SOILS REPORT FOR THE HAYDEN PASS FIRE, JULY 2016, SAN ISABEL NF
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I. Resource Condition Assessment

A. Objectives

Surveyed and analyzed the burned area for:

- Threats of soil productivity loss
- Accelerated soil erosion
- Degradation of water quality, riparian, and fisheries habitat
- Increased risk for flood and debris flow
- Threats to life, safety, property, natural resources, and cultural and heritage resources

B. Methods

Characterized Burned Area Soils: Used existing soil survey information and datasets to map and describe soils burned area soils. Conducted field surveys to verify soil properties and describe soil resource condition.

Reviewed Burned Area Reflectance Classification (BARC) Satellite Image: Utilized the BARC to produce an accurate soil burn severity map in a short timeframe. The Burn Area Emergency Response (BAER) Team acquired and utilized two BARC images which covered most of the burned area. Minor adjustments, following field review, were made. Details on adjustments and development of the final soil burn severity map are available in the project file.

Conducted Soil Burn Severity Survey: The soil burn severity survey was conducted by aerial and ground based reconnaissance of the burned area. Soil burn severity was interpreted according to the definitions in the Field Guide for Mapping Soil Burn Severity (http://www.fs.fed.us/rm/pubs/rmrs_gtr243.pdf). Soil burn severity indicators include depth, color and character of ash; size and amount of live fuels consumed; amount of litter consumed; condition of plant root crowns; loss of soil structure; development of water repellency; and soil crusting. In areas where pre-fire vegetation was primarily conifer forest, live needle consumption and consumption of forest floor litter/duff provide the most useful indicators of burn severity.

Table 1.

General Burn Severity Criteria			
Burn Severity	**Ash Color**	**Canopy Consumed**	**Size of Material Consumed**
High	white/red	More than 80%	More than 3/4 inch
Moderate	black/gray/white	40-80%	1/4-3/4 inch
Low	black/gray	Less than 40%	0-1/4 inch

Determined Hydrophobic Soil Conditions: Collected field data to determine the degree and extent of fire induced water repellent (hydrophobic) conditions for comparison with background (natural) hydrophobicity. Used existing soil survey information and datasets to map and describe hydrologic soil groups.

Predicted Potential Rates of Soil Erosion and Determined Erosion Hazard Ratings for the Burned Area: Calculated pre-fire/post-fire potential soil erosion with the ERMiT model (http://forest.moscowfsl.wsu.edu/cgi-bin/fswepp/ermit/ermit.pl). Used existing information from the San Isabel soil survey and dataset to describe pre-fire soil erosion hazard ratings.

C. Summary of Findings

Dominant Soils: Leadville, Perfrin, Mollic Cryonoralfs-Lithic Cryoboralfs, Bowen, and Leighcan. Soils within the burn area generally have moderate and deep, well-drained, sandy loam and loamy-skeletal characteristics with a gravel and sand component. The granular, sand, and fine particle structure accommodates organic components concentrated at the surface layer. Soils are dominantly a sandy loam texture, containing more nutrients, moisture and humus in pre-fire and low burned conditions. Ground cover, critical for soil stabilization, is lacking throughout most areas mapped as moderate and high soil burn severity. These soils are sensitive to fire effects, and soil productivity is likely impacted where heavy surface fuels were consumed. High rates of erosion are expected in moderate and high burn soil severity where ground cover was burned.

Geologic Types: Marine Limestone – Minturn – Belden Formation, Arkosic Sandstone and Conglomerate – Sangre de Cristo Formation, Lahar, Soda Granite, Boulder Alluvium – Santa Fe Formation, Glacial Till, Slocum Alluvium, Bull Lake Deposits, Pinedale Deposits and Landslide Deposits. The geology in the area lends to pebble, cobble, and sandy soils, mixed with finer organic material. Landslide deposits, dated to the Holocene epoch (current geologic time period), are boulder and derived from bedrock with a hummocky surface.

Potential Physical, Chemical and Biological Fire Effects on Soil Resources: Fire effects on soil productivity range from beneficial to damaging, depending on fire severity, soil type, and site history. Adverse fire effects increase as burn severity increases and the effects are often proportional to the amount of surface litter and soil organic matter consumed.

Physical Effects:

- Loss of litter layer, soil and soil organic matter
- Loss of soil structure
- Hydrophobicity (formation of water repellent layer)
- In extreme cases, destruction of clay minerals

Chemical Effects:

- Increase in pH
- Loss of cation exchange capacity
- Loss of nutrients by volatilization, in fly ash, or by leaching
- Increase plant available N (ammonia) under low severity burns
- Oxidation reactions from extremely severe burning can discolor the surface soil
- Potential for increased release of heavy metals in contaminated soils

Biological Effects:

- Direct mortality of soil organisms and loss of their habitat with soil heating

Severe Burning of Litter, Duff, and Soils: Severe Burning of the litter, duff, and soil effects soil cover, infiltration, organisms, and nutrients.

- Loss of effective ground cover leaves soil susceptible to erosion.
- Debris movement and sediment transport may increase when small organic debris dams are burned out.
- Increased water repellent (hydrophobic) soil limits water infiltration. Surface hydrophobicity may protect the soil from erosion but significantly increase channel scour caused by accelerated runoff. Additionally, when a hydrophobic layer forms below a surface layer, the risk of the surface layer "slicking off" is increased. Stronger (more water repellent) and deeper hydrophobic layers occur in sandy soils.
- Mortality of some soil organisms and combustion of surface soil organic matter.
- Volatilization or release and increased mobility of some soil nutrients.

Soil heating affected the aggregate stability, canopy cover, ground cover, and infiltration rate. Before the fire, most of the area had protective vegetative ground cover in the form of litter, duff, or ground vegetation. In the high burn severity areas, little or no vegetative ground cover remains and the potential for re-establishment of ground cover within the first year following the fire is low. Consumption of ground cover by the fire was extensive within the moderate and high soil burn severity polygons, rendering the soils vulnerable to high rates of post fire erosion. However, other fire effects on soils are generally limited in spatial extent and occur in patchy patterns based on consumption of heavy fuels on the forest floor and the mosaic patterns of soil burn severity.

Burn Severity and Slopes for the Entire Burned Area: Burn severity and slope heavily influence potential soil erosion due to fire-induced reduction of protective ground cover combined with high runoff potential of steep slopes.

- In chaparral (shrub) vegetation types, the soil burn severity was influenced by the density of pre-fire vegetation. The watershed response in moderate and high burned chaparral areas is expected to be high until the native vegetation recovers.
- Forested areas with moderate and high burn severity is expected to have similar post fire erosion and runoff in the first year following the fire.
- 56% of the fire burned at moderate soil severity. 18% of the burned area has high soil burn severity characteristics. Unburned and low soil burn severity comprises 26% and occurs throughout the burned area. (See Soil Burn Severity Map in the Project File.)

Soils with low burn severity still have good surface structure, contain intact fine roots and organic matter, and should recover in the short-term once re-vegetation begins and the soil surface regains cover. The moderate to high classes have minimal evidence of severe soil heating and this is limited to isolated patches. The most severely burned slopes occur where pre-fire vegetation densities and ground fuels accumulations were higher. Water repellency is present throughout the fire area, including unburned areas like rock outcroppings, and was exacerbated by the fire. While a proportion of eroded soil will remain on the hill-slope, delivery of eroded soil to stream channels is expected to occur. These eroded sediments are a primary source of material for debris flows and sediment laden stream flows.

Figure 1. Soil Burn Severity

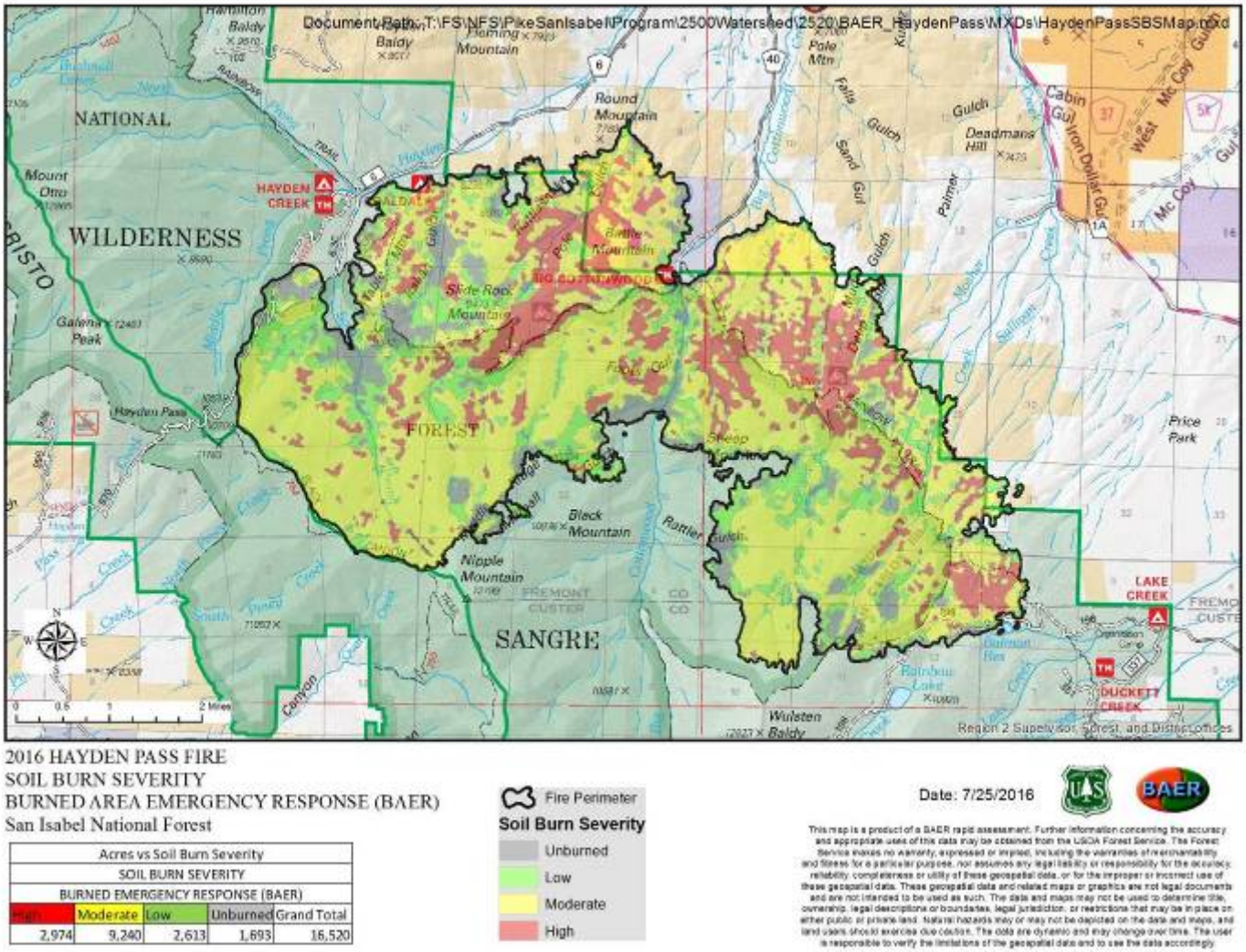


Table 2.

Soil Burn Severity for the Hayden Fire		
Severity	**Acres Burned**	**Percent**
High	2974	18%
Moderate	9240	56%
Low	2613	16%
Unburned	1693	10%

Table 3.

Soil Burn Severity by Vegetation Type			
Vegetation Type	**Soil Burn Severity**	**Acres**	**Percent of total burn area**
Forest	Unburned/Low	2474	15%
	Moderate	488	3%
	High	1105	7%
Shrub	Unburned/Low	1832	11%
	Moderate	8752	53%
	High	1869	11%

Table 4. Hayden Creek Fire Sub-watersheds

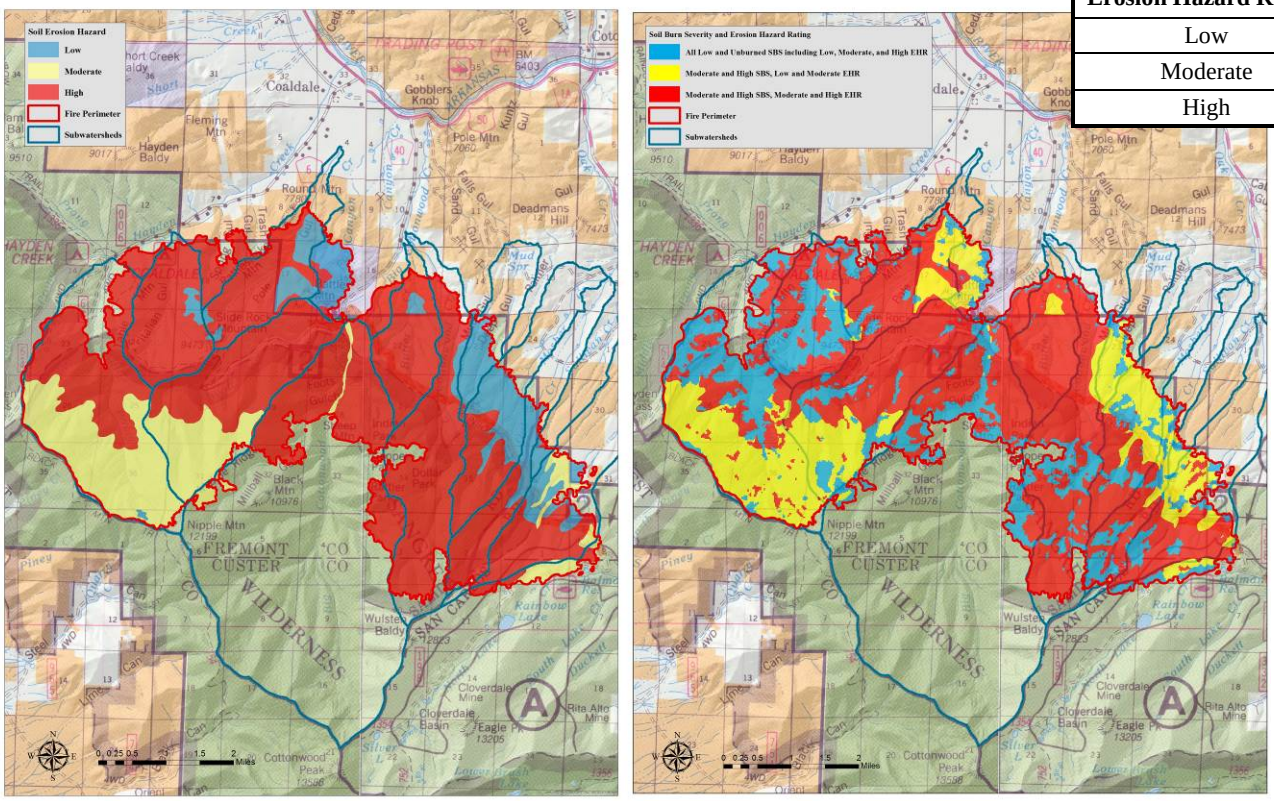
6th Field Watershed	Sub-watersheds	Total Acres	Burn Severity Acres (Percent of Watershed)			
			Unburned Acres (%)	Low Acres (%)	Moderate Acres (%)	High Acres (%)
Hayden Creek	South Prong Hayden Creek	3,434	812 (24%)	548 (16%)	1841 (54%)	197 (6%)
	Italian Gulch	1,245	298 (24%)	297 (24%)	482 (39%)	168 (13%)
Hamilton Creek-Arkansas River	Pole Gulch	1,317	264 (20%)	116 (9%)	501 (38%)	436 (33%)
Big Cottonwood Creek	Wolf Creek	2,399	136 (6%)	259 (11%)	1507 (63%)	497 (21%)
	Big Cottonwood Creek	8,360	7135 (85%)	373 (4%)	758 (9%)	298 (4%)
	Butter Creek	1,017	68 (7%)	13 (1%)	610 (60%)	326 (32%)
	Little Cottonwood Creek	2,379	605 (25%)	285 (12%)	1229 (52%)	260 (11%)
Falls Gulch	Deep Gulch	804	540 (67%)	41 (5%)	89 (11%)	134 (17%)
	Mosher Creek	1,686	734 (46%)	142 (8%)	592 (35%)	218 (13%)
	Oak Creek	1,252	627 (50%)	173 (14%)	405 (32%)	47 (4%)
	Sullivan Creek	2,009	989 (49%)	136 (7%)	605 (30%)	279 (14%)

Erosion Hazard Rating: The pre-fire erosion hazard rating (EHR) for burned area soils was obtained from existing soil erosion hazard rating information in the San Isabel soil dataset. The EHR interpretation is based on soil properties such as soil texture, slope, aggregate stability, infiltration rate, subsoil permeability, depth to restrictive layers, and soil rock content. The rating is the maximum EHR for the soil map units. Actual pre and post fire erosion potential is better reflected by the ERMiT modeling runs for this project.

Table 5.

Erosion Hazard Ratings	
Erosion Hazard Rating	**Acres**
Low	1,994
Moderate	2758
High	11,768

Figure 2. Pre-Fire Soil Erosion Hazard Ratings and Pre-Fire Erosion Hazard Ratings intersected with Soil Burn Severity



Pre-Fire Erosion Hazard Ratings
BURNED AREA EMERGENCY RESPONSE (BAER)
San Isabel National Forest

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D. Erosion Potential

Erosion response is heavily influenced by soil burn severity and hill slope. The burn affected soil aggregate stability, canopy cover, ground cover, and infiltration rates. Before the fire, most of the forested areas had protective ground cover in the form of litter, duff, or ground vegetation. In high and moderate soil burn severity areas, it is highly likely that increased rates of soil erosion and sediment delivery to stream channels will occur, in the first and second year following the fire, particularly on steep slopes.

The ERMiT models allows users to predict the probability of a given amount of sediment delivery to the base of a hillslope following variable burns on forest, rangeland, and chaparral conditions in years following wildfire. The ERMiT model can be accessed at http://forest.moscowfsl.wsu.edu/fswepp/

ERMiT Model Assumptions and Inputs:

- Slope length was 300 feet for all ERMiT runs
- Soil surface texture was sandy loam
- Soil Rock Content was 30% Volume
- There is a low (10%) probability the rates of erosion will exceed the amounts shown in the preceding table in the first year following the fire.

Table 6. ERMiT Erosion Model Outputs for the First Year Following the Fire

Erosion in Tons/Acre by Soil Burn Severity							
Vegetation Type	**Soil Burn Severity**	**Percent Slope**					
		< 10 %	10 - 20 %	20 - 30 %	30 - 40 %	40 – 50%	50 - 60 %
Forest	Low	≤ 1.82	1.82 – 3.25	3.25 – 4.35	4.35 – 5.29	5.29 – 6.05	6.05 – 6.54
	Moderate	≤ 2.67	2.67 – 4.73	4.73 – 6.28	6.28 – 7.74	7.74 – 8.85	8.85 – 9.54
	High	≤ 3.17	3.17 – 5.72	5.72 – 7.76	7.76 – 9.41	9.41 – 10.73	10.73 – 11.77
Shrub	Low	≤ 2.36	2.36 – 4.04	4.04 – 6.19	6.19 – 7.43	7.43 – 8.33	8.33 – 9.01
	Moderate	≤ 3.15	3.15 – 6.00	6.00 – 8.27	8.27 – 10.1	10.1 – 12.02	12.02 – 13.22
	High	≤ 4.02	4.02 – 7.65	7.65 – 10.56	10.56 – 12.91	12.91 – 15.45	15.45 – 17.01

Forested: Mapped burned forested areas ranged from low to high soil burn severity. Extensive removal of forest floor ground cover occurred in moderate and high soil burn severity areas. Some needle cast is likely to occur in the low and moderate soil burn severity polygons and recovery of slope stability and watershed hydrologic response will be accelerated where this occurs.

Shrub: Shrub vegetation within the burned area was mapped ranging from low to high soil burn severity. Although these areas had areas of bare ground before the fire, removal of ground cover was often high and it is expected that erosion and sediment delivery to stream channels from these slopes will be high. Vegetative recovery is likely to occur through sprouting of shrubs and establishment of grasses and herbaceous vegetation. Recovery of watershed hydrologic response depends on many factors and is likely to take at least 3-5 years.

Grass, Bare Ground and Rock Outcrop: Grass, bare ground and rock outcrop areas within the burn were mapped as unburned or low burn severity. Soil heating in these areas was very low and minimally affected by the fire therefore, recovery of watershed response is expected to occur rapidly.

Storm intensity and duration influence erosion, volume and the locations of potentially impacted areas. The values represented in table 6 are based on a rapid assessment model and may not reflect erosion responses for variable circumstances.

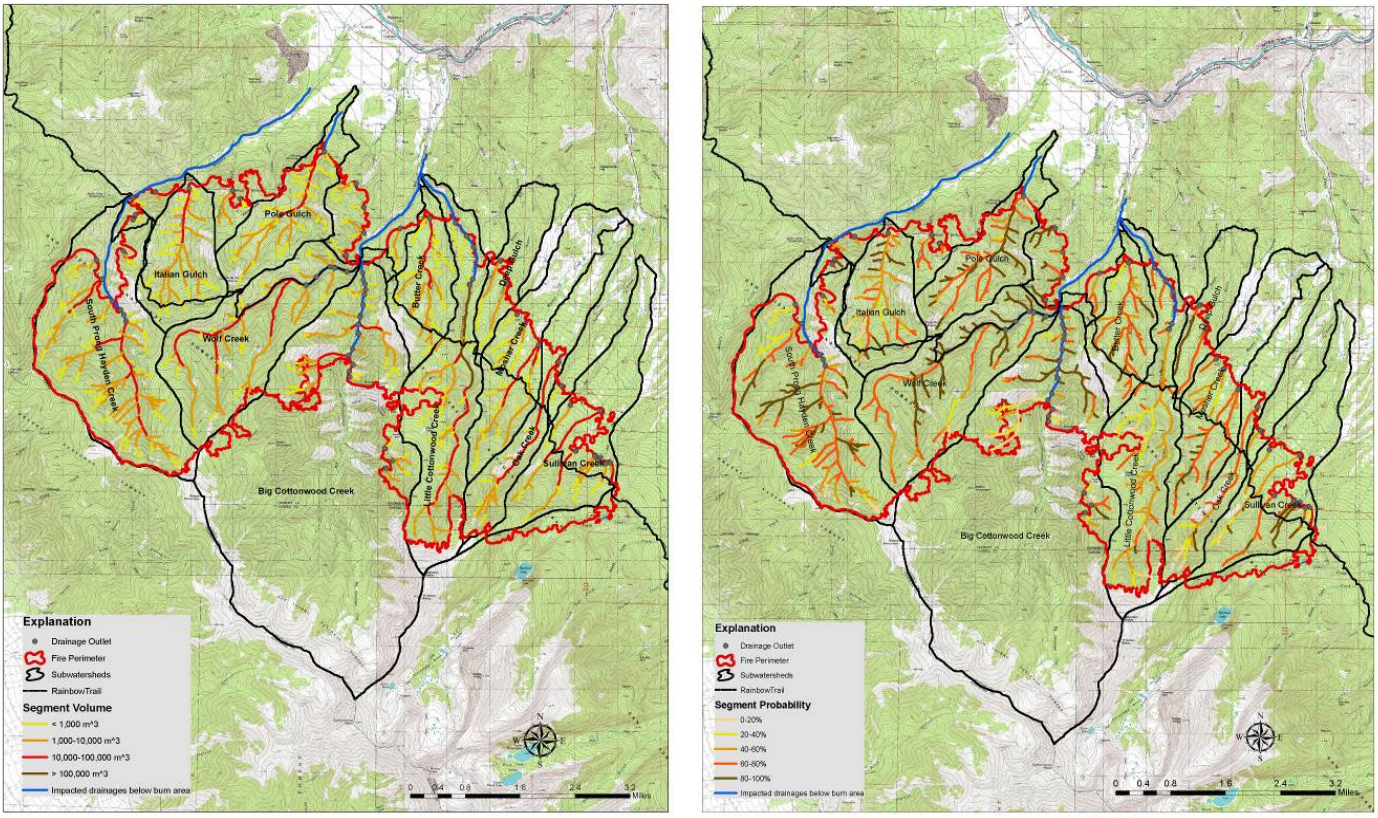
Water Repellent Soils and Increased Runoff: The degree and extent of water repellent soils is estimated to be 3054 acres or 25% of the moderate and high burn severity areas. However, observations indicated strong repellency at the surface over several vegetation types and moderate to high burn severities. Areas with coarse textured surface layers, high burn severities, and/or thick ash layers commonly had strong water repellency at a depth of ½ inch. The pattern of water repellent soils is likely to be patchy and mosaic.

Increased runoff due to hydrophobic conditions is reflected in the peak flow analysis contained in the Hydrology Report. Increased overland flow due to the hydrophobic conditions may increase hill-slope rill and sheet erosion. Hydrophobic layers will usually take six months to two years to break down. Plant root development, soil microbial activity, and freeze-thaw cycling all contribute to the degradation of hydrophobic conditions.

Geologic Response: Debris flows are highly probable in the Hayden Pass Fire Area. Within the burned area, some watersheds show past debris flow activity that will be increased during future storms. The highest potential for debris flows seems to correlate to the Sangre de Cristo Formations. The Sangre de Cristo is a detrital sedimentary rock, typically unconsolidated during aggradation and contains feldspar, sandstone and conglomerate. This geologic formation type is susceptible to becoming brittle and erosive post-fire. Much of the burned area is comprised of the Minturn-Belden Formation, which is a very fine to fine grained marine limestone. This geologic feature holds water well due to the high silts, clays, and fines.

Debris Flow: The United States Geological Survey (USGS)-Geologic Hazards Division provided predictive debris flow model results with quantitative and qualitative results. Analysis show predictions for channel and basin probability, volume, and hazard for a design storm with a 15 minute intensity of 24 millimeters per hour. The channel segment probability model is particularly informative for comparison analysis and to extrapolate results by comparing hydrologic modeling predictions. More information on the USGS model and processes used can be found at the following website. http://landslides.usgs.gov/hazards/postfire_debrisflow/

Figure 3. Debris Flow Probability



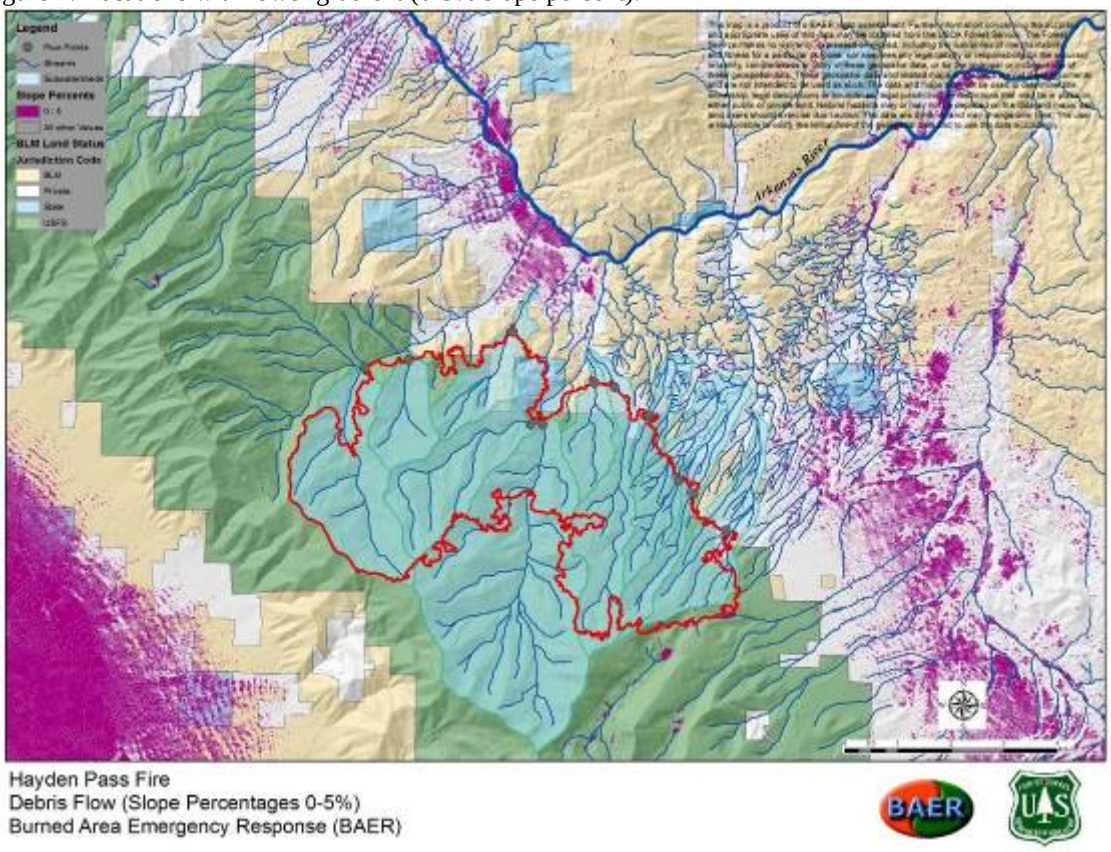
Preliminary Hazard Assessment (USGS)
BURNED AREA EMERGENCY RESPONSE (BAER)
San Isabel National Forest
Volume of debris flow by stream channel (m^3), Likelihood of debris flow by stream channel (%). Preliminary debris flow hazard for a design storm with a15 minute rainfall intensity of 24 millimeters per hour (mm/h).

This map is a product of a BAER rapid assessment. Further information concerning the accuracy and appropriate uses of this data may be obtained from the USDA Forest Service. The Forest Service makes no warranty, expressed or implied, including the warranties of merchantability and fitness for a particular purpose, nor assumes any legal liability or responsibility for the accuracy, reliability, completeness or utility of these geospatial data, or for the improper or incorrect use of these geospatial data. These geospatial data and related maps or graphics are not legal documents and are not intended to be used as such. The data and maps may not be used to determine title, ownership, legal descriptions or boundaries, legal jurisdiction, or restrictions that may be in place on either public or private land. Natural hazards may or may not be depicted on the data and maps, and land users should exercise due caution. The data are dynamic and may change over time. The user is responsible to verify the limitations of the geospatial data and to use the data accordingly.

Throughout the burned area, the combined hazard ratings for debris-flow in first order tributaries to the main stem stream channels are moderate to high. At the fire perimeter exiting the burned area, the hazard ratings are high for all main stem channels, except the Italian Gulch and Deep Gulch channels which have moderate hazard ratings. At the burned area perimeter, volumes are predicted to be >100,000m^3 for Little Cottonwood Creek. Volumes in the range of 10,000 to 100,000m^3 are predicted for Oak Creek, Mosher Creek, Sullivan Creek, Butter Creek, Big Cottonwood Creek, Wolf Creek, Pole Gulch, Italian Gulch and South Prong Hayden Creek.

Pre-fire slope stability and recovery of watershed hydrologic response is dependent on many factors and typically occurs within 3-5 years following the fire. Recovery of high burn severity areas is slower because little or no vegetative ground cover remains, the potential for needle cast is low and soils may be impacted by fire effects. Potential debris flows produced by the burn scar is high. Debris flows will likely deposit in locations of lower gradient but, during higher intensity and subsequent storm events, can migrate farther downstream.

Figure 4. Locations with lower gradient (0-5% slope percent).



II. Emergency Determination

Soil Productivity Emergency Determination: Although very high rates of post fire soil erosion are expected to occur, **an emergency for long-term soil productivity was not caused by the direct effects of fire**. However, threats to long-term soil productivity from increased unauthorized OHV use in the burned area and the expansion of noxious weeds in the burned area were identified (see Roads and Trails Report). Despite high rates of post-fire soil erosion (sediment transport, increased overland flow and wind), soils in the burned area will support recovery of fire adapted vegetation.

III. Treatments to Mitigate the Emergency

Geographic Information System (GIS) analysis to determine a preliminary approximation of the amount and spatial distribution of treatable acres was conducted. The analysis was based on a GIS intersection of high and moderate soil burn severity acres with hill-slopes greater than 30% slope but less than 60%. Additionally, considerations of wilderness area was used to calculate possible treatable acres within each watershed.

Mulch treatments are recommended only when 50% or more of the watershed is directly affected. Based on the GIS exercise, at least 50% of each watershed, meeting the slope and soil burn severity site suitability criteria, would not be effected, except the smallest watershed in the analysis area, Deep Gulch. Treating Deep Gulch with mulch would be ineffective relative to the entire burn scar and other treatment opportunities proposed. At the watershed scale, it is questionable whether application of mulch would significantly lower watershed response. Additionally, mulch treatments could potentially impede recovery of native vegetation in this area.

Much of the Hayden Fire burned area exhibits steep terrain with limited accessibility. Treatment on steep slopes is limited to plausible treatment types and by the effectiveness of treatment. Additionally, steep terrain can be hazardous to life and safety.

Table 7. Acres of high slope percent within the burned area

> 30%	30-60%	Total Acres
8,417 acres	8, 103 acres	16,520 acres

As described in the Hayden Pass Fire BAER Report, a range of values at risk occur in flood and debris flow prone areas within and below the burned area. Threats to human life and safety and other values at risk cannot be reduced to an acceptable level from the application of mulch. Other treatments, identified in the BAER Report, are recommended to address these issues.

Figure 5. Treatable Locations and Wilderness consideration

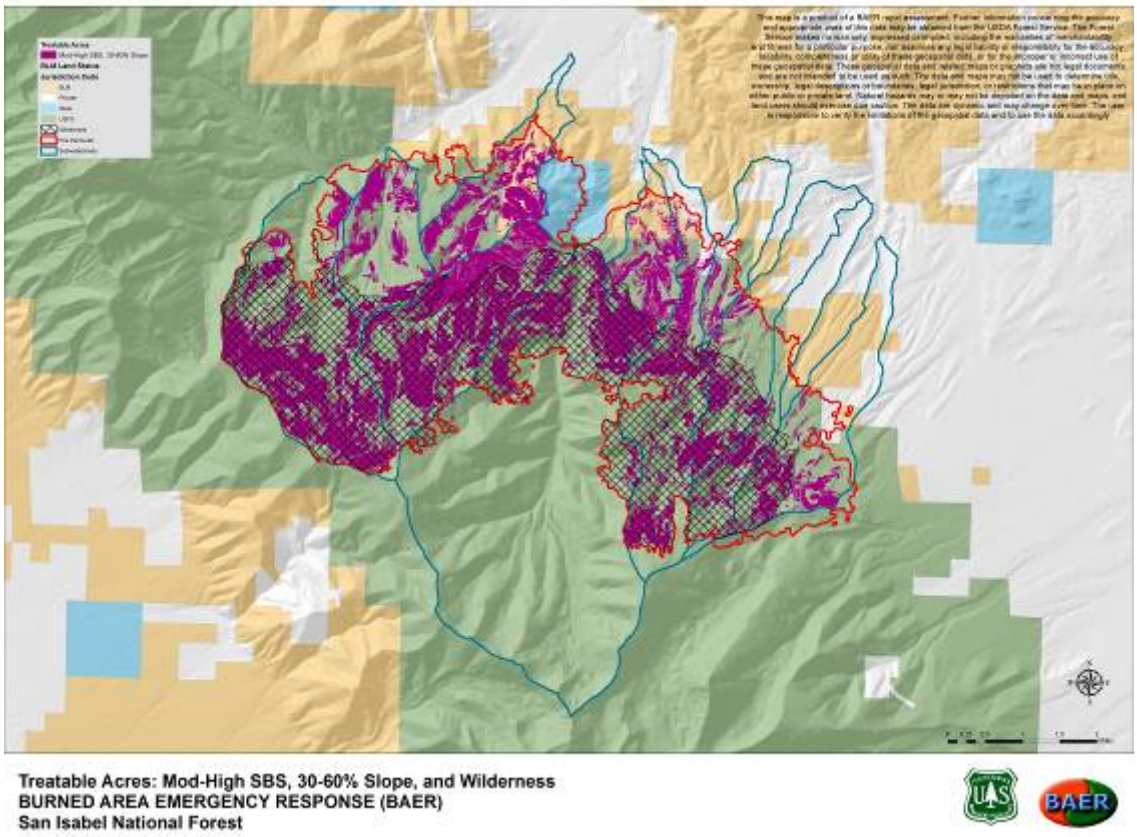


Table 8. Treatable percent of each watershed and, the percent of each watershed with treatable acres outside of wilderness area.

Percent of Watershed with Mod-High Severity and 30-60 Percent Slopes			
Sub-watersheds	**Watershed Acres**	**Total Percent**	**Outside of Wilderness**
South Prong Hayden Creek	3,434	14%	0%
Italian Gulch	1,245	36%	22%
Pole Gulch	1,317	6%	6%
Wolf Creek	2,399	15%	12%
Big Cottonwood Creek	8,360	4%	2%
Butter Creek	1,017	20%	5%
Little Cottonwood Creek	2,379	1%	0%
Deep Gulch	804	60%	60%
Mosher Creek	1,686	58%	6%
Oak Creek	1,252	1%	12%
Sullivan Creek	2,009	60%	13%

IV. References/Consultations:

- BAER team members
- USDA Forest Service, FSH 2509.13; Burned Area Emergency Rehabilitation Handbook
- USDA, NRCS. Soil Survey of Fremont County, Colorado
- NRCS Geospatial Data Gateway Mapping and Tabular Information
- Field Guide for Mapping Post Wildfire Soil Burn Severity
- BAER Treatments Catalog, 0625-1801-SDTC, 2006
- ERMiT model. http://forest.moscowfsl.wsu.edu/cgi-bin/fswepp/ermit/ermit.pl
- USGS Debris Flow Model. http://landslides.usgs.gov/hazards/postfire_debrisflow/