

Section 3 Historical Performance of Upper Reservoir

3.1 Settlement

Settlement of the Upper Reservoir Dam was monitored by a survey of 24 survey monuments located on the base of about every fifth parapet wall section and six monuments on the gaging station platform (Figure 3.1). The survey monuments were installed in 1962 and consist of 1/2 inch by 6 inch bolts embedded in the concrete footings of the parapet wall.

Settlement of the upper dam was measured by level survey with 0.01 foot accuracy. Annual measurements were recorded from installation in 1962 up to 1988, when annual settlement was insignificant. After 1988, surveys were performed once every four or five years. The settlement began to level off in 1975.

A correction was made early in the history of the monitoring to account for a number of pins that were damaged, reducing the elevations from the original survey. It appears that the correction that was applied may have been to add the difference rather than subtract the difference. Hence, some of the settlements shown may be slightly more than the actual settlement. Figure 3.2 shows that the primary settlement occurred prior to August 1976. Apparent movements following this time were very small from year to year and generally fall within the accuracy of the surveys. Figure 3.3 shows a more detailed view of settlement that has occurred during the past 24 years. For reference, Point 19 is within the breach area.

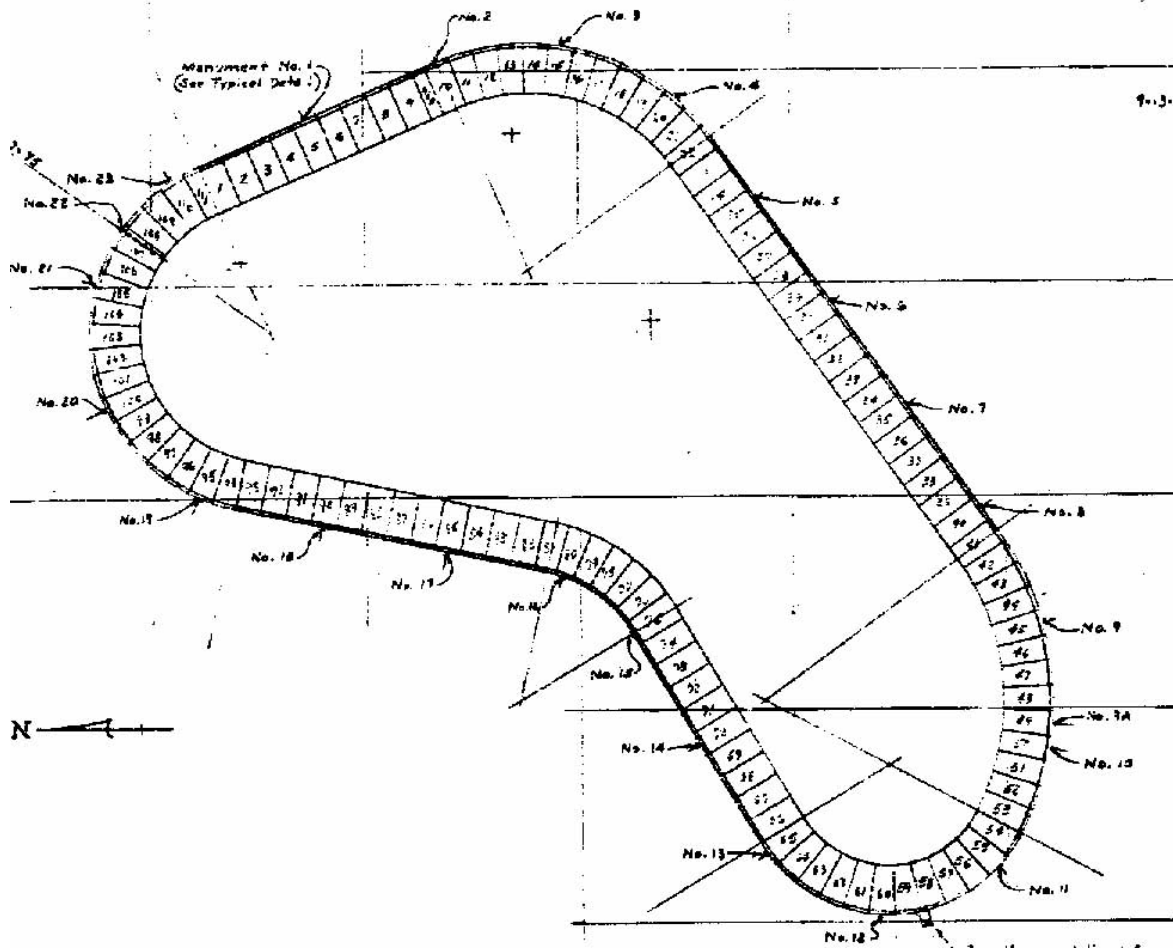


Figure 3.1 - Location of Settlement Survey Pins in Parapet Wall Footer

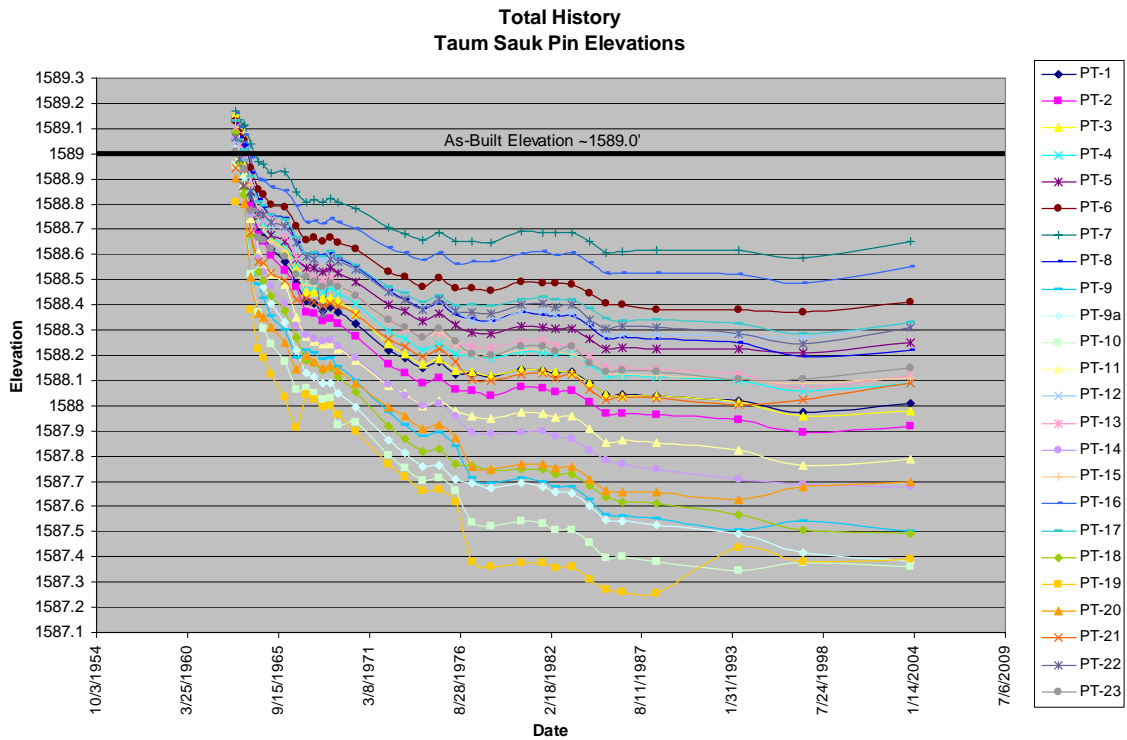


Figure 3.2 - Total History Settlement Data

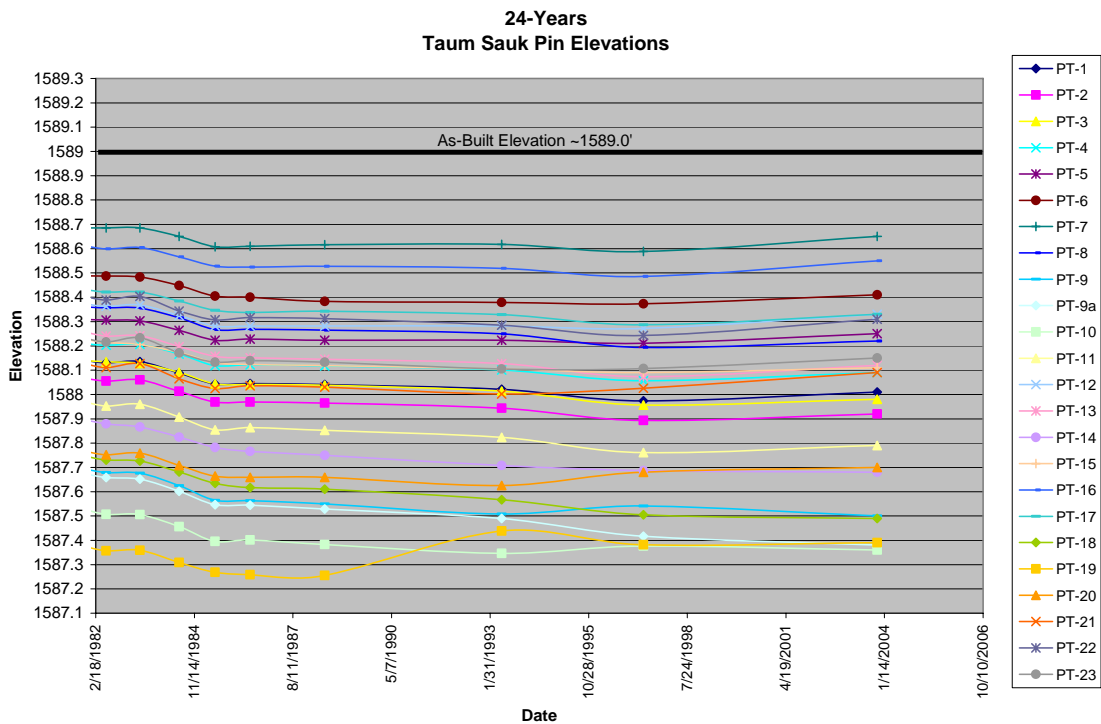


Figure 3.3 - Settlement Data 1983-2006

A crest survey was appended to the 2003 Eighth Part 12D Report after a survey was conducted in November 2003. In the 2003 survey data, it was found that some of the crest elevations were lower by as much as 0.5 foot from the previous survey. Another survey was conducted in October 2004, using the reference original datum, which is the top of copper bolt set in a granite boulder near the base of the Upper Reservoir. The benchmark used in the 2003 crest survey was taken from a different benchmark than used for all the previous survey data. The October 2004 survey data was more in-line with the previous survey data. The licensee has indicated that they used the top of copper bolt set in a granite boulder near the base of the Upper Reservoir to survey the elevations on the new staff gage and for installation of the water level instruments that were installed in 2004.

During construction of the membrane liner, the licensee obtained a parapet crest survey on November 6, 2004 in the area of panels 65-75. The purpose of this survey was to determine the minimum crest elevation of the parapet. These particular panels were chosen because the licensee believed this to be the lowest spot on the crest. The benchmark used for this survey is the top of copper bolt set in a granite boulder near the base of the Upper Reservoir. The November 2004 survey and the post breach survey shows that the minimum crest elevation in the area of panels 65-75 was at Panel 72, elevation 1596.99 ft.

Two survey pins were located in the breach area (Panels 88-99). The 2004 elevation of Footer Pin 18 (Panel 90) was 1587.49 ft. Adding 10 ft for the parapet wall, the top of wall at this location is estimated at 1597.49 ft. The 2004 survey data for Footer Pin 19 (Panel 95) was 1587.39 ft giving the top of the parapet wall adjacent to the monument at 1597.39 ft.

3.2 Crest Elongation

The crest length was originally 6,562 feet. However, in the August 19, 1967, Report on Safety, Mr. Barry Cooke notes crest elongation occurs at the dam due to the center of curvature of the dam axis in the reservoir. In that letter, Mr. Cooke stated the lengthening has been 15 inches between panels 40-67. He indicates this stretch or loosening of fill is associated with slightly higher settlement and could be visualized to cause continued settlement. It was noted that in the first Report on Safety, the five year elongation for the entire wall, based on joint opening measurements was 20 inches. In the 1973 five year report, the elongation increased another 3 inches.

3.3 Vertical Deflections of Parapet Wall

In Mr. Cooke's August 19, 1967 Report on Safety, he explained measures of vertical deflection indicate the parapet walls to be essentially plumb, the amounts out of plumb being usually 1/8 to 1/4 inch with a few at 1/2 inch. About half tilted inward and half tilting outward. The 1973 five-year report described the amounts out of plumb were in the same range. In the 2003 Eighth Part 12D Report, vertical settlement between wall segments varied from no discernable movement to about one inch at a few joints. The consultant states vertical movement at the joints was modest apparently because the rockfill settlement varied with the height of the fill and so varied gradually along the crest.

3.4 Parapet Wall Horizontal Panel Misalignment at Joints

According to Mr. Cook's August 19, 1967 Report on Safety – "Joints (between parapet walls) were originally constructed to 1 inch open. Most have opened due to the curvature of the axis. The amount of opening has been 1/4 to 1/2 inch except for about 10 of the 111 joints which have opened more than 1 inch. Joints approaching 2 inches require an inner seal to be installed." Many types of expansive joint materials have been placed between adjacent parapet wall panels and between the panels and the upstream concrete face slab since the project was constructed. The joints were provided with U-shaped copper water stops during original construction.

In the August 19, 1967 Report on Safety, Mr. Cooke explained offsets in March 1966 were on the order of 1/4 inch **with several** joints near Panel 88 at 1-1.5 inches. Later in September 1966 the movements were generally 1/8 to 1/4 inch with nearly half in the direction of the offset. He stated there was no indication of trouble developing in these small and in many cases restoring movements.

According to the 2003 Part 12D Report, the consultant states horizontal movement included rotation and translation of the wall joints. The report states:

"The maximum horizontal movement observed was at joints 89/90 and 106/107, with about 4-5 inches of translation and rotational movement. Photograph 3 (*of the report – see below Figure 3.4*) shows panel 90 having moved downstream relative to panel 89. The copper waterstop was visible in the joint. This magnitude of movement is likely sufficient to tear the waterstop, but probably does not affect the wall stability."

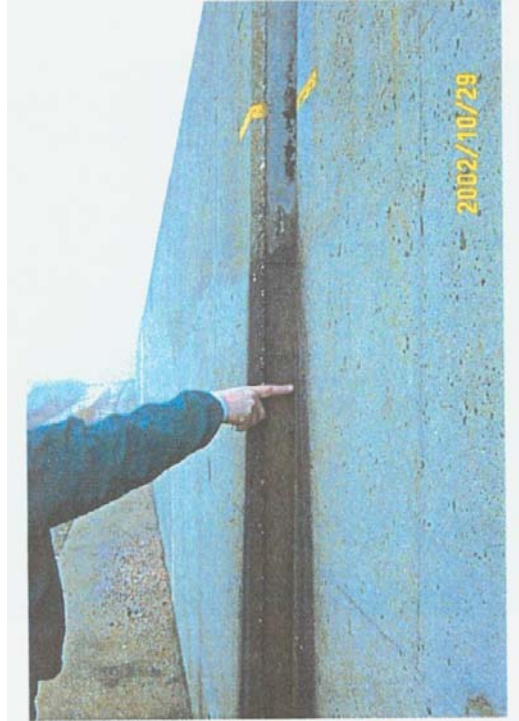


Figure 3.4- Movement at Upper Dam Parapet Wall at Joint 89/90 from 2003 Eighth Part 12D Report

3.5 Parapet Wall Cracking

There are slight vertical cracks in the central area and in the lower one-half of nearly all parapet walls. In Mr. Cooke's August 19, 1967 Report on Safety, he describes the cracking as about 10 feet spacing that start at the bottom and stop near the top and center, indicated high compressive stress. He stated the cracks are not structurally significant. He conjectured that shear at the base of the wall has caused slight movement and leakage in the Panel 10-25 area, in combination with a poor cold joint. He states it is probable that the redistribution of water load on the rock by the stiffness of the wall and its base will keep relative settlement compatible with the stresses in the parapet wall and base slab.

In the 1973 five year report, Mr. Cooke refers to the cracks as thin vertical shrinkage cracks that do not leak.

In the 2003 Part 12D report, the consultant states the parapet wall appeared to be generally in good condition, with some minor crack as would be expected. The exception was from panel 3 through panel 20, where the downstream side was cracked and spalled in a rectangular pattern, apparently at the rebar and due to insufficient cover. This entire section was reinforced with a thickened wall

section during construction; therefore, the cracking and spalling do not appear to be a concern.

3.6 Leakage

Leakage through the reservoir floors, walls, and penstock valve seals was a problem from the first day of operation. The leakage has been reported to be clear of sediment in all the reports that we have reviewed that document the status of the leakage. Early investigations focused on potential leakage in the vortex area floors and shaft. A number of repairs were made through subsequent years focusing more on leakage through the horizontal and vertical joints in the concrete facing. Particular emphasis was on the joints between the concrete facing and bedrock, the joint at the toe of the parapet section, and the joint between the concrete facing and plinth.

Higher rates of leakage began in 1999 following an extended outage. A geomembrane liner was subsequently installed in 2004, which significantly reduced the leakage for the 12 months prior to the breach. Figure 3.5 shows the history of leakage and the periods of repairs (illustrated by periods of zero leakage).

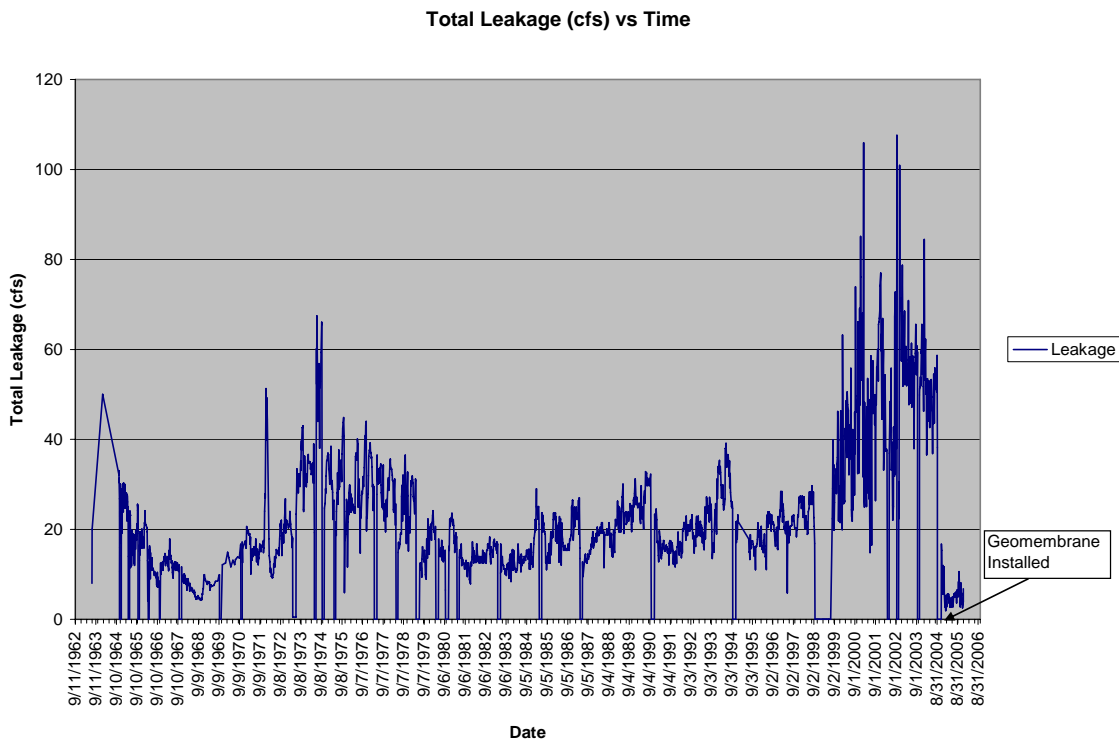


Figure 3.5- Historical leakage Rates

Leakage was historically concentrated in the area of the “fish pond”, and near panel 72, and at a number of areas scattered along the east side of the reservoir. In 1963, a 2 to 8-foot-deep concrete cutoff was installed at the fish pond near panels 90-102. A grout curtain was also installed in the fish pond area to stem leakage through the bedrock foundation. Specific areas and characteristics of the leakage are discussed in the 2003 FERC Operation Inspection Report, at the time the leakage was greatest.

There were no significant trends between pool elevation and leakage rate for reservoir operating ranges above 1589 (Figure 3.6). However, total leakage appears to drop rapidly when the reservoir elevation was dropped below 1540 feet.

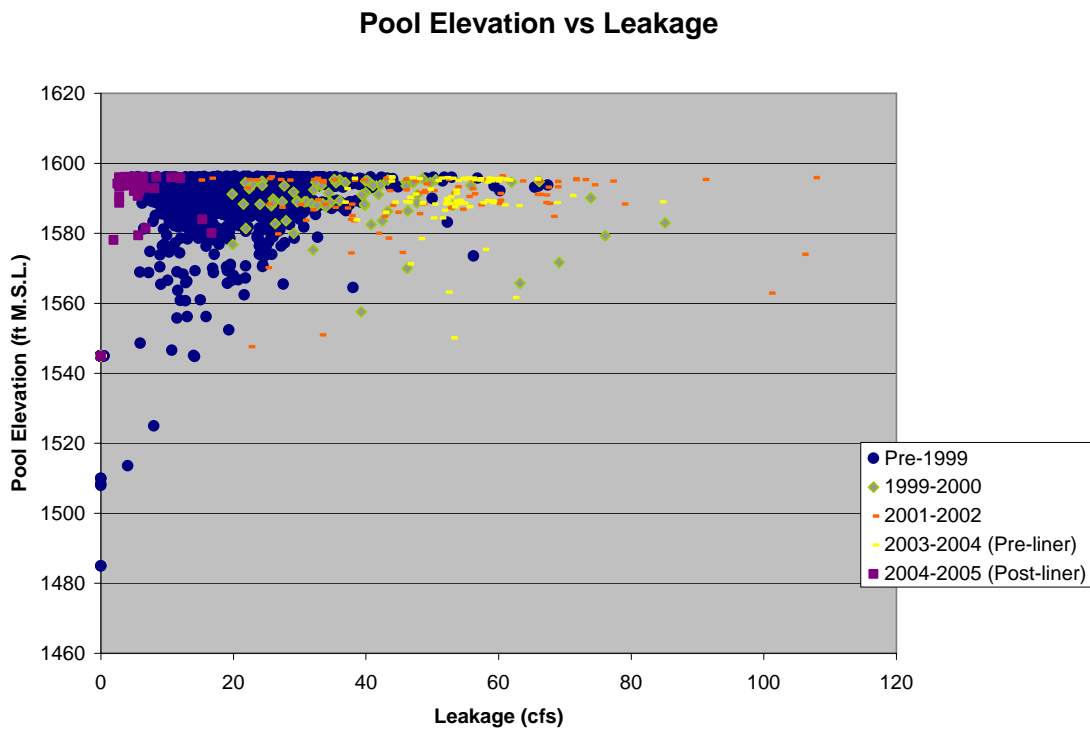


Figure 3.6- Leakage verses Upper Reservoir Pool Elevation



**Figure 3.7 - Concentrated Seep Before liner installation
(2003 FERC Operation Inspection Report)**



**Figure 3.8 - Overflow of the seepage collection Pond before liner installation
(2003 FERC Operation Inspection Report)**