Homewood Mountain Resort Annual Report
Restoration and Monitoring
2007 – 2008

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EXECUTIVE SUMMARY

Homewood Mountain Resort lies in one of the most erosive and heavily impacted watersheds in the Lake Tahoe Basin. Homewood has made significant watershed improvements over the last two seasons (2006-2007) through road restoration and monitoring. Six road restoration projects, ranging in size from 3,500 ft^2 to 48, 300 ft^2, were completed, for a total of over 105,000 ft^2 or 2.4 acres of restoration. Variations of 'full treatment', which includes soil loosening, amendment incorporation, application of fertilizer, native seed, and mulch, were implemented at each site, based on site-specific needs. A wide range of monitoring techniques, including rainfall and runoff simulations, soil density, soil moisture, and surface and vegetative cover and composition, were conducted.

Erosion control capacity, which was quantified through monitoring, increased significantly after treatments. Sediment yield was reduced by 7 to 16 times, while penetrometer depths increased on average by 4.3 times. Specific amendment types were compared, and it was found that 6 inches of woodchips, compared to 2 or 4 inches, reduced soil density, which may increase infiltration. The combination of compost and tub grindings produced higher nutrients than tub grindings alone or woodchips alone. These nutrients are an index of sustainability and can indicate the potential for increased plant cover and desirable composition, as well as increased infiltration and sediment reduction. The information gained from current and future monitoring of restoration sites is essential to provide Homewood with the most current, site-specific, and cost-effective techniques for further restoration.

INTRODUCTION

Homewood Mountain Resort is a ski area located on the west shore of Lake Tahoe in the town of Homewood, California (Figure 1). Integrated Environmental Restoration Services (IERS) has been working with Homewood Mountain Resort for two consecutive seasons, beginning in 2006, to decommission and restore roads that are no longer necessary for mountain operations. During the 2006 season, several different treatment designs were implemented throughout the mountain. These treatments were monitored in 2006 and 2007 to provide IERS and Homewood Mountain Resort with site-specific treatment recommendations to reduce costs, increase infiltration and control sediment movement. This information will be used as the foundation for an area-wide road removal and restoration program. Treatment planning and implementation has been coordinated with both the Tahoe Regional Planning Agency (TRPA) and Lahontan Regional Water Quality Control Board staff in order to allow for maximum agency feedback.

This report describes restoration completed in 2006 and 2007 for Homewood Mountain Resort. After background on the Homewood Mountain environment and sites are presented, this report outlines the project goals for each road restoration. All the treatment techniques and materials are explained, and the plot design and treatments for sites completed in 2006 and 2007 is presented. Next, the monitoring data is presented and discussed. Finally, future treatment specifications are recommended based on the monitoring results.

PROJECT OVERVIEW

The restoration completed in 2006 by IERS included the treatment of three areas: Lower Lombard, Site 31, and Site 37 (Phase I). The 2007 restoration included the removal and treatment of four roads: Creek Road, Rainbow Ridge Road, Wedding Road, and Site 37 (Phase II). All sites treated in 2006 and 2007 were monitored before treatment began, and each site will be monitored for at least one year after treatment is complete. The monitoring data collected to date and future data collected will help determine appropriate, site specific and cost effective treatments for future restoration work at Homewood Mountain Resort.

OVERALL SITE DESCRIPTION

Homewood Mountain Resort is situated in a steep, densely forested mountain environment on the west shore of Lake Tahoe, California (Figure 1). The soil is generally derived from andesitic parent material and mixed glacial outwash, with a relatively high amount of fine clay and silt size particles. Elevations range from 6,230-7,880 feet above mean sea level (AMSL). The vegetation at Homewood is typical of similar environments on the west shore of Lake Tahoe. At elevations below 7,000 feet the over-story is dominated by Jeffrey pine (*Pinus jeffreyi*) and white fir (*Abies concolor*) with some sugar pine (*Pinus lambertiana*) and incense cedar (*Calocedrus decurrens*). Stands dominated by red fir (*Abies magnifica*) and mountain hemlock (*Tsuga mertensiana*) are present at the higher elevations especially on north facing slopes. Due to the dense, often overstocked nature of the forest, there is little understory in many places. The dominant understory shrubs are tobacco brush (*Ceanothus velutinus)* and mountain whitethorn (*Ceanothus cordulatus*). Green leaf manzanita (*Arctostaphylos patula*), huckleberry oak (*Quercus vaccinifolia*), and squaw carpet (*Ceanothus prostratus*) are also present. Willow species including Scouler's willow (*Salix scouleriana*) and shining willow (*Salix lucida* ssp. *lasiandra*) predominate in the wetter areas such as seeps and drainages. In the open areas and on ski runs, there are a wide variety of native grasses and forbs present in addition to shrubs, with lupine (*Lupinus sp*) and coyote mint (*Monardella odoratissima*) as the dominant forbs. Many of the ski runs were at one time seeded with a mixture of wheatgrasses (*Agropyron* species).

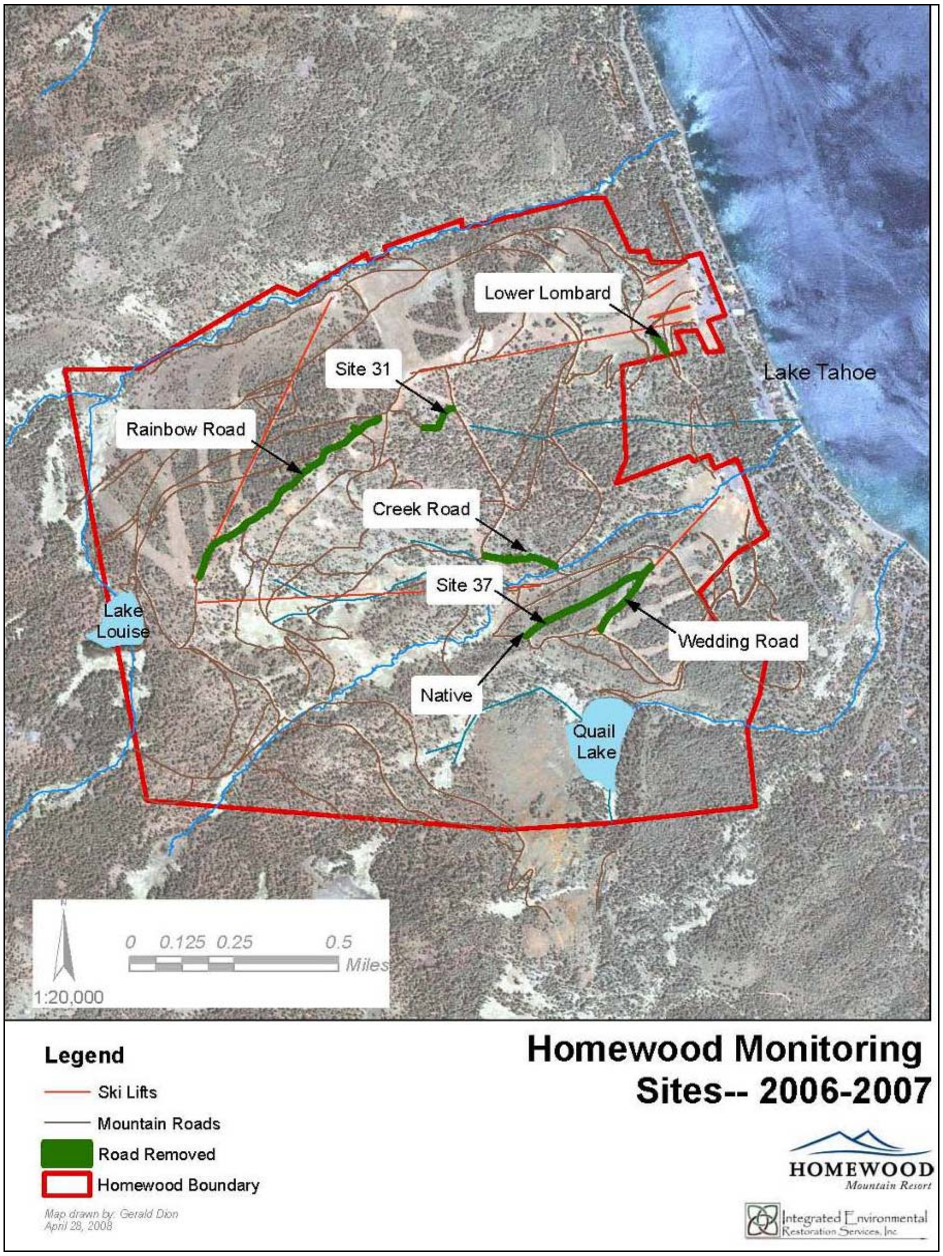

Figure 1. Homewood Restoration and Monitoring Sites, 2006-2007.

PROJECT GOALS

The goals of the road restoration treatment projects and monitoring during 2006 and 2007 were to:

1. Increase watershed function through soil and plant community restoration

2. reduce erosion potential through: increasing infiltration, reducing soil compaction, increasing mulch cover and plant cover, and creating proper nutrient cycling to sustain the plant cover in the long-term
3. monitor each treatment area to determine the level of effectiveness of the range of treatments and determine the most cost effective restoration techniques
4. use this information to develop a long-term treatment strategy for Homewood Mountain Resort

RESTORATION TREATMENT TECHNIQUES, MATERIALS, AND PURPOSES

Road Re-contouring

Re-contouring old road beds re-establishes natural slope contours and drainage patterns. Depending on slope, road width and other site conditions, this is accomplished by pulling material from the fill slopes into the road cross-section and/or importing fill material such that the original or pre-disturbance slope contour and configuration is restored. Re-contouring aids in stabilizing disturbed soils by decreasing or eliminating the steep angles of cut slopes and fill slopes where they meet the road. It also restores disrupted surface and subsurface hydrologic patterns so that roads no longer capture, concentrate and convey runoff. This process also improves the appearance of restored areas.

Soil Loosening (Tilling, Ripping, or Targeted Loosening)

Soil loosening removes compaction from the soil before seeding, fertilizing, and mulching and is performed with an excavator capable of mixing the soil with the applied amendment (Figure 2 and Figure 3). Soil loosening increases infiltration rates, thereby decreasing runoff and the associated sediment transport. An excavator bucket is used for tilling, while the tines attached to the excavator bucket are used for ripping. Soils that are tilled versus ripped have a higher degree of mixing. In targeted loosening, the tines on an excavator bucket are used to loosen areas around established vegetation. The soil is not mixed, like in tilling or ripping, just loosened. Targeted loosening is used to loosen dense soil without disturbing well established shrub or tree roots.

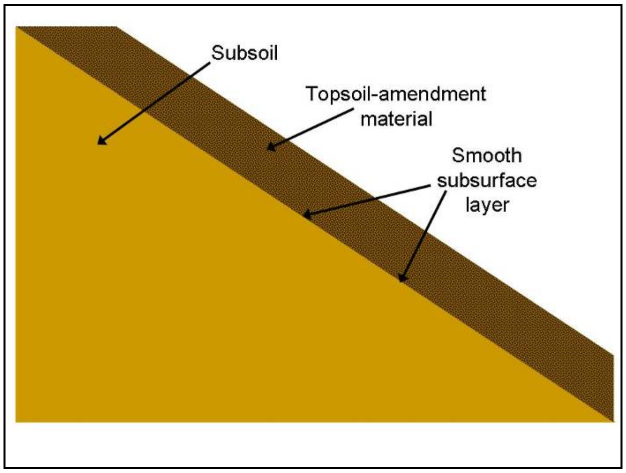

Figure 2. Amendment application.

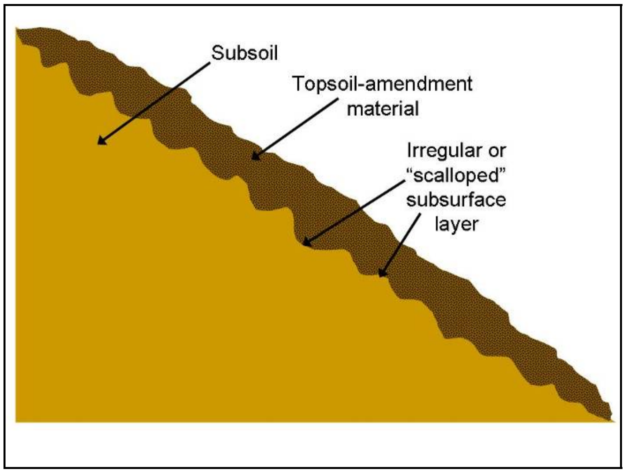

Figure 3. Soil loosening.

Amendments

Amendments are applied to the soil surface in an even layer before tilling. The addition of wood chips, tub grindings, or compost adds organic matter to the soil, which is necessary to create a soil environment in which a healthy microbial community can develop to create the long-term nutrient cycling necessary to support native vegetation over time. Each amendment adds a different amount of nutrients. Soils are tested pre-treatment to determine which amendment will be most successful at a given site.

Biosol

Biosol is an organic slow release fertilizer. It is applied to the soil surface and incorporated into the top 1-2 inches of the soil. The nutrients present in Biosol are released much more gradually than with other commercial fertilizers, providing a more gradual and long-term source of nutrients for the native perennial species.

Seed

Seed is applied to the soil and raked lightly to a ¼ inch under the surface. Only native, perennial seeds (Table 1) are applied since these plants provide a high level of soil stabilization due to their deep root systems. The IERS Upland seed mix was modified for each site based on seed availability. A large proportion of the seed mix consists of grass seeds, which not only have the densest root system of the herbaceous species, but are also part of the natural successional process towards a mature tree and shrub-dominated community.

Table 1. IERS Upland Seed Mix

Common Name	*Scientific Name*	% in Seed Mix
Squirreltail	*Elymus elymoides*	30.5%
Mountain Brome (Bromar)	*Bromus carinatus*	28.8%
Blue Wildrye (Stan 5000)	*Elymus glaucus*	21.8%
Bitterbrush	*Purshia tridentata*	8.7%
Blue Wildrye (Eldorado)	*Elymus glaucus*	6.1%
Greenleaf Manzanita	*Ceanothus velutinus*	1.3%
Sulfur flower buckwheat	*Eriogonum umbellatum*	1.3%
Wax currant	*Ribes cereum*	1.2%
Basin Big Sagebrush	*Artemisia tridentata*	0.2%

Mulch

All types of native mulch have been shown to increase infiltration and reduce sediment transport, when applied consistently over the treated areas. Mulch also decreases evaporation from the soils and contributes to long-term nutrient cycling. The mulch type varied between the treatments. Pine needles, wood chips, and tub grindings were all used.

SITE DESCRIPTIONS

This section contains site descriptions, specific restoration goals and treatment information for each site.

Site 31

Site 31 was a road previously used for tree removal. It had a shallow layer of surface woodchips (less than 1 inch), two water bars, and very little vegetation before treatment. It is located in a mixed conifer forest, with white fir as the dominant over-story species. The understory consists of whitethorn and coyote mint. The site has a slight slope of 8 degrees, faces east, and sits at approximately 7,107 feet above mean sea level (AMSL, Figure 4 and Figure 5).

Site 31 Project Goals

The main goal at Site 31 is to reduce sediment movement and surface erosion by incorporating organic matter and applying fertilizer, native seed, and mulch. It is also important to initiate a successional process that lead to diverse, mid-seral, and self-sustaining native grass and shrub plant communities. Variations in amendment depth and mulch type were tested to determine whether differences exist in either soil density, plant cover, or mulch cover.

Site 31 Treatment Description

Site 31 is 6,180 square feet and was divided into three plots, 1, 2, and 3, with 3 sub-plots within each plot (A, B, and C). Each plot is approximately 2,060 square feet divided into three equally sized sub-plots (Figure 4).

Plots 1, 2, and 3 each has a different type of mulch applied, either wood chips, tub grinding, or pine needles. Each of the three plots was then divided again into three sub-plots, measuring approximately 687 square feet each. Each of the sub-plots has a different rate of woodchip amendment applied: two, four, or six inches. The treatment for each plot is shown in **Table 2**.

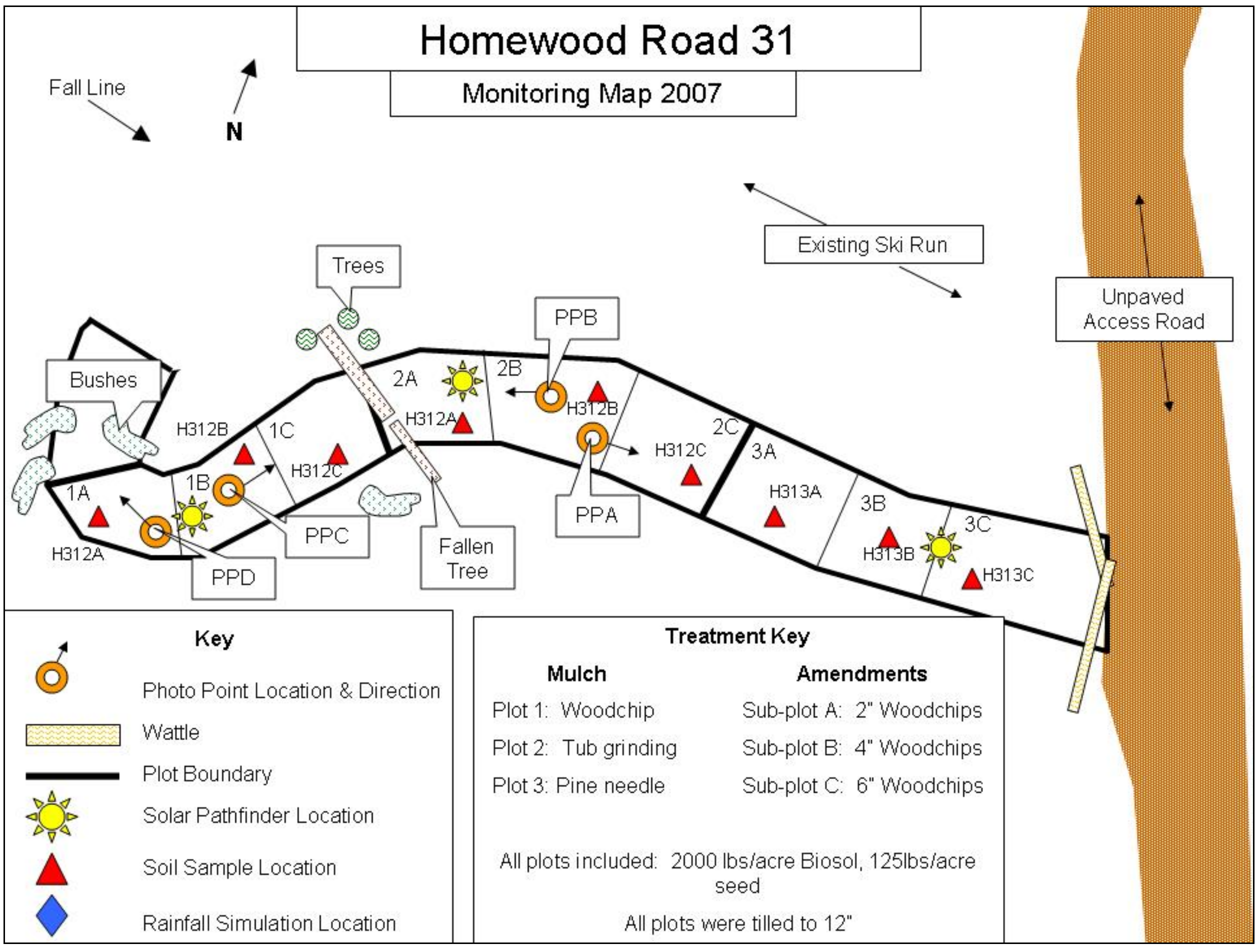

Figure 4. Site 31 Treatment and Monitoring Map. This old road was divided into 3 plots with different mulch types, which were sub-divided into 3 different treatment areas (sub-plots) with different amendment rates.

Table 2. Treatment information for Site 31.

	Amendment depth (inches)	Amendment type	Biosol (lbs/acre)	Seed (lbs/acre)	Mulch (type)	Tilling (inches)
1A	2	woodchips	2000	125	woodchip	12
1B	4	woodchips	2000	125	woodchip	12
1C	6	woodchips	2000	125	woodchip	12
2A	2	woodchips	2000	125	tub grinding	12
2B	4	woodchips	2000	125	tub grinding	12
2C	6	woodchips	2000	125	tub grinding	12
3A	2	woodchips	2000	125	pine needle	12
3B	4	woodchips	2000	125	pine needle	12
3C	6	woodchips	2000	125	pine needle	12

Figure 5, Figure 6, and Figure 7 show Site 31 during treatment and post-treatment.

Figure 5. Site 31, before treatment.

Figure 6. Site 31, after treatment.

Figure 7. Site 31, one season after treatment. Grass is beginning to grow.

Lower Lombard

Lower Lombard, at an elevation of 6,370 feet AMSL, is an old access road that connects the ski trail Lombard Street with maintenance building AA (Figure 8). Pre-treatment, Lower Lombard had large rills running the entire length of the slope, which were a result of water erosion (Figure 9).

Figure 8. Lower Lombard site location.

This road has an average slope of 13 degrees and faces south-east. It is much steeper at the top than at the bottom. The surrounding vegetation includes white fir-dominated forest with an understory of greenleaf manzanita, Scouler's willow, tobacco brush, and snow berry. The canopy cover along the road is approximately 30%.

Figure 9. Water channeling path that caused erosion at the Lower Lombard site. Blue line represents the water pathway.

Lower Lombard Project Goals

The main goal at Site 31 is to reduce sediment movement and surface erosion by incorporating organic matter and applying fertilizer, native seed, and mulch. It is also important to initiate a successional process that lead to diverse, mid-seral, and self-sustaining native grass and shrub plant communities. The amendment types were varied between two treatment areas to determine whether there is an improvement in soil nutrient status.

Lower Lombard Treatment Description

The Lower Lombard site covers approximately 3,500 square feet. The site was divided into two plots: plot A and plot B (Figure 10). Plot A, which is approximately 1,167 square feet in area is at the top of the road. Plot B occupies the lower two thirds of the site and is approximately 2,333 square feet in area.

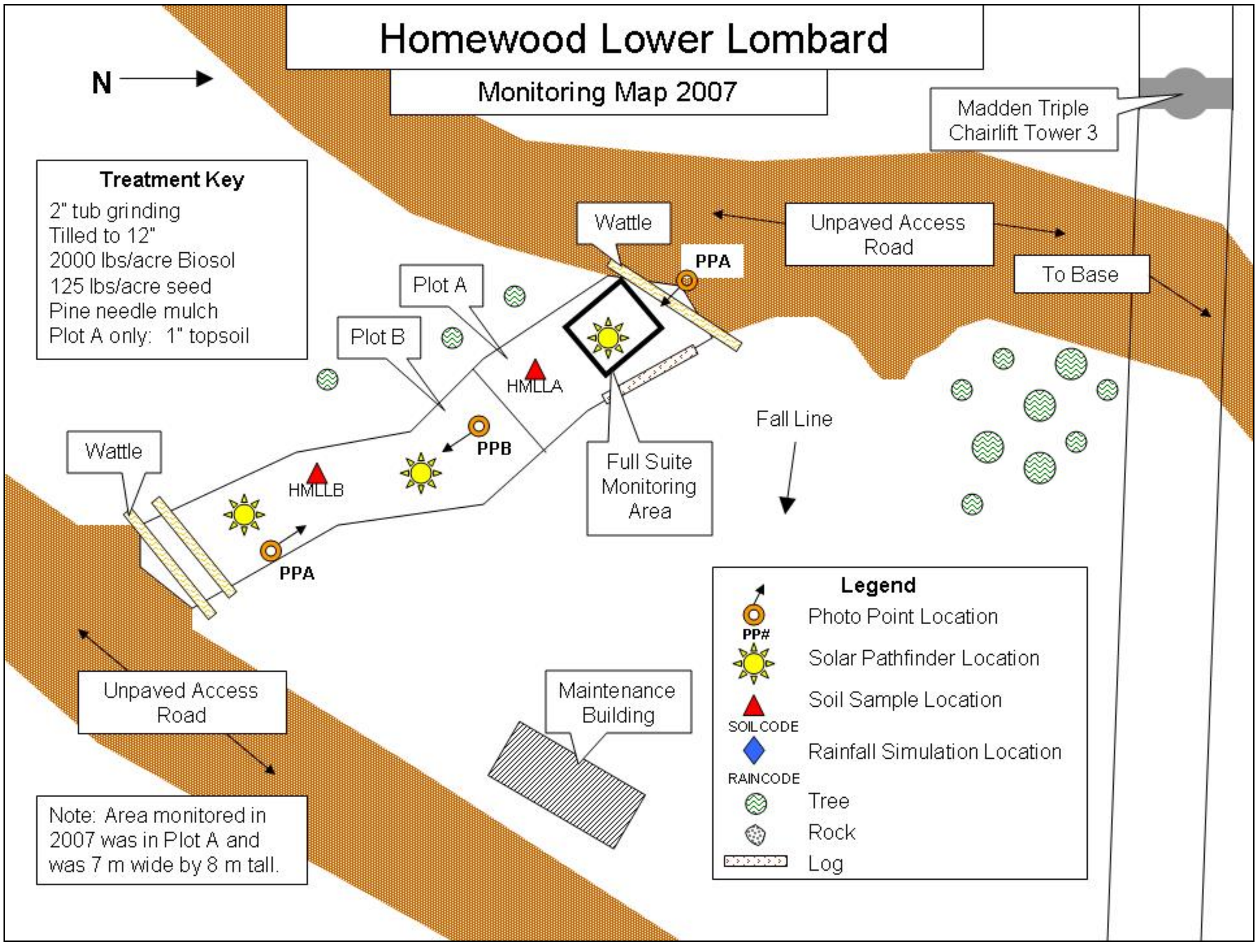

Figure 10. Map of Lower Lombard. Plot A had 1 inch of compost applied in addition to the standard treatment.

The entire area was re-contoured to match natural slope angles. Two inches of tub grindings were spread over both plots and material similar to compost (a blend of organic materials prepared at the Truckee Teichert yard) was then spread one inch thick over Plot A. The tub grindings and/or the compost material was tilled 12” into the soil using the bucket of a mini excavator. Biosol was then applied to the surface of the treatment area at a rate of 2,000 lbs/acre and was hand raked to 1-2 inches below the soil surface. The IERS Upland seed mix was applied at a rate of 125 lbs/acre (Table 1) and was lightly raked approximately ¼ inch into the soil with a spring rake. Pine needle mulch was hand applied to both plots to an average depth of 2 inches and ground coverage of 98%. Figure 11, Figure 12, and Figure 13 show the site pre-treatment, directly after treatment, and one season after treatment.

Figure 11. Lower Lombard pre-treatment. Vegetation is not present and the soil is highly compacted.

Figure 12. Lower Lombard post-treatment. Slope was re-contoured to match natural slope angle and woody debris and large rocks were added.

Figure 13. Lower Lombard one season after treatment. Native grass growth is visible

<u>Site 37</u>

Site 37 Description

Site 37, at an elevation of 6,992 feet above AMSL, is an old road near the top of Overload ski run. It runs eastward across the Shortcut and Drainpipe ski runs and is approximately one hundred vertical feet below the top of Quail Chair. This road is nearly flat and is north facing. Mature vegetation exists on and surrounding the road and consists mainly of white fir, mountain whitethorn, greenleaf manzanita, and tobacco brush.

Site 37 Project Goal

The main goal at Site 37 is to determine whether there is an improvement in infiltration capacity and hydrologic function when an abandoned roadbed with mature vegetation is mowed and the soil is mechanically loosened using the targeted loosening method. Treatment variations in seeding and amendments were applied to determine whether differences existed.

Site 37 Treatment Description

A different approach was taken at Site 37 than at many other Homewood restoration sites. Mature vegetation was already present, but site 37 lacked the capacity for infiltration since penetrometer depths were extremely shallow pre-treatment, indicating high soil compaction. Preservation of the mature shrubs was important during the restoration process. First, the mature shrubs along the road were mowed to a height of approximately 3 inches and the chips were left on-site. A total of 24 plots with four different treatments were applied to site 37 (Figure 14). Each treatment included targeted soil loosening and the addition of Biosol organic fertilizer. Seed was added to select plots (Table 3 and

Table 4). Targeted loosening was chosen for this site to leave the root structure of the established shrubs intact. The treatments used in addition to targeted loosening and Biosol incorporation are shown in Table 3. Large pieces of woody debris were then spread across the road site to discourage vehicular or pedestrian traffic. The total treatment area was approximately 15,500 square feet.

Table 3. Site 37 Treatment Definitions

Map Code	Treatments in addition to targeted loosening and Biosol addition.
A	Tub grindings and seed
B	Tub grindings
C	Seed
D	No additional treatment

Table 4. IERS Upland Seed Mix, modified for Site 37. This mix was also used at Creek Road.

Common Name	*Scientific Name*	% in Seed Mix
Squirreltail	*Elymus elymoides*	26.64%
Mountain Brome (Bromar)	*Bromus carinatus*	15.57%
Blue Wildrye (Stan 5000)	*Elymus glaucus*	16.13%
Bitterbrush	*Purshia tridentata*	8.37%
Blue Wildrye (High Elevation)	*Elymus glaucus*	15.57%
Greenleaf Manzanita	*Ceanothus velutinus*	0.7%
Sulfur flower buckwheat	*Eriogonum umbellatum*	3.12%
Wax currant	*Ribes cereum*	1.13%

Figure 14 shows the layout of the treatment area. Most of the treatments were completed in 2007; however, a small section at the northeast end was completed in 2006.

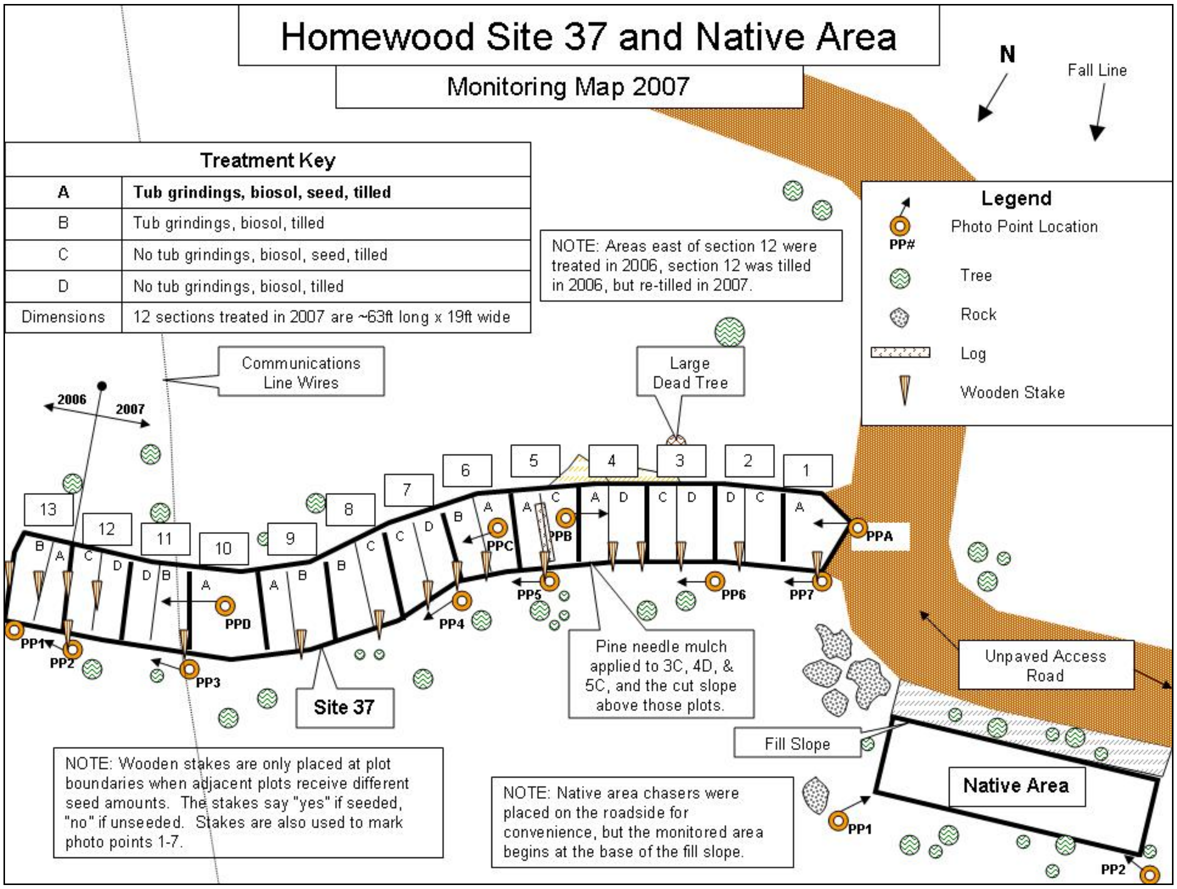

Figure 14. Site 37 Treatment Map.

Figure 15, Figure 16, Figure 17, and Figure 18 show each stage during the site 37 treatment

Figure 15. Site 37 pre-treatment

Figure 16. Site 37 after mowing and amendment application

Figure 17. Site 37, after targeted loosening

Figure 18. Site 37, one season after treatment

Creek Road

Creek Road Description

Creek Road, at an elevation of 6,882 feet above AMSL, is an old road near the bottom of the Ellis chair (Figure 19). The top of creek road intersects with the Smooth Cruise ski run and the bottom intersects a mountain road. This road has a slight slope and faces west. Mature vegetation surrounds the treatment area and consists mainly of white fir (*Abies concolor*), whitethorn (*Ceanothus cordulatus*), alpine prickly currant (*Ribes montigenum*), and pinemat manzanita (*Arcostaphylos nevadensis*). Some native forbs and grasses were also present.

Creek Road Project Goal

The Creek Road project goals are restore an abandoned roadbed, to improve infiltration capacity and hydrologic function, and to initiate a successional process that leads to a diverse native grass and shrub plant community through amendment incorporation, fertilizer, native seed, and mulch addition.

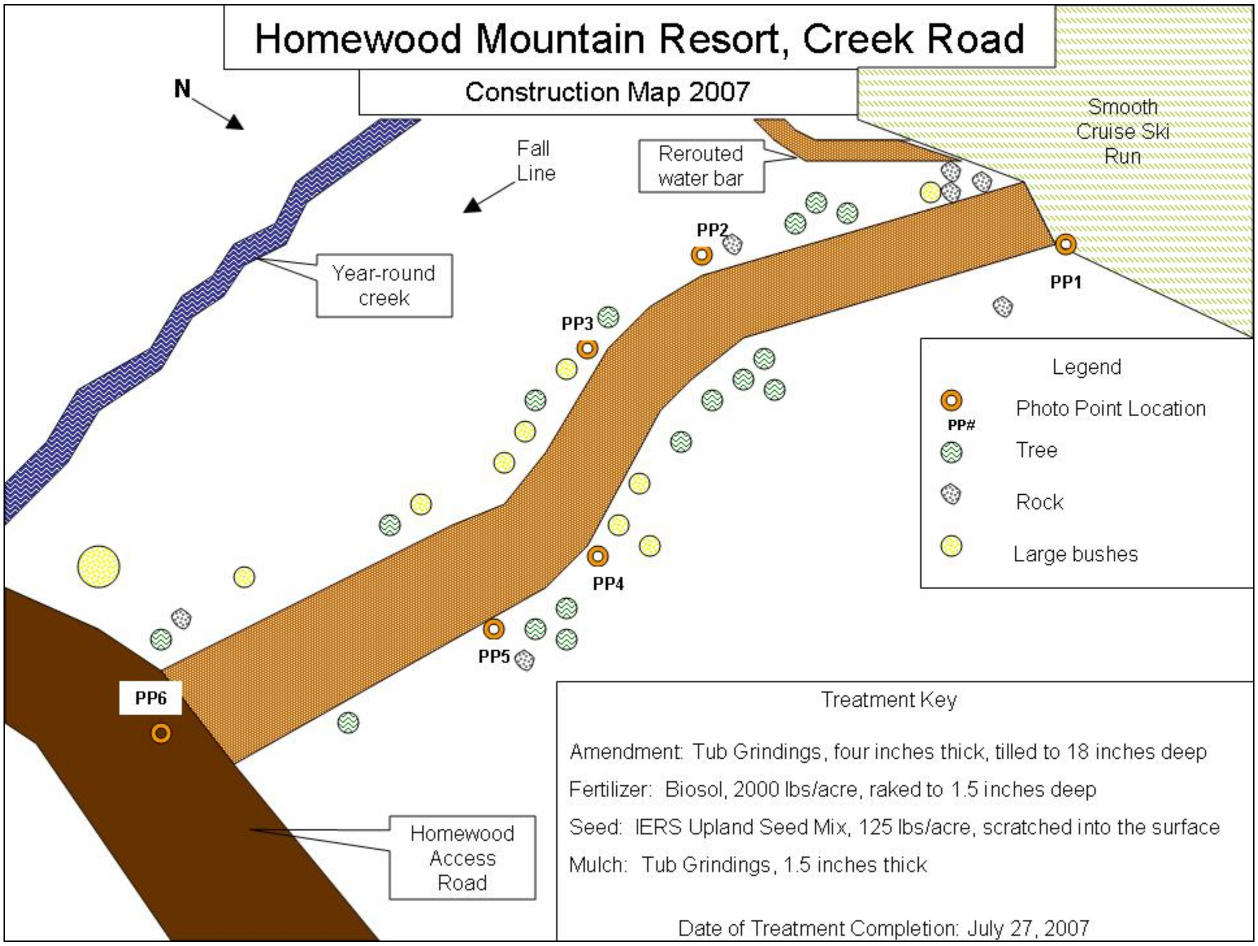

Figure 19. Creek Road Treatment Map.

Creek Road Treatment Description

The Creek Road treatment was consistent over the entire length of the road. Figure 19 shows the layout of the treatment area. All treatments were completed in 2007. Treatment included, tilling 4 inches of tub grindings to 18 inches, 2,000 lbs/acre of Biosol, 125 lbs/acre of native seed, and 1 inch of tub grinding mulch (Table 5).

Figure 20 and Figure 21 show each stage during the Creek Road treatment

Figure 20. Creek Road pre-treatment

Figure 21. Creek Road post-treatment

Table 5. Treatment for Creek Road.

Treatments		
Amendment	Type	Tub grindings
	Depth	4 inches
Tilling	Type	Excavator till
	Depth	18 inches
Fertilizer	Type	Biosol
	Rate	2000 lbs/acre
Seed	Mix	IERS upland mix
	Rate	125 lbs/acre
Mulch	Type	Tub grindings
	Depth	1 inch
Dimensions in ft^2		11,400 square feet

Rainbow Road

Rainbow Road Description

Rainbow Road, at an elevation of 7,338 feet above AMSL, is a decommissioned that runs down the Rainbow Ridge ski run (Figure 22). The road has an average slope of 13 degrees and faces northwest. Mature vegetation surrounds the road and consists mainly of white fir (*Abies concolor*), pinemat manzanita (*Arcostaphylos nevadensis*), mountain pennyroyal (*Monardella odoratissima*), and lupine (*Lupinus* sp.)

Rainbow Road Project Goal

The Rainbow Road project goals are restore an abandoned roadbed, to improve infiltration capacity and hydrologic function, and to initiate a successional process that leads to a diverse native grass and shrub plant community through amendment incorporation, fertilizer, native seed, and mulch addition.

Rainbow Road Treatment Description

Figure 22 shows the layout of the treatment area. The entire treatment was completed in 2007. Treatments included tilling 4 inches of tub grindings to 18 inches, 2,000 lbs/acre of Biosol, 125 lbs/acre of native seed, and 2 inches of pine needle mulch (Table 7).

Table 6. IERS Upland Seed Mix, modified for Rainbow Road.

Common Name	*Scientific Name*	% in Seed Mix
Squirreltail	*Elymus elymoides*	27.26%
Mountain Brome (Bromar)	*Bromus carinatus*	23.35%
Blue Wildrye (Stan 5000)	*Elymus glaucus*	16.51%
Bitterbrush	*Purshia tridentata*	8.57%
Blue Wildrye (High Elevation)	*Elymus glaucus*	15.94%
Sulfur flower buckwheat	*Eriogonum umbellatum*	3.59%

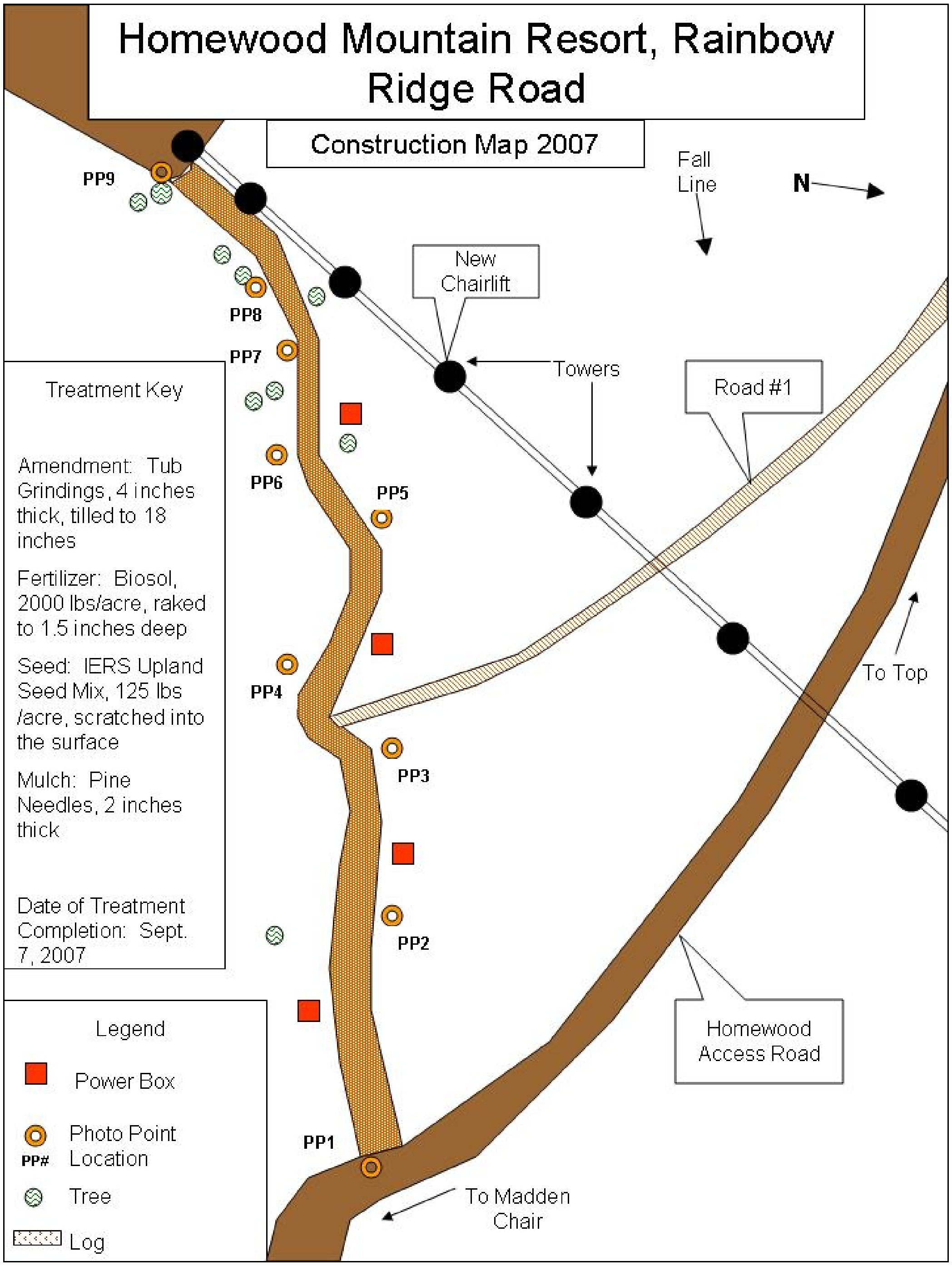

Figure 22. Rainbow Road Treatment Map.

Figure 23 and Figure 24 show Rainbow Road before and after treatment

Figure 23. Rainbow ridge pre-treatment

Figure 24. Rainbow ridge post-treatment

Table 7. Treatment for Rainbow Ridge Road

Treatments		Plot 1
Amendment	**Type**	Tub grindings
	Depth	4 inches
Tilling	**Type**	Excavator till
	Depth	18 inches
Fertilizer	**Type**	Biosol
	Rate	2000 lbs/acre
Seed	**Mix**	IERS upland mix
	Rate	125 lbs/acre
Mulch	**Type**	Pine needles
	Depth	2 inches
Dimensions in ft^2		48,300 sq. ft.

Wedding Road

Wedding Road Description

Wedding road, at an elevation of 6,826 feet above AMSL, is an old road that runs under the top portion of the Quail chairlift and along part of the El Capitan ski run (Figure 25). This road is steep in sections and the slopes range from 12-20 degrees. The upper, treated portion of the road is north facing. Mature vegetation surrounds the road and ski run, and consists mainly of white fir (*Abies concolor*), red fir (*Abies magnifica*), and western white pine (*Pinus monticola*). Ski run vegetation is dominated by tobacco brush

(Ceanothus velutinus), whitethorn (*Ceanothus cordulatus*), alpine prickly current (*Ribes montigenum*), manzanita (*Arctostaphylos* sp.), and native grasses.

Wedding Road Project Goal

The Wedding Road project goals are restore an abandoned roadbed, to improve infiltration capacity and hydrologic function, and to initiate a successional process that leads to a diverse native grass and shrub plant community through amendment incorporation, fertilizer, native seed, and mulch addition.

Seed tests were implemented to determine which mixture of seeds and which seeds alone produced the highest plant cover by seeded species, after one growing season, and throughout subsequent growing seasons.

Wedding Road Treatment Description

Wedding Road received the standard IERS treatment including 4 inches of pine needles tilled to 18 inches, 2,000 lbs/acre of Biosol, 125 lbs/acre of native seed, and 2 inches of pine needle mulch (Table 9). A portion of the treatment area was divided into 12 sections. Each section received one of 4 different seed mixes (Table 8) or an individual species. The plot layout is shown in Figure 26. The individual species are represented in the map by their scientific name abbreviations, which can also be found next to the scientific name of the plant in Table 8. The composition of each seed mix was determined based on the performance of each species in prior research.[1]

Figure 25 shows the layout of the treatment area. Treatment was completed in 2007.

[1] Monitoring and Assessment of Erosion Control Treatments in and around the Lake Tahoe Basin, Caltrans report, unpublished 2008.

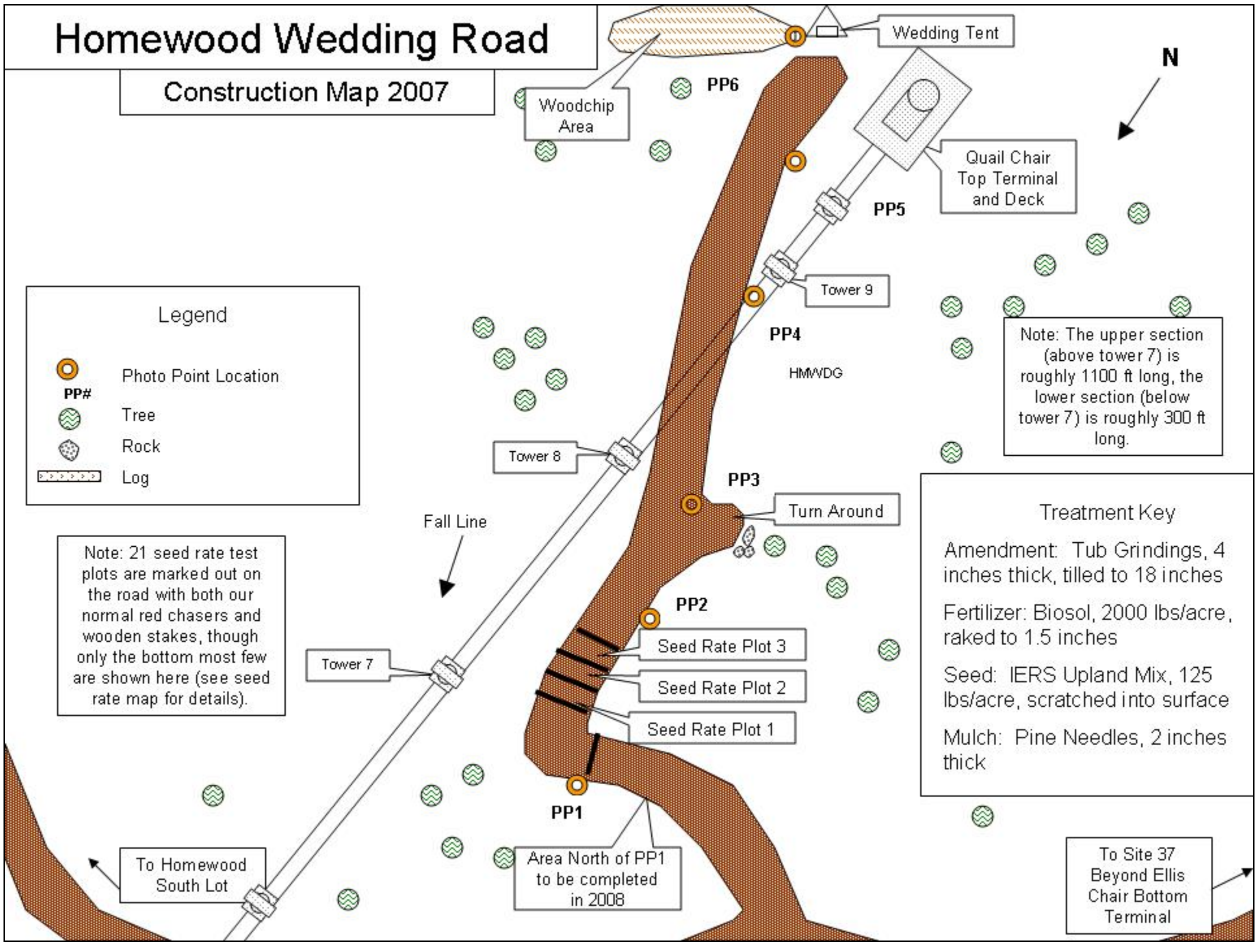

Figure 25. Wedding Road Treatment Map.

Table 8. Species mixes used at Wedding Road and percent composition

Species Common Name	Species Scientific Name	Sun Mix (%)	Shade Mix (%)	Sun/ Shade Mix (%)	IERS Seed Mix (%)
Squirreltail	*Elymus elymoides* (ELY ELY)	36	12	24	25.9
Needlegrass	*Achnatherum occidentale* (ACH OCC)	36	12	24	0
Mountain brome	*Bromus carinatus* (BRO CAR)	12	36	24	25.98
Blue wild rye	*Elymus glaucus* (ELY GLA)	12	36	24	33.75
Greenleaf manzanita	*Arctostaphylos patula*	1.3	1.3	1.3	0

Species Common Name	Species Scientific Name	Sun Mix (%)	Shade Mix (%)	Sun/ Shade Mix (%)	IERS Seed Mix (%)
Sulfur flower	*Eriogonum umbellatum*	1.3	1.3	1.3	3.51
Wax current	*Ribes cereum*	1.2	1.2	1.2	0
Sagebrush	*Artemisia tridentata*	0.2	0.2	0.2	0
Bitterbrush	*Purshia tridentata*	0	0	0	8.15

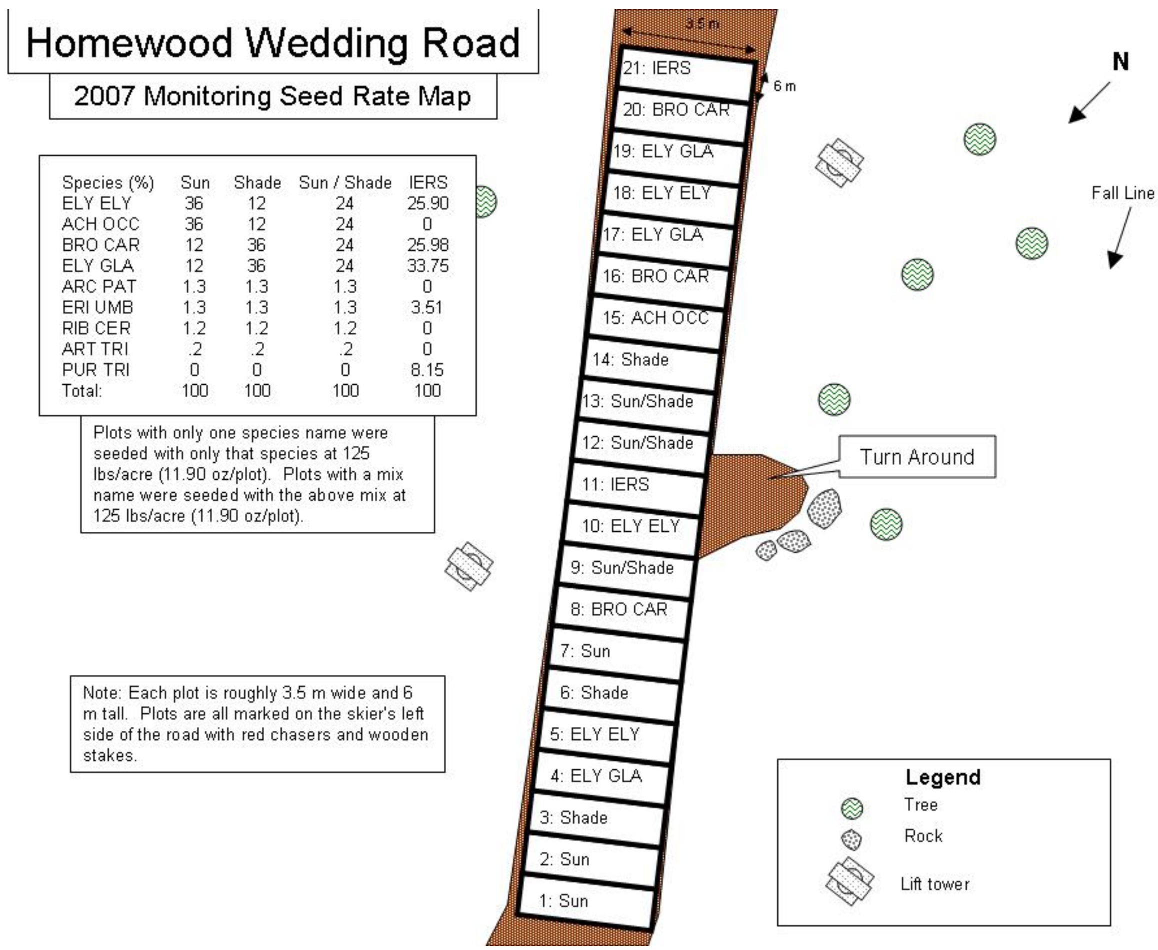

Figure 26. Layout of seed mix test plots at Wedding Road.

Figure 27 and Figure 28 show Wedding Road pre- and post-treatment.

Figure 27. Wedding Road pre-treatment

Figure 28. Wedding Road post-treatment

Table 9. Treatment Table for Wedding Road.

Treatments		
Amendment	**Type**	Tub Grindings
	Depth	4 inches
Tilling	**Type**	Excavator till
	Depth	18 inches
Fertilizer	**Type**	Biosol
	Rate	2000 lbs/acre
Seed	**Mix**	IERS upland mix
	Rate	125 lbs/acre
Mulch	**Type**	Pine Needles
	Depth	2 inches
Dimensions in ft^2		20,840 square feet

MONITORING METHODS

Rainfall Simulation

Rainfall simulation was conducted at Site 31 in 2006, both pre- and post-treatment and at Lower Lombard in 2007, post-treatment. The rainfall simulator consists of a plastic manifold with 900 hypodermic needles on a stand. The rainfall simulator "rains" through the hypodermic needles from water pumped into the manifold onto a 2.1 foot (0.64 meter) square frame from a height of 3.3 feet (1 meter) (Figure 29). The rate of rainfall is controlled and recorded and the runoff is collected from a trough at the bottom of a frame that captures the runoff. The rate of infiltration is calculated by subtracting the rate of runoff from the rate of water applied to the plot during the rainfall simulation trial. The steady state infiltration rate, which will be called infiltration rate hereafter, and the average steady state sediment yield, which will be called sediment yield hereafter, will be presented to enable comparison between sites. The overall infiltration capacity for a site is calculated by taking the average of the separate rainfall simulation runs each at a different location within the site. Two to three rainfall simulations were conducted at each site if ground conditions permitted.

Figure 29. Rainfall simulator and frame.

Runoff Simulation

Runoff simulation was conducted pre-treatment at the Wedding Road in 2007. The runoff simulator is a 3.3 feet (1 meter) wide PVC pipe with 50 evenly spaced holes that are one sixteenth inches in diameter (Figure 30).

Figure 30. The runoff simulator and test area post-simulation. The PVC pipe is visible at the top of the photo and the collection frame is at the bottom.

When water is pumped though the pipe and exits the holes, an even flow of water across the entire width of the pipe is produced, thereby simulating snowmelt runoff through sheet flow. Snowmelt can produce a significant amount of runoff and sediment at ski areas, which can lead to severe erosion problems. The rate of water applied ranges from 2 to19 L/min and is recorded, as with the rainfall simulation. A collection trough is installed 2 meters down slope from the runoff pipe and all runoff is collected as with the rainfall simulator. The same measurements and samples are collected for the runoff simulator as for the rainfall simulator.

Cover

Cover was measured pre-treatment at Rainbow Ridge, Creek Road, and Wedding Road, and post-treatment at Lower Lombard, Site 37, and Site 31.

Cover was measured using the cover point method (Figure 31) along randomly located transects.[2] Two cover measurements were recorded, 1) the first hit cover, which represents the first object intercepted starting from a height of 3.3 feet (1 meter) above the ground and 2) the ground cover hit. The first hit cover measures the foliar cover by plants (leaves and stems). It does not measure the part of the plant actually rooted in the ground. The ground cover hit measures whatever is lying on the ground or rooted in the ground (i.e. litter/mulch, bare

[2] Hogan, Michael, (IERS). Luther Pass Monitoring Report: Plant and Soil Cover Monitoring for Evaluating Sediment Source Control Success in the Lake Tahoe Basin. South Lake Tahoe, CA: Lahontan Regional Water Quality Control Board; 2003 Apr.

ground, basal (or rooted) plant cover, rock and woody debris). Total ground cover represents any cover other than bare ground. Plant cover, both ground and foliar, was recorded by species and then organized into cover groups based on the lifeform and longevity of the plant. The perennial herbaceous category includes seeded grasses, native grasses, forbs and any non-native perennial species, such as wheatgrass (*Agropyron sp.*). The annual herbaceous category includes any annuals, native or alien. Very few non-native plants were found near the six treatment areas. Trees and shrubs form the last category and include any woody species, native or introduced.

Figure 31. The cover point method. A laser pointer mounted on a metal rod determines the cover hit.

Soil and Site Physical Condition

Soil compaction and soil moisture were measured along the same transects as the point cover data for most of the plots (Figure 32, Figure 33, and Figure 34). At Site 37, penetrometer readings were only taken at areas which were tilled using targeted loosening. Sampling on transects would not allow these areas to be sampled separate from un-loosened areas.

Figure 32. Cone penetrometer dial, showing pressure applied in pounds per square inch.

Figure 33. Conducting soil moisture readings along transects.

Figure 34. Conducting cone penetrometer readings along transects.

A cone penetrometer was used to measure depth to refusal, which is used as an index for soil density (Figure 32 and Figure 34). A cone penetrometer with a ½ inch (1.27 centimeters) diameter tip was pushed vertically into the soil until a maximum pressure of 350 pounds per square inch (psi), (2,411 kPa) was reached. The depth at which that pressure was reached was recorded as the depth to refusal (DTR) in inches.

A hydrometer (Figure 33) was used to measure volumetric soil moisture content adjacent to the penetrometer readings at a depth of 4.7 inches (12 centimeters).

Solar input was determined using a Solar Pathfinder (Figure 35). Since solar input affects evaporation rates and soil temperature, which may affect time of seed germination, germination rate, rate and type of plant growth and soil microbial activity, it is an important variable to consider when monitoring plant growth and soil development.

Figure 35. Solar pathfinder in use.

<u>Soil Nutrient Analysis</u>

At each area sampled, three soil sub-samples were taken from beneath the mulch layer to a depth of 12 inches (30 cm). At Site 31 and Lower Lombard, one sample with three sub samples were collected at each plot. Small amounts of soil were collected from each part of the hole to comprise each sub-sample (Figure 36). Sub-samples collected within a plot location were combined and then sieved to remove any material larger than .08 inches (2 mm) in diameter, and sent to A&L Laboratories for S3C analysis, suite of micronutrients and organic matter, and Total Kjeldahl Nitrogen (TKN).

Figure 36. Soil sub-sample collection.

MONITORING RESULTS AND DISCUSSION

All data will be presented as pre- and post-treatment (defined as one season following treatment) if more than one year is presented, except for the pre- and post-treatment rainfall data at Site 31, which was all collected in 2006. Table 10 shows monitoring sites and treatment completion dates.

Table 10. Monitoring areas and treatment completion dates.

2006 Treatment Sites	2007 Treatment Sites
Lower Lombard	Creek Road
Site 31	Rainbow Ridge
Site 37 (section 13 only)	Wedding Road
	Site 37 (sections 1-12)

Rainfall Simulation

At Site 31, sediment yield decreased by 7 times after treatment, from 381 to 54 lbs/acre/in (Figure 37). Before and after treatment, approximately 56% of applied water was infiltrated. At Lower Lombard, the average sediment yield after treatment was 24 lbs/acre/in, which is nearly a 16 times reduction when compared to the pre-treatment sediment yield at Site 31 (Figure 37 and Figure 38). The soil at Lower Lombard infiltrated approximately 85% of the water applied. This data suggests that restoration treatments applied at Site 31 and Lower Lombard were successful in controlling sediment at the source. Although rainfall simulation results were promising at Lower Lombard, the continued foot traffic disturbance most likely has already reduced the erosion control capacity and will continue to affect the treatment until abated.

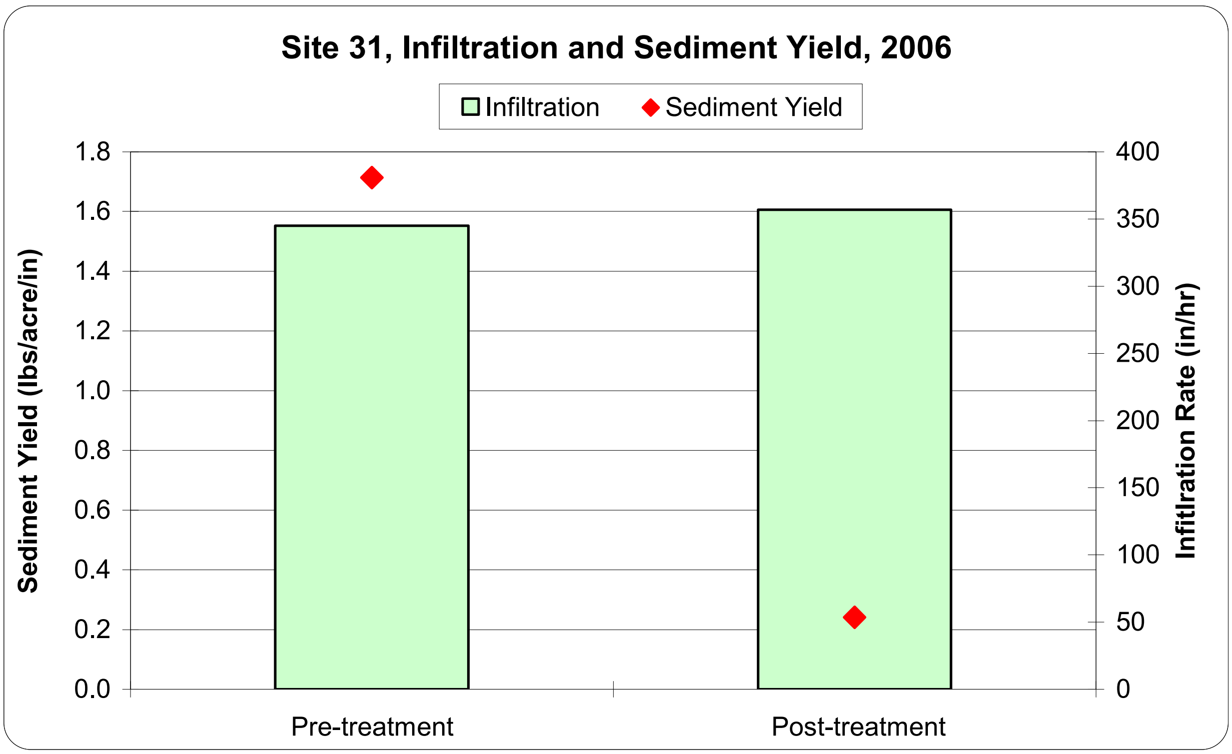

Figure 37. Site 31, Infiltration and Sediment Yield, 2006. Sediment yield decreased by 7 times after restoration treatments.

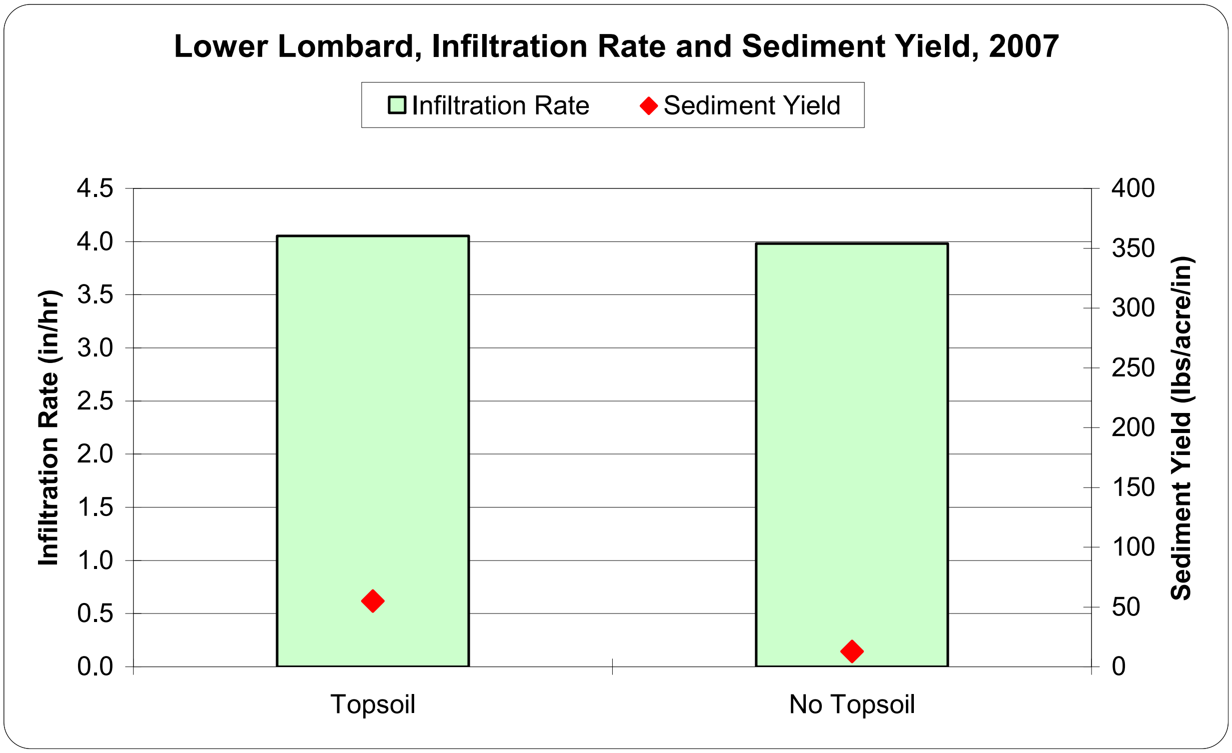

Figure 38. Lower Lombard, Infiltration Rate and Sediment Yield, 2007. Post-treatment rainfall simulations generated low sediment yields. These sediment yields were 16 times less than the pre-treatment rainfall simulation conducted at Site 31.

Runoff Simulation

Pre-treatment runoff simulation at Wedding Road produced a high sediment yield of 20,780 lbs/acre/in. The infiltration rate was 4.44 in/hr, compared to 5.91 in/hr applied. Therefore 75% of the applied water was infiltrated. Post-treatment runoff simulation will be performed during the 2008 field season.

Soil Density

On average, penetrometer DTRs decreased by 4.3 times after restoration treatments. Penetrometer DTRs were 3 inches or less pre-treatment, compared to an average of 13 inches post-treatment (Figure 39). The increases in penetrometer DTRs at Site 31 and Lower Lombard were related to decreases in sediment yield (Figure 37 and Figure 38). Shallow penetrometer DTRs have also been associated with high sediment yields in previous research. Rainfall simulation results in similar soils showed a lower sediment yield in soils when penetrometer DTRs were greater than 4 inches (10 cm).[3]

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[3] Grismer, M.E. et al. Simulated Rainfall Evaluation at SunRiver and Mt Bachelor Highways, Oregon. Unpublished Data.

All post-treatment DTRs were deeper than those measured at the native site, which had a DTR of 8 inches (Figure 39).

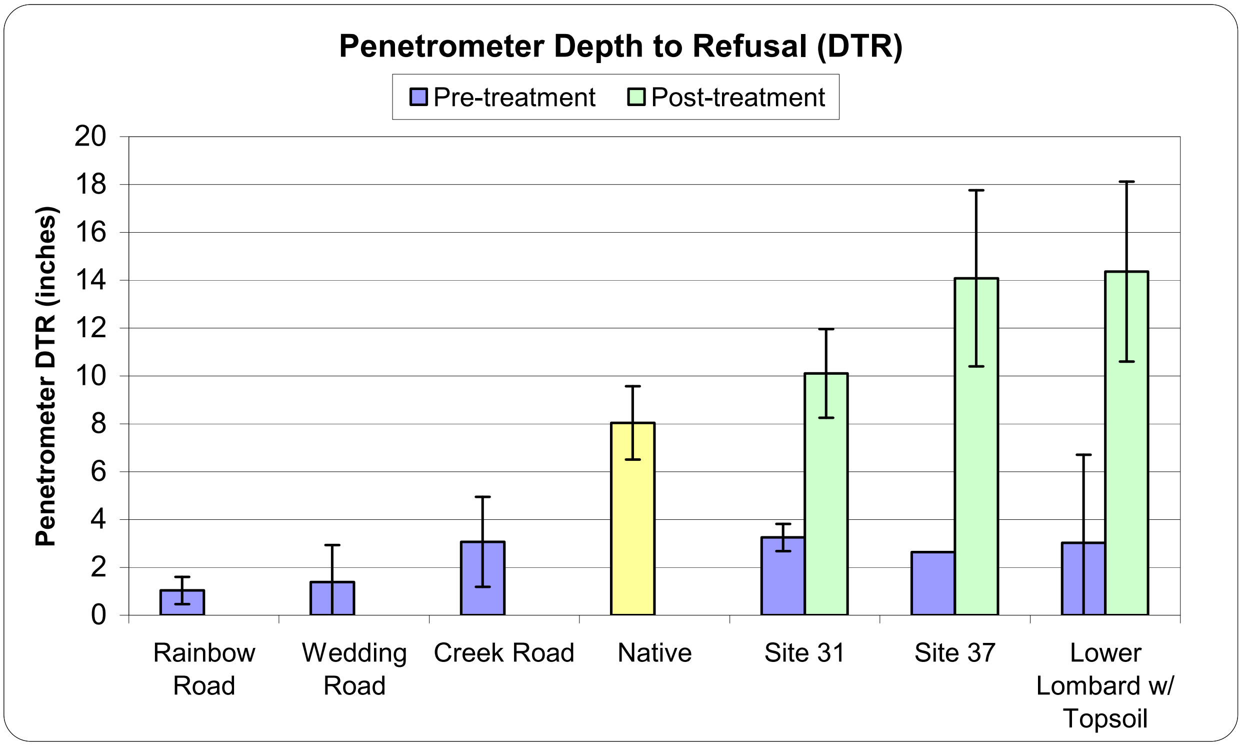

Figure 39. Penetrometer Depth to Refusal (DTR). Penetrometer depths increased by an average of 4.3 after restoration treatments.

The penetrometer DTRs at Site 31 were 22 to 29% higher at plots amended with 6 inches of woodchips, compared to 2 or 4 inches of woodchips (Figure 40). The average DTRs at the plots with 2 or 4 inches of woodchips were 9 and 9.6 inches, respectively, while the average DTR at the plot with 6 inches of woodchips was 11.7 inches.

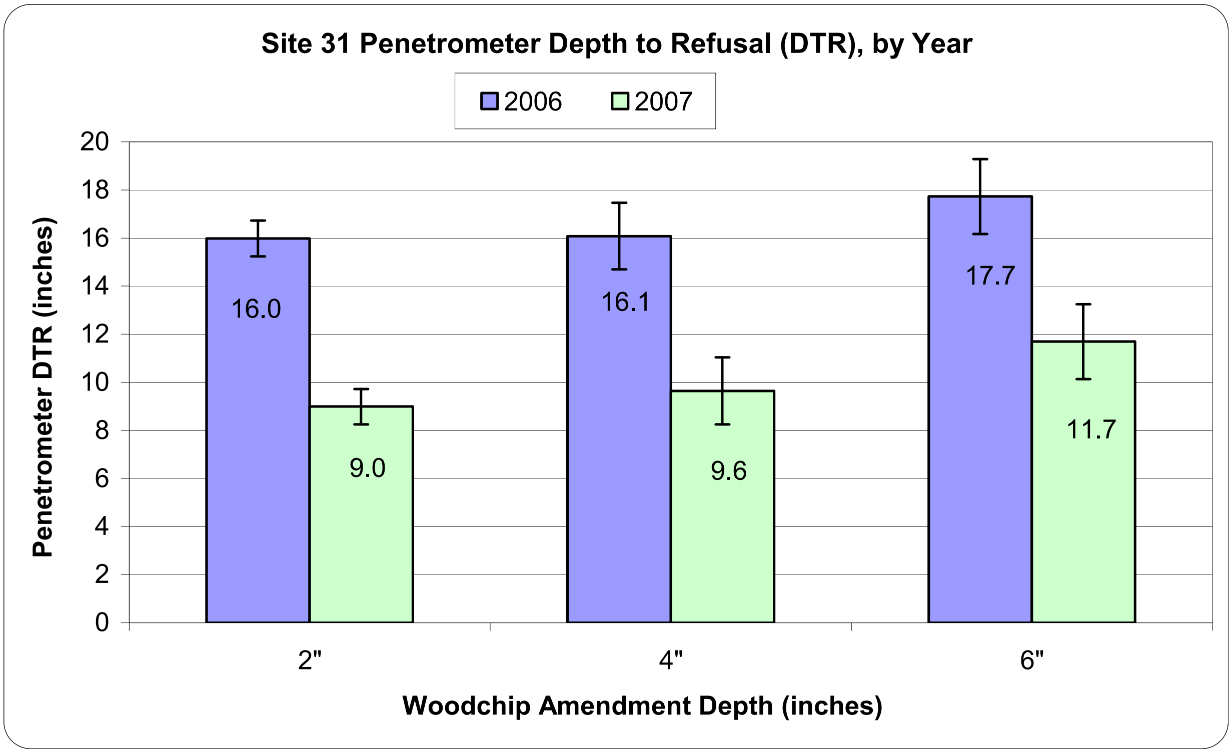

Figure 40. Site 31 Penetrometer DTR, by Year. Penetrometer depths were 22 to 29% higher at plots with 6 inches of woodchips, compared to plots with 2 or 4 inches of amendments.

Soil Moisture

Normal soil moisture levels, which ranged between 5 and 12%, were observed at all sites. Since penetrometer depths can only be compared across similar soil moisture levels, it is important to note that the pre-treatment and post-treatment moisture levels were similar at Lower Lombard and Site 31 (Figure 41).

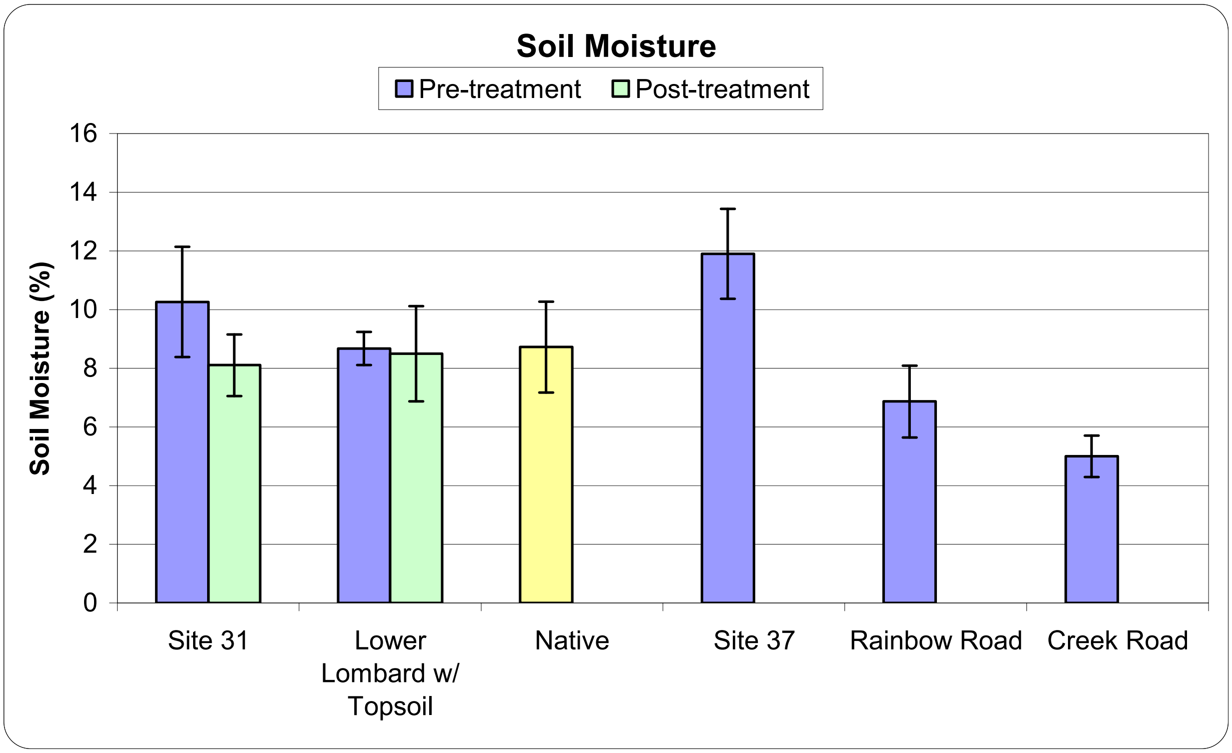

Figure 41. Soil Moisture. Soil moistures were within normal levels and remained consistent at sites pre- and post-treatment. Soil moistures need to be similar to compare penetrometer depths.

<u>Plant Cover</u>

Plant cover was more than 7 times higher at Lower Lombard when compared to Site 31. The plant cover at Lower Lombard was 26%, while the average plant cover at Site 31 was 3%. The higher plant cover at Lower Lombard may be attributed to the amendment, which was a mix of tub grindings and compost. Only woodchips were applied at Site 31. It is likely that the tub grinding and compost mix provides more readily available nutrients for plants. It is important to note that little sediment was produced at Site 31, even though plant cover was low.

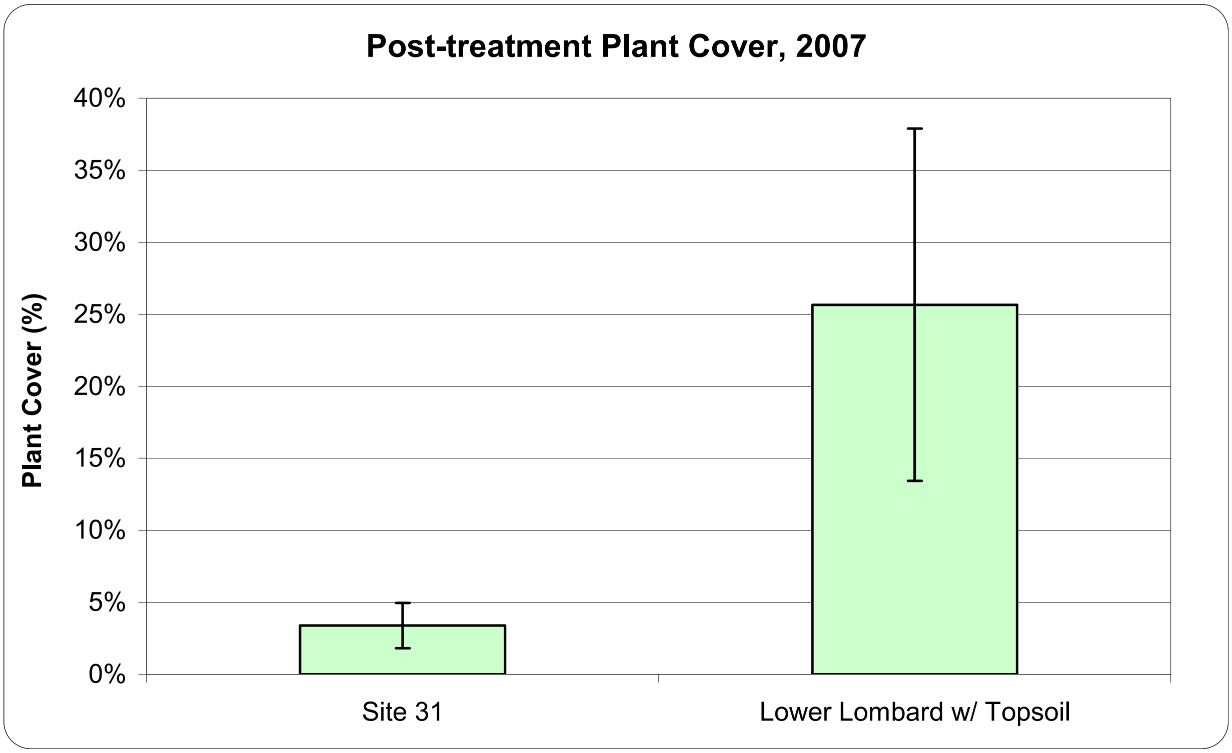

Figure 42. Post-treatment Plant Cover, 2007. Plant cover was more than 7 times higher at Lower Lombard, which was amended with tub grindings and compost. Site 31 was amended with woodchips.

Mulch Cover

Post-treatment mulch cover at Site 31 ranged from 89 to 96% and only varied slightly among different mulch types: woodchips, pine needles, or tub grindings (Figure 43). The mulch cover at Lower Lombard was 97%. In previous studies, high mulch cover has been shown to reduce sediment.[4]

[4] Upper Cutthroat Sediment Source Control Effectiveness Monitoring Project, unpublished, 2008.

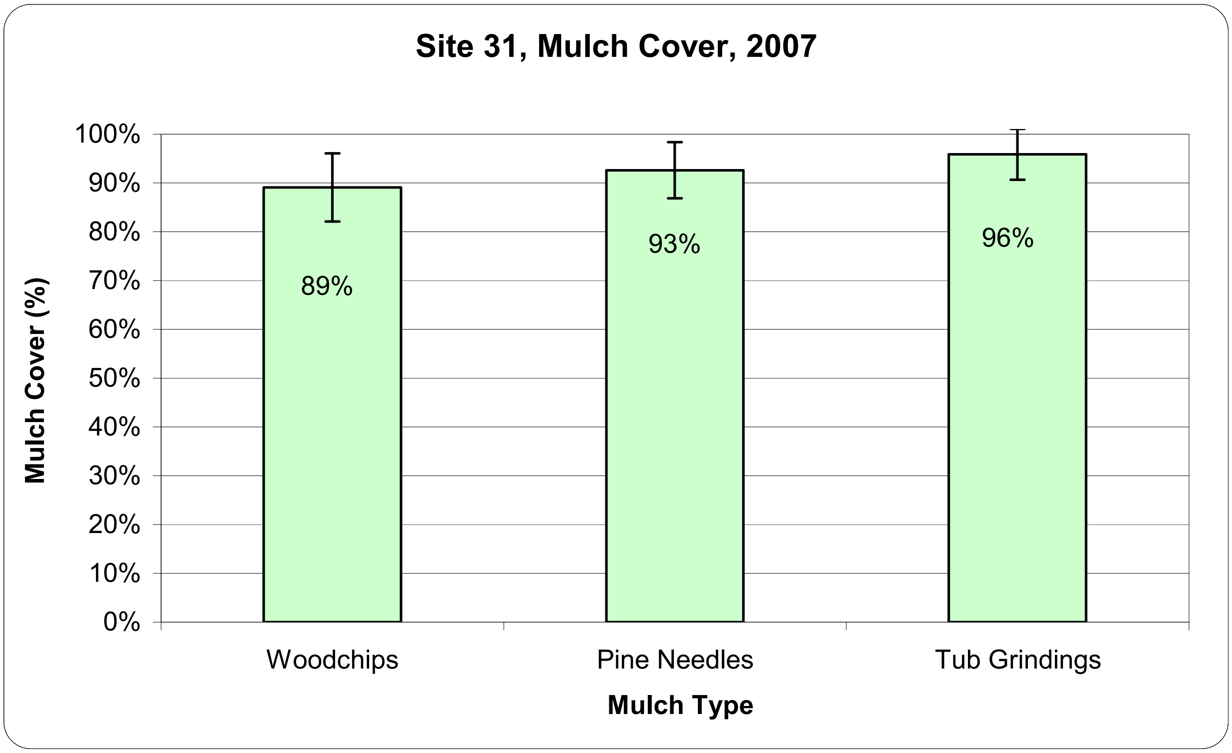

Figure 43. Site 31, Mulch Cover, 2007. Mulch cover was similar among mulch types and ranged from 89 to 96%.

Soil Nutrients

After treatment at Lower Lombard, total Kjeldahl nitrogen (TKN) increased by 1.5 times at the plot with tub grindings only and by 1.8 times at the plot with tub grindings and compost. Post-treatment, the TKN was slightly higher at the plot with compost, compared to the plot without compost. At Site 31, the TKN remained fairly stable after treatment (Figure 44).

At Lower Lombard, organic matter increased by 1.5 times after treatment (Figure 45). The organic matter content was the same at the plot with compost compared to the plot without compost. The organic matter content remained fairly stable at Site 31 before and after treatment. At Lower Lombard and Site 31, TKN and organic matter levels were similar to or above native levels.

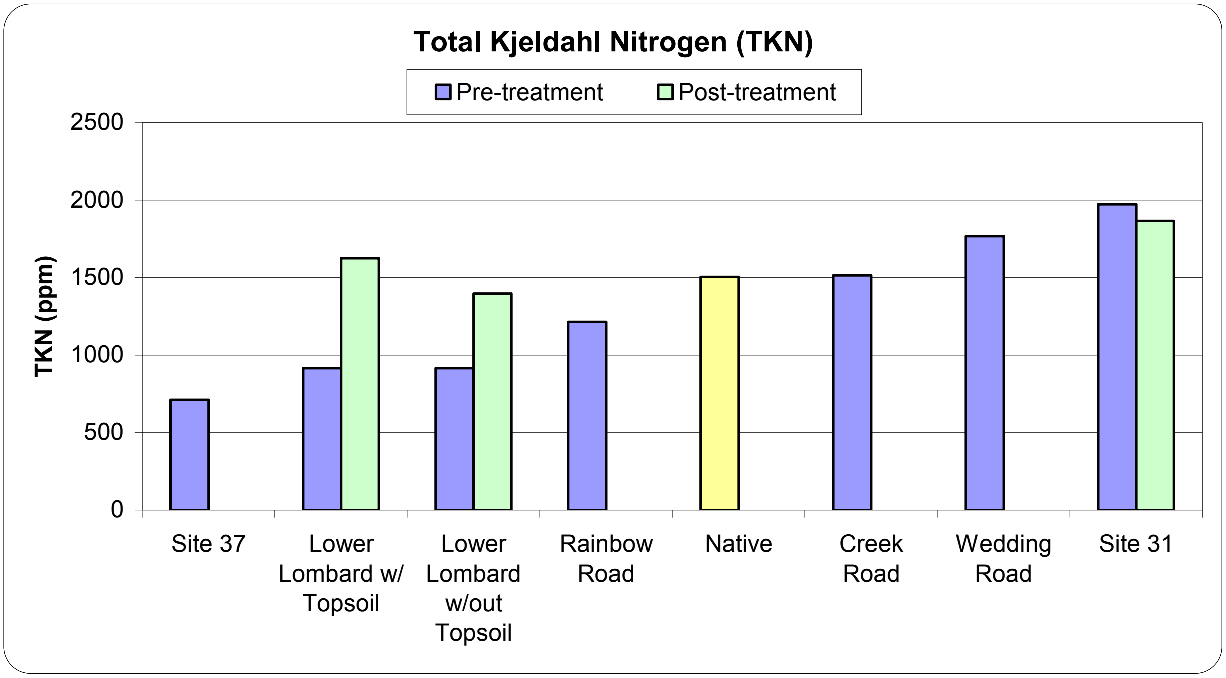

Figure 44. Total Kjeldahl Nitrogen (TKN). Data is sorted by increasing pre-treatment TKN. TKN increased by 1.5 to 1.8 times at Lower Lombard. The TKN at Site 31, which had a pre-treatment TKN higher than the native site, remained fairly stable.

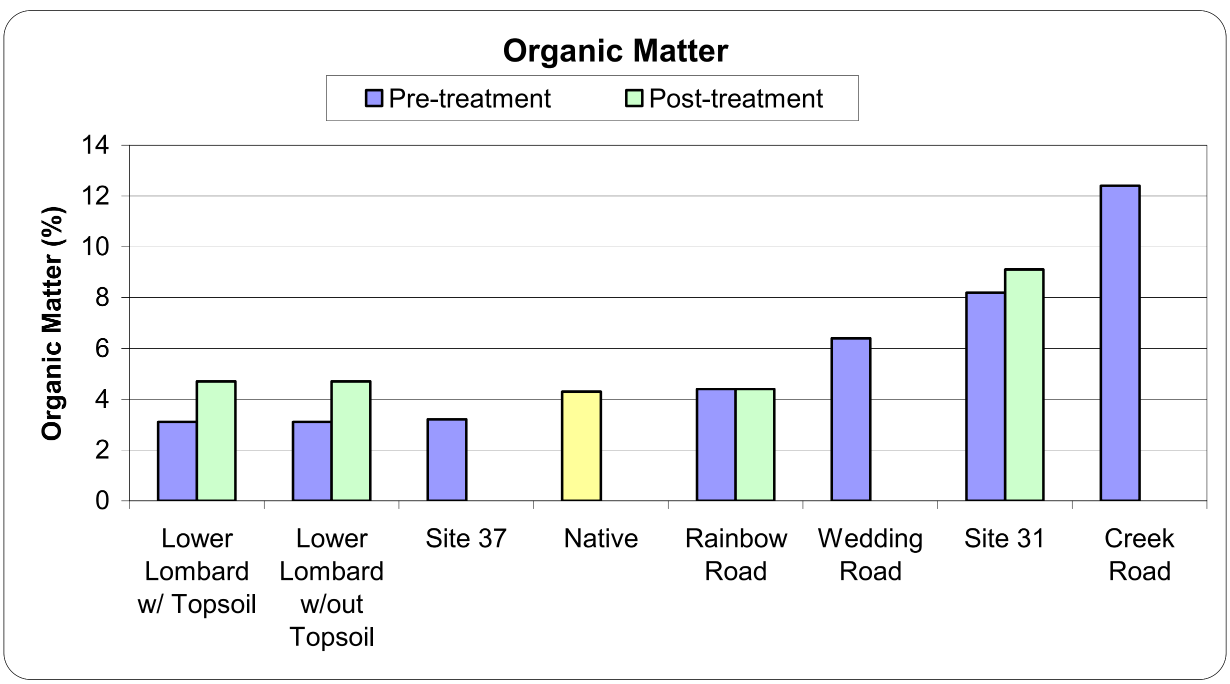

Figure 45. Organic Matter. Data is sorted by increasing pre-treatment organic matter content. Organic matter increased by 1.5 times at Lower Lombard and increased slightly at Site 31. Post-treatment, both sites had organic matter contents that were above native levels.

The TKN and organic matter at Site 31 were highest at the plots with 6 inch amendment depth (Figure 46 and Figure 47). A high level of variability was present in the soil at Site 31, as shown by the standard deviation, therefore, further testing is recommended to determine whether the trend with continue. The TKN and organic matter levels were close to or above native levels at plots with all amendment depths.

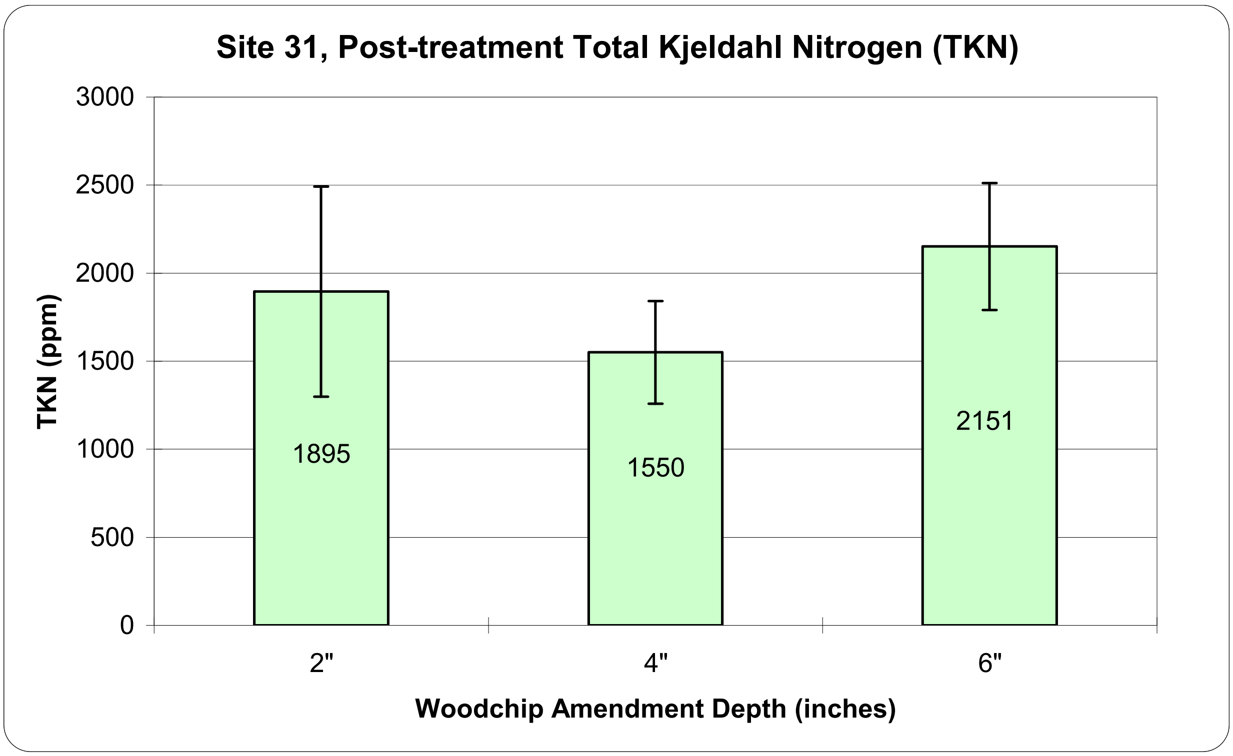

Figure 46. Site 31, Post-treatment Total Kjeldahl Nitrogen (TKN). Plots with 6 inches of woodchips had higher TKN when compared to plots with 2 or 4 inches of woodchips. However, soil samples were variable, leading to high standard deviations.

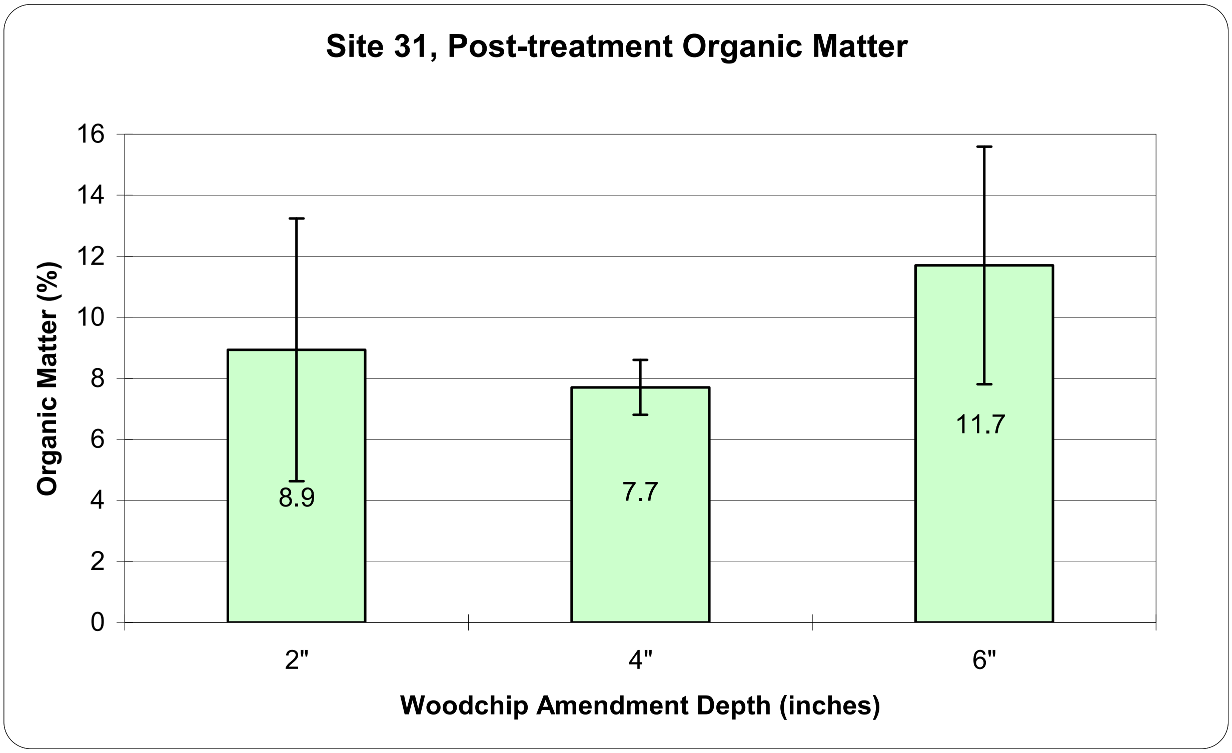

Figure 47. Site 31, Post-treatment Organic Matter. Organic matter content was higher at the plots with 6 inches of woodchips, however, soils were variable and standard deviations were high.

TREATMENT SUCCESS

All treatments performed to a high level. The following table organizes goals and results by site (Table 11).

Table 11. Project Goals

Site	Goals	Results
Site 31	• To reduce sediment movement and surface erosion by incorporating organic matter and applying fertilizer, native seed, and mulch • Initiate a successional process that leads to diverse, mid-seral, self-sustaining, native grass and shrub plant communities. • Determine whether difference exist between plots with varied amendment depths and mulch types	Goals achieved: YES • Sediment was reduced by 7 times. • Penetrometer depths increased by 3 times • Plots with 6 inches of woodchip amendment had 22 to 29% deeper penetrometer depths when compared to plots with 2 or 4 inches of woodchips • Plant cover was less than 5% and differences in plant cover were not observed among different mulch types • Differences in mulch cover were slight among plots with different mulches.
Lower Lombard	• Reduce sediment movement and surface erosion by incorporating organic matter and applying fertilizer, native seed, and mulch • Initiate a successional process that leads to diverse, mid-seral, self-sustaining, native grass and shrub plant communities. • Re-establish natural slope contours and drainage patterns to stabilize disturbed soil and reconnect disrupted surface and subsurface hydrology. • Determine whether compost added to a tub grinding amendment increases soil nutrient levels	Goals achieved: YES • Sediment was reduced by 16 times compared to pre-treatment yield at Site 31. • Penetrometer DTRs decreased by 4.7 times • Plant cover was 26% • Natural slope angles were re-established • TKN increased slightly with the addition of compost and organic matter remained the same.

Site	Goals	Results
Site 37	• To determine whether there is an improvement in infiltration capacity and hydrologic function when an abandoned roadbed with mature vegetation is mowed and the soil is mechanically loosened using the targeted loosening method. • To determine whether any differences were observed in seeding and amendment variations.	Goals achieved: YES • Penetrometer depths, which are often used as an index for infiltration capacity, increased by more than 4.5 times in loosened areas • Visual variations were not observed between plots with different seed and amendment treatments.
Creek Road	• Reduce sediment movement and surface erosion by incorporating organic matter and applying fertilizer, native seed, and mulch • Initiate a successional process that leads to diverse, mid-seral, self-sustaining, native grass and shrub plant communities.	• Native seed was incorporated at the sites that lacked vegetation. Next season's monitoring will determine plant cover of the seeded species.
Rainbow Road	• Reduce sediment movement and surface erosion by incorporating organic matter and applying fertilizer, native seed, and mulch • Initiate a successional process that leads to diverse, mid-seral, self-sustaining, native grass and shrub plant communities.	• Performance monitoring will be conducted in 2008.

Site	Goals	Results
Wedding Road	• Reduce sediment movement and surface erosion by incorporating organic matter and applying fertilizer, native seed, and mulch • Initiate a successional process that leads to diverse, mid-seral, self-sustaining, native grass and shrub plant communities. • To determine which seed types and mixes provide the higher plant cover after one growing season, and in the long-term	• Performance monitoring will be conducted in 2008.

CONCLUSIONS

2006 restoration treatments in the Homewood Mountain Resort watersheds have been shown to be extremely effective in reducing erosion, at least in the short term. All of the restoration goals were met at each 2006 treatment site. Erosion control capacity, which was quantified through monitoring, increased significantly after treatments. Sediment yield was reduced by 7 to 16 times, while penetrometer depths increased on average by 4.3 times.

Valuable information, which can be used for 2008 treatment design, was garnered from the test areas within the road restoration sites. It was found that increasing the rate of woodchips from 2 or 4 inches to 6 inches slightly reduced soil density. However, plots with woodchips produced 7 times less plant cover when compared to plots with tub grindings and compost.

Plots with compost and tub grindings also produced higher soil TKN and organic matter when compared to tub grindings alone. The TKN measurement is an index of sustainability and thus indicates that woody material and compost, when used together, provide a greater potential for long-term sediment reduction and plant cover/plant community development.

Post-treatment disturbance can play a large role in treatment success. The Lower Lombard area was affected by foot traffic during the 2007 growing season. Plant cover and sediment production may have been negatively affected. It is imperative in the planning process to establish steps to eliminate treatment disturbance.

RECOMMENDATIONS

Amendments

Incorporate an amendment that contains both a stable source of organic nutrients (compost) and coarse woody material for the best long-term sediment reduction and plant community development.

Disturbance

Disturbance prevention is a crucial step in restoration treatments and should be part of the planning process. The Lower Lombard area was frequently used by hikers after treatment. Foot traffic has negative effects on soil density and infiltration and over time it will displace mulch. It is recommended that either a designated trail be constructed or foot traffic be re-routed from any treated area. If foot traffic is re-routed, a convenient alternative must be available and signage should clearly explain where the new route is located and why the new route should be used.

Long-term Monitoring

Long term monitoring is essential for determining the long-term success, and thus cost effectiveness of a restoration site. Although post-treatment monitoring conducted one year after treatment provided useful information that will be incorporated into future treatments, the long-term effects are still unknown. For instance, three different mulch types were applied at Site 31. After one season, they all performed well at reducing erosion, but many questions remain. Which mulch will provide the highest level of vegetative and surface cover? Does plant cover vary by mulch type? These types of questions remain at all treatment areas, and can only be answered through monitoring in subsequent seasons.

Test Areas

It is recommended that test areas should continue to be constructed during 2008 road restoration. By monitoring these test area, appropriate, cost-effective, and site specific specifications can be implemented in future restorations. The current test areas have provided important information about amendment types and rates and their affect plant cover and soil density. New information can be implemented in subsequent restoration treatments.