`Channel Response to Dam Removal, Clear Creek, California

Peter Miller and Pilar Vizcaino

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Abstract

Clear Creek drains 720 km^2, joining the Sacramento River south of Redding, California. The 4.6-m high Saeltzer Dam blocked upstream migration of chinook salmon (*Oncorhynchus tshawytscha*) since it was built in 1912 to divert water for irrigation. Saeltzer Dam was removed in 2000 to restore anadramous fish access to upstream reaches. Before the dam was taken down, 19,000 m^3 of sediment stored behind the dam was mechanically removed, but substantial deposits remained. A 2001 survey (Stillwater Sciences and University of California Davis 2001) detected little change over the 2001 flow season (peak flow 35 m^{3}s^{-1}). We resurveyed the channel in 2003 (peak flow 130 m^{3}s^{-1}). Our survey documented post 2001 incision of more than 1 m, over about 320 m upstream of from the former dam site to an active headcut, and lateral erosion of 15-18 m, for total erosion of over 39,750 m^3 from the former reservoir deposit. The incision has led to desiccation of riparian trees (mostly *Alnus spp*.), with over 50 trees visibly dead or dying. Lateral bank erosion has also removed many trees.

I. Introduction

Over the past decade, increasing public support and funding for restoration of salmon stocks has led to the removal of a number of small dams in California and elsewhere. A stronger scientific understanding of the geomorphic response to dam removal is needed to help guide policy decisions. (Heinz Center 2002)

Saeltzer Dam on Clear Creek was a good candidate for removal as a small diversion dam that blocked migration for salmon to 10 miles of upstream spawning habitat. In 2000 it was demolished and 19,000 m^3 of accumulated sediment was removed. A post-project assessment was conducted in 2001 to assess potential effects of sediment transport and deposition in Clear Creek (Stillwater 2001). We returned to the site in 2003 to assess geomorphic changes to the site over a longer period.

II. Background

Clear Creek is 56-kilometer long tributary to the Sacramento River originating in the Trinity mountains between the Trinity River and the Sacramento River basins (Figure 1). With a drainage area of 720 km^2, Clear Creek is the first major tributary to the Sacramento River downstream of Shasta Dam.

The second discovery of gold in California occurred along Clear Creek in 1848 at a location less than one mile upstream from the site of Saeltzer Dam. Subsequently, there was extensive stream channel and floodplain gold dredging throughout the late 1800's and early 1900's. Mining operations transformed the natural landscape into piles of placer, hydraulic, and dredge tailings (NSR/McBain 1999).

Saeltzer Dam was located along lower Clear Creek approximately six miles upstream from the confluence with the Sacramento River. Completed in 1912 to divert water for agriculture and cattle ranching (Bureau of Land Management 2000a), the dam was approximately 15 feet high and 200 feet long.

The next significant impact to lower Clear Creek was the Central Valley Project's (CVP) Trinity River Diversion. Completed in 1963 at a location 10 miles upstream from Saeltzer Dam, Whiskeytown Dam eliminated coarse sediment contributions to lower Clear Creek and greatly reduced the volume and magnitude of historical flows. Instream and off-channel aggregate mining downstream of Saeltzer Dam began in 1950 and continued through 1978. Several hundred thousand cubic yards of aggregate were removed from the lower creek, destroying the bankfull channel and in some areas completely removing the floodplain (NSR/McBain 1999).

In the 1950's, Saeltzer Dam was identified as a principal barrier to fish migration. A variety of approaches to improve fish passage were constructed, including a fish ladder and tunnel, but none proved successful. During the late 1990's, under pressure from both state and federal agencies, negotiations to provide alternate water supplies for Saeltzer Dam users proved successful. Plans for complete removal of the dam were finalized in 2000.

Preparations for the removal of Saeltzer Dam began in July of 2000, including construction of a temporary cofferdam to divert flows around the reservoir and construction area, a diversion channel along the left bank, and a 100-meter wide gravel buttress on the downstream toe of the dam to provide for both support of the dam structure during removal and access for heavy equipment. Approximately 19,000 m^3 of accumulated sediment were excavated from behind the dam to reduce the volume of sediment available for post-dam redistribution, to avoid downstream channel aggradation in a restored reach, to reduce potential free sediment deposition in spawning gravels and to encourage rapid re-establishment of a functional channel gradient (BLM 2000).

The removal of Saeltzer Dam was one of several projects under the Lower Clear Creek Coordinated Resource Management Program (CRMP). Other CRMP projects include introducing spawning gravels into lower Clear Creek, implementing erosion control programs, reducing fuels within the watershed, and the Lower Clear Creek Floodway Rehabilitation Project, in which the channel and floodplain are being rebuilt in reaches disrupted by gold and aggregate mining. Planning and implementation of the Lower Clear Creek CRMP have primarily been funded through the CVP Improvement Act and the CALFED Bay Delta Ecosystem Restoration Program.

In spring 2001, following the first post-dam runoff season UC Davis and Stillwater Sciences surveyed post-dam channel morphology and sediment redistribution and applied a sediment transport model to predict the movement of sediment from the former dam site (Stillwater 2001). In spring 2003, we conducted a one-day field survey of the Saeltzer Dam site to evaluate geomorphic changes since the Stillwater study. We found evidence of significant erosion, incision, and riparian mortality, which we attributed to the high flows in December 2002

(Ferry and Miller, 2003). Following our early April surveys, late spring rains produced extended high flows exceeding in duration 2,800 cfs for 46 hours and peaking at 3,700 cfs on April 29.

II. Methods

In two site visits (September 20-21 and October 18, 2003), we surveyed 5 cross sections and a long profile of the thalweg and water surface from the dam site upstream for approximately 380 meters using level and rod. We monumented the location of our cross section end points and turning points with paint, rebar stakes, and/or large nails in tree roots (Figure 2). For a benchmark, we used the upstream (western) corner of a large concrete box on the right bank just upstream of the dam site.[1]

We scanned aerial photos from the Western Shasta Resource Conservation District and Natural Resource Conservation Service in Redding for 1998 (the latest year prior to removal for which photos were available) and summer 2003. We then georeferenced these photos using topographic maps and located our survey benchmark.

In order to estimate the volume of sediment eroded from the site, we compared the 1998 and 2003 aerial photographs in Arcsoft and used the program to estimate the area of sediment eroded. We estimated an average height of the eroded material from bank heights in the surveyed cross sections and from our field measurements and calculated volume eroded as the product of the area and the bank height at the midpoint of the eroded area.

III. Results

In the upstream 285 meters of the former reservoir, the channel is a shallow channel with a broad gravel bar backed by a steep bank on the left and an abandoned high flow channel on the right (Figure 2). The high flow channel ends at 285 meters and from there to approximately 450

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[1] The box appears to have been the upstream end of the fish tunnel.

meters upstream the gravel bar shifts to the right bank while the channel remains largely broad and shallow.[2] Since dam removal, the left bank has eroded 10-20 meters as shown on cross section #1 (Figure 3).

Comparison of long profiles and cross sections from May 2001 and April 2003[3] show post-dam incision of up to 1.5 meters, decreasing as one moves upstream from the dam site. The lack of a bed profile immediately following dam removal makes it difficult to draw more specific conclusions.

Figure 9 is an aerial photograph of the site with the principal areas of erosion shaded to show their lateral extent. Area A is immediately upstream of the former dam site on the left bank. The spatial extent of Area A is 5,306 sq. meters. The bank height along the left (north) edge of Area A declines fairly linearly from 4.43 meters at cross section 1 to 1.98 meters at cross section 4. (Figure 10) Because slope is relatively smooth and the distribution of Area A is balanced over this distance, we assumed a linear slope between the endpoints and used the average of this range as an estimate of the average height of the eroded volume. [4] This approach produces an average height of 3.2 meters. Simple multiplication of the area and the average height produces an estimate of eroded material of 17,006 m^3.

The other principal area of erosion, Area B, is also on the left bank beginning approximately 300 meters upstream of the dam site. The spatial extent of Area B is 6,631 square meters. We surveyed a single cross section near the midpoint of Area B. Because the bank height along cross section 5 is near the midpoint and is close to the average of the two ends, we

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[2] There is a single approximately 4 meter deep pool against a bedrock bank from approximately 290 to 300 meters upstream of the dam.

[3] Unfortunately, no previous profile of the thalweg is available. The water surface elevation varies in part due to changes in the level of flow.

[4] A simple average of the bank heights from cross sections 1-4, is slightly lower at 2.93 meters, but the cross sections are more heavily weighted to the smaller end of the eroded area.

used this height to estimate the volume of sediment underlying Area B. The bank height along cross section 5 is 3.43 meters, resulting in an estimated volume of 22,744 m^3.

Based on these calculations, we estimate the total volume of sediment eroded to be 39,750 m^3. This estimate is conservative because it excludes any eroded sediment outside the boundaries of these two areas. In particular, we have excluded any sediment from incision into the streambed.

Based on a survey of sediment composition prior to dam removal, Stillwater estimated that 40% of the reservoir deposit was finer than 2 mm (Stillwater 2001),[5] which implies that these two deposits included approximately 16,000 m^3 of sand.

IV. Discussion

While little erosion was observed in the first post- project appraisal following dam removal, our analysis of aerial photographs and field observations clearly show that a large volume of sediment has been washed downstream from the reservoir site since May 2001. We attribute the delayed response to the lack of large flows in the first winter following dam removal and the extant riparian vegetation which increased bank cohesion. In contrast, the high flows of December 2002 and April 2003 mobilized the large volumes of unconsolidated sediment and significantly changed the channel topography.

Our estimate of eroded sediment is significant relative to channel morphology downstream and nearly an order of magnitude larger than volume that was estimated to be available.[6] By way of comparison, it is interesting to note that since Saeltzer Dam was removed,

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[5] Based on a visual inspection of bank sediments near cross section 2, we estimated that 15-25% of the sediment at that location was finer than 2 mm. These estimates are not necessarily inconsistent since the reservoir sediment distribution was coarser upstream and finer downstream.

[6] Stillwater Sciences estimated that only 5,900 yd^3 (4,500 m^3) of sediment was available for downstream transport. (Stillwater 2001, p.1)

there has been deposition of approximately 0.5 - 1 meters of relatively fine sediment downstream at Renshaw Riffle, which in the past had large areas of productive spawning gravel. Without tracer studies, it is impossible to determine whether the erosion at the Saeltzer Dam site is responsible for the aggradation at Renshaw Riffle. However, it is worth noting that the volume of sediment eroded from the Dam site is substantially larger than the deposition at Renshaw. For example, a simple geometric calculation shows that the 16,000 m^3 of fine sediment that we estimate has been eroded from the dam site could add over 0.5 meters of sediment deep across a 30-meter wide channel along a 1 km reach of the river. In contrast, the deposit at Renshaw appears to be approximately 300 meters long with a total volume of perhaps 3,000 m^3.[7]

The study conducted in 2001 following dam removal developed a sediment transport model to assess potential geomorphic and ecological effects of sediment deposition and elevated total suspended solids (TSS) levels in Clear Creek following dam removal. However, this study concluded that the volume of sediment remaining was too small to be modeled relative to background sediment transport conditions which were estimated to range from 0.003 to 11,000 tons/yr. (Stillwater 2001) In contrast, we found that the volume of remaining available sediment at the reservoir site was significant with respect to the background rate.

V. Conclusion

Two and a half years after the removal of Saeltzer Dam, we found the channel reach upstream of the former dam to be in a state of active modification. Erosion of unconsolidated banks, channel widening, and incision of the streambed are evidence of Clear Creek's adjustment to post-dam conditions.

These changes were not yet evident after the first period of winter flows. Instead, our study suggests that the remnant riparian vegetation, which helped to stabilize newly exposed

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[7] Based on a comparison of the five cross-sections available.

banks, and insufficient high flows in the months following dam removal, delayed the initiation of channel adjustment that we documented two years later. Future changes to channel morphology are also likely to depend on the magnitude of future high flows and the status of riparian vegetation.

The changes within our study site appear to be generally beneficial. Moreover, the removal of Saeltzer Dam has had the enormous benefit of opening up an additional 10 miles of spawning habitat. However, the extensive erosion that we documented has undoubtedly resulted in the movement of a large volume of sediment to downstream locations, with potential negative (though likely temporary) repercussions to habitat downstream.

We expect that further erosion of sediment will occur in future high flows. However, because the supply of accumulated sediment is finite and substantially depleted the rate of fine sediment transport should diminish over the next few high flows.

VI. References

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The Removal of Saeltzer Dam on Clear Creek: An Update, Water Resources Library, U.C. Berkeley, June 2003

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Dam Removal: Science and Decision Making, The Heinz Center for Science, Economics, and the Environment, Washington, D.C. 2002

NSR/McBain and Trush/Matthews &Associates 1999
Clear Creek Rehabilitation Project Design Document; June 19, 1999.

Stillwater 2001
Comparison of predicted and observed geomorphic changes following the removal of Saeltzer Dam: Task 6 Deliverable Report. Stillwater Sciences, Berkeley, CA. June 2001

Figure 1: Regional Map

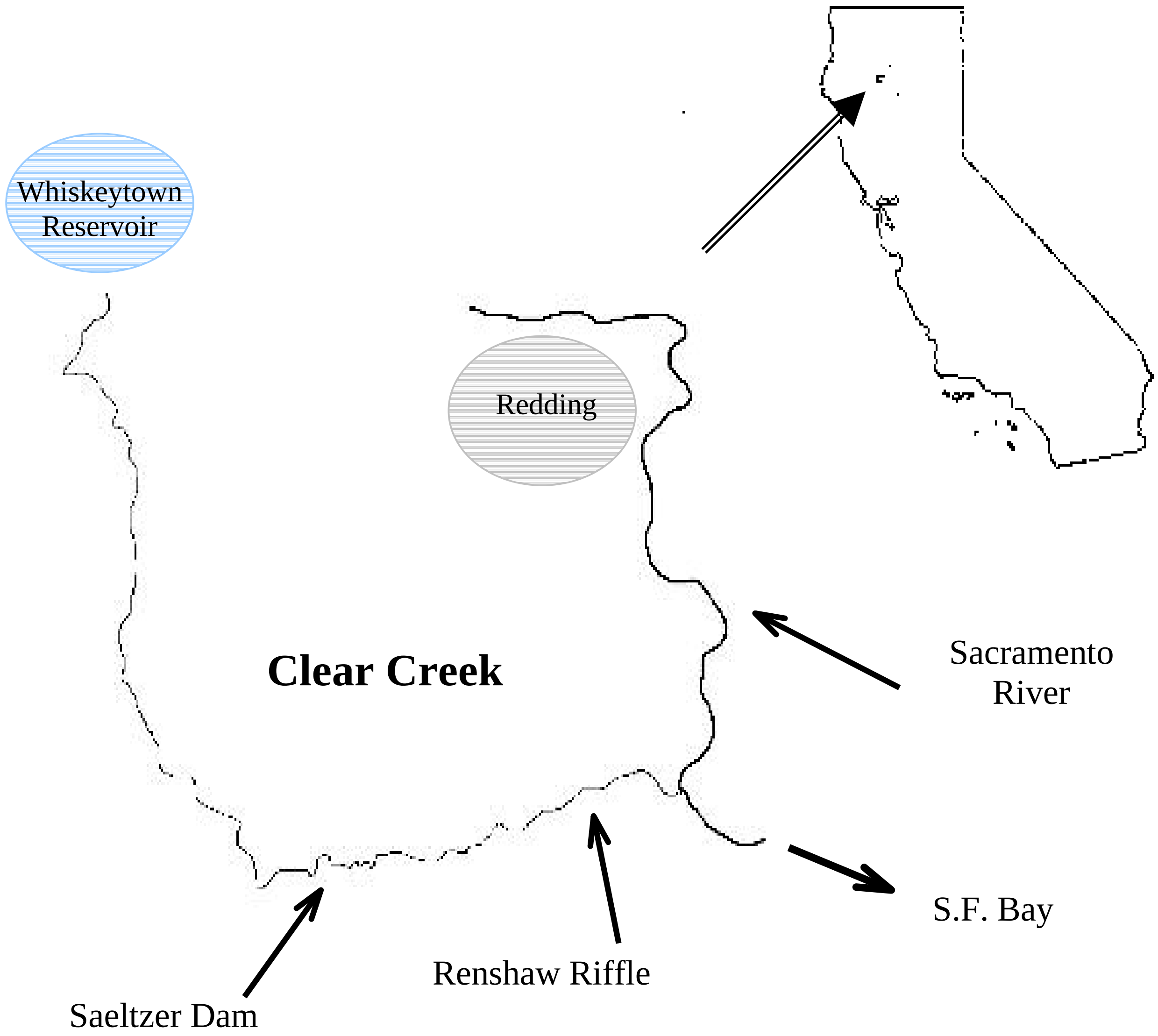

Figure 2: Site Map

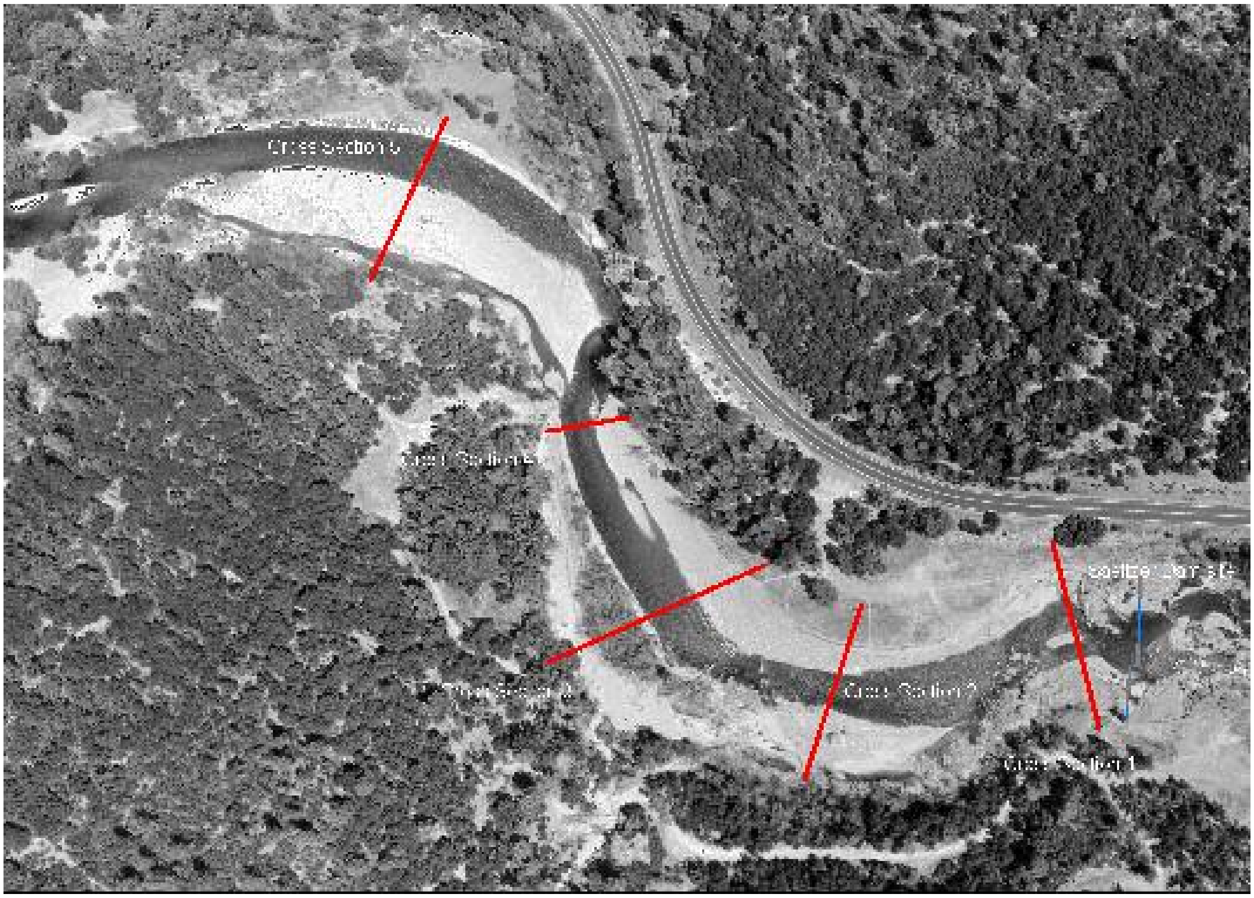

Figure 3: Cross Section 1

Figure 4: Cross Section #2

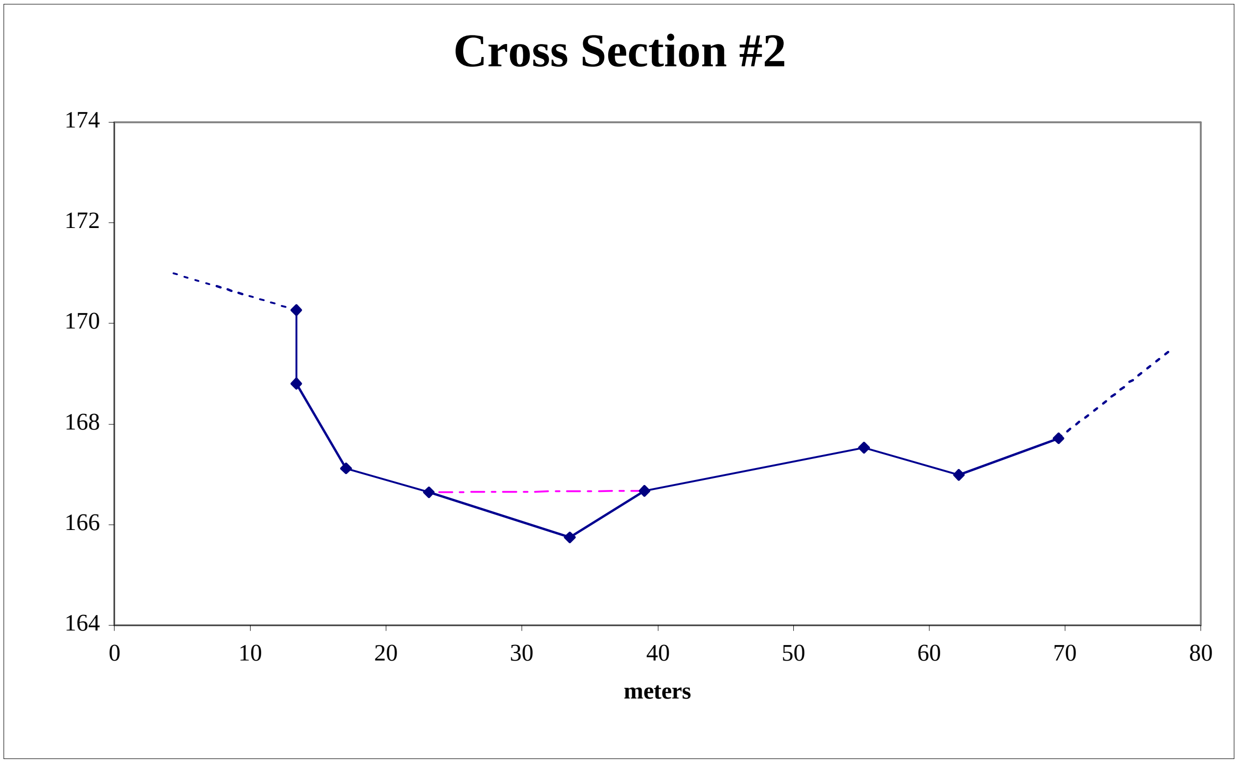

Figure 5: Cross Section #3

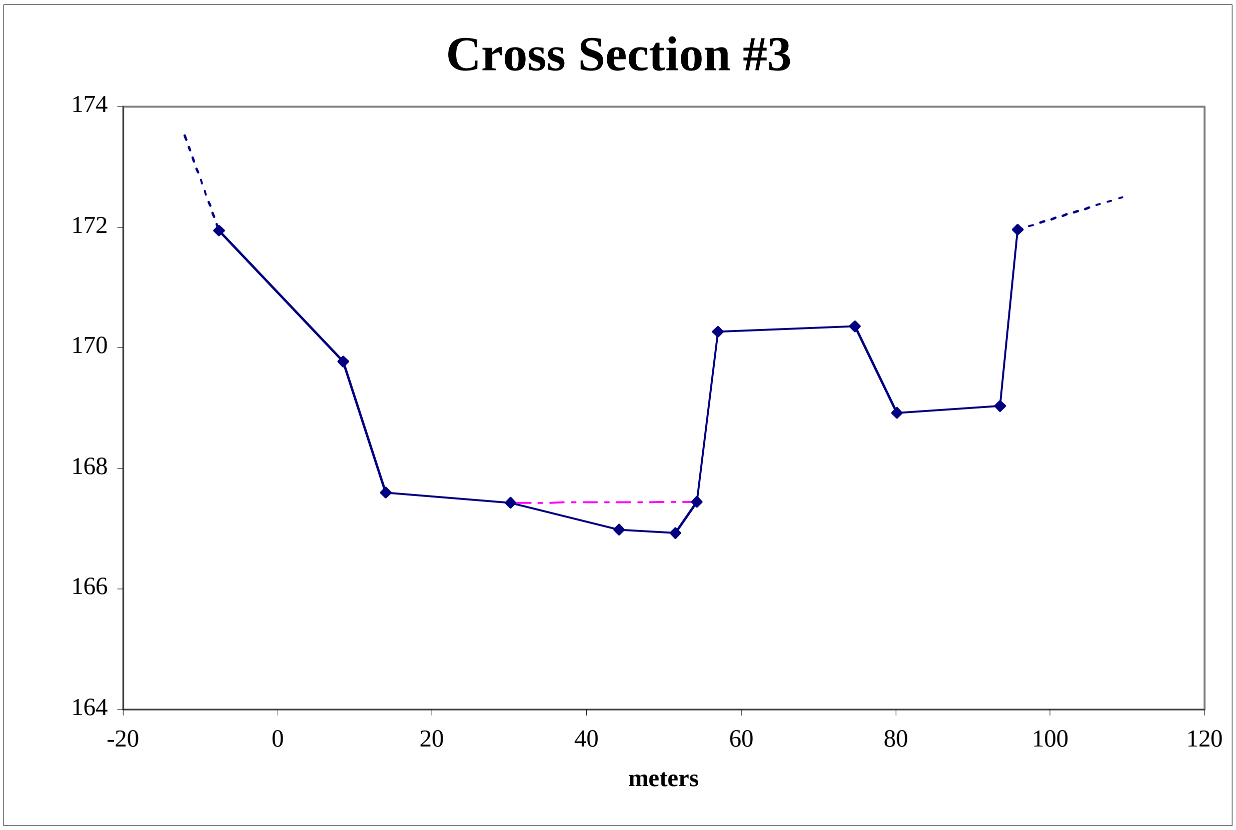

Figure 6: Cross Section #4

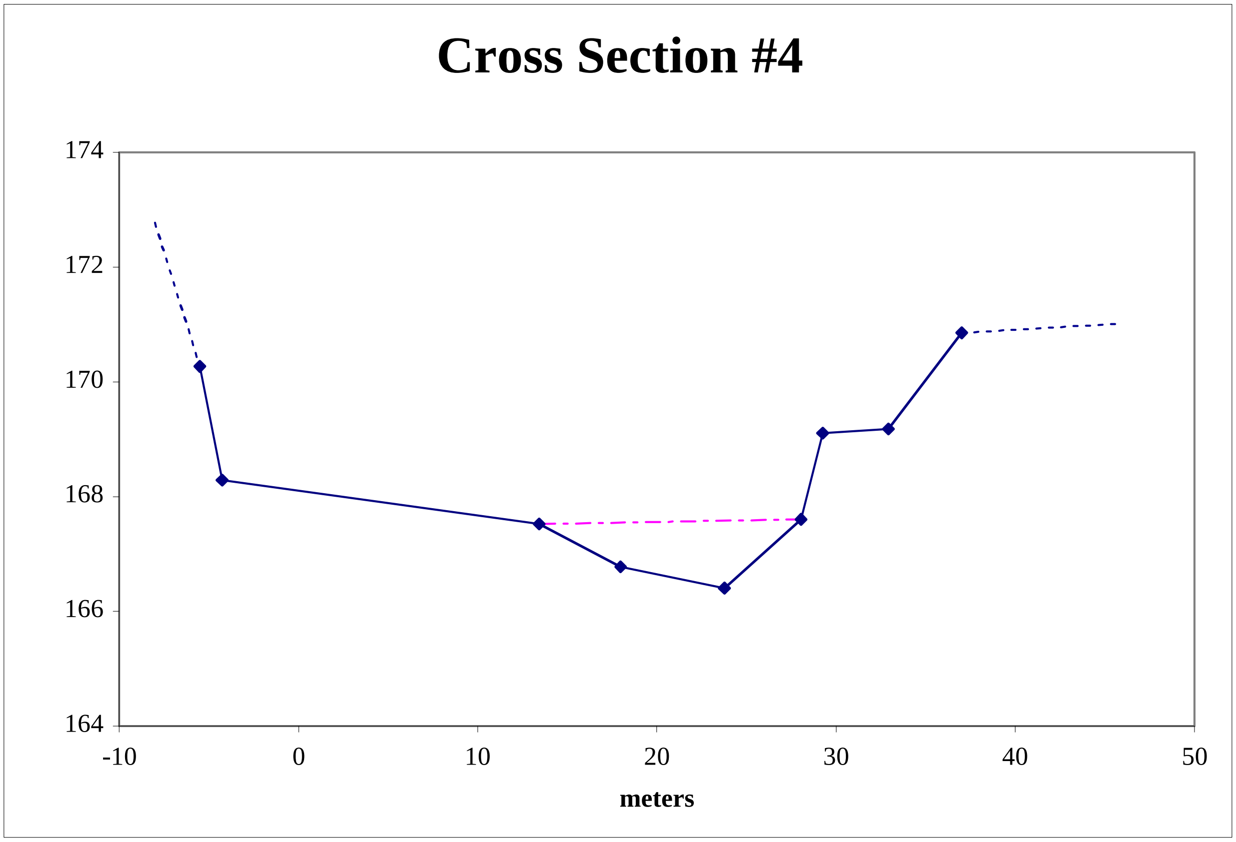

Figure 7: Cross Section #5

Figure 8: Long Profile

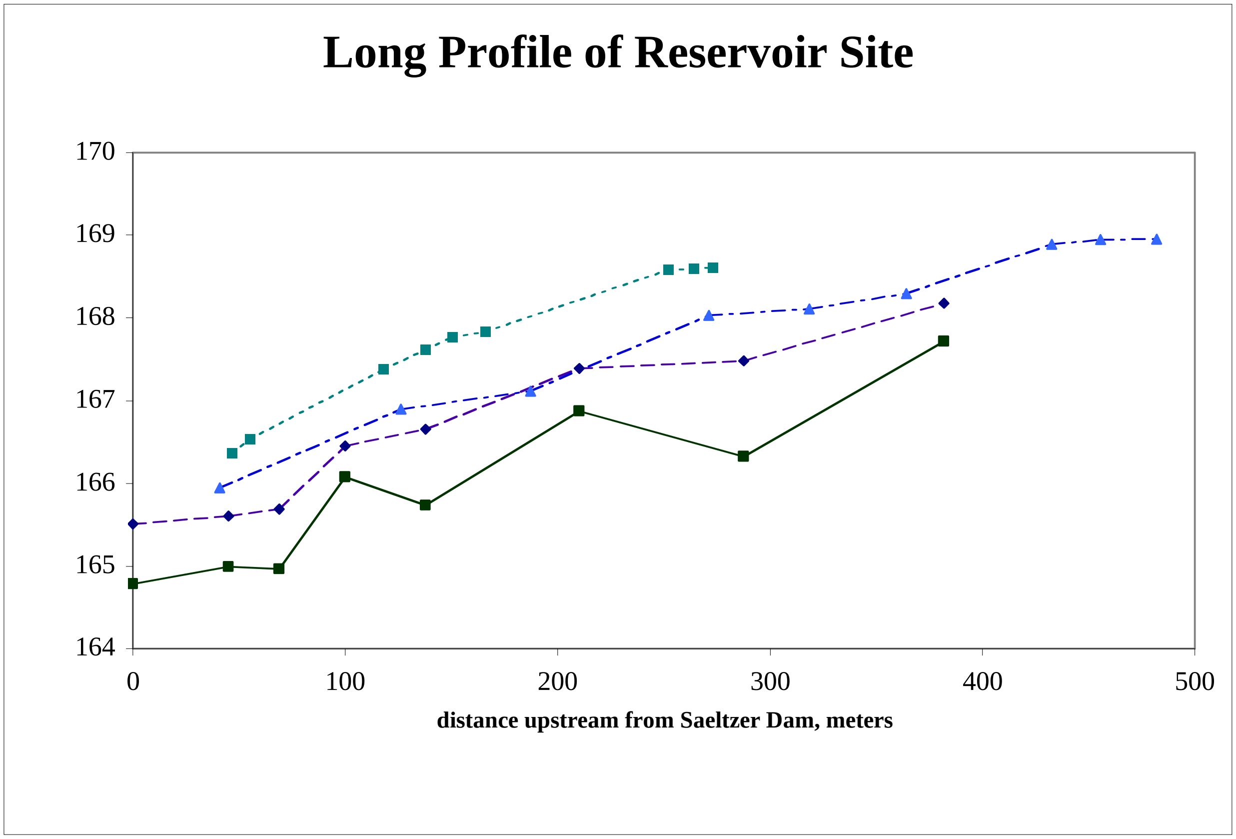

Figure 9: Aerial Photo of Reservoir Site with Areas of Erosion

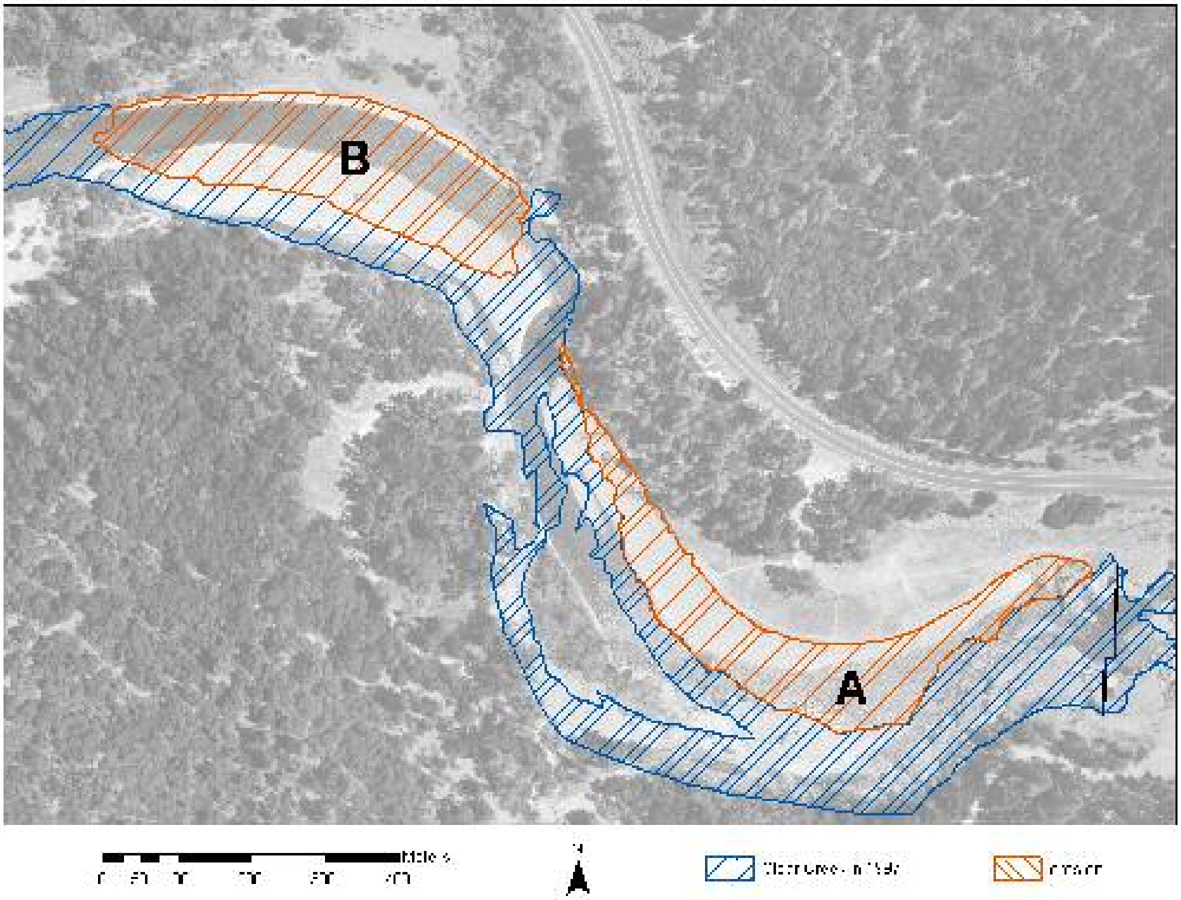

Figure 10: Bank Height for Area A