RECLAMATION

Managing Water in the West

Hydraulic Laboratory Technical Memorandum PAP-1069

Guernsey Dam North Spillway Flow Deflectors

U.S. Department of the Interior
Bureau of Reclamation
Technical Service Center
Hydraulic Investigations and Laboratory Services Group
Denver, Colorado

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Background

Guernsey Dam is located on the North Platte River near the Town of Guernsey Wyoming. The dam was built by the Bureau of Reclamation and completed in 1927. It is 25 miles below Glendo Dam and is part of the North Platte project (Figure 1). It is a 135 ft high embankment dam (92 ft hydraulic height) with 2 spillways and a powerplant. The top of the embankment is at elevation 4430 ft with a 3 foot parapet wall up to elevation 4433 ft.

Figure 1. Location map showing Guernsey Dam

The north spillway is controlled by a 50 ft by 50 ft sluice type gate, known as the Stoney gate (Figure 2). This invert of the north spillway was built at elevation 4370 ft, but in 1983 an 8 in. concrete overlay raised the invert to its current elevation of 4370.67 ft. The south spillway is controlled by two- 64 ft by 14.5 ft drum gates. Downstream of the gates a warped concrete structure transitions into a 31 ft diameter vertical shaft. The shaft transitions into a vertical curve and then an approximately 30 ft diameter horseshoe shaped tunnel that is 723 ft long with a constant invert elevation of 4319 ft. (Figure 3). The South spillway crest elevation is 4405.5 ft when the drum gates are in the open (lowered) position.

The South spillway crest elevation is 4420 ft when the drum gates are in the closed (raised) position.

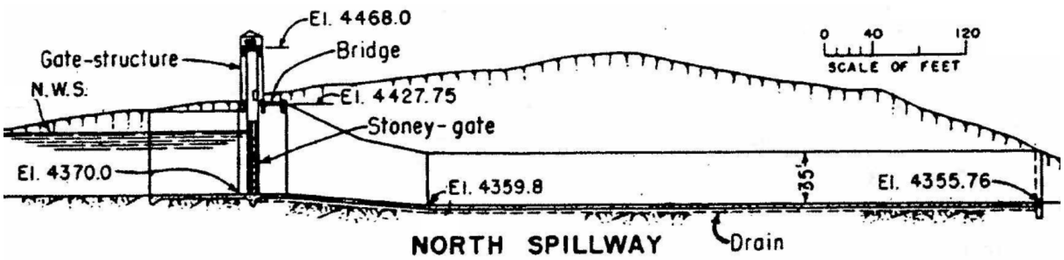

Figure 2. North Spillway, Note this drawing does not indicate the 8 in. concrete overlay that was placed on the spillway invert in 1983

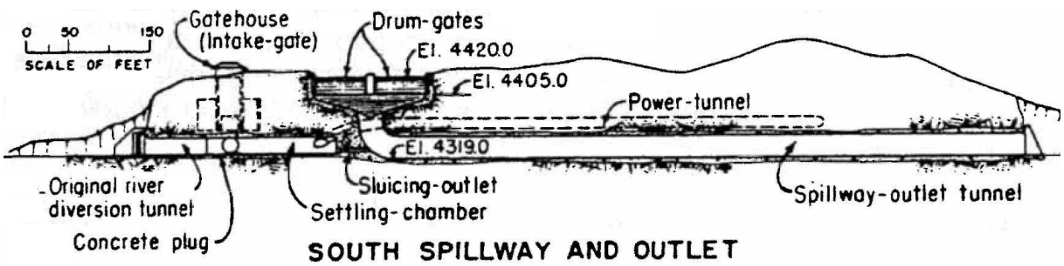

Figure 3. South Spillway and Outlet.

Model Description

Model Scale

A physical hydraulic model of Guernsey Dam including both spillways and approximately 1000 ft of the reservoir immediately upstream of the dam was constructed in Reclamation's hydraulics laboratory in Denver, Colorado in 2012. The purpose of this model was to investigate the hydraulics of the south spillway and the proposed replacement of one of the drum gates with a weir. The model was setup to analyze the south spillway. The north spillway was included only to achieve the correct flow split and flow conditions for the south spillway analysis. In the model, the area downstream of the north spillway gate does not accurately represent the flow conditions in the prototype spillway.

Near the end of the model study the lab was asked to analyze flow deflectors proposed to deflect flow around the north spillway gate slots to protect the gate lifting chains within the slots. Due to time and budget constraints the model was not modified to correctly represent the exact gate dimensions. A qualitative analysis of the deflectors was all that was required. Evaluating the effect the deflectors have to discharge through the gate was not an objective of this study.

In order to include all desired model features in the floor space available the physical hydraulic model was built at a 1:47 geometric scale. Similitude between the model and the prototype is achieved when the ratios of the major forces controlling the physical processes are kept equal in the model and prototype. Since gravitational and inertial forces dominate open channel flow, Froude-scale similitude was used to establish a relationship between the model and the prototype parameters. The Froude number is

$$F_r = \frac{v}{\sqrt{gd}}$$

where v = velocity, g = gravitational acceleration, and d = flow depth. When Froude-scale modeling is used, the following relationships exist between the model and prototype where the r subscript refers to the ratio of the model to the prototype:

Length ratio: $L_r = 1:47$

Velocity ratio: $V_r = L_r^{1/2} = (47)^{1/2} = 6.86$

Time ratio: $T_r = L_r^{1/2} = (47)^{1/2} = 6.86$

Discharge ratio: $Q_r = L_r^{5/2} = (47)^{5/2} = 15{,}144.14$

Model Features and Setup

The flow approach conditions to the north spillway and gate opening correctly represent the prototype spillway. However the gate and gate slots used in the model are smaller than the prototype (Table 1). For the initial purpose of the model the north spillway downstream of the gate did not need to be modeled, just the ability to convey flow. These model vs. prototype differences should be considered when viewing the model results. For further analysis of the flow deflectors it is recommended that a larger scale model that correctly represents the prototype be built.

Table 1. North Spillway gate slot depth and width measurements.

	Model Scaled to Prototype (ft)	Prototype (ft)
Slot Depth	1.39	4.25
Slot Width	3.55	6.88

All tests were conducted at a discharge of approximately 6,000 cfs (prototype), with the Stoney gate entirely out of the water. The depth of flow was approximately 7.8 ft. It is assumed that this flow condition is most critical. Wedge-shaped deflectors were placed upstream of the gate slot. Qualitative visual observations were made between the different deflectors tested. The deflectors tested are shown in Table 2.

Table 2. Wedge shaped deflectors tested.

	Prototype	
Angle (deg)	Length (ft)	Width (ft)
20	2.88	1.05
15	2.88	0.77
10	2.88	0.51
5	2.88	0.25

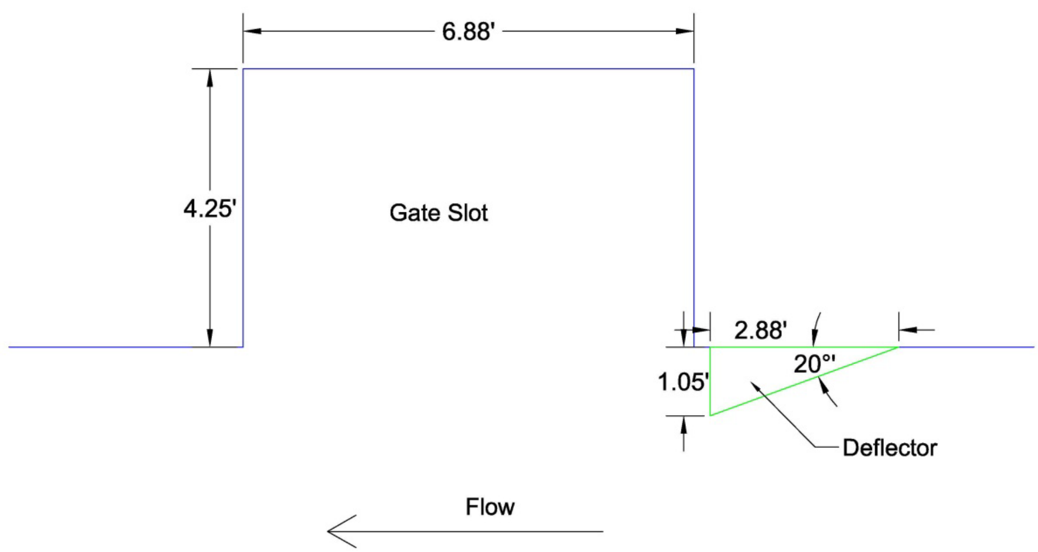

Figure 4. Prototype layout of the north spillway gate slot and 20 degree deflector.

Results

Photo and video documentation were used to analyze the effectiveness of the flow deflectors.

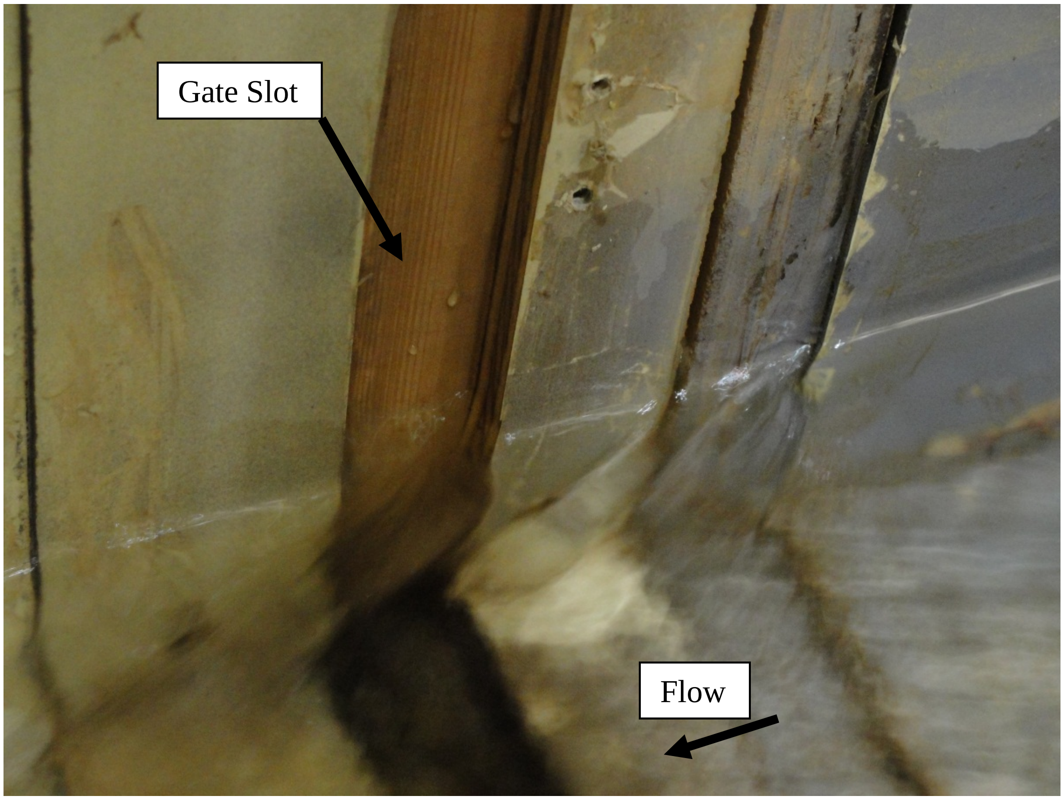

Figure 5. Gate slot without deflector.

Figure 6. 5-degree deflector.

Figure 7. 10-degree deflector

Figure 8. 15-degree deflector.

Figure 9. 20-degree deflector.

Conclusions

The 5-degree deflector did not noticeably change the flow conditions around the slot. All the other deflectors offered varying degrees of effectiveness in preventing the flow from directly impinging the downstream edge of the gate slot, with the 20-degree wedge being the most effective. However, video of the 15-and 20-degree deflectors do not show very much difference in their performance. Given that the model represents a slot width that is approximately ½ the width of the prototype it is recommended that a larger angle deflector of 15 or 20 degrees be utilized. The effect the deflectors have to discharge through the gate were not evaluated in this study.