Final Monitoring Report for Marlette Creek Dam Removal and Restoration Project, Period of Record 2002 to 2008

USDA Forest Service

Lake Tahoe Basin Management Unit

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I. Executive Summary

A small earthen dam on the South Fork of Marlette Creek was removed in August 2003, and restoration efforts were implemented to reconstruct the stream through this area and restore the former dam and reservoir site. When the dam was in place, it trapped sediment in a reservoir formed behind the dam, depriving downstream areas of sediment and causing severe stream bank erosion in downstream channel reaches. Much of the sediment that had been deposited in the reservoir was removed as part of the project, and distributed in the uplands away from the stream. In addition, vegetation was planted and boulders installed in the new stream banks for stream bank stabilization.

A monitoring program was implemented to; 1) evaluate project effectiveness in riparian vegetation establishment, and geomorphic changes in the stream channel and floodplain, and 2) determine whether water quality in terms of sediment and turbidity, improved as a result of the project.

Cross sections indicated (and photographic documentation and field observations confirmed) that significant stream bank erosion and down cutting continued to occur after project completion. Additional stabilization measures were implemented one year following the restoration project along a channel reach of approximately 200 feet in length where the most severe erosion occurred. These efforts were largely unsuccessful, as the erosion continued to cause boulders that were embedded in the stream banks for stabilization to become dislodged and fall into the stream, bringing large quantities of soil with them. Stream bank erosion and channel widening is most severe in the reach that flows through the upstream end of the former reservoir site, where the stream entered the reservoir. The primary causes of the post-project erosion are thought to include; 1) a stream channel design that was too straight and steep for the loose, unconsolidated material through which it flows, 2) not removing enough of the sediment that had accumulated in the upstream end of the reservoir, and 3) inadequate bank stabilization measures that incorporated only boulder-size rocks in the banks without mid-size rocks to secure the boulders.

Examination of photographic documentation and ground cover transects indicate that the vegetation establishment was mostly successful along the stream banks and floodplain, with the exception of the portion of the stream where severe bank erosion occurred. Water quality monitoring was inconclusive, due to the small data set relative to the large variability in precipitation and stream flow over the period of record.

Further restoration actions are not recommended at this time, however, continued monitoring with cross sectional and longitudinal profile surveys, and photographic documentation are recommended to determine if additional restoration actions are needed in the future.

II. Introduction

The Marlette Creek watershed is 562 acres in size and is located on the east side of Lake Tahoe between Sand Harbor to the north and Secret Harbor Creek to the south. The Marlette Creek Dam Removal and Restoration Project was implemented in August of 2003, and involved the removal of a small earthen dam on the South Fork of Marlette Creek and realignment of the stream channel through the reservoir site created by the dam (Figure 1). Before restoration, this was an un-maintained earthen dam with a large gully below the dam's spillway caused by past storm events. The gully eroded approximately 200 cubic yards of soil from one side of the valley, undermining the riparian forest and lowering the base level of the original stream channel. In addition, the reach 50 feet directly upstream from the inlet to the reservoir was experiencing active bank erosion prior to the restoration project and there was a large depositional zone where the stream dropped its sediment load as it flowed into the reservoir.

The dam site is located approximately 1,200 feet upstream of Highway 28 and is easily accessed through the US Forest Service Chimney Beach parking area on road 15N09A (Figure 1). The project reach begins at the former dam and extends upstream for approximately 350 feet. Two water quality monitoring sites were established: one approximately 100 feet downstream of the former dam and the other approximately 160 feet upstream of the upper limit of the project area (Figure 1). The objectives of the project were to restore channel morphology, hydrologic function, and riparian vegetation within the stream environment zone (SEZ) in order to improve fisheries habitat and minimize the potential water quality risks associated with dam failure.

The purpose of the monitoring efforts for this project was to evaluate the success of the dam removal and restoration of the creek. This report presents the results of pre- and post-project monitoring conducted for the Marlette Creek Dam Removal and Restoration Project from 2002 through 2008. Implementation and effectiveness monitoring was conducted with the following goals:

1. Quantify the success of mitigation measures at avoiding or minimizing the short-term effects to water quality by collecting total suspended solids (TSS), turbidity and flow measurements above and below the project area in Marlette Creek.

2. Assess changes in channel morphology and vegetation establishment with photo points at nine locations, three vegetation transects, eight channel cross sections, and a longitudinal profile of the reach.

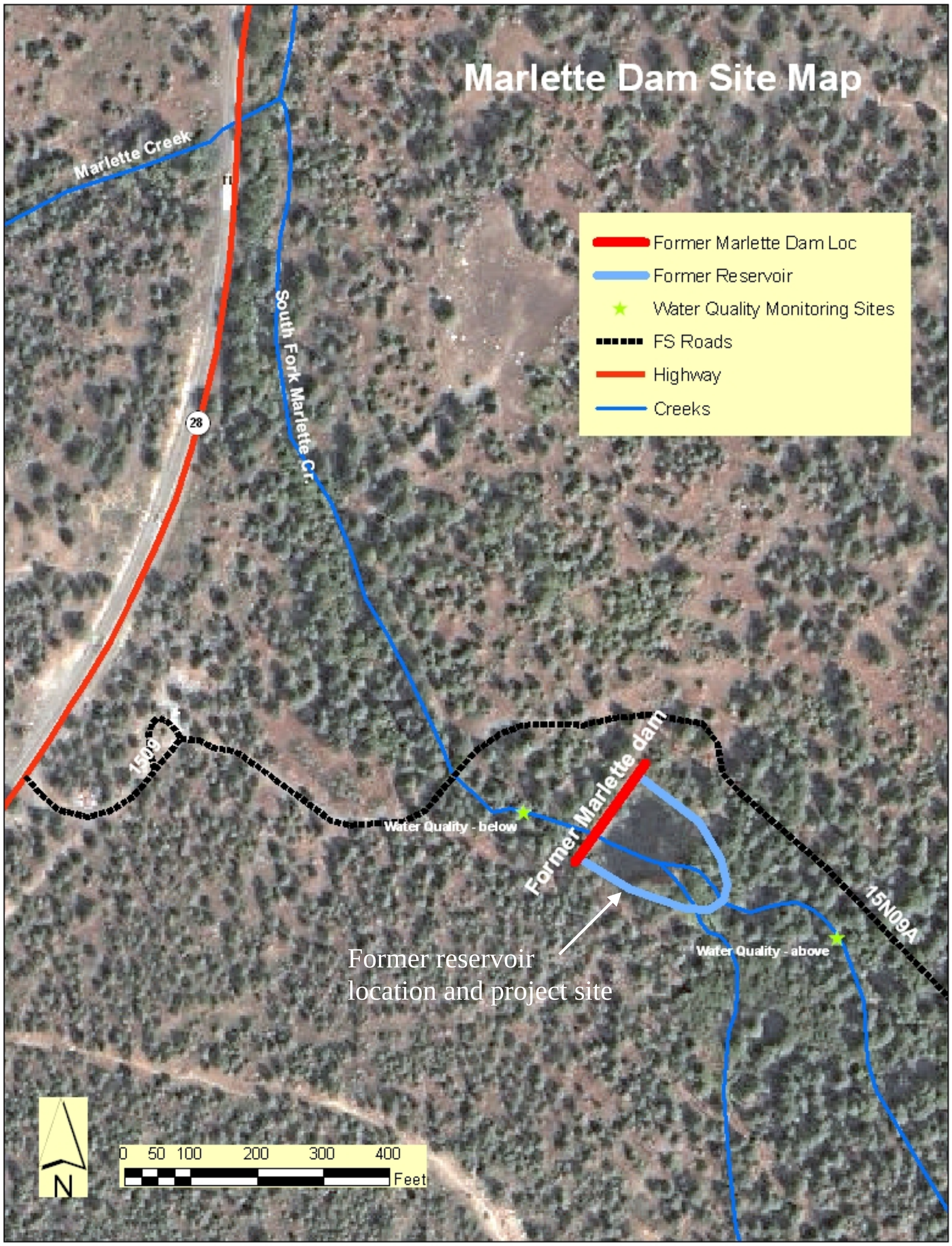

Figure 1. Project site

The following sampling frequency and duration were prescribed for this monitoring project site:

- Flow, TSS, and turbidity data collected weekly during spring runoff and monthly during base flow conditions from spring 2002 to fall 2006.
- Photos taken before the project (June, 2003), immediately after implementation (August, 2003), and again in 2004 and 2006.
- Channel cross-sections surveyed each year from 2003 through 2006.
- The longitudinal profile measured in 2004 (approximately 1 year after project completion) and again in 2008.
- Finally, vegetation and ground cover transects evaluated annually from 2004 to 2006.

In July 2004, monitoring staff noted that the northern tributary to the South Fork of Marlette Creek within the project area, just upstream of the confluence, had begun undercutting the restored stream banks (Photo #10). In addition, down-cutting of approximately 6 to 18 inches in the channel bed substrate was observed at this location. In response to these observations, the Restoration Field Crew re-contoured the stream banks and hillsides, planted sod, and installed coconut matting for erosion control later that year (2004). In 2005, streambank erosion continued and the headcuts progressed upstream. Headcuts upstream of the project area were observed during field visits; however, these appear to be historic and have not been influenced by this project. In January 2006, an interim report was completed to evaluate the success of these additional attempts to stabilize the channel. The interim report concluded that the relatively steep grade and loose, unconsolidated substrate made the restoration construction designs inappropriate for this site, resulting in considerable streambank erosion and down-cutting as the stream adjusted to its new conditions (Valentine and O'Connell, 2006).

III. Results

Water Quality

Water quality samples were collected upstream and downstream of the project site (Figure 1), and mean TSS and turbidity values for pre- and post-project sampling are displayed in Table 1. Summary statistics are presented in Appendix A and raw water quality data is presented in Appendix B. Due to staffing deficiencies in 2003 and 2004, water quality sampling did not occur at the frequency recommended in the monitoring plan for this project. Therefore, only five sampling events occurred in 2003 (June, pre-project) and two in 2004 (August and September, post-project), and these were primarily during periods of base flow conditions. In addition, while extensive monitoring occurred during the 2002 field season to represent pre-project conditions, this was a period of drought in the region, and the creek experienced less than average flow conditions. These issues make comparisons of pre- versus post-project sediment yield for this creek very difficult, and should be considered when reviewing the results contained in this report.

	Pre - Project			Post - Project		
	Turbidity (NTU)	TSS (mg/L)	Flow (cfs)	Turbidity (NTU)	TSS (mg/L)	Flow (cfs)
Above dam	1.352	4.116	0.223	7.2	13.93	0.916
Below dam	1.519	4.423	0.270	11.7	15.81	0.948

Table 1. Mean constituent values pre- and post-project.

Pre- and Post-Project Turbidity Comparison

During the sampling period prior to the dam removal (2002 through June, 2003), the mean turbidity was 1.352 NTU upstream of the project area and 1.519 NTU downstream of the project area, and the mean flow for this time period was approximately 0.25 cfs. Mean turbidity after the project was completed (from 2004 through 2006) increased to 7.2 NTU upstream of the project area and 11.7 NTU downstream of the project area, and mean flow for this time period was 0.93 cfs.

The differences in turbidity values upstream versus downstream of the project were calculated for each sampling event, and compared between pre- and post-project data sets. Prior to project implementation, the median of the differences in turbidity values between the upstream and downstream monitoring locations was 0.27 NTU compared to 1.3 NTU after the project. Thus, the median difference between the upstream and downstream turbidity values increased by 1.03 NTU after project implementation. Executing a Mann-Whitney Rank Sum Test on the pre- and post-project differences indicated that the difference between median turbidity values was greater than would be expected by chance, and is statistically significant ($P = 0.005$). Therefore, the differences between turbidity values from upstream and downstream samples increased after project implementation, and this increase is statistically significant. This data is graphically displayed in the box and whisker plots in Figure 2. The line in the middle of the box displays the median value, the boxes above and below the line represent the 25th and 75th percentile of the data, and the “whisker” displays the full range of the data, excluding outliers. Figure C1 in Appendix C illustrates the turbidity and flow data collected upstream and downstream of the project area.

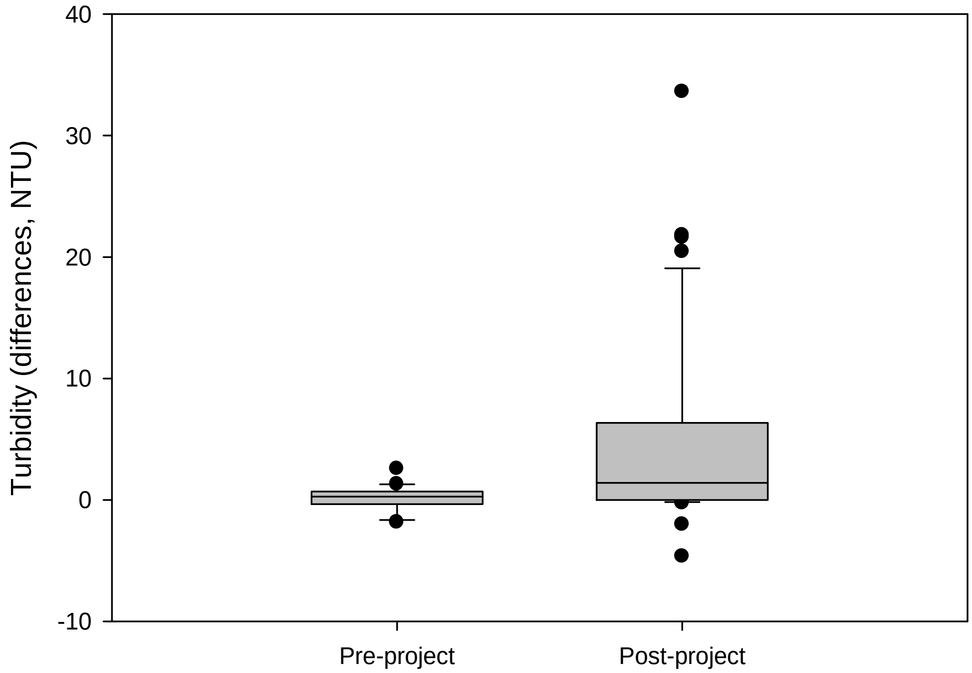

Figure 2: Pre and Post Project Median Turbidity Differences at Marlette Creek

Pre- and Post-Project TSS Comparison

The mean pre-project TSS value was 4.116 mg/L upstream of the project area and 4.423 mg/L downstream (Table 1). The mean TSS values increased for post-project (2004-2006) samples to 13.93 and 15.81 mg/L upstream and downstream of the project area, respectively (Table 1). Surprisingly all of the TSS values upstream of the project area in 2005 were greater than the values downstream (see Appendix B and Figure C2 in Appendix C). This may be a result of the pre-existing headcut and bank erosion mentioned above in the reach upstream of the project area, or other factors that affect the release of sediment (e.g. "pulses" in response to precipitation events that slowly move downstream when mobilized by subsequent precipitation events).

The differences in TSS values between measurements taken upstream of the project site and those taken downstream were also calculated, and are displayed graphically in Figure 3. Prior to implementation of the project, the median difference between the upstream and downstream values was -1.02 mg/L (i.e. TSS downstream of the project area was less than TSS upstream of the project). After the project, the median difference between the upstream and downstream values was 0.40 mg/L. Thus the difference in the median TSS values between upstream and downstream of the project site increased by 1.42 mg/L after the project. Executing a Mann-Whitney Rank Sum Test on the pre- and post-project differences indicated that the difference between median TSS values was greater than would be expected by chance, thus the difference is statistically significant (P = 0.060). Therefore, the differences between upstream and downstream samples TSS values increased after project implementation, and this increase is statistically significant.

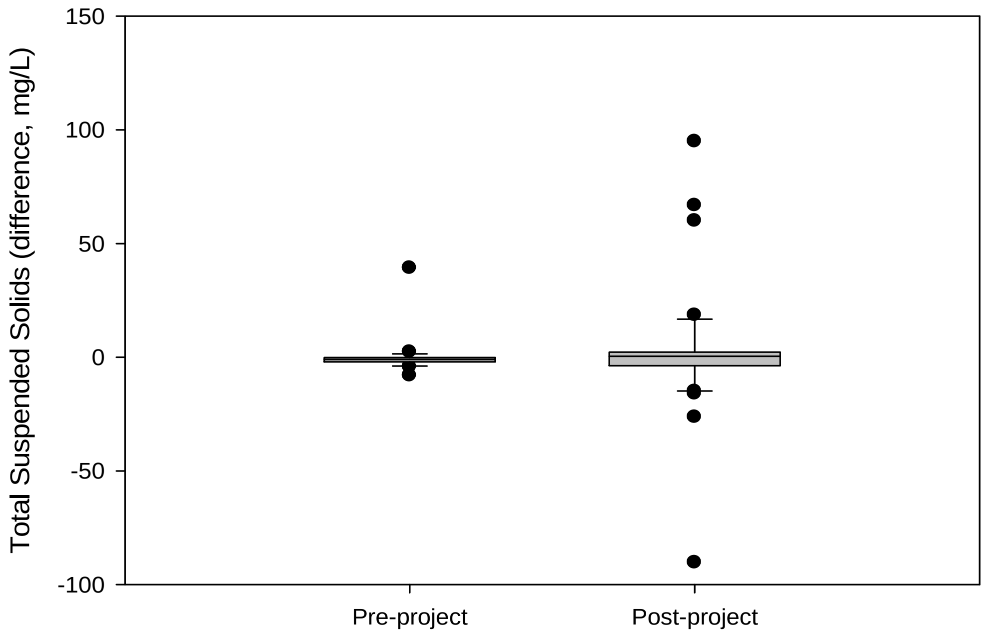

Figure 3: Pre and Post Project Median TSS Differences at Marlette Creek

<u>Comparison to State Water Quality Standards</u>

All individual turbidity values during the pre-project sampling period were well below the “not-to-exceed” (NTE) standard set by the Nevada Department of Environmental Protection (NDEP) of 10 NTU (Table 2). Recall that the pre-project sampling period exhibited drought conditions. However the NTE standard for turbidity was exceeded eleven times (nine times in 2005 and two times in 2006) at the upstream sampling site and fifteen times (twelve times in 2005 and three times in 2006) at the downstream site (Table 2) during the post-project sampling period. The high number of exceedences upstream must be considered evidence that the occurrence of wetter years mobilized a watershed-wide release of sediment that had not yet worked its way out of the system at the time of the measurements. The larger number of exceedences upstream in 2005, followed by the larger number of exceedences downstream in 2006, supports this “pulse” theory.

There was only one instance where the NDEP NTE standard for total suspended solids (TSS) of 25 mg/L was exceeded before the project, and this occurred at the downstream monitoring site. The NDEP standard for TSS was exceeded six times (three in both 2005 and 2006) at the upstream sampling site and five times (two in 2005 and three in 2006) at the downstream site (Table 2) during the post-project sampling period.

	Pre-Project		Post-Project		
	2002	2003	2004	2005	2006
	Exceedances for Suspended Solids (TSS) (25mg/L)				
Above Dam Site	0	0	0	3	3
Below Dam Site	1	0	0	2	3
	Exceedances for Turbidity (10 NTU)				
Above Dam Site	0	0	0	9	2
Below Dam Site	0	0	0	12	3

Table 2. Number of state water quality standard (NDEP) exceedances for turbidity and total suspended solids.

Channel Cross Sections and Longitudinal Profile:

Eight cross sections were installed within the project area to characterize the geomorphic response of the channel to dam removal (displayed in Figure D1 in Appendix D). The cross sections were spaced at intervals of approximately 20-60 ft along the main channel, starting at approximately the base of the dam (i.e., the start of the project reach). Figures D2 through D9 illustrate the changes in cross-sectional dimensions of the channel after project implementation. Upon examination of this data it became apparent that there was poor consistency and varying quality in these measurements. The location of endpoints was not well documented, so it was extremely difficult to achieve accurate “overlay” of cross-section profiles. In addition, the number of points measured in 2004 and 2005 surveys was not as detailed as the 2006 survey. This means that some of the changes illustrated in these figures are more reflective of measurement error, rather the changes in actual floodplain elevations, or channel locations. Never-the-less it was apparent that there was significant overall channel incision and widening within the main stem of Marlette Creek throughout the 8 cross sections measured between 2004 and 2006. These changes are summarized below.

- Cross section #1- the floodplain and channel seem to have changed very little at this location since project implementation.
- Cross section #2 - main stem channel depth increased from 1.4 ’to 5’ and width increased from 13’ to 29’.
- Cross section #3 - main stem channel depth increased from 2.3 ’to 4.4’ and width increased from 13’ to 15’.
- Cross section #4 – main stem channel depth increased from .6 ’to 2.3’, width did not change.
- Cross section #5 - main stem channel depth increased from 1.4 ’to 2.3’ and width increased from 7’ to 11’.
- Cross section #6 - main stem channel depth increased from .6 ’to 1.5’ and width increased from 3’ to 3.5’.
- Cross section #7 - No estimates are made regarding width and depth measurements due to confounding measurement error, but it is apparent that channel widening and deepening has occurred, and that a large boulder placed on the channel bank was undercut, causing the boulder to move away from the bank, and into the channel.

- Cross section #8 - main stem channel depth increased from .1.4 ’to 1.7’ and width increased from 7.2’ to 7.5’.

In addition, a longitudinal profile was conducted along this reach of Marlette Creek in order to track channel bed changes after dam removal (Figure D10). Field observations since 2004 have identified multiple headcuts in the channel upstream of the confluence, which seem to be slowly migrating upstream**.** These were observed to still be present and had increased in affected channel length in 2005. A longitudinal profile was repeated in November 2008. However when this data was analyzed it was determined that no permanent and identifiable beginning and end markers were given in the 2004 survey, and the distance and elevation of the upper water quality monitoring station relative to the confluence between the two years of data were unaccountably different. Other critical reference points were also not given in the 2004 survey. For these reasons, the 2004 data was discarded. The accuracy of the 2008 survey was confirmed by the closure measurements and its starting point is easily identifiable. Therefore, when a longitudinal profile is repeated in the future, a meaningful comparison of the changes in the stream bed can be made at that time.

Overall the cross section and field observations indicate that the channel is still experiencing adjustments.

Vegetation Establishment:

Three vegetation cover transects were established in 2002, prior to removal of the Marlette Dam. Transects detailing the plant species composition were conducted in June 2002 along the same alignment as cross section 2 (vegetation transect 1) and cross section 4 (vegetation transect 2). In October 2002 an additional transect (vegetation transect 3) was conducted starting at the right pin of cross section 8 and proceeding at a bearing of approximately 212°. This survey was repeated in July 2003 for transects 1 and 2, and in September 2004 for transect 3. After the project was completed these three transects were monitored for the following: “riparian vegetation cover”, “non-riparian vegetation cover”, “other cover”, “water”, and “bare soil”. These transects were monitored in November 2004, and June 2005 using this protocol. The transect locations are shown in Figure D1. The results of the 2004 and 2005 transect surveys are presented in Table 3 and they show that from the 2004 season to the 2005 season, riparian vegetation cover increased in all three vegetation transects (by 6 to 9 percent) culminating in a current riparian vegetation cover ranging from 12 to 34 %.

Cover Type	Percent Cover 2004	2005	% Change	Increase / Decrease
Vegetation Transect 1				
Riparian	8.47	14.48	6.01	Increase
Non-Riparian	11.48	6.69	4.79	Decrease
Cover (non-veg.)	75	70.9	4.1	Decrease
Water	1.23	0.96	0.27	Decrease
Bare	3.8	6.97	3.17	Increase
Vegetation Transect 2				
Riparian	25.27	34.06	8.79	Increase
Non-Riparian	8.57	3.58	4.99	Decrease
Cover (non-veg.)	53.58	52.71	0.87	Decrease
Water	1.3	2.71	1.41	Increase
Bare	11.28	6.94	4.34	Decrease
Vegetation Transect 3				
Riparian	4.95	12.08	7.13	Increase
Non-Riparian	2.75	2.74	0.01	Decrease
Cover (non-veg.)	81.32	80.76	0.56	Decrease
Water	3.3	2.74	0.56	Decrease
Bare	7.9	1.64	6.26	Decrease

Table 3. Cover Transect trends for 2004 and 2005

Photos:

Photographic documentation was conducted at nine photo points before, during, and immediately after project implementation, and for two years after project completion (2004 and 2006). Additional photographs were taken to document problems and maintenance that occurred after implementation of the project. Photo point locations are shown in Figure D1 and photos are displayed in Appendix E. The pre-project view of the reservoir and dam are shown in Appendix E**,** Photo #1. Photos #2 and 3 show the same location two months and 3 years after project completion, respectively. Most of the photo points show vegetation establishment to be successful and improving (Appendix E, Photos #4 through #7).

Photographs at locations other than the established photo points document significant erosion problems that have occurred. Photos from 2004 through 2006 show significant problems with bank erosion and scour (which often resulted in boulders falling into the stream), stream channel down-cutting (also evidenced in cross-section graphs), and under-cutting of the coconut matting which was placed to prevent erosion (Photos #8-10). Specifically, scour around several boulders has allowed them to topple into the stream (Photo #9) and cause bank failure and channel widening. Photo #8, near photo point 3, at the upper end of the former lake looking downstream shows erosion that occurred between August 2004 and October 2006.

IV. Conclusions and Recommendations

Evaluating project effectiveness using water quality data was inconclusive in this report because only a very short term data set was collected relative to the large variability in precipitation between pre- and post-project time periods, and because there is evidence of channel adjustments upstream of the project area. Additionally, cross section and photo point data clearly indicate that the channel both within and upstream of the project reach has gone through considerable adjustments since the project was implemented in 2003.

Marlette Creek in the project area flows through a loose, silty, sand material that was deposited on the lake bottom and upstream of the former lake while the dam was in place. Although excavation of the floodplain was a component of this project, this deltaic material was not completely removed during project implementation. Therefore, the channel slope is steeper at the upstream end of the project area than what originally existed. The following factors have all contributed to the instability still present in the stream channel within the project reach after dam removal and channel restoration: 1) a loose, silty, sandy bed material, 2) an overly steep channel, and 3) a lack of sufficient bank and bed stabilizing material including proper placement of established vegetation, large woody debris, and boulder/cobble structures.

In retrospect, the design of the channel restoration project was inadequate in meeting project goals. A few design changes may have resulted in a more successful project. Reducing the channel steepness by removing more of the deltaic deposits and increasing the sinuosity of the constructed stream channel might have improved the overall stability of the stream. Due to the confining nature of the slopes on either side of the stream, an inset floodplain may have been necessary to effectively increase sinuosity; however, the increase in sinuosity would have produced a longer channel and decreased its slope. This decrease in slope would then decrease the stream velocity and its erosive power, and increase the chance for vegetation to become established.

In addition to reducing channel slope, the removal of more of the deltaic deposits would have put the ground surface closer to the ground water table, making the ground water more accessible to vegetation and increasing its likelihood of establishment. Vegetation establishment has been much more successful in parts of the project area where it can easily access groundwater, such as near seeps located just downstream of the confluence. The excessive amount of material left from the delta deposits in some parts of the project limits vegetation access to sufficient moisture for survival.

Structures (i.e. large boulders) placed in the stream banks for stabilization were installed without being underlain or keyed into position using smaller rock material. Course materials such as gravel, cobbles, and small boulders can provide support for larger rock material, and reduce the likelihood of dislodged boulders. Cobbles in the 8 to 11 inch category are also often self-leveling and can perpetuate grade over time. Structures that are “keyed in” are much more resistant to erosion and can be used to confine a creek both laterally and vertically within its banks. These structures can help to establish self-adjusting riffle/pool and cascade pool sequences. Large rocks placed on the bottom of the creek should also have rock structures placed on the adjacent banks to keep the water from falling to either side or bypassing the structure entirely. Keying all structures into the floodplain or above the high water line discourages stream avulsion and stream bank erosion.

The boulders in this case were large, and were not keyed in with smaller rocks, so when they rolled into the creek they pulled stream bank material with them. The boulders settled into the channel, allowing the creek to erode sediment from around the sides of the boulders thereby contributing to an increase in lateral and vertical cutting. The boulders used for this project were also too large to create step-pool sequences in the channel, which would have contributed to overall stream stability.

The stream banks in the lower 300 foot portion of the project area, between the former dam site and approximately 75 below the confluence, are mostly stabilized by vegetation and are therefore experiencing much less bank erosion than other sections of the project reach. However, approximately 150 feet immediately above the confluence, the channel is still actively eroding. This channel segment has a series of headcuts propagating upstream from this location, and has been widened significantly. The stream banks in this area are composed of unconsolidated material and are largely devoid of vegetation. This area may be subject to additional channel widening resulting in further sediment delivery to downstream reaches, and possibly additional propagation of the headcuts. Active erosion is likely eroding the deltaic material deposited while the dam was in place that was not completely removed during the restoration activities.

Additionally, the stream segment downstream of the former dam was deprived of sediment for many years while the dam was in place. Since the dam was removed, sediment transported by the channel can now continue to downstream reaches, and many areas where erosion and incision occurred while the dam was in place are currently aggrading. Therefore, much of the erosion that has, and still is, occurring since project implementation is delivering sediment to downstream reaches and aggrading areas where erosion and incision occurred while the dam was in place.

Continued monitoring and evaluation of this site is recommended to determine if additional channel stabilization measures are needed in the future.

Monitoring Recommendations

Annual photo monitoring should be continued for the next five years. Also, following each high precipitation year, but no later than 2013, the cross section and longitudinal profile should be repeated to determine whether the channel is moving toward a more stable condition, or if the widening and lowering of the channel are continuing and further restoration actions are needed.

Recommendations for Monitoring Future Projects:
When developing monitoring plans for future restoration projects, the goals of monitoring should be carefully considered and articulated, and clear documentation of monitoring

protocols should be included. Some of the monitoring efforts of this project were not as effective as they could have been due to a variety of reasons. For example, the longitudinal profile measured in 2004 did not document the starting and ending points of the profile, and various other points of reference that should have been taken along the profile (i.e. the locations of cross sections). In addition, this survey was not “closed” by surveying back to the original bench mark to confirm that unacceptable survey error didn’t occur. Detailed notes for end point locations for cross sections were also not documented in previous year’s surveys, and often times one or both ends were unable to be located in the field. This meant that the starting and/or ending points and direction had to be approximated in repeat surveys. The result was often lateral and vertical offsets that sometimes did not allow meaningful comparisons to be made, affecting the repeatability of the monitoring efforts.

Visual markers to monument locations of monitoring points and transects in areas where public use is expected can result in impacts to the aesthetic quality of the area and may result in the destruction of the marker. However, a durable and reasonably obvious marker on a fixed, natural object (i.e. a 3” x 3” orange rubber tag attached to a tree limb), with distance and direction to the point of concern printed on it, as well as accurate and unambiguous directions documented on the field forms and electronic files are imperative for re-locating these key reference locations.

Accurate and complete survey data is especially important because evaluation of channel restoration project impacts using water quality monitoring will always be confounded by variations in precipitation and the natural variability of water quality parameters. In addition to the inconsistency that occurred in the sampling frequency during this project, the precipitation regimes (and consequently flow) were drastically different between the limited pre- and post-project water quality data collected. Physical measurements of geomorphology and photo points are often more reliable means to inform managers of the need for adaptive management and overall project success.

V. References

State of Nevada, Department of Conservation and Natural Resources – Division of Environmental Protection . Nevada Administrative Code, Chapter 445A.1915; Water Controls, Standards of Water Quality – Lake Tahoe.

Valentine, Scott and O'Connell, Jeff. *2005 Interim Adaptive Management monitoring Report for Marlette Creek Dam Removal and Restoration Project*. USDA Forest Service, Lake Tahoe Basin Management Unit, January 2006

Appendix A
Marlette Creek Water Quality Data Summary Statistics

		Above Dam			Below Dam		
		Flow cfs	**Turbidity** NTU	**TSS** mg/L	**Flow** cfs	**Turbidity** NTU	**TSS** mg/L
2002	Min	0.04	0.43	1.48	0.05	0.53	0.00
	Max	0.43	3.47	7.20	0.49	2.99	40.68
	median	0.21	0.96	3.03	0.29	1.52	2.49
	mean	0.22	1.21	3.37	0.27	1.54	4.55
	std err	0.03	0.21	0.34	0.03	0.13	2.15
2003	Min	0.03	0.34	0.21	0.15	1.13	2.50
	Max	0.43	7.20	3.47	0.38	2.39	6.70
	median	0.21	3.03	0.96	0.25	1.21	3.65
	mean	0.19	3.08	1.26	0.25	1.63	4.00
	std err	0.07	1.16	0.58	0.03	0.29	0.70
2005	Min	0.25	0.73	1.80	0.21	0.68	1.80
	Max	1.75	57.60	162.00	2.08	91.20	71.67
	median	0.55	10.39	14.20	0.71	12.30	5.40
	mean	0.76	12.52	27.73	0.88	18.45	15.83
	std err	0.12	3.29	23.82	0.15	6.30	6.57
2006	Min	0.11	0.37	0.62	0.17	0.36	1.20
	Max	3.49	22.70	49.02	3.66	36.30	130.00
	median	0.73	1.67	3.00	0.69	1.85	2.60
	mean	1.14	3.51	7.53	1.20	6.56	17.99
	std err	0.21	1.11	2.55	0.23	2.40	7.79

Appendix B
Raw Water Quality Data for Marlette Creek

Date	Turbidity above dam site (NTU)	Turbidity below dam site (NTU)	TSS above dam site (mg/L)	TSS below dam site (mg/L)	Flow above dam site (cfs)	Flow below dam site (cfs)
3/12/2002	1.21	1.35	2.5	0.6	0.194	0.244
3/19/2002	0.94	1.27	2.15	0	0.195	0.218
3/26/2002	0.75	1.52	1.48	**40.68**	0.154	0.31
4/2/2002	3.47	1.62	7.2	2.86	0.255	0.393
4/9/2002	2.62	1.72	4.04	2.01	0.411	0.486
4/16/2002	2.42	2.32	3.21	2.41	0.376	0.422
4/26/2002	0.69	1.55	2.73	2.11	0.29	0.385
4/30/2002	0.96	1.36	2.61	1.82	0.27	0.379
5/9/2002	1.04	0.78	1.69	3.95	0.434	0.31
5/14/2002	1.46	1.42	2.44	1.42	0.302	0.354
5/22/2002	0.89	0.53	3.52	3.07	0.275	0.377
5/28/2002	0.52	1.80	5.84	6.19	0.231	0.265
6/4/2002	1.15	1.42	4.89	2.86	0.18	0.202
6/11/2002	0.56	1.14	3.1	1.39	0.128	0.214
6/18/2002	1.08	1.66	3.7	2.57	0.118	0.128
6/25/2002	N/A	N/A	2.968	3.022	0.061	0.103
7/1/2002	0.43	1.69	2.86	1.84	0.041	0.103
7/9/2002	0.44	2.99	3.651	3.134	0.0441	0.054
6/3/2003	3.00	1.13	11.2	3.1	0.279	0.266
6/12/2003	N/A	N/A	10	6.7	0.23	0.38
6/17/2003	1.55	1.21	5.19	2.5	0.263	0.206
6/24/2003	1.66	2.29	4.7	4.7	0.25	0.253
6/30/2003	1.56	1.13	3	2.8	0.152	0.152
8/17/2004	1.28	8.12	3.01	21.51	0.04	0.05
9/7/2004	0.38	2.32	1.82	5.88	0.04	0.05
3/15/2005	**14.40**	**17.20**	9.43	5.14	0.25	0.29
3/29/2005	**12.90**	**13.50**	N/A	N/A	0.25	0.28
4/05/2005	**20.20**	**23.40**	24.4	15.19	0.36	0.33
4/12/2005	**15.10**	**23.30**	20.8	6.53	0.48	0.54
4/19/2005	**14.60**	**23.10**	18.89	3.85	0.61	0.62
4/25/2005	3.92	**19.80**	18	5.33	0.59	0.54
5/3/2005	**57.60**	**91.20**	**162**	**71.67**	1.74	1.42
5/10/2005	3.01	6.48	8.88	5.48	0.87	0.91
5/17/2005	7.98	**28.40**	**45.6**	19.2	1.05	1.57
5/24/2005	**32.10**	**35.20**	**56.4**	**40.4**	1.75	2.08
5/31/2005	**15.30**	**16.90**	10.4	16	1.56	1.55
6/07/2005	6.63	**12.80**	5.99	5.4	1.18	0.97
6/14/2005	**12.80**	8.14	4.4	4.4	1.12	0.75
6/21/2005	4.73	**11.80**	3.6	2.8	0.50	0.67
6/28/2005	1.05	1.27	2	1.8	0.51	0.43
7/05/2005	1.07	1.52	1.8	2.2	0.32	0.32
7/12/2005	1.15	0.95	N/A	N/A	0.25	0.26
7/19/2005	0.73	0.68	N/A	N/A	0.29	0.21
9/28/2005	N/A	N/A	0.67	1.6	0.32	0.15

11/08/2005	0.37	0.36	1.20	2.40	0.187	0.180
Date	**Turbidity above dam site (NTU)**	**Turbidity below dam site (NTU)**	**TSS above dam site (mg/L)**	**TSS below dam site (mg/L)**	**Flow above dam site (cfs)**	**Flow below dam site (cfs)**
03/14/2006	3.96	1.93	5.68	1.60	0.459	0.615
03/21/2006	1.12	1.48	1.33	1.33	0.513	0.428
03/28/2006	1.06	1.68	1.06	2.00	0.452	0.585
04/04/2006	1.89	4.30	2.60	6.20	0.580	0.754
04/11/2006	1.47	2.33	1.60	2.40	0.930	0.615
04/18/2006	1.87	3.56	3.00	5.50	0.749	0.933
04/25/2006	2.97	5.51	5.20	11.20	1.423	1.522
05/02/2006	**12.80**	**34.40**	**35.20**	**130.00**	3.422	3.316
05/09/2006	9.52	**31.30**	**25.20**	**85.20**	2.420	3.334
05/16/2006	**22.70**	**36.30**	**49.02**	**115.69**	3.485	3.656
05/23/2006	3.35	6.10	6.40	16.00	2.512	2.607
05/30/2006	1.64	2.83	5.20	7.20	1.896	2.248
06/06/2006	1.98	1.91	4.80	5.20	1.913	1.678
06/13/2006	1.80	1.79	9.20	4.40	1.534	1.497
06/20/2006	1.55	1.55	4.40	2.40	0.894	0.979
06/27/2006	1.70	1.44	4.00	4.40	0.728	0.688
07/05/2006	1.51	1.55	1.20	1.20	0.644	0.549
07/12/2006	N/A	N/A	1.00	2.20	0.475	0.436
07/19/2006	1.13	1.18	2.20	2.60	0.351	0.381
07/25/2006	1.14	0.99	2.00	1.60	0.265	0.273
08/02/2006	0.98	0.92	1.00	1.40	0.279	0.256
09/11/2006	0.81	1.01	0.62	1.60	0.111	0.172

Bolded values indicate exceedance of NDEP standard (turbidity = 10 NTU, and TSS = 25 mg/L)

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Appendix C: Figures of Turbidity, TSS and Flow Data

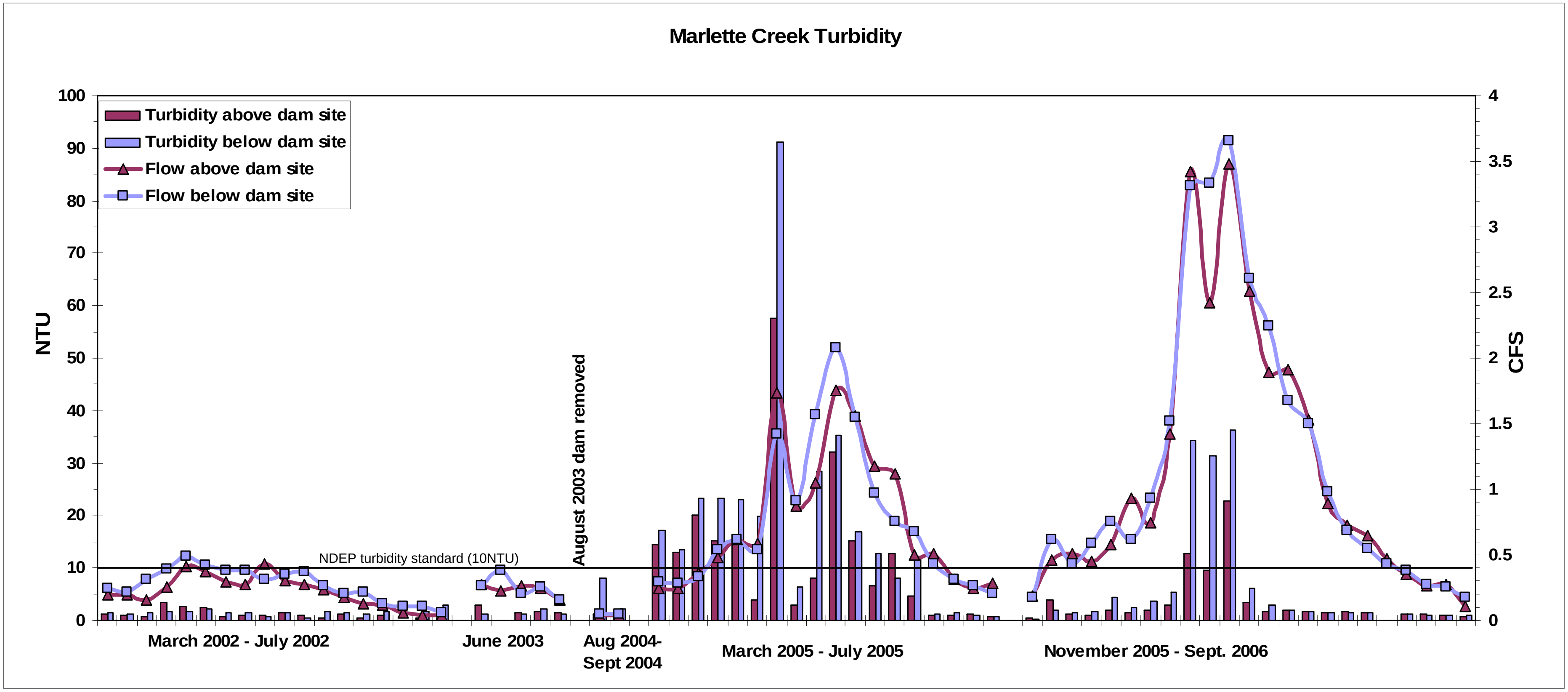

Figure C1. Turbidity above and below dam site with stream flow rate.

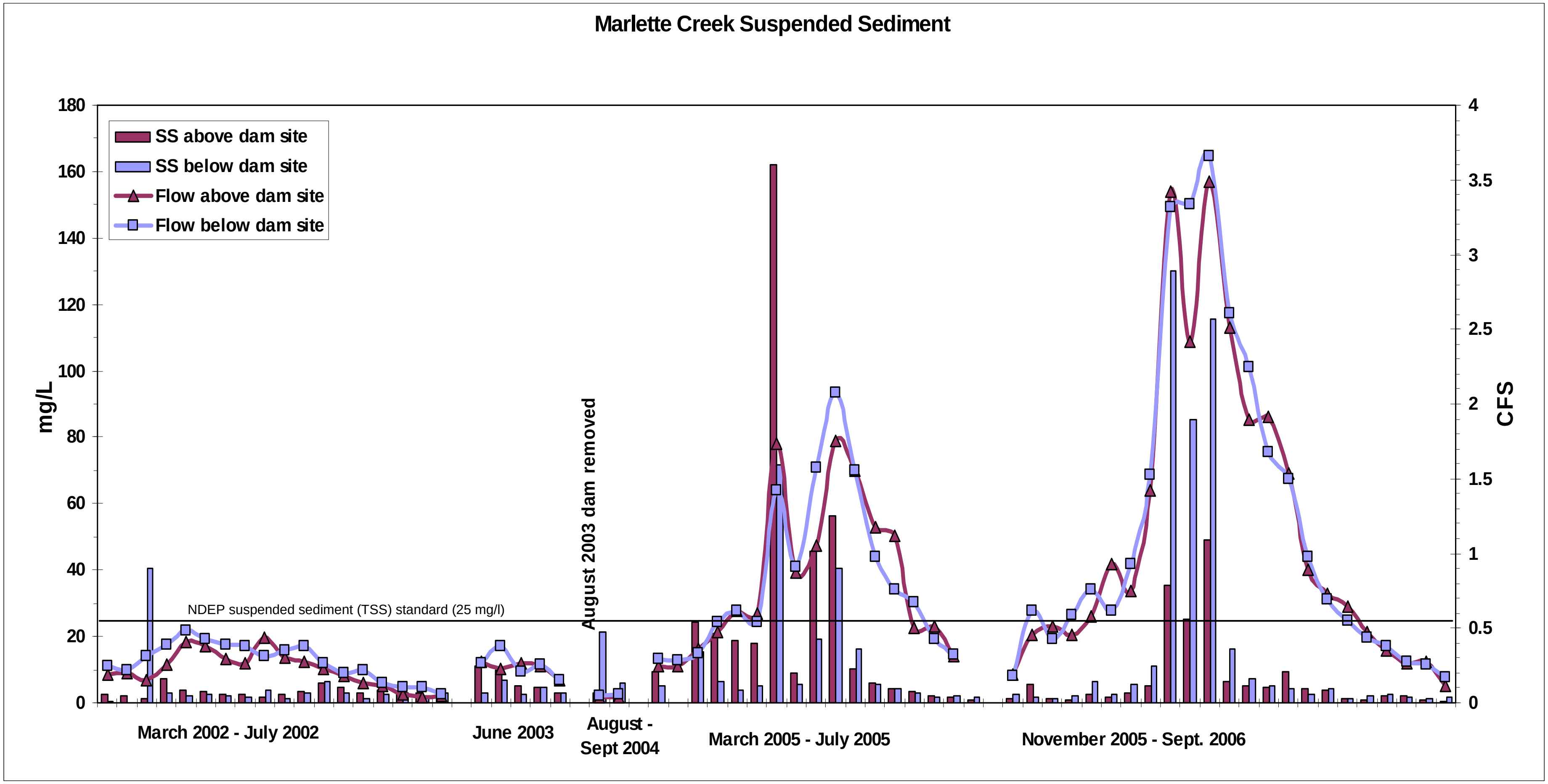

Figure C2. Total suspended solids (TSS) above and below dam site with stream flow rate.

Appendix D:
Figures of Cross Section Data and Longitudinal Profile

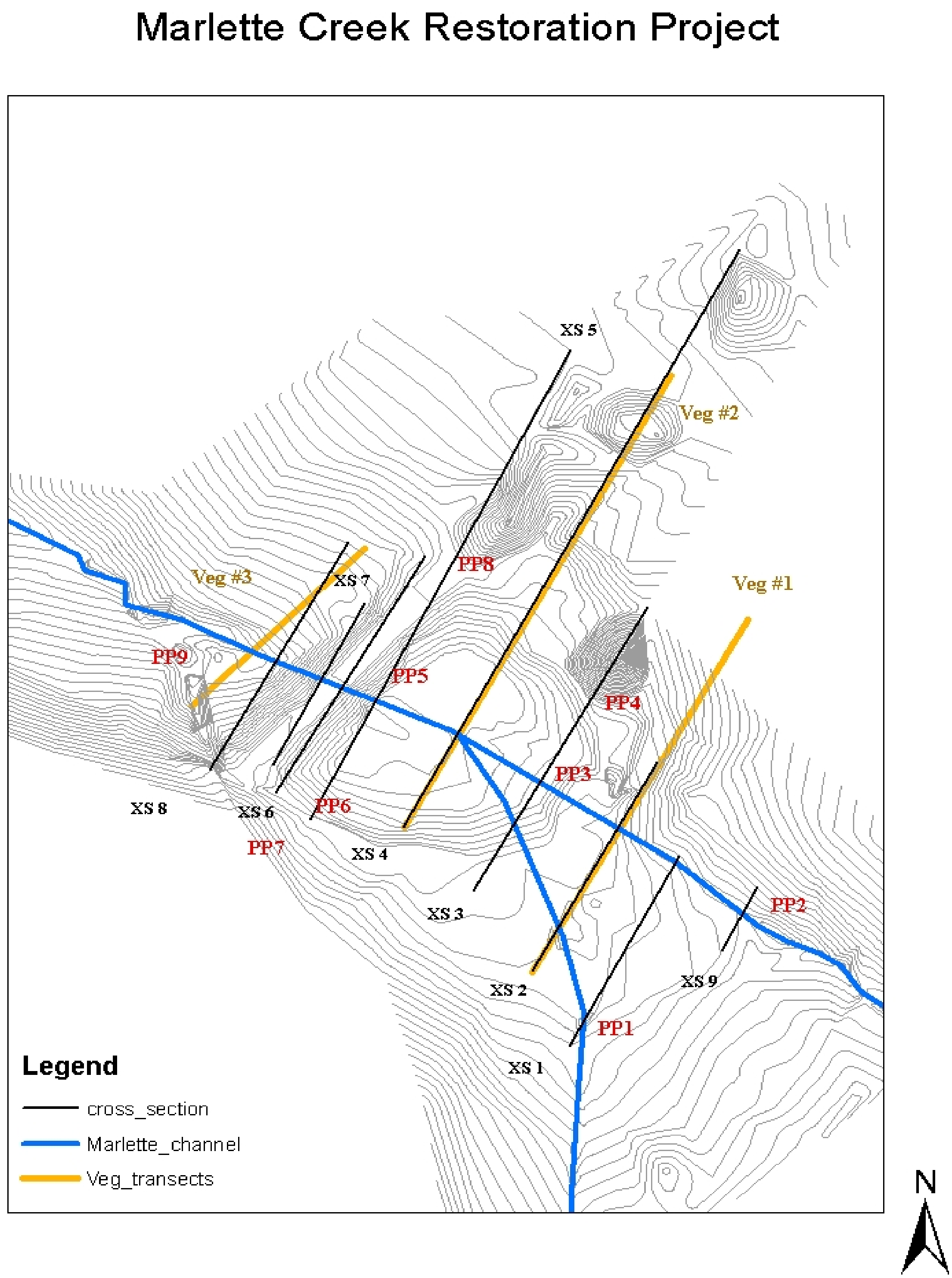

Figure D1. Layout of photo points, cross sections, and vegetation transects.

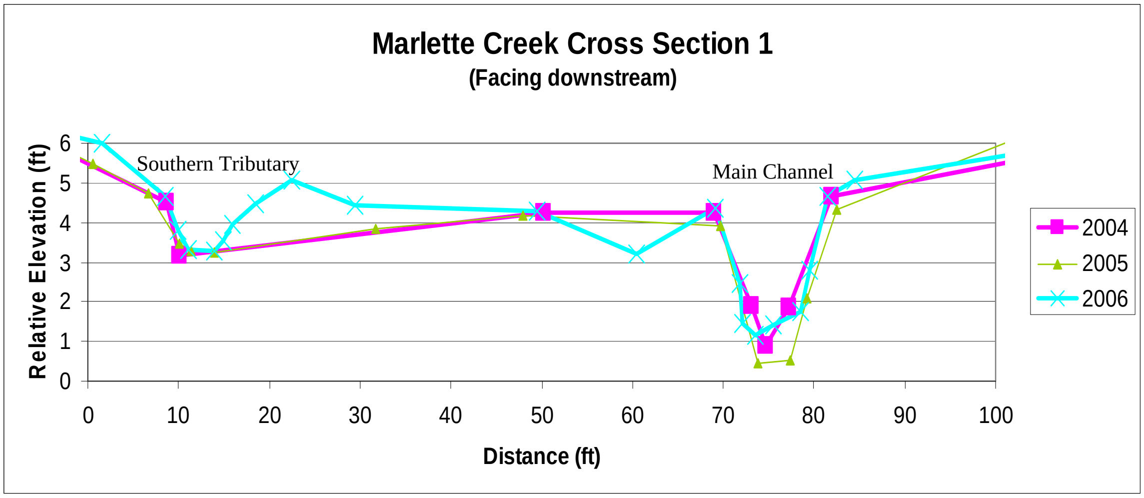

Figure D2. Marlette Creek Cross Section comparison graphs.

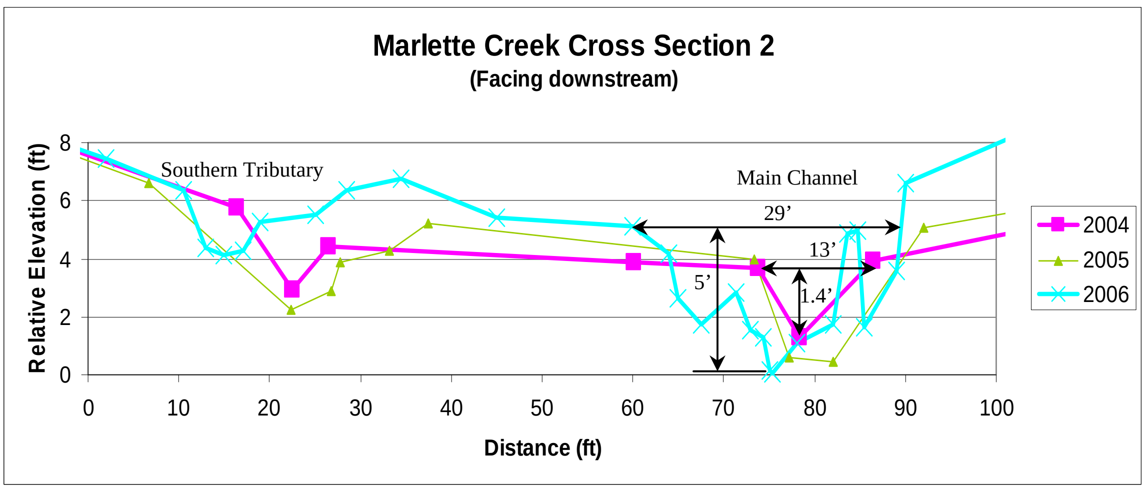

Figure D3. Marlette Creek Cross Section comparison graphs. Channel width and depths shown for 2004 and 2006.

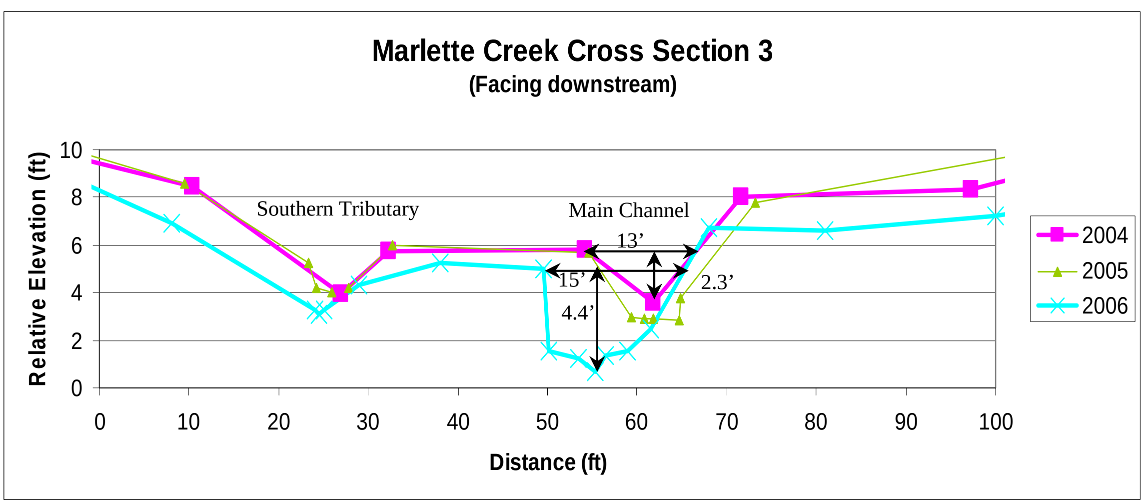

Figure D4. Marlette Creek Cross Section comparison graphs. Channel width and depths shown for 2004 and 2006.

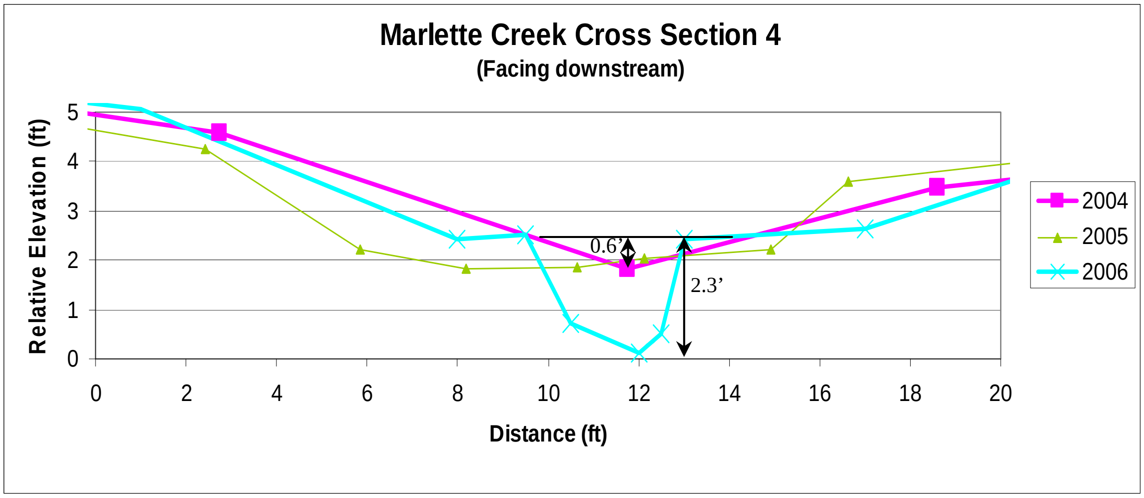

Figure D5. Marlette Creek Cross Section. Channel width and depths shown for 2006.

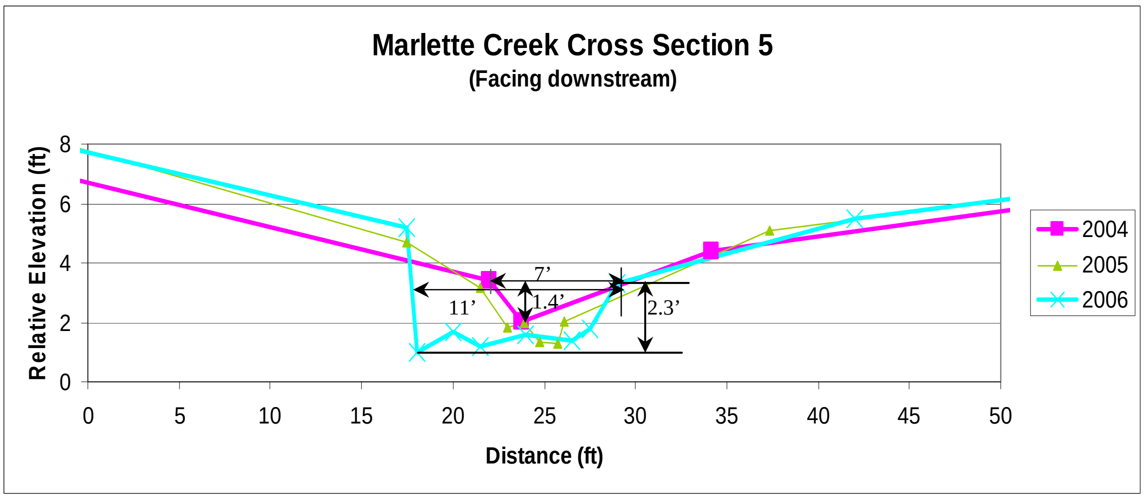

Figure D6. Marlette Creek Cross Section comparison graphs. Channel width and depths shown for 2004 and 2006.

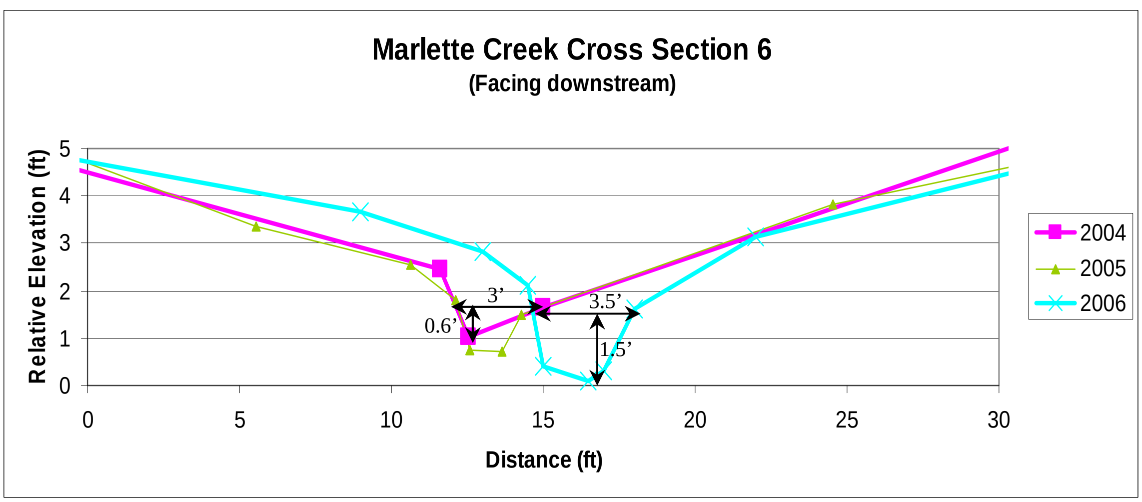

Figure D7. Marlette Creek Cross Section comparison graphs. Channel width and depths shown for 2004 and 2006.

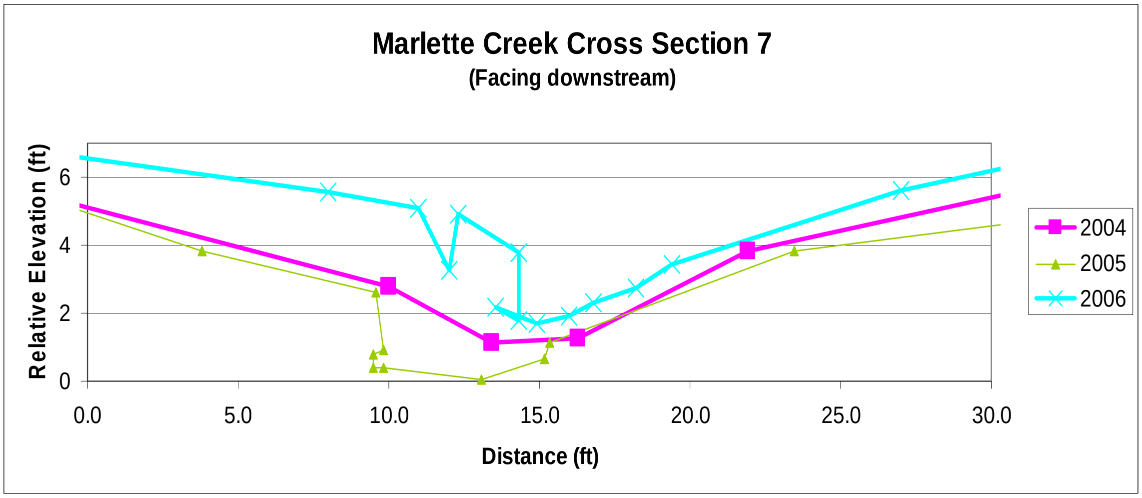

Figure D8. Marlette Creek Cross Section comparison graphs.

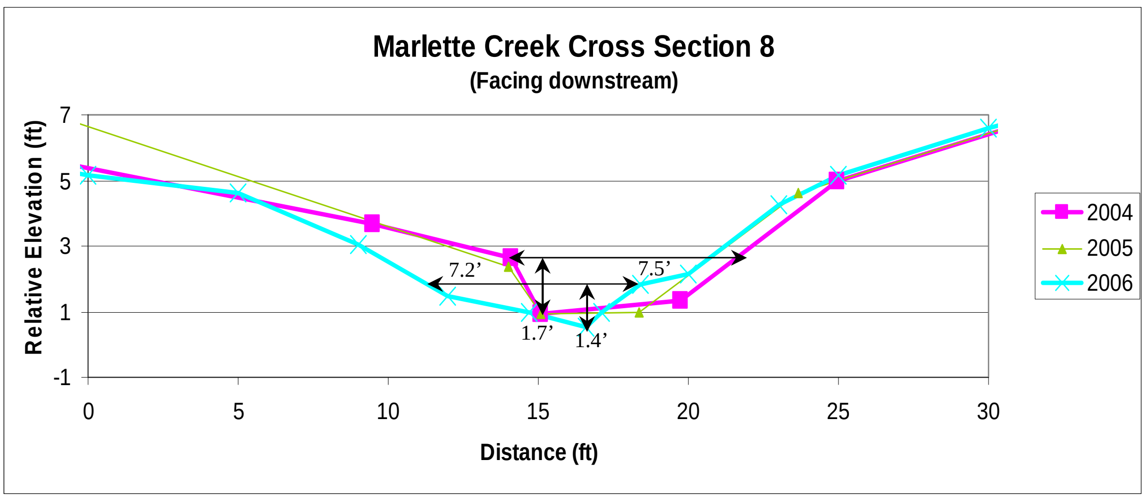

Figure D9. Marlette Creek Cross Section comparison graphs. Channel width and depths shown for 2004 and 2006.

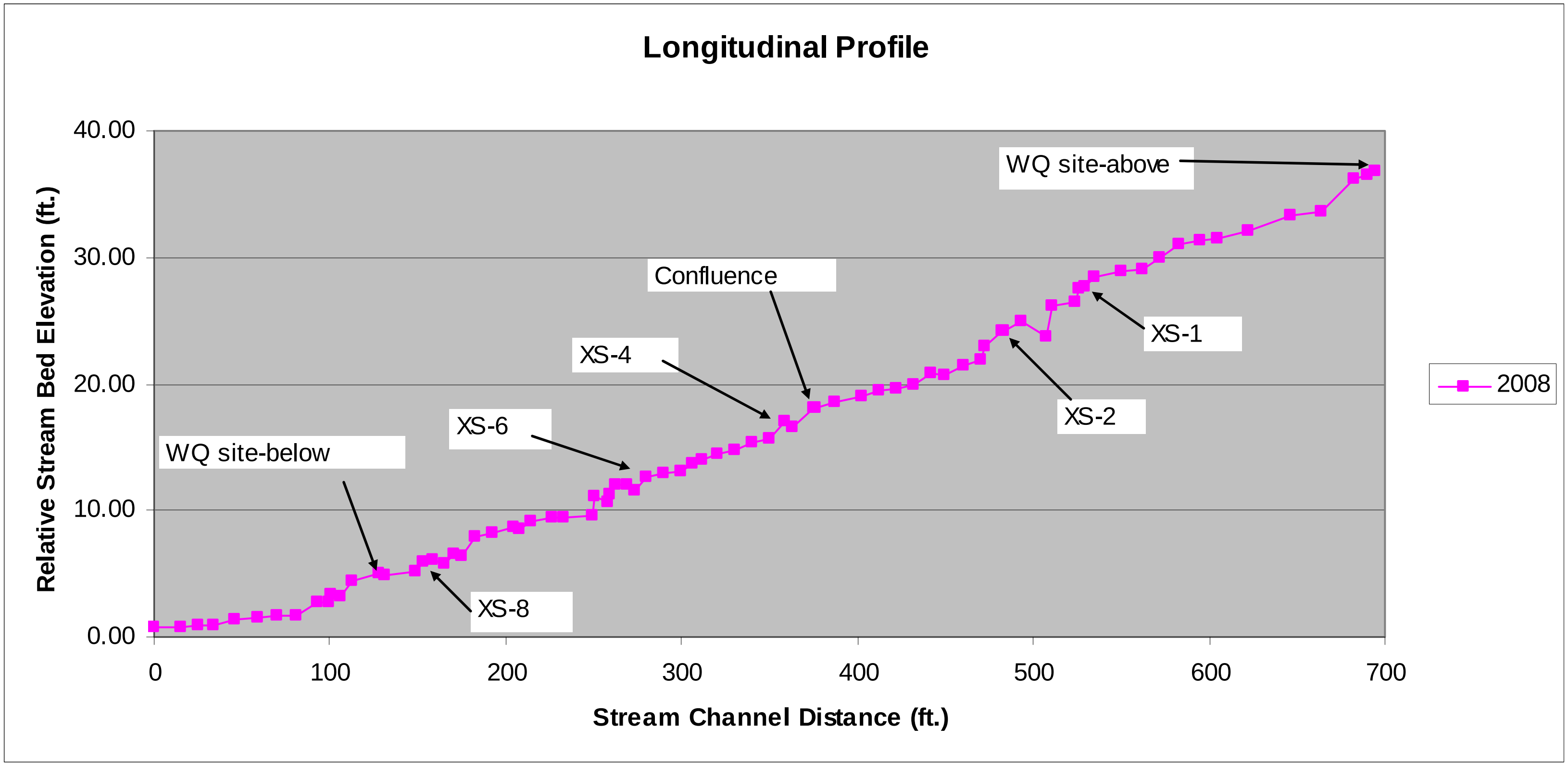

Figure D10. 2008 longitudinal profile.

Appendix E:
Photographic Documentation

Photo #1. Reservoir prior to dam removal (June 2003) at pp4 (view to W - 270°).

Photo #2. Two months after project completion (Oct. 27, 2003) at pp4 (view to W - 270°).

Photo #3. Three years after project completion (Oct. 12, 2006) at pp4 (view to W - 270°).

Photo #4. pp1 (view to NW - 350°). Sep. 09, 2003 (one month after project completion)

Photo #5. pp1 (view to NW - 280°), Oct. 12, 2006 (three years after project completion)

Photo #6. pp5 (view to SE - 110°), Sep. 24, 2003 (one month after project completion).


Photo #7. pp5 (view to SE - 110°), Oct. 12, 2006 (three years after project completion).


Photo 8. Significant bank erosion has occurred at pp 3a, Oct. 12. 2006.

Photo #9. Erosion around boulders has resulted in boulders toppling into stream, Oct. 12, 2006.

Photo #10. Headcuts developing upstream of reservoir site and above confluence. June 14, 2005.