Heavenly Creek SEZ Demonstration Project
2007 Soil Monitoring Report

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Table of Contents

Page #

List of Tables

List of Figures

Executive Summary

The 21-acre Heavenly Creek SEZ Fuels Reduction Project, completed in late summer of 2007, represented the first use of low-ground-pressure CTL forwarder/harvester technology to treat overstocked fuels within lands classified in the Tahoe Basin as stream environment zone (SEZ). SEZs are defined as biological communities that owe their characteristics to the presence of surface water or a seasonally high ground-water table.

The total direct cost of the fuels reduction contract was $174,237, which included $19,000 for mobilization, and $7,056/acre for thinning, removal, and slash cleanup. These costs include the value received by the contractor for material taken from site, which included 78 loads of biomass, chips, fuelwood, and sawlogs. This fuel load (of approximately 88/tons per acre) is almost double that typically removed in forest fuels projects, because all slash and bole material was removed from the SEZ. Approximately 50% of the per-acre costs were for removal of the slash mat on which the equipment was operated.

Project impacts were evaluated through a monitoring program designed to measure changes in soil quality (hydraulic conductivity, bulk density/soil porosity, and soil cover) that affect the capacity of the land to maintain healthy vegetation communities and resistance to erosion. Erosion and runoff model simulations, utilizing the measured changes in soil quality parameters, predict no real erosion or sediment delivery response as a result of project activities (<.03 ton/acre). Also, no changes in soil quality occurred that would affect vegetation response negatively. Rather successional growth of riparian vegetation is expected to be enhanced as a result of the removal of dense overstocked lodgepole stands.

The post-project hydraulic conductivity (Ksat, a measure of the rate water flows through the soil) was 2.4 in/hr, well above the WEPP model predicted erosion response trigger level of 1.0 in/hr. Although Ksat was reduced by over 50%, the overall post-project conditions proved sufficiently favorable to prevent an erosive runoff response. This resiliency is due to a combination of low gradient slopes ($\leq$15%), high level of post-project soil cover (89%), robust vegetation cover, dry soil moistures ($\leq$11%), and the relatively high baseline Ksat values represented by the soils at the site (which are typical of Tahoe Basin SEZs).

The results of this monitoring effort indicate that treatment of many areas of the Tahoe Basin which are classified as SEZ, with CTL forwarder/harvester technology, can be safely implemented under dry soil conditions. Post-project Ksat measurements also detected no significant difference between areas where equipment operated over a slash mat, versus visible equipment tracks with out a slash mat. These results indicate that the high cost associated with creating and removing slash mats may be avoidable in SEZs with low soil moisture and other appropriate settings.

Future projects should be implemented to determine the full range of soil conditions in which this technology can be used without causing adverse impacts to soils and water quality. This includes:

- Utilization of CTL technology with no slash mats in SEZs that have 40% or greater existing grass and shrub cover.

- Utilization of CTL technology with slash mats in SEZs where soil conditions are classified as very moist (utilizing the squeeze test described in the report).

Monitoring should also be conducted where this technology is proposed for use on sites that have significantly different site conditions then the Heavenly SEZ project, including steep slopes, soils with a high silt/clay content, and sites that have less pre-existing vegetation cover in the form of grasses and shrubs. The LTBMU does not propose to utilize mechanical equipment within very wet SEZs such as swamps, bogs, and fens.

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We would like to acknowledge the peer professionals we asked to review and provide guidance for both the monitoring plan, and the analysis report for the Heavenly SEZ Fuels Reduction Monitoring Project. The input provided was critical in the development of both these products.

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I. Introduction

The Heavenly Creek SEZ Fuels Reduction Demonstration Project was initiated September 8 and completed October 5th, 2007. This 21-acre project represented the first use of low-ground-pressure equipment, consisting of a Rottne Rapid Six-Wheel Drive (6-WD) Cut-To-Length (CTL) harvester, and a Rottne Rapid 6-WD forwarder, within lands classified in the Tahoe Basin as stream environment zone (SEZ), to treat overstocked fuels. Stream environment zones are defined as biological communities that owe their characteristics to the presence of surface water or a seasonally high ground-water table.

The specifications for the equipment used within this project are presented below:

- The harvester has a service weight of 31,300 pounds with a ground pressure of six pounds per square inch (psi), without tracks, and four psi with tracks on the paired drive axles.

- The forwarder has a service weight of 26,000 pounds and a payload capacity of 26,000 pounds with a ground pressure of 6 psi unloaded and 13 psi fully loaded.

CTL systems carry the products out of the woods without skidding. CTL can either limb cut trees in the woods or leave limbs attached and forward the entire tree out of the woods. In this project, trees were limbed in the woods and, where available, the limbs were used to create slash mats for the equipment to drive over [to provide additional protection against soil compaction].

The project included a peer-reviewed monitoring plan, developed with extensive input from Lahontan Regional Water Quality Control Board and Tahoe Regional Planning Agency staff. Peer review was provided by US Forest Service research scientists from the Pacific Southwest Research Station, regional USFS soil scientists, and soils science staff with the Natural Resources Conservation Service. The monitoring data acquired and preliminary analyses conducted were reviewed weekly by LTBMU and Lahontan staff, to ensure unacceptable impacts were not occurring during project operations.

Project Description

The project area is located within National Forest System land southwest of the intersection of Al Tahoe Blvd and Pioneer Trail and is displayed in Figures 1 and 2. This area was characterized by dense Lodgepole pine and high conifer mortality within the SEZ [and associated SEZ buffers] of Heavenly Valley Creek. A wildfire in December 2002 burned through the area leaving incompletely burned material and increased levels of mortality. The dense forest stands and heavy fuel loads continued to pose a wildfire threat and encroaching conifer vegetation continued to impact non-conifer riparian vegetation communities. For these reasons, this location was chosen as an area to demonstrate vegetation and fuels reduction treatments within stream environment zones (SEZ) using low-impact mechanical techniques and manual methods at both burned and unburned sites.

The project consisted of 5 units totaling 21 acres as displayed in Figures 1 and 2. Unit 1 of this

project consisted of burned, unburned, and mixed stands (both burned and unburned). Unit 2 consisted of heavy Lodgepole pine mortality and dense Lodgepole stands, Unit 3 was a dense Lodgepole pine and Jeffrey pine stand, Unit 4 was an aspen stand encroached by Lodgepole pine and white fir, and Unit 5c included dense conifers along Al Tahoe Boulevard adjacent to the meadow. (Figure 1 also displays 2 small Units labeled 5a and 5b. These Units were actually treated utilizing hand thinning techniques approximately a month prior to utilization of the mechanical equipment for the rest of the project).

The purpose of this project was to implement treatments to reduce accumulations of hazardous fuels and restore conifer and riparian vegetation to a healthy, diverse, fire-resilient structure that provides desired habitat conditions. Treatments included: 1) mechanical thinning and removal within dense conifer stands; 2) cutting and removing accumulations of dead standing and downed trees; 3) conifer removal to promote non-conifer SEZ vegetation such as willow and aspen, and 4) hand thinning [of Units 5a and 5b only].

Project analysis was largely completed in 2006, however a NEPA decision could not be completed in time for 2006 implementation. In addition pre-project soil moisture data collected in 2006 indicated that soil moisture levels were quite high and almost half the project area would not dry out sufficiently for implementation. Subsequently, the winter of 2006/2007 was much drier and soil moisture sampling confirmed that conditions would be suitable for mechanical equipment operations in most of the project area by late August of 2007.

Operational Data

The total direct cost of the contract was $174,237, which included $19,000 for mobilization, and $7,056/acre for thinning, removal, and slash cleanup. These costs include the value received by the contractor for material taken from the site. This material included 78 loads of biomass, chips, fuelwood, and sawlogs, which equaled 1,950 tons. This fuel load of approximately 88/tons per acres is almost double that typically removed in forest fuels projects, because all slash and bole material was removed from the SEZ. Of significant note, approximately 50% of the per-acre costs were for removal of the slash mat on which the equipment was operated.

II. Management Questions and Monitoring Objectives

The following are the management questions addressed by the monitoring effort.

2) Can innovative technology systems be used in both burned and unburned SEZs, without causing significant adverse impact to soils or water quality? Can these impacts be mitigated utilizing accepted soil restoration techniques (i.e. subsoiling, replacement of soil organic matter, and effective soil cover)?

3) What short-term (2008, 2009) and long-term (2012) impacts will the proposed actions have on the non-target vegetation as it relates to native plant diversity and cover, and the propagation of noxious weeds?

The Monitoring objectives are:

- Determine if the hydraulic conductivity (Ksat, the rate at which water flows through the soil when saturated) has been reduced within the overall treatment area below the erosion threshold (the point at which erosion would be triggered).

    - The erosion threshold was determined to be at 1.0 in/hr for hydraulic conductivity utilizing the Watershed Erosion Prediction Project (WEPP) model[1]. If monitoring during project operations determines that the erosion threshold is being reached, operations would be halted, and appropriate mitigations implemented as needed.

- Determine if the tracks made by major forwarder/harvester routes are developing the characteristics of a Forest Service System road through either (i) visible signs of rutting or depressions, or (ii) Ksat measurements decreasing to or below 0.15 in/hr.

    - This threshold for Ksat was determined using the WEPP: Road model, and is the value established by model developers for native surface forest roads. If any forwarder/harvester trail segments are shown through visual observations or Ksat measurements to exhibit the characteristics of a native surface road, WEPP:Road will be used to evaluate erosion and sediment yield potential, and appropriate mitigations will be implemented as needed.

- Determine if surface organic matter is present as fine organic matter that occurs over at least 50% of the area and is well distributed. Fine organic matter includes plant litter, duff, and woody material less than three inches in diameter. The general soil cover threshold of 50% is established in Regional USFS soil quality standards *(FSH 2509.18-95.01, Section 2.2).* For the more sensitive JaC and Lo soils, cover thresholds may be increased to greater than 50%.

- Determine if there is an increase in visible evidence of erosion, based on visual observations of rills, gullies, and sediment deposition. Determine if soil and water protection BMPs have been implemented correctly and are effective.

- Determine if the vegetation management objectives described below are being achieved.

    - Maintain or increase the pre-project cover and plant diversity of riparian plant species including aspen and native herbaceous plants and shrubs between 2007 and 2012.

[1] The erosion threshold is the Ksat value at which the average annual erosion is predicted to occur from the treatment area by WEPP (for a 50-year precipitation record, assuming 40% canopy and 50% cover conditions). This model was developed by the USFS Rocky Mountain Research Station in Moscow, ID to predict erosion from rangeland and forestland. The model allows the user to input various parameters related to soils, vegetation, soil cover, and climate and produces estimated levels of runoff, erosion, and sediment yield.

- Allow no more than a 25% increase[2] in weed cover between 2007 and 2012.

This report presents the immediate pre- and post-project data collected that are related to soil quality parameters. The first year of vegetation response monitoring and BMP effectiveness evaluations will occur during summer/fall of 2008 and the results will be presented in an end-of-year report.

III. Soil, Vegetation, and SEZ Characterization

The majority of the project area is underlain by soil map unit Ev while portions are underlain by soil map units EfB, GeC, JaC, and Lo based in the 1974 soil survey (see Figure 3).

Under the NRCS 2007 updated soil survey, the names of these soil map units have changed. The majority of the project area is now classified as Marla loamy coarse sand, 0 to 5% slopes, with very small portions of the area in Gefo gravelly loamy coarse sand, Christopher-Gefo complex, Tahoe complex, and Jabu coarse sandy loam. All of these map units contain soil components that have a hydric rating under the hydric criteria of 2B3, which is described as "poorly drained or very poorly drained with a water table at a depth of 1.0 foot or less during the growing season if permeability is less than 6 in/hr in any layer within a depth of 20 inches". The Ev classification under the old soil survey and the Marla classification under the new soil survey both state that background infiltration capacities for this soil map unit range from 2 to 6 inches/yr.

Under the old soil survey, Ev soil is considered to be a primary soil SEZ indicator, and Lo soils are considered to be a secondary SEZ indicator, as described in the TRPA Code of Ordinances. The proposed project area also contains several different dominant vegetation community types as defined in the 1971 TRPA report entitled "Vegetation of the Lake Tahoe Region, A guide for Planning". This project area includes several primary or secondary riparian indicator communities. Many of the primary SEZ vegetation communities defined in the TRPA report are not proposed to be considered for entry by innovative harvesting technology anywhere in the Basin; these include swamps, bogs, and fens. The primary riparian vegetation communities proposed for experimental entry are Broadleaf and Riparian Shrub. The secondary riparian vegetation community indicators include, Broadleaf (high elevation), Lodgepole (wet type), and Herbaceous (wet mesic meadow).

On the ground, the land capability verification of SEZs (performed by the LTBMU soil scientist on this project site) was straightforward; a qualitative evaluation of soil characteristics indicated good correlation with vegetation and geomorphology. SEZ indicators consistently decreased as the elevation above the creek and floodplain increased. Three non-SEZ areas (see Figure 4) were delineated within the project area by LTBMU soil scientists prior to project implementation, on the basis of soils and vegetation indicators and the absence of evidence of surface hydrology. These areas totaled approximately only 2 acres within the 21 acres treated.

[2] Kennedy and Addison (1987) determined that more than a 20% change in cover must be observed before the change can be attributed to factors other than observer bias and annual variation.

IV. Methodology

Parameters

Data were collected for the following soil parameters: soil moisture content, saturated hydraulic conductivity (Ksat), soil cover, soil disturbance class, and bulk density. Descriptions of the protocols utilized can be found in the Heavenly SEZ Demonstration Project Monitoring Plan (Norman, 2007).

Frequency

A primary concern when working in SEZs is ensuring that ground-water levels and soil moisture content are at acceptably low levels. Prior to project implementation, ground-water levels were measured to ensure that they were at least two feet below the ground surface. Soil moisture was also measured prior to project implementation and following storm events during implementation. This was done by digging up the soils from the 6 to 12 inch layer, and trying to form a ball by squeezing a handful of soil very firmly, and then comparing the result to the criteria appropriate for Tahoe Basin soils (presented in Table 1). No operations were to take place on soils which exhibit "very moist" or "wet" characteristics (Table 1). Pre-project soil moisture samples were taken on August 30 and September 4th. Based on those evaluations, all of the project areas but approximately 1/5 of an acre were determined suitable for operation, and most of this 1/5 acre was treated by reaching in with equipment from adjacent drier areas. These soil tests were also repeated on September 20, 23, 24, 29, 30 and October 1, following storm events. With the exception of a small area (less than 1/10 acre) in the mixed (burned-unburned) Unit 1 confines, soil moistures did not increase to an unacceptably moist or wet condition following these storm events. This small area was flagged and the operator reached in with the arm of the CTL harvester to remove fuels in this area.

Table 1. Criteria for Soil Moisture Determination

Soil Moisture % Increases Downward	*Loamy sands, fine sand loam, very fine sands, coarse sands. Fine sandy loams, sandy loams, very fine sandy loam*
Dry soils	Dry, loose, single grained flows thru fingers, will not form a ball with pressure
Moist soil	Tends to stick together slightly, sometimes forms a very weak ball, but will shatter into single grains easily when tossed to a few inches height and caught in the hand
Very moist soil	Forms a weak ball, when tossed in the air may break into smaller chunks but will not shatter easily into single grains.
Wet soils	Upon squeezing, free water may appear. Wet outline is left on hand. Nonplastic.

Soil moisture conditions were also measured within the 24 hours preceding implementation in each phase, (utilizing gravimetric soil-moisture measurement techniques) to help fully characterize the soil moisture conditions throughout project operations, and to determine the

strength of any possible correlation to measured changes in Ksat. A minimum of three samples were collected prior to each phase. Pre-project bulk density measurements were also taken at this time, since the same soil sample could be used for both soil moisture and bulk density tests.

During implementation, post-treatment measurements of Ksat, soil cover, bulk density, and soil-disturbance class were made weekly.

The project was loosely scheduled for implementation in the following phases, to treat the areas deemed most resilient to soil compaction impacts first and then proceed to areas that may be less resilient.

Phase I – Unit 3 and 4b
Phase II – Unit 1a, 4a, 5a, 5b
Phase III Unit 1b
Phase IV- Unit 2 and 5c

At the end of each week, monitoring data were reviewed to determine whether impacts that occurred were acceptable, which would need to be shown to allow operations to continue the following week. The results of the ongoing data collections indicated that project impacts were staying well within the operating criteria described in the monitoring objectives.

In 2008, when the snow has melted and the first major summer or fall rain storm event occurs, BMP effectiveness monitoring will be conducted (with photos) to determine whether visible signs of erosion, sediment transport, or deposition has occurred as a result of project activities. Data collections for Ksat, bulk density, and soil cover will be undertaken in 2012, to evaluate the recovery rates in these parameters.

Sampling Scheme

A sample size analysis test conducted in SigmaStat indicated that 15 sample points are needed to predict whether the Ksat thresholds are being exceeded within a particular stratification of the treatment area, at the 90% confidence interval (CI), assuming that the data demonstrate a log-normal distribution (Norman and Christensen, 2006). Pre-project data were analyzed prior to project implementation to determine whether this number of sample points was adequate to provide a statistically valid representative sample. Based on this analysis it was determined that approximately six sample points would need to be collected per acre.

In previous projects, samples were collected by establishing random transects within the project area. Because of the small size of the treatment area, however, it was decided to collect a more integrated sample of the entire area for the sample pool. Pre-project data were collected by starting from the approximate center of the treatment Unit and collecting samples every 45 feet along radials extending in the cardinal compass directions (N, S, E, W) from the centerpoint.

Post-project samples were collected using one strategy to focus on ”within-the tracks” impacts and another strategy to focus on the overall project impacts.

During the first week of post-project sampling, data were collected [only] within the tracks utilized by the equipment. The entire length of track was measured within the area treated, and one to three samples were collected in each track. These data were utilized to conduct analyses of changes in soil characteristics within the equipment tracks [only].

Subsequently, for the remaining weeks of sampling, samples were collected at random locations across the study areas [not just within the equipment tracks]. In order to randomize the post-project sampling, a stick was thrown from the previous sample location, and the characteristics of that new location were recorded (i.e. tracked or untracked, and type of ground cover). Once each treatment unit had been sampled, an analysis was completed to identify whether or not the samples collected were sufficiently representative of the tracked area within that treatment unit. For example, if 15% of the treatment unit's area was tracked by the equipment, then the target was to have 15% of the samples collected from within the tracks and the remaining 85% of the samples collected from the "untracked" areas of the treatment unit. If the random sampling did not result in a sufficiently representative sample set, then additional samples were collected in that treatment unit.

Sampling Protocol

Sampling protocols are presented in the Heavenly SEZ Fuels Reduction Demonstration Project Monitoring Plan (Norman, 2007). The protocols utilized to collect soil quality data were developed by the Regional USFS soil scientists and staff with the Natural Resources Conservations Service (NRCS).

V. Data Analysis

Hydraulic Conductivity (Ksat)

SigmaStat 3.5 was used to evaluate the soil saturated hydraulic conductivity (Ksat) data. Ksat is a measure of the rate at which water will flow through the soil at saturated conditions. Regional USFS soil quality standards specify that impacts should be measured at 4 to 8 inches below the soil surface to evaluate detrimental soil compaction **.** Therefore the Ksat measurement was taken at 4 inches below the soil surface, using a constant head permeameter.

In the first week of post-project sample collection, Ksat measurements were only collected in the visible tire tracks left by harvesting equipment. The assumption was that measurable impacts would occur in the visible tracks; whereas, outside of these tracks, impacts would not occur or would be relatively insignificant. During this first week, it was established that thresholds for Ksat (determined through WEPP analysis to be 1.0 in/hr for the entire treatment area, and 0.15 in/hr within the equipment tracks) were easily met. Although Ksat values were reduced by over 50%, they were not reduced to or below the erosion threshold; e.g., post-treatment, Ksat averaged 1.9 inches/hr, clearly above the 1.0 inch/hr threshold. Table 2 below provides the summary statistics for a comparison of pre- and post-project Ksat in those project areas impacted by visible equipment tracks. The areas covered by visible equipment tracks were measured in

the field; they ranged from 5 to 28% of the treatment units, with approximately 16% of the entire project area covered with visible equipment tracks.

Table 2. Ksat summary statistics for all pre-project data and post-project collected within visible equipment tracks.

	All Pre- Project	All Tracks	Tracks w/ slash mat	Tracks w/o slash mat
Sample Size	143	69	31	38
Median	4.3	1.9	2.1	1.6
Mean*	4.3	2	2.2	1.9
Std. Dev.*	3.3	2.6	2.7	2.5

*The mean and standard deviation were calculated using log-10 transformed data values, however statistical analysis was conducted on medians with Mann Whitney Rank Sum test, because log transformation did not normalize data.

It is important to note that Ksat is a highly variable soil parameter in nature, with values ranging from 0.23 in/hr to 87.3 in/hr in the pre-project data (extreme outliers were as high as 150 in/hr). The raw data do not exhibit a normal distribution and the standard deviations are large, which are indications that the data may be log normally distributed (for many natural resource parameters, the raw values aren't normally distributed but their logarithms *are*). For the purposes of statistical analysis, the extreme outliers were discarded, and the data were log transformed to achieve a normal distribution. This allowed the use of the "Student's t-test of equivalent means" to determine at what statistical confidence level the pre- and post-project Ksat averages can be considered to be different. Extreme outliers, for the purpose of this analysis, were defined as values greater than 100 in/hr (only 1 measurement pre-project and 1 measurement post-project met this definition and were discarded from the datasets).

For the comparison of post-project "tracked" (visible equipment tracks) data, log transformation was not successful in normalizing the data, so in this case the nonparametric Mann-Whitney Rank Sum test was used to compare median values between two groups. This analysis determined that the difference between the median Ksat measurements pre-project and those measured in the post-project visible equipment tracks is statistically significant at a high level of confidence (P=.001, so the confidence level is 1.000-.001= 99.9%).

Another interesting result from our analyses is revealed by comparing Ksat within those equipment tracks where the equipment was operated on a slash mat of six-inch or greater depth, to those tracks where the equipment was operated with none or with very little slash. The project plans called for equipment to operate on a [6- to 12-inch] thick slash mat for the entire project area, where repeated (3 or more) passes were required. However, minimal slash was available within the treatment units that had been burned in the previous wildfire, so the equipment operated with very little (if any) slash cover in those locations. As soon as LTBMU staff observed this occurring, the number of samples taken in such locations was increased to better define the impacts that may be occurring. As can be seen in Table 2, the lack of slash did not result in statistically significant increases in impacts; because, while there is a difference in the means and medians (mean of 2.2 with slash versus 1.9 without), the Mann-Whitney Rank Sum

test determined that *this difference is not statistically significant* (P=.488, so the confidence level is only 1.000-0.488 = 51.2%).

As stated earlier, it was assumed that a comparison of pre- and post-project Ksat measurements within the tracks would reveal the [only] impacts that may result from the use of forwarder / harvester equipment within the project bounds. Also, it was assumed that a comparison of pre- and post-project Ksat measurements within "untracked" areas would reveal no change occurred at those locations during the project (e.g., if the equipment didn't track on a certain location, the Ksat value there shouldn't change). This turned out ultimately to *not* be the outcome. Table 3 provides summary statistics for these data.

Table 3. Ksat summary statistics for pre-project data, post untracked, and post untracked and tracked data. (Does not include data in Units 3 and 4b)

	Pre- Project (w/o units 3 and 4b)	Post- Project all (tracked & untracked)	Post –Project untracked only
Sample Size	89	86	71
Median	5.7	1.9	1.9
Mean*	5.5	2.4	2.5
Std. Dev.*	3.3	3.5	3.6

* The mean and standard deviation were calculated using log-10 transformed data values. Normalization was achieved through log transformation, so students t-test was used for analysis.

The data presented in Table 3 do not include data points taken in Units 3 and 4b; in these treatment units, post-project data were only collected in the visible equipment tracks. A different strategy was used to collect data throughout the rest of the project area, to get a representative sample of the entire area. Based on field observation notes, the amounts of data representing visible equipment tracks for pre- and post-comparison were scaled to the measured areas of equipment tracks.

This comparison indicates that *the difference between the pre-project Ksat and post-project Ksat measurements (mean of 5.5 in/hr pre-project, versus 2.4 post) was statistically significant* for the entire representative post-project data set, this is also true for the post-project data points collected only outside of the visible equipment tracks (P=.001 for all post-project data and for "untracked only" post-project data). In addition, statistical analysis determined *there was no significant difference between the post-project data collected within the visible equipment tracks and the post-project data collected outside the visible equipment tracks*; the mean for "untracked" is 2.5 in/hr and the combined mean for all tracks is 2.4, at a significance level of P=0.472.

Monitoring crews did not observe signs that equipment had traveled over soils in the "untracked" areas" (e.g., there were no visible signs of flattened vegetation or tire track depressions), yet the impacts were found to be equal to those measured within the visible equipment tracks. Though it is tempting to assume that somehow equipment had made at least one pass over the "untracked"

soils almost everywhere, without leaving any visible tracks, the more likely explanation is that the soil structure (specifically, horizontal layering of the subsoils) spread the impacts horizontally outward from the equipment to an "effective footprint" that is much larger than the width of the visible equipment tracks). The WEPP analysis presented in Section VI describes the minimal estimated runoff and erosion impacts from the observed changes in Ksat.

The differences in median Ksat between treatments units is displayed in Table 4.

Table 4. Ksat and Soil Moisture Measurements, by Treatment Unit

Unit #	3 and 4b	1a and 5a	1b	4a	2
Pre Ksat	3.4	2.6	3.8	10.2	7.0
Post Ksat	2.6	1.4	2.4	3.3	2.0
% Soil Moisture	6	4.1	7.1	7.2	11.2

The data presented in Table 4 illustrate the natural differences in Ksat between treatment units, pre-project, as well as the differences between treatment units post-project. Although there are differences in Ksat values *between* treatment units post-project, the difference are smaller than they were pre-project. The soils of the treatment units are all basically classified the same (Marla soil map unit). However, field observations noted that Unit 4a and most of Unit 2 seemed sandier in texture, and unit 2 had the highest soil moisture content. All the measured percent soil moisture values presented in this table are considered to exhibit very dry conditions. Soil mechanics literature indicates that the sandier, moister soils are more easily compacted. Future monitoring may reveal more about the relative influence of sandier, moister soils on post-project Ksat values.

Bulk Density

SigmaStat 3.5 was also used to evaluate the soil bulk density data. The soil bulk density data exhibited a normal distribution with equal variance for each disturbance type. There were no outliers identified in the bulk density data for any of the disturbance types. Statistical differences were evaluated using the Student's t-test, and determined that no statistically significant difference was observed between any of the pre- and post-project data ($P = 0.55$ for all post, and post untracked, and $P= 0.64$ for post-project tracked areas).

Table 5. Pre- and post-project means of BD (gm/cm3) along with calculated change in porosity (does not include units 3 and 4b).

	Pre-Project	Post-Project tracked and untracked	Post-project untracked	Post-project tracked only	Porosity Change[3] pre vs. post tracked and untracked
Sample Size	69	51	42	20	
Mean	1.188	1.158	1.160	1.217	2 %
Std. Dev.	.253	.210	.203	.201	

The Regional Soil Quality Standards state that "a 10 percent reduction in total soil porosity corresponds to a threshold soil bulk density that indicates detrimental soil compaction" *(FSH 2509.18-95.01, Section 2.2, Soil Management Handbook).*

Bulk densities post-project remain well under the threshold bulk density for this project of 1.334 over the entire project area. The calculated means actually indicate a small overall decrease in bulk density, resulting in an overall increase in porosity (2%). However this small calculated decrease (.03) is well within the standard deviations of the means and as stated previously, was not statistically significant. Therefore we conclude there was no real change in bulk density.

Soil Moisture

Soil moisture was measured as part of the bulk density lab analysis, and pre-project samples were collected within 24 hours prior to equipment entering a particular unit. These data were collected partly to establish what level of soil moisture was actually present when performing the soil moisture squeeze tests to determine operability. In addition we wanted to be able to correlate measured soil moisture to post-project Ksat and bulk density changes, particularly if we observed that post-project data for these variables varied between treatment units. The average soil moisture measured in each treatment unit is presented in Table 6 below.

[3] The change in porosity is given by:

$\Delta P = (Dbi-Dbf)/(Dp-Dbi)$

where Dbi is the initial soil bulk density found under pre-project conditions, Dbf is the final bulk density after the project, and Dp is the density of the individual soil particles, which is assumed to be 2.65 gm/cm^3. Similarly, the equation used to calculate the threshold bulk density (Dbt) corresponding to a 10% decrease in porosity is given by:

$Dbt = 0.1Dp + 0.9Dbi$

Table 6. Pre-project Percent soil moisture content, by treatment unit.

Treatment Unit	Percent soil moisture
Unit 3	5.3
Unit 4b	6.2
Unit 1a	4.5
Unit 4a	7.2
Unit 5 a	4.1
Unit 1b	7.2
Unit 2	11.2
Project Average	**6.7**

As can be seen, the percentage soil moisture was very low, ranging from 4 to 11 %, for an average of 6.7% over the project area. These data can be used when comparing the results of this project to other projects, particularly where pre-project soil moisture conditions may be substantially different. There were only minor observed differences in post-project Ksat and/or BD between units, so it is assumed that the small differences observed in soil moisture did not affect project impacts on these soil parameters.

Soil Cover

The percent ground cover was determined by ocular estimates and the depth of ground cover was measured at each of the sampled locations both before and after the project. The ground cover before the project consisted of duff, needles, and decaying wood, while the ground cover after the project consisted of coarse slash, generally under three inches in diameter, scattered over the relatively undisturbed pre-project ground cover. The percent cover means for pre-project and post-project in the project area were 98% and 89% respectively. The mean values for percent cover and depth of cover are presented in Table 7 below.

Table 7. Summary statistics for pre- and post-project percent cover and depth of cover.

	Pre-project Percent Cover	Pre-project depth of cover (inches)	Post-project Percent Cover	Post-project depth of cover (inches)
Sample Size	100	100	160	160
Mean	98	2.7	89	2.6
Standard Deviation	8	2.7	22	1.9
Range	80 to 100	1 to 3	0 to 100	0 to 8

As can be seen from these data, there was an approximately 10% reduction in soil cover between the pre-project and post-project data; however, soil cover remained extremely high. The Regional Soil Quality Standards require that sufficient soil cover is maintained in order to prevent accelerated soil erosion. The kind, amount, and distribution of soil cover necessary to prevent accelerated erosion is determined using the California Interagency Erosion Hazard

Rating (EHR), developed by the California Soil Survey Committee (FSH 2509.22). Within this project area, an overall value of 50% ground cover is needed to maintain an erosion hazard rating of low on slopes under 26%, and 11% ground cover is required on slopes under 16%. The ground cover within this project is clearly sufficient to prevent the erosion hazard rating from increasing to moderate, and well within the USFS Region 5 standard of 50%.

Further Data Analysis

During the peer review process for this report, concerns were raised regarding the use of some of the Ksat data utilized in this analysis. One of the reviewers observed that a subset of the post-project untracked data collected in November (19 samples total) had uncharacteristically low Ksat values, compared to the rest of the post-project Ksat data.

The November data were collected when LTBMU staff realized that more untracked samples were needed to augment the data initially collected, to provide a more accurate stratified sample of post-project untracked data. The initial post-project data were collected between mid-September through mid -October 12**.** The additional post-project data was collected in mid-November, following a couple of storm events (totaling approximately 1" of precipitation). The crews noted on the field forms that the soils were moist for many of the samples collected during this period.

Two of the reviewers raised concerns that the data collected during this time period may demonstrate lower Ksat values because the soils had not drained to field capacity following the storm events, or due to changes in the viscosity of water (which is dependent on temperature). However, when discussing these concerns with several other reviewers (both internal and external) it became apparent that there was not universal agreement regarding these concerns, and the information is simply not available to prove or disprove these theories. Therefore, for the purposes of this report it was decided to not change the original analysis presented in Table 3 and 4, but instead provide additional analysis in this section that describes the results that would be obtained if the November data are removed from the sample set. Removing the November data resulted in a modest increase in the post-project Ksat means. The post-project untracked Ksat means increased from 2.5 to 2.9 in/hr, which resulted in an overall increase of the post-project Ksat mean from 2.4 to 2.7 in/hr.

Statistical analysis still indicates a significant reduction in pre- vs. post-project Ksat when compared to all post-project data ((p=.001, t-test), as well as compared to the untracked data alone (p=.002, t-test). The statistical results for the comparison between post-project tracked and untracked data do change indicating that there is a statistically significant difference (p=.06, t-test) between the tracked mean of 2.0 in/hr compared to the untracked mean of 2.9 in/hr.

The management implications of these results do not change with this analysis. The results still indicates that while project operations impacted Ksat values throughout the project area (and not just the areas that exhibit visible equipment tracks), the overall impact of Ksat reductions were not ecologically significant in terms of soil hydrologic function and erosion response.

VI. WEPP Estimates of Runoff and Erosion

The Watershed Erosion Prediction Project (WEPP) hillslope model was used to predict runoff and erosion response for both pre- and post-project conditions. Three hillslope profiles were constructed in WEPP to represent three different flow paths within the project area. These flow paths were designed to represent the "worst case scenario" found in the project area, by following the longest flow path present and applying the greatest slope measured within the project area.

The first flowpath is located in Unit 1B and includes a section of the project area that was previously burned by wildfire, with a maximum slope of 10%, and terminates at the Heavenly Valley Creek Channel. The second flowpath is located in Unit 4B, has the steepest slope in the project area, assumed to be constant at 15%, and also terminates at the Heavenly Valley Creek channel. The third flowpath is located in Unit 2, has a maximum slope of 10% and terminates in an ephemeral channel on the NW portion of the project area. Because there are no roads through the project area, and the slope is consistently very low, a convex hillslope was assumed for the 1st and 3rd hillslope profiles, with the maximum slope occurring nearest the respective channel. A constant slope was used for the 2nd hillslope profile because there are portions of Unit 4B that exhibit a constant slope right up to the channel edge. For each of the hillslope simulations, a slope width of 100 m (330 feet) was assumed.

The soil file representing a mature loamy sand soil was used in all simulations, with the following modifications. The key infiltration parameter in the WEPP model is the Green-Ampt effective hydraulic conductivity (Keff). The mean values of Ksat measured in the field were assumed to be the best representation of this parameter to reflect field conditions of Keff in the model simulations. The NRCS Web Soil Survey (2007) was used to determine particle size and the depth to any restrictive layer for the applicable soil map units. The Marla soil map unit was used for each simulation because it is the primary soil type found in the project area, and consists of 77.8% sand, 17.7% silt, and 4.5% clay. The depth to any restrictive layer was reported as 68 inches for this unit. These parameters were assumed to not vary between project phases. The value of Keff in the general project area was set to the mean measured Ksat value of 5.5 in/hr for the pre-project simulations and 2.4 in/hr for the post-project simulations.

The model's management file representing a mature coniferous forest was used for both the pre-project and post-project simulations for the unburned portions of the project area. However, the canopy cover, ground cover, and bulk density values measured in the field were substituted for the default values. Based on stand exam data, the value for canopy cover was set to 25% for the pre-project simulation in the unburned units and 10% for the post-project simulations.

Because the tree canopy cover in Unit 1B was low (5%) due to the previous wildfire, the management files representing several different grasses present within this unit were used for the post-project simulations. Grass cover was estimated at 40% for both pre- and post-project conditions.

The value for ground cover in both the unburned and burned portions of the project area was set to the median value of 100% for the pre-project simulations and to 85% for the post-project

simulations. The bulk density for all units was set to 1.188 gm/cm^3 for the pre-project and post-project simulations (which assumes as described in the data analysis section, no real change in bulk density).

The stochastic weather model CLIGEN, version 4.3, was used to generate 30 years of climate based on data from Tahoe City, CA.

The parameters used for the pre- and post-project simulations are presented in Table 8 below.

Table 8. Field based measurements used in WEPP hillslope simulations for Heavenly SEZ Demonstration Project

Land Use Type	Canopy Cover	Ground Cover	Keff (in/hr)	Bulk Density (gm/cm^3)
Pre-Project				
Unburned units	25%	100%	5.5	1.188
Burned unit	40%	100%	5.5	1.188
Post-Project				
Unburned units	10%	85%	2.4	1.188
Burned units	40%	85%	2.4	1.188

Note* measured post-project ground cover was 89%, however a conservative value of 85% was used for the WEPP analysis.

30-Year Simulations:

The 30-year simulations using the Tahoe, CA climate resulted in an average annual precipitation of 32.7 inches. For both the pre- and post-project simulations, the WEPP model predicted that the average annual sediment yield and runoff for all three hillslope profiles is zero. These metrics are presented in units of tons/acre for the average annual sediment yield and in inches for average annual runoff. The model result of zero for these parameters indicates that the average annual sediment yield was less than 0.001 ton/acre and the average annual runoff was less than 0.01 inches.

When reviewing the daily simulation results, there were some very minor amounts of sediment delivery at the end of the hillslope profiles predicted from several storm events during the 30 years of simulations for post-project simulations only. From these few predicted sediment producing events, each of the hillslope profiles predicted a total volume of runoff of 0.2 inches over the entire 30 year simulation period, resulting in a total sediment delivery estimate of 0.0003, 0.006, and 0.0263 tons/acre respectively for the 3 hillslope simulations.

VII. Conclusions and Discussion

Soil quality data analysis determined that there is a statistically significant difference between Ksat measurements pre- and post-project, resulting in a decrease from 5.5 in/hr to 2.4 in/hr; the fuels reduction treatments did impact the rate at which water will flow through the soil, but not

so much as to fall below the WEPP-determined threshold for erosion of 1.0 inch/hr. The management implication of this result is that the measured reduction in Ksat values were not ecologically significant in regards to impacts to soil hydrologic function (infiltration, permeability, and accelerated surface runoff).

Statistical analysis also determined that there was no significant difference between post-project data collected within visible equipment tracks, whether operated on a slash mat or not. Analysis also indicates that the difference between post-project tracked and "untracked" areas (no visible equipment tracks) was smaller then expected. This indicates that the impacts from forwarder / harvester equipment in these treatment units were sustained fairly equally throughout the area treated, regardless of slash mats, or number of vehicle passes.

These were somewhat unexpected results and stand in contrast to the results of a recently published study which also evaluated the impacts of CTL systems on soils. In that study (Han, 2007), a cone penetrometer was used to evaluate the effects of CTL equipment on "soil resistance to penetration" (SRP), with varying degrees of slash cover (high, light, bare ground) and number of vehicle passes. That study found very distinct difference in SRP as a result of slash cover and vehicle passes (up through 10 passes), with compaction visibly increasing with decreased slash cover, and increase in vehicle passes. There were notable differences in site conditions between that study and this study that explain the discrepancy in results. The soils tested in the Han study were on ashy silt loams (Vassar and Helmer soil series) in north central Idaho, and soil moisture was measured at between 24 to 29 % (depending on soil depth) during project operations. By contrast in the Heavenly SEZ, loamy coarse sands, at between 4 to 11% soil moisture, represent site conditions that are inherently more resistant to compaction.

Soil quality data analysis also determined there were no statistically significant differences in bulk density (and calculated soil porosity), and only an 11% measured decrease in soil cover (100% pre-project, compared to 89% post-project). Therefore, the regional USFS soil quality standards for changes in soil porosity (no more then 10% reduction) and residual soil cover (at least 50% cover) were easily met.

WEPP simulations utilizing this measured pre- and post-project soil quality data predicted that there will be no real sediment delivery response as a result of project activities. Although the rate at which water flows through the soils at levels 4 inches below the soil surface (as represented by Ksat) were reduced by over 50%, the post-project conditions proved to still be very resistant to generating an erosive runoff response. This is due to a combination of low gradient slopes ($\leq$15%), high level of soil cover (89%), robust vegetation cover, and the relatively high baseline infiltration capacities represented by this soil map unit.

The results of this monitoring effort indicate that treatment of Basin SEZs with CTL forwarder/ harvester technology can be safely implemented under favorable soil conditions (e.g., relatively high Ksat and low moisture content). The impacts may extend throughout the treatment units, rather than being limited to the equipment tracks, probably due to horizontal spreading of applied pressures through layered soils. Consequently, this monitoring effort also indicates that there may be little protective value to the use of a slash mat, under favorable soil conditions.

Future projects could be implemented to determine the limits to which this technology can be used without causing adverse impacts to soils and water quality, including:

- Utilization of CTL technology without slash mats, in SEZs that have 40% or greater existing grass and shrub cover.

- Utilization of CTL technology with slash mats, where soil moisture conditions within SEZs are classified as very moist (utilizing the squeeze test described in this report).

Particularly for the two scenarios described above the, a cone penetrometer should be used in addition to the soil moisture squeeze test to evaluate pre-project conditions in terms of soil strength and predicted resiliency to compaction. The cone penetrometer provides a measurement of the bearing strength of the soil reported directly as pounds per square inch. This tool could also be used to obtain an immediate field assessment of site specific equipment impacts, prior to the collection of other soil parameters presented in this report used to evaluate overall ecological impacts from a project.

Monitoring should also be conducted where CTL technology is proposed for use on sites that have significantly different site conditions, including steeper slopes, soils with a higher silt-to-clay content, or less pre-existing vegetation cover in the form of grasses and shrubs. A procedure will be developed by LTBMU staff for comparing the sensitivity of the Heavenly SEZ site relative to other SEZ sites proposed for future mechanical treatment. The delineation criteria for comparison will incorporate the characteristics of SEZs that make them prone to impacts from mechanical operations, such as connectivity to ground water and surface water, soil type, and slope. The criteria and methodology for comparing SEZ characteristics will be reviewed by staff at the Lahonton Regional Water Quality Control Board and the Tahoe Regional Planning Agency prior to its application.

The potential problems described in this report related to the timing of data collection point out the importance of collecting pre- and post-project data as close as possible to the timing of project operations, so that variability is not introduced into the results as a result of climatic influences (temperature and precipitation).

From this study and others (Han, 2007), it is also concluded that using mechanical equipment within wetter SEZ types (swamps, bogs, and fens) could generate unacceptable impacts.

VIII. References

Han, S. et al. 2007. Impacts on soils from cut-to-length and whole tree harvesting. University of Idaho, Moscow, Idaho.

Norman, Sue and Wes Christensen. 2007. 2006 Ward Unit 5 Soil Monitoring Report, Lake Tahoe Basin Management Unit, USDA Forest Service

Norman, Sue, 2007, Heavenly SEZ Fuels Reduction Project Monitoring Plan, Lake Tahoe Basin Management Unit, USDA Forest Service.

US Forest Service, Region 5. FSH 2509.18-95.01, Section 2.2, Soil Management Handbook.

Figure 1: Project Location and Treatment Unit Boundaries

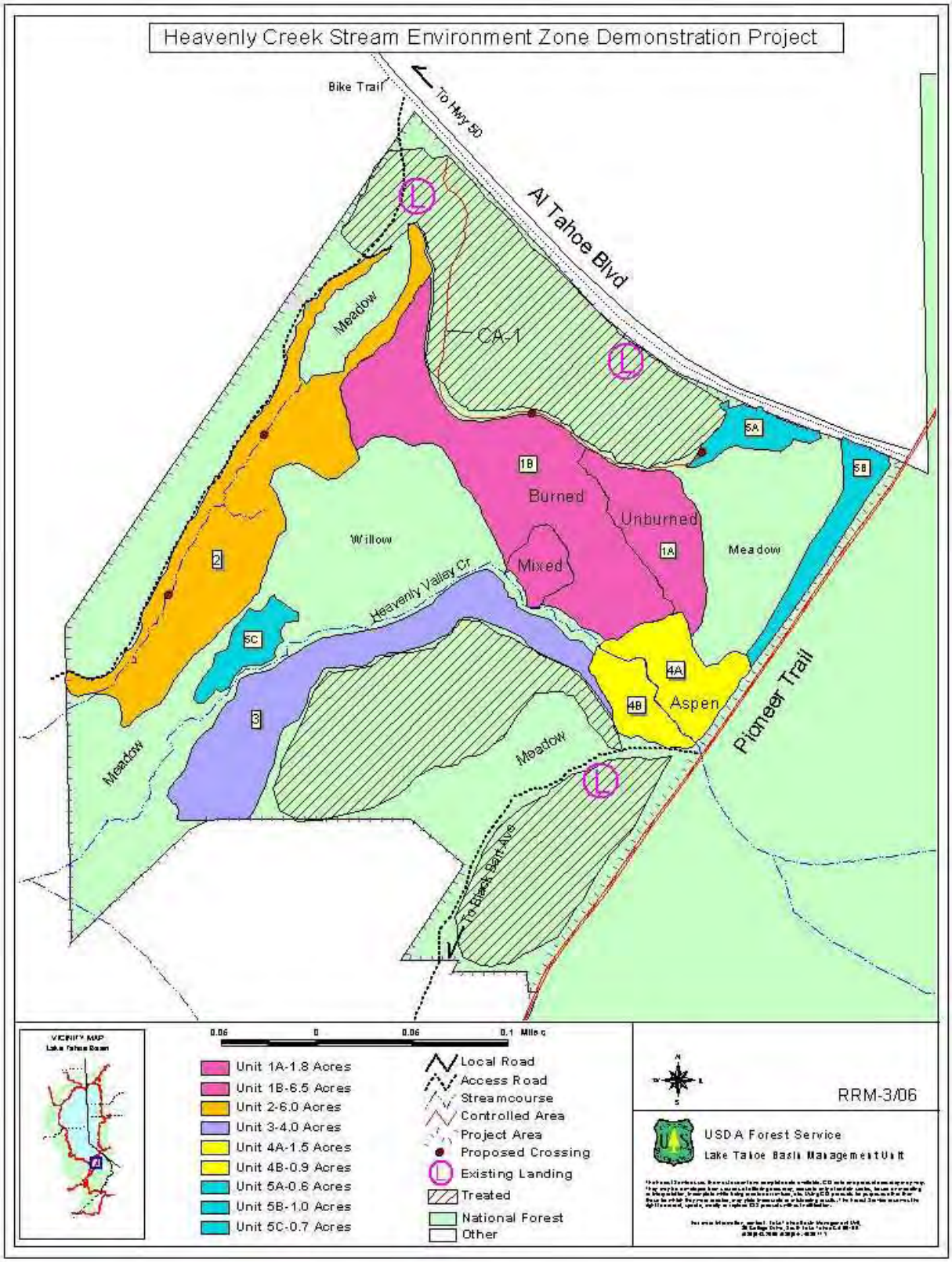


Figure 2: Unit Boundaries overlay onto Aerial Photo

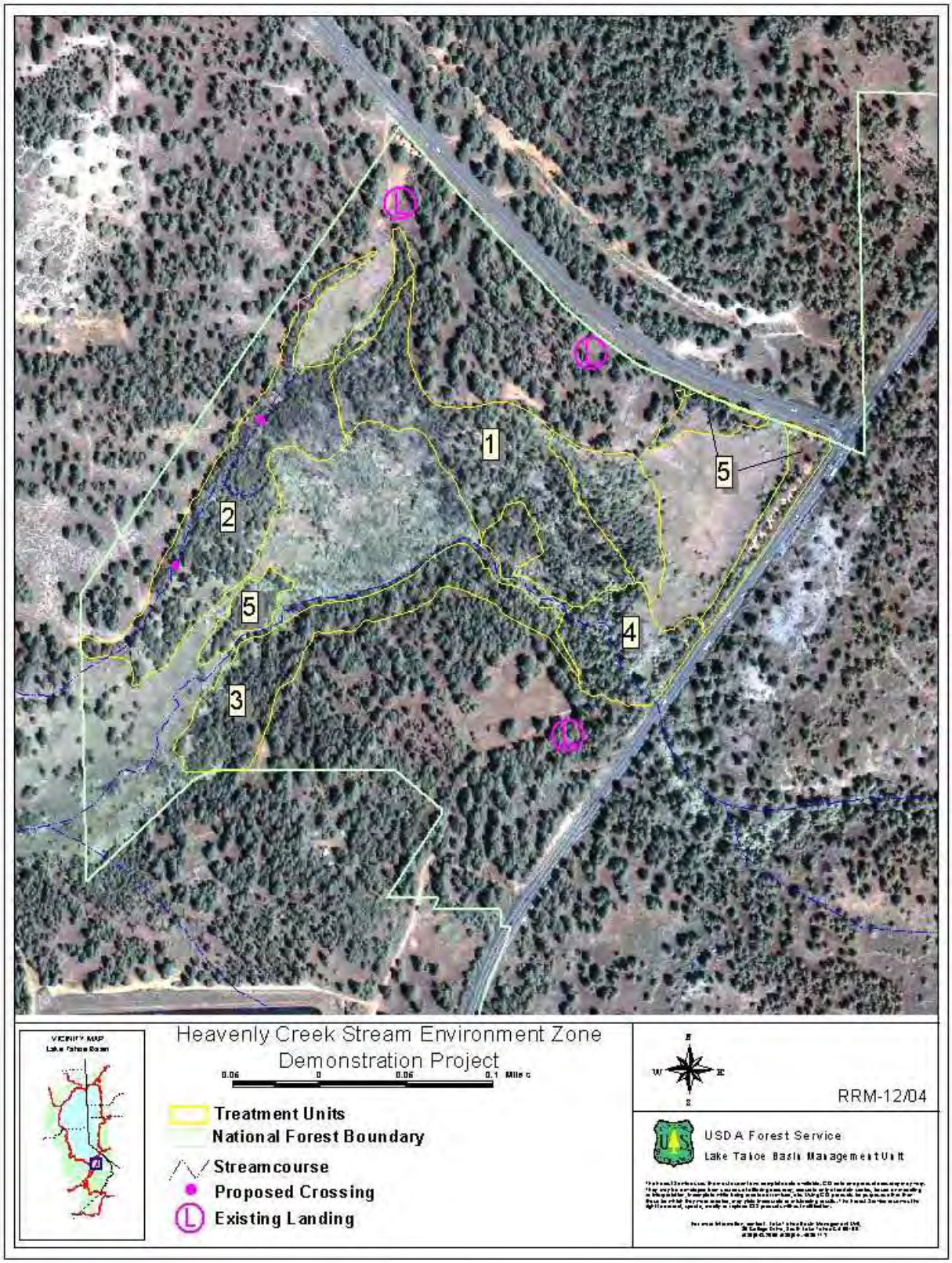


Figure 3: Unit Boundaries and Soil types

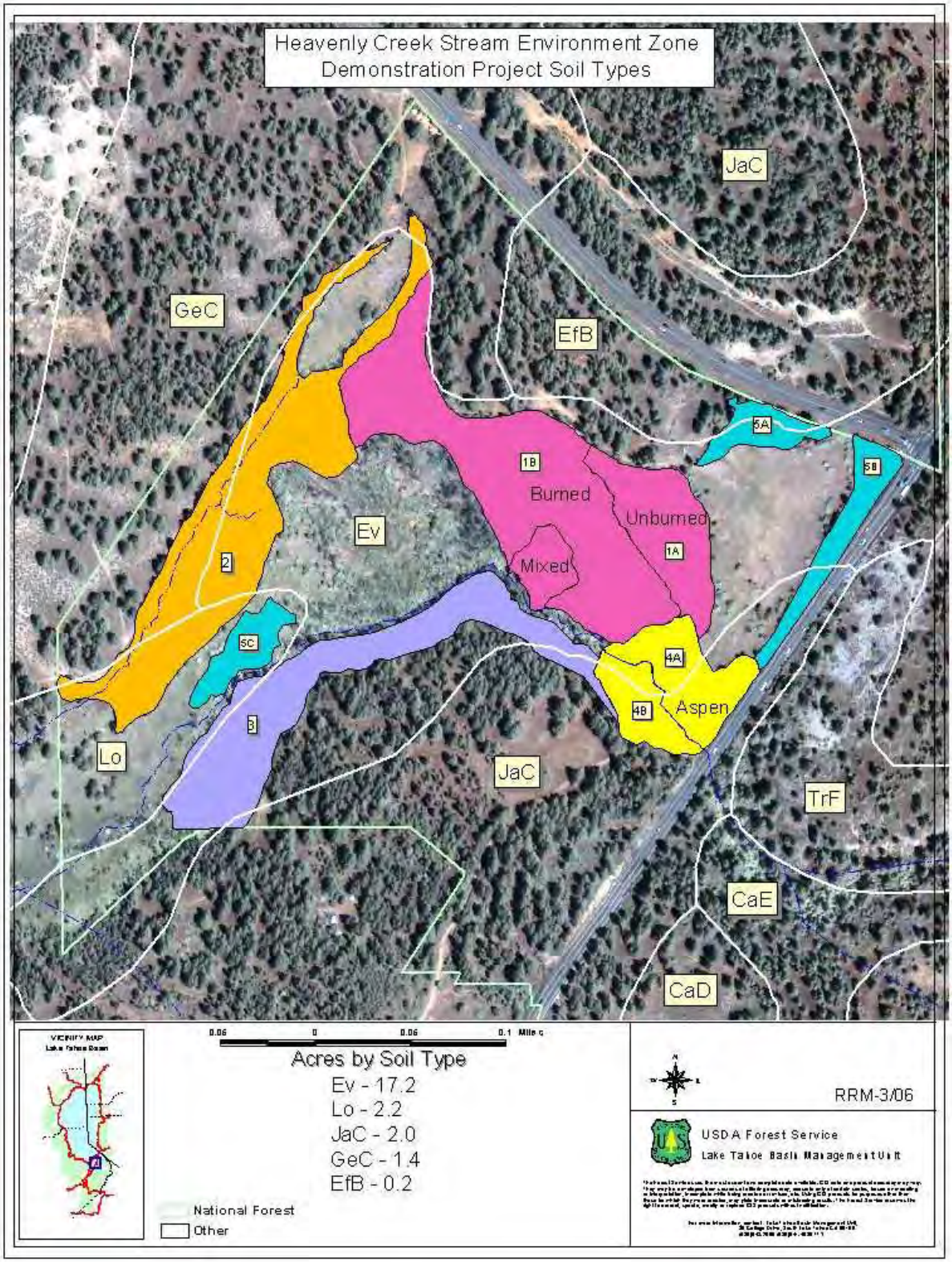
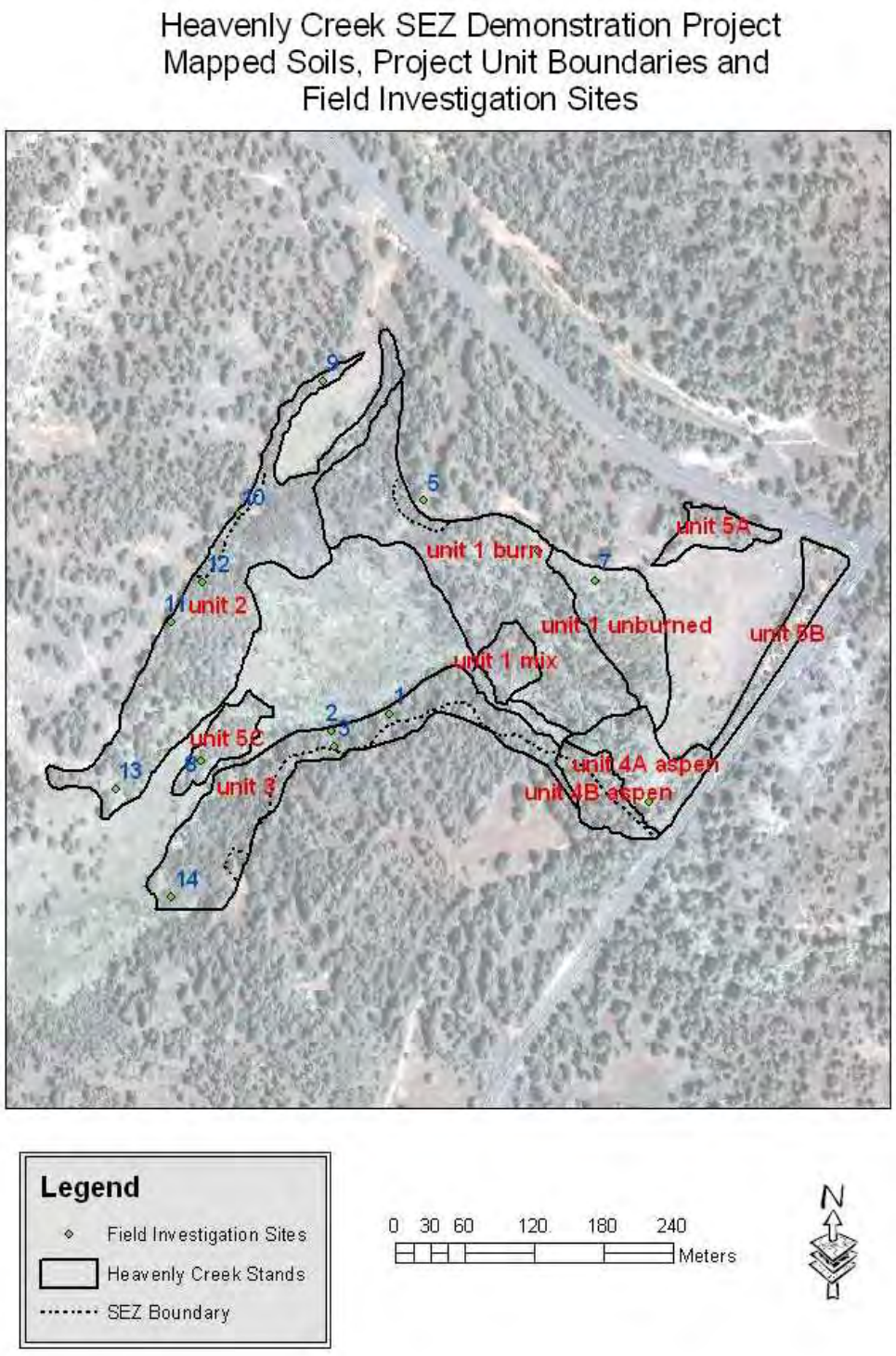


Figure 4 Land Capability Verification and SEZ Map



Appendix A: Raw Data

Appendix A-1: Bulk Density Raw Data

Date Collected	Unit	Moisture Percent	Bulk Density (g/cm^3)	pre / post	in track?	Notes
6/20/2007	1B	19.0%	1.0379	pre	n/a	n/a
6/20/2007	1B	16.9%	1.1030	pre	n/a	n/a
6/20/2007	2	33.7%	1.0166	pre	n/a	n/a
6/20/2007	2	20.8%	1.2912	pre	n/a	n/a
6/20/2007	2	3.1%	1.6206	pre	n/a	n/a
6/20/2007	2	25.8%	1.1638	pre	n/a	n/a
6/20/2007	3	6.2%	1.3957	pre	n/a	n/a
7/11/2007	1B	3.6%	1.2447	pre	n/a	n/a
7/11/2007	1B	7.3%	1.3957	pre	n/a	n/a
7/11/2007	1B	17.8%	0.9980	pre	n/a	n/a
7/11/2007	1B	16.1%	1.3766	pre	n/a	n/a
7/11/2007	1B	3.5%	1.2759	pre	n/a	n/a
7/19/2007	2	15.2%	0.9044	pre	n/a	Coarse soil; no ball
7/19/2007	2	7.9%	0.8842	pre	n/a	Coarse soil; no ball
7/19/2007	2	16.2%	0.7742	pre	n/a	Coarse soil; no ball
7/19/2007	2	9.2%	1.1266	pre	n/a	Medium soil, forms ball, does not stay together
7/25/2007	1A	10.0%	1.3646	pre	n/a	Medium soil, forms ball, stays together
7/25/2007	1A	15.6%	1.4357	pre	n/a	Medium soil, forms ball, stays together
7/25/2007	1A	15.4%	1.4641	pre	n/a	Medium soil; forms ball, stays together
7/25/2007	1B	15.6%	1.1610	pre	n/a	Medium soil, forms ball, stays together
7/25/2007	1B	11.7%	1.1856	pre	n/a	Medium soil, forms ball, stays together
7/25/2007	5A	2.3%	1.6223	pre	n/a	Coarse soil; no ball
7/25/2007	5A	8.0%	1.1807	pre	n/a	Medium soil; forms ball, does not stay together
7/25/2007	3	14.2%	1.2759	pre	n/a	Medium soil; forms ball, stays together
7/25/2007	3	23.1%	1.0653	pre	n/a	Medium soil; forms ball, stays together
7/25/2007	4A	7.8%	1.1851	pre	n/a	Medium soil, does not form ball
8/1/2007	3	5.5%	1.5593	pre	n/a	Coarse/ sandy; no ball
8/1/2007	3	10.4%	1.1041	pre	n/a	Loamy sand; No ball
8/1/2007	3	10.0%	1.3082	pre	n/a	Light sandy loam; forms weak ball
8/1/2007	3	20.9%	1.2015	pre	n/a	Light sandy loam; forms ball, holds together
8/1/2007	3	8.2%	1.6190	pre	n/a	coarse loamy sand; no ball
8/1/2007	3	20.2%	0.9668	pre	n/a	coarse loamy sand; no ball
8/1/2007	3	94.5%	0.8601	pre	n/a	coarse loamy sand; forms ball, holds together

8/1/2007	4A	12.3%	0.5707	pre	n/a	Coarse/ sandy; no ball
8/1/2007	4A	18.3%	0.8989	pre	n/a	Coarse/ Sandy; No ball; top layer medium, mid layer coarse/ sandy
8/1/2007	4A	18.5%	0.7862	pre	n/a	Coarse/ Sandy; No ball
8/2/2007	1 mix	21.7%	1.4302	pre	n/a	Sandy loam; forms ball, holds together
8/2/2007	1 mix	19.3%	1.3323	pre	n/a	moist light soil, weak ball, easily breaks
8/2/2007	1B	19.2%	1.4056	pre	n/a	n/a
8/2/2007	4B	6.9%	1.1276	pre	n/a	Loamy sand; no ball; appears dry
8/2/2007	4B	6.5%	1.1818	pre	n/a	Loamy sand; no ball; appears dry
8/6/2007	1 mix	21.4%	1.1085	pre	n/a	n/a
8/6/2007	1 mix	23.6%	1.1643	pre	n/a	n/a
8/6/2007	2	11.0%	1.1911	pre	n/a	n/a
8/6/2007	2	9.3%	1.0571	pre	n/a	n/a
8/6/2007	5C	16.3%	1.1074	pre	n/a	n/a
8/6/2007	5C	18.5%	1.0138	pre	n/a	n/a
8/6/2007	5C	14.6%	0.8524	pre	n/a	n/a
8/7/2007	1B	16.3%	0.9920	pre	n/a	coarse sandy loam, no ball
8/7/2007	1B	7.5%	1.1654	pre	n/a	coarse loamy sand, no ball
8/7/2007	1B	14.4%	1.2267	pre	n/a	coarse loamy sand, no ball
8/7/2007	2	22.0%	0.8820	pre	n/a	Coarse loamy sand, no ball
8/7/2007	2	29.7%	0.9110	pre	n/a	Coarse loamy sand, forms weak ball, holds together
8/7/2007	2	17.2%	0.8913	pre	n/a	coarse sand, no ball
8/7/2007	3	33.1%	1.2579	pre	n/a	wet (free water when squeezed) light soils, sandy loam
8/7/2007	3	43.7%	0.4344	pre	n/a	moist, light soil, forms ball, many small roots helping hold ball together
8/9/2007	1A	1.7%	1.5336	pre	n/a	very coarse sand,dry,no ball
8/9/2007	1A	4.7%	1.4204	pre	n/a	medium soil,no ball
8/9/2007	1A	11.2%	1.0795	pre	n/a	coarse sand, dry, no ball
8/9/2007	5A	3.3%	1.4029	pre	n/a	loamy sand, dry, no ball
8/9/2007	5A	2.9%	1.3755	pre	n/a	coarse sand, dry, no ball
8/9/2007	2	5.1%	1.2497	pre	n/a	light soil, sandy loam, dry, no ball
8/9/2007	2	2.6%	1.3509	pre	n/a	coarse sandy, dry, no ball
8/13/2007	4B	8.7%	0.9931	pre	n/a	light-medium, dry to slightly moist, no ball
8/13/2007	4B	8.0%	1.0155	pre	n/a	light, dry/slightly moist, no ball
8/13/2007	4A	2.3%	1.7175	pre	n/a	Coarse sand at top 10"
8/13/2007	3	5.7%	1.3388	pre	n/a	light sandy loam, no ball, dry
8/13/2007	3	26.2%	1.1835	pre	n/a	n/a
8/14/2007	4A	9.1%	1.0210	pre	n/a	coarse sand at surface, light soils, fine sandy loam, slightly moist, no ball

8/14/2007	4A	1.2%	1.7623	pre	n/a	coarse sand at surface, coarse, dry, no ball
8/14/2007	4A	5.9%	1.1014	pre	n/a	fine grain, light soils, dry, no ball
8/14/2007	none/4a?	3.8%	1.2267	pre	n/a	light soils with organic matter, dry, no ball
9/4/2007	3	4.2%	1.3531	pre	n/a	(?pre-project soil moisture?)
9/4/2007	3	6.0%	1.2327	pre	n/a	(?pre-project soil moisture?)
9/4/2007	3	4.3%	1.3230	pre	n/a	(?pre-project soil moisture?)
9/4/2007	3	6.7%	1.0467	pre	n/a	(?pre-project soil moisture?)
9/4/2007	4b	6.0%	1.2343	pre	n/a	(?pre-project soil moisture?)
9/4/2007	4b	5.8%	1.1468	pre	n/a	(?pre-project soil moisture?)
9/4/2007	4b	6.9%	1.1845	pre	n/a	(?pre-project soil moisture?)
9/17/2007	1a	7.6%	1.2283	pre	n/a	pre-project soil moisture
9/17/2007	1a	1.7%	1.5413	pre	n/a	pre-project soil moisture
9/17/2007	1a	4.1%	1.1796	pre	n/a	pre-project soil moisture
9/17/2007	4a	11.2%	0.8814	pre	n/a	pre-project soil moisture
9/17/2007	4a	3.1%	1.3520	pre	n/a	pre-project soil moisture
9/17/2007	5a	4.1%	1.3208	pre	n/a	pre-project soil moisture
9/20/2007	1b	13.3%	1.2639	pre	n/a	pre-project soil moisture
9/20/2007	1b	5.2%	1.2639	pre	n/a	pre-project soil moisture
9/20/2007	1b	2.7%	1.3968	pre	n/a	pre-project soil moisture
9/24/2007	4b	5.5%	1.3443	post	?	?
9/24/2007	4b	5.3%	1.3098	post	?	?
9/24/2007	3	16.6%	1.0680	post	?	?
9/24/2007	3	6.3%	1.3377	post	?	?
9/24/2007	3	6.6%	1.4844	post	?	?
9/24/2007	3	6.7%	1.2502	post	?	?
9/24/2007	3	10.9%	1.1446	post	?	?
9/24/2007	3	10.0%	1.1545	post	?	?
9/25/2007	2	19.3%	1.0680	pre	?	pre-project soil moisture
9/25/2007	2	8.3%	1.2803	pre	?	pre-project soil moisture
9/25/2007	2	6.1%	1.5369	pre	?	pre-project soil moisture
9/25/2007	1a	5.4%	1.0926	post	N	Ksat sample: U1a-S01
9/25/2007	1a	22.9%	0.9838	post	N	Ksat sample: U1a-S03
9/25/2007	1a	6.5%	1.4329	post	N	Ksat sample: U1a-S05
9/25/2007	4a	6.8%	1.2387	post	N	Ksat sample: U4a-S01, Medium soil, does not form ball
9/25/2007	4a	11.9%	1.0877	post	**Y**	Ksat sample: U4a-S03TR, Heavily used track w/ moderate cover
9/26/2007	5a	3.3%	1.3952	post	**Y**	Ksat sample: U5a-S01TR, track w/ moderate cover
9/26/2007	4a	6.3%	1.3367	post	N	Ksat sample: U4a-S05
9/26/2007	4a	8.2%	1.2261	post	N	Ksat sample: U4a-S07
9/26/2007	4a	11.5%	1.1320	post	N	Ksat sample: U4a-S08, Coarse/ Sandy; No ball; top layer medium, mid layer Ksat sample: U4a-S10, coarse/

						sandy
9/26/2007	4a	14.7%	1.0516	post	N	Coarse/ Sandy; No ball
10/2/2007	5a	3.9%	1.3711	post	NO	Ksat sample: U5a-S04
10/2/2007	5a	6.6%	1.3470	post	**Y**	Ksat sample: U5a-S05TR
10/2/2007	1mix	11.1%	1.2436	post	N	Ksat sample: U1mix-S02 (in track, but between treads, appears relatively undisturbed)
10/2/2007	1b	11.3%	1.3520	post	N	Ksat sample: U1b-S17
10/2/2007	1b	12.8%	1.1665	post	**Y**	Ksat sample: U1b-S19TR
10/2/2007	1b	4.6%	1.2174	post	N	Ksat sample: U1b-S20 (in track, but between treads, appears relatively undisturbed)
10/2/2007	1b	7.3%	1.3864	post	N	Ksat sample: U1b-S22
10/2/2007	1b	6.7%	1.0904	post	**Y**	Ksat sample: U1b-S24TR
10/3/2007	1mix	9.8%	1.1884	post	N	Ksat sample: U1mix-S03
10/3/2007	1b	22.2%	1.0877	post	N	Ksat sample: U1b-S25
10/3/2007	1b	16.7%	1.1331	post	**Y**	Ksat sample: U1b-S27TR
10/3/2007	1b	5.9%	1.3492	post	N	Ksat sample: U1b-S29
10/3/2007	1b	5.5%	1.2759	post	N	Ksat sample: U1b-S31
10/3/2007	1b	9.4%	1.1041	post	N	Ksat sample: U1b-S33
10/9/2007	1b	5.7%	1.3328	post	**Y**	Ksat sample: U1b-S35TR
10/9/2007	1b	4.6%	1.3684	post	N	Ksat sample: U1b-S37
10/9/2007	1b	5.3%	1.3936	post	**Y**	Ksat sample: U1b-S39TR
10/9/2007	1b	4.5%	1.3531	post	N	Ksat sample: U1b-S41
10/9/2007	1b	5.3%	1.2901	post	N	Ksat sample: U1b-S43
10/9/2007	2	5.3%	1.1408	post	N	Ksat sample: U2-S01
10/9/2007	2	5.7%	1.4056	post	**Y**	Ksat sample: U2-S03TR
10/9/2007	2	25.7%	0.7326	post	**Y**	Ksat sample: U2-S05TR
10/9/2007	2	8.5%	0.8989	post	N	Ksat sample: U2-S07
10/10/2007	2	16.9%	0.7797	post	**Y**	Ksat sample:U2-S08TR, Coarse soil; no ball
10/10/2007	2	12.3%	0.9411	post	N	Ksat sample: U2_S09, Coarse soil; no ball
11/14/2007	1mix	12.2%	1.1785	post	N	BD, Ksat sample: U1mix-S06
11/14/2007	1b	13.4%	1.2404	post	N	BD, Ksat sample: none
11/14/2007	1a	14.3%	1.2546	post	N	BD, Ksat sample: none
11/14/2007	1a	11.5%	1.3766	post	**Y**	BD, Ksat sample: 5 meters from U1a-S08
11/14/2007	1a	9.3%	1.0981	post	N	BD, Ksat sample: U1a-S10
11/14/2007	4a	12.9%	1.2984	post	N	BD, Ksat sample: U4a-S14
11/14/2007	4a	14.2%	1.1501	post	N	BD, Ksat sample: U4a-S16
11/14/2007	4a	16.2%	0.9383	post	N	BD, Ksat sample: U4a-S17
11/14/2007	2	18.9%	1.2951	post	N	BD, Ksat sample: U2-S16
11/14/2007	2	33.7%	0.7085	post	N	BD, Ksat sample: U2-S22
11/14/2007	5a	6.2%	1.2666	post	N	BD, Ksat sample: U5a-S07
11/14/2007	5a	12.7%	1.1359	post	N	BD, Ksat sample: none
11/15/2007	2	29.3%	1.0631	post	N	BD, Ksat sample: U2-S23

11/15/2007	2	28.2%	0.8037	post	N	BD, Ksat sample: U2-S24
11/15/2007	2	22.5%	0.9821	post	N	BD, Ksat sample: U2-S25
11/15/2007	2	47.0%	0.4087	post	N	BD, Ksat sample: U2-S26, much fine roots and some larger roots (one 1/4 in dia x 1in)
11/15/2007	2	17.4%	1.1780	post	N	BD, Ksat sample: U2-S27
11/15/2007	2	8.3%	1.3334	post	N	BD, Ksat sample: U2-S28
11/15/2007	2	8.1%	1.3246	post	N	BD, Ksat sample: none

Appendix A-2: Saturated Hydraulic Conductivity Raw Data for Treatment Units

Date	Unit	Change in Water Level	Time (s)	Ksat (in/hr)	Pre/Post	Notes
8/2/2007	1 mix	0.10	94.00	0.80	pre	live/ dead tree mix
8/2/2007	1 mix	0.10	95.00	0.80	pre	fireweed, grasses, currants, live and dead lodgepole pine
8/2/2007	1 mix	0.10	90.00	0.84	pre	grasses, forbes, live and dead lodgepole pine
8/6/2007	1 mix	0.10	32.33	2.34	pre	near old (former) stream channel; grassy, middle of few lodgepole, live and dead lodgepole mix
8/6/2007	1 mix	0.10	25.33	2.98	pre	live and dead lodgepole mix in a grassy area
8/6/2007	1 mix	0.10	22.00	3.44	pre	live and dead lodgepole mix in a grassy area
6/20/2007	1B	0.1	22.3	3.39	pre	
6/20/2007	1B	0.2	26.5	5.71	pre	
7/11/2007	1B	0.20	17.50	8.64	pre	light vegetative cover of forbs
7/11/2007	1B	0.20	11.00	13.75	pre	
7/11/2007	1B	0.40	11.67	25.91	pre	In a willow patch
7/11/2007	1B	0.20	10.33	14.64	pre	
7/11/2007	1B	0.20	17.00	8.89	pre	
7/11/2007	1B	0.20	21.30	7.10	pre	Thick willow area 2-3 ft. tall
7/11/2007	1B	0.20	10.00	15.12	pre	tall dense grass area, soil has very dense roots, few scattered willows
7/11/2007	1B	0.20	21.00	7.20	pre	
7/11/2007	1B	0.10	23.00	3.29	pre	in willows (2-3 ft. tall)
7/11/2007	1B	0.10	40.67	1.86	pre	
7/11/2007	1B	0.20	29.67	5.10	pre	in willows (2-3 ft. tall)
7/11/2007	1B	0.20	11.33	13.35	pre	
7/25/2007	1B	0.10	17.67	4.28	pre	fireweed patch at dead lodgepoles, grasses
7/25/2007	1B	0.10	53.33	1.42	pre	fireweed patch at dead lodgepoles, grasses
7/25/2007	1B	0.20	51.33	2.95	pre	fireweed patch at dead lodgepoles, grasses
8/2/2007	1B	0.10	80.33	0.94	pre	grass, forbes, edge of willows, standing dead lodgepole
8/2/2007	1B	0.10	48.67	1.55	pre	grass, forbes, standing dead lodgepole pine
8/7/2007	1B	0.10	20.33	3.72	pre	open dead trees, fireweed
8/7/2007	1B	0.10	20.00	3.78	pre	open dead trees, fireweed,much down trees
8/7/2007	1B	0.10	48.67	1.55	pre	open, grassy and fireweed, small firs
8/7/2007	1B	0.10	10.67	7.09	pre	open, much dead and

						downed trees, grassy, dry
8/7/2007	1B	0.10	8.33	9.08	pre	open,dead and downed trees
8/7/2007	1B	0.10	12.00	6.30	pre	open, much dead and downed trees, grasses
7/25/2007	1A	0.10	77.33	0.98	pre	grasses under dense trees (lodgepoles)
7/25/2007	1A	0.10	31.33	2.41	pre	grasses under dense trees (lodgepoles)
7/25/2007	1A	0.10	330.00	0.23	pre	grasses under dense trees (lodgepoles)
7/25/2007	1A	0.10	56.33	1.34	pre	grasses under dense trees (lodgepoles)
7/25/2007	1A	0.20	4.67	32.38	pre	thick grassy meadow with scattered lodgepole, willows
8/9/2007	1A	0.20	8.50	17.79	pre	Edge of meadow thick grasses and sedges, lodgepoles, few willows
8/9/2007	1A	0.10	3.33	22.70	pre	Thick sedges, rushes, nearby willows, lodgepoles
8/9/2007	1A	0.10	55.67	1.36	pre	Edge of meadow, grassy, forbes, willows, lodgepoles
8/9/2007	1A	0.20	70.00	2.16	pre	In grasses next to willows and lodgepoles
8/9/2007	1A	0.20	7.67	19.71	pre	In grasses and sedges by willows and lodgepoles
7/25/2007	5A	0.20	53.33	2.84	pre	edge of meadow/ upland, small lodgepole, narrow strip of lodgepole
7/25/2007	5A	0.50	13.67	27.65	pre	edge of meadow in the strip of young lodgepole
7/25/2007	5A	0.20	18.00	8.40	pre	edge of upland/ meadow, just inside lodgepole stand
7/25/2007	5A	0.10	52.33	1.44	pre	edge of meadow/ lodgepole
8/9/2007	5A	0.10	34.00	2.22	pre	under lodgepoles next to meadow
8/9/2007	5A	0.20	9.33	16.21	pre	UnderJeffery pines near meadow
8/9/2007	5A	0.20	29.67	5.10	pre	In duff under lodgepole/Jjeffery pine mix
8/9/2007	5A	0.10	71.67	1.05	pre	In grasses at edge of meadow near lodgepoles and Jeffery pines
9/25/2007	1a	0.10	9.7	7.82	post	**In track, light slash**
9/25/2007	1a	0.10	6.3	12.10	post	
9/25/2007	1a	0.10	43.3	1.75	post	
9/25/2007	1a	0.10	40.0	1.89	post	
9/25/2007	1a	0.10	66.0	1.15	post	
9/25/2007	1a	0.10	43.3	1.75	post	**In track, moderate slash**
11/13/2007	1a	0.1	126.7	0.60	post	Post-project, grassy, ground wet due to weekend rain/snow
11/13/2007	1a	0.1	64.7	1.17	post	Post-project, grassy, ground wet due to weekend

						rain/snow, 3" pine needle mat
11/13/2007	1a	0.1	245.0	0.31	post	Post-project, grassy, ground wet due to weekend rain/snow, 3" pine needle mat
11/14/2007	1a	0.1	55.0	1.37	post	Post-project, appears undisturbed, pine needle cover
10/2/2007	1b	0.1	46.0	1.64	post	Post-project, undisturbed, moderate grass and forbs, few sticks
10/2/2007	1b	0.1	120.0	0.63	post	Post-project, undisturbed, moderate grass and forbs, downed burned wood around site, few ribes shrubs
10/2/2007	1b	0.1	33.0	2.29	post	Post-project, **in track, light slash layer** over burned ground and fire weed
10/2/2007	1b	0.1	31.0	2.44	post	Post-project, in track (but between tread), relatively undisturbed, very light stick cover on track
10/2/2007	1b	0.1	23.7	3.19	post	Post-project,
10/2/2007	1b	0.1	4.0	18.90	post	Post-project, former stream channel, grassy, undisturbed
10/2/2007	1b	0.1	47.0	1.61	post	Post-project, grass and forb covered
10/2/2007	1b	0.1	145.3	0.52	post	Post-project, **in track , appears to have had pretty heavy slash mat**.
10/3/2007	1b	0.1	94.5	0.80	post	Post-project, grass cover with very light stick slash
10/3/2007	1b	0.1	27.0	2.80	post	Post-project, **in track, no slash mat**, low willows
10/3/2007	1b	0.1	25.3	2.99	post	Post-project, undisturbed, low willows
10/3/2007	1b	0.1	10.0	7.56	post	Post-project, in track but between treads - essentially undisturbed, low willows
10/3/2007	1b	0.1	10.7	7.09	post	Post-project, only lightly disturbed (dragged over), grassy, edge of low willows
10/3/2007	1b	0.1	11.7	6.48	post	Post-project, undisturbed, grass and low willows
10/3/2007	1b	0.1	27.7	2.73	post	Post-project, undisturbed, grass and low willows
10/9/2007	1b	0.1	112.7	0.67	post	Post-project, i**n track, no slash (heavily used)**, moderate grass, edge of willows
10/9/2007	1b	0.1	31.3	2.41	post	Post-project, undisturbed low willow area

10/9/2007	1b	0.1	10.7	7.09	post	Post-project, undisturbed low willow area, few small logs
10/9/2007	1b	0.1	13.0	5.82	post	Post-project, undisturbed low willow area, few small logs
10/9/2007	1b	0.1	14.3	5.28	post	Post-project, undisturbed, low willows, numerous small logs
10/9/2007	1b	0.1	6.3	11.94	post	Post-project, undisturbed, low willows, numerous woody debris
10/9/2007	1b	0.2	12.3	12.34	post	Post-project, dragged area, numerous woody debris, moderate grass, low willows
10/9/2007	1b	0.1	31.4	2.41	post	Post-project, undisturbed , heavy layer of woody debris of small dia., mod. grass
10/9/2007	1b	0.1	124.0	0.61	post	Post-project, dragged area, moderate grass, heavy slash, edge of willows/meadow
10/2/2007	1mix	0.1	83.5	0.91	post	Post-project, lightly dragged over but relatively undisturbed, grassy
10/2/2007	1mix	0.1	114.7	0.66	post	Post-project, in track (but between tread), relatively undisturbed, grassy, few sticks
10/3/2007	1mix	0.1	121.0	0.62	post	Post-project, **in track, moderate stick slash mat**
10/3/2007	1mix	0.1	131.7	0.57	post	Post-project, grass cover, does not appear compacted
11/13/2007	1mix	0.1	136.7	0.55	post	Post-project, grassy, no track, soil wet due to weekend rain/snow
11/13/2007	1mix	0.1	75.0	1.01	post	Post-project, stick and needle duff layer, apprears relatively undisturbed, soil wet due to weekend rain/snow
9/26/2007	5A	0.10	40.7	1.86	post	
9/26/2007	5A	0.10	69.0	1.10	post	
9/26/2007	5A	0.10	104.8	0.72	post	
10/2/2007	5a	0.5	2.0	189.00	post	Post-project, edge of unit next to meadow, light slash, not in track
10/2/2007	5a	0.1	10.0	7.56	post	Post-project, **in track, light to moderate slash mat**, light grass, possibly had heavier slash mat remvoed
10/2/2007	5a	0.1	69.7	1.09	post	Post-project, undisturbed, light grass and forbs, few sticks

11/13/2007	5a	0.1	87.3	0.87	post	Post-project, ~3" pine needle mat, wet soil due to weekend rain/snow, Bulk density sample #U5a-S04 (11-13-07)
11/13/2007	5a	0.1	52.3	1.45	post	Post-project, **in track, moderate slash**, wet soil due to weekend snow/rain
10/3/2007	1b	0.1	52.0	1.45	post	Post-project, **in track, no slash mat,** few sticks, low willows
10/3/2007	1b	0.1	21.3	3.56	post	Post-project, **in track (appears used few times), no slash**, low willows
10/3/2007	1b	0.1	20.0	3.78	post	Post-project, **in track (heavily used), no slash mat**, grass cover
10/9/2007	1b	0.1	17.5	4.32	post	Post-project, **in track, no slash**, few small logs, low willow area
10/1/2007	1a	0.10	37.0	2.04	post	Post-project, **In track, no slash mat**, bare ground
10/1/2007	1b	0.10	68.3	1.11	post	Post-project, **In track, no slash mat**, bare to sparse grass
10/1/2007	1b	0.10	94.0	0.80	post	Post-project, **In track, no slash mat**, bare to sparse grass
10/1/2007	1b	0.10	30.7	2.46	post	Post-project, **In track, no slash mat**, bare w/ few small sticks
10/1/2007	1b	0.10	48.3	1.57	post	Post-project, **In track, no slash mat**, bare to sparse vegetataion
10/1/2007	1b	0.10	138.3	0.55	post	Post-project, **In track, no slash mat**, bare to sparse vegetation and few sticks
10/1/2007	1b	0.10	48.3	1.57	post	Post-project, **In track, no slash mat**, moderate grass cover
10/1/2007	1b	0.10	42.3	1.79	post	Post-project, **In track, no slash mat**, bare to sparse vegetation and few sticks
10/1/2007	1b	0.10	176.0	0.43	post	Post-project, **In track, no slash mat**, mostly bare ground
10/1/2007	1b	0.10	54.0	1.40	post	Post-project, **In track, no slash mat**, bare ground
10/1/2007	1b	0.1	93.0	0.81	post	Post-project, **In track, no slash mat**, bare ground
10/1/2007	1b	0.1	108.7	0.70	post	Post-project, **In track, no slash mat**, mostly bare ground
10/1/2007	1b	0.1	71.3	1.06	post	Post-project, **In track, no slash mat**, mostly bare

						ground
10/1/2007	1b	0.1	33.3	2.27	post	Post-project, **In track, no slash mat**, mostly bare ground, some fireweed and forbs
10/1/2007	1b	0.1	65.3	1.16	post	Post-project, **In track, no slash mat**, mostly bare ground, sparse forbs
10/1/2007	1b	0.1	39.3	1.92	post	Post-project, **In track, no slash mat**, grass cover
10/1/2007	1b	0.1	113.7	0.67	post	Post-project, **In track, no slash mat**, bare soil with grass and forbs, few sticks
6/20/2007	2	0.1	29.67	2.55	pre	
7/11/2007	2	0.20	26.67	5.67	pre	grass at site
7/19/2007	2	0.30	5.00	45.36	pre	grassy, ponderosa pine thicket, many jackstrawed fallen trees
7/19/2007	2	0.20	12.00	12.60	pre	In grasses below trees (lodgepoles)
7/19/2007	2	0.10	10.00	7.56	pre	grassy, thick cover of willows and lodgepole
7/19/2007	2	0.20	13.00	11.63	pre	grassy at edge of willow thicket
7/19/2007	2	0.40	7.67	39.43	pre	grassy, sunny
8/6/2007	2	0.10	35.33	2.14	pre	grassy with lodgepole mixed in
8/6/2007	2	0.10	12.33	6.13	pre	lodgepoles and grassland mix
8/7/2007	2	0.10	183.33	0.41	pre	grassy meadow under lodgepoles, few surrounding willows
8/7/2007	2	0.10	10.00	7.56	pre	grassy under lodgepoles
8/7/2007	2	0.10	8.67	8.72	pre	sedges under dense lodgepole stand, few willows nearby
8/7/2007	2	0.10	6.67	11.33	pre	horsetails under dense lodgepole stand, few willows nearby
8/9/2007	2	0.20	9.00	16.80	pre	Under lodgepoles near meadow
8/9/2007	2	0.10	34.00	2.22	pre	Edge of meadow under lodgepoles, Jeffreys, white fir, short sedge ground cover
6/20/2007	2	0.2	8	18.90	pre	
6/20/2007	2	0.2	15.67	9.65	pre	
6/20/2007	2	0.1	91.67	0.82	pre	
6/20/2007	2	0.1	42	1.80	pre	
8/29/2007	2	0.2	23.67	6.39	pre	
8/29/2007	2	0.1	15	5.04	pre	
8/29/2007	2	0.1	17.67	4.28	pre	

8/29/2007	2	0.1	19	3.98	pre	
8/29/2007	2	0.2	5	30.24	pre	
8/9/2007	2	0.20	15.00	10.08	pre	Grassy, forbes, sedges, willows, live and dead lodgepoles, edge of burn\
8/9/2007	2	0.10	43.67	1.73	pre	Edge of burn and meadow, grasses, sedges, live and dead lodgepoles, few willows, shrubs
10/9/2007	2	0.1	3	25.20	post	Post-project, heavy slash and duff
10/9/2007	2	0.1	64.67	1.17	post	Post-project, Thick tall grass with light slash over it
10/9/2007	2	0.1	31.67	2.39	post	Post-project, **in track, heavy slash mat**
10/9/2007	2	0.1	60	1.26	post	Post-project, heavy stick slash over grass
10/9/2007	2	0.1	32.3	2.34	post	Post-project, grassy area w/ light cover of sticks, appears uncompacted
10/10/2007	2	0.1	136	0.56	post	Post-project, **in track, moderate slash mat**
10/10/2007	2	0.1	74	1.02	post	Post-project, grassy, few branches/slash
10/10/2007	2	0.1	37	2.04	post	Post-project, grassy, appears essentially undisturbed
10/10/2007	2	0.1	75	1.01	post	Post-project, grassy with few dead sticks
10/10/2007	2	0.1	59.67	1.27	post	Post-project, **in track, heavy slash**, sample location in bank of dry "side channel"
10/10/2007	2	0.1	12	6.30	post	Post-project, grassy with small woody debris and needles
10/10/2007	2	0.1	37.33	2.03	post	Post-project, slash covered (sticks of small to medium size - less than 2 inches)
10/10/2007	2	0.1	6	12.60	post	Post-project, thick duff layer
10/10/2007	2	0.1	62	1.22	post	Post-project, **in (secondary) track, moderate slash mat**
10/10/2007	2	0.1	8	9.45	post	Post-project, grassy with few small sticks and needles
10/10/2007	2	0.1	2	37.80	post	Post-project, **in track, no slash, coarse sand**
10/10/2007	2	0.1	16	4.73	post	Post-project, dense, small slash (dead sticks)
11/14/2007	2	0.1	245.0	0.31	post	Post-project, thick slash, appears ndisturbed, rain/snow previous weekend

11/14/2007	2	0.1	24.5	3.09	post	Post-project, appears undisturbed, grass covered, sandy loam top ~ 8"
11/15/2007	2	0.1	376.0	0.20	post	Post-project, undisturbed, rain/snow previous weekend
11/15/2007	2	0.1	45.0	1.68	post	Post-project, rain/snow previous weekend
11/15/2007	2	0.1	65.0	1.16	post	Post-project, rain/snow previous weekend
11/15/2007	2	0.5	3.0	126.00	post	Post-project, rain/snow previous weekend
11/15/2007	2	0.1	53.3	1.42	post	Post-project, rain/snow previous weekend
11/15/2007	2	0.1	8.0	9.45	post	Post-project, rain/snow previous weekend
10/9/2007	2	0.1	19	3.98	post	Post-project, **in track, heavy slash mat**
10/9/2007	2	0.1	6.67	11.33	post	Post-project, **in track (heavily used), light slash mat**, thick grass
10/10/2007	2	0.1	55.67	1.36	post	Post-project, **in (secondary) track, heavy slash mat**
8/7/2007	3	0.10	138.00	0.55	pre	grasses and sedges under lodgepoles, willows nearby
8/7/2007	3	0.10	113.67	0.67	pre	sedges under dense lodgepole stand, appears to be a wet area
7/25/2007	3	0.10	40.33	1.87	pre	In grasses between mixed jeffery and lodgepole pines and creek
7/25/2007	3	0.10	39.33	1.92	pre	in fireweed between jeffery pines and creek
8/1/2007	3	0.10	33.33	2.27	pre	edge of trees (lodgepoles), edge of grass
8/1/2007	3	0.10	32.67	2.31	pre	grassy, lodgepoles
8/1/2007	3	0.10	31.00	2.44	pre	grassy under lodgepoles, near willows
7/25/2007	3	0.10	30.00	2.52	pre	in fireweed between jeffery pines and creek
8/1/2007	3	0.10	28.00	2.70	pre	near creek, grassy, small lodgepole
6/20/2007	3	0.1	23	3.29	pre	
7/25/2007	3	0.10	21.33	3.54	pre	In grasses between jeffery pines and creek
8/1/2007	3	0.10	16.67	4.54	pre	grassy under lodgepoles
8/1/2007	3	0.10	15.00	5.04	pre	grassy under lodgepoles and downed logs
8/7/2007	3	0.10	15.00	5.04	pre	sedges and grasses under lodgepoles, willows nearby
6/20/2007	3	0.2	19	7.96	pre	
8/1/2007	3	0.10	6.67	11.33	pre	grassy under lodgepoles
8/1/2007	3	0.40	12.67	23.87	pre	near creek, grassy, small

						lodgepole
8/1/2007	3	0.50	5.00	75.60	pre	grassy under lodgepoles, near willows
8/13/2007	3	0.10	12.00	6.30	pre	Moderate canopy of lodgepole pine, white fir, grassy with shallow duff ground cover, ~10 m to creek; soil: light sandy loam, no ball, dry
8/13/2007	3	0.10	16.67	4.54	pre	Open edge of white fir, lodgepole pine, Jeffrey pines, anderson thistles, grassy ground cover
8/13/2007	3	0.10	50.00	1.51	pre	Grasses, horsetails, currants under dead/ live lodgepoles; soil: forms weak ball, light soil, moist
8/2/2007	4B	0.10	36.67	2.06	pre	thick with white fir and some lodgepole
8/2/2007	4B	0.10	10.33	7.32	pre	dense live white fir with jeffery pine, lodgepole pine, duff and dead wood on ground
8/2/2007	4B	0.10	55.00	1.37	pre	dense trees, white firs and jeffery pines
8/13/2007	4B	0.10	68.67	1.10	pre	near creek, heavy canopy of lodgepole, fir, Jeffrey; soil: light-medium, dry to slightly moist, no ball
8/13/2007	4B	0.10	19.00	3.98	pre	~10 m to creek, heavy canopy of white fir, lodgepole, Jeffrey pine, numerous downed logs, duff ground cover; soil: light/medium, dry/slightly moist, no ball
8/13/2007	4B	0.10	37.33	2.03	pre	~6 m from creek, heavy canopy of white fir, jeffrey pine, lodgepole pine, thick duff ground cover; soil: light, dry/slightly moist, no ball
8/13/2007	3	0.10	280.00	0.27	pre	In grasses, some horsetail and currants under dead lodgepoles; water moved very slowly
8/16/2007	3	0.10	20.33	3.72	pre	Moderate canopy of lodgepole pine, few willows, thick grassy ground cover; soil: light sandy loam, no ball, (no B.D. done)
8/16/2007	3	0.10	87.00	0.87	pre	Open canopy of lodgepole pine, thick grassy groundcover with forbes; soil: light sandy loam, no

						ball, (no B.D. done)
8/16/2007	3	0.20	16.67	9.07	pre	Open canopy of lodgepole pine, edge of flat to slope, grassy ground cover with forbes; soil: light sandy loam, no ball, (no B.D. done)
8/16/2007	3	0.20	9.67	15.64	pre	Moderate canopy of lodgepole pine, thick grassy ground cover with forbes; soil: coarse loamy sand, no ball, (no B.D. done)
8/16/2007	3	0.10	330.00	0.23	pre	Moderate canopy of lodgepole pine, willows, thick sedge groundcover with forbes; soil: wet soil, light sandy loam, forms ball, holds together, can squeeze out free water, (no B.D. done)
8/16/2007	3	0.10	74.00	1.02	pre	Moderate canopy of lodgepole pine, willows, thick sedge groundcover, ~5m from slope in flat area; soil: wet soil, light sandy loam, forms ball, holds together, can squeeze out free water
8/16/2007	3	0.10	22.67	3.33	pre	Drier uplands, still in lodgepole; soil: dry, no ball, fine grain, light soil, operable
8/16/2007	3	0.10	29.33	2.58	pre	Drier uplands, still in lodgepole; soil: dry, no ball, fine grain silty sand, light soil, operable
8/16/2007	3	0.50	5.33	70.92	pre	Drier uplands, still in lodgepole; soil: dry, no ball, very fine grain silty sand, coarse soil, operable
8/16/2007	3	0.20	5.33	28.37	pre	Small patch of lodgepole, ~2m east of creek bed, grassy, feels soft and wet; soil: moist, light sandy soil, no ball, operable
8/16/2007	3	0.10	21.33	3.54	pre	Edge of lodgepoles (toward creek), grassy, some willows; soil: sandy (coarse) keeps sloughing back into hole, moved about 5 m S.E, very moist, forms ball, light, **not operable**
8/16/2007	3	0.10	60.00	1.26	pre	Upland, but still in lodgepole (in little draw);

						soil: dry, no ball, very fine grain silty sand, light soil, operable
8/16/2007	3	0.10	16.67	4.54	pre	Upland edge of lodgepole; soil: dry, no ball, very fine silty sand, light soil, operable
8/16/2007	3	0.10	19.67	3.84	pre	Upland edge of lodgepole, edge of grass; soil: dry, no ball, very fine silty sand, light soil, operable
8/20/2007	3	0.10	14.00	5.40	pre	Open canopy of live and dead lodgepole, grassy with forbes ground cover; soil: light, slightly moist, no ball (no B.D. done), operable
8/20/2007	3	0.10	30.67	2.46	pre	Moderate canopy of lodgepole, Jeffrey pine, grassy with forbes, horsetails groundcover; soil: slightly moist, no ball, light soil, fine sandy loam, contains gravel to 1" diameter, (no B.D. done), operable
8/20/2007	3	0.10	31.33	2.41	pre	Open canopy of lodgepole, Jeffrey pine, duff, grass, forbes groundcover; soil: slightly moist, light soil, no ball, fine grain sandy loam, operable
8/20/2007	3	0.10	60.33	1.25	pre	Moderate canopy of lodgepole pine, willows, thick grassy groundcover, ~ 3-4 m from creek (dry) channel; soil: slightly moist, light to coarse, coarse sand, sandy loam, operable
8/20/2007	3	0.10	20.00	3.78	pre	Moderate canopy of lodgepole, duff, light grass, forb groundcover, ~10 m from dry creek channel; soil: dry, light soil, no ball, sandy loam, operable
8/20/2007	3	0.10	20.00	3.78	pre	Open canopy of lodgepole, Jeffrey pine, duff with light grass, horsetail groundcover, ~9 m from dry creek channel; soil: slightly moist, light soil, no ball, fine sandy loam, operable
8/20/2007	3	0.10	36.33	2.08	pre	Moderate canopy of lodgepole, Jeffrey pine, duff with sparse grass, horsetail groundcover, ~10 m from

						dry creek; soil: light, fine sandy loam, dry, no ball, operable
8/20/2007	3	0.1	15	5.04	pre	In light grasses and duff below moderate canopy of lodgepole and few white firs; soil: light soil, dry, no ball, fine sandy loam, operable
8/20/2007	3	0.1	48	1.58	pre	In light grasses under lodgepole and Jeffrey pines; soil: fine sandy loam, slightly moist, no ball, light, operable
8/20/2007	3	0.1	4	18.90	pre	In grasses, open canopy surrounded by lodgepole; soil: coarse loamy sand, dry, no ball, operable
8/20/2007	3	0.2	26	5.82	pre	In grasses and forbes under moderate canopy of lodgepole; soil: coarse, loamy sand, dry, no ball, operable
8/20/2007	3	0.2	5.33	28.37	pre	light sedges and duff on edge of lodgepole thicket, moderate canopy; soil: light soil, sandy loam, forms weak ball, falls apart, non operable
9/18/2007	3	0.10	75.33	1.00	post	in track
9/18/2007	3	0.10	15.33	4.93	post	in track
9/18/2007	3	0.10	21.33	3.54	post	in track
9/18/2007	3	0.10	27.80	2.72	post	in track
9/18/2007	3	0.10	20.33	3.72	post	in track
9/18/2007	3	0.10	12.40	6.10	post	in track
9/18/2007	3	0.10	4.00	18.90	post	in track
9/18/2007	3	0.10	56.40	1.34	post	in track
9/18/2007	3	0.10	35.33	2.14	post	in track
9/18/2007	3	0.10	28.75	2.63	post	in track
9/18/2007	3	0.10	31.67	2.39	post	in track
9/18/2007	3	0.10	21.00	3.60	post	in track
9/18/2007	3	0.10	59.33	1.27	post	in track
9/18/2007	3	0.10	38.67	1.96	post	in track
9/18/2007	3	0.10	96	0.79	post	in track
9/18/2007	3	0.10	11.67	6.48	post	in track
9/18/2007	3	0.10	23.33	3.24	post	in track
9/18/2007	3	0.10	59.00	1.28	post	in track
9/18/2007	3	0.10	19.67	3.84	post	in track
9/18/2007	3	0.10	46.67	1.62	post	in track
9/18/2007	3	0.10	29.00	2.61	post	in track
9/20/2007	3	0.10	180.00	0.42	post	in track
9/20/2007	3	0.10	90.00	0.84	post	in track

9/20/2007	3	0.10	82.67	0.91	post	in track
9/20/2007	3	0.10	15.75	4.80	post	in track
9/20/2007	3	0.10	20.67	3.66	post	in track
9/20/2007	3	0.10	36.00	2.10	post	in track
7/25/2007	4A	0.10	17.00	4.45	pre	under lodgepoles near edge of burned trees
7/25/2007	4A	0.10	24.00	3.15	pre	grassy open area
8/1/2007	4A	0.50	4.33	87.30	pre	grassy with aspen and mixed aged lodgepole pine and white fir
8/1/2007	4A	0.10	13.33	5.67	pre	grassy with small aspen, live lodgepole pine, white fir, jeffery pine (mixed age)
8/1/2007	4A	0.10	23.00	3.29	pre	grass and forbes with fairly dense lodgepole pine, white fir, aspen; approx. 4m from creek
8/1/2007	4A	0.20	3.33	45.41	pre	grassy with live lodgepole pine, white fir, aspen
8/13/2007	4A	0.10	19.67	3.84	pre	In young aspen stand, soil: light, very fine grain, no ball, dry/slightly moist
8/14/2007	4A	0.50	9.67	39.09	pre	In grasses near young aspens, ~6 m from creek; light soils, fine sandy loam, slightly moist, no ball
8/14/2007	4A	0.50	10.67	35.43	pre	In duff under aspen stand, near Jeffrey pines; coarse sand at surface, coarse, dry, no ball
8/14/2007	4A	0.50	5.33	70.92	pre	In duff under aspen stand with Jeffrey pines nearby; coarse sand at surface, coarse, dry, no ball
8/14/2007	4A	0.10	13.33	5.67	pre	In grasses and duff below lodgepoles and Jeffrey pines near aspen stand; dry, light soils, no ball
8/14/2007	4A	0.10	10.67	7.09	pre	In duff and some woodchips under lodgepoles near fallen lodgepoles; fine grain, light soils, dry, no ball
8/14/2007	4A	0.10	4.33	17.46	pre	In sedges under a lodgepole at edge of meadow, willows nearby; coarse, dry, no ball
8/14/2007	4A	0.10	5.67	13.33	pre	In duff and few sedges below lodgepoles near meadow; light soils with organic matter, dry, no ball
8/1/2007	4A	1.00	5.00	151.20	pre	grassy under aspens and few lodgepoles near open meadow
9/26/2007	4a	0.2	3.3	46.52	post	

9/26/2007	4a	0.2	3.0	50.40	post	
9/26/2007	4a	0.1	11.4	6.63	post	
9/26/2007	4a	0.1	45.0	1.68	post	
9/26/2007	4a	0.1	35.7	2.12	post	**in track, heavy slash**
9/26/2007	4a	0.1	25.5	2.96	post	
9/26/2007	4a	0.1	13.6	5.56	post	
9/26/2007	4a	0.1	166.7	0.45	post	
9/26/2007	4a	0.1	96.0	0.79	post	
9/26/2007	4a	0.1	22.7	3.33	post	
11/14/2007	4a	0.1	157.5	0.48	post	Post-project, soil appears undisturbed, snow/rain previous weekend
11/14/2007	4a	0.1	49.0	1.54	post	Post-project, in aspens, undisturbed soil,
11/14/2007	4a	0.2	3.3	45.82	post	Post-project, coarse sand upper ~8", more loamy below
11/14/2007	4a	0.1	9.0	8.40	post	Post-project, in aspens, upper ~6" coarse sand, loam beneath
11/14/2007	4a	0.5	7.0	54.00	post	Post-project, in aspens, coarse sand, very rapid infiltration
9/26/2007	4a	0.2	4.0	37.80	post	in track, moderate slash
9/26/2007	4a	0.1	101.7	0.74	post	in track, very light slash
9/26/2007	4a	0.1	104.0	0.73	post	in track, moderate slash

Appendix A-3: Soil Cover Raw Data

Date	Unit	Slope%	Cover %	Depth of Organic Layer	Notes	
8/29/2007	3	0	100	3	Pre-project	
8/29/2007	3	1	100	2	Pre-project	
8/29/2007	3	0	100	3	Pre-project	
8/29/2007	3	1	90	1	Pre-project	
8/29/2007	3	1	80	1	Pre-project	
8/29/2007	3	1	100	3	Pre-project	
8/29/2007	3	0	100	3	Pre-project	Squeeze test
8/29/2007	3	0	100	3	Pre-project	
8/29/2007	3	2	100	2	Pre-project	
8/29/2007	3	1	100	3	Pre-project	
8/29/2007	3	2	100	2	Pre-project	
8/29/2007	3	0	100	3	Pre-project	Squeeze test
8/29/2007	3	1	100	2	Pre-project	
8/29/2007	3	0	100	3	Pre-project	
8/29/2007	3	1	70	1	Pre-project	
8/29/2007	3	0	100	2	Pre-project	
8/29/2007	3	0	100	3	Pre-project	Squeeze test
8/29/2007	3	0	100	3	Pre-project	
8/29/2007	3	0	100	3	Pre-project	Squeeze test
8/29/2007	3	0	100	3	Pre-project	
8/29/2007	3	0	100	4	Pre-project	Squeeze test
8/29/2007	3	0	100	4	Pre-project	
8/29/2007	3	0	100	4	Pre-project	Squeeze test
8/29/2007	3	5	100	3	Pre-project	
8/29/2007	3	2	100	3	Pre-project	
8/29/2007	3	3	100	2	Pre-project	
8/29/2007	3	1	100	2	Pre-project	
8/29/2007	4a	0	100	2	Pre-project	
8/29/2007	4a	0	100	1	Pre-project	
8/29/2007	4a	0	100	3	Pre-project	Squeeze test
8/29/2007	4a	0	100	2	Pre-project	
8/29/2007	4a	0	100	3	Pre-project	
8/29/2007	4a	0	100	2	Pre-project	
8/29/2007	4a	0	100	2	Pre-project	Squeeze test
8/29/2007	4a	0	100	2	Pre-project	

8/29/2007	4a	0	100	3	Pre-project	
8/29/2007	4a	0	100	2	Pre-project	
8/29/2007	4a	0	100	4	Pre-project	
8/29/2007	4a	0	100	3	Pre-project	
8/29/2007	1mix	0	100	3	Pre-project	Squeeze test
8/29/2007	1mix	0	100	3	Pre-project	
8/29/2007	1mix	0	100	3	Pre-project	Squeeze test
8/29/2007	1mix	0	100	3	Pre-project	
8/29/2007	1mix	0	100	3	Pre-project	Squeeze test
8/29/2007	1mix	0	100	2	Pre-project	
8/29/2007	1mix	0	100	2	Pre-project	
8/29/2007	1mix	0	100	3	Pre-project	Squeeze test
8/29/2007	1mix	0	60	1	Pre-project	
8/29/2007	1mix	0	100	2	Pre-project	
8/29/2007	1mix	0	100	3	Pre-project	Squeeze test
9/4/2007	1b	0	100	3	Pre-project	
9/4/2007	1b	0	100	3	Pre-project	Squeeze test
9/4/2007	1b	0	60	1	Pre-project	
9/4/2007	1b	0	100	3	Pre-project	
9/4/2007	1b	0	100	3	Pre-project	
9/4/2007	1b	0	100	2	Pre-project	
9/4/2007	1b	0	100	3	Pre-project	Squeeze test
9/4/2007	1b	0	80	1	Pre-project	
9/4/2007	1b	0	100	2	Pre-project	
9/4/2007	1b	0	90	1	Pre-project	
9/4/2007	1b	0	100	3	Pre-project	
9/4/2007	1b	0	100	3	Pre-project	
9/4/2007	1b	0	100	3	Pre-project	
9/4/2007	1b	0	100	4	Pre-project	Squeeze test
9/4/2007	1b	2	100	3	Pre-project	
9/4/2007	1b	1	80	1	Pre-project	
9/4/2007	1b	0	100	2	Pre-project	
9/4/2007	1b	1	70	1	Pre-project	
9/4/2007	1b	0	100	2	Pre-project	
9/4/2007	1b	0	100	4	Pre-project	Squeeze test
9/4/2007	1b	0	100	3	Pre-project	
9/4/2007	1b	0	100	4	Pre-project	
9/4/2007	1b	0	90	1	Pre-project	
9/4/2007	1b	0	100	3	Pre-project	Squeeze test

9/4/2007	4b	1	100	3	Pre-project	
9/4/2007	4b	0	100	3	Pre-project	Squeeze test
9/4/2007	4b	1	100	4	Pre-project	
9/4/2007	4b	0	100	2	Pre-project	
9/4/2007	4b	1	100	3	Pre-project	Squeeze test
9/4/2007	4b	1	100	4	Pre-project	
9/4/2007	4b	2	100	3	Pre-project	
9/4/2007	4b	3	100	3	Pre-project	
9/4/2007	4b	3	100	3	Pre-project	
9/4/2007	4b	2	100	3	Pre-project	
9/4/2007	1a	0	100	3	Pre-project	
9/4/2007	1a	0	100	3	Pre-project	Squeeze test
9/4/2007	1a	0	100	4	Pre-project	
9/4/2007	1a	0	100	4	Pre-project	Squeeze test
9/4/2007	1a	0	100	4	Pre-project	
9/4/2007	1a	0	100	3	Pre-project	Squeeze test
9/4/2007	1a	0	100	3	Pre-project	
9/4/2007	1a	0	100	4	Pre-project	
9/4/2007	1a	0	100	4	Pre-project	Squeeze test
9/4/2007	1a	0	100	3	Pre-project	
9/4/2007	5a	0	100	3	Pre-project	Squeeze test
9/4/2007	5a	0	90	1	Pre-project	
9/4/2007	5a	1	100	2	Pre-project	
9/4/2007	5a	2	100	2	Pre-project	
9/4/2007	5a	1	100	3	Pre-project	Squeeze test
9/4/2007	5a	0	100	3	Pre-project	
9/20/2007	3	3	100	3	Post-project	
9/20/2007	3	0	100	1	Post-project	
9/20/2007	3	3	100	2	Post-project	
9/20/2007	3	2	100	4	Post-project	
9/20/2007	3	0	90	3	Post-project	
9/20/2007	3	0	100	4	Post-project	
9/20/2007	3	2	80	2	Post-project	
9/20/2007	3	1	100	1	Post-project	
9/20/2007	3	1	100	2	Post-project	
9/20/2007	3	1	80	1	Post-project	
9/20/2007	3	1	95	2	Post-project	
9/20/2007	3	1	100	5	Post-project	
9/20/2007	3	1	90	1	Post-project	

9/20/2007	3	1	100	2	Post-project	
9/20/2007	3	2	100	4	Post-project	
9/20/2007	3	2	60	3	Post-project	
9/20/2007	3	1	80	1	Post-project	
9/20/2007	3	2	100	2	Post-project	
9/20/2007	3	1	80	1	Post-project	
9/20/2007	3	1	100	3	Post-project	
9/20/2007	3	1	100	3	Post-project	
9/20/2007	3	1	100	6	Post-project	
9/20/2007	3	1	100	5	Post-project	
9/20/2007	3	1	80	3	Post-project	
9/20/2007	3	1	100	4	Post-project	
9/20/2007	3	1	100	4	Post-project	
9/20/2007	3	1	100	3	Post-project	
9/20/2007	4b	1	100	6	Post-project	
9/20/2007	4b	0	80	2	Post-project	
9/20/2007	4b	0	100	4	Post-project	
9/20/2007	4b	1	95	5	Post-project	
9/20/2007	4b	1	80	4	Post-project	
9/20/2007	4b	2	95	4	Post-project	
9/20/2007	4b	3	100	6	Post-project	
9/20/2007	4b	2	100	4	Post-project	
9/20/2007	4b	3	100	3	Post-project	
9/25/2007	1a	0	100	2	Post-project	
9/25/2007	1a	0	100	0.5	Post-project, **In track, light slash**	
9/25/2007	1a	0	100	1.5	Post-project	
9/25/2007	1a	0	100	1.5	Post-project	
9/25/2007	1a	0	100	2	Post-project	
9/25/2007	1a	0	100	3	Post-project,	
9/25/2007	4a	0	100	1	Post-project	
9/25/2007	4a	0	100	1.5	Post-project, **in track, moderate slash**	
9/25/2007	4a	0	100	3	Post-project, **in track, moderate slash**	
9/25/2007	4a	0	90	2	Post-project	
9/26/2007	4a	0	100	8	Post-project	
9/26/2007	4a	0	100	8	Post-project, **in track, heavy slash**	

9/26/2007	4a	0	100	2	Post-project	
9/26/2007	4a	0	60	0.5	Post-project, **in track, very light slash**	
9/26/2007	4a	0	100	2	Post-project, **in track, moderate slash**	
9/26/2007	4a	0	30	0.5	Post-project	
9/26/2007	4a	0	90	0.5	Post-project	
9/26/2007	4a	0	100	2	Post-project	
9/26/2007	4a	0	100	3	Post-project	
9/26/2007	5a	2	100	3	Post-project, **in track, moderate slash**	
9/26/2007	5a	1	70	1	Post-project	
9/26/2007	5a	2	100	2	Post-project, **in track, moderate slash**	
10/1/2007	1a	0	40	0 - .5	**In track**	**no slash**
10/1/2007	1b	0	50	0 - 1	**In track**	**no slash**
10/1/2007	1b	0	70	0 - 1	**In track**	**no slash**
10/1/2007	1b	0	30	0	**In track**	**bare w/ few small sticks**
10/1/2007	1b	0	20	0	**In track**	**bare w/ sparse grass**
10/1/2007	1b	0	50	0 - 1	**In track**	**bare w/ sparse grass and few sticks**
10/1/2007	1b	0	60	0 - 1	**In track**	**bare w/ grass cover**
10/1/2007	1b	0	60	0 - 1	**In track**	**bare w/ sparse grass and few sticks**
10/1/2007	1b	0	20	0	**In track**	**no slash, mostly bare ground**
10/1/2007	1b	0	0	0	**In track**	**no slash, bare soil**
10/1/2007	1b	0	10	0	**In track**	**no slash, mostly bare soil**
10/1/2007	1b	0	40	0 - .5	**In track**	**no slash, mostly bare soil**
10/1/2007	1b	0	10	0	**In track**	**no slash, mostly bare soil**
10/1/2007	1b	0	20	0 - .5	**In track**	**no slash, mostly bare soil, sparse veg**
10/1/2007	1b	0	30	0 - .5	**In track**	**no slash, mostly bare soil, sparse veg, few sticks**
10/1/2007	1b	0	100	1	**In track**	**no slash, w/ grass covered**
10/1/2007	1b	0	50	0 - .5	**In track**	**no slash, some grass and forbs, few sticks**
10/2/2007	5a	0	90	1	Light slash and light grass	
10/2/2007	5a	0	90	0 - 2	**in track, w/ light slash** and light grass	
10/2/2007	5a	1	100	1 - 2	undisturbed with few sticks	

10/2/2007	1b	0	100	2	undisturbed, moderate grass and few sticks	
10/2/2007	1b	0	100	2	undisturbed, moderate grass and few sticks	
10/2/2007	1b	0	100	2	**in track, light slash**	
10/2/2007	1b	0	70	1	in track (but between tread)	
10/2/2007	1b	0	80	1		
10/2/2007	1b	0	100	2 - 3	fomer stream channel, grassy	
10/2/2007	1b	0	100	2	grass and forb cover	
10/2/2007	1b	0	100	2	**in track with heavy slash mat**	
10/2/2007	1mix	0	100	2	lightly dragged over, relatively undisturbed	
10/2/2007	1mix	0	100	2.5	in track (but between tread), relatively undisturbed	
10/3/2007	1mix	0	100	3	**In track, moderate stick slash mat**, grass cover	
10/3/2007	1mix	0	100	2	grass cover	
10/3/2007	1b	0	100	3	grass cover with stick slash	
10/3/2007	1b	0	90	1	**In track, no slash mat**, low willows	
10/3/2007	1b	0	100	1	**In track, no slash mat**, few sticks, low willows and grass	
10/3/2007	1b	0	100	1	low willows	
10/3/2007	1b	0	100	1	in tracks but between treads- relatively undisturbed	
10/3/2007	1b	0	90	0.5	**in tracks (appears lightly used), no slash**, low willows	
10/3/2007	1b	0	80	0.5	light disturbance (dragged over), edge of low willows	
10/3/2007	1b	0	90	0.5	grass and low willows	

10/3/2007	1b	0	100	0.5	grass and low willows	
10/3/2007	1b	0	100	1.5	**In track (heavily used), no slash mat**	
10/9/2007	1b	0	90	0.5	Post-project, **in track, no slash**, BD#14	
10/9/2007	1b	0	90	0.5	Post-project, low willows	
10/9/2007	1b	0	100	0.5	Post-project, low willows, few sm. logs, BD#15	
10/9/2007	1b	0	100	0.5	Post-project, low willows, few sm. logs	
10/9/2007	1b	0	80	0.5	Post-project, **in track, no slash**, BD#16TR, low willows, few small logs	
10/9/2007	1b	0	100	0.5	Post-project, low willows, numerous woody debris	
10/9/2007	1b	0	100	0.5	Post-project, low willows, numerous woody debris, BD#17	
10/9/2007	1b	0	100	2	Post-project, low willows, numerous woody debris, moderate grass	
10/9/2007	1b	0	100	10	Post-project, thick layer of woody debris, moderate grass, BD#18	
10/9/2007	1b	0	100	3	Post-project, thick layer slash, moderate grass	
10/9/2007	2	0	100	4	Post-project, thick slash layer (dead woody debris) and duff, BD#01	
10/9/2007	2	0	100	5	Post-project, thick grass w/ light slash on top	
10/9/2007	2	0	100	3	Post-project, **in track, heavy slash mat** (dead sticks and green branches), BD#02TR	

10/9/2007	2	0	100	3	Post-project, **in track, heavy slash mat** (dead sticks and green branches)	
10/9/2007	2	0	90	1	Post-project, **in track (heavily used), light slash**, grass, BD#03TR	
10/9/2007	2	0	100	8	Post-project, slash (dead sticks)	
10/9/2007	2	0	100	3	Post-project, moderate grass with dead sticks on top BD#04	
10/10/2007	2	0	90	2	Post-project, in track, appears moderate slash, BD sample #05	
10/10/2007	2	0	100	2	Post-project, grassy, few sticks, BD sample #06	
10/10/2007	2	0	100	2	Post-project, grass, appears essentially undisturbed	
10/10/2007	2	0	100	5	Post-project, grass, few woody debris	
10/10/2007	2	0	100	1.5	Post-project, in (main) track, heavy slash mat	
10/10/2007	2	0	100	3	Post-project, in (secondary) track, heavy slash mat	
10/10/2007	2	0	100	5	Post-project, grass with needles/small sticks	
10/10/2007	2	0	100	5	Post-project, small slash	
10/10/2007	2	0	100	3	Post-project, thick duff layer	
10/10/2007	2	0	70	0.5	Post-project, in (secondary) track, moderate slash	
10/10/2007	2	0	90	1.5	Post-project, grass, few needles and small sticks	
10/10/2007	2	0	40	0.5	Post-project, in track, no slash, very sandy (coarse)	

10/10/2007	2	0	100	3	Post-project, dense layer of small slash and duff	
12/5/2007	3	5	95	3	Post-project	
12/5/2007	3	1	95	5	Post-project	
12/5/2007	3	0	100	4	Post-project	
12/5/2007	3	0	100	4	Post-project	
12/5/2007	3	0	85	2	Post-project	
12/5/2007	3	0	100	2	Post-project	
12/5/2007	3	5	100	2	Post-project	
12/5/2007	3	2	100	1	Post-project	
12/5/2007	3	2	100	3	Post-project	
12/5/2007	3	1	95	2	Post-project	
12/5/2007	3	1	85	0.5	Post-project	
12/5/2007	3	1	90	3	Post-project	
12/5/2007	3	1	100	4	Post-project	
12/5/2007	3	1	85	2	Post-project	
12/5/2007	3	2	95	1	Post-project	
12/5/2007	3	2	95	4	Post-project	
12/5/2007	3	2	100	3	Post-project	
12/5/2007	3	2	100	3	Post-project	
12/5/2007	3	1	100	6	Post-project	
12/5/2007	3	1	100	3	Post-project	
12/5/2007	3	1	100	8	Post-project	
12/5/2007	3	0	80	2	Post-project	
12/5/2007	3	0	100	2	Post-project	
12/5/2007	3	0	100	2	Post-project	
12/5/2007	4b	0	100	2	Post-project	
12/5/2007	4b	1	100	3	Post-project	
12/5/2007	4b	0	100	5	Post-project	
12/5/2007	4b	2	100	6	Post-project	
12/5/2007	4b	2	100	8	Post-project	
12/5/2007	4b	5	80	3	Post-project	

Appendix A-4: Saturated Hydraulic Conductivity Raw Data for Landings and Access Roads

Date	Unit	Change in Water Level	Time (s)	Ksat (in/hr)	Notes
10/15/2007	acc. Rd off Pioneer	0.1	600	0.13	90% coverage, wood chips/few pine needles, depth ~1"
10/15/2007	acc. Rd off Pioneer	0.1	600	0.13	100% coverage, wood chips/few pine needles, depth ~2"
10/11/2007	acc. Rd off Pioneer	0.1	90	0.84	100% coverage, wood chips and needles, avg. depth ~ .5 in
10/11/2007	acc. Rd off Pioneer	0.1	188	0.40	Post-project, 50% coverage, wood chips and needles, avg. depth < .5 in
10/11/2007	acc. Rd off Pioneer	0.1	495	0.15	Post-project, 90% coverage, wood chips, avg. depth ~ 1 in
10/11/2007	acc. Rd off Pioneer	0.1	203	0.37	Post-project, 40% coverage, sparse pine needles, avg. depth < .5 in
10/11/2007	acc. Rd off Pioneer	0.1	270	0.28	Post-project, 60% coverage, pine needles, avg. depth < .5 in
10/11/2007	acc. Rd off Pioneer	0.1	248	0.30	Post-project, 70% coverage, wood chips, avg. depth ~ .5 in
10/11/2007	acc. Rd off Pioneer	0.1	81.67	0.93	Post-project, 100% coverage, wood chips, avg. depth ~ 3 in
10/11/2007	acc. Rd off Pioneer	0.1	195	0.39	Post-project, 40% coverage, light wood chips and needles, avg. depth ~ .5 in
10/15/2007	acc. Rd off Pioneer	0.1	196.7	0.38	Post-project, 70% coverage, light wood chips and needles, avg. depth ~ .5 in
10/15/2007	acc. Rd off Pioneer	0.1	244.67	0.31	Post-project, 75% coverage, light wood chips and needles, avg. depth ~ .5 in
10/15/2007	acc. Rd off Pioneer	0.1	121.33	0.62	Post-project, 70% coverage, light wood chips and needles, avg. depth ~ .5 in
10/11/2007	acc. Rd off Al tahoe	0.1	33.25	2.27	Post-project, zero % compacted sand soil
10/11/2007	acc. Rd off Al tahoe	0.1	27.33	2.77	Post-project, 10% coverage, sparse wood chips, sandy soil
10/11/2007	acc. Rd off Al tahoe	0.1	25.33	2.98	Post-project, 100% coverage, wood chips, avg. depth ~ 1.5 in
10/11/2007	acc. Rd off Al tahoe	0.1	33.67	2.25	Post-project, 75% coverage, wood chips, avg. depth ~ .5 in
10/11/2007	acc. Rd off Al tahoe	0.1	16.33	4.63	Post-project, 75% coverage, wood chips, avg. depth ~ 1 in
10/11/2007	acc. Rd off Al tahoe	0.1	20.67	3.66	Post-project, 90% coverage, wood chips, avg. depth ~ .5 in
10/11/2007	acc. Rd off Al tahoe	0.1	23.67	3.19	Post-project, 50% coverage, wood chips, avg. depth ~ .5 in
10/11/2007	acc. Rd off Al tahoe	0.1	38	1.99	Post-project, 95% coverage, wood chips, avg. depth ~ 1 in
10/11/2007	acc. Rd off Al tahoe	0.1	26.67	2.83	Post-project, 80% coverage, wood chips, avg. depth ~ 1 in

10/11/2007	acc. Rd off Al tahoe	0.1	23.33	3.24	Post-project, 70% coverage, wood chips, avg. depth ~ 1 in
10/11/2007	acc. Rd off Al tahoe	0.1	16.67	4.54	Post-project, 70% coverage, wood chips, avg. depth ~ .5 in
10/15/2007	landing off Pioneer Tr.	0.1	28.67	2.64	
10/15/2007	landing off Pioneer Tr.	0.1	36	2.10	80% coverage, wood chips/few pine needles, depth ~0.5"
10/15/2007	landing off Pioneer Tr.	0.1	34.67	2.18	90% coverage, wood chips/few pine needles, depth ~1"
10/15/2007	landing off Pioneer Tr.	0.1	41.67	1.81	100% coverage, wood chips/few pine needles, depth ~1"
10/15/2007	landing off Pioneer Tr.	0.1	34.67	2.18	100% coverage, wood chips/few pine needles, depth ~1"
10/15/2007	landing off Pioneer Tr.	0.1	58.67	1.29	95% coverage, mostly very fine/decomposing organic matter, depth ~1"
10/15/2007	landing off Pioneer Tr.	0.1	39	1.94	100% coverage, wood chips/few pine needles, depth ~1.5"
10/15/2007	landing off Pioneer Tr.	0.1	86.67	0.87	100% coverage, wood chips/few pine needles, depth ~1.5"
10/15/2007	landing off Pioneer Tr.	0.1	69.3	1.09	100% coverage, wood chips/few pine needles, depth ~1.5"
10/15/2007	landing off Pioneer Tr.	0.1	63	1.20	100% coverage, wood chips/few pine needles, depth ~1.5"