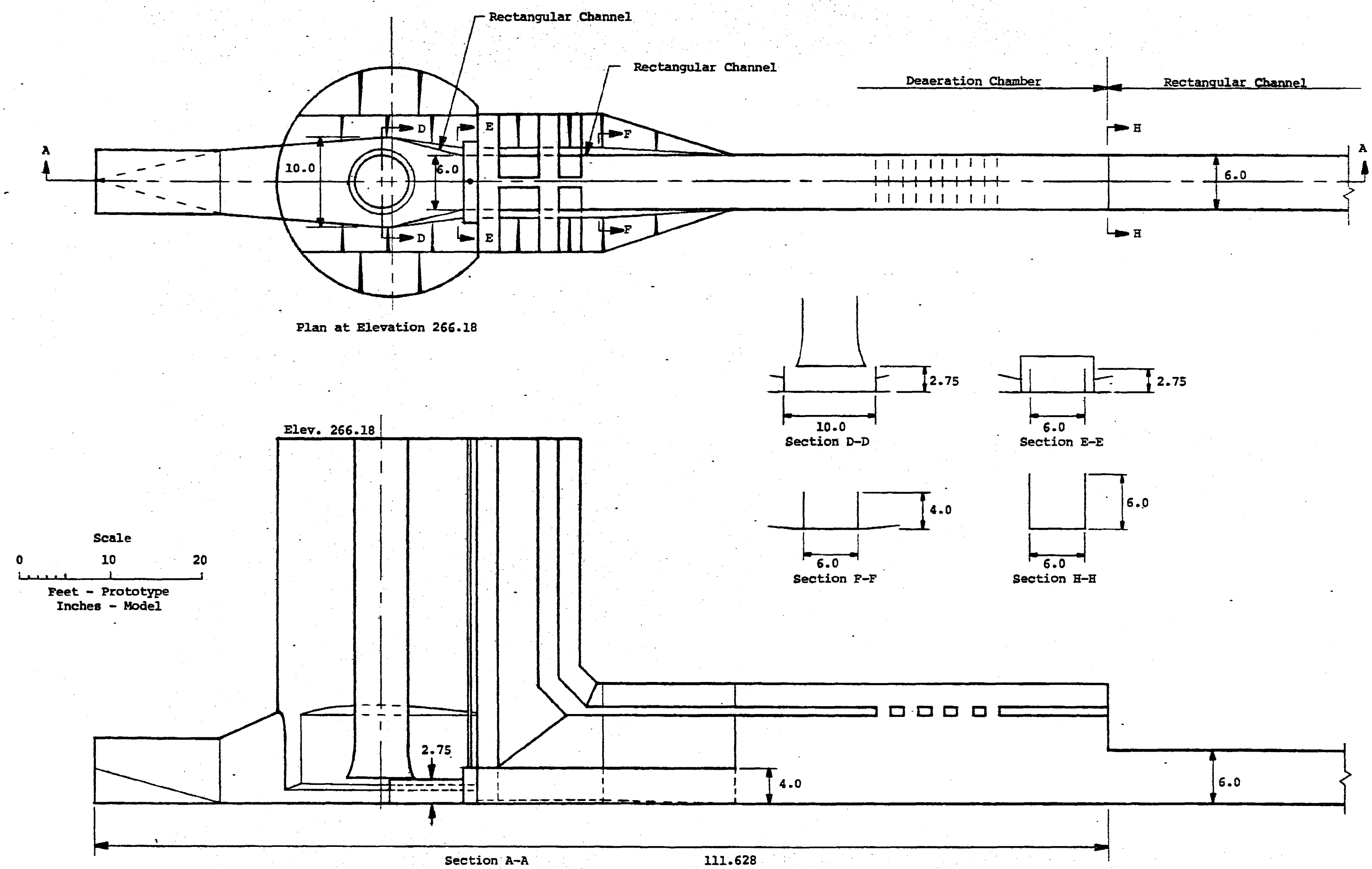


Type CS46 R4 Control Structure is the same as Type CS46 with the changes shown.

ROCHESTER CONTROL STRUCTURE 46
MODEL STUDIES
Type CS46 R4 Control Structure Scale 1:12
Control Structure Types Tested

SAINT ANTHONY FALLS HYDRAULIC LABORATORY UNIVERSITY OF MINNESOTA		
DRAWN BB	CHECKED AG	APPROVED
SCALE	DATE 2/20/84	NO 328B514-6

CHART 8

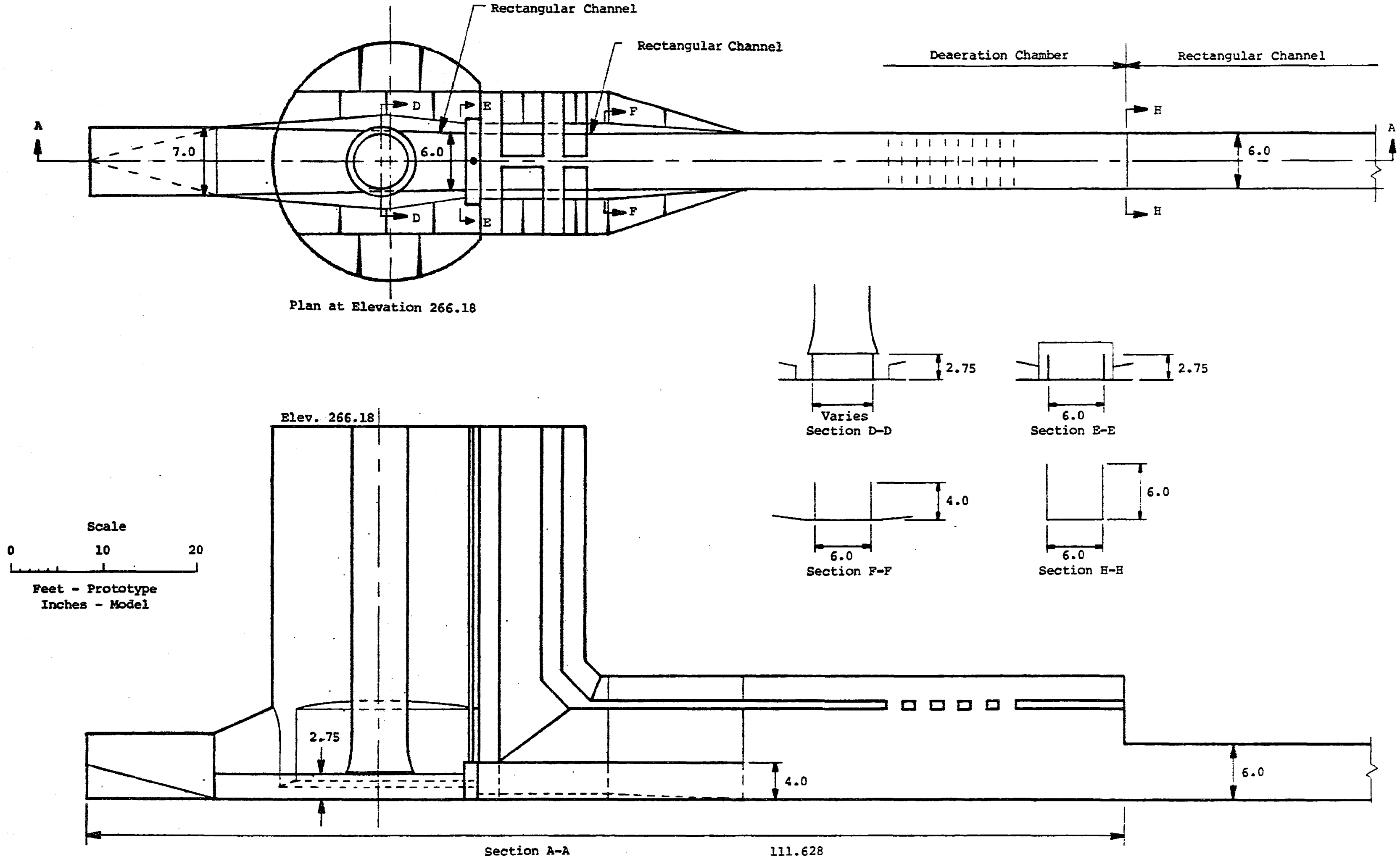


Type CS46 R5 Control Structure is the same as Type CS46 with the changes shown.

ROCHESTER CONTROL STRUCTURE 46
MODEL STUDIES
Type CS46 R5 Control Structure Scale 1:12
Control Structure Types Tested

SAINT ANTHONY FALLS HYDRAULIC LABORATORY UNIVERSITY OF MINNESOTA		
DRAWN BB	CHECKED AG	APPROVED
SCALE	DATE 2/20/84	NO. 328B514-7

CHART 9

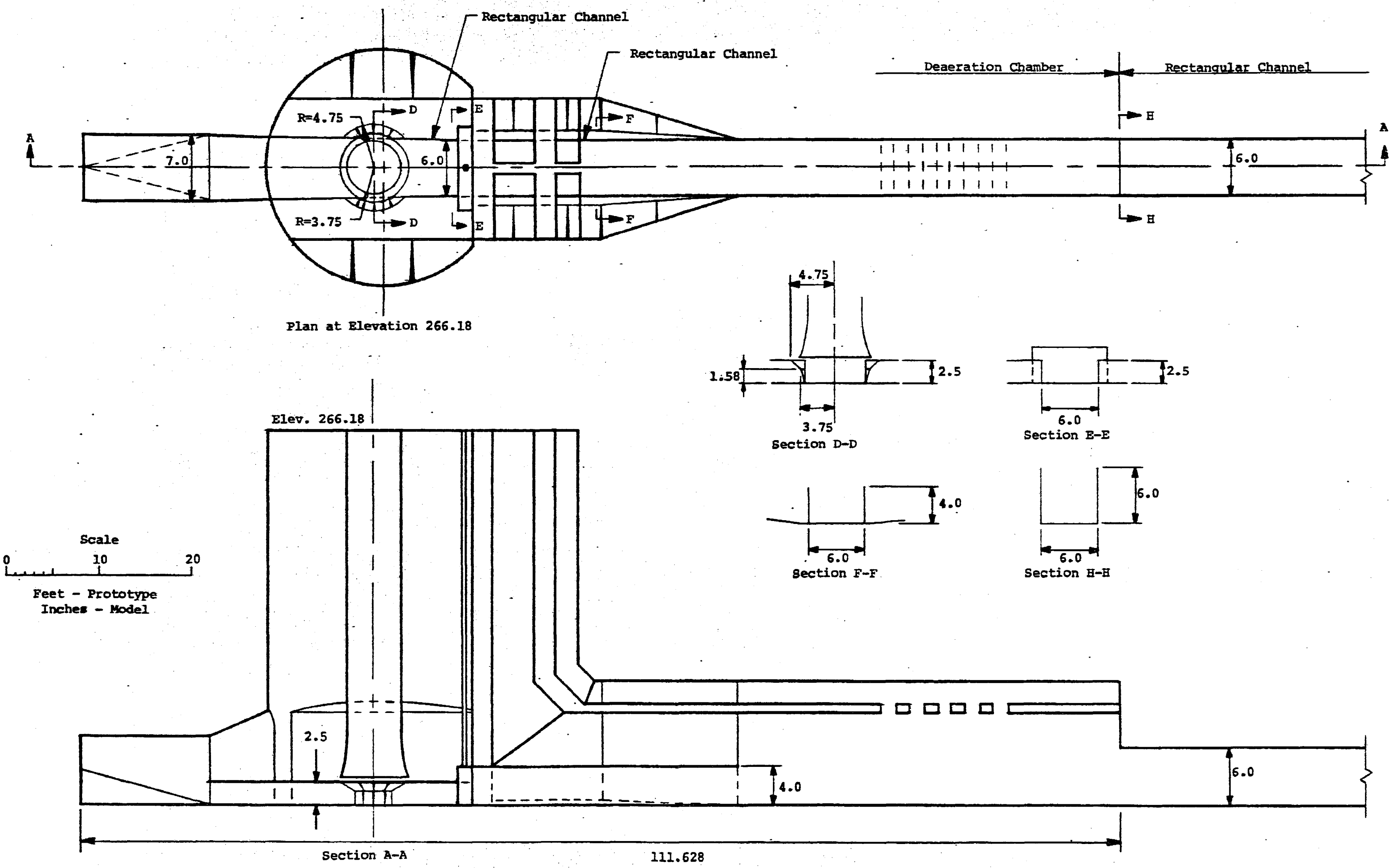


Type CS46 R6 Control Structure is the same as Type CS46 with the changes shown.

ROCHESTER CONTROL STRUCTURE 46
MODEL STUDIES
Type CS46 R6 Control Structure Scale 1:12
Control Structure Types Tested

SAINT ANTHONY FALLS HYDRAULIC LABORATORY UNIVERSITY OF MINNESOTA		
DRAWN BB	CHECKED	APPROVED
SCALE	2/20/84	NO 328B514-8

CHART 10

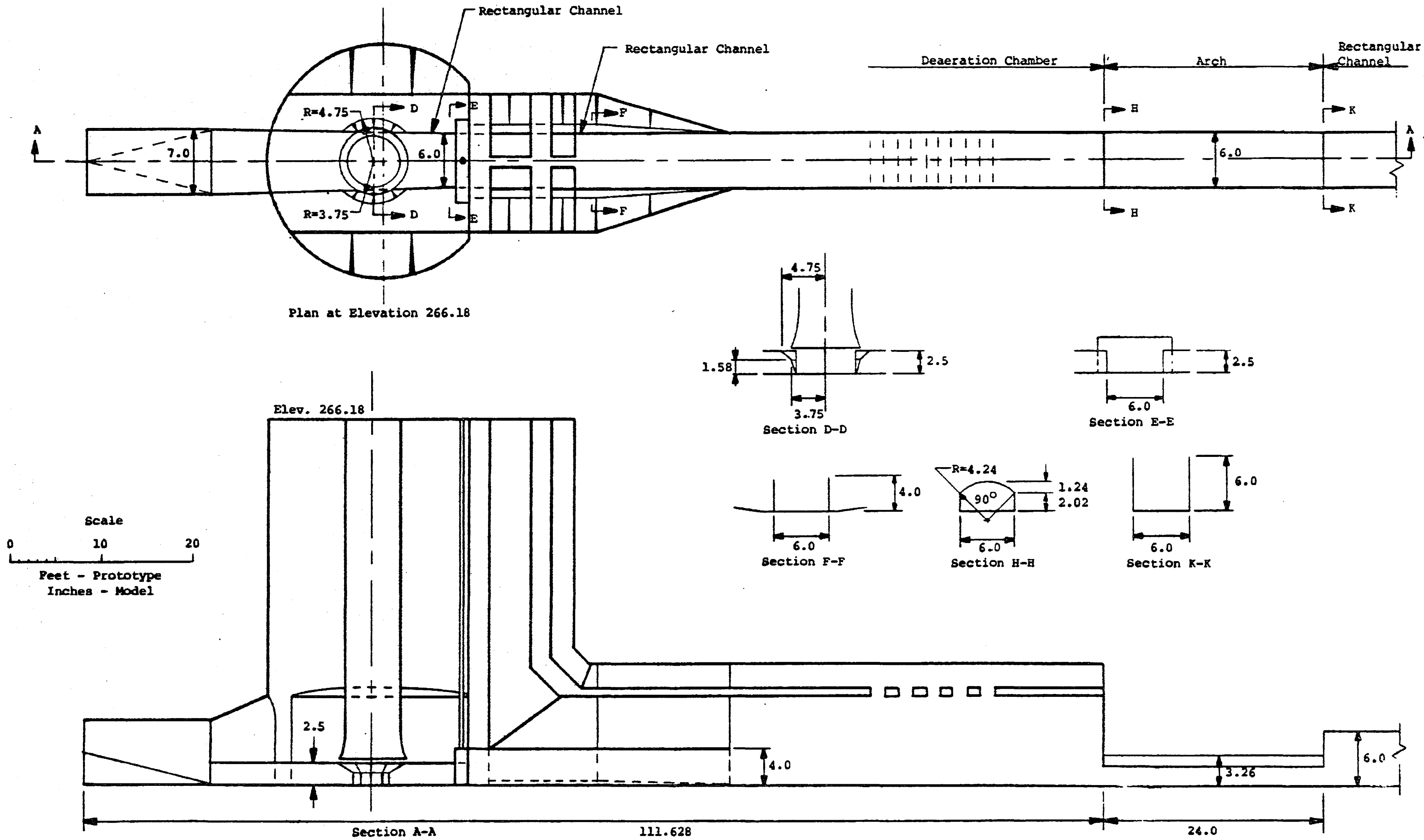


Type CS46 R7 Control Structure is the same as Type CS46 with the changes shown.

ROCHESTER CONTROL STRUCTURE 46
MODEL STUDIES
Type CS46 R7 Control Structure Scale 1:12
Control Structure Types Tested

SAINT ANTHONY FALLS HYDRAULIC LABORATORY UNIVERSITY OF MINNESOTA		
DRAWN AG	CHECKED	APPROVED
SCALE	DATE 6/20/84	NO. 328B514-78

CHART 11

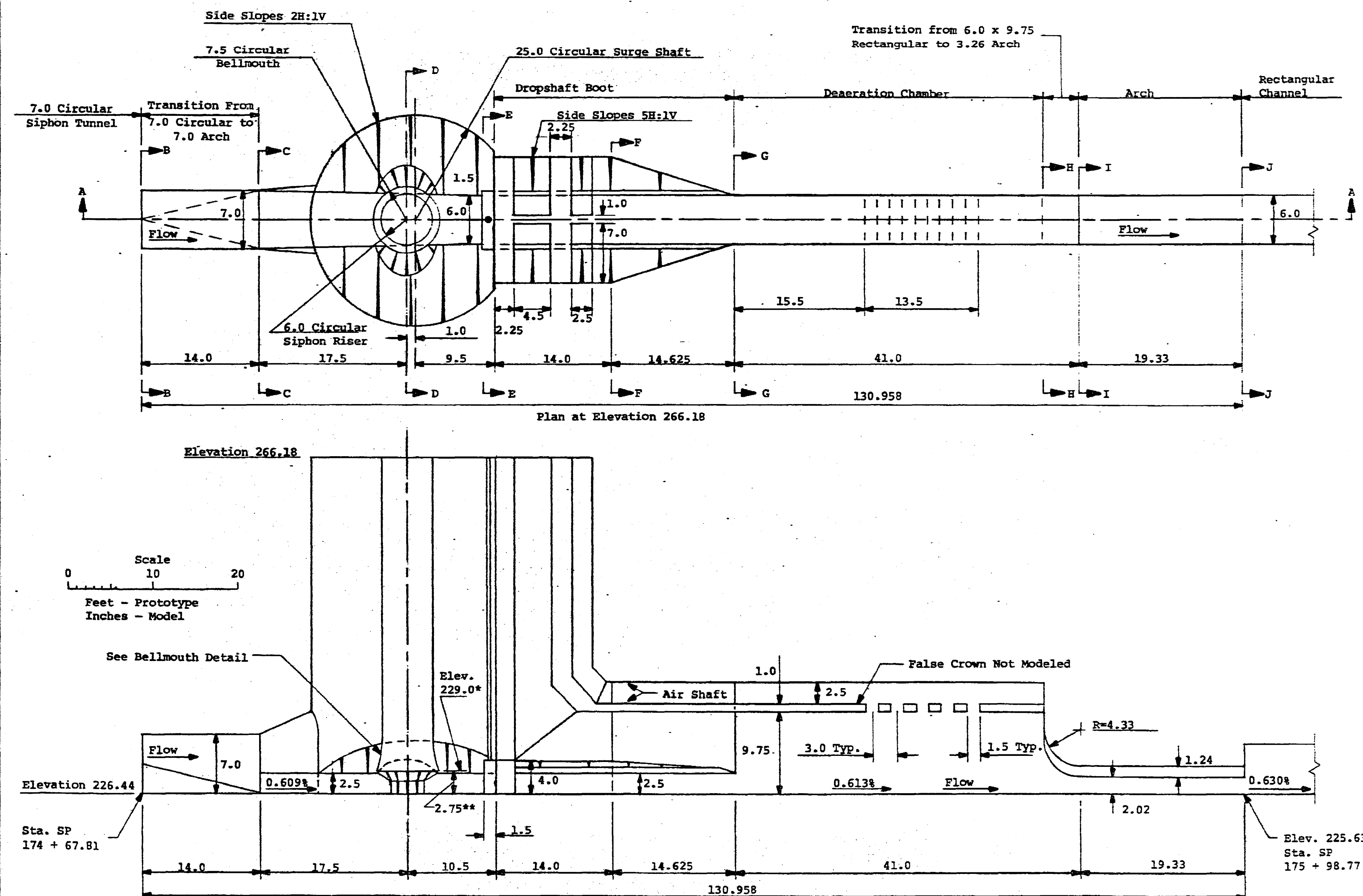


Type CS46 R8 Control Structure is the same as Type CS46 with the changes shown.

ROCHESTER CONTROL STRUCTURE 46
MODEL STUDIES
Type CS46 R8 Control Structure Scale 1:12
Control Structure Types Tested

SAINT ANTHONY FALLS HYDRAULIC LABORATORY UNIVERSITY OF MINNESOTA		
DRAWN AG	CHECKED	APPROVED
SCALE	DATE 6/20/84	NO 328B514-79

CHART 12



Section A - A

* Elevation 229.0 for types R9 and R10, 229.5 for type R11

** 2.75 for types R9 and R10, 3.25 for type R11

ROCHESTER CONTROL STRUCTURE 46
MODEL STUDIES
Types CS46 R9, 10, & 11 Control Structures
Control Structure Types Tested

Scale 1:12

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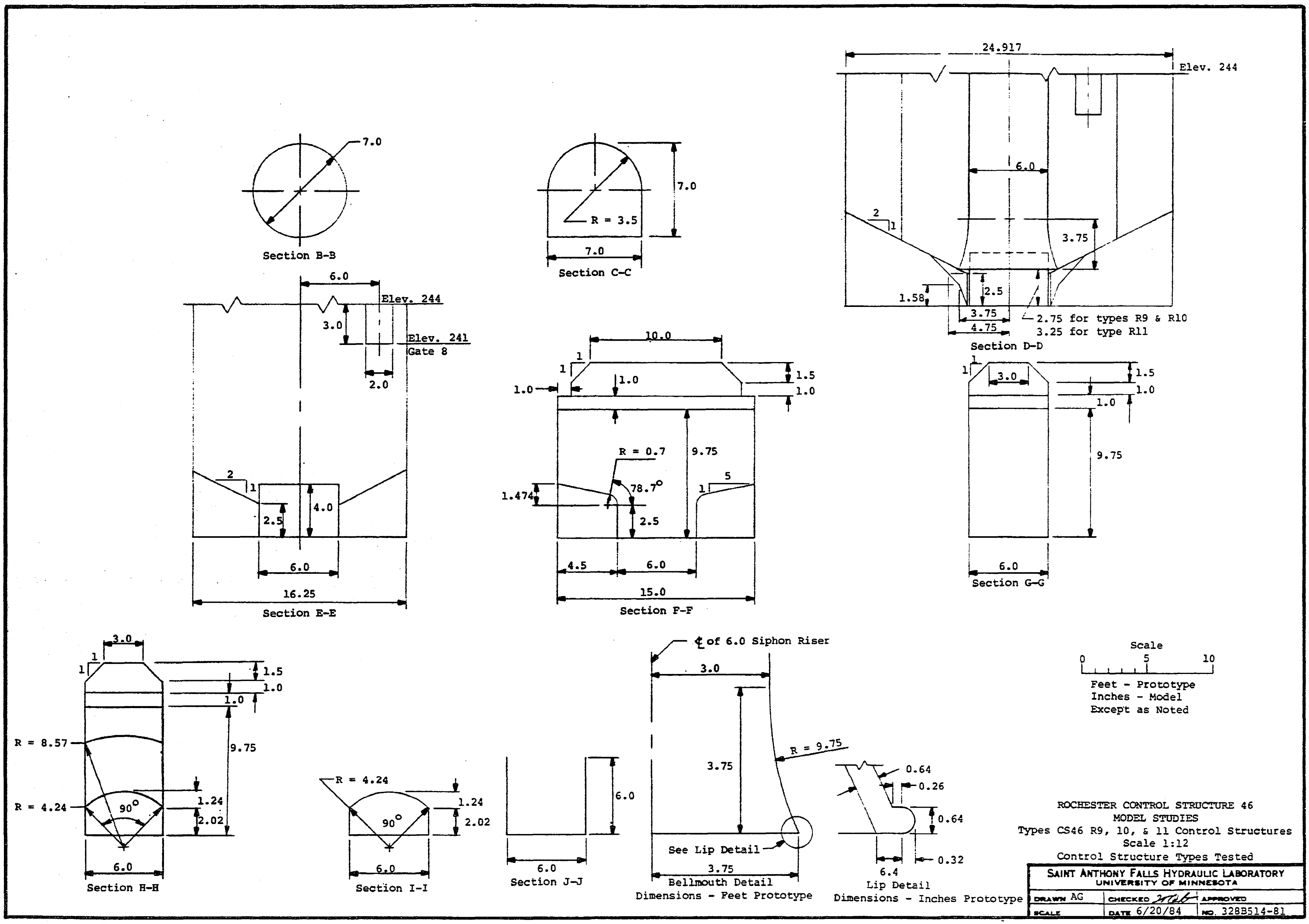
DRAWN AG	CHECKED [signature]	APPROVED
SCALE	DATE 6/20/84	NO. 328B514-80

CHART 13

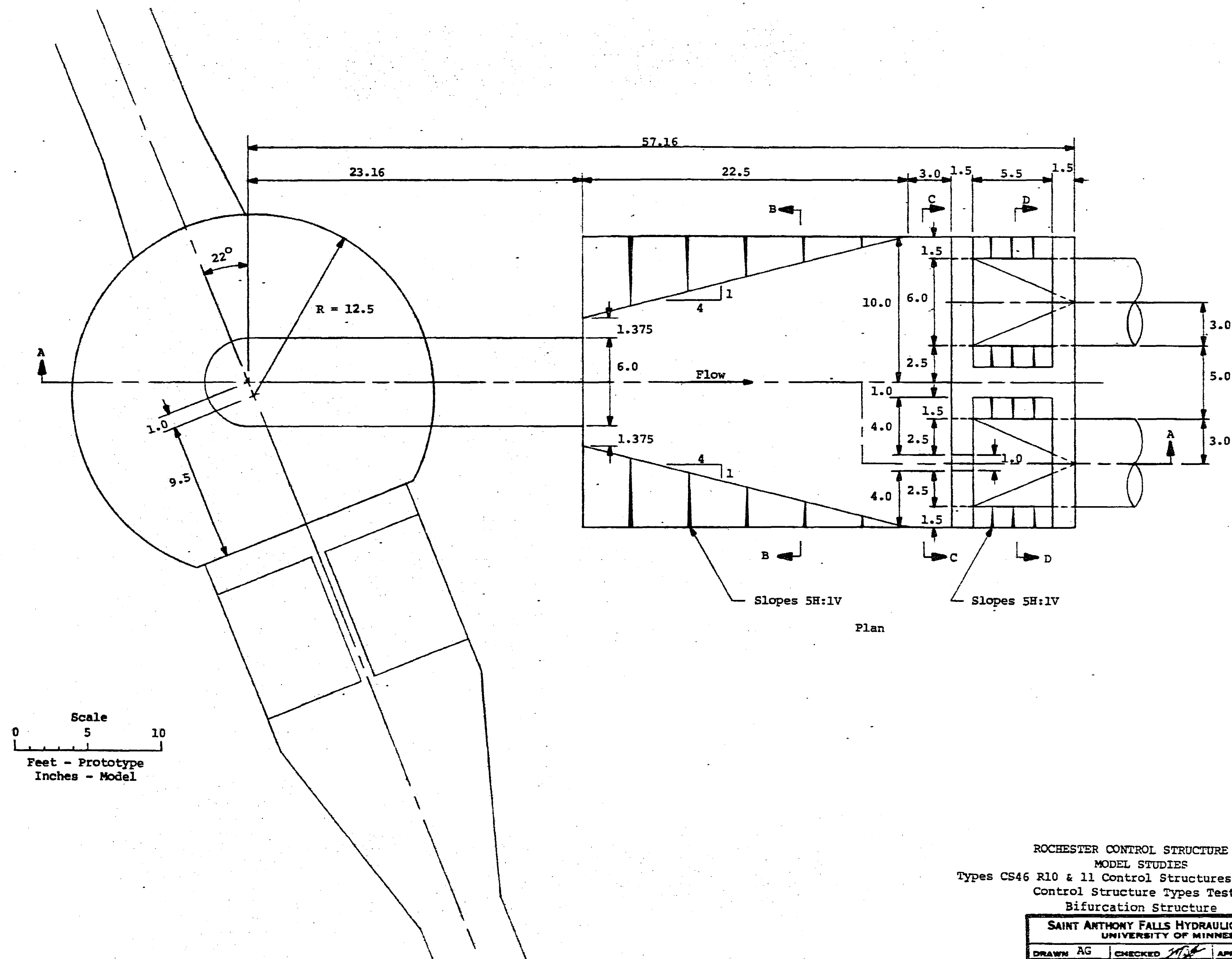


ROCHESTER CONTROL STRUCTURE 46
MODEL STUDIES
Types CS46 R9, 10, & 11 Control Structures
Scale 1:12
Control Structure Types Tested

SAINT ANTHONY FALLS HYDRAULIC LABORATORY
UNIVERSITY OF MINNESOTA

DRAWN AG	CHECKED	APPROVED
SCALE	DATE 6/20/84	NO. 328B514-81

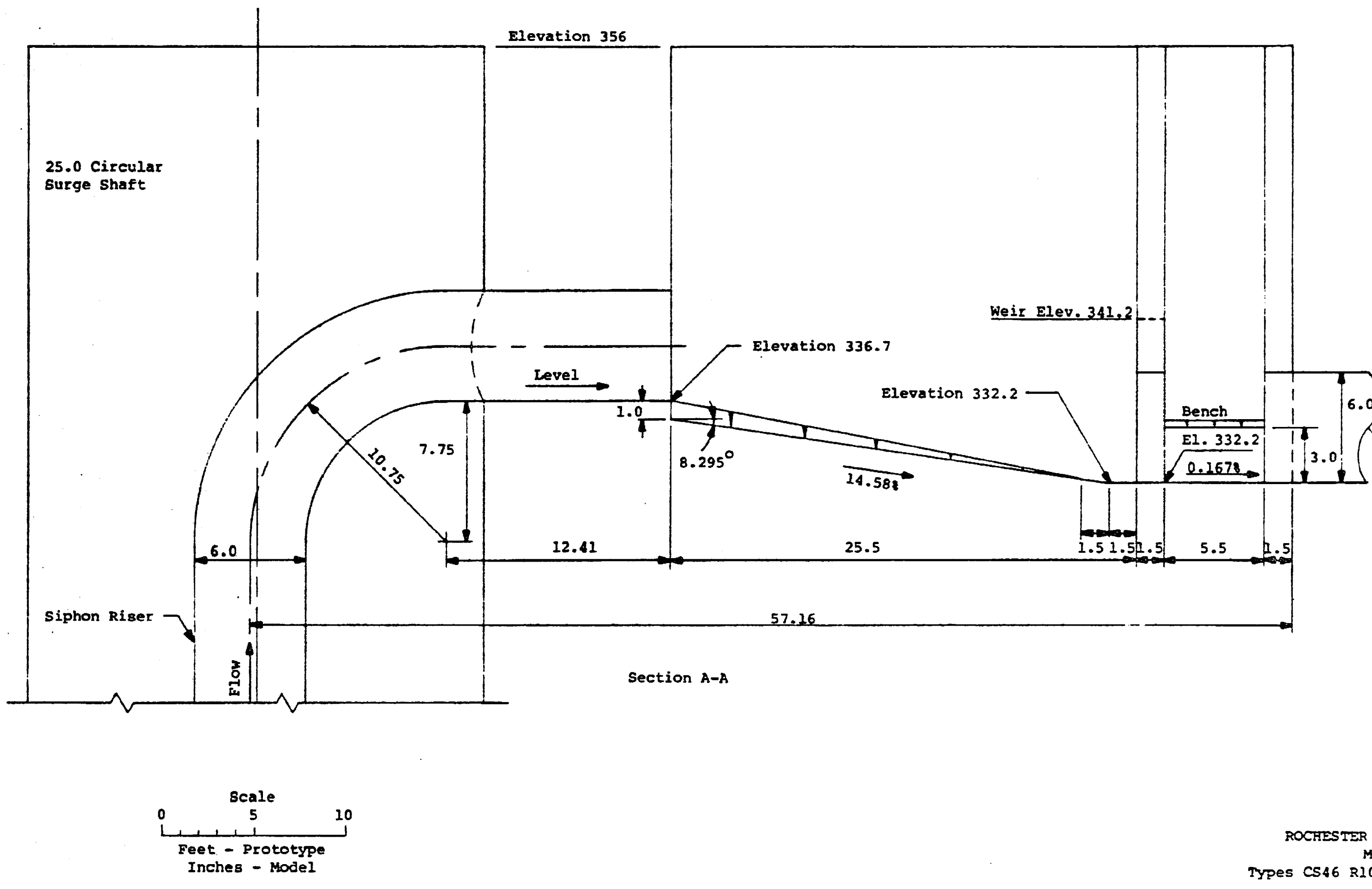
CHART 14



ROCHESTER CONTROL STRUCTURE 46
MODEL STUDIES
Types CS46 R10 & 11 Control Structures Scale 1:12
Control Structure Types Tested
Bifurcation Structure

SAINT ANTHONY FALLS HYDRAULIC LABORATORY UNIVERSITY OF MINNESOTA		
DRAWN AG	CHECKED [signature]	APPROVED
SCALE	DATE 7/2/84	NO. 328B524-83

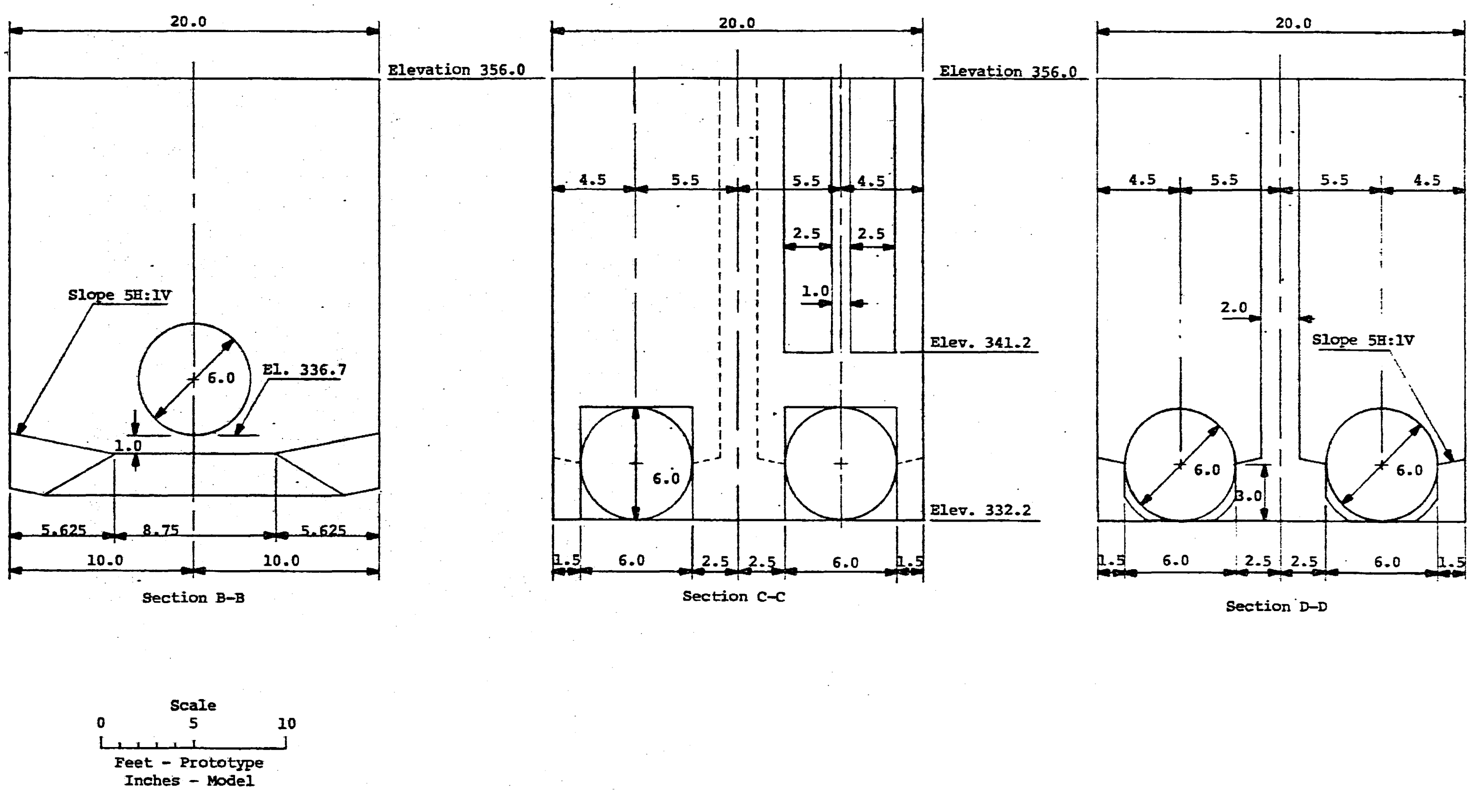
CHART 15



ROCHESTER CONTROL STRUCTURE 46
MODEL STUDIES
Types CS46 R10 & 11 Control Structures
Scale 1:12
Control Structure Types Tested
Bifurcation Structure

SAINT ANTHONY FALLS HYDRAULIC LABORATORY UNIVERSITY OF MINNESOTA		
DRAWN AG	CHECKED	APPROVED
SCALE	DATE 7/2/84	NO. 328B514-84

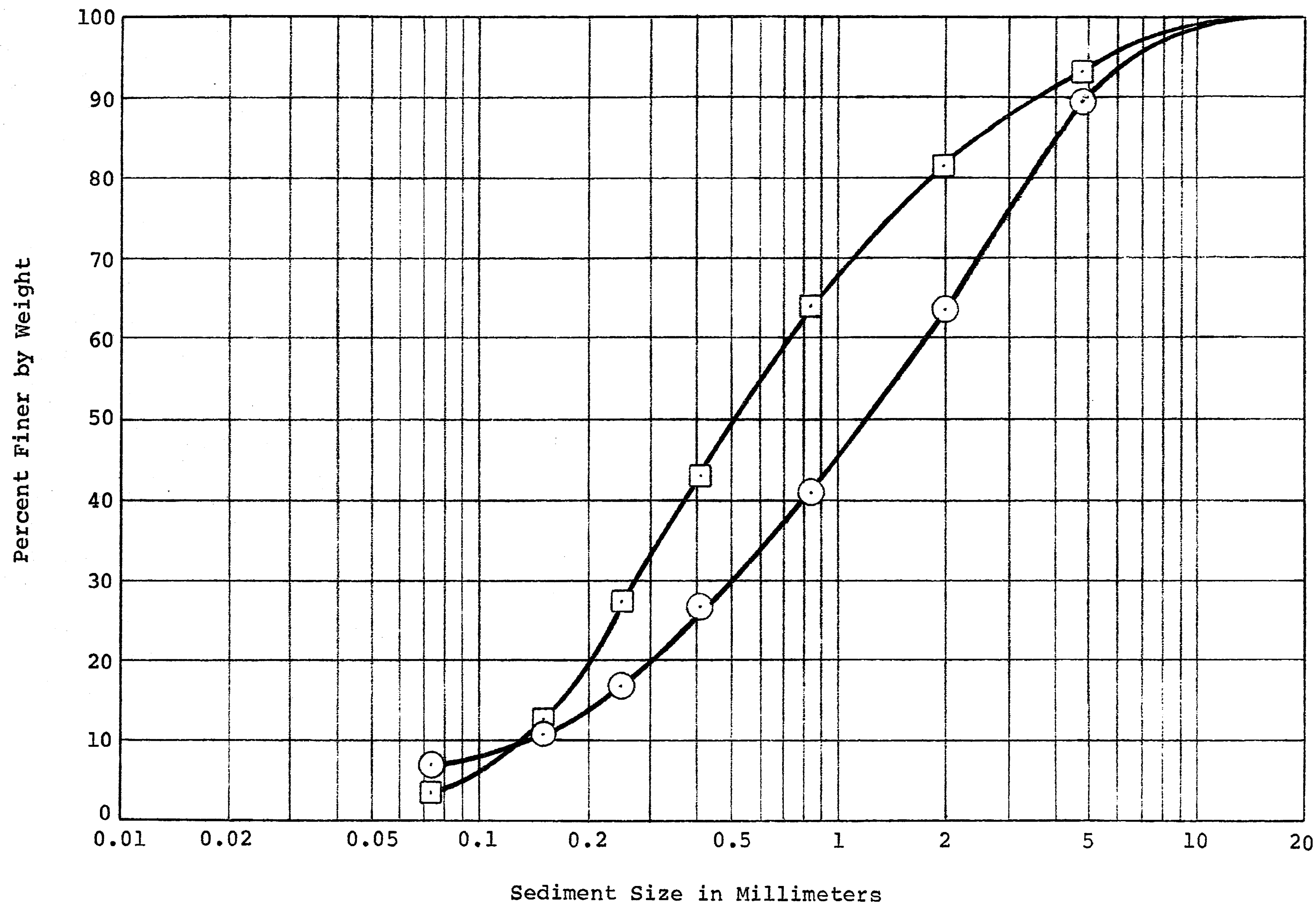
CHART 16



ROCHESTER CONTROL STRUCTURE 46
MODEL STUDIES
Types CS46 R10 & R11 Control Structures
Scale 1:12
Control Structure Types Tested
Bifurcation Structure

SAINT ANTHONY FALLS HYDRAULIC LABORATORY UNIVERSITY OF MINNESOTA		
DRAWN AG	CHECKED [signature]	APPROVED
SCALE	DATE 7/2/84	NO. 328B514-85

CHART 17

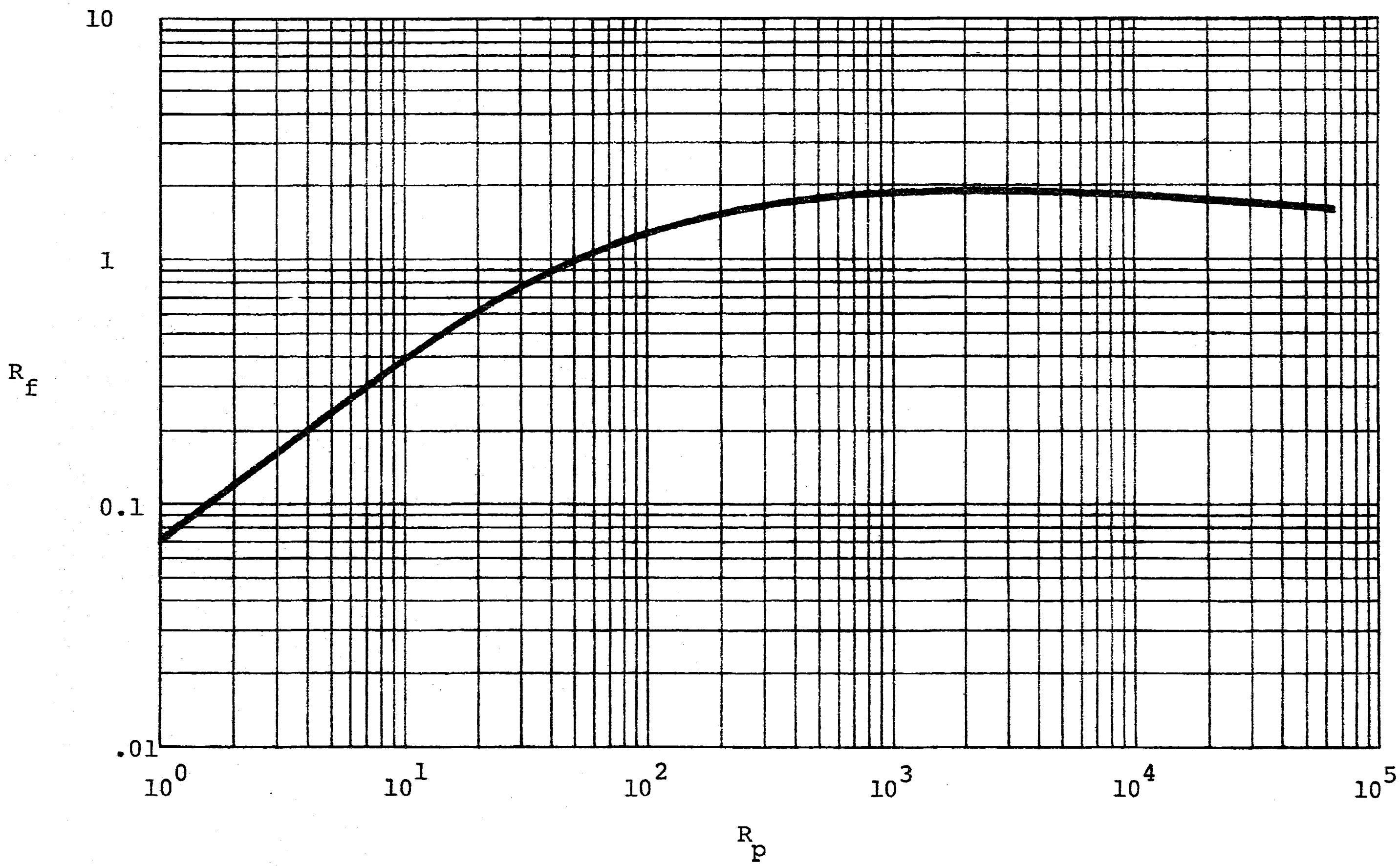


Cross Irondequoit S.G. 1.71
Van Lare S.G. 2.08

ROCHESTER CONTROL STRUCTURE 46
MODEL STUDIES
Model Scale 1:12
Size Distribution of Prototype Sediments

SAINT ANTHONY FALLS HYDRAULIC LABORATORY UNIVERSITY OF MINNESOTA		
DRAWN AG	CHECKED [signature]	APPROVED
SCALE	DATE 7/16/84	NO. 328A2323-60

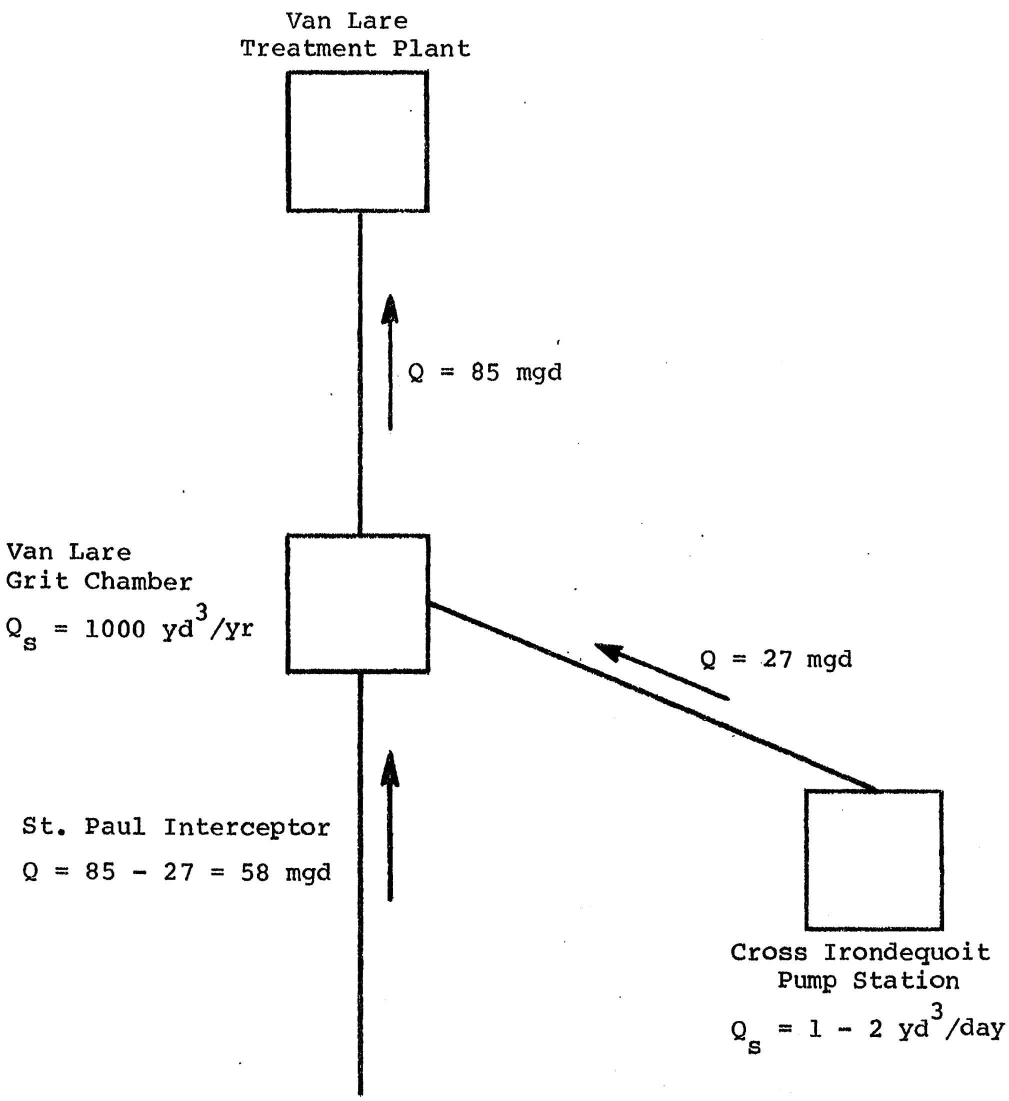
CHART 18



ROCHESTER CONTROL STRUCTURE 46
MODEL STUDIES
Model Scale 1:12
Fall Velocity Determination
R_f Versus R_p

SAINT ANTHONY FALLS HYDRAULIC LABORATORY UNIVERSITY OF MINNESOTA		
DRAWN AG	CHECKED [illegible]	APPROVED
SCALE	DATE 7/16/84	NO. 328A2323-61

CHART 19

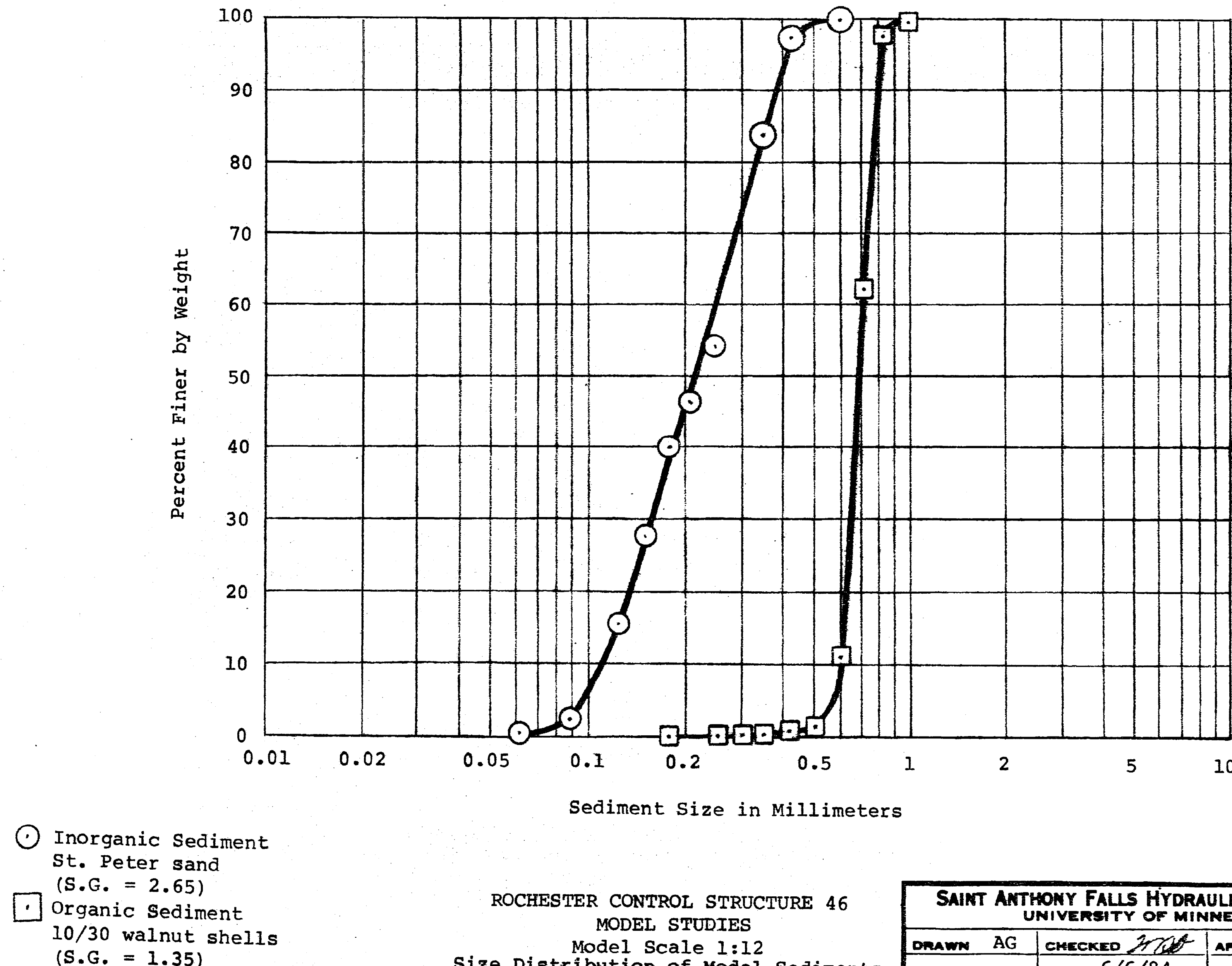


ROCHESTER CONTROL STRUCTURE 46
MODEL STUDIES
Model Scale 1:12
Sediment Removal Rates and Water Discharges

Q = Water Discharge

Q_s = Sediment Removal Rate

SAINT ANTHONY FALLS HYDRAULIC LABORATORY UNIVERSITY OF MINNESOTA		
DRAWN AG	CHECKED WRS	APPROVED
SCALE	DATE 7/16/84	NO. 328A2323-62



ROCHESTER CONTROL STRUCTURE 46
MODEL STUDIES
Model Scale 1:12
Size Distribution of Model Sediments

SAINT ANTHONY FALLS HYDRAULIC LABORATORY UNIVERSITY OF MINNESOTA		
DRAWN AG	CHECKED	APPROVED
SCALE	DATE 6/6/84	NO. 328A2323-54

CHART 21

Flushing Mode Observations

Q cfs	H.W. Elev. ft	T.W. Elev. ft	Depth Surge Shaft ft	Depth Deaeration Chamber ft	Water Surface to Bellmouth	Comments
				Type CS46 Control Structure		
16	0.8	1.0	1.0	1.5	Clear	Jump in transition
25	1.0	1.2	1.5	1.9	Clear	Jump in transition
50	1.5	1.8	2.7	2.8	Clear	Jump in siphon tunnel
75	1.9	2.3	3.6	3.6	Touching	Jump in siphon tunnel
100	2.3	2.7	4.4	4.3	Submerged	Jump in siphon tunnel
125	2.5	3.3	5.4	5.3	Submerged	Jump in siphon tunnel
				Type CS46 R1 Control Structure		
16	0.8	0.7	0.6	1.0	Clear	Jump in surge shaft
25	1.0	1.0	1.1	1.5	Clear	Jump in surge shaft
50	1.5	1.5	2.2	2.4	Clear	Jump in transition
75	1.8	2.0	3.0	3.1	Touching	Jump in transition
100	2.3	2.5	3.9	3.8	Submerged	Jump in siphon tunnel
125	2.5	2.9	4.9	4.5	Submerged	Jump in siphon tunnel
				Type CS46 R2 Control Structure		
16	0.8	0.7	0.6	1.0	Clear	Jump in surge shaft
25	1.0	1.0	1.1	1.5	Clear	Jump in surge shaft
50	1.5	1.5	2.2	2.3	Clear	Jump in surge shaft
75	1.8	2.0	3.0	3.1	Touching	Jump in transition
100	2.2	2.4	3.9	3.7	Submerged	Jump in siphon tunnel
125	2.4	2.8	4.8	4.4	Submerged	Jump in siphon tunnel
				Type CS46 R3 Control Structure		
16	0.8	0.7	0.6	0.9	Clear	All supercritical flow
25	1.0	0.9	1.1	1.3	Clear	Jump in surge shaft
50	1.5	1.5	2.2	2.0	Clear	Jump in transition
75	1.8	2.0	3.0	2.8	Touching	Jump in transition
100	2.2	2.3	3.8	3.4	Submerged	Jump in siphon tunnel
125	2.4	2.8	4.9	4.5	Submerged	All subcritical flow
				Type CS46 R4 Control Structure		
16	0.8	0.3	0.5	0.6	Clear	Disturbance in surge shaft
25	1.0	0.5	0.8	0.7	Clear	Disturbance in surge shaft
50	1.4	0.9	1.4	1.1	Clear	Disturbance in surge shaft
75	1.8	1.2	1.2	1.7	Clear	Disturbance in surge shaft
100	2.1	1.5	2.6	1.8	Touching	Weak jump in surge shaft
125	2.4	1.8	3.7	2.2	Submerged	Jump in transition

ROCHESTER CONTROL STRUCTURE 46
MODEL STUDIES
Model Scale 1:12
Flushing Mode Observations

SAINT ANTHONY FALLS HYDRAULIC LABORATORY
UNIVERSITY OF MINNESOTA

DRAWN WQD	CHECKED AG	APPROVED
SCALE	DATE 7/16/84	NO. 328A2323-65

Flushing Mode Observations

Q cfs	H.W. Elev. ft	T.W. Elev. ft	Depth Surge Shaft ft	Depth Deaeration Chamber ft	Water Surface to Bellmouth	Comments
			Type CS46 R5 Control Structure			
16	0.8	0.3	0.5	0.6	Clear	Disturbance in surge shaft
25	1.0	0.6	0.9	0.8	Clear	Disturbance in surge shaft
50	1.4	0.9	1.7	1.1	Clear	Disturbance in surge shaft
75	1.8	1.3	2.2	1.5	Clear	Jump in surge shaft
100	2.1	1.5	2.9	1.8	Touching	Jump in transition
125	2.4	1.8	3.7	2.2	Submerged	Jump in transition
			Type CS46 R6 Control Structure			
16	0.8	0.3	0.4	0.6	Clear	No jump, all flow supercritical
25	1.0	0.5	0.7	0.7	Clear	No jump, all flow supercritical
50	1.4	0.9	1.1	1.0	Clear	No jump, all flow supercritical
75	1.8	1.2	1.3	1.4	Clear	No jump, all flow supercritical
100	2.1	1.4	1.6	1.6	Clear	No jump, all flow supercritical
125	2.4	1.8	2.0	2.0	Clear	No jump, all flow supercritical
			Types CS46 R7, R8, and R9 Control Structures			
16	0.8	0.3	0.4	0.6	Clear	No jump, all flow supercritical
25	1.0	0.6	0.8	0.8	Clear	No jump, all flow supercritical
50	1.4	1.1	1.1	1.1	Clear	No jump, all flow supercritical
75	1.8	1.3	1.4	1.4	Clear	No jump, all flow supercritical
100	2.1	1.4	1.7	1.6	Clear	No jump, all flow supercritical
125	2.4	1.8	2.0	2.0	Clear	No jump, all flow supercritical

ROCHESTER CONTROL STRUCTURE 46
MODEL STUDIES
Model Scale 1:12
Flushing Mode Observations

SAINT ANTHONY FALLS HYDRAULIC LABORATORY
UNIVERSITY OF MINNESOTA

DRAWN WQD	CHECKED AG	APPROVED
SCALE	DATE 7/16/84	NO. 328A2323-65

List of Sediment Tests Run

Sed. Test Number	Type CS46	Q cfs	H.W. Elev. ft	T.W. Elev. ft	Sed. Feed Rate Gms/Min	Sed. Grade	Model Time Min.	Deposition %	Comments
1	R2	Q_F=100	2.2	2.4	62	3	30 43	- 66*	Deposited mainly in transition and surge shaft, some in siphon tunnel, dropstructure and deaeration chamber
2	R4	Q_F=100	2.1	1.5	35	3	30	0	Trace of sediment in deaeration chamber
3	R4	Q_F=100	2.1	1.5	0	3	40	0	1 inch of sediment placed in surge shaft and flushed out
4	R6	Q_F=100	2.1	1.4	35	3	30	0	
5	R6	Q_F=100	2.1	1.4	0	3	2.3	0	1 inch of sediment placed in surge shaft and flushed out
6	R7	Q_F=100	2.1	1.4	35	3	30	0	
7	R7	Q_F=100	2.1	1.4	0	3	3	0	1 inch of sediment placed in surge shaft and flushed out
8	R9	Q_F=100	2.1	1.4	35	3	30	0	
9	R9	Q_F=100	2.1	1.4	0	3	3	0	1 inch of sediment placed in surge shaft and flushed out
10	R10	Q_S=150			500	2 3	60 60		 Sand dune reached invert below bellmouth
11	R10	Q_S=300			800	3	52		Some deposition in siphon tunnel and surge shaft
12	R10	Q_S=150 Q_F=100	 2.1	 1.4	500 0	3 3	120 19	48 0	Deposition in siphon tunnel and surge shaft Deposition flushed out

* Sediment samples taken for size distribution analysis

ROCHESTER CONTROL STRUCTURE 46
MODEL STUDIES
Model Scale 1:12
List of Sediment Tests Run

SAINT ANTHONY FALLS HYDRAULIC LABORATORY
UNIVERSITY OF MINNESOTA

DRAWN WQD	CHECKED AG	APPROVED
SCALE	DATE 7/16/84	NO. 328A2323-63

CHART 23

List of Sediment Tests Run (continued)

Sed. Test Number	Type CS46	Q cfs	H.W. Elev. ft	T.W. Elev. ft	Sed. Feed Rate Gms/Min	Sed. Grade	Model Time Min.	Deposition %	Comments
13	R11	Q_S=150			500	3	135	92*	Deposition in siphon tunnel and surge shaft
		Q_F=100	2.1	1.4	0	3	22	0	Deposition flushed out
14	R10	Q_S=16			18	1	180	47	Small dune formed just downstream of feed pipe
		Q_S=50			22	1	190	79**	Deposition in siphon tunnel and surge shaft
		Q_S=100			43	3	180	80**	Deposition in siphon tunnel and surge shaft
		Q_S=150			54	3	180	41***	Deposition in siphon tunnel and surge shaft
		Q_S=300			102	3	150	0	Deposition was flushed through siphon riser
15	R10	Q_F=16			11	1	50	0	Trace of sediment in surge shaft and deaeration chamber
		Q_F=50			21	1	120	0	No deposition
		Q_F=100			57	3	120	0	No deposition
16	R10	Q_F=100	2.2	1.5	0	3		0	3 mm of sediment placed in siphon tunnel and flushed out, prototype sweepout velocity determined = 1.20 fps
								0	1 mm of sediment placed in siphon tunnel and flushed out, prototype sweepout velocity determined = 2.07 fps
								0	0.5 mm of sediment placed in siphon tunnel and flushed out, prototype sweepout velocity determined = 2.78 fps

* Sediment samples taken for size distribution analysis

** Accumulative percent of deposition

Model Sediment Grade	Organic Sediment Percent	Inorganic Sediment Percent
1	50	50
2	25	75
3	0	100

ROCHESTER CONTROL STRUCTURE 46
MODEL STUDIES
Model Scale 1:12
List of Sediment Tests Run

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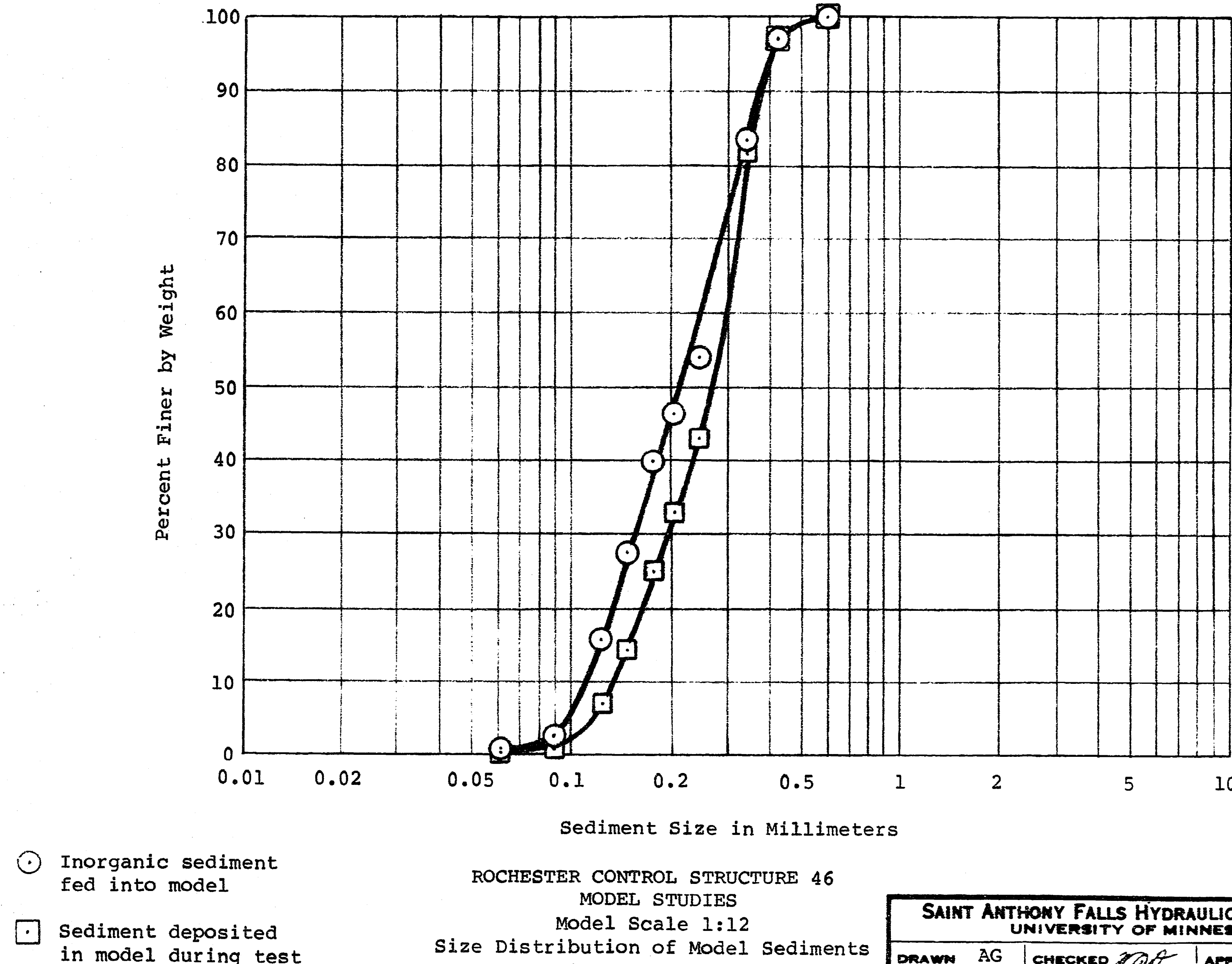
UNIVERSITY OF MINNESOTA

DRAWN WQD	CHECKED AG	APPROVED
SCALE	DATE 7/16/84	NO. 328A2323-64

CHART 23



ROCHESTER CONTROL STRUCTURE 46
MODEL STUDIES
Model Scale 1:12
Size Distribution of Model Sediments
Sediment Test No. 1

SAINT ANTHONY FALLS HYDRAULIC LABORATORY UNIVERSITY OF MINNESOTA		
DRAWN AG	CHECKED	APPROVED
SCALE	DATE 6/6/84	NO. 328A2323-55

CHART 24

Siphon Mode Operating Conditions - Bifurcation Structure

DESIGN CONDITION	Q_S TOTAL cfs	LEFT GATE (VLC #1)			RIGHT GATE (VLC #2)		
		GATE	Q_S cfs	T. W. ELEV. (3) ft	GATE	Q_S cfs	T. W. ELEV. (4) ft
1 (1)	50	Closed	0	0	Open	50	334.5
	100	Closed	0	0	Open	100	335.6
	150	Closed	0	0	Open	150	336.6
2 (1)	200	Open	62	337.0	Open	138	336.3
	250	Open	99	337.1	Open	151	336.6
	300	Open	136	337.3	Open	164	337.0
	375	Open	190	337.8	Open	185	338.2
3 (2)	200	Closed	0	N/A	Closed	200	N/A
	250	Closed	0	N/A	Closed	250	N/A
	300	Closed	0	N/A	Closed	300	N/A
	375	Closed	0	N/A	Closed	375	N/A
4 (1)	16	Open	16	336.9	Closed	0	0
	50	Open	50	336.9	Closed	0	0

(1) Critical Depth at Crest of Riser

(2) Weir Flow, Tailwater Uncontrolled

(3) Tailwater Elevation Set at Tap 43 in the Model

(4) Tailwater Elevation Set at Tap 44 in the Model

ROCHESTER CONTROL STRUCTURE 46
MODEL STUDIES
Model Scale 1:12
Siphon Mode Operating Conditions
Bifurcation Structure

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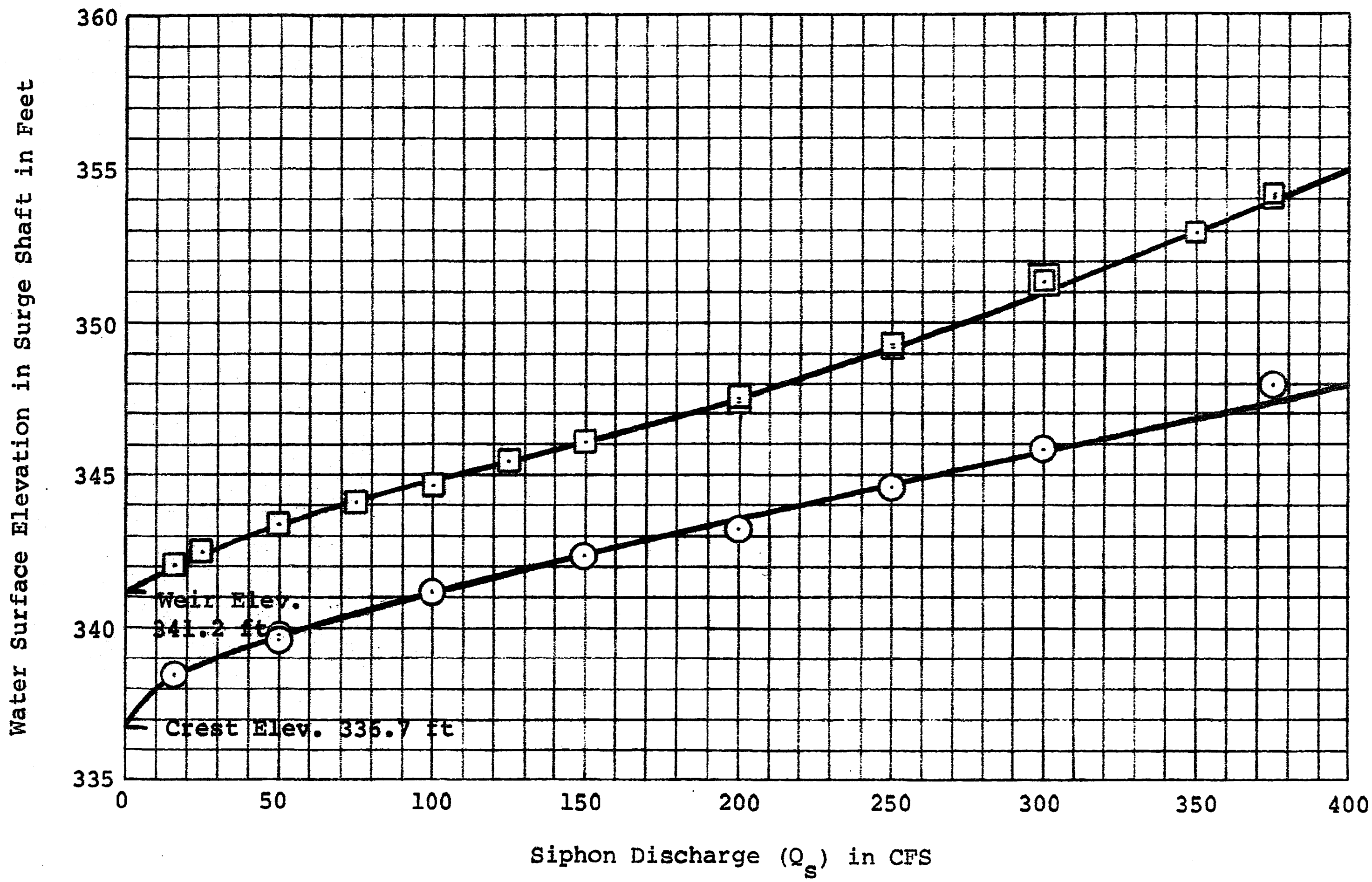
UNIVERSITY OF MINNESOTA

DRAWN WQD	CHECKED AG	APPROVED
SCALE	DATE 7/16/84	NO. 328A2323-58

CHART 25



⊙ Gate operation in bifurcation structure with tailwater control, design conditions 1, 2, & 4.

⊡ Weir flow in bifurcation structure, design condition 3.

ROCHESTER CONTROL STRUCTURE 46
MODEL STUDIES
Type CS46 R10 Control Structure
Scale 1:12
Water Surface Elevation in Surge Shaft versus Siphon Discharge (Q_s)

SAINT ANTHONY FALLS HYDRAULIC LABORATORY UNIVERSITY OF MINNESOTA		
DRAWN AG	CHECKED	APPROVED
SCALE	DATE 6/1/84	NO. 328A2323-53

CHART 26

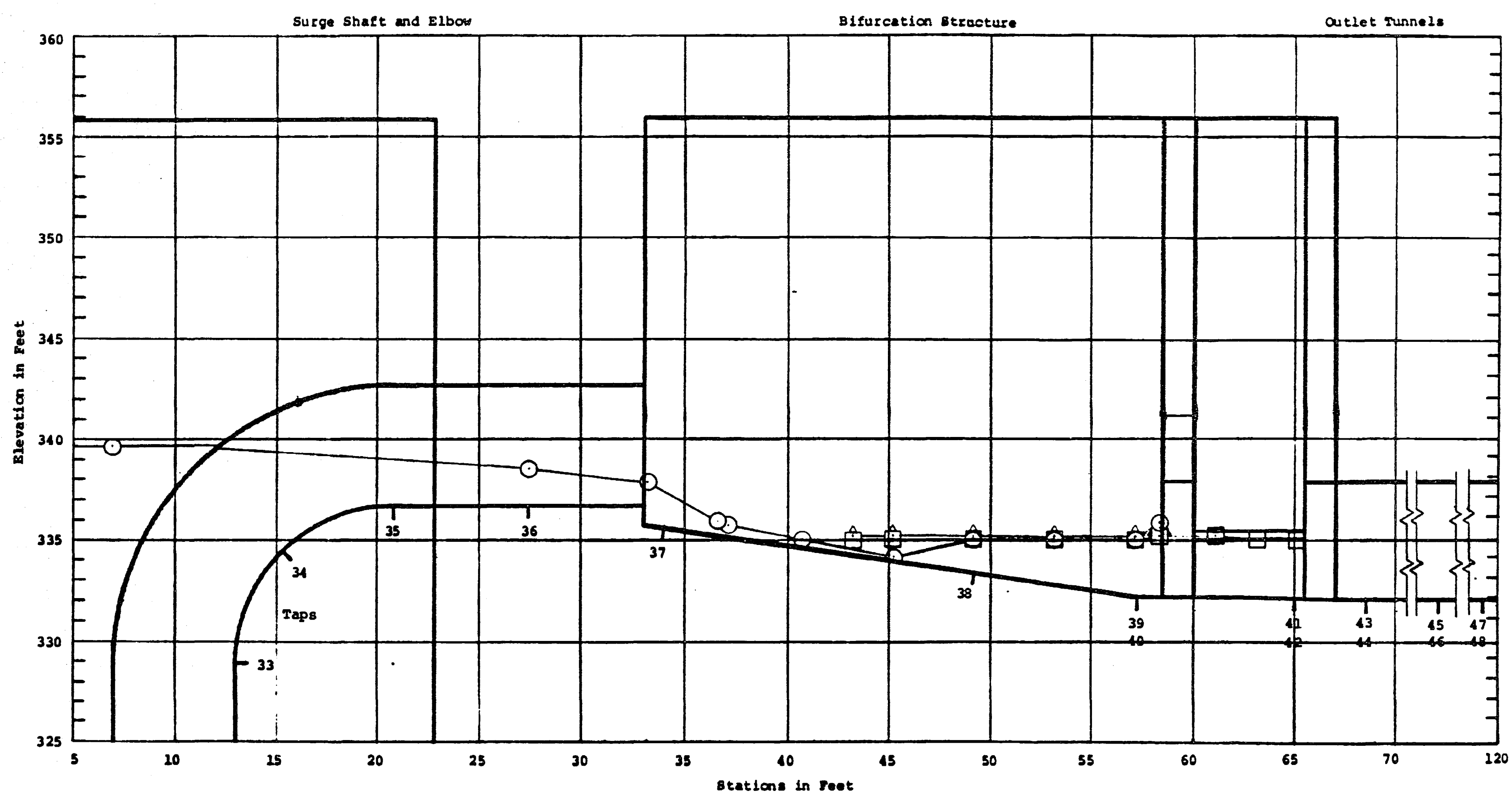
Water Surface Elevation in Surge Shaft versus Siphon Discharge (Q_s)

Design Condition	Gates Open	Q_s cfs	H.W. ft	$T.W._1$ ft	$T.W._2$ ft	Water Surface Elevation in Surge Shaft - ft
1	2	50	112.4	0.0	2.3	339.65
1	2	100	113.8	0.0	3.4	341.15
1	2	150	114.9	0.0	4.4	342.35
2	1&2	200	116.1	4.8	4.1	343.25
2	1&2	250	117.3	4.9	4.4	344.65
2	1&2	300	118.6	5.1	4.8	345.85
2	1&2	375	119.3	5.6	6.0	348.05
4	1	16	111.0	4.7	0.0	338.45
4	1	50	112.2	4.7	0.0	339.75
3	None	200	120.3			347.55
3	None	250	122.3			349.35
3	None	300	123.9			351.35
3	None	375	127.4			354.25
3	None	16				342.05
3	None	25				342.50
3	None	50				343.35
3	None	75				344.10
3	None	100				344.65
3	None	125				345.45
3	None	150				346.10
3	None	200				347.40
3	None	250				349.25
3	None	300				351.35
3	None	350				352.95
3	None	375				354.15

ROCHESTER CONTROL STRUCTURE 46
MODEL STUDIES
Type CS46 R10 Control Structure
Scale 1:12
Water Surface Elevation in
Surge Shaft versus Siphon Discharge (Q_s)

SAINT ANTHONY FALLS HYDRAULIC LABORATORY
UNIVERSITY OF MINNESOTA

DRAWN WQD	CHECKED MR	APPROVED
SCALE	DATE 5/15/84	NO. 328A2323-39



Profile Along Centerline
Profile Along Right Side
Profile Along Left Side

ROCHESTER CONTROL STRUCTURE 46
MODEL STUDIES
Type CS46 R10 Control Structure Scale 1:12
Water Surface Profiles - Siphon Mode
Q_S = 50 cfs, H.W. = 112.4 ft, Gates Open = No. 2
$T.W._1$ = 0 ft, $T.W._2$ = 2.3 ft

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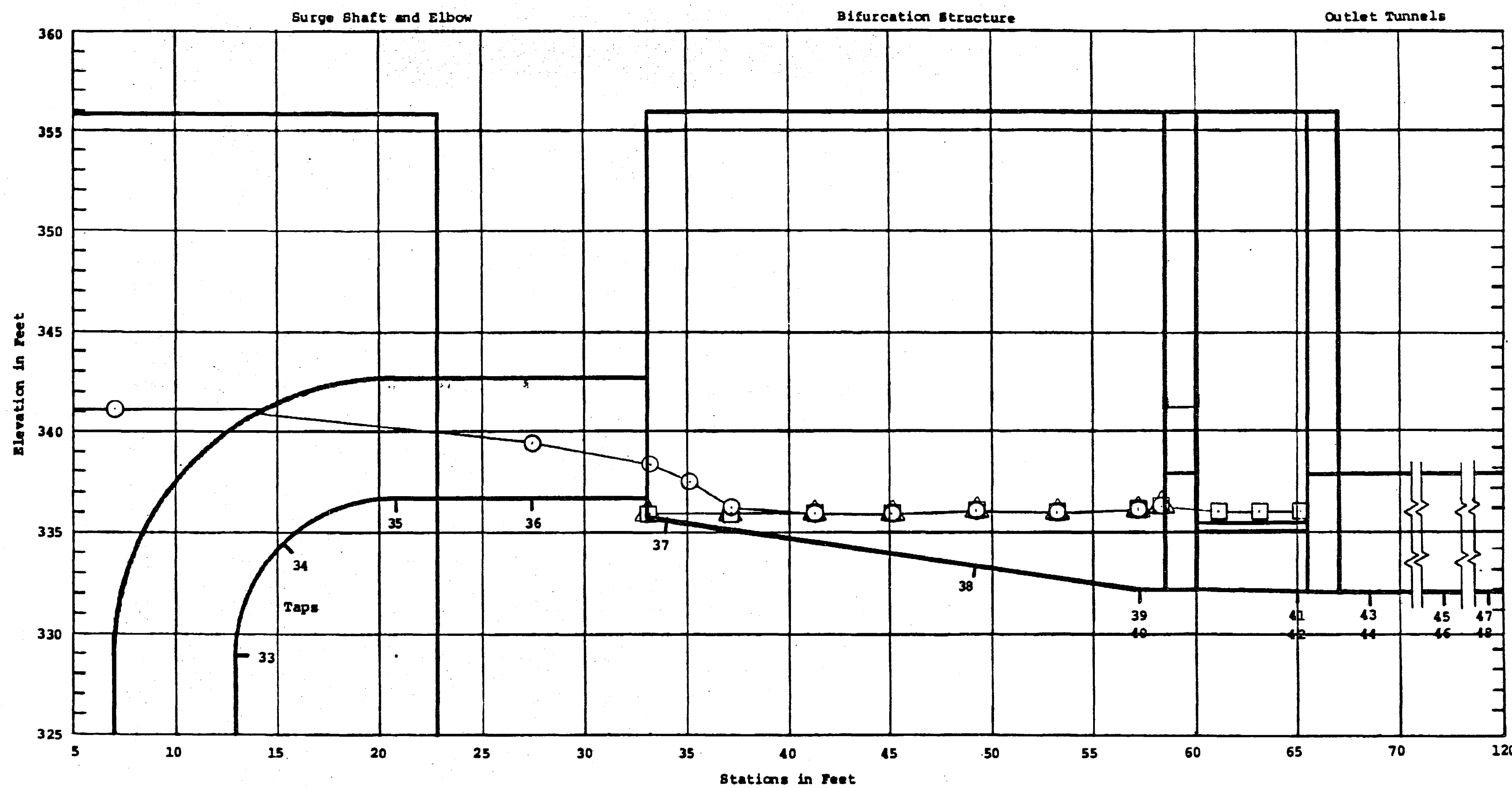
UNIVERSITY OF MINNESOTA

DRAWN BB	CHECKED	APPROVED
SCALE	DATE 3/1/84	NO. 328B514-60

CHART 28



ROCHESTER CONTROL STRUCTURE 46
MODEL STUDIES
Type CS46 R10 Control Structure Scale 1:12
Water Surface Profiles - Siphon Mode
Q_S = 100 cfs, H.W. = 113.8 ft, Gates Open = No. 2
$T.W._1$ = 0 ft, $T.W._2$ = 3.4 ft

⊙ Profile Along Centerline
⊡ Profile Along Right Side
△ Profile Along Left Side

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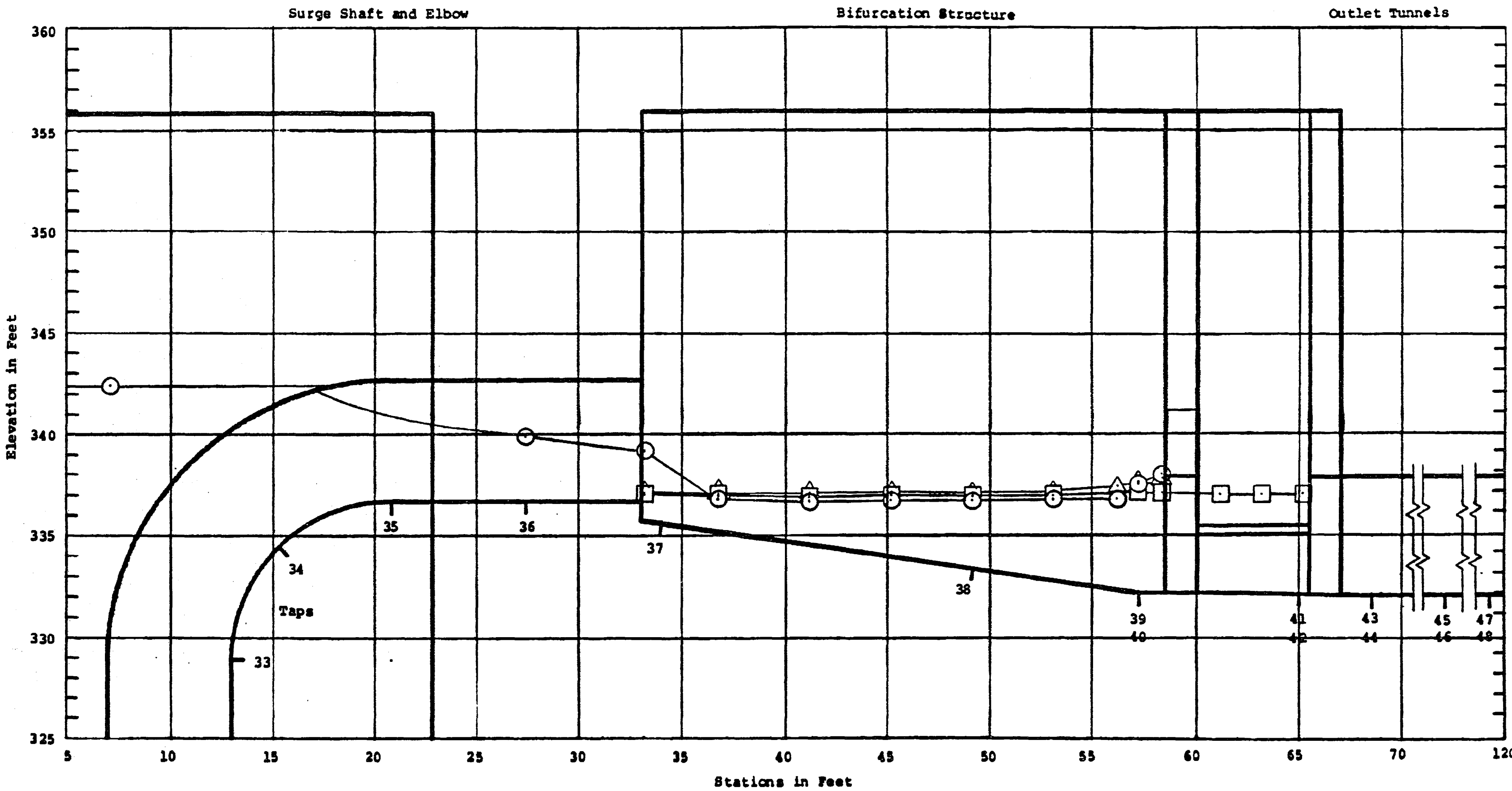
UNIVERSITY OF MINNESOTA

DRAWN RR	CHECKED	APPROVED
SCALE	DATE 3/1/84	NO. 328B514-61

CHART 29

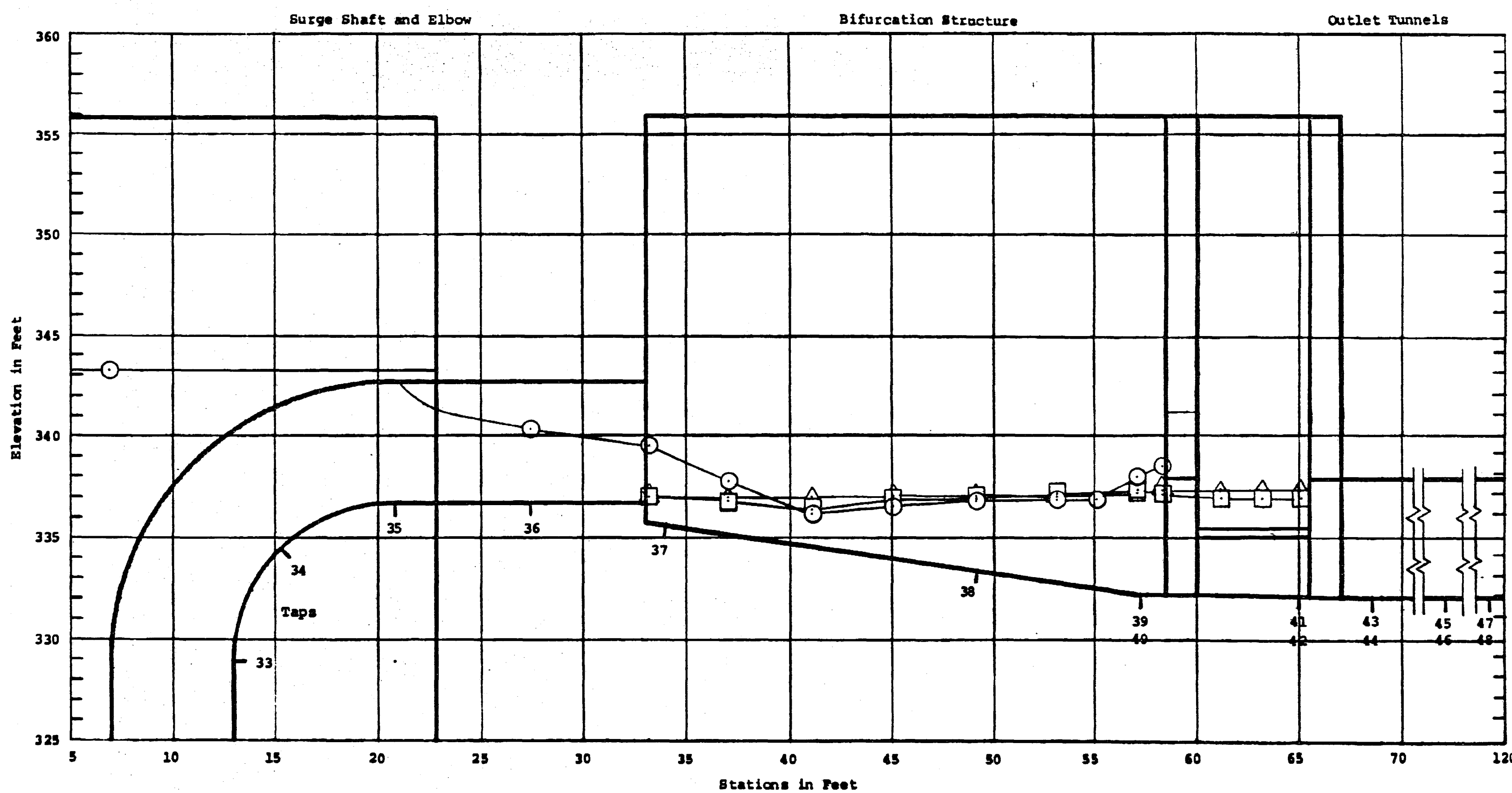


ROCHESTER CONTROL STRUCTURE 46
MODEL STUDIES
Type CS46 R10 Control Structure Scale 1:12
Water Surface Profiles - Siphon Mode
Q_S = 150 cfs, H.W. = 114.9 ft, Gates Open = No. 2
$T.W._1$ = 0 ft, $T.W._2$ = 4.4 ft

⊙ Profile Along Centerline
⊡ Profile Along Right Side
△ Profile Along Left Side

SAINT ANTHONY FALLS HYDRAULIC LABORATORY UNIVERSITY OF MINNESOTA		
DRAWN BB	CHECKED	APPROVED
SCALE	DATE 3/1/84	NO. 328B514- 62

CHART 30

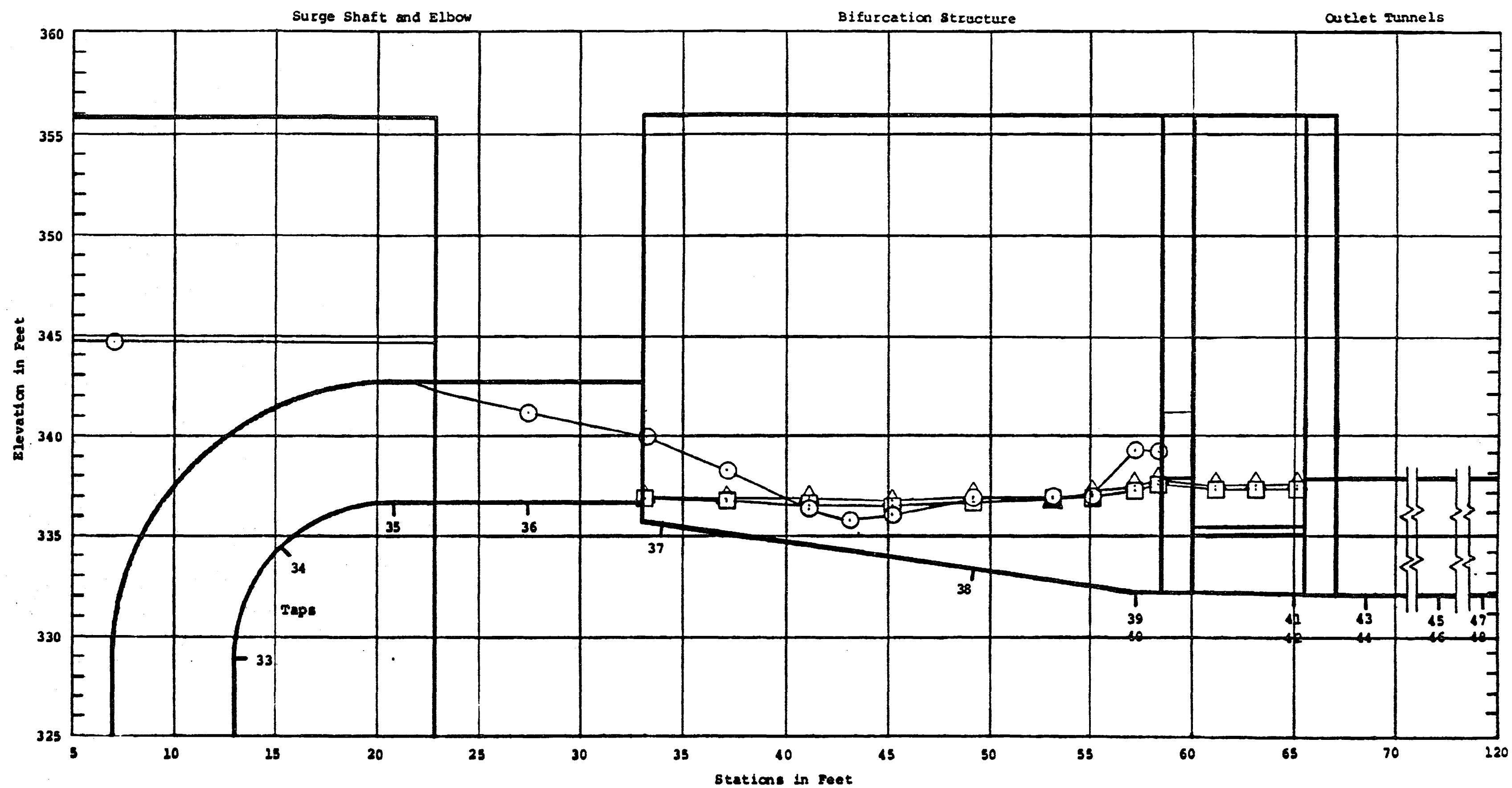


ROCHESTER CONTROL STRUCTURE 46
MODEL STUDIES
Type CS46 R10 Control Structure Scale 1:12
Water Surface Profiles - Siphon Mode
Q_s = 200 cfs, H.W. = 116.1 ft, Gates Open = No.1&2
$T.W._1$ = 4.8 ft, $T.W._2$ = 4.2 ft

⊙ Profile Along Centerline
⊡ Profile Along Right Side
△ Profile Along Left Side

SAINT ANTHONY FALLS HYDRAULIC LABORATORY UNIVERSITY OF MINNESOTA		
DRAWN BB	CHECKED	APPROVED
SCALE	DATE 3/1/84	NO. 328B514- 63

CHART 31

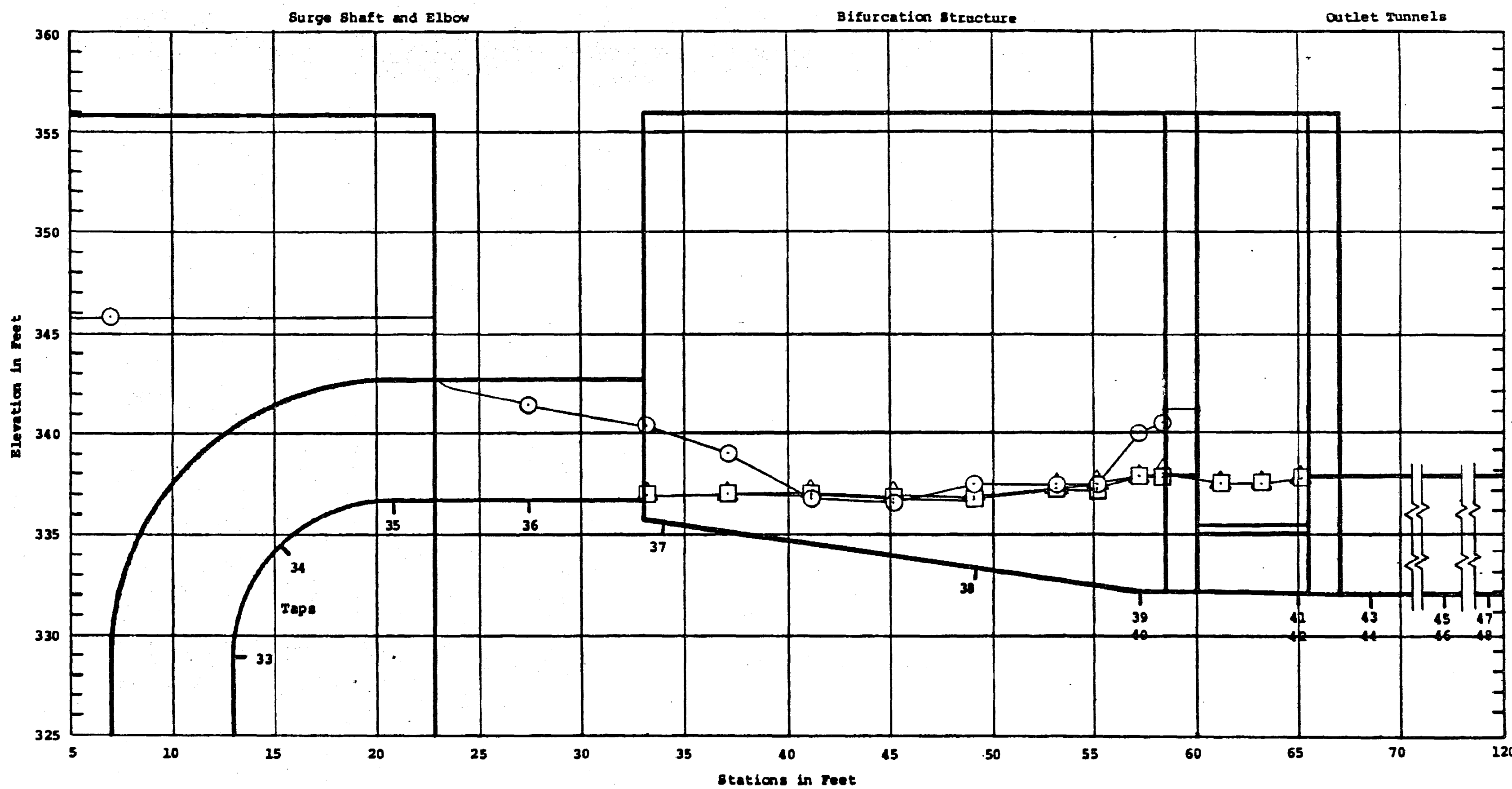


ROCHESTER CONTROL STRUCTURE 46
MODEL STUDIES

Type CS46 R10 Control Structure Scale 1:12
Water Surface Profiles - Siphon Mode
Q_s = 250 cfs, H.W. = 117.3 ft, Gates Open = No. 1&2
$T.W._1$ = 4.9 ft, $T.W._2$ = 4.4 ft

⊙ Profile Along Centerline
⊡ Profile Along Right Side
△ Profile Along Left Side

SAINT ANTHONY FALLS HYDRAULIC LABORATORY UNIVERSITY OF MINNESOTA		
DRAWN BB	CHECKED [illegible]	APPROVED
SCALE	DATE 3/1/84	NO. 328B514- 64

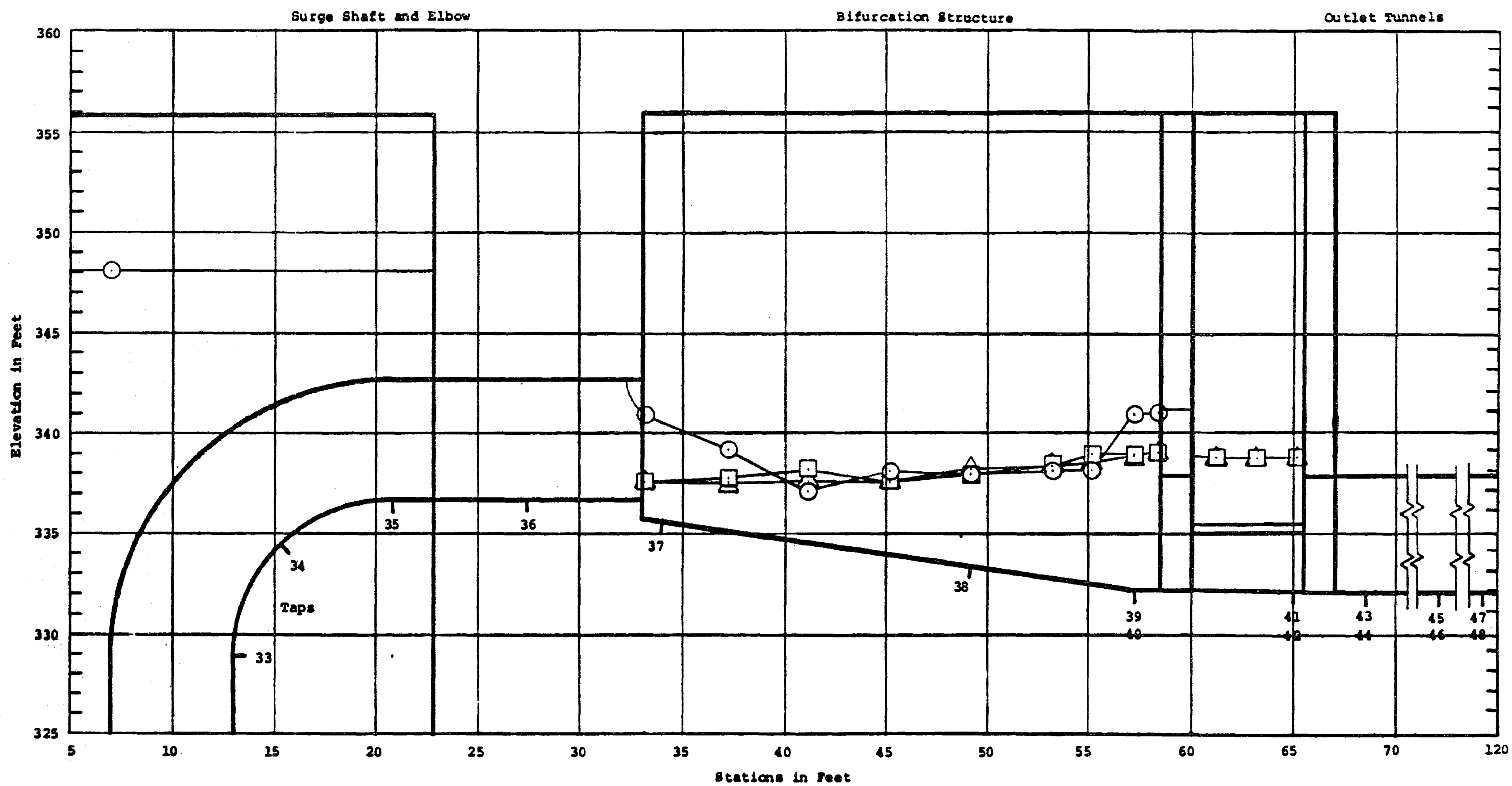


ROCHESTER CONTROL STRUCTURE 46
MODEL STUDIES
Type CS46 R10 Control Structure Scale 1:12
Water Surface Profiles - Siphon Mode
Q_S = 300 cfs, H.W. = 118.6 ft, Gates Open = No. 1&2
$T.W._1$ = 5.1 ft, $T.W._2$ = 4.8 ft

○ Profile Along Centerline
⊡ Profile Along Right Side
△ Profile Along Left Side

SAINT ANTHONY FALLS HYDRAULIC LABORATORY UNIVERSITY OF MINNESOTA		
DRAWN BB	CHECKED	APPROVED
SCALE	DATE 3/1/84	NO. 328B514- 65

CHART 33

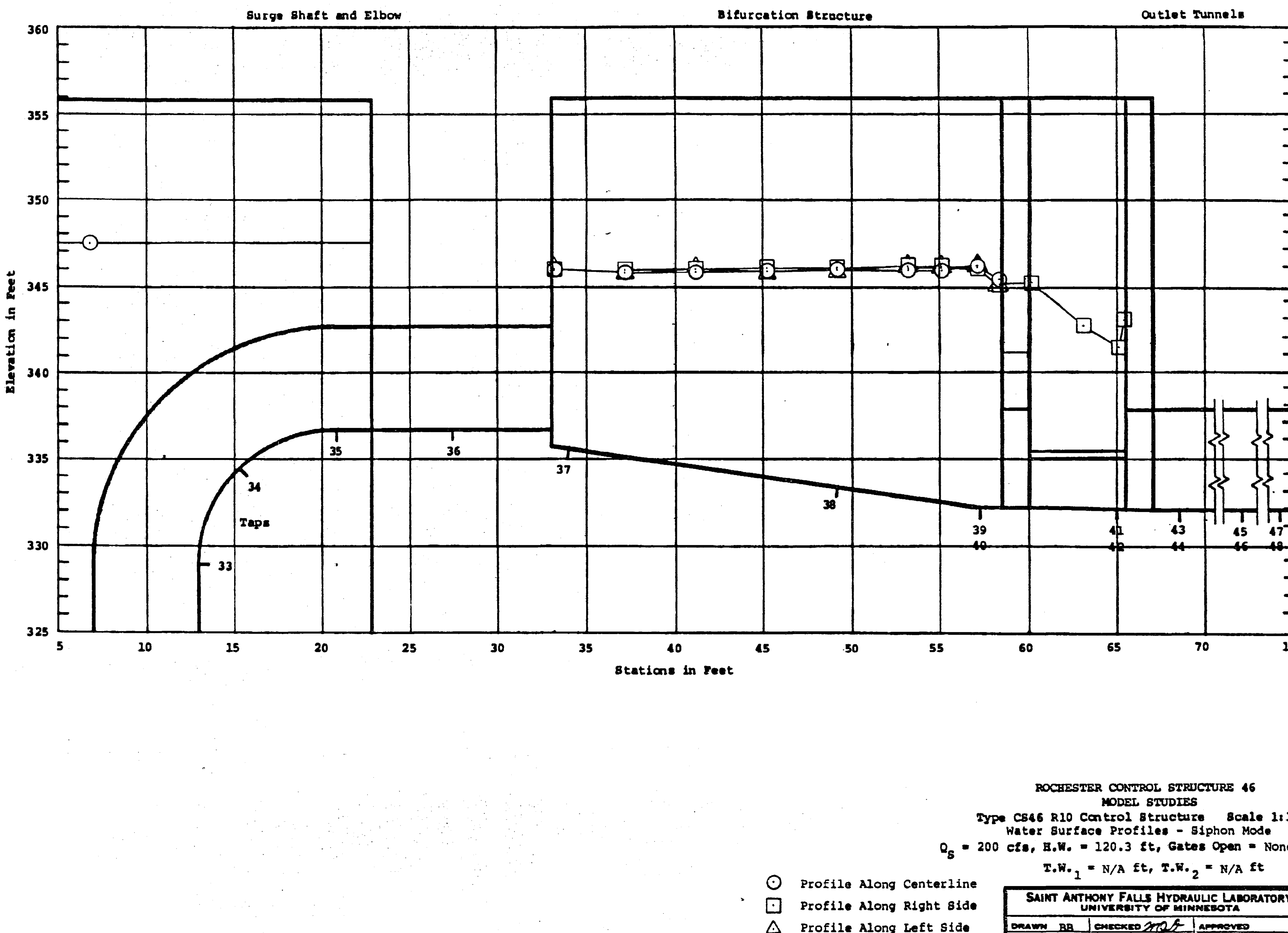


ROCHESTER CONTROL STRUCTURE 46
MODEL STUDIES
Type CS46 R10 Control Structure Scale 1:12
Water Surface Profiles - Siphon Mode
Q_S = 375 cfs, H.W. = 119.3 ft, Gates Open = No. 1&2
$T.W._1$ = 5.6 ft, $T.W._2$ = 6.2 ft

⊙ Profile Along Centerline
⊡ Profile Along Right Side
△ Profile Along Left Side

SAINT ANTHONY FALLS HYDRAULIC LABORATORY UNIVERSITY OF MINNESOTA		
DRAWN BB	CHECKED	APPROVED
SCALE	DATE 3/1/84	NO. 328B514-66

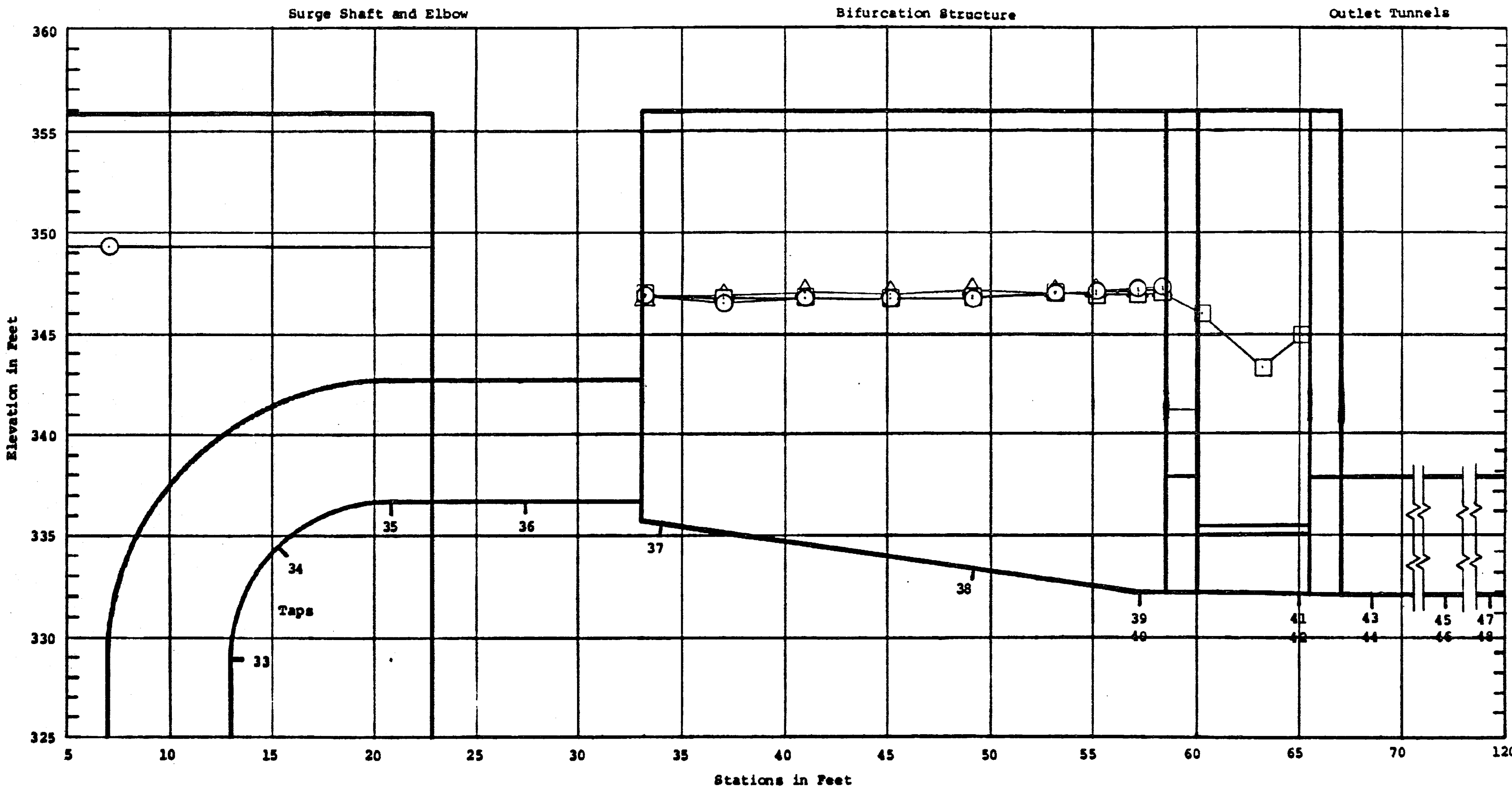
CHART 34



ROCHESTER CONTROL STRUCTURE 46
MODEL STUDIES
Type CS46 R10 Control Structure Scale 1:12
Water Surface Profiles - Siphon Mode
Q_S = 200 cfs, H.W. = 120.3 ft, Gates Open = None
$T.W._1$ = N/A ft, $T.W._2$ = N/A ft

SAINT ANTHONY FALLS HYDRAULIC LABORATORY UNIVERSITY OF MINNESOTA		
DRAWN BB	CHECKED	APPROVED
SCALE	DATE 3/1/84	NO. 328B514-67

CHART 35

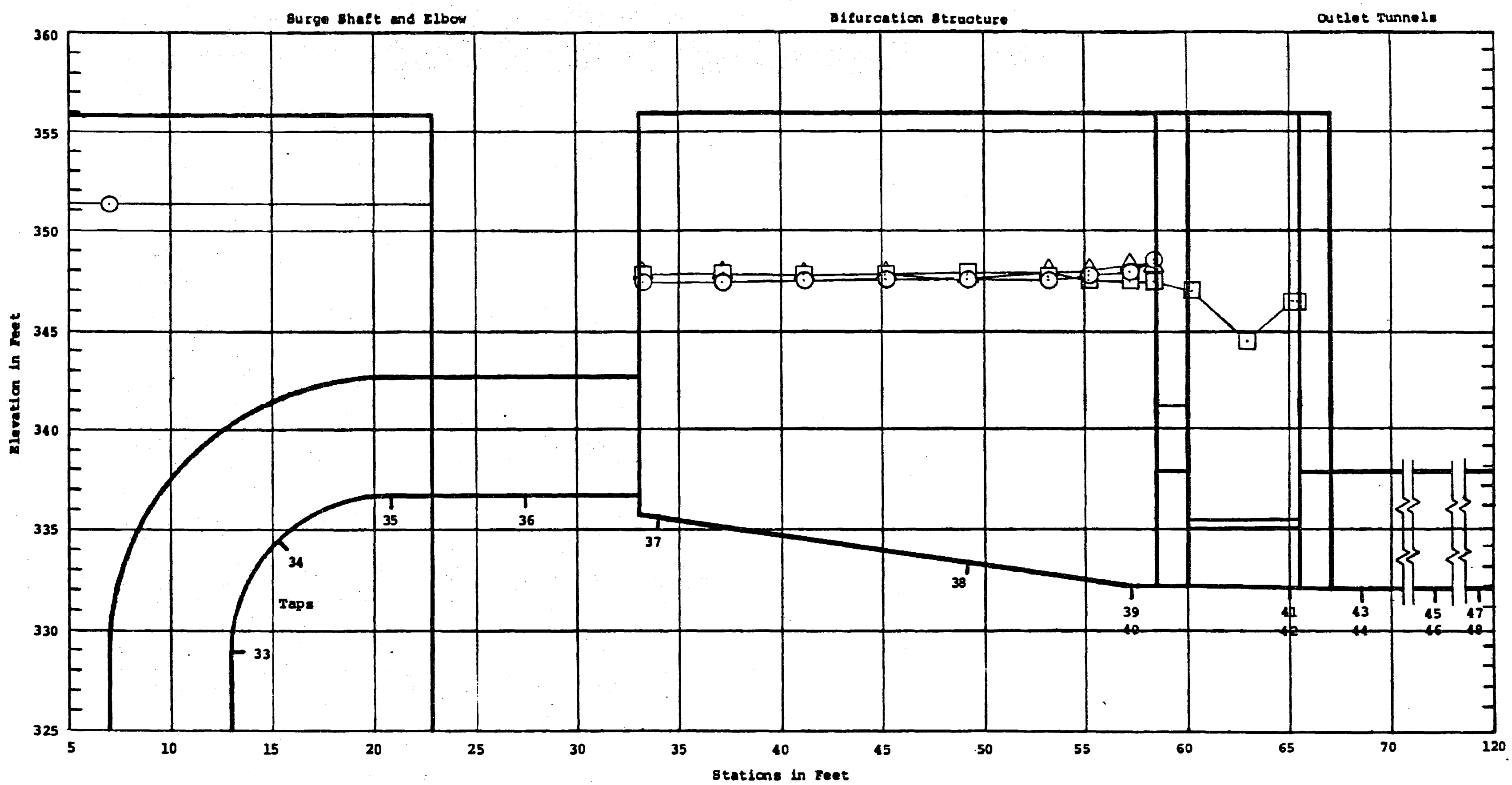


ROCHESTER CONTROL STRUCTURE 46
MODEL STUDIES
Type CS46 R10 Control Structure Scale 1:12
Water Surface Profiles - Siphon Mode
Q_S = 250 cfs, H.W. = 122.3 ft, Gates Open = None
$T.W._1$ = N/A ft, $T.W._2$ = N/A ft

⊙ Profile Along Centerline
⊡ Profile Along Right Side
△ Profile Along Left Side

SAINT ANTHONY FALLS HYDRAULIC LABORATORY UNIVERSITY OF MINNESOTA		
DRAWN BB	CHECKED *mb*	APPROVED
SCALE	DATE 3/1/84	NO. 328B514- 68

CHART 36



⊙ Profile Along Centerline
⊡ Profile Along Right Side
△ Profile Along Left Side

ROCHESTER CONTROL STRUCTURE 46
MODEL STUDIES
Type CS46 R10 Control Structure Scale 1:12
Water Surface Profiles - Siphon Mode
Q_S = 300 cfs, H.W. = 123.9 ft, Gates Open = None
$T.W._1$ = N/A ft, $T.W._2$ = N/A ft

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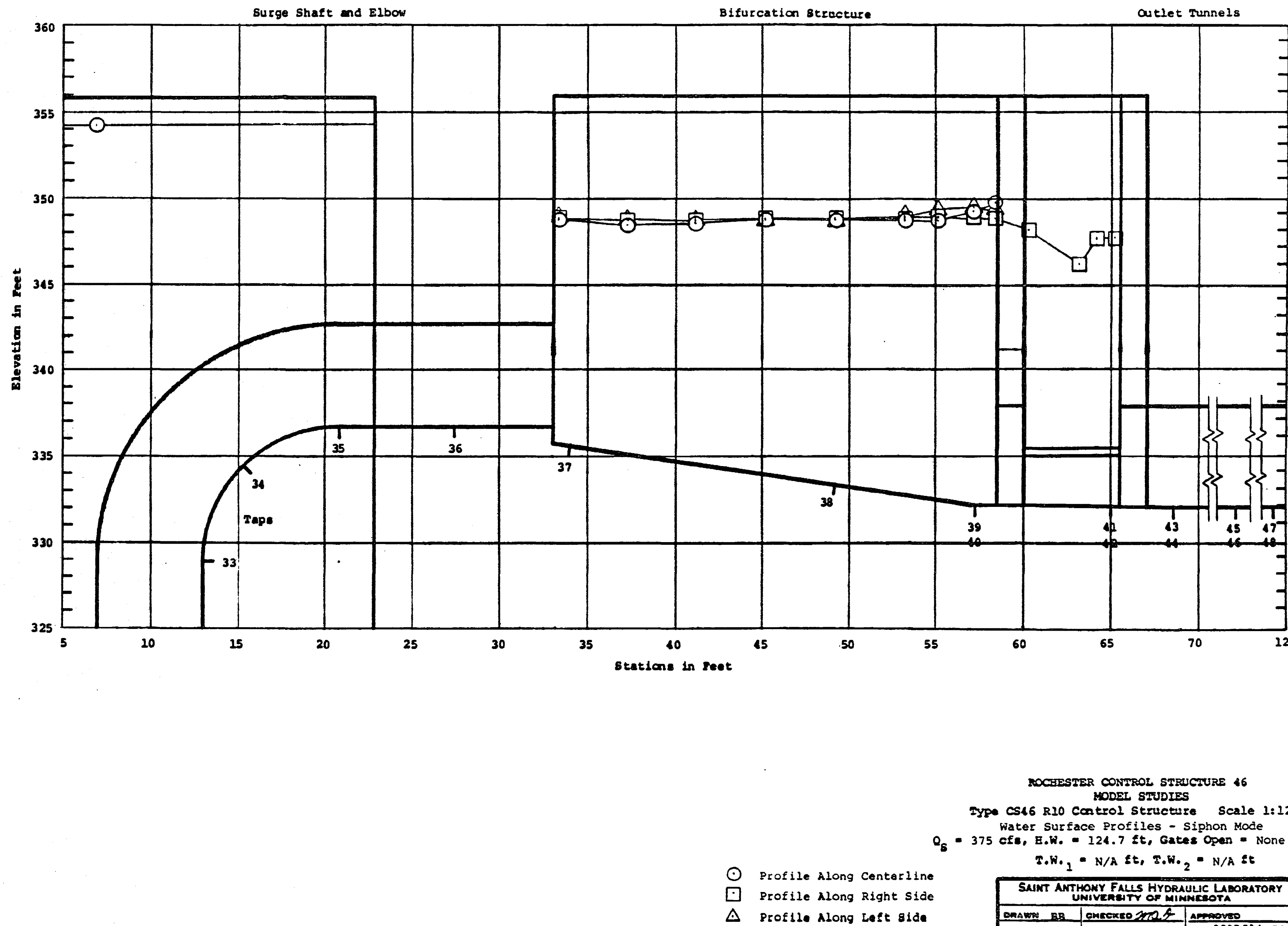
DRAWN BB	CHECKED	APPROVED
SCALE	DATE 3/1/84	NO. 328B514-69

CHART 37



ROCHESTER CONTROL STRUCTURE 46
MODEL STUDIES
Type CS46 R10 Control Structure   Scale 1:12
Water Surface Profiles - Siphon Mode
Q_S = 375 cfs, E.W. = 124.7 ft, Gates Open = None
$T.W._1$ = N/A ft, $T.W._2$ = N/A ft

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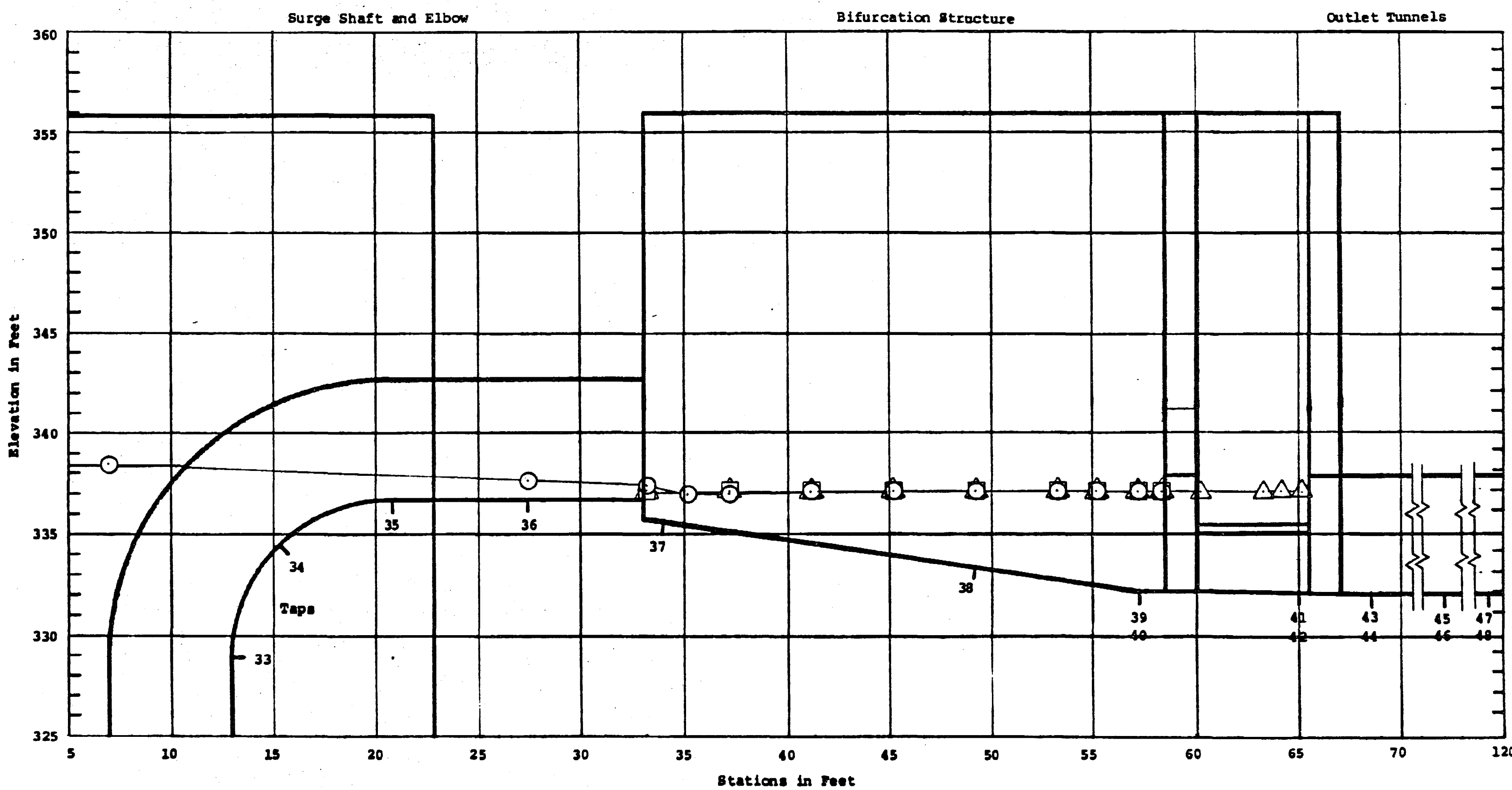
DRAWN BB	CHECKED [illegible]	APPROVED
SCALE	DATE 3/1/84	NO. 328B514-70



ROCHESTER CONTROL STRUCTURE 46
MODEL STUDIES
Type CS46 R10 Control Structure Scale 1:12
Water Surface Profiles - Siphon Mode
Q_s = 16 cfs, H.W. = 111.0 ft, Gates Open = No. 1
$T.W._1$ = 4.8 ft, $T.W._2$ = 0 ft

⊙ Profile Along Centerline
⊡ Profile Along Right Side
△ Profile Along Left Side

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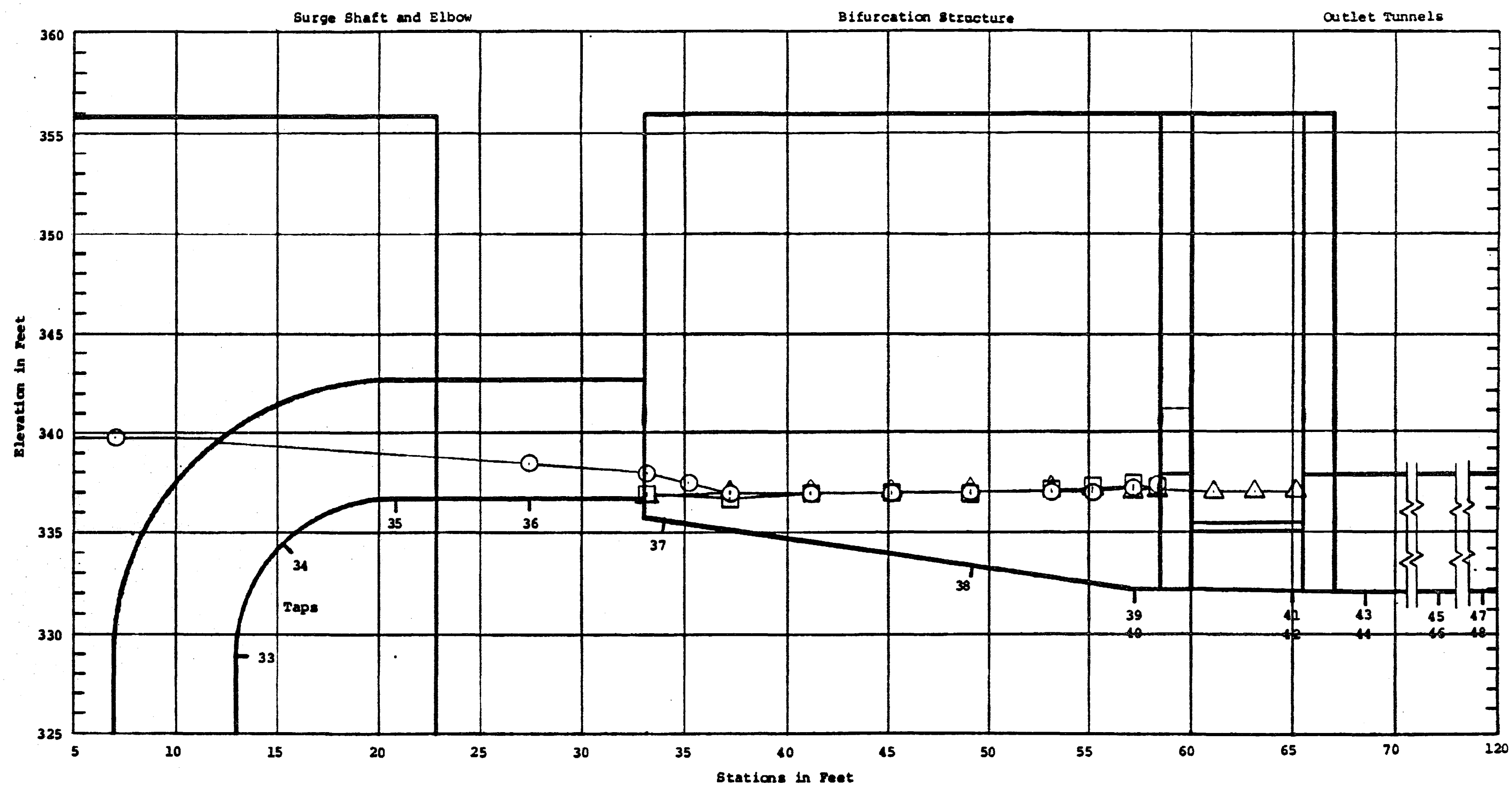
DRAWN RR	CHECKED	APPROVED
SCALE	DATE 3/1/84	NO. 328B514-71

CHART 39



ROCHESTER CONTROL STRUCTURE 46
MODEL STUDIES
Type CS46 R10 Control Structure Scale 1:12
Water Surface Profiles - Siphon Mode
Q_S = 50 cfs, H.W. = 112.2 ft, Gates Open = No. 1
T.W.$_1$ = 4.7 ft, T.W.$_2$ = 0 ft

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DRAWN BB	CHECKED	APPROVED
SCALE	DATE 3/1/84	NO. 328B514-72

CHART 40

Water Depths - Siphon Mode
Bifurcation Structure

Design Condition No. 1
Q_s = 50 cfs
H.W. = 112.4 ft
Gates Open = No. 2 (Right)
$T.W._1$ = 0 ft
$T.W._2$ = 2.3 ft

Station ft	Elevation ft	Water Depths ft		
		Left Side	Centerline	Right Side
Surge shaft	226.25		113.4	
27.58	336.70		1.9	
33.16	335.70		2.20	
36.66	335.19		0.81	
37.16	335.12		0.58	
41.16	334.53		0.47	
43.16	334.24	0.96		0.76
45.16	333.95	1.25	0.35	1.05
49.16	333.37	1.83	1.63	1.63
53.16	332.78	2.42	2.22	2.22
57.16	332.20	3.00	2.80	2.80
58.66	332.20	3.40	3.60	3.00
61.16	332.20			3.00
63.16	332.20			2.80
65.16	332.19			2.81

ROCHESTER CONTROL STRUCTURE 46
MODEL STUDIES
Type CS46 R10 Control Structure
Scale 1:12
Water Depths - Siphon Mode
Bifurcation Structure

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DRAWN MR	CHECKED [signature]	APPROVED
SCALE	DATE 5/3/84	NO. 328A2323-22

Water Depths - Siphon Mode
Bifurcation Structure

Design Condition No. 1
Q_s = 100 cfs
H.W. = 113.8 ft
Gates Open = No. 2 (Right)
$T.W._1$ = 0 ft
$T.W._2$ = 3.4 ft

Station ft	Elevation ft	Water Depths ft Left Side	Centerline	Right Side
Surge shaft	226.25		114.9	
27.58	336.70		2.8	
33.16	335.70	0.20	2.70	0.20
35.16	335.41		2.09	
37.16	335.12	0.78	1.08	0.78
41.16	334.53	1.37	1.37	1.37
45.16	333.95	1.95	1.95	1.95
49.16	333.37	2.53	2.53	2.53
53.16	332.78	3.12	3.12	3.12
57.16	332.20	3.90	3.90	3.90
58.66	332.20	4.10	4.10	4.10
61.16	332.20			3.80
63.16	332.20			3.80
65.16	332.19			3.81

ROCHESTER CONTROL STRUCTURE 46
MODEL STUDIES
Type CS46 R10 Control Structure
Scale 1:12
Water Depths - Siphon Mode
Bifurcation Structure

SAINT ANTHONY FALLS HYDRAULIC LABORATORY UNIVERSITY OF MINNESOTA		
DRAWN MR	CHECKED JRG	APPROVED
SCALE	DATE 5/3/84	NO. 328A2323-23

Water Depths - Siphon Mode
Bifurcation Structure

Design Condition No. 1
Q_s = 150 cfs
H.W. = 114.9 ft
Gates Open = No. 2 (Right)
$T.W._1$ = 0 ft
$T.W._2$ = 4.4 ft

Station ft	Elevation ft	Water Depths ft Left Side	Centerline	Right Side
Surge shaft	226.25		116.1	
27.58	336.70		3.2	
33.16	335.70	1.40	3.50	1.30
37.16	335.12	1.98	1.58	1.88
41.16	334.53	2.57	2.17	2.37
45.16	333.95	3.15	2.75	2.95
49.16	333.37	3.73	3.33	3.53
53.16	332.78	4.32	3.92	4.12
56.16	332.35	5.05	4.35	4.55
57.16	332.20	5.40	5.30	4.90
58.66	332.20	5.60	5.80	4.90
61.16	332.20			4.80
63.16	332.20			4.80
65.16	332.19			4.81

ROCHESTER CONTROL STRUCTURE 46
MODEL STUDIES
Type CS46 R10 Control Structure
Scale 1:12
Water Depths - Siphon Mode
Bifurcation Structure

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UNIVERSITY OF MINNESOTA

DRAWN MR	CHECKED JQB	APPROVED
SCALE	DATE 5/3/84	NO. 328A2323-24

Water Depths - Siphon Mode
Bifurcation Structure

Design Condition No. 2
Q_s = 200 cfs
H.W. = 116.1 ft
Gates Open = No. 1 & 2
$T.W._1$ = 4.8 ft
$T.W._2$ = 4.2 ft

Station	Elevation	Water Depths		
ft	ft	ft		
		Left Side	Centerline	Right Side
Surge shaft	226.25		117.0	
27.58	336.70		3.7	
33.16	335.70	1.30	3.80	1.30
37.16	335.12	1.88	2.58	1.68
41.16	334.53	2.47	1.57	2.17
45.16	333.95	3.05	2.55	2.85
49.16	333.37	3.63	3.33	3.43
53.16	332.78	4.22	4.02	4.22
55.16	332.49		4.31	
57.16	332.20	5.00	5.80	5.00
58.66	332.20	5.20	6.30	5.00
61.16	332.20	5.20		4.80
63.16	332.20	5.20		4.80
65.16	332.19	5.21		4.81

ROCHESTER CONTROL STRUCTURE 46
MODEL STUDIES
Type CS46 R10 Control Structure
Scale 1:12
Water Depths - Siphon Mode
Bifurcation Structure

SAINT ANTHONY FALLS HYDRAULIC LABORATORY UNIVERSITY OF MINNESOTA		
DRAWN MR	CHECKED [signature]	APPROVED
SCALE	DATE 5/3/84	NO. 328A2323-25

Water Depths - Siphon Mode
Bifurcation Structure

Design Condition No. 2
Q_s = 250 cfs
H.W. = 117.3 ft
Gates Open = No. 1 & 2
$T.W._1$ = 4.9 ft
$T.W._2$' = 4.4 ft

Station	Elevation	Water Depths		
ft	ft	ft		
		Left Side	Centerline	Right Side
Surge shaft	226.25		118.4	
27.58	336.70		4.5	
33.16	335.70	1.30	4.30	1.30
37.16	335.12	1.88	3.28	1.68
41.16	334.53	2.47	1.87	2.07
43.16	334.24		1.56	
45.16	333.95	2.85	2.15	2.65
49.16	333.37	3.63	3.53	3.43
53.16	332.78	4.22	4.12	4.22
55.16	332.49	4.71	4.51	4.61
57.16	332.20	5.30	7.10	5.10
58.66	332.20	5.60	7.10	5.40
61.16	332.20	5.30		5.10
63.16	332.20	5.30		5.10
65.16	332.19	5.31		5.11

ROCHESTER CONTROL STRUCTURE 46
MODEL STUDIES
Type CS46 R10 Control Structure
Scale 1:12
Water Depths - Siphon Mode
Bifurcation Structure

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UNIVERSITY OF MINNESOTA

DRAWN MR	CHECKED [illegible]	APPROVED
SCALE	DATE 5/3/84	NO. 328A2323-26

Water Depths - Siphon Mode
Bifurcation Structure

Design Condition No. 2
Q_s = 300 cfs
H.W. = 118.6 ft
Gates Open = No. 1 & 2
$T.W._1$ = 5.1 ft
$T.W._2$ = 4.8 ft

Station ft	Elevation ft	Water Depths ft Left Side	Centerline	Right Side
Surge shaft	226.25		119.6	
27.58	336.70		4.7	
33.16	335.70	1.30	4.70	1.30
37.16	335.12	1.88	3.88	1.88
41.16	334.53	2.47	2.27	2.37
45.16	333.95	2.95	2.65	2.75
49.16	333.37	3.53	4.13	3.33
53.16	332.78	4.42	4.72	4.42
55.16	332.49	5.01	5.01	4.71
57.16	332.20	5.60	7.80	5.60
58.66	332.20	5.80	8.30	5.60
61.16	332.20	5.40		5.40
63.16	332.20	5.40		5.40
65.16	332.19	5.61		5.61

ROCHESTER CONTROL STRUCTURE 46
MODEL STUDIES
Type CS46 R 10 Control Structure
Scale 1:12
Water Depths - Siphon Mode
Bifurcation Structure

SAINT ANTHONY FALLS HYDRAULIC LABORATORY
UNIVERSITY OF MINNESOTA

DRAWN MR	CHECKED MJB	APPROVED
SCALE	DATE 5/3/84	NO. 328A2323-27

Water Depths - Siphon Mode
Bifurcation Structure

Design Condition No. 2
Q_s = 375 cfs
H.W. = 119.3 ft
Gates Open = No. 1 & 2
$T.W._1$ = 5.6 ft
$T.W._2$ = 6.2 ft

Station ft	Elevation ft	Water Depths ft Left Side	Centerline	Right Side
Surge shaft	226.25		121.8	
33.16	335.70	1.9	5.2	1.9
37.16	335.12	2.48	4.08	2.68
41.16	334.53	3.07	2.67	3.67
45.16	333.95	3.65	4.15	3.65
49.16	333.37	4.83	4.63	4.63
53.16	332.78	5.62	5.42	5.62
55.16	332.49	6.01	5.71	6.51
57.16	332.20	6.70	8.80	6.80
58.66	332.20	6.80	8.80	6.80
61.16	332.20	6.60		6.60
63.16	332.20	6.60		6.60
65.16	332.19	6.61		6.61

ROCHESTER CONTROL STRUCTURE 46
MODEL STUDIES
Type CS46 R10 Control Structure
Scale 1:12
Water Depths - Siphon Mode
Bifurcation Structure

SAINT ANTHONY FALLS HYDRAULIC LABORATORY
UNIVERSITY OF MINNESOTA

DRAWN MR	CHECKED [illegible]	APPROVED
SCALE	DATE 5/3/84	NO. 328A2323-28

Water Depths - Siphon Mode
Bifurcation Structure

Design Condition No. 3
Q_s = 200 cfs
H.W. = 120.3 ft
Gates Open = None
$T.W._1$ = - ft
$T.W._2$ = - ft

Station ft	Elevation ft	Water Depths ft Left Side	Centerline	Right Side
Surge shaft	226.25		121.3	
33.16	335.70	10.30	10.30	10.40
37.16	335.12	10.88	10.68	10.88
41.16	334.53	11.47	11.37	11.47
45.16	333.95	12.05	12.05	12.15
49.16	333.37	12.63	12.63	12.73
53.16	332.78	13.32	13.22	13.42
55.16	332.49	13.61	13.51	13.71
57.16	332.20	14.10	14.10	14.00
58.66	332.20	14.30	14.30	14.00
60.16	332.20			13.10
63.16	332.20			10.50
65.16	332.19			9.31
65.66	332.19			10.81

ROCHESTER CONTROL STRUCTURE 46
MODEL STUDIES
Type CS46 R10 Control Structures
Scale 1:12
Water Depths - Siphon Mode
Bifurcation Structure

SAINT ANTHONY FALLS HYDRAULIC LABORATORY
UNIVERSITY OF MINNESOTA

DRAWN MR	CHECKED	APPROVED
SCALE	DATE 5/3/84	NO. 328A2323-29

Water Depths - Siphon Mode
Bifurcation Structure

Design Condition No. 3
Q_s = 250 cfs
H.W. = 122.3 ft
Gates Open = None
$T.W._1$ = - ft
$T.W._2$ = - ft

Station ft	Elevation ft	Water Depths ft		
		Left Side	Centerline	Right Side
Surge shaft	226.25		123.1	
33.16	335.70	11.10	11.20	11.30
37.16	335.12	11.78	11.38	11.68
41.16	334.53	12.47	12.17	12.17
45.16	333.95	13.05	12.75	12.75
49.16	333.37	13.83	13.33	13.43
53.16	332.78	14.32	14.22	14.22
55.16	332.49	14.61	14.61	14.51
57.16	332.20	15.00	15.10	14.80
58.66	332.20	15.00	15.10	14.80
60.16	332.20			13.80
63.16	332.20			11.10
65.16	332.19			12.81
65.66	332.19			12.81

ROCHESTER CONTROL STRUCTURE 46
MODEL STUDIES
Type CS46 R10 Control Structure
Scale 1:12
Water Depths - Siphon Mode
Bifurcation Structure

SAINT ANTHONY FALLS HYDRAULIC LABORATORY UNIVERSITY OF MINNESOTA		
DRAWN MR	CHECKED [illegible]	APPROVED
SCALE	DATE 5/3/84	NO. 328A2323-30

Water Depths - Siphon Mode
Bifurcation Structure

Design Condition No. 3
Q_s = 300 cfs
H.W. = 123.9 ft
Gates Open = None
$T.W._1$ = - ft
$T.W._2$ = - ft

Station ft	Elevation ft	Water Depths ft Left Side	Centerline	Right Side
Surge shaft	226.25		125.1	
33.16	335.70	12.00	11.70	12.10
37.16	335.12	12.68	12.28	12.68
41.16	334.53	13.27	12.97	13.27
45.16	333.95	13.85	13.65	13.85
49.16	333.37	14.43	14.23	14.53
53.16	332.78	15.02	14.72	14.92
55.16	332.49	15.51	15.31	15.01
57.16	332.20	16.10	15.80	15.30
58.66	332.20	16.20	16.40	15.30
60.16	332.20			14.80
63.16	332.20			12.30
65.16	332.19			14.31
65.66	332.19			14.31

ROCHESTER CONTROL STRUCTURE 46
MODEL STUDIES
Type CS46 R10 Control Structure
Scale 1:12
Water Depths - Siphon Mode
Bifurcation Structure

SAINT ANTHONY FALLS HYDRAULIC LABORATORY
UNIVERSITY OF MINNESOTA

DRAWN MR	CHECKED [illegible]	APPROVED
SCALE	DATE 5/3/84	NO. 338A2323-31

Water Depths - Siphon Mode
Bifurcation Structure

Design Condition No. 3
Q_s = 375 cfs
H.W. = 127.4 ft
Gates Open = None
$T.W._1$ = - ft
$T.W._2$ = - ft

Station ft	Elevation ft	Water Depths ft Left Side	Centerline	Right Side
Surge shaft	226.25		128.0	
33.16	335.70	13.10	13.00	13.10
37.16	335.12	13.68	13.38	13.68
41.16	334.53	14.17	14.07	14.27
45.16	333.95	14.75	14.75	14.85
49.16	333.37	15.33	15.33	15.43
53.16	332.78	16.22	15.92	16.02
55.16	332.49	16.81	16.21	16.41
57.16	332.20	17.40	17.10	16.70
58.66	332.20	17.40	17.60	16.80
60.16	332.20			16.10
63.16	333.20			14.10
64.16	332.19			15.51
65.16	332.19			15.51

ROCHESTER CONTROL STRUCTURE 46
MODEL STUDIES
Type CS46 R10 Control Structure
Scale 1:12
Water Depths - Siphon Mode
Bifurcation Structure

SAINT ANTHONY FALLS HYDRAULIC LABORATORY
UNIVERSITY OF MINNESOTA

DRAWN MR	CHECKED [illegible]	APPROVED
SCALE	DATE 5/3/84	NO. 328A2323-32

Water Depths - Siphon Mode
Bifurcation Structure

Design Condition No. 4
Q_s = 16 cfs
H.W. = 111.0 ft
Gates Open = No. 1 (Left)
$T.W._1$ = 4.8 ft
$T.W._2'$ = 0 ft

Station ft	Elevation ft	Water Depths ft Left Side	Centerline	Right Side
Surge shaft	226.25		112.2	
27.58	336.70		0.9	
33.16	335.70	1.40	1.70	1.40
35.16	335.41		1.59	
37.16	335.12	1.98	1.88	1.98
41.16	334.53	2.57	2.57	2.57
45.16	333.95	3.15	3.15	3.15
49.16	333.37	3.73	3.73	3.73
53.16	332.78	4.32	4.32	4.32
55.16	332.49	4.61	4.61	4.61
57.16	332.20	4.90	4.90	4.90
58.66	332.20	4.90	4.90	4.90
60.16	332.20	4.90		
63.16	332.20	4.90		
64.16	332.19	4.91		
65.16	332.19	4.91		

ROCHESTER CONTROL STRUCTURE 46
MODEL STUDIES
Type CS46 R10 Control Structure
Scale 1:12
Water Depths - Siphon Mode
Bifurcation Structure

SAINT ANTHONY FALLS HYDRAULIC LABORATORY UNIVERSITY OF MINNESOTA		
DRAWN MR	CHECKED [signature]	APPROVED
SCALE	DATE 5/3/84	NO. 328A2323-33

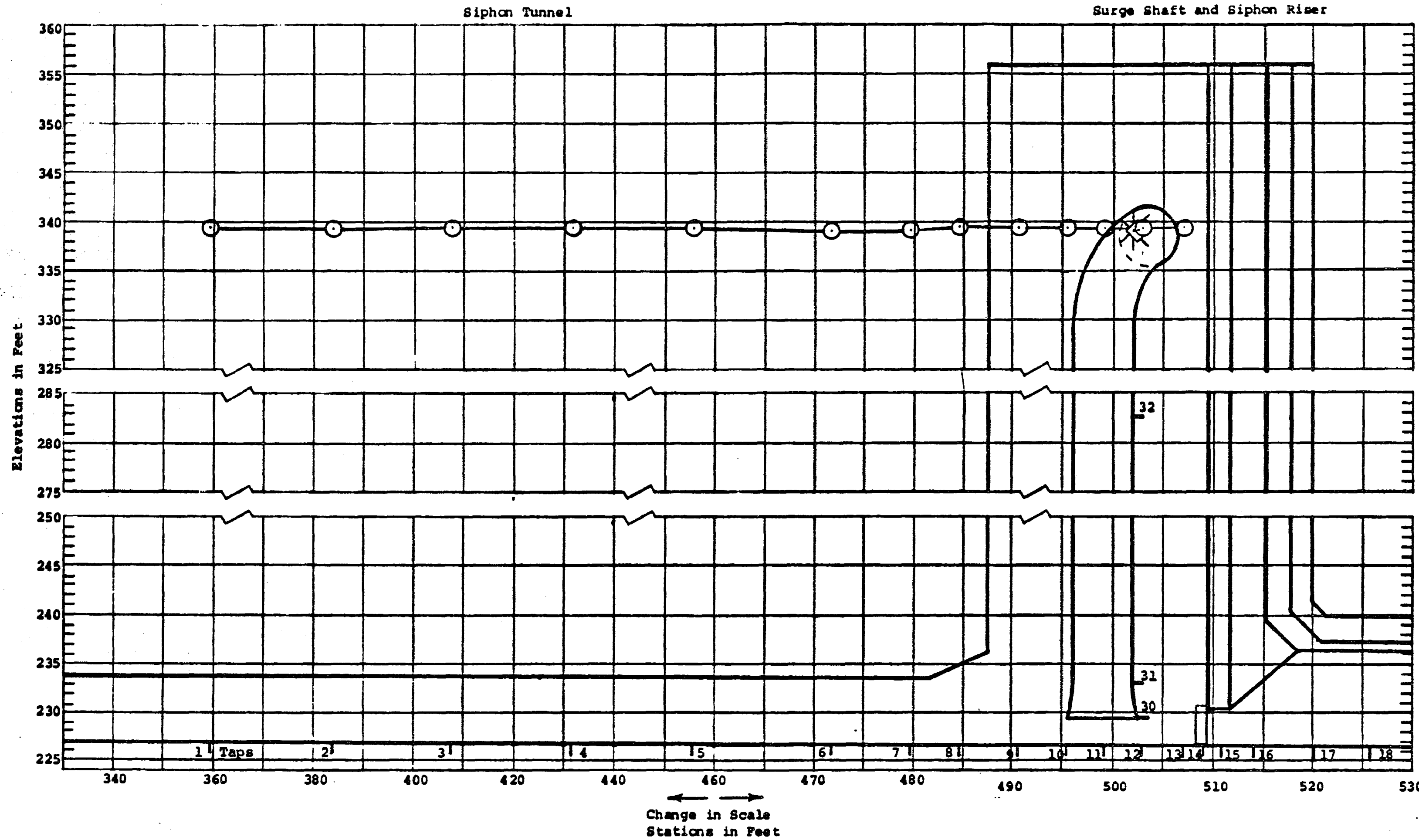
Water Depths - Siphon Mode
Bifurcation Structure

Design Condition No. 4
Q_s = 50 cfs
H.W. = 112.2 ft
Gates Open = No. 1 (left)
$T.W._1$ = 4.7 ft
$T.W._2'$ = 0 ft

Station	Elevation	Water Depths		
ft	ft	ft		
		Left Side	Centerline	Right Side
Surge shaft	226.25		113.5	
27.58	336.70		1.8	
33.16	335.70	1.20	2.30	1.30
35.16	335.41		2.09	
37.16	335.12	1.88	1.78	1.88
41.16	334.53	2.47	2.37	2.37
45.16	333.95	3.05	2.95	2.95
49.16	333.37	3.73	3.63	3.53
53.16	332.78	4.32	4.22	4.32
55.16	332.49	4.61	4.51	4.71
57.16	332.20	4.90	5.00	5.10
58.66	332.20	4.90	5.10	5.00
61.16	332.20	4.90		
63.16	332.20	4.90		
65.16	332.19	4.91		

ROCHESTER CONTROL STRUCTURE 46
MODEL STUDIES
Type CS46 R10 Control Structure
Scale 1:12
Water Depths - Siphon Mode
Bifurcation Structure

SAINT ANTHONY FALLS HYDRAULIC LABORATORY UNIVERSITY OF MINNESOTA		
DRAWN MR	CHECKED [illegible]	APPROVED
SCALE	DATE 5/3/84	NO. 328A2323-34

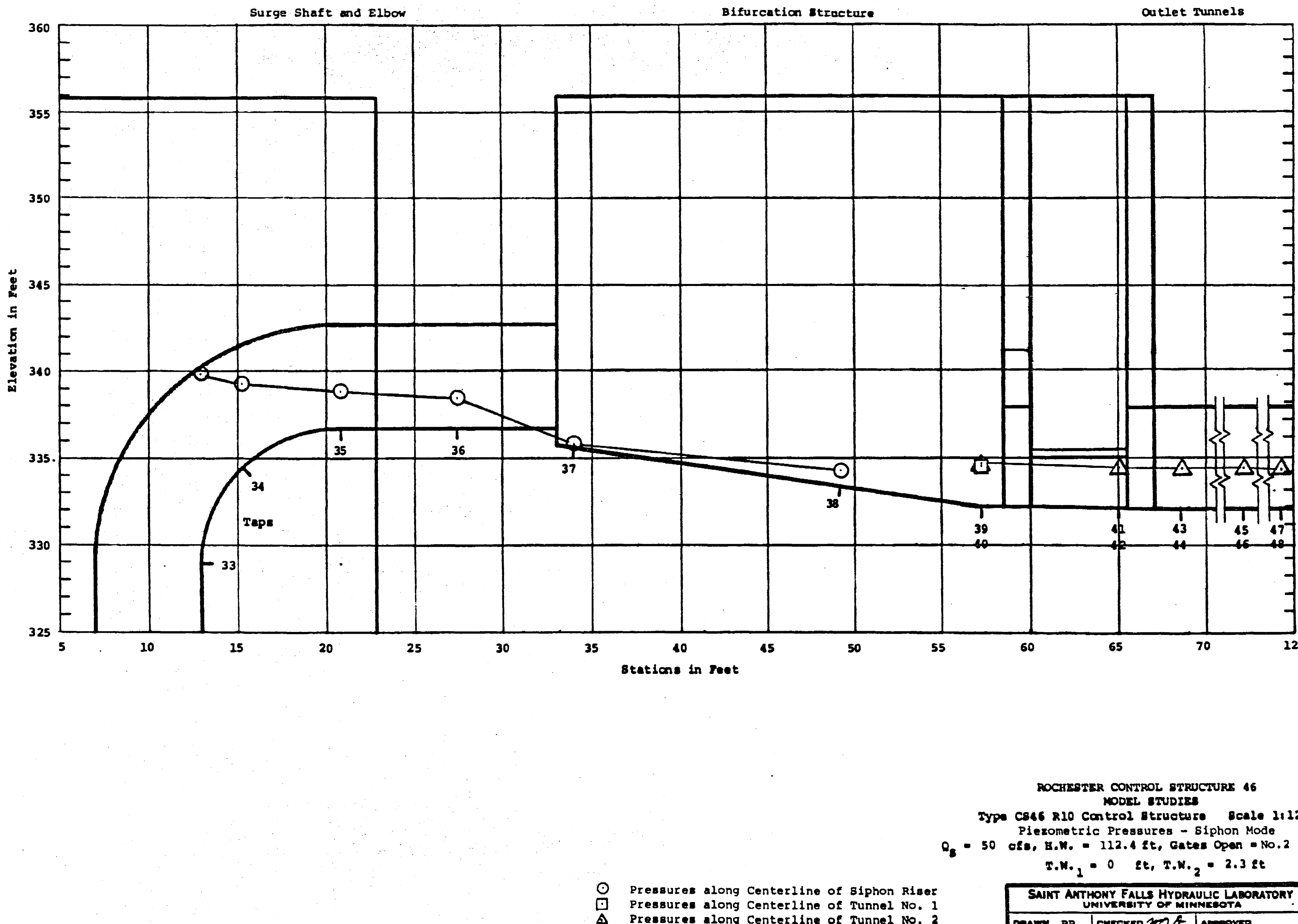


ROCHESTER CONTROL STRUCTURE 46
MODEL STUDIES
Type CS46 R10 Control Structure Scale 1:12
Piezometric Pressures - Siphon Mode
Q_S = 50 cfs, H.W. = 112.4 ft, Gates Open = No. 2
T.W.$_1$ = 0 ft, T.W.$_2$ = 2.3 ft

⊙ Pressures along Centerline
◇ Pressure at tap 30
✕ Pressure at tap 31
+ Pressure at tap 32

SAINT ANTHONY FALLS HYDRAULIC LABORATORY UNIVERSITY OF MINNESOTA		
DRAWN BB	CHECKED [signature]	APPROVED
SCALE	DATE 3/1/84	NO. 328B514-34

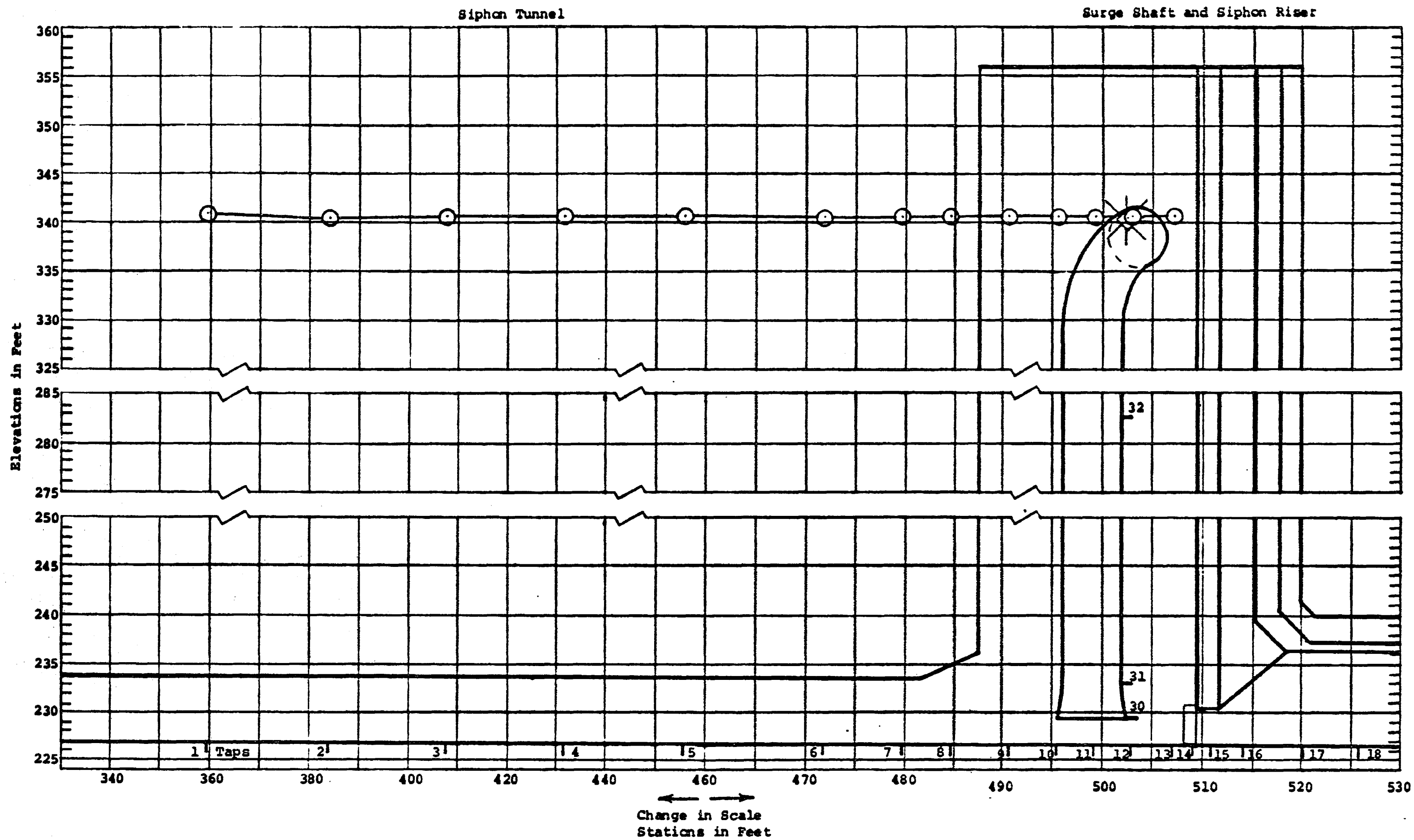
CHART 54



ROCHESTER CONTROL STRUCTURE 46
MODEL STUDIES
Type CS46 R10 Control Structure Scale 1:12
Piezometric Pressures - Siphon Mode
Q_s = 50 cfs, H.W. = 112.4 ft, Gates Open = No.2
$T.W._1$ = 0 ft, $T.W._2$ = 2.3 ft

SAINT ANTHONY FALLS HYDRAULIC LABORATORY UNIVERSITY OF MINNESOTA		
DRAWN BB	CHECKED [initials]	APPROVED
SCALE	DATE 3/1/84	NO. 328B514-47

CHART 55



ROCHESTER CONTROL STRUCTURE 46
MODEL STUDIES
Type CS46 R10 Control Structure Scale 1:12
Piezometric Pressures - Siphon Mode
Q_S = 100 cfs, H.W. = 113.8 ft, Gates Open = No. 2
$T.W._1$ = 0 ft, $T.W._2$ = 3.4 ft

⊙ Pressures along Centerline
◇ Pressure at tap 30
✕ Pressure at tap 31
+ Pressure at tap 32

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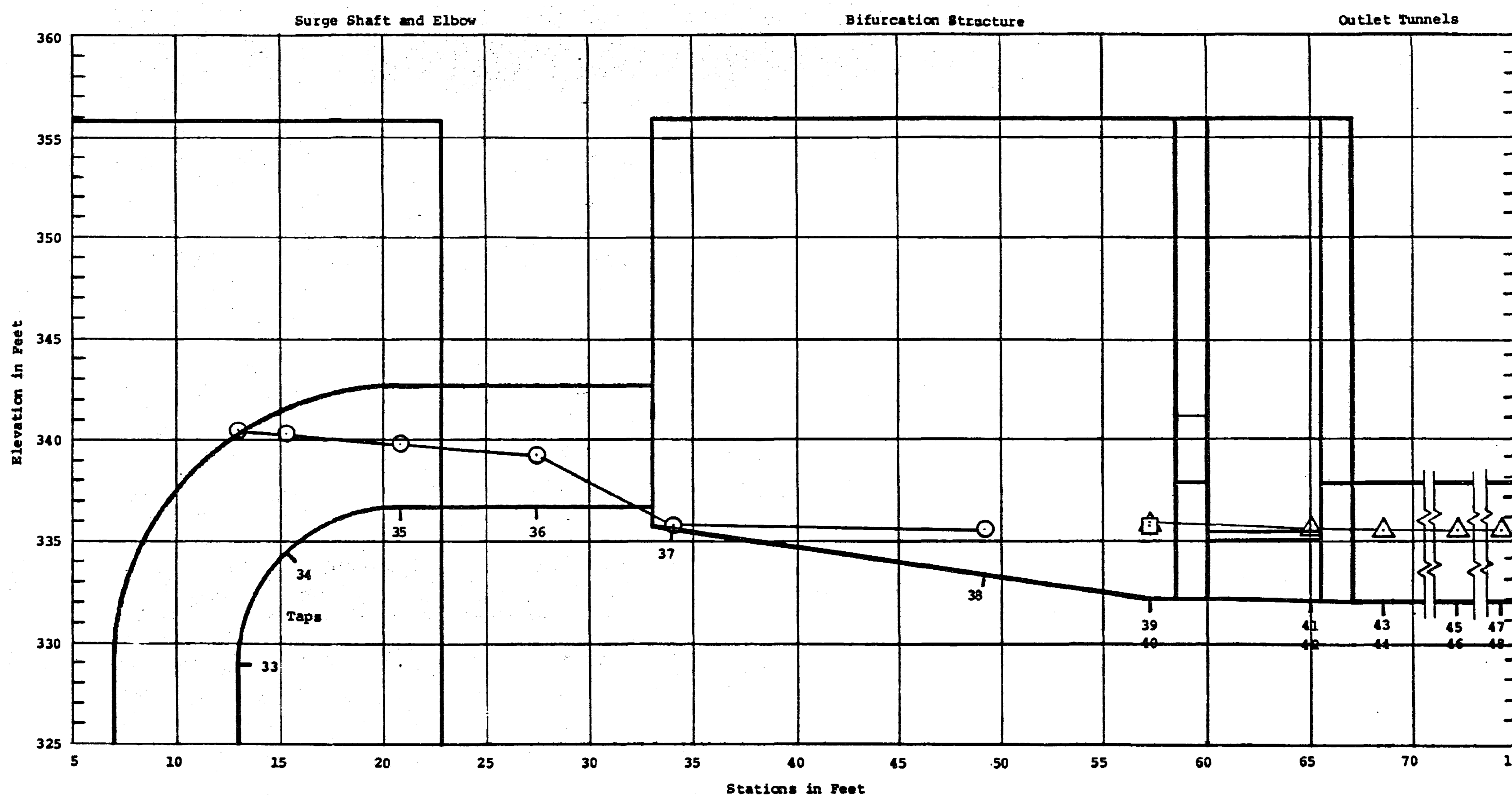
DRAWN BB	CHECKED [signature]	APPROVED
SCALE	DATE 3/1/84	NO. 328B514- 35

CHART 56



ROCHESTER CONTROL STRUCTURE 46
MODEL STUDIES
Type CS46 R10 Control Structure Scale 1:12
Piezometric Pressures - Siphon Mode
Q_s = 100 cfs, H.W. = 113.8 ft, Gates Open = No.2
$T.W._1$ = 0 ft, $T.W._2$ = 3.4 ft

⊙ Pressures along Centerline of Siphon Riser
⊡ Pressures along Centerline of Tunnel No. 1
△ Pressures along Centerline of Tunnel No. 2

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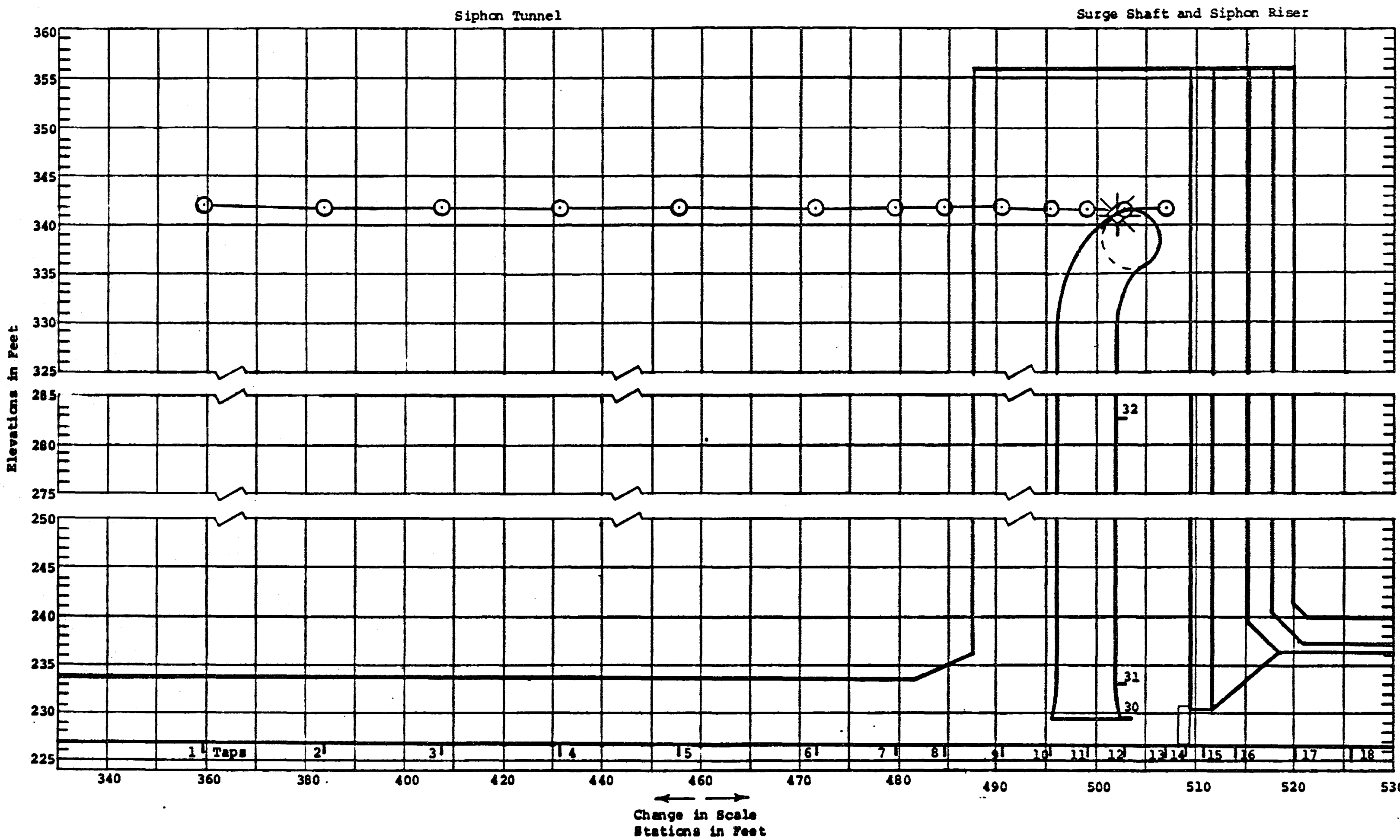
CHART 57



ROCHESTER CONTROL STRUCTURE 46
MODEL STUDIES
Type CS46 R10 Control Structure Scale 1:12
Piezometric Pressures - Siphon Mode
Q_S = 150 cfs, H.W. = 114.9 ft, Gates Open = No.2
$T.W._1$ = 0 ft, $T.W._2$ = 4.4 ft

⊙ Pressures along Centerline
◇ Pressure at tap 30
✕ Pressure at tap 31
+ Pressure at tap 32

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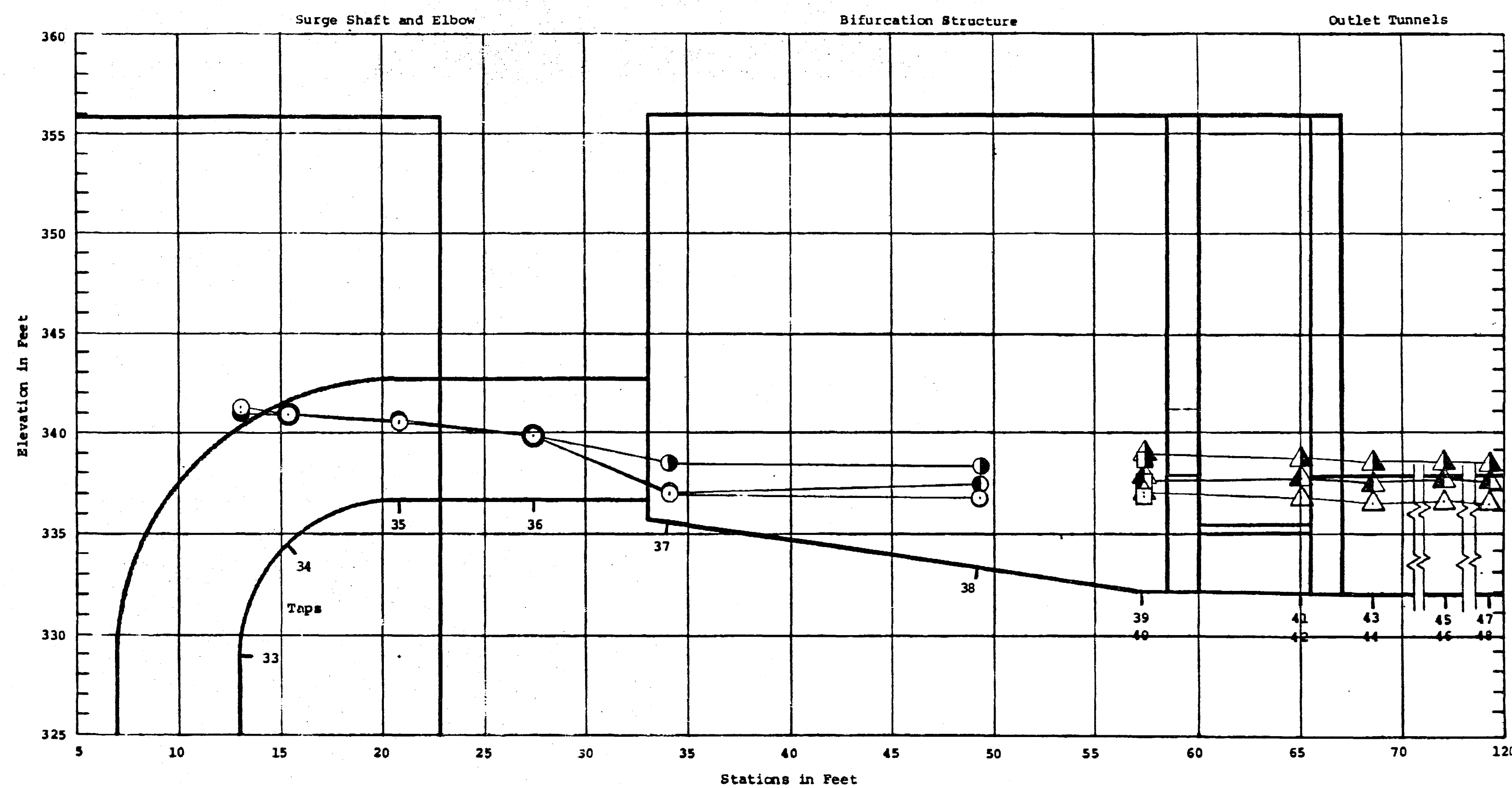
SCALE	DATE 3/1/84	NO. 328B514- 36

CHART 58



T.W.$_1$ = 0 ft T.W.$_2$ = 4.4 ft	T.W.$_1$ = 0 ft T.W.$_2$ = 5.4 ft	T.W.$_1$ = 0 ft T.W.$_2$ = 6.4 ft	
⊙	◐	◑	Pressures along Centerline of Siphon Riser
⊡	◧	◨	Pressures along Centerline of Tunnel No. 1
△	◭	◮	Pressures along Centerline of Tunnel No. 2

ROCHESTER CONTROL STRUCTURE 46
MODEL STUDIES
Type CS46 R10 Control Structure Scale 1:12
Piezometric Pressures - Siphon Mode
Q_s = 150 cfs, H.W. = 114.9 ft, Gates Open = No. 2

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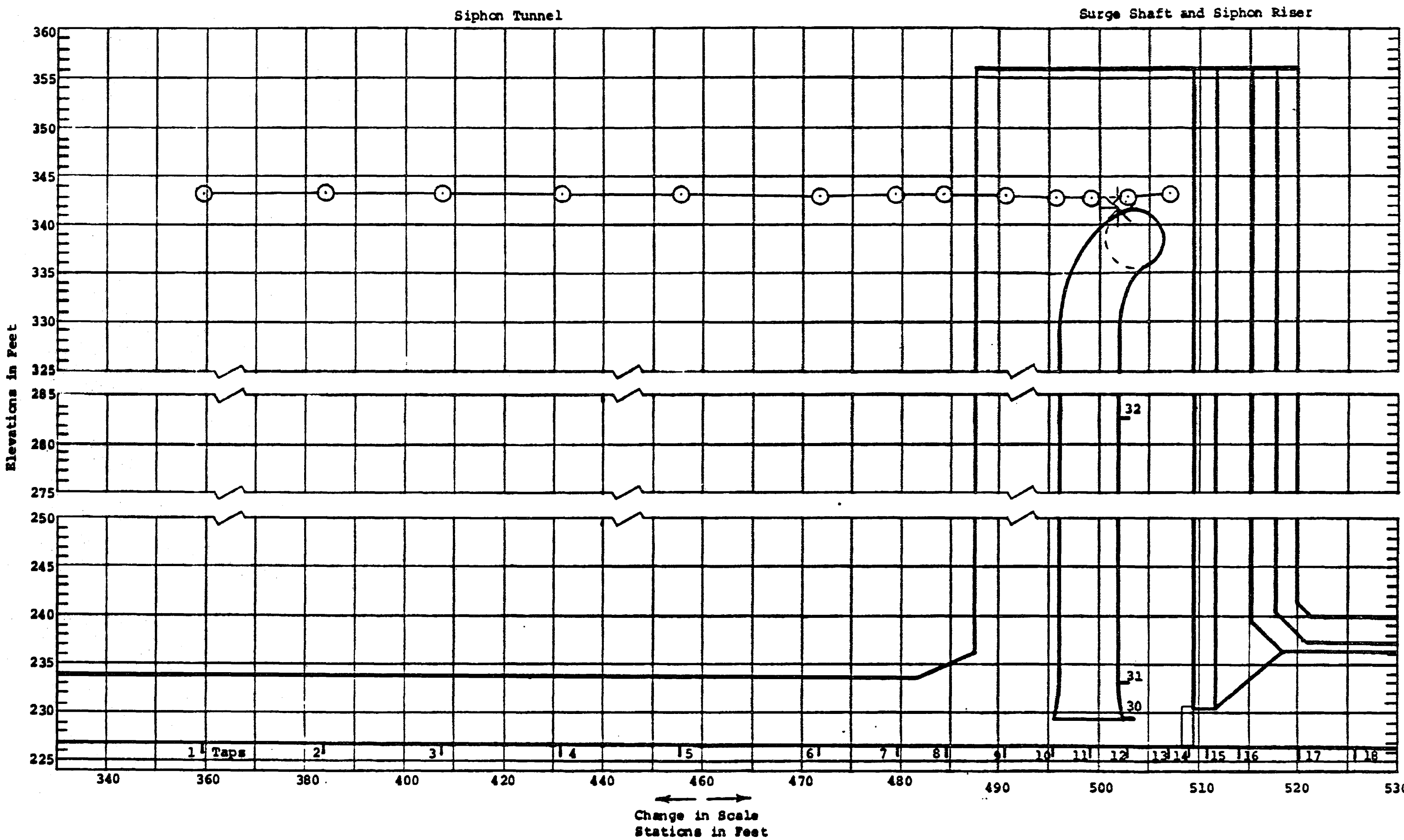
DRAWN BB	CHECKED	APPROVED
SCALE	DATE 3/1/84	NO. 328B514-49

CHART 59



ROCHESTER CONTROL STRUCTURE 46
MODEL STUDIES
Type CS46 R10 Control Structure Scale 1:12
Piezometric Pressures - Siphon Mode
Q_S = 200 cfs, H.W. = 116.1 ft, Gates Open = No.1&2
$T.W._1$ = 4.8 ft, $T.W._2$ = 4.1 ft

⊙ Pressures along Centerline
◇ Pressure at tap 30
✕ Pressure at tap 31
+ Pressure at tap 32

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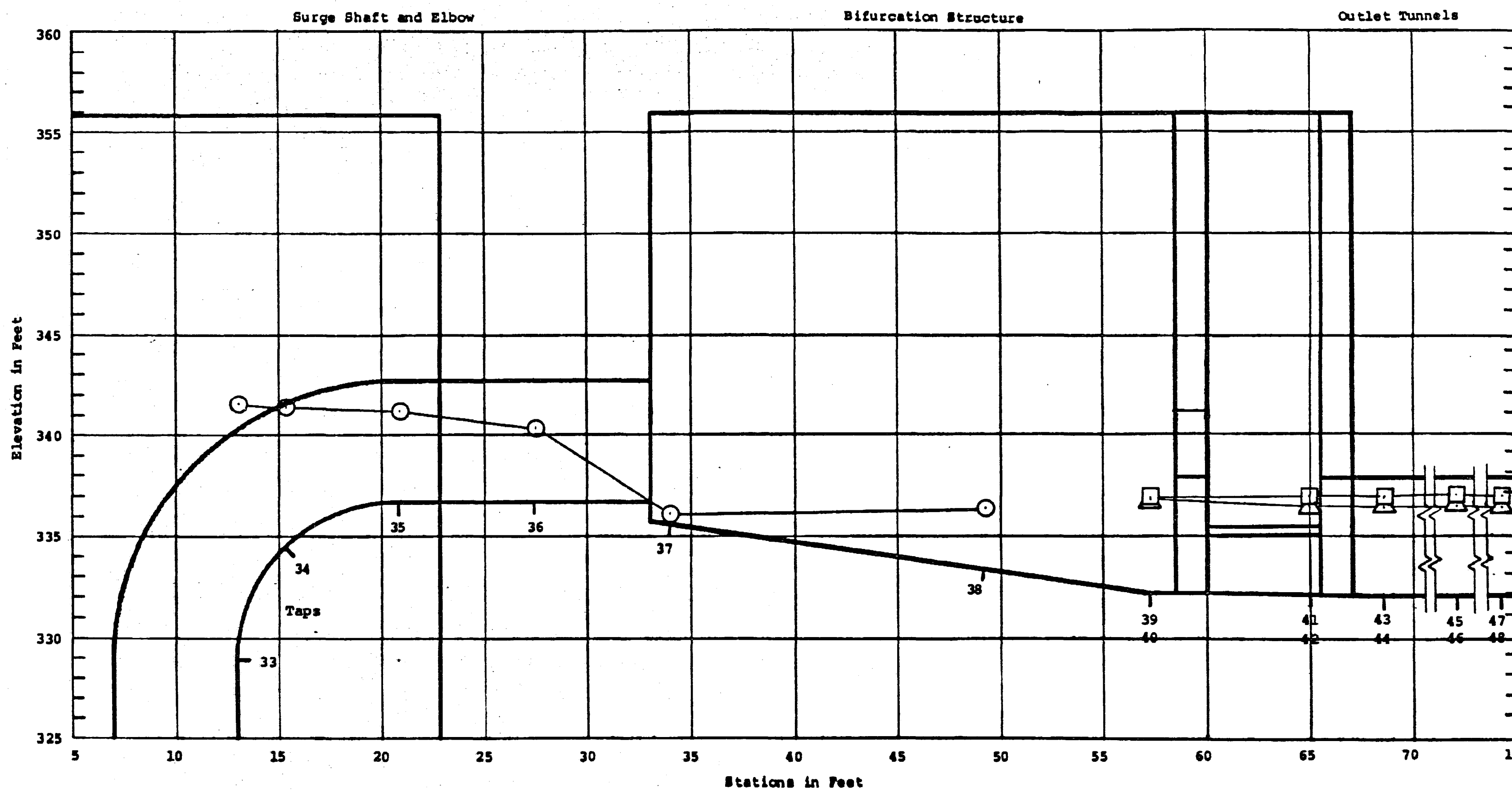
DRAWN BB	CHECKED [signature]	APPROVED
SCALE	DATE 3/1/84	NO. 328B514- 37

CHART 60



ROCHESTER CONTROL STRUCTURE 46
MODEL STUDIES
Type CS46 R10 Control Structure   Scale 1:12
Piezometric Pressures – Siphon Mode
Q_s = 200 cfs, H.W. = 116.1 ft, Gates Open = No. 1&2
$T.W._1$ = 4.8 ft, $T.W._2$ = 4.1 ft

⊙ Pressures along Centerline of Siphon Riser
⊡ Pressures along Centerline of Tunnel No. 1
△ Pressures along Centerline of Tunnel No. 2

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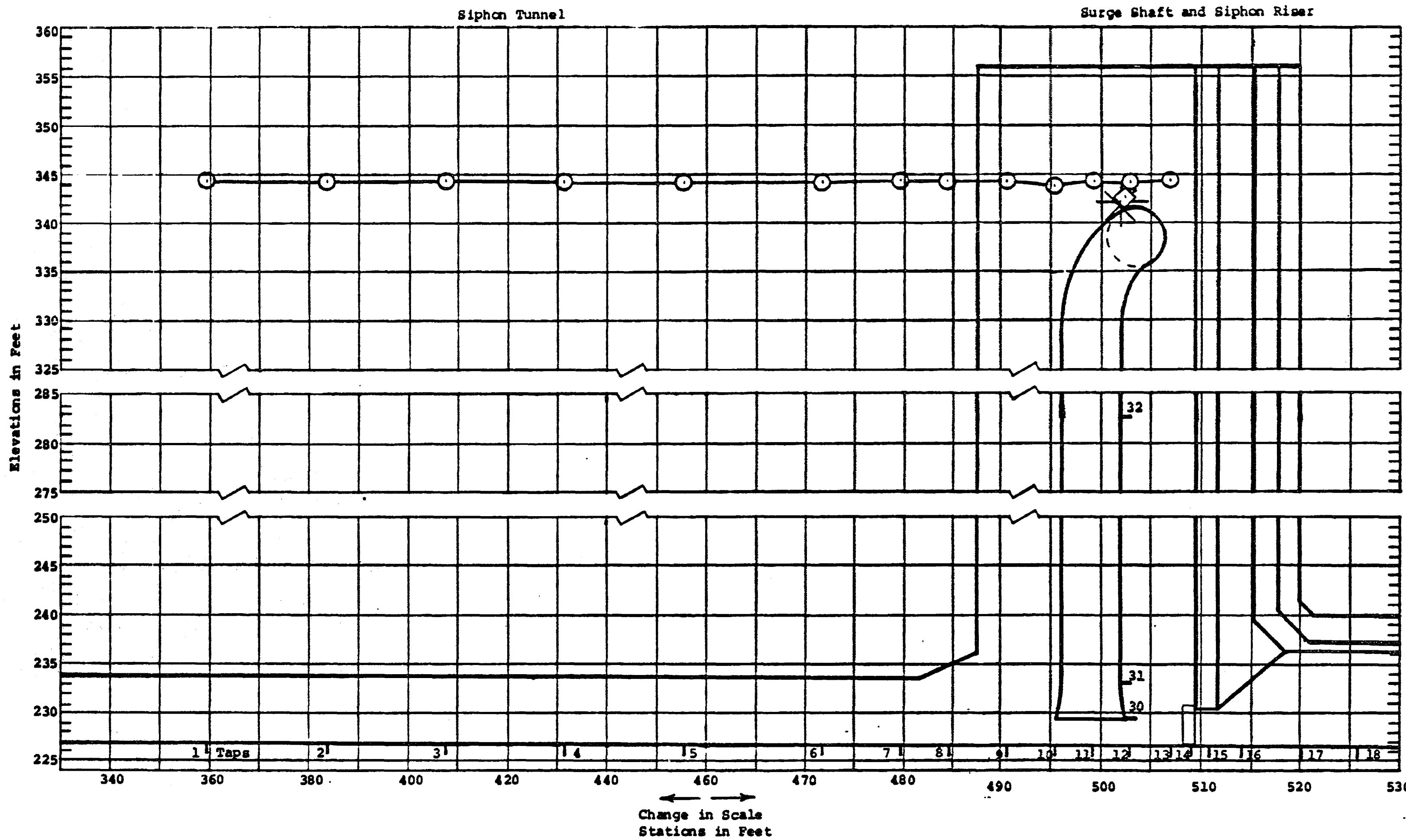
SCALE	DATE 3/1/84	NO. 328B514- 50

CHART 61



ROCHESTER CONTROL STRUCTURE 46
MODEL STUDIES
Type CS46 R10 Control Structure Scale 1:12
Piezometric Pressures - Siphon Mode
Q_s = 250 cfs, H.W. = 117.3 ft, Gates Open = No.1&2
$T.W._1$ = 4.9 ft, $T.W._2$ = 4.4 ft

⊙ Pressures along Centerline
◇ Pressure at tap 30
✕ Pressure at tap 31
+ Pressure at tap 32

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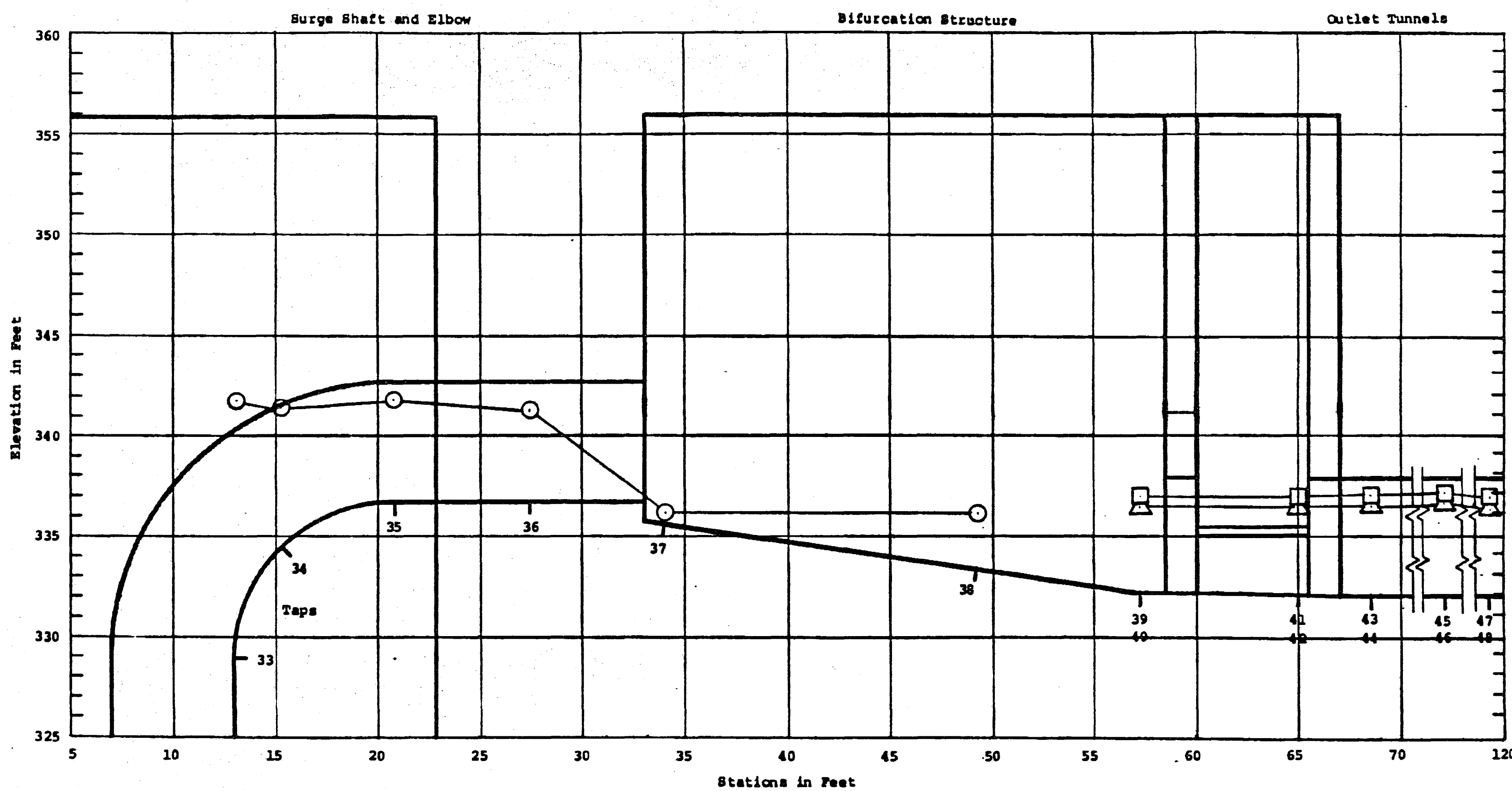
DRAWN BB	CHECKED	APPROVED
SCALE	DATE 3/1/84	NO. 328B514-38

CHART 62



ROCHESTER CONTROL STRUCTURE 46
MODEL STUDIES
Type CS46 R10 Control Structure Scale 1:12
Piezometric Pressures - Siphon Mode
Q_S = 250 cfs, H.W. = 117.3 ft, Gates Open = No.1&2
$T.W._1$ = 4.9 ft, $T.W._2$ = 4.4 ft

⊙ Pressures along Centerline of Siphon Riser
⊡ Pressures along Centerline of Tunnel No. 1
△ Pressures along Centerline of Tunnel No. 2

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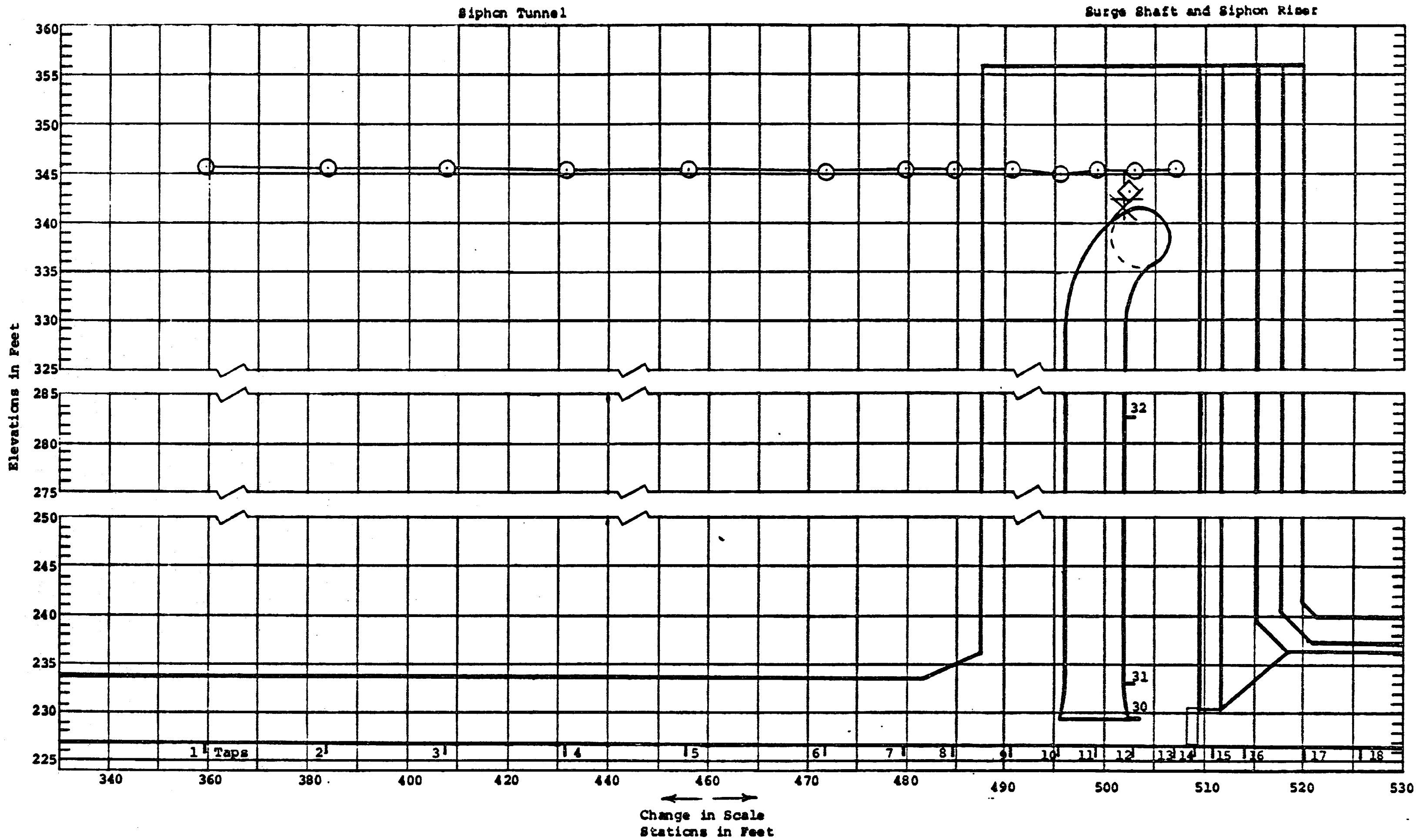
DRAWN BB	CHECKED mgb	APPROVED
SCALE	DATE 3/1/84	NO. 328B514- 51

CHART 63



ROCHESTER CONTROL STRUCTURE 46
MODEL STUDIES
Type CS46 R10 Control Structure Scale 1:12
Piezometric Pressures - Siphon Mode
Q_S = 300 cfs, H.W. = 118.6 ft, Gates Open = No.1&2
$T.W._1$ = 5.1 ft, $T.W._2$ = 4.8 ft

⊙ Pressures along Centerline
◇ Pressure at tap 30
× Pressure at tap 31
+ Pressure at tap 32

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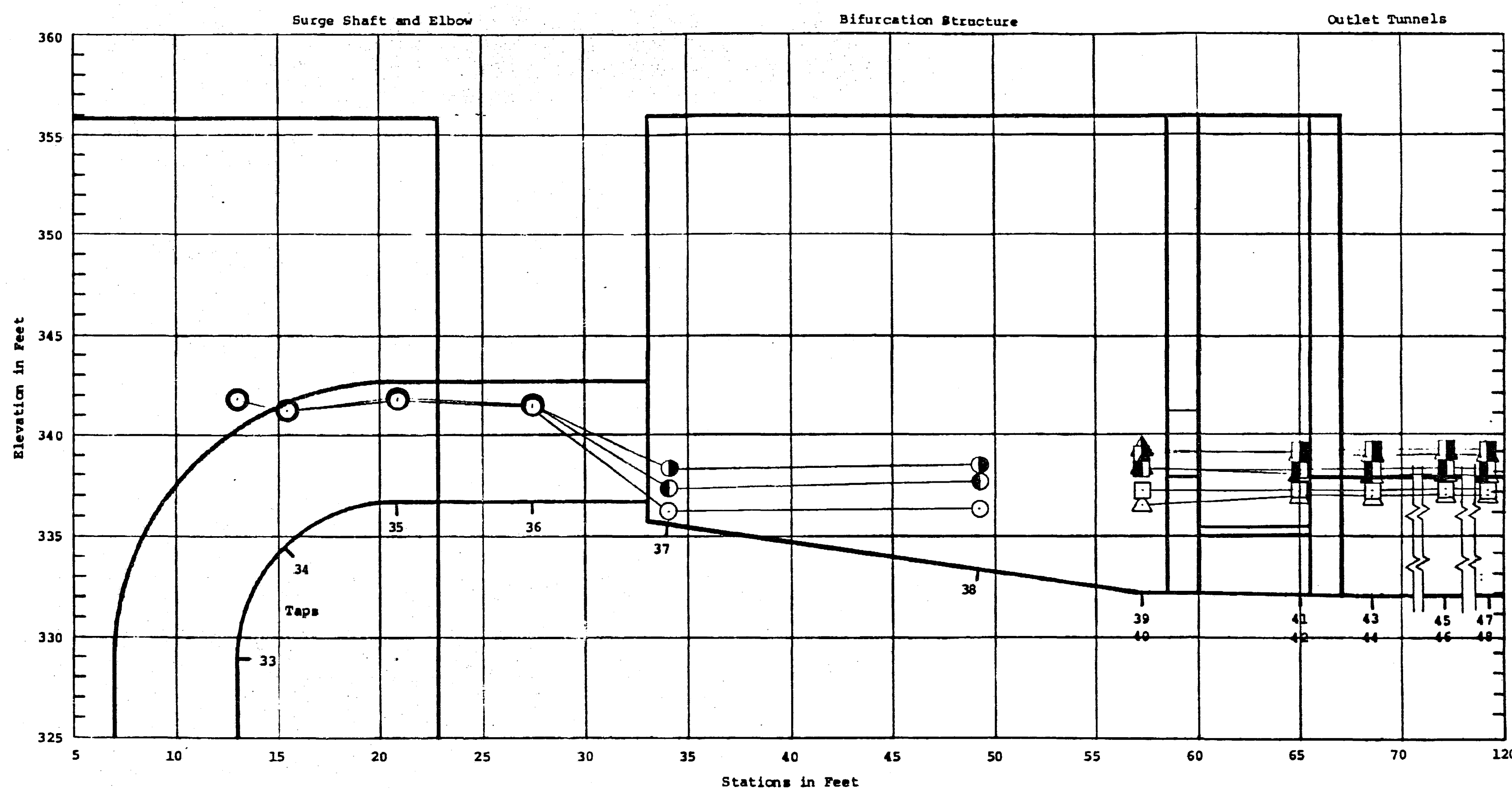
DRAWN BB	CHECKED MA	APPROVED
SCALE	DATE 3/1/84	NO. 328B514-39

CHART 64



ROCHESTER CONTROL STRUCTURE 46
MODEL STUDIES
Type CS46 R10 Control Structure   Scale 1:12
Piezometric Pressures - Siphon Mode
Q_S = 300 cfs, H.W. = 118.6 ft, Gates Open = No.1&2

$T.W._1$ = 5.1 ft	$T.W._1$ = 6.1 ft	$T.W._1$ = 7.[illegible] ft	
$T.W._2$ = 4.8 ft	$T.W._2$ = 5.8 ft	$T.W._2$ = 6.8 ft	
⊙	◐	◑	Pressures along Centerline of Siphon Riser
⊡	◧	◨	Pressures along Centerline of Tunnel No. 1
△	◭	◮	Pressures along Centerline of Tunnel No. 2

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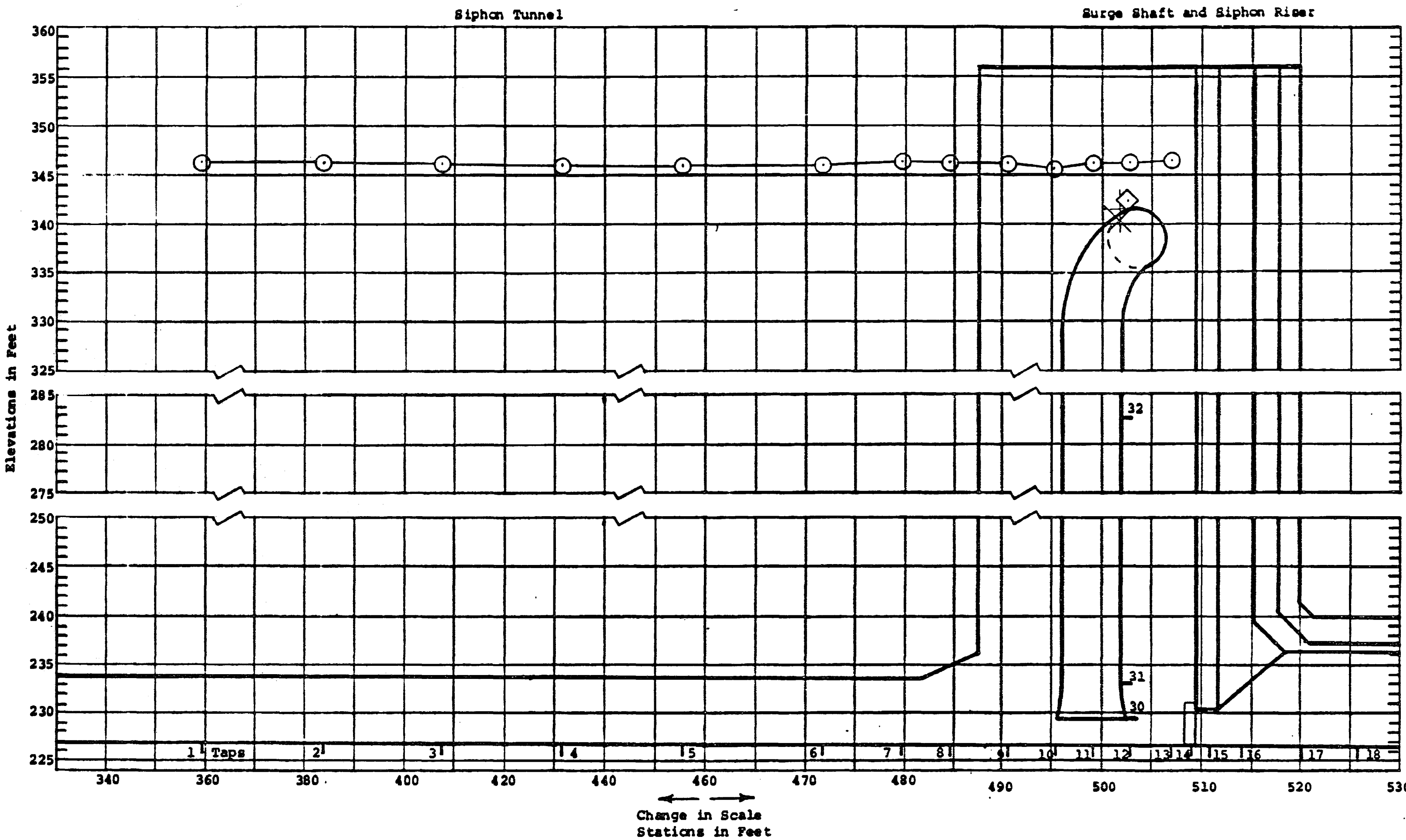
UNIVERSITY OF MINNESOTA

DRAWN BR	CHECKED [illegible]	APPROVED
SCALE	DATE 3/1/84	NO. 328B514-52

CHART 65



ROCHESTER CONTROL STRUCTURE 46
MODEL STUDIES
Type CS46 R10 Control Structure Scale 1:12
Piezometric Pressures - Siphon Mode
Q_s = 375 cfs, H.W. = 119.3 ft, Gates Open = No.1&2
$T.W._1$ = 5.6 ft, $T.W._2$ = 6.0 ft

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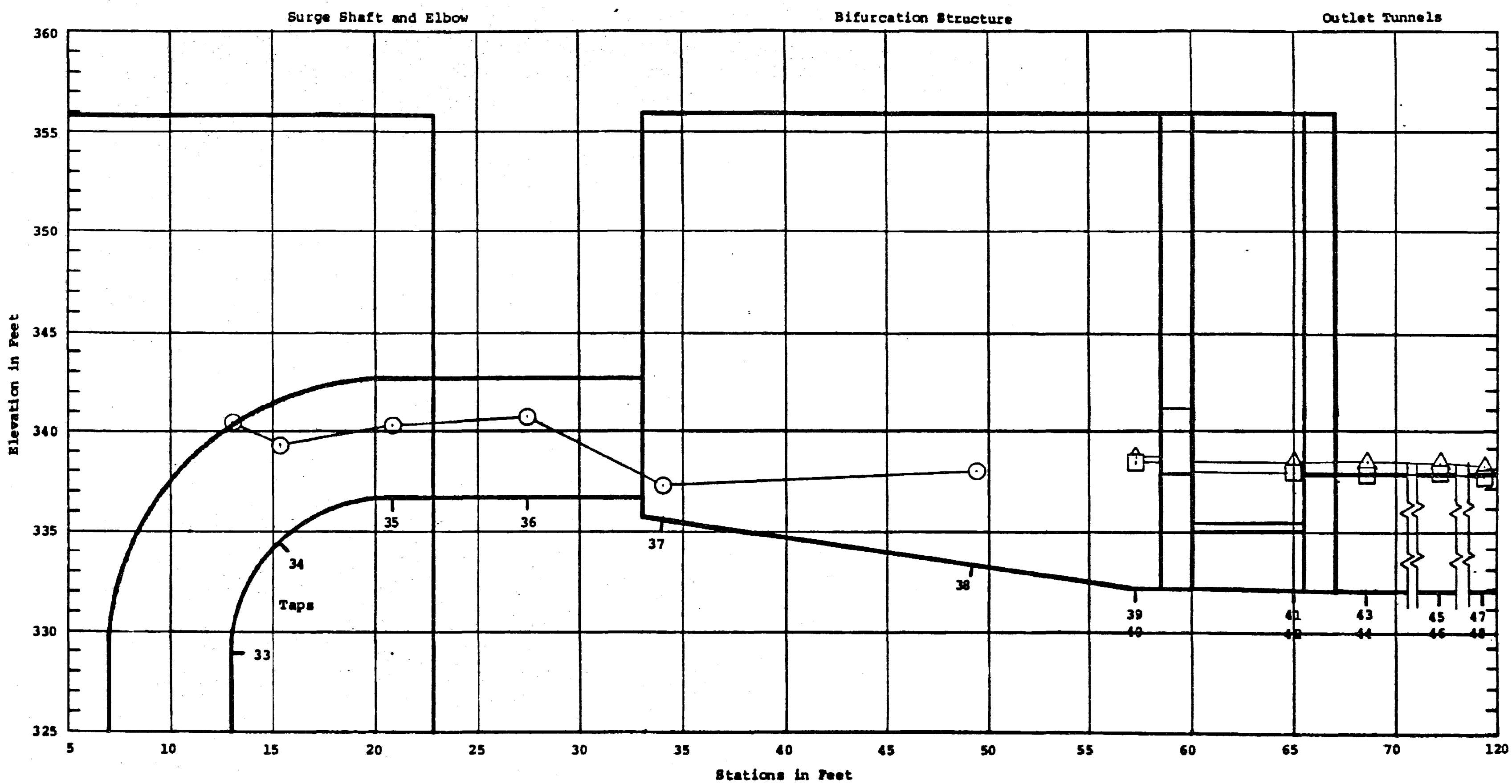
DRAWN BB	CHECKED [signature]	APPROVED
SCALE	DATE 3/1/84	NO. 328B514- 40

CHART 66

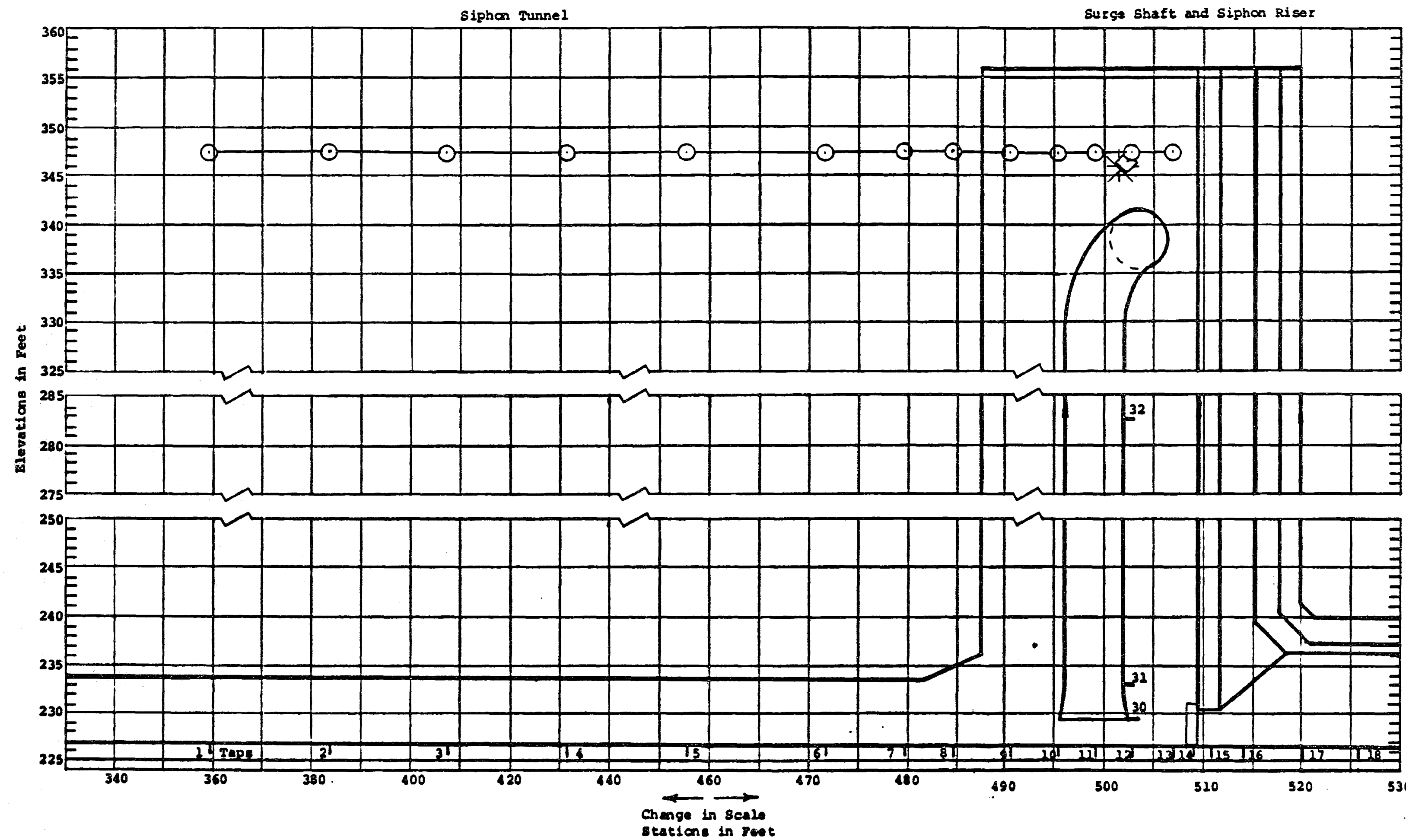


ROCHESTER CONTROL STRUCTURE 46
MODEL STUDIES
Type CS46 R10 Control Structure Scale 1:12
Piezometric Pressures - Siphon Mode
Q_S = 375 cfs, H.W. = 119.3 ft, Gates Open = No.1&2
$T.W._1$ = 5.6 ft, $T.W._2$ = 6.0 ft

⊙ Pressures along Centerline of Siphon Riser
⊡ Pressures along Centerline of Tunnel No. 1
△ Pressures along Centerline of Tunnel No. 2

SAINT ANTHONY FALLS HYDRAULIC LABORATORY UNIVERSITY OF MINNESOTA		
DRAWN BB	CHECKED	APPROVED
SCALE	DATE 3/1/84	NO. 328B514- 53

CHART 67



ROCHESTER CONTROL STRUCTURE 46
MODEL STUDIES
Type CS46 R10 Control Structure Scale 1:12
Piezometric Pressures - Siphon Mode
Q_S = 200 cfs, H.W. = 120.3 ft, Gates Open =None
$T.W._1$ = N/A ft, $T.W._2$ = N/A ft

⊙ Pressures along Centerline
◇ Pressure at tap 30
✕ Pressure at tap 31
＋ Pressure at tap 32

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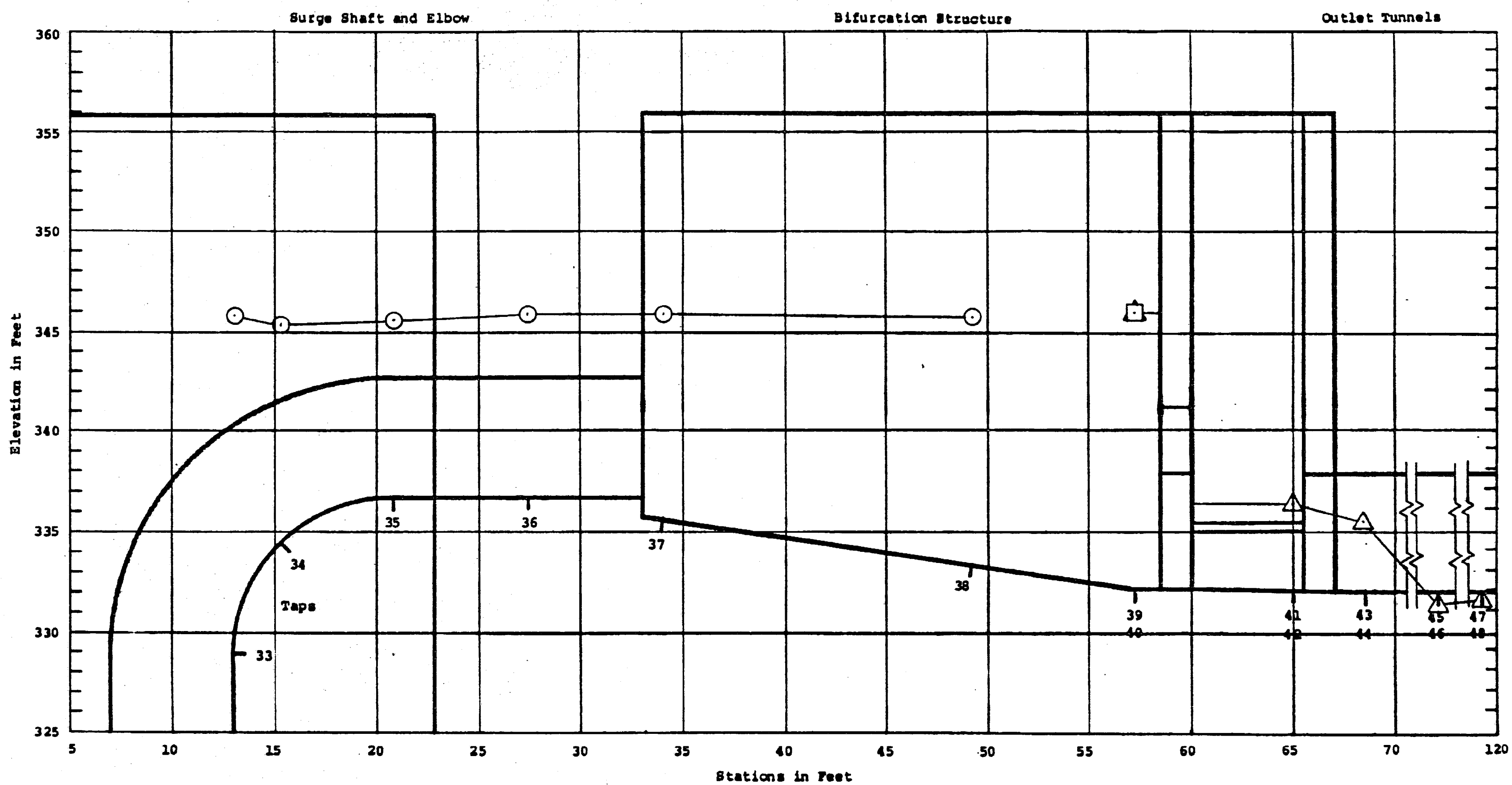
DRAWN BB	CHECKED [signature]	APPROVED
SCALE	DATE 3/1/84	NO. 328B514-41

CHART 68



ROCHESTER CONTROL STRUCTURE 46
MODEL STUDIES
Type CS46 R10 Control Structure Scale 1:12
Piezometric Pressures - Siphon Mode
Q_S = 200 cfs, H.W. = 120.3 ft, Gates Open = None
$T.W._1$ = N/A ft, $T.W._2$ =N/A ft

CHART 69

⊙ Pressures along Centerline of Siphon Riser
⊡ Pressures along Centerline of Tunnel No. 1
△ Pressures along Centerline of Tunnel No. 2

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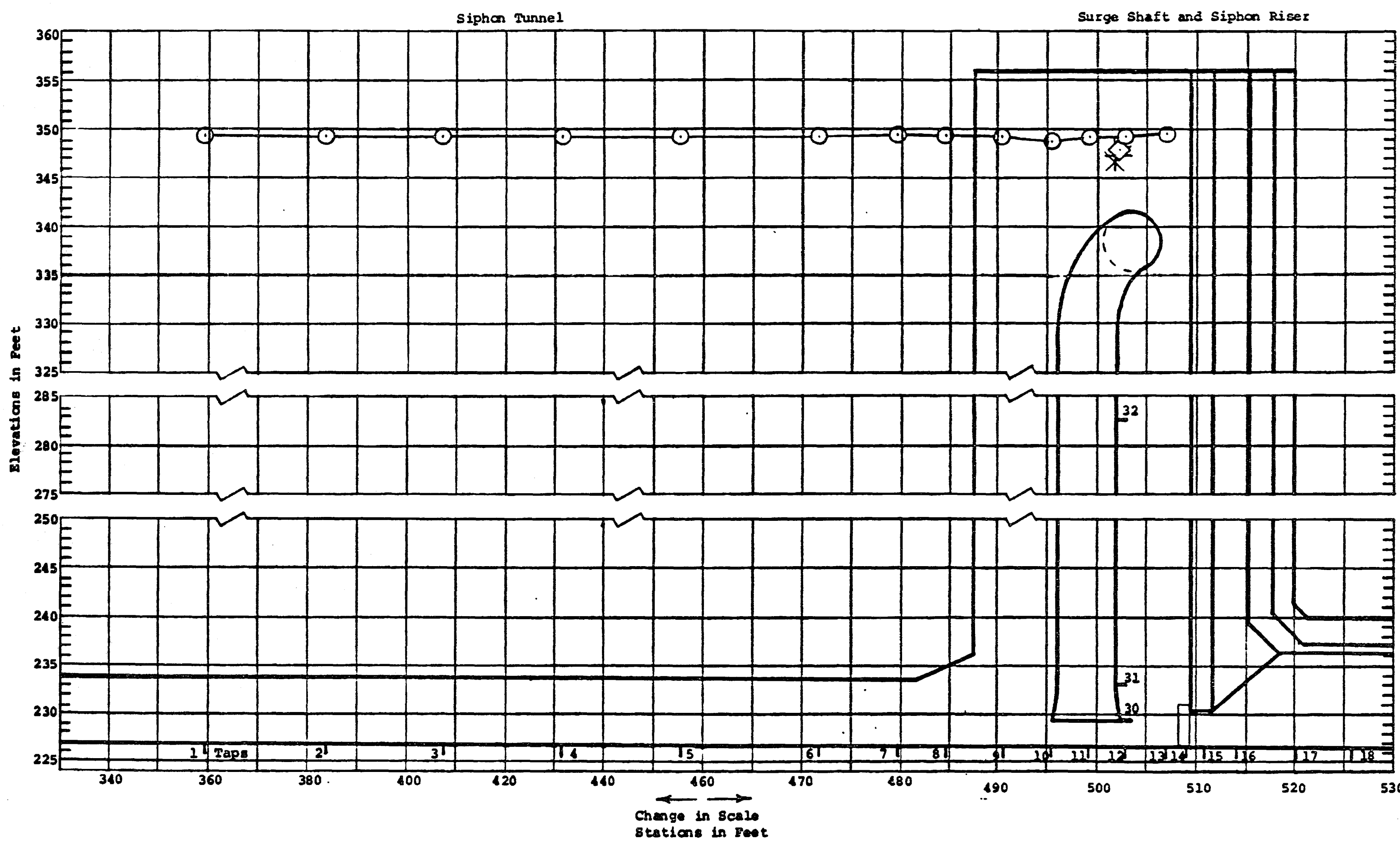
UNIVERSITY OF MINNESOTA

DRAWN BR	CHECKED	APPROVED
SCALE	DATE 3/1/84	NO. 328B514- 54



ROCHESTER CONTROL STRUCTURE 46
MODEL STUDIES
Type CS46 R10 Control Structure Scale 1:12
Piezometric Pressures - Siphon Mode
Q_S = 250 cfs, H.W. = 122.3 ft, Gates Open = None
$T.W._1$ = N/A ft, $T.W._2$ = N/A ft

⊙ Pressures along Centerline
◇ Pressure at tap 30
✕ Pressure at tap 31
+ Pressure at tap 32

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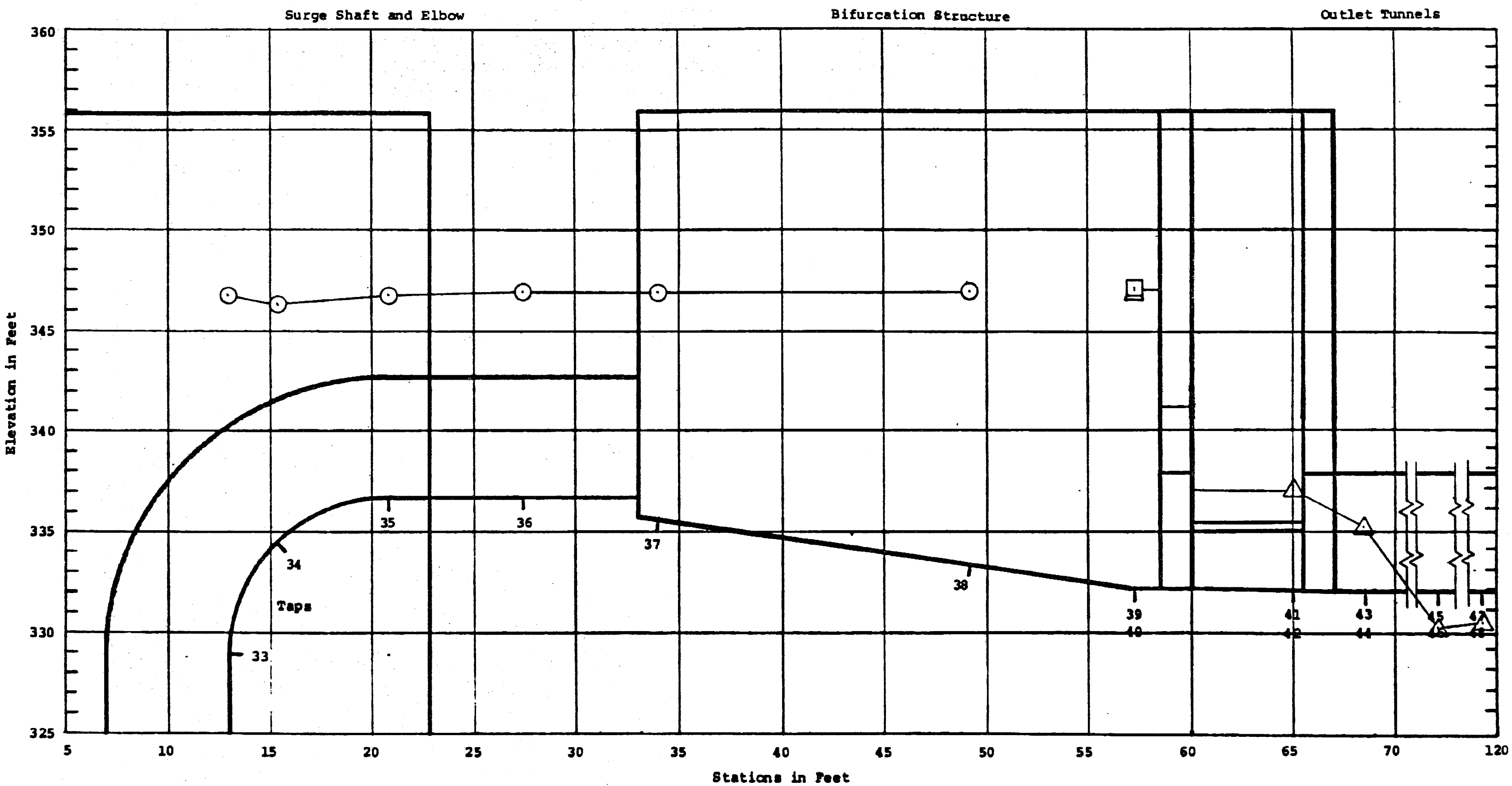
UNIVERSITY OF MINNESOTA

DRAWN BB	CHECKED	APPROVED
SCALE	DATE 3/1/84	NO. 328B514-42

CHART 70



ROCHESTER CONTROL STRUCTURE 46
MODEL STUDIES
Type CS46 R10 Control Structure Scale 1:12
Piezometric Pressures - Siphon Mode
Q_s = 250 cfs, H.W. = 122.3 ft, Gates Open = None
$T.W._1$ = N/A ft, $T.W._2$ = N/A ft

⊙ Pressures along Centerline of Siphon Riser
⊡ Pressures along Centerline of Tunnel No. 1
△ Pressures along Centerline of Tunnel No. 2

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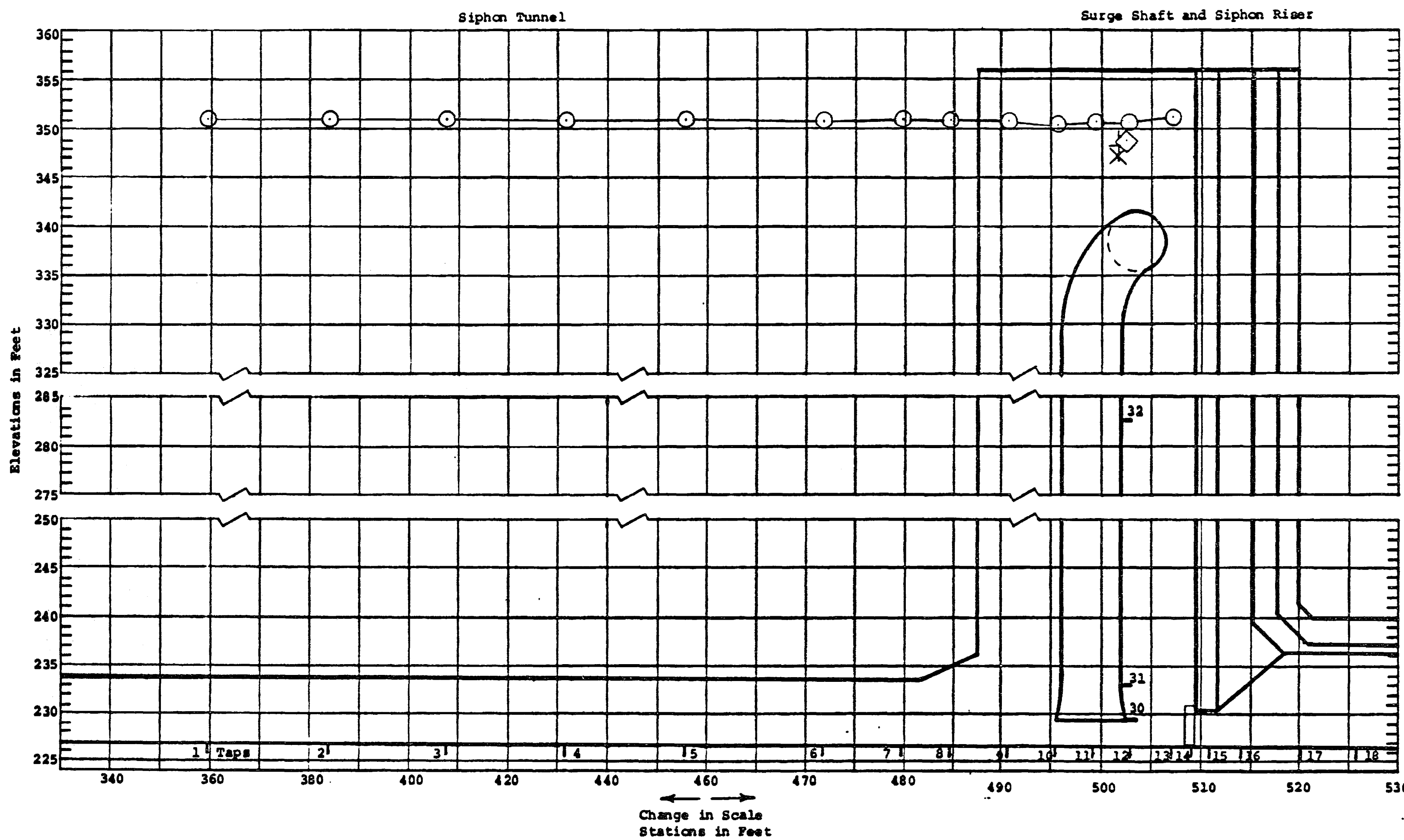
DRAWN RR	CHECKED	APPROVED
SCALE	DATE 3/1/84	NO. 328B514- 55

CHART 71



ROCHESTER CONTROL STRUCTURE 46
MODEL STUDIES
Type CS46 R10 Control Structure Scale 1:12
Piezometric Pressures - Siphon Mode
Q_S = 300 cfs, H.W. = 123.9 ft, Gates Open = None
$T.W._1$ = N/A ft, $T.W._2$ = N/A ft

CHART 72

- ⊙ Pressures above Centerline
- ◇ Pressure at tap 30
- × Pressure at tap 31
- + Pressure at tap 32

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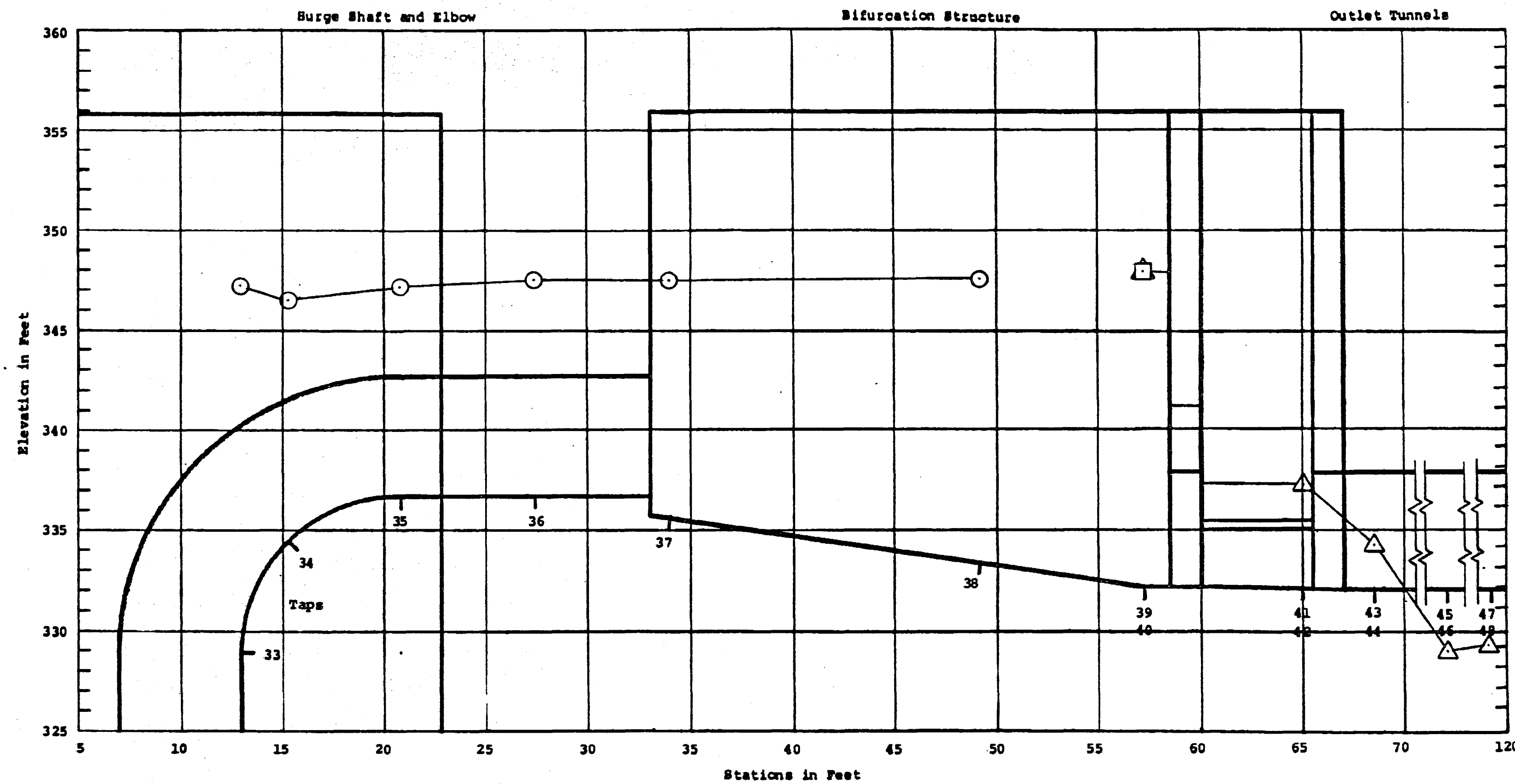
DRAWN BB	CHECKED [signature]	APPROVED
SCALE	DATE 3/1/84	NO. 328B514- 43



ROCHESTER CONTROL STRUCTURE 46
MODEL STUDIES
Type CS46 R10 Control Structure Scale 1:12
Piezometric Pressures - Siphon Mode
Q_S = 300 cfs, H.W. = 123.9 ft, Gates Open = None
$T.W._1$ = N/A ft, $T.W._2$ = N/A ft

⊙ Pressures along Centerline of Siphon Riser
⊡ Pressures along Centerline of Tunnel No. 1
△ Pressures along Centerline of Tunnel No. 2

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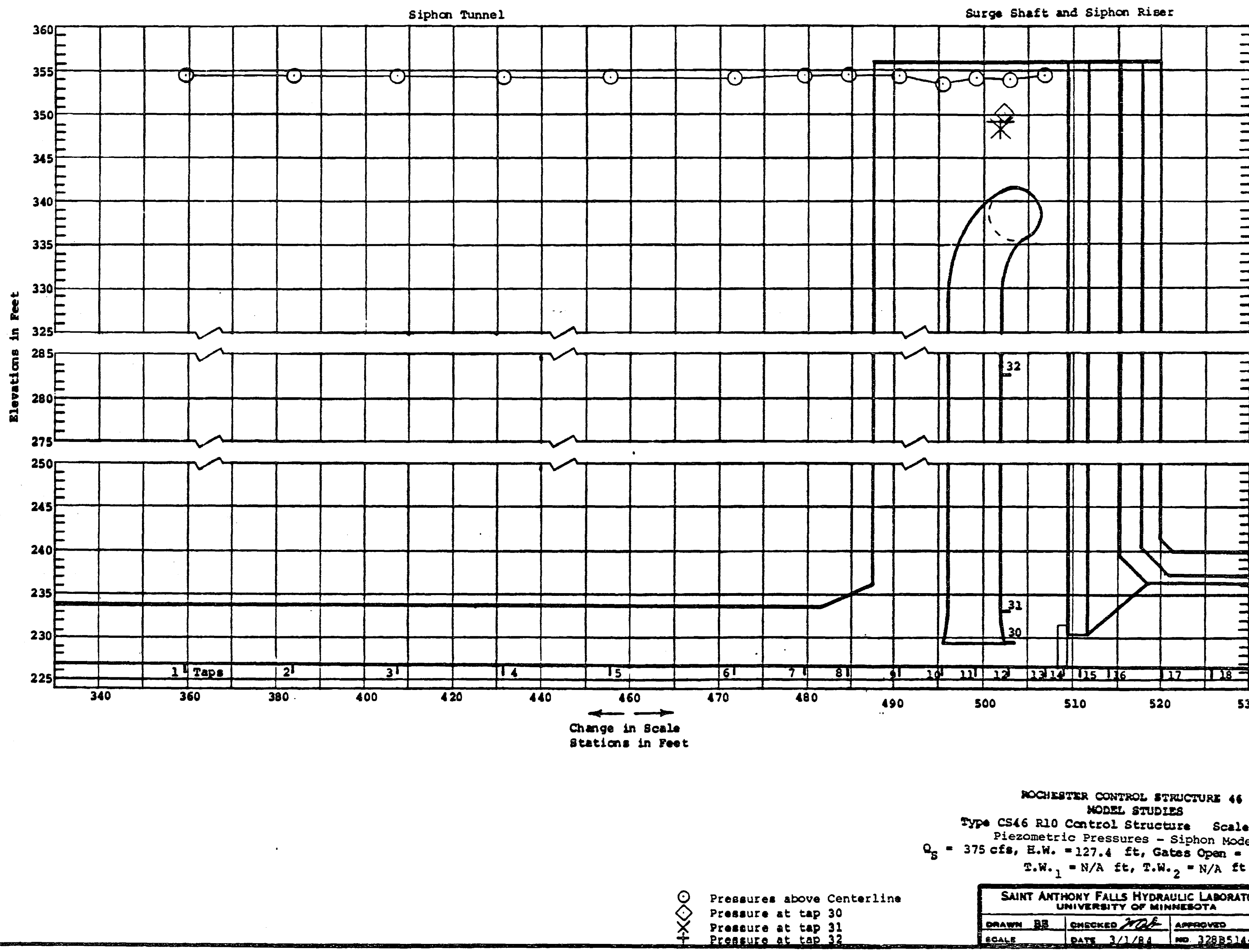
DRAWN BB	CHECKED [signature]	APPROVED
SCALE	DATE 3/1/84	NO. 328B514-56

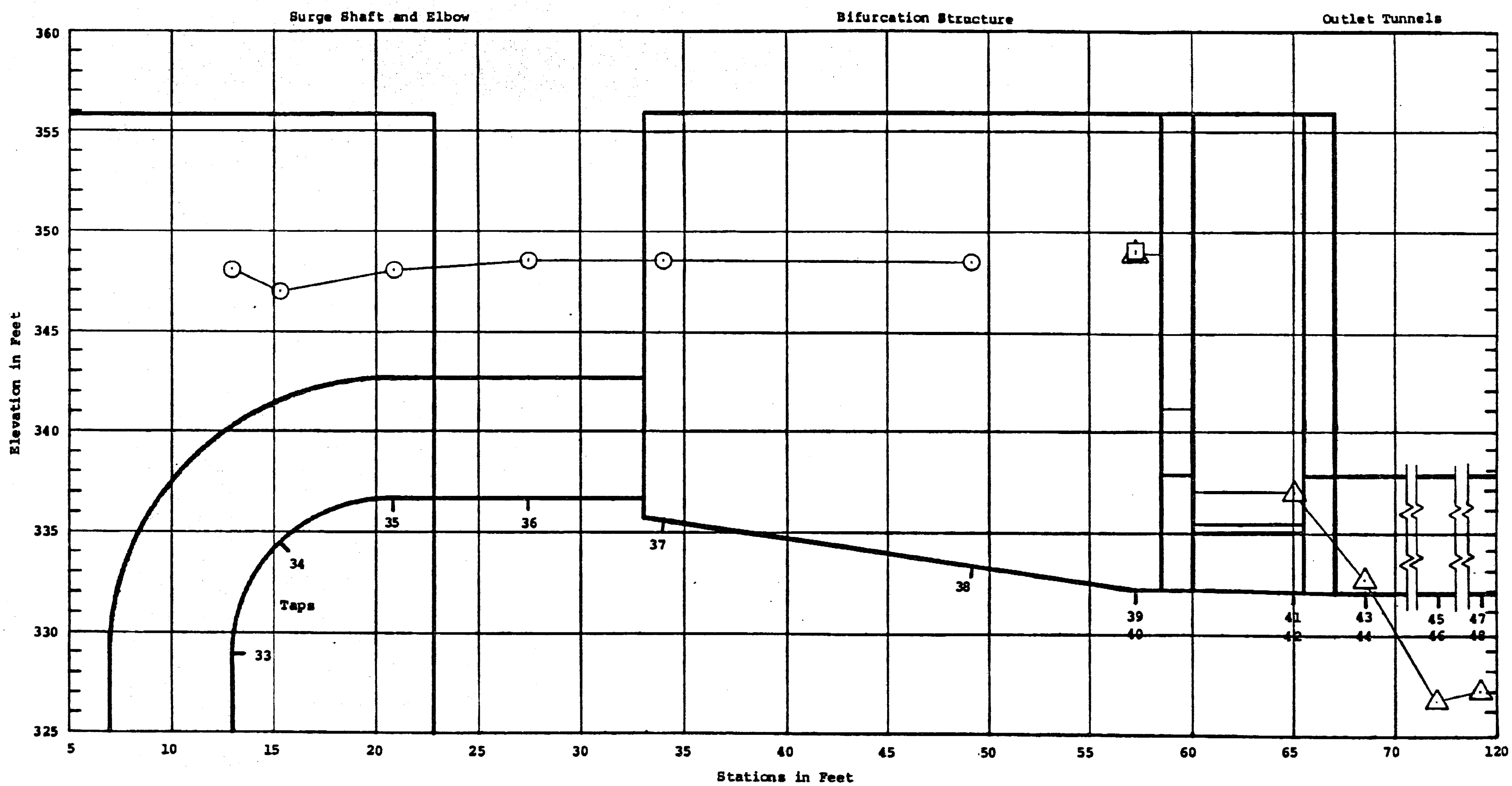
CHART 73



ROCHESTER CONTROL STRUCTURE 46
MODEL STUDIES
Type CS46 R10 Control Structure Scale 1:12
Piezometric Pressures - Siphon Mode
Q_S = 375 cfs, H.W. = 127.4 ft, Gates Open = None
T.W.$_1$ = N/A ft, T.W.$_2$ = N/A ft

SAINT ANTHONY FALLS HYDRAULIC LABORATORY UNIVERSITY OF MINNESOTA		
DRAWN BB	CHECKED [signature]	APPROVED
SCALE	DATE 3/1/84	NO. 328B514- 44

CHART 74



ROCHESTER CONTROL STRUCTURE 46
MODEL STUDIES
Type CS46 R10 Control Structure Scale 1:12
Piezometric Pressures - Siphon Mode
Q_s = 375 cfs, H.W. = 127.4 ft, Gates Open = None
$T.W._1$ = N/A ft, $T.W._2$ = N/A ft

⊙ Pressures along Centerline of Siphon Riser
⊡ Pressures along Centerline of Tunnel No. 1
△ Pressures along Centerline of Tunnel No. 2

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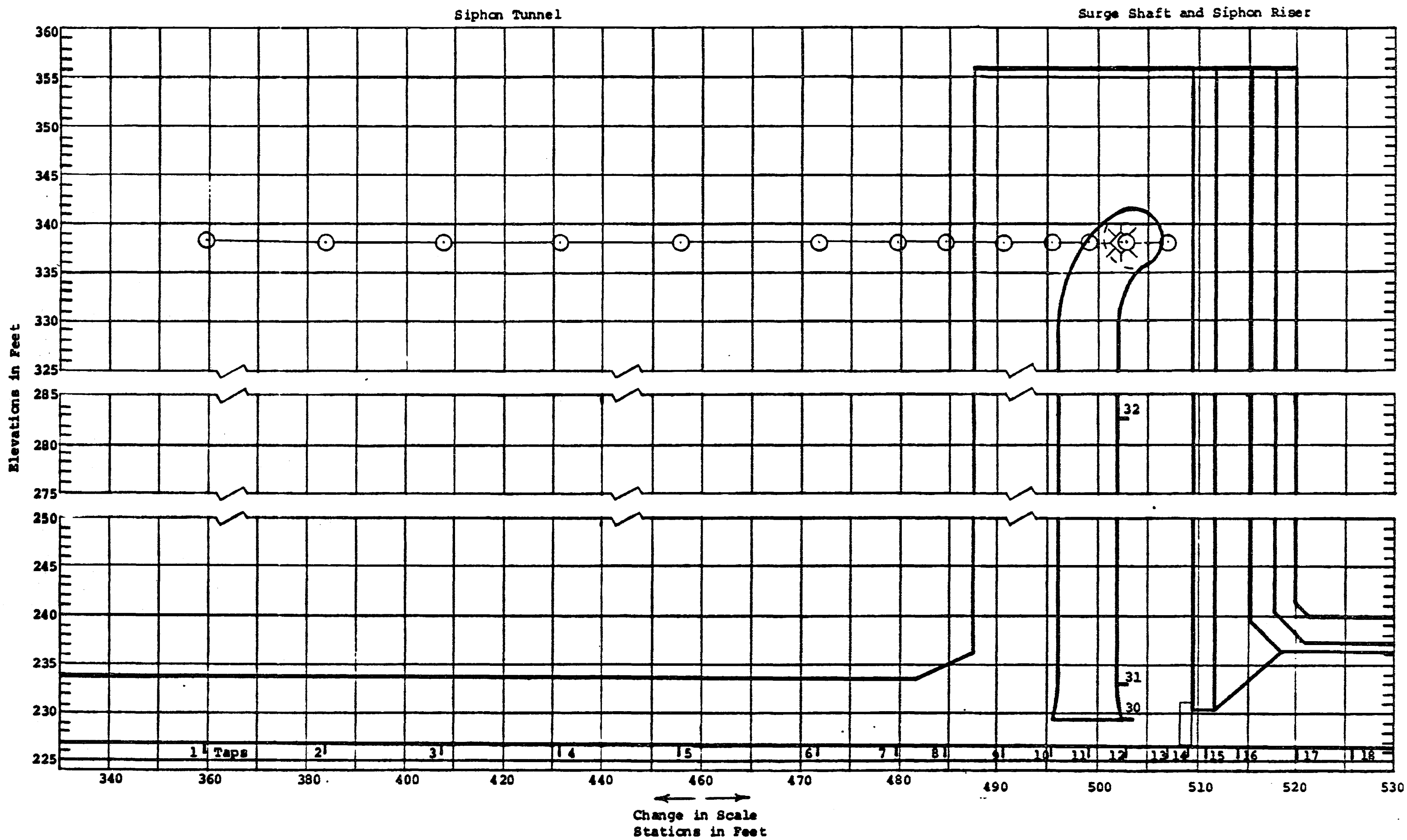
DRAWN BB	CHECKED	APPROVED
SCALE	DATE 3/1/84	NO. 328B514-57

CHART 75



ROCHESTER CONTROL STRUCTURE 46
MODEL STUDIES
Type CS46 R10 Control Structure Scale 1:12
Piezometric Pressures - Siphon Mode
Q_S = 16 cfs, H.W. = 111.0 ft, Gates Open = No.1
$T.W._1$ = 4.7 ft, $T.W._2$ = 0 ft

⊙ Pressures at Centerline
◇ Pressure at tap 30
✕ Pressure at tap 31
+ Pressure at tap 32

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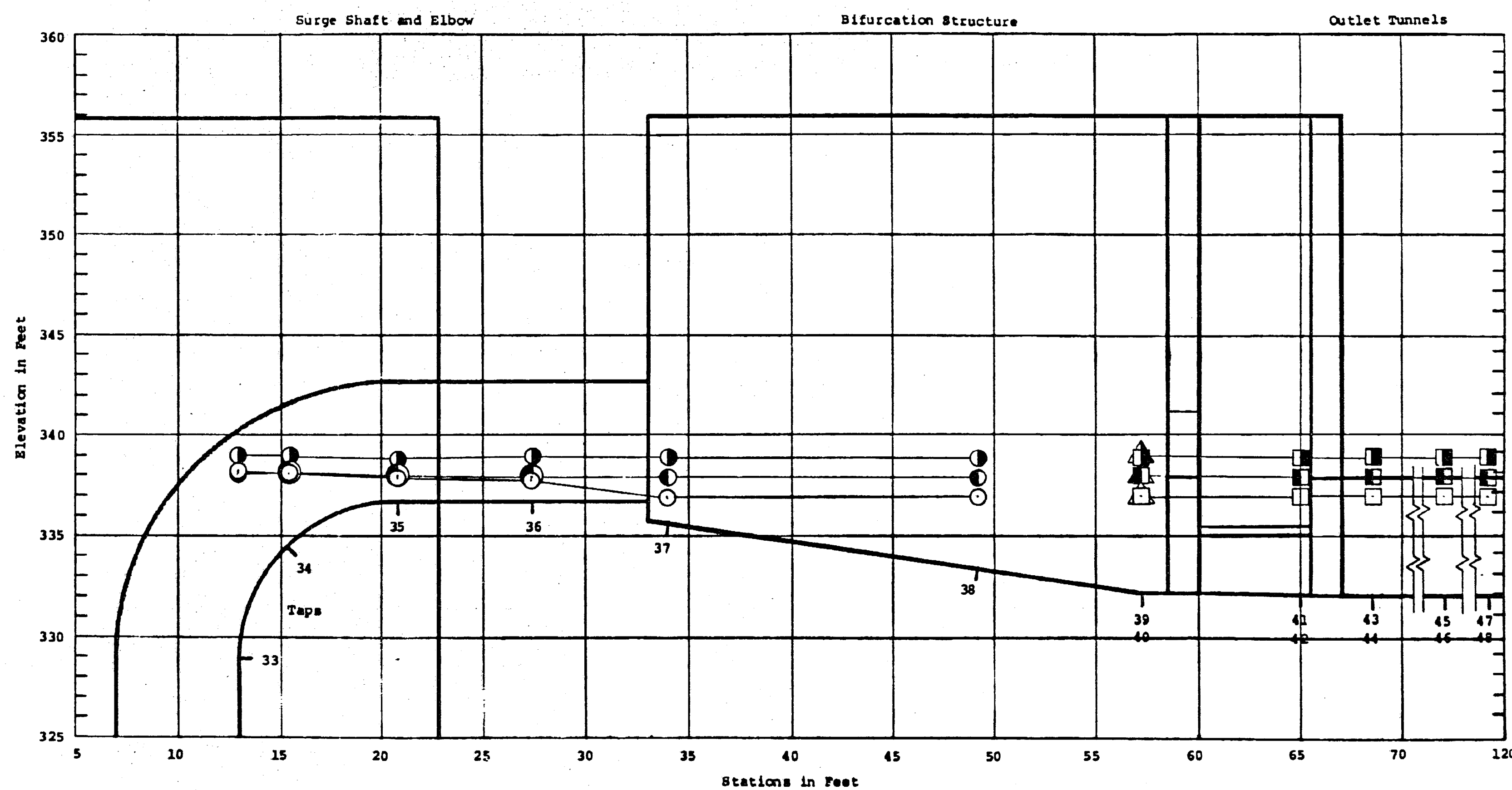
DRAWN BB	CHECKED [signature]	APPROVED
SCALE	DATE 3/1/84	NO. 328B514- 45

CHART 76



T.W.₁	T.W.₂	Symbol

ROCHESTER CONTROL STRUCTURE 46
MODEL STUDIES
Type CS46 R10 Control Structure Scale 1:12
Piezometric Pressures - Siphon Mode
Q_S = 16 cfs, H.W. = 111.0 ft, Gates Open = No.1

$T.W._1$ = 4.7 ft, $T.W._2$ = 0 ft

$T.W._1$ = [illegible].7 ft, $T.W._2$ = 0 ft

$T.W._1$ = 6.[illegible] ft, $T.W._2$ = 0 ft

Pressures along Centerline of Siphon Riser
Pressures along Centerline of Tunnel No. 1
Pressures along Centerline of Tunnel No. 2

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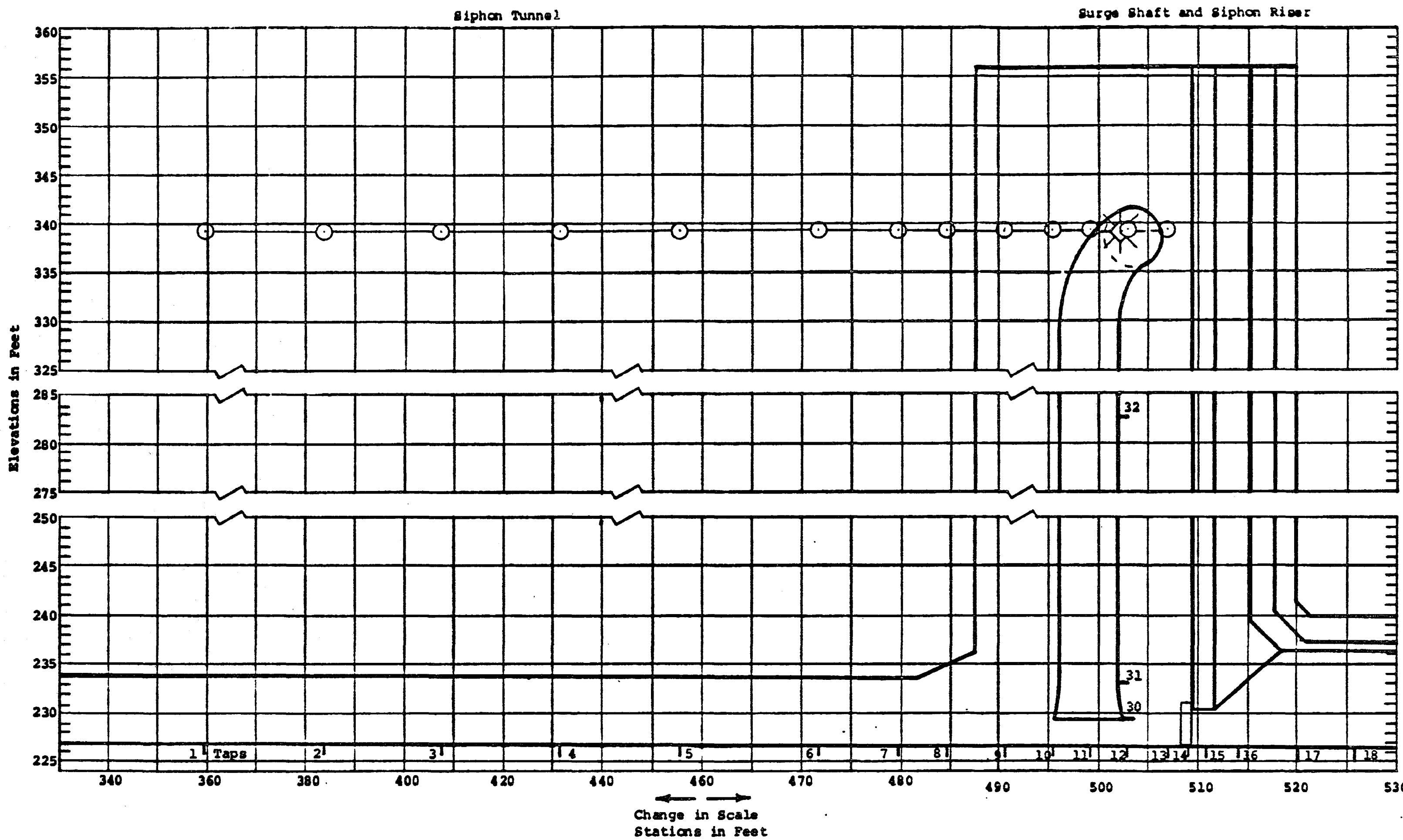
DRAWN BB	CHECKED MQF	APPROVED
SCALE	DATE 3/1/84	NO 328B514-58

CHART 77

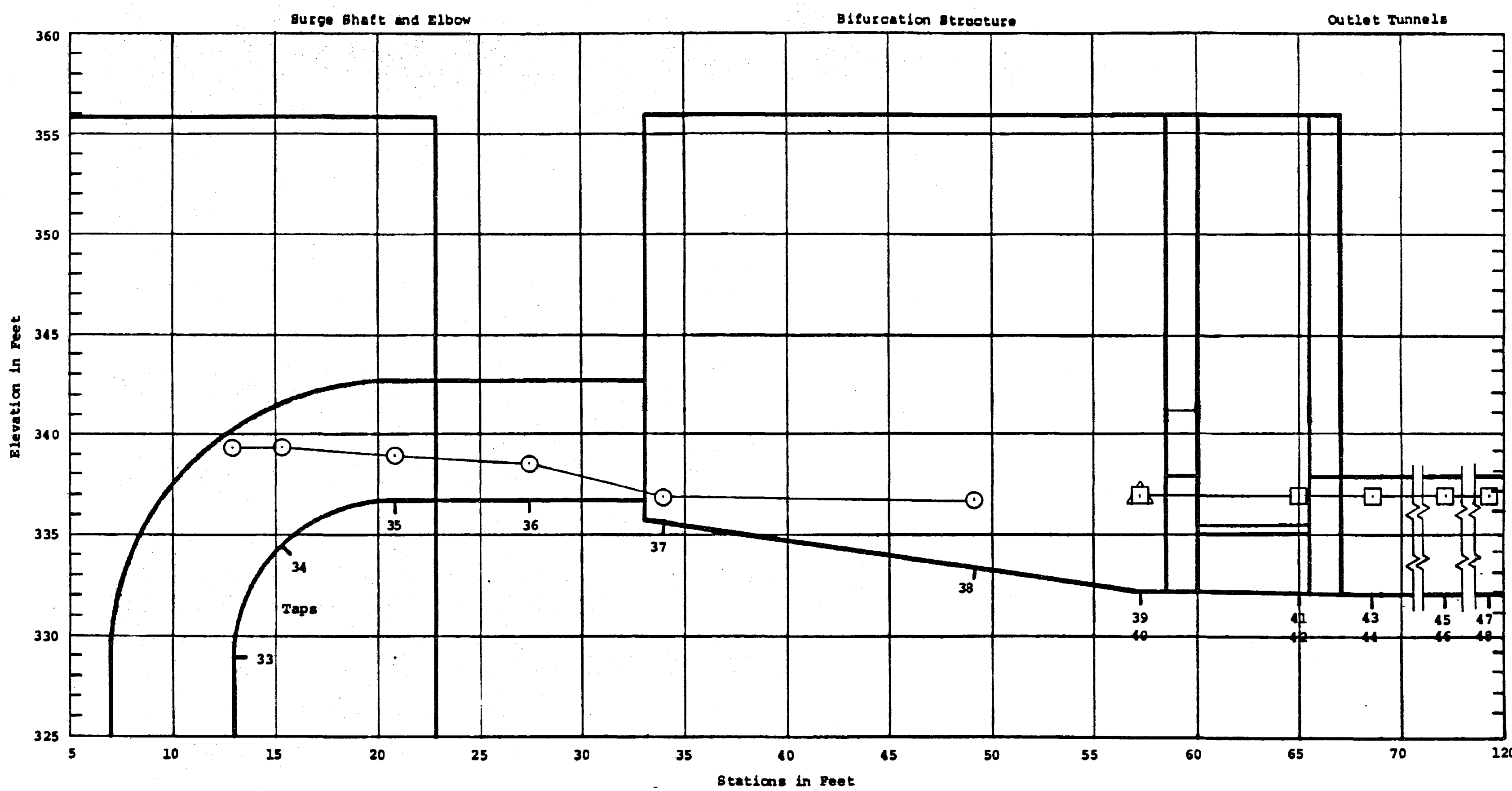


ROCHESTER CONTROL STRUCTURE 46
MODEL STUDIES
Type CS46 R10 Control Structure Scale 1:12
Piezometric Pressures - Siphon Mode
Q_g = 50 cfs, H.W. = 112.2 ft, Gates Open = No.1
$T.W._1$ = 4.7 ft, $T.W._2$ = 0 ft

⊙ Pressures above Centerline
◇ Pressure at tap 30
✕ Pressure at tap 31
+ Pressure at tap 32

SAINT ANTHONY FALLS HYDRAULIC LABORATORY UNIVERSITY OF MINNESOTA		
DRAWN BB	CHECKED [illegible]	APPROVED
SCALE	DATE 3/1/84	NO. 328B514- 46

CHART 78



ROCHESTER CONTROL STRUCTURE 46
MODEL STUDIES
Type CS46 R10 Control Structure Scale 1:12
Piezometric Pressures - Siphon Mode
Q_s = 50 cfs, H.W. = 112.2 ft, Gates Open = No. 1
$T.W._1$ = 4.7 ft, $T.W._2$ = 0 ft

⊙ Pressures along Centerline of Siphon Riser
⊡ Pressures along Centerline of Tunnel No. 1
△ Pressures along Centerline of Tunnel No. 2

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DRAWN BB	CHECKED [signature]	APPROVED
SCALE	DATE 3/1/84	NO. 328B514- 59

CHART 79

Pressure Readings - Siphon Mode

Tap Number	Station (ft)	Tap Elevation (ft)	Design Condition No. 1, Q_S = 50 cfs, H.W. = 112.4 ft, Gates Open=No. 2 (Right), $T.W._1$ = 0.0 ft, $T.W._2$ = 2.3 ft: Piezometric Pressure Elevation (ft)	Pressure at Tap (ft)	Design Condition No. 1, Q_S = 100 cfs, H.W. = 113.8 ft, Gates Open=No. 2 (Right), $T.W._1$ = 0.0 ft, $T.W._2$ = 3.4 ft: Piezometric Pressure Elevation (ft)	Pressure at Tap (ft)
1	359.81	227.10	339.5	112.4	340.9	113.8
2	383.81	226.95	339.3	112.4	340.6	113.7
3	407.81	226.80	339.5	112.7	340.8	114.0
4	431.81	226.66	339.5	112.8	340.8	114.1
5	455.81	226.51	339.4	112.9	340.8	114.3
6	471.81	226.42	339.2	112.8	340.6	114.2
7	479.81	226.37	339.3	112.9	340.8	114.4
8	484.81	226.34	339.5	113.2	340.8	114.5
9	490.81	226.30	339.4	113.1	340.8	114.5
10	495.56	226.27	339.4	113.1	340.7	114.4
11	499.31	226.25	339.4	113.2	340.7	114.5
12	503.06	226.22	339.4	113.2	340.7	114.5
13	507.06	226.20	339.4	113.2	340.8	114.6
30	13.75	229.64	339.3	109.7	340.5	110.9
31	13.00	232.75	339.3	106.6	340.4	107.7
32	13.00	282.85	339.3	56.5	340.4	57.6
33	13.00	328.95	339.8	10.8	340.5	11.5
34	15.27	334.43	339.4	5.0	340.3	5.9
35	20.75	336.70	338.9	2.2	339.8	3.1
36	27.58	336.70	338.5	1.8	339.3	2.6
37	34.15	335.56	335.9	0.3	335.8	0.2
38	48.99	333.39	334.4	1.0	335.6	2.2
39	57.41	332.20	334.6	2.4	335.7	3.5
40	57.41	332.20	334.7	2.5	335.9	3.7
41	65.16	332.19		0.0		0.0
42	65.16	332.19	334.5	2.3	335.6	3.4
43*	68.66	332.18		0.0		0.0
44**	68.66	332.18	334.5	2.3	335.6	3.4
45	88.66	332.15		0.0		0.0
46	88.66	332.15	334.5	2.3	335.6	3.4
47	108.66	332.12		0.0		0.0
48	108.66	332.12	334.4	2.3	335.6	3.5

*Tailwater location for tunnel no. 1 (left side).

**Tailwater location for tunnel no. 2 (right side).

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MODEL STUDIES
Type CS46 R10 Control Structure
Scale 1:12
Pressure Readings - Siphon Mode

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DRAWN KL	CHECKED MR	APPROVED
SCALE	DATE 4/30/84	NO. 328A2323-15

Pressure Readings - Siphon Mode

Design Condition No. 1
Q_s = 150 cfs
H.W. = 114.9 ft
Gates Open = No. 2 (Right)
$T.W._1$ = 0.0 ft
$T.W._2$ = 4.4 ft

Tap Number	Station ft	Tap Elevation ft	Piezometric Pressure Elevation ft	Pressure at Tap ft
1	359.81	227.10	342.0	114.9
2	383.81	226.95	341.9	115.0
3	407.81	226.80	341.9	115.1
4	431.81	226.66	341.9	115.2
5	455.81	226.51	341.9	115.4
6	471.81	226.42	341.8	115.4
7	479.81	226.37	341.9	115.5
8	484.81	226.34	341.9	115.6
9	490.81	226.30	341.9	115.6
10	495.56	226.27	341.8	115.5
11	499.31	226.25	341.8	115.6
12	503.06	226.22	341.9	115.7
13	507.06	226.20	341.9	115.7
30	13.75	229.64	341.3	111.7
31	13.00	232.75	341.1	108.4
32	13.00	282.85	341.2	58.4
33	13.00	328.95	341.3	12.3
34	15.27	334.43	340.9	6.5
35	20.75	336.70	340.5	3.8
36	27.58	336.70	339.9	3.2
37	34.15	335.56	336.9	1.3
38	48.99	333.39	336.7	3.3
39	57.41	332.20	336.9	4.7
40	57.41	332.20	337.0	4.8
41	65.16	332.19		0.0
42	65.16	332.19	336.7	4.5
43*	68.66	332.18		0.0
44**	68.66	332.18	336.6	4.4
45	88.66	332.15		0.0
46	88.66	332.15	336.6	4.4
47	108.66	332.12		0.0
48	108.66	332.12	336.5	4.4

*Tailwater location for tunnel no. 1 (left side).
**Tailwater location for tunnel no. 2 (right side).

ROCHESTER CONTROL STRUCTURE 46
MODEL STUDIES
Type CS46 R10 Control Structure
Scale 1:12
Pressure Readings - Siphon Mode

SAINT ANTHONY FALLS HYDRAULIC LABORATORY
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DRAWN KL	CHECKED MR	APPROVED
SCALE	DATE 4/30/84	NO. 328A2323-16

Pressure Readings - Siphon Mode

			Design Condition No. 2 Q_S = 200 cfs H.W. = 116.1 ft Gates Open=No. 1 & 2 $T.W._1$ = 4.8 ft $T.W._2$ = 4.1 ft		Design Condition No. 2 Q_S = 250 cfs H.W. = 117.3 ft Gates Open=No. 1 & 2 $T.W._1$ = 4.9 $T.W._2$ = 4.4 ft	
Tap Number	Station	Tap Elevation	Piezometric Pressure Elevation	Pressure at Tap	Piezometric Pressure Elevation	Pressure at Tap
	ft	ft	ft	ft	ft	ft
1	359.81	227.10	343.2	116.1	344.4	117.3
2	383.81	226.95	343.2	116.3	344.3	117.4
3	407.81	226.80	343.2	116.4	344.3	117.5
4	431.81	226.66	343.1	116.4	344.2	117 5
5	455.81	226.51	343.1	116.6	344.2	117.7
6	471.81	226.42	343.0	116.6	344.1	117.7
7	479.81	226.37	343.1	116.7	344.3	117.9
8	484.81	226.34	343.1	116.8	344.3	118.0
9	490.81	226.30	343.1	116.8	344.3	118.0
10	495.56	226.27	342.9	116.6	343.9	117.6
11	499.31	226.25	342.9	116.7	344.3	118.1
12	503.06	226.22	343.0	116.8	344.2	118.0
13	507.06	226.20	343.2	117.0	344.4	118.2
30	13.75	229.64	342.4	112.8	342.8	113.2
31	13.00	232.75	341.6	108.9	341.8	109.1
32	13.00	282.85	341.8	59.0	342.2	59.4
33	13.00	328.95	341.5	12.5	341.8	12.8
34	15.27	334.43	341.3	6.9	341.4	7.0
35	20.75	336.70	341.2	4.5	341.7	5.0
36	27.58	336.70	340.4	3.7	341.2	4.5
37	34.15	335.56	336.2	0.6	336.1	0.5
38	48.99	333.39	336.4	3.0	336.2	2.8
39	57.41	332.20	336.9	4.7	337.0	4.8
40	57.41	332.20	336.8	4.6	337.0	4.8
41	65.16	332.19	337.0	4.8	337.0	4.8
42	65.16	332.19	336.5	4.3	336.6	4.4
43*	68.66	332.18	337.0	4.8	337.1	4.9
44**	68.66	332.18	336.3	4.1	336.6	4.4
45	88.66	332.15	337.1	4.9	337.1	4.9
46	88.66	332.15	336.4	4.2	336.6	4.4
47	108.66	332.12	337.0	4.9	337.0	4.9
48	108.66	332.12	336.3	4.2	336.4	4.3

ROCHESTER CONTROL STRUCTURE 46
MODEL STUDIES
Type CS46 R10 Control Structure
Scale 1:12
Pressure Readings - Siphon Mode

*Tailwater location for tunnel no. 1 (left side).
**Tailwater location for tunnel no. 2 (right side).

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DRAWN KL	CHECKED MR	APPROVED
SCALE	DATE 4/30/84	NO. 328A2323-17

Pressure Readings - Siphon Mode

			Design Condition No. 2 Q_s = 300 cfs H.W. = 118.6 ft Gates Open = No. 1 & 2 $T.W._1$ = 5.1 ft $T.W._2$ = 4.8 ft		Design Condition No. 2 Q_s = 375 cfs H.W. = 119.3 ft Gates Open = No. 1 & 2 $T.W._1$ = 5.6 ft $T.W._2$ = 6.0 ft	
Tap Number	Station	Tap Elevation	Piezometric Pressure Elevation	Pressure at Tap	Piezometric Pressure Elevation	Pressure at Tap
	ft	ft	ft	ft	ft	ft
1	359.81	227.10	345.7	118.6	346.4	119.3
2	383.81	226.95	345.6	118.7	346.4	119.5
3	407.81	226.80	345.6	118.8	346.2	119.4
4	431.81	226.66	345.4	118.7	346.1	119.4
5	455.81	226.51	345.4	118.9	346.0	119.5
6	471.81	226.42	345.3	118.9	346.1	119.7
7	479.81	226.37	345.5	119.1	346.4	120.0
8	484.81	226.34	345.5	119.2	346.4	120.1
9	490.81	226.30	345.5	119.2	346.3	120.0
10	495.56	226.27	345.0	118.7	345.7	119.4
11	499.31	226.25	345.5	119.3	346.2	120.0
12	503.06	226.22	345.4	119.2	346.2	120.0
13	507.06	226.20	345.6	119.4	346.5	120.3
30	13.75	229.64	343.2	113.6	342.4	112.8
31	13.00	232.75	341.7	109.0	340.4	107.7
32	13.00	282.85	342.6	59.8	341.6	58.8
33	13.00	328.95	341.8	12.8	340.5	11.5
34	15.27	334.43	341.2	6.8	339.3	4.9
35	20.75	336.70	341.7	5.0	340.3	3.6
36	27.58	336.70	341.4	4.7	340.7	4.0
37	34.15	335.56	336.3	0.7	337.3	1.7
38	48.99	333.39	336.4	3.0	338.1	4.7
39	57.41	332.20	337.3	5.1	338.5	6.3
40	57.41	332.20	336.5	4.3	338.7	6.5
41	65.16	332.19	337.3	5.1	338.1	5.9
42	65.16	332.19	337.0	4.8	338.6	6.4
43*	68.66	332.18	337.3	5.1	337.8	5.6
44**	68.66	332.18	337.0	4.8	338.2	6.0
45	88.66	332.15	337.4	5.2	337.9	5.7
46	88.66	332.15	337.1	4.9	338.2	6.0
47	108.66	332.12	337.3	5.2	337.7	5.6
48	108.66	332.12	337.1	5.0	338.1	6.0

*Tailwater location for tunnel no. 1 (left side).
**Tailwater location for tunnel no. 2 (right side).

ROCHESTER CONTROL STRUCTURE 46
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Scale 1:12
Pressure Readings - Siphon Mode

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DRAWN KL	CHECKED MR	APPROVED
SCALE	DATE 4/30/84	NO. 328A2323-18

Pressure Readings - Siphon Mode

			Design Condition No. 3 Q_s = 200 cfs H.W. = 120.3 ft Gates Open = None $T.W._1$ = - ft $T.W._2$ = - ft		Design Condition No. 3 Q_s = 250 cfs H.W. = 122.3 ft Gates Open = None $T.W._1$ = - ft $T.W._2$ = - ft	
Tap Number	Station	Tap Elevation	Piezometric Pressure Elevation	Pressure at Tap	Piezometric Pressure Elevation	Pressure at Tap
	ft	ft	ft	ft	ft	ft
1	359.81	227.10	347.4	120.3	349.4	122.3
2	383.81	226.95	347.4	120.5	349.3	122.4
3	407.81	226.80	347.3	120.5	349.3	122.5
4	431.81	226.66	347.3	120.6	349.3	122.6
5	455.81	226.51	347.3	120.8	349.2	122.7
6	471.81	226.42	347.3	120.9	349.2	122.8
7	479.81	226.37	347.4	121.0	349.3	122.9
8	484.81	226.34	347.4	121.1	349.3	123.0
9	490.81	226.30	347.4	121.1	349.2	122.9
10	495.56	226.27	347.2	120.9	348.9	122.6
11	499.31	226.25	347.3	121.1	349.2	123.0
12	503.06	226.22	347.3	121.1	349.2	123.0
13	507.06	226.20	347.4	121.2	349.4	123.2
30	13.75	229.64	346.4	116.8	347.9	118.3
31	13.00	232.75	345.7	113.0	346.7	114.0
32	13.00	282.85	346.0	63.2	347.3	64.5
33	13.00	328.95	345.8	16.8	346.7	17.7
34	15.27	334.43	345.4	11.0	346.3	11.9
35	20.75	336.70	345.6	8.9	346.7	10.0
36	27.58	336.70	345.8	9.1	346.9	10.2
37	34.15	335.56	345.8	10.2	346.9	11.3
38	48.99	333.39	345.7	12.3	346.9	13.5
39	57.41	332.20	345.9	13.7	347.1	14.9
40	57.41	332.20	345.9	13.7	347.0	14.8
41	65.16	332.19		0.0		0.0
42	65.16	332.19	336.5	4.3	337.1	4.9
43*	68.66	332.18		0.0		0.0
44**	68.66	332.18	335.6	3.4	335.3	3.1
45	88.66	332.15		0.0		0.0
46	88.66	332.15	331.5	-0.7	330.2	-2.0
47	108.66	332.12		0.0		0.0
48	108.66	332.12	331.7	-0.4	330.5	-1.6

*Tailwater location for tunnel no. 1 (left side)
**Tailwater location for tunnel no. 2 (right side)

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MODEL STUDIES
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DRAWN KL	CHECKED MR	APPROVED
SCALE	DATE 4/30/84	NO. 328A2323-19

Pressure Readings - Siphon Mode

Tap Number	Station	Tap Elevation	Design Condition No. 3, Q_s = 300 cfs, H.W. = 123.9 ft, Gates Open = None, $T.W._1$ = - ft, $T.W._2$ = - ft: Piezometric Pressure Elevation	Pressure at Tap	Design Condition No. 3, Q_s = 375 cfs, H.W. = 127.4 ft, Gates Open = None, $T.W._1$ = - ft, $T.W._2$ = - ft: Piezometric Pressure Elevation	Pressure at Tap
	ft	ft	ft	ft	ft	ft
1	359.81	227.10	351.0	123.9	354.5	127.4
2	383.81	226.95	351.0	124.1	354.4	127.5
3	407.81	226.80	351.0	124.2	354.3	127.5
4	431.81	226.66	350.9	124.2	354.2	127.5
5	455.81	226.51	350.9	124.4	354.2	127.7
6	471.81	226.42	350.8	124.4	354.1	127.7
7	479.81	226.37	350.9	124.5	354.4	128.0
8	484.81	226.34	350.9	124.6	354.5	128.2
9	490.81	226.30	350.9	124.6	354.4	128.1
10	495.56	226.27	350.5	124.2	353.5	127.2
11	499.31	226.25	350.8	124.6	354.1	127.9
12	503.06	226.22	350.8	124.6	354.0	127.8
13	507.06	226.20	351.1	124.9	354.5	128.3
30	13.75	229.64	348.7	119.1	350.3	120.7
31	13.00	232.75	347.4	114.7	348.3	115.6
32	13.00	282.85	348.2	65.4	349.4	66.6
33	13.00	328.95	347.3	18.3	348.1	19.1
34	15.27	334.43	346.6	12.2	347.0	12.6
35	20.75	336.70	347.2	10.5	348.0	11.3
36	27.58	336.70	347.6	10.9	348.5	11.8
37	34.15	335.56	347.6	12.0	348.5	12.9
38	48.99	333.39	347.6	14.2	348.4	15.0
39	57.41	332.20	347.9	15.7	349.0	16.8
40	57.41	332.20	347.9	15.7	348.9	16.7
41	65.16	332.19		0.0		0.0
42	65.16	332.19	337.3	5.1	337.1	4.9
43*	68.66	332.18		0.0		0.0
44**	68.66	332.18	334.2	2.0	332.7	0.5
45	88.66	332.15		0.0		0.0
46	88.66	332.15	329.0	-3.2	326.7	-5.5
47	108.66	332.12		0.0		0.0
48	108.66	332.12	329.4	-2.7	327.0	-5.1

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*Tailwater location for tunnel no. 1 (left side).
**Tailwater location for tunnel no. 2 (right side).

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DRAWN KL	CHECKED MR	APPROVED
SCALE	DATE 4/30/84	NO. 328A2323-20

Pressure Readings - Siphon Mode

Tap Number	Station	Tap Elevation	Design Condition No. 4, Q_s = 16 cfs, H.W. = 111.0 ft, Gates Open=No. 1 (left), $T.W._1$ = 4.7 ft, $T.W._2$ = 0.0 ft — Piezometric Pressure Elevation	Pressure at Tap	Design Condition No. 4, Q_s = 50 cfs, H.W. = 112.2, Gates Open=No. 1 (left), $T.W._1$ = 4.7 ft, $T.W._2$ = 0.0 ft — Piezometric Pressure Elevation	Pressure at Tap
	ft	ft	ft	ft	ft	ft
1	359.81	227.10	338.1	111.0	339.3	112.2
2	383.31	226.95	338.0	111.1	339.3	112.4
3	407.81	226.80	338.0	111.2	339.3	112.5
4	431.81	226.66	338.0	111.3	339.3	112.6
5	455.81	226.51	338.0	111.5	339.3	112.8
6	471.81	226.42	338.0	111.6	339.3	112.9
7	479.81	226.37	338.0	111.6	339.3	112.9
8	484.81	226.34	338.0	111.7	339.3	113.0
9	490.81	226.30	338.0	111.7	339.3	113.0
10	495.56	226.27	338.0	111.7	339.3	113.0
11	499.31	226.25	338.0	111.8	339.3	113.1
12	503.06	226.22	338.0	111.8	339.3	113.1
13	507.06	226.20	338.0	111.8	339.3	113.1
30	13.75	229.64	338.0	108.4	339.2	109.6
31	13.00	232.75	338.0	105.3	339.2	106.5
32	13.00	282.85	338.0	55.2	339.2	56.4
33	13.00	328.95	338.2	9.2	339.3	10.3
34	15.27	334.43	338.2	3.8	338.3	4.9
35	20.75	336.70	337.9	1.2	338.9	2.2
36	27.58	336.70	337.6	0.9	338.5	1.8
37	34.15	335.56	337.0	1.4	336.8	1.2
38	48.99	333.39	337.0	3.6	336.7	3.3
39	57.41	332.20	337.0	4.8	336.9	4.7
40	57.41	332.20	337.0	4.8	336.8	4.6
41	65.16	332.19	337.0	4.8	336.9	4.7
42	65.16	332.19		0.0		0.0
43*	68.66	332.18	336.9	4.7	336.9	4.7
44**	68.66	332.18		0.0		0.0
45	88.66	332.15	336.9	4.8	336.9	4.8
46	88.66	332.15		0.0		0.0
47	108.66	332.12	336.9	4.8	336.9	4.8
48	108.66	332.12		0.0		0.0

*Tailwater location for tunnel no. 1 (left side).
**Tailwater location for tunnel no. 2 (right side).

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MODEL STUDIES
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DRAWN KL	CHECKED MR	APPROVED
SCALE	DATE 4/30/84	NO. 328A2323-21

Pressure Readings - Siphon Mode

Tap Number	Tap Station	Tap Elevation	Design Condition No. 1, Q_s = 150 cfs, H.W. = 114.9 ft, Gates Open=No. 2 (Right), $T.W._1$ = 0.0 ft, $T.W._2$ = 5.4 ft — Piezometric Pressure Elevation	Pressure at Tap	Design Condition No. 1, Q_s = 150 cfs, H.W. = 114.9 ft, Gates Open=No. 2 (Right), $T.W._1$ = 0.0 ft, $T.W._2$ = 6.4 ft — Piezometric Pressure Elevation	Pressure at Tap
	ft	ft	ft	ft	ft	ft
33	13.00	328.95	341.0	12.0	341.0	12.0
34	15.27	334.43	340.9	6.5	340.9	6.5
35	20.75	336.70	340.6	3.9	340.6	3.9
36	28.16	336.70	339.9	3.2	339.9	3.2
37	34.12	335.56	337.1	1.5	338.5	2.9
38	48.99	333.39	337.5	4.1	338.4	5.0
39	58.91	332.20	337.6	5.4	338.7	6.5
40	58.91	332.20	337.9	5.7	339.0	6.8
41	63.66	332.19		0.0		0.0
42	63.66	332.19	337.8	5.6	338.8	6.6
43*	67.16	332.19		0.0		0.0
44**	67.16	332.19	337.6	5.4	338.6	6.4
45	87.16	332.16		0.0		0.0
46	87.16	332.16	337.7	5.5	338.6	6.4
47	107.16	332.13		0.0		0.0
48	107.16	332.13	337.6	5.5	338.5	6.4

*Tailwater location for tunnel no. 1 (left side).
**Tailwater location for tunnel no. 2 (right side).

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SAINT ANTHONY FALLS HYDRAULIC LABORATORY
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DRAWN KL	CHECKED MR	APPROVED
SCALE	DATE 4/30/84	NO. 328A2323-35

Pressure Readings - Siphon Mode

Tap Number	Tap Station ft	Tap Elevation ft	Design Condition No. 2, Q_s = 300 cfs, H.W. = 118.6 ft, Gates Open=No. 1 & 2, $T.W._1$ = 6.1 ft, $T.W._2$ = 5.8 ft — Piezometric Pressure Elevation ft	Pressure at Tap ft	Design Condition No. 2, Q_s = 300 cfs, H.W. = 118.6 ft, Gates Open=No. 1 & 2, $T.W._1$ = 7.1 ft, $T.W._2$ = 6.8 ft — Piezometric Pressure Elevation ft	Pressure at Tap ft
33	13.00	328.95	341.8	12.8	341.8	12.8
34	15.27	334.43	341.2	6.8	341.2	6.8
35	20.75	336.70	341.8	5.1	341.8	5.1
36	28.16	336.70	341.5	4.8	341.5	4.8
37	34.12	335.56	337.4	1.8	338.4	2.8
38	48.99	333.39	337.7	4.3	338.5	5.1
39	58.91	332.20	338.3	6.1	339.1	6.9
40	58.91	332.20	338.4	6.2	339.3	7.1
41	63.66	332.19	338.2	6.0	339.2	7.0
42	63.66	332.19	338.0	5.8	339.1	6.9
43*	67.16	332.19	338.3	6.1	339.3	7.1
44**	67.16	332.19	338.0	5.8	339.0	6.8
45	87.16	332.16	338.4	6.2	339.4	7.2
46	87.16	332.16	338.1	5.9	339.1	6.9
47	107.16	332.13	338.3	6.2	339.3	7.2
48	107.16	332.13	337.9	5.8	339.0	6.9

*Tailwater location for tunnel no. 1 (left side).
**Tailwater location for tunnel no. 2 (right side).

ROCHESTER CONTROL STRUCTURE 46
MODEL STUDIES
Type CS46 R10 Control Structure
Scale 1:12
Pressure Readings - Siphon Mode

SAINT ANTHONY FALLS HYDRAULIC LABORATORY, UNIVERSITY OF MINNESOTA		
DRAWN KL	CHECKED MR	APPROVED
SCALE	DATE 4/30/84	NO. 328A2323-36

Pressure Readings - Siphon Mode

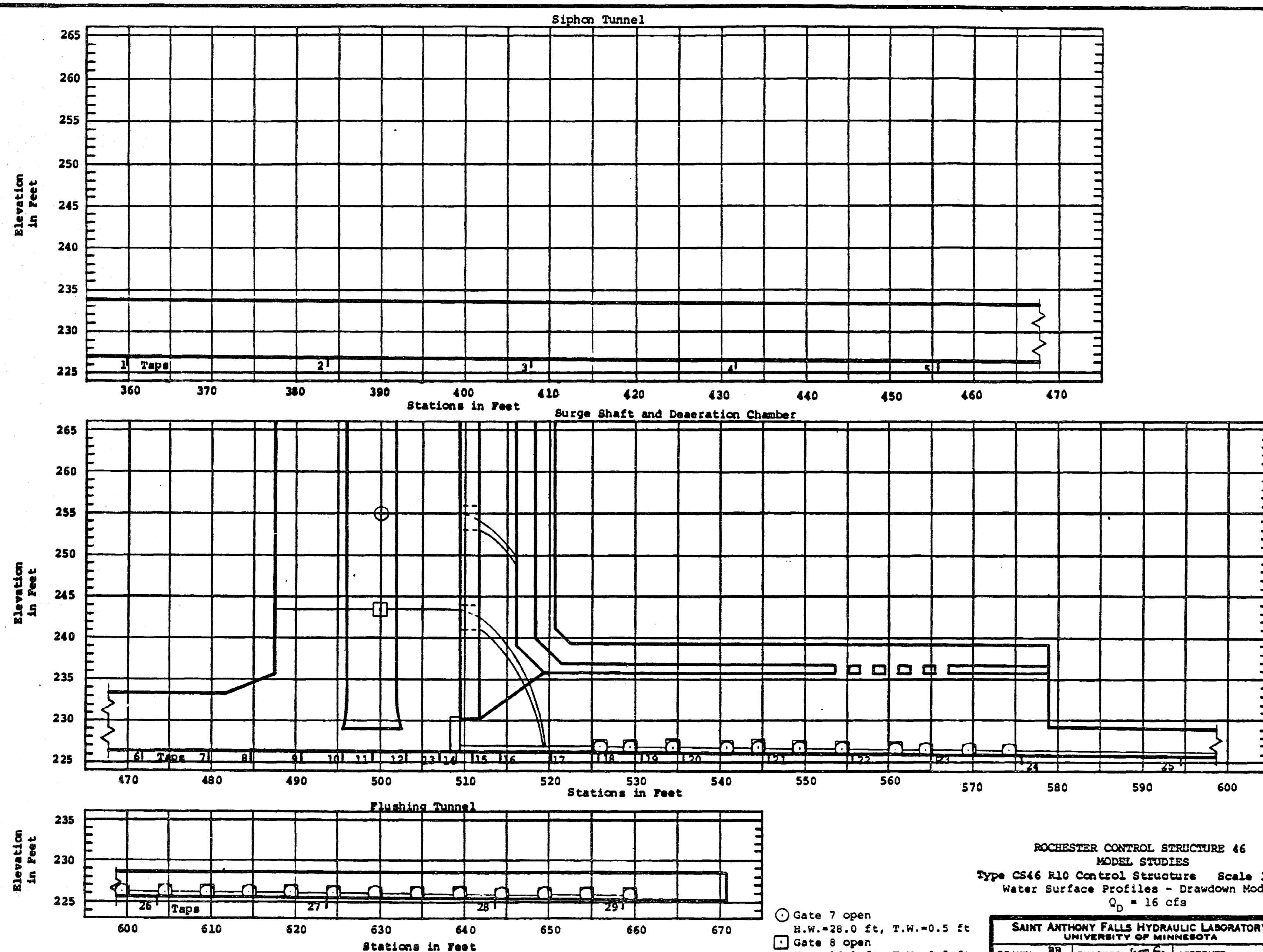
Tap Number	Tap Station	Tap Elevation	Design Condition No. 4, Q_s = 16 cfs, H.W. = 111.0 ft, Gates Open=No. 1 (Left), $T.W._1$ = 5.7 ft, $T.W._2$ = 0.0 ft: Piezometric Pressure Elevation	Pressure at Tap	Design Condition No. 4, Q_s = 16 cfs, H.W. = 111.0 ft, Gates Open=No. 1 (Left), $T.W._1$ = 6.7 ft, $T.W._2$ = 0.0 ft: Piezometric Pressure Elevation	Pressure at Tap
	ft	ft	ft	ft	ft	ft
33	13.00	328.95	338.1	9.1	339.0	10.0
34	15.27	334.43	338.2	3.8	339.0	4.6
35	20.75	336.70	338.0	1.3	338.9	2.2
36	28.16	336.70	337.9	1.2	339.0	2.3
37	34.12	335.56	337.9	2.3	338.9	3.3
38	48.99	333.39	337.9	4.5	338.9	5.5
39	58.91	332.20	338.0	5.8	338.9	6.7
40	58.91	332.20	338.0	5.8	339.0	6.8
41	63.66	332.19	337.9	5.7	338.9	6.7
42	63.66	332.19		0.0		0.0
43*	67.16	332.19	337.9	5.7	338.9	6.7
44**	67.16	332.19		0.0		0.0
45	87.16	332.16	337.9	5.7	338.9	6.7
46	87.16	332.16		0.0		0.0
47	107.16	332.13	337.9	5.8	338.9	6.8
48	107.16	332.13		0.0		0.0

*Tailwater location for tunnel no. 1 (left side).
**Tailwater location for tunnel no. 2 (right side).

ROCHESTER CONTROL STRUCTURE 46
MODEL STUDIES
Type CS46 R10 Control Structure
Scale 1:12
Pressure Readings - Siphon Mode

SAINT ANTHONY FALLS HYDRAULIC LABORATORY
UNIVERSITY OF MINNESOTA

DRAWN KL	CHECKED MR	APPROVED
SCALE	DATE 4/30.84	NO. 328A2323-37

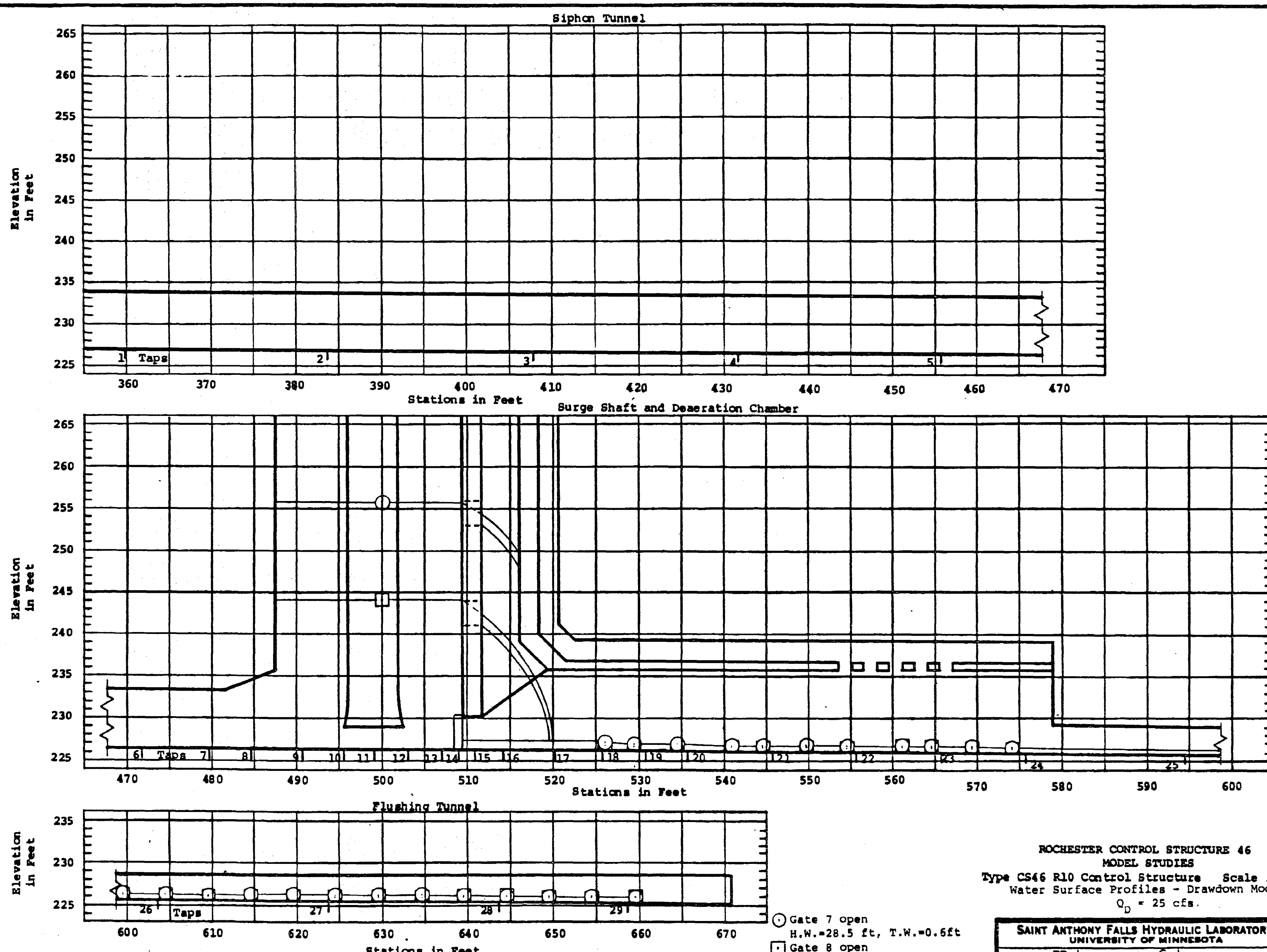


⊙ Gate 7 open
H.W.=28.0 ft, T.W.=0.5 ft
⊡ Gate 8 open
H.W.=16.1 ft, T.W.=0.5 ft

ROCHESTER CONTROL STRUCTURE 46
MODEL STUDIES
Type CS46 R10 Control Structure Scale 1:12
Water Surface Profiles - Drawdown Mode
Q_D = 16 cfs

SAINT ANTHONY FALLS HYDRAULIC LABORATORY UNIVERSITY OF MINNESOTA		
DRAWN BB	CHECKED [illegible]	APPROVED
SCALE	DATE 3/1/84	NO. 328B514-28

CHART 90



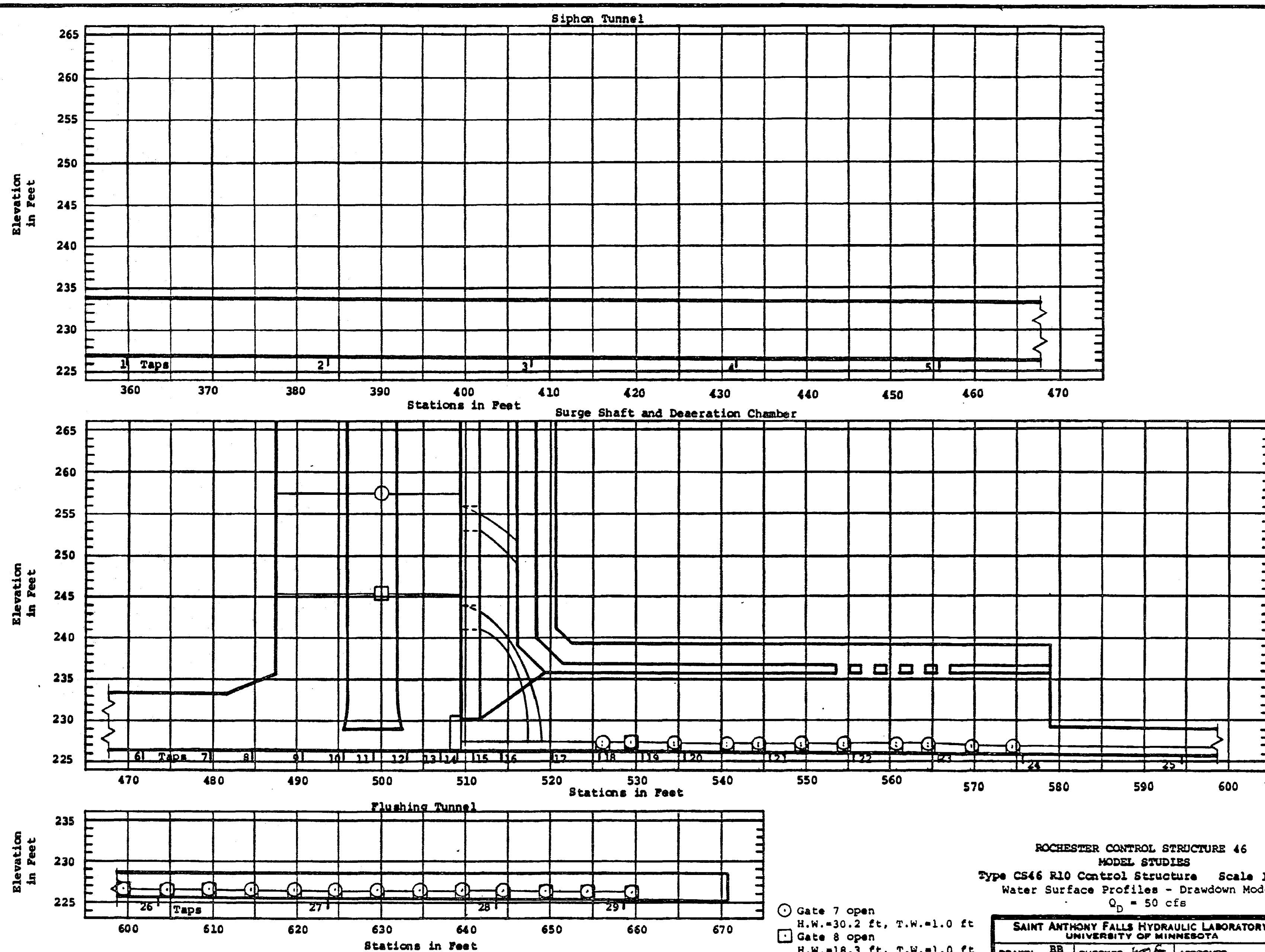
⨀ Gate 7 open
H.W.=28.5 ft, T.W.=0.6ft

⊡ Gate 8 open
H.W.=16.6 ft, T.W.=0.6 ft

ROCHESTER CONTROL STRUCTURE 46
MODEL STUDIES
Type CS46 R10 Control Structure Scale 1:12
Water Surface Profiles - Drawdown Mode
Q_D = 25 cfs.

SAINT ANTHONY FALLS HYDRAULIC LABORATORY UNIVERSITY OF MINNESOTA		
DRAWN BB	CHECKED [signature]	APPROVED
SCALE	DATE 3/1/84	NO. 328B514-29

CHART 91

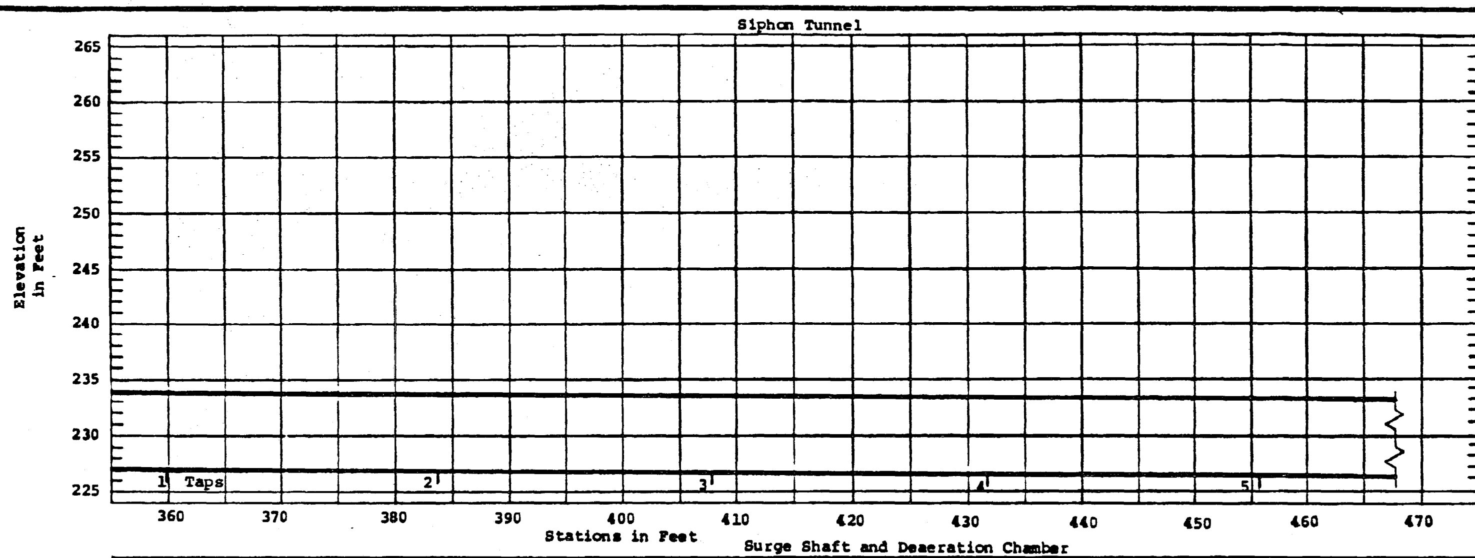


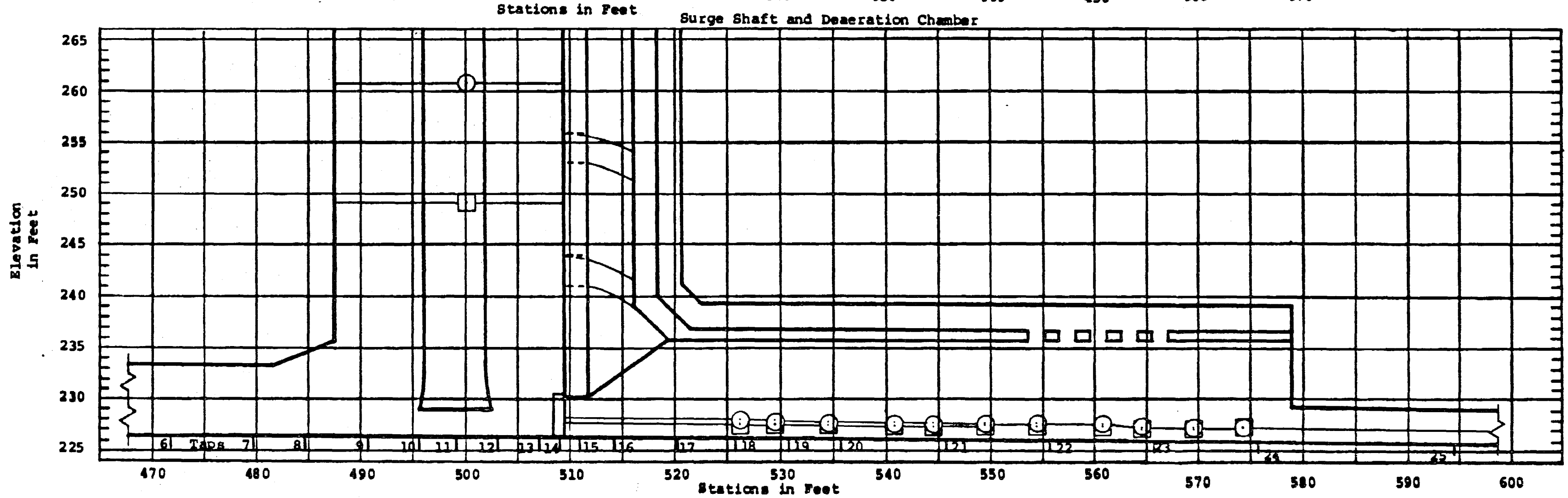
ROCHESTER CONTROL STRUCTURE 46
MODEL STUDIES
Type CS46 R10 Control Structure Scale 1:12
Water Surface Profiles - Drawdown Mode
Q_D = 50 cfs

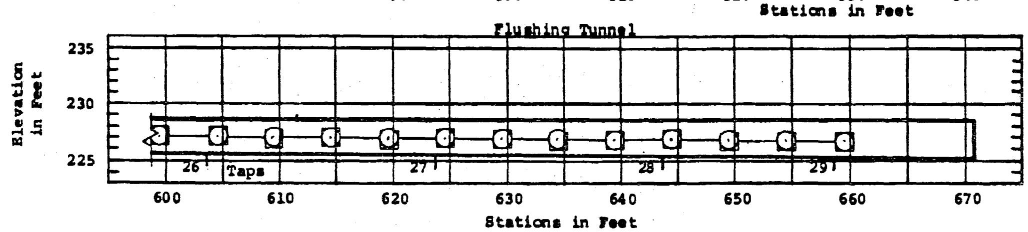
SAINT ANTHONY FALLS HYDRAULIC LABORATORY
UNIVERSITY OF MINNESOTA

DRAWN BB	CHECKED 330	APPROVED
SCALE	DATE 3/1/84	NO. 328B514-30

CHART 92





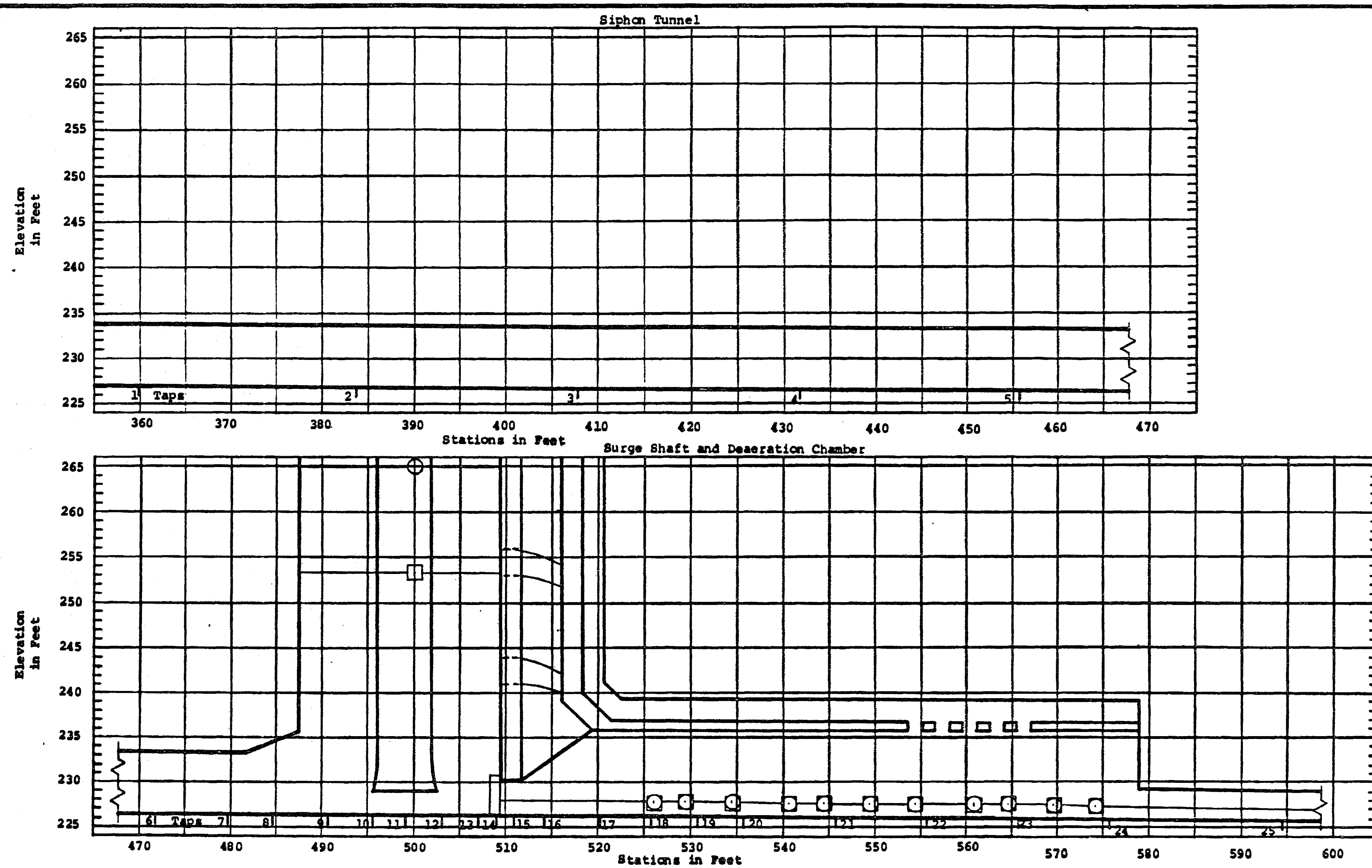


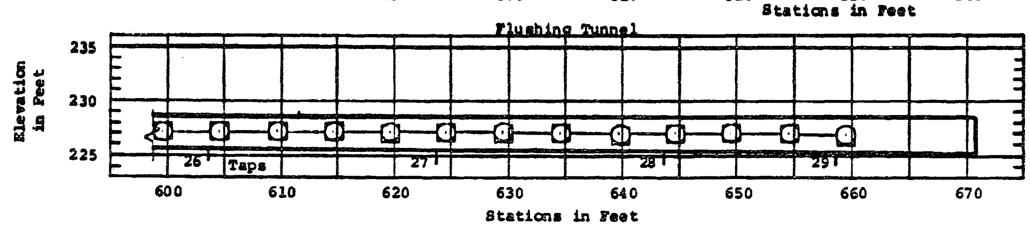
⊙ Gate 7 open
H.W.=33.7 ft, T.W.=1.4 ft
⊡ Gate 8 open
H.W.=21.6 ft, T.W.=1.3 ft

ROCHESTER CONTROL STRUCTURE 46
MODEL STUDIES
Type CS46 R10 Control Structure Scale 1:12
Water Surface Profiles - Drawdown Mode
Q_D = 75 cfs

SAINT ANTHONY FALLS HYDRAULIC LABORATORY UNIVERSITY OF MINNESOTA		
DRAWN BB	CHECKED	APPROVED
SCALE	DATE 3/1/84	NO. 328B514-31

CHART 93





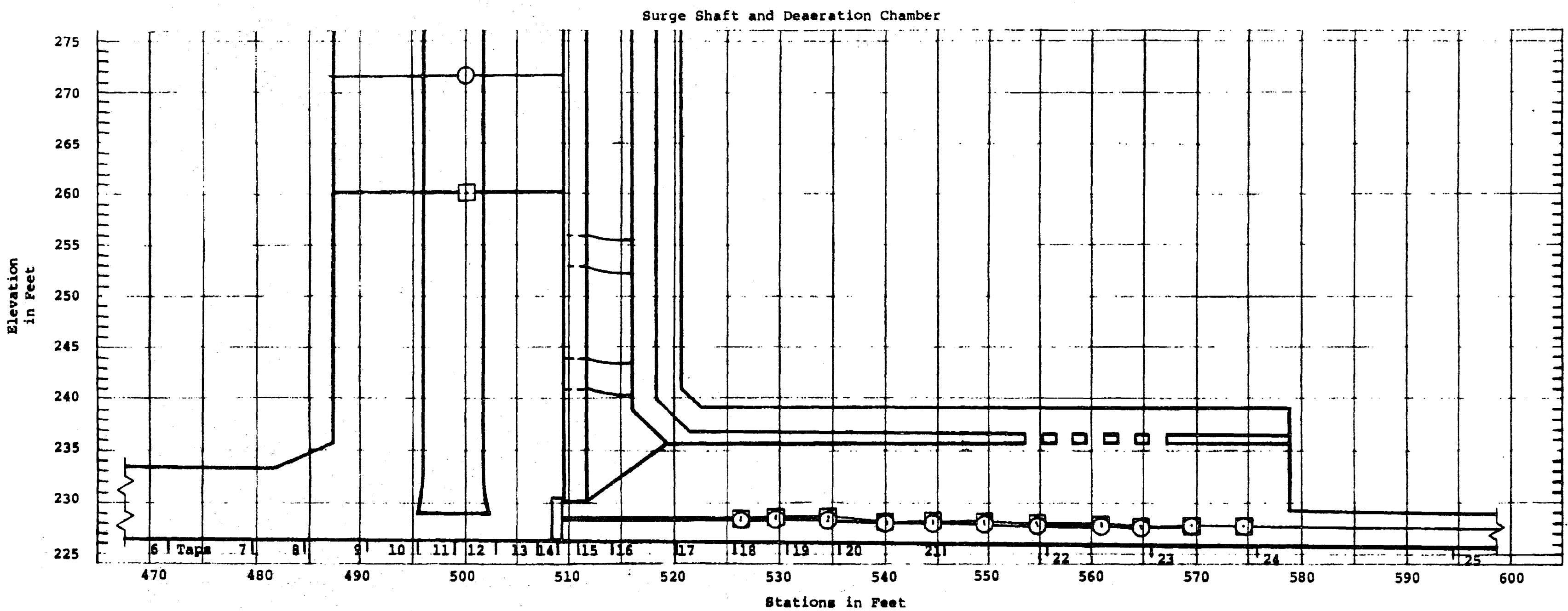
⊙ Gate 7 open
H.W.=38.1 ft, T.W.=1.6 ft

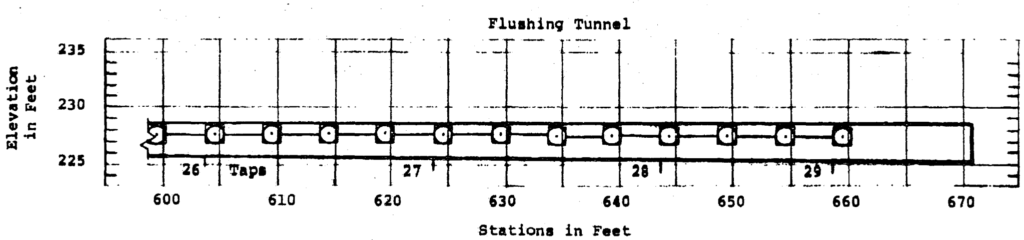
⊡ Gate 8 open
H.W.=26.0 ft, T.W.=1.6 ft

ROCHESTER CONTROL STRUCTURE 46
MODEL STUDIES
Type CS46 R10 Control Structure Scale 1:12
Water Surface Profiles - Drawdown Mode
Q_D = 100 cfs

SAINT ANTHONY FALLS HYDRAULIC LABORATORY UNIVERSITY OF MINNESOTA		
DRAWN BB	CHECKED	APPROVED
SCALE	DATE 3/1/84	NO. 328B514-32

CHART 94





ROCHESTER CONTROL STRUCTURE 46
MODEL STUDIES
Type C846 R10 Control Structure Scale 1:12
Water Surface Profiles - Drawdown Mode
Q_D = 125 cfs

⊙ Gate 7 open
H.W.=44.5 ft, T.W.=1.8 ft
⊡ Gate 8 open
H.W.=32.9 ft, T.W.=1.9 ft

SAINT ANTHONY FALLS HYDRAULIC LABORATORY
UNIVERSITY OF MINNESOTA

DRAWN AG	CHECKED MD	APPROVED
SCALE	DATE 3/1/84	NO. 328B514-33

CHART 95

Water Depths - Drawdown Mode

Station	Q_D = 16 cfs Gate 7 Open H.W. = 28.0 ft T.W. = 0.5 ft Depth	Q_D = 16 cfs Gate 8 Open H.W. = 16.1 ft T.W. = 0.5 ft Depth	Q_D = 25 cfs Gate 7 Open H.W. = 28.5 ft T.W. = 0.6 ft Depth	Q_D = 25 cfs Gate 8 Open H.W. = 16.6 ft T.W. = 0.6 ft Depth
500.00	28.90	17.20	29.50	17.80
526.06	0.61	0.62	1.02	0.65
529.56	0.59	0.61	0.84	0.59
534.56	0.68	0.64	0.79	0.58
540.81	0.49	0.64	0.66	0.58
544.56	0.44	0.56	0.70	0.60
549.56	0.44	0.46	0.66	0.54
554.56	0.43	0.38	0.68	0.49
560.91	0.44	0.41	0.70	0.55
564.56	0.46	0.42	0.67	0.58
569.56	0.47	0.44	0.66	0.54
574.31	0.46	0.41	0.67	0.52
599.56	0.64	0.48	0.67	0.58
604.56	0.56	0.53	0.72	0.61
609.56	0.60	0.55	0.72	0.60
614.56	0.66	0.55	0.72	0.62
619.56	0.60	0.58	0.77	0.64
624.56	0.59	0.56	0.76	0.65
629.56	0.59	0.54	0.73	0.65
634.56	0.62	0.58	0.76	0.62
639.56	0.62	0.59	0.77	0.71
644.56	0.58	0.53	0.74	0.67
649.56	0.55	0.53	0.71	0.64
654.56	0.53	0.53	0.71	0.65
659.56	0.53	0.52	0.67	0.67

ROCHESTER CONTROL STRUCTURE 46
MODEL STUDIES
Type CS46 R10 Control Structure
Scale 1:12
Water Depths - Drawdown Mode

SAINT ANTHONY FALLS HYDRAULIC LABORATORY UNIVERSITY OF MINNESOTA		
DRAWN KL	CHECKED MR	APPROVED
SCALE	DATE 3/15/84	NO. 328A2323-12

Water Depths - Drawdown Mode

Station	Q_D = 50 cfs Gate 7 Open H.W. = 30.2 ft T.W. = 1.0 ft Depth	Q_D = 50 cfs Gate 8 Open H.W. = 18.3 ft T.W. = 1.0 ft Depth	Q_D = 75 cfs Gate 7 Open H.W. = 33.7 ft T.W. = 1.4 ft Depth	Q_D = 75 cfs Gate 8 Open H.W. = 21.6 ft T.W. = 1.3 ft Depth
500.00	31.20	19.10	34.6	22.8
526.06	1.13	0.76	1.76	1.31
529.56	1.15	1.01	1.56	1.33
534.56	1.14	0.83	1.51	1.28
540.81	1.10	0.74	1.54	1.33
544.56	1.08	0.79	1.48	1.26
549.56	1.09	0.82	1.48	1.36
554.56	1.12	0.82	1.46	1.27
560.91	1.09	0.83	1.45	1.30
564.56	1.07	0.78	1.43	1.34
569.56	1.03	0.82	1.40	1.28
574.31	1.03	0.84	1.39	1.36
599.56	1.03	1.00	1.39	1.38
604.56	1.04	0.92	1.39	1.36
609.56	1.08	0.96	1.45	1.39
614.56	1.10	0.97	1.49	1.45
619.56	1.10	0.96	1.51	1.43
624.56	1.14	0.98	1.52	1.46
629.56	1.10	0.97	1.55	1.46
634.56	1.14	1.03	1.55	1.44
639.56	1.16	0.97	1.54	1.48
644.56	1.12	1.04	1.51	1.45
649.56	1.09	1.04	1.46	1.37
654.56	1.10	1.02	1.46	1.44
659.56	1.06	1.03	1.42	1.42

ROCHESTER CONTROL STRUCTURE 46
MODEL STUDIES
Type CS46 R10 Control Structure
Scale 1:12
Water Depths - Drawdown Mode

SAINT ANTHONY FALLS HYDRAULIC LABORATORY UNIVERSITY OF MINNESOTA		
DRAWN KL	CHECKED MR	APPROVED
SCALE	DATE 3/15/84	NO. 328A2323-13

Water Depths - Drawdown Mode

Station	Q_D = 100 cfs Gate 7 Open H.W. = 38.1 ft T.W. = 1.6 ft Depth	Q_D = 100 cfs Gate 8 Open H.W. = 26.0 ft T.W. = 1.6 ft Depth	Q_D = 125 cfs Gate 7 Open H.W. = 44.5 ft T.W. = 1.8 ft Depth	Q_D = 125 cfs Gate 8 Open H.W. = 32.9 ft T.W. = 1.9 ft Depth
500.00	38.8	27.0	45.5	33.8
526.06	1.72	1.62	2.02	2.29
529.56	1.68	1.74	2.16	2.41
534.56	1.69	1.63	2.15	2.36
540.81	1.64	1.58	1.99	2.18
544.56	1.58	1.57	1.86	2.06
549.56	1.60	1.57	1.80	1.98
554.56	1.55	1.55	1.84	1.91
560.91	1.57	1.55	1.78	1.88
564.56	1.56	1.57	1.88	1.85
569.56	1.52	1.55	1.81	1.84
574.31	1.52	1.55	1.84	1.85
599.56	1.60	1.61	1.88	1.90
604.56	1.58	1.63	1.97	2.00
609.56	1.57	1.63	1.96	2.00
614.56	1.62	1.64	2.04	2.00
619.56	1.69	1.62	2.03	2.02
624.56	1.74	1.67	2.05	2.06
629.56	1.74	1.64	2.02	2.06
634.56	1.70	1.67	2.02	2.05
639.56	1.72	1.63	2.00	2.06
644.56	1.69	1.66	2.03	2.08
649.56	1.72	1.67	2.04	2.05
654.56	1.73	1.68	2.03	2.05
659.56	1.70	1.64	2.05	2.05

ROCHESTER CONTROL STRUCTURE 46
MODEL STUDIES
Type CS46 R10 Control Structure
Scale 1:12
Water Depths - Drawdown Mode

SAINT ANTHONY FALLS HYDRAULIC LABORATORY UNIVERSITY OF MINNESOTA		
DRAWN KL	CHECKED MR	APPROVED
SCALE	DATE 3/15/84	NO. 328A2323-14

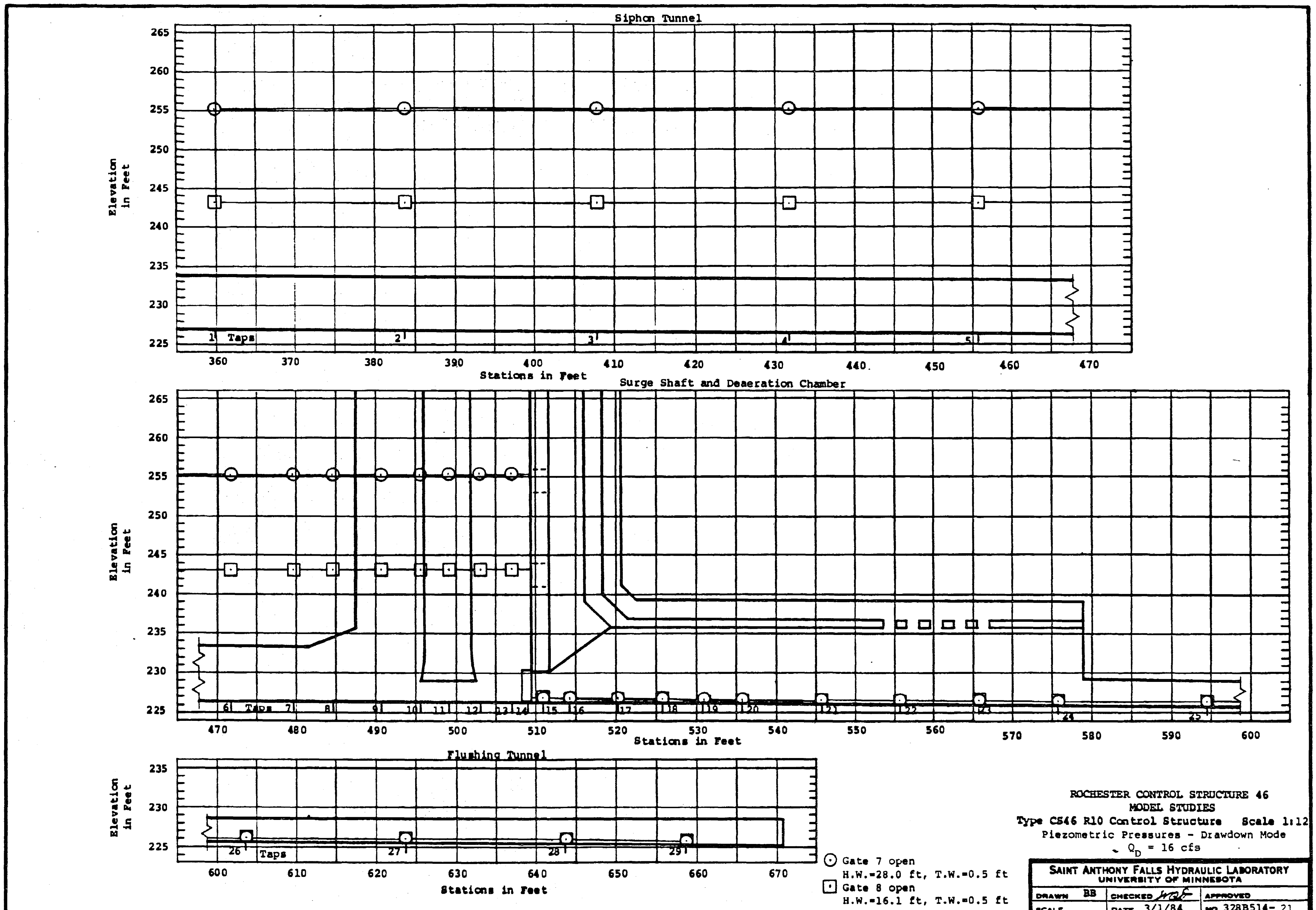
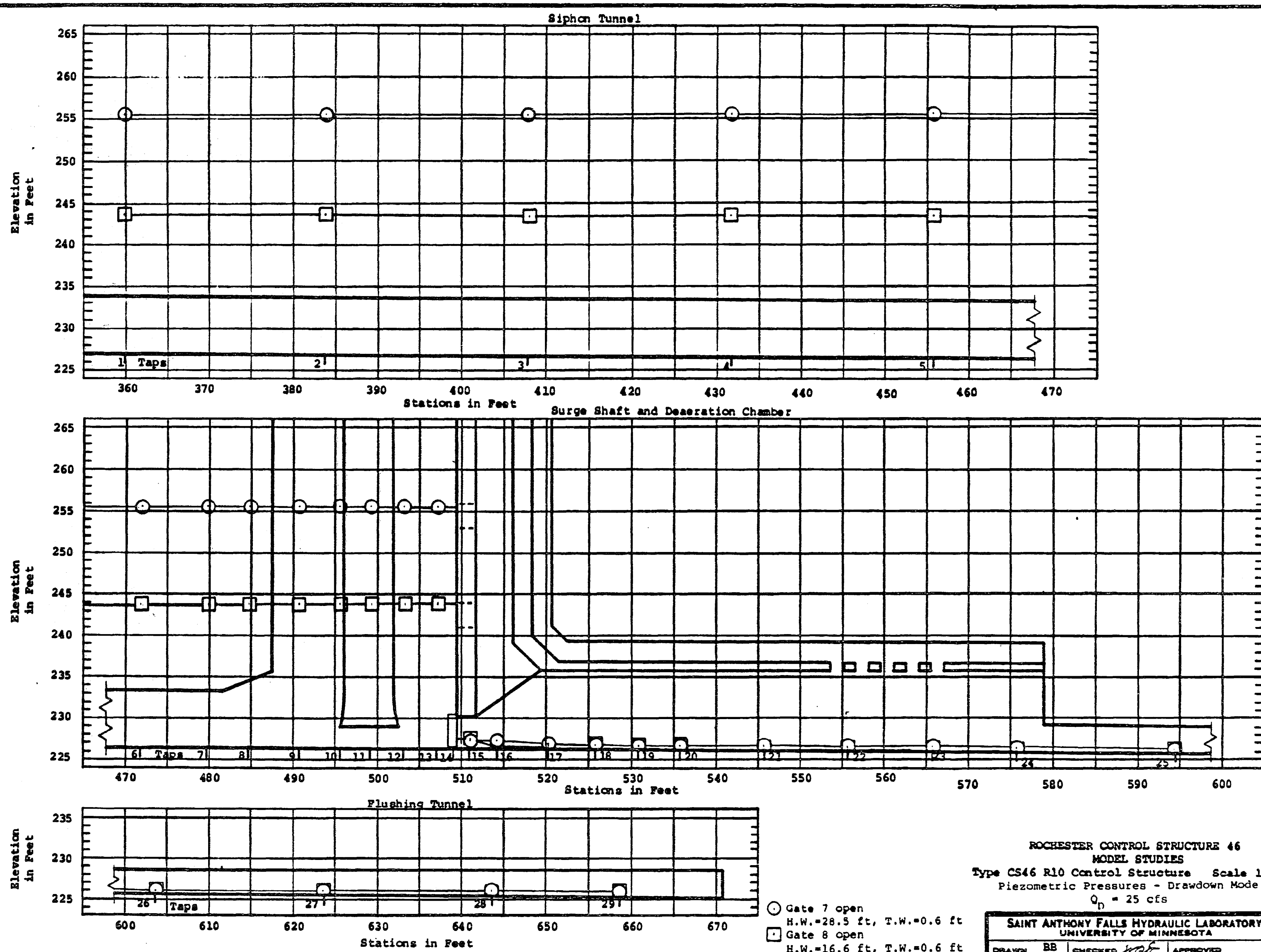

Siphon Tunnel
Elevation in Feet
Stations in Feet
Taps
Surge Shaft and Deaeration Chamber
Elevation in Feet
Stations in Feet
Taps
Flushing Tunnel
Elevation in Feet
Stations in Feet
Taps
Gate 7 open
H.W.=28.0 ft, T.W.=0.5 ft
Gate 8 open
H.W.=16.1 ft, T.W.=0.5 ft
ROCHESTER CONTROL STRUCTURE 46
MODEL STUDIES
Type CS46 R10 Control Structure Scale 1:12
Piezometric Pressures - Drawdown Mode
Q_D = 16 cfs
SAINT ANTHONY FALLS HYDRAULIC LABORATORY
UNIVERSITY OF MINNESOTA
DRAWN BB
CHECKED
APPROVED
SCALE
DATE 3/1/84
NO. 328B514- 21

CHART 99

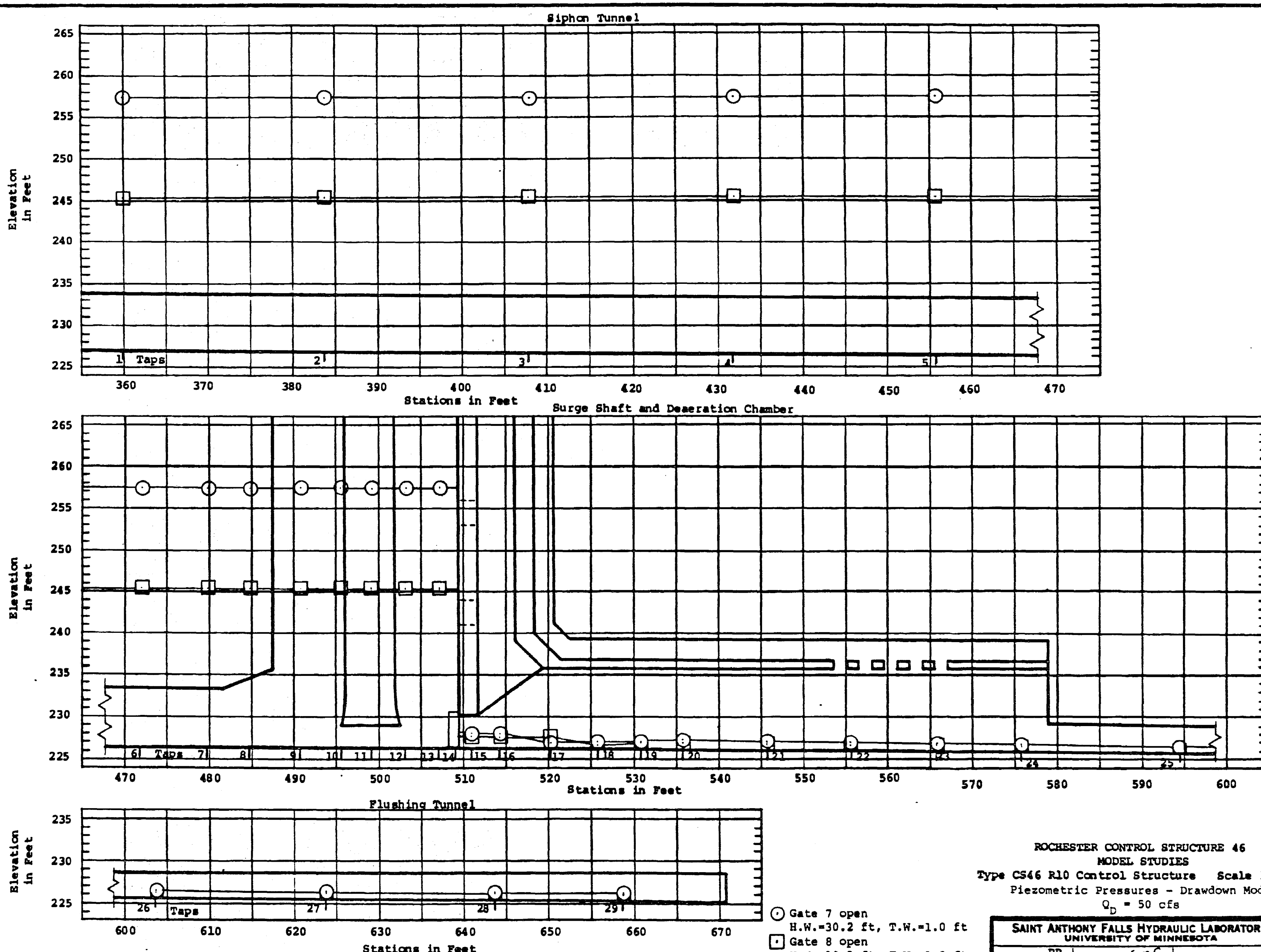


ROCHESTER CONTROL STRUCTURE 46
MODEL STUDIES
Type CS46 R10 Control Structure Scale 1:12
Piezometric Pressures - Drawdown Mode
Q_n = 25 cfs

SAINT ANTHONY FALLS HYDRAULIC LABORATORY
UNIVERSITY OF MINNESOTA

DRAWN BB	CHECKED	APPROVED
SCALE	DATE 3/1/84	NO. 328B514- 22

CHART 100



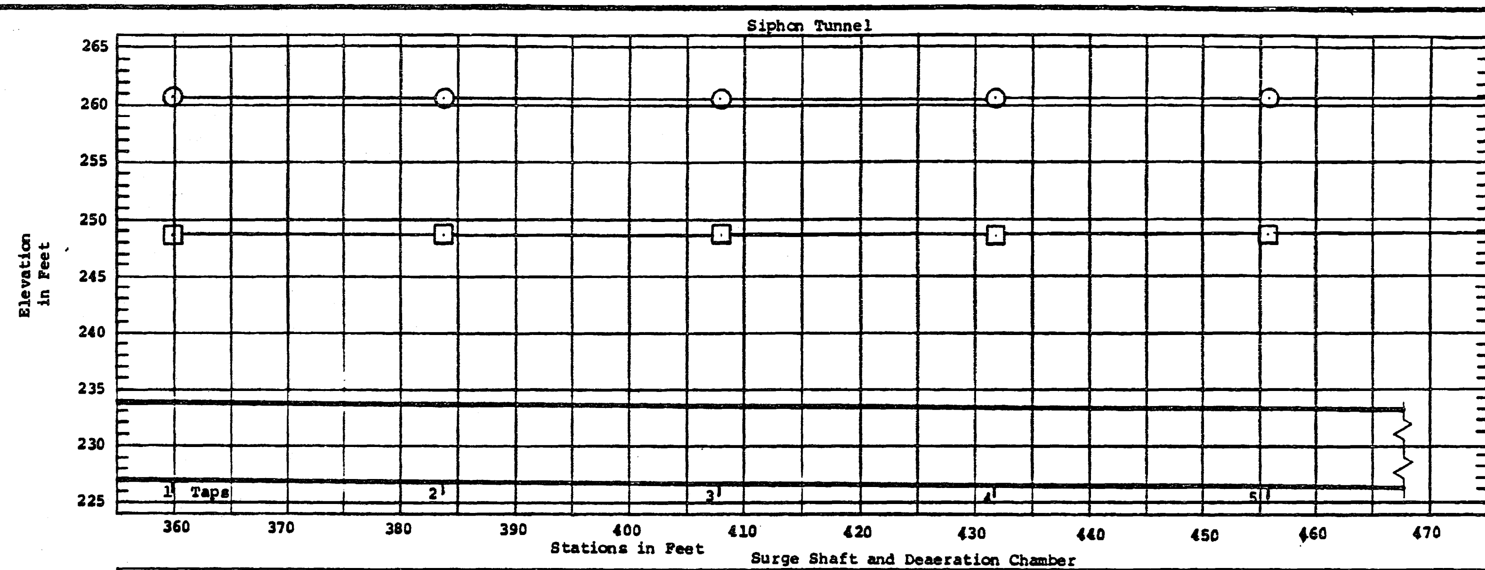
Gate 7 open
H.W.=30.2 ft, T.W.=1.0 ft

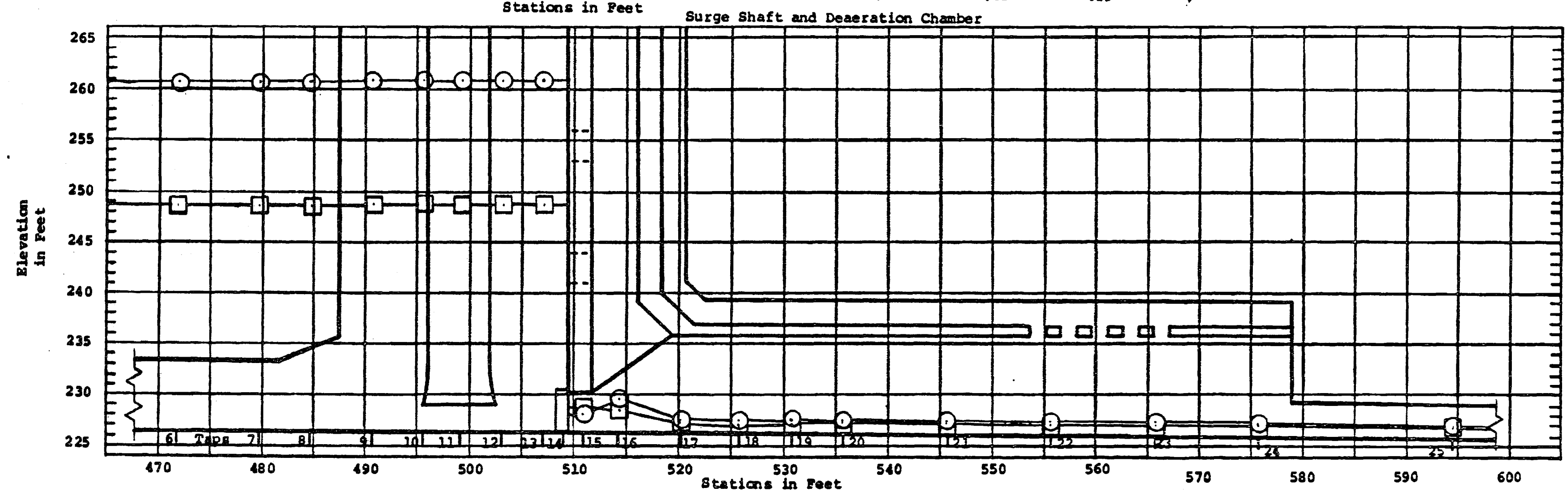
Gate 8 open
H.W.=18.3 ft, T.W.=1.0 ft

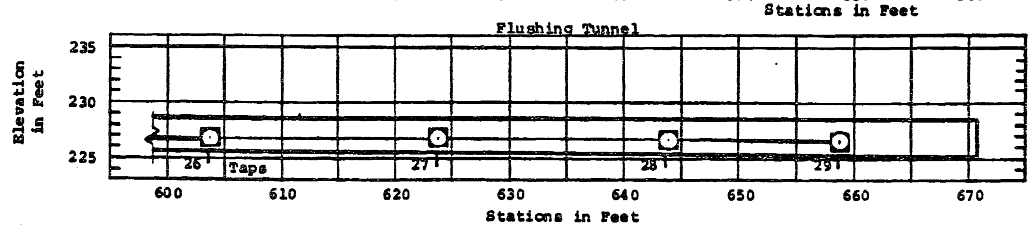
ROCHESTER CONTROL STRUCTURE 46
MODEL STUDIES
Type CS46 R10 Control Structure Scale 1:12
Piezometric Pressures - Drawdown Mode
Q_D = 50 cfs

SAINT ANTHONY FALLS HYDRAULIC LABORATORY UNIVERSITY OF MINNESOTA		
DRAWN BB	CHECKED [signature]	APPROVED
SCALE	DATE 3/1/84	NO. 32BB514-23

CHART 101







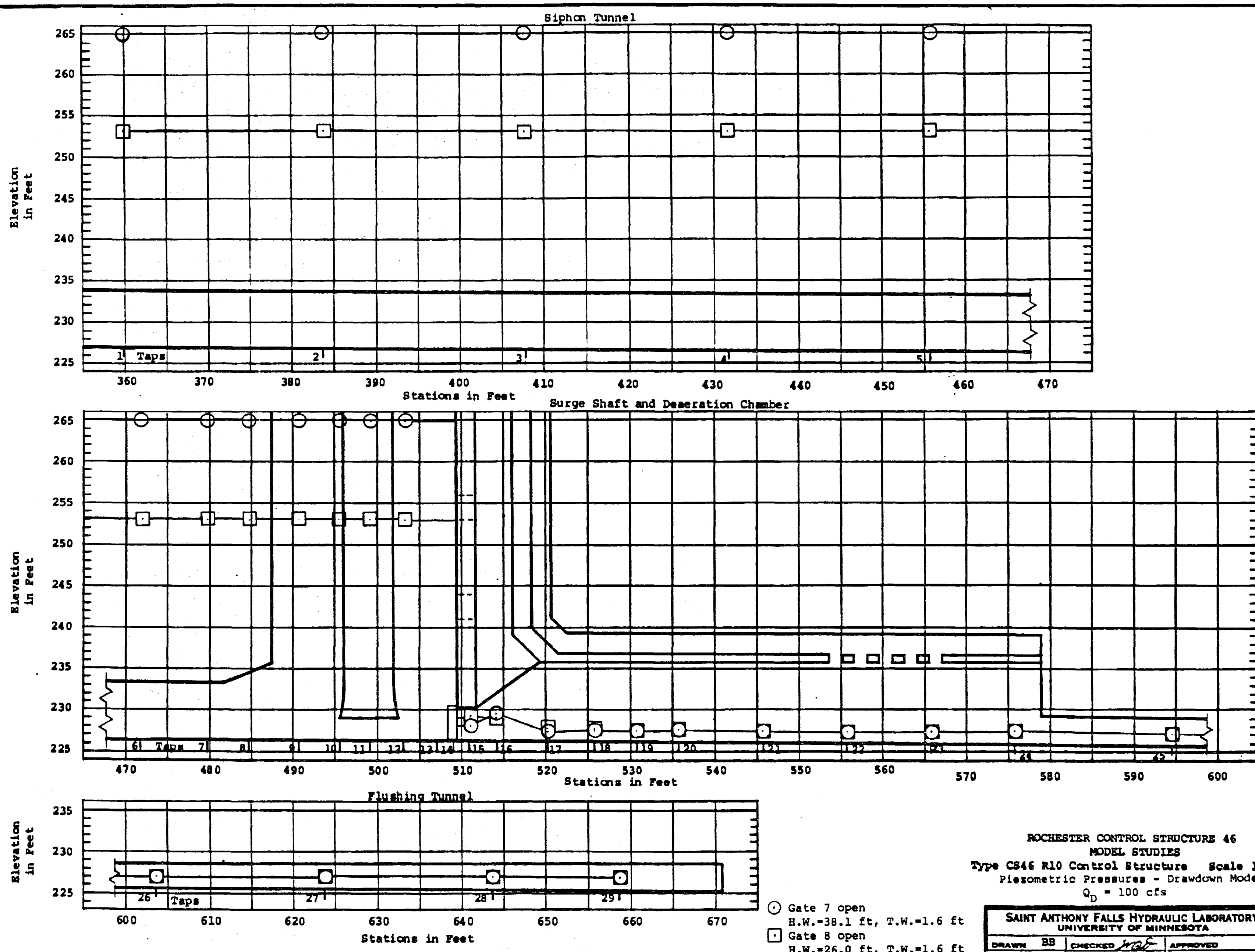
⊙ Gate 7 open
H.W.=33.7 ft, T.W.=1.4 ft

⊡ Gate 8 open
H.W.=21.6 ft, T.W.=1.3 ft

ROCHESTER CONTROL STRUCTURE 46
MODEL STUDIES
Type CS46 R10 Control Structure **Scale 1:12**
Piezometric Pressures - Drawdown Mode
Q_D = 75 cfs

SAINT ANTHONY FALLS HYDRAULIC LABORATORY UNIVERSITY OF MINNESOTA		
DRAWN BB	CHECKED [signature]	APPROVED
SCALE	DATE 3/1/84	NO. 328B514-24

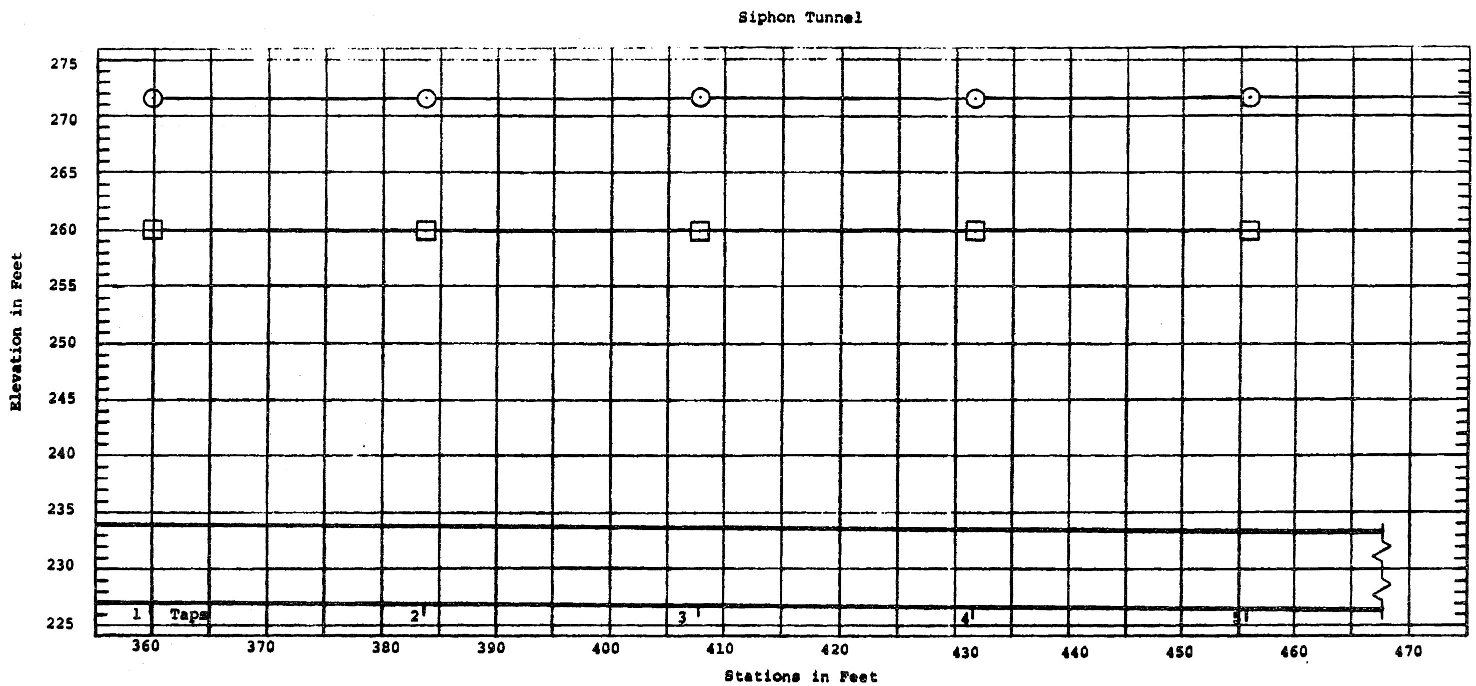
CHART 102



ROCHESTER CONTROL STRUCTURE 46
MODEL STUDIES
Type CS46 R10 Control Structure Scale 1:12
Piezometric Pressures - Drawdown Mode
Q_D = 100 cfs

SAINT ANTHONY FALLS HYDRAULIC LABORATORY UNIVERSITY OF MINNESOTA		
DRAWN BB	CHECKED	APPROVED
SCALE	DATE 3/1/84	NO. 328B514-25

CHART 103



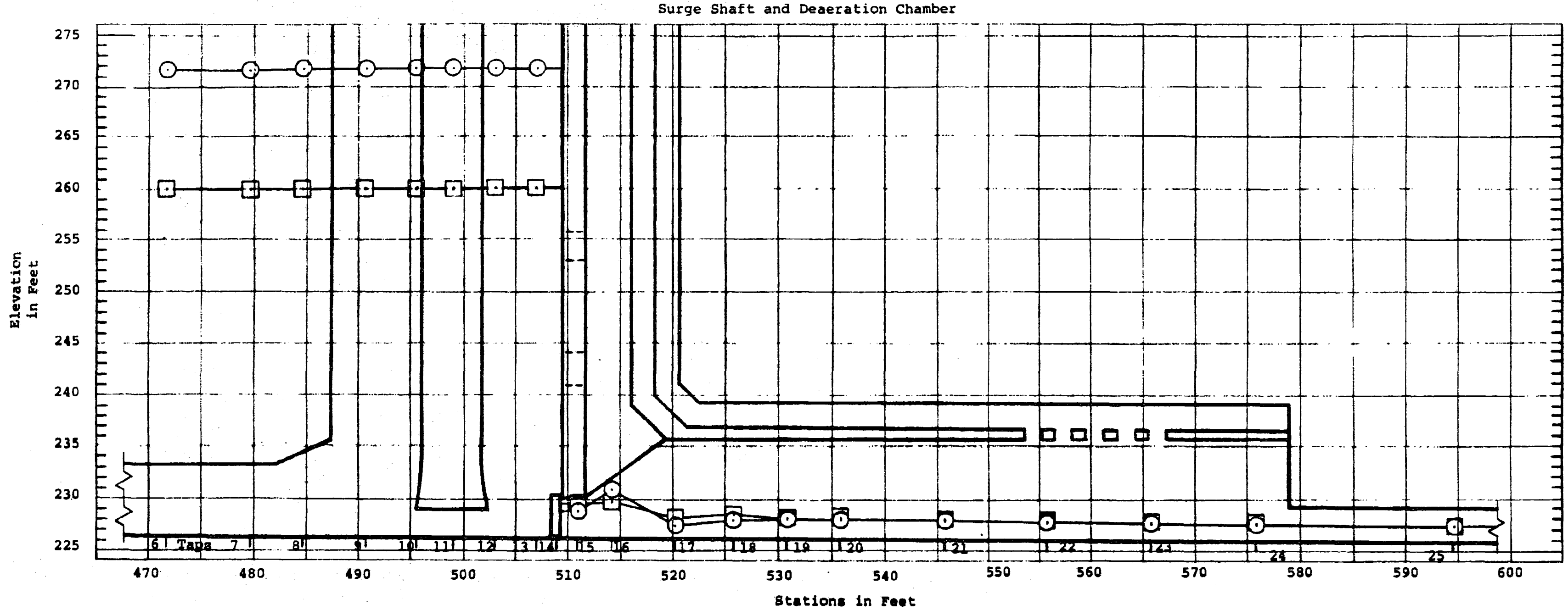
ROCHESTER CONTROL STRUCTURE 46
MODEL STUDIES
Type CS46 R10 Control Structure Scale 1:12
Piezometric Pressures - Drawdown Model
Q_D = 125 cfs

⊙ Gate 7 open
H.W.=44.5 ft, T.W.=1.8 ft
⊡ Gate 8 open
H.W.=32.9 ft, T.W.=1.9 ft

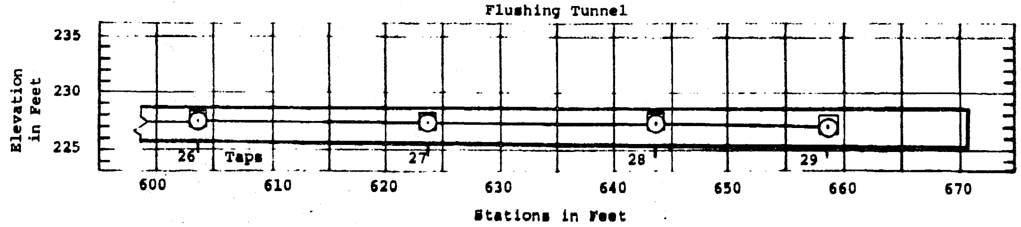
SAINT ANTHONY FALLS HYDRAULIC LABORATORY UNIVERSITY OF MINNESOTA		
DRAWN AG	CHECKED [illegible]	APPROVED
SCALE	DATE 3/1/84	NO. 328B514-26

CHART 104

Surge Shaft and Deaeration Chamber



Flushing Tunnel



ROCHESTER CONTROL STRUCTURE 46
MODEL STUDIES
Type CS46 R10 Control Structure Scale 1:12
Piezometric Pressures - Drawdown Model
Q_D = 125 cfs

⊙ Gate 7 open
H.W.=44.5 ft, T.W.=1.8 ft
⊡ Gate 8 open
H.W.= 32.9 ft, T.W.=1.9 ft

SAINT ANTHONY FALLS HYDRAULIC LABORATORY UNIVERSITY OF MINNESOTA		
DRAWN AG	CHECKED	APPROVED
SCALE	DATE 3/1/84	NO.328B514-27

CHART 105

Pressure Readings - Drawdown Mode

			Q_D = 16 cfs, Gate 7 Open, H.W. = 28.0 ft, T.W. = 0.5 ft		Q_D = 16 cfs, Gate 8 Open, H.W. = 16.1 ft, T.W. = 0.5 ft	
Tap Number	Station	Tap Elevation	Piezometric Pressure Elevation	Pressure at Tap	Piezometric Pressure Elevation	Pressure at Tap
	ft	ft	ft	ft	ft	ft
1	359.81	227.10	255.1	28.0	243.2	16.1
2	383.81	226.95	255.1	28.2	243.2	16.3
3	407.81	226.80	255.1	28.3	243.2	16.4
4	431.81	226.66	255.1	28.4	243.2	16.5
5	455.81	226.51	255.1	28.6	243.2	16.7
6	471.81	226.42	255.1	28.7	243.2	16.8
7	479.81	226.37	255.1	28.7	243.2	16.8
8	484.81	226.34	255.1	28.8	243.2	16.9
9	490.81	226.30	255.1	28.8	243.2	16.9
10	495.56	226.27	255.1	28.8	243.2	16.9
11	499.31	226.25	255.1	28.9	243.2	17.0
12	503.06	226.22	255.1	28.9	243.2	17.0
13	507.06	226.20	255.1	28.9	243.2	17.0
15	510.94	226.18	226.8	0.6	226.8	0.6
16	514.31	226.16	226.8	0.6	226.7	0.5
17	520.31	226.12	226.8	0.7	226.7	0.6
18	525.81	226.09	226.7	0.6	226.7	0.6
19	530.81	226.05	226.6	0.6	226.8	0.8
20	535.81	226.02	226.5	0.5	226.6	0.6
21	545.81	225.96	226.4	0.4	226.5	0.5
22	555.81	225.90	226.4	0.5	226.3	0.4
23	565.81	225.84	226.3	0.5	226.3	0.5
24	575.81	225.78	226.3	0.5	226.3	0.5
25	594.27	225.66	226.1	0.4	226.1	0.4
26	603.77	225.60	226.1	0.5	226.1	0.5
27	623.77	225.47	226.0	0.5	226.0	0.5
28	643.77	225.35	225.9	0.6	225.9	0.6
29	658.77	225.25	225.8	0.6	225.8	0.6

ROCHESTER CONTROL STRUCTURE 46
MODEL STUDIES
Type CS46 R10 Control Structure
Scale 1:12
Pressure Readings - Drawdown Mode

SAINT ANTHONY FALLS HYDRAULIC LABORATORY
UNIVERSITY OF MINNESOTA

DRAWN KL	CHECKED MR	APPROVED
SCALE	DATE 3/15/84	NO. 328A2323-6

Pressure Readings - Drawdown Mode

Tap Number	Station	Tap Elevation	Q_D = 25 cfs, Gate 7 Open, H.W. = 28.5 ft, T.W. = 0.6 ft: Piezometric Pressure Elevation	Pressure at Tap	Q_D = 25 cfs, Gate 8 Open, H.W. = 16.6 ft, T.W. = 0.6 ft: Piezometric Pressure Elevation	Pressure at Tap
	ft		ft	ft	ft	ft
1	359.81	227.10	255.6	28.5	243.7	16.6
2	383.81	226.95	255.6	28.7	243.7	16.8
3	407.81	226.80	255.6	28.8	243.7	16.9
4	431.81	226.66	255.7	29.0	243.7	17.0
5	455.81	226.51	255.7	29.2	243.7	17.2
6	471.81	226.42	255.6	29.2	243.7	17.3
7	479.81	226.37	255.7	29.3	243.7	17.3
8	484.81	226.34	255.7	29.4	243.7	17.4
9	490.81	226.30	255.7	29.4	243.7	17.4
10	495.56	226.27	255.7	29.4	243.7	17.4
11	499.31	226.25	255.7	29.5	243.7	17.5
12	503.06	226.22	255.7	29.5	243.7	17.5
13	507.06	225.20	255.7	29.5	243.7	17.5
15	510.94	226.18	227.2	0.9	226.8	0.6
16	514.31	226.16	227.2	1.0	226.7	0.5
17	520.31	226.12	226.8	0.7	226.7	0.6
18	525.81	226.09	226.8	0.7	226.8	0.7
19	530.81	226.05	226.7	0.7	226.7	0.7
20	535.81	226.02	226.7	0.7	226.7	0.7
21	545.81	225.96	226.7	0.7	226.6	0.6
22	555.81	225.90	226.5	0.6	226.3	0.4
23	565.81	225.84	226.5	0.7	226.4	0.6
24	575.81	225.78	226.4	0.6	226.3	0.5
25	594.27	225.66	226.2	0.5	226.2	0.5
26	603.77	225.60	226.2	0.6	226.2	0.6
27	623.77	225.47	226.1	0.6	226.1	0.6
28	643.77	225.35	226.1	0.8	226.0	0.7
29	658.77	225.25	225.9	0.7	225.9	0.7

ROCHESTER CONTROL STRUCTURE 46
MODEL STUDIES
Type CS46 R10 Control Structure
Scale 1:12
Pressure Readings - Drawdown Mode

SAINT ANTHONY FALLS HYDRAULIC LABORATORY, UNIVERSITY OF MINNESOTA		
DRAWN KL	CHECKED MR	APPROVED
SCALE	DATE 3/15/84	NO. 328A2323-7

Pressure Readings - Drawdown Mode

Tap Number	Station (ft)	Tap Elevation (ft)	Q_D = 50 cfs, Gate 7 Open, H.W. = 30.2 ft, T.W. = 1.0 ft: Piezometric Pressure Elevation (ft)	Pressure at Tap (ft)	Q_D = 50 cfs, Gate 8 Open, H.W. = 18.3 ft, T.W. = 1.0 ft: Piezometric Pressure Elevation (ft)	Pressure at Tap (ft)
1	359.81	227.10	257.3	30.2	245.4	18.3
2	383.81	226.95	257.3	30.4	245.4	18.5
3	407.82	226.80	257.3	30.5	245.4	18.6
4	431.81	226.66	257.3	30.6	245.4	18.7
5	455.81	226.51	257.4	30.9	245.4	18.9
6	471.81	226.42	257.3	30.9	245.4	19.0
7	479.81	226.37	257.3	30.9	245.4	19.0
8	484.81	226.34	257.3	31.0	245.4	19.1
9	490.81	226.30	257.4	31.1	245.4	19.1
10	495.56	226.27	257.4	31.1	245.4	19.1
11	499.31	226.25	257.4	31.2	245.4	19.2
12	503.06	226.22	257.4	31.2	245.4	19.2
13	507.06	226.20	257.4	31.2	245.4	19.2
15	510.94	226.18	228.1	1.9	227.8	1.6
16	514.31	226.16	228.2	2.0	227.7	1.5
17	520.31	226.12	227.1	1.0	227.7	1.6
18	525.81	226.09	227.2	1.1	226.8	0.7
19	530.81	226.05	227.2	1.2	227.1	1.1
20	535.81	226.02	227.3	1.3	226.9	0.9
21	545.81	225.96	227.1	1.1	226.8	0.8
22	555.81	225.90	227.0	1.1	226.7	0.8
23	565.81	225.84	226.9	1.1	226.7	0.9
24	575.81	225.78	226.8	1.0	226.6	0.8
25	594.27	225.66	226.6	0.9	226.4	0.7
26	603.77	225.60	226.6	1.0	226.4	0.8
27	623.77	225.47	226.5	1.0	226.4	0.9
28	643.77	225.35	226.4	1.1	226.3	1.0
29	658.77	225.25	226.3	1.1	226.2	1.0

ROCHESTER CONTROL STRUCTURE 46
MODEL STUDIES
Type CS46 R10 Control Structure
Scale 1:12
Pressure Readings - Drawdown Model

SAINT ANTHONY FALLS HYDRAULIC LABORATORY, UNIVERSITY OF MINNESOTA		
DRAWN KL	CHECKED MR	APPROVED
SCALE	DATE 3/15/84	NO. 328A2323-8

Pressure Readings - Drawdown Mode

Tap Number	Station	Tap Elevation	Q_D = 75 cfs, Gate 7 Open, H.W. = 33.7 ft, T.W. = 1.4 ft: Piezometric Pressure Elevation	Pressure at Tap	Q_D = 75 cfs, Gate 8 Open, H.W. = 21.6 ft, T.W. = 1.3 ft: Piezometric Pressure Elevation	Pressure at Tap
	ft	ft	ft	ft	ft	ft
1	359.81	227.10	260.8	33.7	248.7	21.6
2	383.81	226.95	260.7	33.8	248.7	21.8
3	407.81	226.80	260.7	33.9	248.7	21.9
4	431.81	226.66	260.7	34.0	248.7	22.0
5	455.81	226.51	260.7	34.2	248.7	22.2
6	471.81	226.42	260.7	34.3	248.7	22.3
7	479.81	226.37	260.7	34.3	248.7	22.3
8	484.81	226.34	260.7	34.4	248.7	22.4
9	490.81	226.30	260.8	34.5	248.8	22.5
10	495.56	226.27	260.8	34.5	248.8	22.5
11	499.31	226.25	260.8	34.6	248.8	22.6
12	503.06	226.22	260.8	34.6	248.8	22.6
13	507.06	226.20	260.8	34.6	248.8	22.6
15	510.94	226.18	228.1	1.9	228.9	2.7
16	514.31	226.16	229.6	3.4	228.6	2.4
17	520.31	226.12	227.5	1.4	227.3	1.2
18	525.81	226.09	227.5	1.4	227.3	1.2
19	530.81	226.05	227.6	1.6	227.4	1.4
20	535.81	226.02	227.6	1.6	227.4	1.4
21	545.81	225.96	227.5	1.5	227.3	1.3
22	555.81	225.90	227.4	1.5	227.2	1.3
23	565.81	225.84	227.3	1.5	227.1	1.3
24	575.81	225.78	227.2	1.4	227.1	1.3
25	594.27	225.66	227.0	1.3	226.9	1.2
26	603.77	225.60	226.9	1.3	226.9	1.3
27	623.77	225.47	226.9	1.4	226.9	1.4
28	643.77	225.35	226.8	1.5	226.8	1.5
29	658.77	225.25	226.7	1.5	226.6	1.4

ROCHESTER CONTROL STRUCTURE 46
MODEL STUDIES
Type CS46 R10 Control Structure
Scale 1:12
Pressure Readings - Drawdown Model

SAINT ANTHONY FALLS HYDRAULIC LABORATORY, UNIVERSITY OF MINNESOTA		
DRAWN KL	CHECKED MR	APPROVED
SCALE	DATE 3/15/84	NO. 328A2323-9

Pressure Readings - Drawdown Mode

Tap Number	Station	Tap Elevation	Q_D = 100 cfs, Gate 7 Open, H.W. = 38.1 ft, T.W. = 1.6 ft: Piezometric Pressure Elevation	Pressure at Tap	Q_D = 100 cfs, Gate 8 Open, H.W. = 26.0 ft, T.W. = 1.6 ft: Piezometric Pressure Elevation	Pressure at Tap
	ft	ft	ft	ft	ft	ft
1	359.81	227.10	265.2	38.1	253.1	26.0
2	383.81	226.95	265.0	38.1	253.1	26.2
3	407.81	226.80	265.0	38.2	253.1	26.3
4	431.81	226.66	265.0	38.3	253.1	26.4
5	455.81	226.51	265.0	38.5	253.1	26.6
6	471.81	226.42	265.0	38.6	253.1	26.7
7	479.81	226.37	265.0	38.6	253.1	26.7
8	484.81	226.34	265.0	38.7	253.1	26.8
9	490.81	226.30	265.0	38.7	253.1	26.8
10	495.56	226.27	265.0	38.7	253.1	26.8
11	499.31	226.25	265.0	38.8	253.1	26.9
12	503.06	226.22	265.0	38.8	253.1	26.9
13	507.06	226.20	265.0	38.8	253.1	26.9
15	510.94	226.18	228.3	2.1	229.2	3.0
16	514.31	226.16	229.6	3.4	229.0	2.8
17	520.31	226.12	227.4	1.3	227.7	1.6
18	525.81	226.09	227.6	1.5	227.7	1.6
19	530.81	226.05	227.6	1.6	227.6	1.6
20	535.81	226.02	227.7	1.7	227.7	1.7
21	545.81	225.96	227.5	1.5	227.5	1.5
22	555.81	225.90	227.4	1.5	227.4	1.5
23	565.81	225.84	227.4	1.6	227.3	1.5
24	575.81	225.78	227.3	1.5	227.3	1.5
25	594.27	225.66	227.1	1.4	227.1	1.4
26	603.77	225.60	227.1	1.5	227.1	1.5
27	623.77	225.47	227.1	1.6	227.1	1.6
28	643.77	225.35	227.0	1.7	227.0	1.7
29	658.77	225.25	226.9	1.7	226.9	1.7

ROCHESTER CONTROL STRUCTURE 46
MODEL STUDIES
Type CS46 R10 Control Structure
Scale 1:12
Pressure Readings - Drawdown Model

SAINT ANTHONY FALLS HYDRAULIC LABORATORY, UNIVERSITY OF MINNESOTA		
DRAWN KL	CHECKED MR	APPROVED
SCALE	DATE 3/15/84	NO. 328A2323-10

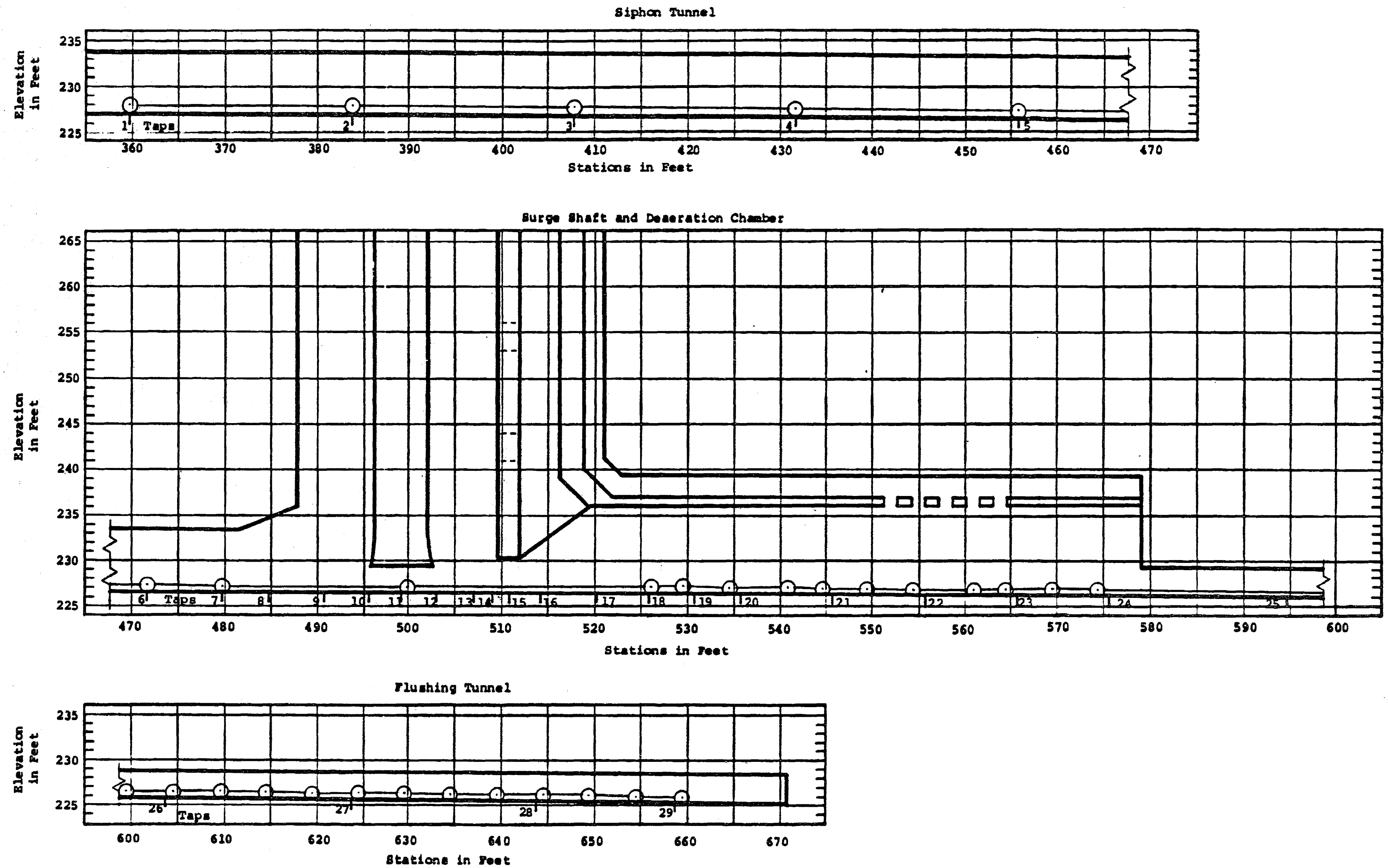
Pressure Readings - Drawdown Mode

Tap Number	Station	Tap Elevation	Q_D = 125 cfs, Gate 7 Open, H.W. = 44.5 ft, T.W. = 1.8 ft: Piezometric Pressure Elevation	Pressure at Tap	Q_D = 125 cfs, Gate 8 Open, H.W. = 32.9 ft, T.W. = 1.9 ft: Piezometric Pressure Elevation	Pressure at Tap
	ft	ft	ft	ft	ft	ft
1	359.81	227.10	271.6	44.5	260.0	32.9
2	383.81	226.95	271.6	44.7	260.0	33.1
3	407.81	226.80	271.6	44.8	260.0	33.2
4	431.81	226.66	271.6	44.9	260.0	33.3
5	455.81	226.51	271.6	45.1	260.0	33.5
6	471.81	226.42	271.6	45.2	260.0	33.6
7	479.81	226.37	271.6	45.2	260.0	33.6
8	484.81	226.34	271.7	45.4	260.0	33.7
9	490.81	226.30	271.7	45.4	260.0	33.7
10	495.56	226.27	271.7	45.4	260.1	33.8
11	499.31	226.25	271.7	45.5	260.1	33.9
12	503.06	226.22	271.7	45.5	260.1	33.9
13	507.06	226.20	271.7	45.5	260.1	33.9
15	510.94	226.18	228.9	2.7	229.5	3.3
16	514.31	226.16	231.0	4.8	229.8	3.6
17	520.31	226.12	227.4	1.3	228.3	2.2
18	525.81	226.09	227.9	1.8	228.4	2.3
19	530.81	226.05	228.0	2.0	228.1	2.1
20	535.81	226.02	228.0	2.0	228.1	2.1
21	545.81	225.96	227.8	1.8	227.9	1.9
22	555.81	225.90	227.7	1.8	227.8	1.9
23	565.81	225.84	227.6	1.8	227.7	1.9
24	575.81	225.78	227.5	1.7	227.6	1.8
25	594.27	225.66	227.4	1.7	227.4	1.7
26	603.77	225.60	227.4	1.8	227.4	1.8
27	623.77	225.47	227.3	1.8	227.4	1.9
28	643.77	225.35	227.3	2.0	227.4	2.1
29	658.77	225.25	227.7	1.9	227.2	2.0

ROCHESTER CONTROL STRUCTURE 46
MODEL STUDIES
Type CS46 R10 Control Structure
Scale 1:12
Pressure Readings - Drawdown Mode

SAINT ANTHONY FALLS HYDRAULIC LABORATORY
UNIVERSITY OF MINNESOTA

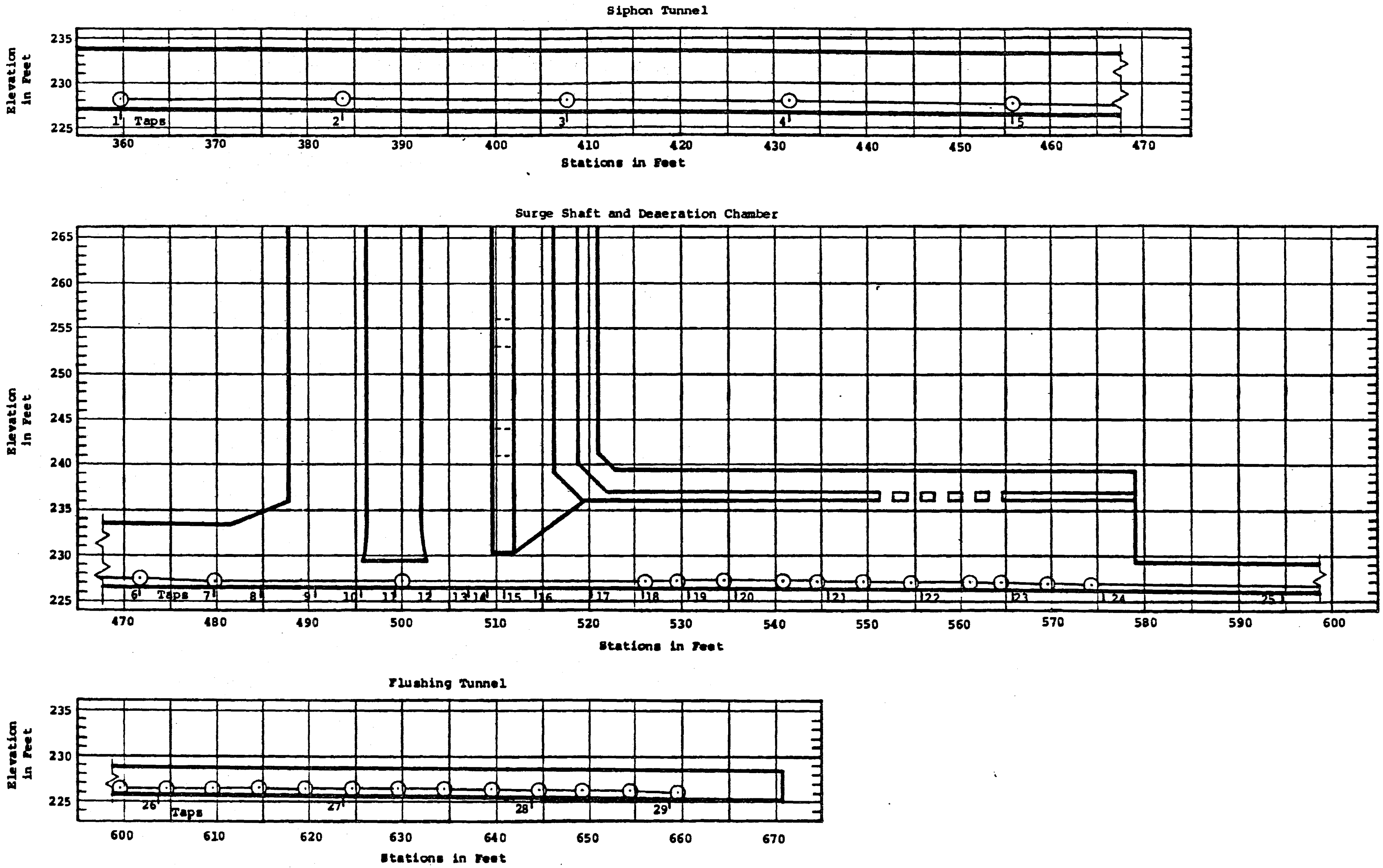
DRAWN KL	CHECKED MR	APPROVED
SCALE	DATE 3/15/84	NO. 328A2323-11



ROCHESTER CONTROL STRUCTURE 46
MODEL STUDIES
Type CS46 R10 Control Structure Scale 1:12
Water Surface Profiles - Flushing Mode
Q_P = 16 cfs, H.W. = 0.8 ft, T.W. = 0.4 ft

SAINT ANTHONY FALLS HYDRAULIC LABORATORY UNIVERSITY OF MINNESOTA		
DRAWN BB	CHECKED [signature]	APPROVED
SCALE	DATE 3/1/84	NO. 328B514-15

CHART 112

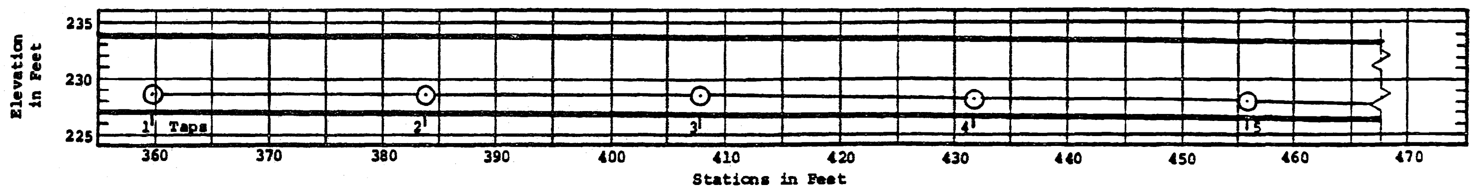


ROCHESTER CONTROL STRUCTURE 46
MODEL STUDIES
Type CS46 R10 Control Structure Scale 1:12
Water Surface Profiles - Flushing Mode
Q_F = 25 cfs, H.W. = 1.1 ft, T.W. = 0.6 ft

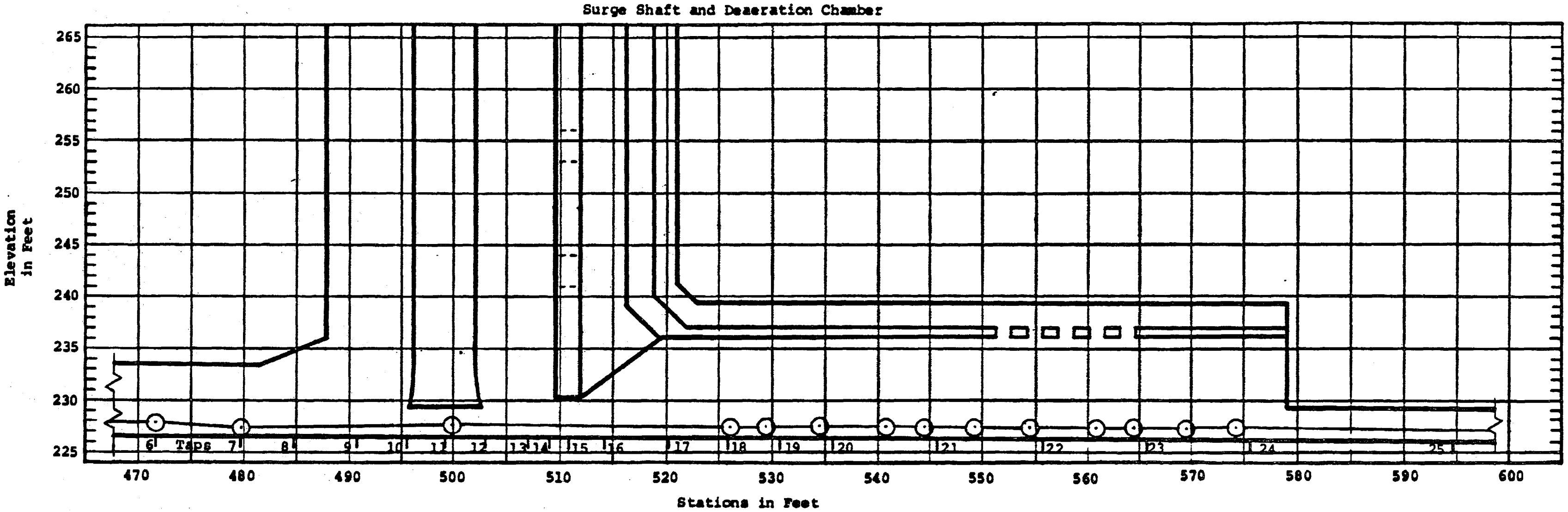
SAINT ANTHONY FALLS HYDRAULIC LABORATORY UNIVERSITY OF MINNESOTA		
DRAWN BB	CHECKED [signature]	APPROVED
SCALE	DATE 3/1/84	NO. 328B514-16

CHART 113

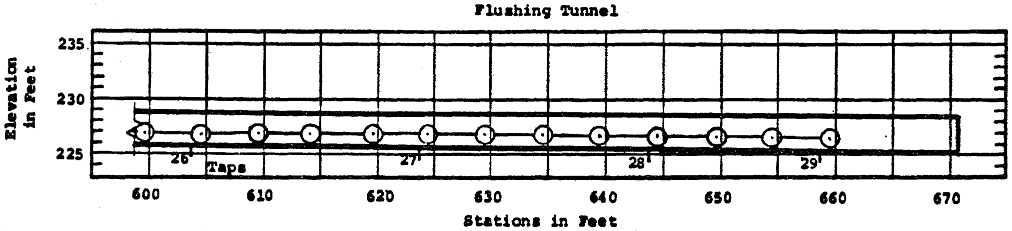
Siphon Tunnel



Surge Shaft and Deaeration Chamber



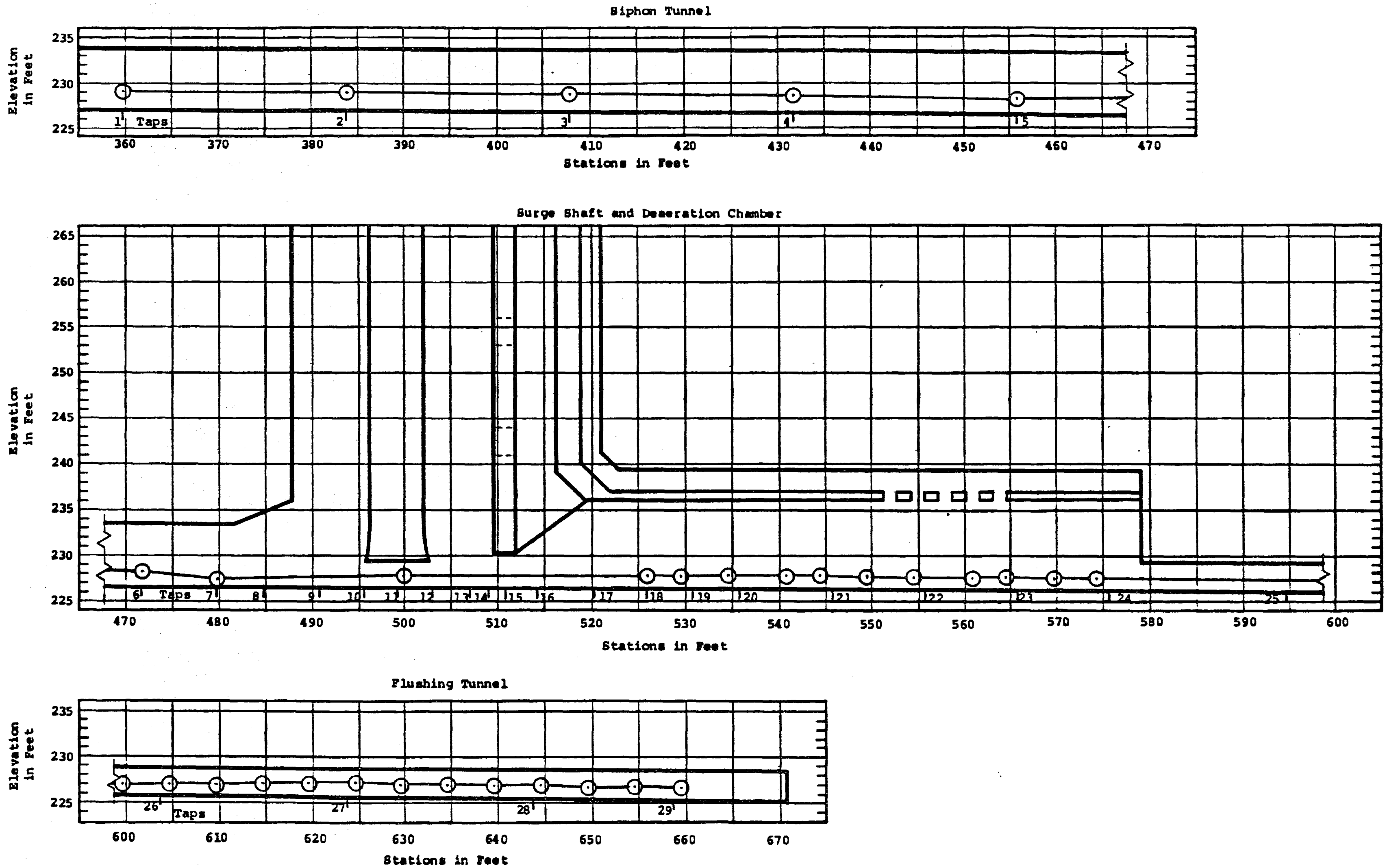
Flushing Tunnel



ROCHESTER CONTROL STRUCTURE 46
MODEL STUDIES
Type CS46 R10 Control Structure Scale 1:12
Water Surface Profiles - Flushing Mode
Q_F = 50 cfs, H.W. = 1.5 ft, T.W. = 1.0 ft

SAINT ANTHONY FALLS HYDRAULIC LABORATORY UNIVERSITY OF MINNESOTA		
DRAWN BB	CHECKED [signature]	APPROVED
SCALE	DATE 3/1/84	NO. 328B514-17

CHART 114



ROCHESTER CONTROL STRUCTURE 46
MODEL STUDIES
Type CS46 R10 Control Structure Scale 1:12
Water Surface Profiles - Flushing Mode
Q_F = 75 cfs, H.W. = 1.9 ft, T.W. = 1.3 ft

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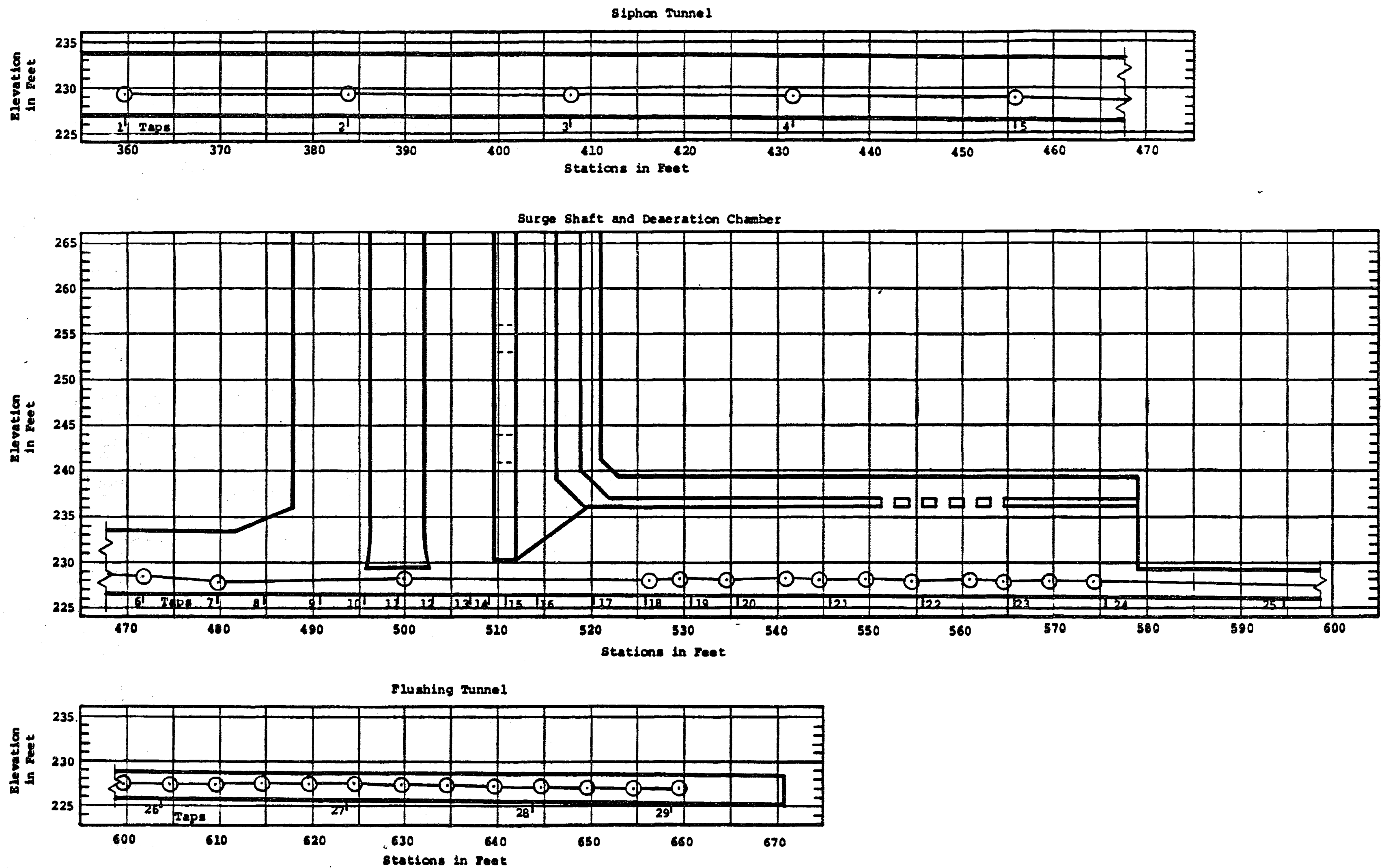
UNIVERSITY OF MINNESOTA

DRAWN BB	CHECKED	APPROVED
SCALE	DATE 3/1/84	NO. 328B514-18

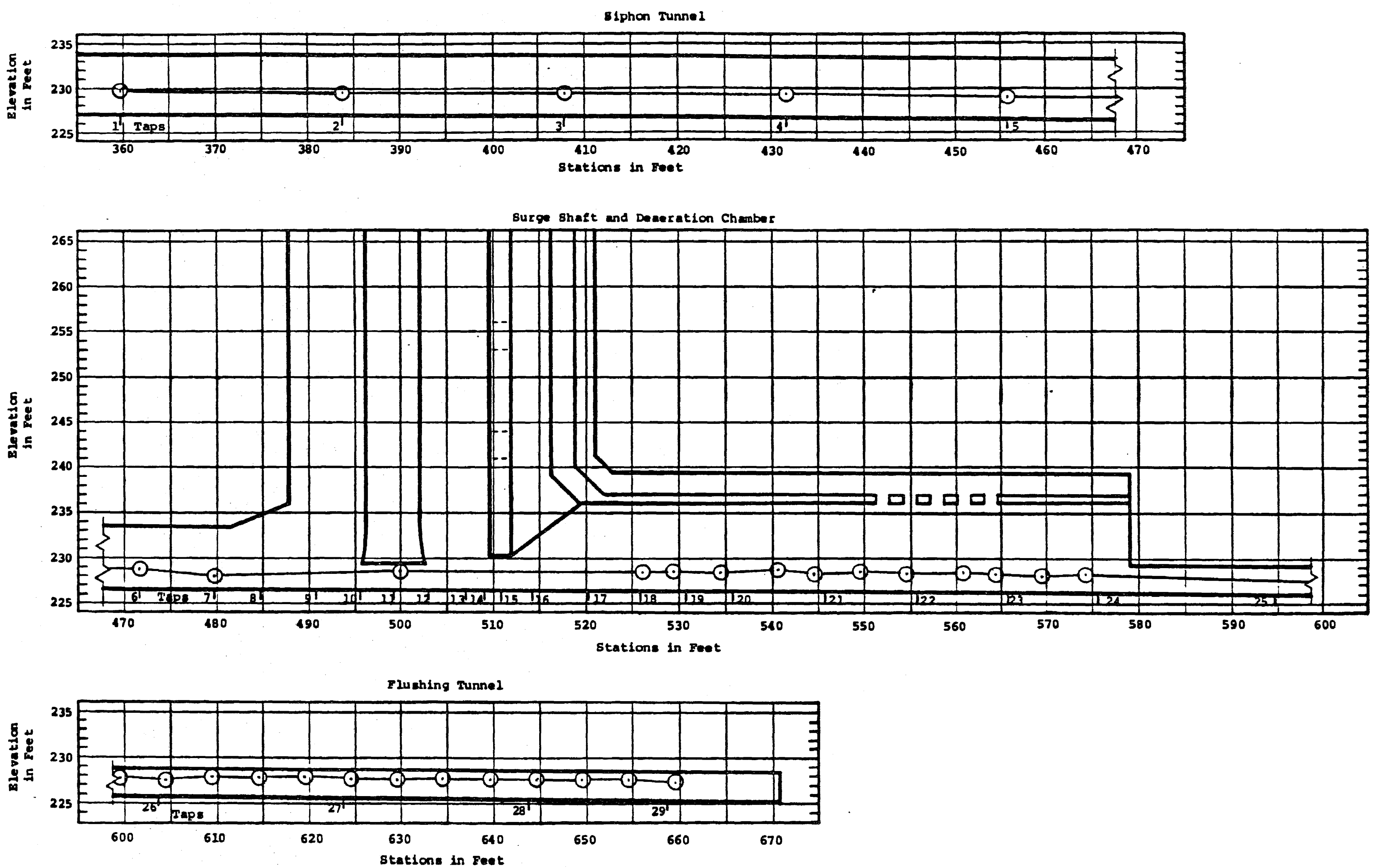
CHART 115



ROCHESTER CONTROL STRUCTURE 46
MODEL STUDIES
Type CS46 R10 Control Structure Scale 1:12
Water Surface Profiles - Flushing Mode
Q_F = 100 cfs, H.W. = 2.2 ft, T.W. = 1.5 ft

SAINT ANTHONY FALLS HYDRAULIC LABORATORY UNIVERSITY OF MINNESOTA		
DRAWN BB	CHECKED	APPROVED
SCALE	DATE 3/1/84	NO. 328B514-19

CHART 116



ROCHESTER CONTROL STRUCTURE 46
MODEL STUDIES
Type CS46 R10 Control Structure Scale 1:12
Water Surface Profiles - Flushing Mode
Q_F = 125 cfs, H.W. = 2.5 ft, T.W. = 1.8 ft

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UNIVERSITY OF MINNESOTA

DRAWN BB	CHECKED	APPROVED
SCALE	DATE 3/1/84	NO. 328B514-20

CHART 117

Water Depth - Flushing Mode

Station	Q_F = 16 cfs H.W. = 0.8 ft T.W. = 0.4 ft Depth	Q_F = 25 cfs H.W. = 1.1 ft T.W. = 0.6 ft Depth	Q_F = 50 cfs H.W. = 1.5 ft T.W. = 1.0 ft Depth
359.81	0.90	1.10	1.60
383.81	0.90	1.10	1.60
407.81	0.90	1.10	1.60
431.81	0.90	1.10	1.50
455.81	0.90	1.10	1.60
471.81	0.70	0.90	1.30
479.81	0.40	0.50	0.80
500.00	0.40	0.80	1.10
526.06	0.60	0.73	1.04
529.56	0.67	0.74	1.07
534.56	0.64	0.77	1.08
540.81	0.58	0.76	1.10
544.56	0.54	0.73	1.06
549.56	0.53	0.68	1.07
554.56	0.53	0.68	1.07
560.91	0.52	0.67	1.02
564.56	0.50	0.67	1.07
569.56	0.49	0.65	1.02
574.31	0.49	0.65	1.07
599.56	0.49	0.65	1.04
604.56	0.55	0.68	1.04
609.56	0.68	0.70	1.07
614.56	0.65	0.83	1.09
619.56	0.61	0.79	1.08
624.56	0.60	0.74	1.12
629.56	0.58	0.74	1.09
634.56	0.61	0.74	1.13
639.56	0.60	0.78	1.14
644.56	0.56	0.73	1.13
649.56	0.55	0.70	1.14
654.56	0.52	0.68	1.12
659.56	0.53	0.67	1.16

ROCHESTER CONTROL STRUCTURE 46
MODEL STUDIES
Type CS46 R10 Control Structure
Scale 1:12
Water Depths - Flushing Mode

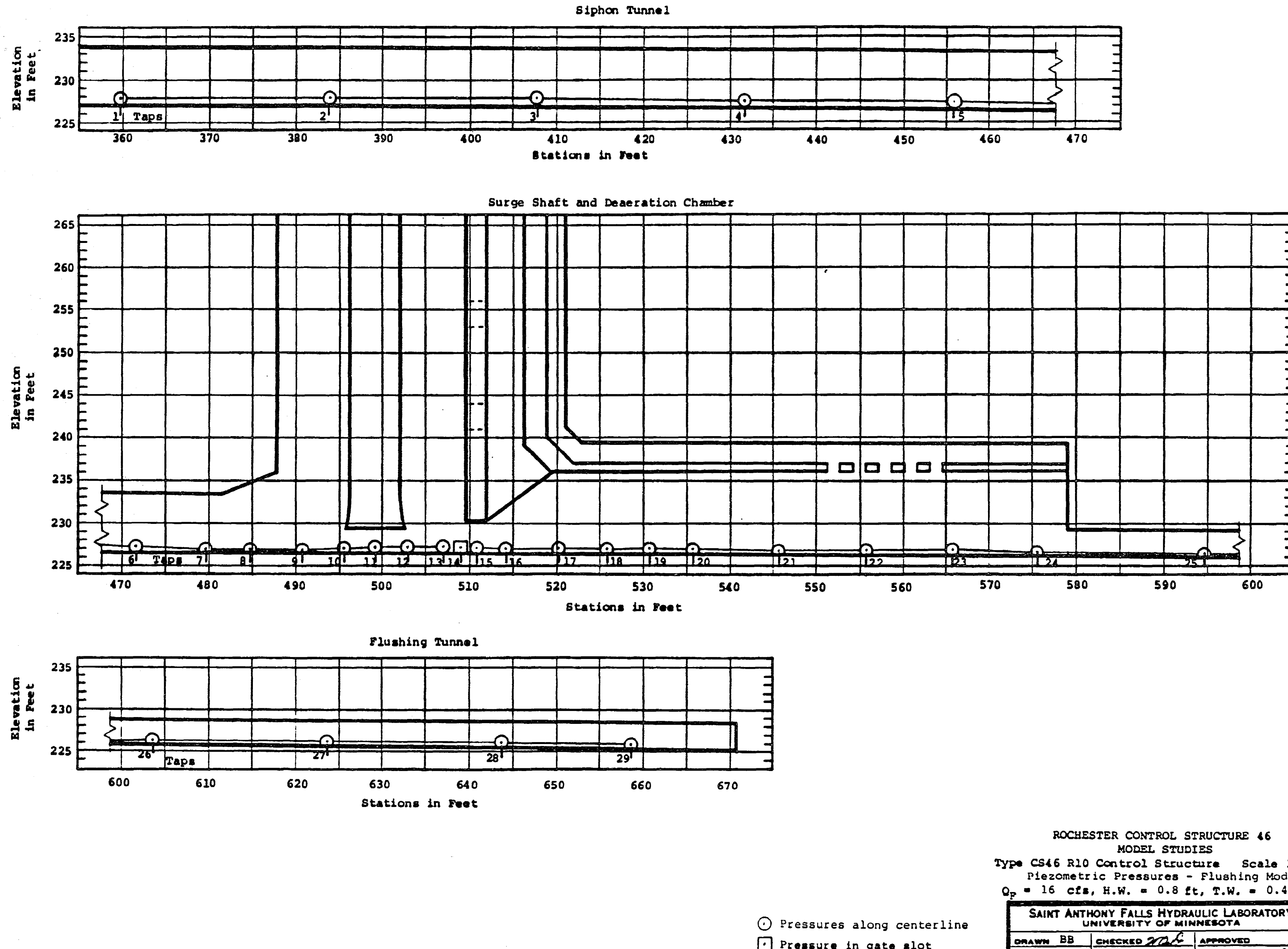
SAINT ANTHONY FALLS HYDRAULIC LABORATORY UNIVERSITY OF MINNESOTA		
DRAWN KL	CHECKED MR	APPROVED
SCALE	DATE 3/15/84	NO. 328A2323-4

Water Depths - Flushing Mode

Station	Q_F = 75 cfs H.W. = 1.9 ft T.W. = 1.3 ft Depth	Q_F = 100 cfs H.W. = 2.2 ft T.W. = 1.5 ft Depth	Q_F = 125 cfs H.W. = 2.5 ft T.W. = 1.8 ft Depth
359.81	2.00	2.30	2.50
383.81	1.90	2.30	2.50
407.81	1.90	2.30	2.50
431.81	1.90	2.30	2.50
455.81	1.80	2.30	2.50
471.81	1.60	2.00	2.20
479.81	0.90	1.30	1.40
500.00	1.40	1.70	2.00
526.06	1.46	1.74	1.98
529.56	1.39	1.86	2.22
534.56	1.46	1.69	1.97
540.81	1.37	1.79	2.18
544.56	1.46	1.68	1.94
549.56	1.39	1.86	2.17
554.56	1.43	1.63	1.97
560.91	1.31	1.79	2.12
564.56	1.40	1.63	1.98
569.56	1.32	1.70	1.93
574.31	1.36	1.67	2.02
599.56	1.20	1.60	1.98
604.56	1.33	1.72	1.90
609.56	1.33	1.64	2.06
614.56	1.39	1.74	1.98
619.56	1.38	1.76	2.15
624.56	1.42	1.79	2.04
629.56	1.40	1.76	2.14
634.56	1.44	1.79	2.10
639.56	1.44	1.78	2.15
644.56	1.45	1.76	2.12
649.56	1.39	1.69	2.06
654.56	1.39	1.70	2.08
659.56	1.38	1.66	1.99

ROCHESTER CONTROL STRUCTURE 46
MODEL STUDIES
Type CS46 R10 Control Structure
Scale 1:12
Water Depths - Flushing Mode

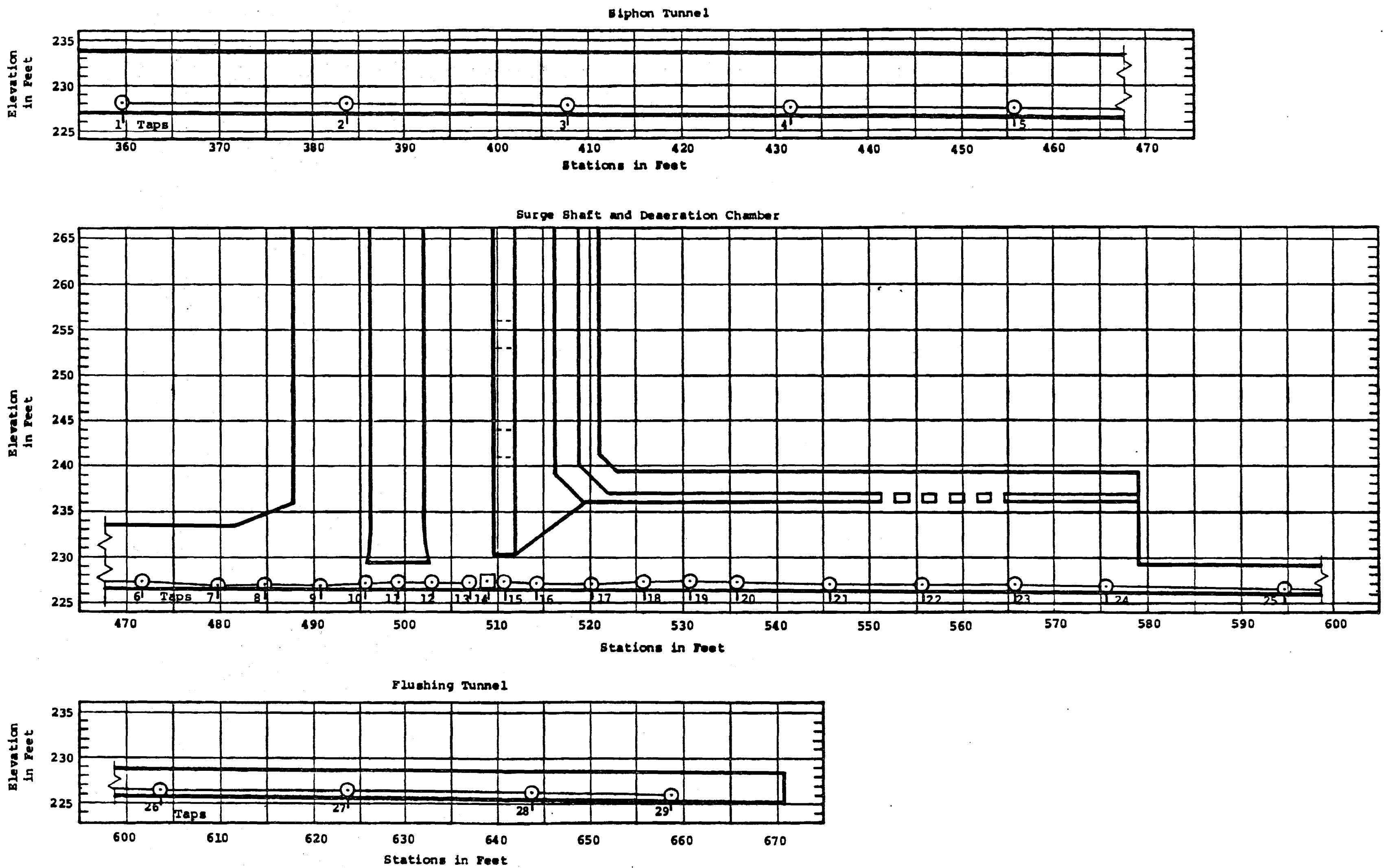
SAINT ANTHONY FALLS HYDRAULIC LABORATORY UNIVERSITY OF MINNESOTA		
DRAWN KL	CHECKED MR	APPROVED
SCALE	DATE 3/15/84	NO. 328A2323-5



ROCHESTER CONTROL STRUCTURE 46
MODEL STUDIES
Type CS46 R10 Control Structure Scale 1:12
Piezometric Pressures - Flushing Mode
Q_p = 16 cfs, H.W. = 0.8 ft, T.W. = 0.4 ft

SAINT ANTHONY FALLS HYDRAULIC LABORATORY UNIVERSITY OF MINNESOTA		
DRAWN BB	CHECKED	APPROVED
SCALE	DATE 3/1/84	NO. 328B514-9

CHART 120



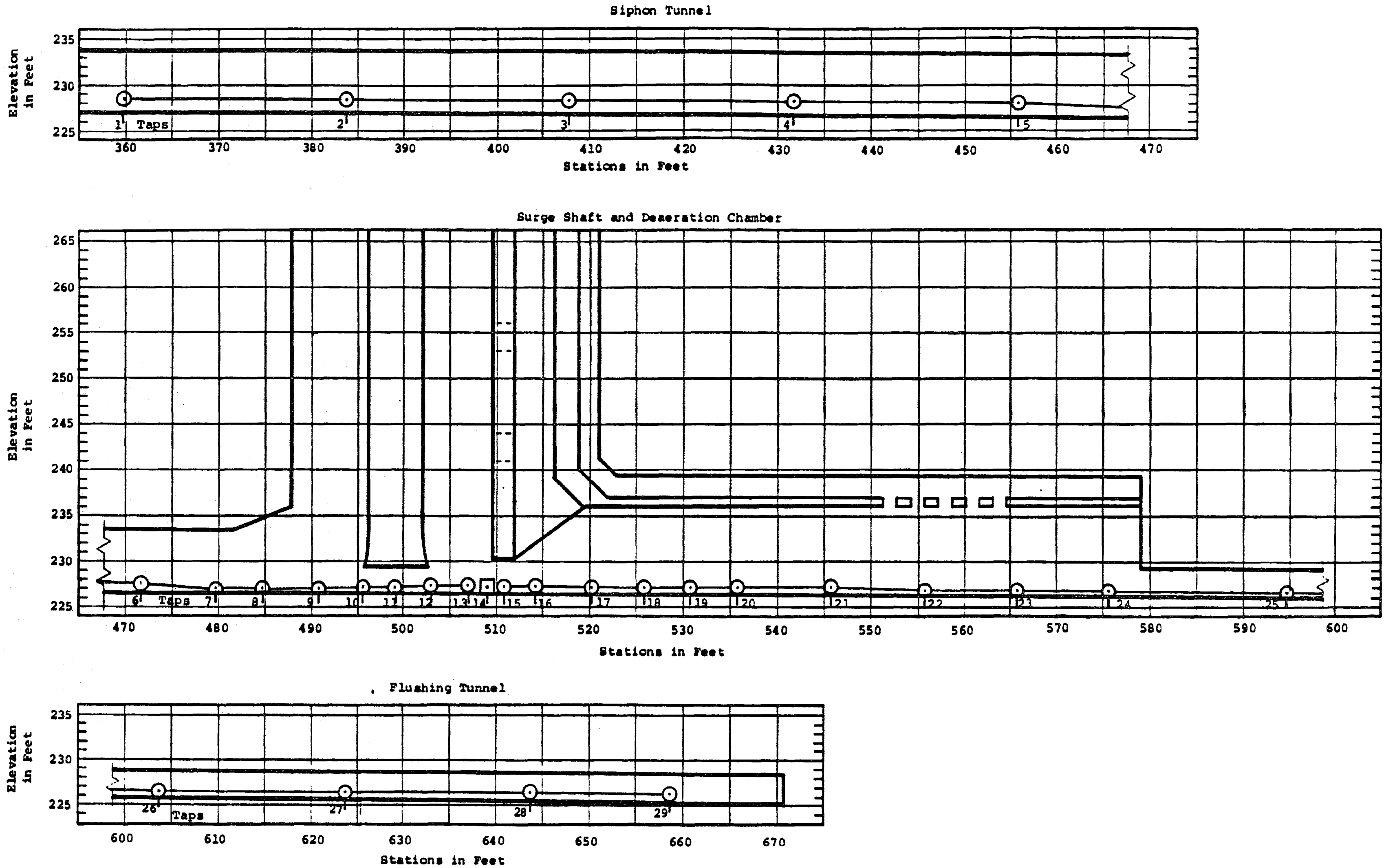
⊙ Pressures along centerline

⊡ Pressure in gate slot

ROCHESTER CONTROL STRUCTURE 46
MODEL STUDIES
Type CS46 R10 Control Structure Scale 1:12
Piezometric Pressures - Flushing Mode
Q_F = 25 cfs, H.W. = 1.1 ft, T.W. = 0.6 ft

SAINT ANTHONY FALLS HYDRAULIC LABORATORY UNIVERSITY OF MINNESOTA		
DRAWN BB	CHECKED [signature]	APPROVED
SCALE	DATE 3/1/84	NO. 328B514-10

CHART 121



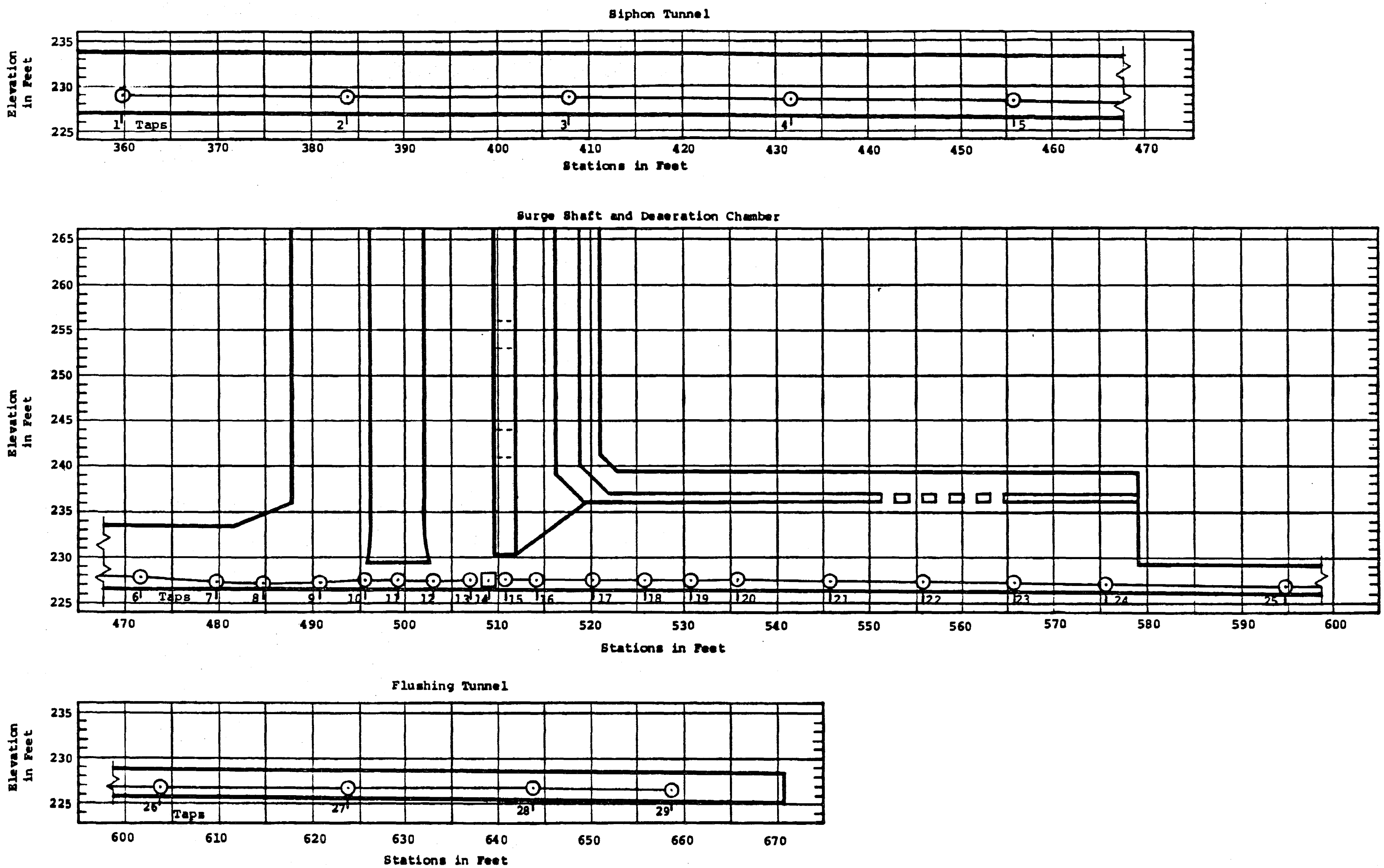
⊙ Pressures along centerline

⊡ Pressure in gate slot

ROCHESTER CONTROL STRUCTURE 46
MODEL STUDIES
Type C646 R10 Control Structure Scale 1:12
Piezometric Pressures - Flushing Mode
Q_F = 50 cfs, H.W. = 1.5 ft, T.W. = 1.0 ft

SAINT ANTHONY FALLS HYDRAULIC LABORATORY UNIVERSITY OF MINNESOTA		
DRAWN BB	CHECKED [signature]	APPROVED
SCALE	DATE 3/1/84	NO. 328B514- 11

CHART 122



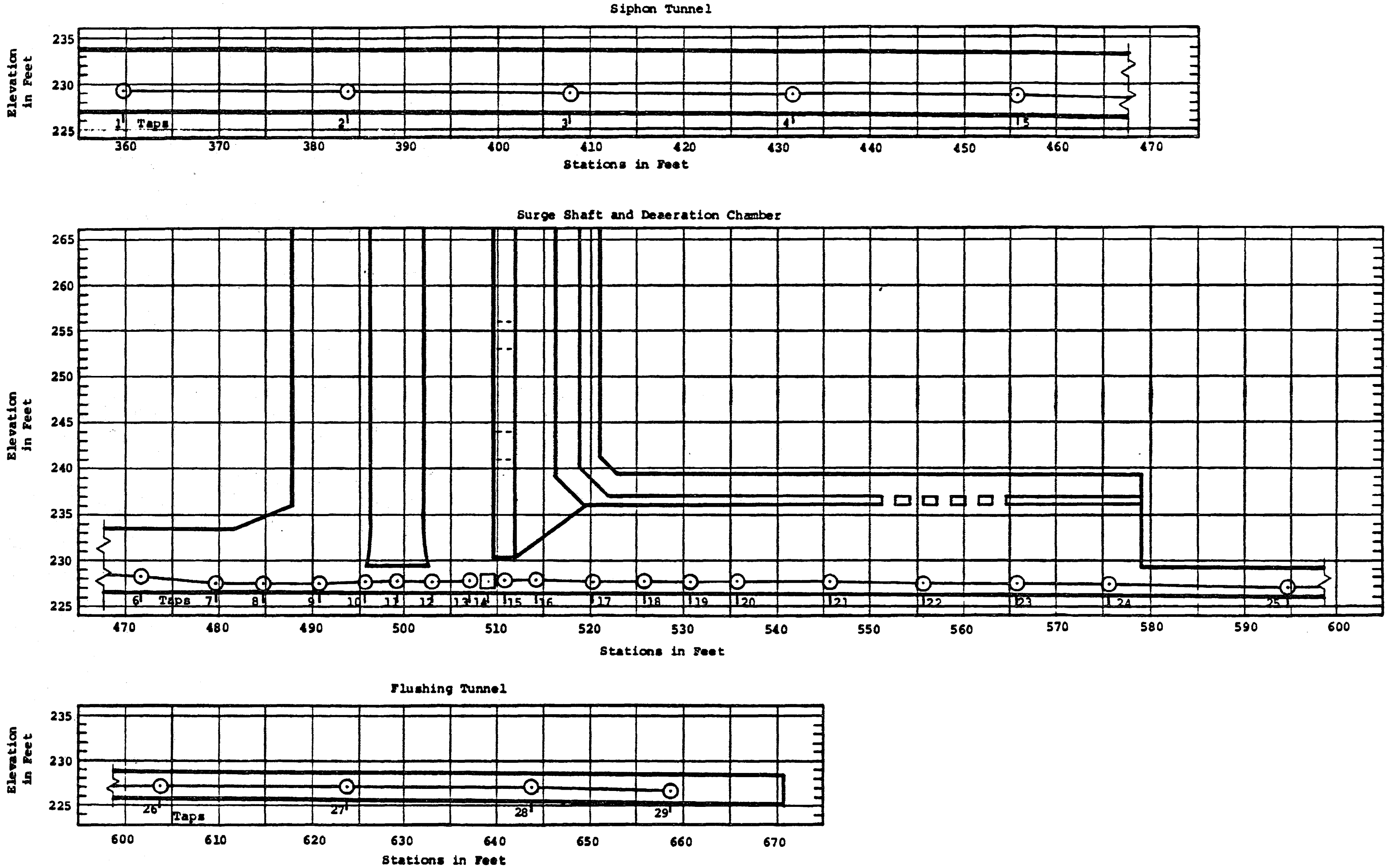
⊙ Pressures along centerline

⊡ Pressure in gate slot

ROCHESTER CONTROL STRUCTURE 46
MODEL STUDIES
Type CS46 R10 Control Structure Scale 1:12
Piezometric Pressures - Flushing Mode
Q_F = 75 cfs, H.W. = 1.9 ft, T.W. = 1.3 ft

SAINT ANTHONY FALLS HYDRAULIC LABORATORY UNIVERSITY OF MINNESOTA		
DRAWN BB	CHECKED mac	APPROVED
SCALE	DATE 3/1/84	NO. 328B514-12

CHART 123



⊙ Pressures along centerline

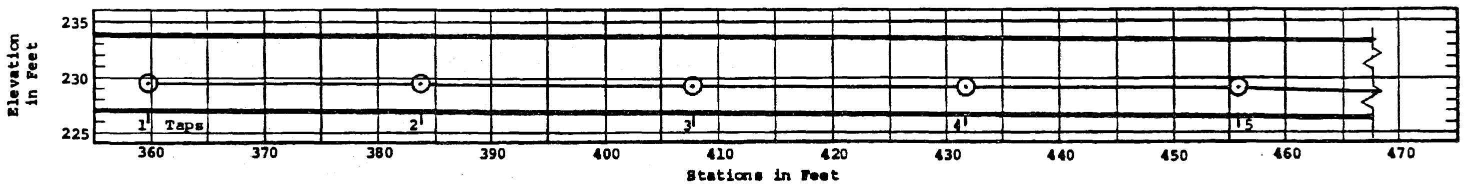
⊡ Pressure in gate slot

ROCHESTER CONTROL STRUCTURE 46
MODEL STUDIES
Type CS46 R10 Control Structure Scale 1:12
Piezometric Pressures - Flushing Mode
Q_F = 100 cfs, H.W. = 2.2 ft, T.W. = 1.5 ft

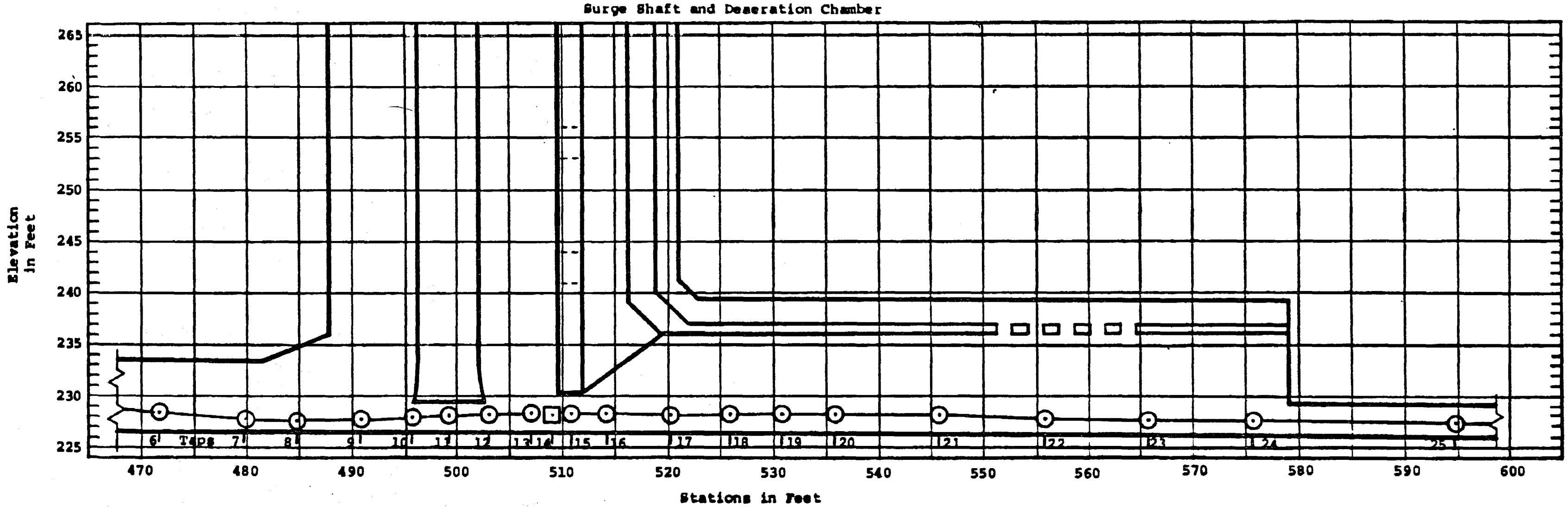
SAINT ANTHONY FALLS HYDRAULIC LABORATORY UNIVERSITY OF MINNESOTA		
DRAWN BB	CHECKED	APPROVED
SCALE	DATE 3/1/84	NO. 328B514-13

CHART 124

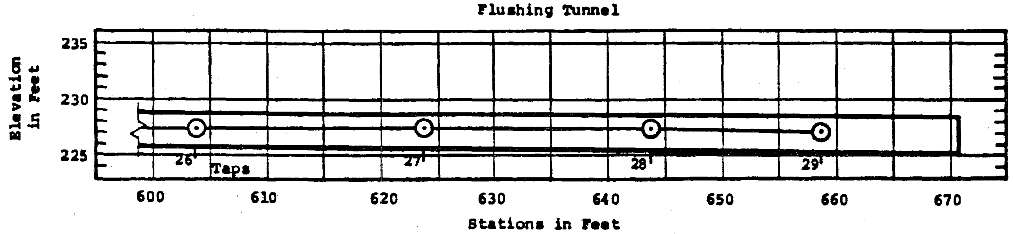
Siphon Tunnel



Surge Shaft and Deaeration Chamber



Flushing Tunnel



⊙ Pressures along centerline

⊡ Pressure in gate slot

ROCHESTER CONTROL STRUCTURE 46
MODEL STUDIES
Type CS46 R10 Control Structure Scale 1:12
Piezometric Pressures - Flushing Mode
Q_p = 125 cfs, H.W. = 2.5 ft, T.W. = 1.8 ft

SAINT ANTHONY FALLS HYDRAULIC LABORATORY UNIVERSITY OF MINNESOTA		
DRAWN BB	CHECKED	APPROVED
SCALE	DATE 3/1/84	NO. 328B514-14

CHART 125

Pressure Readings - Flushing Mode

			Q_F = 16 cfs, H.W. = 0.8 ft, T.W. = 0.4 ft		Q_F = 25 cfs, H.W. = 1.1 ft, T.W. = 0.6 ft	
Tap Number	Station	Tap Elevation	Piezometric Pressure Elevation	Pressure at Tap	Piezometric Pressure Elevation	Pressure at Tap
	ft	ft	ft	ft	ft	ft
1	359.81	227.10	227.9	0.8	228.2	1.1
2	383.81	226.95	227.8	0.9	228.0	1.1
3	407.81	226.80	227.7	0.9	227.9	1.1
4	431.81	226.66	227.5	0.8	227.7	1.0
5	455.81	226.51	227.4	0.9	227.6	1.1
6	471.81	226.42	227.1	0.7	227.2	0.8
7	479.81	226.37	226.7	0.3	226.8	0.4
8	484.81	226.34	226.6	0.3	226.7	0.4
9	490.81	226.30	226.6	0.3	226.7	0.4
10	495.56	226.27	226.8	0.5	226.9	0.6
11	499.31	226.25	226.9	0.7	226.9	0.7
12	503.06	226.22	227.0	0.8	226.9	0.7
13	507.06	226.20	227.0	0.8	226.9	0.7
14	509.06	226.19	226.8	0.6	227.0	0.8
15	510.94	226.18	226.8	0.6	227.0	0.8
16	514.31	226.16	226.7	0.5	226.9	0.7
17	520.31	226.12	226.7	0.6	226.9	0.7
18	525.81	226.09	226.7	0.6	226.9	0.8
19	530.81	226.05	226.7	0.7	226.9	0.9
20	535.81	226.02	226.7	0.7	226.8	0.8
21	545.81	225.96	226.5	0.5	226.7	0.7
22	555.81	225.90	226.4	0.5	226.6	0.7
23	565.81	225.84	226.4	0.6	226.5	0.7
24	575.81	225.78	226.2	0.4	226.4	0.6
25	594.27	225.66	226.0	0.3	226.2	0.5
26	603.77	225.60	226.1	0.5	226.2	0.6
27	623.77	225.47	226.0	0.5	226.2	0.7
28	643.77	225.35	225.9	0.6	226.0	0.7
29	658.77	225.25	225.7	0.5	225.9	0.7

ROCHESTER CONTROL STRUCTURE 46
MODEL STUDIES
Type CS46 R10 Control Structure
Scale 1:12
Pressure Readings - Flushing Mode

SAINT ANTHONY FALLS HYDRAULIC LABORATORY
UNIVERSITY OF MINNESOTA

DRAWN KL	CHECKED [illegible]	APPROVED
SCALE	DATE 3/15/84	NO. 328A2323-1

Pressure Readings - Flushing Mode

Tap Number	Station	Tap Elevation	Q_F = 50 cfs, H.W. = 1.5 ft, T.W. = 1.0 ft: Piezometric Pressure Elevation	Q_F = 50 cfs: Pressure at Tap	Q_F = 75 cfs, H.W. = 1.9 ft, T.W. = 1.3 ft: Piezometric Pressure Elevation	Q_F = 75 cfs: Pressure at Tap
	ft	ft	ft	ft	ft	ft
1	359.81	227.10	228.6	1.5	229.0	1.9
2	383.81	226.95	228.5	1.6	228.8	1.9
3	407.81	226.80	228.3	1.5	228.7	1.9
4	431.81	226.66	228.2	1.5	228.6	1.9
5	455.81	226.51	228.1	1.6	228.4	1.9
6	471.81	226.42	227.6	1.2	227.9	1.5
7	479.81	226.37	227.1	0.7	227.3	0.9
8	484.81	226.34	227.0	0.7	227.2	0.9
9	490.81	226.30	227.0	0.7	227.3	1.0
10	495.56	226.27	227.2	0.9	227.5	1.2
11	499.31	226.25	227.1	0.9	227.5	1.3
12	503.06	226.22	227.2	1.0	227.5	1.3
13	507.06	226.20	227.3	1.1	227.6	1.4
14	509.06	226.19	227.3	1.1	227.5	1.3
15	510.94	226.18	227.2	1.0	227.6	1.4
16	514.31	226.16	227.3	1.1	227.6	1.4
17	520.31	226.12	227.2	1.1	227.5	1.4
18	525.81	226.09	227.2	1.1	227.6	1.5
19	530.81	226.05	227.2	1.2	227.5	1.5
20	535.81	226.02	227.2	1.2	227.5	1.5
21	545.81	225.96	227.1	1.1	227.4	1.4
22	555.81	225.90	226.9	1.0	227.3	1.4
23	565.81	225.84	226.9	1.1	227.2	1.4
24	575.81	225.78	226.8	1.0	227.1	1.3
25	594.27	225.66	226.5	0.8	226.9	1.2
26	603.77	225.60	226.5	0.9	226.9	1.3
27	623.77	225.47	226.5	1.0	226.9	1.4
28	643.77	225.35	226.4	1.1	226.8	1.5
29	658.77	225.25	226.3	1.1	226.6	1.4

ROCHESTER CONTROL STRUCTURE 46
MODEL STUDIES
Type CS46 R10 Control Structure
Scale 1:12
Pressure Readings - Flushing Mode

SAINT ANTHONY FALLS HYDRAULIC LABORATORY
UNIVERSITY OF MINNESOTA

DRAWN KL	CHECKED [illegible]	APPROVED
SCALE	DATE 3/15/84	NO. 328A2323-2

Pressure Readings - Flushing Mode

Tap Number	Station	Tap Elevation	Q_F = 100 cfs, H.W. = 2.2 ft, T.W. = 1.5 ft: Piezometric Pressure Elevation	Pressure at Tap	Q_F = 125 cfs, H.W. = 2.5 ft, T.W. = 1.8 ft: Piezometric Pressure Elevation	Pressure at Tap
	ft	ft	ft	ft	ft	ft
1	359.81	227.10	229.3	2.2	229.6	2.5
2	383.81	226.95	229.2	2.3	229.5	2.6
3	407.81	226.80	229.0	2.2	229.3	2.5
4	431.81	226.66	228.8	2.1	229.2	2.5
5	455.81	226.51	228.7	2.2	229.1	2.6
6	471.81	226.42	228.2	1.8	228.5	2.1
7	479.81	226.37	227.5	1.1	227.8	1.4
8	484.81	226.34	227.5	1.2	227.7	1.4
9	490.81	226.30	227.5	1.2	227.8	1.5
10	495.56	226.27	227.7	1.4	228.0	1.7
11	499.31	226.25	227.8	1.6	228.1	1.9
12	503.06	226.22	227.8	1.6	228.2	2.0
13	507.06	226.20	227.9	1.7	228.3	2.1
14	509.06	226.19	227.7	1.5	228.1	1.9
15	510.94	226.18	227.9	1.7	228.3	2.1
16	514.31	226.16	227.9	1.7	228.3	2.1
17	520.31	226.12	227.8	1.7	228.2	2.1
18	525.81	226.09	227.8	1.7	228.2	2.1
19	530.81	226.05	227.8	1.8	228.2	2.2
20	535.81	226.02	227.8	1.8	228.2	2.2
21	545.81	225.96	227.7	1.7	228.1	2.1
22	555.81	225.90	227.5	1.6	227.9	2.0
23	565.81	225.84	227.4	1.6	227.8	2.0
24	575.81	225.78	227.3	1.5	227.7	1.9
25	594.27	225.66	227.1	1.4	227.4	1.7
26	603.77	225.60	227.2	1.6	227.4	1.8
27	623.77	225.47	227.2	1.7	227.5	2.0
28	643.77	225.35	227.1	1.8	227.4	2.1
29	658.77	225.25	226.8	1.6	227.1	1.9

ROCHESTER CONTROL STRUCTURE 46
MODEL STUDIES
Type CS46 R10 Control Structure
Scale 1:12
Pressure Readings - Flushing Mode

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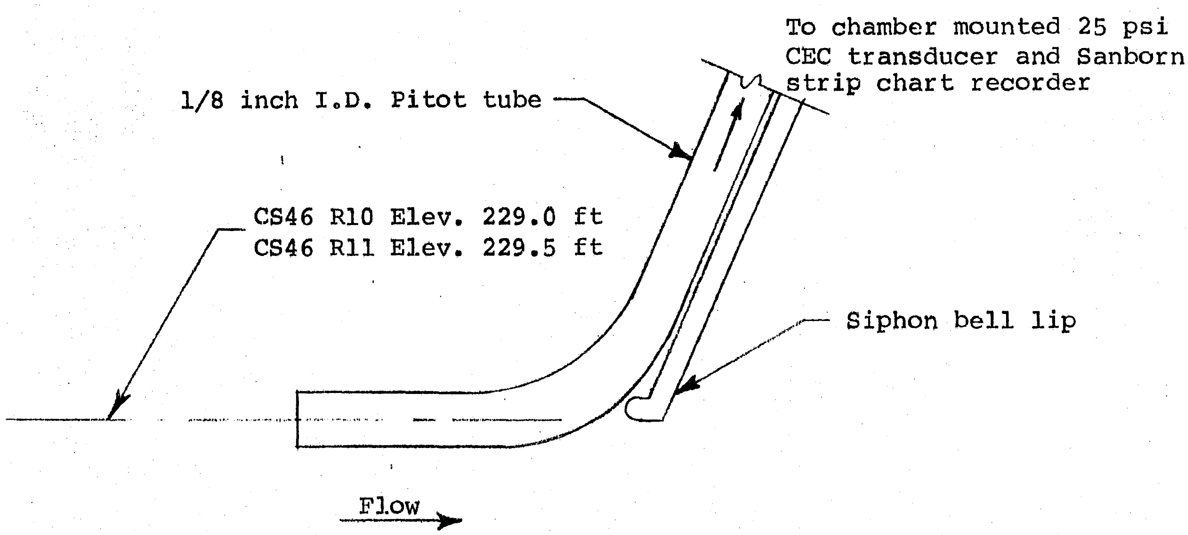
UNIVERSITY OF MINNESOTA

DRAWN KL	CHECKED [signature]	APPROVED
SCALE	DATE 3/15/84	NO. 328A2323-3

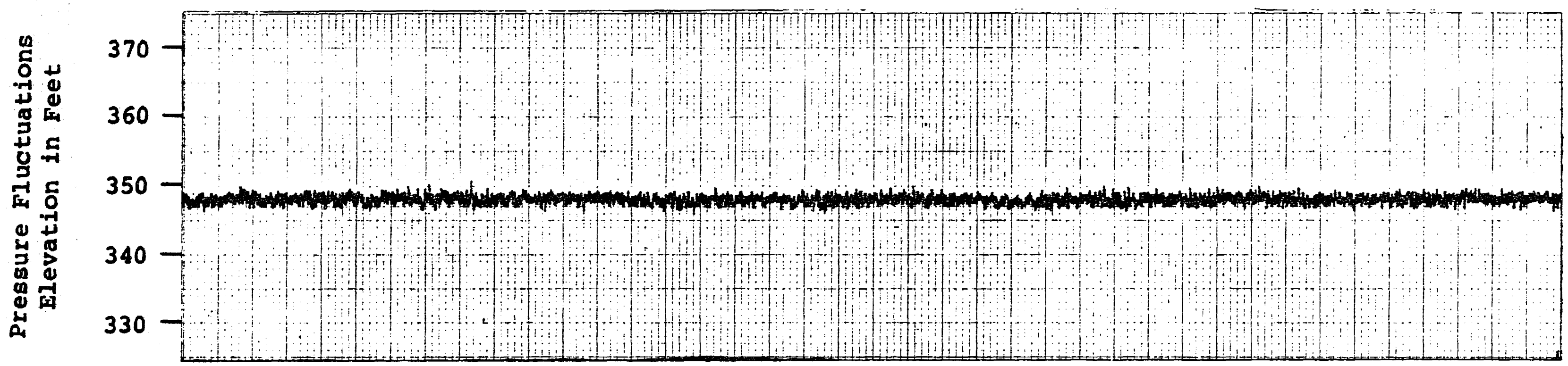
Fluctuating Pressures on Siphon Bell Lip

Operating Mode	Q cfs	Maximum Fluctuating Pressure ft	Frequency Hz
Type CS46 R10 Control Structure			
Siphon	375	8.0	11.5
Drawdown			
1. Near top	-	7.0	13.0
2. Near bottom	-	5.5	13.0
Flushing (with induced hydraulic jump)	100	4.0	14.4
	125	4.5	14.4
	150	4.5	14.4
Type CS46 R11 Control Structure			
Siphon	375	5.2	11.5
Drawdown			
1. Near top	-	7.0	13.0
2. Near bottom	-	10.0	13.0
Flushing (with induced hydraulic jump)	100	4.0	14.4
	125	5.5	14.4
	150	4.2	14.4



ROCHESTER CONTROL STRUCTURE 46
MODEL STUDIES
Type CS46 R10 & R11 Control Structures
Scale 1:12
Fluctuating Pressures on Siphon Bell Lip

SAINT ANTHONY FALLS HYDRAULIC LABORATORY UNIVERSITY OF MINNESOTA		
DRAWN WQD	CHECKED MR	APPROVED
SCALE	DATE 5/30/84	NO. 328A2323-46



Time Scale in Seconds

0 1 2 Model

0 2 4 6 Prototype

ROCHESTER CONTROL STRUCTURE 46
MODEL STUDIES
Type CS46 R10 Control Structure
Scale 1:12
Fluctuating Pressures on Siphon Bell Lip
Siphon Mode Q_s = 375 cfs

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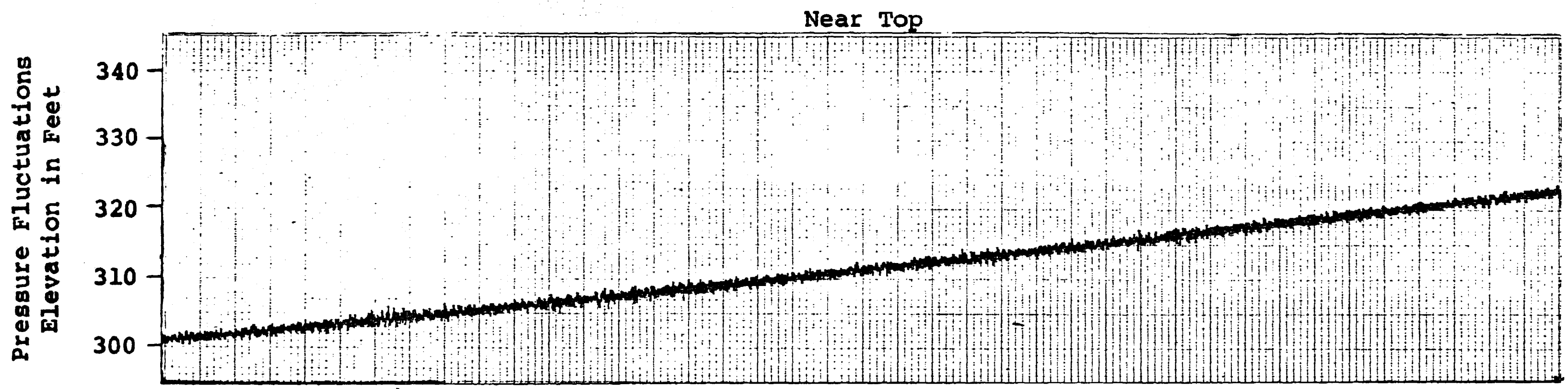
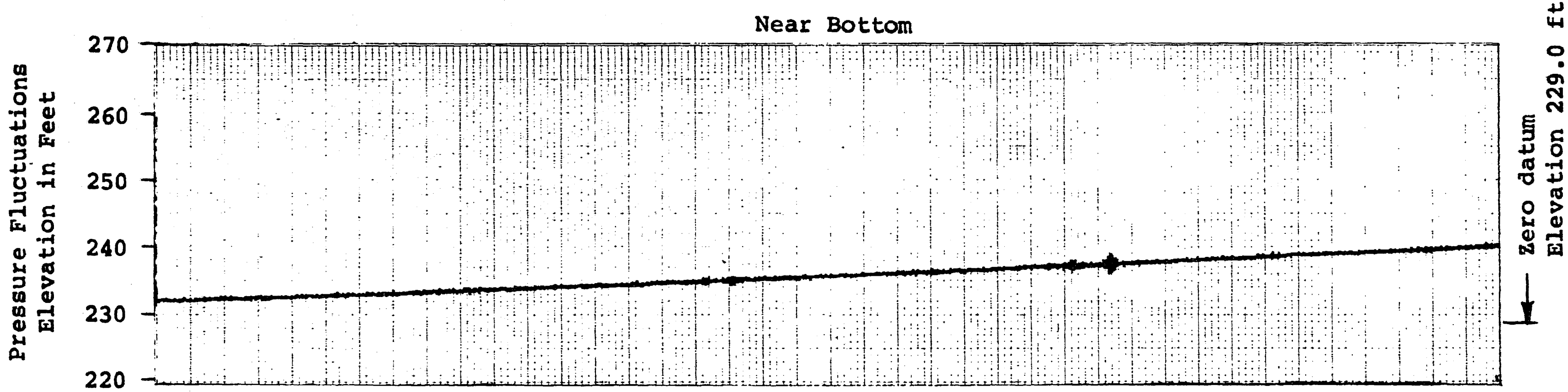
UNIVERSITY OF MINNESOTA

DRAWN WQD	CHECKED	APPROVED
SCALE	DATE 5/31/84	NO.328A2323-47

CHART 130





Time Scale In Seconds

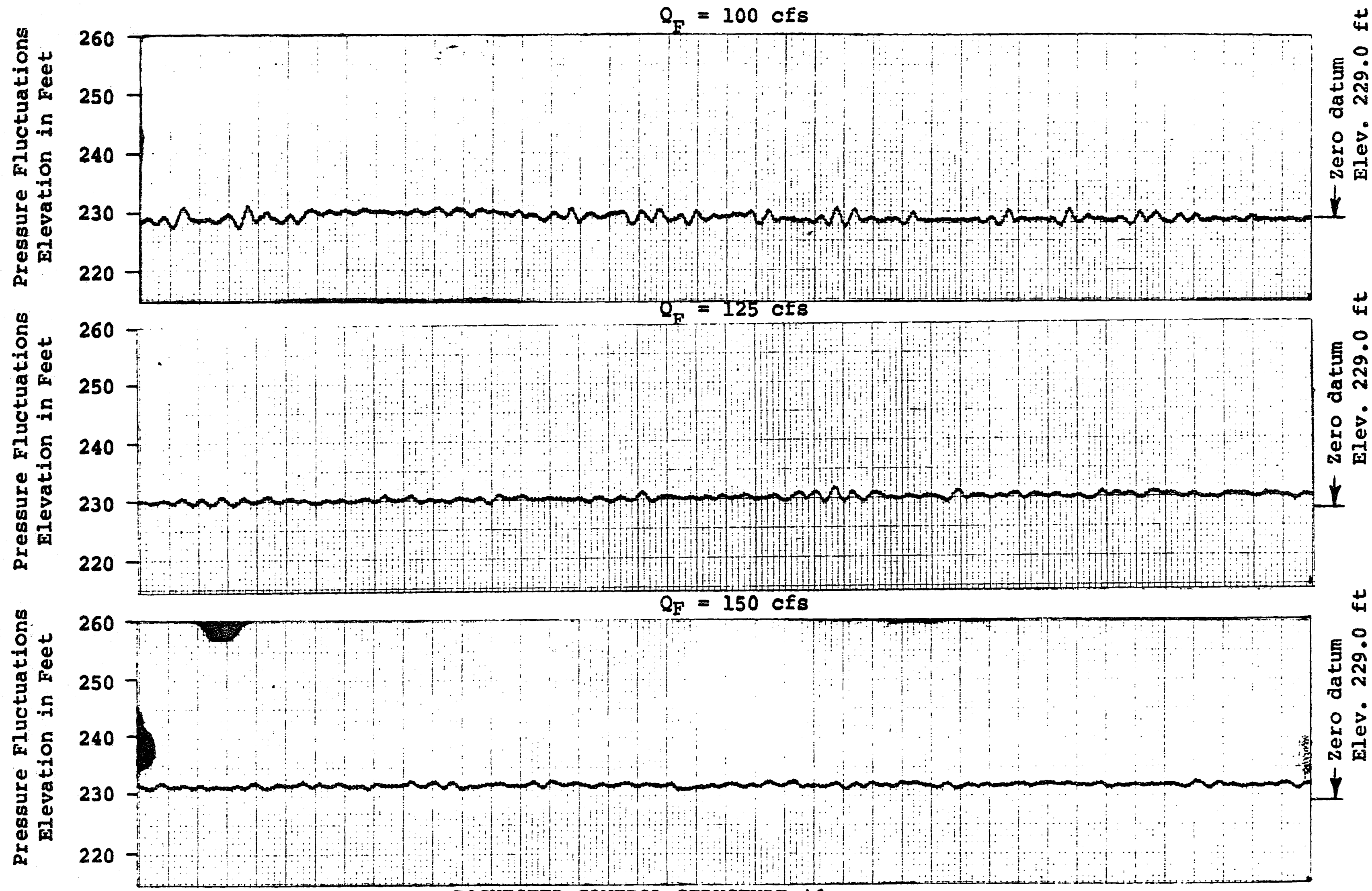
0 1 2 Model

Prototype
0 2 4 6

ROCHESTER CONTROL STRUCTURE 46
MODEL STUDIES
Type CS46 R10 Control Structure
Scale 1:12
Fluctuating Pressures on Siphon Bell Lip
Drawdown Mode

SAINT ANTHONY FALLS HYDRAULIC LABORATORY UNIVERSITY OF MINNESOTA		
DRAWN WQD	CHECKED [signature]	APPROVED
SCALE	DATE 5/31/84	NO. 328A2323-49

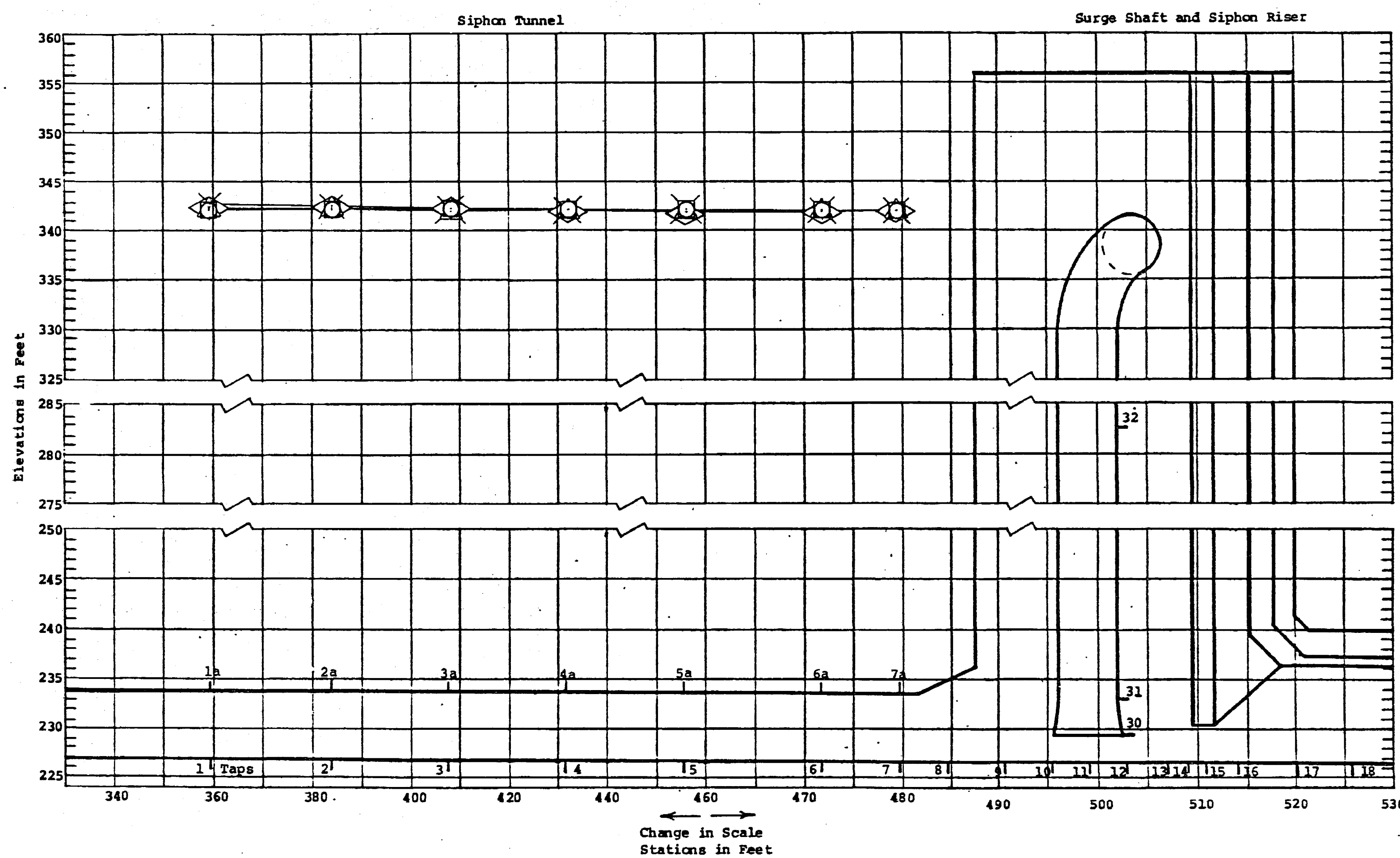
CHART 131



Time Scale in Seconds
0 1 2 Model
0 2 4 6 Prototype

ROCHESTER CONTROL STRUCTURE 46
MODEL STUDIES
Type CS46 R10 Control Structure
Scale 1:12
Fluctuating Pressures on Siphon Bell Lip
Flushing Mode

SAINT ANTHONY FALLS HYDRAULIC LABORATORY UNIVERSITY OF MINNESOTA		
DRAWN WQD	CHECKED	APPROVED
SCALE	DATE 5/31/84	NO. 328A2323-51



Q_s - cfs	150	150	150	150	150
H.W. - ft	115.0	115.1	115.2	115.3	115.6
Time - min	0	30	60	90	120
Symbol	⊙	⊡	△	◇	×

ROCHESTER CONTROL STRUCTURE 46
MODEL STUDIES
Type CS46 R10 Control Structure Scale 1:12
Piezometric Pressures - Siphon Mode
Sediment Test No. 12

SAINT ANTHONY FALLS HYDRAULIC LABORATORY UNIVERSITY OF MINNESOTA		
DRAWN BB	CHECKED [signature]	APPROVED
SCALE	DATE 3/1/84	NO. 328B514-73

CHART 133

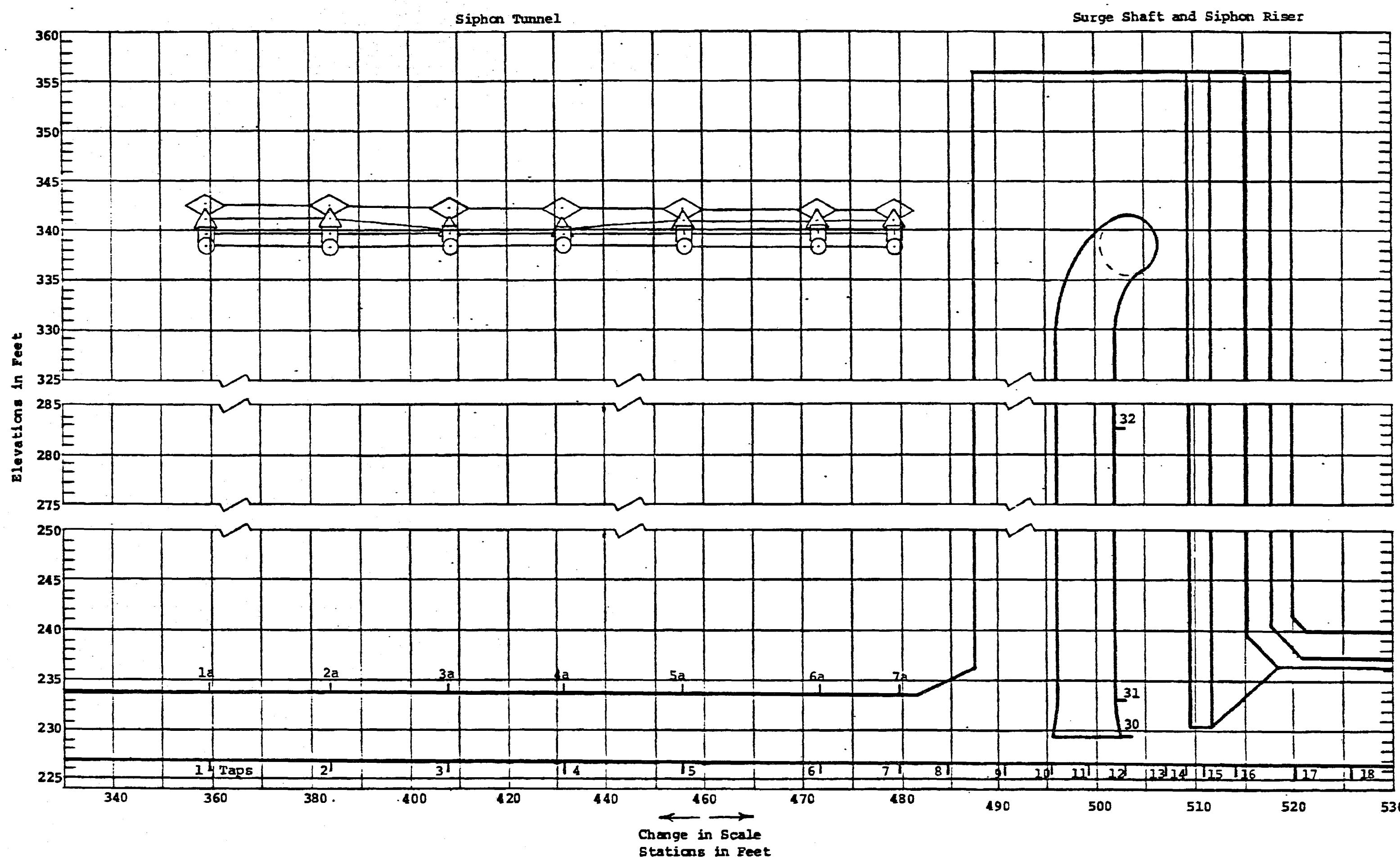
Pressure Readings - Siphon Mode
Sediment Test No. 12

Tap Number	Station	Tap Elevation	Piezometric Pressure Elevation	Pressure at Tap	Piezometric Pressure Elevation	Pressure at Tap
	ft	ft	ft	ft	ft	ft
			Q_s = 150 cfs H.W. = 115.0 ft Time = 0 min		Q_s = 150 cfs H.W. = 115.1 ft Time = 30 min	
1a	359.81	234.10	342.1	108.0	342.2	108.1
2a	383.81	233.95	342.1	108.2	342.1	108.2
3a	407.81	233.81	342.1	108.3	342.1	108.3
4a	431.81	233.66	342.1	108.4	342.1	108.4
5a	455.81	233.51	342.1	108.6	342.1	108.6
6a	471.81	233.42	342.0	108.6	342.0	108.6
7a	479.81	233.37	342.0	108.6	342.0	108.6
			Q_s = 150 cfs H.W. = 115.2 ft Time = 60 min		Q_s = 150 cfs H.W. = 115.3 ft Time = 90 min	
1a	359.81	234.10	342.3	108.2	342.4	108.3
2a	383.81	233.95	342.2	108.3	342.4	108.3
3a	407.81	233.81	341.9	108.1	342.1	108.3
4a	431.81	233.66	342.0	108.3	342.0	108.3
5a	455.81	233.51	342.0	108.5	341.9	108.4
6a	471.81	233.42	342.0	108.6	341.9	108.5
7a	479.81	233.37	342.0	108.6	342.0	108.6
			Q_s = 150 cfs H.W. = 115.6 ft Time = 120 min			
1a	359.81	234.10	342.7	108.6		
2a	383.81	233.95	342.5	108.6		
3a	407.81	223.81	342.2	108.4		
4a	431.81	233.66	342.2	108.5		
5a	455.81	233.51	342.1	108.6		
6a	471.81	233.42	342.0	108.6		
7a	479.81	233.37	342.0	108.6		

ROCHESTER CONTROL STRUCTURE 46
MODEL STUDIES
Type CS46 R10 Control Structure
Scale 1:12
Pressure Readings - Siphon Mode

SAINT ANTHONY FALLS HYDRAULIC LABORATORY
UNIVERSITY OF MINNESOTA

DRAWN MR	CHECKED [illegible]	APPROVED
SCALE	DATE 5/22/84	NO. 328A2323-40



Q_s - cfs	16	50	100	150
H.W. - ft	111.2	112.5	114.0	115.6
Time - min	120	120	120	120
Symbol	⊙	⊡	△	◇

ROCHESTER CONTROL STRUCTURE 46
MODEL STUDIES
Type CS46 R10 Control Structure Scale 1:12
Piezometric Pressure - Siphon Mode
Sediment Test No. 12

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DRAWN BB	CHECKED MAL	APPROVED
SCALE	DATE 3/1/84	NO. 328B514-74

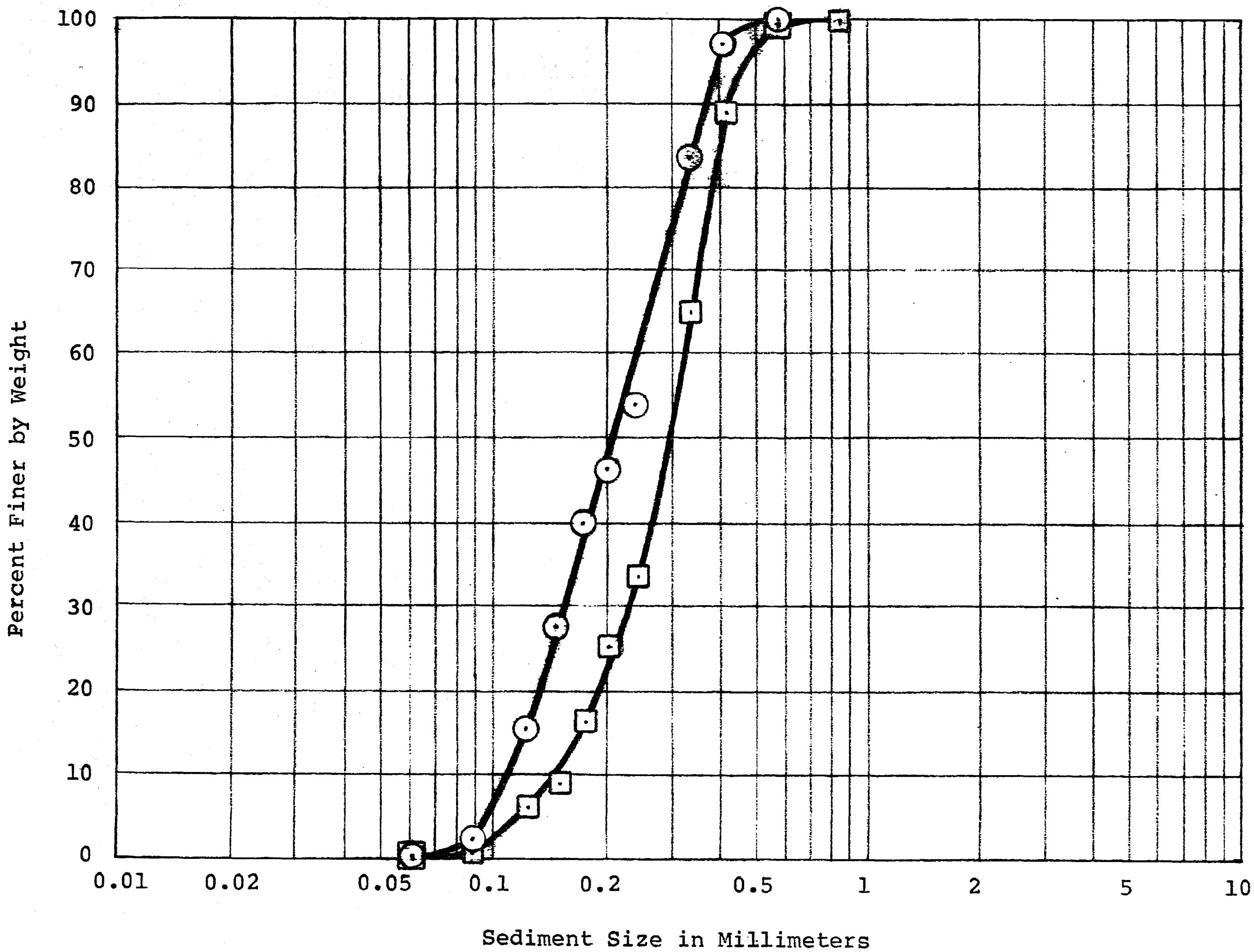
CHART 135

Pressure Readings - Siphon Mode
Sediment Test No. 12

Tap Number	Station	Tap Elevation	Piezometric Pressure Elevation	Pressure at Tap	Piezometric Pressure Elevation	Pressure at Tap
	ft	ft	ft	ft	ft	ft
			Q_s = 16 cfs H.W. = 111.2 ft Time = 120 min		Q_s = 50 cfs H.W. = 112.5 cfs Time = 120 min	
1a	359.81	234.10	338.3	104.2	339.6	105.5
2a	383.81	233.95	338.3	104.4	339.6	105.7
3a	407.81	233.81	338.3	104.5	339.6	105.7
4a	431.81	233.66	338.3	104.6	339.6	105.9
5a	455.81	233.51	338.3	104.8	339.6	106.0
6a	471.81	233.42	338.3	104.9	339.6	106.1
7a	479.81	233.37	338.3	104.9	339.6	106.2
			Q_s = 100 cfs H.W. = 114.0 ft Time = 120 min		Q_s = 150 cfs H.W. = 115.6 ft Time = 120 min	
1a	359.81	234.10	341.1	107.0	342.7	108.6
2a	383.81	233.95	341.1	107.2	342.5	108.6
3a	407.81	233.81	340.0	106.2	342.2	108.4
4a	431.81	233.66	340.0	106.3	342.2	108.5
5a	455.81	233.51	340.9	107.4	342.1	108.6
6a	471.81	233.42	340.9	107.5	342.0	108.6
7a	479.81	233.37	340.9	107.5	342.0	108.6

ROCHESTER CONTROL STRUCTURE 46
MODEL STUDIES
Type CS46 R10 Control Structure
Scale 1:12
Pressure Readings - Siphon Mode

SAINT ANTHONY FALLS HYDRAULIC LABORATORY UNIVERSITY OF MINNESOTA		
DRAWN MR	CHECKED [signature]	APPROVED
SCALE	DATE 5/22/84	NO. 328A2323-41



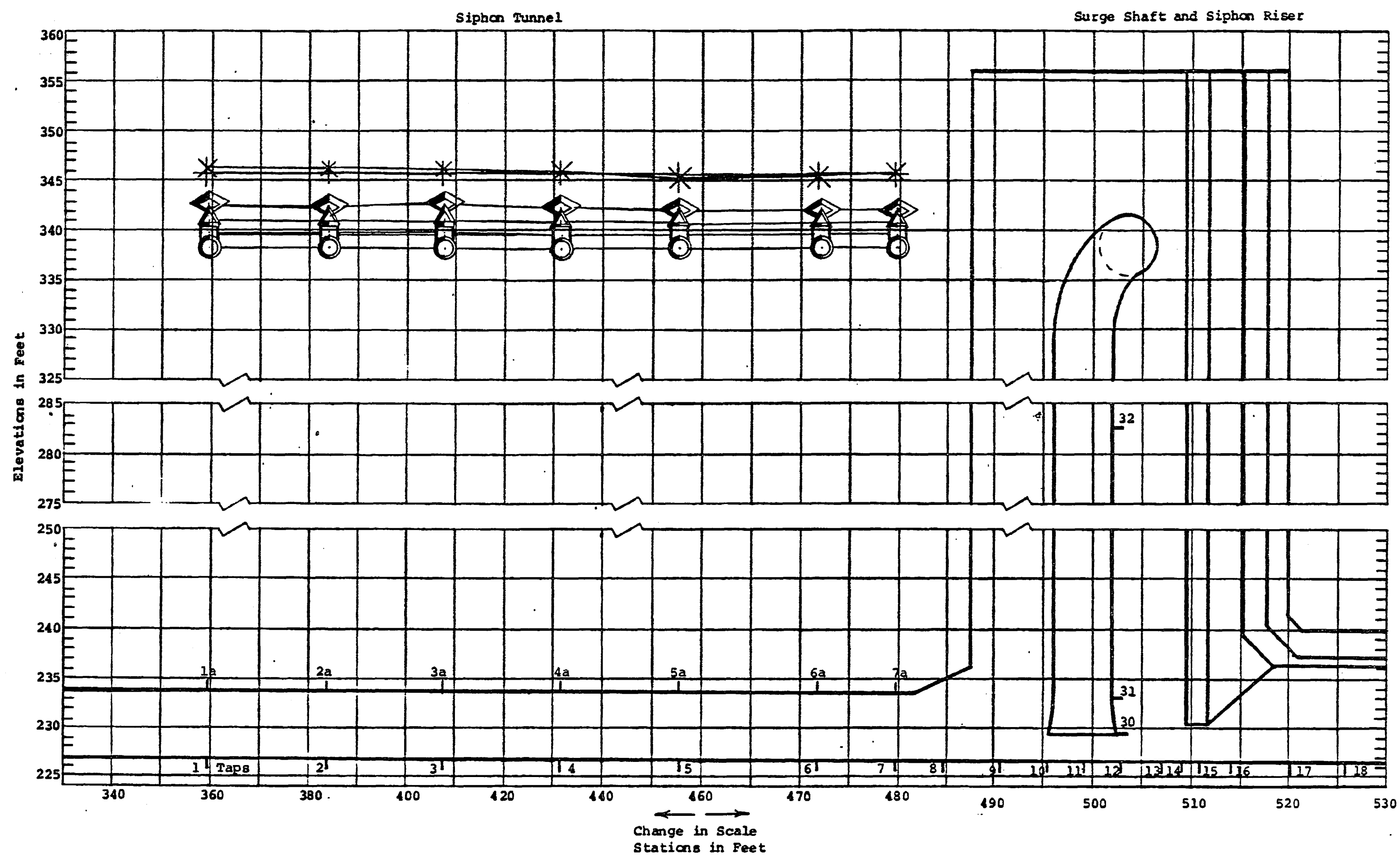
⊙ Inorganic sediment fed into model

⊡ Sediment deposited in model during test

ROCHESTER CONTROL STRUCTURE 46
MODEL STUDIES
Type CS46 R10 Control Structure Scale 1:12
Size Distribution of Model Sediments
Sediment Test No. 14

SAINT ANTHONY FALLS HYDRAULIC LABORATORY UNIVERSITY OF MINNESOTA		
DRAWN AG	CHECKED [signature]	APPROVED
SCALE	DATE 6/6/84	NO. 328A2323-57

CHART 137



Q_s - ft	16	16	50	50	100	100	150	150	300	300
H.W. - ft.	111.1	111.1	112.3	112.5	113.7	113.7	115.1	115.2	119.1	118.6
Time - min	0	180	0	190	0	180	0	180	0	150
Symbol	⊙	◐	⊡	◧	△	▲	◇	◆	×	+

ROCHESTER CONTROL STRUCTURE 46
MODEL STUDIES
Type CS46 R10 Control Structure Scale 1:12
Piezometric Pressures - Siphon Mode
Sediment Test No. 14

SAINT ANTHONY FALLS HYDRAULIC LABORATORY UNIVERSITY OF MINNESOTA		
DRAWN BB	CHECKED [signature]	APPROVED
SCALE	DATE 3/1/84	NO. 328B514- 77

CHART 138

Pressure Readings - Siphon Mode
Sediment Test No. 14

Tap Number	Station ft	Tap Elevation ft	Piezometric Pressure Elevation ft	Pressure at Tap ft	Piezometric Pressure Elevation ft	Pressure at Tap ft
			Q_s = 16 cfs H.W. = 111.1 ft Time = 0 min		Q_s = 16 cfs H.W. = 111.1 ft Time = 180 min	
1a	359.81	234.10	338.2	104.1	338.2	104.1
2a	383.81	233.95	338.2	104.3	338.2	104.3
3a	407.81	233.81	338.2	104.4	338.2	104.4
4a	431.81	233.66	338.2	104.5	338.2	104.5
5a	455.81	233.51	338.2	104.7	338.2	104.7
6a	471.81	233.42	338.2	104.8	338.2	104.8
7a	479.81	233.37	338.2	104.8	338.2	104.8
			Q_s = 50 cfs H.W. = 112.3 ft Time = 0 min		Q_s = 50 cfs H.W. = 112.5 ft Time = 190 min	
1a	359.81	234.10	339.4	105.3	339.6	105.5
2a	383.81	233.95	339.4	105.5	339.6	105.7
3a	407.81	233.81	339.4	105.6	339.6	105.8
4a	431.81	233.66	339.4	105.7	339.4	105.7
5a	455.81	233.51	339.4	105.9	339.4	105.9
6a	471.81	233.42	339.4	106.0	339.4	106.0
7a	479.81	233.37	339.4	106.0	339.4	106.0
			Q_s = 100 cfs H.W. = 113.7 ft Time = 0 min		Q_s = 100 cfs H.W. = 113.7 ft Time = 180 min	
1a	359.81	234.10	340.8	106.7	340.8	106.7
2a	383.81	233.95	340.8	106.9	340.7	106.8
3a	407.81	223.81	340.8	107.0	340.9	107.1
4a	431.81	233.66	340.7	107.0	340.9	107.2
5a	455.81	233.51	340.7	107.2	340.7	107.2
6a	471.81	233.42	340.7	107.3	340.7	107.3
7a	479.81	233.37	340.7	107.3	340.7	107.3

ROCHESTER CONTROL STRUCTURE 46
MODEL STUDIES
Type CS46 R10 Control Structure
Scale 1:12
Pressure Readings - Siphon Mode

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UNIVERSITY OF MINNESOTA

DRAWN MR	CHECKED [illegible]	APPROVED
SCALE	DATE 5/22/84	NO. 328A2323-44

Pressure Readings - Siphon Mode
Sediment Test No. 14

Tap Number	Station	Tap Elevation	Piezometric Pressure Elevation	Pressure at Tap	Piezometric Pressure Elevation	Pressure at Tap
	ft	ft	ft	ft	ft	ft
			Q_s = 150 cfs H.W. = 115.1 ft Time = 0 min		Q_s = 150 cfs H.W. = 115.2 ft Time = 180 min	
1a	359.81	234.10	342.2	108.1	342.3	108.2
2a	383.81	233.95	341.8	107.9	342.2	108.3
3a	407.81	233.81	342.1	108.3	342.2	108.4
4a	431.81	233.66	342.1	108.4	342.2	108.5
5a	455.81	233.51	341.9	108.4	342.1	108.6
6a	471.81	233.42	342.0	108.6	342.0	108.6
7a	479.81	233.37	342.0	108.6	342.0	108.6
			Q_s = 300 cfs H.W. = 119.1 ft Time = 0 min		Q_s = 300 cfs H.W. = 118.6 ft Time = 150 min	
1a	359.81	234.10	346.2	112.1	345.7	111.6
2a	383.81	233.95	346.1	112.2	345.7	111.8
3a	407.81	233.81	346.1	112.3	345.6	112.8
4a	431.81	233.66	345.9	112.2	345.6	111.9
5a	455.81	233.51	345.3	111.8	345.5	112.0
6a	471.81	233.42	345.5	112.1	345.5	112.1
7a	479.81	233.37	345.7	112.3	345.6	112.2

ROCHESTER CONTROL STRUCTURE 46
MODEL STUDIES
Type CS46 R10 Control Structure
Scale 1:12
Pressure Readings - Siphon Mode

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UNIVERSITY OF MINNESOTA

DRAWN WQD	CHECKED MR	APPROVED
SCALE	DATE 5/22/84	NO. 328A2323-45

Sediment Flushing Time
Sediment Test No. 16
Sediment Grade No. 3 (100% inorganic)

Run No.	Distance - ft Model	Distance - ft Prototype	Time - seconds Model	Time - seconds Prototype
	Estimated Depth of Sediment in Model = 3 mm			
1	8	96	22.95	79.50
2	8	96	24.02	83.21
3	8	96	22.73	78.74
4	8	96	22.87	79.22
5	8	96	22.81	79.02
			Average =	79.94
	Prototype Sweepout Velocity = 1.20 fps			
	Estimated Depth of Sediment in Model = 1 mm			
1	6	72	11.03	38.21
2	6	72	9.88	34.23
3	6	72	8.09	28.02
4	6	72	10.38	35.96
5	6	72	10.86	37.62
			Average =	34.81
	*Prototype Sweepout Velocity = 2.07 fps			
	Estimated Depth of Sediment in Model = 0.5 mm			
1	6	72	7.17	24.84
2	6	72	7.82	27.10
3	6	72	7.24	25.08
4	6	72	7.56	26.19
5	6	72	7.54	26.12
			Average =	25.86
	Prototype Sweepout Velocity = 2.78 fps			

*Recommended Prototype Sweepout Velocity

Prototype Flushing Time:

1) Vertical cut down time = 20 min, model = 69.3 min, prototype.

2) Sweepout time for 1 mm layer, 16,000 ft tunnel =

$$\frac{16{,}000}{2.07 \times 60} = 128.8 \text{ min}$$

3) Total flushing time = $\frac{69.3 + 128.8}{60}$ = 3.3 hrs.

Recommend about a 5 hr flushing time.

ROCHESTER CONTROL STRUCTURE 46
MODEL STUDIES
Type CS46 R10 Control Structure
Scale 1:12 V_r = 1:3.464
Sediment Flushing Time
Q_F = 100 cfs, H.W. = 2.2 ft, T.W. = 1.5 ft

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DRAWN WQD	CHECKED [signature]	APPROVED
SCALE	DATE 5/22/84	NO. 328A2323-38

Time Scale in Seconds

0 1 2 Model

Prototype
0 2 4 6

ROCHESTER CONTROL STRUCTURE 46
MODEL STUDIES
Type CS46 R11 Control Structure
Scale 1:12
Fluctuating Pressures on Siphon Bell Lip
Siphon Mode Q_S = 375 cfs

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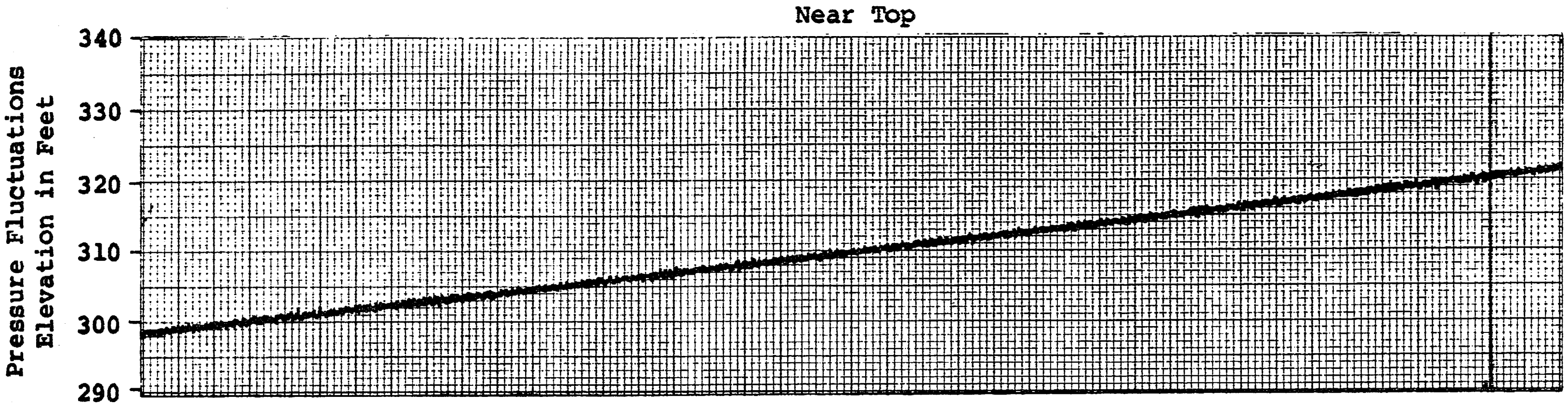
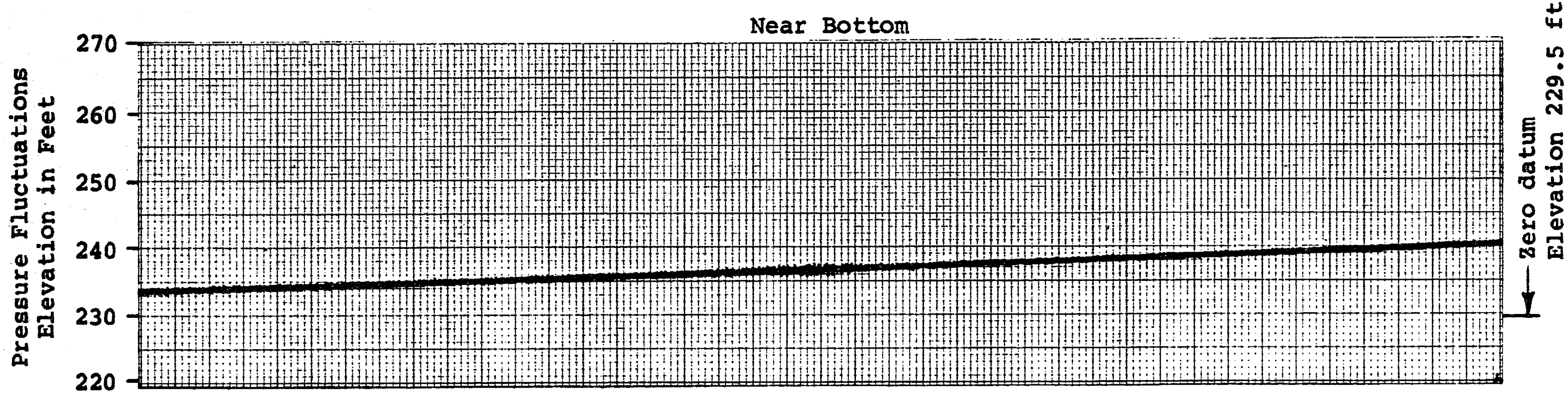
DRAWN WQD	CHECKED	APPROVED
SCALE	DATE 5/31/84	NO. 328A2323-48

CHART 141





Time Scale in Seconds

0 1 2 Model

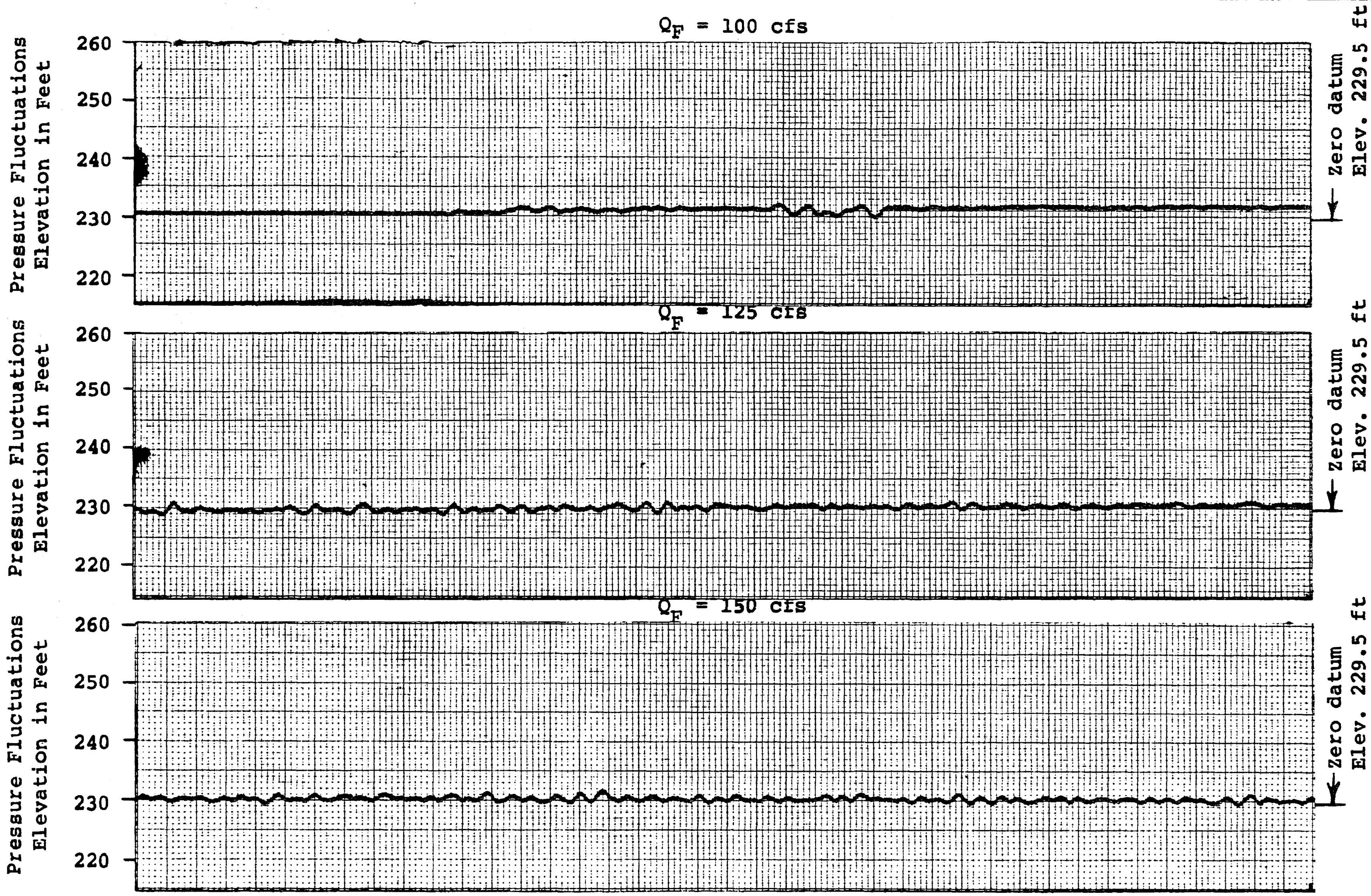
0 2 4 6 Prototype

ROCHESTER CONTROL STRUCTURE 46
MODEL STUDIES

Type CS46 R11 Control Structure
Scale 1:12
Fluctuating Pressures on Siphon Bell Lip
Drawdown Mode

SAINT ANTHONY FALLS HYDRAULIC LABORATORY UNIVERSITY OF MINNESOTA		
DRAWN WQD	CHECKED	APPROVED
SCALE	DATE 5/31/84	NO. 328A2323-50

CHART 142



Time Scale in Seconds

0 1 2 Model

Prototype
0 2 4 6

ROCHESTER CONTROL STRUCTURE 46
MODEL STUDIES
Type CS46 R11 Control Structure
Scale 1:12
Fluctuating Pressures on Siphon Bell Lip
Flushing Mode

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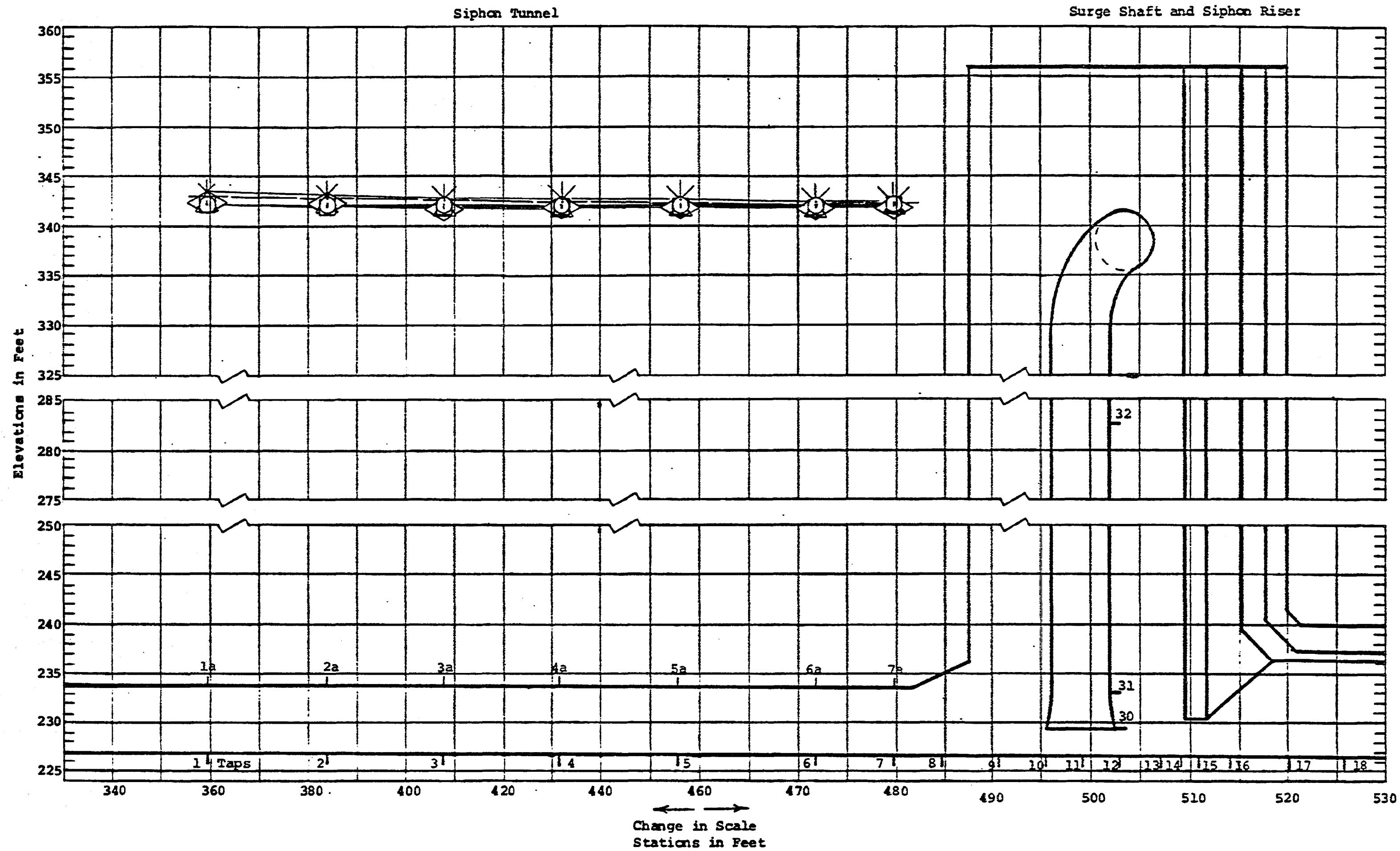
DRAWN WQD	CHECKED [signature]	APPROVED
SCALE	DATE 5/31/84	NO. 328A2323-52

CHART 143



Q_s - cfs	150	150	150	150	150	150
H.W. - ft	115.0	115.0	115.1	115.4	116.2	115.9
Time - min	0	30	60	90	120	135
Symbol	⊙	⊡	△	◇	×	+

ROCHESTER CONTROL STRUCTURE 46
MODEL STUDIES
Type CS46 R11 Control Structure Scale 1:12
Piezometric Pressure - Siphon Mode
Sediment Test No. 13

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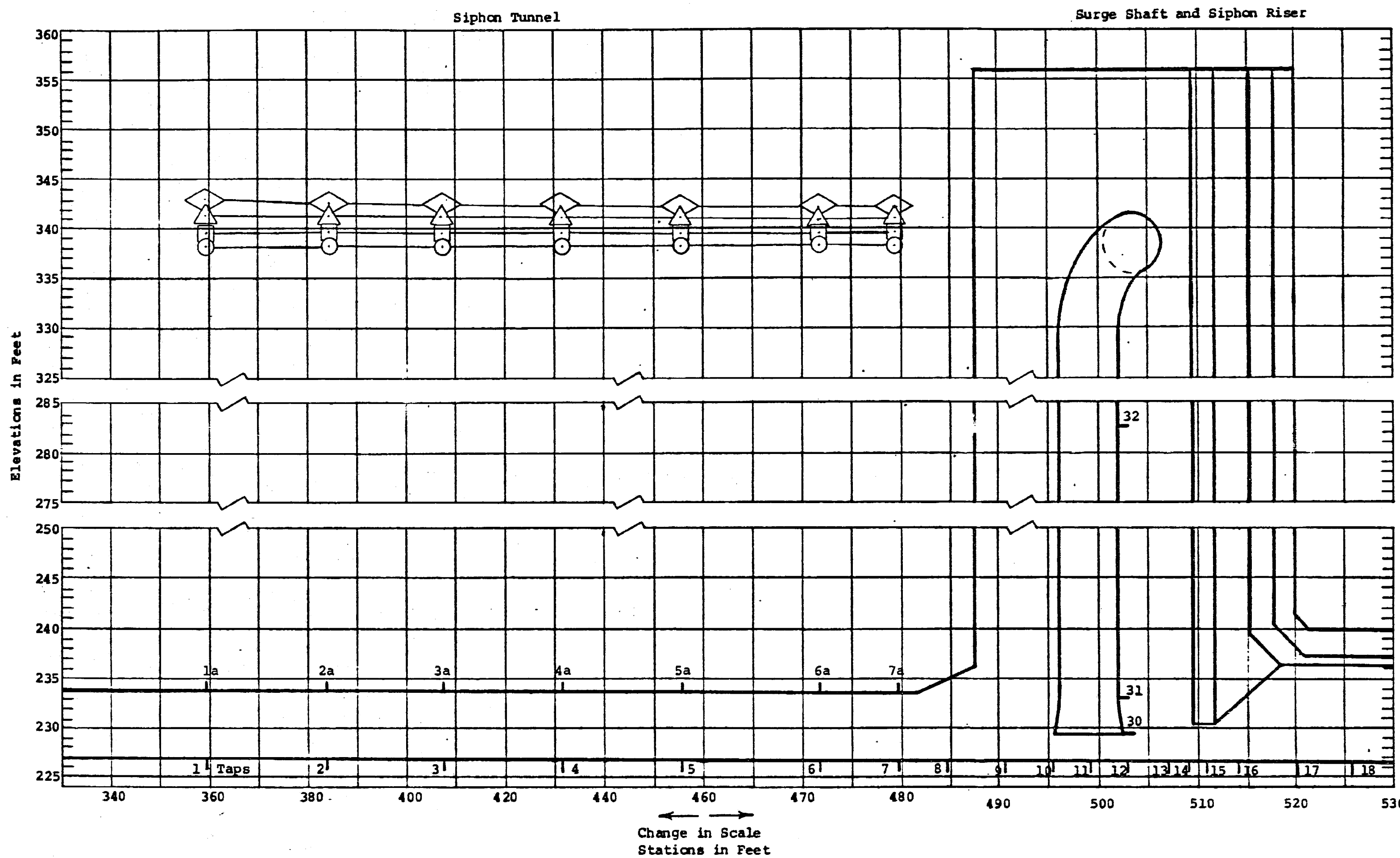
UNIVERSITY OF MINNESOTA

DRAWN BB	CHECKED	APPROVED
SCALE	DATE 3/1/84	NO 328B514- 75

CHART 144



Q_s - cfs	16	50	100	150
H.W. - ft	111.1	112.5	114.3	115.9
Time - min	135	135	135	135
Symbol	⊙	⊡	△	◇

ROCHESTER CONTROL STRUCTURE 46
MODEL STUDIES
Type CS46 R11 Control Structure Scale 1:12
Piezometric Pressure - Siphon Mode
Sediment Test No. 13

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UNIVERSITY OF MINNESOTA

DRAWN BB	CHECKED [signature]	APPROVED
SCALE	DATE 3/1/84	NO. 328B514-76

CHART 145

Pressure Readings - Siphon Mode
Sediment Test No. 13

Tap Number	Station	Tap Elevation	Piezometric Pressure Elevation	Pressure at Tap	Piezometric Pressure Elevation	Pressure at Tap
	ft	ft	ft	ft	ft	ft
			Q_s = 150 cfs H.W. = 115.0 ft Time = 0 min		Q_s = 150 cfs H.W. = 115.0 ft Time = 30 min	
1a	359.81	234.10	342.1	108.0	342.1	108.0
2a	383.81	233.95	342.1	108.2	341.9	108.0
3a	407.81	233.81	342.1	108.3	342.0	108.2
4a	431.81	233.66	342.1	108.4	342.0	108.3
5a	455.81	233.51	342.1	108.6	342.0	108.5
6a	471.81	233.42	342.0	108.6	342.0	108.6
7a	479.81	233.37	342.1	108.7	342.1	108.7
			Q_s = 150 cfs H.W. = 115.1 ft Time = 60 min		Q_s = 150 cfs H.W. = 115.4 ft Time = 90 min	
1a	359.81	234.10	342.2	108.1	342.5	108.4
2a	383.81	233.95	342.0	108.1	342.3	108.4
3a	407.81	233.81	341.8	108.0	341.9	108.1
4a	431.81	233.66	341.8	108.1	341.7	108.0
5a	455.81	233.51	341.8	108.3	341.7	108.2
6a	471.81	233.42	341.8	108.4	341.7	108.3
7a	479.81	233.37	341.9	108.5	341.8	108.4
			Q_s = 150 cfs H.W. = 116.2 ft Time = 120 min		Q_s = 150 cfs H.W. = 115.9 ft Time = 135 min	
1a	359.81	234.10	343.3	109.2	343.0	108.9
2a	383.81	233.95	343.1	109.2	342.7	108.8
3a	407.81	223.81	342.8	109.0	342.5	108.7
4a	431.81	233.66	342.7	109.0	342.4	108.7
5a	455.81	233.51	342.6	109.1	342.2	108.7
6a	471.81	233.42	342.4	109.0	342.1	108.7
7a	479.81	233.37	342.3	108.9	342.2	108.8

ROCHESTER CONTROL STRUCTURE 46
MODEL STUDIES
Type CS46 R11 Control Structure
Scale 1:12
Pressure Readings - Siphon Mode

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UNIVERSITY OF MINNESOTA

DRAWN MR	CHECKED [illegible]	APPROVED
SCALE	DATE 5/22/84	NO. 328A2323-42

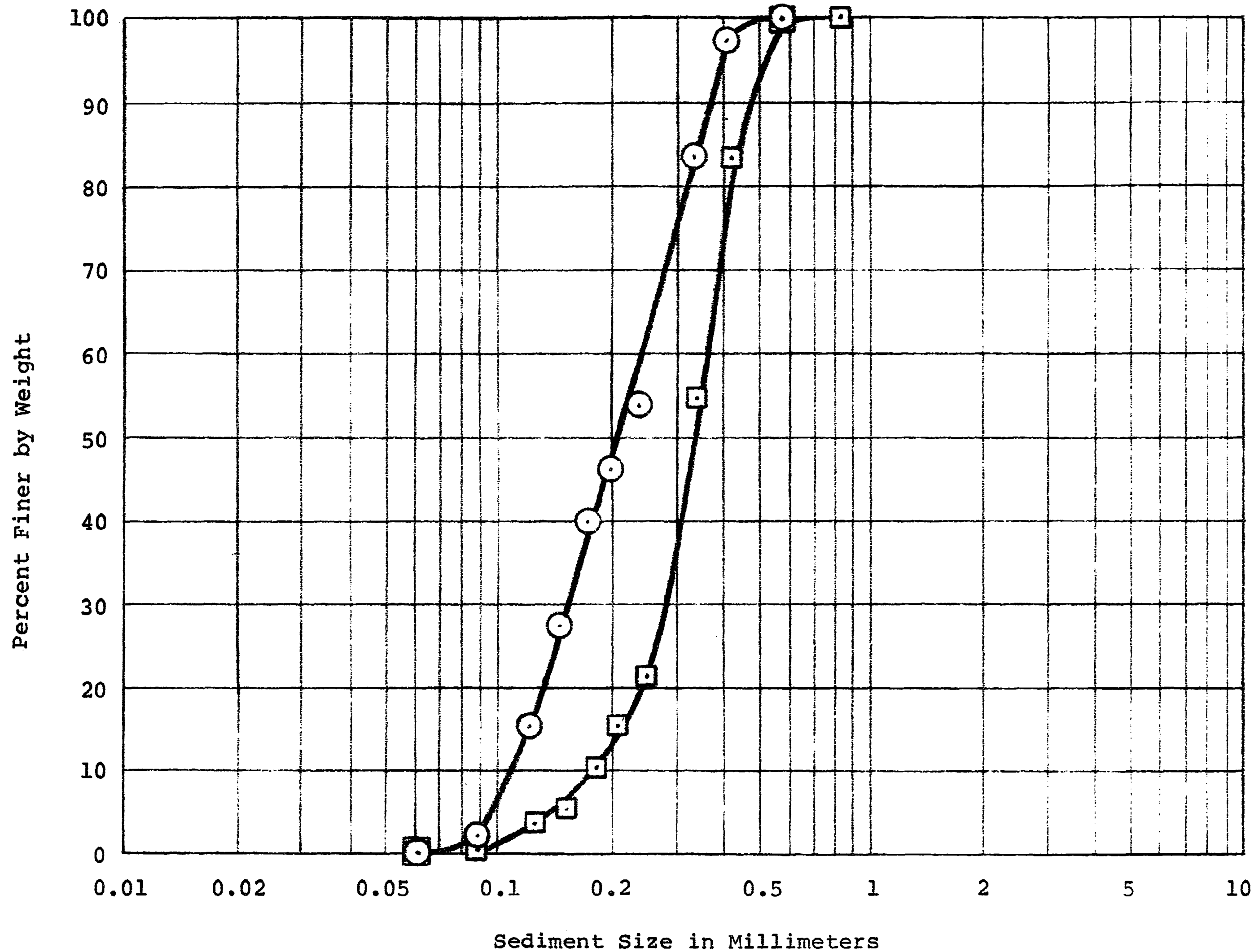
Pressure Readings - Siphon Mode
Sediment Test No. 13

Tap Number	Station ft	Tap Elevation ft	Piezometric Pressure Elevation ft	Pressure at Tap ft	Piezometric Pressure Elevation ft	Pressure at Tap ft
			Q_s = 16 cfs H.W. = 111.1 ft Time = 135 min		Q_s = 50 cfs H.W. = 112.5 ft Time = 135 min	
1a	359.81	234.10	338.2	104.1	339.6	105.5
2a	383.81	233.95	338.2	104.3	339.6	105.7
3a	407.81	233.81	338.2	104.4	339.5	105.7
4a	431.81	233.66	338.2	104.5	339.5	105.8
5a	455.81	233.51	338.2	104.7	339.4	105.9
6a	471.81	233.42	338.2	104.8	339.4	106.0
7a	479.81	233.37	338.2	104.8	339.5	106.1
			Q_s = 100 cfs H.W. = 114.3 ft Time = 135 min		Q_s = 150 cfs H.W. = 115.9 ft Time = 135 min	
1a	359.81	234.10	341.4	107.3	343.0	108.9
2a	383.81	233.95	341.3	107.4	342.7	108.8
3a	407.81	233.81	341.2	107.4	342.5	108.7
4a	431.81	233.66	341.1	107.4	342.4	108.7
5a	455.81	233.51	341.0	107.5	342.2	108.7
6a	471.81	233.42	340.9	107.5	342.1	108.7
7a	479.81	233.37	340.9	107.5	342.2	108.8

ROCHESTER CONTROL STRUCTURE 46
MODEL STUDIES
Type CS46 R11 Control Structure
Scale 1:12
Pressure Readings - Siphon Mode

SAINT ANTHONY FALLS HYDRAULIC LABORATORY
UNIVERSITY OF MINNESOTA

DRAWN MR	CHECKED HGS	APPROVED
SCALE	DATE 5/22/84	NO. 328A2323-43



⊙ Inorganic sediment fed into model

⊡ Sediment deposited in model during test

ROCHESTER CONTROL STRUCTURE 46
MODEL STUDIES
Type CS46 R11 Control Structure   Scale 1:12
Size Distribution of Model Sediments
Sediment Test No. 13

SAINT ANTHONY FALLS HYDRAULIC LABORATORY UNIVERSITY OF MINNESOTA		
DRAWN AG	CHECKED [signature]	APPROVED
SCALE	DATE 6/6/84	NO. 328A2323-56

CHART 148