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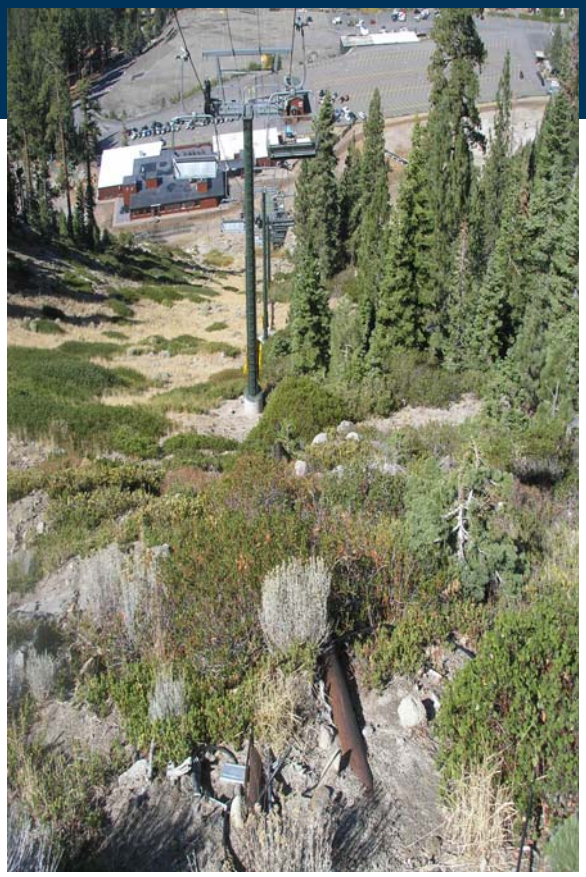

Heavenly Mountain Resort

Annual Report for the 2010 Water Year

March 11, 2011

Prepared For

Heavenly Mountain Resort

Annual Monitoring Report

Heavenly Mountain Resort

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Prepared for

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Acronyms

BMI	Benthic macro-invertebrate
BMPs	Best Management Practices
BMPEP	Best Management Practices Effectiveness Program
CNPS	California Native Plant Society
CWE	Cumulative Watershed Effects
ESC	Effective Soil Cover
EIR/EIS	Environmental Impact Report/Environmental Impact Statement
GIS	Arc-Geo Information Systems
LTBMU	Lake Tahoe Basin Management Unit
LWD	Large woody debris
mg/L	milligrams/liter
MUSLE	Modified Universal Soil Loss Equation
NDEP	Nevada Department of Environmental Protection

NTU	Nephelometric Turbidity Units
RCI	Resources Concepts Inc.
SCI	Stream Control Inventory
SOP	Standard Operating Procedure
TKN	Total Kjeldahl Nitrogen
TMDL	Total Maximum Daily Load
TRPA	Tahoe Regional Planning Agency
TSS	Total Suspended Sediment
USDA	United States Department of Agriculture
USFS	United States Forest Service
USGS	United States Geological Survey
VRAP	Vegetation Rapid Assessment Protocol

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Chapter 1

Introduction

This annual report is submitted in partial fulfillment of monitoring and reporting requirements set forth in the Lahontan Regional Water Quality Control Board Order R6T-2003-0032. It summarizes monitoring and evaluation activities conducted at Heavenly Mountain Resort (Heavenly) during the 2010 water year as a result of the implementation of the Water Quality and Best Management Practices Monitoring Program. This program is a component of the Heavenly Mountain Resort Master Plan (Heavenly 1996) and the Heavenly Mountain Resort Master Plan Amendment (Heavenly 2007).

Heavenly Mountain Resort is located on the south shore of Lake Tahoe within El Dorado and Alpine Counties of California and Douglas County of Nevada (Figure 1.1). Land ownership is shared between the U.S.D.A. Forest Service (USDA Forest Service) and Heavenly. Heavenly operates on National Forest lands through a special use permit, renewed in 2002 for a period of 40 years.

The Water Quality and Best Management Practices Monitoring Program was initiated at Heavenly in 1995 in conjunction with the completion of the Heavenly Mountain Resort Master Plan (Heavenly 1996). The need for such a monitoring program was established during preparation of a Cumulative Watershed Effects (CWE) Analysis required by Tahoe Regional Planning Agency (TRPA) guidelines for ski area expansion. Implementation of the monitoring program was a condition of the Master Plan approval by the USDA Forest Service and TRPA. An amendment to the Heavenly Mountain Resort Master Plan approved by TRPA on April 25, 2007, is currently being implemented by Heavenly in collaboration with Lahontan Regional Water Quality Control Board (Lahontan), the USDA Forest Service, and TRPA. Modifications resulting from the Master Plan Amendment include incorporating all monitoring into a single report that was submitted May 15, 2009 to the TRPA, USDA Forest Service, and Lahontan. This monitoring report is on an ongoing schedule due yearly. The requirements of the 2009/2010 Annual Water Quality and Best Management Practices Monitoring Report remain the same following approval of the Master Plan Amendment.

The Master Plan represents a comprehensive twenty-year development plan for Heavenly Mountain Resort. Master Plan and Master Plan Amendment implementation objectives of Heavenly, TRPA, and the USDA Forest Service regarding protection of the environment include (Heavenly 1996):

- Making optimal use of the natural attributes of the site without creating a significant impact on the environment (Heavenly);
- Restoring the health of sub-watersheds and other natural resource values disturbed by past activities (Heavenly);
- Protecting the environmental quality of the area (USDA Forest Service);

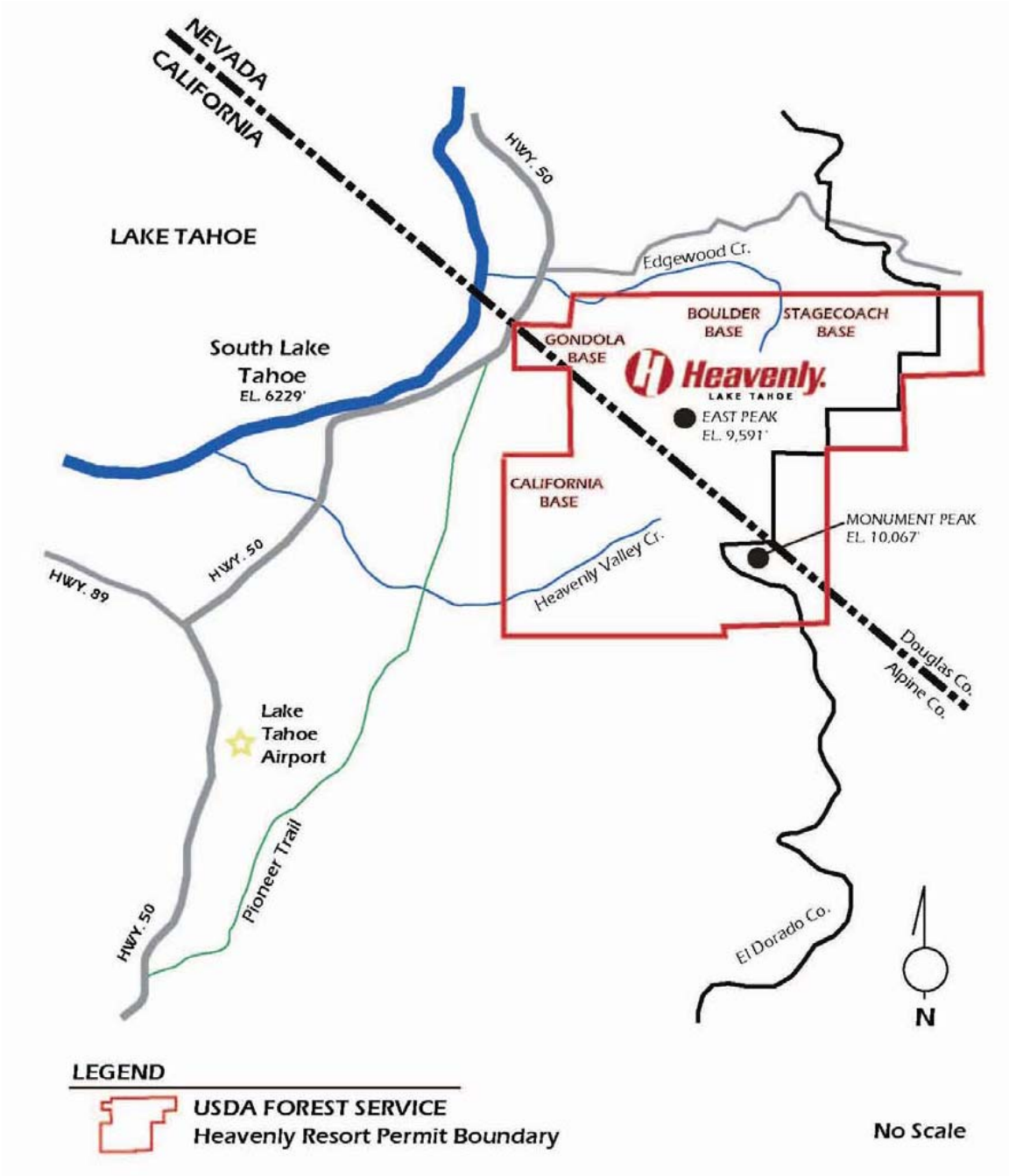

Figure 1.1 Location of Heavenly Mountain Resort (Heavenly 2007)

- Providing a quality ski resort with ski runs and other disturbed areas stabilized to reduce the potential for soil erosion (USDA Forest Service);
- Improving the visual quality of the area (USDA Forest Service); and
- Providing for long-term preservation and restoration of Stream Environment Zones (TRPA).

Implementation of the Collection/Monitoring Agreement between Heavenly and the USDA Forest Service (Monitoring Program) will provide data sufficient to determine compliance with

agency water quality standards and validate the efficiency of management practices in protecting against adverse cumulative watershed effects.

1.1 Environmental Monitoring Program

The overall objective of the Environmental Monitoring Program is to evaluate and monitor water quality and overall ecological health of Heavenly creeks and watersheds while satisfying California, Nevada, and TRPA regulatory water quality requirements. The Environmental Monitoring Program is made up of five major components (Heavenly 1996):

- Water quality monitoring to comply with regulatory monitoring requirements;
- Soil cover monitoring to gain understanding of how to prevent soil loss and protect water quality;
- Monitoring to determine BMP effectiveness under the various conditions at the ski area;
- Riparian condition monitoring to determine riparian area response to Heavenly Mountain Resort activities; and,
- Overall watershed condition and trend monitoring.

1.2 Monitoring Plan

The Environmental Monitoring Program Plan is in Chapter 7 of the 2005 Draft Master Plan Amendment. The Monitoring Program was designed to satisfy the requirements of Lahontan Board Order No. 6-91-36. The Monitoring Plan addresses the five components stated above. Key plan requirements are summarized here.

1.3 Water Quality Monitoring

The waste discharge requirements, monitoring, and reporting program were updated by Lahontan Board Order No. R6T-2003-0032 in 2003. Currently, the Monitoring Program includes water quality monitoring at 6 stations. Two stations are located on Edgewood Creek, in Nevada. Sampling occurs monthly except during the spring snowmelt period when sampling occurs weekly or when flows are too low to measure. Results and discussion are to be reported to Heavenly, TRPA, and Lahontan in this annual report. Additionally, water quality sampling results are reported quarterly to Lahontan as required by Order No. 6-91-36.

Several constituents are identified in the Monitoring Program for sampling at each of the stations. The following primary list of constituents is monitored at each station:

- Discharge
- Specific Conductivity
- Turbidity
- Suspended Sediment
- Total Nitrate/Nitrite as Nitrogen
- Total Kjeldahl Nitrogen

- Dissolved Orthophosphate
- Total Phosphorus
- Dissolved Phosphorus
- Chloride
- Total Iron

The following secondary list of constituents is typically monitored only during storm events at stations associated with parking lots:

- Oil and Grease
- Total Petroleum Hydrocarbons
- Ammonia
- Total Lead

1.4 Effective Soil Cover Monitoring

The Monitoring Program includes soil cover monitoring to determine requirements and effectiveness of various soil covers under different slopes and conditions. Monitoring examines the effectiveness of past and current projects. Soil cover monitoring conducted from 1995 to 2003 was based on the use of random transects at elevations above 7,000 ft. The results were reported in the 2003 Comprehensive Report. Collection of the data was too time-intensive, making it difficult to obtain data for the entire resort and the 2003 Comprehensive Report recommended that the measurements be discontinued. The report also recommended development of new protocol. A new general methodology was developed in 2005 by Cardno ENTRIX (formerly ENTRIX, Inc.) and approved by the USDA Forest Service.

In the 2007 Annual Report and later in the 2008 Effective Soil Cover Workplan, a new protocol was presented that combined the California Native Plant Society's (CNPS) Vegetation Rapid Assessment Protocol (VRAP) and the establishment of permanent photo points. After discussions with the USDA Forest Service, it was determined that the CNPS VRAP method should support an aerial survey, rather than being the only data collected. Heavenly and the USDA Forest Service agreed to share the cost of an over-flight. An infrared aerial flyover of Heavenly Mountain Resort was conducted by 3DiWest in conjunction with the USDA Forest Service in July of 2009. The flight produced a 1:8,000 resolution infrared aerial photo of the entire mountain and was used along with Geographic Information Systems (GIS) and field verification (i.e. ground-truthing) to produce an accurate picture of the soil cover at Heavenly. The VRAP method was augmented in 2009 with the establishment of permanent photo points to better track variability over time. This new methodology is discussed in Chapter 3.

1.5 BMP Effectiveness Monitoring

The Monitoring Program includes BMP monitoring to determine the effectiveness of the BMPs in preventing soil erosion and protecting water quality under various conditions. Based on recommendations contained in the 2003 Comprehensive Report, the USDA Forest Service

designed and implemented a new BMP monitoring strategy modeled after Region 5's Best Management Practices Effectiveness Program (BMPEP) protocols (USDA Forest Service 2002). The BMP monitoring program is currently being implemented by Resource Concepts Inc. (RCI) and is presented in Chapter 4.

1.6 Riparian Condition Monitoring

The Monitoring Program includes riparian and channel condition monitoring, as well as macro-invertebrate monitoring which includes the following objectives:

- Determine which, and by how much, various creek parameters fluctuate between monitoring periods
- Evaluate the impacts of Heavenly management practices on riparian system health

In 2003, the USDA Forest Service made a number of recommendations to improve channel condition monitoring. These recommendations are reflected in the Riparian Conditions Monitoring Plan developed by ENTRIX in 2005. The revised plan was implemented in 2006 and most recently in 2009. Channel condition monitoring occurred only at the Edgewood Creek reaches in 2010 and is discussed in Chapter 5. Macro-invertebrate monitoring occurred in 2006, 2007, 2010, and will continue in 2011. The proposed amended monitoring permit states that an electronic format of the results shall be submitted in accordance the Surface Water Ambient Monitoring Program (SWAMP) template. Results of this study will be included in a separate submittal in May 2011. The second year of monitoring is scheduled for the summer of 2011.

1.7 Condition and Trend Monitoring

Condition and trend evaluations will be conducted on each of the data elements of the monitoring program both individually and cumulatively to gauge overall watershed condition, trends, and to determine if ski area management activities are improving or degrading water quality and ecological health. These evaluations are evaluated in 5-year intervals in Comprehensive Reports. The next Comprehensive Report was scheduled to be completed in June 2011; however revisions to the permit have pushed the due date of this report until January 2012. This comprehensive report will cover six water years (2006-2011) and will better align the monitoring program with the reporting sequencing.

Chapter 2

Water Quality

2.1 Station Descriptions

For the 2010 water year, a set of water quality parameters were measured at six stations on four creeks to determine the effects of ski area development on background conditions (Table 2.2). Stations and sampling rationale are given in Table 2.1. Approximate locations of stations are shown in Figure 2.1.

Table 2.1 Heavenly Valley Mountain Resort Monitoring Program Water Quality Stations

Station ID	Station Name	Rationale
HV-C2	Heavenly Valley Creek Below Patsy's and Groove Lifts	Characterize water quality in Heavenly Valley Creek draining developed ski area
HV-C3	Forest Service Property Line	Characterize water quality in Heavenly Valley Creek leaving National Forest Lands below Heavenly Mountain Resort
HV-C4	Heavenly California Base Parking Lot	Characterize water quality in Bijou Park Creek below California Main Lodge and parking area
HV-E1	Edgewood Creek Above Boulder Parking Lot	Characterize water quality in Edgewood Creek above Boulder parking lot and below ski runs
HV-E2	Edgewood Creek Below Boulder Parking Lot	Characterize water quality at Edgewood Creek below Boulder parking lot
HV-H5	Hidden Valley Creek Baseline Station	Characterize water quality in creek draining a similar, but mostly undeveloped watershed

2.2 Precipitation Summary

Precipitation for the year is shown in Figure 2.2. Data was taken from the National Resource Conservation Service, National Water and Climate Center website (http://www.wcc.nrcs.usda.gov). This graph represents accumulated precipitation and snow water content measured at SNOTEL Station 19L24S ("Heavenly Valley"), operated by the USDA Natural Resource Conservation Service. This station is located in the upper watershed of Heavenly Valley Creek near Sky Meadows, the former HV-C1A monitoring station at latitude 38° 56' N, longitude 119° 54' W, and elevation 8,850 ft.

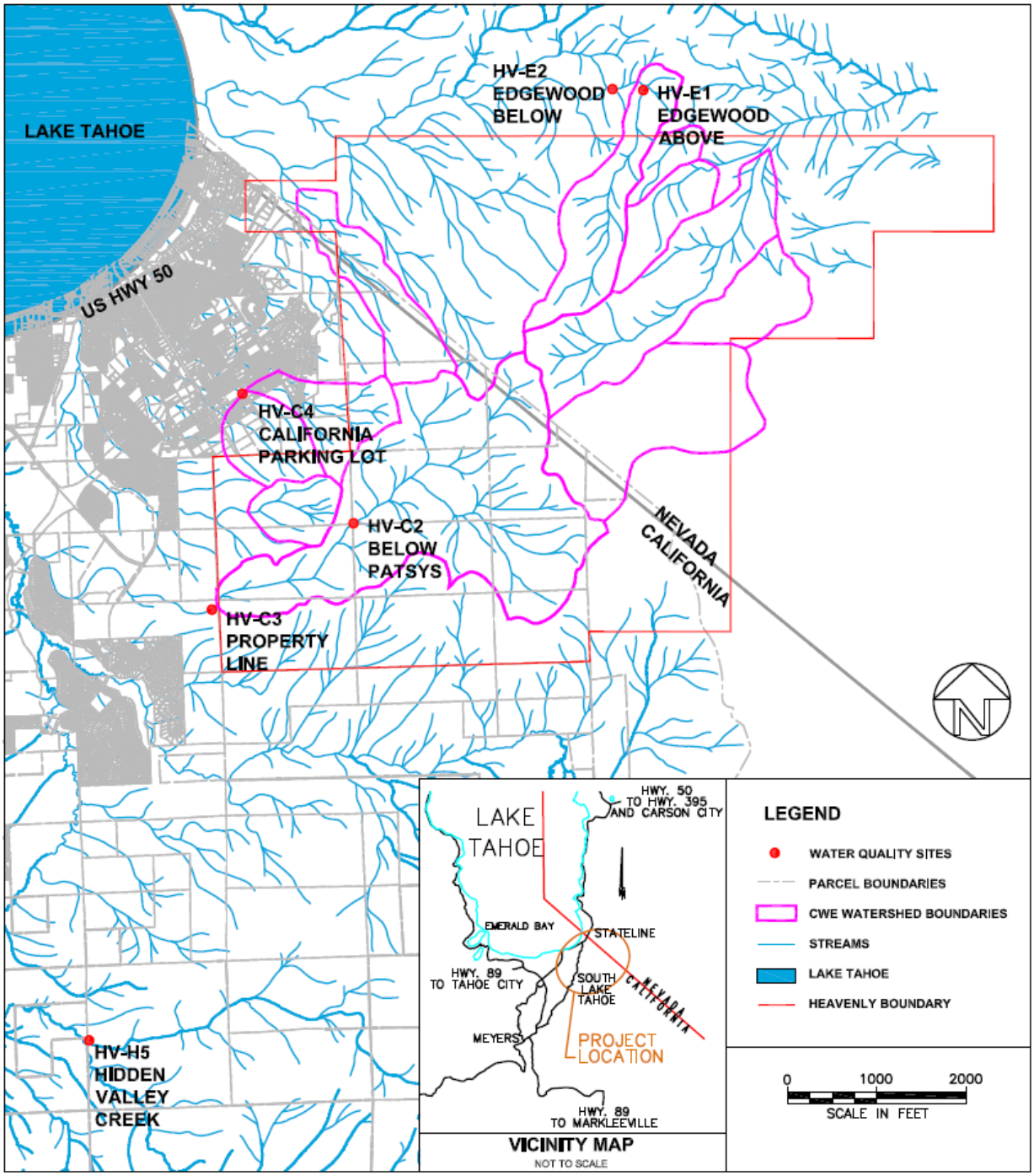

Figure 2.1 Approximate location of water quality sampling sites (MapQuest 2009) (USDA Forest Service 2001)

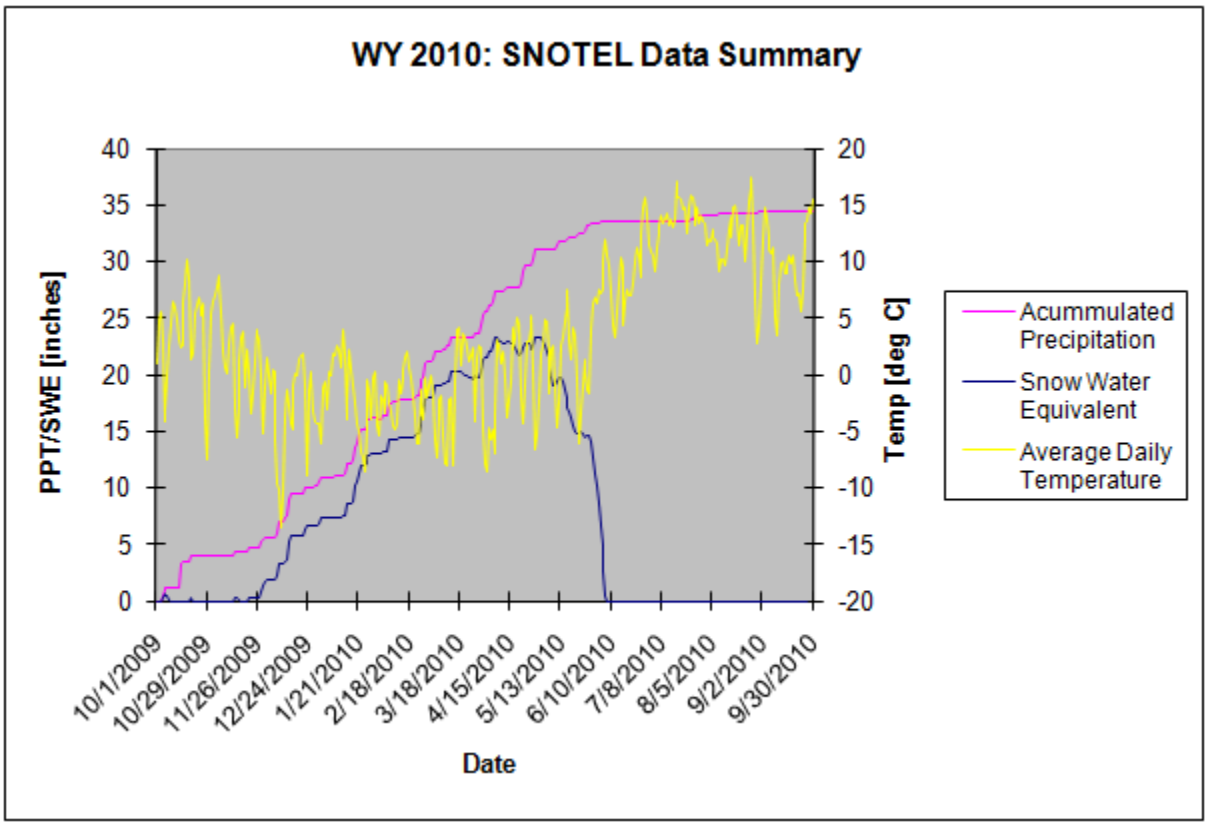

Figure 2.2 SNOTEL weather graph for water year 2010

2.3 Sampling Frequency and Analysis

A total of 78 samples were collected during the 2010 water year. Two of these samples were collected during storm events, one from the California Parking Lot Station (HV-C4), and the other storm sample was from Hidden Creek (HV-H5). All stations were sampled weekly during spring runoff and monthly during baseflow conditions, as flow levels permitted. Table 2-2 provides a summary of sampling and analyses for the 2010 water year.

Analyses for specific conductivity, turbidity, suspended sediment, nitrate/nitrite, total Kjeldahl nitrogen, total nitrogen, total phosphorus, soluble reactive phosphorus, and dissolved phosphorus were performed by High Sierra Water Lab located in Truckee, CA. Analyses for iron, lead, oil and grease, and chloride were performed by Western Environmental Testing Laboratory (WETLab) in Reno, NV. Analytical results by station are provided in Appendix A.

Table 2.2 Summary of Sampling and Analysis Conducted at Heavenly Mountain Resort for the 2010 Water Year.

Station ID	Station Name - abbreviated	Number Samples	Constituents*
HV-C2	Heavenly Below Patsy's	15	Full suite
HV-C3	Heavenly at Property Line	15	Full suite

Table 2.2	Summary of Sampling and Analysis Conducted at Heavenly Mountain Resort for the 2010 Water Year.		
Station ID	Station Name - abbreviated	Number Samples	Constituents*
HV-C4	California Parking Lot-Bijou Park Creek	16	Full suite, oil, grease, TPH, Fe, Pb, Cl, NH_3
HV-E1	Edgewood Creek Above	8	Full suite, Dissolved P
HV-E2	Edgewood Creek Below	8	Full suite, Dissolved P
HV-H5	Hidden Valley Creek	16	Full suite

*Full suite = Discharge, specific conductivity, turbidity, suspended sediment, nitrate/nitrite, TKN, total nitrogen, total phosphorus, soluble reactive phosphorus. Storm and quarterly samples are included in the "full suite" count. Storm and quarterly sampling may also include chloride and iron as additional constituents.

2.4 Results and Discussion

2.4.1 Discharge

The rate of stream flow was measured using a Marsh-McBirney meter at all sites except HV-C2 where flow was calculated from stage values in Parshall flumes. The Heavenly Valley (HV-C2 and HV-C3) and Hidden Valley Creek (HV-H5) stations exhibited peak streamflow discharge values in June. The Bijou Park Creek station (HV-C4) exhibited peak streamflow discharge during a storm event in mid-October; otherwise, exhibited peak flows at the end of April. The peak flows from Heavenly Valley and Hidden Valley Creeks (HV-C2 and HV-H5) were significantly higher than 2009 measurements, and also peaked several weeks later than last year. On the contrary, Heavenly Valley Creek (HV-C3) reported a discharge peak below what was reported in 2009, and peaked approximately slightly earlier than last year. Bijou Park Creek (HV-C4) also reported a discharge peak below last year's, while the timing of the peak flows occurred approximately one month later.

The peak streamflows at the Edgewood Creek sites (HV-E1 and HV-E2) occurred in May, with HV-E1 exhibiting peak discharges in early May, and HV-E2 in late May. These values are much lower than the reported peaks of 2009 since last year's peak discharges occurred as a result of a storm event. Samples from the lower Edgewood site (HV-E2) consistently reported discharge values higher than the upper sampling site (HV-E1). Edgewood Creek is known to have tributaries adding flow to the downstream site from surrounding neighborhoods. In addition, below the Boulder parking area the creek is established in a small ravine which collects groundwater recharge from the adjacent hillside slopes. During storm events, the discharge values are in reverse order. This is most likely the result of the Boulder Parking Lot Treatment System installed in 2005 attenuating flow as it runs downstream to the lower site. In addition, the Lower Edgewood Creek Stream Environment Restoration Project completed in 2007, created plunge pools to increase retention time contributing to the attenuation.

The 2010 water year was an average winter for precipitation. Both the precipitation values and snow water equivalent peak measurements were higher than the past two years, which were a below average winters. Above average temperatures in May and June fueled peak discharge values at a majority of the sampling locations (See Figure 2.2). Figures 2-3, 2-4, and 2-5 are hydrographs representing all six sampling stations.

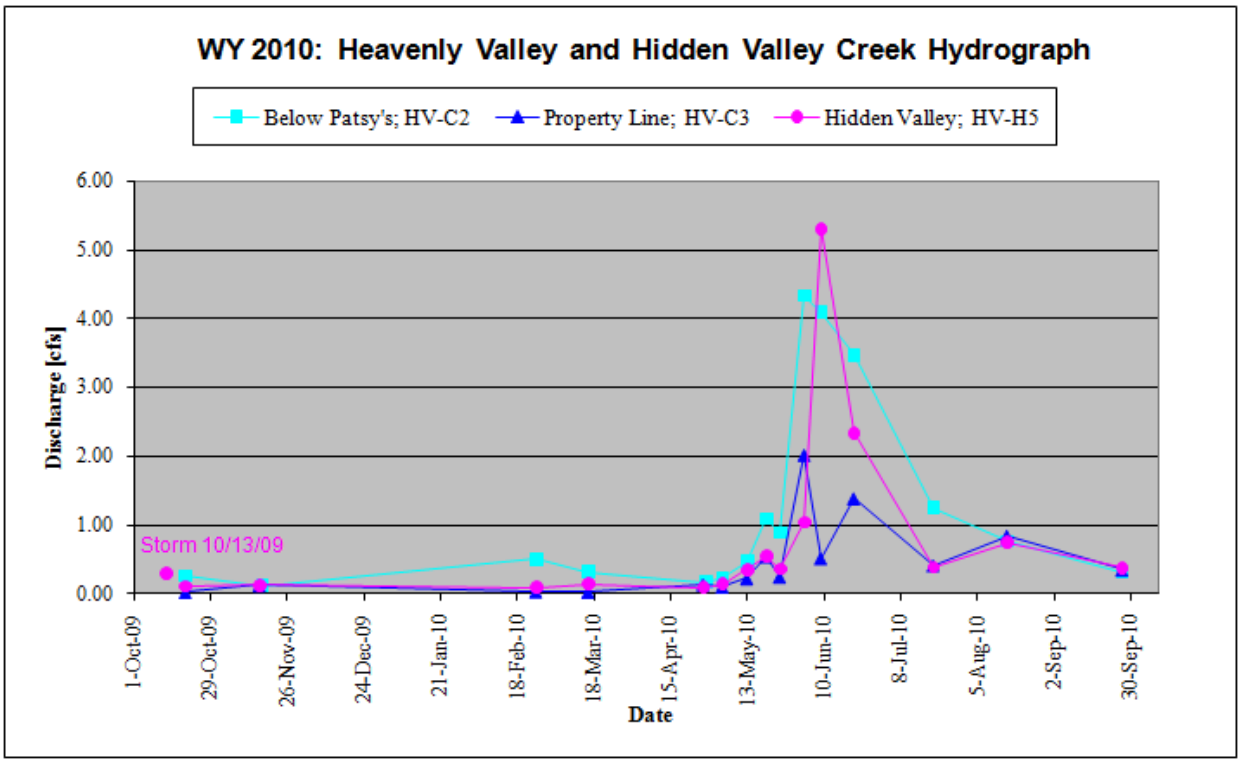

Figure 2.3 Hydrographs for Heavenly Valley and Hidden Valley Creeks during water year 2010. The two Heavenly Valley Creek monitoring sites are depicted in shades of blue. The one Hidden Valley Creek monitoring site is depicted in magenta.

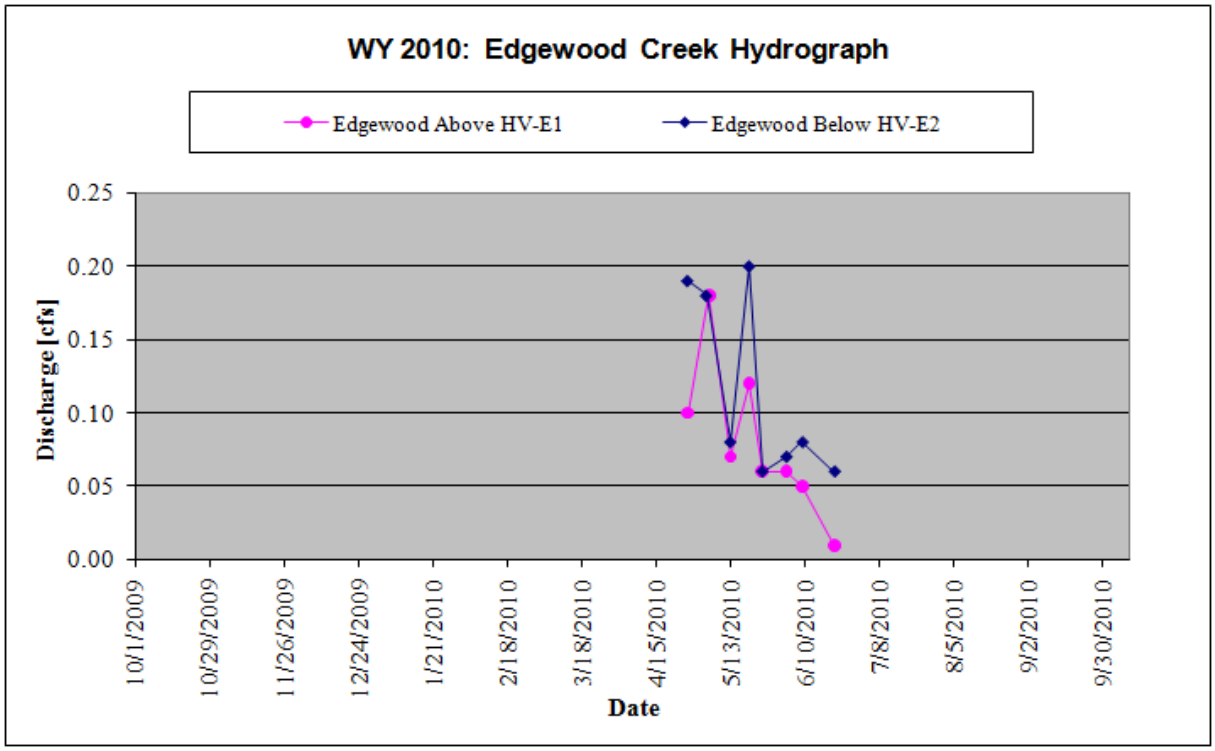

Figure 2.4 Hydrographs for Edgewood Creek during water year 2010.

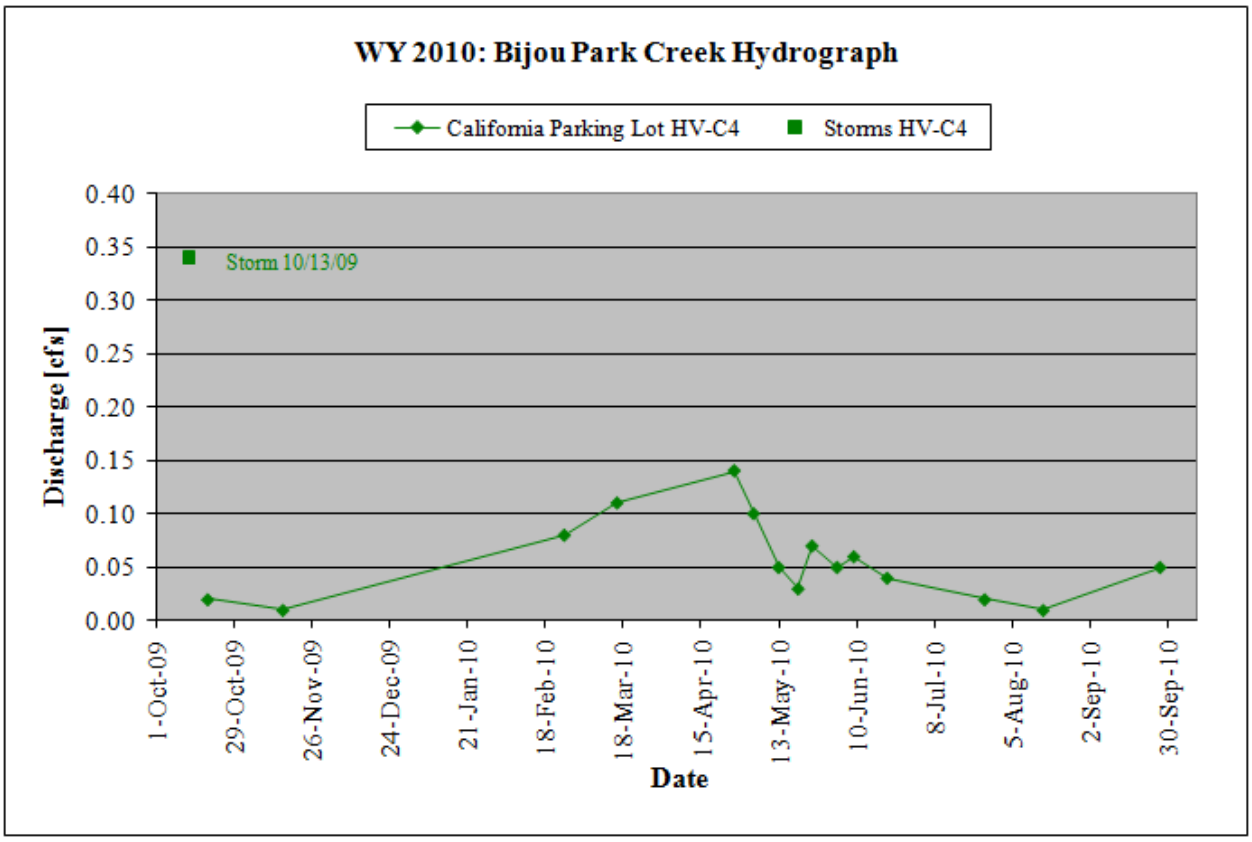

Figure 2.5 Hydrograph for Bijou Park Creek during water year 2010.

2.4.2 Annual Load Estimates

Table 2.3 presents the annual load values calculated from flow-weighted concentration data for total nitrogen, total phosphorus, and suspended sediments at Heavenly Valley Creek's Property Line station and the Hidden Valley Creek baseline station for water year 2010. Annual load values are calculated from flow-weighted concentration data for constituents. The previous Total Maximum Daily Load (TDML) for sediment at Heavenly Valley Creek was 58 tons/year (based on a five-year rolling average). The newly calculated five year average from 2006-2010 is shown in Table 2.4 and equals 12.6 tons/year. This new rolling average is considerably lower than 58 tons/year and is mostly likely associated with below average precipitation and flows from the past three seasons. In addition, this lower rolling average value could also be attributed to BMP implementation and effectiveness throughout the watershed. Although compliance is not determined until the Comprehensive Report, which will include water years 2006-2011, Heavenly continues to fall below the TMDL standard for suspended sediment. The last comprehensive report found that Heavenly was in compliance for the TMDL standard during that monitoring period. This average was verified in the Lahontan TMDL status report.

The method used to calculate annual load values is based on constituent concentrations, discharge, and days between samples. This is the same method that has been used in previous annual reports and verified with Lahontan staff last spring. Storm data was not used in load calculations. The 2010 water year can be considered an average precipitation year, and since last several years (2006-2009) were low precipitation years, the annual load values are considerably

higher than the 2006-2009 water years. Values for total nitrogen, total phosphorus, and suspended sediment are significantly higher than those reported in 2009.

Table 2.3 Annual load values at Heavenly Valley Creek Property Line and Hidden Valley Creek Stations.

Year	Discharge m^3/yr	Total N kg/yr	Total P kg/yr	Suspended Sediment tons/yr
Property Line (HV-C3)				
2010	297,626	180	44	21.6
Hidden Valley Creek (HV-H5)				
2010	455,308	90	18	5.8

Table 2.4 Five Year Rolling Average of Suspended Sediment for Heavenly Valley Creek Property Line and Hidden Valley Creek Stations.

Year	Property Line (HV-C3) Suspended Solids (tons/year)	Hidden Valley Creek (HV-H5) Suspended Solids (tons/year)
2006	39.0	34.0
2007	1.0	3.0
2008	1.0	2.0
2009	0.5	1.6
2010	21.6	5.8
5 Year Rolling Average	12.6 (tons/year)	9.3 (tons/year)

2.5 Heavenly Valley and Hidden Valley Creeks

2.5.1 Summary Statistics for Water Quality Constituents: Water Year 2010

The statistical summary for Heavenly Valley and Hidden Valley Creeks for water year 2010 is contained within Tables 2.5 through 2.7, while raw data is referenced in Appendix A. Annual average standards that were exceeded by the stations on Heavenly Valley Creek were also exceeded by the Hidden Valley Creek reference station. Therefore, the exceedances are likely due to background conditions unrelated to operation of Heavenly. Total phosphorus, chloride and total iron all exceeded the State standard annual averages.

The concentration of Total Suspended Sediment (TSS) at Heavenly Valley and Hidden Valley Creeks fell well below the State Standard of 60mg/L at the 90th percentile. The Below Patsy's (HV-C2) and Property Line station (HV-C3) TSS values were higher than the value of the Hidden Valley Creek reference station (HV-H5) due to exceedances from the June 3rd sampling event. This sampling event resulted in the highest flows at Heavenly Creek for water year 2010, and likely mobilized suspended bed material above normal stage heights.

Lahontan's standard for total nitrogen, 0.19 mg/L, is the sum of the total nitrite/nitrate plus total Kjeldahl nitrogen. Both stations (HV-C2 and HV-C3) on Heavenly Valley Creek exhibited annual averages above the State standard; however, total nitrogen values were similar to that of the reference station, Hidden Valley Creek (HV-H5), which also exceeded the State standard, suggesting that resort operations have a less-than-significant impact on total nitrogen concentrations.

Annual averages for total phosphorus are required to be below the 0.015 mg/L Lahontan standard. Both stations on Heavenly Valley Creek exhibited levels that exceeded the standard. Average values for these stations are as follows: Below Patsy's (HV-C2) 0.13 mg/L, and Property Line (HV-C3) 0.089 mg/L. The reference station on Hidden Valley Creek (HV-H5) also exceeded the annual average standard at 0.043 mg/L. Although vegetation removal at the resort could contribute to phosphorus levels, the levels are only slightly higher than that of the primarily forested and relatively undeveloped watershed of Hidden Valley Creek.

The chloride standard of 0.15 mg/L was also exceeded by all stations on Heavenly Valley and Hidden Valley Creeks. Below Patsy's (HV-C2) and Property Line (HV-C3) exhibited annual averages of 1.34 mg/L, and 0.965 mg/L, respectively. By comparison, the reference station on Hidden Valley Creek (HV-H5) exhibited a chloride value of 0.40 mg/L. Causes for high chloride levels are unknown. The application of salt in the watershed upstream is a possible cause, but does not explain the high background concentrations. The chloride levels at the sample site Below Patsy's (HV-C2) could be attributed to application of sodium chloride on nearby terrain parks on the mountain. The Property Line site (HV-C3) is downstream of the Below Patsy's site and could be affected by salt application on terrain parks also. Chloride results for Heavenly Valley Creek (HV-C2 and HV-C3) are similar to values in previous water years.

The reference station on Hidden Valley Creek (HV-H5) exhibited a chloride value of 0.40 mg/L that was below last year's value of 1.02 mg/L. Although the chloride value dropped from last year, it is not entirely understood why the reference watershed continues to exhibit high background values compared with the State standard. The maximum chloride level measured at Hidden Valley Creek (HV-H5) was 0.75 mg/L on 10/13/09 during a storm event. There is no evidence or knowledge of salt or deicers being used in this remote relatively undisturbed watershed. The high value sampled from the reference station at Hidden Valley Creek (HV-H5) may indicate relatively high background concentrations. Heavenly is investigating practices that will reduce chloride in runoff such as alternative deicers, application practices, and deicer storage. If the reference station (HV-H5) continues to exhibit high chloride levels further management measures and implementation at resort sites may still not meet the water board standard.

Iron was the fourth constituent to be exceeded by all stations. The iron standard is 0.03 mg/L. Below Patsy's (HV-C2) and Property Line (HV-C3) had average values of 1.74 mg/L, and 0.064 mg/L respectively. The reference station on Hidden Valley Creek (HV-H5) exhibited 0.13 mg/L. The high value in the reference station may indicate high background concentrations. Groundwater below the Heavenly Tram was sampled on December 9, 2008 to investigate whether background iron concentrations exceeded the standard. This sample produced an iron level of 0.046 mg/L, which exceeded the standard. Further augmenting the possibility that iron levels are naturally high in Lake Tahoe groundwater is U.S. Geological Survey (USGS) data for Basin streams from 1991 through 2003 (USGS 2000). Data from streams such as Ward Creek,

Blackwood Creek, Logan Creek, and First Creek, among others, demonstrate exceedances of the iron standard on a regular basis. Though this data ceased to be collected after 2003, it offers some insight on background iron levels in the Lake Tahoe Basin. Iron levels at Property Line (HV-C3) and the reference station were slightly lower than last year, although iron levels increased at Below Patsy's (HV-C2). The iron level collected on October 20, 2009 was a value of 6.3 mg/L, which is an unusually high exceedance. Iron levels above 1.0 mg/L have not been reported in previous sampling years (2006-2009), so this sampling event resulted in an annual average above previous water years.

Table 2.5 Below Patsy's Water Year 2010 Statistical Summary.

Exceedances of California Lake Tahoe Receiving Water Limits and Water Year 2010 Summary Statistics for Below Patsy's (HV-C2)

	Q (cfs)	Turbidity (NTU)	TSS (mg/L)	S Cond (mmhos)	Total Phos (mg/L)	SRP (mg/L)	Total Nitrogen (mg/L)	Chloride (mg/L)	Iron (mg/L)
CA State Standard		-	60.00	-	0.015	-	0.19	0.15	0.03
# Samples	15	15	15	15	15	15	15	3	3
Min	0.12	0.40	0.40	28.20	0.016	0.001	0.11	0.64	0.18
Max	4.34	3.00	533.00	120.00	1.07	0.021	3.30	2.10	6.30
Mean	1.22	1.12	41.25	51.31	0.13*	0.005	0.41*	1.34*	1.74*

*Indicates the average annual mean exceeded the state standard

Table 2.6 Property Line Water Year 2010 Statistical Summary

Exceedances of California Lake Tahoe Receiving Water Limits and Water Year 2010 Summary Statistics for Property Line (HV-C3)

	Q (cfs)	Turbidity (NTU)	TSS (mg/L)	S Cond (mmhos)	Total Phos (mg/L)	SRP (mg/L)	Total Nitrogen (mg/L)	Chloride (mg/L)	Iron (mg/L)
CA State Standard		-	60.00	-	0.015	-	0.19	0.15	0.03
# Samples	15	15	15	15	15	15	14	4	4
Min	0.03	0.48	0.27	30.80	0.012	0.001	0.055	0.100	0.031
Max	2.02	102.00	506.00	54.50	1.051	0.008	4.314	1.600	0.130
Mean	0.47	7.71	36.38	43.20	0.089*	0.005	0.387*	0.965*	0.064*

*Indicates the average annual mean exceeded the state standard

Table 2.7 Hidden Valley Creek Water Year 2010 Statistical Summary.

Exceedances of California Lake Tahoe Receiving Water Limits and Water Year 2010 Summary Statistics for Hidden Valley Creek (HV-H5)

	Q (cfs)	Turbidity (NTU)	TSS (mg/L)	S Cond (mmhos)	Total Phos (mg/L)	SRP (mg/L)	Total Nitrogen (mg/L)	Chloride (mg/L)	Iron (mg/L)
CA State Standard		-	60.00	-	0.015	-	0.19	0.15	0.03
# Samples	16	16	16	16	16	16	16	5	5
Min	0.09	0.32	0.80	18.35	0.018	0.002	0.016	0.16	0.01
Max	5.31	10.20	54.40	66.80	0.200	0.042	0.973	0.75	0.38
Mean	0.78	2.58	9.19	45.33	0.043*	0.010	0.221*	0.40*	0.13*

*Indicates the average annual mean exceeded the state standard

2.6 Bijou Park Creek (California Parking Lot)

2.6.1 Summary Statistics for Water Quality Constituents: Water Year 2010

The California Parking Lot site (HV-C4), is sampled for compliance with California state effluent standards for urban runoff and water quality objectives for maximum concentrations for discharge to surface waters, as stated in Lahontan Board Order No.R6T-2003-0032. Prior to November 30, 2008 effluent limits for discharge at this site were regulated under the permit as maximum concentrations for discharge to land treatment values. The new standards were reduced by approximately a factor of ten compared to the land treatment values (see Table 2.8). Proposed, constructed, and implemented improvements to the California Base parking lot dictated by the Lahontan permit triggered these more stringent objectives. California State effluent standards and exceedances are outlined in Table 2.9, while raw data is referenced in Appendix A.

Table 2.8 Lake Tahoe Hydrologic Unit Surface Runoff Effluent Limits

Constituent	Units	Maximum Concentrations for Discharge to Land Treatment [1]	Maximum Concentration for Discharge to Surface Waters [2]
Total Nitrogen	mg/L as N	5.0	0.5
Total Phosphorus	mg/L as P	1.0	0.1
Total Iron	mg/L	4.0	0.5
Turbidity	NTU	200	20
Oil and Grease	mg/L	40	2

[1] The effluent limits for discharge to land were effective for discharges from the California Base area on December 31, 2004.

[2] The effluent limits for discharge to surface waters shall be effective for discharges from the California Base area on November 30, 2008.

As shown in Table 2.9, there were 13 sampled events that exceeded the newly adopted maximum concentration of 0.5 mg/L for total nitrogen. The highest calculated value (the sum of nitrate, nitrite and total Kjeldahl nitrogen) was recorded during the October 13, 2009 storm event at 1.436 mg/L. The percentage of exceedances for total nitrogen at HV-C4 (81% non-compliance) is slightly higher than that recorded for the previous water year (76% non-compliance). Three of

the 16 samples collected were below the State standard; however, 31% of the total nitrogen background levels recorded at the reference site (HV-H5) also exceeded the State standard. Plant uptake and decay may explain seasonal spikes throughout the year for nitrogen readings, but it doesn't explain the relatively high background readings or the increase in the number of exceedances from the 2009 water year.

Five sampled events exceeded the State standard of 0.1 mg/L for total phosphorus. As with total nitrogen, the highest calculated value was recorded during the October storm event. The percentage of exceedances (31% non-compliance) for total nitrogen at HV-C4 is the same as the previous water year; however, all (100% non-compliance) of the total phosphorous background levels recorded at the reference site (HV-H5) also exceeded the State standard. Notably, the 2010 annual average is lower than the reported averages for the past four water years. Phosphorus and nitrogen constituents can vary with plant uptake and subsequent vegetation removal.

As shown in Table 2.9, there were 15 sampled events that exceeded the State standard of 0.5 mg/L for total iron. The percentage of exceedances for total iron at HV-C4 (94% non-compliance) is slightly lower than that recorded for the previous water year (100% non-compliance). While only one of the 16 samples collected were below the State standard, 80% of the total iron background levels recorded at the reference site (HV-H5) also exceeded the State standard. The relatively high iron readings are likely attributed to naturally occurring iron in the soils and nearby springs, as noted in the general permit (Section 12 California Base Area Runoff, page 6). An additional test was performed in December 2008 to test iron levels in and around the parking lot. The iron concentration from the tram sump water measured 0.046 mg/L, while the iron concentration at the parking lot outlet was 12 mg/L. The increase in iron concentration indicates that something in or on the California Parking Lot is contributing iron to the groundwater, which then enters Bijou Park Creek as surface water at the intersection of Saddle and Wildwood. The 5-year comprehensive report will include a trend analysis of the types of deicers used, including the proportion of cinders in the deicing mix, over the period.

Three sampled events exceeded the State standard of 20 NTU for turbidity. The percentage of exceedances (19% non-compliance) for turbidity at HV-C4 is slightly higher than the percentage of exceedances recorded in the previous water year (18% non-compliance). Notably, the annual average for turbidity was below the State standard and dropped substantially compared to last year's annual average of 88.74 NTU.

Two sampled events exceeded the State standard of 2.0 mg/L for oil and grease. While these samples were not collected during storm events, these two sampling events (February 25th and March 16th 2010) contained the largest readings collected for the constituents that exceeded the State standard (total nitrogen, total phosphorous, chloride, oil and grease, total iron). The percentage of exceedances (13% non-compliance) for oil and grease at HV-C4 is lower than the previous water year (35% non-compliance). Continued monitoring and trouble shooting of the treatment systems should provide better data and further understanding of these values.

One sampled event exceeded the State standard of 65 mg/L for total suspended solids, which occurred during the February 25, 2010 sampling event. The percentage of exceedances (6% non-compliance) for total suspended solids at HV-C4 is much lower than the previous water year's 18% non-compliance, as is the annual mean. The decrease in suspended sedimentation is likely the cause of decreased nutrient loading (nitrogen and phosphorous). The addition of two

treatment systems above the sampling location has decreased this value from previous years (prior to 2008 and 2009). Continued monitoring and regular maintenance of the treatment systems should stabilize this value in the coming quarters and years.

All 16 sampled events exceeded the State standard of 3.0 mg/L for chloride, the highest of which was measured during the February 25, 2010 sampling event. The percentage of exceedances (100% non-compliance) for total nitrogen at HV-C4 is slightly higher than the previous water year (94% non-compliance); however, all (100% non-compliance) of the chloride background levels recorded at the reference site (HV-H5) also exceeded the State standard. Excess chloride is most likely due to deicer application that includes sodium chloride. Applications to the California Base Lodge Parking area and surrounding city roads helps to prevent ice build-up and ensure public safety. Summer measurements occurred when no deicers were applied to the California Base Lodge Parking area or surrounding area (June-October); however, chloride levels were still above the State standard. For example, no deicers were applied to the California Parking Lot in June of 2010 when chloride concentrations were measured at 98 mg/L. It is possible that deicer residuals from the previous season had accumulated and were flushed during summer thunderstorms. With the installation of automatic samplers at the influents and effluent locations of the California Parking Lot treatment system, Heavenly should be better able to determine whether chloride originates from the resort application, city road application, or occurs naturally. Heavenly is actively investigating practices that will reduce chloride in runoff such as alternative deicers, application practices, and deicer storage.

Single value non-compliance values are discussed in the pertinent quarterly report and are displayed in Appendix A.

Table 2.9 Exceedances of CA Standards and Water Year 2010 Summary Statistics for HV-C4.

Exceedances of California Effluent Standards and Water Year 2010 Summary Statistics for Bijou Park Creek (HV-C4) below California Parking Lot

	Q (cfs)	Turbidity (NTU)	TSS (mg/L)	S Cond (mmhos)	Total Phos (mg/L)	SRP (mg/L)	NO_2/ NO_3 (mg/L)	TKN (mg/L)	Total N (mg/L)	Chloride (mg/L)	Oil/ Grease (mg/L)	Total Iron (mg/L)	Total Lead (mg/L)
CA State Standards		20.0	65	N/A	0.10	N/A	N/A	N/A	0.5	3.0	2	0.5	N/A
# Non-compliance		3	1	N/A	5	N/A	N/A	N/A	13	16	2	15	N/A
% Non-compliance		19%	6%	N/A	31%	N/A	N/A	N/A	81%	100%	13%	94%	N/A
# Samples	16	16	16	16	16	16	16	16	16	16	16	16	16
Min	0.01	3.10	2.40	151.00	0.043	0.004	0.190	0.014	0.365	21.00	1.20	0.18	ND
Max	0.34	80.00	176.67	1667.00	0.616	0.029	1.436	1.235	1.479	540.00	17.00	6.40	<0.010
Mean	0.07	15.41	20.29	408.31	0.120	0.012	0.466	0.268	0.733	94.88	4.12	2.88	N/A

2.7 Edgewood Creek

2.7.1 Summary Statistics for Water Quality Constituents: Water Year 2010

Although Edgewood Creek is located in Nevada, outside of Lahontan jurisdiction, Edgewood Creek data is included for compliance with the Master Plan Amendment because it is within TRPA's jurisdiction. The Edgewood Creek sites are sampled for compliance with the Nevada Department of Environmental Protection (NDEP) standards. Data are summarized in Tables 2.10 and 2.11, while raw data is referenced in Appendix A. The annual average standard for total nitrogen and total phosphorous was met at both stations during water year 2010.

The not to exceed standard for turbidity was exceeded at the Edgewood Below station (HV-E2) on April 27, 2010. The not to exceed standard for total suspended solids was also exceeded at the HV-E2 station on June 3 and 9th, 2010. The levels of the constituents trended downward after the first sampling event of the season (April 27, 2010), which exhibited high flows, and was likely a spring flush. The initially high values decreased throughout the month of May, and spiked up again in early June in association with higher temperatures and precipitation. As vegetation from the 2007 restoration project continues to mature, the restoration project should help stabilize these temporal shifts in turbidity and suspended sediments.

Table 2.10 Exceedances of Standards and Water Year 2010 Summary Statistics for HV-E1.

Exceedances of State (NDEP) Standards and Water Year 2010 Summary Statistics for Edgewood Creek (HV-E1) Above Boulder parking lot

	Q (cfs)	SC (mmhos)	Turbidity (ntu)	SS (mg/L)	NO_2/ NO_3 (mg/L)	TKN (mg/L)	TN (mg/L)	TP (mg/L)	SRP (mg/L)	DP (mg/L)
NDEP Standards[1]	N/A	N/A	10.00	25.00	N/A	N/A	0.6 [2]	0.10	N/A	N/A
# Noncompliance	N/A	N/A	0	0	N/A	N/A	0	0	N/A	N/A
% Noncompliance	N/A	N/A	0%	0%	N/A	N/A	0%	0%	N/A	N/A
# Samples	8	8	8	8	8	8	8	8	8	8
Min	0.01	58.2	1	0.8	0.001	0.081	0.083	0.016	0.003	0.009
Max	0.18	83.4	5.5	20.8	0.002	0.279	0.280	0.083	0.009	0.021
Mean	0.081	68.950	2.27	5.46	0.002	0.150	0.152	0.030	0.004	0.014

[1]NDEP Standards are from the Nevada Administrative Code (NAC) Chapter 445A.1915. All listed numbers are standards for single values no greater than a given parameter unless otherwise noted.

[2]Annual Average

Table 2.11 Exceedances of Standards and Water Year 2010 Summary Statistics for HV-E2.

Exceedances of state (NDEP) Standards and Water Year 2010 Summary Statistics for Edgewood Creek (HV-E2) below Boulder parking lot

	Q (cfs)	SC (mmhos)	Turbidity (NTU)	SS (mg/L)	NO_2/ NO_3 (mg/L)	TKN (mg/L)	TN (mg/L)	TP (mg/L)	SRP (mg/L)	DP (mg/L)
NDEP Standards[1]*	N/A	N/A	10.00	25.00	N/A	N/A	0.6 [2]	0.10	N/A	N/A
# Noncompliance	N/A	N/A	1	2	N/A	N/A	0	0	N/A	N/A
% Noncompliance	N/A	N/A	13%	25%	N/A	N/A	0%	0%	N/A	N/A
# Samples	8	8	8	8	8	8	8	8	8	8

Table 2.11 Exceedances of Standards and Water Year 2010 Summary Statistics for HV-E2.										
Exceedances of state (NDEP) Standards and Water Year 2010 Summary Statistics for Edgewood Creek (HV-E2) below Boulder parking lot										
Min	0.06	92.50	0.98	2.00	0.018	0.118	0.136	0.022	0.002	0.011
Max	0.20	134.60	14.00	32.80	0.038	0.390	0.426	0.090	0.010	0.021
Mean	0.12	113.31	6.39	14.05	0.028	0.182	0.210	0.035	0.005	0.015

[1]NDEP Standards are from the Nevada Administrative Code (NAC) Chapter 445A.1915. All listed numbers are standards for single values no greater than a given parameter unless otherwise noted.
[2]Annual Average

2.8 Conclusions and Recommendations

The 2010 water year was an average year of precipitation. Increased precipitation results in higher annual loads, and the number of non-compliance exceedances based on annual averages increased by one from last year. Heavenly's operations are consistent with meeting water quality objectives and there is an overall water quality improvement trend. Some of the constituents of non-compliance in this year's monitoring are attributable to background conditions. The reference stream that is unaffected by Heavenly operations in a primarily forested watershed also exceeded specific standards. Other problem constituents are actively being addressed by Heavenly's completion of CWE projects. The following sections include a summary of the monitoring program and the 2010 findings for each creek and any applicable recommendations.

2.8.1 Heavenly Valley Creek

Annual average standards for phosphorus, nitrogen, chloride, and iron were exceeded by both stations on Heavenly Valley Creek (HV-C2 and HV-C3). The same standards were also exceeded at the Hidden Valley Creek reference station (HV-H5). Therefore, these exceedances may not be attributable to Heavenly resort operations and could be a background characteristic of the watersheds.

Chloride and iron exceedances increased from last year's values at Below Patsy's (HV-C2), while levels of both constituents decreased compared to last year's values at Property Line (HV-C3). Chloride and iron levels may be affected by mountain operation of snow condition enhancement. It should be noted that chloride values at the reference site (HV-H5) have been above the water board annual standard since 2005. While snow enhancement may be increasing the chloride readings, mountain operations is not the sole cause for these higher measurements.

Total phosphorous and total nitrogen levels at both Heavenly Valley Creek sites and at Hidden Valley Creek increased compared to last year. Phosphorous, exceedances have been ongoing for the past several water years for Heavenly Valley Creek (HV-C2 and HV-C3) and Hidden Valley Creek; however, the total nitrogen exceedance is a new one for all three sites. Since the nitrogen exceedances are new this year, they will be evaluated in the future to determine if there is a trend, or if the source can be identified.

The Below Patsy's site (HV-C2) is valuable in assessing the effects of upper mountain management on water quality. The Property Line site (HV-C3) is the TMDL compliance point

and will continue to be valuable to monitoring protocol. Heavenly Valley Creek continues to be well within the TMDL limits for suspended solids and all other permitted constituents.

2.8.2 California Parking Lot / Bijou Creek

Water quality constituent results from the Bijou Creek sampling site (HV-C4) have been lower than last year's results. This trend is exemplified as BMP improvement projects and retrofits were completed. While exceedances remain for total phosphorous, total nitrogen, chloride, oil and grease, and total iron, the annual mean for each of these constituents has decreased from last year, resulting in improved water quality. Further, turbidity and suspended sediments have also decreased, and are no longer in exceedance of the State standard as they were last year. The 2009 water year was the first full year where all BMPs for the California Base were installed and operational providing the second year of sampling data with the completed projects in place. A small area of the California Parking Lot was retrofit with storm treatment vaults that have functioned since November 2007. The majority of the California Parking Lot runoff is now treated by large vaults which were installed in 2007, but were not treating water until the filter media cartridges were installed on April 15, 2008. The final piece of the treatment system that collected the remaining parking lot runoff was installed at the intersection of Saddle and Wildwood Roads, just above the sampling site, and became operational on October 24, 2008. In addition to sampling the historical surface water site, three additional sites associated with the automatic samplers, one at each of the two inlets and one at the outlet, are sampled during storm events.

Troubleshooting of the automatic samplers is ongoing. In the fall of 2009, an inspection of the treatment vault systems found sediment in the outlet bay, which should be free of all debris. The exact entry point of the sediment source is unknown, but one possibility is that there were not proper seals on the manhole lids allowing sediment to fall into the system after treatment. In the summer of 2010, each manhole lid was replaced. Additionally, the outlet vaults were cleaned, thoroughly removing all sediment from the treatment system. Unfortunately, data collected from autumn thundershowers was inconclusive. In all cases, not all three of the samplers collected data. In some cases, the two inlet vaults were sampled, but the outlet bay was not. At other times, one inlet and the outlet were sampled, but in all cases there was not one complete sample collected. The goal moving forward is to further refine the sampling tools to ensure grab samples are taken. This may include additional assistance from the vault manufacturer this spring and the possibility of adding a remote modem to signal and trigger sample collection. New permit requirements will require sampling and reporting from the vault system. Inclusion of the data will be included in the annual report next year. If the system is still problematic, grab samples will be collected at all three sampling locations. With complete samples, the vault system may help Heavenly isolate the source of exceedances such as iron and chloride.

Total nitrogen values from the past few water years remain right around 1 mg/L, almost twice the new standard limit of 0.5 mg/L. Now that both treatment systems are in place, monitoring shall continue at this site. If this trend or value remains well above the standard further investigation into nitrogen removal should be looked into to meet compliance standards. The next Comprehensive Report (2012) should review the possibility and feasibility of further nitrogen treatment/removal.

To address the ongoing chloride exceedances, Heavenly has investigated alternative deicers and deicer application and storage practices. Magnesium chloride was examined, but found to be both a human health and safety risk and an environmental hazard (Transportation Research Board 1991 and Chambers 2008). Already banned in Aspen, Colorado, magnesium chloride has been found to have adverse effects on the life cycles of micro- and macro-invertebrates (Lewis 1999). Calcium magnesium acetate (CMA) was also examined, but was found to be prohibitively expensive and required in greater quantities (Transportation Research Board 1991). With the current available research, the combination of sodium chloride and sand or cinders is the least harmful to the environment and water quality. Research has shown that applying deicers before predicted storms and pre-wetting the deicing agents during application increases effectiveness and reduces the amount of deicers required. Along with implementing the aforementioned application practices, Heavenly has been testing the reduction of salt to cinder ratio. The ratio during the 2010 season was two parts cinder to one part deicer. Current application practices include a ratio of one part deicer to three parts cinder. Monitoring of chloride at both the compliance point and with the automatic sampler locations will continue in 2011.

2.8.3 Edgewood Creek

The treatment system, completed in 2005, was constructed to collect and treat runoff originating from the Boulder Parking Lot and Lodge that flows into Edgewood Creek. Additional stream improvements and creek restoration occurred in 2006 and 2007. As vegetation associated with these restoration efforts matures, additional nutrient uptake and subsequent water quality should improve. The next Comprehensive Report (2012) will evaluate these improvements with regards to water quality. For 2011, the current monitoring protocol will continue with an increased effort in collecting more samples to get a better idea of the runoff hydrograph.

Chapter 3

Effective Soil Cover

3.1 Introduction

Vegetation and other organic and inorganic soil cover materials are known to reduce the potential erosivity of soil particles, increase percolation, and reduce runoff rates. The construction of ski trails and access roads requires the removal of vegetation and other obstacles (boulders, tree stumps, etc.) thereby reducing the effective soil cover (ESC). Efforts to stabilize disturbed areas by increasing effective soil cover or increasing the infiltration rate has resulted in reduction of erosion rates, thereby decreasing sediment and nutrient input into adjacent streams, and ultimately Lake Tahoe.

3.2 Background and Objectives

Evaluation of effective soil cover focuses on types and percentages of cover, and identification of erosion features. A Cumulative Watershed Effects (CWE) analysis was initiated in 1991 by the United States Department of Agriculture (USDA) Forest Service to predict soil loss as determined from the modified universal soil loss equation model (MUSLE) and its parameters. Field measurements were taken to evaluate ESC at Heavenly by conducting surveys of fixed plots and random transects from 1995 through 2003. These field measurements were intended to verify the accuracy of the predicted values from the CWE model. The model assumed that 70% ESC is adequate for erosion control on ski slopes (USDA Forest Service 2003).

Findings from the field evaluations, summarized in the 2003 Comprehensive Monitoring Report, indicated that there has been a 21 percent increase in effective soil cover on ski runs at the resort since 1991 (USDA Forest Service 2003). This increase is resulting from a resort wide estimated total percent cover from 49 percent in 1991 and 69 percent in 2003 (USDA Forest Service 2003). However, in many cases transect data did not adequately address the original monitoring objectives. Issues with record keeping, such as mitigation practices, data collection, and inconsistent data collection, along with database management, made processing and analyzing data cumbersome and time-intensive (USDA Forest Service 2003).

A revised methodology was developed by ENTRIX in the Effective Soil Cover Plan (ENTRIX 2005). The revised monitoring plan adopted conclusions and recommendations from the 2003 Comprehensive Monitoring Report and greatly simplified ESC evaluation objectives. Primary objectives of the revised methodology are:

1. Determine if changes in cover result in changes in runoff and sediment volume from ski runs and other project infrastructure.

2. Evaluate utilization of soil amendments/treatments to increase infiltration capacity for those areas resistant to revegetation efforts, or where revegetation is ineffective.

The revised methodology intended to use data derived from remote sensing (originally IKONOS satellite imagery) with limited ground-truthing. No successful evaluations were conducted in 2006 or 2007, although the revised methodology was attempted. In general, suitable satellite images or aerial photographs were either not available for the necessary spatial or temporal periods, and/or pixel resolution was not sufficient for soil cover analysis.

In the 2007 Annual Report and later in the 2008 Effective Soil Cover Workplan, a new protocol was presented that combined the CNPS VRAP and the establishment of permanent photo points.

After discussions with the USDA Forest Service, it was determined that the CNPS VRAP method should support an aerial survey, rather than being the only data collected. Heavenly and the USDA Forest Service agreed to share the cost of an over-flight. An infrared aerial flyover of Heavenly Mountain Resort was conducted by 3DiWest in conjunction with the USDA Forest Service in July of 2009. The flight produced a 1:8,000 resolution infrared aerial photo of the entire mountain and was used along with Geographic Information Systems (GIS) and field verification (i.e. ground-truthing) to produce an accurate picture of the soil cover at Heavenly.

Due to inclement weather conditions and scheduling of the aerial flyover, only half of the field verification was completed using the CNPS VRAP methodology. Therefore, in 2009, only five of the 10 monitoring sites were evaluated and served as the “baseline” for ESC for 2010 field verification. All 10 monitoring sites were evaluated in 2010, so the five sites that were not evaluated in 2009 will be considered the baseline for next year’s (2011) ESC monitoring. Over-flights to take infrared photographs will occur approximately every five years. The next shared purpose over-flight will occur in approximately 5 years (July or August 2014).

3.3 Monitoring Methods

The aerial photographs were used to characterize and map soil cover along and near projects facilities (including ski runs). Mapping was completed using Arc-Geo Information Systems (GIS). Once the images were combined into a representative map covering Heavenly Mountain Resort, a ratio of bare soil verses vegetation was deduced using Arc GIS. This ratio will be used in conjunction with field verifications to extrapolate the effective soil cover in other areas on Heavenly. This will allow for a more efficient and less time consuming way of reporting the general ESC of Heavenly Mountain Resort, by only using the aerial flyover images and limited field information. After baseline studies performed in 2009 and 2010, a comparative analysis will be conducted in five year intervals with a focus on explaining areas resistant to establishing effective soil cover.

The methods used to conduct field verification were derived from the VRAP developed by the California Native Plant Society (CNPS 2004). The VRAP is a semi-quantitative method of vegetation and habitat sampling (CNPS 2004). Quantitative vegetation and site data recorded include, but are not limited to: topography, soil, rock and litter (size and percent cover), vegetation association and alliance, and vegetation cover (by percent cover, stratum and species) (Sawyer and Keeler-Wolf 1995). These data are not based on established test plots, but on a broader scale unit that is appropriate for the vegetation type found on the landscape. VRAP allows enough flexibility to respond to site-specific attributes of the areas, combined with enough quantitative observation to allow comparison between years. These measurements will

be conducted over time, and trends will be analyzed to meet the ESC study objectives. The VRAP method was augmented with the establishment of permanent photo points to better track variability over time. A biologist with experience in botany and soil cover analysis made judgments while conducting the VRAP measurements

In 2009, ten sites were selected on Heavenly Mountain Resort in order to ground-truth the aerial images. Sites were selected as a representative sample of ski run slopes, aspects, and soil types, as well as the erosion control treatment methods applied up to the present. The ten selected sites are outlined in Table 3-1.

Table 3.1 Ten Selected Effective Soil Cover Monitoring Locations

Landscape Unit*	Ski Run Name	Aspect	Ski Run Difficulty	Treatment
3	Gunbarrel	Northwest	Black	Hand raking in seed
6	Groove	Southeast	Green	Rock lined channel between roads
11	Ellie's Swing	North	Blue	Decommissioned road-tilling, mulch, amendments, revegetation
14	Edgewood Meadow	Northeast	Blue	Riparian/Wetland
16	Boulder Chute	North	Blue	Re-seeding
17	Lower Olympic	Northeast	Blue	Revegetation Treatments
18	Cloud Nine	Northeast	Blue	"Lop and Scatter" and Easy Street
24	Double Down/ Lower High Roller	Northwest	Black	Bottom of run has test plots
25	Lower Cal Trail	Southwest	Blue	Decommissioned Road, no treatment
23	Rope Tow Area near Big Easy and Gondola	Southeast	Green	Easy Street Treatment

*Landscape Units from ENTRIX, Inc. 2008 Workplan (ENTRIX 2008).

A field team, which included one biologist with experience in botany and soil cover estimation, visited all 10 of the field verification sites on October 18 and 19, 2010. For the five sites that were not visited in 2009 (Landscape Units 11, 18, 24, 25, and 23), the field crew established a photo point (or points) to enhance comparison of site attributes between measurement periods. Establishment of permanent photo points at selected runs would allows for semi-quantitative assessment of effective soil cover over time. Each photo point was located at a fixed point (GPS location and permanent marker). All photos were from a landscape perspective and the bearing of the camera in relation to the slope was recorded. The area of the photograph was recorded using a long tape measure for length and camera zoom information for width. Recording effective soil cover (i.e., live and dead vegetative cover, substrate, etc.) erosion features, and any

mitigation work performed in the area, was the primary focus of the field of view. Photo documentation considered the elements outlined in the Stream Photo Documentation Procedure of the Standard Operating Procedure (SOP) (SWRCB 2001). The field crew also visited the established photo points taken in 2009 for five of the monitoring sites (Landscape Units 3, 6, 14, 16, and 17) to take updated photos for documenting the vegetation and reassess the ESC.

The size of the landscape unit was estimated as an area that received a certain type of treatment to abate erosion. Boundaries of the landscape units were also defined by "stands", which are the basic physical unit of vegetation in a landscape (CNPS 2004). Stands are defined by two main unifying characteristics, composition and structural integrity. Compositional integrity means that throughout a site, the combination of species is similar (CNPS 2004). A stand is therefore differentiated from adjacent stands by a discernable boundary of changing dominant vegetation types (CNPS 2004). Structural integrity means that a site has a setting that presents similar horizontal and vertical spacing of plant species (CNPS 2004). Additionally, for an area of vegetated ground to meet the requirements of a stand, it must be homogenous; therefore, all boundaries were defined by homogenous vegetation types (CNPS 2004).

After photo documentation and boundary establishment, the field crew assessed the site's soil cover using the CNPS field form. A copy of the field form used during onsite verification can be seen in Figure 3.1. The field crew took notes on their observations at each of the sites and filled out the CNPS field form in as much detail as possible. After the field data was collected, it was recorded into a Microsoft Excel database.

In the summer of 2011, the five field verification sites (Landscape Units 11, 18, 24, 25, and 23) will be assessed based on the methodology above. During field activities in 2011, Cardno ENTRIX will incorporate, to the extent relevant, other studies of soil cover and erosion conducted within the basin. Cardno ENTRIX will contact Michael Hogan at Integrated Environmental Restoration Services in order to include some of his study sites on Heavenly into the field verification efforts. All ten verification sites will be revisited, reassessed, and photographed annually beginning in 2011 for the duration of the 5-year Mitigation and Monitoring Plan. Percentages of effective soil cover and eroded areas for each site will be recorded and reported annually along with qualitative observations made by the field crew. In 2015 another aerial flyover will be conducted over the Project area in coordination with the USDA Forest Service.

CALIFORNIA NATIVE PLANT SOCIETY - VEGETATION RAPID ASSESSMENT FIELD FORM
(Revised Sept. 20, 2004)

For Office Use:	Final database #:	Final vegetation type name:	Alliance_____ Association

I. LOCATIONAL/ENVIRONMENTAL DESCRIPTION

Polygon/Stand #:	Air photo #:	Date:	Name(s) of surveyors:
_____	_____	_____	_____

GPS waypoint #: _____ GPS name: _____ GPS datum: (NAD 27) _____ Is GPS within stand? Yes / No
If No, cite from GPS point to stand, the distance _____(in meters) and bearing _____(in degrees) GPS Error: ±_____ ft / m
UTM field reading: UTME ___ ___ ___ ___ ___ ___ UTMN ___ ___ ___ ___ ___ ___ ___ UTM zone: _____

Elevation: _____ ft / m Photograph #'s: _____
Topography: convex____ flat____ concave____ undulating____ | top____ upper____ mid____ lower____ bottom____
Geology: _____ Soil Texture: _____ Rock: %Large____ %Small ____ %Bare/Fine: ____ %Litter: ____ %BA Stems: ____
Slope exposure (circle one and/or enter actual °): NE_____ NW_____ SE_____ SW_____ Flat__ Variable__
Slope steepness (circle one and enter actual °): 0°__ 1-5° _____ 5-25°_____ > 25°_____ Upland or Wetland/Riparian (circle one)

Site history, stand age, and comments: _____
_____
_____
Type/ Level of disturbance (*use codes*): ____/___ ____/___ ____/___ ____/___ ____/___ ____/___ ____/___ ____/___

II. VEGETATION DESCRIPTION

Field-assessed vegetation alliance name: _____
Field-assessed association name (optional): _____
Size of stand: <1 acre___ 1-5 acres___ >5 acres___ Adjacent alliances: _____ _____
_____ _____ _____ _____

Tree: T1 (<1" dbh), T2 (1-6" dbh), T3 (6-11" dbh), T4 (11-24" dbh), T5 (>24" dbh), T6 multi-layered (T3 or T4 layer under T5, >60% cover)
If Tree, list 1-3 dominant overstory spp.: _____
Shrub: S1 seedling (<3 yr. old), S2 young (<1% dead), S3 mature (1-25% dead), S4 decadent (>25% dead)
Herbaceous: H1 (<12" plant ht.), H2 (>12" ht.) Desert Palm/Joshua Tree: 1 (<1.5" base diameter), 2 (1.5-6" diam.), 3 (>6" diam.)
Desert Riparian Tree/Shrub: 1 (<2ft. stem ht.), 2 (2-10ft. ht.), 3 (10-20ft. ht.), 4 (>20ft. ht.)
% Overstory Conifer/Hardwood Tree cover: ____/____ Shrub cover: ____ Herbaceous cover: ____ Total Veg cover:_____
Overstory Conifer/Hardwood height: ____/____ Tall Shrub/Low Shrub height: ____/____ Herbaceous height: ____
Height classes: 01=<1/2m 02=1/2-1m 03=1-2m 04=2-5m 05=5-10m 06=10-15m 07=15-20m 08=20-35m 09=35-50m 10=>50m

Species (List up to 12 major species), Stratum, and Approximate % cover: (Jepson Manual nomenclature please)
Stratum categories: T=tall, M=medium, L=low; *% cover intervals for reference:* <1%, 1-5%, >5-15%, >15-25%, >25-50%, >50-75%, >75%

Strata	Species	% cover		Strata	Species	% cover

Major non-native species - With % cover: _____

Unusual species: _____

III. PROBLEMS WITH INTERPRETATION

Confidence in identification: (L, M, H) _____ Explain _____
Other identification problems (describe): _____
Polygon is more than one type: (Yes, No) _____ (Note: type with greatest coverage in polygon should be entered in above section)
Other types: _____ _____ _____
Has the vegetation changed since air photo taken? (Yes, No) _____ If Yes, how? What has changed (write N/A if so)? _____
_____

Figure 3.1 CNPS Vegetation Rapid Assessment Field Form, 2004.

3.4 Results

An aerial flyover was conducted by 3DiWest in July 2009. Infrared photographs from the flyover were transmitted to the USDA Forest Service and ENTRIX, Inc. in October 2009. A composite map of the Heavenly Mountain aerial photos is shown in Figure 3.2. The composite map has been modified to represent the area of Heavenly Mountain Resort that is subject to effective soil cover monitoring. The colored area of the map approximates the boundary of Heavenly Mountain Resorts operations. From this composite map, land cover was broken down into four types: 1. shadow, 2. tree/shrub, 3. mix, and 4. bare ground. Area of these land types (in both square feet and acres) is summarized in Table 3.2.

Table 3.2 Land Cover Types and Associated Areas within the Boundary of Heavenly Mountain Resort Operations.

Number	Land Cover Type	Area (Square Feet)	Area (Acres)
1	Shadow	51,559,916	1,183.65
2	Tree/Shrub	146,747,952	3,368.87
3	Mix	33,194,162	762.03
4	Bare Ground	108,758,126	2,496.74

Field verification of the ten monitoring sites was conducted on October 18 and 19, 2010. A summary of results from the field verification efforts conducted in 2010 are presented in Table 3.3. Due to field efforts being conducted at the end of the growing season, it was difficult to observe and record all vegetation species occurring at each site; however, for those that were documented, the field crew was able to identify plant species with high confidence.

3.4.1 2009-2010 Data Comparison

As stated in Section 3.3 above, the field crew visited five of the 10 monitoring sites (Landscape Units 3, 6, 14, 16, and 17) for which photo points were established in 2009. The ESC assessment in 2009 serves as the baseline for the 2010 vegetation reassessment of the five sites. Photographs taken in 2009 and 2010 at the photo points are provided in Appendix F.

According to the CNPS VRAP field forms, the effective soil cover (vegetative cover, substrate, etc.) varied dramatically between 2009 and 2010. For example, the percent total vegetative cover at all five stations (Gun Barrel, Groove, Edgewood Meadow, and Lower Olympic) increased between 25% (at Edgewood Meadow) to 100% (at Boulder Chute). The ESC assessment is highly subjective, so documentation of vegetation and other environmental descriptions can vary significantly. Further, snow cover was prominent during the 2009 assessment, while there was no snow cover in the 2010 reassessment.

Table 3.3 Field Verified ESC Sites and Associated Characteristics.

Landscape Unit	Ski Run Name	Slope Exposure	Topography	Geology	Soil Texture	Slope Steepness	Dominant Veg.	Secondary Veg.	% Rock/Litter	% Veg	% Bare
3	Gunbarrel	NW 310°	Convex, bottom of ski run	Decomposed Granite	Coarse to Medium Sand	25°	Mixed grasses	*Ceanothus velutinus var. hookeri* (Tobacco Brush)	15%	90%	15%
6	Groove	SE 140°	Concave, bottom of ski run	Decomposed Granite	Coarse Sand	20°	Mixed grasses	*Pinus jeffreyi* (Jeffrey Pine) and mixed forbs	36%	70%	15%
11	Ellie's Swing	NW 280°	Flat, mid to upper part of ski run	Decomposed Granite	Coarse to Medium Sand	10°	Mixed grasses	N/A	87%	10%	10%
14	Edgewood Meadow	NE 10°	Flat, bottom of the ski run	Decomposed Granite	Moderately fine silty clay loam	1-5°	*Juncus spp.* (Rush)	*Salix* spp. (Willow)	11%	100%	0%
16	Boulder Chute	N 0°	Concave, bottom of ski run	Decomposed Granite	Medium Sand	15°	*Arctostaphylos nevadensis* (Pinemat Manzanita)	*Salix* spp. (Willow); *Ceanothus velutinus var. hookeri* (Tobacco Brush); and mixed grasses	40%	60%	25%
17	Lower Olympic	NW 340°	Flat & concave, bottom of ski run	Decomposed Granite	Medium Sand	>25°	*Elytrigia intermedia* (Wheatgrass)	*Festuca brevipila* (Hard Fescue)	28%	80%	20%
18	Cloud Nine	NE 40°	Flat & convex, middle of ski run	Decomposed Granite	Coarse to Medium Sand	20°	No vegetation	No vegetation	95%	0%	5%
24	Double Down/Lower High Roller	NW 310°	Concave, bottom of ski run	Decomposed Granite	Coarse to Medium Sand	32°	Mixed conifer seedlings	*Elytrigia intermedia* (Wheatgrass)	45%	55%	5%
25	Lower Cal Trail	SE 140°	Flat & concave, top part of ski run	Decomposed Granite	Coarse to Medium Sand	5°	*Elymus elymoides* (Squirreltail)	*Elytrigia intermedia* (Wheatgrass)	45%	50%	5%
23	Rope Tow Area near Big Easy and Gondola	SW 230°	Concave & undulating, lower part of ski run	Decomposed Granite	Coarse Sand	20°	*Elymus elymoides* (Squirreltail)	N/A	95%	<2%	5%

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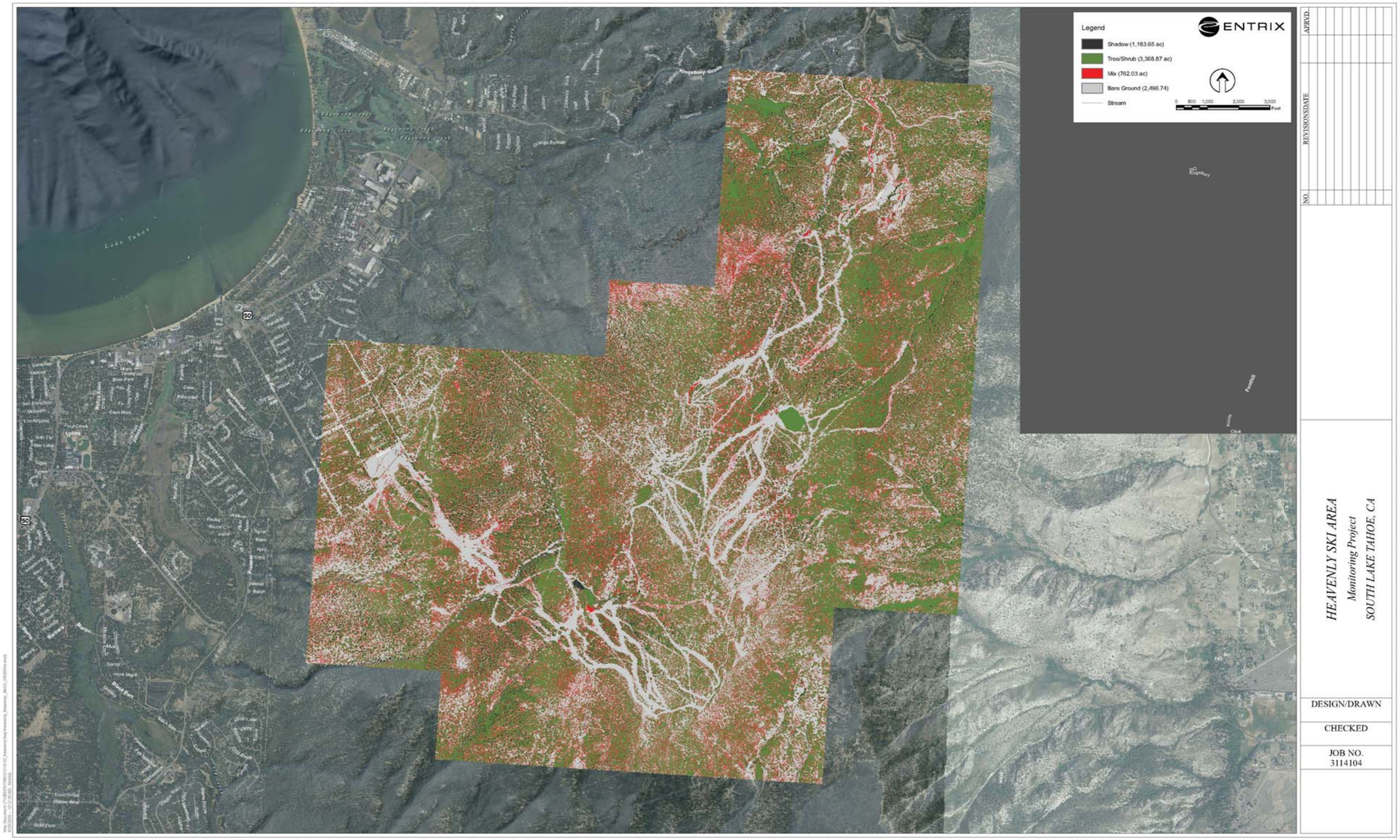

Figure 3.2 Composite Map of the Heavenly Mountain Aerial Photos, Highlighting the Heavenly Mountain Resort's Operational Area, Broken Down by Land Cover Types

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3.5 Discussion and Conclusions

In their 2003 Comprehensive Monitoring Report, the USDA Forest Service concluded that CWE model's 70% soil cover assumption was incorrect. However, the USDA Forest Services' methods were deemed too time consuming and expensive to continue utilizing.

In 2008, ENTRIX with input from the USDA Forest Service completed an Effective Soil Cover Workplan that included monitoring objectives to be accomplished. These objectives are as follows:

1. Maintain and restore soils with favorable infiltration characteristics and diverse vegetative cover to absorb and filter precipitation and to sustain favorable conditions of stream flows.

2. Determine if changes in cover result in changes in runoff and sediment volume from ski runs and other project infrastructure.

3. Evaluate utilization of soil amendments/treatments to increase infiltration capacity for those areas resistant to revegetation efforts, or where revegetation is ineffective.

The use of the air photo analysis combined with ground-truthing, while providing useful information regarding the overall soil cover, does not effectively meet these monitoring objectives. In 2009 an infrared aerial flyover of Heavenly Mountain Resort was conducted in accordance to the USDA Forest Service's recommendations. The imagery from the flyover was useful in that it provided a general overview of soil conditions at Heavenly Resort. From this image it was possible to breakdown soil cover types into four categories; shadow, tree/shrub, mixed, and bare ground. Although useful in a general context, the imagery was not of a high enough resolution to identify grasses and large rock which are both considered soil cover. Additionally, the imagery resolution did not allow staff to see any significant signs of erosion such as rills. Signs of erosion identified on the images would have provided field staff with specific ski runs on which to target for effective soil cover monitoring. As it was, field staff selected a representative sample of ski runs throughout Heavenly in order to gain general knowledge of soil cover conditions.

The CNPS VARP method of ground truthing proved to be effective for obtaining subjective, general information about ski slopes at Heavenly. This methodology however, would be time consuming if needed to be implemented at every ski run at Heavenly in order to determine if soil cover is improving from year to year. Additionally, this methodology is not quantitative, but more qualitative in nature, which means the data is vulnerable to observer subjectivity.

Over the years of attempting to quantitatively measure changes in effective soil cover at Heavenly, the various methods applied have not effectively met the monitoring objectives. In the 2009 Annual Report, ENTRIX recommended following a Best Management Practices (BMP) approach for soil cover, similar to the practices used for erosion control measures. Such BMPs would help deter erosion, enhance infiltration, and promote vegetation growth along ski slopes, and monitoring of the BMPs would focus on the effectiveness of each measure. Soil amendment studies being performed by Integrated Environmental Services at Heavenly should also be incorporated into the BMP development and monitoring. Specific BMPs will be determined in

2011 through a collaborative effort between Cardno ENTRIX, Integrated Environmental Services, USDA Forest Service, and Heavenly, and will be identified in the Comprehensive Report (2012).

Chapter 4

Best Management Practices (BMP) Implementation and Monitoring

BMP monitoring was completed by Resources Concepts Inc. (RCI) and is included in Appendix B.

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Chapter 5

Riparian Condition Summary

5.1 Introduction

This chapter discusses the stream channel monitoring activities that were conducted in July 2010 in accordance with the *Work Plan for Riparian Condition Monitoring* (Work Plan) (ENTRIX 2005). Monitoring on Edgewood Creek was conducted this year in accordance with the work plan that states that monitoring will occur yearly at stream locations that have had significant restoration within the affected watershed. The objective of this continual monitoring is to assess the effectiveness of erosion control measures and restoration activities on stream health. Monitoring is conducted to characterize stream and riparian conditions along selected stream reaches within the Heavenly Mountain Resort area and reference reaches unaffected by Resort activity. The monitoring data is used in conjunction with data from previous monitoring events to assess potential alterations of stream and riparian conditions and, if changes are encountered, determine whether the alterations are associated with operations at the Resort.

Monitoring is conducted every three years on each of the three sites on Heavenly Valley Creek and the two sites located on Hidden Valley Creek. Additional monitoring occurs on the two sites on Daggett creek and a single site on Mott Creek. As discussed above annual monitoring occurs on the two Edgewood Creek sites. The next scheduled round of full monitoring will occur in 2011. This revised schedule was agreed to by all interested parties to synchronize the benthic macro-invertebrate (BMI) and SCI data collection. The next complete survey will not happen again until 2016. The new schedule states that SCI data will be collected during the second year of BMI collection. A new permit formalizing this schedule will be released sometime in 2011.

Stream monitoring follows the protocols and methods outlined in the United States Department of Agriculture Forest Service (USFS) *Stream Condition Inventory Technical Guide: Pacific Northwest Region, Version 5.0* (USFS Technical Document) (2005). The SCI method was developed to collect intensive and repeatable data from stream reaches to monitor conditions over time. In this chapter potential changes along upper and lower Edgewood Creek's instream and riparian conditions are evaluated by comparing the monitoring data collected in 2010 with the data collected in 2006, 2008, and 2009. Due to restoration construction, monitoring during the 2007 season was not collected.

The SCI methodology also includes benthic macro-invertebrate (BMI) sampling, which was conducted in 2006, 2007 and in 2010 on Heavenly Valley and Hidden Valley Creeks in support of bioassessment monitoring required by the 2003 Heavenly Valley Creek Total Maximum Daily Load (TMDL) Bioassessment Monitoring Plan. The next scheduled BMI sampling will occur in 2011, following the two year on and two year off schedule. New protocols and procedures regulated by the California Water Board (Lahontan) require electronic data submittal results due on May 15 of the year after sampling occurred. A short memo will accompany the data set verifying submittal of the data requested, and is not discussed further in this report.

The data included in this report was collected in July 2010 and compares it to data collected in previous years. The locations of both Edgewood sites are shown in Figure 5-1. Upper Edgewood data includes a long profile and cross sections. Data collected for Lower Edgewood consists of cross sections, a long profile encompassing the cross sections, and SCI stream health data shown in Appendix G (Table 5-3).

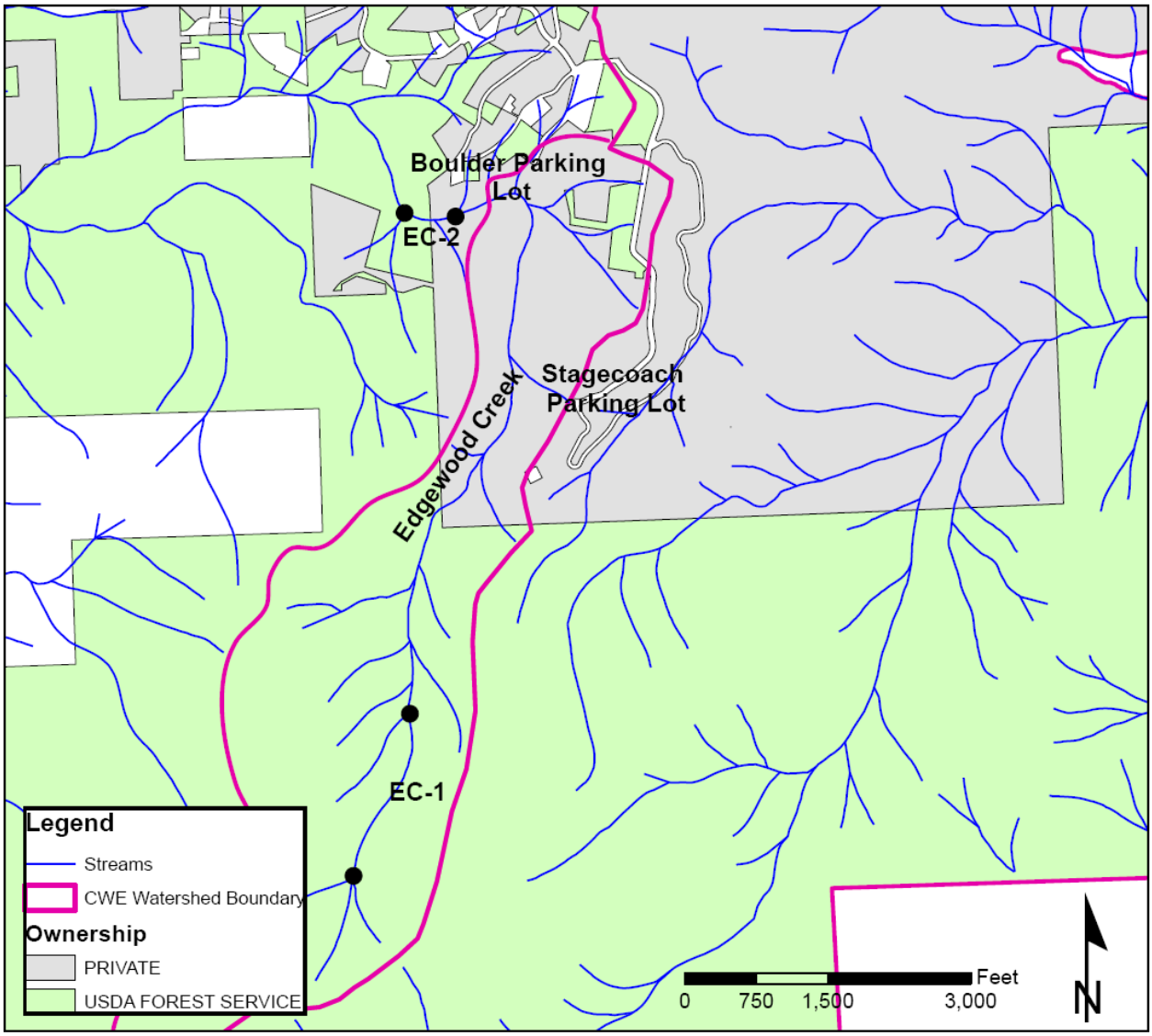

Figure 5-1 Locations of Upper (EC-1) and Lower (EC-2) Edgewood Creek monitoring sites.

5.2 Methodology

During 2010, two reaches on Edgewood Creek were evaluated using SCI methods. The next surveys of all ten reaches will be completed in 2016, though all California sites will be survey this summer (2011). Survey protocols can be referenced in the USDA Forest Service *Stream Condition Inventory Technical Guide: Pacific Northwest Region, Version 5.0* (2005).

The locations of the Edgewood Creek reaches are shown in Figure 5-1 (USDA Forest Service 2009). The Upper Edgewood Creek reach, EC-1, was established upstream of current restoration activities under the proposed alignment for the new North Bowl Express Lift. The Lower Edgewood Creek reach, EC-2, has its downstream limit at the established Edgewood Below water quality site, downstream from the Boulder Lodge parking lot. The full SCI evaluation was only completed for the Lower Edgewood Creek reach because the Upper Edgewood Creek reach contained no water. Stream channel conditions were assessed at EC-1 by surveying permanent cross-sections and a longitudinal bed profile. This data can be compared to the pre-restoration cross-sections and profile observed in 2006.

The USDA Forest Service *Stream Condition Inventory Technical Guide: Pacific Northwest Region, Version 5.0, 2005* (USDA Forest Service SCI protocol) can be referenced for more detailed explanations of methods; however, a synopsis of the full SCI evaluation is as follows. Three cross-sections were established at representative locations within all reaches, permanently marked with monuments, and surveyed. A water surface profile was surveyed for a distance of several channel widths up and downstream of each cross-section to calculate channel gradient. Large woody debris (LWD) counts were completed by tallying all single pieces of wood, aggregates, and root wads. This method differs from past protocol where the LWD was also measured for diameter. Pebble counts were completed with a gravelometer at the locations of bioassessment sites, where applicable. Bankfull measurements were taken at up to eight transects on each reach including the three permanent cross-sections. Stream habitats were documented and measured with a hip chain. Pools were determined using the USDA Forest Service SCI protocol. In order to be considered a pool, water velocity must be slow or not moving. The feature must occupy most of stream width and include the thalweg. Backwater and sidewater pools were not measured. Other criteria include: the length of pool must be greater than wetted width, the depth must be greater than non-pools, and the maximum depth is more than twice pool tail depth. Where pools were identified, pool depth and tail fine sediment measurements were taken. Bank stability and shading evaluations were also completed as part of the full SCI. Per protocol, bank angle and stream shore depth were only measured at streams with gradients greater than two percent. In addition to bank angle and stream shore depth, other evaluations that are normally part of a full SCI may not have been completed due to stream type and conditions. Any individual exceptions to completing a full SCI evaluation are noted in the Results and Discussion Section.

5.3 Upper Edgewood Creek

The Edgewood Creek watershed has been the location of multiple restoration projects. The restoration project in the portion of Edgewood Creek including riparian monitoring site EC-1 is referred to as the North Bowl Restoration Stream Environment Project. Phase 1 of the North Bowl Restoration Stream Environment Project, consisting of the downstream two-thirds of the project, was completed in 2006. Other activities in 2006 included gabion structures added as gully improvements upstream of the North Bowl Restoration Stream Environment Project and best management practices installed on the road that descends from Boulder Parking Lot along Edgewood Creek. Phase 2 of the North Bowl Restoration Stream Environment Project, which contains riparian monitoring site EC-1, was completed in the summer of 2007. Phase 2 involved the installation of more gabion structures, strategic placement of large woody debris, and

vegetation establishment. For a more thorough assessment, please reference the Final Edgewood Watershed Assessment and Enhancement Plan: Upper Edgewood Creek (Swanson 2006).

Reach one of Edgewood Creek, know as Upper Edgewood (EC-1), was dry at the time of stream condition analysis. Therefore, a full SCI could not be completed. The USFS SCI protocol version 5.0 provides measures of channel morphology most applicable to low gradient streams (USFS 2005). Because this reach is a high gradient stream only a longitudinal bed profile (Figure 5-2) and cross section analysis (Figures 5.3) were conducted. The three permanent cross sections extend across the entire valley floor width and were selected in 2006 as to avoid construction disturbance.

The EC-1 reach exhibits characteristics of an "Aa+" type channel using the Rosgen channel classification method (Rosgen 1996). It is very steep (14 percent), somewhat entrenched, and confined. The channel resembles a gully and has a step/pool morphology resulting from the large number of downed trees in the channel (Rosgen 1996). This classification has not changed since the 2006 monitoring of EC-1.

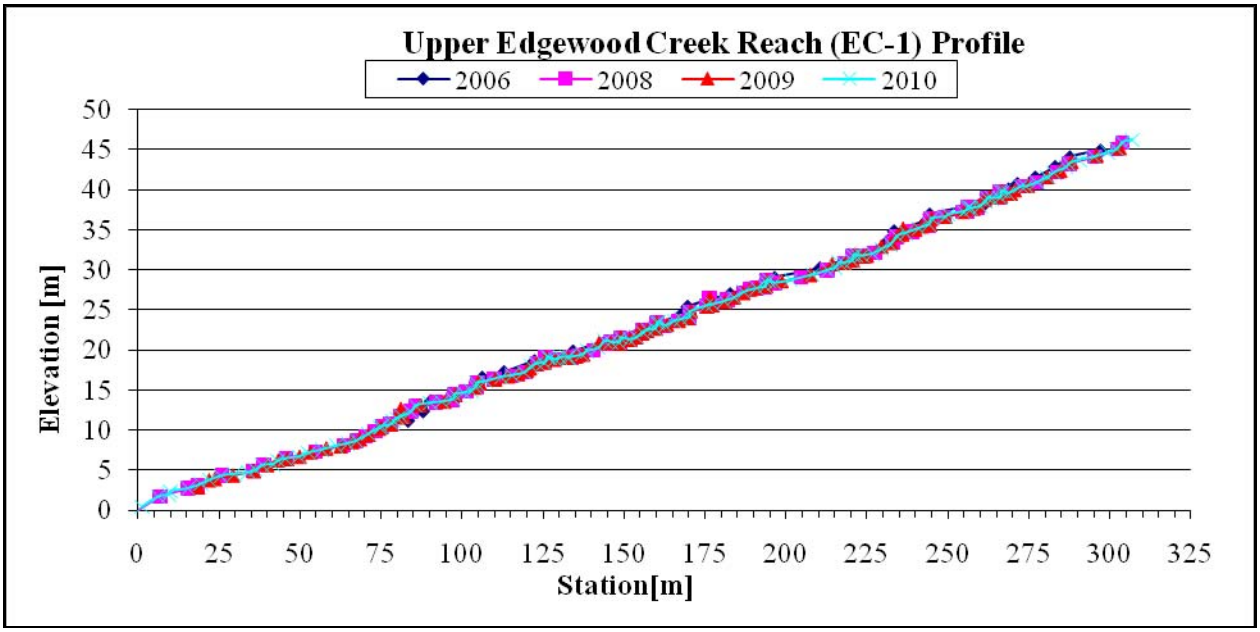

Figure 5-2 Upper Edgewood Creek Reach (EC-1) Profile

Established in 2006, the profile was taken along the entire reach length along the dry bed. Elevation and station measurements are graphed relative to the downstream end of the reach. The downstream end of the reach is point zero, zero. The profile of the Upper Edgewood Reach shows a fairly uniform slope throughout the surveyed reach.

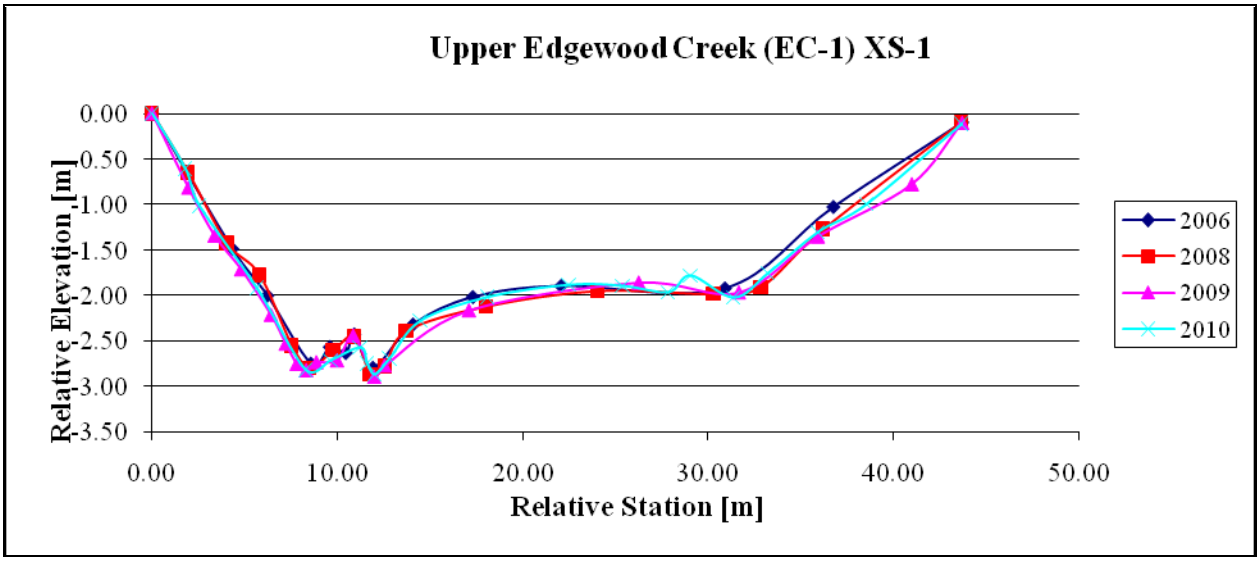

Figure 5-3a Permanent cross-sections for reach EC-1, Upper Edgewood, along Edgewood Creek. Established in 2006, cross-section XS-1

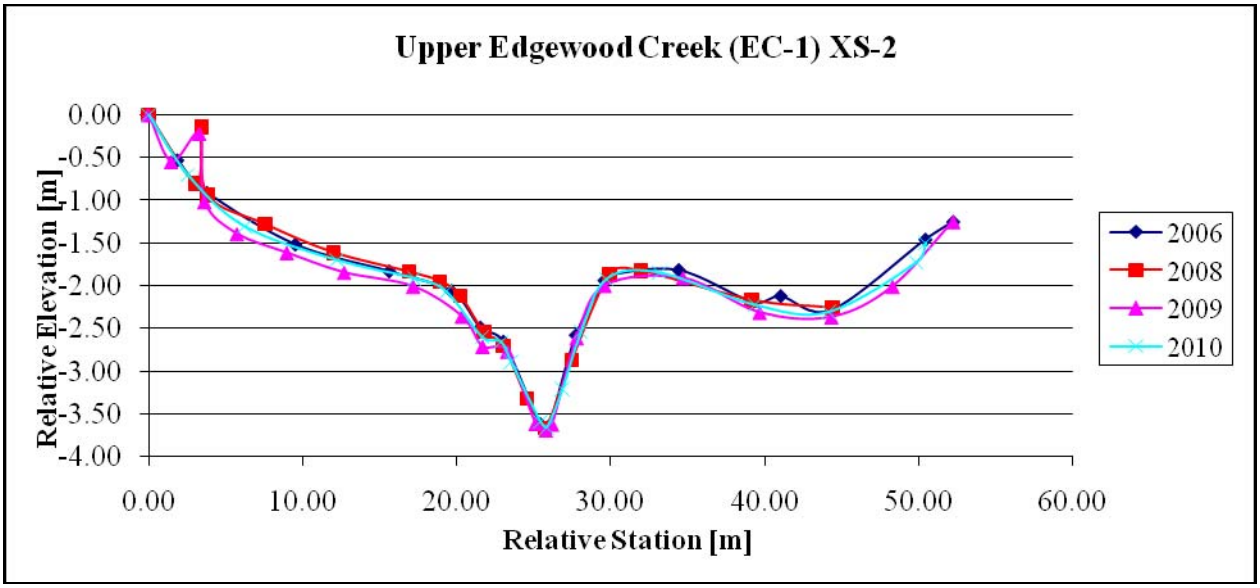

Figure 5-3b Permanent cross-sections for reach EC-1, Upper Edgewood, along Edgewood Creek. Established in 2006, cross-section XS-2

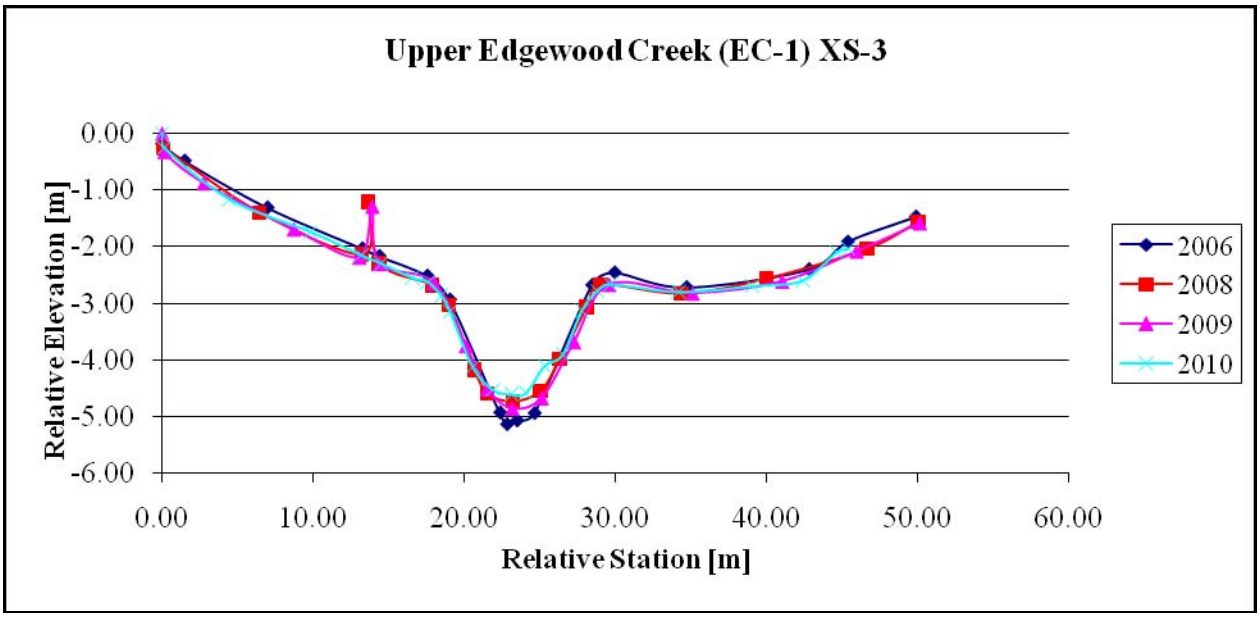

Figure 5-3c Permanent cross-sections for reach EC-1, Upper Edgewood, along Edgewood Creek. Established in 2006, cross-section XS-3

Figures 5-3a through 5-3c represent permanent cross-sections for reach EC-1, Upper Edgewood, along Edgewood Creek. Established in 2006, cross-sections XS-1, XS-2, and XS-3 are graphed from rebar monuments. Elevation and station measurements are graphed relative to the left bank (as viewed looking downstream) rebar stake. The top of the rebar stake on the left bank is the zero elevation, zero point (starting station). The graphical representation of these cross sections show very minute changes in the channel shape.

5.4 Lower Edgewood Creek

Edgewood Creek below Boulder Parking Lot also underwent restoration in 2007. These restoration activities included repair of a headcut by constructing plunge pools and riparian planting. The restoration of Lower Edgewood Creek occurred directly upstream of EC-2, incorporating the upstream cross-section of the riparian monitoring site. A vault treatment system was installed in the Boulder parking lot in 2005.

Lower Edgewood exhibits characteristics of a “G” type channel using the Rosgen channel classification method. "G" channel types typically have very high bank erosion rates and a high sediment supply. Channel degradation and sideslope rejuvenation processes are also typical (Rosgen 1996). A pebble count was not completed because all sediment was less than 8 mm. The dominant pebble class is coarse sand. There were no pools in the reach as defined by the SCI protocol version 5.0.

Table 5-2 (Appendix G) presents the results for full SCI evaluation completed in 2010 and compares these results from 2006, 2008 and 2009 for EC-2. A pebble count was not completed because all sediment was less than 8mm. The dominate pebble class is assumed to be sand. There were no pools as defined by the USFS SCI protocol, therefore the mean pool length, mean residual pool depth, and percent fines were not measured. Most of the collected data is similar to past years results excluding the following measurements:

1. Mean Width to Depth Ratio - This value increased from the previous year's data set since the mean channel depths decreased at some of the cross-sections due to sediment deposition. The decrease in mean channel depth with a constant bankfull width results in a higher width to depth ratio. This trend is evident in cross section two where the depth has decreased in past years.

2. Percent Stable/Vulnerable Banks - This value decreased from last year's assessment, and has a similar value to the 2006 and 2008 assessment.

Table 5-3 (Appendix G) presents the cross sections associated with bankfull width, width-to-depth ratio, and entrenchment ratio for 2006, 2008, 2009, and 2010. All four measurements have changed slightly since 2006. Some of the values in last year's report have been revised to make the calculation methods consistent with this year and previous years by changing the stations used to define the bankfull width. This change was made so that reported differences in channel morphology are attribute to actual erosion and sedimentation of the channel geometry rather than differences in calculation procedure.

Permanent cross-sections XS-1 and XS-2 for Edgewood Creek's Lower Edgewood reach, EC-2, are graphed and presented in Figures 5-4a through 5-4c. The most upstream cross-section, XS-3, had to be relocated in 2008 due to restoration activities destroying the permanent monument. The new location is directly below the rock grade control structure constructed as part of the Lower Edgewood Restoration Project completed in 2007. The cross-sections for XS-3 are graphed and presented in Figure 5-4c. Lower Edgewood Creek's channel morphology is highly influenced by dense riparian vegetation that supplies a large amount of wood to the channel which creates complex channel morphology. The plot for cross-section XS-2 (Figure 5-4b) illustrates how banks along the reach are often undercut on both sides. Some of these undercuts are caused by large tree roots on the banks. All three cross sections show a decrease in the mean depth of the channel due to sediment deposition. Cross-section XS-3 (Figure 5-4c), new in 2008, has undercutting on its left bank as the result of a large root from a nearby mature aspen tree. This cross-section is located directly downstream of the last constructed plunge pool in the Lower Edgewood Restoration Project. Future years of data collection at this point will reveal the effects of the restoration upstream.

Table 5-4 (Appendix G) outlines the positive and negative changes that have occurred in the Lower Edgewood channel (EC-2) since 2008.

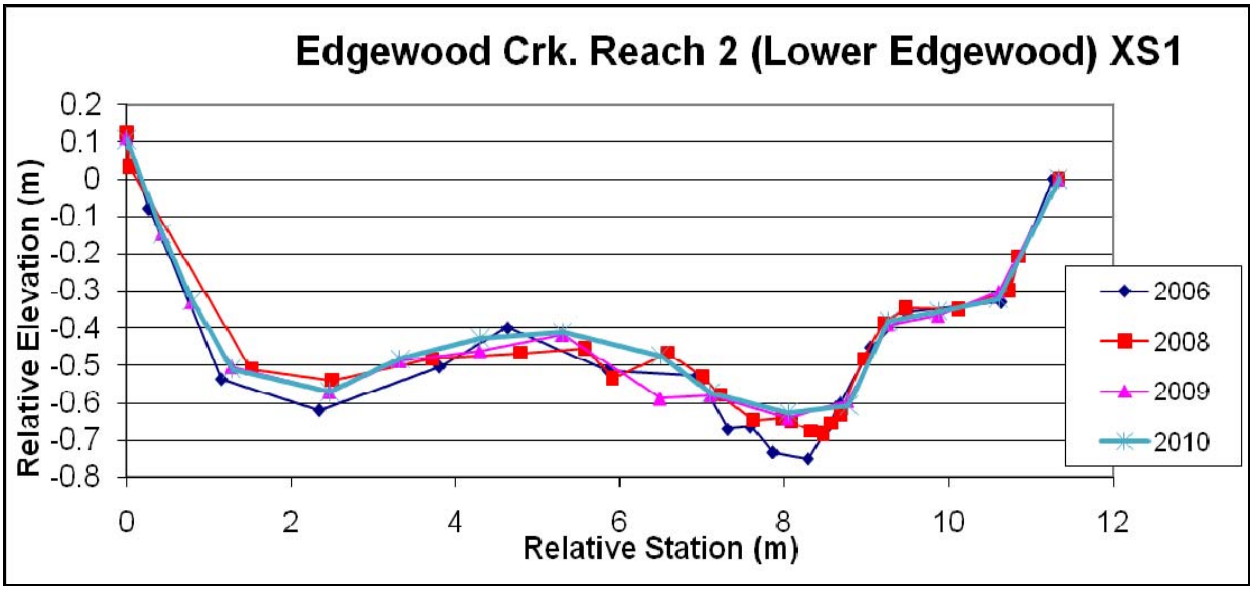

Figure 5-4a Permanent cross-sections for reach EC-2, Lower Edgewood, along Edgewood Creek, XS1.

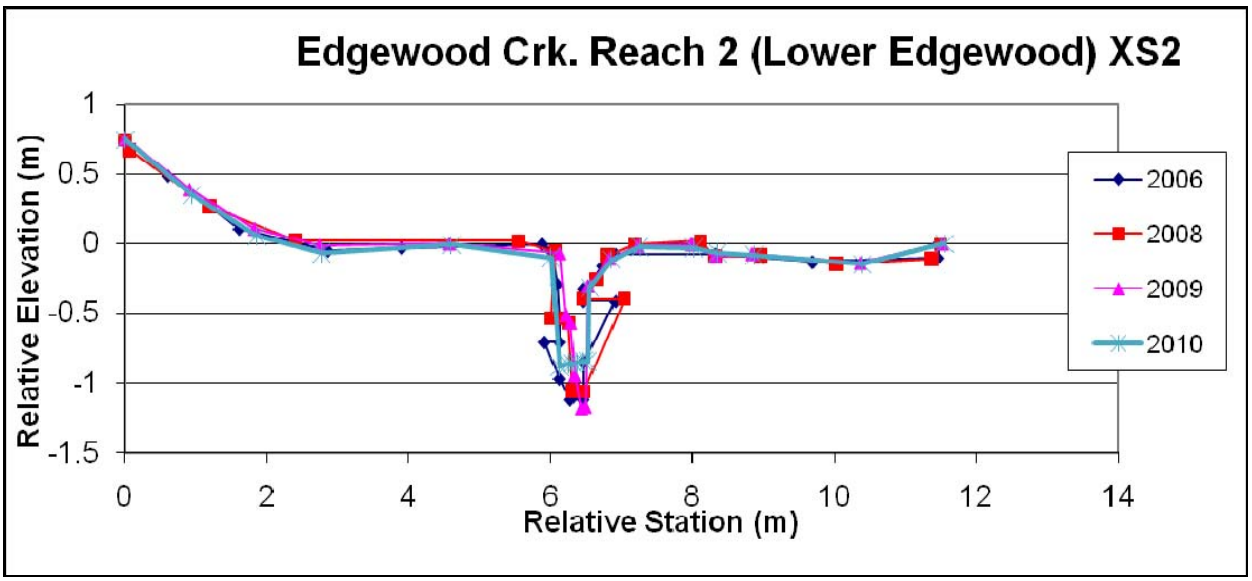

Figure 5-4b Permanent cross-sections for reach EC-2, Lower Edgewood, along Edgewood Creek, XS2.

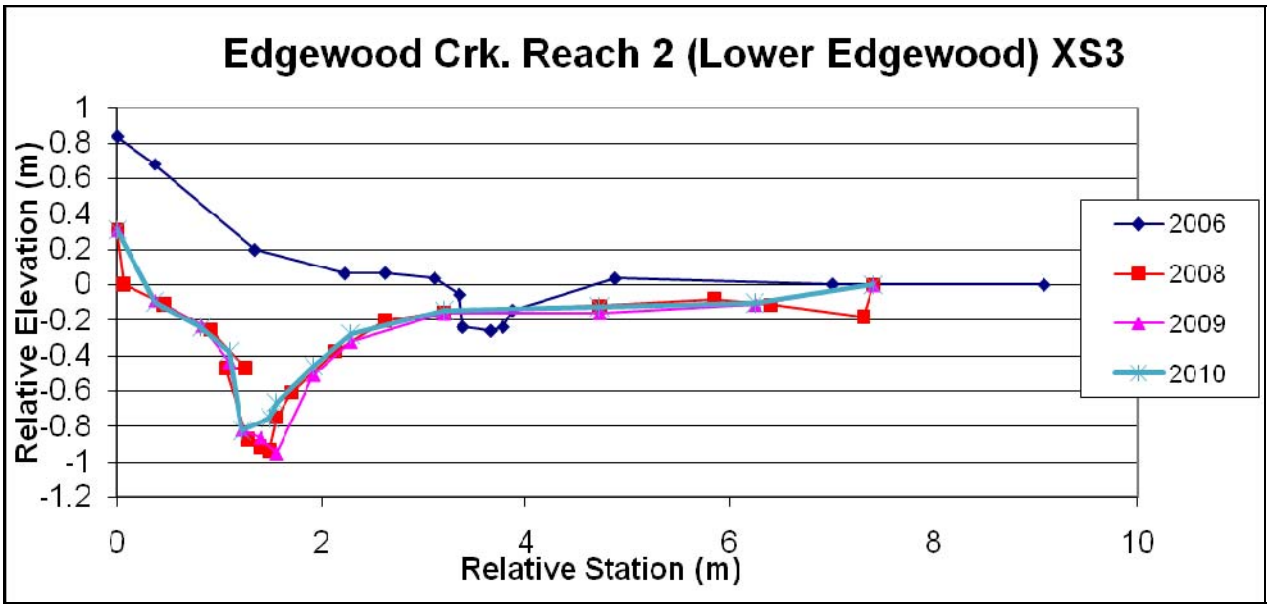

Figure 5-4c Permanent cross-sections for reach EC-2, Lower Edgewood, along Edgewood Creek, XS3. The cross-section location was moved in 2008, after a restoration project was completed in 2007.

Permanent cross-sections for reach EC-2, Lower Edgewood, along Edgewood Creek. Established in 2006, cross-sections are graphed from rebar monuments. Elevation and Station measurements are graphed relative to the left bank (as viewed looking downstream) rebar stake. The top of the rebar stake on the left bank is the zero elevation, zero point (starting station).

5.5 Conclusions

One issue encountered while performing and analyzing field data is observer variability. The following parameters are those that were most subjective on these sites:

- Bankfull Stage (width)
- Width to Depth Ratio
- Entrenchment Ratio
- Bank Stability / Vulnerability

Table 5.1 Data Measurements Subject to Field Interpretation

Measurement	2006 Data	2010 Data	Explanation
Bankfull Stage	1.6	1.38	Bankfull stage was identified in 2010 based on various indicators including changes in bank slope, vegetation, bank material size, and water stains or lichen lines on the substrate. These determining factors may be interpreted differently depending on the observer. These values were standardized for the Lower Edgewood sites and re-calculated (see Table 5-3)
Width to Depth Ratio	4.6	7.83	Width to Depth Ratios depend heavily on the bankfull stage measurement. The bankfull stage measurement can be determined using multiple factors, and can vary depending on the observer (see above). Therefore, width to depth ratios can also vary depending on the observer and the random locations chosen.
Entrenchment Ratio	15.2	16.13	Entrenchment ratio, like width to depth ratio, is highly dependent on bankfull stage, and is therefore affected by observer variability. Additionally, floodprone width is included in this

Table 5.1 Data Measurements Subject to Field Interpretation			
Measurement	2006 Data	2010 Data	Explanation
			measurement. Floodprone width is determined by the same indicators as bankfull width. This adds another element of observer variability to entrenchment ratio.
Bank Stability / Vulnerability	40-60	50-50	Bank stability is a measurement of percent cover and includes stability components. Depending on the location chosen and the observers idea of percent cover and bank instability indicators, this measurement could be skewed.

The measurements bulleted above represent wide-spread changes across the monitoring reach. A discussion on the reach and how it's changed since 2006 is provided below.

5.5.1 Upper Edgewood Creek

The topographic surveying of Upper Edgewood Creek shows that the channel elevations are essentially unchanged in 2010 compare with previous surveys. Both the longitudinal profile and the cross-sections surveys surveyed in 2010 plot nearly directly on the previous data. The monitoring results show that the rock gabions constructed to prevent additional channel degradation are performing as intended in terms of maintaining existing bed elevations.

5.5.2 Lower Edgewood Creek

Topographic surveying and other channel attributes were measured along Lower Edgewood Creek in 2010. The monitoring results show that all three of the cross-sections showed a slight increase in bed elevation. Channel bed elevations have increased in 2010 by approximately 0.1 meters due to sediment deposition and leading to a decrease in mean channel depth. The channel may be recovering from prior downcutting by dropping out sediment and reducing the unnaturally large cross-sectional area in some reaches. Riparian vegetation conditions along the reach are largely unchanged as indicated by the percent shading results. Prior to the restoration project on Edgewood Creek, the channel was down-cutting and showed signs of degradation. Monitoring results from the past three years have shown that the channel no longer is degrading. At this time with the restoration and data collected, the creek shows signs of stability and improvement.

Chapter 6

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