UNITED STATES
DEPARTMENT OF THE INTERIOR
BUREAU OF RECLAMATION

HYDRAULIC MODEL STUDY OF A PROPOSED OUTLET WORKS DESIGN FOR ANCHOR DAM-- MISSOURI RIVER BASIN PROJECT

Hydraulic Laboratory Report No. Hyd.-244

RESEARCH AND GEOLOGY DIVISION

BRANCH OF DESIGN AND CONSTRUCTION
DENVER, COLORADO

JANUARY 1949

The model studies discussed in this report were made during the preliminary design of Anchor Dam to determine whether or not the proposed outlet works design incorporating a vertical stilling well was feasible. The design of the dam and outlet works was later changed. Therefore, the test results reported herein are not applicable to the current Anchor Dam design.

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Date: January, 1949

Laboratory Report No. 244
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Subject: Hydraulic model study of a proposed outlet works design for Anchor Dam--Missouri River Basin Project.

PURPOSE OF STUDY

An outlet works structure of unusual design was proposed for Anchor Dam wherein two 36-inch outlets passed through the dam to release their flow into 13 feet square by 19 feet deep vertical stilling-wells located on the outsides of the spillway training-walls. The water from these wells passed through notches in the training-walls and plunged into the pool in the spillway bucket below. Hydraulic model studies were made to determine the practicability of the proposed design and the feasibility of the vertical stilling-well design previously developed for another structure.

CONCLUSIONS

So far as flow conditions in the spillway bucket and river channel were concerned (with only the outlets operating either singly or simultaneously) the proposed outlet design was entirely satisfactory.

The good performance of the vertical stilling-well, which was made geometrically similar to that developed for the Soap Lake Siphon Blowoff Structure of the Columbia Basin Project, makes it readily adaptable to this structure.

RECOMMENDATIONS

It is recommended that the proposed outlet works design be considered for Anchor Dam.

If this design is adopted further tests should be conducted on the control valve and pedestal to insure a dependable flow-regulating system.

INTRODUCTION

Anchor Dam is a structure proposed for construction in a narrow V-shaped rocky canyon on Owl Creek, 40 miles west of Thermopolis, Wyoming. It is to be either a compacted earth-fill or a concrete structure of the multiple arch or buttress type rising approximately 210 feet above the riverbed. It will provide reservoir storage for irrigation water and for flood control.

To avoid costly excavation or tunneling in the canyon walls, a unique arrangement of the outlet system was suggested for the concrete structure. In this arrangement two 36-inch outlets conduits would pass through the dam and discharge their flow into vertical stilling-wells, located on the outsides of the spillway training-walls. Water flows from the stilling-wells through notches in the training-walls and falls 30 feet into the bucket of the spillway. Each outlet would discharge 225 second-feet of water at a normal head of 162 feet giving a total outlet capacity of 450 second-feet.

Hydraulic model tests were made primarily to determine if the water falling from the stilling-wells into the spillway bucket would produce eddies in and immediately downstream from the spillway bucket, which would cause excessive scour in the river channel and carry riverbed material into the bucket. Additional tests were made to investigate the adaptability of the vertical stilling-well design to this structure.

THE MODEL STUDY

Description and Operation of Model

A 1:10 scale ratio was selected for the model of the proposed outlet structure. The model was contained in two adjoining wooden boxes lined with sheet metal (Figure 1). The water entered the first box through a vertical 4-inch standard pipe which terminated in a 2-1/2-foot length of 3.6-inch-diameter sheet metal pipe representing the 36-inch supply pipe proposed for the prototype structure. A 1-foot square opening in the side of this box represented the 10-foot square notch in each of the prototype spillway training-walls. Water flowed through this opening and fell into the pool in the spillway bucket which was constructed in the second box. The spillway bucket of the type used for Angostura Dam was formed of concrete screeded to metal templates. The center of curvature of the bucket and the center of the discharge notch were on the same vertical line. The equivalent of 60 feet of the 90-foot wide bucket was included. Sand was placed in the box downstream from the bucket lip to represent riverbed material. Water was supplied to the model by the central laboratory system which contained venturi meters for determining the rate of flow. The depth of water in the bucket and river channel was controlled by a tailgate placed at the extreme lower end of the model.

All tests conducted on this model were of a qualitative nature consisting mainly of visual observations of flow conditions in the stilling-well, spillway bucket and river channel immediately downstream.

Flow Conditions in Spillway Bucket and River Channel

The initial tests concerned the flow conditions in the spillway bucket and river channel downstream and their effect upon the movement of riverbed material. All tests were made for the condition of no flow over the spillway, since the outlets would be used mainly for releasing irrigation water when the reservoir surface is below the crest of the spillway. Moreover, this condition produced the greatest drop from the notches in the training-walls to the pool in the bucket giving the water its maximum energy content as it entered the pool and the greatest opportunity to form eddies.

Tests showed that for discharges up to 150 percent of the design capacity of 225 second-feet per outlet, there was no tendency for large eddies to form in the bucket and the water moved on a direct course downstream over the bucket lip (Figure 2). The velocity of flow was somewhat greater toward the center of the spillway than along the training-wall. This was due to the tendency of water to pile up in the center of the pool because of the forward motion of the issuing jet. A negligible amount of riverbed material was dislodged by the water and none was carried upstream into the bucket.

The preceding tests were made using a single outlet and an equivalent spillway width of 60 feet. Since the proposed width of the prototype spillway was 90 feet, each outlet will, in effect, discharge into 45 feet of the bucket pool when both are in operation. To represent this condition with the single outlet in the model, a partition was placed in the bucket normal to the axis of the dam at an equivalent distance of 45 feet from the training-wall (Figure 2). Operation of the model showed no appreciable change from the previous tests in the flow conditions in the pool or river channel. The velocity of the water flowing downstream was slightly greater than previously, due to restricting the width of the bucket. However, the scour was negligible and no riverbed material was carried upstream into the bucket.

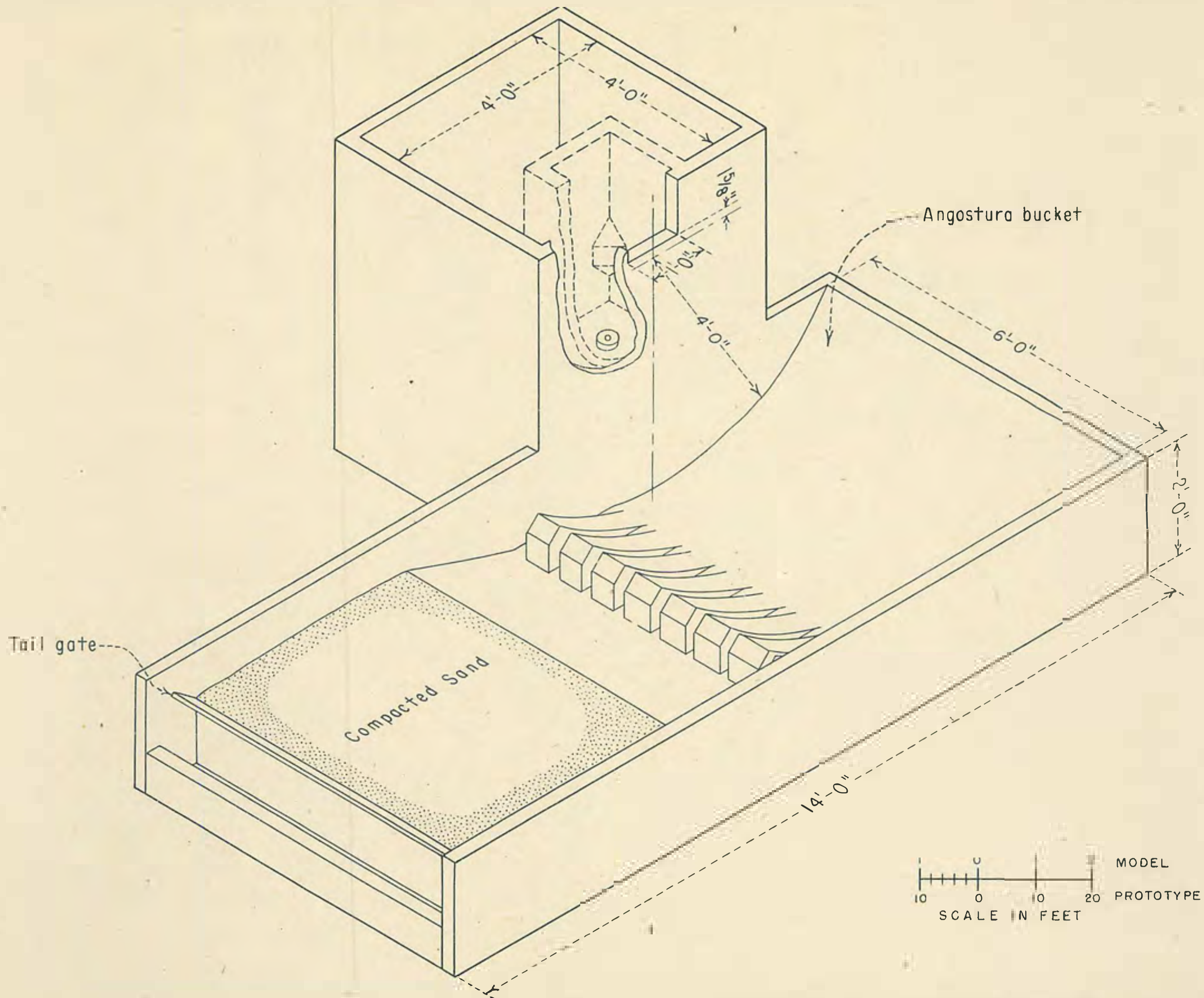
From these tests, it was concluded that insofar as the flow conditions in the spillway bucket and river channel were concerned, with the outlets only operating, the proposed outlet design was entirely feasible.

Study of the Stilling-well

A second study concerned the possibility of using a previously developed vertical stilling-well as an energy dissipater for the Anchor Dam outlets.

The effectiveness and relatively small size of the stilling-well developed in the Hydraulic Laboratory for the Soap Lake Siphon Blowoff Structure, Columbia Basin Project, Washington, made it ideal for this outlet arrangement. Accordingly, a geometrically similar well 13 feet square and 19 feet deep was included in the model. The size was selected so that the average upward velocity of the water in the well would be the same as that for the Soap Lake Siphon Blowoff Structure. A pedestal, equivalent to 72 inches in diameter and 15 inches high, having a 90° right-circular cone with a base diameter of 36 inches centered on it, was placed in the center of the floor (Figure 3). Water entered through a vertical pipe which terminated in the center of the well 36 inches (prototype) above the floor pedestal. The positions of the pipe exit and cone were selected so that the flow characteristics in subsequent tests would represent those which might be obtained with a control valve of the Howell-Bunger type fully opened and placed at the end of the supply line.

Tests showed that the action of the stilling-well was good (Figure 4, A and B). A relatively tranquil water surface existed in the well and the flow leaving through the notch in the training-wall took place smoothly and evenly. The performance of the well appeared entirely satisfactory for the proposed structure. It would be well to point out, however, that before a completely satisfactory regulating system could be assured for the outlet, further model tests of the controlling device will be required.



PROPOSED ANCHOR DAM OUTLET WORKS
1:10 MODEL

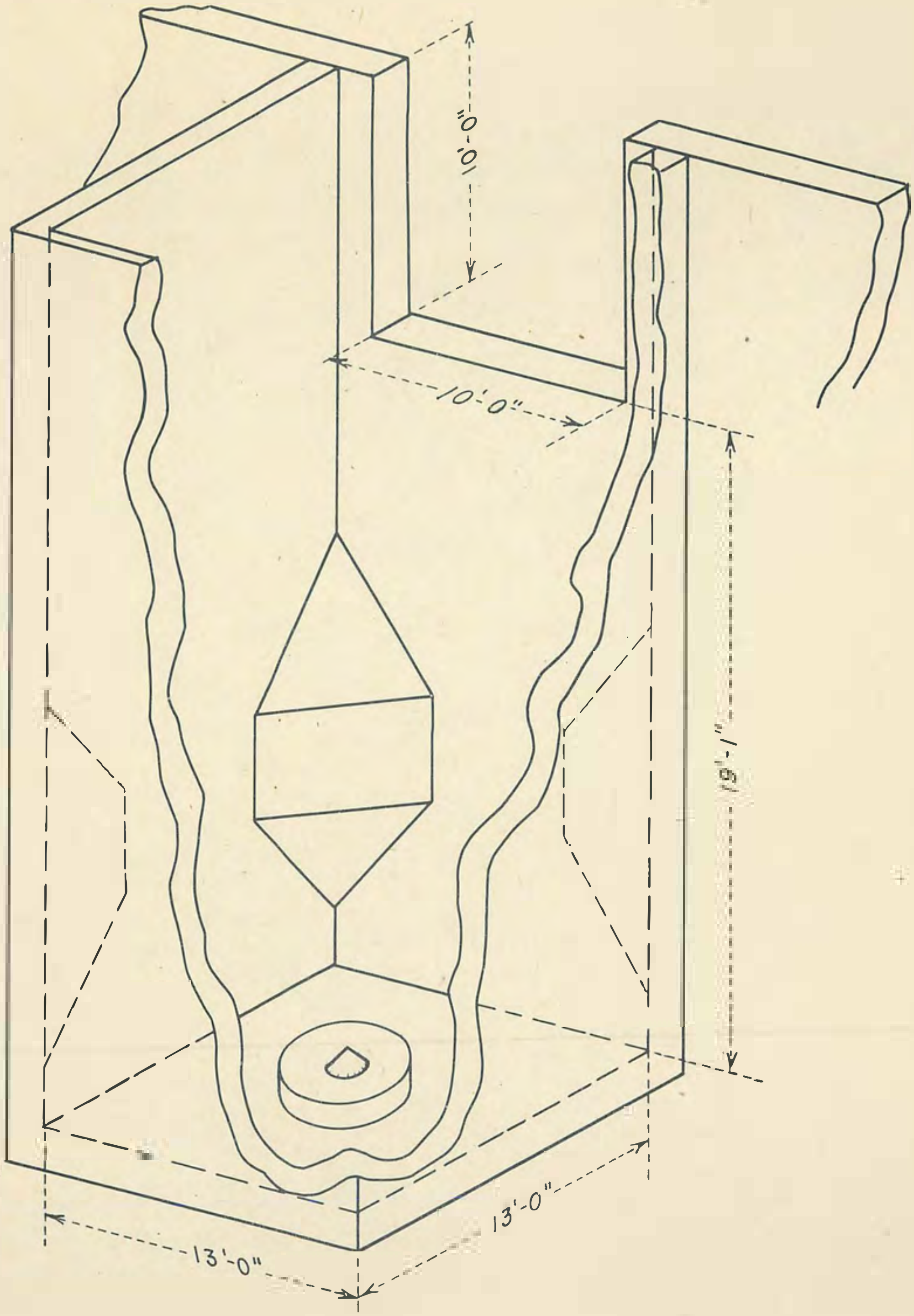
Looking upstream. Flow of 225 sec-ft.

FLOW CONDITIONS IN SPILLWAY BUCKET AND DOWNSTREAM RIVER CHANNEL

ONE OUTLET DISCHARGING

1:10 MODEL OF PROPOSED ANCHOR DAM OUTLET WORKS

FIGURE 3



ANCHOR DAM

PROPOSED OUTLET STILLING WELL

A. View through discharge opening. Flow of 225 sec-ft.

B. Water surface in well. Flow of 225 sec-ft.

FLOW CONDITIONS IN STILLING WELL

1:10 MODEL OF PROPOSED ANCHOR DAM OUTLET WORKS