MODIFICATION OF AN EXISTING PUMP DISCHARGE CONDUIT TO ACCOMMODATE TURBINE FLOW

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NOTES FOR A SLIDE ILLUSTRATED PRESENTATION AT THE ENGINEERING FOUNDATION SPONSORED CONFERENCE "CONVERTING EXISTING HYDRO-ELECTRIC DAMS AND RESERVOIRS INTO PUMP STORAGE FACILITIES," AUGUST 18-24, 1974, AT RINDGE, NEW HAMPSHIRE.

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"Modification of an Existing Pump Discharge Conduit to Accommodate Turbine Flow"*
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The Bureau of Reclamation has modified two of the conduits leading from Lake Roosevelt to Banks Lake, the storage reservoir for the Columbia Basin Project lands. The modifications are necessary for the proper operation of the new pump-turbine and generator/motor units for peak power generation.

The pumping plant was constructed to house 12 pumping units, and all entrances, conduits, etc., were completed. Only six pumps were installed initially, and the first water was pumped in May 1951. By using pump/turbines rather than single-duty pumps in the remaining six installations, Banks Lake can be utilized as the upper reservoir in the pumped-storage concept, as well as the equalizing reservoir for the irrigation facility.

Pumping from Franklin D. Roosevelt Lake into Banks Lake requires a vertical lift varying from 278 to 362 feet. The same head is available for power generation when flows through the units are reversed. (Figure 1) When acting as turbines the units will produce about 50,000 kw of low cost peaking power per unit.

The final details for the necessary changes to the conduit at the Banks Lake Canal headwall were designed by hydraulic model studies. The model included two of the outlet siphon elbows, the entrance transitions for the discharge lines for pump-turbines 7 through 12, and the upstream, or canal side, configuration to assure proper flow for both pumping and for power generation. (Figure 2A) The model did not include conduits 1 through 6. These six conduits serve the six pumps originally installed and will not be changed.

Siphon Crown Pressure

The highest point in the conduit system is the crown of the siphon elbow and would be the location at which vapor pressure would occur most readily. The average barometer at the elevation of the Grand Coulee siphon is 28.4" Hg, and the approximate maximum vacuum at which the vacuum pumps at the Grand Coulee siphons will pump at that ambient pressure is -24.5" Hg. The vacuum pump capability of -24.5" Hg was accepted as the limiting negative pressure at the siphon crown. In the "as built" conduit with normal turbine flow, the minimum acceptable pressure of 27.7 feet of water below atmospheric was reached when the water surface at the headwall was 19.8 feet lower than the siphon crown.

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*Notes for a slide illustrated presentation at the Engineering Foundation sponsored conference "Converting Existing Hydro-Electric Dams and Reservoirs into Pump Storage Facilities," August 18-24, 1974, at Rindge, New Hampshire.

The turbine flow losses from Banks Lake to the canal headwall, and the pumped-flow losses from the canal headwall to Banks Lake, are shown in Figure 3.

Rectangular Conduit

Concern regarding the reduced pressure at the crown of the siphon elbow prompted conceptual changes which lowered the elevation of the elbow crown 3 feet to achieve higher (safer) wall pressures in the critical areas. A rectangular conduit 9 feet high by 12 feet wide was installed in the model. The invert of the rectangular conduit followed the trace of the "as built" conduit. (Figure 2B)

Although the siphon elbow crown was 3 feet lower in elevation than the circular "as built" siphon elbow, the pressure head with the turbine discharging 2,300 cfs was only 0.9 feet lower.

The installation of rectangular conduits in the prototype would be quite costly necessitating the replacement of about 225 feet of each of the presently installed circular conduits. The advantages would be minor - An additional safety cushion of less than 1 foot of pressure head at the siphon crown for normal discharge. Therefore the concept of the rectangular conduit was abandoned.

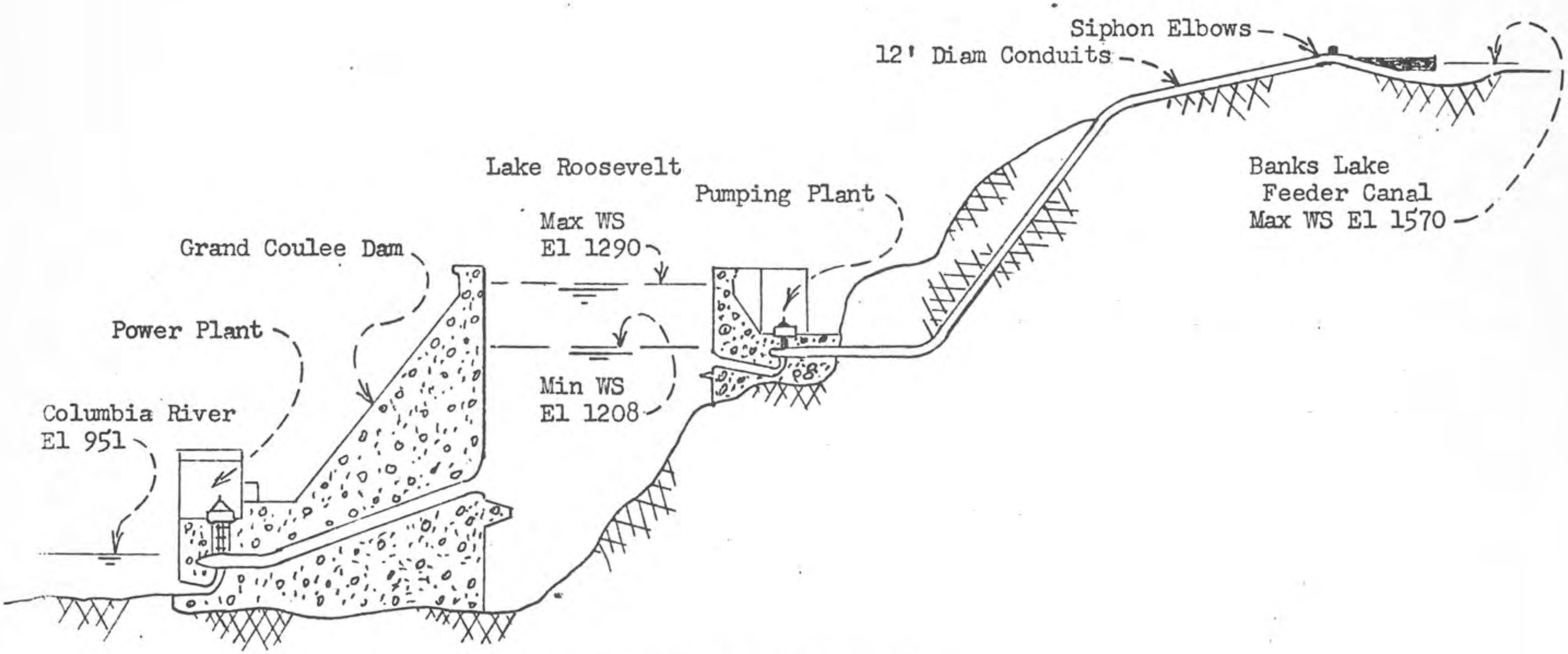
Conduit Entrance Studies

The "as built" conduit entrance (Figure 4) produced unsatisfactory air entraining vortices at the headwall, and high conduit entrance losses. A streamlined conduit entrance (Figure 5) was designed to correct these deficiencies. The streamlined design reduced the conduit losses about 1 foot of head, but vortices persisted in the forebay.

Design considerations dictated that the streamlined modifications on the roof of the conduits should not extend upstream from the "as built" headwall since trashracks, bulkheads, and the slots to accommodate them, would be required for turbine flow. The streamlined conduit entrance concept, to include the "as built" canal headwall, was accepted for prototype construction. The recommended configuration is shown in Figure 6.

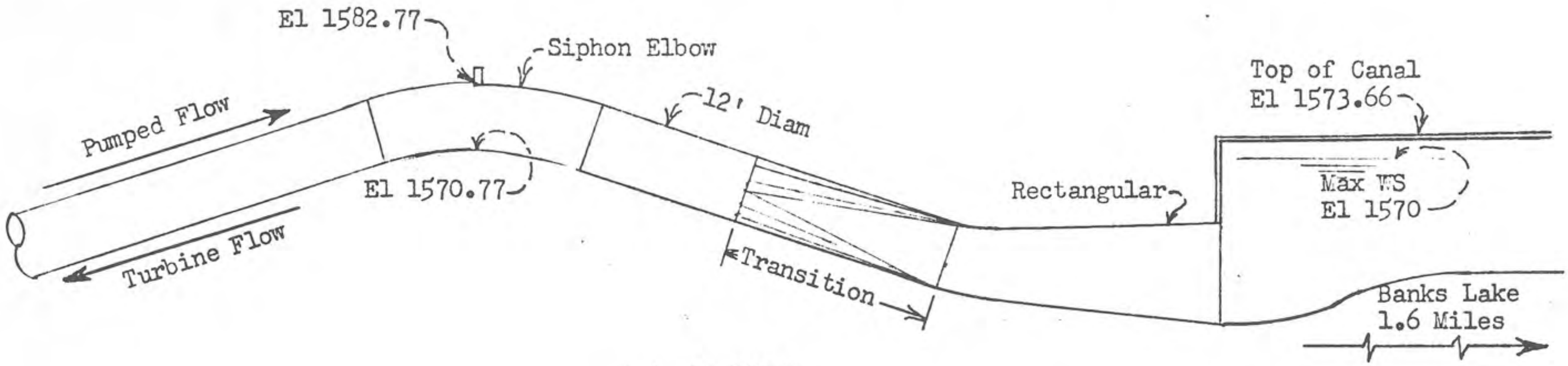
The vortices in the canal at the headwall were reduced to acceptable levels with the addition of a curved guide wall extending 30 feet into the canal, including the underdrain pump well between pump unit No. 6 and pump-turbine unit No. 7. (Figure 7)

Five turbines may be satisfactorily operated in the steady state with the modifications to the "as built" design as shown in Figures 6 and 7.

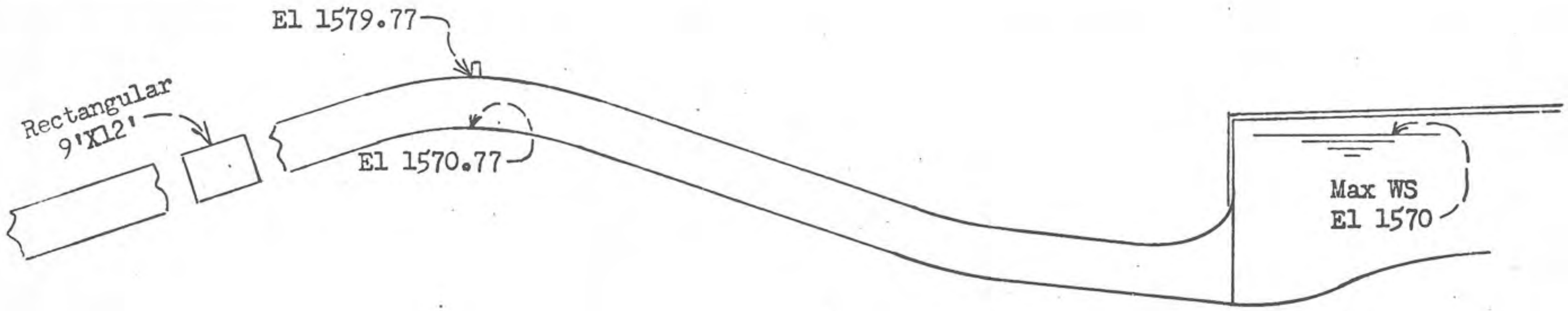


GRAND COULEE PUMPING PLANT

FIGURE 1

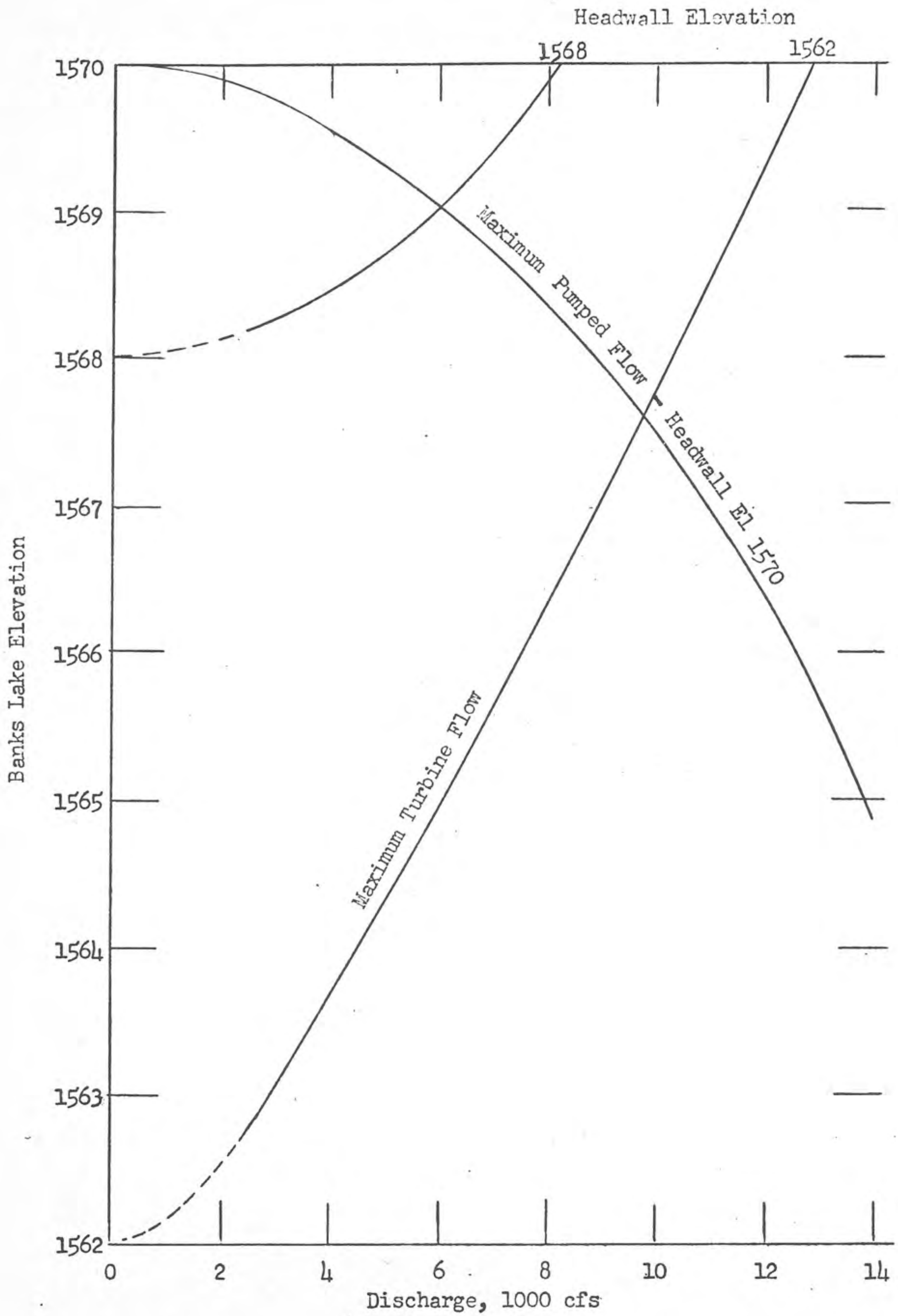


(A) AS BUILT

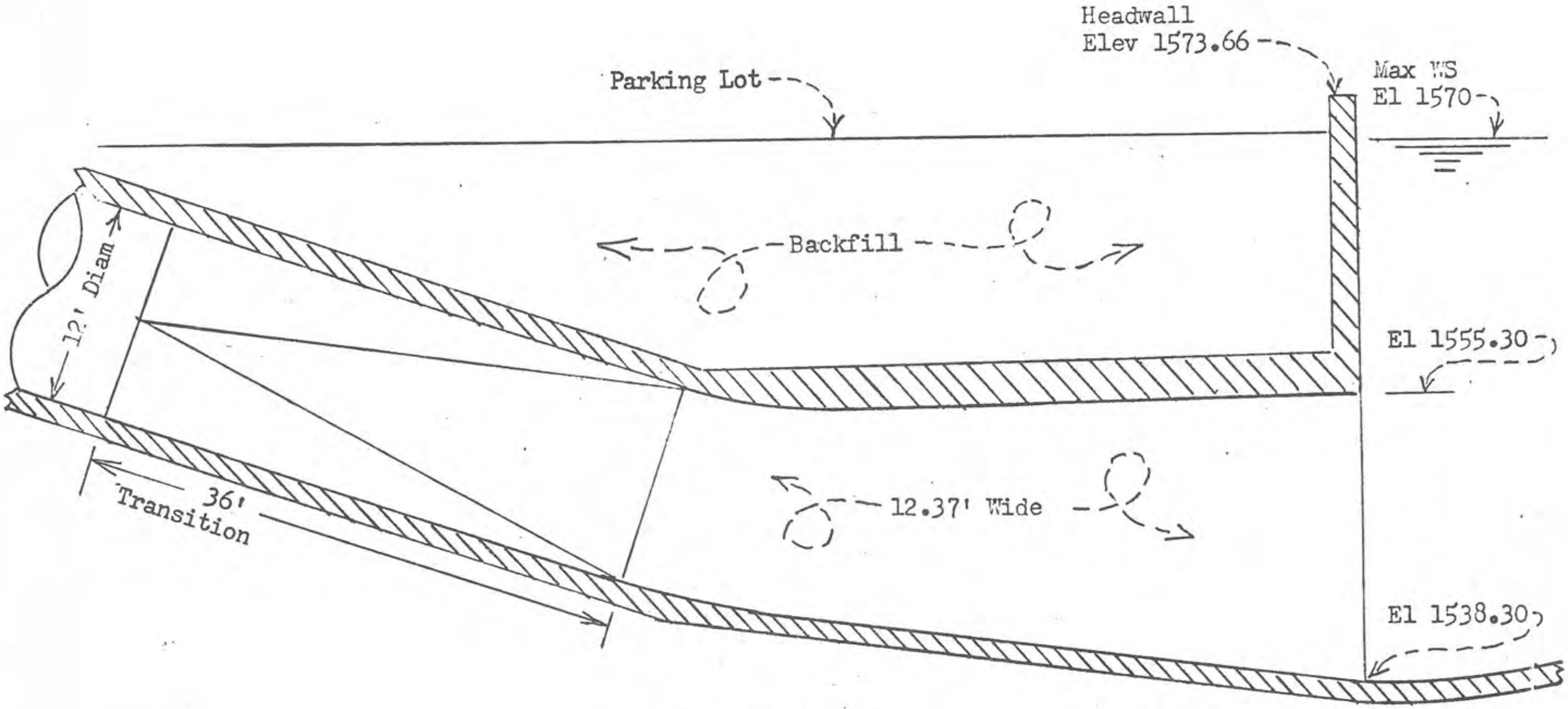


(B) PROPOSED RECTANGULAR CONDUIT

FIGURE 2

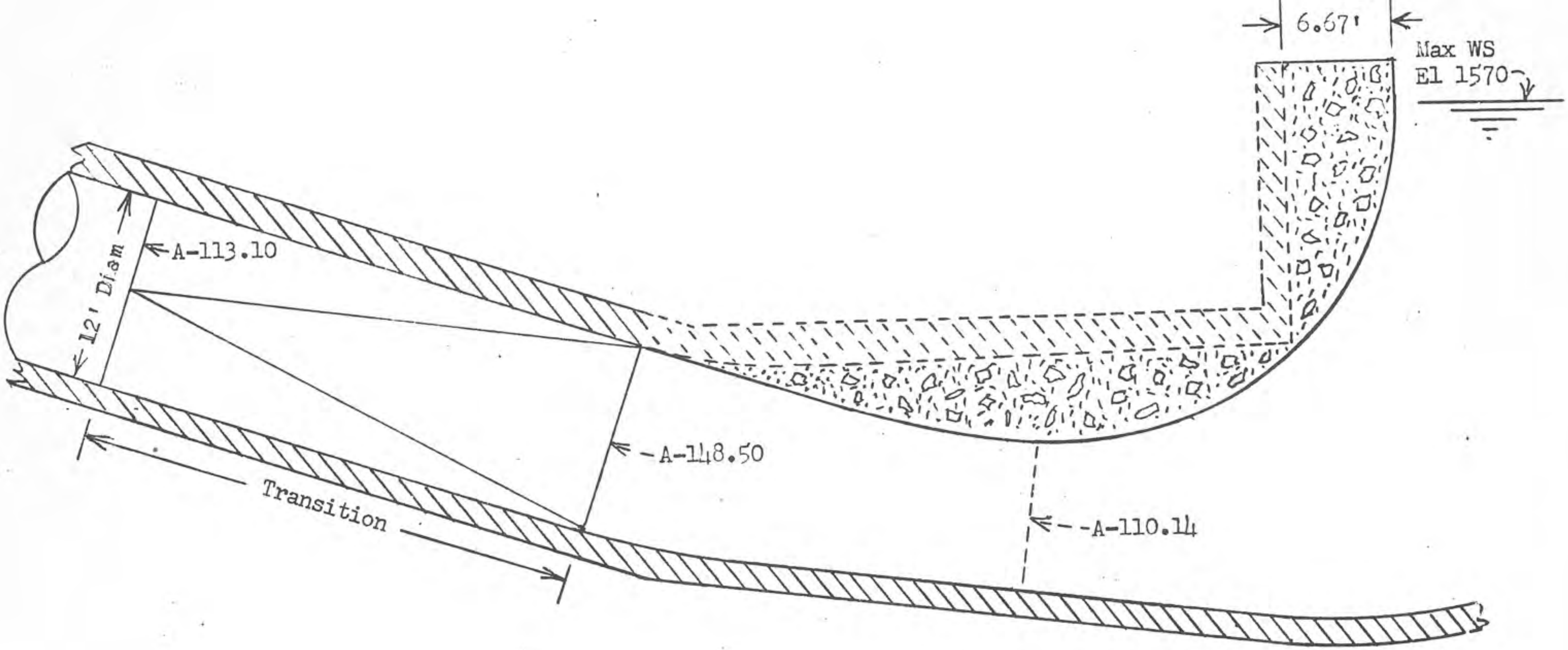


CANAL AS BUILT



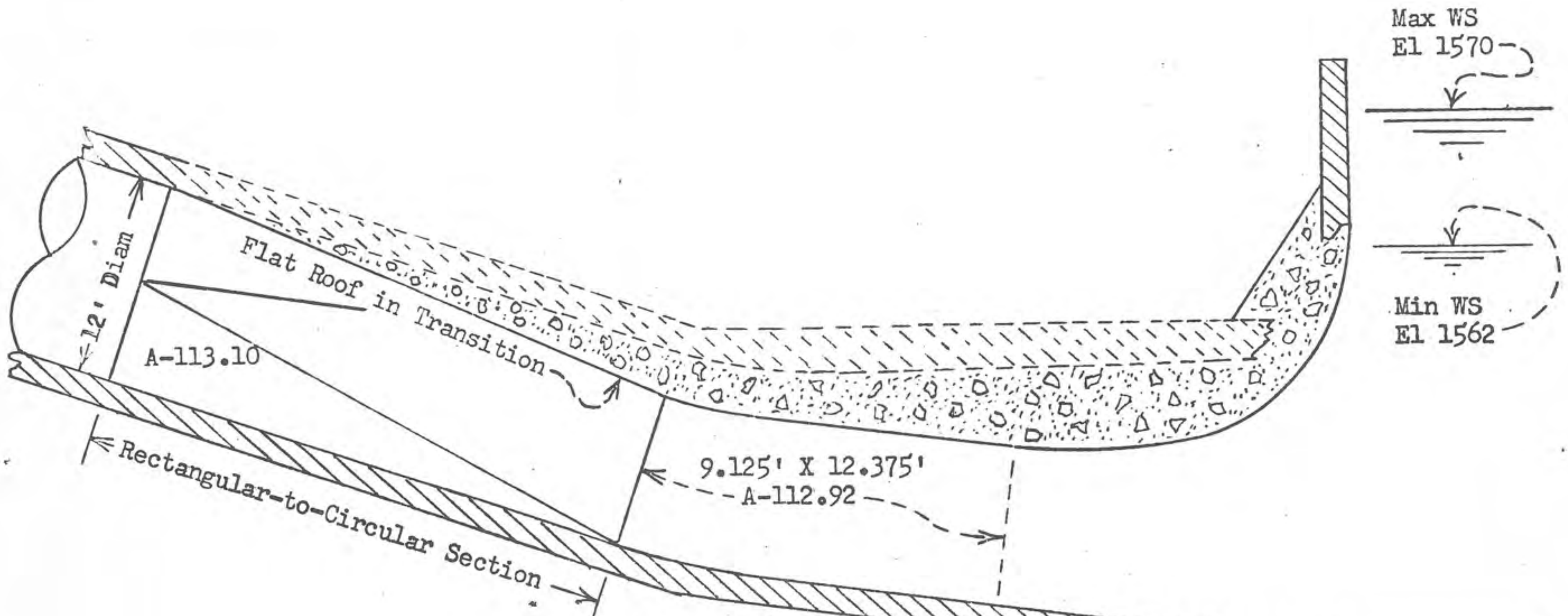
OUTLETS— AS BUILT

FIGURE 4



STREAMLINED ENTRANCE
EXTENDING UPSTREAM FROM THE HEADWALL.

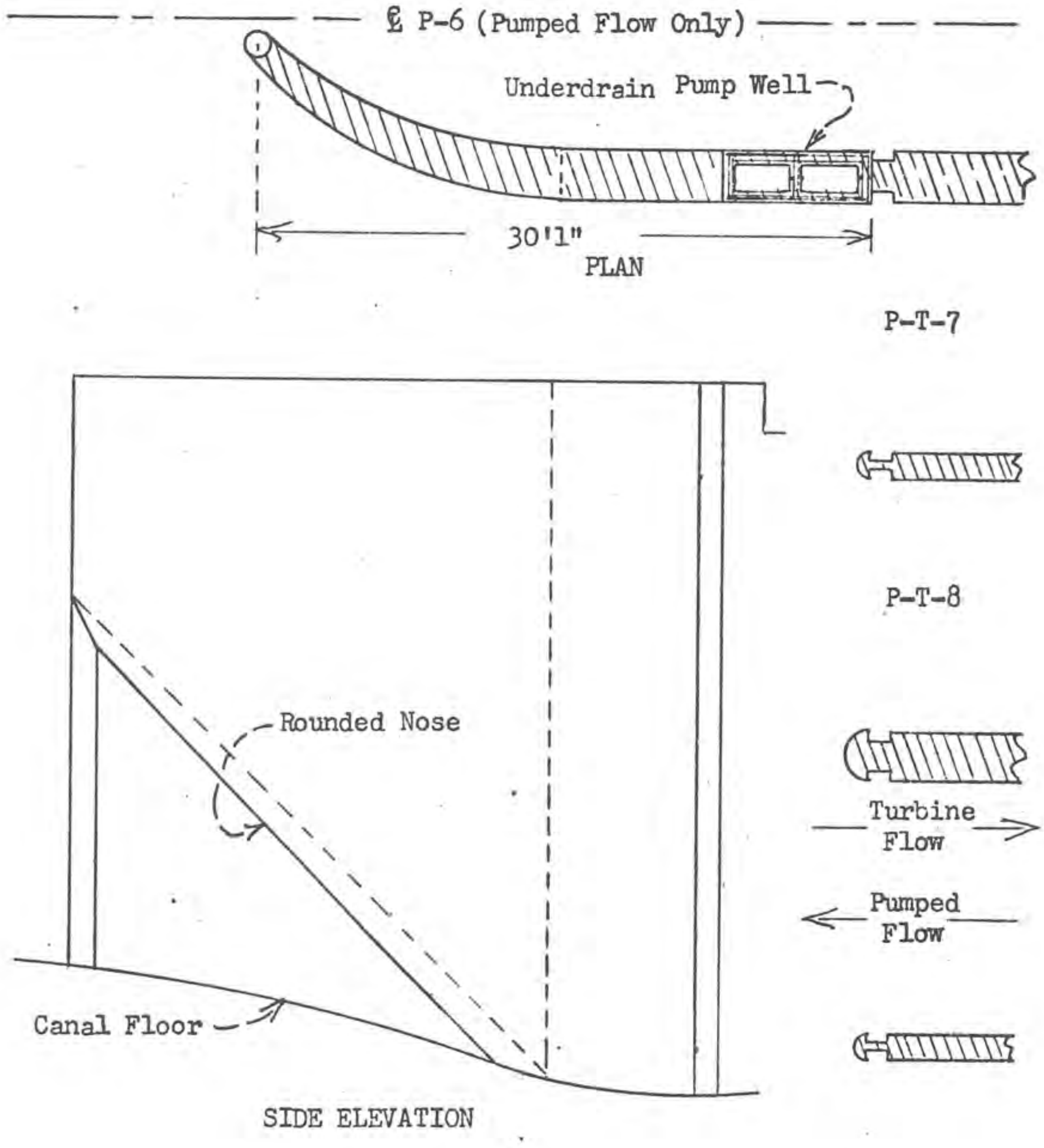
FIGURE 5



SMALL RADIUS STREAMLINED ENTRANCE
FLUSH WITH HEADWALL

RECOMMENDED MODIFICATION

FIGURE 6



CURVED GUIDE WALL BETWEEN P-6 and P-T-7