Telegraph Fire ES&R Soils Report

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General Soil Resources Description

The soils within the Telegraph Fire burned area derived from basic and metabasic igneous rock or from metasedimentary rock. The soils have developed under chaparral, oak woodland or forest vegetation and are typically shallow to moderately deep on mountain slopes or ridges and moderately deep to very deep on toe slopes.

Soils were mapped and identified by the USDA-NRCS. Dominant soils include the Maymen-Mariposa and Auburn-Daulton associations. Maymen and Mariposa soils are well-drained, very shallow or shallow soils weathered from material weathered from metasedimentary rock on moderately steep to very steep slopes. Auburn and Dalton soils are well-drained, very shallow or shallow soils derived from materials weathered from schist and slate on gently sloping to very steep slopes (SCS, 1974). Other included soils are the Boomer, Josephine, and Trabuco series. Surface textures are commonly loam, silt loam, or sandy loam with coarse fragments ranging from 5 to 60 percent consisting of gravels, stones, boulders, channers, and flagstones. Erosion hazards are severe due to long steep slopes. There are areas of exposed bedrock typically on the shoulders of steep slope.

Post-fire Assessment Methods

Natural soil processes essential to the sustainability of healthy ecosystems are often altered by wildfires. Depending on the intensity and severity of a wildfire, soil characteristics like organic matter/nutrient status, soil aggregate stability, and hydrologic function can be reduced, impairing the ability of vegetation to re-establish and increasing runoff and soil erosion following rain events. Due to the potential for increased overland flows, increase soil erosion, high levels of sediment delivery into aquatic systems, and related human concerns, a burned area assessment following a wildfire is necessary.

Soil burn severity varies widely in space and creates a mosaic pattern of low, moderate and high severity across the landscape (Robichaud et.al, 2007). Soil burn severity is based on temperature, moisture content of surface fuels, heat of combustion, and total amount of litter and ground vegetation consumed. Soil burn severity accounts for the amount of conductive and radiant heat that goes down into the soil, affecting soil characteristics. Generally, there is a close correlation between the depth, intensity, and residence time of heat penetrating into a soil and the loss and/or alteration of soil properties. Increased fire intensity promotes the formation of water repellent (hydrophobic) layers at or near the soil surface, and loss of soil structural stability. These changes to the soil environment can dramatically increase the potential for runoff and soil particle detachment by water and transport off-site (erosion) in burned areas.

To mitigate the potential for large-scale erosion events, it is important that predictions be made regarding the hydrologic response of post-burn soils. The production of a Burn Severity map is a tool

used for making these predictions. A satellite BARC (Burned Area Reflectance Characterization) map was produced to try to identify areas of most concern. It became evident that the generated BARC map was inaccurate and did not reflect actual conditions on the ground. It seemed to over predict high burn severity especially on north facing slopes and areas where there was high surface rock content. Therefore, we did not use the generated BARC map; instead, we utilized visual field reconnaissance and plot data to create a Burn Severity map.

The criteria used to evaluate burn severity in the field included assessments of soil hydrophobicity, soil structure and aggregate stability, amount of organic material remaining on the surface, root viability, post fire effective ground cover, and size and amount of residual fuels/vegetation. Eighteen (18) plots throughout the burned area were examined and evaluated based on the criteria above. Of these 18 plots one was on an unburned area as a reference point. Also, 1 plot was examined outside the burned area as a reference point. See project file for the field notes that describes what was found at each site.

Hydrophobic soils are soils that repel water. A thin layer of soil at or below the mineral soil surface can become hydrophobic after intense heating. The hydrophobic layer is the result of a waxy substance that is derived from plant material burned during an intense fire. The waxy substance penetrates into the soil as a gas and solidifies after it cools, forming a waxy coating around soil particles. Hydrophobic soils repel water, reducing the amount of water infiltration. Decreased infiltration into the soil results in damaging flows in creek channels. Erosion increases with greater amounts of runoff. Increased runoff carries large amounts of detached soil particles that can affect water quality (NRCS, 2000).

Soil hydrophobicity was determined qualitatively by using the water drop method. The test procedure was to scrape the ash away and test with water at the bare mineral soil surface. The degree of hydrophobicity and depth of the hydrophobic layer were measured. The degree of hydrophobicity is based on the time for the absorption of a drop of water on a dry mineral soil surface:

Weak – less than 10 seconds

Moderate – between 10 and 40 seconds

Strong – greater than 40 seconds

Based on results from field reconnaissance and evaluations the Telegraph Fire burned area was mapped into four relative burn severity classes: High, Moderate, Low, and Unburned.

The **high burn severity** classification indicates areas where surface soil properties have been modified. The surface soil has a high degree of hydrophobicity. Depth of hydrophobicity is up to one inch deep. In these areas, organic material has been consumed leaving only short (less than 12 inch) stobs of shrubs spaced widely apart. Additionally, soils at these sites contain few viable roots in the upper 3-6 inches of the soil. Recovery of natural vegetation is expected to be very slow; therefore, soils will be exposed to erosive forces for a longer period of time. Sites with a high burn severity classification are highly susceptible to rain-impact erosion at the soil surface, reduced infiltration, and increased runoff and erosion. Erosion modeling estimates soil erosion rates at 33.5 tons/acre the first year after the wildfire based on 50% probability sediment yields will be exceeded. Pre-fire rates are estimated at 3.9 tons/acre. See the Erosion Modeling section below for more detail.

Figure 1. Representation of high burn severity.

The **moderate burn severity** classification indicates areas where most of the organic material has been consumed and some surface soil structure and stability has broken down and been lost. Surface soil hydrophobicity is typically increased compared to the pre-burn condition. Skeletons of shrubs with fine limbs close to the ground remain. These skeletons can be up to 6 feet high. Because some near surface fine root viability (shrubs and/or grasses) is usually lost at these sites, natural vegetative recovery will be somewhat slowed. Areas with a moderate burn severity classification can be highly susceptible to rain-impact erosion, reduced infiltration, and increased runoff and erosion. However, erosion rates would be less than a high burn severity area because of the residual cover of the shrub skeletons reducing rain-drop splash erosion. Erosion modeling estimates soil erosion rates at 27.0 tons/acre the first year after the wildfire based on 50% probability sediment yields will be exceeded.

Figure 2. Representation of moderate burn severity.

The **low burn severity** classification indicates areas where the organic material has only been partially consumed by fire. Due to the insulating qualities of the remaining organic layer, surface soils on these sites show very limited affects from fire. Surface soil structure and stability remain intact, and soil hydrophobicity is similar to pre-burned conditions. In general, there are unburned shrubs unburned tree crowns (where present) and many viable small plant roots just under the soil surface. Natural vegetative recovery on these sites is typically very good. Areas mapped as low burn severity have a limited susceptibility to rain-impact erosion, reduced infiltration, and increased runoff and erosion. Erosion modeling estimates soil erosion rates at 18.7 tons/acre the first year after the wildfire based on 50% probability sediment yields will be exceeded.

Figure 3. Representation of low burn severity.

Findings

Field reconnaissance and evaluations reveled that most of the burned area fell into the moderate burn severity classification. Areas with a high burn severity classification were limited mostly to relatively small areas, except for the slope north of Sherlock Creek and the slope east of North Fork of the Merced.

Table 1. Burn severity acres for the Telegraph Fire burned area.

Burn Severity	Acres	Percent
High	844	2
Moderate	23,841	70
Low	6,355	19
Unburned	3,076	9

Soils in all burn severity classes were examined in the field to assess for post-fire hydrophobic conditions. Field examinations indicated that hydrophobic layers developed. Table 2 shows the degree, depth, and expected duration of hydrophobicity observed for each burn severity classification.

Table 2. Degree, depth, and expected duration of hydrophobic layers for each burn severity classification.

Burn Severity	Degree	Depth (in.)	Anticipated Duration
High	Strong Moderate Weak	.25 .5 1.0	1 year
Moderate	Strong Weak	.25 .5	< 1 year
Low	None	N/A	N/A

It is anticipated that shallow surface hydrophobic layer will break up after the first few moderate intensity precipitation event. It is anticipated the deeper hydrophobic conditions will break up within a year. However, the length of time a soil retains this hydrophobic condition can be quite variable. The persistence of a hydrophobic layer will depend on the strength and extent of hydrophobic chemicals after burning and the many physical and biological factors that can aid in breakdown (DeBano, 1981). This variability makes it difficult to accurately predict and quantify post-fire impacts on watershed conditions. Even once the hydrophobic soil conditions are ameliorated, the loss of surface cover in the burned areas will produce post-fire runoff and erosion.

Erosion Modeling

Erosion was modeled with ERMiT (Erosion Risk Management Tool). ERMiT combines weather variability with spatial and temporal variabilities of soil properties to model the range of post-fire erosion rates that are likely to occur. ERMiT produces a distribution of runoff event sediment delivery rates with corresponding exceedance probabilities for each of five post-fire years (Robichaud, 2007). ERMiT has been found to under-predict erosion values for untreated site (Bill Elliot, U.S. Department of Agriculture, Forest Service, Rocky Mountain Research, personal conversation).

ERMiT is a web-based application that uses Water Erosion Prediction Project (WEPP) technology to predict erosion in probabilistic terms on burned and recovering forest, range, and chaparral lands, with and without the application of mitigation treatments. At best, any predicted runoff or erosion value, by any model, will be within only plus or minus 50 percent of the true value. Erosion rates are highly variable, and most models can predict only a single value (Elliot et. al., 2000).

The data entered into the ERMiT model included the following parameters: Climate data modified from the Hetcy Hetchy site. The dominant surface texture observed in the field was loam; therefore, loam was used. The top of slope was modeled at 0%, the middle slope was modeled at 45%, with the toe slope at 20%. Slope length was assumed to be 600 feet, based on average slope length observation in the field. Pre-fire hillslope vegetation was assumed to be 55% chaparral shrub, 5% grass, and 40% bare, based on best professional judgment of the vegetation specialist. Low, moderate, and high burn severity were modeled. ERMiT estimated that the pre-fire erosion rate was 3.9 tons/acre. This was the value given after the 5 year recovery period for all three severity classifications. Low, moderate, and high severity first year post-fire erosion rates were predicted to be approximately 18.7, 27.0, and 33.5 tons/acre, with 50% probability sediment yields will be exceeded for the first year following the fire.

Approximately 39.1, 50.5, and 65.5 tons/acre can be expected, with a 20% probability (Figures 4,5,6). To validate model output values, coordination with the model developer was conducted. He, Bill Elliot, thought that the values were reasonable (Bill Elliot, U.S. Department of Agriculture, Forest Service, Rocky Mountain Research, personal conversation).

Figure 4. Modeled Sediment Yield Output from ERMiT (Low Severity).

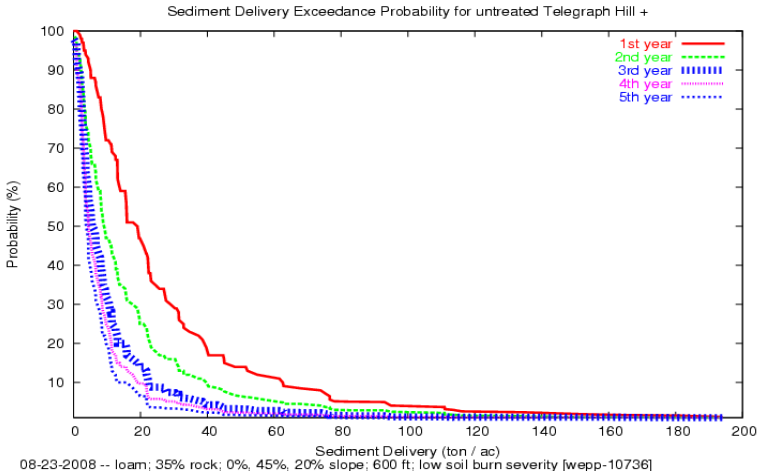


Figure 5. Modeled Sediment Yield Output from ERMiT (Moderate Severity).

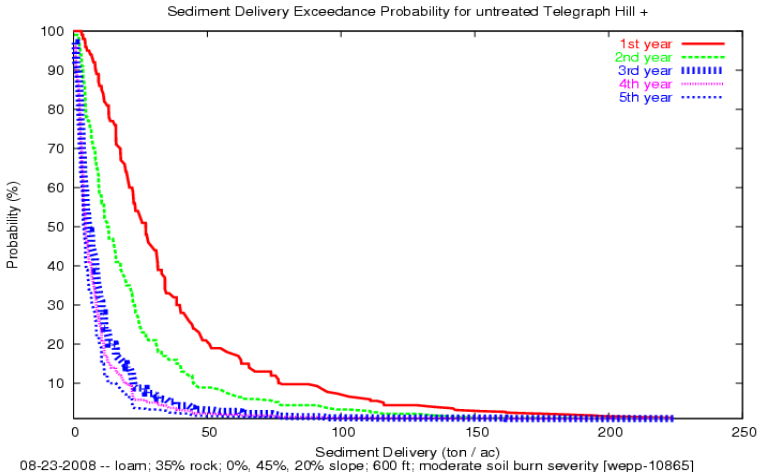
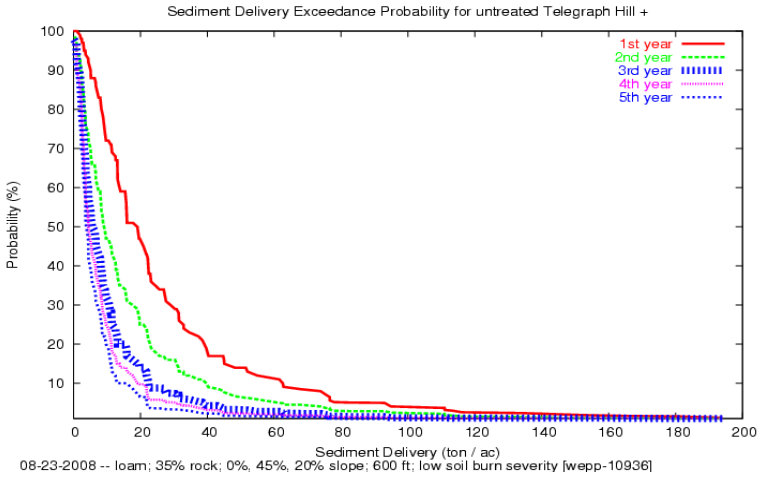


Figure 6. Modeled Sediment Yield Output from ERMiT (High Severity).



Erosion is expected to increase after the fire due to exposed soils on long steep slopes within the burned area. Erosion will be the greatest the first year following the fire and will diminish over the following five years once vegetation re-establishes and covers the soil surface. It is anticipated that post-fire responses in areas where there was moderate or high burn severity to be the following: first, an initial flush of ash from the hillslopes into the creeks/drainages following a precipitation event; and then sheet, rill and/or some small gully erosion on the steep slopes. Upper drainageways, that are not bedrock controlled, will be downcut. The high amount of surface rock in many areas will reduce the raindrop splash erosion, armor the soil surface, and slow runoff by adding surface roughness. If an intense rainstorm were to impact the burned area before hydrophobic soil conditions are ameliorated, there is the strong potential for significant runoff and associated soil erosion to occur on high and moderate burn severity areas.

Treatment Recommendations

Erosion treatments are not recommended for any of the low burn severity areas because of the rapid natural re-vegetation and low soil erosion potential. Erosion treatments are not recommended for most of the moderate burn severity areas for the following reasons: the predicted natural re-vegetation responses, the lack of values at risk that would be directly affected by the potential post-fire erosion/sedimentation, and slope limitations for effective treatment.

Erosion treatments are recommended on some of the high soil burn severity areas associated with the Burma Grade Road, Culvert Gulch, and Sherlock Creek.

Burma Grade Road: The steep slopes above this switch-back road burned at moderate and high severity. Due to the lack of vegetative cover and strong hydrophobic soil conditions, it is expect that there will be an increase of runoff and erosion on the slopes above the road. Culverts will need to be upgraded/improved to handle the increased flow and sediment to prevent failure, which could lead to the loss of the road. Improving drainage on the road would minimize the opportunity for water to be shed off the road onto unarmored slopes that would lead to rills or gullies.

Apply straw mulch on 17 acres at a rate of 1 ton/acre to protect bare soils, improve infiltration, slow runoff and add an organic layer. Reducing runoff on the slopes would result in less water reaching the road, which could lead to failure of culverts.

ERMiT estimated erosion rates at 55.5 tons/acre, with 20% probability for the first year following the fire (Figure 7). A 20% probability was use due to the high value-at-risk of the road and the potential for loss of that value. Applying straw mulch at a rate of 1 ton/acre would reduce the erosion rate to 13.8 tons/acre (Figure 8). This would be a 75% reduction.

Figure 7. Modeled Sediment Yield Output from ERMiT for Burma Grade Treatment Area.

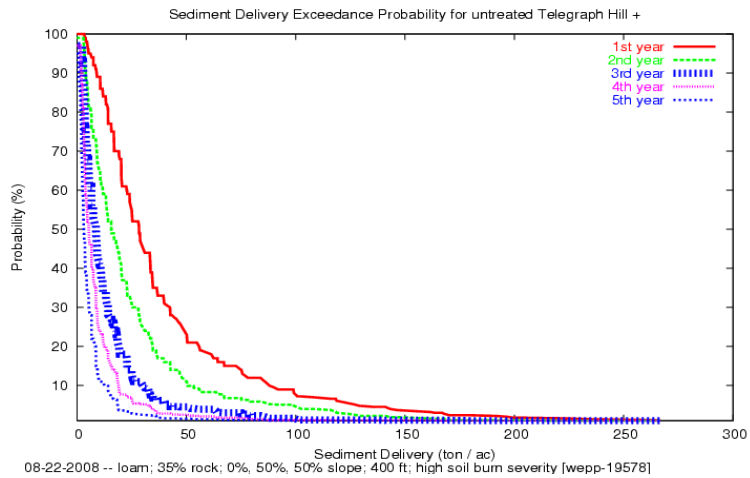


Figure 8. Mitigation Treatment Comparison from ERMiT for Burma Grade Treatment Area.

Mitigation Treatment Comparisons					
Probability that sediment yield will be exceeded 20 % go	Event sediment delivery (ton ac^{-1})				
	Year following fire				
	1st year	2nd year	3rd year	4th year	5th year
Untreated	55.52	34.49	19.19	12.65	8.59
Mulch (1 ton ac^{-1})	13.76	16.9	19.19	12.65	8.59

Culvert Gulch: The steep slopes burned at moderate and high severity. Due to the lack of vegetative cover and strong hydrophobic soil conditions, it is expected that runoff will increase resulting increased soil erosion on the steep slopes.

Apply straw mulch on 25 acres at a rate of 1 ton/acre to protect bare soils, improve infiltration, slow runoff and add an organic layer.

ERMiT estimated erosion rates at 82.0 tons/acre, with 20% probability for the first year following the fire (Figure 9). A 20% probability was use due to the high value-at-risk of the road and the potential for loss of that value. Applying straw mulch at a rate of 1 ton/acre would reduce the erosion rate to 22.8 tons/acre (Figure 10). This would be a 72% reduction.

Figure 9. Modeled Sediment Yield Output from ERMiT for Culvert Gulch Treatment Area.

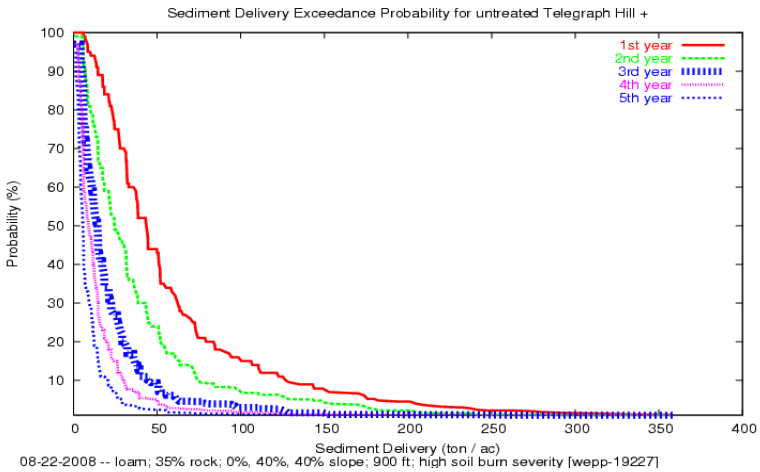


Figure 10. Mitigation Treatment Comparison from ERMiT for Culvert Gulch Treatment Area.

Mitigation Treatment Comparisons					
Probability that sediment yield will be exceeded 20 % go	Event sediment delivery (ton ac^{-1})				
	Year following fire				
	1st year	2nd year	3rd year	4th year	5th year
Untreated	81.99	52.5	30.35	19.83	12.69
Mulch (1 ton ac^{-1})	21.79	26.29	30.35	19.83	12.69

Sherlock Creek: Slopes above the creek experienced high and moderate burn severity, especially the north slope above the creek and the slopes at the upper reaches of the watershed. Slopes are long and very steep. Due to the lack of vegetative cover and strong hydrophobic soil conditions, it is expected that runoff will increase resulting in increased soil erosion on the steep slopes. This erosion will likely increase the sediment load in the creek and impact habit of the yellow legged frog and other aquatic species. Also, due to the high burn severity, re-vegetation of the slopes will be greatly slowed leaving soils exposed for several years.

Apply straw mulch on the two treatment units (151 acres total) at a rate of 1 ton/acre to protect bare soils, improve infiltration, slow runoff, reduce sediment delivery, and add an organic layer.

ERMiT estimated erosion rates to range between 43.0 to 53.1 tons/acre, with 50% probability for the first year following the fire (Figures 11 and 12). Applying straw mulch at a rate of 1 ton/acre to protect bare soils from surface erosion would reduce erosion rates between 9.9 and 11.8 tons/acre (Figures 13 and 14). This would be a 78% reduction.

Figure 11. Modeled Sediment Yield Output from ERMiT for Sherlock Creek Treatment Area.

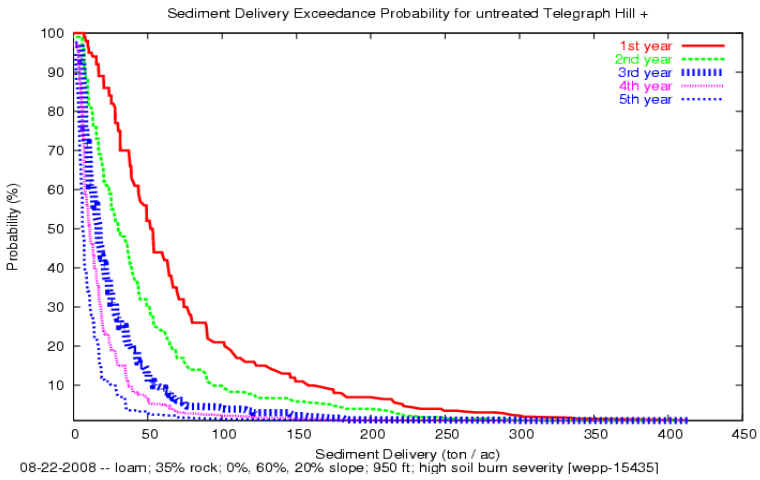


Figure 12. Modeled Sediment Yield Output from ERMiT for Sherlock Creek Treatment Area.

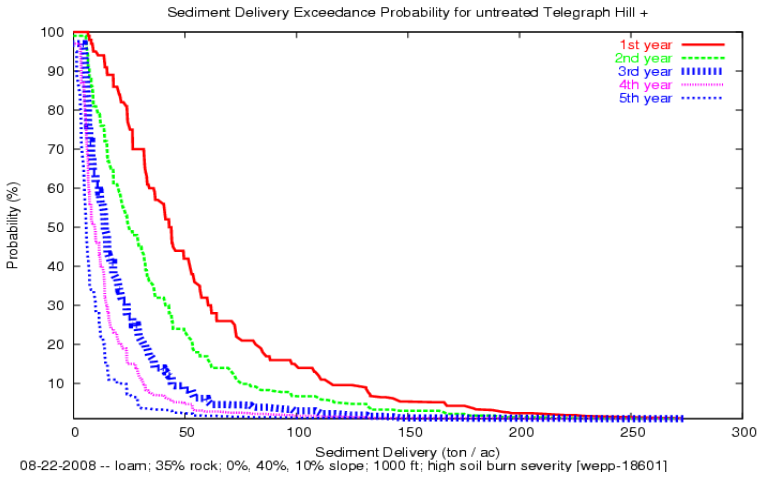


Figure 13. Mitigation Treatment Comparison from ERMiT for Sherlock Creek Treatment Area.

Mitigation Treatment Comparisons					
Probability that sediment yield will be exceeded 50 % go	Event sediment delivery (ton ac^{-1})				
	Year following fire				
	1st year	2nd year	3rd year	4th year	5th year
Untreated	53.05	30.9	16.85	10.86	6.32
Mulch (1 ton ac^{-1})	11.82	12.9	16.85	10.86	6.32

Figure 14. Mitigation Treatment Comparison from ERMiT for Sherlock Creek Treatment Area.

Mitigation Treatment Comparisons					
Probability that sediment yield will be exceeded 50 % go	Event sediment delivery (ton ac^{-1})				
	Year following fire				
	1st year	2nd year	3rd year	4th year	5th year
Untreated	42.92	25.85	14.18	9.53	5.71
Mulch (1 ton ac^{-1})	9.91	11.66	14.18	9.53	5.71

References

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