Climate

Climate Patterns

Summers stay fairly cool in this high mountainous area, with a mean July temperature of 70 to73 degrees F. Rainfall is most frequent in July and August, in the form of short-duration high-intensity storms. The mean January temperature is 32to 34 degrees F, and winters accumulate prolonged snow packs on the mountain peaks. Average annual precipitation is 15 to 18 inches per year (Western Regional Climate Center 2009)

The climate in the Jemez Mountains is influenced by two general patterns. The first is a high-pressure system off the coast of California that produces a general pattern of wet winters and dry summers. The second is an Atlantic sub-tropical high-pressure system that extends into the Gulf of Mexico creating a flow of moist air onto the plains and eastern Rockies throughout the summer, creating the so-called “monsoon” season (Arkell and Richards 1986). The July and August monsoon season is characterized by intense short rainstorms accompanied by thunder and lightning. The climate or weather patterns that occur in the assessment area have a direct relationship to the plant and animal species in the area. The complex terrain in terms of slope, aspect and elevation results in a wide range of microclimates.

The Jemez Springs weather station has a sufficient length of record to establish climatology for the assessment area. The Wolf Canyon and Los Alamos weather stations that lie outside the assessment area at different elevations were also used to help establish the full range of climate variability within the area. The figure (map) in the Air Quality section displays the climate stations in the area, as well as the air quality monitoring sites.

Additionally, there are five Campbell-style meteorological stations operating on the Preserve, along with a NOAA Climate Reference Network (CRN) station. The Preserve’s climate stations collect year-round precipitation (rain and snow), air temperature, wind speed and direction, relative humidity, total solar radiation, and soil temperature and moisture (TDR probes) at three soil depths (data on-line at Preserve web site).

Table 3 shows the period of record for each of the RAWS stations. Data for Jemez Springs was analyzed through 2007 because there is insufficient data available for 2008 from which to compare trends at nearby stations. Los Alamos station data was available prior to 1946, but with significant amounts of missing data, including entire years during the World War II era. Therefore, Los Alamos data is only analyzed after 1946 for precipitation and 1948 for temperature.

Temperature

Average annual temperatures for the past 10, 20, 30, and 50 years are presented in Table 3, as are the coolest and warmest year during the period of record. It is interesting to note that 1991 was the coolest year recorded at both Wolf Canyon and Los Alamos weather stations over the past 50 years. This may have been influenced by the eruption of Mt. Pinatubo in the Philippines in June of that year, however below average temperatures occurred in months both before and after the eruption.

Table 3. Average and extreme temperatures in the Jemez Mountains

Location	Period of Record	Elevation (feet)	Temperature (degrees F)				Coolest (year)	Warmest (year)
			50 yr avg	30 yr avg	20 yr avg	10 yr avg		
Jemez Springs	1914-2007	6,260	52.2	52.6	52.6	53.1	48.3 (1915)	54.9 (2007)
Los Alamos	1948-2008	7,360	48.1	48.3	48.4	49.2	46.1 (1991)	53.6 (1950)
Wolf Canyon	1953-2008	8,220	40.4	40.3	40.2	40.8	38.3 (1991)	43.2 (1954)

Source: Western Regional Climate Center 2009

Each of the three stations shows a warming trend beginning in about 1992, although Los Alamos and Wolf Canyon have leveled off in the past few years. Current temperatures trends are not outside the historic range of variability although in 2007 Jemez Springs recorded its warmest year since 1914. Overall, the Jemez Mountains have experienced significant warming and drying trends over the past 100 years. Data shows summer temperatures increasing faster than winter temperatures, resulting in longer and warmer summer wildfire seasons. Figure 4 shows the warming trend graphically, based on mean annual temperatures since 1914.

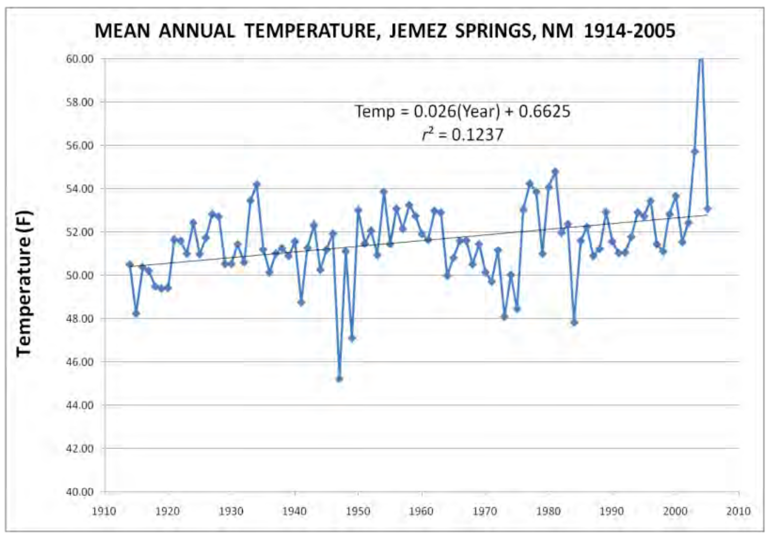

Figure 4. Mean annual temperature for Jemez Springs, 1914-2005

Precipitation

Table 4 summarizes precipitation data. There is a wide range of variability in temperature with periods of drought occurring on a multi-decadal scale. The driest year of record is 1956. The 10-year average is lower than the 20 to 50 year averages, influenced by the drought conditions in the early 2000a. While recent precipitation levels are up, the precipitation trend since 1914 is downward.

Table 4. Average and extreme precipitation in the Jemez Mountains

Location	Period of Record	Elevation (feet)	Precipitation (inches)				Driest (year)	Wettest (year)
			50yr avg	30 yr avg	20 yr avg	10 yr avg		
Jemez Spgs	1914-2007	6,260	16.8	17.6	16.8	14.7	6.2 (1956)	28.7 (1957)
Los Alamos	1946-2008	7,360	18.5	18.7	18.3	16.0	6.8 (1956)	28.4 (1952)
Wolf Cyn.	1953-2008	8,220	23.2	24.2	23.6	21.4	11.2 (1956)	34.0 (1990 & 91)

Source: Source: Western Regional Climate Center 2009

Wind

The prevailing winds in this area are from the southwest to northwest but may shift to easterly during the summer monsoon (rainy) season. Local winds are strongly influenced by terrain variations and may be channeled by canyons. Prevailing winds have driven wildfires in this area toward the northeast, and could drive a crown fire from the forests in the assessment area into Los Alamos and Bandelier National Monument.

Climate Change

In its 2007 report, the Intergovernmental Panel on Climate Change found that “warming of the climate system is unequivocal” (IPCC 2007). The Panel reported that “most of the observed increase in global average temperatures since the mid-20th century is very likely due to the observed increase in anthropogenic (human-caused) greenhouse gas concentrations” (IPCC 2007). Exactly how these changes will translate to the local level remains at the cutting edge of science. Global climate change models are pointing toward warming and drying for the U.S. Southwest (IPCC 2007). However, the models are not yet able to account for climatic variability from factors such as the El Nino/La Niña oscillations (unusually warm or cool Pacific Ocean currents that affect climate), the Southwest monsoon, and the Pacific Decadal Oscillation (a pattern of Pacific climate variability that shifts phases at least every 20 to 30 years).

A study published by The Nature Conservancy (Enquist and Gori 2008) looked at recent climate change in New Mexico. A baseline period from 1961to 1990 was compared to a 15-year period from 1991to 2005 and a six year period from 2000-2005. In both cases the Jemez Mountains were found to be warmer and drier than the baseline. The results should be viewed with some caution, however, because of an extreme drought during the 2000 to 2005 period. Also, while the Jemez Mountains were at the extreme end of warm and dry during the 1991to 2005 period, large areas of New Mexico were wetter than the baseline period.

The long-term temperature record for Jemez Springs (Table 4) indicates an overall warming trend in spite of significant periods of variability. Examination of the precipitation trend (Table 3 and Figure 4), on the other hand, raises the question of whether the recent drying (1984 to 2004) is due to global climate change or a reflection of the apparently cyclical nature of precipitation in this area.

Geological and Paleontological Resources

Geological resources include groundwater, caves, paleontology (fossils), and geologic hazards such as earthquakes and landslides. The New Mexico Bureau of Geology and Mineral Resources recently completed the geologic mapping (at the 1:2,400 7 ½ º quad scale) of most of the project area (Gardner et al. 2006; Goff et al. 2005; Goff et al. 2006a; Goff et al. 2006b; Kelley et al. 2003; Kempter et al. 2007; Lynch et al. 2005; Osburn et al. 2002). These maps, along with the statewide geological map (Stoeser et al. 2005) and the Jemez Mountain geologic map (Smith et al. 1970) were used as the basis of this assessment.

The Jemez Mountains were formed by volcanic activity beginning in the early Tertiary period and extending to the Pliocene. The volcanoes intruded up through earlier sediments, shale, sandstone and limestone. The oldest rocks in the area are much older pre-Cambrian-age granitics. The volcanic rock formations, pyroclastic rhyolites, andesite and basalt flows are interbedded in places with coarse gravel. Fans of eroded material from the rising volcanoes skirt the lower slopes of the Jemez Mountains. The pre-volcanic sedimentary rocks are exposed largely in the southwest portion of the assessment area along the main stem Jemez River valley, and then up the deeply eroded valleys of San Antonio Creek and Rio Guadalupe (Kelley and Dunbar 2008).

The Valles Caldera was created about 1.25 million years ago during an explosive volcanic event or series of events that obliterated the earlier Toledo Caldera and widely deposited the Upper Bandelier Tuff, a rhyolitic ash flow that overlayed older volcanic deposits around the rim of the caldera (Muldavin and Tonn 2003). The Redondo Peak dome followed the creation of the caldera by about 27,000 years. Rhyolitic domes such as South Mountain, Cerro la Jara and Cerro del Medio formed long after caldera creation (0.5 million years ago) along the caldera ring fracture (U.S. Geological Survey 1970). The uplifting volcanic domes created a dense array of faulting that profoundly affected valley development and channel morphology. Episodes of lake formation occurred such as when the East Fork of the Jemez River was blocked by landslides. The valley fill of the caldera created a complex of lake, alluvium and landslide deposits, including mudstones, siltstones, and conglomerates of pumice, tuff and lava.

The head waters of the East Fork Jemez River, San Antonio River, and Redondo Creek are within the boundaries of the Preserve, and the caldera rim encircles the Preserve's outstanding valleys, such as Valle Grande, Valle San Antonio, Valle Jaramillo, Valle Seco, and Redondo Meadow. The valleys are broad grassy plains with moderate gradients of about 0.5 percent. Surface deposits are mostly alluvium from surrounding hills, but also low ridges of lacustrine sediment, particularly in Valle San Antonio.

Caves and Karst

Two geologic units have the potential to contain caves within the assessment area – the Madera limestone and the Tertiary lava flows. The Madera is known to contain extensive solution caves outside of the study area, but none are mapped within the study area. The lava flows present within the study area are known to contain lava tubes outside the study area, but no tubes have been identified within the assessment area.

The desired or reference conditions for caves are found in *The Federal Cave Resources Protection Act of 1988* and in regulations at 36 CFR 290. The Act and regulations require protection of significant caves, and define *significant* caves based on biotic, cultural, mineralogic, paleontologic, geologic, hydrologic, recreational, educational, or scientific characteristics or values. All of the caves on the National Forest should be reviewed to determine if they meet the significance criteria, and significant cave resources should be protected when ground-disturbing projects are planned and implemented (Forest Service Manual, FSM 2800).

Groundwater

The U.S. Geological Survey does not identify major aquifers in the assessment area (Robson and Banta 1995). However, the New Mexico Office of the State Engineer identifies approximately 312 wells in the area, so groundwater is present (OSE 2009). Well depths range from 8 to 660 feet, with the average depth to groundwater of 160 feet.

There was extensive research on the numerous natural hot springs in the study area. A description of the geothermal energy resource is included in the minerals section.

The desired or reference conditions for groundwater are described in New Mexico State Regulations (standards) for groundwater resources.

Geological Disturbances

At least five earthquakes with a magnitude between 2 and 3 occurred between 1962 and 1998 along the Nacimiento Fault zone, which lies along the southwestern edge of the assessment area (Sanford et al. 2000). Magnitude 3 can be felt by residents but would not cause damage. There has been no seismic activity with a magnitude of 2 or greater within the Valle Caldera during this period. There is a 10 percent probability than an earthquake with a maximum horizontal ground motion of 8 to 10 percent of earth’s gravity will occur in the area within the next 50 years (Sanford et al 2000). A horizontal ground acceleration of 20 percent of earth’s gravity can do considerable damage, for example, chimneys broken at roof lines, but not major destruction.

Mass wasting or landslide potential (moderate, high, severe hazard ratings) occurs on approximately 60,000 acres (28 percent) of the 210,000-acre assessment area, according to the Terrestrial Ecosystem Unit (TEU) Inventory of the Santa Fe National Forest (US Forest Service 1993). Figure 5 shows these potential mass wasting areas from the TEU inventory, along with 87 old landslides (Quaternary age, less than 1.8 million years old) that cover 4,273 acres. The old landslides were identified during the geological mapping of the assessment area.

Volcanic activity potential is low, despite the volcanic activity in the past that formed the Valle Caldera and much of the Jemez Mountains (Kelley and Dunbar 2008).

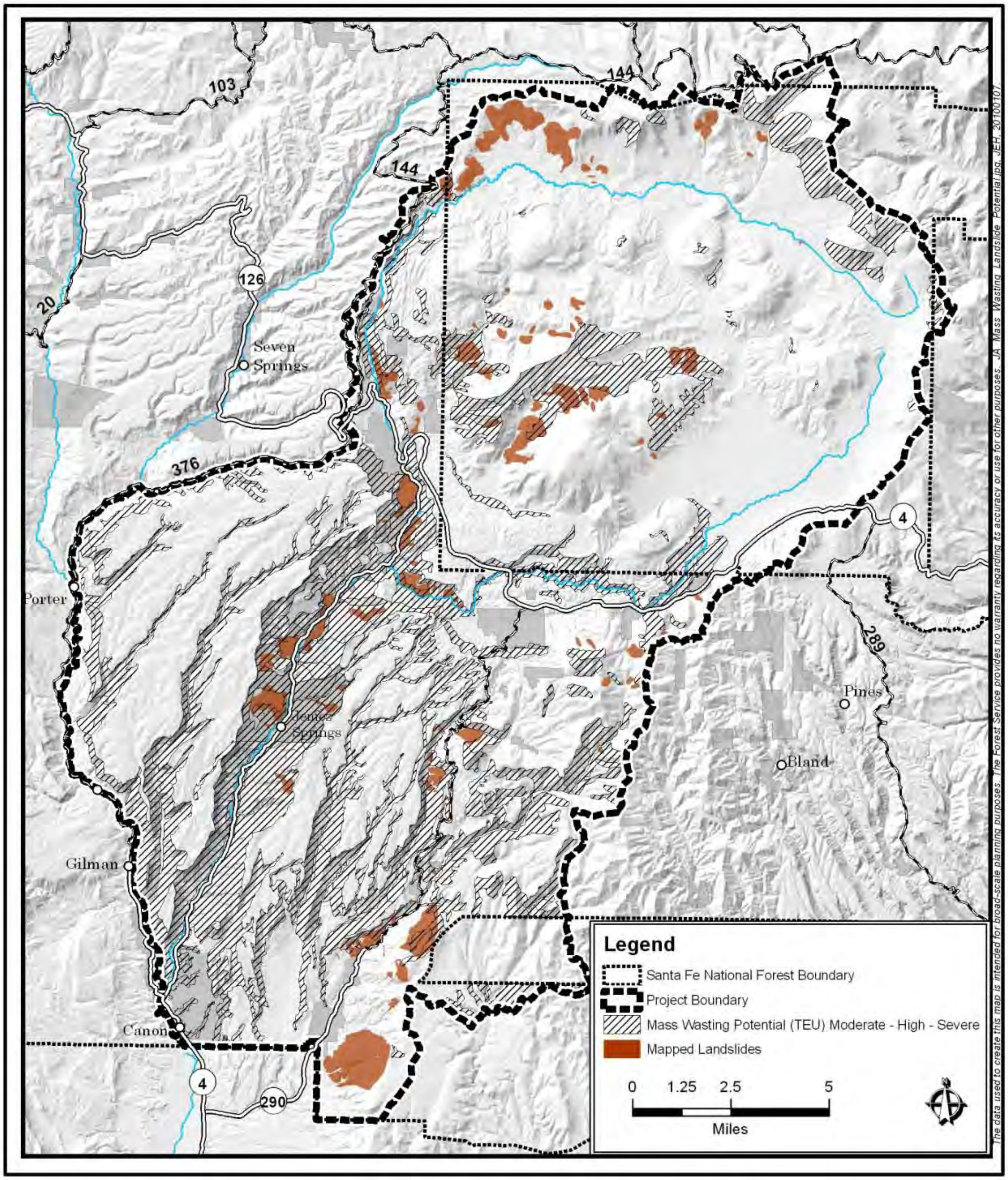

Figure 5. Mass wasting potential and past landslides

Paleontology (Fossils)

Numerous fossilized plants, invertebrates and vertebrates are located throughout the assessment area. The vertebrate fossil sites are considered to be significant under the Paleontological Resource Protection Act. Within the area, the vertebrate sites range from shark teeth and other vertebrate remains in the Pennsylvanian Madera Formation (about 300 million years old) to the fossil horse found in the Pleistocene stream terraces along the Jemez River (about 20 million years old).

For planning purposes, agency policy recommends using the Probable Fossil Yield Classification system (US Forest Service 2009a, US Geological Survey 2009a). Of the five classes, class 1 has the lowest potential to contain fossils and class 5 has the highest potential. These classes are described in the table below, and shown spatially in the following figure. Probable or potential fossil yield classification values were assigned to geologic map units in the assessment area based on empirical data gathered through research and field surveys by Forest Service geologists, as shown in Table 5.

Table 5. Probable fossil yield classes and geologic map units

Probable Fossil Yield Class	Geologic Map Unit
1 – Igneous or metamorphic rocks not likely to contain fossils	6 units
2 – Sedimentary and volcanoclastic units not likely to contain fossils	3 units (Quaternary alluvium, Bandelier Tuff, and Yeso)
3 – Fossiliferous sedimentary units in which the fossils vary in significance, abundance, and predictability	4 units (Madera, San Andres/ Glorieta Formations, Chinle Group, and piedmont alluvium). The Madera Formation limestone contains common invertebrate marine fossils. The piedmont alluvium has at least one significant fossil but it appears such fossils are rare. The other units have no recorded fossils.
4 – Highly fossiliferous units which regularly and predictably produce significant fossils, with a low potential for human or natural degradation	0 units, because the entire assessment area has a high potential for human or natural disturbance
5 – Highly fossiliferous units which regularly and predictably produce significant fossils, with a significant potential for human or natural degradation	1 unit (Abo Formation). This unit has yielded numerous vertebrate fossils

Reference conditions (management direction) for paleontological resources management are contained within the *Paleontological Resources Protection Act (Public Law 111-11, subtitle D).* Regulations to implement this law are still being developed by the Department of Interior and Department of Agriculture. Forest Service directives require protection of paleontological resources during land management activities, and formation of scientific and educational partnerships for managing paleontological geological resources (FSM 2882; US Geological Survey 2009a).

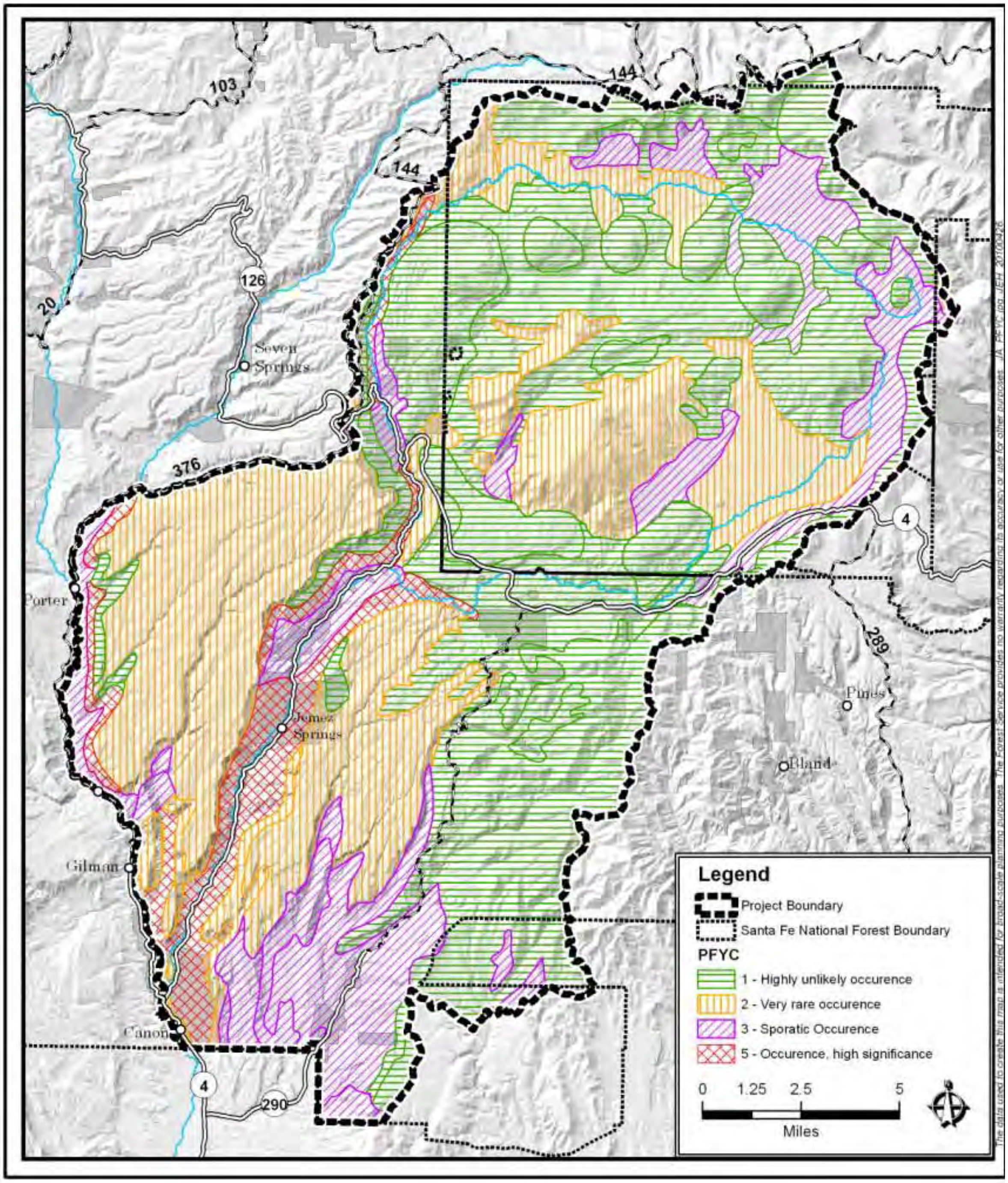

Figure 6. Potential fossil yield map units

Soil

Introduction and Methodologies

This chapter evaluates and compares the existing and reference conditions of the soil resource within the assessment area. Soil loss and erosion hazard were two key factors used to compare existing soil conditions with the reference conditions. Reference conditions for soil erosion and loss are the range of variability in potential natural soil loss rates. The existing and reference conditions are based primarily on the soil inventory database for the National Forest (Terrestrial Ecosystem Unit Inventory), which describes potential, natural, current and tolerance soil loss rates as well as relative erosion hazard. This assessment also used soil condition analyses contained in several NEPA documents for range allotments, such as those for San Diego, Vallecitos, V-Double Slash, Cebolla-San Antonio, and Ponderosa. Refer to the range section of this report for more about the grazing allotments.

Soil Types

Soils in the assessment area are formed about equally from: (1) volcanic ash flows and lavas, and (2) sandstones, siltstones, shales, and carbonates. Soil conditions are influenced by many factors, including parent material (geology), slope and aspect. The higher elevation forests have deeper, moister soils with more organic matter and are fair growing environments. The mesa tops made from largely sedimentary rock have more arid soils with profound clay layers in the subsurface. The montane hillslopes are also fairly harsh environments. The steeper hillslopes tend to have shallower soils. The more granite-based soils in the area are sandy, more erodible and less fertile. The soils in the higher elevations of this Jemez River Watershed (in the Preserve) have more volcanic ash material that generally increases their productivity. Soil creep and sheetwash are very common given the concentrated high intensity rainfall here. Table 6 and Figure 7 show the distribution of soil taxonomic groups in the assessment area.

Soil Erosion and Loss

Soil loss rate is an important factor affecting soil condition and long-term productivity and sustainability. A comparison of current soil loss rate to a “tolerance” reference condition provides a means of classifying soil condition as Satisfactory, Unsatisfactory, and Unsuited. Satisfactory soil loss is where the soil loss rate (tons/acre/year) is less than the soil tolerance (T) threshold defined for each soil type (TEUI unit). Soils in the assessment area are generally in satisfactory condition as their loss rates are below the tolerance (upper threshold). This indicates that long-term soil productivity is being maintained. Small, localized areas show unsatisfactory soil loss rates, due to human-caused disturbances such as: camping, driving and parking, and in areas where cattle use is concentrated. In these localized bare soil areas, soil compaction and erosion are a concern, due to loss of top soil, organic matter, and soil productivity. Excess soil erosion loss rates often lead to excess stream sedimentation. Some soil types are classified as “unsuited” because they are inherently unstable; a condition that land managers cannot change. Historically (pre-European settlement), and without human-caused disturbances, soil loss would probably have been in satisfactory soil loss condition where it is not unsuited (inherently unstable).

Table 6. Distribution of soil taxonomic groups in the assessment area

Soil Class	Acres	Percent
Eutric Glossoboralfs	40,517	19.6
Andic Dystrochrepts	35,059	17.0
Typic Eutroboralfs	30,080	14.5
Typic Ustorthents	26,624	12.9
Mollic Eutroboralfs	14,046	6.8
Andeptic Udorthents	11,682	5.7
Cumulic Haplaquolls	11,854	5.7
Typic Haplustalfs	11,223	5.4
Pachic Argiborolls	5,262	2.5
Mollic Vitrandepts	4,305	2.1
Entic Cryandepts	2,606	1.3
Typic Ustochrepts	2,710	1.3
Aquic Ustifluvents	2,407	1.2
Pachic Cryoborolls	2,448	1.2
Lithic Haplustalfs	2,314	1.1
Typic Cryochrepts	1,545	0.7
Dystric Cryochrepts	968	0.5
Typic Cryoboralfs	580	0.3
Lithic Udorthents	237	0.1
Typic Ustifluvents	238	0.1
Pachic Paleborolls	33	0.0

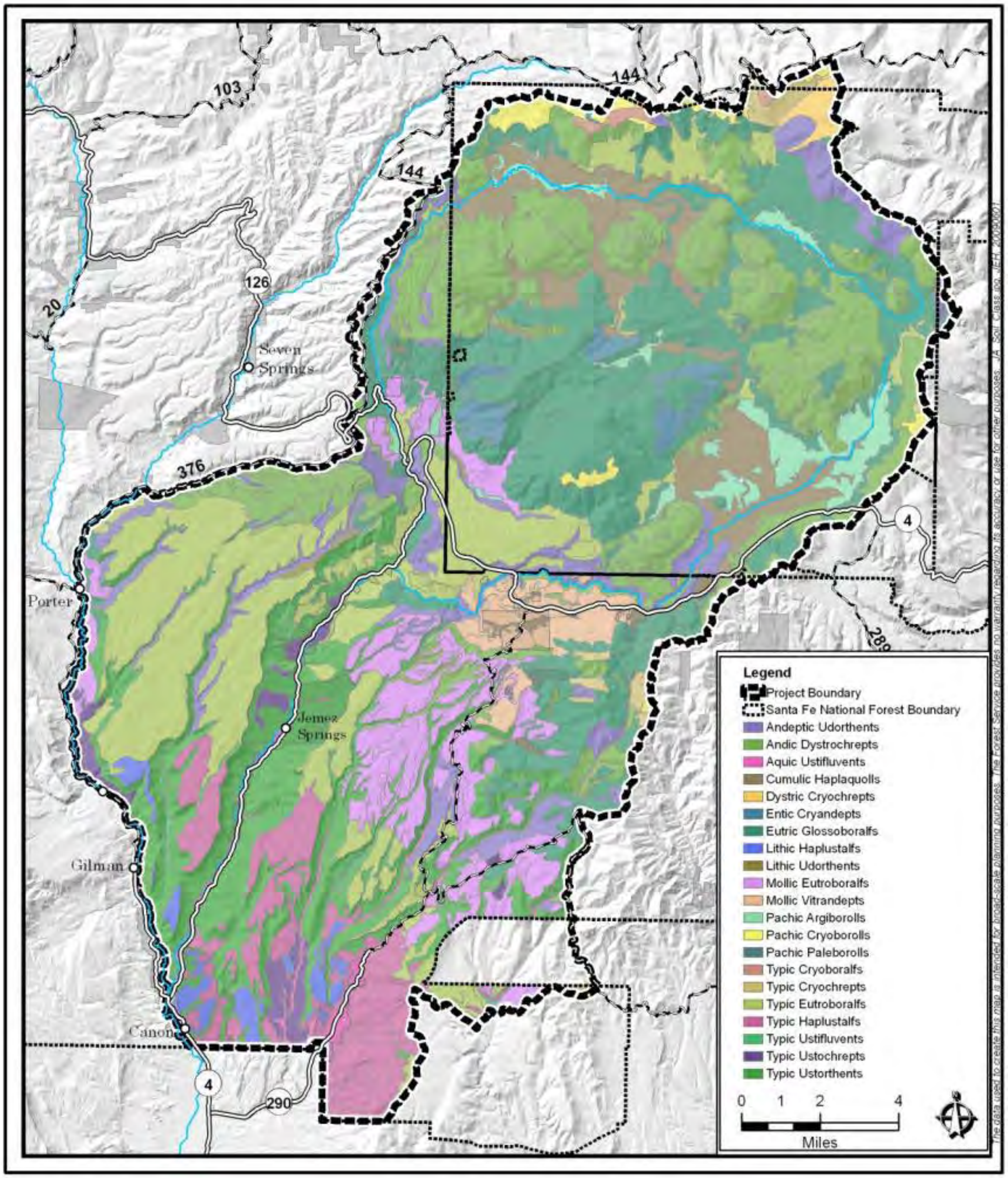

Figure 7. Distribution of soil taxonomic groups (soil types)

Based on the soil analysis, past NEPA analyses, monitoring, and field observations, the piñon-juniper woodlands have the greatest amount of localized unsatisfactory soil loss, or impaired soils approaching the unsatisfactory soil loss level. The worst conditions occur where the piñon-juniper canopy cover approaches or exceeds about 40 percent, resulting in reduced herbaceous understory vegetation, a high amount of bare soil, accelerated soil erosion, and loss of surface organic matter. In these portions of the woodlands, soil erosion and loss are outside their natural range of variability and at risk of not maintaining long-term soil productivity. Where this unsatisfactory soil loss condition occurs, the soil is unable to provide favorable ecosystem and habitat diversity conditions and sustain species that rely on this woodland habitat for survival. It reduces the soil's ability to nourish and support natural tree and plant growth and ecosystem resilience.

The majority of the assessment area is in a satisfactory soil loss condition, particularly in the ponderosa pine, mixed conifer, aspen and riparian vegetation, other than where bare soil patches occur as a result of recreational, vehicular, or livestock uses. Higher elevation forest types have the greatest amount of soil in satisfactory condition and have a higher capacity to maintain long-term soil productivity.

Livestock grazing contributes to reducing herbaceous vegetative ground cover, which contributes to accelerated soil loss, soil compaction and declined soil productivity (especially during periods of drought). However, the extent and amount of current livestock grazing in the assessment area is relatively low, managed within Forest Plan standards and is not impairing long-term soil productivity. Grazing pastures have been removed from riparian areas, although cattle are allowed to trail through riparian areas to get from one pasture to another.

In addition to land management activities such as tree harvesting and public recreation activities such as off-road vehicle use, roads contribute the most to loss of soil productivity and impacts to water quality. The 2008 travel management analysis process identified approximately 400 miles of roads and trails on the National Forest land in the assessment area. These excess roads and trails contribute to the long-term loss of soil productivity and channeling sediment runoff into streams. Most roads in the area are unsurfaced, primitive dirt roads with little or no drainage control. Many roads run along canyon bottoms, and criss-cross drainage channels. The travel management analysis shows that most of these roads pose a risk to water quality, soil, wildlife, and other resources. Density of Forest Service roads in the area averages 2 to 3 miles per square mile, although the number of unauthorized roads and trails doubles that density.

Erosion hazard is a rating given to soils based on a number of attributes such as inherent soil and terrain properties, defined in the agency's Terrestrial Ecosystem Inventory database. Erosion hazard indicates the chance of soil loss exceeding threshold rates as a result of complete removal of vegetation and topsoil. Current erosion hazard is estimated to be equal to historic erosion hazard, and is not compared to a historic or reference hazard rating.

The biggest cause of severe erosion and loss of productivity is high-severity wildfire, as it consumes the vegetation and organic layer of the soil and results in excess erosion rates. Maintaining a protective layer of vegetation is essential in reducing soil erosion and maintaining productivity. Thus, if a soil classified as having a moderate or severe erosion hazard, and a high-intensity fire consumes the vegetation on that soil, on-site erosion may is likely to exceed tolerable limits. Approximately 97 percent of the soils in the assessment area are rated as moderate to severe erosion hazard. These soils have a moderate to high probability of lowering site productivity when vegetation is removed or killed in a fire. In these vulnerable areas, the post-fire runoff of topsoil, soil litter and organic matter, woody material and ash, can wreck havoc on the natural and human environment downstream. The economic costs for rehabilitation of the environment and residential communities would also be exorbitant. The more live and dead fuel there is, the longer the residence time of a fire on the soil and the more severe the effects of the fire will be. For example, a deep layer of needles, branches and logs generally supports long fire residence times which may result in significant impacts to soil, runoff, and the vegetation community (Ice 2004).

Figure 8 and Table 7show the extent of the erosion hazard ratings in the assessment area. Figure 9 and Table 8 show where moderate and severe soil erosion hazard occurs in areas that support crown fire behavior, indicating the areas at most risk of watershed degradation following wildfires.

Table 7. Soil erosion hazard ratings and percent of assessment area

Erosion Hazard	Percent & (Acres)
Severe	48% (97,218)
Moderate	51% (103,491)
Slight	0% (237)
Unknown	1% (5,818)

Table 8. Risk of severe soil loss following high-severity crown fire, by watershed

6th Code Watershed	Watersheds in Assessment Area (acres)	Crown Fire Risk (acres)	Crown Fire & Erosion Hazard Risk (acres)	Crown Fire & Erosion Hazard Risk (% of watershed)
Rio Guadalupe	14,456	3,472	1,512	10
Virgin Canyon	11,447	2,855	1,076	9
Church Cyn- Jemez River	23,310	6,978	3,418	15
Canon de la Canada	14,411	2,288	975	7
Vallecita Ck	26,662	8,894	5,956	22
Outlet San Antonio Ck	14,801	8,269	6,325	43
Sulfur Ck	16,079	8,744	7,485	47
Headwaters San Antonio Ck	36,217	16,079	11,511	32
East Fork Jemez River	38,036	16,208	9,789	26

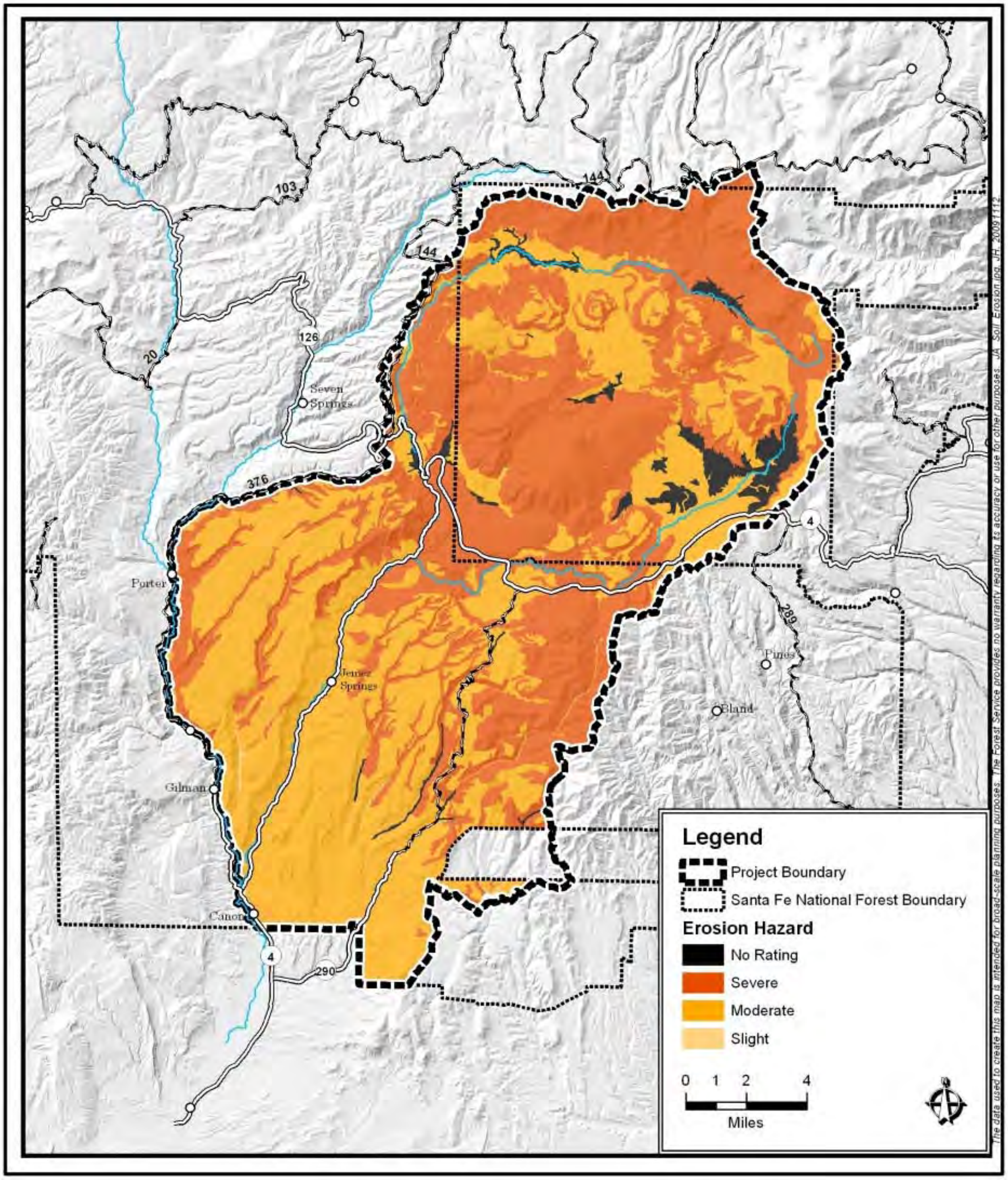

Figure 8. Soil erosion hazard ratings

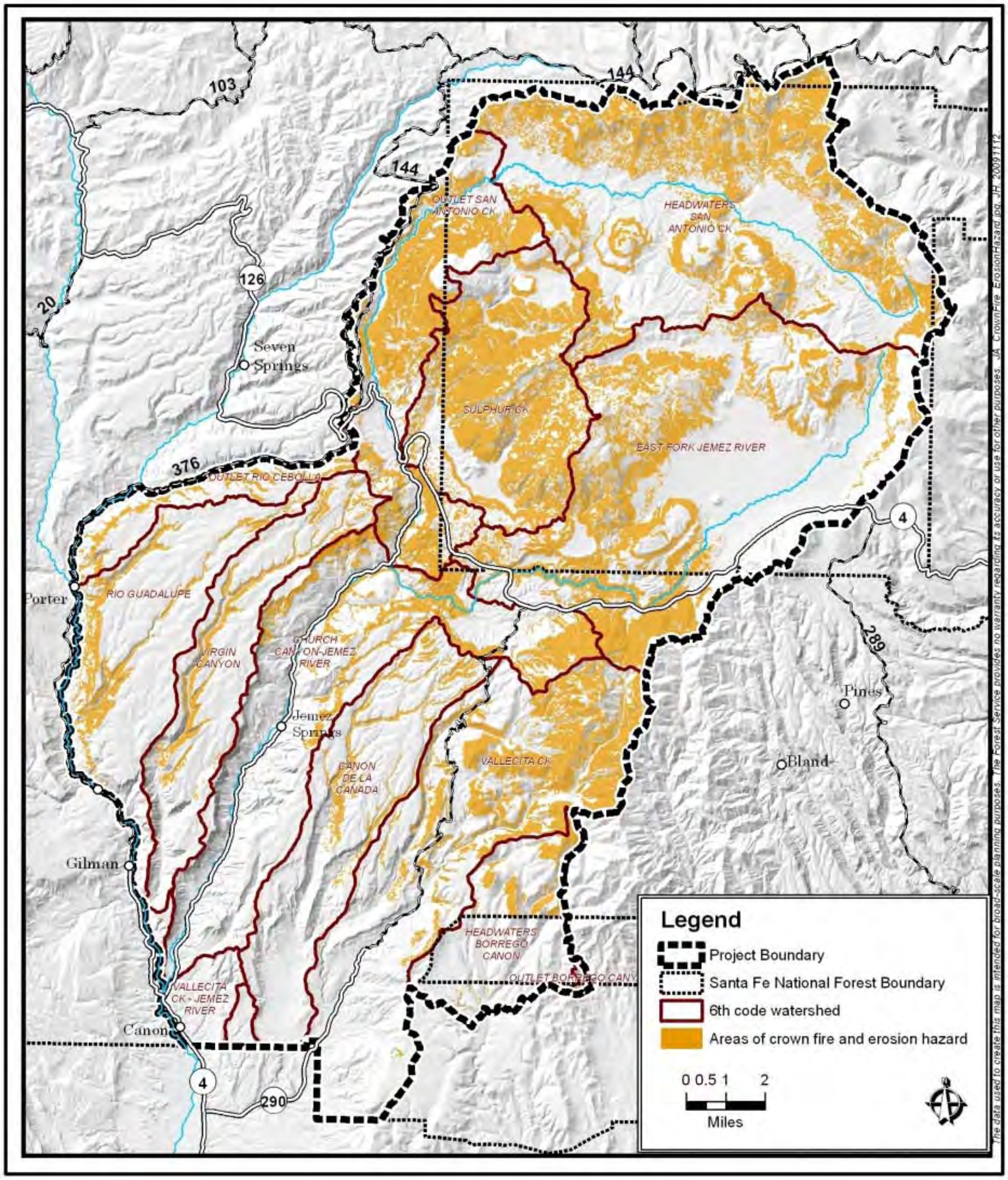

Figure 9. Areas of high crown fire risk and moderate to severe erosion hazard

Water

Introduction and Methodologies

This section evaluates and compares the existing and reference conditions of water resources within the assessment area. It describes stream flows, channel morphology and water quality, which are all strongly influenced by the geology, soils, and climate patterns previously described in this assessment report. Additional information about streams and water quality are described in the Fisheries and Aquatic Habitat section of this report.

Information for this report was primarily derived from comprehensive stream condition inventory reports and hydrologic condition assessments completed by the Santa Fe National Forest and available on their website at http://www.fs.fed.us/r3/sfe/fish/fishreports.htm. These reports include the following: Rio Guadalupe Stream Inventory Report, 2006; Upper and Middle Jemez River Watershed Assessment, 2005; San Antonio Creek Stream Inventory Report, 2005; Rio Guadalupe Hydrologic Condition Assessment, 2004; Rio Cebolla Stream Inventory Report, 2003; and East Fork Jemez River Stream Inventory Report, 2002. Water quality data and information on impaired (non-attainment) stream reaches was obtained from the New Mexico Environment Department, Surface Water Quality Bureau's Clean Water Act 303d-305b report, 2008 to 2010, online at http://www.nmenv.state.nm.us/swqb/303d-305b/2008-2010. Stream flow data gathered by stream gauges on the Jemez River, Rio Guadalupe drainages, and Redondo Creek is from the U.S. Geological Survey website http://waterdata.usgs.gov/nm/nwis/rt. Existing conditions within the Preserve was from stream surveys and field observations made by hydrologists in 2007 to2009.

The assessment area is primarily comprised of the Upper and Middle Jemez River watersheds (5^{th} hydrologic code). This report particularly focuses on conditions in the headwaters of the Jemez River watersheds, which strongly influence watershed and stream conditions downstream. Figure 10 displays the 6^{th} code watersheds and Figure 11 displays the major streams (by name) in the assessment area.

Stream Flow

The headwaters of the Jemez River and most of its tributaries begin in the Preserve, on volcanic domes and slopes of the caldera rim (US Geological Survey 1970, 2008, 2009). These areas are drained largely by swale-like draws that typically lack active scour channels. Surface flow is infrequent and present as dispersed wet areas and seepy ground. With few exceptions the upland slopes of the caldera are hydrologically connected with the valley bottoms only though gullied swales or degraded first order draws that dissect large alluvial and colluvial fan deposits that skirt the base of the slopes. Exceptions to this pattern are the fault-oriented valleys of Redondo Creek and Rito de los Indios, which contained steep gradient perennial streams with cobble and boulder-dominated beds. Because of their confined valleys, there is considerable influence from roads, which constrain the channels and deliver sediment.

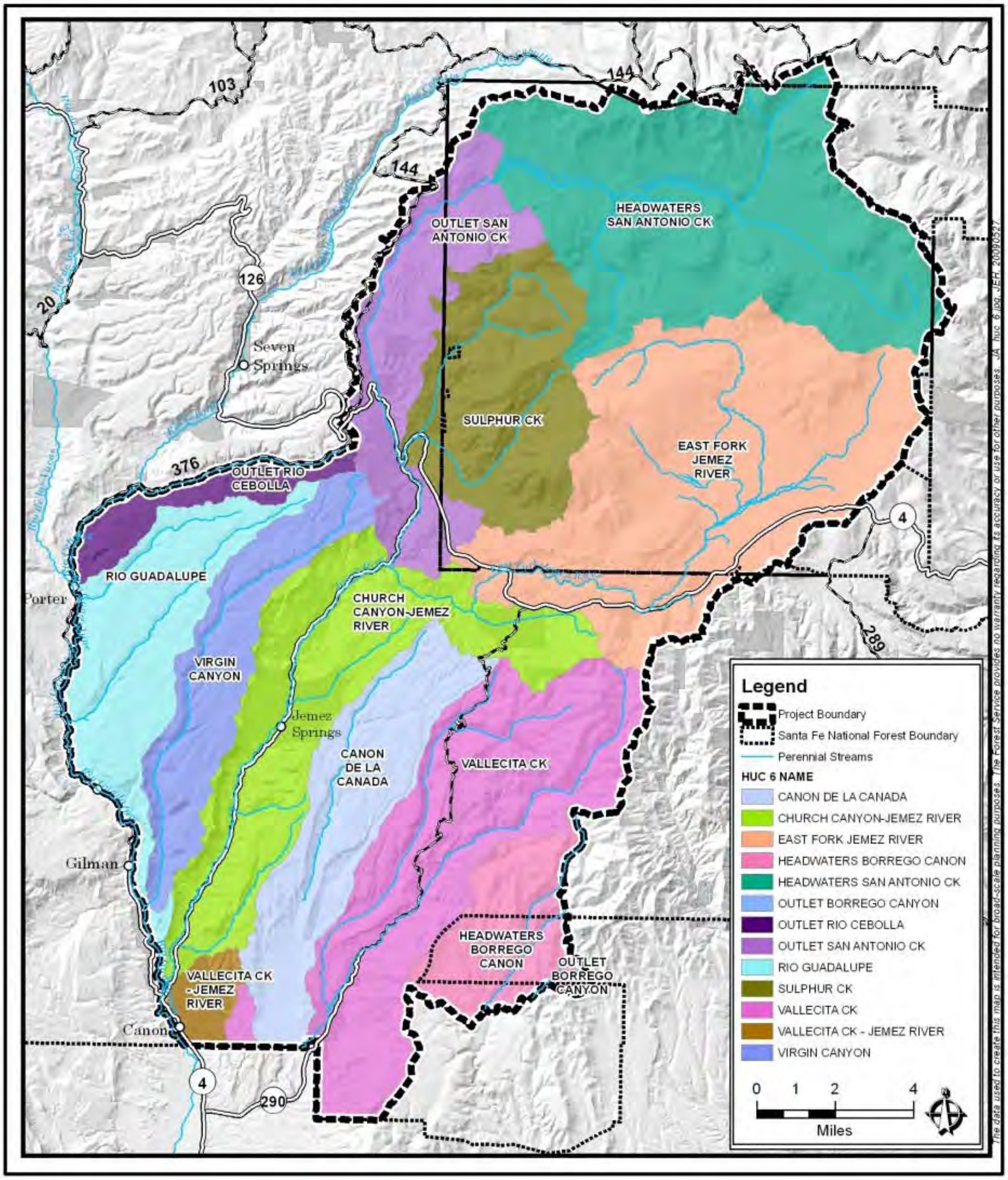

Figure 10. Watersheds - 6th hydrologic unit code (HUC)

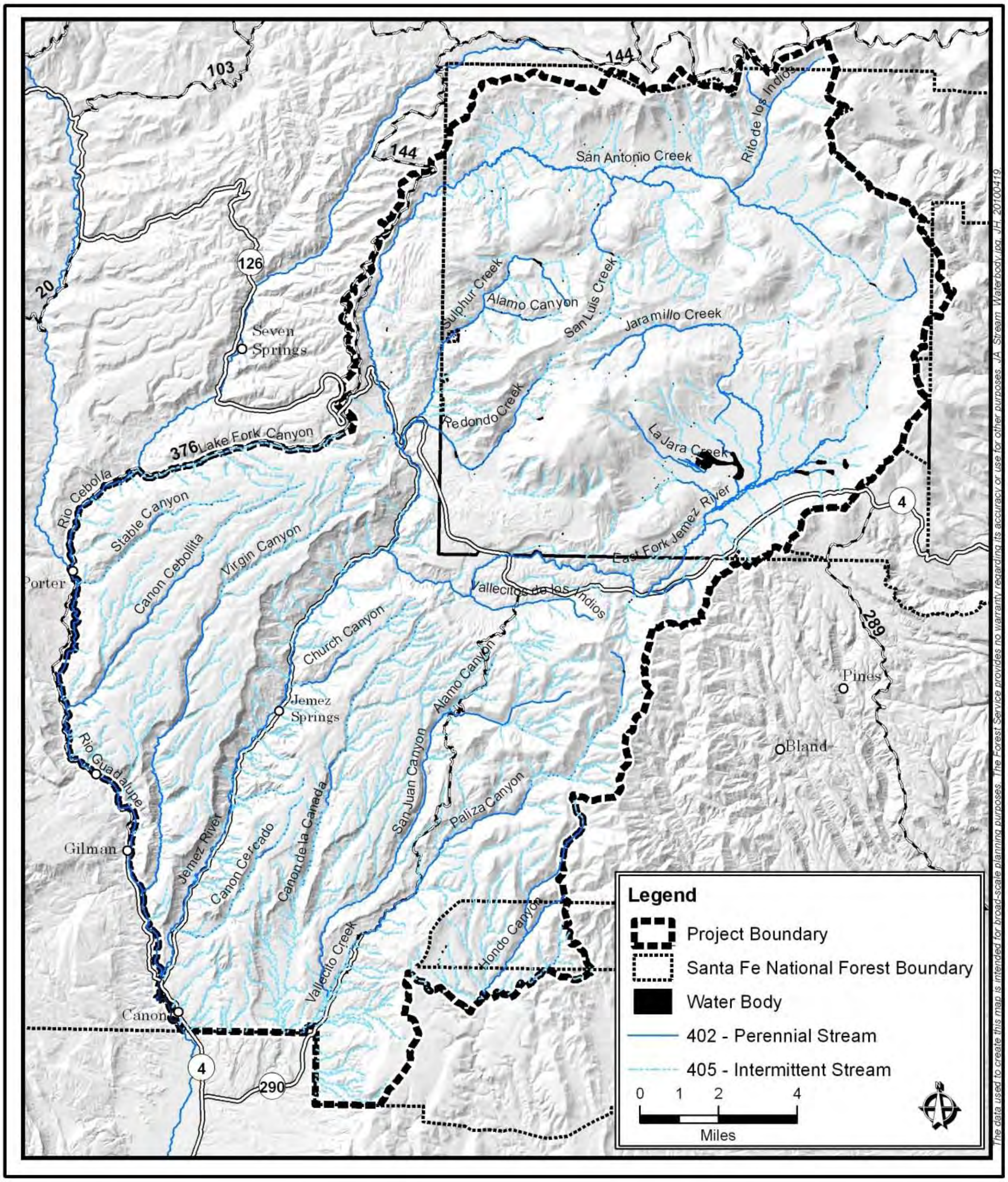

Figure 11. Streams and waterbodies

Aerial photographs from 1935 of the Preserve, on file at the Preserve office, show most if not virtually all of the present gullies were actively eroding, in part due to thousands of sheep that grazed this area. Industrial logging took place in the 1960s and 1970s on the Preserve, which was then a privately owned ranch. The gullies that were actively scouring in the past appear to show marked signs of stabilizing. Comparison of the 1935 photographs with 1996 images give more evidence that erosion was far more prevalent in the past. Sheep grazing was at a magnitude far greater than any of the cattle grazing numbers over the past 50 years.

Road density is very high in the caldera in general and on the domes in particular, although there are relatively few instances of deep or persistent rilling on the steeper slopes. The mountainsides erode almost entirely by weathering of parent material into a mantle of overburden that moves down slope under influence of gravity and pore water as soil creep or larger slumps, accumulating in large fans. Within these fans occur the gullies within swales and shallow draws. In addition, logging roads run up many swales and connect to the uplands through radiating skidding trails. Also, many larger swales have stock tanks and roads that subsequently were used for logging may have been originally placed as access to the tank site.

When rain falls on the caldera rim and domes (recharge areas), it infiltrates into the soil and flows underground into fan deposits until some of it surfaces further down near the valley floors. It often surfaces in the form of distinct seeps and springs. Inflow into channels from direct surface runoff is rare except on ground that is naturally impervious or bare of cover.

Six stream flow gauges monitor flows in the Jemez River system (U.S. Geological Survey 2009), including two gauges along Jemez River, two along Rio Guadalupe, one on Redondo Creek and one on Rio de las Vacas. Although the monitoring period of record on these gauges is variable, they all have recorded flows during the past 30 to 70 years. Analysis of stream flow gauge recordings show that the Jemez River system is driven much more by snowmelt runoff and recharge than summer rains. Spring snowmelt runoff and peak stream flows occur from early March through early June. Minor peaks in flows also occasionally occur during the summer monsoon rain season, July through September. Hydrograph analysis indicates that most streams in the assessment area have a steady decline in surface flow in the summer months due to limited groundwater storage. A few others, like the Jemez River and Rio Guadalupe, have little decline in surface flows during the summer months due to larger groundwater storage capacity in the broad valleys. Stream gauge measurements of surface flow rates (discharge) in the Jemez River show flows have declined by 40 percent over the past 50 years. This is likely the result of less precipitation coupled with increased stand density and snow sublimation (Figure 12); (US Geological Survey 2008-9).

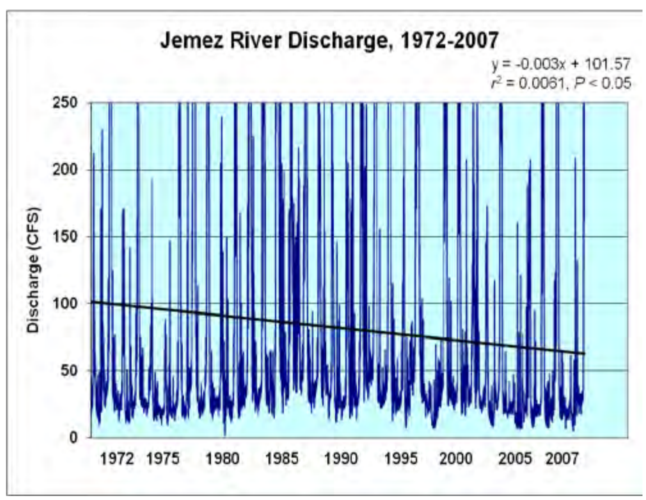

Figure 12. Jemez River surface flow discharge rates, 1972-2007

Stream Channel Morphology and Aquatic Habitat

Sinuous channels wind through broad grassy valleys of the Valle San Antonio and Valle Grande within the Preserve, and the long meadow reaches of the upper Rio Cebolla. The Rio Cebolla channel changes further downstream, where it cuts through steep bedrock and flows through steep-gradient gorges of the Guadalupe Box and the reach above Jemez Falls.

In the broad meadow valleys the channel gradient is shallow to moderate (0.1 to 1.5 percent), with narrow and deep channel cross sections and a bed of sand and gravel. Within the narrower reaches, channel gradient is typically steep; two to three times that of the meadow reaches. Channels are wide and shallow, with a bed of cobble and boulders, and frequent cascades, chutes and falls (US Forest Service 2002a, 2003a-b, 2004a-c, 2005b and 2006a).

Large woody debris and pool habitat are deficient on East Fork Jemez River and San Antonio Creek, which also have a high proportion of fines in riffles (US Forest Service 2002a and 2005b). Given the obvious degree of bank retreat it seems likely that the fines still entrained in the channel are largely from bank erosion. Large woody debris and pool habitat are also deficient in most reaches of the Rio Guadalupe and Rio Cebolla (US Forest Service 2003b and 2006a). Large portions of the San Antonio, Rio Cebolla, and East Fork Jemez River are in broad meadow valleys (69, 76 and 40 percent, respectively). The Rio Guadalupe is steep and confined throughout most of its length, and yet large woody debris and pool habitat still do not meet agency standards. Those stream reaches within grassy valleys have little to no forest cover on the banks from which large woody debris can be recruited. In addition, long meadow reaches will exert some influence on down steam conditions, whatever the forest cover.

Sand size or smaller particles constitute over 20 percent, which exceeds standards on the East Fork Jemez River, Rio Cebolla and San Antonio Creek (US Forest Service 2002a, 2003a, and 2005b). Excessive amounts of fines are another cause of under-developed pool habitat. Again the Rio Guadalupe is an exception as cobble and gravel are the dominant substrate on that stream.

Excessive width to depth ratio (a stream overly wide and shallow) characterized one reach on both East Fork Jemez River and San Antonio Creek and two reaches on the Rio Guadalupe US Forest Service 2002a, 2005b and 2006a). In the reaches on East Fork and San Antonio, excessive width to depth ratio corresponds to bank instability within the reach. Width to depth ratio was within standard for the Rio Cebolla (US Forest Service 2003b). Incidence of unstable banks on the Rio Guadalupe was very low, as the larger cobbles and boulders tend to stabilize stream banks. Bank stability in East Fork Jemez River and San Antonio Creek ranged from 80 to 95 percent.

Channel degradation including some widening and straightening of channel form has occurred primarily as a result of past livestock grazing and trampling in the meadow reaches of the Preserve. Today however, most of the previously slumped and denuded banks have re-vegetated and stabilized with grasses or forbs. Sediment deposit areas in the channels have filled in with sedges, which help in capturing sediments and reducing channel scouring and widening. There is very limited scouring of channels in the headwaters of this watershed. This may be due to the larger bed material and shallower flow column for a given volume of water, which impede flow velocity. Limited channel downcutting has maintained stream flow connection with the valley bottom floodplains, contributing to maintenance of riparian vegetation. Recovery of a narrower channel form and function has occurred in the headwaters area, although these channels remain sensitive to livestock trampling because of their form (undercut banks). If vegetation cover is removed from the stream banks, high intensity summer rains are likely to cause increased surface runoff, stream flow volumes and channel scouring. Currently, surveys indicate the headwater stream channels are in an upward trend with regards to bank stability. They appear to be recovering from their degraded condition and are becoming narrower, deeper and more sinuous.

Outside the Preserve, highly degraded channel forms are mostly confined to the upper half of the Rio Cebolla, from about the Schoolhouse Canyon tributary. The degree of entrenchment of the channel has been more severe typically than in the Preserve, although not as pervasive, with many reaches having good width to depth ratio and robust woody bank vegetation and beaver presence. Overall, stream gradients in meadow reaches on the Rio Cebolla are steeper than other similar reaches on streams in the Preserve, and grazed reaches have greater potential for scour (US Forest Service 2003b). The upper Rio Cebolla follows the trend of a large geologic fault, whereas other streams valleys are cut perpendicularly by faults, which provide strong checks on grade (New Mexico Bureau of Geology and Mineral Resources 2005 and 2007; U.S. Geological Survey 1970).

In a turn from the above scenario, 1935 photographs of the Lower Jaramillo Creek valley show a broad wet bottom with multiple and barely discernible dark channel traces indicating a very dispersed flow through many very slightly incised channels, and as much flow likely occurring as ground interflow as on the surface. In 1996 digital photographs, the valley section has a single, large channel. Ground observations have shown that this reach of creek is recovering from an over-widened, aggraded state. Similar evolutions in channel morphology were found in the upper section of San Antonio valley. The 1935 photos again reveal wetland-like valley bottoms with slight channeling compared to the incised channeling in the 1996 photographs.

These observations suggest the possibility that the extent of perennial wet valley bottoms in the Preserve (fens do still exist) was much greater, and surface flow was more dispersed. Thus, though existing single channel reaches show much recovery, the very pattern of a single channel reach is a degraded form from an original, pre-settlement wetland of highly dispersed flow through multiple shallow channels.

Water Quality

Stream temperature monitoring sites on four streams in the Jemez River Watershed found temperatures exceeded the properly functioning condition standard for coldwater fisheries habitat. On a seven day average during summer months, more than half of the sites on all the streams were not properly functioning, and the rest were at risk on a three day average.

Temperatures exceeded water quality standards most often (10 to 20 percent) on stream reaches dominated by broad meadow valleys, such as East Fork Jemez River, Jaramillo Creek, and San Antonio Creek. Temperatures exceeded water quality standards less frequently (1to 2 percent) for Redondo Creek and Rito de los Indios, which are steep gradient, fast running streams in narrow, steep-sided valleys (New Mexico Environment Dept. 2006b).

The temperature of most stream waters in the Jemez River basin may be naturally warmed. It appears evident from observations of steam pattern and spot measurements and data from monitoring sites, that the warm water temperature of the perennial streams of the Preserve may be influenced by bedrock source area (New Mexico Environment Dept. 2006b; US Forest Service 2002—2006). Similarly, the Rio Guadalupe and its tributary of Rio Cebolla on the National

Forest have strong fault control, and bedrock reaches and temperatures often exceed standards for cold water fishery, even in high elevation headwater areas with good forest cover. On the other hand, Vallecito Creek south of the Preserve is largely derived from slope deposits, indicated by elongated drainage pattern, which was field verified. Spot sampling stream temperatures during field visits showed temperatures only half the temperatures of other streams draining the caldera and its rim.

Water appears noticeably cloudy in the East Fork Jemez River, San Antonio Creek and Jaramillo Creek in observations of springs along the margins of Valle San Antonio and Valle Grande, in September 2007. This condition is possibly from colloidal particles that progressively increase in downstream reaches. Conversely, Rito de los Indios and Redondo Creek run clear. The difference may be the extensive fill of the main valleys containing particles of volcanic ash. While this material is present on the domes and Redondo Peak, the residence time of the water as groundwater before emerging as surface water is undoubtedly much less than in the lower valleys. Spring water coming from hillslopes appeared clear, with no observable turbidity.

Turbidity standards are occasionally exceeded on the East Fork Jemez River, San Antonio Creek and Redondo Creek (New Mexico Environment Department 2002, 2006b). Table 9 shows the selected dates in 1998 where the turbidity value for one or more of these streams exceeded the water quality standard for turbidity. The standard is 25 NTUs (nephelometric turbidity units).

Table 9. Turbidity values for streams when the standard was exceeded in 1998

Dates	E.F. Jemez River NTUs	San Antonio Creek NTUs	Redondo Creek NTUs
April 22, 1998	18.6	**26.5**	17.2
April 23, 1998	20.0	**27.5**	**29.5**
July 13, 1998	**42.6**	8.4	**42.1**
November 2, 1998	**31.5**	**34.7**	11.9

On the April 1998 dates shown in Table 9, stream flow volume on the East Fork Jemez River was 109 cubic feet per second (cfs), well above the average annual peak flow of 54.7 cfs at that gauging station (New Mexico Environment Department 2002). The unusually high flow was probably driven by snow melt runoff at that time. No flow data was recorded at that gauging station for the July and November 1998 dates shown in Table 9. According to the monitoring field crews, the turbidity in the East Fork Jemez River appeared to be from lacustrine (lake-based) sediment from the floor of Valle Grande.

In 2001and 2002, water quality sampling was conducted on East Fork of the Jemez River, Jaramillo, La Jara, Redondo, Rita de los Indios, San Antonio and Sulphur Creeks within the Preserve (New Mexico Environment Department 2006b). Water quality in these mostly headwaters portion of the Jemez River Watershed does not frequently rate as impaired, although there are instances where standards for specific water quality parameters were exceeded. Dissolved aluminum, an element which is naturally high in the rock type of the caldera, was consistently found to be in exceedence of state water quality standards in all the streams. There were also numerous exceedences of dissolved oxygen, water temperature and pH standards. Dissolved oxygen and pH are controlled by growth rate and respiration of aquatic plants, which in turn is somewhat controlled by relatively high levels of phosphorus that were measured. The turbidity standard was exceeded in Jaramillo Creek, East Fork Jemez River and Sulphur Creek, but not in the other streams. Water temperature exceeded standards on all streams to some extent, but was highest on East Fork Jemez River, Jaramillo Creek and San Antonio Creek. Table 10 summarizes results of the surveys.

Table 10. Percent of water quality samples that exceeded standards in 2001-2002

Watershed	Parameters			
	Turbidity	Temperature	pH	Dissolved Oxygen
Jaramillo	40	10	0	14
E.F. Jemez R.	14	21	37	35
La Jara	0	N/A	N/A	N/A
Redondo	5	2	0	0
Indios	1	1	0	0
San Antonio	1	23	51	39
Sulphur	11	N/A	N/A	N/A

Figure 13 shows the stream reaches in the assessment area currently listed as impaired (not meeting the water quality standard for one or more elements). However, much of the impairment status reflects natural causes rather than impairment due to human activity. Several reaches are de-listed after further investigation. In the State’s 2008 integrated 303(d)/305(b) report, several streams on Forest land were de-listed as impaired for sedimentation: Rio Cebolla, Rio Guadalupe and main stem Jemez River. Also delisted for water temperature was the upper Rio Cebolla (above Fenton Lake) and Redondo Creek

On National Forest land, total mean daily loads (TMDLs) remain for Rio Guadalupe for aluminum, San Antonio Creek for water temperature and turbidity, and the Jemez River below the Rio Guadalupe for aluminum and turbidity. Vallecito Creek is listed as impaired for coldwater aquatics, the probable cause being a naturally high level of aluminum. On the Preserve, several streams are listed as impaired for coldwater aquatics due to aluminum, water temperature and turbidity. East Fork Jemez River (within the Preserve), and Jaramillo Creek has TMDL for water temperature and turbidity (New Mexico Environment Department 2006a, 2006b).

It is worth noting that most of the listed impaired reaches on the National Forest and Preserve are due to designation of probable inappropriate use. For example, coldwater aquatic habitat may be unattainable due to naturally high water temperatures and high concentrations of aluminum. These streams are under review by the state of New Mexico. The only reaches in the assessment area which are considered impaired due to probable pollutant sources are the reach of the East Fork Jemez River with the Preserve and the Jemez River below Jemez Springs (New Mexico Environment Department 2008).

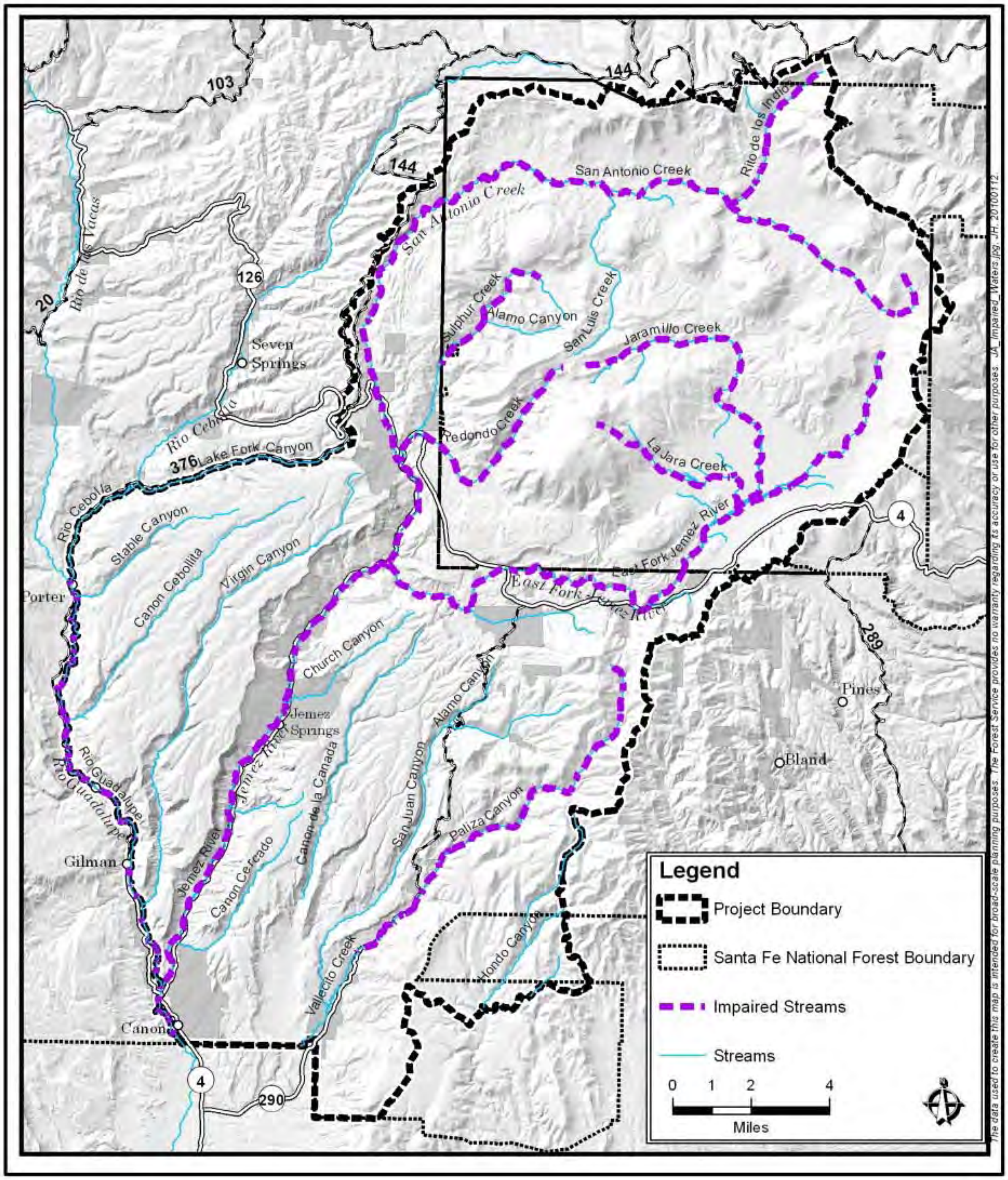

Figure 13. Streams listed as impaired (New Mexico Environment Dept. 2008)

Air

Introduction and Methodologies

This section evaluates and compares the existing and reference conditions of the air resource within the assessment area. Reference conditions refer to the national and state standards for managing air quality.

Three air quality monitors were used in this assessment Two are visibility monitors established for protection of Class 1 areas at San Pedro Parks Wilderness, 15 miles northwest of the assessment area and at Bandelier National Park, 10 miles southeast of the assessment area (Interagency Monitoring for Protection of Visual Environments or IMPROVE 2009). The third is a monitor for ozone and particulate matter ($PM_{2.5}$), located 3 miles south of the assessment area on tribal land. Two other air quality monitoring sites in Sandoval County are strongly influenced by emissions in the Albuquerque metropolitan area, so they are not considered representative for the assessment area. There are no air quality monitors in Rio Arriba or Los Alamos Counties, and those in Santa Fe County are too far upwind and not representative due to their urban location.

Figure 14 displays the air quality monitors, climate monitoring stations, smoke sensitive areas and class 1 airsheds in the assessment area.

Air Quality

Under the Clean Air Act, the Environmental Protection Agency (EPA) establishes National Ambient Air Quality Standards for pollutants that pose a threat to human health and welfare, and the State of New Mexico regulates the federal and state air quality standards within the State.

The reference condition is for all criteria pollutants to remain below (within) the EPA's air quality standards. The criteria pollutants of concern are ozone and $PM_{2.5}$, which are being monitored in the assessment area. Currently, all national air quality standards are being met within the assessment area and in surrounding areas. Thus, the airshed is in attainment status. Additionally, levels of criteria pollutants have shown some improvement (been reduced) in the last 2 to 3 years. There has been some concern for elevated ozone levels in northwestern New Mexico.

Ozone

Ozone is a secondary pollutant that forms as a result of chemical reactions in the atmosphere when the primary pollutants of nitrogen oxides (NOx) and Volatile Organic Compounds (VOC) are exposed to sunlight. The precursors to ozone are generally produced as emissions from combustion of fossil fuels. Sources in this area include two power plants near Farmington in San Juan County, engine exhaust from oil and gas development, and mobile sources including cars, trucks and recreational vehicles.

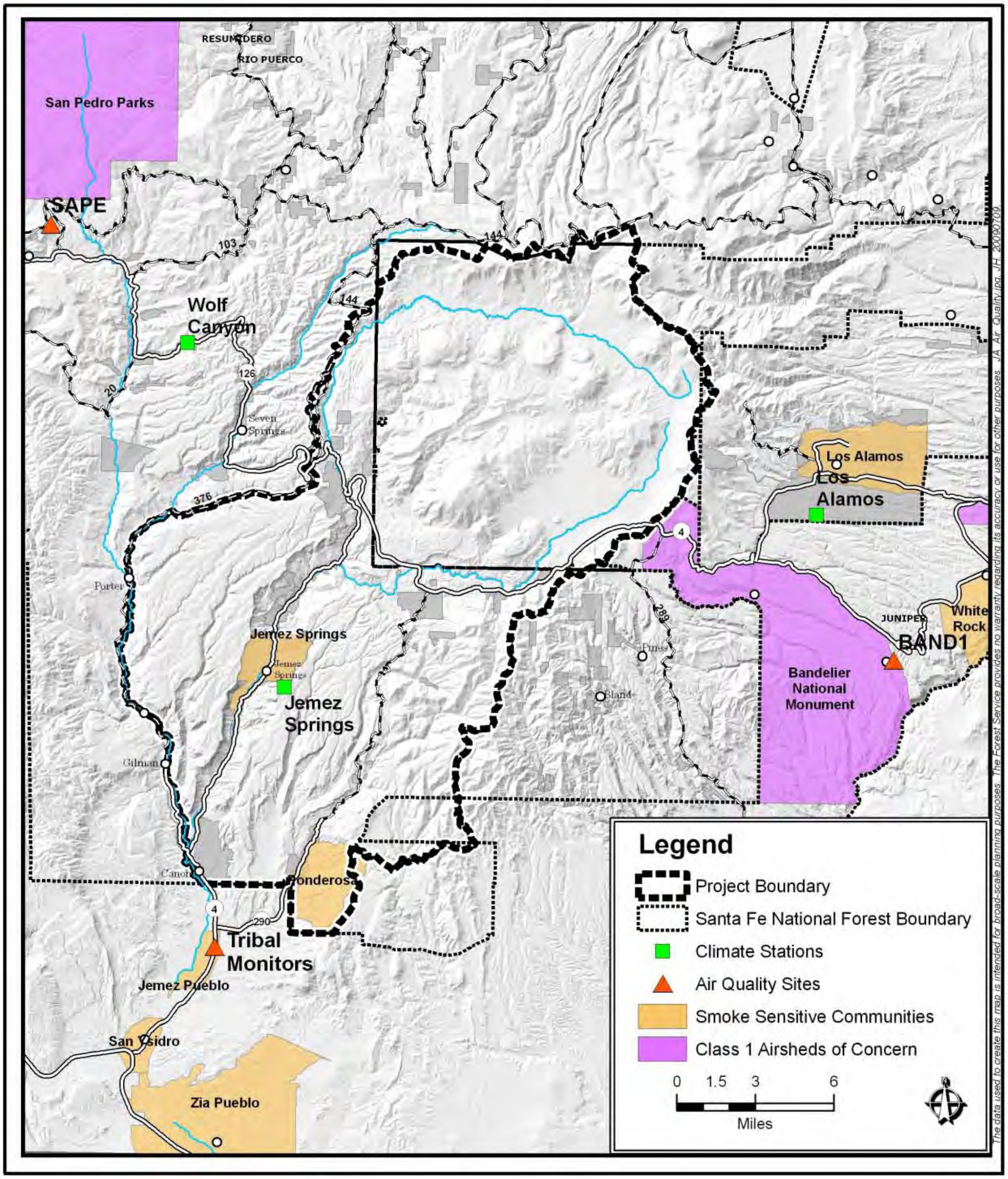

Figure 14. Air quality sites, climate stations, smoke sensitive areas and Class 1 Airsheds of Concern

Ozone levels have been monitored at Jemez Pueblo since 2004. Table 11 shows the 1st through 4th maximum value for 8-hour ozone for each year. Data for 2008 are incomplete but represent all data available from EPA as of June 9, 2009. The ozone standard is 0.075 ppm or less (for the 3-year average of the 4th highest value of 8-hour ozone).

Although standards are being met, the current ozone level has the potential to damage to species such as aspen and ponderosa pine.

Table 11. First through 4th maximum value for ozone at Jemez Pueblo, 2004-2008 (ppm)

Year	1st Maximum	2nd Maximum	3rd Maximum	4th Maximum
2004	0.069	0.069	0.068	0.067
2005	0.078	0.078	0.076	0.076
2006	0.075	0.075	0.072	0.072
2007	0.069	0.068	0.067	0.067
2008	0.069	0.066	0.065	0.065

Particulate Matter

Particulate matter less than 2.5 micrometers in diameter is a criteria pollutant. Two redundant monitors located at Jemez Pueblo in the same location as the ozone monitor have been in operation since 2000. $PM_{2.5}$ is produced by all types of burning including power plants, combustion engines, woodstoves, and wildland fire. Table 12 shows maximum values recorded for 2000 to 2007. It also shows the values recorded during 98th percentile concentrations. The standard for $PM_{2.5}$ requires the 98th percentile of the 24-hour average concentration to be at or below 35ug/m^3. That standard was only exceeded at one monitor one time in 7 years of monitoring, in 2005, as shown in the following table.

Visibility

Visibility relates to conditions that allow humans to see and appreciate the inherent beauty of the landscape features, and these conditions can be greatly impacted by particular matter and gasses that are in smoke or dust (Malm 2000). Visibility and other air quality standards are most stringent within designated Class 1 areas, such as in wilderness areas over 5000 acres and national parks over 6000 acres. Thus, most air quality visibility monitoring is conducted in the Class 1 arisheds, shown on the map.

The IMPROVE network was established in 1985. The IMPROVE site monitors at Bandelier National Park and the San Pedro Parks station measure aerosols and particulate matter that can contribute to reduced visibility and identify the chemicals and emissions responsible for human-caused visibility impairment (FLAG 2002).

Table 12. Monitored values of PM2.5 at Jemez Pueblo, 2000-2007 (ug/m^3)

Year	Monitor No.	Maximum PM2.5	98th Percentile PM2.5
2000	1	26.1	23.9
2000	2	29.9	27.3
2001	1	46.3	28.3
2001	2	46.3	27
2002	1	31.3	29.1
2002	2	32	25.2
2003	1	26.6	26.2
2003	2	27.3	26
2004	1	13.1	13.1
2004	2	13.2	13.2
2005	1	35.5	27.1
2005	2	43.1	**43.1**
2006	1	46.6	28.2
2006	2	45.2	21.3
2007	1	24.9	24.9
2007	2	26.8	26.8

The Regional Haze Rule sets a goal to return these areas to natural visibility conditions by 2064. Figure 15 and Figure 16 show the glide path that must be attained in order to return visibility conditions to normal by 2064 at Bandelier National Park and San Pedro Parks Wilderness. As of 2007, both Class 1 areas were slightly ahead of schedule but further improvements will be needed to meet the national visibility goal.

Figure 17 and Figure 18 show the average visibility conditions at Bandelier National Park and San Pedro Parks Wilderness (Class 1 airsheds) on the 20 percent worst and 20 percent best days. Measurements are in deciviews (an index that approximates the amount of visibility change that can be observed by the human eye) and beta extinction (a more scientific measure of light reduction). Worst days are shown in the top two lines, best days are the bottom two lines. For both Bandelier and San Pedro Parks, the absolute worst days for visibility in 2000 are attributed to smoke from the Cerro Grande Fire. (Visibility Information Exchange WebSystem 2009)

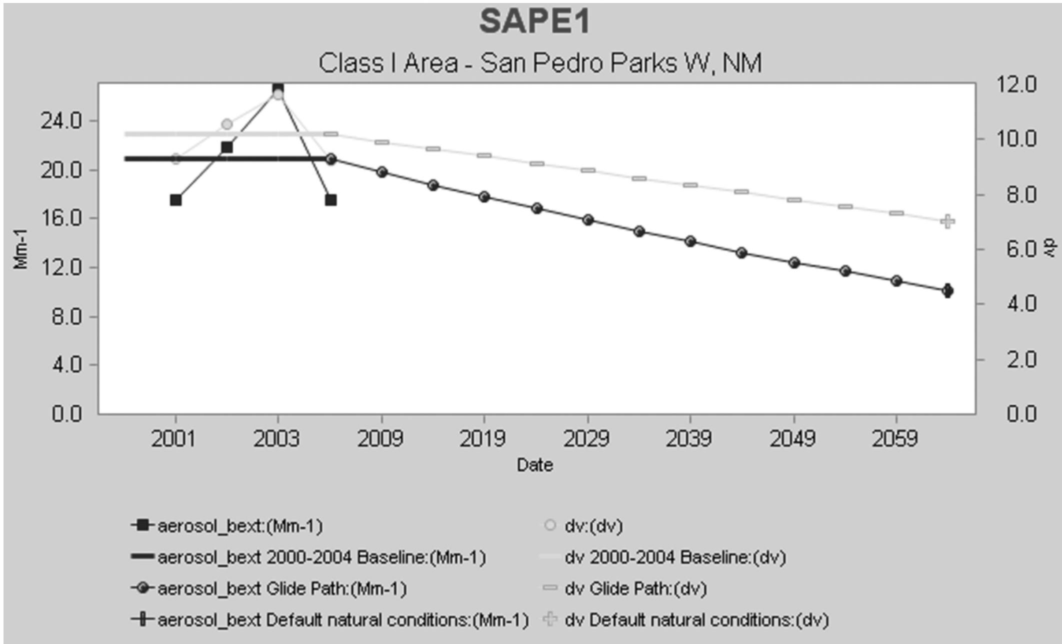

Figure 15. Visibility goals for San Pedro Parks Wilderness

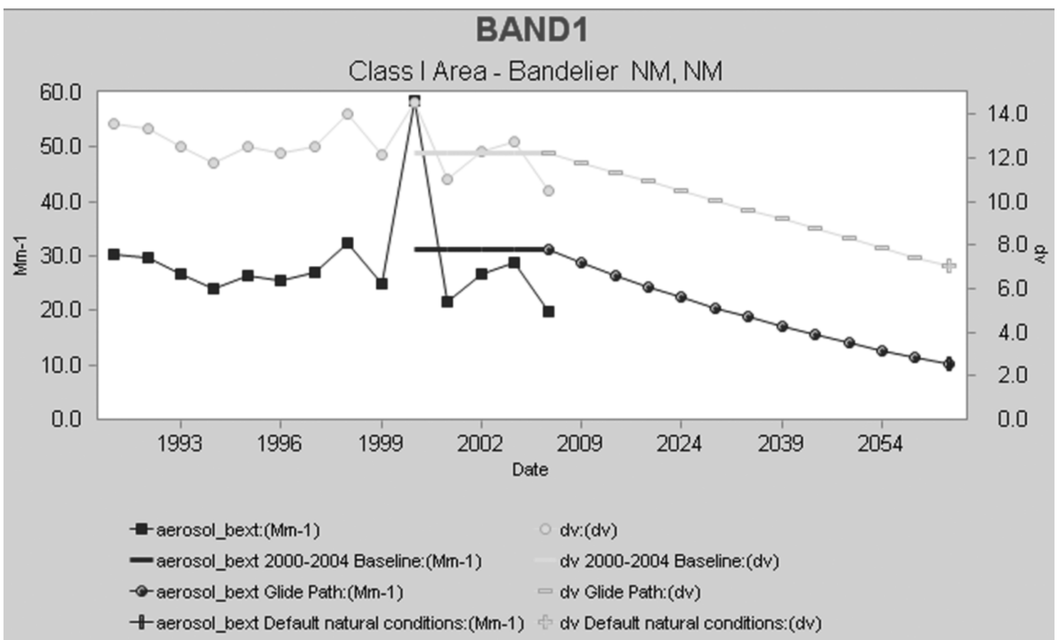

Figure 16. Visibility goals for Bandelier National Park

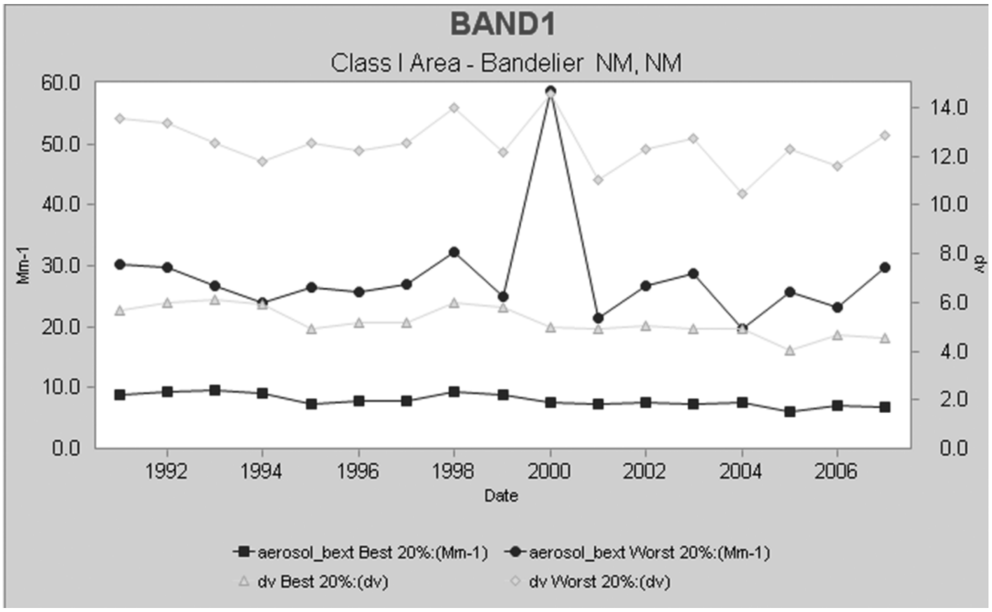

Figure 17. Visibility impairment at Bandalier National Park, 1988-2007

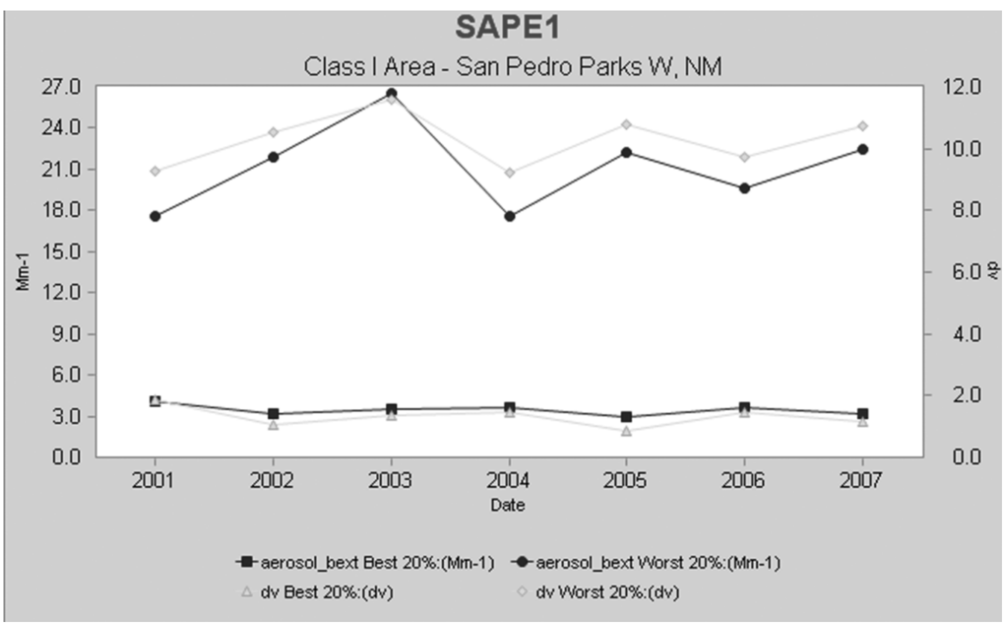

Figure 18. Visibility reduction at San Pedro Parks Wilderness, 2001-2007