RECLAMATION

Managing Water in the West

Hydraulic Laboratory Technical Memorandum PAP-1122

Discharge Curve for Spillway at Lake Isabel Dam

San Isabel National Forest Rocky Mountain Region

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Denver, Colorado

Prepared for:

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Forest Service
Rocky Mountain Region

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** This document was originally signed by all parties on 3/16/2016. New digital signatures were applied after the document was modified to comply with the Section 508 Amendment to the Rehabilitation Act of 1973.*

INTRODUCTION

This study developed a spillway discharge curve for the service spillway at Lake Isabel Dam at the request of Atiq Syed, U. S. Forest Service. Client instructions were to make the best discharge estimate possible within the limited budget while using existing data and reports.

Lake Isabel Dam (Figure 1), on the Saint Charles River in Custer and Pueblo Counties in central Colorado, is about 30.5 miles southwest of Pueblo, 12 miles west of Colorado City and 8 miles northwest of Rye. The dam is located in the Southwest Quarter of Section 6 Township-24-South Range-68-West of the Sixth Principal Meridian. The dam and reservoir were completed in the 1930s and were originally used predominantly as storage for CF&I Steel. Located in the San Isabel National Forest, Lake Isabel now provides fishing, hiking, and camping. The reservoir and recreation facilities are overseen by the Pike and San Isabel Forest Service.

Lake Isabel Dam, originally called St. Charles Dam, is an earthen structure. The original reservoir and dam drawings along with the area and capacity tables show the vertical datum was tied to a local construction elevation that is around 40.5 feet lower than NAVD88. September 2012 measurements on top of the dam and center line of the highway located the lowest section over the spillway near elevation 8,484.0.[1]

The Lake Isabel 2012 Reservoir Survey [1] reported:

> According to original drawings and tables, the spillway crest elevation was 8,437.25 (project vertical datum) at gage height or reservoir depth 74.25, with high water at elevation 8,438.75 (project vertical datum) or gage height 75.75. The 2012 survey elevations were tied to NAVD88, geoid model 2012A (GEOID12A), with a measured spillway crest at elevation 8,477.7. In order to match the original project datum elevations, the NAVD88 elevations must be lowered 40.5 feet. Lake Isabel spillway is located near the left abutment of the dam and consists of a concrete overflow crest and outlet channel (Figure 3). The original invert of the outlet intake was at gage height 0.0 or elevation 8,363.0 on the project vertical datum or elevation 8,403.5 adjusted to NAVD88.

[1] Elevations in feet. All elevations based on the North American Vertical Datum of 1988 (NAVD88) using geoid model 2012A. To match the original project vertical data reduce the NAVD88 elevations around 40.5 feet. The current gage is set at 3.3 feet at spillway crest elevation 8,477.7 (NAVD88).

Figure 1. Isabel Dam spillway

Numeric Modeling

This study used the commercially available Computational Fluid Dynamics program FLOW-3D Version 10.1.1.05 by Flow Science, Inc., which is a finite difference, free surface, transient flow modeling system that was developed from the Navier-Stokes equations, using up to three spatial dimensions.

The finite difference equations are based on a fixed Eulerian mesh of non-uniform rectangular control volumes using the Fractional Area-Volume Obstacle Representation (FAVOR) method. Free surfaces and material interfaces are defined by a fractional volume-of-fluid (VOF) function. FLOW-3D® uses an orthogonal coordinate system as opposed to a body-fitted system.

FLOW-3D was chosen as an analysis tool over traditional analytical methods for rating ogee crest spillway capacity since the value of P-height of the spillway weir crest varies significantly along the length of the crest. This variation and other three-dimensional characteristics of the approach flow can be readily included in the 3D numerical model.

Modeling Assumptions

The aerial photograph in Figure 12 of Technical Report No. SRH-2013-07 [1] along with the point cloud data (Figure 2) in AutoCAD was used in these assumptions and model development. The following was assumed in the development of the model.

- Length of the ogee crest was determined from aerial photography by scaling the photograph in AutoCAD. Design drawings were not available, so the length was estimated at 65 feet.
- Shape of the ogee crest was assumed as an elliptical shape. Design drawings were not available and assuming an ogee shaped crest based on an assumed design head and Reclamation current standards did not seem likely to change results, so an elliptical shape that visually matched point cloud topography data near the crest was used. The area near the critical velocity zone was considered vital while estimating the size and shape of the elliptical section.
- Shape of the guide walls was estimated using aerial photography.
- The downstream chute is hydraulically steep, thus conditions downstream of the crest will not affect discharge. A velocity boundary at the exit of the numerical model maintained supercritical flow in the controlling section.
- Two reservoir-type pressure boundaries simulated upstream conditions of the reservoir, well upstream of the 1 ft/s reservoir velocity contour.

Bathymetry

Topography was created using the “Lake Isabel 2012 Reservoir Survey” [1] and supporting point cloud data. Drawings of the crest structure were not available. Photographs indicate a standard ogee crest, so shape and location was approximated from aerial photographs (Figure 3).

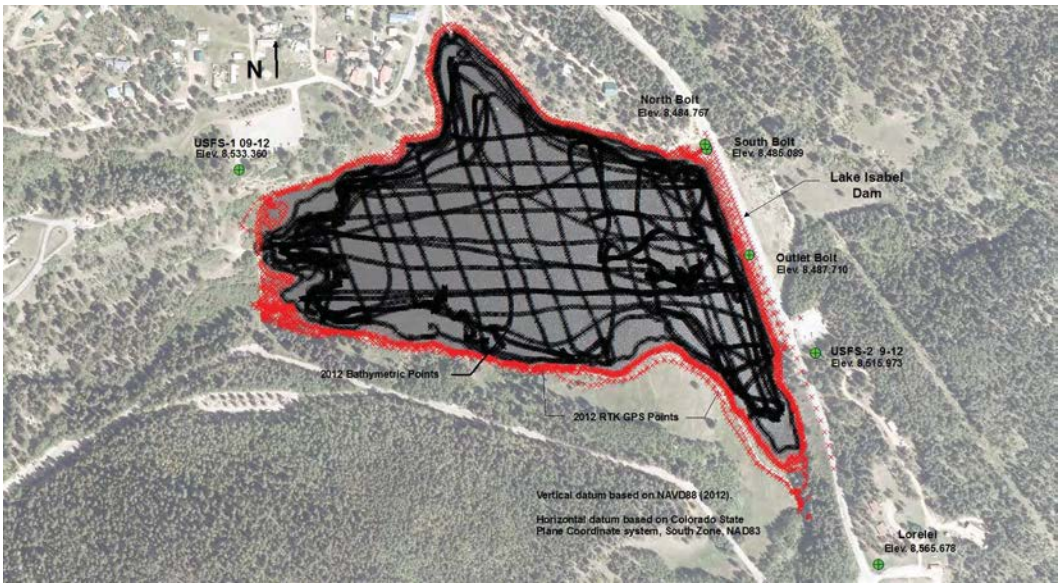

Figure 2. Point cloud data was provided in two files displayed as black and red points.

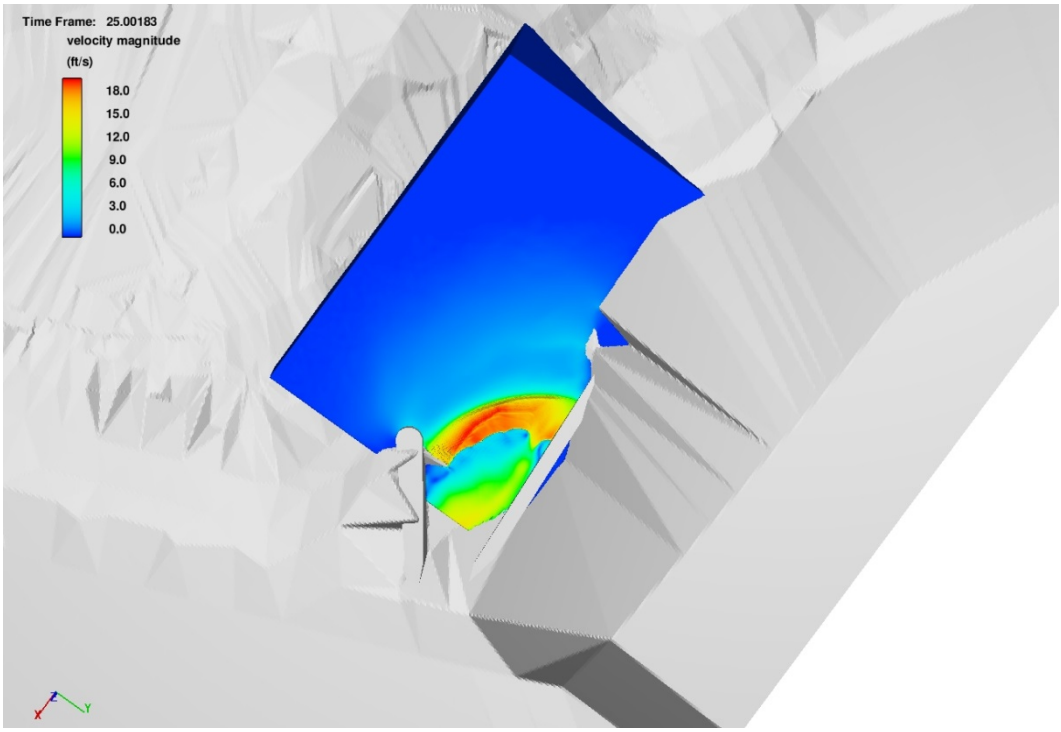

Figure 3. Simulation of 392.8 ft^3/s discharge

Results

Successive mesh reduction results and comparing discharge data for a given water surface elevation indicated the final results were independent of the grid size. The results are shown in Figure 4. These results are assumed to provide adequate accuracy for flood routings, but not accurate enough for water measurement and delivery purposes. Given the assumptions made with the modeling and the lack of as-built drawings the overall error of the rating is assumed to be within ± 10 percent.

Table 1. Water surface elevation - discharge results

Water Surface Elevation (ft)	**Gage Reading** (ft)	**Discharge** (ft^3/s)	**Calculated Discharge Coefficient**
8477.70	3.30	0.0	-
8477.95	3.55	29.7	3.66
8478.20	3.8	76.8	3.34
8478.45	4.05	137.9	3.27
8478.70	4.3	212.0	3.26
8478.95	4.55	293.0	3.23
8479.20	4.8	392.8	3.29

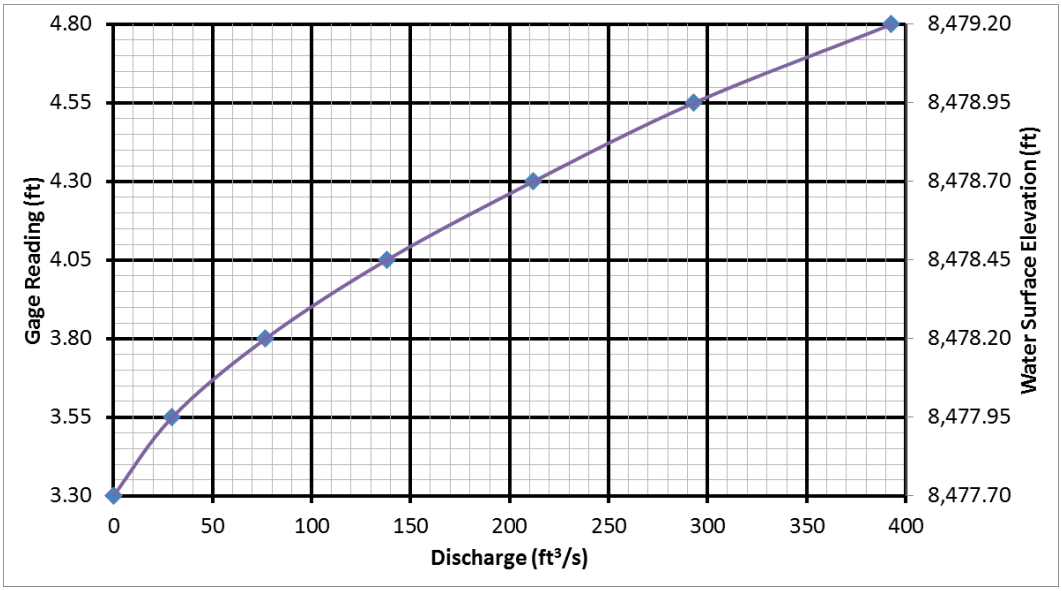

Figure 4. Water surface elevation and staff gage height versus discharge..

References

[1] Technical Report No. SRH-2013-07, Lake Isabel 2012 Reservoir Survey, U.S. Department of the Interior, Bureau of Reclamation, Technical Service Center, Denver, Colorado, November 2012.