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EAGLE MOUNTAIN DAM SPILLWAY MODEL STUDY REVISED DESIGN

Tarrant County Water Control
and Improvement District Number One
FORT WORTH, TEXAS



CIVIL ENGINEERING DEPARTMENT

ENGINEERING RESEARCH CENTER
COLORADO STATE UNIVERSITY
FORT COLLINS, COLORADO

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EAGLE MOUNTAIN DAM SPILLWAY

MODEL STUDY

REVISED DESIGN

Tarrant County Water Control
and Improvement District Number One
Fort Worth, Texas

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EAGLE MOUNTAIN DAM SPILLWAY

MODEL STUDY

REVISED DESIGN

INTRODUCTION

This report describes model testing on a revised design of the side channel spillway for the Eagle Mountain Dam near Fort Worth, Texas. After the original model study¹ was completed, a decision was made to reduce the number of gates from twelve to six. It therefore became necessary to make extensive revisions and retest the model. It was also decided to study the operation of the structure under flooding conditions up to a reservoir elevation of 679 feet.² This condition represents a flood with the water surface 20 feet above the gates in their closed position.

A description of the project and its objectives, including the proposed location of the new spillway relative to the existing dam and spillway, are included in the original report.¹ When possible, references will be made to the original report to eliminate duplication.

Scope of Work

The reduction in the size of the spillway structure and the need for testing under flooding conditions resulted in extensive revisions and retesting of the model. These revisions included:

1. Reduction in the number of gates from twelve to six and the corresponding reduction in size of the side channel.
2. Extending the head box such that the terrain around the revised side channel could be duplicated in the model to simulate flow conditions during flooding.
3. Replacing the sloping walls in the side channel with vertical walls and modifying the approach to the covered conveyance channel.
4. Reduction in the cross sectional area of the covered conveyance channel and the extension of it to the energy dissipator.

5. Extending the height of the sloping walls in the energy dissipator and the relocation of the blocks to handle flows from a minimum discharge to the maximum flooding condition.

The final design for the model is shown in Fig. 1. By comparing Fig. 1 with Fig. 2 of the original report¹, the extent of the modifications can be observed.

The objective in retesting the revised model was to evaluate its performance over its complete range of expected operation. Four areas were investigated.

1. Evaluate the general performance of the revised structure at maximum flood conditions and at all intermediate discharges. Make any necessary revisions to the system so that it can handle all expected flows.
2. Establish rating curves for the revised design up to maximum flood conditions, corresponding to a reservoir elevation of 679 feet. One rating curve was developed over the complete range of reservoir elevations for the structure with the gates removed. A second rating curve was developed for the gates in a closed position for reservoir elevations from the top of the gate at elevation 659 to a maximum of 679 feet.
3. The performance of the system was evaluated at maximum flooding conditions with several combinations of stop-log gates installed in the tunnel. Specifically, these tests were made with one, two, and three sections in place.
4. A few velocity measurements around the side channel were taken to evaluate the possibility of local scour under flooding conditions.

¹Tullis, J. Paul and Karaki, S.; "Eagle Mountain Dam Spillway Model Study," Department of Civil Engineering, Colorado State University, Report No. CER68JPT-SK11. Report to Freeze, Nichols and Endress, September 1968.

²Elevation of the crest is 637 feet.

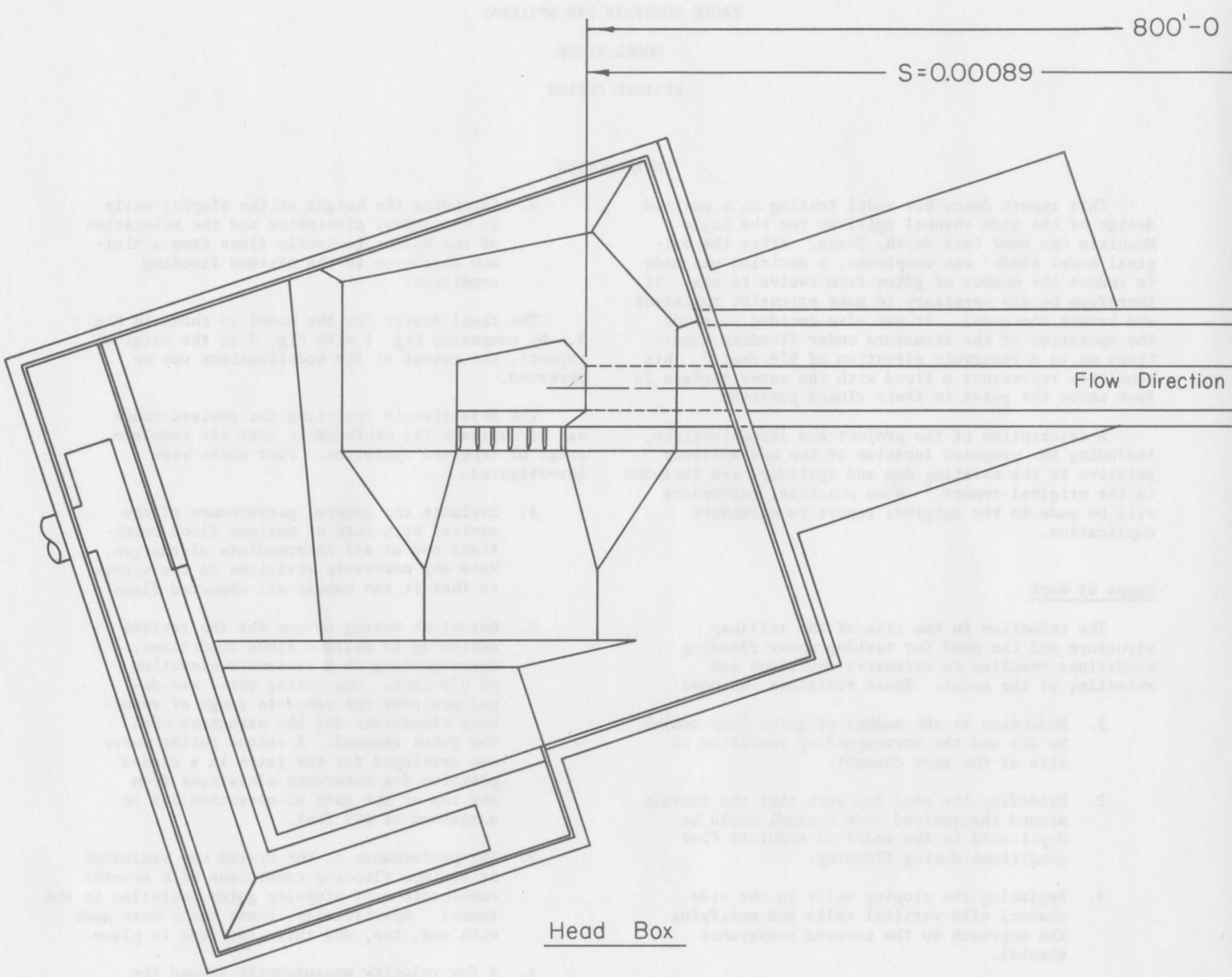
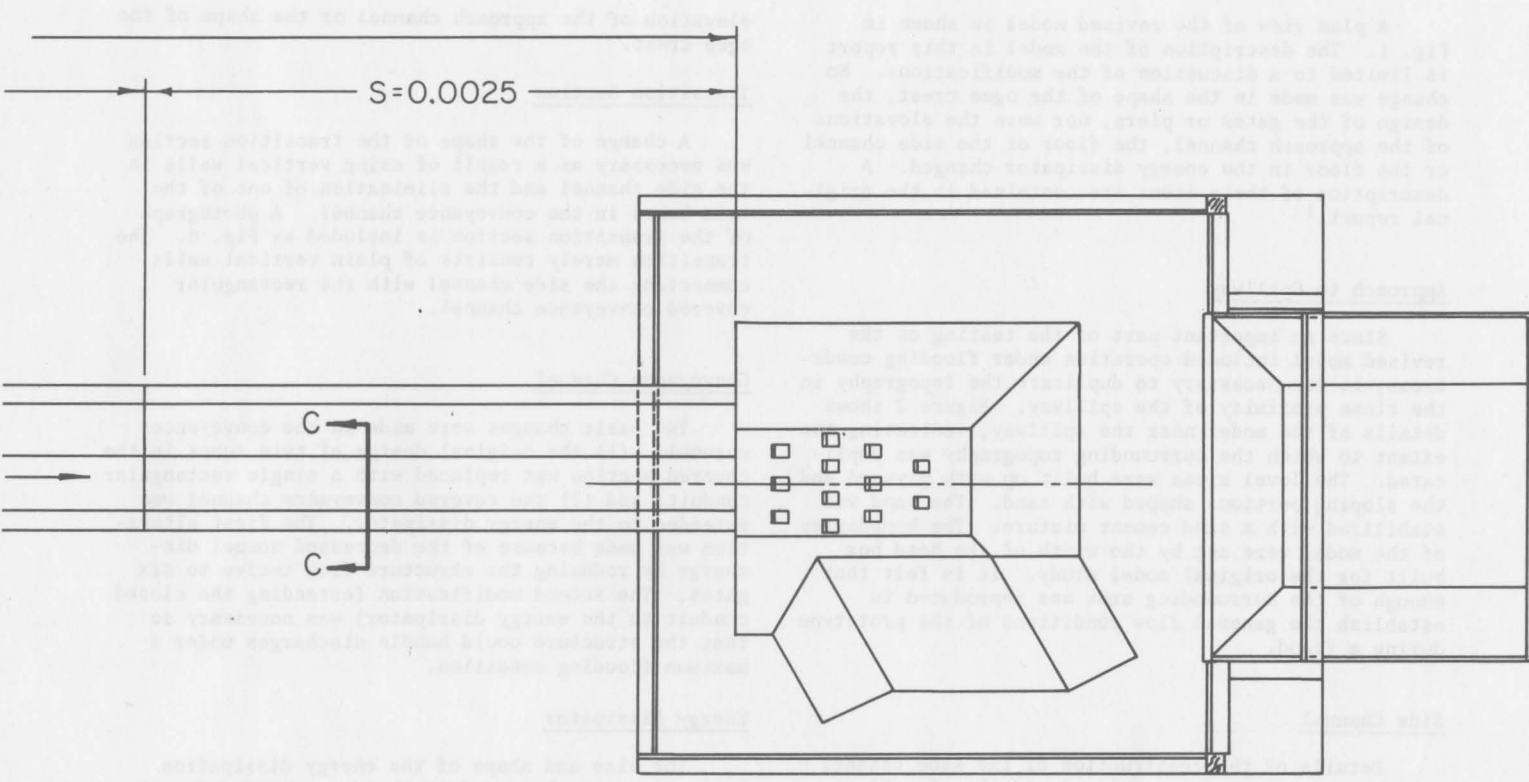
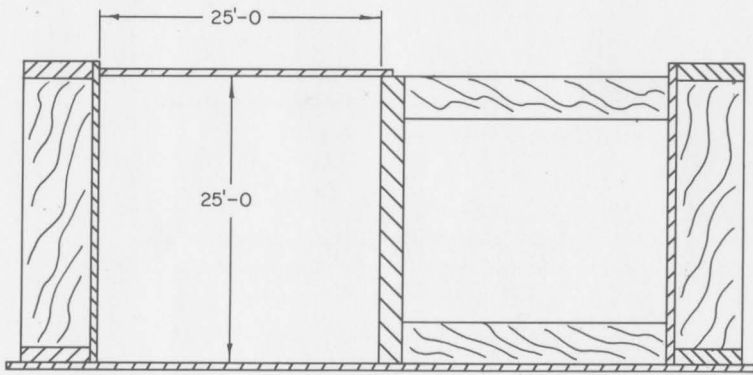


Fig. 1. Plan view of Eagle Mountain Dam revised spillway model.



Tail Box



SECTION C-C

Fig. 1. Plan view of Eagle Mountain Dam revised spillway model.

THE MODEL

A plan view of the revised model is shown in Fig. 1. The description of the model in this report is limited to a discussion of the modifications. No change was made in the shape of the ogee crest, the design of the gates or piers, nor were the elevations of the approach channel, the floor of the side channel or the floor in the energy dissipator changed. A description of these items are contained in the original report.¹

Approach to Spillway

Since an important part of the testing on the revised model included operation under flooding conditions, it was necessary to duplicate the topography in the close proximity of the spillway. Figure 2 shows details of the model near the spillway, indicating the extent to which the surrounding topography was duplicated. The level areas were built up with plywood and the sloping portions shaped with sand. The sand was stabilized with a sand cement mixture. The boundaries of the model were set by the width of the head box built for the original model study. It is felt that enough of the surrounding area was reproduced to establish the general flow conditions of the prototype during a flood.

Side Channel

Details of the construction of the side channel are shown in plan view on Fig. 2 and the elevations are included as Fig. 3. Photographs are included as Figs. 4 and 5. The general shape of the side channel has been retained; however, it has been considerably reduced in size and the original sloping walls have been replaced with vertical retaining walls. The floor of the side channel is still horizontal at an elevation of 617 feet and no changes were made in the

elevation of the approach channel or the shape of the ogee crest.

Transition Section

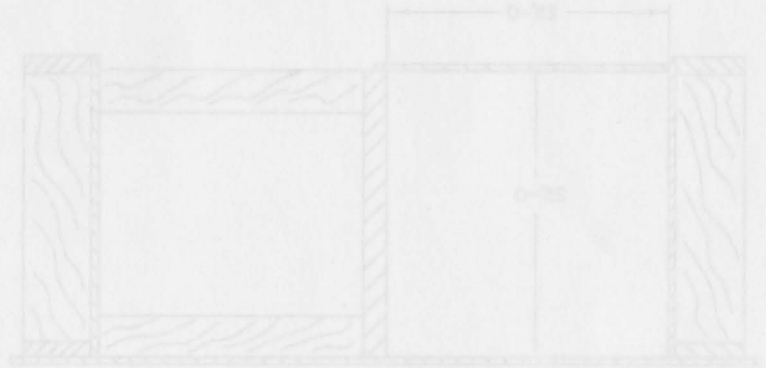
A change of the shape of the transition section was necessary as a result of using vertical walls in the side channel and the elimination of one of the twin tubes in the conveyance channel. A photograph of the transition section is included as Fig. 6. The transition merely consists of plain vertical walls connecting the side channel with the rectangular covered conveyance channel.

Conveyance Channel

Two basic changes were made in the conveyance channel: (1) the original design of twin tubes in the covered section was replaced with a single rectangular conduit; and (2) the covered conveyance channel was extended to the energy dissipator. The first alteration was made because of the decreased normal discharge by reducing the structure from twelve to six gates. The second modification (extending the closed conduit to the energy dissipator) was necessary so that the structure could handle discharges under a maximum flooding condition.

Energy Dissipator

The size and shape of the energy dissipation basin were not changed from that recommended for the original model study. The only change that was made was a redistribution of the number, size, and location of the blocks in the basin. Figure 7 shows the general dimensions of the basin and the layout of the blocks. Additional details are contained in the original report. All blocks are similar to the small blocks shown on Figs. 11 and 12 of the original report.



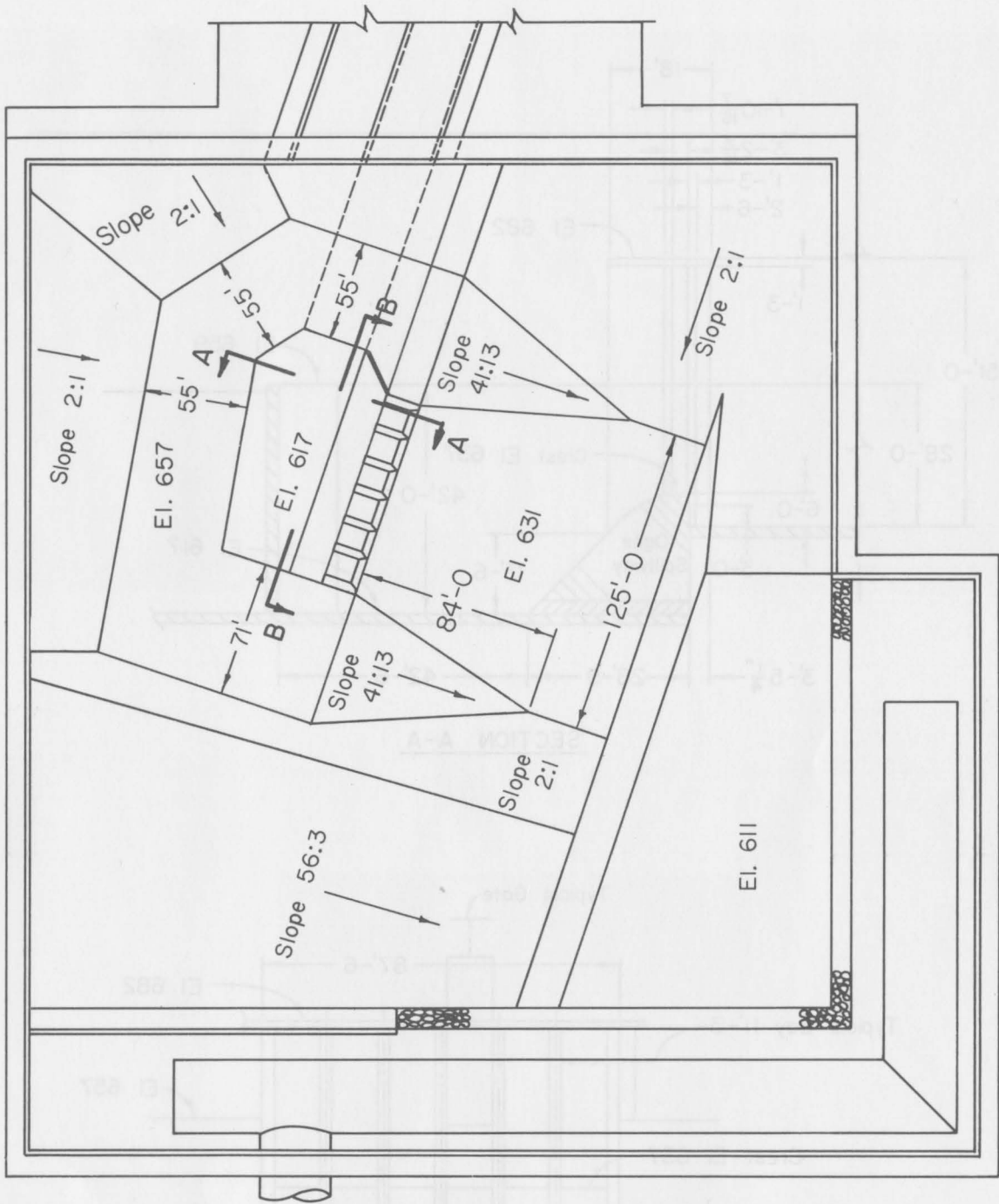


Fig. 2. Head box details

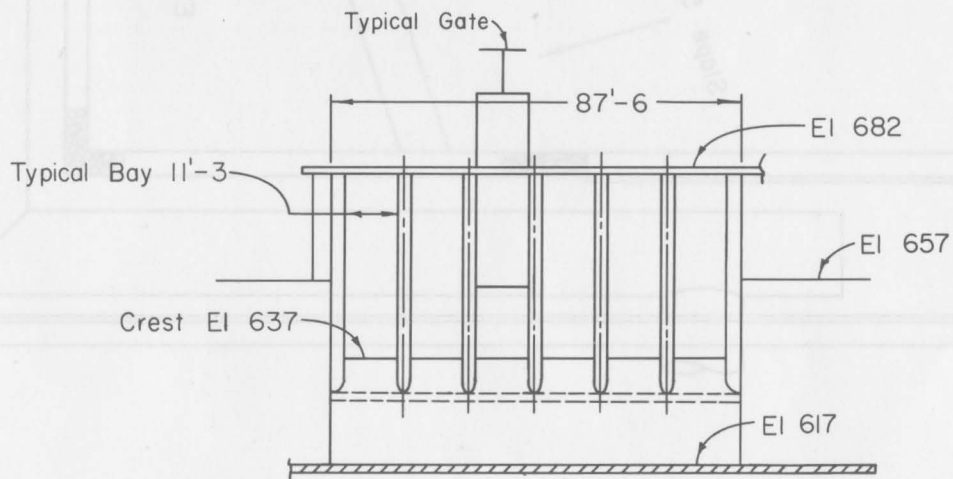
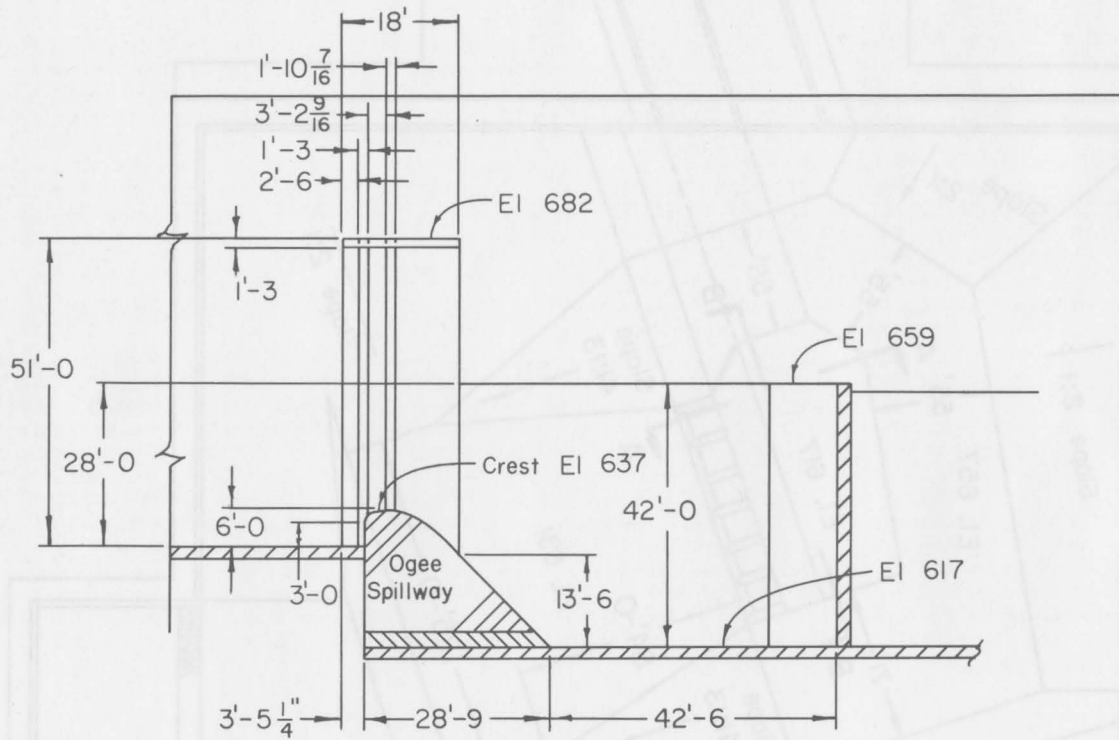


Fig. 3. Details of the side channel spillway

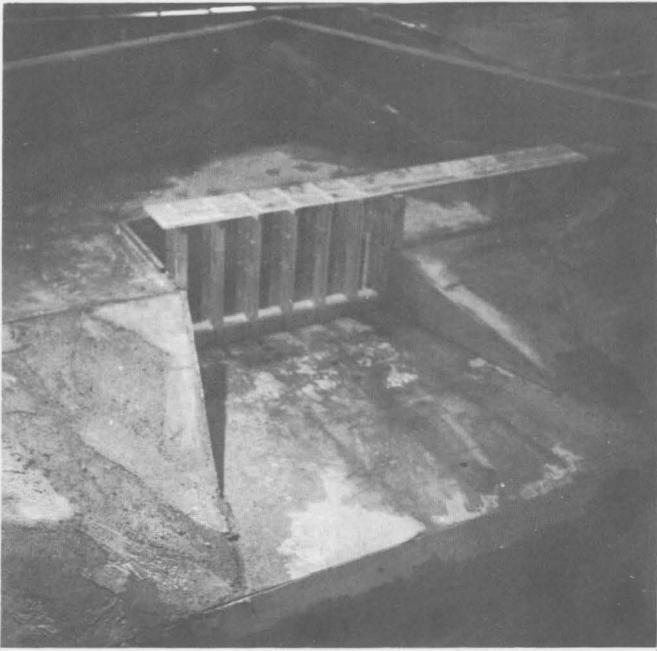


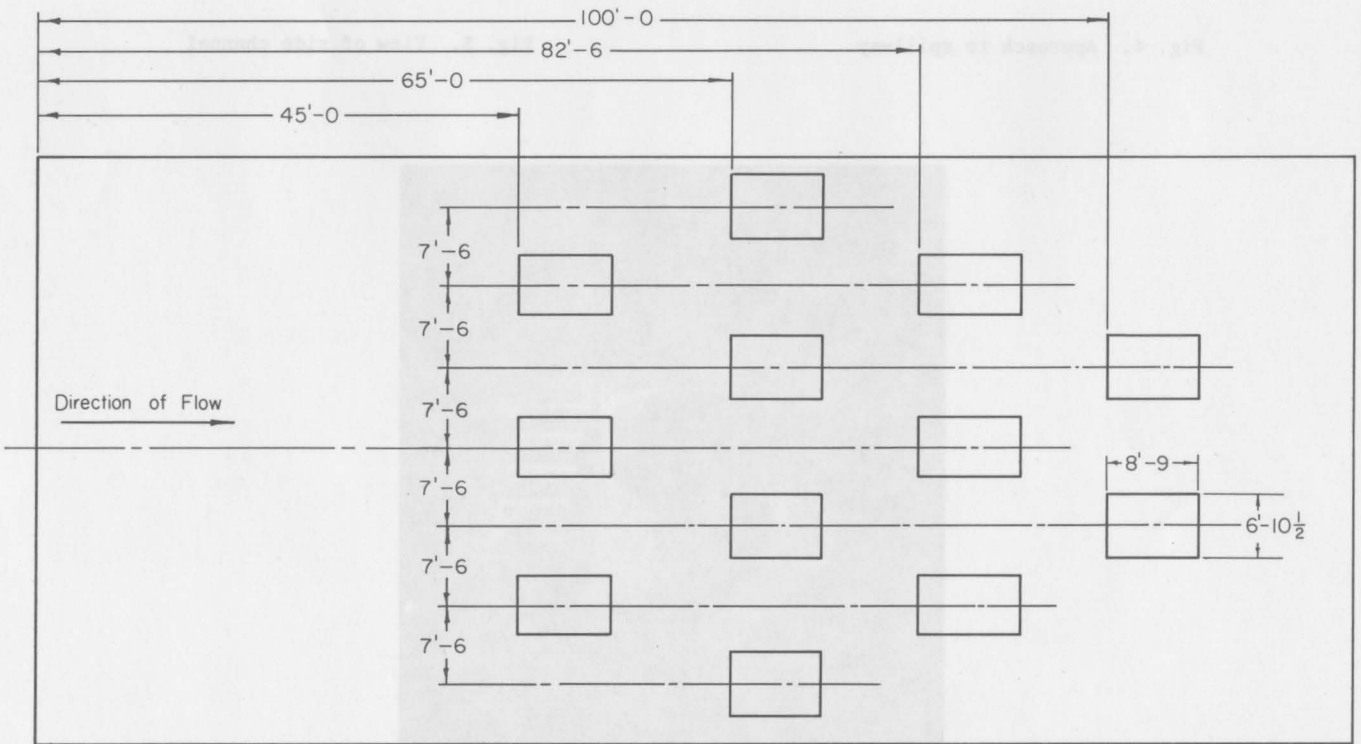
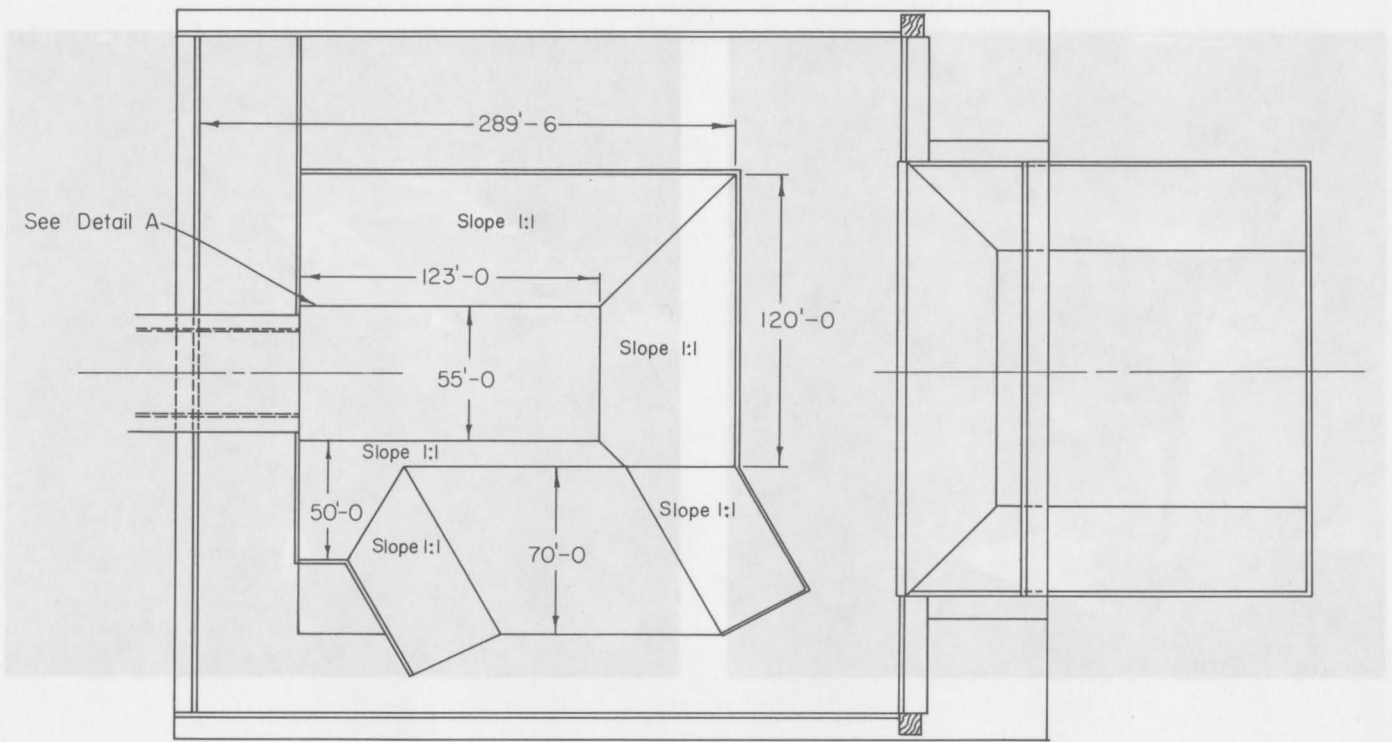
Fig. 4. Approach to spillway



Fig. 5. View of side channel



Fig. 6. Entrance to closed conduit



DETAIL A

Fig. 7. Details of the energy dissipator

RESULTS

The final configuration of the revised model, as described by the drawings included in this report, operated with complete satisfaction over the normal operating range of discharges. Certain hydraulic difficulties exist in the model under flooding conditions which would make it unsatisfactory for continuous operation. However, for short-term operation during floods, the structure appears to be suitable.

Discharge Rating

A complete rating curve was developed for the modified spillway structure up to a reservoir elevation of 679 feet. The new rating curve was needed because modifications in the approach channel made the rating curve for the original design invalid. A second rating curve for the structure with the gates in their closed position was also obtained. These data are shown on Fig. 8.

Operation of Side Channel

Gates open - Up to a reservoir elevation of approximately 648 feet (about 9,000 cfs), the discharge through the structure is controlled by ogee crest and reservoir elevations and no submergence of the crest occurs. The water surface in the side channel is reasonably smooth and no objectional waves are present at the entrance to the covered conduit. At a discharge slightly above 9,000 cfs, the ogee crest becomes submerged. At a discharge slightly above 10,000 cfs, the entrance to the closed conduit submerges. Figures 9 and 10 show the flow conditions in the side channel at 5,000 and 10,000 cfs, respectively.

As the water surface in the lake rises and the entrance to the closed conduit becomes submerged, the discharge control shifts from the ogee crest to the orifice entrance of the closed conduit. Figures 11, 12 and 13 show the flow conditions in the side channel for discharges of 15,000, 20,000 and 24,000 cfs, respectively. At a discharge just under 20,000 cfs, a large vortex forms in the side channel which reduces the discharge efficiency of the structure and causes considerable vibration in the outlet tunnel. It is recommended that the structure not be operated for any extended period of time under these conditions because of possible damage to the structure.

Gates closed - With the gates in the closed position and a reservoir elevation above 659 feet, water enters the side channel over the top of the gates and around the periphery of the channel. For discharges up to approximately 18,000 cfs (reservoir elevation approximately 666 feet), the structure operates similar to a sharp crested weir. Figures 14 and 15 show this condition for discharges of 10,000 and 15,000 cfs, respectively. Between 15,000 and 20,000 cfs the discharge control shifts to the orifice entrance of the closed conduit as it becomes submerged. This is again accompanied by the formation of a large vortex. Figures 16 and 17 show the flow conditions with the gates in their closed positions for discharges of 20,000 and 25,000 cfs, respectively.

Velocity measurements - Velocity measurements around the side channel at a reservoir elevation of 679 feet with the gates closed show that scouring velocities are present. The prototype velocities for these tests are shown on Fig. 18.

Stop gate operation - Operation of the structure with sections of the stop gates installed at discharges sufficient to submerge the entrance to the closed conduit is not recommended. The flow under this condition is very unstable. Excessive vibrations and pounding of the stop gates and adjacent conduit were observed. By looking upstream through the closed conduit, one could observe extreme turbulence and audibly hear an excessive amount of pounding and vibrations. Also, by standing on the conduit section, one could detect the vibrations. Under most flow conditions the downstream conduit was flowing only partially full even though the entrance was submerged and acting as an orifice. This resulted in the vortex being unstable, causing it to appear and disappear alternately as the air demand of the downstream conduit varied.

The worst condition appeared to be with the three stop gates installed. However, similar conditions were observed for one and two sections of gates. With one and two sections installed: (1) the vortex was more stable and only periodically disappeared, and (2) the noise and vibration level was somewhat less. It is strongly advised that the structure never be operated with the entrance to the closed conduit submerged with any sections of the stop gates installed.

Conveyance Channel

The criteria for altering the original design of the conveyance channel were: (1) the reduced normal discharge of the structure, and (2) the large discharge requirement during flooding conditions. The two schemes which were investigated were first, the use of a single covered rectangular conduit extending part way to the energy dissipation basin with an abrupt transition into a trapezoidal open channel. The second scheme consisted of extending the rectangular covered conduit all the way to the energy dissipation basin.

The first scheme proved to be unsatisfactory due to large standing waves in the open channel section caused by the abrupt transition from rectangular to trapezoidal. Figure 19 shows these waves at a discharge of 26,000 cfs. It is observed from the figure that the waves are sufficiently high to be overtopping the original suggested height of the slope paving represented by the black line in the figure. The additional cost of extending the slope paving to a higher elevation or installing a gradual transition section between the rectangular covered section and the trapezoidal open section prompted the decision to eliminate this possibility.

Operation of the structure with the covered conveyance channel extended to the energy dissipator was completely satisfactory over the complete operating range of discharges. No adjustments were made in the slope of the side channel from that tested in the original model. One portion of the conduit, therefore, had a slope of .00089 and the downstream portion had a slope of .0025. It is recommended that a constant slope, probably the .0025 slope, be used to connect the side channel with the energy dissipator. Since there is no pier in the conduit, there is no concern of supercritical standing waves.

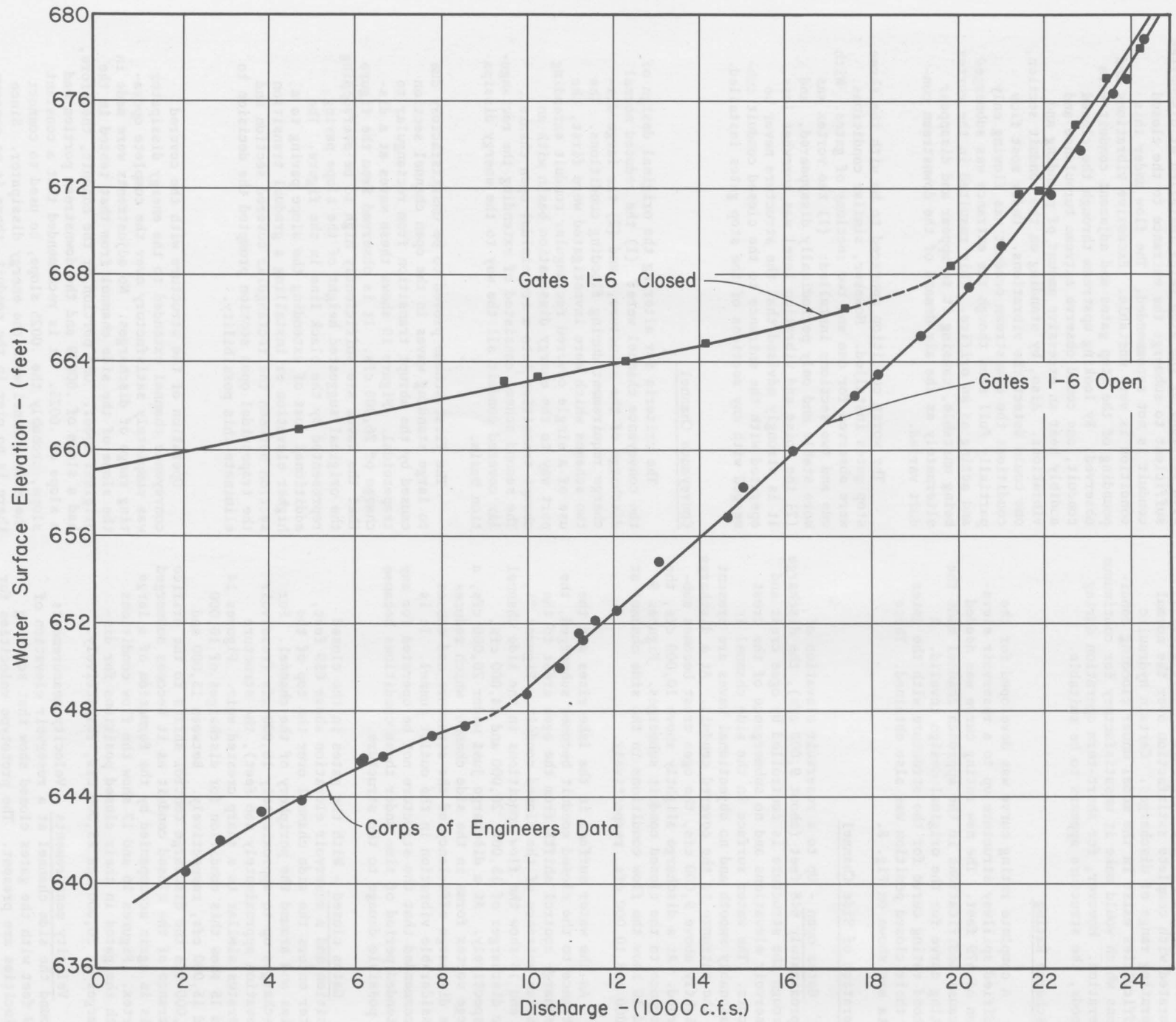


Fig. 8. Stage-discharge curves

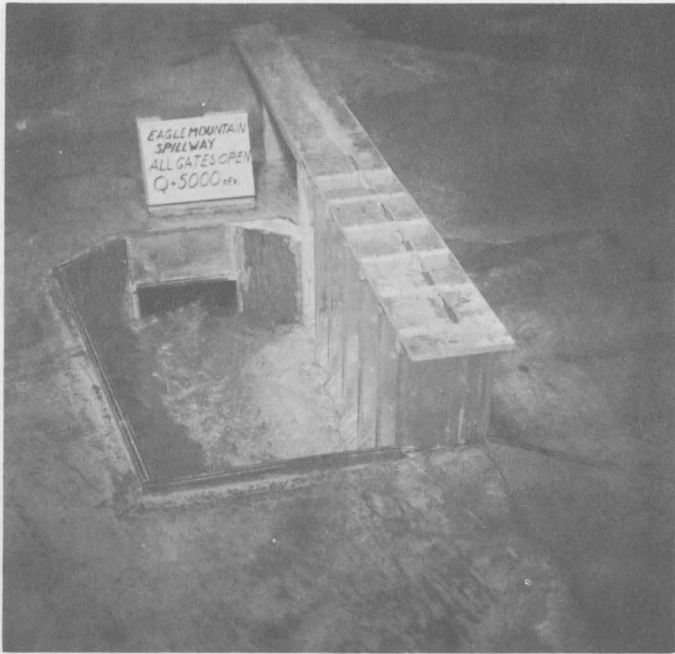


Fig. 9. Flow at 5000 cfs with gates open

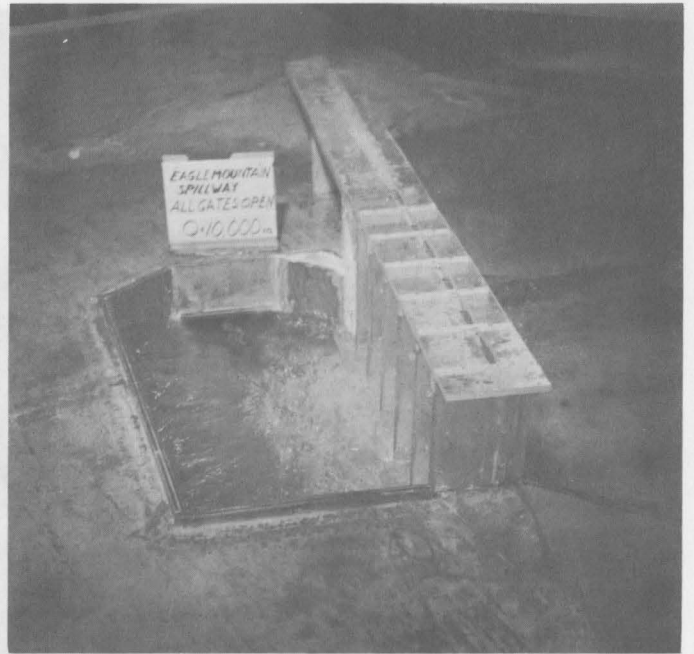


Fig. 10. Flow at 10,000 cfs with gates open



Fig. 11. Flow at 15,000 cfs with gates open

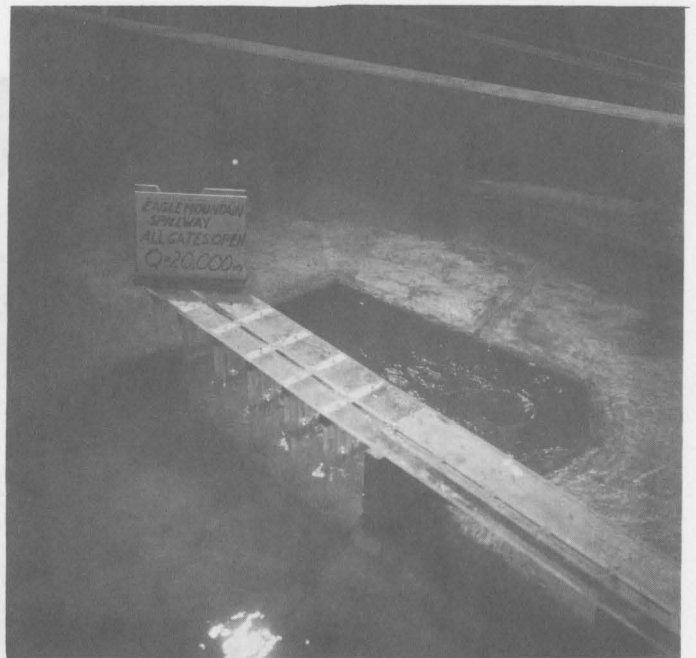


Fig. 12. Flow at 20,000 cfs with gates open

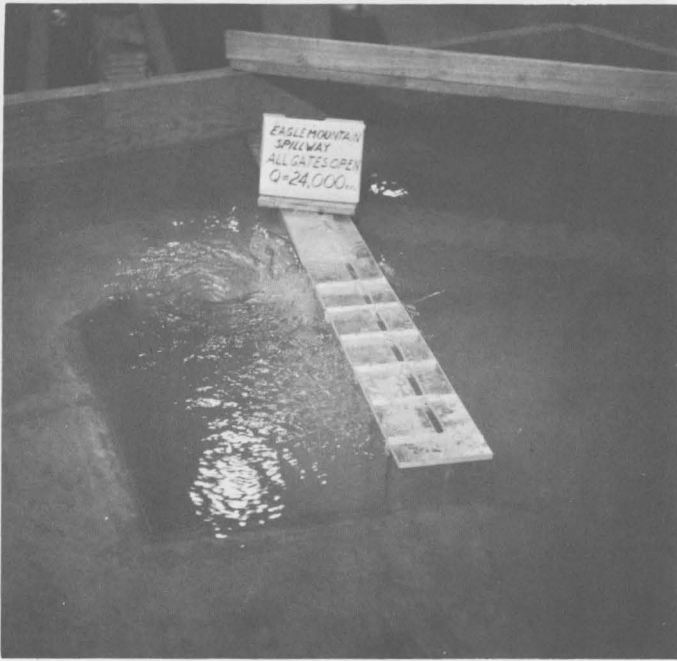


Fig. 13. Flow at 24,000 cfs with gates open

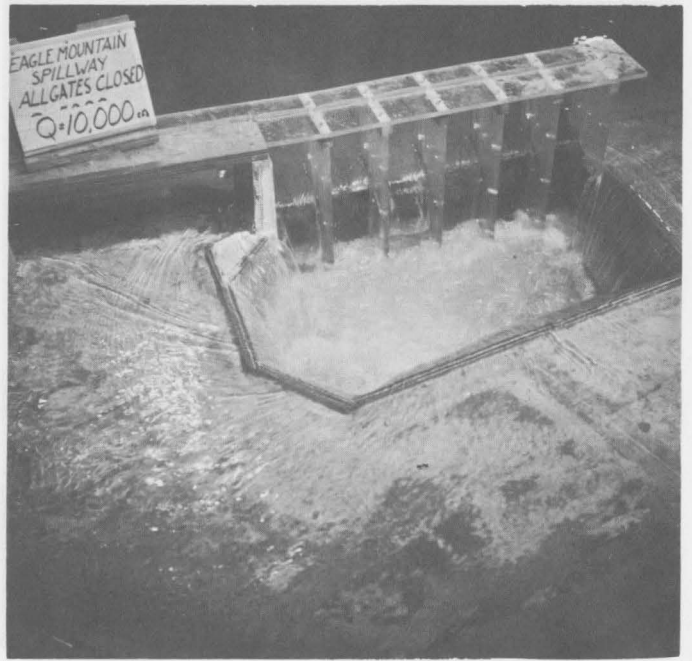


Fig. 14. Flow at 10,000 cfs with gates closed

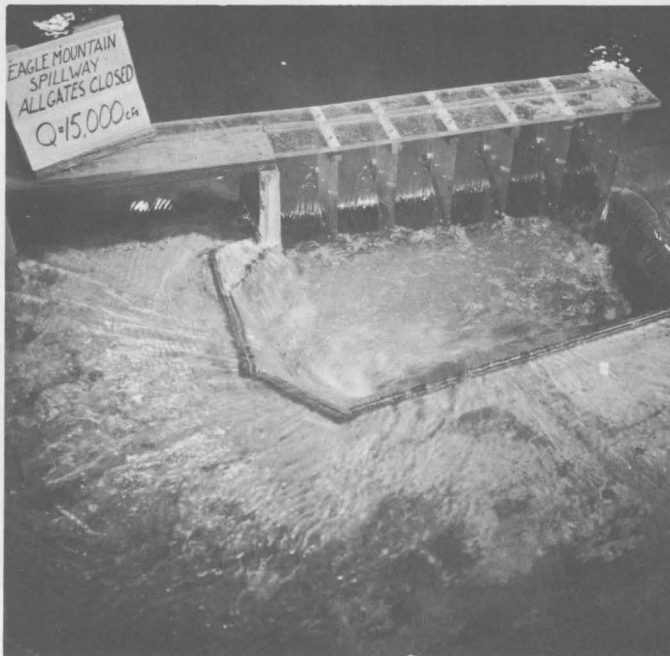


Fig. 15. Flow at 15,000 cfs with gates closed



Fig. 16. Flow at 20,000 cfs with gates closed

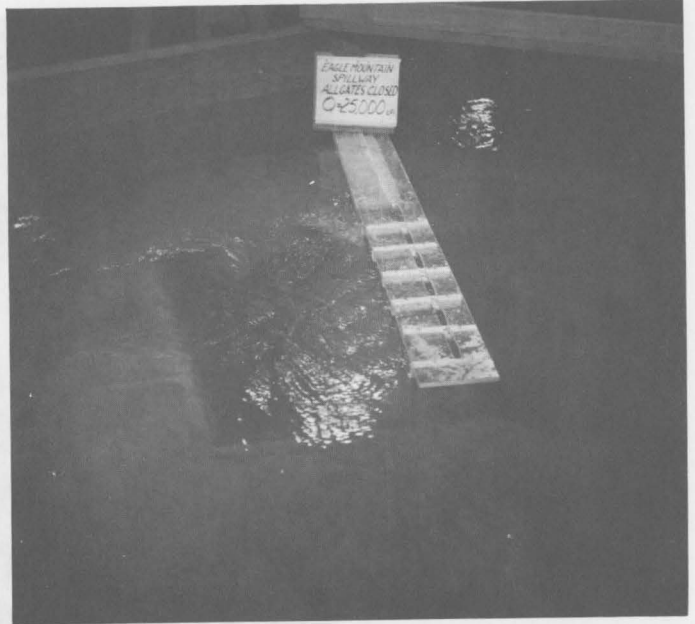


Fig. 17. Flow at 25,000 cfs with gates closed

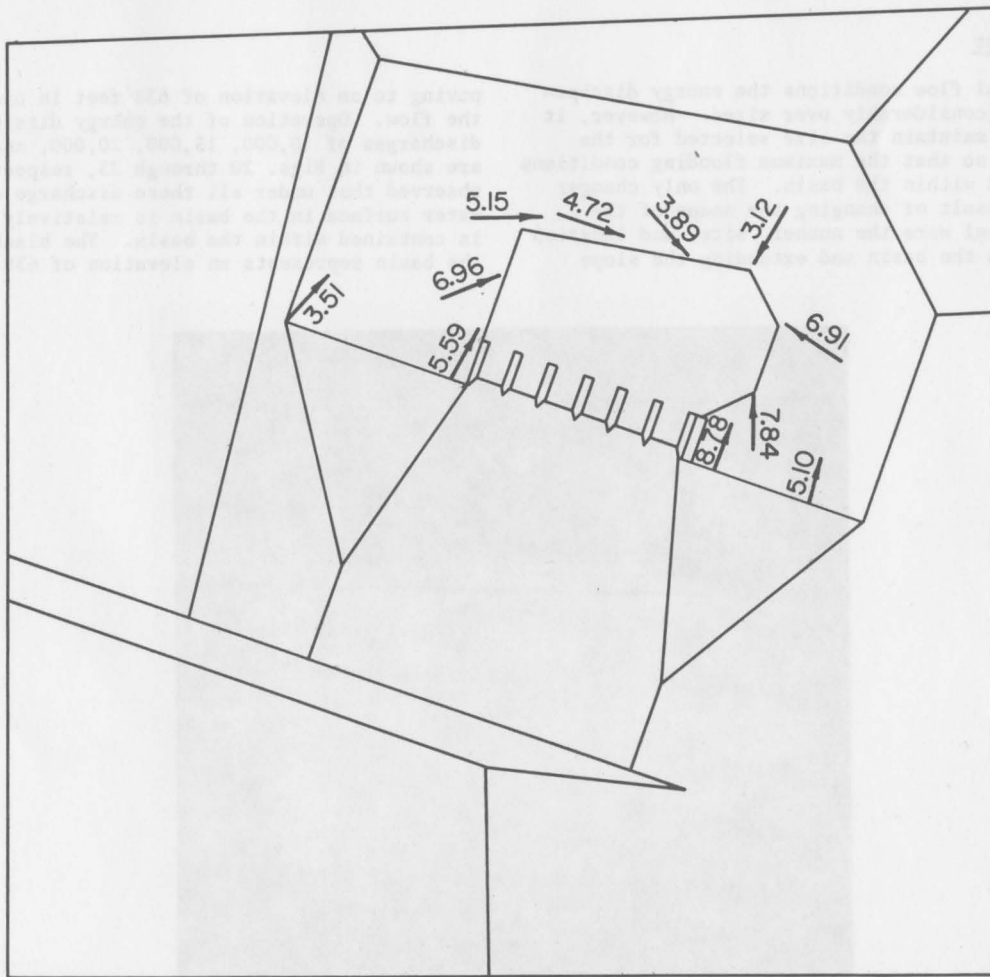


Fig. 18. Velocities around the side channel at a reservoir elevation of 679 feet

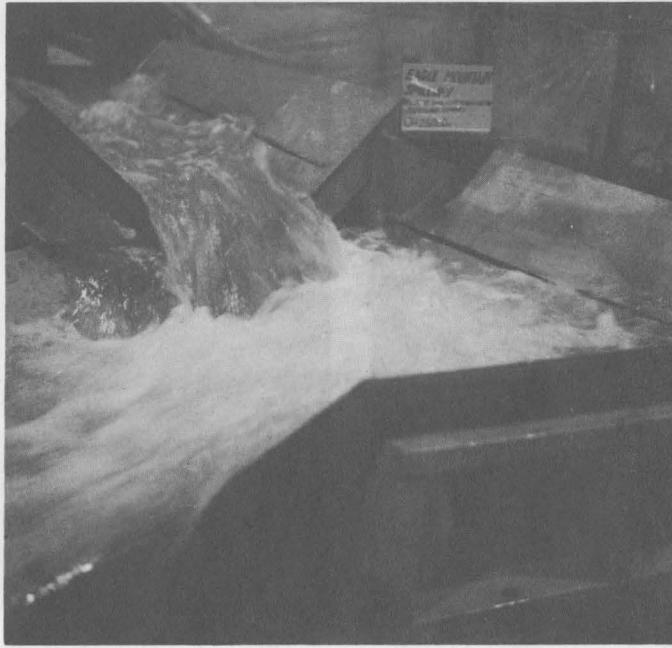


Fig. 19. Standing waves in trapezoidal open channel

Energy Dissipator

Under normal flow conditions the energy dissipation chamber is considerably over sized. However, it is necessary to maintain the size selected for the original design so that the maximum flooding conditions can be contained within the basin. The only changes required as a result of changing the shape of the conveyance channel were the number, size, and location of the blocks in the basin and extending the slope

paving to an elevation of 638 feet in order to contain the flow. Operation of the energy dissipator at discharges of 10,000, 15,000, 20,000, and 24,000 cfs are shown in Figs. 20 through 23, respectively. It is observed that under all these discharge conditions, water surface in the basin is relatively uniform and is contained within the basin. The black line around the basin represents an elevation of 638 feet.

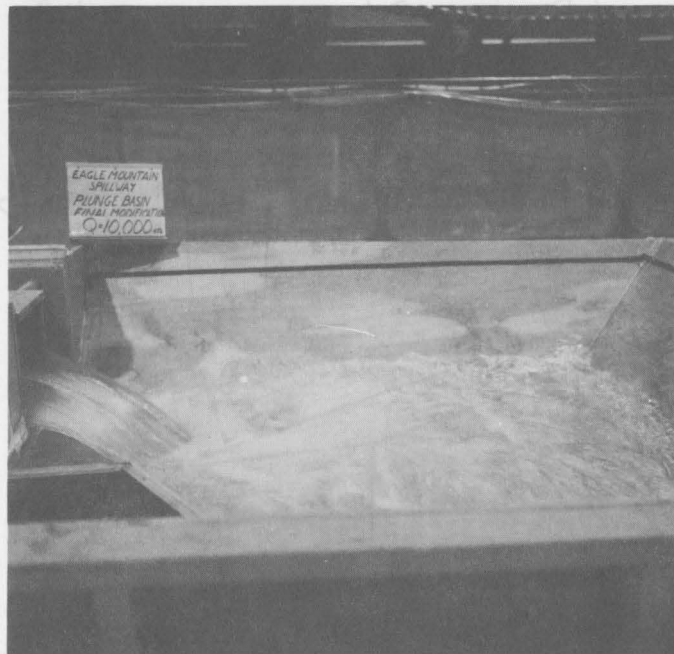


Fig. 20. Operation of energy dissipator at 10,000 cfs

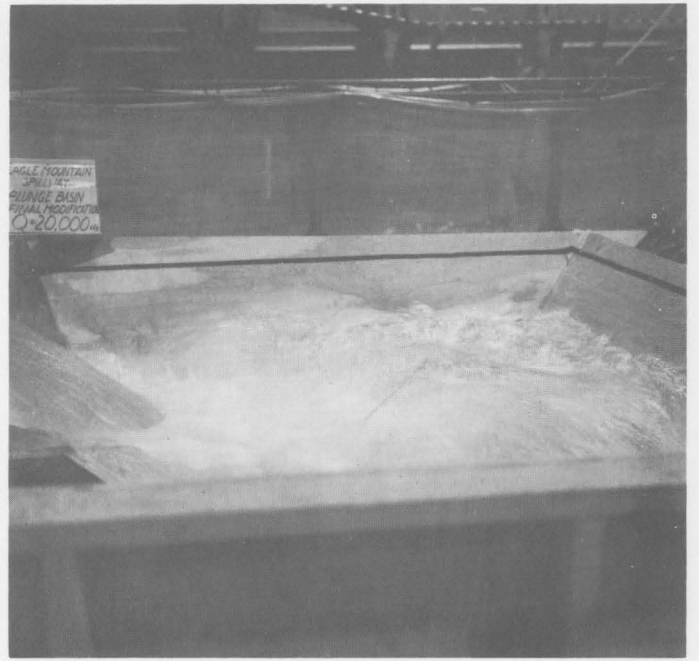
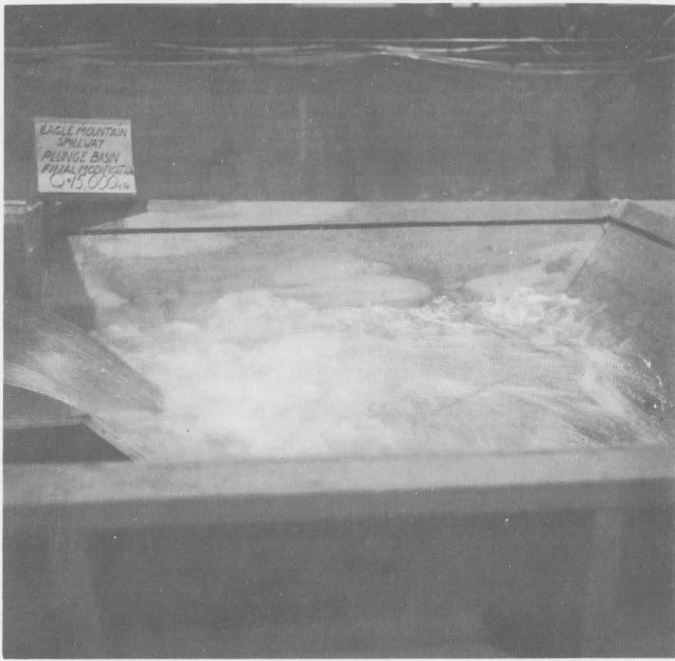


Fig. 21. Operation of energy dissipator at 15,000 cfs

Fig. 22. Operation of energy dissipator at 20,000 cfs



Fig. 23. Operation of energy dissipator at 24,000 cfs