Integrated
Environmental Restoration Services, Inc.

EXECUTIVE SUMMARY

Simulated Rainfall Evaluation at Sunriver and Mt Bachelor Highways, Oregon

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Disturbed road cut slopes often produce more sediment than less disturbed slopes. While grass and plant cover, trackwalking, and other types of soil treatments are generally assumed to reduce sediment yield from disturbed sites, physical quantification of that reduction in sediment is often lacking. We used a portable rainfall simulator to evaluate the erosivity of sandy loam soils derived from volcanic ash parent material on various slope gradients with existing treatments at the Oregon Highway 97 Sunriver Interchange (ODOT) and the Sunriver to Mt Bachelor (FHWA) reconstruction projects. Both projects were under construction in July 2006. These measurements were used to establish a basis upon which sediment source control treatment comparisons could be made and to provide more realistic infiltration, runoff and sediment yield rates to be used in later modeling. Time to runoff, infiltration rate, runoff rate, average sediment concentration and sediment yield were recorded for bare trackwalked soils (TW), trackwalked soils with a mulch cover (TWM), "grubbing and clearing" soils (GC), and "bucket imprinted" soils (BI).

Infiltration rates were high on the GC treatment, which had the least soil disturbance, with no runoff after 45 minutes where 75 mm (3 in) of rainfall was applied. Treatments with high levels of soil disturbance had relatively high runoff rates; the TW and TWM sustained rates of 12.0 mm/hr (0.47 in/hr) and 13.6 mm/hr (0.63 in/hr), respectively, based on a 100 mm/hr (4 in/hr) rainfall rate. The BI treatment had low runoff rates at 1.72 mm/hr (0.07 in/hr). Sediment yield rates were greatest from the TW treatment yielding 19.44 g/hr, followed by the BI treated slopes which yielded 2.35 g/hr. The TWM treatment areas yielded much lower rates at 0.23 g/hr. No sediment was recorded on the GC treatment because no runoff was measured.

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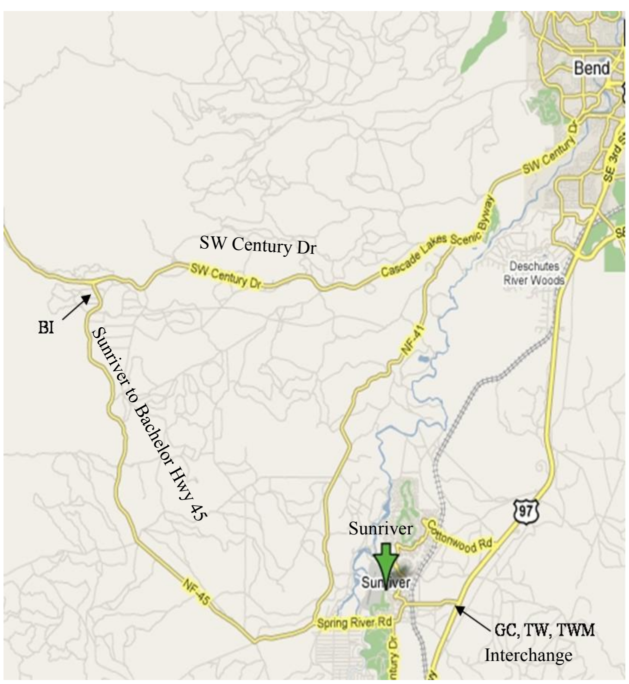
INTRODUCTION

Development of road cuts and fills often result in soil disturbance and displacement making these areas more vulnerable to erosion and soil loss than less disturbed areas. Despite considerable effort and resources, little quantitative information exists about the performance of hill slope erosion control practices such as trackwalking, imprinting, soil tilling, mulch, and grass cover treatments, though such information is under development (Grismer and Hogan 2004, 2005a, and 2005b). In this study we used a rainfall simulator as a means to standardize measurement of erosion from disturbed road cuts on two highway projects near Sunriver, Oregon through replicated rainfall events on multiple plots. We were especially interested in the effects of trackwalking and bucket imprinting, both practices being employed on these projects, on runoff and sediment production.

Figure 1. The study took place on the Sunriver Interchange where Treatments GC, TW, and TWM were located and on the Sunriver to Bachelor project where the BI treatment was located.



PURPOSE

The project objectives were to evaluate the infiltration rates, runoff rates, and sediment yields from trackwalked bare soil (TW), trackwalked mulched soil (TWM), bucket imprinted bare soil (BI), and soils left in grubbing and conditions (GC).

SITE DESCRIPTION

All treatment areas were located along highways near Bend Oregon (Figure 1). The treatment areas were recently disturbed road cuts created during road construction. Soils within the project area are sandy loam soils of volcanic ash origin, generally greater than 90 cm (3 ft) deep. Annual precipitation near Sunriver ranges between 30 and 35 cm (12-14 in) and occurs relatively evenly throughout the year. At higher elevations, where the BI treatment was located, precipitation increases to over 76 cm (30 in) of precipitation, most of which falls as snow between November and April. Summer precipitation in the study area occurs mainly in intense rainstorms.

SURFACE STABILIZATION TREATMENTS

Several finished slope treatments were evaluated in this study. A standard treatment for slope stabilization used on the Sunriver Interchange was trackwalking (TW). Trackwalking is the practice of driving a crawler tractor type equipment up and down a slope, compacting the soil, while leaving a pattern of tracks on the soil surface (Figure 2A). Another method of slope stabilization that was used within the project area was termed “bucket imprinting” (BI). This method involved pressing the bucket of an excavator (with several pieces of rebar welded horizontally onto the bucket) directly onto the slope surface (Figure 3). Both methods (TW and BI) use soil compaction for the purpose of stabilizing a slope and creating an uneven roughened soil surface. Both methods still leave the soil surface exposed. A third treatment (TWM) applied a shredded wood mulch (obtained from Sunriver Environmental, LLC) to trackwalked slopes at a 2 cm (0.8 in) depth (Figure 2B). The fourth treatment, "clearing and grubbing" (GC), is a practice where the site is cleared of vegetative material, including roots and stumps, but not significantly impacted by large equipment. The surface is left relatively roughened and soils are not significantly compacted. This treatment did not include the application of mulch.

Figure 2. The trackwalking treatment (TW) shown in (A) stabilizes the soil through compaction and leaves the surface in a roughened condition. The trackwalking and mulch treatment (TWM) shown in (B) evaluated the effects of blowing a 2 cm (0.8 in) layer of ground wood mulch on a trackwalked soil surface.

METHODS

Rainfall simulation was conducted during a two-day period (July 13-14, 2006). Slopes ranged from 1V:5H (20%) on the TW and GC treatment sites to approximately 1V:3H (33%) for the TWM soils on the Highway 97 Interchange project. The slope for the BI treatment on the Sunriver to Mt Bachelor Highway project was greater, at 1V:2.5H (50%) A "midget" rainfall simulator was used for these measurements. (A detailed descriptions of the rainfall simulator and plot frame are discussed in Grismer and Hogan [2004]). This equipment creates raindrops through a system of syringe needles under equal pressure (Figure 4). The raindrops fall from a 1 meter (3.3 ft) height onto the ground surface within a 0.8 m x 0.8 m (2.6 ft x 2.6 ft) plot frame. Installing the midget rainfall simulator requires leveling the plot frame, then centering and leveling the rainfall simulator over each frame. Prior to the simulation, an aluminum sheet is placed between the rainfall needles and the plot frame until the desired rainfall rates or intensity is reached. The sheet is then quickly removed and rainfall is initiated. Runoff is measured as it moves over the lip of the lower portion of the plot frame. The time between when the sheet is removed and runoff occurs is "time to runoff". All runoff from the plot is collected and measured to calculate infiltration, runoff, and sediment yield. Rainfall is allowed to continue until either steady runoff is obtained or approximately 30 minutes has elapsed.

In this study, rainfall simulation was conducted on three plot frames within each treatment. Three different rainfall intensities, or rates (72, 90 or 120 mm/hr [2.8, 3.5, or 4.7 in/hr]), were applied to the plot frames to determine if higher rainfall rates would increase sediment yields and force runoff to occur. Following field measurements, collected runoff samples were taken to the laboratory for filtration. Samples were vacuum-filtered first through a Whatman #1 filter, followed by a 0.45 μm filter. The filter

Figure 3. Bucket imprinting uses the face of an excavator bucket to create a roughened soil surface similar to trackwalking but with significantly less soil compaction.

papers with sediment were dried at 105 °C and weighed, and total sediment mass per volume of runoff was determined. In addition, particle-size fractions in the runoff sediment samples and organic matter (%OM) content of the filtered sediment were also determined (Grismer and Hogan 2005b).

Prior to rainfall simulation, a hydrometer was used to measure volumetric soil moisture content at a depth of 12 cm (4.7 inches) at several locations in each frame. Soil compaction was inferred using a cone penetrometer with a 1.3 cm (0.5 in) diameter tip pushed vertically into the soil until a maximum pressure of 2411 kPa (250 psi) was reached. The depth at that pressure was recorded as the depth to refusal (DTR). These depth measurements were used as an index for soil compaction and infiltration rates.

RESULTS AND DISCUSSION

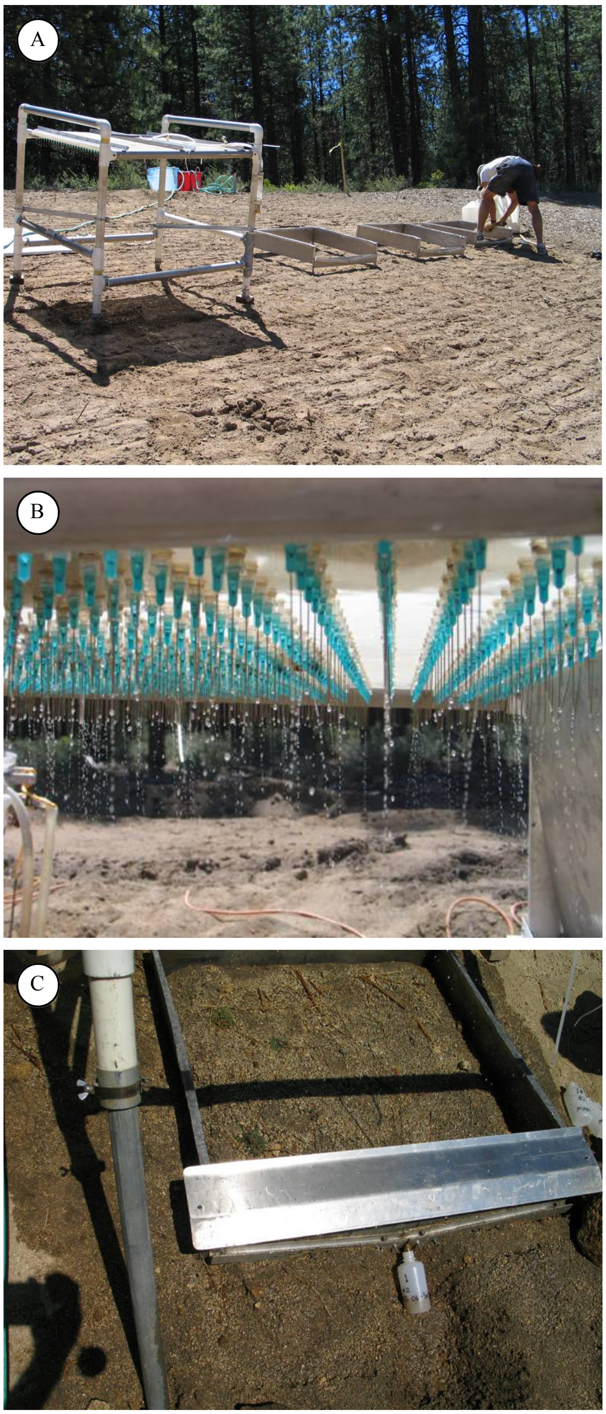
Runoff Rates and Sediment Yield

Table 1 summarizes the average values of measured parameters from the rainfall simulation test plots at the Sunriver Interchange and Sunriver to Bachelor road projects. Infiltration rates were quite high on the GC treatment, which had the least soil disturbance. This treatment did not produce runoff after 45 minutes with 75 mm/hr (3.0 in) of rainfall applied. Treatments with high levels of soil disturbance had relatively high runoff rates (Figure 5), with the TW and TWM sustaining rates of 12.0 mm/hr (0.47 in/hr) and 13.6 mm/hr (0.63 in/hr) respectively based on a 100 mm/hr (4 in/hr) rainfall rate. The BI treatment had low runoff rates (1.72 mm/hr [0.07 in/hr]).

Putting these results into perspective, the rainfall intensity rate of 100 mm/hr (4 in/hr) used in this study can occur in the summer in this geographic area, however it is unlikely that the duration of such events would last more than 15 minutes, or at the most, a half hour. Based on the findings of this study, runoff is likely to occur on the trackwalk slopes (with or without mulch) during an intense thundershower lasting a quarter to a half hour in duration, with minor amounts of runoff on the BI treated slopes and no runoff on the GC slopes.

Sediment yield values as measured by grams of sediment per mm of runoff were greatest from the BI treatment yielding 4.07 g/mm, followed by the TM treated slopes

Figure 4. Rainfall simulation was conducted on three plot frames for each treatment. Plot frames are laid out on the soil surface to capture all runoff (A). The rainfall simulator is centered directly over each plot and rainfall is applied. Rainfall is simulated through a series of syringe needles under equal pressure (B). Runoff that occurs within a plot is collected at the bottom of the frame in a plastic bottle (C).



which yielded 2.12 g/mm. The TWM treatment areas yielded much lower rates at 0.27 g/mm. No sediment was recorded on the GC treatment because no runoff had occurred on these plots. It is important to note that adding mulch to the surface of compacted trackwalk treatments (TWM) did not reduce runoff rates. The mulch layer however, did significantly reduce sediment yields because the mulch in contact with the soil surface reduced rainfall impact and restricted sediment movement.

Infiltration rates generally correlated with cone penetrometer depths to refusal at 250 psi despite the confounding effects of the greater slope at the BI plots (Table 1). Generally, infiltration rates in excess of 100 mm/hr could be expected when penetrometer depths exceeded 4 inches.

That no runoff was generated from any of the GC plots appears to be a result of their minimal soil compaction and gentle slope gradients. The low runoff rates occurring only after very long time periods from the BI plots also reflects the very high infiltration rates associated with minimal soil compaction. Trackwalking with mulch cover appears to perform similarly (with respect to sediment concentrations and sediment yields) to the long-term test plots on Northstar at Tahoe Ski Resort in California, which had compost tilled into the soil and pine needle mulch spread over the surface while the Sunriver trackwalked bare soils resulted in lower sediment concentration and yield than comparable bare ski-run soils in the Tahoe basin (Table 2).

The higher sediment concentration and sediment yield values observed at the BI plots are more an effect of the much greater slope gradient - 50% vs 33% (TWM) and 20%. This relationship between higher sediment yields and greater downslope gradients has been

Table 1. Summary of measured parameters from rainfall simulation test plots on volcanic ash road cut soils near Sunriver, OR.

Treatment Averages		Down Slope (%)	Cone Penet. (in)	Infiltra-tion (mm/hr)	Runoff (mm/hr)	Sed. Conc. (g/L)	Sed. Yield (g/ mm)	Sed. Yield Rate (g/hr)	OM (%)	R^2 (%)
Trackwalk/ bare	TW	1V:5H	1.63	78.0	12.0	2.54	2.12	19.44	8.77	95.1
Clearing and grubbing	GC	1V:5H	3.75	>120	**No Run-off**	NA	NA	NA	NA	NA
Trackwalk/ mulch	TW M	1V:3H	2.93	86.4	13.6	0.33	0.27	0.23	14.98	92.36
Bucket imprint	BI	1V:2.5H	4.97	103.3	1.72	2.57	4.07	2.35	25.79	84.24

Table 2. Comparisons between sediment concentration and yield values at similar slopes for volcanic bare soils from the Tahoe area, Mammoth Resort and Sunriver roadcuts.

Location	**Condition**	**Slope (%)**	**Sed. Conc. (g/ L)**	**Sed. Yield (g/ mm)**
Northstar	Skirun	20.2	4.51	4.05
Homewood Mtn	Skirun	22.1	7.64	5.87
Mammoth Mtn	Skirun	23.5	0.91	5.73
Northstar	Skirun	25.6	5.9	5.8
Sierraville Hwy 267	Road Cut	32.0	3.4	3.0
SunRiver Hwy 97	**Road Cut**	**23.9**	**2.54**	**1.62**

Table 3. Summary of average particle-size distributions (microns) of runoff sediment from rainfall simulation test plots on volcanic road cut soils near SunRiver, OR

Treatment	**% Clay (<2 mm)**	**%Silt (2-63 mm)**	**% Sand (>63 mm)**	**D_{10}**	**D_{30}**	**D_{60}**	**D_{90}**
TW	11.4	75.3	13.4	1.8	5.6	13	186
GC	No Runoff						
TWM	5.0	67.9	27.1	5.0	15.1	36	233
BI	2.8	41.7	55.4	9.1	32.1	154	710

documented in many past erosion studies (Grismer and Ellis 2004).

The sediment yield rate (Figure 6) is the grams of sediment produced per hour of rainfall and is calculated by multiplying sediment yield by runoff rates The TW treatment yielded nearly ten times more sediment (19.44 grams/hr) than the BI (2.35 gr/hr) or 100 times the TWM (0.23 gr/hr) treatment.

From these findings, the project engineer has several tools available for reducing runoff and sediment yields on pumice soil types. Leaving soils in an uncompacted condition (GC) results in the low-

Figure 5

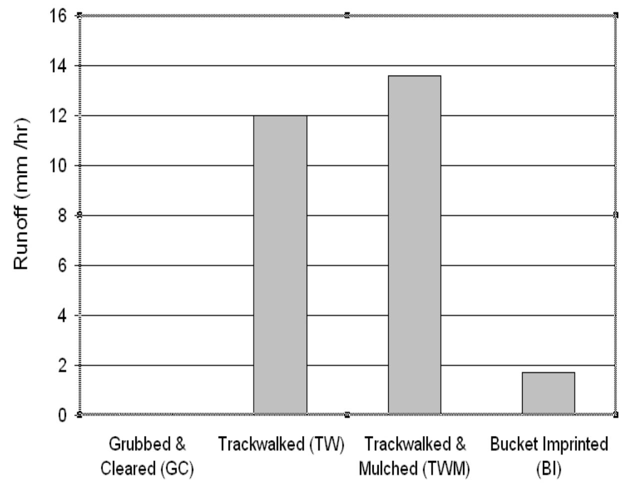
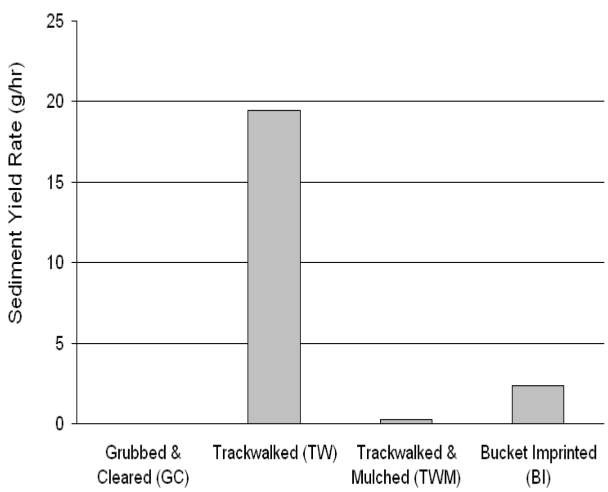


Figure 6



est runoff and sediment yield rates and this option is typically the least expensive. Bucket imprinting was shown to have very low runoff rates but when runoff did occur, the sediment yields were high (though a high percentage was organic sediments). Sediment yields from BI can be reduced by applying a surface mulch. If a site has been trackwalked (TW) or compacted through heavy equipment travel, then high runoff and sediment yield rates should be expected. To reduce sediment yields, mulch can be applied to the soil surface. Adding mulch to compacted pumice soils, as noted previously, does not reduce the amount of runoff that occurs during intense rainstorms. If high runoff rates are not desired, then compacted soils should be ripped to increase infiltration rates.

Runoff and erosion rates from road cut soils were similar in many ways to that from volcanic soils in the Lake Tahoe area, but differed substantially in others. Particle-size fractions in runoff from all treatments at Sunriver were considerably smaller than those from disturbed volcanic soils in the Tahoe Basin. On the other hand, infiltration rates at SunRiver were surprisingly much greater than that encountered at Tahoe. Rainfall simulation within the Tahoe area also suggests that soil loosening to at least 12 inches depth with incorporation of coarse organic material maintains these higher infiltration rates and lower sediment yields over several years (IERS 2007).

Runoff Sediment Particle Sizes

Sediments collected from this study contain a large percentage of clay and silt sized particles (Table 3). In general soil particles in the silt and clay size range tend to stay suspended in the water column longer than coarser particle sizes, reducing water clarity and water quality. Nitrogen and phosphorous also bind onto clay particles often increasing the levels of these nutrients to problematic levels in local water bodies. As such these smaller particle sizes are of greater concern to water quality.

Sediment in runoff from slopes that were trackwalked (TW and TWM) tended to have smaller particle sizes with an increase in clay and silt fractions (Table 3). Of particular concern are the very small particle sizes <10 µm as these particles remain suspended within the water for very long periods of time. These compose ~50% of the particle-size distribution in runoff from the TW bare soils, ~25% of the particle-size distribution in runoff from the TWM mulched soils and

~10% of the particle-size distribution in runoff from the BI soils.

SUMMARY

Rainfall simulation on soils derived from volcanic ash parent material indicates that practices that incur the least amount of soil disturbance or traffic by heavy equipment have much higher infiltration rates and lower runoff rates than soils that have been trackwalked. Sediment rates were also highest on trackwalked soils but this effect can be mitigated through the application of a surface mulch. Surface mulch on trackwalked soils however, will not reduce runoff rates significantly.

LITERATURE CITED

Grismer and Ellis. 2004. Erosion Control Reduces Fine Particles in Runoff to Lake Tahoe. *California Agriculture* 60(2): 72 – 75.

Grismer, M.E. and M.P. Hogan. 2004. Evaluation of Revegetation/Mulch Erosion Control Using Simulated Rainfall in the Lake Tahoe Basin: 1. Method Assessment. Land Degradation & Dev. 13:573-588.

Grismer, M.E. and M.P. Hogan. 2005a. Evaluation of Revegetation/Mulch Erosion Control Using Simulated Rainfall in the Lake Tahoe Basin: 2. Bare Soil Assessment. Land Degradation & Dev. 16:397-404.

Grismer, M.E. and M.P. Hogan. 2005b. Evaluation of Revegetation/Mulch Erosion Control Using Simulated Rainfall in the Lake Tahoe Basin: 3. Treatment Assessment. Land Degradation & Dev. 16:489-501.

IERS, May 2007. Monitoring and Assessment of Erosion Control Treatments in and around the Lake Tahoe Basin, Prepared for Caltrans.