Blackwood Creek Reach 6 Restoration (Phase IIIA)
Effectiveness Monitoring Results

UDSA FOREST SERVICE LAKE TAHOE BASIN MANAGEMENT UNIT

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Cover Photo – Students conducting cross section and water quality measurements as part of the 2012 Watershed Education Summit (WES) in Blackwood Creek. The LTBMU looks forward to working with this program for future long term restoration effectiveness monitoring in Blackwood Creek.

Executive Summary

The reach of Blackwood Creek restored in the Phase IIIA project, was described as being “highly unstable with little evidence of the floodplain recovering from previous erosion”, in a Watershed Assessment completed in 2003 (Swanson, 2003). This reach was considered to have the highest level of vertical instability, lateral instability and riparian vegetation structure loss of any reach along the main stem creek (River Run, 2011). The River Run report also estimated that average annual bank erosion from 1965 to 2007 in the Phase IIIA project area accounted for nearly 50 percent of the total annual fine sediment load generated from bank erosion along the entire length of the main stem channel. The average annual fine sediment yield was 61 tons per year during the 1965 to 2007 period of channel and floodplain destabilization in this reach. The estimated annual load for the entire Blackwood Creek channel was 101 tons per year, roughly 12% of the average annual yield from the Blackwood Watershed during this period (846 tons per year). For comparison, the average annual fine sediment yield from the entire General Creek watershed, (a similar in size, relatively undisturbed watershed on the West Shore) was estimated at 53 tons per year during this period.

Restoration in this reach included constructing 2000 feet of new stream channel (capacity 200-300 cfs) and re-occupying 1,400 feet of abandoned channel. Channel slope was decreased from 0.0074 to 0.0056 and sinuosity increased from 1.33 to 2.1. To maintain the flow dynamics to support the desired channel pattern, 13 rock-log flow deflection structures and 28 log-based floodplain roughness structures were installed. Existing vegetation was transplanted and augmented by riparian vegetation planting to provide a seed source and further promote vegetation recovery.

The rock and log structures were designed to result in a redistribution and decrease in total average flow velocity and shear stress throughout the reach, reducing the potential for headcut and cutbank erosion, increasing floodplain sediment deposition and retention, and raising groundwater levels within the active floodplain. Over the long term, we expect to see the restored reach evolve into a stable (dynamic equilibrium) alluvial channel, with improved aquatic habitats.

In the three years post construction the project has achieved or showed positive trends towards achieving four out of the six stated restoration goals (denoted with a check icon).

✓ Goal 1: Restore geomorphic channel stability to a state of dynamic equilibrium to achieve and maintain Blackwood Creek TMDL targets for sinuosity (1.6) and bank stability (80% stable banks).

> Project area sinuosity of 2.1 and 95% bank stability currently exceeds the TMDL Blackwood Creek targets.

✓ Goal 2: Restore functional channel/floodplain relationship with floodplain inundation occurring every two to three years.

> Post project observations indicate that the two to three year floodplain inundation frequency goal has been met.

- Goal 3: Stimulate riparian vegetation growth and recovery

  Visual observations and photos indicate that planted willow stakes are surviving (especially noticeable in the low energy (slow water) zones on some channel margins and in backwater areas). High plant survivability is expected in these areas because of favorable groundwater levels as a result of restoration. As willow stakes and replanted shrubs mature they can become important seed sources for future vegetation colonization.

  Vegetation recruitment of riparian grasses, willows, and cottonwoods through natural processes is occurring, particularly in areas of new floodplain deposition of fine sediments. It is very early in the vegetation colonization process and therefore no substantial change in the degree of riparian vegetation recovery within the project area: in terms of its influence in providing floodplain and channel stability, riparian habitat, or channel shading. It is expected to take about 5 to 10 years before a substantial degree of woody riparian vegetation recovery occurs.

- ✓ Goal 4: Improve downstream water quality by increasing volume of fine sediment retained on floodplains and preventing wide spread channel erosion.

  Measurements of sediment retained on the floodplain the first year after restoration indicates retention of 142 tons of silt and clay sized particles. Visual observations and photos in the following year indicate sediment deposition continues to occur on constructed floodplain surfaces. Fine sediment retention is expected to continue as vegetation on active floodplain surfaces becomes better established. Physical measurements as well as visual observations indicate stabilization of channel cut banks, with overall bank stability increasing from approximately 30% to 95% within the project reach. The reach has changed from one dominated by processes of net degradation (channel erosion), to one dominated by processes of net aggradation (floodplain deposition).

- ✓ Goal 5: Create aquatic habitat features important to support various forms and life stages throughout the year. Restore habitat sufficient to support actions to restore Lahontan Cutthroat Trout to Blackwood Creek.

  Overall, the increases in pool quality metrics (depth, frequency, and ratio to riffles), lower % riffle fines, lower cross section width/depth ratios, and significantly less relative channel confinement, all suggest aquatic habitat has been significantly improved. Values in the project area are statistically comparable to established reference reaches in Blackwood Creek, as well as values considered healthy in scientific literature. Positive trends in these metrics are expected over the longer term as woody shrub and tree vegetation recovers providing more food, shade, and rearing habitat, for all life stages of aquatic organisms.

- Goal 6: Improve macro invertebrate community structure as compared to reference reaches and California state standards.

  Post project, the macro-invertebrate scores of the restored reach are currently comparable to those of the reference reaches. However, values in all the reaches indicate a degraded condition when compared to data collected in 2003. The restored reach is currently considered to be in “fair” condition, based on California State thresholds (for O/E score).

Although monitoring data for the restoration goals for riparian vegetation and macro invertebrate health (Goal 3 and 6) do not yet indicate that these restoration goals have been fully achieved, corrective actions are not considered necessary within the project reach at this time, and ecosystem function in the project reach is expected to continue to move in a positive trajectory. Long term effectiveness monitoring will continue as documented in the LTBMU Blackwood Creek Restoration Effectiveness Monitoring Plan (USFS, 2013).

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Appendices:

I. Introduction

The Blackwood Creek watershed is located near the town of Homewood on Lake Tahoe's west shore. Blackwood is the third largest watershed in the Lake Tahoe Basin at 11.2 square miles. The main stem of Blackwood Creek stretches approximately six miles, and is fed by six headwater tributaries. Watershed elevation ranges from 8,878 feet at Twin Peaks to 6,229 feet at Lake Tahoe. Valley slope ranges from less than one percent, to four percent.

Blackwood Creek has one of the highest sediment loads per unit area (tons/square mile) of all the streams flowing into Lake Tahoe (Todd 1989 and Simon et al, 2003), yielding approximately 2,095 metric tons per year (Reuter and Miller 2000). Some of this high sediment yield is natural, primarily due to the steep, sparsely vegetated slopes in the upper watershed, mantled by erosive volcanic parent material. Cumulative land use impacts exacerbated an already dynamic condition, and main stem channel condition is believed to be an expression of these effects.

Upper watershed restoration actions (legacy road decommissioning and system road upgrades) have largely been completed. The Blackwood Creek TMDL was adopted by the EPA in 2008 to support actions to restore aquatic habitats in degraded stream segments. The Lake Tahoe TMDL adopted by the EPA in 2011 also identifies Blackwood as one of two priority streams for stream channel restoration in the Lake Tahoe Basin.

Historic aerial photos, dating back to 1939, indicate that much of the main stem channel in the valley was a narrow, sinuous stream with vigorous riparian vegetation and a well-connected floodplain. This was especially true for the channel and floodplain below the Barker Pass crossing at a point in the canyon where a prehistoric landslide pinched the valley off, minimizing coarse sediment supply to the channel below. Cumulative impacts of historic grazing, road building, logging, in-stream gravel mining, direct channel modifications (e.g. channel straightening, and floods in the 1960s), negatively impacted watershed hydrology and disrupted sediment transport and supply dynamics, setting the stage for future widespread channel and floodplain destabilization (Swanson et al., 2003). Widespread channel and floodplain degradation peaked during the 1997 flood, which saw a record peak flow of 2940 cfs. Some segments of channel incised as much as 6 feet with banks retreating over 100 feet, resulting in a straightened channel cut through a sparsely vegetated gravelly inset floodplain bordered by vertical cut banks. Accelerated cut bank erosion continued following the 2005 (2260 cfs) and 2009 (599 cfs) peak flows.

Stream incision transformed active floodplains into terraces bordering much the of the inset floodplain. Sparsely vegetated vertical cut bank faces at terrace edges can erode easily and are a significant source of fine sediment.

Areas where the channel is straighter and sparsely vegetated have diminished capability to support aquatic life at the level they once did. For example, 1934 and 1938 California Department of Fish and Game records describe Blackwood Creek as “a wonderful stream for spawning in normal winters having good natural propagation, containing beautiful pools, continuous shade and shelter” (LWQCB, 2007). In the decades that followed, cumulative land use impacts changed aquatic habitat conditions, resulting in what Swanson (2003) described as places along the creek where “pools are rare and of poor quality with little cover other than water depth”. Despite these impacts the creek still supports a spring run of rainbow trout migrating up from Lake Tahoe. Lahontan cutthroat trout are also spring spawning fish and with management actions focused on restoration of aquatic habitats, the Tahoe Basin Recovery Implementation Team (TBRIT) has Blackwood Creek under consideration as a priority watershed for Lahontan Cutthroat Trout recovery.

II. Restoration Project Goals and Objectives

The first two phases of stream channel restoration planned for Blackwood Creek included: I) removal of a dilapidated fish ladder and associated channel restoration (implemented in 2003); and II) replacement of a non-functioning culvert at the Barker Pass Road with a bridge (implemented in 2006). Phase III included two larger-scale channel and floodplain restorations. Reach 1 addressed restoration of 0.5 miles of channel (IIIB, implemented in 2012) and Reach 6 addressed restoration of 0.75 miles of channel (IIIA, implemented in 2008/2009 and the subject of this report). *(An interim monitoring report was produced by the LTBMU in 2009 to evaluate the effectiveness of the Phase I and II restoration projects, and is posted on the LTBMU external website (LTBMU, 2009)).*

All four projects were designed to provide the physical foundation for natural processes (flooding accompanied by sediment transport/deposition, wood transport and accumulation, etc.) to transform these areas back into higher functioning channel and floodplain forms, existing is a state of dynamic equilibrium. Dynamic equilibrium, it terms of geomorphology, describes a system in which channel erosion rates are matched by aggradation rates, as channel meanders or bends slowly migrate downstream while overall sinuosity is maintained.

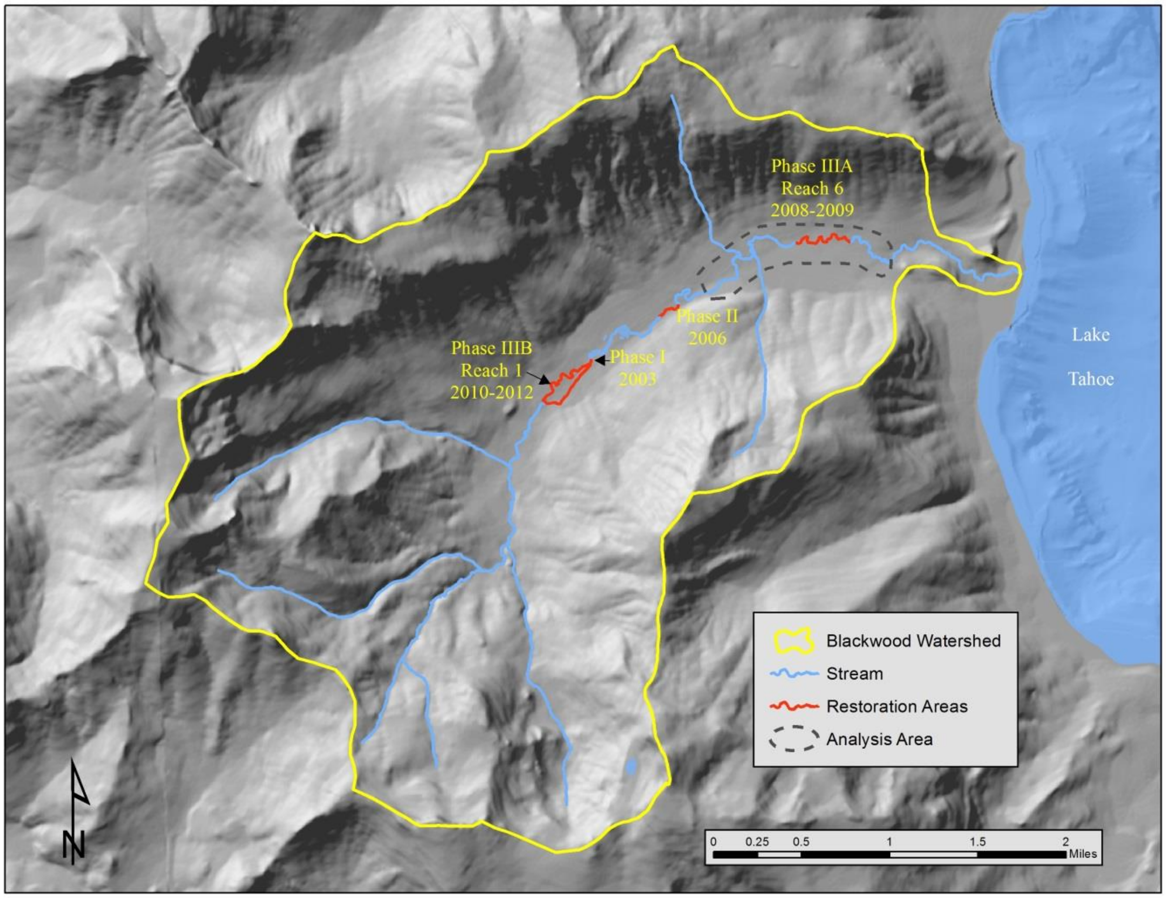


Figure 1: Blackwood Creek Restoration Project Areas

Restored Reach

The reach of Blackwood Creek restored in the Phase IIIA project, was described as being "highly unstable with little evidence of the floodplain recovering from previous erosion", in a Watershed Assessment completed in 2003 (Swanson, 2003). This reach was considered to have the highest level of vertical instability, lateral instability and riparian vegetation structure loss of any reach along the main stem creek (River Run, 2011). The River Run report also estimated that average annual bank erosion from 1965 to 2007 in the Phase IIIA project area (61 tons per year) accounted for over 50 percent of the total annual fine sediment load generated from bank erosion along the entire length of the main stem channel. The estimated annual load for the entire Blackwood Creek channel was 101 tons per year, roughly 12% of the average annual yield from the Blackwood Watershed during this period (846 tons per year). For comparison, the average annual fine sediment yield from the entire General Creek watershed, (a similar in size, relatively undisturbed watershed on the West Shore) was estimated at 53 tons per year during this period.

Restoration in this reach included constructing 2000 feet of new stream channel (capacity 200-300 CFS) and re-occupying 1400 feet of abandoned channel. Channel slope was decreased from 0.0074 to 0.0056 and sinuosity increased from 1.17 to 1.6. To maintain the flow dynamics to support the desired channel pattern, 13 rock-log flow deflection structures and 28 log-based floodplain roughness structures were installed. Existing vegetation was transplanted and augmented by riparian vegetation planting to provide a seed source and further promote vegetation recovery. Restoration actions are illustrated in Appendix A: Blackwood Phase IIIA Project Design Plans.

The rock and log structures were designed to result in a redistribution and decrease in total average flow velocity and shear stress throughout the reach, reducing the potential for headcut and cutbank erosion, increasing floodplain sediment deposition and retention, and raising groundwater levels within the active floodplain. Over the long term, we expect to see the restored reach evolve into a stable (dynamic equilibrium) alluvial channel, with improved aquatic habitats.

Because of the nature of channel erosion dynamics in this watershed, the long-term (20 year) attainment targets identified in the Blackwood TMDL were geomorphically based, rather than based on traditional water quality metrics. These targets are:

- Floodplain vegetative ecological status with similarity to potential natural community. Diversity of age classes of hardwood shrubs is present and regeneration is occurring. Vegetative rooting occurs throughout the soil profile; root masses stabilize stream banks against cutting action.

- Average sinuosity should be greater than or equal to 1.6 in Reach 6, and 1.25 in Reach 1.

- 80% stable streambanks throughout the project areas.

Based on guidance provided in the recently developed SEZ Restoration Monitoring Framework (Environmental Incentives et al, 2010), the following restoration goals and monitoring questions were identified for the project.

Goal 1: Restore dynamic geomorphic channel stability to achieve and maintain Blackwood TMDL targets for sinuosity and bank stability.

- Is sinuosity and bank stability moving towards TMDL targets, and once targets are achieved, are they maintained?

Goal 2: Restore functional channel/floodplain relationship

- Are active floodplain surfaces inundated with water every 2 to 3 years?

Goal 3: Stimulate riparian vegetation growth and recovery

- To what degree are riparian vegetation species colonizing floodplain and stream bank surfaces?

Goal 4: Improve downstream water quality by increasing volume of fine sediment retained on floodplains and preventing wide spread channel bank erosion.

- Are fine sediments being stored on the floodplain and are channel banks stable?

Goal 5: Create aquatic habitat features important to support various life forms and life stages throughout the year. Restore habitat sufficient to support actions to restore Lahontan Cutthroat Trout to Blackwood Creek.

- Are stream channel condition metrics in the restored reach statistically comparable (at the 80% confidence interval) to established "reference" reaches, and/or are they showing positive trends over time?

Goal 6: Improve macro invertebrate community structure as compared to reference reaches and California state thresholds developed for indexes of biological integrity (IBIs) and observed/expected scores (O/E).for streams in good condition (SWRCB, 2006).

- Are overall macro invertebrate IBIs and O/E scores in the restored reach comparable to that measured in established reference reaches in Blackwood Creek and at or above California state thresholds for streams considered to be in good condition?

III. Monitoring Approach

This monitoring approach was designed to evaluate project success in meeting project goals as described in the introduction and targets established in the Blackwood Creek TMDL (EPA, 2008). The Water Board and Forest Service developed the TMDL within a framework that assumed that desired conditions may not be achieved for 20 years. Both the Forest Service and Water Board agree that river systems such as Blackwood can be very dynamic and that a monitoring plan must be designed for efficiency as well as have the ability to adjust based on the magnitude and frequency of significant flood events. Desired conditions are event driven and require the occurrence of moderate to large size floods that occur once every three to ten years on average. Therefore the monitoring is also event driven so ecosystem response can be assessed quickly. Efficient post flood assessment work may lead to beneficial actions such as conducting riparian planting on fresh sediments, or indicate where repairs could be made on flood impacted areas to prevent undesirable changes in geomorphic attributes.

<u>Methodology</u>

A variety of methods was used to collect information and data to answer the monitoring questions identified above within the restored reach. In addition, in 2011 we decided to establish two "reference" reaches in Blackwood Creek, to use as a comparison to the restored reach and future watershed scale assessment. The two nearby reaches are physically similar to the restored reach and are identified as Reference Reach 4 (RR4), and Reference Reach 6 (RR6), based on how they these reaches were designated in the Blackwood Creek Watershed Assessment (Swanson, 2003). Although the reference reaches are not considered to be in "pristine" condition, they do exhibit desired attributes in terms of relative geomorphic stability and aquatic habitat quality, and have data sets from which to evaluate the 10-year trend in geomorphic stability and aquatic habitat condition relative to the restored reach pre and post project condition. There are no suitable pristine undisturbed reaches within the Tahoe Basin that can be used for reference comparisons. However, RR4 represents a reach that demonstrates long term geomorphic recovery, (40 year trend of increasing channel sinuosity as illustrated through aerial photo analysis), and RR6 exhibits persistent desirable aquatic habitat characteristics such as a low relative stream bank height with stable large wood features, and complex floodplain floodplain topography (Swanson, 2003).

The two reference reaches are located upstream (RR4) and downstream (RR6) of the restored reach. Reach gradients are similar in all three reaches, as displayed in the table below.

Table 1: Physical Characteristics of Blackwood Creek Reference Reaches and Restored Reach

Physical Characteristic	**RR 4**	**Restored Reach**	**RR6**
Channel length (m.)	1104	1140	587
Slope	0.006	.0056	0.008

Figure 2 below illustrates the location of the two reference reaches, the restored reach, and the previously established long term stream condition monitoring reach (discussed in more detail below). These methods include:

- **Visual Observations.** Used to document observations in the field relative to flooding and sediment deposition observed in the restored reaches. Also used to document other relevant characteristics or phenomena observed in the restored or baseline reaches. Initial observations are documented in short term post-construction reports (Phase IIIA - USFS 2009, USFS 2010, and USFS 2012).

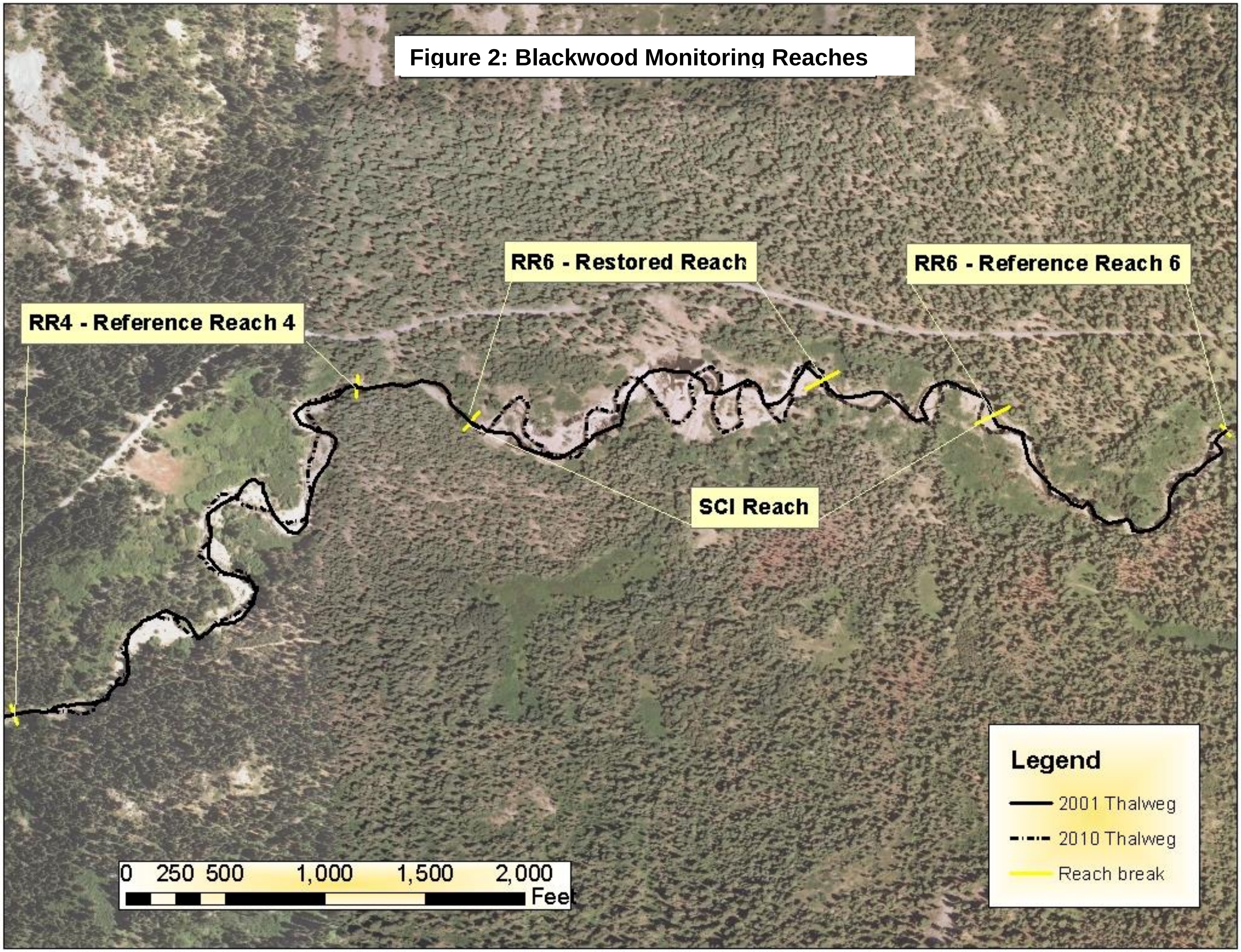


Figure 2: Blackwood Monitoring Reaches
RR6 - Restored Reach
RR6 - Reference Reach 6
RR4 - Reference Reach 4
SCI Reach
Legend
2001 Thalweg
2010 Thalweg
Reach break
0 250 500 1,000 1,500 2,000
Feet

- **Stream Channel Condition Inventory (SCI).** To measure metrics of streambank stability and fish habitat characteristics (ex. pebble counts, pool/riffle ratios, woody debris counts, bankfull width/depth ratios, entrenchment ratios, shade, bank stability, and macro-invertebrates).

  Ideally, the same protocols would have been used, to evaluate conditions right before construction and soon after implementation. However the way SCI monitoring was implemented in this reach was less then ideal, with different protocols used pre and post project, and a large gap between the pre-project data set and the time of actual construction.

  Within this reach both USFS Region 5 and USFS Region 6 Stream Condition Inventory protocols were utilized. The metrics and protocols are very similar between the two SCI protocols, and both are likely to be utilized in the future. In general, the Region 6 Level I and II protocol is considered an assessment tool that can be used as a basic monitoring tool, provided a stringent level of quality control is applied in application. Whereas the Level III measures provided in the Region 5 protocols are already designed to ensure a level of measurement consistency sufficient for project monitoring. Statistical analysis was used in the development of the Region 5 protocol to determine the sampling frequencies needed to measure change for each metric at the 80% confidence limit for a given reach.

  Historically, SCI data was collected in 1996, 1997, 2001 and partial data (only particle counts and cross-sections) in 2003, using the Region 5 protocol on a reach that included all of the restored reach, as well as 354 meters of stream downstream of the restored reach. The SCI reach was established, as representative reach for long term condition monitoring of Blackwood Creek, well before restoration actions were identified.

  Post project SCI monitoring was not planned or implemented after restoration. However in 2011 the LTBMU fisheries crew conducted SCI surveys along most of Blackwood creek utilizing the Region 6 protocols, for the purpose of assessing suitability for Lahontan cutthroat trout re-introduction. Although this data was not collected for the purpose of assessing post restoration effectiveness, we opportunistically utilized the data for this purpose in this report. For some of the metrics, where physical locations of measurements were well identified, the metrics were pulled out so that direct comparisons could be made, within the restored reach only. However for some of the metrics this was not possible, so the data collected post project was compared to the historic data for the entire SCI Reach. In either case, this is noted in each analysis described later in this report.

  Differences exist in sampling frequency and methodology used to collect the data for particular metrics, between the two protocols. We have identified when differences in protocols exist for the metrics being compared, in the report. sThe protocol for measurements is documented in the Region 5 Stream Condition Inventory (SCI) Technical Guide – Level III (USDA FS PSW July 2005) and the Region 6 Stream Inventory Handbook – Level I and II (USDA FS PNW 2009).

  Although comparing data utilizing different protocols introduces error, there was a high degree of confidence in the quality of the crews performing the data collection under both efforts, which reduces the potential for sampling crew error. We do not have funding or resources to test and quantify the degree of error that may have been introduced by either difference in sampling crews, or utilization of different protocols. For the purposes of the analysis presented in this report, we used professional judgment based on our first hand knowledge and visual observations of the project over time, to determine whether it was reasonable to conclude that differences in measured values actually represent a change in project conditions, and therefore were worthwhile to present in this report.

  - **Thalweg Profile Surveys.** In addition to utilizing the standard SCI protcols, thalweg profile surveys were conducted to measure channel gradient, and provide a two dimensional picture of fast and slow water habitats. This data was collected in 2001 (as part of watershed assessment, Swanson, 2003) and in 2011 for post project assessment. Surveyors using an electronic total station survey instrument measure the shape of the bed profile along the entire reach including pools, riffles, runs, and glides within the deepest part of the channel, known as the thalweg. Residual pool depth is determined by measuring the difference in maximum and pool tail crest depth from profiles plotted in excel. The protocol used for thalweg profile surveys is from Stream Channel Reference Sites: An illustrated guide to field technique (Harrelson et al. 1994)

- **Photo Points.** Twenty eight photo points were established at strategic locations prior to project implementation to document existing conditions and changes in channel morphology and vegetation. Photo point locations are identified with GPS coordinates of ground-based monuments in the field. A representative selection of these photo points are presented in Appendix D.

- **Aerial Photos.** Repeat aerial photos analyzed in series will also provide useful information about changes in channel sinuosity, vegetation, and channel and floodplain scour and fill. A set of digital photos that included aerial topographic contour surveys were taken in September 2001, repeated for design purposes in 2007, and repeated again in October 2010 to establish a post project base map. Channel and floodplain scour and fill changes will be analyzed by comparing future aerial surveys with the 2010 digital aerial survey base map. Cost of aerial photos is approximately $12 to $15K per set.

- **Vegetation Plots.** The purpose of this monitoring metric is determine the degree to which restoration structures were successful in promoting vegetation reestablishment, not to evaluate overall project effects on vegetation change. We will rely on photopoints and shade measurements to evaluate overall vegetation change within the floodplain and stream channel banks.

  Fifteen plots were established within the Blackwood Reach 6 project area. Five plots were established on the rock flow deflection structures, five plots at the floodplain roughness structures, and five plots along the stream channel where no structures were placed. At each plot four 10 meter transects were established in four directions from a central point. Transects were oriented upstream, downstream and perpendicular to the stream channel. Depending upon water level, the perpendicular transects could be less than 10 meters.

  Vegetative cover will be monitored using the line intercept method. Percent cover will be sampled by recording the length of intercept for each growth form along each of the 4 plot transects. Growth form will be used rather than species because the objective of these structures was primarily to improve floodplain and stream bank stability, rather than vegetation species diversity.

Growth form categories will include: woody shrubs, trees, rhizomatous species (perennial grasses, sedges), annual graminoids, herbaceous species, *Hypericum perforatum*, and other invasive species**.**

- **Channel - Floodplain Hydraulics Research**

  Channel and floodplain geomorphic response following spring runoff in 2010 presented an opportunity to study how restoration actions changed the project area hydraulic environment. A Masters study conducted by an LTBMU student employee (Immeker, 2012) involved calculating pre and post restoration average cross sectional velocity and shear stress using a calibrated one-dimensional hydraulic model coupled with GIS data (HEC-GEORAS). This study also involved project area wide deposition and scour mapping that concurs with the modeling results.

IV. Monitoring Results

This section describes the analysis results to answer the monitoring questions identified for each restoration goal.

Goal 1: Channel stability – Blackwood TMDL targets for sinuosity and bank stability.

- **Is sinuosity and bank stability moving towards TMDL targets, and once targets are achieved, are they maintained?**

As identified previously, the TMDL sinuosity target for Reach 6 is 1.6 (or greater). Sinuosity is the ratio of valley length to stream channel length for a given reach, and is a measure of how sinuous the channel is. Meandering channels with a lot of bends disperse stream flow energy better than straight channels, resulting is less erosion, more channel bed feature formation, and greater probability of vegetation recruitment and persistence, all of which leads to better aquatic habitat. The table below displays the sinuosity measurement for both the restored reach, as well as the reference reaches, based on measurements of stream channel length obtained from thalweg profile surveys of stream channel measured in 2001 and 2011. Valley length was measured from the USGS topographic map.

Table 2: Blackwood Creek Sinuosity from Thalweg Profile Surveys

Reach Name	2001	2011
Reference Reach 4	1.56	1.61
Reference Reach 6	1.50	1.66
Restored Reach	1.33	2.1
Entire Reach 6	**1.25**	**1.87**

As can be seen in this Table, sinuosity has increased slightly in the reference reaches between 2001 and 2011, and increased substantially in the restored reach as result of the project. Sinuosity over the entire length of Reach 6 is 1.87, which is greater than the TMDL target of 1.6. Aerial photos displaying sinuosity changes in the restored channel are displayed in Appendix C. These photos also display changes in channel sinuosity over time, back to 1939.

The TMDL target for bank stability is 80% stable banks. Channel stability is a key indicator of channel condition. Stable stream banks are essential for achieving desired stream channel morphology and favorable habitat for aquatic and riparian plant and animal species. In many low gradient channels, unstable banks are a major source of erosion.

Region 5 SCI protocols were utilized to obtain bank stability measurements in the SCI Reach 6, in 1996, 1997 and 2001 (this metric was not collected during the 2003 SCI survey). Region 6 SCI protocols were utilized in 2011 to obtain bank stability measurements in both the SCI Reach 6 as well as the two reference reaches in 2011. The protocols for collecting this metric were different. Region 5 protocols called for evaluations of bank stability within a 12 foot wide segment at 50 evenly spaced locations throughout the reach for both left and right banks. Region 6 protocols require measuring the actual length of unstable banks for both left and right banks. Both protocols result in an estimate of the % of stable banks within the reach.

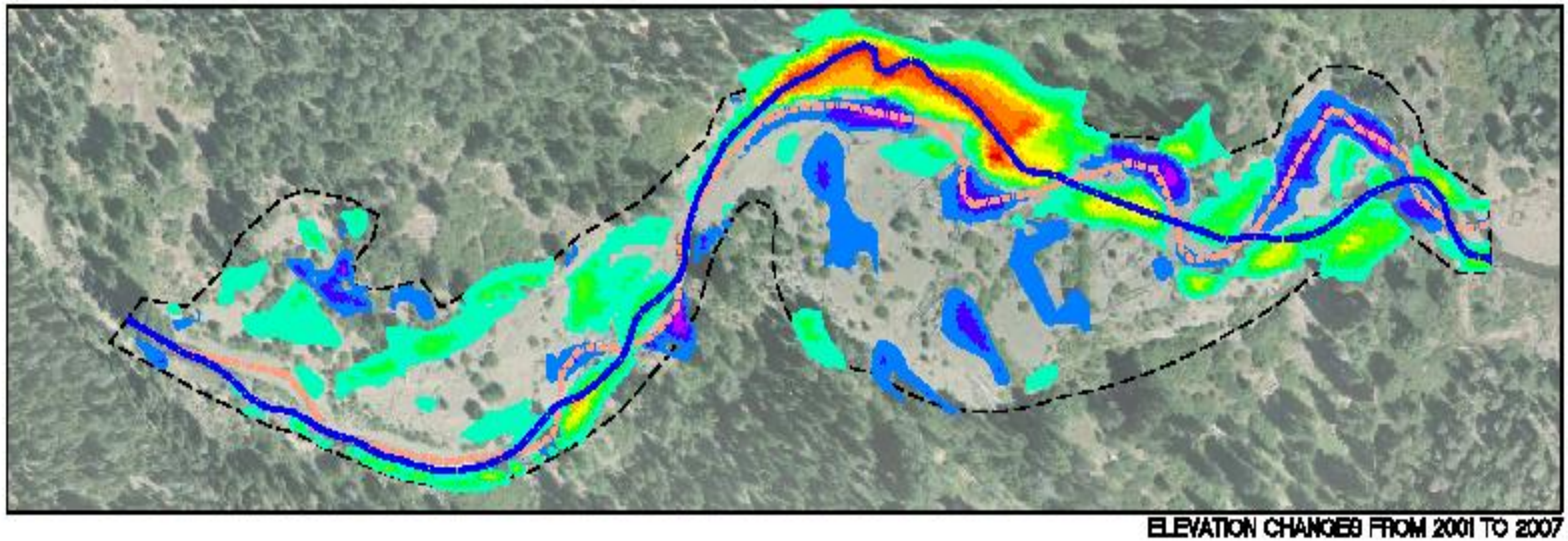
The data is presented in Table 3 below.

Table 3: Percent Stable Banks in Blackwood Creek (obtained from both Region 5 and Region 6 SCI protocols).

	RR4	**(restored reach)**	**RR 6**	**SCI Reach**
2011 (R6 protocol)	79%	95%	74%	70%
2001 (R5 protocol)				30%
1997 (R5 protocol)				15%
1996 (R5 protocol)				45%

Regardless of the amount of error that may be introduced from comparisons of data obtained from using different protocols, it is clear that the restoration project has helped considerably in meeting the TMDL target of 80% stable banks in the short term. It is also apparent that there has been a substantial increase in bank stability between the pre- and post-project data within the SCI Reach, 30% stable banks in 2001 compared to the 70% stable banks in 2011. Although SCI surveys were not conducted, wide spread bank instability was documented in this restored reach after the 2005/2006 flood by comparing 2007 and 2001 project area digital topographic aerial surveys, in an illustration prepared for the USFS by Swanson Hydrology in 2008 (Figure A). As much as 40 feet of cut bank retreat occurred in some areas. Observations and photos during and after the spring flood in 2009, described in a USFS 2012 Report sediment loading analysis report (USFS, 2012), identified an additional 5 to 10 feet of cut bank retreat in some areas.

Since the restored reach is located within this larger SCI reach, we believe this large increase in bank stability can be directly attributed to restoration actions.



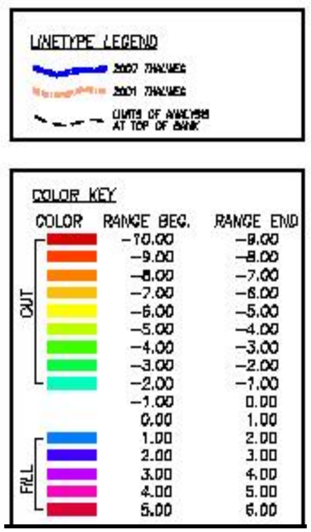


Figure A – Overall scour and fill between 2001 to 2007 at the Blackwood Reach 6 project site. Scour depth is shown in colors ranging from blue/green to red. Fill depth is shown in colors ranging from blue to pink. Mapping accomplished by overlaying the 2007 atop the 2001 project area digital aerial survey. Illustration provided to the LTBMU in 2008 by Swanson Hydrology and Geomorphology (unpublished).

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The 5% percent of unstable banks within the restored reach will continue to be monitored and remedial actions taken in the future if necessary. During higher flows we expect flow patterns to become less predictable than what has already occurred to date, so there is some uncertainty regarding the persistence and performance of low velocity backwater zones near cut banks at higher flows. Immeker's 2012 work indicates that the current flood flow patterns may persist up to the 20-year flood (2000 cfs) implying similar energy, scour, and deposition patterns up to that point. Beyond the 20-year flood flow patterns change (Waterways and River Run, 2011) as the roughness structures get drowned out and general flow pattern becomes parallel to the fall of the valley. Blackwood Creek high flow flood direction can vary further due to large wood inputs and subsequent effects on local hydraulics.

It is important to remember that the long-term monitoring SCI Reach, which was established well before the restoration project reach was identified, extends for 354 meters below the restored reach. The 2011 SCI data also indicates there is still a relatively high level of bank instability within this short section of channel below the restored reach, measured at 46 % unstable banks. Future monitoring will determine whether site specific bank stabilization within this 354 meter reach is needed.

When all the SCI data bank stability data collected in 2011 is evaluated as a whole, from the start of reference reach 4 through the bottom of reference reach 6, the % stable banks is 87 % , well above the Blackwood TMDL standard of 80% bank stability. This section of channel represents approximately 35 % of the entire main stem of Blackwood Creek.

The SCI data collected in 2011 in the restored reach also correlates well to the data presented in the Immeker Masters research, in which approximately 100 meters of bank scour was documented in 2010, which represents 4.8% of the restored reach. Results presented in this research also indicate restoration has decreased the relative sheer stress from stream flows in the restored reach, decreasing the potential for channel bank erosion. The HEC-RAS model was used to calculate the mean cross section shear stress for both pre-project and post-project conditions in the restored reach at the 2, 5, 10 and 20 year recurrence interval flows. The results show mean cross section shear stress was 48 to 63% less for the post-restoration conditions within this range of flows.

Goal 2: Channel/Floodplain function- floodplain inundation frequency

- **Are active floodplain surfaces inundated with water every 2 to 3 years?**

The project was designed to result in overbank flows in the majority of the restored reach at a flow volume of 250 cfs and visual observations indicate that the majority of the channel does exhibit overbanking flows when flows at the USGS gage at the mouth of Blackwood creek are at 250 cfs, Because there are no major tributaries between this gage and the restored reach, it is assumed that stream channel flows within the restored reach are very close to the flows measured at the USGS gage. Figure 3 below illustrates the time periods since the project was completed in October of 2009, in which flows at the Blackwood stream gauge have been equal to or exceed 250 cfs.

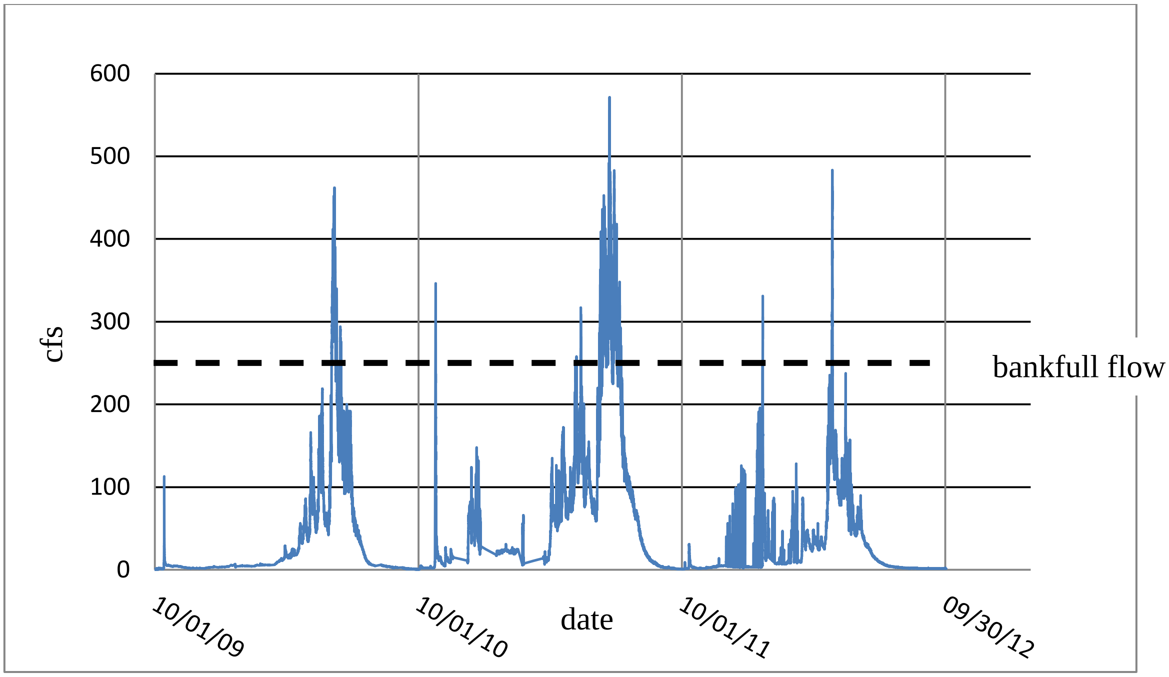


Figure 3: Blackwood Creek instantaneous 15 minute discharge at USGS station at mouth.

From the data illustrated in Figure 3, the restored reach experienced floodplain inundation for 18 days in WY 2010, 37 days in WY 2011, and 6 days in WY 2012 for a total of 61 days in the first three water years post construction. The variability in floodplain inundation is driven by precipitation, and from snowtel precipitation data measured at the NRCS Ward #3 site, the snow water equivalent (SWE) measured from the snowpack for these 3 years are considered to be average, above average, and below average respectively. It is estimated the entire constructed floodplain (excluding the constructed flow deflection structures) is inundated at approximately 600 cfs flows as measured at the Blackwood Creek LTIMP stream gage. The pictures on the following pages illustrate the degree of constructed floodplain inundation during several site visits.

Figure 4: Flood flows in restored reach on June 7, 2010 at approximately 440cfs.

Figure 5: Flood flows in restored reach on June 29, 2011 at approximately 350 cfs.

Figure 6: Flood flows in restored reach on April 26, 2012 at approximately 480 cfs.

Goal 3: Stimulate Riparian Vegetation recovery

Prior to implementation we established on the ground transects/plots to measure plant cover and structural diversity across the reconstructed floodplain (trees, shrubs, perennial graminoids (perennial grasses, rushes, sedges), annual graminoids (herbaceous forbs). In addition these transects/plots will be used to determine whether noxious or invasive plant species are present, which would warrant weed removal actions.

Post project effectiveness monitoring will be repeated every 5 years after restoration, so no quantitative post project effectiveness data is reported at this time. Visual observations and photos (illustrated in Figures 5 and 6 below) indicate that many of the willow stakes planted as part of restoration appear to be taking hold and more importantly graminoids and woody vegetation recruitment are beginning to appear in areas where fine sediment has deposited on floodplain surfaces. Salvaged woody riparian vegetation also survived the process of transplanting. This is illustrated in the photo points presented in Appendix D. One of the most dramatic areas of this transformation is illustrated in the photo sequence presented below. In this area, the elevation of the floodplain was approximately 2 feet below the desired grade because of the impacts of equipment used for temporary staging of rock material. The restoration design incorporated features to create a stable backwater in this area, so that high flows (and associated sediment transported from the upper watershed) would rapidly build up the floodplain in this area. The degree of deposition is discussed further in the next section, but the photos below illustrate the vegetation response in this area. The 2009 photo (Figure 7) is a panorama composite; the 2012 photos (7a and 7b) are standard format photos, located in the approximate area of the inset dashed boxes in the 2009 panorama in Figure 7. Photo 7c, illustrates a close up of the types of vegetation appearing within the more cobble dominated substrate along the channel margins.

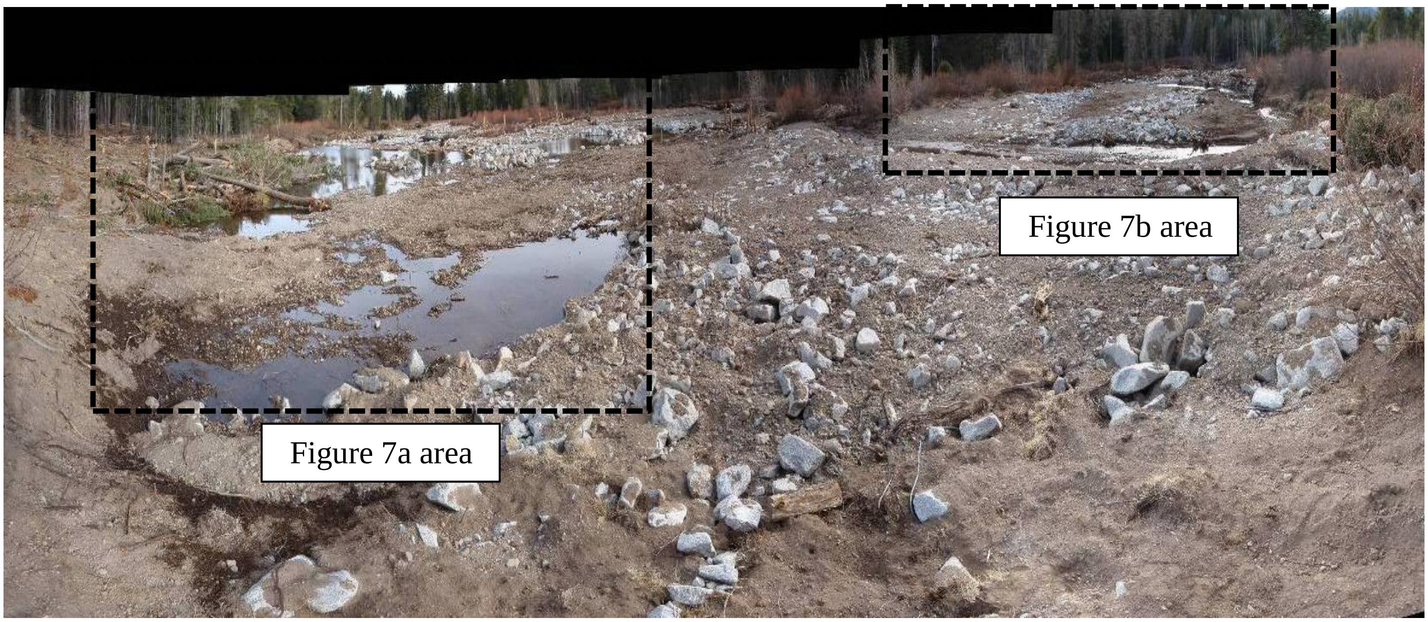


Figure 7: Constructed Floodplain immediately post project (11/9//2009)

Figure 7a: Inset photo shown in Figure 7, riparian grass colonization and sediment deposition, three years post project in constructed floodplain (July 2012).

Figure 7b: Inset photo shown in Figure 7, riparian grass colonization and sediment deposition, three years post project in constructed floodplain (July 2012).

Figure 7c: Graminoid growth within constructed floodplain/channel banks (July 2012).

Goal 4: Floodplain sediment retention, and reduction in channel erosion.

- **Are fine sediments being stored on the floodplain and are channel banks stable?**

Reach 6 was identified in the Blackwood TMDL as being in the worst condition by far, in terms of aquatic habitat impairment from the effects of bedded sediment (EPA, 2008). The area was also a source of chronic cut bank erosion for nearly 50 years prior to completion of restoration actions in 2009. A historic analysis of pre-project erosion rates was recently completed using aerial surveys and other historic information (Waterways and River Run Consulting, 2011), which estimated that approximately 61 tons of fine sediment was released into the channel annually from this reach prior to restoration for the period 1965 to 2007. This Report also estimated that annual project area fine sediment yield during the most active period of channel erosion (1995 through 2000) was 235 tons per year.

A Master's research project was recently completed on the restored reach, which used HEC/RAS modeling and physical measurements of floodplain deposition and scour, to evaluate immediate post project effects on channel erosion and floodplain deposition (Immeker, 2012). Results of this Master's thesis, along with a variety of other analyses, was previously presented in an earlier report produced by the LTBMU which analyzed the short term impacts of the Reach 6 project on sediment loading to Lake Tahoe (USFS, 2011). In summary, this report "Analysis of Impacts of Blackwood Reach 6 Stream Channel and Floodplain Restoration on Sediment Loading to Lake Tahoe during the 2009 and 2010 Water Years" concluded that stream channel sheer stresses and resulting channel erosion were dramatically reduced in this reach as a result of the Reach 6 restoration project, and floodplain deposition in the restored reach measured after the 2010 spring runoff was estimated at 142 tons of silt and clay sized particles.

The visual observations and measured data provided in this previous report indicate that retention of sediment particles on restored floodplain surfaces is occurring as a result of the project and that the restored reach has fundamentally changed from one dominated by channel and cut bank erosion processes, to one that is now dominated by floodplain deposition processes. Please refer to the full 2012 report, located on the LTBMU website for a more thorough discussion of this previous analysis (USFS, 2012). Photopoints illustrating these processes are located in Appendix D, including a Google Earth photo series from 2010 through 2012.

Goal 5: Improve aquatic habitat

- **Are stream channel condition metrics in the restored reach statistically comparable (at the 80% C.I.) to established "reference" reaches, and/or are they showing positive trends over time?**

Established stream channel condition inventory protocols were utilized to gather a variety of metrics relevant for assessing habitat. However it is important to remind the reader that this portion of the monitoring effort was not implemented under ideal circumstances (i.e. timing of data collection, and use of different protocols). It may be useful to re-read the discussion on the stream condition inventory (SCI) protocols presented in section III to understand the limitations this presents for the following analysis.

Pool Quality

Three metrics were used to evaluate the quality of pool habitat in stream reaches; total number of pools, residual pool depth (the depth of pools at extremely low flow conditions), and pool riffle ratios (the total length of pools divided by the total length of riffles). Pools are an important component of habitat for aquatic organisms, for different reasons to different aquatic species. They may provide deep water and cool summer temperatures, winter refuge, and areas for rearing of fish and amphibians.

Table 5 below illustrates these three metrics for the restored reach as well as the two reference reaches, for both 2001 (pre-project) and 2011 (post project), collected from surveyed thalweg profiles. The table also displays p values for statistical comparisons of the residual pool depth data (significance is determined at the 80% confidence limit, i.e. $p \leq 20$).

Table 5: Blackwood Creek Pool Metrics

Pool Metrics	RR 4		RR 6		Restored Reach	
	2001	**2011**	**2001**	**2011**	**2001**	**2011**
Reach Length (m)	1220	1104	584	587	708	1140
Residual Pool Depths						
Mean	0.50	0.65	0.44	0.61	0.51	0.61
Std. Dev.	0.20	0.26	0.15	0.24	0.15	0.27
Median	0.40	0.67	0.36	0.56	0.50	0.64
p values	*0.08**		*0.094**		*0.3**	*0.3/0.6***
# pools	15	23	7	14	8	25
pool/riffle ratio	1.1:1	1.81:1	0.66:1	1.53:1	0.54:1	1.94:1

** p value from Sigma Stat comparison of 2001 to 2011 data (all reaches).*

***p value from Sigma Stat comparison of Restored Reach to reference reaches in 2011.*

There are several key findings from the above table.

- There were significant increases in residual pool depths between 2001 and 2011 for both of the reference reaches (p=.08 for RR4 and p=.094 for RR6). However there was no significant difference in residual pool depth in the restored reach between 2001 and 2011 (p=0.3).

- There was no significant difference in residual pool depths between the restored reach 6 (upper) and reference reach 4 (p=0.3) and reference reach 6 (p=0.9).

- The number of pools increased by over 30% in the two reference reaches, and over 300% in the restored reach, between 2001 and 2011. The total number of pools in the restored reach is comparable to the number of pools in both reference reaches. The number of pools per 100 feet was 2.1 in the restored reach, compared to 2.1 and 2.4 in reference reach 4 and 6, respectively.

- The pool/riffle ratios also increased in all three reaches between 2001 and 2011, with the restored reach experiencing the greatest increase. The 2011 pool/riffle ratios are comparable between all 3 reaches (1.81:1, 1.95:1, and 1.94:1).

What we can conclude from the data is that these metrics of pool quality (residual pool depth, number of pools, and pool-riffle ratios) are steadily improving over time in the reference reaches as these areas recover on their own from past land uses as well as the channel destabilizing flood event of 1997. The project reach did not appear to be on an improving condition trajectory prior to restoration activities. This interpretation is based on measured decreases in sinuosity (1.34 in 2001 falling to 1.23 in 2007) and the absence of near stream vegetation colonization as determined from aerial photo inspection (see Appendix C). Neither of these trends was conducive to pool formation and persistence.

Graphs of the thalweg profile surveys are presented in Appendix E.2, and provide a visual representation of the data presented in table 5.

Particle Size Distribution

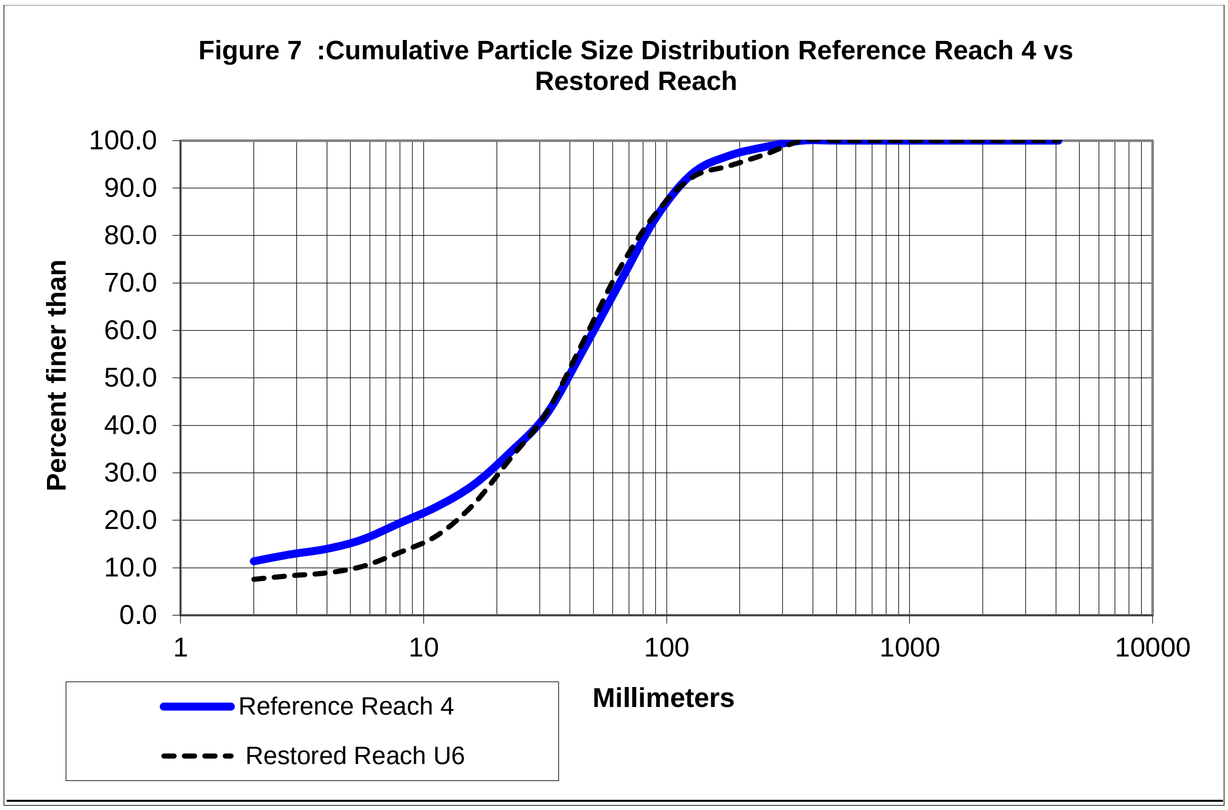
The purpose of this measurement is to detect the status and change of streambed particle size distribution over time. Streambed materials are key elements in the formation and maintenance of channel morphology. These materials influence channel stability, resistance to scour during high flow events, and also act as a supply of sediment to be routed and sorted throughout the channel. The amount and frequency of bedload transport can be critically important to fish spawning and other aquatic organisms that use stream substrate for cover, breeding, or foraging.

Numerous stressors can induce a change in particle size distributions over time. The streambed material can become finer if the stream loses transport capacity when channels become shallower and wider as a result of stream bank collapse, or can coarsen if supply from upstream is cutoff as a result of a dam or obstruction. Streambed fining can also be a result of direct contribution from bank erosion from over grazing, or fines transported in from upstream activities (logging, urbanization, etc.).

Of interest in terms of aquatic performance is the percentage of fine sediment less than 2 mm found in the substrate on the upstream of each riffle. Increased fine particles in the stream substrate can impair macro-invertebrate diversity and abundance and decrease survival of young fish, by filling interstitial spaces in the stream substrate. Research has shown optimal values for percent fines in riffles ranging from 30% for cold water streams in Arizona (ADEQ, 2008), 10 to 15% for streams in Montana's Shields River watershed (MDEP, 2009), and 8% for highest quality juvenile Bull Trout habitat in Oregon (Drambacher and Jones, 1997).

Pre-project coarse particle and fines data was collected in the established SCI reach in 2003, and post project in 2011 at the project reach, and the two reference reaches. Samples were all collected in riffles using Region 5 SCI sampling protocols, but the number and locations of the riffles sampled varied, based on the crews understanding and application of the Region 5 SCI protocols at that time. For instance only three riffles were sampled in 2003, and 8 to 10 riffles were sampled in each of the reaches sampled in 2011. As stated in the Region 5 SCI protocols, riffles are the standard sampling location since they have a relatively homogenous particle size composition, reducing sampling variability and increasing ability to detect change.

The particle size data was analyzed to determine particle size classes and plot cumulative particle size distributions. Figures 7 and 8 display the cumulative particle size distributions in the restored reach compared to the two reference reaches in 2011. Figure 9 displays this information for the pre-project data collected in the SCI reach in 2003 compared to the restored reach 2011 data.



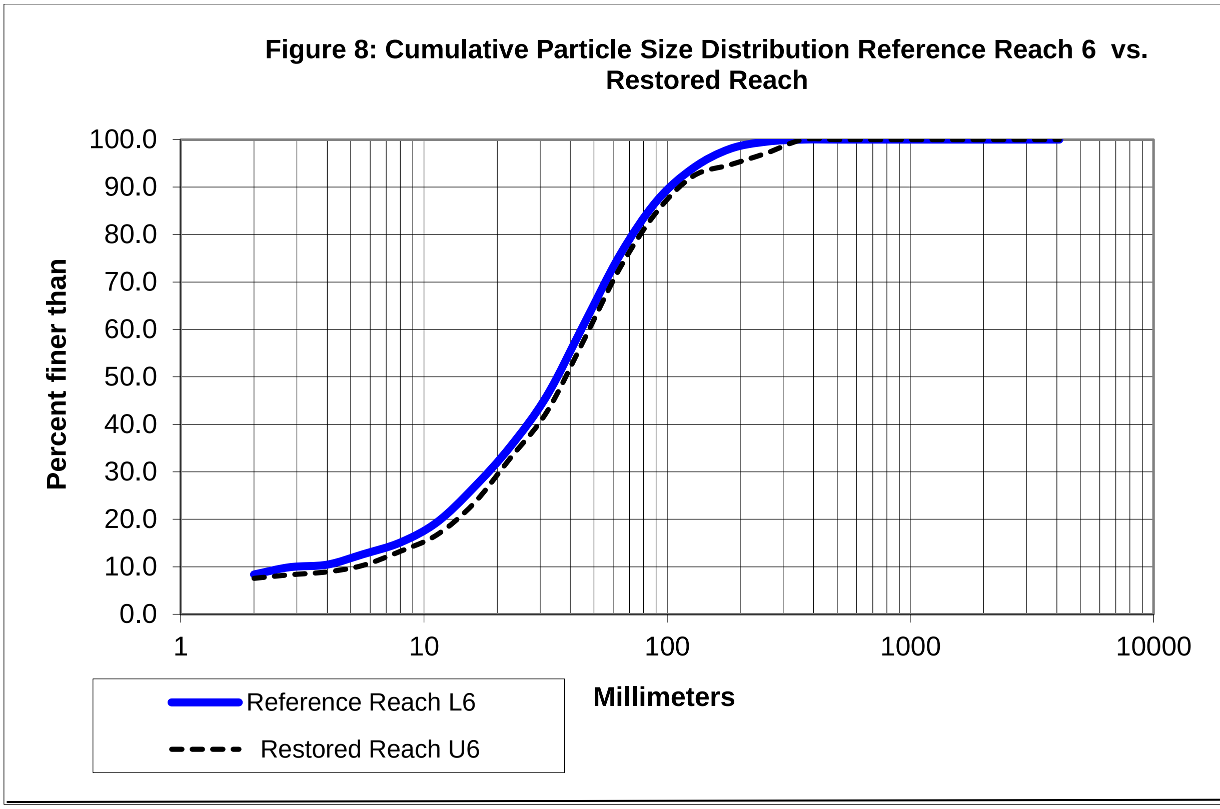


Figure 8: Cumulative Particle Size Distribution Reference Reach 6 vs. Restored Reach
Percent finer than
100.0
90.0
80.0
70.0
60.0
50.0
40.0
30.0
20.0
10.0
0.0
1
10
100
1000
10000
Millimeters
Reference Reach L6
Restored Reach U6

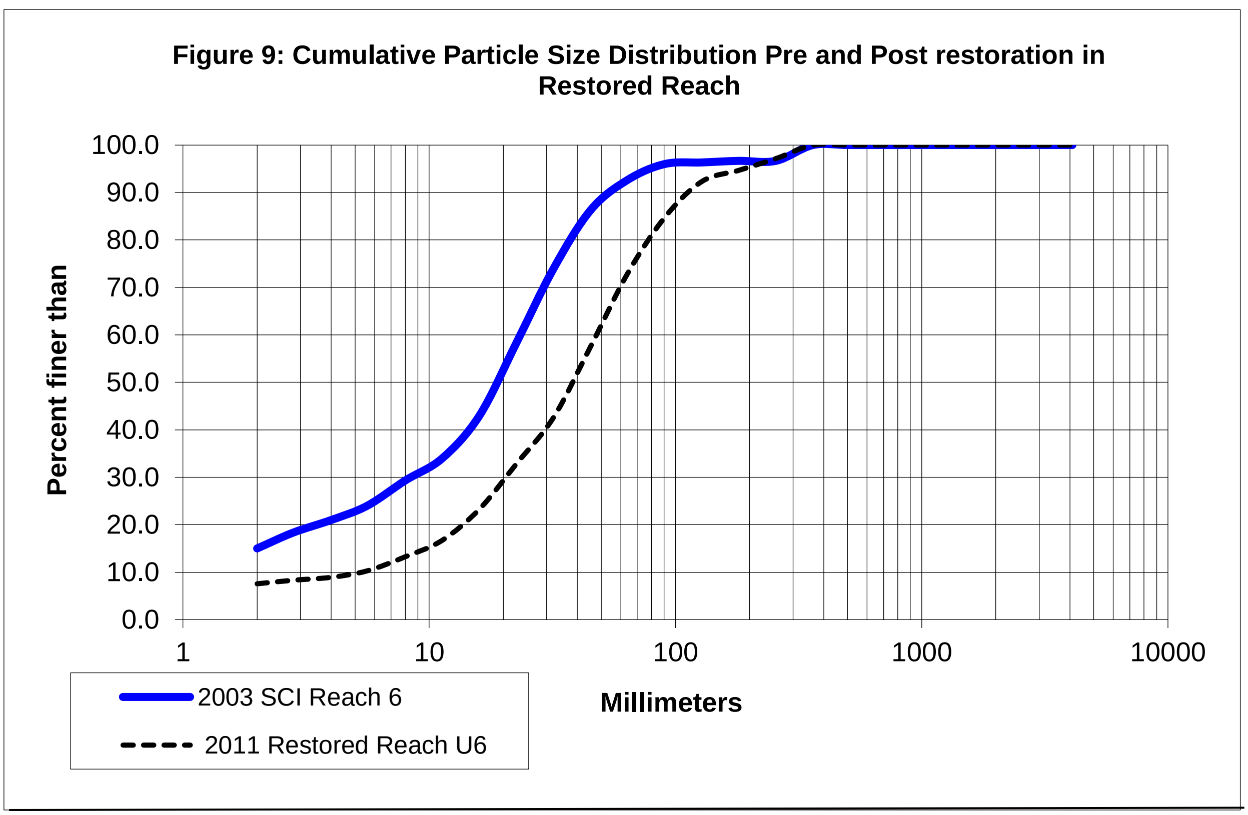


Figure 9: Cumulative Particle Size Distribution Pre and Post restoration in Restored Reach
Percent finer than
100.0
90.0
80.0
70.0
60.0
50.0
40.0
30.0
20.0
10.0
0.0
1
10
100
1000
10000
Millimeters
2003 SCI Reach 6
2011 Restored Reach U6

Figures 7 and 8 indicate that the particle size distributions are very similar between the restored reach and the two reference reaches. The percentage of particles less than 10 mm (medium gravels or smaller) in size is slightly higher (20% compared to 15%) in the reference reach 4 when compared to the restored reach.

From these figures, Table 6 below displays two common particle distribution metrics used to characterize and classify stream types. The D50 indicates the particle size (in mm) at which 50% of the particles counted are that size or smaller, the D84 indicates the particle size at which 84% of particles counted are that size or smaller.

Table 6: Calculated D50 and D84 and % Fines (<2mm) from Pebble Count Data collected in Riffles

	RR4 (2011)	**RR6 (2011)**	**Restored Reach (2011)**	**SCI Reach pre-project (2003)**
D50	39mm	35mm	38mm	19mm
D84	90mm	80mm	90mm	44mm
Fines <2mm	11.4%	8.4%	7.6%	15%

This data indicates these common particle distribution metrics in the restored reach are within the range of that found in the two reference reaches, with 50% of the particles consisting of very course gravels or smaller sized particles, and 84% of the particles consisting of small cobbles or smaller sized particles, for all three reaches.

From an examination of the 2003 pre-project data collected throughout the entire SCI Reach it is apparent that smaller particle size distributions existed compared to that measured in both the restored reach and the reference reach 6 in 2011. The D50 and the D84 in 2003 were approximately 50% smaller than those measured in 2011.

The data also indicates that the % fines is slightly lower in the restored reach than in both the upstream and downstream reference reaches, and is half that measured in the SCI Reach in 2003. Currently % fines in all reaches are in the range of values that represent a healthy surface fines % level for trout streams in the high mountain west.

In summation we conclude that particle size distributions have improved (i.e. become coarser) in the restored reach between 2003 and 2011, and that the distribution in the restored reach is comparable to both reference reaches.

Stream Shading

Stream temperature has impacts on the health, behavior, and survival of aquatic organisms and is strongly influenced by streamside shading. Because shading has a strong effect on stream temperature, temperature targets are often the surrogate for the healthy level of stream side shade; for instance the LTBMU 2011 Forest Plan (Draft) states that *streams are to be managed to attain levels of shading to maintain cold water conditions from June to September at the 7-day mean of* 20^0C *or less*.

Region 5 SCI protocols were utilized to obtain stream shading measurements in the SCI Reach, in 1996, 1997 and 2001. Region 6 SCI protocols were utilized in 2011 to obtain stream shading measurements in all reaches in 2011. Data collected using the Region 6 SCI protocols in 2011 was only collected at fast water units, which ranged between 7 to 11 samples for the 4 reaches displayed in Table 7 below, as opposed to the 50 transects collected during the pre-project years using Region 5 protocols. Therefore the medians are based on much smaller sample sizes in 2011. The sample size is also identified in parenthesis in the table below.

Table 7: Median % Stream Shading in Blackwood Creek obtained from Region 5 and Region 6 SCI protocols.

	RR4	**Restored reach**	**RR6**	**SCI Reach**
2011	12% (11)	5% (7)	27% (7)	11% (9)
2001				4% (50)
1997				8% (50)
1996				8% (50)

Statistical analysis indicates there is no statistically significant difference in percent stream shade between the restored reach and reference reach 4 (p=0.27), however there was a statistically significant difference when compared to reference reach 6 at the 80% confidence interval (p=0.16). There was no statistical difference between the values measure in 2001 and 2011 in the SCI reach (p=0.61).

This metric has not improved as a result of the restoration project, nor do we expect it to improve quickly. Optimal shade level is a function of the presence of mature, streamside riparian trees and shrubs that may take many decades to grow. It is expected that this metric will improve as woody shrub overstory develops in the shorter term, but a measurable improvement in stream shade is not expected for 10 to 15 years, as willow and cottonwood seedlings are just now becoming established in reconstructed floodplains.

There is no set standard established for this metric, but one study (NRCS, 1986) suggests that optimal shade ranges from 50% to 75% for small Cutthroat Trout streams throughout the west; with shading becoming less important as gradient lessens and stream size increases. Based on aerial photo inspection, continuous shade and canopy cover once provided by mature cottonwood trees and dense willow/alder cover (as stated in the Fish and Game descriptions presented earlier) was lost as the stream incised and the floodplain in the project area eroded away. This loss of shade due to channel incision is true of the reference reaches as well.

<u>Width Depth and Entrenchment Ratios</u>

Stream width to depth ratios measured at bank full is a key indicator of channel condition. This metric is measured at a point termed as “ bankfull” which is the area of the stream channel that is filled at the 2 to 5 year recurrence interval flow.   The bankfull channel is identified through geomorphic and vegetation indicators as described in the SCI protocol.

A low width to depth ratio generally indicates good conditions for aquatic flora and fauna and riparian vegetation. Low width to depth ratios result in deeper water for aquatic species, and a higher water table to support growth of riparian and meadow vegetation (in stable channels that have a low relative bank height to the adjacent floodplain).

Entrenchment ratio is defined as the ratio of flood prone width to bankfull width. Flood prone width is the width of the flows as measured at twice the maximum bankfull depth. This measure is intended to quantify channel confinement. Unconfined channels (high entrenchment ratios) result in a higher degree of floodplain connectivity with resulting overbank flooding, and reduction of channel sheer stresses associated with high flow events.

The number of locations where these measurements were obtained varied slightly between reaches and between protocols.   Region 5 SCI protocols direct that these measurements be taken at three permanent cross sections and five randomly selected transects at fast water units (anything besides a pool for a total of eight measurements. The Region 6 protocols direct that these measurements be taken at all fast water units within the reach. Appendix E displays the number of measurements taken at each reach which ranged from seven to 11 sample locations.

Table 8: Median Width Depth Ratios in Blackwood Creek obtained from Region 5 and Region 6 SCI protocols.

	RR4	Restored reach	RR 6	SCI Reach
2011	33	22	29	26
2001				11.9
1997				29
1996				32

Statistical Analysis indicates that median width/ depth ratios in the restored reach are significantly lower than reference reach 4 (p=0.13) and reference reach 6 (p=0.17).   Interestingly, statistical analysis shows a substantial increase in mean width/depth ratios in the SCI Reach between 2001 and 2011 (p=0.014). At this time we think this statistic is misleading because it does not correlate with channel/ floodplain cross sectional changes that occurred during this time period. A possible explanation for this result is misidentification of bank full when measurements were obtained in 2001. The channel was very unstable and braided at that time, and reliable bankfull indicators may not have been present.

Table 9: Median Entrenchment ratios in Blackwood Creek obtained from Region 5 and Region 6 SCI protocols.

	RR 4	Restored reach	RR 6	SCI Reach

2011	2.0	10.4	2.9	5.3
2001				2.0
1997				4.1
1996				2.0

Statistical analysis indicates that entrenchment ratios measured in 2011 in the restored reach are significantly greater than both reference reach 4 (p=.021) and reference reach 6 (p=0.073). The restoration reach therefore has better capacity than either of the reference reaches to dissipate overbank flows and deposit sediment in the adjacent floodplain. Statistical analysis also indicates a a significant difference in the SCI Reach between 2001 and 2011 (p=0.067).

Analysis of trends in the SCI Reach indicates a temporary change in entrenchment ratio in 1997, likely a result of floodplain widening after the 1996/1997 flood event. Subsequently the channel kept incising resulting in entrenchment decreasing substantially again in 2001. The increase in 2011 entrenchment ratio within the long term SCI reach is a result of a combination of raising the base level of the creek and making floodplain topographic modifications in the restored upper two thirds of this SCI reach.

A comparison was also done between the two separate protocols that were applied in 2011 that can be used to derive these metrics. In addition to the previously mentioned Region 6 SCI protocols, six permanent cross sections were also established and measured in the restored reach. A comparison was done between the data collected for these two efforts to see if the results for these width/depth ratios and entrenchment ratios were the same, even though collected by different crews. The results of this analysis are presented below and indicate no statistical difference in the results from these two separate efforts.

Table 10: Comparison of monitoring crew variability for cross section measurements of mean W/D ratio and entrenchment ratios taken through two separate efforts in 2011 in the restored reach.

W/D Ratio			**Entrenchment Ratio**		
Permanent XS 2011	Region 6 SCI 2011	P value	Permanent XS 2011	Region 6 SCI 2011	P value
21	25	*p=.35*	8.4	9.6	*p=.73*

Channel Cross Section Changes

Long term permanent cross sections in the SCI reach are a very striking piece of data documenting channel incision and floodplain loss as Blackwood Creek destabilized. The locations of these cross sections are illustrated in Appendix B2. Changes in Blackwood Creek XS-2 (shown below), located approximately 150 meters downstream of the restored reach, are characteristic of changes occurring at all six long term permanent cross sections (Appendix F) in the SCI reach. These graphs illustrate the dramatic change that occurred as a result of the rain on snow peak flood event during the winter of

1996/1997. The magnitude of floodplain loss (~10 meters) documented at this cross section after the 1997 flood, is actually small in comparison to what was visually observed in the project area after this flood (losses of ~30 meters or more).

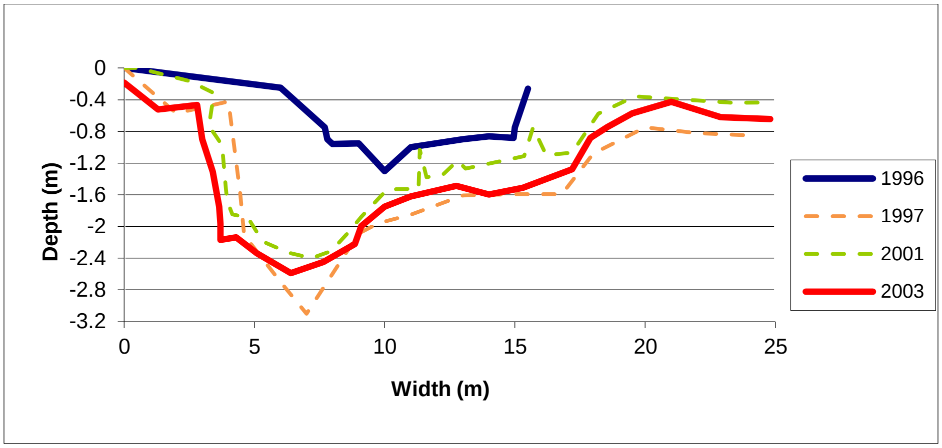


Figure 10: Blackwood Creek Cross Section #2

Figure 11 below illustrates the total cross sectional area of channel scour and fill between 1996 and 2003 at cross section #2, and scour (erosion) and fill (deposition) at the other 5 cross sections are presented in Appendix F.

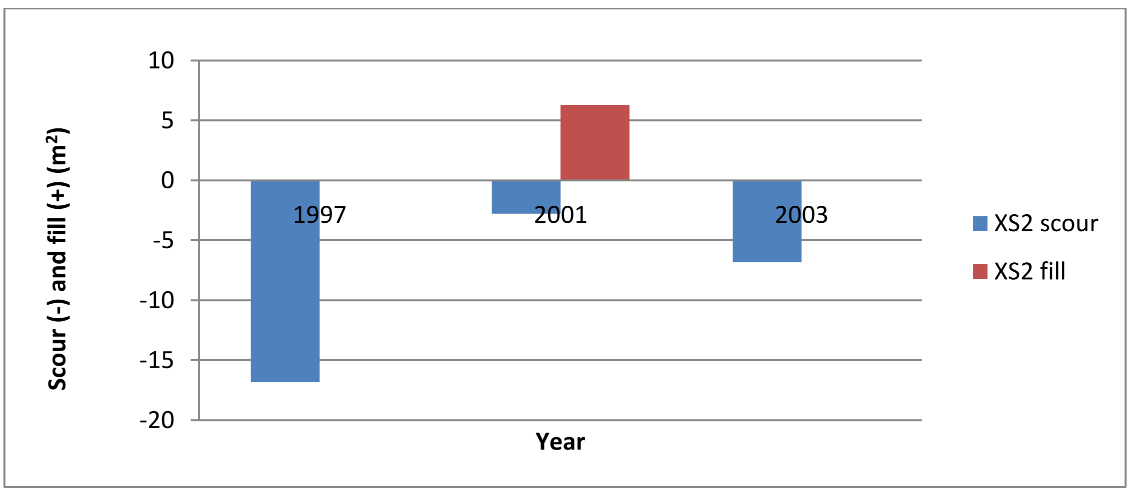


Figure 11: Blackwood Creek Cross Section #2 Erosion and Deposition

Total scour at cross section #2 was 53 square meters. In comparison only 6 square meters of deposition was measured. This cross section analysis provides a representative snapshot of the nature of channel erosion and deposition between 1996 and 2003, and in particular as a result of the 1997 flood.

There are currently a total of 35 USFS cross sections established on 5 reaches within Blackwood creek. Twelve additional permanent cross sections were established between 2011 and 2012 within the project reach, in addition to the two historic cross sections. In 2011, eleven cross sections were established in RR4 and four cross sections in RR6 (added to two historic cross sections in RR6).

Additional cross sections are established upstream of the project reach at other restoration sites, four below the Barker Road Bridge, and five at the Reach 1 restoration site.   All 35 cross sections established within Blackwood Creek from the confluence of the North Fork of Blackwood Creek to Lake Tahoe, will be used to evaluated changes in channel geometry and trends in sediment deposition and erosion processes within the stream channel and floodplain of Blackwood Creek, during the next reporting cycle.

<u>Large Woody Debris</u>

- Large wood is important to the morphology of many streams, especially in streams like Blackwood Creek where large floods transport and deposit large wood. It influences channel width and meander patterns, provides for storage of sediment and bedload, and is often most important in pool formation in streams. Large wood is also an important component of in stream cover for fish, as well as providing habitat for aquatic insects and amphibians.

Region 5 SCI protocols were utilized to obtain large wood measurements in the SCI Reach, in 1996, 1997 and 2001. Region 6 SCI protocols were utilized in 2011 to obtain large wood measurements in both the SCI Reach as well as the two reference reaches. However the Region 5 SCI protocols changed for this metric in 2005, enough so that the data collected prior to this time cannot be compared to the Region 6 SCI data or any future Region 5 SCI data. Therefore the only data provided for this metric at this time is the data collected in 2011. Large wood for these reaches of Blackwood creek is defined as >20” in diameter (any wood longer than one half bankfull width).

Table 11: # Pieces of Large Wood in Blackwood Creek obtained from Region 6 SCI protocols in 2011.

	RR 4	**Restored reach**	**RR 6**	**SCI Reach**
	# LWD / Reach(m)	# LWD / Reach(m)	# LWD / Reach(m)	# LWD / Reach(m)
Reach Total	11 / 1104	5 / 1140	4 / 587	7 / 922

Although some large wood was reintroduced to the channel as part of the restoration project, few pieces placed met the size requirements, and so we consider the restored reach to be deficient in terms of this metric. The number of pieces of large wood in reference reach 4 (which is comparable in length to the restored reach) is twice that found in the restored reach. We expect that this metric will improve over time in all reaches as future floods continue to recruit and transport large wood

Goal 6: Improve macro invertebrate community structure as compared to reference reaches and IBIs.

- **Is overall macro invertebrate species and abundance in the restored reach comparable to that measured in established reference reaches in Blackwood Creek?**

Macro invertebrates have been demonstrated to be very useful as indicators of water quality and habitat condition. They are sensitive to changes in water chemistry, temperature, and their physical habitat. Previous studies have been carried out on the National Forest System lands using macro invertebrates to measure the effectiveness of in-stream channel restoration projects (Herbst and Kane, 2004 and Herbst 2004). Both studies show similar results with increased taxa richness, diversity, and EPT richness in a post-restoration project scenario. Project restoration in these studies resulted in increased pool frequency, decreases in fine and sand sized particles, and increased riparian vegetation in the restored reaches.

Data from the restored and reference reaches in Blackwood Creek also show increased pool frequency and decreased percent riffle fines, however all three reaches are below an average shade percentage considered optimal. Riparian vegetation has been shown to influence the macro invertebrate communities, where taxa richness has increased with increased shading (Rios and Bailey, 2006 and Arnaiz et al. 2011).

Macro invertebrate data for this analysis was collected in 2011 in the first four riffles located at the downstream end of both reference reaches and the restored reach, using Region 5 SCI protocols. IBI and O/E scores were calculated for all three reaches, for comparison to California state thresholds established for these two metrics in the Clean Water Act Section 303b California Water Quality Condition Assessment Report, (SWQRCB, 2006).

The IBI (index of biological integrity) is a multi-metric index developed through a scoring rule on collected data. For the purposes of this analysis the scoring rules documented in a Tahoe Basin specific study by Leska Fore for the TRPA were utilized (Fore, 2007). The O/E score is the ratio of observed scores to expected scores. Expected scores are based on a national reference site data set documented for unique latitudes and longitudes in the United States, and O/E scores are provided by the analytical labs that process the macro-invertebrate samples. These results are presented in Table 12.

Table 12: IBI Metric and O/E Scores from 2011 Blackwood Macro-invertebrate data.

	Metric Score						IBI		O/E
Reach	**Plecoptera taxa**	**Tricoptera taxa**	**Long-lived taxa**	**Intolerant taxa**	**Clinger taxa**	**% non-insect taxa**	**Total Score**	**% of Total Possible**	
Scoring Rule	(x-3)10/7	(x-3)10/7	(x-2)10/9	(x-9)10/17	(x-11)10/14	10-((x-3.6)(10/9.4))			
RRL6	2.9	2.9	0.0	2.4	2.1	0.0	**10.2**	**17.0**	**0.92**
Restored Reach	4.3	2.9	0.0	4.1	2.9	4.4	**18.5**	**30.9**	**0.83**
RR4	7.1	2.9	0.0	2.9	1.4	0.5	**14.9**	**24.8**	**0.84**
Total Possible score	*10*	*10*	*10*	*10*	*10*	*10*	***60***	***100.0***	

The current California State thresholds for non-impaired streams for IBI scores (mountain sites) is greater than 57% of the total possible score, and for O/E scores the threshold is greater than 0 .77. The data in Table 12 indicates that in 2011 the highest IBI score was found in the Restored Reach (IBI=18.5), but IBI scores in all three reaches were much less that the California state threshold for IBI in mountain sites. When looking at O/E scores however, a somewhat different situation is presented, with all three scores greater than the state threshold of 0.77.

The results present a somewhat mixed story when comparing current calculated IBI and O/E metrics for these reaches with current California state standards. We have no explanation for this contradiction, and the standards and protocols for macro invertebrate monitoring are still being refined and adjusted at the State level and for the Sierra Nevada (Herbst, 2009).

All we can conclude from this analysis is that the condition of the restored reach is comparable to that in the upstream and downstream reference reaches, and that none of the reaches are considered to be in poor condition based on O/E scores, when compared to the current California state threshold for this metric.

V. Conclusions and Recommendations

Conclusions

In the two years post construction the project has achieved or made substantial progress towards four out of the six stated restoration goals (denoted by a check icon).

- ✓ Goal 1: Restore dynamic geomorphic channel stability to achieve and maintain Blackwood TMDL targets for sinuosity (1.6) and bank stability (80% stable banks).

    Project area sinuosity of 2.1 and 95% bank stability level suggest the project currently exceeds the TMDL targets for Blackwood Creek, within the restored reach. Larger flood events (Q>850 CFS = > 5 year flood) have yet to occur and so these values may flux, especially if significant woody shrub and tree re-colonization is slow. Modeling results suggests that the general hydraulic environment remains favorable for maintaining sinuosity and bank stability for up to a 20 year flood.

- ✓ Goal 2: Restore functional channel/floodplain relationship with floodplain inundation occurring every two to three years.

    Post project observations indicate that the two to three year floodplain inundation frequency goal has been met.

- Goal 3: Stimulate riparian vegetation growth and recovery

    Visual observations and photos indicate that planted willow stakes are surviving (especially noticeable in the low energy (slow water) zones on some channel margins and in backwater areas). High plant survivability is expected in these areas because of favorable groundwater levels as a result of restoration. As willow stakes and replanted shrubs mature they can become important seed sources for future vegetation colonization.

    Vegetation recruitment of riparian grasses, willows, and cottonwoods through natural processes is occurring, particularly in areas of new floodplain deposition of fine sediments. It is very early in the vegetation colonization process and therefore no substantial change in the degree of riparian vegetation recovery within the project area: in terms of its influence in providing floodplain and channel stability, riparian habitat, or channel shading. It is expected to take about 5 to 10 years before a substantial degree of woody riparian vegetation recovery occurs.

- ✓ Goal 4: Improve downstream water quality by increasing volume of fine sediment retained on floodplains and preventing wide spread channel bank erosion.

  Measurements of sediment retained on the floodplain the first year after restoration indicates retention of 142 tons of silt and clay sized particles. Visual observations and photos in the following year indicate sediment deposition is continuing to occur on constructed floodplain surfaces. Fine sediment retention is expected to continue as vegetation on active floodplain surfaces becomes better established. Physical measurements as well as visual observation indicate stabilization of high terrace cut banks, with overall bank stability increasing from approximately 30% to 95% within the project reach. The reach has changed from one dominated by processes of net degradation (channel erosion), to one dominated by processes of net aggradation (floodplain deposition).

- ✓ Goal 5: Create aquatic habitat features important to support various life forms and life stages throughout the year. Restore habitat sufficient to support actions to restore Lahontan Cutthroat Trout to Blackwood Creek.

  Overall, the increases in pool quality metrics (depth, frequency, and ratio to riffles), lower % of fines in riffles lower cross section width-depth ratios, and significantly less relative channel confinement, all suggest aquatic habitat has been significantly improved. Values in the project area are statistically comparable to established reference reaches in Blackwood creek, as well as values considered healthy in scientific literature. Positive trends in these metrics are expected over the longer term as woody shrub and tree vegetation recovers providing more food, shade, and rearing habitat for all life stages of aquatic organisms. We acknowledge that some uncertainty in the results related to assessment of this goal exists, because of flaws in data collection (i.e. timing of data collection and use of different protocols.) However based on our first hand knowledge based on visual observations over time, we do believe that the improvement in the measured metrics are “real”.

  - Goal 6: Improve macro invertebrate community structure as compared to reference reaches and California state standards.

    Post project, the macro-invertebrate scores of the restored reach are currently comparable to those of the reference reaches. However, values in all the reaches indicate a degraded condition when compared to data collected in 2003. The restored reach is currently considered to be in “fair” condition, based on California State thresholds (based on O/E score).

Although monitoring data for the restoration goals for riparian vegetation and macro invertebrate health (Goal 3 and 6) do not yet indicate that these restoration goals have been fully achieved, corrective actions are not considered necessary within the project reach at this time, and ecosystem function in the project reach is expected to continue to move in a positive trajectory. Long term effectiveness monitoring will continue as documented in the LTBMU Blackwood Creek Restoration Effectiveness Monitoring Plan (USFS, 2013). That information will be used to report periodically on further progress in accomplishment of the six goals.

Monitoring Recommendations

The various metrics described in this report are designed for long term monitoring, and the frequency, scale and scope at which these elements will be monitored is dependent on future budgets and resources. Data collection and analysis will likely be conducted at 3 to 5 year intervals.

The following are changes recommended to improve the quality and utility of data collected for this project.

- Improve internal quality control related to utilization of protocols and tracking of sampling frequency, especially for SCI data. As described in this report, pre-project SCI data was not collected in a timely fashion, which affected the clarity of analysis results. Improved tracking will be facilitated by continuing to produce the LTBMU Annual Monitoring Report, which includes an update to the Forest five-year monitoring plan.

- Repeat photos surveys should implemented with event driven visual surveys, along with date, stream flow totals should be noted on photographic record. Effort should be made to repeat surveys under similar seasonal and hydrologic conditions.

- Revisit the questions to be answered, and change the scale of restoration monitoring and analysis from the reach scale to the watershed/ stream scale for future analysis. All large scale upper watershed and stream channel restoration efforts have been completed in this watershed (three reaches by the USFS, and one reach by the California Tahoe Conservancy). The USFS has collected monitoring data on three separate restoration reaches, and two reference reaches, within Blackwood Creek. The next monitoring effort is scheduled for 2015. Data will be collected on all reaches throughout Blackwood Creek, to assess condition of the channel from the confluence with the North Fork of Blackwood Creek to Lake Tahoe.

  Region 6 SCI protocols will be utilized to provide stream scale comparison over time, and Region 5 SCI protocols to provide a reach scale comparison in the original established SCI reach. This analysis will determine the degree to which Blackwood creek as a whole is achieving the TMDL milestones, and change in overall condition of Blackwood Canyon and its watershed. Data collected by other agencies (TRPA/macro-invertebrates, LTIMP/USGS water quality data, California Tahoe Conservancy restoration effectiveness) will also be included in this analysis.

  Watershed condition at the HUC6 scale will be re-evaluated following the USFS Watershed Condition Framework process. Watershed Condition was assessed in 2010 as part of a National USFS effort, and the Blackwood /Ward Frontal watershed (containing both the Blackwood and Ward Creek HUC 7 watersheds) was rated as “2-functioning at risk” within this 3 tiered rating system. Please go to the following link to learn more about the national watershed condition classification system, http://www.fs.fed.us/publications/watershed.

- The LTBMU has limited expertise in the field of macro invertebrate sampling and analysis, and the protocols and thresholds standards are still being refined at the State level. The data presented in this report was collected utilizing a USFS protocol that is different than that currently adopted by the State of California land management regulatory agencies. It is likely the USFS will be adopting the California protocol in the future. The TRPA has already established a network of long term macro invertebrate monitoring sites in the Lake Tahoe Basin, utilizing the California state protocol. Although no long term monitoring sites exist in Blackwood Creek currently, they will be added next year as part of TRPA's overall probabilistic sampling design. It is recommended that the LTBMU support and coordinate with the TRPA macro invertebrate monitoring effort for future macro-invertebrate sampling in this watershed, for better consistency, cost savings and efficiencies in data collection and analysis.

Peer Review

The LTBMU worked with the Tahoe Science Consortium to obtain three independent science peer reviews of the Draft report. Many of the comments and suggestions provided through this peer review were incorporated in this Final report, as well as modifications to our plan for future monitoring. Some of the suggestions to improve the level of certainty in the results were beyond the financial capacity of the LTBMU to conduct, and were not deemed necessary to provide additional meaningful information; to assess whether the restoration approach implemented within this reach is functioning as expected, and making progress towards achieving both short and long term restoration goals. The specific peer review comments, as well as our responses to those comments can be provided upon request (USFS, 2013)

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