Section 4 Post Breach Survey and Estimates of Overtopping

4.1 Post Breach Survey and Estimate of Overtopping

Following the breach, the licensee conducted a crest survey of the parapet wall (Figure 4.1). This survey was conducted using the same datum as previous surveys. Both horizontal and vertical elevation data is provided from this survey on Sheet S1, prepared by KdG and is dated December 20, 2005. The licensee subsequently reported that the horizontal data on this drawing is incorrect.

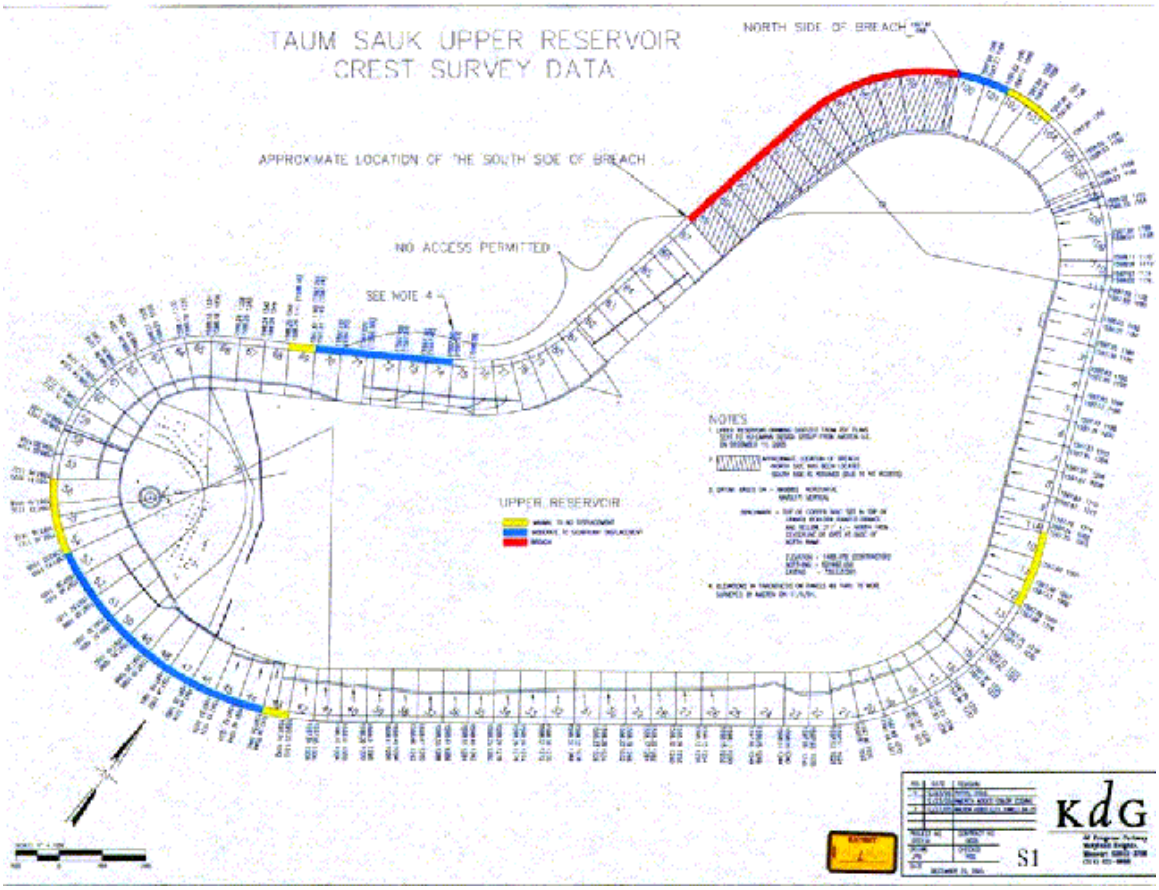

Figure 4.1 From KDG, Maryland Heights Missouri

4.1.1 Estimate of Peak Pool Elevation from Parapet Wall Elevations

Figure 4.1 shows the post breach survey and downstream damage assessment. The figure provides evident of where overtopping occurred:

Parapet wall panel	Wall Elevations	Damage Survey
• Panel 10 yellow	1597.60 -1597.70 ft	minimal to no damage
• Panel 12 yellow	1597.43 -1597.69 ft.	minimal to no damage
• Panel 103 yellow	1597.94 -1597.90 ft	minimal to no damage
• Panel 100 blue	1597.69 ft	moderate to significant
• Panel 43 yellow	1597.7 - 1597.58 ft	minimal to no damage
• Panel 49 blue	1597.2 -1597.33 ft	moderate to significant
• Panel 56 yellow	1597.79 -1597.91 ft	minimal to no damage
• Panel 69 yellow	1598.26 -1597.81 ft.	minimal to no damage
• Panel 72 blue	1596.99 -1597.15 ft	moderate to significant
• Panel 74 blue	1597.42 - 1597.80 ft	moderate to significant

From the above survey data the range of possible peak pool elevation appears to range between 1597.7 ft to 1597.9 ft.[1] (Note that the elevations referenced in this report from various surveys are assumed to be correct. No allowance for systematic error has been considered in the assessment of the overtopping event.)

Assuming a peak pool elevation of 1597.7 ft the maximum overtopping was about 0.7 ft at Panel 72, 0.5 ft at Panel 49, and 0.1 ft at Panel 10. This neglects the wind-induced waves, which may have been on the order of 0.5 foot along the north side of the reservoir on December 14.

The Overtopping in the breach area (blue zone on Figure 4.1) was estimated at two locations where the 2004 elevation data was available at the parapet wall footer survey pins. The elevations and estimate of overtopping in the breach area at the following locations:

Footer Pin 18 (Panel 90) Elev.	1587.49 ft *
Top of wall Elev.	1597.49
Amount of Overtopping	0.2 ft

[1] A peak elevation of about 1597.7 is also confirmed by two other methods. First, adding a four foot correction factor to the Druck pressure transducer reading yields a maximum level of about 1597.7 ft. Second, the HIGH-HIGH Warrick Conductivity sensor also did not get recorded on the event historian meaning the sensor did not see water at any time during December 14, 2005. Since the sensor was set at 1597.67 ft with a 60 second delay, the peak pool could have reached approximately this level.

Footer Pin 19(Panel 95) elev.	1587.39 ft*
Top of wall elev.	1597.39
Amount of Overtopping	0.3 ft

*2004 survey

4.1.2 Estimate of Volume Overpumped on December 14, 2005

AmerenUE's February 7, 2006 filing includes an analysis estimating the volume of water pumped into the Upper Reservoir from the Lower Reservoir on December 7-14, 2005. The analysis developed the volumes by two methods. The first method used pump flow and equipment data (i.e., power used by the pumps, pump curves, total head) to estimate the volume pumped into the upper reservoir. The second method used the drawdown of the lower reservoir and the lower reservoir storage curve to estimate the volume.

During the January 9-12 Site Investigation, AmerenUE staff indicated the volume estimates based on the lower reservoir storage curve were not reliable because the storage curve was not exact. For December 7-14, 2005, the estimated volume based on the lower reservoir storage was between 18 and 114 acre-ft higher than the volume based on pump flow data for each day that AmerenUE estimated.

FERC estimated the amount and duration of overtopping on December 14, 2005, using AmerenUE's volume estimate from pump flow and equipment data – with two exceptions:

(1) The starting elevation of the Upper Reservoir was based on the steady state penstock transducer reading, which should have been close to actual levels during winter months.

(2) The licensee's analysis based total head on the pump/generator units by subtracting the tailrace water level readings from the Upper Reservoir water level readings. The Upper Reservoir water level readings were about four feet lower than actual levels on December 14, 2005. Therefore, we modified the volumes to account for the higher head by the following equation:

$$\text{New Volume} = (\text{Head} + 4)^{0.5} / (\text{Head})^{0.5} * \text{Volume}$$

The following are the volume estimates for December 13-14, 2005:

Date	Time	Total Volume Pumped into the Upper Reservoir (acre-ft)	Upper Reservoir Volume (acre-ft)	Upper Reservoir Elevation Based on Volume (ft)
12/13/2005	22:36	-	1818.23	1547.8
12/14/2005	4:55	2548.11	4366.34	1596.99
12/14/2005	5:16	2617.73	Exceeds top of wall	Exceeds top of wall

Water levels (neglecting wave action) would have overtopped the low point of the parapet walls at around 4:55 am. This would result in about 21 minutes of overtopping until the dam started failing between 5:15 and 5:16 am. The total volume of water pumped into the upper reservoir above the low spot of the parapet wall would have been around 70 acre-ft. The amount of overtopping should be the total volume pumped into the reservoir minus the volume included in the storage. Assuming the maximum water level reached elevation 1597.7 ft, the overtopping volume is about:

70 acre-ft – (55 acre-ft per foot of storage * 0.71 foot of storage) = 31 acre-ft

This would result in an average total overtopping outflow of 1,070 cfs over the 21 minutes.

Referring to the wave height estimates for December 14, 2005 included in Section 8 of this report, 0.5-foot-high waves would have started overtopping the low points of the parapet wall about 8 minutes before the reservoir levels exceeded the low points of the wall.

4.2 Damage on Downstream Slope

Figures 4.2-4.12 document the different levels of damage that occurred on the embankment. The photos indicate the progression of how the embankment behaved as overtopping began and how erosion progressed with time and higher levels of flow. Damage assessments are those shown on KdG drawing S1 dated December 20, 2005 (Figure 4.1)

Figure 4.2 - Panel 10
Note grass is lain over near footing
Damage from overtopping was judged as Minimal
Estimate 0.1 ft. of overtopping

Figure 4.3 - Panel 100
Adjacent to the right side of the Breach
Note erosion at toe of parapet wall footing
Damage which was judged as moderate to significant

The elevations of Panels 100 and 101 were measured between elevations 1597.67 and 1597.82 ft (Figure 4.3). The damage at Panel 100 and 101, which was judged as moderate to severe, does not appear to agree with the estimates of the peak reservoir estimates occurring on December 14, 2005. However, wind-induced waves could have overtopped these walls by several inches on December 14, 2005. Damage may have been the result of the December 14, 2005 event and/or the September 25, 2005 wave overtopping event.

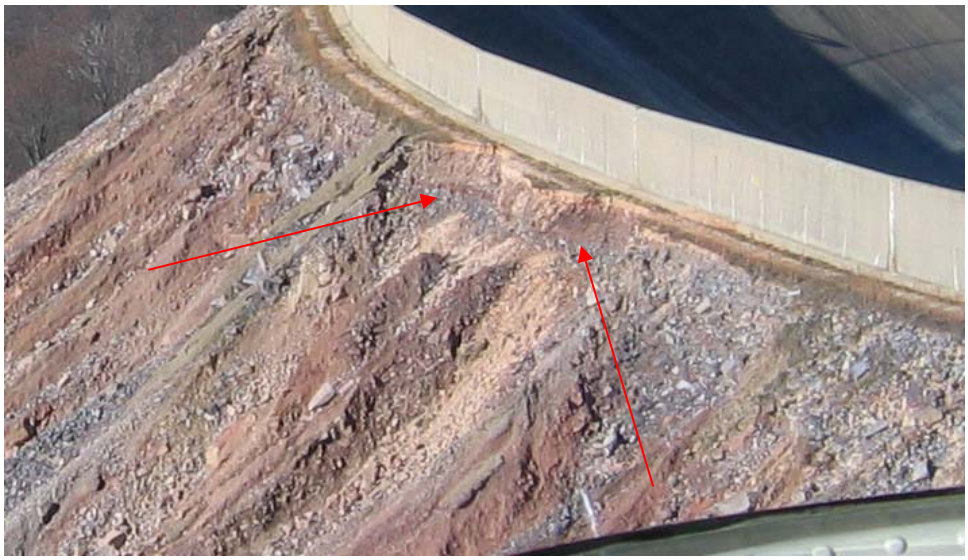

Figure 4.4 - Erosion Panel 48/49
Note scarps that may be the results of a localized slope failure
Damage judged as significant
Estimate 0.5 ft of overtopping

Figure 4.5 - Panels 48 and 49
Scarp near toe of parapet wall footing

Figure 4.6 - Panels 48 and 49
Scarp near toe of parapet wall footing
Note erosion rut adjacent to the footing

Figure 4.7 - Panel 72
Note erosion deep beneath the parapet wall
Damage judged as significant
Estimate 0.7 ft of overtopping

Figure 4.8 - Erosion at Panel 71 footing
Note the horizontal displacement between Panel 70 and 71(foreground) and bowing at the joint between Panels 71 and 72. Erosion at the footing is similar to that described during the September 25, 2005 wave overtopping.

AmerenUE's personnel identified the damage that occurred on September 25, 2005 as "ruts and trenches" adjacent to panels 90-96. The operators reported depths of 6 inches to 1 foot. The operators subsequently repaired and regraded the damage using crushed rock, with most of the rock used to repair and improve the access road. No formal procedure was used to repair the trenches and the ruts.

Figure 4.9 - Possible slope failure between Panel 100 and the full breach section

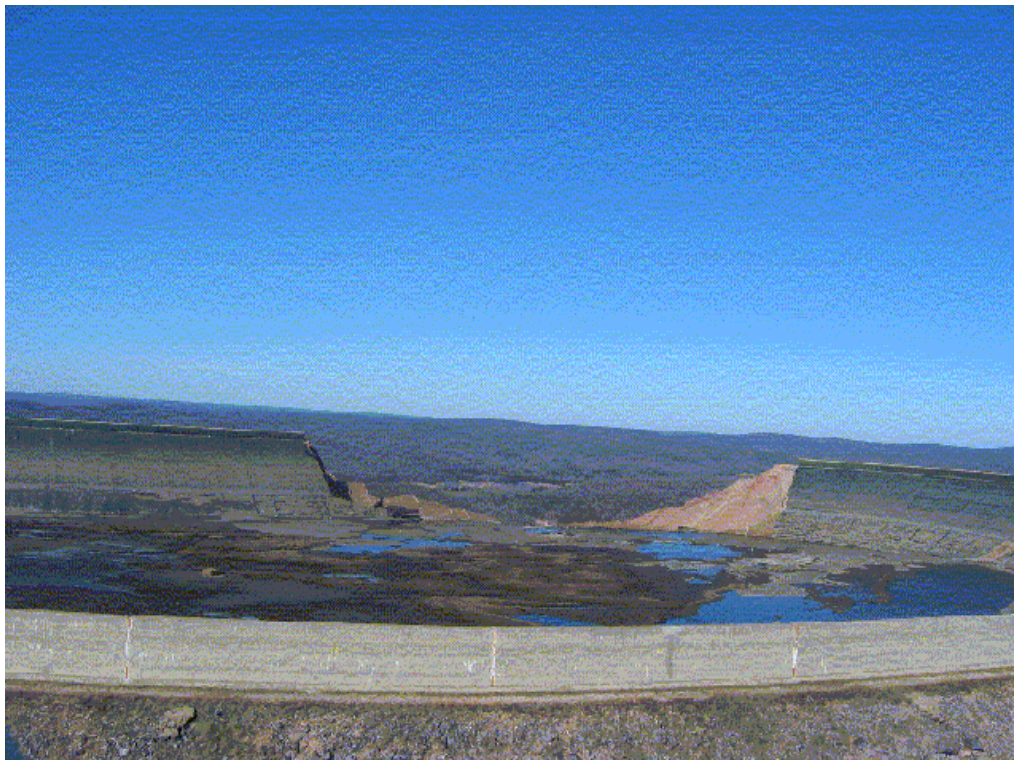

Figure 4.10 – Breach Panels 88 - 99 removed during the event Estimate 0.2 -0.3 ft. of overtopping. (Missouri DNR Photo)

Figure 4.11 - Left side of breach

Figure 4.12 - Right side of breach
Note layering of embankment