PAP 230

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INFORMATIONAL ROUTING

PAP 230

Memorandum
Chief Research Scientist

Denver, Colorado
June 20, 1967

Chief, Hydraulics Branch

Preliminary report on hydraulic model studies, Bartlett Dam Spillway

This report summarizes the investigations on a 1:100 scale model of the Bartlett Dam spillway and discharge channel. Corrective measures as determined from the study are suggested. A formal report on the studies will be distributed as Laboratory Report No. Hyd-576.

GPO 832-606

INTRODUCTION

Bartlett Dam is part of the Salt River Project near Phoenix, Arizona (Figure 1). The spillway in the right abutment is a gate-controlled crest section discharging onto a 170-foot-wide, concrete-lined chute. The chute is superelevated, curves to the left, and terminates in a flip bucket. The design discharge capacity of the spillway is 175,000 cfs.

Originally, flow from the flip bucket fell in an excavated channel leading to the river channel. The drop from the end of the excavated channel to the river bed was about 100 feet. The rock in this area is composed of two types of granite. One is a coarse-grained granite severely weathered to irregular depths.

This weathered rock is weak and easily eroded, but the underlying rock is hard and sound. The other type of granite is fine grained, competent, and resistant to erosion. Three dominant systems of joints affect both rock types--two near-vertical systems and one irregularly developed horizontal system.

Floods in 1942 and 1965-66 severely eroded the excavated channel. Prior to the 1965-66 flood the channel was repaired by placing mass concrete in retaining walls and blocks in the badly eroded portion of the channel near the downstream end of the chute (Figure 2). The 1965-66 spillway flows, estimated at 28,500 cfs from near maximum reservoir elevation, washed out or undermined these concrete slabs and blocks in several areas (Figure 3). Erosion of the rock was quite rapid where the concrete had overlain the weak, weathered granite. At the base of the steep portion of the eroded channel, about 100 feet downstream from the concrete channel, one hole was eroded in the weathered rock to a depth of about 15 feet.

Remedial work in the channel after the 1965-66 flood consisted of repairing damaged concrete blocks and protecting rock surfaces with formed or pneumatically placed concrete anchored to the rock (Figures 4 and 5). The hydraulic model studies described in this report were performed to determine channel improvement or additional protection necessary to prevent further erosion near the spillway chute and to determine the best method of operating the gates.

THE MODEL

The 1:100 scale model of the spillway (Figure 6) included the approach channel, crest, control gates and piers, superelevated concrete-lined chute, and the discharge channel from the chute downstream to the natural stream channel. The spillway and discharge channel were of concrete construction; the piers were formed in wood and the control gates were made of sheet metal. Two portions of the right bank near the downstream end of the discharge channel were made removable in anticipation that additional excavation in this area might improve the prototype operation.

The discharge channel was constructed in accordance with a contour map showing the topographic features as of January 29, 1966 (Figure 7). Enlarged photographic prints were also used as a guide in constructing the model.

THE INVESTIGATION

The model was operated at discharges up to 50,000 cfs to determine flow conditions that might have caused the erosion. At discharges of 10,000, 20,000, and 50,000 cfs, flow from the spillway impinged on the areas that had been badly damaged in the prototype channel (Figure 8). The severest damage appeared to have occurred where the impact forces of the jet had apparently loosened and eroded the rock at the weathered joints. Initial tests made using an erodible channel inadvertently constructed of 3 parts sand to 1 part pozzolan showed that the erosion began at the left downstream corner of the concrete-lined chute and progressed downstream as the discharge increased (Figure 9). This test confirmed the belief that the major portion of the erosion was due to flow impact rather than to rocks churning in the turbulent flow.

Gate Operation

Various combinations of gate openings were tested (Figure 10) to determine the best combination of gates for regulating the flow. These tests showed that closing the right gate will reduce the flow impingement on the right bank along the edge of the paved area and increase the impingement along the left bank. With the left gate closed, the reverse is true. These flow conditions were more pronounced when either the left or right gate was operated singly. The tests showed that all three gates should be opened equally for best operation.

Channel Protection

Even with all three gates equally opened, portions of the flow impinged on the left and right sides of the discharge channel beyond the limits of the paved area. These areas of impingement are subject to erosion during future spillway discharges (Figures 4, 5 and 8). Erosion on the right side will occur far enough downstream that it is not likely to endanger the structure or undermine the paved area (Figure 5). Erosion may occur adjacent to the left concrete wall of the spillway chute and farther downstream along the left bank (Figure 4). Additional paving should be extended to prevent this erosion (Figures 9 and 11).

Spillway discharges have eroded a 15-foot-deep hole at the base of the steep slope in the prototype discharge channel (Figure 4). Further spillway operation possibly will increase the size of this hole and undermine the concrete paving on the steep slope. This hole should be filled with concrete extending from the existing concrete on the upstream side to the rock on the far side of the pool (Figures 7 and 11). Sloping this concrete fill downward from approximately el. 1635 to el. 1615 in the direction of flow along the existing channel (Figure 7) will flush loose rock downstream during spillway operation.

At flows of 100,000 and 175,000 cfs (Figure 12) part of the jet impinged near the first ridge in the downstream portion of the discharge channel beyond the paved area. Discharges of this magnitude will probably cause considerable erosion in the prototype; however, the damage will be remote from the spillway chute and probably not require repair.

Channel Improvement

A high ridge of rock extends partly across the discharge channel about 100 feet downstream from the base of the steep slope; about 250 feet farther downstream, a second confining ridge protrudes into the channel. It was first thought that these ridges might be trapping loose rock in the channel and causing a "ball mill" type of erosion damage.

The two ridges were constructed in the model so that the channel could easily be tested with and without the ridges in place (Figure 13). Tests were run at discharges of 20,000 cfs and 50,000 cfs to determine the effect of removing either or both ridges. The tests showed that any loose rock that might fall into the channel will flush from the area, with or without the ridges in place. Actually the upstream ridge and the existing weir at approximately el. 1640 in the left branch of the discharge channel (Figure 14) aid in maintaining a pool for flows up to 50,000 cfs. This pool appeared to absorb part of the energy of the falling jet which would reduce the erosion damage (Figure 14).

CONCLUSIONS AND RECOMMENDATIONS

1. The model confirmed that the erosion damage in the discharge channel was almost entirely due to the impact of the flow impinging on the badly fractured rock and breaking it loose rather than to the churning of loose rock in the turbulent flow (Figure 9).

2. Repairs made after the 1965-66 floods appear to be well located but the paving should be extended a little higher and farther downstream along the left bank (Figures 4, 9, and 11).

3. The deep erosion hole at the base of the steep slope should be filled with concrete (Figures 4, 7, and 11). This concrete fill should extend from the existing concrete on the upstream side of the hole to sound rock on the far side. The floor should slope downward to the left in the direction of flow to flush loose rock from the channel.

4. At flows greater than about 50,000 cfs, part of the jet will impinge in the downstream portion of the channel beyond the paved area (Figure 12); however, erosion damage will be remote from the spillway and should not require repair.

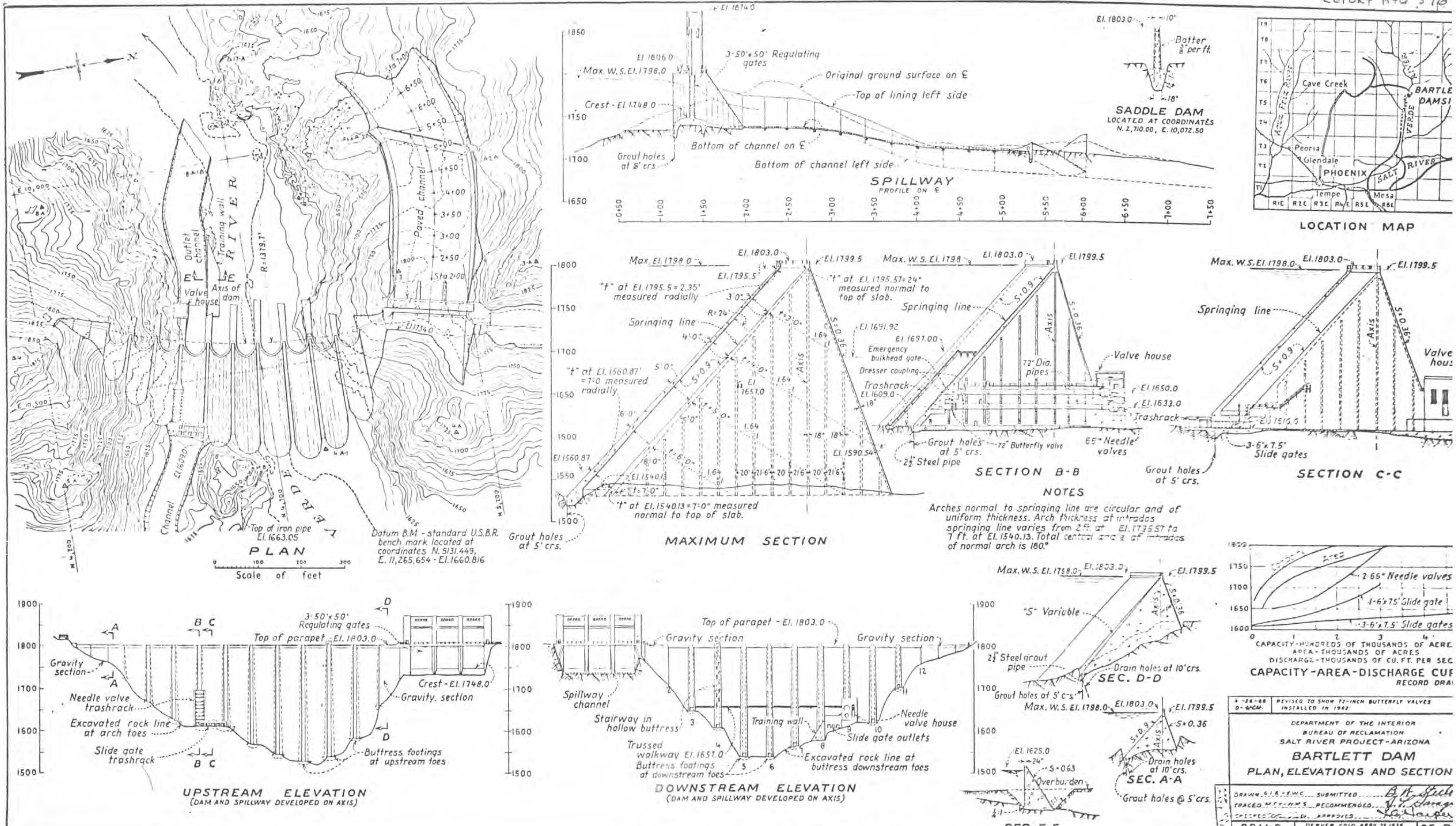
5. The spillway gates should be equally opened for best operation (Figure 8).

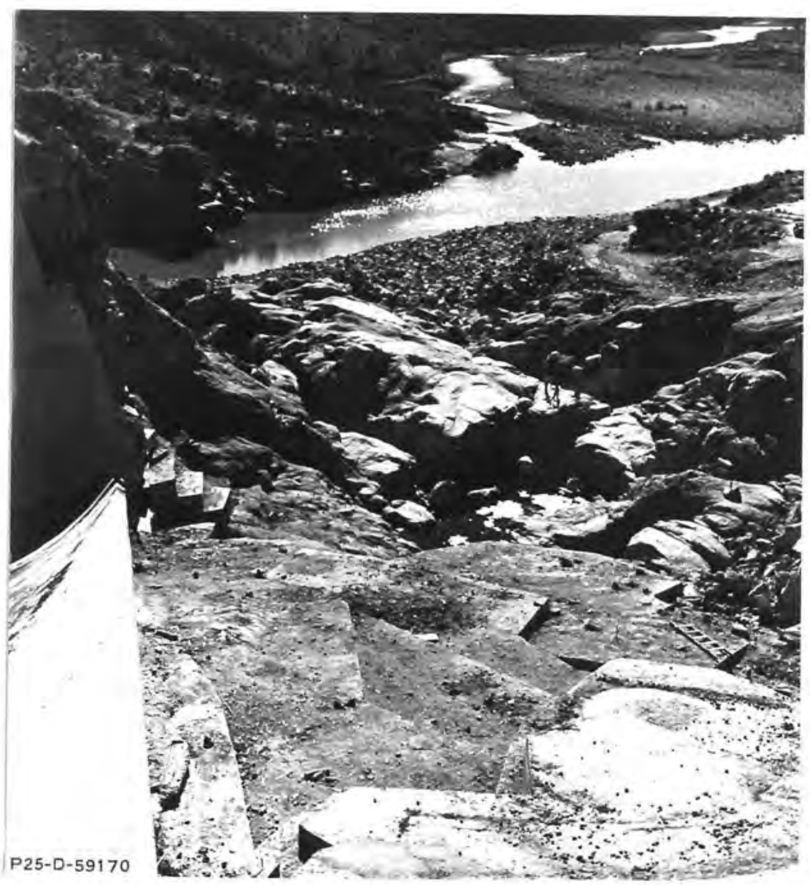
6. The two ridges partially blocking the downstream end of the channel should not be removed (Figure 13).

7. The upstream ridge and the existing weir in the left branch of the channel help form a shallow pool at the base of the paved slope for flows up to 50,000 cfs (Figure 14). This pool aids in absorbing some of the energy in the jet and in reducing the erosion damage.

Harold M. Martin

Figure 1
REPORT HYD 576





BARTLETT DAM SPILLWAY
DISCHARGE CHANNEL EROSION AND REPAIRS
PRIOR TO THE 1965-66 FLOOD

F7

B7

A. Note the undermining of previous channel repairs.

B. View looking towards right bank.

C. Note both vertical and horizontal joints in the weathered rock.

BARTLETT DAM SPILLWAY
DISCHARGE CHANNEL EROSION
Caused by 1965-66 Flood

B7

Water stands in a 15-foot (4.57-meter)-deep hole eroded at the base of the steep slope. Areas subject to future erosion are indicated by the arrows.

BARTLETT DAM SPILLWAY
Repairs to Discharge Channel Following
the 1965-66 Flood

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P25-D-59167

Areas subject to future erosion are indicated by the arrows.

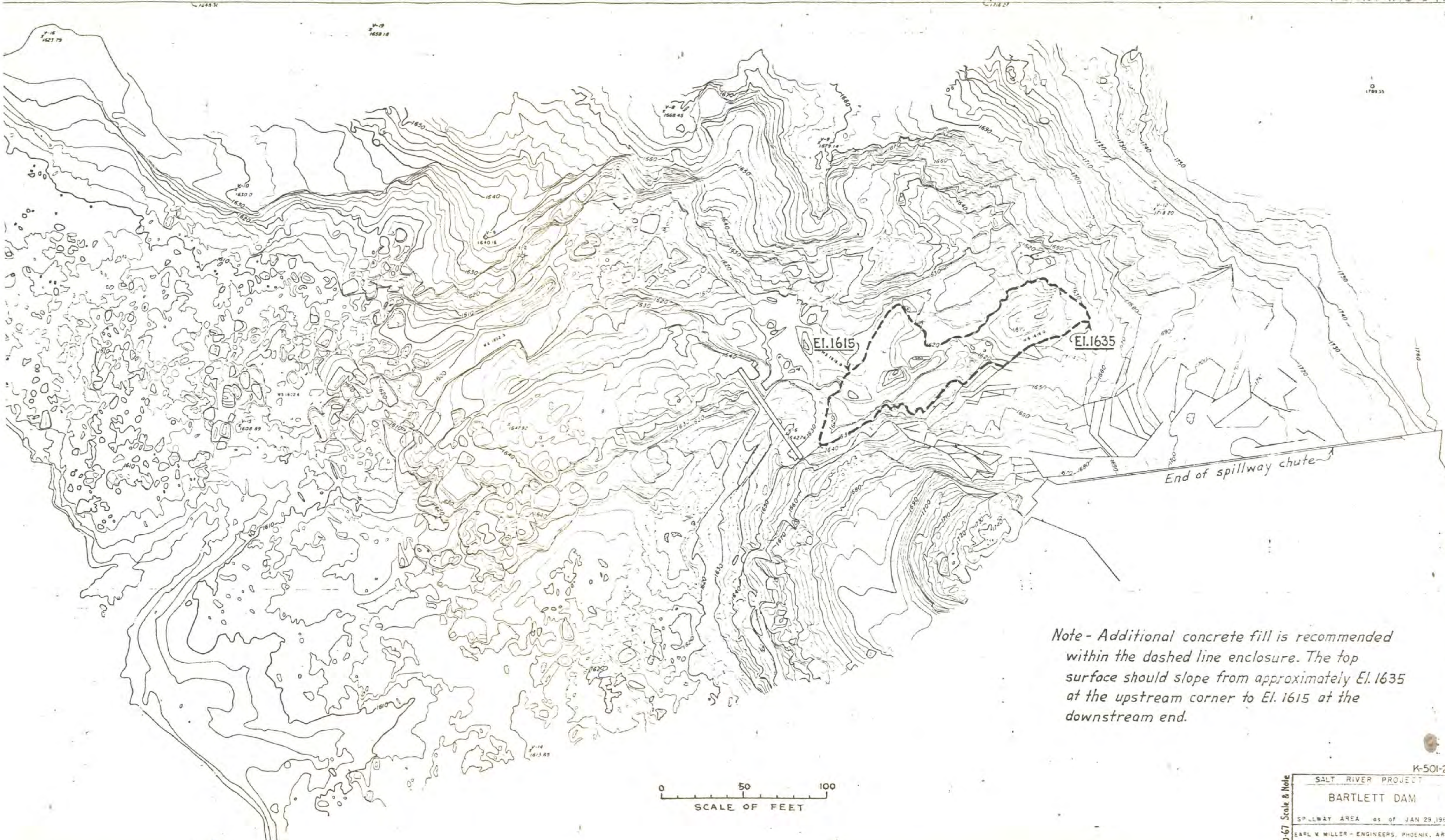
BARTLETT DAM SPILLWAY
Repairs to the Discharge Channel Following the 1965-66 Flood

838-867

88

The extent of concrete paving placed in discharge channel following the 1965-66 flood is painted white.

BARTLETT DAM SPILLWAY
The 1:100 scale model



Note - Additional concrete fill is recommended within the dashed line enclosure. The top surface should slope from approximately El. 1635 at the upstream corner to El. 1615 at the downstream end.

K-501-2

SALT RIVER PROJECT
BARTLETT DAM
SPILLWAY AREA as of JAN 29, 1955
EARL V. MILLER - ENGINEERS, PHOENIX, ARIZ
&
AERIAL MAPPING CO., BOISE, IDA-PHOENIX, ARIZ
Contour Interval 2'

Rev. 6-20-67 Scale & Note

A. 10,000 cfs (283 cms)

B. 20,000 cfs (566 cms)

C. 50,000 cfs (1,415 cms)

All flow through three gates equally open at Reservoir elevation 1803

The areas of flow impingement on the left and right banks beyond the white paved area are indicated by the arrows.

BARTLETT DAM SPILLWAY
Flow in Discharge Channel
1:100 scale model

838-867

F11

A. 30,000 cfs (849 cms)

B. 175,000 cfs (4,952.5 cms)

C. Erosion resulting from flows of 30,000 and 175,000 cfs (849 and 4,952.5 cms)

Areas requiring additional concrete protection are indicated by the arrows.

BARTLETT DAM SPILLWAY
Erosion Test
1:100 scale model

311

A. Left gate closed

B. Right gate closed

14,000 cfs (396.2 cms) at reservoir elevation 1803

C. Left and center gates closed

D. Right and center gates closed

7,000 cfs (198.1 cms) at reservoir elevation 1803

The areas of flow impingment on the left and right banks beyond the white paved area are are indicated by the arrows.

BARTLETT DAM SPILLWAY
Flow with unsymmetrical gate operation
1:100 scale model

A. Recommended additional concrete paving is indicated by the arrows

B. Recommended additional concrete fill is indicated by the arrows

BARTLETT DAM SPILLWAY
Recommended Channel Protection
1:100 scale model

Figure 12
Report No. Hyd-576

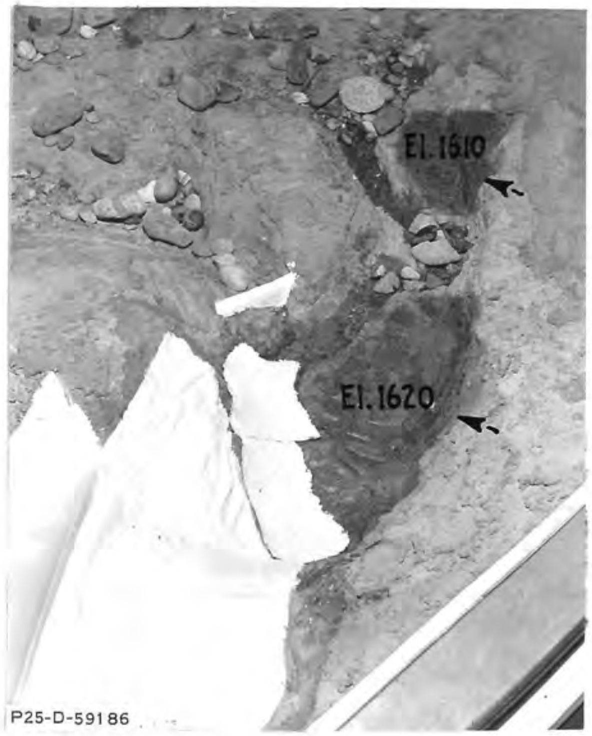
A. 100,000 cfs (2,830 cms)

B. 175,000 cfs (4,952.5 cms)

BARTLETT DAM SPILLWAY
Flow Conditions with Channel Protection

1:100 scale model

B1.



A. First and second ridges are removed to the elevation shown. Ridge locations are indicated by the arrows.

B. First ridge only is removed.

BARTLETT DAM SPILLWAY
Channel Alterations Tested
1:100 scale model

838-867

B13

A. Recommended concrete fill

B. Concrete fill with first ridge removed is not recommended

20,000 cfs (566 cms) at reservoir elevation 1803

C. Same as A

D. Same as B

50,000 cfs (1,415 cms) at reservoir elevation 1803

BARTLETT DAM SPILLWAY
Flow conditions with and without First Ridge

1:100 scale model