Santa Fe National Forest
Geothermal Leasing EIS
Soils and Water Specialist Report

Santa Fe National Forest
11 Forest Lane
Santa Fe, New Mexico 87508
June 2016

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<th>Full Term</th>
</tr>
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<tr>
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<td>United States Department of the Interior, Bureau of Land Management</td>
</tr>
<tr>
<td>BMP</td>
<td>best management practice</td>
</tr>
<tr>
<td>CFR</td>
<td>Code of Federal Regulations</td>
</tr>
<tr>
<td>COA</td>
<td>condition of approval</td>
</tr>
<tr>
<td>CSU</td>
<td>controlled surface use</td>
</tr>
<tr>
<td>EIS</td>
<td>environmental impact statement</td>
</tr>
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<td>Environmental Protection Agency</td>
</tr>
<tr>
<td>Forest Plan</td>
<td>Santa Fe National Forest Plan, as amended</td>
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<td>geographical information system</td>
</tr>
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<td>JNRA</td>
<td>Jemez National Recreation Area</td>
</tr>
<tr>
<td>NFS</td>
<td>National Forest System</td>
</tr>
<tr>
<td>NMWQCC</td>
<td>New Mexico Water Quality Control Commission</td>
</tr>
<tr>
<td>NPDES</td>
<td>National Pollutant Discharge Elimination System</td>
</tr>
<tr>
<td>NRCS</td>
<td>United States Department of Agriculture, Natural Resources Conservation Service</td>
</tr>
<tr>
<td>NSO</td>
<td>no surface occupancy</td>
</tr>
<tr>
<td>SFNF</td>
<td>Santa Fe National Forest</td>
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<tr>
<td>TMDL</td>
<td>total maximum daily load</td>
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<td>United States Department of Agriculture, Forest Service</td>
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Introduction

This soils and water specialist report has been prepared for the United States Department of Agriculture, Forest Service (USFS), Santa Fe National Forest (SFNF) Geothermal Leasing Environmental Impact Statement (EIS). It describes the existing conditions for soil and water resources within the project area and the potential direct and indirect impacts that geothermal leasing and subsequent exploration and development would have on these resources.

The USFS is proposing to facilitate geothermal leasing on National Forest System (NFS) lands on the SFNF that have geothermal potential for electrical power generation. This would be accomplished by the following five specific actions:

- Identify SFNF lands in the project area as being open or closed to leasing
- Provide a comprehensive list of stipulations and procedures to serve as consistent guidance for future geothermal leasing and development
- Incorporate the reasonably foreseeable development scenario for the SFNF Geothermal Leasing EIS (United States Department of the Interior, Bureau of Land Management [BLM] 2015), resource allocations, stipulations, and procedures into the Santa Fe National Forest Plan, as amended (Forest Plan; USFS 1987)
- Make decisions regarding the geothermal lease applications on SFNF lands pending as of October 1, 2014; these decisions will be made after the Forest Plan incorporates the leasing classification, stipulations, and procedures
- Complete an EIS, analyzing the four alternatives, including no action, carried forward under the National Environmental Policy Act

Analysis Area

Direct and Indirect Impacts Boundary

The spatial boundary for direct and indirect impacts is all NFS lands in the project area, which encompasses 194,900 acres on the Coyote, Cuba, Española, and Jemez Ranger Districts of the SFNF (Figure 1, Geothermal Leasing Project Surface Administration).

Regional Overview

The project area is in northern New Mexico in the Jemez Mountain region, to the west of the Rio Grande River Valley and northwest of the city of Santa Fe. Its location puts it at the southern margin of the Rocky Mountain ecoregion, on the west side of the Rio Grande Rift Zone. Surface waters originating in the project area flow into the Rio Grande, which, at more than 1,800 miles long, is the second-longest river in North America. The project area includes both the Upper and Middle Rio Grande watersheds. The Jemez River, which originates in the project area, is one of the major tributaries to the Middle Rio Grande.

To the west of the project area are the San Pedro Mountains and the rugged Sierra Nacimiento. To the north, the Abiquiu Reservoir collects waters draining from the project area. The reservoir then feeds its waters into the Rio Chama, which drains eastward into the Upper Rio Grande. The Rio Chama is the largest tributary to the Upper Rio Grande in New Mexico (New Mexico Office of the State Engineer 2016).

In the south, the Jemez River originates in the Valles Caldera and then flows through the southwest corner of the project area, collecting waters draining from the project area’s southern half. In this area the Jemez
Figure 1
Geothermal Leasing Project
Surface Administration

Forest Service
The geothermal decision area includes Forest Service administered land within the geothermal project area

- National Park Service
- Private
- Pueblo
- Bureau of Land Management
- Department of Defense
- State
- Department of Energy
- State park or wildlife area
- Geothermal project area
- Ranger District

Source: Forest Service GIS 2015
May 12, 2016
SFNFGeo_intro_landstat_V02.pdf
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River cuts through the high mesas and hills at the base of the Sierra Nacimiento to form Cañon de San Diego, one of a series of picturesque and deep, red-walled canyons characterizing the area. The Jemez River then flows southeast to also drain into the Rio Grande. Peak flows vary annually in the Rio Chama and Jemez River, but they generally occur from April to June with snowmelt, and small upticks are seen in the late summer, due to seasonal monsoon rains.

The northern and eastern edges of the Valles Caldera are flanked by north-central New Mexico valleys and mesas. It is dominated by young geologic features of the Espanola rift basin and ancestral Rio Grande floodplain. The area has a cooler climate, with slightly greater precipitation, and streams tend to have more water flow. It has a mix of geology, mostly Tertiary sedimentary or Tertiary and Quaternary volcanic rocks.

The main stem of the Rio Grande cuts through the Arizona/New Mexico Plateau. Once containing a perennially flowing, meandering, braided river, the Rio Grande Floodplain ecoregion has undergone many human alterations to its landscape and hydrology over the past 400 years. The once-shifting Rio Grande had mosaics of riparian woodlands and shrublands, along with a variety of wetland meadows, ponds, and marshes. A long history of irrigation and drainage canals, levees and jetty jacks, and upstream dams have altered river flows and narrowed and straightened the stream channel. The region has been altered by conversion to cropland, orchards, small rural farms, and ranchos and urban and suburban uses.

**Wild and Scenic Rivers**

The East Fork of the Jemez River originates in the Valles Caldera as a small meandering stream in a vast crater. On its way to its confluence with the Rio San Antonio, the river passes through the heart of the Jemez Mountains’ most popular recreation area. The National Wild and Scenic Rivers System-designated Wild and Scenic River (WSR) reach extends from the SFNF boundary to its confluence with the Rio San Antonio. The WSR is 11 miles long, with a corridor averaging 320 acres per mile.

Specific to the East Fork WSR, the “recreation” segment is characterized by low stream gradients and easy access for recreation. In contrast, the “wild” segment includes a tight box canyon, with moderate stream gradient, big boulders, and difficult access. The “scenic” segment is characterized by a steeper gradient, including Jemez Falls, dropping into a narrow canyon with limited access. The stretch before the East Fork WSR joins San Antonio Creek has numerous boulders, pools, and eddies, creating some suitable fish habitat and attractive pools for swimming.

The WSR begins at the boundary of the Valles Caldera National Preserve (VCNP) and extends southward. The first 2-mile segment of the WSR, from the VCNP boundary to the second highway crossing of New Mexico State Highway 4, is designated as the recreation segment. The next 4 miles, from the second water crossing to the third highway crossing, is designated as the wild segment. The last 5 miles, ending at the confluence with San Antonio Creek, is designated as the scenic segment. The WSR corridor lies on lands managed by the SFNF and is in the Jemez National Recreation Area (JNRA), which was designated by Congress.

The WSR Act provision to keep the river in a free-flowing condition prohibits the Federal Energy Regulatory Commission from licensing the construction of hydroelectric facilities on designated rivers; it also prevents other federal agencies from assisting in the construction of any water resources project that would have a direct and adverse impact on the river’s free flowing character, water quality, or WSR values. The WSR lies entirely within the JNRA.

**Jemez National Recreation Area**

The entire 28,900-acre JNRA falls under nondiscretionary closure from geothermal leasing; it is therefore excluded from any geothermal leasing (43 Code of Federal Regulations [CFR], Subpart 3201.11).
JNRA includes important protected surface features, including the Jemez Mountain National Scenic Byway, Jemez Historic Site National Landmark, and Monument Canyon Research Natural Area, in addition to the following geothermal features: La Cueva, Sulphur Flat, and Las Conchas.

Geothermal Potential

New Mexico contains abundant geothermal resources with a large temperature gradient. High temperature gradients can indicate the location and depth of potential underground geothermal reservoirs capable of supporting commercial uses. Resources suitable for most development are concentrated in the west and north-central regions of the state, with high temperature gradients ranging from 1.6 to 2.5 degrees Fahrenheit per 100 feet of depth (BLM and USFS 2008). Based on information in a number of recent studies (Williams and DeAngelo 2008; Williams et al. 2008; Williams et al. 2009; United States Department of Energy and BLM 2003), the USFS identified lands most likely to receive geothermal lease nominations and applications. This area was defined as the project area for the EIS. In the project area, highly favorable geothermal resources are concentrated on lands next to the VCNP. The project area borders the VCNP on its north, east, and southern edges.

In the near term, small-scale geothermal development in New Mexico is likely (BLM and USFS 2008). The United States Geological Survey (USGS) report, Assessment of Moderate- and High-Temperature Geothermal Resources of the United States (Williams et al. 2008), estimates a mean probability of 170 megawatts of electrical power generation for identified geothermal resources on all lands in New Mexico during the next 30 years; it predicts a total low-high range of 53 to 343 megawatts (Williams et al. 2008).

Valles Caldera

The Valles Caldera lies in the center of the Jemez Mountains in northern New Mexico. It was formed by a volcanic eruption 1.25 million years ago, which created the 13-mile wide crater-shaped landscape. It lies above a dormant super volcano that last erupted 40 to 50 thousand years ago (the Banco Bonito lava flow). The highest point in the caldera is the resurgent dome, Redondo Peak, which rises over 3,000 feet from the valley floor to an elevation of 11,253 feet above sea level. Redondo Peak lies entirely within the crater and is the headwaters of the Jemez River. Numerous hot springs and fumaroles can be found in the valley.

Valles Caldera National Preserve

In 2000, the approximately 89,000-acre VCNP was created. It is under the management of the National Park Service and is not part of the project area. On the VCNP, the San Antonio Cabin Hot Spring (commonly referred to as Bathhouse Spring) is a single spring, discharging potable hot water. Twentieth century ranchers built an enclosed concrete bath over the spring, next to a nearby cabin. In addition, the VCNP has numerous hot and cold sulfuric acid fumaroles, particularly in the Alamo Canyon and Redondo Canyon regions. The 40-acre private inholding of Sulphur Springs has at least seven significant named thermal springs and fumaroles; several other acid springs and gas vents are cold. These springs are indicators of subsurface thermal processes, are unique to the region, and are easily accessible for study and research; there are no comparable features in the State of New Mexico. The only other places in the United States that have such systems are Yellowstone National Park; the Long Valley caldera, Lassen Volcano, and The Geysers (all in California); and a very small system at Dixie Valley, Nevada.

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1 The rate of increasing temperature with respect to increasing depth.
2 Openings that are in or near a volcano and through which hot sulfurous gases escape.
Similar to the 1987 listings for Lassen Volcano and Yellowstone National Parks, the NPS is working to propose listing the entire hydrothermal system in the VCNP as one significant thermal feature. It would include San Antonio Cabin Hot Spring, Sulphur Springs (inholding), and numerous hot and cool sulfuric acid fumaroles throughout the western caldera. The magma chamber beneath the VCNP is under the southwest portion of the caldera, with surface geothermal features expressed primarily in the vicinity of Redondo Canyon, Sulphur Creek Canyon, and Alamo Canyon. The sulfuric acid fumaroles and the hot springs are important geologic resources associated with the VCNP and the Jemez Mountains. They contribute to scientific understanding of the geology of the region and to the other values for which the VCNP was established.

Relevant Laws, Regulations, and Policy

Regulatory Framework

Forest Plan
The SFNF operates under the direction of the Forest Plan (USFS 1987). It does not allocate lands as available or unavailable for geothermal leasing, so, in 2015, the USFS began the process of revising it. The decisions made under this EIS will amend the 1987 Forest Plan.

Goals
Goals for the SFNF include the USFS mission, vision, and guiding principles common to all National Forests in the United States. The goals detailed below are specific to the natural resources included in this report.

Soil and Water
- Provide direction and support to all resource management activities, with emphasis on maintaining the soil resource, water quality, and water quantity.
- Manage for a favorable flow of water for users by improving or maintaining all watersheds to a satisfactory condition
- Maintain water quality to meet or exceed state water quality standards
- Identify and protect wetlands and floodplains

Riparian
- Achieve satisfactory condition in riparian ecosystems; maintain areas that are currently in good condition
- Minimize disturbances due to resource activities and other uses in the riparian zone
- Cooperate with New Mexico Department of Game and Fish to achieve management goals and objectives for fisheries and riparian habitat

General Direction, Standards, and Guidelines

Watershed Condition
- Conduct soil, terrestrial ecosystem, multi-level surveys, as required by the National Cooperative Soil Survey
- Inventory existing acequias as part of project planning
• Inventory watershed condition, water resource, and riparian conditions, prioritize improvement needs, and develop comprehensive watershed improvement plans for major SFNF watersheds during the first decade
• Plan and design activities and management strategies specifically for soil and water resources improvement, where watershed condition is unsatisfactory
• Plan watershed rehabilitation where necessary to protect water resources and soil productivity after wildfire.
• Identify the base floodplain (100-year runoff event) on SFNF lands, when facilities or public safety may be affected by flooding
• Work toward improving unsatisfactory watershed conditions to a satisfactory state on those acres that can be cost effectively improved, through a combination of structural methods and management strategies, such as road closures, satisfactory allotment plans, and off-road vehicle restrictions
• Ensure that soil loss due to management activities is within acceptable tolerance limits by the second year following the activity; minimize the impacts on soil and water resources of all ground-disturbing activities

Aquatic Ecosystem Condition
• Update water uses inventory; maintain and protect existing water rights and acquire additional water rights necessary to provide for all SFNF water use needs
• Promote the conservation and efficient use of water at all SFNF water developments; coordinate the development of natural water sources to improve the habitat of all wildlife, including nongame
• Maintain watershed structures that provide benefits and are economically efficient
• Monitor water and soil quality in key locations to aid in identifying and correcting resource problems

Soil and Water Monitoring Plans
Monitoring plans are described in detail in Chapter 5 of the Forest Plan (USFS 1987). The following sections relate to soils and water resource management:

• Watershed condition
• Best management practices (BMPs)
• Riparian condition
• Aquatic ecosystem condition
• Impact of activities on aquatic ecosystem
• Impact of timber harvest and roads on water quality

Management Area
The Forest Plan (USFS 1987) includes specific management direction for different land areas called management areas, 13 of which are in the project area. Figure 2, below, illustrates the entire project area, with the management area delineations. Table 1 displays the management areas in each unit of the project area. Management Areas F, G, and L have specific prescriptions for soil and water resource management, outlined in Table 2.
Figure 2. USFS Management Areas within the Project Area Boundary
Table 1. Management Areas in Each Project Area Unit

<table>
<thead>
<tr>
<th>Project Area Unit</th>
<th>Management Areas</th>
<th>Total Number of Management Areas</th>
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<tbody>
<tr>
<td>North Unit</td>
<td>A, B, G, L, Q</td>
<td>5</td>
</tr>
<tr>
<td>Leasing Unit</td>
<td>A, E, L, N</td>
<td>4</td>
</tr>
<tr>
<td>Middle Unit</td>
<td>A, C, E, N</td>
<td>4</td>
</tr>
<tr>
<td>JNRA Unit</td>
<td>F, M, R, X</td>
<td>4</td>
</tr>
<tr>
<td>South Unit</td>
<td>C, N, P, R</td>
<td>4</td>
</tr>
<tr>
<td>All Units</td>
<td>A, B, C, E, F, G, L, M, N, P, Q, R, X</td>
<td>13</td>
</tr>
</tbody>
</table>

Source: USFS 1987

Table 2. Descriptions of Management Areas with Specific Soil and Water Management Prescriptions

<table>
<thead>
<tr>
<th>Management Area</th>
<th>Management Emphasis</th>
<th>Specific Prescriptions: Soil and Water</th>
</tr>
</thead>
<tbody>
<tr>
<td>F</td>
<td>WSRs</td>
<td>See Forest Plan, Section 5.1.5, Special Area Designations</td>
</tr>
<tr>
<td>G</td>
<td>Key species habitat protection, habitat improvement, forage and firewood production</td>
<td>(F03) Allotments in this management area will receive priority for watershed condition improvement; (F04) unneeded travel ways will be closed or obliterated.3</td>
</tr>
<tr>
<td>L</td>
<td>Semi-primitive nonmotorized recreation</td>
<td>Road building is not consistent with this emphasis. Priority in trail and trailhead development and maintenance. Roads constructed will be closed immediately following the activity, scarified and reseeded.</td>
</tr>
</tbody>
</table>

Source: USFS 1987

Special Area Designations

Wild and Scenic Rivers

The goal for WSRs, as stated in the SFNF Forest Plan (USFS 1987), is to manage the Jemez, Pecos, and Rio Chama Rivers, designated as WSRs, to maintain or enhance their WSR values. The rivers’ free-flowing character should be maintained, while providing quality water-based recreation opportunities, wildlife habitat improvement, and other resource management, consistent with the intent of the 1968 WSRs Act.

The suitability for designating the Rio Guadalupe and Cañones Creek may be reconsidered when the Forest Plan (USFS 1987) is revised. This revision is ongoing and is anticipated to be completed in 2017.

The WSR in the project area is the East Fork of the Jemez, which includes 4.0 miles designated as wild and 5.0 miles designated as scenic. The goal is to manage these rivers to protect and enhance the values for which they were designated. For the wild portions, this involves keeping the river section free of impoundments, accessible only by trail; keeping shorelines in an essentially primitive condition (essentially free of structures, diversion works, and modifications of the waterway, such as riprapping and channelization); and meeting or exceeding State of New Mexico standards for water quality. Scenic sections are to remain free of impoundments, have largely primitive shorelines and shoreline

3 WSRs have been given the management area designation of F on the Forest Plan map. In each case, the management direction overlaps rather than replaces another management area designation.
development, and be accessible by roads but only at certain points. Recreation sections may be paralleled by roads and may have some development and resource management along shorelines, provided the waterway and its surroundings are generally natural and riverine in appearance.

Appendix G-2 (Amendment 10) in the Forest Plan (USFS 1987) outlines specific standards and guidelines for the WSR. The guidelines pertaining to soil and water resources are described here.

**Water and Riparian**

- In cooperation with managers of the VCNP, work to develop a management program for improving water quality and meeting water quality standards in the headwaters of the East Fork (outside the designated corridor); work to avoid impoundments or diversions in the headwaters of the river that would interrupt the natural hydrologic process and prevent periodic bank overflow.
- Restore and maintain riparian and stream conditions, in accordance with properly functioning condition guidelines, including those for sediment, large woody debris, pool development, pool quality, width-to-depth ratios, and streambank stability.
- Stabilize streambanks that have been denuded and take measures to maintain long-term streambank protection.
- Enhance pool development and fish habitat quality by adding large woody debris to the river system, and ensure that this activity will not adversely impact the free-flowing characteristics of the WSR.
- In cooperation with managers of the VCNP and New Mexico State Game and Fish, work toward improving fish habitat conditions to meet the designated use as a “high-quality cold water fishery,” and consider the opportunity for returning the East Fork to an entirely native fishery, including for Rio Grande cutthroat trout, Rio Grande chub, Rio Grande sucker, longnose dace, and fathead minnow.
- Use the latest agency-approved scientific methods to conduct periodic inventories and prioritize resource improvement work along the river.

**Ecology, including Vegetation and Soil**

- Manage land use activities to ensure that soil and vegetation productivity is maintained within the site potential for the area.
- In areas where erosion is exceeding “tolerance rates” and is contributing sediment to the river, take corrective measures to reduce erosion to acceptable levels, based on agency standards.
- Enforce laws that prohibit trespass occupancy, such as squatting and illegal residency.

**Jemez National Recreation Area**

Appendix H (Amendment 11) in the Forest Plan (USFS 1987) outlines specific standards and guidelines for the JNRA. The guidelines pertaining to soil and water resources are described here.

**Soil, Water and Riparian**

- Following wildfires, assess the degree of damage and threats to such resources as roads, soils, and wildlife habitat and property values. Take corrective action to stabilize or minimize adverse impacts on or threats to human life, private property, future soil productivity, and other sensitive resources. Where appropriate, allow nature to gradually heal the land without such management intervention as seeding, contour felling, planting, and installing erosion control structures.

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4 A method of reducing the amount of water that runs down a slope by cutting trees so that they fall perpendicular to the main direction of the slope.
- Manage recreation and other uses to protect soil and water resources using such methods as closures and public education.

**Forest Service Directives**

The USFS Manual 2500 series (USFS 2004) provides regulations and guidance for watershed management on National Forest System lands. Section 2561.25 is specific to geothermal resource operations.

- Evaluate the potential impacts on groundwater quality and quantity and groundwater-dependent ecosystems on NFS lands proposed for leasing by the BLM. If the USFS consents to the BLM leasing geothermal resources on NFS lands, include appropriate lease terms to protect those resources as a condition for issuing geothermal resource leases.
- Before the BLM’s issues an authorization for geothermal resource activities on NFS lands, recommend to the BLM the conditions needed in the authorization to appropriately protect NFS groundwater resources.
- Using the National Pollutant Discharge Elimination System (NPDES), or equivalent adopted by the State of New Mexico for point source discharges and nonpoint source requirements, evaluate potential discharges of produced water from proposed geothermal resource operations. Recommend or require, as appropriate, that the entity authorizing entity protect NFS water resources, including assessing whether the water produced from geothermal resource operations should be allowed to discharge into surface drainages.
- Assist the BLM and the State New Mexico or the US Environmental Protection Agency (EPA), depending on whether the State has received delegated authority from the EPA under the Safe Drinking Water Act, in evaluating the capability of local geological formations to accept water from groundwater injection wells from geothermal resource operations. Where available, use studies of existing groundwater quality and quantity.

**Watershed Conservation Practices**

The following provide direction and BMPs applicable to this project:

- USFS Handbook 2509.18, Soil Management Handbook

**Federal Law**

Title 43, CFR Parts 2800 and 3200, allows approval of a utilization plan, facility construction permit, geothermal drilling permit, site license, and right-of-way authorizations. Reclamation regulations at 43 CFR, Part 429, include approval of use authorizations.

Title 43 CFR, Subparts 4180.2(e) and (f) stipulate that, at a minimum, soils must be managed to maintain vegetation, soil moisture, and permeability rates appropriate for the soils, climate, and land forms found at their location.
National Forest Management Act
The National Forest Management Act of 1976 requires that site-specific project decisions must be consistent with the Forest Plan (USFS 1987), whose goals and objectives guide the identification and selection of potential agency projects. The determination of whether an individual project is consistent with the Forest Plan is based on whether the project adheres to forest and management area standards.

Clean Water Act
The Clean Water Act’s goal is to maintain the chemical, physical, and biological integrity of the nation’s waters. Compliance with state and federal pollution control measures is required. It contains an antidegradation clause and control of nonpoint pollution through the use of BMPs. It prohibits the discharge of pollutants into Waters of the United States without an NPDES permit from the EPA. By issuing NPDES permits, the EPA can regulate the discharge of pollutants to protect water quality.

Memorandum of Agreement on Fostering Collaboration and Efficiencies to Address Water Quality Impairments on National Forest System Lands
The USFS and the EPA signed a Memorandum of Agreement in 2007 to coordinate between the agencies and address issues of water quality impairment regarding the Clean Water Act Section 303(d) list, as well as total maximum daily loads (TMDLs). The leading causes of water quality impairments on National Forest System lands are temperature, excess sediment, and habitat modification. These issues are to be addressed by BMPs as much as possible. In terms of this project analysis area, BMPs can be applied to soil and watershed conditions everywhere.

Beneficial Uses
The State of New Mexico is required under the New Mexico Water Quality Act (Subsection C of Section 74-6-4, New Mexico Statutes Annotated 1978) and the federal the Clean Water Act, as amended (33 United States Code, Section 1251 et seq.) to adopt water quality standards that protect the public health or welfare and enhance the quality of water and that are consistent with and serve the purposes of the New Mexico Water Quality Act and the federal Clean Water Act. The New Mexico Environment Department Water Quality Control Commission (NMWQCC) has assigned beneficial or protected uses of the surface waters in the project area with two documents under Chapter 6 (Water Quality) of Title 20 (Environmental Protection). These include Part 2, Ground and Surface Water Protection, that covers discharges and disposals, and Part 4, Standards for Interstate and Intrastate Surface Waters. These regulations cover water standards for domestic water supply, irrigation, livestock watering, wildlife habitat, and human health. These uses are protected by water quality standards. Waters are classified by their present or intended future suitable uses. Table 3, below, lists the beneficial use classifications for each watershed in the project area.

Clean Water Act 303(d) Impaired Surface Waters and Total Maximum Daily Loads
Under the Clean Water Act’s Section 303(d), states, territories, and authorized tribes are required to develop lists of impaired waters. These are waters that are too polluted or otherwise degraded to meet the water quality standards set by states, territories, or authorized tribes. The law requires that these jurisdictions establish priority rankings and develop TMDLs for waters on these lists. A TMDL is a calculation of the maximum amount of a pollutant that a water body can receive and still safely meet water quality standards. The NMWQCC is the issuing agency of water quality standards for interstate and intrastate waters in New Mexico.
<table>
<thead>
<tr>
<th>Fourth-Level Watershed</th>
<th>Sixth-Level Watershed Name</th>
<th>Main Stems</th>
<th>Designated Beneficial Use</th>
</tr>
</thead>
<tbody>
<tr>
<td>Rio Chama 13020102</td>
<td>Cañones Creek, Coyote Creek, Headwaters Rio Puerco, Polvadera Creek</td>
<td>Cañones Creek, Coyote Creek, Rio Puerco de Chama, Salitral Creek, Polvadera Creek</td>
<td>Domestic water supply, fish culture, high-quality cold water aquatic life, irrigation, livestock watering, wildlife habitat and primary contact, and public water supply on the Rio Brazos and Rio Chama (20.6.4.119)</td>
</tr>
<tr>
<td>Cañones Creek-Abiquiu Reservoir</td>
<td>Rio Chama</td>
<td>Irrigation, livestock watering, wildlife habitat, primary contact, cold water aquatic life, and warm water aquatic life (20.6.4.117)</td>
<td></td>
</tr>
<tr>
<td>Outlet Rio Puerco</td>
<td>Rio Puerco de Chama</td>
<td>Irrigation, livestock watering, wildlife habitat, cold water aquatic life, warm water aquatic life, and primary contact (20.6.4.118)</td>
<td></td>
</tr>
<tr>
<td>Rio Grande-Santa Fe 13020201</td>
<td>Alamo Canyon-Rio Grande</td>
<td>Rio Grande</td>
<td>Domestic water supply, high-quality cold water aquatic life, irrigation, livestock watering, wildlife habitat, and primary contact (20.6.4.121)</td>
</tr>
<tr>
<td>Capulin Canyon-Rio Grande, Peralta Canyon, Rio Chiquito</td>
<td>Rio Grande, Peralta Canyon, Rio Chiquito</td>
<td>Irrigation, livestock watering, wildlife habitat, marginal cold water aquatic life, primary contact and warm water aquatic life, and public water supply on the main stem Rio Grande (20.6.4.114)</td>
<td></td>
</tr>
<tr>
<td>Headwaters Borrego Canyon</td>
<td>Borrego Canyon</td>
<td>Warm water aquatic life, livestock watering, wildlife habitat, and primary contact (20.6.4.99)</td>
<td></td>
</tr>
<tr>
<td>Jemez 13020202</td>
<td>Cañon de la Canada, Church Canyon Jemez River, East Fork Jemez River, Headwaters Rio Cebolla, Headwaters San Antonio Creek, Outlet Rio Cebolla, Outlet San Antonio Creek, Virgin Canyon</td>
<td>Cañon de la Canada, Jemez River, East Fork Jemez River, Rio Cebolla, San Antonio Creek, Virgin Canyon</td>
<td>Domestic water supply, fish culture, high-quality cold water aquatic life, irrigation, livestock watering, wildlife habitat, and primary contact (20.6.4.108)</td>
</tr>
<tr>
<td>Sulphur Creek</td>
<td>Sulphur Creek</td>
<td>Limited aquatic life, wildlife habitat, livestock watering, and secondary contact (20.6.4.124)</td>
<td></td>
</tr>
<tr>
<td>Vallecita Creek</td>
<td>Vallecita Creek</td>
<td>Coldwater aquatic life, primary contact, irrigation, livestock watering and wildlife habitat, and public water supply on Vallecito Creek (20.6.4.107)</td>
<td></td>
</tr>
</tbody>
</table>

Source: New Mexico Environment Department 2014

**Executive Orders**

Presidential Executive Orders 11988 and 11990 direct federal agencies to avoid impacts on floodplains and wetlands, respectively. Agencies are directed to avoid construction and development in floodplains and wetlands whenever there are feasible alternatives.
Protection of Wetlands
Executive Order 11990 directs all federal agencies to avoid impacts on wetlands. The United States Army Corps of Engineers protects wetlands under the Clean Water Act’s Section 404 regulations.

Floodplain Management
Executive Order 11988 requires federal agencies to provide leadership and to take the following actions:

- Minimize adverse impacts associated with occupancy and modification of floodplains and reduce risks of flood loss
- Minimize the impacts of human safety, health, and welfare
- Restore and preserve the natural and beneficial values served by floodplains

State and Local Law

New Mexico Water Quality Act
The purpose of this state legislation is to implement the Water Quality Act, New Mexico Statutes Annotated 1978.

New Mexico Water Quality Control Commission
The role of this state agency is to protect the environmental quality of New Mexico’s surface and groundwater resources, as mandated by the Water Quality Act and the NMWQCC regulations (20.6 New Mexico Administrative Code).

State Nonpoint Source Management Plan (2009)
The purpose of the New Mexico Nonpoint Source Management Program is to develop dynamic programs and progressive actions to prevent nonpoint source pollutants from entering surface water and groundwater. The nonpoint source management program emphasizes watershed-based planning as a means of coordinating watershed restoration, fostering watershed associations, and encouraging partnership among agencies, nongovernmental organizations, and the public. The New Mexico Environmental Department coordinates with other land management agencies that have established resource protection programs and activities.

- The USFS is a designated management agency for nonpoint source control in New Mexico.
- Responsibilities of the USFS include controlling, abating, and preventing nonpoint source pollution, resulting from all activities conducted on National Forests.
- Water quality concerns identified on National Forests include sediment and nutrient inputs from grazing and foraging, road construction and maintenance, timber harvest, and mining.

Water Resources Allocation Program
Under New Mexico water law, all groundwater and surface waters belong to the public and are subject to appropriation under the Doctrine of Prior Appropriation. This is a constitutional provision that says earlier appropriations have priority over later appropriations.

The Water Resources Allocation Program with the New Mexico Office of the State Engineer is responsible for processing water rights applications, conducting the scientific research for making those water rights decisions, maintaining water rights records, and enforcing any conditions or restrictions on water use.
In New Mexico, the Office of the State Engineer permits all surface water and groundwater withdrawals, apart from water rights acquired before 1907 and small-scale stock watering.

Acequias
Acequias, or community ditches, are recognized under New Mexico law as political subdivisions of the state. There are between 800 and 1,000 acequias in New Mexico. Many of the state’s acequia associations have been in existence since the Spanish colonization period of the seventeenth and eighteenth centuries. Historically, they have been a principal local government unit for the distribution and use of surface water. This type of system is specific to arid environments, such as that of New Mexico, and is the most effective way to equitably distribute water to local populations. An acequia is an extension to a river that diverts water upstream, rather than allowing it to flow downstream in its natural path. Therefore, under New Mexico Water Law, downstream water users have senior rights.

The associations have the power of eminent domain and are authorized to borrow money and enter into contracts for maintenance and improvements. Acequia associations do not have the power to tax, so the expenses of maintenance and improvements are borne by the individuals served by the irrigation system. The Office of the State Engineer officially governs acequias, but the overriding structure for management and distribution is custom, experience, and community.

Other Guidance or Recommendations

Programmatic Environmental Impact Statement for Geothermal Leasing Exploration and Development
The BLM and USFS prepared the 2008 Geothermal Programmatic EIS to assess the environmental impacts of developing and implementing the geothermal program. It would facilitate environmentally responsible, utility-scale, geothermal energy development in Alaska, Arizona, California, Colorado, Idaho, Montana, New Mexico, Nevada, Oregon, Utah, Washington, and Wyoming.

Additionally, the 2008 Geothermal Programmatic EIS allocated NFS lands as open or closed to being considered for geothermal leasing. It also adopted stipulations and BMPs and explained the procedures for geothermal leasing and development (BLM and USFS 2008). The Programmatic EIS identified NFS lands as legally opened for geothermal leasing but did not provide a consent determination for specific proposals. Site-specific analyses of future leasing nominations, permit applications, and operation plans can refer back to the Programmatic EIS to reduce processing time of future geothermal development. The Santa Fe National Forest Geothermal Leasing EIS provides a consent determination on the NFS lands included in the project area.

Topics and Issues Addressed in This Analysis

Issues
The following issues specific to water resources were identified during the public scoping period:

- How would geothermal leasing affect surface and subsurface water quantity? Would geothermal leasing change or reduce water allocations for other uses? What are the short- and long-term impacts on the regional aquifer?
- How would geothermal leasing affect water quality, and what size buffers are necessary to protect surface waters? How might these impacts differ, depending on the type of geothermal system?
• How would geothermal leasing affect the Abiquiu Reservoir and dam and the New Mexico Department of Game and Fish Habitat Stamp Program water projects?

There were no issues specific to soil resources identified during the public scoping period.

**Resource Indicators, Measures, and Method**

Soil and water indicators used to characterize existing conditions and measure change or impacts for the alternatives are detailed below.

**Soils**

**Resource Indicators**

Geothermal exploration and potential development would involve surface disturbance from building new access roads, upgrading existing roads, and installing drilling platforms for exploration wells, geothermal power plants, and pipeline and transmission lines. Construction of these facilities, and activity around the facilities, would directly expose soil surfaces and disturb surrounding areas, increasing the likelihood of erosion by wind and water and subsequent sedimentation.

Available soils data for the project area was analyzed to determine the soils’ susceptibility to erosion and potential transport by surface flow. The analysis also examines areas of expansive soils where constructing facilities may be difficult or unsuitable. Loss of soil productivity due to roads, drilling platforms, and power plants is discussed.

Indicators of the impacts of the proposed action and alternatives are as follows:

• Susceptibility of soils in the project area to water erosion, as measured by the Soil Erosion Hazard
• Susceptibility of soils in the project area to wind erosion
• Potential for runoff and sediment transport in the project area, as measured by the hydrologic soil condition
• Area of expansive soils (shrink/swell potential)

The *Affected Environment* section of this report includes a discussion of current mapping of severe erosion hazard, wind erosion potential, and hydrologic soil groups. The presence of expansive soils is also discussed. Alternatives are compared for their likelihood to disturb soils that are susceptible to erosion by wind and water and subsequent transport. The shrink/swell factor is used to discuss limitations in the area for facility development. Alternatives are compared based on the relative loss of long-term soil productivity.

**Method**

**Soil Erosion Hazard**

The soil erosion hazard is a measure of the relative susceptibility (worst case scenario) to sheet and rill erosion on removal of all vegetation and litter. Therefore, it provides a measure of the risk of erosion to exposed soils. The Terrestrial Ecological Unit Inventory classifies ecological types and maps Terrestrial Ecological Units\(^5\) to a consistent standard throughout NFS lands (USFS 2005). Soils are mapped for a variety of characterizations, including soil erosion hazard. A severe rating indicates that predicted

\(^5\) Ecological units are based on environmental factors, including climate, landform, geology, vegetation, and soils.
potential soil loss rates have a high probability of reducing site productivity. Reasonable and economically feasible mitigation measures are required to minimize soil loss rates. Alternatives are compared for their likely disturbance of these areas.

**Wind Erodibility Group**

The Wind Erodibility Group (WEG) is a United States Department of Agriculture, Natural Resources Conservation Service (NRCS) designation for a grouping of soils that have similar properties affecting their resistance to soil blowing in cultivated areas. The groups indicate the susceptibility to wind erosion. There is a close correlation between soil blowing and the size and durability of surface clodiness, fragments, organic matter, and the calcareous reaction. The soil properties that are most important with respect to blowing soil are soil texture class, organic matter content, carbonates in the fine-earth fraction, rock and pararock\(^6\) fragment content, and mineralogy. Soil moisture and the presence of frozen soil also influence soil blowing (NRCS 2015).

Soils are placed into WEGs on the basis of the properties of the soil surface layer. The range of valid entries for WEG data is 1, 2, 3, 4, 4L, 5, 6, 7, and 8, with 1 being the most susceptible to wind erosion. A data group of 1 would include very fine sand, fine sand, sand, and coarse sand. A data group of 8 would indicate soils that are not susceptible to wind erosion, due to rock and pararock fragments at the surface or wetness.

**Hydrologic Soil Group**

The NRCS classifies soils based on their runoff potential from rainfall. The primary consideration is the inherent capacity of bare soil to permit infiltration. A hydrologic soil group is a group of soils that have similar runoff potential under similar storm and cover conditions. The soil properties that affect runoff potential include those that influence the minimum rate of infiltration for a bare soil after prolonged wetting and when not frozen. These properties include saturated hydraulic conductivity after prolonged wetting, depth to seasonal high water table, and depth to a layer with a very slow water transmission rate (NRCS 2015). Slope and vegetation cover are not considered.

There are four hydrologic soil groups:

- **Group A**—Soils with a high infiltration rate when thoroughly wet and a low runoff potential. Water is transmitted freely through the soil. These soils are well drained and sandy or gravelly and are often deep. Group A soils typically are less than 10 percent clay and more than 90 percent sand or gravel. Some soils with loamy sand, sandy loam, loam, or silt loam textures may be included if they are well aggregated or of low bulk density or contain greater than 35 percent rock fragments.

- **Group B**—Soils with a moderately low runoff potential when thoroughly wet. Water transmission through the soil is unimpeded. Group B soils typically have between 10 and 20 percent clay and 50 and 90 percent sand and have loamy sand or sandy loam textures. Some soils having loam, silt loam, silt, or sandy clay loam textures may be placed in this group if they are well aggregated or of low bulk density or contain greater than 35 percent rock fragments.

- **Group C**—Soils with a moderately high runoff potential when thoroughly wet. Water transmission through the soil is somewhat restricted. Group C soils typically have between 20 and 40 percent clay and less than 50 percent sand. They tend to have loam, silt loam, sandy clay loam, clay loam, and silty clay loam textures. Some soils having clay, silty clay, or sandy clay textures may be placed in

\(^6\) Soft rock fragments
this group if they are well aggregated or of low bulk density or contain greater than 35 percent rock fragments.

- **Group D**—Soils with a very slow infiltration rate and a high runoff potential when thoroughly wet. Water movement through the soil is restricted or very restricted. These soils often have a clay pan or clay layer at or near the surface or a permanently high water table or are shallow over nearly impervious bedrock. Group D soils typically have greater than 40 percent clay and less than 50 percent sand and have clayey textures. In some areas, they also have high shrink/swell potential. All soils with a depth to a water-impermeable layer of less than 50 centimeters and all soils with a water table within 60 centimeters of the surface are in this group, although some may have a dual classification if they can be adequately drained.

**Expansive Soils – Shrink/Swell Potential**

Expansive soils are capable of absorbing water and are typically clayey type soils. When they absorb water, they increase in volume. Expansions of 10 percent or more are not uncommon (Colorado Geological Survey 2015), and the extent is influenced by the amount and kind of clay in the soil. The soil shrinks when it dries out. Shrink/swell potential is the relative change in volume to be expected with changes in moisture content. The change in volume can exert enough force on buildings or structures to cause damage, such as cracked foundations and walls. Roads and other structures can also be damaged. A high shrink/swell potential indicates a hazard to buildings built on that particular soil (NRCS 2015).

The affected environment presents the areas of high shrink/swell potential, which indicate a concern for structural integrity. The alternatives are discussed qualitatively in terms of differences in potential limitations in construction or additional precautions to be taken, should areas of high shrink/swell potential be target areas for exploration.

**Loss of Soil Productivity**

Areas that are disturbed will have a loss of soil productivity as soils are removed from productive use during disturbance. This loss may be temporary, as in disturbance surrounding sites or along edges of roads, or it may be long term, due to construction of impermeable surfaces, such as drilling pads and power plants. The loss would not be permanent, because all surfaces would be reclaimed when exploration is unsuccessful or after production ceases. All surface disturbances are to be reclaimed to BLM standards. Reclamation includes removing all facilities and regrading and recontouring all surface disturbances to blend with the surrounding topography and reestablishing a desirable variety of vegetation.

The alternatives are discussed qualitatively in terms of differences in potential loss of short- and long-term productivity.

**Watershed – Surface Water and Groundwater**

**Resource Indicators**

Geothermal energy production could impact the water quality and quantity of both surface water and groundwater. As discussed under *Soils*, above, geothermal exploration and potential development will directly expose soil surfaces and disturb surrounding areas, increasing the likelihood of erosion by wind and water and subsequent transport and possible deposition into surface waters. This is a concern, both for individual water sources and for the health of the watershed as the sediments are transported downstream.

Hot water that is pumped from underground reservoirs often contains high levels of dissolved constituents, potentially including sulfur, boron, and arsenic. The volume of dissolved solids increases
significantly with temperature, and some of these dissolved minerals could contaminate surface water or groundwater (United States Department of Energy 2006). Binary geothermal systems use a closed loop, in which the extracted thermal water is pumped back into the geothermal reservoir after its heat has been used for energy production. In this type of system, the water is contained within steel casings to prevent cross contamination of the thermal brine with cold, meteoric groundwater and surface waters; this protects the subsurface freshwater zones from the extracted geothermal waters. However, should this water come in contact with freshwater due to a leak in the pipes or a surface spill, the toxicity of the water could contaminate the freshwater sources.

There are several natural hydrothermal features in or near the project area. In areas with natural surface thermal features, such as hot springs and steam vents, subsurface depletion of geothermal fluids by production wells could change the rate of flow and vigor of these features. These adverse impacts can be minimized by properly siting injection and production wells to maintain reservoir-fluid pressure at or near preproduction levels. Monitoring hot spring behavior and subsurface reservoir conditions could be used to identify potential problems early enough to allow timely mitigation (Duffield and Sass 2003).

Freshwater would be used in the drilling operations. Water would be required for well drilling, dust control, and operations. No water would be needed for cooling because the air temperature is cool enough to allow for air-cooled water to be reinjected. Freshwater would be trucked in, if possible. However, it is also possible that freshwater would need to be pumped from local springs and water wells, after appropriate water rights are obtained through the New Mexico Office of the State Engineer.

Extracting geothermal fluids, combined with possible near meteoric groundwater depletion for project use, could affect soils. This would come about by reducing the saturated zones, source water for wetlands and riparian areas, vegetation characteristics, and flows in natural springs. Reductions in groundwater levels could decrease the volumes of groundwater stored in the various aquifers and reduce yields to local wells.

Conversely, groundwater levels could mound, due to injection wells. The impacts could include increased saturated zones, increased water availability to wetlands and riparian zones, increased flows in springs, and changes in groundwater flow patterns. The water that is re-injected into the subsurface may or may not recharge the aquifer from which it was extracted.

Indicators of impacts to analyze the above concerns of the proposed action and alternatives are as follows:

- Erosion and sedimentation that could alter or impair perennial or intermittent streams; analysis includes a combined erosion and transport potential for each watershed in the project area, as measured by the soil erosion water factor (Kw) and slope to form the watershed erodibility index
- Possible impacts on beneficial uses and sensitive watersheds, as measured by combining such factors as the watershed erodibility index, watershed condition class, impaired streams, density of roads, and beneficial uses
- Potential for contaminating fresh surface water or groundwater supplies, as indicated by risk of leaks and spills
- Possibility for depleting groundwater supplies or interfering with groundwater recharge, such that the local groundwater table would be lowered to a level that would not support existing land uses
- Potential for groundwater mounding, due to injection that does not result in groundwater being returned to the aquifer that it was extracted from

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7 Meteoric water is derived from atmospheric precipitation or condensation.
• Potential for changes to natural thermal features
• Potential for changes in flow from springs and in surface water drainages
• Potential for changes in groundwater or surface water temperatures
• Potential for changes in groundwater or surface water quality
• Potential for changes in source water and vegetation at wetland areas
• Possible flash flooding impacts on proposed facilities, as indicated by location of 100-year floodplains

Methodology

Watershed Erodibility Index

The watershed erodibility index differs from the soil erosion hazard discussed for soils analysis, in that it provides a measure of the susceptibility of a watershed to soil erosion and transport to the watershed’s streams. The watershed erodibility index analysis uses a combination of two standard erodibility indicators: the inherent susceptibility of soil to erosion by water (Kw factor) and land slope derived from USGS 30-meter digital elevation models. The Kw factor data from the State Soil Geographic Spatial Database was combined with a slope grid using NRCS (1997) slope-soil relationships to create a classification grid divided into slight, moderate, severe, and very severe erodibility-transport risk ratings (Table 4). These ratings are then weighted across the watershed to create an index, ranging from 1 (the entire watershed is at a slight risk of erosion and transport) to 4 (the entire watershed is a very severe risk of erosion and transport). This index can be used to evaluate the relative risk between watersheds as to the inherent erosion and transport risk.

Table 4. NRCS Criteria for Determining Potential Erodibility-Transport

<table>
<thead>
<tr>
<th>Percent Slope</th>
<th>Kw Factor &lt; 0.1</th>
<th>Kw Factor 0.1 to 0.19</th>
<th>Kw Factor 0.2 to 0.32</th>
<th>Kw Factor &gt;0.32</th>
</tr>
</thead>
<tbody>
<tr>
<td>0-14%</td>
<td>Slight</td>
<td>Slight</td>
<td>Slight</td>
<td>Moderate</td>
</tr>
<tr>
<td>15-34%</td>
<td>Slight</td>
<td>Slight</td>
<td>Moderate</td>
<td>Severe</td>
</tr>
<tr>
<td>35-50%</td>
<td>Slight</td>
<td>Moderate</td>
<td>Severe</td>
<td>Very Severe</td>
</tr>
<tr>
<td>&gt; 50%</td>
<td>Moderate</td>
<td>Severe</td>
<td>Very Severe</td>
<td>Very Severe</td>
</tr>
</tbody>
</table>

Source: NRCS 1997

Watershed Condition Framework

A watershed’s condition class integrates the impact of all activities in a watershed; therefore, watersheds provide an ideal mechanism for interpreting the cumulative impact of a multitude of management actions on soil and hydrologic function.

Watersheds that are functioning properly have five important characteristics (Williams et al. 1997), as follows:

• They provide for high biotic integrity, which includes habitats that support adaptive animal and plant communities that reflect natural processes.
• They are resilient and recover rapidly from natural and human disturbances.
• They exhibit a high degree of connectivity longitudinally along the stream, laterally across the floodplain and valley bottom, and vertically between surface and subsurface flows.
They provide important ecosystem services, such as high-quality water, the recharge of streams and aquifers, the maintenance of riparian communities, and the moderation of climate variability and change.

They maintain long-term soil productivity.

The USFS Manual (2521.1; USFS 2004) uses three classes to describe watershed condition:

- Class 1 watersheds exhibit high geomorphic, hydrologic, and biotic integrity, relative to their natural potential condition.
- Class 2 watersheds exhibit moderate geomorphic, hydrologic, and biotic integrity, relative to their natural potential condition.
- Class 3 watersheds exhibit low geomorphic, hydrologic, and biotic integrity, relative to their natural potential condition.

In this context, integrity relates directly to functionality. Geomorphic functionality or integrity can be defined in terms of such attributes as slope stability, soil erosion, channel morphology, and other upslope, riparian, and aquatic habitat characteristics. Hydrologic functionality or integrity relates primarily to flow, sediment, and water quality attributes. Biological functionality or integrity is defined by the characteristics that influence the diversity and abundance of aquatic species, terrestrial vegetation, and soil productivity. In each case, integrity is evaluated in the context of the natural disturbance regime, geoclimatic setting, and other important factors within the context of a watershed. The definition encompasses both aquatic and terrestrial components. This is because water quality and aquatic habitat are inseparably related to the integrity, so the functionality of upland and riparian areas in a watershed.

- Class 1—Functioning properly
- Class 2—Functioning at risk
- Class 3—Impaired function

Figure 3 illustrates the 12 indicator model that the watershed condition framework is based on. This framework takes into account aquatic and terrestrial, physical, and biological indicators. Each has categories by which the watershed condition is determined. The indicators are described in Figure 3.

**Density of Roads and Streams in a Watershed**

Roads can convert subsurface runoff to surface runoff and then route the surface runoff to stream channels, increasing peak flows (Megan and Kidd 1972; Ice 1985; Swanson et al. 1987). Therefore, watersheds with higher road densities have a higher sensitivity to increases in peak flows following natural events and also can result in more sediment reaching stream channels. The density of roads in a watershed generally will increase the risk of that watershed to erosion and sedimentation. However, a higher road density also means that roads may be available for use to access a site without building new roads.

**Information Sources**

**Soils**

The soil erosion hazard is from the Terrestrial Ecological Unit Inventory, which classifies ecological types and maps terrestrial ecological units to a consistent standard throughout NFS lands (USFS 2005). Soils are mapped for a variety of characterizations, including soil erosion hazard.
The Digital General Soil Map of the United States, or STATSGO2, is a broad-based inventory of soils and nonsoil areas that occur in a repeatable pattern on the landscape and that can be cartographically shown at the scale mapped of 1:250,000 in the continental United States. The United States General Soil Map is comprised of general soil association units and is maintained and distributed as a spatial and tabular dataset from the NRCS. This level of soils data was used for the existing condition of soils in the project area.

The WEG was taken from the NRCS designation layer (NRCS 2016).

The roads surface layer is from the USFS SFNF dataset (USFS 2016). This coverage was derived from aerial photo interpretation. It was augmented with road data from USFS field personnel. A road is a motor vehicle travel way over 50 inches wide, unless classified and managed as a trail. A road may be classified or unclassified. Classified roads are those on NFS lands planned and managed for motor vehicle access. This includes state roads, county roads, private roads, permitted roads, and USFS roads. Unclassified roads are those not intended to be a part of nor managed as a part of the forests transportation system. Examples are temporary roads and unplanned, unengineered, unauthorized off-road vehicle tracks and abandoned travel ways. The scale of this layer is 1:24,000.
Watersheds and Surface Water
The surface water layers were taken from the National Hydrography Dataset Stream and Water Body geographic information system (GIS) layers (USGS 2016). The National Hydrography Dataset represents the drainage network with such features as rivers, streams, canals, lakes, ponds, coastlines, dams, and stream gages. This dataset has a scale of 1:24,000. These data are designed to be used in general mapping and in the analysis of surface water systems.

The watershed boundary delineated by the NRCS Geospatial Data Gateway. Both 4th- and 6th-level watershed boundaries from this dataset are used.

The watershed erodibility index analysis uses the Kw factor from the State Soil Geographic Spatial Database and land slope derived from USGS 30-meter digital elevation models.

The watershed condition class framework is from the USFS GIS Layer. The 100-year floodplains are from the Federal Emergency Management Act GIS layer.

Groundwater
The well data is from the New Mexico Office of the State Engineer Enterprise GIS (New Mexico Office of the State Engineer 2015). This site offers an open data source, which is set up for agency transparency for allowing the public and other agencies access to downloadable data from the New Mexico Office of the State Engineer. The point of diversions layer includes well locations, surface declarations, or surface permits. These data were extracted from the New Mexico Office of the State Engineer Water Administration Technical Engineering Resource System database and geo-located. They have varying degrees of accuracy and have not been validated. The data are current as of November 2015.

Affected Environment
Soils
Geologic History of Project Area
The Jemez Mountains and the Valles Caldera are composed of Quaternary Period alluvial and landslide deposits and welded Bandelier tuff, and Tertiary basalt, basaltic-andesite, or rhyolite and breccias, clastic sedimentary rocks, resulting from volcanic activity in the region 13 million years ago. These rocks overlie Tertiary, Mesozoic, and Paleozoic sedimentary rocks, which in turn overlie Precambrian granitic basement rock. More specifically, the Paleozoic Madera limestone underlies the redstones, siltstones, and shale of the Abo Formation, with the Mesozoic Chinle formation and the Tertiary Santa Fe Group and Abiquiu tuff superseding. The more permeable layers of volcanic tuff allow for groundwater to occur in perched aquifers above the relatively impermeable Abo Formation. The unique faulting and rifting of the caldera region offers a unique, and still somewhat unknown, groundwater discharge regime.

The Colorado Plateau rocks are down-faulted to the east into the Rio Grande Rift. Unconsolidated Tertiary sediments of the Santa Fe Formation thicken eastward toward the axis of the rift. The Jemez Mountains volcanics occur at the intersection of the rift with the northeast-trending Jemez lineament, a line of Miocene to Quaternary volcanic fields, extending across the northwest portion of New Mexico (Aldrich and Laughlin 1984; Shevenell et al. 1987).

The lower Rio Chama, below Abiquiu Reservoir, has an average drop of 13.1 feet per mile and cuts through the southeastern Colorado Plateau, which consists of high mesas dissected by tributaries of the
Rio Chama and its main stem. Rock units exposed in the lower reach of the river include the Ojo Caliente sandstone, Abiquiu tuff, and Lobato basalt (Wells 2009).

The valley floors also consist of Tertiary Period partly compacted sands and gravels of the Santa Fe Group or Quaternary Period alluvium. This area is downstream of the Abiquiu Reservoir, to the confluence of the Rio Chama with the Rio Grande, and following the Rio Grande downstream to the southern reaches of the project area and its confluence with the Jemez River. The Santa Fe Group consists of alluvial fans, river channel deposits, and interbedded volcanic rocks. Several of the mesas are capped by Triassic Period basaltic to andesitic lava flows (NRCS 2011a).

**General Characterization**

The soils of the project area are primarily characterized by soils typical of the region. The general texture of soils over the entire project area is silt/loam/clay, with the loamy texture dominating. The average pH is 7.1, with a minimum of 5.1 and a maximum of 8.92. The primary soil taxa in the project area are Inceptisols (49.9 percent of the project area), Alfisols (26.4 percent), Entisols (12.1 percent) and Mollisols (8.0 percent). The remaining 4 percent of the area is a combination of Aridisols and Psamments (see Figure 4 and Table 5). Table 5 details the percentage of each type of soil in each unit of the project area, and Figure 5 illustrates the geographic relationships of the soil taxa in the project area.

**Table 5. Percent of Soil Type by Project Area Unit (STATSGO2)**

<table>
<thead>
<tr>
<th>Inceptisols</th>
<th>Entisols</th>
<th>Alfisols</th>
<th>Mollisols</th>
<th>Aridisols</th>
<th>Psamments</th>
</tr>
</thead>
<tbody>
<tr>
<td>JNRA Unit</td>
<td>49</td>
<td>33</td>
<td>15</td>
<td>4</td>
<td>0</td>
</tr>
<tr>
<td>Lease Interest Unit</td>
<td>57</td>
<td>0</td>
<td>20</td>
<td>23</td>
<td>0</td>
</tr>
<tr>
<td>Middle Unit</td>
<td>54</td>
<td>7</td>
<td>40</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>North Unit</td>
<td>43</td>
<td>7</td>
<td>36</td>
<td>5</td>
<td>10</td>
</tr>
<tr>
<td>South Unit</td>
<td>55</td>
<td>15</td>
<td>23</td>
<td>6</td>
<td>0</td>
</tr>
<tr>
<td>Overall Project Area</td>
<td>50</td>
<td>12</td>
<td>26</td>
<td>8</td>
<td>4</td>
</tr>
</tbody>
</table>

Inceptisols are soils that are in the beginning stages of soil profile development and show minimal horizon development. Some color changes may be evident between the emerging horizons. The beginnings of a B horizon may be seen, with the accumulation of small amounts of clay, salts, and organic matter. They are often found on fairly steep slopes, young geomorphic surfaces, wet sites, and resistant parent materials. They are widely distributed and are found across a wide range of ecological settings. A sizable percentage is found in mountainous areas. The natural productivity of these soils varies widely and depends on clay and organic matter content (US Department of Agriculture [USDA] National Institute of Food and Agriculture 1999).

Inceptisols are widespread, covering 50 percent of the project area. In individual units, they make up from 43 to 57 percent of the unit’s area. Figure 4 illustrates that they are found in all units in expansive areas. The Lease Interest Unit has the largest coverage of land area by Inceptisols, at 57 percent. The lowest is the Northern Unit, with 43 percent coverage by Inceptisols.

Entisols are a diverse group of soils with little profile development. These soils are often found in unstable environments, such as floodplains, sand dunes, and steep slopes. They are often found in very dry or cool locations, where climate limits soil profile development. They are also found at the site of recently deposited materials or in parent materials resistant to weathering (USDA National Institute of Food and Agriculture 1999).
Figure 4. Soil Taxa within each Unit of the Project Area
Figure 5. Terrestrial Ecological Unit Severe Soil Erosion by Project Area Unit
Entisols occur on only 12 percent of the project area, most commonly in the southwest, with a small area in the northeast. In individual units where they occur, they cover between 7 and 33 percent of the unit. The JNRA Unit has the greatest coverage by Entisols of all units, at 33 percent, primarily along the Cañon de San Diego.

Alfisols are moderately leached soils that have a relatively high native fertility. They mainly form under forest cover and have a subsurface horizon in which clays have accumulated (USDA National Institute of Food and Agriculture 1999). Alfisols generally show extensive profile development, with distinct clay accumulations in the subsoil. Extensive leaching often produces a light-colored E horizon below the topsoil. They are generally fertile and productive soils, and have a high concentration of the nutrients calcium, magnesium, potassium, and sodium. They form in regions with sufficient moisture for plants for at least part of the year (USDA National Institute of Food and Agriculture 1999). Because these soils have water and bases, they are, as a whole, intensively used (NRCS 1999).

Alfisols are the second most common soil type in the project area, covering 26 percent of the units. In individual units, they make up from 15 to 40 percent of the unit’s area. Figure 5 illustrates that they are widely distributed throughout the project area and are found in all units. The areas with the least occurrence of this soil type are the eastern half of the JNRA and South Units.

Mollisols are mineral soils that have developed on grasslands, a vegetation type that has extensive fibrous root systems. They characteristically have a thick, very dark brown to black surface horizon that is rich in organic matter, giving the soil high natural fertility. They are typically well saturated with basic cations of calcium, magnesium, sodium, and potassium, which are essential plant nutrients. They are considered to be among the most fertile soils on earth and are the dominant soil order of the North American Great Plains region. Mollisols characteristically form under grass in climates that have a moderate to pronounced seasonal moisture deficit (USDA National Institute of Food and Agriculture 1999; NRCS 1999).

Mollisols occur on only 8 percent of the project area, in all except the Middle Unit, most commonly in the southwest, with a small area in the northeast. In individual units where they occur, they cover between 4 and 23 percent of the unit. The largest block of Mollisols in the project area straddles the North and Lease Interest Units.

**Soil Erosion Hazard**

Soil erosion hazard is a measure of the susceptibility of the soil to erode when its surface is exposed to water. A severe rating indicates that predicted potential soil loss rates have a high probability of reducing site productivity due to erosion (see Resource Indicators and Methodology for Soils). Areas of severe soil erosion are shown on Figure 5, and Table 6 summarizes the area of severe erosion hazard by unit.

There are 107,775 acres of severe erosion hazard in the project area. Figure 5 illustrates the concentration of severe ranking throughout much of the Lease Interest Unit, particularly in the eastern two-thirds. The Middle Unit is also dominated by severe erosion hazard throughout.

The other units have areas ranked as severe, but these areas tend to be interspersed with lower erosion hazard areas. In the Lease Interest Unit and Middle Unit, over 82 percent of the area is rated as severe. In the JNRA Unit, North Unit, and South Unit, the percent of area with a severe erosion hazard rating is much lower, ranging from 43 to 48 percent (Table 6).
Table 6. Area of Severe Erosion Hazard per Unit in Project Area

<table>
<thead>
<tr>
<th></th>
<th>Area of Severe Erosion Hazard in Unit (Acres)</th>
<th>Percent of Unit with Severe Erosion Hazard</th>
</tr>
</thead>
<tbody>
<tr>
<td>JNRA Unit</td>
<td>18,880</td>
<td>48%</td>
</tr>
<tr>
<td>Lease Interest Unit</td>
<td>32,561</td>
<td>83%</td>
</tr>
<tr>
<td>Middle Unit</td>
<td>11,528</td>
<td>82%</td>
</tr>
<tr>
<td>North Unit</td>
<td>29,460</td>
<td>43%</td>
</tr>
<tr>
<td>South Unit</td>
<td>15,346</td>
<td>45%</td>
</tr>
<tr>
<td>Totals</td>
<td>107,775</td>
<td>55%</td>
</tr>
</tbody>
</table>

Source: USFS 2005

Wind Erodibility Group

The WEG is an NRCS designation for a grouping of soils that have similar properties affecting their susceptibility to wind erosion (see Resource Indicators and Methodology for Soils). The ranking ranges from 1 to 8, with 1 being the most susceptible to wind erosion. Data group 1 includes fine sand, sand, and coarse sand. A data group of 8 would indicate soils that are not susceptible to wind erosion due to rock and pararock fragments at the surface. WEGs for the project area are illustrated on Figure 6; Table 7 summarizes the percent of area in each WEG by project area unit.

Table 7. Percent of each WEG in the Project Area

<table>
<thead>
<tr>
<th></th>
<th>WEG 1</th>
<th>WEG 2</th>
<th>WEG 3</th>
<th>WEG 4L</th>
<th>WEG 5</th>
<th>WEG 7</th>
<th>WEG 8</th>
</tr>
</thead>
<tbody>
<tr>
<td>JNRA Unit</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>12</td>
<td>21</td>
<td>35</td>
<td>33</td>
</tr>
<tr>
<td>Lease Interest Unit</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>29</td>
<td>12</td>
<td>59</td>
<td>0</td>
</tr>
<tr>
<td>Middle Unit</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>33</td>
<td>61</td>
<td>0</td>
<td>6</td>
</tr>
<tr>
<td>North Unit</td>
<td>0</td>
<td>23</td>
<td>14</td>
<td>5</td>
<td>10</td>
<td>42</td>
<td>7</td>
</tr>
<tr>
<td>South Unit</td>
<td>1</td>
<td>0</td>
<td>0</td>
<td>12</td>
<td>6</td>
<td>65</td>
<td>15</td>
</tr>
<tr>
<td>Totals</td>
<td>0</td>
<td>8</td>
<td>5</td>
<td>14</td>
<td>16</td>
<td>45</td>
<td>12</td>
</tr>
</tbody>
</table>

The soils of the project area are not particularly susceptible to wind erosion, with the exception of the soils in the North Unit (Figure 6). Twelve percent of the project area is covered with soils that are not susceptible to wind erosion (WEG 8), and only 1 percent of the area, located at the very southern end of the South Unit, is covered with soils that are the most susceptible to wind erosion (WEG 1). Across the project area, 73 percent is covered by soils that are categorized as WEG 5 or higher, with large tracts of land (57 percent of the project area) categorized as WEG 7 or 8.

The North Unit and the Middle Unit have some of the most susceptible soils. Although the North Unit has large areas of WEG 7, 23 percent of its area is in WEG 2 and 14 percent of the area is in WEG 3. The areas of higher wind erosion potential are located in the northern half of the area towards the Rio Chama and Abiquiu Reservoir. The Middle Unit has only 6 percent of its area in WEG 8 and no areas of WEG 7. Most of its area is in the middle erosion groups WEG 4L and WEG 5.
Figure 6. Wind Erodibility Groups within the Project Area
**Hydrologic Soil Group**

A hydrologic soil group has soils with similar runoff potential under similar storm and cover conditions (see *Resource Indicators and Methodology for Soils*). The classification reflects the soil’s runoff potential from rainfall. The rankings range from A to D, with A being the lowest runoff potential and highest infiltration rates and D having the highest runoff potential and lowest infiltration rates. *Figure 7* illustrates the runoff potential represented by the hydrologic soil group for the project area. *Table 8* summarizes the percent of area covered by each hydrologic soil group by project unit and illustrates the hydrologic soil groups in the project area.

*Table 8. Percent of each Hydrologic Soil Group in the Project Area*

<table>
<thead>
<tr>
<th>Hydrologic Soil Group</th>
<th>A Low Runoff Potential High Infiltration Rate</th>
<th>B Moderately Low Runoff Potential</th>
<th>C Moderately High Runoff Potential</th>
<th>D High Runoff Potential Very Slow Infiltration Rate</th>
</tr>
</thead>
<tbody>
<tr>
<td>JNRA Unit</td>
<td>0</td>
<td>68</td>
<td>0</td>
<td>32</td>
</tr>
<tr>
<td>Lease Interest Unit</td>
<td>0</td>
<td>21</td>
<td>41</td>
<td>38</td>
</tr>
<tr>
<td>Middle Unit</td>
<td>0</td>
<td>67</td>
<td>0</td>
<td>33</td>
</tr>
<tr>
<td>North Unit</td>
<td>0</td>
<td>56</td>
<td>19</td>
<td>25</td>
</tr>
<tr>
<td>South Unit</td>
<td>0</td>
<td>45</td>
<td>0</td>
<td>55</td>
</tr>
<tr>
<td>Project Area</td>
<td>0%</td>
<td>50</td>
<td>15</td>
<td>35</td>
</tr>
</tbody>
</table>

Source: NRCS 2016

The soils of the project area tend to have a moderate to high runoff potential. None of the soils fall into hydrologic soil group A, which is the lowest potential for runoff. Thirty-five percent of the project area has a high runoff potential and very slow infiltration rate, as indicated by hydrologic soil group D. The Unit with the most area in hydrologic soil groups C and D is the Lease Interest Unit, with 79 percent of its area having either a moderately high or high runoff potential. Only 21 percent of the Lease Interest Unit has a low runoff potential, which is the smallest area in this category of the units. The North Unit has the least area in hydrologic soil group D, at 25 percent; however, 19 percent is in hydrologic soil group C, so the combination of moderately high to high runoff potential is 44 percent. This can be compared to the JNRA and Middle Units, which have a third of their areas in hydrologic soil group D but no areas in hydrologic soil group C; approximately 70 percent of the area is at moderately low runoff potential.

**Expansive Soils – Shrink/Swell Potential**

Shrink/swell potential is the relative change in volume to be expected with changes in moisture content. The change in volume can exert enough force on a building or structures to cause structural damage to structures and roads. *Figure 8* illustrates the distribution of low, moderate, and high shrink/swell potential in the project area. Most of the area has a low shrink/swell potential. The South Unit has no areas of moderate or high shrink/swell potential. The JNRA and Middle Units have a few limited areas of high moderate and high shrink/swell.

The Lease Interest Unit has a few larger areas of moderate shrink/swell potential, primarily in the center of the unit. Pockets of high shrink/swell potential are scattered throughout the unit. The North Unit is the most affected by expansive soils. There are larger areas of high shrink/swell potential throughout the unit, particularly in the northern portion. There is also a high shrink/swell potential area in the center of the unit and in the southwest, where the unit adjoins the Lease Interest Unit.
Figure 7. Hydrologic Soil Groups in the Project Area
Figure 8. Shrink/Swell Potential within the Project Area
Summary of Affected Environment for Soils by Unit

Table 9 illustrates the previous soils discussion by outlining the impacts on soils described by analysis area, or unit. This table can be used to compare the relative risks to soil resources by unit.

Table 9. Summary of Affected Environment for Soils

<table>
<thead>
<tr>
<th>JNRA Unit</th>
<th>Lease Interest Unit</th>
<th>Middle Unit</th>
<th>North Unit</th>
<th>South Unit</th>
<th>Totals</th>
</tr>
</thead>
<tbody>
<tr>
<td>Area of severe erosion hazard per Unit in the Project Area</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Area of severe erosion hazard (acres)</td>
<td>18,880</td>
<td>32,561</td>
<td>11,528</td>
<td>29,460</td>
<td>15,346</td>
</tr>
<tr>
<td>Percent of unit with severe erosion hazard</td>
<td>48</td>
<td>83</td>
<td>82</td>
<td>43</td>
<td>45</td>
</tr>
<tr>
<td>Percent of Each WEG per Unit in the Project Area</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>WEG 1</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>WEG 2</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>23</td>
<td>0</td>
</tr>
<tr>
<td>WEG 3</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>14</td>
<td>0</td>
</tr>
<tr>
<td>WEG 4</td>
<td>12</td>
<td>29</td>
<td>33</td>
<td>5</td>
<td>12</td>
</tr>
<tr>
<td>WEG 5</td>
<td>21</td>
<td>12</td>
<td>61</td>
<td>10</td>
<td>6</td>
</tr>
<tr>
<td>WEG 7</td>
<td>35</td>
<td>59</td>
<td>0</td>
<td>42</td>
<td>65</td>
</tr>
<tr>
<td>WEG 8</td>
<td>33</td>
<td>0</td>
<td>6</td>
<td>7</td>
<td>15</td>
</tr>
<tr>
<td>Percent of Each Hydrologic Soil Group per Unit in the Project Area</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>A: Low runoff potential/high infiltration rate</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>B: Moderately low runoff potential</td>
<td>68</td>
<td>21</td>
<td>67</td>
<td>56</td>
<td>45</td>
</tr>
<tr>
<td>C: Moderately high runoff potential</td>
<td>0</td>
<td>41</td>
<td>0</td>
<td>19</td>
<td>0</td>
</tr>
<tr>
<td>D: High runoff potential/very slow infiltration rate</td>
<td>32</td>
<td>38</td>
<td>33</td>
<td>25</td>
<td>55</td>
</tr>
<tr>
<td>Percent Area of Soils with Shrink/Swell Potential per Unit</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>High shrink/swell potential (%)</td>
<td>2</td>
<td>3</td>
<td>4</td>
<td>18</td>
<td>0</td>
</tr>
<tr>
<td>Moderate shrink/swell potential (%)</td>
<td>1</td>
<td>6</td>
<td>2</td>
<td>10</td>
<td>0</td>
</tr>
<tr>
<td>Low shrink/swell potential (%)</td>
<td>62</td>
<td>82</td>
<td>63</td>
<td>33</td>
<td>66</td>
</tr>
<tr>
<td>Percent of Each Soil Type per Unit</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Inceptisols (minimal horizon development, found on steep or wet sites)</td>
<td>49</td>
<td>57</td>
<td>54</td>
<td>43</td>
<td>55</td>
</tr>
<tr>
<td>Alfisols (subsurface clay horizon, moderately leached, extensive profile development)</td>
<td>15</td>
<td>20</td>
<td>40</td>
<td>36</td>
<td>23</td>
</tr>
<tr>
<td>Entisols (minimal profile development, unstable environments)</td>
<td>33</td>
<td>0</td>
<td>7</td>
<td>7</td>
<td>15</td>
</tr>
<tr>
<td>Mollisols (rich and fertile soil, thick surface horizon)</td>
<td>4</td>
<td>23</td>
<td>0</td>
<td>5</td>
<td>6</td>
</tr>
<tr>
<td>Aridisols (dry, some horizon development, limited leaching)</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>10</td>
<td>0</td>
</tr>
<tr>
<td>Psamments (very sandy Entisols)</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>1</td>
</tr>
</tbody>
</table>

Source: USFS 2005; NRCS 2016

North Unit

The North Unit includes five soil types. The largest area is covered by Inceptisols and Entisols, which are the soil types that have minimal profile development. A pocket of Mollisols, a rich and fertile soil, is found at the higher elevations of the unit. Alfisols occur throughout and cover 36 percent of the unit. A stretch of Aridisols occurs along the northern edge of the unit, at the lowest elevations. This is the only occurrence of Aridisols in the project area. Aridisols are desert-like, low-organic soils containing calcium carbonate. They are found in semiarid and arid regions and are common in the American Southwest. They tend to be sparsely vegetated by drought and salt-tolerant plants. They exhibit at least some subsurface horizon development.

The North Unit has the smallest area of severe erosion hazard of the project area units, at 43 percent. These areas are distributed throughout the unit. Some of the soils in the northern half of this unit are susceptible to wind erosion, as indicated by 37 percent of the unit being WEG 2 and WEG 3. The runoff...
potential, as indicated by the hydrologic soil groups, indicates that approximately 44 percent of the area has a moderately high to high runoff potential. These areas do tend to overlap many of the areas of severe erosion hazard.

The North Unit has the most area covered by expansive soils. Several larger areas of expansive soils are scattered throughout the unit.

**Lease Interest Unit**

The Lease Interest Unit is covered by three soil types, distributed throughout. Approximately 57 percent of the unit is covered by Inceptisols. The more fertile and developed Alfisols and Mollisols cover 20 percent and 23 percent, respectively.

Eighty-three percent of the Lease Interest Unit is characterized by severe erosion hazard. The eastern two-thirds of the unit has only small pockets that are not identified as severe hazard. The risk of wind erosion is relatively low, because nearly 60 percent of the area is WEG 7 and no area has a lower WEG than 4L. Approximately 79 percent of the unit has a moderately high to high runoff potential.

The combination of the extent and location of area of severe erosion hazard and moderately high to high runoff potential is a concern. The map for severe erosion hazard overlain with the map for runoff potential shows that these areas overlap for much of the unit. Therefore, highly erosive areas are also at risk for erosion, due to runoff and subsequent transport.

The Lease Interest Unit has a few larger areas of moderate to high shrink/swell potential, primarily in the center of the unit. A few smaller areas of high shrink/swell potential are scattered in the eastern half of the unit.

**Middle Unit**

The Middle Unit is primarily covered by Inceptisols and Alfisols, with a small area of Entisols along the western edge. Together, the less developed Inceptisols and Entisols cover 61 percent of the unit.

Like the Lease Interest Unit, the Middle Unit is characterized by severe erosion hazard of over 82 percent. The severe erosion is distributed throughout. However, as opposed to the Lease Interest Unit, the percent of the Middle Unit with a high runoff potential is lower, at 33 percent. Approximately 67 percent of the area has a moderately low runoff potential. However, in areas where they coincide, the combination of severe erosion hazard and high runoff potential is a concern for erosion and transport. The risk of wind erosion of soils is relatively low, although this unit has no area in WEG 7 and only a small area in WEG 8.

The Middle Unit has a small area of high shrink/swell potential, primarily in the south-central part of the unit along the San Antonio Creek.

**Jemez National Recreation Area Unit**

The JNRA Unit is covered primarily by Inceptisols and Entisols, which occur on 83 percent. Entisols are found along the Cañon de San Diego. A small pocket of Mollisols are found along the northern edge of the unit, and small areas of Alfisols are found primarily in the southwest corners.

Approximately 48 percent of the JNRA Unit has a severe erosion hazard. This is similar to the North and South Units. The areas of severe erosion hazard are found primarily in the northern spur and the eastern half. The area around the Cañon de San Diego is not generally characterized as severe. Similar to the Middle Unit, 68 percent of the JNRA Unit has a moderately low runoff potential, with the remaining 32
percent of the area rated at high runoff potential. Areas of severe erosion hazard overlap areas of high runoff potential, primarily in the eastern half of the unit. In these areas, the combination of severe erosion hazard and high runoff potential is a concern for erosion and transport. The risk of wind erosion is low throughout the unit.

The JNRA Unit has a small area of high shrink/swell potential along the San Antonio Creek. This area of expansive soils is an extension of the area in the Middle Unit. There is also one small pocket of high shrink/swell potential in the middle of the unit near the Cañon de San Diego.

South Unit
The South Unit includes five soil types. Inceptisols and Entisols, which are soils with minimal profile development, occur on 70 percent of the unit; The more fertile and developed Mollisols and Alfisols cover 29 percent. The South Unit also has a small pocket of Psamments, on 1 percent of the unit, at the most southern tip. Psamments are similar to Entisols and consist of unconsolidated sand deposits, often found in shifting sand dunes, with no distinct soil horizons.

Similar to the JNRA Unit, 45 percent of the South Unit has a severe erosion hazard, primarily in the eastern half. However, this unit shows a higher runoff potential than the JNRA Unit. Only 45 percent of the South Unit has a moderately low runoff potential, with the remaining 55 percent rated at high. The areas of severe erosion hazard consistently overlap the areas of high runoff potential. In these areas, the combination of severe erosion hazard and high runoff potential is a concern for erosion and transport.

The risk of wind erosion of soils is low throughout most of the unit. However, there is a small area of WEG 1 at the southern tip, in the same area as the Psamments soil.

There are no areas of high shrink/swell potential in the South Unit.

Watershed and Surface Water Resources

Watershed Overview
The project area for the proposed geothermal leasing on the SFNF lies in the Rio Grande River Basin. The Rio Grande flows from its headwaters in southern Colorado, through New Mexico, to the border with Mexico. Here it turns and follows the border between Mexico and Texas, before ending at the Gulf of Mexico.

The route of the river through Colorado and New Mexico was defined by tectonic rifting. This continental rift began forming between 35 and 29 million years ago due to stretching and thinning of the earth’s lithosphere, due to the rising of hot rock deep below the surface. Continental rifts like the Rio Grande typically have an elongated valley bounded by faults. Basins form and then fill with sediment over millions of years. In Albuquerque, New Mexico, the basin sediments are three miles thick. The Rio Grande Rift continues to widen very slowly today (Cooperative Institute for Research in Environmental Studies 2006).

Intense volcanism has occurred in the Rio Grande basin beginning at the onset of rifting millions of years ago. Valles Caldera, surrounded by the project area on three sides, is one of the world’s largest and youngest calderas. It was created 1.2 million years ago through the collapse of a magma chamber (Cooperative Institute for Research in Environmental Studies 2006). The remaining magma is the source of the geothermal heat of interest for geothermal development.
Surface water flows in the Rio Grande River Basin originate primarily in the high mountain elevations as snow melt during the spring and as monsoonal rainfall during the late summer. Typically, the river reaches its highest discharge between April and June, with its peak levels in May. Natural flows also show a great deal of variation from year to year due to drought and climate variability (New Mexico Office of the State Engineer 2006). The northern extent of the leasing area, north of the VCNP, is part of the Upper Rio Grande Basin and includes the Rio Chama Watershed. The Jemez Watershed is in the southern part of the leasing area and includes the Jemez River; the only perennial tributary to the Middle Rio Grande Basin.

While the annual flow of the Rio Grande is quite variable, of the approximate 1.1 million acre-feet (long-term average) of native Rio Grande surface water that leaves the Upper Rio Grande and is measured at the Otowi stream flow gage, about one-third comes from Colorado, one-third comes from the Sangre de Cristo Mountains, and another third comes from the Rio Chama Watershed. Water is stored on the Upper Rio Grande in the Heron, El Vado, and Abiquiu Reservoirs, all of which are north of the project area (New Mexico Office of the State Engineer 2006).

The project area is in the Jemez Mountains, where a handful of warm springs due to subsurface volcanic activity have long been used for bathing and therapy. The Jemez Mountains are relatively wet, as compared with the dry, lower altitude surrounding country. Part of this precipitation, in the form of rain or snow melt, runs off or is lost to evapotranspiration, but part drains more slowly and is stored as groundwater. The water supports a dense forest in the high country.

The Valles Caldera is a defining terrain unit and is surrounded by the project area on three sides. To the west, the Jemez River drains the caldera and then flows south through the project area.

The project area includes parts of three 4th-level watersheds of the Rio Grande: Jemez, Rio Grande-Santa Fe, and Rio Chama. Parts of 22 nested 6th-level subwatersheds are included in the project area.

**Affected 4th and 6th Level Watersheds**

As discussed above, the project area overlaps parts of three 4th-level watersheds and parts of 22 6th-level watersheds. Some of the 6th-level watersheds overlap the project area to a very minimal extent. However, should activities be proposed in these overlapped areas, the activities could affect watershed conditions, both within the project area and in the larger watershed that extends outside of the project area. Therefore, the watershed analysis takes into account all watersheds that overlap part of the project area. Figure 9 shows the 4th- and 6th-level watersheds and their relation to the project area.

**Jemez River Watershed**

The Jemez Watershed covers 44 percent of the project area, primarily in the southwest and south-central portions and along the east edge of the VCNP. All of the Middle Unit is in this watershed and the southernmost spur of the Leasing Unit, as are approximately the western two-thirds of the JNRA Unit and the South Unit. The surface waters draining the Valles Caldera are collected by this watershed’s streams, including the Jemez River and San Antonio Creek. There are six hot springs in this watershed. There are also two drinking water sources, one in the JNRA Unit and the other in the southern end of the South Unit.

The larger Jemez Watershed is at the southern margin of the Rocky Mountains ecoregion, between 5,072 and 11,260 feet. Vegetation ranges from semiarid juniper savanna to high-elevation mixed conifer forest. It originates in the Southern Rocky Mountain physiographic province, on the west side of the Rio Grande Rift zone in the Valles Caldera, and the west flank of the Jemez Mountains (NRCS 2011c).
Figure 9. 6th-Level Watersheds in the Project Area
A central feature of the Jemez Watershed is the caldera, which is a collapsed magma chamber. The caldera interior is a single watershed unit draining through a breach in the caldera wall. The largest of the resurgent domes, Redondo Peak, is in the center of the caldera. The result of this unique geology is that the headwater streams of the Jemez River originate on different aspects of the same mountain. The Jemez River is formed by the East Fork of the Jemez River, which originates on the southeast side of the Valles Caldera, and San Antonio Creek, originating on the northeast side. The Jemez River flows through the steep-walled Cañon de San Diego, between the Jemez Mountains and Sierra Nacimiento. Several hot springs are found along the Jemez River, including Soda Dam and Jemez Hot Springs.

Ongoing watershed processes in the Jemez Watershed include high sediment erosion and water runoff as the result of forest fires. In addition, the lowering of valleys by river incision is a continuing process. Many valleys are flanked by terraces. Rivers respond by aggrading during climates that promote large sediment yield and large, stable discharges; they incise during climates that produce flashy flows and reduce the sediment supply (NRCS 2011c).

There following 10 6th-level watersheds in the larger Jemez Watershed occupy portions of the project area (Table 10): Cañon de la Canada, Church Canyon-Jemez River, East Fork Jemez River, Headwaters Rio Cebolla, Headwaters San Antonio Creek, Outlet Rio Cebolla, Outlet San Antonio Creek, Sulphur Creek, Vallecita Creek, and Virgin Canyon. Figure 9 provides an overview of the 6th-level watersheds of the Jemez Basin. Table 10 lists these watersheds, the percentage of each watershed in the project area, and the percentage of the project area that is covered by the watershed.

Table 10. 6th-Level Watersheds in the Jemez Watershed and their Relation to the Geothermal Project Area

<table>
<thead>
<tr>
<th>6th-Level Watershed Name</th>
<th>Hydrologic Unit Code (HUC 12)</th>
<th>Watershed Area (Acres)</th>
<th>Percent of Watershed in Project Area</th>
<th>Percent of Project Area Covered by Watershed</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cañon de la Canada</td>
<td>130202020401</td>
<td>14,481</td>
<td>72.1</td>
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</tr>
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<td>Church Canyon-Jemez River</td>
<td>130202020205</td>
<td>23,315</td>
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<td>East Fork Jemez River</td>
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<td>38,134</td>
<td>15.1</td>
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<tr>
<td>Headwaters Rio Cebolla</td>
<td>130202020103</td>
<td>22,739</td>
<td>70.1</td>
<td>8.2</td>
</tr>
<tr>
<td>Headwaters San Antonio Creek</td>
<td>130202020201</td>
<td>36,282</td>
<td>1.6</td>
<td>0.3</td>
</tr>
<tr>
<td>Outlet Rio Cebolla</td>
<td>130202020104</td>
<td>19,632</td>
<td>16.3</td>
<td>1.6</td>
</tr>
<tr>
<td>Outlet San Antonio Creek</td>
<td>130202020204</td>
<td>14,805</td>
<td>69.5</td>
<td>5.3</td>
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<tr>
<td>Sulphur Creek</td>
<td>130202020202</td>
<td>16,084</td>
<td>11.0</td>
<td>0.9</td>
</tr>
<tr>
<td>Vallecita Creek</td>
<td>130202020402</td>
<td>32,341</td>
<td>50.0</td>
<td>8.3</td>
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<tr>
<td>Virgin Canyon</td>
<td>130202020106</td>
<td>11,449</td>
<td>22.1</td>
<td>1.3</td>
</tr>
</tbody>
</table>

Source: USGS 2016

Rio Chama Watershed

The Rio Chama Watershed covers approximately 49 percent of the project area, including all of the North Unit and most of the northern portion of the Lease Interest Unit. Waters draining the north-facing sides of the Valles Caldera and the northern Nacimiento Mountains and adjacent mountains and valleys are channeled to the Rio Chama and the Abiquiu Reservoir. Eventually these waters lead to the Rio Grande, north of the project area. Three drinking water wells are along the northern edge of the project area in this watershed. There are no natural thermal features or buffer zones for these types of features within the project area in this watershed.
The western boundary of the larger Rio Chama Watershed is formed by the Continental Divide and the northeastern edge of the Jemez Mountains. In the east, the watershed is hemmed in by the Tusas Mountains and Black Mesa. The Rio Chama headwaters drain the southern San Juan Mountains, and the river ends at its confluence with the Rio Grande, near Española, New Mexico, incorporating areas with elevations ranging from 13,000 to 4,400 feet. The upland areas of the drainage basin are significant contributors to Rio Chama flows, resulting in snowmelt-dominated hydrology. Mean annual precipitation in the basin ranges from 9 to 53 inches, depending on elevation (NRCS 2011a). The large tributaries of the Rio Chama that contribute significant flows are, from upstream to downstream, Cañones Creek, Rio Brazos, Rito de Tierra Amarilla, Rio Nutrias, Rio Cebolla, Rio Gallina, Rito de Canjilon, Rio Puerco de Chama, a second Cañones Creek, El Rito, Rio del Oso, Abiquiu Creek, and Rio Ojo Caliente (New Mexico Office of the State Engineer 2006).

The headwater areas of the Rio Chama are composed primarily of Proterozoic rock, with resistant quartzite forming many of the high peaks in the San Juan Mountains. However, the headwaters region is far from uniform and also contains volcanic and metamorphic rock from various periods. Lower elevation areas contain rock units that represent the Cretaceous intercontinental seaway: shales, mudstones, and sandstones. Specifically, above El Vado, the river flows through Cretaceous Mancos Group shale and Mesa Verde Group sandstone. Through these relatively erodible rocks, the river occupies a wide alluvial valley until it encounters the more resistant Cretaceous Dakota sandstone and becomes confined by steep canyon walls. Areas at elevations above the river contain diverse lithologies, resulting in bed particle sizes ranging between silt and boulders. However, the dominant particle size ranges from sand to gravel (Swanson et al. 2012).

Existing watershed processes are high sedimentation rates caused by landslides in the Mancos shale and high sediment erosion and water runoff as the result of forest fires. In addition, river incision continually lowers the valleys. Many valleys are flanked by terraces. Rivers respond by aggrading during climates that promote large sediment yield and large, stable discharges, and by incising during climates that produce flashy flows and reduce the sediment supply (NRCS 2011a).

There are seven 6th-level watersheds of the larger Rio Chama Watershed that occupy portions of the project area: Cañones Creek, Cañones Creek-Abiquiu Reservoir, Coyote Creek, Headwaters Rio Puerco, Outlet Rio Puerco, Poleo Creek, and Polvadera Creek (Table 11). Many of these subwatersheds have impairments due to bank instability and lack of a healthy riparian zone. These impairments have resulted in excess sediment and higher stream temperatures (Levine et al. 2015). The greatest land use in the Rio Chama Watershed by area is rangeland. These impairments are typical of streams impacted by poor grazing management, which can cause a loss of riparian vegetation, increase habitat and seed source for invasive species that compete with native species, and degrade banks, leading to erosion and sedimentation.

<table>
<thead>
<tr>
<th>6th-Level Watershed Name</th>
<th>Hydrologic Unit Code (HUC) 12</th>
<th>Watershed Area (Acres)</th>
<th>Percent of Watershed in Project Area</th>
<th>Percent of Project Area Covered by Watershed</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cañones Creek</td>
<td>130201021005</td>
<td>36,111</td>
<td>82.0</td>
<td>15.2</td>
</tr>
<tr>
<td>Cañones Creek-Abiquiu Reservoir</td>
<td>130201021006</td>
<td>36,027</td>
<td>21.1</td>
<td>3.9</td>
</tr>
<tr>
<td>Coyote Creek</td>
<td>130201020802</td>
<td>28,850</td>
<td>99.7</td>
<td>14.7</td>
</tr>
<tr>
<td>Headwaters Rio Puerco</td>
<td>130201020803</td>
<td>35,393</td>
<td>21.1</td>
<td>3.8</td>
</tr>
<tr>
<td>Outlet Rio Puerco</td>
<td>130201020804</td>
<td>36,465</td>
<td>47.5</td>
<td>8.9</td>
</tr>
<tr>
<td>Poleo Creek</td>
<td>130201020801</td>
<td>29,541</td>
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<tr>
<td>Polvadera Creek</td>
<td>130201021004</td>
<td>22,145</td>
<td>21.2</td>
<td>2.4</td>
</tr>
</tbody>
</table>

Source: USGS 2016
Rio Grande-Santa Fe Watershed

The Rio Grande-Santa Fe Watershed covers just 7 percent of the project area. In the project area it is located in the southeastern extent, on the eastern side of the JNRA Unit, and the eastern side and southern edge of the South Unit. Waters drain into this watershed from the southeast-facing slopes of the Valles Caldera, joining several streams and canyons leading to the Cochiti Reservoir and eventually the Rio Grande. There are no known drinking water wells or natural geothermal features in the portion of the watershed that is in the project area.

Outside of the project area, portions of the Rio Grande-Santa Fe Watershed extend into Bernalillo, Los Alamos, San Miguel, Sandoval, and Santa Fe Counties. Elevations range between 5,000 and 13,153 feet, and precipitation ranges between 9 and 43 inches annually, depending on elevation.

The hydrologic unit begins at Otowi, west of Pojoaque, New Mexico, in the Upper Rio Grande Valley. Farther downstream, the river enters Cochiti Lake, which marks the northern boundary of the Middle Rio Grande Valley. The hydrologic unit continues downstream to the confluence with the Jemez River.

Watershed processes are erosion and water runoff as the result of forest fires. In addition, river incision continually lowers the valleys. Many valleys are flanked by terraces. Rivers respond by aggrading during climates that promote large sediment yield and large, stable discharges, and incising during climates that produce flashy flows and reduce the sediment supply. This can be exacerbated by mining sand and gravel from the river channels.

There are five 6th-level watersheds in the larger Rio Grande-Santa Fe Watershed that occupy portions of the project area: Alamo Canyon-Rio Grande, Capulin Canyon-Rio Grande, Headwaters Borrego Canyon, Peralta Canyon, and Rio Chiquito (Table 12).

### Table 12. 6th-Level Watersheds in the Santa Fe-Rio Grande Watershed and Relation Their to the Geothermal Project Area

<table>
<thead>
<tr>
<th>6th-Level Watershed Name</th>
<th>Hydrologic Unit Code (HUC) 12</th>
<th>Watershed Area (Acres)</th>
<th>Percent of Watershed in Project Area</th>
<th>Percent of Project Area Covered by Watershed</th>
</tr>
</thead>
<tbody>
<tr>
<td>Alamo Canyon-Rio Grande</td>
<td>130202010205</td>
<td>37,630</td>
<td>6.0</td>
<td>1.2</td>
</tr>
<tr>
<td>Capulin Canyon-Rio Grande</td>
<td>130202010207</td>
<td>26,901</td>
<td>2.1</td>
<td>0.3</td>
</tr>
<tr>
<td>Headwaters Borrego Canyon</td>
<td>130202010605</td>
<td>28,944</td>
<td>0.9</td>
<td>0.1</td>
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<tr>
<td>Peralta Canyon</td>
<td>130202010601</td>
<td>28,444</td>
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<tr>
<td>Rio Chiquito</td>
<td>130202010206</td>
<td>30,188</td>
<td>28.8</td>
<td>4.5</td>
</tr>
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</table>

Source: USGS 2016

100-year Floodplains

**Figure 10** illustrates the locations of 100-year floodplains in the project area, as delineated by the Federal Emergency Management Act. Most of the delineated areas are in the JNRA Unit, along the Jemez River, including the Cañon de San Diego, and extending slightly into San Antonio and Sulphur Creeks. There is also a small section of the East Fork of the Jemez River that crosses into the JNRA Unit that is delineated as a 100-year floodplain.

There is also a 100-year floodplain in the portion of the Middle Unit that is crossed by the Rio Cebolla. The delineation of this floodplain extends into the southwestern corner of the Lease Interest Unit.
Figure 10. 100-year Floodplains in the Project Area
Several small sections of tributaries to the Rio Puerco are found along the northern edge of the North Unit that includes 100-year floodplains.

**Beneficial Uses**

The basic authority for water quality management in New Mexico is provided through the State Water Quality Act, which establishes the NMWQCC. This is the state water pollution control agency for purposes of the federal Clean Water Act. New Mexico’s water quality standards define water quality goals by designating uses for rivers, streams, lakes, and other surface waters. The waters are classified by the uses for which they are presently suitable or intended to become suitable. The standards set criteria to protect these uses and establish antidegradation provisions to preserve water quality. The standards are adopted by the NMWQCC, then approved by the EPA under the federal Clean Water Act. The New Mexico Environment Department is responsible for implementing the federal Clean Water Act in New Mexico and ensuring surface waters meet their designated beneficial uses and New Mexico state water quality standards.

The beneficial uses of the 6th-level project area watersheds are presented in Table 13. All of the watersheds have the beneficial use of livestock watering/wildlife habitat.

**Clean Water Act 303(d) Impaired Surface Waters and Total Maximum Daily Loads**

Under the Clean Water Act, Section 303(d), states, territories, and authorized tribes are required to develop lists of impaired waters. These are waters that are too polluted or otherwise degraded to meet the water quality standards set by states, territories, or authorized tribes. The law requires that these jurisdictions establish priority rankings for waters on the lists and develop a TMDL for these waters (Appendix A). TMDL is a calculation of the maximum amount of a pollutant that a water body can receive and still safely meet water quality standards. The NMWQCC is the issuing agency of water quality standards for interstate and intrastate waters in New Mexico.

**Jemez Watershed**

The Jemez Watershed is a subwatershed of the Rio Grande River Basin. The river and stream reaches total 145.58 miles (234.29 kilometers). Within the Jemez Watershed there is one body of water, the 23.81-acre Fenton Lake, that is listed as impaired as of the 2010 to 2012 listing cycle. This body of water is not in the project area.

The following reaches of the Jemez Watershed are in the 6th-level watersheds that overlap the project area and are listed as 303(d) Impaired Surface Waters:

- East Fork Jemez (San Antonio Creek to the VCNP boundary)
- East Fork Jemez (VCNP boundary to headwaters)
- Fenton Lake
- Jaramillo Creek (East Fork Jemez to headwaters)
- Jemez River (Rio Guadalupe to Soda Dam near Jemez Springs)
- Jemez River (Soda Dam near Jemez Springs to East Fork)
- Redondo Creek (Sulphur Creek to headwaters)
- Rio Cebolla (Fenton Lake to headwaters)
- San Antonio Creek (East Fork Jemez to VCNP boundary)
- San Antonio Creek (VCNP boundary to headwaters)
Table 13. Beneficial Uses of Watersheds in the Project Area

<table>
<thead>
<tr>
<th>4th-Level Watershed</th>
<th>6th-Level Watershed</th>
<th>Domestic Water Supply</th>
<th>Public Water Supply</th>
<th>Irrigation</th>
<th>Irrigation Storage</th>
<th>High-Quality Coldwater Aquatic Life</th>
<th>Coldwater Aquatic Life</th>
<th>Marginal Coldwater Aquatic Life</th>
<th>Warmwater Aquatic Life</th>
<th>Limited Aquatic Life</th>
<th>Livestock Watering, Wildlife Habitat</th>
<th>Primary Contact</th>
<th>Secondary Contact</th>
<th>Fish Culture</th>
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<tbody>
<tr>
<td>Rio Chama</td>
<td>Cañones Creek</td>
<td></td>
<td>X</td>
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<td>X</td>
<td>X</td>
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<td>Rio Chama</td>
<td>Cañones Creek-Abiquiu Reservoir</td>
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</table>

Source: New Mexico Environment Department 2014
• San Antonio Creek (East Fork Jemez to headwaters)
• Sulphur Creek (San Antonio Creek to Redondo Creek)
• Sulphur Creek (Redondo Creek to headwaters)
• Sulphur Creek (VCNP to headwaters)
• Vallecita Creek (perennial diversion above Ponderosa to headwaters)

Natural conditions contribute to high aluminum concentrations throughout the Jemez Watershed, and impacts on aquatic life are unclear. Many 6th-level watersheds in the Jemez Watershed have aluminum listings but no TMDLs yet. Aluminum criteria are under review to identify appropriate and attainable levels.

Rio Chama Watershed
The Rio Chama Watershed is a subwatershed of the Rio Grande River Basin. The Rio Chama Watershed was identified as a priority participant for the New Mexico Office of the State Engineer Active Water Resource Management Plan. The Active Water Resource Management initiative was launched in January 2004 in response to continued drought conditions in New Mexico. It refers to the essential tools and elements needed to enable the State Engineer to manage the state’s limited water resources. The New Mexico constitution makes priority of right the basis for water administration. The tools for Active Water Resource Management are measuring and metering, rules and regulations, creation of water districts and appointment of water masters, and development of water master manuals.

The following reaches of the Rio Chama Watershed are in the 6th-level watersheds that overlap the project area and are listed as 303(d) Impaired Surface Waters:
• Cañones Creek (Abiquiu Reservoir to headwaters)
• Chihuahuenos Creek (Cañones Creek to headwaters)
• Coyote Creek (Rio Puerco de Chama to headwaters)
• Poleo Creek (Rio Puerco de Chama to headwaters)
• Polvadera Creek (Cañones Creek to headwaters)
• Rio Encino (Rio Puerco de Chama to headwaters)
• Rio Puerco de Chama (Abiquiu Reservoir to State Highway 96)

Rio Grande-Santa Fe Watershed
The Rio Grande-Santa Fe Watershed is a subwatershed of the Rio Grande River Basin. The river and stream reaches total 208.23 miles (335.17 kilometers).

The Rito de los Frijoles (Rio Grande to headwaters) of the Rio Grande-Santa Fe Watershed are in the 6th-level watersheds that overlap the project area and are listed as 303(d) Impaired Surface Waters.

Watershed Condition Class
The Watershed Condition Framework is a comprehensive approach for implementing restoration on priority watersheds on national forests and grasslands (USFS 2011). The watershed condition policy goal of the USFS is “to protect NFS watersheds by implementing practices designed to maintain or improve watershed condition, which is the foundation for sustaining ecosystems and the production of renewable natural resources, values, and benefits” (USFS Manual 2520; USFS 2004).

The Watershed Condition Framework also provides a consistent way to evaluate watershed condition at both the national and forest levels. The Watershed Condition Framework has established a nationally
consistent, reconnaissance-level approach for classifying watershed condition. This approach uses 12 indicators that represent the underlying ecological, hydrological, and geomorphic functions and processes that affect watershed condition. Primary emphasis is on aquatic and terrestrial processes and conditions that USFS management activities can influence. The Watershed Condition Framework provides the USFS with an outcome-based performance measure for documenting improvement to watersheds.

The USFS completed an assessment of all 6th-level watersheds on national forests in 2011. The assessment documents the overall function of each watershed within the Watershed Condition Framework (USFS 2011). The condition of each watershed is rated as properly functioning, functioning at risk, and functionally impaired. The watersheds are also given ratings for the 12 condition indicators. The condition rating and indicators for the watersheds in the project area are displayed on Table 14. The USFS’s goal is to improve conditions in the watersheds that are not properly functioning so that their function will improve.

As shown on Table 14, none of the 6th-level watersheds in the analysis are considered to be properly functioning. Two of the watersheds, Headwaters Rio Cebolla and Outlet San Antonio Creek, are functionally impaired. For both of these watersheds, some of the indicators that led to their status were ratings of Poor for riparian and wetland vegetation, water quality, roads and trails, and soil conditions. The outlet at San Antonio Creek also had a rating of poor for fire impacts. Both Headwaters Rio Cebolla and Outlet San Antonio Creek are subwatersheds of the 4th-level Jemez Watershed. Together they cover most of the Middle Unit.

Throughout all of the 6th-level watersheds, the categories that are consistently of concern are riparian and wetland vegetation, roads and trails, soil condition, and fire impacts. None of the watersheds scored a rating of Good in these categories. For both roads and trails, and soil condition, only one watershed scored a rating of Fair: Cañones Creek-Abiquiu Reservoir for soil condition and Outlet Rio Puerco for roads and trails. All the other watersheds were classified as Poor for these categories.

These categories are indicators of the following concerns:

- Riparian and wetland vegetation—Vegetation condition
- Roads and Trails—Open road density, road maintenance, proximity to wear, mass wasting
- Soil conditions—Soil productivity, soil erosion, and soil contamination
- Fire impact—Fire condition class or wildfire impacts

The two impaired function watersheds, Headwaters Rio Cebolla and Outlet San Antonio Creek, are rated Poor for most of these indicators. Problems with soil erosion may be connected to road density and maintenance.

**Watershed Erodibility Index and Road Density**

The Watershed erodibility Index is an indicator of the vulnerability of a watershed to erosion and sedimentation from disturbances. The index classifies watersheds using a combination of two standard erodibility indicators: the inherent susceptibility of soil to erosion by water (Kw factor) and land slope. Therefore, this index evaluates the risk of both erosion and transport to streams. The Kw factor data from the State Soil Geographic Spatial Database was combined with a slope grid using NRCS (1997) slope-soil relationships. This was done to create a classification grid divided into slight, moderate, severe, and very severe erodibility-transport ratings, based on erosion potential measured by Kw and slope (Figure 11).
<table>
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<tr>
<th>6th-Level Watershed</th>
<th>Overall Rating</th>
<th>Aquatic Biota</th>
<th>Riparian and Wetland Vegetation</th>
<th>Water Quality</th>
<th>Water Quantity</th>
<th>Aquatic Habitat</th>
<th>Roads and Trails</th>
<th>Soil Condition</th>
<th>Fire Impacts</th>
<th>Forest Health</th>
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</table>

Source: USFS 2011
Then a single index number was created for each watershed to provide an overall relative evaluation of watershed risk to erosion and sedimentation. This index weights the area in each watershed covered by each erodibility-transport risk (slight, moderate, severe, very severe) to provide an overall watershed index number. This allows watersheds to be compared to each other and to provide a relative risk across the watershed. The index ranges from 1 to 4. An index of 1 would indicate the entire watershed has only a slight erodibility-transport risk and an index of 4 would indicate that the entire watershed would have a very severe erodibility-transport risk.

Figures 11 and 12 present the erodibility-transport risk across all the 6th-level watersheds that overlap portions of the project area. Most of the area in these watersheds is classified as having a slight or moderate erodibility-transport risk. Only 8.4 percent of the area is classified as severe or very severe risk. The watershed erodibility index ranges from 1.2 to 1.9, with an average of 1.5.

These results can be compared to the discussion in Soils – Affected Environment, which shows that a high percentage of the soils in the project area are classified as having severe erosion hazard. That analysis was specific to erosion potential only and did not take into account slope, which indicates ease of transport. Additionally, that analysis applied only to the lands within the project area boundary and did not extend the analysis to incorporate the entire extent of each 6th-level watershed that overlaps a portion of the project area. This analysis extends to the larger affected watersheds and includes slope, which indicates the potential for transport to evaluate potential erodibility and transport risk to the watersheds as a whole.

Problems with road density and poor maintenance can also manifest in soil erosion, due to such factors as increasing exposed and erodible surfaces, decreasing infiltration on these surfaces, concentrating and intercepting water, gully forming, and mass wasting, among others. Furniss et al. (1991), as cited in USFS (2012), concluded that forest roads contribute more sediment into streams than all other forest activities. Additionally, roads can convert subsurface runoff into surface runoff and then route it into stream channels, increasing discharge and peak flows to the receiving channel (Megan and Kidd 1972; Ice 1985; Swanson et al. 1987). Roads can also divert stream channels to adjacent channels through surface runoff, increasing discharge and peak flows to the receiving channel and decreasing discharge and peak flows to the diverted channel. Therefore, watersheds with higher road densities have a higher risk of stream-
channel sedimentation when there are disturbances in the watershed. The average road density for all 6th-level watersheds that overlap the project area is 5.3 miles of road per square mile.

Tables 15 to 17 present the road density and watershed erodibility index for the 6th-level watersheds that overlap the project area. Across all watersheds that overlap a part of the project area, the road densities range from 1.4 miles of road per square mile in the 6th-level Peralta Canyon Watershed (in the Santa Fe-Rio Grande Watershed) to 12.3 miles of road per square mile in the 6th-level Cañones Creek Watershed (in the Rio Chama Watershed). The watershed erodibility index ranges from 1.2 in three 6th-level watersheds: Cañon de la Canada (in the Jemez Watershed), Cañones Creek Abiquiu Reservoir (in Rio Chama Watershed), and Headwaters Borrego Canyon (in the Santa Fe-Rio Grande Watershed). The highest watershed erodibility indexes are two 6th-level watersheds, with indexes of 1.9 and 1.8, respectively: Sulphur Creek (in the Jemez Watershed) and Headwaters Rio Puerco (in the Rio Chama Watershed).

Jemez Watershed

In the Jemez Watershed, the road densities in the 6th-level watersheds that overlap that project area range from a low of 3.0 miles of road per square mile in Sulphur Creek to a high of 10.5 miles of road per square mile in Headwaters Rio Cebolla (Table 15). Road densities in 7 of the 10 6th-level watersheds were higher than the average. Although Headwaters Rio Cebolla has the highest road density, it also has one of the lowest watershed erodibility indices, at 1.3, reflecting a lower risk of erosion and transport than some of the other watersheds. Conversely, Sulphur Creek has the highest watershed erodibility index, at 1.9, but the lowest road density in the Jemez Watershed.

Table 15. Road Density and Watershed Erodibility Index for the 6th-Level Watersheds in the Jemez Watershed

<table>
<thead>
<tr>
<th>6th-Level Watershed Name</th>
<th>Percent of Watershed in Project Area</th>
<th>Road Density (miles road/sq. mi.)</th>
<th>Watershed Erodibility Index Rating</th>
</tr>
</thead>
<tbody>
<tr>
<td>Average for all 6th-level watersheds in project area</td>
<td></td>
<td>5.3</td>
<td>1.5</td>
</tr>
<tr>
<td>Cañon de la Canada</td>
<td>72.1</td>
<td>5.6</td>
<td>1.2</td>
</tr>
<tr>
<td>Church Canyon-Jemez River</td>
<td>77.6</td>
<td>6.1</td>
<td>1.3</td>
</tr>
<tr>
<td>East Fork Jemez River</td>
<td>15.1</td>
<td>3.9</td>
<td>1.6</td>
</tr>
<tr>
<td>Headwaters Rio Cebolla</td>
<td>70.1</td>
<td>10.5</td>
<td>1.3</td>
</tr>
<tr>
<td>Headwaters San Antonio Creek</td>
<td>1.6</td>
<td>5.5</td>
<td>1.5</td>
</tr>
<tr>
<td>Outlet Rio Cebolla</td>
<td>16.3</td>
<td>6.5</td>
<td>1.3</td>
</tr>
<tr>
<td>Outlet San Antonio Creek</td>
<td>69.5</td>
<td>7.1</td>
<td>1.6</td>
</tr>
<tr>
<td>Sulphur Creek</td>
<td>11.0</td>
<td>3.0</td>
<td>1.9</td>
</tr>
<tr>
<td>Vallecita Creek</td>
<td>50.0</td>
<td>6.1</td>
<td>1.3</td>
</tr>
<tr>
<td>Virgin Canyon</td>
<td>22.1</td>
<td>5.0</td>
<td>1.3</td>
</tr>
</tbody>
</table>

Source: USFS 2016

The watersheds with the highest watershed erodibility index ratings are Sulphur Creek, with a rating of 1.9, and East Fork Jemez River and Outlet San Antonio Creek with ratings of 1.6 each. Only 3 of the 10 watersheds have an index rating above the average for the project area watersheds of 1.5. This indicates that much of the area in these watersheds is at a lower risk of erosion and transport of sediments. The 1.9 rating in the Sulphur Creek Watershed is the highest of the project area watersheds. However, only 11 percent of the Sulphur Creek Watershed is in the project area, and most of the severe and very severe erodibility-transport risk areas are in the Valles Caldera, outside of the project area. Only 15 percent of the...
East Fork Jemez Watershed is in the project area, but there is a concentrated area of severe and very severe ratings on the east side of the JNRA Unit.

Almost 70 percent of Outlet San Antonio Creek Watershed is within the project area boundary. In this watershed, some of the areas rated severe and very severe are in the Middle Unit, where high erosion potential overlaps with steeper terrain (see Soils – Affected Environment). This watershed has a road density of 7.1, which is higher than the project area watershed’s average of 5.3.

Rio Chama Watershed

In the Rio Chama Watershed, the road densities in the 6th-level watersheds that overlap the project area range from a low of 2.5 miles of road per square mile, in Cañones Creek-Abiquiu Reservoir Watershed, to a high of 12.3 miles of road per square mile, in Cañones Creek (Table 16). Road densities in four of the seven 6th-level watersheds were higher than the average. Cañones Creek-Abiquiu Reservoir also has the lowest watershed erodibility index at 1.2, reflecting a low risk of erosion and transport, as compared with the other watersheds.

Table 16. Road Density and Watershed Erodibility Index for the 6th-Level Watersheds in the Rio Chama Watershed

<table>
<thead>
<tr>
<th>6th-Level Watershed Name</th>
<th>Percent of Watershed in Project Area</th>
<th>Road Density (miles road per square mile)</th>
<th>Watershed Erodibility Index Rating</th>
</tr>
</thead>
<tbody>
<tr>
<td>Average for all 6th-level watersheds in project area</td>
<td></td>
<td>5.3</td>
<td>1.5</td>
</tr>
<tr>
<td>Cañones Creek</td>
<td>82.0</td>
<td>12.3</td>
<td>1.5</td>
</tr>
<tr>
<td>Cañones Creek-Abiquiu Reservoir</td>
<td>21.1</td>
<td>2.5</td>
<td>1.2</td>
</tr>
<tr>
<td>Coyote Creek</td>
<td>99.6</td>
<td>6.8</td>
<td>1.6</td>
</tr>
<tr>
<td>Headwaters Rio Puerco</td>
<td>21.1</td>
<td>5.7</td>
<td>1.8</td>
</tr>
<tr>
<td>Outlet Rio Puerco</td>
<td>47.5</td>
<td>3.3</td>
<td>1.4</td>
</tr>
<tr>
<td>Poleo Creek</td>
<td>1.3</td>
<td>7.9</td>
<td>1.7</td>
</tr>
<tr>
<td>Polvadera Creek</td>
<td>21.2</td>
<td>5.1</td>
<td>1.7</td>
</tr>
</tbody>
</table>

Source: USFS 2016

Four of the seven watersheds have a watershed erodibility index rating above the average for the project area watersheds of 1.5. These watersheds are Coyote Creek (1.6), Headwaters Rio Puerco (1.8), Poleo Creek (1.7), and Polvadera Creek (1.7). These watersheds are at a higher risk of erosion and transport of sediments. Only a very small corner of Poleo Creek (1.3 percent of the watershed) is in the project area. The overlapping area is primarily at a slight and moderate erodibility-transport risk rating.

Both Headwaters Rio Puerco and Polvadera Creek overlap the project area by only 21 percent; however, the overlapping portions do include concentrated areas of moderate to severe erodibility-transport risk. The Polvadera Creek Watershed affects the eastern edge of the Lease Interest Unit and the southeast corner of the North Unit. The portion in the Lease Interest Unit has a concentrated area of moderate to severe risk. Likewise, the Headwaters Rio Puerco has a concentrated area of moderate to very severe erodibility-transport risk that affects the southwest corner of the North Unit.

Almost all of Coyote Creek Watershed is in the project area. As evident in Figure 12, much of this watershed is at a moderate erodibility-transport risk, with some pockets of greater concern. This watershed spans both the North and Lease Interest Units. Coyote Creek also has a road density of 6.8 miles of road per square mile, higher than the average for the watersheds in the project area of 5.3 miles of road per square mile. It also has a rating of Poor for the condition class category of roads and trails (Table 16).
Figure 12. Watershed Erodibility within 6th-Level Watersheds in the Project Area
Two watersheds, Outlet Rio Puerco and Cañones Creek, have a watershed erodibility index of around 1.5. However, there are concentrated portions of these watersheds in the project area that are at a higher erodibility-transport risk than the watershed average suggests. In the Outlet Rio Puerco Watershed, there is a concentrated area of moderate to very severe risk, at the top of the watershed in the middle of the North Unit. Cañones Creek Watershed has a concentrated area of moderate to very severe risk in most of the portion that overlaps the Lease Interest Unit, extending into the south-central portion of the North Unit. These areas of the watersheds could be susceptible to greater impacts from surface-disturbing activities.

Cañones Creek Watershed also has the highest road density of the project area watersheds. Some of these roads are likely contributing sediments to streams. The watershed condition class (Table 14) of roads and trails in this watershed is rated Poor. However, the higher road density indicates that existing access may be better than some of the other watersheds, and areas of interest might be able to be accessed without building new roads. As 82 percent of this watershed is in the project area, this may allow access to some areas, while minimizing soil disturbance.

Santa Fe-Rio Grande Watershed

There are five 6th-level watersheds in the larger Santa Fe-Rio Grande watershed that overlap the project area. Most have only a small fraction (less than 10 percent) of their watershed in the project area. The exception is Rio Chiquito, which has a nearly 30 percent overlap. The road densities in these watersheds range from a low of 1.4 miles of road per square mile in Peralta Canyon Watershed to a high of 5.3 miles of road per square mile in Rio Chiquito Watershed (Table 17). These watersheds have the lowest road densities of the project area, with all of them at or below the average. Similarly, all of these watersheds have a watershed erodibility index at or below the average of 1.5. Headwaters Borrego Canyon has the lowest index, at 1.2, reflecting a lower risk of erosion and transport, as compared with the other watersheds.

<table>
<thead>
<tr>
<th>6th-Level Watershed Name</th>
<th>Percent of Watershed in Project Area</th>
<th>Road Density (miles road/sq. mi.)</th>
<th>Watershed Erodibility Index Ranking</th>
</tr>
</thead>
<tbody>
<tr>
<td>Average for all 6th-level watersheds in project area</td>
<td>5.3</td>
<td>1.5</td>
<td></td>
</tr>
<tr>
<td>Alamo Canyon-Rio Grande</td>
<td>6.0</td>
<td>2.9</td>
<td>1.5</td>
</tr>
<tr>
<td>Capulin Canyon-Rio Grande</td>
<td>2.1</td>
<td>2.0</td>
<td>1.3</td>
</tr>
<tr>
<td>Headwaters Borrego Canyon</td>
<td>0.9</td>
<td>3.1</td>
<td>1.2</td>
</tr>
<tr>
<td>Peralta Canyon</td>
<td>9.1</td>
<td>1.4</td>
<td>1.5</td>
</tr>
<tr>
<td>Rio Chiquito</td>
<td>28.8</td>
<td>5.3</td>
<td>1.5</td>
</tr>
</tbody>
</table>

Source: USFS 2016

Three of the five watersheds have a watershed erodibility index at the 1.5 average for the project area. These watersheds are Alamo Canyon-Rio Grande, Peralta Canyon, and Rio Chiquito. Only 6 percent of Alamo Canyon-Rio Grande overlaps the project area in the very eastern edge of the South Unit. In the overlapping portion, the erodibility-transport risk is slight and moderate. There are no concentrated areas of severe or very severe erodibility-transport risk.

Nine percent of Peralta Canyon Watershed overlaps the project area. The area of overlap has a mostly moderate erodibility-transport risk, but there are a few areas rated severe to very severe. Although the rating for the overall Peralta Watershed is only 1.5, some of the more erosive soils for that watershed...
appear to overlap portions of the JNRA and South Units. Similarly, Rio Chiquito has a watershed erodibility index of 1.5, but the portion of overlap with the JNRA and South Units have areas of moderate to very severe erodibility-transport risk.

Only 0.9 percent of Headwaters Borrego Canyon and 2.1 percent of Capulin Canyon-Rio Grande overlap the project area. The watershed erodibility indices for these watersheds are 1.3 and 1.2, respectively. The areas of overlap are at a slight to moderate erodibility-transport risk.

As discussed above, nearly 30 percent of Rio Chiquito Watershed overlaps the project area, and it also has some areas of severe to very severe erodibility-transport risk in the overlapping portion. Additionally, this watershed has the highest road density of these five subwatersheds, although it is only at the average for all project area watersheds, at 5.3. Like most of the project area watersheds, the condition class rating for roads and trails in this watershed is Poor.

**Summary of 6th-Level Watersheds**

The following is a detailed summary of the affected environment for all 6th-level watersheds that overlap a portion of the project area and are in the 4th-Level Jemez, Rio Chama and Santa Fe-Rio Grande Watersheds (Table 18).

**Jemez Watershed**

*Cañon de la Canada Watershed*

Cañon de la Canada covers 5.4 percent of the project area. The total watershed area is 14,481 acres, 72.1 percent of which overlaps the South and JNRA Units of the project area. The beneficial uses for this watershed are domestic water supply, irrigation, high-quality coldwater aquatic life, livestock watering, wildlife habitat, primary contact, and fish culture. According to the Office of the State Engineer database, there is one irrigation well in this watershed, in the South Unit of the project area.

There are no 303(d) impaired surface waters in this watershed. The watershed condition class is functioning at risk and the watershed is rated as Poor. This pertains to the condition class metrics of roads and trails, fire impacts, and soil condition. The watershed received ratings of Fair for riparian and wetland vegetation and water quantity. All other metrics were rated as Good.

The watershed erodibility index for this watershed is 1.2, which is below the average for the watersheds that overlap the project area, at 1.5. The road density is 5.6, just slightly above the average of 5.3. As indicated on Figure 12, most of this watershed has an erodibility-transport risk of slight, with a few streaks of moderate and higher severity in portions of the South Unit.

There are no natural geothermal features or 100-year floodplain designations in this watershed.

*Church Canyon-Jemez River Watershed*

Church Canyon-Jemez River Watershed covers 9.3 percent of the project area, which is the third-largest percentage covered by a single 6th-level watershed. It is primarily on the western side of the JNRA Unit, although it overlaps slightly into the western edge of the South Unit. There are several natural geothermal features in this watershed, particularly along the Jemez River: the Jemez and Soda Dam hot springs, along the Jemez River, and the McCauley Hot Spring, to the north at the corner of the VCNP, on the East Fork Jemez River.
Table 18. Summary of 6th-Level Watersheds

<table>
<thead>
<tr>
<th>Watershed Name</th>
<th>Percent of Watershed in Project Area</th>
<th>Percent of Project Area Covered by Watershed</th>
<th>Road Density (Miles of Road per Square Mile)</th>
<th>Watershed Erodibility Index Rating</th>
<th>Impaired Surface Waters</th>
<th>100-Year Floodplain?</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Fourth-Level Watershed: Jemez</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Cañon de la Cañada</td>
<td>72.1</td>
<td>5.4</td>
<td>5.6</td>
<td>1.2</td>
<td>No</td>
<td>No</td>
</tr>
<tr>
<td>Church Canyon-Jemez River</td>
<td>77.6</td>
<td>9.3</td>
<td>6.1</td>
<td>1.3</td>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td>East Fork Jemez River</td>
<td>15.1</td>
<td>3.0</td>
<td>3.9</td>
<td>1.6</td>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td>Headwaters Rio Cebolla</td>
<td>70.1</td>
<td>8.2</td>
<td>10.5</td>
<td>1.3</td>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td>Headwaters San Antonio Creek</td>
<td>1.6</td>
<td>0.3</td>
<td>5.5</td>
<td>1.5</td>
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<td>No</td>
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<tr>
<td>Outlet Rio Cebolla</td>
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<td>6.5</td>
<td>1.3</td>
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<td>No</td>
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<tr>
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<td>5.3</td>
<td>7.1</td>
<td>1.6</td>
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<td>Yes</td>
</tr>
<tr>
<td>Sulphur Creek</td>
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<td>0.9</td>
<td>3.0</td>
<td>1.9</td>
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<td>Yes</td>
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<tr>
<td>Vallecita Creek</td>
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<td>8.3</td>
<td>6.1</td>
<td>1.3</td>
<td>Yes</td>
<td>No</td>
</tr>
<tr>
<td>Virgin Creek</td>
<td>22.1</td>
<td>1.3</td>
<td>5.0</td>
<td>1.3</td>
<td>No</td>
<td>No</td>
</tr>
<tr>
<td><strong>Fourth-Level Watershed: Rio Chama</strong></td>
<td></td>
<td></td>
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<td></td>
</tr>
<tr>
<td>Cañones Creek</td>
<td>82.0</td>
<td>15.2</td>
<td>12.3</td>
<td>1.5</td>
<td>Yes</td>
<td>No</td>
</tr>
<tr>
<td>Cañones Creek-Abiquiu Reservoir</td>
<td>21.1</td>
<td>3.9</td>
<td>2.5</td>
<td>1.2</td>
<td>Yes</td>
<td>No</td>
</tr>
<tr>
<td>Coyote Creek</td>
<td>99.6</td>
<td>14.7</td>
<td>6.8</td>
<td>1.6</td>
<td>Yes</td>
<td>Yes</td>
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<tr>
<td>Headwaters Rio Puerco</td>
<td>21.1</td>
<td>3.8</td>
<td>5.7</td>
<td>1.8</td>
<td>Yes</td>
<td>Yes</td>
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<tr>
<td>Outlet Rio Puerco</td>
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<td>8.9</td>
<td>3.3</td>
<td>1.4</td>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td>Poleo Creek</td>
<td>1.3</td>
<td>0.2</td>
<td>7.9</td>
<td>1.7</td>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td>Polvadera Creek</td>
<td>21.2</td>
<td>2.4</td>
<td>5.1</td>
<td>1.7</td>
<td>Yes</td>
<td>No</td>
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<tr>
<td><strong>Fourth-Level Watershed: Rio Grande-Santa Fe</strong></td>
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</tr>
<tr>
<td>Alamo Canyon-Rio Grande</td>
<td>6.0</td>
<td>1.2</td>
<td>2.9</td>
<td>1.5</td>
<td>Yes</td>
<td>No</td>
</tr>
<tr>
<td>Capulin Canyon-Rio Grande</td>
<td>2.1</td>
<td>0.3</td>
<td>2.0</td>
<td>1.3</td>
<td>No</td>
<td>No</td>
</tr>
<tr>
<td>Headwaters Borrego Canyon</td>
<td>0.9</td>
<td>0.1</td>
<td>3.1</td>
<td>1.2</td>
<td>No</td>
<td>No</td>
</tr>
<tr>
<td>Peralta Canyon</td>
<td>9.1</td>
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<td>1.4</td>
<td>1.5</td>
<td>No</td>
<td>No</td>
</tr>
<tr>
<td>Rio Chiquito</td>
<td>28.8</td>
<td>4.5</td>
<td>5.3</td>
<td>1.5</td>
<td>No</td>
<td>No</td>
</tr>
</tbody>
</table>

Source: USFS 2016
The beneficial uses for this watershed are domestic water supply, irrigation, high-quality coldwater aquatic life, livestock watering, wildlife habitat, primary contact, and fish culture. According to the Office of the State Engineer database, there are 1 irrigation well, 119 single or multiple household domestic wells, and 3 municipal water wells that may be used for drinking in this watershed. Most are within the project area boundary, along the Jemez River and the East Fork Jemez River.

There are two sections of 303(d) impaired surface waters in this watershed, and the NMWQCC has established TMDLs for both, as follows:

- Jemez River, from Rio Guadalupe to Soda Dam near Jemez Springs—Established TMDLs are arsenic, boron, temperature, nutrients, and chronic aluminum. Stream bottom deposits and turbidity had established TMDLs, but these TMDLs were delisted in 2008.
- Jemez River, from Soda Dam near Jemez Springs to East Fork of the Jemez River—Established TMDLs are arsenic and chronic aluminum. Stream bottom deposits and turbidity had established TMDLs, but these TMDLs were delisted in 2008.
- Temperature and pH both affect high-quality coldwater aquatic life as well, but they are thought to be influenced by geothermal groundwater inputs and therefore do not have TMDLs.

The watershed condition class for this watershed is functioning at risk. The watershed is rated as Poor for the condition class metrics of water quality, roads and trails, fire impacts, soil condition, and invasive species. The watershed received a rating of Fair for riparian and wetland vegetation, water quantity, and aquatic habitat. All other metrics were rated as Good.

The watershed erodibility index for this watershed is 1.3, which is below the average for the watersheds that overlap the project area, at 1.5. The road density is 6.1, which is above the average of 5.3. As indicated on Figure 12, most of this watershed has an erodibility-transport risk of slight, with a few streaks of moderate to severe in the JNRA unit.

The largest area of 100-year floodplain delineation in the project area runs through the center of this watershed, along the Jemez River.

**East Fork Jemez River Watershed**

East Fork Jemez River covers 3.0 percent of the project area. The total watershed area is 38,134 acres, 15.1 percent of which overlaps the JNRA Unit. The beneficial uses for this watershed are domestic water supply, fish culture, high-quality coldwater aquatic life, irrigation, livestock watering, wildlife habitat, and primary contact. According to the Office of the State Engineer database, there are 21 single or multiple household domestic wells in this watershed, about half of which are in the project area, in the JNRA Unit.

There are three sections of 303(d) impaired surface waters in this watershed, and the NMWQCC has established TMDLs for all three, as follows:

- East Fork Jemez, from San Antonio Creek to VCNP Boundary—Established TMDLs are temperature, arsenic, and turbidity.
- East Fork Jemez, from VCNP Boundary to headwaters—Established TMDLs are temperature and turbidity; dissolved oxygen, aluminum, and pH are listed but do not yet have established TMDLs.
- Jaramillo Creek, from East Fork Jemez to headwaters—The TMDLs are temperature and turbidity.

The watershed condition class is functioning at risk. The watershed is rated as Poor for the condition class metrics of water quality, roads and trails, and soil condition. The watershed received a rating of Fair for
riparian and wetland vegetation, water quantity, aquatic habitat, and fire impacts. All other metrics were rated as Good.

The watershed erodibility index for this watershed is 1.6, which is just above the average for the watersheds that overlap the project area of 1.5. The road density is 4.0, which is below the average of 5.3. As indicated on Figure 12, most of this watershed has an erodibility-transport risk of slight or moderate, with a few streaks of higher severity on the steeper slopes of the Valles Caldera.

An area of 100-year floodplain delineation runs along the portion of the East Fork of the Jemez River, which has been designated a National Recreation River.

**Headwaters Rio Cebolla Watershed**

Headwaters Rio Cebolla covers 8.2 percent of the project area. The total watershed area is 22,739 acres; 70.1 percent overlaps the very southern tip of the North Unit, the western portion of the Lease Interest Unit, and the northwest portion of the Middle Unit in the project area. The beneficial uses for this watershed are domestic water supply, fish culture, high-quality coldwater aquatic life, irrigation, livestock watering, wildlife habitat, and primary contact. According to the Office of the State Engineer database, there are six single household domestic wells in this watershed; only one is in the project area, in the Lease Interest Area.

There is one section of 303(d) impaired surface waters in this watershed, and the NMWQCC has established TMDLs for it, as follows:

- Rio Cebolla, from Fenton Lake to headwaters—The only established TMDL is stream bottom deposits. Temperature was established in 2003, but this TMDL was delisted in 2008.
- Fenton Lake is listed as impaired for nutrients and eutrophication. There are no TMDLs established yet.

The watershed condition class is impaired function, and the watershed is rated as Poor for the condition class metrics of: riparian and wetland vegetation, water quantity, roads and trails, and soil condition. The watershed received ratings of Fair for aquatic biota, water quantity, and fire impacts. All other metrics were rated as Good.

The watershed erodibility index for this watershed is 1.3, which is below the average for the watersheds that overlap the project area, at 1.5. The road density is 10.5, much higher than the average of 5.3. As indicated on Figure 12, most of this watershed has an erodibility-transport risk of slight with moderate. It has higher severity rankings in a few patches of the northwest and northeast corners and streaks in the Lease Interest and Middle Units of the project area.

There is a 100-year floodplain designation along the Rio Cebolla, from the point at which it forks with Calaveras Canyon.

**Headwaters San Antonio Creek Watershed**

Headwaters San Antonio Creek covers 0.3 percent of the project area. This is the fourth-lowest percentage covered by a single 6th-level watershed. The total watershed area is 36,282 acres, 1.6 percent of which overlaps the Lease Interest Unit. Most of this watershed is in the VCNP, which is not included in the project area; however, it contains the headwaters that feed into much of the project area. The beneficial uses for this watershed are domestic water supply, fish culture, high-quality coldwater aquatic life, irrigation, livestock watering, wildlife habitat, and primary contact. According to the Office of the State Engineer database, there are no wells in this watershed.
There are two sections of 303(d) impaired surface waters in this watershed, and the NMWQCC has established TMDLs for both, as follows:

- San Antonio Creek, from the East Fork Jemez River to headwaters—Established TMDLs are temperature and turbidity.
- San Antonio Creek, from VCNP boundary to headwaters—pH and dissolved oxygen are both listed but do not yet have established TMDLs.

The watershed condition class is functioning at risk, and the watershed is rated as Poor for the condition class metrics of riparian and wetland vegetation, water quality, and soil condition. The watershed received ratings of Poor for aquatic biota, water quantity, roads and trails, fire impacts, and rangeland vegetation. All other metrics were rated as Good.

The watershed erodibility index for this watershed is 1.5, which is the same as the average for the watersheds that overlap the project area, at 1.5. The road density is 5.5, just slightly above the average of 5.3. As indicated on Figure 12, most of this watershed has an erodibility-transport risk of slight, with a significant portion of moderate. There also are some higher severity in in the northern and eastern parts of the watershed, which lies in the northern section of the VCNP and is therefore not in the project area.

There are no 100-year floodplain designations in this watershed.

Outlet Rio Cebolla Watershed
Outlet Rio Cebolla covers 1.6 percent of the project area. The total watershed area is 19,632 acres, 16.3 percent of which overlaps the southwest section of the Middle Unit and the northwest section of the JNRA Unit. The beneficial uses for this watershed are domestic water supply, fish culture, high-quality coldwater aquatic life, irrigation, livestock watering, wildlife habitat, and primary contact. According to the Office of the State Engineer database, there are one irrigation well and 74 single or multiple household domestic wells in this watershed. Almost all of them are just outside the project area boundary, along the Rio Cebolla, but there are three domestic wells in the JNRA Unit.

There are no 303(d) impaired surface waters in this watershed. The watershed condition class is functioning at risk, and the watershed is rated as Poor for the condition class metrics of roads and trails, soil condition, and fire impacts. The watershed received ratings of Fair for aquatic biota, riparian and wetland vegetation, water quality, water quantity, and aquatic habitat. All other metrics were rated as Good.

The watershed erodibility index for this watershed is 1.3, which is below the average for the watersheds that overlap the project area, at 1.5. The road density is 6.5, well above the average of 5.3. As indicated on Figure 12, most of this watershed has an erodibility-transport risk of slight, with a few streaks of moderate and higher severity throughout the watershed, but mostly in portions outside the project area.

There are no 100-year floodplain designations in this watershed.

Outlet San Antonio Creek Watershed
Outlet San Antonio Creek covers 5.3 percent of the project area. The total watershed area is 14,805 acres, 69.5 percent of which overlaps the southeast corner of the Lease Interest Unit, the Middle Unit, and the JNRA Unit. The easternmost sections of this watershed lie in the VCNP. The beneficial uses for this watershed are domestic water supply, fish culture, high-quality coldwater aquatic life, irrigation, livestock watering, wildlife habitat, and primary contact.
According to the Office of the State Engineer database, there are 3 irrigation wells and 150 single or multiple household domestic wells in this watershed, and they all overlap with the project area. There are two main clumped areas of wells, one in the Middle Unit and the other in the JNRA Unit.

There are two known geothermal surface features in this watershed—Spence Hot Springs and San Antonio Hot Springs—both of which are on San Antonio Creek. San Antonio Hot Springs is in the Middle Unit, while Spence Hot Springs is in the JNRA Unit, just north of the McCauley Hot Springs, in the Church Canyon-Jemez River watershed.

There are three sections of 303(d) Impaired Surface Waters in this watershed, and the NMWQCC has established TMDLs for all three, as follows:

- San Antonio Creek, from the East Fork Jemez River to the headwaters. (This is repeated from the Headwaters San Antonio Creek Watershed but includes reaches in both watersheds)—Established TMDLs are temperature and turbidity.
- San Antonio Creek, from VCNP boundary to headwaters. (This is repeated from the Headwaters San Antonio Creek Watershed but includes reaches in both watersheds)—pH and dissolved oxygen are both listed but do not yet have established TMDLs.
- San Antonio Creek, from the East Fork Jemez River to the VCNP boundary—The established TMDL for this reach is arsenic.

The watershed condition class is impaired function, and the watershed is rated as Poor for the condition class metrics of riparian and wetland vegetation, water quality, roads and trails, soil condition, and fire impacts. The watershed received ratings of Fair for aquatic biota, water quantity, aquatic habitat, invasive species, and rangeland vegetation. All other metrics were rated as Good.

The watershed erodibility index for this watershed is 1.6, which is slightly above the average for the watersheds that overlap the project area, at 1.5. The road density is 7.1, well above the average of 5.3. As indicated on Figure 12, most of this watershed has an erodibility-transport risk of slight, with a section of mostly moderate and higher severity on the border between the Middle and JNRA Units. There are also some additional streaks of higher severity hazard in the southern half of the watershed and the northern portion outside the project area, in the VCNP.

There is a 100-year floodplain designation along the San Antonio Creek, where it forks off the Jemez River and where the Church Canyon-Jemez River watershed meets the Outlet San Antonio Creek watershed. The floodplain designation continues northward, through almost the entire JNRA Unit.

**Sulphur Creek Watershed**

Sulphur Creek covers 0.9 percent of the project area. The total watershed area is 16,084 acres, 11.0 percent of which overlaps the eastern edges of the Middle and JNRA Units. The beneficial uses for this watershed are limited aquatic life, wildlife habitat, livestock watering, and secondary contact. The one known geothermal surface feature in this watershed is Sulphur Springs, which lies just east of the project area boundary, along border of the VCNP. However, the required 1-mile radius protection zone around the feature does overlap the Middle Unit of the project area.

According to the Office of the State Engineer database, there are 75 single or multiple household domestic wells in this watershed. Almost all of them are within the project area boundary, along Sulphur Creek, just upstream of its split with Redondo Creek.

There are four sections of 303(d) impaired surface waters in this watershed, and the NMWQCC has established TMDLs for all four, as follows:
- Sulphur Creek, from San Antonio Creek to Redondo Creek—Turbidity and aluminum are both listed but do not yet have established TMDLs.
- Sulphur Creek, from Redondo Creek to headwaters—Established TMDLs are conductivity and pH.
- Sulphur Creek, from VCNP to headwaters—Aluminum is listed but does not yet have an established TMDL.
- Redondo Creek, from Sulphur Creek to headwaters—Established TMDLs are total phosphorus and turbidity. Total phosphorus is pending delisting; a TMDL for temperature was established in 2003 but this TMDL was delisted in 2008.

The watershed condition class is functioning at risk, and the watershed is rated as Poor for the condition class metrics of riparian and wetland vegetation, water quality, roads and trails, and soil condition. The watershed received a rating of Fair for fire impacts. All other metrics were rated as Good.

The watershed erodibility index for this watershed is 1.9, which is above the average for the watersheds that overlap the project area, at 1.5. The road density is 3.0, quite a bit below the average of 5.3. As indicated on Figure 12, much of this watershed has an erodibility-transport risk of moderate, with some sections of slight throughout. This watershed has more area of very severe risk than any other watershed overlapping the project area; however, nearly all of that area is in the VCNP, which is not itself in the project area.

Sulphur Creek and Redondo Creek both have designated 100-year floodplains, which stretch from the fork with the San Antonio Creek to the border of the VCNP.

Vallecita Creek Watershed

Vallecita Creek covers 8.3 percent of the project area. The total watershed area is 32,341 acres, 50.0 percent of which overlaps the JNRA Unit and a large portion of the South Unit. The beneficial uses for this watershed are coldwater aquatic life, primary contact, irrigation, livestock watering and wildlife habitat, and public water supply on Vallecita Creek.

According to the Office of the State Engineer database, there are 3 irrigation wells and 34 single or multiple household domestic wells in this watershed. Most of them are south of the project area, but five wells, including one irrigation well, are in the South Unit.

There is one section of 303(d) impaired surface waters in this watershed, and the NMWQCC has established TMDLs for it as follows: Vallecito Creek, from the perennial diversion above Ponderosa to headwaters—Aluminum and turbidity are both listed but do not yet have established TMDLs.

The watershed condition class is functioning at risk and the watershed is rated as Poor for the condition class metrics of water quality, roads and trails, soil condition, and fire impacts. The watershed received ratings of Fair for riparian and wetland vegetation and water quantity. All other metrics were rated as Good.

The watershed erodibility index for this watershed is 1.3, which is below the average for the watersheds that overlap the project area, at 1.5. The road density is 6.1, above the average of 5.3. As indicated on Figure 12, most of this watershed has an erodibility-transport risk of slight, with very few streaks of moderate and higher severity, mostly in the northern portions of the watershed, which falls in both the South and JNRA Units.

There are no 100-year floodplain designations in this watershed.
Virgin Canyon Watershed

Virgin Canyon covers 1.3 percent of the project area. The total watershed area is 11,449 acres, 22.1 percent of which overlaps, in two distinct sections, the western edge of the JNRA Unit. The beneficial uses for this watershed are domestic water supply, fish culture, high-quality coldwater aquatic life, irrigation, livestock watering, wildlife habitat, and primary contact. According to the Office of the State Engineer database, there are no irrigation or drinking water wells in this watershed.

There are no 303(d) impaired surface waters in this watershed. The watershed condition class is functioning at risk, and the watershed is rated as Poor for the condition class metrics of roads and trails, soil condition, and fire impacts. The watershed received ratings of Fair for riparian and wetland vegetation, water quantity, and aquatic habitat. All other metrics were rated as Good.

The watershed erodibility index for this watershed is 1.3, which is below the average for the watersheds that overlap the project area, at 1.5. The road density is 5.0, just slightly below the average of 5.3. As indicated on Figure 12, most of this watershed has an erodibility-transport risk of slight, with a few streaks of moderate and higher severity in Virgin Canyon, which falls just outside the project area boundary.

There are no 100-year floodplain designations in this watershed.

Rio Chama Watershed

Cañones Creek Watershed

Cañones Creek covers 15.2 percent of the project area, which is the highest percentage of area in the project area covered by a single 6th-level watershed. The total watershed area is 36,111 acres, 82.0 percent of which overlaps the Lease Interest Unit and the eastern side of the North Unit. The beneficial uses for this watershed are irrigation storage, livestock watering, wildlife habitat, primary contact, coldwater aquatic life, and warmwater aquatic life.

According to the Office of the State Engineer database, there are 36 irrigation wells and 74 single or multiple household domestic wells in this watershed. Most of the wells are just east of the project area boundary, but there are four irrigation and nine domestic wells in the project area, mostly along Cañones Creek around the area of its fork with Chihuahuenos Creek.

There are two sections of 303(d) impaired surface waters in this watershed, and the NMWQCC has established TMDLs for both, as follows:

- Cañones Creek, from Abiquiu Reservoir to Headwaters—Established TMDLs are chronic aluminum, fecal coliform, and turbidity. Temperature and E. coli are both listed but do not yet have established TMDLs.
- Chihuahuenos Creek, from Cañones Creek to headwaters—Chronic aluminum and sedimentation/siltation are listed but do not yet have established TMDLs.

The watershed condition class is functioning at risk, and the watershed is rated as Poor for the condition class metrics of riparian and wetland vegetation, water quality, roads and trails, and soil condition. The watershed received ratings of Fair for water quantity, aquatic habitat, fire impacts, invasive species, and rangeland vegetation. All other metrics were rated as Good.

The watershed erodibility index for this watershed is 1.5, which is the same as the average for the watersheds that overlap the project area of 1.5. The road density is 12.3, much higher than the average of 5.3. As indicated on Figure 12, most of this watershed has an erodibility-transport risk of slight. The
northern section is mostly slight, with a few streaks of moderate and higher severity through the North Unit. The southern portion of the watershed is mostly moderate, with a few streaks of both slight and higher severity, mainly in the Lease Interest Unit.

There are no 100-year floodplain designations in this watershed.

**Cañones Creek-Abiquiu Reservoir Watershed**

Cañones Creek-Abiquiu Reservoir covers 3.9 percent of the project area. The total watershed area is 36,027 acres, 21.1 percent of which overlaps the northernmost portion of the North Unit. The beneficial uses for this watershed are irrigation storage, livestock watering, wildlife habitat, primary contact, coldwater aquatic life, and warmwater aquatic life.

According to the Office of the State Engineer database, there are 2 irrigation wells and 45 single or multiple household domestic wells in this watershed. They are mostly north of the project area, in and around the Abiquiu Reservoir; however, there are two domestic wells within the project area boundary in the North Unit,

There is one section of 303(d) impaired surface waters in this watershed, for which the NMWQCC has established TMDLs: Cañones Creek, from Abiquiu Reservoir to headwaters. (Repeated from Cañones Creek Watershed but includes reaches in both watersheds)—Established TMDLs are chronic aluminum, fecal coliform, and turbidity. Temperature and *E. coli* are both listed but do not yet have established TMDLs.

The watershed condition class is functioning at risk, and the watershed is rated as Poor for the condition class metrics of roads and trails and fire impacts. The watershed received ratings of Fair for aquatic biota, riparian and wetland vegetation, water quality, water quantity, aquatic habitat, soil condition, and rangeland vegetation. All other metrics were rated as Good.

The watershed erodibility index for this watershed is 1.2, which is below the average for the watersheds that overlap the project area, at 1.5. The road density is 2.5, much below the average of 5.3. As indicated on Figure 12, most of this watershed has an erodibility-transport risk of slight, with a few small sections of moderate and higher severity in the northernmost reach of the watershed, lying outside the project area.

There are no 100-year floodplain designations in this watershed.

**Coyote Creek Watershed**

Coyote Creek covers 14.7 percent of the project area, which is the second highest percentage of area in the project area covered by a single 6th-level watershed, after the Cañones Creek Watershed. The total watershed area is 28,850 acres, 99.7 percent of which overlaps large portions of the North and Lease Interest Units. The beneficial uses for this watershed are domestic water supply, fish culture, high-quality coldwater aquatic life, irrigation, livestock watering, wildlife habitat, and primary contact and public water supply on the Rio Brazos and Rio Chama.

According to the Office of the State Engineer database, there are 13 irrigation wells and 26 single or multiple household domestic wells in this watershed. All but two wells are in the project area, in both the North and Lease Interest Units. The Lease Interest Unit overlaps with only two domestic wells; the rest are almost entirely situated along Coyote Creek in the North Unit and clumped in the northern section of the watershed, downstream of the fork with Rito de las Sillas. There are also six wells, four irrigation and two domestic, along Rito de las Sillas, also in the North Unit of the project area.
There is one section of 303(d) impaired surface waters in this watershed, for which the NMWQCC has established the following TMDLs: Coyote Creek, from Rio Puerco de Chama to headwaters—Sedimentation and siltation is listed but does not yet have a TMDL.

The watershed condition class is functioning at risk, and the watershed is rated as Poor for the condition class metrics of roads and trails and soil condition. The watershed received ratings of Fair for aquatic biota, riparian and wetland vegetation, water quantity, fire impacts, invasive species, and rangeland vegetation. All other metrics were rated as Good.

The watershed erodibility index for this watershed is 1.6, which is just above the average for the watersheds that overlap the project area, at 1.5. The road density is 6.8, which is above the average of 5.3. As indicated on Figure 12, there is a fairly equal mix of erodibility-transport risk of slight and moderate throughout this watershed. There are also a few small streaks of higher severity throughout.

There is a 100-year floodplain designation for Coyote Creek, from its convergence with the Rio Puerco de Chama and upstream, for a little over a mile.

**Headwaters Rio Puerco Watershed**

Headwaters Rio Puerco covers 3.8 percent of the project area. The total watershed area is 35,393 acres, 21.1 percent of which overlaps the western edge of the North Unit. The beneficial uses for this watershed are domestic water supply, fish culture, high-quality coldwater aquatic life, irrigation, livestock watering, wildlife habitat, and primary contact and public water supply on the Rio Brazos and Rio Chama.

According to the Office of the State Engineer database, there are 6 irrigation wells and 16 single or multiple household domestic wells in this watershed. Many are outside the project area boundary, but there are 11 total wells (2 irrigation wells and 9 domestic wells) in this watershed that overlap the project area in the North Unit.

There is one section of 303(d) impaired surface waters in this watershed, for which the NMWQCC has established the following TMDLs: Rio Puerco de Chama, from Rio Chama to highway 96—Established TMDLs are *E. coli* and temperature. Nutrients and eutrophication are listed but do not yet have established TMDLs.

The watershed condition class is functioning at risk, and the watershed is rated as Poor for the condition class metrics of roads and trails, soil condition, and fire impacts. The watershed received ratings of Fair for riparian and wetland vegetation, water quality, water quantity, and rangeland vegetation. All other metrics were rated as Good.

The watershed erodibility index for this watershed is 1.8, which is just above the average for the watersheds that overlap the project area, at 1.5. The road density is 5.7, just slightly above the average of 5.3. As indicated on Figure 12, most of this watershed has an erodibility-transport risk of slight on its east and west ends, with a large section through the middle with a rating of moderate to severe.

A portion of the Rio Puerco de Chama in this watershed has a 100-year floodplain designation for about a mile, in the northwest corner of the project area.

**Outlet Rio Puerco Watershed**

Outlet Rio Puerco covers 8.9 percent of the project area. The total watershed area is 36,465 acres, 47.5 percent of which overlaps a central portion of the North Unit. This is the third largest 6th-level watershed that overlaps the project area, and it covers the fourth highest percentage of area in the project area.
covered by a single 6th-level watershed. The beneficial uses for this watershed are irrigation, livestock watering, wildlife habitat, coldwater aquatic life, warm water aquatic life, and primary contact.

According to the Office of the State Engineer database, there are 6 irrigation wells and 70 single or multiple household domestic wells in this watershed. They are mostly north of the project area, but 21 wells, 3 irrigation wells, and 18 domestic wells overlap the North Unit, at the northern border of the project area.

There are two sections of 303(d) impaired surface waters in this watershed, and the NMWQCC has established TMDLs for both, as follows:

- **Rio Puerco de Chama, from Rio Chama to highway 96**—Established TMDLs are *E. coli* and temperature. Nutrients and eutrophication are listed but do not yet have established TMDLs. (This section is also included for the Headwaters Rio Puerco Watershed, because it runs through both watersheds.)
- **Rito Encino, from Rio Puerco de Chama to headwaters**—Sedimentation/siltation and *E. coli* are both listed but do not yet have established TMDLs.

The watershed condition class is functioning at risk, and the watershed is rated as Poor for the condition class metric of soil condition. The watershed received ratings of Fair for riparian and wetland vegetation, water quantity, roads and trails, and fire impacts. All other metrics were rated as Good.

The watershed erodibility index for this watershed is 1.4, which is just below the average for the watersheds that overlap the project area, at 1.5. The road density is 3.3, below the average of 5.3. As indicated on Figure 12, most of this watershed has an erodibility-transport risk of slight, with two sections of moderate and higher severity in the northwest and southwest reaches of the watershed. The southwest higher severity section lies in the middle of the North Unit.

There are four 100-year floodplain designations on streams in this watershed, within the project area boundary. One of the streams is El Rito Encino, and the others are intermittent streams. All of the designations in this watershed lie on the northern boundary of the North Unit.

**Poleo Creek Watershed**

Poleo Creek covers 0.2 percent of the project area, which is the second-lowest percentage covered by a single 6th-level watershed. The total watershed area is 29,541 acres, 1.3 percent of which overlaps the northwestern corner of the North Unit in the project area. The beneficial uses for this watershed are domestic water supply, fish culture, high-quality coldwater aquatic life, irrigation, livestock watering, wildlife habitat, and primary contact and public water supply on the Rio Brazos and Rio Chama.

According to the Office of the State Engineer database, there are 12 irrigation wells and 52 single or multiple household domestic wells in this watershed. Most of it lies outside the project area boundary, and therefore most of the wells do too. There are just two wells (one irrigation and one domestic) in this watershed, both of which are in the northwestern corner of the North Unit.

There is one section of 303(d) impaired surface waters in this watershed, for which the NMWQCC has established the following TMDL: Poleo Creek, from Rio Puerco de Chama to headwaters—The established TMDL is turbidity.

The watershed condition class is functioning at risk, and the watershed is rated as Poor for the condition class metrics of roads and trails, soil condition, and fire impacts. The watershed received ratings of Fair
for aquatic biota, riparian and wetland vegetation, water quality, water quantity, invasive species, and rangeland vegetation. All other metrics were rated as Good.

The Watershed Erodibility Index for this watershed is 1.7, which is just above the average for the watersheds that overlap the project area of 1.5. The road density is 7.9, above the average of 5.3. As indicated on Figure 12, there is a relatively equal distribution of slight and moderate erodibility-transport risk, with a few streaks of higher severity in the southwest section of the watershed, lying outside the project area.

Poleo Creek, Cañoncito Seco, and Agua Sarca all have 100-year floodplain designations in this watershed, and all are in the northwest corner of the project area.

**Polvadera Creek Watershed**

Polvadera Creek covers 2.4 percent of the project area. The total watershed is 22,145 acres, 21.2 percent of which overlaps eastern portions of the North and Lease Interest Units. The beneficial uses for this watershed are domestic water supply, fish culture, high-quality coldwater aquatic life, irrigation, livestock watering, wildlife habitat, and primary contact and public water supply on the Rio Brazos and Rio Chama.

According to the Office of the State Engineer database, there are 10 irrigation wells and 6 single or multiple household domestic wells in this watershed, all of which are outside the project area boundary. They are all located along Polvadera Creek, mostly in the northernmost area of the watershed.

There is one section of 303(d) impaired surface waters in this watershed, for which the NMWQCC has established the following TMDL: Polvadera Creek, from Cañones Creek to headwaters—The established TMDL is temperature.

The watershed condition class is functioning at risk, and the watershed is rated as Poor for the condition class metrics of riparian and wetland vegetation, water quality, roads and trails, soil condition, and fire impacts. The watershed received ratings of Fair for water quantity and rangeland vegetation. All other metrics were rated as Good.

The watershed erodibility index for this watershed is 1.7, which is slightly above the average for the watersheds that overlap the project area, at 1.5. The road density is 5.1, just below the average of 5.3. As indicated on Figure 12, there is a relatively equal distribution of slight and moderate erodibility-transport risk, with a section of mostly moderate and higher severity in the southern portion of the watershed, overlapping the eastern section of the Lease Interest Unit.

There are no 100-year floodplain designations in this watershed.

**Rio Grande-Santa Fe Watershed**

**Alamo Canyon-Rio Grande Watershed**

Alamo Canyon-Rio Grande covers 1.2 percent of the project area. The total watershed is 37,630 acres, of which 6.0 percent overlaps the northeastern portion of the South Unit in the project area. The beneficial uses for this watershed are domestic water supply, high-quality coldwater aquatic life, irrigation, livestock watering, wildlife habitat, and primary contact. According to the Office of the State Engineer database, there is one household domestic use well in this watershed, in the north and just outside the project area boundary.
There is one section of 303(d) impaired surface waters in this watershed, for which the NMWQCC has established a TMDL, as follows: Rito de los Frijoles, from Rio Grande to headwaters—Aluminum is listed but does not yet have an established TMDL.

The watershed condition class is functioning at risk, and the watershed is rated as Poor for the condition class metrics of roads and trails, soil condition, and fire impacts. The watershed received ratings of Fair for aquatic biota, riparian and wetland vegetation, water quality, and water quantity. All other metrics were rated as Good.

The watershed erodibility index for this watershed is 1.5, which is the same as the average for the watersheds that overlap the project area. The road density is 2.9, much below the average of 5.3. As indicated on Figure 12, most of this watershed has an erodibility-transport risk of slight, with a few areas rated as having moderate to very severe risk.

There are no 100-year floodplain designations in this watershed.

**Capulin Canyon-Rio Grande Watershed**

Capulin Canyon-Rio Grande covers 0.3 percent of the project area, which is the third-lowest percentage of the project area covered by a single 6th-level watershed. The total watershed is 26,901 acres, 2.1 percent of which overlaps the South Unit. The beneficial uses for this watershed are irrigation, livestock watering, wildlife habitat, marginal coldwater aquatic life, primary contact, and warmwater aquatic life and public water supply on the main stem Rio Grande.

According to the Office of the State Engineer database, there are four single household domestic wells in this watershed, all of which are outside the project area boundary.

There are no 303(d) impaired surface waters in this watershed. The watershed condition class is functioning at risk, and the watershed is rated as Poor for the condition class metrics of roads and trails, soil condition, and fire impacts. The watershed received ratings of Fair for riparian and wetland vegetation, water quality, and water quantity. All other metrics were rated as Good.

The watershed erodibility index for this watershed is 1.3, which is just below the average (1.5) for the watersheds that overlap the project area. The road density is 2.0, well below the project area average of 5.3. As indicated on Figure 12, most of this watershed has an erodibility-transport risk of slight. A few areas are rated as having moderate to very severe risk throughout the watershed, although they mostly occur outside the project area.

There are no 100-year floodplain designations in this watershed.

**Headwaters Borrego Canyon Watershed**

Headwaters Borrego Canyon covers 0.1 percent of the project area, which is the lowest percentage of the project area covered by a single 6th-level watershed. The total watershed is 28,944 acres, 0.9 percent of which overlaps a corner on the southern edge of the South Unit. The beneficial uses for this watershed are warmwater aquatic life, livestock watering, wildlife habitat, and primary contact. According to the Office of the State Engineer database, there are two single household domestic wells in this watershed, both of which are outside the project area boundary.

There are no 303(d) impaired surface waters in this watershed. The watershed condition class is functioning at risk, and the watershed is rated as Poor for the condition class metrics of roads and trails, soil condition, and fire impacts. The watershed received ratings of Fair for; riparian and wetland vegetation and water quantity. All other metrics were rated as Good.
The watershed erodibility index for this watershed is 1.2, which is below the average for the watersheds that overlap the project area, at 1.5. The road density is 3.1, below the average of 5.3. As indicated on Figure 12, most of this watershed has an erodibility-transport risk of slight, with a few small patches of moderate and higher severity throughout the watershed; however, the watershed is almost entirely outside the project area.

There are no 100-year floodplain designations in this watershed.

**Peralta Canyon Watershed**

Peralta Canyon covers 1.3 percent of the project area. The total watershed is 28,444 acres, 9.1 percent of which overlaps the South Unit. The beneficial uses for this watershed include irrigation, livestock watering, wildlife habitat, marginal coldwater aquatic life, primary contact, and warm water aquatic life and public water supply on the main stem Rio Grande. According to the Office of the State Engineer database, there is one irrigation well and one single household domestic well in this watershed, both of which are outside the project area boundary.

There are no 303(d) impaired surface waters in this watershed. The watershed condition class is functioning at risk and the watershed is rated as Poor for the condition class metrics of soil condition and fire impacts. The watershed received ratings of Fair for aquatic biota, riparian and wetland vegetation, roads and trails, and rangeland vegetation. All other metrics were rated as Good.

The watershed erodibility index for this watershed is 1.5, which is the same as the average for the watersheds that overlap the project area. The road density is 1.4, much below the average of 5.3. As indicated on Figure 12, most of this watershed has an erodibility-transport risk of slight, but sections in the north and middle of the watershed have a mixture of moderate and higher severity ratings. The northern section overlaps both the JNRA and South Units, but the middle section lies outside the project area.

There are no 100-year floodplain designations in this watershed.

**Rio Chiquito Watershed**

Rio Chiquito covers 4.5 percent of the project area. The total watershed is 30,188 acres, 28.8 percent of which overlaps eastern portions of the South and JNRA Units. The beneficial uses for this watershed are irrigation, livestock watering, wildlife habitat, marginal coldwater aquatic life, primary contact, and warm water aquatic life and public water supply on the main stem Rio Grande.

According to the Office of the State Engineer database, this watershed has 3 irrigation wells, 26 single or multiple household domestic wells, and 1 municipal water well that may be used for drinking. Fifteen of the domestic wells are within the project area boundary, in both the South and JNRA Units.

There are no 303(d) impaired surface waters in this watershed. The watershed condition class is functioning at risk, and the watershed is rated as Poor for the condition class metrics of roads and trails, soil condition, and fire impacts. The watershed received ratings of Fair for riparian and wetland vegetation and water quantity. All other metrics were rated as Good.

The watershed erodibility index for this watershed is 1.5, which is the same as the average for the watersheds that overlap the project area. The road density is 5.3, which is also the same as the overall average of 5.3. As indicated on Figure 12, this watershed is streaked with erodibility-transport risk of slight and moderate, with some additional streaks of higher severity throughout. The northwestern portion of the watershed that overlaps the JNRA and South Units is the area with the most moderate and higher severity risk. Farther south, the watershed is rated more toward slight, and this area lies outside the project area.
There are no 100-year floodplain designations in this watershed.

Groundwater Resources

The Rio Grande Aquifer System

The groundwater in the project area is in the Rio Grande aquifer system, which is the principal aquifer in a 70,000-square-mile area of southern Colorado, central New Mexico, and western Texas. The main geological feature in the Rio Grande Aquifer is the Rio Grande Rift, a graben, with the sides of the rift uplifted and the middle blocks dropped and rotated. Sediments in the rift valley are deep, approximately 20,000 feet at Albuquerque, New Mexico.

The Rio Grande Aquifer is an unconsolidated sand and gravel aquifer system, consisting of a network of hydraulically interconnected aquifers in basin-fill deposits along the Rio Grande Valley and nearby valleys. Some volcanic rocks (like those that make up most of the bedrock in the project area), solution-altered carbonate rocks, or extensively fractured beds can yield water in some areas; nevertheless, the bedrock as a whole has minimal permeability and is considered to form an impermeable base to the aquifer.

Younger basin fill consists of unconsolidated, poorly to well sorted, interbedded Quaternary gravel, sand, silt, and clay. Alluvial fans and pediment-cover deposits near the mountains generally grade imperceptibly into, and inter-tongue with, either fine-grained playa deposits in valleys or medium- to coarse-grained fluvial deposits. Terrace deposits consist of gravel, sand, and silt and extend 30 to 175 feet above the level of the present floodplain (USGS 1995).

Recharge to the Rio Grande aquifer system primarily comes from precipitation in the mountainous areas that surround the basins. Runoff from snowmelt or rainfall spreads across permeable alluvial fans and percolates downward into the aquifer. Some of the precipitation flows into the bedrock aquifers through fractures and permeable layers in the bedrock. If the volume of runoff is large or becomes part of a perennial stream, groundwater recharge can be distributed over a much longer reach of stream channel. Runoff produces most mountain-front recharge to the aquifer system, and water from the bedrock aquifers is discharged into the basin fill where the mountains front the Rio Grande Valley (Figure 13; Goff 2002).

In some mountainous areas, such as the project area, thick and extensive layers of volcanic rocks are sufficiently permeable to enable large volumes of water to flow through the rocks and directly recharge the basin-fill aquifers. Precipitation falling in the valleys does not contribute to recharging the aquifers, because most of it is lost to evaporation and transpiration.

Project Area Hydrogeology

The project area lies in the Jemez Mountains in north-central New Mexico. The Jemez mountains are a complex mass of Tertiary and Quaternary volcanic rocks that overlie Tertiary, Mesozoic, and Paleozoic sedimentary rocks, which in turn overlie Precambrian basement rock. The volcanic field near the intersection of the Jemez Lineament is part of the western margin of the Rio Grande Rift (Goff et al. 1985). The Jemez Lineament is a northeast-trending chain of volcanic features, extending from east-central Arizona to southeastern Colorado (Aldrich 1986, in Trainer et al. 2000).

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8 A depressed block of land bordered by parallel faults.
The most dominant feature of the Jemez Mountains is the large central caldera, or area of collapse, known as Valles Caldera. It contains a geothermal system that is a classic: a liquid-dominated reservoir that is overlain by a low-pressure vapor cap and is recharged by local meteoric water (Goff et al. 1985; Trainer et al. 2000). The reservoir is most extensive in fractured caldera fill tuffs and associated sedimentary rocks in specific structural zones (Goff et al. 1985). The Valles geothermal system is in the central and western parts of the Valles Caldera but does not extend under the entire caldera (Hulen and Nielson 1986; Wilt and Vender Harr 1986). Extensive sheets of the Bandelier Tuff overlie the older rocks throughout much of the region, inside and outside the caldera. They form radially dissected plateaus that slope away from the caldera (Trainer et al. 2000).

The caldera contains both thermal and nonthermal groundwater. Like the local surface water drainage patterns, groundwater flows radially outward from the rim of the caldera. The most extensive and productive aquifer in the region is the thick sequence of valley-fill deposits and interbedded volcanic rocks that underlie the Pajarito Plateau on the east side of the mountain mass. On the west side, thermal and nonthermal waters discharge from the caldera to the southwest, down Cañon de San Diego, which follows the trace of the Jemez Fault Zone. The principal geothermal reservoir, or aquifer, in the region is under the central and western parts of the caldera (Trainer et al. 2000).
Nonthermal water in Valles Caldera occurs in diverse, perched aquifers and deeper valley-fill aquifers. The nonthermal groundwater is meteoric in origin (Vuataz and Goff 1986). Discharge of nonthermal water from Valles Caldera takes several paths, some of which are not well understood. Some of the nonthermal groundwater discharges from springs, particularly from higher, smaller perched aquifers. Water from the more extensive valley-fill aquifers discharges as spring flow and seepage to the principal streams. Some deeper discharge from the valley-fill aquifers recharges the underlying geothermal reservoir by slowly leaking through relatively impermeable rocks and along fractures and faults (Faust et al. 1984, in Trainer et al. 2000; Vuataz and Goff 1986, in Trainer et al. 2000).

The meteoric water that recharges the geothermal reservoir moves downward from the aquifers in the caldera fill to depths of 6,500 feet or more, reaching temperatures of approximately 330 degrees Celsius (626 degrees Fahrenheit). This heated geothermal water then rises convectively to 2,000 feet or less and mixes with other groundwater as it flows away from the geothermal reservoir. A vapor zone, containing steam, carbon dioxide, and other gases, exists above parts of the liquid-dominated geothermal zone (Trainer 1974).

The principal reservoir of geothermal fluids is at depth, under the central and western parts of the caldera. The heated water of the geothermal system flows out of the caldera to the west and southwest, under the Jemez Plateau and along the Jemez Fault Zone, and in the semipermeable Paleozoic rocks that border the fault zone. This geothermal water mixes with other groundwater as it flows along the fault zone, and some of this mixed or derivative water issues as hot springs in Cañon de San Diego (Trainer 1974). Outflowing mineral water appears to be limited to the western and southwestern parts of the Jemez Mountains.

The geothermal system at Valles Caldera is subdivided into the Redondo, Sulphur Springs, and Jemez Springs geothermal areas, based on the distribution of springs and fumaroles, past geothermal exploration projects and scientific drilling programs. Surface discharges at Redondo and Sulphur Springs are fed by upwelling fluids from chemically distinct, isolated reservoirs beneath the caldera floor (OpenEI 2016). Free gas issues at Sulphur Springs and from smaller springs and fumaroles in the resurgent dome of the caldera (Goff 2002).

The Jemez Springs system lies outside the caldera walls, to the southwest in Cañon de San Diego. Hydrothermal features outside Valles Caldera are restricted largely to this canyon; geothermal waters reach the springs primarily by structurally controlled lateral outflow and by more minor flow through Paleozoic strata. Subsurface escape of reservoir fluid from near and beneath Valles Caldera has formed a discharge plume of reservoir water, mixed with dilute groundwater, which extends down Cañon de San Diego (Trainer 1974; Goff et al. 1988). The Jemez Fault Zone transports a relatively large portion of this flow. Soda Dam and Jemez Springs are derivatives of geothermal outflow from the reservoir. Near Jemez Pueblo, subsurface mineral water merges with the regional aquifer in fill deposits of the Albuquerque Basin (Trainer 1974). Free gas also emerges from several thermal features along the Jemez fault zone, southwest of the caldera.

Natural Geothermal Features

Hot springs are found both inside and outside of the Valles Caldera, a result of deep groundwater circulating over the very hot rocks of the magma chamber that underlies the caldera (New Mexico Natural History 2015). There are numerous natural mineral hot springs throughout the Jemez valley. Some are on public land, others are on private land and are open to the public for a fee. All of these features are found in the Jemez Watershed and are associated with the collapsed caldera. The five natural hot or warm springs in the project area are Jemez, Soda Dam, San Antonio, Spence, and McCauley (Table 19). An additional hot spring, Sulphur Springs, is just outside the project area boundary, in the Valles Caldera.
Table 19. Geothermal Features and Locations

<table>
<thead>
<tr>
<th>Geothermal Feature</th>
<th>Feature Description</th>
<th>Watershed (4th-Level/6th-Level)</th>
<th>Project Unit</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sulphur Springs</td>
<td>Acid-sulfate hot spring system of thermal and nonthermal springs, fumaroles, and mud pots; hottest and most active zone of surface geothermal features of the caldera</td>
<td>Jemez/Sulphur Creek</td>
<td>Not in the project area</td>
</tr>
<tr>
<td>Soda Dam</td>
<td>Warm Springs from fractured rock; includes natural formation due to buildup of mineral deposits creating a spectacular natural dam</td>
<td>Jemez/Church Canyon-Jemez River</td>
<td>JNRA Unit</td>
</tr>
<tr>
<td>Jemez Springs</td>
<td>Warm Springs from alluvium</td>
<td>Jemez/Church Canyon-Jemez River</td>
<td>JNRA Unit</td>
</tr>
<tr>
<td>McCauley Warm Springs</td>
<td>Warm Springs flowing from piles of volcanic rubble near the base of lava flows and tuffs; interpreted as contact springs at a discontinuity within the rhyolite or at the unconformity between the rhyolite and underlying sandstone and shale of the Abo Formation</td>
<td>Jemez/Church Canyon-Jemez River</td>
<td>Middle Unit</td>
</tr>
<tr>
<td>Spence Hot Springs</td>
<td>Same as McCauley Springs</td>
<td>Jemez/Outlet San Antonio Hot Spring</td>
<td>JNRA Unit</td>
</tr>
<tr>
<td>San Antonio Hot Springs</td>
<td>Same as McCauley Springs</td>
<td>Jemez/Outlet San Antonio Hot Spring</td>
<td>Middle Unit</td>
</tr>
</tbody>
</table>

**Sulphur Springs**

Sulphur Springs, along the western edge of the VCNP, are a group of thermal and nonthermal springs, fumaroles, and mud pots. This area is the hottest and most active zone of surface geothermal features in the caldera. These features are part of an acid-sulfate hot spring system centered on a sequence of intersecting faults on the western side of the Redondo Creek resurgent dome (Trainer et al. 2000). Acid-sulfate hot springs and fumaroles discharge at the surface at boiling temperatures. Surface discharges at Sulphur Springs are fed by an underlying vapor-dominated zone that is, in turn, derived from the boiling of a deeper liquid-dominated flow system that does not reach the surface.

**Soda Dam and Jemez Springs**

Soda Dam and Jemez Springs are along the Jemez River in the Cañon de San Diego. These are fault-controlled warm springs issuing from fractured rock at Soda Dam and from alluvium at Jemez Springs. Although the spring water is mineralized and believed to have been derived from the geothermal reservoir beneath the caldera, it is thought to have been modified along its flow path through a solution of country rock and dilution (Trainer 1974). Soda Dam is a natural formation, where water from underground hot springs has flowed for centuries. The buildup of mineral deposits has formed a unique and spectacular natural dam that blocks the Jemez River. The Soda Dam and Jemez Springs waters start at the Valles Caldera, heated by the hot rock and magma beneath. Waters feeding Soda Dam travel as hot groundwater through Pennsylvanian limestones and shales, then rise to the surface along a fault at Soda Dam (Lunar Planetary Institute 2003).

**San Antonio and Spence Hot Springs and McCauley Warm Springs**

Spence Hot Springs and McCauley Warm Springs are found to the north, along the western boundary of the VCNP. San Antonio Hot Spring is in the Middle Unit, along the San Antonio River, a tributary to the
Jemez River. San Antonio Hot Spring, Spence Hot Spring, and McCauley Warm Springs flow from piles of volcanic rubble near the base of lava flows and tuffs. They are interpreted as contact springs at a discontinuity within the rhyolite or at the unconformity between the rhyolite and underlying sandstone and shale of the Abo Formation (Trainer 1974).

**Nonthermal Groundwater Sources**

**Office of the State Engineer Designated Wells**

According to the Office of the State Engineer, there are 659 wells in the project area, all within the Rio Grande Basin Aquifer. Most of these wells are for domestic single household use or domestic and livestock monitoring. Depth to water ranges between 0 and 800 feet, and well depth ranges from 10 to 545 feet, although many water and well depths are not available. **Table 20** shows the number of Office of the State Engineer wells in each leasing unit and the total number in the project area.

<table>
<thead>
<tr>
<th>Project Unit</th>
<th>Number of Wells</th>
</tr>
</thead>
<tbody>
<tr>
<td>JNRA Unit</td>
<td>365</td>
</tr>
<tr>
<td>Lease Interest Unit</td>
<td>10</td>
</tr>
<tr>
<td>Middle Unit</td>
<td>156</td>
</tr>
<tr>
<td>North Unit</td>
<td>98</td>
</tr>
<tr>
<td>South Unit</td>
<td>30</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td><strong>659</strong></td>
</tr>
</tbody>
</table>

Source: New Mexico Office of the State Engineer 2015

**Rio Chama Watershed**

Little information is available on groundwater hydrology in the region. However, groundwater is critically important because most of the region’s residents depend on it for their domestic water supplies, and periodic shortages occur. Aquifer characteristics in much of the region severely limit groundwater availability.

Groundwater in the Mancos shale, an aquiclude, has a low yield and usually fair to poor quality for livestock or crops. Groundwater in the igneous rocks and volcanics is usually along fracture zones that are hard to intercept with water wells (NRCS 2011a).

The Rio Chama watershed consists of three different geologic provinces, each containing distinct aquifer systems. The Española Basin province, in the southern part of the watershed and overlapping the project area, consists of Tertiary Period sediments, primarily the Santa Fe Group. These deposits are moderately permeable, contain large amounts of sand and gravel, transmit a fair amount of water, and have a relatively large recharge potential, meaning that the groundwater is easily renewed by surface water percolating down. Española Basin aquifers usually yield relatively ample supplies of good quality water (New Mexico Office of the State Engineer 2006).

Shallow alluvial aquifers are found throughout the watershed, in all three geologic provinces, and many wells in the region draw water from these aquifers. Alluvial aquifers, composed largely of gravel and

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9 An impermeable body of rock or stratum of sediment that acts as a barrier to the flow of water.
sand, can be a good source of water if the deposits are deep and extensive. However, in the Rio Chama region, the alluvial deposits are shallow and generally not extensive. Wells drawing water from these aquifers often run short of water in dry years.

Additional groundwater production may be possible on a limited scale in certain areas. However, taking the Rio Chama watershed as a whole, there do not appear to be significant untapped groundwater resources that could replace any large fraction of surface water use or provide major new water supplies within or outside the region.

**Jemez Watershed**
The bedrock geology in the west is characterized by Precambrian metamorphic and Permian sedimentary rocks. The bedrock geology in the central and eastern regions of the watershed is comprised of volcanic rocks, largely Bandelier Tuffs associated with the Valles Caldera. Surficial deposits overlying bedrock include wind blow deposits, river alluvium, and developed surface soils. Differences in the geology through that these creeks and rivers flow through influences the surface water chemistry. Groundwater occurs in bedrock and in surficial deposits overlying the bedrock (NRCS 2011c).

Groundwater in the igneous rocks and volcanics is usually along fracture zones that are hard to intercept with water wells. Groundwater quality ranges from fair to poor for livestock or crops (NRCS 2011c).

**Rio Grande-Santa Fe Watershed**
The most significant aquifer is the Santa Fe Group, particularly its lower member, the Tesuque Formation. The upper member, the Ancha, is typically more conductive than the Tesuque but occurs above the water table in much of the Rio Grande-Santa Fe watershed (NRCS 2011b).

Deeper groundwater is nearly continuous in the Tesuque Formation throughout the watershed area, to depths of 2,000 feet or greater in some areas. This deep groundwater has been dated to be older than the most recent ice age, over 10,000 years ago (Johnson et al. 2013) and is recharged little if at all by present-day rainfall and snowmelt (NRCS 2011b).

Precipitation in the high mountains recharges shallow groundwater, which, in some areas, may be contiguous with deeper groundwater (NRCS 2011b). Volcanics often serve as a “floor” or channel to concentrate percolating groundwater and cause it to emerge as spring flow.

Groundwater in the igneous rocks and volcanics is usually along fracture zones that are hard to intercept with water wells. Groundwater quality ranges from good to poor for livestock or crops (NRCS 2011b).

**Environmental Consequences**

**Best Management Practices**
The BMPs detailed in Appendix B would be incorporated as appropriate into the permit application; alternatively, the BLM would include them in its approved use authorization as conditions of approval (COAs). When implementing the BMPs, the BLM and the USFS would work with an affected lessee early in the process to explain how BMPs may fit into the lessee’s development proposals and how BMPs can be implemented with the least economic impact on the lessee.

The BLM and USFS would discuss potential resource impacts with the lessee and would seek the operator’s recommended solutions. The BLM and USFS would also encourage the lessee to incorporate necessary and effective BMPs into the lessee’s project proposals, as determined to be appropriate during
site-specific, project-level environmental analysis. BMPs not incorporated into the lessee’s permit applications may be considered and evaluated through the environmental review process and incorporated into the use authorization as COAs or right-of-way stipulations.

Soils

**Alternative 1 – No Action**

Under Alternative 1, the SFNF would not make an availability determination for geothermal leasing on lands in the project area. Geothermal lease applications and nominations would continue to be processed; however, they would be evaluated on a case-by-case basis under separate National Environmental Policy Act analyses, in accordance with the Forest Plan (USFS 1987) and existing laws and regulations. Geothermal leasing stipulations and closures would not be specifically implemented on soils; however, any geothermal lease applications and nominations would be subject to standards and guidelines outlined in the Forest Plan and environmental analysis.

Under Alternative 1, direct and indirect impacts would include direct disturbance due to the development of roads and facilities associated with exploration and the development of geothermal production sites. Development could lead to soil erosion and sedimentation. There would be some loss of soil productivity. Exposed soil surfaces would be vulnerable to the impacts of wind and surface water runoff during project construction and operation. Surface water erosion could remove some soils from the disturbed sites, potentially carrying them to water sources. In addition, some areas may be subject to deposition of wind-blown material outside the footprint of construction areas or loss of soil due to wind erosion. Soils would be directly impacted by grading during construction. The degree of risk of erosion and transport due to water and wind depends on the eventual location of such disturbances as roads and facilities.

**Alternative 2 – Proposed Action**

Impacts on soils under Alternative 2 include direct disturbance due to development of roads, power lines, and facilities associated with exploration and development of geothermal production sites. Development could lead to soil erosion and sedimentation. There would be some loss of soil productivity. Exposed soil surfaces would be vulnerable to the impacts of wind and surface water runoff during project construction and operation. Surface water erosion could remove some soils from the disturbed sites, potentially carrying them to water sources. In addition, some areas may be subject to deposition of wind-blown material outside the footprint of construction areas or loss of soil due to wind erosion. Soils would be directly impacted by grading during construction. The degree of risk of erosion and transport due to water and wind depends on the eventual location of such disturbances as roads and facilities.

There would be a long-term commitment of soil resources in areas that are converted to nonsoil surfaces; and therefore a loss of soil function. This loss may be temporary, as in disturbance surrounding sites or along edges of roads, or long-term, due to construction of impermeable surfaces, such as drilling pads and power plants. The loss would not be permanent, because all surfaces would be reclaimed when exploration is unsuccessful or after production ceases. All surface disturbances would be reclaimed to BLM standards. This includes removing all facilities, regrading and recontouring all surface disturbances to blend with the surrounding topography, and reestablishing a desirable variety of vegetation.

Alternative 2 stipulates no surface occupancy (NSO) on slopes in excess of 40 percent and on soils with severe erosion hazard. Lands with slopes between 30 and 40 percent would be subject to controlled surface use (CSU). NSO on soils with severe erosion hazard would limit the amount of potential erosion due to soil disturbance. Preventing facility development on slopes in excess of 40 percent would further limit both erosion and sediment transport potential. This would minimize the potential impacts,
particularly in areas that do not have a severe erosion hazard (and therefore subject to NSO) but do have a high runoff potential.

However, roads and power lines could still likely cross areas of severe erosion hazard and potentially in areas of steep slopes, so there would still be a risk of erosion and transport. In all units, implementing BMPs (Appendix B) would minimize any potential impacts.

**Specific Direct and Indirect Impacts by Unit**

**North Unit**

The North Unit has the smallest area of severe erosion hazard in the project area, at 43 percent, distributed across the unit. Approximately 43 percent of the unit has a moderately high to high runoff potential, much of which overlaps areas of severe erosion hazard. Although there would be NSO in these areas, they would be susceptible to erosion and sediment transport due to potential road use or power line construction. Areas most susceptible to erosion and subsequent transport would be where surface disturbance overlaps with areas of both severe erosion hazard and moderately high to high runoff potential (approximately 13,400 acres).

Approximately 37 percent of the unit is characterized by WEGs 2 and 3, primarily in the northern half of the unit. In these areas, soils would be most susceptible to wind erosion.

The most fertile soils are found in a pocket of Mollisols at the higher elevations of the unit. The also fertile Alfisols are scattered throughout the unit. Development or disturbance in these soils would remove some of the more fertile soils in the North Unit from productivity.

The North Unit has the most area of expansive soils of the project area units. There would be no stipulations specific to expansive soils; however, these conditions may be unsuitable for siting geothermal facilities.

**Lease Interest Unit**

Approximately 83 percent of the Lease Interest Unit has a severe erosion hazard, and approximately 79 percent of this unit has a moderately high to high runoff potential. Therefore, the areas of highest erosion potential are also at risk for subsequent transport of eroded materials.

Areas most susceptible to erosion and subsequent sediment transport would be where potential road use or power line construction overlaps with areas of both severe erosion hazard and moderately high to high runoff potential (approximately 25,400 acres).

The Lease Interest Unit is generally characterized by WEG 4L, 5, and 7 soils, and there are no areas with WEG 1, 2, or 3 soils in the unit. Therefore, the susceptibility of soils due to wind erosion in disturbed areas would generally be low.

Approximately 43 percent of the unit is covered by the more fertile and developed Alfisol and Mollisol soil types. Development or disturbance in these soils would remove some of the more fertile soils in the Lease Interest Unit from productivity.

Areas of expansive soils occur primarily in the center of the unit. There would be no stipulations specific to expansive soils; however, these conditions could further limit the siting of geothermal facilities.
Middle Unit
Similar to the Lease Interest Unit, approximately 82 percent of the Middle Unit is characterized by severe erosion hazard soils. However, less of the Middle Unit has a high runoff potential, with 67 percent of the area at a moderately low runoff potential. Therefore, there is less of a risk of transporting eroded materials in much of the area. Areas most susceptible to erosion and subsequent sediment transport would be where potential road use or power line construction overlaps with areas of both severe erosion hazard and moderately high to high runoff potential (approximately 3,700 acres).

The Middle Unit is characterized by WEG 4L and 5 soils. Therefore, the susceptibility of soils due to wind erosion in disturbed areas would generally be low.

Approximately 39 percent of the unit is covered by the more fertile and developed Alfisol soil types. Development or disturbance would remove some of the more fertile soils in the Middle Unit from productivity.

There is only a small area of expansive soils, along San Antonio Creek. All perennial and intermittent creeks are protected with a 500-foot-wide NSO protection zone. Therefore, much of the area of expansive soils along San Antonio Creek would not likely be considered for surface development.

Jemez National Recreation Area Unit
The JNRA Unit is closed to geothermal leasing, so there would be no potential direct or indirect impacts on soils in this unit.

South Unit
Severe erosion hazard covers 45 percent of this unit, and 55 percent of the unit also has a high runoff potential. Areas most susceptible to soil erosion and subsequent transport would be where potential road use or power line construction overlaps areas of both severe erosion hazard and moderately high to high runoff potential (approximately 12,200 acres).

The more fertile and developed soil types of Alfisols and Mollisols cover 29 percent of the unit. Development or disturbance in these soils would remove some of the more fertile soils in the Middle Unit from productivity.

There is little risk of wind erosion and no areas of expansive soils in this unit.

Alternative 3 – No Leasing
This alternative would amend the Forest Plan (USFS 1987) to implement discretionary closures to geothermal leasing on all lands in the project area not already closed to leasing. There would be no direct impacts on soils under Alternative 3. There would be no surface disturbance from road or power line construction, the development of exploration sites, or well development. Because the area would be closed to leasing for the foreseeable future, over time, there would be less soil disturbance than would be expected under the current Forest Plan (USFS 1987).

Alternative 4 – Development
Impacts on soils would be similar to those described under Alternative 2. However, under Alternative 4, allowing surface occupancy on areas of severe erosion hazard by implementing only CSU stipulations on these soils would increase the risk of erosion and sediment transport in areas disturbed for exploration and development of geothermal sites. This would be a particular concern on steeper slopes of between 30 and
40 percent and areas with moderately high to high runoff potential. Implementing BMPs identified in Appendix B to minimize and contain any erosion could reduce the impacts on soil productivity.

Specific Direct and Indirect Impacts by Unit

North Unit
The impacts in the North Unit would be similar to those described under Alternative 2. However, on the 29,460 acres of severe erosion hazard, there would be a greater potential for erosion and sediment transport. This is because these areas would be subject to CSU stipulations, rather than NSO stipulations.

Other impacts would be the same as those discussed under Alternative 2.

Lease Interest Unit
Impacts on the Lease Interest Unit would be similar to those described under Alternative 2. However, on the 32,561 acre of severe erosion hazard, there would be a greater potential for erosion and sediment transport. This is because these areas would be subject to CSU stipulations rather than NSO stipulations.

Other impacts would be the same as those discussed under Alternative 2.

Middle Unit
Impacts in the Middle Unit would be similar to those described under Alternative 2. However, on the 11,528 acres of severe erosion hazard, there would be a greater potential for erosion and sediment transport. This is because these areas would be subject to CSU stipulations, rather than NSO stipulations.

Other impacts would be the same as those discussed under Alternative 2.

Jemez National Recreation Area Unit
Impacts on soils in the JNRA Unit would be the same as those described under Alternative 2.

South Unit
Impacts in the South Unit would be similar to those described under Alternative 2. However, on the 15,346 acres of severe erosion hazard, there would be a greater potential for erosion and sediment transport. This is because these areas would be subject to CSU stipulations, rather than NSO stipulations.

Other impacts would be the same as those discussed under Alternative 2.

Soils Cumulative Impacts
This section presents the potential cumulative impacts of the past, present, and future foreseeable actions, combined with the proposed actions. Reasonably foreseeable future actions are projects, activities, or trends that could impact human and environmental receptors in the defined regions of influence in the project area and in the defined time frames. The reasonably foreseeable future actions for the project area are listed in Table 21.

Water resource repair and replacement projects—the Pueblo of Jemez Red Rocks Dam Repair, the Abiquiu Land Grant Waterline Replacement, and the McKinney County Dam—will initially directly impact soil resources through digging and removing soil resources. These surface-disturbing activities could cause additional erosion and sedimentation into waterways. Mineral development projects—the South Pit Pumice Mine Expansion and the Duran 2010 Pumice Mine—would involve significant soil disturbance for expansion and operation. These activities could increase erosion and reduce soil productivity.
Table 21. Reasonably Foreseeable Future Actions

<table>
<thead>
<tr>
<th>Project Name</th>
<th>General Location</th>
<th>Project Description</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Vegetation Management</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Southwest Jemez Mountains Landscape Restoration Project</td>
<td>Middle Jemez River Watershed</td>
<td>Ecological restoration of up to 110,000 acres in the greater Southwest Jemez Mountains over 10 years</td>
</tr>
<tr>
<td>Supplement to the Final EIS for Invasive Plant Control Project EIS</td>
<td>Carson National Forest and SFNF</td>
<td>Updates information contained in the USFS’s Final EIS for the Invasive Plant Control Project, published September 2005</td>
</tr>
<tr>
<td>Cerro Pelon Timber Stand and Wildlife Habitat Improvement Project</td>
<td>SFNF, Espanola Ranger District</td>
<td>Thinning in a stand of pinyon-juniper of 165 acres to improve the health and fire resilience of the stand. This should result in increased pinyon nut production for birds and other wildlife. This project has been postponed.</td>
</tr>
<tr>
<td><strong>Water Resources</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Pueblo of Jemez Red Rocks Dam Repair</td>
<td>Pueblo of Jemez</td>
<td>The project area is on the east side of New Mexico State Highway 4, in an unnamed ephemeral stream channel and arroyo. This arroyo flows west into the Jemez River, which is less than 0.4 mile downstream. During the federal disaster declared by the president and designated as Federal Emergency Management Agency Number 4152-DR-NM, a major storm and subsequent high water flows eroded the containment berm at Red Rocks Dam. This caused a breach and failure of the stormwater detention facility. This facility provides flood protection for downstream road and irrigation infrastructure at the Pueblo of Jemez. As such, the purpose of the proposed project is to repair the stormwater detention facility and protect downstream infrastructure.</td>
</tr>
<tr>
<td>Pueblo of Jemez Owl Springs Bridge Sediment Removal Project</td>
<td>Pueblo of Jemez</td>
<td>The Natural Resources Department of Jemez Pueblo is proposing to use a track hoe for removing the sedimentation; it will be operated from the banks of the Jemez River.</td>
</tr>
<tr>
<td>Valle Seco Wetland Restoration Project</td>
<td>Valles Caldera</td>
<td>The proposal is to restore severely eroded emergent wetlands in the watershed of Sulphur Creek in the VCNP, Jemez Springs. The project will construct 54 rock and earthen structures along five headwater tributaries (19,580 feet) and 3,600 feet of the main channel. The project proponent will build 25 plug and pond structures, sod dams, one-rock dams, a worm ditch, and contour swales.</td>
</tr>
<tr>
<td>Abiquiu Land Grant Waterline Replacement Project</td>
<td>SFNF, Espanola Ranger District</td>
<td>In 1967, the Merced de Abiquiu Land Grant installed a water collection gallery and water line on NFS lands in order to provide water for livestock. This facility is at the end of its life, and the proposal is to replace it.</td>
</tr>
<tr>
<td>McKinney County Dam</td>
<td>SFNF, Jemez Ranger District</td>
<td>This project to remove McKinney Dam and replace it with a fish barrier is on hold.</td>
</tr>
<tr>
<td><strong>Energy and Mineral Resources</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Valles Caldera: Nomination under the Geothermal Steam Act</td>
<td>VCNP</td>
<td>NPS is seeking to list the Valles Caldera as a significant geothermal feature under the Geothermal Steam Act of 1970 (30 USC, Section 1019). If it were determined that geothermal operations were reasonably likely to result in a significant adverse impact on such a feature, then the BLM would decline to issue the lease. The BLM or USFS would include stipulations to protect any significant thermal features of an NPS unit that could be adversely affected by geothermal development. These stipulations would be added, if necessary, if the lease or permit were issued, extended, renewed, or modified (43 CFR, Subpart 3201.10[b]).</td>
</tr>
</tbody>
</table>
Table 21. Reasonably Foreseeable Future Actions

<table>
<thead>
<tr>
<th>Project Name</th>
<th>General Location</th>
<th>Project Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>South Pit Pumice Mine Expansion</td>
<td>SFNF, Jemez Ranger District</td>
<td>Approval of a 10-year-plan of operations for a pumice mine of approximately 48 acres, next to a recently reclaimed 9-acre pumice mine</td>
</tr>
<tr>
<td>Duran 2010 Pumice Mine</td>
<td>South of Cerro del Pino, Jemez Ranger District, SFNF</td>
<td>Develop an open-pit pumice mine south of Cerro del Pino</td>
</tr>
</tbody>
</table>

**Threatened, Endangered, and Special Status Species**

<table>
<thead>
<tr>
<th>Project Name</th>
<th>General Location</th>
<th>Project Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>New Mexico Meadow Jumping Mouse Critical Habitat Projection Project (EA)</td>
<td>SFNF, Jemez Ranger District</td>
<td>Protection and improvement of habitat conditions for the New Mexico meadow jumping mouse</td>
</tr>
</tbody>
</table>

Restoration projects, such as the Southwest Jemez Mountains Restoration Project, Pueblo of Jemez Owl Springs Bridge Sediment Removal Project, and Valle Seco Wetland Restoration Project, would maintain or improve soil conditions in their respective project areas by removing sedimentation and reducing erosion.

Sedimentation and erosion would likely occur from geothermal development, combined with natural processes, such as fires in project area watersheds. The intensity of the combined impacts of fires and geothermal development would depend on the size and severity of the fire and on local soil conditions.

There would be the fewest cumulative impacts under Alternative 3, due to the restriction of leasing in the entire project area. Cumulative impacts would be similar under Alternatives 1, 2, and 4; however, Alternatives 1 and 4 would likely have the greatest intensity, due to a lack of or reduction of restrictive stipulations on geothermal development.

**Summary of Impacts on Soils**

A summary of soil indicators is presented below in Table 22. Soil erosion and transport are most likely to occur in areas that are open to geothermal leasing and contain soils with both severe erosion hazard and moderately high or high runoff potential.

There would be no impacts on soils in the JNRA Unit under any alternatives, because this unit is closed to geothermal leasing.

The Lease Interest Unit would be most susceptible to soil erosion and sediment transport under Alternatives 1, 2, and 4. That is because this unit contains the most acres of soils classified as severe erosion hazard, with high to moderately high runoff potential (25,432 acres, or 65 percent of the unit). Soil erosion and sediment transport could also occur in the Middle Unit, North Unit, and South Unit, depending on the location of proposed power lines, roads, and geothermal facilities. Under Alternatives 2 and 4, stipulations for soils with severe erosion potential and slopes in excess of 40 percent would minimize erosion impacts. Under Alternative 3, there would be no soil impacts from geothermal leasing and development.
Table 22. Soil Indicators by Unit

<table>
<thead>
<tr>
<th></th>
<th>Unit</th>
<th>JNRA Unit</th>
<th>Lease Interest Unit</th>
<th>Middle Unit</th>
<th>North Unit</th>
<th>South Unit</th>
<th>Totals</th>
</tr>
</thead>
<tbody>
<tr>
<td>Area of Severe Erosion Hazard per Unit in Project Area</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Area of severe erosion hazard in unit (acres)</td>
<td></td>
<td>18,880</td>
<td>32,561</td>
<td>11,528</td>
<td>29,460</td>
<td>15,346</td>
<td>107,775</td>
</tr>
<tr>
<td>Percent of unit with severe erosion hazard</td>
<td></td>
<td>48</td>
<td>83</td>
<td>82</td>
<td>43</td>
<td>45</td>
<td>55</td>
</tr>
<tr>
<td>Percent of Each WEG per Unit in the Project Area</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>WEG 1</td>
<td></td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>1</td>
<td>0</td>
</tr>
<tr>
<td>WEG 2</td>
<td></td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>23</td>
<td>0</td>
<td>8</td>
</tr>
<tr>
<td>WEG 3</td>
<td></td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>14</td>
<td>0</td>
<td>5</td>
</tr>
<tr>
<td>WEG 4L</td>
<td></td>
<td>12</td>
<td>29</td>
<td>33</td>
<td>5</td>
<td>12</td>
<td>14</td>
</tr>
<tr>
<td>WEG 5</td>
<td></td>
<td>21</td>
<td>12</td>
<td>61</td>
<td>10</td>
<td>6</td>
<td>16</td>
</tr>
<tr>
<td>WEG 7</td>
<td></td>
<td>35</td>
<td>59</td>
<td>0</td>
<td>42</td>
<td>65</td>
<td>45</td>
</tr>
<tr>
<td>WEG 8</td>
<td></td>
<td>33</td>
<td>0</td>
<td>6</td>
<td>7</td>
<td>15</td>
<td>12</td>
</tr>
<tr>
<td>Percent of Each Hydrologic Soil Group per Unit in the Project Area</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>A: Low runoff potential/high infiltration rate</td>
<td></td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>B: Moderately low runoff potential</td>
<td></td>
<td>68</td>
<td>21</td>
<td>67</td>
<td>56</td>
<td>45</td>
<td>50</td>
</tr>
<tr>
<td>C: Moderately high runoff potential</td>
<td></td>
<td>0</td>
<td>41</td>
<td>0</td>
<td>19</td>
<td>0</td>
<td>15</td>
</tr>
<tr>
<td>D: High runoff potential/very slow infiltration rate</td>
<td></td>
<td>32</td>
<td>38</td>
<td>33</td>
<td>25</td>
<td>55</td>
<td>35</td>
</tr>
<tr>
<td>Area per Unit with Severe Erosion Hazard Coupled with High to Moderately High Runoff Potential (Hydrologic Soil Group C or D)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Acres per unit</td>
<td></td>
<td>8,539</td>
<td>25,432</td>
<td>3,738</td>
<td>13,375</td>
<td>12,240</td>
<td>63,323</td>
</tr>
<tr>
<td>Percent of unit</td>
<td></td>
<td>22</td>
<td>65</td>
<td>27</td>
<td>20</td>
<td>36</td>
<td>33</td>
</tr>
</tbody>
</table>

Source: USFS 2016

Watershed and Surface Water

Alternative 1 – No Action

Under Alternative 1, the SFNF would not make an availability determination for geothermal leasing on lands in the project area. Geothermal lease applications and nominations would continue to be processed; however, they would be evaluated on a case-by-case basis under separate National Environmental Policy Act analyses, in accordance with the Forest Plan (USFS 1987) and existing laws and regulations. Geothermal leasing stipulations and closures would not be specifically implemented for watershed and surface water; however, any future geothermal lease applications and nominations would be subject to standards and guidelines outlined in the Forest Plan and environmental analysis.

Under Alternative 1, there would be the potential for erosion and subsequent transport of eroded materials into surface waters in areas where vegetation has been removed and soils disturbed. This could increase suspended sediment and turbidity in surface waters following periods of runoff. There could also be
impacts on sensitive riparian zones, due to road construction and any activities that are proposed near stream courses.

Potential short-term impacts on water quality could also occur from accidental releases of chemical compounds, such as fuels, solvents for removing buildup on pipes, working fluids required for drilling and operation activities, or wastewater. Pollutants that could be spilled include petroleum products (primarily diesel fuel and petroleum based lubricants) and solvents (such as hydrochloric acid or hydrofluoric acid to dissolve scale\textsuperscript{10}), stormwater or sanitation water, and working fluids (such as isobutane or n-pentane used in the course of the drilling operations). These working fluids also include drilling mud (bentonite clay, activated montmorillonite clay, and crystalline silica-quartz), drilling mud additives (caustic soda, sodium bicarbonate, and anionic polyacrylamide liquid polymer), Portland cement and calcium chloride, and coolants.

Impacts from accidental release of pollutants described above could include increased concentrations of hydrocarbons and other contaminants in surface waters.

In addition, there is the potential for geothermal fluids to contaminate watershed and surface waters through faulty reinjection practices, geothermal well casing failure, and uncontrolled discharge of waste geothermal fluids to surface waters, such as the accidental release from surface ponds (Aksoy et al. 2008). Potential impacts from geothermal fluid release to surface waters could include increased concentrations of heavy metals.

Water use would occur for drilling wells, constructing infrastructure, stimulating injection wells, operating the power plant, and controlling dust. The applicant would be responsible for obtaining water rights in accordance with state and federal regulations. Water sources could include surface water sources; however, the reasonably foreseeable development scenario anticipates that freshwater used in drilling operations would be trucked in or would come from local springs and wells at depths of less than 1,000 feet (BLM 2015).

**Alternative 2 – Proposed Action**

**Direct and Indirect Impacts for all Watersheds**

Under Alternative 2, indirect impacts from anticipated geothermal exploration and development would generally be the same as those described under Alternative 1, although the location of potential sites would be restricted by administrative withdrawals and stipulations. Approximately 32,000 acres, or 17 percent of the NFS lands in the project area, would be closed to geothermal leasing; approximately 136,650 acres in the project area would be allocated as open to geothermal leasing, subject to existing laws, regulations, formal orders, and stipulations.

NSO stipulations would reduce the potential for direct impacts on the following resources from erosion caused by development and contamination from accidental spills: drinking water sources, points of surface water diversions, developed springs and wells, rivers, streams, wetlands, springs, playas, riparian areas, 100-year floodplains, and other water bodies.

NSO stipulations on slopes greater than 40 percent, soils with severe erosion potential, and CSU stipulations for slopes between 30 and 40 percent would reduce the potential for direct impacts on water resources connected with these sites from erosion caused by development and contamination from accidental spills. However, road and power line development could still impact all of these areas from

\textsuperscript{10} Precipitation of calcium carbonates and metal sulfides
erosion and subsequent transport of eroded materials into surface waters in areas where vegetation has been removed and soils disturbed. This could increase suspended sediment and turbidity in surface water following runoff.

Alternative 2 could have direct impacts on water resources. These impacts could result from the following:

- Exploration
- Potential new road construction to access areas of interest
- Upgrading existing local roads to handle increased traffic and high capacity vehicles

There also could be impacts from constructing exploration wells, and, if exploration is successful, constructing and operating power plants, placing pipes and transmission lines, and finally, reclaiming areas when exploration is unsuccessful or after production ceases.

There would be possible impacts on surface water sources due to ground disturbance during road and facility development. There would be the potential for erosion and subsequent transport of eroded materials into surface waters in areas where vegetation has been removed and soils disturbed. This could increase suspended sediment and turbidity in surface waters following periods of runoff. There could also be impacts on sensitive riparian zones due to road construction and any activities that are proposed near stream courses. This would be of particular concern in areas of highly erodible soils or near impaired stream reaches or in sensitive watersheds.

As with Alternative 1, drilling and operation of a binary geothermal power plant would require fuels, working fluids, and solvents. Any accidental releases of these chemical compounds could contaminate surface water resources. The potential for spills would be minimized by implementing the BMPs identified in Appendix B, such as requiring the development of a spill prevention and response plan.

It is possible that some groundwater flow paths in the deeper aquifers could be modified, but this would be unlikely to affect surface water flows.

There would be no indirect impacts on surface water in the VCNP or Bandier National Monument. This is because surface water from the caldera generally flows into the project area. While headwaters to perennial streams in the South Unit of Bandelier National Monument occur in the south unit of the project area, no impacts on these headwaters are anticipated. This is because NSO stipulations would apply to 33,200 acres (or 97 percent) of the South Unit, including 500 feet from the outer edge of perennial and intermittent rivers and streams.

**Rio Chama 6th-Level Watersheds**

The Affected Environment discussion provides a summary of existing conditions for the Rio Chama 6th-level watersheds that overlap any portion of the project area. Below is a discussion by 6th-level watersheds for direct and indirect impacts for Alternative 2.

**Cañones Creek Watershed**

Road density is currently high in this watershed (12.13 miles of road per square mile). Additional roads, power lines, and other surface-disturbing activities would likely add to existing impacts from roads, including increased peak flows, sediment yield, and erosion. These impacts could occur along Cañones and Chihuahuenuos Creeks, particularly in the headwaters of both creeks, where soils are more erodible and slopes are steep. This alternative stipulates NSO within a 500-foot-wide buffer protection zone along rivers, streams, riparian areas, and other water bodies. This stipulation would minimize the amount of
sediment into Cañones and Chihuahuenos Creeks and other surface water resources, from well exploration or development and power plant construction.

**Cañones Creek-Abiquiu Reservoir Watershed**

Road density (2.5 miles of road per square mile) and watershed erodibility index (1.2) for this watershed are lower than the average for the project area. While most of the watershed has an erodibility-transport risk of slight, there are some areas rated as moderate, severe, and very severe. These areas would be most susceptible to erosion and sedimentation from road or power line construction. Only a small portion of Cañones Creek runs through this watershed until it empties into Abiquiu Reservoir. However, tributaries running through this watershed would empty into Cañones Creek, upstream of Abiquiu Reservoir. These tributaries could carry eroded sediments from disturbed areas into Cañones Creek. This alternative stipulates NSO within a 500-foot-wide buffer protection zone along rivers, streams, riparian areas, and other water bodies. This stipulation would minimize the amount of sediment into Cañones Creek and other surface water resources in the watershed from well exploration or development and power plant construction.

**Coyote Creek Watershed**

This has a watershed erodibility index of 1.6, which is average for the project area. Road density is above average, at 6.8 miles of road per square mile. Additional roads, power lines, and other surface-disturbing activities would likely add to existing impacts from roads, including increased peak flows, sediment yield, and erosion. Impacts could occur along Coyote Creek and Rio Puerco de Chama. Because nearly this entire watershed covers the project area, there is a greater likelihood of impacts, compared with other watersheds that encompass only a small portion of the project area. This alternative stipulates NSO within a 500-foot-wide buffer protection zone along rivers, streams, riparian areas, and other water bodies. This stipulation would minimize the amount of sedimentation into Coyote Creek, Rio Puerco de Chama, and other surface water resources in the watershed.

**Headwaters Rio Puerco Watershed**

This has a watershed erodibility index of 1.8, higher than many of the watersheds in the project area. Road density is 5.7 miles per square mile, which is about average for project area watersheds. Should facilities construction be proposed in this watershed, potential impacts would be from increased peak flows, sediment yield, and erosion. These impacts would be most prone to occur in the southern portion of the watershed, where the erodibility-transport risks are moderate to severe. The 303(d) impaired section of the Rio Puerco de Chama lies outside, and just to the north, of the project area and flows through a portion of the watershed with only slight erodibility-transport risk. New roads, power lines, and other geothermal developments could contribute to increased sediment yield in the Rio Puerco de Chama; however, listed concerns include *E. Coli*, temperature, and nutrient/eutrophication. Increased sediments are less of a concern in this water source. NSO stipulations along rivers, streams, riparian areas, and other water bodies would minimize the amount of sedimentation into Rio Puerco de Chama and other surface water resources in the watershed.

**Outlet Rio Puerco Watershed**

This has a watershed erodibility index of 1.4, just below the average for watersheds in the project area. Road density is 3.3 miles per square mile, lower than the average of 5.3 for project area watersheds. Although most of this watershed has an erodibility-transport risk of slight, there are areas of moderate to very severe risk in its northwest and southwest reaches. Impacts in this watershed would be from the increased risk of erosion and sedimentation due to additional road and power line construction and other surface disturbances. The headwaters of Rito Encino contain soils that are more erodible than other areas in the watershed, and this area would be more prone to erosion and sedimentation. NSO stipulations along
rivers, streams, riparian areas, and other water bodies would minimize the amount of sedimentation into Rito Encino and other surface water resources in the watershed.

**Poleo Creek Watershed**
This has a watershed erodibility index of 1.7, just above the average for watersheds in the project area. Road density is 7.9 miles per square mile, higher than the average of 5.3 for project area watersheds. New road and power line construction and other geothermal developments in this watershed could contribute to increased erosion, sedimentation, and turbidity in such water bodies as Poleo Creek. However, because this watershed covers only 0.2 percent of the total project area, and only 1.3 percent of the total watershed overlaps the project area, there would be a low risk of impacts. Additionally, NSO stipulations along rivers, streams, riparian areas, and other water bodies would minimize the risk of erosion and increased turbidity in Poleo Creek and other surface water resources in the watershed.

**Polvadera Creek Watershed**
This has a watershed erodibility index of 1.7, just above the average for watersheds in the project area. The road density of 5.1 miles per square mile is average for project area watersheds. The watershed condition class metrics of riparian and wetland vegetation, roads and trails, soil condition, and fire impacts are rated as Poor. Should facility construction be proposed in this watershed, impacts could be increased peak flows, sediment influx, and erosion. Polvadera Creek runs the length of this watershed but outside of the project area. This entire reach is a 303(d) impaired surface water. Geothermal development could contribute to increased turbidity in this creek and other surface water resources in the watershed. However, NSO stipulations along rivers, streams, riparian areas, and other water bodies would minimize this risk.

**Jemez 6th-Level Watersheds**
The Jemez Watershed and ten of its 6th-level watersheds cover approximately 43 percent of the project area. This includes approximately one-third of the Lease Interest unit, primarily west of the Valles Caldera, all of the Middle Unit, and most of the JNRA and South Units. In addition to the impacts discussed above under **Direct and Indirect Impacts for all Watersheds**, specific impacts in the Jemez 6th-level watersheds are discussed below.

**Headwaters Rio Cebolla**
This has a watershed erodibility index of 1.3, below the average for watersheds in the project area. Road density (10.5 miles per square mile) is above average for this watershed; additional roads would likely add to existing impacts, including increased peak flows and sediment yield. Power line construction, road construction, and other surface disturbances could contribute to increased sediment in Rio Cebolla and other surface water resources in the watershed. However, NSO stipulations along rivers, streams, riparian areas, floodplains, and other water bodies would minimize this risk.

**Headwaters San Antonio Creek**
This has a watershed erodibility index of 1.5, the average for watersheds in the project area. The road density of 5.5 miles per square mile in this watershed is slightly above the average of 5.3 for project area watersheds. Because this watershed covers only 0.3 percent of the project area, and only 2 percent of the watershed is in the project area, actions proposed under this alternative are unlikely to affect sensitive resources. While surface disturbance in this watershed is possible, NSO stipulations along rivers, streams, riparian areas, floodplains, and other water bodies would minimize the risk of impacts on surface water resources.
Outlet San Antonio Creek
This has a watershed erodibility index of 1.6, just above the average for watersheds in the project area. The road density of 7.1 miles per square mile in this watershed is higher than the average of 5.3 for project area watersheds. San Antonio Creek is a 303(d) impaired surface water, and from the East Fork Jemez River to the headwaters, established TMDLs are temperature and turbidity. Power line construction, road construction, and other surface disturbances could contribute to increased sediment in San Antonio Creek. However, NSO stipulations along rivers, streams, riparian areas, floodplains, and other water bodies would minimize this risk.

Outlet Rio Cebolla
This has a watershed erodibility index of 1.3, below the average for watersheds in the project area. The road density of 6.5 miles per square mile in this watershed is above the average of 5.3 for project area watersheds. Should construction of facilities be proposed in this watershed, potential impacts include increased peak flows, sediment yield, and erosion. Rio Cebolla drains into Fenton Lake, which is listed as impaired for nutrients/eutrophication. However, this reach is located outside of the project area, and activities from the proposed action are unlikely to affect Fenton Lake. NSO stipulations along rivers, streams, riparian areas, floodplains, and other water bodies would minimize the potential for increased sediment in other surface water resources in the watershed.

Sulphur Creek Watershed
This has a watershed erodibility index of 1.9, the highest of the watersheds in the project area. The road density of 3.0 miles per square mile is lower than the average of 5.3 for project area watersheds. Sulphur Creek curves around the northern and western portion of the watershed and enters the project area in an area with a moderate to severe erodibility-transport risk rating.

The section of Sulphur Creek that is in the project area is a 303(d) impaired surface water. The section that is impaired from San Antonio Creek to Redondo Creek has the listed concerns of turbidity and aluminum. This section is entirely in the JNRA Unit, where no leasing would occur. However, there is a portion of Sulphur Creek upstream of this section that flows through the Middle Unit. Activities in this portion of Sulphur Creek Watershed could increase turbidity in the impaired section of Sulphur Creek in the JNRA Unit.

The other section of Sulphur Creek that is impaired is that running through the Middle Unit, from Redondo Creek to the headwaters. Established TMDLs are conductivity and pH. Proposed activities are unlikely to affect these metrics.

Finally, a third section of Sulphur Creek is impaired, from the VCNP border to the headwaters. The listed concern is aluminum. This section is upstream of any possible activities and therefore would not be affected. A small section of the 303(d) impaired surface water of Redondo Creek is in the project area. Established TMDLs are total phosphorus and turbidity. However, the section of Redondo Creek in the project area is in the JNRA Unit, which is not available for leasing. The remaining portion of Redondo Creek is upstream of any potential activities and would not be affected. Therefore, there would be no impacts on Redondo Creek.

Virgin Canyon Watershed
All portions of this watershed that overlap the project area also overlap the JNRA unit, which is closed to geothermal leasing. Therefore, Alternative 2 is unlikely to impact this watershed or its surface waters.
Church Canyon-Jemez River Watershed
This has a watershed erodibility index of 1.3, below the average for watersheds in the project area. The Jemez River runs the length of this watershed and is within the project area boundary; however, it is entirely in the JNRA Unit, which is closed to geothermal leasing, so it is unlikely to be affected by project activities. The only portion of this watershed that overlaps a potential leasing unit is a small section overlapping the western edge of the South Unit. NSO stipulations along rivers, streams, riparian areas, floodplains, and other water bodies would minimize the potential for increased erosion or sedimentation, and no impacts on the Jemez River are would likely occur in this watershed.

Cañon de la Cañada Watershed
This has a watershed erodibility index of 1.5, which is average for watersheds in the project area. The road density of 5.6 miles per square mile is just slightly above the average of 5.3 for project area watersheds. Should facility construction be proposed, impacts could be from increased peak flows, sediment yield, and erosion. NSO stipulations along rivers, streams, riparian areas, floodplains, and other water bodies would minimize these impacts.

Vallecita Creek Watershed
This has a watershed erodibility index of 1.3, below the average for watersheds in the project area. The road density of 6.1 miles per square mile in this watershed is above the average of 5.3 for project area watersheds. Approximately 50 percent of the watershed overlaps the JNRA Unit, which is closed to leasing. Surface-disturbing activities in the portion of this watershed that covers the South Unit could increase sedimentation and erosion, particularly in the portions of the watershed with higher erodibility-transport risk. NSO stipulations along rivers, streams, riparian areas, floodplains, and other water bodies would minimize these impacts.

East Fork Jemez River Watershed
All portions of this watershed that overlap the project area also overlap the JNRA unit, which is closed to leasing. Additionally, the watershed’s surface waters are upstream of any potential activities. Therefore, Alternative 2 would likely have no impacts on this watershed or its surface waters.

Rio Grande-Santa Fe 6th-Level Watersheds
The Rio Grande-Santa Fe Watershed and five of its 6th-level watersheds cover approximately 7 percent of the project area, primarily on the east side of the South and JNRA units. In addition to the impacts discussed above under Direct and Indirect Impacts for all Watersheds, specific impacts in the Rio Grande-Santa Fe 6th-level watersheds are discussed below.

Alamo Canyon-Rio Grande Watershed
This has a watershed erodibility index of 1.5, the average for watersheds in the project area. The road density of 2.9 miles per square mile is lower than the average of 5.3 for project area watersheds. Rito de los Frijoles runs the length of this watershed, from its headwaters to its confluence with the Rio Grande. However, it is outside of the project area boundary throughout its length and is separated from the project area by Obsidian Ridge. Geothermal development is unlikely to affect Rito de los Frijoles. Surface disturbance from power lines, roads, wells, power plants, and other geothermal developments may increase the potential for erosion; however, stipulations along rivers, streams, riparian areas, and other water bodies would minimize the risk of impacts on water quality.
**Capulin Canyon-Rio Grande Watershed**
This has a watershed erodibility index of 1.3, which is below the average for watersheds in the project area. The road density of 2.0 miles per square mile is much lower than the average of 5.3 for project area watersheds. Because this watershed covers only 0.3 percent of the project area, and NSO stipulations would be implemented along rivers, streams, riparian areas, and other water bodies, impacts on the watershed and surface waters in the watershed would be negligible.

**Headwaters Borrego Canyon Watershed**
Headwaters Borrego Canyon Watershed covers only 0.1 percent of the project area, on a corner of the southern edge of the South Unit. Because this watershed covers only a small portion of the project area, and NSO stipulations would be implemented along rivers, streams, riparian areas, and other water bodies, impacts on the watershed and surface waters in the watershed would be negligible.

**Peralta Canyon Watershed**
This has a watershed erodibility index of 1.5, the average for watersheds in the project area. The road density of 1.4 miles per square mile is well below the average of 5.3 for project area watersheds. The headwaters of Peralta Creek are in the JNRA Unit. It then crosses southward, through the section of the watershed in the South Unit. There would be no leasing in the JNRA Unit. In the South Unit, project activities could occur in an area dominated by erodibility-transport risk of moderate to very severe. Potential impacts in this watershed are increased peak flows, sediment yield, and erosion. However, NSO stipulations would be implemented along rivers, streams, riparian areas, and other water bodies, which would minimize the potential for eroded soils from entering Peralta Creek or other surface waters.

**Rio Chiquito Watershed**
This has a watershed erodibility index of 1.5, the average for watersheds in the project area. The road density of 5.3 miles per square mile is the average of 5.3 for project area watersheds. Numerous small canyons run through the watershed, originating in the section that overlaps the JNRA and South Units. Waters from these canyons eventually converge in Rio Chiquito. Surface-disturbing activities in the South Unit may increase the risk of erosion and sediment influx into Rio Chiquito. However, NSO stipulations would be implemented along rivers, streams, riparian areas, and other water bodies, which would minimize this risk.

**Alternative 3 – No Leasing**
This alternative would amend the Forest Plan (USFS 1987) to implement discretionary closures to geothermal leasing on all lands in the project area not already closed to leasing.

There would be no direct impacts on watersheds and surface waters. No surface disturbance would occur from road or power line construction, nor from developing exploration sites, wells, or power plants. The project area would be closed to leasing for the foreseeable future. Therefore, long-term and indirect impacts would be less disturbance than would have been expected under the current Forest Plan (USFS 1987).

**Alternative 4 – Development**
Impacts from Alternative 4 would be similar to those described under Alternative 2. However, there would be no discretionary closures, and there would be reduced protection of specific areas from implementing lease stipulations that are less restrictive.

Although there would be no discretionary closures, approximately 17 percent of the NFS lands in the project area would still be closed to geothermal leasing. NSO would still be stipulated for slopes in excess
of 40 percent, and slopes between 30 and 40 percent would still be subject to CSU. However, implementing CSU rather than NSO stipulations on areas with severe erosion hazard would increase the risk of erosion in areas disturbed by exploration and development of geothermal sites. This would increase sedimentation and turbidity into streams and rivers, particularly on steep slopes and areas with moderately high to high runoff potential. Runoff from development on steep slopes in areas of severe erosion hazard could increase turbidity in surface waters.

CSU rather than NSO stipulations in intermittent streams (the NSO still holds for perennial streams) would increase the risk of erosion and transport to water sources. This would be the case particularly in areas of severe erosion hazard and where the runoff potential is moderate to high. Implementing an additional CSU stipulation for ephemeral drainages would reduce the risk of erosion and sediment transport in these areas.

Impacts from road development and water use under Alternative 4 would be the same as those described under Alternative 2.

Under Alternative 4, NSO stipulations apply to natural geothermal features and a 1-mile-wide buffer around them. NSO stipulations would protect these resources from accidental spills or leaks.

There would be no indirect impacts on surface water in the VCNP or Bandelier National Monument, because surface water from the caldera generally flows into the project area. While headwaters to perennial streams in the South Unit of Bandelier National Monument occur in the South Unit of the project area, no impacts on these headwaters are anticipated. This is because NSO stipulations would apply to 33,200 acres in, or 97 percent of, the South Unit.

**Watershed Cumulative Impacts**

Cumulative impacts for water resources are analyzed at the 6th-level watersheds. Past, present, and reasonably foreseeable future actions are listed in Table 21.

Water resource repair and replacement projects—the Pueblo of Jemez Red Rocks Dam Repair, the Abiquiu Land Grant Waterline Replacement, and the McKinney County Dam—in combination with Alternatives 1, 2, and 4, would likely directly impact water resources, at least initially, through increased erosion and sedimentation into waterways. However, long-term impacts would be improved protection from flooding and erosion and reduced potential for loss of water resources through leakage.

Restoration projects, such as the Southwest Jemez Mountains Restoration Project, Pueblo of Jemez Owl Springs Bridge Sediment Removal Project, and Valle Seco Wetland Restoration Project, would maintain or improve water resource conditions in their respective project areas. This would come about by removing sedimentation and reducing erosion or by maintaining streambank stability.

Under Alternatives 1, 2, and 4, sedimentation and erosion would likely occur from geothermal development. Natural processes, such as fire, could accelerate or amplify the impacts of sedimentation and erosion. The magnitude and intensity of these impacts would depend on the size and severity of the fire, as well as on local soil conditions. In areas affected by previous wildfires, there would be a greater potential for cumulative sedimentation and erosion impacts. Water quality impacts from accidental spills related to geothermal development are possible; they could combine with impacts from sediment transport and erosion or other accidental spills outside of the project area that travel downstream through the 6th-level watersheds.

Road density is currently high in several watersheds. Additional roads in these watersheds would likely add to existing cumulative impacts, including increased peak flows, sediment transport, and deposition.
**Summary of Impacts on Watershed and Surface Waters**

Under Alternatives 1, 2, and 4, geothermal exploration, development, and operation could increase sediment and turbidity in surface water. There would be a risk of contamination of surface water by accidentally released fuels, solvents, working fluids, geothermal fluids, or other waste products. Impacts could occur on most 6th-level watersheds in the project area, depending on the location of proposed developments. However, the following watersheds encompass 0.3 percent or less of the project area and would therefore be at a less risk of impacts:

- Poleo Creek
- Headwaters San Antonio Creek
- Capulin Canyon-Rio Grande
- Headwaters Borrego Canyon

Additionally, there would be no impacts on Virgin Canyon and East For Jemez River, as they are entirely within the JNRA Unit, which is closed to geothermal leasing.

Under Alternatives 2 and 4, geothermal facilities would be restricted in location by administrative withdrawals and stipulations. These stipulations and closures would reduce the potential for sedimentation into streams, compared to Alternative 1, but would exclude potential impacts from road use and power line construction. There would be an increased risk of sedimentation and erosion into streams and rivers under Alternative 4, compared with Alternative 2. This is because there would be no discretionary leasing closures and stipulations that are less restrictive.

There would be no direct impacts on watersheds and surface waters under Alternative 3. However, there would be indirect impacts, because the project area would be closed to geothermal leasing for the foreseeable future. Over time, there would be less soil disturbance than expected under the current Forest Plan.

**Groundwater**

**Alternative 1 – No Action**

Under the No Action Alternative, the SFNF would not make an availability determination for geothermal leasing on lands in the project area. Geothermal lease applications and nominations would continue to be processed; however, they would be evaluated on a case-by-case basis under separate National Environmental Policy Act analyses. This would be in accordance with the Forest Plan (USFS 1987) and existing laws and regulations. Geothermal leasing stipulations and closures would not be specifically implemented for groundwater; however, any geothermal lease applications and nominations would be subject to standards and guidelines outlined in the Forest Plan and environmental analysis.

Potential impacts on groundwater quality could also occur from accidental releases of chemical compounds. Pollutants that could be spilled include petroleum products (primarily diesel fuel and petroleum based lubricants), solvents (such as hydrochloric acid or hydrofluoric acid to dissolve scale), stormwater or sanitation water, and working fluids, such as iso-butane or n-pentane, used in the course of the drilling operations. These working fluids also include drilling mud (bentonite clay, activated montmorillonite clay, and crystalline silica-quartz), drilling mud additives (caustic soda, sodium bicarbonate, and anionic polyacrylamide liquid polymer), and Portland cement, calcium chloride, and coolants.
Impacts from accidental release of pollutants described above could include increased concentrations of hydrocarbons and other contaminants in groundwater.

In addition, there is the potential for geothermal fluids to contaminate groundwater through faulty reinjection practices, geothermal well casing failure, and uncontrolled discharge of waste geothermal fluids to surface waters, such as an accidental release from surface ponds (Aksoy et al. 2008). Impacts could include thermal pollution of cold waters and contamination of subsurface waters with heavy metals (Aksoy et al. 2008).

It has been established that there is a geothermal plume that extends from the caldera southwest to Jemez Springs and Soda Dam (Trainer et al 2000). The delineation of that plume is not exact; most of it likely runs through the JNRA Unit, which is not available for leasing. However, the plume may also extend into the Middle Unit and South Unit, west of the edge of the caldera. Any pumping, including outside of the geothermal system, could affect groundwater pressurization, temperature, and possible flow paths.

Hydro-shearing practices may occur if enhanced geothermal systems\(^\text{11}\) are developed. This would involve injecting water at pressures ranging from 1,500 to 2,300 psi to create an increased network of pore spaces in the formation. Enhanced geothermal system processes do not produce any wastewater by-products, and fluids would be recirculated in the reservoir. Unlike hydraulic fracturing, water is injected without the use of a proppant\(^\text{12}\).

As with conventional geothermal systems, there is the potential risk of geothermal fluids contaminating groundwater through faulty reinjection practices, geothermal well casing failure, and uncontrolled discharge of geothermal fluids, as described above. However, for enhanced geothermal systems, water requirements are generally greater, in order to stimulate the reservoir\(^\text{13}\). Stimulation volume depends on the desired water volume flow rate (Clark et al. 2011). Water consumption (i.e., water that is withdrawn from a resource, such as a river, lake, or non-geothermal aquifer that is not returned to that resource, varies between 0.29 and 0.72 gallon per kilowatt-hour for enhanced geothermal scenarios (Clark et al. 2011).

Depending on the technology employed, geothermal production can lower the water table over time (Tester et al. 2006). Because the applicant would be required to obtain water rights, and the source of makeup water is unknown, the amount of water consumed in the project area is unknown.

The hot springs in Valles Caldera and southwest of the Caldera in San Diego Canyon could be impacted by extracting and reinjecting geothermal waters. Both flow rates and water quality could be impacted. Extraction of groundwater could have short-term impacts in reducing shallow groundwater levels and altering pressures of geothermal sources and fractures. Where there is interconnected flow to springs and seeps in thermal areas, this could alter the mixing of meteoric nonthermal waters with the deeper geothermal waters and alter flow paths to geothermal features. Additionally, temperatures could be lowered if interconnected flow from deeper zones is reduced by returning the cooled geothermal water to the reservoir.

**Alternative 2 – Proposed Action**

The types of impacts under Alternative 2 would be similar to those described under Alternative 1.

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\(^{11}\) Enhanced geothermal systems involves stimulating production and injection wells by injecting water under pressure, and often at a much cooler temperature than the receiving rock

\(^{12}\) Sand or similar particulate material suspended in water or other fluid and used in hydraulic fracturing

\(^{13}\) Stimulation opens existing spaces within the formation and enables or enhances the circulation of fluids.
Alternative 2 could affect groundwater quality, due to spills of chemical compounds and fluids. Drilling activities and operating a binary geothermal power plant would require fuels, working fluids, and solvents. Accidental releases of chemical compounds could contaminate shallow groundwater, as described under Alternative 1. BMPs described in Appendix B would reduce the risk of an accidental spill under Alternative 2.

As with Alternative 1, there is the potential for geothermal fluids to contaminate groundwater through faulty reinjection practices, geothermal well casing failure, and uncontrolled discharge of waste geothermal fluids to surface waters, such as an accidental release from surface ponds (Aksoy et al. 2008). Geothermal fluids contain high concentrations of dissolved constituents that could contaminate freshwater supplies. Protecting groundwater from contamination by geothermal fluids is facilitated by the use of multiple casing strings, whose depths are specified partly on the basis of the depths of groundwater aquifers. In addition, redundant blow-out prevention equipment is used.

Stipulations would provide a buffer between surface water resources (which may recharge shallow groundwater) and geothermal facilities. This buffer would reduce the risk of groundwater contamination, in the event of an accidental spill, or subsurface well casing failures.

Water would be used for drilling wells, constructing infrastructure, stimulating injection wells, operating the power plant, and controlling dust. Water would not be used for cooling, because the air temperature is sufficiently low to allow the air to cool water to be reinjected. The applicant would be responsible for obtaining water rights in accordance with state and federal regulations.

Freshwater used in the drilling operations would be trucked in or would come from local springs and wells at depths of less than 1,000 feet (BLM 2015). Water is used during the well construction as drilling fluids and for cementing the casing in place. Well depth, the total number of wells, the volume of the borehole, and the physical and chemical properties of the formation would affect water volume requirements during drilling. For enhanced geothermal systems, water is also required for stimulating the reservoir. Stimulation volume depends on the desired water volume flow rate (Clark et al. 2011).

Most water would be used during the operations phase. Although extracted water would be reinjected after use, water may be lost to the geologic formation. To maintain pressure and operation, water that is lost must be made up from alternative water sources. Water consumption (i.e., water that is withdrawn from a resource, such as a river, lake, or non-geothermal aquifer that is not returned to that resource) varies between 0.29 and 0.72 gallon per kilowatt hour for enhanced geothermal scenarios (Clark et al. 2011).

Because the applicant would be required to obtain water rights, and the source of makeup water is unknown, the amount of water consumption in the project area is unknown. However, BMPs could be applied in the permit application or be included as approved use authorizations by the BLM as COAs. Examples of these BMPs are evaluating the consumptive use of water in the operation and its impact on water dependent ecosystems and identifying areas of groundwater discharge and recharge and their potential relationship with surface water bodies. These measures would reduce the likelihood of lowering the groundwater table to a level that would not support existing land uses.

During pumping, some groundwater flow paths in the deeper aquifers could be modified by reducing the temperature of reinjected waters, which reduces pressure in the deeper geothermal system and could therefore change flow paths. Upward vertical hydraulic gradients could be reduced by this depressurization, thereby altering flow paths.
It is also possible that the reinjection site would not return the geothermal fluid to the exact hydraulic connection that it was withdrawn from, and water may be lost to the formation. This could locally alter pressurization in the system, thereby altering flow paths.

Flows at nonthermal springs and seeps are not likely to be affected by geothermal groundwater development. Most of these springs are recharged by shallow groundwater with short flow paths that are in turn recharged primarily from precipitation, irrigation, and runoff in the watersheds in mountain ranges and valley bottoms. For most of the project area, geothermal fluids would be extracted at much greater depths than the shallow aquifer and would be reinjected once the heat is extracted. However, there are numerous faults extending from the caldera; where there is an interconnection between deeper groundwater and faults, pumping could change flow paths. There also could be some slight changes in flow paths, due to pressure differences from small differences in the extraction and reinjection zones.

Deeper groundwater is nearly continuous in the Tesuque Formation throughout the Santa Fe-Rio Grande Watershed area, to depths of 2,000 feet or greater in some areas. This deep groundwater dates from the Ice Age, approximately 10,000 years ago, and is recharged little if at all by present-day rainfall and snowmelt. Should geothermal extraction occur in this area, there could be more risk of changes to flow paths and mixing of geothermal fluids with groundwater. However, as geothermal waters are reinjected, any changes in groundwater level would be minor and would result from changes in flow paths, rather than in a reduction in groundwater quantity.

This alternative requires a one-mile-wide no leasing protection zone around geothermal features. This would prevent direct pumping of geothermal fluids in the proximity of these features. However, in this fractured and interconnected system, pumping some distance from the geothermal features could result in changes in temperature, pressurization, chemical composition, flow paths, and flow rates.

The hot springs in Valles Caldera and southwest of the caldera in San Diego Canyon could be impacted by extracting and reinjecting geothermal waters, as described under Alternative 1. However, under Alternative 2, there would be no lands within 2 miles of the NPS boundary open to geothermal leasing, subject to standard lease terms and conditions. Because most decision area lands within 2 miles of the NPS boundary would be closed or subject to NSO stipulations, geothermal wells are unlikely to be developed in this area, and the risk of impacts on geothermal features in the Valles Caldera is low.

**Groundwater Monitoring**

Potential impacts on groundwater and springs can be addressed by developing monitoring plans, implementing monitoring with indicators for impacts on these water resources, and planning actions to mitigate potential impacts. Monitoring BMPs described in Appendix B could be incorporated as appropriate into the permit application, or the BLM could include them in the approved use authorization as COAs.

Monitoring may include collecting and evaluating data necessary to document baseline conditions and impacts on the resources, for example, water level, water quantity, quality, spring flow, and temperature. Monitoring wells can be installed in different locations for measuring water levels and quality characteristics, as necessary or required. Monitoring frequency would need to be determined to sufficiently document potential seasonal changes in the resources. When indicators of change are triggered, contingencies (e.g., modification of geothermal pumping rates) would be implemented to address any potential impacts that may be documented during the monitoring program.
Alternative 3 – No Leasing
This alternative would amend the Forest Plan (USFS 1987) to implement discretionary closures to geothermal leasing on all lands in the project area not already closed to leasing.

There would be no direct impacts on groundwater from implementing Alternative 3, because the area would be closed to leasing for the foreseeable future.

Alternative 4 – Development
Impacts from Alternative 4 would be similar to those described under Alternative 2. However, there would be no discretionary closures, and there would be reduced protection of specific areas from implementing lease stipulations that are less restrictive.

Under Alternative 4, NSO stipulations apply to natural geothermal features and a 1-mile-wide buffer around them. NSO stipulations would protect these resources from accidental spills or leaks from the pumping site and would increase the difficulty of accessing geothermal waters close to the geothermal features. However, this stipulation does not prevent using advanced technology to withdraw water near the geothermal features. Those resources could still be accessed; however, a lessee of an NSO area must develop any surface infrastructure outside the area. The lessee would need to use advanced technology, such as directional drilling, to access the geothermal resource under the NSO area. Therefore, compared to Alternative 2, this alternative is more likely to impact natural geothermal features, potentially affecting temperatures and flow rates. Groundwater monitoring, as described under Alternative 2, would help to identify risks and mitigate potential impacts.

Groundwater Cumulative Impacts
Cumulative impacts for water resources are analyzed at the 4th-level watersheds. Past, present, and reasonably foreseeable future actions listed in Table 21 that affect groundwater in the project area are primarily water extraction for residential, commercial, and agricultural uses.

Although extracted water would be reinjected after use, water may be lost to the geologic formation. To maintain pressure and operation, water that is lost must be made up from alternative water sources, which may contribute to the cumulative demand for water resources in the 4th-level watersheds under Alternatives 1, 2, and 4. While the source of makeup water is unknown, BMPs identified in Appendix B could be applied into the permit application, or the BLM could include them as approved use authorizations as COAs. Examples of the BMPS are evaluating the consumptive use of water in the operation and its impact on water dependent ecosystems and identifying areas of groundwater discharge and recharge and their potential relationship with surface water bodies. These measures would reduce the likelihood of lowering the groundwater table to a level that would not support existing land uses. There would be no cumulative impacts on groundwater under Alternative 3.

Summary of Impacts on Groundwater
Under Alternatives 1, 2, and 4, geothermal development could alter groundwater flow paths or pressurization and change water temperature. Although extracted water would be reinjected after use, water may be lost to the geologic formation. Because the applicant would be required to obtain water rights, and the source of makeup water is unknown, the amount of water consumed in the project area is unknown. Potential impacts on groundwater quality could also occur from accidental releases of chemical compounds, such as fuels, solvents, working fluids, geothermal fluids, or other waste products.

Stipulations and closures under Alternatives 2 and 4 would provide a buffer between surface water resources (which may recharge shallow groundwater) and geothermal facilities. This buffer would reduce
the risk of groundwater contamination, compared to Alternative 1, in the event of an accidental spill or subsurface well casing failures. In addition, when compared to Alternative 1, stipulations and closures under Alternatives 2 and 4 would reduce the risk of impacts on hot springs, such as changes in pressurization, flow rates, or temperature.

There would be no direct impacts on groundwater under Alternative 3. However, there would be indirect impacts. The project area would be closed to geothermal leasing for the foreseeable future. Because of this, over time, there would be fewer disturbances than expected under the current Forest Plan and less potential for changes to subsurface water resources.
Summary of Impacts by Alternative

Table 23 provides a summary of the impacts on soils, watersheds and surface water, and groundwater under each alternative.

| Table 23. Summary of Impacts on Soils, Watersheds, Surface Water, and Groundwater |
|---------------------------------|---------------------------------|---------------------------------|---------------------------------|---------------------------------|
|                                 | Alternative 1                   | Alternative 2                   | Alternative 3                   | Alternative 4                   |
| Soils                           | Geothermal lease applications    | Impacts from geothermal         | There would be no direct        | Impacts from geothermal          |
|                                 | and nominations would continue   | exploration and development     | impacts on soils under          | exploration and development      |
|                                 | to be processed; however, they   | would be similar to those        | Alternative 3. However, there    | would be similar to those         |
|                                 | would be evaluated on a case-    | described under Alternative 1;  | would be indirect impacts,      | described under Alternative 2;    |
|                                 | by-case basis under separate    | however, they would be restricted| because the project area         | however, there would be a        |
|                                 | analysis. Geothermal             | in location by administrative    | would be closed to              | greater potential for impacts    |
|                                 | development could result in     | withdrawals and stipulations.   | geothermal leasing for the      | on slopes between 30 and 40       |
|                                 | physical disturbance,           | NSO stipulations would limit    | foreseeable future. Over       | percent and in areas with        |
|                                 | compaction, changes to erosion   | erosion on soils with severe     | time, there would be less soil   | moderately high to high runoff   |
|                                 | patterns, and loss of soil      | erosion hazards and steep        | disturbance than expected       | potential.                       |
|                                 | productivity. Impacts could      | slopes, but they would exclude   | under the current Forest Plan.  |                                  |
|                                 | result from the development of   | potential impacts from power     |                                  |                                  |
|                                 | roads, power lines, wells,      | line construction and road use. |                                  |                                  |
|                                 | power plants, and other         |                                  |                                  |                                  |
|                                 | geothermal-related surface       |                                  |                                  |                                  |
|                                 | disturbances.                   |                                  |                                  |                                  |
| Watersheds and                  | Geothermal lease applications    | Impacts from geothermal         | There would be no direct        | Impacts under Alternative 4      |
| surface waters                  | and nominations would continue   | exploration and development     | impacts on watersheds and       | would be similar to those         |
|                                 | to be processed; however, they   | would be similar to those        | surface waters under            | described under Alternative 2;    |
|                                 | would be evaluated on a case-    | described under Alternative 1;  | Alternative 3. However, there    | however, there would be no        |
|                                 | by-case basis under separate    | however, facilities would be     | would be indirect impacts,      | discretionary closures, and      |
|                                 | analysis. Exploration,          | restricted in location by        | because the project area         | there would be reduced           |
|                                 | development, and operation       | administrative withdrawals and   | would be closed to              | protection of specific areas     |
|                                 | could increase sediments and    | stipulations. NSO stipulations  | geothermal leasing for the       | from implementing lease           |
|                                 | turbidity in surface water.     | would limit erosion on soils     | foreseeable future. Over        | stipulations that are less       |
|                                 | There would be a risk of        | with severe erosion hazard and   | time, there would be less soil   | restrictive. There would be an   |
|                                 | contamination of surface water  | steep slopes. This would reduce  | disturbance than expected       | increased risk of                 |
|                                 | by accidentally released fuels,  | the potential for sedimentation  | under the current Forest Plan   | sedimentation and erosion        |
|                                 | solvents, working fluids,        | into streams but would exclude   | and less potential for changes  | into streams and rivers,         |
|                                 | geothermal fluids, or other      | potential impacts from road use | to surface water resources.      | compared to Alternative 2.       |
|                                 | waste products.                 | and power line construction.     |                                  |                                  |
Table 23. Summary of Impacts on Soils, Watersheds, Surface Water, and Groundwater

<table>
<thead>
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<th>Alternative 1</th>
<th>Alternative 2</th>
<th>Alternative 3</th>
<th>Alternative 4</th>
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<tr>
<td>Groundwater</td>
<td>Geothermal lease applications and nominations would continue to be processed; however, they would be evaluated on a case-by-case basis under separate analysis. Geothermal development could result in groundwater contamination, altered groundwater flow paths or pressurization, and changed water temperature. Water and geothermal fluids may be lost when reinjected into the formation or through accidental spills or releases.</td>
<td>Impacts from geothermal exploration and development would be similar to those described under Alternative 1; however, geothermal leasing stipulations and closures would reduce the potential for impacts on natural geothermal features, such as hot springs or other surface expressions of geothermal activity. Stipulations and closures would provide a buffer between surface water resources (which may recharge shallow groundwater) and geothermal facilities. This buffer would reduce the risk of groundwater contamination, in the event of an accidental spill or subsurface well casing failures.</td>
<td>There would be no direct impacts on groundwater under Alternative 3; however, there would be indirect impacts. Because the project area would be closed to geothermal leasing for the foreseeable future, over time, there would be fewer disturbances than expected under the current Forest Plan and less potential for changes to subsurface water resources.</td>
<td>Impacts under Alternative 4 would be similar to those described under Alternative 2; however, there would be no discretionary closures under Alternative 4. This alternative is more likely to impact temperature and flow rates of natural geothermal features, compared to Alternative 2.</td>
</tr>
</tbody>
</table>
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Appendix A:
Total Maximum Daily Load Summary
### Table A-1. Total Maximum Daily Load Summary Table

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<tr>
<th>4th-Level Watershed</th>
<th>6th-Level Watershed</th>
<th>Stream Segment</th>
<th>Not Supporting Use</th>
<th>TMDL Parameter</th>
<th>Date of EPA Approval or Estimated Proposal</th>
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<td>Stream Bottom Deposits, Turbidity</td>
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<td>Temperature</td>
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<td>Total Phosphorus</td>
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<td>Temperature</td>
<td>2003; de-listed 2008</td>
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<td></td>
<td>Turbidity</td>
<td>2015 (est)</td>
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<td>Coldwater Aquatic Life, Primary Contact, WWAL</td>
<td>Nutrient/Eutrophication</td>
<td>2011 (est)</td>
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<td></td>
<td>Primary Contact</td>
<td>Temperature</td>
<td>2011</td>
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<td></td>
<td>E. coli</td>
<td>2011</td>
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<td>Rito Encino (Rio Puerco de Chama to headwaters)</td>
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<td>Nutrient/Eutrophication</td>
<td>2011 (est)</td>
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<td>Sedimentation/siltation</td>
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<td>Turbidity</td>
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<td>Fully supporting all</td>
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### Table A-1. Total Maximum Daily Load Summary Table

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<th>4th-Level Watershed</th>
<th>6th-Level Watershed</th>
<th>Stream Segment</th>
<th>Not Supporting Use</th>
<th>TMDL Parameter</th>
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<td>Alamo Canyon-Rio Grande</td>
<td>Rito de los Frijoles (Rio Grande to headwaters)</td>
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<td>Aluminum</td>
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Appendix B:
Best Management Practices and Mitigation Measures
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Appendix B. Best Management Practices and Mitigation Measures

Best Management Practices (BMPs) are state-of-the-art mitigation measures applied on a site-specific basis to avoid, minimize, reduce, rectify, or compensate for adverse environmental or social impacts. They are applied to management actions to aid in achieving desired outcomes for safe, environmentally responsible resource development by preventing, minimizing, or mitigating adverse impacts and reducing conflicts.

The following BMPs provide the BLM, Forest Service, industry, and stakeholders a menu of practices for developing geothermal energy and minimizing impacts to the environment and landscape. The list is not meant to be all inclusive given the constant development of improved practices, diversity of the area, and potential for unique site-specific conditions. Practices which are not included in this appendix may be implemented as needed.

Some BMPs are more suitable for consideration on a case-by-case basis depending on:

- Their effectiveness
- The balancing of increased operating costs vs. the benefit to the public and resource values
- The availability of less restrictive mitigation alternatives that accomplish the same objective
- Other site-specific factors

Guidelines for applying and selecting project-specific requirements include determining whether the measure would:

- Ensure compliance with relevant statutory or administrative requirements
- Minimize local impacts associated with siting and design decisions
- Promote post-construction stabilization of impacts
- Maximize restoration of previous habitat conditions
- Minimize cumulative impacts
- Promote economically feasible development of geothermal energy on Forest Service land

Only those BMPs reasonably necessary to ensure environmentally responsible geothermal development should be selected from the list below. Not all of the individual mitigation measures below will apply to most situations, and selection of appropriated BMPs and mitigation measures should be dependent on factors such as the project size, location, site-specific characteristics, and potential resource impacts. Prior to inclusion, the measures may be further modified to meet site-specific situations and agency requirements.

This list was compiled from several sources, primarily:

- Programmatic EIS for Geothermal Leasing in the Western United States (2008)
- Forest Service Handbook (Southwestern Region) FSH 2509.22 – Soil and Water Conservation Handbook
Appendix B. Best Management Practices and Mitigation Measures

- Santa Fe National Forest Plan (2007 as amended)

In the event that the BMPs listed here are not effective, or do not address a particular resource concern, there are numerous other sources which will be consulted. Some of these are:

- The Gold Book, Surface Operating Standards and Guidelines for Oil and Gas Exploration and Development (current edition)
- BLM Washington Office Fluid Minerals website
- US EPA
- New Mexico Game and Fish
- New Mexico Environment Department

In keeping with the PEIS, the BMPs are listed according to the phase of operations they apply to the most.

B.1 Information Collection & Monitoring

B.1.1 General

- Prior to geothermal exploration and development, a subsurface geotechnical investigation will be conducted to analyze the soil and geologic conditions of each site with proposed surface disturbance. The investigation will evaluate and identify potential geologic hazards and will provide remedial grading recommendations, foundation and slab design criteria, and soil parameters for the design of geothermal power infrastructure.
- The operator will collect available information describing the environmental and socio-cultural conditions in the vicinity of the proposed project and will provide the information to the agency.
- The agency will require suitable geotechnical or stability analyses to ensure that facilities are constructed to acceptable factors of safety using standard engineering practices and considering foundation conditions and material, construction materials and techniques, the seismicity of the area, and the water-related resources at risk.
- A monitoring program will be developed by the operator to ensure that environmental conditions are monitored during the exploration and well drilling, testing, construction, and utilization and reclamation phases. The monitoring program requirements, including adaptive management strategies, will be established at the project level to ensure that potential adverse impacts of geothermal development are mitigated. The monitoring program will identify the monitoring requirements for each major environmental resource present at the site, establish metrics against which monitoring observations can be measured, identify potential mitigation measures, and establish protocols for incorporating monitoring observations and additional mitigation measures into ongoing activities. The operator will provide results of the monitoring program to the agency in an annual report.
- The operator will comply with the Secretary of Agriculture’s rules and regulations:
  - For all use and occupancy of the NFS lands prior to approval of an exploration plan by the Secretary of the Interior
For uses of all existing improvements, such as forest development roads, within and outside the area permitted by the Secretary of the Interior
For use and occupancy of the NFS lands not authorized by an exploration plan approved by the Secretary of the Interior

B.1.2 Paleontological and Cultural Resources

- Before any specific permits are issued under leases, treatment of cultural resources will follow the procedures established by the Advisory Council on Historic Preservation for compliance with Section 106 of the National Historic Preservation Act. A pedestrian inventory will be undertaken of all portions that have not been previously surveyed or are identified by the Forest Service or BLM as requiring inventory to identify properties that are eligible for the NRHP. Those sites not already evaluated for NRHP eligibility will be evaluated based on surface remains, subsurface testing, archival, and/or ethnographic sources. Subsurface testing will be kept to a minimum whenever possible if sufficient information is available to evaluate the site or if avoidance is an expected mitigation outcome. Recommendations regarding the eligibility of sites will be submitted to the Forest Service, and a treatment plan will be prepared to detail methods for avoidance of impacts or mitigation of effects. The Forest Service will make determinations of eligibility and effect and consult with SHPO as necessary based on each proposed lease application and project plans. In consultation with the Forest Service, the BLM may require modification to exploration or development proposals to protect such properties, or disapprove any activity that is likely to result in adverse effects that cannot be successfully avoided, minimized, or mitigated. Avoidance of impacts through project design will be given priority over data recovery as the preferred mitigation measure. Avoidance measures include moving project elements away from site locations or to areas of previous impacts, restricting travel to existing roads, and maintaining barriers and signs in areas of cultural sensitivity. Any data recovery will be preceded by approval of a detailed research design, Native American Consultation, and other requirements for Forest Service issuance of a permit under the Archaeological Resources Protection Act.
- If cultural resources are present at the site, or if areas with a high potential to contain cultural material have been identified, a cultural resources management plan (CRMP) will be developed. This plan will address mitigation activities to be taken for cultural resources found at the site. Avoidance of the area is always the preferred mitigation option. Other mitigation options include archaeological survey and excavation (as warranted) and monitoring. If an area exhibits a high potential, but no artifacts were observed during an archaeological survey, monitoring by a qualified archaeologist could be required during all excavation and earthmoving in the high potential area. A report will be prepared documenting these activities. The CRMP also will:
  - Establish a monitoring program
  - Identify measures to prevent potential looting/vandalism or erosion impacts
  - Address the education of workers and the public to make them aware of the consequences of unauthorized collection of artifacts and destruction of property on public land
- The operator will determine whether paleontological resources exist in a project area on the basis of the sedimentary context of the area, a records search for past paleontological finds in the area, and/or, depending on the extent of existing information, a paleontological survey.
- If paleontological resources are present at the site, or if areas with a high potential to contain paleontological material have been identified, a paleontological resources management plan
will be developed. This plan will include a mitigation plan for avoidance, removal of fossils, or monitoring. If an area exhibits a high potential but no fossils were observed during survey, monitoring by a qualified paleontologist may be required during excavation and earthmoving in the sensitive area. The operator will submit a report to the agency documenting these activities. The paleontological resources management plan also will:

- Establish a monitoring program
- Identify measures to prevent potential looting/vandalism or erosion impacts
- Address the education of workers and the public to make them aware of the consequences of unauthorized collection of fossils on public land

**B.1.3 Water Resources**

The BMPs require suitable characterization of site hydrology commensurate with the potential for impacts to surface water and groundwater resources, to include physical and chemical characteristics of surface and groundwater systems, as needed, for the range of expected seasonal variation in precipitation and potential stormflow events likely to occur at the site for the duration of the minerals activities.

The operator will:

- Evaluate the consumptive use of water in the operation and its effect on water-dependent ecosystems.
- Evaluate the potential for direct and indirect impacts to morphology, stability, and function of waterbodies, riparian areas, and wetland habitats.
- Develop a storm water management plan for the site to ensure compliance with applicable regulations and to prevent offsite migration of contaminated storm water or increased soil erosion.
- Gain a clear understanding of the local hydrogeology. Areas of groundwater discharge and recharge and their potential relationships with surface water bodies will be identified.
- Avoid creating hydrologic conduits between two aquifers during foundation excavation and other activities.
- Identify federal, state, and local permits or requirements needed to implement the project. Examples include water quality standards, CWA 401 certification, CWA 402 permits (including stormwater permits), CWA 404 permits, and Coastal Zone Management Act requirements.
- Plan to limit surface disturbance to the extent practicable while still achieving project objectives.
- Provide adequate buffers and setbacks from waterbodies to avoid or minimize impacts to water quality and aquatic ecosystems.
- Designate specific aquatic management zones (AMZs) around water features in the project area.
- Design activities on or near unstable areas and sensitive soils to minimize management induced impacts.
- Use local direction and requirements for prevention and control of terrestrial and aquatic invasive species.
• Use suitable tools to analyze the potential for cumulative watershed effects (CWE) to occur from the additive impacts of the proposed project and past, present, and reasonably foreseeable future activities on NFS and neighboring lands within the project watersheds.

• Consider the natural sensitivity or tolerance of the watershed based on geology, climate, and other relevant factors.

• Consider the existing condition of the watershed and water quality as a reflection of past land management activities and natural disturbances.

• Estimate the potential for adverse effects to soil, water quality, and riparian resources from current and reasonably foreseeable future activities on all lands within the watershed relative to existing watershed conditions.

• Use land management plan direction; federal, state, or local water quality standards; and other regulations to determine acceptable limits for CWE.

• Modify the proposed project or activity as necessary by changing project design, location, and timing to reduce the potential for CWE to occur.

• Consider including additional mitigation measures to reduce project effects.

• Identify and implement opportunities for restoration activities to speed recovery of watershed condition before initiating additional anthropogenic disturbance in the watershed.

• Coordinate and cooperate with other federal, state, and private landowners in assessing and preventing CWE in multiple ownership watersheds.

• Integrate restoration and rehabilitation needs into the project plan.

• Consider water-quality improvement actions identified in a TMDL or other watershed restoration plan to restore impaired waterbodies within the project area.

• Identify project-specific monitoring needs.

• Document site-specific BMP prescriptions, design criteria, mitigation measures, and restoration, rehabilitation, and monitoring needs in the applicable NEPA documents, design plans, contracts, permits, authorizations, and operation and maintenance plans.

• Delineate all protected or excluded areas, including, for example, AMZs and waterbodies.

• Include 303(d) listed and TMDL waterbodies, and municipal supply watersheds, on the project map.

• Evaluate the condition of aquatic habitat, riparian habitat, and beneficial riparian zone functions and their estimated response to the proposed activity in determining the need for and width of the AMZ.

• Use stream class and type, channel condition, aspect, side slope steepness, precipitation and climate characteristics, soil erodibility, slope stability, groundwater features, and aquatic and riparian conditions and functions to determine appropriate AMZ widths to achieve desired conditions in the AMZ.

• Include riparian vegetation within the designated AMZ and extend the AMZ to include steep slopes, highly erodible soils, or other sensitive or unstable areas.

• Establish wider AMZ areas for waters with high resource value and quality.

• Design and implement project activities within the AMZ to:
  ♦ Avoid or minimize unacceptable impacts to riparian vegetation, groundwater recharge areas, steep slopes, highly erodible soils, or unstable areas.
  ♦ Maintain or provide sufficient ground cover to encourage infiltration, avoid or minimize erosion, and filter pollutants.
Appendix B. Best Management Practices and Mitigation Measures

♦ Avoid, minimize, or restore detrimental soil compaction.
♦ Retain trees necessary for shading and bank stabilization, and as a future source of large woody debris.
♦ Retain floodplain function.
♦ Restore existing disturbed areas that are eroding and contributing sediment to the waterbody.
♦ Mark the boundaries of the AMZ and sensitive areas—like riparian areas, wetlands, and unstable areas—on the ground before land-disturbing activities.

B.1.4 Vegetation and Fish and Wildlife

♦ The operator will conduct surveys for plant and animal species that are listed or proposed for listing as threatened or endangered and their habitats in areas proposed for development where these species could potentially occur, following accepted protocols and in consultation with the USFWS, as appropriate. Particular care should be taken to avoid disturbing listed species during surveys in any designated critical habitat. The operator will monitor activities and their effects on ESA-listed species throughout the duration of the project.
♦ The operator will identify important, sensitive, or unique habitat and biota in the project vicinity and site and should design the project to avoid (if possible), minimize, or mitigate potential impacts on these resources. The design and siting of the facilities will follow appropriate guidance and requirements from the Forest Service and other resource agencies, as available and applicable.

B.1.5 National Scenic and Historic Trails

♦ When any ROW application includes remnants of a National Historic Trail, is located within the viewshed of a National Historic Trail’s designated centerline, or includes or is within the viewshed of a trail eligible for listing on the NRHP, the operator will evaluate the potential visual impacts to the trail associated with the proposed project and identify appropriate mitigation measures for inclusion in the operation plan.

B.1.6 Air Quality and Climate

♦ The operator will coordinate with the New Mexico Environment Department Air Quality Bureau to develop and implement an air-quality monitoring plan.

B.2 Planning, Location, and Design

B.2.1 Bonding

♦ As outlined in the Forest Service Training Guide for Reclamation Bond Estimation and Administration for Minerals Plans of Operation, the Forest Service must consider the direct and indirect costs of stabilizing, rehabilitating, and reclaiming the area of mineral operations to the appropriate standards for water quality and watershed condition as determined from the land management plan, state and federal laws, regulations, plans, or permits when determining the reclamation bond amount. The bond amount determined by the Forest Service must include costs for:
  ♦ Operation and maintenance of facilities designed to divert, convey, store, or treat water.
  ♦ Decontaminating, neutralizing, disposing, treating, or isolating hazardous materials at the site to minimize potential for contamination of soil, surface water, and groundwater.
Appendix B. Best Management Practices and Mitigation Measures

- Water treatment needs predicted during planning and discovered during operations to achieve applicable water-quality standards.
- Earthwork to reclaim roads, backfilling water features (diversions, ditches, and sediment ponds), and construction of diversion channels and drains, stream channels, and wetlands.
- Revegetation to stabilize the site and minimize soil erosion.
- Mitigation to restore natural function and value of streams, wetlands, and floodplains.
- Long-term operations, monitoring, and maintenance of mineral production-related facilities that must perform as designed to avoid or minimize contamination of surface or groundwater resources, including roads, diversion ditches, dams, and water treatment systems.
- Protection of the reclaimed area until long-term stability, erosion control, and revegetation has been established.
- The Forest Service coordinates with the BLM to ensure the reclamation bond required for operations will be sufficient to guarantee reclamation work on NFS lands to the appropriate standards for water quality and watershed condition as determined from the land management plan, state and federal laws, regulations, plans, or permits.

B.2.2 Traffic Planning
- The operator will consult with local planning authorities regarding increased traffic prior to the construction phase, including an assessment of the number of vehicles per day, their size, and type. Specific issues of concern (e.g., location of school bus routes and stops) will be identified and addressed in the traffic management plan.

B.2.3 Roads & Pads
- To plan for efficient use of the land, necessary infrastructure will be consolidated wherever possible.
- The operator will limit roads to the minimum practicable number, width, and total length consistent with the purpose of specific operations, local topography, geology, and climate to achieve land management plan desired conditions, goals, and objectives for access and water-quality management.
- The operator will use existing roads when practicable.
- The operator will plan road networks to have the minimum number of waterbody crossings as is practicable and necessary to achieve transportation system desired conditions, goals, and objectives.
- The operator will design the roads to maintain stable road prism, cut, and fill slopes.
- The operator will design cut and fill slope ratios to reduce soil loss from mass failures.
- The operator will use structural or nonstructural measures as necessary to stabilize cut and fill slopes.
- The operator will use brush mulches or filter fences when necessary to mitigate impacts of roads near water courses.
- The operator will design the road surface drainage system to intercept, collect, and remove water from the road surface and surrounding slopes in a manner that minimizes concentrated flow in ditches, culverts, and over fill slopes and road surfaces.
The operator will use structural or nonstructural measures suitable to the road materials, road gradient, and expected traffic levels. The operator will use an interval between drainage features that is suitable for the road gradient, surface material, and climate.

The operator will use suitable measures to avoid or minimize erosion of ditches.

The operator will design and construct all new roads and drilling pads to a safe and appropriate standard, no higher than necessary to accommodate their intended use.

Existing roads and pad sites will be used to the maximum extent feasible, but only if located in a safe and environmentally sound location. No new roads and pad sites will be constructed without agency authorization. If new roads and pad sites have been authorized, they will be designed and constructed by the operator to the appropriate agency standard, no higher than necessary to accommodate their intended function. Roads and pad sites will be routinely maintained by the operator to maintain public safety and to minimize impacts to the environment, such as erosion, sedimentation, fugitive dust, and loss of vegetation.

An access road siting and management plan will be prepared incorporating existing agency standards regarding road design, construction, and maintenance, such as those described in the Forest Service handbook 7709.56 and the *Surface Operating Standards for Oil and Gas Exploration and Development* (i.e., the Gold Book, current edition).

A traffic management plan will be prepared for the site access roads to ensure that no hazards would result from the increased truck traffic and that traffic flow would not be adversely impacted. This plan will incorporate measures such as informational signs, flaggers when equipment may result in blocked throughways, and traffic cones to identify any necessary changes in temporary lane configuration.

Where possible, access roads will be located to follow natural contours and to minimize side hill cuts and fills. Excessive grades on roads, road embankments, ditches, and drainages shall be avoided, especially in areas with erodible soils.

Roads will be designed so that changes to surface water runoff are minimized and new erosion is not initiated.

Access roads will be located to minimize stream crossings. All structures crossing streams will be located and constructed so that they do not decrease channel stability or increase water velocity. The operator will obtain all applicable federal and state water crossing permits.

Roads will be located away from drainage bottoms and will avoid wetlands, if practicable.

The operator will minimize the period that disturbed areas are not vegetated by revegetating and/or mulching cuts and fill slopes.

Clearing of vegetation along rights-of-way, facilities, and special use sites will be limited to that which poses a hazard to the facility and operational efficiency.

**B.2.4 Geotechnical Analysis**

The operator will perform a detailed geotechnical analysis prior to the construction of any structures, so they will be sited to avoid any hazards from subsidence or liquefaction (i.e., the changing of a saturated soil from a relatively stable solid state to a liquid during earthquakes or nearby blasting).
B.2.5 Well Pads
The operator will:

- Locate well sites on level locations that will accommodate the intended use to reduce the need for vertical cuts and steep fill slopes.
- Use suitable measures to stabilize fill slopes and to minimize potential of slope failures.
- Use suitable measures to provide surface drainage and to manage runoff from the work areas used for mud tanks, generators, mud storage, and fuel tanks in a manner that avoids or minimizes pollutant contamination of surface waters or groundwater.
- Use nontoxic, nonhazardous drilling fluids whenever practicable.
- Construct suitable impervious containment structures with sufficient volume and freeboard to avoid or minimize spills or leakages of oil, gas, salt water, toxic liquids, or waste materials from reaching surface waters or groundwater.
- Avoid mixing of geothermal fluids with surface water or groundwater where the chemical and thermal properties of the geothermal fluids would damage aquatic ecosystems and contaminate drinking water supplies.
- Minimize production of byproducts and wastes to the extent practicable.
- Plan space to properly handle, store, and contain byproducts and wastes.
- Recycle or properly dispose of wastes (e.g., used petroleum products, site garbage, septic effluent, decommissioned equipment, and used barrels or containers).
- Use applicable practices for sanitation systems and solid waste management to avoid contaminating surface water or groundwater from sanitation or solid waste facilities.
- Manage all chemicals, reagents, fuels, and other hazardous or toxic materials used for construction and operations to avoid or minimize contaminating surface water or groundwater.
- Require a transportation spill response plan, where applicable, that describes the petroleum products or other hazardous materials or chemicals that will be used in the operations, including the routes, amount, and frequency of shipments, and the containers and vehicles that are to be used. Describe in this plan the procedures, equipment, and personnel that would be used to respond to a spill.

B.2.6 Visual Mitigation
- The operator will incorporate visual design considerations into the planning and design of the project to minimize potential visual impacts of the proposal and to meet the visual resource management objectives of the area and the agency.

B.2.6.1 Visual Design Considerations
- Construct low-profile structures whenever possible to reduce structure visibility.
- Select and design materials and surface treatments to repeat or blend with landscape elements.
- Site projects outside of the viewsheds of publically accessible vantage points, or if this cannot be avoided, as far away as possible.
- Site projects to take advantage of both topography and vegetation as screening devices to restrict views of projects from visually sensitive areas.
Appendix B. Best Management Practices and Mitigation Measures

- Site facilities away from and not adjacent to prominent landscape features (e.g., knobs and water features).
- Avoid placing facilities on ridgelines, summits, or other locations such that they will be silhouetted against the sky from important viewing locations.
- Collocate facilities to the extent possible to use existing and shared rights-of-way, existing and shared access and maintenance roads, and other infrastructure, so they do not bisect ridge tops or run down the center of valley bottoms.
- Site linear features (aboveground pipelines, rights-of-way, and roads) to follow natural land contours rather than straight lines (particularly up slopes) when possible. Fall-line cuts should be avoided.
- Site facilities, especially linear facilities, to take advantage of natural topographic breaks (i.e., pronounced changes in slope) to avoid siting facilities on steep side slopes.
- Where available, site linear features—such as rights-of-ways and roads—to follow the edges of clearings (where they will be less conspicuous) rather than passing through the centers of clearings.
- Site facilities to take advantage of existing clearings to reduce vegetation clearing and ground disturbance, where possible.
- Site linear features (e.g., trails, roads, and rivers) to cross other linear features at right angles whenever possible to minimize viewing area and duration.
- Site and design structures and roads to minimize and balance cuts and fills and to preserve existing rocks, vegetation, and drainage patterns to the maximum extent possible.
- Use appropriately colored materials for structures or appropriate stains and coatings to blend with the project’s backdrop. Refer to the Standard Environmental Colors chart available from the BLM.
- Use non-reflective or low-reflectivity materials, coatings, or paints whenever possible.
- Paint grouped structures the same color to reduce visual complexity and color contrast.
- Design and install efficient facility lighting so that the minimum amount of lighting required for safety and security is provided but not exceeded and so that upward light scattering (light pollution) is minimized. This may include, for example, installing shrouds to minimize light from straying off-site, properly directing light to only illuminate necessary areas, and installing motion sensors to only illuminate areas when necessary.
- Site construction staging areas and laydown areas outside of the viewsheds of publically accessible vantage points and visually sensitive areas, where possible, including siting in swales, around bends, and behind ridges and vegetative screens.
- Discuss visual impact mitigation objectives and activities with equipment operators prior to commencement of construction activities.
- Mulch or scatter slash from vegetation removal and spread it to cover fresh soil disturbances or, if not possible, bury or compost slash.
- If slash piles are necessary, stage them out of sight of sensitive viewing areas.
- Avoid installing gravel and pavement where possible to reduce color and texture contrasts with existing landscape.
- Use excess fill-to-fill, uphill-side swales resulting from road construction in order to reduce unnatural-appearing slope interruption and to reduce fill piles.
- Avoid downslope wasting of excess fill material.
• Round road-cut slopes, vary cut and fill pitch to reduce contrasts in form and line, and vary slope to preserve specimen trees and nonhazardous rock outcroppings.
• Leave planting pockets on slopes where feasible.
• Combine methods of reestablishing native vegetation through seeding, planting of nursery stock, transplanting of local vegetation within the proposed disturbance areas, and staging of construction-enabling direct transplanting.
• Revegetate with native vegetation establishing a composition consistent with the form, line, color, and texture of the surrounding undisturbed landscape.
• Provide benches in rock cuts to accent natural strata.
• Use split-face rock blasting to minimize unnatural form and texture resulting from blasting.
• Segregate topsoil from cut and fill activities and spread it on freshly disturbed areas to reduce color contrast and to aid rapid revegetation.
• Bury utility cables in or adjacent to the road where feasible.
• Minimize signage and paint or coat reverse sides of signs and mounts to reduce color contrast with existing landscape.
• Prohibit trash burning; store trash in containers to be hauled off-site for disposal.
• Undertake interim restoration during the operating life of the project as soon as possible after disturbances. During road maintenance activities, avoid blading existing forbs and grasses in ditches and along roads.
• Randomly scarify cut slopes to reduce texture contrast with existing landscape and to aid in revegetation.
• Cover disturbed areas with stockpiled topsoil or mulch, and revegetate with a mix of native species selected for visual compatibility with existing vegetation.
• Restore rocks, brush, and natural debris whenever possible to approximate preexisting visual conditions.

B.2.7 Air Quality and Climate

• The operator will prepare and submit to the agency an Equipment Emissions Mitigation Plan for managing diesel exhaust. The Equipment Emissions Mitigation Plan will identify actions to reduce diesel particulate, carbon monoxide, hydrocarbons, and nitrogen oxides associated with construction and drilling activities. The Equipment Emissions Mitigation Plan will require that all drilling/construction-related engines are maintained and operated as follows:
  ♦ They are tuned to the engine manufacturer’s specification in accordance with an appropriate time frame.
  ♦ They do not idle for more than 5 minutes (unless, in the case of certain drilling engines, it is necessary for the operating scope).
  ♦ They are not tampered with in order to increase engine horsepower.
  ♦ Particulate traps, oxidation catalysts, and other suitable control devices are included on all drilling/construction equipment used at the project site.
  ♦ They use diesel fuel having a sulfur content of 15 parts per million or less, or other suitable alternative diesel fuel, unless such fuel cannot be reasonably procured in the market area.
  ♦ They include control devices to reduce air emissions. The determination of which equipment is suitable for control devices should be made by an independent Licensed Mechanical Engineer. Equipment suitable for control devices may include drilling
equipment, work over and service rigs, mud pumps, generators, compressors, graders, bulldozers, and dump trucks.

**B.2.8 Health and Safety**

- The operator will use applicable practices for sanitation systems and solid waste management to avoid contaminating surface water or groundwater from sanitation or solid waste facilities.

- The operator will develop a hazardous materials management plan addressing storage, use, transportation, and disposal of each hazardous material anticipated to be used at the site. The plan will identify all hazardous materials that would be used, stored, or transported at the site. It will establish inspection procedures, storage requirements, storage quantity limits, inventory control, nonhazardous product substitutes, and disposition of excess materials. The plan will also identify requirements for notices to federal and local emergency response authorities and include emergency response plans.

- The operator will develop a waste management plan identifying the waste streams that are expected to be generated at the site and addressing hazardous waste determination procedures, waste storage locations, waste-specific management and disposal requirements, inspection procedures, and waste minimization procedures. This plan will address all solid and liquid wastes that may be generated at the site.

- The operator will develop a spill prevention and response plan identifying where hazardous materials and wastes are stored on-site, spill prevention measures to be implemented, training requirements, appropriate spill response actions for each material or waste, the locations of spill response kits on-site, a procedure for ensuring that the spill response kits are adequately stocked at all times, and procedures for making timely notifications to authorities.

- The operator will develop a transportation spill response plan that describes the petroleum products or other hazardous materials or chemicals that will be used in the operations, including the routes, amount and frequency of shipments, and containers and vehicles used. This plan will describe the procedures, equipment, and personnel that would be used to respond to a spill.

- A safety assessment will be conducted to describe potential safety issues and the means that would be taken to mitigate them, including issues such as site access, construction, safe work practices, security, heavy equipment transportation, traffic management, emergency procedures, and fire control.

- A health and safety program will be developed to protect both workers and the general public during construction and operation of geothermal projects. The program will:
  - Identify all applicable federal and state occupational safety standards
  - Establish safe work practices for each task (e.g., requirements for personal protective equipment and safety harnesses)
  - Include Occupational Safety and Health Administration standard practices for safe use of explosives and blasting agents, and measures for reducing occupational electric and magnetic fields exposures
  - Establish fire safety evacuation procedures
  - Define safety performance standards (e.g., electrical system standards and lightning protection standards)
  - Include a training program to identify hazard training requirements for workers for each task and establish procedures for providing required training to all workers.
Documentation of training and a mechanism for reporting serious accidents to appropriate agencies will be established.

- Establish a safety zone or setback for generators from residences and occupied buildings, roads, ROWs, and other public access areas that is sufficient to prevent accidents resulting from the operation of generators.

- Identify requirements for temporary fencing around staging areas, storage yards, and excavations during construction or rehabilitation activities. It will also identify measures to be taken during the operation phase to limit public access to hazardous facilities (e.g., permanent fencing would be installed only around electrical substations, and facility access doors would be locked).

- The operator will consult with local planning authorities regarding increased traffic during the construction phase, including an assessment of the number of vehicles per day, their size, and type. Specific issues of concern (e.g., location of school bus routes and stops) will be identified and addressed in the traffic management plan.

- The operator will develop a fire management strategy to implement measures to minimize the potential for a human-caused fire.

**B.2.9 Livestock Grazing**

- The operator will coordinate with the Forest and livestock operators to minimize impacts to livestock operations.

**B.2.10 Noxious Weeds and Pesticides**

- The operator will develop a plan for control of noxious weeds and invasive species, which could occur as a result of new surface disturbance activities at the site. The most recent recommendations at the state and local level should be incorporated into any operating plan for the geothermal exploration and development. The plan will address monitoring, education of personnel on weed identification, the manner in which weeds spread, and methods for treating infestations. The use of certified weed-free mulching will be required. If trucks and construction equipment are arriving from locations with known invasive vegetation problems, a controlled inspection and cleaning area will be established to visually inspect construction equipment arriving at the project area and to remove and collect seeds that may be adhering to tires and other equipment surfaces.

- If pesticides are used on the site, an integrated pest management plan will be developed to ensure that applications would be conducted within the framework of all federal, state, and local laws and regulations and entail only the use of EPA-registered pesticides.

**B.2.11 Vegetation and Fish and Wildlife**

- The operator shall prepare a habitat restoration plan to avoid (if possible), minimize, or mitigate negative impacts on vulnerable wildlife while maintaining or enhancing habitat values for other species. The plan will identify revegetation, soil stabilization, and erosion reduction measures that will be implemented to ensure that all temporary use areas are restored. The plan will require that restoration occur as soon as possible after completion of activities to reduce the amount of habitat converted at any one time and to speed up the recovery to natural habitats.
B.2.12 Water Rights and Usage

The operator will:

- Obtain surface water (e.g., instream flow rights) and groundwater under appropriate federal and state legal and regulatory authorities to avoid, minimize, or mitigate adverse effects to stream processes, aquatic and riparian habitats and communities, groundwater-dependent ecosystems, and recreation and aesthetic values.
- Locate monitoring wells according to a monitoring plan to minimize the number of wells needed to achieve monitoring objectives.
- Construct and complete wells consistent with applicable federal and state regulations.
- Use licensed well drilling contractors.
- Use suitable measures to avoid or minimize well contamination, inter-aquifer exchange of water, floodwaters from contaminating the aquifer, and infiltration of surface water.
- Operate wells in such a manner as to avoid excessive withdrawals, maintain suitable groundwater levels, and minimize effects to groundwater-dependent ecosystems.
- Permanently seal abandoned wells consistent with applicable federal, state, and local regulations and requirements.
- Locate the spring box to allow water to flow by gravity from the spring to the spring box to eliminate disturbance from pumps and auxiliary equipment.
- Design the collection system to avoid, minimize, or mitigate adverse effects to the spring development and downstream waters from excessive water withdrawal, freezing, flooding, sedimentation, contamination, vehicular traffic, and livestock as needed.
- Collect no more water than is sufficient to meet the intended purpose of the spring development.
- Ensure that enough water remains in the spring to support the source groundwater-dependent ecosystem and downstream aquatic ecosystems.
- Trap and remove sediment that does enter the system.
- Intercept the spring flow below the ground surface upslope of where the water surfaces.

B.3 Construction

B.3.1 General

The operator will:

- Make adjustments in the plans, authorizations, and bonds if conditions develop that are outside the design criteria and conduct adequate notification, emergency stabilization, or other activities to avoid effects before proceeding with additional operations.
- Establish and maintain construction area limits to the minimum area necessary for completing the project and confine disturbance to within this area.
- Develop and implement an erosion control and sediment plan that covers all disturbed areas, including borrow, stockpile, fueling, and staging areas used during construction activities.
- Limit operation of equipment when ground conditions could result in excessive rutting, soil puddling, or runoff of sediments directly into waterbodies.
- Prepare a certified Spill Prevention Control and Countermeasure (SPCC) Plan for each facility as required by 40 CFR, Part 112.
Appendix B. Best Management Practices and Mitigation Measures

- Install or construct the containment features or countermeasures called for in the SPCC Plan to ensure that spilled hazardous materials are contained and do not reach groundwater or surface water.
- Ensure that cleanup of spills and leaking tanks is completed in compliance with federal, state, and local regulations and requirements.
- Ensure that hazardous spill kits are adequately stocked with necessary supplies and are maintained in accessible locations.
- Stockpile and protect topsoil for reuse in site revegetation.
- Minimize bank and riparian area excavation during construction to the extent practicable.
- Keep excavated materials out of the waterbody.
- Use only clean, suitable materials that are free of toxins and invasive species for fill.
- Properly compact fills to avoid or minimize erosion.

B.3.2 Traffic Management

- Traffic will be restricted to the roads developed for the project. Use of other unimproved roads will be restricted to emergency situations.
- Signs will be placed along roads to identify speed limits, travel restrictions, and other standard traffic control information. Signs directing vehicles to alternative park access and parking will be posted in the event construction temporarily obstructs recreational parking areas near trailheads. Whenever active work is being performed, the area will be posted with “construction ahead” signs on any adjacent access roads or trails that might be affected.
- Project personnel and contractors will be instructed and required to adhere to speed limits commensurate with road types, traffic volumes, vehicle types, and site-specific conditions; to ensure safe and efficient traffic flow; and to reduce wildlife collisions and disturbance and fugitive dust.
- When practical, construction activities will be avoided during high recreational use periods.

B.3.3 Roads & Pads

- The operator will plan and construct, to the extent practicable, exploration roads to be recontoured when operations are complete.
- The operator will limit the extent of open exploratory areas at one time and restore one site before moving on to the next one, to the extent practicable.
- The operator will obtain agency authorization prior to borrowing soil or rock material from agency lands.
- Road use will be restricted during the wet season if road surfacing is not adequate to prevent soil displacement, rutting, and resultant stream sedimentation.
- The operator will implement suitable measures to close and physically block the road entrance so that unauthorized motorized vehicles cannot access the road.
- Access roads and on-site roads will be surfaced with aggregate materials where necessary to provide a stable road surface, support anticipated traffic, reduce fugitive dust, and prevent erosion.
- Dust abatement techniques will be used before and during surface clearing, excavation, or blasting activities. Dust abatement techniques will be used on unpaved, unvegetated surfaces to minimize fugitive dust. Speed limits (e.g., 25 mph [40 kph]) will be posted and enforced to
reduce fugitive dust. Construction materials and stockpiled soils will be covered if they are a source of fugitive dust.

- Culvert outlets will be rip-rapped to dissipate water energy at the outlet and to reduce erosion. Catch basins, roadway ditches, and culverts will be cleaned and maintained regularly.
- The operator will report all label violations that occur during the application of dust suppressants or other surface stabilizers to the appropriate enforcement agency.
- The operator will respond to and report spills and other accidents during the application of dust suppressants or other surface stabilizers.
- The operator will design and locate stream crossings to minimize disturbance to the waterbody.
- The operator will locate stream crossings where the channel is narrow, straight, and uniform, and has stable soils and relatively flat terrain to the extent practicable.
- The operator will select a site where erosion potential is low.
- The operator will orient the stream crossing perpendicular to the channel to the extent practicable.
- The operator will keep approaches to stream crossings to as gentle a slope as practicable.

**B.3.4 Well Pads**

The operator will:

- Locate reserve pits in stable areas on the drill pad to the extent practicable.
- Locate pits away from natural watercourses, riparian areas, wetlands, floodplains, and areas of shallow groundwater wherever practicable.
- Use suitable measures to ensure full containment of drilling fluids where the reserve pit must be placed in a sensitive location or in porous material.
- Design the reserve pit to contain all anticipated drilling muds, cuttings, fracture fluids, and precipitation while maintaining a suitable amount of freeboard to avoid or minimize overtopping.
- Use suitable measures to avoid or minimize seepage from the reserve pit contaminating groundwater.
- Remove any visible or measurable layer of oil from the surface of the reserve pit after cessation of drilling and completion of operations, and continue to keep the pit free of oil.
- Use suitable measures to avoid or minimize surface waters and groundwater from entering open pits.

**B.3.5 Pipelines**

- Pipelines constructed aboveground due to thermal gradient-induced expansion and contraction will rest on cradles above ground level, allowing small animals to pass underneath. Projects should be analyzed to ensure adequate passage for all wildlife species. The pipeline will be raised higher to allow wildlife passage where needed. Because pipeline corridors through certain habitat types can alter local predator/prey dynamics by providing predators with lines of sight and travel corridors, large projects should be analyzed to ensure there will be no significant changes to predator/prey balance.
- The operator will collocate pipelines and transmission lines with roads or their rights-of-way where practicable.
The operator will limit corridor disturbance, particularly in or near AMZs, surface waters, shallow groundwater, unstable areas, hydric soils, or wetlands.

The operator will aggressively address unauthorized uses of the corridor, such as motorized vehicle use, that are exposing soils, increasing erosion, or damaging the facilities.

### B.3.6 Utilities

- Underground utilities will be installed to minimize the amount of open trenches at any given time, keeping trenching and backfilling crews close together. Avoid leaving trenches open overnight. Where trenches cannot be backfilled immediately, escape ramps should be constructed at least every 100 feet.

### B.3.7 Facilities

- The BLM will request a copy of operator’s Clean Water Act (CWA) 401 Certification from designated federal, state, or local entities before approving a plan of operations that may result in any discharge into waters of the United States.
- The operator will consider the following design criteria in facility planning:
  - Locate the facility away from the immediate vicinity of surface waters, AMZs, wetlands, sandy soils, shallow water tables, groundwater recharge areas, floodplains, and other sensitive areas to the extent practicable.
  - Avoid unstable slopes and soils.
  - Minimize the disturbance footprint.
- The operator will use and maintain proper erosion and sediment control practices during and immediately after construction.
- The operator will incorporate suitable stormwater controls in the project design.
- The operator will incorporate requirements from applicable federal, state, and local permits into facility construction and operation plans.
- The operator will develop a contingency plan for implementing appropriate pre-storm or winterization BMPs before the grading permit expires.
- The operator will conform to all applicable federal, state, and local regulations and permits governing water supply, sanitation, and septic systems.
- The operator will determine instream flow needs to minimize damage to scenic and aesthetic values; native plant, fish, and wildlife habitat; and to otherwise protect the environment where the operation of the facility would modify existing streamflow.
- The operator will install and seasonally monitor groundwater quality monitoring wells if a risk of groundwater pollution exists.
- The operator will establish a suitable inspection schedule to ensure that water diversion structures, conveyances, and storage facilities are performing as designed and appropriately maintained.
- The operator will maintain erosion and stormwater controls as necessary to ensure proper and effective functioning.
- The operator will prepare for unexpected failures of erosion control measures.
- The operator will implement corrective actions without delay when failures are discovered to prevent pollutant discharge to nearby waterbodies.
- The operator will routinely inspect construction sites to verify that erosion and stormwater controls are implemented and functioning as designed and are appropriately maintained.
• The operator will use suitable measures in compliance with local direction to prevent and control invasive species.

B.4 Specific Resources

B.4.1 Cultural and Paleontological Resources
• Unexpected discovery of cultural or paleontological resources during construction will be brought to the attention of the responsible BLM Authorized Officer immediately. Work will be halted in the vicinity of the find to avoid further disturbance to the resources while they are being evaluated and appropriate mitigation measures are being developed.

B.4.2 Noise
• The operator will take measurements to assess the existing background noise levels at a given site and compare them with the anticipated noise levels associated with the proposed project.
• Within 2 miles of existing, occupied residences, geothermal well drilling or major facility construction operations will be restricted to non-sleeping hours (7:00 am to 10:00 pm).
• All equipment will have sound-control devices no less effective than those provided on the original equipment. All construction equipment used will be adequately muffled and maintained.
• All stationary construction equipment (e.g., compressors and generators) will be located as far as practicable from nearby residences.
• If blasting or other noisy activities are required during the construction period, nearby residents will be notified by the operator at least 1 hour in advance.
• Explosives will be used only within specified times and at specified distances from sensitive wildlife or streams and lakes, as established by the federal and state agencies.

B.4.3 Noxious Weeds and Pesticides
• The use of certified, weed-free mulch will be required when stabilizing areas of disturbed soil.
• If trucks and construction equipment are arriving from locations with known invasive vegetation problems, a controlled inspection and cleaning area will be established to visually inspect construction equipment arriving at the project area and to remove and collect seeds that may be adhering to tires and other equipment surfaces.
• Fill materials and road surfacing materials that originate from areas with known invasive vegetation problems will not be used.
• Revegetation, habitat restoration, and weed control activities will be initiated as soon as possible after construction activities are completed.
• Use of pesticides must be approved by the agency. Pesticide use will be limited to agency-approved pesticides and will only be applied in accordance with label and application permit directions and stipulations for terrestrial and aquatic applications.

B.4.4 Waste Management
• The operator will plan for suitable equipment refueling and servicing sites during project design.
• All refueling will occur in a designated fueling area that includes a temporary berm to limit the spread of any spill.
• Drip pans will be used during refueling to contain accidental releases.
• Drip pans will be used under fuel pump and valve mechanisms of any bulk fueling vehicles parked at the construction site.
• Any containers used to collect liquids will be enclosed or screened to prevent access to contaminants by wildlife, livestock, and migratory birds.
• Spills will be immediately addressed per the spill management plan, and soil cleanup and removal will be initiated as soon as feasible.
• The operator will use nontoxic, nonhazardous drilling fluids whenever practicable.
• The operator will construct suitable impervious containment structures with sufficient volume and freeboard to avoid or minimize spills or leakages of oil, gas, salt water, toxic liquids, or waste materials from reaching surface waters or groundwater.

B.4.5 Wildlife
• The operator will ensure that employees, contractors, and site visitors avoid harassment and disturbance of wildlife, especially during reproductive (i.e., courtship and nesting) seasons. In addition, pets will be controlled or excluded to avoid harassment and disturbance of wildlife.
• Ponds, tanks, and impoundments (including but not limited to drill pits) containing liquids can present hazards to wildlife. Any liquids contaminated by substances which may be harmful due to toxicity, or fouling of the fur or feathers (detergents and oils), should be excluded from wildlife access by fencing, netting, or covering at all times when not in active use. Liquids at excessive temperature should likewise be excluded. If exclusion is not feasible, such as a large pond, a hazing program based on radar or visual detection, in conjunction with formal monitoring, should be implemented. Clean water impoundments can also present a trapping hazard if they are steep-sided or lined with smooth material. All pits, ponds, and tanks should have escape ramps functional at any reasonably anticipated water level, down to almost empty. Escape ramps can take various forms depending on the configuration of the impoundment. Earthen pits may be constructed with one side sloped 3:1 or greater lined ponds can use textured material; straight-sided tanks can be fitted with expanded metal escape ladders.

B.4.6 Air Quality
• Use of any dust suppressant must be specifically authorized by the Forest Service. The operator must consider the following when requesting the authorization to use dust suppressants:
  ♦ Select chemical products suitable for use on the target species or that meet project objectives.
  ♦ Use chemicals that are registered for the intended uses.
  ♦ Consult the Materials Safety Data Sheet and product label for information on use, hazards, and safe handling procedures for chemical products under consideration for use.
  ♦ Consider chemical solubility, absorption, breakdown rate properties, and site factors when determining which chemical products to use.
  ♦ Use chemicals with properties such that soil residual activity will persist only as long as needed to achieve treatment objectives.
Appendix B. Best Management Practices and Mitigation Measures

- Consider soil type, chemical mobility, distance to surface water, and depth to groundwater to avoid or minimize surface water and groundwater contamination.
- Use a suitable pressure, nozzle size, and nozzle type combination to minimize off-target drift or droplet splatter.
- Specify management direction and appropriate site-specific response measures in project plans and safety plans (FSH 2109.14, chapter 60).
- Ensure that planned chemical use projects conform to all applicable local, state, federal, and agency laws, regulations, and policies.
- Obtain necessary permits, including CWA 402 permit coverage.
- Develop spill contingency plans.
- Obtain or provide training and licensing as required by the label and state regulations.
- Incorporate constraints identified on the label and other legal requirements of application into project plans and contracts.
- Be aware that states may have more restrictive requirements than the label instructions.

B.5 Operations/Utilization

B.5.1 General

- “Good housekeeping” procedures will be developed by the operator to ensure that during all phases of exploration and operation the site will be kept clean of noxious weeds, debris, litter, garbage, fugitive trash or waste, and graffiti. Scrap heaps and dumps are prohibited. Storage yards are to be minimized to that which is absolutely necessary.
- The operator will make adjustments in the plans, authorizations, and bonds if conditions develop that are outside the design criteria and conduct adequate notification, emergency stabilization, or other activities to avoid effects before proceeding with additional operations.
- The operator will inspect drainage structures and road surfaces after major storm events and perform any necessary maintenance.

B.6 Roads

The operator will:

- Maintain the road surface drainage system to intercept, collect, and remove water from the road surface and surrounding slopes in a manner that reduces concentrated flow in ditches, culverts, and over fill slopes and road surfaces.
- Conduct frequent inspections to ensure road drainage is not adversely affecting soil or water resources.
- Clean ditches and catch basins only as needed to keep them functioning.
- Move snow in a manner that will avoid or minimize disturbance of or damage to road surfaces and drainage structures.
- Mark drainage structures to avoid damage during plowing.
- Discontinue road use and snow removal when use would likely damage the roadway surface or road drainage features.
- Modify snow removal procedures as necessary to meet water quality concerns.
• Replace lost road surface materials with similar quality material and repair structures damaged in snow removal operations as soon as practicable.

**B.6.1 Chemical Transport and Storage**
The operator will:

• Transport and handle chemical containers in a manner that minimizes the potential for leaks and spills.
• Inspect containers for leaks or loose caps or plugs before loading.
• Secure containers properly to avoid or minimize shifting in transport.
• Check containers periodically en route.
• Ensure arrangements for proper storage are in place before transporting chemicals.
• Manage and store chemicals in accordance with all applicable federal, state, or local regulations, including label directions.
• Store chemicals in their original containers with labels intact.
• Locate chemical storage facilities at sites that minimize the possibility of impacts to surface water or groundwater in case accidents or fires occur.
• At a minimum, ensure that containment of a complete spill from the largest container being stored is possible with the spill-kit materials at the storage site.
• Check containers before storage and periodically during storage to ensure that they are properly sealed and not leaking.

**B.6.2 Produced Water**
The operator will:

• Discharge or otherwise dispose of produced water in compliance with the CWA and Safe Drinking Water Act, with appropriate approvals from the State and EPA.
• Reinject produced water of suitable quality into acceptable underground reservoirs when authorized and appropriate.
• Avoid, minimize, or mitigate surface-discharge effects including headcuts, stream crossing washouts, impoundments, channel stability, and flooding.

**B.7 Reclamation**

• A reclamation plan meeting the following objectives and standards will be submitted prior to site development:

  **Reclamation Objectives**
  ♦ The objective of interim reclamation is to restore vegetative cover and a portion of the landform sufficient to maintain healthy, biologically active topsoil; control erosion; and minimize habitat, visual, and forage loss during the life of the well or facilities.
  ♦ The long-term objective of final reclamation is to return the land to a condition approximating that which existed prior to disturbance. This includes restoration of the landform and natural vegetative community, hydrologic systems, visual resources, and wildlife habitats. To ensure that the long-term objective will be reached through human and natural processes, actions will be taken to ensure standards are met for site stability, visual quality, hydrological functioning, and vegetative productivity.
Reclamation Performance Standards

Interim Reclamation – Includes disturbed areas that may be redisturbed during operations and will be redisturbed at final reclamation to achieve restoration of the original landform and a natural vegetative community. It will be judged successful when the authorized officer determines that disturbed areas not needed for active, long-term production operations or vehicle travel have been recontoured, protected from erosion, and revegetated with a self-sustaining, vigorous, diverse, native (or as otherwise approved) plant community sufficient to minimize visual impacts, provide forage, stabilize soils, and impede the invasion of noxious, invasive, and non-native weeds.

Final Reclamation – Includes disturbed areas where the original landform and a natural vegetative community have been restored. It will be judged successful when the authorized officer determines that the original landform has been restored for all disturbed areas including well pads, production facilities, roads, pipelines, and utility corridors.

♦ A self-sustaining, vigorous, diverse, native (or otherwise approved) plant community is established on the site, with a density sufficient to control erosion and invasion by non-native plants and to reestablish wildlife habitat or forage production. At a minimum, the established plant community will consist of species included in the seed mix and/or desirable species occurring in the surrounding natural vegetation.

♦ No single species will account for more than [to be determined by site-specific survey] percent of the total vegetative composition unless it is evident at higher levels in the adjacent landscape.

♦ Permanent vegetative cover will be determined successful when the basal cover of desirable perennial species is at least [to be determined by site-specific survey] percent of the basal cover on adjacent or nearby undisturbed areas where vegetation is in a healthy condition.

♦ Plants must be resilient as evidenced by well-developed root systems and flowers. Shrubs will be well established and in a “young” age class at a minimum; therefore, they will not be comprised mainly of seedlings that may not survive until the following year.

♦ Erosion features are equal to or less than the surrounding area, and erosion control is sufficient so that water naturally infiltrates into the soil and gullyng, headcutting, slumping, and deep or excessive rills (greater than 3 inches) are not observed.

♦ The site is free of state- or county-listed noxious weeds, oil field debris and equipment, and contaminated soil. Invasive and nonnative weeds are controlled.

B.7.1 Reclamation Actions

• During initial well pad, production facility, road, pipeline, and utility corridor construction and prior to completion of the final well on the well pad, pre-interim reclamation stormwater management actions will be taken to ensure disturbed areas are quickly stabilized to control surface water flow and to protect both the disturbed and adjacent areas from erosion and siltation. This may involve construction and maintenance of temporary silt ponds, silt fences, berms, ditches, and mulching.

• When the last well on the pad has been completed, some portions of the well location will undergo interim reclamation and some portions of the well pad will usually undergo final reclamation. Most well locations will have limited areas of bare ground, such as a small area around production facilities or the surface of a rocked road. Other areas will have interim reclamation where workover rigs and tanks may need a level area to set up in the future.
Some areas will undergo final reclamation where portions of the well pad will no longer be needed for production operations and can be recontoured to restore the original landform.

The following minimum reclamation actions will be taken to ensure that the reclamation objectives and standards are met. It may be necessary to take additional reclamation actions beyond the minimum in order to achieve the Reclamation Standards.

**B.7.2 Reclamation – General**

- The agency will be notified 24 hours prior to commencement of any reclamation operations.
- The operator will sample and test the site to identify hazardous materials and associated areas that may be contaminated by petroleum products, reactive materials, or other chemicals.
- The operator will use suitable measures to isolate, neutralize, remove, or treat hazardous or contaminated materials—including chemicals, reactive materials, acidic wastes, fuels, pit fluids, sediment, and human waste—consistent with applicable federal, state, and local regulations to achieve applicable standards.
- The operator will properly abandon, plug, and cap all drill holes, cores, and wells per applicable state or federal requirements.
- The operator will reconstruct, maintain, or decommission roads, trails, and staging areas consistent with the land management plan’s desired conditions, goals, and objectives for the area.
- The operator will use suitable measures to limit human, vehicle, and livestock access to the site as needed to allow for recovery of vegetation.

**B.7.2.1 Housekeeping**

- Immediately upon well completion, the well location and surrounding areas(s) will be cleared of, and maintained free of, all debris, materials, trash, and equipment not required for production.
- No hazardous substances, trash, or litter will be buried or placed in pits. Upon well completion, any hydrocarbons in the pit will be remediated or removed.

**B.7.2.2 Vegetation Clearing**

- Vegetation removal and the degree of surface disturbance will be minimized wherever possible.
- During vegetation-clearing activities, trees and woody vegetation removed from the well pad and access road will be moved aside prior to any soil-disturbing activities. Care will be taken to avoid mixing soil with the trees and woody vegetation.
- Trees left for wood gathering will be cut and delimbed. Trunks 6 inches or more in diameter will be removed and placed either by the uphill side of the access road, moved to the end of the road, or moved to a road junction for easy access for wood gatherers and to reduce vehicle traffic on the well pad. Trees with a trunk diameter less than 6 inches and woody vegetation will be used to trap sediment or slow runoff, or they will be scattered on reclaimed areas to stabilize slopes, control erosion, and improve visual resources.

**B.7.2.3 Topsoil Management**

- Operations will disturb the minimum amount of surface area necessary to conduct safe and efficient operations. When possible, equipment will be stored and operated on top of vegetated ground to minimize surface disturbance.
• In areas to be heavily disturbed, the top (to be determined by a site-specific survey) inches of soil material will be stripped and stockpiled around the perimeter of the well location to control run-on and run-off, and to make redistribution of topsoil more efficient during interim reclamation. Stockpiled topsoil may include vegetative material. Topsoil will be clearly segregated and stored separately from subsoils.

• Earthwork for interim and final reclamation will be completed within 6 months of well completion or plugging unless a delay is approved in writing by the BLM Authorized Officer.

• Salvaging and spreading topsoil will not be performed when the ground or topsoil is frozen or too wet to adequately support construction equipment. If such equipment creates ruts in excess of 4 inches deep, the soil will be deemed too wet.

• No major depressions will be left that would trap water and cause ponding.

**B.7.2.4 Seeding**

• Initial seedbed preparation will consist of recontouring to the appropriate interim or final reclamation standard. All compacted areas to be seeded will be ripped to a minimum depth of 18 inches with a minimum furrow spacing of 2 feet, followed by recontouring the surface and then evenly spreading the stockpiled topsoil. Prior to seeding, the seedbed will be scarified and left with a rough surface.

• If broadcast seeding is to be used and is delayed, final seedbed preparation will consist of contour cultivating to a depth of 4 to 6 inches within 24 hours prior to seeding, dozer tracking, or other imprinting in order to loosen up the soil and create seed germination micro-sites.

• Seed application will be conducted no more than 24 hours following completion of final seedbed preparation.

• A certified weed-free seed mix designed by the Forest Service and BLM to meet reclamation standards will be used on all disturbed surfaces, including pipelines and road cut and fill slopes.

• The application rate (to be determined by site-specific survey) is based on drill-seeded to a depth of 0.25 to 0.5 inches, which is the method that will be used where feasible.

• Shrub species will be seeded during the winter on the ground surface or preferably on top of snow.

• In areas that will not be drill-seeded, the seed mix will be broadcast-seeded at twice the application rate shown in the table and covered no more than 0.25 inch deep with a harrow, drag bar, or roller or will be broadcast-seeded into imprints, such as fresh dozer cleat marks.

• Seeding will be done in (season to be determined by site-specific survey).

**B.7.2.5 Erosion Control and Mulching**

• Mulch, silt fencing, wattles, hay bales, and other erosion control devices will be used on areas at risk of soil movement from wind and water erosion.

• Mulch will be used if necessary to control erosion, create vegetation micro-sites, and retain soil moisture and may include hay, small-grain straw, wood fiber, live mulch, cotton, jute, or synthetic netting. Mulch will be free from mold, fungi, and certified free of noxious or invasive weed seeds.

• If straw mulch is used, it will contain fibers long enough to facilitate crimping and to provide the greatest cover.
Appendix B. Best Management Practices and Mitigation Measures

B.7.2.6 Pit Closure
- Reserve pits will be closed and backfilled within 60 days of release of the rig. All reserve pits remaining open after 60 days will require written authorization of the authorized officer. Immediately upon well completion, any hydrocarbons or trash in the pit will be removed. Pits will be allowed to dry, be pumped dry, or solidified in-situ prior to backfilling.
- Following completion activities, pit liners will be completely removed or removed down to the solids level and disposed of at an approved landfill, or treated to prevent their reemergence to the surface and interference with long-term successful revegetation. If it was necessary to line the pit with a synthetic liner, the pit will not be trenched (cut) or filled (squeezed) while containing fluids. When dry, the pit will be backfilled with a minimum of 5 feet of soil material. In relatively flat areas, the pit area will be slightly mounded above the surrounding grade to allow for settling and to promote surface drainage away from the backfilled pit.

B.7.2.7 Management of Invasive, Noxious, and Non-Native Species
- All reclamation equipment will be cleaned prior to use to reduce the potential for introduction of noxious weeds or other undesirable non-native species.
- An intensive weed monitoring and control program will be implemented prior to site preparation for planting and will continue until interim or final reclamation is approved by the authorized officer.
- Monitoring will be conducted at least annually during the growing season to determine the presence of any invasive, noxious, and non-native species. Invasive, noxious, and non-native species that have been identified during monitoring will be promptly treated and controlled.

B.7.3 Interim Reclamation Procedures – Additional

B.7.3.1 Recontouring
- Interim reclamation actions will be completed no later than 6 months from when the final well on the location has been completed, weather permitting. The portions of the cleared well site not needed for active operational and safety purposes will be recontoured to the original contour if feasible, or if not feasible, to an interim contour that blends with the surrounding topography as much as possible. Sufficient semi-level area will remain for setup of a workover rig and to park equipment. In some cases, rig anchors may need to be pulled and reset after recontouring to allow for maximum interim reclamation.
- If the well is a producer, the interim cut and fill slopes prior to reseeding will not be steeper than a 3:1 ratio, unless the adjacent native topography is steeper. Note: Constructed slopes may be much steeper during drilling but will be recontoured to the above ratios during interim reclamation.
- Roads and well production equipment will be placed on location so as to permit maximum interim reclamation of disturbed areas. If equipment is found to interfere with the proper interim reclamation of disturbed areas, the equipment will be moved so proper recontouring and revegetation can occur.

B.7.3.2 Application of Topsoil & Revegetation
- Topsoil will be evenly respread and aggressively revegetated over the entire disturbed area not needed for all-weather operations, including road cuts and fills and to within a few feet of
the production facilities, unless an all-weather, surfaced, access route or small “teardrop” turnaround is needed on the well pad.

- In order to inspect and operate the well or complete workover operations, it may be necessary to drive, park, and operate equipment on restored, interim vegetation within the previously disturbed area. Damage to soils and interim vegetation will be repaired and reclaimed following use. To prevent soil compaction, under some situations, such as the presence of moist, clay soils, the vegetation and topsoil will be removed prior to workover operations and restored and reclaimed following workover operations.

**B.7.3.3 Visual Resources Mitigation for Reclamation**

- Trees, if present, and vegetation will be left along the edges of the pads whenever feasible to provide screening.
- To help mitigate the contrast of recontoured slopes, reclamation will include measures to feather cleared lines of vegetation and to save and redistribute cleared trees, debris, and rock over recontoured cut and fill slopes.
- To reduce the view of production facilities from visibility corridors and private residences, facilities will not be placed in visually exposed locations (such as ridgelines and hilltops).
- Production facilities will be clustered and placed away from cut slopes and fill slopes to allow the maximum recontouring of the cut and fill slopes.
- All long-term, aboveground structures will be painted (color to be determined by site-specific survey; from the “Standard Environmental Colors” chart) to blend with the natural color of the late-summer landscape background.

**B.7.4 Final Reclamation Procedures – Additional**

- Final reclamation actions will be completed within 6 months of well plugging, weather permitting.
- All disturbed areas, including roads, pipelines, pads, facilities, and interim reclaimed areas will be recontoured to the contour existing prior to initial construction or a contour that blends indistinguishably with the surrounding landscape. Resalvaged topsoil will be respread evenly over the entire disturbed site to ensure successful revegetation. To help mitigate the contrast of recontoured slopes, reclamation will include measures to feather cleared lines of vegetation and to save and redistribute cleared trees, woody debris, and large rocks over recontoured cut and fill slopes.
- Water breaks and terracing will only be installed when absolutely necessary to prevent erosion of fill material. Water breaks and terracing are not permanent features and will be removed and reseeded when the rest of the site is successfully revegetated and stabilized.
- If necessary to ensure timely revegetation, the pad will be fenced to exclude livestock grazing for the first two growing seasons or until seeded species become firmly established, whichever comes later.
- Final abandonment of pipelines and flowlines will involve flushing and properly disposing of any fluids in the lines. All surface lines and any lines that are buried close to the surface that may become exposed in the foreseeable future due to water or wind erosion, soil movement, or anticipated subsequent use, must be removed. Deeply buried lines may remain in place unless otherwise directed by the authorized officer.
B.7.4.1 Road Closure

The operator will:

- Remove drainage structures.
- Recontour and stabilize cut slopes and fill material.
- Reshape the channel and streambanks at crossing sites to pass expected flows without scouring or ponding, minimize potential for undercutting or slumping of streambanks, and maintain continuation of channel dimensions and the longitudinal profile through the crossing site.
- Restore or replace streambed materials to a particle-size distribution suitable for the site.
- Restore floodplain function.
- Implement suitable measures to promote infiltration of runoff and intercepted flow and desired vegetation growth on the road prism and other compacted areas.
- Use suitable measures in compliance with local direction to prevent and control invasive species.

B.7.4.2 Reclamation Monitoring and Final Abandonment Approval

- Reclaimed areas will be monitored annually. Actions will be taken to ensure that reclamation standards are met as quickly as reasonably practical.
- Reclamation monitoring will be documented in an annual reclamation report submitted to the authorized officer by (date to be determined). The report will document compliance with all aspects of the reclamation objectives and standards, identify whether the reclamation objectives and standards are likely to be achieved in the near future without additional actions, and identify actions that have been or will be taken to meet the objectives and standards. The report will also include acreage figures for:
  - Initial Disturbed Acres
  - Successful Interim Reclaimed Acres
  - Successful Final Reclaimed Acres

Annual reports will not be submitted for sites approved by the authorized officer in writing as having met interim or final reclamation standards. Monitoring and reporting continues annually until interim or final reclamation is approved. Any time 30 percent or more of a reclaimed area is redisturbed, monitoring will be reinitiated.

- The authorized officer will be informed when reclamation has been completed, appears to be successful, and the site is ready for final inspection.
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