SIGNAL FIRE TREATMENT EFFECTIVENES: INTERIM 1 REPORT

MONITORING SEEDING EFFECTIVENESS IN THE SOUTHWEST

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INTRODUCTION

Seeding was implemented on 1,525 acres of high and moderate soil burn severity areas on the Signal Fire in southwest New Mexico on the Gila National Forest. This report discusses the history of the burn, climate of the region, and methodologies and results from the first year treatment effectiveness monitoring.

SIGNAL FIRE HISTORY AND BURN SEVERITY

The Signal fire started on May 11, 2014. The fire was located in southwestern New Mexico on the southern portion of the Gila National Forest. The Signal fire was about 10 miles northwest of Silver City, NM and was the result of a human caused ignition. The fire had reached 4,700 acres by the evening of May 12th, 2014. A Burned Area Emergency Response (BAER) was brought together on May 19th, 2014. The fire reached 100% containment on May 23rd, 2014 and totaled 5,522 acres. The total high soil burn severity for the Signal fire was 1,244 acres, with 65% of these acres occurring on steep slopes over 40%. The moderate soil severity burn was 697 acres and the low or unburned soil severity class was 3,581 acres. Soil burn severity classes indicate the ecosystems response to different structural and below ground characteristics based on the intensity and severity of the fire. High soil burn severity is usually associated with complete consumption of both canopy and ground fuels and can result in gray to white ash 1-3 cm thick, often leaving minimal effective ground cover. The vegetation types in the Signal fire associated with high soil severity burn were in the mixed conifer and ponderosa pine ecosystems. These systems have thicker duff layers as compared to woodland types and generally have more coarse woody material which can increase fire intensity, severity and residence times. Longer residence times can result in the formation of water repellent layers, charring of roots beneath the surface and destruction of soil structure. Water repellency is when water cannot easily penetrate the soil and causes the water to bead on the surface. This can happen when the soil is heated to a specific temperature during a fire and organic compounds are volatilized and then accumulate through condensation within the soil where the temperature is slightly cooler. Water repellent layers can also be formed during periods of drought when decaying organic matter becomes dry, from specific plant exudates, or from microbial by-products (Neary et. al, 2005). Water repellency can be short term or long term and can depend on how long and how often water stays in contact with the soil as water vapor begins to find sites to bind to and move through the soil profile. When water is unable to penetrate into the soil; it increases the likelihood of erosion. When water repellency (either fire induced or through other causes like prolonged drought) is combined with little effective cover in which to mitigate rain drop impacts; soil erosion can greatly increase. When rain drops impact the soil surface, they can loosen and disperse fine soil particles and start the process of erosion (Neary et. al, 2005). Effective ground cover like litter, rock fragments, basal area and cryptogams absorb the energy of rain drops and increase surface roughness which can slow water movement downslope. Canopy cover provides an excellent barrier for rain drop impact as well. The degree of water saturation of the soil prior to a precipitation event (antecedent soil moisture) can also influence water movement through the soil and can increase the chances of overland flow and soil erosion whether through sheet, rill or gully formation.

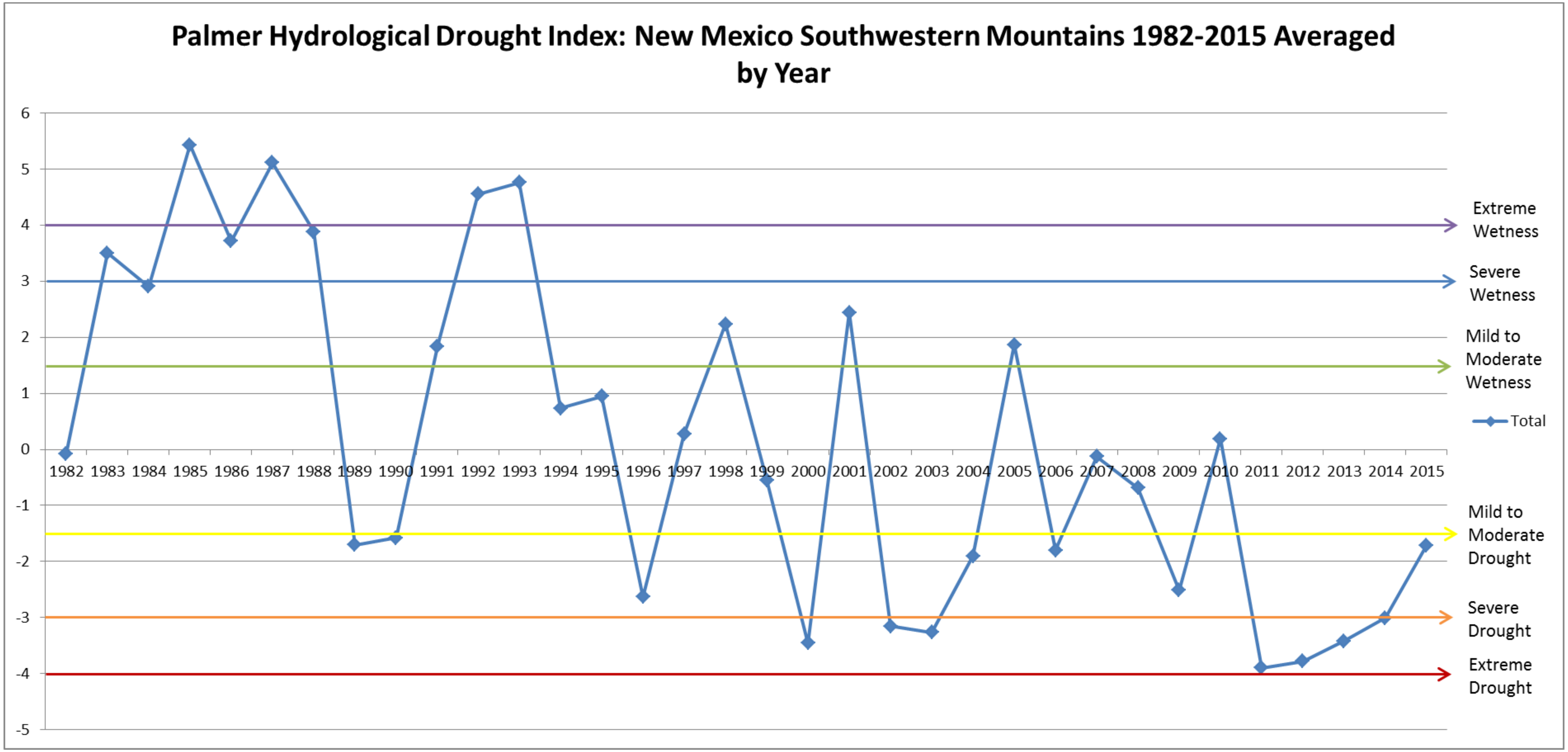
Soil erosion is a natural process, but when certain thresholds are reached the amount of soil lost can have very serious long terms impacts on the landscape due to the interconnected relationship between soil and other ecosystem components. Pedogenesis, or soil formation, involves the specific type of parent materials or the rocks and their associated minerals which are weathered to develop a soil surface. These materials can include recent wind (aeolian) or river deposits (alluvium), material that has moved downslope (colluvium), or older consolidated deposits like those formed from dormant volcanoes or brought to the surface from tectonic activity (residuum). The parent material can greatly influence the type of soil formed and the inherent susceptibility to erosion. Topography of the landscape is another major influence. The elevation of the landscape or the orographic effect of mountain ranges influence temperature and the condensation of water vapor into precipitation on the landscape. The shape and steepness of the slope influences how quickly and where water and sediment moves or collects on the landscape. Topography can also influence air current flow through the system which can also influence temperature and moisture content of the site. Aspect influences the amount of direct solar radiation a site receives, southern slopes get more direct solar radiation while northern slopes receive less direct solar radiation. The northern slopes tend to be cooler and retain moisture longer as compared to southern slopes. Climate is also a major soil forming factor. The average annual changes in temperature and the amount, timing and type of precipitation a region receives influences how long and what type of soil may form in that region. Precipitation influences the development and movement of organic residues left by decaying plant matter and inorganic compounds like clay and calcium carbonate through the soil profile. Ranges in temperature affect freeze-thaw cycles which help physically breakdown rocks. Temperature and precipitation affect the amount and kind of organisms that can live in or on that landscape. Organisms include microorganisms, vegetation, animals and humans. Vegetation can influence the physical structure of the soil by growing roots which helps to retain soil and by adding or subtracting chemical components. Symbiotic relationships with mycorrhiza increase the surface area roots are in contact with the soil and the chemical exchanges within the soil profile. Time is another large factor in soil formation. It can take at least 100 years to form one inch of soil and could even take thousands of years depending on all the above factors and disturbances which change the components of the ecosystem (NRCS, 2015). Soil is therefore "non-renewable" at least within the context of a single human lifespan if not that of generations of people in certain landscapes.

REGIONAL CLIMATE AND TOPOGRAPHY

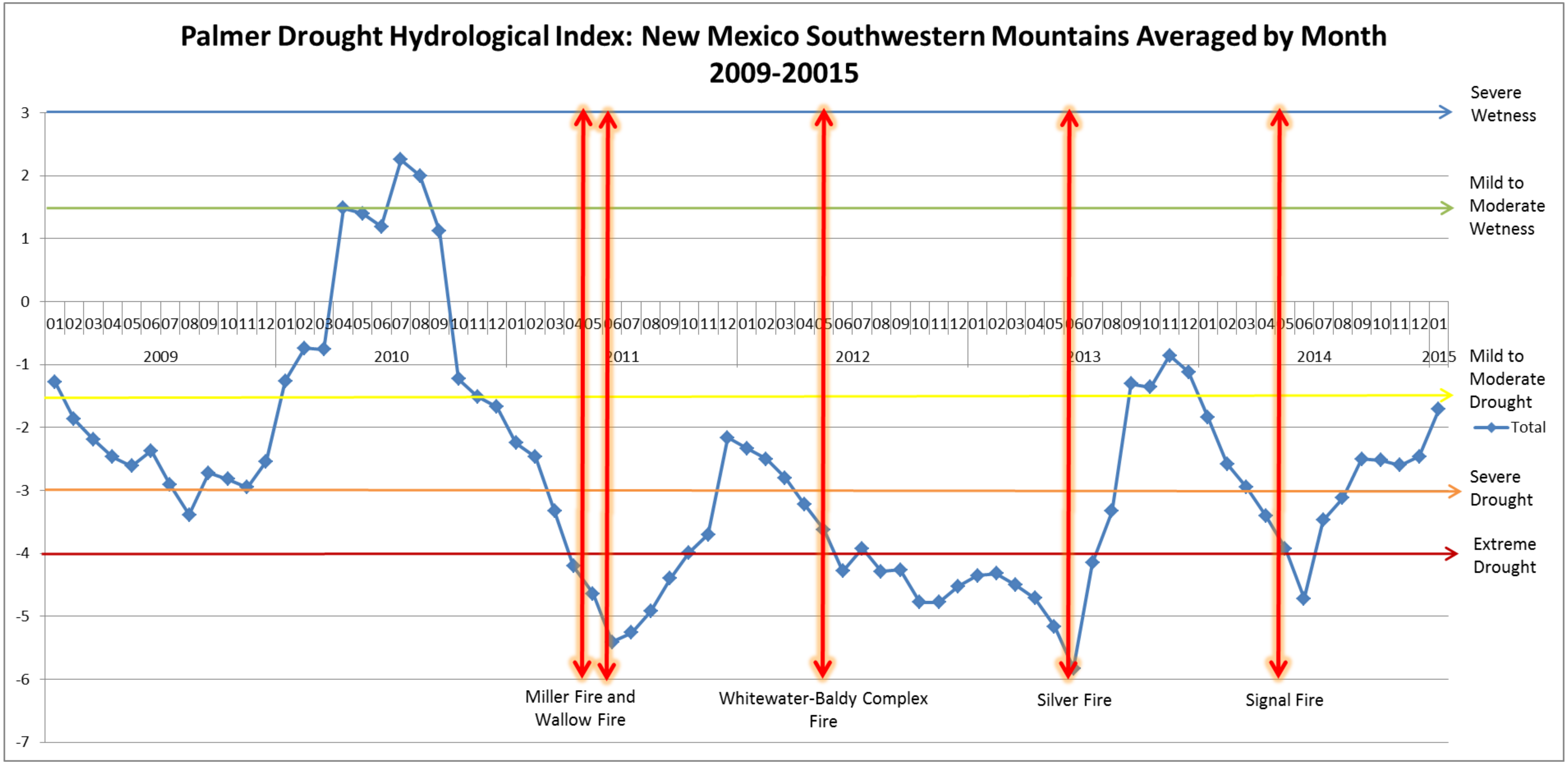
Elevations on the Signal Fire range from 2095 to 2740 meters. Mean annual precipitation of the resource area ranges from 15-34 inches and mean annual air temperature ranges in lower elevations from 38-70^{o}F to 27-65^{o}F in higher elevations (Souders et. al, 1999). Precipitation in southwestern New Mexico is characterized by summer monsoon rain which can be characterized by high intensity, short duration precipitation events. The monsoon season generally begins in late June to early July and lasts through September. The onset of monsoon season is defined by the Southwest Area Wildland Fire Predictive Service as the time period when the minimum relative humidity consistently stays above 20% for five or more days a week (SWCC, 2014). The spring time is generally dry and windy with scattered rain events. Fire season is generally during late spring to early summer before the monsoon has strongly developed. Conditions are usually dry and lightning caused fires are common and can stay active until the monsoon has set and enough precipitation has fallen to mitigate and suppress the fires. There is a very short window between the time the fire starts and the time the majority of precipitation for the region will fall, especially in lower elevations. Lower elevations receive most of the mean annual precipitation during April through September. Higher elevations will receive more precipitation in the form of snowfall from October through March, but still experience the short high intensity rainfall events of the monsoon. These higher elevations are where mixed conifer and spruce fir forests are found. Runoff can occur during the spring at these higher elevations as the snow melts as the days get warmer or by scattered rain events.

The southwest in general has been experiencing drought conditions. The Climatic Division of National Oceanic and Atmospheric Administration (NOAA) produces standard precipitation and drought indices using the National Weather Service (NWS) Cooperative Observing (COOP) program weather station network, National Interagency Fire Center (NIFC) Remote Automatic Weather Stations (RAWS) network and the USDA Snow Telemetry (SNOTEL) network. The Palmer Hydrological Drought Index (PHDI) is a monthly index that indicates the severity of a wet or dry spell and is based on moisture supply and demand and does not factor in man-made changes such as increased irrigation, new reservoirs and added industrial water use into the computation (NCDC, 2015). Negative values indicate drought and positive values indicate periods of wetter conditions. Graph 1 is a summary for New Mexico's southwestern mountain region for the PHDI since 1982 (summarized from data downloaded from NCDC, 2015).

In general the southwestern mountains in New Mexico have been on a drying trend since a wetter period of time in the 1980's and again in the 1990's with sporadic periods of wetness and drought in-between. The past four years or so have been particularly dry and conditions of extreme drought have developed. This has been when the Gila National Forest has experienced some of the largest wildfires in recent history, the Whitewater-Baldy being the largest fire to date in New Mexico at 290,000 acres. Graph 2 shows the PDHI focused on the past five years for New Mexico's southwestern mountains and some larger fires in that time period (summarized from data downloaded from NCDC, 2015).

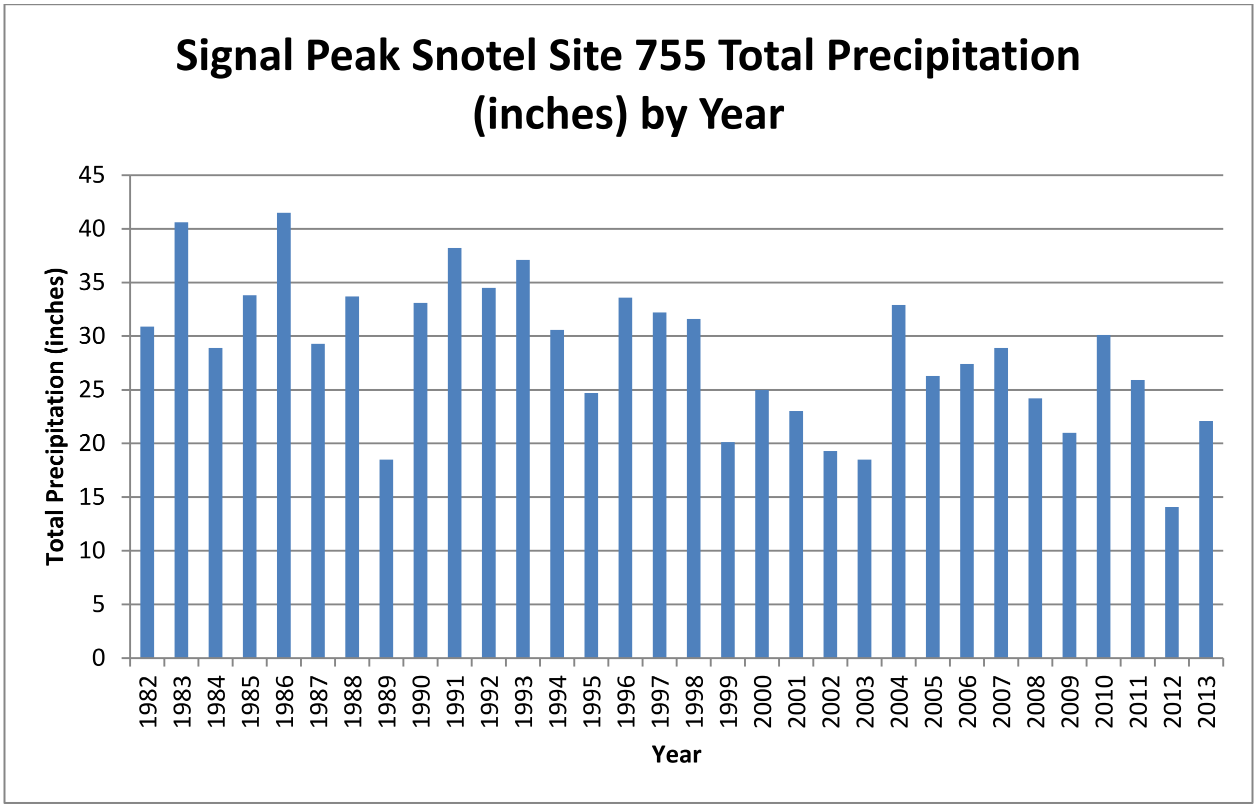


Graph 1: Palmer Hydrological Drought Index for New Mexico southwestern mountains averaged by year from 1982 to 2015. Negative numbers are drought and positive numbers are periods of wetness (summarized from data downloaded from NCDC, 2015).



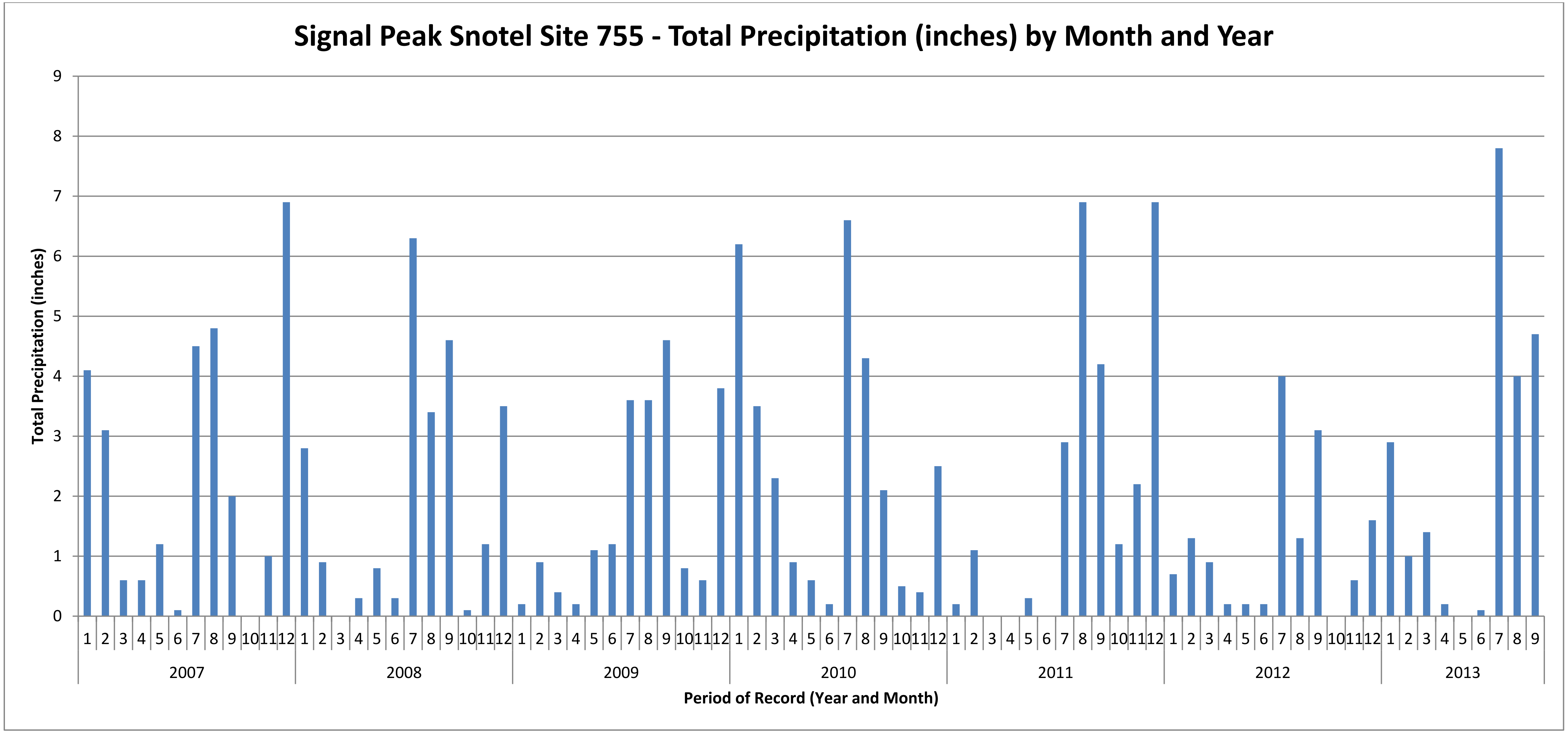
Graph 2: Palmer Hydrological Drought Index for New Mexico southwestern mountains averaged by year from 2009 to 2015 with recent Gila National Forest fire history.

The Signal Peak Snotel Site 755 is located in mixed conifer and was within the perimeter of the Signal fire. Graph 3 is a summary of total precipitation in inches since 1982 until 2013 for the Signal Peak SNOTEL.



Graph 3: Signal Peak Snotel Site 755 total annual precipitation in inches by year from 1982 to 2013.

This site shows a somewhat bimodal weather pattern where there is a peak of precipitation in the summer during monsoons and again during the winter. Graph 4 summarizes the past five years of data from 2007 to 2013.



Graph 4: Signal Peak Snotel Site 755 total precipitation in inches from 2007 through 2013.

BURNED AREA EMERGENCY RESPONSE (BAER)

The climate of the southwest requires a quick turn-around time to complete BAER assessments and implement treatments on the ground prior to the first damaging storms. The BAER assessment for the Signal fire was started on May 14th and completed May 24th. Critical values at risk must be determined, the probability and magnitude of consequences of potential damage are considered, and appropriate actions to manage unacceptable risks must be taken quickly. Treatments must be implemented timely, be effective in reducing risk, the must be practical and technically feasible and need to consider the cost of alternatives. Treatments must be in place before the first damaging storm. Aerial seeding operations for the Signal fire began on July 9th, 2014. The seed mix was a mix of native perennial grass seeds and annual barley seed which was certified weed-free. The annual barley is quick growing while the native perennial grasses take a few years to establish and provide canopy cover and are more effective long term. The annual barley and native seeds are more likely to establish if there is sufficient soil moisture, which is more probable at the mixed conifer elevation and on some lower elevations especially in northern aspects in the southwest during and after a normal monsoon season. This established grass can provide substantial canopy cover which reduces rain drop impact and through root retention of soil. The fibrous root structure can increase water infiltration and hold soil in place (Robichaud et. al, 2000). Annual cereal grains are generally inexpensive and readily available in large quantities, but questions remain as to how long annual cereal grains persist on the landscape and whether these grasses or seeding of any kind whether native or not delays the recovery of native flora (Robichaud et. al, 2000). Winter temperatures at the higher elevations in mixed conifer can get low enough to kill off the annual cereal grains and resulting snow pack can flatten the senescent grass and create mulch for the following year which can lessen rain drop impact and erosion. Table 1 gives a detailed description of the Signal fire grass seed mix used for aerial seeding and the approximate seeds per square feet estimated to fall onto the surface of the treated high severity burn area.

Table 1: Grass seed mix for Signal fire treatment.

Species	Planting Rate (pounds/acre)	Seeds per Square Feet
Barley (*Hordeum vulgare*)	41.80	12.00
Prairie junegrass (*Koeleria macrantha*)	0.09	5.00
Muttongrass (*Poa fendleriana*)	0.25	5.00
Mountain brome (*Bromus marginatus*)	3.40	5.00
Bottlebrush squirreltail (*Elymus elymoides*)	0.23	1.00
Total	**45.77**	**28.00**

There are two kinds of BAER treatment monitoring, one is for implementation and one is for effectiveness. One of the objectives from the BAER assessment was to perform effectiveness monitoring for aerial seeding. This is done to determine if the aerial seeding treatment is functioning as planned and if it is meeting specific emergency objectives. Aerial seeding was done for the Signal fire to reduce soil erosion and lessen the impact on soil productivity and hydrologic function, decrease risk to infrastructure including roads and to decrease risk to human life and safety as people travel these roads and trails. Post-fire areas with steep slopes, high severity burns and little effective ground cover have increased probability of mass movement or large erosional events which can cause substantial damage. Aerial seeding was implemented to reduce erosion and the potential impacts to critical resources. This monitoring project will focus on impacts to soil productivity and hydrologic function. The monitoring was done at the level II scale which is quantitative and appropriate for the forest or regional scale. This monitoring project is proposed to last three years. The purpose of this monitoring is to share the results of the effectiveness of aerial seeding for the greater southwest area where they would be most applicable.

OBJECTIVES

The main objective is to provide more information about the effectiveness of seeding as a post-fire treatment in the southwest and to present the results of this study in order to improve future burned-area rehabilitation projects within similar climatic regions.

- To determine the effect that post fire seeding has on maintenance of site/soil productivity
- To determine how effective seeding is in increasing vegetative ground cover
- To determine what affect this treatment has on site recovery
- To determine if this treatment delays or has a negative effect on natural recovery and diversity
- To determine if this treatment introduces invasive species
- To determine the persistence of annual cereal grain
- To determine if this treatment reduces erosion rates

METHODS

DETERMINATION OF MONITORING PLOT LOCATIONS

Monitoring plots for the Signal Fire were established in locations which would try to minimize the natural variability in the landscape in order to better compare treated or seeded areas with those that were untreated. Draft Terrestrial Ecological Unit Inventory (TEUI) data, burn severity class, geologic maps, topographic contours and digital elevation model derivatives like slope, aspect and elevation were used to initially focus on similar locations that would also have reasonable access in order to establish and monitor the plots over a span of three years. TEUI draft map unit 569 was determined to be a suitable map unit to check in the field to determine an exact location for the plots. This map unit is comprised mainly of douglas fir, ponderosa pine and gambel oak on 40-80% slopes with moderately deep to deep, darker colored and relatively productive (mollic), sometimes rocky with lighter texture (loamy-skeletal to fine-loamy) soils mainly formed in basalt, basaltic andesite or andesite parent material. There was one TEUI transect and one site within the Signal fire perimeter that had data collected before the fire within map unit 569. Table 2 is a summary of species richness and relative abundance collected before the Signal fire from map unit 569 site and transect data within the fire perimeter. Ground cover ranges and soil family phase information are listed from the site and transect data in Tables 2 and 3 below. See Appendix A for pre-fire canopy cover conditions for map unit 569 within the Signal fire high soil burn severity area.

Table 2: Pre-Signal fire range in percent ground cover from draft TEUI site and transect data in map unit 569 near Signal Peak.

Ground Cover	Percent Cover Range
Total Basal Area	3 – 8 %
Litter	55 – 85 %
Bare Soil	1 – 10 %
Total Rock Fragments	5 – 40 %
Rock Outcrop	0 – 6 %

Table 3: Soil family phase and miscellaneous areas from draft site and transect data in map unit 569 near Signal Peak.

Soil Family Phase
Pachic Argiudolls, HSC, 6, -1, fine-loamy, mixed, superactive, frigid, moderately deep, loam
Pachic Argiudolls, HSC, 6, -1, fine-loamy, mixed, superactive, frigid, moderately deep, loam
Pachic Argiudolls, HSC, 6, -1, fine-loamy, mixed, superactive, frigid, moderately deep, loam
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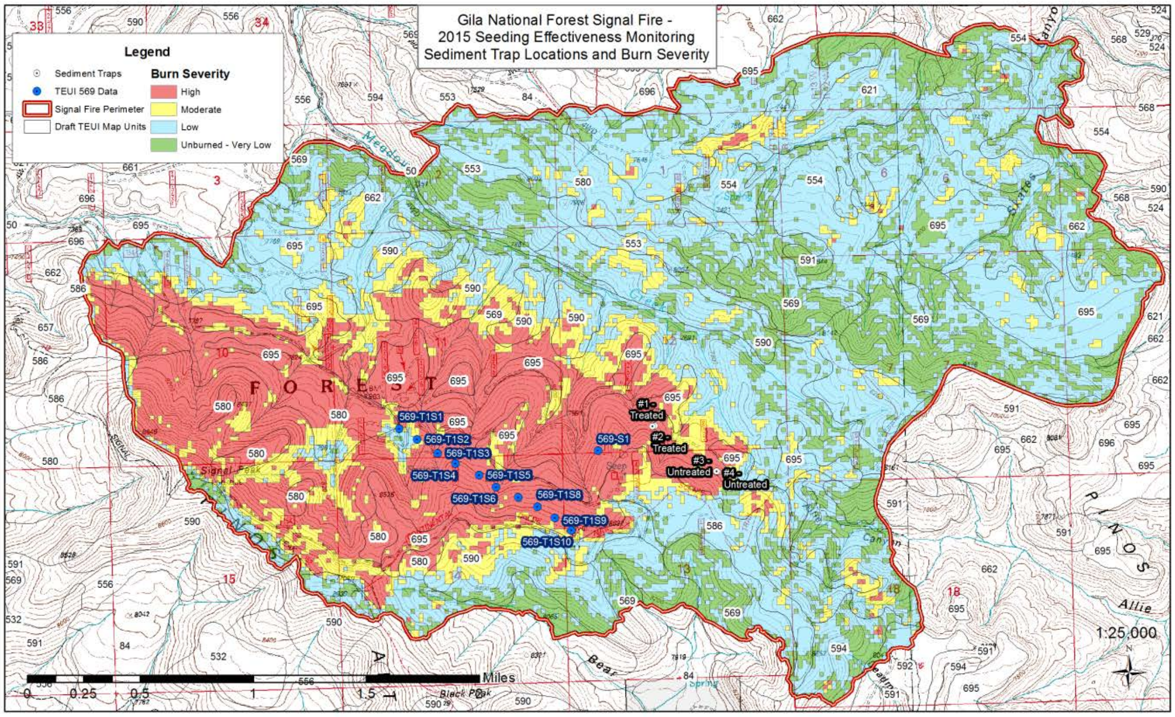
Pachic Argiudolls, HSC, 6, -1, fine-loamy, mixed, superactive, frigid, deep, loam
Pachic Argiudolls, HSC, 6, -1, loamy-skeletal, mixed, superactive, frigid, moderately deep, loam
Pachic Argiudolls, HSC, 6, -1, loamy-skeletal, mixed, superactive, frigid, moderately deep, very gravelly loam
Pachic Argiudolls, HSC, 6, -1, loamy-skeletal, mixed, superactive, frigid, deep, gravelly loam
Pachic Hapludolls, HSC, 6, -1, loamy-skeletal, mixed, superactive, frigid, moderately deep, loam
Pachic Hapludolls, HSC, 6, -1, loamy-skeletal, mixed, superactive, frigid, moderately deep, loam
Rock Outcrop

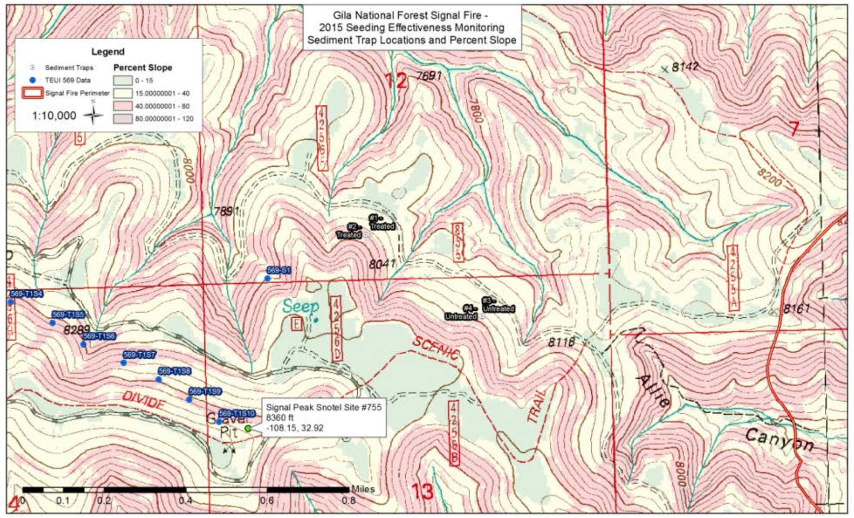
Both monitoring plots were established within map unit 569 and within the high soil burn severity class. Map 1 depicts the location of the monitoring plots, draft TEUI map unit polygons, site and transect locations for map unit 569, and the soil burn severity classes for the Signal fire.

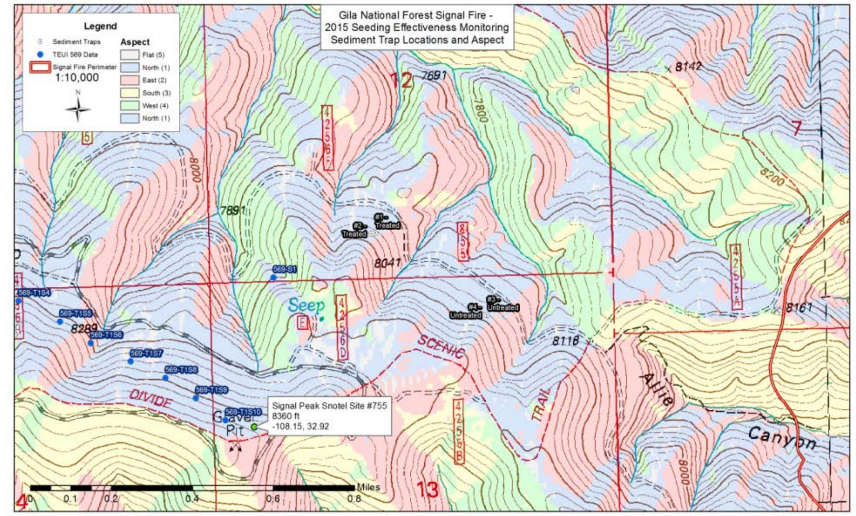


Map 1: Signal fire burn severity map, location of TEUI draft 569 map unit data and location of monitoring plots.

Within the Signal fire burn perimeter there is faulting and intermingled layers of lithology. The upper elevation northern aspects in the high severity burn tend to be over 40% slope overall, but there are small benches of less than 40% within these aspects. There are two such benches about 30 meters or so upslope from each monitoring plot. These act as a natural slope break and help to define the contributing erosional area of the monitoring plots. There is a change in lithology as you move upslope. The geology of the area was determined using USGS "Geologic Map of the Twin Sisters Quadrangle, Grant County, New Mexico" (Finnell, 1976). The summit directly above the monitoring plots is listed as "Tbaa", which is described as porphyritic basaltic andesite. Just below the summit is a small delineation of "Tgra", which is described as arkosic sandstone grading to conglomerate. The monitoring plots were established just below the thin delineation of "Tgra" and are within the "Ttu" formation which is listed as non-welded and welded ash flow tuffs (upper member). The parent material for both plots is colluvial basaltic andesite over residuum derived from ash-flow tuff.

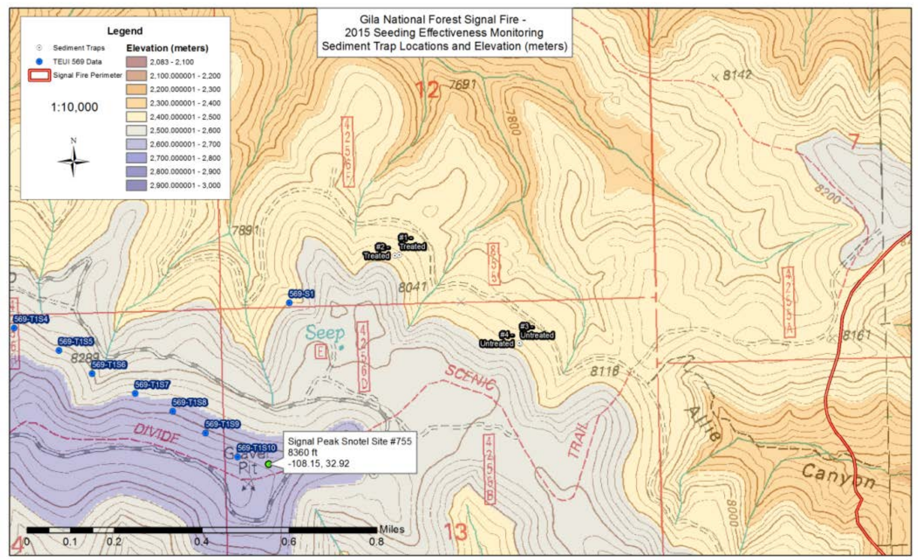
Maps 2 through 4 depict digital elevation model (DEM) derivatives like percent slope, aspect and elevation and the locations of the monitoring plots. The TEUI draft data, burn severity, geologic formations and DEM derivatives determined the general location of the monitoring plots. Field verification was done to refine exact elevation, percent slope, aspect, surface fragments, burn severity class, and to determine slope shape and length.





Map 2: Monitoring plot locations with percent slope.

Map 3: Monitoring plot locations with aspect.



Map 4: Monitoring plot locations with digital elevation in meters.

GROUND COVER AND CANOPY COVER METHODS

Further characterization of the monitoring plots was conducted during field visits by establishing permanent cover frequency analytical plots, line intercepts, ocular macroplots, photo points and rill counts. The soil and general site characteristics like percent slope, aspect, elevation, slope shape, slope length, climate class, location, geomorphology, parent material and geologic formation were assessed using the front side of the TEUI ecological site description ocular macroplot. See Appendix B for an example of the site description sheet. The ocular macroplot is a circular 405 square meter plot. The soil profile was located and described downslope of the sediment trap locations so as to not influence sediment delivery within the plot. This is not a permanent plot and was only performed to determine soil profile characteristics. A permanent ocular macroplot was established within the center of each monitoring plot and marked with a stake. This plot was established to account for species not identified in the cover frequency analytical plots and line intercept plots. Photo points were taken directly above each ocular macroplot center stake and will be repeated throughout the monitoring project.

Surface components were estimated using a cover frequency analytical plot which provides a measure of species abundance, composition by cover and frequency (USDA FS, 2008). This method is repeatable and a statistically rigorous way to detect change (USDA FS, 2008). On each treatment type, two permanent cover frequency transects were established, each 25 meters long and 15 meters apart from one another. Permanent transect starting and ending points were marked with stakes. Data is collected along a transect (tape) and both vegetative canopy cover and ground cover measurements are made along one meter intervals within a frame. The initial cover frequency measurements were made before seeding operations on June 30th, 2014. Table 4 summarizes data from the initial site description macroplot (soil and general site characteristics) and the cover frequency plot canopy cover and ground cover characteristics for both treatments.

Table 4: Monitoring plot initial components for treated (seeded) and untreated plots. * "clayey-skeletal": the weighted-average clay in the particle-size control section for the treated plot was 34.68% and for the untreated was 34.7%. Both of these values round up to 35% which puts them into the clayey-skeletal category, but they are borderline loamy-skeletal.

Parameters	Treated (Seeded) Plot	Untreated Plot
Elevation (meters)	2476	2490
Aspect (degrees)	32	30
Percent Slope	50	50
Horizontal Slope Shape	Linear	Linear
Vertical Slope Shape	Linear	Linear
Slope Length (meters)	40	40
Parent Material	COLL BAAN/RESI TUFF	COLL BAAN/RESI TUFF
Geomorphology	Tectonic, Fault Block, Hillslope	Tectonic, Fault Block, Hillslope
Soil Family Phase	Pachic Argiudolls, clayey-skeletal*, mixed, superactive, frigid, deep, very gravelly sandy clay loam	Pachic Argiudolls, clayey-skeletal*, mixed, superactive, frigid, deep, gravelly sandy loam
NAD 83 UTM 12N coordinates	3646790 N 767001 E	3646448 N 767455 E
Mean Annual Precipitation		
PRISM (cm)	73.6	73.6
Calculated (cm)	69.3	71.0
Climate Class	HSC 6,-1	HSC 6,-1
Burn Severity Class	High	High
Ground Cover %		
Bare Soil	**76**	**86**
Litter (> 1.25 cm thick)	**2**	**0.9**
Total Basal Area	**0.5**	**0.3**
Forb Basal Area	-	-
Graminoid Basal Area	-	-
Shrub Basal Area	-	0.1
Tree Basal Area	0.5	0.2
Total Surface Fragments	**21**	**12**
Fine Gravels (0.2 – 0.5 cm)	10	5
Medium Gravels (0.5 – 2.0	4	3
cm)	4	4
Coarse Gravels (2.0 – 7.5 cm)	2	1
Cobbles (7.5 – 25.0 cm)	1	-
Stones (25.0 – 60.0 cm)	-	-
Boulders (> 60 cm)	**-**	**-**
Rock Outcrop	**-**	**-**
Cryptograms		

SILT FENCE CONSTRUCTION AND RAIN GAUGE INSTALLATION

Silt fences were installed and cleaned out prior to seeding operations. Each treatment had two silt fences constructed. Two large diameter standing dead trees were cut and fell parallel to the slope contours on each monitoring plot thanks to the skills of the local fire crew. These cross-felled logs acted as the beginning point for the erosional area contributing to each silt fence. After the trees were secured in place, a trench was dug out upslope and silt cloth was installed to make a seal between the trench and the upslope side of the log. The trench, silt cloth and log would catch sediment from further upslope and keep this sediment from contributing to the total sediment in the silt fence below the log. The trench had to be cleaned out periodically as it started to fill in with sediment throughout the project. Each monitoring plot had two silt fences installed. One silt fence was 66 feet downslope of the log and one silt fence was 80 feet downslope of another log on each treatment. Each silt fence was 10 feet wide parallel to the slope, about 3 feet tall and about 5 feet long perpendicular to the slope. The back of the frame was made of four t-posts and each side had two rebar stakes pounded into the ground with heavy wire fencing frame attached to all sides to enforce the structure. Silt fence material was installed and was wired to the t-posts, rebar and wire fence and stapled to the soil surface on the edges of the frame. At the mouth of the silt fence, the silt cloth was buried and stapled so that it was level to the surface of the soil and did not have any rough edges sticking up that could get caught or moved upward and allow sediment to collect underneath the trap. The silt fences would be cleaned out periodically. The sediment would be weighed and summed by silt fence number. The wet weight was recorded and the amount of water content in the soil was estimated to determine the dry weight of the sediment.   There were a few small storms before seeding operations that resulted in some sediment collecting in the silt fences, so this sediment was removed just before the seeding operation. Table 5 lists the labels and dimensions of each silt fence.

Photo 1: Final installation of silt fence on Signal fire monitoring plots.

Table 5: Labels and dimensions of silt fences for Signal fire monitoring project.

Silt Fence #	Width (feet)	Slope Length (feet)	Contributing Area (square meters)
1 (treated/seeded)	10	66	660
2 (treated/seeded)	10	80	800
3 (untreated)	10	66	660
4 (untreated)	10	80	800

Tipping bucket rain gauges were installed on the leveled-out surface of one of the fallen tree stumps for each monitoring plot. Before installation, each tipping bucket rain gauge was field calibrated with a controlled flow of water through the tipping-bucket mechanism. The calibration accuracy is reported to be plus or minus 1 percent (Onset, 2001). The rain gauges were located in an area that was clear and unobstructed by standing dead trees. Each rain gauge has a HOBO event data logger with an interface cable you can use to download data.

Data was imported into the Onset BoxCar Pro 4 software and analyzed in the Excel. Data was downloaded periodically for each monitoring plot.

RILL COUNTS

A rill count was conducted along the two permanent 25 meter cover frequency analytical plot transects on each monitoring plot. Whenever a rill was encountered along the analytical plot transect, the width and depth of the rill was recorded in inches. The total rill count will be recorded for each treatment as well. Rill counts will be done for each monitoring plot after the end of the monsoon in the fall.

PRODUCTION ESTIMATES AND SPECIES RICHNESS

Production estimates were also taken for graminoid and forb cover on both treatments. Each monitoring plot had ten 0.96 square foot circular plots clipped for production data during the fall when most grasses are in their mature stage and have set seed. Pin flags were numbered one through ten and placed at each plot to indicate the center point of the plot. Yellow pin flags were used on the treated (seeded) plot and blue pin flags were used on the untreated plot. Photos were taken of each clipped plot; see Appendix C for production pictures for both the treated and untreated monitoring plots. The forb and grass species canopy that was within the 0.96 square foot circular plot was clipped to the level which ungulates normally graze down to with hand shears or clippers. The forb and graminoid canopy cover that was within the circular plot and was clipped and could be from plants rooted directly beneath the circular plot or from overhanging canopy. The clipped vegetation was separated by forb or graminoid and bagged by sample plot. Each sample bag was dried and weighed. Production is reported in dry weight pounds per acre.

RESULTS: INTERIM 1

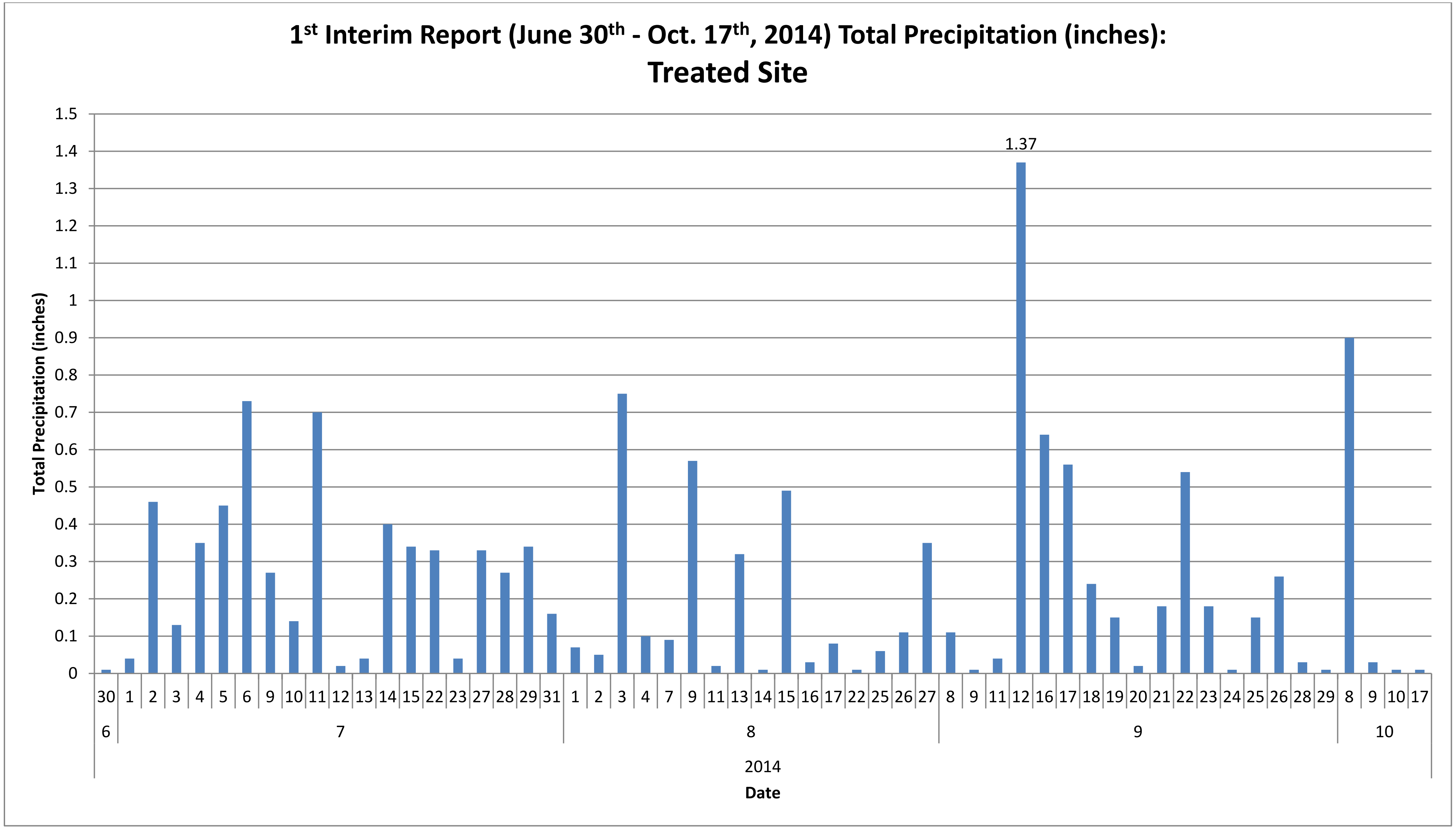
PRECIPITATION

Data collected from the tipping bucket rain gauge was summarized for each monitoring plot. The total precipitation in inches from June 30th, 2014 through October 17th, 2014 for each plot is as follows:

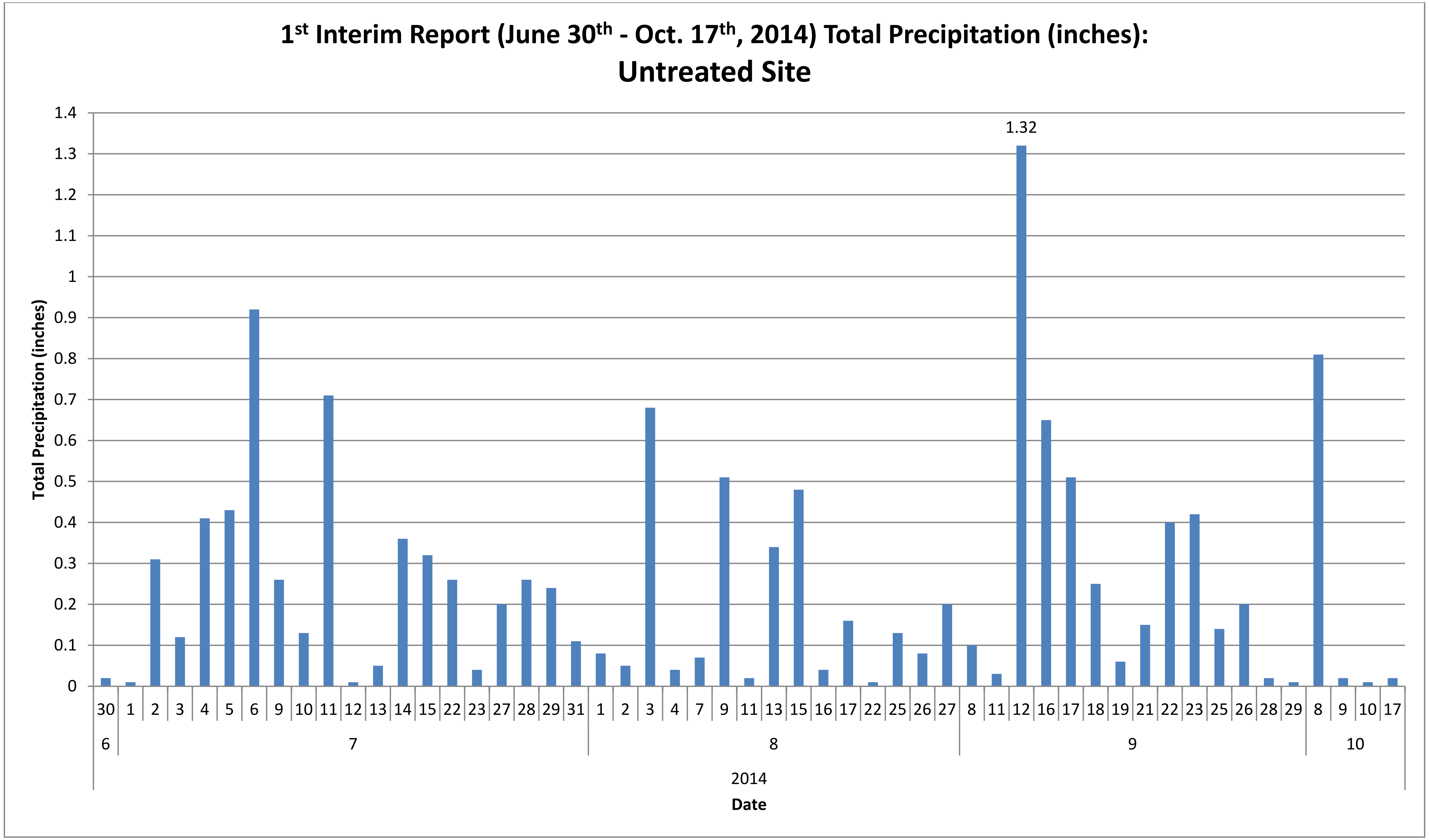
Table 6: Tipping bucket rain gauge data for Signal fire monitoring plots.

Monitoring Plot	Total Precipitation (inches)
Treated (Seeded)	**14.11**
Untreated	**13.18**

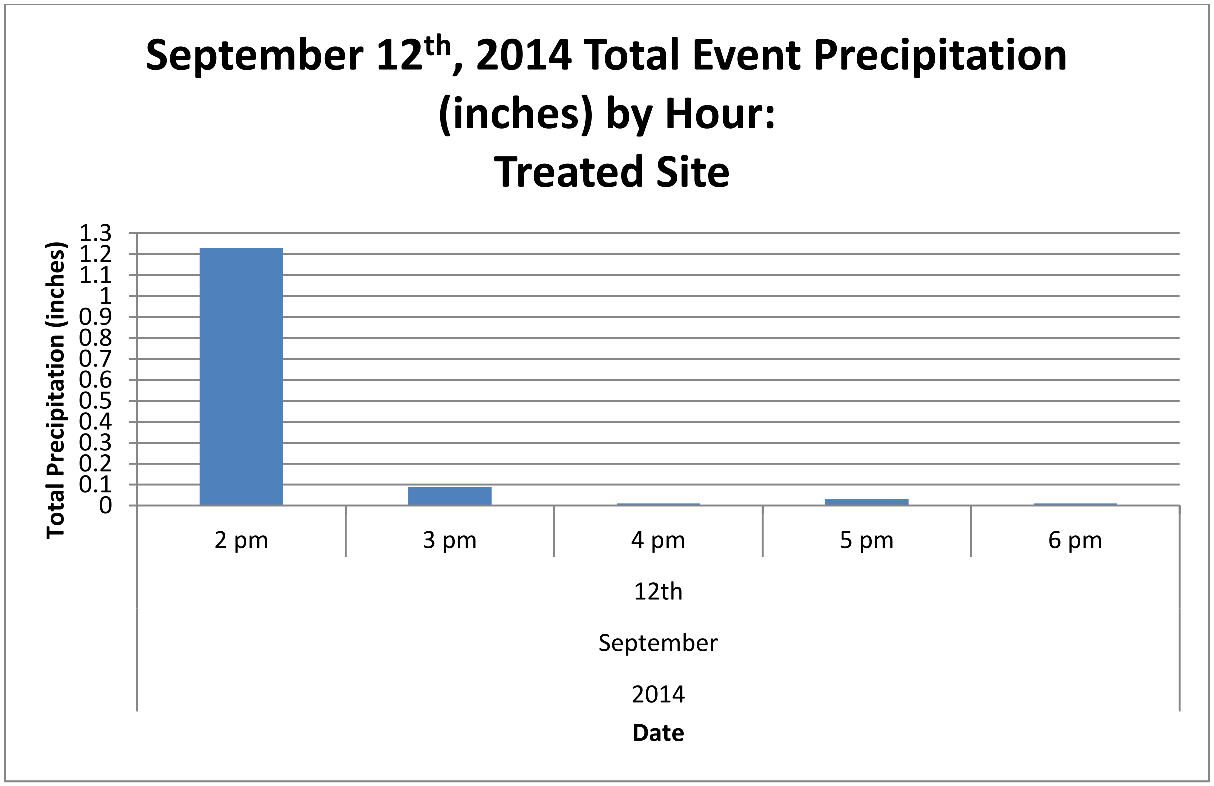
Even though the plots are less than half a mile of one another, localized rain events created some differences in the total precipitation with the treated (seeded) plot receiving 0.93 inches more precipitation. Monsoon storms can be extremely localized in the southwest and this was apparent on the amount of total monsoon precipitation each plot received and the frequency of events. This report includes precipitation data measurements which started on June 30th and summarizes up until October 17th. October 17th is when the sediment traps were cleaned out, which marks the end of the first interim report.   The treated site had a few more daily rain events during the monsoon season (see Graph 5 and Graph 6). The treated site had measureable precipitation for 57 days during the monsoon season, while the untreated site had measureable precipitation for 53 days during the monsoon season. The total monsoon precipitation for the treated plot was 14.11 inches and the untreated plot was 13.18 inches. There was also an intense rainfall event on the afternoon of September 12th, 2014 where over an inch of rain fell within one hour on both sites (see Graph 7 and Graph 8). The treated site had 1.23 inches from 2 pm to 3 pm and the untreated site had 1.17 inches from 2 pm to 3 pm. This was the largest precipitation event for both sites during the monsoon.



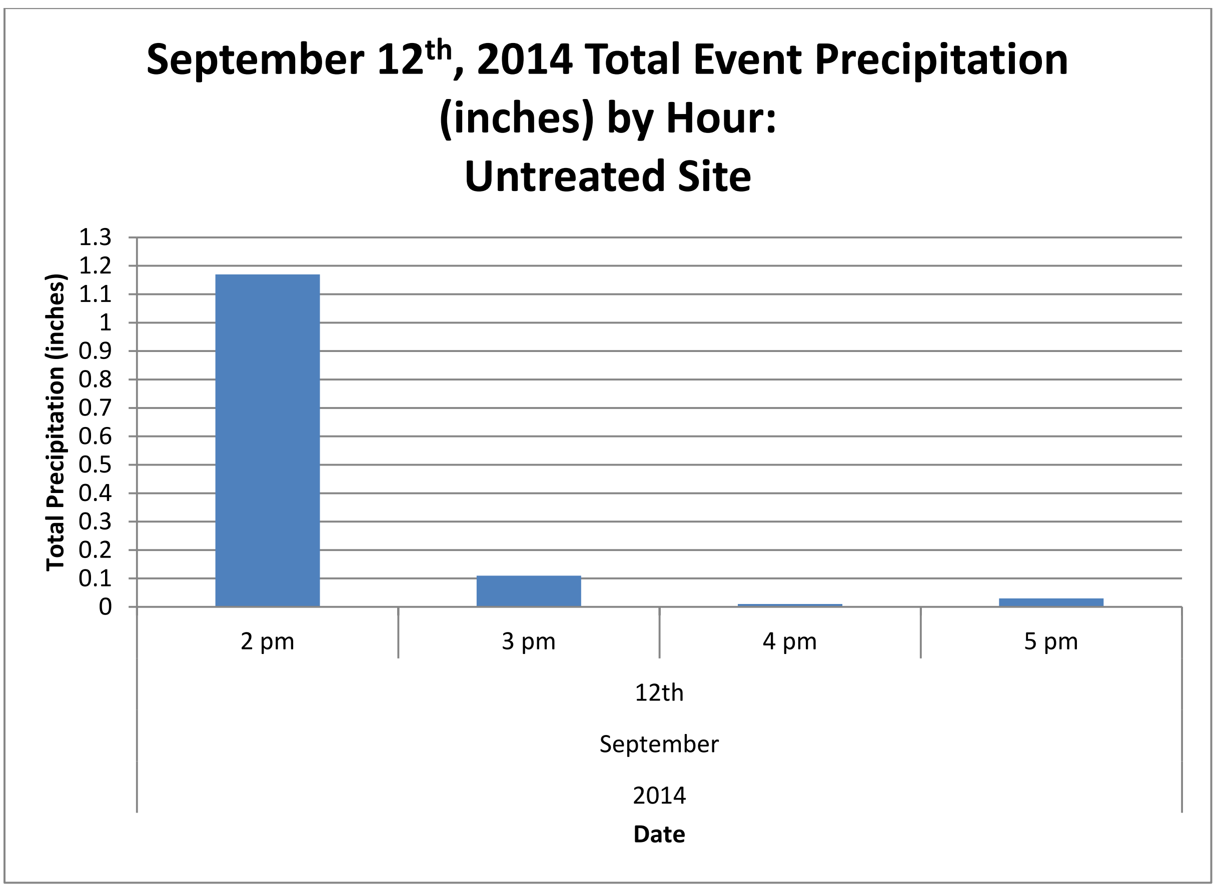
Graph 5: First interim report (June 30th through October 17th, 2014) total precipitation in inches for treated (seeded) monitoring plot.



Graph 6: First interim report (June 30th through October 17th, 2014) total precipitation in inches for untreated monitoring plot.



Graph 7: September 12th, 2014 precipitation event for treated (seeded) monitoring plot.



Graph 8: September 12th, 2014 precipitation event for untreated monitoring plot.

COVER FREQUENCY ANALYTICAL PLOT

The initial cover frequency analytical plots were recorded for both treated (seeded) and untreated monitoring plots on May 28th, 2014 before any damaging storms events had taken place or any treatments. These were done to provide background information for conditions as they were immediately post-fire. Most of the litter recorded during the initial assessment was comprised of charred coarse woody material that had not been completely consumed and was left after the fire or any fallen trees. The basal area of the initial assessment was comprised of standing dead trees and burned shrubs. Ash was still present in the initial assessment and was counted as bare soil. When a burned stump hole was encountered along each transect, it was counted as bare soil.

The cover frequency analytical plots were recorded again towards the end of the growing season on October 16, 2014. This was done to determine changes in ground cover after the 2014 monsoon season had ended. The ash had eroded away by this point. Basal area now included graminoids, forbs and exposed roots. A majority of the basal area increase was due to the barley (*Hordeum vulgare*) on the treated (seeded) plot. Litter was still comprised of charred coarse woody material and fallen trees. Cryptogams started to establish by this point as well, they were more prominent on the treated (seeded) monitoring plot. This may have been due to increased moisture retention as a result of the shade provided by the extra canopy cover of the grass. Total rock fragments increased on both treatments. The untreated monitoring plot had the greatest increase in total rock fragments of 57 percent and the treated plot had a 29 percent increase in rock fragments. Bare soil also decreased for both plots. The untreated plot had about a 21 percent decrease in bare soil and the treated plot had an 18 percent decrease in bare soil. The treated plot had 7 percent more total rock fragments, 45 percent more basal area, about 4 percent less litter, about 130 percent more cryptogams, and about 8 percent less bare soil as compared to the untreated site. Table 7 summaries the ground cover components for both treatments by the initial assessment and the final 2014 assessment towards the end of the growing season.

Table 7: Total percent ground cover components for treated (seeded) and untreated monitoring plots for both the initial assessment on May 28th, 2014 and the final assessment for 2014 on October 16th.

Ground Cover	Untreated Monitoring Plot Percent Ground Cover Values		Treated (Seeded) Monitoring Plot Percent Ground Cover Values	
	Initial 2014	Final 2014	Initial 2014	Final 2014
Total Rock Fragments	**12**	**28**	**21**	**30**
Fine Gravels (0.2-0.5 cm)	5	13	10	15
Medium Gravels (0.5-2.0 cm)	3	6	4	6
Coarse Gravels (2.0-7.5 cm)	4	8	4	7
Cobbles (7.5-25.0 cm)	1	1	2	2
Stones (25.0-60.0 cm)	---	---	1	0.5
Boulders (> 60 cm)	---	---	---	---
Basal Area	**0.3**	**1**	**0.5**	**2**
Tree/shrub (standing dead)	0.3	0.05	0.5	0.1
Graminoid	---	0.95	---	2
Litter (>1.25 cm thick; charred CWM)	**0.9**	**3**	**2**	**3**
Cryptogams	**---**	**Trace**	**---**	**1**
Bare Soil	**87**	**68**	**76**	**63**

SPECIES RICHNESS

The total number of species of shrubs on the treated monitoring plot was twice that of the untreated. The average height of the gambel oak (*Quercus gambelii*) was about 20 inches and the average height of the New Mexico locust (*Robinia neomexicana*) was about 22 inches on the treated (seeded) plot. The untreated plot had an average height of gambel oak (*Quercus gambelii*) at 16 inches, New Mexico locust (*Robinia neomexicana*) at 22 inches and mountain snowberry (*Symphoricarpos oreophilus*) at 27 inches. The treated plot had 6 species of shrub and the untreated had 3 species of shrub. The total number of forbs was relatively close with 17 species on the treated plot and 18 species on the untreated plot. The total number of graminoid species on the treated plot was 5 species and the untreated had 3 species. Perennial grasses were just starting to come up and were hard to identify at the time. The total canopy cover for all species on the treated plot was 49% while the total canopy cover for the untreated plot was 4.8 %. Table 8 lists the species found and percent canopy for each treatment type. See Appendix A for a list of species present on this map unit before the Signal fire.

Table 8: Treated (seeded) and untreated monitoring plots species richness and percent canopy cover values from October 2014.

Treated (Seeded) Species	Treated (Seeded) Canopy Cover Percent	Untreated Species	Untreated Canopy Cover Percent
New Mexico locust (*Robinia neomexicana*)	4	**New Mexico locust (*Robinia neomexicana*)**	0.5
Gambel oak (*Quercus gambelii*)	3	**Gambel oak (*Quercus gambelii*)**	0.3
Mountain snowberry (*Symphoricarpos oreophilus*)	0.01	**Mountain snowberry (*Symphoricarpos oreophilus*)**	Present
Fendler's ceanothus (*Ceanothus fendleri*)	0.01	---	---
Currant (*Ribes sp.*)	0.01	---	---
Unknown Shrub 1	0.01	---	---
Barley (*Hordeum vulgare*)	48	---	---
Perennial grass 1	0.01	**Perennial grass 1**	0.01
Perennial grass 2	0.01	---	---
Brome (*Bromus sp.*)	0.01	**Brome (*Bromus sp.*)**	0.1
White Mountain sedge (*Carex geophila*)	0.3	**White Mountain sedge (*Carex geophila*)**	0.1
Showy goldeneye (*Heliomeris muliflora*)	0.01	**Showy goldeneye (*Heliomeris muliflora*)**	Present
Fetid goosefoot (*Chenopodium graveolens*)	0.01	**Fetid goosefoot (*Chenopodium graveolens*)**	0.01
Pea (*Lathyrus sp.*)	0.01	**Pea (*Lathyrus sp.*)**	0.01
Ticktrefoil (*Desmodium sp.*)	0.01	---	---
Woodsorrel (*Oxalis sp.*)	0.01	**Woodsorrel (*Oxalis sp.*)**	0.3
Pineywoods geranium (*Geranium caespitosum*)	0.1	**Pineywoods geranium (*Geranium caespitosum*)**	Present
Goosefoot (*Chenopodium sp.*)	0.01	---	---

Treated (Seeded) Species	**Treated (Seeded) Canopy Cover Percent**	**Untreated Species**	**Untreated Canopy Cover Percent**
Fragrant snakeroot (*Ageratina herbacea***)**	.1	---	---
American vetch (*Vicia Americana***)**	0.01	**American vetch (***Vicia Americana***)**	0.1
Beardlip penstemon (*Penstemon barbatus***)**	0.01	**Beardlip penstemon (***Penstemon barbatus***)**	0.01
Western yarrow (*Achillea millefolium***)**	0.01	**Western yarrow (***Achillea millefolium***)**	0.01
Vervain (*Verbena sp.)*	0.01	---	---
Sagebrush (*Artemisia sp.)*	0.01	**Sagebrush (***Artemisia sp.***)**	---
Fleabane (Erigeron sp.)	0.01	**Fleabane (***Erigeron sp***.)**	0.01
---	---	**Vetch (***Vicia sp.***)**	0.01
---	---	**Canadian white violet (***Viola canadensis***)**	0.01
---	---	**Scrambled eggs (***Corydalis aurea***)**	Present
---	---	**Pussytoes (***Antennaria sp.)*	Present
---	---	**Birdbill dayflower (***Commelina dianthifolia***)**	Present
---	---	**Fendler's meadowrue (***Thalictrum fendleri***)**	0.01
---	---	---	---
Unknown Forb 1 (Mustard Family)	0.01	---	---
Unknown Forb 2	0.01	---	---
Unknown Forb 3 (Parsley Family)	0.01	---	---
Unknown Forb 4 (*Erigeron sp.* **- Fleabane)**	0.01	---	---
---		**Unknown Forb 5 (Aster Family)**	0.01

Photo 2: Untreated Monitoring Plot Ocular Macroplot Center on October 2014.

Photo 3: Treated (Seeded) Monitoring Plot Ocular Macroplot Center on October 2014.

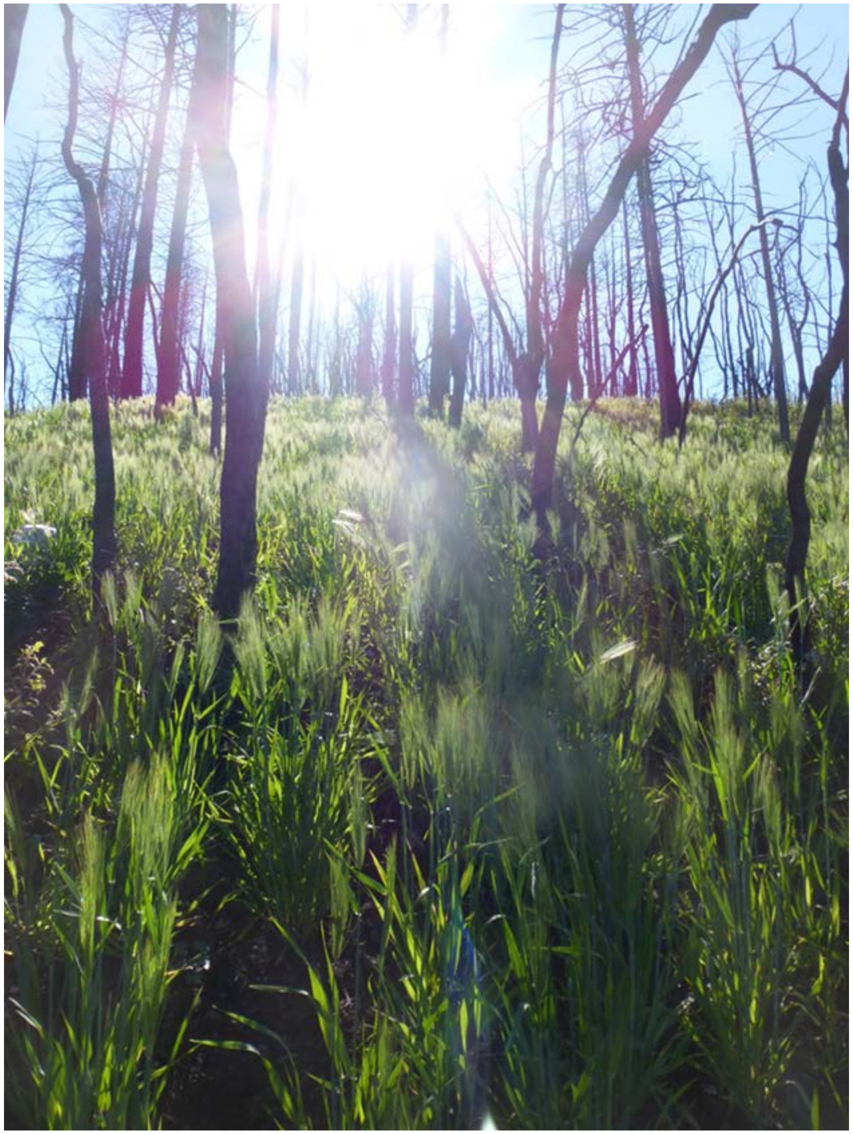


Photo 4: Upslope from ocular macroplot center of treated (seeded) monitoring plot October 2014.

Photo 5: Upslope from ocular macroplot center of untreated monitoring plot October 2014.

Photo 6: West facing from ocular macroplot center on treated (seeded) monitoring plot October 2014.

Photo 7: West facing from ocular macroplot center on untreated monitoring plot October 2014.

Photo 8: East facing from ocular macroplot center on treated (seeded) monitoring plot October 2014.

Photo 9: East facing from ocular macroplot center on untreated monitoring plot October 2014.

Photo 10: Downhill from ocular macroplot center on treated (seeded) monitoring plot October 2014.

Photo 11: Downhill from ocular macroplot center on untreated monitoring plot October 2014.

SILT FENCE

Silt fences were cleaned out on October 17th, 2014 and the sediment was weighed and totaled for each silt fence individually. Initial weights include water weight. Small samples were collected at each location to determine water content of the soil and to estimate dry weight. The weight of the wet sample bag was measured on location. The samples were dried and weighed again to determine the water content of the sediment. The average water content for all samples was estimated to be 40%. Silt fence 4 on the 80 foot slope length for the untreated site experienced a failure at the top of the trap where the sediment cloth was compromised and sediment went through. This could have happened during the September 12th, 2014 rain event were over an inch of rain fell on both monitoring plots. The total amount of sediment collected in silt fence 4 would have likely been higher. This value will not be used for the final assessment. Table 9 summarizes the total tons per acre of sediment collected in each silt fence by treatment type for 2014.

Table 9: Silt fence erosion in tons per acre by treatment as of conclusion of interim one monitoring. *Silt fence 4 failed and data will not be used in final assessment.

Silt Fence	Total Wet Weight (tons/acre)	Total Dry Weight (tons/acre)
1 (treated w/66 ft slope length)	25	15
2 (treated w/80 ft slope length)	27	16
3 (untreated w/66 ft slope length)	63	38
4 (untreated w/80 ft slope length)*	33*	20*

Erosion models were ran to see if there were differences in erosion estimates and to try to calibrate the parameters of the models to more closely match on the ground conditions measured on each treatment plot. WEPP is a physically-based erosion model developed by the USDA Agricultural Research Service (ARS), Forest Service, and Natural Resource Conservation Service, and the US DOI BLM and US Geological Survey. WEPP estimates soil erosion and sediment yield based on soil characteristics like texture and rock fragment content within the soil profile, ground cover components, and topographic components. It uses these values and PRISM derived climate data to determine soil water content, infiltration and runoff. The WEPP model was ran for a simulation period of 100 years. The Rangeland Hydrology and Erosion Model (RHEM) was designed specifically for rangelands as compared to WEPP and other models which were developed initially from experiments on croplands where rill flow transport plays a larger role (Nearing et. al, 2011). Splash and thin sheet-flow transport act as the dominant set of processes in the RHEM model (Nearing et. al, 2011). RHEM was developed and evaluated from a series of rangeland experiments south of Tucson, Arizona (Nearing et. al, 2011). The results of both models are presented in table 10 along with the measured erosion from each treatment plot.

Table 10: WEPP and RHEM modeled erosion and measured erosion from Signal fire sediment traps as of October, 2014. Erosion values are expressed as dry weights in tons per acre. *This sediment trap was compromised and value will not be used in final report

Erosion Rate Dry Weight Comparison (tons/ac)		
	Trap 1 (66' slope length)	Trap 2 (80' slope length)
Untreated Signal Fire Silt Fence	38	20*
Untreated WEPP (5 year return interval)	45	52
Untreated RHEM (2 year return interval)	35	35
Treated Signal Fire Silt Fence	15	16
Treated WEPP (5 year return interval)	14	15
Treated RHEM (2 year return interval)	15	15

RILL COUNT

The data collected on October 16th, 2015 showed that the untreated plot had 9 times more rills than the treated (seeded) plot. The rills on the untreated monitoring plot were also about 4 times deeper and a little over 2 times wider than those of the treated (seeded) monitoring plot. The total rill count for the treated (seeded) monitoring plot was 2 rills while the total rill count for the untreated monitoring plot was 18 rills. The treated (seeded) monitoring plot had rills with a maximum depth of 1.5 inches and a maximum width of 6 inches. The untreated monitoring plot had rills with a maximum depth of 4.5 inches and a maximum width of 16 inches. The depth of the A horizon on the plots was 4 cm, so the untreated site has rills that are starting to cut into the subsoil. Table 11 lists the results of the initial rill count.

Table 11: Rill count data for Signal fire monitoring plots as of 2014.

Monitoring Plot	Total Number of Rills	Maximum Depth (inches)	Maximum Width (inches)
Treated (Seeded)	2	1.5	6
Untreated	18	4.5	16

PRODUCTION DATA

The initial assessment of forb and graminoid production for each treatment was done on October 16th, 2014. See Appendix C for photos from each clipping plot, yellow pin flags represent plots on the treated (seeded) site and blue pin flags represent clipping plots on the untreated site. The treated (seeded) site had over 10 times more total production as compared to the untreated site. The majority of this production came from the barley (*Hordeum vulgare*) annual cereal grain. The untreated site had over 10 times more annual forb production as compared to the treated (seeded) site at the end of the 2014 growing season. The treated (seeded) site had 1,613 pounds per acre of graminoids and 15 pounds per acre of forbs for a total of 1,628 pounds per acre on the site. The untreated site had 11 pounds per acre of graminoids and 113 pounds per acre of forbs for a total of 124 pounds per acre on the site. See table 12 for a summary of pounds per acre by treatment type for the end of the 2014 growing season.

Table 12: 2014 total production data in pounds per acre by treatment.

Monitoring Plot	Graminoid (pounds per acre)	Forb (pounds per acre)	Total (pounds per acre)
Treated (Seeded)	1,613	15	1,628
Untreated	11	113	124

ACKNOWLEDGMENTS

We would like to thank our supervisor, Steve Strenger, for allowing us the time to work on this monitoring project. We would like to thank Mike Natharius for his knowledge and support in the development of the project. Mike and Jenny Natharius also provided much appreciated assistance in constructing and cleaning out the sediment traps and describing the site. The local fire crew provided a much needed service by cross-felling the logs, many thanks to them for coming out and helping us. We would also like to thank Nathan La Fontaine and Daniel Ingham for helping clean out the traps and perform plot measurements.

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APPENDIX A: PRE-SIGNAL FIRE SPECIES RICHNESS AND CANOPY COVER

The table below summarizes species richness and relative abundance by ranges in canopy cover from transect and site data in map unit 569 near Signal Peak before the Signal fire of 2014.

Species	Canopy Cover Range
	2 – 50
Ponderosa Pine (*Pinus ponderosa var. scopulorum*)	2 – 15
	0.01 – 14
Gambel oak (*Quercus gambelii*)	3.5 – 22
	0.01
New Mexico locust (*Robinia neomexicana*)	0.1 – 22
	0.01 – 19
Fendler's ceanothus (*Ceanothus fendleri*)	0.5
	1
Arizona Honeysuckle (*Lonicera arizonica*)	0.5
	2
Red Raspberry (*Rubus idaeus*)	2
	0.01
Muttongrass (*Poa fendleriana*)	0. 1 – 3
	0.1 – 3
White Mountain sedge (*Carex geophila*)	0.1 - 1.5
	2
Western yarrow (*Achillea millefolium*)	0.01 - 0.5
	0.2 – 1
Tasselflower Brickellbush (*Brickellia grandiflora*)	0.01 – 4
	0.1
Strawberry (*Fragaria virginiana*)	0.1 - 0.3
	0.01
Woodsorrel (*Oxalis sp.*)	0.2
	0.1
Solomon's Seal (*Polygonatum cobrense*)	0.3
	0.1
Senecio (*Senecio sp.*)	0.1 – 0.5
	0.01 – 1
Canadian White Violet (*Viola canadensis*)	0.1 – 1.5
	0.1 – 1

Species	Canopy Cover Range
Pineywoods geranium (*Geranium caespitosum*)	0.01 – 0.2
New Mexico Groundsel (*Packeria neomexicana*)	0.5
Western Brackenfern (*Pteridium aquilinum*)	0.5 – 1.5
Fendler's meadowrue *(Thalictrum fendleri)*	0.01
Ragweed Sagebrush (*Artemisia franserioides*)	0.1 – 0.5

APPENDIX B: EXAMPLE TEUI SITE FORM

USDA Forest Service	**ECOLOGICAL SITE DESCRIPTION**	R3-FS-2500-6 (June 2013)

Map Symbol: **Component:**	**Representative for** **Map Unit:** **Taxon:**	**Soil Taxon:**
By:	**Date:**	**Phase:**
NRM-NRIS Data Entry - Date: By:		**Vegetation Taxon:**
Plot - Shape:		**Climax Class:** **MAP** (cm):
Dimension:		**Plant Association:**
Flight/Photo/Stop:		**Stone Boulder Class:** / **Surface Morphometry -** Gradient (%):
GPS File Name:	**DC:** **AVG:**	**Erosion Kind:** / Aspect (deg.): Length (m):
UTM:		**Erosion Degree Class:** / Elevation (m): Complexity:
Township: **Range:**	**Section:**	**Drainage Class:** / Slope Shape - Horizontal:
State:		**Hydrologic Soil Group:** / Slope Shape - Vertical:
County:		**Formation:** / Slope Position: Position Modifier:
Forest:		**Parent Material -** Kind-Origin:
District:		**Site Geomorphology -** GP: LsT:
**		Lf: ELf: CLf:

Horizon/Layer			**USDA Texture**	**Rock Frag**	**Color**	**Struc**	**Surface Features**	**Consist**	**Pores**	**Roots**	**Reaction**	**Accessory Properties**
Symbol	Depth Thick cm	Bdy	Tex Mod Texture % Clay	Gr Cb St By % Vol	p/d p/m c/d r/m	Gr Si Ty	Ki Am Dis Loc	Dr Mo St Pl Ce CA	Qu Si Sh VC	Qu Si Lo	pH CaCO3 Effervesce	Mottles, RMF Stress Features Concen., K_{sat}

Diagnostic Surface Epipedon:			Thickness: to cm
Diagnostic Subsurface Horizon:			Thickness: to cm
			Thickness: to cm
Control Section: cm	Av. Clay (%)	Av. Rock Frag. (%)	Thickness: to cm
Soil Notes:			

VEGETATION

Vegetation Cross Reference:

Trees		**Shrubs**						**Forbs**						**Graminoids**		
Species	%CC	Species	%CC	Ht	Species	%CC	Ht	Species	%CC	Ht	Species	%CC	Ht	Species	%CC	Ht
Totals		*************************					*******************************						***********			***

Dist.	**Treat.**	**Snags**		**Notes:**
Agent	Type	Decay Class	Count	
		1		
		2		
		3		
		4		
		5		

Surface Components	Ocular
Graminoids (BA)	
Forb (BA)	
Shrub (BA)	
Tree (BA)	
Litter (> 1.25 cm)	
Gravel (0.2 – 0.5 cm)	
Gravel (0.5 – 2.0 cm)	
Gravel (2.0 - 7.5 cm)	
Cobble (7.5 - 25.0 cm)	
Stone (25.0 - 60.0 cm)	
Boulder (> 60.0 cm)	
Rock Outcrop	
Bare Soil	
Cryptogams	
Total	
Overstory Cover	

Woodland Species Size Class – DRC (#, Av. Ht., Total CC)																			
Species																			***
≤ 0.9"																			***
1.0" - 2.9"																			***
3.0" - 4.9"																			***
5.0" - 8.9"																			***
9.0" - 11.9"																			***
12.0"- 17.9"																			***
18.0"- 23.9"																			***
> 24.0"																			***
Cords/Acre																			***

Forest Productivity – Site Index									
Species									
Height									
Age									
SI									
Avg SI		**************			**************			**************	

Microbiotic Organisms	Ocular
Mosses	
Lichens	
Liverworts	
Algae/Cyanobacteria	

Down Woody Material			
FWD	#	CWD ≥ 3"	
¼"-1"		Dia.	DC
1"-3"			
*************			

CWD ≥ 3"	
Dia.	DC

***Carnegiea gigantea* Height Class**			
	#	HC	RS
≤ .1m			
.1 -1m			
1-2m			
2-4m			
4-6m			
≥ 6m			
Total			

Forest Species Size Class – DBH (#, Av. Ht., Total CC)												
Species												
≤ 0.9"												
1.0" – 4.9"												
5.0" – 8.9"												
9.0" – 11.9"												
12.0" – 17.9"												
18.0" – 23.9"												
≥ 24.0"												
Basal Area (ft^2/ac)												

APPENDIX C: PRODUCTION PLOT PHOTOS

TREATED (SEEDED) MONITORING PLOT PRODUCTION PHOTOS

UNTREATED MONITORING PLOT PRODUCTION PHOTOS


5





10