ESTANCIA BASIN WATERSHED HEALTH AND MONITORING PROJECT: 2010 ANNUAL REPORT

Prepared for

ESTANCIA BASIN WATERSHED HEALTH, RESTORATION AND MONITORING STEERING COMMITTEE

Composed of: Claunch-Pinto Soil and Water Conservation District, Edgewood Soil and Water Conservation District, East Torrance Soil and Water Conservation District, Estancia Basin Water Planning Committee, Chilili Land Grant, Manzano Land Grant, New Mexico State Forestry, New Mexico Environment Department, New Mexico Forest and Watershed Restoration Institute, New Mexico Department of Agriculture
(with funding through the New Mexico Water Trust Board)

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January 2011

EXECUTIVE SUMMARY

The Estancia Basin Watershed Health, Restoration and Monitoring Steering Committee (Steering Committee) oversees forest thinning projects and monitoring of forest and watershed health in the Estancia Basin in coordination with the New Mexico Forest and Watershed Restoration Institute. The primary goals of the Steering Committee are to improve forest health and create defensible space from wildfire. Funding for forest and watershed monitoring has been provided by the New Mexico Water Trust Board.

In 2007, SWCA Environmental Consultants (SWCA) was awarded a contract to conduct monitoring for forest thinning effectiveness on the eastern slopes of the Manzano Mountains. SWCA finalized a comprehensive monitoring plan in March 2008—which is available online at the New Mexico Forest and Watershed Restoration Institute's website (http://www.nmfwri.org/images/stories/pdfs/Estancia_Basin_Monitoring/EstanciaBasinMonitoring.pdf)—that provides background information, research questions, and a discussion of methods relative to forest thinning and monitoring. The monitoring plan calls for two years of pre-thinning data to provide background information on all study sites prior to implementing thinning treatments and monitoring treatment effectiveness. Results from the 2008 and 2009 monitoring seasons are presented in the 2008 and 2009 annual reports, which can also be found on the New Mexico Forest and Watershed Restoration Institute's website. The principal goals of forest and watershed monitoring are to determine the effectiveness of standard prescribed forest thinning on soils, hydrology, water yield and quality, vegetation, and wildlife. SWCA is responsible for planning and implementing forest thinning monitoring in order to evaluate these resources. SWCA has also assumed responsibility for the South Mountain Weather Station that was previously installed by another contractor in 2006. After monitoring began, three major wildfires (Ojo Peak, Trigo, and Big Spring) occurred in the monitoring area in late 2007 and early 2008. The Trigo fire destroyed one of the forest thinning monitoring sites, which was replaced during summer 2008. SWCA has additionally initiated a monitoring study of post-Trigo fire recovery on private forest lands.

This 2010 Annual Report provides information on the results of forest thinning and post-wildfire monitoring during the calendar year 2010. We also provide summaries of weather data from the South Mountain Weather Station, which serves as a baseline for monitoring area climate data. Initial baseline pre-treatment monitoring data from permanent monitoring study sites provide information on rainfall, ambient and soil temperatures, soil moisture, soil surface profiles to assess erosion over time, soil surface stability, soil chemistry, bird and small mammal composition and relative abundance, and vegetation composition, structure, and cover. The monitoring sampling design employs paired monitoring plots at two piñon/juniper (*Pinus edulis/Juniperus monosperma*) woodland sites and two ponderosa pine (*Pinus ponderosa*) sites. One plot of each pair was randomly selected and designated to be treated by forest thinning in late 2010/early 2011. At this time, those thinning treatments have been largely completed, and SWCA will then monitor the above mentioned parameters until at least 2012 to examine the impacts and effectiveness of forest thinning treatments. Not only will paired study plots be compared to each other in a treatment/control design, but also each treated plot will be monitored over time in order to assess change resulting from thinning treatments.

Results from the third year of pre-treatment baseline monitoring show that few differences in parameters were measured between the paired study plots. In situations where we did find differences between paired treatment and control plots, we will be able to interpret future monitoring data from those naturally occurring differences and focus more on study plot assessments of change over time, relative to each of the paired plots.

Third-year results from the post-wildfire monitoring suggest that the Trigo fire area is slowly regenerating. The high burn severity plots supported a dramatic increase in herbaceous ground cover and reduction in bare ground, with dominance by seeded grasses such as Italian ryegrass (*Lolium perenne*) and tall wheatgrass (*Thinopyrum ponticum*), as well as a variety of native forbs and naturally seeded grasses, such as blue grama (*Bouteloua gracilis*). Early colonizers predominantly made up of annual forbs are now giving way to perennial forbs and grasses as soil and surface litter and duff layers become established. Gambel oak (*Quercus gambelii*) and gray oak (*Q. grisea*) were prevalent throughout the high-severity plots, and alligator juniper (*Juniperus deppeana*) that was 100% consumed by the fire showed basal sprouting from most dead stumps. The low-severity plots also exhibited elevated herbaceous cover when compared to 2008 and 2009 measurements and were beginning to take on similar patterns of cover to the unburned reference plots. Much of the high-severity plots had experienced 100% mortality of the trees, and many of these trees had begun to fall, particularly as a result of wind throw. The low-severity plots had exhibited patchy mortality in 2008 and 2009; some of the worst-hit trees, those that were more than 50% scorched, had begun to die as a result of the physiological stress. Of the trees that were tagged as alive in 2008, 18% had died by 2009; of the trees that were live in 2009, a further 8% had died by 2010. These ranged from small-diameter overtopped trees to larger-diameter dominant canopy trees that received high levels of scorch and damage to the cambium through basal charring. Some of the trees that received less scorch and basal char are surviving, however, and their status will be monitored through 2011.

Soil erosion on the fire plots that appeared to be elevated in 2008 had decreased by 2009 and 2010, but soil movement was highly variable across plots. Soil movement bridge measurements revealed both erosion and deposition at small scales. Regrowth of the herbaceous layer, dominance of seeded grasses, dead and fallen trees, and increased litter layers all contributed to the maintenance of the soil layer. Soil movement measurements will continue through 2011. The automatic wildlife cameras that were originally installed in late 2008 continue to capture wildlife use in the Trigo burn area. Mule deer (*Odocoileus hemionus*) was the dominant species captured in photographs. In order to gain greater coverage across all plots in all seasons, six new wildlife cameras were purchased and installed in summer 2010. Each watershed now has three cameras, one in each severity type.

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1.0 INTRODUCTION

This 2010 Annual Report provides summaries of monitoring data collected during the 2010 calendar year for the Estancia Basin Watershed Health, Restoration and Monitoring Steering Committee (Steering Committee). Details about research questions and the background and administration of this monitoring project may be found in the ―Estancia Basin Watershed Health and Monitoring Project: Monitoring Plan Evaluation" (2008 Monitoring Plan) (SWCA Environmental Consultants [SWCA] 2008), which is available at the New Mexico Forest and Watershed Restoration Institute (Restoration Institute) website (http://www.nmfwri.org). The 2008 Monitoring Plan provides detailed information on the background knowledge of forest thinning in the Southwest and presents the goals and methodologies for the Estancia Basin forest thinning monitoring project. The 2008 Annual Report (SWCA 2009) also provides important background information for the Trigo wildfire monitoring project that was initiated in 2008. Previous years' annual reports for 2008 and 2009 summarize overall monitoring findings from those two years, and they also may be found at the Restoration Institute website.

The Steering Committee oversees forest thinning and effectiveness monitoring of forest thinning on ponderosa pine (*Pinus ponderosa*) forests and piñon/juniper (*Pinus edulis/Juniperus monosperma*) woodlands on private and state lands on the eastern slopes of the Manzano Mountains, New Mexico. Principal members of the Steering Committee include the Claunch-Pinto, East Torrance, and Edgewood soil and water conservation districts; New Mexico State Forestry; and the Restoration Institute. The Restoration Institute is additionally providing oversight and public relations for forest thinning and monitoring activities.

The principal goals of the Steering Committee are to create defensible space around homes and other structures from wildfire and to improve overall forest health, following forest thinning prescriptions determined by New Mexico State Forestry. The primary goals of forest thinning monitoring are to determine the impacts of standard prescribed forest thinning on soils, hydrology, water yield and quality, vegetation, and wildlife.

The scope of work for this monitoring project was described in the Steering Committee's 2007 request for proposals as follows:

1. Plan and implement methods to determine how vegetation thinning and removal affect water yield.
2. Plan and implement methods of establishing reliable and repeatable vegetation monitoring methods to allow for both qualitative interpretation and quantitative documentation of change in vegetative structure and composition over time.
3. Plan and implement methods of monitoring small mammal and avian populations, which are indicators of ecosystem health.

SWCA is currently under contract for five years of monitoring, beginning in 2008, and is responsible for study site maintenance, data collection, data management, data analysis and interpretation, and information dissemination (including monthly meetings, monthly reports, and annual reports). The current Steering Committee plan calls for three years of baseline pre-thinning treatment monitoring (2008–2010), thinning treatments implemented during the winter of 2010 and 2011, and two years of post-treatment monitoring (2011–2012).

Several new subprojects were added to the overall monitoring project in 2008, including post-fire monitoring of soils, hydrology, vegetation, and wildlife on private forest lands following the Trigo wildfire. These tasks involve developing and implementing ephemeral stream and groundwater monitoring to assess the effects of both forest thinning and the Trigo fire on water resources, as well as assuming the operation and reporting for the South Mountain Weather Station (SMWS), initiated by EnviroLogic in 2006. A map of all study sites for these projects is presented in Figure 1.1 (note that the SMWS is located north of Edgewood, New Mexico, and is not on the map presented in Figure 1.1, but is on the map presented as Figure 5.1).

This 2010 Annual Report is similar in format to the previous 2008 and 2009 annual reports, and it provides complete data files (appended on DVD) and summaries of findings from field monitoring measurements conducted during the calendar year 2010 for the four primary subprojects: 1) forest thinning monitoring of weather, soils, hydrology, vegetation, and wildlife; 2) post-Trigo wildfire monitoring of soils, vegetation, and wildlife; 3) overall Manzano watershed ephemeral stream and groundwater monitoring, associated with both forest thinning and post-wildfire monitoring; and 4) SMWS weather and soil moisture data, including addenda representing the four quarterly 2009 reports. Data collected in 2008, 2009, and 2010 represent baseline conditions prior to forest thinning treatments, which were begun in late 2010 and are scheduled to completed in early 2011. Data collected after thinning in 2011 will then provide measures of thinning treatment effectiveness (adherence to the New Mexico State Forestry thinning prescriptions) and a comparison of post-treatment environmental conditions. Monitoring data from subsequent years will provide data on thinning treatment effects over time.

This report provides some analyses of parameter changes over the three years of baseline data to provide an evaluation of natural variation in parameter values over time. Some statistical tests of parameter values between paired study plots are also provided for the three years of baseline data in order to determine if the paired plots differ in parameter values prior to imposed thinning treatments. Additionally, post-Trigo fire monitoring data collected in 2008, 2009, and 2010 provide information on the recovery of soils and vegetation following the fire, and data from subsequent years will provide information on the rate of recovery and change following the impacts of that wildfire.

Numerous discrete datasets have been collected, and SWCA has been active in creating data collection, storage, and management plans for each of the subprojects. SWCA has created metadata for each of these datasets that outline the date range of each dataset, the collection methods, the unit measurements, and the abbreviations and codes used within each data file. The metadata files will also state any caveats or general comments to which the viewer should be aware before analyzing the data.

SWCA is making these data available in a form that can be easily disseminated, using readily available software packages such as Microsoft Word and Excel. Some information, such as those data collected from the WatchDog Mini Weather Stations, is collected using proprietary software. These data are converted into Microsoft Excel files so they can be viewed by the general public. SWCA also intends to make the data available in forms that are easy to analyze.

Some data, such as those related to the flumes, which are recorded in five-minute intervals, must be partitioned into several files, as the data exceeds Microsoft Excel's capacity of data rows. All of these data are being made available to the Restoration Institute for dissemination on its website. Note that measurements from various aspects of monitoring are reported in English units (e.g., feet, acres), while others are reported in metric units (meters, hectares). The protocols for monitoring measurements were obtained from different sources that use different units of measure. The U.S. Department of Agriculture (USDA) Agricultural Research Service Rangeland Monitoring Manual (Herrick et al. 2005) uses metric units, while the U.S. Forest Service (USFS) Forest Inventory and Analysis Guide (USFS 2005) uses English units. In general, scientific research worldwide has adopted the metric system as the standard for measurements, while some federal and state agencies use English units of measure. For ease of comparison, values are presented in this report with both English and metric units, except where not feasible.

This 2010 Annual Report provides summaries of findings from field monitoring measurements conducted during the calendar year 2010 for the above mentioned projects and subprojects. This report is partitioned into different sections for each subproject: 1) forest thinning monitoring; 2) post-wildfire monitoring; 3) ephemeral stream and groundwater monitoring, associated with both forest thinning and post-wildfire monitoring; 4) SMWS data; and 5) planned monitoring for 2011 (year four).

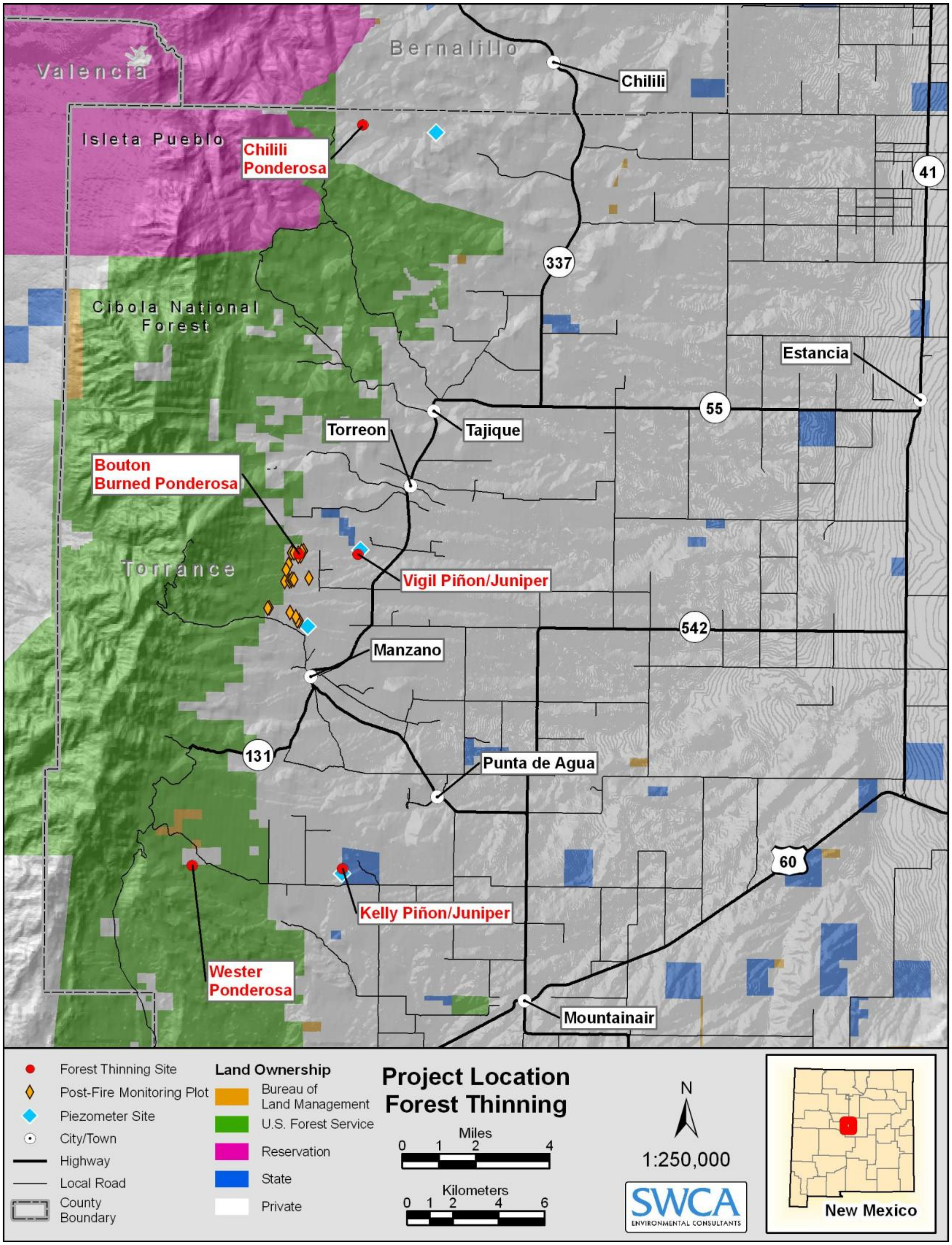


Figure 1.1. Map of all Estancia Basin forest and watershed monitoring locations addressed in this report.

2.0 FOREST THINNING MONITORING

Details of forest thinning monitoring are provided in the 2008 Monitoring Plan (SWCA 2008). Background information on the known environmental effects of forest thinning on southwestern forest ecosystems is presented in the 2008 Monitoring Plan, along with detailed discussions of the experimental study design and methods used in this research to measure various environmental responses to forest thinning treatments.

Forest thinning projects on private lands on the eastern slopes of the Manzano Mountains are overseen by the Steering Committee and include projects in both ponderosa pine forests and piñon/juniper woodlands. Forest thinning monitoring has been designed to address forest thinning in both of these forest types, so four monitoring study sites have been established: two in ponderosa pine forests and two in piñon/juniper woodlands. Each ponderosa pine site has been paired with a piñon/juniper site in the same watershed, so that each of two watersheds has a ponderosa pine and a piñon/juniper monitoring site. One pair of sites is situated at the northern end of the study area (eastern slopes of the Manzano Mountains), and the other at the southern end (see Figure 1.1). Two paired study plots have been installed at each of the four study sites. Descriptions of physical site characteristics such as slope, aspect, parent materials, plant associations, and habitat types are provided in the 2008 Monitoring Plan (SWCA 2008). All study sites chosen are representative of the surrounding area; for example, all sites, excluding the Wester property, undergo a livestock grazing regime, which is typical of the private land use in the Manzano Mountains. One plot of each pair was randomly selected for forest thinning treatments, and the other plot of the pair will serve as an untreated control. Parameters being measured for monitoring at each of the eight study plots include rainfall, ambient temperature, soil moisture and temperature, soil chemistry, soil movement, soil surface stability, soil surface hydrology runoff, vegetation canopy cover and species composition, vegetation vertical structure, tree stand structure, density, composition and health, and bird and small mammal species composition and abundance.

Actual forest thinning treatments were implemented in November 2010 and will be completed by March 2011. This 2010 report presents the third year pre-thinning treatment baseline data and comparisons of paired study plots. From 2011 on, the various environmental parameters being measured will be compared between the treatment and control study plots, and each study plot will be compared to itself over time.

2.1 AUTOMATED RAIN GAUGE AND TEMPERATURE RECORDING STATIONS

Spectrum WatchDog automated data-logging rain gauges installed at each of the paired vegetation and soils monitoring plots at all of the study sites (see Figure 1.1) have run continuously since they were installed in November 2007 (Figure 2.1). The WatchDog stations are located in openings in the tree canopy in order to reduce effects of interception. Additional details regarding the setup of the weather stations are provided in the 2008 Monitoring Plan (SWCA 2008). The tipping bucket rain gauges on the WatchDog stations are set to record rainfall and snowmelt sums at one-hour intervals continuously. In fall 2008, a graduated cylinder rain gauge was added to each of the automated rain gauge locations to serve as backups in case of power failure or other malfunction of the data logger (Figure 2.2). These graduated rain gauges and their recorded values are checked monthly when Time Domain Reflectometer (TDR) soil moisture and temperature readings are taken; mineral oil is also added to these gauges at this time to prevent evaporation of water collected. The WatchDog stations are set to record ambient temperature, soil moisture 10 cm (4 inches) below the soil surface (-10 cm), and soil temperature -10 cm, all at one-hour increments. Soil moisture and temperature data from each WatchDog station provide baseline comparisons for the Field Scout TDR 200 soil water content and soil temperature data that are sampled monthly at each study plot. All data from the stations are off-loaded approximately every three months and entered into a database. Summaries for precipitation, ambient temperature, soil moisture, and soil temperature from 2010 on all thinning plots are presented as examples below.

Figure 2.1. WatchDog mini weather station at the Wester ponderosa pine site.

Figure 2.2. Graduated rain gauges are used for backup in the case of failure from one of the WatchDog weather stations.

2.1.1 PRECIPITATION

Hourly precipitation totals have been summed to monthly totals and show similar monthly precipitation totals between the paired study plots at the Kelly piñon/juniper study sites (Figure 2.3), the Vigil piñon/juniper study sites (Figure 2.4), the Wester ponderosa pine study sites (Figure 2.5), and the Chilili ponderosa pine study sites (Figure 2.6).

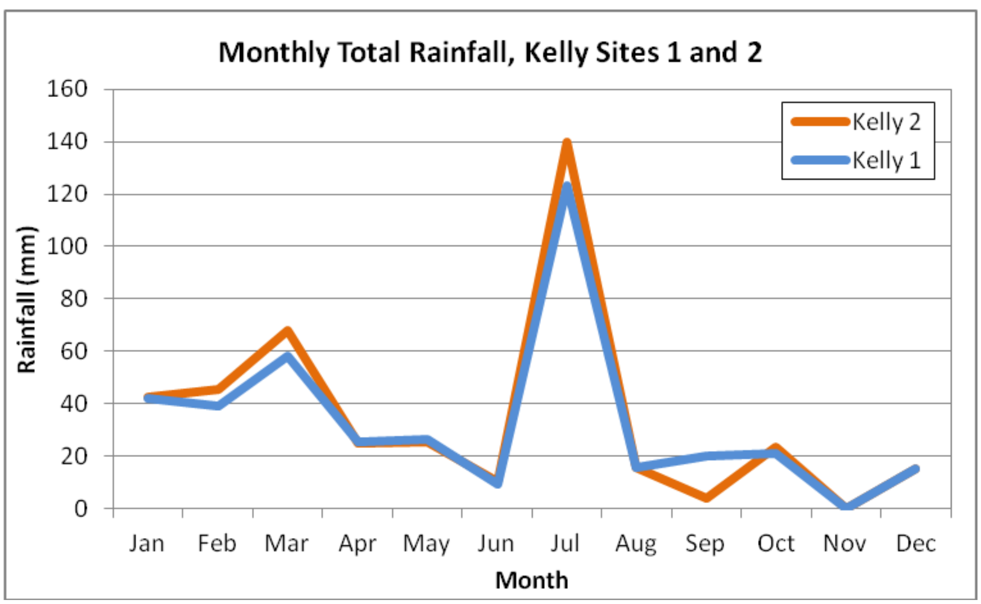


Figure 2.3. Monthly cumulative precipitation (rainfall and snow) from the two paired Kelly piñon/juniper study plots.

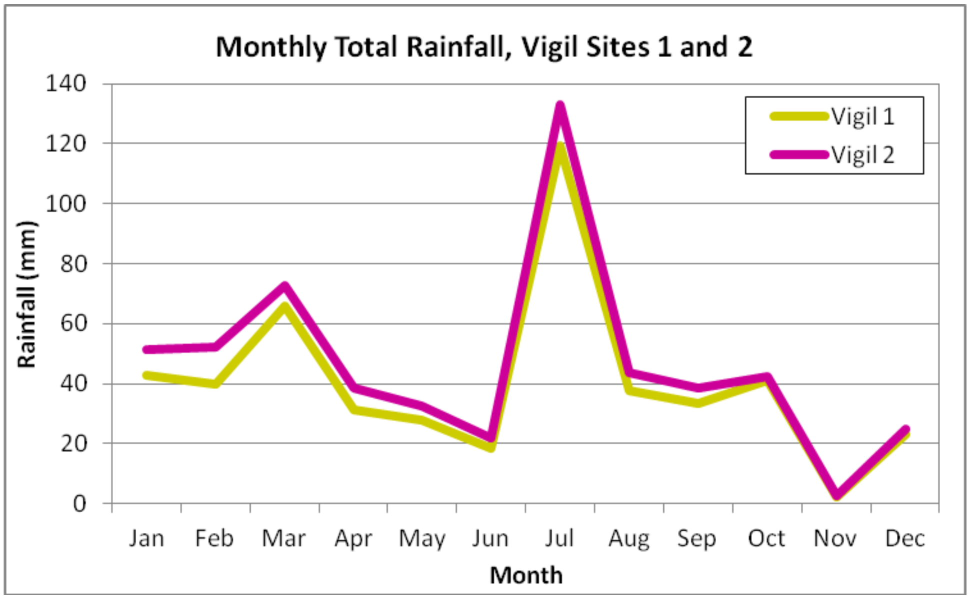


Figure 2.4. Monthly cumulative precipitation (rainfall and snow) from the two paired Vigil piñon/juniper study plots.

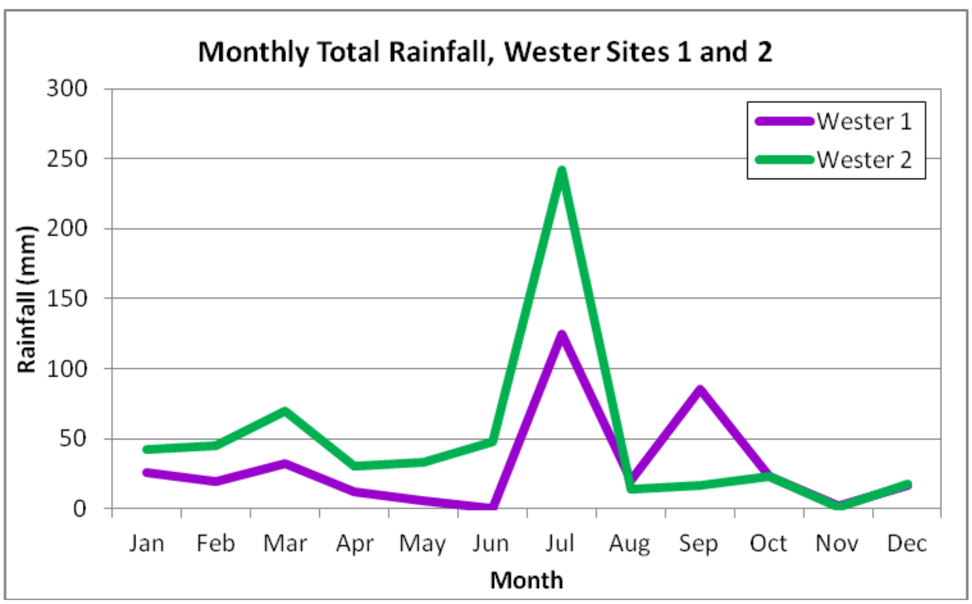


Figure 2.5. Monthly cumulative precipitation (rainfall and snow) from the two paired Wester ponderosa pine study plots.

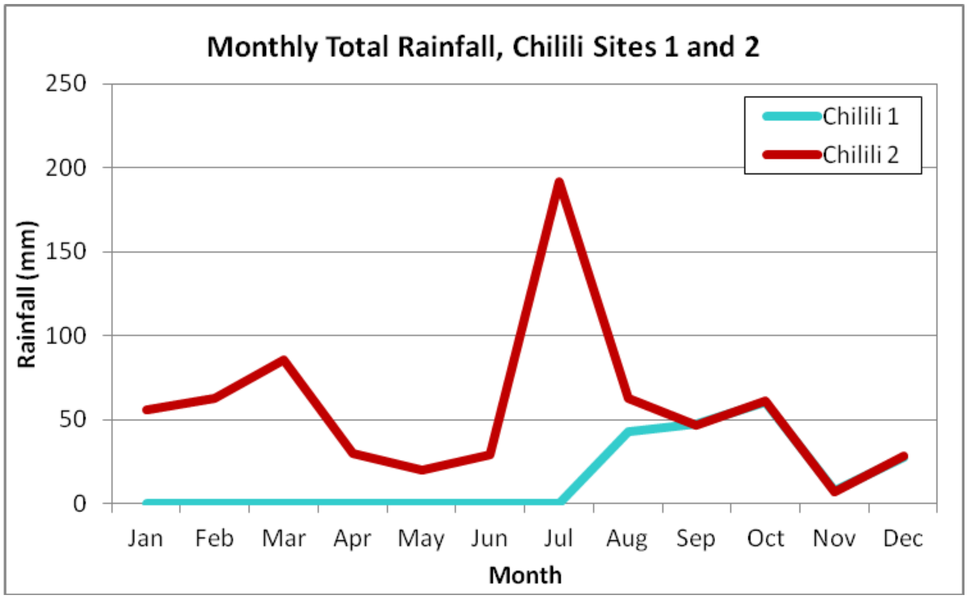


Figure 2.6. Monthly cumulative precipitation (rainfall and snow) from the two paired Chilili ponderosa pine study plots.

Precipitation was not recorded consistently at the Chilili ponderosa site from the WatchDog weather station on plot 1 from January through July because of the persistent damage to the weather station caused by a black bear. However, the WatchDog weather station on plot 2 was not damaged and recorded all the precipitation events. The graduate cylinders that serve as backups to the WatchDog stations also recorded the precipitation events during this period, but only on a monthly basis (not daily).

2.1.2 AMBIENT TEMPERATURE

An example of monthly averages of hourly ambient temperatures is presented for the Kelly piñon/juniper study sites (Figure 2.7). These graphs show similar monthly average ambient temperatures between the paired study plots, as was typical at all of the study sites.

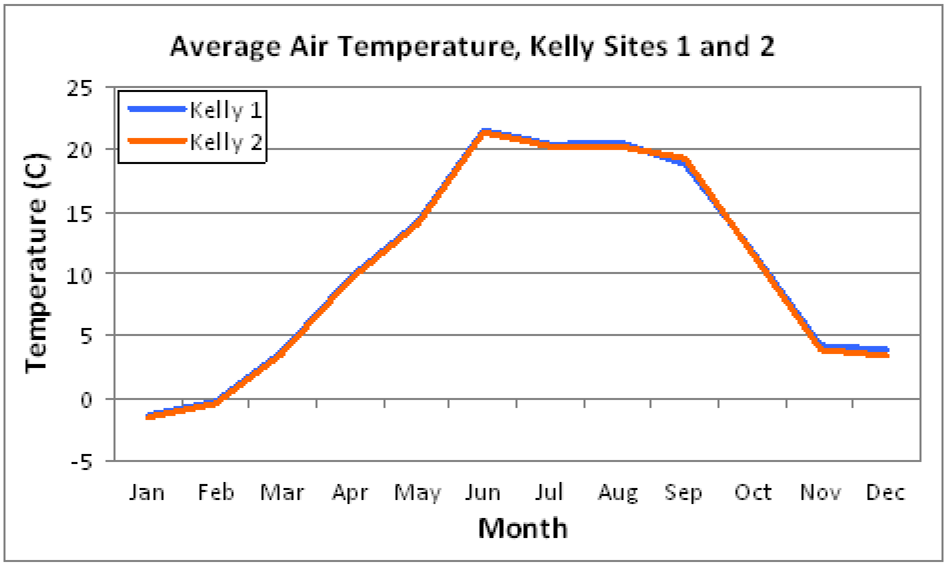


Figure 2.7. Monthly average ambient temperatures from the two paired Kelly piñon/juniper study plots.

An example of monthly averages of hourly -10 cm soil moisture readings are presented for the paired study plots at the Kelly piñon/juniper site (Figure 2.8). Soil moisture was measured with Watermark soil moisture probes that measure soil water tension in kilopascal (kPa) values that are directly equivalent to California Bearing Ratio (cbr) values for soil water saturation. Results for paired plots were generally similar.

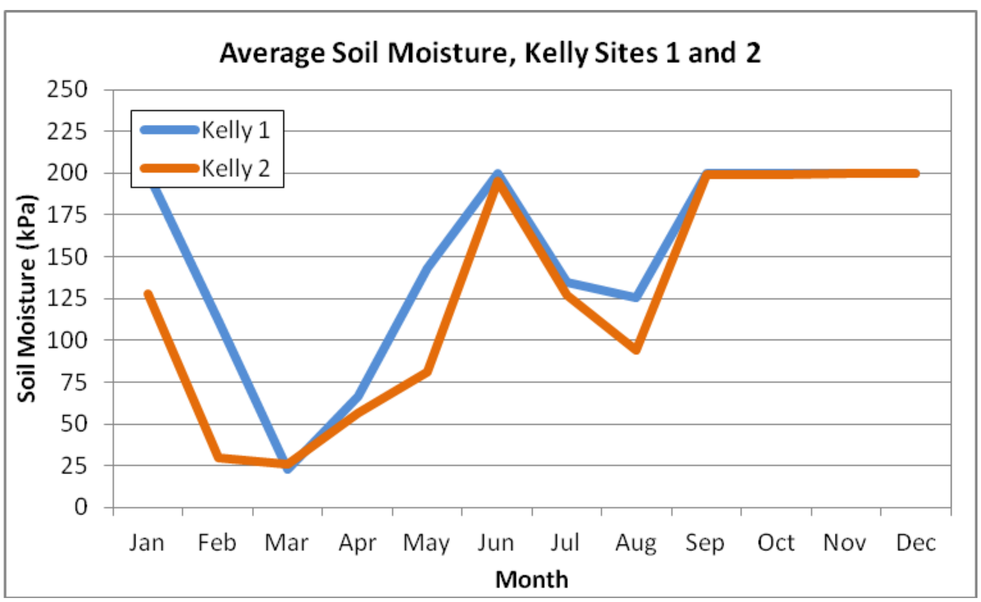


Figure 2.8. Monthly average soil moisture tensions (-10 cm) from the two paired Kelly piñon/juniper study plots.

2.1.3 Soil Temperature

An example of monthly averages of hourly -10 cm soil temperature readings are presented for the paired study plots at the Kelly piñon/juniper sites (Figure 2.9). The graphs show similar monthly average soil temperatures between the paired study plots (1 and 2) at both study sites, which was generally the pattern across all sites.

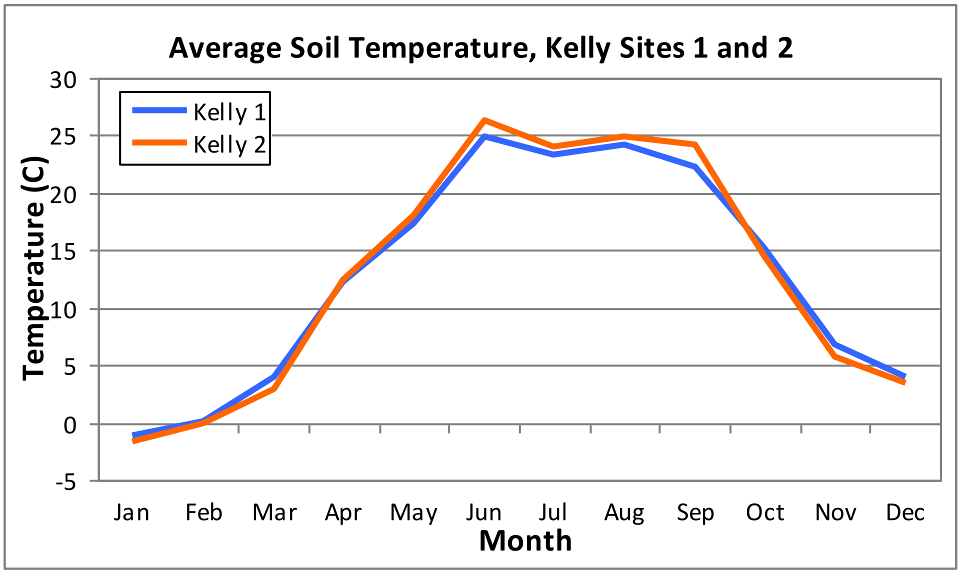


Figure 2.9. Monthly average soil temperature (-10 cm) from the two paired Kelly piñon/juniper study plots.

2.2 Entire Study Plot Soil Water Content and Temperature (TDR)

Continuous hourly soil moisture and temperature measurements recorded by the WatchDog station at each plot only provide a single reference point measurement for each plot, measured and recorded hourly. In order to sample soil moisture and temperature from locations throughout each vegetation and soil monitoring plots, a portable Field Scout TDR 200 soil moisture meter was used. Further information on the detailed methods can be found in the 2008 Annual Report (SWCA 2009).

An example of average percent soil volumetric water content and temperature readings from the Chilili ponderosa pine paired study plots are shown in Figure 2.10 and Figure 2.11. These figures indicate little difference in soil water content and soil temperatures between the two paired plots at the Chilili site. These baseline data show that the subwatersheds are functioning similar in regards to soil moisture and temperature. After thinning treatments are implemented, any significant differences, if they exist, then likely can be attributed to the treatment.

There were several issues with the equipment and scheduling that did not allow for all the measurements to be taken on a monthly basis in 2010. The TDR probe broke sometime after the May measurements and was sent back for repair in June. This probe was returned in working order in September. The soil temperature probe also had mechanical issues, and subsequently data were not gathered in July and August; however, these probes were replaced by September so that the data collection could continue. Monthly readings will be taken throughout 2011 and beyond.

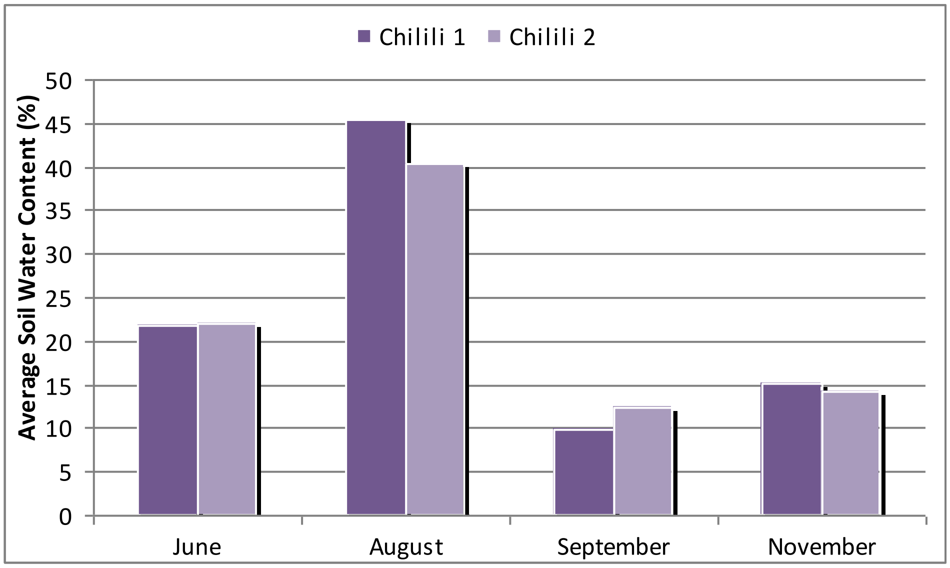


Figure 2.10. Soil moisture readings taken in 2010 with the Field Scout TDR 200 at the Chilili ponderosa pine study plots.

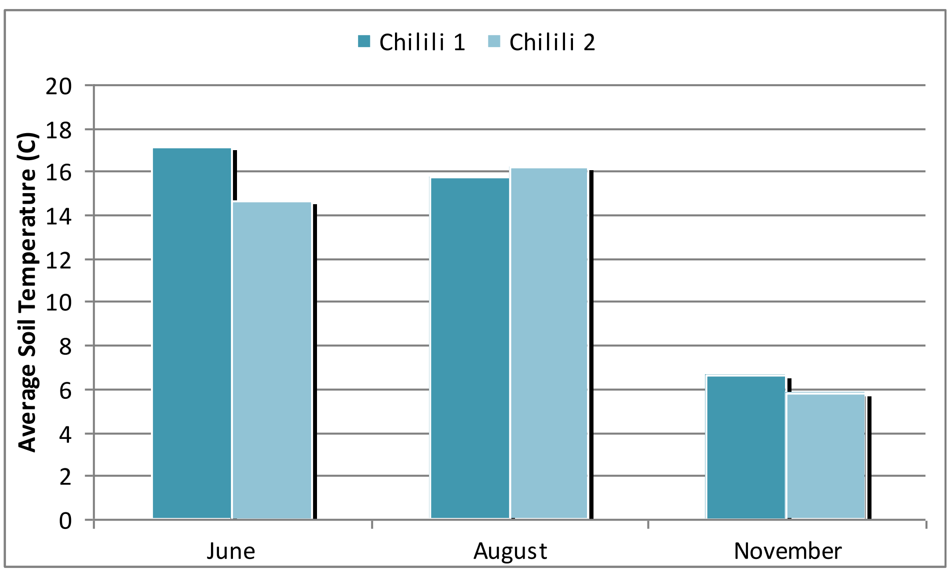


Figure 2.11. Soil moisture readings taken in 2010 with the Field Scout TDR 200 at the Chilili ponderosa pine study plots.

2.3 SOIL SURFACE STABILITY

Soil surface stability was measured and scored in June 2010 using the Soil Stability Test Kits developed by the USDA Agricultural Resource Service (Herrick et al. 2005) (Figure 2.12). Further details of the measurement methods and a review of the literature can be found in the 2008 Monitoring Plan (SWCA 2008). Figure 2.13 provides average soil surface stability scores for each of the eight subplots representing each of the vegetation and soils sampling plots from the four sites (Chilili, Kelly, Vigil, and Wester). Scores are partitioned by subplot and overstory vegetation canopy type. Figure 2.14 provides average soil subsurface (1 cm below the soil surface, or -1 cm) stability scores for each of the eight subplots.

In general, soils under tree canopies had higher scores than at other sites, which was also the case in 2008 and 2009. The higher scores here are due largely to the large accumulation of organic matter that occurs underneath tree canopies, especially within the ponderosa pine vegetation type, which can add as much as 2,000 pounds/acre/year of fine fuels (Ffolliott et al. 1968). Most of those soils at the sites measured were underneath litter layers and contained organic material and fungi. Statistical tests will be conducted next year after treatment to see if the restoration treatments have any effect on soil stability scores.

Figure 2.12. Soil stability test in use on the study sites.

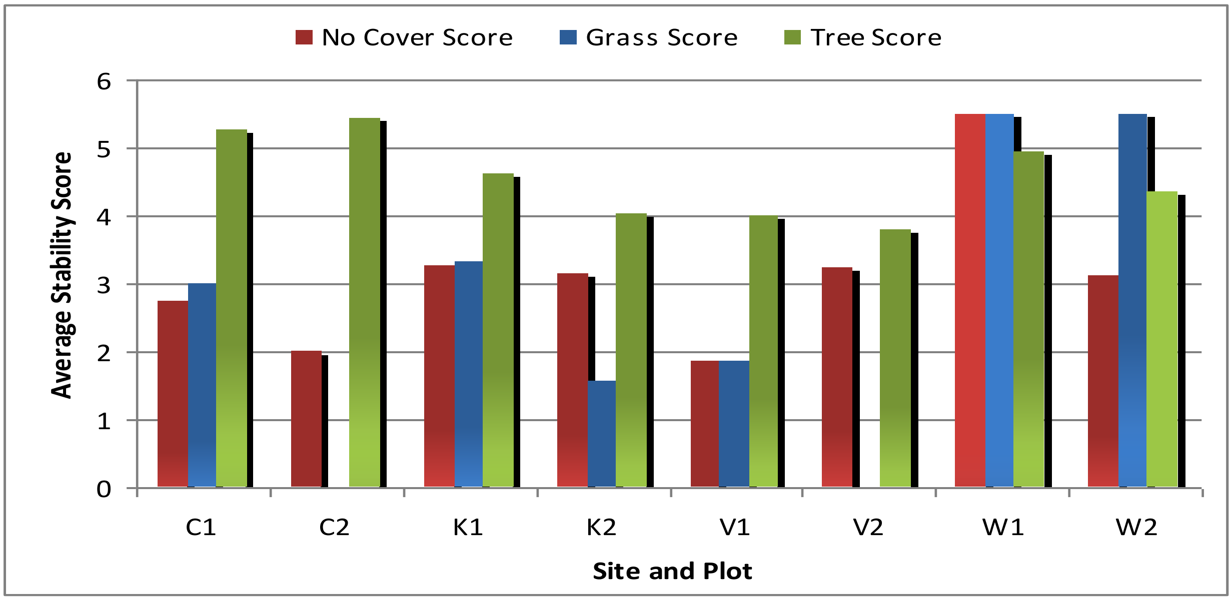


Figure 2.13. Soil surface stability average scores by site, plot, subplot (18 subsamples/subplot), and overstory vegetation canopy type; C= Chilili, K = Kelly, V = Vigil, and W = Wester.

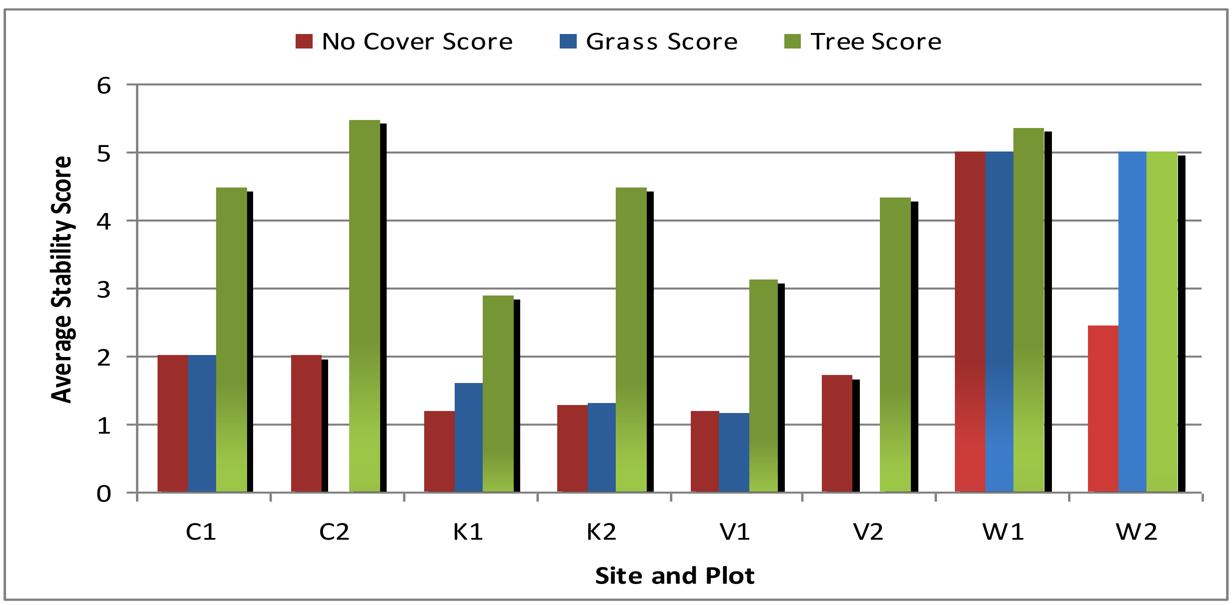


Figure 2.14. Soil subsurface (-1 cm) stability average scores by site, plot, subplot (18 subsamples/subplot), and overstory vegetation canopy type; C= Chilili, K = Kelly, V = Vigil, and W = Wester.

2.4 SOIL MOVEMENT BRIDGES

Soil movement was monitored using soil movement bridges (called soil erosion bridges in the 2008 report) (Figure 2.15) modeled after White and Loftin (2000). Permanent bridge support posts were installed at consistent, systematically determined, and unbiased locations at one of each of the vegetation and soil subplots for a total of three bridges at each paired plot at all four sites. Please refer to the 2008 Annual Report for detailed monitoring protocols and literature associated with soil movement (SWCA 2009). Figure 2.16 shows the micro-soil topography profile from one of the three sampling points at the Kelly piñon/juniper site for 2008, 2009, and 2010. The graph clearly shows the yearly variability associated with soil movement on a plot and a slight trend for overall soil loss over the three-year period. Figure 2.17 shows average soil profile values averaged over all points per bridge, and over three bridges per paired plot, for 2008, 2009, and 2010. This figure shows that there has been little overall change in average soil surface levels over that three-year period of time. The processes of soil erosion and soil deposition can clearly be seen when plotting data from al three years. After thinning treatments are completed, post-treatment data will be available to compare with pre-treatment data. These comparisons will allow us to assess the changes in soil movement potentially caused by restoration treatments. Over a series of years, this study will document losses and/or gains to the soil surface profiles at each bridge site and will provide average values for each of the eight plots in this study (Chilili, Kelly, Vigil, and Wester).

Figure 2.15. Measurement of soil surface topography using a soil movement bridge helps understand the yearly variability associated with soil topography.

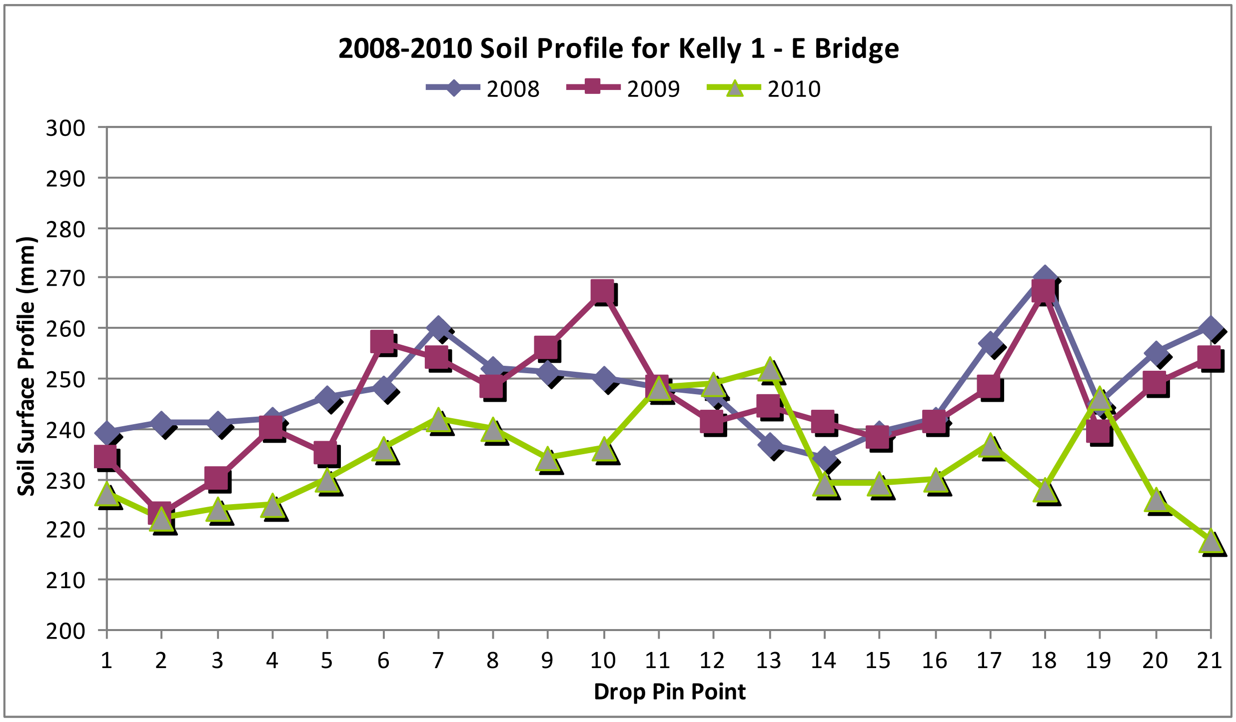


Figure 2.16. Soil surface profile from the soil movement bridge located at the Kelly piñon/juniper site 1 over 2008, 2009, and 2010, showing variation in the soil surface profile over a three-year period. Each point 1–21 on the X axis represents one measurement point from the soil surface to the level bridge above the surface. Point 11 is the set point (head of a spike) for calibration.

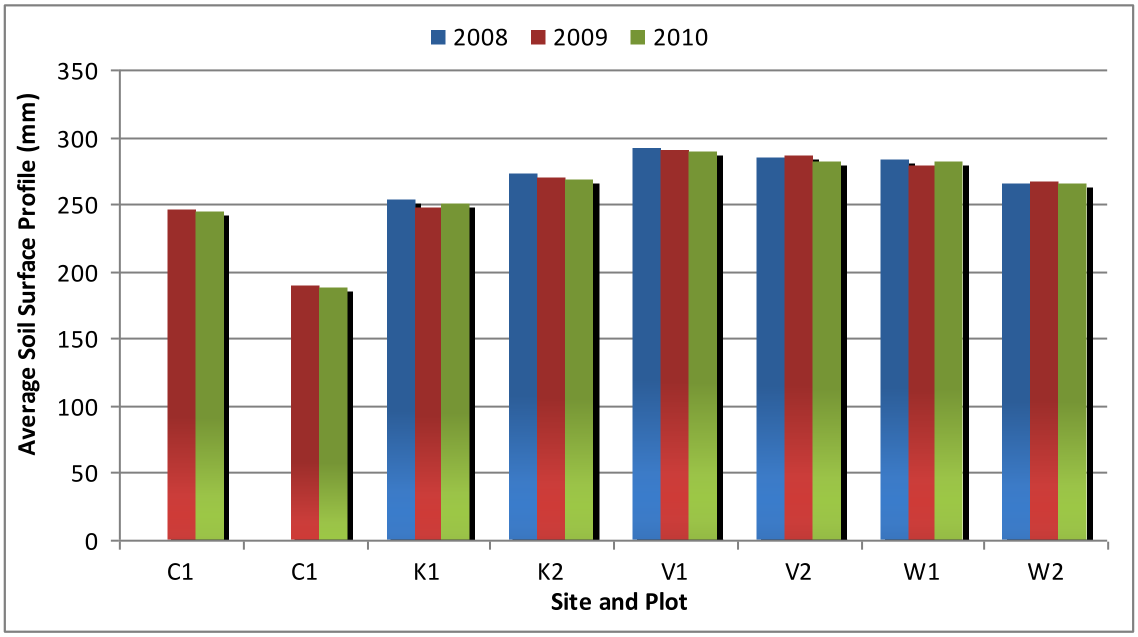


Figure 2.17. Average soil surface profiles, averaged from three soil movement bridges located on each of the paired study plots over the three-year period, 2008–2010.

2.5 SOIL CHEMISTRY

The chemistry comprising the soil is an important parameter in the overall health and functioning of a watershed. In particular, the top layer of soil, the A-horizon, is important because it is the zone where most biological activity occurs and therefore the most fertile layer. The A-horizon is also the layer of soil most susceptible to disturbance because it is exposed at the surface to the elements of nature and man. Soil chemistry plays a key role in sustaining the productivity of plants and soil biota, which directly affect the ability of soil to infiltrate water. Understanding the chemical makeup of a soil before treatment or disturbance can shed light on how restoration techniques affect the chemical composition of the soil.

Baseline measurements of soil chemistry were obtained in 2008, 2009, and 2010 before thinning treatments at the Kelly, Vigil, and Wester sites; Chilili was not included until the 2009 sampling because this plot had yet to be established. The purpose of taking these measurements is to quantify changes to soil chemistry potentially caused by thinning activities. The methods used in 2008, however, were slightly different than those used in 2009 and 2010 and can be a reason for any large differences seen between years. The soil samples were obtained using a 4-cm-diameter (1.6-inch-diameter), 20-cm-deep (8-inch-deep) impact soil corer at the four corners of the three established vegetation plots (Figure 2.18). In 2008 the 12 subsamples were placed in labeled separate bags in order to attempt in house analysis with Cardy soil kits. The variability associated with these kits, however, proved to be too great for reliable results, so the subsamples were combined into one bag for each site and sent to the New Mexico State University Soils and Water Testing (SWAT) laboratory for further analysis. In 2009 and 2010, the collection of the 12 subsamples was combined into the same bag at the time of sampling. These pooled samples were considered to be representative of the study areas. 2009 and 2010 samples were sent to the SWAT laboratory for analysis. These methods followed the USFS Forest Inventory and Analysis Guide procedures (USFS 2005).

Figure 2.18. Soil cores were taken using an impact corer, shown above, for chemical analysis.

The variables measured by the SWAT laboratory included saturated paste pH, electronic conductivity, total soluble salts (sodium, calcium, and magnesium), sodium adsorption ration, organic matter, nitrogen (nitrate) (NO_3), bicarbonate phosphorous, potassium, and a texture estimate. The initial results of soil organic matter and the macro nutrients nitrogen, phosphorus, and potassium from samples taken in 2008, 2009, and 2010 are presented in Figure 2.19 through Figure 2.22.

The various soil chemistry compounds varied quite a bit at a given plot, between paired plots, between sites, and between years. This amount of background variation will be important to consider in determining if thinning treatments affect soil chemistry. Such treatment differences will need to be above this background variation.

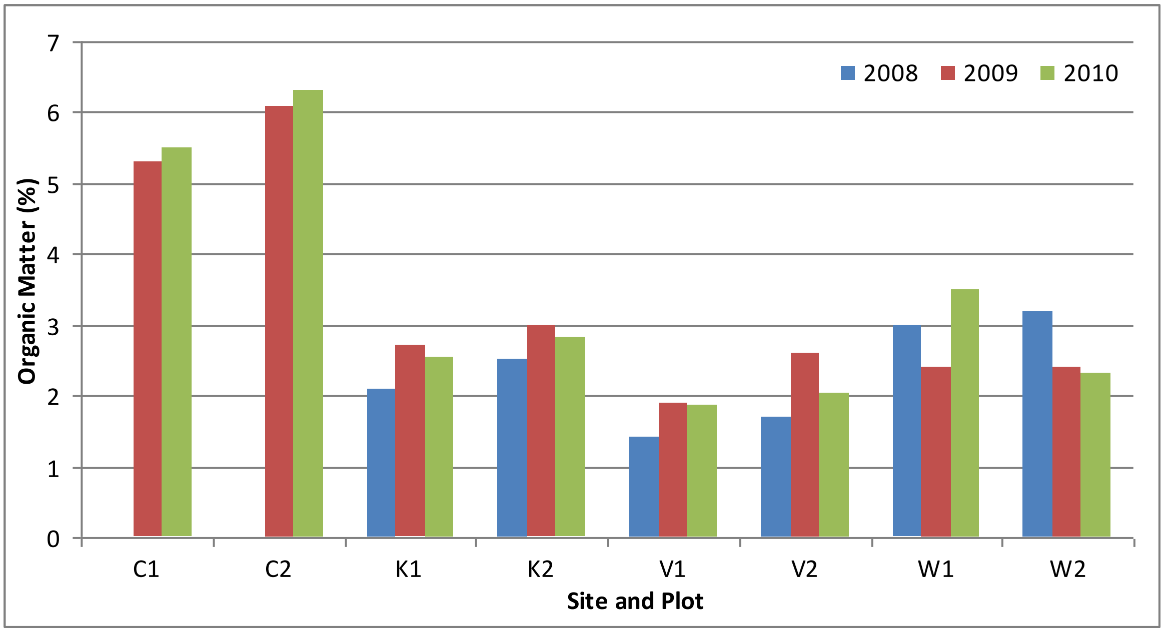


Figure 2.19. Organic matter concentrations measured during 2008, 2009, and 2010; C= Chilili, K = Kelly, V = Vigil, and W = Wester.

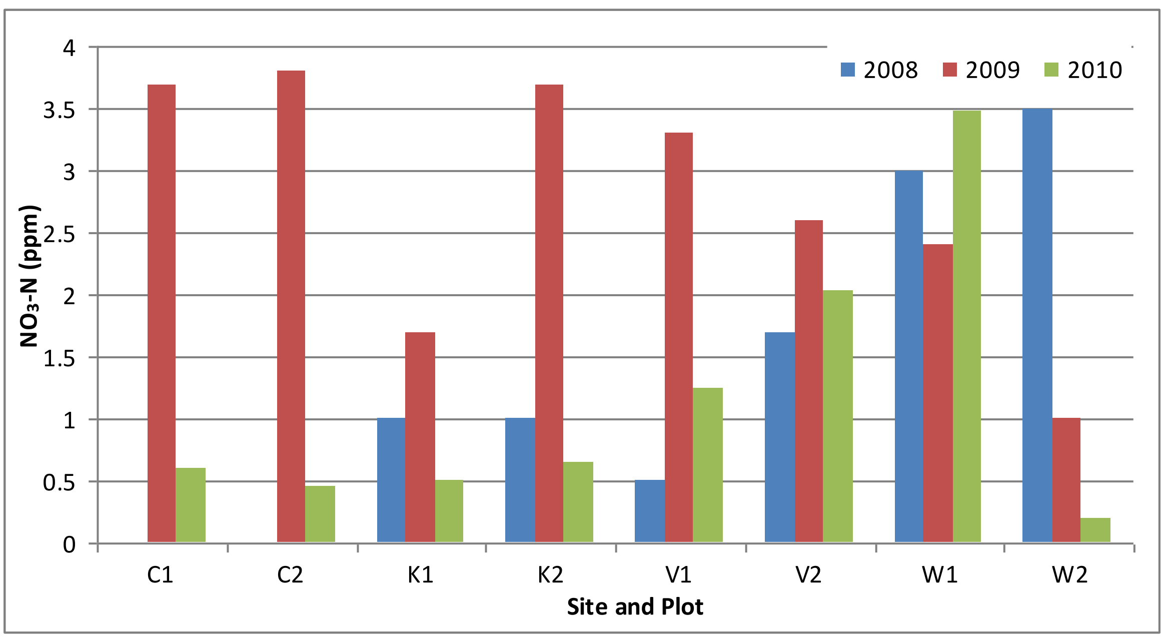


Figure 2.20. NO_3-N concentrations measured during 2008, 2009, and 2010; C= Chilili, K = Kelly, V = Vigil, and W = Wester.

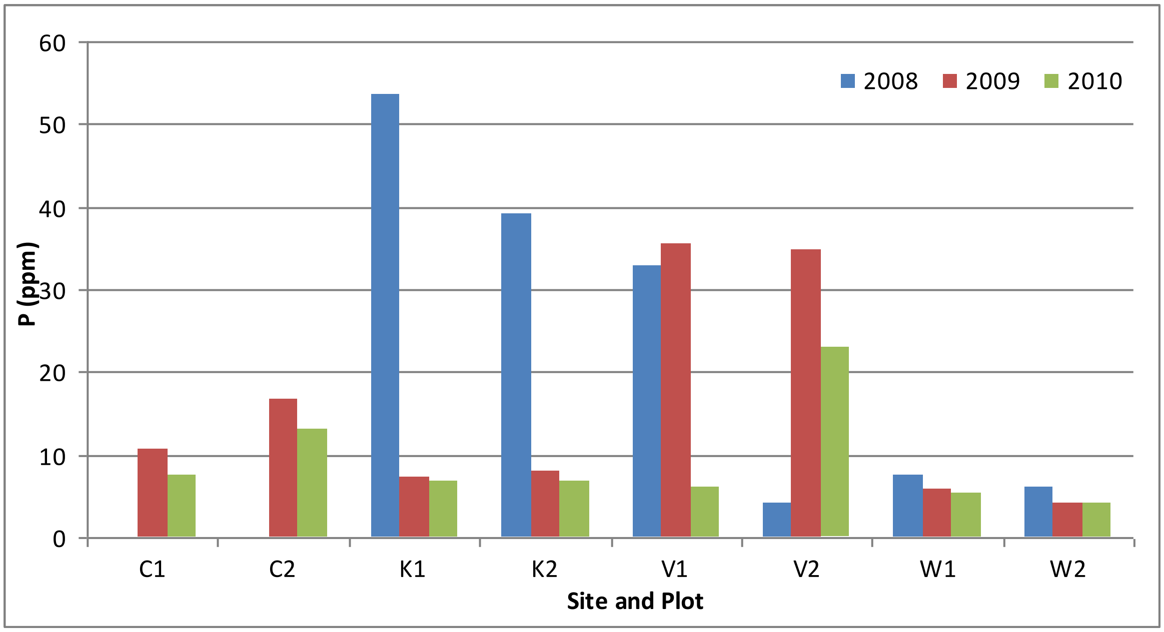


Figure 2.21. Baseline concentrations of phosphorus measured during 2008, 2009, and 2010; C= Chilili, K = Kelly, V = Vigil, and W = Wester.

Figure 2.22. Baseline potassium concentrations measured during 2008, 2009, and 2010; C= Chilili, K = Kelly, V = Vigil, and W = Wester.

2.6 FOREST THINNING HYDROLOGIC MONITORING

Monitoring flumes (Parshall flumes) complete with pressure transducers (Figure 2.23) were installed at study sites in order to study impacts of tree thinning to surface flow. To study this, flumes were installed at all four monitoring sites. For more detailed information on the methodology, site location, and relevant background information, please refer to the 2008 Monitoring Plan (SWCA 2008). Note that the Bouton site was formerly a forest thinning monitoring site, but burned in the 2008 Trigo fire, and has since become a post-fire monitoring site. The flumes have been maintained at that site and are presented here with the other flume results.

Figure 2.23. Parshall flume located at Chilili site plot 1.

During the 2009–2010 monitoring period, rainfall occurred in the project area on 29% of the days monitored. However, about 60% of these rainfall events were relatively small and totaled less than 2.5 mm (0.1 inch). The greatest daily rainfall recorded was 85.34 mm (3.36 inches) at the Wester site (July 2, 2010). During the same monitoring period, 45 flow events were recorded in the flumes across the watersheds on 21 separate days. While a handful of flow events occurred where minimal (or even no) rain was recorded in the nearest rain gauge, flows generally did not generate without at least 7.6 mm (0.3 inch) of rainfall. The sites located in the ponderosa pine study plots generated runoff with slightly less rain (7.6 mm [0.3 inch]), whereas the piñon-juniper sites required about 12.7 mm (0.5 inch) of rain to generate runoff events.

Of the 21 days in which runoff occurred, 16 only saw runoff in one or two flumes. However, four major precipitation events generated runoff in four or more flumes: October 27, 2009; July 25, 2010; July 31, 2010; and August 15, 2010. Runoff for these events is shown in Table 2.1

through Table 2.3 and Figure 2.24 through Figure 2.26. All of the Parshall flumes were functioning properly during the 2010 season.

Table 2.1. Summary of Runoff Events on July 25, 2010

Runoff Parameters	Study Sites					
	Bouton 1	Bouton 2	Vigil 1	Vigil 2	Wester 2	Chilili 2
Flow start	18:30	13:55	14:10	14:12	17:52	21:55
Flow stop	19:55	20:40	19:40	19:22	19:22	22:30
Peak stage (feet)	0.41	0.59	0.15	0.27	0.38	0.25
Peak flow (cubic feet/second)	0.249	0.438	0.052	0.13	0.221	0.116
Flow duration (minutes)	85	330	105	80	90	35
Total volume of flow (cubic feet)	373	1958	160	290	444	179
Watershed area (acres)	1.6	2.06	0.68	0.1	1.03	9.2
Volume of flow per acre (cubic feet/acre)	233	950	235	2,900	431	19
Total rainfall (inches)	1.12	2.26	1.9	2	1.12	0.49
Total volumetric rainfall (cubic feet)	6,505	16,900	4,690	726	4,188	16,364
Rainfall/Runoff ratio	0.057	0.116	0.034	0.399	0.106	0.011

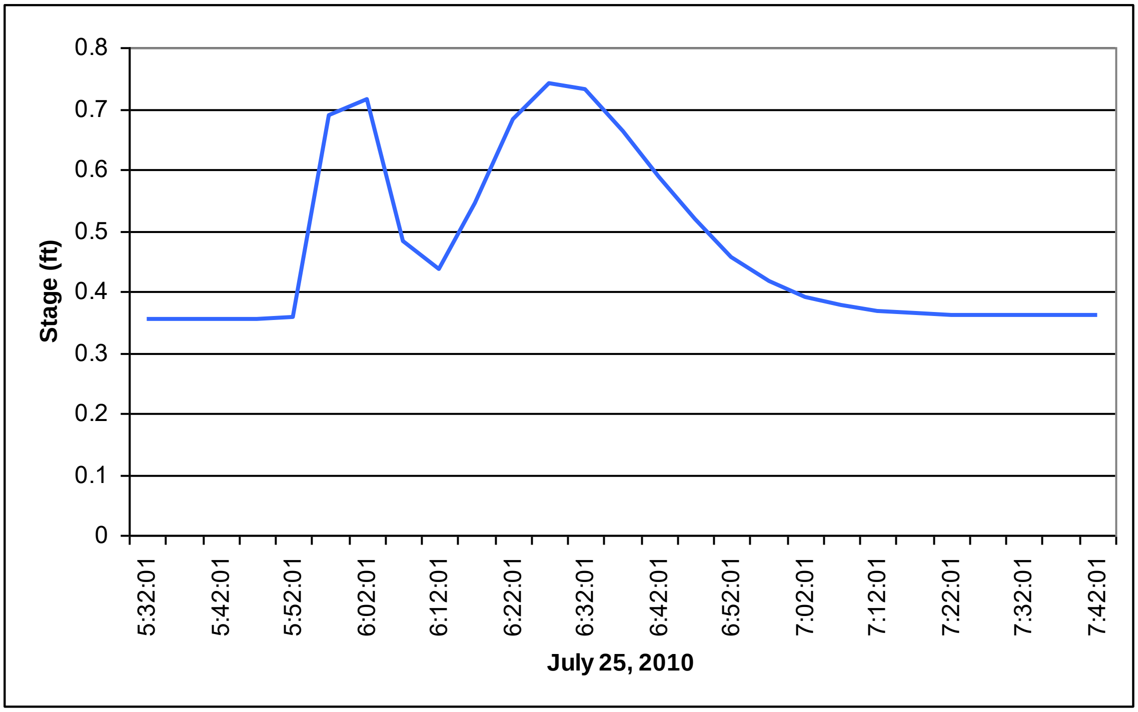


Figure 2.24. Hydrograph showing the peak flow at the Wester 2 site during the flow event on July 25, 2010.

Table 2.2. Summary of Runoff Events on July 31, 2010

Runoff Parameters	Study Sites			
	Kelly 1	Wester 1	Wester 2	Chilili 2
Flow start	20:55	21:12	21:02	19:45
Flow stop	21:30	1:07	22:42	22:50
Peak stage (feet)	0.17	0.15	0.7	0.3
Peak flow (cubic feet/second)	0.064	0.052	0.571	0.153
Flow duration (minutes)	35	235	100	185
Total volume of flow (cubic feet)	67	367	2858	857
Watershed area (acres)	0.29	6.76	1.03	9.2
Volume of flow per acre (cubic feet/acre)	231	54	2,775	93
Total rainfall (inches)	0.64	0.51	0.98	0.91
Total volumetric rainfall (cubic feet)	674	12,515	3,664	30,390
Rainfall/Runoff ratio	0.099	0.029	0.780	0.028

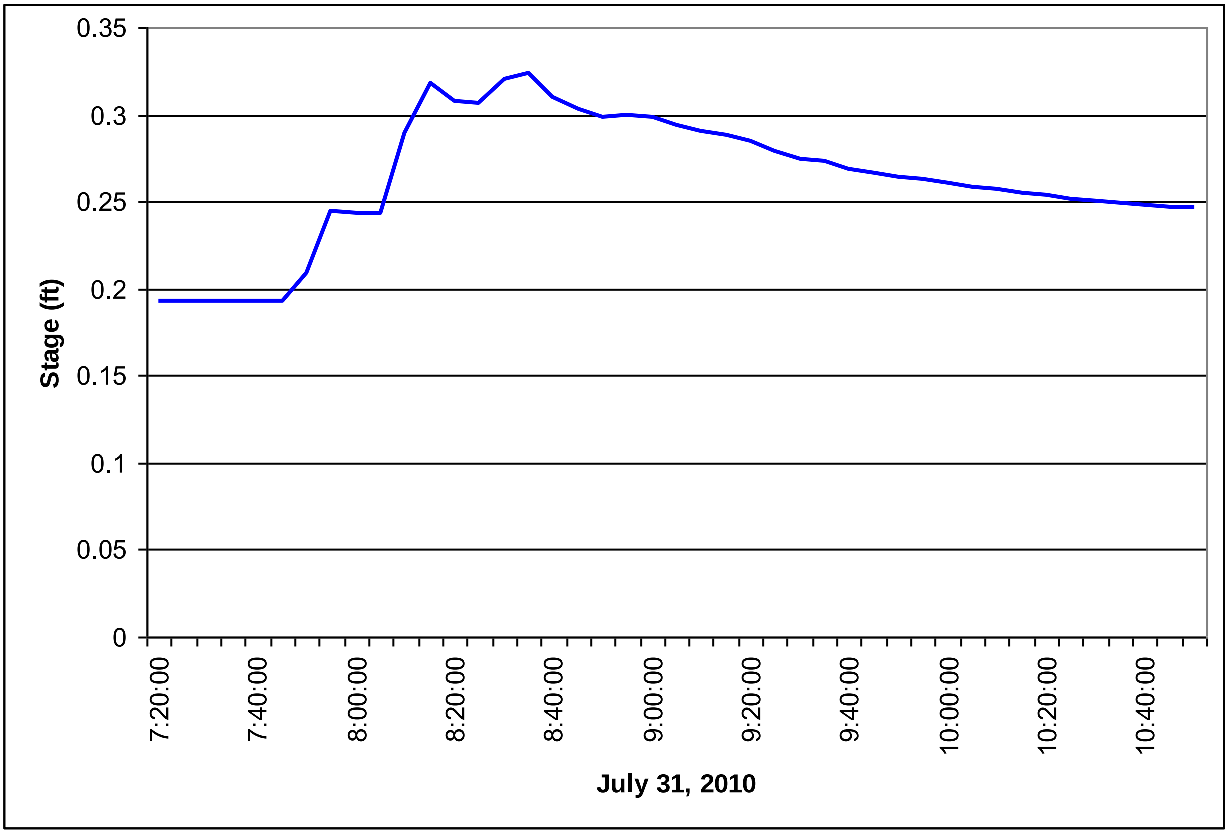


Figure 2.25. Hydrograph showing the peak flow at the Chilili 2 site during the flow event on July 31, 2010.

Table 2.3. Summary of Runoff Events on August 15, 2010

Runoff Parameters	Study Sites			
	Bouton 1	Bouton 2	Vigil 1	Chilili 2
Flow start	19:40	19:10	19:35	20:15
Flow stop	19:55	20:40	20:15	20:40
Peak stage (feet)	0.17	0.16	0.24	0.11
Peak flow (cubic feet/second)	0.064	0.058	0.109	0.032
Flow duration (mintues)	15	90	40	25
Total volume of flow (cubic feet)	35	158	131	36
Watershed area (acres)	1.6	2.06	0.68	9.2
Volume of flow per acre (cubic feet/acre)	22	77	193	4
Total rainfall (inches)	1.13	1.13	0.64	0.41
Total volumetric rainfall (cubic feet)	6,563	8,450	1,580	13,692
Rainfall/Runoff ratio	0.005	0.019	0.083	0.003

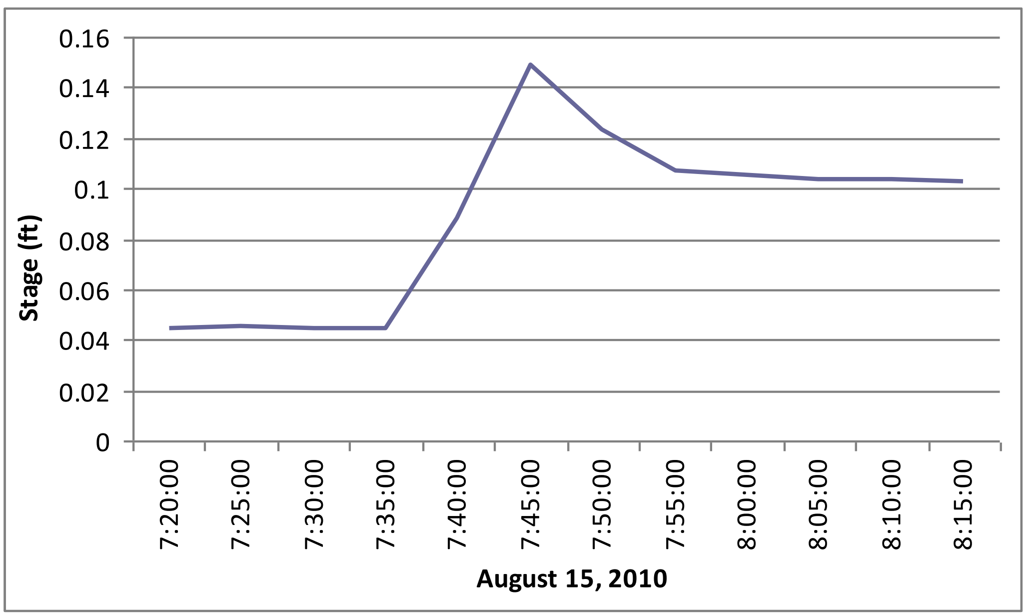


Figure 2.26. Hydrograph showing the peak flow at the Vigil 1 site during the flow event on August 15, 2010.

With respect to site hydrology, there are four conditions that could change because of forest thinning or from the effects of wildfire: 1) increased frequency of flow, 2) greater duration and volume of flow, 3) increased peak flow, and 4) a greater ratio of runoff to rainfall.

2.6.1 Flow Frequency, Duration, and Volume

Frequency of flow will be able to be analyzed over time as data are collected; however, based on the period of record so far a baseline has been established for the remaining parameters. The parameters of flow duration and volume will likely be the least useful in assessing effects from forest thinning, as these parameters are highly dependent on rainfall duration and intensity. In general, the ponderosa sites generated flows of longer duration and greater volume than those in the piñon-juniper sites, which can likely be attributed the elevation differences. A summary of the number of flow events (frequency), flow duration, and flow volume for the observed runoff events is shown in Table 2.4.

Table 2.4. Summary of Flow Frequency, Duration, and Volume

Location	Number of Flow Events	Range of Duration (minutes)	Median Duration (minutes)	Range of Volume (cubic feet)	Median Volume (cubic feet)
Bouton 1	3	15–85	20	35–373	67
Bouton 2	7	30–330	82.5	140–1,958	451.5
Chilili 1	2	185–840	512.5	643–17,751	9,197
Chilili 2	8	25–715	167.5	36–2,564	920.5
Kelly 1	4	25–35	30	38–392	54.5
Kelly 2	1	15	15	69	69
Vigil 1	7	15–115	40	46–197	117
Vigil 2	2	20–80	50	146–290	218
Wester 1	4	10–235	102.5	39–4,765	210
Wester 2	7	10–760	90	42–9,458	444
All ponderosa	31	10–840	95	35–9,458	468.5
All piñon-juniper	14	15–115	32.5	38–392	93

2.6.2 Peak Flow/Stage

Peak flow can be affected by the intensity of rainfall, but it is also a measure of the flashiness of flow; particularly in post-fire monitoring, runoff can occur rapidly with large peaks appearing very quickly. The highest peak stage (0.39 m [1.29 feet]) was recorded at the Wester 2 site on July 2, 2010 (coinciding with the greatest observed daily rainfall) (Figure 2.27). A summary of peak stage for runoff events is shown in Table 2.5.

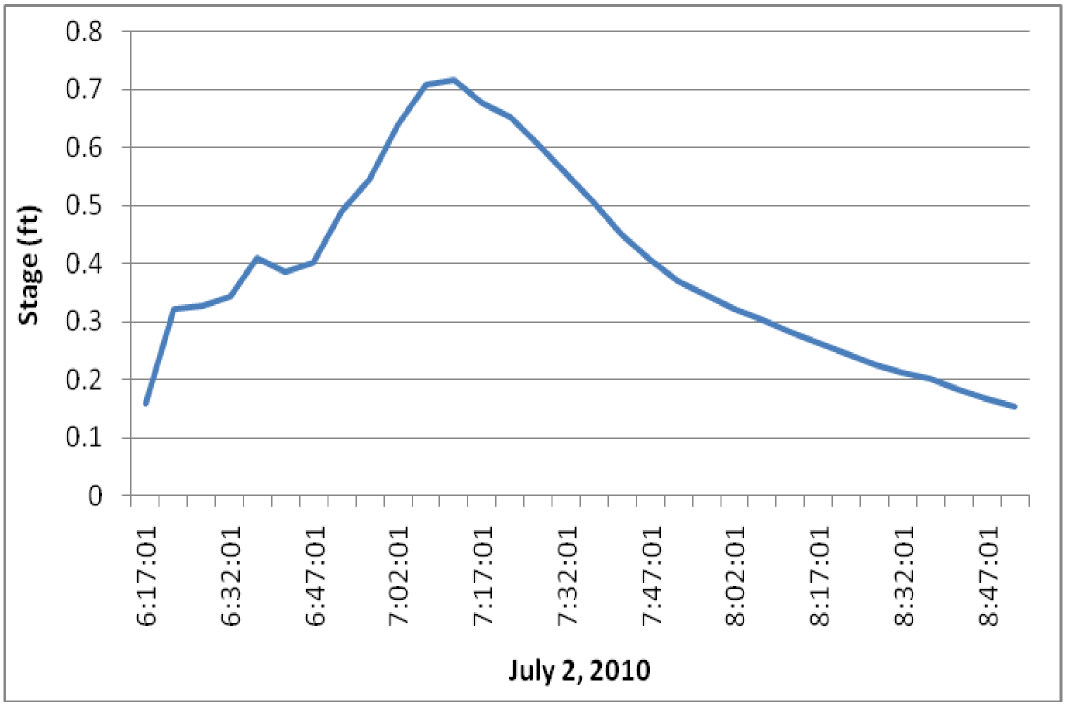


Figure 2.27. Hydrograph showing the peak runoff at the Wester 2 site that occurred on the July 2, 2010.

Table 2.5. Peak Stage of Runoff Events

Location	Number of Flow Events	Range of Peak Stage (feet)	Median Peak Stage (feet)
Bouton 1	3	0.17–0.41	0.26
Bouton 2	7	0.15–0.59	0.4
Chilili 1	2	0.19–0.76	0.475
Chilili 2	8	0.11–0.57	0.375
Kelly 1	4	0.14–0.39	0.175
Kelly 2	1	0.23–0.23	0.23
Vigil 1	7	0.12–0.24	0.16
Vigil 2	2	0.27–0.27	0.27
Wester 1	4	0.15–0.85	0.19
Wester 2	7	0.12–1.29	0.38
All ponderosa	31	0.11–1.29	0.35
All piñon-juniper	14	0.12–0.39	0.175

2.6.3 Rainfall/Runoff Ratio

The rainfall/runoff ratio is perhaps the most useful parameter to observe. All other parameters can vary due solely to the magnitude or intensity of rainfall; the rainfall/runoff ratio normalizes the flow events, although intensity and antecedent soil moisture conditions will still affect the amount of runoff. The rainfall/runoff ratio looks at the percentage of rainfall falling on the watershed leaving as surface runoff. A value of zero indicates no water left the watershed, and a value of 1 would indicate all water falling on the watershed was observed leaving as surface runoff (this is highly unlikely). In natural settings, the rainfall/runoff ratio typically falls in the 0.1 to 0.3 range. The rainfall/runoff ratios observed during flow events from the watersheds are summarized in Table 2.6 and Figure 2.28. Note some rainfall/runoff values were not calculated due to missing rainfall data. In general, rainfall/runoff ratios were highly variable, including some extremely high values; however, almost 70% of the flow events had rainfall/runoff ratios of less than 0.10. Ponderosa sites exhibited a slightly lower rainfall/runoff ratio than piñon-juniper sites, which can likely be attributed to the large amounts of litter and duff that serve as a sponge and retain the water.

Table 2.6. Rainfall/Runoff Ratio for Observed Flow Events

Location	Number of Flow Events	Range of Rainfall/Runoff Ratio	Median Rainfall/Runoff Ratio
Bouton 1	3	0.00–0.057	0.013
Bouton 2	7	0.019–0.157	0.106
Chilili 1	2	0.561–0.561	0.561
Chilili 2	8	0.003–0.550	0.022
Kelly 1	4	0.045–0.460	0.088
Kelly 2	1	–	–
Vigil 1	7	0.034–0.083	0.056
Vigil 2	2	0.399–0.479	0.439
Wester 1	4	0.029–0.058	0.044
Wester 2	7	0.015–0.848	0.407
All ponderosa	31	0.003–0.848	0.058
All piñon-juniper	14	0.034–0.479	0.075

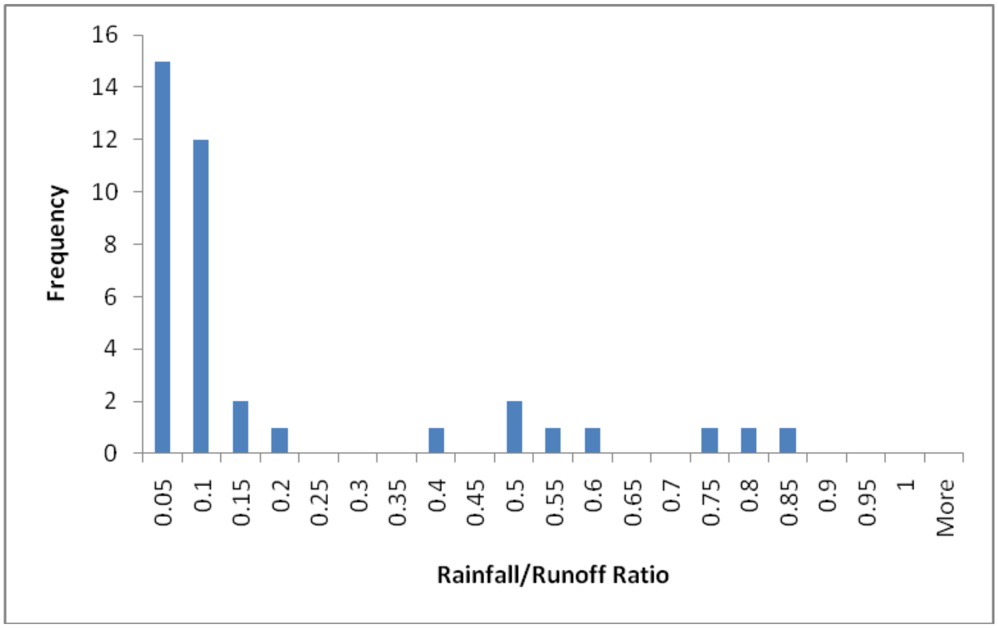


Figure 2.28. Distribution of rainfall/runoff ratios for all observed flow events.

2.7 VEGETATION

For details regarding the research questions, monitoring protocols, and plot design for the vegetation monitoring, as well as a full literature review, please refer to the 2008 Monitoring Plan (SWCA 2008).

2.7.1 REPEAT PHOTO POINTS

Repeat photo points provide a visual means for qualitatively assessing change in woody and herbaceous vegetation over time, and repeat photographs are useful to help interpret quantitative vegetation measurement data from the same locations. Permanent photo points were established on each of the three 10 × 30–m (33 × 98–foot) vegetation and soils measurement subplots for a total of three repeat photographs taken at each of the eight study plots (24 photographs in all). The first baseline photographs were taken in fall 2008. Repeat annual photographs were again taken in fall 2009 and 2010. An example of those repeat photographs comparing the west vegetation subplot of plot 1 at the Vigil site in 2008, 2009, and 2010 is shown in Figure 2.29.

a.

b.


c.

Figure 2.29. Repeat photographs of the Vigil piñon/juniper site, west vegetation subplot photographed in a. fall 2008, b. fall 2009, and c. fall 2010.

2.7.2 VEGETATION STRUCTURE

Vegetation vertical canopy structure was measured on each of the four vegetation and soils subplots. The method was adapted from Herrick et al. (2005) and consisted of a 2-m-long (6.6-foot-long), 5-cm-diameter (2-inch-diameter) white polyvinyl chloride (PVC) pipe pole partitioned into three different 2-m (6.6-foot) height layers, each with continuous 10-cm (4-inch) black/white increment markings (Figure 2.30). The 2-m (6.6-foot) PVC measurement pipe was partitioned into four different vertical 0.5-m (1.6-foot) segments or heights above the ground surface: segment one = 2.0–1.5 m (6.6–4.9 feet), segment two = 1.5–1.0 m (4.9–3.3 feet), segment three = 1.0–0.5 m (3.3–1.6 feet), and segment four = 0.5–0.0 m (1.6–0.0 feet) above the ground surface. An observer recorded vegetation canopy obstruction of the black and white marked areas on the pole, while another person held the pole vertical at three locations across the center line of each 30-m (98-foot) vegetation and soils monitoring subplots, one reading at 10 m (33 feet), one at 20 m (66 feet), and one at 30 m (98 feet). The observer was located 10 m (33 feet) toward the center of the plot from the pole for each canopy measurement. An overall visual obstruction average score was then calculated for each segment of the pole over each of the three lines per subplot, and an overall average score for each segment was then calculated for each plot. Vertical vegetation structure profiles are not only important for assessing wildlife habitat, but also for fire fuels structure. Additional vertical vegetation structure measurements were also initiated on the wildlife plots in 2010.

Figure 2.30. Photograph of vegetation structure pole used to quantify vertical vegetation canopy structure (photograph taken in 2008).

The average vertical vegetation structure measured from nine points on each of the paired study plots in 2010 is presented in Figure 2.31. The percentages of vegetation structure across the four bands and different heights above the ground surface as measured in 2010 are presented in Figure 2.32. The vertical vegetation structure among sites and paired plots tend to differ from each other, and these values will provide the comparison to post-thinning data in 2011. After thinning treatments, decreases in vertical vegetation structure are expected from the thinning treatment plots.

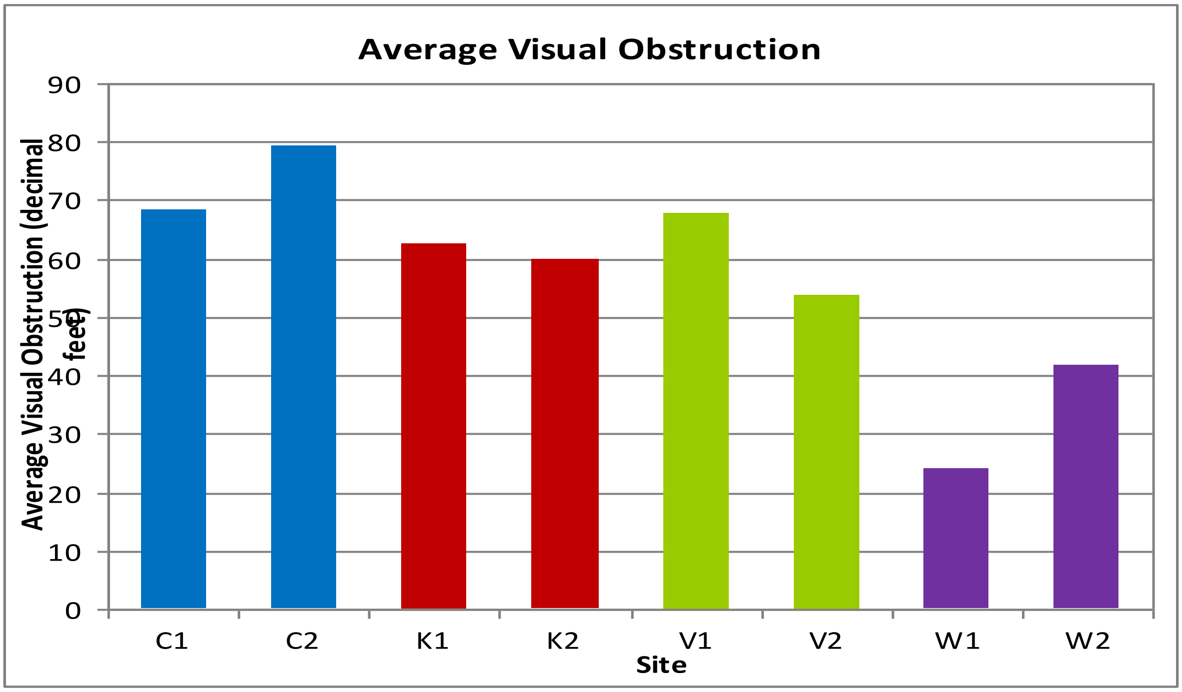


Figure 2.31. Average total visual obstruction values by vegetation foliage from ground level to 2 m (6.6 feet) high measured from all study plots in 2010.

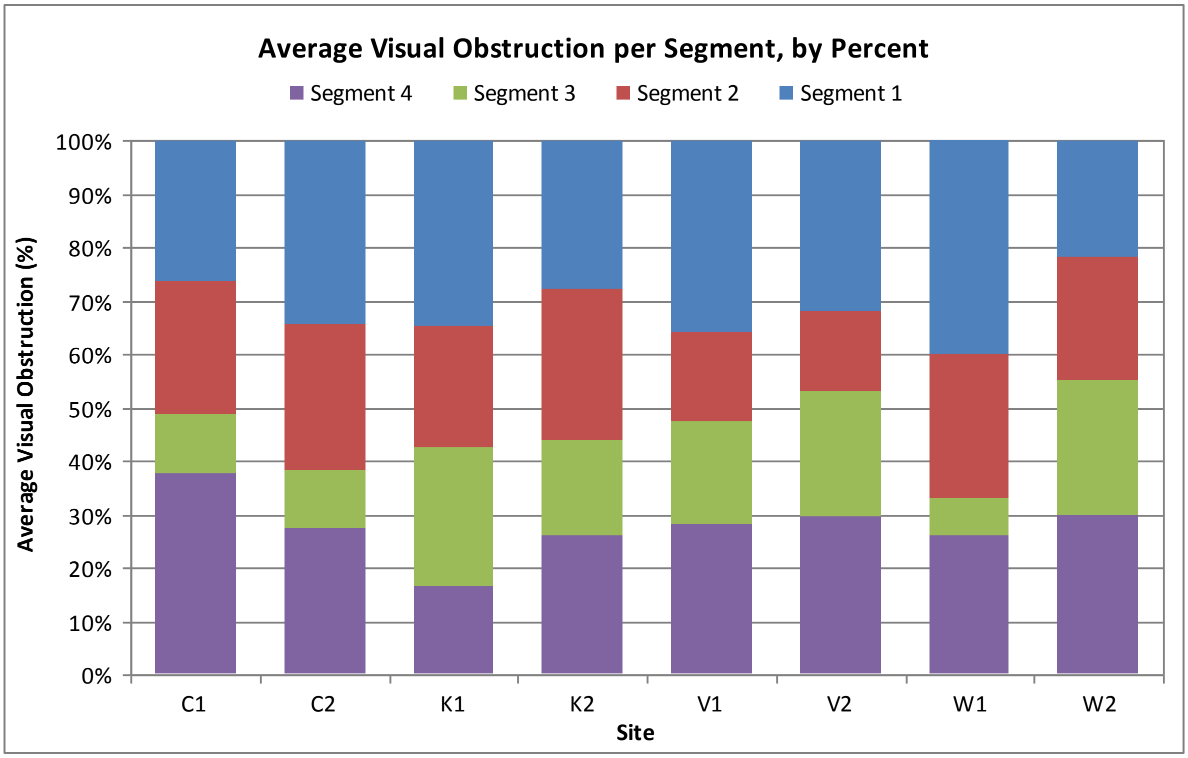


Figure 2.32. Average percent visual obstruction values by 0.5-m (1.6-foot) segments over the entire 2-m (6.6-foot) pole, providing relative measures of vegetation foliage obstruction from ground level to 2 m (6.6 feet) high measured from all study plots in 2010.

2.8 TREES

Tree monitoring measurements in fall 2010 included observations of canopy dieback, disease or damage, live and dead status, and canopy and bole measurements.

In fall 2009 SWCA randomly selected which plot in each paired watershed would be treated in 2010 (Table 2.7). Treatments began in late fall 2010 and will continue through spring 2011.

Table 2.7. Treatment Designation for All Plots (with basal area totals)

Site	Treatment or Control	Average Basal Area (square feet/acre)
Chilili 1	Treatment	192.5
Chilili 2	Control	188.3
Vigil 1	Treatment	123.8
Vigil 2	Control	128.8
Wester 1	Treatment	188.3
Wester 2	Control	182.9
Kelly 1	Control	107.8
Kelly 2	Treatment	158.8

2.8.1 CROWN DIEBACK

Percent crown dieback is the percentage of the leafy canopy of each tree that showed signs of physiological stress (i.e., brown needles and leaves). Crown dieback could result from a number of environmental factors, for example, drought, insect attack, competition, and disease. Measurement of crown dieback is highly dependent on the time of year; as a result, efforts are made to take measurements consistently during late September to early October each year. Figure 2.33 illustrates crown dieback across all sites.

Excluding the Vigil site, all plots showed a decrease in crown dieback from 2008 levels (see Figure 2.33); dieback increased at both Vigil sites in 2009 but decreased considerably in 2010. In 2010 crown dieback continued to decline at both Kelly sites and Wester 2, but increased slightly at both Chilili sites and Wester 1. At this point in the study, it is not possible to isolate the cause of dieback, although observations were made of mistletoe infestation in some ponderosa trees at the Chilili site and some beetle attack on piñon at both piñon/juniper sites. Although crown dieback of individual trees can be highly variable across a plot based on tree size and position, the standard error bars in Figure 2.33 suggest the variation to be minimal for all three years.

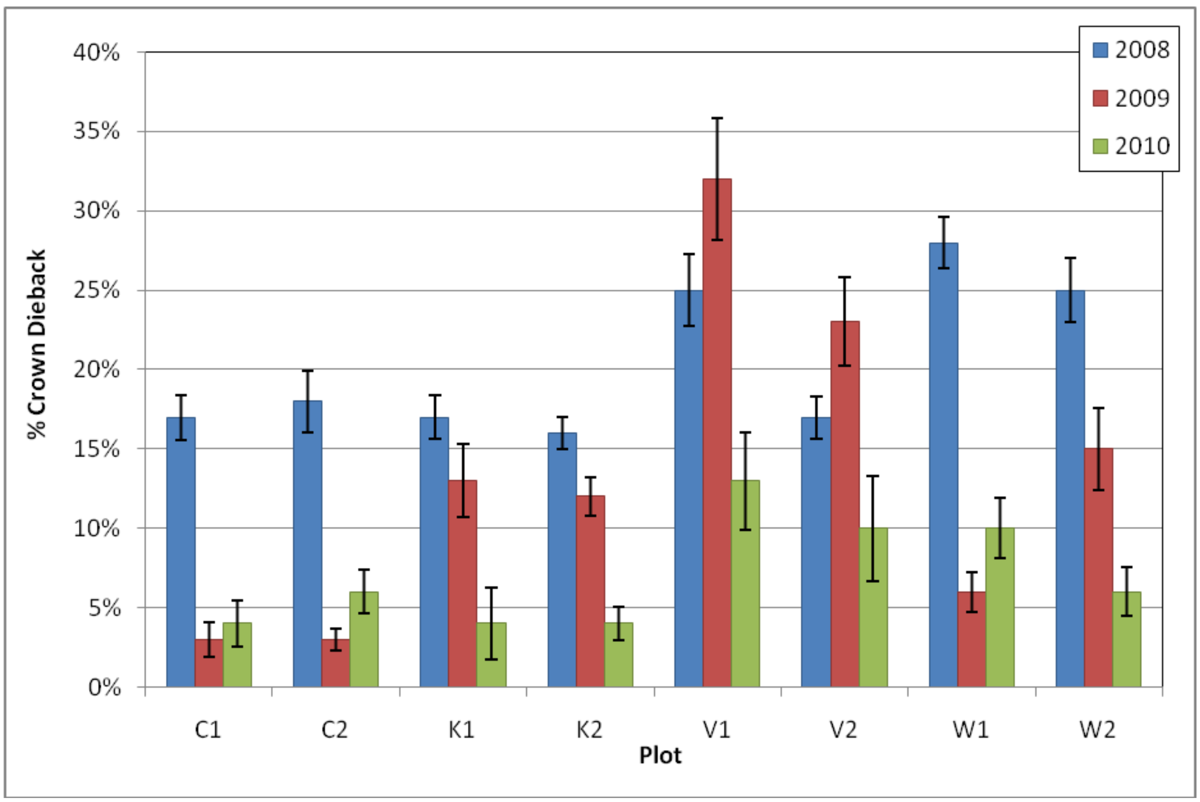


Figure 2.33. Average percent crown dieback of tree canopies for each thinning plot, 2008–2010; C= Chilili, K = Kelly, V = Vigil, and W = Wester.

2.8.2 TREE MORTALITY

In total, 613 trees were tagged across all watersheds in this study with species composition from ponderosa pine, piñon pine, one-seed juniper, and alligator juniper (*Juniperus deppeana*). In 2008 there were no dead trees tagged on any plots. From 2008 through 2010, percent tree mortality has been limited to just three plots: Kelly 1 (9.4%), Wester 1 (1.5%), and Wester 2 (4%) (Figure 2.34). All mortality occurred in 2009. The Vigil plots that had exhibited greater crown dieback than other plots, particularly in 2009, did not experience any mortality over the three years. Conversely, the three plots that did have mortality did not seem to exhibit higher crown dieback than other plots over the study period. The data so far reveals no obvious relationship between crown dieback rates and actual tree mortality. The high mortality at the Kelly site could be attributed to a number of environmental factors, including drought, beetle infestation, and competitive stress. Post-treatment monitoring may help to isolate the cause of the mortality.

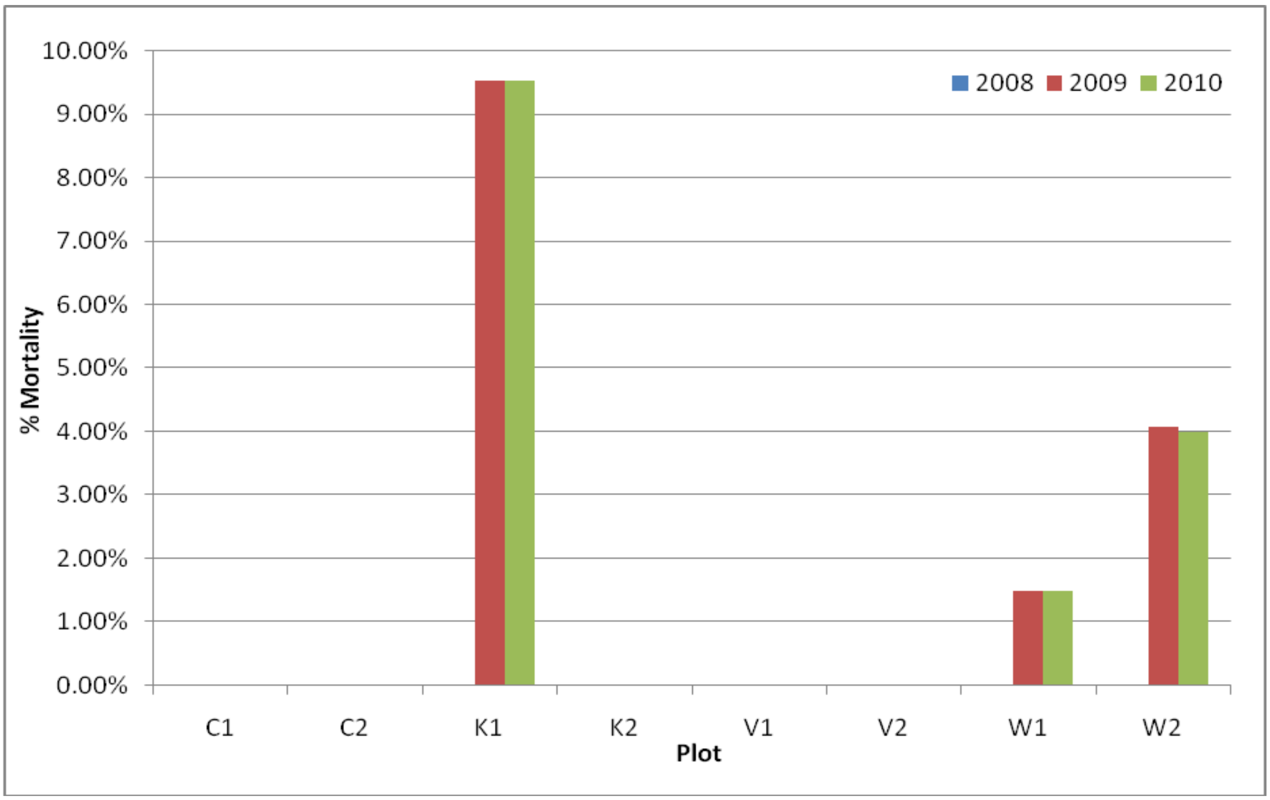


Figure 2.34. Percent tree mortality recorded across all thinning plots from 2008–2010. Percent mortality is recorded in relation to tree status in 2008.

2.8.3 FUELS

Fuel measurements were taken using Brown's transect protocols (Brown 1974) in fall 2010 within the four circular tree plots on each paired watershed. Refer to the 2008 Monitoring Plan for detailed monitoring protocols and an explanation of fuel class sizes (SWCA 2008). Figure 2.35 illustrates the percent cover by the various fuel classes on each thinning plot, and Figure

2.36 displays the average duff and litter depths at each plot. These data will be used as baseline data with which post-treatment data collected in fall 2011 will be compared.

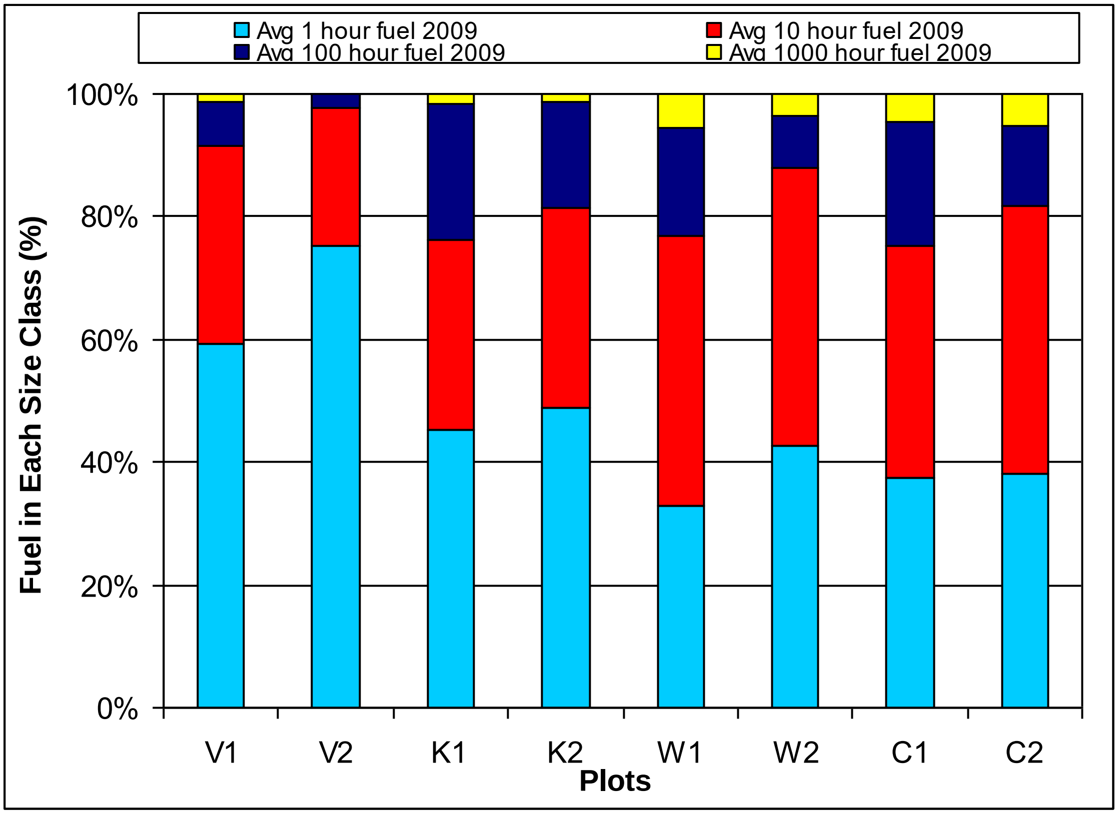


Figure 2.35. Percentage of fuel in each fuel particle size class (1-hour, 10-hour, 100-hour, 1,000-hour) on all thinning plots; C= Chilili, K = Kelly, V = Vigil, and W = Wester.

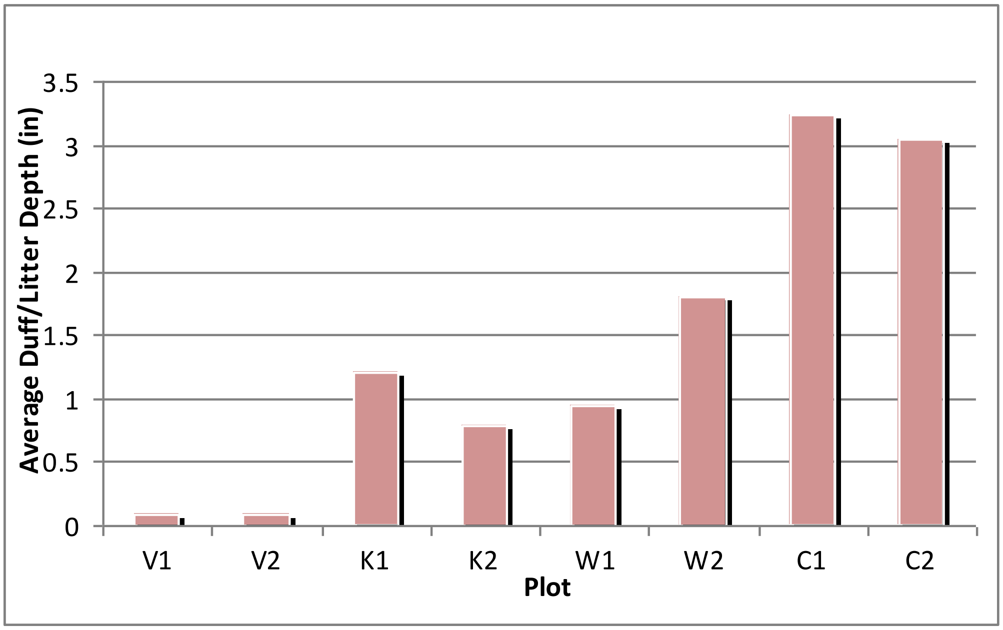


Figure 2.36. Average combined duff and litter depths on all thinning plots, measured in inches; C= Chilili, K = Kelly, V = Vigil, and W = Wester.

With reference to Figure 2.35, the piñon/juniper plots tended to have a slightly higher accumulation of 1-hour fuels (fine fuels 0.0–0.6 cm [0.00–0.25 inches] in diameter) compared to the ponderosa plots. Conversely 100-hour and 1,000-hour fuels (woody debris > 2.5 cm [1 inch] in diameter and > 8 cm [3 inches] in diameter, respectively) were more common at the ponderosa sites. Each paired plot was relatively consistent in terms of fuel loading by size class (see Figure 2.35). Figure 2.36 shows that both Chilili plots had considerably more duff and litter than the other plots. The volume of litter and duff found on the forest floor is related to both productivity and decomposition.

The variation in litter and duff between the Wester and Chilili sites could be related to differing decomposition rates as a result of differences in elevation and moisture regimes. Decomposition has been found to be positively correlated with moisture gradient with greater decomposition on more productive sites (Keane 2008), this would explain the greater depths of duff at Chilili (a higher elevation and more productive ponderosa pine forest) versus Wester (a lower elevation, dryer and more open stand ponderosa pine forest). Overall duff and litter depths were higher on the ponderosa sites than the piñon/juniper sites (Figure 2.37), which is to be expected since litter and duff cover in ponderosa pine is almost continuous across the landscape while litter and duff is isolated in patches immediately below the canopies of trees in piñon/juniper woodlands (Figure 2.38).

Figure 2.39 shows the tons/acre of woody dead and downed fuels at each site. The piñon/juniper sites had relatively low fuel loading compared to the ponderosa sites, because the piñon/juniper sites tended to have fewer large diameter woody fuels. The piñon/juniper sites exhibited greater fine fuel loading, however (see Figure 2.35), likely due to lower canopy cover that permits the growth of graminoids and forbs. Shrub cover was limited at both piñon/juniper sites. The Wester plots also had low loading compared to the Chilili plots; this site was relatively open, and although it exhibited higher levels of 1-hour fuels (see Figure 2.35), there were less 1,000-hour fuels consequently lowering the tons/acre totals (Figure 2.40, see Figure 2.35). Chilili 1 and 2 have noticeably higher fuel loadings than all other sites; these are dense plots with many more 1,000-hour fuels (many downed trees and stumps) (Figure 2.41), which raised their total tons/acre.

Fuel measurements will be repeated in fall 2011 following treatment at each plot to determine changes to fuel loading as a result of thinning.

Figure 2.37. Continuous litter and duff cover and accumulations in an arroyo at Chilili 1.

Figure 2.38. Patchy cover of litter and duff at Vigil 1.

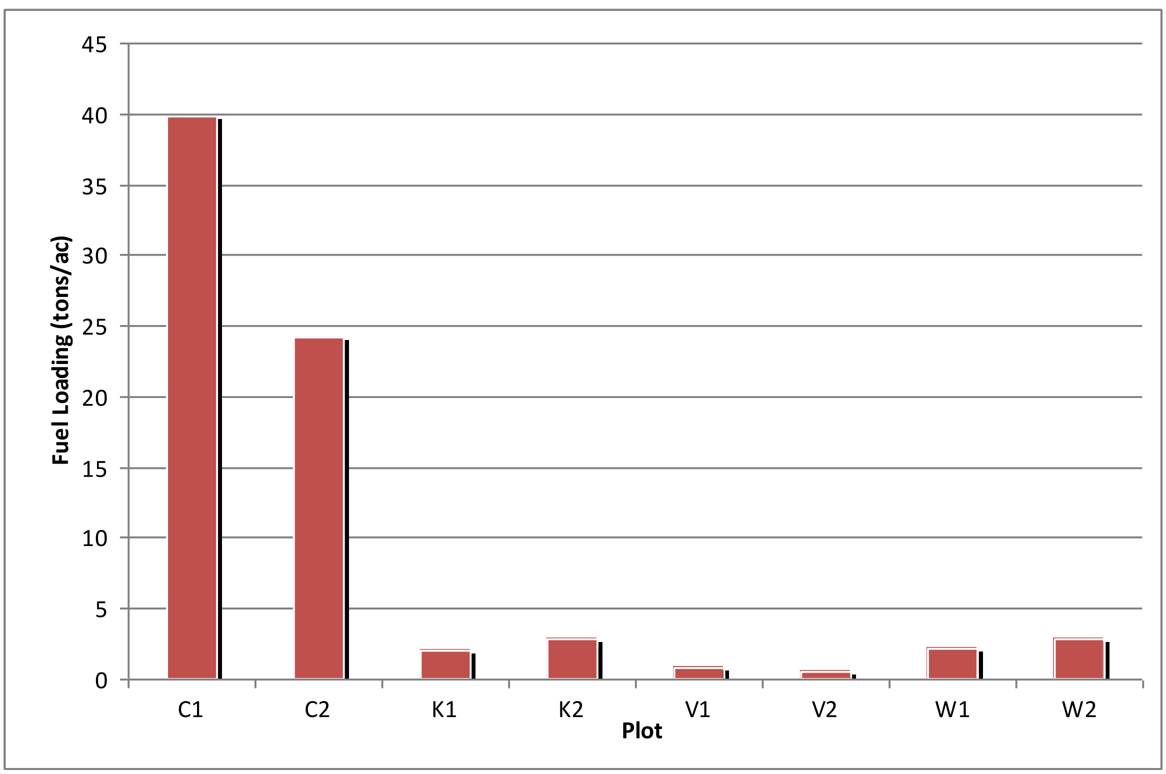


Figure 2.39. Fuel loading (in tons/acre) of dead and downed woody debris for all thinning plots; C= Chilili, K = Kelly, V = Vigil, and W = Wester.

Figure 2.40. Wester 2, showing the low fuel loading on the plot and lack of large diameter dead and downed fuels.

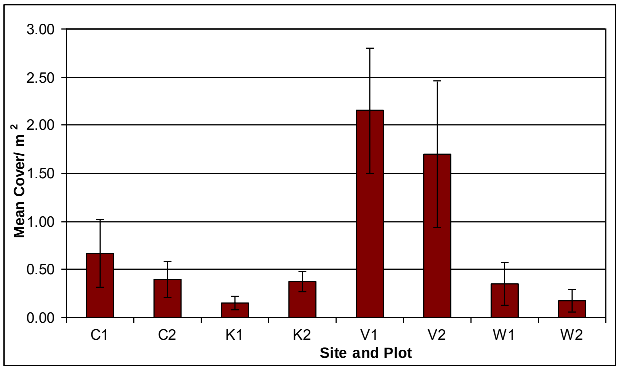
Figure 2.41. Chilili 2, showing high fuel loading with evidence of large diameter dead and downed fuels.

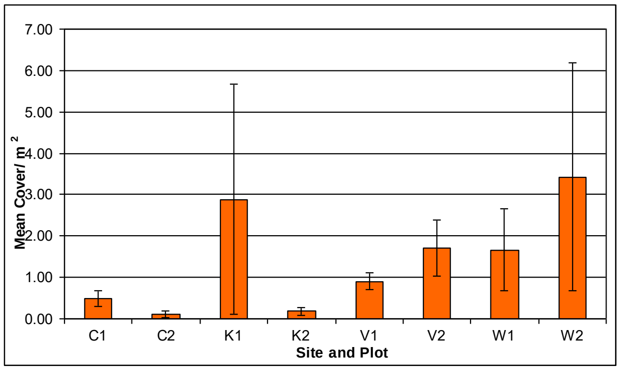
2.9 VEGETATION AND GROUND SURFACE COVER MONITORING

Herbaceous vegetation was again measured along line intercepts and quadrats from the vegetation and soils plots at each site as presented in the 2009 Annual Report. Additionally, in 2010 SWCA initiated more extensive vegetation measurements on the wildlife plots in order to characterize vegetation composition and structure as habitat for wildlife on those plots and to provide quantitative data to determine how vegetation or habitat changed on the wildlife plots relative to forest thinning treatments. Vegetation was measured from 36-m² (10.7-square-foot) quadrats located at each of the 36 permanently marked rodent trapping stations on each wildlife plot in a 6 by 6 grid, with stations at 10-m (33-foot) intervals (50 × 50–m [164 × 164–foot] plot). All plant species including woody trees and shrubs were measured on each of those square-meter quadrats. The total canopy cover and maximum height in centimeters of each species was measured per quadrat. Vegetation quadrat data were also categorized by growth form (e.g., tree, shrub, cacti, grass, forb) and life-history (annual or perennial). Tree canopy cover was often high above the quadrats and was estimated by visually projecting the dimensions of the quadrat above to minimize optical parallax. In addition to vegetation, soil surface cover categories also were measured on the quadrats, including bare soil, leaf litter (and dead and down woody material), rock, and cryptobiotic (cryptogam) soil surface crusts. Cattle dung or bovine feces was also common at the Kelly and Vigil piñon/juniper sites, and was also measured as ground cover.

The vegetation and ground cover data measured from the replicated quadrats on wildlife plots provides the most appropriate data for statistical testing for differences in those cover values resulting from thinning treatments, because there is sufficient sample replication to perform parametric statistical tests. Also, those 36 sampling quadrats were evenly distributed over relative large areas (plots 50 m [164 feet] on a side), providing a good sampling representation of each of the paired study plots. Data from each vegetation and ground cover type were used to test for differences between paired plots using a standard parametric t-test. Ideally, there should be no significant differences between paired plots prior to thinning treatments. If thinning has an effect on any of those cover types, then a significant difference would be expected following thinning treatments.

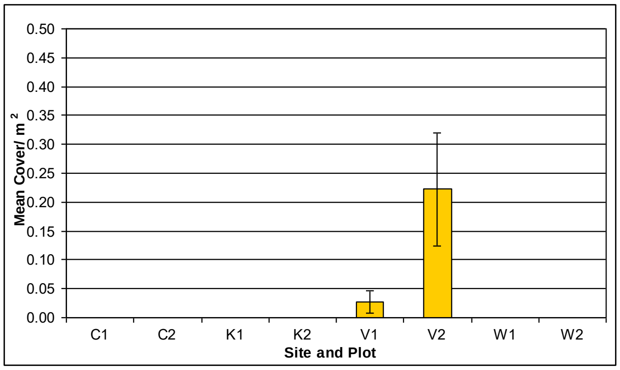
Cover values for vegetation and ground cover types measured in the fall of 2010 are presented in Figure 2.42 through Figure 2.47. Figure 2.42 provides separate graphs for each cover type, scaled appropriately for each cover type on the vertical scales of the graphs. Figure 2.43 through Figure 2.46 present all of the different cover types as paired plot comparisons for each of the four sites, with values presented on the same vertical axis scale to provide a representation of the relative importance of each cover type per plot. Figure 2.47 presents all cover types as percentage of the total cover for each plot, comparatively showing how cover types vary proportionately over all sites and plots. Results of statistical t-tests of differences between mean cover values for each of the different vegetation and ground surface cover types are presented in Table 2.8.

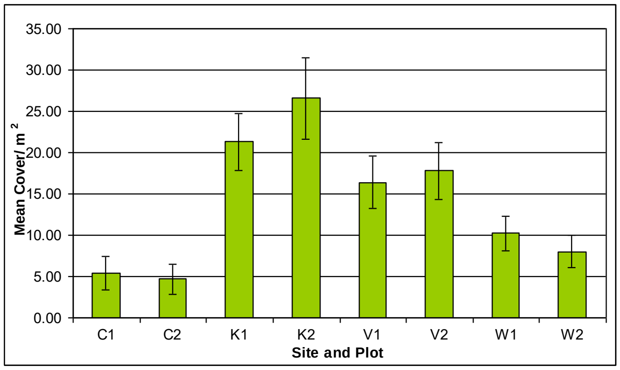




a. Annual forbs.

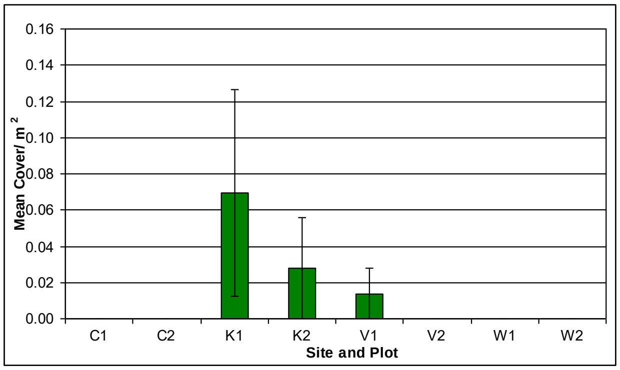
b. Perennial forbs.

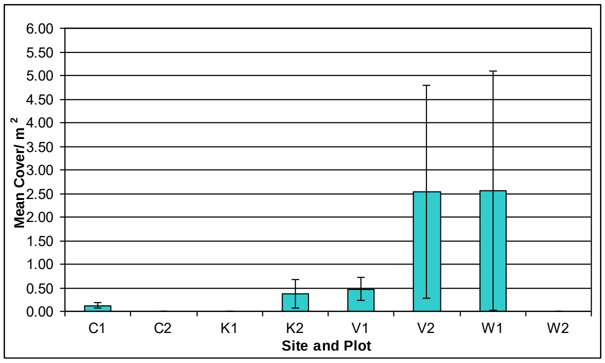




c. Annual grass.

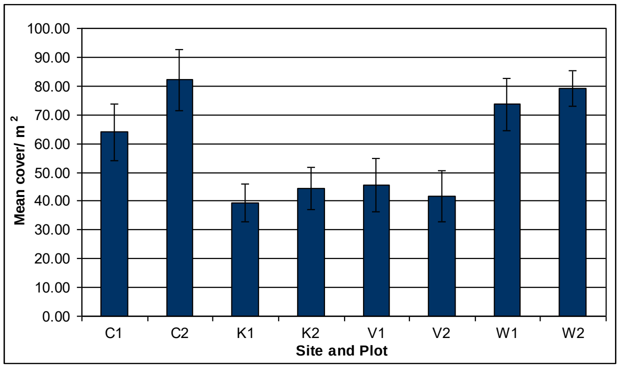
d. Perennial grass.



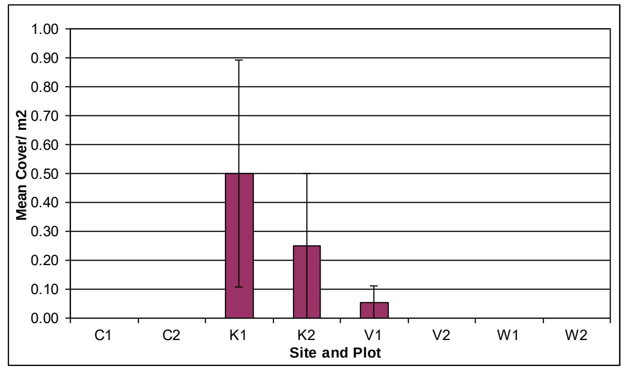


e. Cacti.

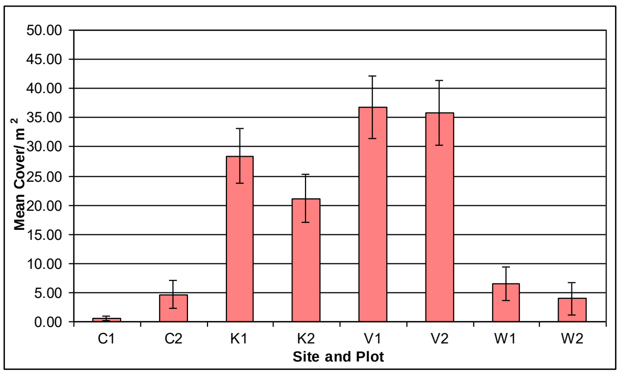
f. Shrubs.



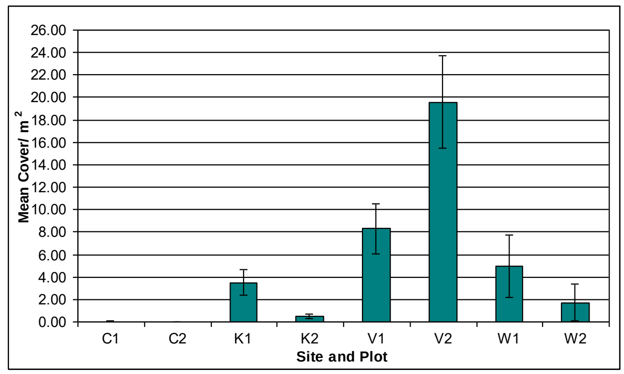
g. Trees.



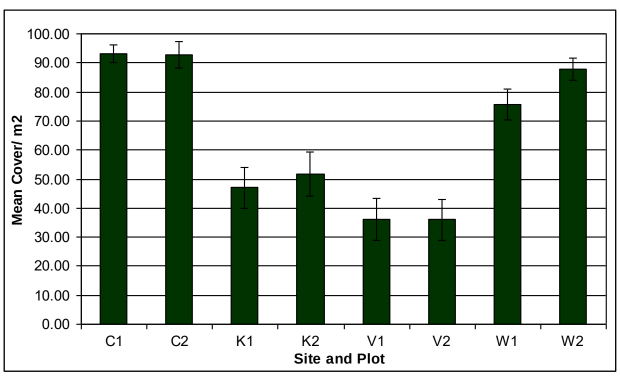
h. Cattle dung.



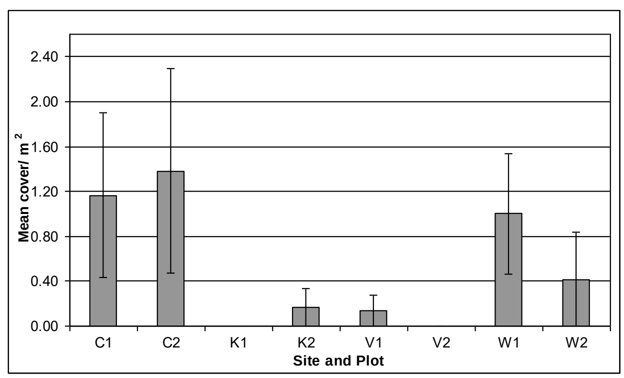
i. Bare soil.



j. Cryptobiotic crust.



k. Leaf litter



l. Rock.

Figure 2.42. These graphs illustrate the mean values cover type found across all vegetation quadrats among all of the study sites and paired study plots in fall 2010. Note that the vertical axis scales vary among these graphs in order to best present each cover type. Error bars represent +/- one standard error of the mean.

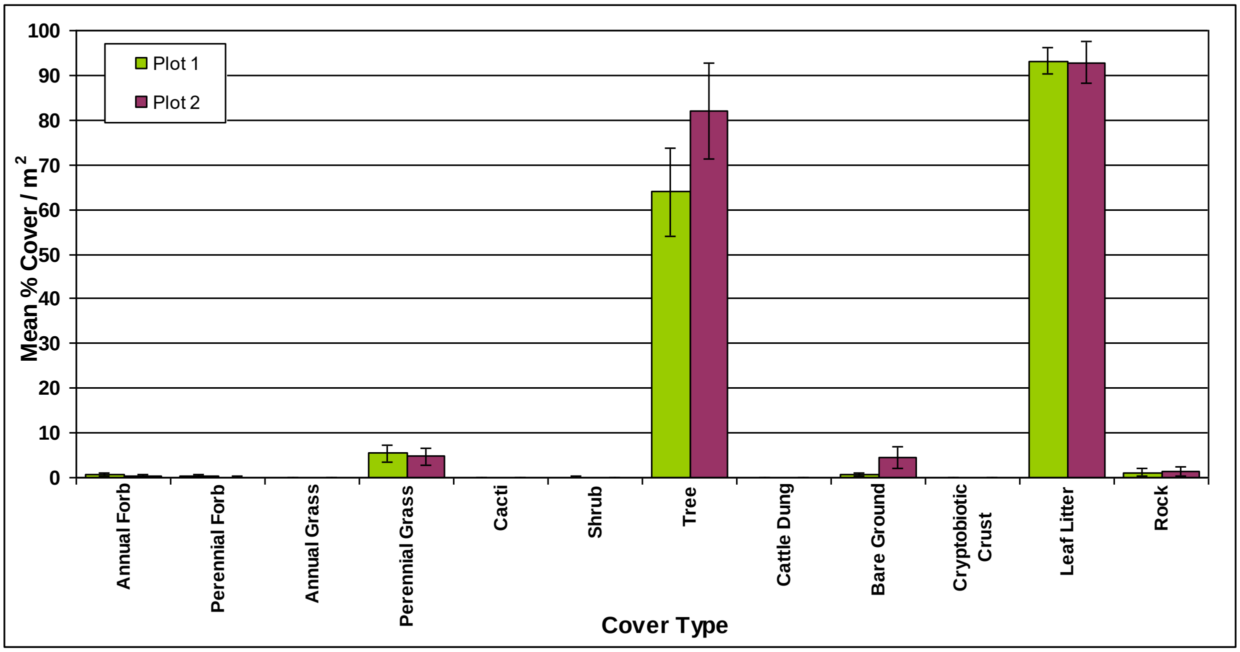


Figure 2.43. Mean cover of various vegetation and ground surface cover types measured over 36-m² (10.7-square-foot) quadrats per wildlife study plot at the Chilili ponderosa pine site in 2010. Error bar represent +/- one standard error of the mean.

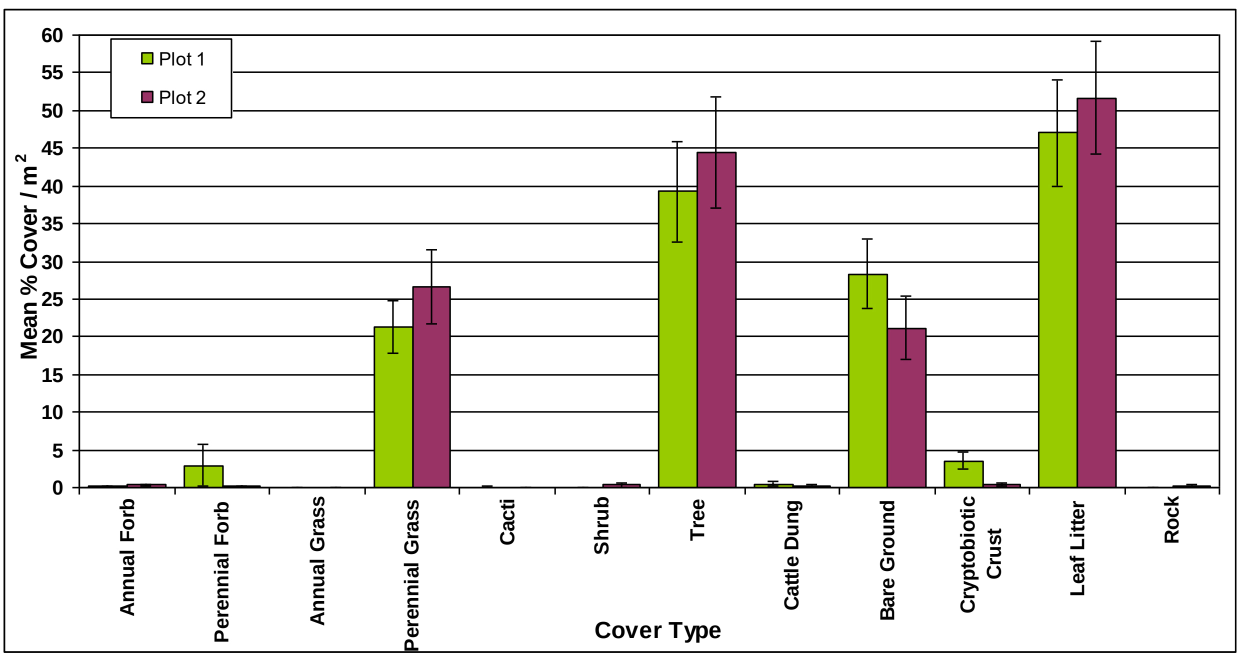


Figure 2.44. Mean cover of various vegetation and ground surface cover types measured over 36-m² (10.7-square-foot) quadrats per wildlife study plot at the Kelly piñon/juniper site in 2010. Error bar represent +/- one standard error of the mean.

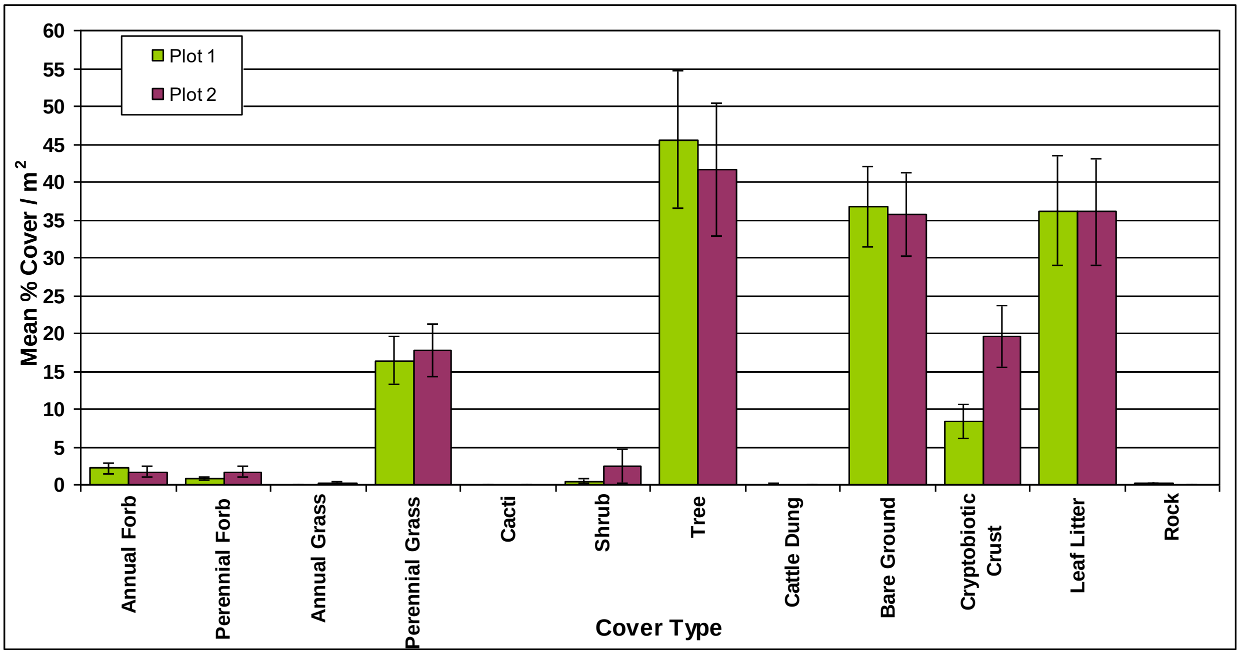


Figure 2.45. Mean cover of various vegetation and ground surface cover types measured over 36-m² (10.7-square-foot) quadrats per wildlife study plot at the Vigil piñon/juniper site in 2010. Error bar represent +/- one standard error of the mean.

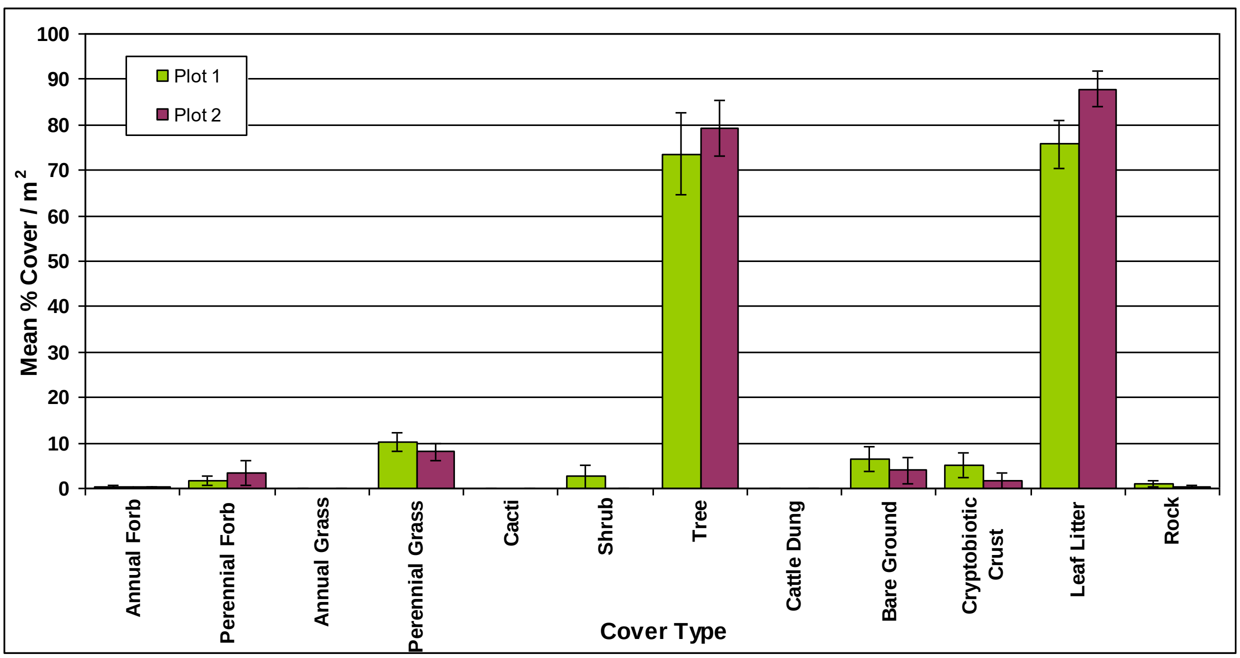


Figure 2.46. Mean cover of various vegetation and ground surface cover types measured over 36-m² (10.7-square-foot) quadrats per wildlife study plot at the Wester ponderosa pine site in 2010. Error bar represent +/- one standard error of the mean.

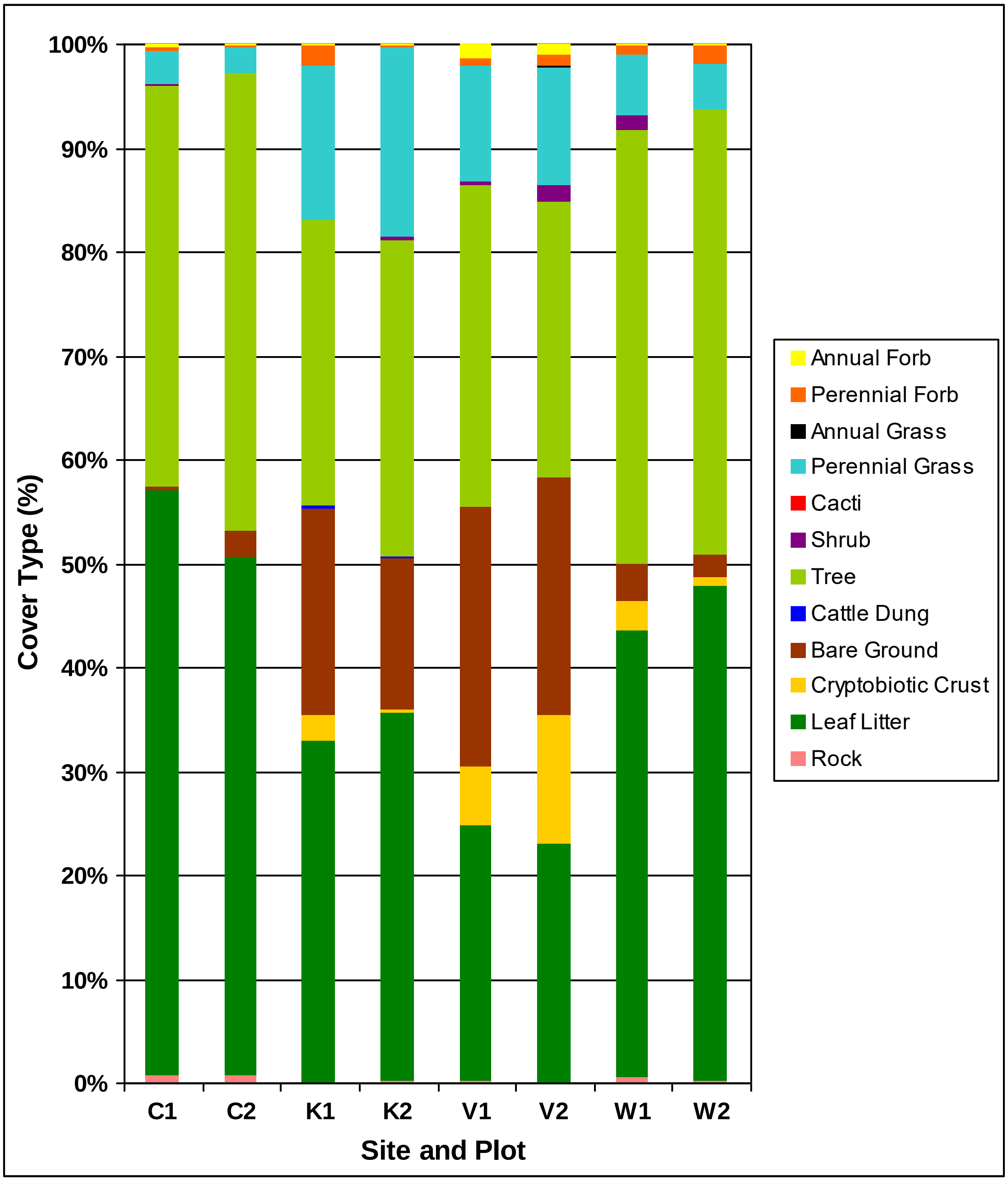


Figure 2.47. Percentages of mean cover of various vegetation and ground surface cover types measured over 36-m² (10.7-square-foot) quadrats per wildlife study plot at all of the forest thinning study plots to illustrate relative differences among sites and plots.

Table 2.8. Test Results for T-tests of No Difference between Mean Values of Vegetation and Ground Cover Types Measured from Vegetation Quadrats on Each Wildlife Study Plot Pair at the Four Study Sites

Site	Parameter	Plot 1 Mean	Plot 2 Mean	p-value (significance
Chilili	Annual forbs	0.67	0.40	0.51
	Perennial forbs	0.49	0.12	0.07
	Annual grass	–	–	–
	Perennial grass	5.42	4.69	0.79
	Cacti	–	–	–
	Shrubs	**0.13**	**0.00**	**0.02**
	Trees	63.93	82.10	0.22
	Bare soil	0.53	4.65	0.09
	Cryptobiotic crust	0.03	0.00	0.33
	Leaf litter	93.22	92.76	0.93
	Rock	1.17	1.38	0.85
	Cattle dung	–	–	–
Kelly	**Annual forbs**	**0.15**	**0.38**	**0.07**
	Perennial forbs	2.89	0.18	0.33
	Annual grass	–	–	–
	Perennial grass	21.29	26.61	0.38
	Cacti	0.07	0.03	0.51
	Shrubs	0.00	0.38	0.22
	Trees	39.29	44.44	0.61
	Bare soil	28.37	20.32	0.26
	Cryptobiotic crust	**3.50**	**0.47**	**0.01**
	Leaf litter	47.08	51.69	0.66
	Rock	0.00	0.17	0.32
	Cattle dung	0.50	0.25	0.59
Vigil	Annual forbs	3.17	3.71	0.65
	Perennial forbs	0.90	1.72	0.25
	Annual grass	0.03	0.22	0.06
	Perennial grass	16.42	17.82	0.77
	Cacti	0.01	0.00	0.32
	Shrubs	0.47	2.53	0.37
	Trees	45.54	41.63	0.76
	Bare soil	36.72	35.78	0.90
	Cryptobiotic crust	**8.31**	**19.58**	**0.02**
	Leaf litter	36.19	36.03	0.99
	Rock	0.14	0.00	0.32
	Cattle dung	0.06	0.00	0.32
Wester	Annual forbs	1.08	0.57	0.51
	Perennial forbs	1.67	3.43	0.55
	Annual grass	–	–	–
	Perennial grass	10.21	8.01	0.44
	Cacti	–	–	–
	Shrubs	2.56	0.00	0.32
	Trees	73.56	79.31	0.60
	Bare soil	6.50	3.94	0.53
	Cryptobiotic crust	5.00	1.72	0.31
	Leaf litter	75.78	87.92	0.07

Table 2.8. Test Results for T-tests of No Difference between Mean Values of Vegetation and Ground Cover Types Measured from Vegetation Quadrats on Each Wildlife Study Plot Pair at the Four Study Sites, continued

Site	Parameter	Plot 1 Mean	Plot 2 Mean	p-value (significance
Wester, continued	Rock	1.00	0.42	0.39
	Cattle dung	–	–	–

All tests were with sample sizes of 36; p-values of less than 0.05 represent significant differences. Parameters in bold represent those with significant differences between paired plots. Refer to Figure 2.42–Figure 2.47 for graphical illustrations of differences in mean values. Dashes represent instances where that particular cover type was not found on either of the paired plots.

Results of vegetation and ground cover data measured from wildlife plot quadrats show that in general, the piñon/juniper sites have more bare ground and more perennial grass cover than the ponderosa pine sites, and the ponderosa pine sites have greater and leaf litter cover than the piñon/juniper sites (see Figure 2.47). Tests of mean cover values between paired plots shows that in general, paired plots tend not to be statistically different from one another (see Table 2.8). However, in some cases paired plots were significantly different for certain parameters such as shrub cover at the Chilili site and cryptobiotic crust cover at the Kelly and Vigil sites. Those known differences will be important relative to evaluating changes in those parameter values resulting from forest thinning treatments. In those cases, analysis will focus on comparing data from different years from the same plot to determine thinning treatment effects.

2.10 WILDLIFE

Birds and small mammals are being monitored in order to determine if forest thinning affects native wildlife species. Both birds and small mammals were recorded from separate 50 × 50–m (164 × 164–foot) wildlife study plots that are immediately adjacent to each of the two vegetation and soils monitoring study plots at the four study sites. Birds and mammals were measured in late spring (May/June) and early fall (September/October) 2008, 2009, and 2010 for three consecutive days on each study plot.

2.10.1 BIRDS

The species composition and relative abundance of birds on all study plots were recorded by observing birds by point counts from one location at the center of each wildlife study plot. Each point count was conducted for 20 minutes at dawn for three consecutive mornings on each study plot in both spring and fall. Spring counts are intended to assess breeding bird use of the forest and woodland habitats, and fall counts are intended to assess migratory bird use of the same habitats. Many of the bird observations were based on hearing songs and calls and identifying those to species. Additionally, visual observations were often recorded. A list of all bird species observed across the four study sites and counts of individuals are presented in Appendix A. SWCA encountered a total of 40 bird species from all of the study sites.

The total numbers of birds observed during the spring and fall counts across the four sites and paired plots in 2010 are shown in Figure 2.48 and Figure 2.49, respectively. Numbers of birds were similar between the paired plots at each site during both seasons. More birds were recorded at the Chilili and Wester (ponderosa pine) sites in spring than in fall, while the opposite pattern was found at the Kelly and Vigil (piñon/juniper) sites.

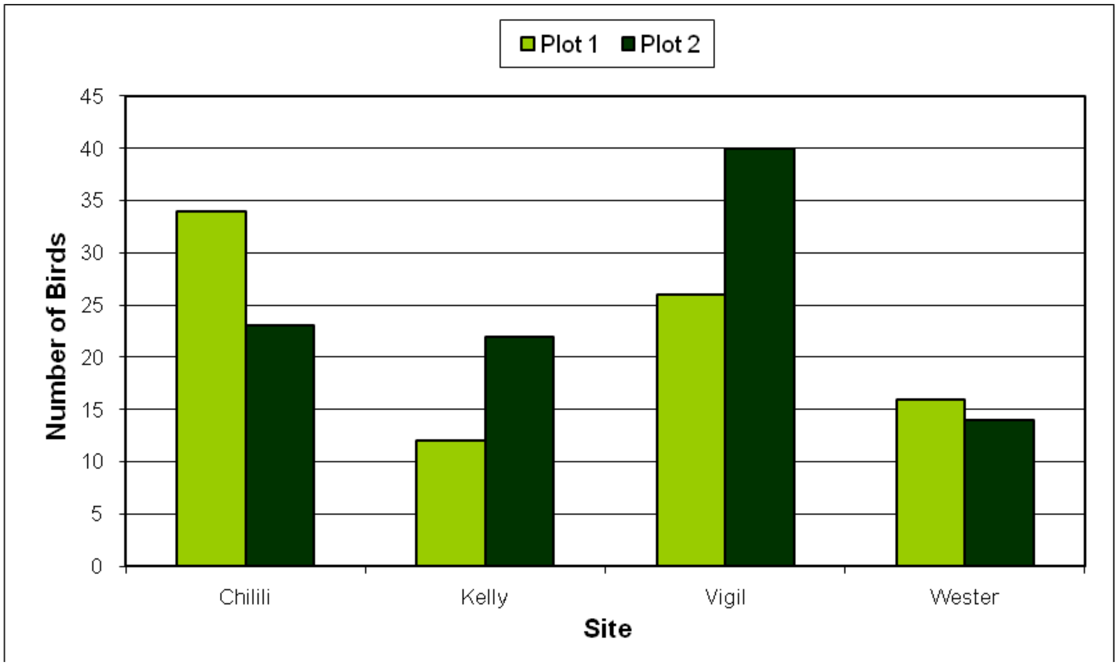


Figure 2.48. Total numbers of all birds observed in spring 2010 on each plot from point counts.

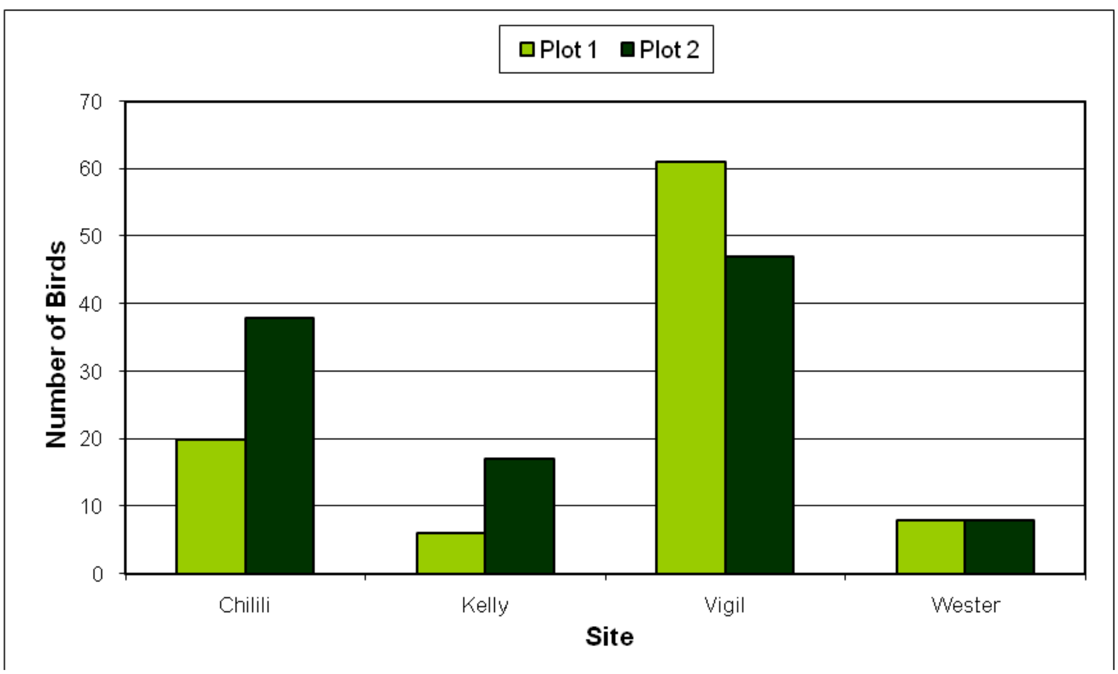


Figure 2.49. Total numbers of all birds observed in fall 2010 on each plot from point counts.

The total number of bird individuals by species during the spring and fall monitoring periods are presented in Figure 2.50 and Figure 2.51, respectively, in order of rank abundance (see Appendix A for full names that correspond to the codes). The most common spring breeding season birds included the white-breasted nuthatch (*Sitta carolinensis*), mountain bluebird (*Sialia currucoides*), mourning dove (*Zenaida macroura*), and juniper titmouse (*Baeolophus ridgwayi*). Common fall bird species included the chipping sparrow (*Spizella passerina*), Grace's warbler (*Dendroica graciae*), juniper titmouse, and American crow (*Corvus brachyrhynchos*). Note that the unknown category includes individuals of all birds that could not be absolutely identified in the field, often sparrows or other small birds that often move in small flocks and are difficult to identify at a distance, especially in woodland habitats. Unknown birds are especially common in the fall when mixed flocks of small migratory birds move through the study areas.

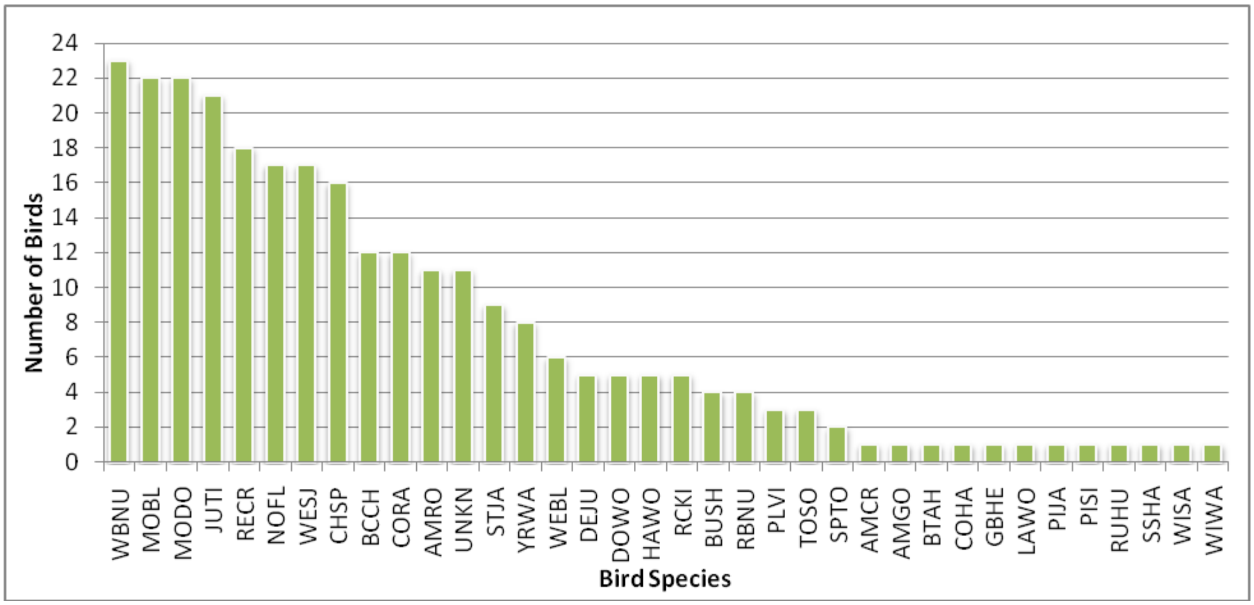


Figure 2.50. Total number of birds by species for spring 2010, on all sites and all plots, from most abundant to least abundant. Refer to Appendix A for full names based on codes.

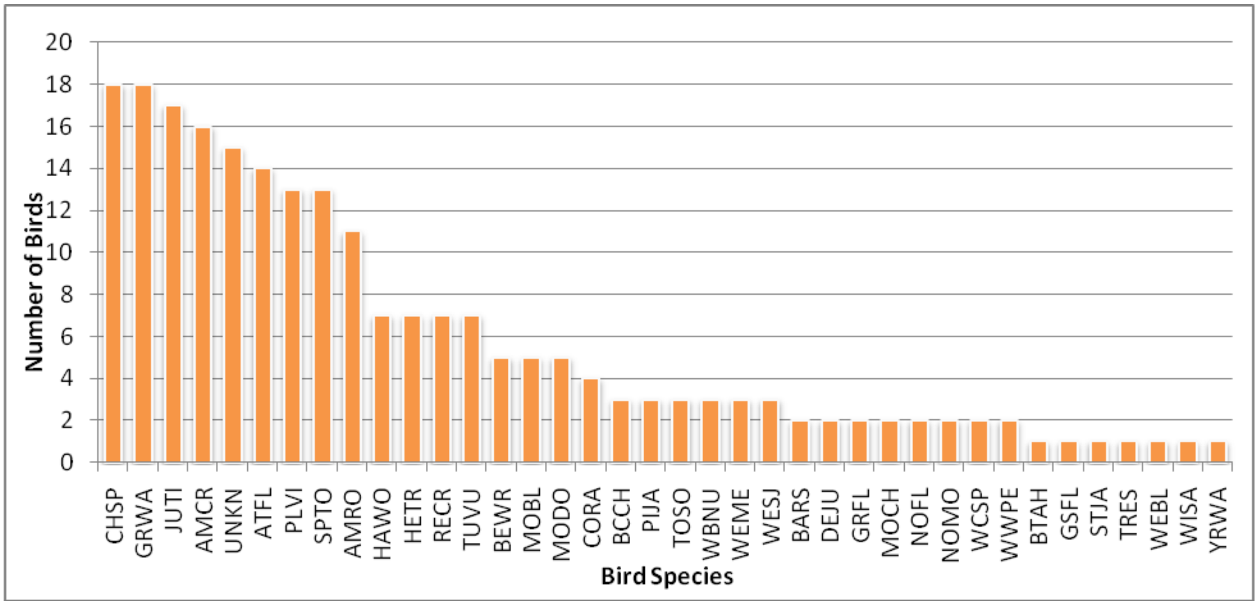


Figure 2.51. Total number of birds by species for fall 2010, on all sites and all plots, from most abundant to least abundant. Refer to Appendix A for full names based on codes.

2.10.2 SMALL MAMMALS

Small mammals (rodents) were sampled from a single 6 × 6–trap grid (36 traps total) of live-capture rodent traps set at 10-m (33-foot) intervals on each of the wildlife monitoring plots for three consecutive nights in spring and fall, the same dates that birds were sampled in 2008, 2009, and 2010. Samples from spring and fall are useful to follow trends in adults and juveniles in order to assess breeding status and production over the year.

The total numbers of rodents observed on paired study plots among the sites in spring and fall 2010 are presented in Figure 2.52 and Figure 2.53, respectively, showing that rodent densities were generally similar between paired plots, but varied across sites and seasons. The Chilili and Vigil sites consistently had the highest rodent densities for both seasons, dominated by the piñon mouse (*Peromyscus truei*) at Vigil and the deer mouse (*P. maniculatus*) at Chilili. Wester consistently had the lowest rodent densities for both seasons. Rodent densities increased between spring and fall at the Vigil piñon/juniper site but decreased at the Kelly piñon/juniper site. Densities stayed relatively constant between spring and fall at the Chilili and Wester ponderosa sites. Over the three year sampling period, rodent densities varied considerably, low in 2008, high in 2009, and then low again in 2010 (Figure 2.54). Dominant species over the three-year period included the piñon mouse, deer mouse, and white-footed mouse (*P. leucopus*) (Figure 2.55).

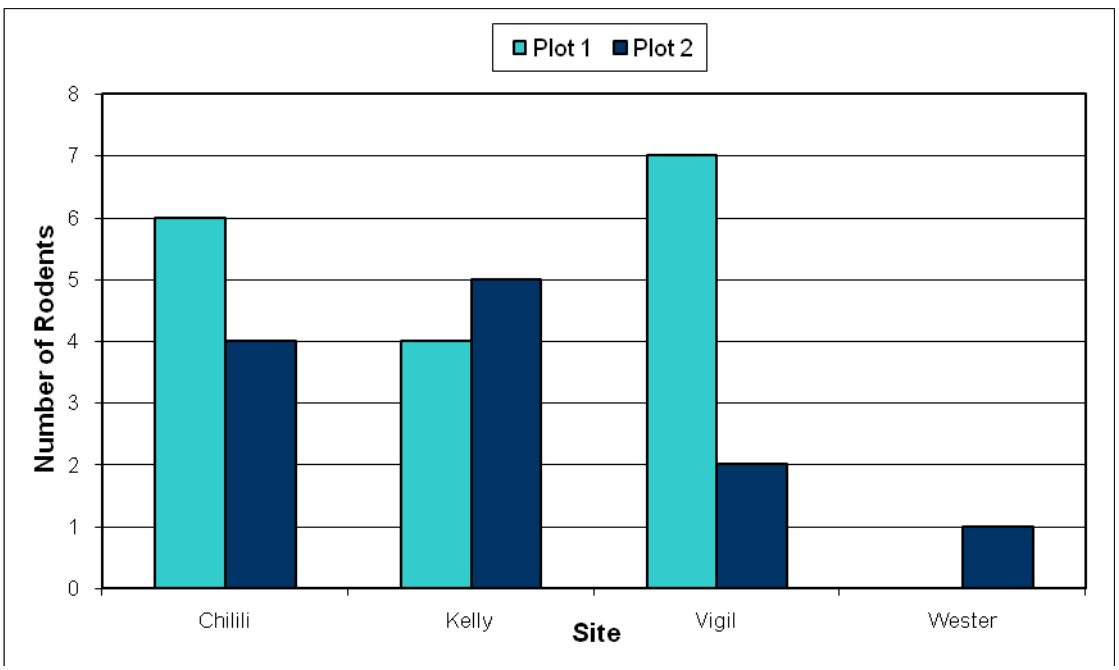


Figure 2.52. Total numbers of rodents trapped from each paired study plot across the four study sites in spring 2010.

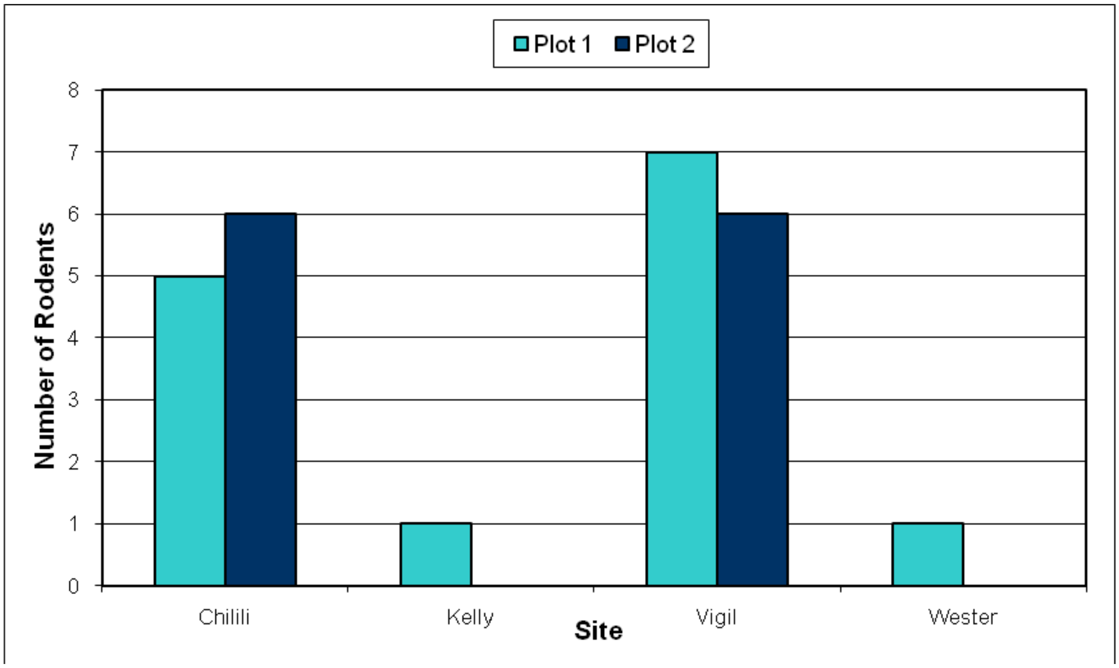


Figure 2.53. Total numbers of rodents trapped from each paired study plot across the four study sites in fall 2010.

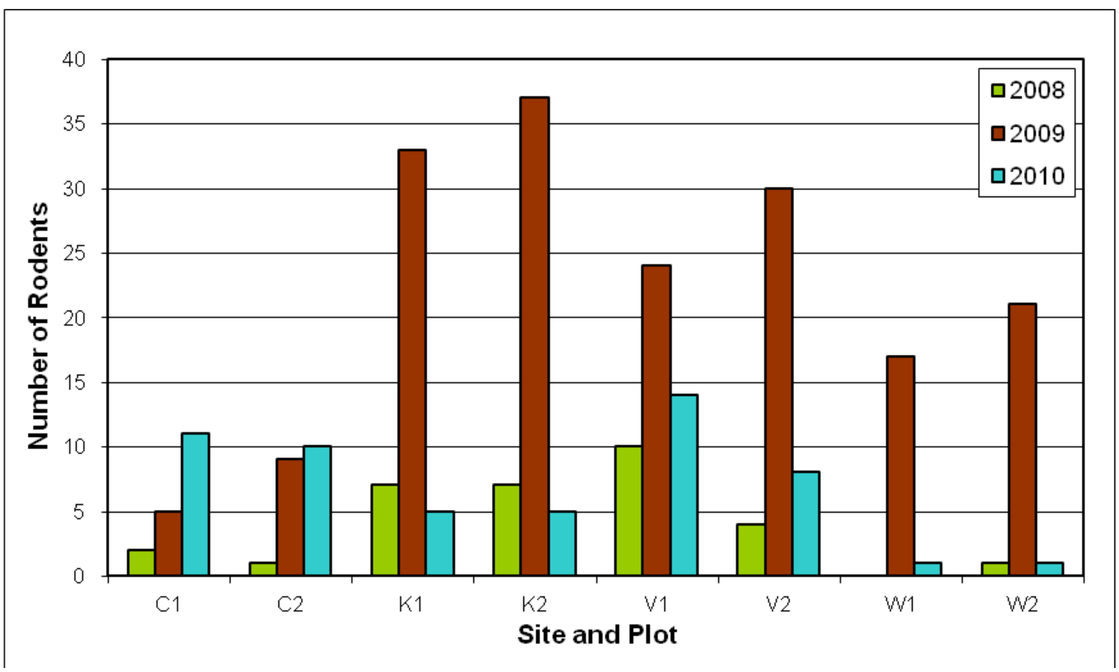


Figure 2.54. Total number of rodents at paired study plot across the four monitoring sites over three years of monitoring.

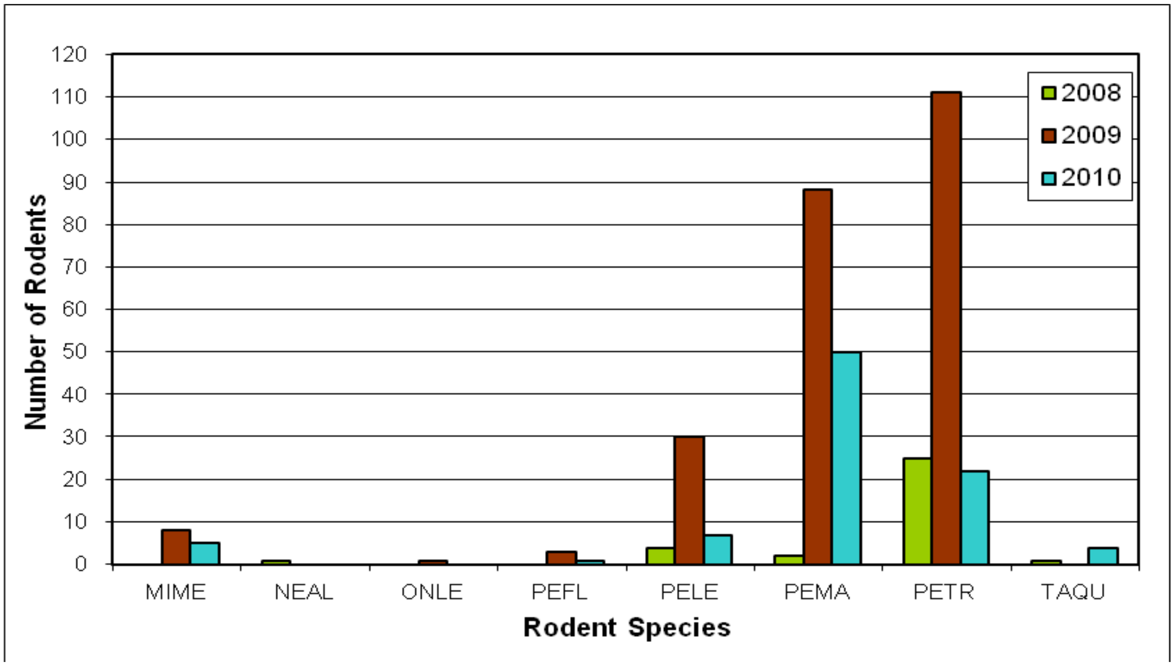


Figure 2.55. Total numbers of individuals of each rodent species across all study plots over the three years of baseline monitoring.

2.11 FOREST THINNING TREATMENTS

One study plot of each forest thinning monitoring pair (plots 1 and 2) was randomly selected to be treated with the standard prescribed thinning treatment (piñon/juniper or ponderosa pine prescriptions) in late 2010. The minimum proposed area and boundaries for thinning treatments were determined for each of those four plots and mapped with a sub-meter accuracy global positioning system (GPS) unit in October and November 2009. These GPS coordinates were used to produce geographic information system (GIS) maps of the proposed treatment areas and boundaries for each of the four treatment study plots (maps of the thinning areas were presented in the 2009 Annual Report (SWCA 2010). The proposed thinning treatment areas for each of those plots includes the entire subwatershed that was previously defined and mapped in 2007, the vegetation/soils measurement plot, and the mammal and bird sampling plot, all within the area of each treatment plot to be thinned. A minimum treatment buffer area of 10 m (33 feet) was extended from the boundaries of each subwatershed and study plot to ensure that all areas from which soil, hydrology, vegetation, and animal measurements are being collected are thinned on those treatment plots. Actual forest thinning treatments began in November 2010, and thinning on all treatment study plots has been completed as of January 2011. The Kelly piñon/juniper site treatment plot was photographed following a thinning treatment in December, 2010 (Figure 2.56).

Figure 2.56. Kelly piñon/juniper site thinning treatment plot after trees have been removed in late 2010.

3.0 POST-FIRE MONITORING

In April 2008 a large area of the Estancia Basin watershed was burned in the 13,709-acre Trigo fire. This burn area encompassed a large portion of the Cibola National Forest and also included 3,712 acres of private land on its eastern fringe. Since three large wildfires (Ojo Peak, Trigo, and Big Spring) have burned a considerable portion of the eastern slopes of the Manzano Mountains, the impacts of wildfire on Estancia Basin watershed health are likely significant. The Steering Committee awarded SWCA additional funding to develop and implement post-fire monitoring to evaluate wildfire impacts to Estancia Basin watershed health. The Trigo fire was chosen for the monitoring because it was the largest of the three fires and was centrally located within the study region and relative to the existing forest thinning monitoring sites. The full fire monitoring plan for this project was prepared and submitted to the Steering Committee in July 2008 (SWCA 2008), and the first year of monitoring was reported in the 2008 Annual Report (SWCA 2009).

The Trigo post-fire monitoring plots were selected in Arroyo de Cuervo (Cuervo 1 and Cuervo 2) and in the Arroyo de Manzano (Manzano 1) watersheds. Three low-severity (Figure 3.1) and three high-severity (Figure 3.2) plots were identified in each watershed, and three unburned (U) plots were located across the watersheds. With the permission of landowners, the plots were selected on seven different private parcels of land: Bouton (BOU), Sanchez (SAN), Manzano Mountain Retreat (MMR), Salazar (SAL), Candelaria (CAN), Mitchell (MIT), and Neff (NEFF), totaling 21 plots for the entire study (Figure 3.3).

This was the third year of monitoring for the Trigo fire study. Monitoring on the 21 fire plots has been completed by SWCA in fall 2008, spring and fall 2009, and spring and fall 2010. Please refer to the 2008 Annual Report for background information and monitoring protocols.

Figure 3.1. Typical low burn severity plot in the Trigo burn area.

Figure 3.2. Typical high burn severity plot in the Trigo burn area.

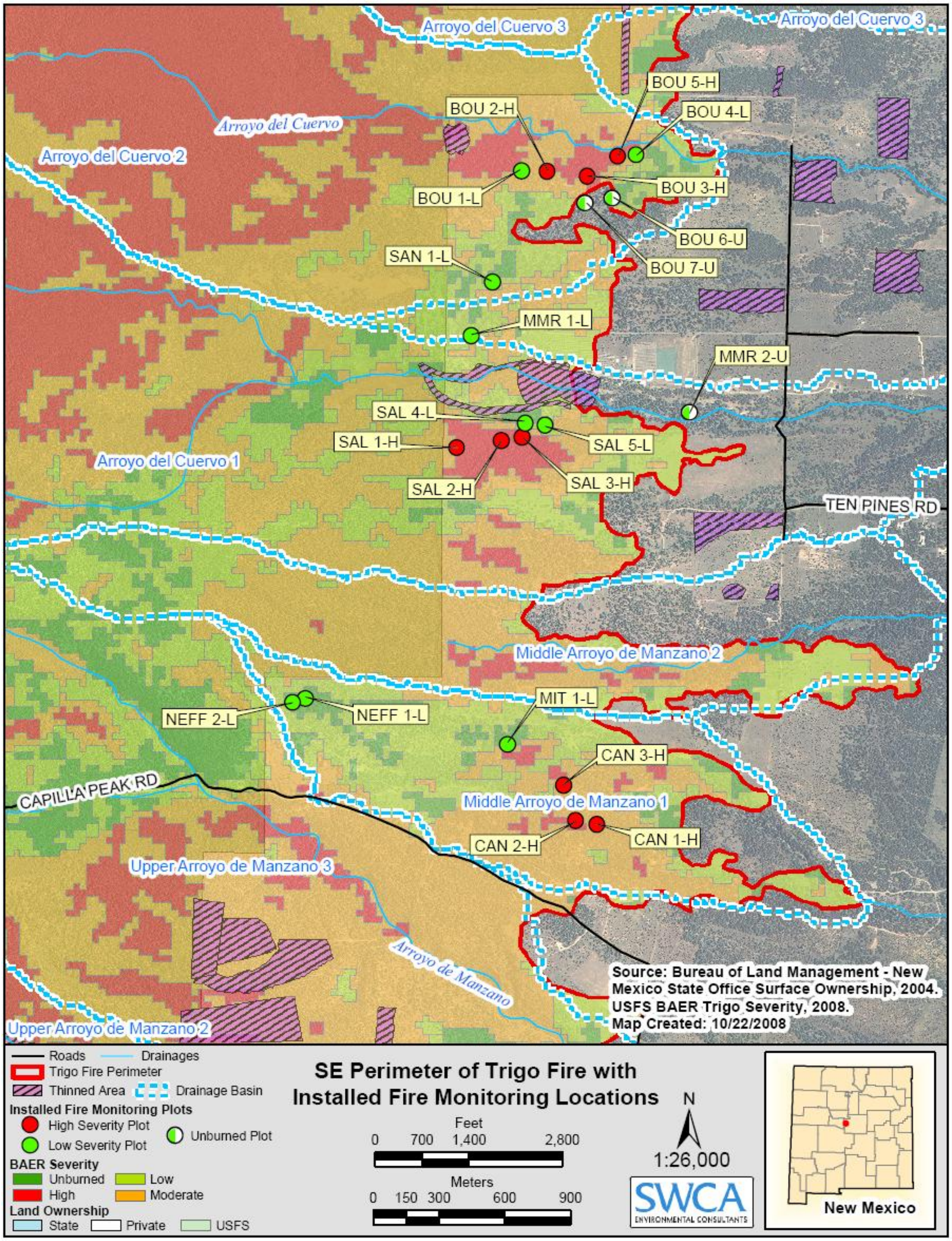


Figure 3.3. Fire monitoring plot locations.

3.1 TREES

Tree monitoring during the 2010 field season included re-measurements of all parameters monitored in 2008. Measurements of diameter at breast height and height were not taken in 2009 because very little change was expected in these parameters on an annual basis.

Of particular interest in 2010 was the record of live and dead status of tagged trees in order to determine tree mortality compared to 2008 and 2009 levels. These data were only collected for the low-severity plots because all high-severity plots received 100% tree mortality. Mortality was noted in relation to the degree of scorch that each individual tree received during the fire in 2008. Figure 3.4 illustrates this relationship and the change in status of trees between 2008, 2009, and 2010. Some of the trees that were killed by the fire in 2008 had also fallen during this period.

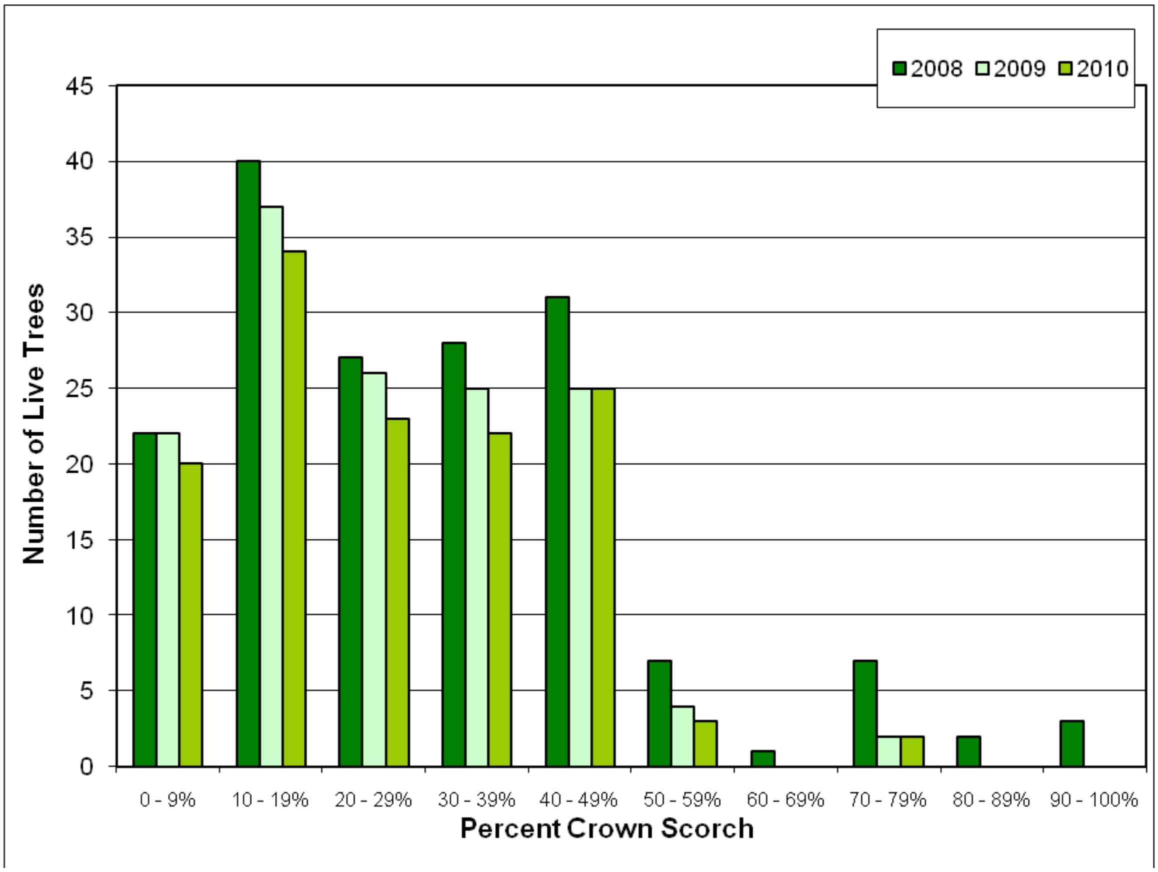


Figure 3.4. Number of live trees in relation to percent crown scorch on all low-severity fire plots.

Figure 3.4 suggests that even if trees survived the first year after the fire, they did not necessarily survive through to 2009 or 2010; 18% of the trees that were live in 2008 were recorded as dead in 2009; of the trees that were live in 2009, a further 8% had died by 2010. The greatest losses were recorded in the more severely burned trees (> 50% mortality); only six of the 25 trees in these categories in 2008 were still surviving in 2010. Similar high levels of post-fire mortality have been recorded in other studies. Ffolliott et al. (2008) observed that two-thirds of ponderosa exposed to high-severity fire during the Rodeo-Chediski Fire (occurred in Arizona, 2002) were dead two years after the event. Fowler and Sieg (2004) have found that in studies, fire related mortality was observed from one to three years post fire. The Trigo fire data also show a notable threshold scorch level (approximately 50% of the crown) past which tree survivorship is compromised (see Figure 3.4). Similar findings have been noted on other fires in ponderosa pine forests; for example, Lynch (1959) notes that ponderosa trees with more than 50% crown injury suffered the most mortality.

A number of trees that were tagged in 2008 and standing in 2008 and/or 2009 had fallen by the fall 2010 monitoring period. The worst hit trees were the fully consumed small diameter trees that had received deep basal charring. Crews also observed that many dead trees were being snapped in half at a height of approximately 1.8 m (6 feet), possibly due to strong winds at this level and structural weakness of the bole as the trees decayed (Figure 3.5).

Figure 3.5. Salazar high-severity plot showing fallen tagged trees and trees snapped at mid bole.

3.2 HERBACEOUS VEGETATION

Herbaceous vegetation measurements are carried out in spring and fall each year beginning in fall 2008. Dramatic changes in ground cover have been observed over the monitoring period, particularly for the high-severity plots (Figure 3.6–Figure 3.12).

Figure 3.6. CAN 3-H west (fall 2008) showing little to no vegetation cover and considerable bare soil.

Figure 3.7. CAN 3-H west (fall 2009) showing dominance by the deep red forb fetid goosefoot (*Chenopodium graveolens*).

Figure 3.8. Can 3-H west (fall 2010) showing dominance by the seeded grass species tall wheatgrass (*Thinopyrum ponticum*).

Figure 3.9. BOU 3-H west (fall 2008) showing little to no vegetation cover.

Figure 3.10. BOU 3-H west (spring 2009) showing increased cover of spring annuals and early colonizers.

Figure 3.11. BOU 3-H west (fall 2009) showing increased vegetation cover dominated by fetid goosefoot.

Figure 3.12. BOU 3-H west (fall 2010) showing greater species diversity, cover, and vertical structure.

3.2.1 LINE INTERCEPT DATA

Line intercept data were taken at each plot on four 23-m (75-foot) transects recording cover by growth form. Figure 3.13 through Figure 3.15 illustrate the change in cover type from 2008 to 2010 by severity. In 2008, 90% of the cover along transect lines in a representative low-severity plot (BOU 1-L) was leaf litter (see Figure 3.11). In 2009, however, leaf litter fell to 40% and dropped a further 10% by 2010 to 30% of the overall cover. Grass cover went from 3% in 2008 to almost 50% in 2010 and was the dominant cover type. Shrub cover has also slowly increased since 2008 but still remains a minor component of the overall cover. Forb and bare ground make up only a fraction of the overall cover and have stayed relatively constant since 2008.

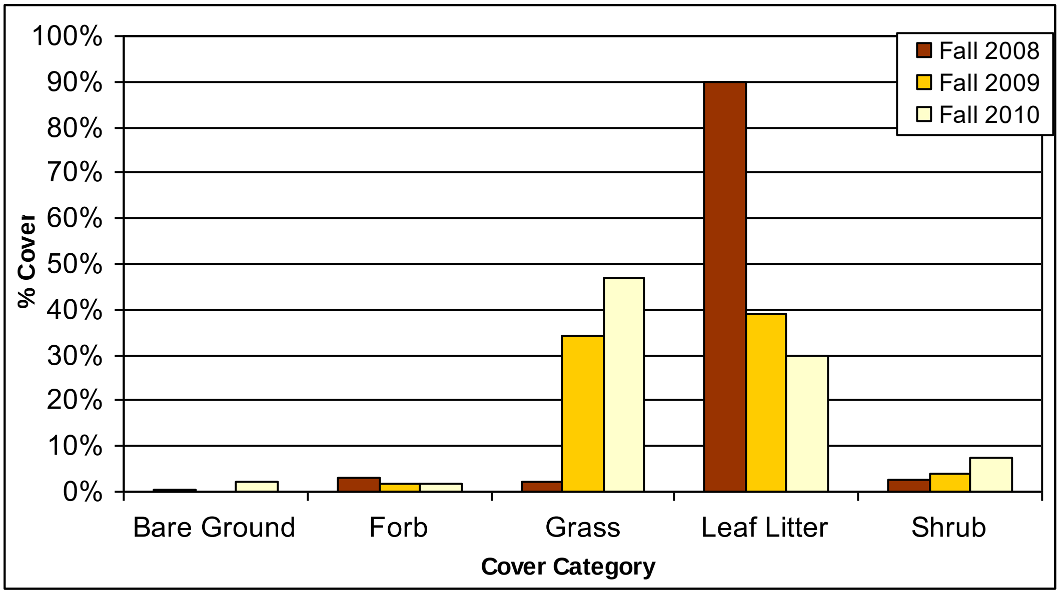


Figure 3.13. Percentage of cover by growth form for BOU 1-L, fall 2008–2010.

For the BOU 2-H plot, the dominant cover along transects in 2008 was bare ground, in 2009 bare ground fell by ~30% and fell a further 12% to approximately 8% in 2010 (see Figure 3.14). In 2009, the dominant cover type was forb cover, which had increased drastically from 2008 levels (15%–70%). In 2010 forb cover fell just over 20% while grass cover increased by approximately 20% in 2010 from 2009 levels. Leaf litter was relatively high in 2008 but fell to just 1% in 2009 and remained low in 2010. Shrub levels have increased slowly since 2008 but remain a minor cover component. Forbs and grasses are the major cover type in this representative high-severity plot.

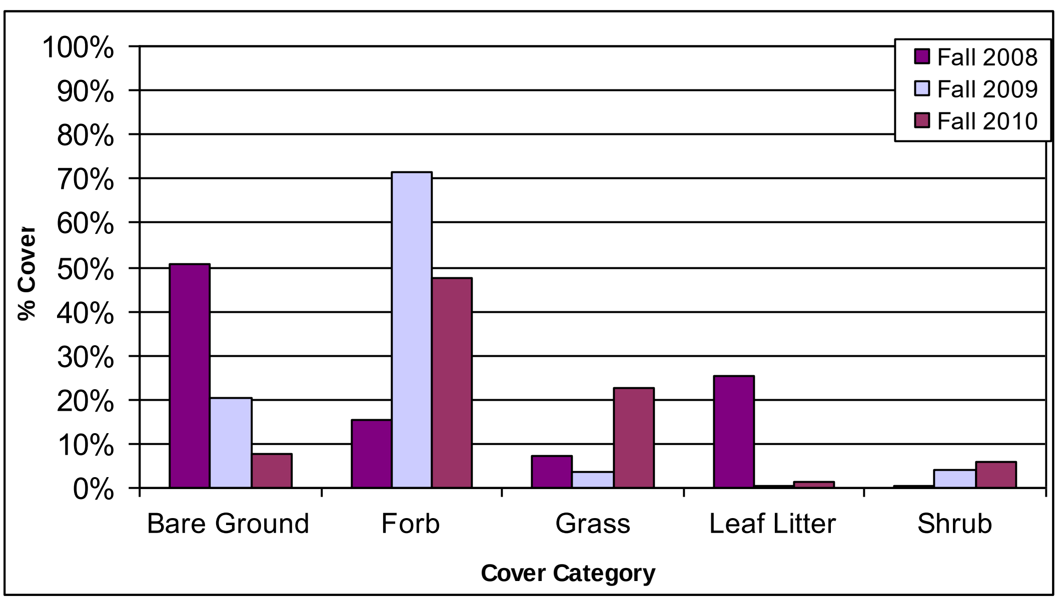


Figure 3.14. Percentage of cover by growth form for BOU 2-H, fall 2008–2010.

In the unburned reference plot (BOU 7-U), leaf litter was the dominant cover type in 2008 and 2009 but levels dropped by over 40% in 2010; bare ground and forb levels are low in all three years (see Figure 3.15). Grass levels have increased slightly over the three years, while shrub levels increased drastically between 2009 and 2010. The relative cover of each type in the unburned plot is similar to the low-severity plot, suggesting the low-severity plot more closely resembles natural unburned conditions. The high-severity plot exhibited abnormally high levels of bare ground and forbs compared to the reference site.

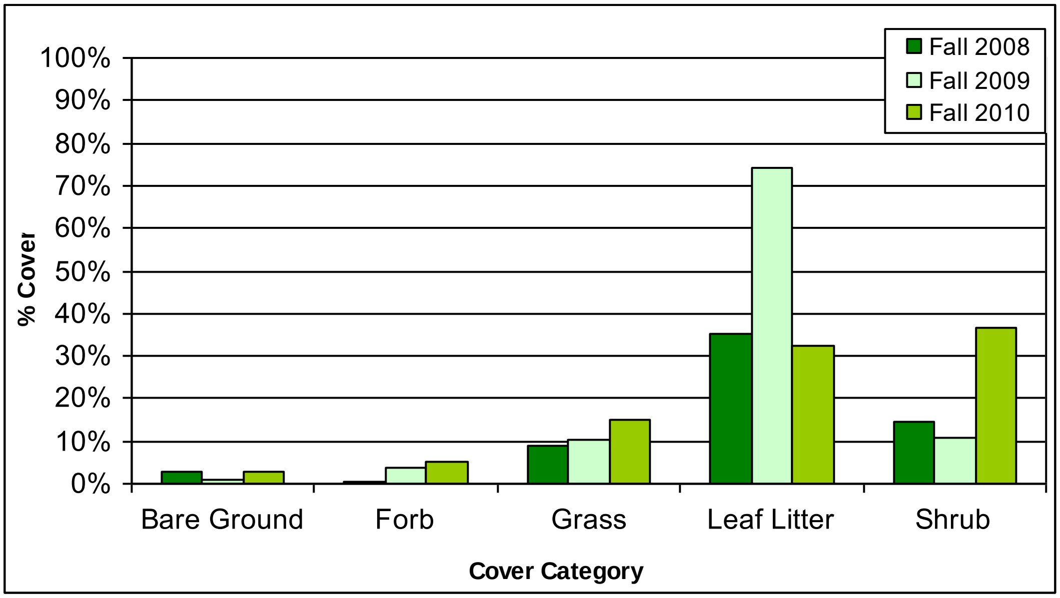


Figure 3.15. Percentage of cover by growth form for BOU 7-U reference plot, fall 2008–2009.

3.2.2 SPRING DATA

Figure 3.16 through Figure 3.18 illustrate the change in cover type by severity on continuous line intercepts for spring 2009 and 2010. Figure 3.16 shows there was minimal change in cover type on a representative low-severity plot (BOU 1-L) across both spring seasons. Leaf litter declines in 2010 and shrub cover increases slightly in 2010, but grass remains relatively constant and forb and bare ground remain negligible.

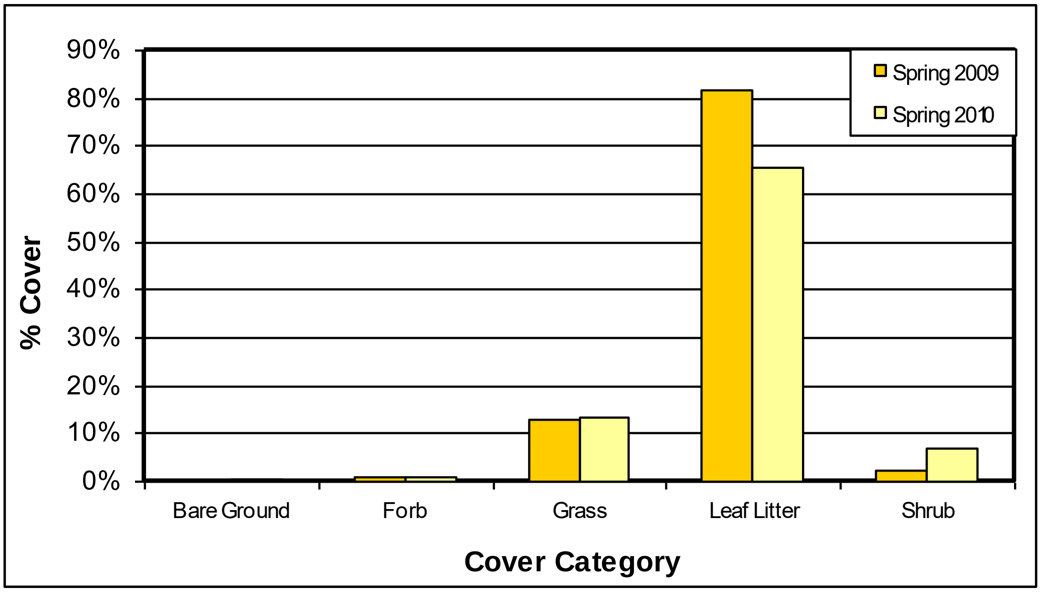


Figure 3.16. Percentage of cover by growth form for BOU 1-L, 2009–2010.

Figure 3.17 illustrates cover on a representative high-severity plot (BOU 2-H) and shows a slight decline in bare ground and forb cover and a doubling of grass, leaf litter, and shrub cover between spring 2009 and 2010.

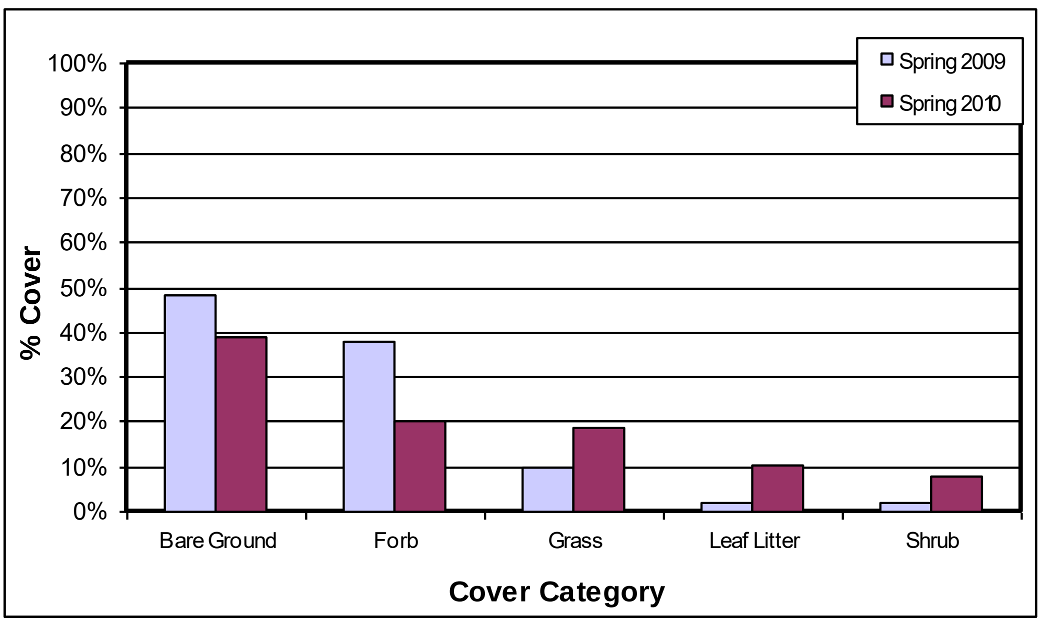


Figure 3.17. Percentage of cover by growth form for BOU 2-H, spring 2009–2010.

Figure 3.18 illustrates cover on a representative unburned plot (BOU 7-U) and shows a very similar pattern of cover as the low-severity plot (see Figure 3.16) with a slight decline in leaf litter and an increase in shrub cover from spring 2009 to 2010. Cover changes in spring show a similar pattern to cover during the fall monitoring seasons. The low and unburned plots for both seasons have similar ratios of each cover type, further supporting the statement that the low-severity plots better resemble natural unburned conditions.

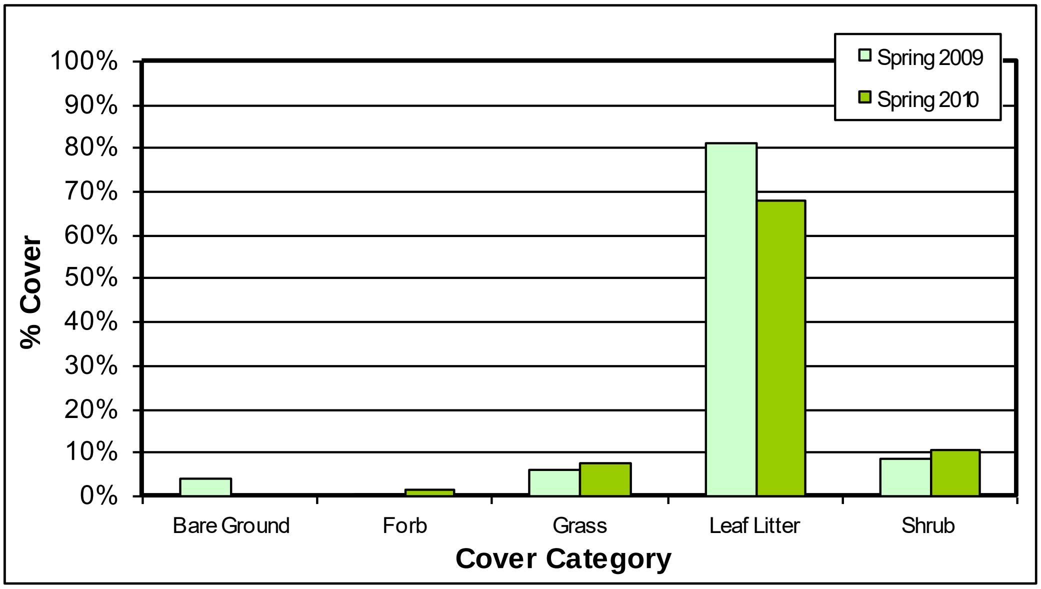


Figure 3.18. Percentage of cover by growth form for BOU 7-U reference plot, spring 2009–2010.

3.2.3 QUADRAT DATA

Quadrat data were recorded in spring 2009 and 2010 and fall 2008, 2009, and 2010. These data are used to determine changes to the major cover types (bare ground, leaf litter, forb, grass, shrub) on plots over time. The data were analyzed using a Kruskal Wallis non-parametric test for variance and are presented by severity type and season below. Graphs for fall monitoring periods are presented first (Figure 3.19–Figure 3.21), followed by spring monitoring results (Figure 3.22–Figure 3.24).

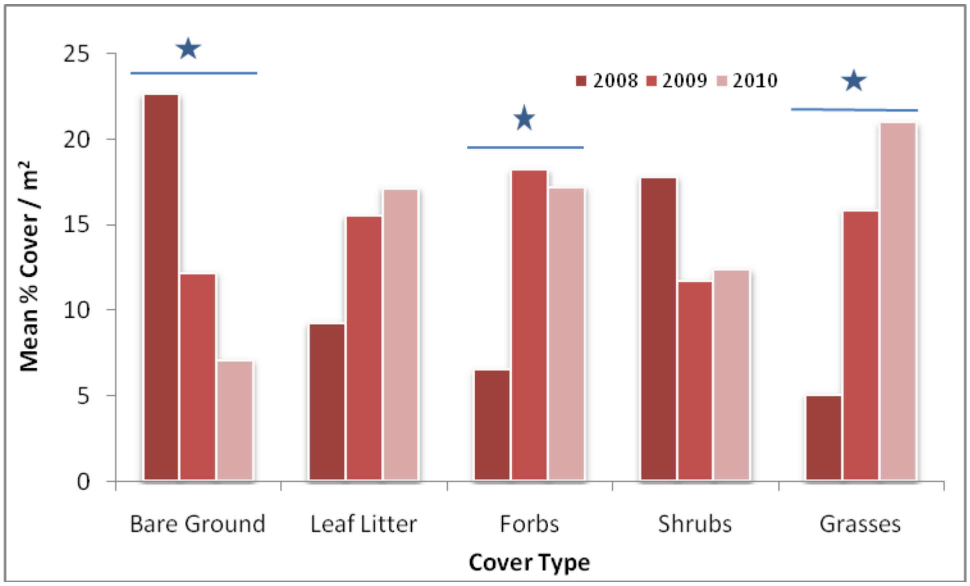


Figure 3.19. Vegetation cover in quadrats for all high-severity burn plots, fall 2008–2010. Star denotes significant difference (p-value < 0.05) between 2008, 2009, and 2010 data using the Kruskal Wallis non-parametric test for variance.

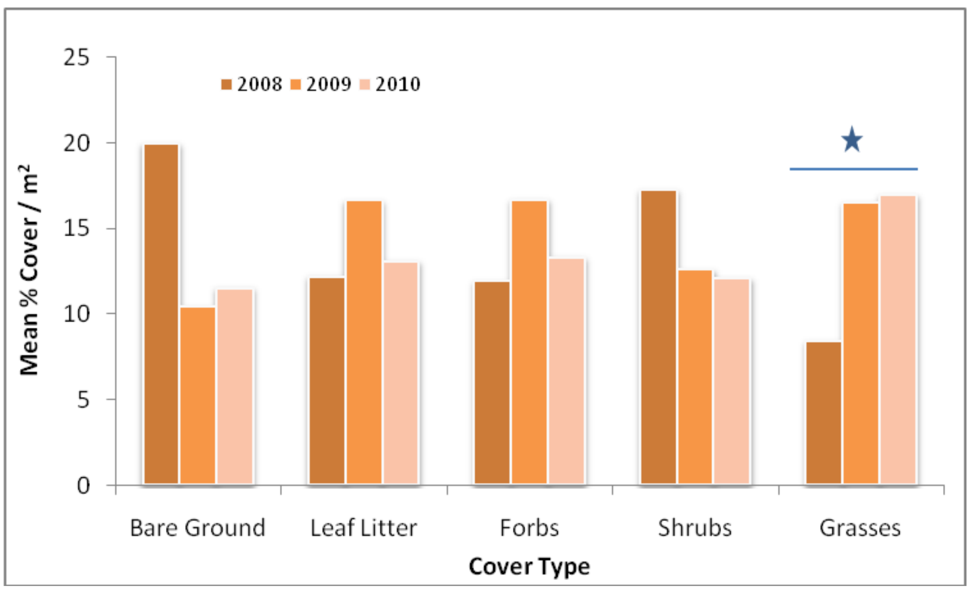


Figure 3.20. Vegetation cover in quadrats for all low-severity burn plots, fall 2008–2010. Star denotes significant difference (p-value < 0.05) between 2008, 2009, and 2010 data using the Kruskal Wallis non-parametric test for variance.

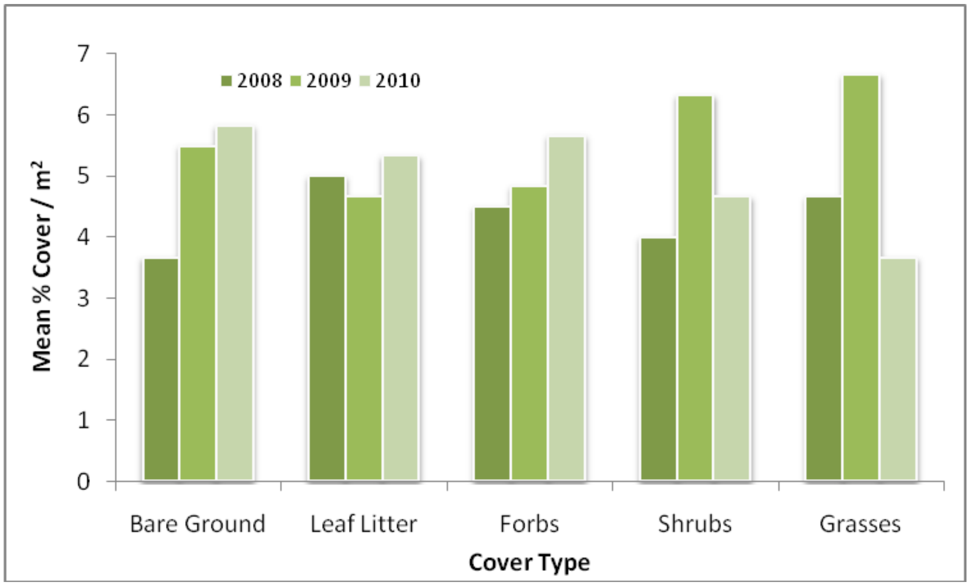


Figure 3.21. Vegetation cover in quadrats for all unburned plots, fall 2008–2010. Star denotes significant difference (p-value < 0.05) between 2008, 2009, and 2010 data using the Kruskal Wallis non-parametric test for variance.

The graphs above illustrate the fall data collection in all vegetation quadrats. The most statistically significant results (those with p-values <0.05) can be seen in the high-severity plots (see Figure 3.19). Over the three field seasons, bare ground has decreased significantly (p-value = 0.0001), while grasses have increased significantly (p-value = <0.0001). Forbs increased in 2009 by a significant amount over 2008 levels (p-value = 0.0025) and then remained relatively constant in 2010. Leaf litter increased over the three field seasons but not significantly. The low-severity plots (see Figure 3.20) did not change as significantly as the high-severity plots. The cover of grasses increased significantly (p-value = 0.036) between 2008 and 2009 and then remained relatively constant in 2010. Bare ground and shrub levels declined over the three years but not significantly.

The unburned plots (see Figure 3.21) reflect some variation in cover between the three monitoring sessions including increased bare ground and forbs and variations in shrub and grass cover; however, statistical tests determined that the variation in cover types between years is not significantly different.

Figure 3.22 through Figure 3.24 illustrate vegetation quadrat data collected in spring 2009 and 2010. Like the fall data, the most statistically significant results (those with p-values <0.05) are observed on the high-severity plots where grass cover increased significantly (p-value = 0.0031) between 2009 and 2010. In spring 2009, some of the seeded grasses had only just started to establish and had minimal biomass; however by spring 2010 the robust perennial tall wheatgrass (*Thinopyrum ponticum*) had begun to dominate the herbaceous ground cover. Bare ground, leaf litter, and shrubs decreased across the two years but not significantly.

The low-severity and unburned plots also showed some variability in cover during spring monitoring, but none of the cover variables changed with any statistical significance.

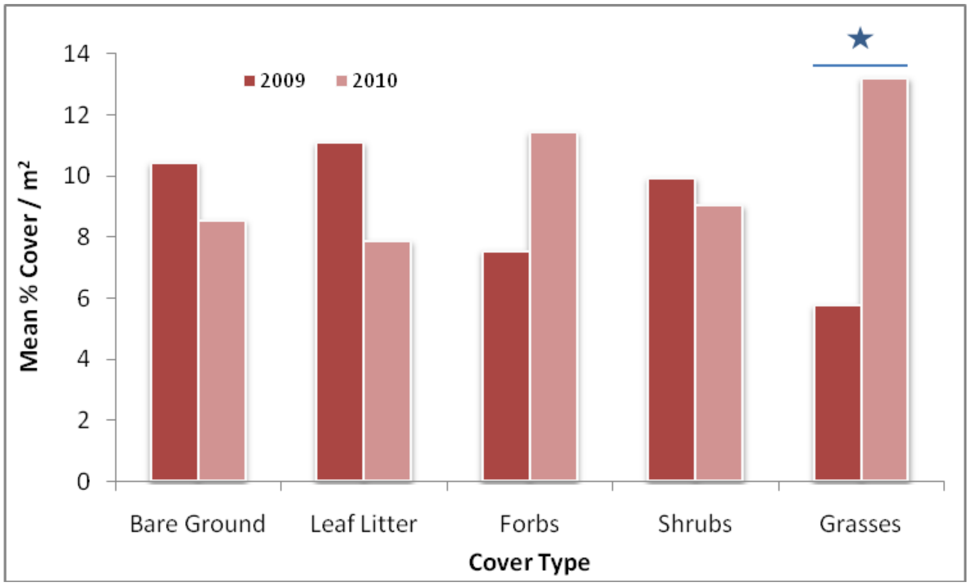


Figure 3.22. Vegetation cover in quadrats for all high-severity burn plots, spring 2009–2010. Star denotes significant difference (p-value < 0.05) between 2008, 2009, and 2010 data using the Kruskal Wallis non-parametric test for variance.

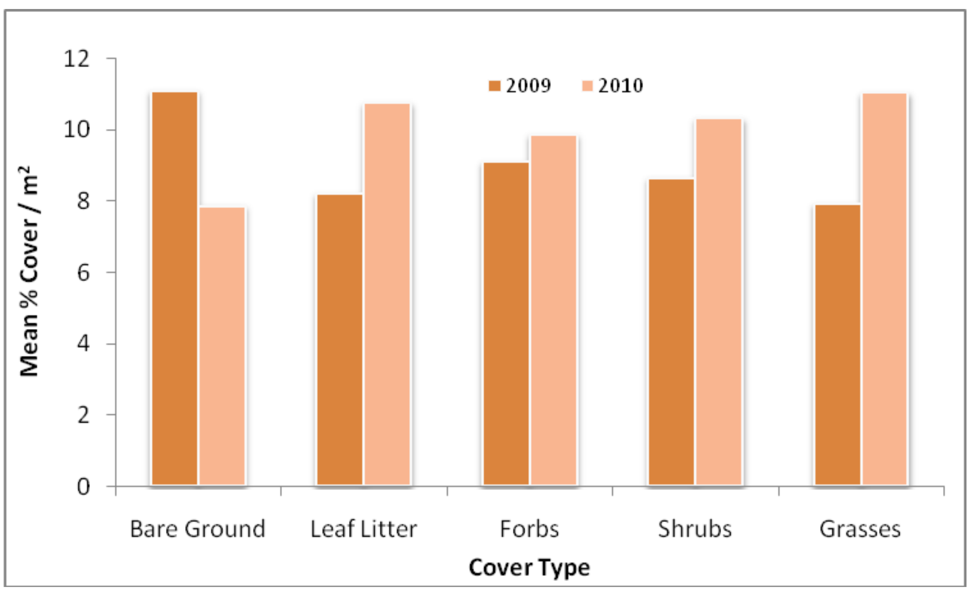


Figure 3.23. Vegetation cover in quadrats for all low-severity burn plots, spring 2009–2010.

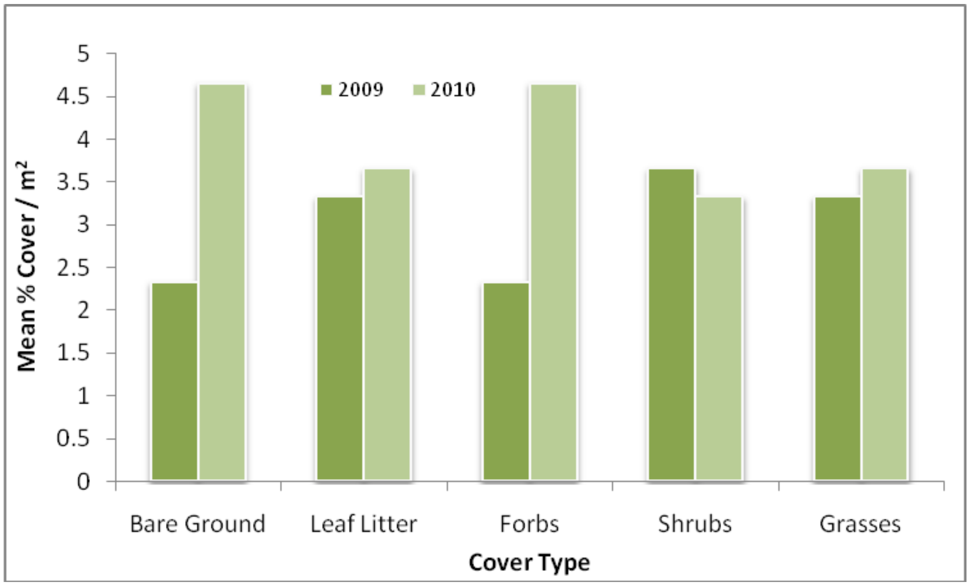


Figure 3.24. Vegetation cover in quadrats for all unburned plots, spring 2009–2010.

Table 3.1 provides names and species codes for the more common plants found on the fire plots and referred to in the following figures (see also Appendix B). From Figure 3.25 the most common species across the low-severity plots in all seasons were fetid goosefoot (*Chenopodium graveolens*) and the tall wheatgrass (*Thinopyrum ponticum*). The cover of tall wheatgrass on the low- and high-severity plots increased drastically in fall 2010 (Figure 3.25–Figure 3.27). Italian ryegrass (*Lolium perenne*) was a dominant species in 2008 through spring 2010 but was not recorded in the fall 2010 monitoring. Both tall wheatgrass and Italian ryegrass are large robust grasses that were present in the seed mix applied following the fire in 2008. Tall wheatgrass is a perennial grass that was expected to increase in dominance since disturbance; Italian ryegrass, an annual grass, was expected to slowly decline as is seen here. Fetid goosefoot, though still dominant in all seasons on both low- and high-severity plots, was seen to decline in fall 2010. This could be because the species is an annual forb that is most abundant immediately following a disturbance and will decline as a site becomes re-established and perennial species become more dominant (Kuenzi et al. 2008).

Table 3.1. List of the Most Common Plants Found on the Fire Plots

Code	Common Name	Scientific Name	Growth Form	Life History
ARCA14	Littleleaf pussytoes	*Artemisia carruthii*	Forb	Perennial
ARLU	White sagebrush	*Artemisia ludoviciana*	Forb	Perennial
ASNU4	Smallflowered milkvetch	*Astragalus nuttallianus*	Forb	Perennial
BADI	Ragleaf bahia	*Bahia dissecta*	Forb	Annual
BLTR	Pine dropseed	*Blepharoneuron trichophyllum*	Grass	Perennial
BOGR2	Blue grama	*Bouteloua gracilis*	Grass	Perennial
BRAR5	Field brome	*Bromus arvensis*	Grass	Annual
CHFR3	Fremont’s goosefoot	*Chenopodium fremontii*	Forb	Perennial
CHGR2	Fetid goosefoot	*Chenopodium graveolens*	Forb	Annual
CHLE4	Narrowleaf goosefoot	*Chenopodium leptophyllum*	Forb	Annual
CYFE2	Fendler’s flatsedge	*Cyperus fendlerianus*	Grass	Perennial
ELCA4	Canada wildrye	*Elymus canadensis*	Grass	Perennial
ERDI4	Spreading fleabane	*Erigeron divergens*	Forb	Biennial
ERFL	Trailing fleabane	*Erigeron flagellaris*	Forb	Biennial
ERME	Mexican lovegrass	*Erogrostis mexicana*	Grass	Annual
ERRA3	Redroot buckwheat	*Eriogonum racemosum*	Forb	Perennial
GECAF	Parry's geranium	*Geranium caespitosum*	Forb	Perennial
GUSA2	Broom snakeweed	*Gutierrezia sarothrae*	Shrub	Perennial
KOMA	Prairie junegrass	*Koeleria macranthus*	Grass	Perennial
LOPE	Italian ryegrass	*Lolium perenne*	Grass	Annual
LOWR	Wright’s deervetch	*Lotus wrightii*	Forb	Perennial
PIMI7	Littleseed ricegrass	*Oryzopsis micrantha*	Grass	Perennial
PHHE4	Ivyleaf groundcherry	*Physalis hederifolia*	Forb	Perennial
QUGA	Gambel oak	*Quercus gambelii*	Shrub	Perennial
QUGR3	Gray oak	*Quercus grisea*	Shrub	Perennial
SPAN3	Copper globemallow	*Sphaeralcea angustifolia*	Forb	Perennial
THME	Hopi tea greenthread	*Thelesperma megapotamicum*	Forb	Perennial
THPO7	Tall wheatgrass	*Thinopyrum ponticum*	Grass	Perennial

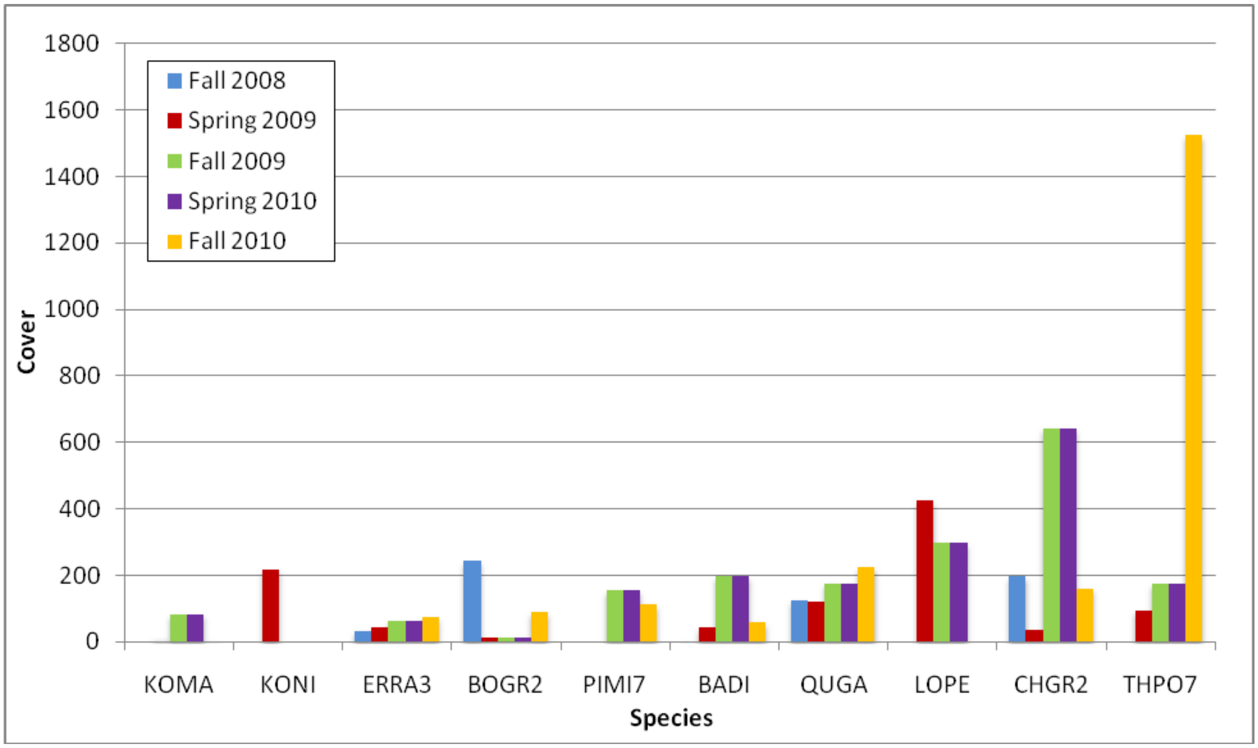


Figure 3.25. Top ten species recorded in quadrats measured on all low-severity fire plots across all seasons.

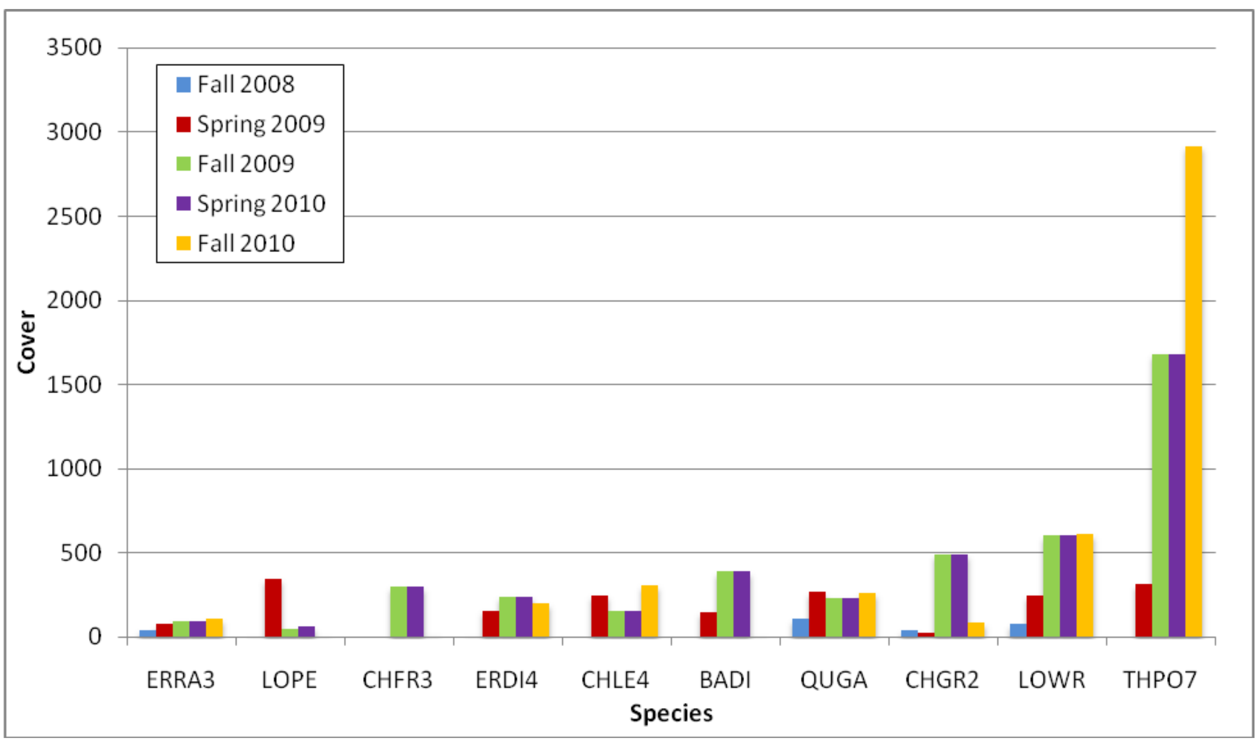


Figure 3.26. Top ten species recorded in quadrats measured on all high-severity fire plots across all seasons.

Figure 3.27. Tall wheat grass that was seeded on a high-severity plot, fall 2010.

A number of the dominant species were specific to the high-severity plots including: Wright's deervetch (*Lotus wrightii*), narrowleaf goosefoot (*Chenopodium leptophyllum*), Fremont's goosefoot (*Chenopodium fremontii*), and spreading fleabane (*Erigeron divergens*). These species are typical of early colonizers following disturbance (Wolfson et al. 2005). Blue grama (*Bouteloua gracilis*), a native grass, was only dominant on the low-severity plots but was observed to be increasing in cover on high-severity plots during 2010. As a native perennial blue grama was expected to become more dominant over the coming years since disturbance. Gambel oak (*Quercus gambelii*) was the dominant shrub on both low- and high-severity plots, and its cover has remained relatively constant across the seasons.

As a whole, annual forb and grass dominance is expected to decline in future years, giving way to increased cover by perennial forbs and grasses. This change is anticipated to be most notable on the high-severity plots where perennial species were largely eliminated from the site due to disturbance of the soil and litter layers, and early colonizers were typically annual species (e.g., ragleaf bahia [*Bahia dissecta*], fetid goosefoot, narrowleaf goosefoot [*Chenopodium leptophyllum*], Italian ryegrass). Because the low-severity plots exhibited minimal loss of duff and litter and limited soil erosion, perennial species were better able to survive the fire, and colonization by annual species in comparison was much reduced.

3.2.4 SOIL MOVEMENT

Soil movement was monitored using soil movement bridges (called soil erosion bridges in the 2008 Annual Report) modeled after White and Loftin (2000). Permanent bridge support posts were installed at consistent, systematically determined, and unbiased locations at the ends of the north and south transects at each plot (refer to the 2008 Annual Report for detailed monitoring protocols and literature associated with soil movement [SWCA 2009]). Soil movement bridges that had been installed in fall 2008 were monitored in spring and fall 2009 and 2010. Figure 3.28 through Figure 3.30 demonstrate the changes in the soil surface profiles between 2008 and 2010 for three plots in the same watershed burned by differing severities.

The soil profile on the high-severity Salazar site (see Figure 3.28) seems to show a general falling trend (soil loss), suggesting that erosional processes dominated at this site for all seasons except fall 2010. Although the fall 2010 profile from pin points 0 to 11 is lower than other seasons, the profile from pin points 11 to 21 is higher than previous periods. This shows the micro-topographic variations across the soil surveying area, where there may be a general erosional trend coupled on a smaller scale with a deposition event. The greatest variation in profile height at this site remains minimal, however, at approximately 20 mm.

The soil profile on the low-severity Salazar site (see Figure 3.29) is more varied than the high-severity site with both erosional and depositional processes occurring throughout the seasons. At installation the low-severity site had more litter accumulation, so the micro-topography across the profile was highly varied, possibly contributing to the variation in soil movement observed across the seasons. The degree of change in the profiles across seasons is higher than the high-severity site, but is still less than 40 mm.

The unburned site at the Manzano Mountain Retreat appears to show a general rising trend (soil gain) in the soil profile (see Figure 3.30), suggesting that depositional processes are dominant at the site. The fall 2010 profile was at some points over 100 mm higher than the fall 2008 profile, suggesting considerable and active soil movement has been occurring.

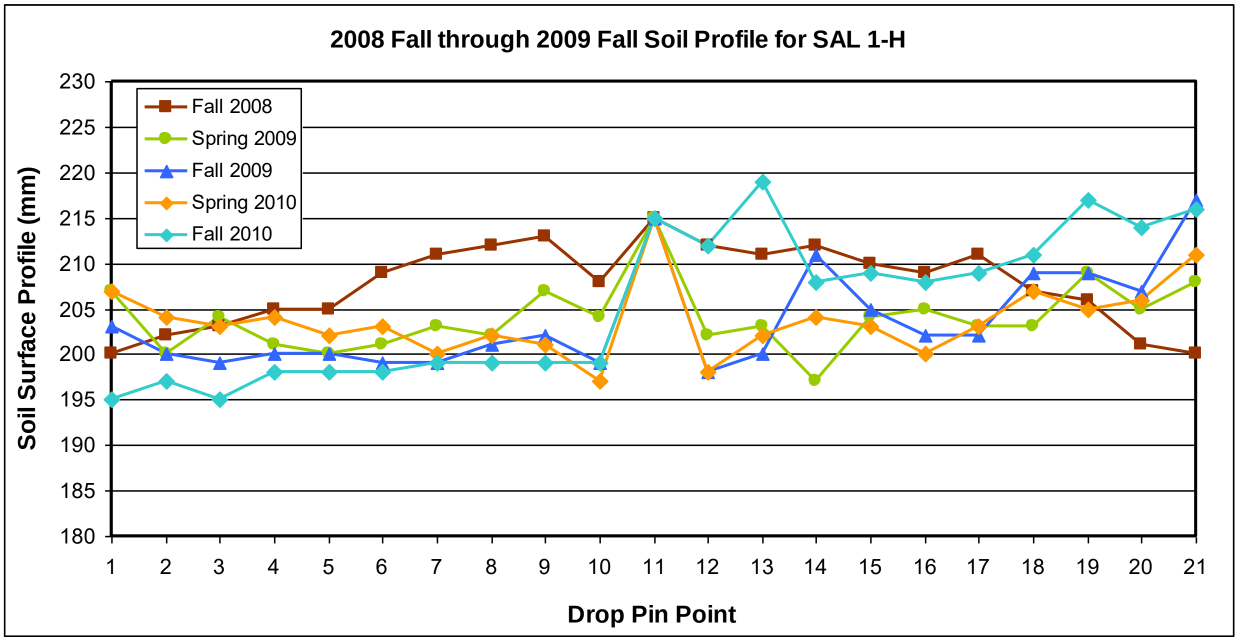


Figure 3.28. Soil movement bridge data on a Salazar high-severity plot across all monitoring seasons. Each point on the X axis represents one measurement point from the soil surface to the level bridge above the surface.

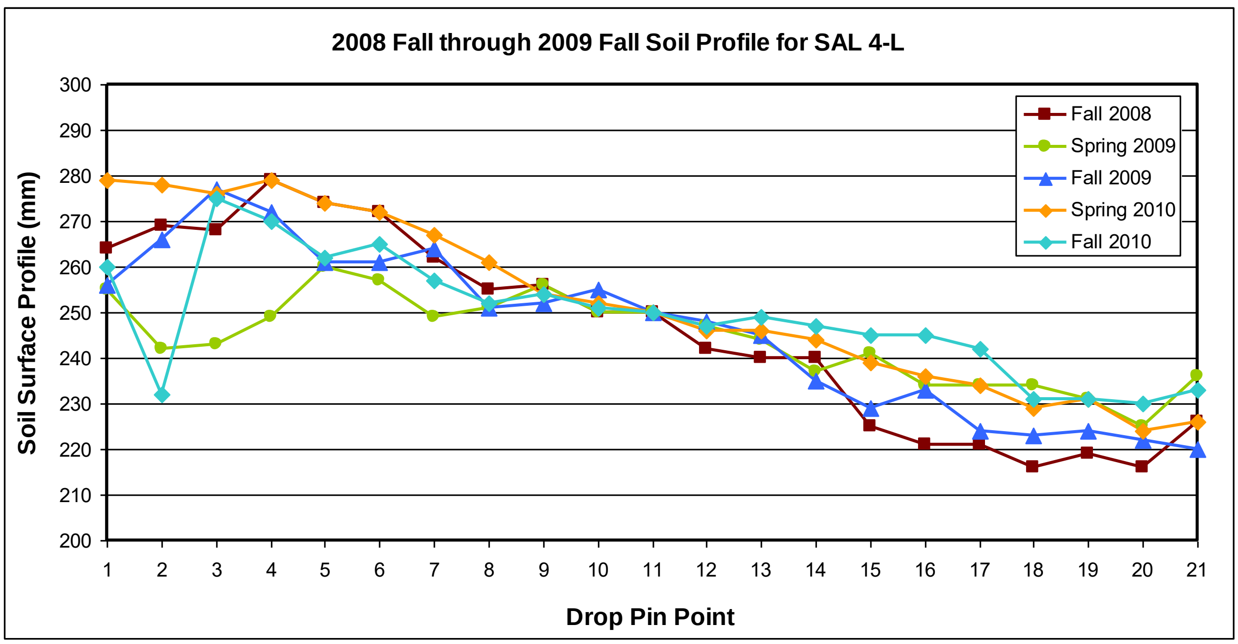


Figure 3.29. Soil movement bridge data on a Salazar low-severity plot across all monitoring seasons. Each point on the X axis represents one measurement point from the soil surface to the level bridge above the surface.

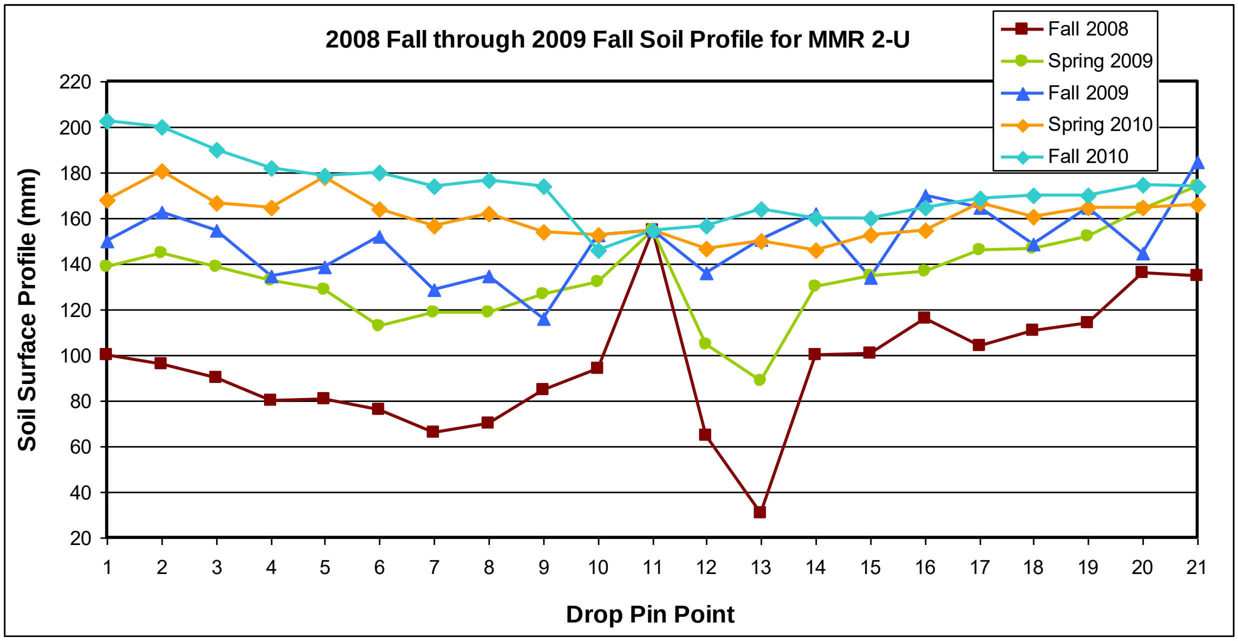


Figure 3.30. Soil movement bridge data on a Manzano Mountain Retreat unburned plot across all monitoring seasons. Each point on the X axis represents one measurement point from the soil surface to the level bridge above the surface.

3.2.5 WILDLIFE CAMERA DATA

Wildlife cameras have been established across the three project watersheds since spring 2009. Until fall 2010 three cameras were rotated between watersheds with one camera in each severity type. In November 2010, six additional cameras were purchased in order to have permanent coverage in each watershed and remove the need for rotation. This will provide increased monitoring of wildlife use of all severity types on all watersheds throughout all seasons.

Table 3.2 and Table 3.3 provide data from wildlife cameras prior to the new camera installs. Because of camera malfunction and irregular offload periods, the cumulative camera days for each severity type vary. This variability was the driving force behind installing permanent cameras on all watersheds.

Table 3.2. 2009 Wildlife Frequency Data for Wildlife Cameras Rotated between the Three Fire Monitoring Watersheds

Severity	Cumulative Camera Days	Species	Counts	Standardized Counts
Unburned	200	Mule deer	3	0.015
Unburned		Wild turkey	4	0.020
Unburned		Bobcat	1	0.005
Low	200	Mule deer	41	0.205
High	200	Mule deer	42	0.210

Note: Standardized counts are calculated by dividing the species count by the number of days each camera was installed at plots in each severity type.

Table 3.3. 2010 Wildlife Frequency Data for Wildlife Cameras Rotated between the Three Fire Monitoring Watersheds

Severity	Cumulative Camera Days	Species	Counts	Standardized Counts
Unburned	130	Mule deer	9	0.069
Unburned		Wild turkey	20	0.154
Low	480	Mule deer	59	0.123
Low		Wild turkey	27	0.056
Low		Gray fox	3	0.006
Low		Abert's squirrel	5	0.010
Low		Cottontail rabbit	5	0.010
Low		Jackrabbit	5	0.010
Low		Various bird species	1	0.002
High	240	Mule deer	2	0.008

Note: Standardized counts are calculated by dividing the species count by the number of days each camera was installed at plots in each severity type.

The most common species recorded at all sites and across both monitoring years is the mule deer (*Odocoileus hemionus*). In 2009 mule deer numbers were relatively constant between the high- and low-severity plots; for both, severities frequencies were considerably greater than on the unburned plots. In 2009 species diversity was greatest on the unburned plots. In 2010 species diversity was greatest on the low-severity plots, including mule deer (Figure 3.31–Figure 3.33), gray fox (*Urocyon cinereoargenteus*) (Figure 3.34), Merriam's wild turkey (*Meleagris gallopavo*) (Figure 3.35), Abert's squirrel (*Sciurus aberti*), cottontail rabbit (*Sylvilagus* sp.), jackrabbit, and various birds. The high- and low-severity plots varied considerably in terms of count for mule deer; however, this could be a consequence of fewer camera days on the high-severity plots.

Differing wildlife frequency and species composition in different severity types may be an artifact of camera sensitivity, as well as the length of time cameras were active at each site.

Greater species composition and higher frequencies of species were expected where cameras were active for longer periods, as demonstrated on the low-severity plots in 2010, which had double the camera days of high-severity plots and considerably greater species diversity and frequencies. Some of the smaller species, rabbits and squirrels (Sciuridae) for example, are more likely to be detected on more open sites where animal movement is sufficient to trigger the camera sensor. This could explain their absence on the high-severity plots that had thick regeneration of the graminoid layer.

Since mule deer are detected in all severity types and in both years, a chi-squared analysis was carried out on the frequency data to determine if the observed distribution is significantly different from some hypothesized distribution. The null hypothesis for this analysis is that mule deer use of plots is independent of burn severity.

For both years the critical chi-squared value (Zar 1984) is 5.991. The calculated chi-squared value in 2009 was 0.172; because this value is less than this critical value, SWCA accepts the null hypothesis that mule deer use of the burn area in 2009 was independent of severity. In 2010 the calculated chi-squared value was 0.099; because this value is less than the critical value of 5.991, the null hypothesis is again accepted.

While considering the potential for biases related to varying camera days and camera sensitivity, wildlife species composition and frequency of use does appear to be greater on low-severity plots in the project area, though the difference in 2009 and 2010 data are not significant. 2011 data will be gathered simultaneously on all watersheds throughout the year, which should resolve some of the issues of varied camera days and seasonal variation due to rotation of cameras.

Figure 3.31. Mule deer at the Sanchez low-severity site.

Figure 3.32. Two young mule deer at the Sanchez low-severity site.

Figure 3.33. Mule deer at the Candelaria high-severity site. Note the thick grass layer.

Figure 3.34. Gray fox observed at night at the Neff low-severity site.

Figure 3.35. Wild turkey (Merriam's) at the Sanchez low-severity site.

3.3 FIRE MONITORING CONCLUSION

Third-year results from the post-wildfire monitoring suggest that the area is slowly regenerating with increased herbaceous cover, particularly grass and forb cover and reduced bare ground on the high- and low-severity plots. Aerial seeding efforts were successful on all high-severity plots with dominance of seeded annual grasses. Much of the high-severity plots had experienced 100% mortality of the tree layer, and many of these trees have now begun to fall, particularly as a result of wind throw. The low-severity plots exhibited patchy mortality in 2008; some of the worst-hit trees, those that were more than 50% scorched, have now begun to die as a result of the physiological stress. Soil erosion is highly variable across plots but appears to continue to be dominant on the high-severity plots. Regrowth of the herbaceous layer, dominance of seeded grasses, dead and fallen trees, and increased litter layers will all contribute to the maintenance of the soil layer.

4.0 EPHEMERAL WATERSHED STREAM MONITORING

Background information on the stream piezometers can be found in the 2009 Annual Report. In addition to the paired watershed flumes, piezometers were installed on three nearby streams in order to gage surface flows on a larger scale (Figure 4.1). Three flows were recorded in the stream near the Vigil site, and a summary of data can be seen below in Table 4.1. Analysis of the surface flow hydrograph indicates a rainfall/runoff ratio on a larger watershed scale (2,900 acres) ranges from 0.109 to 0.198. A stream hydrograph from the vigil piezometer from an event that occurred on July 25, 2010, can be seen below (Figure 4.2 and Figure 4.3).

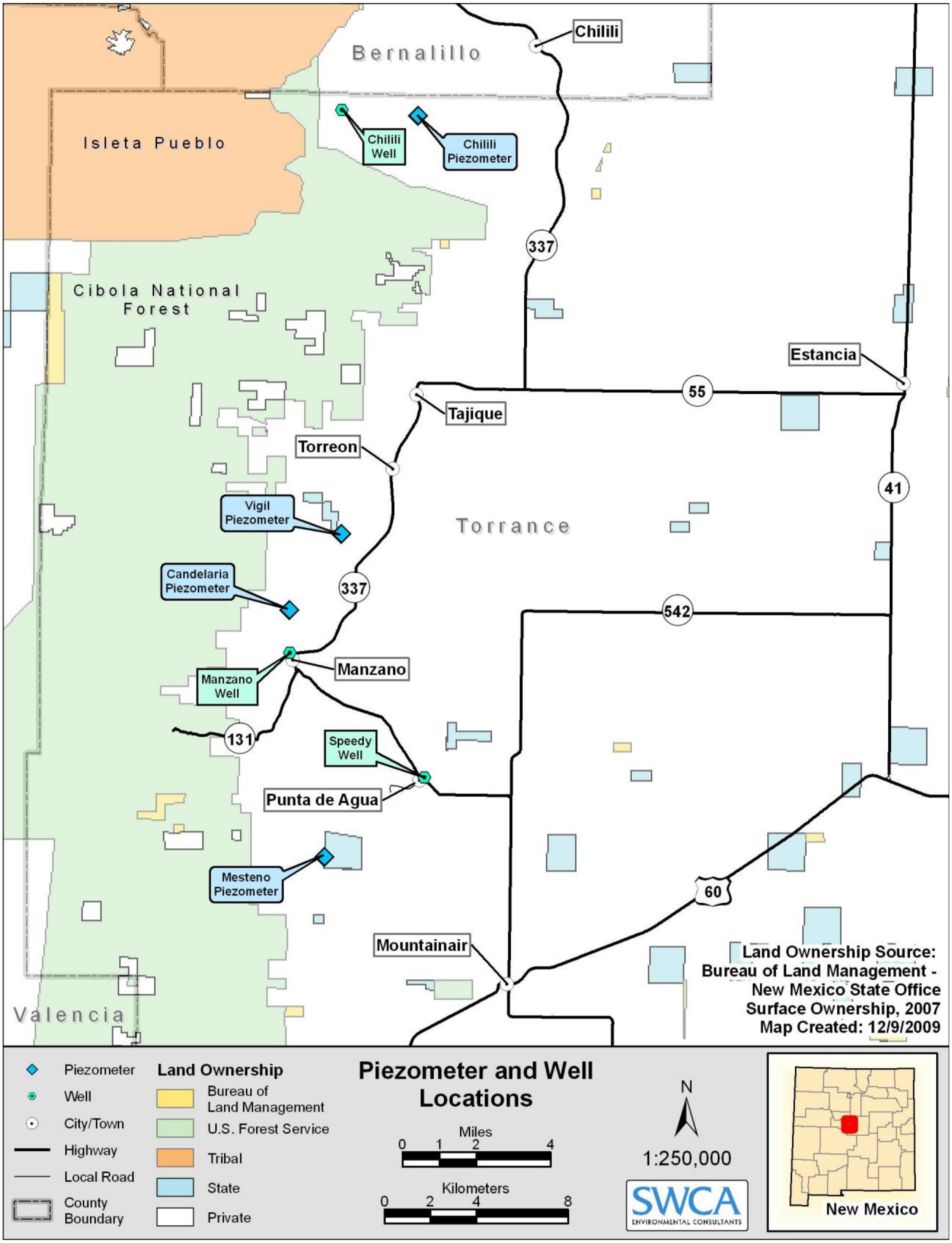


Figure 4.1. Location of the piezometers and wells within the Estancia Basin.

Table 4.1. Summary of Surface Flow Events in Vigil Stream Piezometer

Surface Flow Parameters	Dates		
	7/25/10	8/15/10	10/2/10
Flow start	19:45	20:45	21:30
Flow stop	23:45	Undetermined	1:45
Peak stage	5.144	1.502	3.6
Peak flow (feet)	463	44.39	232
Flow duration (minutes)	240	Undetermined	255
Total volume of flow (cubic feet)	2,717,332	Undetermined	1,897,156
watershed area (acres)	2,900	2,900	2,900
Volume of flow per acre (cubic feet/acre)	909	Undetermined	654
Total rainfall (inches)	2.3	0.96	0.91
Total volumetric rainfall (cubic feet)	24,963,510	10,105,920	9,579,570
Rainfall/Runoff ratio	0.109	Undetermined	0.198

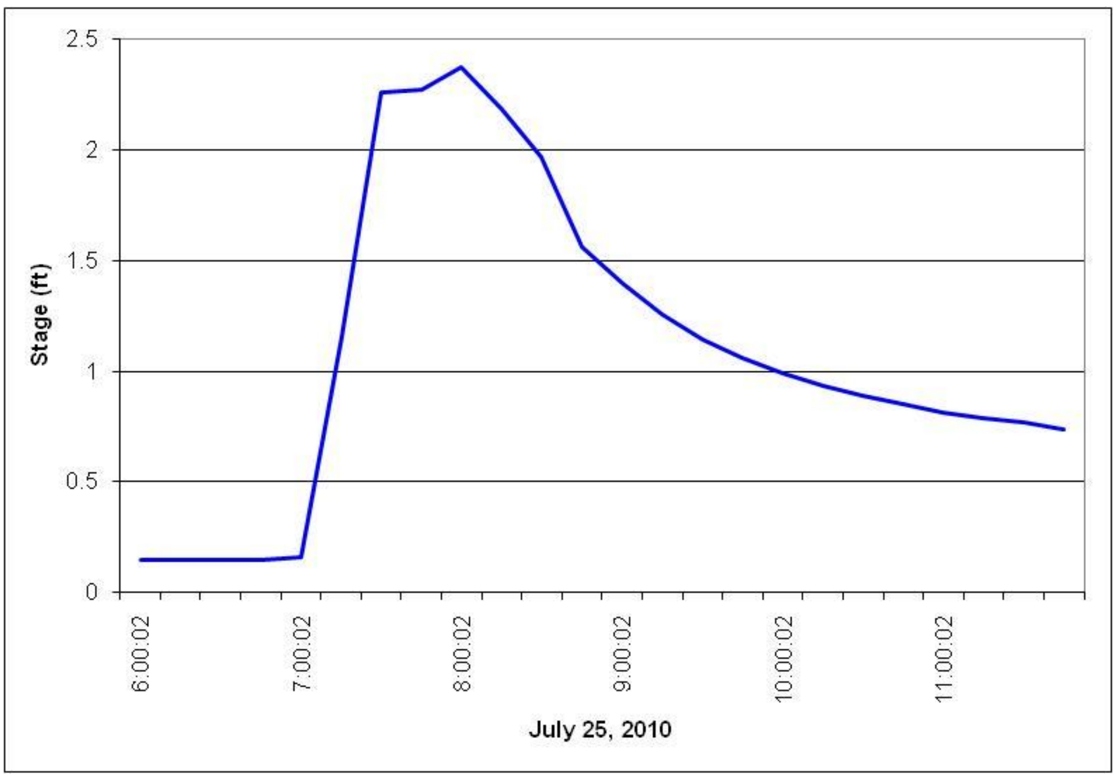


Figure 4.2. Hydrograph from the Vigil piezometer on July 25, 2010.

Figure 4.3. The Vigil piezometer in the fall of 2010 after a storm event lowered the stream bed level to below the piezometer. The shovel shows the location of the high water line determined by the accumulation of debris in the vegetation.

4.1 GROUNDWATER WELL MONITORING

The monitoring study is evaluating infiltration rates in the Estancia Basin by using deep pressure sensors to monitor the level of groundwater in relation to stream flow events. By monitoring the groundwater levels in private wells located close to stream monitoring locations, changes in recharge can be observed, and potentially the impact of thinning and burned areas can be compared to these groundwater levels to asses any changes.

Ideally, this project will evaluate infiltration rates in the control areas versus burned areas and relate this information to nearby groundwater levels. This could be accomplished by monitoring private wells located close to stream monitoring locations. Sandia National Laboratory and the U.S. Geological Survey are currently initiating well monitoring programs. Both entities have been receptive to sharing data when they become available, though neither knows if data would be available near the project's piezometer locations in the immediate future. The monitoring will use deep pressure sensors to monitor the level of groundwater in relation to stream flow events. If these data are available, they will be compared to the collected data from this project.

SWCA installed three well monitoring devices during early to mid June 2009. These well monitoring locations are at Chilili, Manzano, and Punta de Agua (see Figure 4.1). Each monitoring well is equipped with Solinst Levelogger Junior pressure transducers that were programmed to record values hourly. The Chilili site is approximately 30 m (98 feet) from the western flume. The well is approximately 15 m (50 feet) deep, and depth to groundwater when installed is approximately 8 feet (25 feet). The Manzano well is shallow, approximately 8 m (25 feet) deep, and periodically goes dry. The municipal well is nearby and likely contributes to the drawdown in this area. SWCA is looking for an alternative well, but until it is found this well will continue to be monitored. The Punta de Agua well is in "downtown" Punta. The well is approximately 37 m (120 feet) deep, and depth to groundwater is approximately 28 m (91 feet) when installed. SWCA will off-load data quarterly at each well location.

Figure 4.4 through Figure 4.6 display the well data from each of the three locations monitored in the Estancia Basin. During 2010 both the Chilili and Manzano wells showed a response to the spring snowmelt with the well at Chilili rising roughly 300 cm (118 inches) during a two-month period as large snowpack melted. Infiltration from the larger monsoonal storms that occurred in July can also be seen in the Chilili and Manzano groundwater levels. The well in Punta de Agua showed a steady deepening, which is likely from the lack of pumping from this well. One reason for the large response seen at Chilili is that it is higher in elevation and has limestone formations, which are conducive to infiltration and subsequent deep percolation.

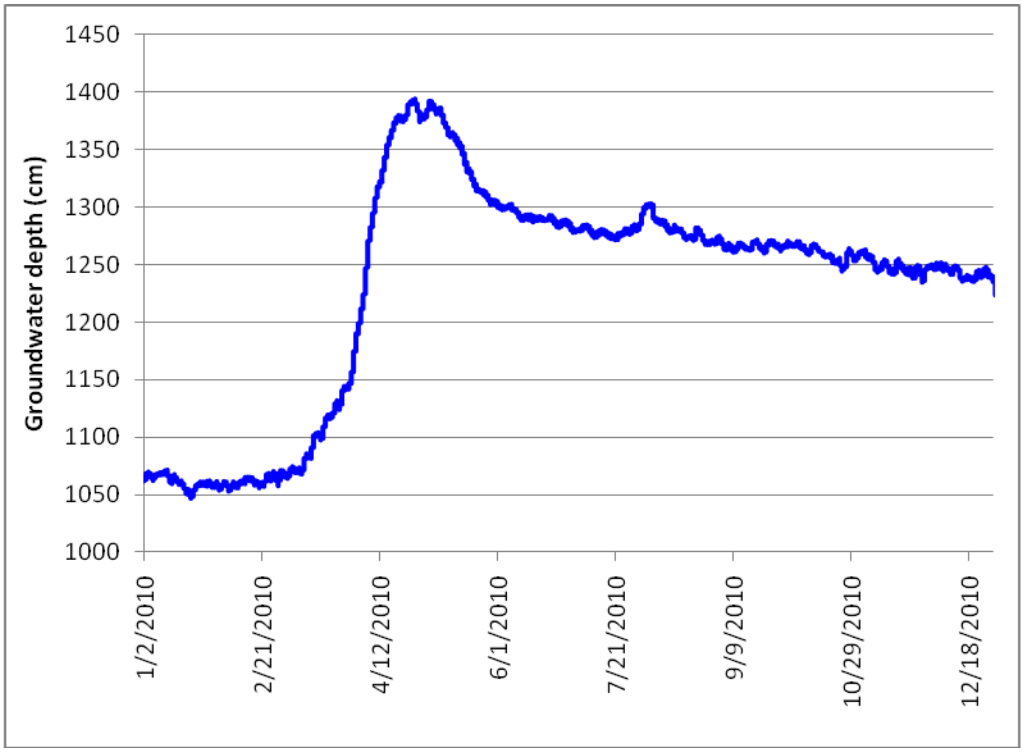


Figure 4.4. Well data from the Chilili site showing its high peak, which is reflective of the spring snowmelt followed by a steady decline over the summer with a few small peaks.

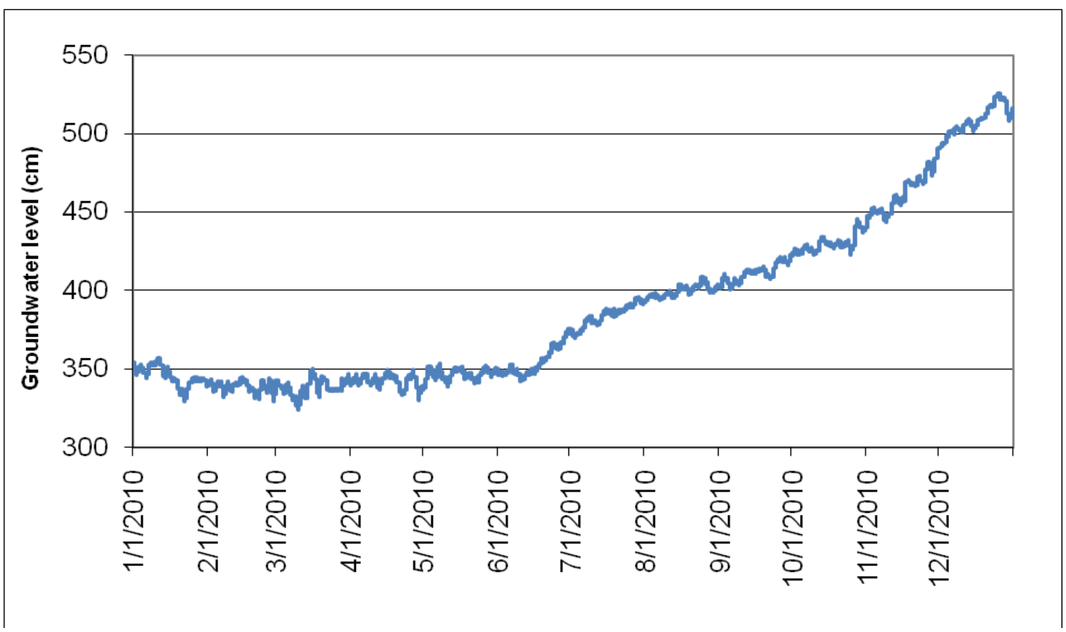


Figure 4.5. Well data from the Punta de Agua site showing steady rise of the groundwater over the summer months.

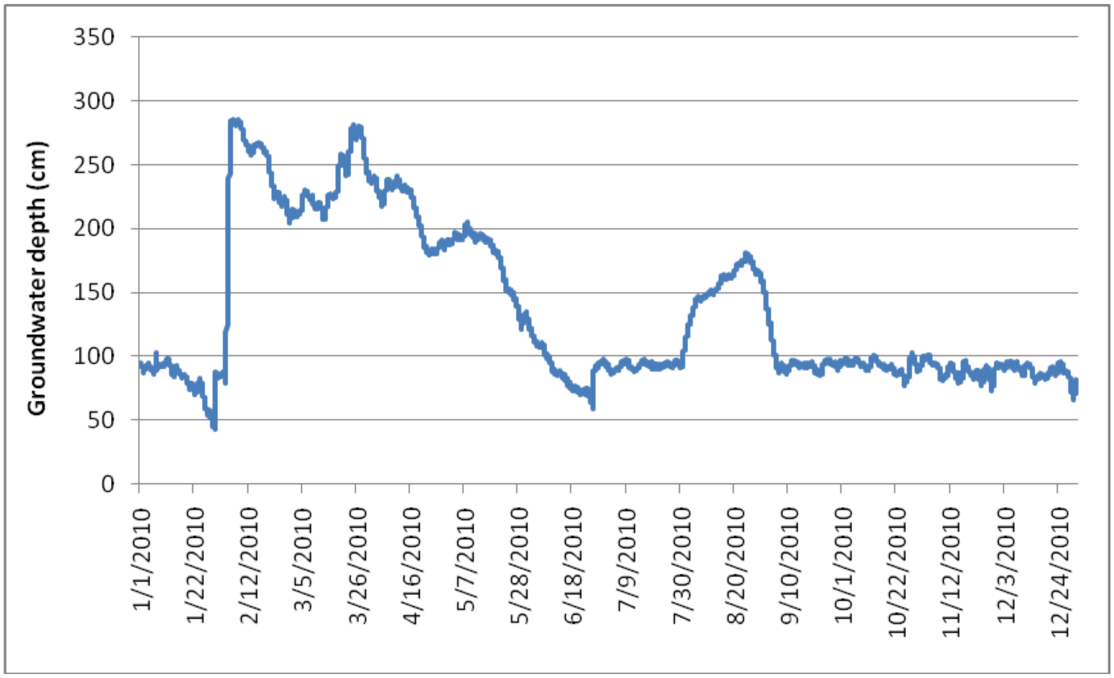


Figure 4.6. Well data from the Manzano site showing the fluctuations in groundwater over the summer months.

5.0 SOUTH MOUNTAIN WEATHER STATION

The SMWS was installed by EnviroLogic to provide meteorological, soil moisture, and temperature data as part of the Estancia Basin Watershed Health and Restoration Program overseen by the Steering Committee. EnviroLogic installed the SMWS in September 2006 to initiate site-specific monitoring of rainfall and soil water content at various soil depths. For details on site selection and monitoring protocols, please refer to the 2008 Monitoring Plan (SWCA 2008). The SMWS is within the Edgewood Soil and Water Conservation District, on the private property, near South Mountain, Santa Fe County, New Mexico, approximately 19 km (12 miles) north of the town of Edgewood (Figure 5.1). The intent of EnviroLogic was to assess water infiltration through soil depths, relate that to meteorological variables, and then compare two measured locations to determine the effects of forest thinning projects on groundwater recharge.

The SMWS measures precipitation, wind speed and direction, air temperature, humidity, and solar radiation. Soil moisture and temperature probes are situated at various depths at two locations with distinct vegetation structure types: one site within a piñon/juniper stand and one site in an adjacent open area consisting of short grasses. EnviroLogic referred to these locations as ―Tree” and ―Meadow,” respectively. The Tree site is situated approximately 30 m (98 feet) northeast of the SMWS within a grouping of one-seed juniper and piñon pine trees. The Meadow site is situated approximately 11 m (36 feet) northwest of the SMWS, in vegetation dominated by blue grama and broom snakeweed (*Gutierrezia sarothrae*).

SWCA is now responsible for the management of the SMWS and the maintenance, summation, and distribution of the data collected at this station. The following sections summarize the data collected since SWCA assumed responsibility for SMWS in April 2008. SWCA prepared a report, ―South Mountain Weather Station: History, Data Summaries, and Continued Operation,” summarizing the data collected from 2006 and 2007 by EnviroLogic, and submitted that report to the Steering Committee. This report is available at the Restoration Institute's website (http://www.nmfwri.org/). The data displayed below in Figure 5.2 through Figure 5.8 are summarized as monthly averages of relevant meteorological data.

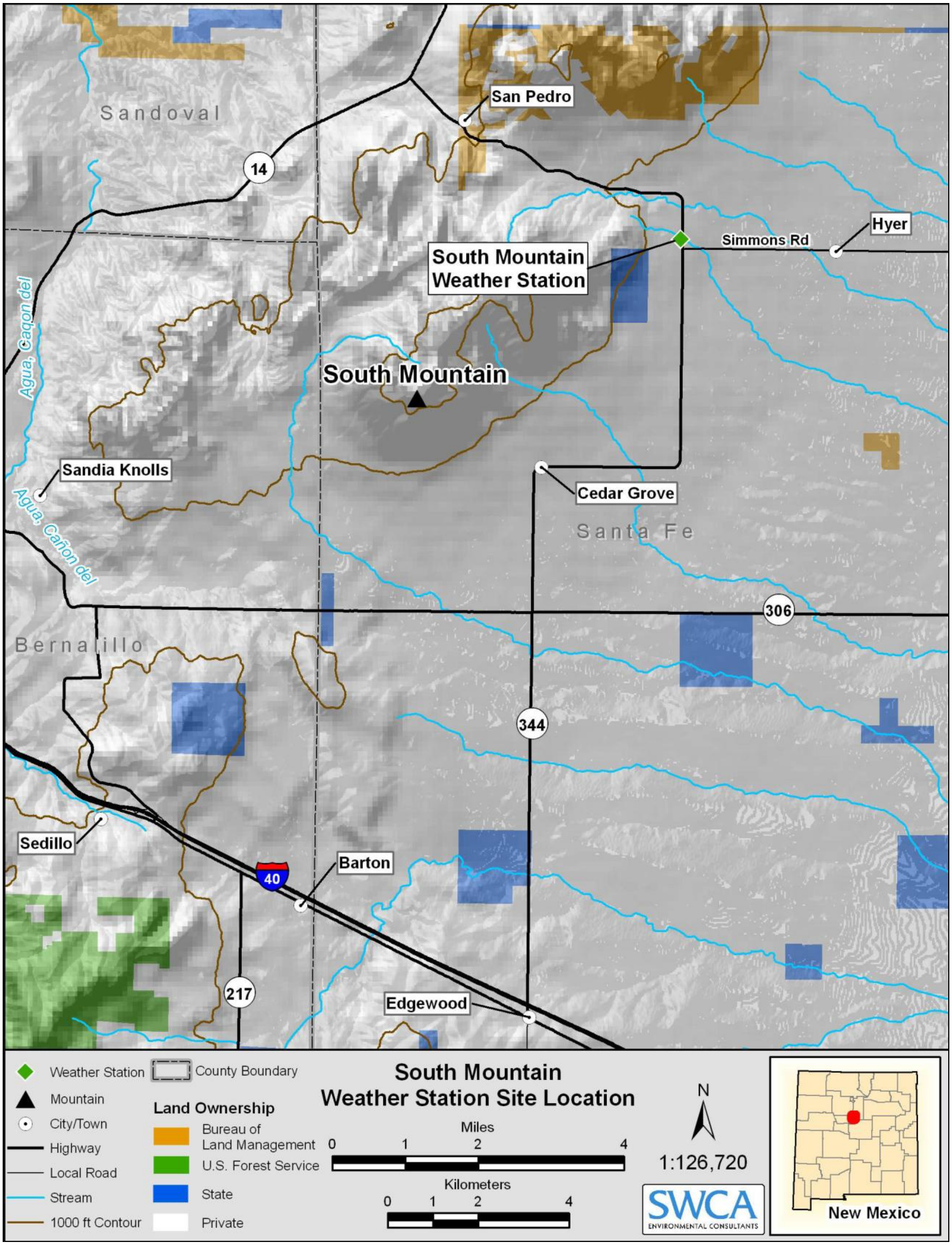


Figure 5.1. Location of the South Mountain Weather Station.

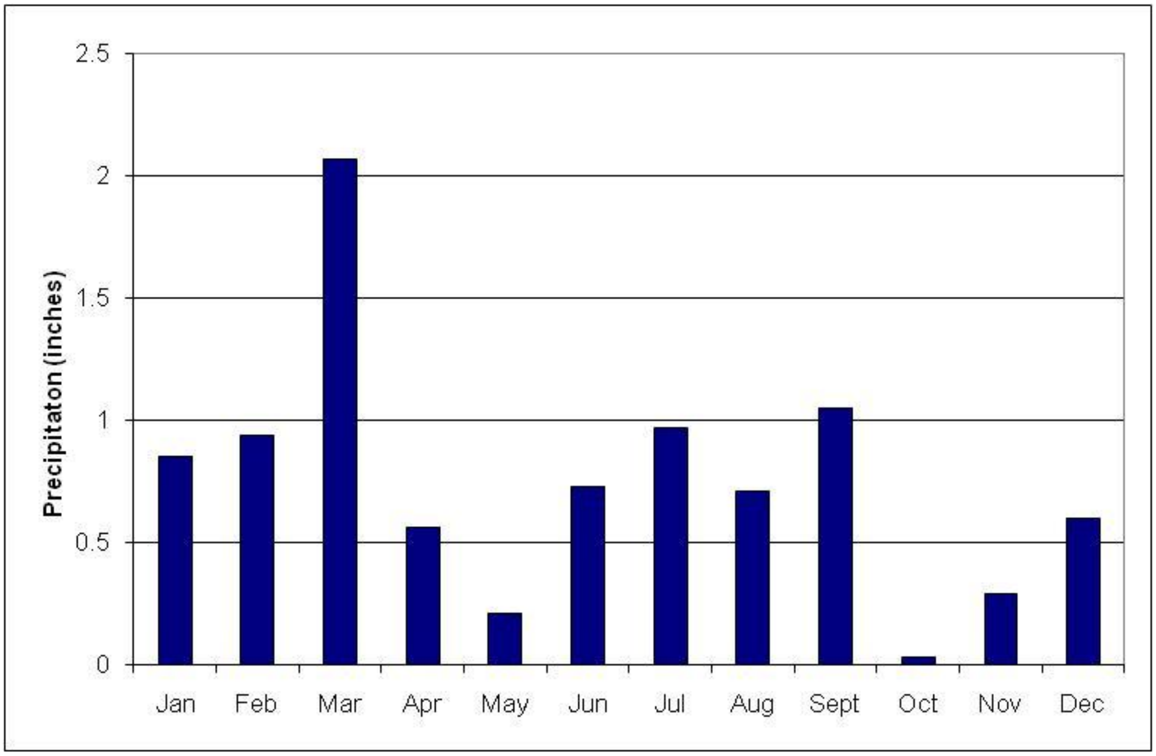


Figure 5.2. Graph showing monthly total rainfall over the course of 2010.

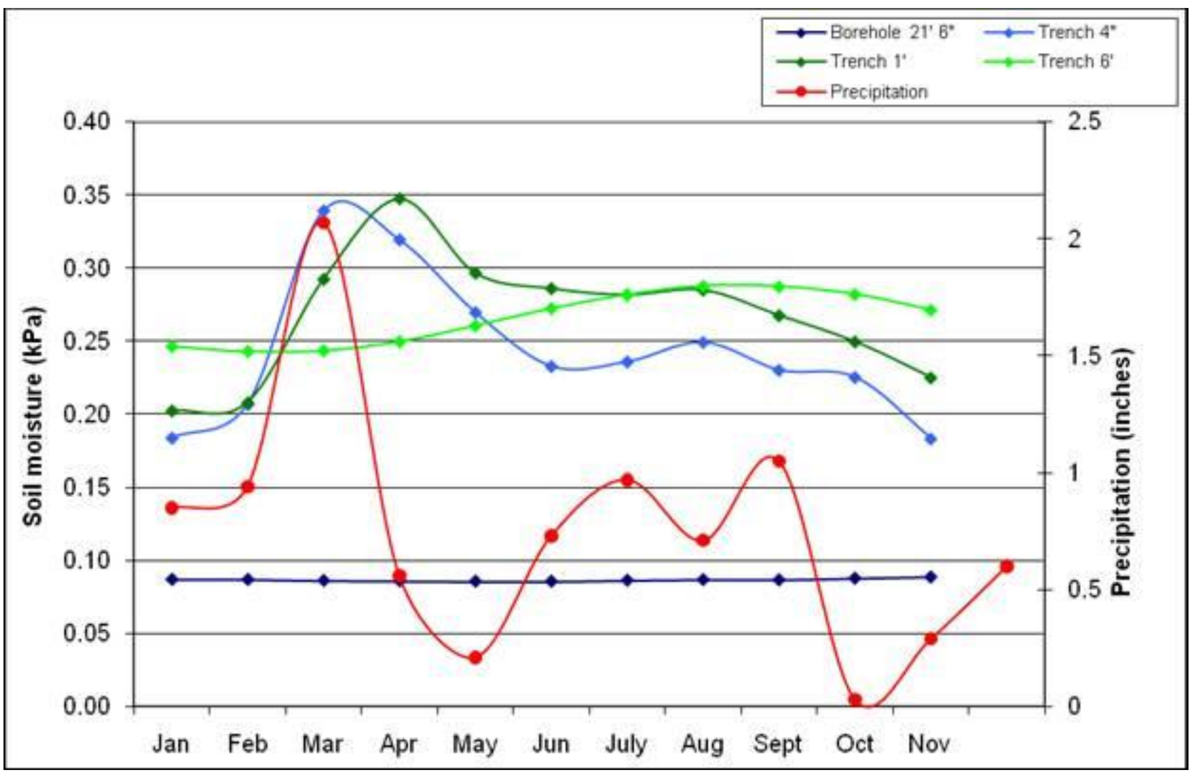


Figure 5.3. Tree site monthly average soil moisture and total precipitation for 2010.

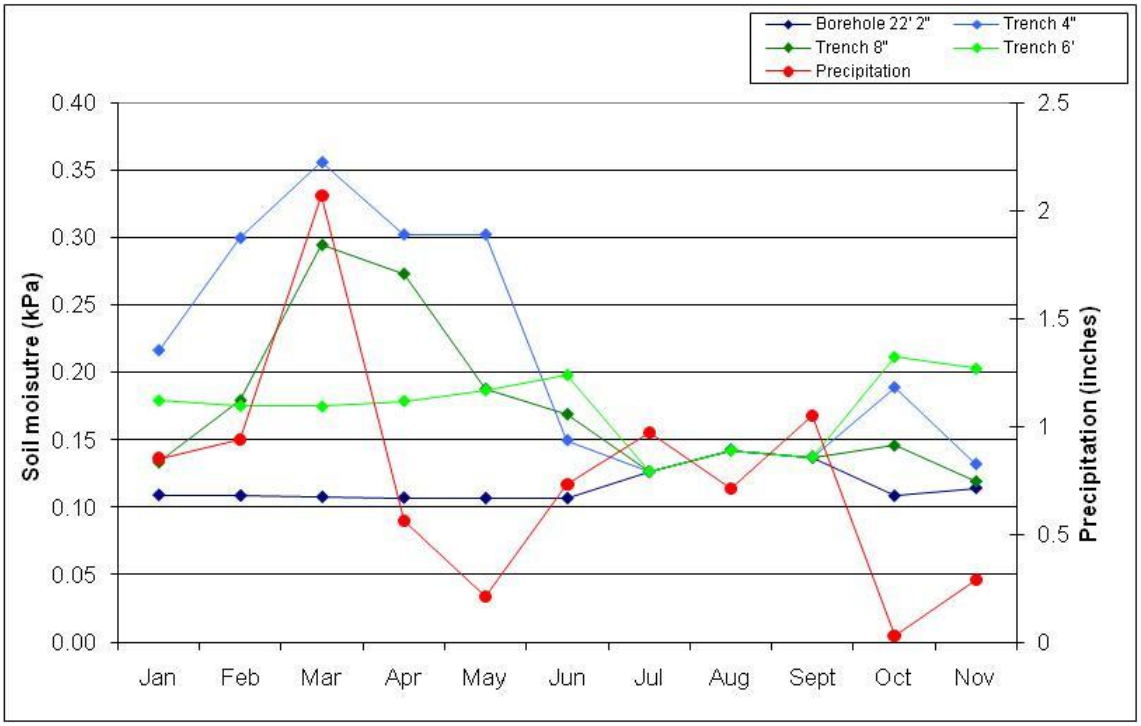


Figure 5.4. Meadow site average monthly soil moisture and total precipitation for 2010.

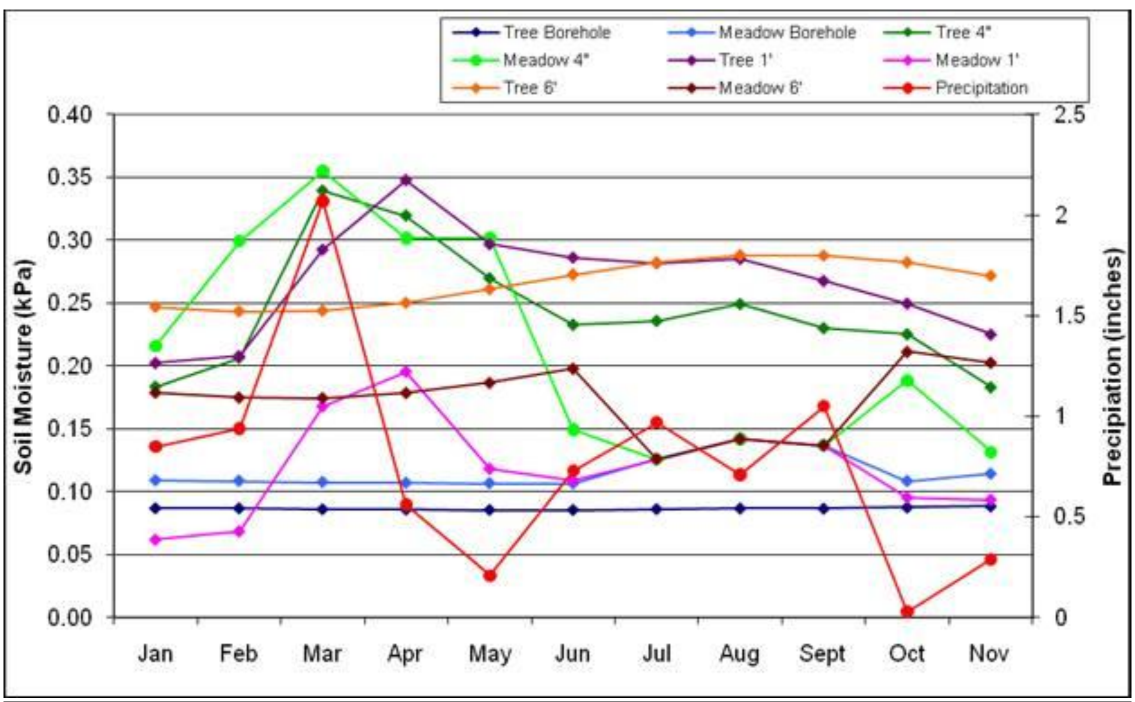


Figure 5.5. Tree and Meadow site average monthly soil moisture and total precipitation for 2010.

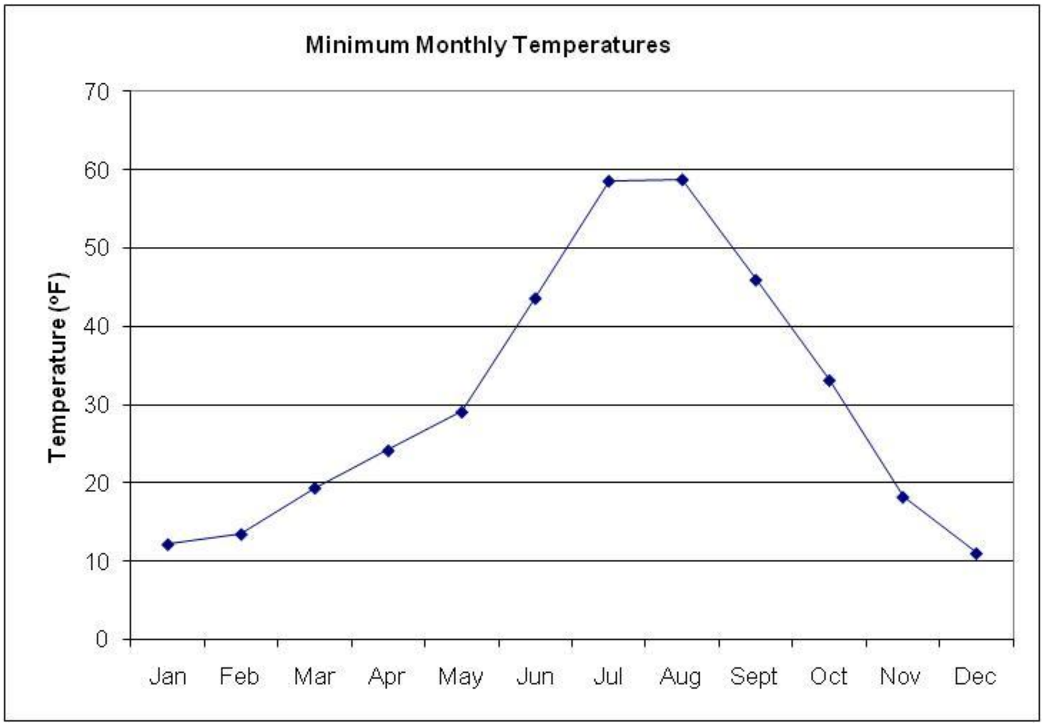


Figure 5.6. Minimum monthly temperature experienced at the SMWS during 2010.

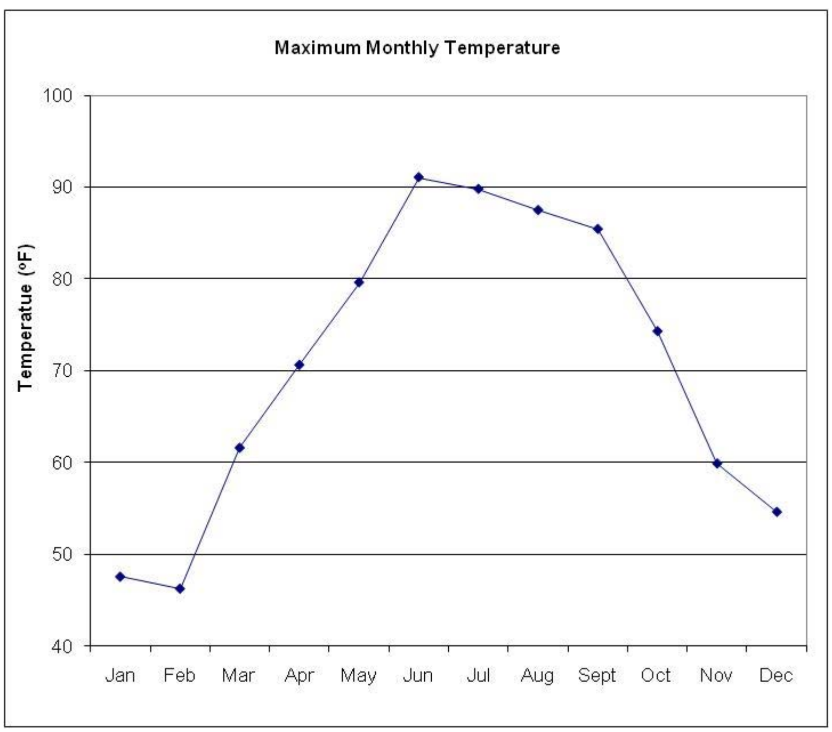


Figure 5.7. Maximum monthly temperature experienced at the SMWS during 2010.

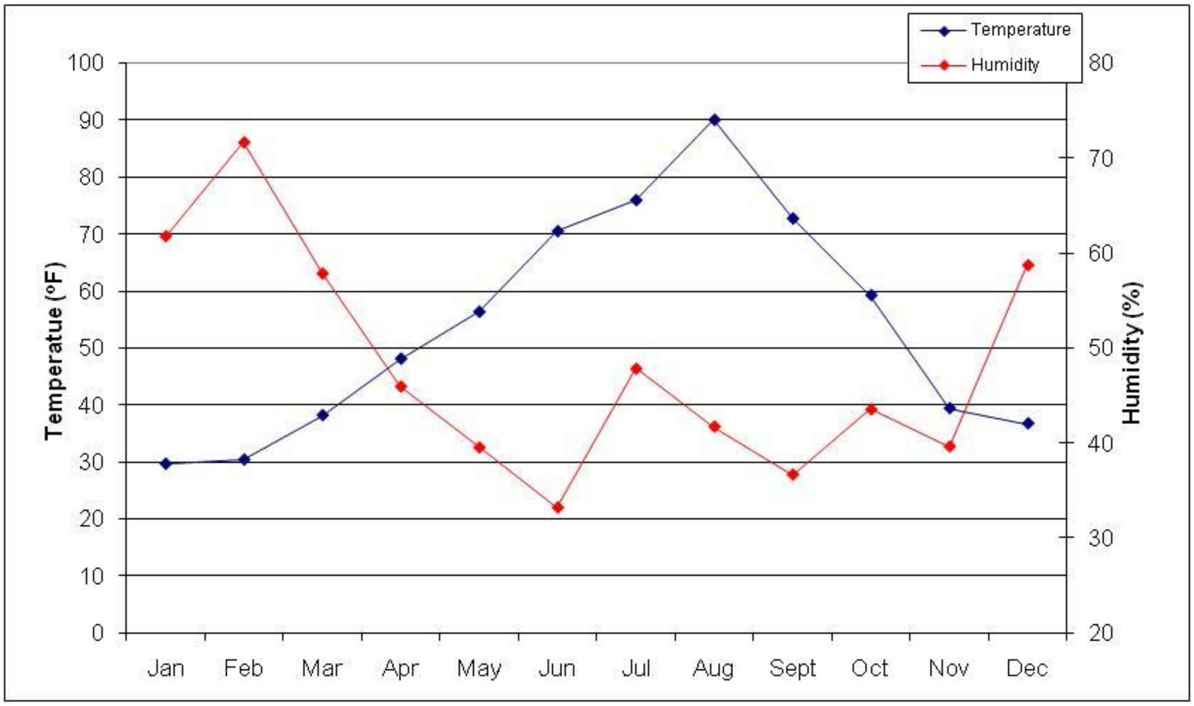


Figure 5.8. Daily average temperature and relative humidity over the course of 2010.

6.0 PLANNED MONITORING FOR 2011 (YEAR FOUR)

SWCA will continue the current monitoring efforts for year four of this project, including the operation of the SMWS. Forest thinning treatments have been implemented and will be completed by early 2011. SWCA will then begin to monitor post-thinning treatment conditions in late spring and fall 2011 and continue to manage the SMWS and the weather data.

Post-wildfire monitoring will continue through spring 2011, and perhaps beyond depending on the availability of funding. At this time, SWCA does not anticipate changes in the current monitoring designs or methods for forest thinning monitoring. Reporting will include regular monthly progress reports and a 2011 Annual Report.

7.0 ACKNOWLEDGEMENTS AND CONTRIBUTORS

The New Mexico Water Trust Board provided funding for this project. The Estancia Basin Watershed Health, Restoration and Monitoring Steering Committee provided oversight and coordination of this project, in cooperation with the New Mexico Forest and Watershed Restoration Institute and New Mexico State Forestry. Deirdre Tarr of the Claunch-Pinto Soil and Water Conservation District and Joe Zebrowski from the New Mexico Forest and Watershed Restoration Institute provided valuable oversight and support. The Bouton, Candelaria, Kelly, Mitchell, Neff, Salazar, Sanchez, Vigil, and Wester families kindly offered access to their land to conduct forest thinning and monitoring research, along with the Chilili Land Grant, Manzano Land Grant, and the Manzano Mountain Retreat. New Mexico State Forestry, the U.S. Forest Service, the U.S. Geological Survey, and the Claunch-Pinto, East Torrance, and Edgewood soil and water conservation districts have all provided advice and support. Vernon Kohler and Kelly Archuleta from the Claunch-Pinto and Edgewood soil and water conservation districts have been assisting with field data collections. Mike Matush from the New Mexico State Environment Department, Surface Water Quality Bureau, has been helpful in designing and installing stream monitoring stations. The Estancia Basin Water Planning Committee also contributed funding to install the new Chilili ponderosa pine monitoring study site. Joseph Fluder is the SWCA project manager and provided guidance, oversight, and quality assurance. In addition to the authors, SWCA staff Ryan Trollinger, Justin Elza, and Alayne Szymanski contributed to the preparation of this report.

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APPENDIX A
ANIMAL SPECIES RECORDED FROM FOREST MONITORING WILDLIFE STUDY PLOTS

Appendix B. Animal Species Recorded from Forest Monitoring Wildlife Study Plots

Common Name	Genus	Species	Code
Bird Species			
American crow	*Corvus*	*branchyrhynchos*	*AMCR*
American robin	*Turdus*	*migratorius*	*AMRO*
Ash-throated flycatcher	*Myarchus*	*cinerascens*	*ATFL*
Bewick's wren	*Thryomanes*	*bewickii*	*BEWR*
Black-capped chickadee	*Poecile*	*atricapillus*	*BCCH*
Black-throated gray warbler	*Dendroica*	*nigrescens*	*BTYW*
Broad-tailed hummingbird	*Cynanthus*	*latirostris*	*BTAH*
Chipping sparrow	*Spizella*	*passerina*	*CHSP*
Common raven	*Corvus*	*corvax*	*CORA*
Common nighthawk	*Chordeiles*	*minor*	*CONI*
Cooper's hawk	*Accipiter*	*cooperii*	*COHA*
Dark-eyed junco	*Junco*	*hyemalis*	*DEJU*
Finch sp.	*Carpodacus*	sp.	UNKN
Grace's warbler	*Dendroica*	*graciae*	*GRWA*
Hermit thrush	*Catharus*	*guttatus*	*HETH*
Juniper titmouse	*Baeolophus*	*ridgwayi*	*JUTI*
Orange crowned warbler	*Vermivora*	*celata*	*OCWA*
Mountain chickadee	*Poecile*	*gambeli*	*MOCH*
Mourning dove	*Zenaida*	*macroura*	*MODO*
Northern flicker	*Colaptes*	*auratus*	*NOFL*
Plumbeous vireo	*Vireo*	*plumbeus*	*PLVI*
Pinyon jay	*Gymnorhinus*	*cyanocephalus*	*PIJA*
Pygmy nuthatch	*Sitta*	*pygmaea*	*PYNU*
Red-breasted nuthatch	*Sitta*	*canadensis*	*RBNU*
Red crossbill	*Loxia*	*curvirostra*	*RECR*
Red-tailed hawk	*Buteo*	*jamaicensis*	*RTHA*
Ruby-crowned kinglet	*Regulus*	*calendula*	*RCKI*
Rufous hummingbird	*Selasphorus*	*rufus*	*RUHU*
Sharp-shinned hawk	*Accipiter*	*striatus*	*SSHA*
Spotted towhee	*Pipilo*	*maculatus*	*SPTO*
Stellar's jay	*Cyanocitta*	*stelleri*	*STJA*
Swainson's thrush	*Catharus*	*ustulatus*	*SWTH*
Townsend's solitaire	*Myadestes*	*townsendii*	*TOSO*
Turkey vulture	*Cathartes*	*aura*	*TUVU*
Western bluebird	*Sialia*	*mexicana*	*WEBL*
Western meadowlark	*Sturnella*	*neglecta*	*WEME*
Western scrub jay	*Aphelocoma*	*californica*	*WESJ*
White-breasted nuthatch	*Sitta*	*carolinensis*	*WBNU*
Wild turkey	*Meleagris*	*gallopavo*	*WITU*
Yellow-rumped warbler	*Dendroica*	*coronate*	*YRWA*
Rodent Species			
Colorado chipmunk	*Tamias*	*quadrivittatus*	*TAQU*
Deer mouse	*Peromyscus*	*maniculatus*	*PEMA*
Mexican vole	*Microtus*	*mexicanus*	*MIME*
Ord’s kangaroo rat	*Dipodomys*	*ordii*	*DIOR*
Pinyon mouse	*Peromyscus*	*truei*	*PETR*
Silky pocket mouse	*Perognathus*	*flavus*	*PEFL*
White-footed mouse	*Peromyscus*	*leucopis*	*PELE*
White-throated woodrat	*Neotoma*	*albigula*	*NEAL*

APPENDIX B
LIST OF PLANT SPECIES ENCOUNTERED ON FOREST MONITORING STUDY PLOTS. TAXONOMY AND NAMES FOLLOW USDA PLANTS DATABASE (2010)

Appendix A. List of Plant Species Encountered on Forest Monitoring Study Plots

Group/Family	Genus	Species	Code	Common Name	Form	Life History
Gymnosperms						
Cypressaceae	*Juniperus*	*deppeana*	JUDE2	alligator juniper	tree	perennial
Cypressaceae	*Juniperus*	*monosperma*	JUMO	one-seed juniper	tree	perennial
Cypressaceae	*Juniperus*	*scopulorum*	JUSC2	Rocky Mountain juniper	tree	perennial
Pinaceae	*Pinus*	*edulis*	PIED	piñon pine	tree	perennial
Pinaceae	*Pinus*	*ponderosa*	PIPO	ponderosa pine	tree	perennial
Angiosperms: Dicotyledons						
Amaranthaceae	*Amaranthus*	*albus*	AMAL	prostrate pigweed	forb	annual
Amaranthaceae	*Amaranthus*	*cruentus*	AMCR	red amaranth	forb	annual
Amaranthaceae	*Amaranthus*	*palmeri*	AMPA	carelessweed	forb	annual
Anacardiaceae	*Rhus*	*trilobata*	RHTR	skunkbush sumac	shrub	perennial
Apiaceae	*Lomatium*	*dissectum*	LODI	fernleaf biscuitroot	forb	perennial
Asteraceae	*Achillea*	*millefolium*	ACMI2	common yarrow	forb	perennial
Asteraceae	*Ageratina*	*herbacea*	AGHE5	fragrant snakeroot	forb	perennial
Asteraceae	*Anaphalis*	*margaritacea*	ANMA	western pearly everlasting	forb	perennial
Asteraceae	*Antennaria*	*microphylla*	ANMI3	forb	perennial	
Asteraceae	*Artemisia*	*carruthii*	ARCA14	littleleaf pussytoes	forb	perennial
Asteraceae	*Artemisia*	*dracunculus*	ARDR4	taragon	forb	perennial
Asteraceae	*Artemisia*	*frigida*	ARFR4	prairie sagewort	forb	perennial
Asteraceae	*Artemisia*	*ludoviciana*	ARLU	white sagebrush	forb	perennial
Asteraceae	*Aster*	*falcatus*	ASFA3	Russian milkvetch	forb	annual
Asteraceae	*Bahia*	*dissecta*	BADI	ragleaf bahia	forb	annual
Asteraceae	*Brickellia*	*eupatorioides*	BREU	false boneset	forb	perennial
Asteraceae	*Brickellia*	*grandiflora*	BRGR	tasselflower brickel	forb	perennial
Asteraceae	*Chaetopappa*	*ericoides*	CHER2	rose heath	forb	perennial
Asteraceae	*Circium*	*undulatum*	CIUN	wavyleaf thistle	forb	annual
Asteraceae	*Conyza*	*canadensis*	COCA5	Canadian horseweed	forb	annual
Asteraceae	*Erigeron*	*divergens*	ERDI4	spreading fleabane	forb	biennial
Asteraceae	*Erigeron*	*flagellaris*	ERFL	trailing fleabane	forb	biennial
Asteraceae	*Erigeron*	*formosissimus*	ERFO3	beautiful fleabane	forb	perennial
Asteraceae	*Erigeron*	*speciosus*	ERSP4	aspen fleabane	forb	perennial
Asteraceae	*Erigeron*	*divergens*	ERDI4	spreading fleabane	forb	biennial
Brassicaceae	*Lepidium*	*alyssoides*	LEAL4	mesa pepperwort	forb	perennial
Brassicaceae	*Schoenocrambe*	*linearifolia*	SCLI12	slimleaf plainsmustard	forb	perennial
Brassicaceae	*Sisymbrium*	*altissimum*	SIAL2	tall tumblemustard	forb	annual/biennial

Group/Family	Genus	Species	Code	Common Name	Form	Life History
Cactaceae	*Cylindropuntia*	*imbricata*	CYIM2	tree cholla	succulent	perennial
Cactaceae	*Echinocereus*	*viridiflorus*	ECVI2	nylon hedgehog cactu	succulent	perennial
Cactaceae	*Escobaria*	*vivipera*	ESVI2	spinystar cactus	succulent	perennial
Cactaceae	*Grusonia*	*clavata*	GRCL	club cholla	succulent	perennial
Cactaceae	*Opuntia*	*engelmannii*	OPEN3	cactus apple	succulent	perennial
Cactaceae	*Opuntia*	*phaeacantha*	OPPH	tulip pricklypear	succulent	perennial
Cactaceae	*Opuntia*	*macrorhiza*	OPMA2	twistspine pricklypear	succulent	perennial
Cactaceae	*Opuntia*	*polyacantha*	OPPO	plains pricklypear	succulent	perennial
Caryophyllaceae	*Cerastium*	*brachypodum*	CEBR3	shortstalk chickweed	forb	perennial
Caryophyllaceae	*Cerastium*	*nutans*	CENU2	nodding chickweed	forb	annual/perennial
Caryophyllaceae	*Pseudostellaria*	*jamesiana*	PSJA2	tuber starwort	forb	perennial
Caryophyllaceae	*Silene*	*scouleri*	SISC7	simple campion	forb	perennial
Chenopodiaceae	*Chenopodium*	*capitatum*	CHCA4	blight goosefoot	forb	perennial
Chenopodiaceae	*Chenopodium*	*fremontii*	CHFR3	Fremont's goosefoot	forb	perennial
Chenopodiaceae	*Chenopodium*	*graveolens*	CHGR2	fetid goosefoot	forb	annual
Chenopodiaceae	*Chenopodium*	*incanum*	CHIN2	mealy goosefoot	forb	annual
Chenopodiaceae	*Chenopodium*	*leptophyllum*	CHLE4	narrowleaf goosefoot	forb	annual
Chenopodiaceae	*Salsola*	*kali*	SAKA	Russian thistle	forb	annual
Euphorbiaceae	*Chamaesyce*	*albomarginata*	CHAL11	whitemargin sandmat	forb	perennial
Euphorbiaceae	*Chamaesyce*	*chaetocalyx*	CHCHC3	bristlecup sandmat	Forb	perennial
Euphorbiaceae	*Chamaesyce*	*fendleri*	CHFE3	threadstem sandmat	forb	perennial
Euphorbiaceae	*Chamaesyce*	*serpyllifolia*	CHSE6	thymeleaf sandmat	forb	annual
Fabaceae	*Astragalus*	*mollisimus*	ASMO7	wooly locoweed	forb	perennial
Fabaceae	*Astragalus*	*nuttallianus*	ASNU4	smallflowered milkvetch	forb	perennial
Fabaceae	*Dalea*	*purpurea*	DAPU5	purple prairie clove	forb	perennial
Fabaceae	*Hoffmannseggia*	*drepanocarpa*	HODR	sicklepod holdback	forb	perennial
Fabaceae	*Lotus*	*wrightii*	LOWR	Wright's deervetch	forb	perennial
Fabaceae	*Lupinus*	*kingii*	LUKI	King's lupine	forb	perennial
Fabaceae	*Psoralidium*	*tenuiflorum*	PSTE5	slimflower scurfpea	forb	perennial
Fabaceae	*Robinia*	*neomexicana*	RONE	New Mexico locust	tree	perennial
Fabaceae	*Vicea*	*americana*	VIAM	American vetch	forb	perennial
Fagaceae	*Quercus*	*gambelii*	QUGA	Gambel's oak	tree	perennial
Fagaceae	*Quercus*	*grisea*	QUGR3	gray oak	tree	perennial
Fagaceae	*Quercus*	*turbinella*	QUTU2	Sonoran scrub oak	tree	perennial
Geraniaceae	*Geranium*	*caespitosum*	GECAF	Fremont's geranium	forb	perennial
Hydrophyllaceae	*Nama*	*dichotomum*	NADI	wishbone fiddleleaf	forb	annual
Lamiacea	*Agastache*	*pallidiflora*	AGPA	Bill Williams Mountain giant hyssop	forb	perennial

Group/Family	Genus	Species	Code	Common Name	Form	Life History
Lamiacea	*Hedeoma*	*drummondii*	HEDR	Drummond's false pen	forb	annual
Lamiacea	*Salvia*	*subincisa*	SASU7	sawtooth sage	forb	annual
Linaceae	*Linum*	*aristatum*	LIAR3	bristle flax	forb	annual
Linaceae	*Linum*	*vernale*	LIVE2	Chihuahuan flax	forb	annual
Malvaceae	*Spheralcea*	*angustifolia*	SPAN3	copper globemallow	forb	perennial
Malvaceae	*Spheralcea*	*coccinea*	SPCO	scarlet globemallow	forb	perennial
Malvaceae	*Spheralcea*	*fendleri*	SPFE	Fendler's globemallow	forb	perennial
Malvaceae	*Spheralcea*	*grossulariifolia*	SPGR2	gooseberryleaf globe	forb	perennial
Malvaceae	*Spheralcea*	*hastulata*	SPHA	spear globemallow	forb	perennial
Monotropaeae	*Monotropa*	*hypopithys*	MOHY3	pinesap	forb	perennial
Nyctaginaceae	*Mirabilis*	*linearis*	MILI3	narrowleaf four o'clock	forb	perennial
Nyctaginaceae	*Mirabilis*	*oxybaphoides*	MIOX	smooth spreading four o'clock	forb	perennial
Oleaceae	*Menodora*	*scabra*	MESC	rough menodora	forb	perennial
Onagraceae	*Oenothera*	*caespitosa*	OECA10	tufted evening primrose	forb	annual
Oxalidaceae	*Oxalis*	*violacea*	OXVI	violet woodsorrel	forb	perennial
Papaveraceae	*Argemone*	*squarrosa*	ARSQ	hedgehog pricklypoppy	forb	perennial
Onagraceae	*Oenothera*	*caespitosa*	OECA10	tufted evening primrose	forb	annual
Polemoniaceae	*Ipomopsis*	*aggregata*	IPAG	scarlet gilia	forb	annual
Polygonaceae	*Eriogonum*	*alatum*	ERAL4	winged buckwheat	forb	annual
Polygonaceae	*Eriogonum*	*annuum*	ERAN4	annual buckwheat	forb	annual
Polygonaceae	*Eriogonum*	*microthecum*	ERMI4	slender buckwheat	shrub	perennial
Polygonaceae	*Eriogonum*	*racemosum*	ERRA3	redroot buckwheat	forb	perennial
Polygonaceae	*Eriogonum*	*wrightii*	ERWR	bastardsage	forb	perennial
Polygonaceae	*Polygonum*	*douglasii*	PODO4	Douglas' knotweed	forb	annual
Portulacaceae	*Phemeranthus*	*brevicaulis*	PHBR15	dwarf fameflower	forb	perennial
Portulacaceae	*Portulaca*	*oleracea*	POOL	little hogweed	forb	annual
Portulacaceae	*Portulaca*	*pilosa*	POPI3	kiss me quick	forb	annual
Primulaceae	*Androsace*	*septentrionalis*	ANSE4	pygmyflower rockjasmine	forb	annual
Ranunculaceae	*Thalictrum*	*fendleri*	THFE	Fendler's meadow-rue	forb	perennial
Santalaceae	*Comandra*	*umbellata*	COUM	bastard toadflax	forb	perennial
Primulaceae	*Androsace*	*septentrionalis*	ANSE4	pygmyflower rockjasmine	forb	annual
Scrophulariaceae	*Castilleja*	*integra*	CAIN14	wholeleaf Indian paintbrush	forb	perennial
Scrophulariaceae	*Cordylanthus*	*tenuis*	COTE3	slender birdbeak	forb	annual
Scrophulariaceae	*Cordylanthus*	*wrightii*	COWR2	Wrights bird's beak	forb	annual
Scrophulariaceae	*Penstemon*	*barbatus*	PEBA2	beardlip penstemon	forb	perennial

Group/Family	Genus	Species	Code	Common Name	Form	Life History
Scrophulariaceae	*Penstemon*	*jamesii*	PEJA	James' beardtongue	forb	perennial
Scrophulariaceae	*Penstemon*	*oliganthus*	PEOL	Apache beardtongue	forb	perennial
Scrophulariaceae	*Penstemon*	*virgatus*	PEVI4	upright blue beardtongue	forb	perennial
Scrophulariaceae	*verbascum*	*thapsus*	VETH	common mullein	forb	biennial
Solanaceae	*Physalis*	*hederifolia*	PHHE4	ivyleaf groundcherry	forb	perennial
Solanaceae	*Solanum*	*elaeagnifolium*	SOEL	silverleaf nightshade	forb	perennial
Solanaceae	*Solanum*	*triflorum*	SOTR	cutleaf nightshade	forb	perennial
Verbanaceae	*Glandularia*	*bipinnatifida*	GLBIC	Davis Mountain mock vervain	forb	perennial
Verbanaceae	*Verbena*	*macdougalii*	VEMA	MacDougal verbena	forb	annual
Viscaceae	*Phoradendron*	*juniperinum*	PHJU	juniper mistletoe	herb	Perennial/juniper parasite
Viscaceae	*Phoradendron*	*macrophyllum*	PHMA18	Colorado desert mist	herb	perennial
Angiosperms: Monocotyledons						
Agavaceae	*Yucca*	*baccada*	YUBA	banana yucca	succulent	perennial
Agavaceae	*Yucca*	*glauca*	YUGL	soapweed yucca	succulent	perennial
Commelinaceae	*Commelina*	*dianthifolia*	CODI4	birdbill dayflower	forb	perennial
Cyperaceae	*Carex*	*geophila*	CAGE	White Mountain sedge	sedge	perennial
Cyperaceae	*Cyperus*	*esculentus*	CYES	yellow nutsedge	sedge	perennial
Cyperaceae	*Cyperus*	*fendlerianus*	CYFE2	Fendler's flatsedge	sedge	perennial
Liliaceae	*Allium*	*cernuum*	ALCE2	nodding onion	forb	perennial
Poaceae	*Achnatherum*	*robustum*	ACRO7	sleepygrass	grass	perennial
Poaceae	*Alopecurus*	*aequalis*	ALAE	shortawn foxtail	grass	perennial
Poaceae	*Andropogon*	*gerardii*	ANGE	big bluestem	grass	perennial
Poaceae	*Aristida*	*adscensionis*	ARAD	sixweeks threeawn	grass	annual
Poaceae	*Aristida*	*arizonica*	ARAR6	Arizona threeawn	grass	perennial
Poaceae	*Aristida*	*divaricata*	ARDI5	poverty threeawn	grass	perennial
Poaceae	*Aristida*	*purpurea*	ARPU9	purple threeawn	grass	perennial
Poaceae	*Blepharoneuron*	*tricholepsis*	BLTR	pine dropseed	grass	perennial
Poaceae	*Bouteloua*	*aristidoides*	BOAR	needle grama	grass	annual
Poaceae	*Bouteloua*	*curtipendula*	BOCU	sideoats grama	grass	perennial
Poaceae	*Bouteloua*	*gracilis*	BOGR2	blue grama	grass	perennial
Poaceae	*Bromus*	*arvensis*	BRAR5	field brome	grass	annual
Poaceae	*Elymus*	*canadensis*	ELCA4	Canada wildrye	grass	perennial
Poaceae	*Elymus*	*elymoides*	ELEL5	squirreltail	grass	perennial
Poaceae	*Elymus*	*hystrix L.*	ELHY	eastern bottlebrush	grass	perennial
Poaceae	*Eragrostis*	*cilianensis*	ERCI	stinkgrass	grass	annual
Poaceae	*Eragrostis*	*curvula*	ERCU2	weeping lovegrass	grass	annual

Group/Family	Genus	Species	Code	Common Name	Form	Life History
Poaceae	*Eragrostis*	*mexicanus*	ERME	Mexican lovegrass	grass	annual
Poaceae	*Koeleria*	*macrantha*	KOMA	prairie junegrass	grass	perennial
Poaceae	*Lolium*	*perenne*	LOPE	perennial ryegrass	grass	annual
Poaceae	*Lycurus*	*phleoides*	LYPH	common wolfstail	grass	perennial
Poaceae	*Lycurus*	*setosus*	LYSE3	bristly wolfstail	grass	perennial
Poaceae	*Monroa*	*squarrosa*	MOSQ	false buffalograss	grass	annual
Poaceae	*Muhlenbergia*	*minutissima*	MUMI2	annual muhly	grass	annual
Poaceae	*Muhlenbergia*	*montana*	MUMO	mountain muhly	grass	perennial
Poaceae	*Muhlenbergia*	*thurberi*	MUTH	Thurber's muhly	grass	perennial
Poaceae	*Muhlenbergia*	*torreyi*	MUTO2	ring muhly	grass	perennial
Poaceae	*Muhlenbergia*	*richardsonii*	MURI	mat muhly	grass	perennial
Poaceae	*Panicum*	*capillare*	PACA6	witchgrass	grass	annual
Poaceae	*Pascopyrum*	*smithii*	PASM	western wheatgrass	grass	perennial
Poaceae	*Piptatherum*	*micranthum*	PIMI7	littleseed ricegrass	grass	perennial
Poaceae	*Pleuraphis*	*jamesii*	PLJA	James' galleta	grass	perennial
Poaceae	*Poa*	*fendleriana*	POFE	muttongrass	grass	perennial
Poaceae	*Setaria*	*viridis*	SEVI4	green bristlegrass	grass	annual
Poaceae	*Sporobolus*	*cryptandrus*	SPCR	sand dropseed	grass	perennial
Poaceae	*Thinopyrum*	*ponticum*	THPO7	tall wheatgrass	grass	perennial
Non-Vascular Plants						
–	multiple	multiple	MOSS	moss	crypt	perennial
–	multiple	multiple	CRUST	cryptobiotic crust	crypt	perennial

Taxonomy and names follow USDA Plants Database (2010).

Attachments

DVD with all raw data files along with an electronic .pdf version of the report

Addenda

(SMWS quarterly reports)