DONNER SUMMIT PUD LAKE ANGELA SUNNY DAY FAILURE INUNDATION STUDY

Dam #89.002, National ID CA00322

February 14, 2019

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LOCATION AND DESCRIPTION

The purpose of this study is to determine the limits of inundation produced by Donner Summit Public Utility District's (DSPUD) Lake Angela in the event of a sunny day breach to satisfy DSOD requirements for a high hazard potential dam.

Lake Angela is located in the southern portion of Nevada County close to the Placer County line. The lake sits just northeast of Donner Ski Ranch on Donner Summit at an elevation of 7,195 feet (See Figure 1). It is located between Donner Pass Road to the south, Donner Ski Ranch to the west, the Pacific Crest Trail to the east, and US Interstate 80 to the north. The area surrounding the lake receives precipitation as rain and snow with an annual average liquid equivalent of approximately 52 inches. The annual precipitation liquid equivalent can be as high as 112 inches during peak wet years and as low as 20 inches during extreme drought years. Lake Angela is owned and maintained by DSPUD and is utilized for water storage. The Lake has a relatively small drainage area and a "sunny day" failure of the Dam was chosen to evaluate inundation limits, flow paths, depths and velocities as part of this analysis.

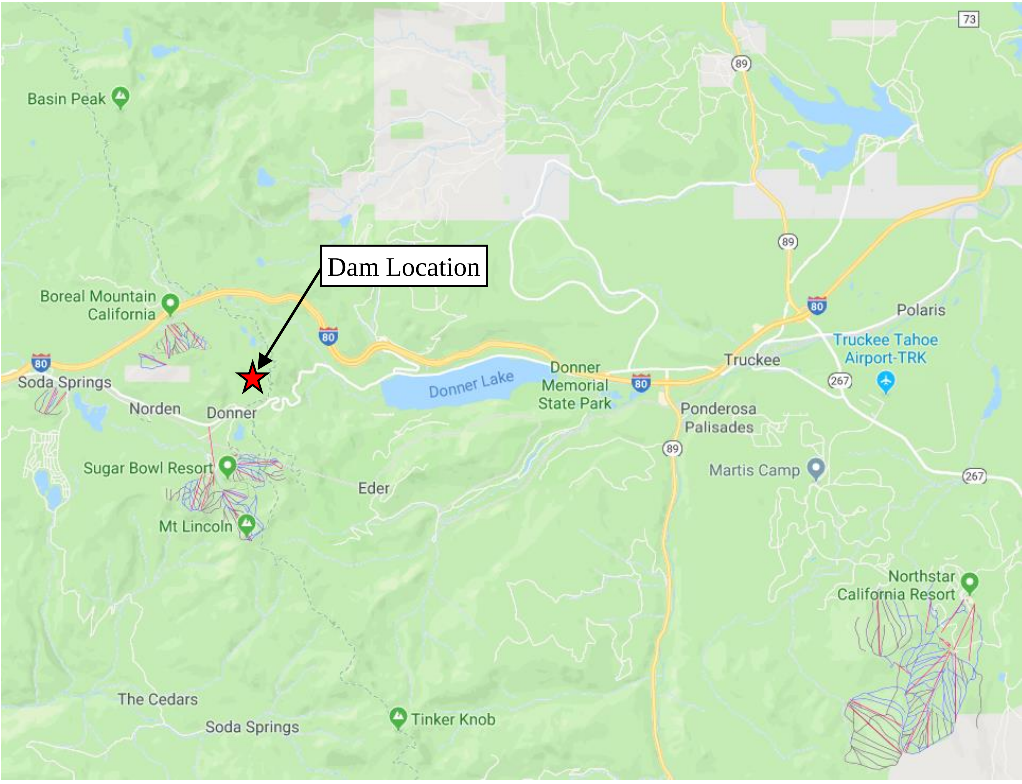

Figure 1. Location Map

Lake Angela Dam is constructed of a concrete gravity dam with rock bolt anchors that extend the full height of the Dam to resist translational and overturning forces. The rock anchors are embedded into granite bedrock and anchor spacing along the Dam varies between 4 to 10 feet. The concrete dam encompasses the southern portion of the lake. On the eastern portion of the Dam there is a small manual sluice gate that operates as the reservoir's spillway. On the same east portion of the dam structure, the Dam section is modified with a rectangular notched overflow weir that is approximately 127-ft long and 3-inches lower than top of the Dam. The southern-most section of the Dam with an outlet structure was selected to break due to the potential for releasing the greatest volume of water and maximum inundation limits. See Figure 2 below for the analyzed break location.

Figure 2. Dam Break Location

The inundation maps are included in the appendices as follows:

- Appendix A – Maximum Depth Inundation Maps (Panel 1 & 2)
- Appendix B – Peak Velocity Inundation Maps (Panel 1 & 2)

For the sunny day failure analysis, Lake Angela is assumed to be filled to the overflow weir crest.

DATUM

The vertical datum for this project is NAVD88 and the horizontal datum is NAD83 California Zone II. Electronic results are provided in Appendix C with projections in both NAD83 CA Zone II and NAD83 California Teale Albers.

2013 and 2014 LiDAR datasets were downloaded from the United States Interagency Elevation Inventory. Both the 2013 and 2014 LiDAR Digital Elevation Models had vertical datums of NAVD88 (GEOID 12a) in meters and horizontal coordinate systems of NAD 1983 (2011) UTM Zone 10N in meters. LiDAR DEMs were combined and converted to NAVD88 (ft) and NAD83 CA Zone II (ft) for modeling purposes. This is discussed further in the "Terrain" section of this study.

Lake Angela's construction as-built drawings were provided in NGVD29. Spillway elevations, overflow weir elevations, dam crest elevations, and area-capacity curves needed to be converted from NGVD29 to NAVD88 for use in the model to match the terrain's datum. To convert from 29 to 88, a National Geodetic Survey GPS and Vertical Control station on Donner Summit was used (PID – AA3449). The conversion was found to be 1.34 meters or 4.4 feet.

FAILURE PATHS

Lake Angela's initial water surface was filled to the modified overflow weir crest elevation. A 60-ft section of the southernmost portion of the dam was set to fail rapidly. This section also had the lowest downstream toe elevation with potential to release the maximum possible volume out of Lake Angela. In the simulated breach, peak outflows are approximately 14,750 cfs. Flood waters flow down the drainage to the Donner Ski Ranch parking lot and cross Donner Pass Road. Once across Donner Pass Road, the flood waters split. The majority continues down the South Yuba River headwater tributary toward Lake Van Norden. The remaining flows enter the Historic Donner Summit Railroad Tunnel and are diverted towards Donner Lake.

Peak flows through the tunnel are approximately 2,563 cfs with approximately 65 acre-ft conveyed to the Donner Lake watershed. Flood waters from the tunnel continue down the upper drainage of Donner Creek, pass through the Old Hwy Drive bridge crossing and South Shore Drive. Near South Shore Drive, Donner Creek's banks overtop inundating some of the adjacent structures. Donner Creek peak flows at this section are approximately 1,165 cfs. In this study, Donner Lake Levels were assumed to be high which result in backwater up a portion of Donner Creek. A volume of approximately 60 acre-ft would enter Donner Lake. This volume does not have a significant impact on Donner Lake levels verifying that Donner Lake is an acceptable downstream limit for this study on the east side of Donner Pass.

Flood waters that continue traveling down the South Yuba River tributary cross Old Donner Summit Road near Donner Ski Ranch's maintenance yard. Flows continue to the Union Pacific Railroad (UPRR) bridge next to the west entrance to the active UPRR Mount Judah Tunnel. The peak flow at the crossing is 7,033 cfs. The railroad bridge was modeled with a 11'x8' box culvert with a mitered slope. The modeled culvert conveys approximately 1,160 cfs, with the rest flowing over the railroad tracks. The UPRR Mount Judah tunnel entrance was not modeled to block flow. Flow depths over the railroad vary from 1 to 3 feet. Old Donner Summit Road is just after the Union Pacific Railroad. Old Donner Summit

Road is modeled with a 60" corrugated metal pipe culvert. Due to the culvert's limited capacity, the majority of flow is weir flow over the road. The peak flow past Old Donner Summit Road is 6,815 cfs. Flood waters continue along the South Yuba River and enter the Lake Van Norden wetland area with a peak flow of 4,360 cfs and a total volume of 200 acre-ft. Lake Van Norden is a large flat wetland meadow with a concrete trapezoidal weir spillway at the west end of the lake. Floodwaters fill Lake Van Norden and spill over the spillway at a rate of 220 cfs. The western downstream limit was set at the Lake Van Norden spillway.

See the attached inundation maps in Appendix A and B for flow paths, detailed depths, and velocities.

FAILURE PARAMETERS

Key parameters required to perform the failure analysis on Lake Angela consist of the following:

1. Bottom Width of Breach
2. Final Bottom Elevation of Breach
3. Side Slopes
4. Formation Time
5. Failure Mode

The breach parameters for a concrete gravity dam were determined by using FEMA's Federal Guidelines for Inundation Mapping of Flood Risks Associated with Dam Incidents and Failures (FEMA P-946, July 2013). FEMA's document highlights recommendations from USACE, FERC, and NWS to use a breach width of multiple concrete monoliths with vertical sides due to the vertical sections of poured concrete monoliths. The southern most portion of the Dam was chosen for failure at the outlet location. The section is approximately 60 feet in length. This section can be viewed below in Figure 3 and above in Figure 2.

Figure 3. Breached Section

Acceptable time for breach formation time is 0.1 to 0.5 hours for concrete gravity dams. 0.1 hours was used in this study for a conservative approach. See Figure 4 below for FEMA's P-946 Table 9-3 for Typical Breach Parameters or Range of Parameters.

Table 9-3: Typical Breach Parameters or Range of Parameters

Earth-Fill Dams	
Average breach width	½ to 5 times the dam height
Side slope of breach	0:1 to 1:1
Breach formation time	0.1 to 4 hours
Concrete Gravity Dams	
Breach width	A multiple of monolith widths
Side slope of breach	0:1
Breach formation time	0.1 to 0.5 hours
Concrete Arch Dams	
Breach width	Entire dam width
Side slope of breach	0:1 to valley wall slope
Breach formation time	Nearly instantaneous, ≤ 0.1 hour

Figure 4. FEMA's P-946, Table 9-3 Typical Breach Parameters

Lake Angela's initial water surface was filled to the overflow weir crest elevation. This elevation was found to be 7,192.80 feet (NGVD29) in the as-built drawings. The converted overflow weir elevation is 7,197.2 feet (NAVD88). Lake Angela stage-storage curves were also created from the construction as-built documents and converted to NAVD88 from NGVD29. The failure mode was set to piping. The final bottom elevations were set to the downstream toe elevations of the embankment. See Table 1 for a summary of the dam failure parameters.

Table 1. Lake Angela Failure Parameters

Parameter	Main Breach
Failure Mode	Piping
Side Slopes	Vertical
Final Bottom Elevation	7,172.35
Final Bottom Width	60 feet
Formation Time	0.1 hours

Figure 5 shows Lake Angela's stage-storage curve.

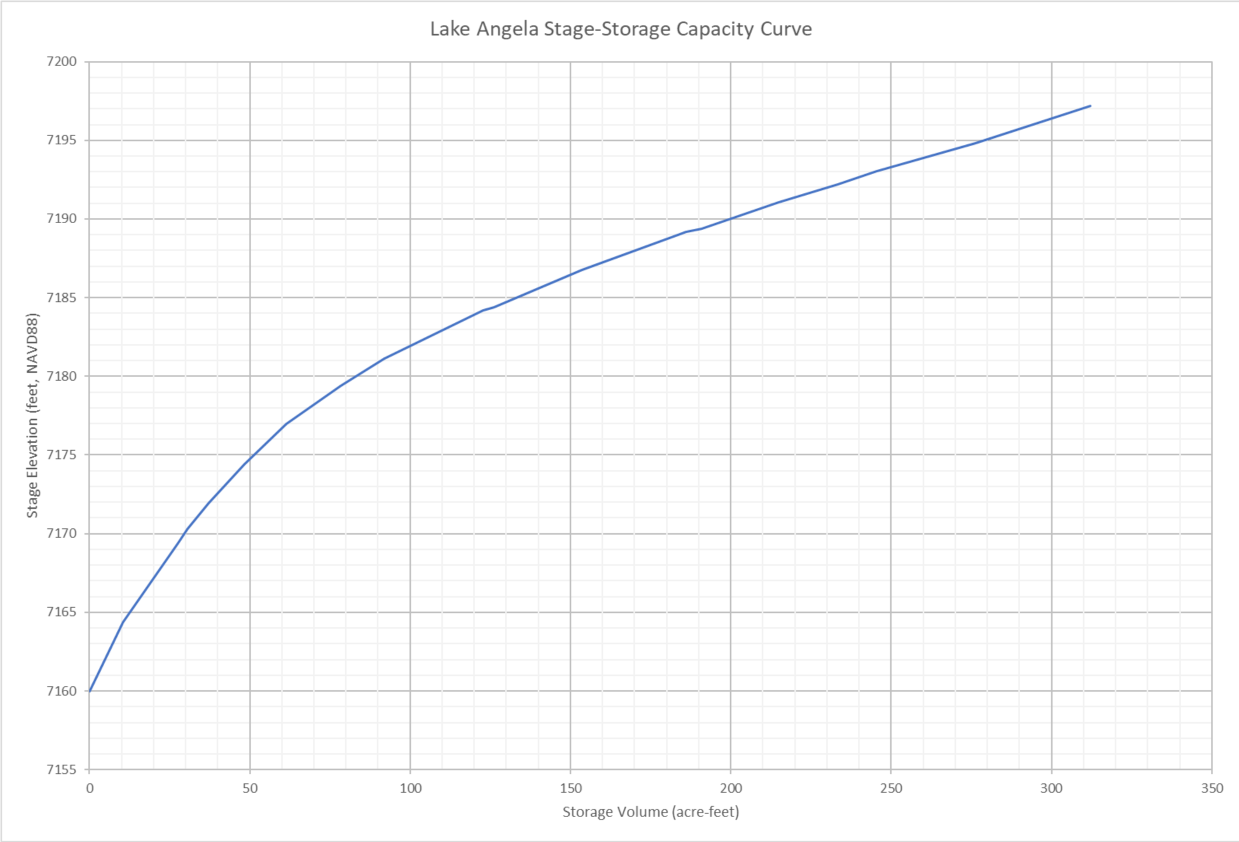

Figure 5. Lake Angela Stage-Storage Curve

TERRAIN DATA

LiDAR datasets were downloaded from the United States Interagency Elevation Inventory. In this project's area of interest, LiDAR data was available from LiDAR surveys of the Tahoe National Forest performed in 2013 and 2014 for the USFS. Both the 2013 and 2014 LiDAR Digital Elevation Models (DEM) had vertical datums of NAVD88 (GEOID 12a) in meters and horizontal coordinate systems of NAD 1983 (2011) UTM Zone 10N in meters. Horizontal grid spacing was 0.5 meters and elevation accuracy ranges between 5-35 cm.

The 2013 and 2014 LiDAR datasets were combined then converted to have units of feet and a horizontal coordinate system of NAD83 CA Zone II. The terrain was modified in AutoCAD Civil 3D to include the Donner Summit historic railroad tunnel. LiDAR ground points just outside of the tunnel were utilized to establish the tunnel's approximate average slope. The modified terrain file was then imported into HEC-RAS for modeling use. Stream centerlines, reservoir outlines, and bridge crossing centerlines were drawn in HEC-RAS for use as break-lines, storage areas, and bridge crossings. Bridge crossings were added as culverts due to HEC-RAS 5.0.6 2D not having the ability to model bridges in the 2D domain. Reservoir areas were outlined on the terrain geometry as "storage areas." A Stage-storage curve was gathered from as-built drawings and assigned to the storage area's properties. Figure 6 below shows the modified combined surface used for analysis in this study.

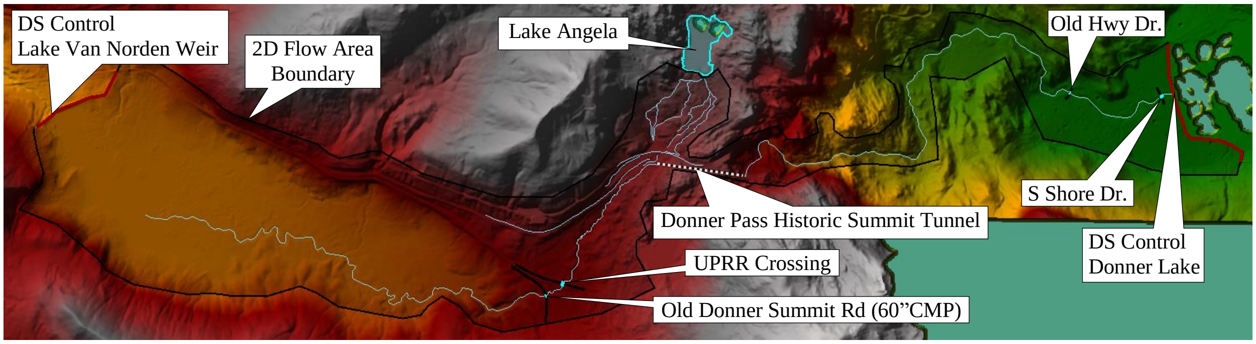

Figure 6. Modified HEC-RAS Terrain

HYDRAULIC MODEL

A HEC-RAS model (Hydrologic Engineering Center River Analysis System version. 5.0.6) was created to analyze the inundation limits in the event of a failure. The model is a 2D model with the above-mentioned terrain data imported into HEC-RAS and used as the terrain. A failure scenario was created for the main dam break location. Lake Angela and the previously listed failure parameters were entered into the model as a storage area at the upstream end of the 2D model and the study was terminated at the Lake Van Norden outlet weir to the west and Donner Lake to the east. Having two downstream control boundaries was necessary due to splitting flows at the Donner Summit Historic Railroad tunnel. The tunnel conveys a portion of the flows to the Donner Lake watershed and into Donner Lake. The Lake Van Norden outlet weir downstream boundary control was set to a normal depth calculation and the Donner Lake downstream control boundary condition was set to a constant stage hydrograph with an elevation of 5,939 ft. Lake Angela's initial water surface elevation was set to 7,197 feet.

For a conservative approach to mapping the inundation area, only bridges and large culverts were modeled. Smaller culverts were considered as plugged with debris. Bridge and culvert crossings were modeled for the Union Pacific Railroad bridge over the South Yuba River headwater tributary, the Old Donner Summit Road 60-inch corrugated metal pipe culvert crossing of the South Yuba River headwater tributary, the Old Hwy Drive bridge over Donner Creek, and the South Shore Drive bridge over Donner Creek.

The UPRR, Old Donner Summit Road, and South Shore Drive bridges were modeled as box culverts. HEC-RAS 5.0.6 2D does not have the ability to model bridges in the 2D domain. By using box culverts with similarly sized openings at bridge crossings, the culverts effectively function as bridge openings. A site visit to bridge and culvert crossings was performed and measurements were made. Modeled box culvert sizes were based on field measurements and comparable conveyance areas for bridges with multiple openings.

The Dam break model uses Manning's 'n' land cover regions to establish various 'n' values throughout the 2D model. Manning's 'n' values range from 0.06 for vegetated areas to 0.02 for paved roads. The default Manning's 'n' value was set to 0.06. Three separate areas were created to represent Manning's 'n' areas for paved roads, dirt roads, railroads, and vegetated areas. These areas were determined from satellite imagery and a site visit. Bridge crossings that were modeled with a box culvert, used a Manning's 'n' value of 0.03 for the bottom to simulate a natural stream bottom and 0.015 on the walls to represent the concrete abutment walls.

The grid for the 2D area within HEC-RAS was set to a spacing of 20-feet. To provide additional accuracy along anticipated flow paths, break-lines were added to capture low-flow pathways. Break-lines were also added to represent flow barriers, such as embankments, at creek and river crossings by "sampling" terrain values along the break-line. Break-line cell spacing was default to 20-ft. The break-lines create a more accurate representation of the underlying terrain profile which helps the model distinguish between flow paths and barriers. With the option to refine cell spacing along break-lines, issues such as "cell leaking" and "low flow blocking" can be minimized to help produce better results.

The computation interval was set to the "adjusted time step based on courant" option within HEC-RAS's Unsteady Computation Options and Tolerances. Timesteps varied from 0.16 second to 5.33 minutes with an initial timestep of 10 seconds. The total simulation time was set to 11 hours to capture the peak flood wave at the boundary limits. Mapping output intervals were set to 1-minute increments.

Each breach scenario was set to start at time t=10 minutes. Figure 7 shows the Lake Angela Dam breach hydrograph.

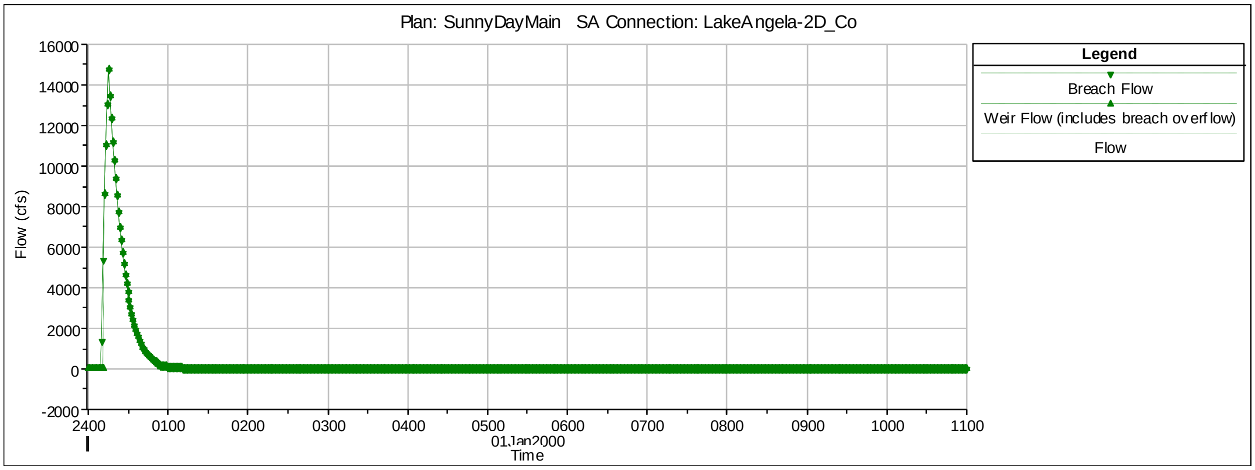

Figure 7. Lake Angela Breach Hydrograph (Max flow = 14,750 cfs, Volume Released = 278 acre-ft)

The modeling was mapped against the modified terrain and georeferenced aerial imagery. Digital shape files were created to compare the inundation limits to aerial sources. Detailed inundation maps with depth and velocity grids are provided as attachments to this study in Appendix A and B. The map will be used in establishing an Emergency Action Plan. Electronic copies and results are provided in Appendix C.

APPENDIX A – INUNDATION MAPS (MAXIMUM DEPTH)

APPENDIX B – INUNDATION MAPS (PEAK VELOCITY)

APPENDIX C – ELECTRONIC FILES