The Removal of Saeltzer Dam on Clear Creek: An Update

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June 2, 2003

Summary

In October 2000, Secretary of the Interior Bruce Babbitt and California Secretary of Resources Mary Nichols joined in a symbolic ceremony to begin the removal of the 90-year old Saeltzer Dam on Clear Creek in northwestern California, a long-known barrier to fish migration. The removal of Saeltzer Dam was intended to benefit populations of federally listed spring-run chinook salmon and steelhead trout by providing access to approximately 10 miles of upstream habitat. In April of 2003, we visited the former site of Saeltzer Dam. Through surveys, sketch maps, and photographs of the area immediately upstream of the former dam site, we identified a number of changes to creek morphology since removal of the dam and a previous geomorphic survey that took place in the spring of 2001. These changes included lateral bank erosion of up to 60 feet in banks composed of mixed unconsolidated sediments, bed incision, deposition of large gravel and cobble bars, desiccation of some upland vegetation, and the complete removal of many riparian areas. We found that the changes to Clear Creek resulting from the removal of Saeltzer Dam generally conformed to the simple predictive models of geomorphic response to dam removal. Specifically, bank erosion, channel degradation, deposition, and riparian mortality are all components of the creek's natural adjustment to post-dam conditions. We believe that the lack of significant changes found in a prior post-project assessment were due to the extant riparian vegetation and lack of significant high flows in the first spring following dam removal.

I. Introduction

Although more than 75,000 dams have been built in the United States in the past century and a half, as of the year 2001 only 497 dams had been partially or completely removed. Dams have a profound influence on fluvial processes and morphology. As the practice of dam removal gains momentum as a restoration strategy, understanding the many changes associated with removing these structures becomes increasingly important. Because few detailed geomorphic studies of dam removal have been conducted, there is currently a lack of direct observational data that can be used for predicting geomorphic effects. Consequently, researchers have relied on the study of comparative processes in order to understand and attempt to predict the effects of dam removed. These processes include natural adjustments to a lowered water table, flow modifications, and riparian die-off.

The report was prepared as a term project for a course titled Hydrology for Planners (LAEP 222), taught by Matt Kondolf and Ausauf Rahman. The scope of the project was to prepare a report based on data collected during one well organized day in the field.

For this study, we visited the former site of Saeltzer Dam three years after its removal in order to document channel adjustments immediately upstream and within the former impoundment area of the dam. Though only a preliminary study based on a single day of fieldwork, we intended not only to document specific changes to the creek, but also to identify the overall processes actively shaping the channel.

II. Site Description and Background

Clear Creek is 35-mile 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 278 square miles, Clear Creek is the first major tributary to the Sacramento River downstream of Shasta Dam. The former Saeltzer Dam was located along lower Clear Creek approximately 6 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. In the 1950's, Saeltzer Dam was identified as a principal barrier to fish migration. Though a variety of approaches to improve fish passage were constructed, including a fish ladder and tunnel, none proved successful.

During the late 1990s, under pressure from both state and federal agencies, negotiations to provide alternate water supplies for Saeltzer Dam users proved successful and plans for complete removal of the dam were finalized in 2000. Saeltzer Dam was finally removed in the fall of 2000. (Vovakes 2000)

Historical Impacts to Lower Clear Creek

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, the area witnessed extensive stream channel and floodplain gold dredging throughout the late 1800's and early 1900's. These activities resulted in major impacts to the stream channel as mining operations transformed the natural landscape into piles of placer, hydraulic, and dredge tailings (NSR/McBain 1999).

Predecessors to Saeltzer Dam were built across Clear Creek as early as the late 1800's, and a permanent dam was built in 1903 for irrigation and mining purposes (Bureau of Land Management 2002a). The dam effectively blocked the upstream migration of salmonids and prevented the downstream movement of course sediment (NSR/McBain 1999).

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 course sediment contributions to lower Clear Creek and greatly reduced the volume and magnitude of historical flows (Table 1 and Figure 2).

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).

Clear Creek Restoration

The removal of Saeltzer dam was merely one component of 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, an extensive effort to restore the natural form and function of the Clear Creek channel and floodplain in areas highly affected 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.

Saeltzer Dam Removal

Preparations for the removal of Saeltzer Dam began in July of 2000. These preparations included construction of a temporary cofferdam to divert flows around the reservoir and construction area, a diversion channel installed along the left bank, and a 300-foot 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. Following the successful diversion of flow, approximately 25,000 cubic yards of accumulated sediment were excavated from behind the dam in order to avoid a rapid and undesirable redistribution of materials after dam removal and restoration of channel flows. In addition, sediment removal was expected to enhance the re-establishment of a functional channel gradient and greatly reduce the likelihood of channel erosion (BLM 2000a). Significantly reducing and even preventing fine sediment movement downstream was also important for the protection of sites within the Lower Clear Creek Floodway Rehabilitation Project as well as recently restored salmonid spawning and rearing habitats.

Post-Project Surveys

After the removal of Saeltzer Dam in October of 2000 and following the first season of winter flows (December 2000 – March 2001), personnel from UC Davis and Stillwater Sciences conducted extensive upstream and downstream surveys of post-dam channel morphology and sediment redistribution (Stillwater 2001). These surveys were conducted primarily to document and predict the movement of sediment from the former dam site to downstream locations, especially those areas of the Lower Clear Creek Floodway Rehabilitation Project.

III. Methods

We began by reviewing analyses of the geomorphic impact of dam removal. A recent series of articles on removal of small dams from the publication *Bioscience* provided a useful overview of the subject matter. (*Bioscience* 52:8) This allowed us to develop a working hypothesis of the impacts associated with the removal of Saeltzer Dam

Our evaluation of the specific impacts began with a review of the studies conducted prior to and following the removal of Saeltzer Dam. We collected various documents ranging from initial evaluations of alternatives to improving fish passage (e.g. Braithwaite 1997) to extensive environmental assessments of the removal of Saeltzer Dam conducted for the U.S. Bureau of Reclamation (Bureau of Land Management 2000 and Bureau of Land Management 2000a), including an aerial photograph of the site prior to dam removal. (Figure 3) Furthermore, we interviewed individuals associated with the environmental review and post-removal assessment. (Table 2)

In addition to research, our primary study method involved one full day of on-site data collection conducted on April 4, 2003. Due to both time constraints and field equipment limitations, we decided to focus our efforts exclusively on the former dam site and approximately 2000 feet of upstream channel, a reach that roughly covered the former impoundment area.

Field Data Collection

Our fieldwork began with a reconnaissance of the reach to gauge overall conditions. We identified the approximate upstream extent of the former impoundment area based on riparian vegetation. We also identified areas of erosion, incision, and changes in riparian vegetation, including a number of dead upland trees. Field documentation included photographs, sketch maps, and field notes. Quantitative data collection involved two cross section surveys of the creek, a long profile of the water surface elevation extending from the dam site to approximately 1,500 feet upstream, and a calculation of flow velocity and discharge. One cross section included a detailed profile of the wetted channel which, combined with a measurement of flow velocity, allowed us to calculate flow.

We used a concrete box (a remnant of a failed fish ladder and tunnel structure) located on the high right bank just upstream from the former dam site as a benchmark for our survey data[1]. Due to the high flow level of Clear Creek during our day at the site, we were unable to collect additional information regarding the creek bed (i.e. a long profile of the thalweg and characterization of bed materials).

Analysis of Field Data

Having collected both quantitative survey data and general site information, we compared our field data with previous surveys, site maps, and photographs. In particular, we directly compared our survey data with the UC Davis/Stillwater data collected two year earlier, and our sketch maps with pre-removal ground and aerial photographs.

Finally, we utilized the USGS gauging station #11372000 (Clear Creek near Igo), located approximately 3 miles upstream of the dam site, in order to prepare a flood

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[1] Our benchmark was the westernmost (i.e. upstream) corner of the top of the box.

frequency analysis and to document peak flows since the removal of Saeltzer Dam. Correlation between flow at the gauging station and flow at the dam site was achieved by comparing the USGS flow data for April 4, 2003 and our own calculation of flow at the study site.

IV. Results

Three pairs of pre- and post-dam removal photographs are presented in Figures 4, 5, and 6. The "pre" photographs were collected as part of the environmental assessment of dam removal and were given to us by Mike Urkov of CH2M Hill (see Table 1). The post-dam photographs were taken by us on April 4, 2003. In each case we attempted to duplicate pre-existing photographs of Saeltzer Dam.

Figure 7 presents a sketch map of the study site overlain on a tracing of Saeltzer Dam and its reservoir. We have indicated on this figure the locations of our two cross sections as well as a corresponding cross section from May 2001. The cross section collected by Stillwater is labeled cross section #0 (or XS#0). Our cross sections are labeled, XS#1, and XS#2. The approximate location of the channel and adjacent features (e.g. sediment deposits, large woody debris, bedrock outcrops and rip rap) are indicated on the map. We were unable to include bed features in the sketch map due to the high water level during our visit.

Figure 8 provides a schematic map indicating the principal geomorphic and riparian impacts from the removal of Saeltzer Dam that we were able to identify. The four types of impacts we identified are erosion, deposition, incision, and riparian mortality.

Erosion and Deposition

We were able to identify erosion of 50 feet or more in the unconsolidated banks along the left (i.e. north) bank of the creek. The erosion was concentrated at two locations: 1.) at the outside of the river bend in the upper half of the former reservoir, and 2.) just above the former dam site, where we believe an erosive eddy caused by bedrock controls on the opposite bank has cut as much as 60 feet into the steep unconsolidated bank.

Evidence for this finding comes, in part, from a comparison of a cross section we surveyed (XS#1) with a cross section surveyed in May 2001(XS#0) by Stillwater Sciences, six months after the dam was removed. The locations of these two cross sections are indicated on Figure 9. As can be seen, XS#1 and XS#0 are slightly offset.[2] However, we believe that the two cross sections are close enough to provide a clear indication of the extent of the changes that have occurred. The two cross sections are plotted in Figure 10. This figure shows erosion of the left bank of approximately 60 feet but with little change in the right bank topography.

This conclusion was corroborated by visual inspection of the bank. (Figure 11) The bank at this point is composed of mixed unconsolidated sediments, with large cobbles in a matrix of sand. The top layer of the bank appears to be a layer of mixed sand, gravel and rip rap approximately two feet thick on top of landscaping fabric. Lengths of the landscaping fabric now emerge from the bank and a number of rip rap rocks line the side of the creek. A large tree (50+ feet tall) which can be identified from

[2] The headings of the two cross sections vary by approximately 20 degrees with the south endpoint in common, which results in an offset of the north endpoints of approximately 40 feet.

site photos that was at least twenty feet from the reservoir edge was completely undercut by the erosion and is now lying partially submerged in the creek.

There also appears to have been substantial erosion at the site of our second cross section (Figure 12). While we do not have cross sectional data from 2001 at this location that we can use to evaluate changes in bed profile, the limited survey data from 2001 for this location suggests that there has been lateral erosion of approximately 50 feet into the left bank. In addition, a line of riparian trees lining this bank can be clearly identified in the aerial photograph taken prior to removal of the dam. These trees are now completely absent, presumably due to erosion of the portion of the bank on which they were located. The bank at this location is likewise composed of unconsolidated fine sediments mixed with cobbles, and it is not difficult to imagine that substantial erosion would occur at high flows.[3]

Finally, though we do not have cross sectional data further upstream, there appears to have been substantial erosion of over ten feet into the left bank at the top of the study reach. A pre-project vegetation survey and aerial photographs taken prior to dam removal show a strip of riparian trees along the edge of this bank that had apparently been entirely eroded away.

Because of the limited time and data available we did not estimate the total volume of eroded sediment since May 2001. However, a rough calculation provides an indication of the amount of erosion that has occurred. At the site of cross section #1, the volume of eroded sediment can be approximated by a half-cylinder with a radius of 20 yards (the extent of lateral erosion into the bank) and a length of 5 yards (roughly the

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[3] What appeared to be bank swallows were observed nesting in the north bank near the location of this cross section.

height of the bank). This approach produces an estimated volume of over 3,000 cubic yards of sediment from this location alone.[4] The erosion from the bank at cross section #2 is of comparable magnitude. Based on these order-of-magnitude estimates, we believe that the total volume of sediment eroded since May 2001 exceeds 10,000 cubic yards.

We also identified deposits of coarse sediments at a number of points along the reach. In particular, there were gravel and cobble deposits along the opposite shore from the areas of erosion. There were also large deposits of coarse sediment along both shores at a point where the channel widens and flow velocity drops.

Incision

Figure 13 provides the results of our survey of water surface elevation along with water surface data from the May 2001 survey. It is important to note that the water surface profiles for our survey and the May 2001 survey vary both due to the difference in flow levels and because of changes in bed topography.[5] Specifically, flow levels in May 2001 were roughly half the 300 cfs measured during our visit, so the differences in water surface profile represent a minimum estimate of the amount of incision.

In general, there has been continued incision of the bed, with greater incision farther upstream (2 to 3 feet) than near the dam site (1 to 1.5 feet). This incision has reduced the average slope of the 750-foot reach immediately upstream of the dam site by 10% (from 1% in 2001, to 0.9% in 2003).

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[4] The volume is calculated as: $V = \pi r^2 L/2$; where r = radius = 20 yards and L = length = 5 yards.

[5] On the other hand, the flow level in May 2001 was likely somewhat lower than the flow of 250-300 cfs during which our data were collected.

We also identified what appeared to be a head cut approximately 1,050 feet upstream of the Dam site (Figure 14). This head cut appeared to create a vertical drop of about 18 inches over a distance of 10 to 20 feet.

It is interesting to note that the pattern of incision appears to be producing a semi-regular alternating pattern of steep and gentle slopes comparable to a riffle/pool morphology The length of each stretch (one riffle and one pool) is 450-500 feet, roughly 6 to 10 times the width of the main channel. Further evolution of the channel and more detailed data will be needed to determine whether this is transient or a persistent pattern.

Riparian Mortality

Finally, we were able to identify a number of locations with a total of approximately 50 - 100 dead or dying riparian trees (see Figure 8). These trees are located on the former waterline of the impoundment area, but are now 10 to 30 feet above the current water surface.

V. Discussion

Channel Response to Dam Removal

Figure 15 identifies a series of geomorphic processes that may occur following removal of a dam. (Stanley and Doyle 2002; see also Pizzuto 2002) Prior to dam removal, the reach is characterized by high, slow water and deep sediment deposits. Following dam removal, the reach proceeds through degradation (incision), widening (bank erosion), and aggradation (through bank collapse and deposition), as it moves toward a state of quasi-equilibrium in which the depth and width of the channel are relatively constant and erosion is greatly reduced. This series of changes occurs both at a particular point and progressively upstream. This pattern is not expected to be fixed, however, and the pattern of changes in each reach will vary depending on the local conditions.

Based on our observation, we believe that Clear Creek is experiencing this general pattern of geomorphic change in response to the removal of Saeltzer Dam. The removal of 25,000 cubic yards of sediment in the section of the reach immediately upstream of the dam accelerated the process of adjustment. In this lower reach, the excavation of sediment down to (or close to) bedrock resulted in relatively little further incision. Instead, the lower reach has been characterized primarily by widening through aggressive erosion of bank sediments. Further upstream we saw greater incision, including what appeared to be a migrating head cut. The upstream reach is also experiencing widening and bank erosion. Deposition is beginning to occur along the reach via the formation of point bars opposite eroding banks.

Causes and Timing of Channel Adjustment

One of the important and interesting outcomes of this study centers on the causes and timing of channel response to the removal of Saeltzer Dam. As mentioned previously, an extensive survey of the Clear Creek channel was conducted after the first season of winter flows following dam removal. (Stillwater 2001) Based on their April 2001 survey, the report prepared by Stillwater Sciences concluded that:

> •"only 122 yd^3 ($93m^3$) of sediment were transported out of the reservoir reach between January and May 2001."
>
> •"The longitudinal profile changed slightly following dam removal. These changes occurred in isolated locations and were not due to slope adjustment in response to dam removal."

•"Because most of the sediment upstream of Saeltzer Dam was removed during excavation ... we expect that there would be no observed changes in channel morphology due to the removal of Saeltzer Dam, and none were observed."

In contrast, we found that there have been dramatic changes in channel morphology including far greater volumes of sediment transport out of the reservoir reach and slope adjustment in response to dam removal. We believe that the changes we observed were due to two factors, differences in flow levels and riparian die-off

Flows on Clear Creek during the winter of 2000-2001 were exceptionally low. The highest level of flow on Clear Creek that winter was only 1,220 cfs, among the lowest over the period of record. (Figure 2, Table 1) In contrast, since that first winter, there were three floods greater than the Q2 level of 2,800 cfs, including a peak flood of 4,600 cfs on December 31, 2002. (Table 3)

In addition, it is likely that the extensive riparian vegetation was still healthy during that first winter and into the spring of 2001 since it had yet to experience a dry season without the lowered water table resulting from dam removal. In contrast, by April 2003, there probably was extensive mortality of riparian vegetation from two dry summers with greatly reduced soil moisture. As a result, by winter 2002-3, there would have been reduced cohesion of bank sediments, enabling increased erosion rates.

It is interesting to note that since our data was collected the steady rains of April 2003 resulted in a flood which exceeded 2,800 cfs for 46 hours and which peaked at 3,700 cfs on April 29. (Table 3) We expect that this flood resulted in substantial additional changes to creek morphology.

VI. Conclusions

Approximately 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 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. 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 repercussions to recently rehabilitated areas located there. To our knowledge, there has been no recent monitoring of downstream sites to gauge the effects of the sediment transport that we documented.

Overall, we believe that the removal of Saeltzer Dam on Clear Creek offers a few lessons for future dam removal: 1) inevitable channel reconfiguration in high energy systems such as Clear Creek can exert a positive influence and enhance channel recovery and restoration, 2) erosion and sediment transport must be viewed in light of both site specific limitations and downstream effects, and 3) long-term monitoring is a necessary component of successful post-dam appraisals due to the delayed effects of riparian die-off and unpredictable high flow events.

VII. References

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Stanley and Doyle 2002

Stanley, E and Doyle, M. A Geomorphic Perspective on Nutrient Retention Following Dam Removal. BioScience: Vol. 52, No. 8, pp. 693-701.

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

Vovakes 2000

"Salmon can't wait as dam begins to fall." Christine Vovakes. Local News, Sacramento Bee. Oct. 7, 2000

VIII. Figures and Tables

Figure 1: Overview Map

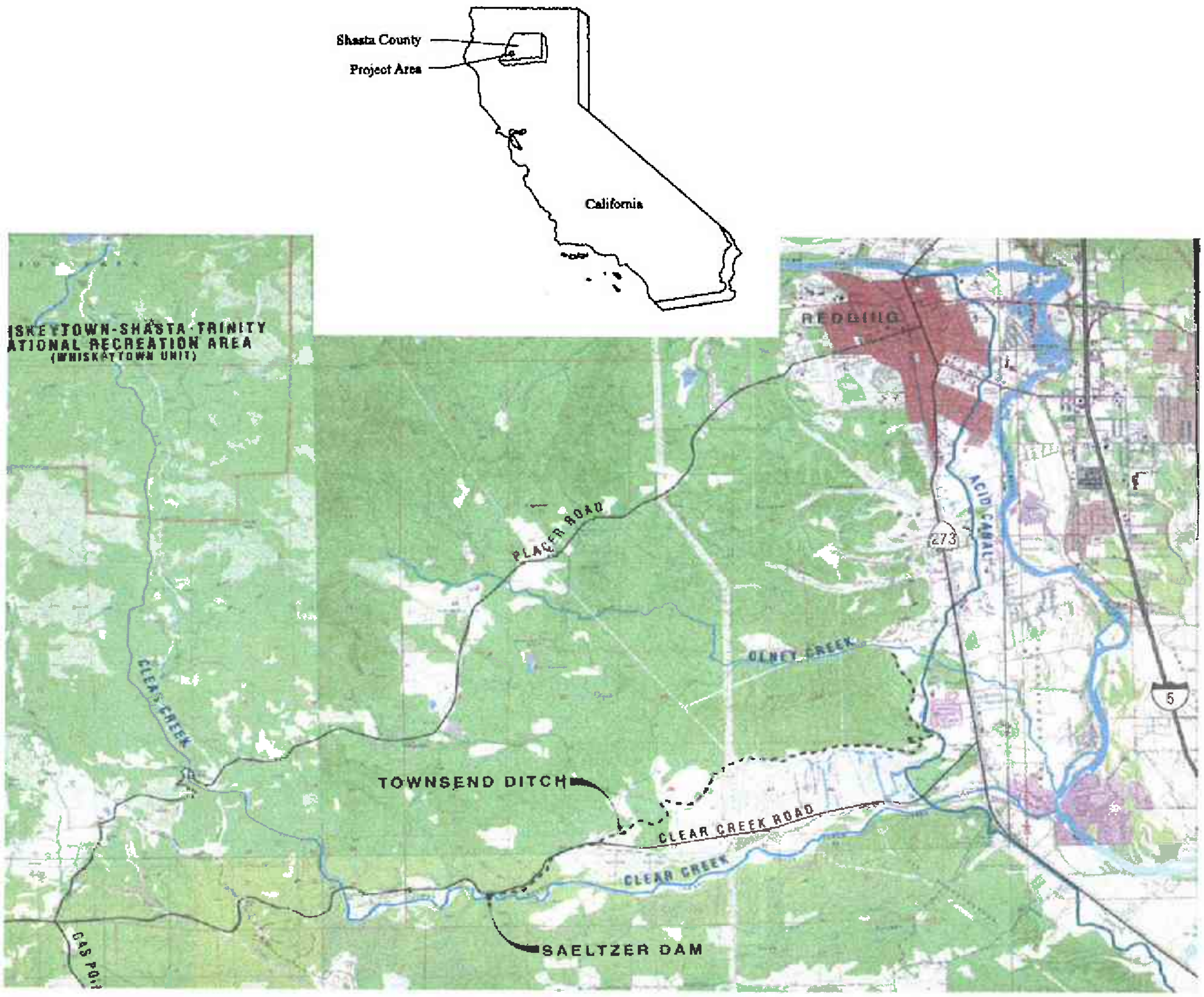


Figure 2: Annual Peak Flows on Clear Creek at Igo

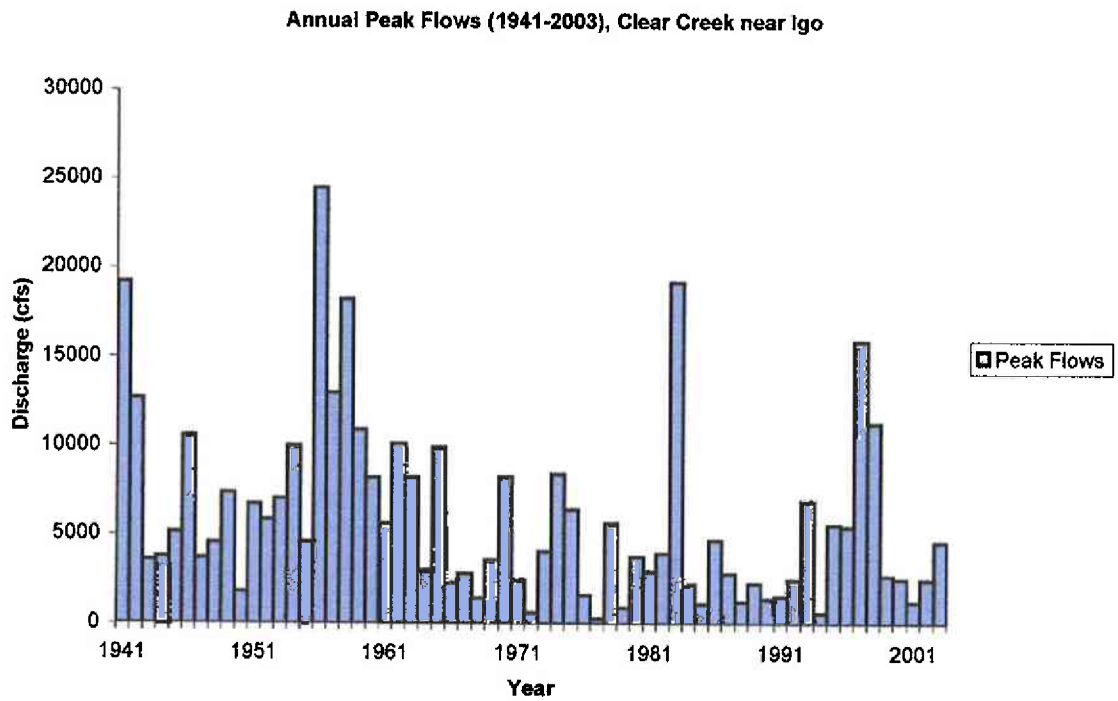


Figure 3: Aerial Photo of Saeltzer Dam Prior to Removal

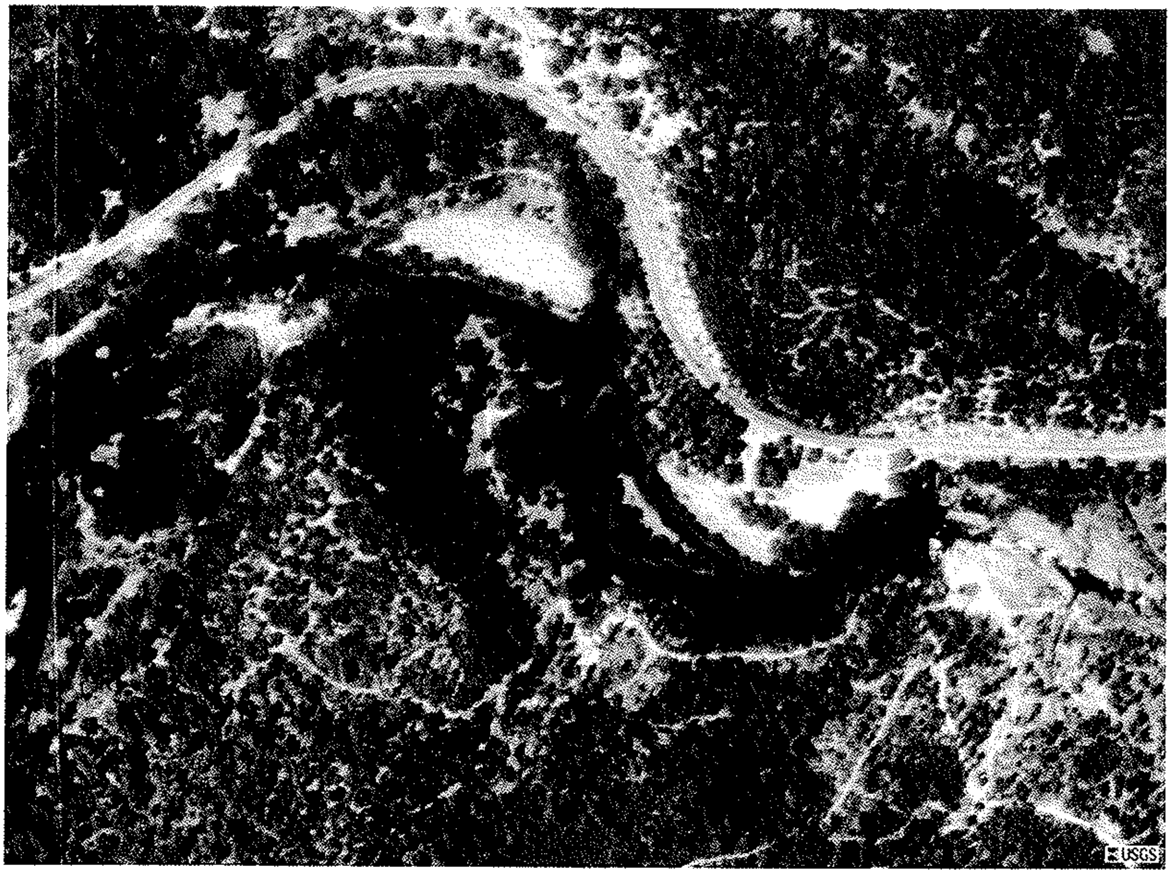


Figure 4: Saeltzer Dam, Before and After Removal, View Upstream

Figure 5: Saeltzer Dam, Before and After Removal, View Downstream

Figure 6: Saeltzer Dam, Before and After Removal, View From North to South Bank

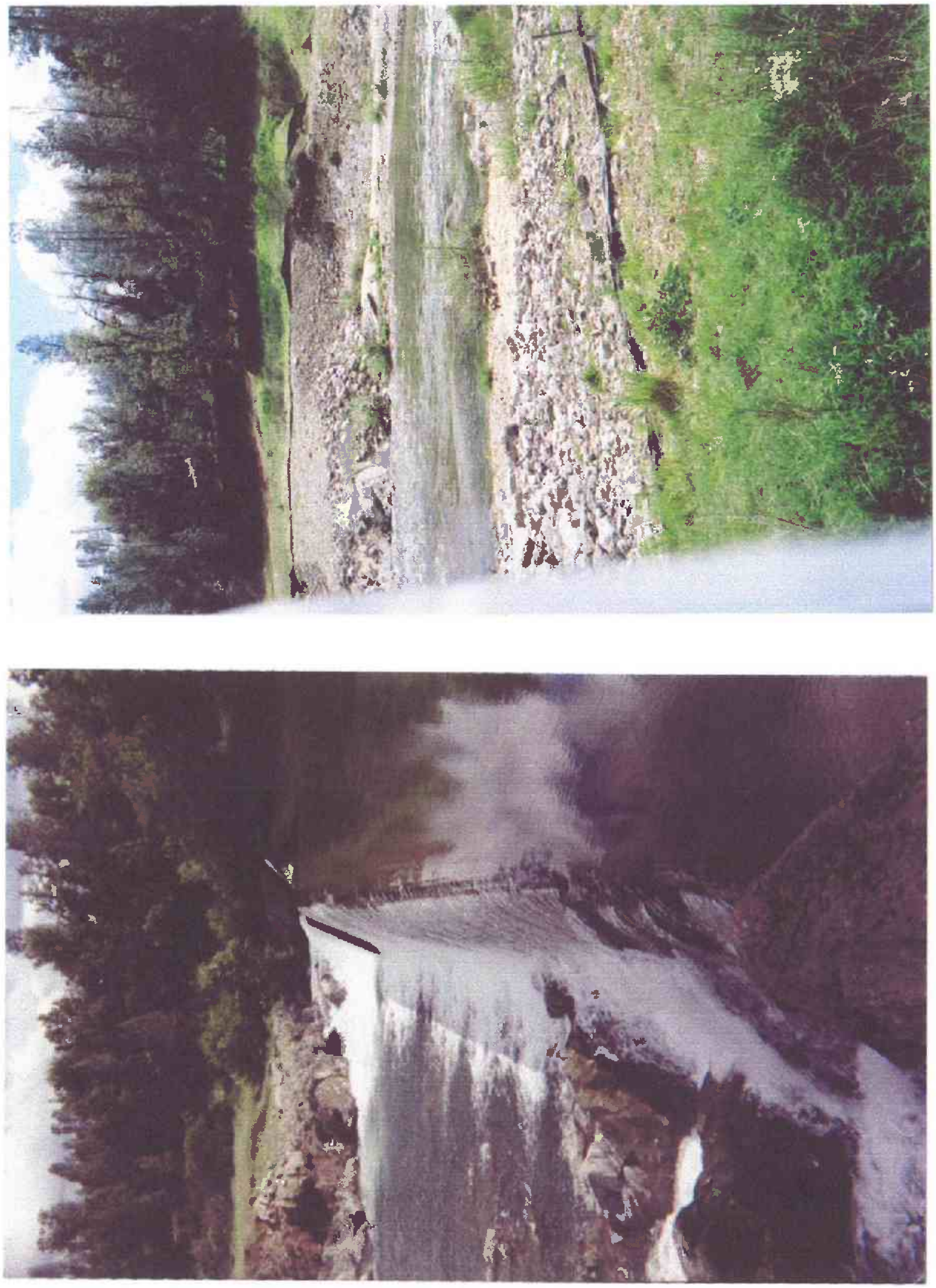


Figure 7: Sketch Map of Study Site

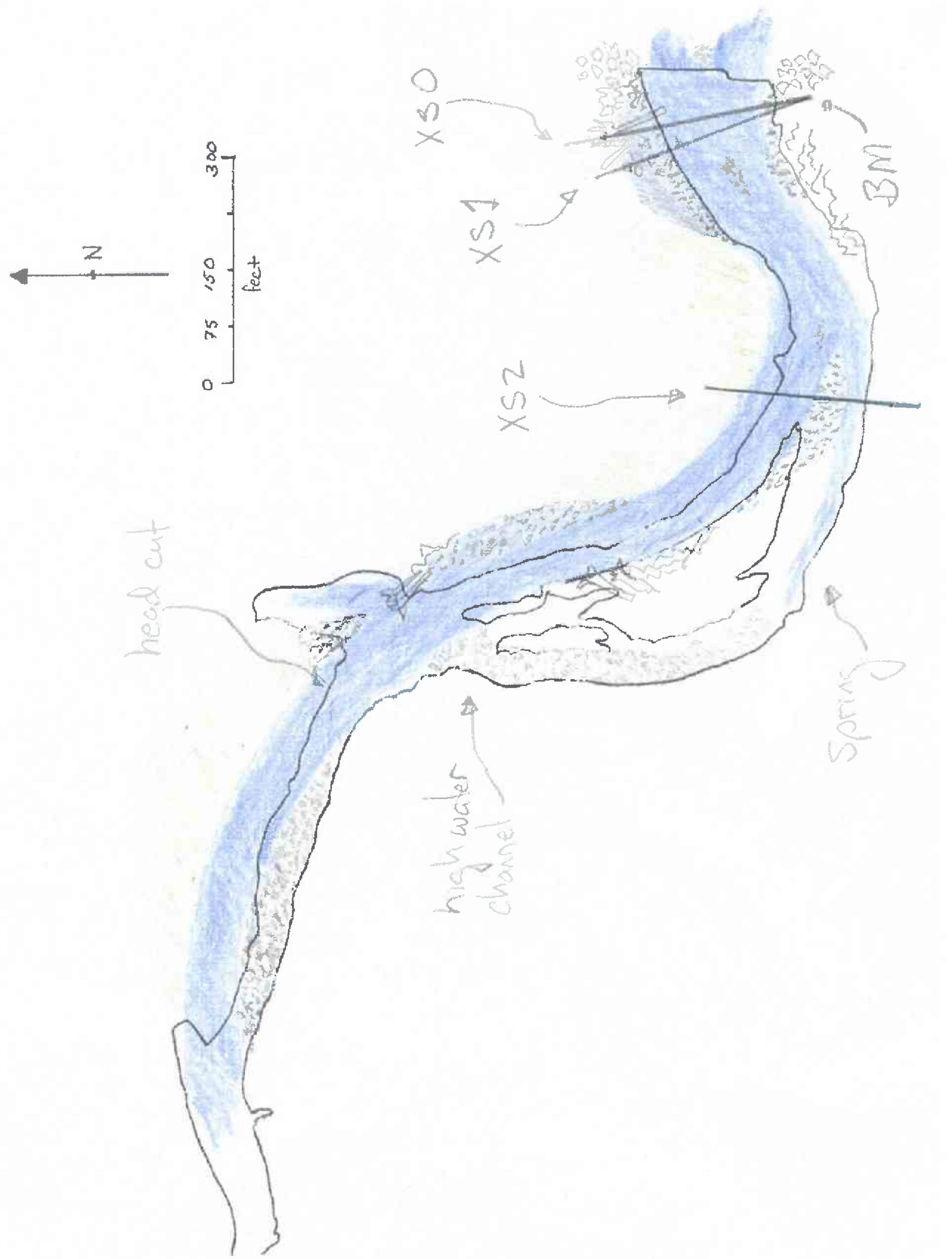


Figure 8: Changes to Study Site Since Removal of Saeltzer Dam

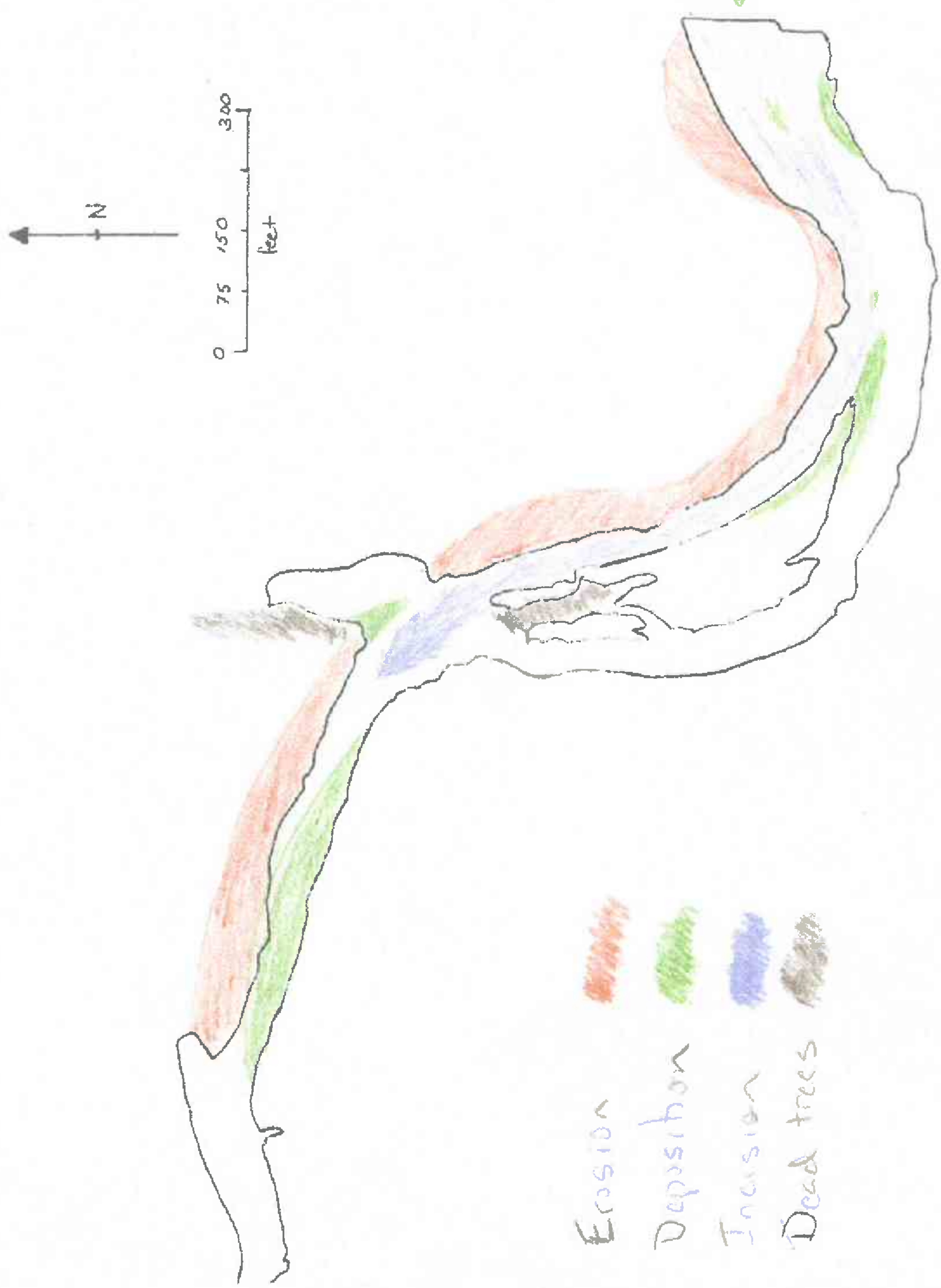


Figure 9: Layout of Data for Study Site

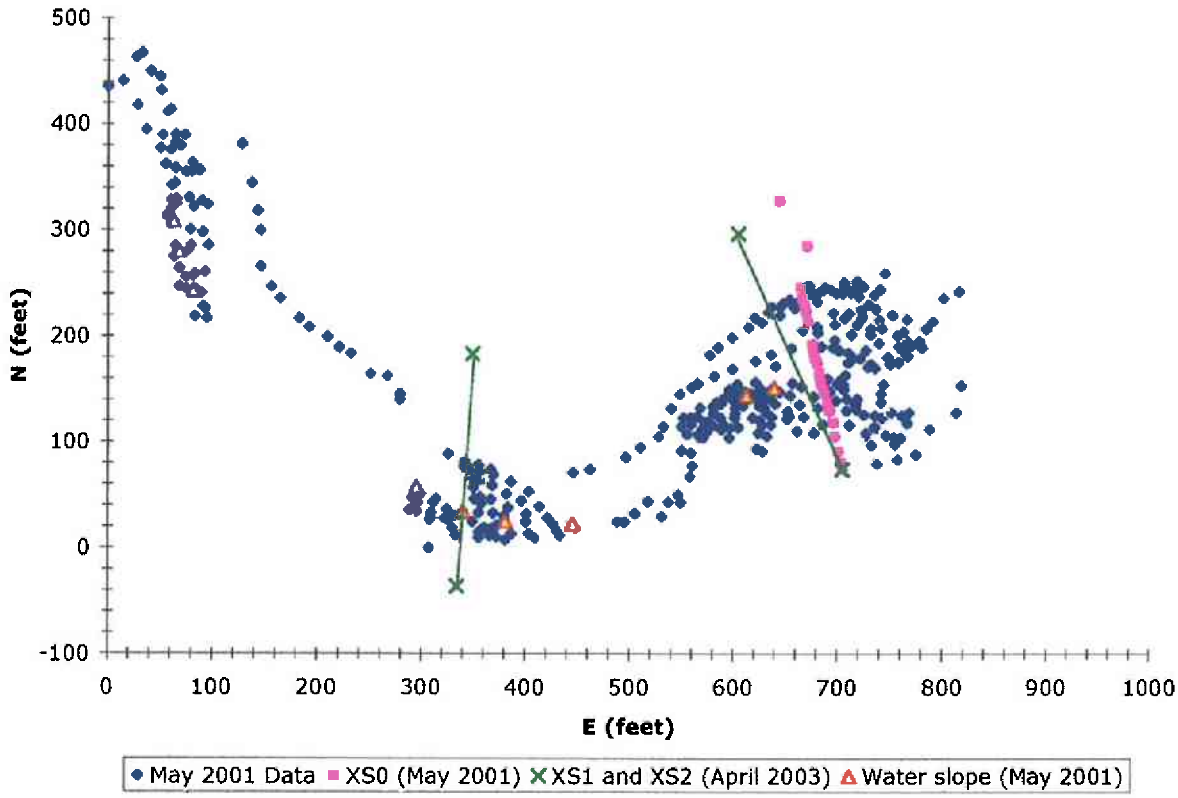


Figure 10: Cross Section #1

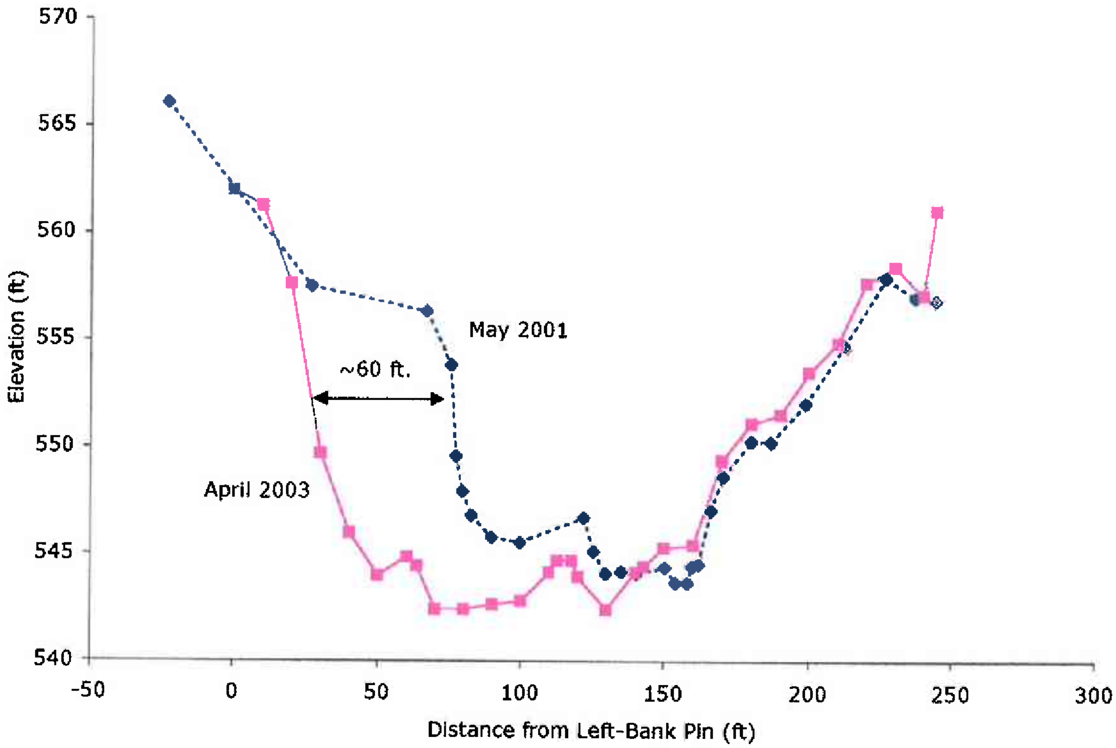


Figure 11: Photograph of Eroded Bank at Cross Section #1

Figure 12: Cross Section #2

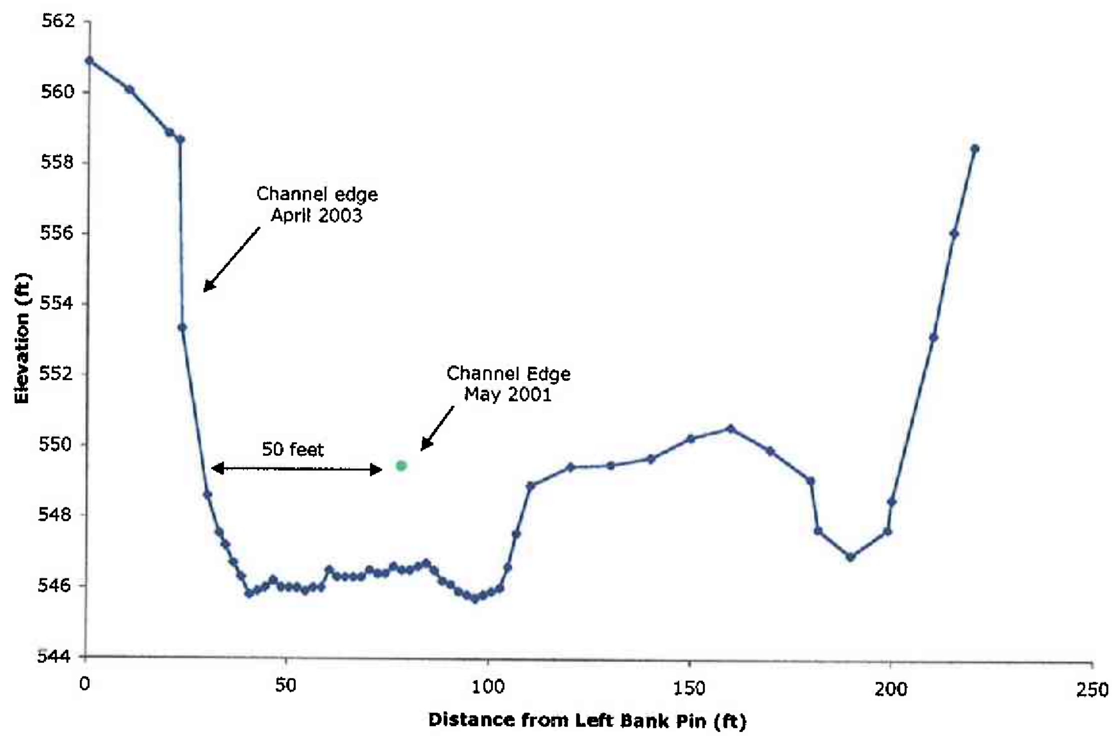


Figure 13: Water Surface Profile

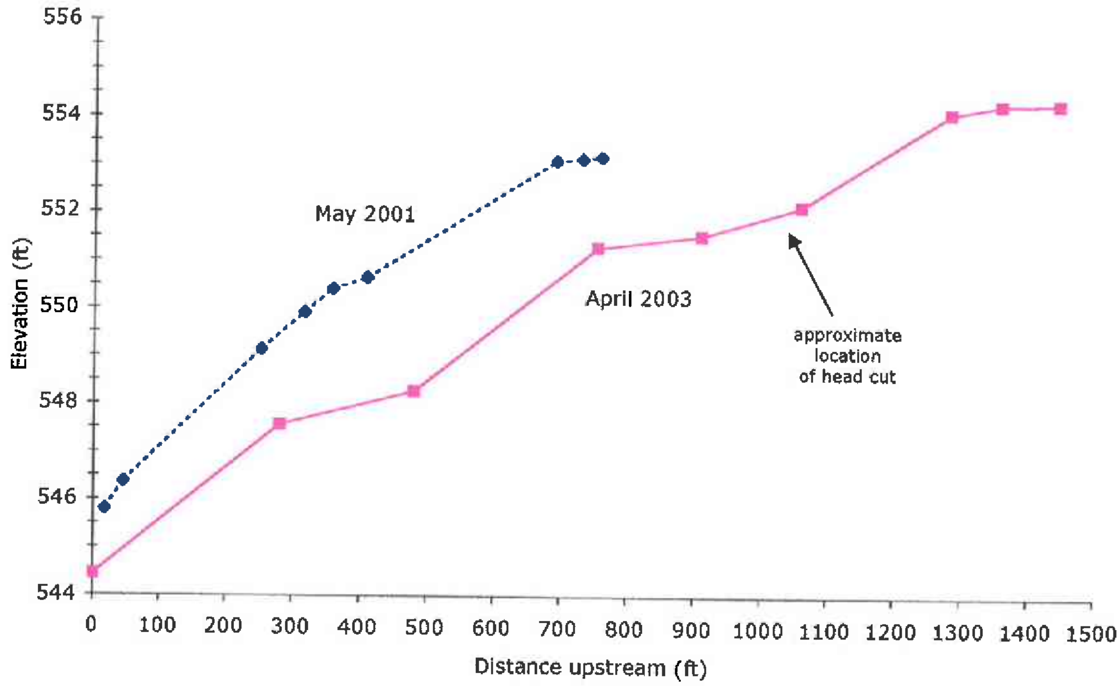


Figure 14: Photograph of Head Cut

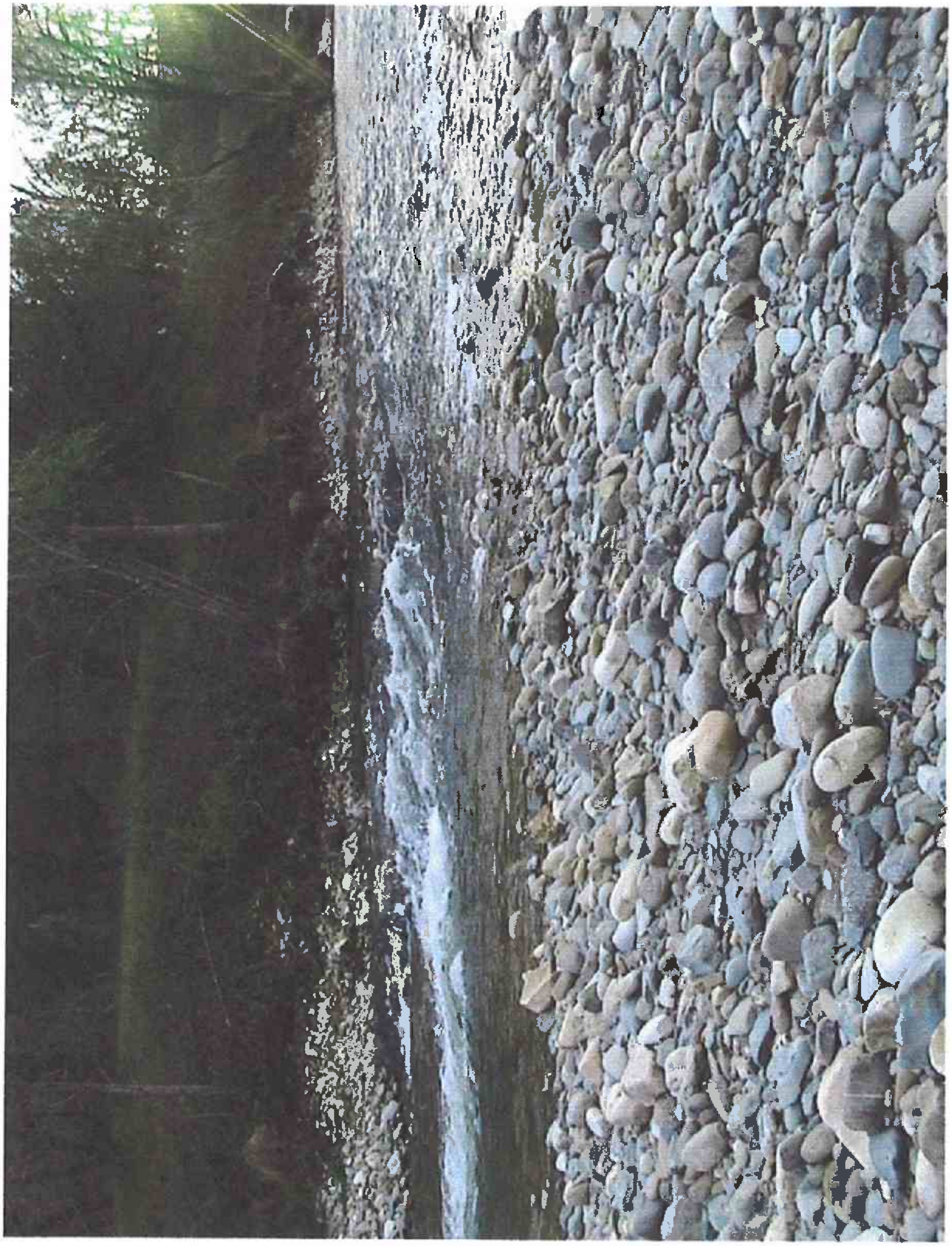
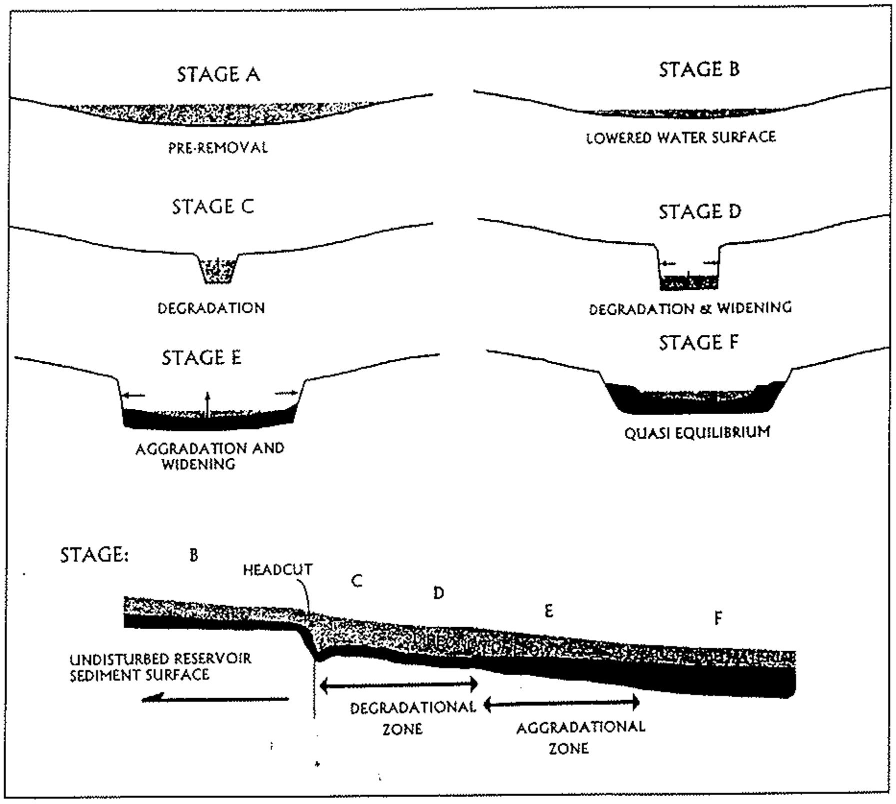


Figure 15: Generalized Pattern of Geomorphic Change Following Removal of a Dam



from: Stanley, E.H. and Doyle, M.W. A Geomorphic Perspective on Nutrient Retention Following Dam Removal. Bioscience 52:8, August 2002

Table 1: List of people contacted in course of this report

Individual	**Organization**	**Contact Information**
Christian Brauderick	Stillwater Sciences	2532 Durant Avenue, Suite 201 Berkeley, California 94704 (510) 848-8098
Mike Yurkov	CH2M Hill	2525 Airpark Dr. Redding, CA (530) 243-5831
Harry Rechtenwald	CA Dept. of Fish and Game	301 Locust St. Redding, CA (530) 225-2300
John Wooster	Entrix Environmental Consultants	590 Ygnacio Valley Road Suite 200 Walnut Creek, CA 94596 925-935-9920

Table 2: Flood Frequency Analysis for Clear Creek near Igo

Flood Analysis Prior to Construction of Whiskeytown Dam (1941-1963)

Year	Discharge (cfs)	Rank	Recurrence Interval
1956	24500	1	24
1941	19200	2	12
1958	18200	3	8
1957	13000	4	6
1942	12700	5	4.8
1959	10900	6	4
1946	10600	7	3.43
1962	10100	8	3
1954	10000	9	2.67
1963	8230	10	2.4
1960	8210	11	2.18
1949	7360	12	2
1953	7020	13	1.85
1951	6740	14	1.71
1952	5870	15	1.6
1961	5640	16	1.5
1945	5170	17	1.41
1955	4600	18	1.33
1948	4580	19	1.26
1944	3790	20	1.2
1947	3700	21	1.14
1943	3600	22	1.09
1950	1810	23	1.04

Flood Analysis Following Construction of Whiskeytown Dam (1964-2003)

Year	Discharge (cfs)	Rank	Recurrence Interval
1983	19200	1	40
1997	15900	2	20
1998	11300	3	13.33
1965	9940	4	10
1974	8430	5	8
1970	8260	6	6.67
1993	6960	7	5.71
1975	6450	8	5
1978	5660	9	4.44
1995	5560	10	4
1996	5480	11	3.64
1986	4700	12	3.33
2003	4600	13	3.08
1973	4060	14	2.86
1982	3940	15	2.67
1980	3760	16	2.5
1969	3580	17	2.35
1964	3030	18	2.22
1981	2950	19	2.11
1987	2840	20	2
1967	2800	21	1.9
1999	2710	22	1.82
2000	2520	23	1.74
1992	2500	24	1.67
1971	2470	25	1.6
1966	2290	26	1.54
1989	2260	27	1.48
1984	2240	28	1.43
1976	1630	29	1.38
1991	1560	30	1.33
1968	1430	31	1.29
1990	1420	32	1.25
1988	1260	33	1.21
2001	1220	34	1.18
1985	1120	35	1.14
1979	906	36	1.11
1972	615	37	1.08
1994	599	38	1.05
1977	295	39	1.03

Table 3: High Flows on Clear Creek Following Removal of Saeltzer Dam

Dates of Importance:

October 2000 – Removal of Saeltzer Dam
March-May 2001 – Stillwater Sciences Assessment
April 4, 2003 – Survey for this paper

Time Period	Number of Flows of Q2 (= 2,800 cfs) Or Greater	Peak Flows During Period
10/00 – 5/01	0	1220 cfs
5/01 – 4/4/03	3	12/16/02 – 2900 cfs peak (0.5 hours above 2800 cfs) 12/30/02 – 3800 cfs peak (3 hours above 2800 cfs) 12/31 – 4600 cfs peak (5.5 hours above 2800 cfs)
4/5/03 – 5/7/03	1	4/29/03 – 3700 cfs peak (46 hours above 2800 cfs)

Appendix 1: Calculation of Flow Levels for April 4, 2003

We calculated the discharge of Clear Creek on April 4, 2003, at the location of Cross section #2, which was just upstream from the former dam site. We measured flow velocity via the orange peel method, timed over a distance of approximately 250 feet, using the average of three separate measurements. Using this estimate of flow velocity we calculated flow rate, with the detailed cross-section of the main channel at cross-section #2, which was located within the 250-foot reach where velocity was measured. In order to compensate for the velocity of the orange peels (which traveled down the center of the channel), we multiplied our measured velocity by 0.8 for the center 50-foot width of channel and by 0.4 for the two 10-foot widths along either bank. Total data and calculations are given below.

Table A1: Calculation of Discharge

	Area (Sq. ft)	Velocity (ft/sec)	Discharge (cfs)
Right Streambank Flow	16.0	1.9	30.4
Main Channel Flow	67.6	3.7	250.1
Left Streambank Flow	11.7	1.9	22.2
		Total Discharge =	302.7

Table A2: Cross Section of Wetted Area at Cross Section #2

	Station	Depth (ft)	Cross-Sectional Area (Sq. ft)
Right Bank Water Edge	73.6	0	0.475
	71.6	0.95	1.9
	69.6	1.55	3.1
	67.6	1.65	3.3
	65.6	1.75	3.5
Thalweg	63.6	1.85	3.7
	61.6	1.75	3.5
	59.6	1.65	3.3
	57.6	1.45	2.9
	55.6	1.35	2.7
	53.6	1.05	2.1
	51.6	0.85	1.7
	49.6	0.95	1.9
	47.6	1.05	2.1
	45.6	1.05	2.1
	43.6	0.95	1.9
	41.6	1.15	2.3
	39.6	1.15	2.3
	37.6	1.05	2.1
	35.6	1.25	2.5
	33.6	1.25	2.5
	31.6	1.25	2.5
	29.6	1.25	2.5
	27.6	1.05	2.1
	25.6	1.55	3.1
	23.6	1.55	3.1
	21.6	1.65	3.3
	19.6	1.55	3.1
	17.6	1.55	3.1
	15.6	1.55	3.1
	13.6	1.35	2.7
	11.6	1.55	3.1
	9.6	1.65	3.3
	7.6	1.75	3.5
	5.6	1.25	2.5
	3.6	0.85	1.7
	1.6	0.35	0.7
Left Bank Water Edge	0	0	0