UNITED STATES
DEPARTMENT OF THE INTERIOR
BUREAU OF RECLAMATION

HYDRAULIC MODEL STUDIES OF THE WANSHIP DAM VERTICAL STILLING WELLS WEBER BASIN PROJECT, UTAH

Hydraulic Laboratory Report No. Hyd. 481

DIVISION OF ENGINEERING LABORATORIES

OFFICE OF ASSISTANT COMMISSIONER AND CHIEF ENGINEER
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Office of Assistant Commissioner and Chief Engineer
Division of Engineering Laboratories
Hydraulic Laboratory Branch
Hydraulic Structures and Equipment Section
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Laboratory Report No. HYD-481
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Subject: Hydraulic model studies of the Wanship Dam vertical stilling wells--Weber Basin Project, Utah

PURPOSE

A model study was made to determine the required depth of two vertical stilling wells for the canal outlets at Wanship Dam. Each well has corner fillets and a sleeve-type valve which seats on a pedestal located in the center of the well floor.

CONCLUSIONS

1. A water depth of 9.3 feet, measured upward from the top of the pedestal, is required for smooth flow conditions in the Wanship Wells. These wells have corner fillets and operate at a maximum design discharge of 16.7 cubic feet per second under total design heads up to 118 feet relative to the top of the pedestal.

2. A water depth of 11.8 feet, measured upward from the top of the pedestal, would be required for smooth flow conditions if the Wanship Wells did not have corner fillets and were to be operated at the maximum design conditions.

3. For best results, the lower fillet slopes should intersect the corners of the well 18 inches above the floor.

ACKNOWLEDGEMENT

The design of the Wanship Dam vertical stilling wells and their valves is the result of cooperative efforts of the Dams Branch, the Mechanical Branch, and the Hydraulic Laboratory Branch.

The data upon which this report is based was obtained by D. Colgate during the period February-May, 1954.

INTRODUCTION

Wanship Dam is located on the Weber River in Utah about 20 miles east of Salt Lake City and about 1-1/2 miles south of the town of Wanship (Figure 1). The dam is a zoned earthfill structure with a crest length of 2,010 feet and a height of about 156 feet. Water stored in the Wanship Reservoir will be distributed through existing canals and ditches to supplement present irrigation supplies in the mountain valleys below the dam. In the future, some reservoir storage will also be used to generate electrical power for the operation of project works and for sale to preferential customers.

The outlet works is designed for a maximum discharge of 1,550 cubic feet per second with the water surface at elevation 6049 and has provision for releases into the Weber River, into the future powerplant penstock, or into the East Wanship Canal and West Wanship Ditch (Figure 2). The outlet works consists of an intake tower, a 12-foot-diameter tunnel from the intake tower to the gate chamber, a 5- by 6-foot high-pressure gate, an 85-inch-diameter steel outlet pipe from the gate chamber to the control house, two 3.5- by 3.5-foot high-pressure control gates, a stilling basin, and a riprapped channel which is sloped to the riverbed. A 72-inch-diameter pipe stub branches off the 85-inch-diameter steel outlet pipe to provide flow to the future powerplant. Pipes of 24- and 16-inch diameter also branch off the 85-inch-diameter steel outlet pipe to release irrigation water into West Wanship Ditch and East Wanship Canal, respectively. These smaller branch pipes terminate in vertical stilling wells (Figure 3). The flows in the 24- and 16-inch-diameter branch pipes are controlled with sleeve-type valves which seat on pedestals located in the centers of the stilling well floors (Figure 4).

A vertical stilling well was considered to be the most economical structure to dissipate the kinetic energy of the high velocity flow; however, there was little information regarding the dimensions required for satisfactory operation. Therefore, studies were made with a hydraulic model in order to determine the required depth and placement of the corner fillets for the two vertical stilling wells. Since both Wanship stilling wells operate under almost identical conditions, a model study of one well sufficed for both.

THE MODEL

The studies were conducted on a 1:2 scale model of the stilling wells which included a 6-inch supply pipe, an 8-inch downspout, a pedestal, valve support brackets, corner fillets similar to those developed on the Soap Lake Siphon Stilling Well 1/, and a short reach of downstream channel (Figures 5 and 6). The well was represented by a 3-foot-square plywood box. One side of the box was constructed from tongue-and-groove boards so that the side could be raised or lowered in a manner similar to stoplogs in canal structures. This type of construction allowed the effective model depth to be varied between 3 and 5.4 feet. A short reach of rectangular downstream channel was placed on top of the uppermost "stoplog" and secured to the model supports with C-clamps. The purpose of this downstream channel section was to prevent drawdown of the water surface in the model stilling well so as to represent the prototype canal.

The Mechanical Branch designed a sleeve-type regulating valve which was used in the prototype (Figure 4). The prototype included a pedestal 1 foot high and 4 feet in diameter placed in the center of the stilling well floor. The valve body was anchored to the pedestal by four 2-1/4-inch angle braces. These braces were connected from the perimeter of the pedestal to the body of the valve. In the model, four wooden angle braces were used to anchor the end of the downspout to the pedestal (Figure 6B). The valve openings were modeled by changing the length of the downspout. The length of the downspout was made adjustable in the following manner. The downspout was constructed from two sections of 8-inch pipe. One section was fixed to the supply line and the other section was movable. A Dresser Coupling flange was welded to the fixed section of the downspout. The movable section of the downspout could then be telescoped about 3 inches into the Dresser Coupling. Three bolts through the coupling were sufficient to insure a watertight seal (Figure 6A).

Discharges in the model were measured with calibrated venturi meters located permanently in the laboratory. The pressure head in the model was determined with a direct-reading differential manometer (pot gage) connected to a piezometer tap placed in the 6-inch supply line. The total head at the pedestal was obtained by adding the velocity head in the downspout to the pressure head in the supply line and accounting for changes in elevation, as well as losses due to friction, bends, and an enlargement to the 8-inch downspout.

In this report all depths and heads refer to the top of the pedestal and all dimensions refer to the prototype, unless otherwise noted.

1/Hydraulic Laboratory Report No. HYD-277, "Hydraulic Model Studies of the Stilling Well for the Blow-off Structure, Soap Lake (inverted) Siphon, Columbia Basin Project," by D. Colgate.

THE INVESTIGATION

Test Procedures

In testing the structure, two separate procedures were used. The first procedure consisted of a test with the corner fillets and holding the design head and discharge constant. The depth was increased until a point was reached where the high-energy flow was dissipated sufficiently to produce a smooth water surface in the well. The second procedure consisted of a series of tests without corner fillets for various discrete well depths. For any particular well depth the length of the downspout was varied to give model valve openings of 1/4, 1/2, 3/4, 1, 1-1/2, 2, and 3 inches. The flow was adjusted at each valve opening to give a smooth water surface in the well. Then pressure readings were taken, from which the discharge and total head on the pedestal could be determined. After a series of valve openings were tested, the well depth was changed and tests with the series of valve openings repeated.

The effectiveness of the corner fillets was determined by comparing the results obtained from the two procedures. The height of the corner fillets from the floor was also changed in those tests conducted at the design head and discharge.

Test Results

The test results are presented in Figure 7 which is a plot of

$$d \quad \text{versus} \quad Q\sqrt{H}$$

where d = depth of water in the well, measured from the top of the pedestal, in feet.

Q = discharge, in cubic feet per second.

H = total head at the pedestal in feet.

The points shown on the solid curve (stilling well without corner fillets) are the root-mean-square values obtained from tests at various valve settings. By using the method of least squares, the curve

$$(1) \quad Q\sqrt{H} = \frac{d+1}{0.5132 - 0.0374d} \quad \text{or} \quad \frac{1}{Q\sqrt{H}} = \frac{0.5506}{d+1} - 0.0374$$

was found to be a good fit for the experimental data for $35 < Q\sqrt{H} < 200$.

Only one experimental point was determined for vertical stilling wells with corner fillets. Therefore, the following procedure was used to formulate the curve for wells with corner fillets:

Assume that the general equation which describes the flow in vertical stilling wells either with or without corner fillets is of the form

$$Q\sqrt{H} = \frac{d+1}{a_1 + a_o(d+1)}$$

where a_o and a_1 are empirically determined constants.

The general equation may also be written in the form

$$\frac{1}{Q\sqrt{H}} = a_o + \frac{a_1}{(d+1)}$$

The first derivative of $\left(\frac{1}{Q\sqrt{H}}\right)$ with respect to $\left(\frac{1}{d+1}\right)$ is

$$\frac{d\left(\frac{1}{Q\sqrt{H}}\right)}{d\left(\frac{1}{d+1}\right)} = a_1 = 0.5506$$

The value of the constant a_1 was obtained from equation (1). a_o can be evaluated for stilling wells with corner fillets by (a) assuming that a_1 is the same constant for the Wanship vertical stilling wells either with or without corner fillets, and (b) using the result of the test conducted in the first procedure. Thus, the equation for vertical stilling wells with corner fillets can be written:

$$(2) \quad Q\sqrt{H} = \frac{d+1}{0.5028 - 0.0478d} \text{ or } \frac{1}{Q\sqrt{H}} = \frac{0.5506}{d+1} - 0.0478$$

for $35 < Q\sqrt{H} < 200$.

The curves in Figure 7 show that for a total head of 118 feet at the pedestal and a discharge of 16.7 cubic feet per second, a water depth above the pedestal of 9.3 feet is required in stilling wells with corner fillets; whereas, a depth of 11.8 feet is required in a stilling well without corner fillets to obtain a smooth water surface.

Flow Conditions

A well was considered to be operating satisfactorily when the flow surface was relatively smooth as judged by the experimenter. Although this does not seem to be an accurate method of evaluation, consistant results are obtained as can be seen from the smooth curve in Figure 7. Actually, the water surface was not smooth 100 percent of the time. Occasionally, a surge of water would come from the well, causing the water surface to be disturbed in a local region (Figure 8A).

Height of Corner Fillets

In Specifications No. DC-4170, Drawing No. 526-D-150, the corner fillets are shown 4 feet above the floor of the well (Figure 3). With the corner fillets placed at this elevation and with the pedestal and valve as designed, the flow in the model was very rough. The corner fillets were then moved down until the lower intersections of the fillets and the corners of the well were 18 inches above the floor. The flow with the fillets in this position became relatively smooth for a prototype discharge of 16.7 cubic feet per second, a total head of 118 feet and a water depth of 9.3 feet (Figure 8B). Therefore, it is recommended that the fillets be placed 18 inches from the well floor.

WELL SIZE DETERMINATION

Procedure

In using Figure 7 for sizing other installations, the following procedure is recommended:

(1) Determine the gross cross-sectional area of the proposed well by limiting the average vertical velocity to 0.5 feet per second. (An average vertical velocity of 0.5 feet per second will result in a smooth water surface. If a rough water surface can be tolerated, the average vertical velocity may be increased to as much as 1.5 feet per second.)

(2) Find the scale factor between the well being considered and the Wanship Well by the following equation:

$$N = \frac{S}{6}$$

where N = scale factor,
S = length of one side of a square well being considered, in feet,
6 = length of one side of the Wanship Well.

(3) Compute $(Q\sqrt{H})_w$ by the following equation:

$$(Q\sqrt{H})_w = \frac{Q_d\sqrt{H_d}}{N^3}$$

where Q_d = design discharge,
H_d = total design head at the pedestal
The subscript w refers to Wanship stilling well data.

The preceding equation is derived as follows:

In the vertical stilling wells, the general flow condition is turbulent with a free-water surface. Therefore, the Froude law scaling ratios are applicable, since the gravity effects outweigh those of viscosity, elasticity, and surface tension. Thus, the following relationships exist:

H_r = Head ratio = L_r.

Hence $(Q\sqrt{H})_r = L_r^{5/2} \times L_r^{1/2} = L_r^{6/2} = L_r^{3} = \left(\frac{L_p}{L_w}\right)^3 = N^3$

where r = ratio of prototype quantities to Wanship quantities

L_p = prototype dimension

L_w = Wanship dimension

Therefore,

$$\frac{(Q_d\sqrt{H_d})}{(Q\sqrt{H})_w} = N^3$$

$$\text{or } (Q\sqrt{H})_w = \frac{Q_d\sqrt{H_d}}{N^3}$$

(4) From the computed value of $(Q\sqrt{H})_w$ and Figure 7 determine the depth, $(d)_w$, corresponding to $(Q\sqrt{H})_w$.

(5) Compute the required depth, d, of the well from the equation:

$$d = N \times (d)_w$$

This procedure is applicable for only those wells that are geometrically similar to the Wanship wells in every respect. Other configurations will require further model studies.

<u>Example</u>

Compute the required dimensions of a square stilling well, using corner fillets and a sleeve-type valve which seats on a pedestal in the center of the well floor. The total head at the pedestal will be up to 100 feet with a maximum discharge of 30 cubic feet per second.

Sleeve spread approx $1\frac{1}{4}$" MC

(1) Required gross area $= \dfrac{30}{0.5} = 60$ square feet.

A well 7 feet 9 inches on a side has an area of 60.06 square feet, which is satisfactory.

(2) Scale Factor

$$N = \frac{7.75}{6.0} = 1.29$$

(3) Computation of $(Q\sqrt{H})_w$:

$$(Q\sqrt{H})_w = \frac{Q_d\sqrt{H_d}}{N^3}$$

$$= \frac{(30)(\sqrt{100})}{(1.29)^3} = 139.2$$

(4) From Figure 7, using the curve for a well with fillets and the results of (3), one obtains

$$(d)_w = 9.0 \text{ feet}$$

(5) The required depth for the well being considered is thus,

$$d = N \times (d)_w$$
$$= (1.29)(9.0) = 11.6 \text{ feet}$$

In order to be geometrically similar in all respects, the following dimensions will apply to the well under consideration:

a. Downspout diameter = (16") N = (16)(1.29)

A 20-inch pipe will be acceptable.

b. Pedestal diameter = (4.0') N = (4.0)(1.29)

= 5.2'

Use a 5' - 2" diameter pedestal.

c. Pedestal height = (1.0') N = (1.0)(1.29)

= 1.29'

Use a pedestal 1' - 4" high.

d. Corner fillet height above the floor of the well

= (18") N = (18)(1.29)

= 23"

Use a height of 2' -0" from the floor of the well to the lower intersection of the fillet and the corner of the well.

e. Corner fillet dimensions

Multiply all corner fillet dimensions as shown in Figure 3, by 1.29 to obtain the required dimensions for the well under consideration. These dimensions may be rounded off to the nearest inch.

FIGURE I
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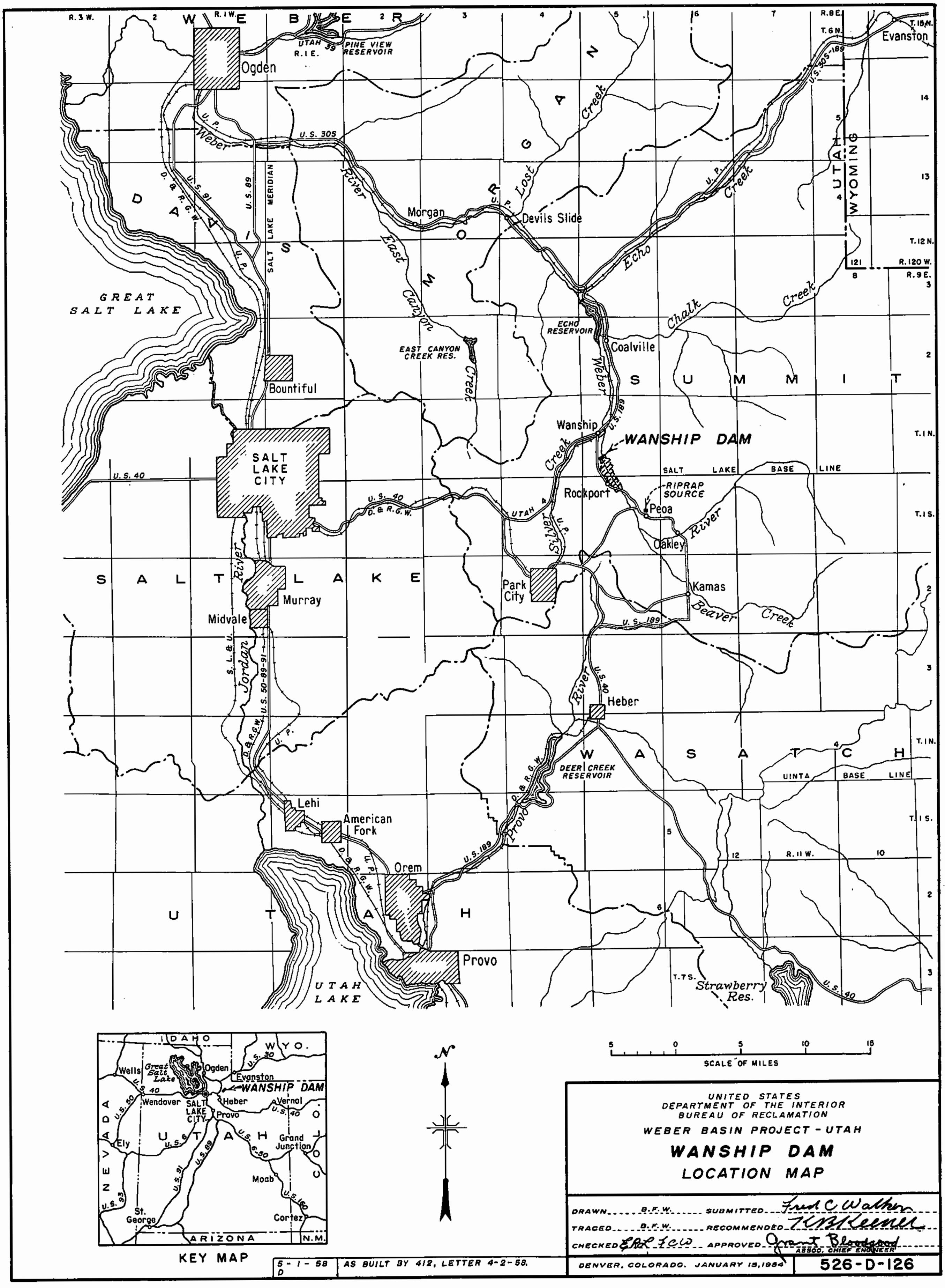
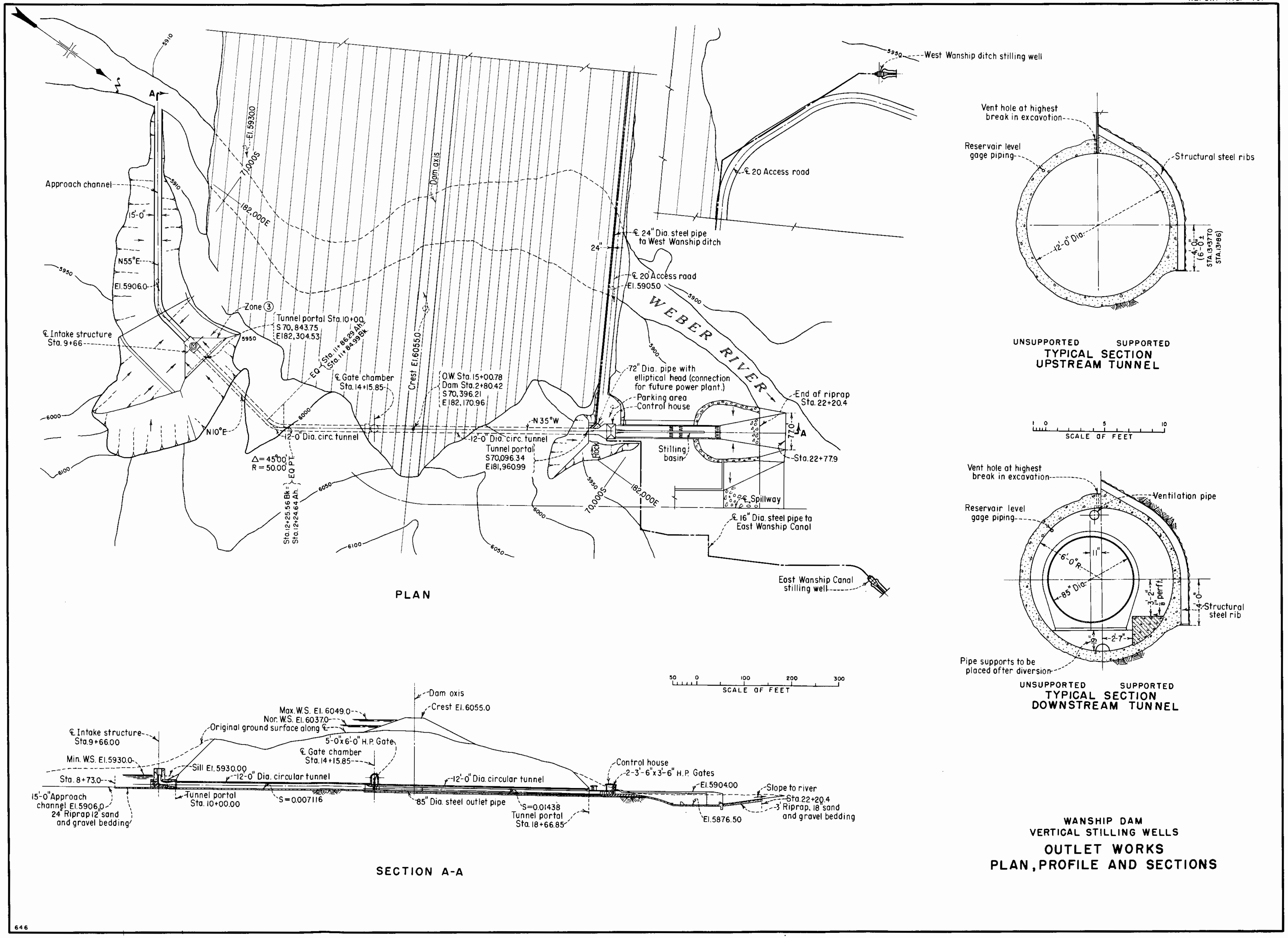
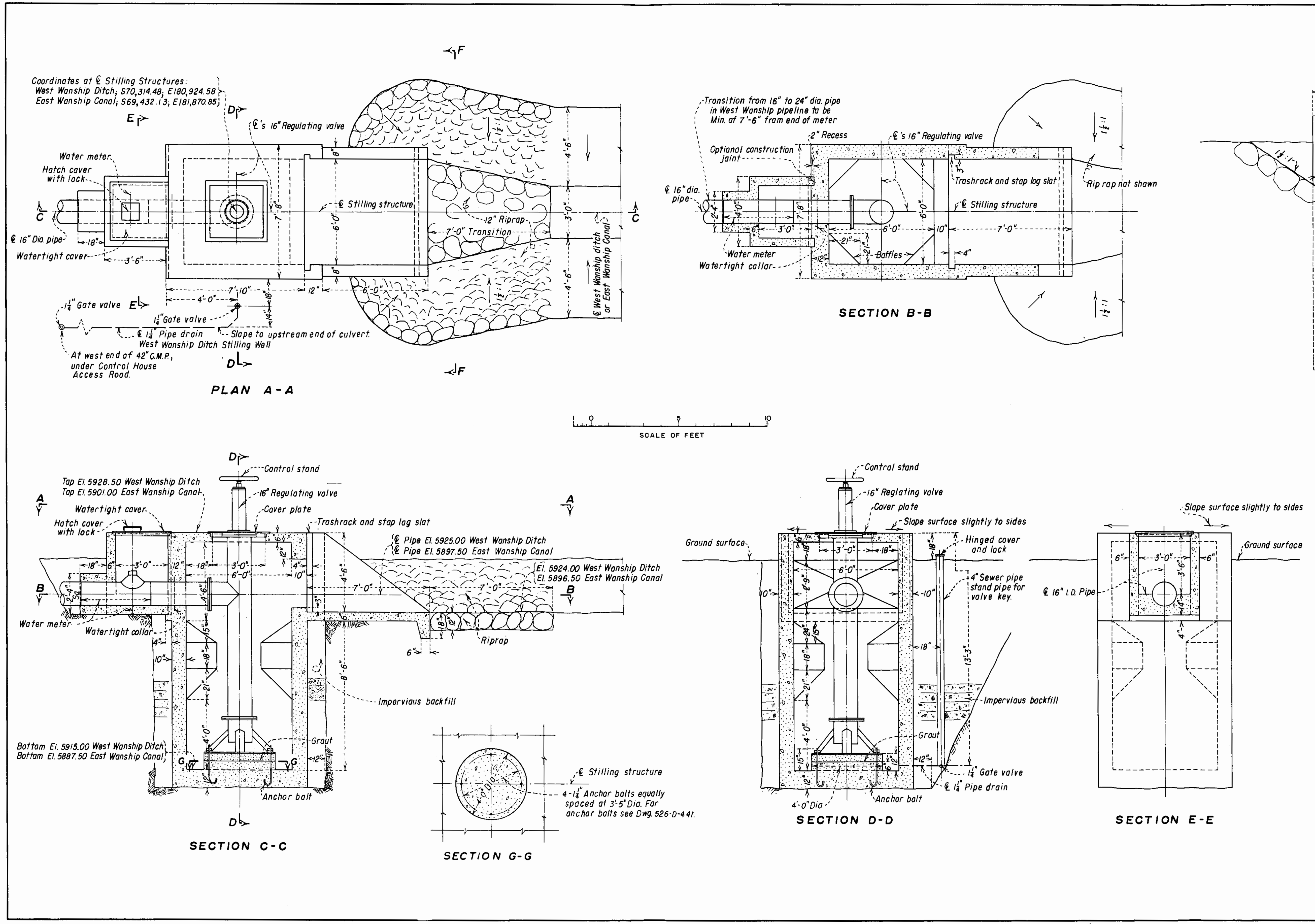




PLAN
Approach channel
15'-0"
N55°E
El. 5906.0
℄ Intake structure Sta. 9+66
Zone ③
Tunnel portal Sta. 10+00, S 70,843.75 E 182,304.53
EQ Sta. 11+86.29 Ah. Sta. 11+84.59 Bk.
℄ Gate chamber Sta. 14+15.85
Crest El. 6055.0
Dam axis
OW. Sta. 15+00.78 Dam Sta. 2+80.42 S 70,396.21 E 182,170.96
N10°E
12'-0" Dia. circ. tunnel
Δ=45°00' R=50.00'
EQ PT. Sta. 12+25.56 Bk. Sta. 12+24.64 Ah.
12'-0" Dia. circ. tunnel
Tunnel portal S 70,096.34 E 181,960.99
N 35°W
72" Dia. pipe with elliptical head (connection for future power plant.)
Parking area
Control house
Stilling basin
Rock
End of riprap Sta. 22+20.4
Sta. 22+77.9
℄ Spillway
℄ 16" Dia. steel pipe to East Wanship Canal
East Wanship Canal stilling well
℄ 24" Dia. steel pipe to West Wanship ditch
℄ 20 Access road
El. 5905.0
WEBER RIVER
West Wanship ditch stilling well
71,000S
182,000E
70,000S
El. 5930.0
24"
SECTION A-A
℄ Intake structure Sta. 9+66.00
Min. WS. El. 5930.0
Sta. 8+73.0
15'-0" Approach channel El. 5906.0
24" Riprap 12" sand and gravel bedding
Sill El. 5930.00
Tunnel portal Sta. 10+00.00
12'-0" Dia. circular tunnel
S=0.007116
Original ground surface along ℄
Max. W.S. El. 6049.0
Nor. W.S. El. 6037.0
5'-0"x6'-0" H.P. Gate
℄ Gate chamber Sta. 14+15.85
Dam axis
Crest El. 6055.0
12'-0" Dia. circular tunnel
85" Dia. steel outlet pipe
S=0.01438
Tunnel portal Sta. 18+66.85
Control house
2-3'-6"x3'-6" H.P. Gates
El. 5904.00
Slope to river
Sta. 22+20.4
3' Riprap, 18" sand and gravel bedding
El. 5876.50
SCALE OF FEET
TYPICAL SECTION UPSTREAM TUNNEL
Vent hole at highest break in excavation
Reservoir level gage piping
Structural steel ribs
12'-0" Dia.
UNSUPPORTED
SUPPORTED
TYPICAL SECTION DOWNSTREAM TUNNEL
Vent hole at highest break in excavation
Ventilation pipe
Reservoir level gage piping
85" Dia.
6'-0" R.
Structural steel rib
Pipe supports to be placed after diversion
UNSUPPORTED
SUPPORTED
WANSHIP DAM
VERTICAL STILLING WELLS
OUTLET WORKS
PLAN, PROFILE AND SECTIONS
646



NOTES

Design based on concrete of 3000 lbs. per sq. in. compressive strength at 28 days.
Chamfer all exposed corners ¾" unless otherwise noted
Concrete finishes: surfaces to be covered by fill F1 and U1. Exposed surfaces F2 and U2.
1¼" Pipe drain installed on West Wanship Ditch stilling well only.

REFERENCE DRAWINGS

OUTLET WORKS- 16" SLEEVE VALVE INSTALLATION	526-D-441
OUTLET WORKS-STILLING WELLS-REINFORCEMENT	526-D-246
FRAMES, COVERS AND TRASHRACK	526-D-686

5-1-58	AS BUILT BY 412, LETTER 4-2-58, FIELD REV. 3-14-58 ADDED STANDPIPE FOR VALVE KEY AND PIPE DRAIN. ADDED NOTE. NOTED EXCAVATION SLOPES.
4-7-55	VALVE BASE REVISED. REFERENCES ADDED

UNITED STATES
DEPARTMENT OF THE INTERIOR
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WEBER BASIN PROJECT - UTAH

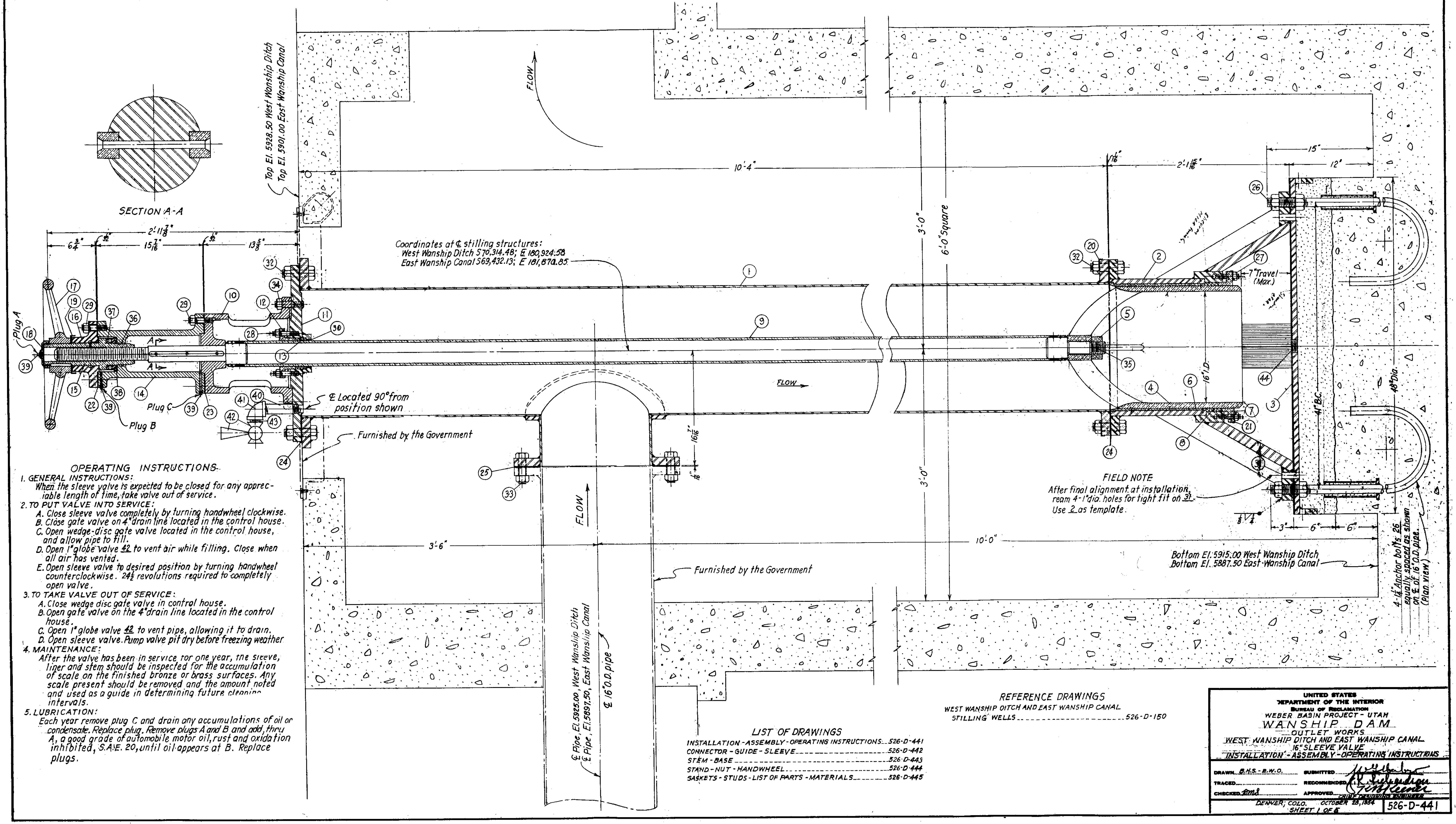
WANSHIP DAM

OUTLET WORKS

WEST WANSHIP DITCH AND EAST WANSHIP CANAL STILLING WELLS

DRAWN C.T.S. SUBMITTED M. A. Jabara
TRACED N.R.W. RECOMMENDED H. W. Taber
CHECKED ... APPROVED L. J. Larsen, ACTG. CHIEF, DAMS BRANCH

DENVER, COLORADO, FEB. 15, 1954 — 526-D-150



OPERATING INSTRUCTIONS

1. GENERAL INSTRUCTIONS:
   When the sleeve valve is expected to be closed for any appreciable length of time, take valve out of service.
2. TO PUT VALVE INTO SERVICE:
   - A. Close sleeve valve completely by turning handwheel clockwise.
   - B. Close gate valve on 4" drain line located in the control house.
   - C. Open wedge-disc gate valve located in the control house, and allow pipe to fill.
   - D. Open 1" globe valve 42 to vent air while filling. Close when all air has vented.
   - E. Open sleeve valve to desired position by turning handwheel counterclockwise. 24½ revolutions required to completely open valve.
3. TO TAKE VALVE OUT OF SERVICE:
   - A. Close wedge disc gate valve in control house.
   - B. Open gate valve on the 4" drain line located in the control house.
   - C. Open 1" globe valve 42 to vent pipe, allowing it to drain.
   - D. Open sleeve valve. Pump valve pit dry before freezing weather
4. MAINTENANCE:
   After the valve has been in service for one year, the sleeve, liner and stem should be inspected for the accumulation of scale on the finished bronze or brass surfaces. Any scale present should be removed and the amount noted and used as a guide in determining future cleaning intervals.
5. LUBRICATION:
   Each year remove plug C and drain any accumulations of oil or condensate. Replace plug. Remove plugs A and B and add, thru A, a good grade of automobile motor oil, rust and oxidation inhibited, S.A.E. 20, until oil appears at B. Replace plugs.

LIST OF DRAWINGS

INSTALLATION - ASSEMBLY - OPERATING INSTRUCTIONS 526-D-441
CONNECTOR - GUIDE - SLEEVE 526-D-442
STEM - BASE 526-D-443
STAND - NUT - HANDWHEEL 526-D-444
GASKETS - STUDS - LIST OF PARTS - MATERIALS 526-D-445

REFERENCE DRAWINGS

WEST WANSHIP DITCH AND EAST WANSHIP CANAL STILLING WELLS 526-D-150

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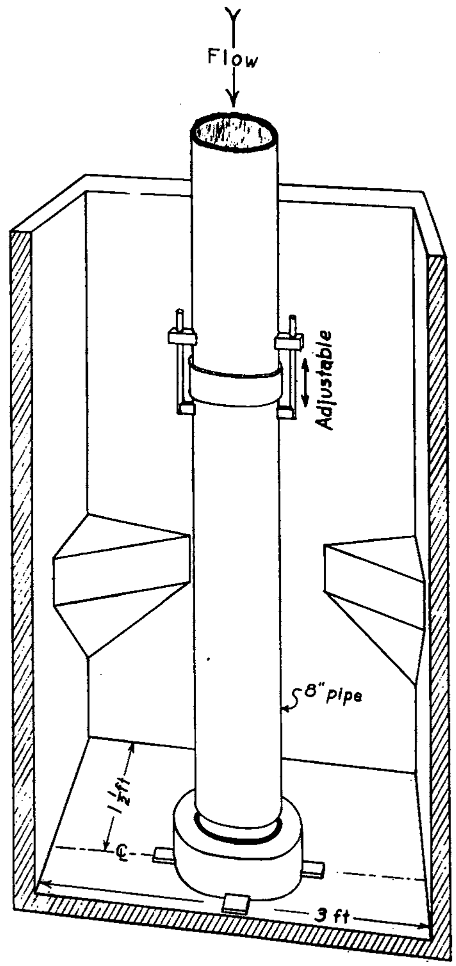
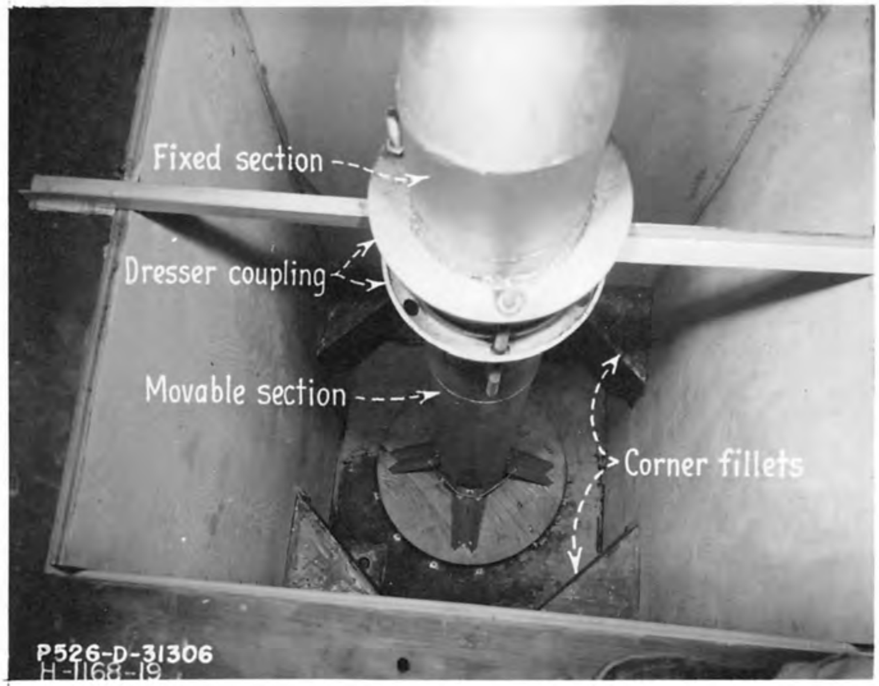
WEBER BASIN PROJECT - UTAH
WANSHIP DAM
OUTLET WORKS
WEST WANSHIP DITCH AND EAST WANSHIP CANAL
16" SLEEVE VALVE
INSTALLATION - ASSEMBLY - OPERATING INSTRUCTIONS

DRAWN B.H.S. - B.W.O. SUBMITTED [signature]
TRACED RECOMMENDED [signature]
CHECKED RMS APPROVED [signature] CHIEF DESIGNING ENGINEER

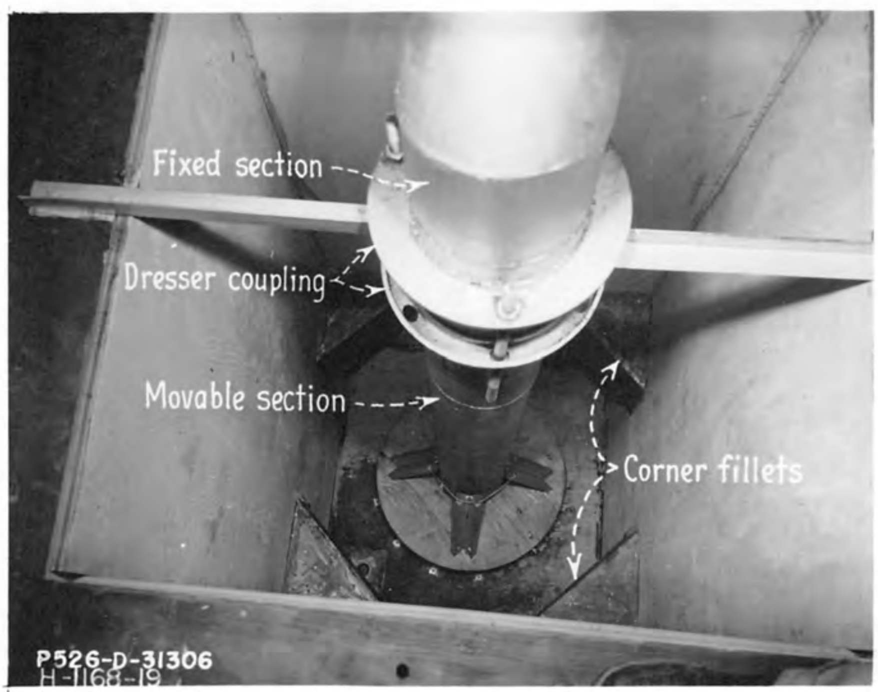
DENVER, COLO. OCTOBER 28, 1954
SHEET 1 OF 5
526-D-441



WANSHIP DAM
VERTICAL STILLING WELL
Schematic View
1:2 Scale Model

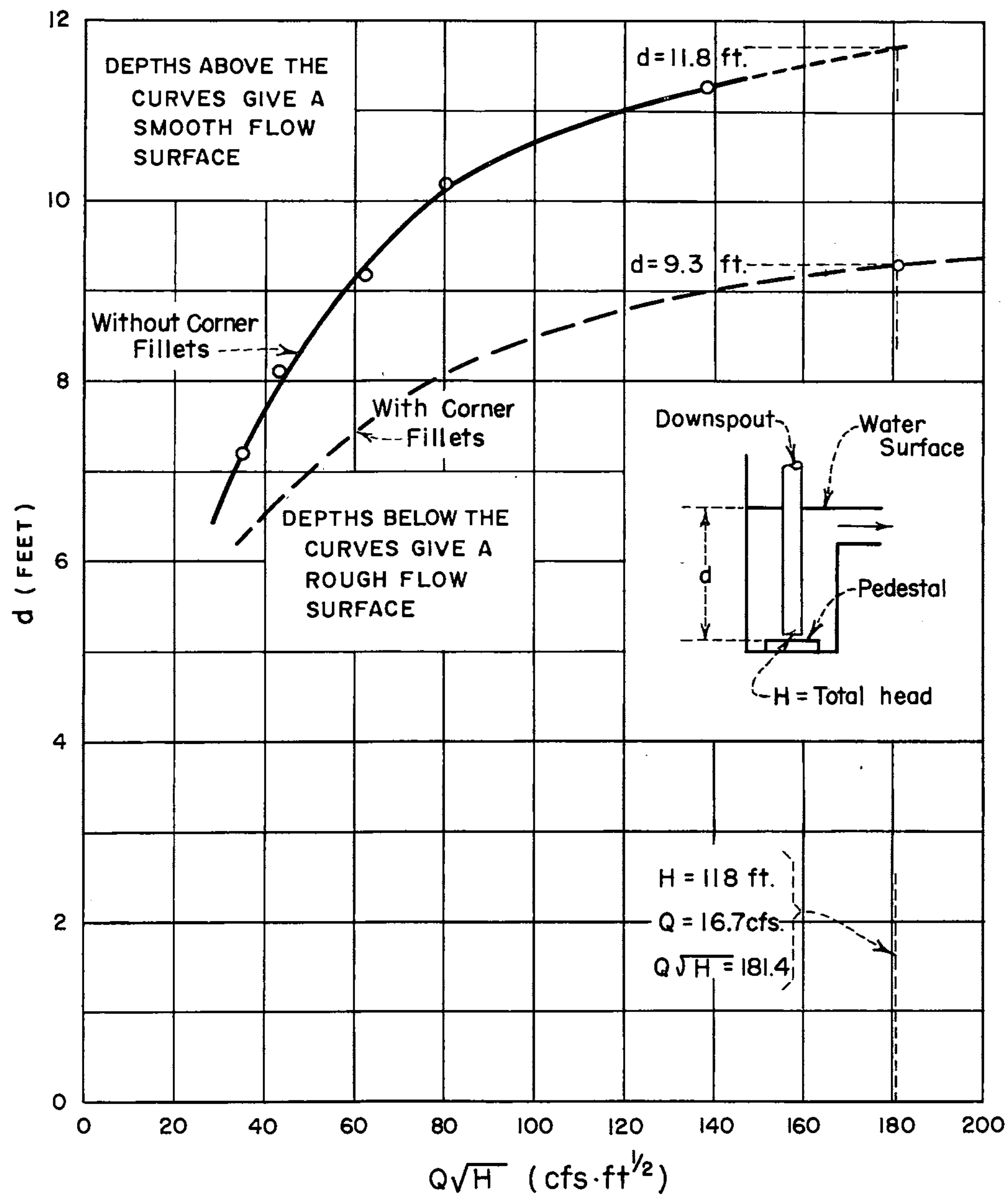


A. Downspout Adjustment Mechanism

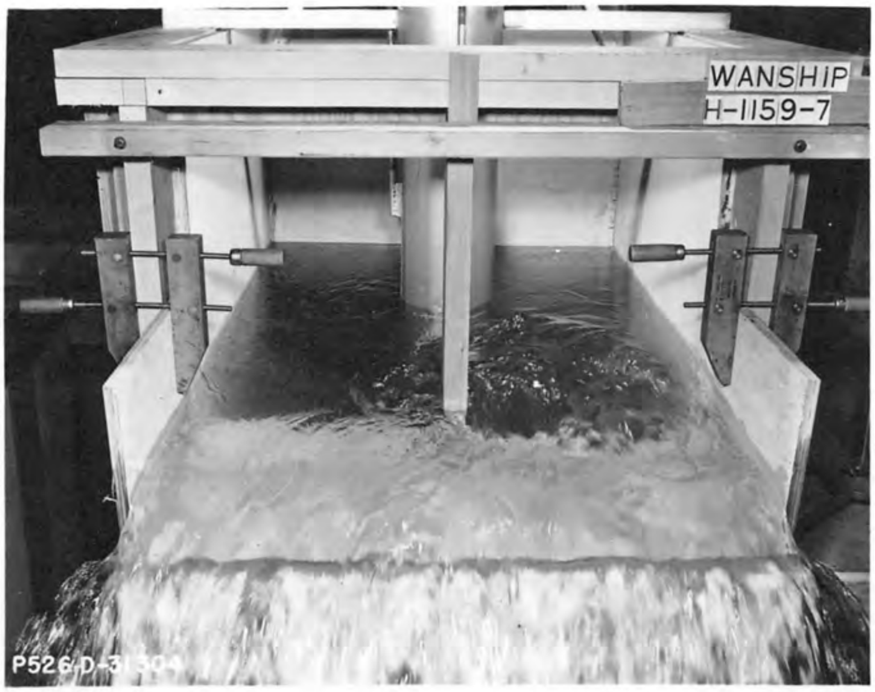


B. Downspout, Pedestal and Valve Support

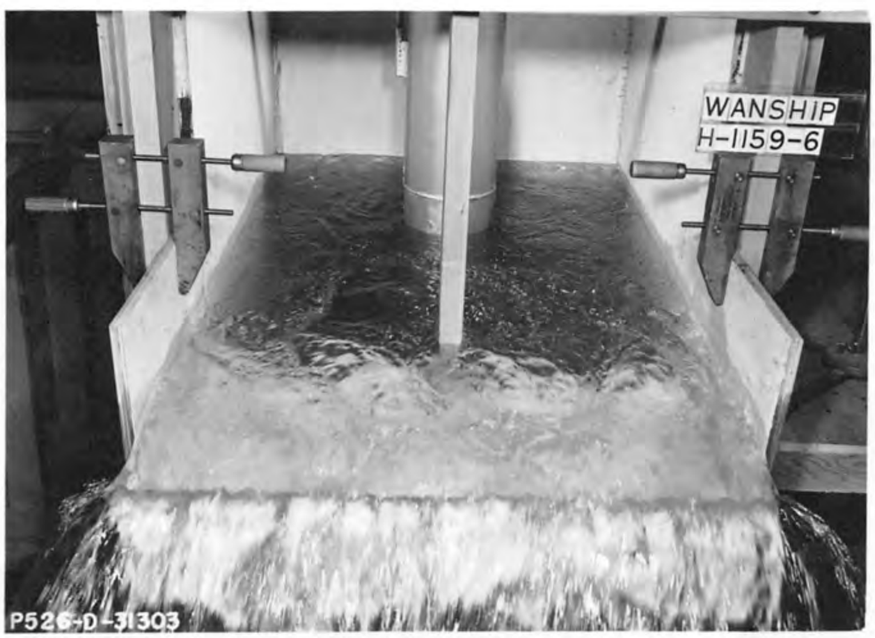
WANSHIP DAM
VERTICAL STILLING WELL
Downspout Adjustment and Valve Support
1:2 Scale Model



WANSHIP DAM
VERTICAL STILLING WELLS
REQUIRED WELL DEPTHS
1:2 SCALE MODEL



A. Water depth from top of pedestal = 10.2 ft.
Note surge on smooth water surface.



B. Water depth from top of pedestal = 9.3 ft.
(Recommended)

WANSHIP DAM
VERTICAL STILLING WELLS
Flow in Wells With Corner Fillets--Excessive & Recommended Depths
Total Head = 118 feet, Discharge = 16.7 cfs, Fillets 18" from well floor.
1:2 Scale Model