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### Title

Post-Project Appraisal of Crocker Creek Dam Removal Project, Sonoma Co., California

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Post-Project Appraisal of Crocker Creek Dam Removal Project,  
Sonoma Co., California

By

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December 13, 2005

## ACKNOWLEDGEMENTS

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## ABSTRACT

Crocker Creek drains 3.3 mi<sup>2</sup>, flowing into the Russian River near Cloverdale, California. A 30-foot high dam built in the early 1900s had filled with sediment, and then experienced two structural failures in 1995 and 1997. In 2002, the Sonoma County Water Agency (SCWA) undertook a restoration project; the main objectives of the project were to restore anadromous salmonid (specifically steelhead trout) passage and stabilize adjacent stream banks. Activities performed by the SCWA include: removal of remaining parts of dam; regrading of steep banks to shallower slopes; revegetation of riparian corridor; and placement of geotextiles, rip-rap, and log structures along areas of the stream bank.

In 2005, we conducted a post-project appraisal involving visual observations, vegetation measurements, channel surveys, and interviews with the project engineer; our objective was to determine whether the project goals were achieved. We determined a pre-project longitudinal profile from construction documents; no longitudinal profile was surveyed after project completion. We measured post-project channel configuration through field surveys, including five channel cross-sections and a 1300-ft longitudinal profile. To evaluate the fish passage objective, we compared the pre-project channel profile to our post-project longitudinal profile and considered our visual observations; our analysis indicates this objective was successfully met. To evaluate the bank stabilization objective, we quantified the success rate of riparian revegetation effort and relied on visual observations. The revegetation effort was partially successful; our visual observations include areas of bank erosion and areas stabilized by rip-rap. We found this objective difficult to assess due to the lack of baseline data.

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## I. INTRODUCTION

### **Objective**

This study is a post-project appraisal of restoration efforts on Crocker Creek. Our objective was to evaluate the level to which the stated project goals have been achieved.

### **Background**

Crocker Creek drains approximately 3.3 square miles of mostly oak woodland, chaparral, and grassland habitat environments, and flows westward into the Russian River near Cloverdale. It is a second order, perennial creek with over 12 miles of stream way, flowing mostly through incised v-shaped canyons (CDFG, 2002). The Crocker Creek Dam was located in a narrow gorge area of Crocker Creek, about 0.5 miles upstream from the confluence with the Russian River.

Not much is known about the history of the Crocker Creek Dam. It was a concrete buttress dam, originally built in the early 1900s for recreation and irrigation. The dam was raised at least three times to its final configuration of approximately 30 feet high and 100 feet wide. Two concrete spillways came off the south side (left bank) of the structure: a lower spillway abandoned after the dam was raised; and a higher spillway that was used until the time of dam removal. The dam sat on property privately owned by the KOA Cloverdale Camping Resort, and the land next to the dam's reservoir was used as picnic area for KOA customers. (SCWA, undated)

Crocker Creek Dam began to show signs of failure in 1974 (SCWA, 2005). In 1995, the entire northern portion of the dam with the exception of the original base failed, and further failure occurred in 1997 (Figure 1). The dam was nearly full of sediment at the times of failure (Scherzinger, personal communication, 8/26/05). These failures released sediment to the downstream areas and aggraded the bed (SCWA, 2005). Upstream areas experienced erosion



and subsequent bank collapse because of the loss of grade control (SCWA, 2005). Steep banks of unconsolidated sediment persisted in many areas of the former reservoir.

Although the dam failures lowered the height of the dam, the remaining portions of the dam and associated debris still created an impassible barrier to fish. Furthermore, the in-stream remnants of the dam created a potential safety hazard, and the KOA Campground placed this site off-limits to its customers. (Scherzinger, personal communication, 11/3/05)

### **Project Description**

The Sonoma County Water Agency (SCWA) received funding from the California Department of Fish and Game (CDFG) for the “Crocker Creek Instream Habitat Restoration Project”. The main project goals were: 1) Provide anadromous fish passage, and 2) Stabilize the adjacent stream banks (SCWA, undated).

In the autumn of 2002, SCWA removed the Crocker Creek Dam. No channel sediment was excavated; remaining sediment directly upstream of the dam could still impede fish passage. Original project plans included the installation of a fish ladder to aid fish passage over the remaining sediment (SCWA, undated). When SCWA returned to the site in spring 2003 to construct the fish ladder, the sediment barrier had incised and dispersed to downstream areas (Scherzinger, personal communication, 11/3/05). No barrier remained and the fish ladder was no longer necessary.

The project effort primarily focused on meeting the goal of stabilizing the adjacent stream banks. We are unsure whether these stream banks are the original stream banks or the banks of the remaining reservoir sediment. Restoration work occurred in 4 project areas. Areas I and II involved the right (north) and left (south) banks that held the dam abutments. In Area I, the stream bank had become unstable after the dam failures (Figure 2). To stabilize it, SCWA

regraded the steep bank at a 2:1 slope. In Area II, the south abutment and spillways were demolished and removed, and a small portion of the bank was recontoured at a 2:1 slope. (SCWA, 2005)

Area III, approximately 150 feet upstream of the dam site, was an erosional scarp 21 feet high and 170 feet long (Figure 3) (SCWA, 2005). The plan for this area was to regrade to a 2:1 slope using the surplus fill created from the Area I activities earlier described. However, during construction, the project manager quickly realized that the cost of transporting the sediment from Area I to Area III was not cost effective. Instead, an area of depression adjacent to Area I became the fill site for remains of the old dam, abutment, and spillway. These remains were buried using fill generated from the grading of Area I SCWA engineers controlled Area III's right bank erosion by placing riprap along the bank. (Scherzinger, personal communication, 11/3/05)

Area IV is located furthest upstream from the former dam site. Previously at this site, KOA owners attempted to stabilize erosion on the right bank through placement of concrete blocks (Figure 4). Though adequately preventing bank erosion, the blocks were in disarray and unnatural in appearance. To restore this area, SCWA recontoured the bank at a 2:1 slope, established willow revetment at the toe, and placed a series of 4 redwood log spurs to direct water away from eroding the right bank. (Scherzinger, personal communication, 11/3/05)

Recontoured slopes in each of the four areas were planted with native vegetation (Figure 5). This was done to stabilize the soil and improve aquatic habitat by providing shade cover (SCWA, 2005).

## **Available Documents**

The following documents were available to us for purposes of our post-project appraisal:

- Funding proposal, written by SCWA for CDFG (SCWA, undated)
- Background information from SCWA website (SCWA, 2005)
- Construction Documents from 2002 and 2003
- 1974 Stream Survey by CDFG (CDFG, 1974)
- 1977 Stream Survey by CDFG (CDFG, 1977)

## **II. METHODS**

Our study consisted of four components: visual observations, vegetation measurements, channel surveys, and interviews with the project engineer. We conducted fieldwork over two days (November 3 and 8, 2005). Our observations consisted of field notes and pictures. We noted occurrences of pools, riffles, woody debris, and undercut banks. We measured the survival rates of the revegetation effort performed during construction by dividing the number of live plants by the total planted. We surveyed one 1240-foot longitudinal profile (thalweg and water surface) and five cross-sections. We surveyed slope breaks such as upstream and downstream ends of pools and riffles, maximum pool depths, and at cross-sections. Elevations are relative to the downstream end of the long profile, which was assigned an elevation of 0 feet. We used the profile to calculate post-project channel slope. We interviewed the SCWA project engineer, Remleh Scherzinger, P.E. on August 26 and November 3, 2005. The construction documents provided by Mr. Scherzinger provided background information and specific features to which we compared the present condition of the channel. We used these construction documents to determine a pre-project longitudinal profile, to calculate pre-project channel slope, and to compare to post-project channel slope.

### III. RESULTS

In this section we present the results of our visual observations, channel surveys, vegetation monitoring, and interviews.

#### Visual Observations

We counted 24 pools along the reach; in six of these pools we observed juvenile steelhead trout. We observed areas of woody debris and undercut banks. We observed areas of dense willow growth. Portions of the stream bank appeared actively eroding; these areas lacked established vegetation and exhibited incision. We observed these eroding areas at cross-sections 3, 4, and 5. We observed portions of the bank protected by rip-rap in Areas I, III, and IV. In Area IV, four large logs were placed to stabilize the stream bank; the two logs furthest downstream are no longer visible, presumably buried or removed by high flows. At the former dam site (station 1127 on longitudinal profile), we observed the remains of the dam were successfully removed. Along the project reach, our observations indicate all vertical steps in water surface elevation are less than one foot.

By observing the sediment terraces and walking upstream, we estimate the upstream extent of the former sediment field is several hundred feet upstream of Area IV. Additionally, walking downstream of the former dam site out to the confluence with the Russian River, we observed dam debris and evidence of bed aggradation. Some tree trunks appeared buried, and a concrete block wall along the left bank showed signs of partial burial (Figure 6). We observed rocks piled near the edge of the left bank, presumably to divert flows away from the stream bank (Figure 7).

## **Channel Surveys**

The pre-construction longitudinal profile, as determined from pre-project documents, shows channel bottom elevation above mean sea level (Figure 8). The slope of the entire reach is 3.0%; the slopes upstream and downstream of the dam are 2.2% and 16%, respectively. Our post-project longitudinal profile indicates elevations of channel bottom and water surface along the thalweg (Figure 9). The starting point for the longitudinal profile (Station 0) is located 40 feet upstream of the project area boundary; the ending point is located 115 feet downstream of the former dam site. The length of the longitudinal profile is 1242 feet; the total change in elevation along the length is 36.4 feet. The average slope along the entire long profile is 2.9%. The slope of the reach upstream of the dam is 2.7%, and the slope of the reach downstream of the dam is 5.1%. Also indicated on the post-project longitudinal profile are the locations of channel cross-sections 1-5. Cross-sections 1-5 are presented in Figures 10-14. The cross-section locations are indicated by the station of intersection with the longitudinal profile. The cross-section plots utilize identical vertical and horizontal scales for ease of comparison along channel reach. The widest cross-section, no. 2, is 134 feet from left bank pin to right bank pin (Figure 11); the narrowest, no. 4, is 28 feet across (Figure 13).

## **Vegetation Monitoring**

Vegetation monitoring results are presented in Table I as percent survival of plants by location and overall survival rate. Vegetation survival in Area II is the highest measured at 67%, followed by Area I at 8%, and Area IV, at 0%. The overall survival rate of the plantings is 13%.

## **IV. DISCUSSION**

Two main objectives drove the design and implementation of the Crocker Creek Dam Removal Project; restoring upstream fish passage and stabilizing adjacent stream banks. In this

section we present our appraisal of these objectives in the following manner: first, we discuss how well the project met the objective; and second, we discuss the suitability of the objective itself for this stream .

## **Fish Passage**

### Appraisal of the project's achievement of the objective:

#### *Objective: Restore Fish Passage*

In this section we appraise whether the Crocker Creek Dam removal achieved the objective of restoring fish passage. The primary method we used to do this was to compare the pre-project long profile with the post project long profile. As noted in the results, the pre-project long profile (Figure 8) indicates that there was a 16% slope from the former dam site downstream approximately 55 ft. This long profile is a snapshot in time of the slope post-dam failure and pre-dam removal. It indicates that the remaining dam debris and upstream sediment wedge was approximately 7-9 ft. above the downstream channel, and prevented fish passage.

Though much of the accumulated sediment in the impoundment was allowed to flow downstream after the dam failures, the remaining dam debris still held back sediment. The gentle 2.2% slope from the dam site upstream results from the remaining sediment in the impoundment.

When a dam is removed, a suite of general expected outcomes can be described. Because the longitudinal profile is out of equilibrium, with a height differential between the upstream and downstream areas, the river will reestablish its equilibrium channel form (Pizzutto, 2002). Upstream changes involve erosion of the reservoir sediment and headward erosion upstream (Pizzutto, 2002). Downstream changes will be affected by the changes in sediment supply over

time. Typically in the beginning, more sediment is flowing through the system and deposition of that sediment, and aggradation of the channel bed, is expected (Pizzutto, 2002).

Therefore, as a result of the dam removal, we expect the long profile slope to level out from upstream to downstream. And that is the result we see from our long profile (Figure 9). The new slope is 2.7% from the former dam site moving upstream, while the slope from the former dam site going downstream is 5.1%. There are no major barriers shown in the profile, leading us to the conclusion that fish passage has been successfully restored. The former dam location is seen in Figure 15; no significant barriers to fish passage are visually evident.

Though it is beyond the scope of appraising the achievement of the objective, we note that our long profile also illustrates that there are several pools of one-to-two feet in depth just upstream of the former dam site, while the upstream portions of the long profile are dominated by runs and riffles (Figure 9).

#### Appraisal of the objective itself:

##### *Objective: Restore Fish Passage*

According to the available documentation, we find that the value of restoring fish passage on Crocker Creek is unclear. We make the assumption that two important factors must be met to validate the objective:

- 1) That the fish species of concern is present and likely to pass the pre-existing barrier.
- 2) That the upstream habitat is suitable for the species of concern.

We looked for evidence of these two factors in the available documents.

The CDFG funding proposal makes the following three statements about fish on Crocker Creek: 1) While oak dominated habitats, such as the Crocker Creek watershed, are typically not optimal for anadromous fish, the CDFG and SCWA have found that such tributaries are in fact

important for steelhead in the Russian River Watershed, 2) The CDFG and SCWA observed juvenile steelhead directly below the dam in 1998, and 3) A CDFG biologist led a team that habitat typed the Crocker Creek watershed.

The first statement does not state anything specific about the Crocker Creek watershed, except that it could be “very important to steelhead”. The third statement informs readers that the habitat has been typed, though it reports nothing of the findings. The second statement holds the greatest weight, and meets the first important factor for validating the objective.

What about the quality of the upstream habitat? Two 1970’s stream surveys conducted by the CDFG report numerous visual observations of the creek, including information about the spawning areas. The 1974 report states:

“Spawning Areas – Little potentially suitable spawning gravel present in this system (5% of the total area)” (J. Bruns, Aug. 19, 1974, CDFG).

Similarly, the 1977 stream survey reports:

“Spawning Areas – Areas: Spawning habitat was generally poor. Much of the streambed had gravel which was overlain with sand and fine gravel” (B. Rowser and D. Fong, Sept. 1&6, 1977, CDFG)

Based on these reports, and without reason to believe the habitat has improved over the last 30 years, we conclude that it remains unclear whether providing fish passage on Crocker Creek is a valid objective.

#### Recommendations:

To clarify this issue and validate the objective, we recommend the following:

- 1) Conduct fish counts in the upstream segments of Crocker Creek.
- 2) Release reports of the fish count results to the public.



## **Bank Stability**

### Appraisal of the project's achievement of the objective:

#### *Objective: Stabilize Stream Banks of the Creek*

The second major goal of this project was to stabilize the current banks of the creek. These current banks may be the historical banks of the creek; however, it is likely that the creek has not removed the full extent of the sediment deposits retained when the dam was in place. As well as stabilizing the area adjacent to the creek for use by the bordering campground (Scherzinger, personal communication, 11/3/05), there may be additional reasons for preventing erosion and transport of sediment downstream from the project location. Some techniques used in the project to stabilize the stream banks include: regrading of the banks to a more stable configuration; revegetation of the banks; and placement of geotextiles, rock, and bioengineered structures along the banks (SCWA undated). Due to a lack of post construction survey data or proposed finish elevations, our evaluation of this objective is based largely on visual observations. We observed both areas of erosion and successful bank stabilization at the project site and documented them with photos and cross sectional surveys.

Installation of geotextile material in regraded areas, along with placement of rock at the toe of the bank in various areas (Appendix A) was an attempt to prevent erosion. We visually observed that in the areas along the bank and on the regraded slopes where rock or geotextile material had been installed, little erosion had occurred. Although the installation of rock rip-rap along the banks of streams limits the natural processes of the channel (e.g., channel migration), preventing further erosion of the banks of Crocker Creek within the project site was deemed necessary by the designers.

Revegetation efforts attempted to stabilize the projects regraded slopes as well as the bank of the creek. The success of the revegetation varies with the type of area considered within the project. Willows located on in-channel bars and on the banks near the waters edge appear established; whereas some areas of plantings further from the channel had a low survival rate (Table 1). The upstream end of the restored reach (Area IV) exhibits the establishment of willows in and adjacent to the channel along with an area of less successful plantings higher up on the regraded bank, Figure 16.

The regraded hillside north of the former dam location (Area I) was the target of a large revegetation planting which we found unsuccessful. A thick mattress of willows covers the eastern end of Area I (Appendix A); however the majority of the slope has few survivors from the initial planting. While willows may still eventually establish on the slope, to stabilize this slope, the root systems of trees or shrubs may be needed.

The survival rate of plantings in Area II, Appendix A, just downstream of the former dam location, is the highest in our study, at 67%. This area of revegetation appears to be establishing itself on the hillside where it is located, and with continued survival, may help stabilize the surrounding soil with its root networks.

We identified several areas of bank erosion during fieldwork at the project site. One such area is along the right bank just downstream of Area IV, Appendix A. The channel splits just down stream of the log structures in Area IV, with the northern channel running directly into the bank at this location, where it is forced to turn 90 degrees to the left (south) to rejoin the main channel. The flow appears to be eroding the bank at this location, Figure 17.

The second eroding area is located at the downstream end of Area III, Appendix A. A vertical wall of unconsolidated sediment makes up the right bank at this location and has signs of

active erosion. Erosion of the left bank is occurring just downstream from the above-mentioned right bank location, suggesting that the flow is possibly being deflected from the right bank into the left bank. The cross section of this area, Figure 12, exhibits the vertical banks at this location. Due to the vertical nature and height of the right bank, undercutting would cause a large section of the bank to collapse, thus depositing large amounts of sediment into the channel.

One area of successful bank stabilization is the north abutment of the dam, Appendix A. The slope of the bank at this location prior to the project was extremely steep. Grading the bank at this location to a shallower slope has apparently prevented mass failures. There is however, erosion at the transition of the upper slope to a slope of steeper grade leading to the channel, Figure 18. This erosion may be due to a lack of vegetation on the slope just above the channel.

Initially, to stabilize the right bank of the channel in Area IV, four cable-anchored log structures were installed to hold the channel in its pre-project location, Appendix A. During the first winter following installation, the channel re-established itself between the middle two log structures. Based on conversations with the project engineer, Remleh Scherzinger (personal communication, 11/3/05), this failure occurred due to additional flow from an unknown gully entering the creek from the North just upstream of the first of the four logs structures, which had not been included on the pre-project survey. Regrading the bank and placing rock, vegetation, and geotextile material were performed to protect the right bank in the area where the channel is currently located, Figure 19. A second channel then formed paralleling the original as shown in Figure 19. The progression of the channel in Area IV from before the project in 1998 until our post-project appraisal in November 2005 is seen in Figure 20. Comparing the vegetation highlighted by arrows in this progression, the channel appears to have incised since the completion of the project.

Appraisal of the objective itself:

*Objective: Stabilize the Stream Banks of the Creek*

Due to the complex issues considered in making the decision to stabilize the creek banks in this project, we feel this objective itself can not be appraised without speculation of the designers' motivations regarding this decision.

## V. CONCLUSIONS

Evaluation of the Crocker Creek Dam Removal Project is based on our observations and data collected at the project site. Evaluation criteria consist of how well the stated goals of the project were met and our assessment of the suitability of the project objectives to this stream. Based on the previous discussion, we present the following conclusions:

- Upstream fish migration was successfully restored through the removal of the dam remnants and fish habitat has been created within the project reach. Many pools and riffles exist with features such as overhanging banks and woody debris to provide protection for juvenile fish.
- Success of bank stabilization efforts is difficult to quantify due to the lack of baseline data against which to compare the data we collected during our post project appraisal. Based on our visual observations and data analysis, the stream banks where rip-rap was installed are protected against erosion; however, we observed areas of erosion downstream of each of these areas. Also, regrading the north abutment of the dam (Area I) has thus far prevented a mass failure of the bank at this location. The revegetation effort was partially successful. Willows are established in many areas along the bank and in Area II, stabilizing local sediment and restoring the riparian corridor. Plantings in

Area I were generally not successful with the exception of the eastern end, where willows are established.

- Additional baseline data would have significantly enhanced our ability and others' future ability to quantitatively analyze and track the erosion of the bank, channel migration, aggradation or incision of the channel bed, and changes in the number or size of pools and riffles within the project reach.

## VI. REFERENCES CITED

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**FIGURE 1.** View upstream of failed Crocker Creek Dam in 2002. Unknown photographer, image courtesy of SCWA.



**FIGURE 2.** View of the north abutment (Area I), after the '95 and '97 Crocker Creek dam failures in 2002, prior to restoration. Unknown photographer, image courtesy of SCWA.



**FIGURE 3.** View upstream of Area III prior to restoration in 2002. The channel was eroding the right bank. Unknown photographer, image courtesy of SCWA.



**FIGURE 4.** View upstream of Area IV prior to restoration in 2002. Concrete blocks were placed along the right bank to prevent bank erosion. Unknown photographer, image courtesy of SCWA.





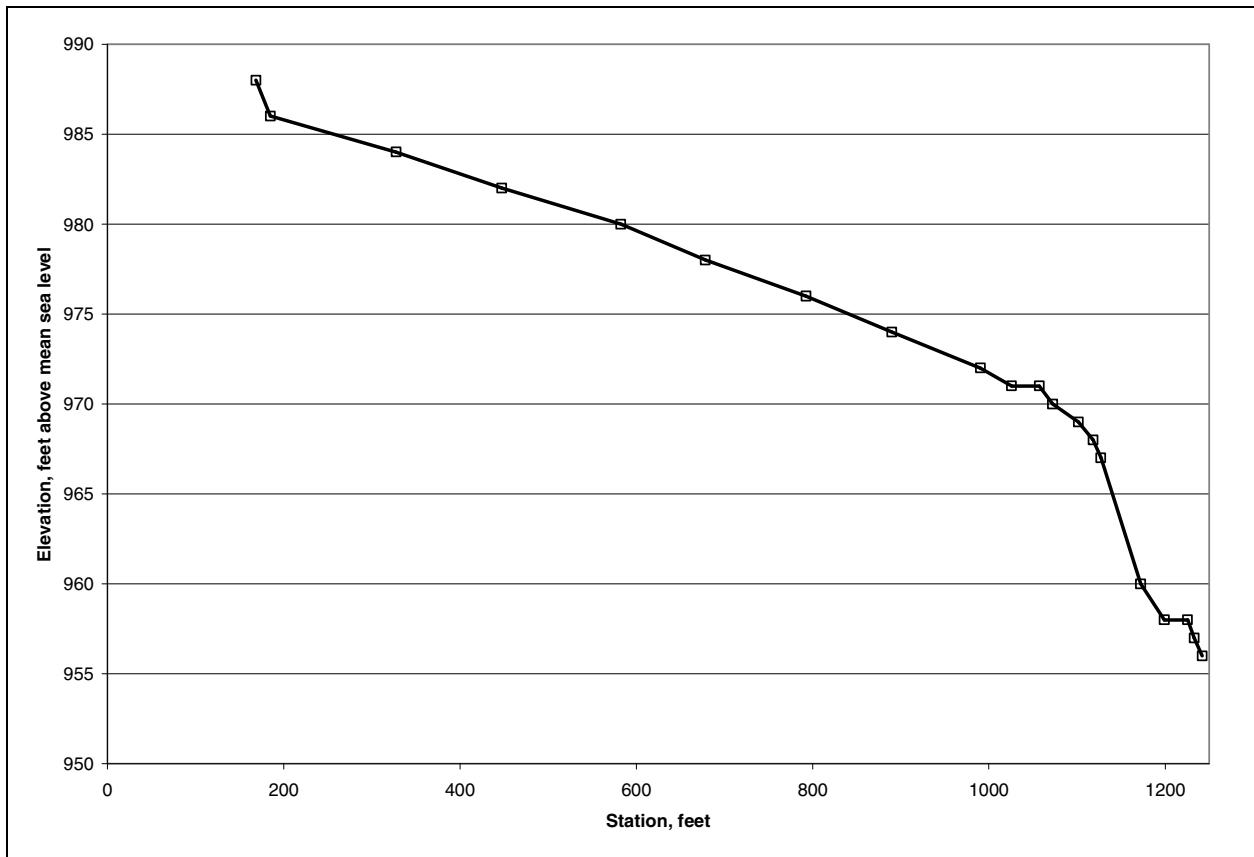
**FIGURE 5.** View of revegetation effort at Area 1 in 2005. Plantings were staked and protected by plastic tubing. Photo taken by Alicia Gilbreath on November 3, 2005.



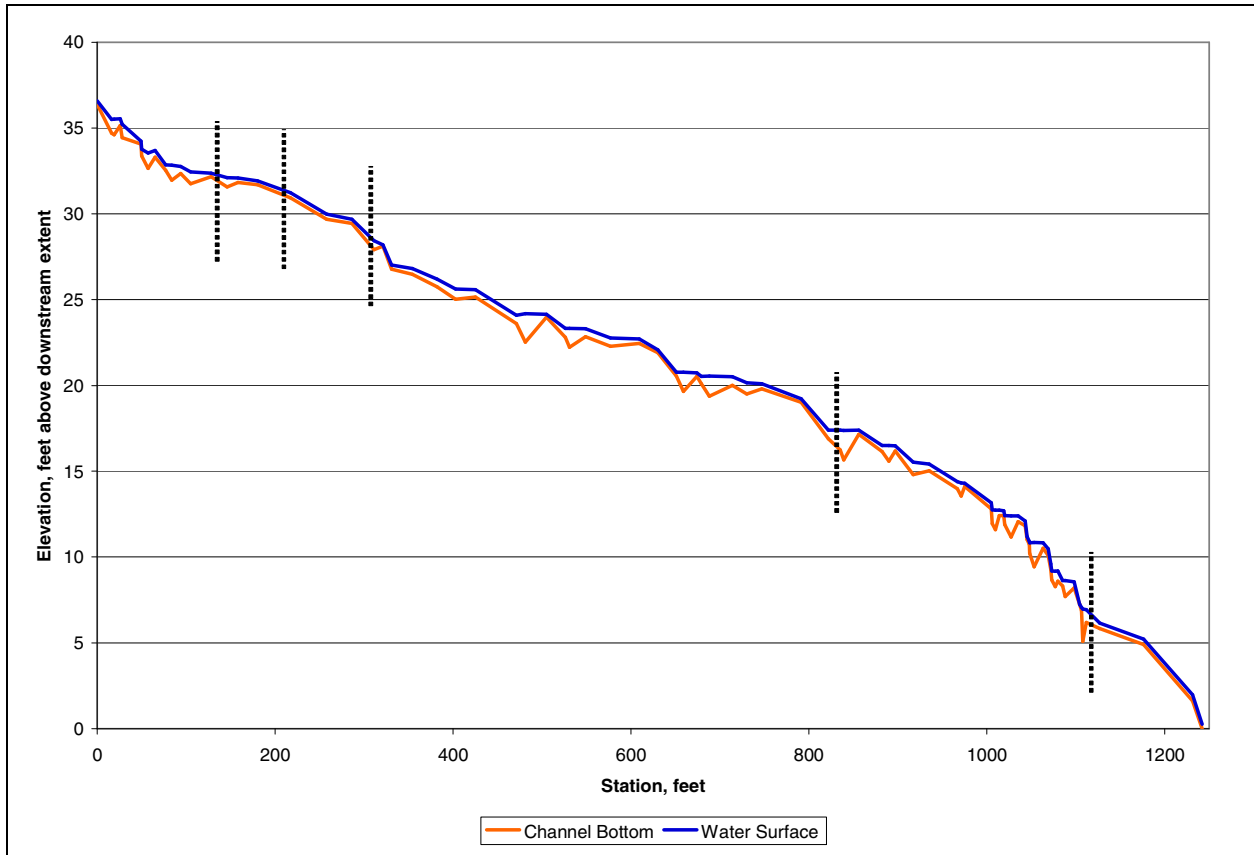
**FIGURE 6.** Concrete block wall on left bank of channel, downstream of Crocker Creek Dam removal site. Rocks on top of wall appear to be in place to raise effective height. Looking upstream. Photo taken by Alicia Gilbreath on November 3, 2005.



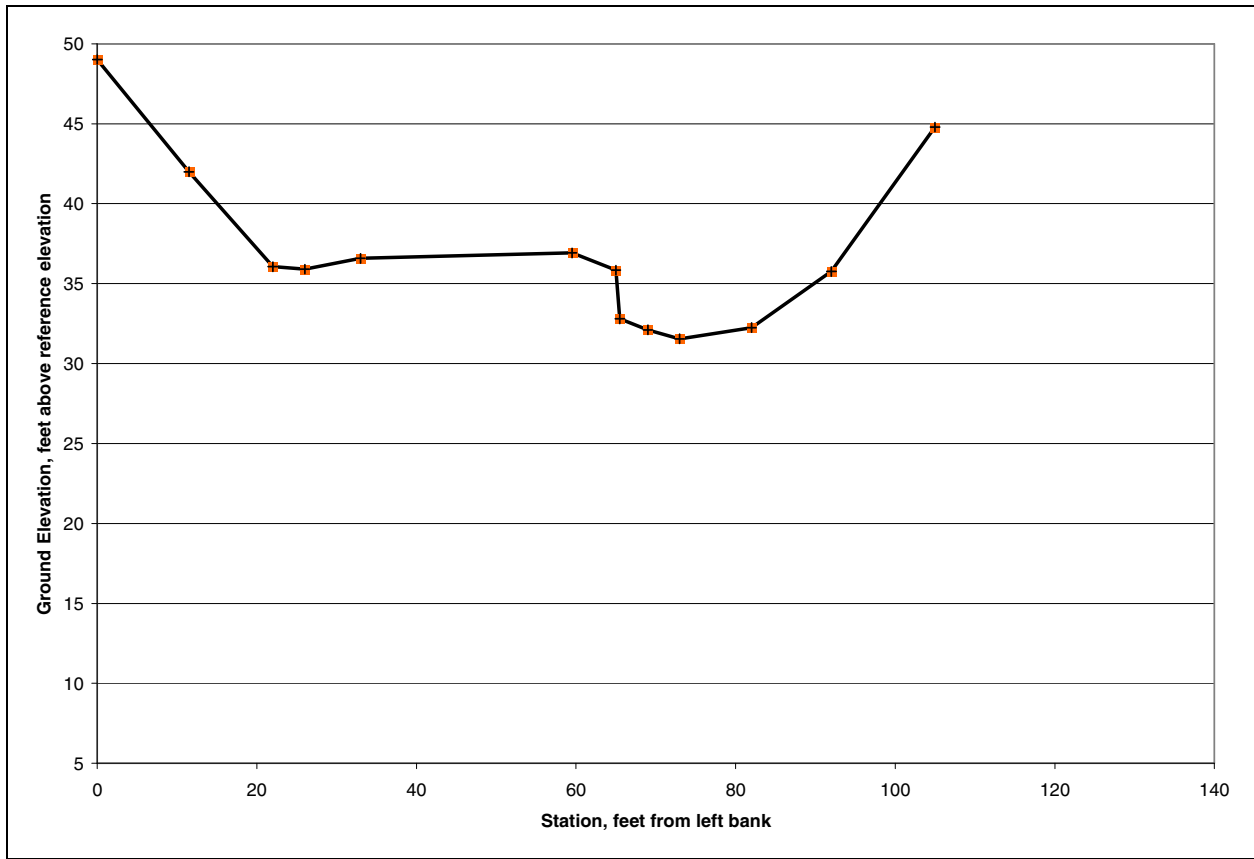
**FIGURE 7.** Rocks piled near left bank downstream of Crocker Creek Dam removal site. Looking downstream. Photo taken by Maureen Downing-Kunz on November 3, 2005.



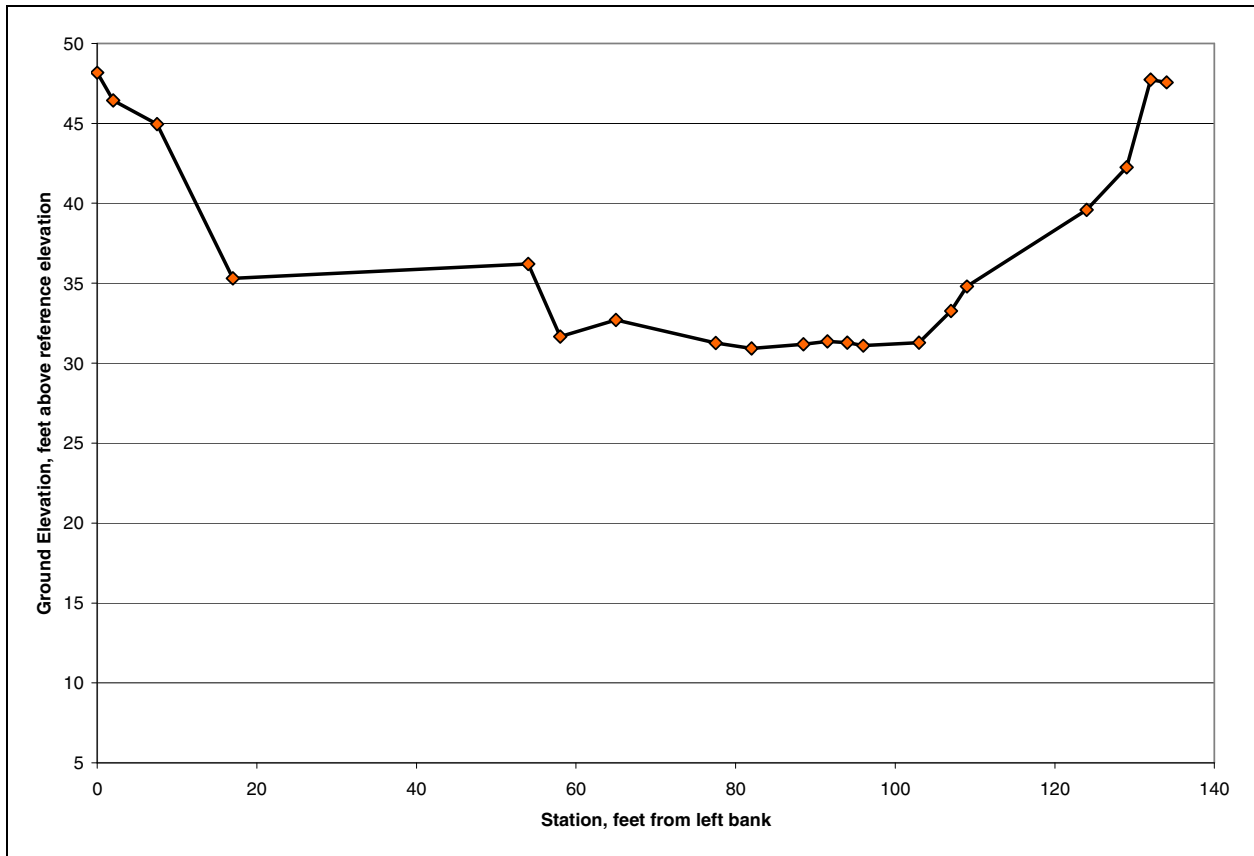
**FIGURE 8.** Pre-project longitudinal profile of stream, as determined from construction documents. Elevation of channel bottom, in feet above mean sea level, is plotted vs. Station, in feet.



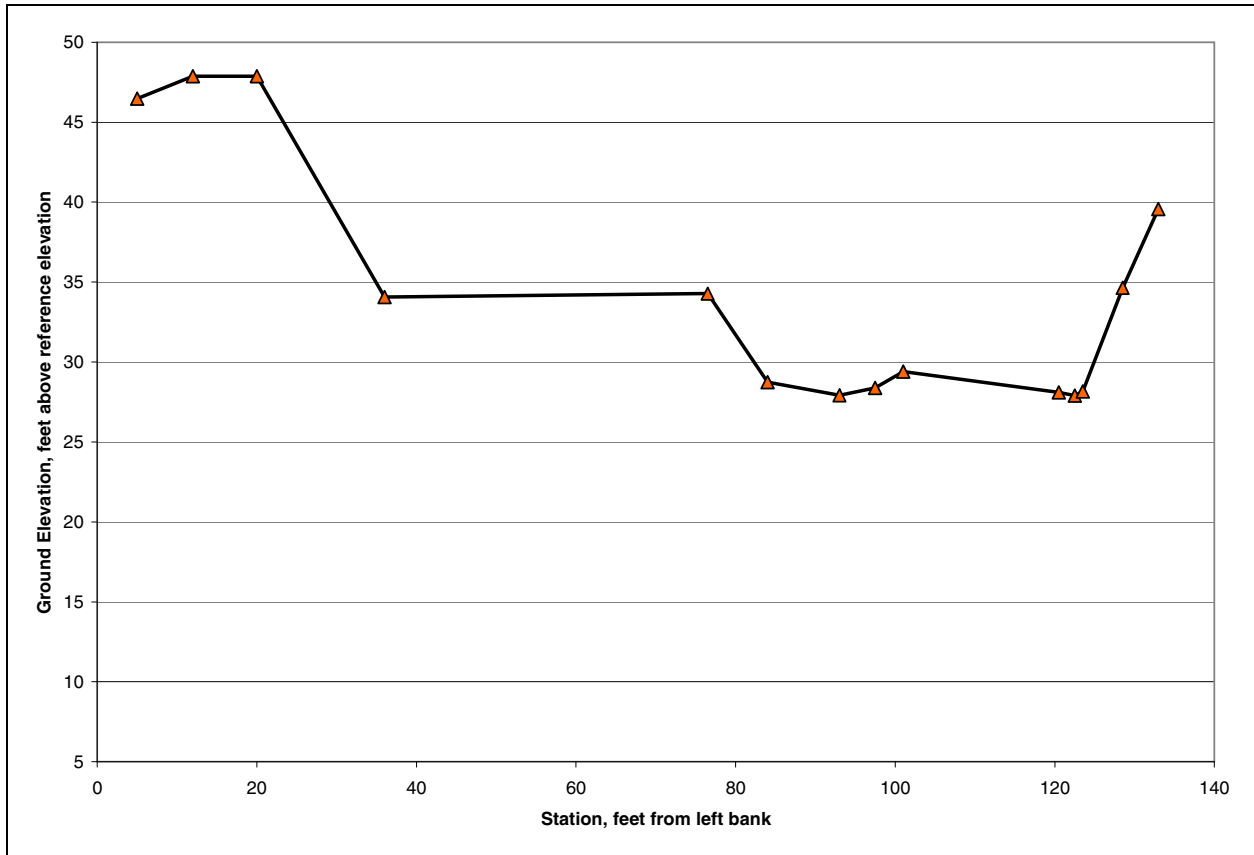
**FIGURE 9.** Post-project longitudinal profile of stream along thalweg, beginning at upstream boundary of project area (Station 0). Elevation of channel bottom and water surface are plotted relative to downstream extent (feet). Channel cross-section locations are indicated by vertical, dashed lines.



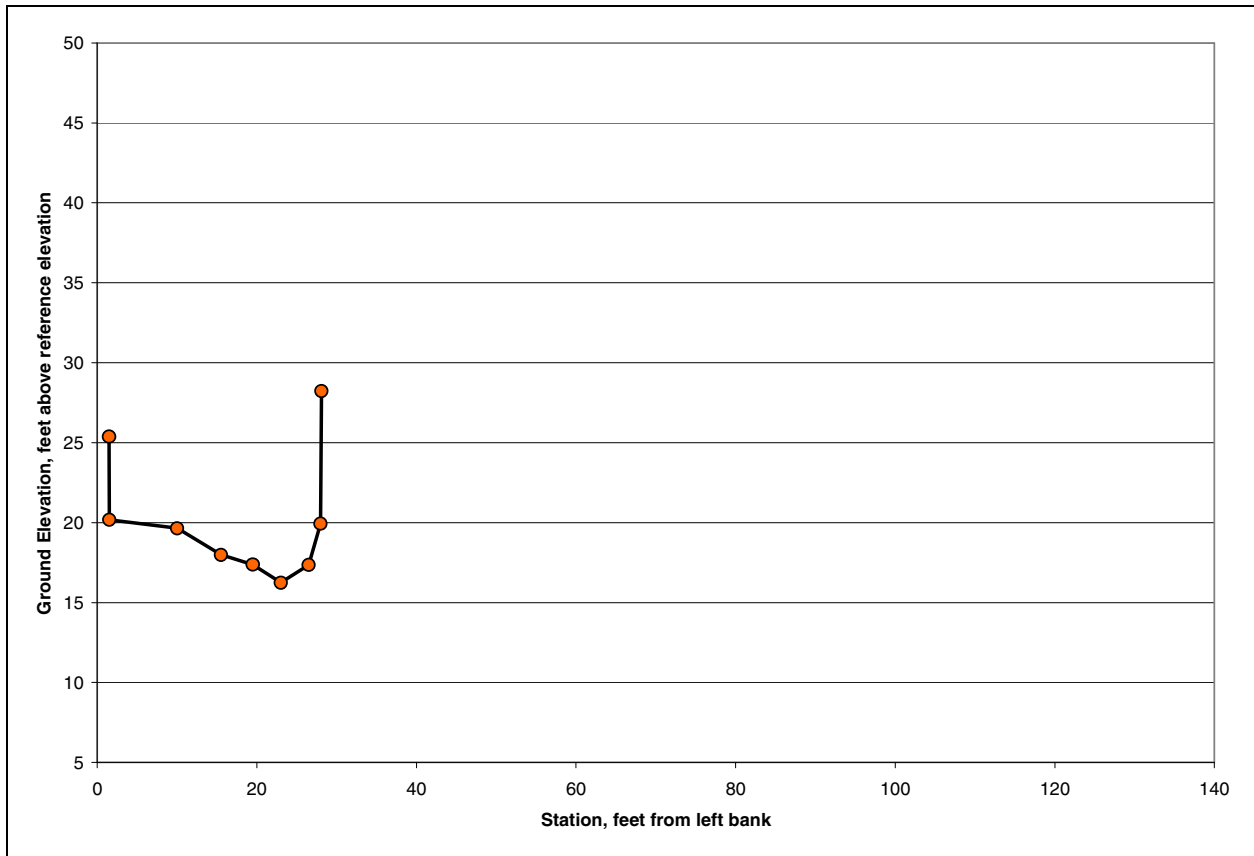
**FIGURE 10.** Cross-section 1 (CS1) located at Station 146 on longitudinal profile. Cross-section intersects longitudinal profile at thalweg (CS1 Station 73). Ground elevation, in feet above reference elevation (0 ft at Station 1242), is plotted vs. Station, as feet from left bank.



**FIGURE 11.** Cross-section 2 (CS2) located at Station 217 on longitudinal profile. Cross-section intersects longitudinal profile at thalweg (CS2 Station 82). Ground elevation, in feet above reference elevation (0 ft at Station 1242), is plotted vs. Station, as feet from left bank.

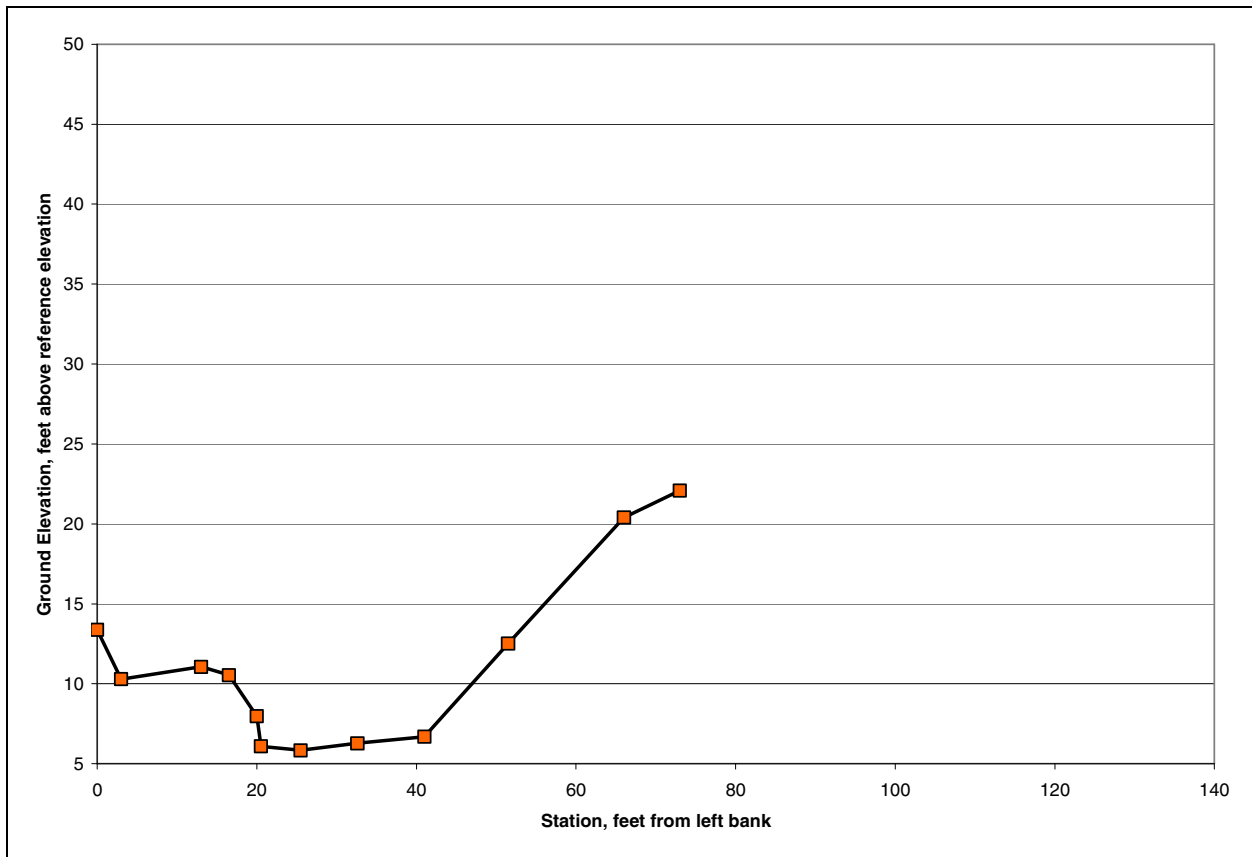


**FIGURE 12.** Cross-section 3 (CS3) located at Station 311 on longitudinal profile. Cross-section intersects longitudinal profile at thalweg (CS3 Station 93). Ground elevation, in feet above reference elevation (0 ft at Station 1242), is plotted vs. Station, as feet from left bank.



**FIGURE 13.** Cross-section 4 (CS4) located at Station 835 on longitudinal profile. Cross-section intersects longitudinal profile at thalweg (CS4 Station 23). Ground elevation, in feet above reference elevation (0 ft at Station 1242), is plotted vs. Station, as feet from left bank.





**FIGURE 14.** Cross-section 5 (CS5) located at Station 1127 on longitudinal profile. Cross-section intersects longitudinal profile at thalweg (CS5 Station 25.5). Ground elevation, in feet above reference elevation (0 ft at Station 1242), is plotted vs. Station, as feet from left bank.

**TABLE I.** Vegetation Monitoring—Percent Survival by Location

Location	Quantity Alive	Total	Percent Survival
Area I, LP <sup>1</sup> station 1127	28	338	8
Area II, LP station 1176	28	42	67
Area IV, LP station 77	0	36	0
Overall Total	56	380	13

<sup>1</sup>Long Profile



**FIGURE 15.** View downstream of Cross Section 5 at former dam site, Station 1127 on longitudinal profile. Photo taken by Alicia Gilbreath on November 3, 2005.



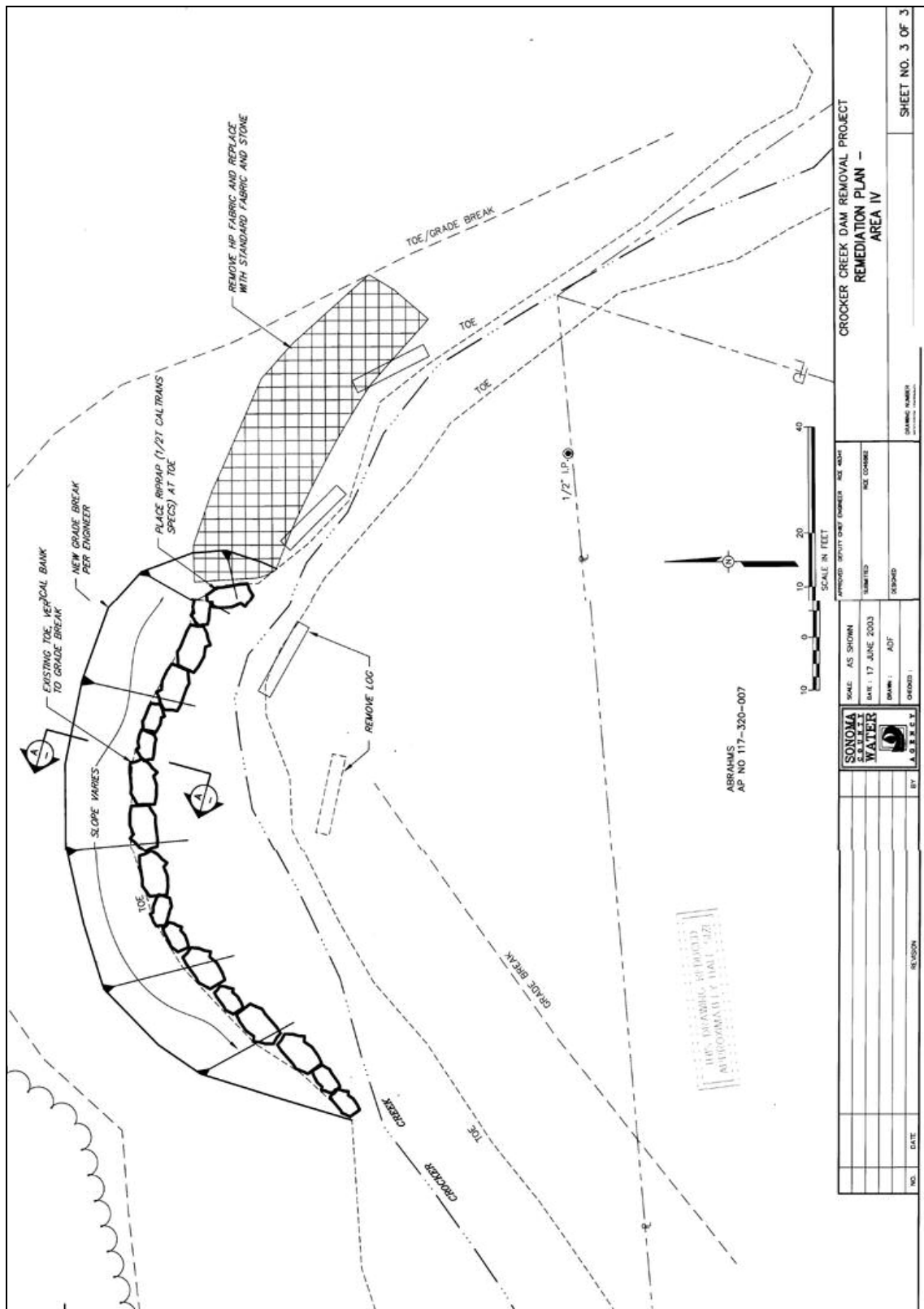
**FIGURE 16.** View downstream at Area IV. Established willows can be seen bordering the channel and in the floodplain; however, there were no survivors in the planting tubes higher on the bank (picture foreground). Photo taken by Colin Dudley on November 3, 2005.



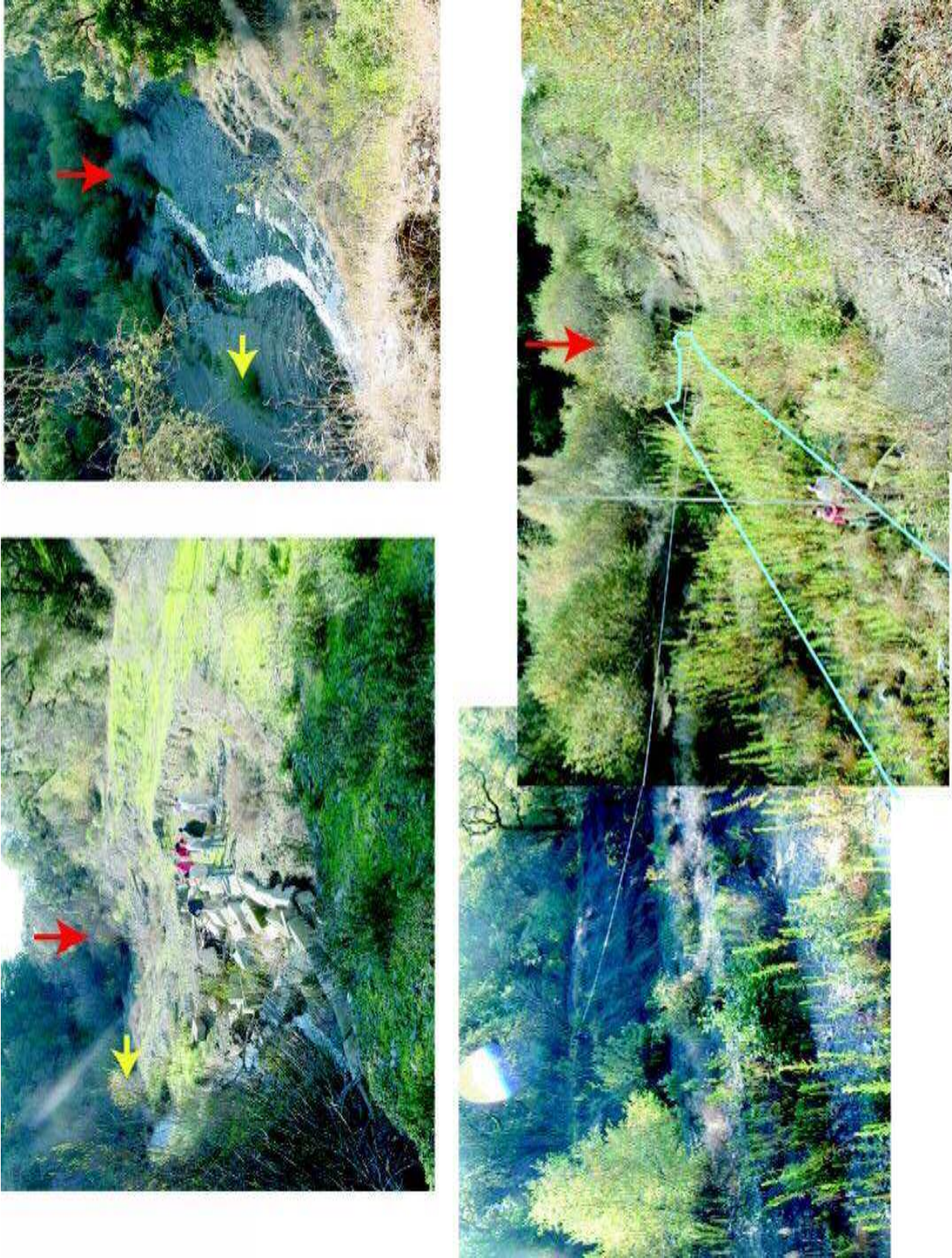
**FIGURE 17.** View of bank downstream of Area IV. Bank erosion is evident next to north channel just before joining south channel. Photo taken by Colin Dudley on November 3, 2005.



**FIGURE 18.** View of north bank of Area I. Erosion at transition from stream bank to regraded hillslope is evident. Photo taken by Alicia Gilbreath on November 3, 2005.



**FIGURE 19.** Construction plans for Area IV from 2003. Plan view of Area IV showing log structures, rip-rap, bank recontours, geotextile mats, planting locations, and flow line. Courtesy of SCWA.



**FIGURE 20.** Photo sequence of Area IV looking downstream in 2003 (top two photos) and 2005 (bottom two photos), showing progression of channel and development of secondary channel. Top two photos courtesy of SCWA, bottom two photos by Alicia Gilbreath on November 3, 2005.

APPENDIX A—FEATURE MAP OF PROJECT AREAS