Simulated Rainfall Evaluation of Revegetation/Mulch Erosion Control in the Lake Tahoe Basin: 2. Bare Soil Assessment

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ABSTRACT

Slopes that have been disturbed through roadway, ski slope or other construction often produce more sediment than less disturbed sites. Reduction, or elimination of sediment loading from such disturbed slopes to adjacent streams is critical in the Lake Tahoe Basin. Here, use of a portable rainfall simulator (RS), described in the first paper of this series, is used to evaluate slope effects on erosion from bare volcanic and granitic soils (road cut and ski run sites) common in the Basin in order to establish a basis upon which revegetation treatment comparisons can be made. Rainfall simulations (60 mm h^{-1}, approximating a 100-yr, 15-min storm) at each site included multiple replications of bare soil plots as well as some adjacent "native", or relatively undisturbed soils below trees where available. Field measurements of time to runoff, infiltration, runoff, sediment discharge rates, and average sediment concentration were obtained. Laboratory measurements of particle-size distributions using sieve and laser counting methods indicated that the granitic soils had larger grain sizes than the volcanic soils and that road cut soils of either type also had larger grain sizes than their ski run counterparts. Particle-size distribution based estimates of saturated hydraulic conductivity were 5-10 times greater than RS determined steady infiltration rates. RS measured infiltration rates were similar, ranging from 33-50 mm h^{-1} for disturbed volcanic soils and 33-60 mm h^{-1} for disturbed granitic soils. RS measured runoff rates and sediment yields from the bare soils were significantly correlated with plot slope with the exception of volcanic road cuts due to the narrow range of road cut slopes encountered. Sediment yields from bare granitic soils at slopes of 28 to 78% ranged from ~1 – 12 g m^{-2} mm^{-1}, respectively, while from bare volcanic soils at slopes of 22 – 61% ranged from ~3 – 31 g m^{-2} mm^{-1}, respectively. Surface roughness did not correlate with runoff or erosion parameters, perhaps also as a result of a relatively narrow range of roughness values. The volcanic ski run soils and both types of road cut soils exhibited nearly an order of magnitude greater sediment yield than that from the corresponding native, relatively undisturbed sites. Similarly, the granitic ski run soils produced nearly four times greater sediment concentration than the undisturbed areas. A possible goal of restoration/erosion control efforts could be re-creation of "native" like soil conditions.

Keywords: Rainfall simulation, sub-alpine environment, semi-arid, slopes, ski runs, roadcuts, volcanic soils, granitic soils

INTRODUCTION

Development during the past 50 years in the Lake Tahoe Basin has caused an increased flux of sediment and nutrients into the Lake contributing to the loss of Tahoe's exceptional clarity by 25 percent from approximately 30 to 21 m. Efforts to slow nutrient input to the Lake have taken many forms most of which focus on containment of sediment on-site, or within the drainages from which they originate. Unfortunately, despite considerable effort and resources, little quantitative information exists about the performance of hillslope erosion control measures employed in the Basin (Schuster and Grismer, 2004; Grismer and Hogan, 2005). However, there are ample examples of visible failures in erosion control in this semi-arid, high-altitude environment of relatively shallow soils, minimal summer rains and long winters. This second of three papers is directed at using the rainfall simulator (RS) to establish infiltration, runoff and erosion rates from bare granitic and volcanic soils in the Basin.

Construction of road cuts and ski runs in the Basin often results in loss of nutrient containing topsoil essential for plant growth while exposing the remaining oft-compacted, readily erodible decomposed granite (DG), or volcanic subsoils to erosion. The resulting low-organic matter content of the volcanic and DG subsoils may also limit mycorrhizal infection, a potentially important component in native grass re-establishment. Compounding soil degradation and subsequent lack of plant establishment is that continued erosion may result in persistent nitrogen deficiency (Claassen *et al*., 1995).

When comparing soil physical conditions or parameters of ski runs and roadcuts it is important to note the difference in construction methodologies. Ski runs are often cut and smooth-graded using a crawler-type tractor. This process usually results in a highly compacted surface. Ski runs seldom consist of 'C' horizon material but meet the definition of 'drastic disturbance' (Box, 1978). Conversely, road cuts, while also defined as 'drastically' disturbed (as differentiated from road fills) are often cut directly into C horizons and/or parent material, with the top of the cut slope made up of remnant native soil that immediately grades into the B, C and parent material horizons. Thus, road cuts, while not always compacted, usually consist of an inherently high-density material.

Here, we use a rainfall simulator (RS) as a means by which to standardize measurement of erosion from disturbed, bare granitic and volcanic soils through replicated rainfall events of the same intensity, or kinetic energy on multiple plots having a range of slopes thereby enabling evaluation of slope and soil type effects on hydrologic parameters of interest. The primary advantages of the RS are (a) the ability to transport it to a variety of field locations as needed in order to evaluate a sufficient number of plots at any one location with statistical significance and (b) to test a number of assumptions regarding erosion behavior using real-time measurements rather than relying on locally untested model parameters.

PROJECT OBJECTIVES

Overall, we hypothesized that native grass, or revegetation will be reflected in greater infiltration rates and less runoff or sediment yield from native, or successfully restored disturbed sites (Grismer and Hogan, 2005). The specific objective of this paper was to establish baseline bare soil infiltration and runoff rates and sediment yields from disturbed (i.e. roadcuts, ski runs) granitic and volcanic soils common in the Basin to which subsequent evaluation of revegetation efforts can be compared.

METHODOLOGY

Rainfall simulation tests were conducted at several granitic and volcanic soil sites at road cuts and ski runs around the Basin. Where possible, we also conducted RS tests on less-disturbed soils having some pine needle cover often located below established conifers and adjacent to the bare soil sites. Volcanic soils sites were located on ski runs at Homewood Mountain (along the Lake's west shore south of Tahoe City) and Northstar-at-Tahoe Resort (southeast of Truckee) as well as road cuts at the Highway 89-Sierraville exit on I-80 east of Truckee, on Dollar Hill (State Hwy 28 east of Tahoe City), on Brockway Summit slopes (State Hwy 267 north of Kings Beach) and in Blackwood Canyon (along access road 2.5 miles west from Hwy 89 and about 4 miles south of Tahoe City). All these sites were in California. Granitic soil sites were located on ski runs at Heavenly Valley Mountain Resort at South Lake Tahoe and at road cuts at Luther Pass-Grass Valley along Highway 89 and mileposts 22.8 (Rubicon) and 18.5 (Bliss) also along State Hwy 89 south of Tahoe City, all in California. Smaller road cuts were located at Cave Rock Estates on the east shore of Lake Tahoe in Nevada. Table 1 summarizes the locations of the sites at which RS experiments were conducted.

Following a preliminary land survey of a site and establishment of plots and installation of plot frames (0.8m x 0.8m), the RS is centered over the plot frame and leveled. Detailed descriptions of the RS and plot frame are provided by Battany and Grismer (2000) and discussed again by Grismer and Hogan (2005). The front adjustable legs of the RS tower allowed access to steeper slopes and a combination of two ladders with ladder jacks laid on the slope were used to support the front legs with minimal disturbance to the site. Three soil samples were collected from around the plot frame and later dried for 48 hours at 105 C to determine pre-rainfall soil moisture at each plot. A plexiglass sheet was placed on the simulator structure above the plot frame and the rainfall rate established at 60 mm h^{-1} after which the sheet was quickly removed and rainfall initiated. [This rainfall intensity approximately corresponds to a 15-min, 100-yr event across the Basin.] Rainfall was allowed to continue until either a steady runoff rate was obtained from the plot frame, or ~60 minutes had elapsed. Runoff from the plot frame was collected in sequential 175 ml labeled bottles and the elapsed time noted. Infiltration rates were determined as the difference between the rainfall rate and the measured runoff rate. Following removal of the RS, the surface micro-topography of the plot was measured perpendicular to the slope ("downslope") and at each diagonal ("cross-slope") using a pin gage resulting in 20-30 point measurements per transect depending on slope, or ~100 points per plot. "Roughness" was determined as the average of the absolute value of the deviation (mm) from the mean slope for both down- and cross- slope determinations. Visible wetting front depth was also noted. Soil samples were also collected for later particle-size analyses using sieve sizes of 63, 150, 250, 500 μm and 1, 2, 4, 8, 11.2, 16 and 22.4 mm (see Table 2). Following Eshel et al., (2004), laser (Coulter) counting methods were applied to determine particle size distributions of the less than 63 μm size fraction (see Table 3).

Following field measurements, collected runoff samples are taken to the laboratory for filtration and chemical analyses. Samples were vacuum filtered first through a Whatman #1 filter followed by a 0.45 μm filter. The filter papers with sediment were dried at 105 C, weighed and total sediment mass per volume of runoff was determined. Sediment yield (sediment mass per mm of runoff; g mm^{-1}, or g m^{-2} mm^{-1}) was determined as the linear slope (zero intercept) between cumulative sediment collected in runoff and cumulative runoff depth.

Table 1. Locations of bare soil roadcut and ski run sites in the Tahoe Basin.

Location (WGS'84)	**Condition**	**Latitude (N)**	**Longitude (W)**	**Elevation (m)**	**Aspect**
Granitic Soils					
Bliss	Road cut	39° 03.27	120° 06.78	2010	NE
Cave Rock	Road cut	39° 25.27	120° 56.78	1950	NE
Heavenly	Ski run	38° 55.37	119° 54.97	2440	N
Luther Pass	Road cut	38° 47.82	119° 58.07	2100	NW
Rubicon	Road cut	39° 01.10	120° 07.53	2000	E
Volcanic Soils					
Blackwood	Road cut	39° 06.27	120° 11.78	1950	N
Brockway	Road cut	39° 15.49	120° 03.39	2090	WSW
Dollar Hill	Road cut	39° 11.73	120° 06.00	1950	S
Homewood	Ski run	39° 08.27	120° 09.78	1950	E
Northstar	Ski run	39° 16.04	120° 07.80	2150	E
Prosser	Road cut	39° 21.27	120° 08.75	1785	N
Sierraville	Road cut	39° 20.33	120° 10.15	1815	E

Table 2. Summary of sieving particle-size distribution measurements for the Tahoe Basin disturbed soils (>63 μm size fraction).

Soil Type	**n**	**D_{10} (μm)**	**D_{30} (μm)**	**D_{60} (μm)**	**[a]C_u**	**[b]K_{sat} (mm/hr)**
Granitic - mean	33	117.06	322.48	946.36	8.23	332
Std. Deviation ([c]*CV* %)	33	20.4 (17.4)	73.9 (22.9)	208 (22.0)	1.96 (23.8)	116 (34.8)
Volcanic - mean	56	100	278	1320	13.6	248
Std. Deviation (*CV* %)	56	23.2 (23.2)	120 (43.3)	568 (48.5)	6.58 (53.1)	125 (50.4)

[a] C_u is the Coefficient of Uniformity = D_{60}/D_{10} ; in geotechnical engineering, values greater than 4 indicate "well-graded" (i.e. broad range) of particles sizes.
[b] K_{sat} = (Constant)xD_{10}^2 from Harleman *et al.*(1963).
[c] *CV* = Standard Deviation / Mean.

Table 3. Summary of laser particle-size distribution measurements (means and standard deviations) for the Tahoe Basin disturbed soils (<63 μm size fraction).

Soil Type	n	D_{10} (μm)	D_{30} (μm)	D_{50} (μm)	D_{60} (μm)	D_{90} (μm)	Specific Surface (cm^2/mL)
Granitics							
Heavenly- Skirun	12	4.69	16.41	29.25	36.22	65.28	8952
Std. Dev.	12	0.92	2.19	3.84	4.57	7.11	1702
Luther Pass- RC	16	4.55	16.32	31.04	39.15	72.00	7140
Std. Dev.	16	1.03	2.99	5.76	6.88	11.21	1943
Granitics - Average		**4.62**	**16.37**	**30.14**	**37.68**	**68.64**	**8046**
Volcanics							
Blackwood -RC	1	1.94	9.06	16.57	20.94	43.50	15530
Dollar Hill-Yar. - RC	1	1.76	8.71	18.20	23.09	46.40	15334
DeathTrap -RC	1	1.74	6.77	15.57	22.32	61.98	14344
Homewood-Skirun	18	2.22	9.54	18.22	23.53	48.71	14044
Std.Dev.	18	0.38	1.41	2.15	2.69	4.42	1010
Northstar-Skirun	29	2.44	9.71	18.37	23.42	47.40	11327
Std.Dev.	29	0.79	1.82	1.76	1.86	3.06	3376
NorthStar-Unit7 - RC	1	1.05	4.46	12.31	16.87	37.21	25993
Prosser I-80 - RC	3	1.42	5.94	13.74	19.05	46.78	18385
Sierraville I-80 - RC	1	1.31	5.44	12.43	17.11	44.06	19070
SnowKing - Skirun	1	1.47	5.96	13.89	18.71	42.40	16847
Volcanics – Average (w/o Unit7)		**1.79**	**7.64**	**15.87**	**21.02**	**47.65**	**15610**

RESULTS & DISCUSSION

Results from previous rainfall simulation tests (Grismer & Hogan, 2005) indicated that erosion and runoff rates depended largely on whether the base soils were of granitic or volcanic origin regardless of the surface treatment. This observation is supported by particle-size analyses of the soils collected from the sites considered here in which the mean D_{10}, D_{30}, D_{50} and D_{60} particle sizes of the granitic soils were approximately twice that of the volcanics (see Table 3). [Larger average particle sizes in the granitic soils suggest greater infiltration capacity, however, larger erosion events are commonly seen with granitic soils as compared to the volcanics, a matter that requires further investigation.] The volcanic soils, on the other hand, had a broader particle-size range as indicated by a much greater C_u value and larger mean D_{60} particle size. Estimated mean hydraulic conductivity values (K_{sat}) of the granitic soils were more than 50% greater than that of the volcanics, an observation consistent with the greater infiltration rates measured in the RS tests. On the other hand, variability in particle-size parameters was greater in the volcanics as indicated by much greater coefficient of variation (*CV*) values despite the greater number of samples. Segregating the particle size data from ski runs and road cuts resulted in road cut soils having larger D_{10}, D_{30} and K_{sat} values than their ski run counterparts in both the granitic and volcanic soils. In terms of slope effects on erosion and runoff rates, particle-size distribution parameters from volcanic and granitic soil samples from ski runs at Homewood Mountain and Heavenly Valley Resorts, respectively, showed somewhat similar dependence on slope. For example, Figure 1 illustrates that increasing slope results in decreasing D_{10} particle size for both soil types.

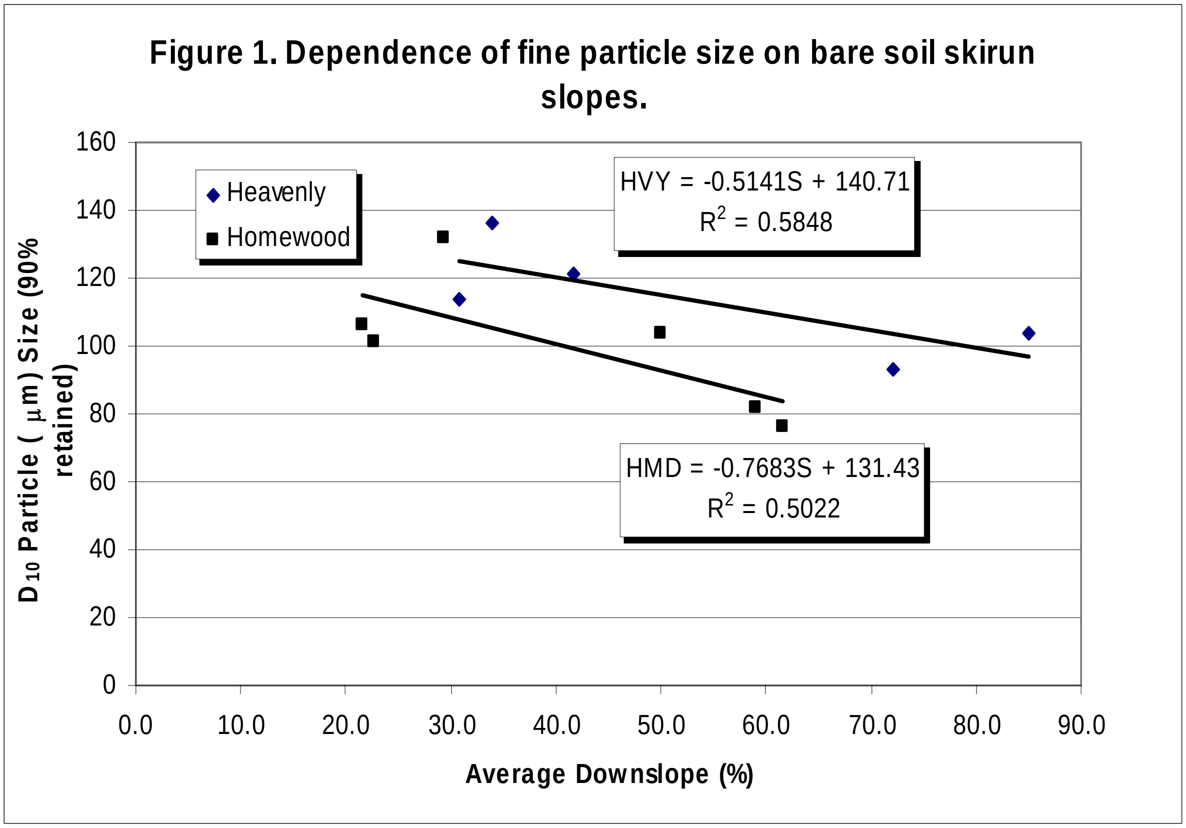
Figure 1. Dependence of fine particle size on bare soil skirun slopes.
Heavenly
Homewood
HVY = -0.5141S + 140.71
R2 = 0.5848
HMD = -0.7683S + 131.43
R2 = 0.5022
D10 Particle (μm) Size (90% retained)
Average Downslope (%)
0
20
40
60
80
100
120
140
160
0.0
10.0
20.0
30.0
40.0
50.0
60.0
70.0
80.0
90.0

Tables 3 and 4 summarize the average values of measured parameters from the RS test plots on granitic and volcanic soils, respectively. In some relatively undisturbed "native" soil plots, no runoff was observed, thus, zeros were used in averaging runoff and erosion parameters. Examination of the values reported in Tables 3 and 4 leads to appropriate correlation analyses between the independent parameters of slope and roughness (for each soil type) and the dependent runoff and erosion parameters. In terms of sediment yields, values for granitic soils differed significantly from those of volcanic soils at any particular slope where a comparison was possible. Clearly, rainfall on road cuts results in different runoff and erosion characteristics than from ski runs perhaps as a result of differing particle sizes and levels of soil compaction.

Not surprisingly, correlation analyses between the surface topography parameters and the runoff and erosion values indicated that downslope (%) was generally important, cross-slopes were less important (correlated significantly less than did downslope) and surface roughness was not important (no significant correlations). Significant correlations were not found when considering the granitic and volcanic data sets as a whole. Rather, significant correlations were only found when segregating the ski run, road cut and native soil results. Table 5 summarizes the significant correlations found for both the granitic and volcanic soils as well as linear regression results.

Table 3. Summary of averages of measured parameters from RS test plots on bare granitic soils (RC = Road Cut).

Location	**Slopes (%)**		**Rough-ness (mm)**	**Time to Runoff (s)**	**Cumulative @ 15 min**		**Steady**			**Sediment Yield**		**Sed. Yield R^2 (%)**
	Down	**Cross**			**Runoff (mm)**	**Sed. (g)**	**Infilt. (mm h^{-1})**	**Runoff (mm h^{-1})**	**Sed. Conc (g L^{-1})**	**(g mm^{-1})**	**(g m^{-2} mm^{-1})**	
Bliss RC	56.3	39.9	6.71	354	1.00	2.40	49.5	11.5	2.43	2.16	3.38	86.0
	72.3	42.9	6.25	69	1.64	12.7	44.7	14.3	14.6	8.04	12.6	98.5
CaveRock RC	59.5	39.1	7.41	465	0.56	1.39	45.6	13.7	5.29	1.32	2.06	91.4
Heavenly skiruns	35.5	26.8	11.8	1900	0	0	59.1	0.63	0.80	0.82	1.28	100
ski runs	78.6	44.7	26.5	145	1.77	5.18	47.4	11.6	4.06	3.06	4.78	98.9
LT native	36.1	24.4	12.2	326	3.73	1.79	35.4	24.6	0.59	0.56	0.88	89.5
LT ski runs	27.5	22.8	11.6	159	5.06	5.14	32.5	27.5	1.44	1.36	2.13	86.4
LT ski runs	47.9	34.2	14.0	226	3.91	4.94	35.6	24.4	1.83	1.64	2.56	89.8
LT ski runs												
L. Pass RC '02	51.0	35.0	11.6	147	3.27	2.41	38.09	22.58	1.08	0.91	1.42	97.3
L. Pass RC '03	51.0	39.5	13.8	350	1.92	2.97	48.31	11.69	1.59	1.48	2.31	90.5
Rubicon RC	52.4	35.3	6.16	1272	0.05	0.02	58.06	1.14	0.29	0.19	0.30	96.4
Native*	37.4	24.2	13.3	395*	0.6	0.30	45.0	15.0	0.40	0.50	0.78	69.6
Rubicon RC Fill	58.1	38.1	11.0	187	1.70	2.17	42.0	17.0	1.32	1.30	2.03	94.6

* Of the four plots averaged here, only one plot resulted in runoff, hence the values in columns (5) and following are results from this one plot.

Table 4. Summary of averages of measured parameters from RS test plots on bare volcanic soils (RC = Road Cut).

Location	**Slopes (%)**		**Rough-ness (mm)**	**Time to Runoff (s)**	**Cumulative @ 15 min**		**Steady**			**Sediment Yield**		**R^2 (%)**
	Down	**Cross**			**Runoff (mm)**	**Sed. (g)**	**Infilt. (mm h^{-1})**	**Runoff (mm h^{-1})**	**Sed. Conc (g L^{-1})**	**(g mm^{-1})**	**(g m^{-2} mm^{-1})**	
Blackwd. native	61.4	37.9	10.6	857	0.06	0.03	60	0.47	1.89	1.23	1.92	99.7
Brockway RC	51.5	32.4	10.6	242	2.35	16.0	36.2	23.5	11.3	7.84	12.3	99.4
Dollar Hill RC	52.2	35.4	10.0	297	1.36	4.26	45.0	15.8	4.84	3.31	5.17	99.6
Homewood	22.1	15.6	10.9	510	0.94	8.18	42.9	17.1	7.64	5.87	9.17	96.3
ski run	32.8	23.6	8.94	343	1.64	8.62	33.3	26.7	4.58	4.61	7.20	94.6
ski run	56.9	37.8	14.4	233	2.78	18.0	39.6	20.4	13.5	8.40	13.1	99.3
native	74.4	48.3	18.0	350	1.97	3.58	47.1	12.9	1.98	1.39	2.17	99.1
Northstar	20.2	33.8	11.6	435	1.29	5.26	46.8	13.2	4.51	4.05	6.33	97.3
ski run	25.6	17.1	8.21	374	1.81	12.4	37.9	22.4	5.90	5.80	9.06	94.1
ski run	31.7	22.5	4.95	300	2.70	27.6	37.3	23.7	13.6	9.44	14.8	99.7
ski run	37.0	24.0	9.47	297	2.88	58.0	37.4	23.6	19.1	15.6	24.4	96.0
ski run	42.1	26.5	8.08	268	3.50	50.1	33.1	27.0	16.6	16.6	25.9	98.6
ski run	60.7	37.9	10.9	196	2.55	59.3	38.4	19.6	30.6	23.2	36.3	98.6
LOM np ski run[a]	39.8	26.7	14.6	233	2.11	18.0	33.3	26.7	12.6	9.94	15.5	94.4
LOM pl ski run[b]	34.0	21.4	23.7	420	0.73	3.34	47.5	12.5	5.80	4.61	7.20	99.0
LOM native	45.0	31.0	14.4	390	1.37	1.28	49.1	10.9	1.35	1.20	1.88	91.7
Prosser RC	60.9	43.9	9.31	83	4.22	43.6	39.3	21.7	15.6	10.3	16.1	99.3
Sierraville RC	32.4	29.8	9.49	236	0.89	2.41	54.4	5.60	3.40	3.00	4.69	98.5

[a] np = non-planed ski-run (no stump removal, grading or “smoothing”) at Look Out Mountain (LOM) lift.
[b] pl = planed ski-run (includes stump removal, grading and “smoothing”).

Table 5. Correlations of significance (> 50% Correlation Coefficient) and regressions between runoff and erosion parameters as affected by downslope, **S,** (%) for bare granitic and volcanic soils (roadcuts and ski runs).

Soil Type - Condition	**Dependent Factor**	**Linear Regression**	**R^2 (%)**
Granitic - RC	15 min Cum. Sed. (g)	Se15 = 0.48 **S –** 24.0	73.0
	Sed. Conc. (g L^{-1})	SeC = 0.628 **S** – 32.1	88.4
		SeC = 0.084 **S**	21.0[a]
	Sed. Yield (g mm^{-1})	SeY = 0.313 **S** – 15.6	80.8
		SeY = 0.048 **S**	22.0[a]
Granitic - Ski run	Sed. Conc. (g L^{-1})	SeC = 0.064 **S** – 1.13	85.0
		SeC = 0.042 **S**	73.7
	Sed. Yield (g mm^{-1})	SeY = 0.044 **S** – 0.47	79.8
		SeY = 0.034 **S**	75.8
Volcanic - RC	No significant correlations	NA	NA
Volcanic – Ski run	Time to Runoff (s)	TtR = **-** 6.44 **S +** 564	72.4
	15 min Cum. Sed. (g)	Se15 = 0.968 **S –** 11.0	34.5[a]
	Sed. Conc. (g L^{-1})	SeC = 0.476 **S** – 5.20	60.5
		SeC = 0.348 **S**	55.6
	Sed. Yield (g mm^{-1})	SeY = 0.337 **S** – 2.50	50.0
		SeY = 0.275 **S**	48.2

[a] Non-significant correlations; regressions included for comparison purposes.

The correlation analyses between downslope and the runoff and erosion parameters for the granitic soils indicates that only erosion related parameters were significantly correlated with downslope; specifically, steady sediment concentration and sediment yield. For the granitic road cuts, the 15-min cumulative sediment values also correlated significantly with downslope. Somewhat surprisingly, infiltration and runoff rates did not depend on downslope for both the granitic and volcanic soils. While different regression equations were obtained for the granitic road cuts versus ski runs, it is apparent from these equations that greater erosion occurs from the road cuts as compared to the ski runs at a given slope, a seemingly anomalous result considering the somewhat larger D_{10} particle size of the road cut soils.

Correlations between downslope and runoff and erosion parameters for the volcanic soils also resulted in significant correlations between downslope and erosion parameters, but only for the ski runs and not the road cuts. Lack of correlation between slope and runoff and erosion values for the volcanic road cuts was probably more an artifact of the limited number of the road cut plot slopes. In the ski run plots, not only were 15-min cumulative sediment and sediment concentration and sediment yield values correlated significantly with downslope, but also time-to-runoff. However, the 15-min cumulative runoff/erosion regression relationships were somewhat poor with R^2 values around 35%. Based on the linear regression slopes, erosion from the volcanic soil ski runs was more than eight times greater than that from the granitic ski runs (i.e. 0.275 *vs.* 0.034 g mm^{-1}) underscoring the more erodible surfaces of these soils.

The correlation analyses were completed without including results from the "native" soil plots as these did not "fit" with results from either the road cut or ski run groups. Runoff and erosion from the native soils was dramatically less for both soil types. The average 15-min cumulative runoff and erosion values as well as the sediment concentrations and yields from the "native" soils were nearly an order of magnitude less than for volcanic ski runs and granitic road cuts and roughly a quarter of that for granitic ski runs. Clearly, the "native" soil conditions (deeper duff, less compaction, some decomposed pine needle cover) provide some runoff and erosion control that should be considered in restoration efforts.

SUMMARY & CONCLUSIONS

Reduction of sediment loading to Lake Tahoe is critically important in the Tahoe Basin to both environmental and economic interests. Revegetation efforts have often failed in terms of substantially reducing sediment loading despite apparent presence of some grass and plant cover, but little quantitative information about erosion control measures is available. Here, use of the portable rainfall simulator (RS) described in the first paper of this series is used to evaluate slope effects on erosion from disturbed bare volcanic and granitic soils common in the Basin in order to establish a basis upon which revegetation treatment comparisons can be made.

Measurements of particle-size distributions using sieve and laser counting methods indicated that the granitic soils had larger grain sizes than the volcanic soils and that road cut soils of either type also had larger grain sizes than their ski run counterparts. Particle-size distribution based estimates of saturated hydraulic conductivity were 5-10 times greater than RS determined steady infiltration rates. RS measured infiltration rates were similar for both soil types, ranging from 33-50 mm h^{-1} for disturbed volcanic soils and 33-60 mm h^{-1} for disturbed granitic soils. RS measured runoff rates and sediment yields from the bare soils were significantly correlated with plot slope with the exception of volcanic road cuts due to the very limited range of road cut slopes encountered. Sediment yields from bare granitic soils at slopes of 28 to 78% ranged from ~1 – 12 g m^{-2} mm^{-1}, respectively, while from bare volcanic soils at slopes of 22 – 61% ranged from ~3 – 31 g m^{-2} mm^{-1}, respectively. Surface roughness did not correlate with runoff or erosion parameters, perhaps as a result of a relatively narrow range of roughness values. The volcanic ski run soils and both types of road cut soils exhibited nearly an order of magnitude greater sediment yield than that from the native/relatively undisturbed sites. Similarly, the granitic ski run soils produced nearly four times greater sediment concentration than the undisturbed areas. Not surprisingly, these results for the "native" soils suggest that most of the sediment loading to the Lake is associated with Basin erosion from disturbed soils. On the other hand, a possible goal of restoration/erosion control efforts should be re-creation of "native" like soil conditions. Preliminary use of a cone penetrometer indicated that it may be a versatile rapid assessment tool for determining hillslope susceptibility to surface erosion. Future use of a cone penetrometer is suggested to quickly evaluate field infiltration conditions.

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