National Park Service
U.S. Department of the Interior

Natural Resource Stewardship and Science

Fort Union National Monument

Natural Resource Condition Assessment

Natural Resource Report NPS/FOUN/NRR—2011/440

ON THE COVER
Shortgrass prairie at Fort Union National Monument.
Photograph by Robert Bennetts.

Fort Union National Monument

Natural Resource Condition Assessment

Natural Resource Report NPS/FOUN/NRR—2011/440

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The National Park Service, Natural Resource Stewardship and Science office in Fort Collins, Colorado publishes a range of reports that address natural resource topics of interest and applicability to a broad audience in the National Park Service and others in natural resource management, including scientists, conservation and environmental constituencies, and the public.

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Publisher's Note: Some or all of the work done for this project preceded the revised guidance issued for this project series in 2009/2010. See Prologue (p.xiv) for more information.

Executive Summary

Fort Union National Monument was congressionally authorized by Public Law 83-429 on June 28, 1954, "to preserve and protect, in the public interest, the historic Old Fort Union, situated in the county of Mora, State of New Mexico, and to provide adequate public access thereto…." The monument was formally established by the [NPS] on April 5, 1956. Additionally, under Public Law 100-35, the 100th United States Congress authorized the Santa Fe National Historic Trail on May 8, 1987 to commemorate the over 1,100 mile-long Santa Fe Trail from Old Franklin, Missouri to Santa Fe, New Mexico.

According to the Fort Union National Monument Resource Management Plan (2000), the "Mission of FOUN is to preserve the ruins of the historic fort, to provide for public access, and to educate the public about its significant role in the American Southwest, the Santa Fe Trail, and the development of United States rules in the Southwest."

Extracted from: NPS, Southern Plains Inventory and Monitoring Network. 2008. Southern Plains Network Vital Signs Monitoring Plan. Natural Resource Report NPS/SOPN/NRR-2008/028. National Park Service, Fort Collins, CO.

Because of park management policies and mandates, the National Park Service collaborated with Natural Heritage New Mexico, Univeristy of New Mexico Biology Department, to conduct a Natural Resource Condition Assessment (NRCA). NRCAs represent a relatively new approach to assessing and reporting on park resource conditions. They are meant to complement, but not replace, traditional issue- and threat-based resource assessments. NRCAs evaluate current conditions for a subset of natural resources and resource indicators in national parks.

This report includes condition analyses and reports on trends (as possible), critical data gaps, and general levels of confidence for study findings. The Southern Plains Inventory and Monitoring Network and park staff helped identify indicators targeted for evaluation. Considerations in this process included the monument's resource setting, status of park-level resource stewardship planning and science in identifying priority indicators for that park, and availability of useful data and qualified expertise to assess current conditions for each indicator included on a list of potential study indicators. The background, analysis, and condition summaries for the 16 key resource are presented in the project framework. In each section, we discuss the key resources and their measures, stressors, and reference conditions. We discuss prevalent threats to FOUN natural resources: climate change, exotic species, water pollutants, and human impacts/adjacent land use.

Prologue

Publisher's Note: This was one of several projects used to demonstrate a variety of study approaches and reporting products for a new series of Natural Resource Condition Assessments in national park units. Projects such as this one, undertaken during initial development phases for the new series, contributed to revised project standards and guidelines issued in 2009 and 2010 (applicable to projects started in 2009 or later years). Some or all of the work done for this project preceded those revisions. Consequently, aspects of this project's study approach and some format and/or content details may not be consistent with the revised guidance and may differ in comparison to what is found in more recently published reports from this series.

Publisher's Note: Some or all of the work done for this project preceded the revised guidance issued for this project series in 2009/2010. See Prologue (p.xiv) for more information.

1. Introduction and Resource Setting

1.1. Natural Resource Condition Assessment Background Information

Natural Resource Condition Assessments (NRCAs) evaluate current conditions for a subset of natural resources and resource indicators in national park units, or "parks." For these condition analyses, they also report on trends (as possible), critical data gaps, and general levels of confidence for study findings. The indicators targeted for evaluation depend on a park's resource setting, status of park-level resource stewardship planning and science in identifying priority indicators for that park, and availability of useful data and qualified expertise to assess current conditions for each indicator included on a list of potential study indicators.

NRCAs represent a relatively new approach to assessing and reporting on park resource conditions. They are meant to complement, but not replace, traditional issue- and threat-based resource assessments. Credibility for study findings derives from the data, methods, and reference values used in the project work—are they appropriate for the stated purpose and adequately documented? For each study indicator where current condition or trend is reported, it is important to identify critical data gaps and describe level of confidence in at least qualitative terms. Involvement of park staff and National Park Service (NPS) subject matter experts at critical points during the project timeline is also important to: (1) assist selection of study indicators; (2) recommend study data sets, methods, reference conditions, and values; and (3) help provide a multi-disciplinary review of draft study findings and products.

Due to their modest funding, relatively quick timeframe for completion, and reliance on existing data and information, NRCAs are not intended to be exhaustive. Study methods typically involve an informal synthesis of existing data from multiple and diverse sources, at a level of rigor and sophistication that reflects our present data and knowledge base for each resource or indicator evaluated. A successful NRCA delivers science-based information that is credible and has practical uses for a variety of park decision making, planning, and partnership activities.

1.2. Introduction to Fort Union National Monument

1.2.1. Enabling Legislation and Management Guidance

This section is extracted from NPS, Southern Plains Inventory and Monitoring Network (2008).

> *[FOUN] was congressionally authorized by Public Law 83-429 on June 28, 1954, "to preserve and protect, in the public interest, the historic Old Fort Union, situated in the county of Mora, State of New Mexico, and to provide adequate public access thereto…." The monument was formally established by the [NPS] on April 5, 1956. Additionally, under Public Law 100-35, the 100th United States Congress authorized the Santa Fe National Historic Trail on May 8, 1987 to commemorate the over 1,100 mile-long Santa Fe Trail from Old Franklin, Missouri to Santa Fe, New Mexico.*
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> *According to the Fort Union National Monument Resource Management Plan (2000), the mission of FOUN is to preserve the ruins of the historic fort, to provide for public access, and to educate the public about its significant role in the American Southwest, the Santa Fe Trail, and the development of United States rules in the Southwest." The Resource*

Management Plan is a strategic planning document for management and conservation of the cultural and natural resources of [FOUN]. Objectives of this planning document pertaining to natural resources include the desires to: "preserve and manage the resources, and to maintain and perpetuate the integrity of the historic remains of the three forts, the archeological resources, and the historic landscapes; … increase knowledge, understanding, and appreciation of both the natural and cultural resources;" and "… instill an awareness and sensitivity toward the fragility of the resources and the need for continued preservation and protection." These stated objectives are in keeping with those of the 1984 General Management Plan and Environmental Assessment, which included an additional objective "to seek a continuation of compatible activities on lands adjacent to the monument to protect the fort's historic scene."

1.2.1.1. Park Purpose

Consistent with the enabling legislation and as outlined in a 2008 Fort Union National Monument (FOUN) concept planning document (Fort Union National Monument 2008), the purpose of the monument can be summarized as follows:

- To preserve the historical remains and setting of Fort Union and its inextricable link to the Santa Fe Trail, to provide for public use and education, and to interpret Fort Union's role in westward expansion.
- To comprehensively interpret Fort Union, encompassing the time before and after its establishment, as well as the multiple perspectives of the cultures that contributed to, and were affected by, the fort.
- To preserve the natural resources and values of Fort Union and the Santa Fe Trail, in order to maintain an authentic historical setting in which to experience them.

1.2.1.2. Park Significance Statements

Among the Statements of Significance presented in the concept planning document, the following three statements convey the strongest sense of direct linkages to natural resources and natural-resource related values at FOUN (Fort Union National Monument 2008):

- This area is the traditional homeland and/or hunting and gathering grounds of several indigenous peoples, including the Jemez Pueblo, Pecos Pueblo, Jicarilla Apache, Navajo, Southern Ute, and other tribal nations and contains landmarks and sacred sites embedded in their cultures.
- The cultural landscape of Fort Union National Monument possesses a high degree of historical integrity, as its viewshed has changed little since the fort's establishment in 1851. The natural resources and values preserved here - such as natural sounds, clear night skies, unobstructed views, and short-grass prairie - contribute to an authentic historical setting.
- Fort Union National Monument is one of the few federally managed sites preserving physical remains of the Santa Fe Trail.

The role and importance of natural resources at FOUN are also highlighted in two of the Primary Interpretive Themes presented in the concept planning document (Fort Union National Monument 2008):

- Fort Union National Monument's architectural remains, Santa Fe Trail ruts, and little changed landscape provide an authentic setting for visitors to imagine and reflect on human activity and military life on the western frontier and defining events that shaped the developing nation.
- The natural resources that provided subsistence here for centuries and a strategic place to build Fort Union offer today's visitors an authentic and premier setting to recreate and reflect on a bygone era.

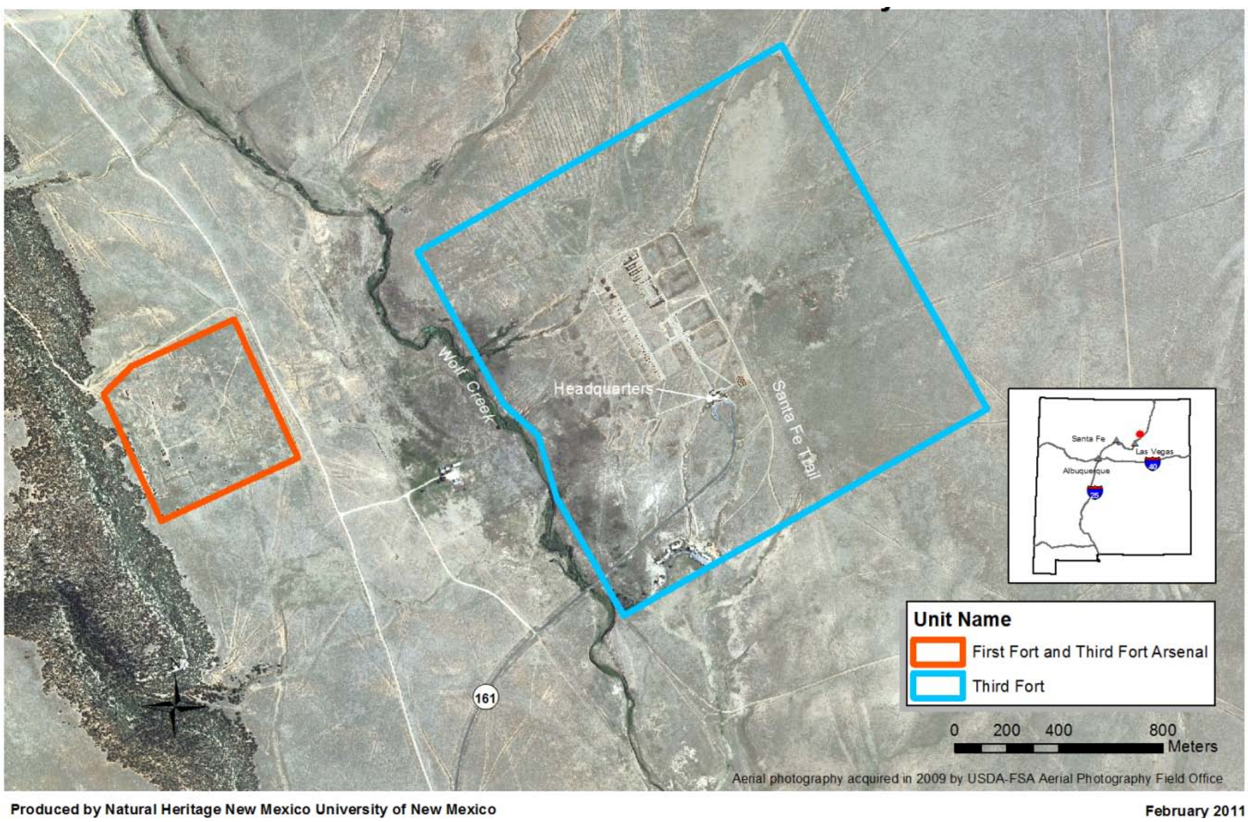

Figure 1-1. Boundaries of FOUN, and Natural Resource Condition Assessment area.

1.2.2. Geographic Setting

Monument boundaries and location in northeastern New Mexico are shown in Figure 1-1. This section is extracted from Muldavin et al. (2004).

> *Fort Union Nation Monument is located in northeast New Mexico, approximately 10 miles northwest of Watrous and Valmora in Mora County (Figure 1). The monument comprises*

721 acres (292 ha), and was established in 1956 to preserve the remains of Fort Union, a complex of three historical forts established beginning in 1851 along the Mountain route of the Santa Fe Trail. The fort was abandoned in 1891, but the previous 40 years brought extensive changes to landscape as the fort became a focal point for not only military activities but also trade and agriculture in the Mora Valley and the region (Harrison and Ivey 1993; Schackel 1983). Following abandonment, the land reverted to general rangeland use up until the site was donated by the Fort Union Ranch to a local preservation society and then to the National Park Service. Since that time, the park has been exclosed from livestock to protect the cultural resources as well as improve range conditions.

The climate of Fort Union National Monument is semi-arid, with an average rainfall of 16.70 in (424 mm) and a mean annual temperature of 49.3°F (9.61°C). The majority of the precipitation (70%) falls during the summer "monsoon" rainy season (May through September), primarily derived from frontal storms off the Gulf of Mexico and to a limited degree the Gulf of California (Table 1; Figure 2). The remainder of precipitation comes in the form of rain and snow from storms out of the west. Seasonal temperature ranges can be extreme with daily fluxes of 30°F (16.8°C) or more. This, in combination with low rainfall, generates a semiarid, continental climate for the monument. With the exception of June 2000, summer monsoon rainfall during the period of sampling between 2000 and 2002 was significantly below normal, which was in keeping with regional drought conditions

The monument is located in a wide valley of the lower Wolf Creek watershed, a tributary of the Mora River. Elevations range from approximately 6,700 to 6,840 ft (2,040 to 2,085 m). There are two units to the monument. The largest comprises 637 acres and lies to the east of the creek and upslope along a broad alluvial fan piedmont that extends to the base of the Turkey Mountains. This unit houses the park headquarters and the ruins of the "Star Fort" and "Third Fort," and was the focus of the heaviest usage during the active days of the fort. This gentle terrain is primarily broken by old trails and arroyos that are artifacts of the old Santa Fe Trail system that converged at the forts. While the creek proper lies outside the boundaries of the units and within the Fort Union Ranch, there are small spring and seepage areas associated with the relatively steep slope that leads down to the creek bottom.

The smaller unit of 83.6 acres lies to the west of the creek up against a bluff that is an extension of Black Mesa. This unit sits on a short piedmont slope that leads down to the creek to the east, but it also contains a small amount of granitic rock outcrop along its western edge against the base of the mesa. This is the site of the "First Fort" established in 1851, which later became an arsenal site after the building of the Third Fort on the opposite slope. Hence, this smaller site also carries the legacy of heavy historical use that is reflected in the vegetation patterns we see today.

1.2.3. Visitation Statistics

FOUN visitation fluctuates from year to year, but during 2005-2011 it ranged from 9,000-11,000 visitors. Visitation activities included attendance at ranger-led programs, viewing of the ruins and exhibits, and attendance at special FOUN events (Marie Frias Sauter pers. comm.).

1.3. Natural Resources

This section is extracted from NPS, Southern Plains Inventory and Monitoring Network (2008). The material in this section of Chapter 1 is intended to serve as general background information on park resources. See Chapter 3 for more specific, current information on individual resources and assessments of resource condition.

> *[FOUN] is comprised of 721 acres (292 ha) of shortgrass prairie contained within two separate units, located in northeastern New Mexico, approximately 10 miles (16 km) northwest of Watrous and Valmora in Mora County. Established in 1851, Fort Union served the region for forty years as a military supply depot, arsenal, and frontier military post protecting the Mountain Branch of the Santa Fe Trail. [Later, significant military campaigns were operated out of FOUN against Native American Tribes and in the U.S.–Mexican and Civil wars.] Three successive forts were constructed in the area, and the majority of the remains of each fort are contained within the monument boundaries, resulting in the largest grouping of adobe ruins in the United States (Johnson et al. 2003a). Wolf Creek divides the largest unit of 637 acres (258 ha), containing the remains of two forts, from the disjunct 84-acre (34 ha) second unit that contains remnants of the original fort (Muldavin et al. 2004). Of additional significance, the monument encloses the remnants of the largest accumulation of Santa Fe Trail ruts (Koch and Santucci 2003) in the U.S. FOUN continues to be surrounded by a 96,000-acre (38,850 ha) cattle ranch that predates the 1891 closure of the fort (Johnson et al. 2003a). The primary ecosystem present at FOUN is shortgrass prairie. The two largest natural resource concerns for FOUN managers are invasive plant species and burrowing animals, which affect the ruins.*

1.3.1. Resource Descriptions

1.3.1.1. Valuable resources/Species of interest

The resources described in this section are treated in detail in Chapter 3. This section is extracted and adapted from NPS, Southern Plains Inventory and Monitoring Network (2008).

> *The most significant natural resource at [FOUN] is the native shortgrass prairie community. After bearing the brunt of tremendous historical use reflected in current vegetation patterns (Muldavin et al. 2004), the shortgrass prairie has begun to tentatively restore itself after grazing was halted in 1956. There are no threatened or endangered species of plants or animals documented within the monument. The adobe ruins may provide habitat for breeding and migrating birds, as well as roosts for bats and shelter for reptiles (Johnson et al. 2003a).*

1.3.1.2. Geology and soils

This section is extracted and adapted from NPS, Southern Plains Inventory and Monitoring Network (2008).

> *[FOUN] is located on the east side of a southward trending valley of Wolf Creek, a tributary of the Mora River. The valley is bordered to the west by a prominent sandstone*

mesa and on the east and northeast by the Turkey Mountains (Fort Union National Monument 2000). The primary geologic formation exposed at FOUN is the Upper Cretaceous Graneros Shale. No fossils have been discovered within the park, although they have been found elsewhere in New Mexico from this same formation (Koch and Santucci 2003). Layers encountered in drilling the monument well were: top soil and gravel (first 7 feet [2 m]), black shale (7-140 feet [2-43 m]), white limestone (140-150 ft [43-46 m]), sandstone (150-300 ft [46-91 m]) and blue sandy shale (300-325 ft [91-99 m]) (Southwest Region 1984). Soils at FOUN are classified as Aridic Argiustolls, largely comprised of silt and stony (Partri) loams formed in alluvial material from the adjacent basalt formations and other eolian material, ranging in depth from very shallow to moderate, and unstable when devegetated (Freitag 1994).

1.3.1.3. Land use

This section is extracted and adapted from NPS, Southern Plains Inventory and Monitoring Network (2008).

[FOUN] is located in Mora County, an area of sparse population and low growth, where ranching is the predominant land use. The land immediately outside of the monument has been owned by the Fort Union Cattle Ranch since the early 1900's and has been grazed since that time (Fort Union National Monument 2000).

1.3.1.4. Hydrology

This section is extracted and adapted from NPS, Southern Plains Inventory and Monitoring Network (2008).

FOUN contains no perennial surface water resources within its boundaries but Wolf Creek, adjacent to the Park, intermittently produces small springs and seepage areas within the Park. Drought is increasing the susceptibility of FOUN to exotic plant invasions, so insufficient water resources is a concern to Park managers. Another concern is the potential for anthropogenic sources of contaminants being introduced to the groundwater, particularly from nearby ranching operations, storm water runoff, recreational use, and atmospheric deposition. FOUN personnel collect groundwater samples twice a month for bacteriological analyses and results have consistently complied with health standards. A basic water quality assessment has been completed ([NPS Water Resources] Division 1998).

While there are no perennial surface water resources within FOUN boundaries, unpublished maps on file at FOUN (e.g., 1866 historical map titled "Military Reservation at Fort Union, Eight Miles Square") identify the (at least historical) existence of springs in the larger 40,000 acre area of the historical Fort Union reservation (Marie Frias Sauter pers. comm.).

1.3.1.5. Air Quality

This section is extracted and adapted from NPS, Southern Plains Inventory and Monitoring Network (2008).

> *FOUN is a [NPS] Class II air quality area. No quantitative air data exists for the FOUN region and there are no air quality concerns at present (Fort Union National Monument 2000). The low levels of ozone exposure make the risk of foliar damage to plants negligible. While there are a few ozone-sensitive plants at FOUN - Sagewort (*Artemisia ludoviciana*) and Skunkbush (*Rhus trilobata*) - there are no bioindicator species at the site ([NPS] 2005).*

1.3.1.6. Wildlife

This section is extracted and adapted from NPS, Southern Plains Inventory and Monitoring Network (2008).

- *Mammals: Natural Heritage New Mexico surveyed FOUN during 2001 and 2002. They documented 16 species of mammals. Bats were not surveyed but were observed and tentatively identified as Mexican free-tailed bats (*Tadarida brasiliensis*). Ord's kangaroo rat (*Dipodomys ordii*) was the most commonly caught species in the grassland. Two elk bulls (*Cervus elaphus*) and large herds of pronghorns (*Antilocapra americana*) have been observed near the park boundary (Johnson et al. 2003b).*

- *Birds: Natural Heritage New Mexico surveyed FOUN during 2001 and 2002 and detected 52 species during the breeding season. Of these, 32 species (55.2%) were found in grassland habitats, 25 species (43.1%) were found in pinion-juniper habitats, and riparian habitats accounted for 20 species (34.5%). Brown-headed cowbird (*Molothrus ater*) was the most commonly detected bird, with 48.5% of detections. Cliff swallow (*Petrochelidon pyrrhonota*) and western meadowlark (*Sturnella neglecta*) were the second and third commonest species, with 13.3% and 12.2% of total detections, respectively (Johnson et al. 2003a). Six species of birds listed as high priority on the Partners In Flight Watch List for the "Physio 85 Mesa and Plains" region have been documented at Fort Union: Swainson's hawk (*Buteo swainsonii*), black-chinned hummingbird (*Archilochus alexandri*), canyon towhee (*Piplio fuscus*), Cassin's sparrow (*Aimophila cassinnii*), Cassin's kingbird (*Tyrannus vociferans*), and Virginia's warbler (*Vermivora virginiae*). As the shortgrass prairie continues to improve, it may be possible to encourage the residence of several nearby species of interest - burrowing owl (*Athene cunicularia*) is known to inhabit the area, mountain plover (*Charadrius montanus*) might be found near, ferruginous hawk (*Buteo regalis*) and peregrine falcon (*Falco peregrinus*). The absence of livestock grazing on FOUN has apparently encouraged diversity of grassland birds, especially ground- and shrub-nesting birds and has probably allowed the persistence of a small marshy area near the westernmost corner of the monument. The stabilization of historical structures has also allowed nesting by several species favoring cavities for nest placement. Clusters of planted and naturally occurring deciduous trees have* *likely also encouraged canopy birds, while modern building structures provide nesting substrates for others (Johnson et al. 2003a).*

- *Reptiles/Amphibians: Natural Heritage New Mexico surveyed FOUN during 2001 and 2002 and documented only nine reptile and amphibian species. Severe drought during the survey period likely affected these results. Lack of habitat diversity, the small size of the park, and its proximity to grazed rangeland may also reduce the number of species that permanently inhabit the monument (Johnson et al. 2003b).*

1.3.1.7. Vegetation

This section is extracted and adapted from NPS, Southern Plains Inventory and Monitoring Network (2008).

> *FOUN is located in the southern parks and ranges section (i.e., Section M3315 – Southern Parks and Rocky Mountain Ranges) of the Southern Rocky Mountain Steppe ecoregion… The Grama-Buffalograss groundcover was thought to be similar to that of 1884 (Stubbendieck and Willson 1986). A more recent survey of vegetation by Natural Heritage New Mexico in 2004 described the plant life at FOUN as relatively diverse, with the shortgrass prairie still dominant yet reflecting the impacts of historic use. Drought was prevalent during the three summer seasons of this survey, resulting in the identification of 142 taxa, 16 plant associations and 11 alliances. The most abundant grass was blue grama (*Bouteloua gracilis*), the characteristic species of the shortgrass prairie, and the most common associations were the Blue Grama/Fringed Sage Grassland (*Bouteloua gracilis/Artemisia frigida*) and the Blue Grama-Purple Threeawn (*Bouteloua gracilis-Aristida purpurea*), indicative of a long disturbance history. The remnants of the Santa Fe Trail have a different vegetation pattern - hairy grama (*Bouteloua hirsuta*) is associated with more compacted soils, while western wheatgrass (*Agropyron smithii*) and sleepygrass (*Achnatherum robustum*) reflect the concentration of water in the trails during rainfall events. The most diverse vegetation community at FOUN is found around the seeps and springs along the lower western slope of the monument (Muldavin et al. 2004).*
>
> *There is little need for restoration efforts at FOUN, although management strategies need to be investigated. Lack of grazing on these prairies, while initially beneficial, may now limit range improvement. The reintroduction of fire, of interest to the surrounding landowner, and should be explored.*
>
> *The vegetation survey carried out by Natural Heritage New Mexico found only twelve species they considered "non-native alien introductions," with none posing significant threats to native species (Muldavin et al. 2004). An earlier survey points out revegetation efforts on disturbed areas had been unsuccessful, allowing an influx of invasive species (Johnson et al. 2003a). A noxious weed inventory conducted March to August, 2003, determined that field bindweed (*Convolvulus arvensis*) was the only exotic species of concern, occupying an estimated 3.3 acres along the roadside and in the residence area. Many of the other exotic species identified at FOUN were only found in the low, wet area adjacent to Wolf Creek (Natumalani et al. 2004). In all cases, vigilance against*

infestation of disturbed areas was recommended as the major control method for [FOUN].

1.4. Resource Issues Overview: Threats and Stressors

The diverse landscape and the monument's location also contribute to many of the threats faced by its natural resources. The most prevalent threats and stressors are discussed in this section.

1.4.1. Climate Change

This section is extracted from http://science.nature.nps.gov/im/climate/index.cfm.

Climate is a factor that presents a potential stress to many ecosystem components. Climate change may have direct and/or indirect effects on streamflow, water quality, and groundwater resources. Changes in climate, combined with anthropogenic effects, are expected to alter the type (e.g., rain versus snow) and amount of precipitation and the seasonality of large precipitation events, with unknown implications for grassland systems. Increased drought has the possibility of altering seasonality, severity, and frequency of fire as well as post-fire regeneration. The anthropogenic effect of increased atmospheric carbon has been considered an enhancement to shrub encroachment into grasslands. Climatic changes are also predicted to provide exotic plant species with new opportunities for invasion. Because they fragment native ecosystems, displace native plants and animals, and alter ecosystem function, invasive exotics are one of the most serious threats to natural ecosystem integrity. They can also alter fire regimes by causing fires to burn more swiftly or intensely. An increase in exotic invasions, in combination with decreasing soil moisture that may accompany climate change, could set the stage for fires with the potential to dramatically impact grassland ecosystems. Despite being relatively mobile, birds may be affected by climate change in a variety of ways. For example, it may lead to a change in the timing of migration, changes in vegetation and insect abundance (which could affect life history constraints or reproductive strategies), and shifts in the latitudinal range for some species.

1.4.2. Exotic Plants and Problems of Burrowing Animals

This section is extracted and adapted from NPS, Southern Plains Inventory and Monitoring Network (2008).

*The most critical natural resource issues at [FOUN] are "the need for effective means of dealing with unwanted vegetation and the problems of burrowing mammals" (Fort Union National Monument 2000). Botta's pocket gophers (*Thomomys bottae*), rabbits, and other rodents are excavating large patches of the monument. Many soils in and around the ruins that have been recently deposited or dug up for other purposes have become ideal habitats for these animals (Muldavin et al. 2004). This small mammal community that includes mice, voles, shrews and moles also provides a possible vector for introduction of diseases such as hanta virus and bubonic plague. Efforts at re-vegetation with native grasses following disturbance have met with limited success, resulting in invasive species colonizing these areas. While invasive plant species are not welcome, the establishment of native vegetation within the perimeter of the stone foundations of the ruins is desired by the park management, but as yet unattained (Johnson et al. 2003a).*

1.4.3. Human Impacts/Adjacent Land Use

This section is extracted and adapted from NPS, Southern Plains Inventory and Monitoring Network (2008).

> *The expansive landscape surrounding [FOUN] is an important part of the monument's story, and preservation of the historic scene is a goal stated in the monument's General Management Plan. Possible intrusions on the historic scene could include a variety of incompatible land uses: both mining and timber harvesting in the Turkey Mountains have been considered in the past. Power lines, road improvements, and resort/retirement residential developments are examples of other activities that could intrude on the fort's pristine setting. The [NPS] maintains a dialog with the owners of the surrounding range land, regional utilities, and transportation agencies to encourage compatible uses of land within the Fort's viewshed (Fort Union National Monument 2000).*

1.4.4. Effects of the Drought/Monsoon Cycle

This section is extracted and adapted from NPS, Southern Plains Inventory and Monitoring Network (2008).

> *The drought/monsoon cycle is well documented in northeastern New Mexico, bringing its own unique set of stressors. Periods of drought stress the prairie ecosystem and provide beneficial conditions for hanta virus. Fortunately, the historic dust storms from the days of "Fort Windy" are no longer a problem now that vegetation has been re-established, yet dust particles are still lifted into the atmosphere, affecting air quality.*

1.4.5. Fire Issues

This section is extracted and adapted from NPS, Southern Plains Inventory and Monitoring Network (2008).

> *The need to introduce fire as a management tool for the shortgrass prairie has been discussed. While prairie fire is thought to increase biodiversity and reinvigorate ecosystem processes, the effects of various intensities and frequencies on more arid shortgrass systems must be explored. Use of this management tool is limited by the size of the monument and the need to protect the cultural resources, but areas within the monument might benefit from a prescribed burn (Muldavin et al. 2004).*

1.4.6. Santa Fe Trail Ruts

This section is extracted and adapted from NPS, Southern Plains Inventory and Monitoring Network (2008).

> *The ruts of the Santa Fe Trail have either grown over with vegetation that threatens to obscure them or have eroded into active arroyos. Stabilizing erosion by re-vegetating affected areas runs the risk of obscuring the ruts with vegetation. It is hoped that a balance between erosion and vegetative deposition can be found to preserve these cultural relics (Muldavin et al. 2004).*

1.5. Resource Stewardship

1.5.1. Management Directives and Planning Guidance

The Southern Plains Inventory & Monitoring (I&M) Network (SOPN), in addition to FOUN staff input, guided the selection of natural resources for this report.

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2. Study Scoping and Design

This NRCA is a collaborative project between Natural Heritage New Mexico and the NPS. Stakeholders in this project include the FOUN park resource management team and Intermountain Region I&M Program staff. Before embarking on the project, it was necessary to identify the specific roles of Natural Heritage New Mexico and the NPS. Based on preliminary discussions, a task agreement and a scope of work document were created cooperatively between Natural Heritage New Mexico and the NPS.

Even though the resources assessed during the NRCA process (Table 2-1) are limited to natural resources, identification and discussion of important cultural resources helped to understand the cultural context in which natural resources would be considered and, in some cases, formed the basis for reference conditions used as part of the assessment.

In addition to identifying resources, management overlays were discussed during project scoping. These overlays represent within-park reporting areas where the management priorities differ and define the spatial context for some resources. The process for project scoping and study design is outlined in Figure 2-1, the core assessment team in Table 2-2.

2.1. Scoping

A scoping meeting was held at FOUN to identify:

1. and roughly delineating areas of interest (management overlays);
2. important natural and cultural resources, management priorities, and concerns in each area. For this exercise we relied heavily on the newly developed foundation plan for FOUN and input from park staff; and
3. preliminary management and interpretive themes for areas within the management overlays.

Based on input from this meeting, a study framework was developed and the list of natural resources to be included in the assessment was prioritized (Table 2-1), based on:

1. importance to park;
2. importance as information needed for ongoing planning efforts; and
3. availability and characteristics of data and/or potential for reliable assessment.

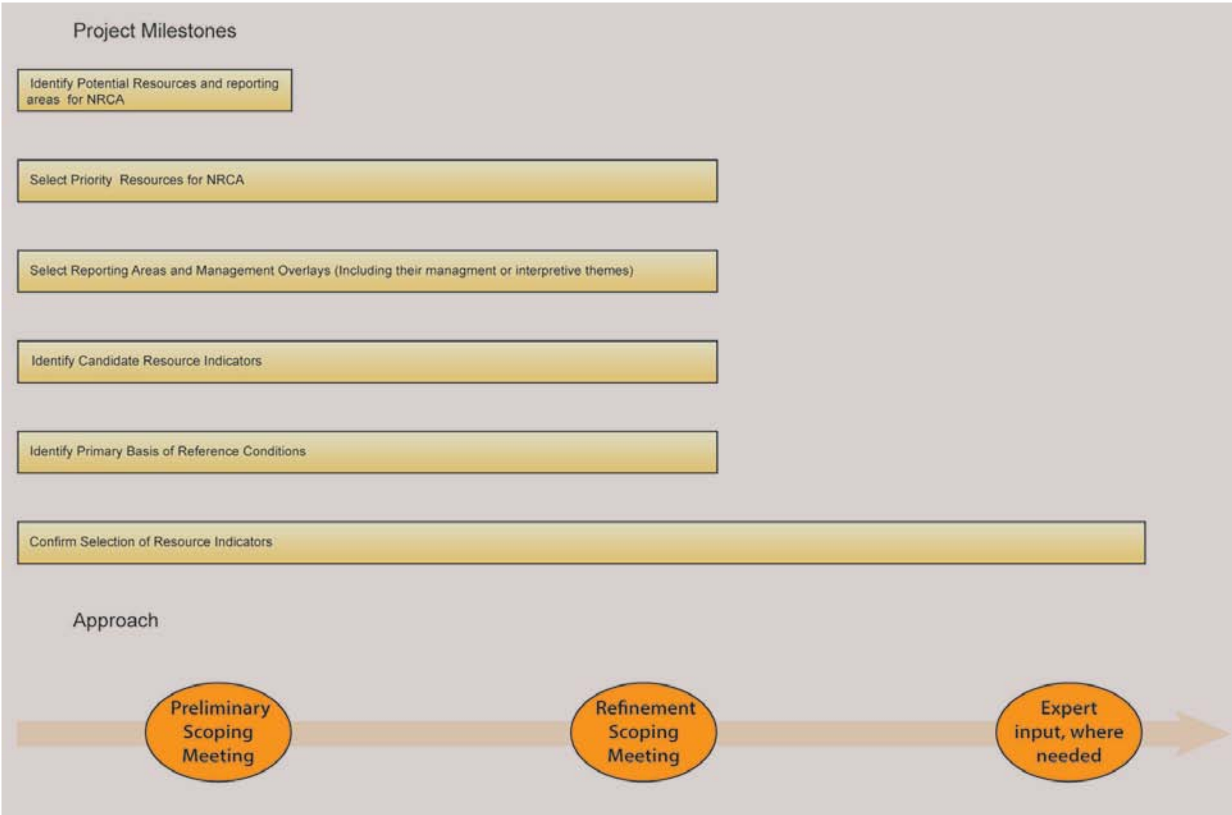

Figure 2-1. The general relationship among primary project milestones and the approach for participation during the scoping and design phase of the Fort Union National Monument Natural Resource Condition Assessment.

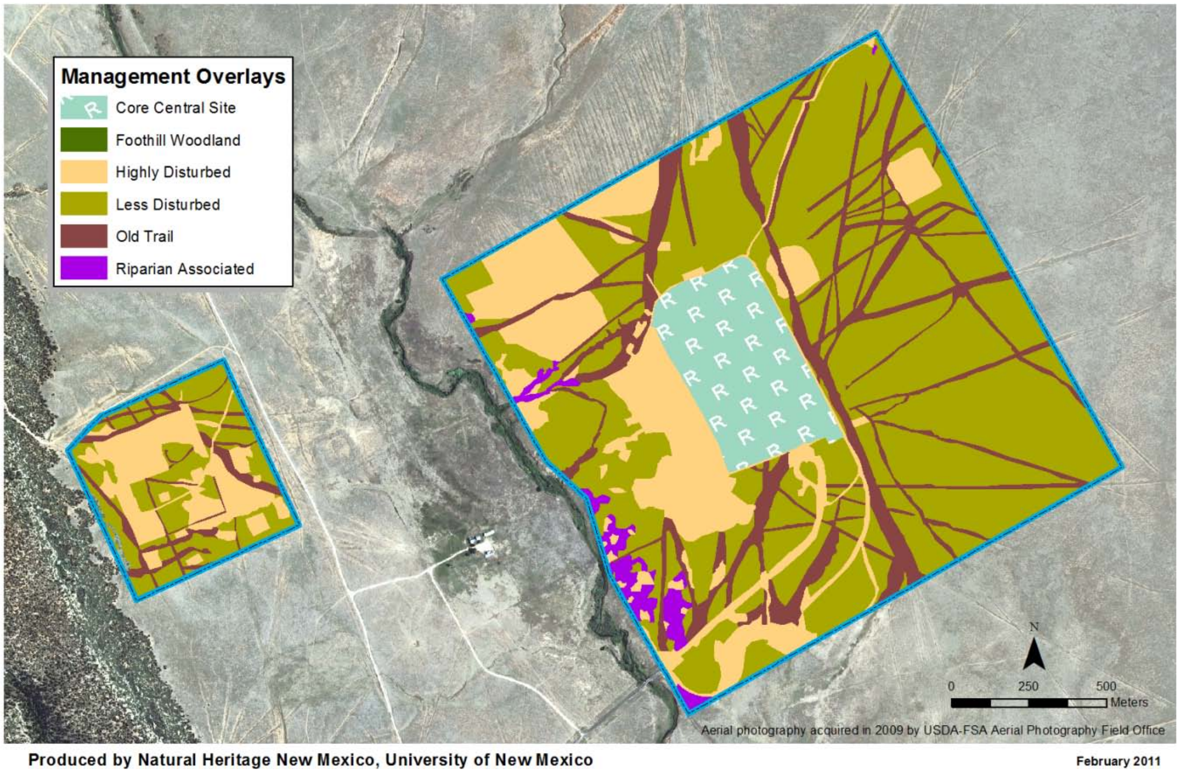

Figure 2-2. FOUN management overlays.

2.1.1. Reporting Units

As part of the initial scoping process, areas of management interest for the park were identified. It is important to note, however, that these do *not* represent any form of officially designated management zones. Such zones, if deemed appropriate, will be identified later during future stages of the planning process. Rather, these areas of management interest merely represent an initial attempt to identify areas that differ in the resources they contain, which may have implications for how an area is managed. Our intent for identifying them for this report is that they constitute a convenient unit of consideration as a management overlay (Figure 2-2).

2.1.2. Study Priorities: Resources and Indicators

It was neither practical nor feasible to conduct a condition assessment for all resources of interest to FOUN. Budget limitations necessitated limiting the assessment to resources of high priority. In addition, data were not available to assess all of the natural resources of high priority. First we asked whether the resource was considered a high priority by the park. We also confirmed our list of priorities with resource specialists to ensure we were not overlooking resources that may have high ecological significance, but which were not especially apparent to the park or other stakeholders. If a given resource was not considered a high priority by the park or specialists, it was not considered within the scope of this assessment. If, however, the resource was considered a high priority, we then determined whether sufficient data existed for an assessment and/or whether we had any reasonable basis to assess the current condition. In contrast to resources of lower priority, resources lacking data or an appropriate context were not excluded from the assessment; rather, they were included at a level less than that of a full assessment, but commensurate with the supporting information. This would include identification of important data gaps, as well as an appropriate descriptive narrative. The idealized process for determining resources, indicators, and data sets to include in the project is depicted in Figure 2-3.

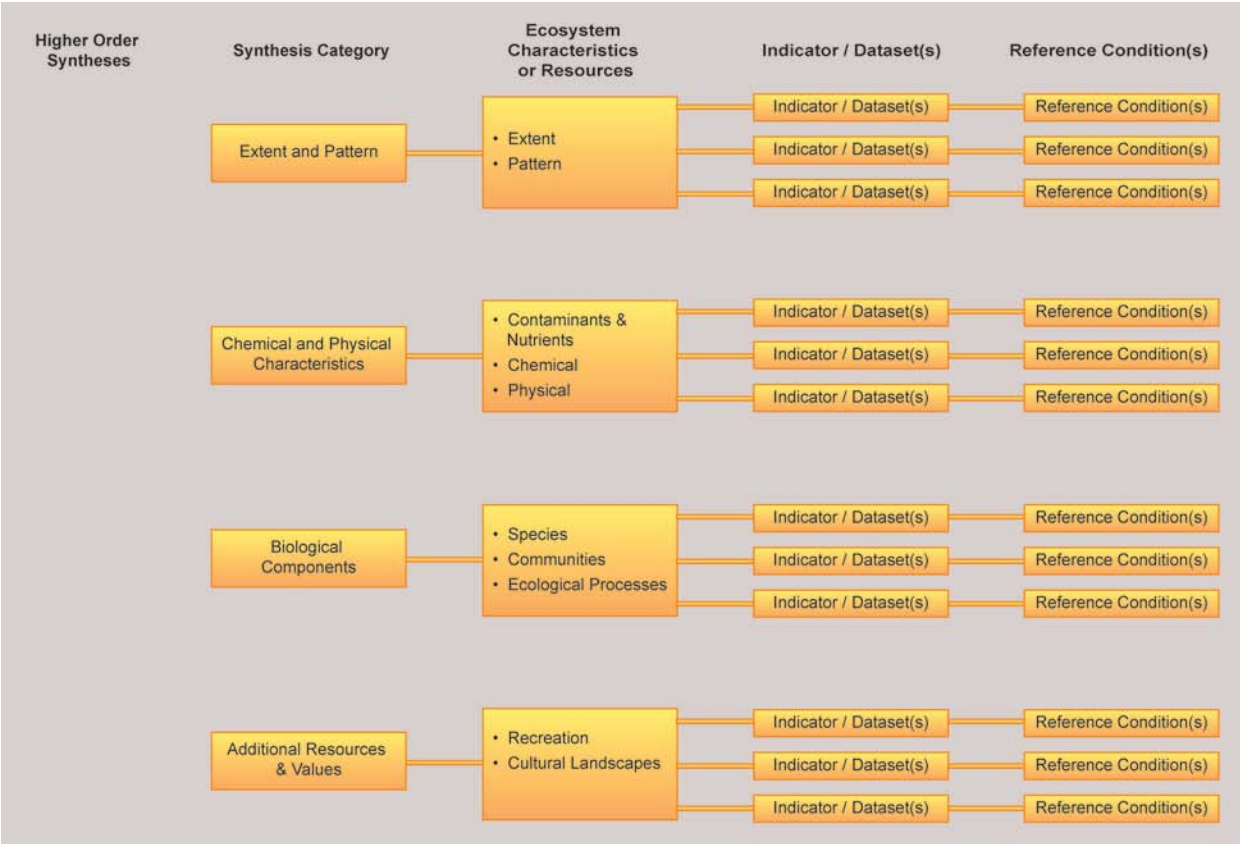

Figure 2-3.The sequence of primary criteria used to determine whether a given resource was included in the assessment, and at what level of consideration.

Table 2-1. Summary of resources presented in this assessment

Resource	Intended Assessment Level	Indicator	Reference Condition	Park Condition	Data Gaps	Confidence	Section in Report
Natural Lightscapes	Full	Light levels	Identified in night skies assessment	Report pending	Night skies assessment	NA	
Soundscapes	Full	Decibels, vibration level	Natural ambient level 24-26 dBA	27-36 dBA in prelim. report	Acoustic monitoring needed	NA	
Air Quality	Full	N deposition	< 1 good	2.12 kg/ha/y	None	High; better collected at park	
		S deposition, kg/ha/y	< 1 good	1.22 kg/ha/y	None	High; better collected at park	
		Ozone, ppb	≤ 60 ppb good	71.04 ppb	None	High; better collected at park	
		Visibility, dv	< 2 good	4.13 dv	None	High; better collected at park	
		Total mercury in rain, snow, ng/l	2-3 recommended	14-16 ng/l est.	None	High; better collected at park	
Geology	Full	Not available	Unavailable	Unavailable	Lacking geology evaluation report	NA	
Water Quality	Full	EPA standards	EPA standards or 1954, 1977 park data	No exceedences in 1954, 1977	Monitoring data for temp., ph, DO, Spec. Cond. needed	Low	
Groundwater	Partial	Static water level below ground surface	Stable over years	84-90 ft. Below ground for > 50y	Rigorous well test needed	Moderate	
Soils	Full	Measures in standard soils assessment	Unavailable	Unavailable	Soils assessment needed	High re: map	
Ruts	Full	Soil stability, minimal exotics	Absence of erosion, sedimentation, exotics	Fairly stable	Hydrology study and monitoring of erosion, exotics needed	High	
Adobe Fields	Full	Soil stability, minimal exotics	Absence of gophers, erosion, exotics invasion	Unknown	Survey and monitoring of erosion, exotics, gophers needed	NA	
Second Fort	Full	Soil stability, minimal exotics	Absence of gophers, erosion, exotics invasion	Unknown	Survey and monitoring of erosion, exotics, gophers needed	NA	

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Resource	Intended Assessment Level	Indicator	Reference Condition	Park Condition	Data Gaps	Confidence	Section in Report
Vegetation	Full	Plant diversity	Unknown	235 taxa	None	High re: species list	
		Native grassland condition, absence of livestock	Pre-settlement	Likely higher plant diversity at foun than surrounding grasslands	Data from undisturbed reference sites; comparison with fort union ranch	Low	
		Ruderal vegetation over cultural features	Absence of erosion, sedimentation, pocket gopher threats	Ruts currently stable, other features not assessed	Assessment and monitoring of second fort, adobe fields, etc.; gopher surveys	Low	
Wetland Vegetation	Partial	Not available	USACOE jurisdictional wetland conditions	Unknown	USACOE jurisdictional wetland assessment	Na	
Exotic Plants	Full	State, federally listed noxious weeds	None	2 state listed species	Ongoing monitoring	High	
		Dominance of exotic species	Absence of impacts on native species	Bindweed an immediate threat to native species	Ongoing monitoring	High	
		Other exotics	Absence of impacts on native species	Present but not threatening	Ongoing monitoring	High	
Birds	Full	Species richness	Target list	Meets target list	Data on wintering, migrating, density, trend	High	
Mammals	Full	Species richness	32 species on target list	16 species	Repeated surveys including un-surveyed taxa	Low	
Herpetofauna	Full	Species richness	33 species on target list	10 species	Repeated surveys including un-surveyed taxa using required methods	Low	

Note: NA = Not Applicable

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Table 2-2. Core Natural Resource Condition Assessment team

Name	Affiliation	Role	Team Function
Jeff Albright	NPS Water Resources Division	NPS Co-Lead/Key Official	Provides project direction consistent with NRCA Guidelines
Robert Bennetts	NPS Southern Plains Network	NPS Co-Lead	Provides project direction consistent with NRCA Guidelines
Kristine Johnson	Natural Heritage New Mexico, University of New Mexico	Principal Investigator	Leads NRCA study effort, working within NRCA Guidelines
Teri Neville	Natural Heritage New Mexico, University of New Mexico	GIS Coordinator	Provides primary GIS support
Marie Frias Sauter	NPS	FOUN Superintendent	Ensures direction is consistent with FOUN information needs

3. Natural Resource Condition

This chapter presents the background, analysis, and condition summaries for the 16 key resources in the project framework. The following sections discuss the key resources and their measures and reference conditions. The order of indicators follows the project framework (Table 2-1). The summary for each indicator is arranged around the following sections:

- Resource Description
- Data and Methods
- Reference Conditions
- Resource Description
- Condition of Data
- Data Gaps
- Literature Cited

3.1. Natural Lightscapes

3.1.1. Background

Astronomers were the first to notice that artificial light was impacting views of night skies, causing stars and faint objects to be lost from view due to reduced contrast with a lighter sky. Light pollution is the illumination of the night sky by artificial light sources, caused by outdoor lights aimed toward the sky or sideways. Light that escapes into the sky scatters through the atmosphere and brightens the night sky, thereby diminishing the view of stars and other bright objects. Air pollution increases this scattering (NPS 2007).

Light pollution disrupts the habitat of nocturnal animals, thereby impacting their ability to hide, hunt, and navigate. Light pollution can also affect the life cycles of plants and can annoy neighbors, which is called “light trespass.” Natural lightscapes can be integral to a park’s cultural landscape, especially in remote historical parks such as FOUN (NPS 2007).

National parks harbor some of the last remaining dark skies in the United States; however, because of the ability of light to travel long distances, even remote parks are not immune from light pollution. The NPS has identified night skies as one of the scenic vistas under its stewardship. Night skies at FOUN (Figure 3-1) are still relatively dark, and visitors have the rare opportunity to view vast and spectacular night skies, with only the wind and animal sounds as accompaniment. In addition to local light sources depicted in Figure 3-1, other light sources at greater distances (e.g., Albuquerque, NM) are likely to be visible at night (Chad Moore pers. comm.) FOUN has identified natural lightscapes as an important resource for this assessment (NPS 2007).

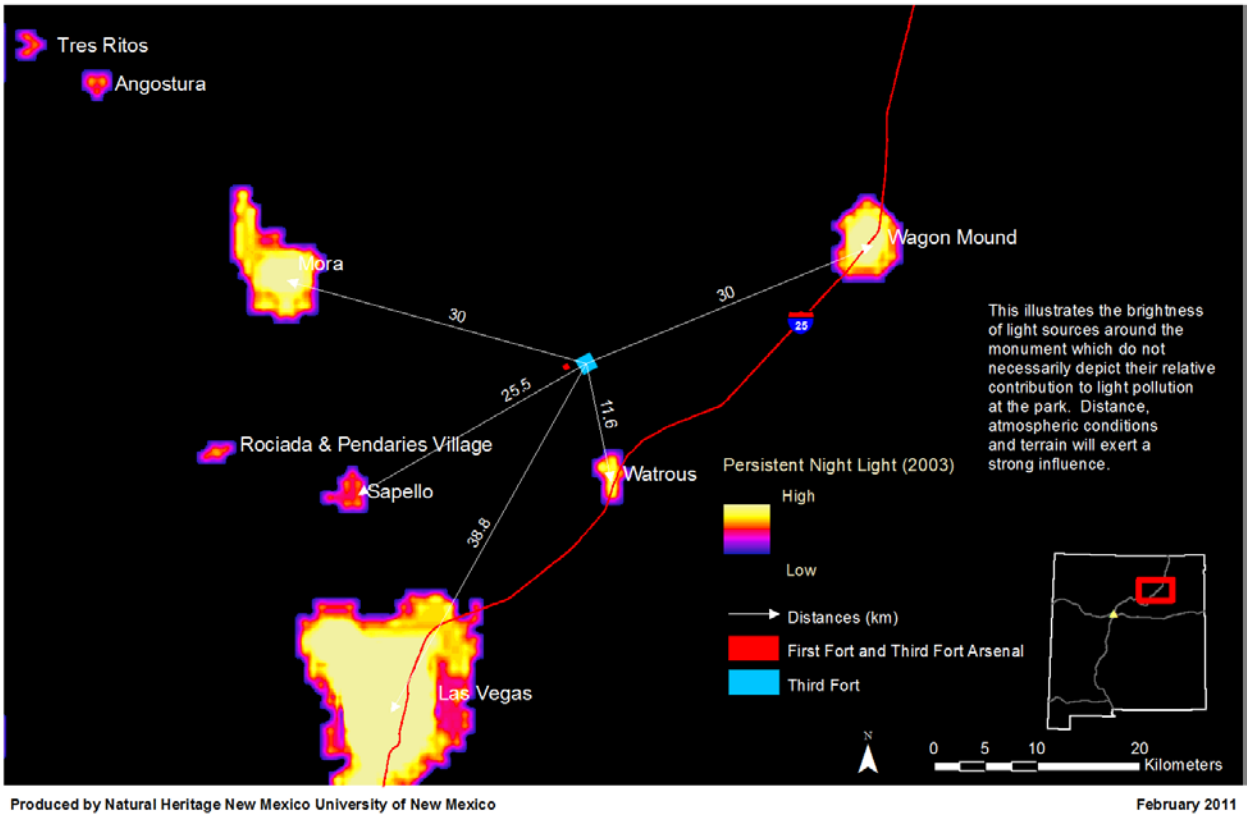

Figure 3-1. Threats to night skies at Fort Union National Monument using distance to and brightness of light sources near FOUN, from Elvidge et al. 1997.

3.1.2. Data and Methods

In February 2010, the NPS Night Sky Team visited FOUN and assessed the night skies of the park. The report from this assessment was not available as of this writing in November 2010.

3.1.3. Reference Conditions

The FOUN night sky assessment report will identify measures that can be used as reference conditions for a night sky assessment, for example, a natural lightscape lacking artificial light.

3.1.4. Resource Description

The night sky report will report on the current condition of night skies at FOUN.

3.1.5. Data Gaps

The night sky report has not yet been completed.

3.1.6. Literature Cited

Moore, Chad. Night Skies Team Leader, National Park Service, Fort Collins, CO. (970)267-7212. Chad_Moore@nps.gov.

Elvidge, C. D., K. E. Baugh, E. A. Kihn, H. W. Kroehl, E. R. Davis. 1997. Mapping city lights with nighttime data from DMSP operational linescan system. Photogrammetric Engineering and Remote Sensing, Volume 63:727-734. Data downloaded from http://www.ngdc.noaa.gov/dmsp/downloadV4composites.html.

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3.2. Acoustic Resources

3.2.1. Background

3.2.1.1. Sound Terminology

The natural soundscape is an inherent component of "the scenery and the natural and historic objects and the wild life" protected by the Organic Act of 1916. NPS Management Policies (§ 4.9) require the NPS to preserve the monument's natural soundscape and restore the degraded soundscape to the natural condition wherever possible. Additionally, the NPS is required to prevent or minimize degradation of the natural soundscape from noise (i.e., inappropriate/undesirable human-caused sound).

Although management policies currently refer to the term *soundscape* as the aggregate of all natural sounds that occur in a park, the Natural Sounds Program aims to update this terminology. Because the NPS works to protect and enhance park resources and visitor experiences, the Natural Sounds Program differentiates between the physical sound sources and human perceptions of those sounds. Currently, the Natural Sounds Program refers to the physical sound resources (i.e., wildlife, waterfalls, wind, rain, and cultural or historical sounds), regardless of audibility, at a particular location as the *acoustical environment*, while the human perception of that acoustical environment is defined as the soundscape. The Natural Sounds Program would like to move away from using soundscape as a blanket definition for both the physical sounds and the human perception of those sounds. Making this distinction will allow managers to create objectives for safeguarding both the acoustical environment and visitor experience.

The NPS recognizes the acoustical environment as a resource in itself, separate from its relationship to wildlife and visitors. This section of the document will focus specifically on the monument's acoustical environment. For a discussion on sound and its importance to wildlife and visitor experience, please see those sections of the document.

3.2.1.2. Characteristics of Sound

Humans perceive sound as an auditory sensation created by pressure variations that move through a medium such as water or air and measured in terms of amplitude and frequency (Harris 1998; Templeton and Sacre 1997). Noise, essentially the negative evaluation of sound, is defined as extraneous or undesired sound (Morfey 2001). Sound pressure level is proportional to sound power and is measured in decibels (dB). The decibel is a logarithmic scale unit commonly used to relate sound pressures to some common reference level, thus producing a smaller, more manageable range of numbers. The loudness of a sound as heard by the human ear is estimated by an A-weighted decibel scale, where the A-weighting provides a formula for discounting sounds at low (<1 kHz) and high (> 6 kHz) frequencies. This adjustment for human hearing is expressed as dB(A). For this discussion, the A-weighted values are used to describe potential effects on the monument's acoustical environment and soundscape. Table 3-1 provides examples of A-weighted sound levels.

Table 3-1. Examples of sound levels

Reference Sound	dB(A) Level[1]
Normal breathing	10
Leaves rustling	20
Crickets (16 feet)	40
Light traffic at 100 feet	50
Normal conversation (5 feet)	60
2 stroke snowmobile (30 mph at 50 feet)	70
Helicopter landing at 200 feet	80
Heavy truck or motorcycle (25 feet)	90
Thunder	100
Military jet (110 feet)	120
Shotgun firing	130

[1] An increase of 10 dBA represents a perceived (to human hearing) doubling of sound pressure level; that means 20 dBA would be perceived as twice as loud as 10 dBA, 30 dBA would be perceived as 4 times louder than 10 dBA, etc.

3.2.1.3. Importance of Sound

3.2.1.3.1 Wildlife

The preservation of the monument's acoustical environment is vitally important to overall ecosystem health. Peer-reviewed literature widely documents the critical role of sound in intra-species communication, courtship and mating, predation and predator avoidance, and effective habitat use. Additionally, wildlife can be adversely affected by sounds and sound characteristics that intrude on their habitats. While the severity of the impacts varies by species and other conditions, research strongly suggests that wildlife can suffer adverse behavioral and physiological changes from intrusive sounds (noise). Documented responses of wildlife to noise include increased heart rate, startle responses, flight, disruption of behavior, and separation of mothers and young (Selye 1956; Clough 1982; NPS 1994; US Department of Agriculture, Forest Service 1992; Anderssen et al. 1993).

When noise elevates ambient sound levels, signals that might otherwise have been detected and recognized are missed. The noise is said to mask these signals. Masking degrades an animal's auditory awareness of its environment and fundamentally alters interactions among predators and prey. Many animal species rely almost exclusively on sounds to locate their prey (e.g., owls, gleaning bats). Masking also affects acoustic communication. Animals have been shown to alter their calling behavior and shift their vocalizations in response to noise (Brumm and Slabbekoorn 2005; Patricelli and Blickley 2006; Slabbekoorn and Ripmeester 2008; Warren et al. 2006). These shifts have been documented in a variety of signal types: begging calls of bird chicks (Leonard and Horn 2007), alarm signals in ground squirrels (Rabin et al. 2006), echolocation calls of bats (Gilman and McCracken 2007), and sexual communication signals in birds and anurans (Brumm and Slabbekoorn 2005; Patricelli and Blickley 2006; Warren et al. 2006; Slabbekoorn and Ripmeester 2007; Parris et al. 2009). Vocal adjustment likely comes at a cost to both energy balance and information transfer; however, no study has addressed receivers. Some species are unable to adjust the structure of their sounds to cope with noise even within the same group of organisms (Lengagne 2008). These differences in vocal adaptability could partially explain why some species do well in loud environments and others do poorly (Patricelli and Blickley 2006; Slabbekoorn and Ripmeester 2007).

Some large herbivores have been observed to habituate to acoustic stimuli (Krausman et al. 1998; Weisenberger et al. 1996). Habituation is a decreased responsiveness to a stimulus upon repeated exposure. For several reasons, reports of habituation to noise should be interpreted with caution. A reduction in one form of response may represent a shift to another, unobserved mode of response rather than development of complete tolerance. A more tolerant population may be the result of sensitive individuals leaving the area (Bejder et al. 2006). Animals that remain may not have other viable options. Lastly, a completely habituated animal has learned to ignore a class of stimuli, some of which may contain biologically significant information.

3.2.1.3.2 Visitor Experience

Our ability to see is a powerful tool for experiencing our world, but sound adds a richness that sight alone cannot provide. In many cases, hearing is the only option for experiencing certain aspects of our environment. Natural sounds often present the best opportunities to find wildlife because animals can be heard at much greater distances than they can be seen. Noise impacts the acoustical environment much like smog impacts the visual environment; it obscures the listening horizon for both wildlife and visitors. Places of deep quiet are most vulnerable to noise. Therefore, wildlife in remote wilderness areas and park visitors who journey to these quiet places are likely to be especially sensitive to noise.

The opportunity to experience an unimpaired acoustical environment is an important part of overall visitor experience and enjoyment. This perception of the acoustical environment represents what is referred to as the soundscape (see the “Natural Soundscape” section for further clarification on definitions). Many natural sounds, such as bird songs or the rustling of leaves, can have a calming and relaxing effect. Sounds can also trigger memories.

Noise can distract visitors from the resources and purposes of the park. Increasingly, even those parks that appear as they did in a historical context do not sound like they once did. Natural sounds are being masked or obscured by a wide variety of human-caused sounds. Thus, soundscape preservation and noise management are complex tasks within the NPS mission of preserving park resources unimpaired for the enjoyment of future generations.

Visitors to national parks often indicate that an important reason for visiting the parks is to enjoy the relative quiet that parks can offer. In a 1998 survey of the American public, 72% of people identified opportunities to experience natural quiet and the sounds of nature as an important reason for having national parks (Haas and Wakefield 1998). Additionally, 91% of NPS visitors “consider enjoyment of natural quiet and the sounds of nature as compelling reasons for visiting national parks” (McDonald et al. 1995). In studies of visitor preferences, respondents consistently rate many natural sounds such as birds, other animals, wind, and water as very pleasing. As a result, the presence of unwanted, uncharacteristic, or inappropriate sounds can interfere with or alter the soundscape and degrade the visitors’ experience. Uncharacteristic sounds or sound levels affect visitors’ perceptions of solitude and tranquility and can be annoying. Visitor evaluations of annoyance are affected by many factors, including the setting in which the sounds occur, the visitor’s recreational activities, and their expectations of quiet and solitude.

Characteristics of the sound also contribute to levels of annoyance. Annoyance is related to rate of occurrence, duration, loudness, and sporadic nature of sounds (Newman et al. 2005).

Impacts to visitors can also be quantified at particular decibel levels (Table 3-2). These impacts could include increases in blood pressure and heart rate, sleep interruption, and speech interference. If the sound level goes over the particular decibel level listed in Table 3-2, the potential for that impact increases.

Table 3-2. Explanation of sound level values

Sound Levels (dBA)	Relevance
35	Blood pressure and heart rate increase in sleeping humans (Haralabidis et al. 2008)
45	World Health Organization's recommendation for maximum noise levels inside bedrooms (Berglund et al. 1999)
52	Speech interference for interpretive programs (US Environmental Protection Agency 1974)
60	Speech interruption for normal conversation (US Environmental Protection Agency 1974)

Sources:
Haralabidis et al. 2008
Berglund et al. 1999
US Environmental Protection Agency 1974

3.2.1.3.3 Cultural Soundscape

The primary mission for many national parks is to protect the resources and values related to the culture, ethnic heritage, and history of a group or a place. Many locations in national parks are significant because of the meaning, memories, and experiences people associate with them. Cultural resources include tangible materials such as structures and artifacts, as well as intangible aspects of cultural expression such as cannon fire, black powder demonstrations, and historical music. In protecting the monument's cultural soundscape (§ 5.3.1.7 of NPS Management Policies), the NPS improves a visitor's opportunity to understand our heritage in a direct and personally meaningful way.

An appropriate acoustical environment is an important element in the experience of cultural and historical resources in national parks. Unwanted or inappropriate sounds can detract from the visitor experience of the historical time period or cultural expressions associated with a site. Additionally, noise can distract visitors from opportunities for reflection about the historical setting and the solemnity of memorials, battlefields, prehistoric ruins, and sacred sites. In order to provide a more accurate interpretation of a monument's period of significance, it is important to manage parks as they would have appeared and sounded during that time.

3.2.2. Data and Methods

The first season of acoustic monitoring at FOUN was completed in August/September 2010 by the John A. Volpe National Transportation Systems Center. Additional monitoring is planned for the winter season. A preliminary report of the data collected during the first season has been developed (Lee 2011). A description of these data, along with a qualitative assessment of the monument's natural and cultural sounds and the management of unnatural sounds is included below.

3.2.3. Reference Conditions

A potential reference condition for natural sounds might be the current ambient sound level or the absence of human-caused sound. The cultural perspective suggests alternative, historical reference conditions. For example, the park might want the acoustical environment to resemble pre-Santa Fe Trail conditions. Another potential reference might be the sounds created by Fort Union at its peak activity, which would have included sounds from military drills, wagons, livestock, and Santa Fe Trail traffic. Planning will include a comparison of the current acoustical environment with various reference conditions.

The acoustic monitoring recently conducted at the park provides metrics for characterizing the acoustical environment at FOUN and identifying a quantitative reference condition for this resource. Natural ambient sound level refers to the acoustical conditions that exist in the absence of human-caused noise and represents the level from which the NPS measures impacts to the acoustical environment. Existing ambient sound level refers to the current sound intensity of an area, including both natural and human-caused sounds.

3.2.4. Resource Description

FOUN is located in a relatively remote area and is surrounded by only one neighbor, the Fort Union Ranch, owned by the Union Land and Grazing Company. Visitors to FOUN frequently have tranquil and transcendent experiences owing to the beauty of the night skies, open vistas, and sound of the wind in the prairie grasses. However, FOUN's current acoustical environment is quite different from that of the historical period the park commemorates. At its peak, Fort Union was the largest military operation in the Southwest and featured wagons, horses, oxen, cattle, and military drills. The military activity of the fort and the commerce associated with Santa Fe Trail made Fort Union a bustling, noisy, and dusty place. The cultural value of historical authenticity contrasts the current acoustical environment, which consists of predominantly natural sounds. Currently, unwanted human-caused sounds occasionally impact visitors' experience, wildlife, and the monument's acoustic resources.

3.2.4.1. Acoustical Conditions at the Monument

During August and September 2011, the John A. Volpe National Transportation Systems Center conducted acoustical monitoring at three sites (two remote sites and one near visitor center) within the monument. These sites were representative of either the dominant vegetation zones or management zone in the monument. The assumption is that similar wildlife, physical processes, and other sources of natural sounds occur in similar areas with similar attributes. The acoustical monitoring effort provided information on natural and existing ambient sound levels and types of sound sources.

Natural ambient sound levels measured at the three sites ranged from 24–26 dBA. Existing ambient sound levels ranged from 27–36 dBA (Lee 2011). The similarity between the natural and existing ambient provide evidence of the quiet nature of the monument and dominance of natural sounds. In the two remote areas, natural sounds were audible between 70% and 88% of the time (over a 12-day). At the visitor center site, natural sounds were audible 28% of the time. Natural sounds included birds, wind, water and insects (see section 3.2.4.2 for detailed description of natural sounds). The dominant human-caused sound heard at the two remote areas was aircraft (see section 3.2.4.3 for detailed description of human-caused sounds). Time audible for aircraft ranged from 11–22% of the daytime hours. At the visitor center site, aircraft was heard 12% of the day, while sounds related to visitor activity and maintenance work accounted were heard 60% of the day.

3.2.4.2. Natural and Cultural Sounds

The absence of noise is the most characteristic feature of the acoustical environment at FOUN. Frequently, only the wind and the sound of the blowing grasses can be heard. Electrical storms provide dramatic shows of thunder and lightning in all directions. The occasional songs of grassland birds or honking of geese flying overhead punctuate the nearly constant sound of the wind. Frogs call in the sewage pond and Wolf Creek; insects buzz in the grass. Coyote calls are rare; more common is the rush of air over raven wings.

Cultural sounds support the visitor’s experience of the monument’s historical resources. Public events are held by the park and include living history groups, which portray period military units. At these events, the military units perform drills in Spanish and English and visitors hear bugle calls and watch black powder demonstrations, including firing of muskets and canons. Using historical musical instruments, bands perform military marches and dance music, and at other park events such as the Candlelight Tours, violinists have performed. In the fort, visitors may hear taped bugle calls throughout the day as they would have sounded while the fort was in operation. The monument does not attempt to recreate all aspects of the historical acoustical environment, avoiding, for example, livestock and wagons, and preferring to provide evocative sounds, such as daily bugle calls, to convey historical meaning.

3.2.4.3. Human-caused Sounds

The monument’s ruins consist of sun-baked, adobe brick and stone construction, with the earliest dating to 1863 when construction of the fort post, quartermaster depot, and ordinance depot occurred. Now without roofs and many walls, the fort ruins, totaling about 125,000 square feet, are perhaps the largest collection of adobe ruins in the United States. The structurally fragile walls are braced with steel supports. Wind, rain, hail, ice, and snow all impact the ruins. The monument crew, 8–20 preservation workers during summer seasons, continues a more than 50-year effort of year-round stabilization and preservation of the adobe ruins.

The human-caused sounds with the largest potential impact on FOUN’s cultural resources, acoustic resources, visitors, and wildlife are produced by private aircraft, particularly rotary aircraft. Private pilots apparently use the park as a landmark and often drop low when flying over the park. Various types of aircraft have been observed flying over the park at altitudes as low as 300–500 feet. Park staff are concerned that low flying aircraft, particularly helicopters, threaten the structural integrity of the ruins. Rotor wash and the intense beating of the blades could damage the fragile adobe brick walls, causing further destabilization of the historical structures. Additionally, the noise can be a nuisance to visitors walking on interpretive trails among ruins and to park staff who must work to stabilize the ruins and perform preservation maintenance.

Occasionally, private planes such as crop dusting or surveying aircraft fly over or neat the park. Visitors parking is far enough from the ruins that the noise from the vehicles probably does not significantly impact the visitor experience.

3.2.4.4. Management of Unnatural Sounds

FOUN's primary means of management of unnatural sounds is to attempt to investigate the sources of aircraft noise. Park staff consistently make observations of aircraft, but they are rarely able to see identifying information or make photographs. Without identification numbers or photographs, it is nearly impossible to determine the owners of the aircraft. The monument is located in the middle of VHF Omnidirectional Range (a flight navigation system) flight vector V 263-611 on the Denver Sectional Aeronautical Chart.

FOUN is an "air tour management park," meaning that the Federal Aviation Administration has granted aviation companies interim authority for 32 flights per year over the park. The Natural Sounds Program works with the FAA to create Air Tour Management Plans for parks, but an Air Tour Management Plan has not been developed for FOUN. FOUN works with the Natural Sounds Program and Intermountain Regional Office to reduce overflight impacts as much as possible.

The monument is replacing outdated wayside interpretive recordings. These are now being replaced by new waysides with companion audio devices and with the option of auditory recordings for the visually impaired. This change will help preserve quiet around the ruins.

3.2.5. Condition of Data

Confidence is high in the 2010 data, but data have been collected for only one season and a final report is needed.

3.2.6. Data Gaps

A final report for the 2010 work is needed. FOUN managers are hoping to collect acoustical data in the winter season in the next one to two years. In addition, vibration monitoring would help address the question of impacts to the ruins. Currently, the Natural Sounds Program does not conduct vibration monitoring but could arrange for the work to be done by contract.

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3.3. Air Quality

3.3.1. Background

Poor air quality can potentially affect plants, wildlife, water quality, and cultural resources in national parks. The goal of the NPS Air Resources Division is to preserve, protect, enhance, and understand air quality and other resources sensitive to air quality in the National Park System. The U.S. Environmental Protection Agency (USEPA) sets standards for air quality in the United States, and the NPS Air Resources Division administers an air monitoring program that measures air pollution in national parks. These data are used to assess long-term air pollution trends that affect park resources and to determine compliance with National Ambient Air Quality Standards (NPS 2010). In addition, FOUN has identified air quality as an important resource for this condition assessment.

The main types of data NPS uses to assess air quality are those for ozone, nitrogen (N) and sulfur (S) deposition, and visibility. Other parameters such as mercury are important in specific parks.

3.3.1.1. Ozone

Ozone in the stratosphere protects against ultraviolet radiation, but ground-level ozone is an oxidizing pollutant that affects human health and vegetation. The main sources of ground-level ozone are vehicles, factories, and power plants. Although ozone sources are primarily located in urban areas, ozone precursors can travel long distances to national parks in remote areas. Human health effects include respiratory problems, such as asthma and reduced lung capacity, and impaired immune function. Laboratory studies have documented impacts to birds and other wildlife, but these findings have not been confirmed in the wild (NPS 2005).

Ample evidence does exist on the impacts of ozone to vegetation. Ozone enters plants through the stomata and oxidizes plant tissues, causing leaf injury and affecting growth (NPS 2005). Bioindicator species for ozone injury meet most or all of the following: (1) they exhibit foliar symptoms recognizable by experts; (2) their ozone sensitivity has been confirmed at realistic ozone concentrations in exposure chambers; (3) they are widely distributed regionally; and (4) they are easily identified in the field. The NPS has identified two ozone-sensitive plant species for FOUN, *Artemisia ludoviciana* and *Rhus trilobata.* A 2004 risk assessment of Southern Plains Inventory and Monitoring Network parks found FOUN to be at low risk for ozone damage to plants (NPS 2005).

3.3.1.2. Deposition

When combined with water, atmospheric nitrogen and sulfur compounds can affect soils, water, and vegetation by forming acids. FOUN is unlikely to be greatly impacted by acidification, however, because soils and water in the area are generally high in cations such as calcium and magnesium that have acid-buffering effects. In contrast, the fertilization effects of deposited nitrogen compounds can impact nitrogen-limited systems in the Southwest. Native plants adapted to low-nitrogen soils can be out-competed by nitrogen-loving exotics. Thus, excessive deposited nitrogen could affect FOUN by altering species composition, increasing biomass, and, as a consequence, increasing fire frequency (NPS 2005).

3.3.1.3. Visibility

Pollution affects visibility − how far and how well visitors can see landscapes and other features. Visibility is thus an indicator of pollutant particles and is an important value in national parks. Visibility is not monitored within any of the SOPN parks, but data on visibility-impairing particles and gases are collected at nearby monitoring sites through the Interagency Monitoring of Protected Visual Environments (IMPROVE) program. Each IMPROVE site has a fine-particle sampler that measures the types and amounts of particles that obscure visibility (NPS 2005).

3.3.1.4. Mercury

Mercury is a persistent, bioaccumulative toxin, which means that it persists in the environment by cycling between air, water, and soil in various chemical forms, and it bioaccumulates in plant and animal tissues. Some bacteria convert mercury to methylmercury, a form that is more toxic than inorganic mercury. As methylmercury moves up the food chain, it becomes concentrated at higher levels, as much as a million-fold in aquatic food chains. Humans bioaccumulate methylmercury by consuming fish containing mercury. Mercury is a neurotoxin; low-level exposure is associated with learning disabilities in children. It also interferes with reproduction in fish-eating animals, and both methylmercury and mercuric chloride are potentially carcinogenic to humans (NADP 2008). Most mercury deposition comes from the burning of coal for electricity production.

3.3.2. Data and Methods

Two IMPROVE Program visibility-monitoring sites are located close to FOUN, at Bandelier National Monument and Wheeler Peak in New Mexico. A National Atmospheric Deposition Program/National Trends Network (NADP/NTN) site located at Bandelier National Monument monitors precipitation chemistry (NPS 2005). Mercury wet-deposition monitoring stations are located at Valles Caldera National Preserve in Sandoval County, New Mexico, and Navajo Lake in Rio Arriba County, New Mexico (Mercury Deposition Network 2010).

3.3.2.1. Ozone

The following description of the NPS standards for ozone is extracted from NPS (2009):

> *The ozone standard is used as a benchmark for rating current ozone condition. This standard was revised in 2008 in order to be more protective of human health. To attain this standard, the three-year average of the fourth-highest daily maximum eight-hour average ozone concentrations measured at each monitor within an area over each year must not exceed 75 parts per billion (ppb). To derive an estimate of the current ozone condition at parks, the five-year average of the annual fourth-highest, eight-hour ozone concentration is determined for each park from the interpolated values described above. If the resulting five-year average is greater than or equal to 76 ppb then the condition Significant Concern is assigned to that park. Moderate condition for ozone is assigned to parks with average five-year, fourth-highest, eight-hour ozone concentrations from 61 to 75 ppb (concentrations greater than 80 percent of the standard). Good condition for ozone is assigned to parks with average five-year ozone concentrations less than 61 ppb (concentrations less than 80 percent of the standard).*

Ozone concentration	
Significant Concern	≥ 76 ppb
Moderate	61-75 ppb
Good	≤ 60 ppb

3.3.2.2. Deposition

The following description of the NPS standards for deposition is extracted from NPS (2009).

> *Park scores for current condition of atmospheric deposition were based on wet deposition because dry deposition data is not available for most areas. Wet deposition for sites within the continental U.S. is calculated by multiplying [nitrogen (N)] or [sulfur (S)] concentrations in precipitation by a normalized precipitation amount. (For sites outside the continental U.S., where interpolations cannot be calculated and normalized precipitation amounts are not available, five-year averages of on-site deposition are used. Deposition data are obtained from the National Atmospheric Deposition Program.)*
>
> *Several factors are considered in rating deposition condition, including natural background deposition estimates and deposition effects on ecosystems. Estimates of natural background deposition for total deposition are approximately 0.25 kilograms per hectare per year (kg/ha/yr) in the West and 0.50 kg/ha/yr in the East for either N or S. For wet deposition only, this is roughly equivalent to 0.13 kg/ha/yr in the West and 0.25 kg/ha/yr in the East. Certain sensitive ecosystems respond to levels of deposition on the order of 3 kg/ha/yr total deposition, or about 1.5 kg/ha/yr wet deposition. Evidence is not currently available that indicates that wet deposition amounts less than 1 kg/ha/yr cause ecosystem harm. Therefore, parks with wet deposition less than 1 kg/ha/yr are considered to be in Good condition for deposition; parks with from 1-3 kg/ha/yr are considered be in Moderate condition; parks with greater than 3 kg/ha/yr are considered to have a Significant Concern for deposition.*

Deposition Condition	Wet Deposition (kg/ha/y)
Significant Concern	> 3
Moderate	1-3
Good	< 1

> *Scores for parks with ecosystems potentially sensitive to N or S were adjusted up one category (e.g., a park with N deposition from 1-3 kg/ha/yr that contains N-sensitive ecosystems would be assigned the deposition condition Significant Concern).*

3.3.2.3. Visibility

The following description of the NPS standards for visibility is extracted from NPS (2009).

> *Individual park scores for visibility are based on the deviation of the current Group 50 visibility conditions from estimated Group 50 natural visibility conditions, where Group 50 is defined as the mean of the visibility observations falling within the range from the 40th through the 60th percentiles. For parks within the continental U.S., current visibility*

is estimated from the interpolation of the five-year averages of the Group 50 visibility. For sites outside the continental U.S., five-year averages are computed from on-site data. Visibility in this calculation is expressed in terms of a Haze Index in deciviews (dv). As the Haze Index increases, the visibility worsens. The visibility condition is expressed as

Visibility Condition = current Group 50 visibility – estimated Group 50 visibility under natural conditions.

Good condition is assigned to parks with a visibility condition estimate of less than two dv above estimated natural conditions. Parks with visibility condition estimates ranging two to eight dv above natural conditions are considered to be in Moderate condition, and parks with visibility condition estimates greater than eight dv above natural conditions are considered to have a Significant Concern. The dv ranges of these categories, while somewhat subjective, were chosen to reflect as nearly as possible the variation in visibility conditions across the monitoring network.

Visibility Condition	Current Group 50 – Estimated Group 50 Natural (dv)
Significant Concern	> 8
Moderate	2-8
Good	< 2

3.3.2.4. Mercury

Deposition is a function of concentration and amount of precipitation. The small volume of rain and snow in New Mexico results in a relatively low wet-deposition rate. However, in the Southwest, most mercury probably falls as dry deposition in the form of gases or particles; thus total deposition could be quite high (Ellen Porter, NPS Air Quality Division, pers. comm.).

3.3.3. Reference Conditions

Because ozone concentrations equal to or less than 60 ppb are considered to be good (NPS 2009), we use this cutoff as the reference condition for ozone. Nitrogen and sulfur depositions of less than 1 kg/ha/y are considered to be good (NPS 2009), and we use this cutoff as the reference condition for deposition. Because visibility less than 2 deciviews (dv) above the natural condition is considered to be good (NPS 2009), we use this cutoff as our reference condition for visibility. The NPS Air Resources Division recommends a reference condition value for total mercury concentrations in rain and snow within the range of 2–3 ng/l, based on estimated pre-industrial natural background values (Meili et al. 2003; Schuster et al. 2002).

3.3.4. Resource Description

Ozone concentration at FOUN is 71.04, higher than the reference condition. This value places the park in the moderate range for ozone (NPS 2009). These condition ranges are likely to be revised after August 2010, when the EPA is planning to set an even more protective ozone standard no higher than 70 ppb.

Nitrogen and sulfur deposition at FOUN are 2.12 and 1.22, respectively. Both quantities are higher than the reference condition. Deposition at FOUN is rated as moderate for both nitrogen and sulfur (NPS 2009).

Visibility at FOUN is 4.13 dv, higher than the reference condition. The NPS rates FOUN visibility as moderate (NPS 2009).

Mercury concentrations in rain at FOUN are estimated to be in the 14–16 ng/l range (NADP 2010), some of the highest concentrations in rain and snow in the country. The probable source is coal-fired power plants.

Deposition is a more accurate representation of mercury loading on the ecosystem than is concentration, and wet deposition in the area is relatively low at 4–6 $\mu g/m^2$/year (National Atmospheric Deposition Program 2010). Data on mercury dry deposition or background concentration are not available for FOUN (Caldwell 2006; Ellen Porter, NPS Air Quality Division, pers. comm.). However, in one recent study, measurements of dry deposition at Caballo Reservoir in Sierra County, New Mexico, were estimated at 5.9 $\mu g/m^2$/year, compared to wet-deposition rates of 4.2 $\mu g/m^2$/year from a nearby Mercury Deposition Network site (Caldwell 2006). This paper suggests that dry-deposition rates can be higher than wet-deposition rates in arid south-central New Mexico. Although measured mercury wet-deposition rates in New Mexico are some of the lowest in the nation, it is likely that these wet-deposition rates significantly underestimate the actual amount of mercury that is entering the ecosystem at FOUN (Ellen Porter, NPS Air Quality Division, pers. comm.).

In summary, total mercury concentrations in rain and snow at FOUN are much higher than the recommended reference condition (14.2 vs. 2–3 ng/L). Although mercury wet deposition is relatively low in the area, dry deposition, which is unknown, likely adds significant mercury to the ecosystem. Given the high total mercury concentration in rain and snow, atmospheric mercury from coal-fired power plants in the region is likely a major mercury source. This hypothesis is corroborated by the relatively high mercury concentrations in Pecos River fish (Johnson et al. 2011).

3.3.5. Condition of Data
Confidence in the data from the above air-quality monitoring stations is high. There is no information on how these values might differ if data were collected at the park.

3.3.6. Data Gaps
The only information available for air quality at FOUN comes from monitoring stations in other parts of New Mexico. Although data from the monument would be desirable, air-quality monitoring stations are widespread, and data from the monument itself are therefore unlikely to be forthcoming. The NPS Air Quality Resources Division considers the data from these monitoring stations to be reliable for their purposes.

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3.4. Geology

3.4.1. Resource Description

Geologic features and processes underlie and influence park ecosystems and are therefore important natural resources to be included in NRCAs. The Geologic Resource Evaluation Program, administered by the NPS Geologic Resources Division, carries out geologic inventories of parks. The goal of the Geologic Resource Evaluation Program is to provide each park with a digital geologic map, a resource evaluation report, and a geologic bibliography.

3.4.2. Data and Methods

On March, 28 2006, the Geologic Resources Division held a scoping meeting to discuss FOUN geologic resources, address the status of existing maps, assess resource management needs, and identify monitoring and research needs. Participants included staff from the NPS Geologic Resources Division, FOUN, Pecos National Historical Park, Colorado State University, and the New Mexico Bureau of Geology and Mineral Resources. Outcomes of the scoping process include the scoping summary (NPS 2006), a digital geologic map (available from the Natural Resource Information Portal Reference Application at https://nrinfo.nps.gov/Reference.mvc/Reference , and a geologic evaluation report, which was not completed as of July 2010. Except where noted, the information in this chapter is condensed from the scoping summary (NPS 2006).

Geologic data are useful for helping to identify FOUN's historical places and events, such as the Sante Fe Trail, quarries and their building stones, and adobe fields. Geologic information can also assist in identifying potential threats to cultural resources, such as erosion and seismic activity. The FOUN geologic map, published in 1974 by the US Geological Survey, covers the Fort Union quadrangle (Johnson 1974). This map was digitized by the Geologic Resources Division. Natural Heritage New Mexico created Figure 3-2 for this report using the digital data from the Geologic Resources Division.

3.4.3. Reference Conditions

Reference conditions for geology have not been identified, due to the lack of a final geologic evaluation report. However, a few reference conditions that might be useful for processes of interest relate to soil erosion. In the past, winds caused soil erosion, but bare soil has now mostly been covered in vegetation, and wind erosion is no longer an issue. The park could adopt the absence of wind erosion and blowing dust as a reference condition for soils. The Santa Fe Trail ruts, corrals, and areas of clay excavation could be considered disturbed lands, but they are also cultural resources which the park wants to preserve. For this type of feature, a reference condition of no further erosion could be adopted. These and other disturbed features of cultural importance are discussed in the Ruts, Adobe Fields, and Second Fort and Vegetation Communities chapters.

Earthquakes could pose potential threats to the adobe ruins. A reference condition might be the absence of seismic effects on the ruins. However, no seismic activity is known to have impacted the ruins in the past (Figure 3-3), this reference condition would appear to have little current relevance. A potential reference condition for Wolf Creek could be that it continues not to impact the sewage lagoon.

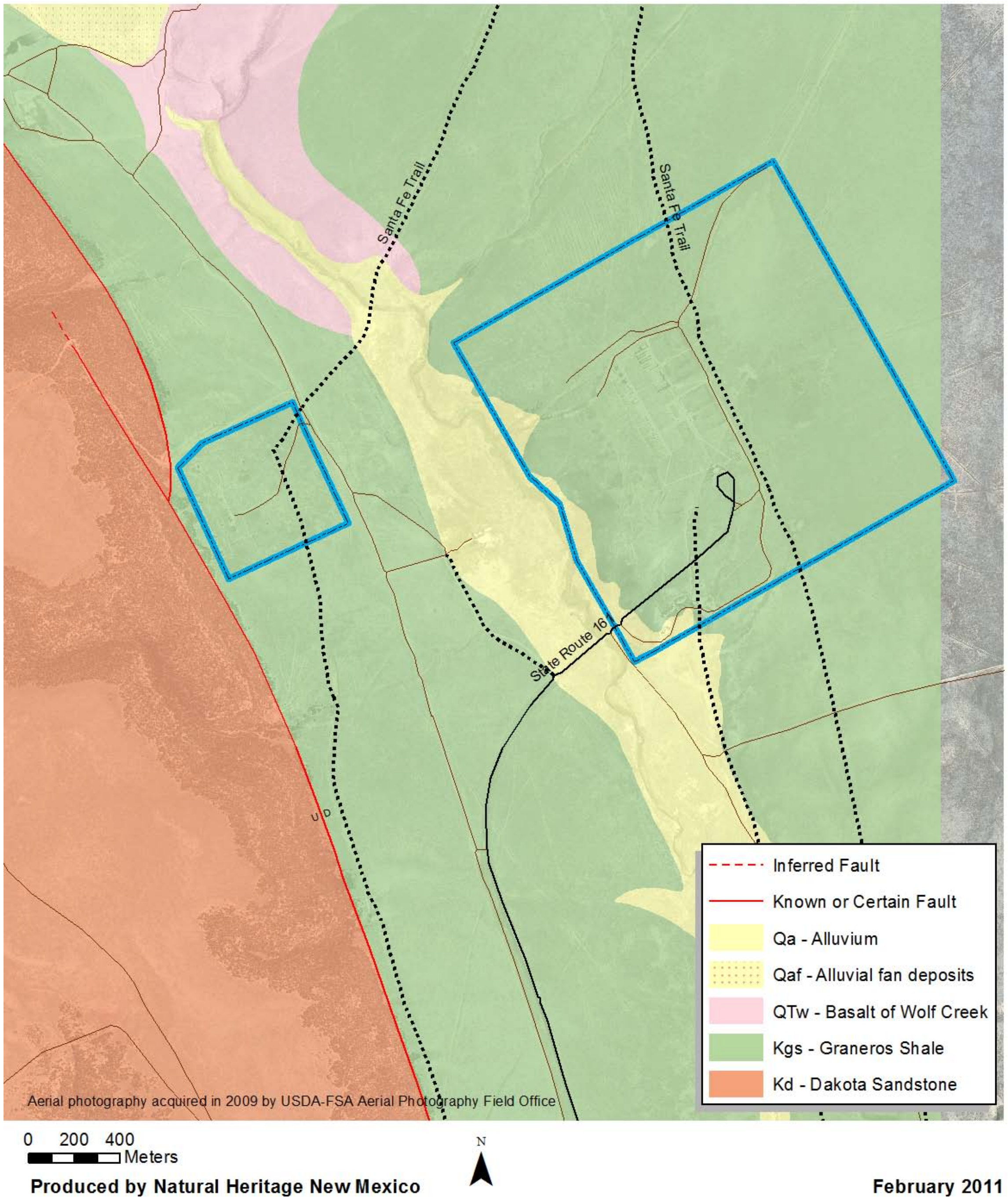

Figure 3-2. Geologic map of FOUN. Produced by Natural Heritage New Mexico from 1974 U.S. Geological Survey digital data provided by NPS Geologic Resources Division.

3.4.4. Resource Description

FOUN sits at the western edge of the Great Plains, in the Pecos Valley section of the Great Plains Province. The Sangre de Cristo Mountains to the west are part of the southern Rocky Mountains. This portion of the Great Plains west of the 100th meridian is known as the High Plains. The information in this section is taken from Price (2010).

In this part of the High Plains, erosion has removed the thick Tertiary sedimentary rocks evident to the north, exposing Cretaceous marine sediments, which are in turn covered in places with later Tertiary volcanic rock. The monument sits on Upper Cretaceous Graneros Shale (Figure 3-2). Dakota Group sandstones are exposed in the cliff at the turnoff from Interstate 25 Exit 366 and on the west side of New Mexico 161 between Interstate 25 and FOUN. Black Mesa, to the northwest of the monument, is covered with over 35 m of basalt from the Ocate Volcanic Field.

During the late Cretaceous, the interior of North America from northern Canada to Mexico was largely covered by a vast inland sea called the Western Interior Seaway. The seaway was present for 30 million years, peaking in area about 90 million years ago. Dakota Sandstone was deposited as this sea first advanced. The younger Graneros Shale was formed from muds deposited in deeper waters as the shoreline migrated south and southwest. Shorelines likely migrated forward and backward through time, creating complex, interbedded rock types that are sometimes difficult to classify.

The Rocky Mountains, including the Sangre de Cristos, were born during the Laramide orogeny, between 70 and 30 million years ago. This period also marked the end of the Western Interior Seaway toward the end of the Cretaceous. Enormous volumes of sediment eroded from the rising Rocky Mountains and accumulated on the High Plains, followed by uplift over the past 5 to 10 million years. Rivers such as the Pecos and Canadian incised their channels into this thick sedimentary layer.

Volcanic features near FOUN are part of the Ocate volcanic field of the Jemez Lineament, which stretches from the Raton/Clayton area through the Valles Caldera, Mount Taylor, the Zuni-Bandera Volcanic Field, and into Arizona. This field was active from about eight to one million years ago. Black Mesa to the northwest of the park is covered in black Pliocene basalts. A young lava flow (about 1.6 million years) originates at Maxson Crater east of the park and follows the Mora River to its confluence with the Canadian River. The Turkey Mountains to the north resulted from a laccolith and are now surrounded by younger lavas of the Ocate volcanic field.

3.4.4.1. Geologic Features, Processes, and Issues

The only surface water near FOUN is Wolf Creek, an intermittent stream tributary of the Mora River that flows along the southwestern edge of the boundary of the FOUN Third Fort Unit (Edwards Aquifer Research and Data Center 2007). It flows near the monument's sewage lagoons and could affect the integrity of the lagoons (NPS 2006).

No caves or karstic features are known on FOUN, but lava tubes are thought to occur in the nearby volcanic flows. Geochronological dating data are available for many of these flows (Wilks and Chapin 1997 and Olmstead 2000 in NPS 2006).

Mass wasting is not a major issue at FOUN, but rockfall does occur from the Dakota Sandstone cliffs outside the park boundary to the west of the First Fort and Third Fort Arsenal Unit. A small amount of displacement has occurred on the Fort Union fault that passes near the monument (Figure 3-2).

Seismic catalogues indicate that seismic activity has occurred in the vicinity of FOUN, although no earthquakes have been recorded at the park (Figure 3-3; Sanford et al. 2002, 2006; Morton 2008). Seismic activity could dislodge boulders that could impact the ruins. The Fort Union fault lies along the western boundary of the First Fort and Third Fort Arsenal Unit.

Disturbed lands at FOUN often represent important cultural resources such as clay excavation for adobe production or Santa Fe Trail ruts. Dust storms were a characteristic occurrence in 1850–1890 when FOUN was occupied by a thousand people and two thousand horses. Today, the vegetation is restored and grazing no longer occurs. Although dust storms can still occur on occasion, wind erosion is not a significant concern.

No fossil discoveries have been reported from FOUN, but paleontological resources have been found in Cretaceous Graneros Shale from other areas and so would also be expected at FOUN. Kauffman et al. (1969, cited in Koch and Santucci 2003) describe the following biostratigraphic zones in Graneros Shale from the Raton Basin, from oldest to youngest: *Ostrea beloiti*, *Inoceramus bellvuensis*, *Calycoceras* spp., *Acanthoceras wintoni*, and *Ostrea noctuensis*. Additional fauna from the Graneros Shale include the following bivalves and gastropods: *Callistina lamarensis*, *Euomphalceras lonsdalei*, *Tarrantoceras stantoni*, *Johnsonites sulcatus*, *Exogyra columbella levis*, *Exogyra columbella columbella*, *Crassatellia excavata*, and *Turritella* cf. *thompsonina* (Kauffman et al. 1969). Eicher (1965, cited in Koch and Santucci 2003) found specimens of Foraminifera from Graneros Shale in Colorado, Kansas, Utah, and Wyoming. Most were arenaceous benthonic species, with some calcareous planktonic and rare calcareous benthonic species. That study found five new species and one new subspecies: *Trochamminoides apricarius*, *Haplophragmoides gilberti*, *Ammobaculites impexus*, *Ammobaculoides mosbyensisi*, *Verneuilina alameda*, and *Trochammina rutherfordi mellariolum*.

3.4.5. Condition of Data

Without the geologic evaluation report and identified reference conditions for FOUN, it is not possible to conduct a complete assessment this resource. Confidence in this assessment is therefore low.

3.4.6. Data Gaps

As of July 2010, the geologic evaluation report for FOUN was not complete. The geologic evaluation for FOUN cannot be completed without this final report. The presence of paleontological resources in other Cretaceous Graneros Shale deposits suggests that undiscovered fossil resources might occur at FOUN. However, excavation to survey for fossils would likely conflict with the conservation of soil and cultural resources.

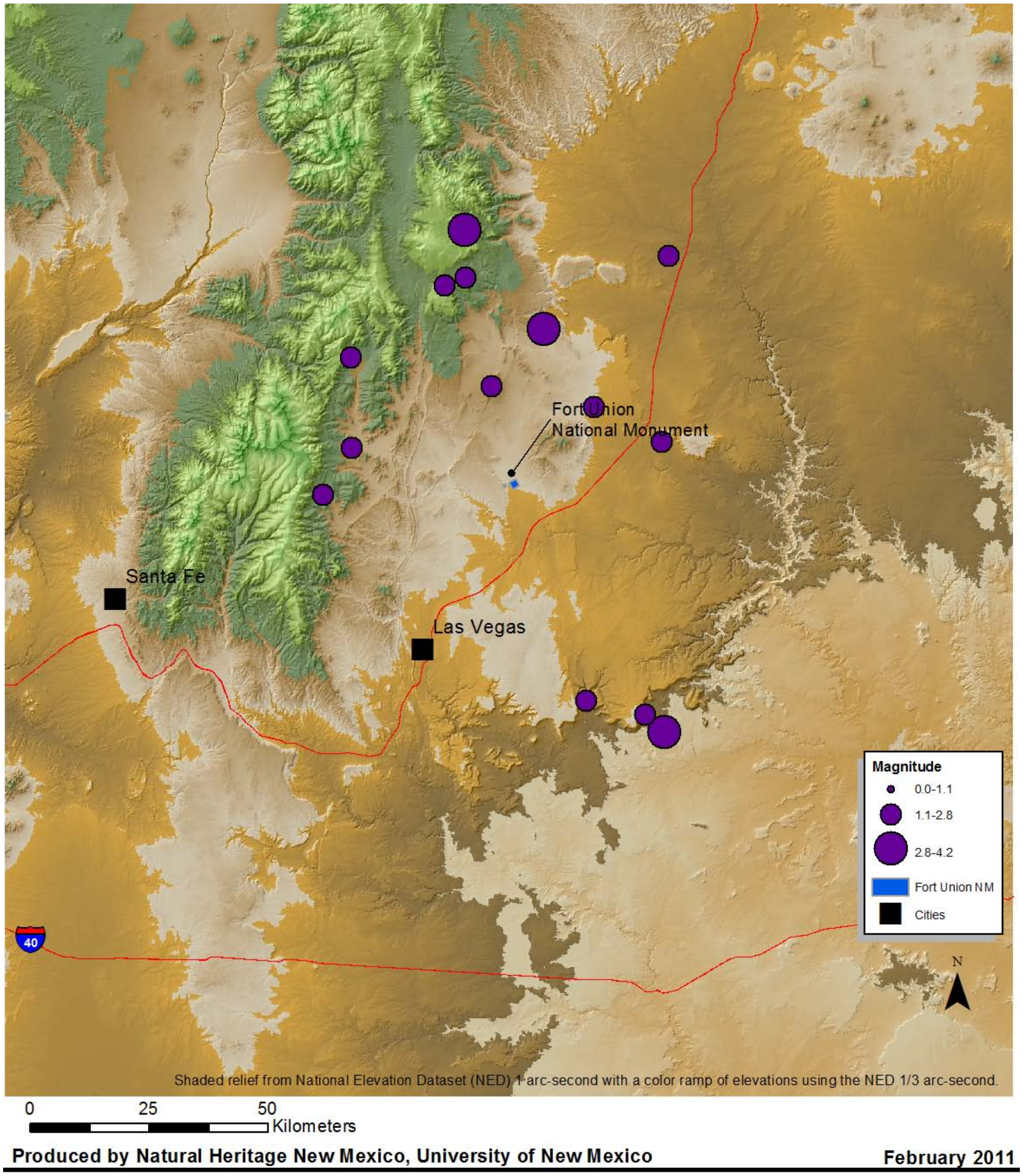

Figure 3-3. Earthquakes detected within 0.5 degrees of FOUN, 1962–1998. Data from Sanford et al. 2002, 2006 and Morton 2008.

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3.5. Surface Water Quality

3.5.1. Background

Surface water is crucial for riparian ecosystems, aquatic organisms, wildlife, and humans in national parks. The Southern Plains Inventory and Monitoring Network identified surface water quality as a vital sign for its parks, and FOUN identified water quality as an important resource for assessment. Water quality parameters such as temperature, dissolved oxygen, conductance, and pH provide an overview of water quality. *Escherichia coli* and fecal coliforms indicate presence of biological contaminants from septic systems, livestock, and sewage effluent. In addition, the USEPA and the New Mexico Environment Department monitor suites of ions, toxic metals, and antibiotics. However, none of these parameters is being monitored at historical water monitoring sites near FOUN.

No natural surface water, other than small seeps, exists within the FOUN boundaries. Intermittent stream flow occurs in Wolf Creek, a tributary to the Mora River that runs along the west side of the Third Fort Reporting Unit (Figure 3-4). A sewage lagoon is situated inside the southern corner of the Third Fort Reporting Unit.

3.5.2. Data and Methods

The only comprehensive analysis of FOUN water quality data was produced by the NPS Water Resources Division (WRD) in 1998 (NPS 1998). That analysis reviewed data from the U.S. Environmental Protection Agency STORET database and USGS National Geochemical Database: National Uranium Resource Evaluation Data for the Coterminous United States. Five monitoring stations were situated within the study area for the study, but no STORET stations occurred within FOUN boundaries, nor are any being monitored within the park at present. The five stations within the study area for the NPS (1998) study are shown in Figure 3-4. The only data available for these five sites were collected in 1959 (sites 002-005) and 1977 (sites 004, 005, and 002/017) (EARDC 2007).

A query of the STORET database for the FOUN NRCA project yielded data for an additional site within the park, called FOUN_NURE_0016. This site, shown within the Third Fort Reporting Unit on Figure 3-4, was apparently a soil sample and yielded no water quality data. The query also produced 2002 data for a site on Wolf Creek (07WOLFCR000.6), approximately 16 river km downstream from FOUN002. Because it is distant from the park and downstream, we do not consider data from this site useful for assessing surface water in/near the monument. Data from a third STORET site, FOUN_NURE_0017, is from the same site previously called FOUN0002 and noted above (NPS 1998). These sites are indicated on Figure 3-4.

3.5.3. Reference Conditions

For water quality parameters, reference conditions should be the USEPA standards. The historical data collected in 1956 and 1977 (NPS 1998) could serve as reference conditions against which to measure changes in water quality, when and if newer data were collected.

3.5.4. Resource Description

No exceedences of standards were detected in the samples reported in NPS (1998). However, the data are so old (54 years for some sites and 33 years for others), that they are essentially of no value by themselves in assessing current condition.

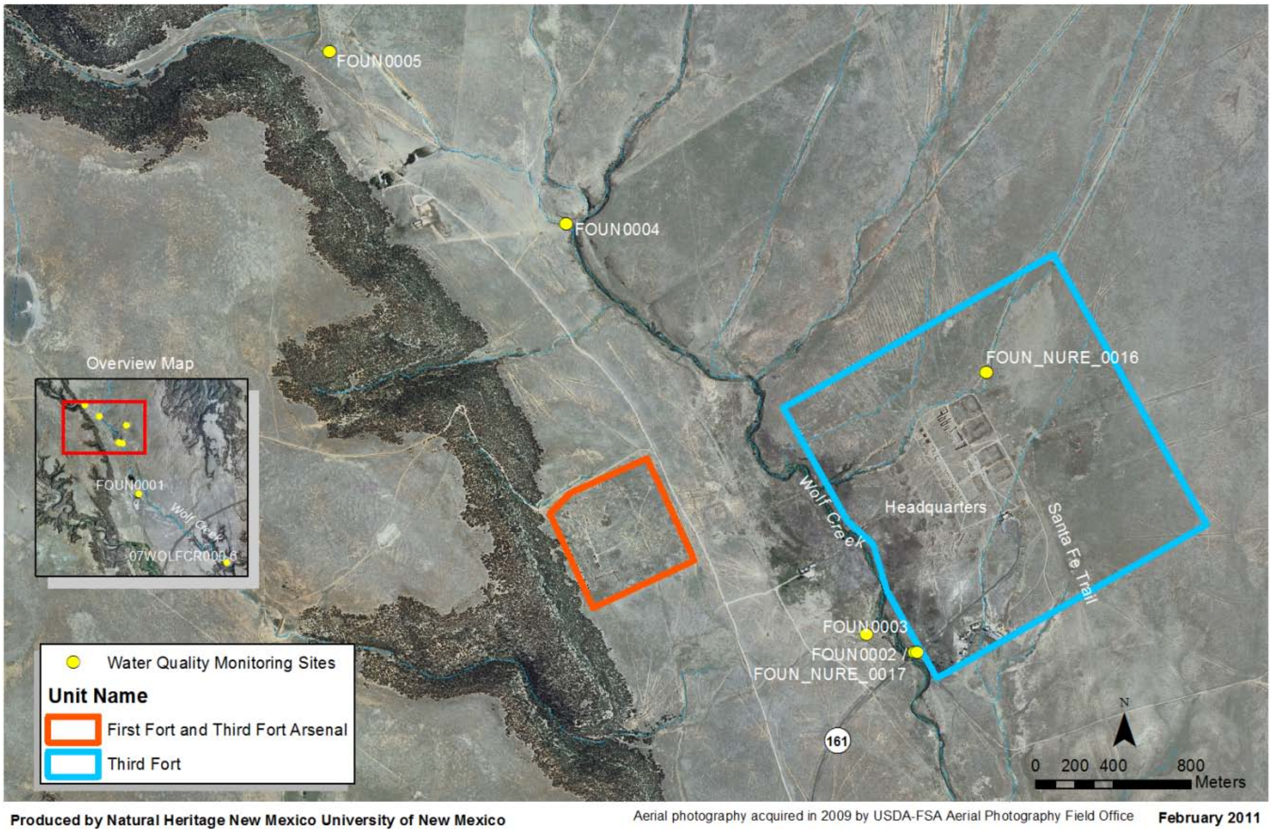

Figure 3-4. Locations of water quality monitoring sites. Data from the five sites outside the park (FOUN0001-0005) were summarized in NPS (1998). FOUN_NURE_0016 within the park was sampled in 1977; data from STORET database. 07WOLFCR0000.6 was sampled in 2002 but is not considered here because it is so far downstream from the park.

3.5.5. Condition of Data

The water quality data are so old (54 years for some sites and 33 years for others), that they are essentially of no value by themselves in assessing current condition, and thus an assessment of water quality is not possible. The old data could be of use for historical comparison with new data, if such data were collected. A confidence level cannot be assigned because no assessment is possible due to data gaps.

3.5.6. Data Gaps

Water quality data for Wolf Creek near the park have not been collected since 1956 for some sites and since 1977 for others. This constitutes an important data gap for the primary water course near the park, a source for groundwater recharge, and a water source for FOUN wildlife. The Edwards Aquifer Research and Data Center recommended that water quality monitoring for core vital sign constituents (temperature, pH, DO, specific conductance, and *E. coli*) be initiated on Wolf Creek during periods of stream flow at the location of FOUN0002 (EARDC 2007). The center also recommended that a survey of terrestrial and aquatic organisms be considered to serve as a baseline reference condition to detect future environmental changes. A good reference for survey methods for benthic macroinvertebrates is the Jacobi and Jacobi (1998) benthic macroinvertebrate survey for Pecos National Historical Park. The above EARDC recommendations have not been implemented.

3.5.7. Literature Cited

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3.6. Groundwater

3.6.1. Background

Groundwater is estimated to comprise about 21% of the world's fresh water and 97% of its unfrozen water (Dunn and Leopold 1978, cited in Brown et al. 2007). Next to glaciers and ice caps, groundwater reservoirs are the largest holdings of fresh water in the hydrologic cycle and are thus crucial to ecological health and human life (Brown et al. 2007).

Natural disturbances (e.g., fire) and human activities (e.g., livestock grazing, agriculture-related clearing and irrigation, and groundwater pumping) can impact watershed conditions and hence groundwater levels. Many wetlands and most lakes are directly connected to groundwater (Brown et al. 2007), and depletion of groundwater can affect channel width and sinuosity of rivers and reduce habitat for fish and mammals (NPS 2010).

Monitoring the spatial and temporal distributions of groundwater can contribute to understanding local hydrology, informing regulatory decisions, and predicting future water availability (EARDC 2007). Given that the NPS may often be the only entity monitoring groundwater in an area, NPS data are likely to provide the first indication of locally lowered groundwater levels or related changes. Groundwater level has been identified as a vital sign for the Southern Plains Inventory and Monitoring Network and a natural resource for this assessment.

3.6.2. Data and Methods

A single well (FOUN well #1), constructed in July–August 1957, is the sole source of water for facilities at FOUN. The water levels and production of the well were tested in 1974, 1983, and 1984 and have been monitored since 2007.

In 2007, the EARDC recommended that the depth of the water table in the local alluvial aquifer be measured on an approximately quarterly basis from FOUN well #1 (EARDC 2007) and that the data be consolidated in a database and coordinated with an appropriate database system such as the U.S. Geological Survey Ground-Water Site-Inventory System. This recommendation presumably led to the routine monitoring that has occurred since 2007 (Martin 2009; Portillo 2010).

Park staff conduct routine monitoring of well yield from one to several times a month (Martin 2009). The current monitoring program includes recording the water meter reading at the start and end of each pumping cycle, recording the start and end time of each pumping cycle, and occasionally measuring the static and pumping water levels in the well. Results of testing and routine monitoring are summarized in a recent report (Martin 2009), which includes data collected from May 2, 2008 to January 12, 2009. We obtained data from January 12, 2009 to September 13, 2010 from FOUN Facilities Manager Roger Portillo (Portillo 2010).

3.6.3. Reference Conditions

Static water level (water level in a well when the pump is not running) indicates groundwater availability. Although it is normal for the static well water level to fluctuate a few feet between seasons or between wet and dry years, a relatively stable static water level can be used as a reference condition for water availability (Martin 2009).

The pumping water level after several hours of pumping provides an indication of the ability of groundwater to flow into the well. If the pumping water level trends downward in the well, it might be an indication of plugged perforations in the steel casing or some plugging of the pore spaces in the aquifer in the vicinity of the well (Martin 2009).

If the average pumping rate shows a decreasing trend, it likely indicates the pump is wearing out and should be replaced. Hence, a stable static water level is a reasonable reference condition for groundwater, while pumping water level and pumping rate are measures of groundwater access to the well and pump function, respectively (Martin 2009).

3.6.4. Resource Description

Static water levels are typically between 84–90 feet below ground surface for FOUN well #1, suggesting that no great changes in groundwater availability have occurred in the time since its construction in the 1950s (Martin 2009; Portillo 2010). This result is not surprising, given that no large-scale groundwater pumping such as irrigation or municipal use occurs in the area.

3.6.5. Condition of Data

Rigorous testing of the well water level has not been completed since 1994. In addition, static water levels have been measured at inconsistent intervals in recent years. Therefore, based on data gaps identified by Martin (2009), confidence in this assessment is moderate.

3.6.6. Data Gaps

Drawdown and yield of the well have not been tested since 1984. Martin (2009) recommends the following:

> *A more rigorous test of the well could be conducted to provide a dataset that could be compared with the last pumping test in 1984. This could be easily accomplished by pumping the well at a constant rate for 8-12 hours while monitoring the water level in the well and the pumping rate. Monitoring the water level recovery after pumping has stopped is equally important. Data from this test could then be compared to previous tests to determine whether the efficiency of the well has changed since 1984 (25 years). There is no urgency for performing this more rigorous test as the current data from the routine monitoring program do not indicate there might be a problem with the well production or pump.*

In addition, Martin recommends quarterly measures of the well's static and pumping water levels.

3.6.7. Literature Cited

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Portillo, R. 2010. Well pump data log 2007-2010. Data sheets provided to Natural Heritage New Mexico.

3.7. Soils

3.7.1. Background

Soil is "the unconsolidated portion of the Earth's crust modified through physical, chemical, and biotic processes into a medium capable of supporting the growth of land plants" (Biggam 2008). Soil includes a mineral portion derived from the crust; an organic portion including living, dead, and decomposing organisms; and space containing air and water. It is three-dimensional, with layers (horizons) that vary in arrangement and thickness across the landscape (Biggam 2008). Soils are hierarchically classified by soil family, series, and phase (NPS 2007).

Soils are important indicators of ecosystem health and influence both natural and cultural resources at national parks. The natural features and diverse plant and animal communities of parks depend on healthy soils that support plant growth and limit soil erosion (Biggam 2008).

Soil change on the geologic time scale is normal, but accelerated change, such as compaction or the loss of topsoil, can cause degradation of soil resources and associated ecosystems. Understanding how soils change is important for many park management issues, including:

- natural resources
- wildlife habitat
- cultural resources
- threatened and endangered species
- exotic/invasive species
- roads and facilities
- fire management
- recreation and visitor management
- soil, water, and air quality (Biggam 2008).

NPS soil management objectives are:

1. *Preserve intact, functioning, natural systems by preserving native soils and the processes of soil genesis in a condition undisturbed by humans to the extent possible.*

2. *Maintain significant cultural objects and scenes by conserving soils consistent with maintenance of the associated historic practices, and by minimizing soil erosion to the extent possible.*

3. *Protect property and provide safety by working to ensure that developments and their management take into account soil limitations, behavior, and hazards.*

4. *Minimize soil loss and disturbance caused by special-use activities and ensure that soils retain their productivity and potential for reclamation* (NPS 2007).

The Southern Plains Inventory and Monitoring Network identified soil structure and chemistry as a vital sign (NPS 2007), and FOUN management included soils in this assessment.

3.7.2. Data and Methods

Digital soils layers and associated documents for New Mexico were published by the U.S. Department of Agriculture Natural Resource Conservation Service (NRCS) in the Soil Survey

Geographic Database (NRCS 2010). Natural Heritage New Mexico compiled layers from the Soil Survey Geographic Database into a geodatabase in July 2004. The database included several descriptive documents related to the soil map layers. Additional digital documents relating to FOUN soils were provided by Pete Biggam, Soils Program Manager of the NPS Geologic Resource Division (NRCS 2010).

See below for map unit descriptions of each soil map unit at FOUN. Values for potential erosion hazard are taken from an NRCS document on the potential soil erosion hazard at FOUN (NRCS 2010). Additional recommendations regarding erosion are from an assessment of Santa Fe Trail ruts (NPS 2008). These assessments do not eliminate the need for a comprehensive, on-site investigation of the condition of FOUN soils.

3.7.3. Reference Conditions

Because a comprehensive assessment was not performed for this resource, reference conditions were not identified. However, general reference conditions have been established for an assessment protocol developed by Pellant et al. (2005). For example, the reference for bare ground might be 20–30% bare ground, with bare patches less than 8–10 inches in diameter and not connected. In this method, departures from this reference condition are ranked as extreme-to-total, moderate-to-extreme, moderate, slight-to-moderate, or none-to-slight (Pellant et al. 2005).

3.7.4. Resource Description

3.7.4.1. Soil Types

Five soil map units occur at FOUN (Figure 3-5). La Brier silty clay loam occurs on 0–3% slopes. The La Brier component makes up 85% of the map unit. This component occurs on swales, plains, and flood plains. The parent material consists of alluvium derived from sandstone, and the natural drainage class is well drained. This soil rarely floods and is not ponded. Depth to a root restrictive layer is greater than 60 inches (NRCS 2010). This map unit runs along the west edge of the Third Fort Reporting Unit and is present in only a narrow section along the west side of the unit (Figure 3-5).

Partri loam occurs on gentle slopes. The Partri component makes up 85% of the map unit and occurs on slopes of 1–3%. The parent material consists of mixed alluvium derived from limestone and sandstone, and the natural drainage class is well drained. Water in the most restrictive layer is moderately low, and this soil is not flooded or ponded. Depth to a root restrictive layer is greater than 60 inches (NRCS 2010). This map unit covers most of the area in the Third Fort Reporting Unit, except for the southwest corner and a narrow strip on the west side (Figure 3-5).

The Partri-Carnero-Bernal association comprises 45% Partri, 20% Bernal, and 20% Carnero components. It covers the southwestern quarter of the Third Fort Reporting Unit, except for a small area in the southwestern corner, and almost the entire First Fort Reporting Unit (Figure 3-5). The Partri component is on uplands and hillsopes of 1–3%. The parent material consists of mixed alluvium derived from limestone and sandstone. Depth to a root restrictive layer is greater than 60 inches. The natural drainage class is well drained and water movement in the most restrictive layer is moderately low. The soil is neither flooded nor ponded, and available water to a depth of 60 inches is high (NRCS 2010).

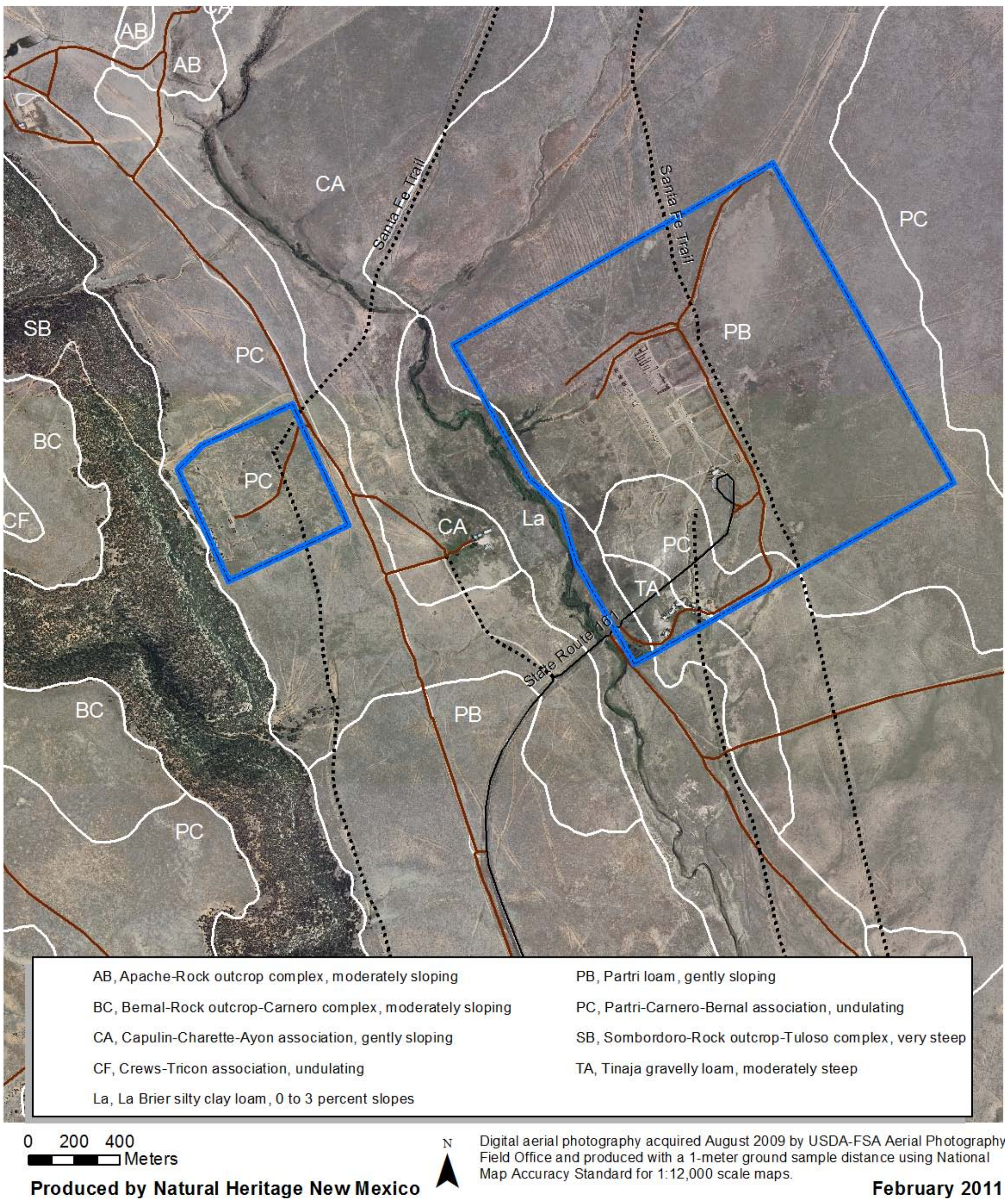

Figure 3-5. Soils of Fort Union National Monument.

The Bernal component is on plains and ridges with slopes of 3–8%. The parent material consists of eolian deposits and residuum weathered from sandstone. Depth to a root restrictive layer is 8–20 inches. The natural drainage class is well drained, available water to a depth of 60 inches is low, and this soil is neither flooded nor ponded (NRCS 2010).

The Carnero component occurs on uplands and plains with slopes of 2–5%. The parent material consists of eolian deposits and residuum weathered from sandstone. Depth to a root restrictive layer is 20–40 inches. The natural drainage is well drained, and water movement in the most restrictive layer is moderately low. Available water to a depth of 60 inches is low. The soil is neither flooded nor ponded (NRCS 2010).

The Tinaja gravelly loam map unit is moderately steep and is dominated by the Tinaja component, which makes up 80% of the map unit. This map unit occurs in the southwest corner of the Third Fort Reporting Unit (Figure 3-5). The Tinaja component occurs on terraces and plains with slopes of 5–30%. The parent material consists of gravelly alluvium derived from igneous, metamorphic, and sedimentary rock. Depth to a root restrictive layer is greater than 60 inches. The natural drainage class is well drained, and water movement in the most restrictive layer is moderately high. Available water to a depth of 60 inches is low. This soil is neither flooded nor ponded. Organic content in the surface horizon is about 1%. Surface horizon organic content in the other map units is 2%, except for the Sombordoro-Rock outcrop-Tuloso, which, like the Tinaja, has 1% organic matter content (NRCS 2010).

The Sombordoro-Rock outcrop-Tuloso complex comprises mainly the Somordoro (35%) and Tuloso (20%), with Rock outcrop as a minor component. It covers only a very small area on the west side of the First Fort Reporting Unit. Most of this map unit lies outside the monument (Figure 3-5). The Sombordoro component occurs on uplands and structural benches of 15–45% slope. The parent material consists of alluvium weathered from sandstone and shale. Depth to a root restrictive layer is 8–20 inches. The natural drainage class is well-drained, and water movement in the most restrictive layer is moderately low. Available water to a depth of 60 inches is very low. This soil is neither flooded nor ponded (NRCS 2010).

The Tuloso component occurs on uplands and structural benches of 15–45% slope. The parent material consists of local sediment and residuum weathered from sandstone. Depth to a root restrictive layer is 10–20 inches. The natural drainage class is well drained, and water movement in the most restrictive layer is moderately high. Available water to a depth of 60 inches is very low. This soil is neither flooded nor ponded (NRCS 2010).

3.7.4.2. Erosion Hazard

Erosion hazards and suitability of soils for roads were determined for the monument by NRCS, based on soil characteristics (NRCS 2010). These values, potentially ranging from 0.01 to 1.0, indicate the potential for erosion based on soil type and characteristics, but are not based on an on-site investigation of the monument's soils. The larger the value assigned, the greater the potential for erosion.

The La Brier and Partri loam soils show a slight potential for erosion on and off trails and roads. Both types are moderately suited for roads, with an assigned limitation value of 0.50.

Of the Partri-Carnero-Bernal association, all components are moderately suited for roads, with values of 0.50, and are slightly hazardous for off-road or off-trail erosion. The Partri component shows slight hazard for erosion on roads and trails, while the Bernal and Carnero components show moderate hazard due to slope and values of 0.50 (NRCS 2010).

All three components of the Sombordoro-Rock outcrop-Tuloso complex are poorly suited for roads due to slope, with erosion hazard values of 1.0, and show severe erosion hazards for roads and trails (value 0.95). The Sombordoro and Tuloso components are rated moderate for off-road and off-trail hazard (value 0.50), and the Rock outcrop component is rated severe (0.5 off-road, 0.75 off-trail; NRCS 2010).

Tinaja soils show moderate hazard for off-road and off-trail erosion (0.50) and severe hazard for on road and trail erosion (0.95). They are poorly suited for roads, with a value of 1.00 (NRCS 2010).

3.7.4.3. Hydrology

The NPS (2008), as part of an assessment of Santa Fe Trail rut stability, made the following recommendations regarding runoff-related soil erosion in gullies at the park.

1. The location of a headcut near the visitor center should be marked with rebar and monitored for upstream movement. If it migrates toward the ruins, grade control should be constructed to prevent further advancement.

2. The grade control structure in the southeast corner of the monument should be monitored.

3. All areas should be inspected following major rainfall events for signs of new erosion or problems associated with infrastructure such as hardened trail surfaces or culverts.

4. The runoff/erosion implications of any new infrastructure should be carefully considered; impermeable surfaces should be minimized.

5. Stormwater drainage should be dispersed from developed areas rather than concentrated into a single culvert, to reduce channel formation.

6. The role of infrastructure such as culverts in preventing erosion should be considered before making changes.

3.7.5. Condition of Data

The data depicted in the soils map are recent and confidence in the map is high. However, a soils assessment has not been performed at FOUN. As a result, this section is primarily descriptive.

3.7.6. Data Gaps

No soil chemistry data are available for FOUN; therefore, it was not possible to assess soil chemistry for this report. Rates of erosion have not been measured at FOUN. Rather, *potential* erosion hazards have been noted, based on soil properties (NRCS 2010; see "Erosion hazard", above). The FOUN map (Figure 3-5) does not constitute a soils assessment; however, in combination with additional data that could be collected, it could provide a basis for a soils assessment.

To address the lack of a soils assessment, a qualitative assessment using the approach described in Pellant et al. (2005) could be performed. This approach, which relies mainly on expert opinion, could serve as a rapid assessment. Alternatively, a quantitative assessment incorporating on-site measurements could be performed. A quantitative assessment would be more useful for monitoring, to allow detection of changes over time (Pellant et al. 2005). Recommendations for data collection for a quantitative assessment can also be found in Pellant et al. (2005). The park could request that the NPS Soils Program Manager provide technical assistance with the desired assessment.

3.7.7. Literature Cited

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3.8. Santa Fe Trail Ruts, Adobe Fields, and Second Fort

3.8.1. Background

One of the most striking features of the FOUN vegetation map (Muldavin et al. 2004) is that the vegetation reveals the presence of significant cultural resources of Fort Union, such as the Santa Fe Trail ruts, adobe fields, and sites of the three historical forts. These features, though unused for more than 120 years, are covered in vegetation communities that express their legacy of historical human use (Figure 3-6). The vegetation not only reveals the cultural features but also protects them from erosion. Hence, at FOUN, many cultural resources are inextricable from natural processes and resources. In this section, we discuss that unique relationship, with emphasis on several cultural features selected by the park for the FOUN NRCA.

Fort Union was established in 1851 on the Santa Fe Trail, a commercial and military highway that connected Santa Fe, New Mexico, with Missouri (Freitag 1994). The ruts formed by wagon trains and animals that traveled the trail are preserved in a few areas, including private and federal property such as FOUN (Figure 3-7). These historically significant ruts, now preserved as part of the NPS Santa Fe National Historic Trail, are covered by a characteristic vegetation type different from the surrounding grasslands (Figure 3-6).

Adobe fields are situated inside and outside the park boundary north of the Third Fort on minimal slopes. These fields provided large amounts of the dark brown, high clay content soils used to produce the adobe bricks that comprise the fort’s buildings (Freitag 1994). The scars formed by soil extraction are visible in modern aerial photographs, and the fields are covered in a characteristic vegetation type (Figure 3-6). The fields are valuable cultural resources indicating the sequence and quality of adobe construction at the fort and are sources of information for architectural conservators interested in stabilizing the ruins (Freitag 1998).

In 1862, the Second Fort, a massive, bastioned earthwork, was constructed partially underground with pine logs and un-sodded parapets (extended walls used to defend against shelling). Heavy rains turned the roofs and floors to mud, sending the soldiers into tents. The Second Fort was mostly abandoned by 1863 (NPS 2005). In 1867, an order was issued for its demolition (Freitag 1994). The Second Fort “is associated with the Battle of Glorieta (March 26–28, 1862), a crucial western engagement of the Civil War and a decisive Union victory that ended Confederate incursions into the American Southwest… is the sole surviving earthen star fort erected west of the Mississippi River….and is the most intact, least-disturbed Civil War-era bastioned earthen fort surviving anywhere within the United States today” (Veech 2010). The star shape of the Second Fort (Figure 3-8) is visible from higher elevations and from the air (NPS 2005). It is currently covered in vegetation that naturally stabilizes the remaining earthworks and reveals their location (Figure 3-6).

3.8.2. Data and Methods

On August 20–21, 2007, a team of staff from FOUN, the NPS Regional Support Office in Santa Fe, and the NPS Water Resources Division inspected the Santa Fe Trail ruts at or near the monument to assess whether “active erosion is enlarging ruts, causing degradation of cultural resources, or threatening cultural resources in the future” (NPS 2008). The results of this inspection provide information that serves as an assessment of rut stability for this NRCA. Descriptions of adobe fields and second fort are taken from Muldavin et al. (2004).

3.8.3. Reference Conditions

The monument preserves its cultural resources while making them available for public viewing. Uncontrolled erosion would ultimately destroy the trail ruts, but slowing erosion through installing vegetation controls could obscure the trails and allow them eventually to fill with sediments (Muldavin et al. 2004). The desired condition for these resources is a balance between accelerated erosion and excess deposition that will preserve these hallmark features of the park (Muldavin et al. 2004). The proposed reference condition for the trail ruts is the current condition, with the occurrence of minimal erosion, expansion into channels, infilling, or obscuring by tall or woody vegetation.

The park also identified the preservation of the adobe fields and Second Fort as priorities. The adobe fields are acquiring vegetative cover, but this process appears to have been slower than it has been for the ruts, perhaps because topsoil was removed to harvest adobe. The fields will probably become less and less discernable with time as vegetation stabilizes them (although further erosion is still a possibility). Reference conditions for these resources would, as for the ruts, provide a standard against which to measure degradation due to erosion. Reference conditions should be established as part of a thorough assessment of their condition, which should also recommend monitoring procedures and preservation measures if these features are found to be unstable.

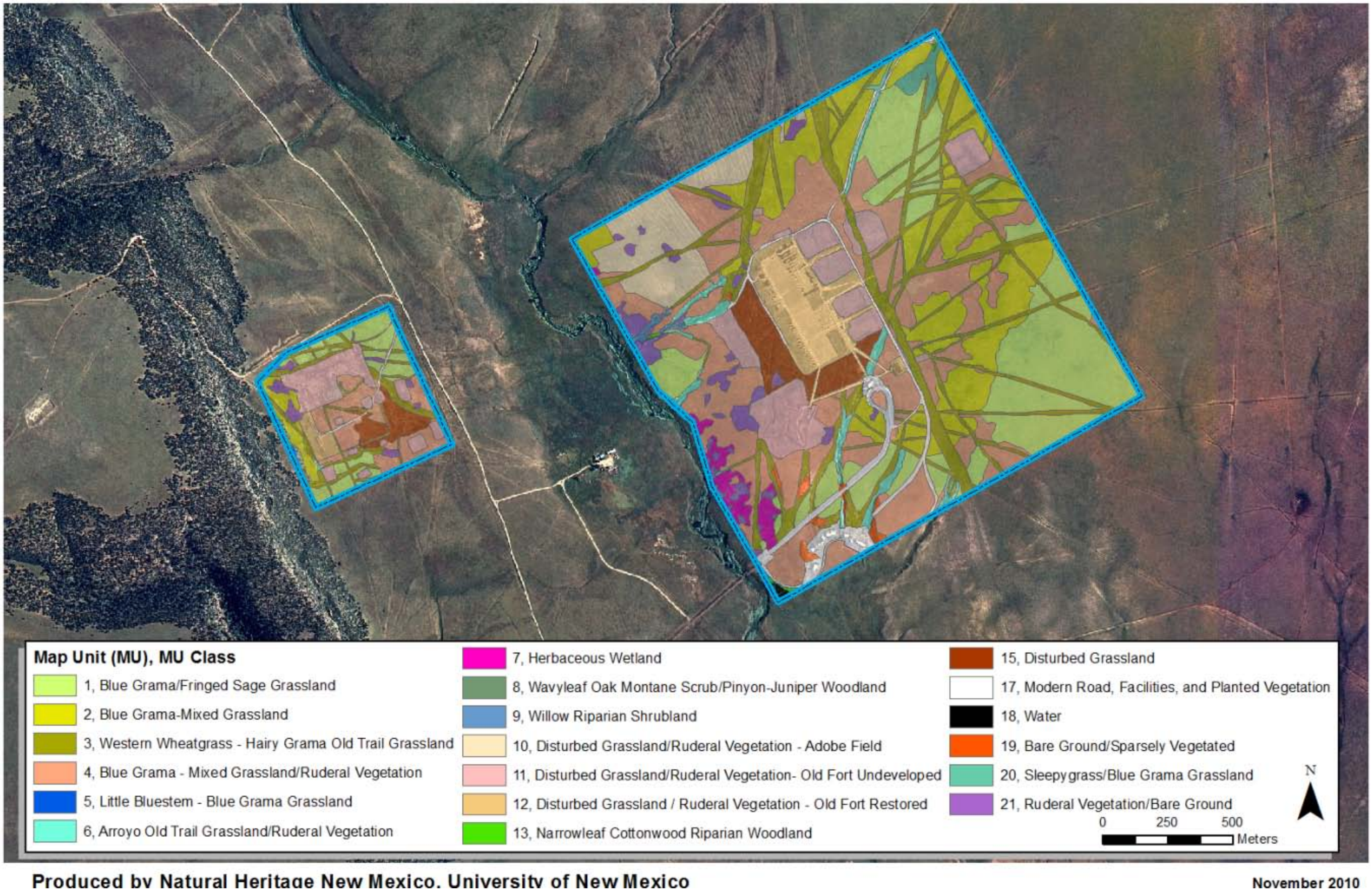

Figure 3-6. Fort Union National Monument vegetation map (Muldavin et al. 2004). Santa Fe Trail ruts, adobe fields, and Second Fort are covered in map units 3, 10, and 11, respectively.

Figure 3-7. Santa Fe Trail ruts, showing characteristic Arroyo Old Trail Grassland/Ruderal Vegetation type. Photo courtesy NPS.

3.8.4. Resource Description

3.8.4.1. Santa Fe Trail Ruts

The Santa Fe Trail ruts are represented by Western Wheatgrass/Hairy Grama Old Trail Grasssland and Arroyo Old Trail Grassland/Ruderal Vegetation map units (Figure 3-6, map units 3 and 6). These units comprise distinctive sets of plant associations that differ from surrounding grasslands. The primary components of Western Wheatgrass/Hairy Grama Old Trail Grasslands are Blue Grama-Western Wheatgrass (*Bouteloua gracilis-Pascopyrum smithii*), and Hairy Grama-Fringed Sage Grassland (*Bouteloua hirsute-Artemisia frigida*). The Arroyo Old Trail Grassland/Ruderal Vegetation map unit includes primarily Blue Grama-Western Wheatgrass and Weakleaf Bur Ragweed-Lacy Tansyaster (*Ambrosia confertiflora-Machaeranthera pinnatifida*) plant associations. Hairy grama is often associated with more compacted soils, while western wheatgrass and sleepygrass are associated with more mesic conditions. This reflects water concentrating in the trails during rainfall, which resulted in some degradation of the trails through water erosion into arroyos now dominated by combinations of western wheatgrass grasslands and ruderal (disturbed or weedy) herbaceous vegetation, dominated by the Weakleaf Bur Ragweed-Lacy Tansyaster plant association and areas of bare ground (Muldavin et al. 2004).

The wagon rut assessment team concluded that most of the wagon ruts were fairly stable. They detected very few channels with angular, unvegetated banks, which would indicate recent and/or active erosion. Many ruts "were only slightly incised, had good grass cover, and were in adjustment with local grade controls such as culverts or hardened trail surfaces" (NPS 2008).

They noted a few incised channels that probably developed from ruts. These were located south and west of the visitor center, east of the housing area, west of the northwest corner of the fort complex, and between the water tank and the northeast corner of the fort complex. None of the channels noted was threatening the main ruins area (NPS 2008).

Channels near the visitor center, housing area, and to the northwest in the monument are situated in steeper terrain. The authors of the rut assessment speculate that wagon routes in these steeper areas might have been more prone to erosion in the past, with erosion possibly exacerbated by heavy livestock grazing or the 1930s drought. Whatever the origins of these channels, those conditions no longer appear to be present and the areas are recovering and fairly stable. The gully northeast of the main fort area was not thought to be an artifact of fluvial erosion of a wagon rut, was not currently enlarging, and did not appear to threaten the fort (NPS 2008).

Some gullies, although apparently not active, could potentially migrate upstream through headcutting, which could threaten cultural resources. The authors recommend that a riprap-grade control structure, like that at the gully east of the housing area, might be useful in other areas if headcutting becomes an issue in the future. The report does not recommend structural measures to control the erosion of wagon ruts, since the area seems to be in recovery and holding together. A monitoring program should be developed to detect changes in the ruts (NPS 2008). One method of monitoring could be to perform repeated measures of topographical cross sections (E. Muldavin, pers. comm.).

Figure 3-8. Aerial view of Second Fort. Photo courtesy NPS; Source is probably Skidmore, Owings, Merrill LLC.

3.8.4.2. Adobe Fields

The historical adobe fields are included in the Disturbed Grassland/Ruderal Vegetation map unit (Figure 3-6, map unit 10). This unit comprises primarily blue grama-purple threeawn (*Bouteloua gracilis-Aristida purpurea*), blue grama-western wheatgrass, and weakleaf bur ragweed-lacy tansyaster plant associations. Blue grama-purple threeawn and weakleaf bur ragweed-lacy tansyaster plant are particularly indicative of significant past disturbance (Muldavin et al. 2004).

3.8.4.3. Second Fort

The Second Fort is covered in the Disturbed Grassland/Ruderal Vegetation/Old Fort Undeveloped map unit (Figure 3-6, map unit 11). The primary components of this unit are blue grama-western wheatgrass and weakleaf bur ragweed-lacy tansyaster plant associations. This is a major map unit associated with fort ruins that have not been extensively excavated for archeological purposes, including old corrals and shed sites. The vegetation is a mix of disturbance-related vegetation that can reflect both historical impacts and recent activity by pocket gophers (Muldavin et al. 2004).

3.8.5. Condition of Data

Confidence is high in the vegetation map (Muldavin et al. 2004), and the assessment of the current rut conditions (NPS 2008). However, because monitoring is not being conducted it is not possible to know for certain what degree of change the ruts are undergoing or how they can be expected to change over time. Thus, confidence in our assessment of the ruts is moderate. Similar assessments of the stability of the adobe fields and Second Fort have not been conducted.

3.8.6. Data Gaps

Water flowing in the wagon ruts will eventually impact them, through erosion, deposition, or both. The ruts assessment should suffice for the next few decades, but if FOUN wishes to preserve the wagon ruts for 50, 100, or more years, a hydrological study to assess long-term processes and impacts should be performed. In addition, monitoring of the wagon ruts is not being conducted; to address this data gap, a monitoring program should be developed and implemented (NPS 2008).

Similarly, assessments of the stability of the adobe fields and Second Fort have not been conducted. A rapid assessment like that conducted for the ruts, followed by a more quantitative monitoring program (such as repeated measures of topographical cross sections) for these and other focal resources would address these data gaps. The NPS (2008) report makes additional recommendations regarding park planning to avoid erosion. These are summarized in the Soils section.

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3.9. Vegetation

3.9.1. Background

The vegetation at FOUN, with its mix of grassland communities, can enhance the visitor experience of a late 1800s military fort in the midst of a vast prairie. In addition, the cultural history of the area and the forts is recorded in the vegetation patterns linked to cultural resources such as the Santa Fe Trail ruts and the adobe fields. In this context, the integrity of the park within the landscape depends on maintaining a healthy local ecosystem along with its cultural legacy in the larger context of the short grass prairie of northeastern New Mexico.

FOUN's vegetation is dominated by native grassland communities, with ruderal (disturbed or weedy) associations covering some cultural features. There are also small areas of oak montane scrub/pinyon-juniper woodland, herbaceous wetlands, and willow and cottonwood riparian vegetation types. No rare, threatened, endangered, or species of concern have been found to date at FOUN, but several exotic plant species occur there (Appendix A).

Grassland vegetation community maintenance and early detection of exotic plants have been identified as core vital signs by the SOPN. Important measures of condition in grassland communities are trends in species composition, structure, diversity, cool-season (C3) versus warm-season (C4) vegetation, woody species distribution/invasion, and exotic plant abundance and distribution, (USDI 2008). Throughout the SOPN, threats to vegetation communities include exotic species invasions, agriculture, overgrazing, mining, and other sources of fragmentation (NPS 2011).

3.9.2. Data and Methods

The FOUN vegetation communities were classified and mapped in 2004 (Figure 3-9; Muldavin 2004). This study also included an extensive floristic survey. Muldavin and coworkers added to this survey in 2005 with surveys at additional points on FOUN (Muldavin et al. 2005, unpublished data). Folts-Zettner conducted a pilot survey of FOUN plants (Foltz-Zettner, unpublished data) in 2008–2009 (Figure 3-9). In 2009, she conducted an additional, cursory survey of the exotics and an evaluation of the grassland communities at FOUN (Folts-Zettner 2009). Narumalani and co-authors (2004) used the plant list compiled by Muldavin and co-authors (2004) and conducted visual surveys to evaluate which exotic plants at FOUN should and could feasibly be controlled.

The data from these surveys are combined into a plant list for the park (Appendix A). Each survey at FOUN detected previously undetected plant species, which suggests that the species list may not be complete. To assess the completeness of the plant list, we looked at rainfall data (Western Regional Climate Center 2010) from the years when field surveys were performed, assuming that some species would not be evident in dry years.

3.9.3. Reference Conditions

One reference condition for vegetation could be the condition of the grasslands before Fort Union was established. This approach would require evidence of the historical condition of the grasslands as a standard. Unfortunately, most of the southern short grass prairie of Colorado and New Mexico has been under continuous use for livestock and agriculture since settlement, with few or no extant refugia for defining a standard, particularly in the context of fire. Hence, the park may need to adopt relative standards based on the best available local conditions as inferred from past and current land use.

The native blue grama grasslands in the southeastern areas of the park were likely less disturbed with roads and corrals than areas nearer to the fort structures. These sites have been out of grazing or other impacts since 1956 when the park was established, and because they have been protected for 55 years, they likely represent the benchmark of best local grassland conditions.

Muldavin et al. (2004) observed that much of the FOUN vegetation reflects the legacy of previous human use during settlement and thus provides a record of the cultural history of FOUN. Features such as the Santa Fe Trail ruts are still evident and are covered in characteristic vegetation communities (see “Santa Fe Trail Ruts, Adobe Fields, and Second Fort”, above). A pre-settlement reference condition would not be appropriate for these cultural features that are currently covered in grassland/ruderal vegetation. For the grassland/ruderal vegetation types that cover cultural features, reference conditions would focus less on the specific vegetation type and more on factors such as erosion, sediment deposition, and pocket gopher threats to cultural features.

The herbaceous wetland vegetation in the southwest part of the park has both biological and cultural significance. This moist area was historically fed by springs that made habitation of Fort Union possible. A historical reference from July 1851 (Chapter 2, 1851 Pope journal, as reported in Oliva 1993) states that in the valley where Fort Union was established as a 40,000 acre military reservation, many springs and ponds were observed:

Lieutenant Pope described Los Pozos in the valley of Wolf Creek as "large holes of spring water 15 or 20 feet deep. A chain of these holes & small lakes extend several miles down the valley." He reported that "grass is very abundant & of excellent quality & wood plenty in the neighborhood." Like Lieutenant Colonel Sumner, Pope was impressed with this location. "There are," he recorded, "many springs of clear, cold, water in the vicinity and this valley is in short by far the most desirable portion of country I have seen since leaving Missouri."

In addition, it contains a unique vegetation type at the park and likely contributes to invertebrate and vertebrate animal biodiversity. A thorough wetland assessment following U.S. Army Corps of Engineers Jurisdictional Wetlands guidelines (EPA and U.S. Army Corps of Engineers 2011) would provide potential reference conditions. The reference conditions for this area should consider the importance of wetland vegetation, as represented by wetland indicator species, and wetland-associated animals.

A potential reference condition with respect to exotic species could be the absence of any exotics, but this condition may be neither attainable nor necessary for a healthy vegetation community at FOUN. A more practical and attainable reference condition would be the absence of listed noxious weeds and prevention of exotics from dominating such that they reduce the diversity and distribution of native species.

3.9.4. Resource Description

Muldavin et al. (2004) found 140 taxa, including twelve species considered exotic to FOUN (Appendix A). That study concluded that none of the exotic species posed a threat to native species at the time, but that plants such as horehound (*Marrubium vulgare*), kochia (*Kochia* *scoparia*), or cheat grass (*Bromus tectorum, B. japonicus*) may cause problems in the future. One species was listed as a New Mexico noxious weed (Siberian elm [*Ulmus pulmila*]; NMDA 2009).

Their additional survey in 2005 (Muldavin et al. 2005, unpublished data) added 56 species to the list, six of which are nonnative, including nodding plumeless thistle (*Carduus nutans*), a New Mexico noxious weed (Appendix A; NMDA 2009).

In her pilot survey of 2008–2009, Folts-Zettner (2010, unpublished data) found 92 total plant taxa, including 35 which had not been identified by Muldavin and co-authors (2004 and unpublished) (Appendix A; Folts-Zettner 2010, unpublished data). Eleven of the unique species she found are considered to be nonnative, including *Euphorbia dentate*, of which some infra-taxa are native and others are introduced in New Mexico (USDA 2011). None of the 11 species is listed as a noxious weed (NMDA 2009).

In Folts-Zettner's (2009) additional inspection, she found healthy grasslands with a few common lambsquarters (*Chenopodium album*) in the corrals and kochia (*Kochia scoparia*) on the berms around the corrals. She also found Siberian elm (*Ulmus pulmila*) at the water tank, large quantities of cheatgrass (*Bromus tectorum*) near the hospital ruins, and horehound (*Marrubium vulgare*) growing on and around the ruins in the fort complex.

In her historical study of the vegetation at the site of FOUN before and during the time it was an active fort, Shackel (1983) concludes that the vegetation before the fort was founded was more lush and productive than it was in 1983. Blue grama (*Bouteloua gracilis*) was the dominant grass at the time of her study, as it was before the fort was established. Due to an overabundance of this species in 1983, Shackle concluded that the condition of the grasslands had degraded since the fort was built. Blue grama is grazing tolerant, and sites that have seen long-duration grazing can be driven to near monocultures of the species. This may have been the case during fort occupation, but currently, the grasslands are quite diverse with respect to grasses, forbs, and sub-shrubs (Appendix A).

The wetlands, while composed of a mix of wetland species and ruderal forbs and grasses (some exotic), are a significant biotic resource in the area and potentially could be enhanced through management of the exotics and a more complete understanding of the underlying hydrology.

Although 32 nonnative plant species have been recorded in the park, only two species listed by the state of New Mexico and no federally listed species were detected. Narumalani et al. (2004) determined that only one plant, field bindweed (*Convolvulus arvensis*), was both an immediate problem and was feasible to control. Narumalani et al. mapped the occurrence of field bindweed at FOUN and recommended that herbicides be applied or mechanical methods such as hand pulling be used to eradicate the plant. They concluded that, although there are many introduced plant species at FOUN, none of them present a threat to the park because of the dryness of the habitat.

3.9.5. Condition of Data

As an indication of the completeness of the combined plant list, we retrieved annual precipitation data for the years in which surveys were conducted at FOUN (Western Regional Climate Center 2010). For the 89-year period of record from 1917–2006, the mean annual precipitation at

Valmora, New Mexico, the nearest station to FOUN, was 16.73 in (range = 6.56–27.22, SD = 4.16). Annual precipitation for 2004 was 17.04 and for 2005 it was 15.14. These annual means are within a standard deviation of the mean (one higher, one lower) for the period of record, suggesting that the 2004 and 2005 surveys were not performed in especially dry years. However, these were not wet years, and Folts-Zettner's 2008–2009 survey turned up 35 additional taxa. Therefore, it is likely that these surveys missed at least a few species.

Confidence is high in the plant list and vegetation map of FOUN. Assessments of grasslands, springs, and gopher disturbance are needed but have not been performed.

3.9.6. Data Gaps

The most recent thorough study of the vegetation at FOUN was in 2000–2002 (Muldavin et al. 2004), with additional surveys in 2004 (Narumalani et al. 2004), 2005 (Muldavin et al. 2005, unpublished data), and 2008–2009 (Folts-Zettner 2010, unpublished data). Although these surveys could have missed some plant species, especially those that would be more evident in a wet year, a complete resurvey is probably a lower priority at this time than grassland, wetland, and gopher assessments.

A rigorous assessment of the native grasslands at FOUN has not been performed, in part because vegetation ecologists have not established standards for assessing native grasslands in northern New Mexico. Aside from the small patch at FOUN, nearly all the grasslands in New Mexico and Colorado have been continuously grazed or farmed since settlement and almost no undisturbed grassland exists for comparison. The species diversity of the FOUN grasslands could be assessed by comparing them to grazed lands on the Fort Union Ranch across the fence from the park. Because it has not been grazed, FOUN likely has higher native grassland plant diversity.

Because the springs have historical and biological significance, the small patch of wetland vegetation should be assessed and monitored. We suggest a thorough wetland assessment following U.S. Army Corps of Engineers Jurisdictional Wetlands guidelines (EPA and U.S. Army Corps of Engineers 2011) as a first step towards conducting a thorough assessment of the wetland vegetation.

There is a need to monitor the impacts of gopher activity on vegetation and cultural resources. These burrowing mammals could be a threat to both cultural and vegetation resources, but it is not known whether or not gopher disturbance is expanding. A baseline survey of gopher populations and activity, followed by monitoring, should be conducted.

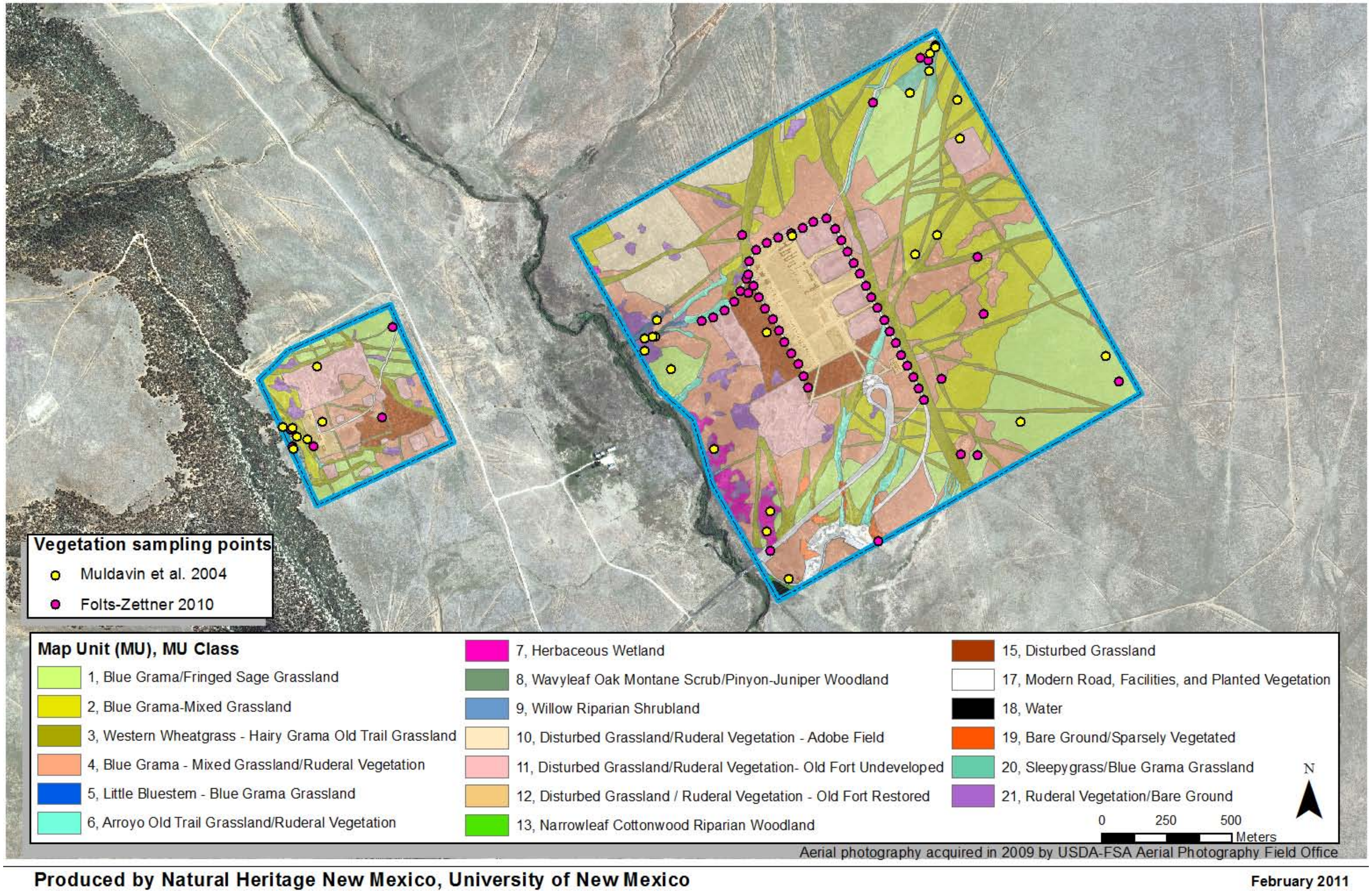

Figure 3-9. Vegetation of Fort Union National Monument showing vegetation sampling points.

3.9.7. Literature Cited

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3.10. Animal Communities

3.10.1. Background

Animal biodiversity is an important natural resource that is integral to a healthy ecosystem (McCann 2000). Diverse ecosystems are more resistant to invasive species and to collapse. In addition, native animals are an important cultural resource for a historical park like FOUN. Important measures of this resource could be species richness, abundance, population trends, and, for migratory animals such as birds, whether FOUN is used for breeding, migration, or wintering grounds. Bird communities are one of the 11 core vital signs chosen to indicate ecosystem health and trends for the Southern Plains Inventory and Monitoring Network. Terrestrial invertebrates (native pollinators, and moths and butterflies), amphibian communities, and mammals (ungulates, and small mammal communities) were designated as vital signs (NPS 2008).

3.10.2. Invertebrates

3.10.2.1. Data and Methods

No invertebrate survey has been conducted at FOUN.

3.10.2.2. Reference Condition

No information is available regarding a reference condition for invertebrates at FOUN. No museum records regarding invertebrates exist for FOUN or Mora County (Arctos 2010), and NatureServe lists only one invertebrate for the Mora watershed, the star gyro (*Gyraulus crista*), an aquatic snail critically imperiled in New Mexico (NatureServe 2010). Wolf Creek runs intermittently along the west side of the Third Fort Reporting Unit, but no natural aquatic habitat occurs in the monument.

3.10.2.3. Resource Description

Due to a lack of data, this resource was not assessed.

3.10.2.4. Condition of Data

Not applicable.

3.10.2.5. Data Gaps

Lack of information on invertebrates constitutes a significant data gap. Edwards Aquifer Research and Data Center (EARDC 2007) recommended that a survey of terrestrial and aquatic invertebrates be conducted to serve as a baseline reference condition to detect future environmental changes. A good reference for survey methods for benthic macroinvertebrates is the Jacobi and Jacobi (1998) benthic macroinvertebrate survey for Pecos National Historical Park. The Edwards Aquifer Research and Data Center recommendations have not yet been implemented.

3.10.3. Reptiles and Amphibians

3.10.3.1. Data and Methods

Only one recent survey of the herpetofauna has been conducted at FOUN (Johnson et al. 2003b). It was done at about the same time as the mammal survey: August 7–9 and October 19–20, 2001, and July 2–4 and July 29–August 1, 2002. Surveys (one nocturnal) were conducted in person by active searching and capturing of herpetofauna. Pitfall trapping would have required digging in archeologically sensitive areas and was not permitted. Auditory surveys were also conducted for calling amphibians. Four funnel traps were set near natural and manmade features for four days (16 trap-days) at the end of July 2002.

3.10.3.2. Reference Condition

Johnson et al. (2003b) created a target list (Table 3.3) of expected herpetofauna at FOUN based on historical records (Degenhardt et al. 1996), University of New Mexico Museum of Southwestern Biology records, and expert opinion.

3.10.3.3. Resource Description

Only 10 (27%) of the 33 species on the target list were observed during the 2001 and 2002 surveys or by park staff. It is possible that the small size (720 acres) of the monument and its proximity to grazed rangeland reduce both the number of species and the abundance of individuals of those species, making them more difficult to detect. These surveys, however, did not have much power to detect herpetofauna because pitfall traps were not allowed. Surveyors had to encounter animals during searches, which is a much less effective survey method (Ryan et al. 2002). In addition, the survey year was especially dry, which could have impacted amphibian activity and food availability for reptiles.

3.10.3.4. Condition of Data

We have low confidence that this resource has been thoroughly surveyed. More thorough and extensive surveys need to be conducted.

3.10.3.5. Data Gaps

The large discrepancy between the target list and list of detected species suggests that surveys missed many species likely to have been present. This gap is likely largely a result of the restriction on using pitfall traps, an important trapping method for herpetofauna

Table 3-3. Reptiles and amphibians present in Fort Union National Monument.

Order	Family	Common name	Scientific name	Target List (Johnson et al. 2003)	Observed (Johnson et al. 2003)
Anura	Bufonidae	Great Plains toad	*Bufo cognatus*	X	X
Anura	Bufonidae	Red-spotted Toad	*Bufo punctatus*	X	
Anura	Bufonidae	Woodhouse's toad	*Bufo woodhousii*	X	X
Anura	Hylidae	Western Chorus Frog	*Pseudacris triseriata*	X	
Anura	Pelobatidae	New Mexico Spadefoot	*Spea multiplicata*	X	
Anura	Ranidae	Bullfrog	*Rana catesbeiana*	X	X
Caudata	Ambystomatidae	Tiger salamander	*Ambystoma tigrinum*	X	X
Cryptodeira	Emydidae	Ornate Box Turtle	*Terrapene ornata*	X	
Squamata	Colubridae	Glossy Snake	*Arizona elegans*	X	
Squamata	Colubridae	Racer	*Coluber constrictor*	X	X
Squamata	Colubridae	Ringneck Snake	*Diadophis punctatus*	X	
Squamata	Colubridae	Red Cornsnake	*Pantherophis guttatus*	X (Elaphe guttata)	
Squamata	Colubridae	Western Hognose Snake	*Heterodon nasicus*	X	
Squamata	Colubridae	Desert King Snake	*Lampropeltis getula*	X	
Squamata	Colubridae	Milk Snake	*Lampropeltis triangulum*	X	
Squamata	Colubridae	Coachwhip	*Masticophis flagellum*	X	X
Squamata	Colubridae	Striped Whipsnake	*Masticophis taeniatus*	X	
Squamata	Colubridae	Gopher snake	*Pituophis catenifer*	X	X
Squamata	Colubridae	Ground Snake	*Sonora semiannulata*	X	
Squamata	Colubridae	Plains Black-headed Snake	*Tantilla nigriceps*	X	
Squamata	Colubridae	Blackneck Garter Snake	*Thamnophis cyrtopsis*	X	
Squamata	Colubridae	Western Terrestrial Garter Snake	*Thamnophis elegans*	X	
Squamata	Colubridae	Plains Garter Snake	*Thamnophis radix*	X	
Squamata	Colubridae	Lined Snake	*Tropidoclonion lineatum*	X	
Squamata	Iguanidae	Collared Lizard	*Crotaphytus collaris*	X	
Squamata	Iguanidae	Lesser Earless Lizard	*Holbrookia maculata*	X	
Squamata	Iguanidae	Short-horned lizard	*Phrynosoma hernandesi*	X (P. douglasii)	X
Squamata	Leptotyphlopidae	Texas Blind Snake	*Leptotyphlops dulcis*	X	
Squamata	Scincidae	Many-lined Skink	*Plestiodon multivirgatus*	X	
Squamata	Scincidae	Great Plains Skink	*Plestiodon obsoletus*	X	
Squamata	Teiidae	Chihuahuan Spotted Whiptail Lizard	*Aspidoscelis exsanguis*	X	
Squamata	Teiidae	Plateau Striped Whiptail Lizard	*Aspidoscelis velox*	X	
Squamata	Viperidae	Prairie rattlesnake	*Crotalus viridis*	X	X

3.10.4. Birds

3.10.4.1. Data and Methods

Two recent point-count surveys at FOUN (Table 3.4) used different methods and point locations and therefore cannot be used to compare numbers of individuals. A 1960s checklist shows bird species and their relative abundances in the four seasons (Fort Union National Monument, n.d.). These three sources may not reveal trends in numbers of individuals, but they do provide a general indication of change in species composition over time.

The checklist of birds of FOUN seems aimed at recreational birders visiting FOUN and lists species by season, indicating their relative abundance (Fort Union National Monument, n.d.). Johnson et al. (2003a) state that the checklist appears to have come from the records of Robert and Sarah Paxton from observations in the 1960s. The introduction to the checklist indicates that it covers the area from Interstate 25 to the monument. Little or no habitat exists at FOUN for some species on the list, such as wetland, shrubland, and woodland birds.

In 2002, Johnson et al. (2003b) established point transects in grassland, pinyon-juniper, and riparian habitats in the monument, along with additional points in areas around the residential area, visitor center, adobe ruins, the sewage ponds, and the southwest boundary near Wolf Creek (Figure 3-10). These transects (a total of 14 points surveyed twice) and additional points (17 surveyed once) were surveyed in late May and early June 2002 (Johnson et al. 2003b). Birds found during those surveys, seen by park personnel, and found during research for the New Mexico Breeding Bird Atlas (Breeding Bird Atlas Explorer 2011) are listed in Table 3.4 under "SOPN Inventory" (58 species).

In 2009, Rocky Mountain Bird Observatory (R. Bennetts, pers. comm., October 5, 2009) staff established and surveyed new transects with points distributed across both parcels of the park (Figure 3-10, 65 points, each twice) between June 3 and 10, 2009. The results of this survey are listed in Table 3.4 under "NPS 2009."

3.10.4.2. Reference Condition

A target list of bird species was created for the Southern Plains Inventory and Monitoring Network (Johnson et al. 2003a; Table 3.4). This list included bird species expected in the monument at the time of the inventory, given available records in the area and habitats at the park. The only historical bird data for the park come from the checklist from the 1960s mentioned above (Fort Union National Monument, n.d.). Other data used in compiling the target list were from the Breeding Bird Survey route at Wagon Mound (U.S. Geological Survey Patuxent Wildlife Research Center 2003). The current condition of the grassland habitat seems to be similar to what it was before the fort was established in 1851 (Shackel 1983).

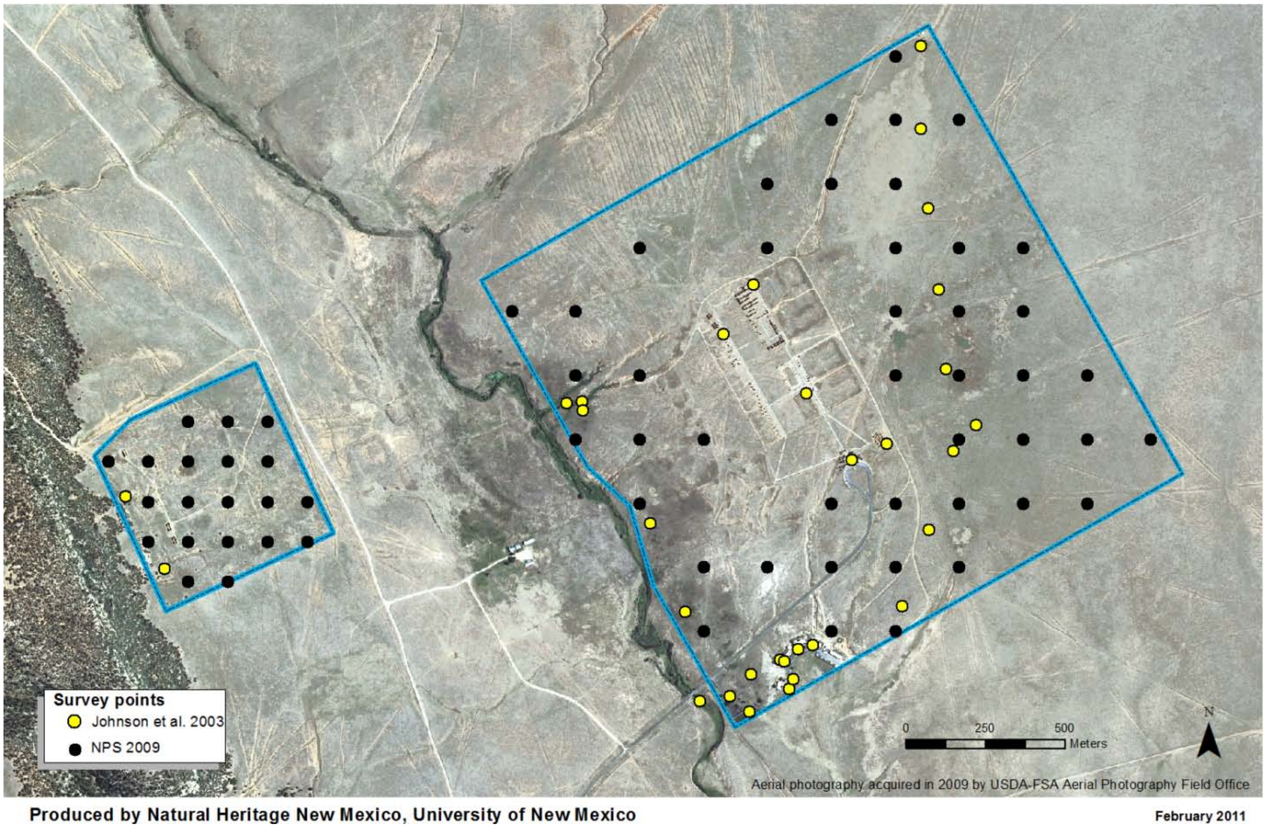

Figure 3-10. Point transects established for bird surveys by Johnson et al. (2003b) and NPS (2009).

3.10.4.3. Resource Description

Johnson et al. (2003a) detected 58 species in breeding season surveys. Rocky Mountain Bird Observatory (NPS 2009) detected 29 species, also during the breeding season. All bird species on the target list either were seen in the two recent surveys or were on the checklist from the 1960s. Three species on the target list were not detected in the recent surveys: scaled quail (*Callipepla squamata*), golden eagle (*Aquila chrysaetos*), and common poorwill (*Phalaenoptilus nuttallii*). When the target list was created, sufficient habitat was thought to occur for those species at the monument, but perhaps they occur in low enough numbers to escape detection in only two surveys. With more survey effort, they might be detected.

Eighteen species were seen in recent surveys but were not on the checklist, indicating that species composition might have changed since the checklist was made. Some species may occur at the monument now because of increased population sizes, expanded ranges, or change in habitat at the monument since the 1960s. Grazing ceased with the establishment of the monument in 1956, and this may have caused a change in the birds present through the 1960s and beyond. Brewer's blackbird (*Euphagus cyanocephalus*) is a human commensal that may have come into the area with increased human habitation (Martin 2002). Great-tailed grackle (*Quiscalus mexicanus*), brown-headed cowbird (*Molothrus ater*), and common grackle (*Quiscalus quiscula*) populations and ranges have expanded (Sauer et al. 1999, as cited in Johnson and Peer 2001 and Johnson and Peer 2001). Mallard (*Anas platyrhynchos*; Drilling et al. 2002) and Eurasian collared-dove (*Streptopelia decaocto*) have experienced dramatic population increases (Romagosa 2002); vesper sparrow (*Pooecetes gramineus*) has undergone less dramatic increases (Jones and Cornely 2002). Blue-gray gnatcatcher (*Polioptila caerulea*) has also experienced a range expansion (Ellison 1992). This may explain why these species were not recorded on the checklist but were present in the recent surveys. Other changes in species composition since the 1960s may be due to habitat changes. For instance, increases in height of riparian trees may account for the presence of Bullock's oriole (*Icterus bullockii*; Rising and Williams 1999,) and black-chinned hummingbird (*Archilochus alexandri*; Baltosser and Russell 2000).

It is difficult to determine if birds on the checklist but not detected in recent surveys actually indicate changes at the park. As mentioned above, the checklist covers a larger area than the monument itself. The checklist may also represent more effort than went into the more recent surveys. Surveys typically represent a few days in the field, whereas the checklist may be based on years of observations. If the checklist is based on years of observation, it would be more likely than the survey data to include rare species.

3.10.4.4. Condition of Data

We have a high level of confidence that the combined list of bird species is a relatively complete indication of the species that occur at the park.

Table 3-4. Bird species present in Fort Union National Monument.

Common Name	**Scientific Name**	**Johnson et al. 2003 Target List**	**Johnson et al. 2003**	**NPS 2009**	**FOUN, n.d.**
Canada Goose	*Branta canadensis*	X	X	X	X
Mallard	*Anas platyrhynchos*	X	X		
Blue-winged Teal	*Anas discors*				X
Scaled Quail	*Callipepla squamata*	X			X
Wild Turkey	*Meleagris gallopavo*			X	X
Great Blue Heron	*Ardea herodias*			X	X
Turkey Vulture	*Cathartes aura*	X	X	X	X
Northern Harrier	*Circus cyaneus*				X
Cooper's Hawk	*Accipiter cooperii*				X
Swainson's Hawk	*Buteo swainsoni*	X	X		
Red-tailed Hawk	*Buteo jamaicensis*	X	X		X
Ferruginous Hawk	*Buteo regalis*				X
Golden Eagle	*Aquila chrysaetos*	X			X
American Kestrel	*Falco sparverius*	X	X	X	X
Prairie Falcon	*Falco mexicanus*	X	X		X
Killdeer	*Charadrius vociferus*	X	X		X
Long-billed Curlew	*Numenius americanus*				X
Eurasian Collared-Dove	*Streptopelia decaocto*			X	
Mourning Dove	*Zenaida macroura*	X	X	X	X
Greater Roadrunner	*Geococcyx californianus*				X
Great Horned Owl	*Bubo virginianus*	X	X		X
Burrowing Owl	*Athene cunicularia*				X
Common Nighthawk	*Chordeiles minor*	X	X	X	X
Common Poorwill	*Phalaenoptilus nuttallii*	X			X

Common Name	Scientific Name	Johnson et al. 2003 Target List	Johnson et al. 2003	NPS 2009	FOUN, n.d.
Black-chinned Hummingbird	*Archilochus alexandri*	X	X		
Broad-tailed Hummingbird	*Selasphorus platycercus*	X	X		X
Downy Woodpecker	*Picoides pubescens*				X
Hairy Woodpecker	*Picoides villosus*				X
Northern Flicker	*Colaptes auratus*	X	X		X
Olive-sided Flycatcher	*Contopus cooperi*				X
Western Wood-Pewee	*Contopus sordidulus*		X		X
Eastern Phoebe	*Sayornis phoebe*			X	
Say's Phoebe	*Sayornis saya*	X	X	X	X
Ash-throated Flycatcher	*Myiarchus cinerascens*	X	X	X	X
Cassin's Kingbird	*Tyrannus vociferans*	X	X		X
Western Kingbird	*Tyrannus verticalis*	X	X	X	X
Loggerhead Shrike	*Lanius ludovicianus*	X	X		X
Western Scrub-Jay	*Aphelocoma californica*		X		
Pinyon Jay	*Gymnorhinus cyanocephalus*			X	X
Black-billed Magpie	*Pica hudsonia*	X	X		X
American Crow	*Corvus brachyrhynchos*	X	X		X
Common Raven	*Corvus corax*	X	X	X	X
Horned Lark	*Eremophila alpestris*	X	X	X	X
Violet-green Swallow	*Tachycineta thalassina*			X	X
Northern Rough-winged Swallow	*Stelgidopteryx serripennis*	X	X	X	X
Cliff Swallow	*Petrochelidon pyrrhonota*	X	X	X	X
Barn Swallow	*Hirundo rustica*	X	X	X	X
Rock Wren	*Salpinctes obsoletus*	X	X	X	X
Canyon Wren	*Catherpes mexicanus*		X		
House Wren	*Troglodytes aedon*		X		
Blue-gray Gnatcatcher	*Polioptila caerulea*		X		
Mountain Bluebird	*Sialia currucoides*	X	X	X	X
American Robin	*Turdus migratorius*	X	X		X
Northern Mockingbird	*Mimus polyglottos*	X	X	X	X
Curve-billed Thrasher	*Toxostoma curvirostre*				X
European Starling	*Sturnus vulgaris*	X	X		X
Virginia's Warbler	*Vermivora virginiae*		X		
Yellow Warbler	*Dendroica petechia*		X		X
Yellow-rumped Warbler	*Dendroica coronata*				X
Common Yellowthroat	*Geothlypis trichas*	X	X		
Wilson's Warbler	*Wilsonia pusilla*				X
Green-tailed Towhee	*Pipilo chlorurus*		X		X
Spotted Towhee	*Pipilo maculatus*		X		X
Canyon Towhee	*Pipilo fuscus*	X	X		X
Cassin's Sparrow	*Aimophila cassinii*	X	X	X	
Chipping Sparrow	*Spizella passerina*	X	X		X
Brewer's Sparrow	*Spizella breweri*	X	X		X
Vesper Sparrow	*Pooecetes gramineus*	X	X	X	
Lark Sparrow	*Chondestes grammacus*	X	X	X	X

Common Name	Scientific Name	Johnson et al. 2003 Target List	Johnson et al. 2003	NPS 2009	FOUN, n.d.
Lark Bunting	*Calamospiza melanocorys*				X
White-crowned Sparrow	*Zonotrichia leucophrys*				X
Black-headed Grosbeak	*Pheucticus melanocephalus*		X		X
Blue Grosbeak	*Passerina caerulea*	X	X		X
Red-winged Blackbird	*Agelaius phoeniceus*	X	X	X	X
Western Meadowlark	*Sturnella neglecta*	X	X	X	X
Brewer's Blackbird	*Euphagus cyanocephalus*	X	X		
Common Grackle	*Quiscalus quiscula*		X		
Great-tailed Grackle	*Quiscalus mexicanus*	X	X		
Brown-headed Cowbird	*Molothrus ater*	X	X	X	
Bullock's Oriole	*Icterus bullockii*	X	X		
House Finch	*Carpodacus mexicanus*	X	X		X
Lesser Goldfinch	*Spinus psaltria*	X	X	X	X
House Sparrow	*Passer domesticus*	X			X

Sources: Johnson et al. 2003, Johnson et al. 2003, NPS 2009, (FOUN) Fort Union National Monument, n.d.

3.10.4.5. Data Gaps

Available data provide a good picture of species richness at the park in the breeding season, but data are lacking on wintering and migrating birds. In addition, data are not sufficient to allow assessment of density, abundance, or trends. These gaps could be addressed with surveys repeated several times within each of the four seasons and designed to capture these measures.

3.10.5. Mammals

3.10.5.1. Data and Methods

In 2001 and 2002, mammals were surveyed by experienced observers (Johnson et al. 2003b; Table 3.5). These surveys, conducted August 6–9 and October 18–20, 2001, on the main parcel and September 19–23, 2002, on both parcels, consisted of live trapping with various sized traps, direct observations, and/or observations of sign such as scat or tracks. Several animal taxa were not surveyed because they require special methods. Shrews (Soricidae) were not surveyed because this requires pitfall traps, which are not permitted at FOUN. Bats (Chiroptera) were not sampled because mist-netting was beyond the scope of the study. Gophers (Geomyidae) were not surveyed because gopher traps must be buried, and digging was not permitted (Johnson et al. 2003b). Incidental mammal observations occurred during the vegetation mapping of FOUN (Muldavin et al. 2004).

3.10.5.2. Reference Conditions

Johnson et al. (2003b) created a target list of mammals (Table 3.5) expected at FOUN using historical accounts (Findley et al. 1975), University of New Mexico Museum of Southwestern Biology records, and expert opinion. This list does not cover shrews, bats, or gophers, which were not targeted by Johnson et al. (2003b).

3.10.5.3. Resource Description

Sixteen of the 32 mammal species on the target list were detected (Johnson et al. 2003b; Table 3.5). Some of the species on the target list that were not detected may be present at FOUN but are difficult to capture or detect. For instance, gray fox (*Urocyon cinereoargenteus*), swift fox (*Vulpes velox*), striped skunk (*Mephitis mephitis*), and raccoon (*Procyon lotor)* were on the target list and not detected, but all are primarily nocturnal or nocturnal and crepuscular (NatureServe 2010), making them more difficult to detect by direct observation. Also, animals that occur at low densities such as the larger carnivores would be more difficult to detect.

Muldavin et al. (2004) found extensive evidence of Botta's pocket gophers (*Thomomys bottae*). At that time, the gophers had excavated large areas of the park in areas of past disturbance and were expanding into the open grasslands.

3.10.5.4. Condition of Data

Because there has been only one mammal survey at FOUN, conducted over a total of 11 days in two years, our confidence is low that the present list of mammals at FOUN is complete. Surveys over multiple years and specifically targeting undetected species would likely produce a more complete species list.

3.10.5.5. Data Gaps

Data gaps exist for the groups not surveyed: bats, gophers, and shrews. Surveys should be conducted over multiple years and should target as-yet-undetected species.

Table 3-5. Mammals documented in Fort Union National Monument.

Order	Family	Common Name	Scientific Name	Target List (Johnson et al. 2003)	Observed/Habitat	Reference
Chiroptera	Vespertilionidae	Townsend's big-eared bat	*Corynorhinus townsendii*		unk.	MSB specimen 8/2/70
Chiroptera	Vespertilionidae	Big brown bat	*Eptesicus fuscus*		unk.	MSB specimen 7/24/66
Chiroptera	Vespertilionidae	Fringed myotis	*Myotis thysanodes*		unk.	MSB specimen 8/2/70
Chiroptera	Vespertilionidae	Yuma myotis	*Myotis yumanensis*		unk.	MSB specimen 7/2/70
Lagomorpha	Leporidae	Desert cottontail	*Sylvilagus audubonii*	X	Grassland	Johnson et al. 2003
Lagomorpha	Leporidae	Southwestern cottontail	*Sylvilagus nuttallii pinetis*	X	Grassland	Johnson et al. 2003
Rodentia	Cricetidae	Prairie vole	*Microtus ochrogaster*	X		
Rodentia	Cricetidae	Meadow vole	*Microtus pennsylvanicus*	X		
Rodentia	Cricetidae	White-throated woodrat	*Neotoma albigula*	X	Grassland/pinyon-juniper woodland transition, grassland with bushes or trees	Johnson et al. 2003
Rodentia	Cricetidae	Southern plains woodrat	*Neotoma micropus*	X	Grassland with scattered bushes	Johnson et al. 2003
Rodentia	Cricetidae	Northern grasshopper mouse	*Onychomys leucogaster*	X	Grassland	Johnson et al. 2003
Rodentia	Cricetidae	White-footed Mouse	*Peromyscus leucopus*	X	Grassland	Johnson et al. 2003
Rodentia	Geomyidae	Botta's pocket gopher	*Thomomys bottae*		unk.	Muldavin et a. 2004
Rodentia	Heteromyidae	Hispid pocket mouse	*Chaetodipus hispidus*	X		
Rodentia	Heteromyidae	Ord's kangaroo rat	*Dipodomys ordii*	X	Grassland	Johnson et al. 2003
Rodentia	Heteromyidae	Silky pocket mouse	*Perognathus flavus*	X	Grassland	Johnson et al. 2003
Rodentia	Muridae	Brush mouse	*Peromyscus boylii*	X		
Rodentia	Muridae	North american deer mouse	*Peromyscus maniculatus*	X	Grassland	Johnson et al. 2003
Rodentia	Muridae	Northern rock deermouse	*Peromyscus nasutus*	X	Grassland/pinyon-juniper woodland transition	Johnson et al. 2003
Rodentia	Muridae	Western harvest mouse	*Reithrodontomys megalotis*	X	Grassland/arroyo	Johnson et al. 2003
Rodentia	Sciuridae	Least chipmunk	*Neotamias minimus*	X		
Rodentia	Sciuridae	Thirteen-lined ground squirrel	*Spermophilus tridecemlineatus*	X	Grassland	Johnson et al. 2003
Rodentia	Sciuridae	Rock squirrel	*Spermophilus variegatus*	X		

Order	Family	Common Name	Scientific Name	Target List (Johnson et al. 2003)	Observed/Habitat	Reference
Carnivora	Canidae	Coyote	*Canis latrans*	X	Grassland	Johnson et al. 2003
Carnivora	Canidae	Gray fox	*Urocyon cinereoargenteus*	X		
Carnivora	Canidae	Swift fox	*Vulpes velox velox*	X		
Carnivora	Mustelidae	Striped skunk	*Mephitis mephitis*	X		
Carnivora	Mustelidae	American badger	*Taxidea taxus*	X	Grassland (tracks; near arroyo)	Johnson et al. 2003
Carnivora	Procyonidae	Common raccoon	*Procyon lotor*	X		
Artiodactyla	Antilocapridae	Pronghorn	*Antilocapra americana*	X	Grassland	Johnson et al. 2003
Artiodactyla	Cervidae	Elk	*Cervus canadensis*	X	Grassland	Johnson et al. 2003
Artiodactyla	Cervidae	Mule deer	*Odocoileus hemionus*	X		

Note: MSB = University of New Mexico Museum of Southwestern Biology

3.10.6. Literature Cited

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Appendix A: **Summary of Vegetation Found in Fort Union National Monument**

Appendix A. Plant species found in Fort Union National Monument.

Family	Scientific Name	New Mexico Common Name	Nonnative[a]	New Mexico Weed Class[b]	Federal Weed Status[a]	Muldavin et al. 2004	Narum-alani et al. 2004	Muldavin et al. 2005, unpubl.	Folts-Zettner 2010, unpubl.	Former Name
Agavaceae	*Nolina greenei*	Green's beargrass				X		X		
Agavaceae	*Yucca glauca*	soapweed yucca				X		X	X	
Amaranthaceae	*Amaranth.*								X	
Amaranthaceae	*Amaranthus hybridus*	slim amaranth				X		X	X	
Amaranthaceae	*Amaranthus palmeri*	carelessweed				X		X		
Anacardiaceae	*Rhus trilobata*	skunkbush sumac				X		X		
Anacardiaceae	*Toxicodendron rydbergii*	western poison ivy				X		X		*T. radicans*
Apiaceae	*Berula erecta*	cutleaf waterparsnip						X		
Asclepiadaceae	*Asclepias latifolia*	broadleaf milkweed						X		
Asclepiadaceae	*Asclepias speciosa*	showy milkweed						X		
Asclepiadaceae	*Asclepias spp.*	milkweed						X		
Asclepiadaceae	*Asclepias subverticillata*	whorled milkweed				X		X	X	
Asteraceae	*Ambrosia confertiflora*	weakleaf bur ragweed				X		X	X	
Asteraceae	*Ambrosia psilostachya*	Cuman ragweed						X		
Asteraceae	*Ambrosia spp.*	ragweed						X		
Asteraceae	*Ambrosia tomentosa*	skeletonleaf burr ragweed							X	
Asteraceae	*Artemisia carruthii*	Carruth's sagewort				X		X		
Asteraceae	*Artemisia filifolia*	sand sagebrush							X	
Asteraceae	*Artemisia frigida*	fringed sagewort				X		X	X	
Asteraceae	*Artemisia ludoviciana*	white sagebrush				X		X		
Asteraceae	*Bahia spp.*	bahia						X		

Family	Scientific Name	New Mexico Common Name	Nonnative[a]	New Mexico Weed Class[b]	Federal Weed Status[a]	Muldavin et al. 2004	Narum-alani et al. 2004	Muldavin et al. 2005, unpubl.	Folts-Zettner 2010, unpubl.	Former Name
Asteraceae	*Berlandiera lyrata*	lyreleaf greeneyes				X		X		
Asteraceae	*Bidens spp.*	beggartick						X		
Asteraceae	*Brickellia brachyphylla*	plumed brickellbush				X		X		
Asteraceae	*Brickellia californica*	California brickellbush				X		X		
Asteraceae	*Brickellia eupatorioides var. chlorolepis*	false boneset				X		X		
Asteraceae	*Brickellia microphylla var. scabra*	rough brickellbush				X		X		
Asteraceae	*Carduus nutans*	nodding plumeless thistle	X	B				X		
Asteraceae	*Chaetopappa ericoides*	rose heath				X		X		
Asteraceae	*Cirsium spp.*	thistle						X	X	
Asteraceae	*Cirsium undulatum*	wavyleaf thistle				X		X	X	
Asteraceae	*Cirsium wheeleri*	Wheeler's thistle				X		X		
Asteraceae	*Conyza canadensis*	Canadian horseweed				X		X	X	
Asteraceae	*Dieteria canescens var. ambigua*	hoary tansyaster				X		X		*Machaerant -hera canescens* var. ambigua
Asteraceae	*Dyssodia papposa*	fetid marigold				X		X	X	
Asteraceae	*Engelmannia peristenia*	Engelmann's daisy				X		X	X	
Asteraceae	*Ericameria nauseosa var. latisquamea*	rubber rabbitbrush				X		X		
Asteraceae	*Erigeron canus*	hoary fleabane				X		X		
Asteraceae	*Erigeron divergens*	spreading fleabane						X		
Asteraceae	*Grindelia squarrosa*	curlycup gumweed				X		X		*G. nuda* var.

Family	Scientific Name	New Mexico Common Name	Nonnative[a]	New Mexico Weed Class[b]	Federal Weed Status[a]	Muldavin et al. 2004	Narum-alani et al. 2004	Muldavin et al. 2005, unpubl.	Folts-Zettner 2010, unpubl.	Former Name
										aphanactic
Asteraceae	*Gutierrezia sarothrae*	broom snakeweed				X		X	X	
Asteraceae	*Helianthus annuus*	common sunflower				X		X	X	
Asteraceae	*Heterotheca fulcrata*	rockyscree falsegoldenaster						X		
Asteraceae	*Heterotheca villosa*	hairy goldenaster						X	X	
Asteraceae	*Heterotheca villosa var. minor*	hairy false goldenaster				X		X		
Asteraceae	*Hymenopappus filifolius*	fineleaf hymenopappus				X		X		
Asteraceae	*Lactuca serriola*	prickly lettuce	X				X	X	X	
Asteraceae	*Liatris punctata*	dotted gayfeather				X		X	X	
Asteraceae	*Lygodesmia juncea*	rush skeletonplant				X		X		
Asteraceae	*Lygodesmia texana*	Texas skeletonplant						X		
Asteraceae	*Machaeranthera biglovii*	Bigelow's tansyaster							X	
Asteraceae	*Machaeranthera pinnatifida*	lacy tansyaster				X			X	
Asteraceae	*Machaeranthera spp.*	tansyaster						X		
Asteraceae	*Packera spp.*	ragwort						X		
Asteraceae	*Picradeniopsis oppositifolia*	oppositeleaf bahia							X	
Asteraceae	*Ratibida columnifera*	upright prairie coneflower						X		
Asteraceae	*Ratibida tagetes*	green prairie coneflower				X		X	X	
Asteraceae	*Senecio spartioides*	broom groundsel				X		X	X	
Asteraceae	*Solidago mollis*	velvety goldenrod				X		X		
Asteraceae	*Sonchus asper*	spiny sowthistle	X				X		X	
Asteraceae	*Symphyotrichum ericoides*	heath aster				X		X	X	

Family	Scientific Name	New Mexico Common Name	Nonnative[a]	New Mexico Weed Class[b]	Federal Weed Status[a]	Muldavin et al. 2004	Narum-alani et al. 2004	Muldavin et al. 2005, unpubl.	Folts-Zettner 2010, unpubl.	Former Name
Asteraceae	*Symphyotrichum falcatum var. crassulum*	white prairie aster				X		X		
Asteraceae	*Symphyotrichum lanceolatum ssp. hesperium*	white panicle aster				X		X		
Asteraceae	*Taraxacum officinale*	common dandelion	X				X	X		
Asteraceae	*Tetraneuris acaulis*	stemless hymenoxys				X		X		
Asteraceae	*Thelesperma megapotamicum*	Hopi tea greenthread				X		X	X	
Asteraceae	*Thelesperma spp.*	greenthread						X		
Asteraceae	*Thymophylla aurea*	manyawn pricklyleaf							X	
Asteraceae	*Tragopogon dubius*	yellow salsify	X				X		X	
Asteraceae	*Tragopogon pratensis*	meadow salsify	X			X	X	X		
Asteraceae	*Tragopogon sp.*								X	
Asteraceae	*Verbesina encelioides*	golden crownbeard				X		X		
Asteraceae	*Xanthisma spinulosum*	lacy tansyaster						X		
Asteraceae	*Zinnia grandiflora*	Rocky Mountain zinnia				X		X	X	
Boraginaceae	*Cryptantha minima*	little cryptantha						X		
Boraginaceae	*Cryptantha thyrsiflora*	calcareous cryptantha				X		X		
Boraginaceae	*Lappula occidentalis*	flatspine stickseed						X		
Boraginaceae	*Lithospermum incisum*	narrowleaf gromwell						X		
Boraginaceae	*Onosmodium molle ssp. occidentale*	western marbleseed							X	
Brassicaceae	*Descurainia sp.*								X	
Brassicaceae	*Erysimum spp.*	wallflower						X		

Family	Scientific Name	New Mexico Common Name	Nonnative[a]	New Mexico Weed Class[b]	Federal Weed Status[a]	Muldavin et al. 2004	Narum-alani et al. 2004	Muldavin et al. 2005, unpubl.	Folts-Zettner 2010, unpubl.	Former Name
Brassicaceae	*Lepidium spp.*	pepperweed						X		
Brassicaceae	*Lesquerella sp.*								X	
Cactaceae	*Coryphantha sp.*								X	
Cactaceae	*Echinocereus coccineus*	scarlet hedgehog cactus				X		X		
Cactaceae	*Echinocereus viridiflorus*	nylon hedgehog cactus				X		X	X	
Cactaceae	*Opuntia phaeacantha*	tulip pricklypear				X		X		
Cactaceae	*Opuntia polyacantha*	plains pricklypear				X		X		
Caryophyllaceae	*Arenaria lanuginosa ssp. saxosa*	spreading sandwort				X		X		
Chenopodiaceae	*Atriplex canescens*	fourwing saltbush				X		X		
Chenopodiaceae	*Chenopodium album*	lambsquarters	X						X	
Chenopodiaceae	*Chenopodium graveolens*	fetid goosefoot						X		
Chenopodiaceae	*Chenopodium hians*	hians goosefoot				X		X		
Chenopodiaceae	*Chenopodium incanum*	mealy goosefoot				X		X		
Chenopodiaceae	*Chenopodium leptophyllum*	narrowleaf goosefoot				X		X	X	
Chenopodiaceae	*Chenopodium sp.*								X	
Chenopodiaceae	*Kochia scoparia*	common kochia	X			X	X	X	X	
Chenopodiaceae	*Krascheninnikovia lanata*	winterfat				X		X		
Chenopodiaceae	*Salsola tragus*	prickly Russian thistle	X			X	X	X	X	
Commelinaceae	*Commelina dianthifolia*	birdbill dayflower				X		X		
Convolvulaceae	*Convolvulus arvensis*	field bindweed	X			X	X	X	X	
Convolvulaceae	*Ipomoea purpurea*	tall morningglory	X			X		X	X	

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Cucurbitaceae	*Cucurbita foetidissima*	buffalo gourd				X		X	X	
Cupressaceae	*Juniperus monosperma*	oneseed juniper				X		X		
Cupressaceae	*Juniperus scopulorum*	Rocky Mountain juniper				X		X		
Cyperaceae	*Carex inops ssp. heliophila*	sun sedge						X		
Cyperaceae	*Carex inops ssp. heliophila*	Crins sun sedge				X				*C. rossii*
Cyperaceae	*Carex occidentalis*	western sedge				X		X		
Cyperaceae	*Carex spp.*					X				
Cyperaceae	*Cyperus fendlerianus*	Fendler's flatsedge				X		X	X	
Cyperaceae	*Schoenoplectus pungens*	common threesquare						X		
Euphorbiaceae	*Chamaesyce fendleri*	Fendler's sandmat				X		X	X	
Euphorbiaceae	*Chamaesyce serpyllifolia*	thymeleaf sandmat				X		X	X	
Euphorbiaceae	*Euphorbia davidii*	David's spurge	X			X		X	X	
Euphorbiaceae	*Euphorbia dentata*	toothed spurge	intro.&native						X	
Fabaceae	*Amorpha canescens*	leadplant						X		
Fabaceae	*Amorpha fruticosa*	desert indigobush				X		X		
Fabaceae	*Astragalus agrestis*	purple milkvetch							X	
Fabaceae	*Astragalus spp.*	milkvetch						X		
Fabaceae	*Dalea candida*	slender white prairieclover							X	
Fabaceae	*Dalea candida var. oligophylla*	white prairieclover				X		X		
Fabaceae	*Dalea purpurea*	purple prairieclover				X		X		
Fabaceae	*Dalea spp.*	prairieclover						X		

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Fabaceae	*Glycyrrhiza lepidota*	American licorice				X		X		
Fabaceae	*Lathyrus eucosmus*	bush peavine				X		X	X	
Fabaceae	*Lathyrus spp.*					X				
Fabaceae	*Medicago lupulina*	black medick	X				X			
Fabaceae	*Medicago sativa*	alfalfa	X				X		X	
Fabaceae	*Melilotus officinalis*	yellow sweetclover	X			X	X	X	X	
Fabaceae	*Oxytropis spp.*	crazyweed				X		X		
Fabaceae	*Psoralidium tenuiflorum*	slimflower scurfpea				X		X		
Fagaceae	*Quercus ×pauciloba*	wavyleaf oak				X		X		
Fagaceae	*Quercus grisea*	gray oak				X		X		
Geraniaceae	*Erodium cicutarium*	redstem stork's bill	X				X		X	
Grossulariaceae	*Ribes cereum*	wax currant				X		X		
Juncaceae	*Juncus arcticus var. balticus*	Baltic rush				X		X		
Lamiaceae	*Marrubium vulgare*	horehound	X			X	X	X	X	
Lamiaceae	*Monarda pectinata*	pony beebalm						X		
Lamiaceae	*Salvia reflexa*	lanceleaf sage				X		X	X	
Lamiaceae	*Teucrium laciniatum*	lacy germander				X		X	X	
Liliaceae	*Allium cernuum*	nodding onion				X		X		
Liliaceae	*Zigadenus elegans*	mountain deathcamas				X		X		
Linaceae	*Linum lewisii*	prairie flax							X	
Linaceae	*Linum puberulum*	plains flax						X		
Loasaceae	*Mentzelia multiflora*	manyflowered mentzelia				X		X		
Malvaceae	*Malva neglecta*	common mallow							X	
Malvaceae	*Sphaeralcea coccinea*	scarlet globemallow				X		X	X	
Malvaceae	*Sphaeralcea hastulata*	spear globemallow				X		X		
Malvaceae	*Sphaeralcea incana*	gray globemallow				X		X	X	

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Nyctaginaceae	*Mirabilis linearis*	narrowleaf four o'clock				X		X		
Onagraceae	*Epilobium ciliatum*	hairy willowherb						X		
Onagraceae	*Gaura coccinea*	scarlet beeblossom				X		X		
Onagraceae	*Gaura mollis*	velvetweed						X	X	
Onagraceae	*Oenothera coronopifolia*	crownleaf evening-primrose				X		X		
Pinaceae	*Pinus edulis*	pinyon pine				X		X		
Pinaceae	*Pinus ponderosa var. scopulorum*	ponderosa pine				X		X		
Plantaginaceae	*Plantago lanceolata*	narrowleaf plantain	X				X			
Plantaginaceae	*Plantago major*	common plantain	X				X			
Plantaginaceae	*Plantago patagonica*	woolly plantain						X		
Poaceae	*Achnatherum robustum*	sleepygrass				X		X	X	
Poaceae	*Agrostis gigantea*	redtop	X			X	X	X		
Poaceae	*Agrostis stolonifera*	creeping bentgrass	X					X		
Poaceae	*Andropogon gerardii*	big bluestem						X		
Poaceae	*Aristida divaricata*	poverty threeawn				X		X	X	
Poaceae	*Aristida purpurea*	purple threeawn				X		X	X	
Poaceae	*Aristida purpurea var. purpurea*	purple threeawn						X		
Poaceae	*Bouteloua curtipendula*	sideoats grama				X		X	X	
Poaceae	*Bouteloua gracilis*	blue grama				X		X	X	
Poaceae	*Bouteloua hirsuta*	hairy grama				X		X	X	
Poaceae	*Bromus anomalus*	nodding brome				X		X		
Poaceae	*Bromus catharticus*	rescuegrass	X			X	X	X		
Poaceae	*Bromus japonicus*	Japanese brome	X				X	X		
Poaceae	*Bromus lanatipes*	woolly brome						X		
Poaceae	*Bromus tectorum*	cheatgrass	X				X			

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Poaceae	*Buchloe dactyloides*	buffalograss						X		
Poaceae	*Cynodon dactylon*	bermudagrass	X				X		X	
Poaceae	*Dasyochloa pulchella*	fluffgrass							X	
Poaceae	*Distichlis spicata*	inland saltgrass				X		X		
Poaceae	*Elymus canadensis*	Canada wildrye				X		X		
Poaceae	*Elymus elymoides*	bottlebrush squirreltail				X		X	X	
Poaceae	*Elymus trachycaulus*	slender wheatgrass				X		X		
Poaceae	*Eragrostis cilianensis*	stinkgrass	X						X	
Poaceae	*Koeleria macrantha*	prairie junegrass						X		
Poaceae	*Lycurus phleoides*	common wolfstail						X		
Poaceae	*Lycurus setosus*	bristly wolfstail				X		X	X	
Poaceae	*Muhlenbergia montana*	mountain muhly				X		X		
Poaceae	*Muhlenbergia repens*	creeping muhly						X		
Poaceae	*Muhlenbergia torreyi*	ring muhly				X		X	X	
Poaceae	*Muhlenbergia wrightii*	spike muhly				X		X		
Poaceae	*Munroa squarrosa*	false buffalograss						X		
Poaceae	*Panicum capillare*	witchgrass				X		X	X	
Poaceae	*Panicum obtusum*	vine mesquite				X		X		
Poaceae	*Panicum virgatum*	switchgrass				X		X		
Poaceae	*Pascopyrum smithii*	western wheatgrass				X		X	X	
Poaceae	*Piptatherum micranthum*	littleseed ricegrass				X		X		
Poaceae	*Pleuraphis jamesii*	galleta							X	
Poaceae	*Poa annua*	bluegrass	X					X		
Poaceae	*Poa fendleriana*	muttongrass						X		
Poaceae	*Poa pratensis*	Kentucky bluegrass						X		

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Poaceae	*Schedonnardus paniculatus*	tumblegrass						X	X	
Poaceae	*Schizachyrium scoparium*	little bluestem				X		X	X	
Poaceae	*Setaria pumila*	yellow bristlegrass	X						X	
Poaceae	*Setaria viridis*	green bristlegrass	X						X	
Poaceae	*Sporobolus airoides*	alkali sacaton				X		X		
Poaceae	*Sporobolus cryptandrus*	sand dropseed				X		X	X	
Poaceae	*Stipa comata*	needle-and-thread grass							X	
Polygalaceae	*Polygala spp.*	milkwort						X		
Polygonaceae	*Eriogonum alatum*	winged buckwheat				X		X		
Polygonaceae	*Eriogonum jamesii*	James' buckwheat				X		X		
Polygonaceae	*Eriogonum wrightii*	Wright's buckwheat						X		
Polygonaceae	*Polygonum convolvulus*	black bindweed	X						X	
Polygonaceae	*Polygonum douglasii*	Douglas' knotweed							X	
Polygonaceae	*Rumex sp.*								X	
Portulacaceae	*Phemeranthus parviflorus*	sunbright				X		X		
Portulacaceae	*Portulaca oleracea*	common purslane				X		X	X	
Ranunculaceae	*Clematis ligusticifolia*	western white clematis				X		X		
Rosaceae	*Fallugia paradoxa*	Apacheplume				X		X		
Rosaceae	*Physocarpus monogynus*	mountain ninebark				X		X		
Rosaceae	*Rosa woodsii*	Woods' rose				X		X		
Salicaceae	*Populus angustifolia*	narrowleaf cottonwood				X		X		
Salicaceae	*Salix amygdaloides*	peachleaf willow				X		X		

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Salicaceae	*Salix exigua*	coyote willow				X		X		
Santalaceae	*Comandra umbellata ssp. pallida*	pale bastard toadflax				X		X		
Scrophulariaceae	*Castilleja integra*	wholeleaf Indian paintbrush				X		X	X	
Scrophulariaceae	*Penstemon spp.*	beardtongue						X		
Scrophulariaceae	*Verbascum thapsus*	common mullein	X			X	X	X	X	
Solanaceae	*Chamaesaracha coniodes*	gray fiveeyes							X	
Solanaceae	*Chamaesaracha coronopus*	greenleaf five eyes							X	
Solanaceae	*Physalis hederifolia*	ivyleaf groundcherry							X	
Solanaceae	*Physalis hederifolia var. comata*	ivyleaf groundcherry				X		X		
Solanaceae	*Solanum elaeagnifolium*	silverleaf nightshade				X		X		
Typhaceae	*Typha latifolia*	broadleaf cattail						X		
Ulmaceae	*Ulmus pumila*	Siberian elm	X	C		X	X	X		
Urticaceae	*Urtica dioica*	stinging nettle						X		
Verbenaceae	*Verbena macdougalii*	MacDougal verbena				X		X		
Total						140	22	192	92	

Sources:

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[b] (NMDA) New Mexico Department of Agriculture. 2009. New Mexico Noxious Weed List Update. New Mexico Department of Agriculture, NM State University, Las Cruces, NM.

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