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# HYDRAULIC MODEL STUDIES OF THE LOW-LEVEL OUTLET WORKS, LG-2 DEVELOPMENT, QUEBEC, CANADA

Engineering and Research Center
Bureau of Reclamation

January 1974

Prepared for
**JAMES BAY ENERGY CORPORATION**
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16. ABSTRACT


Studies were performed, using a 1:16 scale model of the low-level outlet works for the LG-2 power development in the province of Quebec, Canada. The energy dissipator includes a deflector ring and baffle piers in a steel-lined oval section downstream from the two 96-inch (2,438.4-mm) Howell-Bunger valves. The energy dissipator section is followed by a flat-bottomed tunnel. Operation was improved by moving the deflector ring downstream from its original locations and substituting small floor baffles for the large baffles of the preliminary design. The elevation of the valves (as set according to previous USBR experience) was determined to be satisfactory and velocities in the unlined portion of the tunnel were within acceptable limits. Data were obtained for computation of required tunnel air supply and for structural design of the deflector ring and energy dissipator walls.



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by
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Hydraulics Branch
Division of General Research
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UNITED STATES DEPARTMENT OF THE INTERIOR ★ BUREAU OF RECLAMATION
Rogers C. B. Morton, Secretary
Gilbert G. Stamm, Commissioner

## ACKNOWLEDGMENT

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## PURPOSE

The purpose of the study was to develop an energy dissipator for the Howell-Bunger valves in the low-level outlet works for the LG-2 Power Development at James Bay in the northern part of the province of Quebec, Canada.

## CONCLUSIONS

1. The deflector ring in the preliminary design was located too close to the valves (35 feet (10.7 meters) from the valves) and was moved 8 feet (2.4 meters) downstream. The model verified the acceptability of this new location.

2. Instead of two rows of large floor baffles in the preliminary design, the final design included one row of three small baffles which proved to be adequate to prevent sweep out during operation at minimum tailwater and to maintain a relatively smooth water surface downstream.

3. Velocities in the unlined portion of the tunnel were within acceptable limits. The maximum wall velocity of about 20 feet/sec (6.1 meters/sec) for one valve operation was believed to present no threat to the stability of the rock.

4. Data were obtained to allow computation of required air supply for the tunnel based on air pressure at the tunnel-plug bulkhead.

5. Ring and wall pressures were obtained to aid in structural design. Steel lining is recommended for the entire barrel upstream of the deflector ring, the deflector ring itself, the baffle piers, and a portion of the barrel to the baffle piers. Determination of the frequencies of pressure fluctuation were not possible because of vibration of the model.

6. The elevation of the valves was set at 123.0 feet (37.5 meters) in the original design. Based on experience in previous designs, the valves were lowered to 120.66 feet (36.78 meters) in the model. This location was verified as satisfactory during model testing. Valve spacing remained the same as in the preliminary design.

7. The shape of the tunnel remained as in the preliminary design.

## APPLICATION

Although these studies were for specific application to design of the low-level outlet works for the LG-2 Power Development, the results should have general application to other structures of this type.

## INTRODUCTION

The LaGrande Complex of the James Bay Energy Corporation, now under construction on the LaGrande River in the northern part of the province of Quebec, is expected to generate 8.3 million kilowatts of hydroelectric power. The LG-2 underground powerhouse is the largest in the four-powerhouse complex, with an installed capacity of 4.4 million kilowatts.

The LG-2 development is located 73 miles (117 km) from the mouth of the river, which empties into James Bay, Figure 1. The low-level outlet works for LG-2 includes two Howell-Bunger valves, each 8 feet (2.4 meters) in diameter, and an energy dissipation chamber with a deflector ring and baffle piers, Figure 1. The outlet works will be installed downstream from a plug in the diversion tunnel in the south (left) abutment of the dam. An air vent tunnel will provide ventilation from the downstream tunnel to the energy dissipation chamber on the upstream side of the deflector ring. The valves will have a maximum discharge capacity of 7,000 cfs (198.2 meters$^3$/sec) each. The static head on the valves will vary from 240 to 420 feet (73.2 to 128.0 meters). The energy dissipation chamber will discharge into an unlined, rock-excavated, flat-bottomed tunnel.

## THE MODEL

**Test Requirements**

The following test requirements were specified under the negotiated contract agreement, with deletion of a few items which were later mutually agreed upon as unnecessary:

1. Optimization of the location and dimensions of the deflector ring.

2. Determination of means of forming a hydraulic jump immediately downstream from the deflector

ring by optimizing the position of baffles or any other appropriate devices; investigation of the necessity of baffles; and possible modification of the cross section of the conduit downstream from the valves.

3. Determination of the zones requiring lining and evaluation of the intensity, frequency, and fluctuations of pressures on the barrel on the upstream side of the deflector ring and on the deflector ring itself.

4. Determination of the final elevation setting of the valves.

5. Evaluation of the quantity of air required through the air vent.

6. Observation and comment on the general flow conditions and performances.

The following additional requirements are quoted in part:

"Tests will be performed under variable heads and discharges. Tests will be done with two valves in operation and also with one valve in operation. For the case with two valves in operation these will be operated synchronously so that the valves open an equal amount.

"The following three tests will be performed:

"1. Tests with two gates in operation and constant discharge of 5,000 cfs (141.5 meters$^3$/sec) through each valve.—Tests as described above will be performed for a constant discharge of 5,000 cfs per valve with different heads upstream of the plug (gross head). Heads will vary from the minimum value necessary to obtain 5,000 cfs up to the maximum gross head of 420 feet (128.0 meters). Upstream water level for the model will be established taking into account the head loss upstream of the valves.

"2. Tests with two valves in operation with variable heads and variable discharges.—Tests as described above will be performed for variable heads upstream of the plug (gross head). For each head, study the performance of the system with different discharges. Discharges will vary from 2,500 cfs (70.8 meters$^3$/sec) up to the maximum with the valves fully open. These may be combined with those of 1. above to establish the rating curve for various discharges and different heads. Gross heads upstream of the plug will vary from a minimum value of 75 feet (22.9 meters) up to a maximum value of 420 feet (128.0 meters). Head loss upstream of the valves will be considered in determining upstream water level for the model.

"3. Tests with one valve closed.—Tests as described in 1. and 2. will be performed with one valve closed. For the purposes of this study, the south valve will be closed. Nevertheless, results obtained with the south valve closed should be checked with the north valve closed for the case of 5,000 cfs and maximum gross head."

### Calibration of Model Valves

The 6-inch (152.4-mm) model valves were calibrated as designed for installation in the LG-2 tunnel plug. The pressure head was measured and the total head was computed at a station 2.75 pipe diameters upstream from the face of the valves. The coefficient of discharge curve, Figure 2, is based on the relationship:

$$Q = C_d A \sqrt{2g H_t}$$

where:

$C_d$ = the coefficient of discharge,
$A$ = the inlet pipe area, and
$H_t$ = the total head.

Valve opening is defined in this report as the valve sleeve travel divided by the pipe diameter. Beyond 50 percent (0.5) valve opening, the control point tends to shift and $C_d$ will show scattered values. Therefore, the curve in Figure 2 terminates at a valve opening of 0.5.

Figure 3 shows the computed relationships among the energy head 2.75D upstream from the face of the valves, the valve discharge coefficient, and the discharge. The values in the chart are independent of the valve setting and may be used for any valve for which the coefficient of discharge is known.

### Tailwater Elevations

Tailwater elevations shown in Figure 4 were taken from a chart furnished by JBEC for a station 222.9 feet (67.9 meters) downstream from the valves. As may be seen in Figure 23, the model water surface 222.9 feet from the valves (near the center of the photograph) is affected by bulking attributed to air in the water. Therefore, the tailwater criteria were transposed to near the downstream end of the model, 510 feet (155.4 meters) from the valves, to allow a more accurate measurement of the model water surface.

## Model Configuration

The model was constructed to a geometrical scale of 1:16, and overall dimensions for the preliminary installation, Figure 5, were taken from JBEC Drawings No. 700-303 and 700-304. The deflector ring dimensions and location, the valve spacing and elevation, and the size, location, and number of baffles were determined by referring to previous model studies for the Oroville Dam River Outlets in California[1] and the Portage Mountain Low Level Outlet Works in British Columbia.[2] The oval barrel in the model was inadvertently made 10 feet (3.0 meters) (prototype) shorter than that shown in the drawings (which proved to be inconsequential for the model study), and the unlined portion of the tunnel was represented for a distance of 540 feet (164.6 meters) downstream from the valves. Figure 6 is an overall view of the completed model.

The water surface in the tunnel was controlled with a slat-type control gate, which had a minimal effect on the velocity distribution upstream from the gate, Figure 7.

The energy dissipator portion of the model is shown in Figure 8, with the energy dissipator deflector ring near the center of the photograph. At the right of the photograph is a pressure tank from which the two outlet conduits extend through the tunnel-plug bulkhead and lead to the Howell-Bunger valves upstream from the deflector ring.

The effectiveness of the energy dissipator was evaluated by measuring the velocity distribution in the tunnel with a Type "A" current meter 185 feet (56.4 meters) downstream from the valves, as shown in Figures 8 and 9.

The air-demand measuring station just above the Howell-Bunger valves is shown in Figure 10. The air-supply tunnel was not included in the model. An air-supply port above the Howell-Bunger valves was enclosed in a plenum chamber on which various-sized, sharp-edged orifices could be mounted. Each orifice caused a unique restriction to the airflow. For a given waterflow condition, various orifices were mounted on the chamber and the air supply and bulkhead pressure were determined. The ring and wall pressure leads and a few of the pressure cells used may also be seen in Figure 10.

# THE INVESTIGATION

## Preliminary Design

The preliminary design is shown in Figures 5, 11, and 12. The downstream row of large baffles tended to deflect the flow upward and caused the water surface in the unlined tunnel to be quite rough for flows greater than about 8,000 cfs (226.5 meters$^3$/sec), Figure 13. Furthermore, for single-valve operation the jet from the valve missed the deflector ring on the side of the tunnel opposite the opened valve, indicating that the ring was too close to the valves (35 feet (10.7 meters) from the valves).

## Effectiveness of Baffle Piers

With the downstream row of large baffles removed, an excessively high boil existed in the oval section, Figure 14. With all baffles removed, the jump swept from the oval barrel for discharges above 12,000 cfs (339.8 meters$^3$/sec) and with minimum tailwater, Figure 15. The jump was unstable in the oval barrel, and the water surface in the unlined tunnel was quite rough for all flows greater than about 8,000 cfs (226.5 meters$^3$/sec) with minimum tailwater and about 10,000 cfs (283.2 meters$^3$/sec) with maximum tailwater. These tests suggested that one row of small baffles would be sufficient and necessary to provide satisfactory energy dissipation.

## Recommended Design

In the recommended design, a single row of three small baffles was installed in the oval section, Figure 16, and the deflector ring was moved 8 feet (2.4 meters) farther downstream to a point 43 feet (13.1 meters) from the valves. The elevation and spacing of the valves and the length and shape of the oval section remained the same as in the preliminary design.

Photographs of the recommended design are shown in Figures 17 and 18.

The new location of the deflector ring proved to be satisfactory for both two- and single-valve operation.

*Jump performance*.—Sweepout is defined as the condition for which the high-velocity jet moves through the oval section into the unlined tunnel section. Figure 19 includes sweepout data for the

[1] Colgate, D., "Hydraulic Model Studies of the River Outlet Works at Oroville Dam," Report Hyd-508, October 1963.
[2] Beichley, G. L., "Hydraulic Model Studies of Portage Mountain Development Low Level Outlet Works," Report Hyd-562, June 1966.

design without baffles, for comparison. Without baffles, the jet swept through the oval barrel at minimum tailwater for 12,000 cfs (339.8 meters$^3$/sec) and at 2.5 feet (0.8 meter) above minimum tailwater for 14,000 cfs (396.5 meters$^3$/sec). At lower flows without baffles, the flow in the oval barrel was unstable and tended to oscillate longitudinally causing rough water surface conditions in the unlined tunnel.

With the recommended design, the three small baffles retained the jump in the oval barrel for all design discharges with minimum tailwater in the tunnel. Under anticipated tailwater conditions the water surface in the oval barrel was rough, but stable, Figures 21 and 22, and was tranquil in the unlined portion of the tunnel, Figure 23. Figure 20 shows flow conditions in the barrel as the hydraulic jump was swept from the barrel at near-maximum discharge with tailwater less than minimum.

*Air demand.*—Bulkhead pressure versus air supply for various waterflow conditions is presented in Figure 24. These charts may be used to design the air-supply tunnel desired to maintain an accepable tunnel-plug bulkhead pressure. The designer must choose the bulkhead pressure. Then the air demand for that pressure with a specific valve discharge is determined from the curves. The air quantity is then used, along with the desired maximum air velocity, to size the air-supply tunnel. The curves indicate that the maximum air demand will occur with maximum two-valve discharge and minimum tailwater. Furthermore, the curves show that the air demand can be minimized by allowing negative bulkhead air pressures to exceed about minus 3 feet (1 meter) of water. Although scaling relationships for air demand have not been conclusively defined, the approach described herein has been used previously without any reported problems.

*Velocity distribution.*—The velocity distribution with the recommended design and both valves operating was excellent for all design flow conditions, Figure 25. The flow with a single valve operating was concentrated on the tunnel side opposite the opened valve. Velocity distributions were the same for one-valve operation whether using the large baffles, no baffles, or the recommended small baffles. However, without baffles, the water surface was quite rough and the point velocities tended to vary with time. No attempt was made to improve conditions for one-valve operation since this mode of operation would be employed only in extreme emergencies.

*Wall and ring pressures.*—Eighteen piezometer taps in the deflector ring and tunnel wall upstream from the ring, Figure 26, were used to determine the local pressure in critical areas during operation and to evaluate dynamic pressure fluctuations. Water column pressures were measured for all taps for one flow condition, Table 1, to define needs for closer examination, then pressure cell recordings were made for several conditions for those taps which appeared to generate erratic or fluctuating results. Considerable air entered the piezometer lines from the heavily aerated flow; therefore, lines were purged just before the oscillograph records were made. The pressures recorded for the taps in the deflector ring were repeatable and indicated realistic response. The recorded pressures for the taps in the plastic tunnel wall were erratic and violent, indicating excessively high and low peaks. Measurements of the wall vibration in the jet impact area, using both a linear variable differential transducer and a strain-gage-equipped cantilever beam, indicated that the wall was vibrating violently and rapidly (150 hz plus or minus). Obviously, the wall vibration was responsible for the violent high and low peaks indicated on the pressure cell charts. These chart peaks were therefore considered excessive and were eliminated from the data to give the results shown in Tables 1, 2, and 3. Excessive vibration of the model also made determination of the probable frequency of prototype pressure fluctuations impossible. A model rigid enough to be free of vibration would not allow use of important materials such as plastic, which makes viewing of the flow conditions possible.

*Wall impact.*—The jet impact on the wall of the oval section is as shown in Figure 27. Variations in valve opening and head had negligible effect on the location of impact. Steel lining is recommended for the entire barrel upstream of the deflector ring, the deflector ring itself, the baffle piers, and the portion of the downstream barrel shown in Figure 16. Because of the fluctuating forces in the barrel, the steel lining should be well anchored and completely grouted to minimize the possibility of vibration.

*General observations.*—Test runs were made at heads and discharges over the full range of expected operation, including conditions somewhat greater than maximum and somewhat less than minimum. The recommended design performed satisfactorily for all conditions.

Flow conditions in the energy dissipator and tunnel with the north valve closed were similar to those with the south valve closed.

Table 1

## WALL AND RING PRESSURES

| Piezometer No. | Gate opening Right–0.39D Left–0.39D Discharge–12,260 cfs Tailwater–El. 118.5 Water column reading in feet of water referred to piezometer elevation | Gate opening Right–0.50D Left–0.50D Discharge–14,150 cfs Tailwater–El. 118.5 Pressure transducer reading in feet of water referred to piezometer elevation | | Gate opening Right–0.50D Left–0.50D Discharge–14,150 cfs Tailwater–El. 125 Pressure transducer reading in feet of water referred to piezometer elevation | |
|---|---|---|---|---|---|
| | | Average | Peak | Average | Peak |
| 1 | 144.35 | 160 | 304 | 160 | 272 |
| 2 | –6.97 | | | | |
| 3 | 18.30 | 16 | 112 | 24 | 96 |
| 4 | 13.42 | 16 | 96 | 16 | 80 |
| 5 | 15.02 | | | | |
| 6 | –1.78 | | | | |
| 7 | 35.49 | 38 | 96 | 56 | 96 |
| 8 | 21.22 | 32 | 224 | | |
| 9 | –4.61 | –8 | 40 | 0 | 40 |
| 10 | 1.65 | | | | |
| 11 | 126.19 | 80 | 288 | 95 | 224 |
| 12 | 15.42 | | | | |
| 13 | 26.29 | | | | |
| 14 | Inoperative | | | | |
| 15 | 48.45 | 80 | 320 | 64 | 272 |
| 16 | 42.42 | | | | |
| 17 | 74.02 | | | | |
| 18 | 37.62 | | | | |

See Figure 26 for piezometer location and numbers.

Table 2

WALL AND RING PRESSURES

| Piezometer No. | Gate opening Right–0.50D Left–0.50D Discharge 10,000 cfs Tailwater–El. 117 | | Gate opening Right–0.30D Left–0.30D Discharge 10,000 cfs Tailwater–El. 117 Pressure transducer readings feet of water referred to piezometer elevation | | Gate opening Right–0.125D Left–0.125D Discharge 5,000 cfs Tailwater–El. 115 | |
|---|---|---|---|---|---|---|
| | Average | Peak | Average | Peak | Average | Peak |
| 1 | 64 | 128 | 120 | 224 | 112 | |
| 2 | | | | | | |
| 3 | 8 | 72 | 8 | 80 | 0 | 32 |
| 4 | 8 | 32 | 12 | 44 | 4 | 32 |
| 5 | | | | | | |
| 6 | | | | | | |
| 7 | 37 | 64 | 32 | 90 | 32 | 64 |
| 8 | | | | | | |
| 9 | 6 | 29 | 0 | 32 | 13 | 22 |
| 10 | | | | | | |
| 11 | 32 | 128 | | | | |
| 12 | | | | | | |
| 13 | | | | | | |
| 14 | | | | | | |
| 15 | 32 | 160 | | | | |
| 16 | | | 40 | 104 | 19 | 54 |
| 17 | | | 16 | 96 | 0 | 6 |
| 18 | | | | | | |

See Figure 26 for piezometer location and number.

Table 3

WALL AND RING PRESSURES

| Piezometer No. | Gate opening Right–0.50D Left–0 Discharge–7,000 cfs Tailwater–El. 116 | | Gate opening Right–0.50D Left–0 Discharge–7,000 cfs Tailwater–El. 119.5 Pressure transducer readings feet of water referred to piezometer elevation | | Gate opening Right–0.30D Left–0 Discharge–5,000 cfs Tailwater–El. 117.5 | |
|---|---|---|---|---|---|---|
| | Average | Peak | Average | Peak | Average | Peak |
| 1 | 80 | 168 | 80 | 176 | 64 | 160 |
| 2 | | | | | | |
| 3 | 20 | 120 | 24 | 144 | 0 | 160 |
| 4 | 80 | 400 | 80 | 400 | 16 | 192 |
| 5 | | | | | | |
| 6 | | | | | | |
| 7 | 35 | 46 | 34 | 46 | 36 | 48 |
| 8 | | | | | | |
| 9 | 18 | 29 | 18 | 29 | 21 | 27 |
| 10 | | | | | | |
| 11 | | | | | | |
| 12 | | | | | | |
| 13 | | | | | | |
| 14 | | | | | | |
| 15 | | | | | | |
| 16 | 0 (Not submerged) | | 0 (Not submerged) | | Not submerged | |
| 17 | 0 (Not submerged) | | 0 (Not submerged) | | Not submerged | |
| 18 | | | | | | |

See Figure 26 for piezometer location and number.

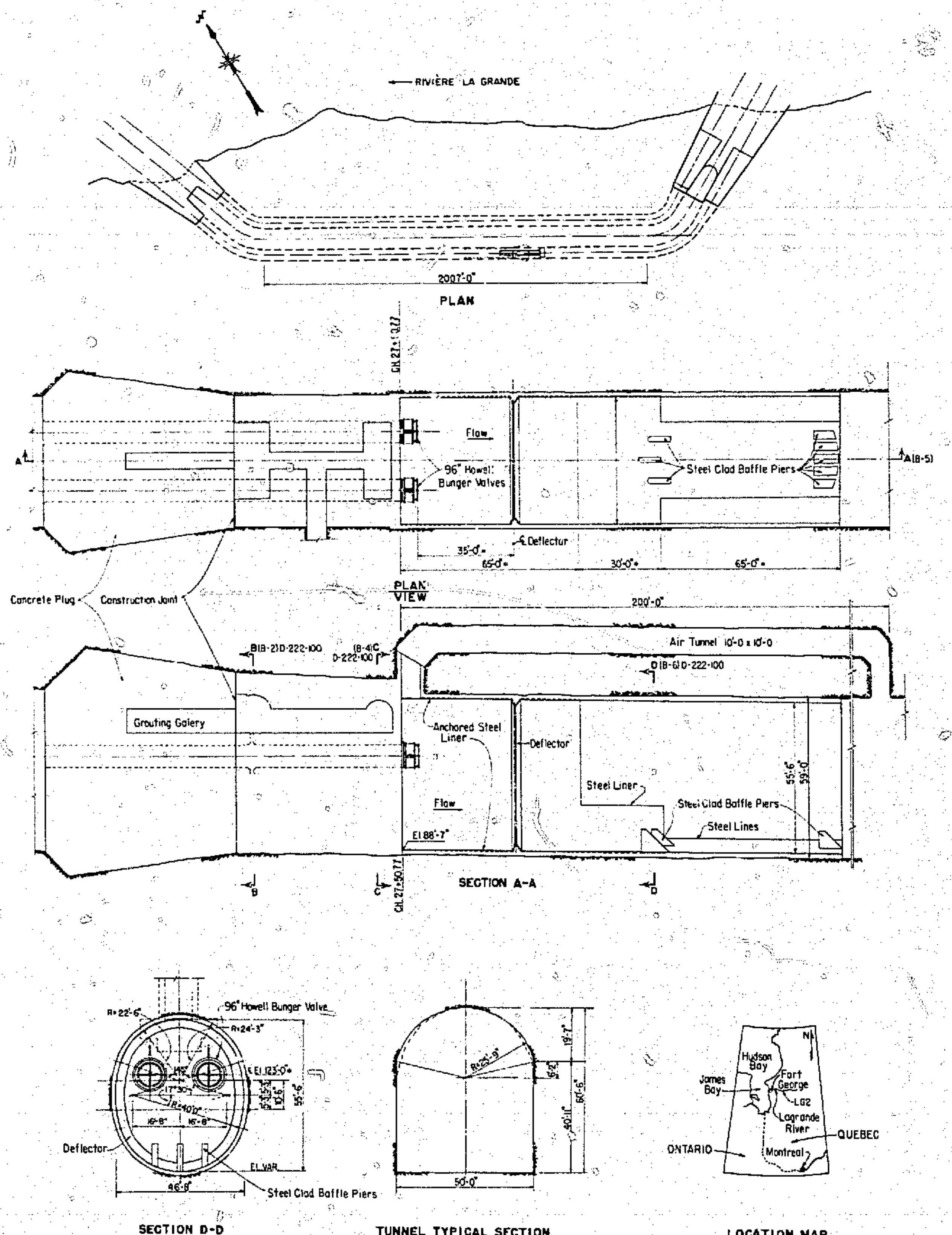



Figure 1. Prototype design and location.

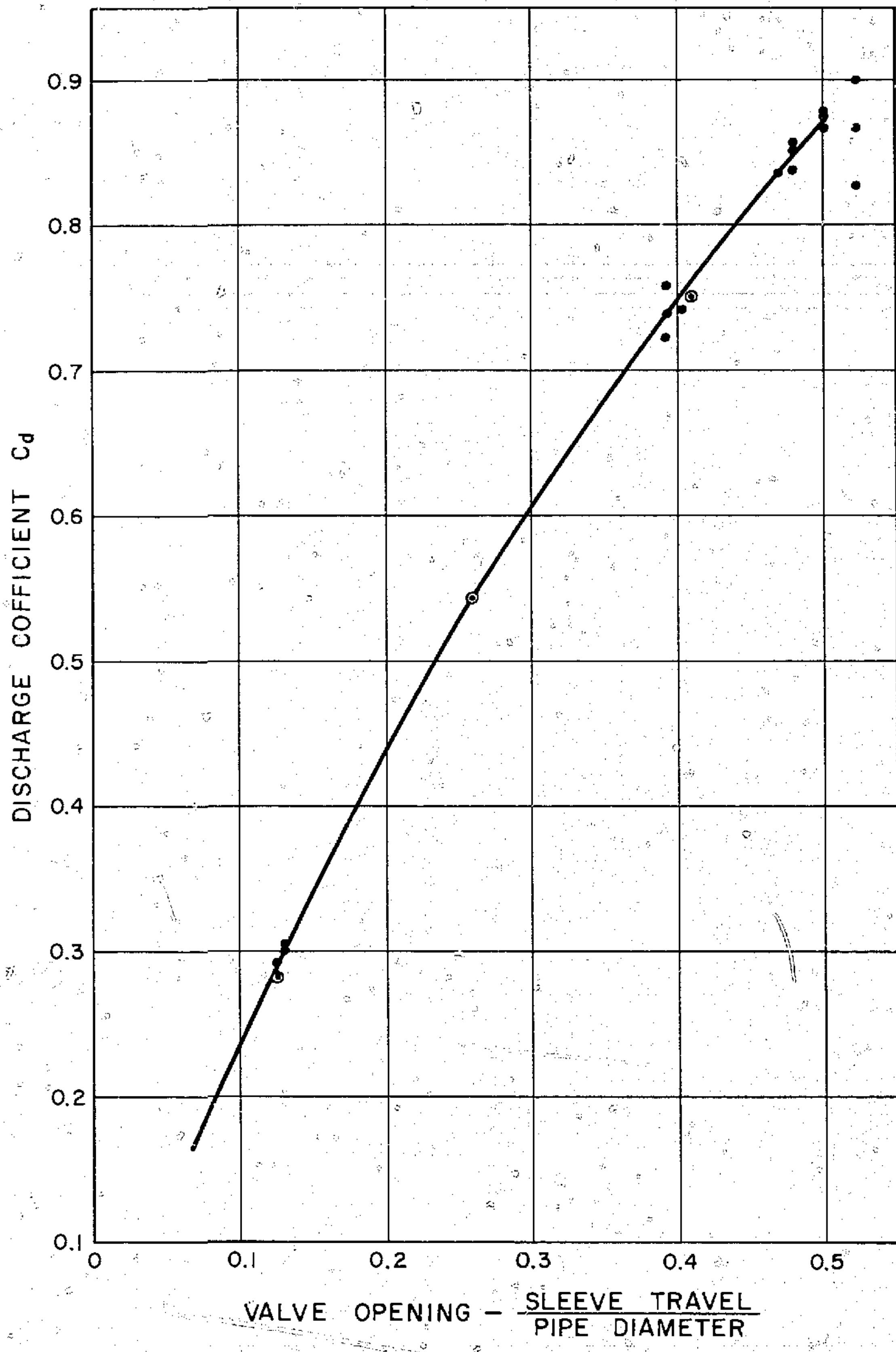



Figure 2. Discharge coefficients for model valves.

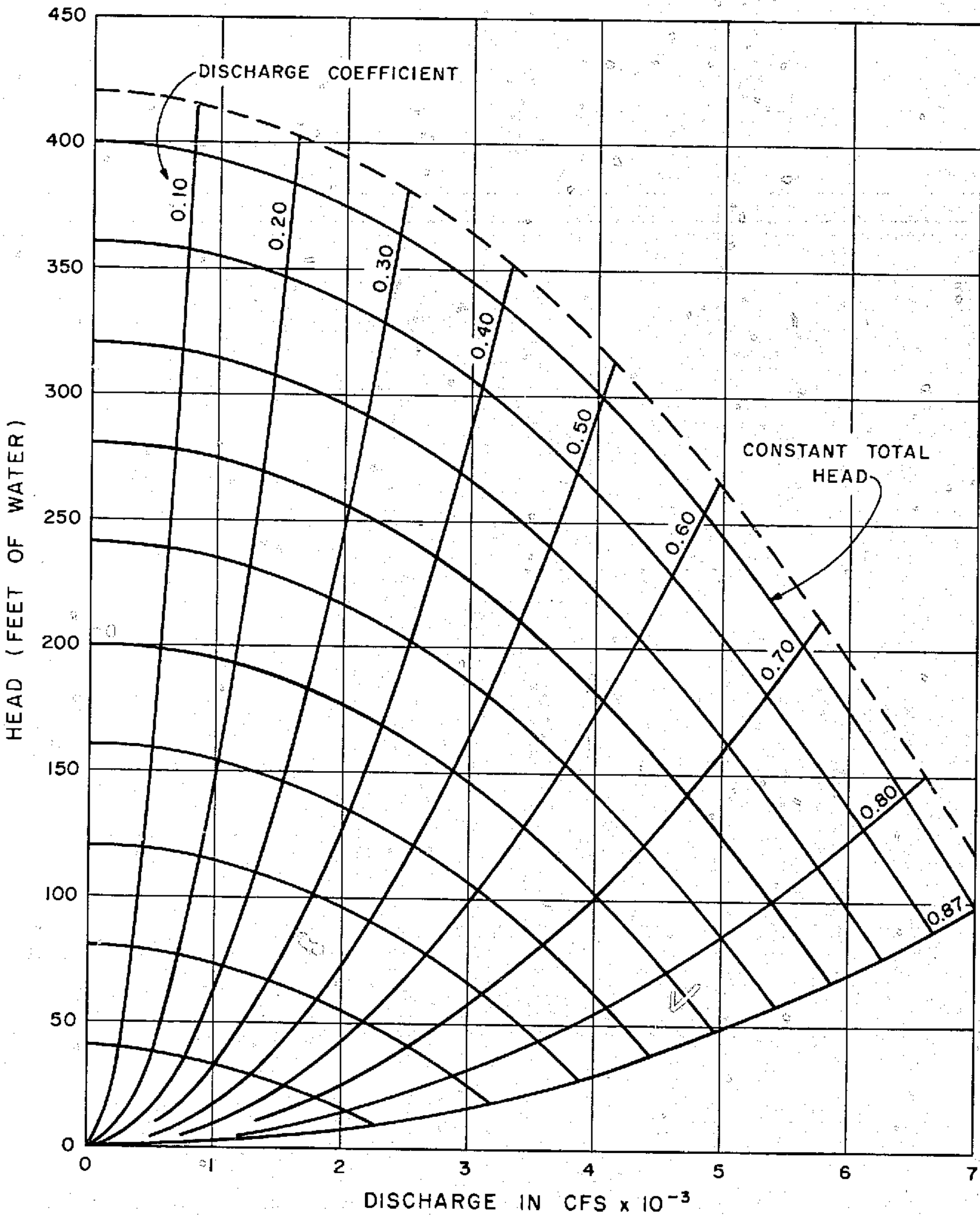



Figure 3. Head-discharge relationships for various valve discharge coefficients.

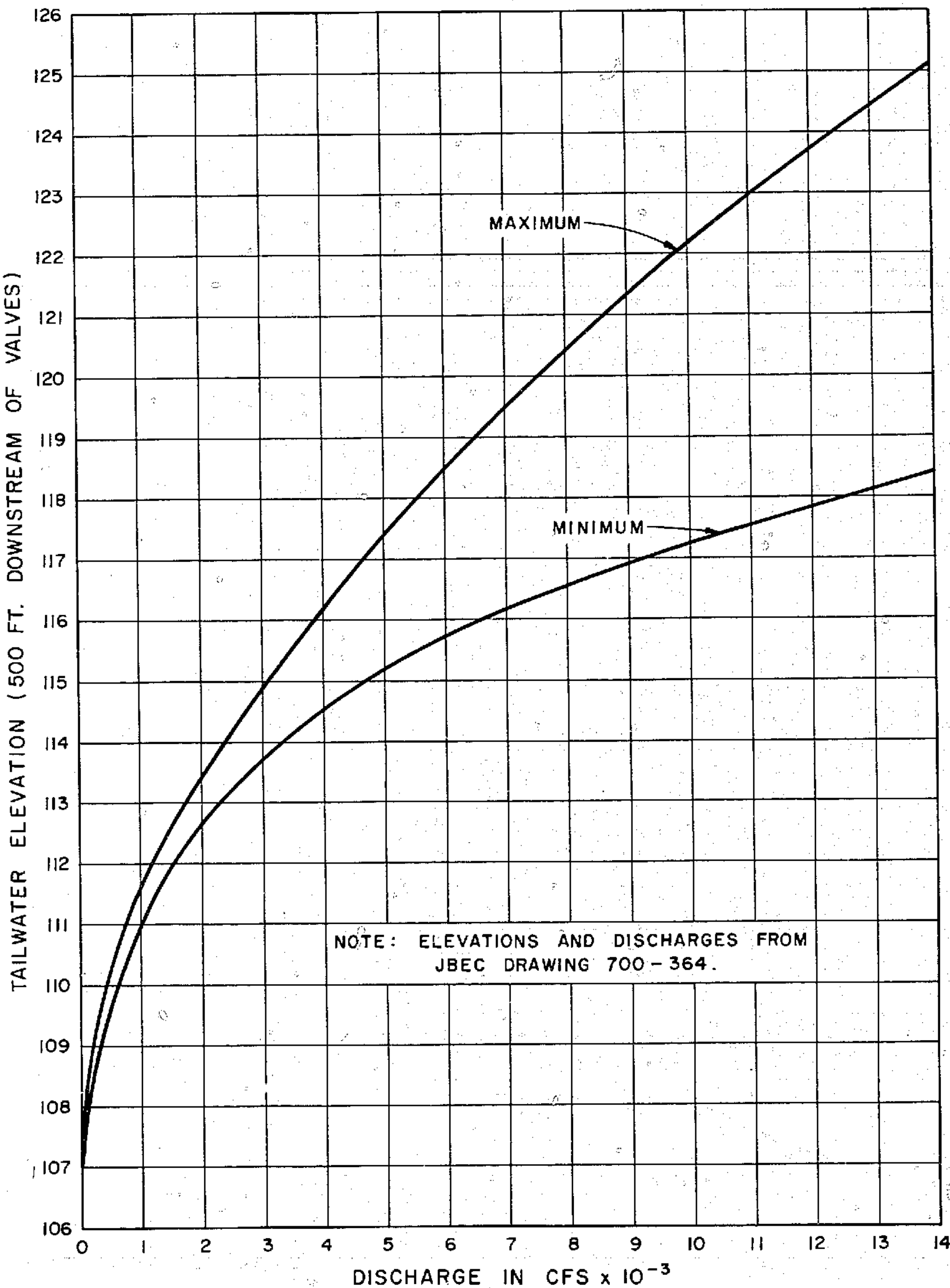



Figure 4. Tailwater elevations.

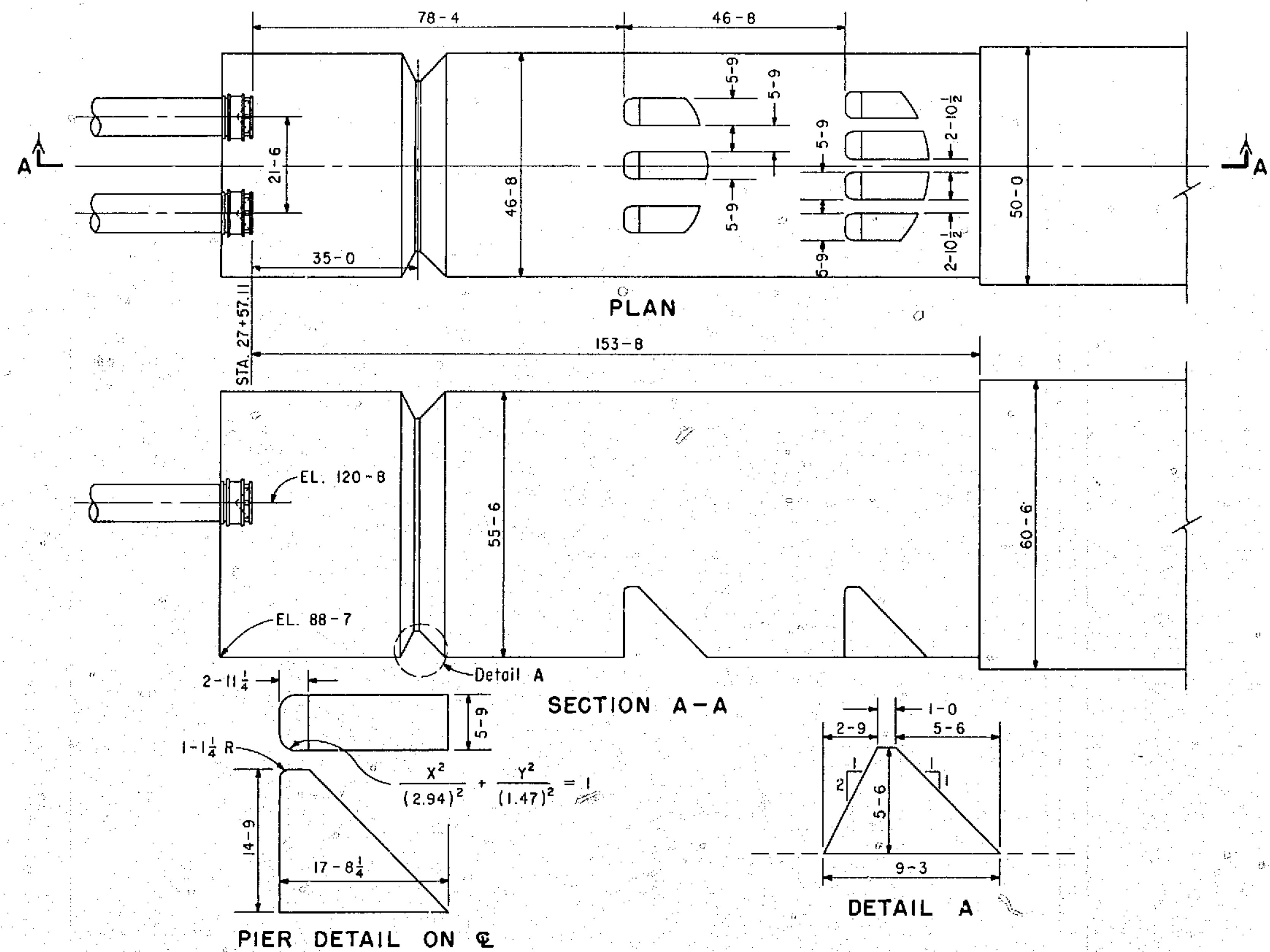



Figure 5. Preliminary design.

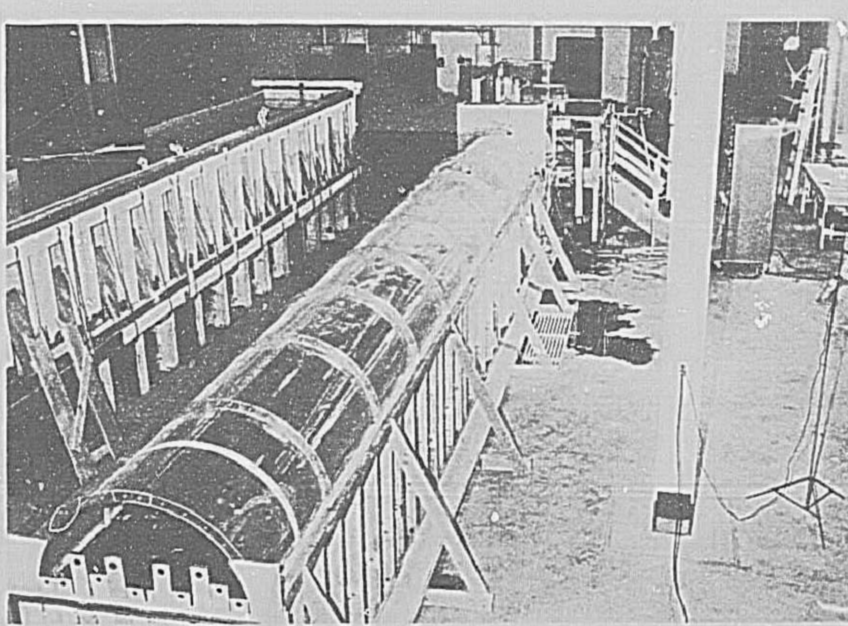


Figure 6. Overall view of the model, looking upstream. Photo P801-D-74263

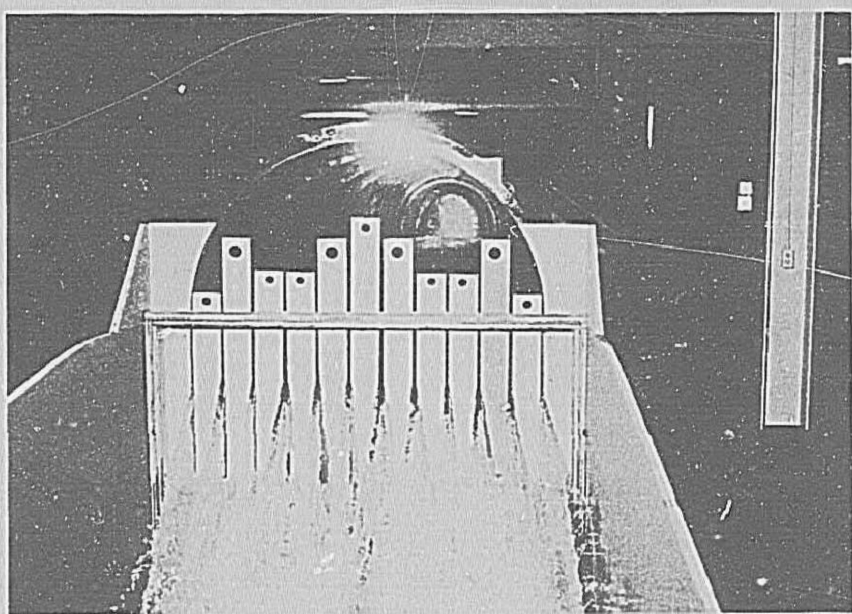


Figure 7. Slat-type water level control gate. Photo P801-D-74264

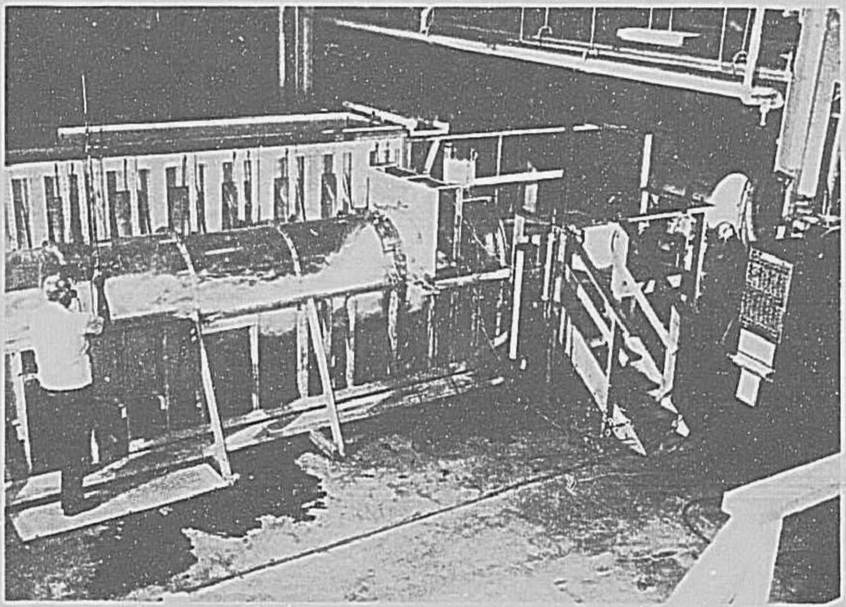


Figure 8. View of the upstream portion of the model. The right valve is opened 0.30D discharging 5,000 cfs (141.6 cubic meters per second). Photo P801-D-74265

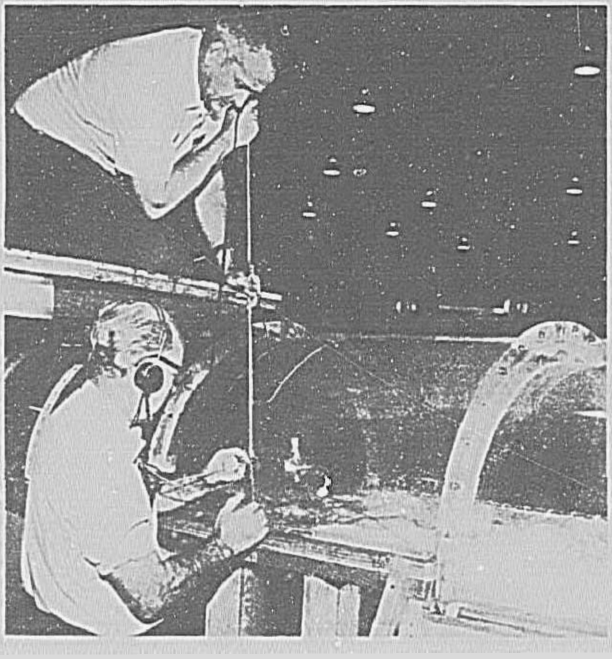


Figure 9. Velocity measuring station 185 feet (56.4 meters) downstream from the valves. Photo P801-D-74266

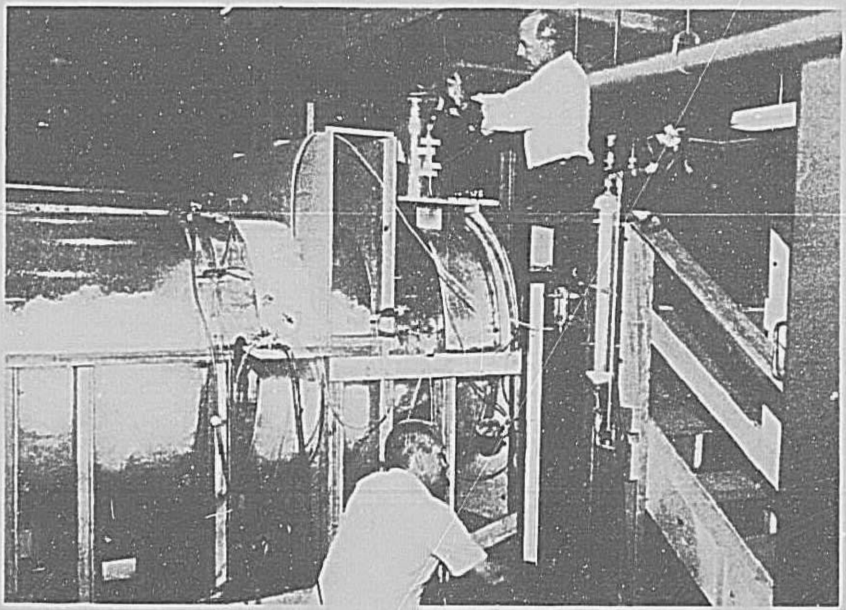


Figure 10. Air demand measuring station above the valves. Photo P801-D-74267

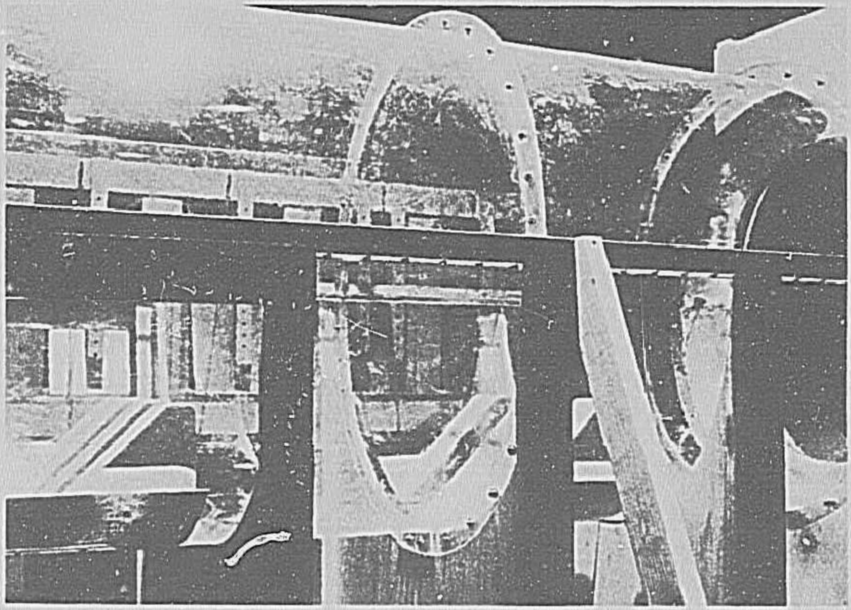


Figure 11. Preliminary design, side view. Photo P801-D-74268

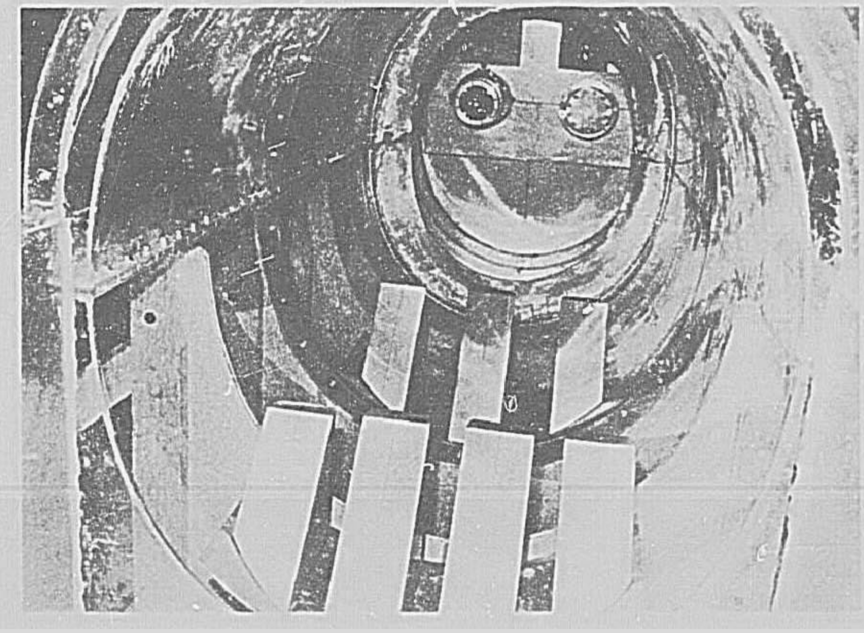


Figure 12. Preliminary design, looking upstream. Photo P801-D-74269

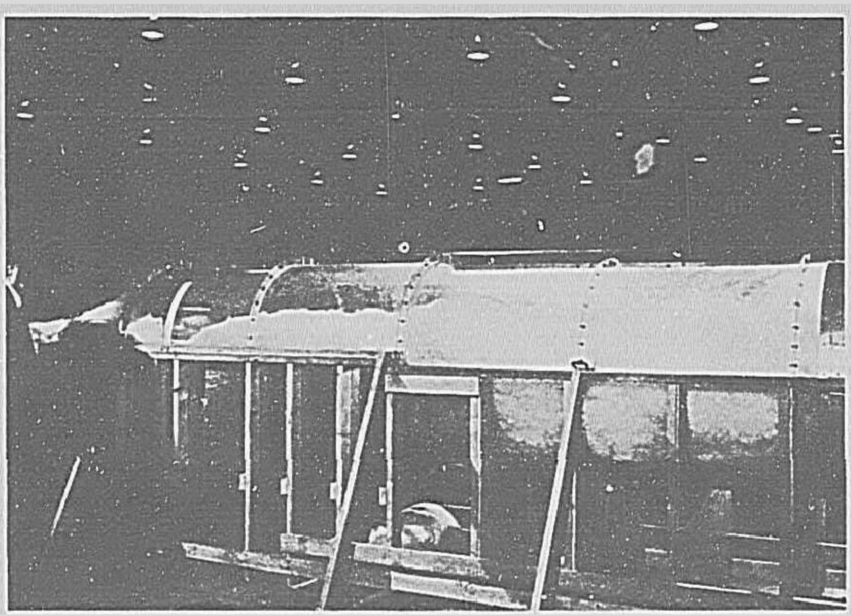


Figure 13. Preliminary design. Valves opened 0.50D discharging 12,600 cfs (356.8 cubic meters per second). Similar conditions for flows greater than about 8,000 cfs (226.5 cubic meters per second). Photo P801-D-74270

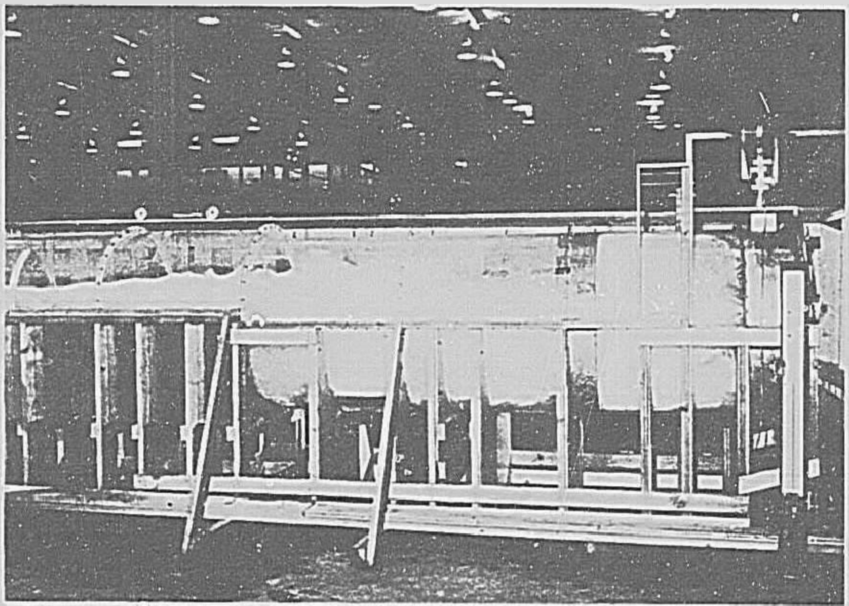


Figure 14. One row of large baffles. Valves opened 0.50D discharging 14,000 cfs (396.5 cubic meters per second). Photo P801-D-74277

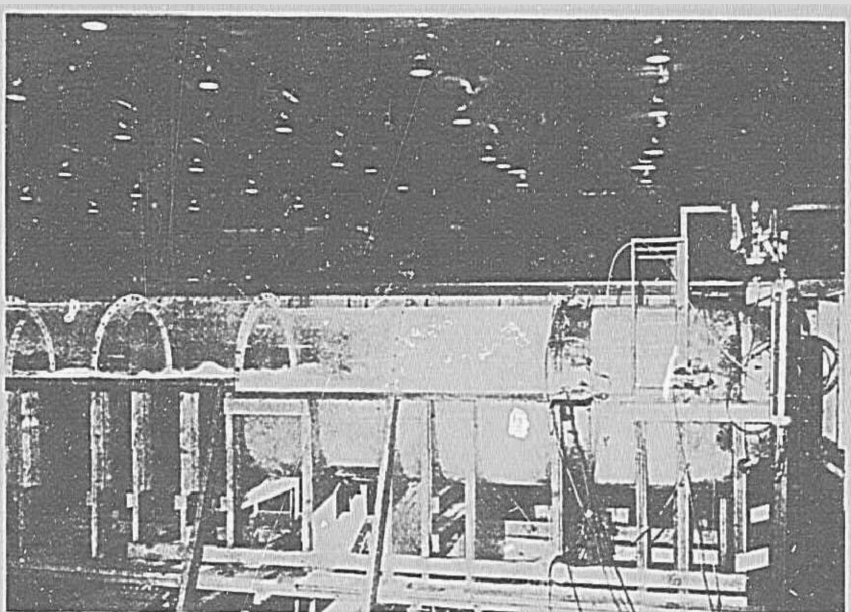


Figure 15. No baffles. Valves opened 0.38D discharging 12,000 cfs (339.8 cubic meters per second). Tunnel WS elevation 117.5 (35.8 meters)—Incipient sweep-out. Photo P801-D-74278

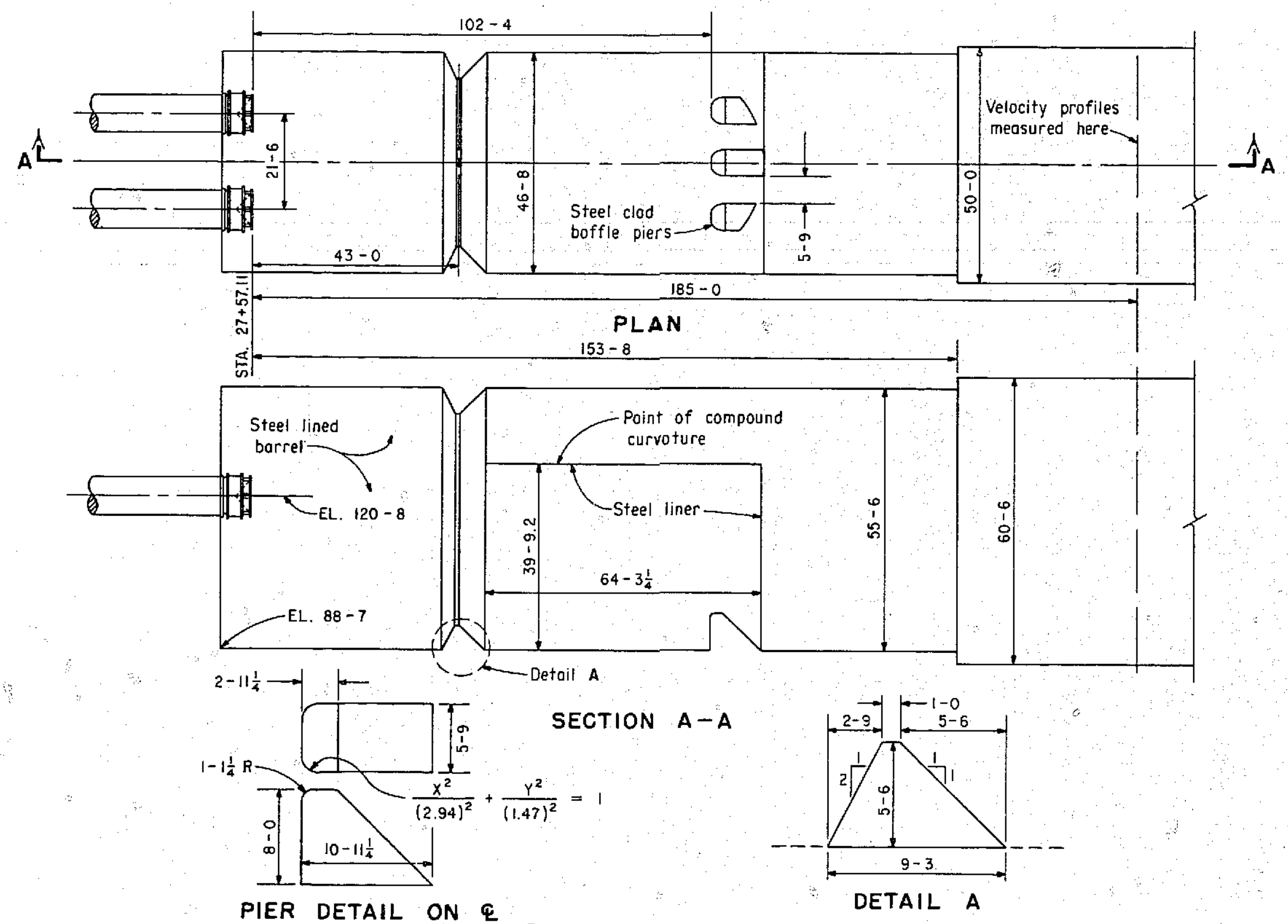



Figure 16. Recommended design.

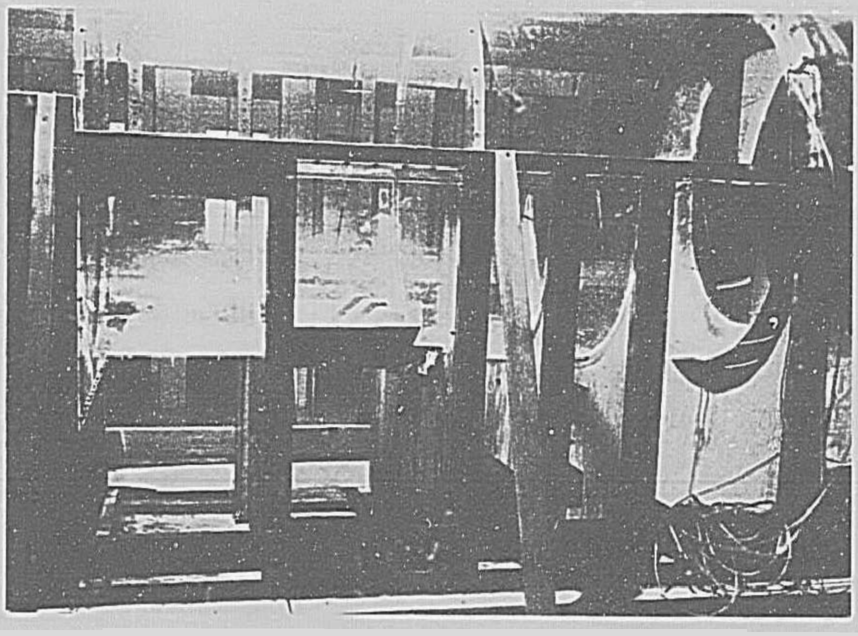


Figure 17. Recommended design, side view. Photo P801-D-74271

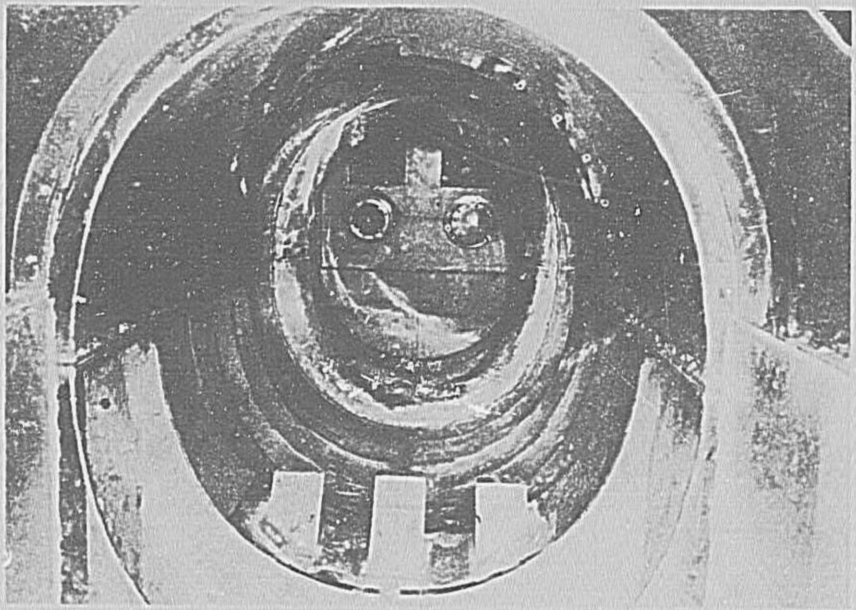


Figure 18. Recommended design, looking upstream. Photo P801-D-74272

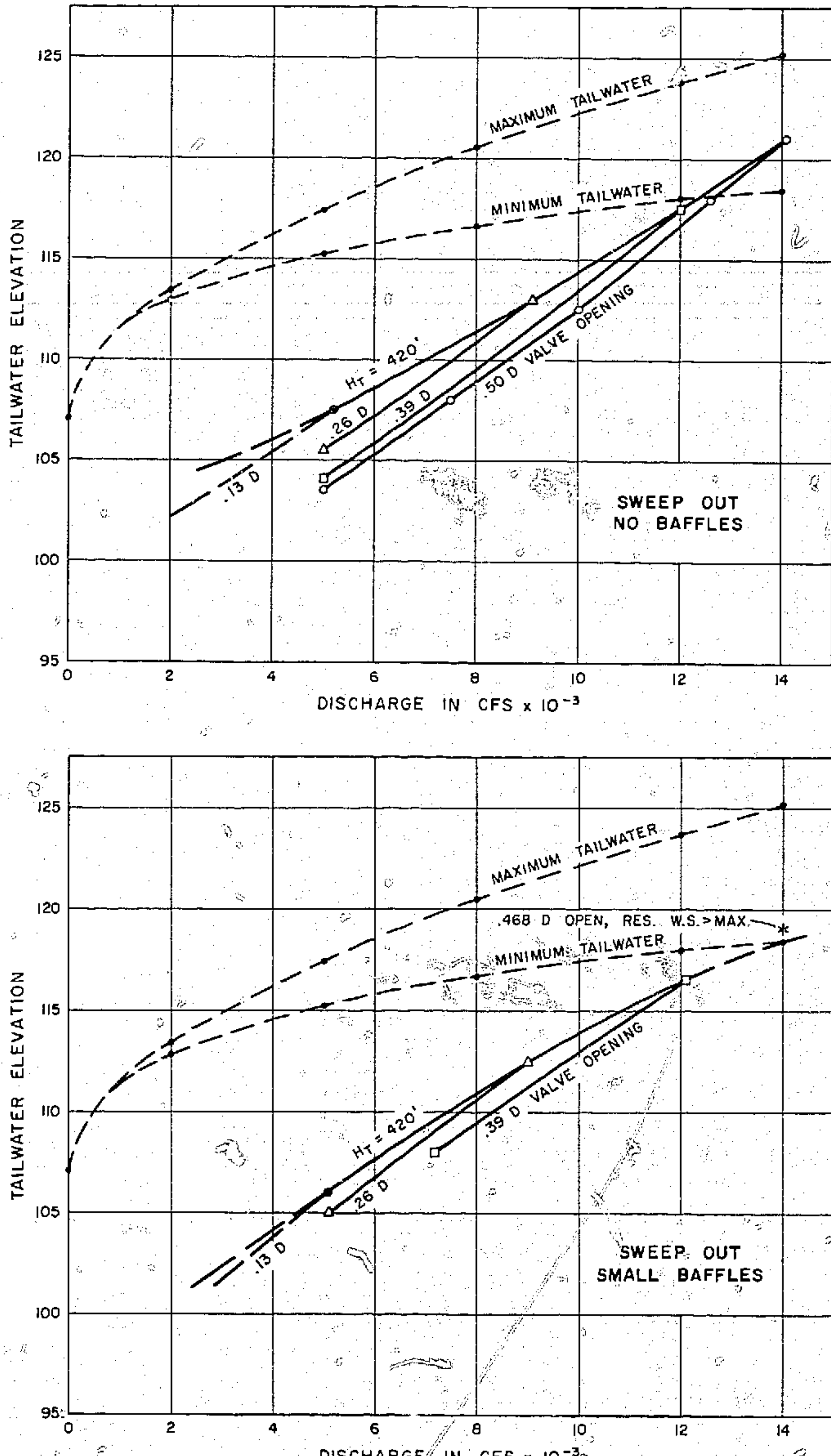

TAILWATER ELEVATION
DISCHARGE IN CFS x 10⁻³
MAXIMUM TAILWATER
MINIMUM TAILWATER
$H_T$ = 420'
.13 D
.26 D
.39 D
.50 D VALVE OPENING
SWEEP OUT
NO BAFFLES
.39 D VALVE OPENING
.468 D OPEN, RES. W.S. > MAX.
SWEEP OUT
SMALL BAFFLES

Figure 19.

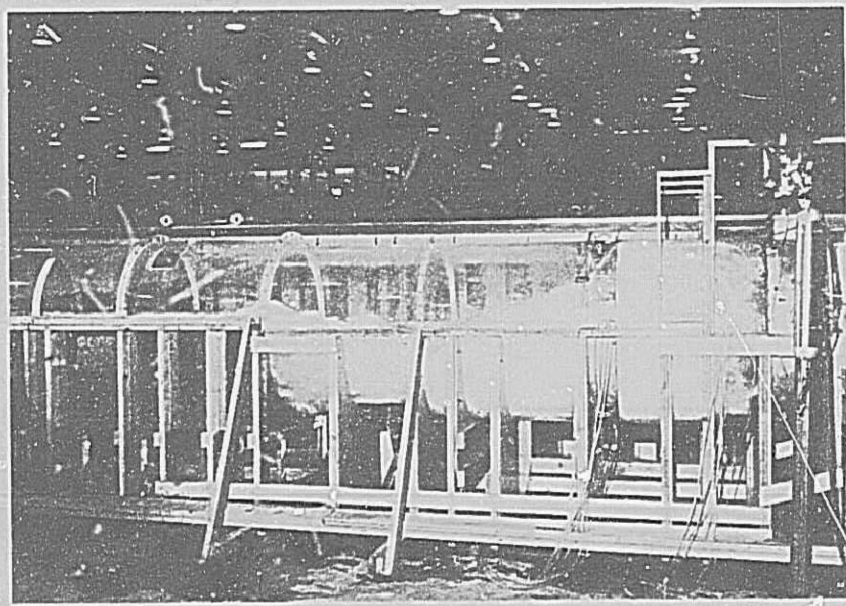


Figure 20. Recommended design—Valves opened 0.40D discharging 12,260 cfs (347.2 cubic meters per second). $H_e$ = 411 feet (125.3 meters). Tunnel WS elevation 115 (35.1 meters)—Incipient sweep-out. Photo P801-D-74273

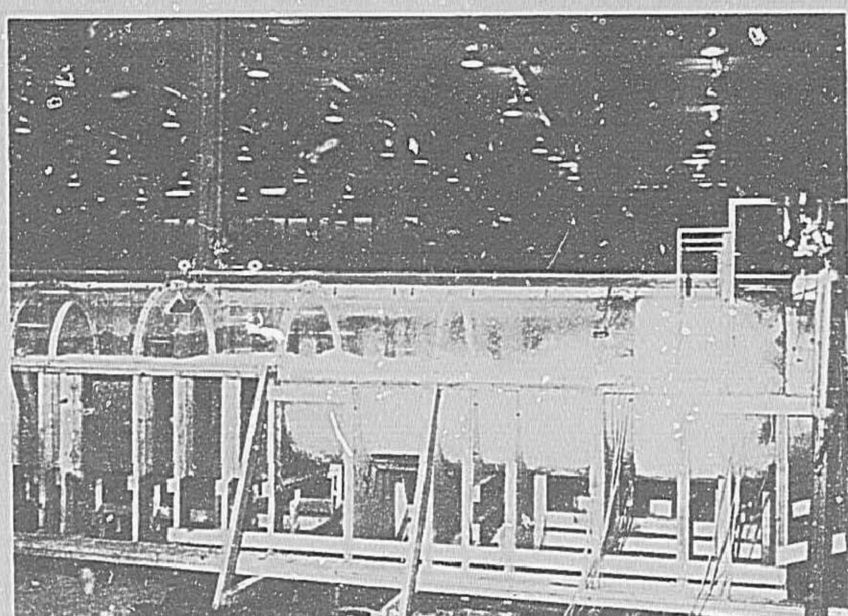


Figure 21. (Same conditions as Figure 20.) Tunnel WS elevation 118 (36.0 meters) (minimum). Photo P801-D-74274

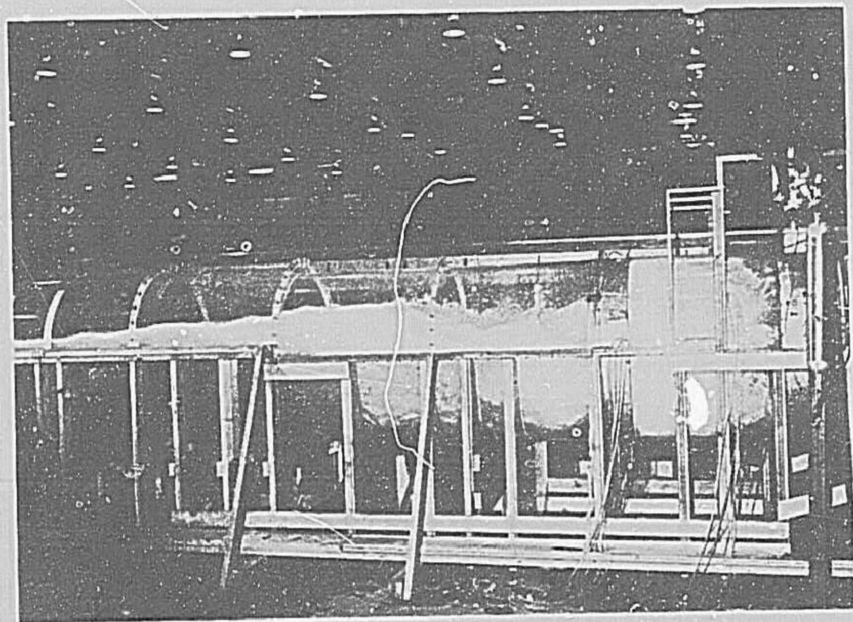


Figure 22. (Same conditions as Figure 20.) Tunnel WS elevation 123 (37.5 meters) (maximum). Photo P801-D-74275

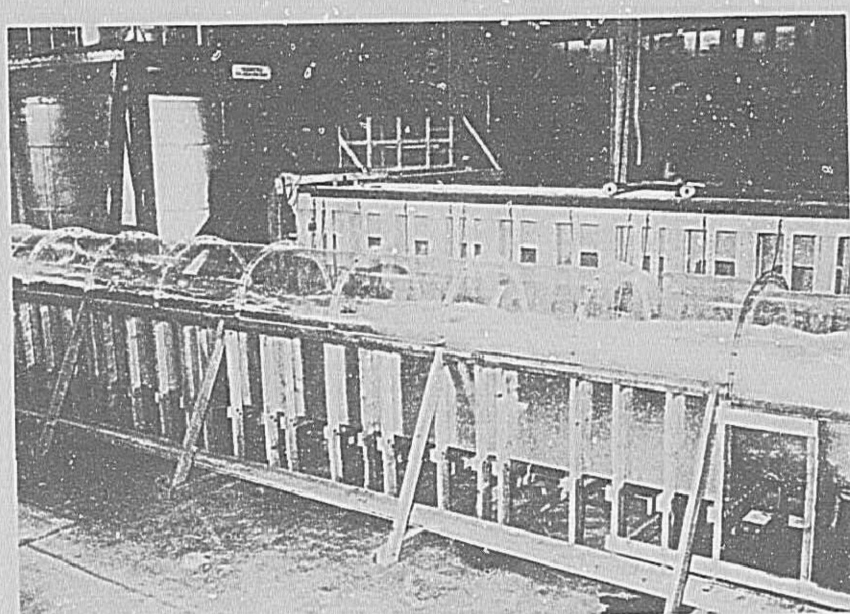


Figure 23. (Same conditions as Figure 22.) Looking downstream. Note the tranquil water surface in the unlined tunnel. Photo P801-D-74276

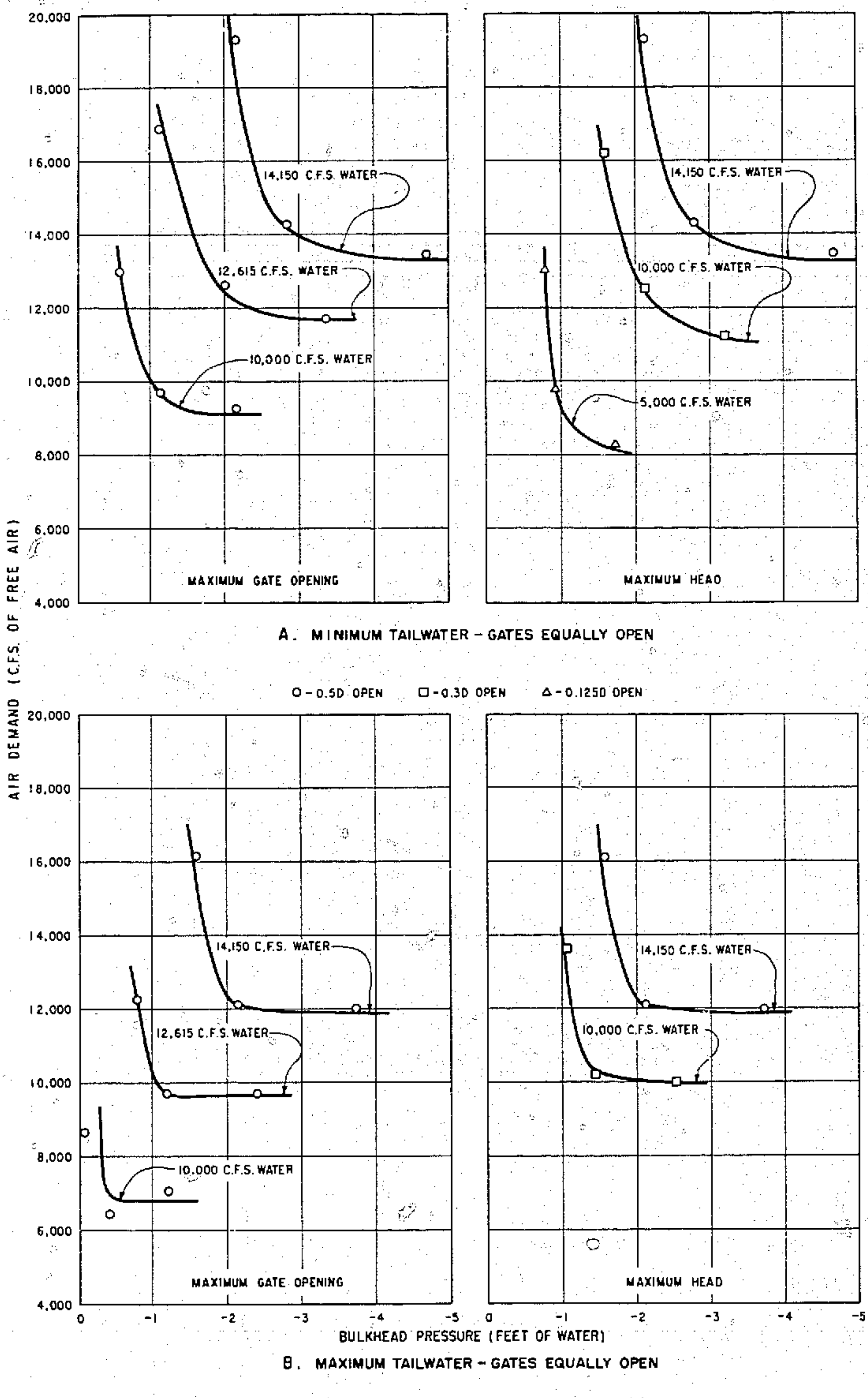



Figure 24. Bulkhead pressure in feet of water.

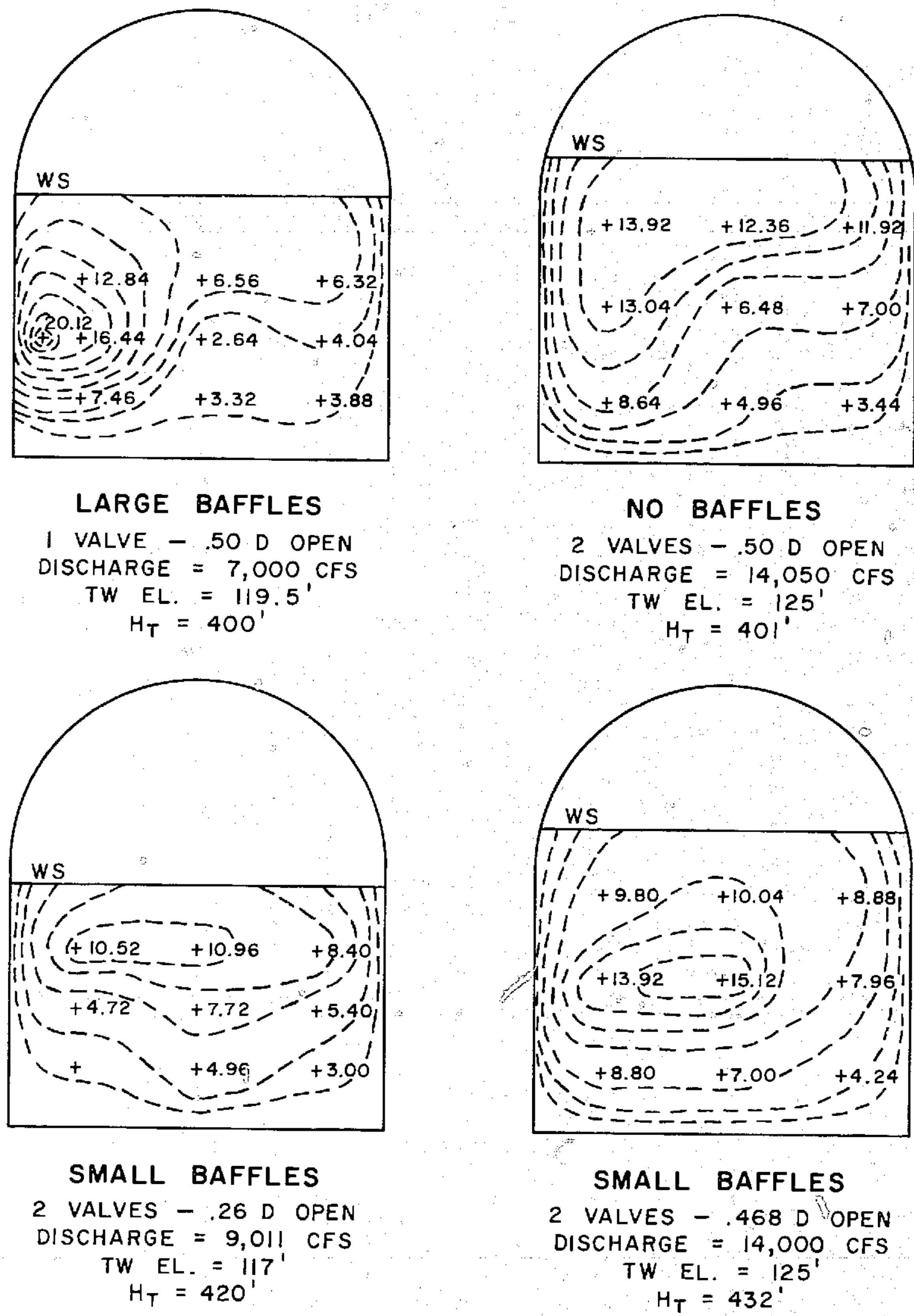
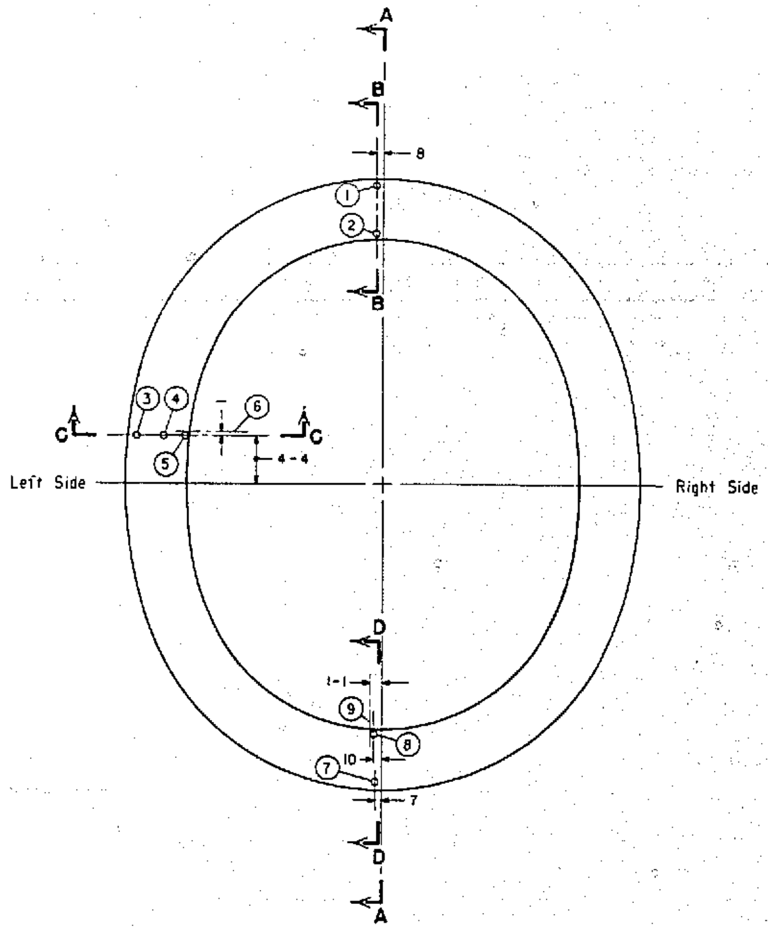
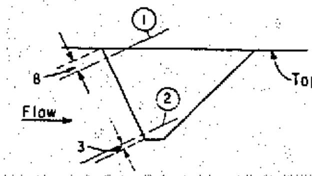


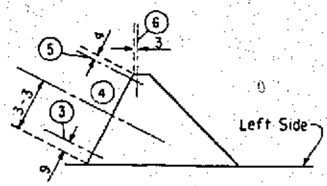

Figure 25. Velocity distribution for various energy dissipator configurations.



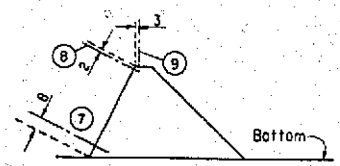

DEFLECTOR RING IN OVAL SECTION



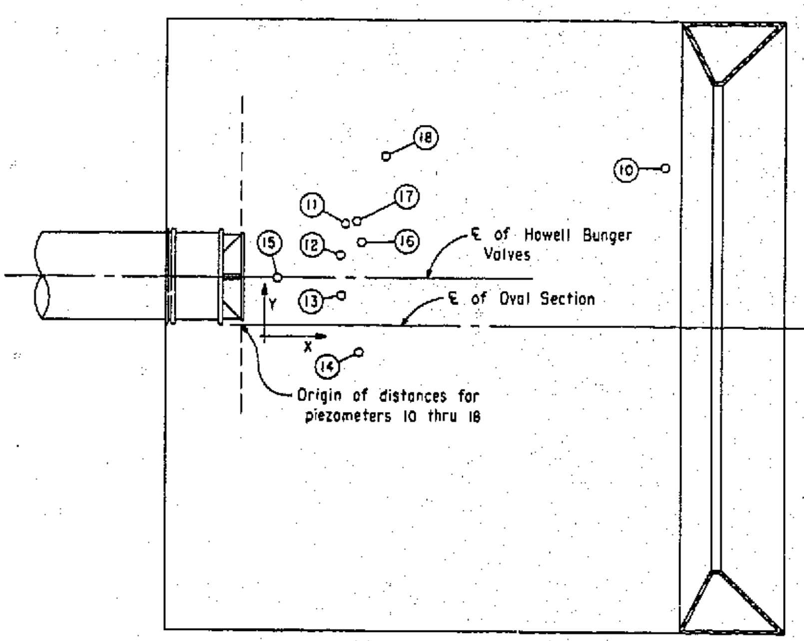

SECTION B-B




SECTION C-C




SECTION D-D
EXPANDED RING SECTIONS




SECTION A-A

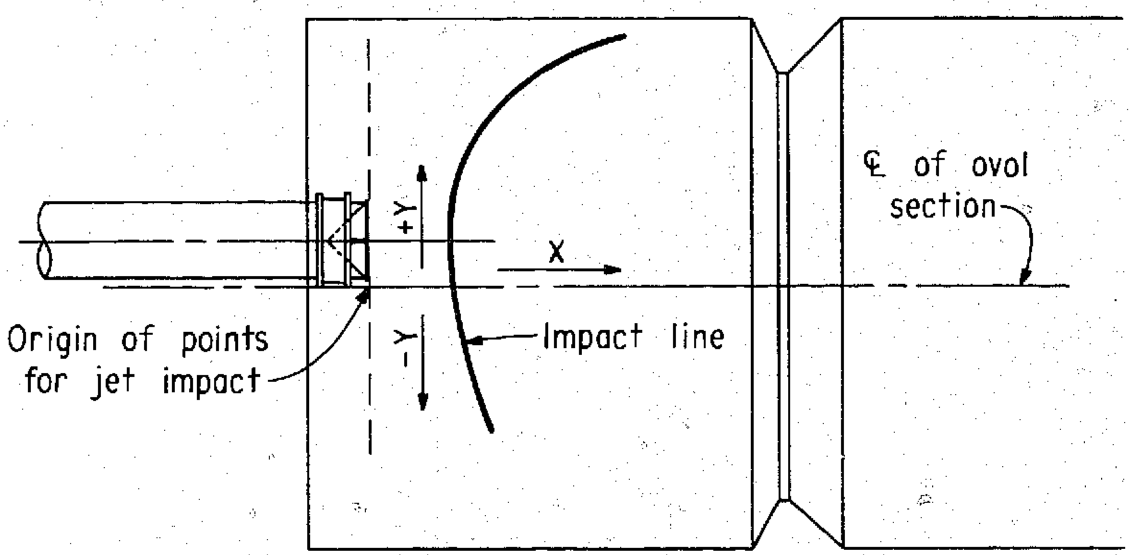
PIEZOMETER LOCATION

| PIEZOMETER NUMBER | DISTANCE FROM ORIGIN X | Y |
|---|---|---|
| 10 | 38'-3" | 14'-8" |
| 11 | 9'-5" | 9'-4" |
| 12 | 8'-11" | 6'-6" |
| 13 | 9'-0" | 2'-10" |
| 14 | 10'-8" | -2'-4" |
| 15 | 3'-3" | 4'-4" |
| 16 | 10'-10" | 7'-6" |
| 17 | 10'-5" | 9'-6" |
| 18 | 13'-1" | 15'-6" |

Figure 26. Piezometer locations.

Point Coordinates For Jet Impact

| X | Y |
|---|---|
| 12.67' | −15.45' |
| 11.33' | −11.77' |
| 10.00' | −7.92' |
| 9.00' | −3.98' |
| 8.67' | +3.98' |
| 8.75' | +7.92' |
| 9.42' | +11.77' |
| 10.67' | +15.45' |
| 13.50' | +18.82' |
| 16.92' | +21.76' |
| 21.17' | +24.19' |
| 26.92' | +26.03' |




SIDE ELEVATION

Figure 27. Location of jet impact in oval section.

## ABSTRACT

Studies were performed, using a 1:16 scale model of the low-level outlet works for the LG-2 power development in the province of Quebec, Canada. The energy dissipator includes a deflector ring and baffle piers in a steel-lined oval section downstream from the two 96-inch (2,438.4-mm) Howell-Bunger valves. The energy dissipator section is followed by a flat-bottomed tunnel. Operation was improved by moving the deflector ring downstream from its original locations and substituting small floor baffles for the large baffles of the preliminary design. The elevation of the valves (as set according to previous USBR experience) was determined to be satisfactory and velocities in the unlined portion of the tunnel were within acceptable limits. Data were obtained for computation of required tunnel air supply and for structural design of the deflector ring and energy dissipator walls.

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REC-ERC-74-3
Colgate, D
HYDRAULIC MODEL STUDIES OF THE LOW-LEVEL OUTLET WORKS, LG-2 DEVELOPMENT, QUEBEC, CANADA
Bur Reclam Rep REC-ERC-74-3, Div Gen Res, Jan 1974. Bureau of Reclamation, Denver 26 p, 29 fig, 3 tab, 2 ref

DESCRIPTORS—/ *outlet works/ hydraulic models/ *energy dissipation/ stilling basins/ jets/ baffles/ model studies/ hydraulic valves/ deflectors/ hydraulic structures/ energy dissipators/ structural design
IDENTIFIERS—/ Howell-Bunger valve

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