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Lopez Dam Breach Inundation Study Comparison – 1999 Vs 2017

San Luis Obispo County, California

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Abbreviations and Acronyms

AF	acre-feet
cfs	cubic feet per second
DSOD	California Division of Safety of Dams
DWR	California Department of Water Resources
ft	feet
GEI	GEI Consultants, Inc.
HEC-RAS	Hydrologic Engineering Center's River Analysis System
NAVD 88	North American Vertical Datum of 1988
NGVD 29	National Geodetic Vertical Datum of 1929
USGS	United States Geological Survey

1 Introduction

1.1 Purpose

GEI Consultants, Inc. (GEI) was retained by San Luis Obispo County Department of Public Works to perform a dam breach and inundation mapping study for Lopez Dam located in San Luis Obispo County in December 2017. Results from the 2017 inundation maps were compared to the previously performed dam breach inundation study (URS Greiner Woodward Clyde, 1999) showing differences in inundation extents. GEI was asked to compare the two studies and write a technical memorandum describing the differences in inundation mapping.

2 Dam Breach Inundation Study for 1999

2.1 Topographic Data

Hydraulic models are highly dependent upon input topography and can influence results significantly. The dam breach inundation model produced in 1999 utilized multiple sources of topographic data including USGS quadrangle maps (7.5 minute) and local topographic maps between Fair Oaks Avenue in Arroyo Grande, CA and the Pacific Ocean (SLO County 1962). The equivalent resolution of a 7.5-minute quad is approximately a 33 x 33 ft. grid averaging to a single elevation over that area.

2.2 Hydraulic Model and Assumptions

The models generated for the 1999 inundation study were developed using National Weather Service (NWS) software. The BREACH model (Fread 1988) software was used to develop breach outflow hydrographs and the DAMBRK model (NWS 1988) software was used to route the breach hydrograph through 1-dimensional cross sections developed from the topographic data.

The breach model utilized a "sunny-day" failure model assuming that the dam crest had been degraded due to a seismic event, eventually eroding and failing the dam due to overtopping. The breach scenario with the highest discharge was selected for mapping, this scenario utilized a full reservoir at the spillway crest (Elevation 520, NGVD29). The storage elevation curve used in the model was based on a San Luis Obispo County topographic map (1967), having a storage capacity of 51,800 ac-ft. The bottom breach width was 2 ft with a top of breach width of 444 ft, having a total breach depth of 150 ft. This breach produced a peak outflow of 738,000 cfs.

The routing model utilized a 1-Dimensional (1D) routing methodology. The 1D methodology routes inflow hydrographs through modeled cross sections using Manning's Flow Equation. This methodology allows flows to be routed upstream to downstream based on the cross-section locations and allows flow spreading through increased depth in each cross section but does not allow for 2-dimensional spreading of flows.

The model extent is from Lopez Dam to the Pacific Ocean. The model consisted of 39 cross sections over the 12-mile span. Field observations were made to classify channel roughness coefficients. Model roughness values ranged from 0.045 (natural stream bed) to 0.1 (trees and heavy vegetation) in the main channel and ranged from 0.035 (cultivated crops) to 0.09 (heavy residential) in the floodplain overbanks. Bridges were not included in the routing model because they occupy such a small portion of the flow conveyance area during a dam breach scenario and would not significantly impact water surface elevations. Peak flows are attenuated by 60% by the time the flood wave reaches the Pacific Ocean. Table 1 summarizes the 1999 dam breach results.

Table 1: 1999 Dam Breach Study - Results

Station	Milepost	Peak Discharge	Peak	Maximum	Peak	Location
	(MP)	(cfs)	WSEL (ft - NGVD)	Depth (ft)	Time (hr)	
0+00	0	738,000	520	150	1.05	Lopez Dam
135+17	2.56	686,000	331.9	46.9	1.18	Tally Farms Road
404+61	7.663	573,000	116.3	46.1	1.61	Highway 101 NB
405+35	7.677	573,000	115.5	45.4	1.61	Highway 101 SB
493+68	9.35	533,000	58.4	23.4	1.82	Highway 1
630+96	11.95	297,000	18.7	15.7	2.71	Outlet to Pacific

3 Dam Breach Inundation Study for 2017

3.1 Topographic Data

The dam breach inundation study performed in 2017 (GEI) utilized multiple datasets to develop the 2-Dimensional dam breach model terrain. LiDAR data from NOAA and PG&E were obtained through a San Luis Obispo County data request, two surveys were obtained from 2011 and 2013 with 1 x 1 ft grid cell resolution. USGS National Elevation Data was utilized to fill in gaps where the existing LiDAR surveys did not cover, this data is classified as 1/3-arc-second and is approximately the same resolution as the 7.5-minute quads at a 33 x 33 ft grid cell size.

3.2 Hydraulic Model and Assumptions

The breach model utilized a "sunny-day" failure model, this scenario utilized a reservoir full to the spillway crest (Elevation 520, NGVD29), HEC-RAS was used to perform the breach analysis. The storage elevation curve used in the model was based on a San Luis Obispo County survey performed in 2002, having a full storage capacity of 49,388 ac-ft. The bottom breach width was 500 ft with a top of breach width of 650 ft, having a total breach depth of 150 ft. This breach produced a peak outflow of 833,330 cfs.

The models generated by GEI for the 2017 dam breach and inundation study were developed using the Hydrologic Engineering Center's River Analysis System (HEC-RAS) Version 5.0.3. Two-Dimensional (2D) hydraulic routing has been available within HEC-RAS software since the release of HEC-RAS 5.0 (2015). This routing methodology was utilized for the dam breach and inundation analysis in the 2017 study. Each 2D cell is comprised of a storage-elevation curve (similar to a reservoir) and multiple cell face cross sections which have similar hydraulic properties as 1D cross sections. This methodology allows for directional spreading of flows based on topographic elevation and hydraulic roughness. The 2D modeling characteristics are very important for dam breach modeling due to the likelihood of the flood wave rising outside of river or stream banks and spreading overland. The 2D routing model also used the Full Momentum (Saint Venant) equations available in RAS to account for local and convective accelerations of a rapidly varied flood wave, for a dam breach.

The model extent ranges from Lopez Dam to the Pacific Ocean, the model consisted of a single 2D flow area with an average grid cell size of 100 ft x 100 ft. The cell size does not diminish the detail of the terrain data, this is utilized in the cell face and volume characteristics. Break lines were also included in the 2-D Flow area to align cell faces with grade breaks in the model terrain, these break lines prevent water from artificially traveling through high ground based on the cell face alignments. USGS National Land Cover Database (2011) shapefiles were used to classify manning's roughness coefficients for the model. The land-use classifications available from USGS were assigned roughness coefficients based on values reported for natural stream channels (Chow 1959) and best engineering judgement. Model roughness values ranged from 0.03 (natural stream bed) to 0.1 (trees and heavy vegetation) in the main channel and ranged from 0.035 (cultivated

crops) to 0.2 (heavy residential) in the floodplain overbanks. Bridges were included in the routing model but these structures occupy such a small portion of the flow conveyance area during a dam breach scenario, they will not significantly impact water surface elevations. Peak flows are attenuated by 70% by the time the flood wave reaches the Pacific Ocean. Table 2 summarizes the 2017 dam breach results.

Table 2: 2017 Dam Breach Study - Results

Station	Milepost	Peak Discharge	Peak	Maximum	Peak	Location
	(MP)	(cfs)	WSEL (ft - NGVD)	Depth (ft)	Time (hr)	
0	0	833,330	520	150	1	Lopez Dam
153+20	2.9	820,185	326.18	35.7	1.01	Tally Farms Road
467+83	8.9	745,518	134.18	47.2	1.35	Highway 101 NB
467+83	8.9	745,518	134.18	47.2	1.35	Highway 101 SB
560+97	10.6	712,253	66.18	23	1.5	Highway 1
667+86	12.6	243,239	28.18	22.7	2.3	Outlet to Pacific

4 Model Results Comparison

Tabulated below in table 3 is a comparison of peak discharge for both models. Overall the peak discharge at the dam is around 10% different. As the flow is routed downstream the difference in peak flow is approximately 20% different.

Tabulated below in table 4 is a comparison of peak water surface elevation for both models. As the flow is routed downstream the difference in peak water surface elevation is approximately 12% different.

Tabulated below in table 5 is a comparison of peak depth for both models. As the flow is routed downstream the difference in maximum depth is approximately 20% different.

Tabulated below in table 6 is a comparison of time to peak water surface elevation for both models. Overall the time to peak at the dam is around 5% different. As the flow is routed downstream the difference in time to peak is approximately 20% different.

Table 3: Cross Sectional Results Comparison - Peak Discharge

Peak Discharge 1999	Peak Discharge 2017	Difference	% Difference	Location
(cfs)	(cfs)	(cfs)	(%)	
738,000	833,330	-95,330	-11.4	Lopez Dam
686,000	820,185	-134,185	-16.4	Tally Farms Road
573,000	745,518	-172,518	-23.1	Highway 101 NB near City of Arroyo Grande
573,000	745,518	-172,518	-23.1	Highway 101 SB near City of Arroyo Grande
533,000	712,253	-179,253	-25.2	Highway 1 near Oceano
297,000	243,239	53,761	22.1	Outlet to Pacific

Table 4: Cross Sectional Results Comparison - Peak WSE

Peak WSEL 1999	Peak WSE 2017	Difference	% Difference	Location
(ft -NGVD)	(ft -NGVD)	(ft)	(%)	
520	520	0	0.0	Lopez Dam
331.9	326.18	6	1.8	Tally Farms Road
116.3	134.18	-18	-13.3	Highway 101 NB near City of Arroyo Grande
115.5	134.18	-19	-13.9	Highway 101 SB near City of Arroyo Grande
58.4	66.18	-8	-11.8	Highway 1 near Oceano
18.7	28.18	-9	-33.6	Outlet to Pacific

Table 5: Cross Sectional Results Comparison – Peak Depth

Maximum Depth 1999	Maximum Depth 2017	Difference	% Difference	Location
(ft)	(ft)	(ft)	(%)	
150	150	0	0.0	Lopez Dam
46.9	35.7	11	31.4	Tally Farms Road
46.1	47.2	-1	-2.3	Highway 101 NB near City of Arroyo Grande
45.4	47.2	-2	-3.8	Highway 101 SB near City of Arroyo Grande
23.4	23	0	1.7	Highway 1 near Oceano
15.7	22.7	-7	-30.8	Outlet to Pacific

Table 6: Cross Sectional Results Comparison – Time to Peak

Peak Time 1999	Peak Time 2017	Difference	% Difference	Location
(hr)	(hr)	(hr)	(%)	
1.05	1	0	5.0	Lopez Dam
1.18	1.01	0	16.8	Tally Farms Road
1.61	1.35	0	19.3	Highway 101 NB near City of Arroyo Grande
1.61	1.35	0	19.3	Highway 101 SB near City of Arroyo Grande
1.82	1.5	0	21.3	Highway 1 near Oceano
2.71	2.3	0	17.8	Outlet to Pacific

5 Conclusion

While there have been significant improvements to available data resolution and modeling sophistication since the 1999 dam breach inundation study was performed the results are generally comparable within a margin of error that would be caused by these computing improvements and data resolution.

6 References

URS Greiner Woodward Clyde (1999). Downstream Flooding Due to the Hypothetical Failure of Lopez Dam, Final Report.

GEI Consultants (2017). Lopez Dam Inundation Technical Study.

7 Attachments

- 1999 Dam Breach Inundation Study Map
- 2017 Dam Breach Inundation Study Map