STUDENT SUMMER INTERNSHIP TECHNICAL REPORT

2D Dam-Break Analysis of L Lake and PAR Pond Dams Using HEC-RAS

DOE-FIU SCIENCE & TECHNOLOGY
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ABSTRACT

The Savannah River Site (SRS) has two high hazard dams, the Steel Creek Dam and the PAR Pond Dam. Because of this classification steps must be taken to prepare in the event of a dam breach. In 1991 Bechtel Savannah River Inc. preformed a dam break analysis under Probable Maximum Flood (PMF) and a fair-weather condition. However, no inundation maps were produced from the study. Moreover, newer modeling programs have better output capabilities such as time series animations. The goal of this project was to take the previous data used in the original study to develop inundation maps needed for emergency response. From the new results it was shown that all roads downstream of the dams will be overtopped in the event of a breach. While the visual results of this project are adequate, further refinement of the model is needed to improve numerical results.

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1. INTRODUCTION

In 1991 a dam-break study was conducted for the high hazard dams located at L Lake and PAR Pond on the Savannah River Site (Bechtel 1991). Two scenarios were considered, over topping from a Probable Maximum Flood (PMF), and a fair-weather dam-break for either or both dams. Unfortunately, no inundation map was developed from the study. The purpose of this project was to redo the original dam-break study with improved data and methodology to generate inundation maps to assist with emergency response and evacuation plans.

The program used in the original study *DamBRK*, which was developed by the National Weather Service, is no longer supported. The Hydrologic Engineering Center's River Analysis System (HEC-RAS) is a free to download river analysis modeling program developed by the US Army Corps of Engineers capable of 1D and 2D hydraulic calculations. Version 5.0.7 (released March 2019) was used for this project.

2. EXECUTIVE SUMMARY

This research work has been supported by the DOE-FIU Science & Technology Workforce Initiative, an innovative program developed by the US Department of Energy's Environmental Management (DOE-EM) and Florida International University's Applied Research Center (FIU-ARC). During the summer of 2019, a DOE Fellow intern Amanda Yancoskie spent 10 weeks doing a summer internship at the Savannah River Site under the supervision and guidance of Dr. Grace Maze. The intern's project was initiated on May 28, 2019, and continued through August 1, 2019 with the objective of developing inundation maps in the event of a failure of the high hazard dams located on site.

3. RESEARCH DESCRIPTION

1/3 arc-second (10m) digital elevation models (DEM) for the area were retrieved from the US Geological Survey National Map download client. The original cross-section data from the 1991 study was incomplete; files were missing, and some cross section were synthesized. While DEM data does not contain bathymetry values, for this study it is not critical since the stream bed is relatively shallow and an extreme high flow scenario is being considered, making the bathymetry negligible.

The DEM data is input into HEC-RAS Mapper module and converted into an HDF file (Figure 1). Then, the perimeter of the 2D flood area and 1D storage areas were drawn (outlined in blue) based off the plotted contours (Figure 2). A 2D flood area was used because of the size of the flood basin, elevation range, the flood waves potential to back flow into upstream tributaries, and data availability (US Army Corps, 2016a). No land use layer was input into the program so a single friction (Manning's n) coefficient (0.07) was used throughout the 2D area. This lower value used results in a lower resistance to flows resulting in an increased downstream velocity (Bechtel 1991). The grid for the 2D flood basin was generated from 250x250 ft cells. A finer grid resolution was not possible because of the size of the flood basin and the computational limits of HEC-RAS. Both L Lake and PAR Pond were input as 1D storage areas because the DEM do not contain elevation values below the water surfaces. An elevation vs volume curve was available and used for both storage areas (Table 3, Table 4).

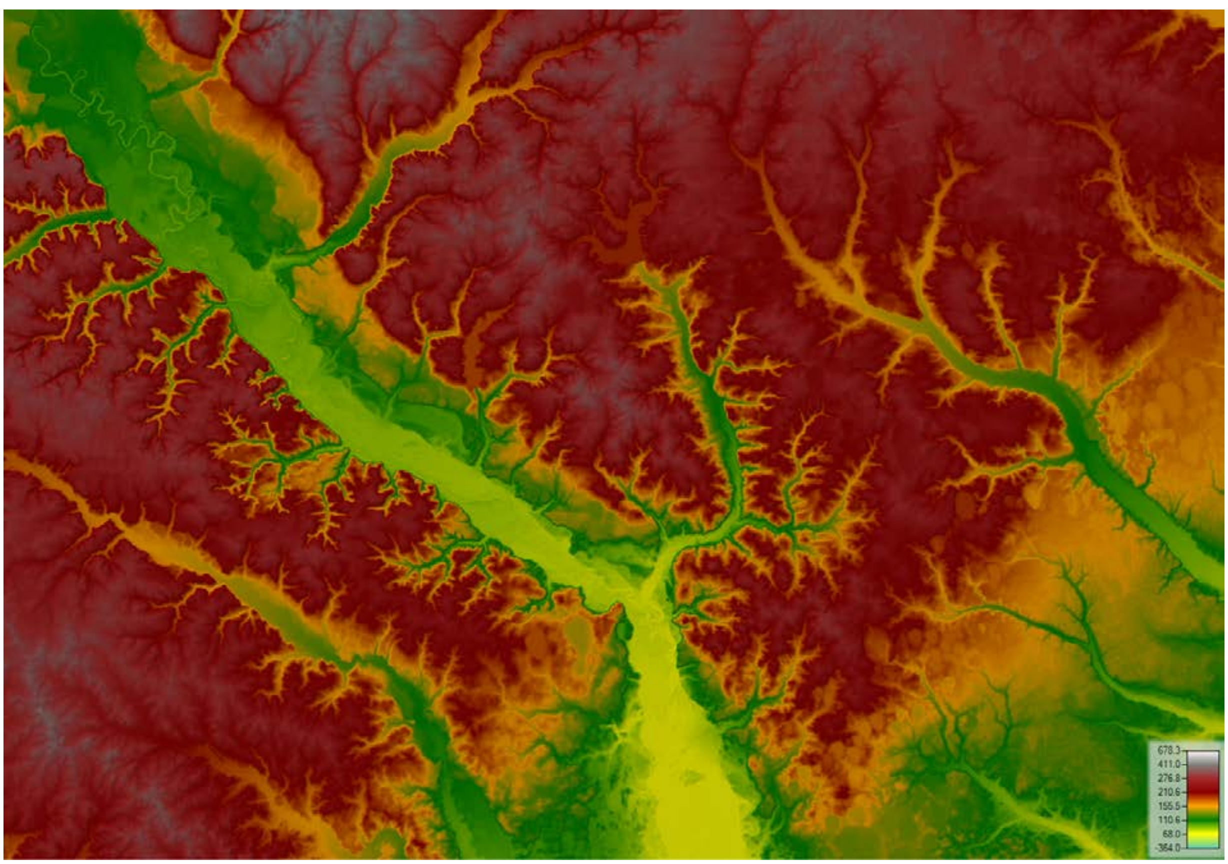

Figure 1: Terrain (ft) After Being Converted from a DEM to An HDF File

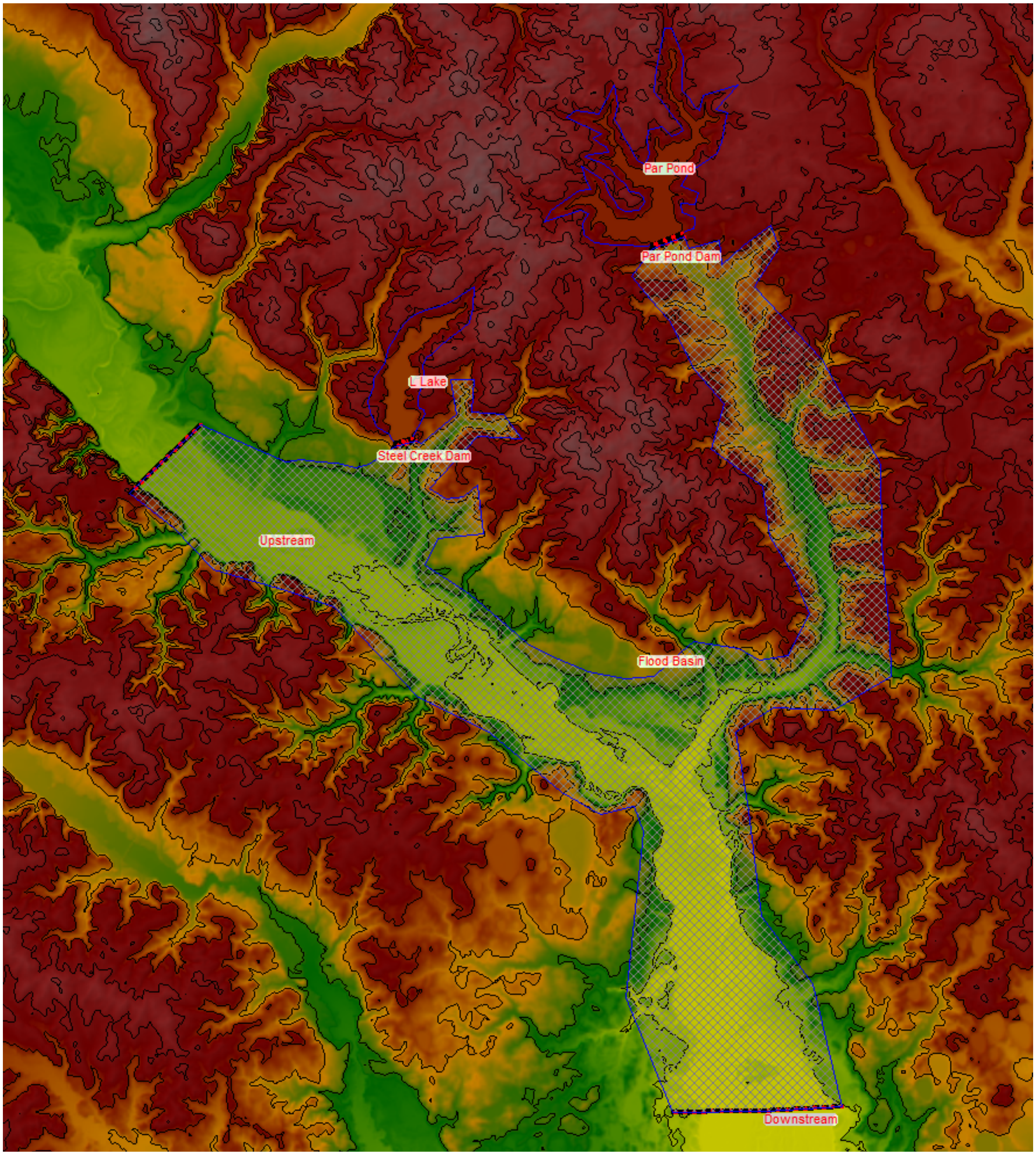

Figure 2: Display Of 2D Flood Basin, 1D Storage Areas, And Dams.

The majority of dams that have failed have been earthen dams (US Army Corps, 2014). The two dams on site, Steel Creek Dam and PAR Pond Dam, are earthen dams and are considered high hazard based on the Federal Energy Regulatory Commission (FERC) federal guidelines for dam safety (2004).

The dams are input as storage area/2D area connections using simplified dam geometric data (Table 7). In the connection data editor, only the dam's cross-section is displayed (Figure 3, Figure 4) The Steel Creek Dam at L Lake has 6 ft diameter conduit with an upper and lower sluice gate. PAR Pond Dam consists of a weir connected to an 8x8 ft channel. Both outlets were modeled with a pool elevation vs discharge curve (Table 5, Table 6). The Steel Creek Dam sluice gates were assumed to be fully open in all cases.

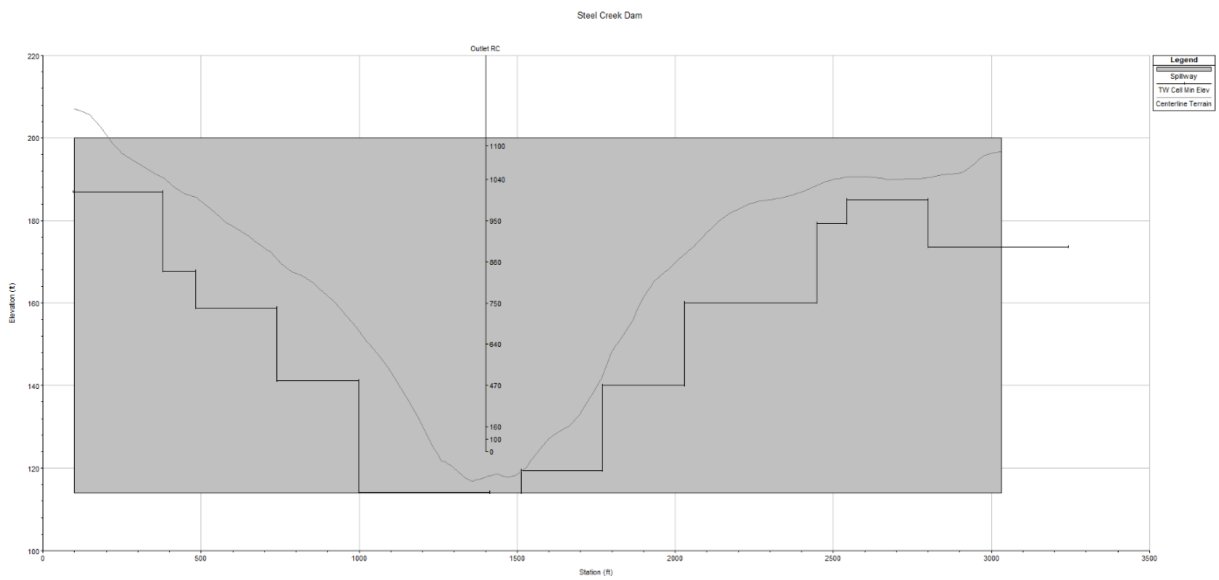

Figure 3: Cross Section of Steel Creek Dam

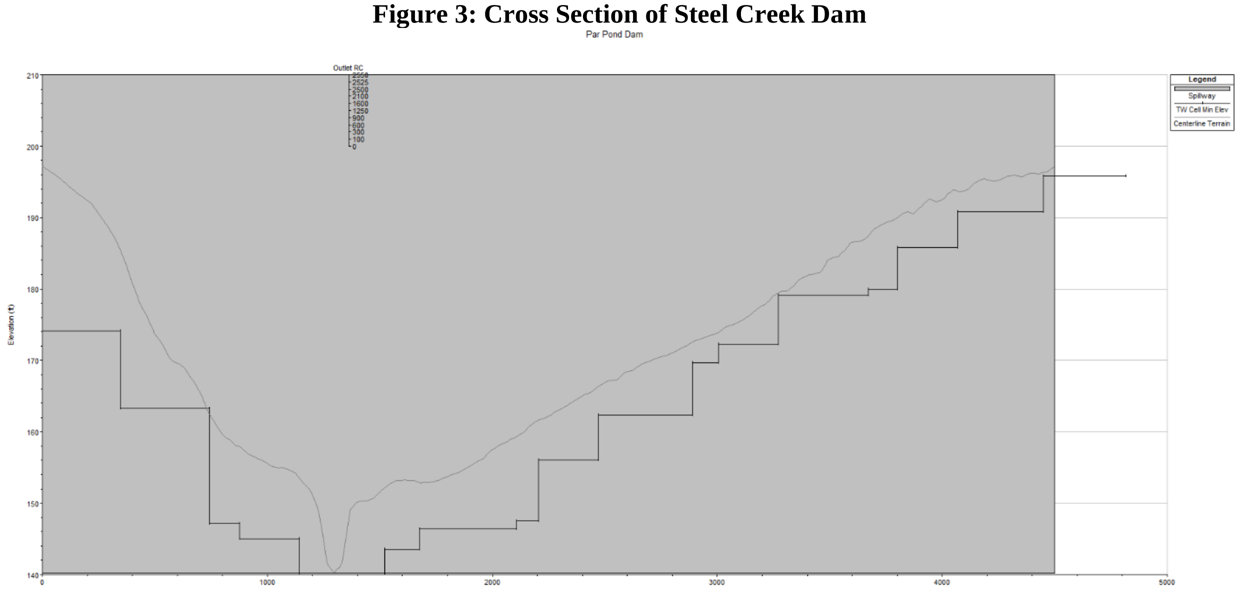

Figure 4: Cross Section of PAR Pond Dam

As in the previous study, the dams were set to breach when they were overtopped by 1.5 ft during PMF conditions (Figure 5). A fair-weather breach was set to be due to a piping failure (Figure 6). In the dual dam break during fair weather conditions the PAR Pond Dam is set to fail 3 hours after the Steel Creek Dam to achieve maximum flooding potential in the downstream reaches.

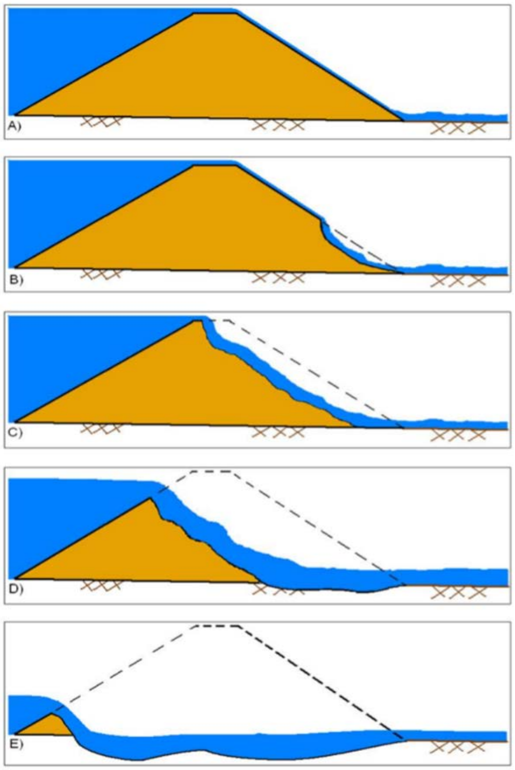

Figure 5: Dam Breach Process by Overtopping

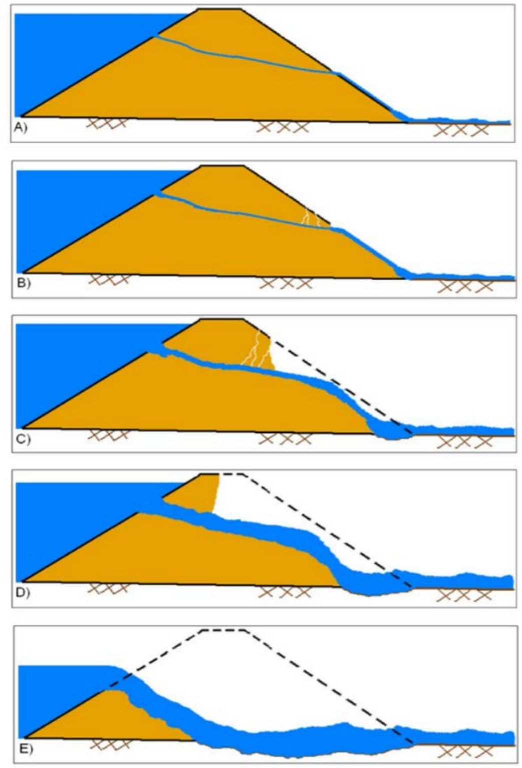

Figure 6: Dam Breach Process by Pipe Failure

Flow data was taken directly from the 1991 study (Bechtel 1991). Inflow hydrographs for L Lake and PAR Pond found in appendix A (Table 1, Table 2). Flow for the upstream part of the Savanah River was set at 87,100 cfs for the PMF simulation and 9,000 cfs for the fair-weather simulations. For the fair-weather simulations, the initial water levels in the storage areas were set to their respective normal operating pools (Table 7). For the PMF simulation the initial water surface elevation was assumed to be 2 feet above the normal operating pools.

For details regarding the specific hydraulic methodologies HEC-RAS uses please refer to the Hydraulic Reference Manual (2016b).

4. RESULTS AND ANALYSIS

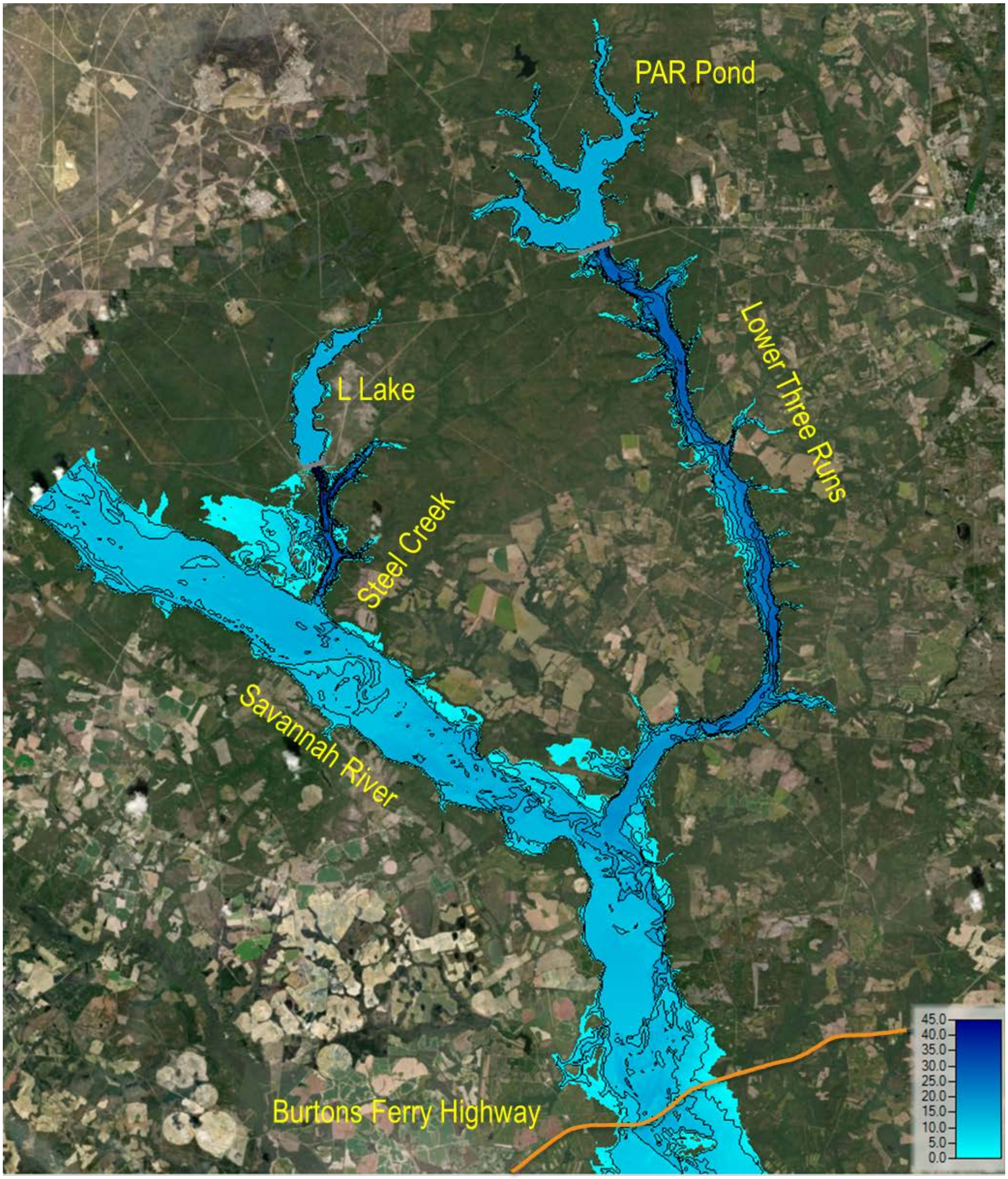

Figure 7: Maximum Depth (ft) During PMF Conditions.

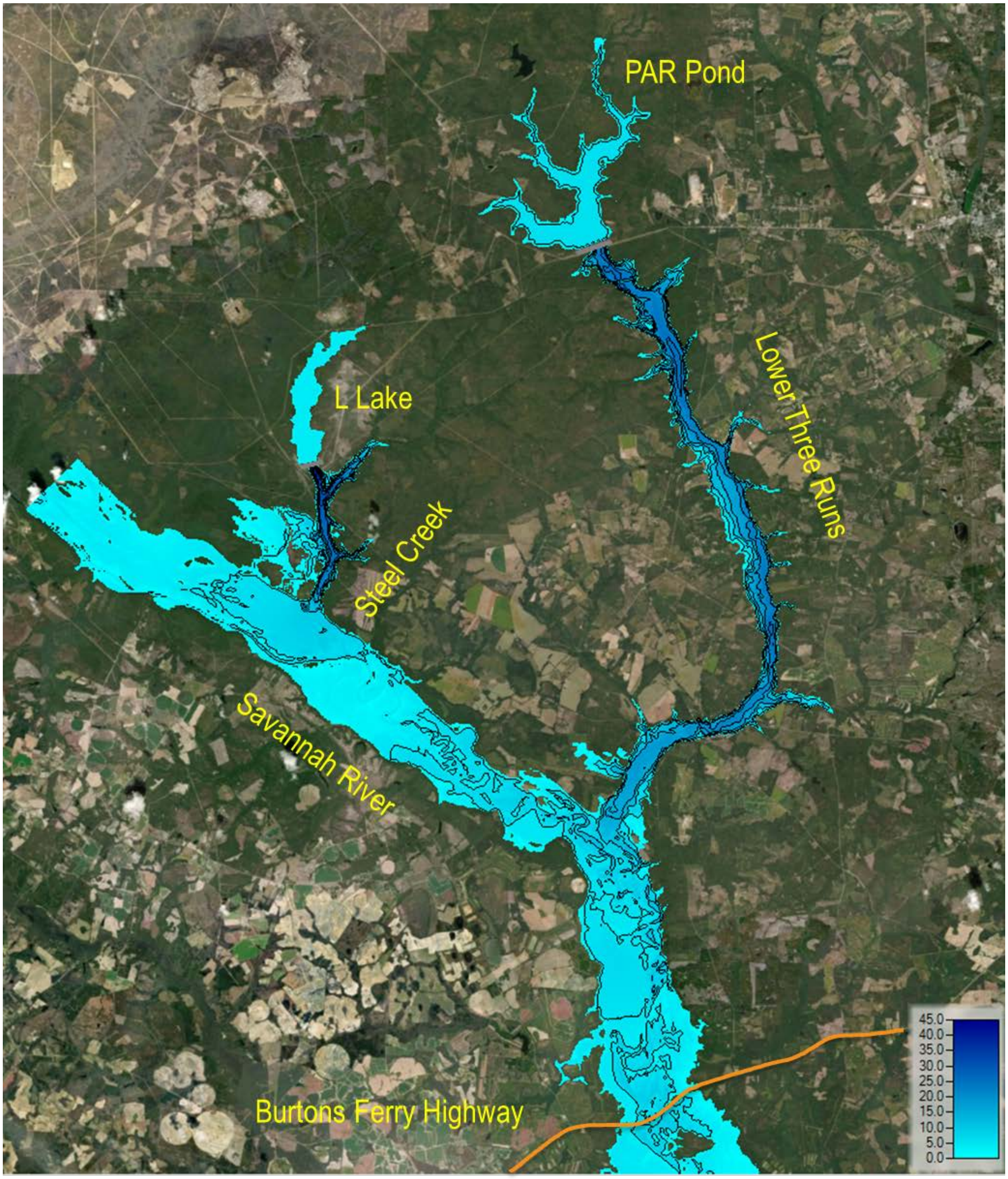

Figure 8: Maximum Depth (ft) During Fair-Weather Conditions with Both Dams Failing

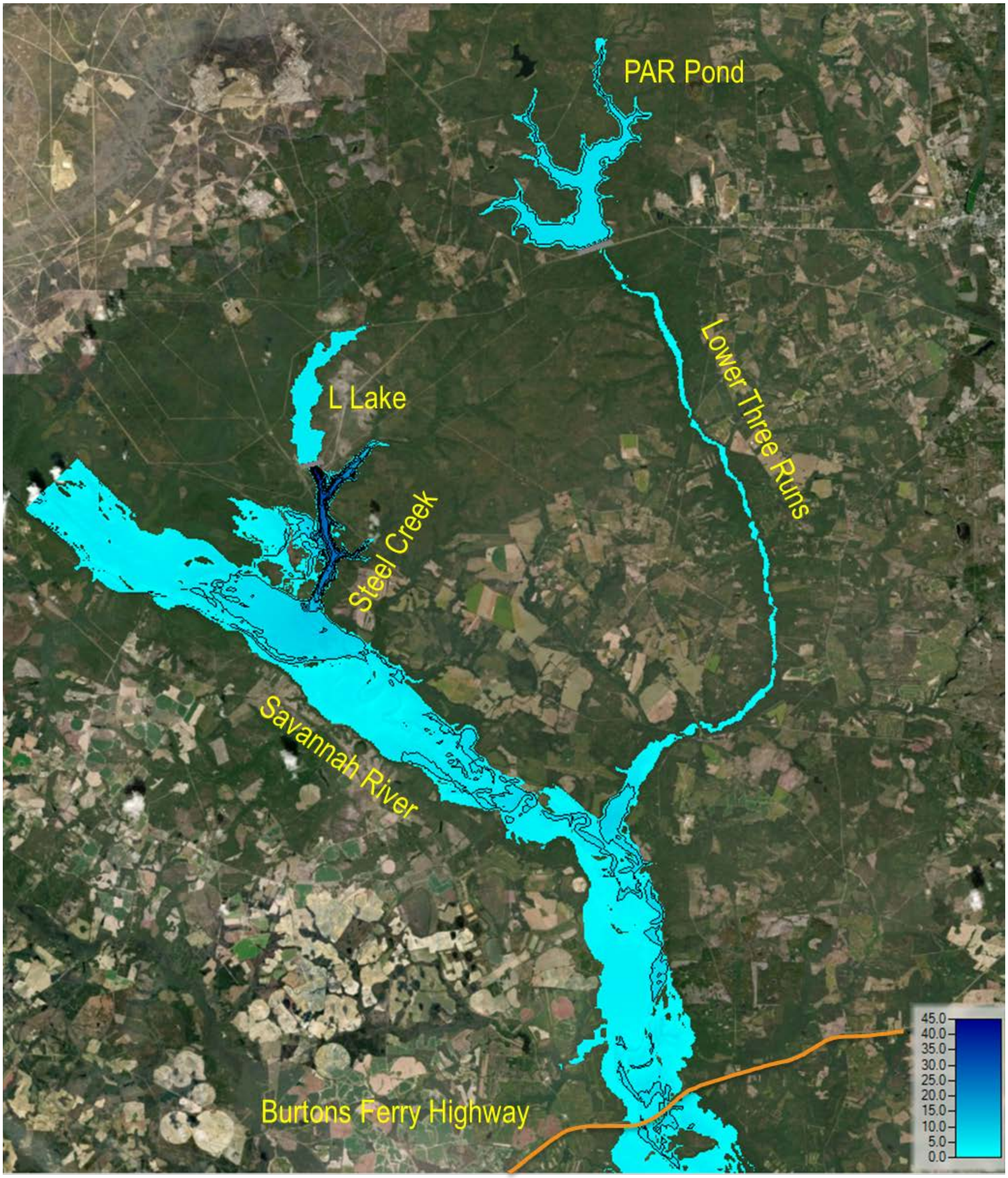

Figure 9: Maximum Depth (ft) During Fair-Weather Conditions with Only Steel Creek Dam Failing

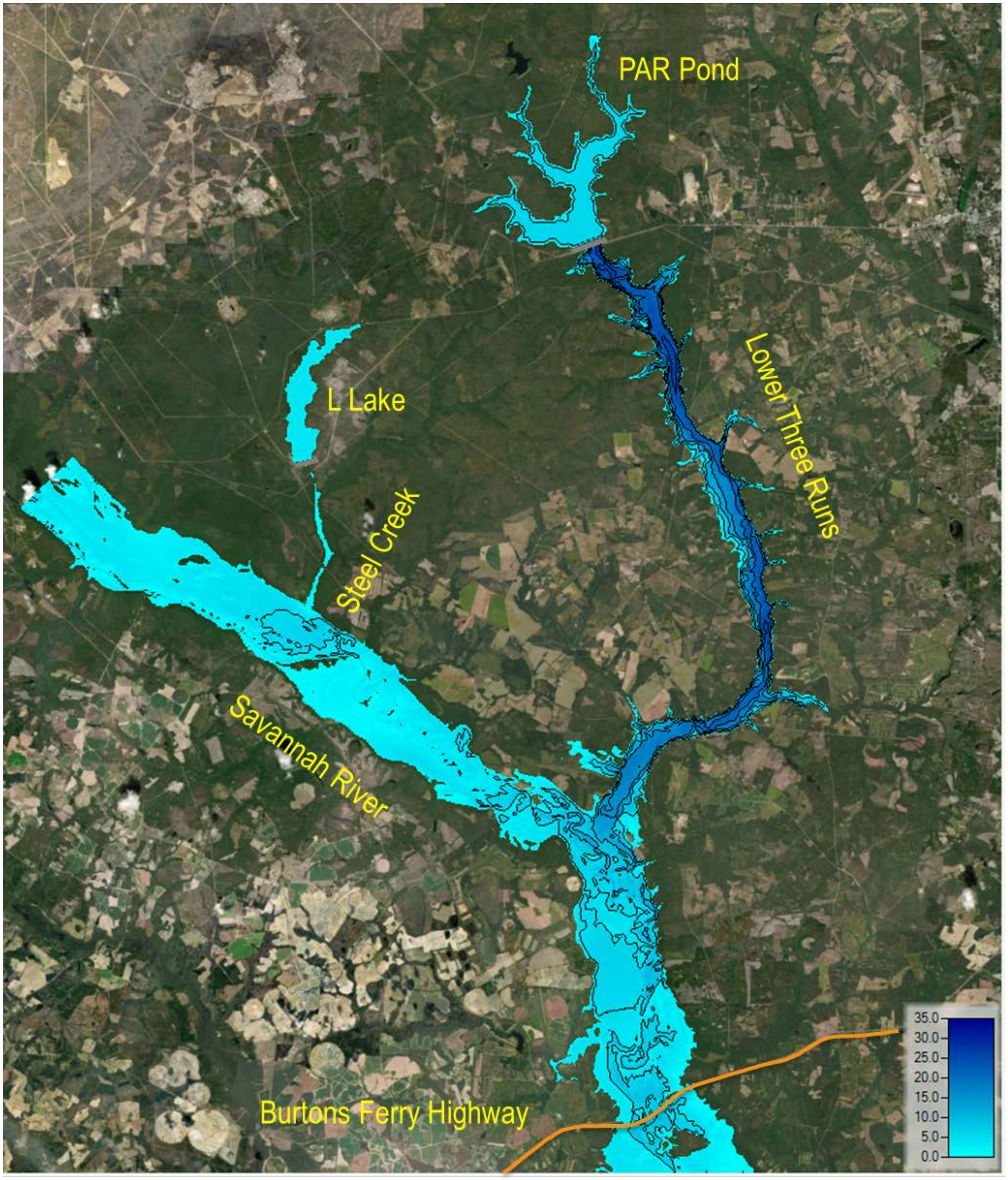

Figure 10: Maximum Depth (Ft) During Fair-Weather Conditions with Only PAR Pond Dam Failing

5. CONCLUSION

Maximum flooding occurs under PMF conditions with the failure of both dams (Figure 7). PAR Pond Dam fails first, 16 hours and 32 minutes after the start of the simulation with the Steel Creek Dam failing 6 minutes later. In all cases, the bridges and roads spanning Steel Creek and Lower Three Runs will be inundated and potentially washed away. The Burtons Ferry Highway south of the storage areas will be partially flooded during PMF dam failure, dual dam fair-weather failure, and PAR pond dam failure under fair weather conditions.

Possible future work would include adding bathometric data to current model, developing a Manning's n layer, preforming a sensitivity analysis on higher vs lower Manning’s n values, and a contaminant transport analysis.

6. REFERENCES

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APPENDIX A.

Table 1: Inflow Data for L Lake

Time (hrs)	Flow (cfs)	Time (hrs)	Flow (cfs)
0	1,000	25	2,417
1	1,500	26	2,333
2	1,700	27	2,250
3	1,900	28	2,167
4	2,100	29	2,083
5	2,300	30	2,000
6	2,500	31	1,833
7	4,000	32	1,667
8	4,500	33	1,500
9	5,000	34	1,333
10	6,000	35	1,167
11	6,500	36	1,000
12	7,000	37	942
13	11,000	38	883
14	18,000	39	825
15	52,000	40	767
16	36,000	41	708
17	20,000	42	650
18	11,000	43	592
19	5,000	44	533
20	3,000	45	475
21	2,875	46	417
22	2,750	47	358
23	2,625	48	300
24	2,500		

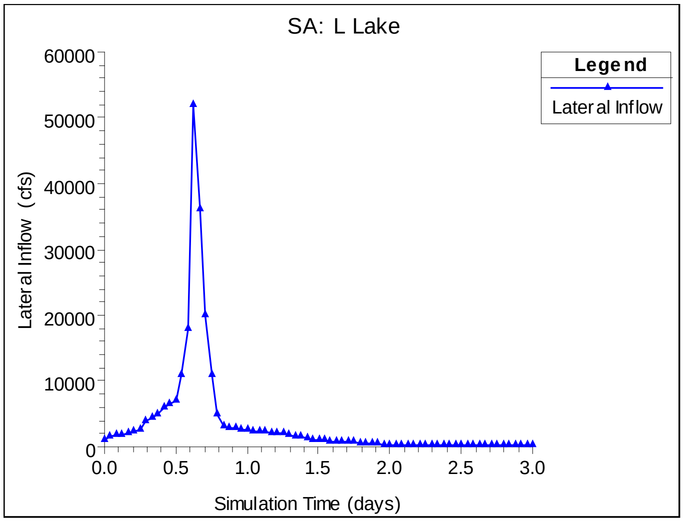

Figure 11: PMF Inflow Hydrograph to L Lake Reservoir

Table 2: Inflow Data for PAR Pond

Time (hrs)	Flow (cfs)	Time (hrs)	Flow (cfs)
0	2,500	25	5,000
1	3,000	26	4,000
2	3,500	27	3,750
3	4,000	28	3,500
4	4,250	29	3,250
5	4,500	30	3,000
6	5,000	31	2,917
7	7,000	32	2,833
8	9,000	33	2,750
9	11,000	34	2,667
10	12,000	35	2,583
11	14,000	36	2,500
12	16,000	37	2,417
13	27,000	38	2,333
14	43,000	39	2,250
15	60,000	40	2,167
16	66,000	41	2,083
17	58,000	42	2,000
18	40,000	43	1,833
19	20,000	44	1,667
20	11,000	45	1,500
21	8,000	46	1,333
22	7,000	47	1,167
23	6,500	48	1,000
24	6,000		

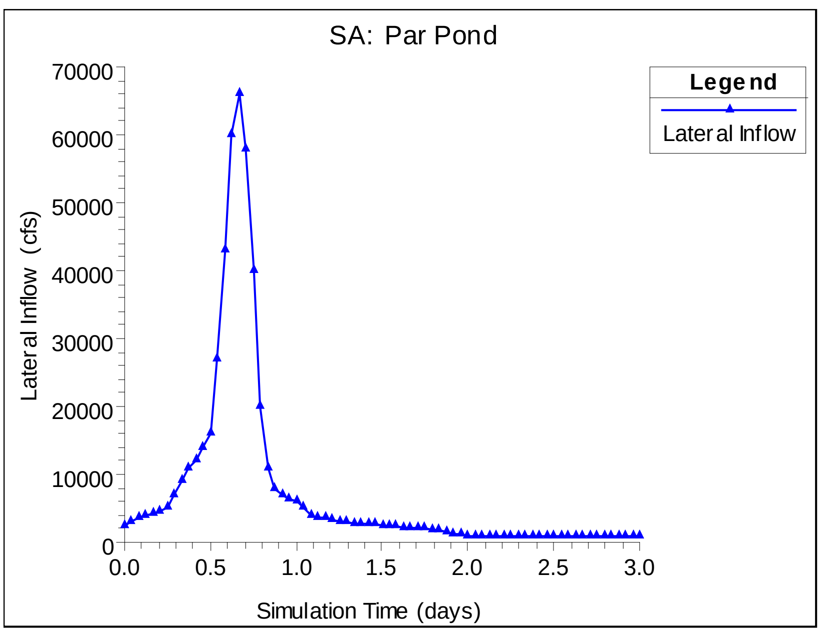

Figure 12: PMF Inflow Flood Hydrograph to PAR Pond Reservoir

Table 3: Elevation vs Volume Curve Values for L Lake

Elevation (ft)	Volume (ac-ft)
115	0
130	300
140	1,250
150	2,500
160	5,000
170	10,500
180	16,000
190	25,000
200	37,500

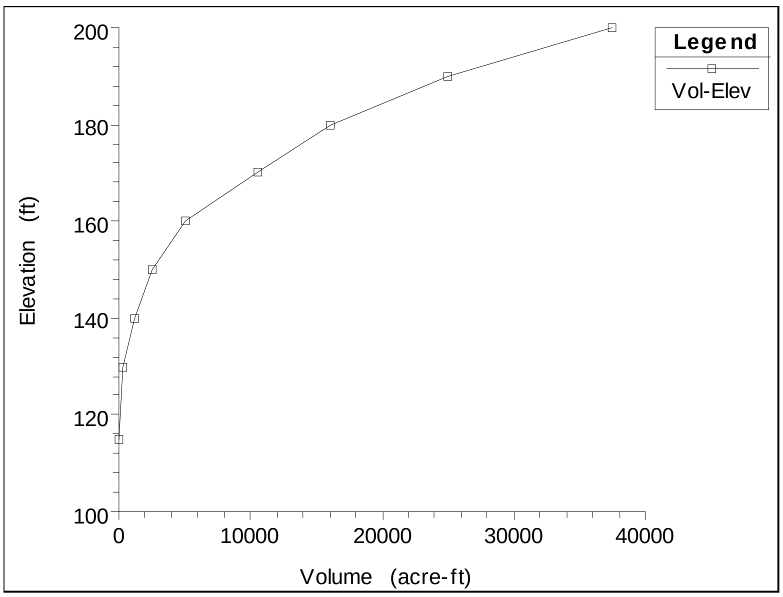

Figure 13: Elevation vs Volume Curve for L Lake

Table 4: Elevation vs Volume Curve Values for PAR Pond

Elevation (ft)	Volume (ac-ft)
144	0
150	100
160	500
170	5,000
180	17,500
190	32,500
201	60,000
208	77,500
210	85,000

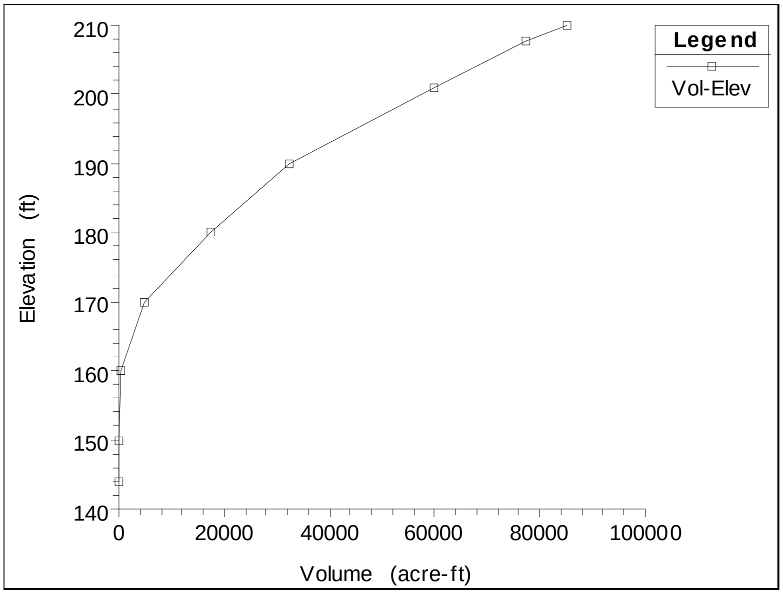

Figure 14: Elevation vs Volume Curve for PAR Pond

Table 5: Steel Creek Dam Outlet Rating Curve Values

Water Surface Elevation (ft)	Flow (cfs)
124	0
127	100
130	160
140	470
150	640
160	750
170	860
180	950
190	1,040
198	1,100

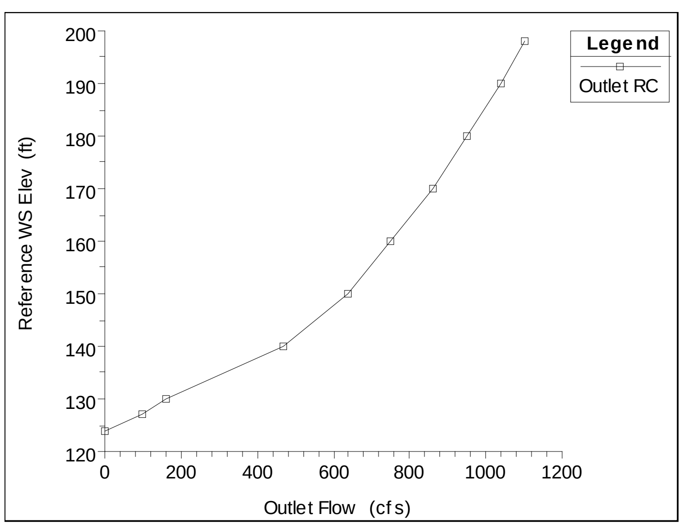

Figure 15: Steel Creek Dam Outlet Rating Curve - Fully Open

Table 6: PAR Pond Dam Outlet Rating Curve Values

Water Surface Elevation (ft)	Flow (cfs)
200	0
201	100
202	300
203	600
204	900
205	1,250
206	1,600
207	2,100
208	2,500
209	2,525
210	2,550

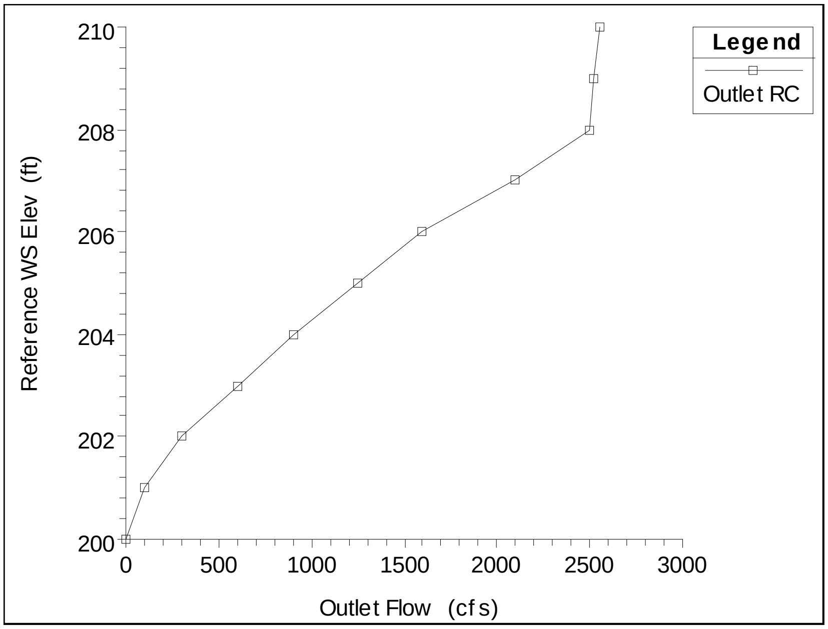

Figure 16: PAR Pond Dam Outlet Rating Curve

Table 7: Dam Geometric Information

	L Lake	PAR Pond
Dam crest elevation (ft)	200	210
Reservoir normal pool elevation (ft)	190	202
Dam base elevation (ft)	120	144
Dam height (ft)	80	66
Dam crest length (ft)	4,000	4,470
Surface area of reservoir at normal pool (ac)	1,034	2,820
Volume of reservoir at normal pool (ac-ft)	25,500	60,000
Spillway discharge at normal pool (cfs)	1,040	300

Table 8: Breach Parameters for L Lake and PAR Pond Dams

	L Lake	PAR Pond
Average width of breach (ft)	400.0	330.0
Height of dam (ft)	80.0	66.0
Bottom width of breach (ft)	380.0	313.5
Horizontal component of breach side slope	0.25	0.25
Breach formation time (hrs)	0.25	0.25