National Park Service
U.S. Department of the Interior

Natural Resource Stewardship and Science

Lake Meredith National Recreation Area/ Alibates Flint Quarries National Monument

Natural Resource Condition Assessment

Natural Resource Report NPS/SOPN/NRR—2016/1124

ON THE COVER

Top: View of Lake Meredith. Amylia Williams
Bottom: Flint found in Alibates Flint Quarries NM. Heidi Sosinski

Lake Meredith National Recreation Area/ Alibates Flint Quarries National Monument

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All manuscripts in the series receive the appropriate level of peer review to ensure that the information is scientifically credible, technically accurate, appropriately written for the intended audience, and designed and published in a professional manner. This report received formal peer review by subject-matter experts who were not directly involved in the collection, analysis, or reporting of the data, and whose background and expertise put them on par technically and scientifically with the authors of the information.

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Appendices

Executive Summary

The Natural Resource Condition Assessment (NRCA) Program, administered by National Park Service's (NPS) Water Resources Division, aims to provide documentation about current conditions of important park natural resources through a spatially explicit, multi-disciplinary synthesis of existing scientific data and knowledge. The NRCA for Lake Meredith National Recreation Area and Alibates Flint Quarries National Monument began in 2014, and 13 focal study natural resources were chosen for the parks' NRCA. These resources were organized into three categories that ranged in contexts from broader to narrower including landscape-scale, supporting environment (i.e., physical resources), and biological integrity, which included wildlife and vegetation topics.

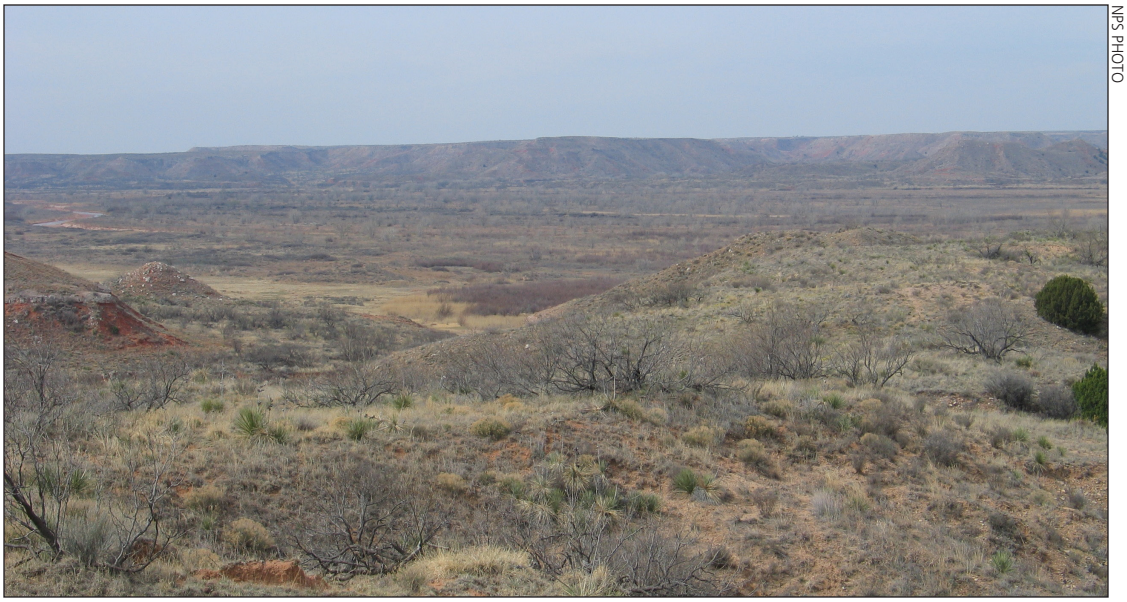
The landscape scale resources chosen for this assessment included viewshed, night sky, and soundscape. The night sky and soundscape are in moderate condition, but the viewshed is in good condition, given that the area surrounding both parks is rural to moderately developed in concentrated areas.

The parks' supporting physical environment resource topics included air quality, geology, groundwater, and surface water quality. The condition for each of these resources varied between moderate for air quality and geology, significant concern for surface water quality, and unknown for the groundwater resource.

The biological integrity resources assessed included grasslands, riparian habitat, and exotic plants for vegetation and landbirds, herpetofauna, and fish for wildlife. The riparian habitat and exotic plants were considered to be of significant concern, while the grasslands were in moderate conditon. The landbirds were determined to be in good condition but the fish in Lake Meredith were of significant concern. The conditions for herpetofauna and river fish could not be determined without additional data.

Acknowledgements

We wish to thank Jeff Albright, program lead of the Natural Resource Condition Assessment Program, Water Resources Program Center, National Park Service, who provided programmatic insight and guidance on project development and review and Donna Shorrock, Intermountain Region Natural Resource Condition Assessment Coordinator for her guidance and assistance. The authors are grateful to the staff at the National Park Service Natural Resource Stewardship and Science Directorate for their technical expertise, guidance, and reviews of their respective subjects, with a special thanks to Michael Martin for researching and writing the groundwater section. We are extremely grateful to all subject matter experts who provided valuable information pertaining to their respective areas of research and expertise. Their input helped to create a relevant, scientifically based document that provided new insights into the communities and processes found and occurring throughout the parks. Finally, we would like to express our gratitude and thanks to Lake Meredith National Recreation Area and Alibates Flint Quarries National Monument staffs, whose assistance with field data collection, input and reviews were very informative and helpful. To all those remaining who reviewed and commented on this report, thank you. Your contributions have increased its professional value.



NPS PHOTO

Chapter 1: NRCA Background Information

Natural Resource Condition Assessments (NRCAs) evaluate current conditions for a subset of natural resources and resource indicators in national park units, hereafter "parks." NRCAs also report on trends in resource condition (when possible), identify critical data gaps, and characterize a general level of confidence for study findings. The resources and indicators emphasized in a given project depend on the park's resource setting, status of resource stewardship planning and science in identifying high-priority indicators, and availability of data and expertise to assess current conditions for a variety of potential study resources and indicators.

NRCAs represent a relatively new approach to assessing and reporting on park resource conditions. They are meant to complement — not replace — traditional issue- and threat-based resource assessments. As distinguishing characteristics, all NRCAs:

- are multi-disciplinary in scope;[1]
- employ hierarchical indicator frameworks;[2]
- identify or develop reference conditions/values for comparison against current conditions;[3]
- emphasize spatial evaluation of conditions and GIS (map) products;[4]
- summarize key findings by park areas; and[5]
- follow national NRCA guidelines and standards for study design and reporting products.

NRCAs Strive to Provide…

- Credible condition reporting for a subset of important park natural resources and indicators
- Useful condition summaries by broader resource categories or topics, and by park areas

1. The breadth of natural resources and number/type of indicators evaluated will vary by park.
2. Frameworks help guide a multi-disciplinary selection of indicators and subsequent "roll up" and reporting of data for measures [conditions for indicators] condition summaries by broader topics and park areas
3. NRCAs must consider ecologically-based reference conditions, must also consider applicable legal and regulatory standards, and can consider other management-specified condition objectives or targets; each study indicator can be evaluated against one or more types of logical reference conditions. Reference values can be expressed in qualitative to quantitative terms, as a single value or range of values; they represent desirable resource conditions or, alternatively, condition states that we wish to avoid or that require a follow-on response (e.g., ecological thresholds or management "triggers").
4. As possible and appropriate, NRCAs describe condition gradients or differences across a park for important natural resources and study indicators through a set of GIS coverages and map products.
5. In addition to reporting on indicator-level conditions, investigators are asked to take a bigger picture (more holistic) view and summarize overall findings and provide suggestions to managers on an area-by-area basis: 1) by park ecosystem/habitat types or watersheds, and 2) for other park areas as requested.

Important NRCA Success Factors

- Obtaining good input from park staff and other NPS subject-matter experts at critical points in the project timeline
- Using study frameworks that accommodate meaningful condition reporting at multiple levels (measures / indicators) broader resource topics, and park areas
- Building credibility by clearly documenting the data and methods used, critical data gaps, and level of confidence for indicator-level condition findings

Although the primary objective of NRCAs is to report on current conditions relative to logical forms of reference conditions and values, NRCAs also report on trends, when appropriate (i.e., when the underlying data and methods support such reporting), as well as influences on resource conditions. These influences may include past activities or conditions that provide a helpful context for understanding current conditions, and/or present-day threats and stressors that are best interpreted at park, watershed, or landscape scales (though NRCAs do not report on condition status for land areas and natural resources beyond park boundaries). Intensive cause-and-effect analyses of threats and stressors, and development of detailed treatment options, are outside the scope of NRCAs.

Due to their modest funding, relatively quick timeframe for completion, and reliance on existing data and information, NRCAs are not intended to be exhaustive. Their methodology typically involves an informal synthesis of scientific data and information from multiple and diverse sources. Level of rigor and statistical repeatability will vary by resource or indicator, reflecting differences in existing data and knowledge bases across the varied study components.

The credibility of NRCA results is derived from the data, methods, and reference values used in the project work, which are designed to be appropriate for the stated purpose of the project, as well as adequately documented. For each study indicator for which current condition or trend is reported, we will identify critical data gaps and describe the 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. These staff will be asked to assist with the selection of study indicators;

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A NRCA is intended to provide useful science-based information products in support of all levels of park planning.

recommend data sets, methods, and reference conditions and values; and help provide a multi-disciplinary review of draft study findings and products.

NRCAs can yield new insights about current park resource conditions, but in many cases, their greatest value may be the development of useful documentation regarding known or suspected resource conditions within parks. Reporting products can help park managers as they think about near-term workload priorities, frame data and study needs for important park resources, and communicate messages about current park resource conditions to various audiences. A successful NRCA delivers science-based information that is both credible and has practical uses for a variety of park decision making, planning, and partnership activities.

However, it is important to note that NRCAs do not establish management targets for study indicators. That process must occur through park planning and management activities. What a NRCA can do is deliver science-based information that will assist park managers in their ongoing, long-term efforts to describe and quantify a park's desired resource conditions and management targets. In the near term, NRCA findings assist strategic park resource planning[6] and help parks to report on government accountability measures.[7] In addition, although in-depth analysis of the effects of climate change on park natural resources is outside the scope of NRCAs, the condition analyses and data sets developed for NRCAs will be useful for park-level climate-change studies and planning efforts.

NRCA Reporting Products…

- Provide a credible, snapshot-in-time evaluation for a subset of important park natural resources and indicators, to help park managers:
- Direct limited staff and funding resources to park areas and natural resources that represent high need and/or high opportunity situations (near-term operational planning and management)
- Improve understanding and quantification for desired conditions for the park's "fundamental" and "other important" natural resources and values (longer-term strategic planning)
- Communicate succinct messages regarding current resource conditions to government program managers, to Congress, and to the general public ("resource condition status" reporting)

NRCAs also provide a useful complement to rigorous NPS science support programs, such as the NPS Natural Resources Inventory & Monitoring (I&M) Program.[8] For example, NRCAs can provide current condition estimates and help establish reference

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A NRCA uses a variety of data to assess the condition of a park's natural resources.

6. An NRCA can be useful during the development of a park's Resource Stewardship Strategy (RSS) and can also be tailored to act as a post-RSS project.

7. While accountability reporting measures are subject to change, the spatial and reference-based condition data provided by NRCAs will be useful for most forms of "resource condition status" reporting as may be required by the NPS, the Department of the Interior, or the Office of Management and Budget.

8. The I&M program consists of 32 networks nationwide that are implementing "vital signs" monitoring in order to assess the condition of park ecosystems and develop a stronger scientific basis for stewardship and management of natural resources across the National Park System. "Vital signs" are a subset of physical, chemical, and biological elements and processes of park ecosystems that are selected to represent the overall health or condition of park resources, known or hypothesized effects of stressors, or elements that have important human values.

conditions, or baseline values, for some of a park's vital signs monitoring indicators. They can also draw upon non-NPS data to help evaluate current conditions for those same vital signs. In some cases, I&M data sets are incorporated into NRCA analyses and reporting products.

Over the next several years, the NPS plans to fund a NRCA project for each of the approximately 270 parks served by the NPS I&M Program. For more information on the NRCA program, visit http://www.nature.nps.gov/water/nrca/..


MARK BRUNSON

A view of the Canadian River within Lake Meredith NRA looking towards Alibates Flint Quarries NM.

Chapter 2: Introduction and Resource Setting

2.1. Introduction

2.1.1. Enabling Legislation/Executive Orders

Lake Meredith National Recreation Area (NRA) and Alibates Flint Quarries National Monument (NM) are adjacent parks and administered by the National Park Service. Sanford Reservoir, which later became Lake Meredith National Recreation Area on November 28, 1990, (Public Law 101-628) was established on August 31, 1964, when Congress passed Public Law 88-536 and construction of the dam began. "The 1964 law authorized the Secretary of Interior to provide for basic public outdoor recreation facilities..." (NPS 2013, p. 11). When management of the area was transferred to the National Park Service in 1990, it was to provide for outdoor recreation as well as primarily serve as a water supply reservoir (NPS 2013).

The purpose of the National Recreation Area was identified to *"provide public access to diverse land- and water-based recreational opportunities in the Canadian River breaks of the Texas panhandle, consistent with the protection of the area's scenic, scientific, and cultural resources and with other values that contribute to public enjoyment"* (NPS 2013 p. 14).

The NRA's significance statements include providing access to both water and land-based recreational activities; supporting habitats including aquatic, wetland, riparian, and treed uplands supporting a wide variety of wildlife; and preserving the unique geologic features and processes (NPS 2013).

Alibates Flint Quarries NM was established on August 31, 1965 (Public Law 89-154 to *"provide for the preservation, protection, interpretation, and scientific study of Alibates flint deposits associated with the activities and*

cultural resources of the indigenous peoples for the benefit of all" (NPS 2013, p. 18).

The NM's significance statements include the uniqueness of the flint including its physical characteristics and that the monument contains the only known exposed bedrock source of Alibates flint; the long history of flint use and associated archaeological sites, artifacts and quarries; and became listed on the National Register of Historic Places on October 15, 1966 (NPS 2013).

2.1.2. Geographic Setting

Lake Meredith National Recreation Area contains 44,978 acres (18,202 hectares) of land and Alibates Flint Quarries NM encompasses 1,371 acres (555 hectares) of land, which includes private inholdings (NPS 2013).

The NRA is located approximately 40 miles north of Amarillo, Texas along U.S. Route 287 and Alibates Flint Quarries NM is located along the NRA's southeastern boundary, approximately 5 miles southwest of Fritch, Texas (Figure 2.1.2-1). The parks are located in the Texas Panhandle where the climate is arid and the water reservoir, which is created by the Sanford Dam on the Canadian River, "is the largest body of water within a 200-mile radius and provides water to more than three-quarters of a million nearby residents" (NPS 2015).

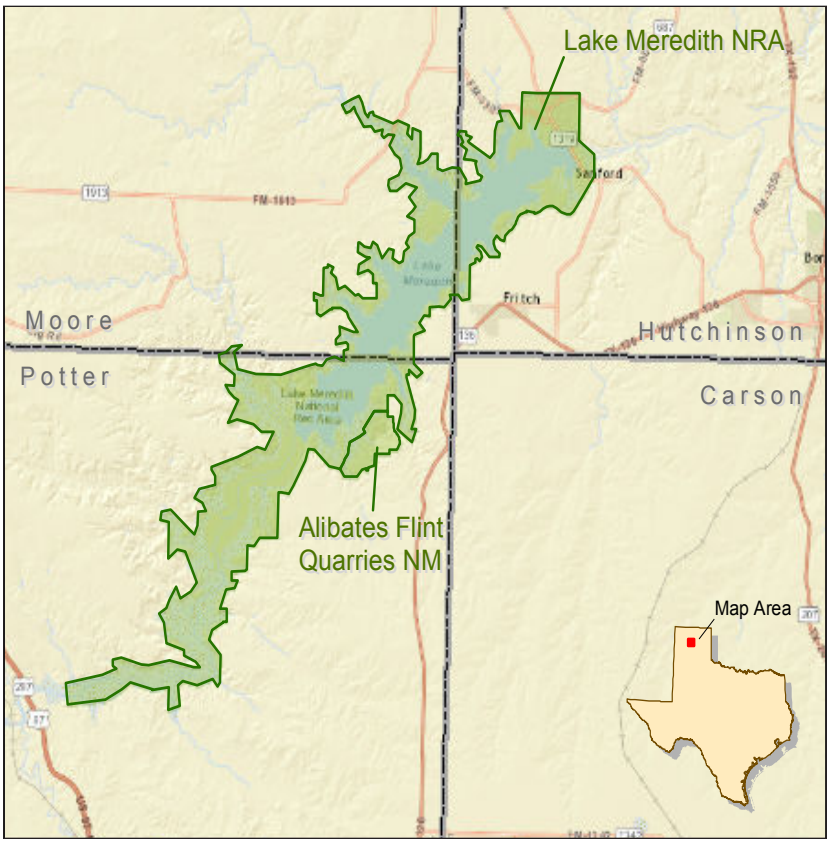


Figure 2.1.2-1. Setting of Lake Meredith NRA and Alibates Flint Quarries NM.

Climate

Lake Meredith NRA and Alibates Flint Quarries NM are located in the Texas panhandle within the Great Plains ecoregion, characterized by highly variable and stormy weather patterns. Moist air masses from the Pacific Ocean lose their moisture over the Rocky Mountains, causing precipitation over the mountains and drier conditions on the leeward side. These drier conditions result in the short-grass ecosystem of the western plains. As these air masses continue across the broad, flat plain, they experience increasing interaction with arctic air masses from the north and more humid air masses to the east. The increased precipitation in these areas supports the mixed-grass prairie of the central plains and the tall-grass prairie of the eastern plains.

The organisms that live in this area must be adapted to surviving extreme climate conditions. In some cases, native plants take advantage of these climate extremes in order to colonize new areas. Drought can lead to massive local extinctions of annual forbs and grasses that have invaded stands of perennial species (Davey et al. 2007).

Temperature

The general temperature gradient across the southern plains is from cooler temperatures in the northwest to warmer temperatures in the southeast. Winter temperatures in the southern plains, like mean annual temperatures, generally follow a northwest-southeast gradient across the Great Plains. The El Niño-Southern Oscillation (ENSO) causes inter-annual climate variations. El Niño conditions (warm ENSO phases) are associated with cooler, wetter conditions while La Niña conditions (cool ENSO phases)

are associated with warmer, drier conditions (Davey et al. 2007).

On average, the warmest month at Lake Meredith is July; the highest recorded temperature was 111°F in 2011. On average, the coolest month is January; the lowest recorded temperature was -12°F in 1951 (Figure 2.1.2-2).

Precipitation

Precipitation in the southern plains generally increases from west to east, although localized higher precipitation amounts are also evident in the higher elevations of New Mexico. Precipitation in the southern plains generally peaks in mid- to late-summer, with some additional autumn maxima in central Texas. The maximum average precipitation occurs in August. The amount of precipitation varies across years, ranging from over 30 inches a year to as little as 10 inches (Figure 2.1.2-3).

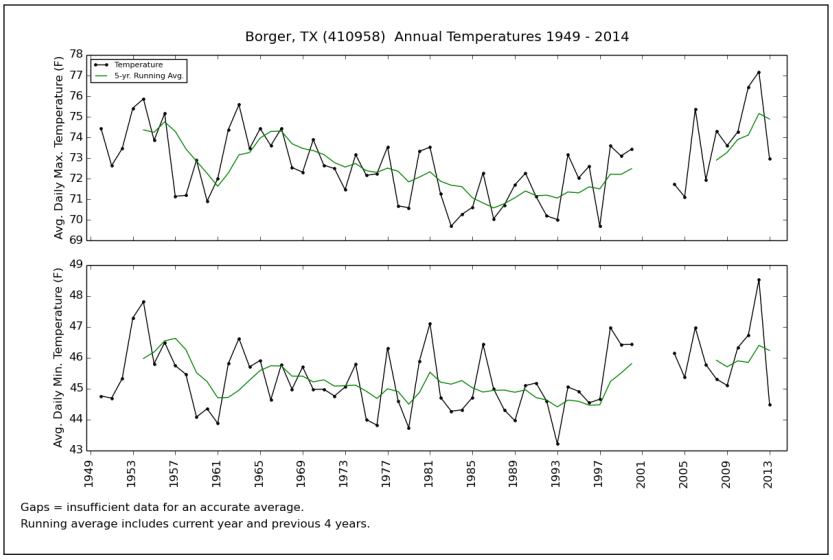


Figure 2.1.2-2. Trends in the average daily temperatures annually from 1949-2014, recorded at Borger, TX (www.climateanalyzer.org).

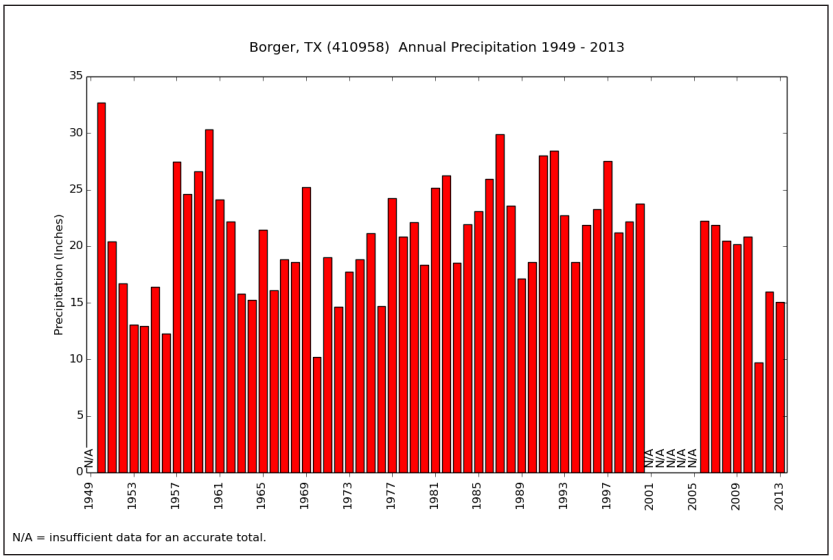


Figure 2.1.2-3. Annual precipitation, 1949-2013 (www.climateanalyzer.org).

2.1.3. Visitation Statistics

Monthly visitation data for the NRA and NM are available for 1979-2014. The total number of visitors each year ranged from 505,840 (in 2012) to 1,946,899 (in 1984). The number of visitors in 2014 was 696,708. Visitation data by month are available for 1979-2014. Although there has been substantial monthly variation by year, the months receiving the greatest average number of visitors over the recording period were May, June, July, and August for the NRA; and May and October for the NM (Figure 2.1.3-1 and -2) (NPS Public Use Statistics Office 2015).

2.2. Natural Resources

A summary of the natural resources at Lake Meredith NRA and Alibates Flint Quarries NM is presented in this section. For some of the resource topics, new data were gathered and compiled as a result of meetings, field visits, and literature reviews pertaining to each natural resource topic. Discussion of the new findings is included in each resource topic's Chapter 4 condition assessment.

2.2.1. Ecological Units and Watersheds

The ecoregion in which the Recreation Area and National Monument occur is Southwestern Tablelands (TPWD 2012) situated between the High and Rolling Plains of Texas. Most of the region is covered in shortgrass prairie but the NRA contains trees throughout its riparian corridors. This region is characterized by a cold semi-arid climate (Pidwirny 2006) with relatively flat to rolling topography, ranging from 2,700 - 3,600 feet in elevation (Fenton et al. 2007).

The NRA is located within the East Amarillo Creek-Canadian River, Big Blue Creek, Lake Meredith, and Rock Creek-Canadian River watersheds, encompassing 723,280 acres (292,701 hectares) and the NM is

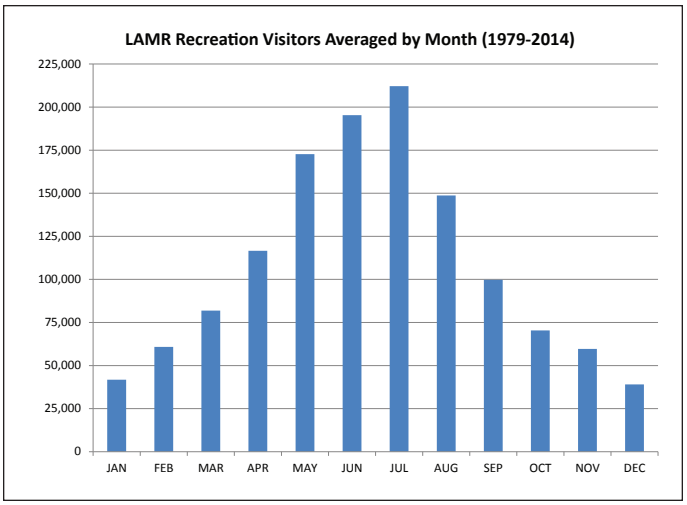


Figure 2.1.3-1. Average number of visitors to Lake Meredith NRA by month, 1979-2014.

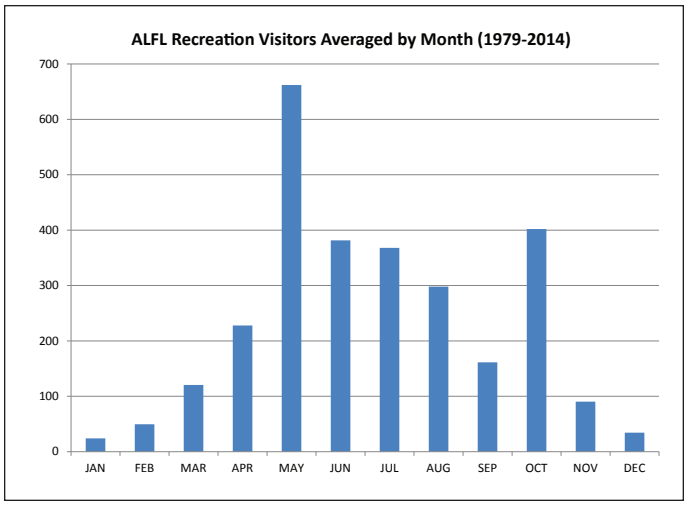


Figure 2.1.3-2. Average number of visitors to Alibates Flint Quarries NM by month, 1979-2014.

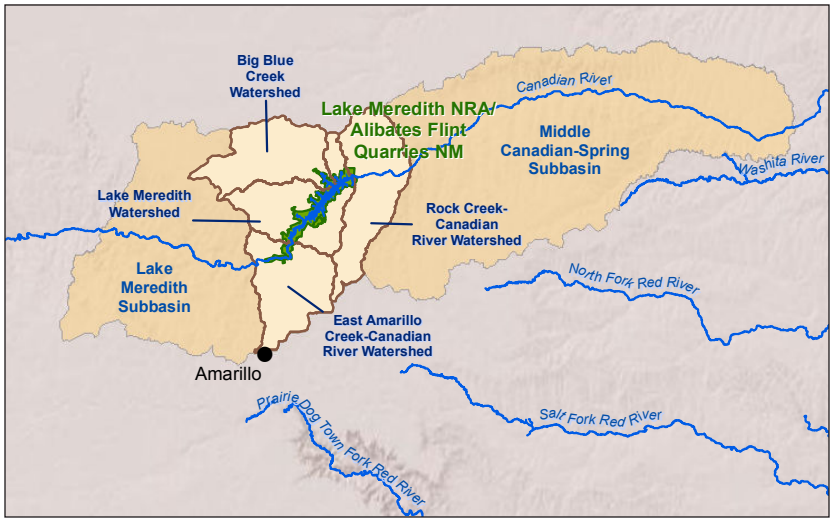


Figure 2.2.1-1. Lake Meredith NRA and Alibates Flint Quarries NM is within the the East Amarillo Creek-Canadian River, Big Blue Creek, Lake Meredith and Rock Creek-Canadian River watersheds, of the Lake Meredith and Middle Canadian-Spring subbasins.

located within the Lake Meredith watershed, encompassing 178,324 acres (72,165 hectares) (Figure 2.2.1-1).

2.2.2. Resource Descriptions

Viewshed, Night Sky, and Soundscape

No formal studies for viewshed or night sky have been conducted at the parks, but two acoustical monitoring studies were conducted (Wyle 2011 and Foch 2000). The Foch (2000) study was to gather baseline data for natural and ambient sound levels in preparation for oil and gas activities and Wyle (2011) gathered data in the Rosita and Blue Creek areas where off road vehicle (ORV) use is permitted.

Geology (*italicized text was excerpted from KellerLynn (2011)*)

A Geologic Resources Inventory Scoping Summary report (KellerLynn 2011) was completed for Lake Meredith NRA and Alibates Flint Quarries NM in 2011. Distinctive geologic features of this area of the panhandle are the Permian red beds exposed in the "breaks" of the Canadian River. The breaks were formed when the Canadian River cut through the "caprock" and the underlying Triassic strata into the Permian beds below. The caprock is a widespread layer of caliche (erosion-resistant, calcium-carbonate rock) that marks the top of the Tertiary Ogallala Formation in Texas and New Mexico. The Ogallala Formation, which underlies much of the Great Plains, makes up the land surface above the breaks. The Ogallala Formation has particular significance for the area because it contains the Ogallala aquifer—the major source of water for agricultural and domestic use on the Southern High Plains of Texas and New Mexico (Gustavson 1996, as cited in KellerLynn 2011). Notably, the Ogallala Formation also yields fossils.

Geohydrology

There are three distinct aquifers that support, to varying degrees, the riparian resources of the NRA: the High Plains Aquifer, which covers the upland plains; units in the Docken Group exposed in the canyon; and Quaternary age alluvium that fills the river and stream drainages. In the Panhandle of Texas, the Ogallala Formation has essentially been split into northern and southern units

by the Canadian River, which has downcut through the surface formations into the underlying Triassic Dockum Group (Bell and Morrison 1982). This relatively thick series of formations generally serves as a minor aquifer in the region but because of the deep canyon of the Canadian River through the NRA, it may be a substantial source of groundwater to the riparian resources of the park.

Hydrology *(italicized text was excerpted from NPS (1996))*

Lake Meredith National Recreation Area is located in the Canadian River Basin in the high plains of Texas (Arkansas-White-Red, Region II, ASA 05 + 06). The lake is a man-made impoundment behind Sanford Dam on the Canadian River encompassing a maximum 21, 640 acres (control storage) of lake surface; the recreation area includes the lake and 23,311.3 acres of land to provide campsites and lake access. Alibates Flint Quarries National Monument is located on the southeastern shore of the lake, south of the Canadian River. The land surface is nearly flat and slopes to the southeast approximately 8 to 10 feet per mile (Cronin, 1958 as cited in NPS 1996). In the vicinity of Lake Meredith, this flat surface has been downcut by the Canadian River and its tributaries, causing canyons or "breaks", some of which are now being filled by Lake Meredith.

The Canadian River rises at Raton Pass in Colfax County, New Mexico and flows south and southeastward where it enters Texas in Oldham County. It crosses the Texas panhandle, flowing through Oldham, Potter, Moore, Hutchinson, Roberts and Hemphill counties, and continues where it joins the North Canadian. The combined streams continue on to flow into the Arkansas River at Webber's Falls in Oklahoma. Two major dams in New Mexico at Conchas Lake and Ute Lake effectively cut off the flow at the Texas border, restricting water levels in a river which even in historic times was seldom a perennial stream.

Drainage into the lake is from tributary streams, rather than the main channel. Beginning at the Texas Boundary, these are Rita Blanca Creek and its tributary Major Long's Creek, Amarillo Creek, Bonito Creek, Chicken Creek, Coetas Creek, Mullinaw Creek, McBride Creek, South Turkey Creek, Short Creek, Big Blue Creek, and Bugbee Creek. Numerous dry canyons also empty into the river during summer thunderstorms, including Windmill Creek, Horse Creek, Ranch Creek, Rosita Creek, Corral Creek, Saddlehorse Canyon, Hackberry Canyon, Big Canyon, Devil's Canyon, Plum Creek, Alibates Creek, Evans Canyon, Martins Canyon, Fritch Canyon, North Turkey Creek, Cedar Canyon, and South Canyon. Below the dam, Spring Canyon is a perennial stream from two or more springs, but seldom flows more than 100 yards below the junction of the two branches, except in periods of heavy rainfall.

Air Quality

Different categories of air quality areas have been established through the authority of the Clean Air Act (CAA) of 1970: Class I and II. Like most National Park Service areas, both the NRA and NM are designated as Class II airsheds.

These classes are allowed different levels of permissible air pollution, with Class I receiving the greatest protection and strictest regulation. The CAA gives federal land managers responsibilities and opportunities to participate in decisions being made by regulatory agencies that might affect air quality in the federally protected areas they administer (NPS-ARD 2012).

It's important to note that even though the CAA gives Class I areas the greatest protection against air quality deterioration, the legislation also aims to limit the level of additional pollution allowed in Class II areas, and potential impacts to these areas are to be considered. (NPS 2006).

Vegetation *(italicized text was excerpted from Fenton et al. (2007))*

The parks [LAMR] lie within the Dry Domain, Tropical/Subtropical Steppe Division, Southwest Plateau and Plains Dry Steppe and Shrub Province, Texas High Plains Section as described by Bailey (1995). This ecoregion is characterized by arid grasslands and the presence of open stands of mesquite among the grasses. The land-surface form consists of flat to rolling plains as well as a mesa-and-butte landscape in some areas.

The parks [LAMR] reside in two of the major plant zones of Texas, the Rolling Plains and High Plains, as mapped in various forms by several authors including V.L. Cory and H. B. Parks (1937) and more recently by F.W. Gould (1962).

Birds

There have been a total of 134 bird species reported at Lake Meredith NRA / Alibates Flint Quarries NM from the 2002-2003 TNC inventory (Patrikeev 2004) and/or the 2009-2013 RMBO point-count surveys (Buckland et al. 2001 and Lock et al. 2014) and 32 of these are listed as species of conservation concern. Refer to the Breeding Landbirds condition assessment for assessment details.

Herpetofauna

A total of about 44 species of amphibians and reptiles have been recorded at Lake Meredith NRA and Alibates Flint Quarries NM during 2002-2003 surveys at the parks by The Nature Conservancy (Patrikeev 2004/2008) or during past studies. Seven are listed as Species of Greatest Conservation Need with Texas Parks and Wildlife Department.

Game Species

Hunting is allowed at Lake Meredith NRA (though not allowed in Alibates Flint Quarries National Monument), and managed through the Texas Parks and Wildlife Department. A variety of game species are open to hunting, including upland game, upland game birds, waterfowl, and small game and furbearers. Lake Meredith is popular among local hunters as one of the few places to hunt both mule deer (*Odocoileus hemionus*) and white-tailed deer (*O. virginianus*) in the same area. Upland bird hunting includes mourning dove (*Zenaida macroura*), white-winged dove (*Z. asiatica*), and white-tipped (white-fronted) doves (*Leptotila verreauxi*); turkey (*Meleagris gallopavo*), quail (*Colinus virginianus*), and pheasant (*Phasianus colchicus*). The most popular waterfowl hunting on Lake Meredith includes blue-winged (*Anas discors*), green-winged (*A. carolinensis*), and cinnamon teal (*A. cyanoptera*). Small game and furbearers that can be hunted on the NRA include rabbit (*Sylvilagus floridanus*), coyote (*Canis latrans*), and raccoon (*Procyon lotor*).

Fish

Eighteen species of fish have been documented in the Canadian River and associated creeks, including the threatened Arkansas River shiner. Approximately 30 species of fish have been recorded in Lake Meredith and are sampled on the lake on a regular basis by the Texas Parks and Wildlife Department. The most popular sports fish in Lake Meredith include Walleye, Large Mouth Bass, Small Mouth Bass, Sand (White) Bass, Crappie, Bluegill and other sunfish, and a variety of catfish. The decrease in water levels is impacting the sports fishery.

2.2.3. Resource Issues Overview

Drought

Drought is frequent in this region with prolonged drought between 1965 and 1981, and again starting in 2000 through now, with just a few wet years providing relief (2007 and 2009) (Figures 2.2.3-1, -2, -3). Vegetation stress as well as decrease in the water level in both the reservoir and surrounding rivers and streams has occurred. Impacts to aquatic dependent species has resulted (refer to Chapter 4 fish condition assessment).

Climate Change

The impact of global climate change may be exacerbated in the southern plains due to the region's periodic droughts and the large number of habitat specialists. Species extinctions may occur due to the inability to re-colonize in response to future climate changes (Davey et al. 2007). Warming temperatures and increased impacts of drought are likely to increase the stress on water resources at Lake Meredith, including flow in the Canadian River, water temperature, and lake levels.

Oil and Gas Production (excerpted from NPS 2013)

"Nonfederal oil and gas production occurs within the national recreation area. Currently, there are 168 active well sites and associated roads and pipelines. The one oil and gas wellhead within the boundary predates creation of the national monument. The national monument is designated as a special management area under the oil and gas management plan (NPS 2002) and, as a result,

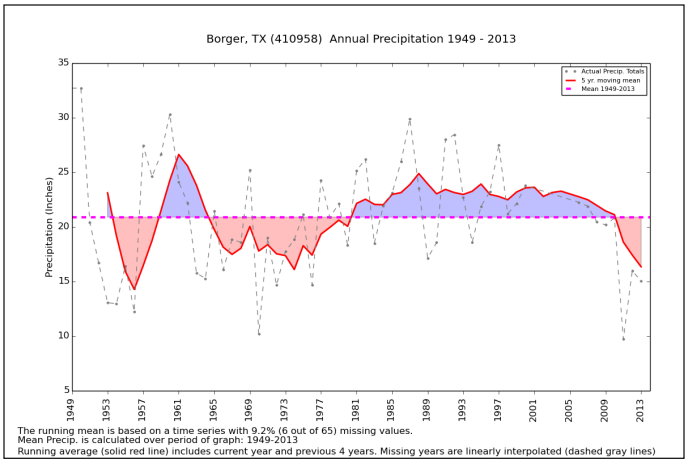


Figure 2.2.3-1. Annual precipitation compared to the mean, showing drought years between 1965 and 1981, and again starting in 2009 (www.climateanalyzer.org).

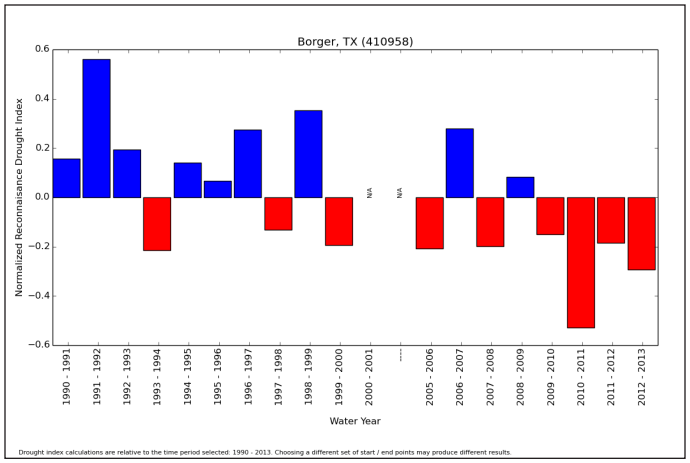


Figure 2.2.3-2. Another way to illustrate drought is the normalized drought index by water year (www.climateanalyzer.org).

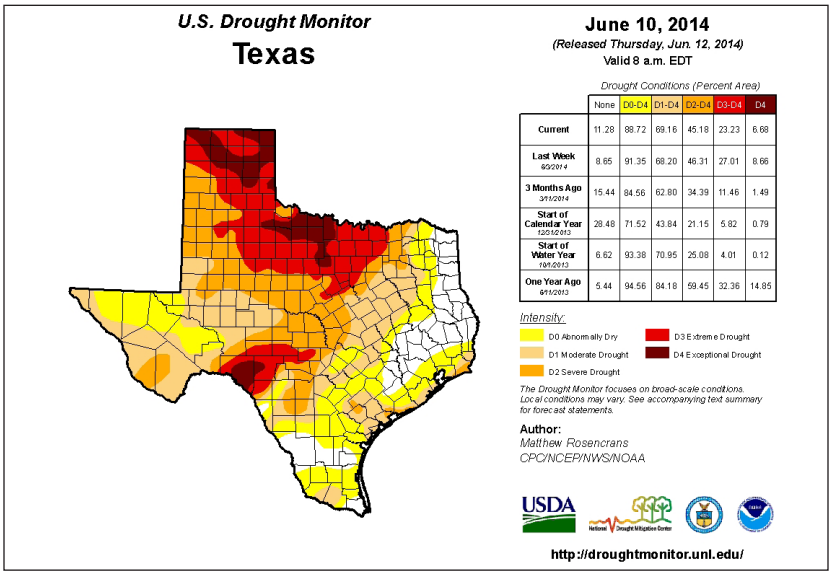
future development of petroleum resources under the national monument would require directional drilling from outside the national monument boundary."

ORV Use

Areas with heavy ORV use has impacted vegetation, streambanks, and soils along Blue Creek and the Canadian River. The use destabilizes banks causing sedimentation, which in turn widens the river/stream channel and can result in stream braiding.

Exotic Plants

Several exotic plant species, with wide extents, are found throughout the parks. Some plants have the ability to change the ecosystem structure, alter nutrient cycles, and soil chemistry, as well as limit water availability (e.g., tamarisk).



	None	D0-D4	D1-D4	D2-D4	D3-D4	D4
Current	11.28	88.72	69.16	45.18	23.23	6.68
Last Week 6/3/2014	8.65	91.35	68.20	46.31	27.01	8.66
3 Months Ago 3/11/2014	15.44	84.56	62.80	34.39	11.46	1.49
Start of Calendar Year 12/31/2013	28.48	71.52	43.84	21.15	5.82	0.79
Start of Water Year 10/1/2013	6.62	93.38	70.95	25.08	4.01	0.12
One Year Ago 6/11/2013	5.44	94.56	84.18	59.45	32.36	14.85

Figure 2.2.3-3. The U.S. Drought Monitor (http://droughtmonitor.unl.edu/Home/StateDroughtMonitor.aspx?TX, accessed 17 June 2014) shows the panhandle of Texas, where Lake Meredith is located, in extreme to exceptional drought.

Game Species

No specific game species conditions have been identified, so at this time it is not known whether the game species populations and habitats are in good condition or need assistance in restoration. Recent fires and drought can reduce and degrade habitat. Other management concerns around hunting include the increased access of OHVs and visitor safety. Additional roads and more vehicle travel can increase harassment of animals and may result in accidental road kills and animal injuries. Adjoining land uses can also impact game populations. For example, the effects of oil and gas activity on wildlife may have various impacts. Some activities may affect only certain species, and possibly only during certain periods of the year such as nesting or rutting seasons. Fatalities of wildlife could also occur due to leaks and spills, especially where hydrogen sulfide gas is involved. Open mud pits, sumps, and evaporating pits may trap and drown animals, especially birds and game species.

2.3. Resource Stewardship

2.3.1. Management Directives and Planning Guidance

In addition to NPS staff recommendations, the Washington (WASO) level programs guided the selection of key natural resources for this condition assessment. This included Southern Plains Inventory and Monitoring Network (SOPN) Program, Air Resources Division for air quality, Water Resources Division for riparian habitat, and the Natural Sounds and Night Skies Program for the soundscape and night sky sections. In addition, NPScape data, developed by the Inventory & Monitoring's Washington Office, were used in the viewshed analysis.

SOPN Program

In an effort to improve overall national park management through expanded use of scientific knowledge, the Inventory & Monitoring (I&M) Program was established to collect, organize, and provide natural resource data as well as information derived from data through analysis, synthesis, and modeling (NPS 2011). The primary goals of the I&M Program are to:

- inventory the natural resources under NPS stewardship to determine their nature and status;
- monitor park ecosystems to better understand their dynamic nature and condition and to provide reference points for comparisons with other altered environments;
- establish natural resource inventory and monitoring as a standard practice throughout the National Park System that transcends traditional program, activity, and funding boundaries;
- integrate natural resource inventory and monitoring information into NPS planning, management, and decision making; and
- share NPS accomplishments and information with other natural resource organizations and form partnerships for attaining common goals and objectives (NPS 2011).

To facilitate this effort, 270 parks with significant natural resources were organized into 32 regional networks. Lake Meredith NRA and Alibates Flint Quarries NM are part of the SOPN, which also includes nine additional parks. Through a rigorous multi-year, interdisciplinary scoping process, each network selected a number of important physical, chemical, and/or biological elements and processes for long-term monitoring. These ecosystem elements and processes are referred to as 'vital signs', and their respective monitoring programs are intended to provide high-quality, long-term information on the status and trends of those resources. For the SOPN, notable core vital signs were identified. Inventories on a wide variety of natural resource topics have been completed, and long-term monitoring programs are currently underway.

Resource Stewardship Strategy

National Parks are encouraged to develop a Resource Stewardship Strategy (RSS) as part of the park management planning process. Indicators of resource condition, both natural and cultural, are selected by the park. After each indicator is chosen, a target value is determined and the current condition is compared to the desired condition. An RSS has not yet been started for the NRA and NM, but the NRCA will provide valuable information for the RSS process, if started. Management plans may then be developed based upon information from the RSS and NRCA to outline actions to be taken over the next 15 to 20 years that will help achieve or maintain the desired condition(s) for each indicator.

2.3.2. Status of Supporting Science

Available data and reports varied significantly depending upon the resource topic. The existing data used for each indicator to assess condition or to develop reference conditions are described in each indicator summary in Chapter 4. Part of SOPN's mission is to collect, manage, analyze, and report long term ecological data to support each park in determining the status, condition, and trend of important natural resources (USDI NPS 2008). In addition to data from the SOPN Program and research by other scientists and programs, subject matter experts provided significant information pertaining to riparian habitat, grassland ecology, and exotic plants. Washington level programs, including night sky, soundscape, riparian habitat, and air

quality also provided a wealth of information for this NRCA.

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NPS PHOTO

A grassland monitoring transect at Lake Meredith NRA.

Chapter 3: Study Scoping and Design

This NRCA is a collaborative project between the Lake Meredith NRA and Alibates Flint Quarries NM staff and the SOPN, all of the NPS. Stakeholders in this project include the National Recreation Area and National Monument's natural resource managers, management staff, and SOPN staff. The purpose of the condition assessment is to provide a "snapshot-in-time" evaluation of the condition of a select set of National Recreation Area and National Monument natural resources that were identified and agreed upon by the project team during the scoping session. Project findings will aid National Recreation Area and National Monument staff in the following objectives:

- Develop near-term management priorities
- Engage in watershed or landscape scale partnership and education efforts
- Conduct park planning (e.g., compliance, Resource Stewardship Strategy, and resource management plans).

The approach we used to select natural resources was to assess the fundamental and important values of the National Recreation Area and National Monument as well as to consider broader natural resources as identified by the NPS' Natural Resource Program Center. The resources assessed are limited to natural-based topics, but cultural resources were also taken into consideration within the context of the chosen natural resources.

3.1. Preliminary Scoping

The selection of resources to assess resulted from meetings and subsequent discussions. For a complete list of team members, please refer to Appendix A.

These meetings and discussions focused on:

1. Confirming the purpose of the National Recreation Area and National Monument and their related significance statements and related values as they relate to the chosen NRCA topics
2. Identifying important natural and cultural resources and concerns for each topic
3. Identifying data sources and gaps for each resource topic.

Certain constraints are placed NRCAs, including the following:

- Condition assessments are conducted using existing data and information.
- Identification of data needs and gaps is driven by the project framework categories.
- A preliminary study framework was developed as a result of the meetings and discussions, which lists the chosen resources and the degree of assessment (e.g., full or limited) based upon existing data and information (refer to Table 3.2.1-1).

Specific project expectations and outcomes included the following:

- For key natural resource components, consolidate available National Recreation Area and National Monument data, reports, and spatial information from appropriate sources including: National Recreation Area and National Monument resource staff, scientific literature, NatureBib, NPSpecies, Inventory and Monitoring data, and available third-party sources.
- Enlist the help of subject matter experts for each resource topic when appropriate and feasible (refer to Appendix A for subject matter expert list).
- Define an appropriate description of reference condition for each of the key natural resource topics and indicators so statements of current condition can be developed for the NRCA report.
- Where applicable, develop GIS products and graphic illustrations that provide spatial representation of resource data, ecological processes, resource stressors, trends, or other valuable information that can be better interpreted visually.
- Conduct analysis of specific existing data sets to develop descriptive statistics about key natural resource indicators.
- Discuss the issue of key natural resource indicators that are not contained within the National Recreation Area and National Monument or controlled directly by National Recreation Area and National Monument management activities (e.g., viewshed condition). There are important stressors that impact key natural resource components in the National Recreation Area and National Monument but are not under NPS jurisdiction.

National Recreation Area and National Monument natural resource staff participated in on-site meetings and reviewed interim and final products. National Recreation Area and National Monument staff, I&M staff, and writer/editors data mined information for each of their assigned resource topic(s).

3.2. Study Design

3.2.1. Indicator Framework, Focal Study Resources and Indicators

The National Recreation Area and National Monument's NRCA utilizes an assessment framework adapted from "The State of the Nation's Ecosystems 2008: Measuring the Lands, Waters, and Living Resources of the United States", by the H. John Heinz III Center for Science, Economics and the Environment. This framework was endorsed by the National NRCA Program as an appropriate framework for listing resource components, indicators/measures, and resource conditions.

Each NRCA project represents a unique assessment of key natural resource topics that are important to the specific park that is being assessed. As a result, the project framework is developed by the project participants to reflect the key resources of the park. For the purposes of this NRCA, 14 key National Recreation Area and National Monument resources were identified and are listed under the "Resource" column in Table 3.2.1-1. This list of focal study resources is not all inclusive of every natural resource at the National Recreation Area and National Monument, but it includes natural resources and processes that were of greatest concern at the time of this assessment.

Reference conditions were identified with the intent of providing a benchmark to which the current condition of each indicator/measure could be compared. Attempts were made to utilize existing research and documentation to identify reference conditions; however, many of the indicators lack a quantifiable reference condition according to literature

Table 3.2.1-1. Lake Meredith National Recreation Area and Alibates Flint Quarries National Monument Natural Resource Condition Assessment Framework

Resource	Assessment Level	Indicators And Measures
I. Landscape Condition Context		
Viewshed	Full Assessment	• Scenic And Historic Integrity (Intactness Of View And Conspicuousness Of Non-Contributing Features)
Night Sky	Full Assessment	• Sky Brightness (Anthropogenic Light Ratio, Zenith Sky Brightness) • Sky Quality (Bortle Dark-Sky Scale)
Soundscape	Full Assessment	• Audibility (Percent Time Audible) • Sound Levels (Amplitude - On Site Monitoring And Modeled Sound Leve Impact)
II. Supporting Environment		
Air Quality	Full Assessment	• Visibility (Haze Index) • Level Of Ozone (Annual 4Th-Highest 8-Hour Concentration) • Atmospheric Wet Deposition (Total N and Total S in kg/ha/yr)
Geology	Limited Assessment	• Geologic Integrity
Surface Water Quality	Full Assessment	• Field Properties (4 Measures) • Alkalinity (Total And Phenolphthhalein) • Primary Nutrients (Nitrate And Phosphate) • Major Constituents (9 Measures)
Groundwater	Full Assessment	• Groundwater Elevation (Change In Groundwater Elevation)
III. Biological Integrity		
Vegetation		
Riparian Habitat	Full Assessment	• Hydrology (5 Indicators) • Vegetation (7 Indicators) • Erosion/Deposition (5 Indicators)
Grasslands	Full Assessment	• Hydrology Soil/Site Stability And Hydrologic Function (10 Indicators) • Biotic Integrity (5 Indicators)
Exotic Plants	Full Assessment	• Potential To Alter Native Plant Communities (3 Measures) • Prevalence of Exotic Plants (1 Measures)
Wildlife		
Landbirds	Full Assessment	• Species Occurrence (Temporal. Spatial, And Conservation Context)
Herpetofauna	Limited Assessment	• Species Occurrence (Presence/Absence)
Fish	Limited Assessment	• Species Occurrence (Presence/Absence)

and data reviewed for this project. When a specific reference condition for the National Recreation Area and National Monument resources was unknown, an attempt was made to include a qualitative framework to provide some context for interpreting condition.

3.2.2. Reporting Areas

The reporting area was treated as one unit (unless otherwise noted in the resource topic section) and encompassed the entire acreage within the National Recreation Area and National Monument's boundaries. Due to the nature of some of the focal study resources, areas outside of the National Recreation Area and National Monument's boundary were assessed to determine overall condition within the National Recreation Area and National Monument (e.g., viewshed, air quality, night sky, etc.).

3.2.3. General Approach and Methods

This study involved reviewing existing literature and data for each of the resources listed, and, where appropriate, analyzing the data to provide summaries or to create new spatial representations. After gathering data regarding current condition of indicators and measures, a quantitative or qualitative statement was developed comparing the current condition(s) at the National Recreation Area and National Monument to the reference condition(s) when possible.

Data Mining

Data and literature were found in multiple forms: NPS reports and monitoring plans (National Recreation Area and National Monument, regional, and national levels), other reports from various state and federal agencies, published and unpublished research documents, non-governmental organization reports, databases, and tabular data. Spatial data were provided by the National Recreation Area, the SOPN staff, and by the Natural Resource Program Center. Data and literature acquired throughout the data mining process were inventoried and analyzed for thoroughness, relevancy, and quality pertaining to the indicators identified in the project framework. All reasonably accessible and relevant data were used to conduct this assessment.

Subject Matter Experts

Several researchers and subject matter experts were consulted while developing this assessment. Consultations ranged from on-site visits to personal communication, and reviews of resource sections. A full list of the team of experts can be found in Appendix A.

Data Analyses and Development

Data analyses and development/writing tasks were performed for specific resources based on the data mining process and recommendations provided by NPS staff. Data analyses and development were resource specific, and the methodology for individual analyses can be found within each section of chapter four or in an appendix.

Geographic Information System (GIS) technology was utilized to graphically depict the status and distribution of considered resources when possible.

Final Assessments

Final assessments were made by incorporating comments provided by subject matter experts, reviewers, and National Recreation Area and National Monument staff during the review of draft chapters. Additionally, continued contact with National Recreation Area and National Monument staff to address questions and comments pertaining to each resource topic was maintained throughout the data analysis and report writing phase to ensure accurate representation of staff knowledge. The final assessments represent the most relevant and timely data available for each resource topic based on the recommendations and insight provided by National Recreation Area and National Monument staff, researchers, subject matter experts, and assessment writers.

Indicator/Measures Assessment Format

Indicator assessments are presented in a standard format that is consistent with *State of the Park* reporting (NPS 2012). The major components are as follows:

The condition/trend/level of confidence graphic provides a visual representation for each resource indicator and is intended to give readers a quick interpretation of the authors' assessments of condition. The level of confidence ranges from high-low and indicates how confident we are with the data used to determine condition. The written statements of condition, located under the "*Condition and Trend*" heading within each resource topic section, provides a more in-depth description of each indicator and associated measure(s)' condition. Figure 3.2.3-1 shows the condition/trend/confidence level scorecard used to describe each indicator/measure.

Circle colors provide indication of condition based upon the chosen indicators/measures and reference conditions. Red circles signify that a resource is of significant concern; yellow circles signify that a resource is in

Condition Status		Trend in Condition		Confidence in Assessment	
	Warrants Significant Concern		Condition is Improving		High
	Warrants Moderate Concern		Condition is Unchanging		Medium
	Resource is in Good Condition		Condition is Deteriorating		Low
	An open (uncolored) circle indicates that current condition is unknown or indeterminate; this condition status is typically associated with unknown trend and low confidence				

Figure 3.2.3-1. Condition, trend, and level of confidence key used in the NRA and NM NRCA.

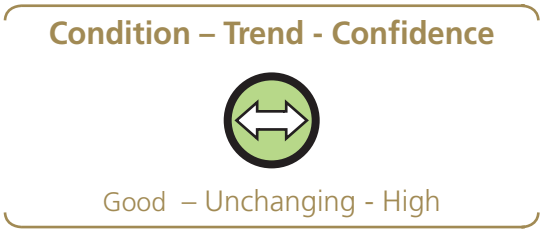

Figure 3.2.3-2. An example of a good condition, unchanging trend, and high confidence level in the assessment graphic used in NRCAs.

moderate condition; and green circles denote that an indicator and/or measure is currently in good condition. A circle without any color, (which is almost always associated with the low confidence symbol-dashed line), signifies that there is insufficient information to make a statement about condition of the indicator, therefore, condition is unknown.

We include an indicator condition and overall rationale summary table at the end of each resource topic's section to convey the relevancy of each measure to the overall condition interpretation.

Arrows inside the circles signify the trend of the indicator/measure condition. Upward pointing arrows signify that the indicator is improving; right pointing arrows signify that the indicator's condition is currently unchanging; downward pointing arrows indicate that the indicator's condition is deteriorating. No arrow denotes that the trend of the indicator's condition is currently unknown. Figure 3.2.3-2 is an example of a final condition graphic used in the indicator assessments.

An Overview of NRCA Chapter 4 Sections

Background and Importance

This section of the NRCA report provides information regarding the relevance of the resource to the National Recreation Area and National Monument. This section also explains the characteristics of the resource that help the reader understand subsequent sections of the document.

Data and Methods

This section describes the existing datasets used for evaluating the indicators/measures. Methods used for processing or evaluating the data are also discussed where applicable. The indicators/measures are listed in this section as well, describing how we measured or qualitatively assessed the natural resource topic.

Reference Conditions

This section explains the reference conditions that were used to evaluate the current condition for each indicator. Additionally, explanations of available data and literature that describe the reference conditions are located in this section.

Condition and Trend

This section provides a summary of the condition and trend of the indicator/measure at the National Recreation Area and National Monument based on available literature, data, and expert opinions. This section highlights the key elements used in defining the condition and trend designation, represented

by the condition/trend graphic, located at the beginning of each resource topic.

The level of confidence and key uncertainties are also included in the condition and trend section. This provides a summary of the unknown information and uncertainties due to lack of data, literature, and expert opinion, as well as our level of confidence about the presented information.

Sources of Expertise
Individuals who were consulted for the focal study resources are listed in this section. A short paragraph describing their background is also included.

Literature Cited
This section lists all of the referenced sources. A DVD is included in the final report with copies of all literature cited unless the citation was from a book. When possible, links to websites are also included.

3.3. Literature Cited

The H. John Heinz III Center for Science, Economics and the Environment. 2008. The State of the Nation's Ecosystems 2008: Measuring the Lands, Waters, and Living Resources of the United States. Washington, D.C.

National Park Service. 2012. A Call to Action: Preparing for a Second Century of Stewardship and Engagement. Washington, D.C. 28pp

Chapter 4: Natural Resource Conditions

In this chapter, we present the background and importance, methods, and condition assessment for each focal study resource that we considered for Amistad NRA. In many cases, we did not have a quantitative measure for the indicators but tried to present meaningful categorical measures qualitatively that reflect the condition. We also explained why each indicator was chosen and what we considered as a good, moderate or significant concern reference condition for each indicator. We provide a summary of all focal study resource indicators and their page numbers for explanations of our methods and natural resource conditions in Table 4.1.

Table 4-1. Page numbers where the description, methods, and condition for each indicator(s) are presented within this chapter.

Resource	Indicator	Description/ Methods	Condition
I. Landscape Condition Context			
Viewshed	Scenic and Historic Integrity	24	30
Night Sky	Sky Brightness	40	43
	Sky Quality	40	43
Soundscape	Audibility	50	54
	Sound Level	51	55
Air Quality	Visibility	61	63
	Level of Ozone	62	63
	Atmospheric Wet Deposition in Total N and Total S	62	63
Geology	Geologic Integrity	70	70
Surface Water	Field Properties	80	83
	Alkalinity	80	85
	Major Constituents	83	86
	Primary Nutrients	83	86
Groundwater	Groundwater Elevation	96	98
III. Biological Integrity			
Vegetation			
Riparian Habitat	Hydrology	104	107
	Riparian Vegetation	105	114
	Erosion/Deposition	106	116
Grasslands	Hydrology Soil/Site Stability and Hydrologic Function	123	130
	Biotic Integrity	125	131
Exotic Plants	Potential to Alter Native Plant Communities (Significance of Exotic Plant Impact)	148	156
	Prevalence of Exotic Plants (3 Measures)	149	156

Table 4.1. Page numbers where the description, methods, and condition for each indicator are presented within this chapter (cont.).

Resource	Indicator	Description/ Methods	Condition
Wildlife			
Landbirds	Species Occurrence	166	173
Herptofauna	Species Occurence	184	186
Fish	Species Occurence	191	192

4.1. Viewshed

Indicators/Measures

- Scenic and Historic Integrity (2 Measures)

Condition – Trend - Confidence

Good – Insufficient Data - Meduim

4.1.1. Background and Importance

The conservation of scenery is established in the National Park Service (NPS) Organic Act ("… to conserve the scenery and the wildlife therein…"), reaffirmed by the General Authorities Act, as amended, and addressed generally in the NPS Management Policies (Section 1.4.6 and 4.0; Johnson et al. 2008). Although no management policy currently exists exclusively for scenic or viewshed management and preservation, parks are still required to protect scenic and viewshed quality as one of their most fundamental resources. According to Wondrak-Biel (2005), aesthetic conservation, interchangeably used with scenic preservation, has been practiced in the NPS since the early twentieth century. Aesthetic conservation strove to protect scenic beauty for park visitors to better experience the values of the park. The need for scenic preservation management is as relevant today as ever, particularly with the pervasive development pressures that challenge park stewards to conserve scenery today and for future generations.

Visitor Experience

Viewsheds are considered an important part of visitor experience. Inherent in virtually every aspect of this assessment is how features on the visible landscape influence the enjoyment, appreciation, and understanding of the NRA and NM by visitors. The indicators we use for condition of the viewshed are based on studies related to perceptions people hold toward various features and attributes of the viewsheds. We also focus on how the historic integrity of the viewshed enhances the opportunity for visitors to better understand the historical significance at Alibates Flint Quarries NM .

From a cultural and historical perspective, the views are not just about the scenery, but an important way to better understand the connection between natural and cultural resources at Alibates Flint Quarries NM. Visualizing this connection as part of the

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View to the west, from the Harbor Bay East at Lake Meredith NRA.

landscape is a critical part of the visitor experience.

4.1.2. Data and Methods

Viewsheds are considered in this assessment within two interrelated contexts: natural scenic integrity and historic integrity. Impacts that degrade one aspect likely degrade the other as well. For example, modern structures or roadways visible on the landscape may detract from the natural scenic integrity of the viewshed as well as the sense of place that a historically authentic landscape evokes. Depending on the context, scenic and historic integrity may be distinct, or there may be so little practical difference that they are the same. We qualitatively assess how features on the landscape contribute (or not) to the scenic and historic integrity of the site.

Indicator
Scenic and Historic Integrity

The overall indicator of viewshed condition we use in this assessment is a combination of scenic and historic integrity. For this overall indictor we used two measures (intactness and conspicuousness) from key vantage points (Table 4.1.2-1). Each of these measures are described in greater detail below.

Scenic integrity is defined as the state of naturalness or, conversely, the state of disturbance created by human activities or alteration (USFS 1995). This focuses on the features of the landscape related to non-contributing human alteration.

Historic integrity is the authenticity of a site's historic identity, evidenced by the survival of physical characteristics that existed during its historic period. Historic integrity is based on those features of the cultural and natural landscape, from the perspective of an observer, that contribute to the sense of place and enhance the visitor experience. In this assessment, we focus on those features that have a visual impact and contribute to the story of Alibates NM such as the cultural history of collecting and trading flint. We evaluate features as contributing (i.e., enhancing the scenic and historic features of the landscape) or noncontributing (i.e., detracting from the scenic and historic integrity).

We assess scenic and historic integrity by evaluating specific human-made features that can be seen from key vantage points and whether or not those features are contributing or noncontributing to the scenic and historic integrity of the view. For noncontributing features, we further assess the characteristics that make them more or less conspicuous, which influences the level of impact they have. We then supplement this assessment with a GIS-based map showing areas that are or are not visible from key vantage points. The GIS analysis provides spatial orientation of key features.

Viewshed Vantage Points

For this assessment we focused primarily on the views visitors are most likely to experience. The vantage points we used included McBride Canyon, Alibates, Harbor Bay East, and Fritch Fortress (Figure 4.1.2-1). These views are the highest overlooks within the site, receive high visitation, and represent the points from which most visitors view the surrounding landscape. As such, these views play a major role in how visitors perceive

Table 4.1.2-1. Indicators and measures of viewshed and why these are important to the resource condition.

Indicators of Condition	Measures	Why are these indicators/measures important to resource condition?
Scenic and Historic Integrity	Intactness of View	Intactness represents how much the viewshed has been altered from its reference state, which in turn influences scenic quality as well as the sense of place in a natural and historic context.
	Conspicuousness of non-contributing features	Non-contributing features that are more conspicuous tend to detract more from the scenic quality and/or the sense of place in an historic context.

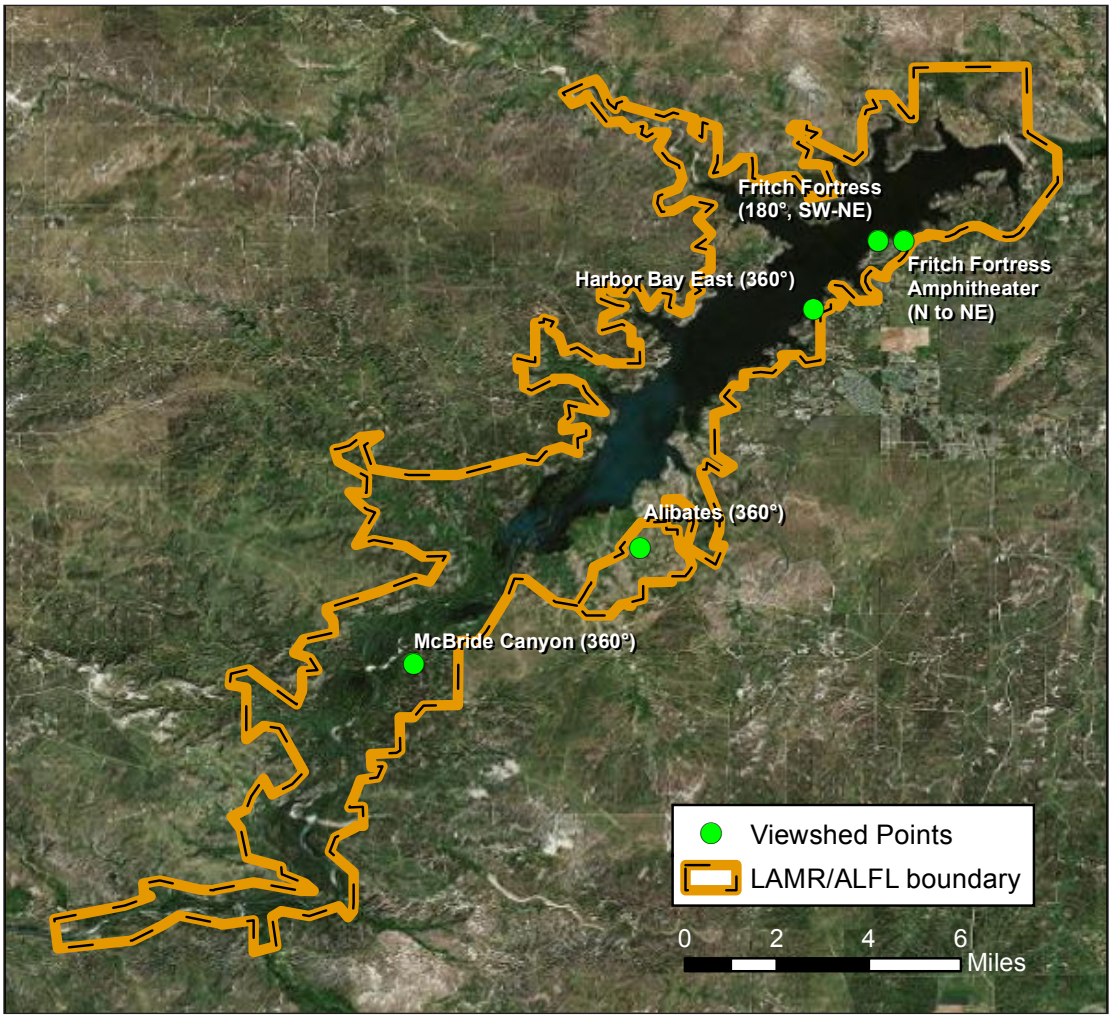


Figure 4.1.2-1. The location of the vantage points used in this assessment .

the NRA and NM within the context of its surrounding landscape.

Measure
Intactness

The extent of intactness provides a measure of the degree to which the viewshed is unaltered from its original (reference) state, particularly the extent to which intrusive or disruptive elements may diminish the character of the scene (USFS 1995, Johnson et al. 2008).

We used a series of panoramic images to portray the viewshed from an observer's perspective. These images were taken using a Canon PowerShot digital camera and the GigaPan Epic 100 system, a robotic camera mount coupled with stitching software (Figure 4.1.2-2). A series of images are automatically captured and the individual photographs are stitched into a single high-resolution panoramic image. These photographs provided a means of illustrating the features on the landscape related to viewshed integrity.

We recognize that visitor perceptions of an altered landscape are highly subjective, and there is no completely objective way to measure this. Research has shown, however, that there are certain landscape types and characteristics that people tend to prefer over others. In general, there is a wealth of research demonstrating that people tend to prefer natural over human-modified landscapes (Zube et al. 1982, Kaplan and Kaplan 1989, Sheppard 2001, Kearny et al. 2008, Han 2010). Human-altered components of the landscape (e.g., roads, buildings, powerlines, and other features) that do not contribute to the scenic or historic context are often perceived as detracting from the scenic and historic character of the viewshed.

Despite this generalization for natural landscape preferences, studies have also

Figure 4.1.2-2. The GigaPan system takes a series of images that are stitched together to create a single panoramic image.

shown that not all human-made structures or features have the same impact on visitor preferences. Visitor preferences can be influenced by a variety of factors including cultural background, familiarity with the landscape, and their environmental values (Kaplan and Kaplan 1989, Virden and Walker 1999, Kaltenborn and Bjerke 2002, Kearney et al. 2008).

Measure

Conspicuousness of Noncontributing Features

Substantial research has demonstrated that human-made features on a landscape are perceived more positively when they are considered in harmony with the landscape (e.g., Kaplan and Kaplan 1989, Gobster 1999, Kearney et al. 2008). For example, Kearney et al. (2008) showed that survey respondents tended to prefer development that blended with the natural setting through use of colors, smaller scale, and vegetative screening. For this measure, we focused on four characteristics, or groups of characteristics, that have been demonstrated to contribute to the conspicuousness of man-made features: (1) distance from a given vantage point, (2) size, (3) color and shape, and (4) movement and noise. A general relationship between these characteristics and their influence on conspicuousness is presented in Table 4.1.2-2 and more detailed descriptions of these human-made features are presented below.

Distance. The impact that individual human-made features have on perception is substantially influenced by the distance from the observer to the feature(s). Viewshed assessments using distance zones or classes often define three classes: foreground, middle ground, and background (Figure 4.1.2-3). For this assessment, we have used the distance classes that have been recently used by the National Park Service:

- *Foreground* = 0-½ mile from vantage point
- *Middle ground* = ½-3 miles from vantage point
- *Background* = 3-60 miles from vantage point.

Over time, different agencies have adopted minor variations in the different specific distances use to define these zones, but the overall logic and intent has been consistent.

Table 4.1.2-2. Characteristics that influence how less conspicuous human-made features are within a viewshed and the general effect.

Characteristic	Less Conspicuous	More Conspicuous
Distance	Distant from the vantage point	Close to the vantage point
Size	Small relative to the landscape	Large relative to the landscape
Color and Shape	Colors and shapes that blend into the landscape	Colors and shapes that contrast with the landscape
Movement and Noise	Lacking movement or noise	Exhibits obvious movement or noise

MARK BRUNSON

Figure 4.1.2-3. An example of approximate distance classes used in this assessment.

The foreground is the zone where visitors should be able to distinguish variation in texture and color, such as the relatively subtle variation among vegetation patches, or some level of distinguishing clusters of tree boughs. Large birds and mammals would likely be visible throughout this distance class, as would small or medium-sized animals at the closer end of this distance class (USFS 1995). Within the middle ground there is often sufficient texture or color to distinguish individual trees or other large plants (USFS 1995). It is also possible to still distinguish larger patches within major plant community types (such as riparian areas), provided there is sufficient difference in color shades at the farther distance. Within the closer portion of this distance class, it still may be possible to see large birds when contrasted against the sky, but other wildlife would be difficult to see without the aid of binoculars or telescopes. The background distance class is where texture tends to disappear and colors flatten. Depending on the actual distance, it is sometimes possible to distinguish among major vegetation types with highly contrasting colors (for example, forest and grassland), but any subtle differences within these broad land cover classes would not be apparent without the use of binoculars or telescopes, and even then may be difficult.

Size

Size is another characteristic that may influence how conspicuous a given feature dominates the landscape, and how it is perceived. For example, Kearney et al. (2008) found human preferences were lower for human-made developments that tended to dominate the view, such as large, multi-storied buildings) and were more favorable toward smaller, single family dwellings. In another study, Brush and Palmer (1979) found that farms tended to be viewed more favorably than views of towns or industrial sites, which ranked very low on visual preference. This is consistent with other studies that have reported rural family dwellings, such as farms or ranches, as quaint and contributing to rural character (Schauman 1979, Sheppard 2001, Ryan 2006), or as symbolizing good stewardship (Sheppard 2001).

We considered the features on the landscape surrounding Lake Meredith NRA and Alibates NM as belonging to one of six size classes (Table 4.1.2-3), which reflect the preference groups reported by studies. Using some categories of perhaps mixed measures, we considered size classes within the context of height, volume, and length.

Color and Shape

Studies have shown that how people perceive a human-made feature in a rural scene depends greatly on how well it seems to fit or blend in with the environment (Kearney et al. 2008, Ryan 2006). For example, Kearney et al. (2008) found preferences for homes that exhibit lower contrast with their

Table 4.1.2-3. A matrix describing the six size classes used for visible human-made features.

	Low Volume	Substantial Volume
Low Height	Single family dwelling (home, ranch house)	Small towns, complexes
Substantial Height	Radio and cell phone towers	Wind farms, oil derecks
Substantial Length	Small roads, wooden power lines, fence lines	Utility corridors, highways, railroads

surroundings as a result of color, screening vegetation, or other blending factors (see Figure 4.1.2-4). It has been shown that colors lighter in tone or higher in saturation relative to their surroundings have a tendency to attract attention (contrast with their surroundings), whereas darker colors (relative to their surroundings) tend to fade into the background (Ratcliff 1972), O'Connor 2008). This is consistent with the findings of Kearney et al. (2008) who found that darker color was one of the factors contributing to a feature blending in with its environment and therefore preferred. Some research has indicated that color can be used to offset other factors, such as size, that may evoke a more negative perception (O'Connor 2009). Similarly, shapes of features that contrast sharply with their surroundings may also have an influence on how they are perceived.

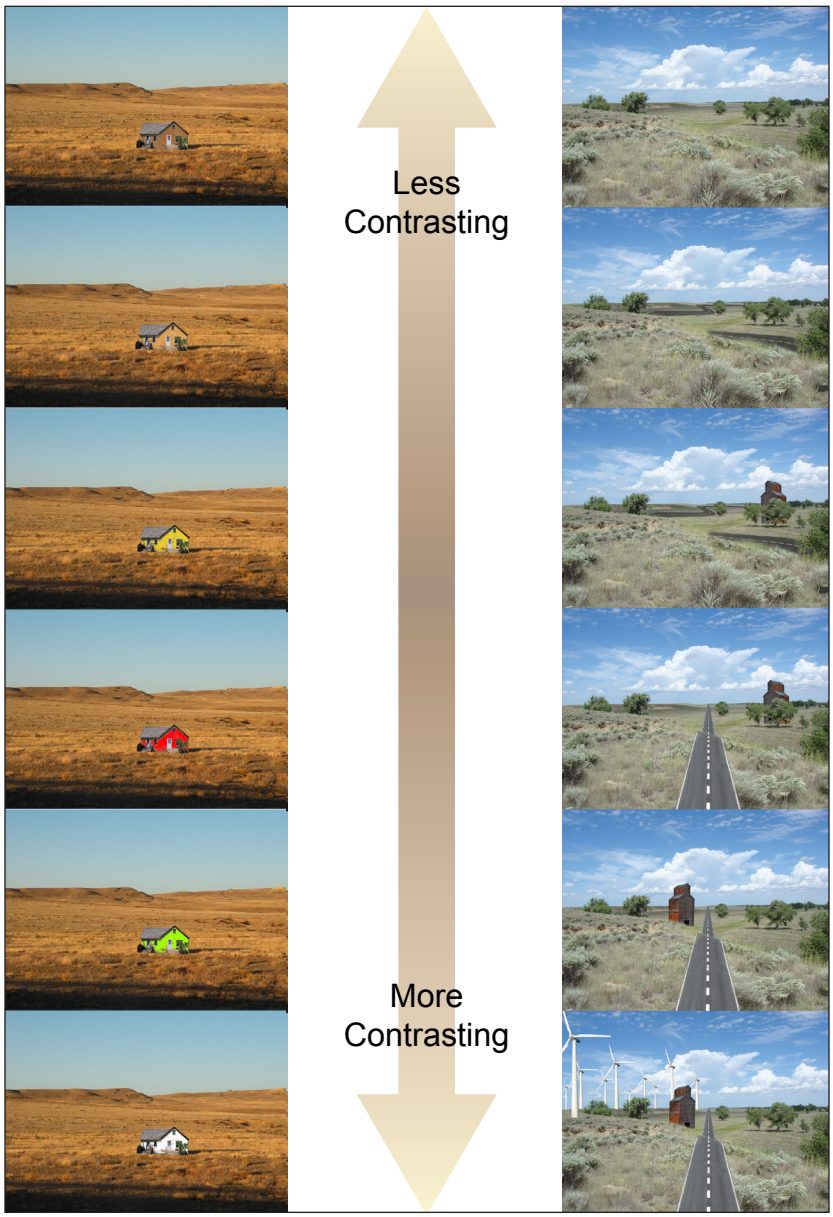


Figure 4.1.2-4. Graphic illustration of how color (left) and shape (right) can influence whether features are in harmony with the environment, or are in contrast.

This has been a dominant focus within visual resource programs of land management agencies (Ribe 2005). The Visual Resource Management Program of the BLM (BLM 1980), for example, places considerable focus on design techniques that minimize visual conflicts with features such as roads and power lines by aligning them with the natural contours of the landscape. Based on these characteristics of contrast, we considered the color of a feature in relative harmony with the landscape if it closely matched the surrounding environment, or if the color tended to be darker relative to the environment. We considered the shape of a feature in relative harmony with the landscape if it was not in marked contrast to the environment.

Movement and Noise

Motion and sound can both have an influence on how a landscape is perceived (Hetherington et al. 1993), particularly by attracting attention to a particular area of a viewshed. Movement and noise parameters can be perceived either positively or negatively, depending on the source and context. For example, the motion of running water generally has a

very positive influence on perception of the environment (Carles et al. 1999), whereas noise from vehicles on a highway may be perceived negatively. In Carles et al.'s 1999 study, sounds were perceived negatively when they clashed with aspirations for a given site, such as tranquility. We considered the conspicuousness of the impact of movement and noise to be consistent with the amount present (that is, little movement or noise was inconspicuous, obvious movement or noise was conspicuous).

Hierarchical Relationship among Conspicuousness Measures

The above-described characteristics do not act independently with respect to their influence on the conspicuousness of features; rather, they tend to have a hierarchical effect. For example, the color and shape of a house would not be important to the integrity of the NRA's viewshed if the house was located too far away from the vantage point. Thus, distance becomes the primary characteristic that affects the potential conspicuousness. Therefore, we considered potential influences on conspicuousness in the context of a hierarchy based on the distance characteristics having the most impact on the integrity of the viewshed, followed by the size characteristic, then both the color and shape, and movement and noise characteristic (Figure 4.1.2-5).

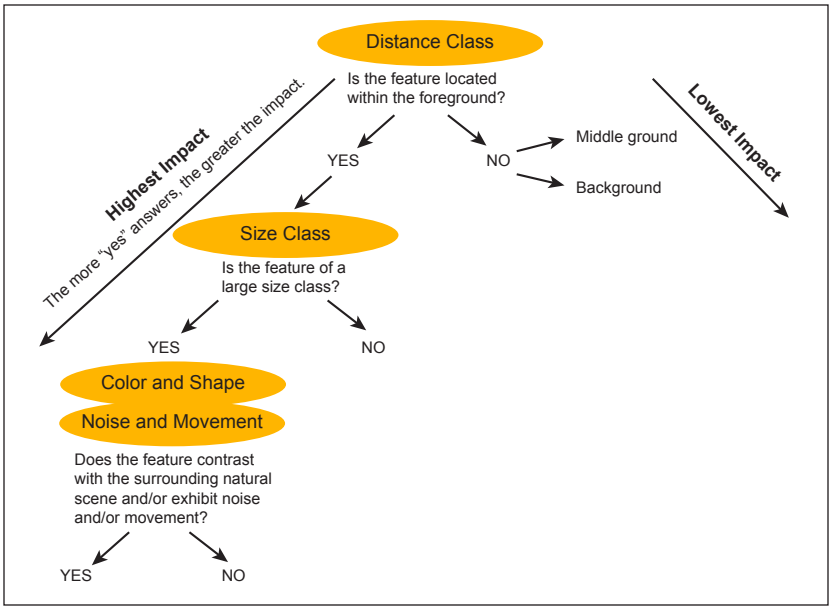


Figure 4.1.2-5. Conceptual framework for hierarchical relationship of characteristics that influence the conspicuousness of features within a viewshed.

GIS Viewshed Analyses

We supplement our assessment with a Geographic Information System (GIS) analysis to provide spatial context for these measures.

Viewshed analyses were conducted to depict the total visible area seen from each of the two key vantage points. Aerial maps of each of the vantage points were generated based on digital elevation models (DEMs) to predict the area visible from a given vantage point taking into account changes in elevation and other obstructions such as tree, mountain, or building heights. We limited this approach to an area of 30 km from the site, since features at greater distances have relatively less impact on scenic or historic integrity than those in greater proximity. Complete details of the viewshed analysis process are listed in Appendix B.

In addition, using 2010 data provided by NPScape (NPS 2011), road density and housing density were overlaid on the maps to provide an additional measure of viewshed integrity (intactness). NPScape was developed by the NPS Natural Resource Stewardship and Science by compiling and analyzing landscape-scale U.S. Census Bureau data that linked measurable attributes of landscape (i.e., road density, population and housing density, and others) to resources within natural resource-based parks, resulting in the NPScape database (Budde et al. 2009, Monahan et al. 2012).

4.1.3. Reference Conditions

The indicators and measures of viewshed condition at Lake Meredith NRA and Alibates NM are inter-related and intended to provide information about how well the views maintain their scenic quality and their ability to evoke a sense of place in an historic context.

The basis for determining condition in an assessment such as this is a comparison between current condition and a reference condition. We used a qualitative reference state for the scenic and historic integrity of

Table 4.1.3-1. Qualitative reference condition classes used for scenic and historic integrity within the viewshed at Lake Meredith NRA and Alibates Flint Quarries NM*.

Class	Scenic & Historic Integrity
High Integrity *(Good Condition)*	Some noncontributing features or developments may be visible, but the vast majority of the landscape is dominated by natural or historic features. The integrity of the natural and historic context is well preserved such that an observer can easily visualize the historic aspect of the viewshed. As such, the features that contribute to the natural and historic integrity are well preserved and the noncontributing features are generally absent or are sufficiently inconspicuous so as to not detract from the sense of place.
Moderate Integrity *(Moderate Concern)*	Noncontributing features or developments occupy a moderate portion of the landscape and/or are moderately conspicuous, but sufficient intactness retains much of its integrity. The integrity of the natural and historic context is also largely preserved such that an observer can experience a natural viewshed.
Low Integrity *(Significant Concern)*	The vast majority of the landscape is dominated by noncontributing features or developments that are conspicuous enough that little integrity or "sense of place" remains. The integrity of the natural and historic context is essentially lost either from the contributing factors not being well preserved or the noncontributing features overwhelming the potential to experience a natural viewshed.

* Historic Integrity components are considered for Alibates Flint Quarries NM only

the viewshed (Table 4.1.3-1). Embedded within these reference conditions is both the intactness and conspicuousness of features that do not contribute to the scenic and historic integrity relative to that period.

4.1.4. Condition and Trend

Overall, the scenic integrity of the viewsheds at Lake Meredith NRA and the scenic and historic integrity of the viewsheds at Alibates NM are in good condition. The landscape surrounding site remains largely intact (Figures 4.1.4-1 through 4.1.4-4; Table 4.1.4-1).

Non-contributing features are relatively minor, primarily consisting of roads and some homes and buildings. For example, in the western view from Alibates (Figure 4.1.4-1) there are some buildings in the middle ground, but their size and coloring makes them inconspicuous. The road seen in the southern view is also made inconspicuous because it is contoured and curves with the landscape. Relatively inconspicuous, unpaved roads are also seen from the McBride Canyon views (Figure 4.1.4-2).

The views from Harbor Bay East are probably the most altered due to the number of homes and power poles seen in the middle ground of the northern and eastern views (Figure 4.1.4-3). In the case of the northern view, the visitor's eye is likely drawn away from the homes and toward the view of the lake. The recent fire (shown in the images) may have decreased the vegetation screening around some of the ranch structures, but otherwise the impacts of the fire on viewsheds is temporary and negligible.

The road visible from the Fritch Fortress vantage point (Figure 4.1.4-4) is more conspicuous because it is in the foreground and paved; however, since it is contoured

Table 4.1.4-1. Indicator and measures of viewshed condition, their corresponding assigned condition class, and the rationale for assigning condition class.

Indicator of Condition	Measures	Condition	Rationale for Condition
Scenic and Historic Integrity	Intactness of View	Good	Views are mainly intact with few non-contributing features, consistent with good condition.
	Conspicuousness of non-contributing features	Good	Non-contributing features are relatively inconspicuous; consistent with good condition conditions

Figure 4.1.4-1. Panoramic views in each direction from the Alibates vantage point (from top: north, east, south, and west).

Figure 4.1.4-2. Panoramic views in each direction from the McBride Canyon vantage point (from top: north, east, south, and west).

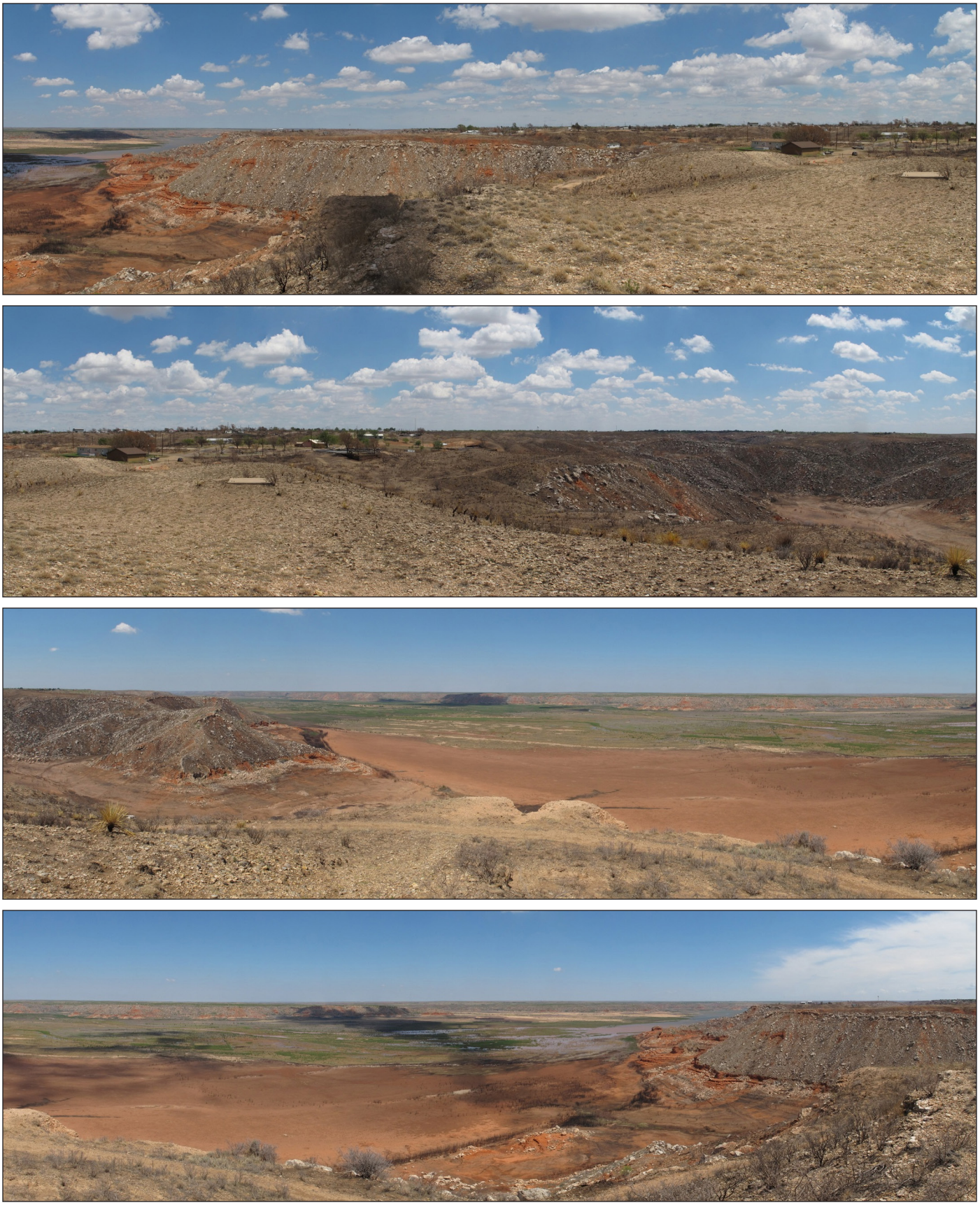


Figure 4.1.4-3. Panoramic views in each direction from the Harbor Bay East vantage point (from top: north, east, south, and west).

Figure 4.1.4-4. Panoramic views in each direction from the Fritch Fortress vantage point (from top: north, west, and from the amphitheater).

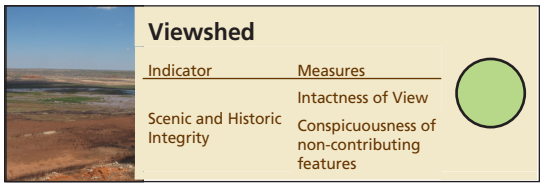
around the lake and does not have poles or other obstructions associated with it, it is still relatively inconspicuous.

GIS-based Assessment

For our GIS-based analysis, we estimated the areas visible or not visible from the vantage points (Figure 4.1.4-5). It is important to keep in mind that these estimates of visible area are approximations based on digital evaluation models. These are estimates; it should not be assumed that they are exactly correct for the purposes of planning specific projects. Such cases may require verification, and adjustment if necessary, for the specific context intended.

Housing density and road density are other measures to consider regarding their intrusion into the landscape. The closest town to the NRA/NM is Fritch (about 10 miles away), which has a population of about 4,000 people. The majority of housing density

is related to town and the low-density farm and ranch houses around the site. Road density is associated not only with the town and ranches, but also with the oil and gas development in the area (Tables 4.1.4-2 and 4.1.4-3 and Figures 4.1.4-6 and 4.1.4-7). These factors can degrade the visual integrity of the landscape and viewsheds. In this case, the roads and housing developments were not considered significant enough to warrant a moderate condition rating for scenic integrity at Lake Meredith NRA, or scenic and historic integrity at Alibates Flint Quarries NM.



Overall Condition

Based on this assessment, we considered the viewshed at Lake Meredith NRA and Alibates Flint Quarries NM to be in good condition. Non-contributing features were relatively few and inconspicuous leaving the site primarily intact from a scenic standpoint, which also allows the visitor to imagine the landscape from an historic point of view at Alibates Flint Quarries NM.

Table 4.1.4.2. Housing density surrounding Lake Meredith NRA and Alibates Flint Quarries NM.

All Areas		
Density Class	Area (km²)	Percent
Private undeveloped	4,117.52	71.62%
< 1.5 units / square km	1,141.27	19.85%
1.5 - 6 units / square km	182.58	3.18%
> 6 units / square km	281.85	4.90%
Commercial / Industrial	26.12	0.45%
Total Area	**5,749.34**	
Visible Areas Only		
Density Class	Area (km²)	Percent
Private undeveloped	81.51	82.25%
< 1.5 units / square km	11.98	12.09%
1.5 - 6 units / square km	2.55	2.57%
> 6 units / square km	3.05	3.08%
Commercial / Industrial	0.01	0.01%
Total Area	**99.10**	

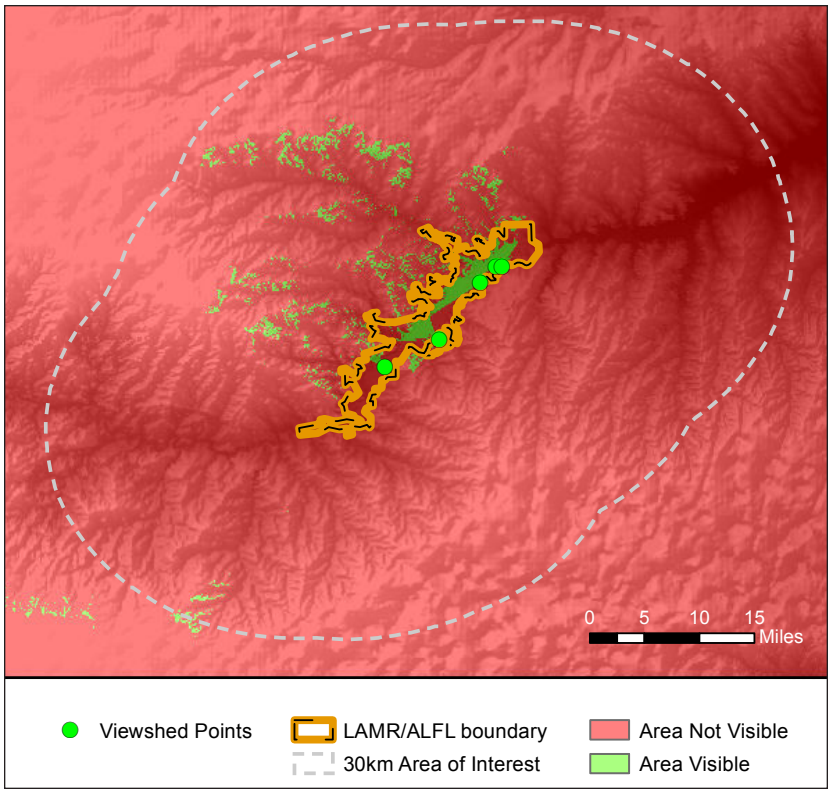


Figure 4.1.4-5. Area visible and not visible from the vantage points at Lake Meredith NRA and Alibates NM.

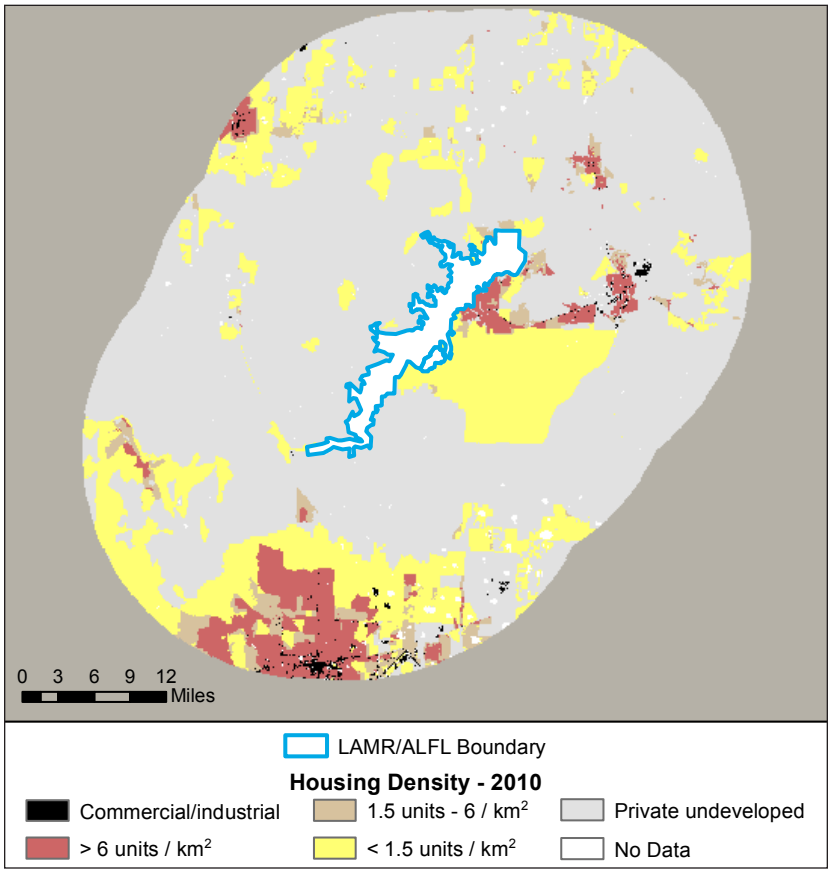


Figure 4.1.4-6. Housing density surrounding Lake Meredith NRA and Alibates NM.

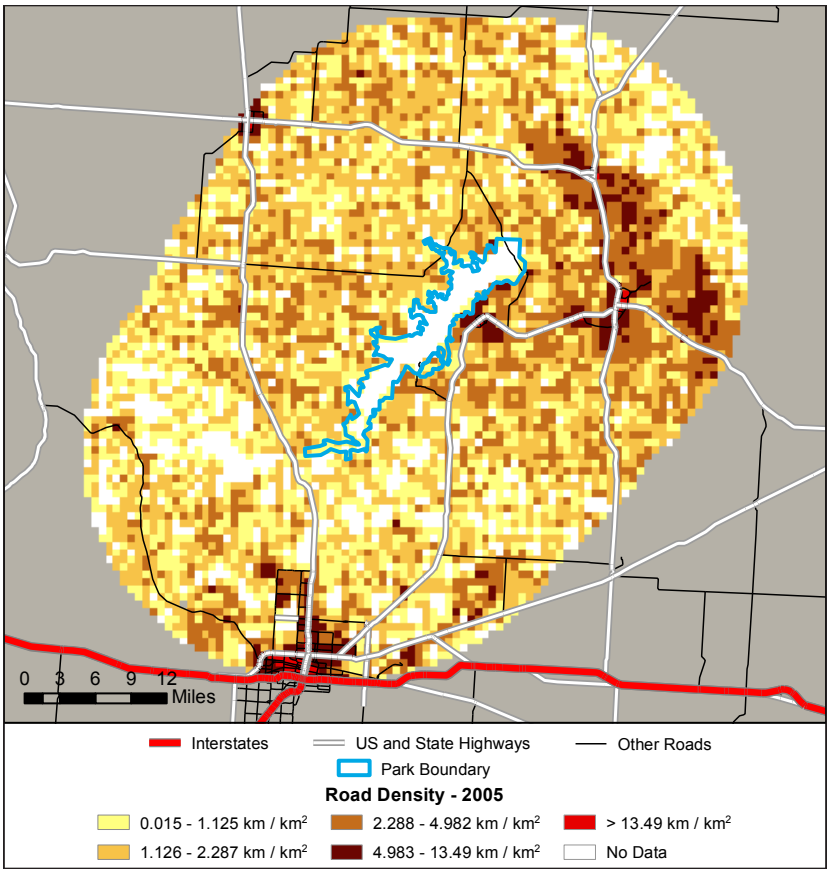


Figure 4.1.4-7. Road density surrounding Lake Meredith NRA and Alibates NM.

Table 4.1.4.3. Road density surrounding Lake Meredith NRA and Alibates Flint Quarries NM.

All Areas		
Density Class	Area (km²)	Percent
0.015 - 1.125	1,533	29.87%
1.126 - 2.287	2,047	39.89%
2.288 - 4.982	1,280	24.94%
4.983 - 13.49	246	4.79%
> 13.49	26	0.51%
Total Area	**5,132**	

Visible Areas Only		
Density Class	Area (km²)	Percent
0.015 - 1.125	22	23.66%
1.126 - 2.287	43	46.24%
2.288 - 4.982	27	29.03%
4.983 - 13.49	1	1.08%
Total Area	**93**	

4.1.5. Sources of Expertise

For assessing the condition of this resource, we relied primary on literature for this topic. Heidi Sosinski provided GIS expertise.

Key Uncertainties

How a view is perceived is quite subjective and will always have an element of uncertainty. We have tried to base our assessment on the findings of an extensive body of literature, and have tried to be transparent with our assessment.

Another element of uncertainty is our GIS analysis. This analysis is based on digital elevation models and does not take into account visibility limitations from vegetation, and other variables, and has not been verified in the field.

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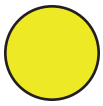
4.2. Night Sky

Indicators/Measures

- Sky Brightness (Anthropogenic Light Ratio, Zenith Sky Brightness)
- Sky Quality (Bortle Dark-Sky Scale)

Condition – Trend – Confidence



Moderate - Insufficient Data - Medium

4.2.1. Background and Importance

Natural dark skies are a valued resource within the NPS, reflected in NPS management policies (NPS 2006) which highlight the importance of a natural photic environment to ecosystem function, and the importance of the natural lightscape for aesthetics. The NPS Natural Sounds and Night Skies Division makes a distinction between a *lightscape*—which is the human perception of the nighttime scene, including both the night sky and the faintly illuminated terrain, and the *photoic environment*—which is the totality of the pattern of light at night at all wavelengths (Moore et al. 2013).

Lightscapes are an aesthetic and experiential quality that are integral to natural and cultural resources (Moore et al. 2013). A 2007 visitor survey conducted throughout Utah national parks found that 86% of visitors thought the quality of park night skies was "somewhat important" or "very important" to their visit. Additionally, in an estimated 20 national parks, stargazing events are the most popular ranger-led program (NPS 2010).

The values of night skies goes far beyond visitor experience and scenery. The photic environment affects a broad range of species, is integral to ecosystems, and is a natural physical process (Moore et al. 2013). Natural light intensity varies during the day-night (diurnal) cycle, the lunar cycle, and the seasonal cycle. Organisms have evolved to respond to these periodic changes in light levels in ways that control or modulate movement, feeding, mating, emergence, seasonal breeding, migration, hibernation, and dormancy. Plants also respond to light levels by flowering, vegetative growth, and their direction of growth (Royal Commission on Environmental Pollution 2009). Given the effects of light on living organisms, it is likely that the introduction of artificial light into the natural light/darkness regime will disturb the normal routines of many plants and animals (Royal Commission on Environmental Pollution 2009), as well as diminish stargazing recreational opportunities offered to national park visitors.

Lake Meredith National Recreation Area (NRA) and Alibates Flint Quarries National Monument (NM) is enjoyed by visitors for the recreation opportunities provided by the lake, the canyons and trails, and geological and historical features. Protecting the park's night sky resources benefits the natural resources and is important for visitor experience.

4.2.2. Data and Methods

The NPS Natural Sounds and Night Skies Division goals of measuring night sky brightness are to describe the quality of the lightscape, quantify how much it deviates from natural conditions, and how it changes with time due to changes in natural conditions, as well as artificial lighting in areas within and outside of the national parks (Duriscoe et al. 2007).

Based on new guidance (Moore et al. 2013), the NPS Natural Sounds and Night Skies Division recommends that the all-sky Anthropogenic Light Ratio (ALR) is the best single parameter for characterizing the overall sky condition. When available, additional indicators and measures should also be considered in an assessment of night sky condition, but the ALR measure is the primary data source for condition assessment (see Table 4.2.2-1).

We conducted a supplemental rapid assessment of the park's night sky condition on March 25, 2014 using the Bortle Dark Sky

Scale, a qualitative assessment commonly used by amateur astronomers to evaluate the potential quality for star gazing. This rapid assessment is supplementary and is intended only to illustrate the night sky condition.

Measure
Anthropogenic Light Ratio and Zenith Sky Brightness

The anthropogenic light ratio (ALR) is the average anthropogenic sky luminance presented as a ratio over natural conditions. It is a useful metric to average the light flux over the entire sky (measuring all that is above the horizon and omitting the terrain). Recent advances in modeling of the natural components of the night sky allow the separation of anthropogenic light from natural features, such as the Milky Way. This metric is a convenient and robust measure. It is most accurately obtained from ground-based measurements with the NPS Night Skies Program's photometric system, however, it can also be modeled with moderate confidence when such measurements are not available. No ground-based data were colleced for the parks; modeling data are reported here.

Sky brightness describes the amount of light in the night sky. One method of assessing sky brightness uses a Unihedron Sky Quality Meter (SQM) that samples the night sky in a broad spectrum band roughly corresponding to the entire human visual range. The SQM measures an aggregate average brightness for the entire sky that is skewed to zenith brightness over an 80 degree field of view (Moore 2013). Readings were taken at a location within Alibates NM (March 25, 2014) an hour and a half after sunset.

Measure
Bortle Dark Sky Scale

The Bortle Dark Sky Scale (Appendix C) was proposed by John Bortle (Bortle 2001) based on 50 years of astronomical observations. Bortle's qualitative approach uses a nine-class scale that requires a basic knowledge of the night sky and no special equipment (Bortle 2001, Moore 2001, White et al. 2012, Table 4.2.2-2). The Bortle scale uses both stellar objects and familiar descriptors to distinguish among the different classes. Another advantage of the Bortle scale is that it is suitable for conditions ranging from the darkest skies to the brightest urban areas (Moore 2001, Figure 4.2.2-1).

4.2.3. Reference Conditions

The ideal night sky reference condition, regardless of how it's measured, is one devoid of any light pollution. However, results from night sky data collection throughout more than 90 national parks suggest that a pristine night sky is very rare (NPS 2010). A natural night sky has an average brightness across the entire sky of 78 nL (nanolamberts, a measure of luminance), and includes features such as the Milky Way, Zodiacal light, airglow, and other starlight. This is figured into the ratio, so that an ALR reading of 0.0 would indicate pristine natural conditions where the anthropogenic component was 0 nL. A ratio of 1.0 would indicate that anthropogenic light was 100% brighter than the natural light from the night sky. For a summary of

Table 4.2.2-1. Indicators and measures of the night sky and why they are important to resource condition.

Indicator	Measure	Description
Sky Brightness	Anthropogenic Light Ratio and Zenith Sky Brightness	The all-sky anthropogenic light ratio describes light due to man-made sources compared to light from a natural dark sky. Understanding the lightscape and sources of light is helpful to managers to maintain dark skies for the benefit of wildlife and people alike.
Sky Quality	Bortle Scale Class	The Bortle Dark Sky classification system describes the quality of the dark night sky by the celestial bodies and night sky features an observer can see. Observing the stars has been an enjoyable human pastime for centuries.

Table 4.2.2-2. Bortle Dark Sky Scale.*

Bortle Scale	Milky Way (MW)	Astronomical Objects	Zodiacal Constellations	Airglow and Clouds	Nighttime Scene
Class 1 Excellent Dark Sky Site	MW shows great detail, and appears 40° wide in some parts; Scorpio-Sagittarius region casts an obvious shadow	Spiral galaxies (M33 and M81) are obvious objects; the Helix nebula is visible with the naked eye	Zodiacal light is striking as a complete band, and can stretch across entire sky	The horizon is completely free of light domes, very low airglow	Jupiter and Venus annoy night vision, ground objects are barely lit, trees and hills are dark
Class 2 Typical Dark Site	MW shows great detail and cast barely visible shadows	The rift in Cygnus star cloud is visible; the Prancing Horse in Sagittarius and Fingers of Ophiuchus dark nebulae are visible, extending to Antares	Zodiacal band and gegenschein are visible	Very few light domes are visible, with none above 5° and fainter than the MW; airglow may be weakly apparent, and clouds still appear as dark voids	Ground is mostly dark, but object projecting into the sky are discernible
Class 3 Rural Sky	MW still appears complex; dark voids and bright patches and a meandering outline are visible	Brightest globular clusters are distinct, pinwheel galaxy visible with averted vision	Zodiacal light is easily seen, but band of gegenschein is difficult to see or absent	Airglow is not visible, and clouds are faintly illuminated except at zenith	Some light domes evident along horizon, ground objects are vaguely apparent
Class 4 Rural-Suburban Transition	MW is evident from horizon to horizon, but fine details are lost	Pinwheel galaxy is a difficult object to see; deep sky objects such as M13 globular cluster, Northern Coalsack dark nebula, and Andromeda galaxy are visible	Zodiacal light is evident, but extends less than 45° after dusk	Clouds are just brighter than the sky, but appear dark at zenith	Light domes are evident in several directions (up to 15° above the horizon), sky is noticeably brighter than terrain
Class 5 Suburban Sky	MW is faintly present, but may have gaps	The oval of Andromeda galaxy is detectable, as is the glow in the Orion nebula, Great rift in Cygnus	Only hints of zodiacal light may be glimpsed	Clouds are noticeably brighter than sky	Light domes are obvious to casual observers, ground objects are easily seen
Class 6 Bright Suburban Sky	MW only apparent overhead, and appears broken as fainter parts are lost to sky glow	Cygnus, Scutum, and Sagittarius star fields just visible	Zodiacal light is not visible; constellations are seen, and not lost against a starry sky	Clouds appear illuminated and reflect light	Sky from horizon to 35° glows with grayish color, ground is well lit
Class 7 Suburban-Urban Transition	MW may be just barely seen near the zenith	Andromeda galaxy (M31) and Beehive cluster (M44) are rarely glimpsed	Zodiacal light is not visible, and brighter constellations are easily seen	Clouds are brilliantly lit	Entire sky background appears washed out, with a grayish or yellowish color
Class 8 City Sky	MW not visible	Pleiades are easily seen, but few other objects are visible	Zodiacal light not visible, constellations are visible but lack key stars	Clouds are brilliantly lit	Entire sky background has uniform washed out glow, with light domes reaching 60° above the horizon
Class 9 Inner City Sky	MW not visible	Only the Pleiades are visible to all but the most experienced observers	Only the brightest constellations are discernible	Clouds are brilliantly lit	Entire sky background has a bright glow, ground is illuminated

* Table 4.2.2-1 also incorporates the Bortle Dark Sky Scale Key for the Summer Sky for Latitudes 30° to 50° N, White et al. 2012.

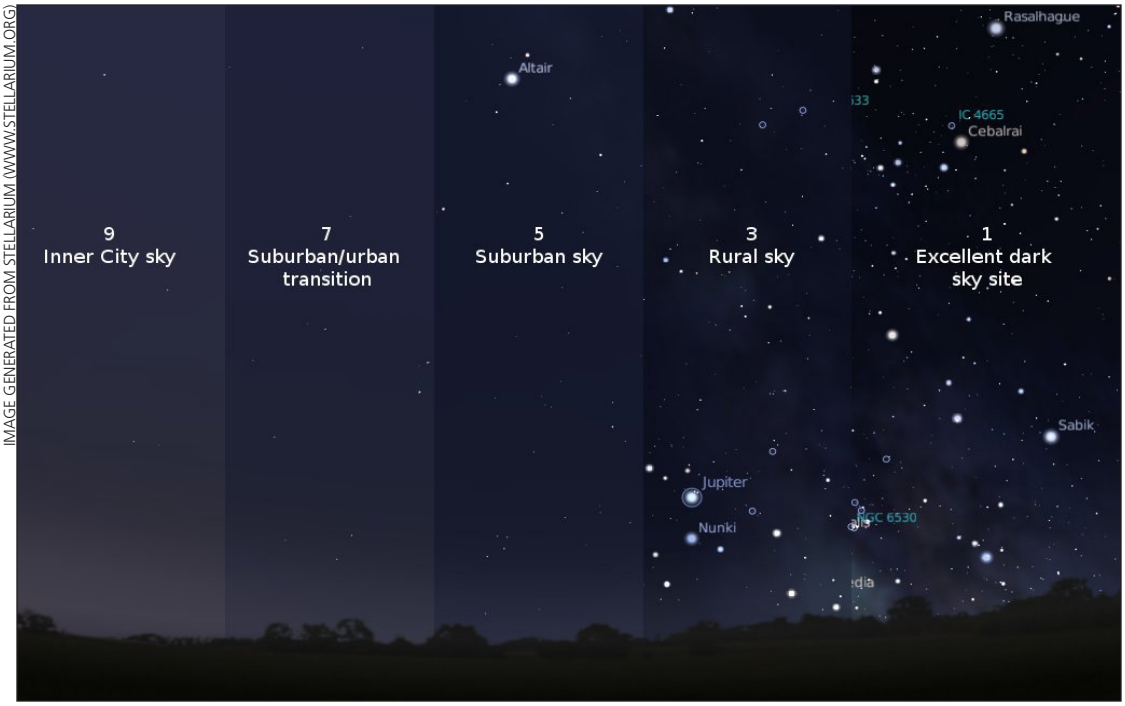


Figure 4.2.2-1. Composite image illustrating the range of night sky conditions based on the Bortle Dark Sky Scale.

condition assessment categories for all night sky indicators, see Table 4.2.3-1.

Anthropogenic Light Ratio

The threshold for night skies in good condition is an ALR <0.33 and the threshold for a moderate condition is ALR 0.33-2.0. An ALR >2.0 suggests significant concern (Moore et al. 2013).

Zenith Sky Brightness

Reference conditions for night sky brightness can vary moderately based on the time of night (time after sunset), time of the month (phase of the moon), time of the year (the position of the Milky Way), and the activity of the sun which can increase "airglow"—a kind of faint aurora. For the *minimum* night sky brightness measure, the darkest part of a natural night sky is generally found near the zenith. A value of 22.0 magnitudes per square arc second (msa) is considered to represent a pristine sky, though it may vary naturally by more than +0.2 to -0.5 depending on natural conditions (Duriscoe 2013 [submitted]). Lower (brighter) values indicate increased light pollution and a departure from natural conditions. The astronomical magnitude scale is logarithmic, so a change of 2.50 magnitudes corresponds to a difference of l0x (100%); thus a 19.5 msa sky would be 10x brighter than natural conditions. *Minimum* night sky brightness values of 21.4 to 22.0 msa, are generally considered to represent natural (unpolluted) conditions (Duriscoe et al. 2007).

Table 4.2.3-1. Night sky condition class summary.

Condition Class	ALR*	SQM	Bortle Scale
Good	ALR <0.33 (<26 nL average anthropogenic light in sky)	≥21.60	1-3
Moderate	0.33-2.0 (26-156 nL average anthropogenic light in sky)	21.2-21.59	4
Significant concern	ALR >2.0 (>156 nL average anthropogenic light in sky)	<21.2	5-9

* At least half of the NRA's geographic area should meet the standard described

The *maximum* night sky brightness is often found within the Milky Way of a natural sky. A typical measurement from the Sagittarius region of the Milky Way in a natural sky yields 19.2 msa. Other regions of the Milky Way are somewhat dimmer, or around 20.0-21.0 msa. A value brighter than 19.0 msa will result in impairment to human night vision and may be noticeable by casting faint shadows or causing glare. A value lower (brighter) than 17.0 represents very bright areas of the night sky and would significantly impair human night vision and cast obvious shadows. Values for the brightest portion of the sky are of interest to the NPS because they represent unnatural intrusions on the nightscape, will prevent human dark-adapt vision, and may have effects on wildlife (Duriscoe et al. 2007)

Bortle Dark Sky Scale

A night sky with a Bortle Dark Sky Scale class 1 is considered in the best possible condition (Bortle 2001); unfortunately, a sky that dark is so rare that few observers have ever witnessed it (Moore 2001). Non-urban park skies with a Bortle class 3 or darker are considered to be in good condition, class 4 of moderate condition, and class 5 are considered poor condition. At class 4 and higher, many night-sky features are obscured from view due to artificial lights (either within or outside the park). Skies class 7 and higher have a significantly degraded aesthetic quality that may introduce ecological disruption (Moore et al. 2013). It is important to note that such degraded conditions may be restored toward a more natural state by modifying outdoor lighting, depending on the surrounding conditions that exist outside the Historic Site.

4.2.4. Condition and Trend

Modeling data provided by the NPS Night Skies Program show an ALR of 1.09 for Lake Meredith NRA and 1.02 for Alibates Flint Quarries NM indicating moderate condition (the models have an error of ±0.1 ALR; Figure 4.2.4-1.).

Ground-based SQM readings taken from Alibates NM as part of the supplementary rapid assessment as 21.08, indicating significant concern.

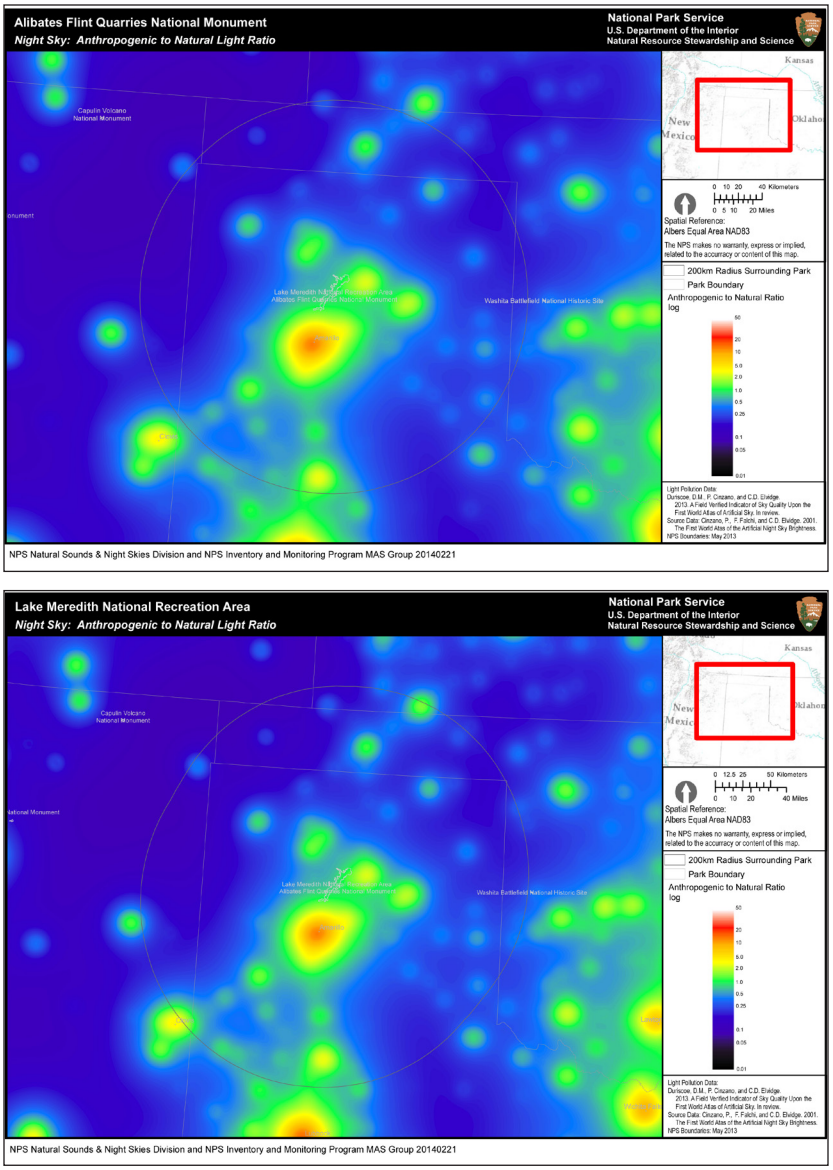


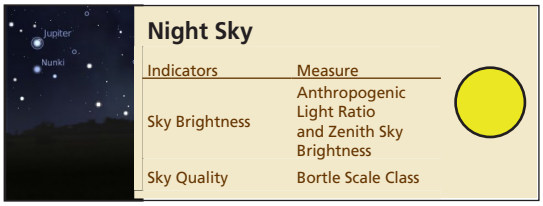
Figure 4.2.4-1. ALR maps for Alibates Flint Quarries NM (above, top) Lake Meredith NRA (above, lower).

The qualitative Bortle Scale assessment estimated the night sky quality to class 4, consistent with a suburban sky, which indicates moderate condition.

Local and Regional Context

Lake Meredith NRA and Alibates Flint Quarries NM are located just 10 miles from Fritch (population 2,117). Light domes from Borger (about 24 miles away, population 13,251) and Dumas (less than 50 miles away, population 14,691) are visible. Most impact comes from Amarillo, just 33 miles away with a population of 190,695 (U.S. Census Bureau 2010). The light domes from these population centers impact the night sky. Other sources of

artificial light include numerous towers and oil/gas pads.



Overall Condition

Quantitative modeling of sky brightness (all-sky anthropogenic light ratio and zenith sky brightness) and a qualitative assessment of sky quality (the Bortle Dark Sky Scale) were used to assess the condition of the night sky. These indicators are summarized and interpreted in Table 4.2.4-1. The overall condition of the park's night sky is moderate, based on the more reliable ALR reading and the significant influence from nearby light domes.

Uncertainties

The Bortle Dark Sky Scale estimates have inherent uncertainties and error. The principle drawback of the Bortle Scale is that it relies upon human visual observers. Differences in visual acuity, experience and knowledge, as well as time and effort expended can influence the estimates (Bortle 2001, Moore 2001). Modeled data are based on 1996 satellite imagery, and ground truthed with NPS ground-based measures. Changes in population levels, private and commercial building growth, and energy development could impact current ALR values. This assessment should be interpreted as interim until ground-based measures of all-sky ALR are taken (C. Moore, NPS, pers. comm.).

4.2.5. Sources of Expertise

Chad Moore and Jeremy White, Natural Sounds and Night Skies Division, part of the NPS Natural Resource Stewardship and Science Directorate, provided information pertaining to night sky data collection methodology and interpretation of results. Moore earned a master's degree in earth science in 1996 and began working for the NPS shortly thereafter. Moore is the Night Skies Program manager for a small team of scientists that measure, restore, and promote the proper management of the night sky resource. He and team member Dan Duriscoe have developed an automated all-sky camera capable of precise measurement of light pollution. White earned his Bachelors degree in Ecology and Systematic Biology in 2004 and began working with the NPS in 2005. White is a Physical Scientist with the Night Skies Program responsible for data collection and analysis, interpretation, and public outreach. Since 2001 the team has collected sky quality inventories at over 110 U.S. national parks.

4.2.6. Literature Cited

Bortle, J. E. 2001. Introducing the Bortle DarkSky Scale. *Sky and Telescope* February:126-129.

Table 4.2.4-1. Summary of night sky indicators and measures and assessment of night sky condition at Lake Meredith National Recreation Area and Alibates Flint Quarries NM.

Indicator	Measure	Condition	Condition Rationale
Sky Brightness	Anthropogenic Light Ratio (1.09, 1.02)	Moderate	This measure results from modeled data from the NPS Night Sky Program. Specific thresholds for condition classes have been set by the NPS. In this case, the moderate condition results from the significant light domes of nearby cities. The confidence level in this assessment is medium.
	Zenith Sky Brightness (21.08)	Significant Concern	Zenith sky brightness indicates significant concern, based on the impact from light domes from nearby cities and point sources of light. Confidence level is medium.
Sky Quality	Bortle Scale Class (4)	Moderate	The Milky Way was partly visible, but not complete or well defined. Light domes from nearby cities were clearly visible. Because this measure is qualitative, it has a low confidence level.

Duriscoe, D. M. 2013 (submitted). Measuring anthropogenic sky glow using a natural sky brightness model. *Mon. Not. R. Astron. Soc*.

Duriscoe, D., C. B. Luginbuhl, and C. A. Moore. 2007. Measuring night sky brightness with a wide-field CCD camera. *Publications of the Astronomical Society of the Pacific* 119:192-213.

Moore, C. A. 2001. Visual estimations of night brightness. *George Wright Forum* 18:4655.

Moore, C. A., J. M. White, and F. Turina. 2013. Recommended indicators of nightskyquality for NPS state of the park reports, interim guidance. Natural Sounds and Night Skies Division, WASO-Natural Resource Stewarship and Science. April 10, 2013.

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Royal Commission on Environmental Pollution. 2009. Artificial light in the environment. The Stationery Office Limited, London.

U.S. Census Bureau. 2010. Profile of general population and housing characteristics. Available at http://factfinder2.census.gov/faces/nav/jsf/pages/index.xhtml (accessed 17 June 2014).

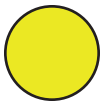
White, J., D. Duriscoe, and C. Moore. 2012. Bortle Dark-Sky Scale: Key for the summer sky, latitudes 30° to 50° North. NPS Natural Sounds and Night Skies Division.

4.3. Soundscape

Indicators/Measures

- Audibility (% Time Audible)
- Sound Level (2 measures)

Condition – Trend – Confidence



Moderate - Insufficient Data - Medium

4.3.1. Background and Importance

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. An unimpaired acoustical environment is an important part of overall NPS visitor experience and enjoyment, as well as vitally important to overall ecosystem health.

Visitors to national parks often indicate that an important reason for visiting the parks is to enjoy the relative quiet they can offer. In a 1998 survey of the American public, 72% of respondents 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). Despite this desire for quiet environments, noise continues to intrude upon natural areas and has become a source of concern in national parks (Lynch et al. 2011) (Figure 4.3.1-1).

Sound also plays a critical role in intraspecies communication, courtship and mating, predation and predator avoidance, and effective use of habitat. Studies have shown that wildlife can be adversely affected by sounds that intrude on their habitats. While the severity of the impacts varies depending on the species being studied and other conditions, research strongly supports the fact that wildlife can suffer adverse behavioral and physiological changes from intrusive sounds (noise) and other human disturbances. Documented responses of wildlife to noise include increased heart rate, startle responses,

AMYLIA WILLIAMS

Figure 4.3.1-1. A variety of sounds, including natural and noise, can be heard throughout the National Recreation Area and National Monument.

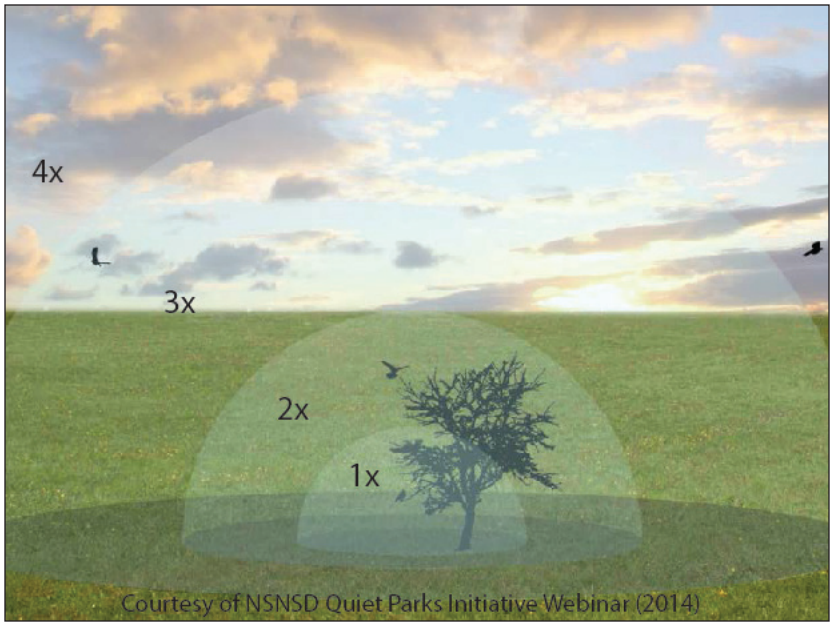


Figure 4.3.1-2. A 6 dB reduction in background noise level would produce a 4x increase in listening area (NSNSD 2014a).

flight, disruption of behavior, and separation of mothers and young (Selye 1956, Clough 1982, USDA 1992, Anderssen et al. 1993, NPS 1994).

A park's natural soundscape is an inherent component of "the scenery and the natural and historic objects and the wildlife" protected by the Organic Act of 1916. NPS Management Policies (§ 4.9) (2006) require preservation of parks' natural soundscapes and restoration of degraded soundscapes to natural conditions wherever possible. Additionally, NPS is required to prevent or minimize degradation of the natural soundscapes from noise (i.e., any unwanted sound). Although the management policies currently refer to the term soundscape as the aggregate of all natural sounds that occur in a park, differences exist between the physical sound sources and human perceptions of those sound sources. The physical sound resources (i.e., wildlife, waterfalls, wind, rain, and cultural or historical sounds), regardless of their audibility, at a particular location, is referred to as the acoustical environment, while the human perception of that acoustical environment is defined as the soundscape. Clarifying this distinction will allow managers to create objectives for safeguarding both the acoustical environment and the visitor experience.

Sound Characteristics

Humans and wildlife perceive sound as an auditory sensation created by pressure variations that move through a medium such as water or air. Sound is measured in terms of frequency (pitch) and amplitude (loudness) (Templeton and Sacre 1997, Harris 1998).

Frequency, measured in Hertz (Hz), describes the cycles per second of a sound wave and is perceived by the ear as pitch. Humans with normal hearing can hear sounds between 20 Hz and 20,000 Hz and are most sensitive to frequencies between 1,000 Hz and 6,000 Hz. High frequency sounds are more readily absorbed by the atmosphere or scattered by obstructions than low frequency sounds. Low frequency sounds diffract more effectively around obstructions. Therefore, low frequency sounds travel farther.

Besides the pitch of a sound, we also perceive the amplitude (or loudness) of a sound, which is measured in decibels (dB). The decibel scale is logarithmic, meaning that every 10 dB increase in sound pressure level (SPL) represents a tenfold increase in sound energy. This also means that small variations in SPL can have significant effects on the acoustical environment. For instance, a 6 dB reduction in background noise level would produce a 4x increase in listening area (Figure 4.3.1-2). Changes in the background noise level cause a change in listening opportunity. These lost opportunities will approach a halving of alerting distance and a 75% reduction of listening area for each 6 dB increase in affected band level (Barber et al. 2010).

SPL is commonly summarized in terms of dBA (A-weighted SPL). This metric significantly discounts sounds below 1,000 Hz and above 6,000 Hz to approximate the variation in human hearing sensitivity.

4.3.2. Data and Methods

Two soundscape assessments have been conducted at Lake Meredith NRA and Alibates Flint Quarries NM (Wyle 2011 and Foch 2000). The most recent acoustic monitoring study conducted by Wyle (2011) was to monitor and model off road vehicle use in the Rosita Creek and Blue Creek areas

of the NRA for the purposes of the park's Off Road Vehicle Management Plan. Wyle's (2011) monitoring locations did not overlap with our 2014 soundscape rapid assessment locations.

Foch's (2000) acoustic monitoring occurred in 1998 and three locations overlapped with our rapid assessment: McBride Canyon, Alibates Flint Quarries NM, and Fritch Fortress. Results between Foch (2000) and the 2014 rapid assessment will be discussed in the condition and trend section below.

For the purposes of this assessment, we conducted on-site listening sessions at four locations from May 28- May 29, 2014 (Figure 4.3.2-1). Table 4.3.2-1 summarizes the time and conditions of the recording sessions.

During these sessions, an observer was situated at the designated listening location with an Apple device using the listening app. developed by Natural Sounds and Night Skies Division (NSNSD). The observer listened for the designated period of time and identified all sound sources and respective durations. The monitoring took full advantage of human binaural hearing capabilities while providing the closest match to a park visitor's experience. Several limitations to this method included a short sample period, a small sample size, and qualitatively assessing amplitude. This technique primarily provided a baseline for future monitoring efforts and a "snapshot" of soundscape condition for the purposes of this assessment.

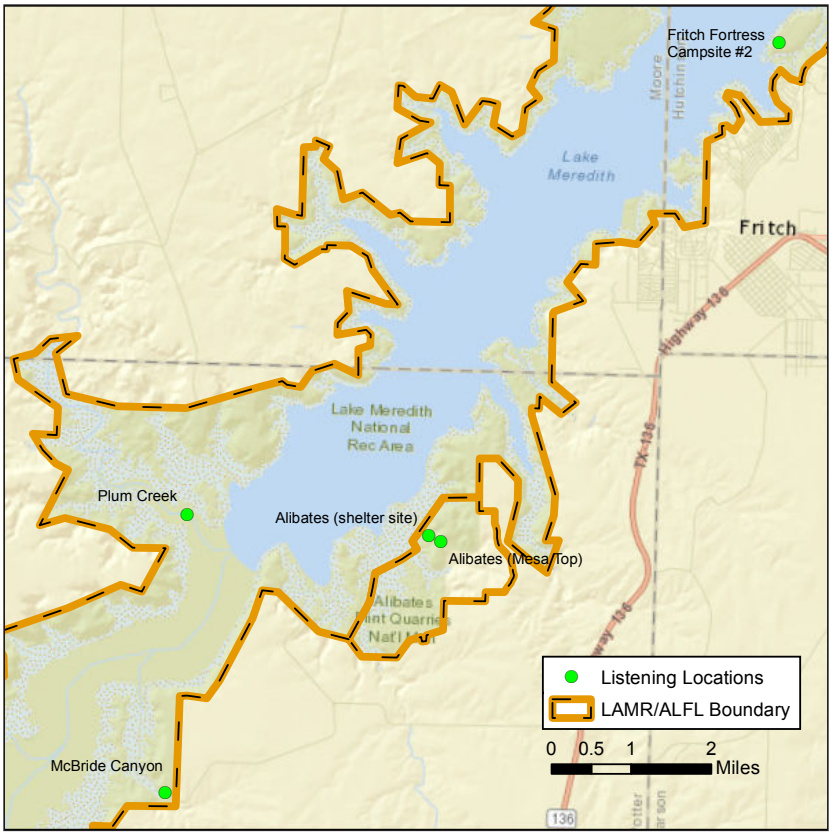


Figure 4.3.2-1. On-site acoustical monitoring locations.

Table 4.3.2-1. Summary of on-site listening sessions at Lake Meredith NRA and Alibates Flint Quarries NM.

Location	Date	Time(s)	Session Duration	Weather
Fritch Fortress (Campsite #2)	May 28, 2014	Morning - 8:05-9:05 AM	60 minutes	55-79 °F, clear, 1-3 mph wind speed
		Noon - 11:30-12:30 PM	60 minutes	55-79 °F, clear, 4-7 mph wind speed
		Afternoon	60 minutes	80-99 °F, partly cloudy, 8-12 mph wind speed
Lower Plum Creek	May 28, 2014	Morning - 8:22-9:22 AM	60 minutes	55-79 °F, clear, calm wind speed
		Noon - 11:58-12:58 PM	60 minutes	80-99 °F, clear, calm wind speed
		Afternoon	60 minutes	80-99 °F, mostly clear, 1-3 mph wind speed
McBride Canyon	May 29, 2014	Morning - 8:05-9:05 AM	60 minutes	55-79 °F, clear, calm wind speed
		Noon - 11:25-12:25 PM	60 minutes	80-99 °F, clear, 4-7 mph wind speed
		Afternoon - 3:15- 4:15 PM	60 minutes	80-99 °F, partly cloudy, 4-7 mph wind speed
Alibates Flint Quarries NM	May 29, 2014	Morning - 8:15-9:15 AM (Mesa Top)	60 minutes	55-79 °F, clear, 1-3 mph wind speed
		Noon	Equipment overheated on top of Mesa and data were lost.	
		Afternoon- 3:28-4:28 PM (Shelter by parking lot)	60 minutes	80-99 °F, clear, 8-12 mph wind speed

Table 4.3.2-2. Indicators and measures used to assess the soundscape at Lake Meredith NRA and Alibates Flint Quarries NM.

Indicator	Measure	Definition
Audibility	% Time Audible	The percent of time that a particular sound may be detected by the human ear is the measure for audibility. This measure was obtained from the on-site listening results. We categorized sounds based on noises, natural, or recreational sounds.
Sound Level	Amplitude (on-site monitoring)	Loudness or amplitude of a sound is typically measured in decibels (dB). The decibel scale is logarithmic, meaning that every 10 dB increase in sound pressure level (SPL) represents a tenfold increase in sound energy. Amplitude was assessed by comparing sounds heard to the relative sound levels shown in in Figure 4.3.2-2 to qualitatively determine the relative loudness of noise(s) that were heard.
	Amplitude (Mennitt et al. (2013) modeled sound levels)	"Using long-term sound pressure level measurements from hundreds of sites across the contiguous United States, geospatial models were developed to predict sound levels. These sound models incorporated spatial representations of biological, geophysical, climatic, and anthropogenic factors to assess expected contributions to the existing sound pressure level from both anthropogenic and natural sources, which enable mapping of sound pressure levels at regional and national scales" (cited from Mennitt et al. 2013). This quantitative sound level information supplements the May 28 - May 29, 2014 on-site listening results.

We augmented the on-site data collection using the NSNSD's sound level model data for the area surrounding the National Recreation Area and National Monument. The model provided a quantitative sound level impact that measured the difference between the NRCA and NM's natural /ambient sound levels versus the existing sound levels. These maps are included in Appendix D.

On-site Monitoring Locations

Fritch Fortress Campsite #2:

Fritch Fortress is located in the northern part of the NRA within the developed zone that offers developed campground recreational opportunities. On-site acoustical monitoring occurred on May 28, 2014 at campsite #2, a couple of weeks after the May 2014 wildland fire. Three one-hour monitoring sessions occurred at this location.

Lower Plum Creek (Meadows):

This monitoring location was situated within the primitive campground and along the trail. It is located in the developed zone and three one-hour monitoring sessions occurred at this location.

McBride Canyon

McBride Canyon is located in the rural management zone and offers primitive camping opportunities for a more secluded and quiet visitor experience. A cultural zone is located adjacent to this monitoring location surrounding the McBride Ranch House. Three one-hour monitoring sessions occurred at this location.

Alibates Flint Quarries NM

The monitoring sites at Alibates Flint Quarries NM were located in the cultural management zone. Two, one-hour monitoring sessions occurred at this location. Equipment failure prevented data collection for the mid-day monitoring session.

Indicators and Measures

The indicators we used to assess soundscape condition were audibility and sound level, with one and two measures, respectively (Table 4.3.2-2).

Indicators/Measures

Audibility (% Time Audible)

During the on-site listening sessions, we gathered information about the types of audible sounds, how long they were heard, and the number of events for each sound that was heard, using the NSNSD app. We present the results as percent time audible for each

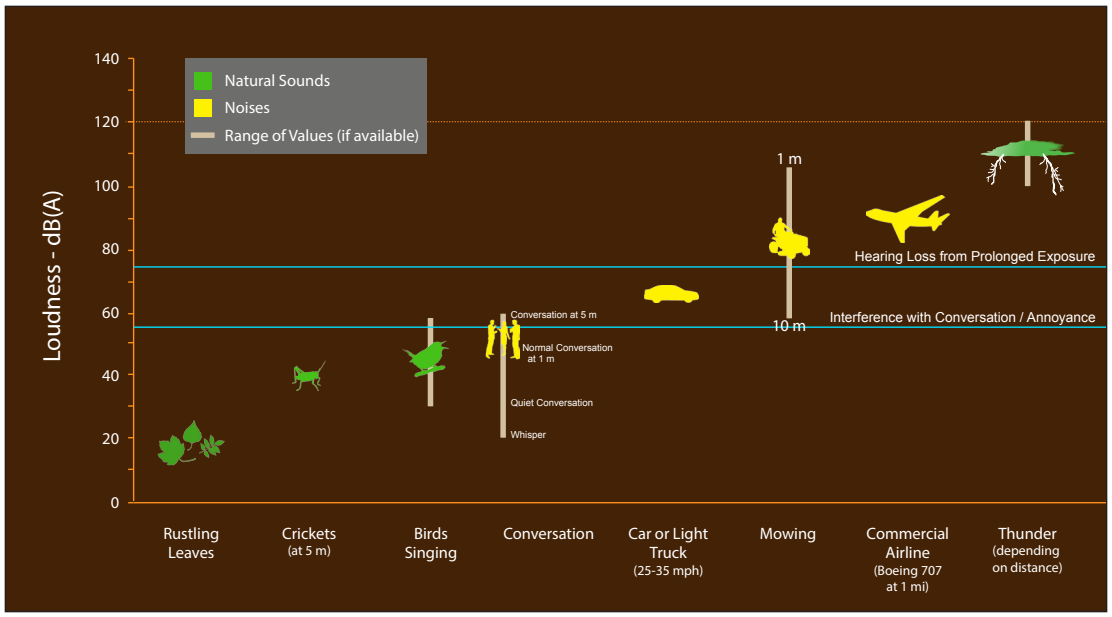


Figure 4.3.2-2. Reference dB(A) levels for qualitative sound level assessment sounds at Lake Meredith NRA and Alibates Flint Quarries NM.

type of sound heard at each on-site listening location.

Indicators/Measures
Sound Level (2 measures)

Sound levels were assessed in two ways (1) using sound models created by Mennitt et al. (2013) to provide quantitative parkwide/regional sound levels, and (2) using on-site monitoring information to qualitatively determine sound levels by referencing common sound levels reported in literature.

Mennitt et al. (2013) Model
Mennitt et al. (2013) created sound level models at regional and national scales. The model used spatial, meteorological, and actual sound level measurements from 100s of sites (primarily located in the west) to model sound levels for natural and existing conditions, as well as to model the impact of the sound levels based on the difference between the modeled natural and existing sound levels. We used the results from this model to provide a predicted quantitative assessment of sound level at Lake Meredith NRA and Alibates Flint Quarries NM.

Qualitative Sound Level Assessment
For the qualitative sound level assessment, we evaluated the relative levels of sounds heard while monitoring on-site to common sound levels reported throughout the literature (Figure 4.3.2-2). While we are aware of the fact that this qualitative approach did not capture the sound levels in a repeatable way, we believe this method still provided important on-site information to help assess condition.

Context for Evaluating Sounds
Whether or not a given sound contributes to or detracts from the soundscape condition depends largely on whether or not that sound is appropriate for the context in which it is heard.

If this were a wilderness setting, natural sounds versus noises might be a pertinent distinction for how a sound is perceived. However, the context and setting at Lake Meredith NRA and Alibates Flint Quarries NM is quite different in that there are sounds within the recreational context that are acceptable, even though they may not be natural. Thus, for the purposes of this assessment, we may consider sounds that are consistent with the designated activities to not detract from soundscape condition depending upon where the noises are heard.

In contrast, some sounds, such as low flying aircraft, vehicles, or excessive human voices/boat motors may detract from the soundscape experience and consequently be perceived negatively as noise, detracting from the condition of the soundscape.

Table 4.3.2-3. Designated activities and associated sounds expected within each management zone as defined in the NRA and NM's general management plan preferred alternative (NPS 2013, 2014) where soundscape monitoring occurred.

Management Zone	Typical Activities and Associated Sounds
Developed (Lower Plum Creek and Fritch Fortress)	A developed zone in the NRA/NM is highly modified and where the majority of visitation occurs. Facilities are developed for day and night use. Visitors can expect interactions with others, including park staff. Developments are situated away from highly sensitive areas.
Rural (McBride Canyon)	Natural conditions predominate in this zone but modifications are made to accommodate moderate visitation. Some interaction with others can be expected, but there are opportunities for solitude, natural quiet, and undirected discovery if visitors are willing to venture away from the developed areas within this zone.
Cultural (Alibates Flint Quarries NM)	Protection of archeological resources is a priority within this management zone. While visitors can access this site, it is by NPS guided tours only. As a result, visitors can expect some interaction with others while experiencing this part of the park, but it is generally low to moderate, with natural sounds predominating.

For these reasons, we considered sound types within the context of belonging to two classes: (1) natural and recreational-appropriate sounds, and (2) noise (any unwanted/out of context sound). The first class was considered as having a neutral or positive influence on soundscape condition; whereas excessive noise, especially in locations where noise is unexpected due to designated use, was considered to have a negative effect, contributing to a more impacted soundscape condition.

Additionally, the locations where sounds were heard based upon the NRA and NM's designated management zones, affected the assessment of soundscape condition. The areas where on-site monitoring occurred included three of the NRA and NM's preferred alternative management zones, identified in the 2013 General Management Plan (NPS 2013).

Each zone is defined by designated activities, which in turn, helped us assess whether the sounds heard were appropriate to the soundscape within that area. The three zones where on-site listening occurred are summarized in Table 4.3.2-3.

4.3.3. Reference Conditions

Studies identifying effects of noise on human health and well being and effects of noise on wildlife serve as guides for the quality of visitor soundscape experience reference conditions shown in Table 4.3.3-1.

We considered the soundscape to be in good condition if sounds heard were consistent with National Recreation Area and National Monument designated activities, if no excessive sound/noise levels were present, regardless of designated use, and if noise-free intervals were common.

We considered a moderate condition soundscape to be one where the designated uses for a higher activity area (e.g. parking lot) began to infiltrate into lower use zones (e.g., rural), noise-free intervals became only moderately common, and higher noise levels were commonly heard throughout all areas.

A significant concern soundscape condition occurred when noises became incongruent with designated activities and/or were loud regardless of the management zone designation. Significant concern would also be warranted if noises generated by military overflights, fast moving traffic, etc., dominated the types of sounds heard.

These reference conditions were evaluated within the context of two categories: (1) the effects of noise on the quality of visitor experience, and (2) the effect of location where noise is heard, which are explained below.

Effects of Noise on Human Health (serves as a reference to help assess visitor soundscape experience)

There have been numerous studies on the effects of noise on human health, and probably the most commonly studied

Table 4.3.3-1. Reference conditions used to assess the soundscape at Lake Meredith NRA and Alibates Flint Quarries NM.

Indicator	Measure	Good	Moderate	Significant Concern
Audibility	% Time Audible	Dominant sounds are consistent with management zone designated activities. Natural ambient sounds such as wind, leaves rustling, birds singing, thunder claps, etc. and sounds related to visitor activities are expected. Some sources of noise (e.g., automobiles) are acceptable in the development zones provided they are consistent with the expectations for that location and are audible for a low percentage of the time.	The dominant sounds are generally consistent with the management zone designated activities, but noise occurs more frequently and noises from other areas (e.g., traffic along highway) begin to infiltrate into park areas.	A high percentage of the audible sounds heard are from noises such that the recreational experiences are compromised and disrupted.
Sound Level	Amplitude (loudness)	Visitors typically maintain quiet to normal conversational levels (e.g., 40-50 dB), and interpreters talking to larger groups rarely exceed 55-60 dB. There is a higher tolerance for noise levels in the developed zones (especially along the lake area due to motorcrafts).	Noises > 55 dB cause occasional interference with normal conversations although noises greater than approximately 65 dB is still quite rare throughout the majority of the NRA and NM.	Communication among interpreters and visitors is frequently interrupted by loud noise impacting visitor enjoyment and recreation. These are the same sound levels that may interfere with wildlife behavior and auditory signals.
	Mean L_{50} impact (dBA)	Non-urban park threshold ≤ 1.5 Listening area reduced by ≤ 30%.	Non-urban park threshold 1.5 < ≤ 3.0. Listening area reduced by 30 - 50%.	Non-urban park threshold 3.0 <. Listening area reduced by > 50%.

effects are cardiovascular. The World Health Organization (Berglund et al. 1999) suggests that even prolonged exposure to noise levels below 75dB will not result in noise-induced hearing loss. They also conclude that prolonged exposure to air and road traffic noises above 65-70 dB are associated with cardiovascular effects, but this is from exposure times that far exceed what is likely to be encountered during a National Recreation Area/National Monument visit. The threshold levels for responses such as raising of blood pressure are much lower (i.e., 35 dBA in sleeping humans; Haralabidis et al. 2008). However, these human health responses, at the levels of noise exposure at Lake Meredith NRA and Alibates Flint Quarries NM are not likely to cause any physical damage. Thus, for the most part, noise levels exceeding thresholds for damage to human health are not of high concern at the parks. The most likely exception to this is for park staff operating machinery (e.g., mowers, tractors, etc.). Although damage to human health is not of high concern, this does not imply that there are no physiological responses to noise.

Effects of Noise on Wildlife (serves as a reference to assess visitor soundscape experience)

Research has indicated that the effects of noise on wildlife populations can vary widely among species and conditions, although birds have probably been most widely studied. Most effects fall into one of three categories: (1) behavioral and/or physiological effects, (2) damage to hearing from acoustic over-exposure, and (3) interference with communication (Dooling and Popper 2007). Since birds are probably more resistant to hearing loss or damage from noises than are humans (Dooling and Popper 2007), the threshold identified for damage to human hearing should be adequate to also account for damage to wildlife hearing. Similarly, the noise levels that interfere with human communication are also similar to the thresholds identified for interference with communication and/or annoyance.

For example, Dooling and Popper (2007) suggest that it is unlikely that a traffic noise level below an overall level of about 50-60 dBA would have much of an effect on acoustic

communication or the biology of a bird in a quiet suburban area (see also Kaseloo 2006). Because the thresholds for wildlife appear to be similar to the thresholds we identified for human health and because the responses by wildlife are varied and complex, we have assumed for the purposes of this assessment that a degraded condition for visitors would also likely have potential impacts to birds, specifically.

Effects of Noise on the Quality of Visitor Experience

An essential component of the designated purpose of Lake Meredith NRA and Alibates Flint Quarries NM relative to the soundscape is to provide for visitor enjoyment and recreational opportunities. We consider condition of the soundscape relative to a visitor being able to have conversations at speaking levels. The U.S. Environmental Protection Agency (USEPA) uses a speech interference threshold (52 dBA) for speaking in a raised voice to an audience at 10 meters (USEPA 1974). This threshold addresses the effects of noise on interpretive programs in parks. Also, a threshold of 60 dBA provides a basis for estimating impacts on normal voice communications at 1 meter (USEPA 1974).

Condition is deteriorated when noise is frequent or loud enough to interrupt visitor conversations or interpretive programs.

Effect of Location (Resource Opportunity Area / Management Zone) on Reference Condition

Inherent in our condition assessment is how sounds are perceived by visitors and whether or not the sounds contribute to or detract from visitor enjoyment of the National Recreation Area and National Monument. Whether or not sounds are perceived negatively depends not only on the types of sounds heard but also where they are heard. For example, a visitor is probably going to be less disturbed by noises from vehicles if they are in the parking lot or camping in a developed campground than if they are in McBride Canyon or at the National Monument. Consequently, we take into consideration where sounds are heard based upon the expectations within different management zones.

4.3.4. Condition and Trend

Audibility at Monitoring Locations

The highest percent time audible of sounds heard were natural sounds from birds and insects at all monitoring locations or the noise generated from the energy production operations, which were heard over 99% of the time at Alibates Flint Quarries NM and almost 44% of the time at McBride Canyon. The additional types of sounds heard and their percent time audibility are shown in bar graphs in Figure 4.3.4-1.

The widest variety of sounds were heard at Fritch Fortress campground, which is adjacent to the town of Fritch, Texas and located within a developed campground. Our acoustical monitoring occurred one-two weeks after to a wildland fire that destroyed approximately 75 homes between Sanford and Fritch, Texas. Many of the homes were adjacent to the Fritch Fortress campground boundary and as such many of the noises heard were related to on-site clean-up throughout the surrounding area. In addition, vehicles were audible 62.4% of the time and plane noises, including jets and helicopters were heard a little more than 11% of the time. Recreational sounds that were heard included people walking and talking and sounds from horses at the Lower Plum Creek monitoring location.

From a percent time audibility perspective noises heard from the energy production operations at Alibates Flint Quarries NM mesa top shelter are the most concerning since the noise could be heard almost 100% of the total monitoring time. In addition the noise from the energy production operations could be heard 43.7% of the time at McBride Ranch. Both of the sites are located in fairly remote locations and are within the cultural and rural management zones where natural sounds are expected to predominate. According to Foch (2000) acoustical assessment, the distant 'diesel hum' from the energy production operations were also audible at McBride Canyon just at very low sound levels.

While natural sounds were common at all monitoring locations, and were audible for a higher percentage of time at Fritch Fortress, Lower Plum Creek, and McBride Ranch,

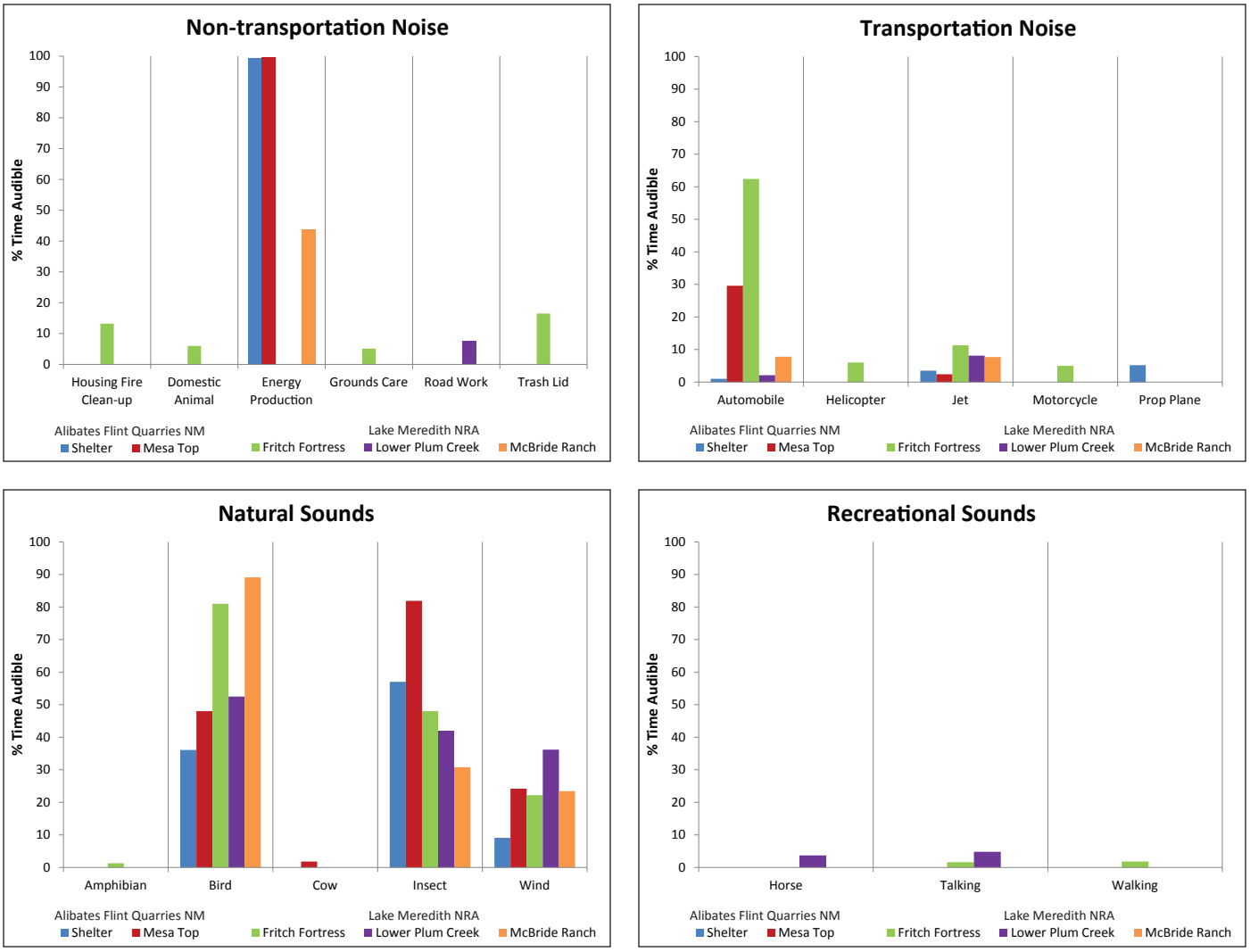


Figure 4.3.4-1. Sound sources heard and percent time audible at each on-site acoustical monitoring location.

they did not predominate at Alibates Flint Quarries NM, and with the exception of bird sounds, did not predominate at McBride Ranch, where we would expect less noises, we consider the percent time audibility of sounds heard to warrant moderate to significant concern.

Sound Levels at Monitoring Locations(on-site listening results)

We determined the relative sound levels at the NRA and NM qualitatively by using information presented in Figure 4.3.2-2, and using the thresholds for normal conversation levels that were presented in Table 4.3.3-1. While the most audible noise heard was from energy production operations within the rural and cultural management zones, the level of sound was well below the decibel level of human conversation. It was a distant background hum, which was continuous versus erratic, minimizing its impact.

The loudest sounds heard were at Fritch Fortress from motorcycles and automobiles driving through the campground. In addition, noise levels were higher at this location due to the fire clean-up efforts that were occurring in the adjacent neighborhood. Very distant traffic noise along the highways could be heard from the mesa top at Alibates Flint Quarries NM, but at sound levels much lower than a normal conversation.

Overall, with the exception of periodic automobiles and motorcycles at Fritch Fortress, which is located within a developed zone, birds vocalizing were the loudest sounds heard at the monitoring locations. We

Table 4.3.4-1. Summary of the soundscape indicators/measures and their contribution to the overall soundscape condition.

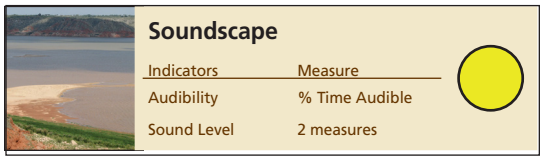
Indicators of Condition	Measures	Condition	Rationale for Condition
Audibility	% Time Audible	Moderate to Significant Concern	The sounds heard with the highest percent time audibility were from the energy production operations at Alibates Flint Quarries NM and McBride Ranch and from automobiles at Fritch Fortress. Many natural sounds were audible a high percentage of the time at all monitoring locations, but the near constant energy production noises heard at the NM warrant a moderate to significant concern condition for this measure.
Sound Level	Amplitude (on-site monitoring)	Good	The loudest sounds heard were at Fritch Fortress due to motorcycles, automobiles, and fire clean-up efforts adjacent to the fortress. The vehicle activity is expected for the Fritch Fortress area since it is located in the developed zone. Even though the energy production noises were audible over 99% of the time at the NM, the sound level was very low and distant. Overall, we consider this measure to be in good condition relative to the sound levels heard during the on-site monitoring
	Amplitude (modeled sound level impact)	Moderate to Significant Concern	The modeled impact sound levels (Mennitt et al. 2013) for the NRA ranged between 2.4 - 6.1 dBA and from 2.9 - 4.0 dBA for the NM. These results are considered to be of moderate to significant concern for non-urban parks (Turina et al. 2013).

consider the qualitative sound level measure to be in good condition.

Sound Level for Monitoring Sites Based on Mennitt et al. (2013) Model

Mennitt et al.'s (2013) model results for the predicted natural ambient sound levels ranged from 30.0-34.2 dBA for the National Recreation Area and from 30.3-32.2 dBA for the National Monument (Mennitt et al. 2013 and E. Lynch, NSNSD 2014b, Excel spreadsheet of dB(A) values). The modeled existing sound levels for the NRA and NM ranged from 32.4-40.3 dBA and 33.2-36.2 dBA, respectively. Mennitt et al. (2013) suggested that in a natural environment, the average summertime L_{50}, which is the sound level exceeded half of the time and is a fair representation of expected conditions, is not expected to exceed 41 dBA. Based upon the modeled existing minimum and maximum sound levels, both the NRA and NM are less than the 41 dBA threshold.

The difference between existing and natural sound level range is referred to as the impact level. According to Mennitt et al. (2013), "an impact of 3 dBA suggests that anthropogenic noise is noticeable at least 50% of the hour or more." The impact sound level range for the NRA ranged from 2.4 - 6.1 dBA and from 2.9 - 4.0 dBA for the NM. This implies that the area surrounding the NM is expected to be quieter than in areas throughout the NRA. This is consistent with our on-site assessment, but both locations impact sound levels ranged between the moderate to significant concern condition thresholds for non-urban parks as referenced in Table 4.3.3-1 (Turina et al. 2013).



Overall Condition and Trend

For assessing the condition of Lake Meredith NRA and Alibates Flint Quarries NM soundscape, we used two indicators and three measures, which are summarized in Table 4.3.4-1. When combining all indicators and measures, we consider the overall soundscape to be in moderate condition.

Level of Confidence and Key Uncertainties

This was a very brief, rapid assessment of the National Recreation Area and National Monument's soundscape to assess current

condition. With such a small dataset, short sample period, and modeled data our confidence is low.

4.3.5. Sources of Expertise

The NPS Natural Sounds and Night Skies Division scientists help parks manage sounds in a way that balances the various expectations of park visitors with the protection of park resources. They provide technical assistance to parks in the form of acoustical monitoring, data collection and analysis, and in developing acoustical baselines for planning and reporting purposes.

The NSNSD provided an NRCA soundscape template, which was used to develop Lake Meredith NRA and Alibates Flint Quarries NM's soundscape assessment. They also generated reports from the on-site listening results and provided Mennitt et al's (2013) sound level model maps for the NRA and NM, which are included in Appendix D. For more information on NSNSD, see http://www.nature.nps.gov/sound/.

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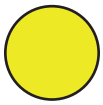
4.4. Air Quality

Indicators/Measures

- Visibility
- Level of Ozone
- Atmospheric Wet Deposition in Total N and Total S

Condition – Trend – Confidence



Moderate - Insufficient Data - Medium

4.4.1. Background and Importance

Under the direction of the NPS' Organic Act, Air Quality Management Policy 4.7.1 (NPS 2006), and the Clean Air Act (CAA) of 1970 (U.S. Federal Register 1970), the NPS has a responsibility to protect air quality and any air quality related values (e.g., scenic, biological, cultural, and recreational resources) that may be impaired from air pollutants.

One of the main purposes of the CAA is "to preserve, protect, and enhance the air quality in national parks" and other areas of special national or regional natural, recreational, scenic or historic value. The CAA includes special programs to prevent significant air quality deterioration in clean air areas and to protect visibility in national parks and wilderness areas (NPS-ARD 2012a).

Different categories of air quality areas have been established through the authority of the CAA: Class I and II. Like most National Park Service areas, Lake Meredith National Recreation Area and Alibates Flint Quarries National Monument (parks) are designated as a Class II airsheds (Figure 4.4.1-1).

These classes are allowed different levels of permissible air pollution, with Class I receiving the greatest protection and strictest regulation. The CAA gives federal land managers responsibilities and opportunities to participate in decisions being made by regulatory agencies that might affect air quality in the federally protected areas they administer (NPS-ARD 2012b).

It's important to note that even though the CAA gives Class I areas the greatest protection against air quality deterioration, the legislation also aims to limit the level of additional pollution allowed in Class II areas, and potential impacts to these areas are to be considered. (NPS 2006).

NPS

Figure 4.4.1-1. Lake Meredith National Recreation Area and Alibates Flint Quarries National Monument are Class II airsheds.


NPS

Figure 4.4.1-2. A partly cloudy day at Lake Meredith NRA.

Air Quality Standards

Air quality is deteriorated by many forms of pollutants that either occur as primary pollutants, emitted directly from sources such as power plants, vehicles, wildfires, and wind-blown dust, or as secondary pollutants, which result from atmospheric chemical reactions. The CAA requires the Environmental Protection Agency (EPA) to establish National Ambient Air Quality Standards (NAAQS) (40 CFR part 50) to regulate these air pollutants that are considered harmful to human health and the environment (EPA 2012a). The two types of NAAQS are primary and secondary, with the primary standards establishing limits to protect human health, and the secondary standards establishing limits to protect public welfare from air pollution effects, including decreased visibility, damage to animals, crops, vegetation, and buildings (EPA 2012a).

The NPS' Air Resources Division (NPS-ARD) air quality monitoring program uses EPA's NAAQS, natural visibility goals, and ecological thresholds as benchmarks to assess current conditions of visibility, ozone, and atmospheric deposition throughout Park Service areas.

Visibility affects how well (acuity) and how far (visual range) one can see (NPS-ARD 2002), but air pollution can degrade visibility. Both particulate matter (e.g. soot and dust) and certain gases and particles in the atmosphere, such as sulfate and nitrate particles, can create haze and reduce visibility.

Visibility can be subjective and value-based (e.g. a visitor's reaction viewing a scenic vista while observing a variety of forms, textures, colors, and brightness) (Figure 4.4.1-2) or it can be measured objectively by determining the size and composition of particles in the atmosphere that interfere with a person's ability to see landscape features (Malm 1999). The viewshed section (4.1) of this assessment addresses the subjective aspects of visibility, whereas, this section addresses measurements of particles and gases in the atmosphere affecting visibility.

Ozone is a gaseous constituent of the atmosphere produced by reactions of nitrogen oxides (NO_x) from vehicles, powerplants, industry, and fire and volatile organic compounds from industry, solvents, and vegetation in the presence of sunlight (Porter and Biel 2011). It is one of the most widespread air pollutants (NPS-ARD 2003a), and the major constituent in smog. Ozone can be harmful to human health, and it is also phytotoxic, causing foliar damage to plants

(NPS-ARD 2003a). The foliar damage requires the interplay of several factors, including the interaction of the plant to the ozone, the level of ozone exposure, and the exposure environment. The highest ozone risk exists when the species of plants are highly sensitive to ozone, the exposure levels of ozone significantly exceed the thresholds for foliar injury, and the environmental conditions, particularly adequate soil moisture, foster gas exchange and the uptake of ozone by plants (Kohut 2007).

Ozone penetrates leaves through stomata (openings) and oxidizes plant tissue, which alters the physiological and biochemical processes (NPS-ARD 2012c). Once the ozone is inside the plant's cellular system, the chemical reactions can cause cell injury or even death (NPS-ARD 2012c), but more often reduces the plant's resistance to insects and diseases, reduces growth, and reduces reproductive capability (NPS-ARD 2012d).

Air pollutants can be deposited to ecosystems through rain and snow (wet deposition) or dust and gases (dry deposition). Nitrogen and sulfur air pollutants are commonly deposited as nitrate, ammonium, and sulfate ions and can have a variety of effects on ecosystem health, including acidification, fertilization or eutrophication, and accumulation of toxins (NPS-ARD 2010a). Atmospheric deposition can also change soil pH, which in turn, affects microorganisms, understory plants, and trees (NPS-ARD 2010a). Certain ecosystems are more vulnerable to nitrogen or sulfur deposition than others, including high-elevation ecosystems in the western United States, upland areas in the eastern part of the country, areas on granitic bedrock, coastal and estuarine waters, arid ecosystems, and some grasslands (NPS-ARD 2013a). Increases in nitrogen have been found to promote invasions of fast-growing annual grasses (e.g., cheatgrass) and exotic species (e.g., Russian thistle) at the expense of native species (Brooks 2003, Allen et al. 2009, Schwinning et al. 2005). Increased grasses can increase fire risk (Rao et al. 2010), with profound implications for biodiversity in non-fire adapted ecosystems. Nitrogen may also increase water use in plants like big sagebrush (Inouye 2006).

According to the EPA, in the United States, roughly two thirds of all sulfur dioxide (SO_2) and one quarter of all NO_x come from electric power generation that relies on burning fossil fuels. Sulfur dioxide and nitrogen oxides are released from power plants and other sources, and ammonia is released by agricultural activities, feedlots, fires, and catalytic converters. In the atmosphere these transform to sulfate, nitrate, and ammonium and can be transported long distances across state and national borders, impacting resources, including at Lake Meredith National Recreation Area and Alibates Flint Quarrie National Monument (EPA 2012b).

4.4.2. Data and Methods

The approach we used for assessing the condition of air quality within the parks airshed was developed by the NPS-ARD for use in Natural Resource Condition Assessments (NPS-ARD 2013a, 2010b). Given no on-site or nearby representative monitors, interpolated values generated by NPS-ARD, are averaged over five years and used to assess condition. NPS-ARD used all available data from NPS, EPA, state, tribal, and local monitors to generate the interpolated values across the contiguous U.S., with a specific value assigned to the center of each park. These values provided estimates for visibility, ozone, and atmospheric wet deposition in the absence of onsite monitoring. Even though the data are derived from all available monitors, the data from the closest monitor will "outweigh" the rest.

Indicators/Measures

Visibility

Visibility is monitored by the Interagency Monitoring of Protected Visual Environments (IMPROVE) Program (NPS-ARD 2010a). The NPS-ARD assesses visibility based on the deviation of the current Group 50 visibility conditions from estimated Group 50 natural visibility conditions; (i.e., those estimated for a given area in the absence of human-caused visibility impairment, EPA-454/B003-005). Group 50 is defined as the

mean of the visibility observations falling within the range of the 40th through the 60th percentiles, as expressed in terms of a Haze Index in deciviews (dv). A factor of the haze index is light extinction, which is used as an indicator to assess the quality of scenic vista and is proportional to the amount of light lost due to scattering or absorption by particles in the air as light travels a distance of one million meters (NPS-ARD 2003a). The haze index for visibility condition is calculated as follows:

Visibility Condition/Haze Index (dv) = current Group 50 visibility – estimated Group 50 visibility (under natural conditions)

The deciview scale scores pristine conditions as a zero and increases as visibility decreases (NPS-ARD 2013a).

Indicators/Measures
Level of Ozone

Ozone is monitored as part of the NPS Gaseous Pollutant Monitoring Program, in partnership with the EPA's CASTNet Program (Porter and Biel 2011). The assessment for ozone levels at the parks was made by referencing NPS ARD's five-year interpolated values.

Indicators/Measures
Atmospheric Wet Deposition in Total N and Total S

Atmospheric deposition can be monitored in both wet and dry forms, but for the purposes of this assessment, we will use wet deposition monitoring data only because most areas of the country do not have dry deposition data available, including the parks. Atmospheric wet deposition is monitored across the United States as part of the National Atmospheric Deposition Program/National Trends Network (NADP/NTN) (NPS-ARD 2003a). The values for wet deposition condition are expressed as the average amount of nitrogen (N) or sulfur (S) in kilograms deposited over a one-hectare area in one year (kg/ha/yr) (NPS-ARD 2003a).

4.4.3. Reference Conditions

The reference conditions against which current air quality indicators are assessed are identified by NPS ARD (2013a) for NRCAs and listed in Table 4.4.3-1.

Visibility

A visibility condition estimate of less than 2 dv above estimated natural conditions indicates a "good" condition, estimates ranging from 2-8 dv above natural conditions indicate "moderate" condition, and estimates greater than 8 dv above natural conditions indicate "significant concern." Although the dv ranges of these categories were selected somewhat subjectively, the NPS-ARD chose them to reflect the variation in visibility conditions across the monitoring network as closely as possible.

Ozone

The ozone standard set by the EPA at a level to protect human health, 75 parts per billion (ppb) averaged over an eight-hour period, is used as a benchmark for rating current ozone condition. The three-year average of the fourth-highest daily maximum eight-hour average ozone concentrations measured at each monitor in an area must not exceed 75 ppb in order to be in compliance with the EPA standard.

The NPS-ARD rates ozone condition as "good" if the ozone concentration is less than or equal to 60 ppb, "moderate" if the ozone concentration is between 61 and 75 ppb, and of "significant concern" if the concentration is greater than or equal to 76 ppb.

Table 4.4.3-1. Reference conditions for air quality indicators.

Air Quality Indicator	Significant Concern	Moderate	Good
Visibility	>8 dv	2-8 dv	< 2 dv
Ozone	≥ 76 ppb	61-75 ppb	≤ 60 ppb
Wet deposition (total N and total S)	>3 kg/ha/yr	1-3 kg/ha/yr	< 1 kg/ha/yr

Source: NPS-ARD 2013a

Wet Deposition

The NPS-ARD considers parks with less than 1 kg/ha/yr of atmospheric wet deposition of nitrogen or sulfur compounds to be in "good" condition, those with 1-3 kg/ha/yr to be in "moderate" condition, and parks with wet deposition greater than 3 kg/ha/yr to be of "significant concern."

4.4.4. Condition and Trend

Condition for all air quality indicators are listed in Table 4.4.4-1.

Visibility

All visibility data used for the condition assessment were derived from NPS ARD Air Atlas interpolated five-year average values (2008-2012) (NPS-ARD 2014a). The 5-year interpolated values average for the parks' visibility condition fell within the moderate condition rating, which indicates visibility is degraded from the good reference condition of <2 dv above the natural condition. No visibility trend was reported specifically for Lake Meredith National Recreation Area and Alibates Flint Quarries National Monument, but in considering the overall trend of visibility throughout national parks, NPS-ARD (2013b) analyzed visibility data for 157 parks during the period of 2000-2009. During that time, visibility on the clearest days improved at most sites; and visibility on the haziest days was relatively unchanged at many sites.

Ozone

Ozone data used for the condition assessment were derived from the five-year interpolated values average (2008-2012) (NPS-ARD 2014b), which resulted in a moderate ozone condition rating.

Five ozone-sensitive plant species were found within the parks (NPS-ARD 2006), and one is an ozone bioindicator (Table 4.4.4-2) (Porter 2003).

An ozone risk assessment was conducted by Kohut (2007) for Southern Plains parks, including at Lake Meredith National Recreation Area and Alibates Flint Quarries National Monument. The overall ozone ranking at the parks was considered low, which is less than the current condition reported by NPS-ARD (2014b).

Wet Deposition

The data for atmospheric wet deposition condition were derived from NPS-ARD's 2008-2012 interpolated values (NPS-ARD 2014c). The average value for total nitrogen resulted in a significant concern rating and the condition rating was moderate for total sulfur.

Table 4.4.4-1. Condition results for air quality indicators at Lake Meredith National Recreation Area and Alibates Flint Quarries National Monument.

Data Span	Ozone	Visibility	Total N (kg/ha)	Total S (kg/ha)
2008-2012	Moderate (70.0)	Moderate (7.6)	Significant Concern (3.7)	Moderate (1.5)

Source: NPS-ARD (2014 a,b,c) Air Quality Estimate Tables

Table 4.4.4-2. Ozone sensitive plants found at Lake Meredith National Recreation Area and/or Alibates Flint Quarries National Monument (NPS-ARD 2006, Porter 2003).

Scientific Name	Common Name	Bioindicator
Apocynum cannabinum	Dogbane	No
Artemisia ludoviciana	Silver wormwood	Yes
*Parthenocissus quinquefolia**	Virginia creeper	No
Prunus virginiana	Choke cherry	No
*Robinia pseudoacacia**	Black locust	No

*These species only were identified by Kohut (2007) as ozone sensitive. Kohut (2007) also identified *Platanus occidentalis* as present at the park.

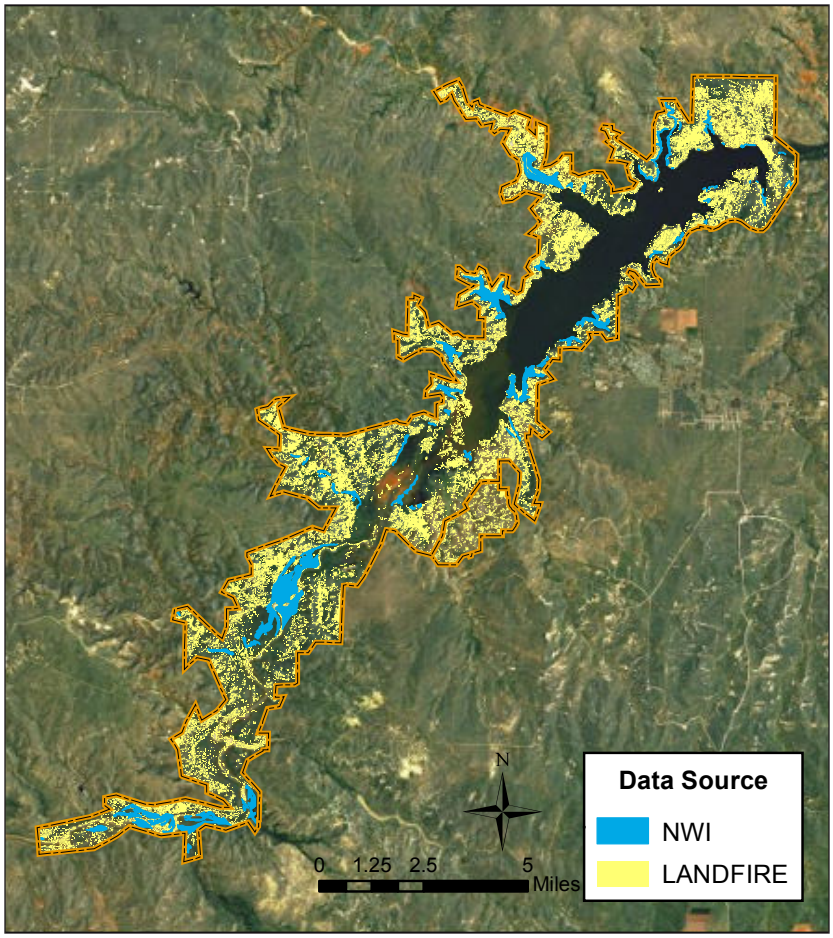


Figure 4.4.4-1. Locations of nitrogen sensitive vegetation at Lake Meredith National Recreation Area and Alibates Flint Quarries National Monument.

Sullivan et al. (2011a), studied the risk from acidification for acid pollutant exposure and ecosystem sensitivity for Southern Plains parks, including at the parks. Pollutant exposure included the type of deposition (i.e., wet, dry, cloud, fog), the oxidized and reduced forms of the chemical, if applicable, and the total quantity deposited. The ecosystem sensitivity considered the type of terrestrial and aquatic ecosystems present at the parks and their inherent sensitivity to the atmospherically deposited chemicals. These risk rankings were considered moderate for acid pollutant exposure at both parks and low for ecosystem sensitivity to acidification at Alibates Flint Quarries NM and moderate at Lake Meredith NRA due to the presence of aquatic habitat.

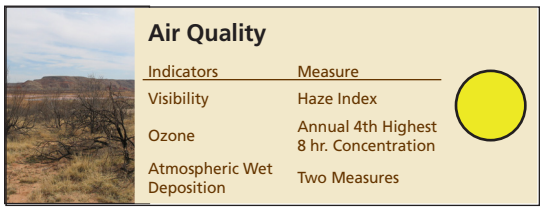
Sullivan et al. (2011b), also developed risk rankings for nutrient N pollutant exposure and ecosystem sensitivity to nutrient N enrichment, which were ranked as moderate for both at the parks. As part of this nitrogen screening project, sensitive vegetation types were identified throughout the parks using two datasets: LANDFIRE and National Wetlands Inventory (NWI). Data from and National Land Cover Data (NLCD) dataset was also used, but had no data for the area. Figure 4.4.4-1 shows the locations of these vegetation types, if present.

In general, nitrate, sulfate, and ammonium deposition levels have changed over the past 20 years throughout the United States (Figure 4.4.4-2). Regulatory programs that mandated a reduction in emissions have proven effective for decreasing both sulfate and nitrate ion deposition primarily through reductions from electric utilities, vehicles, and industrial boilers, although a rise in ammonium ion deposition has occurred in large part due to the agricultural and livestock industries (NPS-ARD 2012e). A study conducted by Lehmann and Gay (2011), indicated a decrease in sulfate concentrations from 1985-2009 in the area surrounding the parks, as well as a decrease in nitrate concentrations. Only the sulfate trend was statistically significant.

It seems reasonable to expect a continued improvement in sulfate deposition levels because of Clean Air Act requirements, however, at this time, ammonium levels are not regulated by the EPA and may continue to rise as a result (NPS-ARD 2010a).

An air emissions inventory was conducted for Lake Meredith NRA in 2001 (NPS-ARD 2003b) that identified typical air emission sources both within and surrounding the NRA. Most of the pollutants except for carbon monoxide and carbon dioxide are included in the air quality indicators and measures used to assess the current air quality condition at both the NRA and NM. In summary, the largest air emissions contributor was from the oil and gas operations, emitting 52.84 tons of NO_x and marine vessels emitting carbon monoxide (344.55 tons) and Volatile Organic Compounds (VOCs) (103.36 tons). These data were based on a personal watercraft environmental assessment (NPS 2003b). The VOC emissions are reflected in the current

ozone values and the NO_x emissions are reflected in the total N-values reported by NPS-ARD.

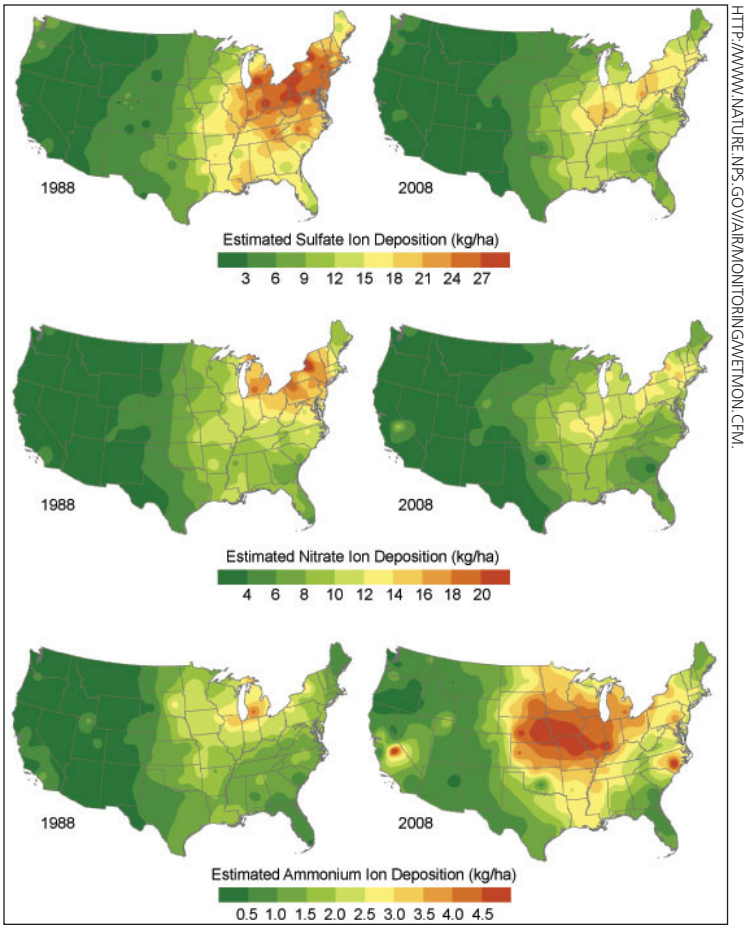


Overall Condition and Trend

For assessing the condition of air quality, we used three air quality indicators. Our indicators/measures for this resource were intended to capture different aspects of air quality, and a summary of how they contributed to the overall condition is summarized in Table 4.4.4-3.

We consider the overall condition of air quality at Lake Meredith National Recreation Area and Alibates Flint Quarries National Monument to be of moderate condition, with a medium confidence level due to the interpolated values.

Trends cannot be derived for any of the air quality indicators since no monitoring sites are located near enough to be representative



HTTP://WWW.NATURE.NPS.GOV/AIR/MONITORING/WETMON.CFM.

Figure 4.4.4-2. Change in wet deposition levels From 1988-2008 throughout the United States.

Table 4.4.4-3. Summary of the air quality indicators/measures and their contributions to the overall air quality Natural Resource Condition Assessment.

Indicator	Measure(s)	Condition	Condition Rationale
Visibility	Haze Index	Moderate	For 2008-2012, estimated average visibility in the NRA was 7.6 deciviews above natural conditions, therefore, the condition status warrants significant concern based on NPS Air Resource Division benchmarks. No trend information is available because there are not sufficient on-site or nearby visibility monitor stations.
Level of Ozone	Annual 4th-Highest 8-hour Concentration	Moderate	The estimated ozone level for 2008-2012 at the Historic Site was 70.0 parts per billion, therefore, the condition status warrants moderate concern based on NPS Air Resource Division benchmarks. There are five ozone-sensitive plants in the NRA and one in the NM, with one as a bioindicator. No trend information is available because there are not sufficient on-site or nearby ozone monitor stations.
Atmospheric Wet Deposition in Total N and total S	Total N in kg/ha/yr	Significant Concern	For 2008-2012, estimated wet nitrogen deposition was 3.7 kilograms per hectare per year, therefore, the condition status warrants significant concern based on NPS Air Resource Division benchmarks. No NPS-ARD trend information is available for nitrogen.
	Total S in kg/ha/yr	Moderate	For 2008-2012, estimated wet sulfur deposition was 1.5 kilograms per hectare per year, therefore, the resource is in moderate condition based on NPS Air Resource Division benchmarks. No NPS-ARD trend information is available for sulfur.

of the conditions at the parks and onsite monitoring does not occur.

Level of Confidence/Key Uncertainties
The key uncertainty of the air quality section is knowing the effect(s) of air pollution, especially nitrogen deposition, on ecosystems at the parks.

It's worth mentioning that the Pantex Plant, a nuclear weapons production facility located in Carson County Texas, is a Superfund Site due to contaminated soils and groundwater (EPA 2014). Primary contaminants of concern include high explosive compounds, chlorinated solvents, hexavalent chromium, and perchlorate. Plant operations to remediate contamination may impact air quality and air quality related values at the NRA and NM. The plant is approximately 20 miles from these two Class II areas. (Global Security 2014).

4.4.5. Sources of Expertise

The National Park Service's Air Resources Division oversees the national air resource management program for the NPS. Together with parks and NPS regional offices, they monitor air quality in park units; provide air quality analysis and expertise related to all air quality topics.

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4.5. Geology

Indicators/Measures

- Geologic Resource Integrity

This section is extracted from the Geologic Resources Inventory Scoping Summary (KellerLynn 2011) for Lake Meredith NRA and Alibates Flint Quarries NM. For more information, go to http://www.nature.nps.gov/geology/inventory

Condition – Trend – Confidence

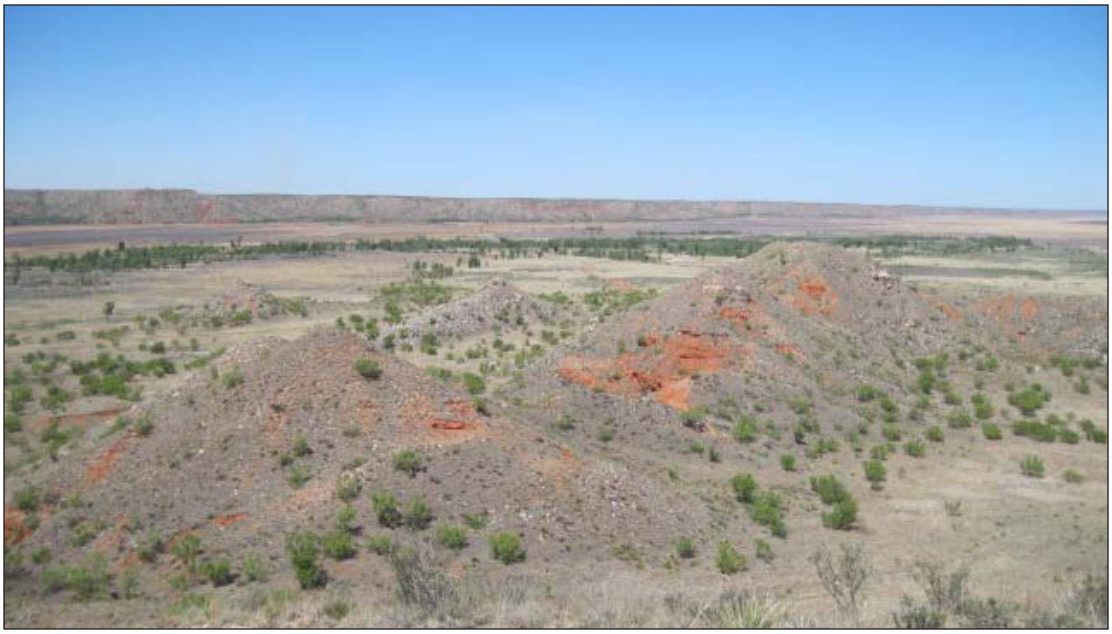
Moderate - Insufficient Data - Low

4.5.1. Background and Importance

Geologic resources serve as the foundation of ecosystems and yield important information needed for science-based decision making in National Park System units. Geology is a major determinant of topography, water and soil chemistry, fertility of soils, stability of hill slopes, and flow styles of surface water and groundwater. These factors, in turn, influence biology, including the distribution of habitats and the locations of threatened and endangered species. Geology also influences human settlement patterns and how people use natural resources—for farming, ranching, industry, construction, hunting, fishing, and recreation.

Lake Meredith National Recreation Area (NRA) and Alibates Flint Quarries National Monument (NM) are located northeast of Amarillo, Texas, in the Texas Panhandle. In 1962, the Bureau of Reclamation began construction of the Sanford Dam on the Canadian River, which created Lake Meredith. The lake was named for A. A. Meredith, an early promoter of the dam; the dam was named for the nearby town of Sanford, Texas. In 1965, the National Park Service became the steward of the land surrounding the reservoir—more than 18,203 ha (44,978 ac)—and has been responsible for developing recreational and interpretive facilities. Formerly "Sanford National Recreation Area," Congress renamed and established "Lake Meredith National Recreation Area" in 1972. Today, visitors enjoy hiking, fishing, hunting, picnicking, camping, and when lake levels allow, boating and other forms of water-based recreation.

Alibates Flint Quarries NM was established in 1965 to protect the prehistoric quarries of flint, prized for both its excellent tool-making properties and its beauty. The national monument encompasses 555 ha (1,371 ac) of



KATIE KELLERLYNN

Site of potential geologic trail. As a result of lack of water in Lake Meredith, managers at the NRA are focusing their planning efforts on land-based recreation, including a proposed trail leading to geologic features characteristic of the area.

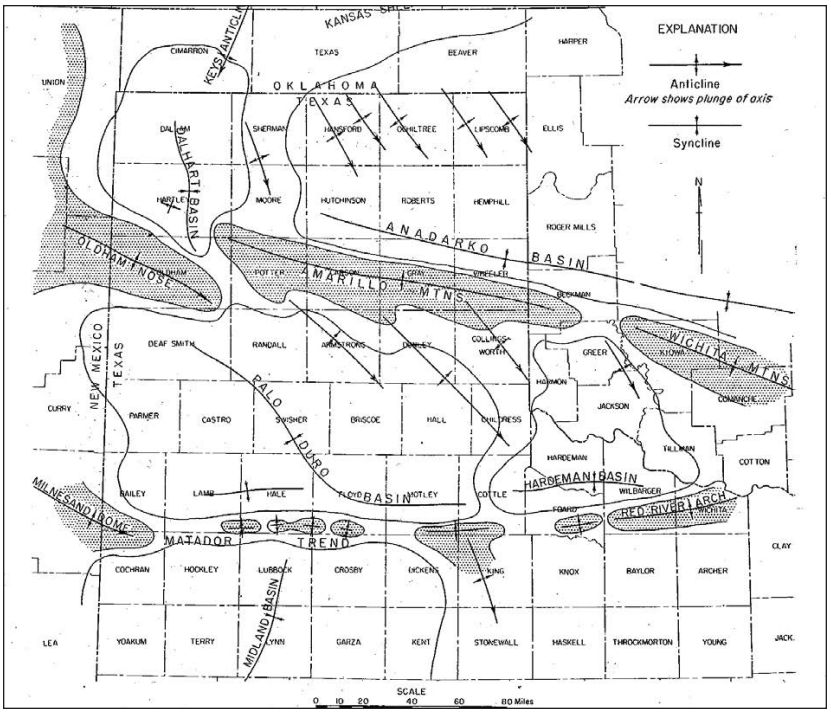


Figure 4.5.1-1. Major structural features of the Texas Panhandle. The NRA covers parts of Hutchinson, Moore, and Potter counties. Alibates Flint Quarries National Monument is in Potter County (from Nicholson 1960).

land adjacent to the east-central part of Lake Meredith NRA. The national recreation area and national monument are administered jointly by the National Park Service.

The two units of the National Park System straddle a major structural boundary between two basins, the Palo Duro Basin and the Anadarko Basin. This structural boundary is referred to as the "Amarillo uplift" that extends southeast-northwest from New Mexico to central Oklahoma. As a result of the Amarillo uplift, the stratigraphy of the southwestern end of Lake Meredith NRA is distinct from the rest of the recreation area and Alibates Flint Quarries NM. In particular, Triassic strata, namely the Tecovas and Trujillo formations, are only preserved in the southwest part of the national recreation area. These formations are part of the Palo Duro Basin stratigraphy to the south.(Figure 4.5.1-1).

4.5.2. Data and Methods

This limited assessment summarizes the findings from a geologic resources inventory scoping summary conducted by the National Park Service Geologic Resources Division (KellerLynn 2011). The summary documents the scoping meeting and field trips with park staff and geologic experts to identify geologic issues, features, and processes. For more information about the Geologic Resources Division, visit http://www.nature.nps.gov/geology/.

4.5.3. Reference Conditions

The reference conditions by which geology condition was assessed are listed in Table 4.5.3-1.

Good condition is assigned to parks where no concerns or issues about geologic resources have been identified. Geologic resources and processes are in a generally natural state and function.

Moderate condition is assigned to parks if there are some areas of moderate concern either inside the park, or outside the park that may impact it. Examples of this could be moderate disturbance due to soil erosion, oil and gas, or mining exploration in the region.

Significant concern is assigned to parks that have identified areas of concern in assessments conducted by the NPS Geologic Resources Division or have significant impacts occurring inside or outside the park that have the potential to impact park resources.

Level of confidence is assessed depending on the level of information we have on which to base the condition assessment. A Geologic Resources Inventory Report produced by the NPS Geologic Resources Division, or similar report produced by the U.S. Geological Survey or state geologic survey specifically focused on a park's geology, results in a high confidence level for the assessment. A Geologic Resources Scoping Report (or the equivalent) provides a moderate level of confidence. If a Scoping Summary is all that is available and little is known or available about the geologic resources, then a low confidence level is assigned.

4.5.4. Condition and Trend

Specific indicators and measures related to soil erosion are presented in section 4.9 on grasslands. Discussions on surface water

Table 4.5.3-1. Qualitative description for determining condition of geologic resources.

Class	Description
Good Condition	No concerns or issues about geologic resources have been identified. Geologic resources and processes are in a generally natural state and function.
Moderate Concern	Some areas of moderate concern either inside the park, or outside the park that may impact it. Examples of this could be moderate disturbance due to soil erosion or mining exploration in the region.
Significant Concern	Areas of concern have been identified in assessments conducted by the NPS Geologic Resources Division or significant activities are occurring outside the park that have the potential to impact park resources.

(4.6) and groundwater (4.7) are presented in separate sections in this report. Based on the geologic scoping completed to date, a few areas of geologic concern have been identified. The condition of the NRA/NM is considered to be of moderate condition (T. Connors, NPS Geologist, pers. comm. July 2014).

The following discussion on geologic features, processes, and issues are excerpts summarized from the geologic inventory scoping summary (KellerLynn 2011).

Geologic Features and Processes

Alibates Flint

Significant for the Alibates Flint Quarries, silica replaced dolomite in various locales, resulting in the formation of "Alibates flint," also referred to as "Alibates chert," "Alibates agate," "Alibates agatized dolomite," and "Alibates silicified dolomite" (Quigg et al. 2009, as cited in KellerLynn 2011).

As described by Barnes and Eifler (1981, as cited in KellerLynn 2011), the Alibates Dolomite is composed of two layers of dolomite, separated by shale. Only the upper dolomite layer has been completely replaced by silica. The lower dolomite member contains minor amounts of flint in the form of spheres and nodules (Bowers and Reaser 1996). At Alibates Flint Quarries NM, the upper dolomite unit forms massive, tabular sheets that range in thickness from 0.2 m (0.7 ft) to 0.6 m (2 ft) and extend laterally for more than 1,000 m (3,280 ft) in an outcrop (Bowers and Reaser 1996) that was the source for the quarries. The flint is mottled or banded red, pink, pale blue, pale purple, gray, brown, and black (Figure 4.5.4-1).

Hillslope Features and Processes

The topography within Lake Meredith NRA and Alibates Flint Quarries NM is relatively rugged because of the Canadian Breaks. The breaks make up an area of undulating hills, slopes, and canyons in sharp contrast to the flat prairies of the High Plains. Steep slopes, especially around the perimeter of Lake Meredith, are susceptible to mass wasting (gravity-driven processes). Rotational slumping is the most common type of mass wasting at the NRA and NM (National Park Service 2000). Most of the slumps are on the north side of Lake Meredith on south-facing slopes, for example at North Turkey Creek. At higher pool levels, wave action and fluctuating water levels are factors in mass wasting. During the site visit, scoping participants noted slump features at Fritch Fortress (Figure 4.5.4-2). In addition, boulders of Alibates flint up to 2 m (7 ft) in diameter commonly roll down slopes

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Figure 4.5.4-1. Where the Alibates Dolomite was replaced by silica, Alibates flint formed.

KATIE KELLERLYNN

Figure 4.5.4-2. Mass wasting in the form of rotational slumps and scarps, shown here at Fritch Fortress, occurs primarily around the perimeter of Lake Meredith. Mass wasting is induced by wave action and fluctuating water levels.

and settle on the lake bed, for example at Cedar Canyon. Slumping also occurs at the borrow pit between North Canyon and the road; sand extraction created this site during construction of the Sanford Dam.

Lacustrine Features and Processes, Lake Meredith

Although the reservoir filled during the first year after construction of the Sanford Dam, it has never reached its projected capacity level of 39 m (127 ft). The highest pool level ever reached, according to park officials, was 31 m (103 ft). The last "high"—27 m (90 ft)—was reached in 1999 after a period of heavy flooding in the Canadian River watershed. There are a growing number of beaches and direct water access for visitors without boats. As a result of lower lake levels, future plans for the NRA are focusing on land-based activities.

Eolian Features and Processes

There are three prominent types of eolian features: windblown sand (sand sheets), sand dunes, and loess. Loess (windblown silt) covers a vast expanse south of the NRA, but was not mapped within the NRA or NM. Sand dunes occur at Rosita in the southern part of the NRA. Some of the dunes are now stabilized with vegetation.

A distinctive eolian feature in the Texas Panhandle is windblown ash from the Yellowstone caldera. Izett and Wilcox (1982) mapped late Cenozoic ash fall tephra from the Huckleberry Ridge, Mesa Falls, and Lava Creek volcanic fields (known as the "Pearlette family" of ash) across the Great Plains and parts of the western United States, including Texas, New Mexico, Oklahoma. These ashes are from the Pliocene (5.3 million to 2.6 million years ago) and Pleistocene (2.6 million to 11,700 years ago) epochs. Additionally, Cepeda and Perkins (2006) identified an ash bed on the east bank of West Amarillo Creek in Potter County. This 9.5-million-year-old ash was deposited during the Miocene Epoch. Occurrences of ash from the Miocene Epoch are rare in Texas compared to ash of the Pearlette family. Cepeta and Perkins (2006) suggested that the source of the West Amarillo Creek ash was the Twin Falls volcanic field in southern Idaho, which is part of an earlier explosive stage of volcanism than the Pearlette ashes along the Yellowstone hot-spot track.

A further distinction of the ash is that it was used in making Borger cordmarked pottery. This style of pottery is best known from the 160-km (100-mi) stretch of the Canadian River and its tributaries in the north-central part of the Texas Panhandle (Lynn and Black 2003). The exterior surface of a cordmarked pot has hundreds of parallel indentations—cord impressions—left by the use of a cord-wrapped paddle in concert with an anvil stone. Because pure clay may be too flexible to hold its shape, shrinking and cracking as it dries, ash is used to "temper" the clay (Lynn and Black 2003).

Paleontological Resources

Koch and Santucci (2003), in the paleontological resource inventory for the Southern Plains Network, documented the paleontological resources at Lake Meredith NRA and Alibates Flint Quarries NM. In addition, Hunt and Santucci (2001) reported on the fossils from the Triassic, Miocene, Pliocene, Pleistocene, and Holocene strata within the NRA and NM. Furthermore, Santucci et al. (2001) provided information about procedures for locating and protecting

paleontological resources in areas with oil and gas operations.

Perhaps the most notable fossil-bearing unit within Lake Meredith NRA and Alibates Flint Quarries NM is the Ogallala Formation. The NRA and NM host six fossil localities within this formation. These sites have yielded the following: (1) a mastodon or gomphothere tooth; (2) turtle specimens; (3) a bone bed with fossilized remains of unspecified vertebrates; (4) root casts, silicified grass anthoecia, endocarps of *Celtis* sp., and insect burrows; (5) gastropods, imprints of two fish, and Clarendonian (late middle Miocene) vertebrate fossils; and (6) oysters, fossiliferous limestone, and bone scraps (Hunt and Santucci 2001).

Terrace gravels, fluvial and alluvial sandstone, fluvial conglomerate, and loess have yielded Pleistocene fossils such as the remains of *Bison latifrons,* gastropods, a rodent burrow, mammoth remains, petrified wood, and shell fragments within the NRA and NM (Anderson 1977, as cited in KellerLynn 2011, Hunt and Santucci 2001). A rare, well-preserved skull of a female *Bison latifrons* from Lake Meredith NRA is displayed at the Panhandle-Plains Historical Museum in Canyon, Texas. This museum is the repository for both paleontological and archaeological materials from Lake Meredith NRA and Alibates Flint Quarries NM. In addition to *Bison latifrons*, there is potential for fossils of *Ischrocyon gidleii* ("bear dog" from the Miocene Epoch) within the boundaries of the NRA (Gerry Schultz, vertebrate paleontologist, West Texas A&M University, personal communication, May 12, 2011, as cited in KellerLynn 2011).

Holocene (less than 11,700 years old) deposits of alluvium, eolian sand, and soils have produced some fossil material within the NRA. Many of these paleontological resources are associated with archeological sites and include fossil remains of fish, turtle, snake, crow, antelope, rabbit, badger, gopher, mole, squirrel, rat, and prairie dog (Hunt and Santucci 2001).

Generally speaking, the Permian rocks in Lake Meredith NRA and Alibates Flint Quarries NM do not host fossils; however, the Alibates Dolomite preserves algal mats. During the Permian Period on supratidal mud flats, algae bound together aragonite mud and gypsum crystals to form laminated dolomite and interlaminated anhydrite and dolomite (McGillis and Presley 1981, as cited in KellerLynn 2011). The Triassic Tecovas and Trujillo formations within the NRA host petrified wood. Investigators such as Lucas (1993 and 2001, as cited in KellerLynn 2011) and Hunt and Santucci (2001) correlated these rocks to the famous Chinle Formation of Petrified Forest National Park in Arizona. Also, a deposit of Lava Creek B ash (Pleistocene) at the NRA hosted crayfish burrows and abundant plant material (Hunt and Santucci 2001).

Seismic Features and Processes

Tectonic activity created the Amarillo uplift that defines the Palo Duro and Anakarko basins in the vicinity of Lake Meredith; however, this activity occurred primarily during the Pennsylvanian Period (318 million to 299 million years ago) and was largely completed by the end of that period (Gustavson et al. 1980, as cited in KellerLynn 2011). Folding and faults in the Permian beds record minor movement since Permian time (251 million years ago), but this movement may have resulted from differential compaction of the basin sediments (Gustavson et al. 1980, as cited in KellerLynn 2011).

Earthquakes (estimated magnitude 4) have been felt at Lake Meredith, but no seismic-related damage has occurred. The U.S. Geological Survey (USGS) Earthquake Hazards Program posts information about seismicity in Texas, including earthquake history, seismic hazard maps, notable earthquakes, and recent earthquakes (USGS 2014).

Geologic Issues

Geologic issues are those that may warrant attention from resource managers at Lake Meredith NRA/Alibates Flint Quarries NM as they are relevant for maintenance of facilities,

mitigation of hazardous conditions, and protection of resources.

Alibates Flint
The distinctive appearance of the flint makes it readily identifiable to archeologists at sites all over the country (Parent 1993). With the advent of Google Earth, the locations of protected sites of Alibates flint are accessible for public viewing. The primary concern is theft. Park staff are particularly vigilant after fires, when the quarries really "stand out" with the lack of protective vegetation.

Canadian River
In the Texas Panhandle, the flat surface of the Great Plains is broken by the valley of the Canadian River. This valley is referred to as the "Canadian Breaks." The valley formed mostly from regional subsidence following dissolution of salts in the Permian red beds (Gustavson 1986, as cited in KellerLynn 2011).

Today, the Canadian River is a small stream that intermittently flows in this large valley. Human activities such as irrigation diversion and dam construction have affected the hydrology of the Canadian River and caused significant changes in channel morphology (Buchanan 1994). Because floods no longer scour the "lake bottom," as they did in the 1950s, salt cedar (*Tamarix* spp.) has invaded thousands of acres of the riparian corridor, resulting in the loss of habitat and native species such as cottonwood (*Populus* spp.). The park has been treating the invasion, and has removed a good deal of the invasive salt cedar.

The headwaters of the Canadian River are in the Sangre de Cristo Mountains of New Mexico. Two dams upstream in New Mexico, domestic use for 11 municipalities, stock ponds, and irrigation have intercepted streamflow and lowered the water table. Human activities have also affected the tributaries to the Canadian River. Most of the streams at Lake Meredith NRA are spring fed, with springs serving as the headwaters. The springs/headwaters are outside the NRA, and most host stock ponds, which intercept streamflow at the source. Additional water wells for Amarillo will likely result in the loss of flow in some of the tributaries, for example Chicken Creek, near the south end of the NRA. Bonita Creek, south of Chicken Creek, sometimes hosts ponds as a result of beaver use. One of the only side streams that has consistently flowing water is Big Blue Creek, at the north end of the national recreation area. This creek flows seasonally in the winter but is dry during other times of the year.

Disturbed Lands
Off-road vehicles are allowed in two areas within Lake Meredith NRA: Big Blue Creek, covering 79 ha (194 ac); and Rosita, covering 980 ha (2,421 ac). Recreationists may use motorcycles, three- and four-wheelers, and dune buggies (NPS 2002). Some restoration efforts are occurring at Big Blue Creek, namely minimizing and closing unauthorized trails.

Energy Development
Lake Meredith NRA and Alibates Flint Quarries NM lie within the enormous oil and gas–producing Panhandle Field, which extends into Oklahoma and Kansas. Locally, the field is called the Panhandle West Field and is continuous with the Panhandle Field and Panhandle East Field to the east, and the Hugoton Field to the north (NPS 2002). The field is a structural trap that is draped over fractured Precambrian basement rocks of the Amarillo uplift (NPS 2002). Oil and gas exploration and development have been actively pursued at Lake Meredith and Alibates Flint Quarries since the late 1920s (NPS 2002). The earliest well on record in the vicinity of Lake Meredith is the W. T. Mudget well in the Sanford-Yake area, which was completed in 1927. The first well of the Panhandle Field, south of the NRA, was drilled in 1918.

Today, there are more than 170 active well sites in Lake Meredith and Alibates Flint Quarries (GRI scoping notes, May 11, 2011, as cited in KellerLynn 2011). In addition, evidence of 15 abandoned oil and gas–operation sites, 64 km (40 mi) of active oil field access roads, 167 km (104 mi) of abandoned roads, and 63 km (39 mi) of pipelines occur within the NRA and NM (NPS 2002). In 2000, managers

Table 4.5.4-1. Indicator, measure, and rationale of geology condition.

Indicator of Condition	Measure	Condition	Rationale for Condition
Geologic Integrity	None	Moderate	The main issues impacting geologic resources at Lake Meredith NRA include natural erosion processes due to wind and water; lands disturbed by off-road vehicle recreation; and energy development (primarily oil and gas) near its borders. Alibates flint is a critical resource at Alibates Flint Quarries NM, and is impacted by the potential for theft, and sediment transport (due to wind erosion) that is filling in the quarry sites. A geologic resource inventory scoping summary was completed in 2011.

at Lake Meredith NRA and Alibates Flint Quarries NM completed an oil and gas management plan. The Geologic Resources Division assisted in development of the plan and prepared a reasonably foreseeable development (RFD) scenario for future oil and gas exploration and production.

Oil and gas access roads, especially unmaintained ones on steep slopes, can cause severe erosion. Many of the access roads to oil and gas pads are unsurfaced, not adequately sloped, and lack drainage structures such as culverts and ditches (NPS 2002). During rainstorms, the roads serve as spillways for flowing water, cutting gullies into the road surface and adjacent slopes. In the past decade, the National Park Service has improved many of the problem roads by installing water bars and diversion ditches to more adequately handle heavy rains.

Wind is ubiquitous across the Texas Panhandle. For this reason, Texas is first in the nation in wind farms, surpassing California in 2006. By 2008, Texas had provided more than 3% of its electricity through wind generation (compared to 1% nationally)—enough power for one million homes (Krauss 2008).

Wind Erosion

Receding lake levels are exposing large, formerly submerged areas of lake bed to eolian processes; this is particularly apparent in the Big Blue Creek area. In addition, oil and gas activities can denude vegetation and expose the ground surface to wind erosion. On some pads, oil and gas operators have placed mats to reduce the amount of material available for eolian transport. Windblown dust is filling in the historic quarries at an estimated rate of 23 cm (9 in) in the last 500 years (GRI scoping notes, Lake Meredith NRA and Alibates Flint Quarries NM, May 11, 2011, as cited in KellerLynn 2011).

Geology

Indicators	Measures
Geologic Integrity	None

Overall Condition

In parks that do not have a geologic resource focus, that is, they do not have significant canyons or volcanoes or other prominent geologic features, no specific indicators or measures have been identified by which to assess geologic condition. In these cases, we use professional judgment and qualitative assessment of general geologic integrity to assign condition class and level of confidence. Table 4.5.4-1 clearly states how condition was assessed.

The condition of the geologic resources at Lake Meredith NRA/Alibates Flint Quarries NM is in moderate condition due to several concerns, with a low level of confidence.

4.5.5. Sources of Expertise

The National Park Service's Geologic Resources Division conducts geologic inventories and resource evaluations, and produces digital geologic maps in close partnership with the Inventory and Monitoring Program, park staff, and partners. This section is based entirely on a report

(KellerLynn 2011) produced by the Geologic Resources Division, and was reviewed by Tim Connors, Geologist at the National Park Service Geological Resources Division. The paleontological resources section was reviewed by Vincent Santucci, Paleontologist for the National Park Service.

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4.6. Surface Water Quality

Indicators/Measures

- Field Properties (4 measures)
- Alkalinity (2 measures)
- Major Constituents (9 measures)
- Primary Nutrients (2 measures)

Condition – Trend - Confidence

Significant Concern– Insufficient Data - High

4.6.1. Background and Importance

Lake Meredith is a water supply storage reservoir providing drinking water to populations in 11 cities in Texas and was built by the Bureau of Reclamation in the mid-1960s (Figure 4.6.1-1). The Canadian River Municipal Water Authority (CRMWA) manages the water supply and water quality of Lake Meredith, and the Lake Meredith National Recreation Area manages the recreational aspects that the lake offers. In recent years, drought has impacted water levels to an all time low of 8 meters (26.14 feet), recorded in August 2013 (CRMWA 2014a), impacting both the drinking water supply and recreational uses.

4.6.2. Data and Methods

According to the U.S. Geological Survey Water Science School, water quality is "a measure of the suitability of water for a particular use based on selected physical, chemical, and biological characteristics" (USGS 2014). Surface water quality is important for maintaining a healthy habitat for many aquatic organisms, wildlife, and humans and can provide insights into overall system productivity, can shift species abundance and distributions, and alter nutrient cycles (USDI NPS 2008).

The CRMWA monitors Lake Meredith's surface water quality at three locations - intake, mid lake, and end lake (Figure 4.6.2-1). In general, measurements have been made monthly from 2003 - present at the intake tower but were discontinued at mid lake from Sept. 2011 - May 2014, with only four months of recent data and discontinued at the end lake location beginning in 2006, due to lowering lake levels (Rod Goodwin, CRMWA Chief of Water Quality, pers. comm. 2015). As a result, data are presented for the intake tower monitoring site only (CRMWA 2014b), which is the primary site Edwards Aquifer Research and Data Center recommended for

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Figure 4.6.1-1 Lake Meredith was created in the mid-1960s to provide drinking water to populations in Texas.

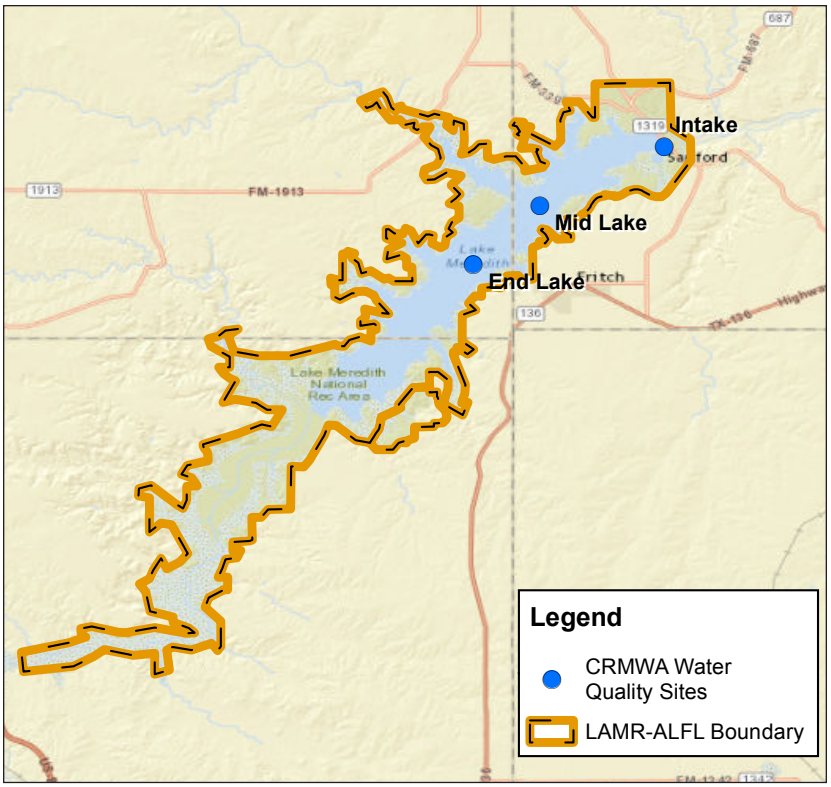


Figure 4.6.2-1 The Canadian River Municipal Water Authority has monitored water quality at three locations in Lake Meredith.

long-term data and trend analysis (EARDC 2007). Sampling methodology was not provided by CRMWA so is not included in the methods discussion.

Data analysis followed procedures outlined in NPS (2000), presenting a summary of simple statistics for each parameter. The figures presented in the section include ones that have established water quality standards. Figures for the remaining parameters with no water quality standards are included in Appendix E. The water quality parameters were divided into four indicators, which are discussed below. Parameter summaries are provided in Tables 4.6.2-1, -2, and -3.

Indicators/Measures

Field Properties: temperature, specific conductance, pH, and turbidity

The field properties measured included temperature, specific conductance (the ability of a solution to conduct an electrical current, i.e., the lower the conductivity, the "purer" the water), turbidity, and pH. Results for the data collected at the intake tower are shown in Figures 4.6.2-2 - 4.6.2-9.

Indicators/Measures

Alkalinity: Total and Phenolphthalein

The water quality sampling results for total and phenolphthalein alkalinity collected at the intake tower are included in Appendix E.

Table 4.6.2-1. Annual parameter summary from 2003-2014 at the Intake Tower.

Parameter	No. of Observations	Median	Mean	Max	Min
Water Temperature: (°C)	134	17.6	17.50	70	2.7
pH	135	8.6	8.55	9.1	7.41
Specific Conductance	135	3127	3710.99	7770	2398
P. Alkalinity	134	4.8	5.75	16	0
T. Alkalinity	134	184.2	187.11	224	160
Fluoride	132	0.8	0.81	2.14	0.067
Chloride (IC)	135	673	822.63	1981	435
Nitrate	133	0.1	0.10	0.96	0
Phosphate	131	0.3	0.36	0.93	0.03
Sulfate	132	441.5	518.11	1054	336
Sodium	130	516.5	687.38	1979	308
Potassium	130	9.9	11.41	23.1	0.66
Calcium	128	78.4	90.42	401	43
Magnesium	130	59.4	65.79	117	32.5
Hardness	123	400	456.26	824	256
Total Dissolved Solids	103	2102	2469.69	4776	1526
Turbidity	99	8.5	9.67	28.2	2.69

Table 4.6.2-2. Late spring to early fall seasonal parameter summary from 2003-2014 at the Intake Tower (date range 4/15 - 10/31).

Parameter	No. of Observations	Median	Mean	Max	Min
Water Temperature: (°C)	77	23.0	23.4	70.0	14.4
pH	77	8.56	8.58	9.00	7.80
Specific Conductance	77	3103	3778	7770	2577
P. Alkalinity	75	6	6	16	0
T. Alkalinity	75	185	187	224	162
Fluoride	74	0.784	0.806	1.860	0.067
Chloride (IC)	76	693	832	1885	472
Nitrate	75	0.05	0.10	0.43	0.00
Phosphate	74	0.26	0.29	0.67	0.03
Sulfate	74	441	519	1054	348
Sodium	71	521	715	1979	308
Potassium	71	9.6	11.3	23.1	0.7
Calcium	71	83.5	95.6	401.0	43.0
Magnesium	71	57.0	62.9	117.0	32.5
Hardness	68	405	461	824	330
Total Dissolved Solids	59	2188	2482	4776	1577
Turbidity	56	9.50	11.03	28.20	2.69

Table 4.6.2-3. Late fall to early spring seasonal parameter summary from 2003-2014 at the Intake Tower (date range 11/1 - 4/14).

Parameter	No. of Observations	Median	Mean	Max	Min
Water Temperature: (°C)	57	9.0	9.5	22.7	2.7
pH	58	8.55	8.51	9.10	7.41
Specific Conductance	58	3131	3622	6440	2398
P. Alkalinity	59	4	5	16	0
T. Alkalinity	59	184	187	216	160
Fluoride	58	0.771	0.820	2.140	0.379
Chloride (IC)	59	664	811	1981	435
Nitrate	58	0.06	0.11	0.96	0.01
Phosphate	57	0.42	0.43	0.93	0.13
Sulfate	58	443	516	871	336
Sodium	59	515	653	1316	365
Potassium	59	10.5	11.5	18.4	6.6
Calcium	57	76.8	84.0	135.0	49.6
Magnesium	59	58.6	65.1	102.0	42.1
Hardness	55	400	450	720	256
Total Dissolved Solids	44	2006	2454	4076	1526
Turbidity	43	7.42	7.91	25.50	2.88

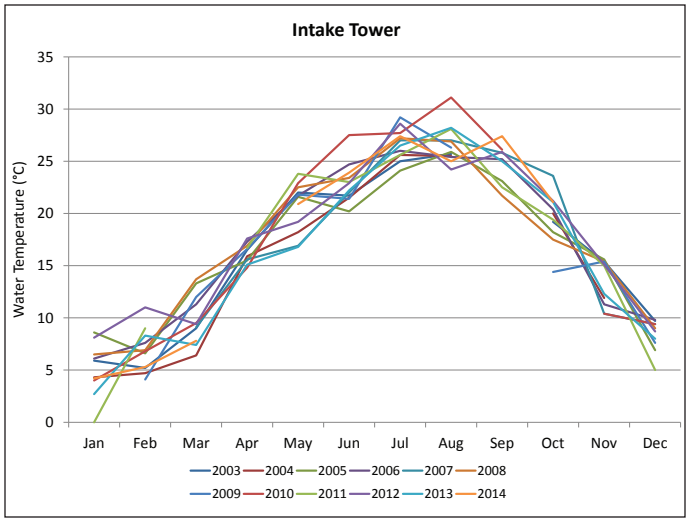


Figure 4.6.2-2 Water temperature time series for the Intake Tower site.

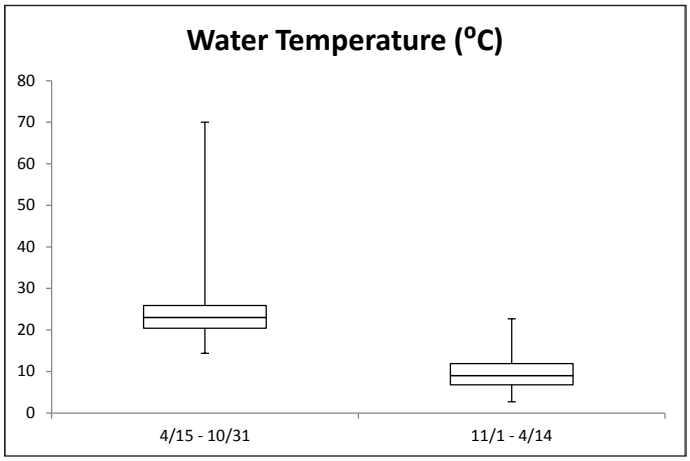


Figure 4.6.2-3 Water temperature seasonal analysis for the Intake Tower site.

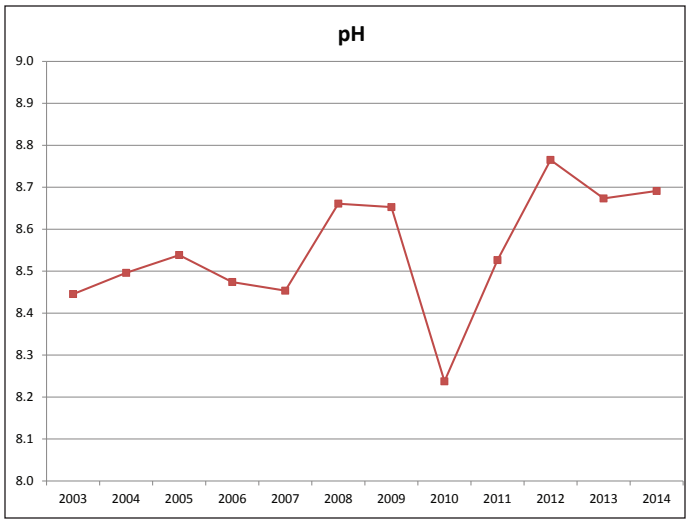


Figure 4.6.2-4 pH time series for the Intake Tower site.

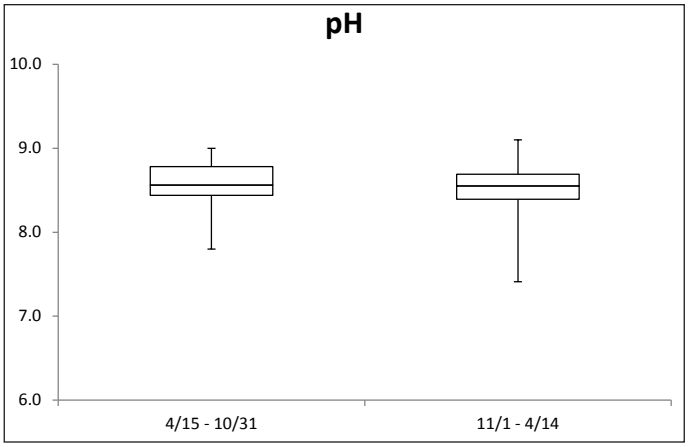


Figure 4.6.2-5 pH seasonal analysis for the Intake Tower site.

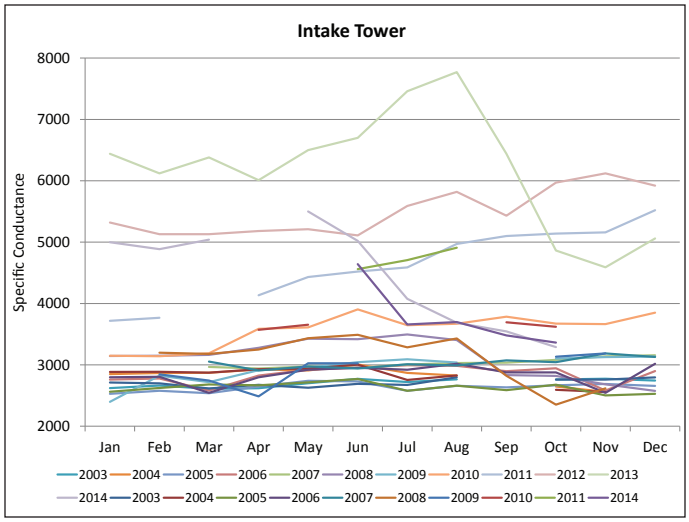


Figure 4.6.2-6 Specific conductance time series for the Intake Tower site.

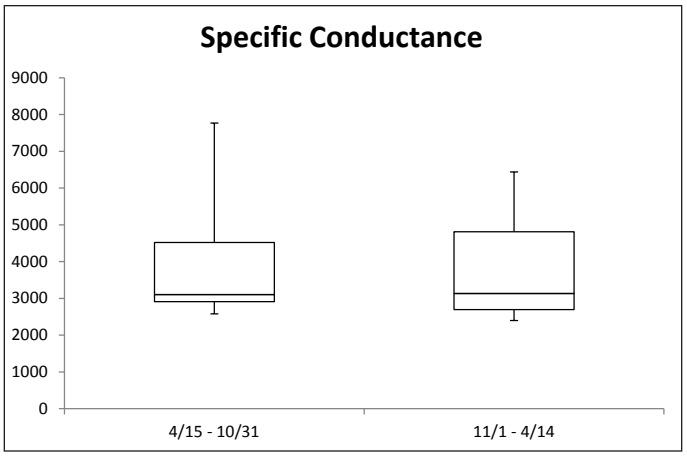


Figure 4.6.2-7 Specific conductance seasonal analysis for the Intake Tower site.

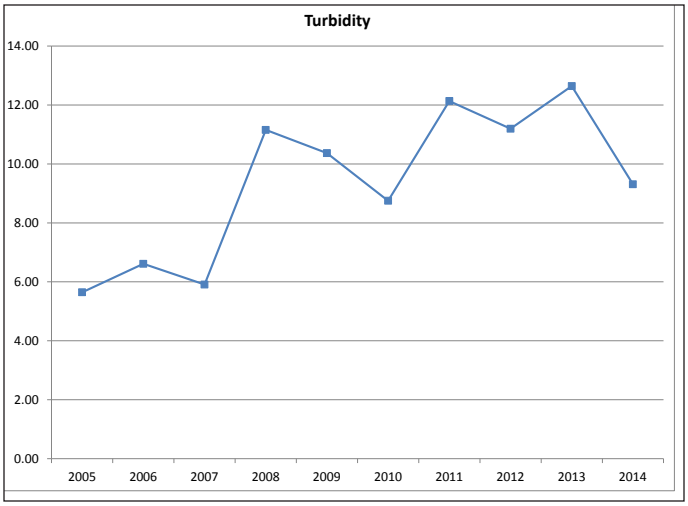


Figure 4.6.2-8 Turbidity time series for the Intake Tower site.

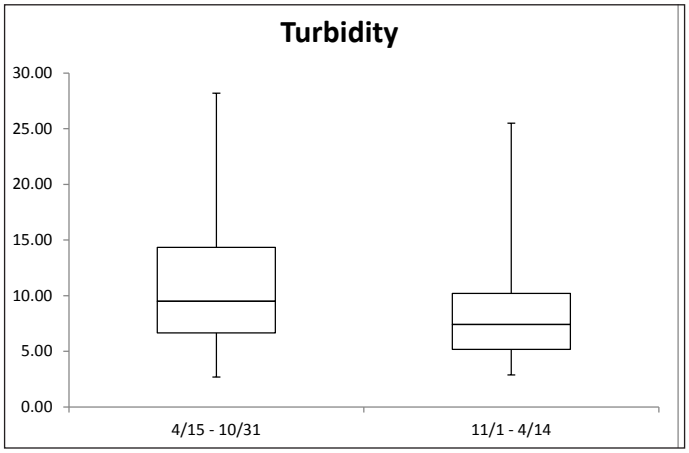


Figure 4.6.2-9 Turbidity seasonal analysis for the Intake Tower site.

Indicators/Measures
Major Constituents (9 measures)

Results for major constituents measured at the intake tower included fluoride, chloride, sulfate, and total dissolved solids, which are shown in Figures 4.6.2-10 - 4.6.2-19. Results for sodium, potassium, calcium, phosphate, magnesium, and hardness are included in Appendix E.

Indicators/Measures
Primary Nutrients: nitrate and phosphate

The results for primary nutrient sampling, which included nitrate and phosphate are shown in Figures 4.6.2-18 and 4.6.2-19 for nitrate and in Appendix E for phosphate.

4.6.3. Reference Conditions

The water quality results were compared to the water quality standards/guidelines established by the Texas Commission on Environmental Quality Control Commission (TCEQ 2010, 2014, 2015), which were reviewed by the EPA beginning in 2007 to determine compliance with standards set forth by the Clean Water Act.

TCEQ standards establish goals for the quality of waterbodies and were developed to maintain the quality of surface waters so that they support public health and enjoyment and protect aquatic life. The standards identified appropriate uses, which included primary recreational contact, exceptional aquatic life, and public water supply for drinking water for Lake Meredith (TCEQ 2014).

Some of TCEQ's standards are specific to the Canadian River Basin - Lake Meredith segment number 0102 - while other standards are statewide, and in many cases, no standards exist. All available standards for the monitored water quality parameters are listed in Table 4.6.3-1.

4.6.4. Condition and Trend

Field Properties

The field properties reflect the function of the physical and biological environment with which water interacts and constitute a means

Table 4.6.3-1. Surface water quality standards for the Lake Meredith classified segment (#0102) and statewide criteria according to Texas Commission of Environmental Quality (2010, 2014, 2015).

Parameter	Standard Value	Standard Type
Water Temperature	29.4 ^{0}C (max)	These standards were established by TCEQ (2014) for primary recreational contact, exceptional aquatic life use, and public water supply.
pH	6.5 - 9.0 SU	
Chloride	400 mg/L	
Sulfate	350 mg/L	
Total Dissolved Solids	1300 mg/L	
Fluoride	4	Drinking Water
Nitrate	10	Drinking Water
Turbidity	50 Jackson Candle Units	Other-High Lim.
Specific Conductivity	µS/cm	-

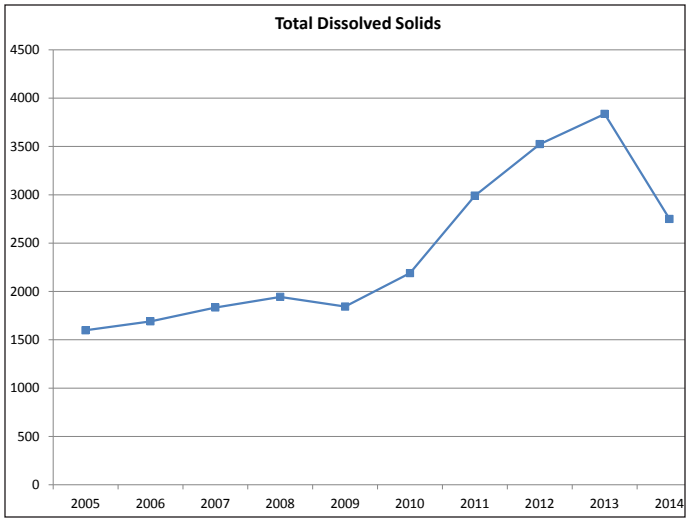


Figure 4.6.2-10 Total dissolved solids time series for the Intake Tower site.

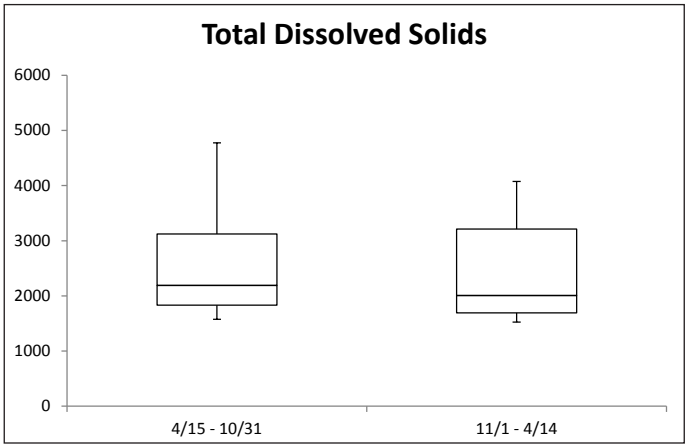


Figure 4.6.2-11 Total dissolved solids seasonal analysis for the Intake Tower site.

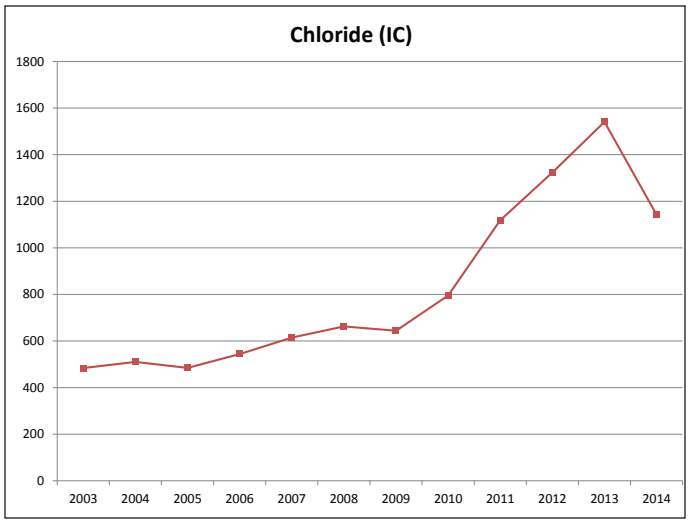


Figure 4.6.2-12 Chloride time series for the Intake Tower site.

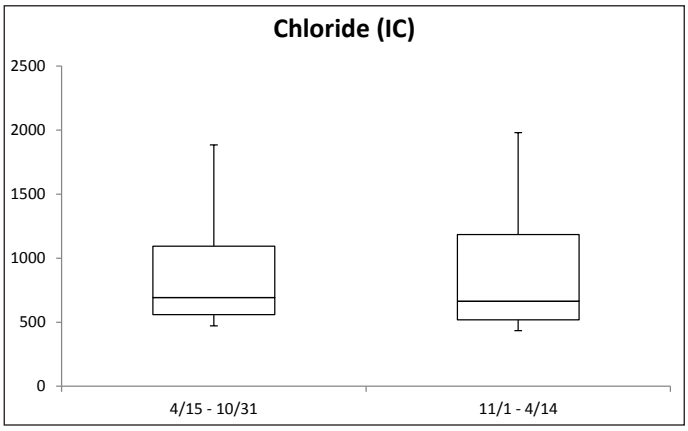


Figure 4.6.2-13 Chloride seasonal analysis for the Intake Tower site.

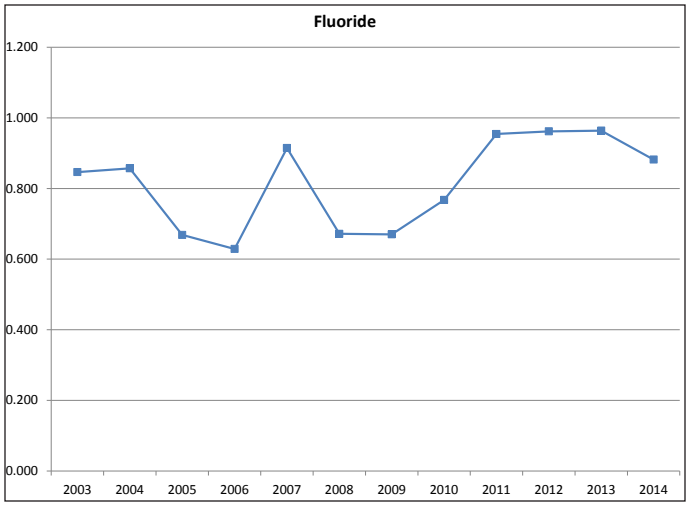


Figure 4.6.2-14. Fluoride time series for the Intake Tower site.

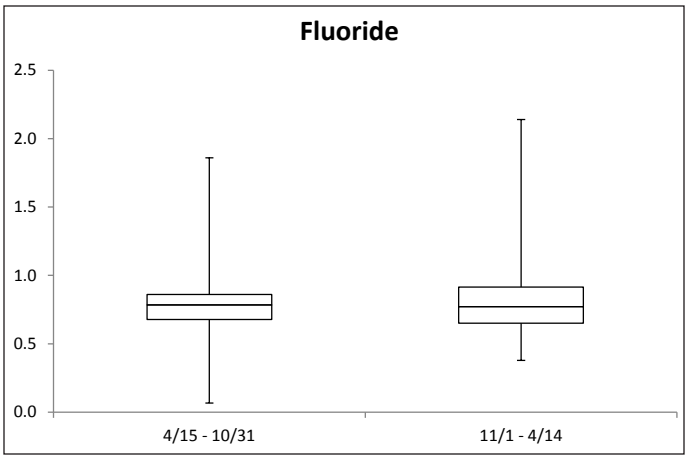


Figure 4.6.2-15. Fluoride seasonal analysis for the Intake Tower site.

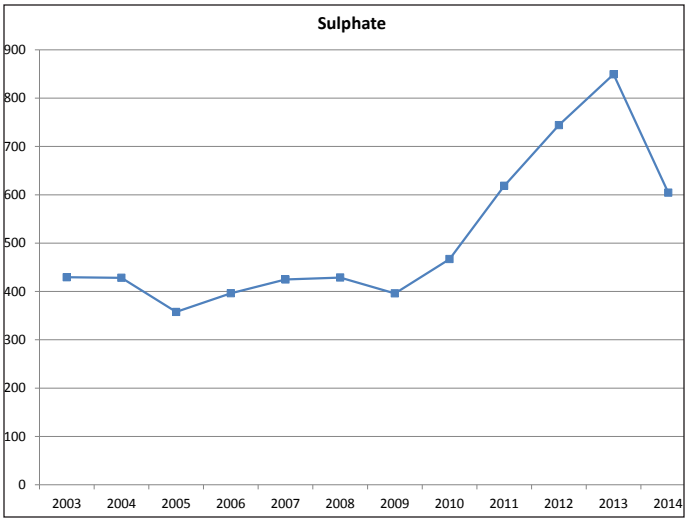


Figure 4.6.2-16. Sulfate time series for the Intake Tower site.

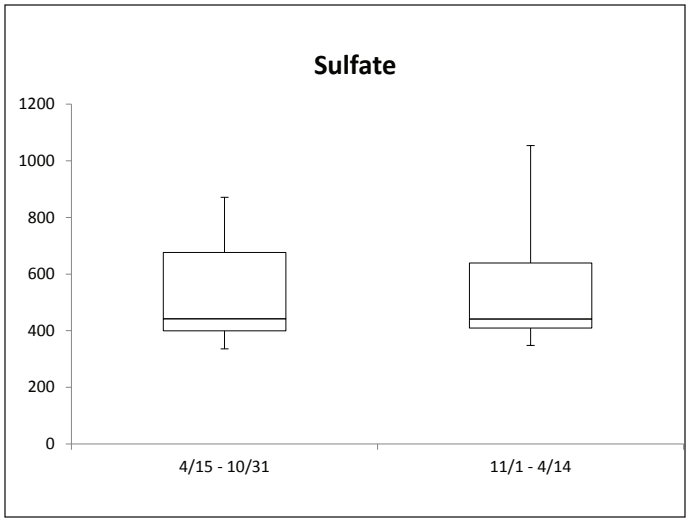


Figure 4.6.2-17. Sulfate seasonal analysis for the Intake Tower site.

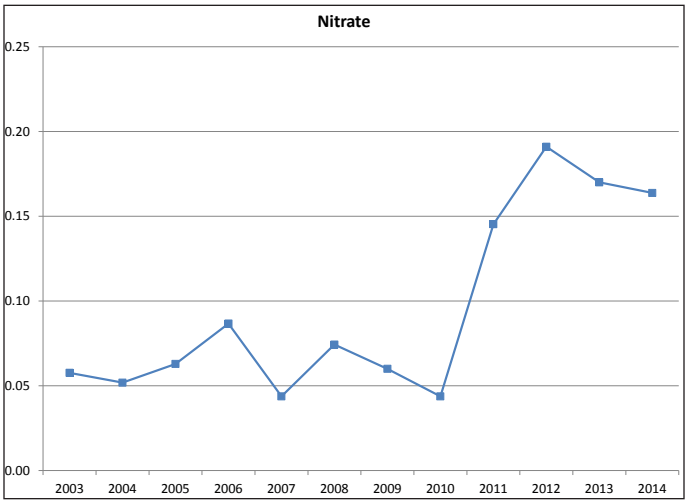


Figure 4.6.2-18. Nitrate time series for the Intake Tower site.

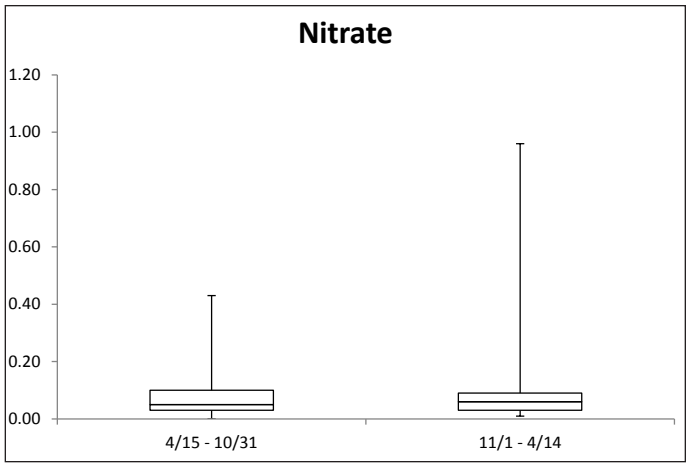


Figure 4.6.2-19. Nitrate seasonal analysis for the Intake Tower site. Values <0.02 are not represented.

of characterizing potential stressors to the health of aquatic systems.

Results for temperature, pH, and turbidity were within Texas state standards except for one temperature reading, which was likely a recording error and one pH reading of 9.1 SU, which exceeded the state's maximum level of 9 SU.

Specific conductance, an indicator of dissolved solids (salinity), ranged from 2398-7770 uS/cm at the intake tower location, far exceeding specific conductance guidance (Wet-USA n.d.), although no standard is identified by the state. However, the state's standard for total dissolved solids in Lake Meredith is 1300 mg/L, which is equivalent to a specific conductance of about 1800 uS/cm (Wet-USA n.d.). We consider this measure to be of significant concern due to the extremely high specific conductance values.

Alkalinity

Alkalinity characterizes the ability of a water body to buffer changes in pH. Naturally occurring ions buffer from sudden changes in pH due to the addition of acid. Alkalinity of a water body is influenced by surrounding geology and soils and by effluent. It also protects fish and other organisms against sudden changes in pH, and under the right conditions, carbonate and bicarbonate ions facilitate the precipitation of metals from

solution, reducing the exposure of aquatic biota to high dissolved metal concentrations. Alkalinity is tied to hardness, and these values indicate that the water condition in Lake Meredith is hard to very hard. According to the USGS (2013), patterns of surface water throughout the United States show that waters in Texas are some of the hardest (greater than 1,000 mg/L) throughout the country. In addition, USGS (2013) indicates that total alkalinity throughout much of the country, including Texas, has some of the highest concentrations. We consider this parameter to be within the expected range of values, although among the highest end of values, given the regional patterns.

Major Constituents

Only four of the nine major constituents that are monitored have state water quality standards established. These include chloride, fluoride, sulfate, and total dissolved solids. According to the CRWMA (2015), an increasing trend of chloride content (salt) has occurred in Lake Meredith, with drought cycles producing chloride contents up to 1500 mg/L. Federal Drinking Water Standards recommend maximum chloride contents of 250 mg/L and state standards recommend 400 mg/L for Lake Meredith segment 0102, which are less stringent (TCEQ 2014) due to its higher concentrations. The high salt concentrations can cause problems with corrosiveness and produce a salty taste if used for public water supply.

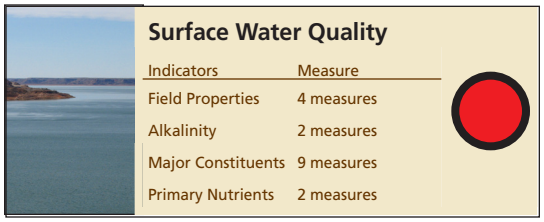
The Bureau of Reclamation and other consultants estimated that about 70 percent of the chlorides reaching Lake Meredith originate from an area in New Mexico just downstream from Ute Dam near Logan (CRMWA 2015). A Lake Meredith Salinity Control Project became operational in September of 2001 to attempt to control the salt-water flow into Lake Meredith (CRMWA 2015). Despite its attempts, Lake Meredith remains on the State's 303(d) impaired waters list for exceeding chloride levels (TCEQ 2012) even with the lower state standard established for the Lake Meredith segment.

Other constituents, including total dissolved solids, consistently exceeded the state criterion of 1300 mg/L. Total dissolved solids are tied to the high specific conductance values discussed previously. The remaining constituents with state standards included fluoride and sulfate, which were within the limits for fluoride and exceeded the limits for sulfate, resulting in being listed on the State's 303(d) list for high sulfate levels. Overall, this indicator is of significant concern.

Primary Nutrients

Nitrogen and phosphorus are essential macronutrients for plant and animal life but in excess, they can interact with the biological and physical environment to reduce availability of high-quality aquatic habitat, altering the composition and species diversity of aquatic communities. Measures of nitrates and phosphates indicate the potential for biological effects resulting from nutrient loading.

Both nitrate and phosphate levels were lower than the established standards, often with phosphate not being detected. This indicator was considered to be in good condition



Surface Water Quality

Indicators	Measure
Field Properties	4 measures
Alkalinity	2 measures
Major Constituents	9 measures
Primary Nutrients	2 measures

Overall Condition

A summary of each indicator and its contribution to the overall water quality condition at Lake Meredith is listed in Table 4.6.4-1.

Likely the largest issue impacting Lake Meredith is its low water levels and high salt concentrations. The Texas Water Development Board (2015) reported that the reservoir is only at 4% of its storage capacity, although it has increased by 6% since a year ago (Mar. 2014) and is at 27,928 acre/feet (refer to the fish assessment for more discussion about the impacts to natural resources as a result of low water levels). There's concern that

Table 4.6.4-1. Summary of the surface water quality indicators and their contributions to the overall condition at Lake Meredith NRA.

Indicator of Condition	Measure	Condition	Rationale for Condition
Field Properties	4 Measures	Significant Concern	With a few exceptions, most of the field properties were within state standards, however, the specific conductance levels ranged between 2,398 - 7,770 micro Siemens/cm. While no water quality standard exists for specific conductance, damage to agricultural crops has been shown to occur when specific conductance is between 950-1200 micro Siemens/cm (USGS 1987). Because of the very high specific conductance results, we consider this measure to be of significant concern.
Alkalinity	2 Measures	Good	The alkalinity results were within the expected range of values, although represent some of the highest concentrations throughout the country (USGS 2013).
Major Constituents	9 Measures	Significant Concern	Based on TCEQ's (2012) 303(d) list for chloride, sulfate, and total dissolved solids impairments in Lake Meredith, this indicator was considered to be of significant concern.
Primary Nutrients	2 Measures	Good	Both nitrate and phosphate levels were low, often with phosphate not being detected. This indicator was considered to be in good condition.

evaporation (Figure 4.6.4-1) will concentrate salts in the lake leading to further water quality degradation.

Clean Water Act 303(d) Impairment

Waterbodies that failed to comply with water quality standards or is threatened for one or more designated uses by one or more pollutants were identified by the TCEQ and included on the State's 303(d) list for impaired waters. At two locations, from Sanford Dam in Hutchinson County to a point immediately upstream of the confluence of Camp Creek in Potter County, up to normal pool level of 2936.5 feet (impounds Canadian River) and from the reservoir upstream of a line from red starboard 14 at blue west campground to green port marker 11 north of Fritch Canyon, Lake Meredith had impairments for chloride, sulfate, total dissolved solids, and mercury in fish (TCEQ 2012).

For all impairments, the TCEQ stated that additional data or information will be collected and/or evaluated for one or more parameters before a management strategy is selected (TCEQ 2012). Only the mercury in fish impairment was a previously listed impairment that did not have adequate data to re-assess in 2010 and was carried forward from 2008 and remains impaired (TCEQ 2012).

Level of Confidence/Key Uncertainties/ Threats

This assessment was intended to capture current water quality conditions at Lake Meredith, which included one monitoring site where the water level remained sufficient for data collection. Trend analyses were beyond the scope of the assessment, but simple descriptive statistics were presented. The level of confidence in the condition rating was high given the fact that CRMWA monitors monthly and that certain water

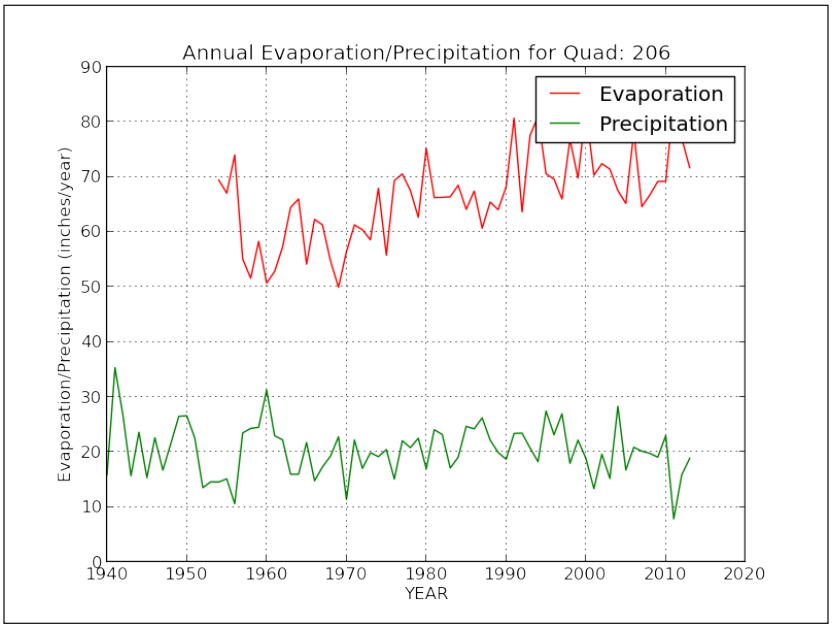


Figure 4.6.4-1 Annual evaporation (1954-2013) and precipitation (1940-2013) amounts at Lake Meredith (TWDB 2013).

quality parameters are included on the State's 303(d) list of impairments.

4.6.5. Sources of Expertise

Rod Godwin is the Chief of Water Quality with the Canadian River Municipal Water Authority. He and his staff conduct monthly water quality monitoring at Lake Meredith and provided the data for this assessment per Lake Meredith's Chief of Resources Arlene Wimer's suggestion.

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4.7. Groundwater

Indicators/Measures

- Groundwater Elevation (Change in Groundwater Elevation)

Condition - Trend - Confidence

Unknown- Unknown - Low

This section was written by Michael Martin, Hydrologist with the National Park Service Water Resources Division.

4.7.1. Background and Importance

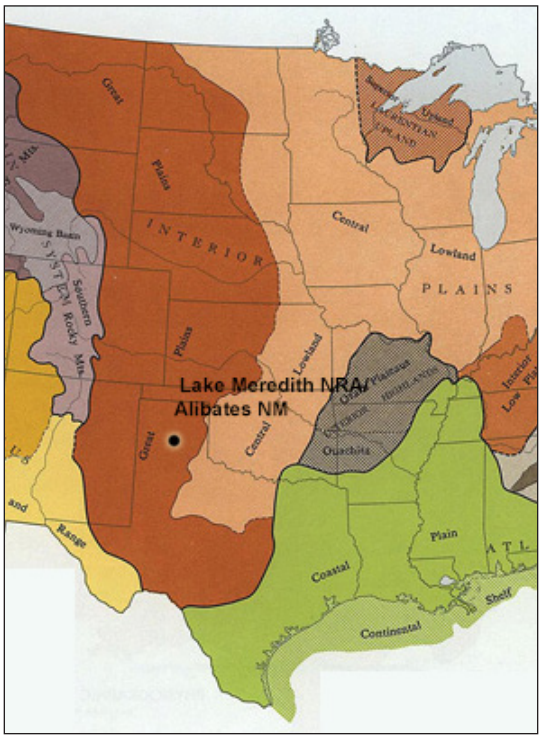
Lake Meredith National Recreation Area (NRA) and Alibates Flint Quarries National Monument (NM) are situated in the High Plains of Texas, which is the southernmost extension of the Great Plains physiographic province of Western North America (Fenneman 1931) (Figure 4.7.1-1). The surface of the plains is remarkably flat throughout much of the area and gently undulating in the remainder. Features of relief that interrupt the flat surface are numerous shallow depressions or playas, sand dunes, and small stream valleys (Cronin 1969). This area has a semi-arid climate where precipitation averages only about 14 to 23 inches annually. Additionally, mild winters and hot summers impose a very high evaporation potential over the area. Previous estimates suggest that annual evaporation may exceed annual precipitation by a factor of 3.5 for open water environments (Knowles et al. 1984). The combination of low precipitation and high evaporation results in surface water resources being extremely limited. Consequently, the relative importance of groundwater systems in maintaining park natural resources is extremely high.

National Park Service (NPS) Management Policy 4.6.1 states that the NPS will perpetuate surface waters and ground water as integral components of park aquatic and terrestrial ecosystems (NPS 2006). It is the policy of the NPS to determine the quality of park surface and groundwater resources and avoid, whenever possible, the pollution or other types of degradation of park waters by human activities occurring within and outside of parks.

<u>Occurrence and Movement of Groundwater in the Vicinity of the NRA and NM</u>

Most of the potable groundwater resources in the Canadian River Basin occur in the sands and gravels of the Tertiary Ogallala Formation, although there is also usable water in some of the Cretaceous, Jurassic, and Triassic rocks underlying the Ogallala in places (Manford et al. 1960). For the most part, these underlying formations (principally red clay, sand, and shale) serve as a nearly impermeable floor, or a basal confining layer for the surficial Ogallala aquifer.

Specific to the NRA and NM, there are three geologic units that may provide water to the resources of the parks; the Triassic Docken group, the Tertiary Ogallala formation, and various surficial deposits of Quarternary age



WWW.BLUE.UTB.EDU

Figure 4.7.1-1. Lake Meredith NRA) and Alibates Flint Quarries NM are situated in the High Plains of Texas, which is the southernmost extension of the Great Plains physiographic province of Western North America (Fenneman 1931, www.solpas.org 2014)

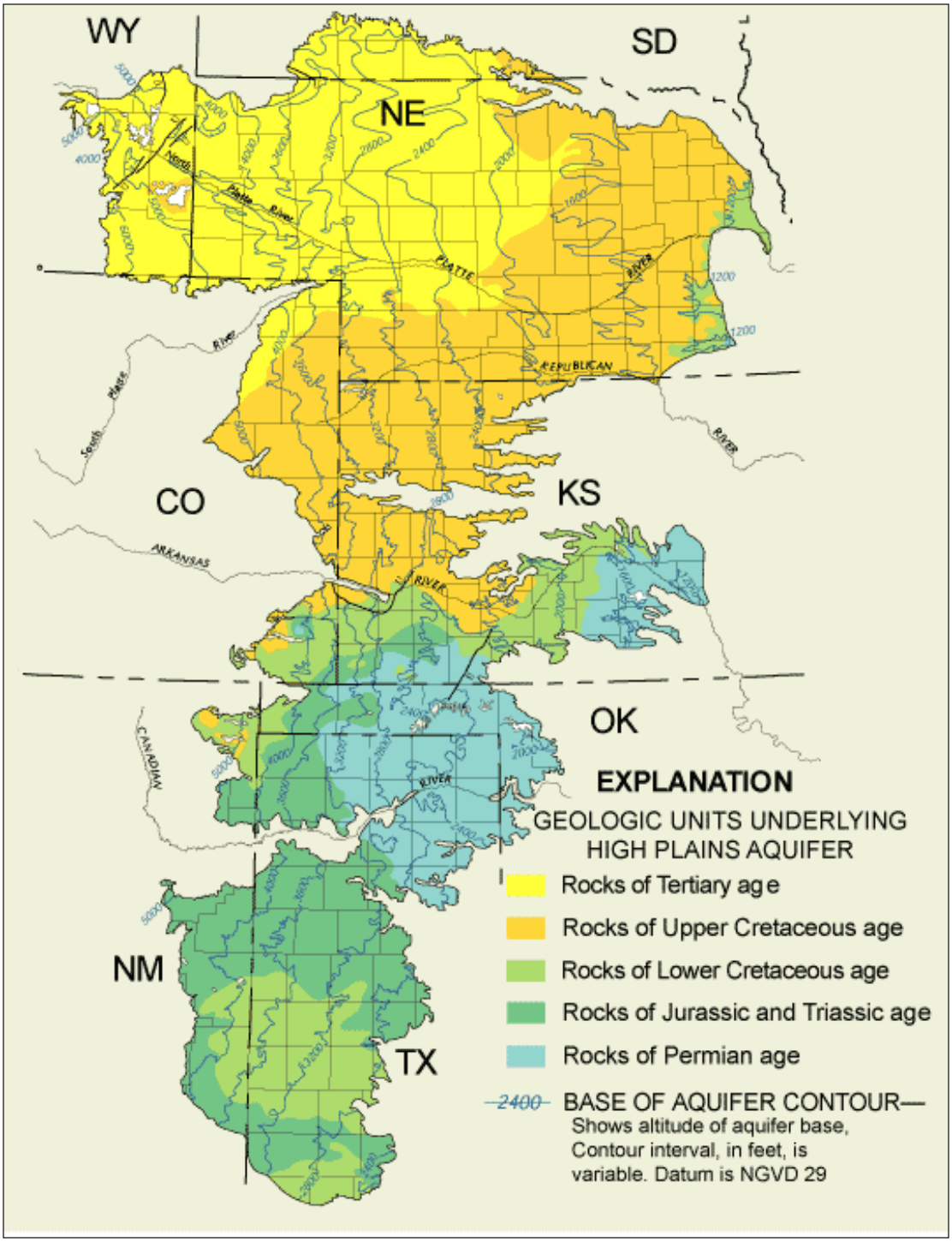


Figure 4.7.1-2. Overview of the geologic units underlying the High Plains Aquifer (http://ne.water.usgs.gov/ogw/hpwlms/images/aqbase.gif).

that include alluvium, lacustrine (playa) and eolian sediments (Figure 4.7.1-2).

The principle aquifer in the Lake Meredith area is the High Plains Aquifer, which is composed chiefly of the Ogallala Formation but may include other underlying or overlying formations when they are hydraulically connected. The Ogallala is essentially a horizontal formation overlying older geologic units that have been faulted and folded to varying degrees. Pleistocene and Holocene deposits may form a thin mantle over the Ogallala in some areas. Caliche horizons (secondarily precipitated calcium carbonate) underlie most of the region and may be found at a depth of one to six feet deep (Knowles et al. 1984). These deposits, often times referred to as caprock or hardpan, are generally one to two feet thick and may greatly impede

downward infiltration of meteoric water unless fractured.

The Tertiary Ogallala Formation was deposited by a series of shifting stream systems primarily as alluvial fans between the Miocene and Pliocene Epochs. These fluvial sediments were derived from the eroding Southern Rocky Mountains to the west while these mountains were tectonically active and uplifting. The hydraulic properties of the Ogallala aquifer vary spatially and are dependent on its lithology, which is a heterogeneous mix of sand, silt, clay, and some gravels. (Knowles et al. 1984). In most areas, the Ogallala supports water table conditions, but there may be minor artesian conditions is some isolated zones. Where artesian conditions occur, it is generally where lenses of relatively impermeable shales and clays overlie more permeable sands and gravels (Manford et al. 1960).

The thickness of the Ogallala Formation varies greatly and is primarily a function of the underlying bedrock surface that was eroded in different areas and to different degrees prior to the deposition of the Ogallala. The greatest thicknesses occur where the Tertiary sediments have filled paleo drainage channels, which generally trend east and/or southeast. Overall, the thickness of the Ogallala Formation may range from 0 to over 900 feet (Manford et al. 1960).

Recharge to the Aquifer

Recharge to the High Plains Aquifer in the area of the parks occurs primarily as infiltration of meteoric water, and due to several factors, (i.e., limited precipitation, high evaporation, and low infiltration rates) averages only about 0.2 inches to less than 0.5 inches per year (Manford et al. 1960; Klemt 1981; Bell and Morrison 1982; and Knowles et al. 1984).

The actual amount of recharge that could occur over any given time period is difficult to estimate due to all of the controlling factors. The amount, distribution, and intensity of the precipitation, as well as vegetative cover and permeability of the materials at the site of infiltration result in a wide variation of potential recharge in any given area (Cronin 1961). Of local importance, recharge by infiltration is greatly hampered by caliche layers near the surface, which can have permeabilities near zero unless fractured. Additionally, a great deal of the incident precipitation and local runoff is captured by shallow playa lakes that occur on the land surface throughout this area. The bottoms of these ephemeral water features are often lined with accumulated clays and silts and any water impounded will ultimately be evaporated (Manford et al. 1960).

Discharge from the Aquifer

Discharge of groundwater from the aquifer to the surface water systems occurs naturally through seeps and springs and artificially through wells. Groundwater from the Ogallala may be discharged along the streams and other channels that have cut into the zone of saturation; some of this water is discharged through springs but a large portion is discharged from seeps and consumed by plants and evaporation.

The few springs that may have existed naturally in this region have probably been greatly affected by the lowering of the water table due to groundwater withdrawal. The amount of water withdrawn by wells has increased continuously as more and more wells are drilled (Manford et al. 1960). Additionally, a small amount of water may move downward from the Ogallala Formation into underlying aquifers (Cronin 1969).

Hydraulic properties of the High Plains Aquifer

As mentioned, the hydraulic properties of the High Plains Aquifer are closely related to the local lithologic characteristics of the formation. Both permeability and specific yield (a measure of how much water may be produced from an aquifer) are primarily dependent on sediment grain size and shape, degree of sorting, and amount of cementation. Additionally, layers of silt, clay and caliche may have a great effect on groundwater movement, especially in the vertical direction. Previous estimates of permeabilities range from 22 to 1,934 gallons per day per square foot (gal/d/ft^2), with an average of 400 (gal/d/

ft^2). Specific yields range from 7.23 - 19.54%, with an average of 16% (Knowles et al. 1984).

The rate of movement (velocity) of groundwater in a water table aquifer is controlled by the permeability of the saturated material and the gradient of the water table. Groundwater in the High Plains Aquifer generally moves toward the east to east-southeast at an average rate of approximately 7 inches (18 cm) per day. This "bulk aquifer" average velocity is extremely variable because of the variability in permeability. The gradient of the water-level surface ranges from 5 to 50 feet per mile, with an average of approximately 15 feet per mile. More specific to the NRA and NM, some distance north of the Canadian River, movement is generally toward the east while at some distance south of the river, movement is predominantly toward the east-southeast. However, in the vicinity of the Canadian River, which essentially bisects the High Plains Aquifer, movement is toward the river and its associated canyons (Bell and Morrison 1980).

In addition to natural flow, groundwater movement may be locally affected by pumpage, which has occurred extensively in the High Plains Aquifer. When groundwater is withdrawn from a well, the water table in the vicinity of the well is drawn down and a cone of depression is formed around the well or wells. The hydraulic gradient around the pumping well or wells will be altered within the cone of depression, which in turn, will alter the rate and direction of flow. The areal extent of this influence is dependent on the rate and duration of pumping, thickness of saturated material above the pump, and the geohydrologic characteristics of the aquifer.

Other Aquifers in the area of The NRA and NM

On a regional scale, the other aquifers that exist in this area are mostly of marginal importance to industry, agriculture and domestic use, but probably are the most closely connected to the riparian resources of the NRA and NM, therefore, may be of great importance to park resources.

In the Panhandle of Texas, the Ogallala Formation has essentially been split into northern and southern units by the Canadian River, which has downcut through the surface formations into the underlying Triassic Dockum Group (Bell and Morrison 1982). This relatively thick series of formations generally serves as a minor aquifer in the region but because of the deep canyon of the Canadian River through the NRA, it may be a substantial source of water to the riparian resources of the park.

The Dockum Aquifer includes all of the Dockum Group, which in turn, contains from oldest to youngest, the Santa Rosa Formation, the Tecovas Formation, the Trujillo Sandstone, and the Cooper Canyon Formation. Lithologically, the Dockum Group consists of gravel, sandstone, siltstone, mudstone, shale, and conglomerate, with the gravel and sandstone serving as the primary water bearing zones. The water-bearing sandstones are locally referred to as the Santa Rosa Aquifer, which generally has poor quality water with high hardness and salinity values. Additionally, naturally occurring radioactivity measured as gross alpha radiation, as well as Radium-226 and -228 occur in amounts above the state's primary drinking water standard. However, water from this aquifer has been reported as suitable for agriculture (Alexander 1961).

Uses of the water from this aquifer may include: irrigation, municipal water supply, and petro-chemical operations, and water levels have both declined and risen in different areas of the aquifer. The regional water planning groups have previously recommended several water management strategies that utilize water from the Dockum Aquifer (Figure 4.7.1-3) (George et al. 2011.)

Younger, Quaternary (post-Ogallala) sediments consist of windblown sand and silt (eolian), playa lake deposits, and most important, alluvium. Eolian deposits occupy the largest surface area of the High Plains of Texas and are of both Pleistocene and more recent Holocene age. These fine grained, permeable deposits range in thickness from near 0 to about 10 feet and may locally serve

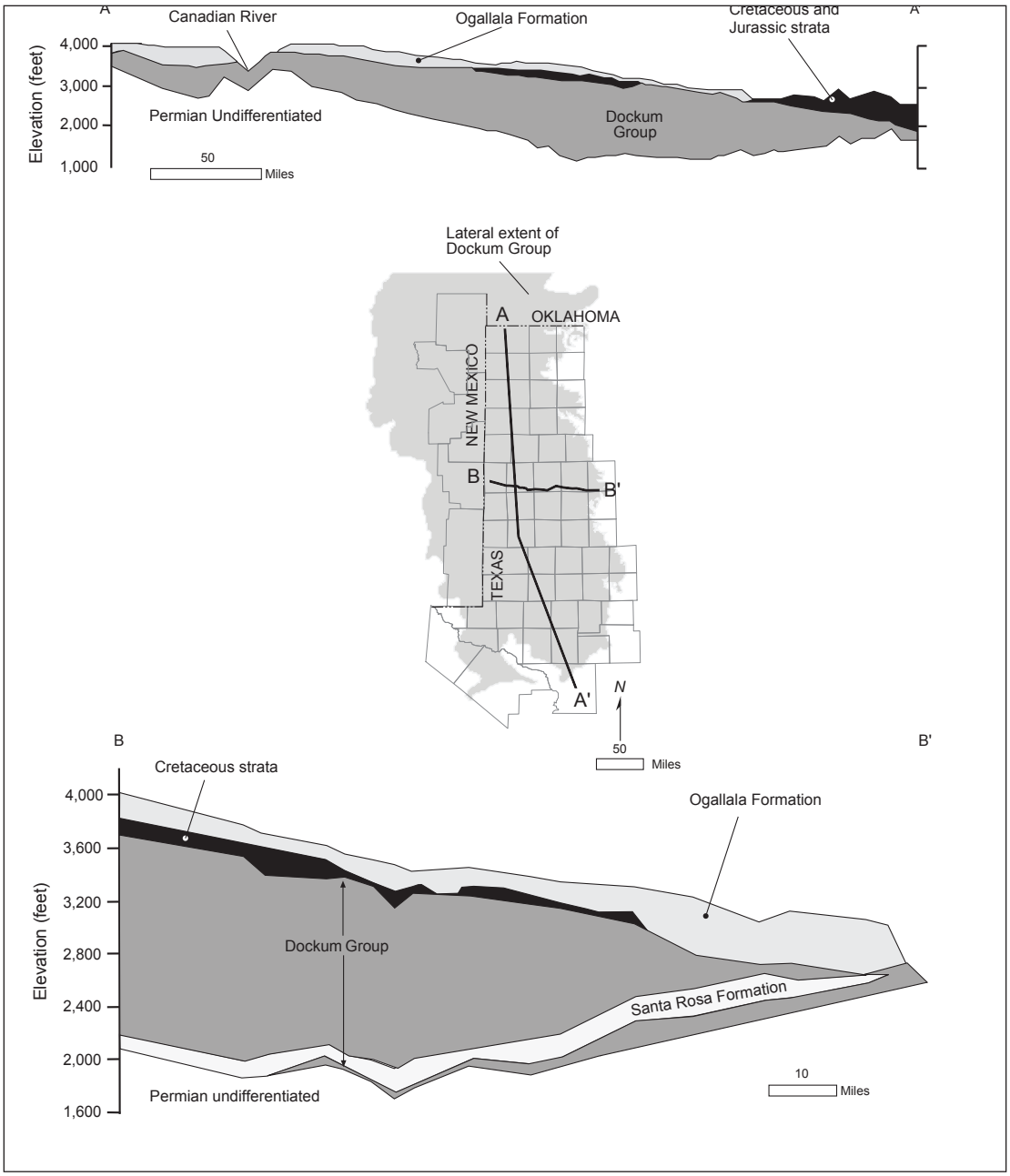


Figure 4.7.1-3. Geologic cross sections of the Dockum Aquifer (taken from George et al. 2011 and modified from Bradley and Kalaswad 2003).

as surficial aquifers. Lacustrine deposits, consisting primarily of clay and silt, line the bottom of the many playa lakes on the High Plains. These sediments are generally impermeable, thus restricting natural recharge to the underlying formation(s), storing precipitation on the surface for later evaporation (Manford et al. 1960).

Probably the most important water bearing strata in the NRA and NM are the quarternary sediments that fill the active river and stream valleys, ephemeral tributaries, and to a lesser extent, some of the associated terraces. Generally, these sedimentary deposits are composed of poorly sorted gravel, sand and silt (Knowles et al. 1984) and may reach depths that exceed 100 feet along the Canadian River (Manford et al. 1960; Alexander 1961). It is these very linear, continuous aquifers that are most closely associated with the riparian habitat.

4.7.2. Data and Methods

Water use in the NRA and NM

Development of groundwater resources in Texas began in the early part of the 20th Century with agriculture wells tapping the High Plains Aquifer. Use of this resource

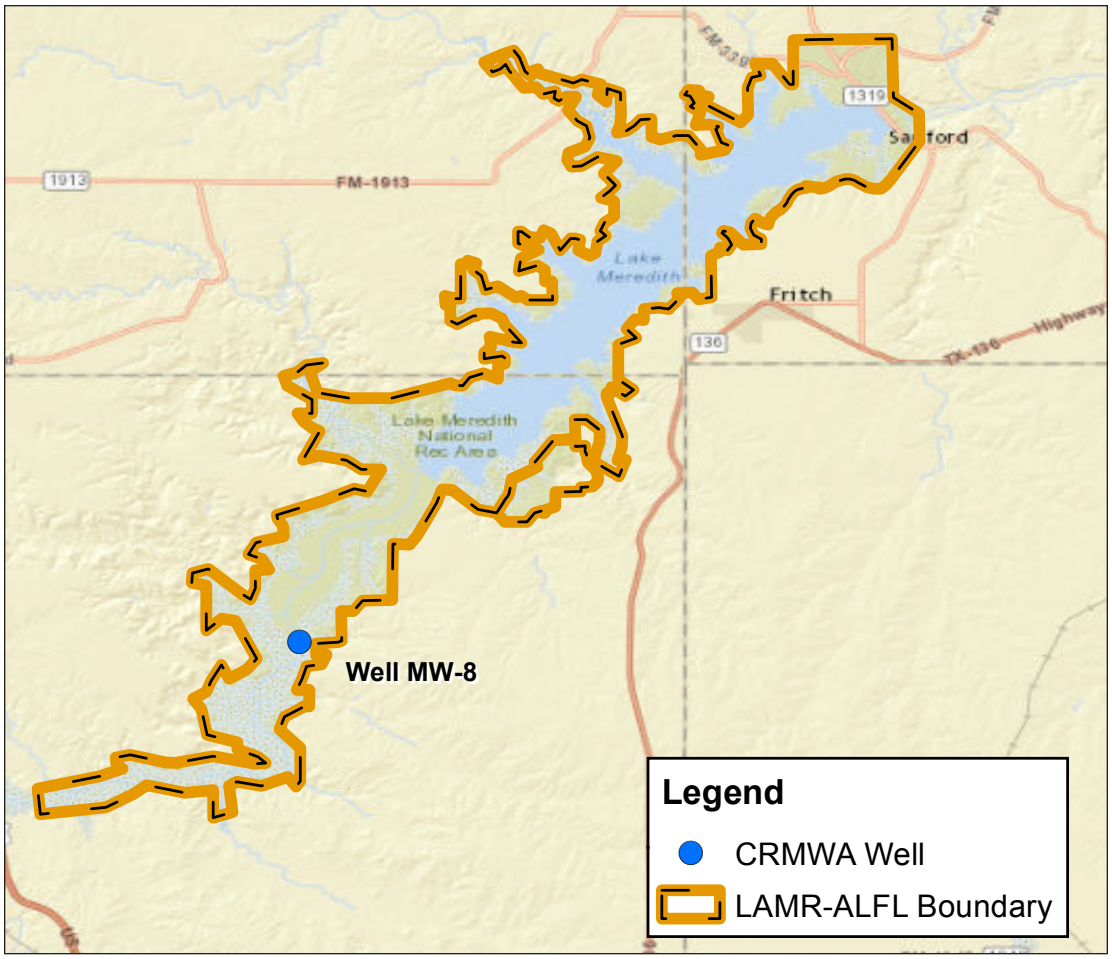


Figure 4.7.2-1. The Canadian River Municipal Water Authority monitors the groundwater level in the alluvial aquifer near Mullinaw Creek in the NRA.

increased rapidly, especially from the mid-1940s onward. By 1959 the Ogallala Formation furnished water to more than 1,200 irrigation wells in the area with production rates as high as 700 gallons per minute(Alexander 1961). The current uses of groundwater include agriculture, industry, petroleum extraction and refining, and municipal consumption. In the State of Texas, the landowner is also the owner of any underground water. However, underground water conservation districts may be formed and regulate groundwater for the purpose of conservation (Cronin 1961). Currently there two groundwater conservation districts (GCD) that include parts of the NRA and NM: the North Plains and the Panhandle GCDs.

Indicator/Measure

Groundwater Elevation (Change in groundwater elevation)

The Canadian River Municipal Water Authority (CRMWA) has been measuring diurnal fluctuations caused by saltcedar transpiration on the alluvial aquifer pre and post herbicide treatment in the alluvium aquifer since 2008 at a well located near Mullinaw Creek (Well ID MW-8) (Figure 4.7.2-1). The relationship between the well level and the river discharge is actually secondary to the well's purpose.

To evaluate the relationship of alluvial aquifer and the Canadian River in order to determine groundwater condition in the NRA/NM, we examined time plots that compared depth of groundwater in the monitoring well (CRMWA 2014). Discharge was measured at the Hwy 287 gage, and precipitation was measured from the National Weather Service at Amarillo. The records, which include data from 2008 to 2013, through each growing season, clearly shows a relationship between the water level in the monitoring well and flow in the river (Figure 4.7.2-2). The only exception to this is the 2011 data do not follow any of the patterns apparent in the

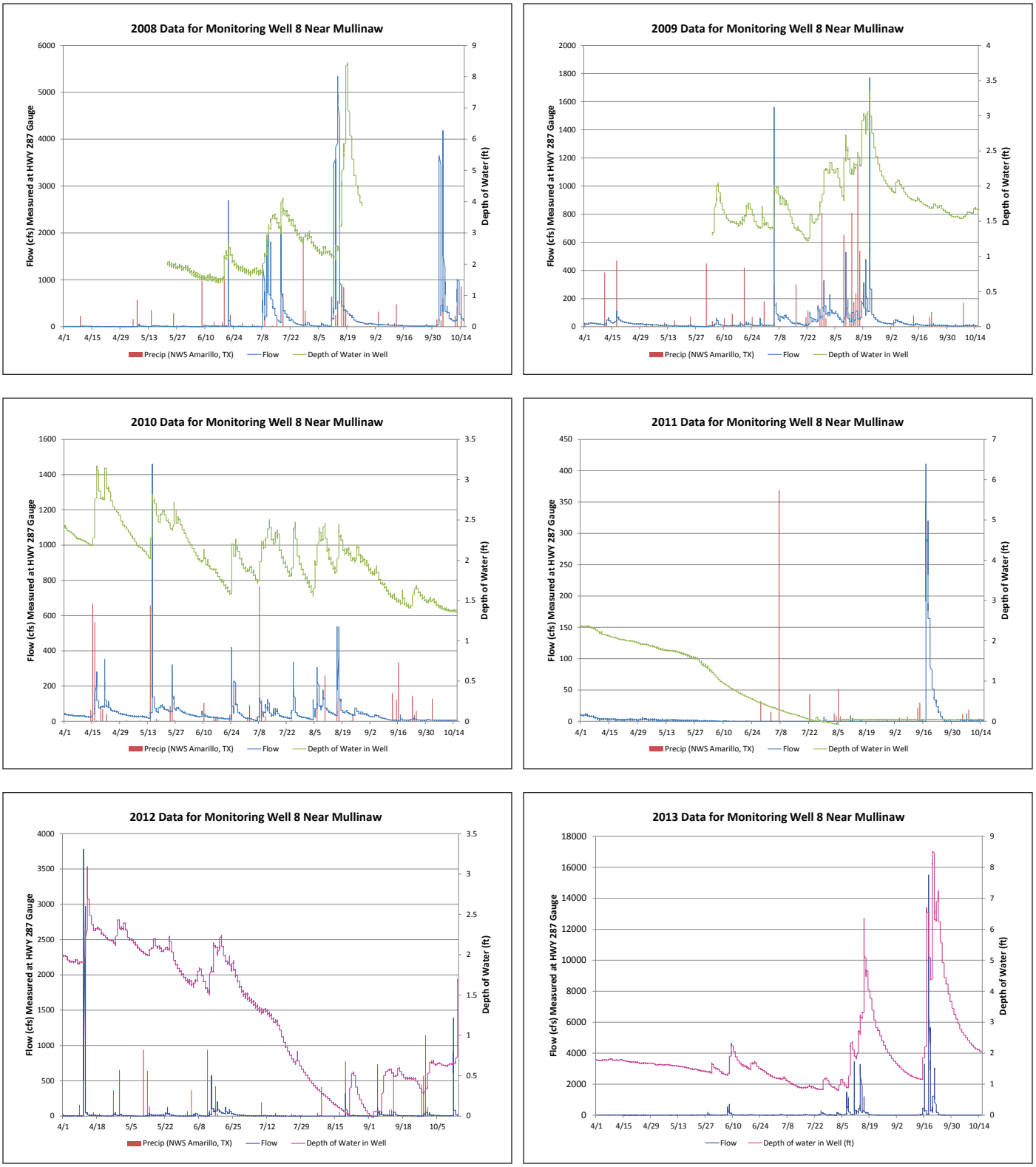


Figure 4.7.2-2. Comparison of groundwater levels, river flow and precipitation from 2008-2013 during the growing season.

other years. However, data from years 2008 to 2010 and 2012 to 2013 all demonstrate that there is a rise in groundwater level following increases in Canadian River flow. There also appears to be a weak relationship between precipitation and river flow, but this is a much less consistent pattern. No long term trend in the groundwater depth or the river flow is evident from the data. It does appear from this cursory analysis that both of these hydrologic parameters are very dependent on prevailing climate.

4.7.3. Reference Conditions

From a natural resource perspective the most important groundwater use in the NRA and NM is to support the riparian resources associated with the drainages in the parks. For the most part, the aquifers that support this resource are the Quarternary fluvial deposits previously described and monitored by CRMWA at the Mullinaw well. The reference conditions are described in Table 4.7.3-1.

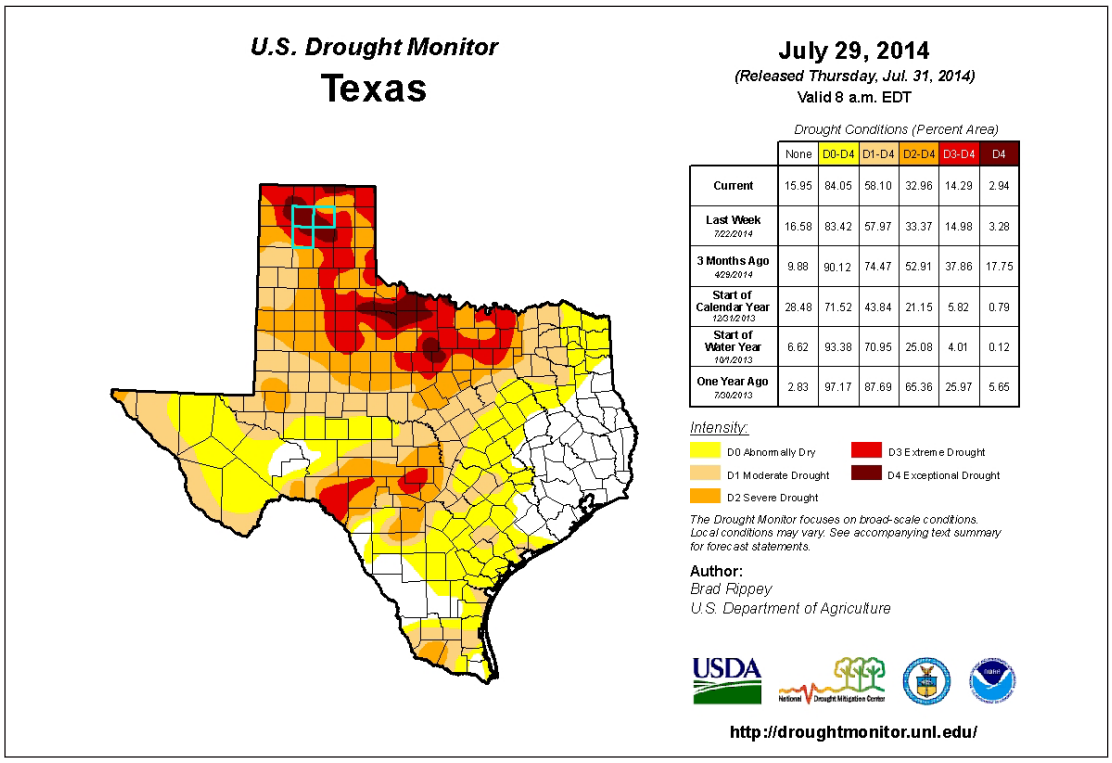
4.7.4. Condition and Trend

Overuse of the groundwater resources in this area have been a concern for many years. Numerous studies of the High Plains Aquifer have determined that this resource is being "mined", which means that the water is being pumped at a much faster rate than it is being recharged. Continued large-scale withdrawals of water from the Ogallala Formation will result in further decline of the water table. As the water level continues to decline, the zone of saturation will become progressively thinner and the yields of the wells will decrease (Cronin 1961). Ultimately, this trend could affect park wells that draw water from the High Plains Aquifer. While riparian resources could be affected somewhat from overuse of the High Plains Aquifer, the greatest threat to that system is probably prolonged drought. (Figure 4.7.4-1).

While it appears that the water table fluctuates quite a bit from year to year, we don't know exactly how much of a drop affects the wetland riparian vegetation. During the June 2014 riparian assessment, conducted by NPS Water Resources Division and Southern Plains Inventory and Monitoring, scientists noted some cottonwoods that appeared stressed but were uncertain whether it was from recent overspray of herbicide application to Tamarisk or due to water stress from a low water table (T. Folts-Zettner, SOPN Biologist, pers. comm). Additionally, scientists noted during their May 2014 riparian habitat assessment in the NRA that for the most part, the riparian vegetation overall looked good, with the exception of a few cottonwoods (M. Martin, NPS WRD Hydrologist, pers. comm.). Without a detailed study of the alluvial aquifer, specifically examining the depth-duration below ground (root zone) during the growing season, it's difficult to determine anything directly about resource support and condition.

Table 4.7.3-1. Classes for assessing groundwater condition at Lake Meredith National Recreation Area and Alibates Flint Quarries National Monument.

Condition Class	Description
Good	A good reference condition is one of sustainability; where on average, supply meets demand and associated resources, specifically the riparian-wetland system are well supported. When supply meets demand, we expect variability that reflects annual variation in environmental conditions (e.g., rainfall, evapotranspiration, pumping), but lacks an overall long-term declining water level trend. Riparian systems, when well supported by the local water table, are generally resilient enough to maintain viability through natural variations in hydrology, including periods of drought.
Moderate	A moderate condition is when groundwater levels fluctuate around a water table elevation that only provides marginal support for the wetland riparian system. In this scenario prolonged drought or excessive withdrawals could result in loss of the wetland-riparian system.
Significant Concern	A significant concern condition is when groundwater levels are so low in the alluvial aquifer that there is no hydrologic support for the wetland riparian system.

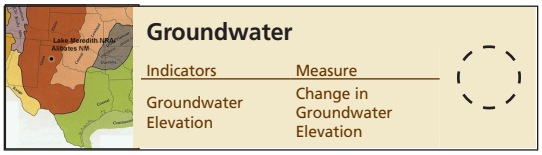


	None	D0-D4	D1-D4	D2-D4	D3-D4	D4
Current	15.95	84.05	58.10	32.96	14.29	2.94
Last Week 7/22/2014	16.58	83.42	57.97	33.37	14.98	3.28
3 Months Ago 4/29/2014	9.88	90.12	74.47	52.91	37.86	17.75
Start of Calendar Year 12/31/2013	28.48	71.52	43.84	21.15	5.82	0.79
Start of Water Year 10/1/2013	6.62	93.38	70.95	25.08	4.01	0.12
One Year Ago 7/30/2013	2.83	97.17	87.69	65.36	25.97	5.65

Figure 4.7.4-1. The U.S. Drought Monitor for Texas shows that Moore, Hutchinson, and Potter Counties (outlined in blue) are in extreme to exceptional drought conditions but improving since the start of the water year (7/29/2014) (NOAA 2014).

Table 4.7.4-1. Indicator, measure, and rationale of groundwater condition.

Indicator of Condition	Measure	Condition	Rationale for Condition
Groundwater Elevation	Change in Groundwater Elevation	Unknown	The alluvial aquifer and riparian vegetation are interconnected, and while it appears that the water table fluctuates quite a bit from year to year, we don't know exactly how much of a drop affects the wetland riparian vegetation. Without a detailed study of the alluvial aquifer, specifically examining the depth-duration below ground (root zone) during the growing season, it's difficult to determine anything directly about resource support and condition.



Overall Condition/Trend

For assessing the condition of groundwater at the NRA and NM, we chose one indicator (groundwater elevation) (Table 4.7.4-1). Based upon our review of the apparent groundwater condition relative to the ecological reference condition for the riparian vegetation, we are uncertain about the condition of this resource without more in depth analysis. The overall trend for the High Plains Aquifer is decreasing, which could impact the availability of groundwater within the alluvial aquifer in the future.

Key Uncertainties

There are numerous factors that may affect the trend of both the water table elevation in the alluvial aquifer and the stage of the Canadian River. One of the greatest variables is the natural hydrologic input, which affects both the river flows and groundwater elevations directly, and indirectly. The hydrologic input is unpredictable and may vary naturally from year to year and with climate change.

The alluvial aquifer is an extensive system and without adequate data, it is difficult to assess

the current condition of the groundwater resource without additional information.

4.7.5. Source of Expertise

The groundwater assessment was written by Michael Martin who is a hydrologist with the NPS Water Resources Division and has his Masters of Science in Watershed Science. His specialty areas include open channel flow, geomorphology, flood analysis, wetlands, and hydrology.

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4.8. Riparian Habitat

Indicators/Measures

- Hydrology (4 measures)
- Vegetation (6 measures)
- Erosion/Deposition (5 measures)

Condition – Trend– Confidence

Significant Concern - Insufficient Data - High

***This section is excerpted from the Proper Functioning Condition Assessment of the Canadian River and Blue Creek in Lake Meredith NRA report developed for the purposes of the condition assessment (Martin et al. 2015). For more information, go to http://www.nature.nps.gov/publications/nrpm/nrr.cfm.*

4.8.1. Background and Importance

Riparian wetlands are a type of non-tidal wetland formed along river and stream floodplains. These wetlands serve many functions including water purification, flood control, buffering riverbank erosion, habitat for numerous wildlife, fish, shellfish, and plant species, and also provide many recreational opportunities. In the arid west, riparian habitat is often in marked contrast with the surrounding terrestrial vegetation and is strongly influenced by the presence or absence of water (NPS-WRD 2011).

The National Park Service (NPS) has several wetland protection procedures and policies (Director's Order #77-1: Wetland Protection (2002), Procedural Manual #77-1 (2012), and NPS Management Policies (2006) to ensure a "no net loss" of wetlands throughout the NPS.

Setting

Lake Meredith National Recreation Area (Lake Meredith NRA) is situated in the High Plains of Texas, which is the southernmost extension of the Great Plains physiographic province of Western North America (Fenneman, 1931). The surface of the plains is remarkably flat throughout much of the area and, gently undulating in the remainder. Near the valley of the Canadian River, the land surface is highly dissected forming the "Canadian Breaks," which is an erosional terrain made up of rolling to steep hills. In addition to the "breaks," there are a few other features of surface relief; numerous

MICHAEL MARTIN

Figure 4.8.1-1. Blue Creek is the largest tributary that feeds into Lake Meredith.

shallow depressions or playas, sand dunes, and small stream valleys (Cronin, 1969). The regional climate is arid with only about 14 to 23 inches of rain falling per year. Additionally, mild winters and hot summers impose a very high evaporation potential over the area. The combination of low precipitation and high evaporation results in surface water resources being extremely limited.

Geohydrology

There are three distinct aquifers that support, to varying degrees, the riparian resources of the NRA: the High Plains Aquifer, which covers the upland plains; units in the Docken Group exposed in the canyon; and Quaternary age alluvium that fills the river and stream drainages. Groundwater from the Ogallala may be discharged along the higher elevation streams and other channels that have cut into the zone of saturation; some of this water is discharged through springs but a large portion is discharged from seeps and is consumed by plants and evaporation. Likewise, water bearing units that may exist in the Dockum Group likely discharge to springs and seeps in the tributary drainages of the canyon. However, the most important water bearing strata in Lake Meredith NRA are the Quaternary sediments that fill the active river and stream valleys, ephemeral tributaries, and to a lesser extent, some of the associated terraces. Generally, these recently deposited sediments are composed of poorly sorted gravel, sand and silt (Knowles, Nordstrom, and Klemt 1984) and may reach depths that exceed 100 feet along the Canadian River (Manford et al. 1960; Alexander 1961). It is these very linear, continuous aquifers that are in hydrologic connection with the river and stream channels, and most closely associated with the riparian resources of Lake Meredith NRA.

Canadian River Characteristics

All of the land encompassed by Lake Meredith NRA is in the immediate watershed of the Canadian River, and primarily consists of the relatively level uplands of the High Plains, the rolling to steep Canadian Breaks, and the Canadian River Canyon. The overall form of this canyon is a broad outer valley, with the "breaks" along the north and south margins, and an inner, steep-walled canyon leading down to the river. The outer valley is cut through the Ogallala Formation and the inner valley has cut through the Triassic Dockum Group. The bed of the Canadian River in the canyon is about 650 feet below the surrounding plains.

Elevations along the river in Texas range from about 3510 feet at the New Mexico state line to about 2936 feet at the normal pool elevation of Lake Meredith (Wilson and O'Brien 2000). The bottom of the Canadian River Canyon upstream of the lake is filled with extensive deposits of Quaternary alluvium and the river channel is mostly alluvial but has some limited interaction with the bedrock walls of the canyon. Specifically, within the study reach, there are about seven locations where meanders are constrained by bedrock cliffs. The overall form of the river is a sizable meandering stream with a moderate sinuosity. The scale of the system is quite large with the alluvial valley that may be as much as 5000 feet wide, and corresponding channel meanders with amplitudes of upwards of 1000 feet.

The meandering, sediment rich channel form that is characteristic of the Canadian River through Lake Meredith NRA is fairly consistent upstream to the New Mexico state line. Channel widths vary mostly between 50 and 100 feet, but some areas may exceed 200 feet. Except during higher flows, the active channel typically contains a continuous, shallow body of flowing water that is approximately one-fifth the size of the bank to bank width. Water depths of this inner channel are shallow, in the range of about 0.3-1.6 feet. The overall inner channel form varies with respect to flow depth. Many of the reaches display a meandering, single thread channel pattern, but because the river is transport limited, excess sediment maybe deposited as mid- and side-channel bars, shoals, and braided reaches.

The headwaters of the Canadian River originate on the east slopes of the southern Rocky Mountains in New Mexico, and from there, the river flows predominantly east, through the Texas Panhandle into Oklahoma, where it ultimately forms a confluence with

the Arkansas River west of Fort Smith, Arkansas. There are two major tributaries to the Canadian River in New Mexico; the Conchas River, and Ute Creek. Both of these tributaries enter the Canadian River above large reservoirs, of like names, respectively. Due to the operation of these facilities, most of the upstream runoff is stored at those locations, and very little of the New Mexico derived runoff reaches Lake Meredith NRA. Other tributaries to the Canadian River in New Mexico, downstream of Ute Creek include: Revuelto Creek, Tuscocoillo Canyon, Rana Canyon, Trujillo Creek, and Nara Visa Arroyo, but these drainages do not contribute substantial flow to the Canadian (Wilson and O'Brien 2000). The Canadian River through Lake Meredith NRA is most affected by the watershed in Texas, which includes about 115.8 river miles from the New Mexico state line to the confluence of Camp Creek at the headwaters of Lake Meredith. The total basin drainage area in Texas above Lake Meredith is in excess of 15,000 square miles.

The main Texas tributaries to the Canadian River include: Punta de Agua Creek, Carrizo Creek, Rita Blanca Creek, Red Deer Creek, and both East and West Amarillo Creeks, all of which provide most of the runoff through Lake Meredith NRA (Wilson and O'Brien 2000) . Additionally, at least eight drainages feed directly into the lake, the largest of which is Big Blue Creek (Figure 4.8.1-2). Most of the tributary creeks to the Canadian River are ephemeral and do not support perennial flow. Only substantial rainfall events will produce flow in most of these drainages. One exception is Punta de Agua Creek, which flows year round due to a substantial connection to the Ogallala Aquifer (Wilson and O'Brien 2000).

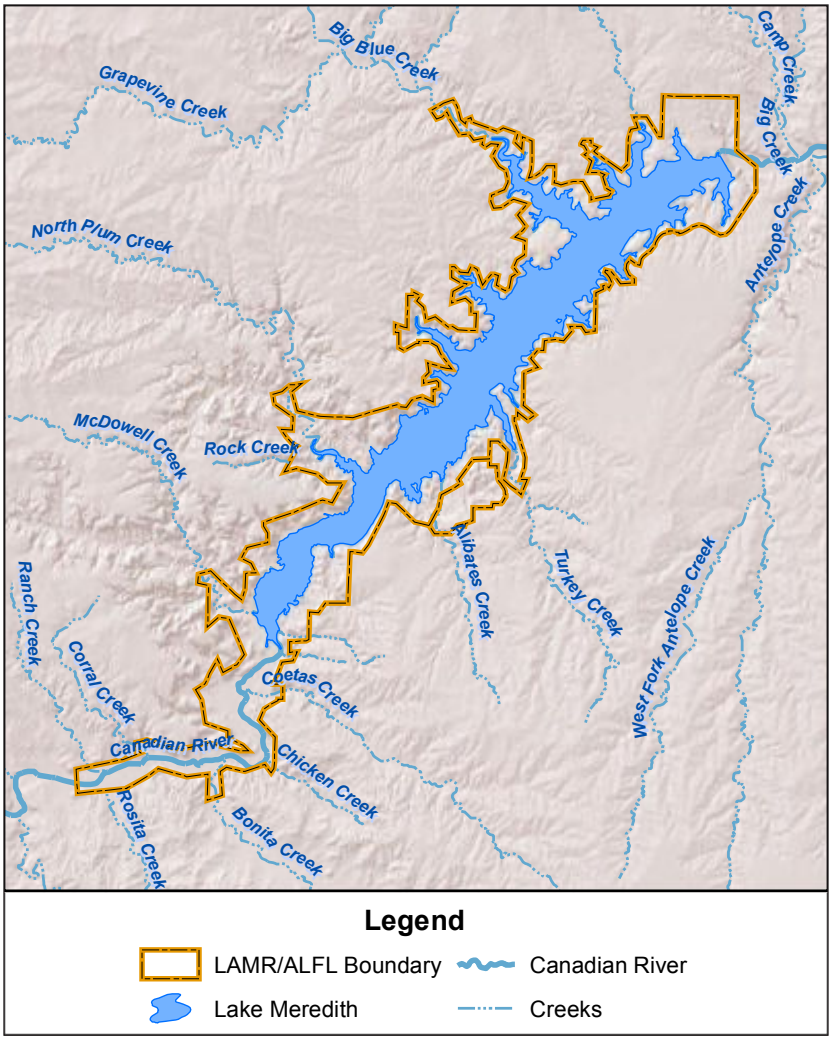

Figure 4.8.1-2. Several rivers and creeks feed into Lake Meredith, including the Canadian River and Blue Creek shown on the map.

4.8.2. Data and Methods

The purpose of our assessment was to determine the overall functional condition or ecological "health" of the river channel and its associated riparian corridor. To complete this assessment, we used "A User Guide to Assessing the Proper Functioning Condition (PFC) and the Supporting Science for Lotic Areas" (Prichard et. al. 1998). For this method, "Proper Functioning Condition" is the highest rating that can be given to a riparian area based on the perceived stability of the physical system, which in turn is dictated by the interaction of geologic formations, soil, water, and vegetation. This determination was made by an interdisciplinary team of technical experts from NPS' Water Resources Division and the SOPN I&M, who evaluated 15 hydrology, vegetation and erosion/deposition measures for three reaches along the Canadian River and for two reaches along Blue Creek (Figure 4.8.2-1). The river and creek were divided into shorter assessment reaches based on differences in geomorphology, hydrology, vegetation, land use or other factors

A riparian area in PFC is in dynamic equilibrium with its stream flow forces and channel processes. The system adjusts to handle larger runoff events with limited change in channel characteristics and associated

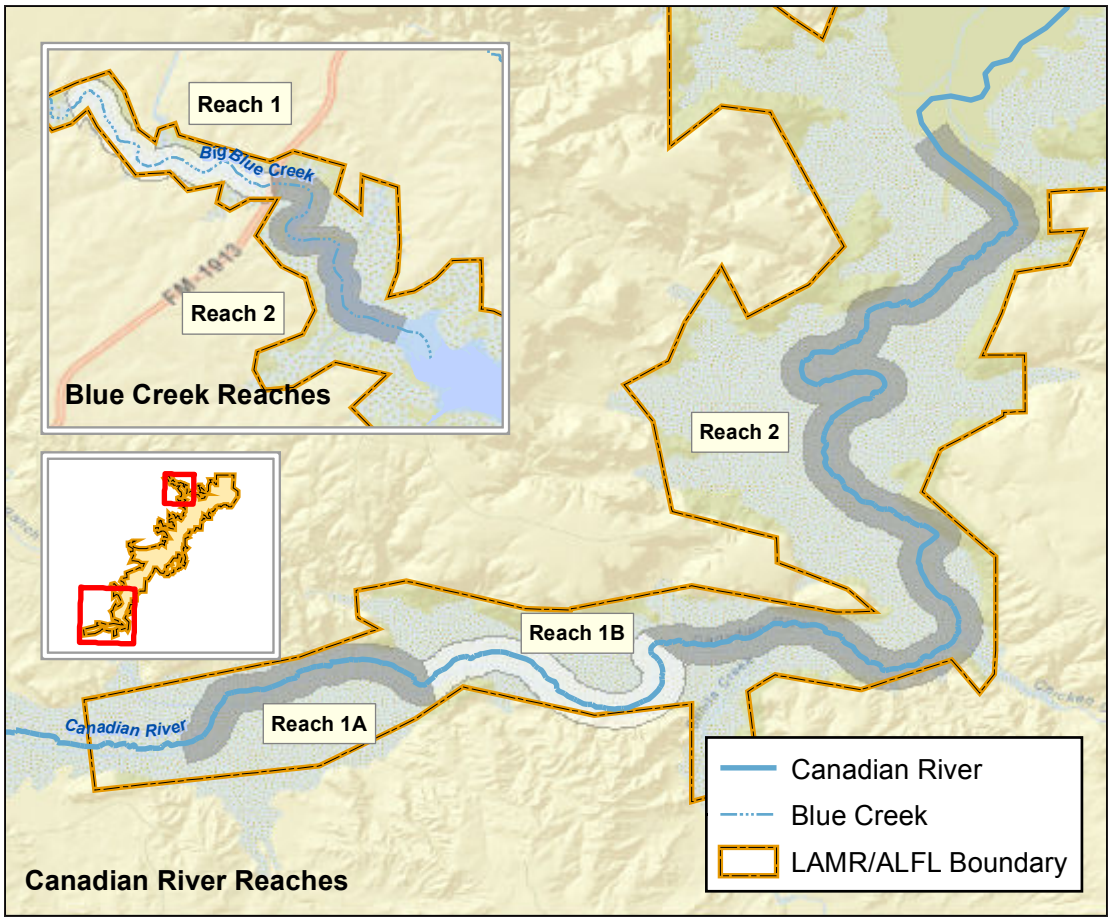

Figure 4.8.2-1. The riparian habitat rapid assessment along the Canadian River consisted of three reaches and two reaches along Blue Creek.

riparian-wetland plant communities. This limited change, such as some cutbank erosion and point bar expansion in stream meanders, is within the context of natural stream evolution and provides new geomorphic features for riparian-wetland vegetation recruitment. Because of this resiliency, riparian areas in PFC can maintain aquatic habitat, water quality enhancement and other important ecosystem functions, even after moderately large runoff events. In contrast, nonfunctional systems subjected to the same flows might exhibit excessive erosion and sediment loading, loss of aquatic and wetland habitat, and so on.

Both terrestrial and aquatic attributes and processes are important in riparian wetland areas and are used to assess the condition of a given area. This indicators used for this assessment included hydrology, vegetation, and erosion/deposition. The measures within each of these three categories, which included both attributes and processes are listed below

Indicator
Hydrology (4 measures)

Streamflow forces and channel processes are characteristics of a riparian wetland's hydrologic function, and four measures were assessed for this indicator.

Measure: Floodplain inundated frequently

A floodplain is topographically flat, a landform of unconsolidated sediments originating from the stream, and subject to periodic flooding, usually a recurrence interval between 1 and 3 years (Prichard et al. 1998). The floodplain's role is to handle a basin's discharge and sediment load by spreading out the water and sediment onto a low area adjacent to the stream. This hydrologic function dissipates energy, which keeps a riparian wetland in functioning condition. Periodic flooding also promotes vegetation growth, which contributes to a properly functioning riparian area as well.

Measure: Sinuosity, width/depth ratio, and gradient are in balance

Several channel parameters; specifically sinuosity, gradient, and width-to-depth ratio are closely related to a stream's ability to dissipate hydraulic energy during flood flows. When these parameters are in balance with the landscape setting, the channel is able to convey larger runoff events with limited change in channel characteristics and associated riparian-wetland plant communities. In a broad valley composed of fluvial sediments like the Canadian River Valley, these channel parameters have well-defined ranges of stability based on flow mechanics (Prichard et. al. 1998).

Measure: Riparian wetland area is widening or has achieved potential extent

Sediment capture develops floodplains, which in turn, aids functionality of a riparian wetland area. In addition, as sediment is deposited, vegetation can "take root", increasing certain types of vegetation such as sedges, willows, and rushes.

Measure: Upland watershed is not contributing to riparian wetland degradation

Assessing changes in water and/or sediment supply from uplands can help determine functionality of the riparian wetland area affected. Changes in upland conditions can affect the discharge, timing, and duration of streamflow events in lower areas, possibly degrading a riparian wetland's condition.

Indicator

Vegetation (6 measures)

Most riparian wetlands require some amount of vegetation to achieve functionality (Prichard et al. 1998). Different factors such as type, amount, and proportion of vegetation contribute to a wetland's condition. In order to accommodate periodic flooding, lateral distribution of vegetation is necessary. In addition, plants must be vigorous and able to maintain or recruit into the plant community to serve their various functions. Six measures were used to assess the condition of riparian vegetation.

Measure: There is a diverse age-class distribution of riparian wetland vegetation

Age class distribution is often associated with vigor of a system, and multiple age classes of vegetation provide recruitment and replacement. Not all age classes need to be present for a system to maintain or recover from a severe event, and the older age classes can usually persist even with degraded conditions.

Measure: There is diverse composition of riparian wetland vegetation

Not all plants need to be present within a riparian wetland for the system to maintain itself, but there needs to be enough variety for a wetland to recover and maintain its vegetative component. Limited number of species makes an area more vulnerable to extreme climatic changes or disease, although areas that contain unique water regimes or soils may naturally only support a limited number of plant species.

Measure: Species present indicate maintenance of riparian wetland soil moisture characteristics

Plants that grow in wetlands are hydrophytes and must be in contact with the water table in order to survive. Different types of plants require different wetness regimes and different plants vary in root depths. The root depths sometimes suggest that a water table may not be close to the surface if the plants growing are ones that usually have deeper root systems. Wetland plants are divided into different categories, indicating their preference for growing in wetlands or uplands and degree of wetness required.

Measure: Streambank vegetation is comprised of those plants or plant communities that have root masses capable of withstanding high streamflow events

Plants that have adapted to riparian wetland conditions, such as cottonwood, aspen, alder, willow, sedge, rush, and some grasses, develop root masses that help stabilize riverbanks, especially during high-flow events. If banks are undercut during storm or high runoff events, many changes can occur

to the channel's width/depth ratio, gradient, and sinuosity, which in turn, may decrease the system's ability to dissipate energy. The presence of obligate and facultative wetland plants is usually a good indication that the streambank will remain stabilized.

Measure: Riparian wetland plants exhibit high vigor

If plants are weakened or stressed, they are less able to withstand stressors making the riparian wetland more susceptible to degradation. On the other hand, plants that exhibit vigor are usually more equipped to maintain or recover from stressors.

Measure: Adequate riparian wetland vegetation cover is present to protect banks and dissipate energy during high flows

The amount of vegetation present indicates a wetland's ability to dissipate energy, protect riverbanks from collapse, filter sediment, and aid floodplain development, which also dissipates energy during storms or high runoff. Some bank erosion is a natural part of river channel evolution, but excessive erosion usually indicates some failure in the system.

Indicator
Erosion/Deposition (5 measures)

Erosion and depositional processes are naturally occurring within a stream or river system, however, excessive amounts of either indicate an imbalance in the system. Five measures were used to assess the erosion/deposition condition for this assessment.

Measure: Floodplain and channel characteristics are adequate to dissipate energy

Energy dissipation results from the presence of a floodplain, which distributes the water over a larger area, and channel characteristics such as sinuosity, which reduces the velocity of waterflow. In addition, objects such as rocks or large woody debris can also aid in energy dissipation.

Measure: Point bars are revegetating

In some channels, point bars form as part of the natural depositional process and subsequent vegetation colonization aids in erosion control when high runoff events occur. The vegetative type has to be ones that are capable of forming root masses that can withstand high flow occurrences.

Measure: Lateral stream movement is associated with natural sinuosity

Streams naturally adjust their channel by moving side to side without degrading the overall wetland environment. The movement is affected by many factors such as the type of stream, the type of materials that form the streambanks, and the types and amounts of vegetation growing along the banks. For example, streambanks composed of sandy materials will more easily erode than materials such as clay or silt, which provide more cohesiveness. Excessive movement can negatively impact a river/riparian area by diminishing the system's ability to dissipate energy.

Measure: System is vertically stable

This measure is used to determine whether a channel is lowering at a natural versus an accelerated rate. Naturally occurring channel lowering usually occurs over hundreds or more years, whereas, some accelerated lowering can occur over a decade or less. The channel lowering reduces the landscape's overall elevation including the valley bottom through erosion.

Measure: Stream is in balance with the water and sediment being supplied by the watershed

Stream channels adjust to water and sediment loads and are classified as either single thread or braided channels. Most braided channels indicate unnaturally high sediment loads, whereas, excessive erosion indicates an imbalance in water flow.

4.8.3. Reference Conditions

A riparian wetland area needs to be in dynamic equilibrium with its streamflow forces and channel processes to be considered in proper functioning condition. This requires the system to maintain itself and/or recover after large runoff events without significant changes to the stream channel characteristics or to the riparian wetland

Table 4.8.3-1. The reference conditions used to determine whether the condition of the riparian habitat is good, moderate, or of significant concern as adapted from Prichard et al. 1998.

Good	Moderate	Significant Concern
A good condition is referred to as a Proper Functioning Condition or PFC. PFC is a state of resiliency that allows a riparian wetland area to hold together during high flow events with a high degree of reliability. The resiliency allows an area to establish vegetative communities that create the structure necessary for fish and waterfowl habitat, to establish floodplains that help dissipate energy, and channel characteristics such as sinuosity and lower gradients, which help prevent streambank erosion.	A moderate concern condition is considered to be "Functional-At Risk" , which means that the riparian wetland area is in fundamental condition, but an existing soil, water, or vegetation indicator(s) is compromised making it susceptible to degradation. However, the majority of the riparian wetland indicators do not need to be compromised to receive a moderate condition rating.	A significant concern condition is considered to be "Nonfunctional". The riparian wetland area is not providing adequate vegetation, landform, or large woody debris to dissipate stream energy associated with high flows, therefore, erosion is not reduced and water quality degradation is occurring. In addition, channel characteristics are such that high flow events either deposit an inordinate amount of sediment or water flow results in excessive erosion.

vegetative communities. However, some change is expected and even necessary to maintain resiliency. In contrast, systems that are functional but susceptible to degradation due to failure in one or more of the attributes associated with either the hydrology, vegetation, or erosion/depositional processes are considered to be in moderate condition. Those systems that are not providing adequate functioning and subsequent protection are considered nonfunctional. These three states: proper function, functional-at risk, and nonfunctional, comprise the reference conditions against which the Historic Site's riparian wetland was assessed and is based on the condition definitions developed by Prichard et al. (1998) (Table 4.8.3-1). Prichard et al. (1998) also included a fourth condition class-Unknown- when sufficient information was unavailable to make a condition determination, however, this class was not applicable to the NRA's assessment therefore was excluded.

4.8.4. Condition and Trend

Table 4.8.4.1 summarizes the measures that were assessed for the Canadian River and Blue Creek reaches' condition assessments.

Canadian River Hydrology

Flow in the Canadian River is highly variable, both from year to year and within any given year. This variability of flow is well demonstrated by extensive flow data collected since the early part of the 20th Century. Over recent decades there have been numerous gage locations that have recorded discharge and other hydrologic parameters on the upstream reaches of the river. Currently, there are about 10 gages between the headwaters of the river and Lake Meredith NRA, three of which are in Texas. Daily reservoir storage data are also available from Canadian River Municipal Water Authority for Lake Meredith since it was built in 1964.

The nearest USGS gage is located at Amarillo TX (#07227500) about 17 miles upstream of Lake Meredith at the US 87-287 crossing. This gage has a datum of 2,989 feet (NGVD 29) and reports a contributing area of 15,376 square miles. It has been operated continuously since April 1938 and has a 77 year record of peak flows. Annual peaks range from about 1,000 cubic feet per second (cfs) to 135,000 cfs with most of the values well over 10,000 cfs. Mean annual flow, a rough measure of the relative "wetness" between years, shows wide variability with a low of 8 cfs in 2011 to a high of over 2,000 cfs in 1941 (USGS 2015a) (Figure 4.8.4-1).

Regulation of the Canadian River began in the upper watershed with the completion

Table 4.8.4-1. Results for the riparian habitat condition assessment along the Canadian River and Blue Creek at Lake Meredith NRA (Martin et al. 2015).

Indicator/ Measure	Canadian River			Blue Creek	
	Reach 1A	Reach 1B	Reach 2	Reach 1	Reach 2
Hydrology					
Floodplain	3000-5000 cfs flows within the previous 2-3 days obviously inundated broad portions of the floodplain to a substantial depth. Even at the present 900-1000 cfs most of the reach is above bank full.			The channel was not incised. Therefore, it was expected that the floodplain would be inundated in "relatively frequent" precipitation events. For some sub-reaches this was true, but in others where the channel had widened extensively and had developed a braided form, there was little to no opportunity for channel/floodplain connectivity.	
Sinuosity, width/ depth ratio, and gradient	This reach was subject to heavy ORV use and included several major ORV river access points. Width/depth ratio increased substantially where ORVs operated near or on channel banks. Many bank and point bar locations were devoid of vegetation, and resulting destabilized sediment was deposited in the channel as bars, deltas and shoals in these areas. This resulted in a wide, shallow, sediment-choked channel form that was braided in many areas.	This reach had a moderate sinuosity of 1.4, and a bedrock controlled gradient of less than one percent, but width-to-depth ratios were well above the expected value for this setting due to channel braiding and bank loss.	Sinuosity of about 1.9, bedrock supported gradient of less than one percent and width to depth ratios in the range of about 12.	Channel sinuosity of 1.3 was appropriate but the width/ depth ratio was much higher than expected for this landscape setting. Bedrock control prevented the channel from incising. In most of the reach the channel was aggrading due to excess sediment supply.	Excess sediment loading associated with absence of soil-stabilizing vegetation on many upland, floodplain and streambank locations resulted in a braided channel form in much of the reach. The channel sinuosity was 1.4 and the gradient was controlled by shallow bedrock. Because the channel was very wide and shallow (*braided)* in many segments, the W:D ratio was not in balance with the landscape setting.
Riparian wetland area achieved potential	Bank destabilization and channel widening associated with ORV activity caused riparian area narrowing.	Much of this reach was a meandering form with associated regeneration of riparian-wetland vegetation. However, in some sections excess sediment led to a braided channel form and a widening of the active channel that occured at the expense of the adjacent riparian system.	Yes, area achieved potential.	Large areas including point bars and banks of straight reaches were devoid of vegetation. The channel was widening, narrowing the riparian zone.	
Upland watershed	ORV use was degrading or eliminating bank-stabilizing and riparian area vegetation at many locations, allowing excessive sediment to enter the channel. There was often a direct, vegetated path for sediment disturbed by ORVs to be transported from the uplands into the river.	There were obvious signs of upland degradation and excessive sediment input.	no comment	Many upland areas just above the floodplain were missing expected soil-stabilizing vegetation and there were direct pathways for exposed sediment to be transported to the floodplain and channel. Although sediment inputs to the channel may be more directly affected by bank destabilization, the unvegetated upland areas were contributing to channel sedimentation.	On many upland and streambank locations the expected soil-stabilizing vegetation is in poor condition or was completely absent, and there were direct pathways for exposed sediment to be transported to the channel. Although sediment inputs to the channel may be more directly affected by streambank destabilization, the destabilized upland areas were also contributing to channel sedimentation.

Table 4.8.4-1. Results for the riparian habitat condition assessment along the Canadian River and Blue Creek at Lake Meredith NRA (Martin et al. 2015) (cont.)

Indicator/ Measure	Canadian River			Blue Creek	
	Reach 1A	Reach 1B	Reach 2	Reach 1	Reach 2
Vegetation					
Diverse age-class distribution of riparian-wetland vegetation	Three age classes of cottonwoods (*Populus deltoides)* were present except where ORV use and camping were concentrated.	Three age classes of cottonwoods (*Populus deltoides)* were present.	Three age classes of cottonwoods (*Populus deltoides)* were present, including a recruitment class. Great Plains false willow (*Baccharis salicina)* was common along the banks and is healthy and apparently spreading. Young tamarisk plants were found at some locations (*spotty, not dominant)*. In the herbaceous layer, common reed (*Phragmites australis)* and common threesquare (*Schoenoplectus pungens)* were dominant and vigorous. Switchgrass (*Panicum virgatum)* and giant sandreed (*Calamovilfa gigantea)* were also present and vigorous, but not dominant.	In most sub-reaches, ORVs appear to use one side of the stream much more heavily than the other. On the less-used sides there are often multiple age classes of cottonwood (*Populus deltoides)*, including a recruitment age class. Other woody species such as desert false indigo (*Amorpha fruiticosa)*, golden currant (*Ribes aureum)*, Great Plains false willow (*Baccharis salicina)* and grape (*Vitis sp.)* appear to be in fairly good condition. Common threesquare (*Schoenoplectus pungens)* and switchgrass (*Panicum virgatum)* are present on some of these banks, but at most sites these herbaceous species are patchy in distribution and are not vigorous or spreading. On stream sides that appear to experience more ORV use, bank-stabilizing herbaceous vegetation is typically in poor condition or is absent. The condition of vegetation on the less-used streambanks led us to believe that there is a potential for recovery of riparian-wetland vegetation in the higher use areas if vegetation loss could be significantly reduced	On less-impacted sub-reaches there are often multiple age classes of cottonwood (*Populus deltoides)*, including a recruitment age class. Other woody species in these sub-reaches, including desert false indigo (*Amorpha fruiticosa)*, narrowleaf willow (*Salix exigua)* and Great Plains false willow (*Baccharis salicina)*, appear to be in fairly good condition and are reproducing. Common threesquare (*Schoenoplectus pungens)*, switchgrass (*Panicum virgatum)*, spikerush (*Eleocharis palustris)*, Indian dogbane (*Apocynum cannabinum)* and horsetail (*Equisetum sp.)* are present on these less-impacted banks. However, in the sub-reaches where the channel has widened or point bars appear to be heavily used by ORVs, such stabilizing herbaceous riparian-wetland vegetation is in poor condition or is completely absent. The vegetation on the less-impacted stream banks led us to believe that there is a potential for recovery of riparian-wetland vegetation in the higher use areas if vegetation loss could be significantly reduced
Diverse composition of riparian-wetland vegetation	In addition to cottonwoods, Great Plains false willow (*Baccharis salicina)* was abundant along the banks except where directly impacted or destroyed by ORV use. Grasses were also present in vegetated bank areas, but not dominant and some exotics were present as well.				
Species present indicate maintenance of riparian-wetland soil moisture characteristics	Species present indicated maintenance of riparian-wetland soil moisture characteristics in all reaches				

Table 4.8.4-1. Results for the riparian habitat condition assessment along the Canadian River and Blue Creek at Lake Meredith NRA (Martin et al. 2015) (cont.)

Indicator/ Measure	Canadian River			Blue Creek	
	Reach 1A	Reach 1B	Reach 2	Reach 1	Reach 2
Root masses are capable of withstanding high-stream flow events	No obvious evidence of vegetation loss associated with the recent 5000 cfs flow event.			Common threesquare was the only obligate herbaceous wetland species observed in this reach, and it was patchy, small in stature and not vigorous or spreading. We suspected that several potential/ expected herbaceous wetland species are missing from the stream banks.	Yes, plants capable of withstanding high streamflow events were present.
Vigorous plants	Herbaceous and woody vegetation had been severely damaged or completely destroyed by ORV use on many river bank, floodplain and point bar locations, especially at ORV river access points and along favored travel corridors	Many cottonwoods on the floodplain had substantial numbers of dead limbs. This could be due to ongoing "extreme" to "exceptional" drought conditions over the past few years, but park staff note that drift from aerial herbicide applications to control tamarisk (*2011)* may also be a factor.	Same as Reach 1B comments and some very dense cottonwood galleries did not show such dead material.		Yes, plants were vigorous.
Vegetative cover is present to protect banks and dissipate energy		no comments	Almost all banks had 90-100% cover with native riparian-wetland species.	n/a	No, adequate plant cover was absent.
Erosion/Deposition					
Floodplain and channel characteristics	Floodplain and channel characteristics were adequate to dissipate energy.			The channel and floodplain features of this reach are mostly devoid of anchoring vegetation, and this lack of stable bank structure results in energy dissipation through erosion and sediment transport, further degrading the system	The channel and floodplain features of this reach are mostly devoid of anchoring vegetation, and this lack of stable bank structure results in energy dissipation through erosion and sediment transport, further degrading the system.
Point bars	Point bars tended to be heavily used by ORVs in this reach, leading to substantial vegetation loss.	In general, point bars were present but appeared to be more heavily used by off-road vehicles than other areas, and they exhibited substantial, localized vegetation loss.	Yes, point bars were revegetating.	Point bars, where present, were devoid of most vegetation	
Lateral stream movement	Much of the lateral stream movement is associated with bank loss and channel widening at the expense of the riparian system.	Lateral stream movement was not associated with the reach's natural sinuosity.	Yes, movement was associated with natural sinuosity.	Loss of bank vegetation and structure resulted in channel widening not associated with natural sinuosity.	Braided channel form was not consistent with natural sinuosity.
Vertical stability	System was vertically stable.			Periodic bedrock outcrops provide evidence of likely vertical bedrock control	System was vertically stable.
Balance of water and sediment	Excessive sediment input in some areas exceeded the river's transport capacity, resulting in sediment deposition in the channel as bars, deltas and shoals.		Yes, reach was in balance with the water and sediment being supplied by the watershed.	In isolated sub-reaches a single-thread meandering channel was transporting sediment supplied to it, but the majority of reach was aggrading due to oversupply of sediment.	Much of the reach had a braided channel form due to oversupply of sediment.

of the Conchas Dam in 1939, and in 1963, a second dam, the Ute Creek Dam was constructed. Together these structures have altered the natural flow of the Canadian River through Lake Meredith NRA by decreasing the magnitude of the annual peak flows and changing the overall timing of the annual hydrograph. The effect of these dams is even more pronounced upstream. The USGS gage near Logan, New Mexico (#07227000) about 1.5 miles downstream from Ute Dam, has a record from 1904 to the present and demonstrates a dramatic shift in peak flows first in the early 1940s and again in the mid-1960s (USGS 2015b) (Figure 4.8.4-2).

In addition to changing the flow regime, dams also alter the sediment regime of a river. Based on a 1992 survey, the Ute Reservoir had accumulated a volume of 27,809 acre-feet of sediment since its construction, which accounts for about 10 percent of the initial storage, or an average annual loss of about of 930 acre-feet of sediment from the river system (Ferrari 1993). This volume of sediment, while not able to pass downstream to Texas, probably has little measurable effect on the river system in the area of Lake Meredith NRA. Examination of aerial imagery suggests that the Canadian River above Lake Meredith NRA upstream to the state line has an abundance of sediment, and it appears that the inner channel is very transport limited throughout its length.

Even though there has been an obvious reduction in peak flows on the Canadian River below the two structures, the effect at Lake Meredith NRA is much more subdued because of several large tributaries that feed the Canadian downstream of New Mexico. With that, frequent flows are still capable of exceeding channel capacity and inundating broad areas of the floodplain. At the time of the site visit (May 28 and 29, 2014), the river had recently responded to substantial local rainfall events and had peaked at about 5000 cfs. This flow greatly exceeded the channel capacity and flooded broad reaches of the geomorphic floodplain leaving extensive areas of sediment deposition as well as zones of scour in overflow channels and other floodplain features. This was not a rare event.

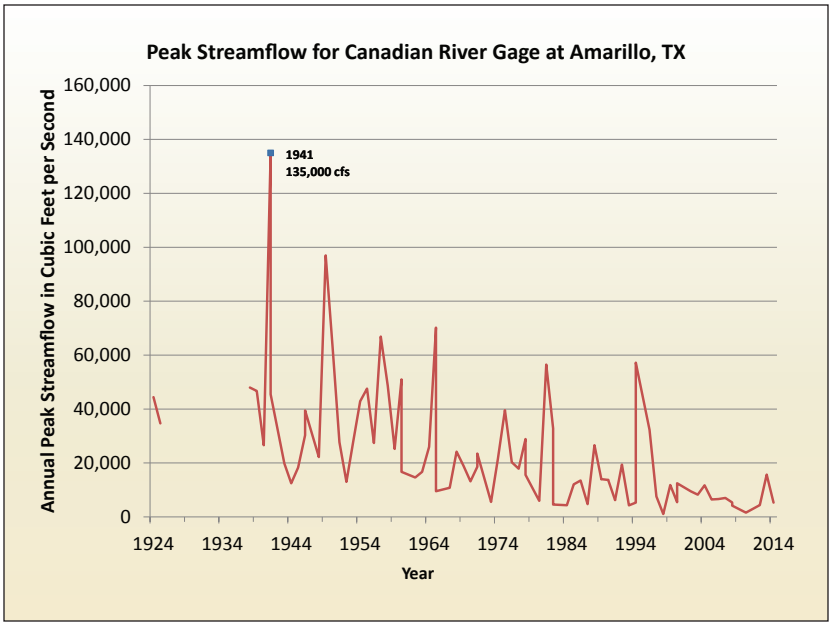

Figure 4.8.4-1. Annual peak flow record for the Canadian River at Amarillo, TX, gage #07227500. Note the apparent downward trend over time (USGS 2015a)

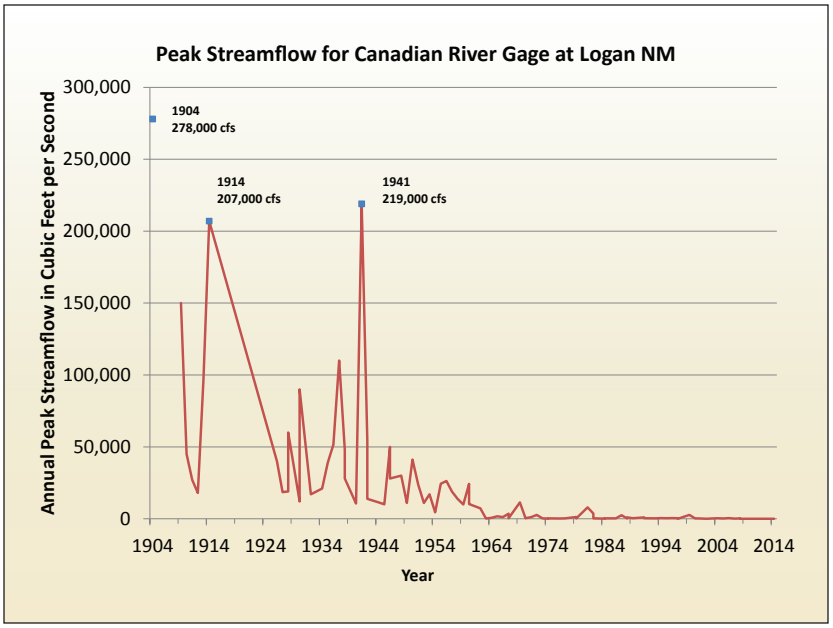

Figure 4.8.4-2. Annual peak flow record for the Canadian River at Logan NM, gage #07227000. Note the stepped decrease in values, first in the 1940s and again in the mid-1960s (USGS 2015b).

The discharge value of about 5000 cfs was approached or exceeded at least four times in the remaining summer months of 2014. Furthermore, the gage record has recorded numerous annual peaks that have exceeded 5000 cfs both before and since completion of the Ute Dam about 50 years ago.

To support a healthy riparian system, high flows must exceed the channel capacity and spill onto the floodplain on a fairly frequent basis. Under natural conditions, the Canadian River would have experienced sizable flows that exceeded channel capacity every few years, on average. However, even with the regulated flow regime that currently exists, flow still appears to access the floodplain regularly. At the time of our site visit, the river stage was in excess of bankfull at a discharge of about 600 cfs. A few days prior to our visit, the flow had reached 4800 cfs and the associated stage had inundated broad areas of the adjoining floodplains. As already explained, a discharge in the range of 5000 cfs is a fairly modest flow for this river, occurring at least once almost every year. So, based on observations made during the site visit and our knowledge of the Canadian River flow regime from the flow record, we concluded that the lower terraces and other near-channel features are inundated on a relatively frequent basis and considered the inundation of floodplain measure to be in good condition for all three reaches.

The sinuosity (channel length/linear distance) along this portion of the Canadian River varies from about 1.2 in Reach 1-A to about 1.9 in Reach 2. Reach1-B has an intermediate sinuosity of 1.4. These values are at or above the expected "stable" value of 1.2 for this channel type and landscape setting, and the well-developed meander pattern would result in good energy dissipation during bankfull and overbank flows. The channel gradient (rise/run) in the assessed reaches of the Canadian River were all in the range of about 0.1 percent, well within the stable range of less than 2.0 percent for this channel type.

Prevailing width-to-depth ratios varied between all of the reaches. In sections where a single thread channel was dominant, channel widths varied between about 50 and 70 feet and associated width-depth were in the range of the expected value of 12. In the braided reaches, however; the channel widths generally exceed 150 feet and in the sections with the greatest bank loss approach 200 feet. With the corresponding reduced depths, resulting width-depth were much greater than expected for this geomorphic setting. Reach 1-A was dominated by these braided reaches. In Reach 1-B, much of the channel was a single thread form but there were still enough segments undergoing braiding and widening. Reach 2 was dominated by a single-thread channel and was the only section considered to be in good condition.

Along most of the length of the Canadian River reaches we assessed, the channel form was meandering and was constantly allowing opportunity for regeneration of riparian-wetland vegetation. However, in some reaches, most notably several locations in Reach 1-A, and to a lesser extent 1-B, excess sediment led to a braided channel form and a widening of the active channel that occurs at the expense of the adjacent riparian system. Consequently, we consider this measure to be in a degraded condition for these two upstream reaches. In Reach 2 of the Canadian River we did not observe the same distinct channel widening suggesting that the riparian-wetland area is at or near its potential extent and is considered to be in good condition for this lower reach.

Throughout the upper two reaches, Reach 1-A and 1-B of the Canadian River, we observed extensive degradation of the uplands adjacent to the channel. Additionally, there was a great deal of bedload sediment within the active channel along these two reaches of the river, often times resulting in braiding and shoaling. Although the entire Canadian River system in Texas appears to be very sediment rich and transport limited, the aggradation in the channel along these reaches suggests excessive input of sediment from the adjacent uplands. Consequently, we concluded that the upland watershed is contributing to riparian-wetland degradation and considered this measure to be degraded for both of these reaches. Conversely, in the lower reach of the Canadian River Reach 2, there were no obvious signs of upland degradation or excessive sediment input and consider this reach to be in good condition for this measure.

Blue Creek Hydrology

Blue Creek is a tributary to the Canadian River that drains directly into Lake Meredith from the north. There is a USGS gage on Blue Creek (#07227890) where highway FM 1913 crosses over the creek. The elevation of the gage is 2,933.19 feet (NGVD88) and it is reported to drain a watershed of 407 square miles. The gage has only been in operation since 2010, and in that time interval, the four recorded annual peak flows have ranged from 22 to 535 cfs. Based on the daily discharge record at the gage, Blue creek appears to be ephemeral, flowing only in response to rainfall. Also, it appears that the creek may have a very "flashy" or rapid response to rainfall (USGS 2015c) (Figure 4.8.4-3). Moreover, the peaks that do occur probably exceed the channel capacity by a fair margin, inundating the low terraces and adjacent floodplains.

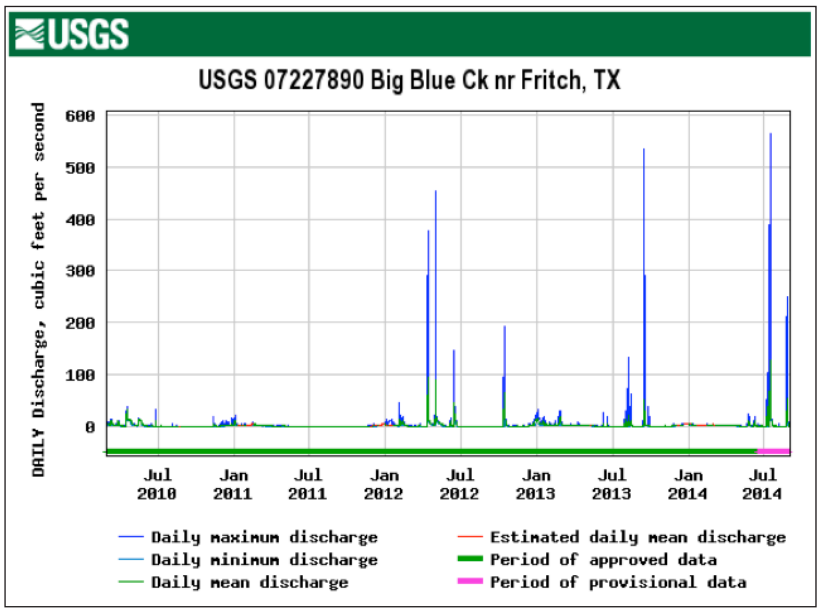

Figure 4.8.4-3. Mean daily flow record for the Big Blue Creek (Blue Creek). Note the near-zero baseflow versus the isolated peaks (USGS 2015c).

At the time of our site visit, the stage of Blue Creek was below bankfull at a discharge of about 1-2 cfs. A few days prior to our visit, the flow had exceeded 20 cfs and the associated stage had inundated areas adjacent to the channel. There is not a substantial difference in elevation between the active channel and the associated floodplain, where present (i.e., the channel is not incised) so, even during moderate runoff events, we expect the floodplain would be inundated. Based on the observations we made regarding channel capacity, and our knowledge of the flashy nature of Blue Creek, we concluded that when there is a well-defined floodplain adjacent to the active channel, it is inundated on a relatively frequent basis and consider this measure to be in good condition for both reaches.

The sinuosity (channel length/linear distance) along this portion of Blue Creek varied from about 1.3 in the upper reach to only about 1.4 in the lower reach. These values were both above the expected "stable" value of 1.2 for this channel type and landscape setting. Bedrock control prevents the channel from incising and "locks" the gradient at less than 1 percent. In most of the stream segments, the channel was aggrading due to excess sediment supply and the resulting width-depth are well above what would be expected for this setting. Because of the excessive width-depth values, we consider this measure to be degraded for both reaches.

Excessive sediment inputs from the destabilized channel banks and overbank areas have led to development of a braided channel form along most of Blue Creek (Figures 4.8.4-4). As this type of channel widens in response to bank erosion and sediment deposition, there is an associated narrowing of the adjacent riparian habitat. Consequently, we consider this measure to be degraded for the two Blue Creek assessment reaches.

Along both Blue Creek assessment reaches it was common for riparian-wetland vegetation on channel banks and overbank areas (floodplains) to be in poor condition or completely absent. Additionally, many upland areas just above the floodplains are missing expected soil-stabilizing vegetation and there were direct pathways for exposed sediment to be transported toward and into the channel. Sediment deposition in the channel in most of these two assessment reaches was excessive for this landscape setting, often times resulting in braiding and shoaling. Consequently, we concluded that the upland


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Figure 4.8.4-4. Excessive sediment inputs along the reaches assessed for Blue Creek has led to the development of braided channels.

watershed is contributing to riparian-wetland degradation in both reaches.

Canadian River Vegetation

Plains cottonwood (*Populus deltoides*), Great Plains false willow (*Baccharis salicina*) and narrowleaf willow (*Salix exigua*) were the key native woody riparian species we observed along the Canadian River. For cottonwood, there were three age classes present on all three assessment reaches (including recruitment age class). However, in Reach 1-A, this was the case only on the north side of the river. On the south side where ORV tracks and trails were very evident, middle-aged and older cottonwoods near the river were often highly stressed or dead, and recruitment was minimal. Great Plains false willow was a common and often dominant species on the upper banks and point bars of all three assessment reaches. This species was healthy and apparently spreading on Reaches 1-B and 2, however, in Reach 1-A the plants were in poor condition or entirely missing where vehicles appear to access the river from the floodplain and on heavily used point bars. Narrowleaf willow was not observed along the two reaches subject to ORV use (Reaches 1-A and 1-B), but became a co-dominant of the riparian shrub community throughout much of Reach 2. Tamarisk was also present as young plants in Reaches 1-A and 1-B, but distribution was spotty and it was never a dominant species. Tamarisk was more common and had several age classes along parts of Reach 2, but it was not a dominant species there either.

Common reed (*Phragmites australis*) and common threesquare (*Schoenoplectus pungens*) were the dominant herbaceous species on the river banks, point bars, side-channel bars and other near-channel features of all three Canadian River assessment reaches. Switchgrass (*Panicum virgatum*) and giant sandreed (*Calamovilfa gigantea*) were also components of these herbaceous communities, but they were not dominant. On Reach 2, and to a lesser extent on Reach 1-B, these plant species were vigorous and covered the majority of the river bank and other near-channel surfaces, where expected and considered to be in good condition. On Reach 1-A these species were observed in some areas, but there were many river bank, point bar and lower floodplain locations where vegetation was in poor condition or completely absent for this measure.

The woody and herbaceous riparian-wetland species described above represent adequate diversity (as defined by the PFC method) for Reaches 1-B and 2. Although there was substantial loss of riparian-wetland vegetation along Reach 1-A as described previously, key species were still present in this reach to support recovery of a properly functioning riparian system if vegetation loss could be significantly reduced or eliminated. For these reasons, we considered this measure to be in good condition for all three assessment reaches.

All of the plant species present were characteristic of riparian-wetland plant communities in the region, and therefore indicate maintenance of appropriate soil

moisture conditions. There was no evidence of a shift from riparian-wetland vegetation to upland vegetation, therefore, considered this measure to be good for all three assessment reaches on the Canadian River.

The dominant herbaceous plant species (common reed and common threesquare) on the streambanks and bar features of the three assessment reaches were rhizomatous wetland plants with dense root systems that bind the soil and prevent erosion during high flows. The other herbaceous species (switchgrass and giant sandreed) occupied drier locations higher up on the banks, but both have root systems that are excellent soil stabilizers and can withstand the energy of higher flows. The dominant woody riparian species (plains cottonwood, Great Plains false willow and narrowleaf willow) also have root masses capable of withstanding high flow events.

Despite the absence of expected streambank vegetation along much of Reach 1-A, the vegetation that does exist was composed of riparian-wetland species that had root masses capable of withstanding high streamflow events, so we consider this to be in good condition for all assessment reaches.

On Reach 1-A, expected herbaceous and woody riparian-wetland vegetation was missing along many river bank, point bar and floodplain locations. Riparian-wetland vegetation was also missing along some portions of Reach 1-B, but this condition was less common than on Reach 1-A. The riparian-wetland vegetation on the channel banks, point bars and other low floodplain features of Reach 2 was vigorous.

Many middle-aged to older cottonwood trees on the floodplains of all three Canadian River assessment reaches had substantial numbers of dead limbs. This could be due to ongoing "extreme" to "exceptional" drought conditions over the past few years, but park staff noted that drift from aerial herbicide applications to control tamarisk (2011) may also be a factor. Dead limbs were very common on Reach 1-A, and quite a few trees appeared to be completely dead. ORV use, which can cause soil compaction or root damage, may be an additional factor affecting the condition of cottonwoods on this reach.

We considered Reach 2 to be in good condition because the riparian-wetland vegetation along the river banks, point bars and other low floodplain features was vigorous. We rated Reach 1-A as degraded because of the poor condition or absence of herbaceous and woody vegetation at many bank, point bar and floodplain locations. Reach 1-B was in good condition because absence of bank vegetation was much less common than on Reach 1-A, and the overall vigor of such vegetation was adequate to support functional riparian conditions.

There wasn't adequate riparian-wetland vegetative cover present to protect banks and dissipate energy during high flows along Reach 1-A as described previously. Banks on this reach were clearly eroding and depositing excessive sediment into the river channel. Reach 2 was rated in good condition because, where expected, the banks were at or near 100% cover of native riparian-wetland vegetation that can withstand the energy of frequent to moderately large floods. Reach 1-B was also rated in good condition despite absence of expected bank vegetation at some locations because this condition was much less frequent than on Reach 1-A, and we didn't perceive an overall threat to bank stability under current conditions.

<u>Blue Creek Vegetation</u>

Riparian-wetland vegetation on most channel banks, point bars and other low floodplain features in Reach 1 and Reach 2 of Blue Creek was in poor condition or was missing entirely. However, in the less-impacted sections there were often multiple age classes of cottonwood (*Populus deltoides*), including a recruitment class. Other woody species such as desert false indigo (*Amorpha fruiticosa*) and Great Plains false willow (*Baccharis salicina*) were in fairly good condition in these segments, and they appeared to be reproducing in portions of Reach 2. Narrowleaf willow (*Salix exigua*), an excellent soil/bank-stabilizing woody species that spreads rapidly, was present and

reproducing in Reach 2, but was not observed Reach 1.

Common threesquare (*Schoenoplectus pungens*) and switchgrass (*Panicum virgatum*) were present on some of the less-impacted banks in Reach 1, but in most cases these herbaceous species were patchy in distribution and were not vigorous or spreading. The herbaceous riparian-wetland communities in the less-impacted portions of Reach 2 were more diverse than in Reach 1, with common threesquare, switchgrass, spikerush (*Eleocharis palustris*), Indian dogbane (*Apocynum cannabinum*) and horsetail (*Equisetum sp.*) present on banks and other low surfaces.

We observed only one rhizomatous herbaceous wetland species (common threesquare) on the less-impacted channel banks and some other low floodplain surfaces, and where this species did exist, it was very patchy in distribution and was not vigorous or spreading and as a result considered the condition to be degraded for Reach 1. Reach 2 was considered to be in good condition because in the less impacted sub-reaches there were several herbaceous wetland-riparian species that were fairly vigorous and spreading, narrowleaf willow was part of the woody community, and there appeared to be a better overall potential for riparian-wetland vegetation recovery.

As described above, common threesquare was the only herbaceous wetland plant species with the capacity to anchor streambanks, point bars and other low floodplain features during high flow events. For that reason we consider this measure to be degraded for Reach 1 but in good condition for Reach 2 because of the greater diversity of both herbaceous and woody riparian-wetland species.

Where they existed in the less-impacted segments of both Blue Creek assessment reaches, the species present indicated maintenance of riparian-wetland soil moisture characteristics and was considered to be in good condition.

Although common threesquare was present on some of the less-impacted creek banks and other near-channel surfaces along Reach 1, it was very patchy in distribution, small in stature, and not vigorous or spreading. But we considered Reach 2 to be in good condition because in the less-impacted segments, there was much broader diversity of woody and herbaceous streambank species with root systems that could withstand higher stream flows, including narrowleaf willow, horsetail, common threesquare, spikerush and others. In addition, both woody and herbaceous wetland-riparian species were in fairly good condition and reproducing.

Throughout most of both Blue Creek assessment reaches the channel had widened substantially. Riparian-wetland vegetation was in poor condition or was completely absent from many point bars and channel banks, which substantially reduced the system's capacity to resist erosion and dissipate energy during high flows. We consider this measure to be degraded for Reach 1 and Reach 2.

<u>Canadian River Erosion/Deposition</u>

Given the sheer scale of the Canadian River system through Lake Meredith NRA, channel and overbank roughness, including extensive floodplains and broad point bars with cutoff chutes, provided considerable energy dissipation during frequent to moderately large floods. Also, on these extensive floodplains there was woody vegetation that added to energy dissipation through hydraulic roughness and consider this measure to be in good condition for all three assessment reaches of the Canadian River.

In Reach 1-B and Reach 2, we observed distinct signs of recruitment for plains cottonwood and Great Plains false willow and vigorous growth of common reed and common threesquare on point bars, side-channel bars, low terraces, and other near-channel features. On some point bar locations in Reach 1-B, we observed vegetation degradation or loss, but overall there was recruitment and spreading of these species on these and other near-channel features. Consequently, we considered Reaches 1-B and 2 to be in good condition for this

measure. Conversely, we saw little in the way of riparian-wetland vegetation recruitment on point bars or other near-channel features on most of Reach 1-A, and considered it to be in a degraded condition.

Natural lateral channel migration occurs in many locations along the Canadian River as was evidenced by numerous cutbank/point bar pairings, meander scars and similar features. However, in the two reaches within the designated off-road vehicle area there was significant channel widening resulting from absence of bank-stabilizing vegetation, excessive sediment inputs and channel braiding only considered Reach 2 to be in good condition.

Vertical stability is a very important element in evaluating conditions of erosion and deposition in riparian systems. The Canadian River assessment reaches did not exhibit typical attributes of vertically unstable riparian systems such as a v-shaped (incised) channels, steep eroding banks, headcuts, or disconnection of the channel from the floodplain. Also, although the river is almost completely alluvial, there are about seven locations where the active channel encounters the bedrock wall of the canyon, suggesting the presence of vertical bedrock control resulting in a good condition for all three reaches.

The balance between the river system and incoming sediment was not consistent across the three Canadian River assessment reaches. The two upper reaches, 1-A and 1-B, were receiving a large amount of sediment from the destabilized channel banks and uplands adjacent to the river. Consequently, we rated the two upper reaches as degraded.

For Reach 2 we did not see areas that were receiving large amounts of sediment from the watershed (including adjacent uplands), nor did we see the absence of riparian-wetland vegetation that exists along the upstream reaches. Furthermore, there were no signs of systemic bank instability along this reach, and few indications of channel braiding. We found Reach 2 to be in balance with the water and sediment being supplied by the watershed.

Blue Creek Erosion/Deposition

Many of the geomorphic features that help to disperse flow energy, such as well-vegetated floodplains and point bars with cutoff chutes, were generally absent along Blue Creek. In the sub-reaches where such geomorphic features were present, they were mostly devoid of vegetation. The stream energy that was focused on unvegetated/destabilized banks and floodplain features generated large volumes of sediment that exceeded the available transport energy of the creek. As this sediment was deposited in the channel it aggraded and more erosive pressure was put on the unstable banks, further adding to excessive erosion. For these reasons, we rated this measure to be degraded for both reaches of Blue Creek.

Practically all of the point bars along both Blue Creek assessment reaches were devoid of most vegetation, therefore considered degraded for both reaches.

There was a widespread absence of streambank vegetation and structure throughout both reaches of Blue Creek. Stable cut bank/point bar morphology expected for this landscape setting was largely absent. The channel was widening and was often braided, again not the expected channel form and process for this landscape setting. As such, observed lateral stream movement was not related to natural sinuosity, and considered degraded for both reaches.

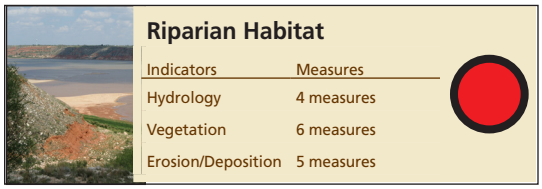
Blue Creek appeared to have shallow bedrock control through most of its length, as evidenced by a few bedrock outcrops adjacent to the channel and on the valley margins. Additionally, we did not observe typical attributes of vertically unstable riparian systems such as a v-shaped (incised) channels, steep eroding banks, headcuts, or disconnection of the channel from the floodplain. Consequently, we this measure to be in good condition for both assessment reaches.

In isolated sub-reaches, a single-thread meandering channel was transporting the sediment supplied by the adjacent uplands. However, in the majority of both reaches the

Table 4.8.4-2. Summary of the riparian habitat indicators/measures categories and their contributions to the overall riparian habitat resource condition assessment.

Indicators	Canadian River Condition			Blue Creek Condition	
	Reach 1A	Reach 1B	Reach 2	Reach 1	Reach 2
Hydrology, Riparian Vegetation, and Erosion/Deposition	Significant Concern	Moderate	Good	Significant Concern	Significant Concern

channel was aggrading due to an oversupply of sediment and exhibited extensive braiding and loss of expected channel structure for this landscape setting. Consequently, we rated this measure as degraded for both reaches.



Overall Condition and Trend

The Canadian River and its riparian corridor at Lake Meredith NRA is a very large system with extensive floodplains and a large–scale morphology that has formed under very high magnitude flows. Due to the size of this system, it has a great deal of inherent stability and is very resilient to stressors. On Reach 2 (downstream of the designated off-road vehicle area) the broad floodplains had substantial cover of vigorous, soil-stabilizing riparian-wetland vegetation, and the system included many fluvial features like vegetated bars and chute cutoffs that provided riparian ecosystem structure and stability. The channel banks also were very well-vegetated with appropriate riparian-wetland species and the channel form was as expected for this landscape setting. These characteristics help improve floodwater and sediment retention, enhance groundwater recharge, and support formation and maintenance of riparian habitats that support fish and wildlife. However, in portions of the assessment reaches within the designated off-road vehicle areas (Reaches 1-A and 1-B), streambank and floodplain vegetation was often in poor condition or was completely absent, many bank locations were destabilized, sediment inputs were often excessive, and the channel was often widening. Such conditions were severe and widespread in Reach 1-A but were more localized and moderate in Reach 1-B.

Based on our responses to the PFC Checklist Items, we rated the downstream reach (Reach 2) of the Canadian River as being in "Proper Functioning Condition," (good) the uppermost reach (Reach 1-A) as "Nonfunctional" (significant concern) and Reach 1-B as "Functional – at Risk" (moderate). We could not detect a condition "trend" in Reach 1-B, meaning that neither recovery toward "Proper Functioning Condition" nor degradation toward a "Nonfunctional" condition were apparent at this time.

We rated Blue Creek as "Nonfunctional" (significant concern) for both the upstream and downstream reaches due to the degraded and destabilized banks and floodplain, the resulting excessive sediment delivery to the channel, and the loss of the expected channel/floodplain form for this landscape setting.

Our observations indicated that substantially greater protection of riparian-wetland vegetation from disturbance could allow the "Nonfunctional" and "Functional - at Risk" reaches of the Canadian River and Blue Creek to recover toward "Proper Functioning Condition" over time. Conversely, a significant increase in vegetation disturbance in Reach 1-B of the Canadian River could cause it to degrade from a "Functional - at Risk" to a "Nonfunctional" condition. For a summary of the overall condition assessment ratings for each reach, refer to Table 4.8.4-2.

Level of Confidence/Key Uncertainties

NPS' Water Resources Division scientists and SOPN biologist conducted the riparian assessment through a technical assistance request to evaluate the functional condition of the NRA's riparian habitat. Based on the expertise of the scientists, we're confident that the findings accurately reflected the

condition of the NRA's riparian wetland at the time of the assessment.

4.8.5. Sources of Expertise

The National Park Service's Water Resources Division scientists, Michael Martin and Joel Wagner, and SOPN I&M Biologist, Tomye Folts-Zettner provided the expertise for this assessment.

Michael Martin is a hydrologist with the NPS Water Resources Division and has his Masters of Science in Watershed Science. Specialty areas include open channel flow, geomorphology, flood analysis, wetlands, and hydrology.

Joel Wagner is the Wetlands Program Team Leader with the NPS Water Resources Division and has his Masters of Science in Environmental Science (Water Resources). Specialty areas include wetlands science, hydrology, restoration and regulatory issues.

Tomye Folt-Zettner is a biologist/botanist with the SOPN I&M and has her Masters in Natural Resource Management. She specializes in native and exotic vegetation and their ecosystems.

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4.9. Grasslands

Indicators/Measures

- Hydrology Soil/Site Stability and Hydrologic Function (10 Measures)
- Biotic Integrity (5 measures)

Condition – Trend - Confidence

Moderate – Improving - High

4.9.1. Background and Importance

As described by Bailey (1995), Lake Meredith NRA lies within the Dry Domain, Tropical/Subtropical Steppe Division, Southwest Plateau and Plains Dry Steppe and Shrub Province, Texas High Plains Section. This ecoregion is characterized by arid grasslands and the presence of open stands of mesquite among the grasses. The land-surface form consists of flat to rolling plains as well as a mesa-and-butte landscape in some areas. Much of the terrain surrounding the parks consists of flat grasslands. The majority or park land is located below the Llano Estacado, in the "breaks" created by the Canadian River as it meanders west-east across the Texas Panhandle. LAMR resides in two of the major plant zones of Texas, the Rolling Plains and High Plains and the predominant vegetative cover is comprised of blue grama (*Bouteloua gracilis*), sideoats grama (*B. curtipendula*) little bluestem (*Schizachyrium scoparium*), and buffalo grass (*Buchloe dactyloides*) (Folts-Zettner et al. 2011).

Alibates Flint Quarries NM sits within the boundary of LAMR. The vegetative region occupied by the Alibates National Monument is a transitional area between the true High Plains and the eroded Rolling Plains. ALFL is comprised primarily of upland vegetation, although is still a part of the rough breaks. The native flora is a mixture of species that typify both of those vegetative regions (Bell et al. 2000). The area can be classified as a grassland ecosystem made up of short, mid and tall grass species. The rolling topography with a variety of slopes and exposures, plus the variability in soils and parent material contribute to a more diverse plant community than on the nearby High Plains (Bell et al. 2000).

The Canadian River Basin climate is characterized as semiarid with an average annual rainfall of 20 inches (51 cm) per year. Seventy percent of the precipitation falls between April and September, which is the primary growing season. This area has hot


NPS

Figure 4.9.1-1. An example of grasslands at Lake Meredith NRA.

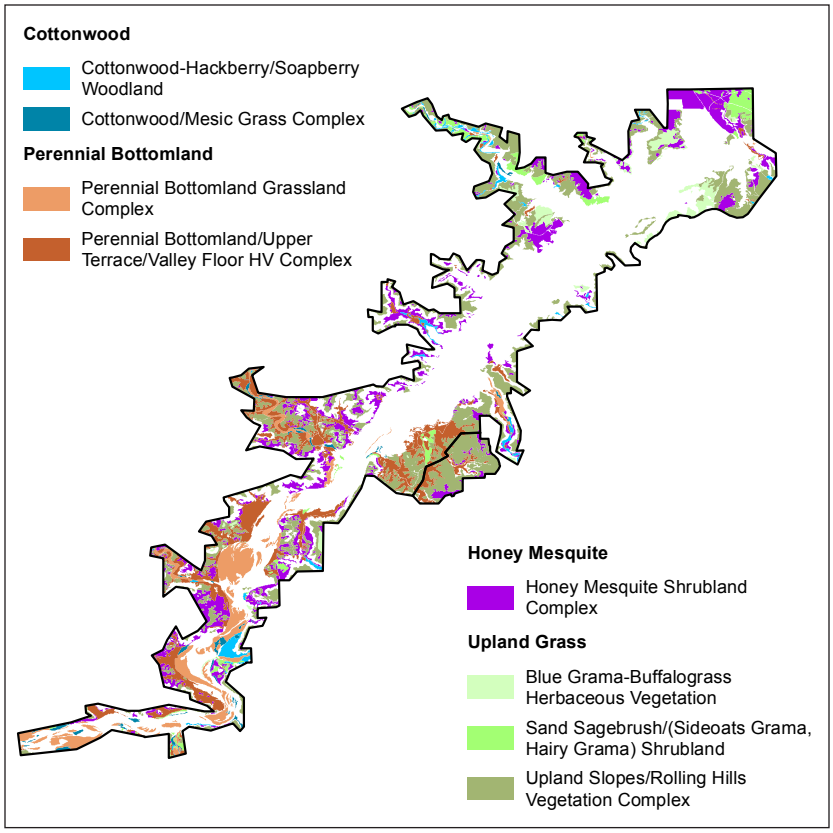


Figure 4.9.1-2. Vegetation map showing communities visited during grasslands monitoring.

summers and cold winters with strong winds that work to increase evaporation rates, which have been estimated to average 60-65% of the total precipitation. The elevation ranges from 2800 to 3320 feet (853-1,012 m) (Folts-Zettner et al. 2011).

Vegetation Mapping

The Bureau of Reclamation conducted vegetation classification and mapping at Lake Meredith NRA and Alibates Flint Quarries NM in 2004-2006 as part of the USGS-NPS Vegetation Characterization Program; a cooperative effort by the U.S. Geological Survey (USGS) and the National Park Service (NPS) to classify, describe, and map vegetation communities in more than 280 national park units across the United States. This program uses a hierarchical classification scheme, the National Vegetation Classification Standard (NVCS, http://biology.usgs.gov/npsveg/nvcs.html), as a basis for classifying vegetation.

The Bureau of Reclamation mapped a total of 88,479 acres (35,806 ha) comprising LAMR, ALFL and its environs. The area mapped within NPS boundaries was 43,037 acres (17,417 ha). Thirty-four map units were developed to describe the landscape. Of these, the most frequently occurring within the entire mapping area was Honey Mesquite Shrubland with 825 polygons ranging in size from under 0.01 acres to over 285 acres. The most abundant map unit in terms of area was Upland Slopes/Rolling Hills Vegetation Complex at 27,128 acres or about 31% of the total mapped area and 18% of the NPS land (US Bureau of Reclamation 2007). SOPN grassland monitoring plots are located within eight of these vegetation types within LAMR (Figure 4.9.1-2, Table 4.9.1-1).

Table 4.9.1-1. Map Units Table

USGS-NPS Vegetation Map Classes / Classified Community Names	Common Names	Primary Class	Acres	Hectares
Cottonwood (*Populus deltoides*) / Mesic Grass Complex	Cottonwood / Mesic Grass Complex	Woodland (with grass component)	302	122
Bouteloua gracilis-Buchloe dactyloides Herbaceous Vegetation	Blue Grama - Buffalograss Herbaceous Vegetation	Grassland	842	341
Perennial Bottomland Grassland Complex	Perennial Bottomland Grassland Complex	Grassland	1996	808
Perennial Bottomland/Upper Terrace/Valley Floor HV Complex	Perennial Bottomland/Upper Terrace/Valley Floor HV Complex	Grassland	3575	1447
Upland Slopes/Rolling Hills Vegetation Complex	Upland Slopes/Rolling Hills Vegetation Complex	Shrubland (with grass component)	7777	3147
Populus deltoides-Celtis laevigata/Sapindus saponaria Woodland	Cottonwood - Hackberry / Soapberry Woodland	Woodland	499	202
Honey Mesquite (*Prosopis glandulosa*) Shrubland Complex	Honey Mesquite Shrubland Complex	Shrubland (with grass component)	4467	1808
Artemisia filifolia / Bouteloua (*curtipendula*, *gracilis*) Shrubland	Sand Sagebrush / (Sideoats Grama, Hairy Grama) Shrubland	Shrubland	947	383

Prior to the mapping project, several inventories were made at the park. Wright and Meador (1981) described the vegetation of the LAMR by using data collected with a 'step point' sampling method at sites selected to characterize five plant associations. They described location and structure of each stand, as well as characteristic species, and anthropogenic influences. A species list and a map of these five associations are included in the report.

Several years later, Nesom and O'Kennon (2005) provided an account of all vascular plant species found at LAMR and ALFL based on vouchered records. They used accounts from their own field observations plus those made by NPS staff in 1970-1973 when herbarium specimens were collected. The inventory by Nesom and O'Kennon reported 459 naturally occurring species of vascular plants in 272 genera and 77 families. The three families most heavily represented were Asteraceae (89 species) and Poaceae (83), followed by Fabaceae (41). The authors suggest that there may be approximately another 146 species that are likely to occur in the park based on past observations and county surveys, but not yet vouchered.

Bell et al (2000) conducted a survey of threatened and endangered plant species at ALFL. They described four community types at the monument using data collected along two 200-foot transects in each community (eight transects total). No threatened or endangered plant species were found.

Nesom and O'Kennon (2008) went on to 12 describe plant communities at LAMR/ALFL. Recognizing that species may overlap, this assessment defined the major plant associations based on physiographic and geologic boundaries, as these generally are correlated with the sharpest discontinuities between vegetation types.

Conditions During Assessment

It is important to recognize that drought conditions occurred during four of the five year assessment period. During the summer of 2010, LAMR/ALFL were experiencing conditions that were very moist; whereas during 2011 and 2012, they experienced extreme drought, followed by a year of severe drought before returning to moderate drought conditions in 2014 (Figure 4.9.1-3). We have tried to take these conditions into account in our interpretations, but the reader should be aware that such conditions may have a significant impact on our assessment.

4.9.2. Data and Methods

We considered three categories of measures/indicators for the assessment of grassland condition at LAMR/ALFL using a modified approach based on methods presented by Pellant et al. (2005). The three categories are: soil/site stability, hydrologic functioning, and biological integrity and are defined by Pellant et al. (2005) as follows:

Soil/Site Stability - The capacity of an area to limit redistribution and loss of soil resources (including nutrients and organic matter) by wind and water.

Hydrologic Function - The capacity of an area to capture, store, and safely release water from rainfall, run-off, and snowmelt (where relevant), to resist a reduction in this capacity, and to recover this capacity when a reduction does occur.

Biotic Integrity -The capacity of the biotic community to support ecological processes within the normal range of variability expected for the site, to resist a loss in the capacity to support these processes, and to recover this capacity when losses do occur. The biotic community includes plants, animals, and microorganisms occurring both above and below ground.

In combination, the measures from each of these categories provide the basis for this assessment. Note that we only looked at extant vegetation as the primary indicator for biotic integrity in this assessment. We have summarized the measures for each of these groups below.

Please note that we relied primarily on SOPN fire and vegetation monitoring datasets to assess biotic integrity while the soil/ site stability/hydrologic function measures were

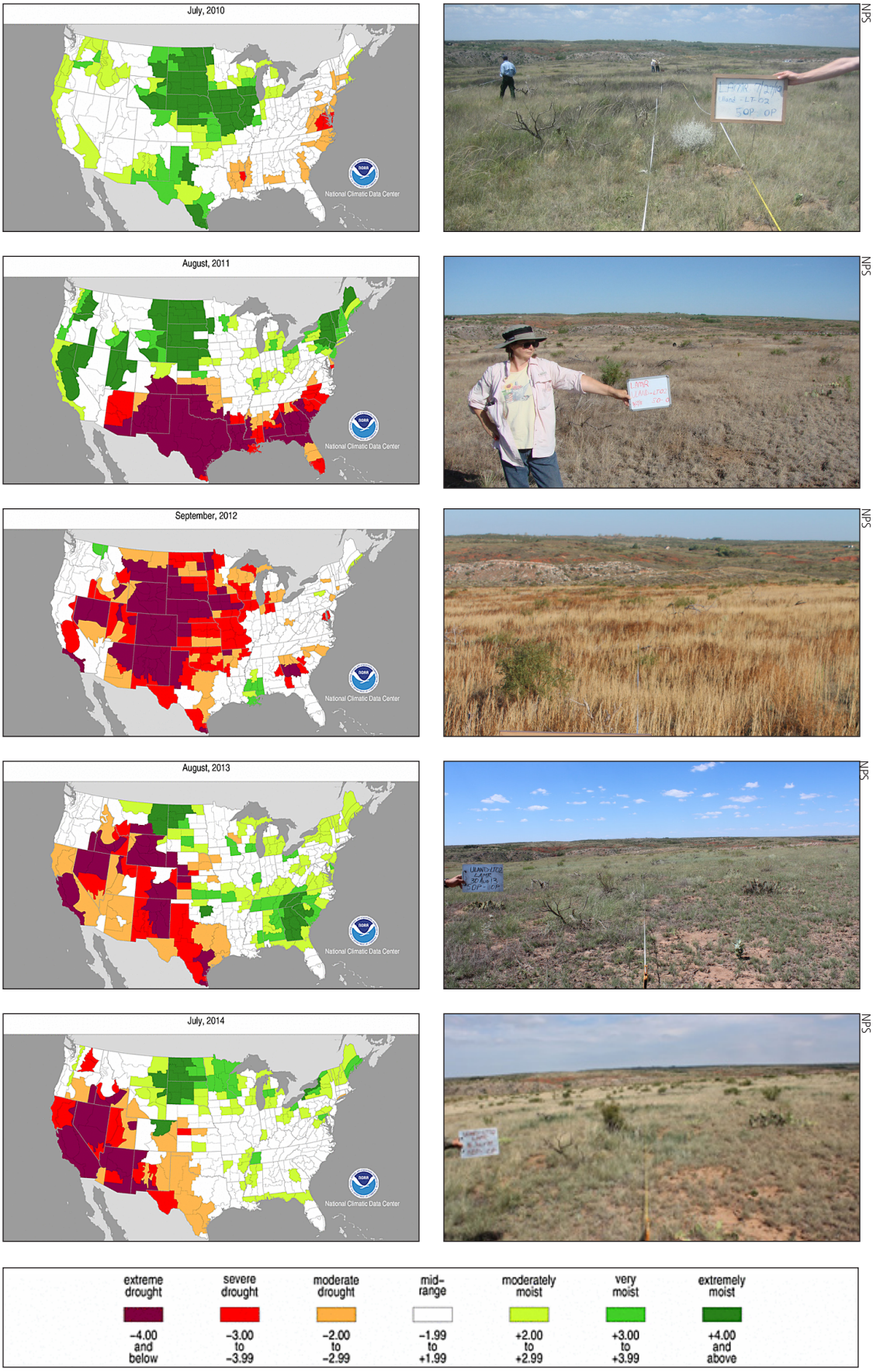


Figure 4.9.1-3. The Palmer Modified Drought Index for each of the five years for which data from Lake Meredith NRA and Alibates Flint Quarries NM were available. Also shown to the right of each map are photos taken from a monitoring transect (ULAND-LT-02) for the corresponding time period.

assessed primarily through a site visit and rapid assessment in early July 2014 conducted by Tomye Folts-Zettner, (Folts-Zettner, unpublished) who is the biologist with the Southern Plains I&M Network, and who had trained in the assessment methods with soil scientist, Pete Biggam, recently retired from the NPS' Geoscience and Restoration Branch.

Indicator
Soil/Site Stability and Hydrologic Function

The rapid soil assessments consisted of evaluating eight selected sites at LAMR/ALFL (Figure 4.9.2-1).

The methodology for these assessments used an approach based on those described in the qualitative assessment protocol "Interpreting Indicators of Rangeland Health (Pellant et al. 2005), in which Soil/Site Stability qualitative measures (Table 4.9.2-1) were used to assess the ability of an area to limit redistribution and loss of soil resources by wind and water.

Qualitative measures can provide land managers and technical assistance specialists with a good communication tool, and when used in association with quantitative monitoring and inventory information, they can be used to provide early warnings of resource problems on upland rangelands.

These measures were used in conjunction with soil survey information and ecological site descriptions for the eight selected evaluation areas, each of which were approximately ¾ to 1 acre in size. It is important to note that only the Soil/Site Stability qualitative measures were observed and documented on site, and these were used to perform the rapid soil assessments. This assessment was used to determine the departure from the expected soil/site stability attributes.

Indicator
Biotic Integrity

The assessment for the biotic integrity of grasslands was made via a combination of a field assessment by grassland experts Fred Smeins (Texas A&M University) and SOPN Biologist, Tomye Folts-Zettner,

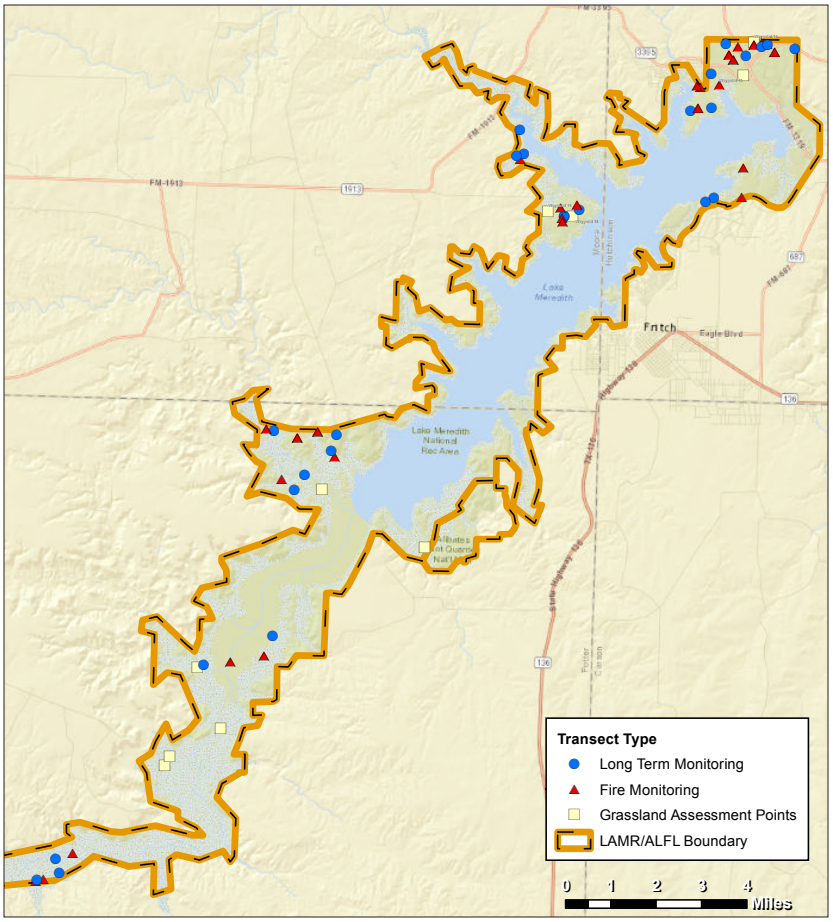


Figure 4.9.2-1. Locations of long-term monitoring plots, fire plots and grassland rapid assessment plots.

and data collected as part of the SOPN's ongoing grassland monitoring. Criteria used for evaluating biotic integrity followed those established by SOPN staff with input from academic rangeland specialists and ecologists. Using the qualitative measures of rangeland health presented in (Pellent et al. 2005) as a starting point, this ad hoc scientific committee developed a suite of five measures of grassland biotic integrity that was deemed appropriate for this assessment. These measures are summarized in Table 4.9.2-1 and described in greater detail below.

Based on these measures, a rapid field assessment was conducted based on visits to multiple sites at LAMR/ALFL. Each site was qualitatively evaluated by the experts based on the measures developed. We then used data collected during the past five years of monitoring to augment the opinions of our experts and to provide a more quantitative baseline for future assessment. These data were collected by the Southern Plains

Table 4.9.2-1. Indicators and measures used to assess grasslands at Lake Meredith NRA and Alibates Flint Quarries NM.

Indicator	Measure	Definition
Soil/Site Stability and Hydrologic Function	Rills	A small, intermittent water course with steep sides, usually only several centimeters deep (SSSA 1997). Rills generally are linear erosion features.
	Water Flow Patterns	Flow patterns are the path that water takes as it moves across the soil surface during overland flow.
	Pedestals and/or terracettes	"Plants or rocks that appear elevated as a result of soil loss by wind or water erosion (does not include plant or rock elevation as a result of non-erosional processes such as frost heaving), and "Benches" of soil deposition behind obstacles caused by water erosion."
	Bare ground	All land surface not covered by vegetation, rock, or litter (SRM 1999). As used in this document, visible biological crusts and standing dead vegetation are included in cover estimates or measurements and therefore are not bare ground (e.g., mineral soil).
	Gullies	A furrow, channel, or miniature valley, usually with steep sides through which water commonly flows during and immediately after rains or snowmelt (SRM 1999). Small channels eroded by concentrated water flow.
	Wind-scoured, blowout and/or depositional areas	Areas, generally in interspaces, where the finer soil particles have blown away sometimes leaving residual gravel, rock, or exposed roots on the soil surface
	Litter Movement	The uppermost layer of organic debris on the soil surface, essentially the freshly fallen or slightly decomposed vegetal material (SRM 1999). In this document, it includes persistent and non-persistent organic matter that is in contact with the soil surface.
	Soil surface resistance to erosion	The top layer underneath vegetation canopy and characteristics of presence/absence/configuration of debris
	Soil surface loss or degradation	Intactness of uppermost soil layer
	Compaction layer	A near surface layer of dense soil caused by the repeated impact on or disturbance of the soil surface. When soil is compacted, soil grains are rearranged to decrease the void space and bring them into closer contact with one another, thereby increasing the bulk density (SSSA 1997).
Biotic Integrity	Landscape-scale Diversity	The extent to which landscape-scale diversity reflects spatial pattern of soils and disturbance.
	Local Species Composition	The extent to which species composition within a site (e.g., ecological site) deviates substantially from the expected native species assemblage either from exotics or native species.
	General Life Cycles Relative to Disturbance	The proportion of annual, biennial and perennial species relative to the time since disturbance.
	Relative proportion of functional groups (e.g., graminoid, forbs, shrubs, etc.)	The relative proportions of functional groups relative to what would be expected based on site characteristics (e.g., lack of forbs, excessive shrub density, etc.)
	Relative proportion of C3 and C4 species.	The relative proportions of C3 and C4 plants relative to what would be expected based on site characteristics

Inventory and Monitoring Network (SOPN) and the Southern Plains Fire Group, following Folts-Zettner et al. (2011). Grassland monitoring data were collected in 2010-2014 along 42 transects (19 read annually plus fire effects plots read at varying intervals), each with five subplots, as part of this monitoring effort (Folts-Zettner et al. 2012, 2013, 2014a, 2014b) (Figure 4.9.2-1). At each subplot, the percent cover was estimated for each species within a 1x2m quadrat.

Landscape-scale Diversity

The plant communities and alliances are generally expected to reflect local conditions of soils, moisture, disturbance, etc. As such, we would expect the diversity across a broader region to generally reflect the variation in these site characteristics. However, it is not reasonable to expect a one-to-one correspondence between local communities and their corresponding sites because a multitude of factors can

influence the local expression of vegetation communities at a given site. Rather, we are trying to determine that some reasonable level of landscape diversity exists and that it generally corresponds to changes in ecological conditions. To assess this, we compared the vegetation communities observed during the LAMR/ALFL vegetation mapping (US Bureau of Reclamation 2007) with soil types (NRCS 2014) and ecological sites (NRCS 2004).

Local Species Composition

The intent behind this measure is to see if species composition is generally consistent with what might be expected for the site, given the local conditions (soils, disturbance, moisture, etc). We considered this from two perspectives. First, we examined the degree to which the local communities consisted of native vs exotic species. Details about which exotic species are present and their effect on the site are presented in greater detail in Chapter 4.11. Here we just provide an initial indication of the extent of invasion by exotic species by looking at the proportion of native and exotic species. Second, we looked at the species composition of the native species relative to what might be expected for that site. This was based on a combination of NRCS Ecological Site Descriptions and expert opinion. As we have done for other measures, this assessment is based primarily on percentage cover, rather than the number of individual species because most species are quite rare and cover provides a more realistic description of species abundance (i.e. dominance or lack thereof) on the landscape.

General Life Cycles Relative to Disturbance

It is generally expected that the number of annual species at a given site would be higher immediately following a disturbance, and would shift toward an increasing number of perennials as time passes since a disturbance. The persistence of annuals long after a disturbance could indicate some basis for concern. For example roadside areas that are frequently and unnaturally disturbed might be expected to have a greater persistence of annual species compared to interior sites.

Relative Proportion of Functional Groups

The composition of functional groups can have a dramatic effect on grassland ecosystems and their associated processes (Tilman et al. 1997, Pellant et al. 2005). Tilman et al. (1997) found that functional composition and functional diversity were principal factors explaining plant productivity, plant percent nitrogen, plant total nitrogen, and light penetration. They further concluded that habitat modifications and management practices that change functional diversity and functional composition would likely have a dramatic effect on ecosystem processes.

Relative Proportion of C3 and C4 Species -

The natural plant communities comprising the grasslands at LAMR/ALFL are a mixture of short, mid and tallgrasses. Primarily because of the climate, southern prairie types often have a high proportion of perennial C4 (warm season) grasses (Lauenroth et al. 2008). The morphological and physiological characteristics of these plants make them highly adaptable to withstand stressors such as drought or grazing by large herbivores such as cattle (Lauenroth et al. 2008). The proportion of C3 and C4 grasses can also dramatically influence how these grassland communities respond to climate change and levels of CO2, although the nature of such response has been much debated (Wand et al. 1999).

4.9.3. Reference Conditions

Soil/Site Stability and Hydrologic Function

Pellant et al. (2005) described general reference conditions they considered to be an optimal functional state (their "none to slight" category) under natural disturbance regimes (Table 4.9.3-1). They then provided general descriptions for departures from that optimal state into four other categories of condition. These categories ranged from their optimal state to an extreme or total state of degradation.

We considered the condition of grasslands as "good" if the current condition fell either within Pellant et al.'s (2005) "none to slight", or "slight to moderate" categories. The "moderate" ranking was assigned if the departure from optimal fell within the

Table 4.9.3-1. Reference conditions for soil/site stability/hydrologic function measures.

Measure	Significant Concern		Moderate	Good	
	Extreme to Total	Moderate to Extreme	Moderate	Slight to Moderate	None to Slight
Soil/site Stability and Hydrologic Function					
Rills	Rill formation is severe and well defined throughout most of the site.	Rill formation is moderately active and well defined throughout most of the site.	Active rill formation is slight at infrequent intervals; mostly in exposed areas	No recent formation of rills; old rills have blunted or muted features.	Current or past formation of rills as expected for the site.
Water Flow Patterns	Water flow patterns extensive and numerous; unstable with active erosion; usually connected	Water flow patterns more numerous and extensive than expected; deposition and cut areas common; occasionally connected.	Number and length of water flow patterns nearly match what is expected for the site; erosion is minor with some instability and deposition.	Number and length of water flow patterns match what is expected for the site; some evidence of minor erosion. Flow patterns are stable and short.	Matches what is expected for the site; minimal evidence of current or past soil deposition and erosion.
Pedestals and/or terracettes	Abundant active pedestalling and numerous terracettes. Many rocks and plants are pedestaled; exposed plant roots are common.	Moderate active pedestalling; terracettes common. Some rocks and plants are pedestaled with occasional exposed plant roots.	Slight active pedestalling; Most pedestals are in flow paths and interspaces and/or on exposed slopes. Occasional terracettes present.	Active pedestalling or terracette formation is rare; some evidence of past pedestal formation, especially in flow patterns on exposed slopes.	Current or past evidence of pedestaled plants or rocks as expected for the site. Terracettes uncommon or absent.
Bare ground	Much higher than expected for the site. Bare areas are large and generally connected.	Moderate to much higher than expected for the site. Bare areas are large and occasionally connected.	Moderately higher than expected for the site. Bare areas are of moderate size and sporadically connected.	Slightly to moderately higher than expected for the site. Bare areas are small and rarely connected.	Amount and size of bare areas match that expected for the site.
Gullies	Common with indications of active erosion and downcutting; vegetation is infrequent on slopes and/or bed. Nickpoints and headcuts are numerous and active.	Moderate in number to common with indications of active erosion; vegetation is intermittent on slopes and/or bed. Headcuts are active; downcutting is not apparent.	Moderate in number with indications of active erosion; vegetation is intermittent on slopes and/or bed. Occasional headcuts may be present.	Uncommon, vegetation is stabilizing the bed and slopes; no signs of active headcuts, nickpoints, or bed erosion.	Match what is expected for the site; drainages are represented as natural stable channels; vegetation common and no signs of erosion.
Wind-scoured, blowout, and/or depositional areas	Extensive	Common	Occasionally present	Infrequent and few.	Match what is expected for the site.
Litter movement	Extreme concentrated around obstructions. Most size classes of litter have been displaced.	Moderate to extreme; loosely concentrated near obstructions. Moderate to small size classes of litter have been displaced.	Moderate movement of smaller size classes in scattered concentrations around obstructions and in depressions.	Slightly to moderately more than expected for the site with only small size classes of litter being displaced.	Matches that expected for the site with a fairly uniform distribution of litter.
Soil surface resistance to erosion	Extremely reduced throughout the site. Biological stabilization agents including organic matter and biological crusts virtually absent.	Significantly reduced in most plant canopy interspaces and moderately reduced beneath plant canopies. Stabilizing agents present only in isolated patches.	Significantly reduced in at least half of the plant canopy interspaces or moderately reduced throughout the site.	Some reduction in soil surface stability in plant interspaces or slight reduction throughout the site. Stabilizing agents reduced below expected	Matches that expected for the site. Surface soil is stabilized by organic matter decomposition products and/or a biological crust.

Table 4.9.3-1. Reference conditions for soil/site stability/hydrologic function (continued).

Measure	Significant Concern		Moderate	Good	
	Extreme to Total	Moderate to Extreme	Moderate	Slight to Moderate	None to Slight
Soil surface loss or degradation	Soil surface horizon absent. Soil structure near surface is similar to, or more degraded, than that in subsurface horizons. No distinguishable difference in subsurface organic matter content.	Soil loss or degradation severe throughout site. Minimal differences in soil organic content and structure of surface and subsurface layers.	Moderate soil loss or degradation in plant interspaces with some degradation beneath plant canopies. Soil structure is degraded and soil organic matter is significantly reduced.	Some to no soil loss has occurred and/or soil structure shows signs of degradation, especially in plant interspaces	Soil surface horizon intact. Soil structure and organic matter content match that expected for site.
Compaction layer (below soil surface)	Extensive; severely restricts water movement and root penetration.	Widespread; greatly restricts water movement and root penetration.	Moderately widespread, moderately restricts water movement and root penetration.	Rarely present or is thin and weakly restrictive to water movement and root penetration.	Matches that expected for the site; none to minimal, not restrictive to water movement and root penetration.

"moderate" class. And finally, we considered the condition of grasslands to be of "significant concern" if the departure from optimal fell within Pellant et al.'s "moderate to extreme" or "extreme to total" classes.

Biotic Integrity

Determining definitive quantitative reference conditions for grassland communities is somewhat problematic given the dynamic nature of these resources. Part of our consideration in choosing the measures we have used for biotic integrity is that they are moderately robust to the potentially substantial seasonal and annual variation that plant communities often exhibit. We began with a conceptual framework for assigning condition based on what might be expected for the site conditions at LAMR/ALFL (Table 4.9.3-2). We recognize, however, that seasonal and annual variation in such things as rainfall and disturbance can results in dramatic shifts in specific measurement that are still within an acceptable range of natural variation. In particular, the drought that has occurred at LAMR/ALFL in recent years (2011 to 2014) may have influenced some measures of biotic integrity.

Our measure of landscape-scale diversity focuses on whether or not the diversity of plant communities reflects the diversity in site characteristics to a reasonable extent. As such, we used the spatial pattern of soil types (NRCS 2014) and ecological sites (NRCS 2004) as a general reference for the extent and pattern of landscape diversity that might be expected.

For the remaining measures, we used a combination of the Natural Resources Conservation Service's ecological site descriptions (NRCS 2004) and expert opinion as a general reference for plant community characteristics that might be expected given the soil types and ecological sites that occur at LAMR/ALFL. It is important to note however, the values in the ecological site descriptions are typically only provided for what are considered the historic climax plant communities (HCPCs), and variations in the dynamics of those communities are presented only through qualitative descriptions and/or generalized state and transition models. Consequently we do not strictly adhere to the HCPCs as a reference condition in the sense that departures from that reference necessarily represent a degraded quality; rather as a general guide to be used in conjunction with expert opinion to determine resource condition.

Table 4.9.3-2. Reference conditions used to assess the current condition for measures of grassland biotic integrity.

Measure	Significant Concern	Moderate	Good
Landscape- scale diversity	Significant lack of spatial landscape heterogeneity that does not reflect the expected diversity for the soil types and sites	Moderate lack of spatial landscape heterogeneity that does not fully reflect the spatial pattern of soils and disturbance	Landscape-scale diversity reflects spatial pattern of soils and disturbance
Local species composition	Species assemblage deviates substantially from the native species compliment that would typically occur at such sites. Such a deviation could also be either from exotics or native species.	Species assemblage moderately deviates from the expected native species compliment either from exotics or native species in such a way that does reflect typical types of natural disturbance (e.g., fire or prairie dogs).	Species assemblage reflects expected native species compliment consistent with the site characteristics (e.g., from ESDs). Species composition need not reflect expected climax communities if their current state reflects typical types of natural disturbance (e.g., fire or prairie dogs).
General Life Cycles Relative to Disturbance	Substantially higher proportion of annual species than expected in sites not recently disturbed.	Proportion of perennial species is moderately lower that what might be expected given the site and time since disturbance.	Proportion of perennial species is approximately what would be expected given the site and time since disturbance.
Relative proportion of functional groups (e.g., graminoids, forbs, shrubs, etc.)	Proportions of functional groups differ substantially from what might be expected based on- site characteristics (e.g., lack of forbs, excessive shrub density, etc.)	Proportions of functional groups exhibit moderately departure from what might be expected given the site and disturbance history.	Proportions of functional groups (e.g., grasses, forbs, and shrubs) are consistent with what might be expected given the site characteristics.
Relative proportion of C3 and C4 species.	Sites dominated by C3 grasses at shortgrass sites traditionally dominated by C4 grasses.	Higher than expected proportion of C3 grasses given the ecological site and disturbance history.	Appropriate mix and natural variability of C4 (warm season) and C3 (cool season) grasses for the site (to maximize resilience)

4.9.4. Condition and Trend

Field notes from the grassland assessment are presented in Appendix F.

Soil/Site Stability / Hydrologic Function (included map of RA sites)

The results from Folts-Zettner's rapid assessment indicated that the overall current condition of the soil/site stability/hydrologic function at the sites sampled at LAMR/ALFL was good, with moderate departures from expected occurring at two of the rapid assessment sites (Table 4.9.4-1). Both of these sites were in honey mesquite communities. One of these sites had recently burned in a prescribed fire. The fire-bared soils showed some erosion but should be more stable in a few months when vegetation has regenerated. Rank was assigned based on current conditions but would likely be higher under normal conditions. The second mesquite site in moderate condition (#5) was thought to be representative of most honey mesquite habitat in the Blue West area. At least twice as much bare ground was present than what would be expected for this site. There was also evidence of major sheet flow and surface erosion as well as litter/organic matter washed toward drainages. It should be noted that some measures were undoubtedly influenced by the moderate to extreme drought conditions that have occurred over the past four years (Figure 4.9.4-1). However, we are confident that the drought conditions do not account for all of the concerns with respect to soil stability and hydrologic function, and a moderate condition rating is warranted even after taking drought into consideration.

The soils at the remaining six rapid assessment sites were all in good condition and quite stable. A few sites exhibited minor water flow patterns or scouring, but not enough to cause concern.

Biotic Integrity

Landscape-scale Diversity

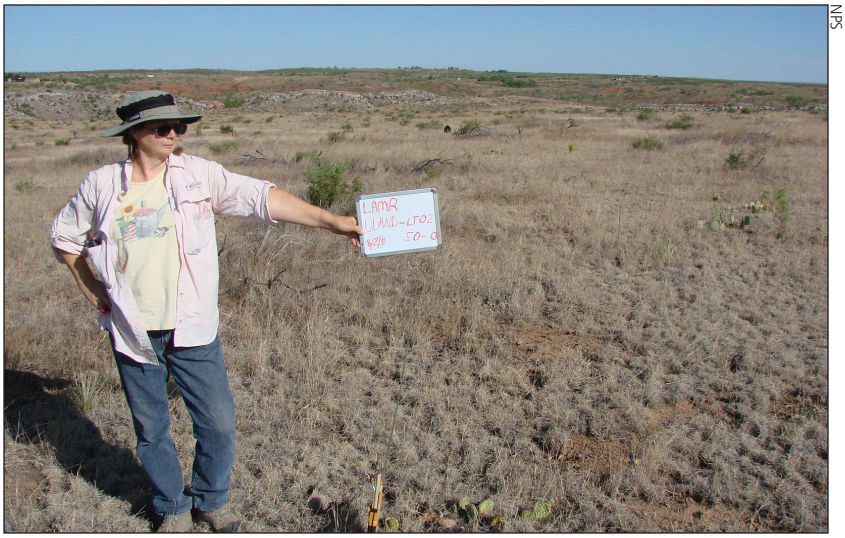
The spatial patterns of plant community distribution generally coincide with that of

Table 4.9.4-1. The assessment of measures used to assess soil/site stability/hydrologic function at each of eight rapid-assessment points at Lake Meredith NRA.

Indicator	Measure	Site Assessment							
		1	2	3	4	5	6	7	8
Soil/Site Stability and Hydrologic Function	Rills	SM	NS	NS	NS	M	NS	M	NS
	Water Flow Patterns	M	NS	NS	NS	ME	NS	ME	NS
	Pedestals and/or terracettes	SM	NS	NS	NS	M	NS	M	NS
	Bare ground	SM	NS	NS	NS	ME	NS	ME	NS
	Gullies	SM	NS	NS	NS	SM	NS	M	NS
	Wind-scoured, blowout and/ or depositional areas	SM	NS	NS	NS	SM	NS	M	SM
	Litter Movement	SM	NS	NS	NS	M	NS	M	SM
	Soil surface resistance to erosion	SM	NS	NS	NS	M	NS	ME	SM
	Soil surface loss or degradation	SM	NS	NS	NS	M	NS	M	SM
	Compaction layer	SM	NS	NS	NS	M	NS	M	SM
Overall Soil and Site Stability Rating		**SM**	**NS**	**NS**	**NS**	**M**	**NS**	**M**	**NS**

[1] NS = None to Slight, SM = Slight to Moderate, M = Moderate, ME = Moderate to Extreme, ET = Extreme to Total

the ecological sites (Figure 4.9.4-2). Further, during the rapid assessment, our grassland expert categorized landscape-scale diversity as Good at six out of the eight sites visited. At one cottonwood community site, she expressed moderate concern about the dieback of the cottonwood trees, but this can likely be attributed to overspray from tamarisk herbicide treatment rather than a lowering of the water table as there is ongoing cottonwood recruitment. There was one assessment site that caused significant concern. This was a honey mesquite shrubland that had very little diversity and appeared stressed in response to years of drought. Condition will likely improve once drought conditions ease. Thus, landscape-scale diversity was considered in reasonably good condition with no evidence for any degrading trend.



NPS

Figure 4.9.4-1. A grassland plot visited during drought conditions.

Local Species Composition

Species composition at local sites has clearly been affected by ongoing drought conditions and we have tried to take that into account in our assessment. As previously indicated, we do not have an expectation for species composition to match the species list for historic climax plan communities of the appropriate ecological site descriptions (NRCS 2004), although we did take these descriptions into account along with expert opinion.

The condition of local species diversity was quite variable among sites and ranged from relatively good (taking into account the drought) at the upland and bottomland sites to sites of moderate condition in both honey mesquite and cottonwood habitats and ranging even to significant concern at one of the honey mesquite sites (Appendix F). In some cases, condition is expected to improve following the drought and with more time to recover from recent fire disturbance;

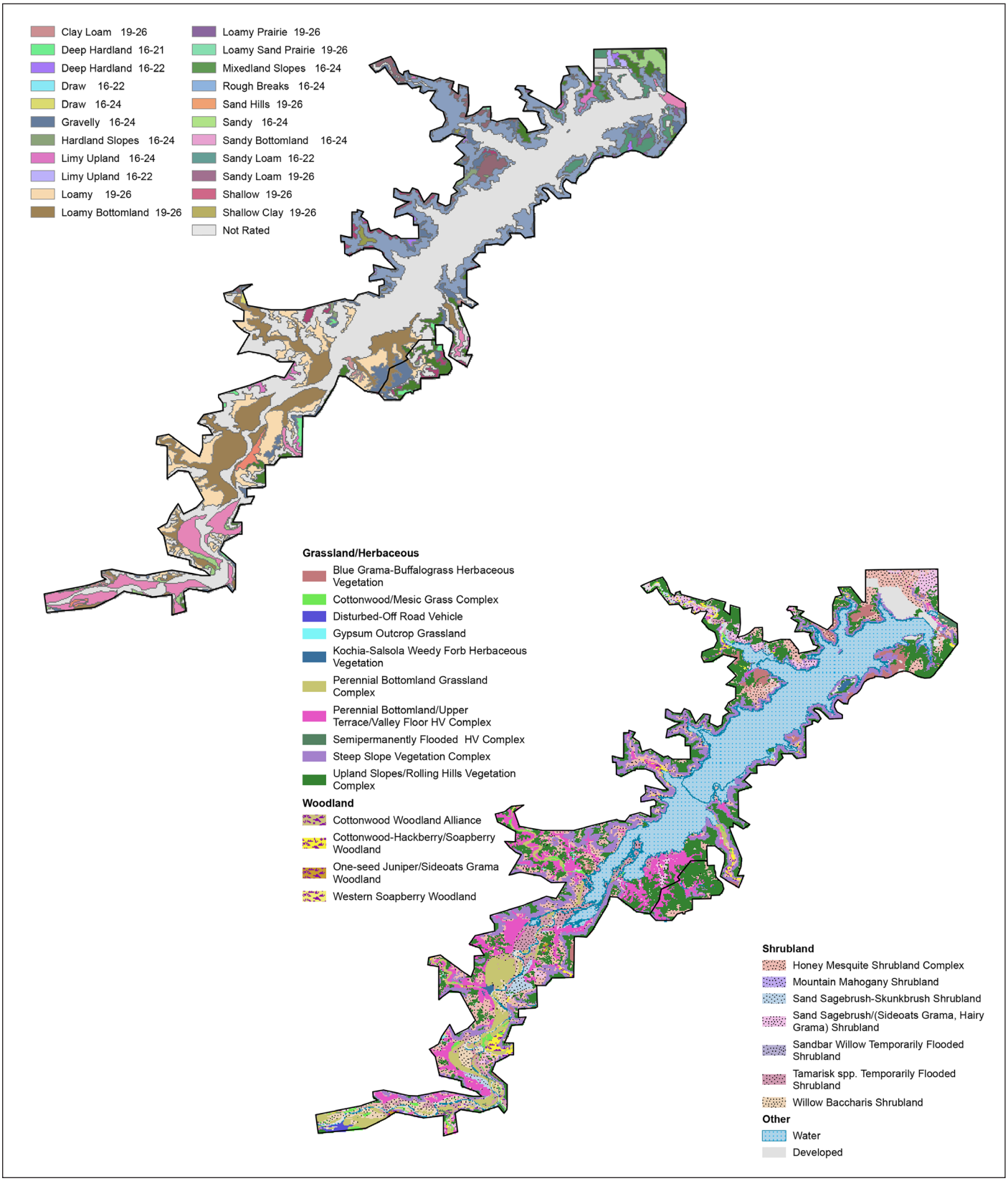


Figure 4.9.4-2. Ecological sites based on NRCS (2007) (upper map) and plant communities based on USBOR (2007) (lower map).

Table 4.9.4-2. The number and percentage of native and exotic species of each life form found on Lake Meredith NRA during the 2010-2014 grassland monitoring sampling.

Life Form	Native	Exotic	Total	Percent Native
Forb	109	10	119	92%
Grass	37	5	42	88%
Shrub	6	0	6	100%
Subshrub	5	0	5	100%
Tree	6	0	6	100%
Vine	2	1	3	67%

in other cases, management activities such as revegetation and control of exotics would be required to improve condition. At the bottomland and cottonwood sites, outside of altered hydrologic condition, exotic, invasive species such as tamarisk and spiny aster pose the greatest threat to ecological condition and should be monitored and controlled. The condition at local sites probably reflects the historical land use and/or disturbance at those sites more so than the ecological site, although undoubtedly some ecological sites are more resilient to historical land uses than others.

Nativity -- One of the major threats to grasslands and other plant communities is invasive, exotic species. Invasive, exotic species have been directly linked to the replacement of dominant native species (Tilman 1999), the loss of rare species (King 1985), changes in ecosystem structure, alteration of nutrient cycles and soil chemistry (Ehrenfeld 2003), shifts in community productivity (Vitousek 1990), and changes in water availability (D'Antonio and Mahall 1991).

Based on five years (2010-2014) of grassland sampling, 165 of 181 (91%) species we observed were native (Table 4.9.4-2). Of these, the proportion of native species was generally higher for forbs (92%) than grasses (88%). However, the number of species does not take into account how prevalent those species are on the landscape. Based on the percentage of cover, grass canopy on our sample plots were almost exclusively native species (97%) while native forb cover varied widely, ranging from 37% to 77% (mean=53%) (Table 4.9.4-3 and Figure 4.9.4.3). One species alone, Russian thistle (*Salsola tragus*), accounted for 37% forb cover averaged across five years of monitoring, and 87% of exotic forb canopy cover.

Even though nine percent of species documented in monitoring plots since 2010 are exotic, there is significant canopy cover of exotic forbs at some sites. Even though local species diversity was primarily good in the upland and bottomland habitats, the extent of the presence of exotics, highly variable conditions within the cottonwood communities, and significantly degraded condition observed at the honey mesquite sites compelled us to describe the overall condition of this measure to be moderate.

These results are based on grassland monitoring plots, which are located throughout the national recreation area and national monument. Two additional sources of information about exotics are the SOPN exotic monitoring transects and a supplementary rapid assessment grid that was sampled in 2011. Both of these sources of information are presented in depth in Chapter 4.10. However, both of these sources of data focused explicitly and exclusively on exotic species in order to gain a better understanding of their distribution and density; thus do not consider how prevalent these exotics are relative to native species. The SOPN exotic monitoring transects focus explicitly on areas considered as high risk for invasion of exotics; thus are not representative of grasslands in general. The supplementary rapid assessment grid includes three subsamples at 150 m intervals, each in different habitats of LAMR/ALFL; thus does represent the overall park

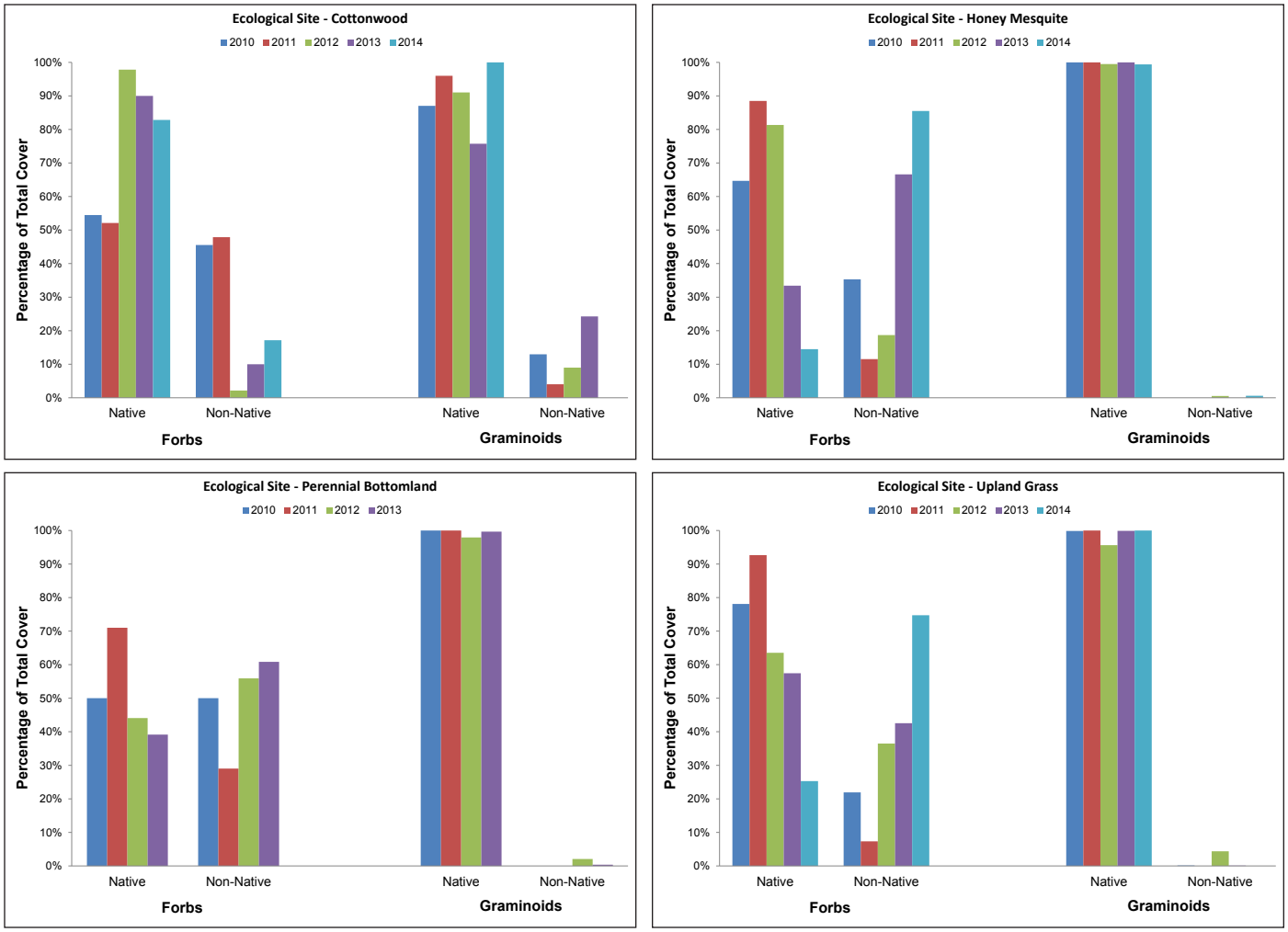


Figure 4.9.4-3. The percentage of native and exotic grasses and forbs for each ecological site samples in 2010-2014.

Table 4.9.4-3. The abundance of native species of each life form found in each vegetation community on Lake Meredith NRA during the 2010-2014 grassland monitoring sampling.

Lifeform	Cottonwood	Honey Mesquite	Perennial Bottomland	Upland Grass	Mean % Native
Forb	77%	37%	48%	52%	53%
Grass	89%	100%	99%	100%	97%
Shrub	100%	100%	100%	100%	100%
Subshrub	100%	100%	100%	100%	100%
Tree	100%	100%	100%	89%	97%
Vine	100%	100%	100%	100%	100%

units, but does not take into account native species.

General Life Cycles Relative to Disturbance

The proportion of annual, biennial and perennial species provides an indication of the stability of a site, and it is generally expected that the proportion of annual species at a given site would be higher immediately following a disturbance, but would shift toward an increased proportion of perennials as time passes since a disturbance. Data from our grassland monitoring samples indicated that grasses were nearly all perennial (Figure 4.9.4-4). Forbs were considerably more variable among sites and years. Based on

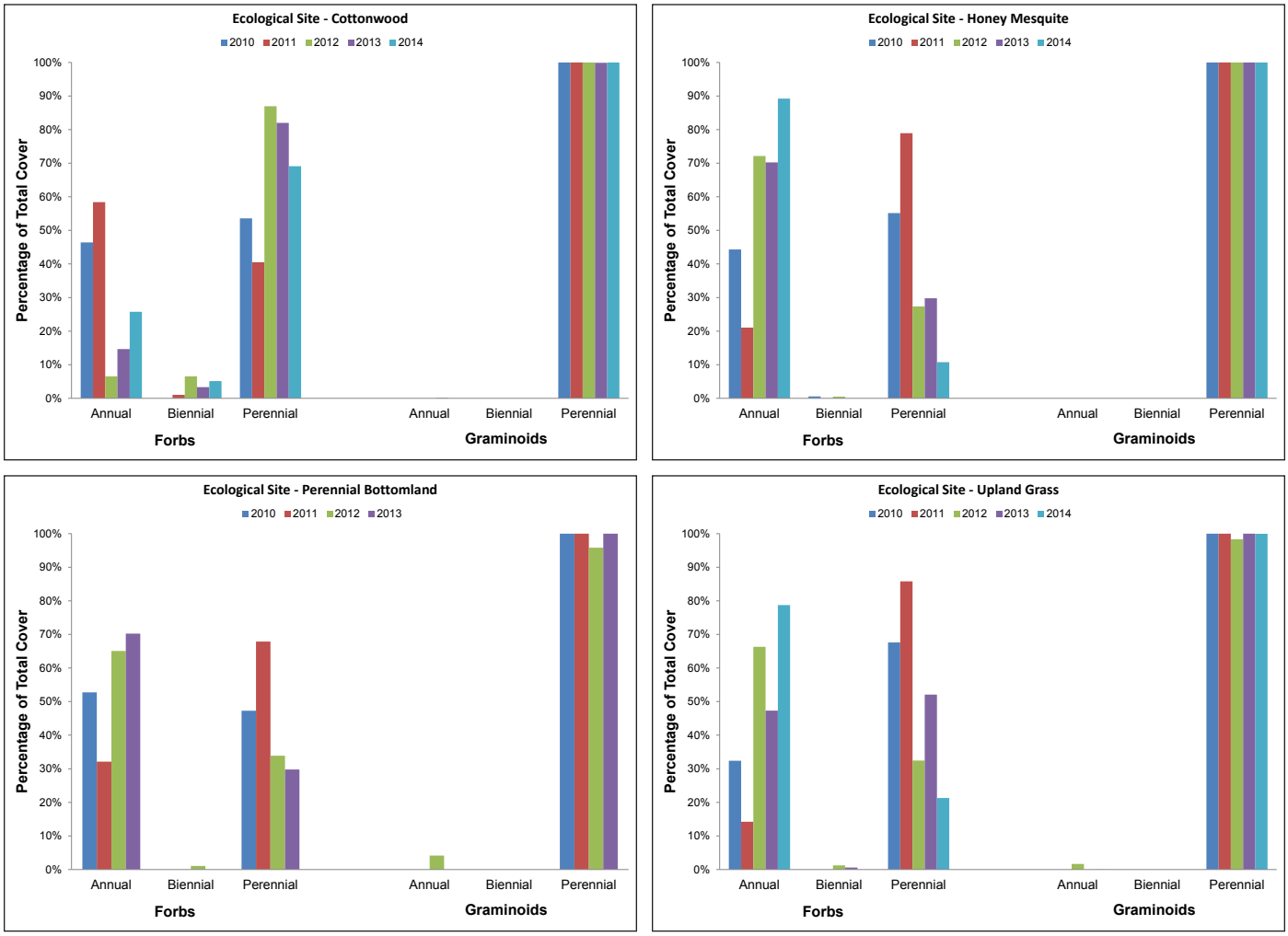


Figure 4.9.4-4. The percentage of annual, biennial, and perennial grasses and forbs for each community type, 2010-2014

what is considered the historic climax plant communities (NRCS 2004), the proportion of perennial species was generally expected to be high for grasses and more variable for forbs (Table 4.9.4-4), so these results, alone, were not cause for concern.

As previously discussed, we did not have any expectation for the proportion of annuals, biennials, and perennials, to coincide exactly with historic climax plant communities, in part because of local site variability and not all sites are at a climax stage. At Lake Meredith NRA/Alibates Flint Quarries NM, sites that exhibited relatively low proportion of perennials were generally sites that have experienced disturbance from fire treatment and more pronounced response to recent drought. Thus, it not surprising that we observe a higher proportion of annual species on these sites. The time frames over which we might expect a shift toward increasing perennial species probably depends on the intensity and duration of the disturbance.

Table 4.9.4-4. The percentage of annual, biennial, and perennial grasses and forbs for each community type, 2010-2014

SOPN Plant Community	Life Form	Percent Perennials Observed 2010-2014
Cottonwood	Forb	65.54%
	Graminoid	99.97%
Honey Mesquite Shrubland	Forb	35.47%
	Graminoid	100.00%
Perennial Bottomland	Forb	43.25%
	Graminoid	98.60%
Upland Grass	Forb	45.50%
	Graminoid	99.59%

Native grasses seemed to be faring well at the monitoring sites with abundance and diversity meeting expectations, but the disproportionately high percentage of annual forb cover at sites not recently

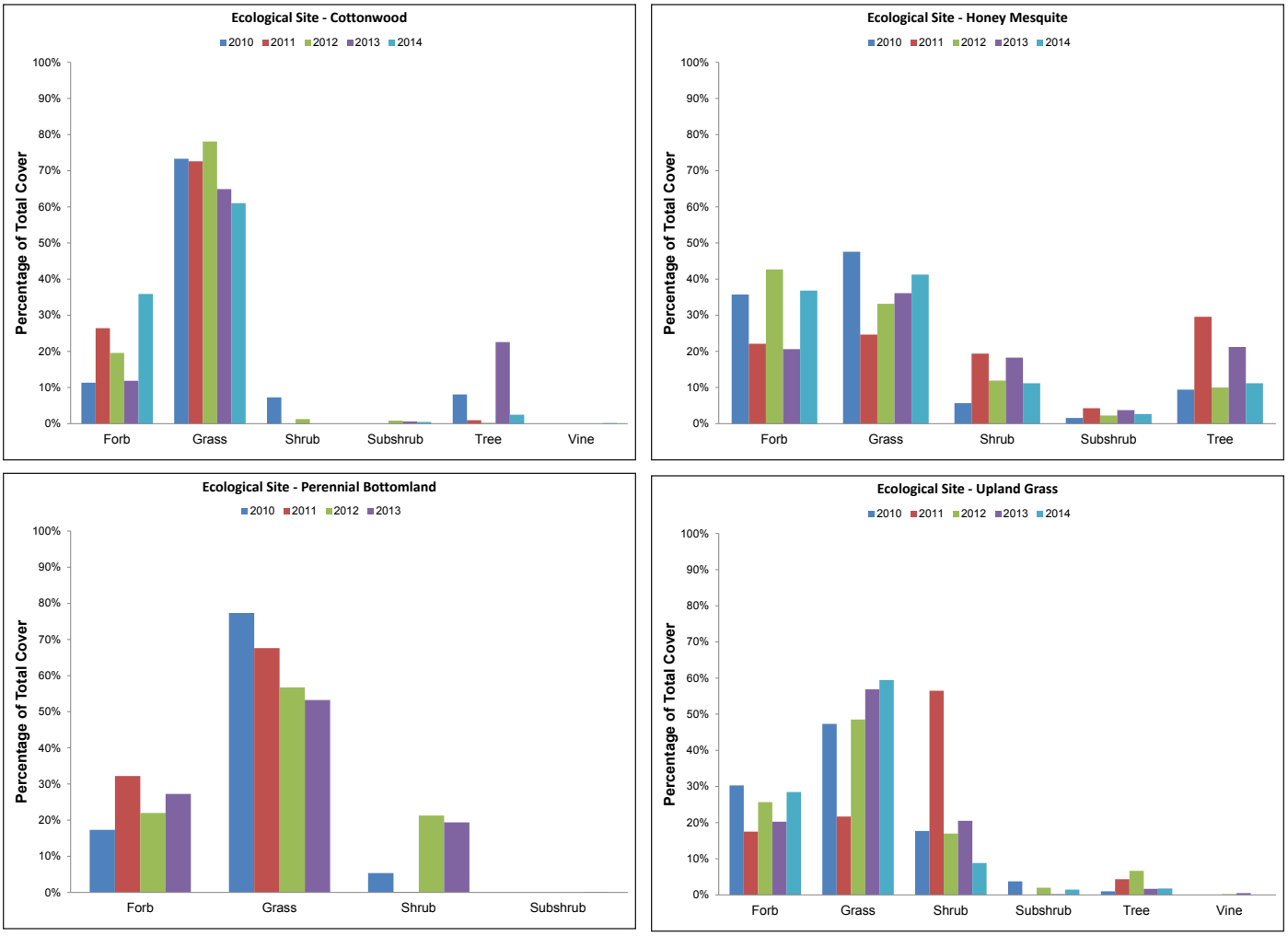


Figure 4.9.4-5. The percentage of lifeforms for each community type, 2010-2014

Table 4.9.4-5. The percentage of lifeforms for each community type, 2010-2014

SOPN Plant Community	Life Form	Percent Observed 2010-2014
Cottonwood	Forb	21.31%
	Grass	68.07%
	Shrub	1.52%
	Subshrub	0.42%
	Tree	8.61%
	Vine	0.06%
Honey Mesquite Shrubland	Forb	33.80%
	Grass	39.95%
	Shrub	10.21%
	Subshrub	2.53%
	Tree	13.50%
	Vine	0.00%

SOPN Plant Community	Life Form	Percent Observed 2010-2014
Perennial Bottomland	Forb	24.75%
	Grass	61.88%
	Shrub	0.00%
	Subshrub	0.00%
	Tree	13.34%
	Vine	0.03%
Upland Grass	Forb	25.98%
	Grass	49.49%
	Shrub	19.61%
	Subshrub	1.83%
	Tree	2.99%
	Vine	0.11%

disturbed is reason for concern. The pervasiveness and abundance of the invasive, exotic annual forb Russian thistle, and to a lesser degree, kochia (*Kochia scoparia*), accounted for a large portion of the annual forb cover and frequency.

Based on this assessment considering both forbs and grasses combined, we considered Lake Meredith NRA/ Alibates Flint Quarries NM to be in moderate condition overall.

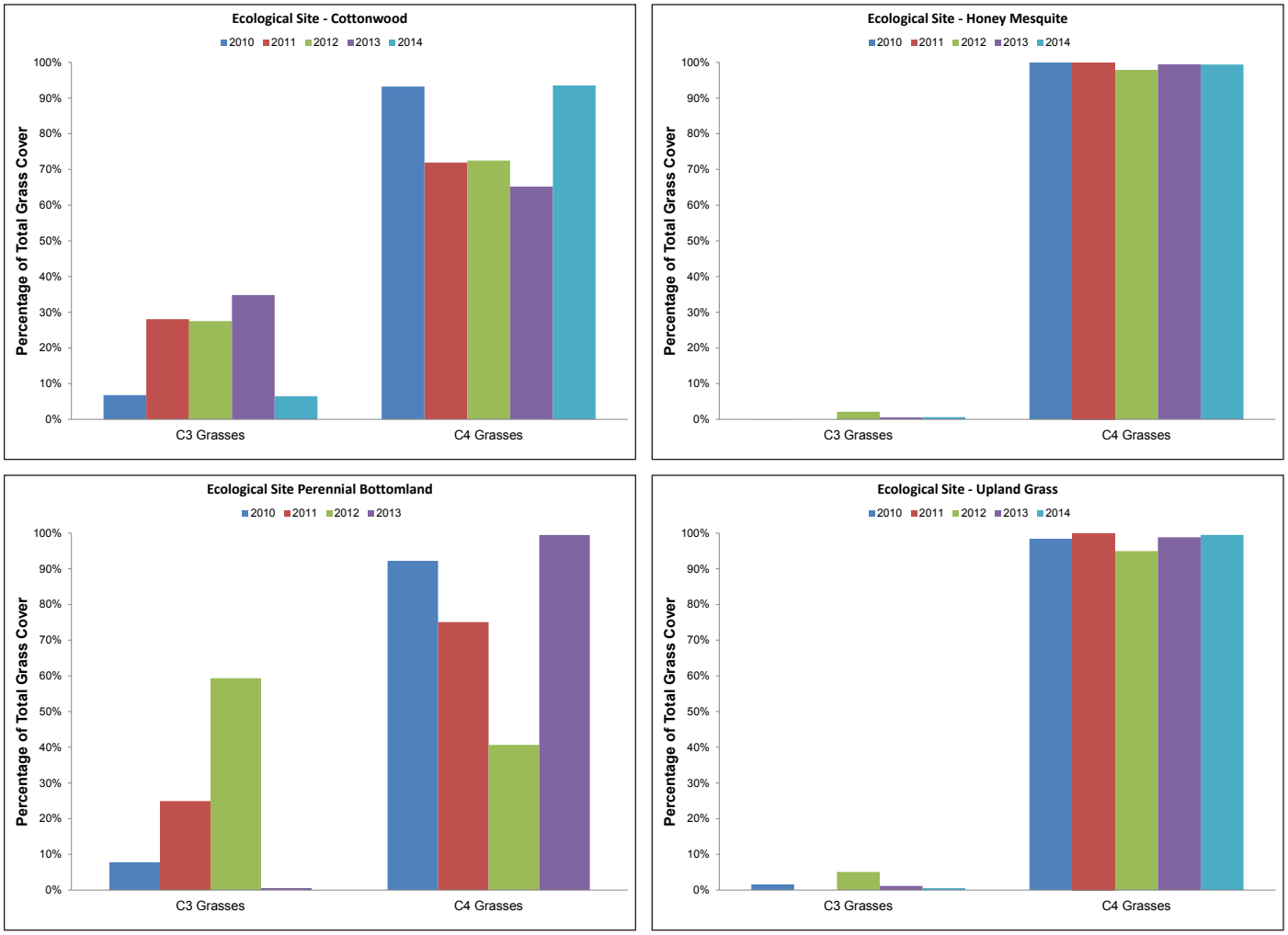


Figure 4.9.4-6. The percentage of C3 and C4 grasses by community type, 2010-2014

Relative Proportion of Functional Groups

Similar to our other measures, the proportion of functional groups and relative concern regarding this measure was highly variable among both rapid assessment sites and ecological sites (Table 4.9.45) and showed some annual variability among years (Figure 4.9.4-5). Sites where perennial, warm season grasses were most prevalent with lesser amounts of forb and shrub cover were considered to be in good condition as life forms were in line with expectations. Upland sites where forb, and especially shrub canopy cover was considerably higher, were thought to be in poorer condition as this increased cover often indicates an extended history of overgrazing coupled with fire suppression. The presence of soap weed yucca (*Yucca glauca*) and sand sage (*Artemisia filifolia*), two commonly occurring shrub species in the monitoring plots, often indicates this type of land use (NRCS 2004). That said, many assessment and monitoring sites are in good condition and areas that are in less than ideal condition are not degraded to the point that good ecological condition could not be restored through proper land management practices that park management already routinely implements and maintains. Therefore, condition is moderate with an indication of trending upward.

Table 4.9.4-6. The percentage cover of C3 and C4 grasses by community type at Lake Meredith NRA during the 2010-2014 grassland monitoring sampling.

Community	Percent C4 (vs C3)
Cottonwood	80.5%
Honey Mesquite	99.5%
Perennial Bottomland	71.8%
Upland Grass	98.1%

Relative Proportion of C3 and C4 Species

Results from the SOPN monitoring data indicated C4 grasses strongly dominated; percent cover ranged from 72% in bottomland habitats to 99% at honey mesquite sites (Table

4.9.4-6). Relative cover of C4 grasses varied widely in both cottonwood and bottomland habitats over the sampling years with values as low as 41% in 2012 (year following aerial spraying for tamarisk, which top-killed a lot of grass) and as high as 94% in 2014 (Figure 4.9.4-6). The rapid assessment sites were a bit more varied with some sites having a mix of C3 and C4 grasses (e.g., site 4) while others (e.g., site 2) were dominated by C3 grasses and still others (e.g., site 1) dominated by C4 grasses.

Grasslands in this region are typically dominated by C4 grasses. Sims et al. (1978) found that C4 grasses comprise 75% of the average above ground biomass in a site near Amarillo TX (as cited in Lauenroth 2008), and this is also consistent with what Paruelo et al. (1996) observed at Pantex, just northeast of Amarillo, TX, where they recorded 72% of the vegetation to be C4 grasses. Some of the variation in C3 to C4 ratios may be explained by the different ecosites, and some may be explained by land use history, including restoration activities. At other sites, especially in honey mesquite and cottonwood community types, this imbalance might be explained by aerial herbicide spraying. Although the experts did not express alarming concern over these patterns, there was enough to warrant us considering this measure as good to moderate overall.

Predicted, generalized climate change impacts for this region are drier, hotter, and more severe storms (and more frequent, severe fires). Should these predictions be correct, it may alter C4 and C3 species composition.

<u>The Role of Fire in Grassland Condition at Lake Meredith NRA/ Alibates Flint Quarries NM</u>

Historical records of fire frequencies for prairies of the southern Great Plains before settlement are generally nonexistent or unreliable because there are no trees to carry fire scars from which to estimate fire frequency (Ford and McPherson. 1996). Although fire is generally reported to play a prominent role in health and functioning of grasslands (e.g., Joern and Keeler 1995), this role likely varies substantially among grassland types. In particular, the role of fire as a primary determinant of grassland structure likely decreases strongly from tallgrass prairie to shortgrass steppe as a result of the gradient in productivity and fuel (Kucera 1981, Oesterheld et al. 1999, Scheintaub et al. 2009). In fact, grassland experts Drs. Alan Knapp and William Lauenroth (pers comm.) suggest that fire probably plays a much lesser role in maintaining a healthy prairie in the shortgrass steppe than other drivers such as herbivory and climate variation.

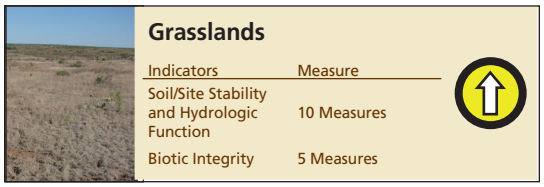
The ecological setting of grasslands at LAMR/ ALFL is a mixture of tall-, mid- and shortgrass prairie. Historically, natural fire has helped to shape the native vegetation and local ecosystems encompassing these park units. The shortgrass prairie was/is a fire dependent ecosystem in that fire fends off woody plant encroachment in concert with other factors (Wright and Bailey 1980). Return intervals typically ranged from 5-10 years prior to settlement (Wright and Bailey 1980), with ignitions from lightning or native peoples, (who utilized fire for multiple reasons; Pyne 2001, as cited in Ecosystem Management, Inc. in prep). American/ European settlement of the area reduced the number and frequency of natural, lightning caused fires by overgrazing, then by fire suppression in modern times. But fire suppression only works for so long; warming climate, drought, and the build-up of decadent fuels has allowed a resurgence of large, intense fires that have been damaging to humans, their property, and facilities in west Texas especially in the last 15-20 years (Ecosystem Management, Inc. in prep).

One of the perceived benefits of fire in grassland systems is the reduction of litter. In tallgrass prairie, litter removal increases soil temperature and light leading to increased productivity (Hulbert, 1988; Knapp and Seastedt, 1986). However, shortgrass steppe has minimal litter accumulation (Burke et al. 1998), and Scheintaub et al. (2009) reported a positive relationship between litter and productivity, suggesting that litter may facilitate, or at least not inhibit productivity as it does in tallgrass prairie. However, Scheintaub et al. (2009) also suggest that further research is needed on the relationship

between litter and productivity in shortgrass steppe.

LAMR has an active long-term prescribed fire program. There have also been several incidents of wildfire (Figure 4.9.4-7). A goal of the recently updated fire management plan (Ecosystem Management, Inc. in prep) is to safely emulate natural wildfires to restore and maintain primary natural resources and their processes by maintaining the shortgrass prairie and surrounding natural vegetation mosaics; and to reduce woody species (i.e., mesquite) from becoming overabundant and more predominant in the grasslands (Ecosystem Management, Inc. in prep). In general, there has been excellent herbaceous response to fire, but results are not showing the woody brush control as hoped. Shifting timing of the prescribed burns may control mesquite more effectively. However, this directive is challenging under ongoing and extended drought conditions as drought restricts use of prescribed fire due to safety considerations and since vegetation will not recover from fire when severely drought stressed (NPS 2014).

The absence of fire is also generally thought to have contributed to fuel accumulation, such that when fires do occur it is possible that they fires burn at a greater severity than they did historically, especially where shrubs have encroached. However, whether fire has a positive, neutral or negative benefit on grassland condition will depend on several factors (season, frequency, potential for exotic plant response, etc.) that will need to be considered carefully by Lake Meredith NRA/ Alibates Flint Quarries NM and fire management program. The uncertainty associated with the use of fire as a vegetation management tool might also warrant that such action be undertaken under an adaptive management framework including monitoring of the response.



Grasslands

Indicators	Measure
Soil/Site Stability and Hydrologic Function	10 Measures
Biotic Integrity	5 Measures

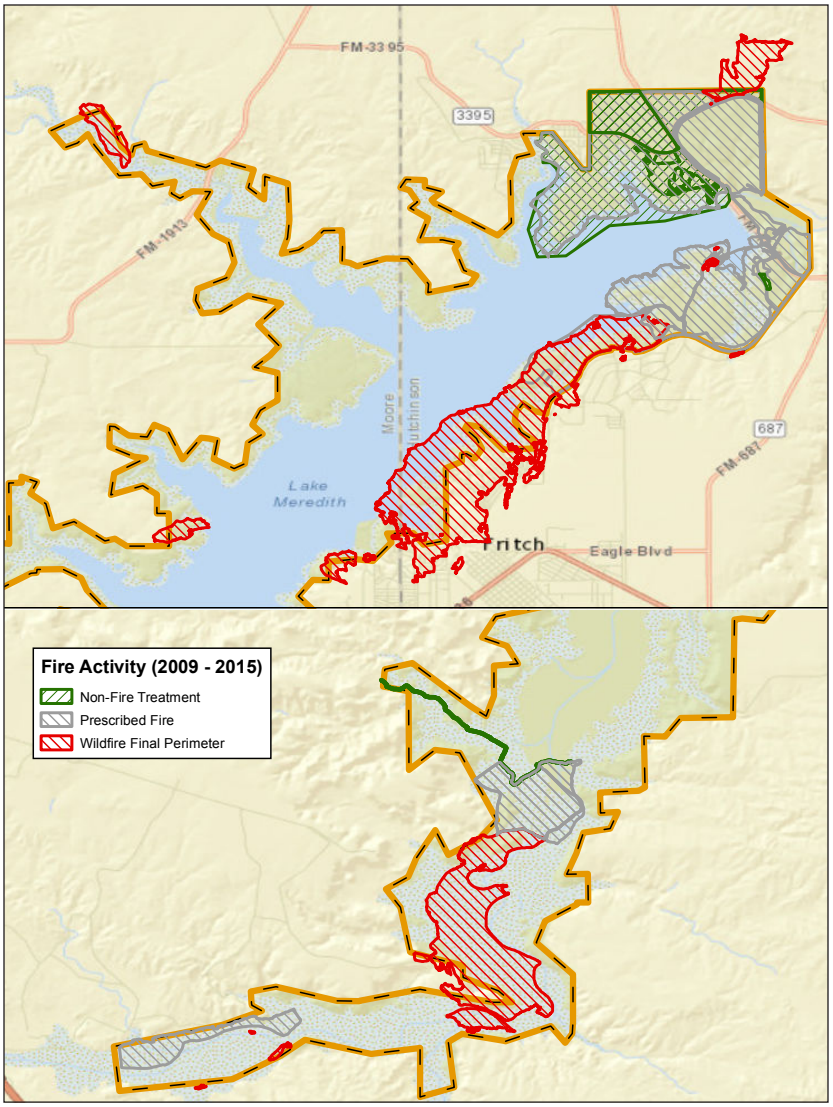


Figure 4.9.4-7. Wildland fires, prescribed fires and non-fire treatments at Lake Meredith NRA, 2009-2015.

Overall Condition

For assessing the condition of grasslands, we used a variety of indicators/measures that were not mutually exclusive but were intended to be different ways of capturing the essence of what we thought represented the condition of the Lake Meredith NRA/ Alibates Flint Quarries NM's grasslands. Grassland condition can be assessed from many different angles, but we chose two main categories for this resource. A summary of how they contributed to the overall grassland condition is summarized in Table 4.9.4-7. Based on the measures, data, and expert opinion, we consider the overall condition of the grasslands at Lake Meredith NRA/ Alibates Flint Quarries NM's to be in moderate condition with an improving trend. For nearly

Table 4.9.4-7. Summary of the grassland indicators and measures and their contributions to the overall assessment of grassland condition.

Indicator	Measure	Condition	Condition Rationale
Soil/Site Stability and Hydrologic Function	10 measures	Moderate	Departures from expected conditions for most measures of Soil/Site Stability and Hydrologic Function were typically minimal at many sites. There were a sufficient number of exceptions at sites in moderate condition, perhaps more heavily impacted by drought conditions, to justify a moderate condition rating overall.
Biotic Integrity	5 measures	Moderate	Measures of biotic integrity were highly variable among sites, often ranging from significant concern to good. Sites consistently either scored well or poorly for all five measures of biotic integrity. The moderate condition rating overall reflects the variability of conditon among sites.

all indicators and measures, condition was highly variable among sites, often ranging from good to significant concern. A few sites were overrun by Russian thistle or displaying a greater response to drought through reduced canopy cover of warm season grasses or large patches of bare soil, while other sites are in relatively good condition. Thus, our moderate condition rating reflects a balance between these variable results.

It should also be noted that the condition of grasslands is the result of a long history of land use and ecological conditions that began long before the establishment of Lake Meredith NRA/ Alibates Flint Quarries NM. Consequently, we do not consider the sites with grassland problems to be a result of NPS management; quite the contrary. Lake Meredith NRA/ Alibates Flint Quarries NM natural resource staff have been actively engaged in restoring areas in more degraded condition. Thus, we believe that many areas of Lake Meredith NRA/ Alibates Flint Quarries NM would be in substantially worse condition if it were not for the efforts of NPS staff. We are also anticipating conditions to be improving as the region shifts from extreme drought conditions to more normal rainfall patterns and as resource management continues to address exotic plants and restoration of native prairies.

Level of Confidence/Key Uncertainties

Overall, our confidence in this assessment is high, although as is generally the case, there are uncertainties. Some of the key uncertainties for the grassland assessment include annual variability, the effect of drought conditions, and the potential success of ongoing management actions.

Annual variability in rainfall, temperatures, diseases, etc. can have a dramatic effect on some measures (e.g., plant species composition), which in turn, affects our interpretation of grassland condition. However, this assessment was conducted, at least in part, during drought conditions. The stress from drought conditions has likely influenced some of our measures, but this influence would also likely imply our assessment is a bit conservative. That is, conditions may have appeared even better had they been assessed under more typical rainfall period.

4.9.5. Sources of Expertise

During the course of this assessment, we consulted with the following individuals who provided subject matter expertise as well as an on-site rapid assessment.

Dr. Fred Smeins is a professor at Texas A&M University, Department of Ecosystem Science and Management, College Station, Texas. Dr Smeins' research focuses on understanding the structure and dynamics of rangeland (grassland, wetland, savannah) ecosystems as influenced by herbivory, soil, fire and weather.

Tomye Folts-Zettner is the biologist/ vegetation specialist for the Southern Plains Inventory and Monitoring Network and has

an in-depth knowledge of the vegetation of the Southern Plains.

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4.10. Exotic Plants

Indicators/Measures

- Potential to Alter Native Plant Communities (1 measure)
- Prevalence of Exotic Plants (3 measures)

Condition – Trend - Confidence

Significant Concern – Stable - Medium

4.10.1. Background and Importance

Globalization of commerce, transportation, human migration, and recreation in recent history has introduced invasive exotic species to new areas at an unprecedented rate. Biogeographical barriers that once restricted the location and expansion of species have been circumvented, culminating in the homogenization of Earth's biota. Approximately 4-19% of species introduced into the United States may become invasive (USFWS 2012).

Invasive species have been directly linked to displacing several native species of plants (Pimentel et al. 1999). Approximately 42% of threatened and endangered species are at risk primarily because of alien-invasive species (Pimentel et al. 2005). Exotic plants cause changes in ecosystem structure, alteration of nutrient cycles and soil chemistry, alteration of normal successional trajectory of a system (Ehrenfeld 2003, Emery 2012), negative impacts to agriculture (Pimentel 2009), and limitations on water availability (USFWS 2012) (Figure 4.10.1-1).

The spread of invasive species is one of the most environmentally serious global changes, causing economic and environmental damage in the United States and worldwide (UCSUSA 2008). Consequently, the dynamic relationships among plants, animals, soil, and water established over many thousands of years are at risk of being destroyed in a relatively brief period. For the National Park Service (NPS), the consequences of these invasions present a significant challenge to the management of the agency's natural resources "unimpaired for the enjoyment of future generations." National parks, like land managed by other organizations, are deluged

NPS

Figure 4.10.1-1. *Salsola tragus* (prickly Russian thistle) is especially competitive with native species during drought periods.

by new exotic species arriving through predictable (e.g., road, trail, and riparian corridors), sudden (e.g., long-distance dispersal through cargo containers and air freight), and unexpected anthropogenic pathways (e.g., weed seeds in restoration planting mixes). Nonnative plants claim an estimated 4,600 acres per day on federal lands alone in the western United States, quadrupling their range from 1985-1995, claiming approximately 17 million acres (BLM 2011) and significantly altering local flora. For example, in Great Smoky Mountains National Park, over ¼ of the plants (27%) are non-native species. On the big island of Hawaii 35% of the plants are non-native (Pimentel et al. 2005). Invasive plants are dominant on approximately 5% of the lands managed by the NPS (NPS 2009).

4.10.2. Data and Methods

In assessing current condition and trend for exotic plants at Lake Meredith NRA and Alibates Flint Quarries National Monument (hereafter referred to as Lake Meredith NRA), we used two indicators. The first indicator, which has one measure, evaluates the overall impact an exotic plant has on the native plant communities throughout the recreation area. This indicator utilizes known natural history characteristics of exotic plant species in order to characterize their impact on natural ecosystems.

The second indicator, with three measures, was used to assess the prevalence of the exotic plant species on park lands. Data for the prevalence indicator and measures were collected by Southern Plains Inventory and Monitoring (SOPN) staff between 2012 and 2014. The Lake Meredith area experienced at least moderate drought for the last 24 months of the monitoring period which ended in June 2014 (Folts-Zettner, SOPN biologist, personal communication, 2014). Seventeen of those months were at least severe drought levels. Ten months were extreme to exceptional Drought including the four months immediately preceding the June 2014 monitoring. Folts-Zettner (SOPN biologist, personal communication, 2014) thinks that this drought has had a major impact on the plant communities in the recreation area during the time interval covered by this assessment.

<u>SOPN Annual Exotic Plants Monitoring</u>

The SOPN's systematic monitoring program gathers information in a financially feasible means about the occurrence of exotic plants in select areas in NPS units that can be spatially represented and used for data analysis (Folts-Zettner et al. 2013). The protocol involves regular monitoring of blocks along high priority vectors (e.g., roads and trails) that have been identified based on their potential risk for invasion by exotic plants. The overall

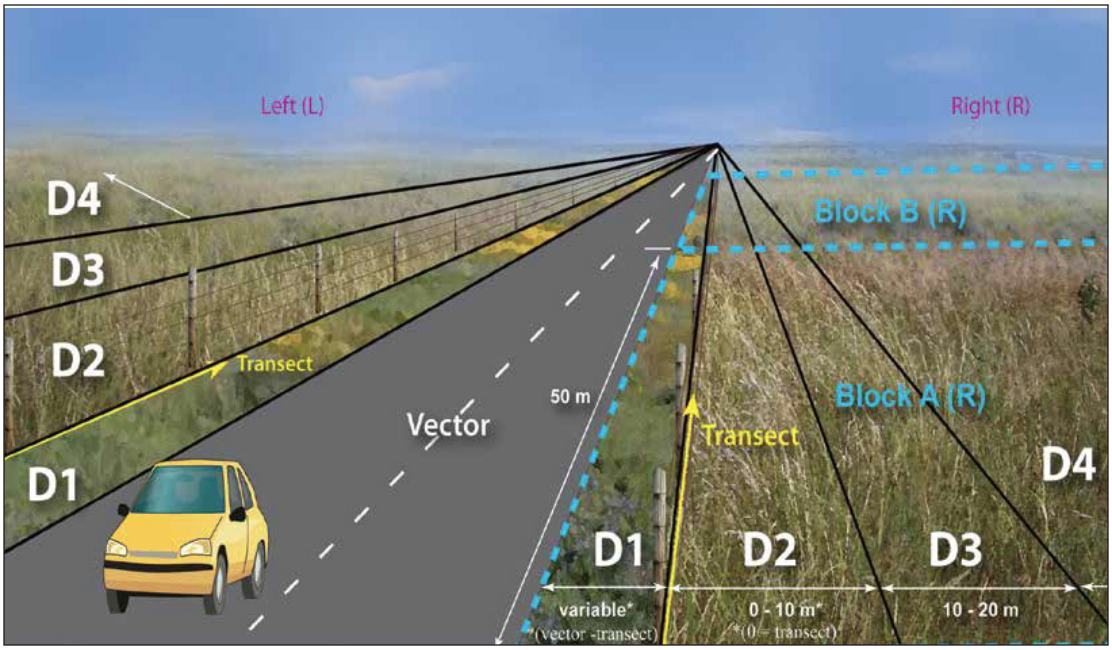


Figure 4.10.2-1. Fifty meter blocks are sampled on each side of a high-risk vector (e.g., road or trail).

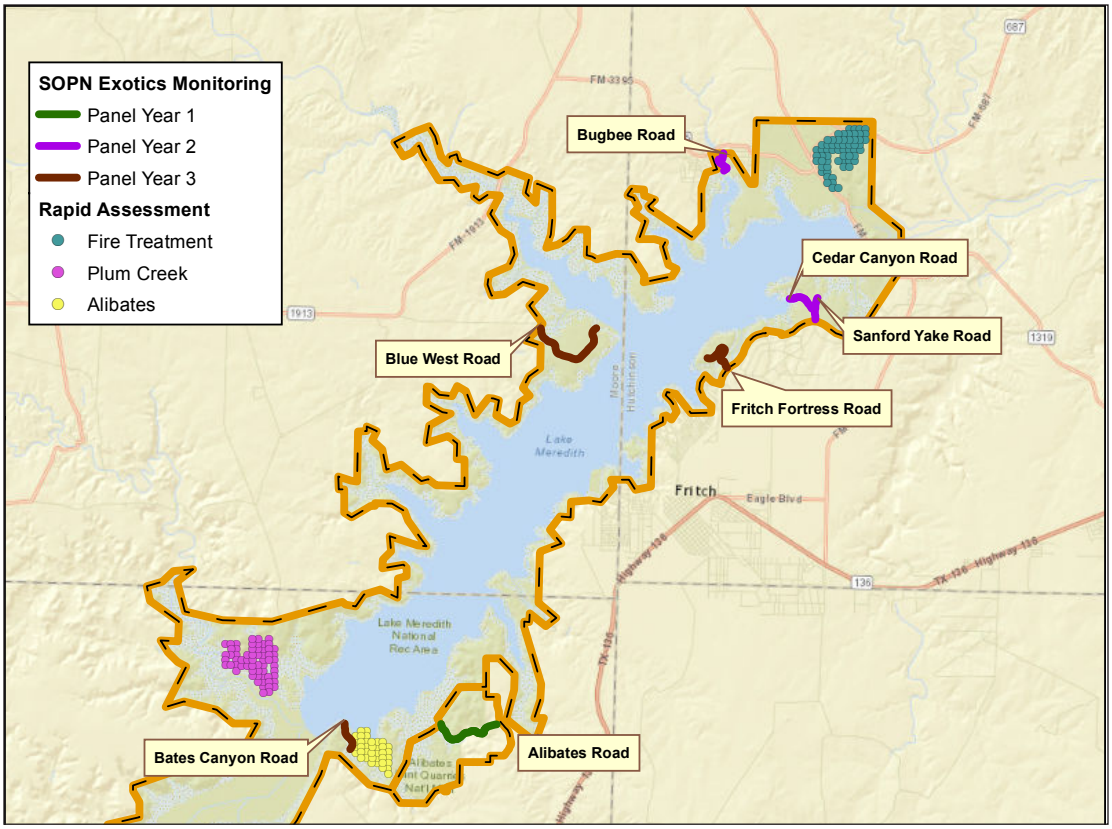


Figure 4.10.2-2. Areas within Lake Meredith NRA surveyed during SOPN annual monitoring and during the one-time 2014 SOPN rapid assessment.

approach is based on a generalized linear model, where 50-meter blocks on both sides of the vector (right [R] and left [L]) are surveyed from a transect running along (e.g., trails) or adjacent to (e.g., along the mow strip of roads) the vector (Figure 4.10.2-1). Four distances classes per block are assessed in order to provide information that may indicate that a given species has invaded interior habitats or whether it remained localized near the likely source of invasion (Folts-Zettner et al. 2013).

The standard sampling scheme uses a three-year rotating panel design, whereby a new area is surveyed each year (a panel) for three years, then repeated (Figure 4.10.2-2). We utilized SOPN's annual monitoring data collected between 2012 - 2014 to report the most current condition of the recreation area's exotic plants (Folts-Zettner and Sosinski 2012a; 2013; 2014). Monitoring took place in mid June each year.

The SOPN monitored blocks along the paved Alibates Road in 2012, along the Bugbee, Sanford-Yake, and Cedar Canyon Roads in 2013, and along the Blue West, Fritch Fortress and Bates Canyon Roads in 2014.

The 2012-2014 vector monitoring was the second full panel of sampling at Lake Meredith. Monitoring along the same vectors also occurred in 2009-2011, with the exception of the addition of two additional vectors (Fritch Fortress and Bates Canyon Roads) monitored in 2014 because the survey crew was available (Sosinski, SOPN data manager, personal communication, 2014). Data from the 2009-2011 monitoring will be discussed in Section 4.10.4, Condition and Trend.

Other sources of information about exotic plant species found in Lake Meredith NRA include the recreation area's vascular plant floristic inventory (Nesom and O'Kennon 2005), vegetation map (Fenton et. al. 2007), and the exotic species list maintained by the SOPN (Folts-Zettner 2014).

It is important to emphasize that SOPN's sampling approach does not provide a complete survey of exotic plants throughout the recreation area. Instead, it provides a repeated snapshot for limited areas with high potential (e.g., along roads or trails) for new invasions.

SOPN 2014 Rapid Assessment (one-time only)

In addition to the annual SOPN monitoring program, a one-time rapid assessment of exotic plant occurrence was conducted by SOPN staff in June 2014 (Horsley and Schafer 2014). The purpose of the rapid assessment was to collect information about the presence of exotic species in other areas of the recreation area for this condition assessment.

For the rapid assessment, a point grid was developed (Folts-Zettner, SOPN biologist, personal communication, 2014). Points are usually 150 meters apart, and exotic species were observed within a 10-meter radius of that point. Data for occurrence and density of exotic species found in these supplemental plots were recorded in the same way as in the standard monitoring described in Folts-Zettner et al. (2013), but without utilizing distance classes as in the vector monitoring.

Because of the large size of Lake Meredith NRA (45,000 acres) monitoring during the 2014 rapid assessment occurred in three areas (Figure 4.10.2-2) that represent the major environments found in the recreation area (Folts-Zettner, SOPN biologist, personal communication, 2014). The Alibates area is upland habitat and the Plum Creek area includes typical canyon habitat. The Fire Treatment area was burned by wildfire earlier in 2014. A planned fourth area for Rapid Assessment monitoring in bottomland habitat, Pipeline, was inaccessible due to muddy conditions. The SOPN plans to monitor that area in 2015 as a supplement to this report (Folts-Zettner, SOPN biologist, personal communication, 2014).

Both SOPN annual monitoring locations and locations of the one-time rapid assessment that took place in 2014 are shown in Figure 4.10.2-2.

Indicator/Measure

Potential to Alter Native Plant Communities: Significance of Exotic Plant Impact)

The first indicator and measure, potential to alter native plant communities (significance of exotic plant impact), was derived from the Handbook for Ranking Exotic Plants for Management and Control (Hiebert and Stubbendieck 1993). The handbook's analytical approach provides NPS managers with scientific information that encompasses the full array of significant factors that measure the ecological impact of an exotic species.

For the purposes of this assessment, Hiebert and Stubbendieck's significance of exotic plant impact was modified to capture only its innate ability to become a pest. The innate ability for a species to become a pest section quantifies the characteristics, such as ability to reproduce vegetatively, the number of seeds per plant, germination requirements, and the plant's competitive ability, that preadapt it to become a problem.

The numerical ranking for this measure ranged between 0 - 50 possible points, with 50 representing the highest possibility of impacting and altering the native plant communities and zero being the lowest. We assigned the numerical rankings to the following categories:

- 40 - 50 = Highest Concern
- 35 - 39 = High Concern
- 30 - 34 = Medium Concern
- 0 - 29 = Low Concern

The significance of exotic plant impact rankings for each exotic species found during SOPN's annual (2012-2014) and 2014 rapid assessment monitoring at the NRA are reported in Table 4.10.2-1. Six species were ranked as having the highest concern, with three additional species having high concern. Two of the species of highest concern, *Convolvulus arvensis* (field bindweed) and *Tamarix spp.* (saltcedar) are Texas state noxious weeds (USDA-NRCS 2014).

The nativity of the *Euphorbia spp.*(spurge), (*Euphorbia davidii*, David's spurge, and *Euphorbia dentata*, toothed spurge) in the Lake Meredith area is in question. The species are included in SOPN monitoring in order to track their occurrence (Folts-Zettner, SOPN biologist, personal communication, 2014).

Table 4.10.2-1. Significance of exotic plant impact ranking for species detected in SOPN 2012-2014 monitoring (Folts-Zettner and Sosinski 2012a, 2013, 2014) and the 2014 Rapid Assessment (Horsley and Schafer 2014), using a subset of Hiebert and Stubbendieck's (1993) Handbook for Ranking Exotic Plants for Management and Control.

Species	Common Name	Noxious	Ranking
Amaranthus retroflexus	redroot pigweed		Low
Bothriochloa ischaemum[1]	king ranch bluestem		Highest
Bromus catharticus	rescue brome		Low
Bromus japonicus[1]	Japanese brome		High
Bromus tectorum[1]	cheatgrass		Highest
Chenopodium album	lamb's quarters		Low
Convolvulus arvensis[1]	field bindweed	X	Highest
Cynodon dactylon[1]	Bermudagrass		High
Elaeagnus angustifolia[1]	Russian olive		Highest
Eragrostis cilianensis	stinkgrass		Low
Euphorbia spp.[1,3]	David's or toothed spurge		High
Kochia scoparia	kochia		Medium
Lactuca serriola	prickly lettuce		Medium
Medicago minima	burr medick clover		Medium
Melilotus officinalis	yellow sweetclover		Low
Polygonum arenastrum	prostrate knotweed		Low
Salsola tragus[2]	prickly Russian thistle		Medium
Sorghum halepense[1]	Johnsongrass		Highest
Tamarix spp.[1,3]	saltcedar	X	Highest
Tragopogon dubius	western salsify		Low
Tribulus terrestris	puncturevine		Medium

[1] Species considered to be of highest or high concern using the significance of exotic plant impact, innate ability to become a pest measure (Hiebert and Stubbendieck 1993) are highlighted in the darker tone.

[2] Species of special concern (Folts-Zettner, SOPN biologist, personal communication, 2014) is highlighted in the lighter tone.

[3] *Euphorbia spp.* include *Euphorbia davidii* and *Euphorbia dentata*. *Tamarix ssp.* include *Tamarix chinensis* and *Tamarix ramosissima*.

Indicators/Measures
Prevalence of Exotic Plants (3 measures)

The prevalence of exotic plants includes three measures: extent, density, and distribution (Table 4.10.2-2). These measures describe how often, how many, and where respectively that exotic plant species were located during the annual and the 2014 rapid assessment monitoring.

Measure
Extent of Exotic Plants

Extent is a measure of the area (e.g., block in annual SOPN vector monitoring, or plot in 2014 rapid assessment monitoring) in which exotic species have been found. Extent is a proportional measure that indicates that an exotic species was identified a certain number of times. Extent is reported as the percentage

Table 4.10.2-2. Definitions of the three measures used for the prevalence of exotic plants indicator.

Measure	Description
Extent	*Answers how often.* A measure of the percent of surveyed park monitoring locations (blocks or plots) that has exotic species occurring in it.
Density	*Answers how many.* The number of exotic plants per unit of area (block or plot)
Distribution	*Answers where.* A measure of the location of exotic plant occurrence.

of the surveyed blocks or plots that contained a specific exotic species, and the frequency that blocks or plots contained exotic plant species. This measure only indicates whether the plant was found in the surveyed area, and does not include its density (e.g., number of plants found per block or plot) or where the block or plot was located. Extent is reported for all species identified during the SOPN 2012-2014 monitoring in Table 4.10.2-3, in Table 4.10.2-4 for the rapid assessment, and in Appendix F.

SOPN Annual Exotic Plants Monitoring

Twenty-one species of exotic plants were encountered during vector monitoring in 2012-2014 (Table 4.10.2-3), including the nine species of highest or high concern for their innate ability to become a pest. Only 8.2% of the blocks did not contain exotic species. *Salsola tragus* (prickly Russian thistle) was the most common exotic plant found along the vectors, and was detected in 76.6% of the blocks. *Bothriochloa ischaemum* (king ranch bluestem), a species of highest concern, was found in 30.4% of the blocks. It was especially common along the Sanford-Yake Road where it was present in 79.2% of the blocks, and the Bates Canyon Road were it was found in 50% of the blocks. B*romus japonicus* (Japanese brome), a species of high concern, was detected in 9.9% of the blocks. *Kochia scoparia* (kochia), *Chenopodium album* (lamb's quarters), and *Tragopogon dubius* (salsify) also had significant extent and were found in 15.5%, 15.2% and 9.9% of the blocks respectively. *Chenopodium album* was particularly extensive along the Alibates Road and was found in 80.6% of the blocks along that vector. The fifteen other species detected during vector monitoring all had limited extent and were found in 3.2% of the blocks or less.

SOPN 2014 Rapid Assessment

Seven species were detected during the SOPN 2014 rapid assessment (Table 4.10.2-4), with *Salsola tragus* in 81% of the plots. *Euphorbia spp.*, a species of high concern for its innate ability to become a pest but which is potentially native in Lake Meredith, was present in 61.3% of the plots. No exotic plants were found in 1.9% of the plots surveyed.

Table 4.10.2-3. Extent of exotic plant species detected in annual SOPN high priority monitoring blocks sampled in 2012-2014.

Species	No. Blocks	% (N=342)
Salsola tragus[2]	262	76.6%
Bothriochloa ischaemum[1]	104	30.4%
Kochia scoparia	53	15.5%
Chenopodium album	52	15.2%
Bromus japonicus[1]	34	9.9%
Tragopogon dubius	34	9.9%
No plants detected	28	8.2%
Sorghum halepense[1]	11	3.2%
Bromus catharticus	8	2.3%
Convolvulus arvensis[1]	8	2.3%
Tribulus terrestris	8	2.3%
Tamarix spp.[1]	7	2.1%
Lactuca serriola	6	1.8%
Bromus tectorum[1]	5	1.5%
Medicago minima	5	1.5%
Amaranthus retroflexus	3	0.9%
Cynodon dactylon[1]	3	0.9%
Elaeagnus angustifolia[1]	2	0.6%
Melilotus officinalis	2	0.6%
Eragrostis cilianensis	1	0.3%
Euphorbia spp.[1]	1	0.3%
Polygonum arenastrum	1	0.3%

[1] Species considered to be of highest or high concern in (Table 4.10.2-1) are highlighted in the darker tone.

[2] Species of special concern (Table 4.10.2-1) is highlighted in the lighter tone.

Table 4.10.2-4. Extent of exotic plant species detected in SOPN rapid assessment plots sampled in 2014.

Species	No. Plots	% (N=160)
Salsola tragus[2]	130	81.3%
Euphorbia spp.[1]	98	61.3%
Kochia scoparia	45	28.1%
Chenopodium album	27	16.9%
Amaranthus retroflexus	16	10.0%
Sorghum halepense[1]	5	3.1%
Tribulus terrestris	3	1.9%
No plants detected	3	1.9%

[1] Species considered to be of highest or high concern in (Table 4.10.2-1) are highlighted in the darker tone.

[2] Species of special concern (Table 4.10.2-1) is highlighted in the lighter tone.

Kochia scoparia was present in 28.1% of the plots surveyed, but all these plots were in the Alibates area where 60.5% of plots contained the species. *Sorghum halepense* (Johnsongrass), of highest concern for its impact on native plant communities, was present in 3.1% of the plots.

Two species that had minimal presence along the surveyed vectors occurred in a significant proportion of the rapid assessment plots. *Euphorbia spp.* was found in one vector block, but in 61.3% of the rapid assessment plots, *Amaranthus retroflexus* (redroot pigweed) was present in only three vector blocks, but occurred in 10% of the rapid assessment plots.

Measure
Density of Exotic Plants

The density measure is the number of exotic plants per unit of area (block or plot). During the annual SOPN and 2014 SOPN rapid assessment monitoring, the occurrence of each observed exotic species was assigned to one of five density classes, representing a range from not observed to a small number of individual plants to a continuous matrix within the block or plot.

These density classes are:

- 0 = Not observed
- 1 = 1-5 plants present
- 2 = Scattered in patches
- 3 = Scattered fairly evenly
- 4 = Forming a matrix (Folts-Zettner et al. 2013).

Density is reported for all species identified during the SOPN 2012-2014 annual monitoring in Table 4.10.2-5 and for all exotic species found during the 2014 one-time rapid assessment in Table 4.10.2-6.

The density of the species (*Salsola tragus*) with the widest extent is shown in Figure 4.10.2-3 For the annual monitoring, these maps only show the densities of the plants in the distance class closest to the actual vector.

SOPN Annual Exotic Plants Monitoring

Exotic species were most often found in density class 2 (scattered patchy) during the 2012-2014 monitoring of high priority vectors (Table 4.10.2-5).

Only four species were detected at evenly scattered densities (class 3) in the 2012-2014 monitoring, including two species, *Bothriochloa ischaemum* and *Sorghum halepense*, of highest concern for their potential to alter native plant communities. No exotic species formed a matrix along any of the vectors.

Most of the species that had significant extent along the vectors (e.g., found in at least 10% of the blocks) were present mostly in density class 2 (scattered patchy), with the exception of *Tragopogon dubius* which occurred in density class 1 (1-5 individuals per block) nearly 85% of the time.

SOPN 2014 Rapid Assessment

Exotic plant species were also mostly detected in density class 2 or higher during the 2014 rapid assessment (Table 4.10.2-6). Less than 1% of the occurrences of *Salsola tragus* were in density class 1 (1-5 individuals). Nearly 73% of the plots contained the species in density class 2 (scattered patchy) and 26.7% were in density class 3 (scattered even).

Euphorbia spp. and *Kochia scoparia* were present in density class 3 (scattered even) 21.2% and 31.1% of the time respectively, with *Kochia scoparia* forming the matrix (density class 4) in 4.4% of the plots.

Measure
Distribution of Exotic Plants

The distribution measure evaluates the occurrence of exotic plant species in different areas of the recreation area, including in different habitats. Some species, such as *Tamarix spp.* and *Elaeagnus angustifolia* (Russian olive), only grow in specific habitats, such as riparian or bottomland, while others, such as *Salsola tragus,* germinate only in areas of bare ground.

Table 4.10.2-5. Density of exotic plants in SOPN 2012-2014 high priority vector blocks with the density class information in percentage of total occurrences recorded for each species.

Species	Number of Occurrences	Density Classes			
		Class 1 (%) 1-5 individuals	Class 2 (%) Scattered patchy	Class 3 (%) Scattered even	Class 4 (%) Matrix
Salsola tragus[2]	598	8.9%	87.6%	3.5%	
Bothriochloa ischaemum[1]	144	18.1%	78.5%	3.5%	
Chenopodium album	132	12.1%	86.4%	1.5%	
Kochia scoparia	88	13.6%	86.4%		
Bromus japonicus[1]	45	22.2%	77.8%		
Tragopogon dubius	39	84.6%	15.4%		
Sorghum halepense[1]	17	11.8%	70.6%	17.6%	
Tribulus terrestris	11	27.3%	72.7%		
Convolvulus arvensis[1]	10	90.0%	10.0%		
Bromus catharticus	8	37.5%	62.5%		
Tamarix spp.[1]	8	87.5%	12.5%		
Lactuca serriola	7	71.4%	28.6%		
Medicago minima	6	33.3%	66.7%		
Bromus tectorum[1]	5		100.0%		
Amaranthus retroflexus	4	25.0%	75.0%		
Melilotus officinalis	4	25.0%	75.0%		
Cynodon dactylon[1]	3	66.7%	33.3%		
Elaeagnus angustifolia[1]	2	100.0%			
Eragrostis cilianensis	2		100.0%		
Euphorbia spp.[1]	1	100.0%			
Polygonum arenastrum	1		100.0%		

The number of occurrences includes those in all distance classes from the vector. Density classes are from (Folts-Zettner et al. 2011). Density class 0 measures are not reported in this table.

[1] Species considered to be of highest or high concern in (Table 4.10.2-1) are highlighted in the darker tone.

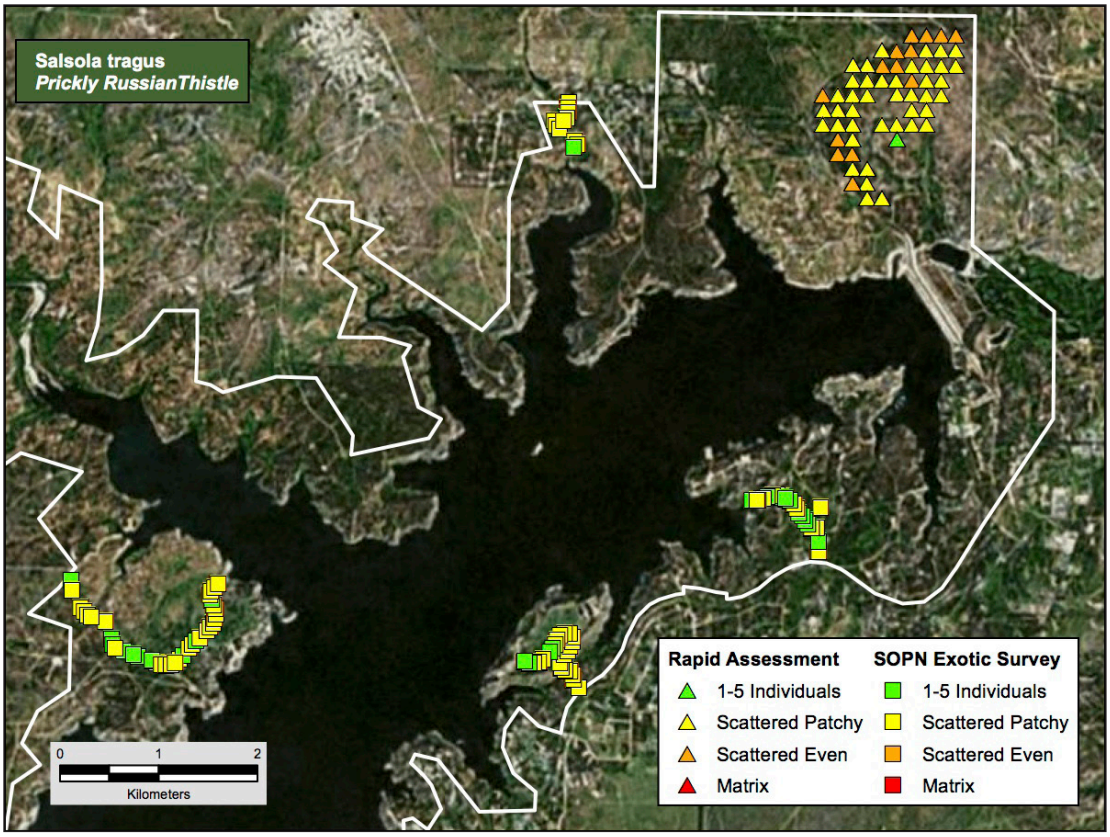
[2] Species of special concern (Table 4.10.2-1) is highlighted in the lighter tone.

Table 4.10.2-6. Density of exotic plants in SOPN 2014 rapid assessment plots, with the density class information in percentage of total occurrences recorded for each species.

Species	Number of Occurrences	Density Classes			
		Class 1 (%) 1-5 individuals	Class 2 (%) Scattered patchy	Class 3 (%) Scattered even	Class 4 (%) Matrix
Salsola tragus[2]	131	0.8%	72.5%	26.7%	
Euphorbia spp.[1]	99	11.1%	67.7%	21.2%	
Kochia scoparia	45		64.4%	31.1%	4.4%
Chenopodium album	27	18.5%	81.5%		
Amaranthus retroflexus	15	6.7%	93.3%		
Sorghum halepense[1]	5	20.0%	80.0%		
Tribulus terrestris	3	33.3%	66.7%		

[1] Species considered to be of highest or high concern in (Table 4.10.2-1) are highlighted in the darker tone.

[2] Species of special concern (Table 4.10.2-1) is highlighted in the lighter tone.



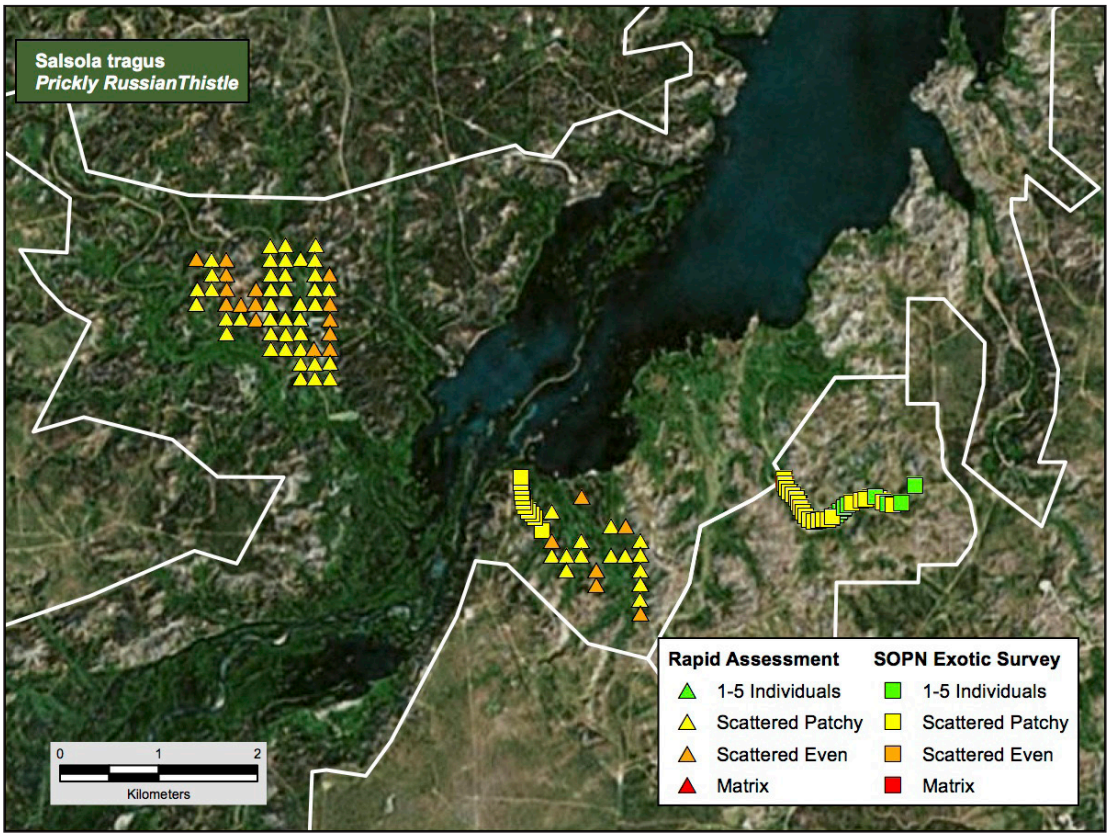


Figure 4.10.2-3. *Salsola tragus* plant density based on surveys conducted during SOPN's 2012-2014 annual monitoring and SOPN's 2014 rapid assessment.

Table 4.10.2-7. Distribution of exotic plants found in Lake Meredith NRA, with the proportion of infested blocks in each of the vectors monitored during 2012-2014 SOPN monitoring.

Species	Alibates Rd (N=62)	Bugbee Rd (N=30)	Cedar Canyon Rd (N=34)	Sanford-Yake Rd (N=24)	Blue West Rd (N=104)	Bates Canyon Rd (N=34)	Fritch Fortress (N=54)
Amaranthus retroflexus							5.6%
Bothriochloa ischaemum[1]	12.9%	16.7%	29.4%	79.2%	26.9%	50.0%	31.5%
Bromus catharticus			8.8%	4.2%		11.8%	
Bromus japonicus[1]	4.8%	43.3%	26.5%	33.3%		2.9%	
Bromus tectorum[1]						14.7%	
Chenopodium album	80.6%					5.9%	
Convolvulus arvensis[1]		6.7%	2.9%		3.8%		1.9%
Cynodon dactylon[1]							5.6%
Elaeagnus angustifolia[1]		6.7%					
Eragrostis cilianensis	1.6%						
Euphorbia spp.[1]						2.9%	
Kochia scoparia	3.2%	6.7%	20.6%	33.3%	1.9%	67.6%	14.8%
Lactuca serriola	3.2%	3.3%				8.8%	
Medicago minima			5.9%	12.5%			
Melilotus officinalis		3.3%		4.2%			
Polygonum arenastrum						2.9%	
Salsola tragus[2]	82.3%	66.7%	44.1%	37.5%	85.6%	82.4%	92.6%
Sorghum halepense[1]		3.3%			3.8%	8.8%	5.6%
Tamarix spp.[1]		16.7%			1.9%		
Tragopogon dubius	6.5%	10.0%	23.5%	12.5%	3.8%	35.3%	
Tribulus terrestris						11.8%	7.4%

[1] Species considered to be of highest or high concern in (Table 4.10.2-1) are highlighted in the darker tone.

[2] Species of special concern (Table 4.10.2-1) is highlighted in the lighter tone.

Table 4.10.2-8. Distribution of exotic plants found in the rapid assessment areas in Lake Meredith NRA, with the proportion of infested plots in each of the areas monitored during the 2014 rapid assessment.

Species	Alibates (N=38)	Fire Treatment (N=60)	Plum Creek (N=62)
Amaranthus retroflexus	23.7%		11.3%
Chenopodium album	28.9%		25.8%
Euphorbia spp.	86.8%	30.0%	78.3%
Kochia scoparia	60.5%		
Salsola tragus[2]	52.6%	93.3%	36.7%
Sorghum halepense	2.6%	3.3%	3.3%
Tribulus terrestris	5.3%	0.1%	

A total of 160 plots were monitored during SOPN's 2014 rapid assessment.

[1] Species considered to be of highest or high concern in (Table 4.10.2-1) are highlighted in the darker tone.

[2] Species of special concern (Table 4.10.2-1) is highlighted in the lighter tone.

The distribution measure is the proportion of blocks or plots infested with exotic plants reported for each of the distinct areas surveyed in SOPN 2012-2014 vector monitoring (Table 4.10.2-7) and the 2014 rapid assessment (Table 4.10.2-8) (Horsley and Schafer 2014). This information shows whether the infestations of exotic species are widespread and found in multiple areas of the recreation area or restricted to certain areas.

The species with the greatest extent and density also had the greatest distribution: *Salsola tragus*, *Bothriochloa ischaemum* and *Kochia scoparia* were prevalent along all the high priority vectors. *Salsola tragus* was also prevalent in the three areas surveyed during the rapid assessment. However, *Bothriochloa ischaemum* was not found during the rapid assessment. *Kochia scoparia* was present in

60.5% of the Alibates rapid assessment plots, but not found in either Plum Creek or the fire treatment area.

Tragopogon dubius also had wide distribution and was present along all vectors except for the Fritch Fortress Road, which had burned earlier in the season where it likely did not have time to regenerate (Folts-Zettner, SOPN biologist, personal communication, 2014). The species was not present in any of the rapid assessment plots.

While *Sorghum halepense* was found in just over 3% of the units (blocks and plots) surveyed, it had wide distribution: it was found along five of the seven vectors, and in all three areas surveyed in the rapid assessment.

Bromus japonicus (Japanese brome), a species of high exotic plant impact, was present in five of the seven vectors, including in 43.3% of the blocks along the Bugbee Road, but also was not identified during the rapid assessment.

Euphorbia spp. was only present along one vector, the Bates Canyon Road and in only 2.9% of the blocks, but was found in all three rapid assessment areas, including 86.8% of the plots in the Alibates area, and 78.3% of the plots in Plum Creek.

Table 4.10.2-9 shows the number of different species found in along each of the vectors, and in the areas included in the rapid assessment. All the vectors had more species of exotic plants than in the rapid assessment areas, which had less diversity of exotic plant species. Blocks along Bates Canyon Road contained thirteen species of exotic plants, and twelve species were found along Bugbee Road.

Table 4.10.2-9. Number of species found in each location during SOPN monitoring.

Location	Monitoring Type	# of Species
Alibates Rd	Vector	9
Bugbee Rd	Vector	12
Cedar Canyon Rd	Vector	9
Stanford-Yake Rd	Vector	9
Blue West Rd	Vector	8
Bates Canyon Rd	Vector	13
Fritch Fortress Rd	Vector	9
Alibates	Rapid Assessment	6
Fire Treatment	Rapid Assessment	5
Plum Creek	Rapid Assessment	5

The distribution of exotic plants in the rapid assessment areas is at least partly dependent on the available habitat. For example, fast growing annuals such as *Salsola tragus* dominated in the fire treatment area. *Kochia scoparia* was absent in the canyon habitat in the Plum Creek rapid assessment area.

4.10.3. Reference Conditions

Whenever an exotic plant is present that has the biological characteristics to alter native plant communities, there is cause for concern. However, early detection of these species provides managers with the necessary information to apply a rapid response management strategy before the exotic plant becomes established. If a rapid response is not implemented, the exotic plant may become established and potentially degrade the integrity of the native plant communities.

Our good, moderate, and significant concern reference conditions are based upon both an exotic plant's ability to alter native plant communities as well as its prevalence (i.e., extent, density, and distribution). A summary of the reference conditions is shown in Table 4.10.3-1.

A good reference condition is the capability for primary communities to be maintained. By this, we mean that ecological attributes (e.g., species composition, structure, etc.) and natural processes remain within the natural variation for the community type.

A moderate condition is assigned to exotic plant species that have been ranked as high concern but prevalence remains low, or when a plant has been assigned a medium impact ranking score and is found in medium prevalence.

A condition of significant concern is assigned when an exotic plant is ranked as highest for its ability to alter native plant communities. A

Table 4.10.3-1. Descriptions for determining condition based on exotic plant potential to alter native plant communities impact ranking and degree of prevalence.

Prevalence of Exotic Plant	Potential to Alter Native Plant Communities Impact Ranking			
	Low	Medium	High	Highest
Low	Good Condition[1]	Good Condition[1]	Moderate Condition	Significant Concern
Medium	Variable[1]	Moderate Condition	Significant Concern	Significant Concern
High	Variable[1]	Significant Concern	Significant Concern	Significant Concern

[1] Species in these cells may warrant further consideration of condition on a case by case basis.

species is of significant condition with a high for impact ranking and occurring at medium to high prevalence levels. A species with a moderate impact ranking and high prevalence is also of significant condition.

Further consideration of condition is warranted on a case by case basis, especially for species with low prevalence, or when a species' prevalence may be increasing. Given the early detection and rapid response model for the control of exotic plants, species with low prevalence may be considered to be in moderate condition even though they may have low or medium impact rankings. Further, species that scored low in the Hiebert and Stubbendieck's (1993) innate ability to become a pest ranking system, may considered to be of moderate condition depending on the individual characteristics of a species, and the unique attributes of the NPS site, regardless of prevalence.

4.10.4. Condition and Trend

Twenty-one exotic species were found within Lake Meredith NRA during monitoring by the SOPN between 2012 and 2014 (Folts-Zettner and Sosinski 2012a; 2013; 2014, and Horsley and Schafer 2014). Altogether, 68 species of exotic plants (Appendix F) have been recorded in the recreation area (Folts-Zettner 2014).

Nine of the species found during SOPN's annual and one-time rapid assessment monitoring are considered to be the highest or high concern based upon their potential to alter native plant communities (Table 4.10.2-1). Combining the results of the significance of impact indicator with prevalence data from the three measures, eight species are in the condition of significant concern (Table 4.10.4-1). Of these eight species, *Euphorbia spp.* was highly prevalent in the recreation area, and *Bothriochloa ischaemum*, *Sorghum halepense* and *Bromus japonicus* had medium prevalence. The other four species were ranked at the highest concern for their innate ability to become a pest were not prevalent in the NRA. Three additional species are of moderate condition.

<u>Condition of Significant Concern Species with High or Medium Prevalence</u>

Based on combining the two indicators with four measures, four species are in the condition of significant concern with highest or high impact ranking and high or medium prevalence. Of these four species, two, *Bothriochloa ischaemum* and *Sorghum halepense,* were ranked of highest concern for their innate ability to become a pest.

Bothriochloa ischaemum had a wide extent along the vectors, and was present along all roadsides monitored in 2012-2014. The species was found in more than 30% of the blocks, usually in density class 2, scattered patchy. The species was particularly prevalent along the Sanford-Yake Road where it was present in 79% of the blocks and the Bates Canyon Road where it occurred in 50% of the blocks. However, it was not detected in SOPN monitoring along these same vectors in 2009-2011 (Folts-Zettner and Sosinski 2012b), and was not present in any of the areas surveyed

Table 4.10.4-1. Exotic species found within Lake Meredith NRA that are considered to have the most impact to native habitats throughout the recreation area based upon combined indicators and measures.

Scientific Name	Common Name	Rationale for Rating[1]
Condition of Significant Concern (with highest or high impact and high or medium prevalence)		
Bothriochloa ischaemum	king ranch bluestem	King ranch bluestem had medium prevalence along the vectors monitored in 2012-2014, but was not detected in the rapid assessment. The density of the infestations were mostly at density class 2, scattered patchy. The species was also widely distributed, and found along all of the vectors. Ranked as highest concern for its ability to become a pest, this species' impact on native plant communities includes its drought tolerance, its great seed production, a thick basal growth that can displace native species and decrease plant and animal biodiversity. This grass can become a monoculture when left unmanaged. It also adds to fire threat by providing abundant fine fuel (Folts-Zettner and Sosinski 2012b).
Bromus japonicus	Japanese brome	With a high significance of exotic plant impact, Japanese brome was also prevalent in the park. It alters fire regime and outcompetes native cool season grasses. It was found along five of the vectors, but not detected in the rapid assessment.
Euphorbia spp.	David's or toothed spurge	Although the nativity of this plant in Texas is in question, the species is tracked during SOPN exotic plant monitoring (Folts-Zettner and Sosinski 2012b). Spurge was ranked as having a high innate ability to become a pest, as it reproduced both vegetatively and by seed, is many-seeded, and has great potential for long-distance dispersal. While it was detected in only one block along the vectors, it was highly prevalent in the 2014 rapid assessment areas and found in 61.3% of the plots.
Sorghum halepense	Johnsongrass	A highly invasive species that is very disruptive to natural ecosystems, Johnsongrass was ranked as highest concern for its innate ability to become a pest. *Sorghum halepense* was widely dispersed in the NRA, but in only 3.1% of the vector blocks, and 3.2% of the rapid assessment plots, but most often in density class 2, scattered patchy. The species has the capacity to colonize large areas, and once established, Johnsongrass persists in the landscape despite eradication efforts (Folts-Zettner and Sosinski 2012b).
Condition of Significant Concern (with highest or high impact and lower prevalence)		
Bromus tectorum	cheatgrass	Cheatgrass is a highly invasive plant that can have a significant adverse impacts on natural ecosystems. In Lake Meredith NRA, it was only found along one vector in 2012-2014, the Bates Canyon Road, where it occurred in 14.7% of the blocks.
Convolvulus arvensis	field bindweed	*Convolvulus arvensis* is listed as a noxious species in Texas. It was present in 2.3% of the vector blocks and found along four different vectors. It was not present in the rapid assessment plots. Field bindweed is extremely difficult to control once established.
Elaeagnus angustifolia	Russian olive	This species was found only along the Bugbee Road, in 6.7% of the blocks. Russian olive is both of highest concern for its exotic plant impact and difficult to control.
Tamarix spp.	saltcedar	A riparian species that utilizes a great deal of water and outcompetes native plants and reduces biodiversity, saltcedar has been the target of control efforts at the NRA, including both the aerial application of herbicides and biological control via the tamarisk leaf beetle. During SOPN surveying, *Tamarix spp.* was only encountered along the Bugbee and Blue West Roads, where it occurred in 16.7% and 1.9% of the blocks respectively.
Condition of Significant Concern (with medium impact and high prevalence)		
Salsola tragus	prickly Russian thistle	The most prevalent exotic plant species at Lake Meredith, *Salsola tragus* had wide extent and distribution, and usually occurred in density class 2, scattered patchy, or higher. Prickly Russian thistle is highly drought tolerant and is competitive in drought conditions. Prickly Russian thistle, also known as a type of tumbleweed, has great seed dispersal potential and the seeds germinate readily in disturbed or open areas.
Moderate Condition (with high impact and low prevalence)		
Cynodon dactylon	Bermudagrass	This sod-forming grass has a tendency to form a monoculture and has a very adverse impact on native wildflower populations (Folts-Zettner, SOPN biologist, personal communication, 2014). It was present in 5.6% of the blocks along the Fritch Fortress Road.
Moderate Condition (with medium impact and medium prevalence)		
Kochia scoparia	kochia	Kochia was found in 15.5% of the vector blocks, and in 28.1% of the rapid assessment plots, including 60.5% of the plots in a Alibates area. It was the only exotic species in Lake Meredith to form the matrix, which it did in two plots in the Alibates rapid assessment. The species mostly occurred in density class 2. The plant was widely distributed and found along all of the vectors and in the Alibates rapid assessment area.

[1] The rationale is comprised of the four measures: a species' innate ability to become a pest, and the current extent, density and distribution of the exotic plant.

during the 2014 rapid assessment. This species can dominate grassland communities, and reduce insect, landbird, and mammal diversity, and is difficult to manage (Institute for the Study of Invasive Species 2014). Given the impacts of this species to natural ecosystems, it is good that it does not appear in the landscape (Folts-Zettner, SOPN biologist, personal communication, 2014).

Sorghum halepense was present in just over 3% of the blocks surveyed during vector monitoring, and in 3.2% of the plots visited during the 2014 rapid assessment. However, where the species occurred, it usually did so in density class 2 or 3, scattered patchy or patchy. The species also had wide extent, and was found along four vectors and in the three areas monitored during the rapid assessment. While the detections of the species were limited during monitoring, the species is widespread in the park and occurs in dense stands in places (Folts-Zettner, SOPN biologist, personal communication, 2014). Johnsongrass is a highly invasive species that can outcompete native grasses. It reproduces both by seed and from rhizomatous roots, and grows well in disturbed sites (Institute for the Study of Invasive Species 2014). The species is also very difficult to eradicate.

Exotic bromes are well known to dramatically change the character of an ecosystem, including such changes as major shifts in community composition and structure (Knapp 1996) as well as substantial alteration of fire regimes (Whisenant 1990). In many cases these changes have become, for all practical purposes, irreversible (Knapp 1996).

B*romus japonicus* adds biomass to the ecosystem, and outcompetes other cool season grasses (Folts-Zettner, SOPN biologist, personal communication, 2014). The species was prevalent along the Bugbee, Cedar Canyon, and Sanford-Yake Roads. It was not detected in the rapid assessment.

Euphoria spp. was not present in any of the blocks surveyed in annual SOPN monitoring. However, it was prevalent in all three areas surveyed during the 2014 rapid assessment. It is unclear whether this species is native in the Lake Meredith region, but the plant is tracked during SOPN exotic plant monitoring (Folts-Zettner, SOPN biologist, personal communication, 2014).

Condition of Significant Concern Species with Low Prevalence

Four species were ranked as the highest concern for their innate ability to become a pest, but had low prevalence in the park. These species are *Bromus tectorum*, *Convolvulus arvensis, Elaeagnus angustifolia,* and *Tamarix spp*.

From a standpoint of significance of impact to a park's native grassland community, *Bromus tectorum* is one of the highest exotic plant concerns (Folts-Zettner SOPN biologist, personal communication, 2014). B*romus tectorum* has many of the same adverse impacts to native plant communities that B*romus japonicus* has, and is additionally especially competitive during times of drought. Cheatgrass was found only along the Bates Canyon Road where it was present in 14.7% of the blocks.

Convolvulus arvensis was not present in any of the rapid assessment plots, but it was identified along four vectors, and occurred in 2.3% of the total vector blocks. Once field bindweed gets established, it is very difficult to control and is highly competitive with native species.

Growing in riparian habitats or open areas, *Elaeagnus angustifolia* can displace native species while using a great deal of water. During 2012-2014 monitoring, it was only detected in two blocks along the Bugbee Road. Russian olive was not found during the 2014 rapid assessment. It was observed several times in the Canadian River riparian area during the 2014 riparian assessment Folts-Zettner, SOPN biologist, personal communication, 2014).

Tamarix spp., which is on the Texas list of noxious plants, was found along two vectors, including the Bugbee Road, where it was present in 16.7% of the blocks. Tamarisk is highly competitive in riparian habitats and outcompetes native species and reduces

natural biodiversity. A joint project with the Canadian River Municipal Water Authority to control saltcedar included aerial spraying in 2011 (Folts-Zettner, SOPN biologist, personal communication, 2014). Biological control of the species is also underway with the tamarisk leaf beetle having been introduced,.Native riparian vegetation is recovering in areas where saltcedar trees have been eradicated. But seedlings and resprouts of tamarisk were observed all along the Canadian River during the 2014 Riparian Assessment (Folts-Zettner, SOPN biologist, personal communication, 2014).

Condition of Significant Concern Species with Medium Impact and High Prevalence

Salsola tragus is of significant condition because of its medium impact ranking and high prevalence in the park. It was by far the most prevalent exotic plant species found in 2012-2014 annual monitoring and in the 2014 rapid assessment. It was present in 76.6% of the blocks along the high priority vectors surveyed in 2012-2014, and in 81.3% of the rapid assessment plots. It occurred mostly in density class 2, scattered patchy, along both the vectors and in the rapid assessment plots, but also occurred in density class 3 in 26.7% of the rapid assessment plots.

Lake Meredith NRA was in at least drought conditions for the 24 months prior to the 2014 monitoring by the SOPN (Folts-Zettner, SOPN biologist, personal communication, 2014). The four months prior to the June 2014 monitoring were extreme or exceptional drought conditions.

The prevalence of *Salsola tragus* increased dramatically during this drought (see Table 4.10.4-2). It is unknown how the species will respond with a change to wetter conditions. It may be outcompeted by grass species (Folts-Zettner, SOPN biologist, personal communication, 2014). Prickly Russian thistle has been prevalent in the Texas panhandle since the Dust Bowl, and its seeds will remain a viable part of the seed bank ((Folts-Zettner, SOPN biologist, personal communication, 2014). The abundance of this plant in the recreation area will likely continue to change depending on the climate conditions.

Table 4.10.4-2. Extent of exotic plants found during 2009-2011 (first full panel) and 2012-2014 (second full panel) SOPN annual monitoring.

Species	2009-2011 (N=254)	2012-2014 (N=254)*
Salsola tragus[2]	38.2%	72.4%
Bothriochloa ischaemum[1]	ND	27.6%
Chenopodium album	ND	19.7%
Bromus japonicus[1]	20.5%	13.0%
No Plant	9.1%	10.6%
Kochia scoparia	22.8%	8.7%
Tragopogon dubius	7.9%	8.7%
Tamarix spp.[1]	2.0%	2.8%
Convolvulus arvensis[1]	2.0%	2.8%
Medicago minima	0.4%	2.0%
Sorghum halepense[1]	2.4%	2.0%
Bromus catharticus	ND	1.6%
Lactuca serriola	ND	1.2%
Elaeagnus angustifolia[1]	ND	0.8%
Melilotus alba/officnalis	15.4%	0.8%
Eragrostis cilianensis	ND	0.4%
Bromus tectorum[1]	4.3%	ND[3]
Chenopodium glaucum	1.2%	ND
Cirsium arvensis	28.4%	ND
Cynodon dactylon[1]	9.8%	ND[3]
Digitaria sanguinalis	20.9%	ND
Erodium cicutarium	1.2%	ND
Euphorbia spp.[1]	3.9%	ND[3]
Poa pratensis	1.2%	ND
Polypogon monspeliensis	0.4%	ND
Salsola collina	0.8%	ND
Scorzonera laciniata	0.4%	ND
Seteria viridus	9.5%	ND
Taraxacum officinale	2.0%	ND
Tribulus terrestris	4.3%	ND[3]
Triticum aestivum	0.8%	ND

*2012-2014 data excludes results from 2014 monitoring along the Fritch Fortress and Bates Canyon roads since they were not part of the first full panel rotation (2009-2011).

ND = Not detected.

[1]Species considered to be of highest or high concern in (Table 4.10.2-1) are highlighted in the darker tone.

[2]Species of special concern (Table 4.10.2-1) are highlighted in the lighter tone.

[3]Species was present in either the vector surveying of the Fritch Fortress and Bates Canyon roads and/or the 2014 rapid assessment.

Species not found in 2012-2014 monitoring were not ranked for exotic plant impact.

Moderate Condition Species with High Impact and Low Prevalence

Cynodon dactylon (Bermudagrass) was ranked as high for its innate ability to become a pest, but was only found along the Fritch Fortress vector in three blocks. The species is extremely difficult to control once established.

Moderate Condition Species with Medium Impact and Medium Prevalence

Kochia scoparia was ranked according to Hiebert and Stubbendieck (1993) as having a medium potential to alter native plant communities. It was also prevalent at Lake Meredith. It was detected in 15.5% of vector blocks and in 28.1% of the rapid assessment plots. It was also widely distributed, and was found along all of the vectors and in the Alibates rapid assessment area where it was present in 60.5% of the plots. The species occurred mostly in density class 2, scattered patchy, or higher. In the rapid assessment plots in which it was found, it occurred in density class 2 64.4% of the time, density class 3, scattered even, 31.1%, and formed the matrix (density class 4) in 4.4% of the plots.

Like *Salsola tragus,* Kochia grows well on disturbed land and disperses its seeds as a tumbleweed.

Trend

Comparing the results of the annual vector surveying for exotic plants over the two full 3-year panel rotations (2009-2011 and 2012-2014) provides information on the trend of exotic plant infestation at Lake Meredith (Table 4.10.4-2) (Folts-Zettner and Sosinski 2012a; 2012b; 2013; 2014). We utilized only the extent, or proportion of infested blocks, for the trend determination. For the comparison of the two complete panel rotations, we excluded the two vectors (Fritch Fortress and Bates Canyon roads) added in 2014 since they were not part of the first full panel rotation.

Overall, the number of exotic plant species found along the vector decreased from the first full panel rotation (2009-2011) from 24 species to 15 species in the second full rotation (2012-2014). Fifteen species that were recorded in the first panel rotation were not found in the second rotation, including *Cirsium arvensis* (Canadian thistle) and *Digitaria sanguinalis* (hairy crabgrass) that were in 28.4 and 20.9% of the blocks respectively in 2009-2011 (Folts-Zettner and Sosinski 2012b).

The extent of three species decreased significantly between the first and second rotations: *Bromus japonicus* from 20.5% to 13.0%, *Kochia scoparia* from 22.8% to 8.7% and *Melilotus alba/officinalis* (white/yellow sweetclover) from 15.4% to 0.8%.

Three species increased their extent from the first rotation including two species (*Bothriochloa ischaemum* and *Chenopodium album)* that were not detected in 2009-2011 monitoring. The proportion of blocks infested by *Salsola tragus* increased dramatically from 38.2% to 72.4%. This increase may be the result of the recent moderate to exceptional drought experienced in the Lake Meredith area and the fact that *Salsola tragus* is well adapted to drought conditions. Four additional species were detected in 2012-2014 that were not found during the first panel rotation.

Many of the changes in the species assemblage present and the extent of individual plant species from the first panel rotation to the second rotation may be a result of drought conditions that began in 2012.

Exotic Plants

Indicators	Measure
Potential to Alter Native Plant Communities	1 Measure
Prevalence of Exotic Plants	3 Measures

Overall Condition and Trend

For assessing the condition of exotic plants in the NRA, we used two indicators and four measures that were not mutually exclusive but were intended to be different ways of capturing the essence of what we thought represented an exotic plant's potential for concern.

Several factors contribute to an exotic's ability to threaten the integrity of a native ecosystem including its current extent, density, distribution and inherent ability to alter native

plant communities. Thus, our measures for this resource were intended to capture different aspects of these contributing factors, and a summary of how they contributed to the overall exotic plants condition assessment is in Table 4.10.4-3.

The potential for exotic species present in the NRA to alter native plant communities is of significant concern because nine species, 43% of the exotic species present, were ranked as highest or high for their significance of exotic plant impact based on their innate ability to become a pest.

Exotic plants also had a broad extent throughout the park, with most monitored blocks and plots infested. Only 8.2% of the blocks along the high priority vectors did not contain exotic plants, and only 1.9% of the rapid assessment plots were not infested. This wide extent of exotic plants in the NRA is also of significant concern. However, exotic species mostly occurred in densities that are at a level of moderate concern.

The distribution of exotic plant species was also at level of significant concern. Sixteen of the 21 species found during 2012-2014 annual monitoring and the 2014 rapid assessment were found in multiple areas of the park. Altogether, the prevalence of exotic plants for the park is of significant concern.

By combining the four measures and evaluating the species individually, eight exotic plant species were in a condition of significant concern, and three species were in moderate condition (Table 4.10.4-1).

The overall trend for the condition of exotic plants at the NRA was determined to be stable, although the occurrence of exotic plants along the high priority vectors changed

Table 4.10.4-3 Indicators, measures, and their contributions to the overall exotic plants condition rationale.

Indicator of Condition	Measure	Condition	Rationale for Condition.
Potential to Alter Native Plant Communities	Significance of Exotic Impact	Significant Concern	This measure is based on the premise that species with the highest innate ability to become a pest generally cause the most severe problems in natural ecosystems. Nine of the 21 species of exotic plants found during SOPN monitoring were ranked as having the highest or high innate ability to become a pest. Therefore, we consider this measure to be of significant concern.
Prevalence of Exotic Plants	Extent of Exotic	Significant Concern	Exotic plants were found in 91.8% of the blocks along high priority vectors, and in 98.1% of the plots in the rapid assessment areas. Twenty-one exotic species were found during monitoring between 2012-2014, including four species that were found in more than 10% of vector blocks. Seven species were found during the 2014 rapid assessment, with five species were found in more than 10% or more of the plots.
	Density of Exotic	Moderate	Most of the exotic species occurrences in Lake Meredith NRA were in moderate to low densities in monitored parts of the park. Species were most often found in density class 2 (scattered patchy). Only kochia was found to form a matrix in a monitored site, and did so in only two plots. Six species were found in density class 3 (scattered even) or higher.
	Distribution of Exotic	Significant Concern	Exotic plants were found in widely distributed in the park, especially along the high priority vectors. *Salsola tragus* was found along all vectors and in all three rapid assessment areas. Two other species (*Bothriochloa ischaemum* and *Kochia scoparia)* were found along all vectors. Four additional species were found along more than half the vectors, including *Convolvulus arvensis* and *Sorghum halepense,* both species of highest ranking for exotic plant impact, and *Bromus japonicus* which is of high concern. Species were also widely distributed among the three rapid assessment areas: of the seven species found in the rapid assessment, three were found in all rapid assessment areas, and three additional species were present in two areas.

in composition and quantity between the first full panel rotation (2009-2011) and the second full panel rotation (2012-2014). While the number of exotic species found in the recreation area decreased markedly from the first full panel rotation (from 24 to 15), five species were present during the second rotation that were not found during the first rotation, Further, the extent of two species, *Bothriochloa ischaemum* and *Salsola tragus,* increased dramatically. Many of these changes may be consequent on the 24-month drought in the Lake Meredith area, the last four months of which were extreme to exceptional. *Salsola tragus* was one of the few plants that can grow in extreme drought conditions, and the drought also opened up bare ground that favors germination of prickly Russian thistle seeds (Folts-Zettner, SOPN biologist, personal communication, 2014).

After analyzing all the available information about exotic plant species at Lake Meredith NRA, we consider the overall condition for exotic plants to be of significant concern with a stable trend. However, the current condition of exotic plants in the recreation area may be at least in part a result of the recent drought conditions that may be masking the impact of other changes in the site's exotic plant communities

Level of Confidence/Key Uncertainties

The SOPN exotic plants monitoring program is designed to occur during a time of year when spring plants are still identifiable and rosettes are present for fall blooming plants. This strategic timing ensures the highest degree of detection. Further, with the three year rotation cycle, SOPN staff feel confident that they will identify new plants before they become established even if the plant is introduced right after the rotation cycle has been completed.

The 2014 rapid assessment provided a one-time snapshot of the condition of three areas that represent the major habitat types in the recreation area: upland, canyon, and recent fire treatment. This assessment is missing information about the bottomland community, the site's fourth major habitat type, because the area was inaccessible due to mud. The SOPN plans on conducting a supplemental rapid assessment of bottomland habitat in 2015 (Folts-Zettner, SOPN biologist, personal communication, 2014). It is expected that some species that prefer bottomland or riparian habitat such as *Tamarix spp.* and *Sorghum halepense* may be more prevalent in the recreation area than this condition assessment indicates since the data upon which it is based did not sample those environments.

Other sources of uncertainty in this assessment is the fact that the Canadian River corridor was not surveyed for the presence of exotic plants. Rivers are major vectors for the spread of exotic plant species. Additionally, it is unknown what overall effect the recent drought has had on the condition of exotic plants, and especially the trend, at Lake Meredith.

Another key uncertainty is the general variability in how a given exotic plant species will respond to localized conditions. What may be considered a non-threatening plant in one region may become a nuisance in a different region.

4.10.5. Sources of Expertise

Surveys for exotic plants at Lake Meredith NRA were conducted by the SOPN exotic plants monitoring team well trained in species identification and methods. Our confidence is very high regarding the reliability of their surveys.

Tomye Folts-Zettner is a biologist/botanist with the SOPN and is also the project lead for monitoring exotic plants and grasslands in parks of the SOPN.

Jonathan Horsley is a biological technician for both the Chihuahuan Desert Network and the Southern Plains Network. He is the crew leader for the exotic plant monitoring crews.

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4.11. Breeding Landbirds

Indicators/Measures

- Species Occurrence (3 Measures)

Condition – Trend – Confidence

Good - Insufficient Data - Medium to High

4.11.1. Background and Importance

The National Park Service's mission is to manage park resources "unimpaired for future generations." Protecting and managing some of our nation's most significant natural resources requires basic knowledge of the condition of ecosystems and species that occur in national parks. Landbirds are a conspicuous component of many ecosystems (Figure 4.11.1-1). Birds have high body temperatures and rapid metabolisms, and they occupy high trophic levels. As such, changes in landbird populations may indicate changes in the biotic or abiotic components of the environment upon which they depend (Canterbury et al. 2000; Bryce et al. 2002). Relative to other vertebrates, landbirds are also highly detectable and can be efficiently surveyed with the use of numerous standardized methods (Bibby et al. 2000; Buckland et al. 2001). Changes in landbird population and community parameters can be an important element of a comprehensive, long-term monitoring program, such as that being implemented for the Southern Plains Network (SOPN) parks. The SOPN began annual monitoring of landbirds at Lake Meredith NRA and the other SOPN parks in the spring (breeding season) of 2009.

Birds select habitat based on behavioral cues triggered by the environment (Hutto 1985; Alcock 2005). In some environments, however, especially those that vary unpredictably, habitat may not be saturated and changes in resources may not always be tracked by changes in animal populations (Wiens 1985). In these situations, relating changes in bird populations to environmental features can be complex, especially when confounded by time lags that are characteristic of site-tenacious bird species. Additional complications occur if birds respond more sensitively to environmental change than we can detect, and when cyclical environmental changes result in erratic changes in population size that are ultimately inconsequential. However, the utility of monitoring landbirds is strengthened by concurrent monitoring of a broad suite of environmental parameters (Dale and Beyeler 2001) that may assist in relating changes in the bird community to other environmental factors. Such a broad-based approach is now being undertaken by the SOPN program (NPS 2008) and other programs/organizations (e.g., Ringold et al. 1996; Stevens and Gold 2003; Barrows et al. 2005).

Perhaps the most compelling reason to monitor landbird communities in SOPN parks is that birds themselves are inherently valuable. The high aesthetic and spiritual values that humans place on native wildlife are acknowledged in the agency's Organic Act: "to conserve . . . the wildlife therein . . . unimpaired for the enjoyment of future generations." Bird watching, in particular, is a popular, longstanding recreational pastime in the United States and forms the basis of a large and sustainable industry (Sekercioglu

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Figure 4.11.1-1 Western Meadowlark, found during RMBO surveys at Lake Meredith NRA in every year from 2009-2013.

2002). This section of the condition assessment addresses breeding landbirds at Lake Meredith NRA, largely through the use of data from the annual network monitoring.

4.11.2. Data and Methods

In 2009, Rocky Mountain Bird Observatory (RMBO) began systematic surveys of birds at Lake Meredith NRA as part of the SOPN Monitoring program. Alibates Flint Quarries NM and Lake Meredith NRA are treated as one park unit during the sampling, and no sampling is conducted specifically at the National Monument. There are now five years of data for the park. Although these data will enable quantitative evaluation of trends in birds in the future (e.g., in occupancy), such analyses are only just now beginning to be explored (Rob Bennetts, SOPN, pers. com.). Five years of data are about the minimum required to attempt such analyses, but additional years of data will render analyses more reliable. Therefore, for this assessment, we focus on species occurrence (presence/absence), focusing on what species are, or are not, observed at the Recreation Area.

The most recent data we have for occurrence of birds at the park are the RMBO surveys. With the use of additional data sources, we evaluated species occurrence in three contexts: (1) a temporal context (i.e., differences between time periods), (2) a spatial context (i.e., comparison with surrounding region), and (3) a conservation context (i.e., the occurrence and status of species of conservation concern). We describe each of these below, followed by descriptions of the data sources used to support the comparisons.

Indicators/Measures
Species Occurrence

Temporal Context – Changes over Time

To evaluate birds in a temporal context, we compared the occurrence of species detected during 2009-2013 RMBO surveys at Lake Meredith NRA (described below) to 2002 and 2003 surveys/searches for birds at the Recreation Area conducted by The Nature Conservancy (Patrikeev 2004). This analysis compares information from 2002-2003 to 2009-2013-- a relatively short time span. Our analysis is not intended as a rigorous or quantitative comparison given the limitations of the available information (e.g., for a small number of years); rather, it is intended as a crude qualitative indicator of major changes over time. To do this in the most meaningful way, we needed the sources to be as comparable as possible. For example, the recent RMBO surveys were conducted during the breeding season; thus it is not reasonable to compare these results with species that occur at the Recreation Area during other seasons. The 2002-2003 TNC breeding bird inventory was conducted between late May and mid-July, 2002 (surveys from variable circular plots). Also, searches were made for nesting birds and nests in late May to late July, 2002, and in late April to early June, 2003. These searches were made to record additional species and obtain vouchers of breeding activity. Winter grassland surveys were also conducted in December 2001 and January 2002, but results from these surveys were not used for the condition assessment.

The RMBO surveys were conducted during the breeding season in late April and May. We focused our comparisons on those species for which Lake Meredith NRA is within their normal breeding range. We made this determination based primarily on the Birds of North America (BNA) species accounts (Cornell Lab of Ornithology 2014). Given the potential for us to have made errors in determining whether the Recreation Area was within the normal breeding range from online and hard copy maps (GIS data were not available), we included for consideration species outside of their normal breeding range but within 100 miles of their breeding range edge. Unlike field guides that are often written by persons with general knowledge of birds, the BNA accounts for each species are written by persons that have extensive experience and knowledge working with that particular species. Consequently, these accounts constitute a comprehensive summary of our current knowledge for a given species (including range) written by experts for that species. Note that by "normal breeding range" we mean the area designated by the BNA accounts where a species is known to consistently breed. Some birds may

Table 4.11.2-1. Breeding habitat classes assigned to species reported to occur at Lake Meredith NRA that are within or near their reported breeding ranges.

Breeding Habitat Class	Class Description
Exists	This class was assigned when the habitat at the Recreation Area is characteristic of habitats where a given species might be expected to breed.
Possibly Exists	This class was assigned when it was unlikely that the habitat at the Recreation Area would support consistent or widespread breeding, but does not preclude some breeding in limited numbers.
Limited to None	This class was assigned when it is unlikely that the habitat at the Recreation Area would support breeding by that species. This does not imply that the species would not occur at the Recreation Area in limited numbers or during other seasons, but rather that it would be unlikely to breed there.

breed in small numbers outside of these areas, however.

We further refined our comparisons to species for which reasonably suitable breeding habitat exists at the Recreation Area (since comparisons are based on the breeding season). We assigned each species to one of three breeding habitat classes (Table 4.11.2-1) based primarily on the input of avian expert Mr. Moez Ali (see Section 4.11.5, Sources of Expertise).

Spatial Context – Comparisons with Surrounding Region

We also evaluated species occurrence in a spatial context. Again, this is intended only as a qualitative indicator rather than a rigorous quantitate estimate (which will be possible in the future). For this assessment, we compared the recent RMBO surveys at the Recreation Area to those from Breeding Bird Surveys (BBSs; described below) conducted in similar habitats within the surrounding area; the regional surveys serve as a general spatial reference for species occurrence within the region. As with the temporal comparison, we focused our comparisons on those species for which the Recreation Area is within their normal breeding range, but we also considered species outside of but within 100 miles of their normal breeding range.

Conservation Context – The Occurrence and Status of Species of Conservation Concern

Our intent for this context was to determine which species that occur at Lake Meredith NRA and Alibates Flint Quarries NM are considered species of conservation concern at either national or local scales, to assess the current status (occurrence) of those species at the Recreation Area, and to evaluate the potential for the Recreation Area to play a role in their conservation. For the latter, we assigned each species of conservation concern to one of three classes representing the potential for the park to play a role in its conservation during the breeding season (Table 4.11.2-2). This was based primarily on whether or not the Recreation Area was within the normal breeding range of the species and the availability of breeding habitat at the park.

To develop a candidate list for species of conservation concern, we used the lists developed by several organizations. There have been a number of such organizations that focus on the conservation of bird species. Such organizations may differ, however, in the criteria they use to identify and/or prioritize species of concern based on the mission and goals of their organization. They also range in geographic scale from global organizations, such as the International Union for Conservation of Nature (IUCN), who maintains a "Red List of Threatened Species," to local organizations or chapters of larger organizations. This has been, and continues to be, a source of confusion, and perhaps frustration, for managers and others who need to make sense of and apply the applicable information. In recognition of this, the U.S. North American Bird Conservation Initiative (NABCI) was started in 1999; it represents a coalition of government agencies, private organizations, and bird initiatives in the United States working to ensure the conservation of North America's native

Table 4.11.2-2. Classes assigned to species of conservation concern regarding the potential for Lake Meredith NRA to play a role in their conservation.

Potential for Conservation	Conservation Class Description
High	These are species for which the Recreation Area is within the normal breeding range or in proximity to the edge of that range. They are also species for which we considered the Recreation Area to have good breeding habitat. We assigned species to this class if we believed, based on the evidence, that the potential for breeding was good, regardless of whether they currently occur at the Recreation Area in substantial numbers.
Moderate	These are the species for which the Recreation Area is within the normal breeding range or in proximity to the edge of that range, and for which there is some habitat at the Recreation Area that might support occurrence or even some breeding in limited numbers.
Low to None	These are the species that are either outside of their normal breeding range and/or for which the habitat at the Recreation Area is unlikely to support breeding. This does not preclude limited occurrences of the species, but the potential for the Recreation Area to play any significant role in its conservation during the breeding season is very limited.

bird populations. Although there remain a number of sources at multiple geographic and administrative scales for information on species of concern, several of which are presented below, the NABCI has made great progress in developing a common biological framework for conservation planning and design.

One of the developments from the NABCI was the delineation of Bird Conservation Regions (BCRs) (U.S. North American Bird Conservation Initiative 2014). Bird Conservation Regions are ecologically distinct regions in North America with similar bird communities, habitats, and resource management issues (Figure 4.11.2-1). Lake Meredith NRA and Alibates Flint Quarries NM lie within the Short Grass Prairie Unit (BCR-18) (Figure 4.11.2-2).

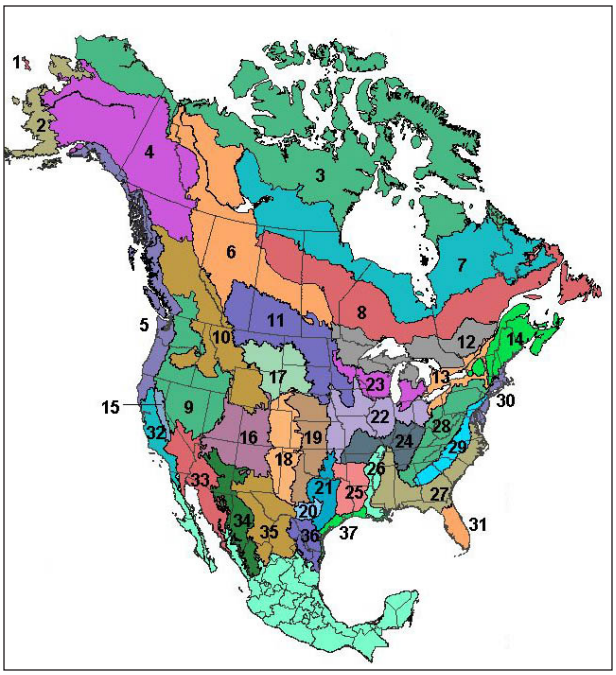

Figure 4.11.2-1. Bird Conservation Regions in North America.

Conservation Organizations Listing Species of Conservation Concern

Below we identify some of the organizations/efforts that list species of conservation concern; these are the listings we used for the condition assessment. Appendix H presents additional details on each of the organizations/efforts.

- U.S. Fish & Wildlife Service: Under the Endangered Species Act, the U.S. Fish and Wildlife Service (USFWS) lists species as threatened, endangered, or candidates for listing.
- State of Texas: In 1973, the Texas Parks and Wildlife Department (TPWD) was authorized to develop a list of endangered and threatened animal species in the state. Legal protection of endangered and threatened animals is provided by laws and regulations contained in Chapters 67 and 68 of the Texas Parks and Wildlife Code and Sections 65.171-65.176 of Title 31 of the Texas Administrative Code (TPWD 2014a).
- USFWS: This agency also developed lists of birds of conservation concern

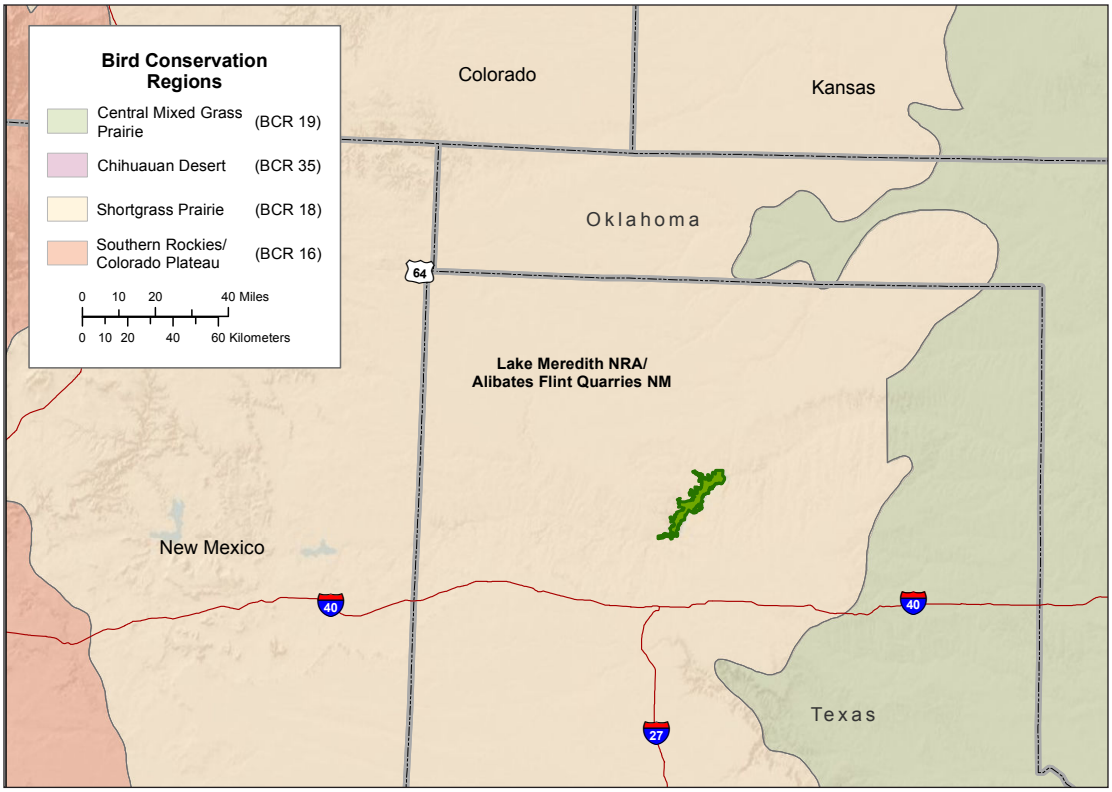

Figure 4.11.2-2. Bird Conservation Regions in the vicinity of Lake Meredith NRA and Alibates Flint Quarries NM.

according to: the Nation, USFWS Region, and BCR.

- The National Audubon Society (NAS) and American Bird Conservancy (ABC): These groups combined efforts to produce a "Watch List," based on, but not identical to, the Partners in Flight approach to species assessment (see below). The 2007 WatchList has two primary levels of concern: a "Red Watchlist," which identifies what these organizations consider as species of highest national concern; and a "Yellow WatchList," which is made up of species that are somewhat less critical.
- Partners in Flight (PIF): This is a cooperative effort among federal, state, and local government agencies, as well as private organizations. PIF has adopted BCRs as the geographic scale for updated regional bird conservation assessments. At the scale of the individual BCRs, there are species of Continental Importance (Continental Concern [CC] and Continental Stewardship [CS]) and Regional Importance (Regional Concern [RC] and Regional Stewardship [RS]). We did not include the CS or RS species in our assessment.
- Texas Species of Greatest Conservation Need: The State of Texas also designated species that, "due to limited distributions and/or declining populations, face the threat of extirpation or extinction but lack legal protection" (TPWD 2014b). The lists were developed for the TPWD's Texas Conservation Action Plan. Species are rated or ranked using a system developed by NatureServe.

Primary Data Sources

Data used as part of the condition assessment include: surveys conducted by RMBO at Lake Meredith NRA in 2009-2013; the bird inventory conducted by TNC in 2002 and 2003 (Patrikeev 2004); and data collected from Breeding Bird Surveys (BBSs) in the general vicinity of the Recreation Area. The NPSpecies list for the park (NPS 2014) was also reviewed and is mentioned in the report where applicable. Each of these data sources are described below.

RMBO Surveys at the Recreation Area in 2009-2013

RMBO used point-transect surveys (Buckland et al. 2001) during the breeding season to estimate and monitor landbird population

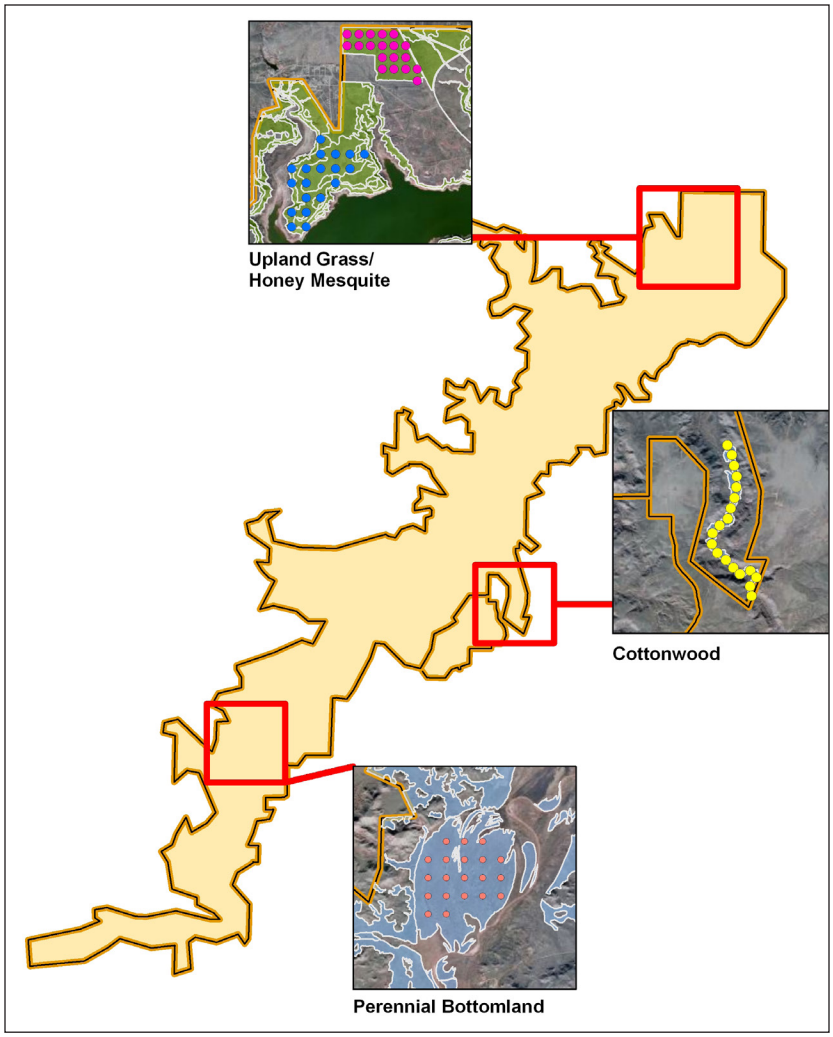

Figure 4.11.2-3. Survey points sampled by the Rocky Mountain Bird Observatory at Lake Meredith NRA and Alibates Flint Quarries NM in 2009-2013.

parameters at Lake Meredith NRA (Lock et al. 2014). A total of about 76 unique points in grassland (upland grassland; n=38) and riparian (cottonwood bottom/bottomland grassland; n=38) habitats were sampled three times each in late April and May in 2009-2013 (Figure 4.11.2-3) (Lock et al. 2014). All birds detected at a given point were recorded. Observers spent six minutes at each point along the transect or grid and used a rangefinder to estimate the linear distance to each bird or group detected. This protocol of spending six minutes per site is consistent with other efforts being conducted by RMBO. After counts were completed, observers used a handheld GPS (Global Positioning System) unit to locate successive survey points. While walking between points, observers noted only species that were not recorded during the count period; sometimes these represented species that had not been previously reported for the Recreation Area. It should be noted that although surveys are conducted during the breeding season, some species recorded may not be breeding in the park. Field technicians note evidence of breeding when such evidence is observed; however, birds with no such evidence may or may not be breeding in the park.

TNC Inventory/Surveys

In 2002 and 2003, The Nature Conservancy (TNC) conducted vertebrate inventories that included breeding birds (Patrikeev 2004). The breeding bird inventory was conducted between 23 May and 11 July 2002; eight surveys were done in this timeframe, and each route surveyed used five or six circular plots (Figure 4.11.2-4; circles). Because little evidence of nesting was observed during the surveys, TNC also conducted searches for nesting birds and nests throughout the study area in late May to late July in 2002 and in late April to early June in 2003 (Patrikeev 2004). Two nights of owl searches were also conducted in April and May 2003. Seventy-two species of birds were observed during the breeding bird surveys.

Regional Surveys- BBS Routes

Breeding Bird Surveys are conducted on over 4,100 survey routes located across the continental U.S. and Canada (Patuxent Wildlife Research Center 2014). Each year during the height of the avian breeding season, participants skilled in avian identification sample birds along roadside survey routes. Each survey route is 24.5 miles (39.4 kilometers [km]) long with stops at 0.5-mile (0.8-km) intervals. At each stop, a 3-minute point count is conducted. During the count, every bird seen within a 0.25-mile (0.4-km) radius or heard is recorded. Surveys start one-half hour before local sunrise and take about 5 hours to complete. There are several BBS routes in the general vicinity of the Recreation Area/National Monument. For the spatial comparison of species occurrence, we used data from three routes that appeared to have habitat similar to that at the parks (Figure 4.11.2-5). We compared data from the three routes to 2009-2013 RMBO data at the park.

We used BBS data from 2009-2013 when available (see Reference Conditions below).

Secondary Data Sources

The list of birds for the park from NPSpecies was also reviewed (NPS 2014; obtained from IRMA in March 2014). We used the list on a case by case basis as supporting information for particular species, and we reviewed the list for additional species (compared to RMBO and TNC lists) that have been observed at the park.

4.11.3. Reference Conditions

Temporal Reference Condition for Species Occurrence

The first bird monitoring or inventory effort at Lake Meredith NRA/Alibates Flint Quarries NM was that made by TNC in 2002-2003 (i.e., Patrikev 2004). A total of 72 species was recorded during the inventory. Appendix I shows which species were recorded and whether they were recorded at the Recreation Area, the National Monument, or both.

We compared the species list from the 2002-2003 surveys/inventory to the list of species observed during the 2009-2013 RMBO surveys to see if there were any differences. Differences in the two lists may represent changes over time. Specifically, we looked at species that were not observed during 2009-2013 RMBO surveys that had been documented in 2002-2003. We "refined" the list of species where there were differences by excluding those species that were outside of their normal breeding range (and more than 100 miles from the edge of their normal breeding range). Although this analysis is a crude measure and only spans a relatively short time differential, it does potentially provide some insights as to major shifts that might have occurred at the Recreation Area. Table 4.11.3-1 summarizes the qualitative condition classes we assigned for the temporal and spatial indicators.

Spatial Reference Condition for Species Occurrence

In a spatial context, we compared the species observed during recent RMBO surveys (2009-2013) at Lake Meredith NRA/Alibates Flint Quarries NM to those recorded during

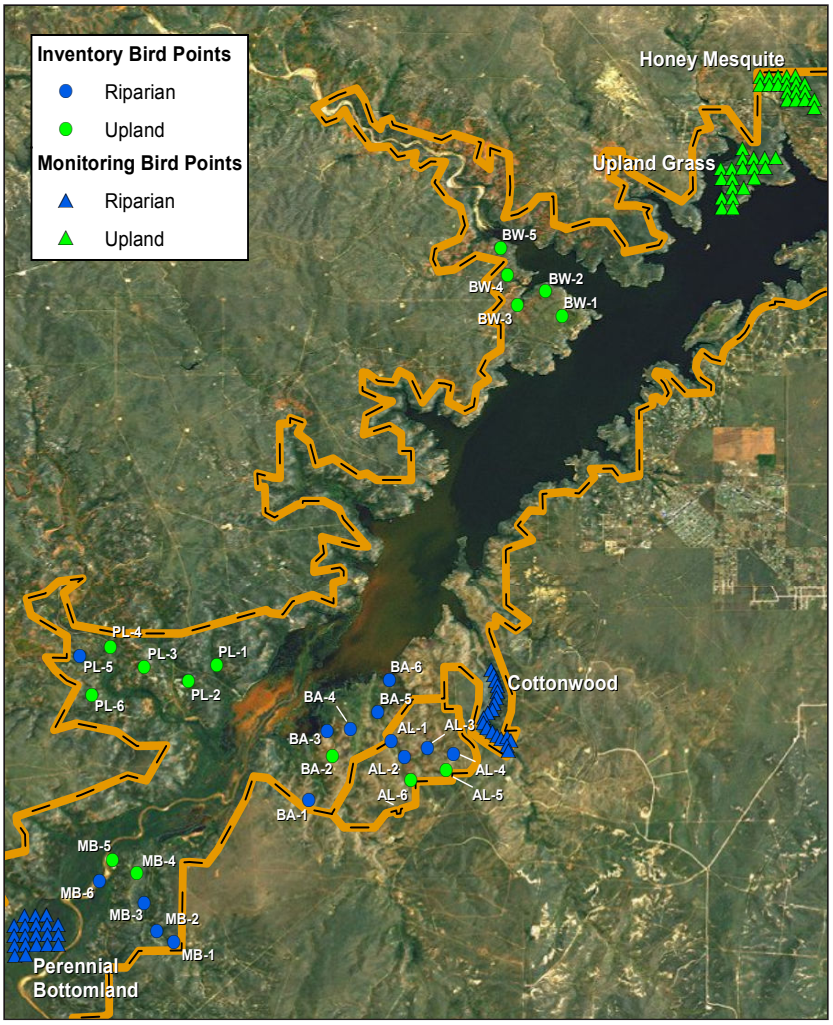

Figure 4.11.2-4. Location of RMBO survey points (triangles) and TNC (Patrikeev 2004) inventory points (circles).

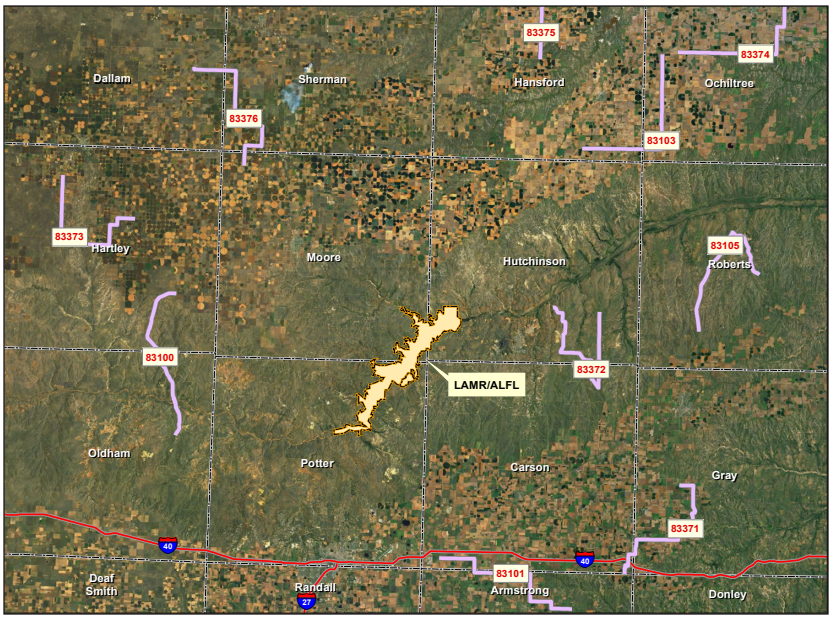

Figure 4.11.2-5. BBS routes in the vicinity of Lake Meredith NRA and Alibates Flint Quarries NM. The three routes used for the spatial comparison are 83100, 83372, and 83105.

Table 4.11.3-1. Reference conditions used to assess the current condition of breeding landbird species occurrence in temporal and spatial contexts.

Occurrence Indicator	Significant Concern	Moderate Concern	Good
Temporal Context	We considered condition to be of significant concern if several species of birds that are within their normal breeding range and have existing breeding habitat at the park were detected in the 2002-2003 surveys but not in recent RMBO surveys, particularly if those species had previously been considered common at the Recreation Area.	We considered condition to be of moderate concern if a few bird species that were detected during 2002-2003 surveys that are within their normal breeding range and have breeding habitat at the park were not detected during recent RMBO surveys.	We considered condition to be good if all, or nearly all, birds that were detected during 2002-2003 surveys that are within their normal breeding range and have breeding habitat at the park were detected during recent RMBO surveys.
Spatial Context	We considered condition to be of significant concern if several species of birds that are within their normal breeding range and have breeding habitat at the Recreation Area were detected during regional surveys but not during recent RMBO surveys.	We considered condition to be of moderate concern if a few bird species that were detected during regional surveys and are within their normal breeding range and have breeding habitat at the park were not detected during recent RMBO surveys.	We considered condition to be good if all, or nearly all, birds that were detected during regional surveys and are within their normal breeding range and have breeding habitat at the park were detected during recent RMBO surveys.

BBSs in the vicinity of the Recreation Area / National Monument. BBS data were not available for all years from 2009-2013; data for each of the three routes were only available for 2009 and 2010. As noted previously, for the BBS data we chose routes located in habitats roughly comparable to those at the parks. Both surveys were conducted during the breeding season. As in the temporal comparison, we refined the comparison by excluding species that are more than 100 miles from the edge of their normal breeding ranges.

Reference Condition for Species of Conservation Concern

This aspect of the assessment is somewhat different than the other two in that the focus is on the avian species for which the Recreation Area can play a role in their conservation. From the list of species detected at the Recreation Area during recent RMBO surveys, we identified the species that occurred on one or more of the lists of species of conservation concern. Those considered as having the greatest potential for conservation at the Recreation Area are those within their breeding range and for which breeding habitat exists at the park. In our analysis, we also considered species that were not detected in recent RMBO surveys but were reported during the 2002-2003 TNC (Patrikeev 2004) inventory (eleven species) and two species that appear on the NPSpecies List (NPS 2014).

4.11.4. Condition and Trend

There have been a total of 134 bird species reported at Lake Meredith NRA / Alibates Flint Quarries NM from the 2002-2003 TNC inventory and/or the 2009-2013 RMBO point-count surveys (Appendix I). Fourteen additional species are on the NPSpecies list of birds for the park (NPS 2014) but not on the lists from the two sets of surveys. Two of these species are noted as present in the park (American Tree Sparrow and Spotted Sandpiper) by NPS (2014); three of the species are noted as not in the park and are either historical records or observations on adjacent lands; and nine species are noted by NPS (2014) as unconfirmed records for the park (e.g., Chimney Swift, Hairy Woodpecker, and Least Bittern).

Table 4.11.4-1 Species reported in 2002-2003 by TNC (Patrikeev 2004) at Lake Meredith NRA/Alibates Flint Quarries NM that were not observed during the 2009-2013 RMBO surveys. Also shown is the range status based on Birds of North America species accounts, and breeding habitat class for each species.

Common Name	Range Status	Breeding Habitat Class
American Robin	Breeding and Wintering	Possibly Exists
Black-crowned Night-Heron [1]	Breeding	Possibly Exists
Black-necked Stilt [1]	Breeding	Limited to None
Cinnamon Teal [1]	Outside Normal Breeding Range [2]	Limited to None
Common Gallinule [1, 3]	Scattered Breeding	Possibly Exists
Double-crested Cormorant [1]	Outside Normal Breeding Range	Possibly Exists
Eastern Screech-Owl	Year-round	Exists
Gadwall [1]	Wintering	Limited to None
Green Heron [1]	Outside Normal Breeding Range	Possibly Exists
Green-winged Teal [1]	Wintering	Limited to None
Virginia Rail [1]	Outside Normal Breeding Range [2]	Limited to None

[1] Wetland species not expected to be observed on RMBO Surveys, although its occurrence/detection is possible.
[2] Outside Normal Breeding Range but within 100 miles of breeding range edge.
[3] The name of this species was changed from Common Moorhen in 2011 by the American Ornithologists' Union.

Species Comparisons using the 2002-2003 TNC Inventory (Temporal Context)

A total of 72 species of birds were observed at Lake Meredith NRA and Alibates Flint Quarries NM in the 2002 and 2003 TNC bird inventory (Patrikeev 2004; Appendix I). Of these 72 bird species, 11 were not observed on recent (2009-2013) RMBO surveys (Table 4.11.4-1). However, all but two of these species are associated primarily with wetlands, so they would not be expected to be observed during RMBO surveys given the location of the transects that focus on grasslands and riparian habitat (primarily cottonwoods).Of the remaining two species, only one falls into the "exists" habitat class, in which the habitat at the park is characteristic of the habitat in which the species would be expected to breed. It is possible that this species has not been observed by RMBO because it is an owl species. Nocturnal owl species may go unobserved during the daytime surveys of RMBO. Recall that the Patrikeev (2004) inventory included night-time owl searches. Additionally, RMBO recorded all of the 29 species that TNC recorded in their breeding bird surveys (the variable circular plots); all of the 11 species not recorded by RMBO were detected by TNC in the subsequent searches.

It should also be noted that taking the list of 11 species as a whole, out of the species within their normal breeding ranges (or within 100 miles of the ranges [seven species]), only the Eastern Screech-Owl falls into the "exists" breeding habitat class. Out of the other six species within (or within 100 miles of) their normal breeding ranges, only three fall into the "possibly exists" class; the other three fall into the "limited to none" class. Also, of these eleven species, all but one (Black-crowned Night-Heron) are noted as uncommon or rare on the NPSpecies List (NPS 2014).

A different set of species (63) was recorded in the 2009-2013 surveys but not in the 2002-2003 inventory (see Appendix I). From the comparison of species detected in 2002-2003 to 2009-2013, we do not have any particular concerns for species occurrence at the Recreation Area.

Species Comparisons to Surrounding Region (Spatial Context)

Two species were detected during the BBSs that were not detected during the 2009-2013 RMBO surveys at Lake Meredith NRA (Table 4.11.4-2). Of the two species, American Robin was recorded at the Recreation Area during

Table 4.11.4-2 Bird species recorded in 2009-2010 BBSs in the vicinity of Lake Meredith NRA/Alibates Flint Quarries NM that were not detected at the Recreation Area during the 2009-2013 RMBO point-count surveys. BBS data were not available for 2011-2013.

Common Name	Range Status	Breeding Habitat Class: Exists, Probably Exists, Limited to None
American Robin [2]	Breeding and Wintering	Possibly Exists
White-winged Dove	Outside Normal Breeding Range [1]	Possibly Exists

[1] But within 100 miles of its breeding range edge.
2 = Recorded by Patrikeev (2004) in 2002-2003.

the 2002-2003 TNC inventory (designated with a "2" in the table) and is also addressed in the temporal comparison. Both of the species are either within their normal breeding range or within 100 miles of the breeding range edge. However, neither species falls into the "exists" breeding habitat class; both are in the "possibly exists" category, meaning that while some breeding may occur in limited numbers, it is unlikely that the habitat at the Recreation Area would support consistent or widespread breeding. Furthermore, both species were recorded in the BBSs in very small numbers-three American Robins and two White-winged Doves in total. Also, the NPSpecies List (NPS 2014) lists American Robin as rare, and the White-winged Dove does not appear on the list.

Given their breeding ranges and breeding habitat classes, we do not have any particular concerns with these two species. It is also possible that one or both of the species will be observed on RMBO surveys in the future. Therefore, based on the spatial comparison, the condition of breeding landbirds at the Recreation Area is good.

Species of Conservation Concern

There are 32 species that have been detected at Lake Meredith NRA during 2009-2013 RMBO surveys that are listed as species of conservation concern on one or more of the lists described in Section 4.11.2 and Appendix H (Table 4.11.4-3). Many of the 32 species were also recorded by Patrikeev (2004). We also reviewed the list of eleven species recorded only by Patrikeev (2004) and the two species from the NPSpecies List (NPS 2014) that were listed as "present," but none of these additional species appeared on the species of conservation concern lists.

- USFWS / Listed Species: There are no bird species listed by the USFWS as endangered or threatened that are known to occur at the Recreation Area / National Monument or in the vicinity (USFWS 2014a). Two species listings appear in the table, but they are for subspecies or sub-populations that do not occur in either the state or the vicinity of the parks (see the table for details).
- State of Texas / Listed Species: One species (White-faced Ibis) shown in the table is listed by the State as threatened, and a second listing may apply (the *anatum* subspecies of Peregrine Falcon is listed as threatened) (TPWD 2014a).
- USFWS / Birds of Conservation Concern: There are 13 species that have been recorded at the Recreation Area that have been identified by the USFWS as having the greatest conservation need at a National, USFWS Regional, or BCR geographic scale (USFWS 2008).
- NAS / ABC: There are ten species that occur or have occurred at Lake Meredith NRA that have been listed on the NAS/ ABC 2007 WatchList. Two species, Baird's Sparrow and Bell's Vireo, are on the Red List. The other eight species are on the Yellow List, either because of population declines or because they are rare.
- PIF: Eleven of the 32 birds in Table 4.11.4-3 are listed by PIF as either CC or RC (recall we did not include the stewardship categories). Two of the 11

Table 4.11.4-3. Summary of species detected during 2009-2013 RMBO surveys (excluding the exotic Ring-necked Pheasant) at Lake Meredith NRA/Alibates Flint Quarries NM of conservation concern, as listed by government agencies and non-governmental organizations.

Common Name	Listed Species		Species of Conservation Concern Lists							Comments
	Federal[1]	State[2]	US Fish & Wildlife Service			NAS/ ABC[3]	Partners in Flight National Conservation Strategy[4]		State (TPWD) [5]	
	USFWS	TPWD	National	Region 2	BCR 18	2007 Watch List	BCR 18 CC	BCR 18 RC	Species of Greatest Conservation Need	
Baird's Sparrow			●	● A		●				A = according to the Region 2 list, this species is non-breeding in the Region.
Bell's Vireo			● B	● B	● B	●	●	●	●	B = listing applies to the non-listed subspec. or population (that occurs in TX) of a federally T or E species (that occurs in CA).
Burrowing Owl				●	●			●	●	
Carolina Chickadee									●	
Cassin's Sparrow								●	●	
Common Nighthawk								●		
Dickcissel			●						●	
Eastern Meadowlark									●	
Field Sparrow									●	
Grasshopper Sparrow				● C				●	●	C = listing is for *ammolegus* subspec., which, according to the BNA account, breeds only in southeast AZ and southwest NM to northern Sonora, MX. Other listings apply.
Lark Bunting				●	●	●		●		
Lark Sparrow									●	
Loggerhead Shrike			●	●					●	
Mississippi Kite									●	
Northern Bobwhite									●	
Northern Harrier								●	●	
Northern Pintail									●	
Olive-sided Flycatcher			●			●				
Orchard Oriole									●	
Painted Bunting			●	●		●			●	
Peregrine Falcon		ST D	●	●						D = TPWD lists anatum subspecies as threatened.

[1] **Federal Listed Species Codes**
T = Threatened PT= Proposed Threatened
E = Endangered

[2] **State Listed Species Codes**
ST = Threatened
SE = Endangered

[3] **NAS/ABC - 2007 Watchlist**
● = Red List
● = Declining or Rare

[4] **PIF NCS Categories**
CC = Continental Concern RC = Regional Concern

[5] **Species of Greatest Conservation Need**
in the Southwestern Tablelands region

Table 4.11.4-3. Summary of species detected during 2009-2013 RMBO surveys (excluding the exotic Ring-necked Pheasant) at Lake Meredith NRA/Alibates Flint Quarries NM of conservation concern, as listed by government agencies and non-governmental organizations (continued).

Common Name	Listed Species		Species of Conservation Concern Lists							Comments
	Federal[1]	State[2]	US Fish & Wildlife Service			NAS/ ABC[3]	Partners in Flight National Conservation Strategy[4]		State (TPWD) [5]	
	USFWS	TPWD	National	Region 2	BCR 18	2007 Watch List	BCR 18 CC	BCR 18 RC	Species of Greatest Conservation Need	
Red-headed Woodpecker			●	●		●	●		●	
Rufous-crowned Sparrow									●	
Scaled Quail						●		●	●	
Scissor-tailed Flycatcher									●	
Swainson's Hawk			●			●			●	
Virginia's Warbler			●			●				
Western Meadowlark								●		
White-faced Ibis		ST								
Wild Turkey									●	
Willow Flycatcher	E [E]	SE [E]	●		●	●				E = Listings with "E" are for a sub-species that does not occur in the Panhandle of TX / near LAMR; however, the other listings apply.
Yellow-billed Cuckoo	PT [F]		● [F]	● [F]				●		F = listings with "F" are for the Western U.S. Distinct Population Segment, which occurs in areas including western and southern TX, but not in the Panhandle of TX (Hughes 1999; USFWS 2014b). However, the other listing applies.

[1] **Federal Listed Species Codes**
T = Threatened PT= Proposed Threatened
E = Endangered

[2] **State Listed Species Codes**
ST = Threatened
SE = Endangered

[3] **NAS/ABC - 2007 Watchlist**
● = Red List
● = Declining or Rare

[4] **PIF NCS Categories**
CC = Continental Concern RC = Regional Concern

[5] **Species of Greatest Conservation Need**
in the Southwestern Tablelands region

species are listed only by PIF and not by the other agencies or groups.

- Texas Species of Greatest Conservation Need: Twenty-two of the species recorded during RMBO surveys and those by Patrikeev (2004) are considered Species of Greatest Conservation Need in the Southwestern Tablelands (part of Rolling Plains) region of Texas (TPWD 2012).Twelve of the species appear only on this list.

Summary of Species Listed as Birds of Conservation Concern (Conservation Context)

For this summary, we emphasize species for which Lake Meredith NRA has the greatest potential to positively impact their conservation during the breeding season, based on their breeding habitat and range. We do not mean to imply that other seasons are not important for the conservation of birds. Rather, we have limited this

assessment to the breeding season because that is the only season for which we have current information. We also recognize that there is uncertainty and subjectivity in our assessment. Thus, we do not mean to imply that the breeding habitat classes we assigned are the only "correct" categories. Rather, this represents our interpretation from the available evidence, but we expect that other interpretations might be appropriate.

Of the 32 species listed by one or more organization as being of conservation concern (Table 4.11.4-3), we believe that 19 have sufficient habitat at the Recreation Area to be considered as having high conservation potential (Table 4.11.4-4). These are the species that are generally within their normal breeding ranges and for which sufficient habitat exists at the park to support their breeding. All of these 19 species have been observed on recent (2009-2013) RMBO surveys (in one or more years). Furthermore, 14 of the species have been observed in four or five of the years (Table 4.11.4-5). Several of the species, such as Cassin's Sparrow, Western Meadowlark, Rufous-crowned Sparrow, and Grasshopper Sparrow, have been observed in relatively high numbers (559 total, 301 total, 195 total, and 184 total, respectively).

Three species are considered to have moderate potential for the Recreation Area to contribute to their conservation. These are Bell's Vireo, Carolina Chickadee, and Swainson's Hawk.

In summary, all species of conservation concern that are within their normal breeding range and have "existing" breeding habitat at the Recreation Area (i.e., high potential species) have been observed during recent (2009-2013) RMBO surveys (in one or more of the years). The majority of the 19 species were recorded in most years. We consider the condition for species of conservation concern to be good.

Overall Condition

For assessing the condition of landbirds, we used one indicator with three measures that assessed landbird occurrence. This indicator is summarized in Table 4.11.4-6.

Although our assessment is based on a limited amount of data (e.g., two years of BBS data for the three routes), we found no justification to warrant concern for landbird occurrence at Lake Meredith NRA at this time.

The temporal comparison found 11 species that were not detected during recent RMBO surveys. However, nine of these species (e.g., ducks and wading birds) are associated primarily with wetlands, so they would not be expected to be observed during the RMBO surveys at the park. Only one of the remaining species is within its normal breeding range and falls into the "exists" habitat class. It is possible that this species has not been observed by RMBO because it is an owl species (nocturnal). Also, of the eleven species, all but one are noted as uncommon or rare on the NPSpecies List (NPS 2014). Sixty-three different species were recorded in the 2009-2013 surveys but not in the 2002-2003 inventory.

Similarly, there was nothing particularly surprising or alarming when comparing species observed during recent RMBO surveys to the species observed during BBSs in the area surrounding the parks. Two species were recorded during the BBSs but not during the RMBO surveys. Altough both species are within their normal breeding range or within 100 miles of the range, neither falls into the "exists" breeding habitat class; both are in the "possibly exists" category. Also, both species were observed in very low numbers during the BBSs (just a few birds each). For these reasons, we do not have any particular concerns with the two species and consider the condition of breeding landbirds at the Recreation Area to be good.

For the third measure of species occurrence, we found 19 species that we believe have high conservation potential at Lake Meredith NRA/Alibates Flint Quarries NM. Some of these species have been observed on recent

Table 4.11.4-4. Species detected at Lake Meredith NRA/Alibates Flint Quarries NM during 2009-2013 surveys (or the 2002-2003 TNC inventory) that have been identified as species of conservation concern on one or more watch list. Species are organized by whether they have high, moderate, or low potential for the parks to contribute to their conservation.

Common Name	Detected During		Range Status	Breeding Habitat Class
	2009-2013 RMBO Surveys	2002-2003 Survey/ Inventory		
High Potential				
Cassin's Sparrow	•	•	Breeding	Exists
Common Nighthawk	•	•	Breeding	Exists
Dickcissel	•		Peripheral Breeding Range	Exists
Eastern Meadowlark	•	•	Year-round	Exists
Field Sparrow [4]	•	•	Outside Normal Breeding Range [1]	Exists
Grasshopper Sparrow	•		Breeding	Exists
Lark Sparrow [4]	•	•	Breeding	Possibly Exists
Loggerhead Shrike	•	•	Year-round	Exists
Mississippi Kite	•	•	Breeding	Exists
Northern Bobwhite	•	•	Breeding and Wintering	Exists
Orchard Oriole	•	•	Breeding	Exists
Painted Bunting	•	•	Breeding	Exists
Red-headed Woodpecker	•	•	Breeding and Wintering	Exists
Rufous-crowned Sparrow	•	•	Year-round	Exists
Scaled Quail	•	•	Year-round	Exists
Scissor-tailed Flycatcher	•	•	Breeding	Exists
Western Meadowlark	•	•	Year-round	Exists
Wild Turkey	•	•	Year-round	Exists
Yellow-billed Cuckoo	•	•	Breeding	Exists
Moderate Potential [2]				
Bell's Vireo [5]	•		Breeding	Exists
Carolina Chickadee	•	•	Year-round	Possibly Exists
Swainson's Hawk	•		Breeding	Possibly Exists
Low to No Potential [3]				
Baird's Sparrow	•		Outside Normal Breeding Range	Limited to None
Burrowing Owl	•		Breeding	Limited to None
Lark Bunting	•		Breeding and Wintering	Limited to None
Northern Harrier	•		Year-round	Limited to None
Northern Pintail	•		Wintering	Limited to None
Olive-sided Flycatcher	•		Outside Normal Breeding Range	Limited to None

[1] Outside Normal Breeding Range, but within 100 miles of breeding range edge.

[2] Species for which some breeding may occur, but the potential for the Recreation Area to play a significant role in its conservation is limited (e.g., due to low quality or small area of breeding habitat).

[3] Species is in the lowest category of conservation potential, meaning that the Recreation Area is unlikely to play a significant role in its conservation.

[4] Species might have been placed in Moderate Potential, but Patrikeev (2004) described it as a common nester (Lark Sparrow) or an uncommon nester (Field Sparrow) at the park.

[5] Species was only detected one time in RMBO surveys (1bird in 2009).

Table 4.11.4-4. Species detected at Lake Meredith NRA/Alibates Flint Quarries NM during 2009-2013 surveys (or the 2002-2003 TNC inventory) that have been identified as species of conservation concern on one or more watch list. Species are organized by whether they have high, moderate, or low potential for the parks to contribute to their conservation (continued).

Common Name	Detected During		Range Status	Breeding Habitat Class
	2009-2013 RMBO Surveys	2002-2003 Survey/ Inventory		
Peregrine Falcon	•		Outside Normal Breeding Range	Possibly Exists
Virginia's Warbler	•		Outside Normal Breeding Range	Limited to None
White-faced Ibis	•	•	Outside Normal Breeding Range	Limited to None
Willow Flycatcher	•		Outside Normal Breeding Range	Possibly Exists

[1] Outside Normal Breeding Range, but within 100 miles of breeding range edge.

[2] Species for which some breeding may occur, but the potential for the Recreation Area to play a significant role in its conservation is limited (e.g., due to low quality or small area of breeding habitat).

[3] Species is in the lowest category of conservation potential, meaning that the Recreation Area is unlikely to play a significant role in its conservation.

[4] Species might have been placed in Moderate Potential, but Patrikeev (2004) described it as a common nester (Lark Sparrow) or an uncommon nester (Field Sparrow) at the park.

[5] Species was only detected one time in RMBO surveys (1bird in 2009).

Table 4.11.4-5. The number of individuals of species with highest conservation potential recorded at Lake Meredith NRA and/or Alibates Flint Quarries NM during recent RMBO surveys.

Species	Survey Year					
	2009	2010	2011	2012	2013	Total
Cassin's Sparrow	48	87	166	119	139	559
Common Nighthawk	0	1	0	1	0	2
Dickcissel	33	33	21	6	0	93
Eastern Meadowlark	9	36	32	36	71	184
Field Sparrow	9	9	13	14	34	79
Grasshopper Sparrow	1	1	2	0	180	184
Lark Sparrow	5	8	0	17	64	94
Loggerhead Shrike	0	4	0	1	1	6
Mississippi Kite	7	21	17	21	0	66
Northern Bobwhite	76	41	17	43	2	179
Orchard Oriole	8	6	23	19	0	56
Painted Bunting	15	32	17	27	0	91
Red-headed Woodpecker	17	26	14	23	0	80
Rufous-crowned Sparrow	1	7	6	54	127	195
Scaled Quail	0	0	0	1	0	1
Scissor-tailed Flycatcher	9	24	11	20	27	91
Western Meadowlark	0	2	17	133	149	301
Wild Turkey	0	0	0	19	1	20
Yellow-billed Cuckoo	2	2	0	0	0	4

Table 4.11.4-6. Summary of the breeding landbirds indicator/measures and their contributions to the overall landbirds condition.

Indicator	Measure	Condition	Condition Rationale
Species Occurrence	Temporal Context	Good	Eighty-five percent of 72 species observed in 2002-2003 bird inventories were observed in 2009-2013 RMBO bird surveys at the Recreation Area. Of the 11 species not observed: 1) most are primarily associated with wetlands (habitats not surveyed by RMBO); and 2) only one species was within its normal breeding range and fell into the "exists" breeding habitat class. This species is an owl and may have gone undetected to date because of its nocturnal nature. Additionally, 63 species were observed in the 2009-2013 RMBO surveys but not in the 2002-2003 inventory. In a temporal context, the condition of breeding landbirds at the Recreation Area is good. Data are available for a relatively small number of years, so no trend information is available at this time.
	Spatial Context	Good	In a comparison of the results of BBSs in the vicinity of the Recreation Area to RMBO surveys within the park, there were only two species that were not observed during the RMBO surveys. Although both species are within or in proximity to their normal breeding ranges, neither falls into the "exists" breeding habitat class. Also, both species were recorded in very low numbers during the BBSs. Based on this comparison, the condition of breeding landbirds is good. No trend information is available at this time.
	Conservation Context	Good	There are 32 species that have been observed during 2009-2013 surveys that are listed by one or more organization as being of conservation concern. Many of the species were also observed during the 2002-2003 inventory. We believe that 19 of these species have high conservation potential at the Recreation Area. These are species that are within their normal breeding range and sufficient habitat exists at the park to support their breeding. All of these species have been observed on recent RMBO surveys (in one or more years), with 14 of the species observed in nearly every year. Therefore, we consider the condition for species of conservation concern at the Recreation Area to be good. No trend information is availalbe at this time.

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Figure 4.11.4-1 Cassin's Sparrow was recorded every year in RMBO surveys at the Recreation Area.

RMBO surveys in most years and in relatively high numbers (Figure 4.11.4-1).

Based on the information presented here, we consider the condition of breeding landbirds at the Recreation Area to be good. Unfortunately, we do not have sufficient data to justify a trend in that condition, although ongoing monitoring should provide such an estimate for future assessments.

Level of Confidence/Key Uncertainties

The key uncertainties related to this assessment are the overall lack of data (e.g., one-two years of prior data and limited BBS data) and subjectivity with respect to assigning individual species to range, habitat, or conservation classes. Although we are currently collecting data that will provide for a quantitatively rigorous analysis in the future,

at the present time we relied primarily on qualitative indicators to assess the condition of landbirds.

We determined the breeding ranges primarily from the BNA species accounts and had to judge from online and hard copies whether or not the Recreation Area was within those ranges. We tried to account for this uncertainty by also including species that were on the edge of their ranges (i.e., less than 100 miles from the breeding range edge). Similarly, there is subjectivity in our assignment of breeding habitat classes. However, we based this judgement on avian expert Moez Ali (see below).

4.11.5. Sources of Expertise

Moez Ali, an avian expert, provided input on the breeding habitat classes for each species in Tables 4.11.4-1, 4.11.4-2, and 4.11.4-4. Mr. Ali will lead the annual landbird monitoring at the Recreation Area in 2015 and has become the lead for field efforts for the landbird monitoring in the Southern Plains Network, Chihuahuan Desert Network, and Sonoran Desert Network.

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4.12. Herpetofauna

Indicators/Measures

- Species Occurrence: Presence/absence of herpetofaunal species

Condition – Trend - Confidence

Insufficient Data - Insufficient Data - Medium

4.12.1. Background and Importance

The American Southwest is well known for its abundance and diversity of reptiles. The region is less well known for its amphibians, but they are abundant in some habitats, particularly during favorable weather conditions. Amphibians and reptiles are, together, referred to as herpetofauna or "herps." The state of Texas supports 215 native herpetofaunal species (Brown et al. 2012). The number of species of amphibians and turtles reportedly decreases from east to west in Texas, following decreases in moisture and increases in temperature, while the number of species of lizards increases from east to west (Owen and Dixon 1989).

Amphibians and reptiles are important members of aquatic and terrestrial ecosystems. Amphibians constitute an important part of the food web; they consume insects and other invertebrates, and they are prey for a long list of fish, reptile, bird, and mammal species. Reptiles too serve as both predators and prey for many animals, such as small mammals, birds, and other reptiles. Amphibians are viewed as indicators of wetland ecosystem health. They are sensitive to a variety of threats due to their permeable skin and complex life histories, and, thus, can serve as early indicators of ecosystem change when monitored over long time scales. Like birds, reptiles and amphibians are also of aesthetic value to visitors of national park units.

No current information is available on the herpetofauna of Lake Meredith NRA or Alibates Flint Quarries NM. The most recent information is from a survey of vertebrates at the parks, including reptiles and amphibians, that was conducted by The Nature Conservancy (TNC) in 2002-2003 (Patrikeev 2004 and Patrikeev 2008). As it is the best source of information on herpetofauna for the parks, this chapter summarizes the Patrikeev reports. Unfortunately, current condition and trends can not be assessed due to the lack of current data.

Prior to the 2002-2003 TNC survey (Patrikeev 2004, 2008), no thorough assessment of the herpetofauna of Lake Meredith NRA or Alibates Flint Quarries NM had been conducted (Patrikeev 2008). There had been two studies of herpetofauna at two nearby ranches, one in Hutchinson County (Fouquette and Lindsay 1955 as cited in Patrikeev 2008) and one in Oldham County (Scudday and Scudday 1975 as cited in Patrikeev 2008) in 1950 and in 1974, respectively. The only information for the parks themselves, prior to Patrikeev (2004), was a list preprared by Philips (1989); however, it was not clear what information was used to prepare the list, and no specimens or photographs were provided (Patrikeev 2008).

4.12.2. Data and Methods

This limited assessment is based on the 2002-2003 vertebrate surveys conducted by TNC (Patrikeev 2004, later published as Patrikeev 2008). We used one indicator/measure of

Figure 4.12.1-1. Texas horned lizard, one of the reptile species observed at both Alibates Flint Quarries NM and Lake Meredith NRA during 2002-2003 surveys.

condition-- species occurrence: presence/absence.

Indicators/Measures
Species Occurrence: Presence/Absence

Species Occurrence: Presence/Absence
Because there is no recent information to assess current condition, we used the 2002-2003 surveys to assess the occurrence of amphibian and reptile species at the Recreation Area/National Monument. Patrikeev (2004, 2008) included a comparison of the species he recorded at the parks to species that had been reported in the past at the park units and adjacent counties.

The Occurrence of Species of Conservation Concern
We also used the surveys by Patrikeev (2004/2008) to generate a list of species of conservation concern. The list was complied by comparing the list of species observed during 2002-2003 surveys to a federal/state list of endangered and threatened species (described later) and those of Greatest Conservation Need in Texas (described later).

Primary Data Sources
The survey methods of Patrikeev (2004, 2008) for amphibians and reptiles consisted of six types of surveys/observations: visual encounters, coverboard stations, night road surveys, auditory amphibian surveys, turtle surveys using hoop traps, and examination of four university herpetofaunal collections. Visual encounters included systematic and opportunistic searches, such as overturning rocks and logs, and looking into crevices and cracks in rocks and structures. Randomly selected sites were used for coverboard stations, which were checked between May-August 2002 and April-June 2003. Road surveys were conducted on rainy or warm and humid nights on paved park roads and many unpaved roads. Auditory surveys were conducted in freshwater habitats for frogs and toads in March-June in both years. Large hoop traps were used for turtle surveys at Sanford Marsh and the Canadian River during two survey periods in 2002. Additional details on these methods are provided in Patrikeev (2004) and Patrikeev (2008). Patrikeev (2008) pointed out that while the work of Fouquette and Lindsay (1955) took place during a wet period, his work occurred during a drought. Patrikeev (2004) used photographic evidence of species observations as much as possible.

Protected/Rare Species Lists
In 1973, the Texas Parks and Wildlife Department (TPWD) was authorized to develop a list of endangered and threatened animal species in the state. Legal protection of endangered and threatened animals is provided by laws and regulations in Chapters 67 and 68 of the Texas Parks and Wildlife Code and Sections 65.171-65.176 of Title 31 of the Texas Administrative Code (TPWD 2014a). Under the Endangered Species Act, the U.S. Fish and Wildlife Service (USFWS) lists species as threatened, endangered, or candidates for listing. A list of federal and state-listed amphibian and reptile species was obtained from the TPWD website (TPWD 2014b).

The State of Texas also designated species that, "due to limited distributions and/or declining populations, face the threat of extirpation or extinction but lack legal protection" (TPWD 2014c). The lists were developed for the TPWD's Texas Conservation Action Plan (TCAP). Species are rated or ranked using a system developed by NatureServe. The TCAP divides the state into different ecoregions, and the one in which the Recreation Area and National Monument occur is the Southwestern Tablelands (TPWD 2012). The list of the species for the Southwestern Tablelands included a total of 13 herpetofaunal species.

4.12.3. Reference Conditions
No reference conditions were developed for this resource topic.

4.12.4. Condition and Trend
A total of about 44 species of amphibians and reptiles have been recorded at Lake Meredith NRA and Alibates Flint Quarries NM during 2002-2003 surveys at the parks by The Nature Conservancy (Patrikeev 2004/2008) or during past studies.

Table 4.12.4-1 Amphibian and reptile species recorded in Lake Meredith NRA and Alibates Flint Quarries NM during surveys in 2002-2003 by TNC (Patrikeev 2004, 2008). Three species (designated with "*") were not observed in the parks but in areas immediately adjacent.

Common Name	Scientific Name	Recorded at LAMR	Recorded at ALFL
Amphibians			
Barred tiger salamander *	Ambystoma tigrinum mavorium*		
Blanchard's cricket frog	*Acris crepitans blanchardi*	X	
Western green toad	*Bufo debilis insidior*	X	
Red-spotted toad	*Bufo punctatus*	X	
Woodhouse's toad	*Bufo woodhousii woodhousii*	X	X
Couch's spadefoot	*Scaphiopus couchii*	X	
Plains spadefoot	*Spea bombifrons*	X	
Plains leopard frog	*Rana blairi*	X	
Bullfrog	*Rana catesbeiana*	X	
Reptiles			
Common snapping turtle	*Chelydra serpentina serpentina*	X	
Yellow mud turtle	*Kinosternon flavescens flavescens*	X	
Ornate box turtle	*Terrapene ornata ornata*	X	X
Red-eared slider	*Trachemys scripta elegans*	X	
Eastern collared lizard	*Crotaphytus collaris collaris*	X	X
Prairie lizard	*Sceloporus consobrinus*	X	X
Texas horned lizard	*Phrynosoma cornutum*	X	X
Prairie racerunner	*Cnemidophorus sexlineatus viridis*	X	X
Colorado checkered whiptail	*Cnemidophorus tesselatus*	X	X
Great Plains skink	*Eumeces obsoletus*	X	X
New Mexico blind snake	*Leptotyphlops dulcis dissectus*	X	X
Kansas Glossy Snake	*Arizona elegans elegans*	X	
Yellowbelly Racer	*Coluber constrictor flaviventris*	X	
Prairie Ringneck Snake	*Diadophis punctatus arnyi*	X	
Northern Plains rat snake	*Elaphe emoryi emoryi*	X	
Texas night snake	*Hypsiglena torquata jani*	X	
Desert king snake	*Lampropeltis getula splendida*	X	
Western coachwhip	*Masticophis flagellum testaceus*	X	X
Blotched water snake	*Nerodia erythrogaster transversa*	X	
Bullsnake	*Pituophis catenifer sayi*	X	X
Texas longnose snake	*Rhinocheilus lecontei tesselatus*	X	X
Ground snake	*Sonora semiannulata*	X	
Plains blackhead snake	*Tantilla nigriceps*		X
Marcy's checkered garter snake	*Thamnophis marcianus marcianus*	X	
Texas garter snake	*Thamnophis sirtalis annectens*	X	
Lined snake *	*Tropidoclonion lineatum**		
Western diamondback rattlesnake	*Crotalus atrox*	X	X
Prairie rattlesnake *	*Crotalus viridis viridis**		

Table 4.12.4-2. Species detected during 2002-2003 surveys at Lake Meredith NRA and/or Alibates Flint Quarries NM (* and adjacent to the parks) that are of conservation concern, as listed by the state (Texas Parks and Wildlife Department) and/or federal government (U.S. Fish and Wildlife Service).

Common Name	Scientific Name	Federal List (USFWS)	State List (TPWD)	TX SGCN[1] (TPWD)	SGCN Abundance Designation [2]
Common snapping turtle [3]	*Chelydra serpentina serpentina*			•	
Ornate box turtle [3]	*Terrapene ornata ornata*			•	G5, S3
Red-eared slider [3]	*Trachemys scripta elegans*			•	
Texas horned lizard [3]	*Phrynosoma cornutum*		T	•	G4G5, S4
Texas garter snake [3]	*Thamnophis sirtalis annectens*			•	G5, S2
Western diamondback rattlesnake[3]	*Crotalus atrox*			•	S4
Prairie rattlesnake [3, *]	*Crotalus viridis viridis**			•	

[1] Species of Greatest Conservation Need, as listed by Texas Parks and Wildlife Department, for the Southwestern Tablelands Ecoregion. Species listed are shown with a bullet. The last column of the table shows information on abundace for some species, according to the state list.

[2] Definitions of designations shown: **G4**: Apparently Secure — Uncommon but not rare; some cause for long-term concern due to declines or other factors. **G5**: Secure — Common; widespread and abundant. **G4G5**: A numeric range rank (e.g., G4G5) is used to indicate the range of uncertainty in the status of a species. **S2**: Imperiled — Imperiled in the nation or state because of rarity due to very restricted range, very few populations (often 20 or fewer), steep declines, or other factors making it very vulnerable to extirpation from the nation or state. **S3**: Vulnerable — Vulnerable in the nation or state due to a restricted range, relatively few populations (often 80 or fewer), recent and widespread declines, or other factors making it vulnerable to extirpation. **S4**: Apparently Secure — Uncommon but not rare; some cause for long-term concern due to declines or other factors.

3 = Species notes from Patrikeev (2008): **Common snapping turtle**: uncommon or under-recorded semiaquatic species. **Ornate box turtle**: common. The most frequently encountered turtle in both parks (> 40 records). **Red-eared slider**: common locally in marshes of the Canadian River and bays of Lake Meredith. As many as 36 observed basking in Sanford Marsh on 29 March 2002. **Texas horned lizard**: common and widespread in the study area (46 records including 15 in Lake Meredith NRA and 3 in Alibates Flint Quarries NM). More common in ranches bordering the study area. **Texas garter snake**: rare (2 records) during the survey. **Western diamondback rattlesnake**: common and widespread (21 records). One of the two most frequently encountered snake species in the study area. **Prairie rattlesnake**: Rare or uncommon; detected outside of the park in 2002-2003 surveys.

Species Occurrence: Presence/Absence

Of the 44 species, 37 were recorded during the 2002-2003 surveys (Table 4.12.4-1). Nine of the 37 species are amphibians, and 28 of the species are reptiles.

Patrikeev (2008) compared the list of species he recorded during surveys to previous reports at the park or museum specimens. There were seven species reported previously for the parks that were not recorded in 2002-2003. Of these seven species, Patrikeev (2008) reported that one of them was probably rare (Plains hognose snake [*Heterodon nasicus nasicus*]), one was cryptic or rare (Roundtail horned lizard [*Phrynosoma modestum*]), and four were probably rare or extirpated (Great plains toad [*Bufo cognatus*], Texas spotted whiptail [*Cnemidophorus gularis gularis*], Eastern hognose snake [*Heterodon platirhinos*], and Diamondback water snake [*Nerodia rhombifer rhombifer*]). If they were rare at the time of the surveys, that would help to explain why they may not have been observed. No additional comments were provided for the seventh species, the Western ribbon snake (*Thamnophis proximus proximus*). No published reports are available for the period since the TNC surveys, so we can not provide any additional information as to whether the species exist in the park(s) or not at this time. Patrikeev (2008) also provided a list of 13 species that might be present in the Recreation Area and/or the National Monument based on their occurrence at the time or in the past in the surrounding area; these species include spotted chorus frog (*Pseudacris clarkii*), New Mexico spadefoot (*Spea multiplicata*), Texas toad (*Bufo speciosus*), Western spiny softshell (*Apalone spinifera hartwegi*), Western slender glass lizard (*Ophisaurus attenuatus*), and plains garter snake (*Thamnophis radix*).

Conservation Context – The Occurrence of Species of Conservation Concern

There are seven species that have been observed at Lake Meredith NRA and Alibates Flint Quarries NM during 2002-2003 surveys that are listed as species of conservation

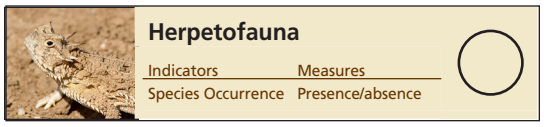
Table 4.12.4-3. Indicator and measure of herpetofauna condition.

Indicator of Condition	Measure	Condition	Rationale for Condition.
Species Occurrence	Presence/absence	Unknown	There is no current information available on amphibians and reptiles at the Recreation Area and National Monument. The most recent surveys were conducted by TNC in 2002-2003 (i.e., Patrikeev 2004, 2008). Although condition can not be determined at this time, the 2002-2003 work provides baseline information for future monitoring and assessment..

concern on one or more of the lists described in Section 4.12.2 (Table 4.12.4-2).

No federally-listed amphibian or reptile species were recorded at the Recreation Area or National Monument during the 2002-2003 surveys. One state-listed species, the Texas horned lizard, was observed during the surveys; the Texas horned lizard is listed as threatened by the TPWD.

Out of the 37 species recorded during 2002-2003 surveys, seven are listed as Species of Greatest Conservation Need with TPWD. This includes the Texas horned lizard and the prairie rattlesnake, a species observed outside of but adjacent to the parks by Patrikeev (2004/2008). Information on abundance of the species (global- or state-wide) was provided for four of the seven species (see Table 4.12.4-2). The designations (e.g., G5, S3) and their definitions are provided in the table.



Summary of Condition and Trend

To assess condition of herpetofauna at Lake Meredith NRA and Alibates Flint Quarries NM, we used one indicator/measure, summarized in Table 4.12.4-3. Current condition can not be assessed due to the lack of recent data. The information presented in this chapter is from the last survey at the parks, conducted in 2002-2003 by TNC. That survey documented 37 species in the parks. Trends in species occurrence can not be assessed due to the lack of available data. However, the 2002-2003 surveys provide good baseline information for future monitoring and condition assessment.

4.12.5. Sources of Expertise

No experts were consulted for this resource topic.

4.12.6. Literature Cited

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4.13. Fish

Indicators/Measures

- River Fish Species: Species Occurrence, presence/absence (1 Indicator / Measure)
- Lake Fish Species: Species Occurrence, presence/absence (1 Indicator / Measure)

Condition – Trend - Confidence

River Fish Species	Lake Fish Species
Insufficient Data - Insufficient Data - Moderate	Significant - Unchanging - Moderate

4.13.1. Background and Importance

Lake Meredith National Recreation Area (NRA) contains Lake Meredith, the largest lake in the Texas and Oklahoma panhandles, a portion of the Canadian River, and portions of several creeks (Figure 4.13.1-1). No surface waters exist within Alibates Flint Quarries National Monument (NM), except for ephemeral waters that may develop during periods of heavy rainfall (NPS, SOPN 2008). Lake Meredith is a 10,000-acre (4,047 ha) reservoir (Figure 4.13.1-2) formed in 1962 by constructing the Sanford dam on the Canadian River. The Canadian River, which originates in the Sangre de Cristo Mountains in New Mexico, flows from west to east and has a total watershed of about 13,000 square miles (33,670 square km). Below the Sanford dam, the Canadian River flows through dense vegetation (Charles Munger, Texas Parks and Wildlife Department [TPWD], pers. comm.).

Lake Meredith had provided an average of approximately 100,000 acre-feet of water every year to eleven communities for municipal and industrial uses (NPS, SOPN 2008). However, drought conditions in recent years have led to increasingly lower lake levels and the need for the Canadian River Municipal Water Authority (CRMWA) to supplement water supply with greater amounts of groundwater pumping (CRMWA 2014). The current drought is the longest that the lake has experienced, and it has led to new lows in river inflows (CRMWA 2014).

Field sampling to document the presence of fish species at the Recreation Area has been conducted in the Canadian River, and a list of fish species that may be found in Lake Meredith has also been compiled. One federally- and state-listed species is found in the Recreation Area, the Arkansas River shiner (*Notropis girardi;* Figure 4.13.1-3), which is a small fish, rarely exceeding 2.5 inches (6.35 cm) in length (Oklahoma Department of Wildlife Conservation [ODWC] 2014). This minnow once inhabited most of the Arkansas River Basin's major rivers, including the Cimarron, North Canadian and Canadian Rivers, and the Arkansas River itself (ODWC 2014). However, the range of the species

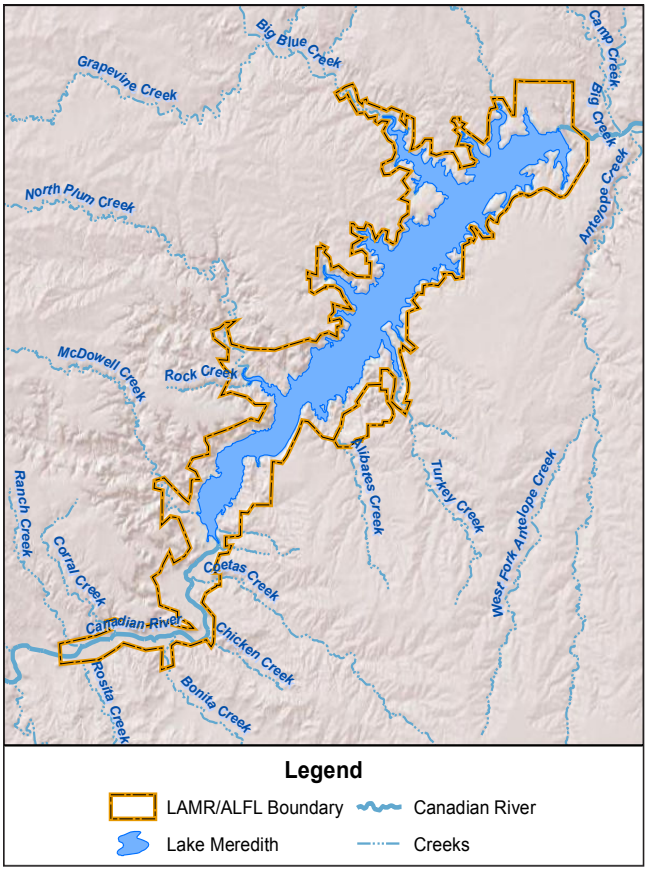


Figure 4.13.1-1. Surface water resources in the vicinity of Lake Meredith NRA and Alibates Flint Quarries NM.

PHOTO: G NESOM

Figure 4.13.1-2. Lake Meredith, the largest lake in the Texas and Oklahoma panhandles.

decreased by about 80% over the last 40 years (U.S. Fish & Wildlife Service [USFWS] 2005). The species is threatened by habitat destruction and modification from the dewatering of its stream habitat through surface water and groundwater pumping, water quality degradation, and construction of impoundments. Other concerns include competition with non-native fish species, incidental collection during the capture of bait fish, and drought. The species' Arkansas River Basin population was listed under the Endangered Species Act (ESA) in 1998. At the present time, the species has no federal recovery plan (USFWS 2014), but a cooperative management plan has been developed (CRMWA 2005) and is described below.

The Arkansas River shiner's current distribution is primarily within about 510 miles (821 km) of the Canadian/South Canadian River in New Mexico, Texas, and Oklahoma (USFWS 2005), although a few small or remnant populations exist elsewhere. Habitat for the species consists of the main channels of shallow, wide, sandy-bottomed rivers and larger streams in the Arkansas River Basin. To complete its reproductive cycle, the species is thought to require more than 130 miles (209 km) of flowing, unimpounded water (USFWS 2005). Adult fish spawn after heavy rains, and the eggs develop as they are carried downstream with the current (ODWC 2014).

PHOTO: D FENNER, USFWS

Figure 4.13.1-3. Arkansas River shiner, a federally- and state-listed threatened species. Photo used by permission.

The management plan for the species (i.e., CRMWA 2005) is a cooperative effort between various federal, state, and local entities. A Memorandum of Agreement was signed by "major participating agencies" (which include NPS) to specify activities to be undertaken and express support for the plan (CRMWA 2005), but many additional groups were/are involved in the development and implementation of the plan. The plan emphasizes the need to improve existing stream habitat for the shiner by removing invasive plant species and encouraging the preservation/protection of habitat through conservation programs.

At Lake Meredith, sport fishing is an important recreational activity, with walleye (*Sander vitreus*), smallmouth bass (*Micropterus dolomieu*), largemouth bass (*Micropterus salmoides*), white bass (*Morone chrysops*), white crappie (*Pomoxis annularis*), and catfish being some of the most popular species. The Texas Parks and Wildlife Department (TPWD) monitors the lake's sport fish, and they have stocked the reservoir with various sport fish species over the years (TPWD 2014a). The most recent stocking efforts took place in 2000 and 2001, when over 65,000 largemouth bass fingerlings and 290,100 walleye fingerlings were released.

4.13.2. Data and Methods

For fish in the Canadian River and associated creeks, this limited assessment is based primarily on 1) 2002-2003 vertebrate surveys at the Recreation Area and the National Monument (fish were surveyed only in 2003) conducted by The Nature Conservancy (TNC; Patrikeev 2004), and 2) May 2009-January 2010 presence-absence surveys of the Arkansas River shiner and associated fish species within the Recreation Area (Wilde 2010). We also used information provided by the TPWD (Munger 2002) on species recorded during older surveys of the river. For fish in Lake Meredith, we based the limited assessment on the list of fish species that may be found in the lake (Munger 2002), as well as recent information on the status of fish (particularly sport fish) in the lake from TPWD (Munger and Clayton 2013). We separated the fish resources at the Recreation Area into these two components, fish in the river and fish in the lake, and used one indicator and measure of condition, species occurrence: presence/absence of fish species, for each.

Indicators / Measures

Species Occurrence: Presence/absence

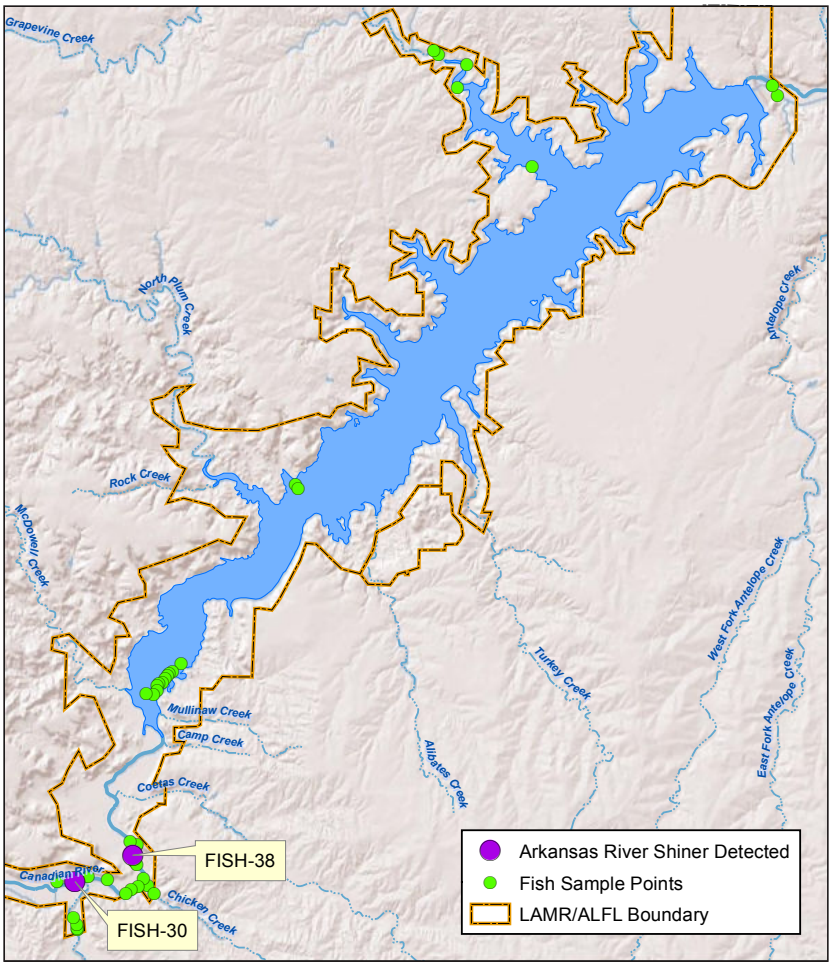


Figure 4.13.2-1. Fish sampling points (green and purple) of Patrikeev (2004) in 2003. Purple points show where Arkansas River shiner were recorded.

Species Occurrence: Presence/Absence of Fish in the Canadian River

Because there is no more recent information to assess current condition of fish in the Canadian River and associated creeks, we used the 2009-2010 Wilde surveys and 2003 TNC surveys to assess the occurrence of fish species. We also used information from the TPWD (Munger 2002), which lists species that were recorded during surveys of the Canadian River on two occasions - June 1954 to May 1955 and in 1983.

The 2003 surveys for fish by TNC were focused in areas of the Canadian River and associated creeks that provided potential habitat for the federally-threatened Arkansas River shiner (Patrikeev 2004), previously reported to occur in the Recreation Area. Lake Meredith was generally not sampled, except for the shallow shoreline areas of Big Blue Creek Bay. In June of 2003, 25 stations were sampled in the Canadian River upstream of Mullinaw Crossing and downstream of Chicken Creek, Bonita Creek, Big Blue Creek, and shoreline areas of Big Blue Creek Bay (Patrikeev 2004; Figure 4.13.2-1). In November of 2003, sampling was conducted at 18 stations, primarily in the Canadian River downstream from Bonita Creek and in the Plum Creek area, and at Sanford Marsh. Several sampling methods were used during both time periods, depending on factors such as water depth: seines, dip nets, an electro-shocker, and minnow traps.

Wilde's (2010) field sampling for the NPS within the Recreation Area was conducted between May 2009 and January 2010. The study's purpose was to determine the occurrence and abundance of the Arkansas River shiner and other riverine fish in the park within the Rosita area. Nine sampling sites were used from the mouth of Chicken

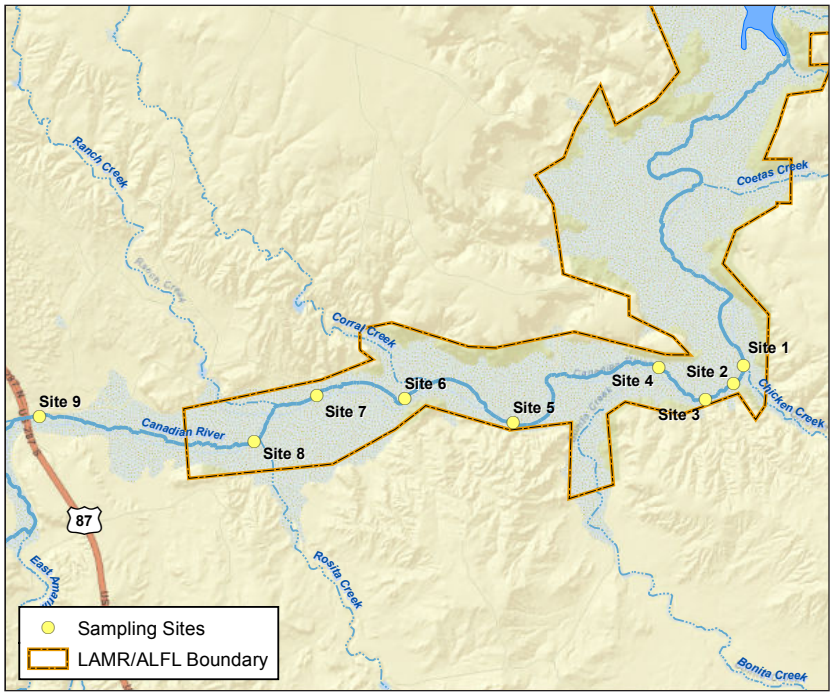


Figure 4.13.2-2. Fish sampling locations of Wilde (2010) in the Canadian River. Points shown are the starting points for sites sampled in Spring (May) 2009.

Creek (Site 1, the most downstream site) to about 100 m downstream from the U.S. Highway 87 bridge, north of Amarillo, (Site 9; Figure 4.13.2-2). Only sites 1-8 were within the Recreation Area. Sites were surveyed four times: spring (May 2009); summer (July for Sites 6-9 and September, 2009 for Sites 1-5), fall (December, 2009), and winter (January, 2010). Five to eight transects were sampled at each site during each sampling occasion, for a total of about 20 seine hauls per site per occasion. In addition to recording data on the individual fish captured, habitat measurements were also taken (e.g., water depth, current velocity, temperature).

We also examined the list of fish species recorded in the Recreation Area (rivers and creeks and lake) for any species that are federally or state-listed as endangered or threatened (in addition to the Arkansas River shiner), and for those considered Species of Greatest Conservation Need (SGCN). In Texas, SGCN are those species that, "due to limited distributions and/or declining populations, face the threat of extirpation or extinction but lack legal protection" (TPWD 2014b). The lists were developed for the TPWD's Texas Conservation Action Plan (TCAP), which divides the state into different ecoregions. The ecoregion in which the Recreation Area and National Monument occur is Southwestern Tablelands (TPWD 2012).

Species Occurrence: Presence/Absence of Fish in Lake Meredith

As noted above, to assess the condition of fish in the lake, we used the list compiled by Munger (2002) and recent reports by the TPWD by the same author (especially Munger and Clayton 2013). The field sampling work described in Munger and Clayton (2013) consisted of gill netting (5 net nights at 5 stations) and trap netting (5 net nights at 5 stations). Biologists were unable to use electrofishing because of the high conductivities caused by the low water conditions. Overall, sampling effort was lower than in previous years due to lake conditions. Some additional details on the TPWD reports are provided in Section 4.13.4, Condition and Trend. As described above for fish in the Canadian River and associated creeks, the list of fish in the lake was reviewed for species of conservation concern (e.g., threatened/endangered species or SGCN).

4.13.3. Reference Conditions

No reference conditions were developed for this resource topic.

4.13.4. Condition and Trend

The list of SGCN for the Southwestern Tablelands region includes a total of five fish species. Two of the species, Arkansas River shiner and peppered chub (*Macrhybopsis tetranema*), have been recorded in the park. As already noted, the Arkansas River shiner is listed as threatened with both the USFWS and the TPWD (USFWS 2014, TPWD 2014c). The peppered chub has no status in Texas other than as a SGCN.

Fish Species in the Canadian River and Associated Creeks

The fish sampling work of Patrikeev (2004) recorded 18 species of fish, all of which appear on the NPSpecies List for the park (NPS 2014) as "present" (Table 4.13.4-1), except for peppered chub (which may have been recorded as the speckled chub in the past; see the fifth note under Table 4.13.4-1).

Fourteen of the 18 species were recorded in the Canadian River previously, in either 1983 (one species) or 1954-1955 (four species), or during both periods (nine species). Only three species (or four if the peppered chub is included) were recorded in 2003 only: the river shiner (*Notropis blennius*), bullhead minnow (*Pimephales vigilax*), and flathead catfish (*Pylodictis olivaris*). Patrikeev et al. (2005) reported that the river shiner was likely introduced, as it was outside of its reported range and had not been reported in the area from 1954-1996; they concluded its presence probably originated with released bait fish. Eight species (excluding speckled chub/peppered chub) were recorded in the 1983 and/or 1954-1955 surveys but not in 2003. Patrikeev (2004) suggested that four of these speces, three native and one introduced (black bullhead [*Ameiurus melas*], warmouth [*Lepomis gulosus*], sand shiner [*Notropis stramineus*], and golden shiner [*Notemigonus chrysoleucas*], respectively) probably disappeared from the river after construction of the reservoir, as they were recorded prior to the reservoir only. However, Wilde (2010; see below) recorded black bullhead during surveys in 2009-2010.

Of the 18 species recorded in the 2003 survey, those accounting for the greatest proportion of the total catch (i.e., of all fish species combined), were flathead chub (*Platygobio gracilis*, 35.6%), red shiner (*Cyprinella lutrensis*, 4.9%), plains minnow (*Hybognathus placitus*, 13.7%), and bluegill (*Lepomis macrochirus*, 5.9%; Patrikeev 2004). These four species accounted for 70.1% of the total catch. The Arkansas River shiner was recorded at two sites in the general vicinity of Chicken Creek (see Figure 4.13.2-1, purple circles). The specific areas were in a riffle downstream from Chicken Creek (station 38, Figure 4.13.2-1) and in a shallow channel with slighly varying water depths (0.2-0.5m) between Chicken and Bonita Creeks (station 30; Patrikeev 2004). Three fish and two fish were recorded at Station 38 and Station 30, respectively. Patrikeev (2004) also reported that P. Eubank (a pers. comm.) indicated that the species was also observed near Coetas Creek, but that area of the Canadian River and the creek were completely dry when TNC did their sampling in November 2003. No Arkansas River shiner were captured during sampling in June.

Patrikeev (2004) expressed some concern for the peppered chub because of the small number of fish caught in the river during sampling. The species was recorded at 14 stations during sampling, for a total of 52 individuals and 3.6% of the total catch of all fish. Wilde (2010), however, reported this fish in higher numbers during 2009-2010 sampling.

The sampling by Wilde (2010) within the Canadian River in the Rosita area documented 16 species. A total of 4,383 fish were captured during the four sampling occasions. Arkansas River shiner was the species most often captured, comprising 31.4% of the total fish captured. The next most common species during sampling were plains minnow (27.2%), peppered chub (16.6%), red shiner (13.7%), and Western mosquitofish (*Gambusia affinis*; 6.4%). The occurrence of the Arkansas River shiner in samples varied by season, occurring in 18% of samples in the spring, 63% in summer, 38% in fall, and 24% in winter. The researcher reported that the observed increase in abundance from spring to summer for the Arkansas River shiner (i.e., 157 to 473 individuals captured, respectively), as well as for some other species, coincided with spawning and the production of young fish. Also of interest, this species was present in a greater proportion of seine hauls as sites moved upstream (i.e., from Site 1 upstream to Site 9). Wilde (2010) also found that the presence of the species in individual samples was significantly related to depth in three of the four seasons (and noted that the lack of a relationship in summer may have been an artifact of sampling). Based on his and previous sampling in other portions of the Canadian River, Wilde (2010) concluded that the fish community in the Canadian River within the Recreation Area was similar in composition to areas of the river upstream.

Altough there were a few differences, most of the species reported by Wilde (2010) were also reported by Patrikeev (2004). Patrikeev (2004) reported several species that Wilde

(2010) did not report, but this may have been due to the differences in sampling locations.

Because no fish sampling/monitoring has been conducted in the Recreation Area in the Canadian River since the 2009-2010 work, current condition and trends of fish in the river / creeks are unknown.

Fish Species in Lake Meredith

The list of fish species that may occur in Lake Meredith contains 30 species (Munger 2002; seventh column of Table 4.13.4-1), some of which may also occur in the Canadian River and/or associated creeks. Munger (2002) notes that some of the species are not usually found in the reservoir and may be found only in the lake's upper reaches after flooding events; these are typcial riverine species (e.g., plains minnow, Arkansas River shiner, red shiner). Orangespotted sunfish (*Lepomis humilis*) and grass carp (*Ctenopharyngodon idella*, non-native) were not listed by Munger (2002), but both were recorded by Munger and Clayton (2013) during 2012-2013 sampling. The first species appears on the NPSpecies List as "unconfirmed," while the second fish does not appear on the list.

The TPWD Inland Fisheries Division releases a fisheries management survey report for Lake Meredith every few years. The most recent report covered data collected in 2012-2013 and revealed that the channel catfish (*Ictalurus punctatus*) was the only game fish found in the lake during the survey period (Munger and Clayton 2013). Furthermore, based on their data, the channel catfish population appears to be in decline. A total of six additional fish species were recorded in 2012-2013 (common carp [*Cyprinus carpio*], green sunfish [*Lepomis cyanellus*], river carpsucker [*Carpiodes carpio*], orangespotted sunfish, channel catfish, fathead minnow [*Pimephales promelas*], and grass carp). Additionally, no gizzard shad or bluegill, prey species, have been recorded during surveys in the last few years. The previous fisheries

Table 4.13.4-1. Fish species detected during sampling at the Recreation Area by TNC (Patrikeev 2004) in 2003 and Wilde (2010) in 2009-2010, as well as those recorded during older surveys in 1983 and 1954-1955 (lists from Munger 2002) in the Canadian River. A list of species occurring in Lake Meredith (Munger 2002) and notes from the NPSpecies list for the park (NPS 2014) are also provided.

		Patrikeev (2004)	Wilde (2010)	Munger (2002)			NPSpecies List (NPS 2014) [2]
		Canadian River & Creeks	Canadian River	Canadian River		Lake Meredith [1]	
Scientific Name	Common Name	2003	2009-2010	1983	1954-1955		Occurrence Notes
Ameiurus melas	Black Bullhead		•		•	•	not in park
Ameiurus natalis [3]	Yellow bullhead		•				NA (not on list)
Carpiodes carpio	River Carpsucker			•		•	prob present
Cyprinella lutrensis	Red Shiner	•	•	•	•	•	present
Cyprinus carpio	European Carp, Common Carp	•	•	•		•	present
Dorosoma cepedianum	Gizzard Shad			•		•	probably present
Fundulus zebrinus	Plains Killifish	•	•	•	•		present
Gambusia affinis	Western Mosquitofish	•	•	•	•		present
Hybognathus placitus	Plains Minnow	•	•	•	•	•	present
Ictalurus punctatus	Channel Catfish	•	•	•	•	•	present
Lepomis cyanellus	Green Sunfish	•	•	•	•	•	present
Lepomis gulosus	Warmouth				•	•	not in park
Lepomis humilis [4]	Orangespotted Sunfish		•			•	unconfirmed
Lepomis macrochirus	Bluegill	•	•	•	•	•	present

Table 4.13.4-1. Fish species detected during sampling at the Recreation Area by TNC (Patrikeev 2004) in 2003 and Wilde (2010) in 2009-2010, as well as those recorded during older surveys in 1983 and 1954-1955 (lists from Munger 2002) in the Canadian River. A list of species occurring in Lake Meredith (Munger 2002) and notes from the NPSpecies list for the park (NPS 2014) are also provided. (cont.)

		Patrikeev (2004)	Wilde (2010)	Munger (2002)			NPSpecies List (NPS 2014) [2]
		Canadian River & Creeks	Canadian River	Canadian River		Lake Meredith [1]	
Scientific Name	Common Name	2003	2009-2010	1983	1954-1955		Occurrence Notes
Lepomis megalotis	Longear Sunfish	•			•	•	present
Lepomis microlophus	Redear Sunfish	•			•		present
Macrhybopsis aestivalus [5]	Speckled Chub			•	•	•	present
Macrhybopsis tetranema [5]	Peppered Chub	•	•				NA (not on list)
Menidia beryllina	Inland Silverside		•			•	unconfirmed
Micropterus salmoides	Largemouth Bass	•			•	•	present
Notemigonus chrysoleucas	Golden Shiner				•	•	not in park
Notropis blennius	River Shiner	•					present
Notropis girardi	Arkansas River Shiner	•	•	•	•	•	present
Notropis stramineus	Sand Shiner				•		not in park
Percina caprodes	Logperch			•		•	unconfirmed
Pimephales promelas [6]	Fathead Minnow	•	•	•	•	•	present
Pimephales vigilax	Bullhead Minnow	•				•	present
Platygobio gracilis	Flathead Chub	•	•		•		present
Pomoxis annularis	White Crappie			•		•	probably present
Pylodictis olivaris	Flathead Catfish	•				•	present
Species reported in the reservoir only							
Ctenopharyngodon idella [6]	Grass Carp					•	NA (not on list)
Ictalurus furcatus	Blue Catfish					•	unconfirmed
Micropterus dolomieu	Smallmouth Bass					•	unconfirmed
Morone chrysops	White Bass					•	unconfirmed
Oncorhynchus mykiss	Rainbow Trout					•	unconfirmed
Perca flavescens	Yellow Perch					•	unconfirmed
Pomoxis nigromaculatus	Black Crappie					•	unconfirmed
Sander vitreus [7]	Walleye					•	unconfirmed

[1] In this column, species with blue dots (as well as others not specified by Munger 2002), are not typically found in the reservoir, but may be in the upper reaches of the reservoir following flooding events (Munger 2002).

[2] Note that about 15 additional species are on the NPSpecies list for the park, but all were indicated as "unconfirmed" occurrence; the species did not appear on other lists, so we did not include them here.

[3] Wilde (2010) recorded one individual in the river but noted the species is most likely to occur in small tributaries to the river.

[4] The species was not reported from Munger (2002), but it was recorded in the lake by Munger and Clayton (2013). Also, Wilde (2010) recorded two individuals in the river but noted the species is most likely to occur in small tributaries to the river.

[5] These entries may be the same fish; Eisenhour (1999) considered *M. tetranema* as a distinct species within the *M. aestivalus* complex. Also, Texas State University (2014) reports that the peppered chub is the only member of the *M. aestivalus* complex to occur in the Canadian River drainage.

[6] The species was not reported in the lake by Munger (2002), but it was recorded in the lake by Munger and Clayton (2013).

[7] The scientific name for this species was formerly *Stizostedion vitreum*.

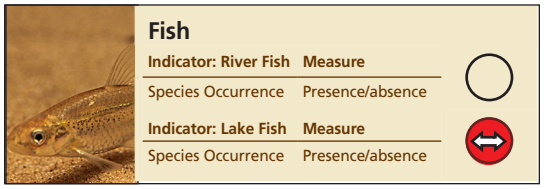
management survey report summarized data from 2010-2011, and although declines in some species had been reported, prey species, walleye, bass (smallmouth, largemouth, and white), crappies, and catfish were all captured during lake sampling at that time (Munger and Clayton 2011).

Lake Meredith water levels have been in decline since 2000 (Munger and Clayton 2013, CRMWA 2014). Water levels had reached a record low (of 2,841.15 feet MSL) on April 8, 2013 (Munger and Clayton 2013). According to data available from U.S. Geological Survey (USGS; USGS 2014), water levels dropped further into July 2013, but then began to increase somewhat through the remainder of 2013 and through June, 2014; the monthly average for June 2014 was 2,849.33 feet MSL. Drought conditions / low water levels have affected the nature of the habitat in the reservoir for fish and increased chloride levels (Munger and Clayton 2013). Chloride levels were measured at over 1,350 ppm in 2012, and one standard method of sampling, electrofishing, could not be used because of the high conductivities (Munger and Clayton 2013). Historic chloride levels have been below about 700 ppm, and current levels (Fall 2014) are about 600 ppm with the recent rise in water level (C. Munger, TPWD, pers. comm.).

Lake Meredith also experienced golden alga blooms in 2010-2011 and 2012 (Munger and Clayton 2013). Golden alga (*Prymnesium parvum*) is a naturally occurring alga, but it may lead to massive fish and bivalve kills under certain environmental conditions (TPWD 2014d). The alga is typically found in estuarine waters, and it may be found in freshwaters with a relatively high salt concent. In Texas, documentation of fish kills from the alga date back to 1985. According to Munger and Clayton (2013), on Lake Meredith, "the blooms appear to have eliminated all major sport species except channel catfish." Annual blooms of the alga have occurred since the report was released, and they will probably continue to occur until lake salinity levels decrease (C. Munger, TPWD, pers. comm.). TPWD conducts quarterly monitoring at Lake Meredith for golden alga.

One of the management strategies included in Munger and Clayton (2013) is to "consider restocking forage and sport species if reservoir conditions improve." Sport fish recovery will depend on restocking. There are many variables that would affect a decision to restock fish, but as long as golden alga blooms and the fish kills they can cause are an annual event, TPWD will not restock fish (C. Munger, TPWD, pers. comm.). TPWD continues to monitor sport fish populations and golden alga blooms at Lake Meredith (Munger and Clayton 2013).

Because of the decrease in the number of species present and the condition of the lake for fish, the current conditon of fish species in Lake Meredith is of significant concern.



Overall Condition and Trend

Because we were able to determine condition for fish in Lake Meredith but not in the Canadian River within the Recreation Area, we did not attempt to combine the indicators for an overall condition rating of fish at the Recreation Area. Instead, we report condition separately for these two components of the fish resource.

One federally-/state-threatend fish species has been recorded at the Recreation Area, the Arkansas River shiner, and one SGCN in Texas has been recorded, the peppered chub. Both species are known to occur primarily in the Canadian River. Eighteen species of fish, including these two species, were recorded by TNC sampling in the Canadian River and associated creeks in 2003. Most of the species had been recorded in the Recreation Area in the river previously. The 2009-2010 sampling by Wilde (2010), which was conducted around and upstream of Chicken Creek only (i.e., within the Rosita area) documented 16 species. Many of the same species were recorded by Wilde (2010) and Patrikeev (2004), but there were some differences. The Arkansas River shiner was found in

much greater numbers during the 2009-2010 sampling than in the 2003 sampling. Wilde (2010) found a greater proportion of the seine hauls contained Arkansas River shiner as his sites moved upstream from Chicken Creek. Based on the species recorded, the fish community in the Canadian River within the Recreation Area was similar in composition to areas of the river upstream (Wilde 2010).

Because no fish sampling/monitoring has been conducted in the Recreation Area in the river since the 2010 work (which was in the Rosita area only), current condition and trends of fish in the river/creeks is currently unknown. See Table 4.13.4-2 for the indicator and condition summary.

However, recent and current information is available to assess the condition of fish in Lake Meredith. At least 29 fish species have been recorded in the lake. In 2011-2012, prey species (gizzard shad and bluegill), as well as many species of sport fish (e.g., walleye, smallmouth and largemouth bass, white bass, and black and white crappies) were recorded (Munger and Clayton 2011). In the next sampling period (2012-2013), none of the sport fish were documented, except for channel catfish (Munger and Clayton 2013), which appeared to be in decline. Only six other fish species (non-sport; mentioned previously) were documented. Using the species occurrence-presence/absence indicator/measure, the current condition of fish in Lake Meredith is of significant concern. Based on the fisheries management survey reports of the TPWD, the trend had been decreasing over the last few years, at least until the summer of 2013. As there are now no sport species remaining

Table 4.13.4-2. Indicator and measures of fish condition.

Indicator of Condition	Measure	Condition	Rationale for Condition.
Species Occurrence	Presence/absence of fish in Canadian River	Insufficient Data	In 2003, 18 species of fish were documented in the Canadian River and associated creeks, including the threatened Arkansas River shiner. Most of these fish had been recorded previously according to TPWD information (Munger 2002). Approximately eight species were recorded in Canadian River surveys in 1983 and/or 1954-55 that were not observed in 2003. In 2009-2010, 16 species were documented in the river from nine sampling sites (eight of which were in the Recreation Area, starting at Chicken Creek and moving upstream). Most of these 16 species were also recorded in 2003, and all but two had been recorded in the Canadian River previously. The Arkansas River shiner and peppered chub were found in much higher numbers in the 2009-2010 sampling compared to 2003 sampling. More than 1,300 Arkansas River shiner and more than 700 peppered chub were recorded by Wilde (2010), accounting for 31.4% and 16.6% of his catch, respectively. Because no sampling has been conducted since 2010, the presence/absence of fish in the river, and hence current condition, is unknown.
Species Occurrence	Presence/absence of fish in Lake Meredith	Significant Concern	Approximately 30 species of fish have been recorded in Lake Meredith. Fish are sampled on the lake on a regular basis by TPWD. The number of species documented during sampling in 2010-2011 (12) dropped to 7 in 2012-2013. The number of sport fish documented during sampling decreased from 6 species in 2010-2011 to 1 in 2012-2013. Additionally, two important prey species (gizzard shad and bluegill) that were recorded in 2010-2011 were not recorded in 2012-2013. The condition of fish species based on presence/absence of fish species in the lake is of significant concern. Based on TPWD sampling, the condition of fish species in the lake had been declining, at least until the summer of 2013. Water levels have been dropping since around 2000. In the last few years, water levels reached their lowest since the creation of the reservoir, and chloride and salinity levels have increased. In the past year (up to Fall 2014), water levels have increased somewhat and chloride levels have decreased. Golden alga blooms have occurred annually since 2010 at a level significant enough to kill fish. Because only one sport fish species remained in the lake as of summer 2013, the trend in sport fish occurrence had bottomed out and appears to be no longer declining. At the present time, the status appears to be neither increasing or decreasing, but condition is of significant concern.

except for channel catfish, the decline in sport fish species has reached a bottom level and cannot decline further. Based on the available information, we assigned a trend of unchanging at this time.

4.13.5. Sources of Expertise

This section is based on the 2003 fish surveys at the Recreation Area (in the Canadian River and associated creeks) conducted by TNC (Patrikeev 2004), the 2009-2010 surveys for the Arkansas River shiner in the Rosita area of the Canadian River (Wilde 2010), and information from the TPWD on fish in the lake (Munger 2002, and Munger and Clayton 2013). We also contacted Charles Munger, District Fisheries Biologist with TPWD, to obtain additional details on the current status of the lake and its sport fish resources. Mr. Munger also reviewed a draft of this section and provided comments.

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Monitoring data are used to determine resource conditions that are reported in NRCAs.

Chapter 5: Discussion of Natural Resource Condition Assessment Findings and Considerations for Park Planning

5.1. Introduction

The primary purpose of the Natural Resource Condition Assessment (NRCA) Chapter 5 is to provide a "big picture" - broader application of resource condition findings (Albright 2010). We will fulfill this purpose by:

- creating a framework that connects the natural resource findings to Lake Meredith NRA and Alibates Flint Quarries NM purpose, significance, and fundamental resource and value statements
- delivering completed State of the Park natural resource condition summary tables and resource briefs for each of the topics assessed; and
- highlighting potential management and project considerations, if applicable.

These Chapter 5 reporting pieces are *value added* products that can be used by park managers for a variety of resource planning and comprehensive park management purposes (Jeff Albright, NRCA Program Coordinator, pers. comm. August 23, 2013). Additionally, efficiencies are gained by providing these "ready to use products" because they deliver information to park staff that directly meet other reporting requirements, such as those for the *State of the Park* report, or they provide information that can be easily modified as needed (re: resource narratives) to be used for PMIS proposals as background information and problem statements, for other funding proposals, priority setting, or for interpretive purposes.

5.2. Connecting Natural Resource Condition Assessment Findings to Park Purpose, Significance, and Fundamental Resources & Values

Managing the natural resources at the NRA and NM is inextricably tied to their purpose, significance and fundamental resources and values (FRVs). It is most often within this interdisciplinary perspective that managers consider potential actions and alternatives when addressing resource issues or needs. As such, we have created a table (Table 5.2-1) where natural resource topic relevance is presented within a framework of both park's purpose, significance, and FRVs statements (NPS 2013). This provides a "snapshot" look

Table 5.2-1. Summary of natural resource topic relevance (denoted by black dots) as it relates to Lake Meredith National Recreation Area and Alibates Flint Quarries's purpose, significance, and fundamental resources and values as identified in NPS (2013).

Natural Resource Condition Assessment Topics	Viewshed	Night Sky	Soundscape	Air Quality	Geology	Water Quality	Groundwater	Riparian Habitat	Grassland	Exotic Plants	Landbird	Herpetofauna	Fish
Ia. Park Purpose - Lake Meredith NRA													
Provide public access to land- and waterbased recreational opportunities in the Canadian River breaks of the Texas panhandle.						•							•
Ib. Park Purpose - Alibates Flint Quarries NM													
Provide for the preservation, protection, interpretation, and scientific study of Alibates flint deposits associated with the activities and cultural resources of the indigenous peoples for the benefit of all.					•								
IIa. Park Significance - Lake Meredith NRA													
Lake Meredith NRA is the largest area of public lands in the Texas panhandle.													
Lake Meredith and the Canadian River basin feature aquatic, wetland, and riparian habitats, and provide habitat for diverse plant and animal species.								•			•	•	•
The natural and geologic resources of the national recreation area have enabled human survival, subsistence, and adaptation in the Texas panhandle for more than 13,000 years.					•								
Geologic features of the Canadian River breaks reveal active geologic processes that are easily visible to an extent not present elsewhere in the region.					•								
IIb. Park Significance - Alibates Flint Quarries NM													
The national monument contains part of the only known exposed bedrock source of Alibates flint, and the flint is present in the national monument in high concentrations.					•								
The physical characteristics of the Alibates flint made it highly desirable for tool-making. And its distinctive color pattern makes it identifiable, so the movement of the flint can be documented.					•								
The national monument contains evidence of more than 13,000 years of lithic resource detection, extraction, manipulation, and use.													
An unusually high number and variety of artifacts representing the entire spectrum of flint extraction and manufacturing have been recovered from the national monument.													
The Plains Village archeological sites in the national monument include the only protected, and best remaining, type-site for the Antelope Creek people, who occupied the area between AD 1150 and 1450.													

Table 5.2-1. Summary of natural resource topic relevance (denoted by black dots) as it relates to Lake Meredith National Recreation Area and Alibates Flint Quarries's purpose, significance, and fundamental resources and values as identified in NPS (2013) (continued).

Natural Resource Condition Assessment Topics	Viewshed	Night Sky	Soundscape	Air Quality	Geology	Water Quality	Groundwater	Riparian Habitat	Grassland	Exotic Plants	Landbird	Herpetofauna	Fish
Alibates Flint Quarries National Monument, together with Lake Meredith National Recreation Area, manages 623,000 collected objects associated with the area													
The national monument was listed in the National Register of Historic Places on October 15, 1966													
IIIa. Fundamental Resources and Values - Lake Meredith NRA													
Public Land.													
Recreation Opportunities						•							•
Exposed Geological Features of the Canadian River Breaks.					•								
Diverse Habitats and Ecological Transition Zones.								•	•				
Wide Range of Sites and Artifacts.													
IIIb. Fundamental Resources and Values - Alibates Flint Quarries NM													
Alibates Flint					•								
Alibates Ruin Archeological Site													
Quarries					•								
Museum Collection													

Literature Cited: National Park Service. 2013. Lake Meredith NRA and Alibates Flint Quarries NM Draft General Management Plan/Environmental Impact Statement. 319pp.

at how each natural resource ties into the parks' primary reasons for establishment.

The resource condition highlights for each resource topic, if applicable, will be presented in the *State of the Park* resource brief (section 5.3). Condition findings relative to potential resource issues/data gaps, opportunities and management considerations will be presented in the resource narratives section 5.4.

5.3. State of the Park Reporting

As part of the stewardship of national parks for the American people, the NPS has begun to develop *State of the Park* reports to assess the overall status of each park's resources. The NPS will use the *State of the Park* report information to improve park priority setting and to synthesize and communicate complex park condition information to the public in a clear and simple way (NPS 2011a,b).

The key purposes of each *State of the Park* report are to:

- Provide to visitors and the American public a snapshot of the status and trend in the condition of a park's priority resources and values.
- Summarize and communicate complex scientific, scholarly, and park operations factual information and expert opinion using non-technical language and a visual format.
- Highlight park stewardship activities and accomplishments to maintain or improve the *State of the Park*.
- Identify key issues and challenges facing the park to help inform park management planning.

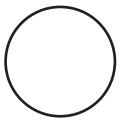
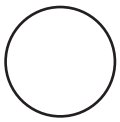
We integrate resource condition findings from the NRCA into the required format for the

parks' *State of the Park* reports. This includes an overall natural resource summary table showing the resource topic conditions and rationale for ratings. A summary of the Status and Trend symbols for condition ratings can be found in Chapter 3, Table 3.2.3-1. We then present each natural resource topic individually, including all indicators and/or measures by which resource topics were assessed. Finally, a resource brief summarizing the condition rationale, will follow the condition table and include any significant resource highlights.

Table 5.3-1 *State of the Park* Natural Resource Summary Table

Priority Resource or Value	Condition Status/Trend	Summary of Overall Condition Rating
Natural Resources		
Viewshed		Viewshed condition is assessed based on scenic and historic integrity. The measures of integrity include intactness of view (that is, how much the viewshed has been altered from its reference state) and the conspicuousness of noncontributing factors (that is, how obvious the features are that are inconsistent with the scenic and historic integrity of the site).The viewshed at Lake Meredith NRA and Alibates Flint Quarries NM is in good condition, with a medium level of confidence. Insufficient data are available to determine trend.
Night Sky		Two indicators were used to assess the condition of night sky: sky brightness (measured by anthropogenic light ratio and zenith sky brightness) and sky quality (measured using the Bortle dark-sky scale). The overall condition of the park's night sky is moderate, with a medium level of confidence. Insufficient data are available to determine trend.
Soundscape		We used two indicators and three measures to assess soundscape condition. The percent time audibility of noises was moderate to significant concern and the sound level condition varied between the on-site monitoring, which was considered good, versus the national sound model, which was of moderate to significant concern. Overall, the soundscape condition is of moderate concern.
Air Quality		The air quality assessment included visibility, ozone, and wet deposition for total nitrogen and total sulfur. Three of the four air quality condition indicator values warranted moderate concern. Only wet deposition of nitrogen was considered to be within a level to warrant significant concern. The overall condition rating for air quality was moderate.
Geology		We used one indicator, geologic resource integrity, to assess the condition of the geologic resources. Level of integrity (condition) is based on the extent of management issues or concerns evident in the park, and whether or not geologic resources and processes are within a natural range of state and function. The condition of the geologic resources at Lake Meredith NRA/Alibates Flint Quarries NM is in moderate condition, with a low level of confidence. Insufficient data are available to determine trend.
Surface Water		The Canadian River Municipal Water Authority monitors water quality at Lake Meredith. Four indicators and 17 measures were used to assess the lake's condition. Using water quality standards developed by Texas Commission on Environmental Quality Control Commission and the EPA, the overall condition of water quality in Lake Meredith was of significant concern.
Groundwater		Based upon our review of the apparent groundwater condition relative to the ecological reference condition for the riparian vegetation, we are uncertain about the condition of this resource without more in depth analysis, therefore, the condition is unknown. The overall trend for the High Plains Aquifer is decreasing, which could impact the availability of groundwater within the alluvial aquifer in the future.
Riparian Habitat		Both the Canadian River and Blue Creek riparian resources including hydrology, vegetation, and erosion/deposition characteristics were assessed. The Canadian River was divided into three reaches and condition ratings were significant concern, moderate, and good. The Blue Creek assessment included two reaches and both were of significant concern. The overall condition rating is for riparian habitat is of significant concern.

Table 5.3-1 State of the Park Natural Resource Summary Table (continued)

Priority Resource or Value	Condition Status/Trend	Summary of Overall Condition Rating
Grasslands		Grasslands at Lake Meredith NRA and Alibates Flint Quarries NM are within the ecoregion generally characterized by arid grasslands and the presence of open stands of mesquite among the grasses. The grasses themselves are largely native species, but historic land uses and drought have all contributed to moderate concerns about the condition. However, park staff have been actively engaged in restoration and exotic plant removal efforts, and the resulting outlook is for continued improvement.
Exotic Plants		We used two indicators, potential to alter native plant communities and prevalence of exotic plants, to assess the condition of exotic plants at the park. The condition for the significance of exotic plant impact measure was of significant concern. Two of the measures for prevalence of exotic plants, extent and distribution, were of significant concern, and the third, density, was of moderate concern. Overall, the condition of exotic plants is of significant concern. The trend appears to be stable although the presence of some species increased dramatically, the overall number of exotic species is lower.
Breeding Landbirds		We used one indicator, species occurrence (presence/absence), in three separate contexts (or measures; temporal, spatial, and conservation), to assess the condition of breeding landbirds at the Recreation Area. For each measure, we found the current condition of breeding landbirds to be good. We do not have sufficient data to justify a trend in the condition at this time.
Herpetofauna		We used one indicator/measure, species occurrence (presence/absence), to assess the condition of amphibians and reptiles at the Recreation Area/National Monument. Although a substantial survey effort was conducted in 2002-2003 by The Nature Conservancy at the parks, we were unable to assess current condition because there is no current information available. The 2002-2003 work provides baseline information for future monitoring and condition assessment.
River Fish		We used one indicator/measure, species occurrence (presence/absence), to assess the condition of fish in the Canadian River at the Recreation Area/National Monument, and one indicator/measure, species occurrence (presence/absence), to assess the condition of fish in Lake Meredith. Although two survey efforts have been conducted for fish in the Canadian River within the Recreation Area (in 2003 and 2009-2010), we were unable to assess current condition because no current information is available. The condition of fish in the lake, however, was determined to be of significant concern because of the decrease in the number of sport and non-sport fish species since 2010-2011. Lake conditions over the last several years have included low lake levels, high chloride levels, and blooms of golden alga.
Lake Fish		

5.4. Viewshed Resource Brief

The contents of sub-chapter 5.4 were designed to be placed into a stand-alone Vewshed resource brief at a later date. The final resource brief will follow NPS Graphic Identity Program (http://www.nps.gov/hfc/services/identity/) format and layout policy standards, and include the contact information of at least one NPS employee as a point contact for the public.

5.4.1. Condition Rationale

Viewsheds are considered an important part of visitor experience. Inherent in virtually every aspect of this assessment is how features on the visible landscape influence the enjoyment, appreciation, and understanding of the NRA and NM by visitors. The indicators we use for condition of the viewshed are based on studies related to perceptions people hold toward various features and attributes of the viewsheds. We also focus on how the historic integrity of the viewshed enhances the opportunity for visitors to better understand the historical significance at Alibates Flint Quarries NM.

From a cultural and historical perspective, the views are not just about the scenery, but an important way to better understand the connection between natural and cultural resources at Alibates Flint Quarries NM. Visualizing this connection as part of the landscape is a critical part of the visitor experience.

Based on this assessment, we considered the viewshed at Lake Meredith NRA and Alibates Flint Quarries NM to be in good condition, with a medium level of confidence. Non-contributing features were relatively few and inconspicuous leaving the site primarily intact from a scenic standpoint, which also allows the visitor to imagine the landscape from an historic point of view at Alibates Flint Quarries NM.

Four vantage sites were considered in this assessment. In the western view from Alibates there are some buildings in the middle ground, but their size and coloring makes them inconspicuous. The road seen in the southern view is also made inconspicuous because it is contoured and curves with the landscape. Relatively inconspicuous, unpaved roads are also seen from the McBride Canyon views. The views from Harbor Bay East are probably the most altered due to the number of homes and power poles seen in the middle ground of the northern and eastern views. In the case of the northern view, the visitor's eye is likely drawn away from the homes and toward the view of the lake. The road visible from the Fritch Fortress vantage point is more conspicuous because it is in the foreground and paved; however, since it is contoured around

Table 5.4.2-1. Summary of overall viewshed condition, indicators and measures, and rationale for assigning condition assessment at Lake Meredith NRA and Alibates Flint Quarries NM.

Viewshed			
Indicators of Condition	Specific Measures	Condition Status/Trend	Rationale
Scenic and Historic Integrity	Intactness of View		Views are mainly intact with few non-contributing features, consistent with good condition.
	Conspicuousness of non-contributing features		Non-contributing features are relatively inconspicuous; consistent with good condition conditions

the lake and does not have poles or other obstructions associated with it, it is still relatively inconspicuous. Although there are insufficient data to assess trend, housing and road density indicate there are some areas of the park that are highly developed (for example, the town of Fritch), and other areas that are less developed and are likely to maintain high-quality views.

5.4.2. Management and Project Considerations

The biggest concern for the viewshed is the growing number of wind turbines in the area. In the past decade the area has gone from zero to thousands of turbines. Each new group is a little closer to being in the park's viewshed. They are particularly noticeable with the blinking red lights at night.

5.5. Night Sky Resource Brief

The contents of sub-chapter 5.5 were designed to be placed into a stand-alone Night Sky resource brief at a later date. The final resource brief will follow NPS Graphic Identity Program (http://www.nps.gov/hfc/services/identity/) format and layout policy standards, and include the contact information of at least one NPS employee as a point contact for the public.

5.5.1. Condition Rationale

Natural dark skies are a valued resource within the NPS, reflected in NPS management policies that highlight the importance of a natural photic environment to ecosystem function, and the importance of the natural lightscape for aesthetics. The value of night skies goes far beyond visitor experience and scenery. The photic environment affects a broad range of species, is integral to ecosystems, and is a natural physical process. Natural light intensity varies during the daynight (diurnal) cycle, the lunar cycle, and the seasonal cycle. Organisms have evolved to respond to these periodic changes in light levels in ways that control or modulate movement, feeding, mating, emergence, seasonal breeding, migration, hibernation, and dormancy. Plants also respond to light levels by flowering, vegetative growth, and their direction of growth

Lake Meredith National Recreation Area (NRA) and Alibates Flint Quarries National Monument (NM) is enjoyed by visitors for the recreation opportunities provided by the lake, the canyons and trails, and geological and historical features. Protecting the park's night sky resources benefits the natural resources and is important for visitor experience.

The overall condition of the park's night sky is moderate, based on the more reliable ALR reading and the significant influence from nearby light domes. The Milky Way was partly visible, but not complete or well defined. Light domes from nearby cities were clearly visible.

5.5.2. Management and Project Considerations

Although little can be done to minimize the impact of nearby city lights creating light domes and local point sources adding to the light pollution, the park can improve local infrastructure around boat ramps, kiosks, and campgrounds to encourage dark night skies.

Table 5.5.1-1. Summary of overall night sky condition, indicators and measures, and rationale for assigning condition assessment at Lake Meredith NRA and Alibates Flint Quarries NM.

Night Sky			
Indicators of Condition	Specific Measures	Condition Status/ Trend	Rationale
Sky Brightness	Anthropogenic Light Ratio (1.09, 1.02)		This measure results from modeled data from the NPS Night Sky Program. Specific thresholds for condition classes have been set by the NPS. In this case, the moderate condition results from the significant light domes of nearby cities. The confidence level in this assessment is medium.
	Zenith Sky Brightness (21.08)		Zenith sky brightness indicates significant concern, based on the impact from light domes from nearby cities and point sources of light. Confidence level is medium.
Sky Quality	Bortle Scale Class (4)		The Milky Way was partly visible, but not complete or well defined. Light domes from nearby cities were clearly visible. Because this measure is qualitative, it has a low confidence level.

The increasing number of blinking red lights related to the wind farms will detract from the parks' Class 2 night sky. Within the parks, light is directed toward the targeted area not at a 360- degree array to minimize light pollution.

5.6. Soundscape Resource Brief

The contents of sub-chapter 5.6 were designed to be placed into a stand-alone Soundscape resource brief at a later date. The final resource brief will follow NPS Graphic Identity Program (http://www.nps.gov/hfc/services/identity/) format and layout policy standards, and include the contact information of at least one NPS employee as a point contact for the public.

5.6.1. Condition Rationale

Soundscape condition was assessed at four locations using audibility and sound levels as measures of condition. The percent time audibility of noise from the surrounding energy production operations was nearly constant at Alibates Flint Quarries NM and McBride Ranch, which are located at the more remote sites throughout the park. While the sound levels of noises heard were relatively low and considered to be in good condition, the sound levels modeled by Mennitt et al. (2013) suggest a moderate to significant concern soundscape condition for the parks. When combining all three condition measures, we consider the soundscape to be in moderate condition.

5.6.2. Management and Project Considerations

Sounds generated from the oil and gas industry are being taken into consideration in the Plan of Operation for operations taking place with the park boundaries. The ever present winds in the Texas Panhandle do help dissipate noise, and with mitigation the sounds are noticeable on still days.

Table 5.6.2-1. Summary of overall soundscape condition, indicators and measures, and rationale for assigning condition assessment at Lake Meredith NRA and Alibates Flint Quarries NM.

Soundscape			
Indicators of Condition	Specific Measures	Condition Status/Trend	Rationale
Audibility	% Time Audible		The sounds heard with the highest percent time audibility were from the energy production operations surrounding Alibates Flint Quarries NM and McBride Ranch and from automobiles at Fritch Fortress. Many natural sounds were audible a high percentage of the time at all monitoring locations, but the near constant energy production noises heard at the NM warrant a moderate to significant concern condition for this measure.
Sound Level	Amplitude (on-site monitoring)		The loudest sounds heard were at Fritch Fortress due to motorcycles, automobiles, and fire clean-up efforts adjacent to the fortress. The vehicle activity is expected for the Fritch Fortress area since it is located in the developed zone. Even though the energy production noises were audible over 99% of the time at the NM, the sound level was very low and distant. Overall, we consider this measure to be in good condition relative to the sound levels heard during the on-site monitoring
	Amplitude (modeled sound level impact)		The modeled impact sound levels (Mennitt et al. 2013) for the NRA ranged between 2.4 - 6.1 dBA and from 2.9 - 4.0 dBA for the NM. These results are considered to be of moderate to significant concern for non-urban parks (Turina et al. 2013).

5.7. Air Quality Resource Brief

The contents of sub-chapter 5.7 were designed to be placed into a stand-alone Air Quality resource brief at a later date. The final resource brief will follow NPS Graphic Identity Program (http://www.nps.gov/hfc/services/identity/) format and layout policy standards, and include the contact information of at least one NPS employee as a point contact for the public.

5.7.1. Condition Rationale

We used four measures to assess air quality condition including ozone levels, visibility, and wet deposition of sulfur and nitrogen. Currently, all air quality indicators and measures are in moderate condition except for wet deposition of nitrogen, which is of significant concern. Between the two parks, five ozone-sensitive plant species, one of which -*Artemisia ludoviciana*- is a bioindicator. No trends are reported for any of the measures since no monitoring station is within the required distance from the parks. Like most airsheds, the parks air quality is largely influenced by activities and operations that occur outside its boundaries and the future of its air quality condition is ultimately dependent on local, regional, and national planning.

5.7.2. Management and Project Considerations

Air quality hasn't been a topic of concern for the parks to date. The consistent winds keep any pollution moving. Dust and smoke can be issues due to short term, local events. The incresing sizes of the Agrium and Phillips plants may alter the air quality once they are both up to full production. There has been an increase in humidity with the enlargement of the Agrium plant releasing so much steam from its production process.

Table 5.7.1-1. Summary of overall air quality condition, indicators and measures, and rationale for assigning condition assessment at Lake Meredith NRA and Alibates Flint Quarries NM.

Air Quality			
Indicators of Condition	Specific Measures	Condition Status/Trend	Rationale
Visibility	Haze Index		For 2008-2012, estimated average visibility in the NRA was 7.6 deciviews above natural conditions, therefore, the condition status warrants significant concern based on NPS Air Resource Division benchmarks. No trend information is available because there are not sufficient on-site or nearby visibility monitor stations.
Level of Ozone	Annual 4th-Highest 8-hour Concentration		The estimated ozone level for 2008-2012 at the Historic Site was 70.0 parts per billion, therefore, the condition status warrants moderate concern based on NPS Air Resource Division benchmarks. There are five ozone-sensitive plants in the NRA and one in the NM, with one as a bioindicator. No trend information is available because there are not sufficient on-site or nearby ozone monitor stations.
Atmospheric Wet Deposition in Total N and total S	Total N in kg/ha/yr		For 2008-2012, estimated wet nitrogen deposition was 3.7 kilograms per hectare per year, therefore, the condition status warrants significant concern based on NPS Air Resource Division benchmarks. No NPS-ARD trend information is available for nitrogen.
	Total S in kg/ha/yr		For 2008-2012, estimated wet sulfur deposition was 1.5 kilograms per hectare per year, therefore, the resource is in moderate condition based on NPS Air Resource Division benchmarks. No NPS-ARD trend information is available for sulfur.

5.8. Geology Resource Brief

The contents of sub-chapter 5.8 were designed to be placed into a stand-alone Geology resource brief at a later date. The final resource brief will follow NPS Graphic Identity Program (http://www.nps.gov/hfc/services/identity/) format and layout policy standards, and include the contact information of at least one NPS employee as a point contact for the public.

5.8.1. Noteworthy Highlights

Alibates Flint Quarries NM was established in 1965 to protect the prehistoric quarries of flint, prized for both its excellent tool-making properties and its beauty.

Distinctive geologic features of Lake Meredith NRA and this area of the Texas panhandle are the Permian red beds exposed in the "breaks" of the Canadian River. The breaks were formed when the Canadian River cut through the "caprock" and the underlying Triassic strata into the Permian beds below. The caprock is a widespread layer of caliche (erosion-resistant, calcium-carbonate rock) that marks the top of the Tertiary Ogallala Formation in Texas and New Mexico. The Ogallala Formation, which underlies much of the Great Plains, makes up the land surface above the breaks. The Ogallala Formation has particular significance for the area because it contains the Ogallala aquifer—the major source of water for agricultural and domestic use on the Southern High Plains of Texas and New Mexico. Notably, the Ogallala Formation also yields fossils.

5.8.2. Condition Rationale

Geologic resources serve as the foundation of ecosystems and yield important information needed for science-based decision making in National Park System units. Geology is a major determinant of topography, water and soil chemistry, fertility of soils, stability of hill slopes, and flow styles of surface water and groundwater. These factors, in turn, influence biology, including the distribution of habitats and the locations of threatened and endangered species. Geology also influences human settlement patterns and how people use natural resources—for farming, ranching, industry, construction, hunting, fishing, and recreation.

The condition of the geologic resources at Lake Meredith NRA/Alibates Flint Quarries NM is in moderate condition due to several concerns, with a low level of confidence (a geologic resource inventory scoping summary was completed in 2011). The main issues impacting

Table 5.8.1-1. Summary of overall geology condition, indicators and measures, and rationale for assigning condition assessment at Lake Meredith NRA and Alibates Flint Quarries NM.

Geology			
Indicators of Condition	Specific Measures	Condition Status/Trend	Rationale
Geologic Integrity	None		The main issues impacting geologic resources at Lake Meredith NRA include natural erosion processes due to wind and water; lands disturbed by off-road vehicle recreation; and energy development (primarily oil and gas) near its borders. Alibates flint is a critical resource at Alibates Flint Quarries NM, and is impacted by the potential for theft, and sediment transport (due to wind erosion) that is filling in the quarry sites. A geologic resource inventory scoping summary was completed in 2011.

geologic resources include natural erosion processes due to wind and water; lands disturbed by off-road vehicle recreation; and energy development (primarily oil and gas) near its borders. Alibates flint is a critical resource at Alibates Flint Quarries NM, and is impacted by the potential for theft, and sediment transport (due to wind erosion) that is filling in the quarry sites.

5.8.3. Management and Project Considerations

The major geologic issue that the park has some influence over is erosion control. Managing runoff waters is considered during the planning process for all projects.

Geologic issues that may warrant attention from resource managers include:

- Natural erosion processes due to wind and water. Oil and gas access roads, especially unmaintained ones on steep slopes, can cause severe erosion. Many of the access roads to oil and gas pads are unsurfaced, not adequately sloped, and lack drainage structures such as culverts and ditches. During rainstorms, the roads serve as spillways for flowing water, cutting gullies into the road surface and adjacent slopes. Receding lake levels are exposing large, formerly submerged areas of lake bed to eolian processes; this is particularly apparent in the Big Blue Creek area. In addition, oil and gas activities can denude vegetation and expose the ground surface to wind erosion. On some pads, oil and gas operators have placed mats to reduce the amount of material available for eolian transport. Windblown dust is filling in the historic quarries at an estimated rate of 23 cm (9 in) in the last 500 years.
- Disturbed land. Off-road vehicles are allowed in two areas within Lake Meredith NRA: Big Blue Creek, covering 79 ha (194 ac); and Rosita, covering 980 ha (2,421 ac). Recreationists may use motorcycles, three- and four-wheelers, and dune buggies (NPS 2002). Some restoration efforts are occurring at Big Blue Creek, namely minimizing and closing unauthorized trails.
- Protection of flint quarries. Alibates flint is a critical resource at Alibates Flint Quarries NM, and is impacted by the potential for theft, and sediment transport (due to wind erosion) that is filling in the quarry sites. The distinctive appearance of the flint makes it readily identifiable to archeologists at sites all over the country. With the advent of Google Earth, the locations of protected sites of Alibates flint are accessible for public viewing. The primary concern is theft. Park staff are particularly vigilant after fires, when the quarries really "stand out" with the lack of protective vegetation.
- Oil and gas exploration and development impacts. Lake Meredith NRA and Alibates Flint Quarries NM lie within the enormous oil and gas–producing Panhandle Field, which extends into Oklahoma and Kansas. Oil and gas exploration and development have been actively pursued at Lake Meredith and Alibates Flint Quarries since the late 1920s. Today, there are more than 170 active well sites in Lake Meredith and Alibates Flint Quarries.

5.9. Surface Water Resource Brief

The contents of sub-chapter 5.9 were designed to be placed into a stand-alone Surface Water resource brief at a later date. The final resource brief will follow NPS Graphic Identity Program (http://www.nps.gov/hfc/services/identity/) format and layout policy standards, and include the contact information of at least one NPS employee as a point contact for the public.

5.9.1. Condition Rationale

Lake Meredith's surface water quality is monitored by the Canadian River Municipal Water Authority. A total of 17 parameters are regularly measured for water quality condition. Three of these parameters, chloride, sulfate, total dissolved solids are impaired and listed on the State of Texas' 303(d) impairment list. As a result, the water quality condition at Lake Meredith is of significant concern.

5.9.2. Management and Project Considerations

Park has no control over surface water. We do have a concern that when water chemistry becomes conducive for the reintroduction of game fish, the increased boating traffic will eventually introduce zebra and quahog mussels.

Table 5.9.1-1. Summary of overall surface water quality condition, indicators and measures, and rationale for assigning condition assessment at Lake Meredith National Recreation Area.

Surface Water			
Indicators of Condition	Specific Measures	Condition Status/Trend	Rationale
Field Properties	4 Measures		With a few exceptions, most of the field properties were within state standards, however, the specific conductance levels ranged between 2,398 - 7,770 micro Siemens/cm. While no water quality standard exists for specific conductance, damage to agricultural crops has been shown to occur when specific conductance is between 950-1200 micro Siemens/cm (USGS 1987). Because of the very high specific conductance results, we consider this measure to be of significant concern.
Alkalinity	2 Measures		The alkalinity results were within the expected range of values, although represent some of the highest concentrations throughout the country (USGS 2013).
Primary Nutrients	9 Measures		Based on TCEQ's (2012) 303(d) list for chloride, sulfate, and total dissolved solids impairments in Lake Meredith, this indicator was considered to be of significant concern.
Major Constituents	2 Measures		Both nitrate and phosphate levels were low, often with phosphate not being detected. This indicator was considered to be in good condition.

5.10. Groundwater Resource Brief

The contents of sub-chapter 5.10 were designed to be placed into a stand-alone Groundwater resource brief at a later date. The final resource brief will follow NPS Graphic Identity Program (http://www.nps.gov/hfc/services/identity/) format and layout policy standards, and include the contact information of at least one NPS employee as a point contact for the public.

5.10.1. Condition Rationale

Overuse of the groundwater resources in this area have been a concern for many years. Numerous studies of the High Plains Aquifer have determined that this resource is being "mined", which means that the water is being pumped at a much faster rate than it is being recharged. Continued large-scale withdrawals of water from the Ogallala Formation will result in further decline of the water table. As the water level continues to decline, the zone of saturation will become progressively thinner and the yields of the wells will decrease (Cronin 1961). Ultimately, this trend could affect park wells that draw water from the High Plains Aquifer. While riparian resources could be affected somewhat from overuse of the High Plains Aquifer, the greatest threat to that system is probably prolonged drought.

While it appears that the water table fluctuates quite a bit from year to year, we don't know exactly how much of a drop affects the wetland riparian vegetation. During the June 2014 riparian assessment, conducted by NPS Water Resources Division and the Southern Plains Inventory and Monitoring Network, scientists noted that some cottonwoods appeared stressed but were uncertain whether it was from recent overspray of herbicide application to Tamarisk or due to water stress from a low water table (T. Folts-Zettner, SOPN Biologist, pers. comm). Additionally, scientists noted during their May 2014 riparian habitat assessment in the NRA that for the most part, the riparian vegetation overall looked good, with the exception of a few cottonwoods (M. Martin, NPS WRD Hydrologist, pers. comm.). Without a detailed study of the alluvial aquifer, specifically examining the depth-duration below ground (root zone) during the growing season, it's difficult to determine anything directly about resource support and condition of the groundwater resource.

5.10.2. Management and Project Considerations

The park practices water conservation and tries to explain to visitors the importance of water conservation in preserving the groundwater resources in the area.

Table 5.10.1-1. Summary of overall groundwater condition, indicators and measures, and rationale for assigning condition assessment at Lake Meredith National Recreation Area.

Groundwater			
Indicators of Condition	Specific Measures	Condition Status/Trend	Rationale for Resource Condition
Groundwater Elevation	Change in Groundwater Elevation		The alluvial aquifer and riparian vegetation are interconnected, and while it appears that the water table fluctuates quite a bit from year to year, we don't know exactly how much of a drop affects the wetland riparian vegetation. Without a detailed study of the alluvial aquifer, specifically examining the depth-duration below ground (root zone) during the growing season, it's difficult to determine anything directly about resource support and condition.

5.11. Riparian Habitat Resource Brief

The contents of sub-chapter 5.11 were designed to be placed into a stand-alone Riparian Habitat resource brief at a later date. The final resource brief will follow NPS Graphic Identity Program (http://www.nps.gov/hfc/services/identity/) format and layout policy standards, and include the contact information of at least one NPS employee as a point contact for the public.

5.11.1. Condition Rationale

The Canadian River and its riparian corridor at Lake Meredith NRA is a very large system with extensive floodplains and a large–scale morphology that has formed under very high magnitude flows. Due to the size of this system, it has a great deal of inherent stability and is very resilient to stressors. On Reach 2 (downstream of the designated off-road vehicle area) the broad floodplains had substantial cover of vigorous, soil-stabilizing riparian-wetland vegetation, and the system included many fluvial features like vegetated bars and chute cutoffs that provided riparian ecosystem structure and stability. The channel banks also were very well-vegetated with appropriate riparian-wetland species and the channel form was as expected for this landscape setting. These characteristics help improve floodwater and sediment retention, enhance groundwater recharge, and support formation and maintenance of riparian habitats that support fish and wildlife. However, in portions of the assessment reaches within the designated off-road vehicle areas (Reaches 1-A and 1-B), streambank and floodplain vegetation was often in poor condition or was completely absent, many bank locations were destabilized, sediment inputs were often excessive, and the channel was often widening. Such conditions were severe and widespread in Reach 1-A but were more localized and moderate in Reach 1-B. Based on our field assessment, we rated the downstream reach (Reach 2) of the Canadian River as being in "Proper Functioning Condition," (good) the uppermost reach (Reach 1-A) as "Nonfunctional" (significant concern) and Reach 1-B as "Functional – at Risk" (moderate). We could not detect a condition "trend" in Reach 1-B, meaning that neither recovery toward "Proper Functioning Condition" nor degradation toward a "Nonfunctional" condition were apparent at this time.

We rated Blue Creek as "Nonfunctional" (significant concern) for both the upstream and downstream reaches due to the degraded and destabilized banks and floodplain, the resulting excessive sediment delivery to the channel, and the loss of the expected channel/floodplain form for this landscape setting.

Overall, Our observations indicated that substantially greater protection of riparian-wetland vegetation from disturbance could allow the "Nonfunctional" and "Functional - at Risk" reaches of the Canadian River and Blue Creek to recover toward "Proper Functioning Condition" over time. Conversely, a significant increase in vegetation disturbance in Reach 1-B of the Canadian River could cause it to degrade from a "Functional - at Risk" to a "Nonfunctional" condition. The overall condition assessment rating for riparian habitat at the park was of significant concern.

5.11.2. Management and Project Considerations

Riparian areas are few in the Texas Panhandle and thus park staff try to protect them. The recently signed ORV Management Plan will help the riparian areas in the ORV use areas by concentrating use by designating trails.

Table 5.12.1-1. Summary of overall riparian habitat condition, indicators and measures, and rationale for assigning condition ratings at Lake Meredith National Recreation Area.

Riparian Habitat			
Indicators of Condition/ Specific Measures	Reach	Condition Status/Trend	Rationale
Hydrology (5 measures) Riparian Vegetation (7 measures) Erosion/Deposition (5 measures)	Canadian River: Reach 1A		Streambank and floodplain vegetation was often in poor condition or was completely absent, many bank locations were destabilized, sediment inputs were often excessive, and the channel was often widening. Such conditions were severe and widespread in Reach 1-A and warranted significant concern.
	Canadian River: Reach 1B		Streambank and floodplain vegetation was often in poor condition or was completely absent, many bank locations were destabilized, sediment inputs were often excessive, and the channel was often widening. Such conditions were more localized and of moderate condition in Reach 1-B.
	Canadian River: Reach 2		The broad floodplains had substantial cover of vigorous, soil-stabilizing riparian-wetland vegetation, and the system included many fluvial features like vegetated bars and chute cutoffs that provided riparian ecosystem structure and stability along this reach. The channel banks also were very well-vegetated with appropriate riparian-wetland species and the channel form was as expected for this landscape setting and considered to be in good condition.
	Blue Creak: Reaches 1 & 2		The condition of both reaches along Blue Creek were considered to be of significant concern due to the degraded and destabilized banks and floodplain, the resulting excessive sediment delivery to the channel, and the loss of the expected channel/floodplain form for this landscape setting.

5.12. Grasslands Resource Brief

The contents of sub-chapter 5.12 were designed to be placed into a stand-alone Grasslands resource brief at a later date. The final resource brief will follow NPS Graphic Identity Program (http://www.nps.gov/hfc/services/identity/) format and layout policy standards, and include the contact information of at least one NPS employee as a point contact for the public.

5.12.1. Noteworthy Highlights

It should also be noted that the condition of grasslands is the result of a long history of land use and ecological conditions that began long before the establishment of Lake Meredith NRA and Alibates Flint Quarries NM. Consequently, we do not consider the sites with grassland problems to be a result of NPS management; quite the contrary. Lake Meredith NRA/ Alibates Flint Quarries NM natural resource staff have been actively engaged in restoring areas in more degraded condition. Thus, we believe that many areas of Lake Meredith NRA/ Alibates Flint Quarries NM would be in substantially worse condition if it were not for the efforts of NPS staff. We are also anticipating conditions to be improving as the region shifts from extreme drought conditions to more normal rainfall patterns and as resource management continues to address exotic plants and restoration of native prairies.

5.12.2. Condition Rationale

Measures of biotic integrity for grassland condition were highly variable among sites, often ranging from good to significant concern. Sites consistently either scored well or poorly for all five measures of biotic integrity, with the overall moderate condition rating reflecting the variability of condition among sites. Departures from expected conditions for most measures of Soil/Site Stability and Hydrologic Function were typically minimal at many sites. There were a sufficient number of exceptions at sites in moderate condition, perhaps more heavily impacted by drought conditions, to justify a moderate condition rating overall as well. The overall condition of grasslands at both parks is in moderate condition and improving.

Table 5.12.2-1. Summary of overall grasslands condition, indicators and measures, and rationale for assigning condition assessment at Lake Meredith NRA and Alibates Flint Quarries NM.

Grasslands			
Indicators of Condition	Specific Measures	Condition Status/Trend	Rationale
Soil/Site Stability and Hydrologic Function	10 measures		Departures from expected conditions for most measures of Soil/ Site Stability and Hydrologic Function were typically minimal at many sites. There were a sufficient number of exceptions at sites in moderate condition, perhaps more heavily impacted by drought conditions, to justify a moderate condition rating overall.
Biotic Integrity	5 measures		Measures of biotic integrity were highly variable among sites, often ranging from significant concern to good. Sites consistently either scored well or poorly for all five measures of biotic integrity. The moderate condition rating overall reflects the variability of conditon among sites.

5.13. Exotic Plants Resource Brief

The contents of sub-chapter 5.13 were designed to be placed into a stand-alone Exotic Plants resource brief at a later date. The final resource brief will follow NPS Graphic Identity Program (http://www.nps.gov/hfc/services/identity/) format and layout policy standards, and include the contact information of at least one NPS employee as a point contact for the public.

5.13.1. Condition Rationale

The condition of exotic plants at Lake Meredith National Recreation Area is of significant concern (Table 5.13.1-1). We evaluated exotic plants using two indicators, with four measures. The significance of exotic plant impact measure for the potential to alter native plant communities indicator examined species' innate ability to become a pest. This measure utilized the ranking system from the Handbook for Ranking Exotic Plants (Heibert and Stubbendieck 1993). Nine of the 21 exotic plant species (43%) found during SOPN monitoring and the 2014 rapid assessment were ranked as either highest or high for their significance of exotic

Table 5.13.1-1. Summary of overall exotic plants condition, indicators and measures, and rationale for assigning condition assessment at Lake Meredith National Recreation Area.

Exotic Plants			
Indicators of Condition	Specific Measures	Condition Status/Trend	Rationale
Potential to Alter Native Plant Communities	Significance of Exotic Impact		This measure is based on the premise that species with the highest innate ability to become a pest generally cause the most severe problems in natural ecosystems. Nine of the 21 species of exotic plants found during SOPN monitoring were ranked as having the highest or high innate ability to become a pest. Therefore, we consider this measure to be of significant concern.
Prevalence of Exotic Plants	Extent of Exotic		Exotic plants were found in 91.8% of the blocks along high priority vectors, and in 98.1% of the plots in the rapid assessment areas. Twenty-one exotic species were found during monitoring between 2012-2014, including four species that were found in more than 10% of vector blocks. Seven species were found during the 2014 rapid assessment, with five species were found in more than 10% or more of the plots.
	Density of Exotic		Most of the exotic species occurrences in Lake Meredith NRA were in moderate to low densities in monitored parts of the park. Species were most often found in density class 2 (scattered patchy).Only kochia was found to form a matrix in a monitored site, and did so in only two plots. Six species were found in density class 3 (scattered even) or higher.
	Distribution of Exotic		Exotic plants were found in widely distributed in the park, especially along the high priority vectors. *Salsola tragus* was found along all vectors and in all three rapid assessment areas. Two other species (*Bothriochloa ischaemum* and *Kochia scoparia)* were found along all vectors. Four additional species were found along more than half the vectors, including *Convolvulus arvensis* and *Sorghum halepense,* both species of highest ranking for exotic plant impact, and *Bromus japonicus* which is of high concern. Species were also widely distributed among the three rapid assessment areas: of the seven species found in the rapid assessment, three were found in all rapid assessment areas, and three additional species were present in two areas.

plant impact. Five additional species (24%) were of medium concern. Based on the fact that the majority of exotic plant species found in the park are at medium to highest concern for their innate ability to become a pest, we found the condition for this indicator is of significant concern. The prevalence of exotic plants indicator had three measures: extent (how often an exotic species was detected during monitoring), density (how many individuals of exotic plant species found per sampling unit) and distribution (where the exotic plants were found). Exotic plants had a wide extent, and were found in more than 92% of the block and plots sampled. Individual species were found in as many as 77% of the blocks sampled in annual monitoring and 81% of the one-time rapid assessment plots. Hence, the extent of exotic plants in the recreation area is of significant concern. Exotic plants were found mostly in medium to low densities in the park indicating a moderate level of concern for this measure. The distribution of exotic plants is also of significant concern. They are found in all areas of the park that were surveyed, including 6 species that were found in at least half of the surveyed areas. Further, by combining the four measures and evaluating the species on an individual basis, nine exotic plant species were in a condition of significant concern, and two species were in moderate condition.

5.13.2. Management and Project Considerations

Lake Meredith National Recreation Area experienced drought in at least at least moderate level during the 24 months prior to the 2014 SOPN annual monitoring of high priority vectors and the 2014 rapid assessment, including 17 months of at least severe drought, and ten months of extreme or exceptional drought (Folts-Zettner, SOPN biologist, personal communication, 2014). This drought likely had significant impact on composition and quantity of exotic plants found during 2012-2014 monitoring. Salsola tragus (a species that is especially competitive in drought conditions) was found in 87% of the blocks along the high priority vectors in 2014, and in 81% of the rapid assessment plots. Additionally, 15 species of exotic plants that were found along the high priority vectors in SOPN monitoring in 2009-2011 were not present along the same vectors when revisited during the second full panel rotation in 2012-2014.

Two-thirds of the exotic plants found in the recreation area have at least medium impact on native plant communities, including 42% that were ranked as having highest or high impact on native plant communities. Many of these species, including *Convolvulus arvensis, Kochia scoparia, Lactuca serriola, Salsola tragus, Sorghum halepense* and *Tribulus terrestris*, grow preferentially in disturbed lands. Uses of park land such as recreational activities, including OHV use and oil and gas development, that create disturbed lands and also serve as vectors for exotic plant invasions provide particular challenges in preserving and protecting the natural resources of the recreation area.

The park contains exotic species that are well established, e.g., species such as Salsola tragus and Kochia scoparia, and species that may be more recent arrivals or experiencing a renewed period of spreading. More recent arrivals may include the two species (Bromus tectorum, and Chenopodium album) detected in 2012-2014 SOPN monitoring that were not previously documented by the SOPN (Folts-Zettner 2014).

Prevention and early detection of new infestations are integral aspects of successful invasive exotic plant management. While there is a need for long-term suppression programs to address high-impact species that are already prevalent, management agencies tend to direct resources toward control of weed species that are already major problems, and not much toward the prevention, early detection, and or even early containment of new exotic plants (Radosevich 2007). The SOPN annual monitoring program is an outstanding tool that managers can use to detect small or new infestations of exotic plants at NPS sites. At the recreation area, annual monitoring along high priority vectors since 2009 has provided an extensive data set on the exotic plant species found along those park roads. For example,

monitoring data shows that Cynodon dactylon (Bermudagrass), a species of high potential for exotic plant impact, was only detected in 2014 when it was 5.6% of the blocks along the Fritch Fortress Road (Folts-Zettner and Sosinski 2014). Data such as this can provide managers with tools to plan strategies for control of high priority exotic plant species before they get well established or potentially spread to other park areas. Early detection followed by control efforts while infestations are small or localized may prevent exotic plant species from spreading to other areas of the park, or prevent the species from becoming more prevalent than their current limited extent.

Additionally, the 2014 exotic plants rapid assessment provided a one-time measurement of exotic plants found in areas that represent that major habitats of the recreation area: upland, canyon, and an area impacted by wildfire. The SOPN exotic plant monitoring crew was unable to access the bottomland habitat because of muddy conditions (Folts-Zettner, SOPN biologist, personal communication, 2014). Only seven of the 21 species identified in annual monitoring of the high priority vectors were present in the rapid assessment areas. With the exception of two species, the prevalence of exotic plants was similar along the high priority vectors and in the rapid assessment areas. However, *Euphorbia spp*. was present in only 0.3% of the vector blocks, but was detected in 61.3% of the rapid assessment plots, and *Amaranthus retroflexus* (redroot pigweed) was present in 0.9% of the vector blocks, but in 10.0% of the rapid assessment plots.

The majority of the exotic species with highest or high exotic plant impact found in the recreation area also are difficult to control (Table 5.13.2-1). Ten of the eleven species ranked as extremely difficult or difficult for feasibility of control or management, ease of control, using the Hiebert and Stubbendieck (1993) ranking system, are species with a highest or high potential to alter native plant communities. Indeed, the various characteristics that make the impact of an exotic plant to natural plant ecosystems significant such as vegetative reproduction, potential for long distance dispersal and prolific seed production, also make a plant inherently difficult to control. Given the correlation between a species innate ability to become a pest and the difficulty of controlling the species, the early detection rapid response model for the control of exotic plant infestations becomes an especially powerful management tool.

Park staff will continue to chemically treat exotic species in small areas. They are creating a strategy to boost native seeds in small plot restoration areas in hopes of developing healthy areas that can reseed surrounding area thru wind dispersal.

Table 5.13.2-1. Feasibility of management, ease of control ranking for species detected in SOPN 2012 -2014 monitoring (Folts-Zettner and Sosinski 2012, 2013, 2014) and the 2014 Rapid Assessment (Horsley and Schafer 2014), using a subset of Hiebert and Stubbendieck's (1993) Handbook for Ranking Exotic Plants for Management and Control.

Species	Common Name	Feasibility of Management Ranking
Convolvulus arvensis	field bindweed	Extremely Difficult (6)
Cynodon dactylon	Bermudagrass	Extremely Difficult (11)
Euphorbia spp.	David's or toothed spurge	Extremely Difficult (11)
Medicago minima	burr medick clover	Extremely Difficult (15)
Amaranthus retroflexus	redroot pigweed	Difficult (25)
Bothriochloa ischaemum	king ranch bluestem	Difficult (16)
Bromus catharticus	rescue brome	Difficult (16)
Bromus japonicus	Japanese brome	Difficult (21)
Bromus tectorum	cheatgrass	Difficult (16)
Elaeagnus angustifolia	Russian olive	Difficult (16)
Eragrostis cilianensis	stinkgrass	Difficult (20)
Melilotus officinalis	yellow sweetclover	Difficult (21)
Salsola tragus	prickly Russian thistle	Difficult (21)
Sorghum halepense	Johnsongrass	Difficult (21)
Tamarix spp.	saltcedar	Difficult (21)
Kochia scoparia	kochia	Medium (30)
Lactuca serriola	prickly lettuce	Medium (32)
Tragopogon dubius	western salsify	Medium (31)
Tribulus terrestris	puncturevine	Medium (30)
Chenopodium album	lamb's quarters	Easily Controlled (50)
Polygonum arenastrum	prostrate knotweed	Easily Controlled (40)

[1] Species considered to be of highest or high concern using the significance of exotic plant impact, innate ability to become a pest measure (Hiebert and Stubbendieck 1993) are highlighted in the darker tone.

[2] Species of special concern (Folts-Zettner, SOPN biologist, personal communication, 2014) are highlighted in the lighter tone.

5.14. Landbirds Resource Brief

The contents of sub-chapter 5.14 were designed to be placed into a stand-alone Landbirds resource brief at a later date. The final resource brief will follow NPS Graphic Identity Program (http://www.nps.gov/hfc/services/identity/) format and layout policy standards, and include the contact information of at least one NPS employee as a point contact for the public.

5.14.1. Noteworthy Highlights

Approximately 134 bird species have been reported to occur at the Recreation Area, recorded during either the RMBO surveys (2009-2013) or the 2002-2003 inventory by The Nature Conservancy. Thirty-two of the species are considered species of conservation concern by one or more organization. Nineteen of these 32 species have high conservation potential

Table 5.14.2-1. Summary of overall landbirds condition, indicators and measures, and rationale for assigning condition assessment at Lake Meredith National Recreation Area.

Breeding Landbirds			
Indicators of Condition	Specific Measures	Condition Status/Trend	Rationale
Species Occurrence	Temporal Context		Eighty-five percent of 72 species observed in 2002-2003 bird inventories were observed in 2009-2013 RMBO bird surveys at the Recreation Area. Of the 11 species not observed: 1) most are primarily associated with wetlands (habitats not surveyed by RMBO); and 2) only one species was within its normal breeding range and fell into the "exists" breeding habitat class. This species is an owl and may have gone undetected to date because of its nocturnal nature. Additionally, 63 species were observed in the 2009-2013 RMBO surveys but not in the 2002-2003 inventory. In a temporal context, the condition of breeding landbirds at the Recreation Area is good. Data are available for a relatively small number of years, so no trend information is available at this time.
	Spatial Context		In a comparison of the results of BBSs in the vicinity of the Recreation Area to RMBO surveys within the park, there were only two species that were not observed during the RMBO surveys. Although both species are within or in proximity to their normal breeding ranges, neither falls into the "exists" breeding habitat class. Also, both species were recorded in very low numbers during the BBSs. Based on this comparison, the condition of breeding landbirds is good. No trend information is available at this time.
	Conservation Context		There are 32 species that have been observed during 2009-2013 surveys that are listed by one or more organization as being of conservation concern. Many of the species were also observed during the 2002-2003 inventory. We believe that 19 of these species have high conservation potential at the Recreation Area. These are species that are within their normal breeding range and sufficient habitat exists at the park to support their breeding. All of these species have been observed on recent RMBO surveys (in one or more years), with 13 of the species observed in nearly every year. Therefore, we consider the condition for species of conservation concern at the Recreation Area to be good. No trend information is available at this time.

at the Recreation Area, because they are within their normal breeding ranges and breeding habitat exists for them at the park. Several of the species, such as Cassin's Sparrow, Western Meadowlark, and Rufous-Crowned Sparrow, have been observed in relatively high numbers during RMBO surveys. Three additional species are considered to have moderate potential for the park to contribute to their conservation during the breeding season.

5.14.2. Condition Rationale

The condition of breeding landbirds at the Recreation Area, assessed using one indicator, species occurrence (presence/absence), is good. We evaluated species occurrence using three measures/contexts (temporal, spatial, and conservation contexts), all of which were determined to be in good condition. Although our assessment was not based on extensive data (such as one-two years of data prior to RMBO surveys, and limited BBS data), we found no justification to warrant concern for landbird species occurrence at this time. The temporal comparison found 11 species (out of 72) that were not detected during recent RMBO surveys, but only one of the species was within its normal breeding range and was in the "exists" breeding habitat class, in which the habitat at the Recreation Area is characteristic of the habitat(s) where the species would be expected to breed. Additionally, most of the species not observed are associated primarily with wetland habitats not surveyed by RMBO. It is very possible that the one species with "existing" breeding habitat has not been observed because it is an owl and would be most active at night (when RMBO surveys are not conducted). Also, 63 different species were observed in recent RMBO surveys but not in the older inventory. The spatial comparison found only two species that were observed during surveys in the vicinity of the park but not during RMBO surveys. Although both species are within or near their normal breeding ranges, neither falls within the "exists" breeding habitat class; also, both were observed in very low numbers during the BBSs. Thirty-two species that have been recorded at the Recreation Area are listed by one or more organization as being of conservation concern. Of these, we consider 19 to have high conservation potential at the park; these are species that are within their normal breeding range and that have sufficient habitat at the park to support their breeding. The majority of the 19 species were recorded in most of the survey years, with some of the species recorded in relatively high numbers (such as a total of 559 Cassin's Sparrows, 301 Western Meadowlarks, and 195 Rufous-crowned Sparrows). The condition of landbirds at the Recreation Area is good. Adequate information does not exist at this time to evaluate trends in the condition.

5.14.3. Management and Project Considerations

Habitat protection and monitoring are identified by park staff as landbird management needs.

5.15. Herpetofauna Resource Brief

The contents of sub-chapter 5.15 were designed to be placed into a stand-alone Herpetofauna resource brief at a later date. The final resource brief will follow NPS Graphic Identity Program (http://www.nps.gov/hfc/services/identity/) format and layout policy standards, and include the contact information of at least one NPS employee as a point contact for the public.

5.15.1. Noteworthy Highlights

A total of 44 herpetofaunal species have been reported to occur at the Recreation Area/ National Monument, with 37 of the species observed during 2002-2003 surveys by The Nature Conservancy (Patrikeev 2004 and 2008). Of the 37 species recorded during the surveys, seven are listed as species of conservation concern (as either state-threatened or species of greatest conservation need).

5.15.2. Condition Rationale

The current condition of amphibians and reptiles at the Recreation Area/National Monument, assessed using one indicator, species occurrence (presence/absence), is unknown. There is no current information available on the herpetofauna of the parks. The most recent surveys were conducted by The Nature Conservancy in 2002-2003 (Patrikev 2004, 2008). Although condition cannot be determined, the 2002-2003 work provides baseline information for future assessment.

5.15.3. Management and Project Considerations

The Texas Horned-lizard is the only member of this group that the park selectively considers their habitat prior to project development.

COLORADO DIVISION OF WILDLIFE

Couch's spadefoot

Table 5.15.2-1. Summary of overall herpetofauna condition, indicators and measures, and rationale for assigning condition assessment at Lake Meredith National Recreation Area.

Herpetofauna			
Indicators of Condition	Specific Measures	Condition Status/Trend	Rationale
Species Occurrence	Presence/absence		There is no current information available on amphibians and reptiles at the Recreation Area and National Monument. The most recent surveys were conducted by TNC in 2002-2003 (i.e., Patrikeev 2004, 2008). Although condition can not be determined at this time, the 2002-2003 work provides baseline information for future monitoring and assessment..

5.16. Fish Resource Brief

The contents of sub-chapter 5.16 were designed to be placed into a stand-alone Fish resource brief at a later date. The final resource brief will follow NPS Graphic Identity Program (http://www.nps.gov/hfc/services/identity/) format and layout policy standards, and include the contact information of at least one NPS employee as a point contact for the public.

5.16.1. Noteworthy Highlights

Eighteen and sixteen species of fish were recorded during 2003 and 2009-2010 surveys, respectively, in the Canadian River at the Recreation Area. The two surveys recorded many of the same species, including the Arkansas River shiner, a federally and state-threatened species, and the peppered chub, a Texas species of greatest conservation need. Additional species were recorded in the river during earlier surveys. Although only a small number of Arkansas River shiner were recorded in 2003, this species was the most commonly captured during the 2009-2010 sampling. The composition of fish within the river in the park was similar to that in upstream areas of the Canadian River (Wilde 2010). An important recreational activity at Lake Meredith is sport fishing, with walleye, smallmouth and largemouth bass, white bass, and white crappie being some of the most popular species. The Texas Parks and Wildlife Department (TPWD) monitors the lake's sport fish, and they stock the reservoir with various sport fish species on occasion. At least 30 species of fish have been recorded in the lake. Drought conditions in recent years have led to challenging conditions for fish. The number of sport fish documented during sampling decreased from six species in 2010-2011 to one in 2012-2013. Annual golden alga blooms since 2010 have resulted in fish kills.

5.16.2. Condition Rationale

Because we were able to determine condition for fish in Lake Meredith but not in the Canadian River within the Recreation Area, we did not attempt to combine the indicators for an overall condition rating of fish. Instead, we assessed condition separately for these two components of the fish resource. One federally- and state-threatened fish species has been recorded at the Recreation Area, the Arkansas River shiner, and one species of greatest conservation need in Texas has been recorded, the peppered chub. Both species are known to occur primarily in the Canadian River. Both species were found in much higher numbers in the 2009- 2010 sampling compared to 2003 sampling, perhaps at least partially due to the use of different sampling locations. Most of the eighteen species of fish recorded during sampling in 2003 and the 16 species of fish recorded during sampling in 2009-2010 were known previously to occur in the Canadian River. Based on the species recorded, Wilde (2010) concluded that the fish community in the river within the Recreation Area was similar in composition to areas of the river upstream. Because no fish sampling/monitoring has been conducted in the river in the park since the 2010, current condition and trends of fish in the river are currently unknown (Table 5.16.2-1).

At least 30 fish species have been recorded in Lake Meredith. Recent information is available to assess the condition of fish in the lake. The Texas Parks and Wildlife Department (TPWD) monitors fish on a regular basis. In 2011-2012, important prey species (gizzard shad and bluegill), as well as many species of sport fish (e.g., walleye, smallmouth and largemouth bass, white bass, and black and white crappie) were recorded (Munger and Clayton 2011). In the next sampling period (2012-2013), only one sport fish species was documented, and it appeared to be in decline (Munger and Clayton 2013). Only six other fish species were documented. Using the species occurrence-presence/absence indicator/measure, the current condition of fish in Lake Meredith is of significant concern. Based on TPWD sampling, the condition of fish species in the lake had been declining, at least until the summer of 2013. Water levels had been dropping since around 2000. Water levels reached their lowest since the creation of the reservoir, and chloride and salinity levels had increased. Golden alga blooms have occurred

annually since 2010 at a level significant enough to kill fish. In the past year (up to Fall 2014), water levels have increased somewhat and chloride levels have decreased. As there are now few sport species remaining, the decline in sport fish species has slowed/halted. At the present time, the status of lake fish does not appear to be increasing or decreasing, but condition is of significant concern (Table 5.16.2-1).

5.16.3. Management and Project Considerations

In general, fish management falls under Texas Parks and Wildlife, although he park does have management controls for the protection of the Arkansas River shiner.

Table 5.16.2-1. Summary of overall fish condition, indicators and measures, and rationale for assigning condition assessment at Lake Meredith National Recreation Area.

Fish			
Indicators of Condition	Specific Measures	Condition Status/Trend	Rationale
Species Occurrence	Presence/absence of fish in Canadian River		In 2003, 18 species of fish were documented in the Canadian River and associated creeks, including the threatened Arkansas River shiner. Most of these fish had been recorded previously according to TPWD information (Munger 2002). Approximately eight species were recorded in Canadian River surveys in 1983 and/or 1954-55 that were not observed in 2003. In 2009-2010, 16 species were documented in the river from nine sampling sites (eight of which were in the Recreation Area, starting at Chicken Creek and moving upstream). Most of these 16 species were also recorded in 2003, and all but two had been recorded in the Canadian River previously. The Arkansas River shiner and peppered chub were found in much higher numbers in the 2009-2010 sampling compared to 2003 sampling. More than 1,300 Arkansas River shiner and more than 700 peppered chub were recorded by Wilde (2010), accounting for 31.4% and 16.6% of his catch, respectively. Because no sampling has been conducted since 2010, the presence/absence of fish in the river, and hence current condition, is unknown.
Species Occurrence	Presence/absence of fish in Lake Meredith		Approximately 30 species of fish have been recorded in Lake Meredith. Fish are sampled on the lake on a regular basis by TPWD. The number of species documented during sampling in 2010-2011 (12) dropped to 7 in 2012-2013. The number of sport fish documented during sampling decreased from 6 species in 2010-2011 to 1 in 2012-2013. Additionally, two important prey species (gizzard shad and bluegill) that were recorded in 2010-2011 were not recorded in 2012-2013. The condition of fish species based on presence/absence of fish species in the lake is of significant concern. Based on TPWD sampling, the condition of fish species in the lake had been declining, at least until the summer of 2013. Water levels have been dropping since around 2000. In the last few years, water levels reached their lowest since the creation of the reservoir, and chloride and salinity levels have increased. In the past year (up to Fall 2014), water levels have increased somewhat and chloride levels have decreased. Golden alga blooms have occurred annually since 2010 at a level significant enough to kill fish. Because only one sport fish species remained in the lake as of summer 2013, the trend in sport fish occurrence had bottomed out and appears to be no longer declining. At the present time, the status appears to be neither increasing or decreasing, but condition is of significant concern.

5.17. Status of Lake Meredith's Sport Fish

The contents of sub-chapter 5.17 were designed to be placed into a stand-alone Sport Fish resource brief at a later date. The final resource brief will follow NPS Graphic Identity Program (http://www.nps.gov/hfc/services/identity/) format and layout policy standards, and include the contact information of at least one NPS employee as a point contact for the public.

5.17.1. Background

Lake Meredith National Recreation Area (NRA) contains Lake Meredith, the largest lake in the Texas and Oklahoma panhandles and a portion of the Canadian River. Lake Meredith was formed in the early 1960's with construction of the Sanford dam on the river. An important recreational activity at Lake Meredith is sport fishing, with walleye (*Sander vitreus*), smallmouth and largemouth bass (*Micropterus dolomieu* and *Micropterus salmoides*, respectively), white bass (*Morone chrysops*), white crappie (*Pomoxis annularis*), and catfish being some of the most popular species. The Texas Parks and Wildlife Department (TPWD) monitors the lake's sport fish, and they have stocked the reservoir with various sport fish species on occasion (TPWD 2014a). The most recent stocking efforts took place in 2000 and 2001, when over 65,000 largemouth bass fingerlings and 290,100 walleye fingerlings were released. Approximately 30 species of fish have been recorded in the lake. However, drought conditions in recent years have led to changes in the lake and challenging conditions for fish.

5.17.2. Fish Status and Lake Conditions

Lake conditions in recent years have included low lake levels, high chloride levels, and blooms of golden alga (*Prymnesium parvum*). Overall, water levels have been dropping since around 2000, and they reached their lowest (during Spring-Summer 2013) since the creation of the reservoir (Munger and Clayton 2013; CRMWA 2014). After the low point in July 2013, levels began to increase somewhat through the remainder of 2013 and through June, 2014 (data available from U.S. Geological Survey; USGS 2014).

Chloride levels were measured at over 1,350 ppm in 2012 (Munger and Clayton 2013), much higher than historic levels which have been below about 700 ppm (C. Munger, District Fisheries Biologist with TPWD, pers. comm.). The higher chloride levels made conditions more favorable for the golden alga, which is typically found in estuarine waters, but may be found in freshwaters with a relatively high salt content. Golden alga is naturally occurring, but it may lead to massive fish and bivalve kills in some situations (TPWD 2014b). Golden alga blooms have occurred annually since 2010 at a level significant enough to kill fish (Munger and Clayton 2013; C. Munger, TPWD, pers. comm.).

The TPWD Inland Fisheries Division releases a fisheries management survey report for Lake Meredith every few years. The most recent report covered data collected in 2012-2013 and revealed that, based on sampling, the channel catfish (*Ictalurus punctatus*) was the only game fish found in the lake during the survey period (Munger and Clayton 2013). Furthermore, based on their data, the channel catfish population appears to be in decline. Several additional fish species were recorded in 2012-2013 (common carp [*Cyprinus carpio*], green sunfish [*Lepomis cyanellus*], river carpsucker [*Carpiodes carpio*], orangespotted sunfish [*Lepomis humilis*], fathead minnow [*Pimephales promelas*], and grass carp [*Ctenopharyngodon idella*]). No gizzard shad (*Dorosoma cepedianum*) or bluegill (*Lepomis macrochirus*) (prey species) have been recorded during surveys in the last few years. The previous fisheries management survey report summarized data from 2010-2011, and although declines in some species had been reported, prey species, walleye, bass (smallmouth, largemouth, and white), crappies, and catfish were all captured during lake sampling at that time (Munger and Clayton 2011).

One of the management strategies included in Munger and Clayton (2013) was to consider the restocking of forage and sport species if reservoir conditions improve. Sport fish recovery will depend on restocking. There are many variables that would affect a decision to restock fish, but as long as golden alga blooms and the fish kills they can cause continue to occur, TPWD will not restock fish (C. Munger, TPWD, pers. comm.). TPWD continues to monitor sport fish populations and golden alga blooms at Lake Meredith (Munger and Clayton 2013).

In summary, the condition of fish in Lake Meredith is of concern because of the decrease in the number of sport and non-sport fish species since around 2010-2011. The last sampling effort found only one sport fish species, the channel catfish. In the fall of 2014, chloride levels were lower (at about 600 ppm, C. Munger, TPWD, pers. comm.) than the high level recorded, for example, in 2012. Also in Fall 2014, water levels had increased somewhat.

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Appendix A: Team Members and Subject Matter Experts

Table A.1. Lake Meredith National Recreation Area and Alibates Flint Quarries National Monument NRCA Project Team Members

Lake Meredith National Recreation Area and Alibates Flint Quarries National Monument NRCA Project Team
Jeff Albright, NPS Water Resources Division's Coordinator of the NRCA Series
Robert Maguire, NPS Lake Meredith National Recreation Area and Alibates Flint Quarries National Monument Superintendent
Roseythia Pollard, NPS Lake Meredith National Recreation Area and Alibates Flint Quarries National Monument Former Acting Superintendent
Rob Bennetts, NPS Southern Plains Inventory and Monitoring Network Program Manager
Nina Chambers, Northern Rockies Conservation Cooperative, Writer/Editor
Tomye Folts-Zettner, NPS Southern Plains Inventory and Monitoring Network Biologist
John Lysaught, NPS Lake Meredith National Recreation Area and Alibates Flint Quarries National Monument Biological Technician
Donna Shorrock, NPS Intermountain Region Natural Resource Condition Assessment Regional Coordinator
Heidi Sosinski, NPS Southern Plains Inventory and Monitoring Network Data Manager
Kim Struthers, Utah State University, Writer/Editor
Patty Valentine-Darby, University of West Florida, Biologist and Writer/Editor
Arlene Wimer, NPS Lake Meredith National Recreation Area and Alibates Flint Quarries National Monument Chief Resources Management

Table A.2. Lake Meredith National Recreation Area and Alibates Flint Quarries National Monument NRCA Subject Matter Experts

Subject Matter Expert	Topic	Project Deliverables
Jeff Albright, National Park Service Water Resources Division, Natural Resource Condition Assessment Series Coordinator	All	Program Level Review
Mark Meyer, National Park Service Air Resources Division, Renewable Energy Visual Resource Specialist	Viewshed	Reviewed viewshed section
Jeremy White, National Park Service Natural Sounds and Night Skies Division Physical Scientist	Night Sky	Provided NPS guidance/data on night sky monitoring
Chad Moore, National Park Service Natural Sounds and Night Skies Division Night Sky Program Manager	Night Sky	NPS guidance on night sky monitoring and reviewed of night sky section
Emma Lynch National Park Service Natural Sounds and Night Skies Division Acoustical Research Specialist	Soundscape	Reviewed soundscape section
Colleen Flanagan, National Park Service Air Resources Division	Air Quality	Reviewed air quality section
Bruce Heise, National Park Service Geologic Resources Division Geologist	Geology	Reviewed geology section
Katie KellerLynn, Colorado State University, Research Associate	Geology	Reviewed geology section
Rod Goodwin, Canadian River Municipal Water Authority Chief of Water Quality	Surface Water Quality and Groundwater	Provided CRMW monitoring data and reviewed surface water quality and groundwater sections
Michael Martin, National Park Service Water Resources Division Hydrologist	Groundwater and Riparian Wetlands	Wrote groundwater section and provided expert opinion and report on riparian wetland assessment during June 2013 field visit
Joel Wagner, National Park Service Water Resources Division, Wetlands Program Leader	Riparian Wetlands	Provided expert opinion and report on riparian wetlands during June 2013 field visit

Table A.2. Lake Meredith National Recreation Area NRCA Subject Matter Experts (cont.)

Subject Matter Expert	Topic	Project Deliverables
Dr. Fred E. Smeins, Rangeland Ecologist for the Ecosystem Science and Management Department at Texas A&M University in College Station, Texas	Grasslands	Provided grasslands expert opinion during June 2014 field visit
Mike Wrigley, NPS Intermountain Regional Wildlife Biologist	Breeding Landbirds	Reviewed landbird section
Charles Munger Texas Parks and Wildlife Department District Fisheries Biologist	Fish	Provided expert information and reviewed section
Authors Who Served as Subject Matter Experts	**Topic**	**Project Deliverables**
Tomye Folts-Zettner National Park Service Southern Plains Inventory and Monitoring Network Biologist/ Botanist	All	Provided expert opinion and assistance on grasslands and exotic plants and reviewed all sections
Heidi Sosinski, National Park Service Southern Plains Inventory and Monitoring Network Data Manager	All	Viewshed analyses, maps, graphs, and remaining graphics

Appendix B: Viewshed Analysis Steps

The process Heidi Sosinski used to complete the Lake Meredith NRA's and Alibates Flint Quarries NM's viewshed analyses is listed below.

Downloaded 1/3 arc second national elevation dataset (NED) grid (roughly equivalent to a 30 m digital elevation model [DEM]) from The National Map Seamless Server (http://seamless.usgs.gov/). The x and y values for the NED are in arc seconds while the z data are in meters. Projected NED into NAD83 UTM 13 to get all data in meters.

Downloaded Lake Meredith NRA and Alibates Flint Quaries NM boundaries, roads, and trails layers from NPS Integrated Resource Management Applications (IRMA) portal (https://irma.nps.gov).

Prepared Observation Point layers for Viewshed Analyses.
Created point layers for Harbor Bay East, Fritch Fortress, Fritch Fortress Ampitheater, McBride Canyon and Alibates..

Used Edit > Create New Feature tool to create 5 observation points. Saved file as obs_point.shp.

Added field named "OFFSETA" (type = double) to shapefile and set value to 1.68 for each respective record in the attribute table. The value in the field "OFFSETA" represents an observer height of 1.68m (~5'6")

Ran Viewshed Analysis using ESRI Spatial Analyst Viewshed Tool.
Using the Viewshed Tool in ESRI's ArcGIS 10, Spatial Analyst Toolbox, ran viewsheds using the following inputs.

- Input raster = 1/3 arc second NED modified to include area tree cover.
- Input point observer feature = obs_point.shp.

After the viewshed analyses were complete, housing and road density data were obtained and modified to depict past, present, and future densities around the National Recreation Area and National Monument. These datasets were created by the NPS's Natural Resource Program Center by compiling and analyzing landscape-scale US Census Bureau data that linked measurable attributes of landscape (i.e., road density, population and housing density, etc.) to resources within natural resource based parks. This resulted in the creation of a dataset titled NPScape (Budde et al. 2009; Gross et al. 2009). The following modifications were made to NPScape data for purposes of this assessment:

Downloaded spatial data from Internet.
Downloaded Historic Site-specific NPScape data from the NPScape website (http://science.nature.nps.gov/im/monitor/npscape/index.cfm).

Simplified NPScape Housing Density Projections.
Converted Lake Meredith NRA and Alibates Flint Quarries NM 30 km housing density projection rasters to polygon shape files.

Combined classes to reduce number of original classes to five (Table B.1).

Table B.1. The original classes from NPScape and new classes assigned to housing densities for this assessment of the viewshed at Lake Meredith NRA and Alibates Flint Quarries NM

Original Class	New Class
Private undeveloped	Private undeveloped
<1.5 units/km^2	<1.5 units/km^2
1.5–3 units/km^2	1.5–6 units/km^2
4–6 units/km^2	
7–12 units/km^2	> 6 units / km^2
13–24 units/km^2	
25–49 units/km^2	
50–145 units/km^2	
146–494 units/km^2	
495–1234 units/km^2	
Commercial / Industrial	Commercial / Industrial

Appendix C: Bortle Dark-Sky Scale

Key for the Summer Sky— Latitudes 30° to 50° N

The Milky Way is not visible and sky glow extends above 35 degrees. Little to no dark adaptation is possible. Ground texture is easily seen, and artificial light dominates the landscape. Visible constellations are limited to the very brightest if any. The sky has a uniform washed out appearance.[1]

If this describes your nighttime environment, continue below

If the nighttime environment appears darker than this description, jump to the next section

Sky appears nearly completely washed out, and is luminous. Dark adaptation is not possible, ground is brightly illuminated and fewer than 200 stars are visible. Only the most major constellations are identifiable. For instance, the entire keystone of Hercules or the five stars of Delphinus are not completely visible.

this is accurate **Bortle Class 9** if darker—proceed below

Constellations are visible but may be missing key stars, sky background has a uniform washed out glow with light domes reaching 60 degrees above the horizon. Stars such as the tip of Sagitta or epsilon Lyrae are not visible. If clouds are present they are brilliantly lit.

this is accurate **Bortle Class 8** if darker—proceed below

Brighter constellations are easily seen in full, yet sky background has greyish or yellow background. Milky Way may be just barely seen near the zenith. The Scutum and Cygnus star clouds are not visible.If clouds are present they are brilliantly lit. Ground texture is still visible.

this is accurate **Bortle Class 7**

The Milky Way is visible but discontinuous, and lost to light domes near the horizon. Fine details and structure are not easily visible, if at all. Ground texture is still visible, and shadows are cast from light pollution. Light domes are clearly visible along the horizon and appear brighter than any portion of the visible Milky Way.[2]

If this describes your nighttime environment, continue below

If the nighttime environment appears darker than this description, jump to the next section

The Milky Way is just visible overhead, but is not continuous and is diminished to obvious skyglow. Cygnus ,Scutum, and Sagittarius star fields just visible. If clouds present they are illuminated and reflecting light. Ground texture is seen with difficulty.

this is accurate **Bortle Class 6** if darker—proceed below

Milky Way is faintly present, but may have occasional gaps and is lost to skyglow near the horizon. Great rift in Cygnus is just visible. Any clouds present are brighter than the background sky and reflect light back. Zodiacal light may be glimpsed, but is difficult to see amidst the light pollution. Ground texture is not visible but forms are easily seen.

this is accurate **Bortle Class 5** if darker—proceed below

Milky Way is evident from horizon to horizon, but fine details are lost. Clouds are just brighter than background sky, but appear dark at zenith. Light domes are much brighter than brightest part of Milky Way and extend to up to 15 degrees above the horizon. Zodiacal light is evident in west after sunset or in east before dawn. Deep sky objects such as the M13 globular cluster and Northern Coal Sac are visible.

this is accurate **Bortle Class 4**

The Milky Way has a defined outline with visible structure and detail. Very few light domes are visible just along the horizon and do not cast shadows. You may see color in the Zodical light when compared to bluish-white color of the Milky Way. Scattered clouds appear dark against the night sky except those clouds just above light domes.[3]

If this describes your nighttime environment, continue below

Milky Way appears complex with visible outline, however some light pollution is still evident along the horizon. Light domes only slightly brighter than brightest part of the Milky Way. Zodiacal light easily seen, but band and gegenschein difficult or absent. Many summer globular clusters and emission nebulae are visible with the naked eye despite distracting light domes along the horizon. Venus casts an obvious shadow.

this is accurate **Bortle Class 3** if darker—proceed below

Very few light domes are visible; with none extending above 5 degrees and fainter than the Milky Way. Airglow is often visible, and character in its brightness may be seen. Ground is mostly dark. The Zodiacal band (away from the Milky Way and at least 45 degrees above the horizon) and gegenschein are visible. The rift in the Cygnus star cloud is visible. The Prancing Horse in Sagittarius and Fingers of Ophiuchus dark nebulae are visible, extending to Antares. Jupiter and Milky Way cast barely visible shadows.

this is accurate **Bortle Class 2** if darker—proceed below

The Milky Way is intricate, marbled, and veined with Sagittarius region of the Milky Way casting obvious shadows. Milky Way appears 40 degrees wide in some parts with a convoluted outline. The horizon completely free of light domes, though some distant light domes may be visible from mountain tops. Transparency and seeing are excellent (among the best of the year) with very low airglow. Many objects such as M81 or the Helix nebula are visible with the naked eye. Zodical light is striking as a complete band. Any clouds are very difficult to see.

this is accurate **Bortle Class 1**

The Bortle Dark-Sky Scale is a qualitative scale developed by John Bortle and published in Sky & Telescope Magaine in 2001. It provides a useful complement to quantitative measures. The National Park Service is testing this dichotomous key for use by professional and citizen scientists. Some knowledge of the night sky and visual observational techniques are required to properly implement this assessment.

note 1) At least 5 minutes of dark adaptation is required to properly differentiate Class 7,8 & 9 skies.

note 2) At least 10 minutes of dark adaptation is required to properly differentiate Class 4, 5 & 6 skies.

note 3) 20 to 120 minutes of dark adaptation is required to properly differentiate Class 1, 2 & 3 skies.

Developed by Jeremy White, Dan Duriscoe, and Chad Moore of the NPS Natural Sounds & Night Skies Division, www.nature.nps.gov/night

August 2, 2012

Appendix D: Sound Level Model Maps

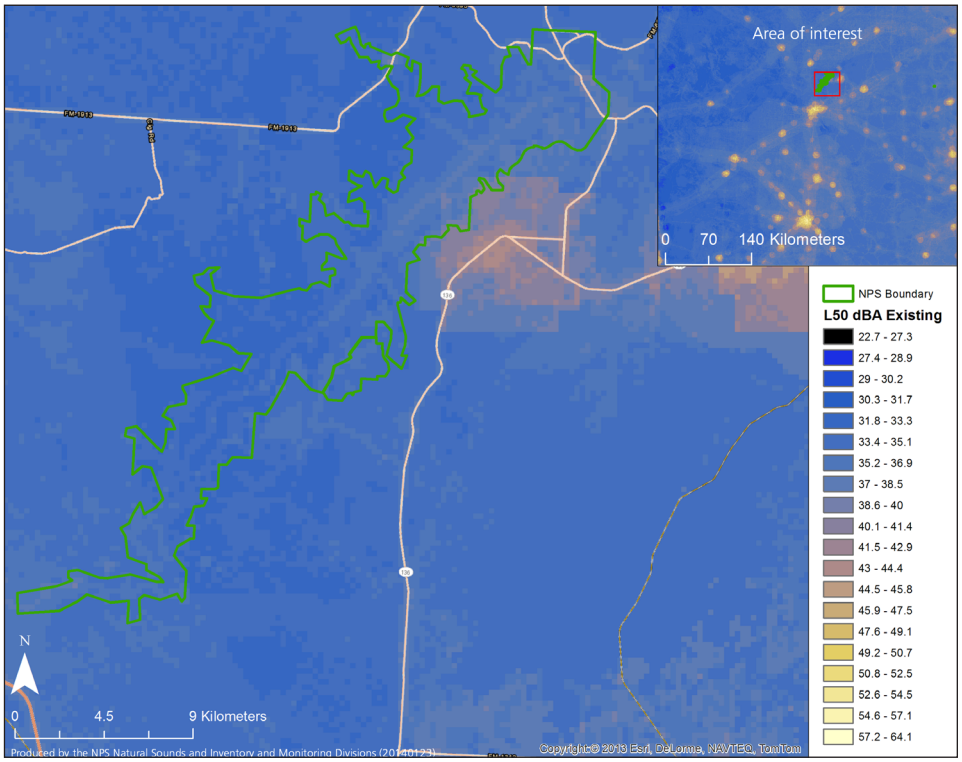

Figure D-1. Existing CONUS soundscape model zoomed to Lake Meredith NRA.

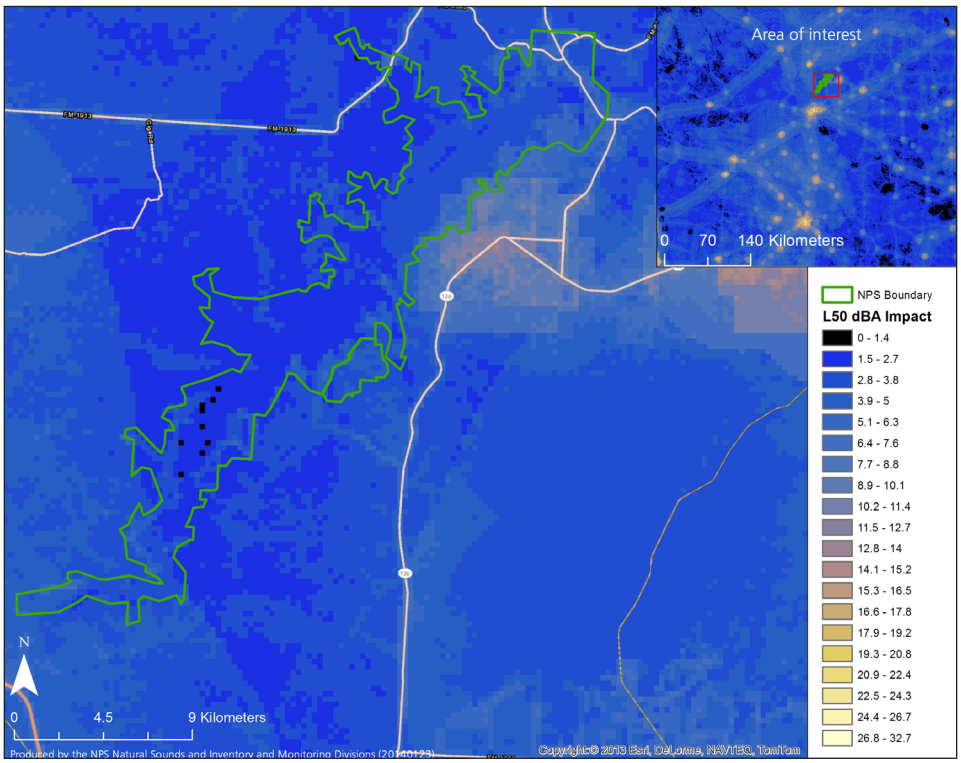

Figure D-2. Impact between existing and natural CONUS soundscape models zoomed to Lake Meredith NRA.

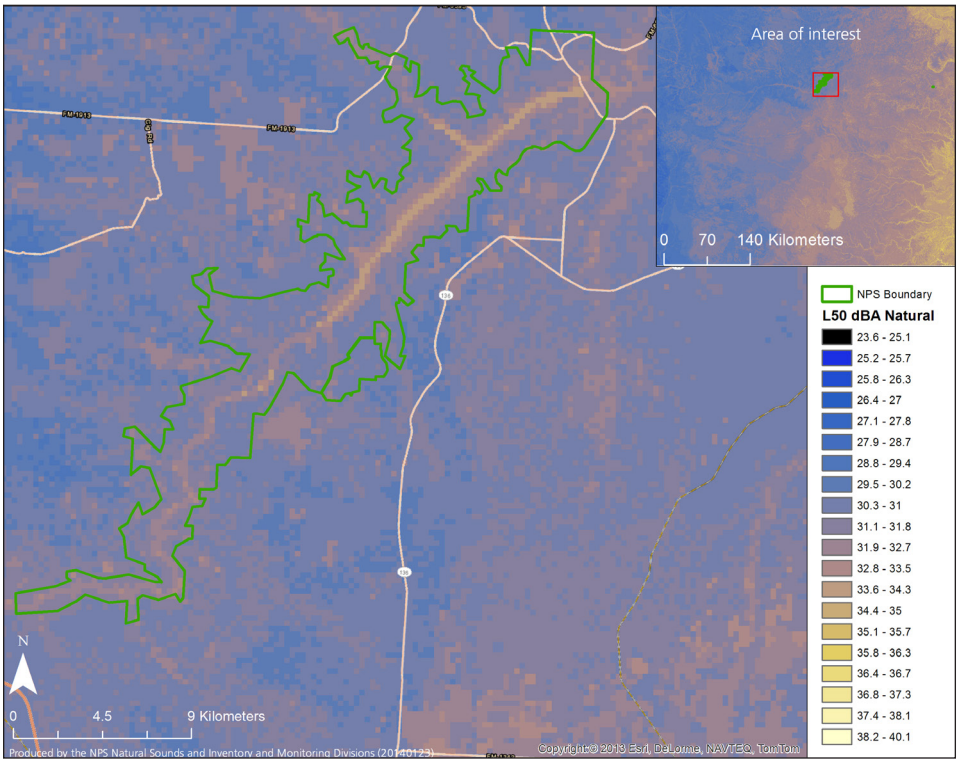

Figure D-3. Natural CONUS soundscape model zoomed to Lake Meredith NRA.

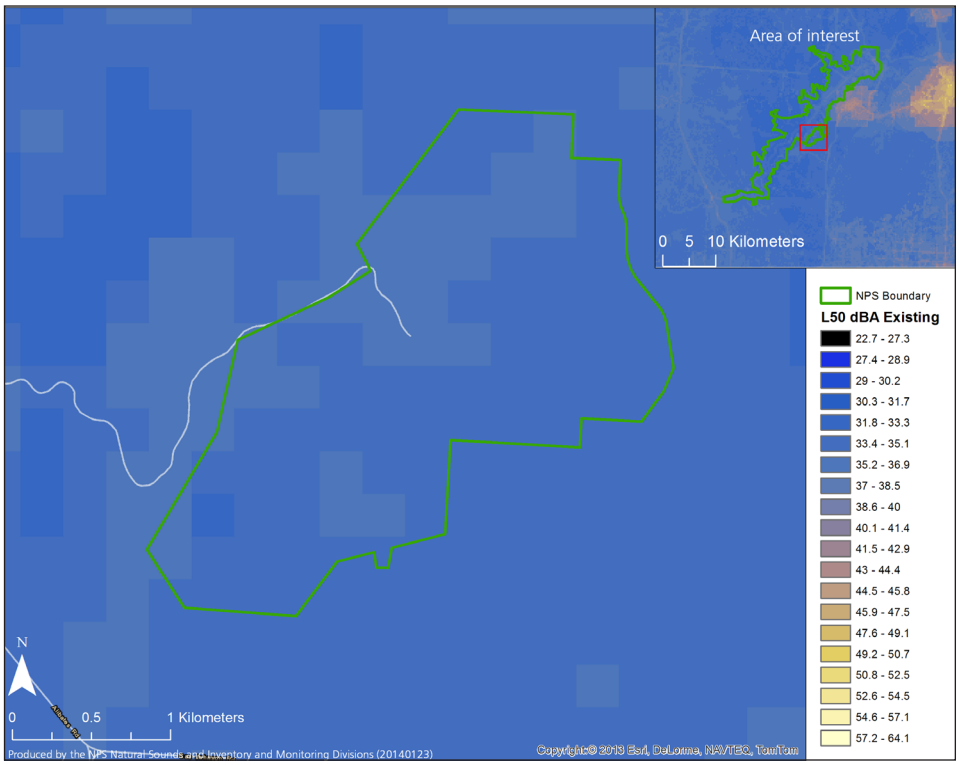

Figure D-4. Existing CONUS soundscape model zoomed to Alibates Flint Quarries NM.

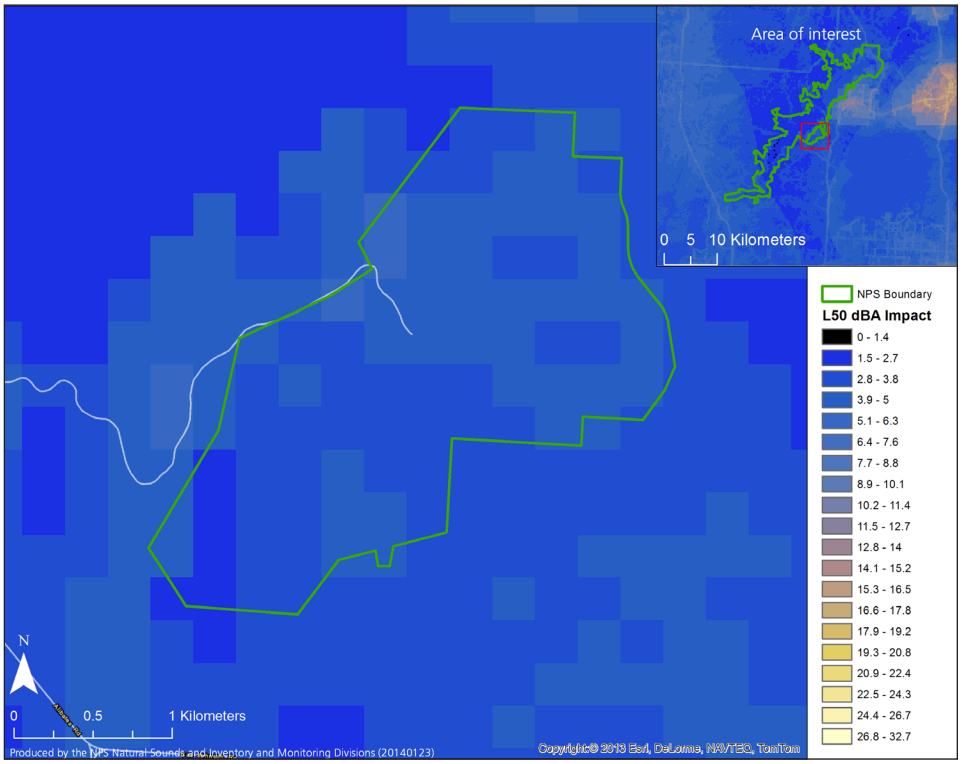

Figure D-5. Impact between existing and natural CONUS soundscape models zoomed to Alibates Flint Quarries NM.

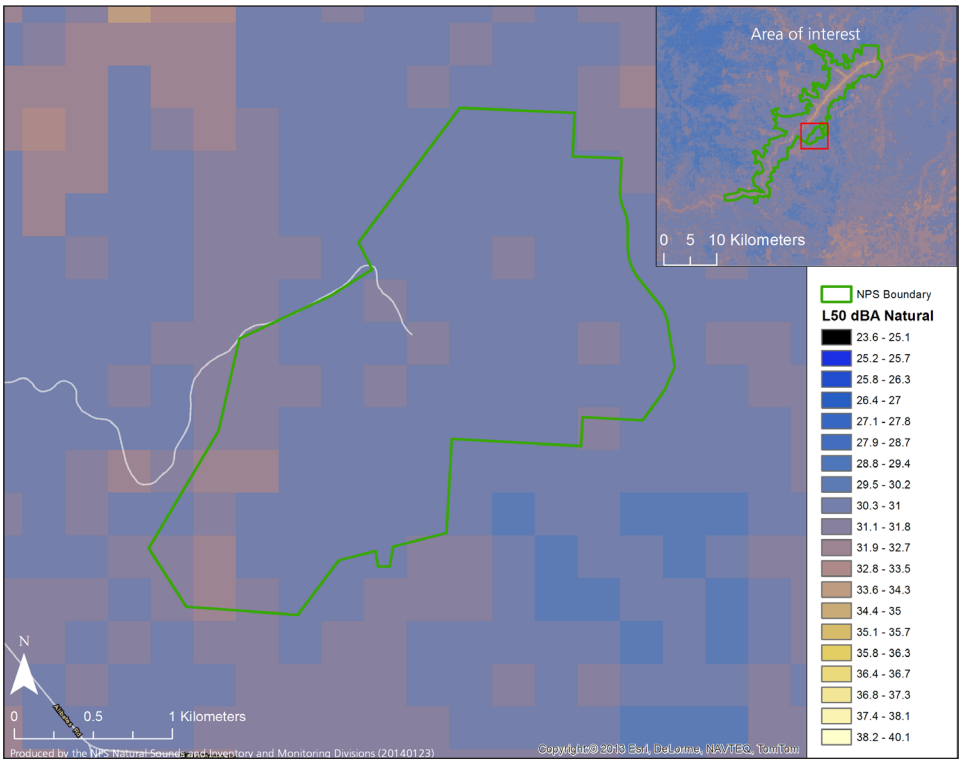

Figure D-6. Natural CONUS soundscape model zoomed to Alibates Flint Quarries NM.

Mennitt et al. (2013) with the NPS NSNSD developed a geospatial sound model by mapping sound pressure levels on a continental U.S. scale. The model included biological, climatic, geophysical, and anthropogenic factors to assess expected sound pressure levels for natural and existing conditions. The model results for the predicted natural ambient sound levels ranged from 30.0-34.2 dBA for the National Recreation Area and from 30.3-32.2 dBA for the National Monument (Mennitt et al. 2013 and E. Lynch, NSNSD 2014b, Excel spreadsheet of dB(A) values). The modeled existing sound levels for the NRA and NM ranged from 32.4-40.3 dBA and 33.2-36.2 dBA, respectively. The impact sound level range, which is the existing L50 dBA minus natural L50 dBA, for the NRA ranged from 2.4 - 6.1 dBA and from 2.9 - 4.0 dBA for the NM. According to Mennitt et al. (2013), "an impact of 3 dB suggests that anthropogenic noise is noticeable at least 50% of the hour or more." This implies that based upon the model, the existing impact of sound levels to the NRA and NM warrants moderate to significant concern.

Appendix E: Additional Water Quality Graphs

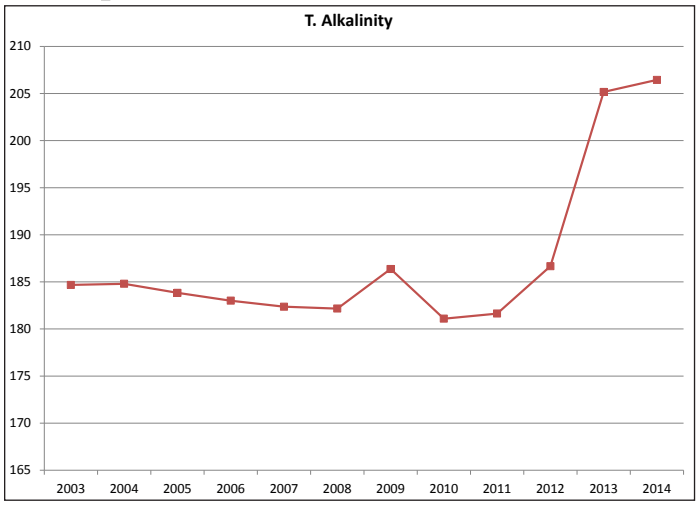

Figure E-1. Total alkalinity time series for the Intake Tower site.

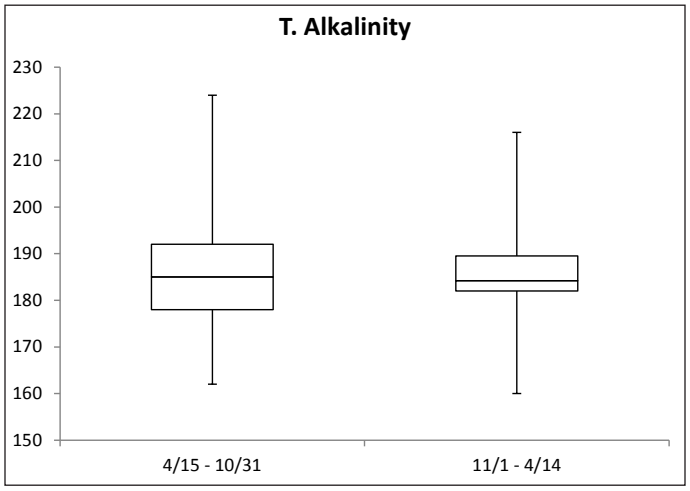

Figure E-2 Total alkalinity seasonal analysis for the Intake Tower site.

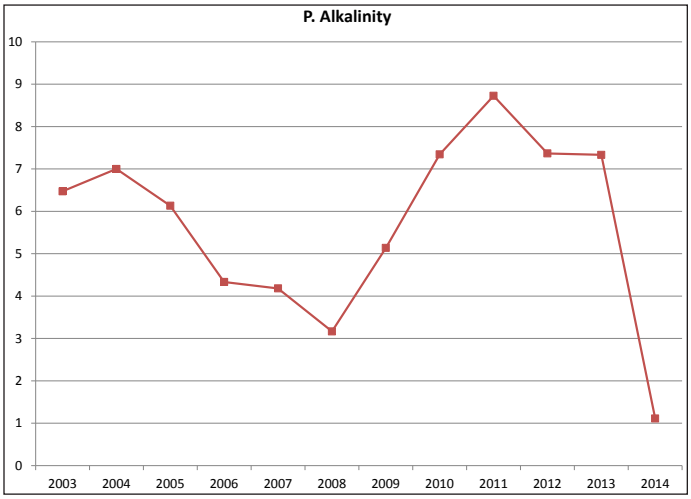

Figure E-3. Phenolphthalein alkalinity time series for the Intake Tower site.

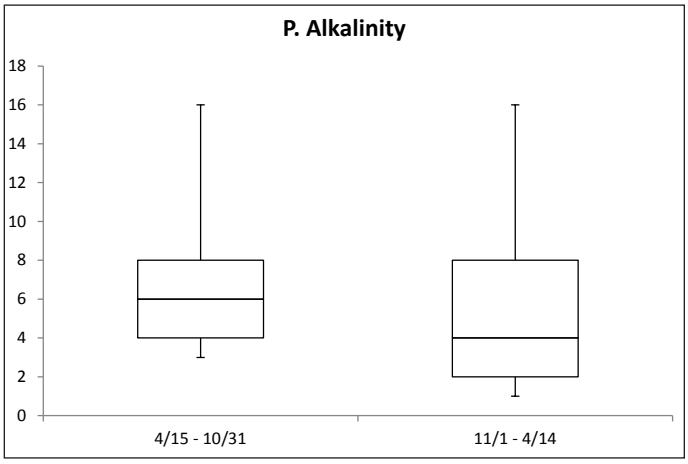

Figure E-4. Phenolphthalein alkalinity seasonal analysis for the Intake Tower site.

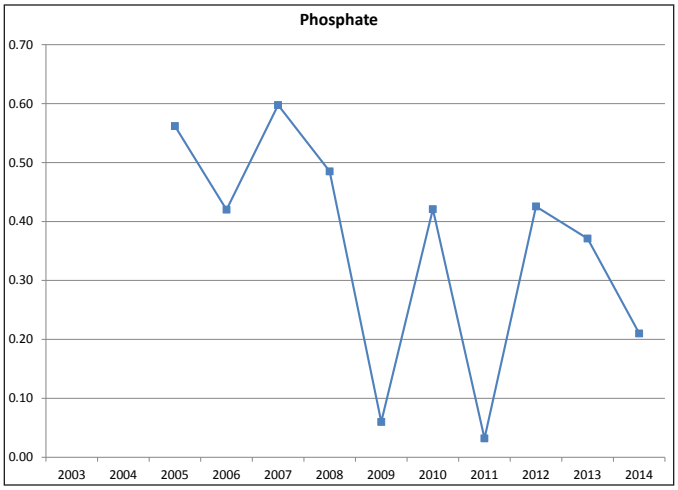

Figure E-5. Phosphate time series for the Intake Tower site.

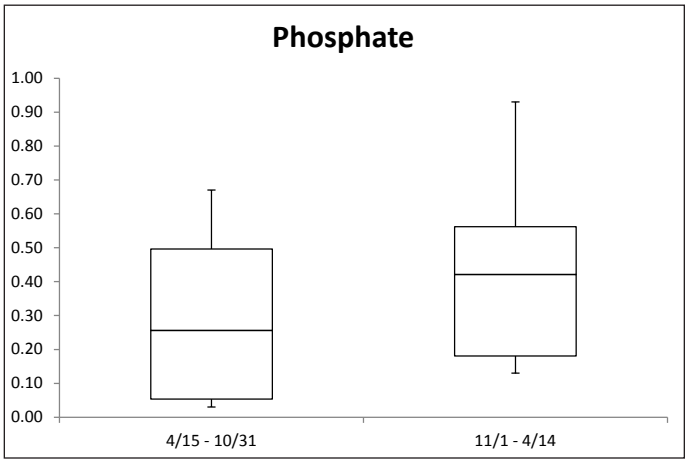

Figure E-6. Phosphate seasonal analysis for the Intake Tower site.

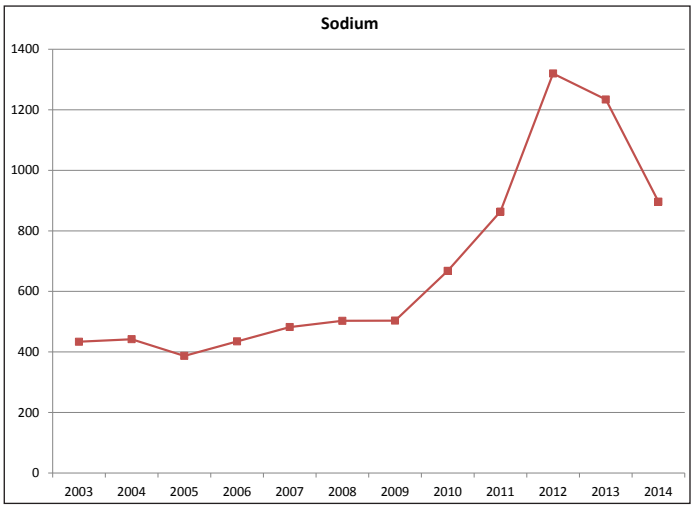

Figure E-7. Sodium time series for the Intake Tower site.

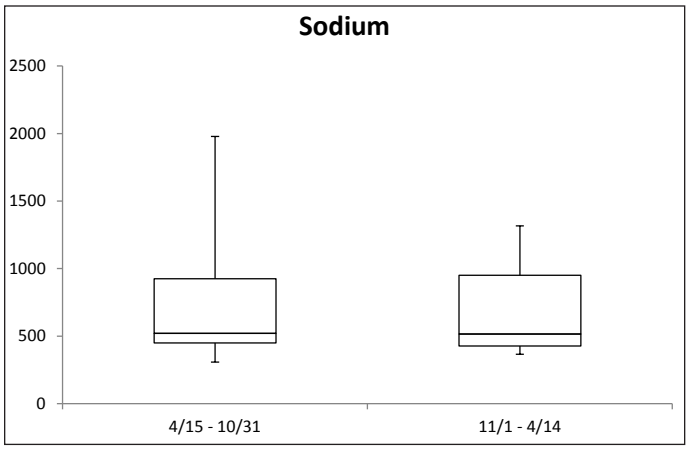

Figure E-8. Sodium seasonal analysis for the Intake Tower site.

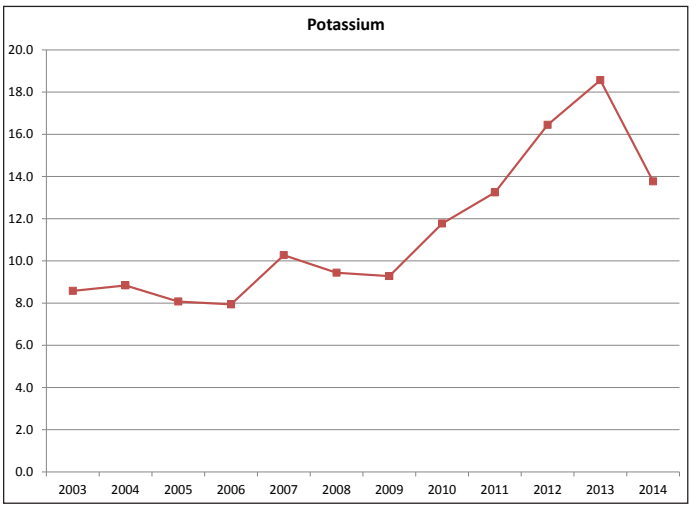

Figure E-9. Potassium time series for the Intake Tower site.

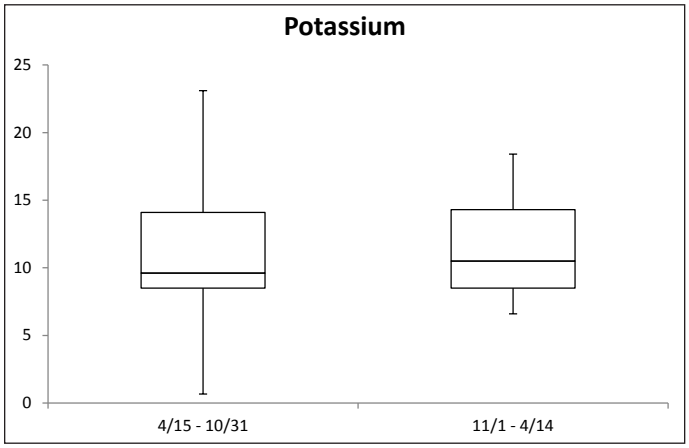

Figure E-10. Potassium seasonal analysis for the Intake Tower site.

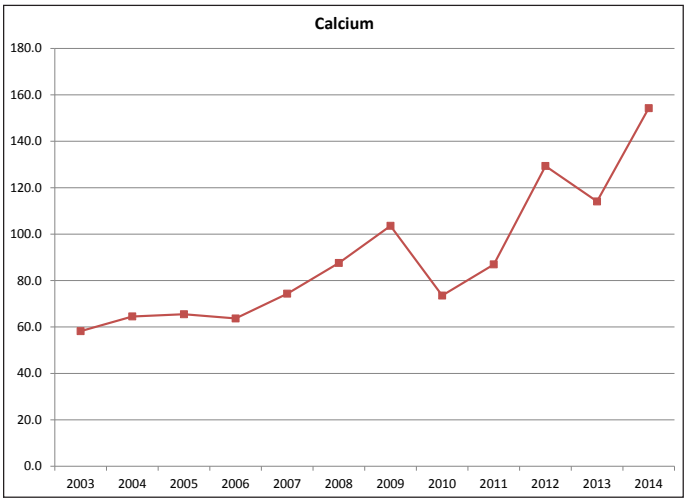

Figure E-11. Calcium time series for the Intake Tower site.

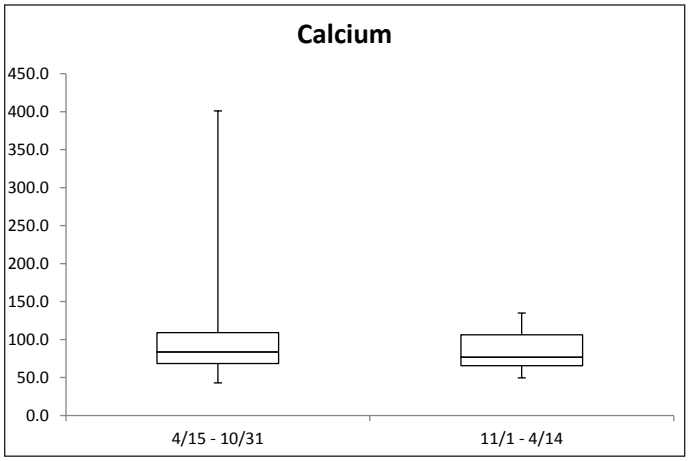

Figure E-12. Calcium seasonal analysis for the Intake Tower site.

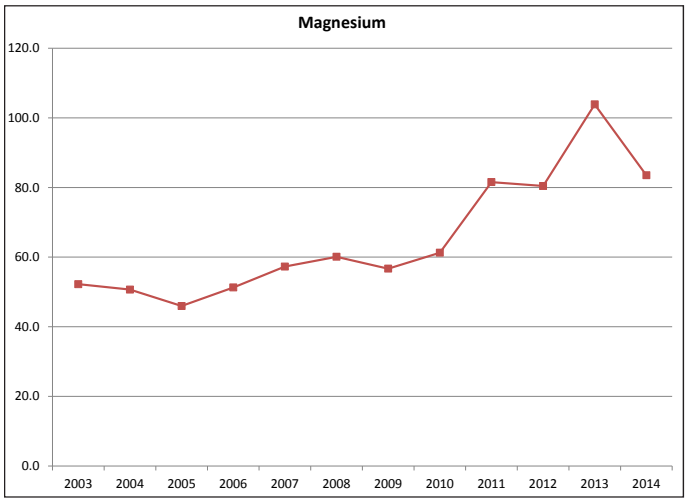

Figure E-13. Magnesium time series for the Intake Tower site.

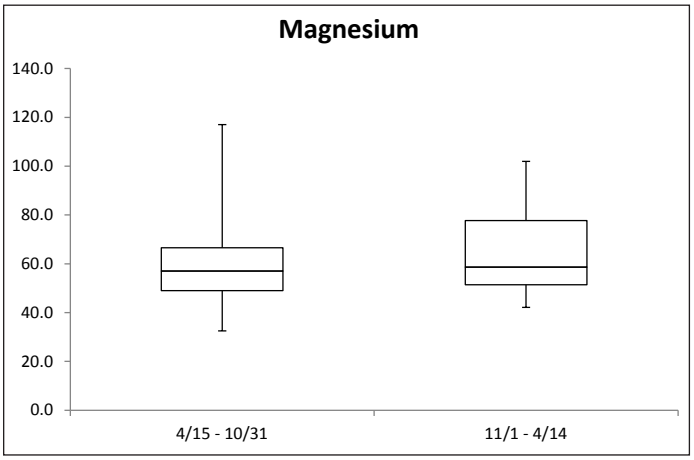

Figure E-14. Magnesium seasonal analysis for the Intake Tower site.

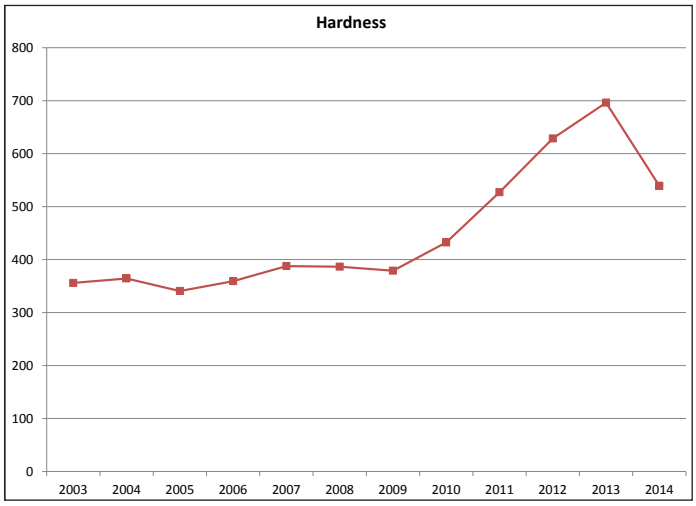

Figure E-15. Hardness time series for the Intake Tower site.

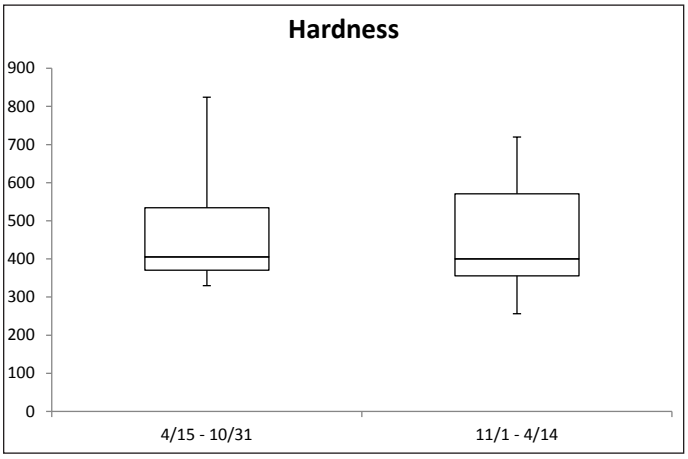

Figure E-16. Hardness seasonal analysis for the Intake Tower site.

Appendix F: Lake Meredith NRA Grassland Vegetation and Soils Assessment - June 17-18, 2014

Part 1: Overview Assessment by Fred E. Smeins

This section was written by Fred E. Smeins, a rangeland ecologist for the Ecosystem Science and Management Department at Texas A&M University in College Station, Texas

Introduction

A two day field observational survey of eight sites on the Lake Meredith National Recreation Area (NPS) was conducted to assess the current status of the vegetation of these sites within the Area. This report consists of two components of the assessment. First a general historical and ecological characterization of the vegetation will be presented to relate current vegetation condition of the Area to the regional context. Second a qualitative field assessment is presented of the current condition of the vegetation/environment the eight sites.

General Vegetation Conditon Of The Lake Meridith Area

The USDA recognizes the Canadian and Beaver Rivers, including their floodplains and adjacent moderate to steep, dissected escarpments, as a distinct Major Land Resource Area, MLRA 77E , entitled the Southern High Plains, Breaks. This includes the Canadian River floodplain and associated streams and drainages as well as the bordering roughland escarpments/breaks. This is a unique area within the broader High Plains Region. This MLRA contrasts with the surrounding High Plains Region which is typically, relatively flat to moderately rolling plains. Early observations of the broader High Plains region, referred to it as the Llano Estacado (Staked Plains), and variously described it in different ways depending upon the season of observation, time since the last significant precipitation, following widespread fires, following recent heavy grazing by bison and other plains ungulates and the particular part of the High Plains that was observed. General agreement existed in terms of the extensive flat to rolling plains resembling an "ocean prairie" smooth , flat and boundless and covered with a carpet of buffalograss and other short and midgrasses. In many places shallow playa lakes and arroyos were found and following sufficient rainfall water was available for wildlife, livestock and humans but during dry seasons or long term droughts water could be very limiting. Descriptions varied from characterization of the area as the "Great Zahara of North America" (Marcy 1849-in Weniger 1984) to some of the best grazing lands in the Southwest (Gray 1854-in Weniger 1984), depending upon the time and area of observation. The Plains were often described as having an absence of woody plants, however, mesquite was often encountered and varied from short, scattered individuals to sometimes fairly dense stands of small to large plants, however, it was most commonly observed along draws and canyons. Lack of understanding of the environment and vegetation of the Region by European settlers eventually lead to extensive misuse of the land. Overgrazing by confined livestock, reduction or removal of periodic fires, periodic severe droughts and severe winters lead ultimately to degradation of the herbaceous vegetation, spread of woody species, particularly mesquite, and major die-offs of livestock and ultimately reduction in the productive capacity of the land in many areas (Wester 2007)). Much of the High Plains today are in cropland agriculture but where native rangeland exists it still often continues to recover from this past history of over use.

Several major rivers have their origin or cross the High Plains; the Canadian is an example of the latter. It has its origin in New Mexico, crosses the northern portion of the Southern High Plains and continues into Oklahoma. Early accounts of the River and its vegetation vary according to where it was encountered by the observers. In the vicinity of Potter, Moore

and Hutchinson Counties, where Lake Meredith is located, Weniger (1984) summarized the landscape and vegetation of the area as viewed by early observers.

> "We have seen that the Canadian River proper originally consisted of a wide sand-choked ditch. In normal times the water permeated the sand, with some left over for flowing in little channels over parts if it surface—sediment-filled, but still running water. In dry seasons, there might not be enough water to appear on the surface at all, the whole flow working in hidden streams through the sand, leaving the surface to become dry. One does not have to wait long, today, as originally, to witness the sand storms which can arise before a panhandle gale from this sandy thread with a river in its bowels, but dry on its surface. On either side, low banks rose above this sand river only a few feet to a flat bottom which was rich, heavily covered with coarse grass (including Phragmites), trees and bushes and often treacherous with marshes not produced by the river, but by the springs along the high bluffs at the edges of the valley. This was the rich and extensive bottom, well timbered with hackberry, cottonwood, oak, etc. ……These bottoms were also once the prime pastures of the early ranches. The very richness of these trees and this grass in the panhandle, where such have always been at a premium, contributed to their destruction. The trees were cut for lumber and fuel, and D. B. Hiatt (1914-in Weniger 1984), who was there in the years when the changes were the most drastic, has told what happened to the grass: "The great hay meadows were becoming ruined with every rain. First a section was over-pastured, letting the overflow cut into the sand and wash it over the grass below, to be repeated again,……The result is that most of the once-rich Canadian bottom is so long vanished that many would now doubt it ever existed as it was".

It is useful and necessary to consider past human-driven disturbances and alterations to the Canadian River ecosystem along with natural disturbance regimes of a riverine system in terms of flooding, sedimentation, etc. when assessing the current condition of the vegetation/environment.

Assessment Of Eight Selected Sites

(Details of local and landscape scale species composition, functional-types, diversity and representative photographs were prepared as part of this report)

<u>Bottomland Sites</u>

Site #1-Waypoint #16, Site #2-Waypoint #17, Site#3-Waypoint #18, Site#4-Waypoint #20

All of these sites occur on the broad floodplain of the Canadian River and receive floodwaters following high rainfall on the adjacent uplands. They vary from frequently to occasionally flooded. They occur on Lincoln and Clairemont soil series which are intermixed to form a mosaic of sandy to sandy loam to silty clay loams to clayey soils across the floodplain. Floodplains by their very nature are highly variable in minor topographic elevation of a few inches, presence of old distributary streams and channels and soil texture and soil profile. All of the above can have significant influence on species abundance and diversity. In addition it is apparent that erosional materials from the adjacent uplands are frequently deposited, mainly clayey sediments, that are unevenly deposited depending on depth, duration, flow rate and hydroperiod of the flooding events. Relatively unvegetated clayey patches occur near the river channel due to recent flooding events. These factors create a favorable environment for a high degree of species diversity if disturbance events are not too severe. As indicated above these sites can have a cover of productive native grasses but past overgrazing and now accentuated flooding events slow the natural successional processes for establishment of these species. In general most of the later successional grass species are present but in lesser quantities than at full potential, however, due to the active environment in these floodplains succession can be accelerated or reverse depending on disturbance events and development to pre-European conditions may be a long process. Some areas could support more trees such as Cottonwood

and other native trees and shrubs. The greatest concern is the presence of the exotic Tamarisk. It creates problems in that it is very invasive and once established is difficult to control and methods to control it can also have negative effects on native trees such as cottonwood which apparently was a problem relative to herbicide and fire control attempts on some of these sites. Also a few patches of spiny aster (?) were observed. This is an aggressive invader and difficult to control and should be controlled before it increases its abundance. Site 4 is more of a terrace site, occasionally flooded, but well-drained. Of all the wetter sites this one is in the best condition with a good diversity of native herbaceous and woody species and only minor exotic species present. This site would be a good educational/demonstration site for the public.

Upland Sites

Site #5-Waypoint #21

This site is in rather poor condition. It has medium to large mesquite trees scatter across the area with poor herbaceous ground cover and more than expected bare ground. A dominant weedy species is Russian thistle which is indicative of the poor vegetation condition of the site.

This area should be considered for some active revegetation/restoration.

Site #6-Waypoint #22

This type of site occurs over much of the upland gravelly slopes of the Area and is a good representative of this site in good to excellent vegetation condition. It has most of the late successional herbaceous grass and forb species as well as the expected diversity of shrubs and cacti. No invasive species were observed on the site and the site should be carefully monitored to remove any that may appear.

Site #7-Waypoint #24

This recently burned site has a relatively good composition of native grasses but due to the fire and recent dry conditions recovery is poor and currently much bare soil exists and high intensity rainfall events could create erosion problems. With a period of good soil moisture the site would be expected to recover to a good ground cover and a high diversity of grasses, forbs and shrubs.

Site#8-Waypoint #25

Similar to Site #6 and is generally in good vegetation condition. Recent dry conditions make it difficult to assess its potential but most expected plant species for this site in good condition are present and they would be expected to respond favorably to improve moisture conditions. Monitor for any invasion of exotic species and control them before they become a problem.

F.19. References

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Part 2: Detailed Assessment Notes by Dr. Fred Smeins and Tomye Folts-Zettner

General Info: The area of LAMR has been in at least Moderate drought for 24 months prior to this assessment; 17 of those months were Severe or worse; 10 months were Extreme to Exceptional Drought including the 4 months months immediately preceding this assessment. Rain returned to the area two weeks prior to this assessment.

SITE #1 – southernmost BOTTOMLAND – Waypoint #16 ***GOOD***

General Notes: Well-drained site. Tamarisk reduced in number – rootsprouts but no seedlings. While not at historic potential, this site appears to be headed that way if water table and salinity does not change.

ESD: Sandy Bottomland R077EY065TX (Lincoln soils, frequently flooded)

Landscape-scale Diversity: A lot of topography resulting in a diversity of microsites. **Good**

Local-scale Diversity: Diversity is adequate for a frequently disturbed site. Dominant grasses include Sand lovegrass (*Eragrostis trichodes)* and switchgrass (*Panicum virgatum)*. Other species present include: western wheatgrass (*Pascopyrum smithii)*, sand reedgrass (*Calamovilfa gigantea)*, sand dropseed (*Sporobolus cryptandrus)*, wedgegrass (??*)*, common reedgrass (*Phragmites australis)*, inland saltgrass (*Distichlis spicata)*,and American basketflower (*Centaurea Americana)*. **Good (recovering)**

Disturbance Response: No annual grasses seen, just forbs, and those in limited number. Looks to have been some time since last disturbance. **Good**

Functional Groups: No annual grasses and few perennial forbs. Warm season midgrass >> warm season tall-grass >> cool season grass > forbs > shrubs. Expected for site. **Good**

C3 vs C4: Dominated by C4s but perennial C3s are present. No annual C3s seen. **Good**

Soils: Exhibit a very slight departure from what would be expected, possibly due to late-stage recovery from last disturbance. **Slight-Moderate**

SITE #2 – southernmost COTTONWOOD – Waypoint # 17 MODERATE CONCERN

General Notes: Similar to Site #1 but with a cottonwood (*Populus deltoids)* component. Cottonwood dieback has occurred but not certain if because of herbicide spraying for tamarisk or a drop in the water table due to drought.

ESD: Sandy Bottomland R077EY065TX (Lincoln soils, frequently flooded)

Landscape-scale Diversity: Cottonwood dieback of concern. While water table may be a factor, the number of tamarisk surrounding them that have been sprayed points to overspray damage. There is rootsprouting and some recruitment taking place which points to the water table being intact. Would have ranked better if not for defoliation **Moderate Concern**

Local-scale Diversity: Poor in many areas but better in a few. There are many grass species but the abundance is very low. Forb diversity is also low, with few perennial species. Species found include: switchgrass (*Panicum virgatum)*, western wheatgrass (*Pascopyron smithii)*, sideoats grama (*Bouteloua curtipendula)*, vine mesquite (*Panicum obtusum)*, sand lovegrass (*Eragrostis trichoides)*, alkaline sacaton (*Sporobolus airoides)*, blue grama (*Bouteloua gracilis)*,

sand dropseed (*Sporobolus cryptandrus)*, purple threeawn (*Aristida purpurea)*,plum (*Prunus angustifolia)*, skunk bush (*Rhus trilobata)*, Hopi tea (*Thelasperma megapoticum)*, milkweed (*Asclepias species)*, souring rush (*Equisetum laevigatum)*, tamarisk (*Tamarix species)* and suspected spiny aster (*Chloracantha spinosa)* **Moderate Concern**

Disturbance Response: There is an abundance of annual forbs, but most are exotic species or annual ragweed (*Ambrosia psilostachya)*. Annual grasses are minimal. Site will likely remain invaded for quite some time. **Significant Concern**

Functional Groups: Cool season midgrass > warm season midgrass> (dead) trees > shrubs > forbs. Out of balance but trying to recover. **Moderate Concern**

C3 vs C4: C4 grasses have been hampered by the perceived aerial herbicide spraying and are only beginning to recover three years later. **Moderate Concern**

Soils: The soils are quite stable. This area is slightly higher than Site #1. **None - Slight**

Site #3 – perennial BOTTOMLAND – Waypoint #18 GOOD

General Notes: Close to river. Inundated two weeks prior to assessment. Numerous low spots held water longer, resulting in more bare ground than one might expect. Upland sheet flow contributed to floodplain moisture. No active erosion of concern. This area receives intermittent prescribed burns, the last in 2010.

ESD: Loamy Bottomland R078BY080TX (Clairemont silty clay loam, occasionally flooded)

Landscape-scale Diversity: A lot of varying topography providing microsites. **Good**

Local-scale Diversity: Very good diversity of all functional groups. Species include: little bluestem (*Schiachyrium scoparium)* and switchgrass (*Panicum virgatum)* close to the river, sand bluestem (*Andopogon hallii)*, Canada eildrye (*Elymus canadensis)*, purple threeawn Aristida purpurea), western wheatgrass (*Pascopyrum smithii)*, indiangrass (*Sorghastrum nutans)*, sand dropseed (*Sporobolus cryptandrus)*, western ragweed (*Machaeranthera tanacetum)*, velvet gaura (*Gaura mollis)*, Illinois bundleflower (*Desmanthus illinoisensis)*. Exotics include: Johnsongrass (*Sorghum halepense)*, Bermudagrass (*Cynodon dactylon)*, possibly spiny aster (*Chlorocantha spinosa)*, salt cedar (*Tamarisk species)*, Russian olive (*Elaeagnus angustifolia)*. **Good**

Disturbance Response: Annuals appear to be quickly filling bare areas. Some native – some exotic. System appears very dynamic and productive. **Good**

Functional Groups: C4 midgrass > C3 midgrass > tallgrass > trees > forbs. **Good**

C3 vs C4: C4s dominate slightly, as they should, and appear to be increasing in abundance. **Good**

Soils: Very stable. **None - Slight**

SITE– UPPER TERRACE/BOTTOMLAND Waypoint #19 SIGNIFICANT CONCERN

General Notes: Upon further consideration, this point seems to be outside of our target assessment area. Additionally, this area has not been rated for an ESD. Therefore, this Site will be dropped from our assessment. This site is located in the area of an old homestead and is highly degraded.

SITE #4– COTTONWOOD (Plum Creek) Waypoint #20 GOOD

General Notes: Best site seen. In climax state and should be harbored by park as a refugia. Exotic invasion patchy and controllable. Was driven through during a wet period, leaving ruts that require rehabilitation.

ESD: Loamy Bottomland R078BY080TX (Clairemont silty clay loam, occasionally flooded)

Landscape-scale Diversity: Very good. Gentle slope from uplands to Plum Creek. **Good**

Local-scale Diversity: Excellent diversity of grasses and forbs. Some cottonwood and hackberry recruitment. Species include: sand bluestem (*Andropogon hallii)*, indiangrass (*Sorghastrum nutans)*, switchgrass (*Panicum virgatum)*, little bluestem (*Schizachyrium scoparium)*, tall dropseed (*Sporobolus compositus)*, sideoats grama (*Bouteloua curtipendula)*, blue grama (*Bouteloua gracilis)*, western wheatgrass (*Pascopyrum smithii)*, vine mesquite (*Panicum obtusum)*, buffalograss (*Buchloe dactyloides)*, inland saltgrass (*Distichlis spicata)*, Fall witchgrass (*Digitaria cognata)*, Illinois bundleflower (*Desmanthus illinoisensis)*, heath aster (*Symphiotrichum ericoides)*, plum (*Prunus angustifolia)*, skunkbush sumac (*Rhus trifoliata)*, coyote willow (*Salix exigua)*, hackberry (*Celtis occidentalis)*, and beautiful healthy cottonwood (*Populus deltoids ssp. monolifera)*. Exotic species include: Johnsongrass (*Sorghum halepense)*, salt cedar (*Tamarisk species)*, Japanese brome (*Bromus japonica)*. **Good**

Disturbance Response: Few to no annual grasses or forbs. Well vegetated **Good**

Functional Groups: Excellent. Warm season tall grass > warm season midgrass > cool season midgrass > trees > forbs = shrubs. **Good**

C3 vs C4: Great balance and diversity **Good**

Soils: Very stable. **None - Slight**

SITE #5 – HONEY MESQUITE (Blue West) Waypoint 21 SIGNIFICANT CONCERN

General Notes: Representative of all mesquite habitat observed in the Blue West area. Area had not received as much rain as other parts of the park. All vegetation looked drought-stressed. Entire area not meeting its potential. At least twice as much bare ground present than is expected for the site.

ESD: Sandy Loam R078BY088TX (Enterprise very fine sandy loam)

Landscape-scale Diversity: Very limited. Site has gentle drainage flowing through center. **Significant Concern**

Local-scale Diversity: Very limited. Grass species limited to small patches except for vine mesquite in the drainage. Forbs primarily annual and exotic. Species include: blue grama (*Bouteloua gracilis)*, buffalograss (*Buchloe dactyloides)*, Halls's panicum (*Panicum hallii)*, sand dropseed (*Sporobolus cryptandrus)*, hairy tridens (*Erioneuron pilosum)*, vine mesquite (*Panicum obtusum)*, sideoats grama (*Bouteloua curtipendula)*, hotsprings dichanthelium (*Dichanthelium acuminatum)*, soapweed yucca (*Yucca glauca)*, bigroot pricklypear (*Opuntia macrorhiza)*, honey mesquite (*Prosopis glandulosa)*, Indian rushpea (*Hoffmannseggia glaucs)*, chicken-thief (*Mentzelia oligosanthes)*, and the exotic prickly Russian thistle (*Salsola tragus)*. **Significant Concern**

Disturbance Response: While annual do try to stabilize the area, it is primarily Russian thistle (*Salsola)*. It completely fills large bare spaces. **Significant Concern**

Functional Groups: C3 midgrass =C4 mid- and short grass > trees > forbs. Should have much, much more C4 grasses, including some tall grasses. **Significant Concern**

C3 vs C4: Out of balance. Abundance of C4 grasses sorely lacking. **Significant Concern**

Soils: Evidence of major sheetflow and surface erosion. Litter/organic matter washed toward drainages. **Moderate**

SITE #6 – Blue West UPLAND – Waypoint 22 GOOD

General Notes: Beautiful! Soil unmapped on Soil Web but matched the description. West/southwest aspect, therefor more arid.

ESD: Gravelly R077EY053TX (Tascosa Gravelly Loam)

Landscape-scale Diversity: Common on rough breaks at LAMR but difficult to access by cattle or humans. **Good**

Local-scale Diversity: Excellent. Contains every species you would want to see. Lots of nostoc and crust. All types of cactus. Species include: blue grama (*Bouteloua gracilis)*, sideoats grama (*Bouteloua vurtipendula)*, Hall's panicum (*Panicum hallii)*, hairy tridens (*Erioneuron pilosum)*, sand dropseed (*Sporobolus cryptandrus)*, buffalograss (*Buchloe dactyloides)*, slim tridens (*Tridens muticus)*, Fall witchgrass (*Digitaria cognate)*, curly mesquite (*Hilaria berlangeri)*, vine mesquite (*Panicum obtusum)*. Hackberry (*Celtis occidentalis)*, honey mesquite (*Prosopsis glandulosa)*, soapweed (*Yucca glauca)*, skunkbush sumac (*Rhus trifloiata)*, cat-claw mimosa (*Mimosa borealis)*, southwestern rabbit brush (*Chrysothamnus pulchellus)*, plains prickly pear (*Opuntia polyacantha)*, broom snakeweed (*Gutierrezia sarothrae)*, blackfoot daisy (*Melampodium leucanthum)*, ten-petal blazingstar (*Mentzelia decapetala)*, trailing ratany (*Krameria lanceolata)*. **Good**

Disturbance Response: No evidence of disturbance and few annuals present. **Good**

Functional Groups: C4 grasses > forbs > subshrubs > shrubs > trees. Grasses are healthy but scattered, as opposed to large patches. What one would expect from a site with arid aspect. **Good**

C3 vs C4: C4s dominate; few C3 grasses present. **Good**

Soils: Surprisingly stable. Gravel and rock provide good covering, augmented by biological soil crust. Some water flow patterns but no active erosion. **None - Slight**

SITE – HONEY MESQUITE west – Waypoint #23 SIGNIFICANT CONCERN

General Notes: This area fell outside of the habitat we were looking for and does not have an associated ESD or soils description. Therefore we will not include this in the assessment. The site is highly degraded and may have received historic impact from road and/or dam construction. There is considerable erosion and a large exotic component of prickly Russian thistle (*Salsola tragus)*. Mesquite treatment has occurred but resprout is evident. There are scattered examples of desirable perennial native grasses in the draws, but most vegetation is early successional. Soil stabilization may be of highest concern in management. One Texas horned toad was observed din this area.

SITE #7 – triangle HONEY MESQUITE – Waypoint #24 MODERATE CONCERN

General Notes: This site had been recently burned and was just beginning recovery. This is a prescribed burn area and was previously burned in 2009. Have observed this site in the past (pre-drought) when it was well vegetated with native perennials. Ranking based on current conditions but trend should positively increase quickly.

ESD: Sandy R0077EY064TX (Likes loamy fine sand)

Landscape-scale Diversity: Diverse topography but currently fire limited. **Good**

Local-scale Diversity: Has great potential, but currently impacted by fire. Amazingly long runners of vine mesquite everywhere! It is possible that several native perennial grasses were not yet expressing due to drought and recent burn. Species include: purple threeawn (*Aristida purpurea)*, sand dropseed (*Sporobolus cryptandrus)*, Fall witchgrass (*Digitaria cognate)*, buffalograss (*Buchloe datyloides)*, Hall's panicum (*Panicum hallii)*, blue grama (*Bouteloua gracilis)*, squirreltail (*Elymus elymoides)*, vine mesquite (*Panicum obtusum)*, curly mesquite (*HIlaria berlangeri)*, sand sage (*Artemisia filifolia)*, mesquite (*Prosopis glandulosa)* regrowth, hackberry (*Celtis occidentalis)*, soapweed (*Yucca glauca)*, prickly pear (*Opuntia species)*, prickly Russian thistle (*Salsola tragus)*, trailing ratany (*Krameria lanceolata)*, western ragweed (*Ambrosia psilostachya)*, goosefoot (*Chenopodium species)*, annual sunflower (*Helianthus annuus)*, silverleaf nightshade (*Solanum elaeagnifolium)*, queens delight (*Stillingia sylvatica)*, heliotrope (*Heliotropium currassavicum)*, sandmat (*Chamaesyce species)*, scarlet beeblossom (*Gaura coccinum)*, Chinese lantern Physalis species), tansyaster (*Machaeranthera pinnatifida)*, portulacca (*Portullaca oleraceae)*, annual buckwheat (*Eriogonum annuum)*, sand bur (*Tribulus terrestris)*, copper mallow (*Sphraealcea coccinea)*, chickenthief (*Mentzelia oligosanthes)*. **Moderate concern**

Disturbance Response: Annuals are responding to the recent fire and rains to stabilize ground. Most are native except for prickly Russian thistle and sand bur. A lot of grass seedlings were observed (two weeks after the first decent rain), but too small to identify. **Good**

Functional Groups: The proportion of functional groups looked good, but difficult to assess due to fire. Assigning rank based on prior knowledge of system. **Good**

C3 vs C4: Unable to assess at this time. Was good in the past.

Soils: These fire-bared soils are showing some erosion but should be more stable in a few months when vegetation has regenerated. Rank is assigned based on current conditions but is probably higher under normal conditions. **Moderate**

SITE #8 – Alibates UPLAND – Waypoint 25 GOOD

General Notes: Northern aspect but generally assessed all sides of rise. Near roadway but not impacted; positioned above/upslope of road. Large rocks instead of more gravelly at out UPLAND Site #6.

ESD: Gravelly R077EY053TX (Tascosa Gravelly Loam)

Landscape-scale Diversity: This type of site is common throughout the park but access limited due to steep slope. **Good**

Local-scale Diversity: Great! Mainly perennial grasses and forbs. Species include: Hall's panicum Panicum hallii), Fall witchgrass (*Digitaria cognate)*, slender tridens (*Tridens muticus)*, purple threeawn (*Aristida purpurea)*, sideoats grama (*Bouteloua gracilis)*, sand bluestem (*Andropogon hallii)*, needle and thread (*Heterostipa comata)*, switchgrass (*Panicum virgatum)*, hairy grama (*Bouteloua hirsuta)*, feather dalea (*Dales Formosa)*, soapweed (*Yucca glauca)*, prickly pear (*Opuntia species)*, sand sage (*Atemisia filifolia)*, catclaw mimosa (*Mimosa borealis)*, annual buckwheat (*Eriogonum annuum)*, prickly Russian thistle (*Salsola tragus)*, trailing ratany (*Krameria lanceolata)*, scarlet beeblossom (*Guara coccinea)*, ten-petal blazingstar (*Mentzelia decapetala)*, rushpea (*Hoffmannseggia glauca)*, annual pricklypoppy (*Argemone polyanthemos)*, calylophus (*Calylophus species)*, blackfoot daisy (*Melampodium leucanthemum)*, erect dayflower (*Commellina erecta)*, queen's delight (*Stillingia sylvatica)*, David's spurge (*Euphorbia davidii)*. **Good**

Disturbance Response: Some areas of prickly Russian thistle and silverleaf nightshade (*Solanum elaeagnifolium)* but in manageable numbers. Not recently disturbed. **Good**

Functional Groups: Good balance, warm season midgrass >> cool season grass > shrubs > forbs > subshrub. **Good**

C3 vs C4: Did not observe many cool season grasses, but habitat looks balanced. **Good**

Soils: Drought-impacts of last three years evident, primarily due to less plant cover and exposure to wind. Still what one would expect for the area for most measures. Scouring falls between two measures (Slight) so I would rank as **None - Slight**

Appendix G: Exotic Plant Species at Lake Meredith NRA

The following table lists exotic species that are and have been documented within Lake Meredith (Folts-Zettner 2014). Only the species recorded during SOPN monitoring 2012-2014, including the 2014 rapid assessment, were ranked for significance of impact (e.g., the species' innate ability to become a pest), and for feasibility of management using the Handbook for Ranking Exotic Plants for Management and Control (Hiebert and Stubbendieck 1993). Other species that have been documented in the park were not ranked because they were found during recent monitoring.

Scientific Name	Common Name	2012-2014 Survey[1] (N=342)	2014 Assess.[2] (N=160)	Noxious[3]	Significance of Impact[4]	Feasibility of Management[5]
Achillea millefolium	common yarrow					
Aegilops cylindrica	jointed goat grass					
Agrostis gigantea	redtop bentgrass					
Amaranthus blitoides	prostrate pigweed					
Amaranthus retroflexus	redroot pigweed	0.9%	10.0%		Low (29)	Difficult (25)
Bothriochloa ischaemum var. songarica	king ranch bluestem	30.4%	ND		Highest (41)	Difficult (16)
Bromus catharticus	rescue brome	2.3%	ND		Low (25)	Difficult (16)
Bromus japonicus	Japanese brome	9.9%	ND		High (35)	Difficult (21)
Bromus tectorum[6]	cheatgrass	1.5%	ND		Highest (41)	Difficult (16)
Camelina microcarpa	smallseed false flax					
Chenopodium album[6]	lamb's quarters	15.2%	16.9%		Low (27)	Easily Controlled (50)
Chenopodium glaucum	oakleaf goosefoot					
Cichorium intybus	chicory					
Convolvulus arvensis	field bindweed	2.3%	ND	X	Highest (46)	Extremely Difficult (6)
Coronilla varia	purple crownvetch					
Cynodon dactylon	Bermudagrass	0.9%	ND		High (39)	Extremely Difficult (11)
Cyperus esculentus	yellow nutsedge					
Cyperus rotundus	cocograss					
Descurainia sophia	flixweed					
Digitaria sanguinalis	hairy crabgrass					
Echinochloa crus-galli	barnyardgrass					
Elaeagnus angustifolia	Russian olive	0.6%	ND		Highest (40)	Difficult (16)
Eragrostis barrelieri	Mediterranean lovegrass					
Eragrostis cilianensis	stinkgrass	0.3%	ND		Low (27)	Difficult (20)
Eragrostis curvula	weeping lovegrass					
Erodium cicutarium	redstem stork'sbill					
Erysimum repandum	bushy wallflower					
Euphorbia spp[7]	David's or toothed spurge	0.3%	61.3%		High (37)	Extremely Difficult (11)
Kochia scoparia	kochia	15.5%	28.1%		Medium (32)	Medium (30)

Scientific Name	Common Name	2012-2014 Survey[1] (N=342)	2014 Assess.[2] (N=160)	Noxious[3]	Significance of Impact[4]	Feasibility of Management[5]
Lactuca serriola	prickly lettuce	1.8%	ND		Medium (34)	Medium (32)
Lamium amplexicaule	henbit					
Lolium perenne	perennial ryegrass					
Lolium temulentum	Darnel ryegrass					
Malva neglecta	roundleaf mallow					
Marrubium vulgare	horehound					
Medicago lupulina	black medik clover					
Medicago minima	burr medick clover	1.5%	ND		Medium (32)	Extremely Difficult (15)
Medicago sativa	alfalfa					
Melilotus alba	white sweetclover					
Melilotus indicus	annual yellow sweetclover					
Melilotus officinalis	yellow sweetclover	0.6%	ND		Low (29)	Difficult (21)
Moluccella laevis	shellflower					
Morus alba	white mulberry					
Myriophyllum spicatum	Eurasian water-milfoil					
Panicum miliaceum	proso millet					
Poa pratensis	Kentucky bluegrass					
Polygonum arenastrum	prostrate knotweed	0.3%	ND		Low (29)	Easily Controlled (40)
Polygonum aviculare	yard knotweed					
Polygonum convolvulus	climbing buckwheat					
Polypogon monspeliensis	annual rabit's-foot grass					
Polypogon viridis	beardless rabbit'sfootgrass					
Rumex crispus	curley dock					
Rumex stenophyllus	narrowleaf dock					
Salsola collina	slender Russian thistle					
Salsola tragus[8]	prickly Russian thistle	76.6%	81.3%		Medium (32)	Difficult (21)
Schedonorus arundinaceus	tall fescue					
Scorzonera laciniata	cutleaf vipergrass					
Setaria pumila ssp. pallidifusca	yellow bristlegrass					
Setaria viridis	green bristlegrass					
Sisymbrium altissimum	tumble mustard					
Sonchus asper	spiny sowthistle					
Sorghum halepense	Johnsongrass	3.2%	3.1%		Highest (45)	Difficult (21)
Tamarix spp.[7]	saltcedar	2.1%	ND	X	Highest (48)	Difficult (21)
Taraxacum officinale	dandelion					
Tragopogon dubius	western salsify	9.9%	ND		Low (25)	Medium (31)
Tribulus terrestris	puncturevine					
Trifolium repens	ladino clover					
Ulmus pumila	Siberian elm	2.3%	1.9%		Medium (32)	Medium (30)

Table Notes:

ND = Not Detected.

[1] Data from monitoring of the SOPN Annual Exotic Plant monitoring along high priority vectors 2012 - 2014 (Folts-Zettner and Sosinski 2012b; 2013; 2014).

[2] Data from the SOPN 2014 Rapid Assessment (Horsley and Schafer 2014).

[3] Noxious = Texas state noxious status (USDA-NRCS 2014).

[4] Significance of Impact measures the species potential to alter native plant communities. This measure was derived the Handbook for Ranking Exotic Plants for Management and Control (Hiebert and Stubbendieck 1993). Significance of Exotic Plant Impact, Innate Ability of Species to Become a Pest is a numerical ranking between 0 and 50. The numerical rankings were assigned into the following categories: 40 - 50 = Highest Concern; 35 - 39 = High Concern; 30 - 34 = Medium Concern; 0 - 29 = Low Concern. Numbers in parentheses after the descriptive ranking are the actual assigned numeric scores. Species that are potentially native were not ranked. Rankings by Kimberly Struthers, Allyson Mathis and Tomye Folts-Zettner.

[5] Feasibility of Management was derived from the Handbook for Ranking Exotic Plants for Management and Control (Hiebert and Stubbendieck 1993). Species were ranked for this measure excluding some ranking elements (A, Abundance in Park, and B4, Abundance and proximity of propagules near park) in order to evaluate management feasibility independent of population numbers for the exotic species. The measure is a numeric ranking between 0 and 75, with lower values indicating that an infestation of this species is difficult to manage. The numerical rankings were assigned into the following categories: 0 - 15 = Extremely Difficult; 16 - 25 = Difficult; 26 - 35 = Medium; 36 - 75 = Easily Controlled. Numbers in parentheses after the descriptive ranking are the actual assigned numeric scores. Species that are potentially native were not ranked. Rankings by Kimberly Struthers, Allyson Mathis and Tomye Folts-Zettner.

[6] Species found during SOPN monitoring 2012-2014 (Folts-Zettner and Sosinski 2012b; 2013; 2014) not previously reported in SOPN exotic species data for the park (Folts-Zettner 2014).

[7] *Euphorbia davidii* and *Euphorbia dentata* were found in 2012-2014 SOPN monitoring, but were treated together in this assessment. *Tamarix chinensis*, and *Tamarix ramosissima* were found in 2012-2014 SOPN monitoring, but were treated as together in this assessment. T*amarix gallica* is also on the Lake Meredith species list (Folts-Zettner 2014).

[8] Species of special concern (Folts-Zettner, personal communication, 2014).

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Appendix H: Background on Bird Species of Conservation Concern Lists

This appendix provides background information on the organizations and efforts to determine species of birds that are in need of conservation. The information presented here supports Section 4.11.2, Data and Methods, of the breeding landbirds chapter. This appendix contains some of the same, but additional, information as that section of the report.

One component of the landbird condition assessment was to assess species occurrence in a conservation context. We compared the list of species that occur at Lake Meredith National Recreation Area (NRA) / Alibates Flint Quarries National Monument (NM) (i.e., those detected during Rocky Mountain Bird Observatory [RMBO] surveys at the parks during 2009-2013) to lists of species of conservation concern developed by several organizations. There have been a number of such organizations that focus on the conservation of bird species. Such organizations may differ, however, in the criteria they use to identify and/or prioritize species of concern based on the mission and goals of their organization. They also range in geographic scale from global organizations such as the International Union for Conservation of Nature (IUCN), who maintains a "Red List of Threatened Species," to local organizations or chapters of larger organizations. This has been, and continues to be, a source of confusion, and perhaps frustration, for managers and others who need to make sense of and apply the applicable information. In recognition of this, the U.S. North American Bird Conservation Initiative (NABCI) was started in 1999; it represents a coalition of government agencies, private organizations, and bird initiatives in the U.S. working to ensure the conservation of North America's native bird populations. Although there remain a number of sources at multiple geographic and administrative scales for information on species of concern, the NABCI has made great progress in developing a common biological framework for conservation planning and design.

One of the developments from the NABCI was the delineation of Bird Conservation Regions (BCRs) (U.S. North American Bird Conservation Initiative 2014). Bird Conservation Regions are ecologically distinct regions in North America with similar bird communities, habitats, and resource management issues.

The purpose of delineating these BCRs was to:

- facilitate communication among the bird conservation initiatives;
- systematically and scientifically apportion the U.S. into conservation units;
- facilitate a regional approach to bird conservation;
- promote new, expanded, or restructured partnerships; and
- identify overlapping or conflicting conservation priorities.

H.1. Conservation Organizations Listing Species of Conservation Concern

Below we present a summary of some of the organizations that list species of conservation concern and briefly discuss the different purposes or goals of each organization.

U.S. Fish & Wildlife Service

The Endangered Species Act, passed in 1973, is intended to protect and recover imperiled species and the ecosystems upon which they depend. It is administered by the U.S. Fish and Wildlife Service (USFWS) and the Commerce Department's National Marine Fisheries Service (NMFS). USFWS has primary responsibility for terrestrial and freshwater organisms, while the responsibilities of NMFS are mainly marine wildlife, such as whales, and anadromous fish.

State of Texas

In 1973, the Texas Parks and Wildlife Department (TPWD) was authorized to develop a list of endangered and threatened animal species in the state. Legal protection of endangered and threatened animals is provided by laws and regulations contained in Chapters 67 and 68 of the Texas Parks and Wildlife Code and Sections 65.171-65.176 of Title 31 of the Texas Administrative Code (TPWD 2014a).

USFWS Birds of Conservation Concern

The USFWS has responsibilities for wildlife, including birds, in addition to endangered and threatened species. The Fish and Wildlife Conservation Act, as amended in 1988, further mandates that the USFWS "identify species, subspecies, and populations of all migratory nongame birds (i.e., Birds of Conservation Concern) that, without additional conservation actions, are likely to become candidates for listing under the Endangered Species Act" (USFWS 2008). The agency's 2008 effort, *Birds of Conservation Concern*, is one effort to fulfill the Act's requirements. The report includes both migratory and non-migratory bird species (beyond those federally-listed as threatened or endangered) that USFWS considers the highest conservation priorities. Three geographic scales are included--National, USFWS Regional, and the NABCI BCRs. The information used to compile the lists came primarily from the following three bird conservation plans: the Partners in Flight North American Landbird Conservation Plan, the U.S. Shorebird Conservation Plan, and the North American Waterbird Conservation Plan. The scores used to assess the species are based on factors such as population trends, distribution, threats, and abundance.

National Audubon Society/American Bird Conservancy

The National Audubon Society and American Bird Conservancy each formerly published their own lists of bird species of concern, but have recently combined efforts into a single "Watch List". This collaborative effort was based on a concern by these organizations that there were too many lists with similar purposes (Butcher et al. 2007). Their 2007 WatchList is based on, but not identical to, the Partners in Flight (PIF) approach to species assessment (see below).

The 2007 WatchList has two primary levels of concern: a "Red WatchList" and a "Yellow WatchList", although the latter is subdivided into two categories. The Red WatchList identifies what these organizations consider as species of highest national concern. This list overlaps considerably with the IUCNs "Red List" (not presented here), thus, can essentially be considered as a list of globally threatened birds that occur in the United States (Butcher et al. 2007). The Yellow WatchList is made up of species that are somewhat less critical, but serves as an early warning list of birds that have the potential of being elevated to the Red WatchList. Species on this list can be there either because their populations are declining or because they are considered rare.

Partners in Flight

Partners in Flight is a cooperative effort among federal, state, and local government agencies, as well as private organizations. One of its primary goals, relative to listing species of conservation concern, is to develop a scientifically based process for identifying and finding solutions to risks and threats to landbird populations. Their approach to identifying and assessing species of conservation concern is based on biological criteria to evaluate different components of vulnerability (Panjabi et al. 2005). Each species is evaluated for six components of vulnerability: population size, breeding distribution, non-breeding distribution, threats to breeding, threats to non-breeding, and population trend. The specific process is presented in detail in the species assessment handbook (Panjabi et al. 2005).

The PIF assessments are conducted at multiple scales. At the broadest scale, the North American Landbird Conservation Plan (Rich et al. 2004) identifies what PIF considers "Continental Watch List Species" and "Continental Stewardship Species." Continental Watch List Species are those that are most vulnerable at the continental scale,

due to a combination of small and declining populations, limited distributions, and high threats throughout their ranges (Panjabi et al. 2005). Continental Stewardship Species are defined as those species that have a disproportionately high percentage of their world population within a single Avifaunal Biome during either the breeding season or the non-migratory portion of the non-breeding season.

More recently, PIF has adopted BCRs, the common planning unit under the NABCI, as the geographic scale for updated regional bird conservation assessments. These assessments are available via an online database (http://www.rmbo.org/pif/pifdb.html) maintained by RMBO. At the scale of the individual BCRs, these same principles of concern (sensu Continental Watch List Species) or stewardship (sensu Continental Stewardship Species) are applied at the BCR scale. The intention of this approach is to emphasize conservation of species where it is most relevant, as well as the recognition that some species may be experiencing dramatic declines locally even if they are not of high concern nationally, etc. There are two categories (concern and stewardship) each for Continental and Regional levels. The details of the criteria for inclusion in each can be found in Panjabi et al. (2005), and a general summary is as follows. Note that in our Chapter 4 breeding landbird analysis, we did not use the two stewardship categories.

Criteria for Species of Continental Importance

A. Continental Concern (CC)

- Species is listed on the Continental Watch List (Rich et al. 2004).
- Species occurs in significant numbers in the BCR.
- Future conditions are not enhanced by human activities.

B. Continental Stewardship (CS)

- Species is listed as Continental Stewardship Species (Rich et al. 2004).
- Relatively high density (compared to highest density regions) and/or a high proportion of the species occurs in the BCR.
- Future conditions are not enhanced by human activities.

Criteria for Species of Regional Importance

Regional scores are calculated for each species according to which season(s) they are present in the BCR. The formulae include a mix of global and regional scores pertinent to each season (see Panjabi et al. 2005 for details). The criteria for each category are:

A. Regional Concern (RC)

- Regional Combined Score > 13 (see Panjabi et al. 2005 for details).
- High regional threats or moderate regional threat combined with significant population decline.
- Occurs regularly in significant numbers in the BCR.

B. Regional Stewardship (RS)

- Regional Combined Score > 13 (see Panjabi et al. 2005 for details).
- High importance of the BCR to the species.
- Future conditions are not enhanced by human activities.

Texas Species of Greatest Conservation Need

The State of Texas also designated species that, "due to limited distributions and/or declining populations, face the threat of extirpation or extinction but lack legal protection" (TPWD 2014b). The lists were developed for the TPWD's Texas Conservation Action Plan (TPWD 2012). Species are rated or ranked using a system developed by NatureServe, and lists are available for each of 11 ecoregions in the state.

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Appendix I: Lake Meredith NRA and Alibates Flint Quarries NM Bird Lists

Listed below are the bird species recorded during 2009-2013 RMBO surveys (in one or more of the years) and the 2002-2003 inventory by The Nature Conservancy during the breeding season (Patrikeev 2004) at Lake Meredith National Recreation Area (NRA) and Alibates Flint Quarries National Monument (NM).

Common Name	2009-2013 Surveys (RMBO)	Patrikeev (2004): Lake Meredith NRA [1]	Patrikeev (2004): Alibates Flint Quarries NM
American Avocet	X	X	
American Coot	X	X	
American Crow	X	X	
American Goldfinch	X		
American Kestrel	X	X	X
American Pipit	X		
American Robin		X	
Ash-throated Flycatcher	X	X	X
Baird's Sparrow	X		
Bank Swallow	X		
Barn Owl	X	X	
Barn Swallow	X		
Bell's Vireo	X		
Belted Kingfisher	X	X	
Bewick's Wren	X	X	
Black-crowned Night-Heron		X	
Black-headed Grosbeak	X		
Black-necked Stilt		X	
Black-throated Sparrow	X		
Blue Grosbeak	X	X	X
Blue Jay	X	X	
Blue-gray Gnatcatcher	X		
Blue-winged Teal	X	X	
Brewer's Blackbird	X		
Brown Thrasher	X	X	
Brown-headed Cowbird	X	X	X
Bullock's Oriole	X	X	X
Burrowing Owl	X		
Cactus wren	X		
Canyon Wren	X		
Carolina Chickadee	X	X	
Cassin's Sparrow	X	X	X
Chihuahuan Raven	X		
Chipping Sparrow	X		
Cinnamon Teal		X	

[1] Patrikeev (2004) also recorded an unidentified raven, either Common Raven or Chihuahuan Raven.

[2] Common name used to be Common Moorhen, which is how Patrikeev (2004) listed the species.

Common Name	2009-2013 Surveys (RMBO)	Patrikeev (2004): Lake Meredith NRA [1]	Patrikeev (2004): Alibates Flint Quarries NM
Clay-colored Sparrow	X		
Cliff Swallow	X	X	
Common Gallinule [1]		X	
Common Grackle	X	X	
Common Nighthawk	X	X	X
Common Poorwill	X	Adjacent to park	
Common Yellowthroat	X	X	
Cooper's Hawk	X		
Dark-eyed Junco	X		
Dickcissel	X		
Double-crested Cormorant		X	
Downy Woodpecker	X	X	
Eared Grebe	X		
Eastern Bluebird	X	X	
Eastern Kingbird	X	X	
Eastern Meadowlark	X	X	X
Eastern Phoebe	X		
Eastern Screech-Owl		X	
Eurasian Collared-Dove	X		
European Starling	X	X	X
Field Sparrow	X	X	
Franklin's Gull	X		
Gadwall		X	
Grasshopper Sparrow	X		
Gray Flycatcher	X		
Gray-cheeked thrush	X		
Great Blue Heron	X	X	
Great Horned Owl	X	X	X
Greater Roadrunner	X	X	X
Great-tailed Grackle	X		
Green Heron		X	
Green-winged Teal		X	
Hermit Thrush	X		
Horned Lark	X		
House Finch	X		
House Sparrow	X	X	
House Wren	X		
Indigo Bunting	X		
Killdeer	X	X	
Ladder-backed Woodpecker	X	X	X
Lark Bunting	X		
Lark Sparrow	X	X	X
Loggerhead Shrike	X	X	X

[1] Patrikeev (2004) also recorded an unidentified raven, either Common Raven or Chihuahuan Raven.

[2] Common name used to be Common Moorhen, which is how Patrikeev (2004) listed the species.

Common Name	2009-2013 Surveys (RMBO)	Patrikeev (2004): Lake Meredith NRA [1]	Patrikeev (2004): Alibates Flint Quarries NM
Long-billed Dowitcher	X		
Mallard	X	X	
Mississippi Kite	X	X	
Mourning Dove	X	X	X
Northern Bobwhite	X	X	X
Northern Cardinal	X	X	X
Northern Flicker	X	X	X
Northern Harrier	X		
Northern Mockingbird	X	X	X
Northern Pintail	X		
Northern Rough-winged Swallow	X		
Northern Shoveler	X	X	
Olive-sided Flycatcher	X		
Orange-crowned Warbler	X		
Orchard Oriole	X	X	
Painted Bunting	X	X	X
Peregrine Falcon	X		
Pied-billed Grebe	X		
Pine Siskin	X		
Red-bellied Woodpecker	X		
Red-headed Woodpecker	X	X	X
Red-tailed Hawk	X	X	X
Red-winged Blackbird	X	X	X
Ring-necked Pheasant	X	X	
Rock Pigeon	X		
Rock Wren	X	X	X
Rose-breasted grosbeak	X		
Ruby-crowned Kinglet	X		
Ruddy Duck	X	X	
Rufous-crowned Sparrow	X	X	X
Say's Phoebe	X		
Scaled Quail	X	X	
Scissor-tailed Flycatcher	X	X	X
Sharp-shinned Hawk	X		
Song sparrow	X		
Spotted Towhee	X		
Summer Tanager	X		
Swainson's Hawk	X		
Turkey Vulture	X	X	X
Vesper Sparrow	X		
Virginia Rail		X	
Virginia's Warbler	X		

[1] Patrikeev (2004) also recorded an unidentified raven, either Common Raven or Chihuahuan Raven.

[2] Common name used to be Common Moorhen, which is how Patrikeev (2004) listed the species.

Common Name	2009-2013 Surveys (RMBO)	Patrikeev (2004): Lake Meredith NRA [1]	Patrikeev (2004): Alibates Flint Quarries NM
Western Kingbird	X	X	X
Western Meadowlark	X	X	X
Western Scrub-Jay	X		
Western Wood-Pewee	X		
White-breasted Nuthatch	X		
White-crowned Sparrow	X		
White-faced Ibis	X	X	
Wild Turkey	X	X	
Willow Flycatcher	X		
Wilson's Phalarope	X		
Yellow Warbler	X		
Yellow-billed Cuckoo	X	X	X
Yellow-headed Blackbird	X		
Yellow-rumped Warbler	X		

[1] Patrikeev (2004) also recorded an unidentified raven, either Common Raven or Chihuahuan Raven.

[2] Common name used to be Common Moorhen, which is how Patrikeev (2004) listed the species.

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