National Park Service
U.S. Department of the Interior

Natural Resource Stewardship and Science

Grant-Kohrs Ranch National Historic Site

Natural Resource Condition Assessment

Natural Resource Report NPS/GRKO/NRR—2015/1071

ON THE COVER
View from the back porch of the Grant-Kohrs Ranch House, looking northwest
Photograph by: Kathy Allen, SMUMN GSS

Grant-Kohrs Ranch National Historic Site

Natural Resource Condition Assessment

Natural Resource Report NPS/GRKO/NRR—2015/1071

Kathy Allen
Sarah Gardner
Kevin Benck
Andy Nadeau
Lonnie Meinke
Thomas Walker
Mike Komp
Keaton Miles
Barry Drazkowski

GeoSpatial Services
Saint Mary's University of Minnesota
890 Prairie Island Road
Winona, Minnesota 55987

October 2015

U.S. Department of the Interior
National Park Service
Natural Resource Stewardship and Science
Fort Collins, Colorado

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

The Natural Resource Report Series is used to disseminate comprehensive information and analysis about natural resources and related topics concerning lands managed by the National Park Service. The series supports the advancement of science, informed decision-making, and the achievement of the National Park Service mission. The series also provides a forum for presenting more lengthy results that may not be accepted by publications with page limitations.

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.

This report is available in digital format from the Integrated Resource Management Applications website (http://irma.nps.gov) and the Natural Resource Publications Management website (http://www.nature.nps.gov/publications/nrpm/). To receive this report in a format optimized for screen readers, please email irma@nps.gov.

Please cite this publication as:

Allen, K., S. Gardner, K. Benck, A. Nadeau, L. Meinke, T. Walker, M. Komp, K. Miles, and B. Drazkowski. 2015. Grant-Kohrs Ranch National Historic Park: Natural resources condition assessment. Natural Resource Report NPS/GRKO/NRR—2015/1071. National Park Service, Fort Collins, Colorado.

NPS 451/130317, October 2015

Contents

Contents (continued)

Page

Contents (continued)

Page

Contents (continued)

Page

Contents (continued)

Page

Contents (continued)

Figures

Page

Figures (continued)

Page

Figures (continued)

Page

Figures (continued)

Page

Figures (continued)

Page

Tables

Page

Tables (continued)

Page

Tables (continued)

Page

Tables (continued)

Page

Photos

Photos (continued)

Page

Appendices

Page

Executive Summary

The Natural Resource Condition Assessment (NRCA) Program aims to provide documentation about the current conditions of important park natural resources through a spatially explicit, multi-disciplinary synthesis of existing scientific data and knowledge. Findings from the NRCA will help Grant-Kohrs Ranch National Historic Site (GRKO) managers to develop near-term management priorities, engage in watershed or landscape scale partnership and education efforts, conduct park planning, and report program performance (e.g., Department of the Interior's Strategic Plan "land health" goals, Government Performance and Results Act).

The objectives of this assessment are to evaluate and report on current conditions of key park resources, to evaluate critical data and knowledge gaps, and to highlight selected existing stressors and emerging threats to resources or processes. For the purpose of this NRCA, staff from the National Park Service (NPS) and Saint Mary's University of Minnesota – GeoSpatial Services (SMUMN GSS) identified key resources, referred to as "components" in the project. The selected components include natural resources and processes that are currently of the greatest concern to park management at GRKO. The final project framework contains 13 resource components, each featuring discussions of measures, stressors, and reference conditions.

This study involved reviewing existing literature and, where appropriate, analyzing data for each natural resource component in the framework to provide summaries of current condition and trends in selected resources. When possible, existing data for the established measures of each component were analyzed and compared to designated reference conditions. A weighted scoring system was applied to calculate the current condition of each component. Weighted Condition Scores, ranging from zero to one, were divided into three categories of condition: low concern, moderate concern, and significant concern. These scores help to determine the current overall condition of each resource. The discussions for each component, found in Chapter 4 of this report, represent a comprehensive summary of current available data and information for these resources, including unpublished park information and perspectives of park resource managers, and present a current condition designation when appropriate. Each component assessment was reviewed by GRKO resource managers, NPS Rocky Mountain Network staff, and outside experts, when appropriate.

Existing literature, short- and long-term datasets, and input from NPS and other outside agency and academic scientists support condition designations for components in this assessment. However, in some cases, data were unavailable or insufficient for several of the measures of the featured components. In other instances, data establishing reference condition were limited or unavailable for components, making comparisons with current information inappropriate or invalid. In these cases, it was not possible to assign condition for the components. Current condition was not able to be determined for 3 of the 13 components (23%) due to these data gaps.

For those components with sufficient available data, the overall condition varied. Six components were determined to be in good condition: pastures and hayfields, birds, periphyton, aquatic macroinvertbrates, air quality, and viewscape. However, periphyton and aquatic macroinvertbrates scores were at the edge of the good condition range, and any small decline in the community could shift them into the moderate concern range. Of the components in good condition, only viewscape showed a declining trend, due to increasing development outside the park. The remaining four components (riparian area, water quality, soundscape, and soils) were of moderate concern. Water quality showed a slightly improving trend while soundscape showed a declining trend, due to increased traffic (air, train, and road). No components were considered to be of significant concern. Detailed discussion of these designations is presented in Chapters 4 and 5 of this report.

Several park-wide threats and stressors influence the condition of priority resources in GRKO. Those of primary concern include invasive exotic plant species, historic mining contamination, and associated Superfund remediation activities. Understanding these threats, and how they relate to the condition of park resources, can help the NPS prioritize management objectives and better focus their efforts to maintain the health and integrity of the park ecosystem, as well as its cultural landscape.

Acknowledgments

We acknowledge Grant-Kohrs Ranch National Historic Site staff (present and past) for the technical expertise provided during scoping, through multiple stages of review, and via phone and email; specifically, Jason Smith, Jeff Johnson, Chris Ford, and Eric Mason. Bret Olson and Peter Rice assisted with project scoping, data gathering, and document review. Rocky Mountain Inventory and Monitoring Network staff, including Mike Britten and Billy Schweiger, offered logistical insight and critical review of interim documents. Donna Shorrock, Intermountain Region NRCA Coordinator, and Jeff Albright, Natural Resource Condition Assessment Coordinator, provided program guidance. Thank you to all others who assisted the development of this document.

Acronyms and Abbreviations

AUM - Animal Unit Month

BLM – Bureau of Land Management

CAA - Clean Air Act

CBC - Christmas Bird Count

CGS - Columbian Ground Squirrel

CLR - Cultural Landscape Report

dB - Decibels

DEM – Digital Elevation Model

DO - Dissolved Oxygen

EPA – Environmental Protection Agency

GIS – Geographic Information System

GRKO - Grant-Kohrs Ranch National Historic Site

HCPC - Historic Climax Plant Community

I&M - Inventory and Monitoring

IMPROVE - Interagency Monitoring of Protected Visual Environments Program

IMR - Intermountain Region

MMI - Multimetric Indices

MSU - Montana State University

MT DEQ - Montana Department of Environmental Quality

NAAQS - National Ambient Air Quality Standards

NADP - National Atmospheric Deposition Program

NCDC - National Climatic Data Center

NLCD – National Land Cover Dataset

NPS - National Park Service

NPS ARD – National Park Service Air Resources Division

NRCA – Natural Resource Condition Assessment

NRCS - Natural Resources Conservation Service

NRM EPMT - Northern Rocky Mountain Exotic Plant Management Team

NVC – National Vegetation Classification

NWI - National Wetland Inventory

PLFA - phospholipid fatty acid

PM – Particulate Matter

P.Z. - Precipitation Zone

RIVPACS - River Invertebrate Prediction and Classification

ROMN - Rocky Mountain Network

SMUMN GSS – Saint Mary's University of Minnesota, Geospatial Services

TSS - Total Suspended Sediment

USDA - United States Department of Agriculture

USFS – United States Forest Service

USFWS – United States Fish and Wildlife Service

USGS – United States Geological Survey

VCSS - Vegetation Composition, Structure, and Soils

WCS - Weighted Condition Score

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 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

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.

---

[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.

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; 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 decisionmaking, planning, and partnership activities.

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

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 an 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.

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 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://nature.nps.gov/water/nrca/index.cfm.

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)

[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.

Chapter 2 Introduction and Resource Setting

2.1 Introduction

2.1.1 Enabling Legislation

Grant-Kohrs Ranch National Historic Site (GRKO) was established by President Richard Nixon on 25 August 1972:

> Be it enacted by the Senate and House of Representatives of the United States of America in Congress assembled that in order to provide an understanding of the frontier cattle era of the Nation's history, to preserve Grant-Kohrs Ranch, and to interpret the nationally significant values thereof for the benefit and inspiration of present and future generations, the Secretary of the Interior is hereby authorized to designate not more than two thousand acres in Deer Lodge Valley, Powell County, Montana, for the establishment as the Grant-Kohrs Ranch National Historic Site. (PL 92-406)

The ranch at GRKO was founded in 1862 by John Grant and was later purchased by Conrad Kohrs, who operated the ranch from 1866-1920. On 19 December 1960, GRKO was designated as a National Historic Landmark (John Milner Associates et al. 2004). GRKO is considered an exceptional demonstration of the open range cattle industry that was present in the American West during the 19th and early 20th centuries (John Milner Associates et al. 2004). The 1972 historic site legislation created a boundary that included 558 ha (1,378 ac). In 1988, an additional 48.6 ha (120 ac) were purchased from Conrad Kohrs-Warren and added to the park under public law (PL 91-646).

Photo 1. Rear yard of the Grant-Kohrs Ranch House, circa 1890 (Grant-Kohrs Ranch NHS Archives 6280H).

On 11 July 2003, Grant-Kohrs Ranch-Warren Ranch historic district was listed on the National Register of Historic Places by the Montana State Historic Preservation Office for its importance to the state of Montana under Criteria A and C in the areas of agriculture and architecture (John Milner Associates et al. 2004). The GRKO historic district boundary encompasses all of the land within the National Historic Landmark boundary and also includes the Warren Hereford Ranch. GRKO continues to be an actively operating ranch with ongoing activities facilitated by the NPS that include: livestock grazing, hay production, irrigation, fencing, and noxious weed control (John Milner Associates et al. 2004).

2.1.2 Geographic Setting

GRKO is located in the intermountain grassland region of western Montana, along the Clark Fork of the Columbia River in Deer Lodge Valley (John Milner Associates et al. 2004; Figure 1). The ranch is positioned just northwest of the city of Deer Lodge in Powell County. When GRKO was established by Congress in 1972, the NPS was given permission to acquire no more than 810 ha (2,000 ac) of land in Deer Lodge Valley. After the initial founding of the park, land acquisitions and scenic easements were purchased throughout the 1980s and 1990s, increasing the park from its original 88 ha (217 acres) to 655 ha (1,618 acres) (John Milner Associates et al. 2004).

Figure 1. Location of GRKO in Deer Lodge Valley.

The Deer Lodge Valley has a semi-arid inland mountain climate, with average annual high and low temperatures of 13.3°C (55.9°F) and -3.1°C (26.4°F) degrees, respectively (NCDC 2015; Table 1). On average, 27 cm (10.6 in) of precipitation occurs per year, with the majority during the months of May and June (NCDC 2015).

Table 1. 30-year climate normals (1981-2010) for the Deer Lodge 3W weather station near GRKO (NCDC 2015).

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
Average Temperature (°C)													
Max	1.2	3.2	8.2	12.9	17.3	21.6	26.8	26.7	21.1	14.1	5.9	0.1	13.3
Min	-11.4	-10.5	-6.3	-3.2	0.7	4.5	6.6	5.5	1.2	-3.4	-8.4	-12.7	-3.1
Average Precipitation (cm)													
Total	0.6	0.8	1.0	1.8	4.8	5.2	4.2	3.3	2.5	1.4	0.7	0.6	27.0

2.1.3 Visitation Statistics

From 2010 to 2014, GRKO received an average of 19,775 recreational visitors per year (NPS 2015a). During that 5-year period, visitation peaked in 2010 when just over 22,000 people visited. In 2012, 17,095 people visited GRKO, which is the second lowest number during the 36 years of tracking recreational visitation (there were 16,663 visitors in 2008) (NPS 2015a).

Photo 2. The Grant-Kohrs ranch house (photo by Sarah Gardner, SMUMN GSS 2013).

The main activities that attract visitors to GRKO are the interpretive programs. Interpretive uses are focused within the Home Ranch Complex, which contains interpretive exhibits coupled with the surrounding landscape (Photo 2); this provides context for visitors to acquire an understanding of historic ranching operations (Figure 2). There are a large variety of interpretive programs, including: demonstrations by cowboys and ranch hands of the different skills needed in ranching (e.g., cattle wrangling and haying), tours of the main ranch house, interpretive tours in horse-drawn wagons, and costumed interpretation of ranch life (NPS 2015b).

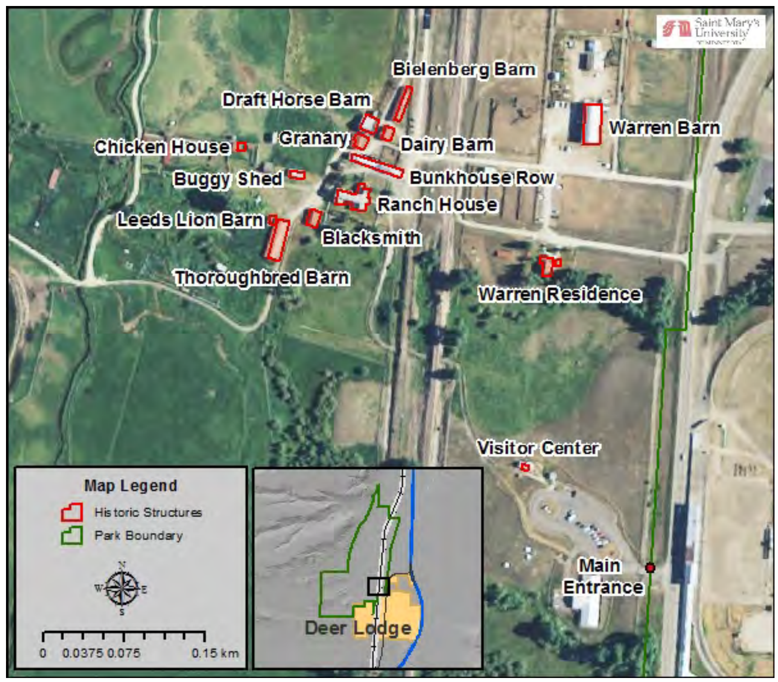


Figure 2. Main historic buildings and features, including the Visitor Center and main entrance to the park.

2.2 Natural Resources

2.2.1 Ecological Units and Watersheds

The ranch lies within the Northern Rocky Mountains Physiographic Province, which contains recent alluvial and glacial deposits in addition to rocks of Precambrian to Tertiary age (Thornberry-Ehrlich 2007). GRKO also falls within the Environmental Protection Agency's (EPA) Middle Rockies Level III Ecoregion. According to the EPA (2010, p. 4), intermontane valleys in this ecoregion "are grass- and/or shrub-covered and contain a mosaic of terrestrial and aquatic fauna that is distinct from the nearby mountains. Many mountain-fed, perennial streams occur and differentiate the intermontane valleys from the Northwestern Great Plains."

GRKO sits within the Clark Fork River-Deer Lodge Watershed. The Clark Fork River (Photo 3) and its tributaries are responsible for depositing the rich alluvial soils found on the ranch that are a fertile mixture of sand, clay, and organic matter (John Milner Associates et al. 2004). The topography, rich soils, and abundant fresh water provide the necessary natural resources to support domestic and ranching activities (John Milner Associates et al. 2004).

Photo 3. The Clark Fork River in GRKO (photo by Sarah Gardner, SMUMN GSS 2013).

2.2.2 Resource Descriptions

GRKO's greatest resource is its historical significance and its accurate portrayal of its history to the public, along with the preservation of the landscape. It should be noted that the small size of GRKO may limit management's influence over the natural resources because not all of the resources that fall within the park boundaries stay within park boundaries.

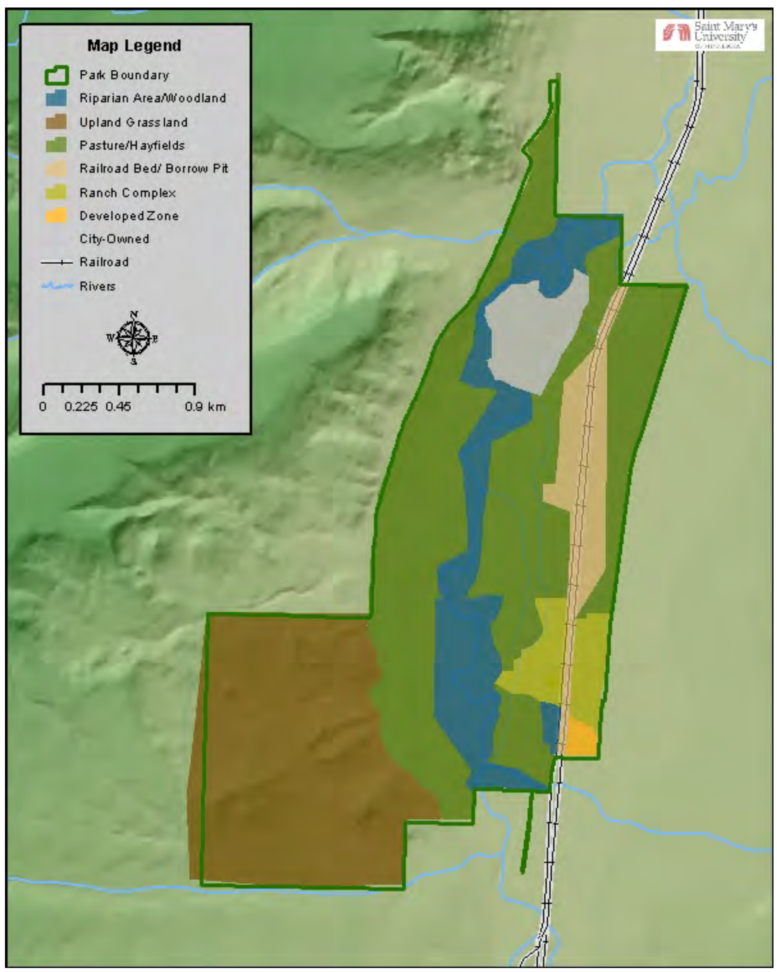


Figure 3. Landscape components of GRKO.

GRKO supports a number of vegetation communities and a variety of plant species. Originally, this area was dominated by native grasses with trees and shrubs along the riparian areas (Rice et al. 2012). Today, the ranch can be divided into three broad vegetation communities: upland grasslands, irrigated pastures and hayfields, and riparian areas (Figure 3). The upland grasslands are still dominated by native species and are not irrigated, while the pastures and hayfields contain primarily introduced grasses to provide forage for livestock (Rice et al. 2012). The riparian areas include the Clark Fork floodplain, several tributaries, and a small number of isolated wetlands. These areas support herbaceous species (grasses and forbs) as well as shrubs and trees.

Photo 4. Native grasses growing on northern slope of foothill in GRKO upland grassland (photo by Kathy Allen, SMUMN GSS 2013).

According to the NPS (2014), 341 plant species have been documented in the park. Approximately 25% of these species are non-native, although many were introduced for ranching purposes and are now considered part of the cultural landscape of the park (John Milner Associates et al. 2004). Native grasses present include bluebunch wheatgrass (*Pseudoroegneria spicata*), western wheatgrass (*Pascopyrum smithii*), needle-and-thread (*Hesperostipa comata*), and blue grama (*Bouteloua gracilis*) (Photo 4; Rice et al. 2012). Common introduced grasses are smooth brome (*Bromus inermis*), timothy (*Phleum pratense*), Kentucky bluegrass (*Poa pratensis*), and redtop (*Agrostis stolonifera*). The riparian areas support several species of willow (*Salix* spp.) and isolated stands of black cottonwood (*Populus balsamifera* ssp. *trichocarpa*) (Rice et al. 2012).

Since the park is a working ranch, cattle, horses, and ranch cats are the most commonly seen animals at GRKO. The cattle population consists of three cow breeds: Hereford, Shorthorn, and Longhorn (Photo 5; NPS 2013). GRKO is also abundant in wildlife, with at least 35 species of mammals that either pass through seasonally or live on the ranch year round (NPS 2013). These species include white-tailed deer (*Odocoileus virginianus*), moose (*Alces alces*), coyote (*Canis latrans*), beaver (*Castor canadensis*), and many small mammals (NPS 2013).

Photo 5. Cattle breeds managed on GRKO, including Hereford, Shorthorn, and Longhorn (from left to right) (NPS photo).

A wide variety of bird species also inhabit the ranch at various times of year. According to NPS (2014), 230 bird species are classified as "present" or "probably present" in GRKO. Some common resident birds include bald eagles (*Haliaeetus leucocephalus*), chickadees (*Poecile* spp.), and black-billed magpies (*Pica pica*). Common breeding birds are great blue heron (*Ardea herodias*), red-tailed hawk (*Buteo jamaicensis*), and several duck species (family Anatidae) (NPS 2013). Osprey (*Pandion haliaetus*) are uncommon, but have nested on a power pole inside the park.

Photo 6. Bull trout (NPS photo).

The Clark Fork River and its associated creeks are home to 11 fish species, both native and non-native (NPS 2014). Common native species in GRKO include suckers (*Catostomus* spp.), mottled sculpin (*Cottus bairdii*), and redside shiner (*Richardsonius balteatus*). The Clark Fork River is also critical habitat for bull trout (*Salvelinus confluentus*), a federally threatened species (Photo 6), although none have been documented within the park recently (NPS 2011a). The bull trout is just one species that has been adversely affected by polluted waters; however, habitat conditions seem to be improving due to remediation efforts along the Clark Fork (described in Section 2.2.2 below) (Eric Mason, former GRKO Superfund Manager, oral communication, 30 October 2013). The three non-native species found in the park are rainbow trout (*Oncorhynchus mykiss*), brown trout (*Salmo trutta*), and brook trout (*Salvelinus fontinalis*) (NPS 2014). Trout are an important park resource, as fishing opportunities in the Clark Fork have been known to draw visitors to the ranch.

The riparian areas also provide habitat for reptiles, amphibians, and aquatic macroinvertebrates. Reptiles such as the painted turtle (*Chrysemys picta*) and common garter snake (*Thamnophis sirtalis*) are found at the park. Amphibian species documented in the park include the western toad (*Anaxyrus boreas*), and Columbia spotted frog (*Rana luteiventris*) (NPS 2013).

2.2.2 Resource Issues Overview

Effectively allocating resources associated with sustaining a working ranch in an environmentally responsible manner, while simultaneously conducting public education through interpretation as a National Historic Site provides many challenges. A working ranch can be described as a self-sustaining agricultural business with the intent to generate profit from the production of livestock (John Milner Associates et al. 2004). The GRKO ranch is unlike a privately-owned ranch, since its purpose is for public education and preservation of the historic ranching lifestyle, rather than generating a profit from livestock production (NPS 1993). In addition to the difficulties that are associated with maintaining a working cattle ranch, there are difficulties that arise when presenting an interpretation of the history of the western U.S. range cattle industry. For example, the ranch must operate efficiently, but the animals must also be visible to park visitors while still remaining within the necessary constraints of public safety, animal welfare, and responsible land use (John Milner Associates et al. 2004). Further challenges are posed by trying to meet ranching and interpretive objectives while preventing further "wear and tear" on the various historic features (e.g., fences, barns, other outbuildings) as well as natural community processes (John Milner Associates et al. 2004).

Much of the vegetation found on the ranch consists of non-native species of grasses and forbs, many of which were introduced as hay species and pasture grasses. Although these intentionally-introduced species are non-native, they are considered "contributing features" on the cultural landscape, as they represent the history of ranching in the area (John Milner Associates et al. 2004). Other non-native species are considered invasive and have become a significant concern at GRKO. These include spotted knapweed (*Centaurea stoebe*), leafy spurge (*Euphorbia esula*), yellow toadflax (*Linaria vulgaris*), Canada thistle (*Cirsium arvense*), and field bindweed (*Convolvulus arvensis*) (Rice 2003, Wood and Rew 2005). These invasive species can alter plant community composition and ecological processes (e.g., water and nutrient cycling) and contribute to biodiversity and habitat losses (Lacey et al. 1989, NPS 2008). At GRKO, invasive plants also threaten the cultural landscape the park was set aside to protect, and can reduce forage quality (Manier et al. 2011). A full list of non-native species documented in GRKO is included as Appendix A. Species classified as noxious weeds by the state of Montana or identified as priority species for control by the Northern Rocky Mountains Exotic Plant Management Team (NPS 2011b) are noted in this appendix.

The GRKO riparian area is located within the Upper Clark Fork River Superfund Site, which was designated by the EPA in 1992 (NPS 2007). The upper reaches and tributaries of the Clark Fork River contain heavy metals, such as arsenic, cadmium, copper, zinc, and lead as a result of historic mining, milling, and smelting activities occurring in Anaconda and Butte, Montana (MT DEQ 2013). Mining for gold and silver in the Upper Clark Fork (south of GRKO) began on a small scale in the 1860s and 1870s (Horstman 1984). However, the completion of a transcontinental railroad line in 1883 allowed heavy equipment to be transported into the area and mining activities intensified (Horstman 1984). The wastes from these mining activities, called "tailings", accumulated along the stream banks where mining occurred. The flood of 1908, which is the largest recorded flood event for the area, washed these tailings downstream and into GRKO. According to Thornberry-Ehrlich (2007), there is a 10 km (6 mi) stretch of river in the Deer Lodge River Valley with as much as

704,000 m^3 (24,862,00 ft^3) of contaminated sediment in a 274 ha (677 ac) area. These metal tailings, now mixed in with the soils on the floodplain, pose a threat to wildlife and human health (Photo 7; MT DEQ 2013). In the coming years, Superfund remediation efforts will remove approximately 296,110 m^3 (387,297 yd^3) of soil to an average depth of 0.7 m (2.3 ft) from the GRKO riparian zone in order to restore the health of area (Jeff Johnson, GRKO CERCLA Project Manager, written communication, 17 October 2014). These areas will be backfilled with clean soil to support native plant revegetation and return the floodplain to a 2-year flood level (NPS 2007).

Photo 7. Clark Fork River bank with visible metal tailings approximately one to two feet below the vegetation layer (photo by Sarah Gardner, SMUMN GSS 2013).

Global climate change is expected to impact the entire U.S. during this century, although the expected changes vary across the country. Since 1951, the regional climate around GRKO has shown little change; annual mean temperatures have remained relatively stable, although mean spring temperatures have increased slightly (Figure 4; PRISM 2014). Mean annual precipitation also increased slightly (Figure 5; PRISM 2014). Over the next century, mean annual precipitation around GRKO is predicted to remain stable or increase slightly (2-3% by 2100), but summer precipitation is actually predicted to decrease (~10% by 2050, ~19% by 2100) (Figure 7, Figure 9; Maurer et al. 2007). Annual mean temperature is expected to increase by 2.2-2.8°C (4-5°F) by 2050 and 3.3-3.9°C (6-7°F) by 2100 (Figure 6, Figure 8; Maurer et al. 2007). Even though annual precipitation is predicted to increase slightly in the area, the expected warmer temperatures will increase evaporation rates and plant transpiration (i.e., plant water use). This is predicted to result in greater aridity, meaning overall drier conditions, particularly in the summer (Figure 10; Maurer et al. 2007).

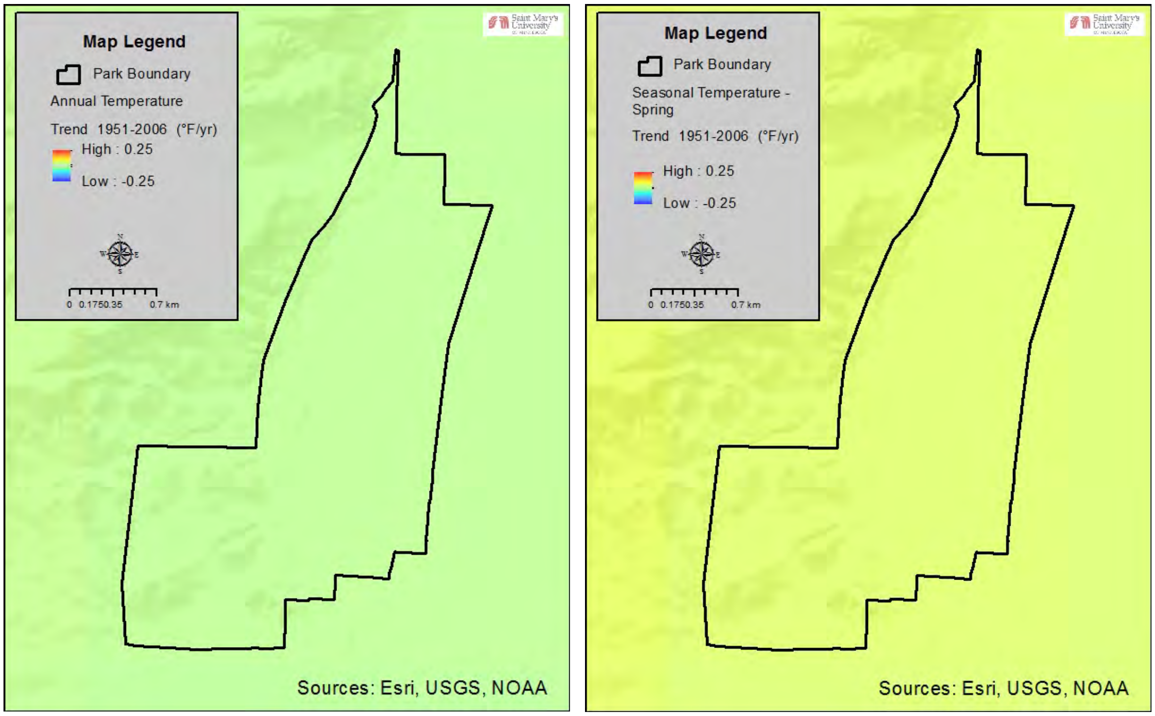


Figure 4. Change in mean annual temperature (left) and mean spring temperature (right) in the GRKO region between 1951 and 2006 (PRISM 2014).

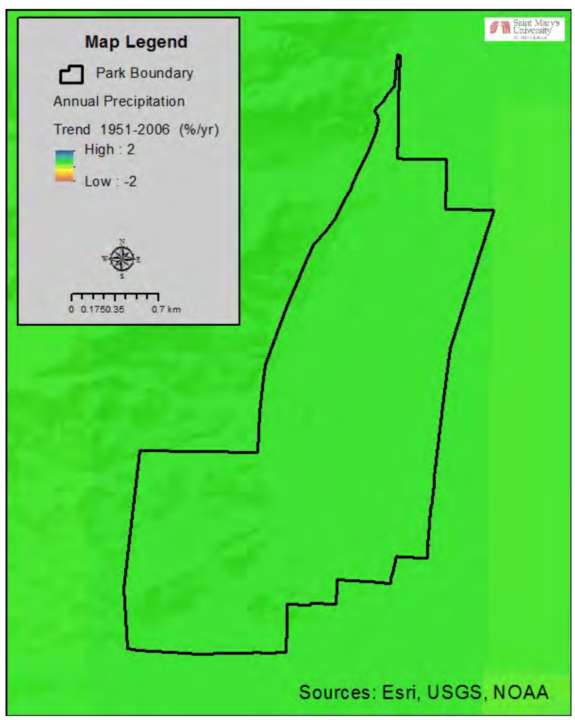


Figure 5. Change in mean annual precipitation in the GRKO region between 1951 and 2006 (PRISM 2014).

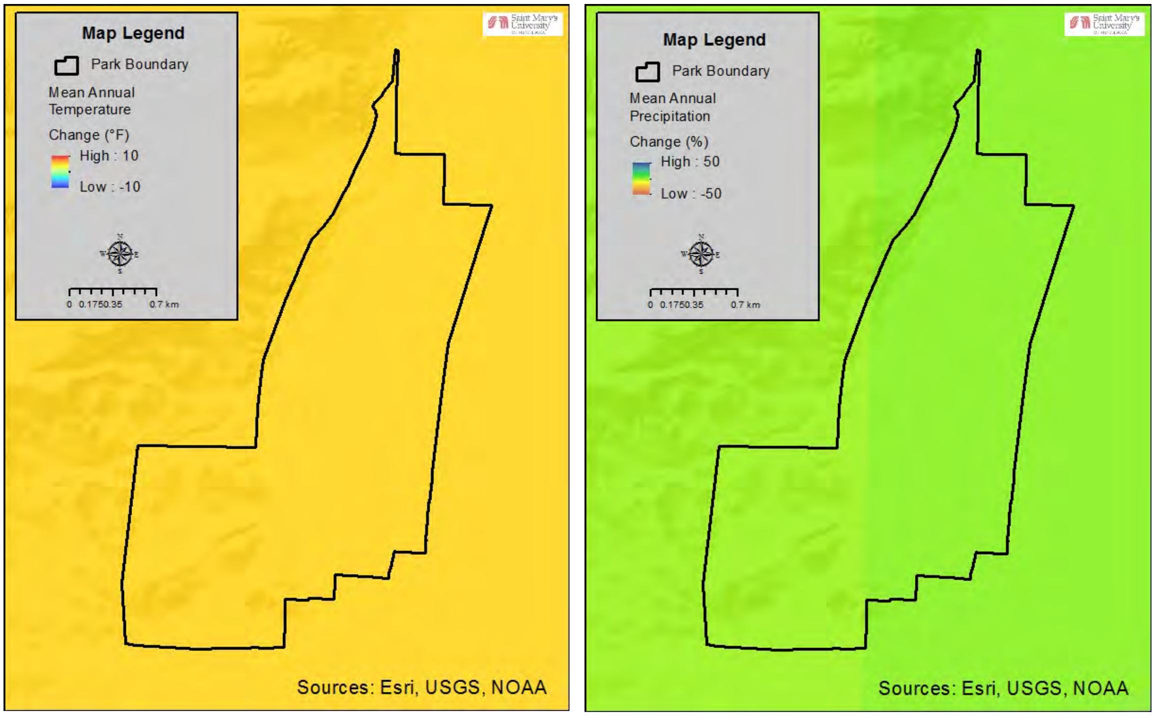


Figure 6. Projected change in mean **annual** temperature (left) and mean **annual** precipitation (right) in the GRKO region by 2050 (Maurer et al. 2007). Projections based on an ensemble average (E-50) circulation model and the A1B (medium) emissions scenario.

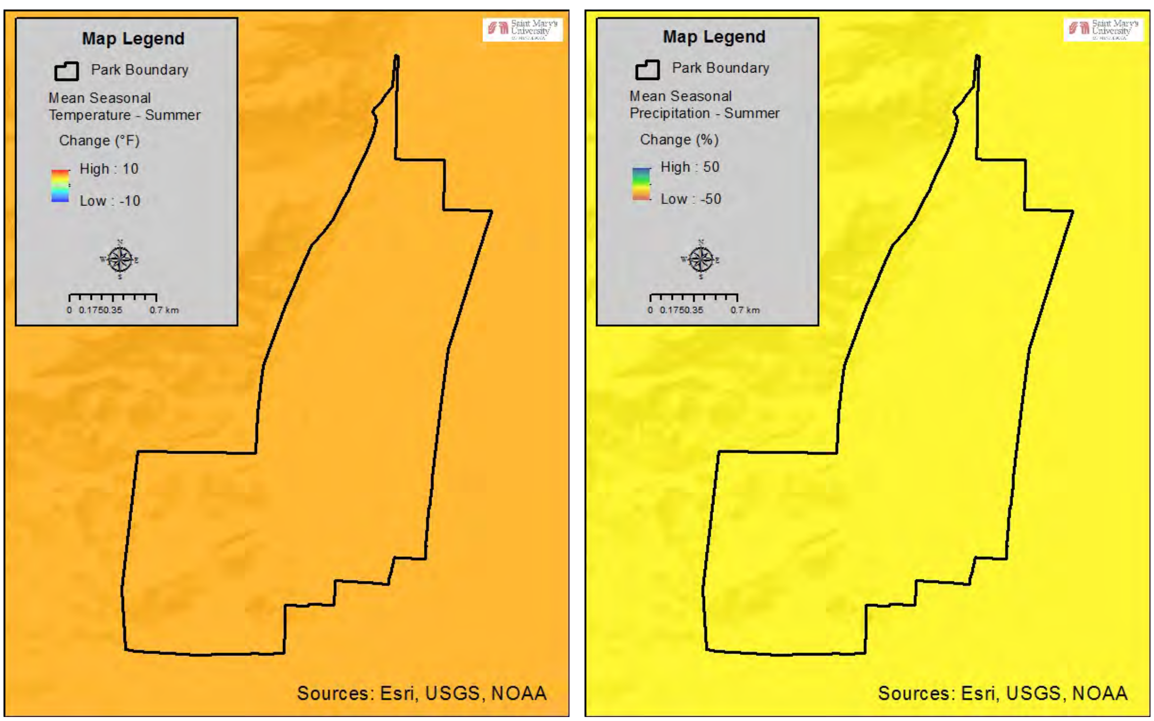


Figure 7. Projected change in mean **summer** temperature (left) and mean **summer** precipitation (right) in the GRKO region by 2050 (Maurer et al. 2007). Projections based on an ensemble average (E-50) circulation model and the A1B (medium) emissions scenario.

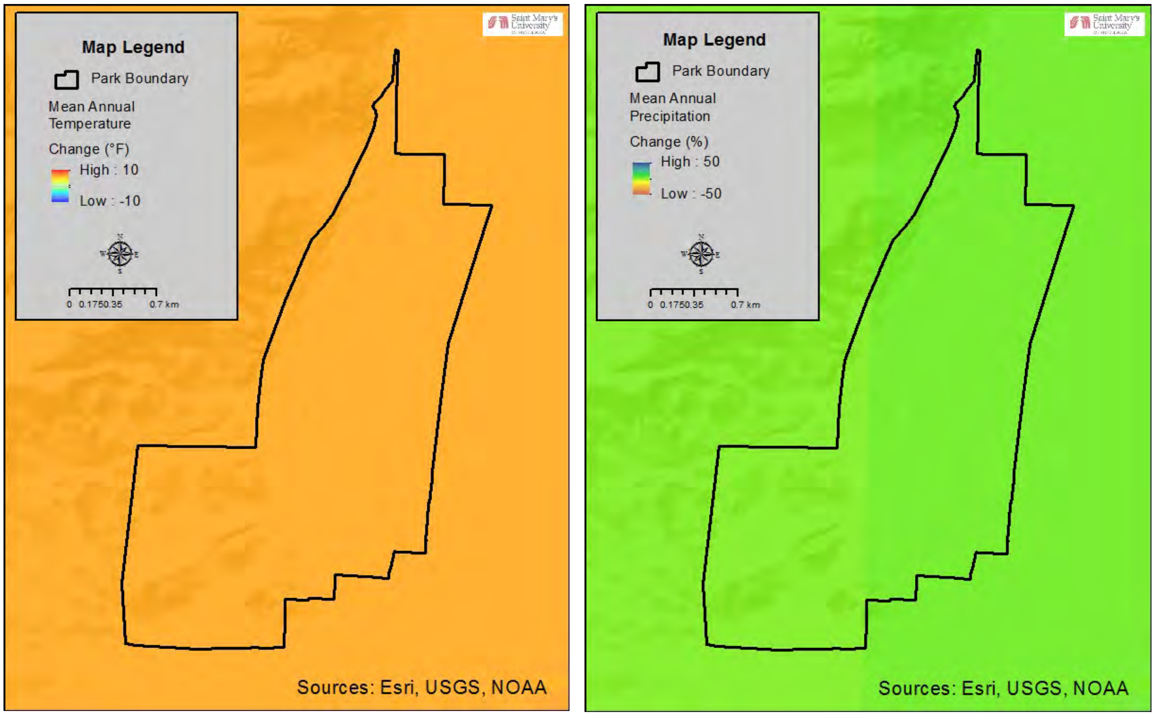


Figure 8. Projected change in mean **annual** temperature (left) and mean **annual** precipitation (right) in the GRKO region by 2100 (Maurer et al. 2007). Projections based on an ensemble average (E-50) circulation model and the A1B (medium) emissions scenario.

Figure 9. Projected change in mean **summer** temperature (left) and mean **summer** precipitation (right) in the GRKO region by 2100 (Maurer et al. 2007). Projections based on an ensemble average (E-50) circulation model and the A1B (medium) emissions scenario.

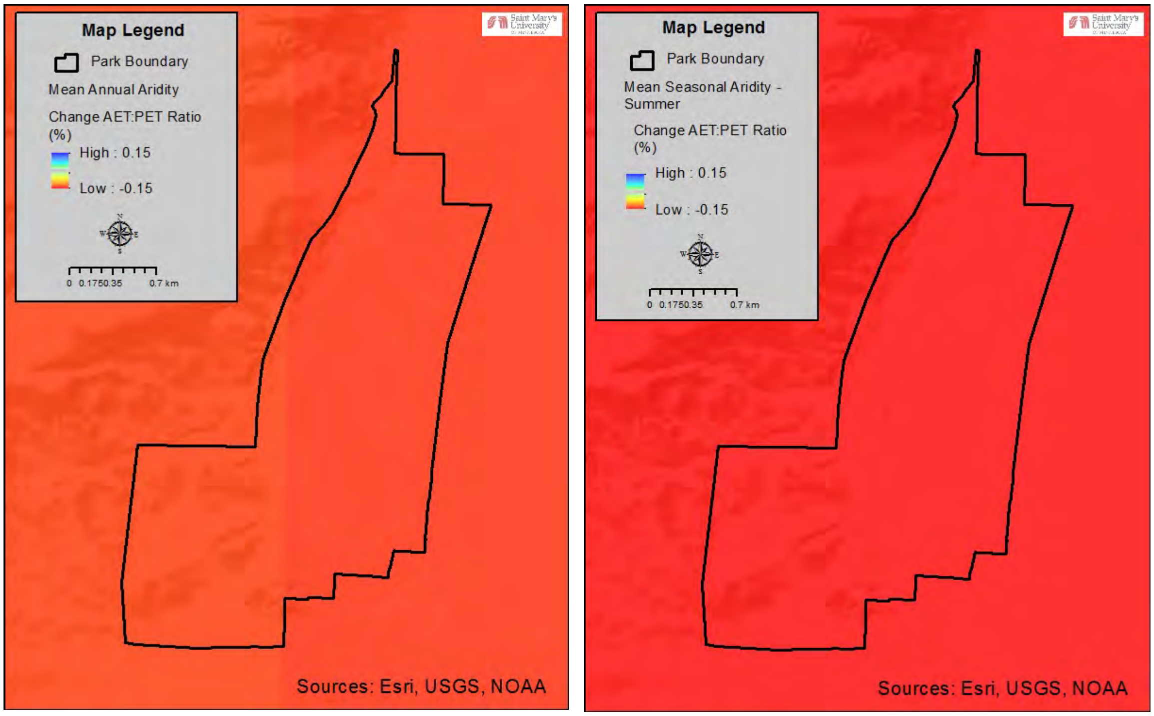


Figure 10. Projected change in mean annual aridity (left) and mean summer aridity (right) by 2100, as predicted by the change in AET:PET ratio (Maurer et al. 2007). Projections based on an ensemble average (E-50) circulation model and the A1B (medium) emissions scenario.

2.3 Resource Stewardship

2.3.1 Management Directives and Planning Guidance

GRKO's general management plan (NPS 1993, p. 3) established three management objectives for the park:

- To provide opportunities for the visitor to understand the cattle industry and its evolution from the open range of the mid-1860s, to mechanized feedlot operations that began in the 1930s and extended until establishment of the park in the 1970s.
- To maintain historic structures, buildings, objects, and landscapes in such a manner as to complement the ranch's primary purpose and enhance visitor understanding and appreciation of cattle ranch operations.
- To manage natural resources in such a manner as to compliment the historic context of the ranch and cattle ranching operations.

GRKO also strives towards sustainable ranching, which "maintains and improves grassland and riparian health, supports vigorous livestock and wildlife populations that result in economic success, educational opportunity and community benefit beyond a single generation" (NPS 2011c).

2.3.2 Status of Supporting Science

The Rocky Mountain Network (ROMN) identifies key resources network-wide and for each of its parks that can be used to determine the overall health of the parks. These key resources are called

Vital Signs. In 2007, the ROMN completed and released a Vital Signs Monitoring Plan (Britten et al. 2007). Table 2 shows the network vital signs selected for monitoring in GRKO.

Table 2. ROMN Vital Signs selected for monitoring in GRKO (Britten et al. 2007). Bold indicates Vital Signs being monitored by a network park, another NPS program, or another federal or state agency, using other funding.

Category	ROMN Vital Signs
Air and Climate	**Weather and climate**
Geology & Soils	Stream/ river channel characteristics, soil function and dynamics (grasslands)
Water	Water chemistry, surface water dynamics, aquatic macroinvertebrates and algae, groundwater dynamics
Biological Integrity	Invasive/exotic plants, grassland vegetation
Landscapes (Ecosystem Pattern and Processes)	Land cover and use

In addition to the ROMN, researchers from several universities in the region (e.g., University of Montana in Missoula and Montana State University in Bozeman) have contributed to the scientific knowledge base for GRKO. This work provided valuable information for the NRCA.

Literature Cited

Britten, M., E. W. Schweiger, B. Frakes, D. Manier, and D. Pillmore. 2007. Rocky Mountain Network Vital Signs monitoring plan. Natural Resource Report NPS/ROMN/NRR-2007/010. National Park Service, Fort Collins, Colorado.

Environmental Protection Agency (EPA). 2010. Primary distinguishing characteristics of Level III and IV Ecoregions of the continental United States. http://www.epa.gov/wed/pages/ecoregions/level_iii_iv.htm (accessed 17 February 2015).

Horstman, M. C. 1984. Historical events associated with the Upper Clark Fork drainage. Montana Department of Fish, Wildlife, and Parks, Helena, Montana.

John Milner Associates, Rivanna Archaeological Consulting, Susan Maxman and Partners Architects. 2004. Cultural landscape report. National Park Service, Deer Lodge, Montana.

Lacey, J. R., C. B. Marlow, and J. R. Lane. 1989. Influence of spotted knapweed (*Centaurea maculosa*) on surface runoff and sediment yield. Weed Technology 3(4):627-631.

Manier, D., D. Shorrock, E. W. Schweiger, I. Ashton, B. Frakes, M. Britten, D. Pillmore, and J. Burke. 2011. Rocky Mountain Network vegetation composition structure and soils monitoring protocol: Small park grasslands, shrublands, and woodlands; Version 1.0. Natural Resource Report NPS/ROMN/NRR-2011/383. National Park Service, Fort Collins, Colorado.

Maurer, E. P., L. Brekke, T. Pruitt, and P. B. Duffy. 2007. Base climate projections (downscaled): 2050 mid century (2040-2069), 2100 end century (2070-2099) (12km resolution). http://www.climatewizard.org/ (accessed 28 July 2014).

Montana Department of Environmental Quality (MT DEQ). 2013. Clark Fork River operable unit. Montana.gov official website. http://deq.mt.gov/fedsuperfund/cfr.mcpx (accessed 15 January 2014).

National Climatic Data Center (NCDC). 2015. 1981-2010 normals for Deer Lodge 3W. http://www.ncdc.noaa.gov/cdo-web/datatools/normals (accessed 17 February 2015).

National Park Service (NPS). 1993. Grant-Kohrs Ranch National Historic Site: Environmental impact statement for a general management plan and development concept plan. National Park Service, Deer Lodge, Montana.

National Park Service (NPS) 2007. Federal restoration plan for Grant-Kohrs Ranch National Historic Site. National Park Service, Deer Lodge, Montana.

National Park Service (NPS). 2008. Exotic plant management team: 2008 annual report. National Park Service, Biological Resources Management Division, Fort Collins, Colorado.

National Park Service (NPS). 2011a. Fisheries biological assessment and evaluation (bull trout). Appendix Q *in* Northern Rocky Mountains invasive plant management plan and environmental assessment. National Park Service, Fort Collins, Colorado.

National Park Service (NPS). 2011b. Northern Rocky Mountains invasive plant management plan. National Park Service, Fort Collins, Colorado.

National Park Service (NPS) 2011c. Grant-Kohrs Ranch: Sustainable ranching. http://www.nps.gov/grko/learn/management/upload/Sustainable-Ranching-2-28-11.pdf (accessed 17 February 2015).

National Park Service (NPS). 2013. Animals. http://www.nps.gov/grko/naturescience/animals.htm (accessed 18 December 2013).

National Park Service (NPS). 2014. NPSpecies. http://irma.nps.gov/NPSpecies/Search/ (accessed 18 November 2014).

National Park Service (NPS). 2015a. Visitor use statistics. https://irma.nps.gov/Stats/Reports/Park (accessed 17 February 2015).

National Park Service (NPS). 2015b. Grant-Kohrs National Historic Site: Guided tours. http://www.nps.gov/grko/planyourvisit/guidedtours.htm (accessed 17 Februrary 2015).

PRISM Climate Group. 2014. Climate data: United States (Lower 48 and Conterminous) past 50 years (1951-2006) (4km resolution). http://www.prism.oregonstate.edu/historical/ (accessed 28 July 2014).

Rice, P. M. 2003. Discussion outline for Grant-Kohrs Ranch weed management and restoration. National Park Service unpublished report, Deer Lodge, Montana.

Rice, P. M., E. W. Schweiger, W. Gustafson, C. Lea, D. Manier, D. Shorrock, B. Frakes, and L. O'Gan. 2012. Vegetation classification and mapping project report, Grant-Kohrs Ranch National Historic Site. Natural Resource Report NPS/ROMN/NRR-2012/589. National Park Service, Fort Collins, Colorado.

Thornberry-Ehrlich, T. 2007. Grant-Kohrs Ranch National Historic Site geologic resource evaluation report. Natural Resource Report NPS/NRPC/GRD/NRR—2007/004. National Park Service, Denver, Colorado.

Wood, S. D., and D. L. J. Rew. 2005. Non-native plant survey at Grant-Kohrs Ranch National Historic Site. Montana State University, Bozeman, Montana.

Chapter 3 Study Scoping and Design

This NRCA is a collaborative project between the NPS and Saint Mary's University of Minnesota Geospatial Services (SMUMN GSS). Project stakeholders include the GRKO resource management team and ROMN Inventory and Monitoring Program staff. Before embarking on the project, it was necessary to identify the specific roles of the NPS and SMUMN GSS. Preliminary scoping meetings were held, and a task agreement and a scope of work document were created cooperatively between the NPS and SMUMN GSS.

3.1 Preliminary Scoping

A preliminary scoping meeting was held on 29-31 October 2013. At this meeting, SMUMN GSS and NPS staff confirmed that the purpose of the GRKO NRCA was to evaluate and report on current conditions, critical data and knowledge gaps, and selected existing and emerging resource condition influences of concern to GRKO managers. Certain constraints were placed on this NRCA, 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;
- The analysis of natural resource conditions includes a strong geospatial component;
- Resource focus and priorities are primarily driven by GRKO resource management.

This condition assessment provides a "snapshot-in-time" evaluation of the condition of a select set of park natural resources that were identified and agreed upon by the project team. Project findings will aid GRKO resource managers in the following objectives:

- Develop near-term management priorities (how to allocate limited staff and funding resources);
- Engage in watershed or landscape scale partnership and education efforts;
- Consider new park planning goals and take steps to further these;
- Report program performance (e.g., Department of Interior Strategic Plan "land health" goals, Government Performance and Results Act [GPRA]).

Specific project expectations and outcomes included the following:

- For key natural resource components, consolidate available data, reports, and spatial information from appropriate sources including: GRKO resource staff, the NPS Integrated Resource Management Application (IRMA) website, Inventory and Monitoring Vital Signs program, and available third-party sources. The ROMN report will provide a resource assessment and summary of pertinent data evaluated through this project.

- When appropriate, define a reference condition so that statements of current condition may be developed. The statements will describe the current state of a particular resource with respect to an agreed upon reference point.

- Clearly identify "management critical" data (i.e., those data relevant to the key resources). This will drive the data mining and gap definition process.

- Where applicable, develop GIS products that provide spatial representation of resource data, ecological processes, resource stressors, trends, or other valuable information that can be better interpreted visually.

- Utilize "gray literature" and reports from third party research to the extent practicable.

3.2 Study Design

3.2.1 Indicator Framework, Focal Study Resources and Indicators

Selection of Resources and Measures

As defined by SMUMN GSS in the NRCA process, a "framework" is developed for a park or preserve. This framework is a way of organizing, in a hierarchical fashion, bio-geophysical resource topics considered important in park management efforts. The primary features in the framework are key resource components, measures, stressors, and reference conditions.

"Components" in this process are defined as natural resources (e.g., birds, plant communities), ecological processes or patterns (e.g., natural fire regime), or specific natural features or values (e.g., geological formations) that are considered important to current park management. Each key resource component has one or more "measures" that best define the current condition of a component being assessed in the NRCA. Measures are defined as those values or characterizations that evaluate and quantify the state of ecological health or integrity of a component. In addition to measures, current condition of components may be influenced by certain "stressors," which are also considered during assessment. A "stressor" is defined as any agent that imposes adverse changes upon a component. These typically refer to anthropogenic factors that adversely affect natural ecosystems, but may also include natural processes or disturbances such as floods, fires, or predation (adapted from GLEI 2010).

During the GRKO NRCA scoping process, key resource components were identified by NPS staff and are represented as "components" in the NRCA framework. While this list of components is not a comprehensive list of all the resources in the park, it includes resources and processes that are unique to the park in some way, or are of greatest concern or highest management priority in GRKO. Several measures for each component, as well as known or potential stressors, were also identified in collaboration with NPS resource staff.

Selection of Reference Conditions

A "reference condition" is a benchmark to which current values of a given component's measures can be compared to determine the condition of that component. A reference condition may be a historical condition (e.g., flood frequency prior to dam construction on a river), an established ecological threshold (e.g., EPA standards for air quality), or a targeted management goal/objective (e.g., a bison herd of at least 200 individuals) (adapted from Stoddard et al. 2006).

Reference conditions in this project were identified during the scoping process using input from NPS resource staff. In some cases, reference conditions represent a historical reference before human activity and disturbance was a major driver of ecological populations and processes, such as "pre-fire suppression." In other cases, peer-reviewed literature and ecological thresholds helped to define appropriate reference conditions.

Finalizing the Framework

An initial framework was adapted from the organizational framework outlined by the H. John Heinz III Center for Science's "State of Our Nation's Ecosystems 2008" (Heinz Center 2008). Key resources for the park were primarily adapted from the ROMN Vital Signs monitoring plan (Britten et al. 2007). This initial framework was presented to park resource staff to stimulate meaningful dialogue about key resources that should be assessed. Significant collaboration between SMUMN GSS analysts and NPS staff was needed to focus the scope of the ROMN project and finalize the framework of key resources to be assessed.

The NRCA framework was finalized in January 2014 following acceptance from NPS resource staff. It contains a total of 13 components (Figure 11) and was used to drive analysis in this NRCA. This framework outlines the components (resources), most appropriate measures, known or perceived stressors and threats to the resources, and the reference conditions for each component for comparison to current conditions.

Figure 11. Grant Kohrs Ranch National Historical Park natural resource condition assessment framework.

GRKO NRCA Framework
Natural Resource Condition Assessment Framework

Component	Measures	Stressors	Reference Condition
Ecosystem Extent and Function			
Disturbance Regimes			
Grazing	Range condition/Similarity index, rangeland health (17 indicators)	Drought, invasive species (unpalatable), drought, climate change, management actions, Columbian ground squirrels	Range/Ecological site descriptions
Biotic Composition			
Ecological Communities			
Riparian area	Species richness, species composition, extent of wetlands, NRCS riparian health assessment, Greenline assessment, ecological effect size (A)	Located within and adjacent to Superfund site (to be remediated in the next few years), invasive species, climate change, wildlife browsing, beaver activity, overgrazing, flooding, irrigation practices	Hansen et al. 1995
Pastures/ hayfields (improved/irrigated)	Hay & forage production (tons/acre), abundance of invasives vs. desired species, hay nutrient analysis	Invasive species, drought, climate change, improper grazing (amount, timing, distribution), irrigation practices, unplanned fire, Columbian ground squirrels, grasshopper outbreaks	Production estimates from soil survey, < 1% invasives, beef cattle nutrient requirements
Uplands (grasslands, non-irrigated)	Range condition/Similarity index), rangeland health (17 indicators), ecological effect size (A)	Invasive species, drought, climate change, improper grazing (amount, timing, distribution), unplanned or extreme fire, Columbian ground squirrels, grasshopper outbreaks	Range/ecological site descriptions, Mueggler & Stewart (1980)
Birds			
Birds	Species richness, distribution (riparian, upland), abundance, status of species of special concern	Contamination from Superfund site and other mining activity (and remediation); grazing/ranching practices (disturbance), climate change	Undetermined
Freshwater Biota			
Periphyton	Sediment increaser model metrics (percent relative abundance, probablity of impairment)	Contamination from Superfund site, point & non-pont sources, dewatering, climate change (water temps, flow rates & timing)	MT DEQ criteria
Aquatic Macroinvertebrates	RIVPACS modeling (observed to expected [O:E] and Bray Curtis metrics), MMI (multimetric indices)	Contamination from Superfund site, point & non-pont sources, dewatering, climate change (water temps, flow rates & timing)	From Schweiger et al. (2014), based on MT DEQ criteria
Environmental Quality			
Air Quality	Sulfate deposition, nitrogen deposition, ozone, particulate matter (PM 2.5), visibility	Burning (agricultural, riparian), climate change; air pollution could be a threat to historical buildings	NPS ARD air quality index values
Water Quality	Water temperature, specific conductance, pH, total suspended sediment, dissolved oxygen, coliform bacteria, nutrients, metals	Mining contamination, fertilizer, point and nonpoint source discharge, drought, dewatering	MT DEQ criteria
Soundscape	Characteristics of sounds - types of sounds, sound levels (loudness)	Increased airport traffic, increased train traffic, increased interstate traffic (semis), Superfund remediation, ranch construction activities, increased development outside park	Types of sounds - keep the percentage of new sounds (using NPS 2012 as a baseline) that are non-contributing below 10%; Sound levels - below 60 dBA for non-contributing sounds
Viewscape	Change in land use cover type inside the park (internal viewscape), change in land use cover type outside the park (external viewscape), change at selected photo points	Gravel mining south of park, invasive species, Superfund remediation activities, development, conspicuousness of non-contributing features	Maintain viewscapes contributing to cultural landscape significance (see cultural landscape report)
Physical Characteristics			
Geologic and Hydrologic			
Hydrology (surface and groundwater dynamics)	Stream discharge (amount, timing), irrigation flow inputs, timing and amount of precipitation, depth to groundwater	Climate change (precipitation), drought, dewatering, human alteration of river (removal of contamination ponds upstream)	Hydrograph conditions (1980-2012), historic precipitation records for Deer Lodge, Woessner & Johnson (2001) (groundwater)
Soils	Soil aggregate stability, chemistry (nutrients & organic matter), soil microbial composition (and activity/respiration), bulk density	Erosion, contamination from Superfund site, remediation activities, improper grazing, improper irrigation, removal of vegetation	NRCS and Montana State Extension guidelines

3.2.2 General Approach and Methods

This study involved gathering and reviewing existing literature and data relevant to each of the key resource components included in the framework. No new data were collected for this study; however, where appropriate, existing data were further analyzed to provide summaries of resource condition or to create new spatial representations. After all data and literature relevant to the measures of each component were reviewed and considered, a qualitative statement of overall current condition was created and compared to the reference condition when possible.

Data Mining

The data mining process (acquiring as much relevant data about key resources as possible) began at the initial scoping meeting, at which time GRKO staff provided data and literature in multiple forms, including: NPS reports and monitoring plans, reports from various state and federal agencies, published and unpublished research documents, databases, tabular data, and charts. GIS data were also provided by NPS staff. Additional data and literature were acquired through online bibliographic literature searches and inquiries on various state and federal government websites. Data and literature acquired throughout the data mining process were inventoried and analyzed for thoroughness, relevancy, and quality regarding the resource components identified at the scoping meeting.

Data Development and Analysis

Data development and analysis was highly specific to each component in the framework and depended largely on the amount of information and data available for the component, as well as recommendations from NPS reviewers and sources of expertise including NPS staff from GRKO and the ROMN. Specific approaches to data development and analysis can be found within the respective component assessment sections located in Chapter 4 of this report.

Scoring Methods and Assigning Condition

Significance Level

A set of measures are useful in describing the condition of a particular component, but all measures may not be equally important. A “Significance Level” represents a numeric categorization (integer scale from 1-3) of the importance of each measure in assessing the component’s condition; each Significance Level is defined in Table 3. This categorization allows measures that are more important for determining condition of a component (higher Significance Level) to be more heavily weighted in calculating an overall condition. Significance Levels were determined for each component measure in this assessment through discussions with park staff and/or outside resource experts.

Table 3. Scale for a measure's Significance Level in determining a components overall condition.

Significance Level (SL)	Description
1	Measure is of low importance in defining the condition of this component.
2	Measure is of moderate importance in defining the condition of this component.
3	Measure is of high importance in defining the condition of this component.

Condition Level

After each component assessment is completed (including any possible data analysis), SMUMN GSS analysts assign a Condition Level for each measure on a 0-3 integer scale (Table 4). This is based on all the available literature and data reviewed for the component, as well as communications with park and outside experts.

Table 4. Scale for Condition Level of individual measures.

Condition Level (CL)	Description
0	Of **NO** concern. No net loss, degradation, negative change, or alteration.
1	Of **LOW** concern. Signs of limited and isolated degradation of the component.
2	Of **MODERATE** concern. Pronounced signs of widespread and uncontrolled degradation.
3	Of **HIGH** concern. Nearing catastrophic, complete, and irreparable degradation of the component.

Weighted Condition Score

After the Significance Levels (SL) and Condition Levels (CL) are assigned, a Weighted Condition Score (WCS) is calculated via the following equation:

$$WCS = \frac{\sum_{i=1}^{\#\ of\ measures} SL_i * CL_i}{3 * \sum_{i=1}^{\#\ of\ measures} SL_i}$$

The resulting WCS value is placed into one of three possible categories: good condition (WCS = 0.0 - 0.33); condition of moderate concern (WCS = 0.34 - 0.66); and condition of significant concern (WCS = 0.67-1.0). Table 5 displays the potential graphics used to represent a component's condition in this assessment. The colored circles represent the categorized WCS; red circles signify a significant concern, yellow circles a moderate concern and green circles that a resource is in good condition. White circles are used to represent situations in which SMUMN GSS analysts and park staff felt there were currently insufficient data to make a statement about the condition of a component. For example, condition is not assessed when no recent data or information are available, as the purpose of an NRCA is to provide a "snapshot-in-time" of current resource conditions. The arrows inside the circles indicate the trend of the condition of a resource component, based on data and literature from the past 5-10 years, as well as expert opinion. An upward pointing arrow indicates the condition of the component has been improving in recent times. A horizontal arrow indicates an unchanging condition or trend, and an arrow pointing down indicates deterioration in the condition of a component in recent times. These are only used when it is appropriate to comment on the trend of condition of a component. In situations where the trend of the component's condition is currently unknown, no arrow is given.

Table 5. Description of symbology used for individual component assessments.

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 *(explanation is required if a trend symbol or a medium/high confidence band is shown)*				

Examples of how the symbols should be interpreted:

Resource is in good condition, its condition is improving, high confidence in the assessment.

Condition of resource warrants moderate concern; condition is unchanging; medium confidence in the assessment.

Condition of resource warrants significant concern; trend in condition is unknown or not applicable; low confidence in the assessment.

Current condition is unknown or indeterminate due to inadequate data, lack of reference value(s) for comparative purposes, and/or insufficient expert knowledge to reach a more specific condition determination; trend in condition is unknown or not applicable; low confidence in the assessment.

Preparation and Review of Component Draft Assessments

The preparation of draft assessments for each component was a highly cooperative process among SMUMN GSS analysts and GRKO and ROMN staff. Though SMUMN GSS analysts rely heavily on peer-reviewed literature and existing data in conducting the assessment, the expertise of NPS resource staff also plays a significant and invaluable role in providing insights into the appropriate direction for analysis and assessment of each component. This step is especially important when data or literature are limited for a resource component.

The process of developing draft documents for each component began with a detailed phone or e-mail conversation with an individual or multiple individuals considered local experts on the resource components under examination. These conversations were a way for analysts to verify the most relevant data and literature sources that should be used and also to formulate ideas about current condition with respect to the NPS staff opinions. Upon completion, draft assessments were forwarded to component experts for initial review and comments.

Development and Review of Final Component Assessments

Following review of the component draft assessments, analysts used the review feedback from resource experts to compile the final component assessments. As a result of this process, and based on the recommendations and insights provided by GRKO resource staff and other experts, the final component assessments represent the most relevant and current data available for each component and the sentiments of park resource staff and outside resource experts.

Format of Component Assessment Documents

All resource component assessments are presented in a standard format. The format and structure of these assessments is described below.

Description

This section describes the relevance of the resource component to the park and the context within which it occurs in the park setting. For example, a component may represent a unique feature of the park, it may be a key process or resource in park ecology or it may be a resource that is of high management priority. Also emphasized are interrelationships that occur among the featured component and other resource components included in the NRCA.

Measures

Resource component measures were defined in the scoping process and refined through dialogue with resource experts. Those measures deemed most appropriate for assessing the current condition of a component are listed in this section, typically as bulleted items.

Reference Conditions/Values

This section explains the reference condition determined for each resource component as it is defined in the framework. Explanation is provided as to why specific reference conditions are appropriate or logical to use. Also included in this section is a discussion of any available data and literature that explain and elaborate on the designated reference conditions. If these conditions or values originated with the NPS experts or SMUMN GSS analysts, an explanation of how they were developed is provided.

Data and Methods

This section includes a discussion of the data sets used to evaluate the component and if or how these data sets were adjusted or processed as a lead-up to analysis. If adjustment or processing of data involved an extensive or highly technical process, these descriptions are included in an appendix for the reader or a GIS metadata file. Also discussed is how the data were evaluated and analyzed to determine current condition (and trend when appropriate).

Current Condition and Trend

This section presents and discusses in-depth key findings regarding the current condition of the resource component and trends (when available). The information is presented primarily with text but is often accompanied by detailed maps or plates that display different analyses, as well as graphs, charts, and/or tables that summarize relevant data or show interesting relationships. All relevant data and information for a component are presented and interpreted in this section.

Threats and Stressor Factors

This section provides a summary of the threats and stressors that may impact the resource and influence to varying degrees the current condition of a resource component. Relevant stressors were described in the scoping process and are outlined in the NRCA framework. However, these are elaborated on in this section to create a summary of threats and stressors based on a combination of available data and literature, and discussions with resource experts and NPS natural resources staff.

Data Needs/Gaps

This section outlines critical data needs or gaps for the resource component. Specifically, what is discussed is how these data needs/gaps, if addressed, would provide further insight in determining the current condition or trend of a given component in future assessments. In some cases, the data needs/gaps are significant enough to make it inappropriate or impossible to determine condition of the resource component. In these cases, stating the data needs/gaps is useful to natural resources staff seeking to prioritize monitoring or data gathering efforts.

Overall Condition

This section provides a qualitative summary statement of the current condition that was determined for the resource component using the WCS method. Condition is determined after thoughtful review of available literature, data, and any insights from NPS staff and experts, which are presented in the Current Condition and Trend section. The Overall Condition section summarizes the key findings and highlights the key elements used in determining and justifying the level of concern, if any, that analysts attribute to the condition of the resource component. Also included in this section are the graphics used to represent the component condition.

Sources of Expertise

This is a listing of the individuals (including their title and affiliation with offices or programs) who had a primary role in providing expertise, insight, and interpretation to determine current condition (and trend when appropriate) for each resource component.

Literature Cited

This is a list of formal citations for literature or datasets used in the analysis and assessment of condition for the resource component. Note, citations used in appendices referenced in each section (component) of Chapter 4 are listed in that component's "Literature Cited" section.

Literature Cited

Britten, M., E. W. Schweiger, B. Frakes, D. Manier, and D. Pillmore. 2007. Rocky Mountain Network Vital Signs monitoring plan. Natural Resource Report NPS/ROMN/NRR-2007/010. National Park Service, Fort Collins, Colorado.

Great Lakes Environmental Indicators Project (GLEI). 2010. Glossary, Stressor. http://glei.nrri.umn.edu/default/glossary.htm (accessed 31 January 2013).

The H. John Heinz III Center for Science, Economics, and the Environment. 2008. The state of the nation's ecosystems 2008: Measuring the land, waters, and living resources of the United States. Island Press, Washington, D.C.

Stoddard. J. L., D. P. Larsen, C. P. Hawkins, R. K. Johnson, and R. J. Norris. 2006. Setting expectations for the ecological condition of streams: the concept of reference condition. Ecological Applications 16(4):1267-1276.

Chapter 4 Natural Resource Conditions

This chapter presents the background, analysis, and condition summaries for the 13 key resource components in the project framework. The following sections discuss the key resources and their measures, stressors, and reference conditions. The summary for each component is arranged around the following sections:

1. Description
2. Measures
3. Reference Condition
4. Data and Methods
5. Current Condition and Trend (including threats and stressor factors, data needs/gaps, and overall condition)
6. Sources of Expertise
7. Literature Cited

The order of components follows the project framework (Figure 11):

4.1 Grazing
4.2 Riparian Area
4.3 Pastures and Hayfields
4.4 Uplands (Grasslands, Non-irrigated)
4.5 Birds
4.6 Periphyton
4.7 Aquatic Macroinvertebrates
4.8 Air Quality
4.9 Water Quality
4.10 Soundscape
4.11 Viewscape
4.12 Hydrology
4.13 Soils

4.1 Grazing

4.1.1 Description

Grazing is a key component of the cultural experience that GRKO was set aside to preserve. Cattle were first brought to the Deer Lodge Valley in 1857, when Johnny Grant overwintered his herd in the vicinity of what is now GRKO (John Milner Associates et al. 2004). Grazing has shaped the landscape over time; ditches were dug to irrigate pastures and hayfields and non-native grasses were introduced in an effort to improve forage for livestock (John Milner Associates et al. 2004, Rice et al. 2012). Currently, approximately 332 ha (820 ac) of the irrigated pastures and hayfields are utilized by park managers for grazing, as well as 95 ha (235 ac) of the upland grasslands (Jason Smith, GRKO Natural Resource Specialist, written communication, January 2015). Fields are grazed on a rotational basis to prevent overgrazing and protect other park resources (e.g., vegetation, wildlife).

Photo 8. Cattle grazing at GRKO (Photo by Kathy Allen, SMUMN GSS 2013).

Native plant species respond differently to even light grazing by cattle. Some species decrease in abundance or density with grazing, whereas others will increase. Common grassland species in GRKO that typically decrease with grazing include bluebunch wheatgrass (*Pseudoroegneria spicata*) and green needlegrass (*Nassella viridula*), whereas species such as western wheatgrass (*Pascopyrum smithii*) and needle-and-thread (*Hesperostipa comata*) tend to increase (NRCS 1982). Additional "increasers" and "decreasers" are listed in Table 6.

Table 6. Plant species that decrease or increase in density with light to moderate cattle grazing (NRCS 1982).

Decreasers		Increasers	
Scientific name	**Common name**	**Scientific name**	**Common name**
Pseudoroegneria spicata	bluebunch wheatgrass	*Hesperostipa comata*	needle-and-thread
Nassella viridula	green needlegrass	*Pascopyrum smithii*	western wheatgrass
Festuca campestris	rough fescue	*Carex* spp.	sedges
Achnatherum hymenoides	Indian ricegrass	*Festuca idahoensis*	Idaho fescue
Glyceria spp.	mannagrasses	*Cornus* spp.	dogwood
Catabrosa aquatica	brookgrass	*Tetradymia* spp.	horsebrush
Deschampsia cespitosa	tufted hairgrass	*Rosa* spp.	rose
Elymus caninus	bearded wheatgrass	*Potentilla fruticosa*	shrubby cinquefoil
Elymus cinereus	basin wildrye		native perennial forbs
Carex nebrascensis	Nebraska sedge		
Krascheninnikovia lanata	winterfat		
Atriplex nuttallii	Nuttall saltbush		
Vicia americana	American vetch		

Grazing has the potential to benefit the ecosystems in which it occurs. At low levels, grazing can increase plant primary productivity and improve forage quality (Briske et al. 2008). The manure produced by grazing animals contributes to nutrient cycling and can increase soil fertility (Metera et al. 2010). Grazing can also create and maintain habitat for a variety of wildlife species, including native ungulates, grassland birds, and invertebrates (Severson and Urness 1994, Derner et al. 2009, Metera et al. 2010). With grassland birds, a group of species that have declined in recent decades, grazing can be managed to increase vegetation heterogeneity, creating the range of habitats required by many species to complete their breeding cycles (Derner et al. 2009).

Photo 9. Longhorn cattle grazing in a GRKO hayfield (Photo by Sarah Gardner, SMUMN GSS 2013).

The number and type of livestock maintained at the ranch varies, depending on available resources and economic viability (John Milner Associates et al. 2004). GRKO's cattle herd, which remains on-site year-round, presently includes three breeds: Herefords, Longhorns, and Shorthorns (NPS 2013; Photo 9). These three breeds were all raised on the ranch historically (John Milner Associates et al. 2004). As of 1 June 2014, the herd included 47 cows, 17 yearlings (seven heifers and 10 steers), 13 two-year old steers, and three bulls (Smith, written communication, January 2015). The park also keeps three saddle horses (quarter horses) and two draft horse teams (Belgian and Percheron) that perform ranch management tasks, such as hay harvest, and contribute to educational programs.

A pasture or range site's grazing potential can be estimated in "animal unit months" (AUMs). An AUM is defined as the amount of forage required to feed one "animal unit" for 1 month (Metz 2007). An "animal unit" is typically one 454 kg (1,000 lb) cow and a calf up to 6 months old, or their equivalent. The Natural Resources Conservation Service (NRCS) considers 13.6 kg (30 lbs) of air-dry forage per day the standard forage demand for one AUM (Metz 2007). Based on this demand estimate, an AUM would require 415 kg (915 lbs) of forage per month. In 1994, the NRCS conducted a feed and forage inventory at GRKO and determined that there were 1,676 AUMs available annually through pasture and hay production (Smith, e-mail communication, 19 September 2014). In 2012, park staff used data from the NRCS Web Soil Survey (http://websoilsurvey.nrcs.usda.gov) to calculate potential annual forage production and, subsequently, AUMs. Without any irrigation inputs, GRKO's fields and pastures are estimated to yield 1,679 AUMs in a favorable year, 1,320 AUMs in a normal year, and 820 AUMs in an unfavorable year (Smith, e-mail communication, 19 September 2014). Given that irrigation is occurring in many hayfields, these numbers are likely even higher. In 2011and 2012, park livestock utilized 1,248 AUMs and 1,224 AUMs, respectively, meaning the ranch had a surplus of AUMs in those years (Smith, e-mail communication, 19 September 2014).

4.1.2 Measures

- Range Condition/Similarity Index
- Rangeland Health (17 indicators)

4.1.3 Reference Conditions/Values

For the purposes of this assessment, the reference condition for the Range Condition measure in upland, non-irrigated pastures will be scores in the good or excellent range, which suggest that grazing has not significantly altered the vegetation community. The reference condition for Rangeland Health will be ratings in the "none to slight" category, which indicate that ecological processes are not significantly altered by grazing. However, it is important to keep in mind that Range Condition and Rangeland Health measures *can* be influenced by factors other than grazing (e.g., drought, fire, human activity) (Bret Olson, Montana State University [MSU] Professor of Range Ecology, written communication, 4 January 2015).

4.1.4 Data and Methods

Two methods are commonly used to assess the status of grazed lands throughout the U.S.: Range Condition/similarity index and Rangeland Health. Regarding the Range Condition/similarity index, the USDA Soil Conservation Service (SCS) developed the Range Condition concept in the 1940s. Range Condition is determined by comparing the present vegetation community on a "range site" to a historic reference (the "climax" community), whereby the soils, geography and climate dictate the potential characteristic, native plant community that would be expected on that "range site", barring significant natural or human-induced disturbances (Pellant et al. 2005). To determine Range Condition, plant biomass on appropriately selected plots is clipped and weighed, or estimated, to determine percent species composition. Using a technical guide, these current percentages are compared with percentages expected for a climax community for that site to determine a Range Condition score (i.e., how similar they are) (Olson, written communication, 6 January 2015). Scores range from 0-100%, with 100% indicating a site's species composition is identical to the historic climax plant community. With this approach, vegetation communities are classified as excellent (76-100%), good (51-75%), fair (26-50%), or poor (0-25%). The NRCS range site descriptions (NRCS 1982) were used as the historical reference or "climax" condition (Olson, email communication, 3 October 2014). As mentioned above, the reference condition for this NRCA will be scores in the good or excellent categories.

In the mid-1990s, the SCS changed its name to the Natural Resources Conservation Service; with this change, they began to institute the concept of Similarity Index (SI), which is similar to but not the same as Range Condition (Olson, written communication, 6 January 2015). The primary difference is that when plant biomass on plots is clipped and weighed, or estimated, the actual (dry) weights are compared with dry weights of plant species expected to represent historic climax plant communities (HCPC, from an Ecological site description [ESD]). Ecological site descriptions have not yet been developed for western Montana and are therefore not available for GRKO. The NRCS has dropped the terms "excellent", "good", "fair" and "poor", and simply presents SIs, which reflect the successional status of a plant community (i.e., its departure from HCPC). Using the same data set, Range Condition (based on percent species composition) and similarity indices (based on actual biomass) were calculated for six pasture locations within GRKO during the summer of 2014. Although ESDs have not been developed for western Montana yet, a best fit ESD from central Montana was used to determine the SIs (Olson, written communication, 6 January 2015). Ecological site descriptions for GRKO should be available soon, as the NPS has entered into a cooperative agreement with NRCS to identify ecological sites and prepare ESDs that include reference state conditions (Smith, written communication, January 2015).

Rangeland Health, in contrast, focuses on the integrity of soils, ecological processes (e.g., water and nutrient cycling), and the ecosystem as a whole (Pellant et al. 2005). Rangeland Health Assessment methods are intended to, "provide a preliminary evaluation of soil/site stability, hydrologic function, and biotic integrity (at the ecological site level)" and "provide early warnings of potential problems and opportunities by helping land managers identify areas that are potentially at risk of degradation or where resource problems currently exist" (Pellant et al. 2005, p. 1). Since ecological processes are often challenging to measure, Rangeland Health techniques utilize biological and physical characteristics that can serve as indicators of ecosystem integrity. Rather than taking quantitative measurements, researchers assign a qualitative rating based on the degree of variance from expected levels. The three main attributes in such an assessment and the indicators used for each are summarized in Table 7. Rangeland Health indicators and assessment methods are described in further detail in Pellant et al. (2005). Although GRKO managers and grazing experts agree that this method would be useful for assessing the condition of the ranch's grazed lands, full Rangeland Health Assessments have not been completed at the park.

Table 7. Attributes and indicators used in Rangeland Health Assessments (Pellant et al. 2005). Each indicator is assigned one of the five following ratings based on the variance from expected conditions: None to slight, slight to moderate, moderate, moderate to extreme, extreme to total.

Indicators	Attributes		
	Soil/Site Stability	Hydrologic Function	Biotic Integrity
Rills	x	x	
Water flow patterns	x	x	
Pedestals and/or terracettes	x	x	
Bare ground	x	x	
Gullies	x	x	
Wind-scoured, blowouts, and/or deposition areas	x		
Litter movement	x		
Soil surface resistance to erosion	x	x	x
Soil surface loss or degradation	x	x	x
Plant community composition & distribution relative to infiltration		x	
Compaction layer	x	x	x
Functional/structural groups			x
Plant mortality/decadence			x
Litter amount		x	x
Annual production			x
Invasive plants			x
Reproductive capability of perennial plants			x

4.1.5 Current Condition and Trend

Range Condition/Similarity Index

Range Condition and similarity indices were determined for six grazed fields at GRKO during the summer of 2014 (locations shown in Figure 12). Four of these fields are upland grasslands dominated by native species, while two (the effluent fields) are irrigated pastures that have been planted with non-native grasses. Range Condition is based on percent species composition (by dry weights) whereas similarity index is based on species composition directly based on dry weights (Table 8). Range Condition scores showed that two of the upland pastures (Ridge Road and Gravel Pit) were in the *excellent* condition class and two (Taylor Ridge and Upper Northwest Range) were in the *good* condition class (NPS 2014a). The two irrigated pastures received index scores in the *poor* condition class (Table 8). However, this is because the historic reference condition used for comparison includes only native species and does not account for non-native species that are accepted as part of the cultural landscape at GRKO (Smith, e-mail communication, 26 September 2014). If these culturally acceptable species (particularly smooth brome [*Bromus inermis*]) were considered part of the historic reference condition, the two effluent fields would likely fall in the *good* condition class. The similarity indices for the six fields show that the two pastures with *excellent* Range Condition scores (Ridge Road and Gravel Pit) are also closest to the HCPC, with scores above 92% (Table 8). Upper Northwest Range was also very similar to the HCPC with a score just below 92%. Taylor Ridge Pasture was much lower with a similarity index of just 55%. The effluent fields yielded the lowest similarity indices (11.3% and 20%) because these areas are dominated by non-native species that are not considered part of the HCPC.

Table 8. Range Condition scores and classes (based on percent composition) and similarity indices (based on dry weight) for six grazed locations at GRKO in 2014 (NPS 2014a). Class designations are applied **only** for Range Condition scores and are not used with similarity indices.

Field	Range Condition - % Compostion	Range Condition Class	Similarity Index - Dry weight
Ridge Road Pasture	79%	Excellent	92.2%
Upper Northwest Range	72%	Good	91.8%
Taylor Ridge Pasture	54%	Good	55%
Gravel Pit Pasture	93%	Excellent	92.7%
Effluent Field 3	10%	Poor	11.3%
Effluent Field 4	15%	Poor	20%

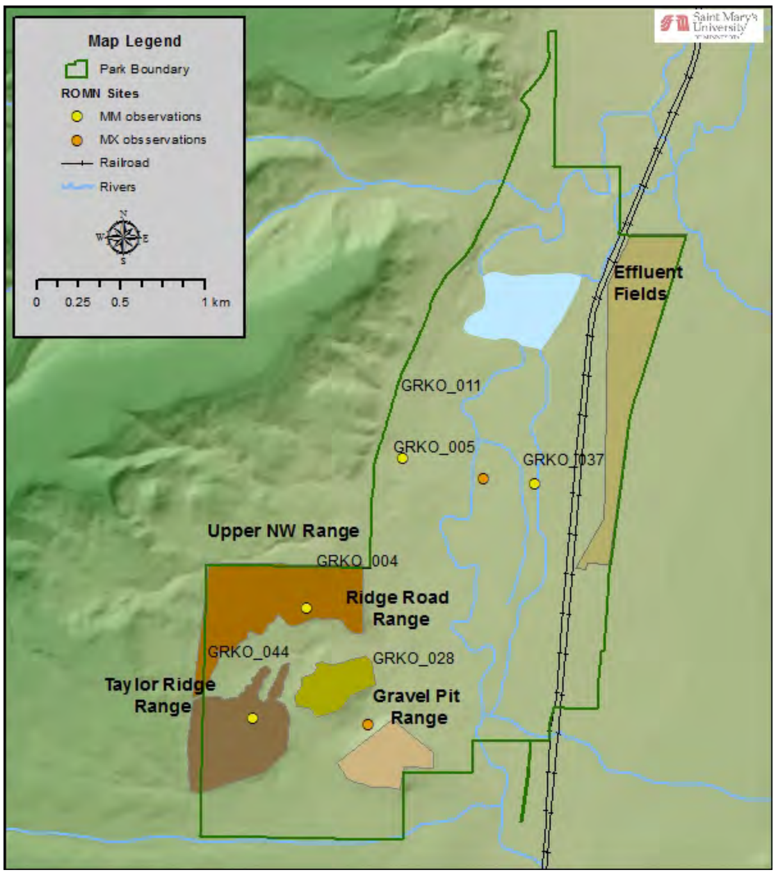


Figure 12. Location of grazed fields where Range Condition was calculated and ROMN sampling sites where moderate (MM) or moderate to extreme (MX) evidence of disturbance/erosion were observed (see below). Note that only sites GRKO_004 and GRKO_044 are in upland grassland ranges and all others are in irrigated pastures/hayfields.

<u>Rangeland Health</u>

Rangeland Health scores, as described by Pellant et al. (2005), have not been calculated at GRKO. However, the ROMN Vegetation Composition, Structure and Soils (VCSS) monitoring protocol has recorded observations on several of the soil/site stability indicators (surface flow patterns, rills/gullies, and pedestals) from 2006-2012. These features may suggest that grazing is causing disturbance and/or erosion, which can negatively impact soil stability (Pellant et al. 2005). Monitoring crews recorded whether evidence of these indicators at 27 sampling locations in grazed areas was none to slight (NS), slight to moderate (SM), moderate (MM), moderate to extreme (MX), or extreme (XX) (Table 9). Evidence of pedestals has been NS during all observations except for one location, which received an SM in 2011. Although the vast majority of locations have also shown NS evidence of surface flow (87%) and rills/gullies (92%), MX observations have been recorded for rills/gullies at two locations (Table 9). One of these locations also showed MX evidence of surface flow in the same year (2009). However, these data represent only three of the 17 indicators used by Pellant et al. (2005) to calculate Rangeland Health and do not provide a comprehensive picture of the condition of GRKO's grazed lands alone.

Table 9. Indicators of disturbance and/or erosion documented in GRKO's grazed lands (ROMN 2006-2012). For vegetation type, P/H = irrigated pastures and hayfields and UG = upland grasslands (non-irrigated). NS - none to slight, SM = slight to moderate, MM = moderate, MX = moderate to extreme.

Plot (Veg type)	# of Observations	Surface Flow	Rills/Gullies	Pedestals
2006				
GRKO_001 (P/H)	6	5 NS, 1 SM	NS	NS
GRKO_004 (UG)	5	2 NS, 3 SM	NS	NS
GRKO_005 (P/H)	6	3 NS, 3 SM	NS	NS
GRKO_007 (P/H)	6	NS	NS	NS
GRKO_008 (P/H)	3	NS	NS	NS
GRKO_009 (P/H)	3	NS	NS	NS
GRKO_010 (P/H)	3	SM	NS	NS
GRKO_011 (P/H)	6	3 NS, 1 SM, 2 MM	4 NS, 2 SM	NS
GRKO_012 (P/H)	3	NS	NS	NS
GRKO_015 (P/H)	3	NS	NS	NS
GRKO_016 (P/H)	6	SM	NS	NS
GRKO_020 (P/H)	6	NS	NS	NS
GRKO_027 (P/H)	6	NS	NS	NS
Totals	**62**	**43 NS, 17 SM, 2 MM**	**60 NS, 2 SM**	**62 NS**
2007				
GRKO_001 (P/H)	3	NS	NS	NS
GRKO_004 (UG)	3	2 NS, 1 MM	NS	NS
GRKO_005 (P/H)	3	NS	NS	NS
GRKO_007 (P/H)	3	NS	2 NS, 1 SM	NS
GRKO_008 (P/H)	3	NS	2 NS, 1 SM	NS
GRKO_009 (P/H)	3	NS	NS	NS
GRKO_010 (P/H)	3	NS	NS	NS
GRKO_011 (P/H)	3	NS	NS	NS
GRKO_012 (P/H)	3	NS	NS	NS
GRKO_015 (P/H)	3	NS	NS	NS
GRKO_016 (P/H)	3	2 NS, 1 SM	NS	NS
GRKO_018 (P/H)	3	NS	NS	NS
GRKO_019 (P/H)	3	NS	NS	NS
GRKO_020 (P/H)	3	NS	NS	NS
GRKO_021 (P/H)	3	NS	NS	NS
GRKO_022 (P/H)	3	NS	NS	NS
GRKO_024 (P/H)	3	NS	NS	NS
GRKO_027 (P/H)	3	NS	NS	NS
Totals	**54**	**52 NS, 1 SM, 1 MM**	**52 NS, 2 SM**	**54 NS**

Table 9. Indicators of disturbance and/or erosion documented in GRKO's grazed lands (ROMN 2006-2012). For vegetation type, P/H = irrigated pastures and hayfields and UG = upland grasslands (non-irrigated). (continued)

Plot (Veg type)	# of Observations	Surface Flow	Rills/Gullies	Pedestals
2008				
GRKO_001 (P/H)	3	NS	NS	NS
GRKO_004 (UG)	3	NS	NS	NS
GRKO_005 (P/H)	3	NS	NS	NS
GRKO_007 (P/H)	6	NS	NS	NS
GRKO_008 (P/H)	6	NS	NS	NS
GRKO_009 (P/H)	3	NS	NS	NS
GRKO_010 (P/H)	3	NS	NS	NS
GRKO_011 (P/H)	3	NS	NS	NS
GRKO_012 (P/H)	3	NS	NS	NS
Totals	**33**	**33 NS**	**33 NS**	**33 NS**
2009				
GRKO_001 (P/H)	1	NS	NS	NS
GRKO_012 (P/H)	1	NS	NS	NS
GRKO_028 (P/H)	1	MX	MX	NS
GRKO_032 (UG)	1	NS	NS	NS
GRKO_033 (P/H)	1	NS	NS	NS
GRKO_036 (UG)	1	SM	SM	NS
Totals	**6**	**4 NS, 1 SM, 1MX**	**4 NS, 1 SM, 1MX**	**6 NS**
2010				
GRKO_001 (P/H)	1	NS	SM	NS
GRKO_004 (UG)	1	NS	NS	NS
GRKO_005 (P/H)	1	MM	MX	NS
GRKO_012 (P/H)	1	NS	NS	NS
GRKO_037 (P/H)	1	NS	MM	NS
GRKO_040 (UG)	1	NS	SM	NS
GRKO_041 (UG)	1	NS	SM	NS
GRKO_043 (P/H)	1	NS	NS	NS
GRKO_044	1	NS	MM	NS
Totals	**9**	**8 NS, 1 MM**	**3 NS, 3 SM, 2 MM, 1 MX**	**9 NS**
2011				
GRKO_007 (P/H)	1	NS	NS	NS
GRKO_008 (P/H)	1	NS	NS	NS
GRKO_009 (P/H)	1	NS	NS	NS
GRKO_010 (P/H)	1	NS	NS	NS
GRKO_011 (P/H)	1	NS	NS	NS
GRKO_015 (P/H)	1	NS	NS	NS
GRKO_016 (P/H)	1	NS	NS	NS
GRKO_020 (P/H)	1	NS	NS	NS
GRKO_040 (UG)	1	NS	SM	NS
GRKO_041 (UG)	1	NS	NS	NS
Totals	**10**	**10 NS**	**9 NS, 1 SM**	**10 NS**
2012				
GRKO_015 (P/H)	1	NS	NS	NS
GRKO_016 (P/H)	1	NS	NS	NS
GRKO_018 (P/H)	1	NS	NS	SM

Table 9. Indicators of disturbance and/or erosion documented in GRKO's grazed lands (ROMN 2006-2012). For vegetation type, P/H = irrigated pastures and hayfields and UG = upland grasslands (non-irrigated). NS - none to slight, SM = slight to moderate, MM = moderate, MX = moderate to extreme. (continued)

Plot (Veg type)	# of Observations	Surface Flow	Rills/Gullies	Pedestals
2012 (cont.)				
GRKO_019 (P/H)	1	NS	NS	NS
GRKO_021 (P/H)	1	NS	SM	NS
GRKO_022 (P/H)	1	NS	NS	NS
GRKO_024 (P/H)	1	NS	NS	NS
GRKO_027 (P/H)	1	NS	NS	NS
Totals	**8**	**8 NS**	**7 NS, 1 SM**	**7 NS, 1 SM**
Grand Totals	**182**	**158 NS, 19 SM, 4 MM, 1 MX**	**168 NS, 10 SM, 2MM, 2MX**	**181 NS, 1 SM**

Threats and Stressor Factors

Threats to grazing at GRKO include invasive plant species, Columbian ground squirrels (*Spermophilus columbianus*), management actions (i.e., decisions that impact where and when to graze or not graze), fire, drought, and climate change. Invasive species are widely recognized as a major threat to native vegetation communities and ecosystems as a whole. They can also negatively impact grazing, a key cultural component at GRKO. Invasion by noxious weeds can increase soil erosion and reduce livestock carrying capacity on grazed lands, as invasive species often outcompete desirable native species (Mack et al. 2000, Davison et al. 2006). Some noxious weeds are avoided by livestock for a variety of reasons. They may contain high levels of toxins, have physical defenses (e.g., thorns), or simply be low in nutrients and/or digestibility (Molyneaux and Ralphs 1992, Davison et al. 2006). For example, yellow toadflax (*Linaria vulgaris*) contains alkaloids and glucosides that may be toxic to livestock in large amounts. Houndstongue (*Cynoglossum officianale*) and leafy spurge (*Euphorbia esula*) also contain toxins that can be harmful to cattle and horses during the plant's active growth phase (Lym and Kirby 1987, Molyneaux and Ralphs 1992). Livestock often avoid these species unless no other forage is available (Olson, written communication, 31 July 2015).

Precipitation has been linked to forage production on shortgrass rangelands. Lower May and June precipitation levels resulted in lower forage yields in a shortgrass prairie dominated by needle-and-thread, western wheatgrass, and blue grama (*Bouteloua gracilis*) (Smoliak 1956). Although GRKO is not classified as a shortgrass prairie, two of the dominant species in this study (needle-and-thread and western wheatgrass) are common in the park's upland grasslands. This study suggests that decreased precipitation (i.e., drought) has the potential to negatively impact grazing by reducing forage yields. Global climate change may cause an increase in droughts, as well as higher temperatures and shifts in precipitation regimes (Gray and Andersen 2009, McWethy et al. 2010). Research suggests that climate change will impact grazers. Craine et al. (2010) analyzed forage quality data from across the continental U.S. over 14 years. According to their analysis, dietary crude protein and digestible organic matter decreased with increasing temperatures and declining precipitation for regions with continental climates. This suggests that cattle nutritional stress will likely increase with climate change (Craine et al. 2010). The increased CO_2 levels associated with climate change may also impact grazing. Morgan et al. (2004) found that elevated CO_2 levels during growth reduced the digestibility of blue grama, western wheatgrass, and needle-and-thread (the latter two species are common in GRKO). This suggests that increased CO_2 will reduce forage quality, and livestock will have to consume more to achieve the same weight gains (Morgan et al. 2004).

Photo 10. Columbian ground squirrel (NPS photo).

When Columbian ground squirrel (Photo 10) numbers are high, their feeding and digging can reduce forage production in pastures and croplands (Swant 2011, MDA 2013). Their burrows and dirt mounds are also a hazard to grazing livestock and haying equipment (Swant 2011). Columbian ground squirrels (CGS) prefer short grass habitats with deep soils. They typically avoid areas with taller grasses, rocky soils, or high water tables and fields that are flood irrigated (Swant 2011). In GRKO, CGS are often found on south-facing foothills or along fencerows adjacent to irrigated hayfields, or in portions of the hayfields that are rarely reached by floodwaters (Swant 2011). NPS staff have conducted visual surveys for CGS throughout the park every May since 2009 (NPS 2014b). During this survey period, squirrel numbers in grazed areas peaked in 2010 with 209 individuals observed (Table 10, Figure 13). Only 34 squirrels were observed in grazed areas in 2014. During early surveys, the highest numbers were observed in Big Gulch, but in 2013-2014, squirrel numbers were highest in Upper Taylor (Table 10). Ground squirrel burrows were also counted each June. With the exception of 2012, burrow numbers in grazed areas have increased every year, peaking around 700 in 2014 (Figure 13).

Table 10. Number of ground squirrels observed in grazed fields throughout GRKO during May surveys (NPS 2014b).

Field	# of Waypoints	2009	2010	2011	2012	2013	2014
Effluent Field 1	2	3	0	NS	1	0	0
Effluent Field 2	2	0	0	0	0	0	0
Effluent Field 3	3	0	0	0	2	0	0
Effluent Field 4	5	4	17	0	8	17	3
Effluent Field 5	3	0	0	0	0	0	0
Big Gulch	4	78	69	0	0	8	5
Little Gulch	4	45	27	0	0	14	6
Lower Taylor	2	12	3	4	0	7	3
Upper Taylor	2	22	47	0	0	39	11
West Field 3	5	23	46	0	1	11	2
West Field 4	4	7	NS	7	0	3	4
Feedlots	2	NS	NS	NS	16	NS	NS

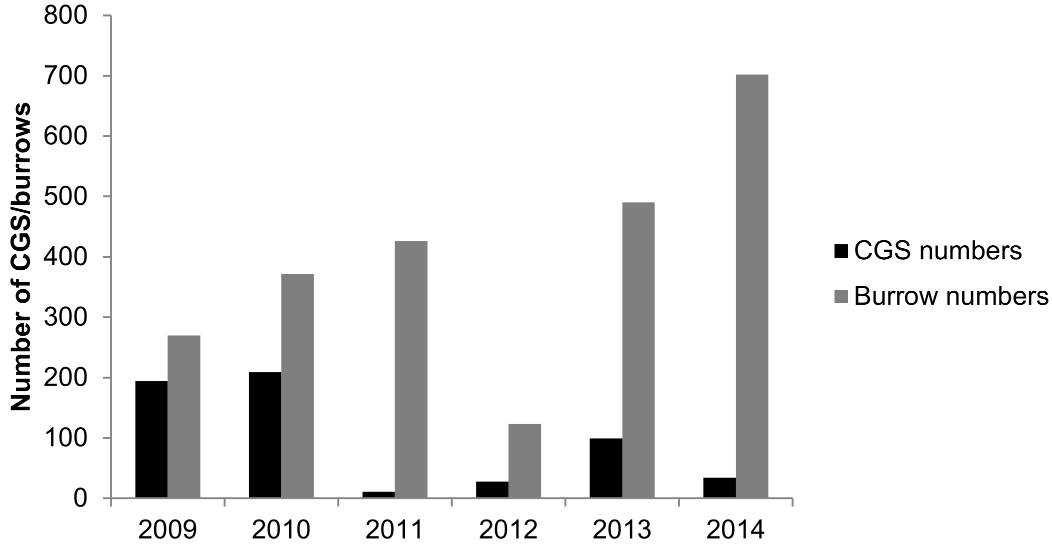


Figure 13. Columbian ground squirrel and burrow numbers at GRKO, 2009-2014 (NPS 2014b).

Data Needs/Gaps

Full Rangeland Health Assessments have not been completed at GRKO. Some of the 17 indicators used in these assessments have been documented in the park's grazed lands, but others have not (e.g., litter movement, reproductive capability of perennial plants). Repetition of the Range Condition assessments and similarity indices in the future will help determine if grazing is impacting any of the pastures at GRKO. Similarity indices could also be re-calculated to include culturally acceptable non-native species in the reference or "desired" plant community.

Overall Condition

Range Condition /Similarity Index

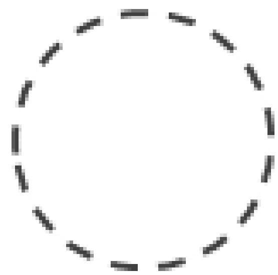
The Range Condition measure was assigned a *Significance Level* of 3. Similarity indices were calculated for six of GRKO's grazed fields during the summer of 2014. The four upland pastures met the selected reference condition with scores in the excellent and good ranges. The two irrigated fields, which have been planted with non-native grasses to enhance forage production, were rated as poor. However, this is because the historic reference condition used for comparison did not include non-native grasses that are considered part of the cultural landscape at GRKO. This measure is currently of low concern (*Condition Level* = 1).

Rangeland Health

Rangeland Health was also assigned a *Significance Level* of 3. Full Rangeland Health Assessments have not been completed for any of the grazed lands at GRKO. The ROMN VCSS monitoring protocol has recorded observations on several of the soil/site stability indicators, but these are only three of the 17 indicators used to calculate Rangeland Health. Although the ROMN observations do not suggest any cause for concern regarding the condition of grazed lands, they do not provide enough information to fully assess this measure at this time. Therefore, a *Condition Level* has not been assigned.

Weighted Condition Score

A *Weighted Condition Score* was not calculated for grazing at GRKO, since condition could not be assigned for one of the two measures. Given that Range Condition has only been assessed during one year, no trends could be identified. The current condition and trend for grazing at GRKO are unknown.

Grazing			
Measures	Significance Level	Condition Level	**WCS = N/A**
Range Condition	3	1	
Rangeland Health	3	n/a	

4.1.6 Sources of Expertise

Jason Smith, GRKO Natural Resource Specialist

Bret Olson, Professor of Range Ecology, Montana State University

4.1.7 Literature Cited

Briske, D. D., J. D. Derner, J. R. Brown, S. D. Fuhlendorf, W. R. Teague, K. M. Havstad, R. L. Gillen, A. J. Ash, and W. D. Willms. 2008. Rotational grazing on rangelands: Reconciliation and experimental evidence. Rangeland Ecology and Management 61(1):3-17.

Craine, J. M., A. J. Elmore, K. C. Olson, and D. Tolleson. 2010. Climate change and cattle nutritional stress. Global Change Biology 16:2901-2911.

Davison, J. C., E. Smith, and L. M. Wilson. 2006. Livestock grazing guidelines for controlling noxious weeds in the western United States. Western Region Sustainable Agriculture Research and Education, Logan, Utah.

Derner, J. D., W. K. Lauenroth, P. Stapp, and D. J. Augustine. 2009. Livestock as ecosystem engineers for grassland bird habitat in the western Great Plains of North America. Rangeland Ecology and Management 62(2):111-118.

Gray, S., and C. Andersen. 2009. Assessing the future of Wyoming's water resources: Adding climate change to the equation. William D. Ruckelshaus Institute of Environment and Natural Resources. University of Wyoming, Laramie, Wyoming.

John Milner Associates, Rivanna Archaeological Consulting, Susan Maxman and Partners Architects. 2004. Cultural landscape report. Grant-Kohrs Ranch National Historic Site, Deer Lodge, Montana.

Lym, R. G., and D. R. Kirby. 1987. Cattle foraging behavior in leafy spurge-infested rangeland. Weed Technology 1(4):314-318.

Mack, R. N., D. Simberloff, W. M. Lonsdale, H. Evans, M. Clout, and F. A. Bazzaz. 2000. Biotic invasions: Causes, epidemiology, global consequences, and control. Ecological Applications 10(3):689-710.

McWethy, D. B., S. T. Gray, P. E. Higuera, J. S. Littell, G. T. Pederson, A. J. Ray, and C. Whitlock. 2010. Climate and terrestrial ecosystem change in the U.S. Rocky Mountains and Upper Columbia Basin: Historical and future perspectives for natural resource management. Natural Resource Report NPS/GRYN/NRR–2010/260. National Park Service, Fort Collins, Colorado.

Metera, E., T. Sakowski, K. Sloniewski, and B. Romanowicz. 2010. Grazing as a tool to maintain biodiversity of grassland - a review. Animal Science Papers and Reports 28(4):315-334.

Metz, R. 2007. Montana grazing animal unit month (AUM) estimator. Range Technical Note No. MT-32. Natural Resources Conservation Service, Bozeman, Montana.

Molyneaux, R. J., and M. H. Ralphs. 1992. Plant toxins and palatability to herbivores. Journal of Range Management 45:13-18.

Montana Department of Agriculture (MDA). 2013. The Columbian ground squirrel: Its biology and control. Montana Department of Agriculture, Helena, Montana.

Morgan, J. A., A. R. Mosier, D. G. Milchunas, D. R. LeCain, J. A. Nelson, and W. J. Parton. 2004. CO_2 enhances productivity, alters species composition, and reduces digestibility of shortgrass steppe vegetation. Ecological Applications 14(1):208-219.

National Park Service (NPS). 2013. Grant-Kohrs Ranch: Cattle. http://www.nps.gov/grko/naturescience/cattle.htm (accessed 21 November 2013).

National Park Service (NPS). 2014a. Range site and condition record data sheets. Unpublished data collected by Bret Olson and Jarrett Payne, Montana State University. Received from Jason Smith, 26 September 2014.

National Park Service (NPS). 2014b. Grant-Kohrs Ranch National Historic Site: Annual survey for Columbian ground squirrel. Microsoft Excel spreadsheet. Received from Jason Smith, 20 August 2014.

Natural Resources Conservation Service (NRCS). 1982. Technical range site descriptions. Field office technical guide, section II-E-8. Natural Resources Conservation Service, Washington, D.C.

Pellant, M., P. Shaver, D. A. Pyke, and J. E. Herrick. 2005. Interpreting indicators of Rangeland Health, version 4. Technical Reference 1734-6. U.S. Department of the Interior, Bureau of Land Management, National Science and Technology Center, Denver, Colorado.

Rice, P. M., E. W. Schweiger, W. Gustafson, C. Lea, D. Manier, D. Shorrock, B. Frakes, and L. O'Gan. 2012. Vegetation classification and mapping project report, Grant-Kohrs Ranch National Historic Site. Natural Resource Report NPS/ROMN/NRR—2012/589. National Park Service, Fort Collins, Colorado.

Rocky Mountain Inventory and Monitoring Network (ROMN). 2006. Vegetation composition, structure, and soils (VCSS) yearly master database - 2006. Microsoft Access database. Obtained from https://irma.nps.gov/App/ (accessed 16 July 2014).

Rocky Mountain Inventory and Monitoring Network (ROMN). 2007. Vegetation composition, structure, and soils (VCSS) yearly master database - 2007. Microsoft Access database. Obtained from https://irma.nps.gov/App/ (accessed 16 July 2014).

Rocky Mountain Inventory and Monitoring Network (ROMN). 2008. Vegetation composition, structure, and soils (VCSS) yearly master database - 2008. Microsoft Access database. Obtained from https://irma.nps.gov/App/ (accessed 16 July 2014).

Rocky Mountain Inventory and Monitoring Network (ROMN). 2009. Vegetation composition, structure, and soils (VCSS) yearly master database - 2009. Microsoft Access database. Obtained from https://irma.nps.gov/App/ (accessed 16 July 2014).

Rocky Mountain Inventory and Monitoring Network (ROMN). 2010. Vegetation composition, structure, and soils (VCSS) yearly master database - 2010. Microsoft Access database. Obtained from https://irma.nps.gov/App/ (accessed 16 July 2014).

Rocky Mountain Inventory and Monitoring Network (ROMN). 2011. Vegetation composition, structure, and soils (VCSS) yearly master database - 2011. Microsoft Access database. Obtained from https://irma.nps.gov/App/ (accessed 16 July 2014).

Rocky Mountain Inventory and Monitoring Network (ROMN). 2012. Vegetation composition, structure, and soils (VCSS) yearly master database - 2012. Microsoft Access database. Obtained from https://irma.nps.gov/App/ (accessed 16 July 2014).

Severson, K. E., and P. J. Urness. 1994. Livestock grazing: A tool to improve wildlife habitat. Pages 232-249 *in* Ecological implications of livestock herbivory in the west. Vavra, M., A. Laycock, and R. D. Pieper (eds.). Society for Range Management, Denver, Colorado.

Smoliak, S. 1956. Influence of climatic conditions on forage production of shortgrass rangeland. Journal of Range Management 9(2):89-91.

Swant, G. D. 2011. Grant-Kohrs Ranch National Historic Site: Survey protocol for Columbian ground squirrel (*Spermophilus columbianus*). National Park Service, Deer Lodge, Montana.

4.2 Riparian Area

4.2.1 Description

Riparian and wetland areas are of critical importance in semiarid regions of the west, such as in and around GRKO. These areas influence water quality and quantity, stream stability, and provide habitat for terrestrial and aquatic wildlife (Hansen et al. 1995). Riparian vegetation stabilizes streambanks, protecting them from erosion by water (streamflow and runoff), wind, and trampling (Hansen et al. 1995, Griffin and Smith 2001). This vegetation also provides shade and cover for wildlife and contributes detritus to streams to provide habitat for aquatic organisms such as fish and invertebrates (Hansen et al. 1995, Rice and Hardin 2002). The shade from vegetation can prevent water temperature fluctuations, which are harmful for aquatic life (Meehan et al. 1977, Hansen et al. 1995). Riparian areas typically have higher soil moisture than surrounding areas and, therefore, are more productive and can support different plant species than the neighboring uplands. This attracts wildlife and adds to the overall diversity of the landscape (Hansen et al. 1995).

Photo 11. The Clark Fork riparian area within GRKO (photo by Kathy Allen, SMUMN GSS 2013).

The riparian areas of GRKO are dominated by a mix of shrubs and herbaceous species with scattered stands of trees, primarily black cottonwood (*Populus balsamifera* ssp. *trichocarpa*). Dominant shrubs include a variety of willows (*Salix* spp.), water birch (*Betula occidentalis*), and western snowberry (*Symphoricarpos occidentalis*) (Bedunah and Jones 2001). Common graminoids are redtop (*Agrostis stolonifera*), smooth brome, Baltic rush (*Juncus balticus*), quackgrass (*Elymus repens*), and bluegrasses (*Poa* spp.) (Bedunah and Jones 2001). Many of the graminoids are non-native but are important components of the cultural landscape. The distribution of riparian vegetation communities within GRKO is shown in Figure 14 and Figure 15, while natural (e.g., not planted by humans) cottonwood tree locations are depicted in Figure 16.

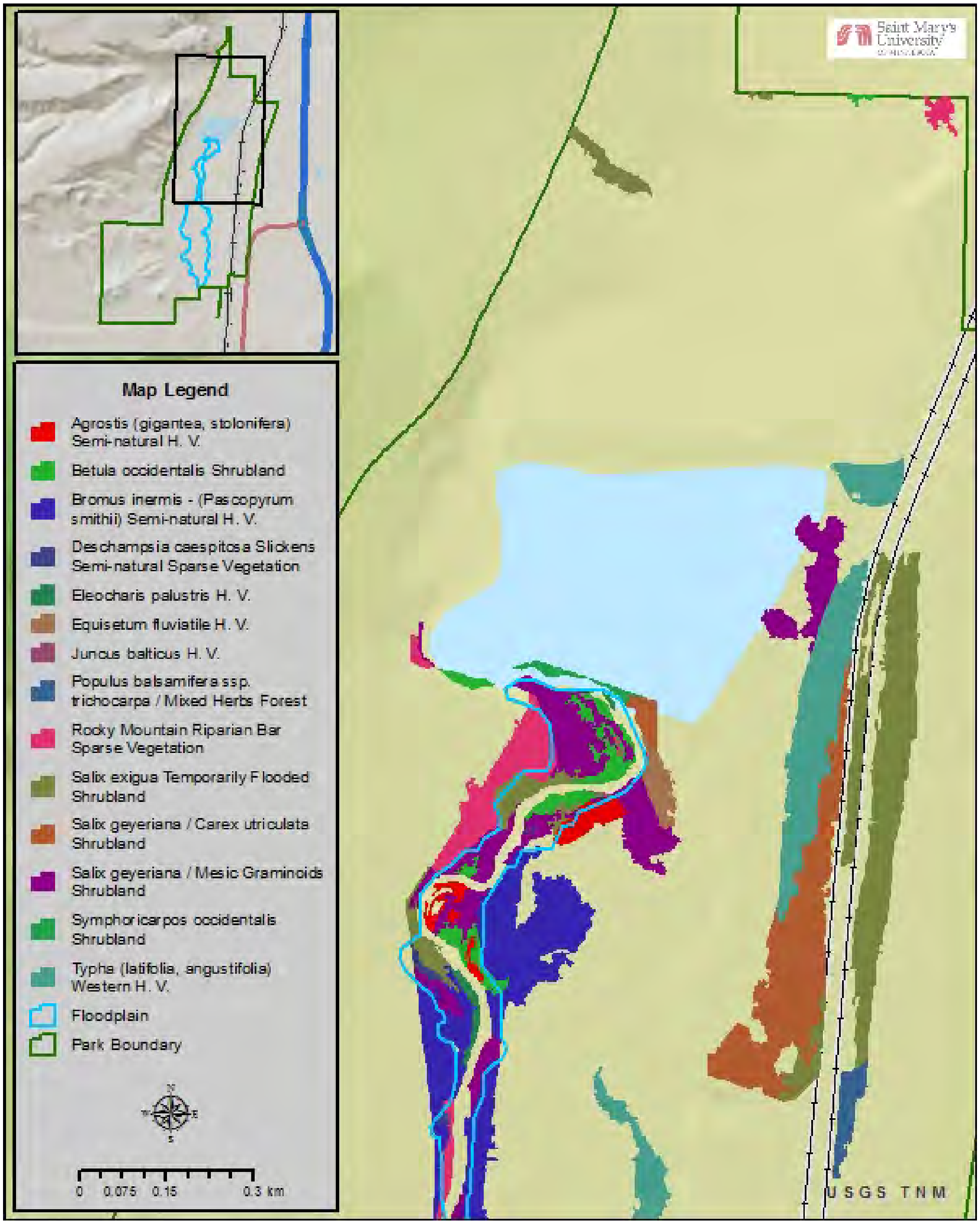


Figure 14. Riparian vegetation community distribution in the northern portion of GRKO (Rice et al. 2012). H.V. = Herbaceous Vegetation.

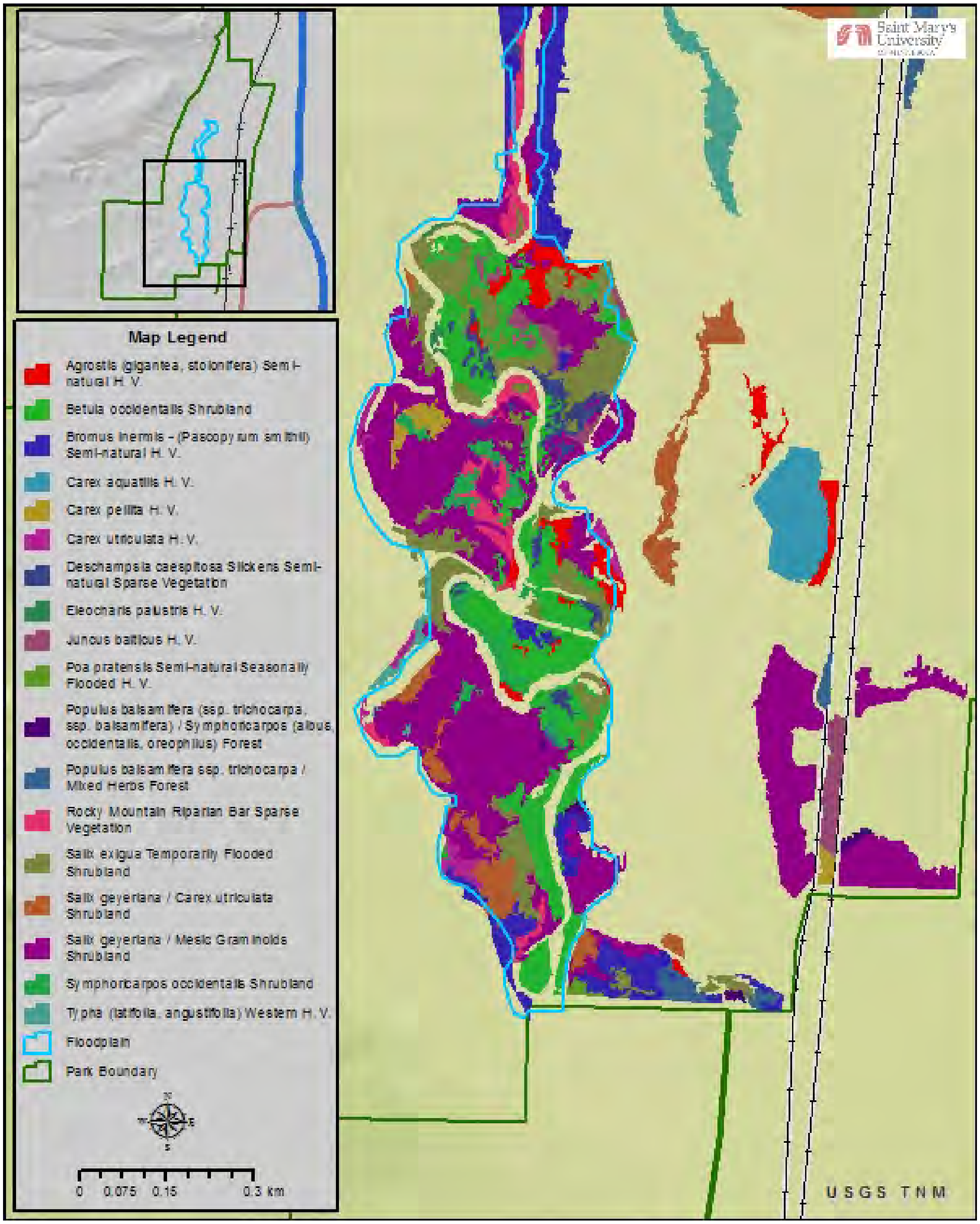


Figure 15. Riparian vegetation community distribution in the southern portion of GRKO (Rice et al. 2012). H.V. = Herbaceous Vegetation.

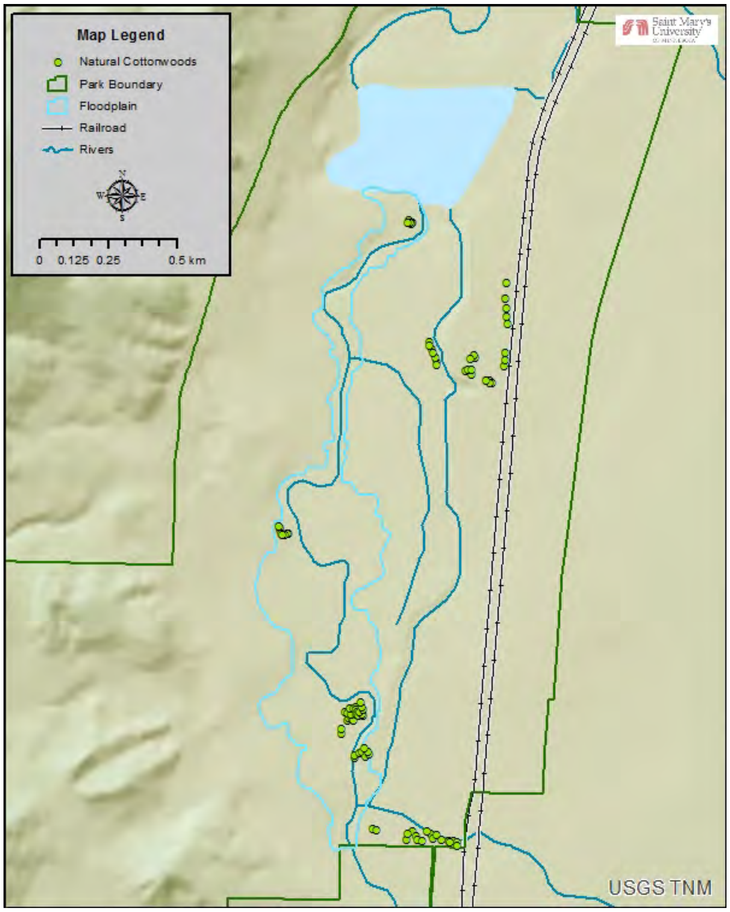


Figure 16. Locations of natural cottonwood trees (e.g., not planted) within GRKO as of 2002 (NPS 2002).

The riparian areas at GRKO have been heavily impacted by past human disturbance, especially mining contamination from upstream and livestock grazing (Bedunah and Jones 2001). The dominant vegetation communities were classified by Thompson et al. (1995) and Bedunah and Jones (2001) as "disturbance type communities" (as originally defined by Hansen et al. 1995). The riparian areas within the park were fenced off in 1994 to exclude cattle (Bedunah and Jones 2001).

Photo 12. A slickens area within the GRKO riparian zone (photo by Kathy Allen, SMUMN GSS 2013).

Mining occurred in the Clark Fork watershed for over a century and flooding washed mining wastes downstream. Toxic metals were deposited throughout the Deer Lodge Valley floodplain, contaminating soils and impacting riparian vegetation (Rice 2003a). Some patches in the riparian area, called slickens (Photo 12), are so contaminated that they are completely devoid of vegetation (Rice and Hardin 2002). Tufted hairgrass (*Deschampsia cespitosa*), a native grass, is known to be metal tolerant and is often associated with these slickens areas (Rice and Ray 1984, Bedunah and Jones 2001).

4.2.2 Measures

- Species richness
- Species composition (cover/biomass)
- Extent of wetlands
- NRCS riparian health assessment
- Greenline assessment
- Ecological effect size (A)

4.2.3 Reference Conditions/Values

The reference condition for species richness and composition is Hansen et al. (1995). Hansen et al. (1995) surveyed riparian and wetland areas across Montana to develop a vegetation-based ecological site classification system for wetlands and riparian areas across the state. Nineteen of the riparian vegetation communities described by Hansen et al. (1995) occur at GRKO; these communities, along with their equivalent map unit names from the Rice et al. (2012) vegetation classification system, are presented in Table 11. Hansen et al. (1995) is also used as the reference condition for ecological effect size analyses (see Appendix B).

Table 11. Riparian vegetation communities described by Hansen et al. (1995) that occur within GRKO and their equivalent map unit name in Rice et al.'s (2012) vegetation mapping and classification system for GRKO. Hansen et al. (1995) communities in bold are considered climax communities while all others are seral (i.e., successional) stages.

Hansen et al. (1995) Community	Rice et al. (2012) Map Unit Name
Agrostis stolonifera	Pasture - Redtop
Betula occidentalis	Riparian Birch
Bromus inermis	Pasture - Smooth Brome
Carex aquatilis	Herbaceous Wetland - Water Sedge
Carex lasiocarpa	Herbaceous Wetland - Woollyfruit Sedge
Carex rostrata	Wetland - Beaked Sedge
Eleocharis palustris	Herbaceous Wetland - Spike Rush
Equisetum fluviatile	Herbaceous Wetland - Horsetail
Juncus balticus	Herbaceous Wetland - Baltic Rush
Poa pratensis	Pasture - Kentucky Bluegrass
Populus trichocarpa/herbaceous understory	Riparian Cottonwood
Populus trichocarpa/Symphoricarpos occidentalis	Riparian Cottonwood - Symphoricarpos
Rosa woodsii	Shrub Rose
Salix bebbiana	Riparian Bebb Willow
Salix exigua	Riparian Narrowleaf Willow
Salix geyeriana	Mesic Geyer Willow
Salix geyeriana/Carex rostrata	Riparian Geyer Willow - Beaked Sedge
Symphoricarpos occidentalis	Shrub Snowberry
Typha latifolia	Herbaceous Wetland - Broadleaf Cattail - Narrowleaf Cattail

4.2.4 Data and Methods

The earliest botanical survey of GRKO was Rice and Ray (1984). While the authors did not generate a species list solely for the riparian area, they did document the most dominant plant species and explored metal contamination levels in vegetation. Just over a decade later, Thompson et al. (1995) completed a vegetative inventory and studied the distribution of communities across the park. A total of 48 polygons were surveyed, comprising 359 ha (888 ac); 33 of the surveyed polygons contained riparian areas or wetlands (Thompson et al. 1995).

In 2000, Bedunah and Jones (2001) re-surveyed the riparian polygons sampled by Thompson et al. (1995) that had been fenced off to exclude livestock in 1994. The final study area included 17 polygons with a total area of 49 ha (122 ac). Community composition metrics were compared to results from Thompson et al. (1995) to determine if changes had occurred since grazing exclusion (Bedunah and Jones 2001). Also in 2000, Rice and Hardin (2002) mapped and surveyed GRKO's riparian areas. Similarity indices were used to compare the park's riparian vegetation communities to the community types developed by Hansen et al. (1995) for the Montana Riparian and Wetlands Association.

Rice and Smith (2011) surveyed vegetation plots in the riparian area in 2009 and 2010 to explore the efficacy of herbicide treatments on invasive species, particularly leafy spurge and yellow toadflax. The study focused on an area known to be impacted by invasive plants, as identified in a 2003 park-wide survey (Wood and Rew 2005), and did not represent a random sampling of the entire riparian zone. Both species richness and species composition were documented.

To evaluate the extent of wetlands within GRKO, SMUMN GSS analysts used National Wetland Inventory (NWI) data for Powell County based on 1984 aerial photos that were converted into GIS data by SMUMN GSS in 2007 (USFWS and SMUMN GSS 2007). The conversion involved scanning hard copies of maps with delineated wetlands, orthorectifying the images, and converting the mapped wetlands to polygon features in a GIS database. Narrow wetlands (e.g., ditches or small streams) are sometimes mapped as linear features. The data are available through the U.S. Fish and Wildlife's "Wetlands Mapper" website at http://www.fws.gov/wetlands/. Vegetation mapping efforts by Thompson et al. (1995) and Rice et al. (2012) may also provide some insight into the extent of wetlands within the park.

In 2014, GRKO assessed the riparian health in the park using the NRCS Riparian Assessment Method (NRCS 2012) at four different locations: Taylor Creek, Cottonwood Creek, North and South Fork Johnson Creek, and No Name Creek (NPS 2014a; Figure 17). The method evaluates physical and ecological attributes and can be a source for defining long-term trends. Ten parameters are used to make this assessment: stream incisement; lateral cutting; stream balance; deep, binding rootmass; riparian/wetland vegetative cover; noxious weeds; undesirable plants; woody species establishment; browse utilization; and riparian area/flood plain characteristics (NRCS 2012). These parameters are scored based on potential and actual conditions, and the final score is a percentage (actual/potential). Scores are placed into one of three categories: sustainable (80-100%), at risk (50-80%), and not sustainable (<50%) (NRCS 2012).

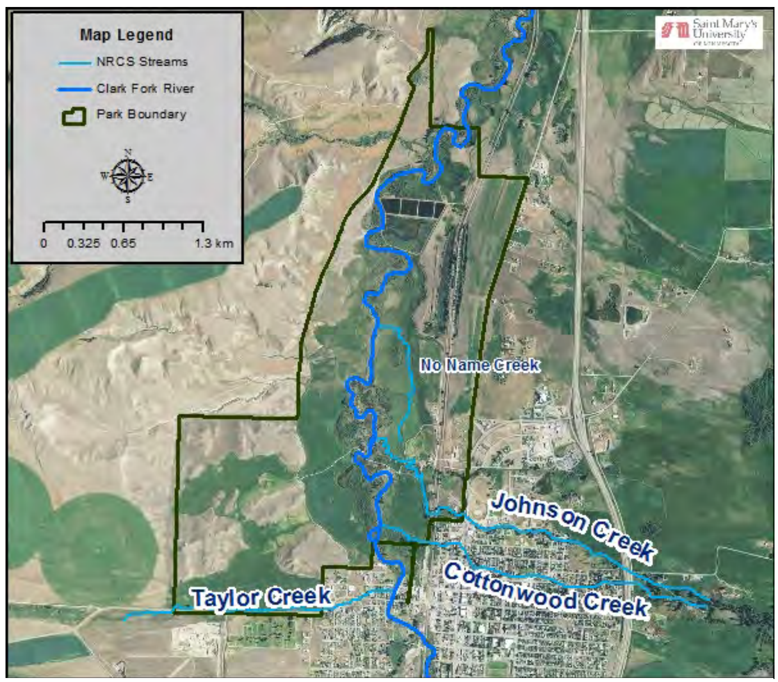


Figure 17. Locations of four creeks sampled in 2014 using the NRCS Riparian Assessment Method.

Winward (2000) describes a three-phase method for analyzing riparian vegetation. Part of this is a Greenline composition assessment. The Greenline is defined by Winward (2000, p. 3) as "the first perennial vegetation that forms a lineal grouping of community types on or near the water's edge. Most often it occurs at or slightly below the bankful stage." Sampling the Greenline according to Winward's (2000) methods occurs by walking transects and recording the composition of each step, which results in a percent composition measurement for the entire transect. At GRKO, Montana State

University researchers examined two locations in 2014 using the Greenline Assessment method (NPS 2014b). The first was along the Clark Fork and consisted of three total transects; the second was along Cottonwood Creek and consisted of one transect.

4.2.5 Current Condition and Trend

Species Richness

A total of 184 plant species have been documented in the GRKO riparian area (Appendix C). This is over 50% of the total number of plant species found within the park as a whole. One of the earliest efforts to inventory riparian vegetation within the park was Rice and Hardin (2002). During this study, 172 plant species were observed: two tree species, 18 shrubs, 39 graminoids, and 113 forbs. More recently, Rice and Smith (2011) recorded 69 and 61 species in riparian sample plots in 2009 and 2010, respectively. However, these observations included 10 species not previously documented in the riparian area by Rice and Hardin (2002). As of 2010, 58 non-native plant species have been confirmed in the riparian area (Rice 2003b, Rice and Smith 2011), which is nearly one-third of the species in the riparian area.

Appendix C contains a list of all 667 plant species documented by Hansen et al. (1995) across Montana in the 19 riparian community types that occur within GRKO. Only 151 of these species have been confirmed in the GRKO riparian area. However, 55 of the species documented in Montana by Hansen et al. (1995) that have not been found in GRKO are non-native species and would be undesirable at GRKO (e.g., saltcedar [*Tamarix chinensis*]). An additional 67 species on the Hansen et al. (1995) list have been documented at GRKO but not in the riparian area. It is also worth noting that Hansen et al. (1995) covered the entire state of Montana and some of the species observed may have ranges that do not include the area around GRKO.

Species Composition (cover/biomass)

Rice and Ray (1984) documented the dominant plant species in the Clark Fork and Cottonwood Creek riparian areas within GRKO (Table 12). Only two species were among the five most dominant species in both riparian areas: redtop and narrowleaf willow (*Salix exigua*). In the Clark Fork riparian area, eight of the 13 dominant species were graminoids (four native and four non-native), with the other species including three shrubs, one forb and one tree (Rice and Ray 1984). Nine of the 13 dominant species were graminoids within the Cottonwood Creek riparian area (six non-natives and three natives); the remaining species included two non-native forbs, one shrub, and one tree (Table 12). Rice and Ray (1984) identified eight low-density cottonwood groves scattered throughout the ranch, with up to 10 trees each.

Table 12. Dominant plant species (in descending order) in the Clark Fork and Cottonwood Creek riparian zones, as documented by Rice and Ray (1984). An asterisk denotes a non-native species.

Clark Fork Riparian Zone		Cottonwood Creek Riparian Zone	
Scientific Name	**Common Name**	**Scientific Name**	**Common Name**
*Agrostis stolonifera**	redtop; creeping bentgrass	*Bromus inermis**	smooth brome
Salix exigua	narrowleaf willow	*Agrostis stolonifera**	redtop; creeping bentgrass
Juncus filiformis	thread rush	*Poa pratensis**	Kentucky bluegrass
Betula occidentalis	water birch	*Alopecurus pratensis**	meadow foxtail
Salix bebbiana	Bebb willow	*Salix exigua*	narrowleaf willow
*Bromus inermis**	smooth brome	*Populus balsamifera* ssp. *trichocarpa*	black cottonwood
Deschampsia cespitosa	tufted hairgrass	*Elymus repens**	quackgrass
*Poa pratensis**	Kentucky bluegrass	*Juncus filiformis*	thread rush
*Trifolium repens**	white clover	*Trifolium repens**	white clover
Carex nebrascensis	Nebraska sedge	*Centaurea stoebe**	spotted knapweed
Carex stipata	awlfruit sedge	*Carex stipata*	awlfruit sedge
*Alopecurus pratensis**	meadow foxtail	*Agropyron cristatum**	crested wheatgrass
Populus balsamifera ssp. *trichocarpa*	black cottonwood	*Carex nebrascensis*	Nebraska sedge

Bedunah and Jones (2001) studied GRKO's riparian communities and compared their results to those of Thompson et al. (1995). They found little difference in species composition and community structure between 1993 and 2000. The dominant and co-dominant plant species were similar, although percent cover varied significantly for three shrub, four graminoid, and three forb species (Table 13). The three shrub species and total shrub cover decreased, as did two non-native grasses and one non-native forb (white clover [*Trifolium repens*]). The two grasses and white clover typically increase with disturbances such as grazing, so these species likely decreased because grazing was excluded from the riparian area in 1994 (Bedunah and Jones 2001). While percent cover of shrubs decreased, shrub regeneration increased and utilization (i.e., browsing by animals) decreased between 1993 and 2000 (Bedunah and Jones 2001). This change would be expected with the elimination of grazing (Ehrhart and Hansen 1997). Bedunah and Jones (2001) also noted that two of the four cottonwood stands sampled in 2000 consisted of only mature and decadent trees with no seedlings, as was the case with all three cottonwood stands sampled by Thompson et al. (1995) in 1993.

Table 13. Percent cover composition of dominant, co-dominant, or community type indicator species in the GRKO riparian area in 1993 (Thompson et al. 1995) and 2000 (Bedunah and Jones 2001).

Species	1993 (Thompson et al. 1995)	2000 (Bedunah and Jones 2001)
Trees		
Populus trichocarpa	0.6	1.78
Shrubs		
Alnus incana	0.25	0.11
Betula occidentalis	12.94	11.12
Cornus stolonifera	0.38**	0.09
Ribes spp.	1.08	0.37
Rosa woodsii	1.00*	0.37
Salix bebbiana	2.17	3.29
Salix boothii	9.45	9.44
Salix exigua	5.80**	3.51
Salix geyeriana	0.28	0.52
Salix lasiandra	0.12	0.09
Symphoricarpos occidentalis	2.25	1.94
Other shrubs	0.07	0.19
Total Shrubs	35.79*	31.05
Graminoids		
Agrostis stolonifera^	24.17*	16.72
Elymus repens^	3.58	4.89
Bromus inermis^	4.71*	10.70
Carex spp.	1.03	1.53
Deschampsia cespitosa	0.53*	3.16
Juncus balticus	5.57	9.82
Poa pratensis^	5.91*	1.39
Phleum pratense^	0.53	0.30
Other grasses	0.57	1.69
Non-native grasses	39.45	34.00
Total graminoids	46.60	50.20
Forbs		
Centaurea stoebe ssp. *micranthos*^	0.77	0.80
Cirsium arvense^	7.71	7.00
Equisetum spp.	0.11	0.31
Euphorbia esula^	1.35*	4.41
Glycyrrhiza lepidota	0.15*	2.93
Argentina anserina	0.62	0.13
Solidago spp.	0.48	0.56
Trifolium repens^	3.64*	0.08
Other forbs	1.66	2.93
Noxious forbs[1]	9.15	12.9
Total forbs	16.49	19.15

* Means of the same species are significantly different ($p \leq 0.10$) between the 2 years.
** Means of the same species are significantly different ($p \leq 0.05$) between the 2 years.
^ Non-native species
[1] Noxious forbs = sum of *Centaurea stoebe* ssp. *micranthos*, *Cirsium arvense*, and *Euphorbia esula*.

Rice and Smith (2011) also documented the most dominant plant species in a portion of the GRKO riparian area in 2009 and 2010 (Table 14). The study plots were dominated by non-native species, averaging 72% canopy cover, with introduced grasses being most common (Rice and Smith 2011). Approximately 10% of the area in the monitoring plots was bare ground or litter, primarily in spots where noxious weeds had been treated with herbicide (Rice and Smith 2011). Total noxious forb cover in 2010 was less than 2%, an improvement over the 12.9% cover reported by Bedunah and Jones (2001) in 2000. Seven of the 15 most dominant species identified by Rice and Smith (2011) were also among the most dominant species documented by Rice and Ray (1984), and 11 species were also considered dominant or co-dominant by Bedunah and Jones (2001).

Table 14. The fifteen most dominant plant species in riparian area monitoring plots in 2009 and 2010 (Rice and Smith 2011). Note that the study area was selected because it was known to be impacted by non-native species and did not represent a random sampling of the entire riparian zone.

2009		2010	
Scientific Name	**% Cover**	**Scientific Name**	**% Cover**
*Elymus repens**	25.3	*Elymus repens**	30.4
*Bromus inermis**	19.3	*Bromus inermis**	22.6
*Agrostis stolonifera**	13.0	*Poa secunda*	11.1
Poa secunda	10.5	*Agrostis stolonifera**	9.3
Juncus balticus	3.3	*Juncus balticus*	4.2
Deschampsia caespitosa	2.5	*Deschampsia caespitosa*	2.5
Salix bebbiana	2.0	*Salix bebbiana*	2.1
*Linaria vulgaris**	0.6-1.8	*Salix boothii*	1.3
*Euphorbia esula**	1.1	*Euphorbia esula**	1.1
*Cirsium arvense**	1.1	*Iris missouriensis*	1.0
Salix boothii	1.0	*Betula occidentalis*	0.5
Betula occidentalis	1.0	*Symphoricarpos occidentalis*	0.5
*Poa compressa**	0.8	*Sonchus arvensis**	0.5
Salix exigua	0.6	*Poa compressa**	0.4
Iris missouriensis	0.6	*Linaria vulgaris**	0.4

* Non-native species

Extent of Wetlands

According to the NWI database, wetland polygons cover just over 170.1 ha (420.3 ac) (Table 15, Figure 18; USFWS and SMUMN GSS 2007). This is based on interpretation of aerial imagery from 1984. However, the vast majority (102 of the 170 ha) is river or stream (R3UBH; see Table 15). Wetlands with emergent vegetation (herbaceous plants) cover approximately 44.5 ha (110 ac) while scrub-shrub wetlands cover 9.4 ha (23.2 ac) and forested wetlands cover less than 0.4 ha (<1 ac) (USFWS and SMUMN GSS 2007). The total area of vegetated wetland polygons (emergent, scrub-shrub, and forested) is 54.3 ha (134.1 ac).

Table 15. Area of NWI wetland polygons (ha and ac) within GRKO (USFWS and SMUMN GSS 2007).

Wetland code*	Number	Area		Wetland code*	Number	Area	
		(ha)	(ac)			(ha)	(ac)
PEMA	4	6.6	16.3	PSSA	7	8.0	19.8
PEMB	1	0.05	0.1	PSSC	5	1.4	3.5
PEMC	16	31.4	77.6	PABF	15	2.3	5.7
PEMF	3	3.2	7.9	PABKx	5	9.1	22.5
PEMKx	1	3.4	8.4	R3UBH	1	102.7	253.8
PFOA	1	0.4	1.0	R3USA	24	1.8	4.4
				Total	**83**	**170.1**	**420.3**
				Vegetated Wetlands	**38**	**54.3**	**134.2**

* PEMA = Palustrine, emergent vegetation, temporarily flooded
PEMB = Palustrine, emergent vegetation, saturated
PEMC = Palustrine, emergent vegetation, seasonally flooded
PEMF = Palustrine, emergent vegetation, semipermanently flooded
PEMKx = Palustrine, emergent vegetation, artificially flooded, excavated
PFOA = Palustrine, forested, temporarily flooded
PSSA = Palustrine, scrub-shrub vegetation, temporarily flooded
PSSC = Palustrine, scrub-shrub vegetation, seasonally flooded
PABF = Palustrine, aquatic bed, semipermanently flooded
PABKx = Palustrine, aquatic bed, artificially flooded, excavated
R3UBH = Riverine, upper perennial, unconsolidated bottom, permanently flooded
R3USA = Riverine, upper perennial, unconsolidated shore, temporarily flooded

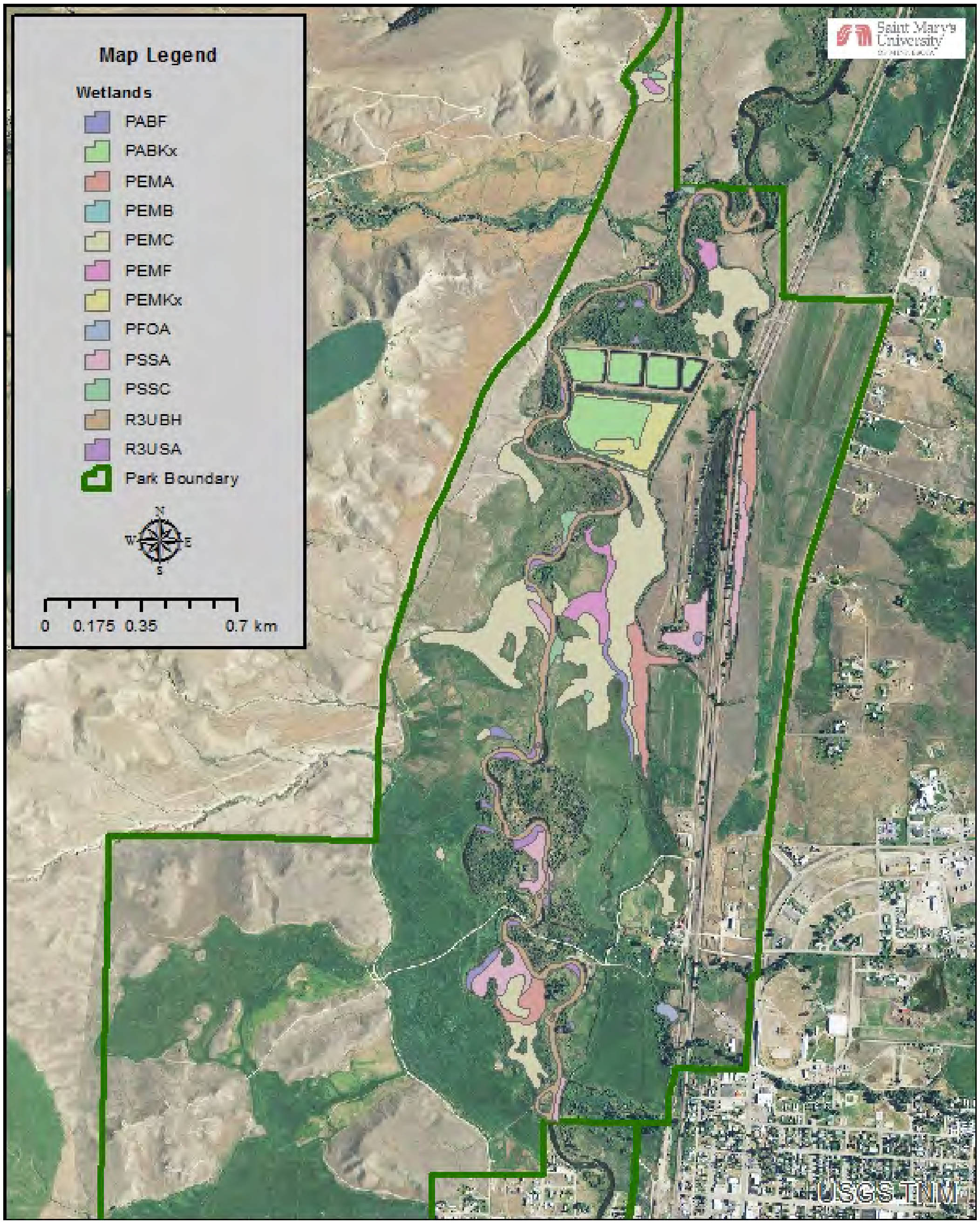


Figure 18. Extent of wetlands (polygons) within GRKO according to the NWI database (USFWS and SMUMN GSS 2007). See footnote of Table 15 above for explanation of wetland codes.

The NWI also identified an additional 44,737.8 m (146,780.0 ft) of linear wetlands (e.g., ditches or small, often intermittent streams) (Table 16, Figure 19). Most of these wetlands (74% of the total length) were vegetated (emergent or forested).

Table 16. Length of NWI linear wetlands (m) within GRKO (USFWS and SMUMN GSS 2007).

Wetland code*	Number	Length (m)	Wetland code*	Number	Length (m)
PEMA	2	389.9	PABF	2	472.7
PEMC	38	9,692.1	R3UBF	1	10,713.9
PEMCh	1	151.8	R3USC	2	357.9
PEMCx	8	21,695.2	**Total**	**60**	**44,737.8**
PEMF	4	391.0	**Vegetated Wetlands**	**55**	**33,193.3**
PFOA	2	873.3			

*PEMA = Palustrine, emergent vegetation, temporarily flooded
PEMC = Palustrine, emergent vegetation, seasonally flooded (x = excavated, h = impounded)
PEMF = Palustrine, emergent vegetation, semipermanently flooded
PFOA = Palustrine, forested, temporarily flooded
PABF = Palustrine, aquatic bed, semipermanently flooded
R3UBF = Riverine, upper perennial, unconsolidated bottom, semipermanently flooded
R3USC = Riverine, upper perennial, unconsolidated shore, seasonally flooded

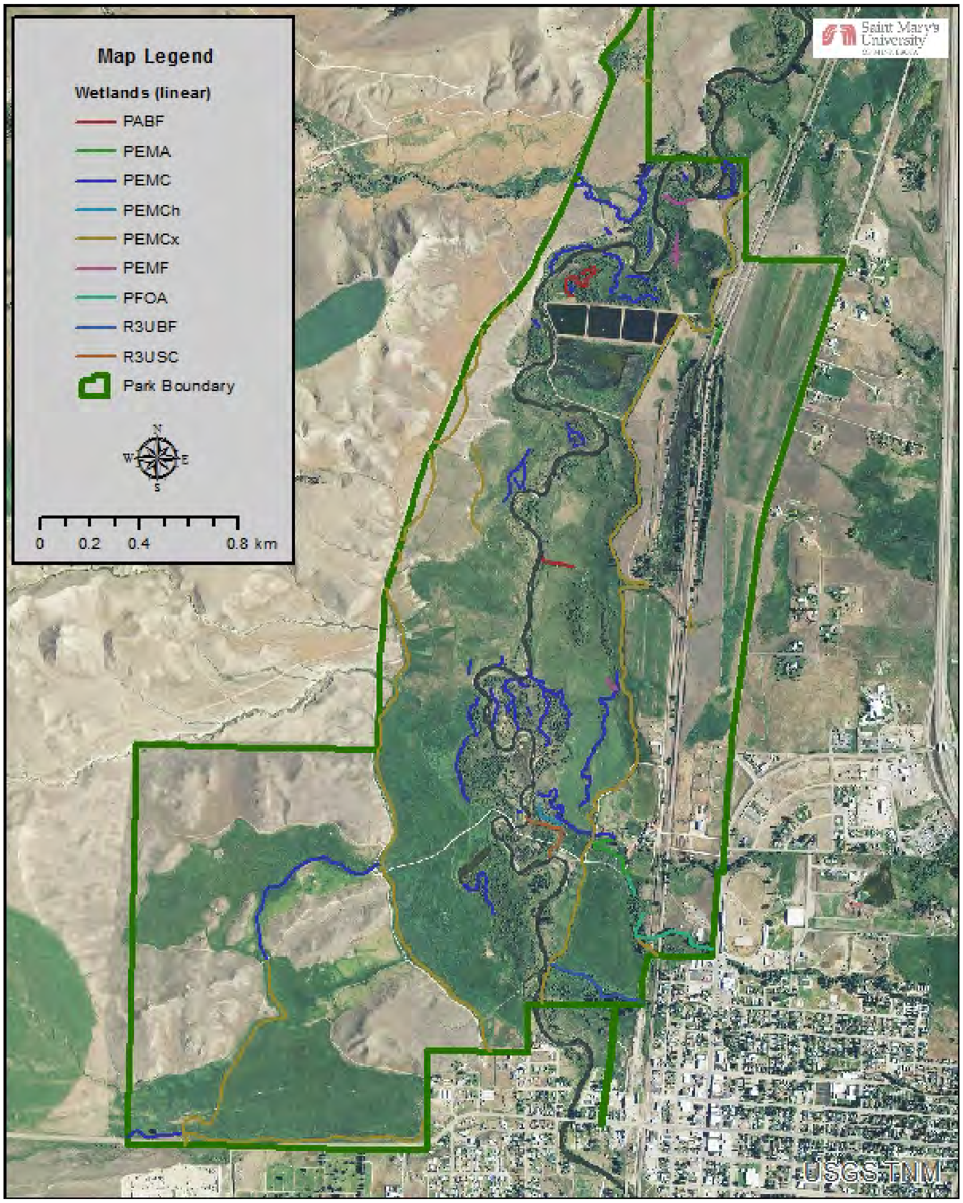


Figure 19. Extent of linear wetlands within GRKO according to the NWI database (USFWS and SMUMN GSS 2007). See footnote of Table 16 above for explanation of wetland codes.

Thompson et al. (1995) and Rice et al. (2012) mapped the extent of vegetation communities within GRKO. The total area of vegetation communities typically found in riparian/wetland areas can provide a rough estimate of wetland extent within the park at the time of mapping. However, these communities may extend outside wetlands, or communities not identified as primarily riparian may actually extend into wetlands. Based on 1993 surveys, Thompson et al. (1995) identified 168.6 ha (416.5 ac) of primarily riparian vegetation communities (Table 17). With field surveys completed in 2006-2007, Rice et al. (2012) mapped 87.1 ha (215.2 ac) of riparian vegetation communities, plus 21.8 ha (53.8 ac) of open water (Table 17; also see Figure 14 and Figure 15). The extent of riparian/wetland communities mapped by Rice et al. (2012) is notably lower than riparian communities mapped by Thompson et al. (1995). Whether this difference is due to an actual change in wetland extent or due to differences in classification and methodologies between the two studies is unclear.

Table 17. Extent of primarily riparian/wetland vegetation communities within GRKO, according to Thompson et al. (1995) and Rice et al. (2012). H.V. = Herbaceous vegetation.

		Extent in ha (ac)	
Thompson et al. (1995) Community Code	**Rice et al. (2012) community name**	**Thompson et al. (1995)**	**Rice et al. (2012)**
SALGEY	Geyer's willow /Mesic Graminoids Shrubland	41.0 (101.3)	24.8 (61.4)
SALGEY/CALCAN[1]		4.5 (11.1)	
SALGEY/CARROS	- Not identified/mapped -	8.6 (21.3)	--
- Not identified -	Geyer's willow/NW Territory Sedge Shrubland	--	8.1 (19.9)
JUNBAL	Baltic Rush H.V.	31.7 (78.4)	1.3 (3.2)
POPTRI/CORSTO	Black Cottonwood/Snowberry Forest	14.5 (35.8)	0.2 (0.6)
BROINE	Smooth Brome - (Western Wheatgrass) H.V.	11.0 (27.1)	8.8 (21.8)
AGRSTO	(Giant Bentgrass, Spreading Bentgrass) H.V.	10.3 (25.4)	2.9 (7.1)
BETOCC	Water Birch Shrubland	9.6 (23.7)	9.3 (22.9)
CARROS	- Not identified/mapped -	9.6 (23.7)	--
- Not identified -	Northwest Territory Sedge (*Carex utriculata*) H.V.	--	0.7 (1.7)
TYPLAT	(Broadleaf Cattail, Narrowleaf Cattail) Western H.V.	9.6 (23.6)	5.6 (13.8)
POAPRA	Kentucky Bluegrass Seasonally Flooded H.V.	6.2 (15.3)	0.1 (0.3)
SALBEB	Riparian Bebb Willow	5.0 (12.3)	--
SALEXI	Narrowleaf (Coyote) Willow Temporarily Flooded Shrubland	3.6 (8.8)	13.7 (33.8)
CARAQU	Aquatic Sedge H.V.	2.0 (5.0)	2.1 (5.2)
SPAGRA[2]	- Not identified/mapped -	0.5 (1.2)	--
ALNINC[3]	- Not identified/mapped -	0.3 (0.8)	--
Slickens	- Unvegetated, not mapped -	0.3 (0.7)	--
DESCES	Tufted Hairgrass Slickens Sparse Vegetation	0.2 (0.5)	1.4 (3.4)
POPTRI/herbaceous	Black Cottonwood/Mixed Herbs Forest	0.2 (0.4)	1.2 (3.0)
ROSWOO	- Not identified/mapped -	0.04 (0.1)	--
- Not identified -	Wooly Sedge (*Carex pellita*)H.V.	--	0.6 (1.4)
- Not identified -	Marsh Spikerush (*Eleocharis palustris*) H.V.	--	0.4 (0.9)
- Not identified -	Water Horsetail (*Equisetum fluvitale*) H.V.	--	0.5 (1.2)
- Not identified -	Rocky Mountain Riparian Bar Sparse Vegetation	--	3.9 (9.6)
- Not identified -	Western Snowberry Shrubland	--	1.6 (4.0)
	Totals	168.6 (416.5)	87.1 (215.2)
	Open Water	--	21.8 (53.8)

[1]CALCAN = bluejoint (*Calamagrostis canadensis*)
[2] Alkali cordgrass (*Spartina gracilis*)
[3] Gray alder (*Alnus incana*)

NRCS Riparian Health Assessment

The full record sheets of the Riparian Health Assessment are located in Appendix D. Overall, the four creeks' percent potential scores in 2014 were 68%, 73%, 78%, and 80% for Taylor Creek, Johnson Creek, Cottonwood Creek, and No Name Creek, respectively (NPS 2014a). Three parameters received an "actual score" of 0, indicating highly degraded conditions: woody species establishment at No Name Creek and Taylor Creek, and riparian/wetland vegetative cover at Taylor Creek (Table 18). Johnson, Cottonwood, and Taylor Creeks fall into the category of "at risk" according to the assessment; No Name Creek is right on the border between "sustainable" and "at risk" (NPS 2014a).

Table 18. NRCS Riparian Health Assessment scores for No Name, Johnson, Cottonwood, and Taylor Creeks (NPS 2014a).

	Potential	No Name Creek	North and South Fork Johnson Creek	Cottonwood Creek	Taylor Creek
Stream Incisement	8	8	6	8	8
Lateral Cutting	8	8	8	5	8
Stream Balance	6	6	6	6	6
Deep, Binding Rootmass	6	6	4	6	4
Riparian/Wetland Vegetative Cover	6	4	2	2	0
Noxious Weeds	3	2	2	2	2
Undesirable Plants	3	3	3	3	3
Woody Species Establishment	8	0	4	6	0
Browse Utilization	4	3	3	3	4
Riparian Area/Flood plain Characteristics	8	8	6	6	6
Total	**60**	**48**	**44**	**47**	**41**
Percent of Potential	**N/A**	**80%**	**73%**	**78%**	**68%**

Non-native pasture grasses make up a large portion of the riparian vegetation at Taylor Creek. In addition, recruitment and cover associated with woody species at Taylor Creek is poor. In certain stretches of the stream, woody riparian species appear to be colonizing; assessors predict this trend will continue into the future. Overall, the stream appears stable (NPS 2014a).

Lower portions of Cottonwood Creek (near the confluence with the Clark Fork) show apparent lateral cutting; non-native grass colonization may be causing this to occur. Riparian wetland cover and cottonwood/willow recruitment are also a concern at Cottonwood Creek. Overall, the stream's riparian health appears to be improving though, with evidence of willow recruitment, bank stabilizations and beaver (*Castor canadensis*) activity along the extent of the waterway (NPS 2014a).

The major concerns at Johnson Creek are stream down-cutting, low numbers of woody species, noxious weed prevalence, and insufficient in-stream structure (e.g., woody debris or rocks) to dissipate stream energy and trap sediment. A railroad runs near the stream and in those locations bank stabilization is a concern. Yet overall, the stream appears to be improving. Assessors note that active weed management should be successful in eliminating noxious species along this waterway (NPS 2014a).

No Name Creek was on the border between "sustainable" and "at risk". However, the threat of pasture grass expansion and low willow recruitment could push this stream into the "at risk" category. Noxious weeds could also negatively impact riparian health if they are not controlled or eliminated. The stream's health appears to be improving, but is vulnerable to disturbance and subsequent vegetation changes in the future (NPS 2014a).

Greenline Assessment

The Greenline Assessment of three transects on the Clark Fork revealed a high percent composition of mesic graminoids (NPS 2014b, Table 19). Mesic graminoids accounted for 70% of the composition of community types and many of the other communities present include mesic graminoids. *Agrostis stolonifera* was the second most prevalent community in the analyzed area and is also a non-native species.

Table 19. Greenline Assessment results for transects on the Clark Fork in GRKO, September 2014 (NPS 2014b).

Community Type	Transect 1		Transect 2		Transect 3		Total Steps	Percent Composition
	Left	Right	Left	Right	Left	Right		
Mesic Graminoid	85	56	70	64	119	95	489	69.66
Carex spp.	9	0	0	0	0	0	9	1.28
Juncus balticus	12	7	1	8	0	10	38	5.41
Betula occidentalis / Mesic Graminoid	2	33	2	14	0	0	51	7.27
Agrostis stolonifera	0	23	41	34	1	0	99	14.10
Deschampsia cespitosa	0	0	2	4	0	0	6	0.85
Salix exigua / Mesic Graminoid	0	0	0	5	0	0	5	0.71
Salix boothii / Mesic Graminoid	0	0	0	0	1	0	1	0.14
Calamagrostis stricta ssp. *stricta*	0	0	0	0	0	2	2	0.28
Scirpus microcarpus	0	0	0	0	0	2	2	0.28

Woody species regeneration was present along Transects 2 and 3 of the assessment. Beaver browsing was also present along the transects, resulting in die off. Overall, the riparian area appears to have sufficient and continued woody species establishment along the Clark Fork (NPS 2014b).

A Greenline Assessment along Cottonwood Creek also took place in 2014 (Table 20). Mesic graminoids accounted for 42.1% of the community composition at this location (NPS 2014b). *Agrostis stolonifera* presence was minimal and *Phalaris arundinacea* was the second most prevalent community type.

Table 20. Greenline Assessment results for transect on the Cottonwood Creek in GRKO, September 2014 (NPS 2014b).

	Transect 1			
Community Type	Left	Right	Total Steps	Percent Composition
Salix exigua / Mesic Graminoid	2	0	2	0.87
Carex utriculata	13	5	18	7.83
Phalaris arundinacea	38	15	53	23.04
Salix boothii / Mesic Graminoid	5	0	5	2.17
Agrostis stolonifera	3	1	4	1.74
Mesic Graminoid	34	63	97	42.17
Populus tremuloides / Mesic Graminoid	3	15	18	7.83
Scirpus microcarpus	12	5	17	7.39
Woody Litter	2	0	2	0.87
Salix amygdaloides / Mesic Graminoid	3	11	14	6.09

Surveyors at Cottonwood Creek noted that this is a relatively small reach and that is why only one transect was examined. Beaver impacts were not as substantial here as along the Clark Fork transects. Overall, woody seedlings were limited on the transect, possibly due to no flooding during the previous spring to promote regeneration (NPS 2014b).

Greenline Assessment results can be used to determine successional status and to calculate a bank stability rating (Winward 2000). However, this can only be done if the individual community types at a site have been assigned a stability class and successional status. Not all the community types documented at GRKO have stability classes and successional status assigned. Communities for which these classifications are known are presented in Table 21.

Table 21. Stability classes and successional status for community types documented during the GRKO Greenline Assessment (Winward 2000). For stability class, 1-2 = very low, 3-4 = low, 5-6 = mid, 7-8 = high, and 9-10 = excellent. For successional status, E = early, L = late.

Community type name	Stability class	Successional status
Betula occidentalis/Mesic graminoid	6-8	E/L*
Salix boothii/Mesic graminoid	7-10	E/L*
Salix exigua/Mesic graminoid	7-10	E/L*
Agrostis stolonifera	3	E
Calamagrostis stricta ssp. *stricta*	7	L
Carex utriculata	9	L
Deschampsia cespitosa	4	E
Juncus balticus	9	L
Scirpus microcarpus	9	L

* These types are considered late seral only if the following, or similar, mesic/hydrophytic graminoids dominate the undergrowth (at least 25% cover): *Carex lanuginosa, Carex nebrascensis, Juncus balticus.*

<u>Ecological Effect Size (A)</u>

In simple terms, an "effect size" describes the magnitude of the difference between two groups (see Appendix B). In the case of vegetation, the two "groups" being compared would be the existing plant community and an identified reference community, sometimes referred to as a potential natural community (PNC). For the GRKO riparian area, the riparian area vegetation communities described in Hansen et al. (1995) can be used as a reference. Using multi-response permutation procedure tests (MRPP) to calculate ecological effect size, Rice and Hardin (2002) determined that the species composition of ten GRKO riparian communities evaluated differed significantly from the Hansen et al. (1995) reference communities (Table 22). As of 2000, those ten communities comprised 63% (32.2 ha) of the fenced riparian zone within the park (Rice and Hardin 2002). Several of the GRKO riparian communities could not be evaluated for ecological effect size by Rice and Hardin (2002), as there was only one plot for the community either within GRKO or in Hansen et al. (1995).

Table 22. Ecological effect size (A) calculations and significance (p) for riparian communities at GRKO. Community types in bold differed significantly between GRKO and Hansen et al. (1995). For this study, p<0.05 is considered a significant result (Rice and Hardin 2002).

Community type	Number of plots: Hansen et al. (1995)	Number of plots: GRKO	Ecological effect size (A)	p<
Salix geyeriana	67	43	0.0878	0.0000
Betula occidentalis	20	28	0.1428	0.0000
Salix geyeriana/Carex rostrata	70	5	0.0323	0.0100
Salix exigua	114	25	0.0645	0.0001
Juncus balticus	10	9	0.0334	0.1130
Symphoricarpos occidentalis*	53	9	0.0370	0.0026
Carex rostrata*	232	7	0.0077	0.0189
Salix bebbiana*	28	6	0.0499	0.0205
Populus trichocarpa/Symphoricarpos occidentalis	21	2	0.0135	0.3080
Rosa woodsii	56	5	0.0179	0.0819
Carex lasiocarpa*	32	5	0.0782	0.0061
Deschampsia cespitosa*	35	6	0.1467	0.0000
Typha latifolia *	81	4	-0.0011	0.4183
Carex aquatilis *	64	2	0.0117	0.1011
Eleocharis palustris	60	3	0.0195	0.0423

* Species constancy was 5%; all other community types used 20% constancy. A 20% constancy means that only plant species present in at least 20% of sampled plots were used in the evaluation.

Threats and Stressor Factors

Threats to GRKO's riparian areas include Superfund contamination and remediation activities, invasive plants, overgrazing, wildlife browsing, beaver activity, flooding, dewatering (e.g., for irrigation), and climate change. As mentioned previously, 58 non-native species have been documented in GRKO's riparian areas; however, many of these are considered part of the cultural landscape. Non-native, invasive species that are of particular concern are those designated as noxious weeds by the state of Montana (Table 23). These aggressive species have the potential to outcompete and displace desirable plant species, alter ecological processes (e.g., nutrient and water cycling) and diminish wildlife habitat (NPS 2008). In the early 2000s, leafy spurge and yellow toadflax invasions in the GRKO riparian area became particularly extensive. A massive effort to reduce these infestations was initiated by the Northern Rocky Mountains Exotic Plant Management Team (NRM EPMT) in 2006. In the first two years, 32.6 ha (80.5 ac) and 46.5 ha (115 ac) were treated with Plateau herbicide, respectively (NPS 2011). In 2008, 21.9 ha (54 ac) were retreated; since then, the size of infestations requiring herbicide treatment has been below 4 ha (10 ac) (NPS 2011). Between 2003 and 2009, canopy cover of leafy spurge and yellow toadflax in the Clark Fork riparian zone decreased by 93% and 91%, respectively (Rice and Smith 2011). Further information on changes in invasive species coverage throughout the park over the past decade can be found in Appendix E.

Table 23. Invasive plant species documented in the Clark Fork riparian area by Rice (2003b).

Scientific Name	Common Name	Scientific Name	Common Name
Montana noxious weeds			
*Cirsium arvense**	Canada thistle	*Linaria vulgaris**	yellow toadflax
*Euphorbia esula**	leafy spurge	*Tanacetum vulgare**	common tansy
*Lepidium latifolium**	perennial pepperweed	*Rhaponticum repens**	Russian knapweed
Centaurea stoebe ssp. *micranthos**	spotted knapweed	*Potentilla recta**	sulfur cinqufoil
*Lepidium draba**	hoary cress, whitetop	*Cynoglossum officianale**	houndstongue
Introduced grasses			
Poa pratensis	Kentucky bluegrass	*Poa compressa*	Canada bluegrass
Elymus repens	quackgrass	*Bromus tectorum**	cheatgrass, downy brome
Agrostis gigantea	redtop	*Phalaris arundinacea*	reed canarygrass
Bromus inermis	smooth brome	*Phleum pratense*	timothy
Alopecurus pratensis	meadow foxtail	*Lolium pratense*	meadow fescue
Potential problem forbs			
Melilotus officinalis	sweetclover	*Sonchus arvensis*	perennial sowthistle
Silene latifolia	bladder campion	*Verbascum thapsus*	common mullein

*Also identified as priority species by the NRM EPMT (2011).

The heavy metal contamination from mining wastes that triggered the Superfund designation in the Upper Clark Fork region is a serious concern at GRKO (Thornberry-Ehrlich 2007). Heavy metals in the soil and water can impact plant health and productivity as well as ecological processes such as decomposition and nutrient cycling (Gannon and Rillig 2002, Kapustka 2002). In the early 1980s, Rice and Ray (1984) used redtop samples to evaluate metal contamination in GRKO's vegetation. In grass from the riparian zone, metal concentrations were 10.4 µg/g for copper, 1.4 µg/g for arsenic, and 0.12 µg/g for cadmium. All of these levels were at least twice as high as would be expected in an uncontaminated area (Rice and Ray 1984). Kapustka (2002) conducted field and lab tests to determine the toxicity of GRKO soils to plants (i.e., phytotoxicity). This study found that metals concentration accounted for 85% of the variation in maximum plant growth. Higher metal concentrations negatively impacted shoot height, number of leaves and branches, root length, and total plant mass (Kapustka 2002).

Beginning in late 2015, a massive remediation effort will take place along the Clark Fork within GRKO to remove much of this heavy metal contamination from the site. Areas targeted will be those within the 100-year channel migration zone (i.e., primarily riparian areas) where the cumulative contaminants of concern (COC) exceed 800 mg/kg and the depth of contamination is 61 cm (24 in) or greater. This will involve removing approximately 296,110 m^3 (387,297 yd^3) of soil to an average depth of 0.7 m (2.3 ft) (Johnson, written communication, 17 October 2014). These areas will be backfilled with clean soil and "uncontaminated rooting medium" to support native plant revegetation and return the flood plain to a 2-year flood level (NPS 2007, p. 3-2). While the removal of this contamination will benefit GRKO in the long run, the short-term damage to riparian area vegetation will be extensive.

It has long been known that livestock grazing can negatively impact riparian communities if not carefully managed (Marcuson 1977, Platts 1979). Improper use of these areas by livestock can alter or eliminate vegetation, as well as changing channel morphology, typically by widening and shallowing the stream (Platts 1979). Excessive cattle grazing alters the number, size, and shape of live and dead willow stems in a riparian community (Knopf and Cannon 1982). Willow seedlings are especially sensitive to grazing and trampling damage (Kovalchik and Elmore 1992). Marcuson (1977) found that shrub production was 13 times greater and canopy cover 82% greater in an ungrazed area than in a severely overgrazed area. Nearly all riparian areas at GRKO were fenced off to exclude cattle in 1994, partly to protect these areas from the negative impacts of grazing, but also to protect livestock and visitors from the contamination there (John Milner Associates et al. 2004). However, cattle may still occasionally get into these areas if fences are damaged or worn. While livestock grazing has potential negative impacts, a complete absence of disturbances (e.g., grazing, fire, flooding) can also impact riparian communities. Pearson and Dyer (2006) compared plant and arthropod communities in an unmanaged (i.e., ungrazed) grassland intermixed with riparian forest and a grazed, flood irrigated pasture on a ranch in northern Colorado. This study showed that the unmanaged grassland had lower plant abundance and species richness, as well as lower arthropod abundance and richness, than the grazed and irrigated pasture (Pearson and Dyer 2006).

Photo 13. Moose (*Alces alces*) in the GRKO riparian area, captured by a park wildlife camera in August 2013 (NPS photo).

Wildlife browsing (particularly ungulates such as moose [Photo 13] and deer) can also affect riparian vegetation. Several studies have shown that native ungulate herbivory slows the restoration or recovery of degraded riparian areas (Case and Kaufmann 1997, Opperman and Merenlender 2000). Extremely high concentrations of native ungulates can eliminate woody vegetation such as willows and cottonwoods, partly by reducing seed production (Kay 1994). Grazing and trampling by ungulates also tends to decrease shrubs and tall forbs in favor of grasses and sedges. These two factors combined can reduce the cover value of riparian habitats for other wildlife (Kay 1994). Bedunah and Jones (2001) noted evidence of shrub browsing by wild ungulates in the GRKO riparian area, averaging almost 5%, during their 2000 study.

Beavers are a natural part of riparian ecosystems in the western United States and can be beneficial to these systems in many ways. Beaver dams impound water that can raise the water table and actually expand riparian communities (Kay 1994; Photo 14). These impoundments can also regulate stream flow, reducing flooding and supplementing low flows during dry periods (Kay 1994). However, beavers are often considered a nuisance to agriculture, as they can block irrigation ditches and culverts (Grasse and Putnam 1955). In other areas, including GRKO, they are a threat to large cottonwoods which are a key component of the visual landscape (Photo 14). The removal of large shade trees along streams could increase water temperatures, which may negatively impact aquatic organisms (Churchill 1980, Kay 1994). Cottonwood stands are not common within the park and are seen as a valuable resource for both the natural and cultural landscape. Some of the largest trees are protected with wire fencing wrapped around the base of the trunk.

Photo 14. On left, a beaver dam on Cottonwood Creek in GRKO. On right, beaver damage to a large cottonwood at GRKO after protective wire broke and fell off (Photos by Sarah Gardner, SMUMN GSS 2013).

Flooding is also a natural and important process in riparian systems, particularly for cottonwood regeneration (Kalischuk et al. 2001), but extreme floods can do significant damage to riparian vegetation. Floodwaters can uproot or damage plants and long periods of inundation can kill vegetation or severely set back its growth (Richardson et al. 2007). Erosion from flood flows can cause riverbanks to collapse, eliminating the bank vegetation. Floodwaters can spread invasive plants and create disturbed areas for these invaders to colonize (Tickner et al. 2001, Richardson et al. 2007).

Irrigation water for GRKO's hayfields is diverted through historic ditches from the Clark Fork and its tributaries during the growing season (Rice et al. 2012). Some of this water returns to the river through surface or groundwater flow and may enhance riparian communities in some areas or allow them to expand. However, if too much water is removed from the river for irrigation, the water available for some riparian communities could be reduced. This could influence community composition and extent. Irrigation practices and other dewatering activities in the watershed but outside the park could also impact GRKO's riparian areas.

Climate has a strong influence on vegetation communities, both directly and indirectly through its impact on ecological processes (e.g., nutrient and water cycling, erosion) (McWethy et al. 2010). As a result of climate change, the western U.S. is projected to experience more frequent dry periods (droughts) during the 21st century, due to increased temperatures and evapotranspirtation, as well as changes in surface hydrology (Gray and Andersen 2009, as cited by McWethy et al. 2010). In the last half of the 20th century, snowmelt and peak runoff were already occurring earlier on average, reducing surface water storage and river baseflows during the summer months (McWethy et al. 2010). An increase in drought frequency or duration could impact riparian community extent and composition, as some riparian plant species are more tolerant of drought than others, while climate warming may influence plant phenology (Loehman 2009, Perry et al. 2012).

Data Needs/Gaps

The riparian area is the most studied vegetation community within GRKO. However, riparian areas along the Clark Fork are expected to change drastically due to Superfund remediation efforts over the next several years. Much of the research described in this assessment could be repeated following remediation to document likely changes in the composition of the riparian area. Ecological effect sizes could be revisited to determine if remediation brings GRKO's riparian communities closer to the Hansen et al. (1995) reference communities. NRCS Riparian Health and Greenline Assessment techniques should also be repeated to identify any changes over time. In addition, an update of NWI data using more recent aerial imagery would be helpful in determining any changes in wetland extent.

Overall Condition

Species Richness

This measure was assigned a *Significance Level* of 2. A total of 184 plant species have been documented in the GRKO riparian area, nearly one-third of which are non-native. However, many of these non-native species, particularly pasture grasses, are an important part of the ranch's cultural landscape. Species richness is currently of low concern (*Condition Level* = 1).

Species Composition

The species composition measure was assigned a *Significance Level* of 3. Many of the plant species that were identified as most dominant in the early 1980s (Rice and Ray 1984) were still dominant in 2009-2010 (Rice and Smith 2011). Bedunah and Jones (2001) also found little change in riparian area species composition between 1993 (Thompson et al. 1995) and 2000, despite the exclusion of grazing in 1994. Noxious forbs such as leafy spurge and yellow toadflax expanded their coverage in the riparian area in the late 1990s and early 2000s, but efforts by the EPMT have greatly reduced these weeds in the past 5 years (NPS 2010). The *Condition Level* for this measure is 2, indicating moderate concern

Extent of Wetlands

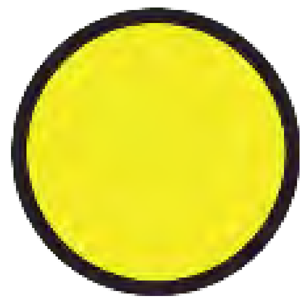
The project team assigned this measure a *Significance Level* of 2. According to the NWI data, wetland polygons cover 170.1 ha (420.3 ac) and 44,737.8 m (146,780.0 ft) in linear features within GRKO. However, these data are based on interpretation of 1984 aerial imagery and wetland extent may have changed since that time. Vegetation mapping identified 168.6 ha (416.5 ac) of primarily riparian or wetland communities in 1993 (Thompson et al. 1995) and 87.1 ha (215.2 ac) in 2006-07 (Rice et al. 2012). Whether the difference in riparian/wetland community extent between these two mapping efforts is due to an actual change or differences in methodology and classification systems is unclear. An update of the NWI data for the park could help determine if wetland area has changed over time. The extent of wetlands is of low concern at this time (*Condition Level* = 1).

NRCS Riparian Health Assessment
This measure was also assigned a *Significance Level* of 2. Three of the four creeks evaluated with this method in 2014 within GRKO fell into the "at risk" category, while one (No Name Creek) was right on the border between "at risk" and "sustainable" (NPS2014a). As a result, this measure is assigned a *Condition Level* of 2, indicating moderate concern.

Greenline Assessment
The Greenline assessment measure was assigned a *Significance Level* of 2. While Greenline assessment results can be used to determine successional status and to calculate a bank stability rating, this can only be done if all the individual community types identified have been rated. At GRKO, several of the communities along the Greenline have not been rated. Therefore, a *Condition Level* was not assigned.

Ecological Effect Size (A)
The project team assigned this measure a *Significance Level* of 3. Using ecological effect size, Rice and Hardin (2002) determined that 10 of the 15 GRKO riparian communities sampled were significantly different from the reference communities described by Hansen et al. (1995). As a result, this measure is of moderate concern (*Condition Level* = 2).

Weighted Condition Score (WCS)
The *Weighted Condition Score* for GRKO's riparian areas is 0.54, indicating moderate concern. An overall trend could not be determined. Some measures appear stable (e.g., species richness) but others only have data from one point in time, so no change can be detected.

Riparian Area			
Measures	Significance Level	Condition Level	**WCS = 0.54**
Species Richness	2	1	
Species Composition	3	2	
Extent of Wetlands	3	1	
NRCS Riparian Health	2	2	
Greenline Assessment	3	n/a	
Ecological Effect Size	3	2	

4.2.6 Sources of Expertise

Peter Rice, University of Montana Research Ecologist

Jason Smith, GRKO Natural Resource Specialist

Bret Olson, Professor of Range Ecology, Montana State University

4.2.7 Literature Cited

Bedunah, D., and T. Jones. 2001. Flood plain vegetation changes on the Grant-Kohrs Ranch National Historic Site between 1993 and 2000. National Park Service, Deer Lodge, Montana.

Case, R. L., and J. B. Kauffman. 1997. Wild ungulate influences on the recovery of willows, black cottonwood and thin-leaf alder following cessation of cattle grazing in northeastern Oregon. Northwest Science 71(2):115-126.

Churchill, J. E. 1980. Beaver are killing our trout streams. Trout 21(4):22-25.

Ehrhart, R. and P. L. Hansen. 1997. Effective cattle management in riparian zones: A field survey and literature review. Montana BLM Riparian Technical Bulletin No. 3. Bureau of Land Management, Montana State Office, Billings, Montana.

Gannon, J. E., and M. Rillig. 2002. Relationship of heavy metal contamination to soil respiration. National Park Service, Deer Lodge, Montana.

Grasse, J. E., and E. F. Putnam. 1955. Beaver management and ecology in Wyoming. Second edition. Wyoming Game and Fish Commission, Cheyenne, Wyoming.

Gray, S., and C. Andersen. 2009. Assessing the future of Wyoming's water resources: Adding climate change to the equation. William D. Ruckelshaus Institute of Environment and Natural Resources. University of Wyoming, Laramie, Wyoming.

Griffin, E. R., and J. D. Smith. 2001. Analysis of vegetation controls on bank erosion rates, Clark Fork of the Columbia River, Deer Lodge Valley, Montana. U.S. Geological Survey, Denver, Colorado.

Hansen, P. L., R. D. Pfister, K. Boggs, B. J. Cook, J. Joy, and D. K. Hinckley. 1995. Classification and management of Montana's riparian and wetland sites. Montana Riparian and Wetland Association, University of Montana School of Forestry, Missoula, Montana.

John Milner Associates, Rivanna Archaeological Consulting, Susan Maxman and Partners Architects. 2004. Cultural landscape report. Grant-Kohrs Ranch National Historic Site, Deer Lodge, Montana.

Kalischuk, A. R., S. B. Rood, and J. M. Mahoney. 2001. Environmental influences on seedling growth of cottonwood species following a major flood. Forest Ecology and Management 144(1):75-89.

Kapustka, L. A. 2002. Phytotoxicity tests on soils from the Grant-Kohrs Ranch National Historic Site, Deer Lodge, Montana. National Park Service, Deer Lodge, Montana.

Kay, C. E. 1994. The impact of native ungulates and beaver on riparian communities in the intermountain west. Natural Resources and Environmental Issues 1:23-44.

Knopf, F. L., and R. W. Cannon. 1982. Structural resilience of a willow riparian community to changes in grazing practices. Pages 198-209 *in* Wildlife-livestock relationships symposium: Proceedings 10. University of Idaho Forest, Wildlife, and Range Experiment Station, Moscow, Idaho.

Kovalchik, B. L., and W. Elmore. 1992. Efects of cattle grazing systems on willow dominated plant associations in central Oregon. Pages 111-119 *in* Proceedings - Symposium on ecology and management of riparian shrub communities, May 29-31, 1991. U.S. Forest Service, Intermountain Research Station, Ogden, Utah.

Loehman, R. 2009. Understanding the science of climate change: Talking points - impacts to prairie potholes and grasslands. Natural Resource Report NPS/NRPC/NRR—2009/138. National Park Service, Fort Collins, Colorado.

Marcuson, P. E. 1977. The effect of cattle grazing on brown trout in Rock Creek, Montana. Project Number F-20-R-21-11a. Montana Department of Fish and Game, Helena, Montana.

McWethy, D. B., S. T. Gray, P. E. Higuera, J. S. Littell, G. T. Pederson, A. J. Ray, and C. Whitlock. 2010. Climate and terrestrial ecosystem change in the U.S. Rocky Mountains and Upper Columbia Basin: Historical and future perspectives for natural resource management. Natural Resource Report NPS/GRYN/NRR–2010/260. National Park Service, Fort Collins, Colorado.

Meehan, W. R., F. J. Swanson, and J. R. Sedell. 1977. Influences of riparian vegetation on aquatic ecosystems with particular reference to salmonid fishes and their food supply. Pages 137-145 *in* Importance, preservation and management of riparian habitat: a symposium. Johnson, R. R., and D. A. Jones (eds.). U.S. Forest Service General Technical Report RM-43. Rocky Mountain Forest and Range Experiment Station, Fort Collins, Colorado.

National Park Service (NPS). 2002. nat_ctnwd.shp ArcGIS shapefile. National Park Service, Deer Lodge, Montana.

National Park Service (NPS). 2007. Federal restoration plan for Grant-Kohrs Ranch National Historic Site. National Park Service, Deer Lodge, Montana.

National Park Service (NPS). 2008. Exotic plant management team: 2008 annual report. National Park Service, Biological Resources Management Division, Fort Collins, Colorado.

National Park Service (NPS). 2010. Northern Rocky Mountain exotic plant management team: FY 2010 report. National Park Service, Biological Resources Management Division, Fort Collins, Colorado.

National Park Service (NPS). 2011. Northern Rocky Mountains invasive plant management plan. National Park Service, Fort Collins, Colorado.

National Park Service (NPS). 2014a. NRCS riparian assessment data sheets. Unpublished data collected by Bret Olson and Jarrett Payne, Montana State University. Received from Jason Smith, 8 July 2014.

National Park Service (NPS). 2014b. Greenline assessment data sheets. Unpublished data collected by Bret Olson and Jarrett Payne, Montana State University. Received from Jason Smith, 26 September 2014.

National Park Service (NPS). 2014c. NPSpecies online database. https://irma.nps.gov/App/Species/Search (accessed 18 November 2014).

Natural Resources Conservation Service (NRCS). 2012. Riparian assessment: Using the NRCS riparian assessment method. Environment Technical Note No. MT-2 (Rev. 1). Natural Resource Conservation Service, Washington, D.C.

Opperman, J. J., and A. M. Merenlender. 2000. Deer herbivory as an ecological constraint to restoration of degraded riparian corridors. Restoration Ecology 8(1):41-47.

Pearson, C. V., and L. A. Dyer. 2006. Trophic diversity in two grassland ecosystems. Journal of Insect Science 6(1):25.

Perry, L. G., D. C. Andersen, L. V. Reynolds, S. M. Nelson, and P. B. Shafroth. 2012. Vulnerability of riparian ecosystems to elevated CO_2 and climate change in arid and semiarid western North America. Global Change Biology 18:821-842.

Platts, W. S. 1979. Livestock grazing and riparian/stream ecosystems: An overview. Pages 39-45 *in* Proceedings, Forum - Grazing and Riparian/Stream Ecosystems. Trout Unlimited, Inc., Vienna, Virginia.

Rice, P. M., and P. C. Ray. 1984. Floral and faunal survey and toxic metal contamination study of the Grant-Kohrs Ranch National Historic Site. National Park Service, Deer Lodge, Montana.

Rice, P. M., and J. Hardin. 2002. Riparian plant community structure at Grant-Kohrs Ranch. National Park Service, Deer Lodge, Montana.

Rice, P. M. 2003a. Baseline vegetation types for Grant-Kohrs Ranch. National Park Service, Deer Lodge, Montana.

Rice, P. M. 2003b. Discussion outline for Grant-Kohrs Ranch weed management and restoration. National Park Service unpublished report, Deer Lodge, Montana.

Rice, P. M., and J. Smith. 2011. Evaluation of the effectiveness of noxious weed management through inventory and establishment of long-term monitoring plots at Grant-Kohrs NHS. National Park Service, Deer Lodge, Montana.

Rice, P. M., E. W. Schweiger, W. Gustafson, C. Lea, D. Manier, D. Shorrock, B. Frakes, and L. O'Gan. 2012. Vegetation classification and mapping project report, Grant-Kohrs Ranch National Historic Site. Natural Resource Report NPS/ROMN/NRR—2012/589. National Park Service, Fort Collins, Colorado.

Richardson, D. M., P. M. Holmes, K. J. Esler, S. M. Galatowitsch, J. C. Stromberg, S. P. Kirkman, P. Pysek, and R. J. Hobbs. 2007. Riparian vegetation: degradation, alien plant invasions, and restoration prospects. Diversity and Distributions 13:126-139.

Thompson, B., B. Ehrhart, and P. Hansen. 1995. Vegetation mapping any analysis of the Grant-Kohrs Ranch National Historical Site. Montana Riparian and Wetland Association, University of Montana School of Forestry, Missoula, Montana.

Thornberry-Ehrlich, T. 2007. Grant-Kohrs Ranch National Historic Site geologic resource evaluation report. Natural Resource Report NPS/NRPC/GRD/NRR—2007/004. National Park Service, Denver, Colorado.

Tickner, D. P., P. G. Angold, A. M. Gurnell, and J. O. Mountford. 2001. Riparian plant invasions: Hydrogeomorphological control and ecological impacts. Progress in Physical Geography 25(1):22-53.

U.S. Fish and Wildlife Service (USFWS) and St. Mary's University of Minnesota Geospatial Services (SMUMN GSS). 2007. National Wetlands Inventory data for Powell County, Montana. http://www.fws.gov/wetlands/ (accessed 12 December 2014).

Winward, A. H. 2000. Monitoring the vegetation resources in riparian areas. General Technical Report RMRS-GTR-47. U.S. Forest Service, Rocky Mountain Research Station, Ogden, Utah.

Wood, S. D., and D. L. J. Rew. 2005. Non-native plant survey at Grant-Kohrs Ranch National Historic Site. Montana State University, Bozeman, Montana.

4.3 Pastures and Hayfields

4.3.1 Description

Pastures and hayfields were critical to the western ranches of the late 19th and early 20th centuries and are a key component of GRKO today. Pastures provide forage for livestock during the growing season, while hayfields are harvested to feed livestock through the winter. Ranchers often converted bottomlands and rich meadows to irrigated crop fields in order to meet the needs of their herds. At GRKO, many of the native plant communities were altered or replaced with pasture grasses as early as the 1870s (Rice et al. 2012). European grasses were introduced in an effort to increase hay production. By the 1930s, approximately 365 ha (900 ac) were in cultivation at GRKO (Photo 15; Rice et al. 2012). Starting in 1862, many of these fields were flood or sub-irrigated with water diverted through ditches from the Clark Fork or its western tributaries, a practice that continues to this day (NPS 2011a, Rice et al. 2012). The current Kohrs-Manning Ditch is believed to include portions of the earliest ditches excavated by Johnny Grant, one of the first ranchers in the valley in the late 1850s and early 1860s (Shapins Belt Collins 2009).

Photo 15. Historic haying operations at the ranch, circa 1937 (NPS photo, from GRKO archives).

Currently, around 60% of GRKO consists of irrigated pastures and hayfields (Rice et al. 2012). These areas provide visitors with an opportunity to view a vast open range landscape, stand in healthy pastures and hayfields, and experience haying with horses (NPS 2008a). The majority of hayfields lie just west of the Clark Fork, extending up wide gullies into the upland grasslands (Figure 20). Additional sub-irrigated fields are found in the southeast portion of the park, while pastures in the northeast have recently been sprinkler irrigated with treated effluent from the municipal sewage system (Rice et al. 2012). GRKO's goal with regard to these hayfields is to maintain sustained yields "to ensure that the continued historic and cultural landscape remains indefinitely" (Olson and Leinard

2013, p. 29). Hayfields can also serve as pastures for cattle after the hay is harvested in late summer or fall (NPS 2011a).

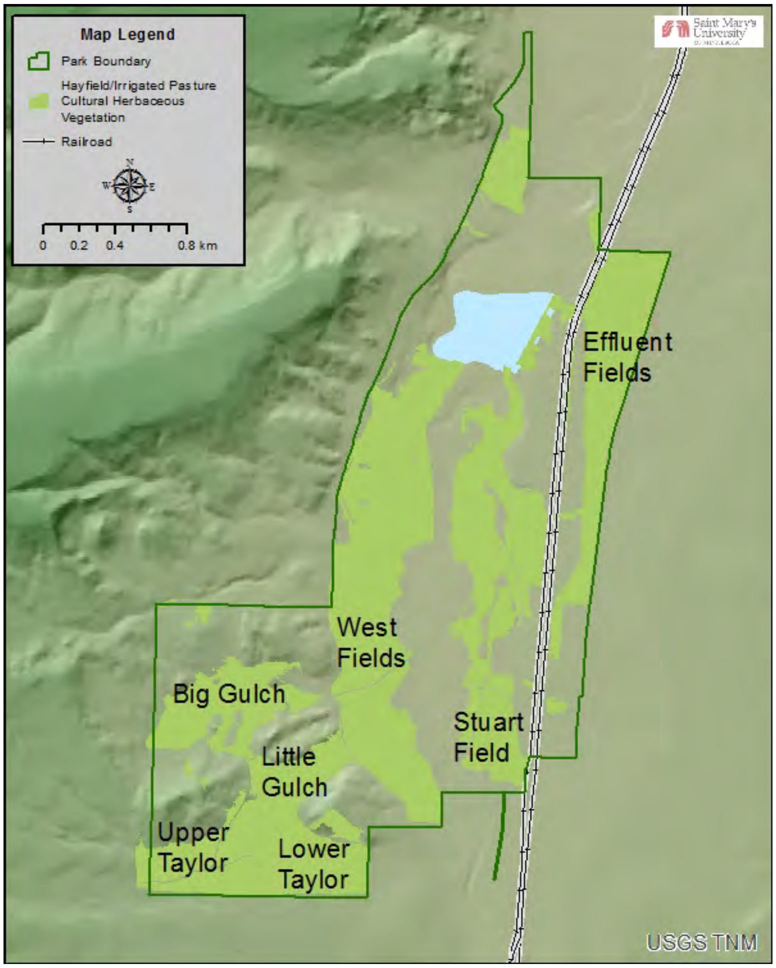


Figure 20. Irrigated pastures and hayfields of GRKO.

The irrigated hayfields and pastures are dominated by introduced grasses such as smooth brome, timothy (*Phleum pratense*), quackgrass, Kentucky bluegrass (*Poa pratensis*), meadow fescue (*Festuca pratensis*), and redtop (Shapins Belt Collins 2009, Rice et al. 2012; Photo 16). Additional grasses that occur in these areas, including some native species, are western wheatgrass, meadow foxtail (*Alopecurus pratensis*), crested wheatgrass (*Agropyron cristatum*), needle-and-thread, and orchardgrass (*Dactylis glomerata*). Hayfield community composition is variable over time, since many fields have been seeded with several grass species, and the dominance of these species is dependent on the amount, timing, and distribution of water (irrigation and subsurface flow) (Rice et al. 2012).

Photo 16. An irrigated hayfield at GRKO with introduced pasture grasses (NPS photo).

Several of the hayfields at GRKO have been designated as prime farmland by the U.S. Department of Agriculture (USDA). These areas include Taylor Field and portions of the West Fields with Varney Clay Loam and Con Loam soils and 0-4% slopes (NPS 2011a). Prime farmland is "land that has the best combination of physical and chemical characteristics for producing food, feed, fiber, forage, oilseed, and other agricultural crops with minimum inputs of fuel, fertilizer, pesticides, and labor, and without intolerable soil erosion, as determined by the Secretary [of Agriculture]" (7 USC 73 §§ 4201 et seq., 1981) (NPS 2011a). GRKO's protected prime farmlands are a valuable resource, as prime farmlands are threatened with conversion across the country and in Montana. Between 1982 and 2007, 9,227 ha (22,800 ac) of prime farmland were converted to developed land across Montana (Farmland Information Center 2010).

4.3.2 Measures

- Hay and forage production (tons per acre)
- Abundance of invasive vs. desired species
- Hay nutrient analysis

4.3.3 Reference Conditions/Values

Each of the measures listed above has a separate reference condition. For hay and forage production, reference condition will be taken from the recently completed soil survey (NPS 2013a). Production estimates vary by rangeland sites (described in NRCS 1982) and include numbers for normal, favorable, and unfavorable years (Table 24). The normal year estimates will be the reference condition for this assessment. Based on this information, the majority of fields at GRKO (Big and Little Gulch, Upper and Lower Taylor, and the West Fields) will have an estimated production of 0.6 tons/acre in a normal year. Only Stuart Field and Bull Pasture have a higher estimated production, with 1.75 tons/acre. These estimates are without irrigation, which typically increases production.

Table 24. Productivity estimates (without irrigation) by rangeland site and soil map unit (NPS 2013a). P.Z. = precipitation zone.

Rangeland Site	Soil map units	Total dry-weight production (tons/ac)		
		Favorable year	Normal year	Unfavorable year
Silty, 10-14" P.Z.	24B, 24C, 24D, 31B, 31C, 34B, 36C, 36D, 351E	0.75	0.6	0.4
Wet meadow, 10-14" P.Z. & 15-19" P.Z.	109, 635, 735, 835	2.25	1.75	1.0
Shallow to gravel, 10-14" P.Z.	132B, 132C, 332B	0.55	0.4	0.2
Subirrigated, 10-14" P.Z.	444, 545	1.25	1.0	0.75

With regard to the abundance of invasive and desired plant species, the reference condition selected by park managers is no more than 1% invasive species. Grasses or other plants that are non-native but were planted for ranching purposes are considered desired species, not invasive species. For hay nutrients, the reference condition will be the beef cattle nutrient requirements published by the National Research Council (NRC 2000). These nutrient requirements vary with the condition of the animal (e.g., age, sex, weight, gestating, lactating, etc.). For the purpose of this assessment, GRKO staff selected three conditions that are common for cattle at the ranch, to provide a general idea of what the nutrient requirements of the herd may be (Table 25).

Table 25. Beef cattle nutrient requirements (in % of dry matter) from NRC (2000). TDN = total digestible nutrients, CP = crude protein, Ca = calcium, P = phosphorous, BCS = body condition score, ADG = average daily gain (weight in pounds).

	TDN	CP	Ca	P
1,200 lb mature weight pregnant yearling replacement heifer, middle 1/3 of pregnancy, BCS=5 at 850 lbs, 1.5 ADG	56%	9.1%	0.41%	0.18%
1,200 lb lactating cow, 20 lb peak milk	58%	9.8%	0.28%	0.19%
2,000 lb mature bull at 1,500 lbs, 0.5 ADG	50%	7.0%	0.17%	0.12%

4.3.4 Data and Methods

Hay and forage production data and hay nutrient analysis information for 2008-2013 were provided by GRKO. Hay nutrient analyses were performed by Montana State University (MSU) in 2008, by AgSource Laboratories in 2013, and by Midwest Laboratories, Inc. from 2009-2012 and in 2014.

Information regarding the abundance of invasive and desired species was calculated from ROMN vegetation monitoring data for 2009-2012 (ROMN 2009, 2010, 2011, 2012). Only data from monitoring plots located in hayfields or pastures (as mapped by Rice et al. 2012) were used in this assessment. Invasive species included those listed as noxious by the state of Montana, those treated by the NRM EPMT, any species identified as "non-contributing" features in the GRKO cultural landscape report (Shapins Belt Collins 2009), and additional species identified by park staff (Smith, email communication, 17 September 2014). SMUMN GSS analysts highlighted invasive species within ROMN percent cover data and added the percentages to determine invasive species abundance by plot. Each sampling location included 10 plots along three different transects. The percent invasive species from each plot was then averaged, resulting in overall mean invasive species abundance by sampling location. The number of hayfield/pasture locations sampled each year ranged from four in 2009 to eight in 2011 and 2012.

4.3.5 Current Condition and Trend

<u>Hay and Forage Production</u>

Annual forage production by field from 2008-2013 is presented in Table 26. Yields during this time typically ranged between 1 and 2 tons per acre, with annual means for all fields combined of 1.4 to 1.7 tons per acre.

Table 26. Forage production in GRKO hayfields, 2008-2013 (NPS 2008b, 2009a, 2010, 2011b, 2012, 2013b).

Year	Field	Acres harvested	Hay harvest (tons)	Yield (tons/ac)
2008[1]	Big Gulch	35.1	36.6	1.0
	Little Gulch	17.0	22.5	1.3
	Taylor	38.0	67.4	1.8
	Stuart	18.6	44.9	2.4
	Stuart - loose hay	6.7	16.3 (approx.)	--
	Bull Pasture	8.8	10.9	1.2
	West Field 1	47.0	67.4	1.4
	West Field 2	26.7	31.7	1.2
	Totals	**197.9**	**297.6**	**1.5**

Table 26. Forage production in GRKO hayfields, 2008-2013 (NPS 2008b, 2009a, 2010, 2011b, 2012, 2013b) (continued).

Year	Field	Acres harvested	Hay harvest (tons)	Yield (tons/ac)
2009	Big Gulch	45.4	57.2	1.3
	Little Gulch	17.7	23.6	1.3
	Lower Taylor	62.1	97.5	1.6
	Upper Taylor	15.3	30.4	2.0
	Stuart	25.3	52.1	2.1
	West Field 1	49.7	60.6	1.2
	West Field 3	28.0	5.1	0.2
	Totals[2]	**216 (244)**	**321 (326)**	**1.5 (1.3)**
2010	Big Gulch	45.1	60.9	1.3
	Little Gulch	6.1	10.4	1.7
	Lower Taylor	63.6	104.3	1.6
	Upper Taylor	16.6	24.3	1.5
	Stuart	25.3	47.8	1.9
	West Field 1	52.6	80.0	1.5
	West Field 2	40.1	53.9	1.3
	West Field 3	19.4	17.4	0.9
	Totals	**269**	**399**	**1.5**
2011	Big Gulch	55.6	100.2	1.8
	Little Gulch	12.7	24.5	1.9
	Lower Taylor	63.7	105.5	1.7
	Upper Taylor	15.5	29.8	1.9
	Stuart	24.9	54.2	2.2
	West Field 1	51.6	83.1	1.6
	West Field 2	38.2	57.3	1.5
	West Field 3	5.1	5.1	1.0
	Totals	**267**	**446**	**1.7**
2012	Big Gulch	45.6	79.3	1.7
	Little Gulch	14.0	20.1	1.7
	Lower Taylor	63.9	77.4	1.2
	Upper Taylor	16.3	30.1	1.8
	Stuart	25.3	45.2	1.8
	West Field 1	51.3	66.9	1.3
	West Field 2	39.8	49.7	1.2
	West Field 3	10.7	6.8	0.6
	Totals	**267**	**376**	**1.4**
2013	Big Gulch	53.0	90.3	1.7
	Little Gulch	16.8	23.6	1.4
	Lower Taylor	65.0	94.0	1.4
	Upper Taylor	16.6	28.9	1.7
	Stuart	24.4	43.3	1.8
	West Field 1	52.9	87.8	1.7
	West Field 2	40.5	63.1	1.6
	Totals	**269**	**431**	**1.6**

[1] In 2008, total harvest was not weighed, but the number of bales was recorded; 14 bales were weighed and averaged 6o lbs. Hay harvests for 2008 were estimated by SMUMN GSS based on the number of bales and the 60 lb. average per bale.

[2] West Field 3 was not scheduled for hay production and, as a result, was not irrigated, but was cut for hay in order to perform ditch and field maintenance in 2010. Therefore, annual totals and averages are calculated first without West Field 3, and with West Field 3 in parentheses.

Nearly every field met or exceeded the estimated production numbers from the GRKO soil survey (NPS 2013a) for a normal year (see Table 24). Annual yields for the most frequently harvested fields in comparison to the selected reference condition are shown in Figure 21. Many fields exceeded the "favorable year" production estimate of 0.75 tons/acre. Stuart Field was consistently the most productive field, likely due to its soil type.

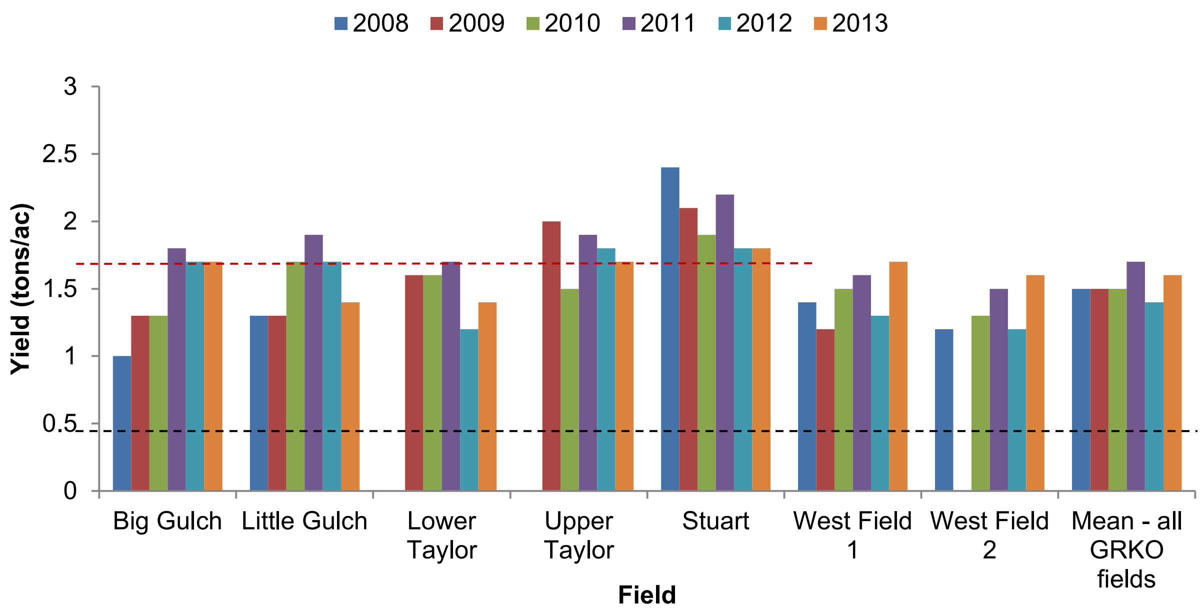


Figure 21. Forage yield (tons/acre) by field and overall for GRKO from 2008-2013 (NPS 2008b, 2009a, 2010, 2011b, 2012, 2013b). The black dashed line represents the estimated production of 0.6 tons/acre in a normal year for all fields shown except Stuart. The red dashed line represents the estimated production of 1.75 tons/acre in a normal year, the reference condition for Stuart Field.

Abundance of Invasive vs. Desired Species

The earliest documentation of invasive species abundance in GRKO was during efforts to suppress Canada thistle (*Cirsium arvense*) in the West Fields during the early 2000s (Rice and Hardin 2004). In 2001, the frequency of Canada thistle in these four fields ranged from 11.5% to 19.9%, with a mean of 15.4% (Rice and Hardin 2004). Three of the four fields were then treated with herbicide in 2002 and 2003, while one was left untreated as a control. After 2 years of treatment, the frequency of Canada thistle in the three treated fields decreased to a mean of 1.8% while frequency in the untreated field increased in 2002 and then decreased to 6.9% in 2003 (Rice and Hardin 2004).

The first ranch-wide efforts to quantify invasive species abundance occurred during a 2003 non-native plant survey (Wood 2005). This survey found that several of GRKO's hayfields had large and complex infestations (Wood 2005), particularly of Canada thistle and field bindweed (*Convolvulus arvensis*). The affected fields, percent of the field infested, and estimated percent cover (i.e., abundance) of the invasive species are presented in Table 27. Based on these estimates, the three listed fields would not have met the reference condition of no more than 1% invasive species.

Table 27. GRKO hayfields with large infested areas identified during the 2003 non-native plant survey (Wood 2005).

Field	Species	% of Field Infested	Est. % Cover
Lower Taylor	*Convolvulus arvensis*	50	2
	Cirsium arvense	80	5
Big Gulch	*Cirsium arvense*	50	5
Little Gulch	*Convolvulus arvensis*	30	10

The current abundance of invasive versus desired plant species varies greatly across GRKO, depending on environmental factors and land history. According to ROMN sampling data, some hayfield sub-plots are weed-free, while a few are dominated by invasives (ROMN 2009-2012). Table 28 shows the abundance of invasive species by ROMN sampling location (a mean across 10 plots) during 4 years of monitoring and the percent of plots meeting the selected reference condition of no more than 1% invasive species. The invasive species of highest concern are those designated as noxious weeds by the state of Montana, and species identified as "high priority" by the NRM EPMT. Therefore, SMUMN GSS analysts also calculated the abundance of these invasives alone. Data show that lower priority invasive species, such as common dandelion (*Taraxacum officinale*), made up a relatively large percentage of invasives in several fields, frequently pushing locations above the 1% reference condition. With all invasive species included, only five of the 25 locations (20%) sampled from 2009-2012 had an invasives abundance of 1% or less. When only state-designated noxious weeds and high priority species are considered, the number increases to 17 out of 25 (68%). Sampling locations and whether or not they met the reference condition are shown in Figure 22.

Table 28. Invasive species abundance by ROMN sampling location (ROMN 2009-2012). The middle column contains mean percent cover of all invasive species (10 plots per location) while the final column contains the percent cover when lower priority species are subtracted. The reference condition for this measure is no more than 1% invasive species. Note that results are not comparable between years, as different locations were sampled each year.

Sampling Location	Total % Invasives	% Invasives without Lower Priority Species
2009		
GRKO_001_05	7.1	3.6
GRKO_012_04	0	0
GRKO_028_01	0.3	0.1
GRKO_033_01	16	13.1
% of plots meeting reference	50%	50%
2010		
GRKO_001_06	5	1.2
GRKO_005_05	0.5	0.3
GRKO_012_05	0.5	0.1
GRKO_037_01	2.8	0.4
GRKO_043_01	1.6	1.1
% of plots meeting reference	40%	60%

Table 28. Invasive species abundance by ROMN sampling location (ROMN 2009-2012). Note that results are not comparable between years, as different locations were sampled each year. (continued)

Sampling Location	Total % Invasives	% Invasives without Lower Priority Species
2011		
GRKO_007_06	15.7	0.2
GRKO_008_05	1.6	0.7
GRKO_009_04	3	0.2
GRKO_010_04	1.4	0
GRKO_011_05	0.8	0.2
GRKO_015_03	1.4	0.2
GRKO_016_04	7.5	6.6
GRKO_020_04	7.2	4.3
% of plots meeting reference	12.5%	75%
2012		
GRKO_015_04	2.2	0.4
GRKO_016_05	10.2	8.1
GRKO_018_02	9.4	0.9
GRKO_019_02	1.9	0
GRKO_021_02	9.1	0.2
GRKO_022_02	7.9	0.1
GRKO_024_02	4.5	2.3
GRKO_027_04	1.3	0.5
% of plots meeting reference	0%	75%
Total % of plots meeting reference over all years	**20%**	**68%**

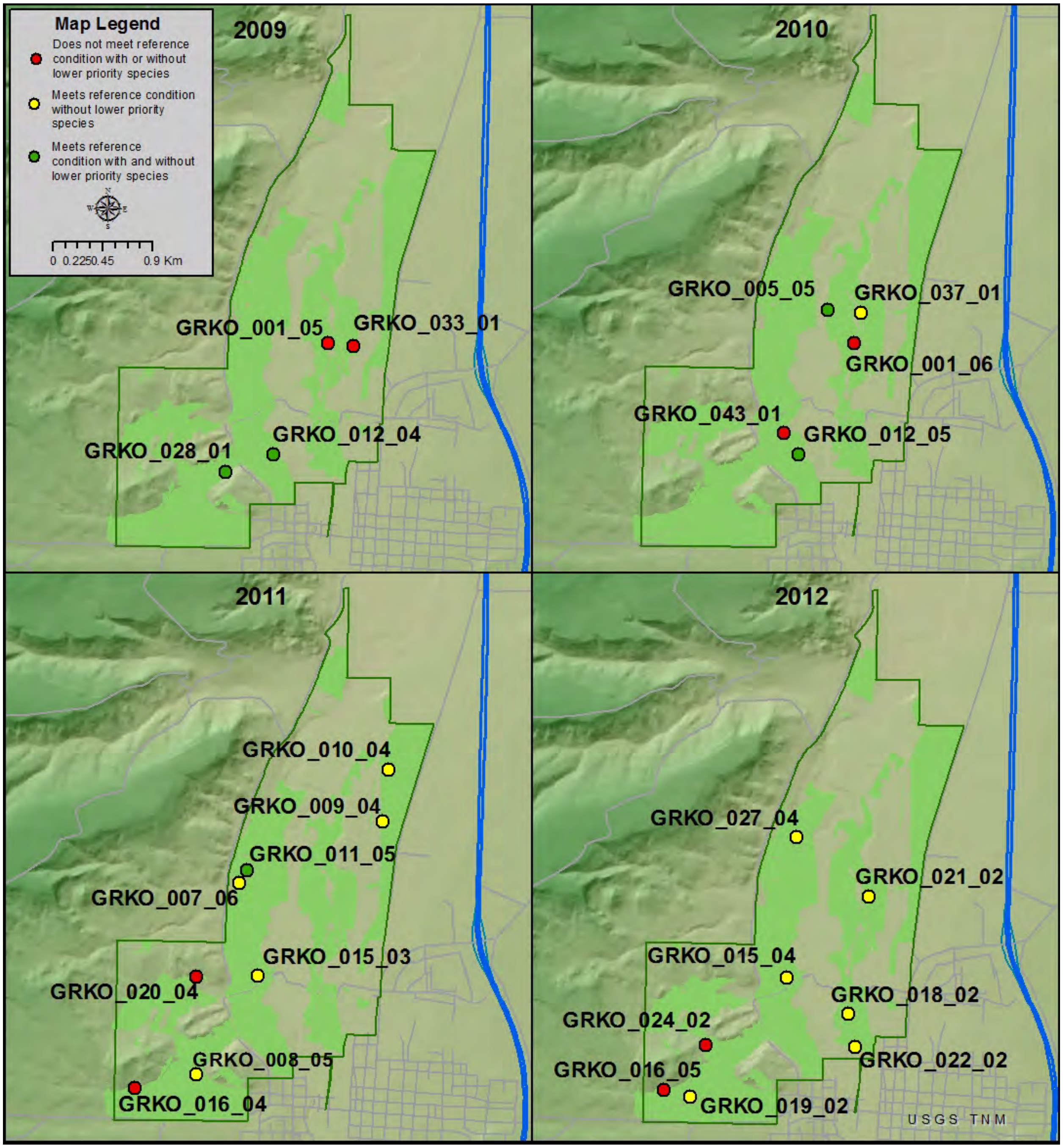


Figure 22. ROMN sampling sites in GRKO hayfields, 2009-2012, that met the reference condition of no more than 1% invasive species (green), met the reference condition when lower priority species such as dandelion were excluded (yellow), and that did not meet the reference condition with or without lower priority species included (ROMN 2009-2012).

Threats and Stressor Factors

The park's pastures and hayfields are threatened by invasive species, drought, climate change, improper grazing or irrigation practices, unplanned fires, Columbian ground squirrels, and grasshopper outbreaks. Invasive plant species are a major concern at GRKO and are recognized globally as a significant threat to ecosystem stability (NPS 2008c, Rice et al. 2012). Some invasives can alter ecosystems by changing soil chemistry and water availability, which are particularly important in hayfields (NPS 2008c). At GRKO, invasive plants also threaten the cultural landscape the park was set aside to protect, and often reduce forage quality in the pastures and hayfields (NPS 2011a, Manier et al. 2011). Invasive species common in GRKO's hayfields include Canada thistle (Photo 17), field bindweed, and annual weeds from the Brassicaceae family, such as field pennycress (*Thlaspi arvense*), herb sophia (*Descurainia sophia*), and madworts (*Alyssum* spp.) (Wood 2005, Rice et al. 2012). The park has used mowing to reduce seed production of annual weeds in irrigated pastures and has experimented with prescribed grazing (e.g., training livestock to eat weeds) to reduce Canada thistle and other invasive plants (NPS 2011a). However, there is no evidence that prescribed grazing has been effective. Further information on changes in invasive species coverage throughout the park over the past decade can be found in Appendix E.

Photo 17. Canada thistle (NPS photo, courtesy of Rocky Mountain National Park).

Two processes that are a natural part of grassland ecosystems - grazing and fire - can be stressors to hayfields that are managed for forage production. Unplanned fires have the potential to destroy the entire crop in a hayfield, and may cause erosion or nutrient loss if the ash from the burned vegetation is blown or washed off the field. Overgrazing, particularly during peak vegetative growth periods, reduces the amount of leaf area to capture sunlight and generate energy for growth; if fields are not given time to recover, stand vigor can be reduced (Olson and Leinard 2013). Milchunas et al. (1994) found that heavy grazing (60% consumption) over long periods (25-50 years) can reduce forage production by 12-18% in dry or average years. Grazing when soils are wet often causes soil compaction, which can affect plant growth and field productivity (da Silva et al. 2003).

Columbian ground squirrels play an important role in natural ecosystems, as their digging activity creates habitat diversity and improves soil aeration and moisture retention (MDA 2013). However, in agricultural areas, this digging may contribute to soil erosion and create disturbed areas where invasive species can colonize. The squirrel's feeding and digging can cover and kill crops, which reduces forage production. Additionally, their holes are a possible hazard for grazing livestock and can damage harvesting equipment (MDA 2013). At GRKO, ground squirrels occasionally burrow into irrigation ditches, which can weaken the ditches and eventually cause them to wash out (Shapins Belt Collins 2009). Grasshoppers are also an important natural part of western ecosystems, but increased herbivory during population outbreaks often results in serious forage losses (Branson et al. 2006). Large outbreaks could temporarily reduce the productivity of GRKO's hayfields and pastures.

Climate has a strong influence on vegetation communities, both directly and indirectly through its impact on ecological processes (e.g., nutrient cycling, erosion) (McWethy et al. 2010). Climate change is projected to trigger more frequent dry periods (droughts) the western U.S. during the 21st century, due to increased temperatures and evapotranspiration, as well as changes in surface hydrology (Gray and Andersen 2009, as cited by McWethy et al. 2010). Snowmelt and peak runoff were already occurring earlier on average in the last half of the 20th century, reducing surface water storage and river baseflows during the summer months (McWethy et al. 2010). This would likely impact the amount of water available for irrigation of hayfields at GRKO. An increase in drought frequency or duration could also impact grassland composition and production, while climate warming may influence plant phenology (Loehman 2009, Bloor et al. 2010) and forage quality (Craine et al. 2010). Since GRKO receives an average of only 26.9 cm (10.6 in) of precipitation annually (NPS 2009b), any small change in the amount or timing of this precipitation would likely influence plant growth and species composition (Peter Rice, University of Montana Research Ecologist, written communication, January 2015).

Data Needs/Gaps

A recently completed best management practices (BMP) plan for GRKO (Olson and Leinard 2013) recommends establishing sustainable and realistic yield goals for hayfields, "based on soil productivity, information from the soil survey, historical yield data, climatic conditions, level of management and/or local research on similar soil, cropping systems, and soil and manure/organic byproducts tests" (Olson and Leinard 2013, p. 30). It also suggests utilizing a "nutrient budget" for nitrogen, phosphorus, and potassium, to track all nutrients applied to hayfields and pastures. Potential nutrient sources to be considered include commercial fertilizer, animal manure, crop residue, legume credits, and irrigation water (Olson and Leinard 2013).

Beginning in 2015, effluent from the city's sewage system will no longer be used to irrigate pastures in the northeast section of the park (NPS 2014). A plan is needed for managing these fields once this water source is no longer available.

Overall Condition

Hay and Forage Production

Hay and forage production was assigned a *Significance Level* of 3. Nearly all hayfields harvested from 2008-2013 met or exceeded the production estimates established in the recent GRKO soil survey (NPS 2013a). As a result, this measure is assigned a *Condition Level* of 0, meaning it is currently of no concern.

Abundance of Invasive vs. Desired Species

This measure was also assigned a *Significance Level* of 3. Invasive species have long been an issue at GRKO, and are a particular concern in pastures and hayfields where they can reduce forage quality. Recent ROMN vegetation sampling shows that invasive species abundance is highly variable across the park. Of the 25 irrigated pasture and hayfield locations sampled by the ROMN, only five (20%) met the selected reference condition of 1% or less invasive species abundance. However, when only “high priority” species are considered, the number of locations meeting the reference condition increases to 17 (68%). Therefore, this measure is of moderate concern (*Condition Level* = 2).

Hay Nutrient Analysis

The project team assigned this measure a *Significance Level* of 1. Measures with a *Significance Level* of 1 are not discussed in detail in the Current Condition section of this text, rather they are briefly summarized here in the Overall Condition section. The low significance of this measure is due partially to the fact that hay nutrient levels can be influenced by so many factors other than the condition of the vegetation itself. For example, nutrient levels are affected by the life stage at which the plant is cut, how long the hay lays in the field before being baled, or if it is rained on before being baled (Smith, written communication, January 2015). Hay nutrient analyses were performed for several GRKO fields between 2008 and 2013 (Table 29). When compared to beef cattle nutrient requirements (see Table 25), it appears that hay from most GRKO fields sampled are meeting the nutritional needs of at least two of the three selected cattle conditions. Crude protein (CP) values appear to fall below nutrient requirements most often, with four fields falling below the requirements for all three selected cattle conditions, each in a different year. Calcium (Ca) levels consistently meet requirements while phosphorous (P) levels are regularly just below the requirements for lactating and pregnant cows. These results are typical for the type of grass species in GRKO’s hayfields (Smith, email communication, 25 September 2014). The USDA Agricultural Marketing Service adopted grass hay quality guidelines based on crude protein content (USDA 2003); the majority of GRKO fields would fall into the “fair” category (5-9%) with a few results in the “good” category (9-13%) (Table 29). This measure was assigned a *Condition Level* of 1, indicating low concern. It is interesting to note that the total digestible nutrients (TDN) results that fall below requirements are from the 2 years when analyses were not performed by Midwest Laboratories (2008, 2012). The variance in results could be due to differences in analytical methods rather than actual variance in hay nutrient levels.

Table 29. Hay nutrient analysis (MSU 2008, Midwest Laboratories 2009, 2010, 2012, 2014, AgSource Laboratories 2013). TDN = total digestible nutrients, CP = crude protein, Ca = calcium, P = phosphorous. Red numbers indicate results that are below the nutrient requirements for all three cattle conditions selected by GRKO staff while purple numbers are below just one or two of the nutrient requirements among the three conditions (typically lactating and/or pregnant cows).

Year	Field	TDN	CP	Ca	P
2008[1]	Big Gulch	53.5%	6.5%		
	Little Gulch-Taylor	53.4%	7.5%		
	Stuart-Bull Pasture	53.2%	7.5%		
	West Field 1 and 2	52.8%	6.9%		
2009	Big Gulch-Little Gulch	68.9%	6.73%	0.56%	0.16%
	Stuart	63.2%	7.18%	0.56%	0.15%
	Lower Taylor	63.8%	7.84%	0.51%	0.17%
	Upper Taylor	61.7%	13.3%	1.30%	0.25%
2010	Upper Taylor		10.4%	0.49%	0.21%
	Lower Taylor		7.18%	0.38%	0.17%
	Stuart		7.21%	0.60%	0.15%
	West Field 1		6.45%	0.58%	0.15%
	West Field 2		7.33%	0.52%	0.16%

Table 29. Hay nutrient analysis (MSU 2008, Midwest Laboratories 2009, 2010, 2012, 2014, AgSource Laboratories 2013). TDN = total digestible nutrients, CP = crude protein, Ca = calcium, P = phosphorous. Red numbers indicate results that are below the nutrient requirements for all three cattle conditions selected by GRKO staff while purple numbers are below just one or two of the nutrient requirements among the three conditions (typically lactating and/or pregnant cows). (continued)

Year	Field	TDN	CP	Ca	P
2011	Lower Taylor	67.3%	9.36%	0.85%	0.19%
	Upper Taylor	65.4%	13.0%	1.08%	0.23%
	Stuart	63.2%	7.89%	0.96%	0.16%
	West Side	66.8%	7.94%	0.65%	0.17%
	Weed free	65.5%	9.07%	0.83%	0.17%
2012[2]	Stuart	47.7%	6.8%	0.33%	0.17%
	West Field 1 - North	48.1%	7.0%	0.21%	0.19%
	West Field 1 - South	49.0%	8.1%	0.41%	0.18%
2013	Big Gulch-West Field 2	61.4%	7.45%	0.56%	0.14%
	Taylor	64.2%	9.8%	0.78%	0.21%

[1] TDN values for 2008 are reported on an "as received" basis (i.e., before drying), not as % dry matter. Dry matter values would likely be slightly higher.

[2] According to lab reports, TDN values from this year are estimates.

Weighted Condition Score

The *Weighted Condition Score* for GRKO's pastures and hayfields is a 0.33, indicating the resource is in good condition. However, this score is at the top of the good condition range, and a small decline in condition could shift the resource into the "moderate concern" range. The measures considered in this assessment have been relatively consistent in recent years, suggesting the condition of this community is stable.

Pastures and Hayfields			
Measures	Significance Level	Condition Level	**WCS = 0.33**
Hay/Forage Production	3	0	
Abundance of Invasive vs. Desired Species	3	2	
Hay Nutrient Analysis	1	1	

4.3.6 Sources of Expertise

Jason Smith, GRKO Natural Resource Specialist

Peter Rice, University of Montana Research Ecologist

Bret Olson, Professor of Range Ecology, Montana State University

4.3.7 Literature Cited

AgSource Laboratories. 2013. Hay nutrient analysis, 2012 crop. AgSource Laboratories, Jerome, Idaho.

Bloor, J. M. G., P. Pichon, R. Falcimagne, P. Leadley, and J. Soussana. 2010. Effects of warming, summer drought, and CO_2 enrichment on aboveground biomass production, flowering phenology, and community structure in an upland grassland ecosystem. Ecosystems 13:888-900.

Branson, D. H., A. Joern, and G. A. Sword. 2006. Sustainable management of insect herbivores in grassland ecosystems: New perspectives in grasshopper control. Bioscience 56(9):743-755.

Craine, J. M., A. J. Elmore, K. C. Olson, and D. Tolleson. 2010. Climate change and cattle nutritional stress. Global Change Biology 16:2901-2911.

da Silva, A. P., S. Imhoff, and M. Corsi. 2003. Evaluation of soil compaction in an irrigated short-duration grazing system. Soil and Tillage Research 70:83-90.

Farmland Information Center. 2010. 2007 NRI: Changes in land cover/use - data tables. http://www.farmlandinfo.org/sites/default/files/FIC_NRI%202007%20Data%20Tables.pdf (accessed 8 September 2014).

Gray, S., and C. Andersen. 2009. Assessing the future of Wyoming's water resources: Adding climate change to the equation. William D. Ruckelshaus Institute of Environment and Natural Resources. University of Wyoming, Laramie, Wyoming.

Loehman, R. 2009. Understanding the science of climate change: Talking points - impacts to prairie potholes and grasslands. Natural Resource Report NPS/NRPC/NRR—2009/138. National Park Service, Fort Collins, Colorado.

Manier, D., D. Shorrock, E. W. Schweiger, I. Ashton, B. Frakes, M. Britten, D. Pillmore, and J. Burke. 2011. Rocky Mountain Network vegetation composition structure and soils monitoring protocol: Small park grasslands, shrublands, and woodlands; Version 1.0. Natural Resource Report NPS/ROMN/NRR-2011/383. National Park Service, Fort Collins, Colorado.

McWethy, D. B., S. T. Gray, P. E. Higuera, J. S. Littell, G. T. Pederson, A. J. Ray, and C. Whitlock. 2010. Climate and terrestrial ecosystem change in the U.S. Rocky Mountains and Upper Columbia Basin: Historical and future perspectives for natural resource management. Natural Resource Report NPS/GRYN/NRR–2010/260. National Park Service, Fort Collins, Colorado.

Midwest Laboratories, Inc. 2009. Hay nutrient analysis, 2009. Midwest Laboratories, Inc., Omaha, Nebraska.

Midwest Laboratories, Inc. 2010. Hay nutrient analysis, 2010. Midwest Laboratories, Inc., Omaha, Nebraska.

Midwest Laboratories, Inc. 2012. Hay nutrient analysis, 2011 crop. Midwest Laboratories, Inc., Omaha, Nebraska.

Midwest Laboratories, Inc. 2014. Hay nutrient analysis, 2013 crop. Midwest Laboratories, Inc., Omaha, Nebraska.

Milchunas, D. G., J. R. Forwood, and W. K. Lauenroth. 1994. Productivity of long-term grazing treatments in response to seasonal precipitation. Journal of Range Management 47:133-139.

Montana Department of Agriculture (MDA). 2013. The Columbian ground squirrel: Its biology and control. Montana Department of Agriculture, Helena, Montana.

Montana State University (MSU). 2008. Hay nutrient analysis, 2008. Agriculture Experiment Station Analytical Laboratory, Montana State University, Bozeman, Montana.

National Park Service (NPS). 2008a. Grant-Kohrs Ranch National Historic Site: Foundation for planning and management. National Park Service, Deer Lodge, Montana.

National Park Service (NPS). 2008b. 2008 Fields cut for hay: Grant-Kohrs Ranch. National Park Service, Deer Lodge, Montana.

National Park Service (NPS). 2008c. Exotic plant management team: 2008 annual report. National Park Service, Biological Resources Management Division, Fort Collins, Colorado.

National Park Service (NPS). 2009a. Grant-Kohrs Ranch NHS: 2009 fields cut for hay. National Park Service, Deer Lodge, Montana.

National Park Service (NPS). 2009b. Annual climate report for Grant-Kohrs Ranch National Historic Site, 2007. National Park Service, Deer Lodge, Montana.

National Park Service (NPS). 2010. Grant-Kohrs Ranch NHS: 2010 fields cut for hay. National Park Service, Deer Lodge, Montana.

National Park Service (NPS). 2011a. Northern Rocky Mountains invasive plant management plan. National Park Service, Fort Collins, Colorado.

National Park Service (NPS). 2011b. Grant-Kohrs Ranch NHS: 2011 fields cut for hay. National Park Service, Deer Lodge, Montana.

National Park Service (NPS). 2012. Grant-Kohrs Ranch NHS: 2012 fields cut for hay. National Park Service, Deer Lodge, Montana.

National Park Service (NPS). 2013a. Grant-Kohrs Ranch National Historic Site, Montana: Soil survey – DRAFT. National Park Service, Fort Collins, Colorado.

National Park Service (NPS). 2013b. Grant-Kohrs Ranch NHS: 2013 fields cut for hay. National Park Service, Deer Lodge, Montana.

National Park Service (NPS). 2014. Foundation document: Grant-Kohrs Ranch National Historic Site. National Park Service, Deer Lodge, Montana.

National Research Council (NRC). 2000. Nutrient requirements of beef cattle. Seventh edition. National Academy Press, Washington, D.C.

Natural Resources Conservation Service (NRCS). 1982. Technical range site descriptions. Field office technical guide, section II-E-8. Natural Resources Conservation Service, Washington, D.C.

Olson, B., and B. Leinard. 2013. BMP Report: Grant-Kohrs Ranch National Historic Site. National Park Service, Deer Lodge, Montana.

Rice, P. M., and J. Hardin. 2004. Suppression of Canada thistle at the Grant-Kohrs Ranch NHS: Year 3 progress report. National Park Service unpublished report, Deer Lodge, Montana.

Rice, P. M., E. W. Schweiger, W. Gustafson, C. Lea, D. Manier, D. Shorrock, B. Frakes, and L. O'Gan. 2012. Vegetation classification and mapping project report, Grant-Kohrs Ranch National Historic Site. Natural Resource Report NPS/ROMN/NRR—2012/589. National Park Service, Fort Collins, Colorado.

Rocky Mountain Inventory and Monitoring Network (ROMN). 2009. Vegetation composition, structure, and soils (VCSS) yearly master database - 2009. Microsoft Access database. Obtained from https://irma.nps.gov/App/ (accessed 16 July 2014).

Rocky Mountain Inventory and Monitoring Network (ROMN). 2010. Vegetation composition, structure, and soils (VCSS) yearly master database - 2010. Microsoft Access database. Obtained from https://irma.nps.gov/App/ (accessed 16 July 2014).

Rocky Mountain Inventory and Monitoring Network (ROMN). 2011. Vegetation composition, structure, and soils (VCSS) yearly master database - 2011. Microsoft Access database. Obtained from https://irma.nps.gov/App/ (accessed 16 July 2014).

Rocky Mountain Inventory and Monitoring Network (ROMN). 2012. Vegetation composition, structure, and soils (VCSS) yearly master database - 2012. Microsoft Access database. Obtained from https://irma.nps.gov/App/ (accessed 16 July 2014).

Shapins Belt Collins. 2009. Grant-Kohrs Ranch cultural landscape report, part two. National Park Service, Fort Collins, Colorado.

U.S. Department of Agriculture (USDA). 2003. USDA announces hay quality designations for nationwide market news reporting. http://www.nass.usda.gov/Statistics_by_State/Kansas/Publications/Crops/Hay/hay01.html (accessed 12 January 2015).

Wood, S. D. 2005. Non-native plant survey 2004 geodatabase for Grant-Kohrs Ranch National Historic Site. ArcGIS geodatabase. National Park Service, Deer Lodge, Montana

4.4 Uplands (Grasslands, Non-irrigated)

4.4.1 Description

The upland grasslands at GRKO primarily occur west of the Clark Fork River, in the southwest corner of the park. These rolling foothills with a mix of primarily native and some introduced grass species have been utilized for grazing since the beginning of the ranching era (Rice and Hardin 2002; Photo 18). The uplands "are among the best examples of native plant communities within the park, and they may constitute some of the last native prairie remnants in the Deer Lodge Valley" (Shapins Belt Collins 2009, p. 3). The remaining natural character may reflect the fact that these areas were historically grazed in the fall, which has less impact on native grasses than grazing in the spring when plants are actively growing (Rice et al. 2012). Small patches of native upland grasses also occur east of the Clark Fork (e.g., along the railroad bed) (Rice and Hardin 2002).

Photo 18. Upland grassland within GRKO (Photo by Sarah Gardner, SMUMN GSS 2013).

Rice et al. (2012) identified five different upland grassland types within the GRKO boundary, three dominated by native grasses and two types characterized by significant levels of introduced grasses (Figure 23). The native grassland types are Bluebunch Wheatgrass - Western Wheatgrass (*Pseudoroegneria spicata - Pascopyrum smithii*) Mixedgrass Prairie, Bluebunch Wheatgrass – Curly (or Sandberg) Bluegrass (*Pseudoroegneria spicata – Poa secunda*) Grassland, and Needle-and-Thread - Blue Grama - Threadleaf Sedge (*Hesperostipa comata – Bouteloua gracilis – Carex filifolia*) Mixedgrass Prairie. Additional native grasses found in the park include prairie junegrass (*Koeleria macrantha*), green needlegrass, and fescues (*Festuca* spp.). The two grassland types characterized by introduced species are Crested Wheatgrass - (Western Wheatgrass, Needle-and-Thread Grass) (*Agropyron cristatum* – [*Pascopyrum smithii, Hesperostipa comata*]) Semi-natural Grassland and Intermediate Wheatgrass (*Thinopyrum intermedium*) Semi-natural Grassland. The Intermediate Wheatgrass Grassland occurs in only a single strip historically seeded along the railroad in the northeast part of the park (Rice et al. 2012). The non-native cheatgrass (*Bromus tectorum*) is also found in both the native and semi-natural upland grasslands.

Upland grasslands have been a vital resource throughout the ranching era and are still utilized for grazing within GRKO today. Given the purpose of GRKO (to preserve and interpret this historical period), the maintenance of this unique landscape and plant community is very important to park staff (Shapins Belt Collins 2009).

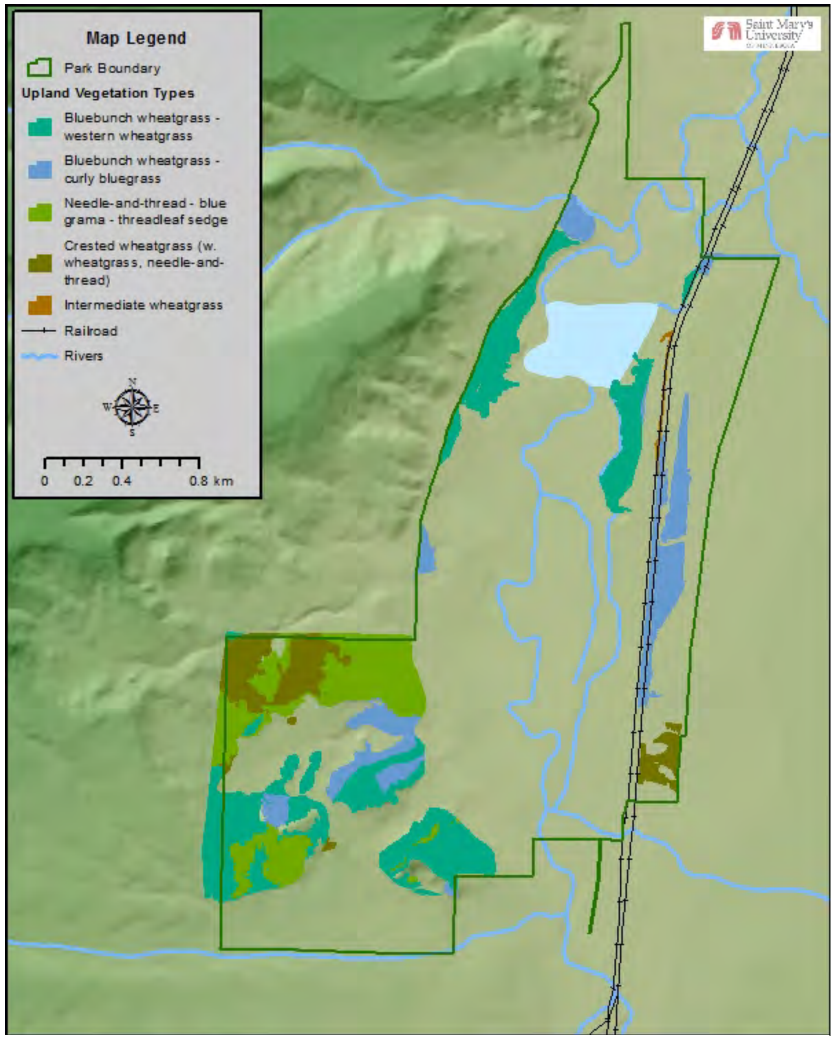


Figure 23. Location of upland grassland vegetation types within GRKO (Rice et al. 2012).

4.4.2 Measures

- Range Condition/ Similarity Index
- Rangeland Health (17 indicators)
- Ecological effect size (A)

4.4.3 Reference Conditions/Values

Reference conditions for GRKO's upland grasslands can be found in Mueggler and Stewart (1980) and in NRCS range site descriptions (NRCS 1982). Mueggler and Stewart (1980) studied grasslands and shrublands in western Montana and generated a habitat type classification system for these habitats in the region. Six of the grassland habitat types identified by Mueggler and Stewart (1980) occur within GRKO. Information provided in their report includes plant species composition, physical characteristics (e.g., landscape position, soils), productivity, and responses to grazing and fire.

Technical range sites are classified based on geography/location, soil characteristics, and precipitation zones. Range site descriptions (NRCS 1982) provide information similar to that in Mueggler and Stewart (1980) and also provide a guide to initial stocking rates (for grazing purposes). The majority of upland grasslands at GRKO fall within the silty 10-14" precipitation zone (P.Z.) technical range site, with just a few small areas of shallow to gravel 10-14" P.Z. range sites. According to the NRCS (1982) description for silty 10-14" P.Z. range sites, these grasslands are typically composed of 93% graminoids, 5% forbs, and 2% woody species. Common species and percent composition ranges are listed in Table 30. With grazing pressure, palatable grasses like bluebunch wheatgrass and green needlegrass tend to decrease, while prairie junegrass, needle-and-thread, and western wheatgrass increase (NRCS 1982). According to the range site description, species most likely to invade include cheatgrass, leafy spurge, knapweed, and toadflax.

Table 30. Typical plant species composition of silty 10-14" P.Z. rangeland sites (NRCS 1982).

Scientific name	Common name	% Composition
Graminoids		
Pseudoroegneria spicata	bluebunch wheatgrass	60-80
Festuca campestris	rough fescue*	0-30
Nassella viridula	green needlegrass	0-5
Festuca idahoensis	Idaho fescue*	0-5
Hesperostipa comata	needle-and-thread	0-5
Pascopyrum smithii	western wheatgrass	0-5
Carex spp.	sedges	0-5
	other native perennial grasses	5-15
Forbs		
Lupinus spp.	lupine	
Astragalus spp.	milkvetch	
Heterotheca villosa	hairy goldenaster	
Vicia americana	American vetch	
Gaillardia spp.	blanketflower	4-7
Phlox spp.	phlox	
Lomatium spp.	desert parsley, biscuitroot	
Antennaria spp.	pussytoes	
	other native perennial forbs	
Woody species		
Krascheninnikovia spp.	winterfat	
Artemisia tridentata	big sagebrush	
Tetradymia spp.	horsebrush	0-5
	other native shrubs	

* Rough and Idaho fescue usually occur near the upper end of the P.Z. or in favorable, sheltered pockets.

For the purposes of this assessment, the reference condition for the Range Condition measure will be scores in the good or excellent range, while the reference condition for Rangeland Health will be ratings in the "none to slight" category.

4.4.4 Data and Methods

Vegetation surveys were conducted at GRKO in the early 1980s (Rice and Ray 1984) and in 2002 (Rice and Hardin 2002). A vegetation classification and mapping project was completed for the park in 2012 (Rice et al. 2012). The initial mapping and community typing primarily used the Mueggler and Stewart (1980) classifications for the uplands, then in the post accuracy assessment stage these were cross-walked to the classification followed the National Vegetation Classification Standards (NVCS) established by the Federal Geographic Data Committee (FGDC). Additional information on GRKO vegetation, particularly invasive species, was obtained from NRM EPMT reports (NPS 2011, 2012) and Rice (2003). The GRKO cultural landscape report for upland pastures (Shapins Belt Collins 2009) identified contributing (i.e., culturally acceptable) and non-contributing (undesirable or invasive) plant species for the upland grassland landscape.

The ROMN recently established a Vegetation Composition, Structure and Soils (VCSS) protocol for small parks (Manier et al. 2011) that includes GRKO. This protocol utilizes transect and plot-based methods to estimate cover and frequency of vegetation, litter, bare ground extent, and invasive species. Field crews also recorded evidence of disturbance, both natural and human-induced. See Manier et al. (2011) for a detailed description of methods. Results from 2009 monitoring at GRKO are found in Shorrock et al. (2010).

Two common methods for assessing the condition of grazed grasslands are Range Condition/similarity index and Rangeland Health. As explained in Chapter 4.1 of this assessment, Range Condition is determined by comparing the present vegetation community on a "range site" to a historic reference (the "climax" community) (Pellant et al. 2005). Lower scores do not necessarily indicate lower ecosystem function, they simply mean that there are lower percentages of the climax plant community represented (i.e., a greater percentage of earlier successional stages). Range Conditions and similarity indices were determined for four upland grasslands at the ranch during the summer of 2014. The methodology utilized at GRKO is described in Chapter 4.1.

Rangeland Health, in contrast, focuses on the integrity of soils, ecological processes (e.g., water and nutrient cycling), and the ecosystem as a whole (Pellant et al. 2005). Rangeland Health Assessment methods are intended to, "provide a preliminary evaluation of soil/site stability, hydrologic function, and biotic integrity (at the ecological site level)" and "provide early warnings of potential problems and opportunities by helping land managers identify areas that are potentially at risk of degradation or where resource problems currently exist" (Pellant et al. 2005, p. 1). Since ecological processes are often challenging to measure, Rangeland Health techniques utilize biological and physical characteristics that can serve as indicators of ecosystem integrity. The three main attributes in such an assessment and the indicators used for each were summarized previously in Section 4.1 of this assessment (see Table 7). Rangeland Health indicators and assessment methods are described in further detail in Pellant et al. (2005). Although Rangeland Health scores have not been calculated for any of GRKO's vegetation communities, the ROMN VCSS monitoring protocol has recorded observations on several of the soil/site stability indicators (surface flow patterns, rills/gullies, and pedestals) in recent years (ROMN 2006-2011). However, very few of the ROMN sampling locations have been within the park's upland grasslands. Four upland grassland plots were sampled in 2010, two in 2009, and one each in 2006-2008 and 2011.

4.4.5 Current Condition and Trend

<u>Range Condition/Similarity Index</u>

Range Condition and similarity indices were determined for four upland grassland pastures during the summer of 2014: Ridge Road, Upper Northwest, Taylor Ridge, and Gravel Pit (locations shown in Figure 24). Range Condition is based on percent species composition (by dry weights) whereas similarity index is based on species composition directly based on dry weights (Table 31). The Range Condition scores showed that two grasslands (Ridge Road and Gravel Pit) were in the excellent condition class and two (Taylor Ridge and Upper Northwest Range) were in the good condition class (NPS 2014). All of these scores fall within the reference condition selected for this measure (good or excellent class), although Taylor Ridge's scores are near the bottom of the good class. Similarity indices show that the two pastures with *excellent* Range Condition scores are also closest to the climax plant community, with scores above 92% (Table 31). Upper Northwest Range was also very similar to the HCPC with a score just below 92%, whereas Taylor Ridge Pasture was much lower with a similarity index of just 55%.

Table 31. Range Condition scores and classes (based on percent composition) and similarity indices (based on dry weight) for four upland grasslands at GRKO in 2014 (NPS 2014). Class designations are applied **only** for Range Condition scores and are not used with similarity indices. Grassland locations are shown in Figure 24.

Field	Range Condition - % Compostion	Range Condition Class	Similarity Index - Dry weight
Ridge Road Pasture	79%	Excellent	92.2%
Upper Northwest Range	72%	Good	91.8%
Taylor Ridge Pasture	54%	Good	55%
Gravel Pit Pasture	93%	Excellent	92.7%

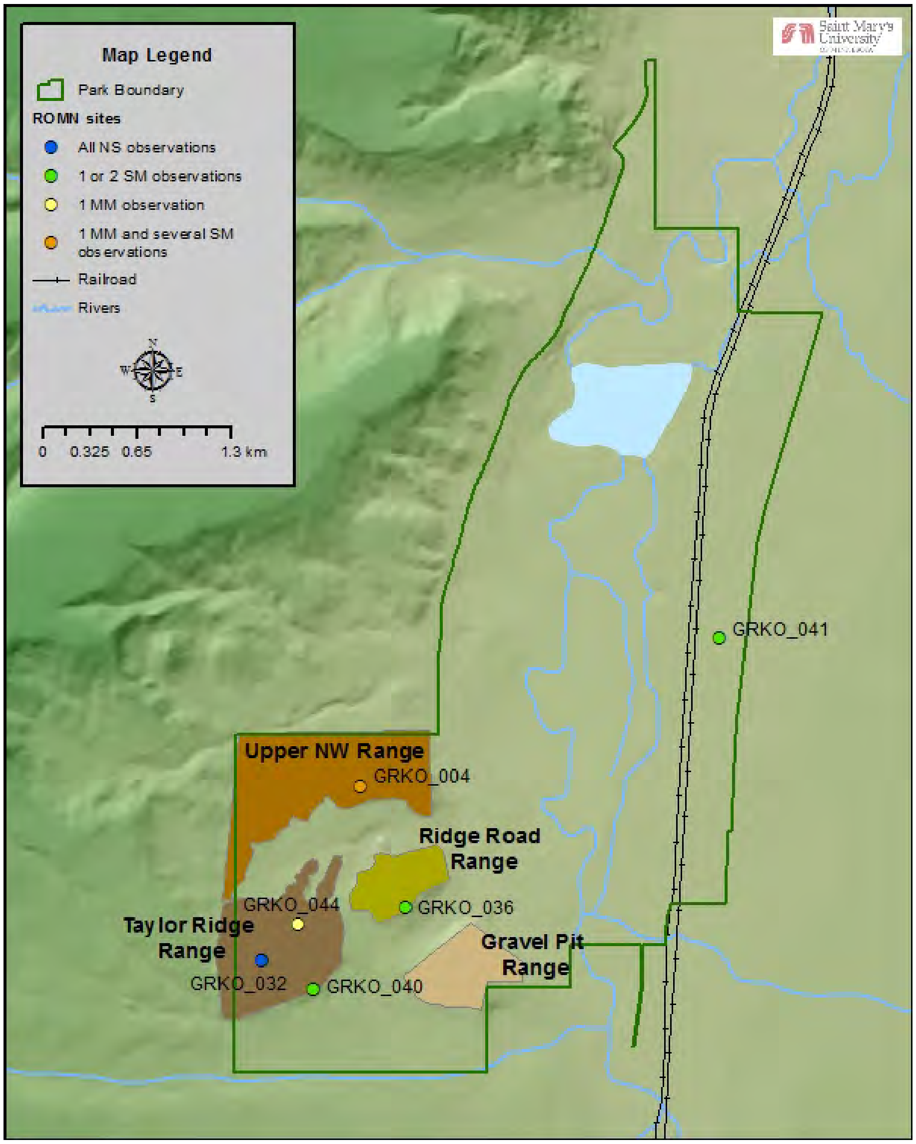


Figure 24. Upland grasslands with Range Condition determinations (names in bold), and ROMN sampling locations (discussed below) where soil/site stability indicator observations have been recorded (ROMN 2006-2011). NS = none to slight, SM = slight to moderate, MM = moderate.

<u>Rangeland Health (17 indicators)</u>

Rangeland Health scores have not been calculated for any vegetation communities in GRKO. However, the ROMN VCSS monitoring protocol has recorded observations on several of the soil/site stability indicators (surface flow patterns, rills/gullies, and pedestals) used in Rangeland Health Assessments. The presence of these indicator features would suggest that disturbance and/or erosion are occurring and negatively impacting soil stability (Pellant et al. 2005). Monitoring teams recorded whether evidence of these indicators was none to slight (NS), slight to moderate (SM), moderate (MM), moderate to extreme (MX), or extreme (XX). No MX or XX observations have been recorded at the GRKO upland grassland sampling locations since monitoring began in 2006 (Table 32). Moderate evidence of these indicators has only been noted twice (once for surface flow in 2007 and once for rills/gullies in 2010). Four SM observations have been reported for surface flow and rills/gullies; evidence of pedestals has been NS at every location during the monitoring period. It is important to note that these data represent only three of the 17 indicators used to calculate Rangeland Health and do not provide a comprehensive picture of the grassland community's condition alone.

Table 32. Indicators of disturbance and/or erosion documented in GRKO's upland grasslands (ROMN 2006-2011). NS - none to slight, SM = slight to moderate, MM = moderate.

Year/Plot	# of Observations	Surface Flow	Rills/Gullies	Pedestals
2006				
GRKO_004	5	2 NS, 3 SM	5 NS	5 NS
2007				
GRKO_004	3	2 NS, 1 MM	3 NS	3 NS
2008				
GRKO_004	3	3 NS	3 NS	3 NS
2009				
GRKO_032	1	NS	NS	NS
GRKO_036	1	SM	SM	NS
2010				
GRKO_004	1	NS	NS	NS
GRKO_040	1	NS	SM	NS
GRKO_041	1	NS	SM	NS
GRKO_044	1	NS	MM	NS
2011				
GRKO_040	1	NS	SM	NS
Totals	**18**	**13 NS, 4 SM, 1 MM**	**13 NS, 4 SM, 1 MM**	**18 NS**

Ecological Effect Size (A)

As previously described in Chapter 4.2 of this assessment, an "effect size" describes the magnitude of the difference between two groups, in this case the existing plant community and an identified reference community. For the upland grasslands at GRKO, Mueggler and Stewart's (1980) grassland type descriptions (community composition, etc.) could be used as reference communities. While some current information on upland grassland community composition has been gathered through the ROMN monitoring program, not enough recent data are available to calculate ecological effect size for these communities (Rice, email communication, 31 July 2014).

Threats and Stressor Factors

Threats to GRKO's upland grasslands include invasive species, drought, climate change, improper grazing, unplanned or extreme fire, Columbian ground squirrels, and grasshopper outbreaks. Invasive plant species are a major concern at GRKO and are recognized globally as a significant threat to ecosystem stability (NPS 2008, Rice et al. 2012). These species can alter plant community composition and ecological processes (e.g., water and nutrient cycling) and contribute to biodiversity and habitat losses (Lacey et al. 1989, NPS 2008). In GRKO, invasive plants also threaten the park's cultural landscape and can reduce forage quality (NPS 2011, Manier et al. 2011). Invasive species common in the upland grasslands include spotted knapweed (*Centaurea stoebe* ssp. *micranthos*), cheatgrass, field bindweed, and smooth brome (Rice 2003, Rice et al. 2012). Species documented in the park's upland grasslands by Rice (2003) are listed in Table 33. Spotted knapweed is one of the most destructive invaders of western grasslands, reducing native plant diversity and cover by 90% in some areas (Ridenour and Callaway 2001, Callaway et al. 2004). The NRM EPMT has been intensively treating spotted knapweed at the park since 2004, leading to a noticeable decrease in density in recent years (NPS 2012). The park has also used biological control insects and experimented with prescribed grazing (e.g., training livestock to eat weeds) to reduce spotted knapweed and other invasive plants (NPS 2011). However, there is no evidence that prescribed grazing has been effective.

Table 33. Invasive plant species documented in upland grasslands by Rice (2003).

Scientific Name	Common Name	Railroad Remnant	Upland Ranges			
			Gravel Pit	Taylor Ridge	Upper NW	No Name
Montana noxious weeds						
*Cirsium arvense**	Canada thistle	X			X	
*Euphorbia esula**	leafy spurge	X	X			
*Lepidium latifolium**	perennial pepperweed	X				
Centaurea stoebe ssp. *micranthos**	spotted knapweed	X	X	X	X	X
*Convolvulus arvensis**	field bindweed			X	X	
*Lepidium draba**	hoary cress, whitetop				X	
*Cynoglossum officianale**	houndstongue	X				
Introduced grasses						
Poa pratensis	Kentucky bluegrass	X	X	X	X	
Elymus repens	quackgrass	X			X	
Agrostis gigantea	redtop	X				
Bromus inermis	smooth brome	X	X	X	X	X
Agropyron cristatum	crested wheatgrass	X	X	X	X	X
Poa compressa	Canada bluegrass	X	X	X	X	
*Bromus tectorum**	cheatgrass	X	X	X	X	
Thinopyrum intermedium	intermediate wheatgrass	X	X	X	X	X
Bromus arvensis	field brome				X	
Potential problem forbs						
Melilotus officinalis	sweetclover	X	X	X	X	X
Silene latifolia	bladder campion				X	
*Gypsophila paniculata**	baby's breath		X	X	X	X
Verbascum thapsus	common mullein	X				

*Also identified as priority species by the NRM EPMT (NPS 2011).

Two processes that are a natural part of grassland ecosystems - grazing and fire - can be stressors to the community in certain situations. If fires are followed by dry periods, the production of some native grasses (e.g., needle-and-thread) can be negatively impacted for 2-3 years (Whisenant and Uresk 1989). Overgrazing in the ranch's upland grasslands could impact plant species composition and soil characteristics (Fleischner 1994, Manier et al. 2011). With heavy grazing, more palatable grasses such as western wheatgrass, bluebunch wheatgrass, prairie junegrass, and green needlegrass usually decrease (Mueggler and Stewart 1980). Unpalatable woody species and forbs, including fringed sagebrush (*Artemisia frigida*), broom snakeweed (*Gutierrezia sarothrae*), rubber rabbitbrush (*Ericameria nauseosa*), and plains pricklypear (*Opuntia polyacantha*), often increase with heavy grazing (Mueggler and Stewart 1980).

Columbian ground squirrels play an important role in natural ecosystems, as their digging activity creates habitat diversity and improves soil aeration and moisture retention (MDA 2013). However, in agricultural and ranching areas, this digging may contribute to soil erosion and create disturbed areas where invasive species can colonize. Additionally, their holes are a possible hazard for grazing livestock (MDA 2013). Grasshoppers are also an important natural part of grassland ecosystems, but increased herbivory during population outbreaks often creates serious competition with grazing livestock (Branson et al. 2006). Large outbreaks could temporarily reduce the productivity of GRKO's grasslands and decrease vegetative cover, possibly increasing the risk of erosion.

Climate has a strong influence on vegetation communities, both directly and indirectly through its impact on ecological processes (e.g., fire, nutrient cycling) (McWethy et al. 2010). As a result of climate change, the western U.S. is projected to experience more frequent dry periods (droughts) during the 21st century, due to increased temperatures and evapotranspirtation, as well as changes in surface hydrology (Gray and Andersen 2009, McWethy et al. 2010). In the last half of the 20th century, snowmelt and peak runoff were already occurring earlier on average, reducing surface water storage and river base flows during the summer months (McCabe and Clark 2005, Stewart et al. 2005, McWethy et al. 2010). An increase in drought frequency or duration could impact grassland composition and production, while climate warming will likely influence plant phenology (Loehman 2009, Bloor et al. 2010).

Data Needs/Gaps

Additional community surveys are needed in the upland grasslands in order to calculate ecological effects sizes for the five grassland types. This will be aided by the development of Ecological Site Descriptions (similar to range site descriptions but more detailed) by the NRCS, which are currently in the initial stages (Smith, written communication, 5 May 2015). Further surveying is also required to complete full Rangeland Health Assessments. While some of the 17 indicators used in these assessments have been documented at GRKO, others have not (e.g., litter movement, reproductive capability of perennial plants). Repetition of the Range Condition assessments in the future will help determine if any changes are occurring in the upland grassland community.

Overall Condition

Range Condition/Similarity Index

The Range Condition measure was assigned a *Significance Level* of 3. All of the four upland grasslands for which Range Condition was determined during 2014 met the selected reference condition of good or excellent class. However, Taylor Ridge was near the bottom of the good class with similarity indices of 54% and 55%. This measure is currently considered of low concern (*Condition Level* = 1).

Rangeland Health (17 Indicators)

The project team also assigned this measure a *Significance Level* of 3. Rangeland Health scores have not been calculated for any vegetation communities in GRKO. While the ROMN VCSS monitoring protocol has recorded observations on several of the soil/site stability indicators, these are only three of the 17 indicators used to calculate Rangeland Health and do not provide a comprehensive picture of the grassland community's condition. Therefore, a *Condition Level* has not been assigned.

Ecological Effect Size (A)
This measure was assigned a *Significance Level* of 3. However, not enough recent data on upland community composition is available to reliably calculate ecological effect sizes. As a result, a *Condition Level* could not be assigned.

Weighted Condition Score
A *Weighted Condition Score* was not calculated for GRKO's uplands due to a lack of data for two of the three measures. The current condition and any trend for the upland grassland community are unknown.

Uplands (Grasslands, Non-irrigated)			
Measures	Significance Level	Condition Level	WCS = N/A
Range Condition	3	1	
Rangeland Health	3	n/a	
Ecological Effect Size	3	n/a	

4.4.6 Sources of Expertise

Peter Rice, University of Montana Research Ecologist

Bret Olson, Professor of Range Ecology, Montana State University

4.4.7 Literature Cited

Bloor, J. M. G., P. Pichon, R. Falcimagne, P. Leadley, and J. Soussana. 2010. Effects of warming, summer drought, and CO2 enrichment on aboveground biomass production, flowering phenology, and community structure in an upland grassland ecosystem. Ecosystems 13:888-900.

Branson, D. H., A. Joern, and G. A. Sword. 2006. Sustainable management of insect herbivores in grassland ecosystems: New perspectives in grasshopper control. Bioscience 56(9):743-755.

Callaway, R. M., G. C. Thelen, S. Barth, P. W. Ramsey, and J. E. Gannon. 2004. Soil fungi alter interactions between the invader Centaurea maculosa and North American natives. Ecology 85(4):1062-1071.

Fleischner, T. L. 1994. Ecological costs of livestock grazing in western North America. Conservation Biology 8(3):629-644.

Gray, S., and C. Andersen. 2009. Assessing the future of Wyoming's water resources: Adding climate change to the equation. William D. Ruckelshaus Institute of Environment and Natural Resources. University of Wyoming, Laramie, Wyoming.

Lacey, J. R., C. B. Marlow, and J. R. Lane. 1989. Influence of spotted knapweed (Centaurea maculosa) on surface runoff and sediment yield. Weed Technology 3(4):627-631.

Loehman, R. 2009. Understanding the science of climate change: Talking points - impacts to prairie potholes and grasslands. Natural Resource Report NPS/NRPC/NRR—2009/138. National Park Service, Fort Collins, Colorado.

Manier, D., D. Shorrock, E. W. Schweiger, I. Ashton, B. Frakes, M. Britten, D. Pillmore, and J. Burke. 2011. Rocky Mountain Network vegetation composition structure and soils monitoring protocol: Small park grasslands, shrublands, and woodlands; Version 1.0. Natural Resource Report NPS/ROMN/NRR-2011/383. National Park Service, Fort Collins, Colorado.

McCabe, G. J., and M. P. Clark. 2005. Trends and variability in snowmelt runoff in the western United States. Journal of Hydrometeorology 6:476-482.

McWethy, D. B., S. T. Gray, P. E. Higuera, J. S. Littell, G. T. Pederson, A. J. Ray, and C. Whitlock. 2010. Climate and terrestrial ecosystem change in the U.S. Rocky Mountains and Upper Columbia Basin: Historical and future perspectives for natural resource management. Natural Resource Report NPS/GRYN/NRR–2010/260. National Park Service, Fort Collins, Colorado.

Montana Department of Agriculture (MDA). 2013. The Columbian ground squirrel: Its biology and control. Montana Department of Agriculture, Helena, Montana.

Mueggler, W. F., and W. L. Stewart. 1980. Grassland and shrubland habitat types of western Montana. USDA Forest Service General Technical Report INT-66. U.S. Forest Service, Intermountain Forest and Range Experiment Station, Ogden, Utah.

National Park Service (NPS). 2008. Exotic plant management team: 2008 annual report. National Park Service, Biological Resources Management Division, Fort Collins, Colorado.

National Park Service (NPS). 2011. Northern Rocky Mountains invasive plant management plan. National Park Service, Fort Collins, Colorado.

National Park Service (NPS). 2012. Northern Rocky Mountains exotic plant management team: FY 2012 report. National Park Service, Fort Collins, Colorado.

National Park Service (NPS). 2014. Range site and condition record data sheets. Unpublished data collected by Bret Olson and Jarrett Payne, Montana State University. Received from Jason Smith, 26 September 2014.

Natural Resources Conservation Service (NRCS). 1982. Technical range site descriptions. Field office technical guide, section II-E-8. Natural Resources Conservation Service, Washington, D.C.

Pellant, M., P. Shaver, D. A. Pyke, and J. E. Herrick. 2005. Interpreting indicators of Rangeland Health, version 4. Technical Reference 1734-6. U.S. Department of the Interior, Bureau of Land Management, National Science and Technology Center, Denver, Colorado.

Rice, P. M. 2003. Discussion outline for Grant-Kohrs Ranch weed management and restoration. National Park Service Unpublished Report, Deer Lodge, Montana.

Rice, P. M., and G. J. Ray. 1984. Floral and faunal survey and toxic metal contamination study of the Grant-Kohrs Ranch National Historic Site. National Park Service, Deer Lodge, Montana.

Rice, P. M., and J. G. Hardin. 2002. Vascular plant survey of Grant-Kohrs Ranch National Historic Site. National Park Service, Deer Lodge, Montana.

Rice, P. M., E. W. Schweiger, W. Gustafson, C. Lea, D. Manier, D. Shorrock, B. Frakes, and L. O'Gan. 2012. Vegetation classification and mapping project report, Grant-Kohrs Ranch National Historic Site. Natural Resource Report NPS/ROMN/NRR—2012/589. National Park Service, Fort Collins, Colorado.

Ridenour, W. M., and R. M. Callaway. 2001. The relative importance of allelopathy in interference: The effects of an invasive weed on a native bunchgrass. Oecologia 126:444-450.

Rocky Mountain Inventory and Monitoring Network (ROMN). 2006. Vegetation composition, structure, and soils (VCSS) yearly master database - 2006. Microsoft Access database. Obtained from https://irma.nps.gov/App/ (accessed 16 July 2014).

Rocky Mountain Inventory and Monitoring Network (ROMN). 2007. Vegetation composition, structure, and soils (VCSS) yearly master database - 2007. Microsoft Access database. Obtained from https://irma.nps.gov/App/ (accessed 16 July 2014).

Rocky Mountain Inventory and Monitoring Network (ROMN). 2008. Vegetation composition, structure, and soils (VCSS) yearly master database - 2008. Microsoft Access database. Obtained from https://irma.nps.gov/App/ (accessed 16 July 2014).

Rocky Mountain Inventory and Monitoring Network (ROMN). 2009. Vegetation composition, structure, and soils (VCSS) yearly master database - 2009. Microsoft Access database. Obtained from https://irma.nps.gov/App/ (accessed 16 July 2014).

Rocky Mountain Inventory and Monitoring Network (ROMN). 2010. Vegetation composition, structure, and soils (VCSS) yearly master database - 2010. Microsoft Access database. Obtained from https://irma.nps.gov/App/ (accessed 16 July 2014).

Rocky Mountain Inventory and Monitoring Network (ROMN). 2011. Vegetation composition, structure, and soils (VCSS) yearly master database - 2011. Microsoft Access database. Obtained from https://irma.nps.gov/App/ (accessed 16 July 2014).

Shapins Belt Collins. 2009. Grant-Kohrs Ranch cultural landscape report, part two. National Park Service, Fort Collins, Colorado.

Shorrock, D, I. Ashton, M. Britten, J. Burke, D. Pillmore, and E. W. Schweiger. 2010. Vegetation composition, structure and soils monitoring at Grant-Kohrs Ranch National Historic Site: 2009 annual data report. Natural Resource Data Series. Published Report-2165172. Natural Resource Program Center, Fort Collins, Colorado.

Stewart, I. T., D. R. Cayan, and M. D. Dettinger. 2005. Changes toward earlier streamflow timing across western North America. Journal of Climate 18:1136-1155.

Whisenant, S., and D. Uresk. 1989. Burning upland, mixed prairie in Badlands National Park. The Prairie Naturalist 21 (4):221-227.

4.5 Birds

4.5.1 Description

Bird populations often act as excellent indicators of an ecosystem's health (Morrison 1986, Hutto 1998, NABCI 2009). Birds are typically highly visible components of ecosystems, and bird communities often reflect the abundance and distribution of other organisms with which they co-exist (Blakesley et al. 2010). Migratory birds can serve as ecological indicators of broad environmental conditions because a disturbance adversely affecting any of the habitats used by these species (e.g., stopover, wintering, or breeding habitats) can cause declines in populations and a decrease in species' reproductive success (Zöckler 2005). Conversely, trends in resident bird species' populations are likely due to changes occurring in their immediate habitat or ecosystem, and (in theory) it is possible to study all of their population processes directly throughout the year (Koskimies 1989).

Photo 19. Bobolink (NPS Photo).

GRKO is unique among NPS units, as it is actively managed as a functional ranch by the NPS. Ranching activities that are facilitated by the NPS include livestock grazing, hay production and harvest, irrigation, fencing, and noxious weed control (John Milner Associates et al. 2004). Ranching activities can create unique habitats for bird species, particularly in the grassland and hayfield areas. Some species, such as the bobolink (*Dolichonyx oryzivorus,* Photo 19), have exhibited a preference for agricultural fields when there is an absence of true grasslands (Dale et al. 1997, Larson 2011). However, mowing and cutting of hayfields has been cited as a major disturbance for breeding grassland bird species (Warner and Etter 1989, Bollinger et al. 1990, Frawley and Best 1991, Herkert et al. 1996, Perlut et al. 2006).

NPS (2014) confirmed the presence of 143 bird species within the park, and another 87 species have been identified as probably occurring in the park. Among the confirmed species are several birds designated as species of concern by at least one agency (Appendix F). Grassland species have been experiencing range-wide declines in recent years (NABCI 2009), and GRKO is home to several grassland species of concern. Examples of these species include the ferruginous hawk (*Buteo regalis*), long-billed curlew (*Numenius americanus*), and the bobolink (NPS 2014).

4.5.2 Measures

- Species richness
- Distribution
- Abundance
- Status of species of special concern

4.5.3 Reference Conditions/Values

A reference condition was not established for birds during project scoping. Much of the research that has been done for birds in GRKO has occurred since 2004. The synthesis and summary of research from 2004-present that is provided in this document could likely serve as a baseline or reference condition for future condition assessments. This baseline data will be particularly important in the riparian areas, as a decontamination and excavation project is slated to begin in 2015. This large-scale disturbance will likely affect the bird community in the riparian areas for several years, and baseline data will be valuable to monitor the recovery of the bird community.

4.5.4 Data and Methods

The NPS Certified Bird Species List (NPS 2014) for GRKO was used for this assessment; this list represents all of the confirmed bird species present in the park (Appendix G).

Rice and Ray (1984) investigated the floral and faunal communities of GRKO, in addition to studying the toxic metal contamination of the park's riparian habitats. Avian surveys were informal, and the procedure used to identify birds is poorly documented. However, from 1982-1983 Rice and Ray (1984) documented 27 species of birds within the park.

In 2004, Giroir and Beason (2005) completed an avian inventory of GRKO, with the following specific objectives:

1. To document the occurrence of bird species;
2. To describe the distribution and, where possible, the population densities of those species;
3. To identify critical bird habitats;
4. To identify bird species of special management concern;
5. To recommend a long-term bird monitoring program (Giroir and Beason 2005, p. iii).

Giroir and Beason (2005) surveyed the breeding, wintering, migratory, and nocturnal bird species in GRKO. Two transect locations in the park were selected to monitor the breeding bird populations: one situated in a grassland habitat, and one along the park's riparian habitat near the Clark Fork River. The grassland transect had 14 point counts, while the riparian transect had 20 point counts. At each point, all birds seen and heard were recorded during a 5-minute period. Approximate distances were also recorded using a laser rangefinder. Informal surveys were also conducted throughout the park to inventory the wintering, migratory, and nocturnal species of the ranch. Complete methodology is detailed in Giroir and Beason (2005).

In 2010, Larson (2011) surveyed the breeding bird species of the Stuart, Taylor, and West Fields in GRKO, in order to develop best management practices (BMPs) for the pasture and hayfields of the park. Fourteen survey points were selected arbitrarily, with nine located in Taylor Field, two in West Field, and three in Stuart Field. Each point was surveyed for 10 minutes, and all species that were observed visually and aurally were recorded. Larson (2011) also documented active nests that were found, as well as informal species observations that occurred outside of the survey time frame.

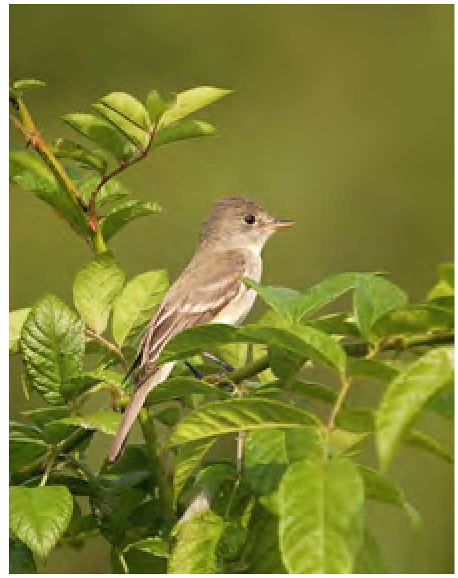


Photo 20. Willow flycatcher (Photo ©Jim Schmidt)

Atkinson and Smucker (2013) surveyed two habitat types in GRKO (grassland and riparian) in 2013, with the objective of establishing a baseline for the pre-restoration bird community in GRKO. A point count transect was established in both the riparian and grassland areas of the park; each transect had 16 randomly selected points in a square kilometer. Field methodology closely resembled that of the Integrated Monitoring in Bird Conservation Regions (IMBCR) program; this is the same procedure that Giroir and Beason (2005) utilized, and allows for some comparisons between the two studies. Observers walked to each point and recorded the number of birds observed visually and aurally during a 6-minute period. In addition to the point counts, Atkinson and Smucker (2013) also conducted nest searches and recorded informal species observations (i.e., species observed, but not during a point count period or nest search).

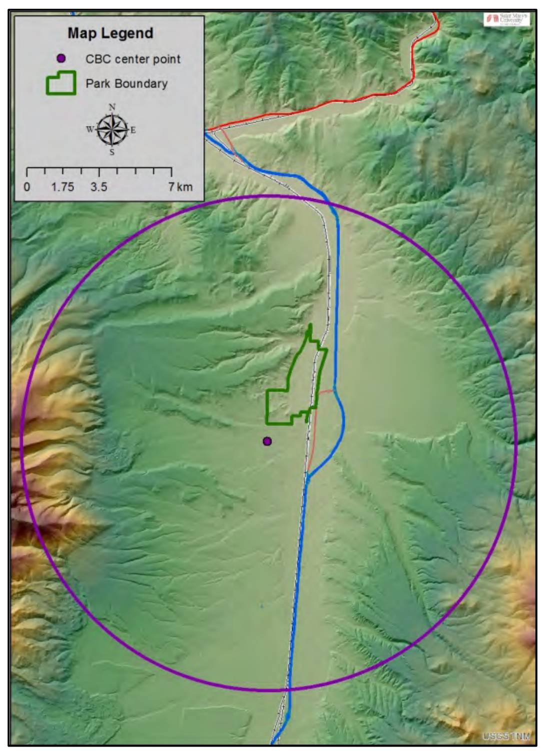


Figure 25. Approximate extent of the CBC survey area (purple circle) including GRKO.

The GRKO Christmas Bird Count has occurred annually since 2006 and is part of the International Christmas Bird Count (CBC), which started in 1900 and is coordinated internationally by the Audubon Society. The CBC surveys overwintering and resident birds that are not territorial and singing; this often results in different survey results than other breeding bird surveys or inventories. Typically, a CBC will be completed by multiple volunteers who survey a 24-km (15-mi) diameter on one day. Volunteers record the total number of species and individuals each year; data for the GRKO CBC are current through 2012 (National Audubon Society 2014). The boundary of the GRKO CBC circle extends beyond park borders, and data from this count includes records that are likely located outside of the park itself (Figure 25).

4.5.5 Current Condition and Trend

<u>Species Richness</u>

The species richness measure allows for an assessment of the number of species present across the park for the entire land bird community. This measure can also indicate overall habitat suitability for birds. However, there may be undetected changes in species richness of native species compared to non-native species, or in Neotropical migrant species compared to resident species. Such changes would not be apparent in the tables and figures presented in this document. The various surveys that have occurred in the park have utilized different methodologies, habitats, and seasons. The unique timing and survey methodology means that each survey will present unique results that may or may not accurately compare to each other or the reference condition.

NPS Certified Bird Species List (NPS 2014)

The NPS Certified Bird Species List (NPS 2014) identifies 230 bird species as either 'present' or 'probably present' in GRKO (Appendix G). This list, however, does not allow for an analysis of species richness as no data are collected other than the potential presence of the listed species.

Rice and Ray (1984)

Rice and Ray (1984) documented all bird species that were visually observed during an informal survey of the ranch from 1982-1983 (Appendix G). The authors documented 27 species throughout GRKO.

Giroir and Beason (2005)

As part of an avian inventory at GRKO in 2004, Giroir and Beason (2005) surveyed the grassland and riparian areas of the park during the breeding season, and conducted informal surveys during the migratory and winter periods. Survey efforts resulted in positive identification of 104 bird species in GRKO. Intensive surveys in the grassland and riparian habitats identified 54 species (Appendix G); the remaining 50 species were documented during informal surveys in the migratory and winter periods.

Larson (2011)

From mid-May to mid-July 2010, Larson (2011) surveyed 14 point count locations in GRKO hayfields. Survey sites were located in Stuart Field (3 points), West Field (2 points), and Taylor Field (9 points), and corresponded with hay mowing and other agricultural activities (Larson 2011). A total of 46 species were observed during survey efforts (Appendix G).

Atkinson and Smucker (2013)

On 12 June and 20 June 2013, Atkinson and Smucker (2013) surveyed two point count transects within GRKO, which resulted in 42 species being observed (Appendix G, Appendix H). In addition to the point counts, Atkinson and Smucker (2013) also conducted a nest search in portions of the park, and found 13 nests of 10 species, two species of which were not observed on the point counts (American crow [*Corvus brachyrhynchos*] and bank swallow [*Riparia riparia*]). Bird banding and mist netting resulted in 51 species being observed (35 of which were not observed on the point counts; Appendix H). Area searches yielded the highest number of observed species, with 104 species, 65 of which were not observed on the point counts (Appendix H). Figure 26 displays the species richness values for each of the survey methods used by Atkinson and Smucker (2013).

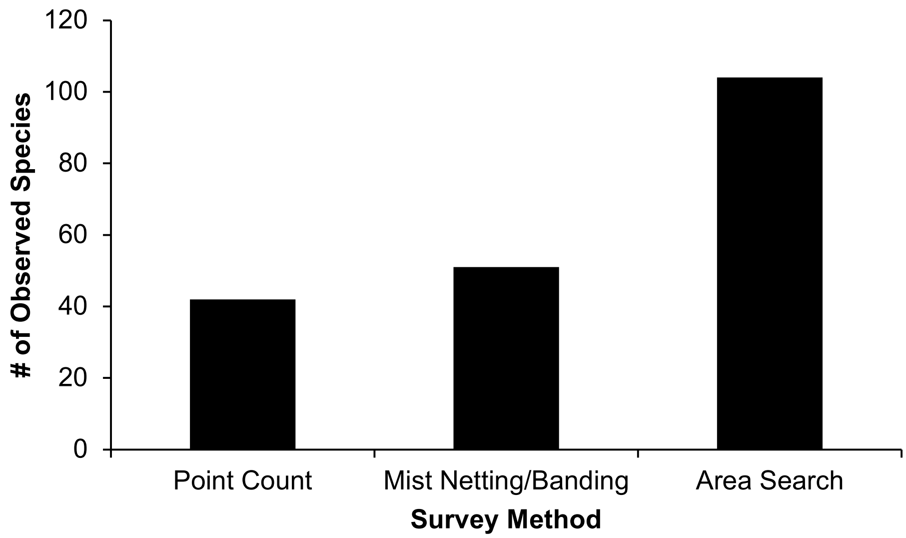


Figure 26. Species richness values for each of the survey methods utilized by Atkinson and Smucker (2013).

Christmas Bird Count Data (2006-2012)

The CBC efforts in GRKO have been conducted on a regular basis since 2006, and represent the largest source of continuous bird data for the park. Unlike most other bird surveys conducted in the park, the CBC surveys overwintering, migratory, and resident birds that are not territorial and singing. Because of this, the species richness estimates obtained from the CBC may not be directly comparable to the results of other surveys that have occurred in the park. The CBC count circle also includes areas both inside and outside park boundaries.

The total number of bird species identified annually during GRKO CBC efforts is presented in Figure 27. From 2006-2012, the average number of bird species observed on the CBC was 38 species (Figure 27), and the number of species observed each year ranged from 32 (2006) to 48 (2011). While the range of species observed per year does not appear to be extremely large, variations from year to year could be attributed to the level of effort for the survey, which may have a direct effect on the number of species observed.

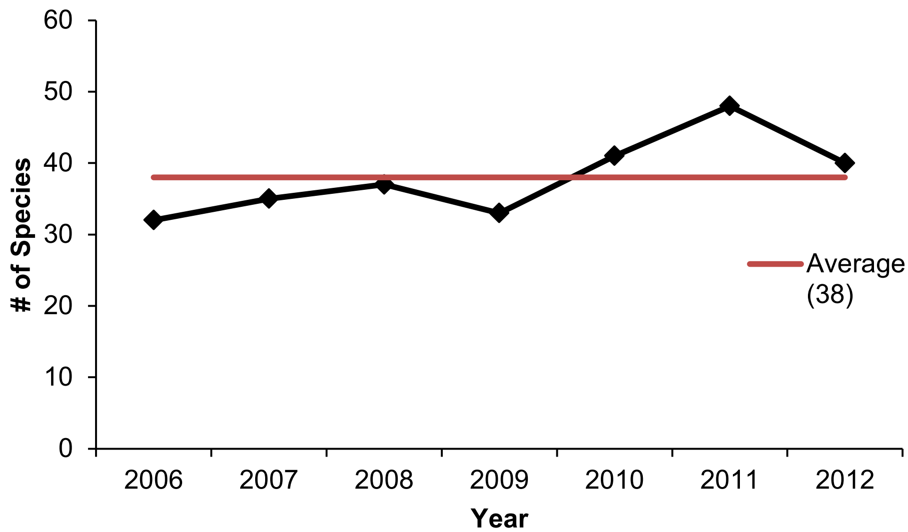


Figure 27. Species richness values during each year of GRKO's annual Christmas Bird Count. The average species richness value for the duration of the count is represented by the continuous red line.

Figure 28 displays the species richness values from each of the studies that have taken place in GRKO from 1982-present. The average number of species observed for the duration of each survey was 46.6. The Giroir and Beason (2005) data includes only the species that were documented on formal surveys, and the Atkinson and Smucker (2013) data includes only species that were observed during point count surveys. When all years of data are pooled, the CBC has observed the highest number of species (64). Excluding the CBC, overall species richness has ranged from 27 species (Rice and Ray 1984) to 54 species (Giroir and Beason 2005).

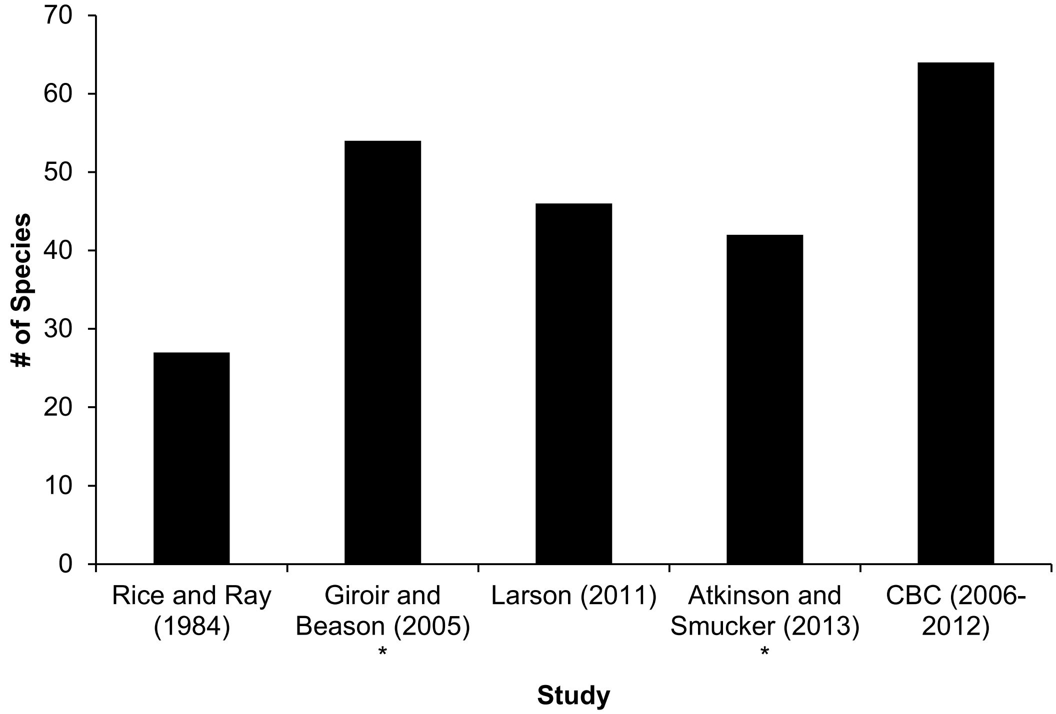


Figure 28. Species richness values reported from each of the surveys completed in GRKO. * indicates data that only includes species that were observed on formal point count surveys.

Distribution

The two primary habitat types utilized by the bird community in GRKO are the riparian areas along the Clark Fork River, and the grassland/agricultural areas. The riparian habitat (Photo 21) in the park is dominated by cottonwood, willows, alder (*Alnus* sp.), and birch species (Giroir and Beason 2005); several other types of riparian vegetation, such as cattail (*Typha* sp.), are also present along the shores of the Clark Fork. The grassland and agricultural areas of GRKO are dominated by grass species, and lack many tree and shrub species. In addition to the native grassland species, the grassland areas of the park also include irrigated hayfields dominated by non-native grasses.

Photo 21. Riparian habitat along the Clark Fork River in GRKO (Photo by Sarah Gardner, SMUMN GSS).

Understanding the current distribution of the bird species in GRKO, and how species utilize those habitats, is of particular importance for GRKO managers, as the critical areas of the park are actively managed for non-avian related activities. Heavy metal contamination in the Clark Fork River and along its shorelines is a major concern to land managers in the GRKO area. Starting in 2015, the riparian habitat along the Clark Fork River in GRKO is scheduled to be excavated in order to remove soils that are contaminated by heavy metals and toxins (Atkinson and Smucker 2013). While these areas will be replanted after excavation and decontamination processes are complete, it is important to document baseline distribution and abundance levels in these areas of the park to monitor recovery efforts.

Stuart, Taylor, and West Fields in GRKO are cut and harvested annually, and understanding which species utilize these fields, and during what season, is important to managers to minimize potential disturbances during critical periods for grassland species. The establishment of baseline distribution, richness, and abundance values in these harvested areas is vital to park managers.

Three surveys have occurred in the park that have documented the distribution of bird species in GRKO (Giroir and Beason 2005, Larson 2011, Atkinson and Smucker 2013). These surveys have all been 1-year efforts, and have had different methodologies, timing, and sampling locations. Individually, these surveys are not sufficient to determine trends, or the overall health of the GRKO bird community. However, it is possible to synthesize the results of these surveys to gather a better understanding of the distribution of bird species in the park, particularly in regards to the species' utilization of the riparian and grassland areas.

Giroir and Beason (2005)

Giroir and Beason (2005) documented 557 individuals during a 2004 avian inventory of the park. The majority of individuals (412, 74% of all individuals observed) and species (49, 91% of all species observed) were located in the riparian habitat (Figure 29, Table 34). The most commonly observed species in the grassland habitat were the savannah sparrow (*Passerculus sandwichensis*; 21% of all observations) and the western meadowlark (*Sturnella neglecta*; 20%). In the riparian habitat, the savannah sparrow was also the most commonly observed species (11%), followed by the brown-headed cowbird (*Molothrus ater*; 7.5%) and the yellow warbler (*Septophaga petechia*; 6%) (Appendix I). While the grassland habitat that was surveyed had a noticeable reduction in birds observed compared to the riparian area, this result was not unexpected; fewer survey points were utilized in the grassland habitat (14 compared to 20 in the riparian), and riparian habitats provide vital habitat for a wider variety of species (Giroir and Beason 2005).

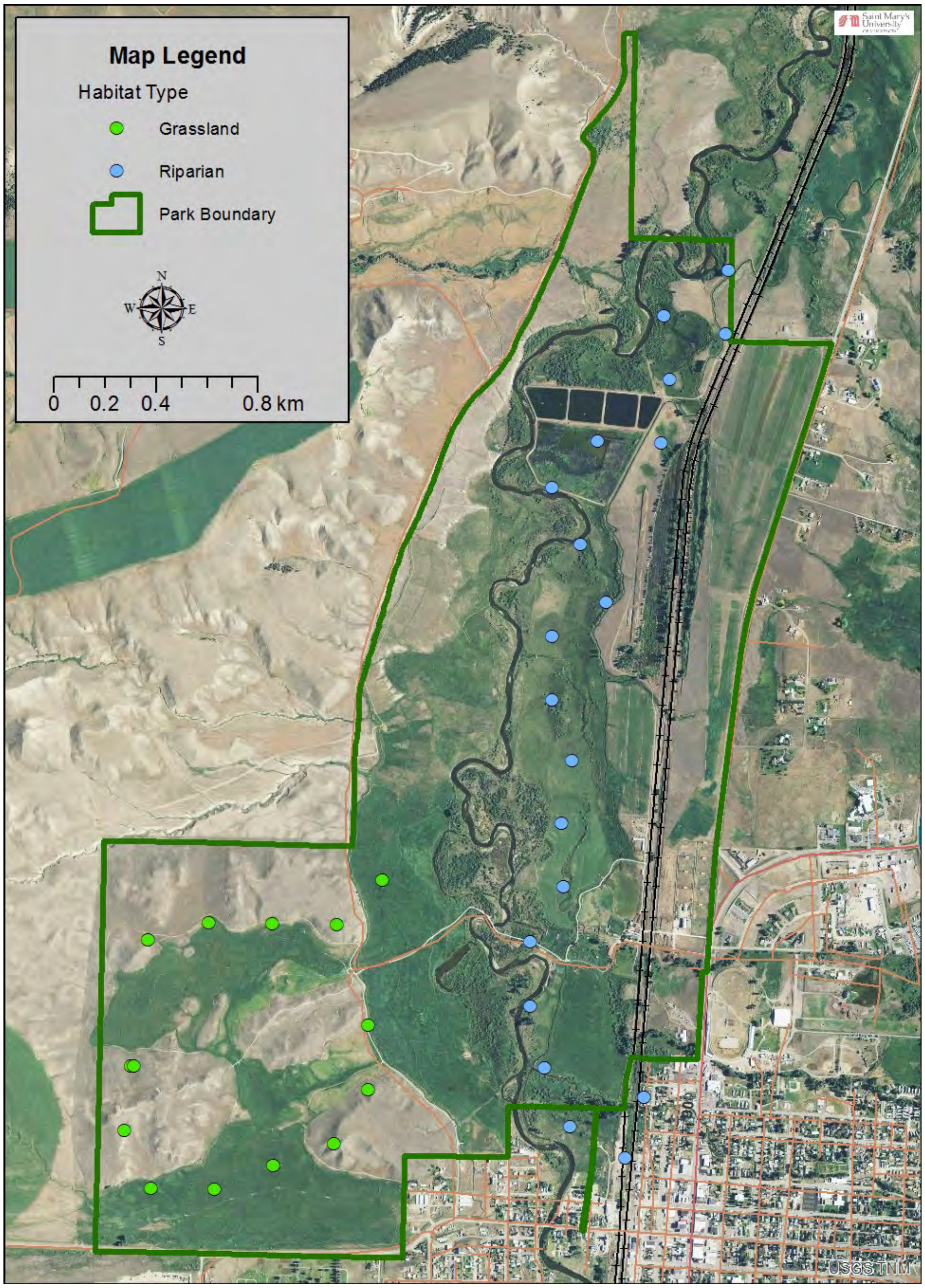


Figure 29. Survey points in riparian and grassland habitats that were used during the Giroir and Beason (2005) avian inventory of GRKO.

Table 34. Species richness and abundance values for the two habitat types that were sampled during the Giroir and Beason (2005) survey of GRKO in 2004.

Habitat	# of Point Counts	# of Species	# of Individuals
Grassland	14	19	145
Riparian	20	49	412
Total	**34**	**54**	**557**

Larson (2011)

The 2010 bird surveys completed by Larson (2011) were focused only on the grassland and agricultural fields of GRKO, and there is no discussion of distribution beyond these habitat types. Three general survey locations were used (Taylor, Stuart, and West Fields), each with a separate subset of survey point locations (14 in total) (Figure 30). Four hundred eighty-nine individuals of 46 species were observed at the survey points in the grassland/agricultural habitats of GRKO. The savannah sparrow was the most commonly observed species in 2010 (31 % of all observations), followed by the bobolink (11%), and the western meadowlark (9%) (Appendix J).

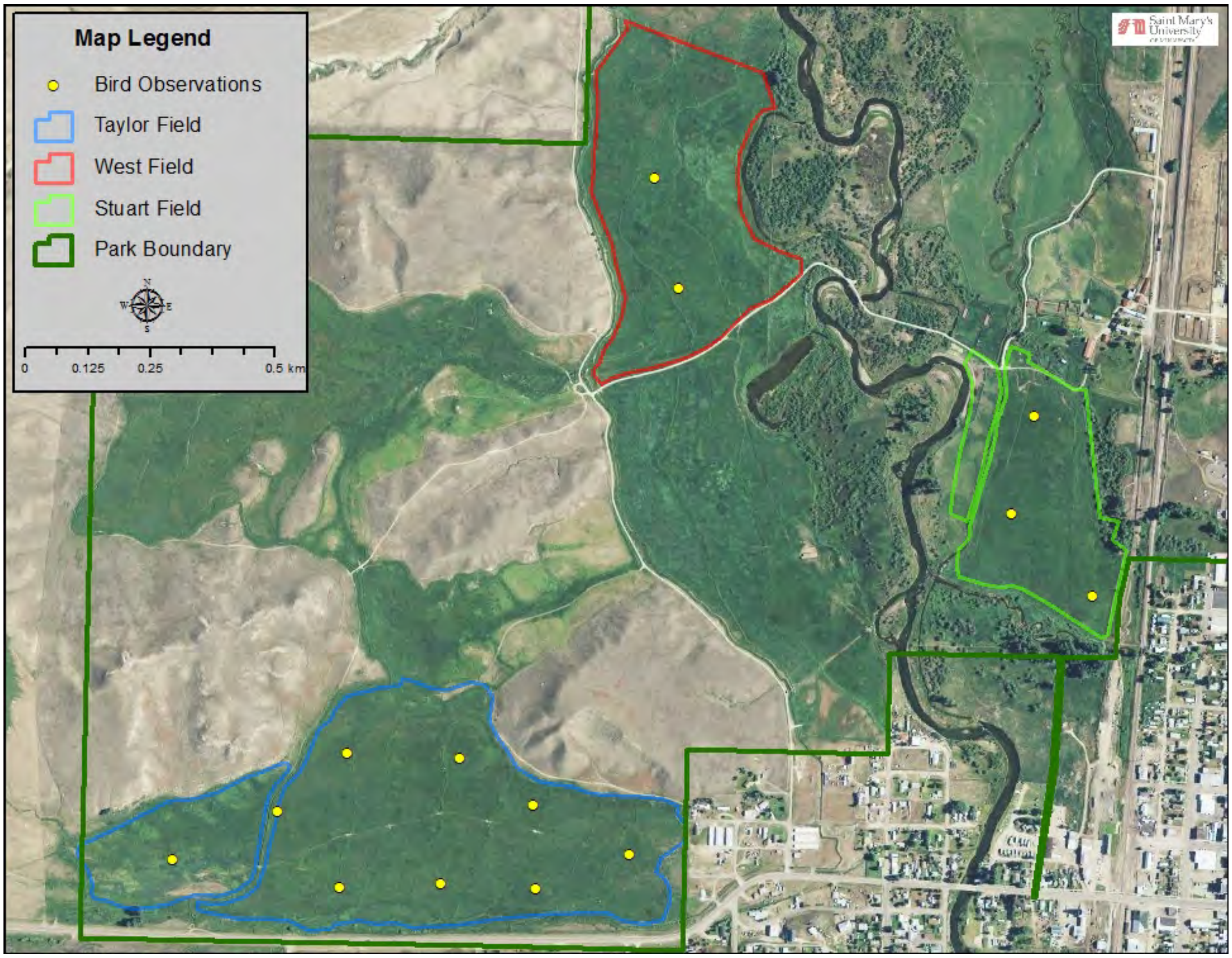


Figure 30. Survey areas during the Larson (2011) grassland and agricultural avian surveys.

Atkinson and Smucker (2013)

Atkinson and Smucker (2013) surveyed the grassland/agricultural and riparian habitats of GRKO in the summer of 2013. The data presented in this section represent only the point count survey data; area searches and nest searches also yielded observations, and are included in Appendix H.

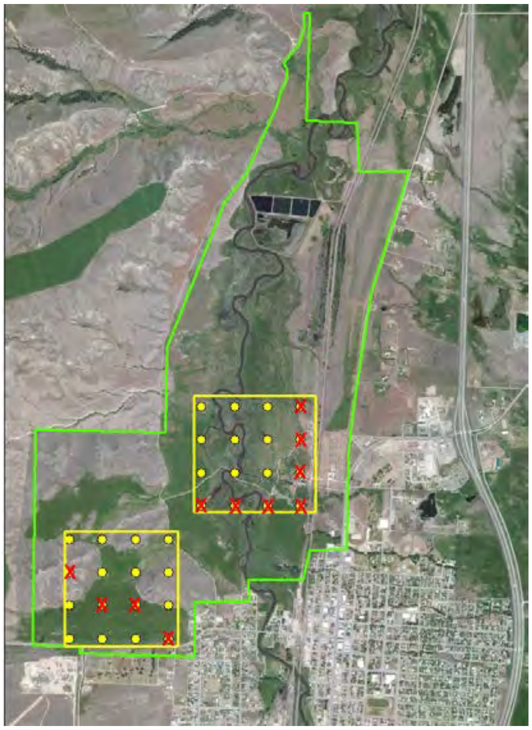


Figure 31. The two point count transects that were established in GRKO by Atkinson and Smucker (2013). Point count locations that have a red X were not surveyed in 2013 due to time constraints (Image reproduced from Atkinson and Smucker 2013).

Atkinson and Smucker (2013) observed 321 individuals in 2013; the majority of individuals (175, 55% of all individuals observed) and species (35, 83% of all species observed) were located in the grassland/agricultural habitat (Figure 31, Table 35). In the grassland/agricultural habitat, the most commonly observed species were the savannah sparrow (26% of all observations) and the red-winged blackbird (*Agelaius phoeniceus*; 17%). The savannah sparrow (17%) and black-billed magpie (*Pica hudsonia*; 14%) were the most commonly observed species in the riparian habitat (Appendix K).

Atkinson and Smucker (2013) documented more species and individuals in the grassland/agricultural areas of the park whereas Giroir and Beason (2005) (the only other study to survey both riparian and grassland habitats) observed more species and individuals distributed along the Clark Fork River in the riparian areas of the park (Figure 32, Figure 33). A potential reason for this result is that Atkinson and Smucker (2013) had a higher number of point count locations in the grassland/agricultural area (14) compared to the riparian and wetland areas (8; Table 35); Giroir and Beason (2005) exhibited a similar trend, albeit in reverse, as 20 point count locations were in riparian habitats and only 14 were in grassland habitats (Table 34). Figure 32 and Figure 33 represent a rough comparison of the number of species and individuals observed during each survey in the park. Comparison across surveys with the purpose of evaluating trends or current condition is not advisable, as biases in each survey may make comparisons unreliable.

Table 35. Species richness and abundance values for the two habitat types that were sampled during the Atkinson and Smucker (2013) survey of GRKO in 2013.

Habitat	# of Point Counts	# of Species	# of Individuals
Grassland/Agriculture	14	35	175
Riparian/Wetland	8	29	146
Total	**22**	**42**	**321**

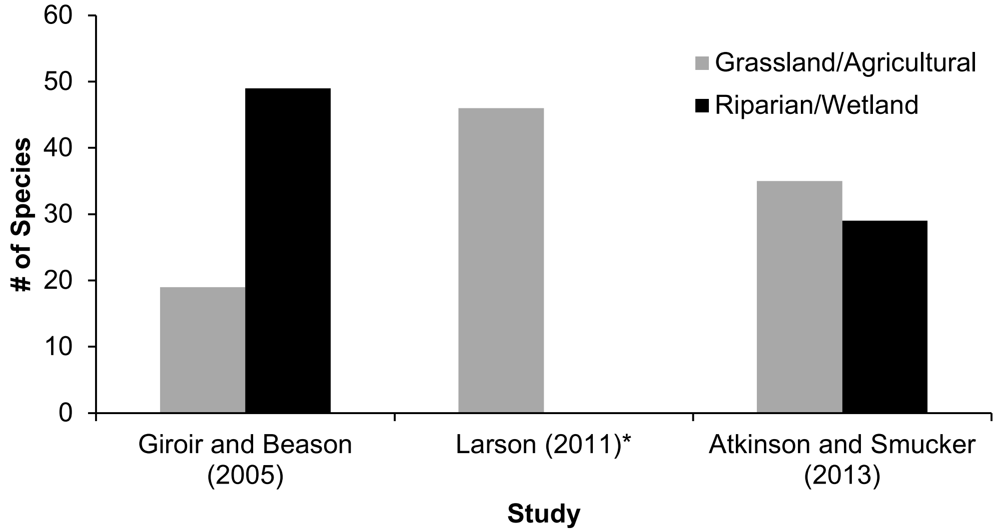


Figure 32. Number of species observed in each habitat type during the three major surveys in GRKO. * indicates a survey that did not have any riparian/wetland survey points.

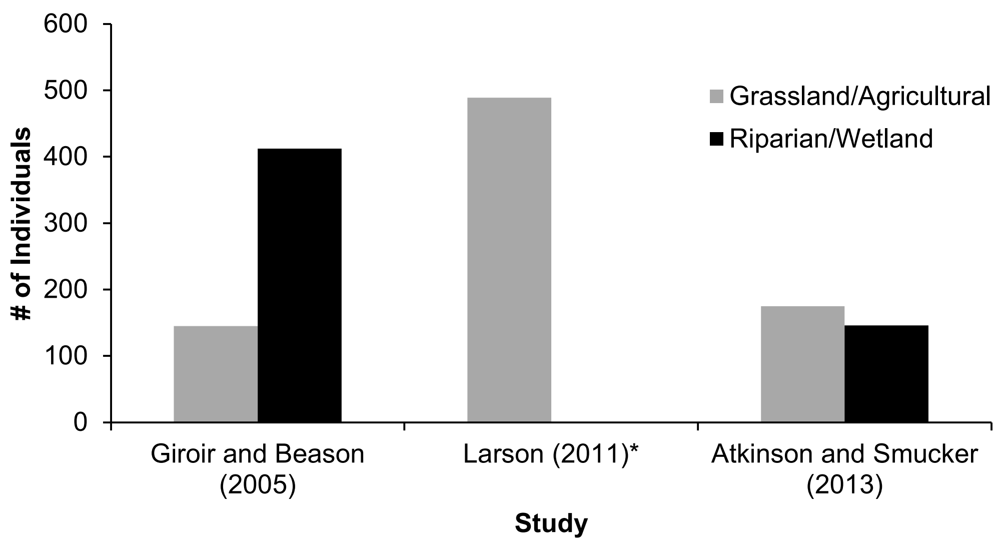


Figure 33. Number of individuals observed in each habitat type during the three major surveys in GRKO. * indicates a survey that did not have any riparian/wetland survey points.

Status of Species of Special Concern

The Montana Natural Heritage Program (MTNHP) and the Montana Department of Fish, Wildlife, and Parks (MFWP) compiled a list of avian species of concern (MTNHP and MFWP 2009) which was used for this assessment. This list includes a species' global, state, and federal status, as well as the species' current conservation tier as identified in MFWP (2005). Additionally, species of conservation concern identified as Priority Tiers I-III by the Montana Partners in Flight Bird Conservation Plan (MTPIF 2000) were included in this assessment; all species of conservation concern that have been documented in the park can be found in Appendix F.

Assessing the trends and current status of species of special concern in GRKO is difficult, as many of the recent studies that have taken place in the park were 1-year studies that utilized different survey protocols. Additionally, many of the species of special concern in the park are migratory, and their presence/absence in GRKO is often erratic (Giroir and Beason 2005).

NPS Certified Bird Species List (NPS 2014)

Of the 230 species identified on the NPS Certified Species List (NPS 2014), 72 species of special concern are identified (31% of all species on NPS 2014). Because NPS (2014) only documents the historic presence/absence of species in the park, trend estimates for priority species are not possible from this data source.

Rice and Ray (1984)

Rice and Ray (1984) documented eight species of special concern (30% of all species observed) during an informal survey of the ranch from 1982-1983. Similar to NPS (2014), Rice and Ray (1984) only documented the presence of species, so it is not possible to analyze trends in priority species from these data.

Giroir and Beason (2005)

Giroir and Beason (2005) observed 13 species of special concern during a 2004 survey of the grassland and riparian habitats of the park. All 13 species were identified as either a Priority Tier II or III species by MTPIF (2000). Two other priority species, the bobolink and long-billed curlew were identified on multiple conservation lists (Appendix F). The bobolink has a state rank of S3B, indicating that this breeding species is "potentially at risk because of limited and/or declining numbers, range, and/or habitat, even though it may be abundant in some areas" (MTNHP and MFWP 2009, p. 3). The long-billed curlew also has a state rank of S3B, and is identified as a sensitive species by the Bureau of Land Management (BLM) (MTNHP and MFWP 2009). MFWP (2005) listed the long-billed curlew as a tier I species, indicating it is a species of greatest conservation need in Montana.

Abundance data for the species of special concern that were observed during Giroir and Beason (2005) are presented in Figure 34. Due to the duration of the survey, trend analysis is not possible using only the data from this study. The red-winged blackbird was observed most frequently (23 individuals), followed by the willow flycatcher (*Empidonax traillii*; 21), and the song sparrow (*Melospiza melodia*; 18).

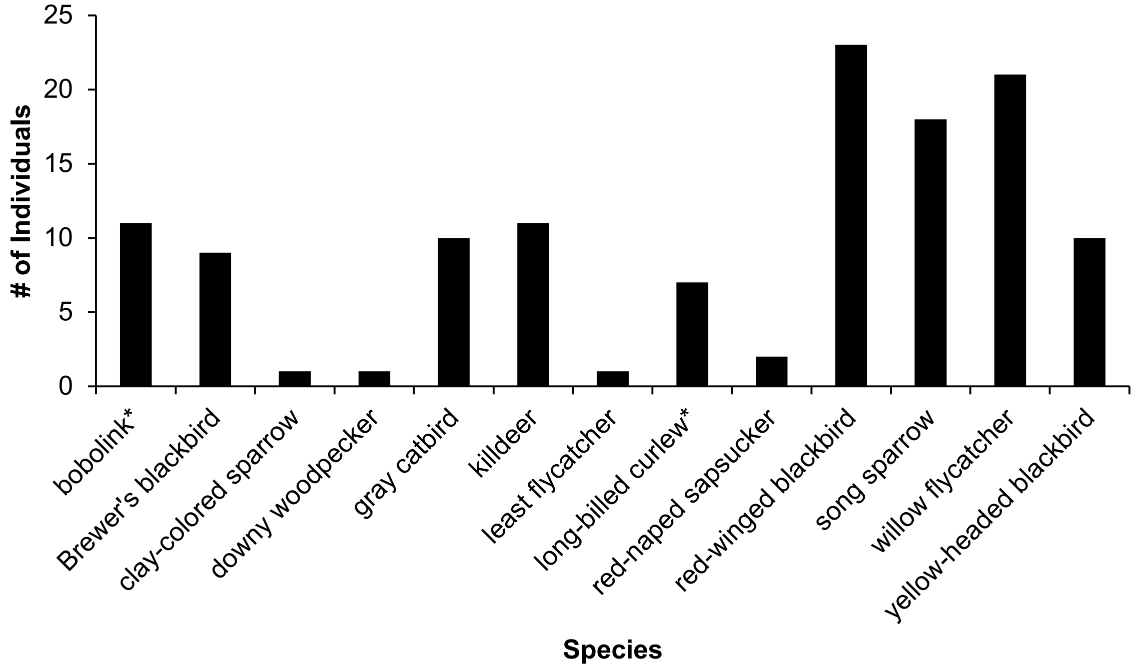


Figure 34. Abundance of species of special concern observed during the Giroir and Beason (2005) survey of GRKO. * indicates species that was on two or more conservation lists.

Larson (2011)

Larson (2011) documented 11 species of special concern during a survey of the agricultural and grassland habitats of GRKO in 2010; one of these species, the killdeer (*Charadrius vociferus*), was observed only between point counts. Nine of the species observed were classified as a Priority Tier III species by MTPIF (2000), while the willow flycatcher was the only Priority Tier II species observed. Both the bobolink and the alder flycatcher (*Empidonax alnorum*) were designated S3 species by MTNHP and MFWP (2009); the alder flycatcher was further designated as a tier II-I species by MFWP (2005).

The bobolink was the most abundant species of special concern observed during 2010, with 57 observations. The red-winged blackbird was the only other species of special concern with double-digit observations (28; Table 36). Table 36 shows the Larson (2011) abundance data for all species of special concern observed in GRKO.

Table 36. Number of individuals identified as species of special concern observed during the Larson (2011) survey of GRKO.

Species	# of Individuals
alder flycatcher*	2
bobolink*	57
Brewer's blackbird	1
chipping sparrow	3
killdeer †	n/a
lark sparrow	1
northern harrier	1
red-winged blackbird	28
song sparrow	9
Swainson's hawk	2
willow flycatcher	3

* Species documented on two or more conservation lists

† Species observed between point counts but not counted.

Atkinson and Smucker (2013)

Nine species of special concern were documented during surveys completed by Atkinson and Smucker (2013). Eight species were identified by MTPIF (2000) as priority species; six species were assigned to Priority Tier III, while two species (long-billed curlew, willow flycatcher) were assigned to Priority Tier II (Appendix F). The bobolink and long-billed curlew were also classified as S3B species by MTNHP and MFWP (2009); the great blue heron (*Ardea herodias*) was classified as an S3 species, which is the same designation as S3B, only it indicates it is not a breeding species in the state.

The red-winged blackbird was by far the most numerous species of special concern observed during the Atkinson and Smucker (2013) surveys, with 40 individuals observed. The bobolink was the second most commonly observed species of special concern with five observations. Table 37 shows the Atkinson and Smucker (2013) abundance data for all species of special concern observed in GRKO.

Table 37. Number of individuals identified as species of special concern observed during the Atkinson and Smucker (2013) survey of GRKO.

Species	# of Individuals
bobolink*	5
great blue heron*	2
killdeer	1
long-billed curlew*	3
MacGillivray's warbler	2
northern harrier	1
red-winged blackbird	40
song sparrow	4
willow flycatcher	2

* Species documented on two or more conservation lists

Christmas Bird Count Data (2006-2012)

Care must be taken when interpreting count data sources, such as the CBC, as the data are largely dependent upon the effort of the observers. The counts may not provide an accurate depiction of the trends or current status of species of special concern in GRKO.

From 2006-2012, 17 species of special concern have been observed during the annual CBC in GRKO. Fifteen of the observed species were identified as Priority Species by MTPIF (2000), with the brown creeper being the only Priority Tier I Species (indicating it is a "Conservation Action" species; MTPIF 2000). The gray-crowned rosy-finch has been observed during two CBCs, and has a state conservation ranking of S2B, indicating this breeding species is "at risk because of very limited and/or declining numbers, range, and/or habitat, making it vulnerable to global extinction or extirpation in the state" (MTNHP and MFWP 2009, p. 3).

The most commonly observed species of special interest from 2006-2012 were the bald eagle (*Haliaeetus leucocephalus*; 119 individuals), Townsend's solitaire (*Myadestes townsendi*; 94), and Brewer's blackbird (*Euphagus cyanocephalus*; 57). Only three species of special concern were observed during all seven CBC efforts: the bald eagle, downy woodpecker (*Picoides pubescens*), and Townsend's solitaire. The highest number of species/individuals observed occurred from 2010-2012 (Table 38, Figure 35).

Table 38. Annual abundance of species of special concern during the GRKO Christmas Bird Count, 2006-2012.

Species	2006	2007	2008	2009	2010	2011	2012
American dipper	3	1		1	1	1	2
bald eagle	13	8	14	19	14	29	22
Barrow's goldeneye				1	4	2	5
Brewer's blackbird						37	20
brown creeper						1	
Clark's nutcracker	1		2	6	10	2	3
downy woodpecker	4	2	3	7	8	6	2
gray-crowned rosy-finch			1			3	
great blue heron		4		1		2	3
killdeer		4					
northern goshawk		1			1		
northern harrier		3	7	1	3	4	2
red crossbill			20				
red-winged blackbird					30		4
sharp-shinned hawk	1				3	4	1
song sparrow		1			3	2	1
Townsend's solitaire	8	2	4	9	26	32	13

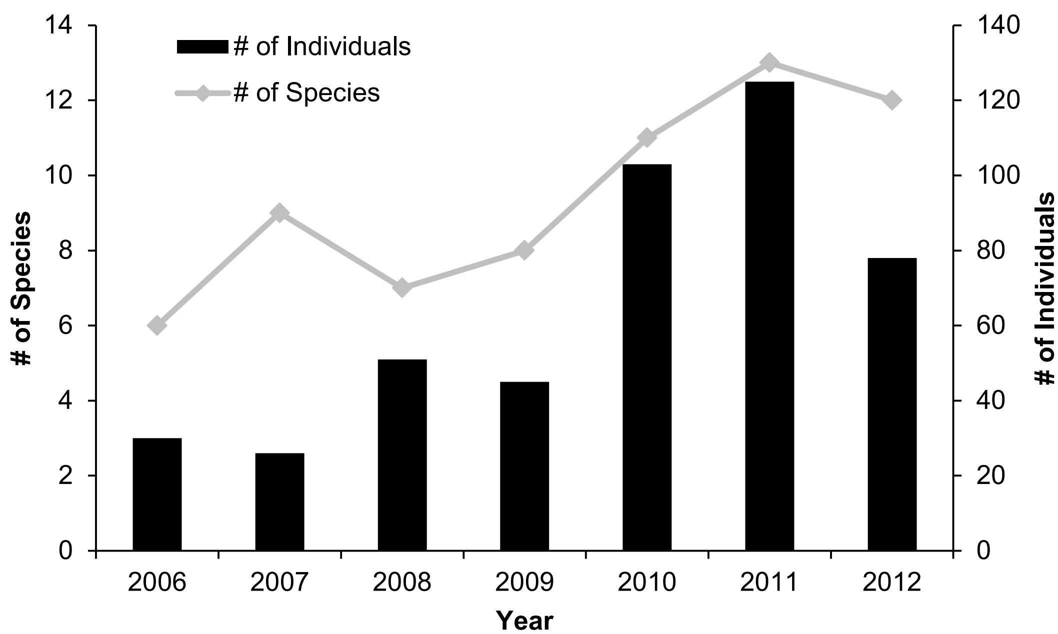


Figure 35. Number of species and number of individual species of special concern observed during the annual GRKO Christmas Bird Count, 2006-2012.

Figure 36 represents a chronological depiction of the species richness data for the species of conservation concern that have been documented during the various avian surveys/inventories, while Figure 37 depicts the abundance data for species of conservation concern. The average number of species of conservation concern observed during the surveys was 9.73, while the average number of individuals was 75 (Figure 36, Figure 37).

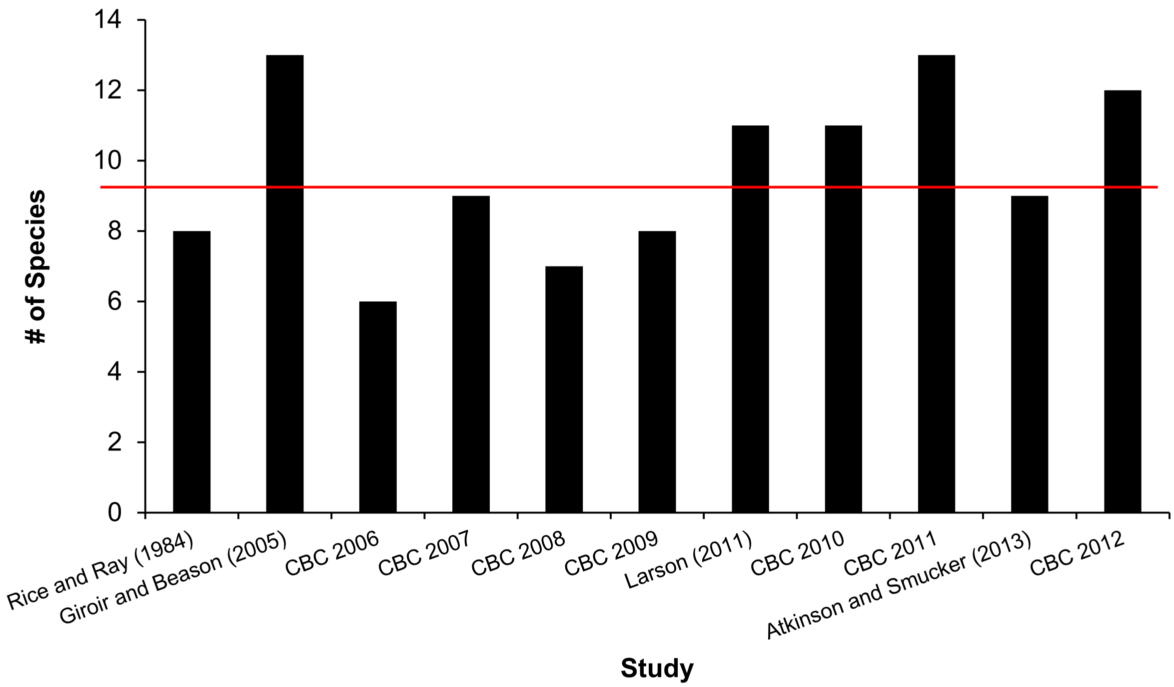


Figure 36. Number of species of special concern observed during each of the major survey efforts in GRKO. The red line indicates the average number of species of special concern observed during the surveys (9.73).

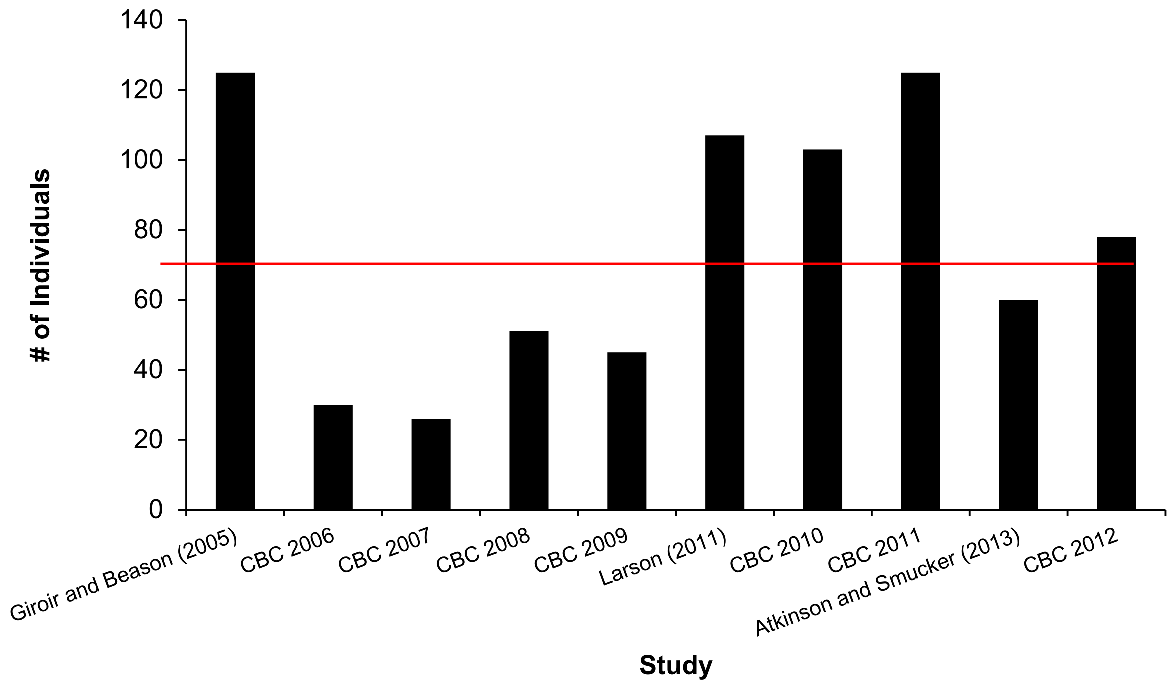


Figure 37. Number of individuals of special concern observed during each of the major survey efforts in GRKO. The red line indicates the average number of individuals observed during a survey (75).

Nationwide Trends

Grassland bird species are among North America's most threatened bird communities; grassland birds have experienced "steeper, more consistent, and more geographically widespread declines than any other behavioral or ecological guild" (Knopf 1994, p. 251). NABCI (2009) indicates that grassland birds have been rapidly declining over the past 50 years, and that 55% of grassland species are showing significant population declines. Furthermore, 48% of North American grassland-breeding bird species are of conservation concern.

Many of the declines in grassland species appear to be the result of loss and degradation of grassland habitats (Noss et al. 1995, Vickery and Herkert 2001). Three iconic grassland species found in GRKO, the bobolink, western meadowlark, and short-eared owl (*Asio flammeus*), have declined globally by 38-77% since 1968 (NABCI 2009).

Nearly 25% of all North American bird species rely on riparian and wetland habitats (NABCI 2009). Several riparian/wetland species that are found in GRKO are experiencing global declines. The rusty blackbird (*Euphagus carolinus*) has experienced a 75% population decline during the last 40 years, and the lesser scaup (*Aythya affinis*) has experienced almost a 50% population decline during the same period (NABCI 2009). Despite the decline in many species, management and conservation efforts in these habitats have had success in many areas. Species such as the bald eagle, osprey (*Pandion halieatus*), sandhill crane (*Grus canadensis*), and American white pelican (*Pelecanus erythrorhynchos*) have all benefitted from wetland restoration and management practices.

Threats and Stressor Factors

Contamination from the Clark Fork River represents a major threat to the bird community of GRKO. The Clark Fork River has been exposed to heavy metal contamination for over a century. Metals washed downstream from the historic copper sulfate mining districts of Anaconda and Butte, MT; large amounts of metallic mining waste were washed downstream during record floods in the early 1900s and were deposited and settled beneath the soil sediments along the Clark Fork River floodplain in GRKO (Kapustka 2002, Ramsey et al. 2005). Mining wastes were unevenly distributed and further agitated by subsequent floods and channel migration, leading to extensive spatial variation in contaminant concentration within the soils (Ramsey et al. 2005). In 1992, the EPA designated the Clark Fork River upstream of the Milltown Dam to the Warm Springs Ponds a Superfund Site.

High trophic level avian predators with a primarily piscivorous diet, such as the bald eagle and osprey, have been used as sentinels for studying environmental contamination (Toschik et al. 2005, Hopkins et al. 2007, Rattner et al. 2008, Rivera-Rodriguez and Rodriguez-Estrella 2011, Langner et al. 2011). The osprey is a frequently observed species in GRKO, as many visitors spot the birds nesting on electrical poles in the park (Photo 22). Recently, Langner et al. (2011) documented variable levels of copper, arsenic, cadmium, lead, zinc and mercury in the blood of osprey chicks along the Clark Fork River. The most notable finding of the study, though, was that the lowest blood concentrations of mercury were observed in the osprey chicks located along the most upstream river sections, including GRKO. The highest mercury concentrations in osprey chicks were documented downstream from contaminated tributaries (Langner et al. 2011), which enter the Clark Fork downstream of GRKO. Continued monitoring of the contaminant levels in the blood of high trophic level raptors, especially as remediation efforts continue, will provide GRKO managers with valuable information regarding both the health of the bird community and the health of the Clark Fork River.

Photo 22. Osprey nest on top of an electrical pole in GRKO (Photo by Sarah Gardner, SMUMN GSS).

Beginning in 2015, the riparian habitat along the Clark Fork River in GRKO is scheduled to be excavated as part of the Superfund site remediation process (Atkinson and Smucker 2013). The riparian areas will be replanted after the excavation and decontamination processes are complete, but the large-scale disturbance that will affect the riparian-dependent bird species may have major, short-term impacts on this community. The increase in human presence in the park (i.e., machinery, construction workers, and noise) may also have secondary impacts on the neighboring communities, such as the grassland and agricultural bird communities.

The annual haying of the agricultural fields poses a threat to the grassland bird communities of GRKO. Earlier and more frequent harvests are commonly cited as major causes of grassland songbird population declines (Perlut et al. 2006). Since most grassland species nest on or near the ground, the haying process often results in total nest failure if completed during the incubating or brooding stage. During a 2002-2005 study of grassland songbirds in Vermont and New York, Perlut et al. (2006) reported that haying caused 99% of active savannah sparrow nests and 100% of active bobolink nests to fail. In GRKO, haying typically begins in mid-July, which is nearing the end of the bobolink's nesting period (the bobolink is a late nester and is a well-suited indicator of when the grassland breeding period concludes; Larson 2011). GRKO has purposely delayed haying until the latest possible date to minimize negative impacts to nesting birds in these fields. These delayed harvests (as suggested by Larson 2011) should continue, as a shift in the haying timeline could have significant impacts on the breeding grassland bird species in the park.

Avian brood parasite species (e.g., brown-headed cowbird) may pose a threat to several avian species in GRKO. Brood parasites are species that lay their eggs in the nests of other breeding species, which then in turn incubate and care for the young (Payne 1977). Brood parasitism generally reduces the reproductive success of the host species, as host species typically fledge fewer young compared to other non-parasitized parents of the same species (Payne 1977). Brown-headed cowbirds are native to the GRKO region, and can directly contribute to the reduced nesting success of host species, as they will often puncture or remove host species eggs (Friedmann 1963). Brown-headed cowbirds often hatch earlier than host species eggs, and grow larger and faster than the host species, which often results in the death of the host chicks due to starvation, neglect, overcrowding, or direct mortality by trampling or removal from the nest (Friedmann 1963, Payne 1977). Many breeding species are targeted by brood parasites, although warblers, blackbirds, and vireos are among the most commonly parasitized species. While a natural phenomenon, brood parasitism can be actively managed against; instances of cowbird egg removal from host nests has resulted in increased reproductive success in various parts of the species' home range (Walkinshaw 1972, Payne 1977).

Another threat facing bird populations is climate change; of particular concern are shifts in the reproductive phenology of breeding bird species. Several bird species depend on temperature ranges or weather cycles to cue their breeding. As global temperatures change, some bird species have adjusted by moving their home range north (Hitch and Leberg 2007). Other species have adjusted their migratory period and have begun returning to their breeding grounds earlier in the spring; American robins (*Turdus migratorius*) in the Colorado Rocky Mountains are now returning to their breeding grounds 14 days earlier compared to 1981 (NABCI 2009). A concern is that this shift in migration may be out of sync with food availability and could ultimately lead to lowered reproductive success.

The North American Bird Phenology Program (BPP) is currently analyzing the migration patterns and distribution of migratory bird species across North America (USGS 2008). Information from this analysis will provide new insights into how bird distribution, migration timing, and migratory flyways have changed since the later part of the 19^{th} century. This information may also be applied to estimate changes in breeding initiation periods in specific habitats.

Data Needs/Gaps

GRKO has had several bird surveys and inventories in the last two decades; however, these have all been 1 year efforts. The establishment of an annual survey with increased yearly sampling (>1 survey/year) and a spatially balanced bird protocol (similar to Atkinson and Smucker 2013) would allow for density and occupancy estimates in the future. These estimates could provide baseline values that would serve as sources of comparison for future studies.

Christmas bird counts provide snapshots in time of species richness. However, only one survey/visit per year yields little information in terms of population trends. Further observations in the winter could help to remedy this data gap and could potentially help the park better understand the status of wintering bird species in the park.

Overall Condition

Species Richness

The species richness measure was assigned a *Significance Level* of 3 during project scoping. While no long-term monitoring of birds has occurred in GRKO, the several 1-year surveys and inventories that have occurred have recorded species richness values, and suggest that species richness is relatively stable in the park. Most surveys have taken place during the breeding season, and have documented species richness values between 42-54 species. The average species richness value for the surveys completed after 2000 was 47 species. CBC efforts have yielded species richness values ranging from 32-48 species; these counts do not sample breeding birds and do not count many of the migratory species that pass through the park in the spring and fall. A *Condition Level* of 0, indicating no current concern, was assigned for species richness in GRKO.

Distribution

Distribution was assigned a *Significance Level* of 2 by GRKO staff. There are two major habitat types utilized by the GRKO bird community: riparian and grassland/agricultural. Giroir and Beason (2005) observed more avian usage of the riparian habitat (74% of individuals observed, 91% of species), while Atkinson and Smucker (2013) documented more avian species and individuals in the grassland habitat (55% of individuals, 83% of species). However, the dominant habitat type in each study had a higher number of survey points, which likely influenced the number of species and individuals observed. There does not appear to be major concern regarding the current distribution of birds in GRKO, and a *Condition Level* of 1 was assigned to this measure. With Superfund remediation efforts set to take place in the riparian habitat of GRKO in 2015, monitoring of the distribution of avian species in the park will be needed to document any potential shifts in abundance or habitat utilization, particularly during the breeding season.

Abundance

The abundance measure was assigned a *Significance Level* of 1 during project scoping. Measures with a Significance Level of 1 are not discussed in the body of the text, rather they are briefly summarized in the Overall Condition section. In addition to the annual CBC in GRKO, three surveys have documented avian abundance in the park (Appendix I, Appendix J, Appendix K). Figure 33 in the Current Condition section of this document displays the abundance, by habitat type, of all individuals observed during these three studies. There is no evidence to indicate any cause for concern regarding avian abundance in the park, but it is difficult to compare results across these three surveys. The three studies were 1-year efforts, and it is difficult to combine the results to assess current condition and trend; sampling biases, such as survey duration, location, and timing, may contribute to the differing results regarding species abundance.

The CBC represents a continuous source of abundance data for GRKO, as it has occurred annually since 2006. The CBC in GRKO saw a large increase in abundance from 2010-2011, while 2012 was still an above average year (Figure 38). No data are currently available from 2013 or 2014. However, biases such as number of observers, ability of the observers, and weather conditions/seasonal timing may contribute to annual variations in abundance.

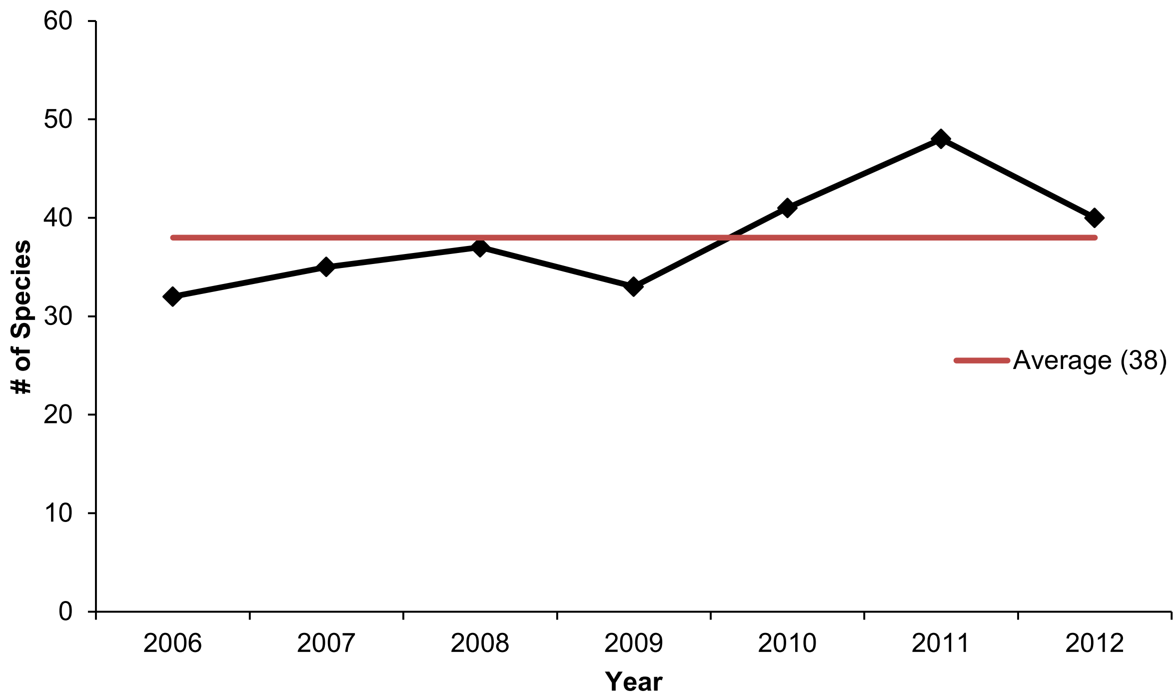


Figure 38. Avian abundance during the annual GRKO CBC, 2006-2012.

A *Condition Level* of 1 was assigned to the abundance measure, indicating the measure is currently of low concern. The establishment of an annual breeding bird survey or inventory would be beneficial for future assessments of condition, and would allow for a more thorough comparison of yearly abundance estimates.

Status of Species of Special Concern
The status of species of special concern measure was assigned a *Significance Level* of 3. In GRKO, the three major surveys that have taken place identified 9.73 species of special concern on average (Figure 11). The average number of individuals of special concern observed during these surveys was 75 (Figure 12). The CBC in the park observed 17 species of special concern from 2006-2012, and abundance values fluctuated annually (Figure 11). The CBC data contains observations from outside of the park boundaries, and it is impossible to know exactly how many of these observed species were detected within park boundaries.

It is difficult to ascertain any trends in species of special concern in GRKO, as surveys that have taken place utilize different methodologies and have occurred during different time periods. The CBC does not observe many migratory or breeding species of special concern, and the surveys that took place during breeding likely missed species that only overwinter in the park. Nationwide trends for species of special concern suggest that the grassland and riparian obligate species (the two dominant types in the park) are experiencing population declines of great numbers (NABCI 2009). While the status of species of special concern is currently of low concern in the park (*Condition Level* of 1), the trends across the nation and the future remediation efforts in the riparian habitats may increase this level in future condition assessments.

Weighted Condition Score
The birds component was assigned a *Weighted Condition Score* of 0.22, indicating that this component is currently in good condition. Survey efforts in the last 10 years have resulted in estimates that indicate this component's current trend is stable. However, remediation efforts along the Clark Fork River will likely impact the bird community of the park, and will warrant future monitoring efforts to verify that the community does not begin to show signs of declining health.

Birds			
Measures	Significance Level	Condition Level	WCS = 0.22
Species Richness	3	0	
Distribution	2	1	
Abundance	1	1	
Status of Species of Special Concern	3	1	

4.5.6 Sources of Expertise

This assessment relied on published literature as the primary source of expertise, with review by GRKO staff.

4.5.7 Literature Cited

Atkinson, K., and K. Smucker. 2013. Grant-Kohrs Ranch National Historic Site bird monitoring project. Avian Science Center, Division of Biological Sciences, University of Montana, Missoula, Montana.

Blakesley, J. A., D. C. Pavlacky Jr., and D. J. Hanni. 2010. Monitoring bird populations in Wind Cave National Park. Technical Report M-WICA09-01. Rocky Mountain Bird Observatory, Brighton, Colorado.

Bollinger, E. K., P. B. Bollinger, and T. A. Gavin. 1990. Effects of hay-cropping on eastern populations of the bobolink. Wildlife Society Bulletin 18(2):142-150.

Dale, B. C, P. A. Martin, and P. S. Taylor. 1997. Effects of hay management on grassland songbirds in Saskatchewan. Wildlife Society Bulletin 25(3):616-626.

Frawley, B. J., and L. B. Best. 1991. Effects of mowing on breeding bird abundance and species composition in alfalfa fields. Wildlife Society Bulletin 19:135-142.

Friedmann, H. 1963. Host relations of the parasitic cowbirds. Bulletin of the United States National Museum 233. Smithsonian Institution, Washington, D. C.

Giroir, G., and J. Beason. 2005. Report on the general avian inventory of Grant-Kohrs Ranch National Historic Site, Montana. Rocky Mountain Bird Observatory, Fort Collins, Colorado.

Herkert, J. R., D. W. Sample, and R. E. Warner. 1996. Management of Midwestern grassland landscapes for the conservation of migratory birds. Pages 89-116 *in* Management of midwestern landscapes for the conservation of Neotropical migratory birds. Edited by F. R. Thompson, III. General Technical Report NC-187.United States Department of Agriculture, St. Paul, Minnesota.

Hitch, A. T., and P. L. Leberg. 2007. Breeding distributions of North American bird species moving north as a result of climate change. Conservation Biology 21(2):534-539.

Hopkins, W. A., L. B. Hopkins, J. M. Unrine, J. Snodgrass, and J. D. Elliot. 2007. Mercury concentrations in tissues of osprey from the Carolinas, USA. Journal of Wildlife Management 71:1819-1829.

Hutto, R. L. 1998. Using landbirds as an indicator species group. Pages 75-92 *in* Avian conservation: Research and management. Island Press, Washington, D.C.

John Milner Associates, Rivanna Archaeological Consulting, Susan Maxman and Partners Architects. 2004. Cultural landscape report. Grant-Kohrs Ranch National Historic Site, Deer Lodge, Montana.

Kapustka, L. A. 2002. Phytotoxicity tests on soils from the Grant-Kohrs Ranch National Historic Site, Deer Lodge, Montana. National Park Service, Deer Lodge, Montana.

Knopf, F. L. 1994. Avian assemblages on altered grasslands. Studies in Avian Biology 15:247-257.

Koskimies, P. 1989. Birds as a tool in environmental monitoring. Annales Zoologici Fennici 26:153-166.

Langner, H. W., E. Greene, R. Domenech, and M. R. Staats. 2011. Mercury and other mining-related contaminants in ospreys along the Upper Clark Fork River, Montana, USA. Archives of Environmental Contamination and Toxicology 62:681-695.

Larson, M. 2011. Summary of 2010 bird surveys, Grant-Kohrs Ranch National Park: Stuart and Taylor Field Sites. University of Montana, Missoula, Montana.

Montana Fish Wildlife and Parks (MFWP). 2005. Montana's comprehensive fish and wildlife conservation strategy. Montana Fish, Wildlife and Parks, Helena, Montana.

Montana Natural Heritage Program and Montana Fish Wildlife and Parks (MTNHP and MFWP). 2009. Montana animal species of concern. Montana Natural Heritage Program and Montana Department of Fish Wildlife and Parks, Helena, Montana.

Montana Partners In Flight (MTPIF). 2000. Partners In Flight Draft Bird Conservation Plan, Montana: Version 1.0. Montana Partners In Flight, Kalispell, Montana.

Morrison, M. L. 1986. Bird populations as indicators of environmental change. Current Ornithology 3:429-451.

National Audubon Society. 2014. The Christmas Bird Count Historical Results. http://www.christmasbirdcount.org (accessed 14 August 2014).

North American Bird Conservation Initiative, U.S. Committee (NABCI). 2009. The State of the Birds, United States of America, 2009. U.S. Department of the Interior, Washington, D.C.

Noss, R. F., E. T. LaRoe III, and J. M. Scott. 1995. Endangered ecosystems of the United States: a preliminary assessment of loss and degradation. National Biological Service Biological Report 28, National Biological Service, Washington, D.C.

National Park Service (NPS). 2014. NPSpecies. http://irma.nps.gov/NPSpecies/Search/ (accessed 14 August 2014).

Payne, R. B. 1977. The ecology of brood parasitism in birds. Annual Review of Ecology, Evolution, and Systematics 8:1-28.

Perlut, N., A. Strong, T. Donovan, and N. Buckley. 2006. Grassland songbirds in a dynamic management landscape: behavioral responses and management strategies. Ecological Applications 16:2235-2247.

Ramsey, P. W., M. C. Rillig, K. P. Feris, J. N. Moore, and J. E. Gannon. 2005. Mine waste contamination limits soil respiration rates: A case study using quantile regression. Soil Biology and Biochemistry 37:1177-1183.

Rattner, B. A., N. H. Golden, P. C. Toschik, P. C. McGowan, and T. W. Custer. 2008. Concentrations of metals in blood and feathers of nestling ospreys (*Pandion haliaetus*) in Chesapeake and Delaware Bays. Archives of Environmental Contamination and Toxicology 54:114–122.

Rice, P. M., and P. C. Ray. 1984. Floral and faunal survey and toxic metal contamination study of the Grant-Kohrs Ranch National Historic Site. National Park Service, Deer Lodge, Montana.

Rivera-Rodrıguez, L. B., and R. Rodriguez-Estrella. 2011. Incidence of organochlorine pesticides and the health condition of nestling ospreys (*Pandion haliaetus*) at Laguna San Ignacio, a pristine area of Baja California Sur, Mexico. Ecotoxicology 20:29–38.

Toschik, P. C, B. A. Rattner, P. C. McGowan, M. C. Christman, D. B. Carter, and R. C. Hale. 2005. Effects of contaminant exposure on reproductive success of ospreys (*Pandion haliaetus*) nesting in Delaware River and Bay, USA. Environmental Toxicology and Chemistry 24:617–628.

U.S. Geological Survey (USGS). 2008. North American bird phenology program. http://www.pwrc.usgs.gov/bpp/about.cfm (accessed 11 August 2014).

Vickery, P. D., and J. R. Herkert. 2001. Recent advances in grassland bird research: where do we go from here? The Auk 118:11-15.

Walkinshaw, L. H. 1972. Kirtland’s warbler-endangered. American Birds 26(1):3-9.

Warner, R. E., and S. L. Etter. 1989. Hay cutting and the survival of pheasants: a long-term perspective. Journal of Wildlife Management 53:455-461.

Zöckler, C. 2005. Migratory bird species as indicators for the state of the environment. Biodiversity 6(3):7-13.

4.6 Periphyton

4.6.1 Description

Periphyton are primary producers that serve many purposes in aquatic ecosystems; they are an important part of stream food webs, stabilize substrata, and provide habitat for other organisms (Stevenson and Bahls 2012). There are several types of periphyton in most streams and rivers. Diatoms (phylum Chrysophyta, class Bacillariophyceae) and soft-bodied algae (phyla Chlorophyta, Cyanophyta, Chrysophyta, and Rhodophyta; Photo 23) are most commonly used in environmental monitoring. Diatoms are the primary focus of monitoring in Montana (MT DEQ 2011) because they are abundant in most stream ecosystems, have rapid reproduction rates, have a well understood range in tolerance to stressors such as nutrients and metals, and are the focus of similar monitoring efforts in the western states (Stevenson and Bahls 2012; Spaulding et al. 2010). Stream communities, which include diatoms, are one of the ROMN's Vital Signs, chosen to represent the overall health and condition of the park's water resources (Schweiger et al. 2014).

Photo 23. Benthic, soft-bodied algae in Cottonwood Creek in GRKO (Photo by SMUMN GSS 2013).

The Clark Fork River provides much of the periphyton habitat within GRKO. The river has been impacted by human activities for over 100 years (Bahls 1993). Mining activities are responsible for contaminating these river reaches with both metal and organic pollutants (McGuire 1990). Metals from mine wastes upstream (south) of GRKO, such as tailings and contaminated sediment, have been washed into the river and spread throughout the watershed (Atkins et al. 2012). Contaminants settle in the river sediment and floodplain soils, where they are taken up by vegetation and small aquatic organisms (including periphyton), eventually accumulating in higher-level consumers such as fish and birds. These contaminants have been documented in the water, sediments, and aquatic organisms (insects and fish) of the Upper Clark Fork (Smith et al. 1998).

The Montana Department of Environmental Quality (MT DEQ) has developed several models and associated thresholds that describe the biological condition of diatoms in a body of water (Teply and Bahls 2005; Teply 2010a, 2010b; MT DEQ 2011). These include the sediment, nutrient, and metal increaser models. The most current of these three models is a sediment increaser model created specifically for cold water steams in the Middle Rockies Ecoregion (Teply 2010a). This assessment will focus on the sediment increaser model, given its specificity to the ecoregion surrounding the Clark Fork and its use by MT DEQ. This model estimates a probability of impairment as a result of fine sediments, using diatom taxa on an increaser taxa list (Table 1) and their percent relative abundance (PRA) (Teply 2010a). Diatoms on this list are considered useful indicators of sediment impairment.

Table 39. Sediment increaser taxa used in the sediment increaser model for the Rocky Mountain Ecoregion (Teply 2010a, 2010b).

Sediment Increaser Taxa	
Amphora inariensis	*Navicula lanceolata*
Cocconeis pediculus	*Navicula tripunctata*
Cocconeis pseudolineata	*Nitzschia recta*
Eolimna minima	*Planothidium frequentissimum*
Geissleria acceptata	*Planothidium lanceolatum*
Gomphonema drutelingense	*Reimeria sinuata*
Meridion circulare	*Sellaphora pupula*
Navicula gregaria	*Staurosirella leptostauron*

4.6.2 Measures

- Sediment increaser model metrics

4.6.3 Reference Conditions/Values

The reference conditions assigned to periphyton in the Upper Clark Fork River at GRKO are MT DEQ criteria. Schweiger et al. (2014) provides sediment increaser thresholds used by the MT DEQ (Table 2). The current criteria to determine impairment by sediment is a probability threshold of 51%, which corresponds to a PRA of sediment increaser taxa greater than 15.3%. The MT DEQ would consider any site with a value above this for a sediment-impairment designation.

Table 40. Sediment increaser model metrics and thresholds (i.e., reference assessment points) according to Montana DEQ standards (Teply 2010a, 2010b).

Sediment Increaser Metric	Reference Assessment Point
Percent Relative Abundance	<15.3%
Probability of Impairment	≤51%

4.6.4 Data and Methods

Schweiger et al. (2014) presented results from several years of monitoring the ecological integrity of the Clark Fork River at GRKO, including 2 years of periphyton data (2008 and 2009). Biological samples were collected from 11 transects systematically spread along a 500-m (1,640 ft) sample reach (Figure 39) using methods largely derived from the EPA Environmental Monitoring and Assessment Program (EMAP) (Stoddard et al. 2005) and the MT DEQ (MT DEQ 2012). All biological data were collected at base flow. Methods used to assess periphyton communities included the sediment increaser model, as well as increaser models for nutrients and metals (Teply and Bahls 2005) and a suite of historic diatom metrics (Bahls 1993).

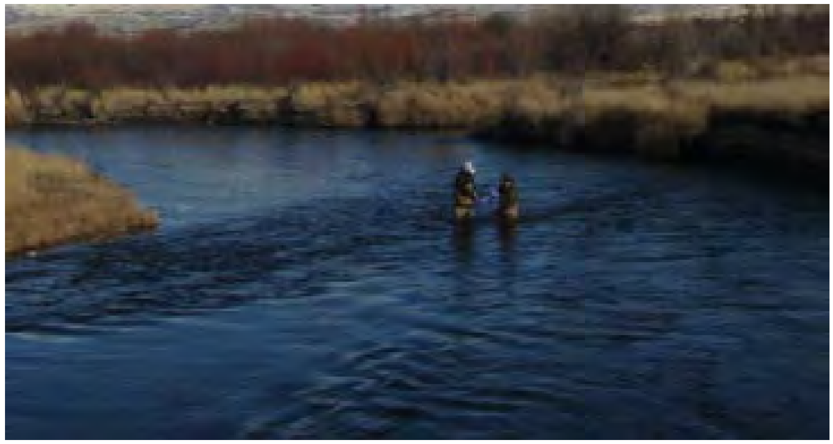


Photo 24. ROMN sampling in the Clark Fork at GRKO (NPS photo by Billy Schweiger).

Atkins et al. (2012) produced an environmental monitoring report for the Clark Fork River Operable Unit in 2011. Aquatic biota samples were collected once during the year from seven monitoring sites along the Clark Fork, including one at the U.S. Geological Survey (USGS) gaging station in Deer Lodge just south of GRKO (Figure 39). The periphyton community was assessed using the sediment increaser model (Atkins et al. 2012).

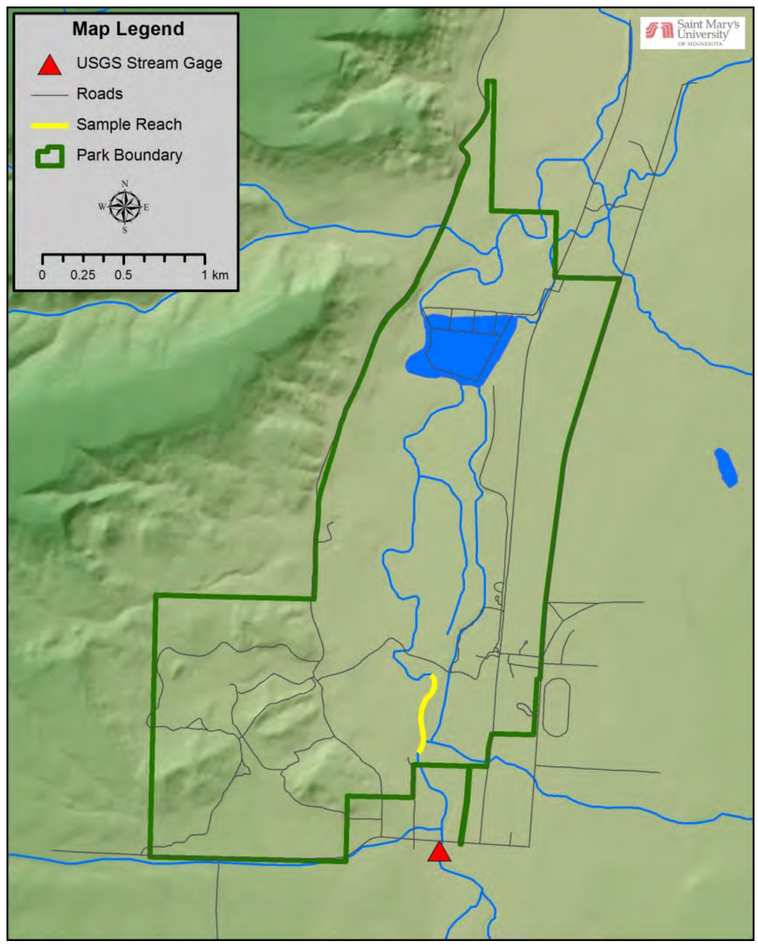


Figure 39. The location of the sample reach (yellow) in relation to the USGS stream gage (outside the park) (Schweiger et al. 2014).

4.6.5 Current Condition and Trend

Sediment Increaser Model

Schweiger et al. (2014) documented sediment increaser taxa in the Middle Rockies Ecoregion in 2008 and 2009. Seven sediment increaser taxa were found in 2008, and 10 in 2009. The percent relative abundance (PRA) in 2008 and 2009 were 13.1% and 10.8%, respectively (Table 3). Both of these values were below the threshold value for the state of 15.3%, indicating that the MT DEQ would not classify the site as sediment impaired. These PRA values suggest the GRKO site had approximately a 42% and 36% probability of being impaired as a result of sediment in 2008 and 2009, respectively; both were less than the MT DEQ threshold (51%). Schweiger et al. (2014) observed diatoms, cyanobacteria, green algae, and red algae. The most common taxa were *Diatoma moniliformis*, *Gomphonema parvulum*, *Nitzschia inconspicua*, *N. dissipata*, *Cocconeis pediculus*, and *Reimeria sinuata*. Of these, only the last two are on the sediment increaser taxa list (Table 39). *D. moniliformis*, the most abundant diatom, is considered relatively intolerant of general anthropogenic disturbance (Spaulding et al. 2010). Two other common species (*G. parvulum* and *C. pediculus*) can be indicative of nutrient enrichment, particularly associated with sedimentation (van Dam et al. 1994, Schweiger et al. 2014).

Table 41. Sediment increaser model metrics for the Clark Fork River at GRKO in 2008 and 2009 (Schweiger et al. 2014).

Metric	Base Flow Summer 2008	Base Flow Summer 2009
Number of Sediment Increaser Taxa	7	10
Percent Relative Abundance (PRA)	13.1%	10.8%
Probability of Impairment	42.4%	35.8%

Atkins et al. (2012) documented six sediment increaser taxa in the Clark Fork River at GRKO in 2011. The PRA was 6.5%, well below the Montana threshold value. The Deer Lodge site had approximately 20% probability of being impaired as a result of sediment, which was also below the Montana threshold value of 51%.The dominant species observed during this study was *N. dissipata*, a diatom that is relatively tolerant to pollution, although it is not on the sediment increaser list. Atkins et al. (2012) collected eight metal tolerant taxa (7% of the total taxa) at the Deer Lodge site, suggesting a low probability of impairment due to metal contamination. However, the presence of a green algae species (*Stigeoclonium* spp.) suggested that nutrient enrichment was occurring (Atkins et al. 2012).

Threats and Stressor Factors

NPS staff identified several major threats to periphyton at GRKO. Most of the threats involve point source and non-point anthropogenic disturbances, including metals contamination, excess nutrients, sedimentation, riparian habitat modification, dewatering, and shifts in temperature and precipitation due to climate change.

Point sources of contamination in the Clark Fork watershed that threaten the park's periphyton include historic mining and smelting operations. Those point sources leaking or running off into the Upper Clark Fork River resulted in the Superfund site designation. Mining contamination includes high concentrations of metals, dissolved solids, and salts, all of which can impact and reduce populations of aquatic organisms, including diatoms (Medley and Clements 1998, Fore and Grafe 2002). Fore and Grafe (2002) found that diatom communities near mining sites in Idaho differed from other communities in taxa richness, community composition, and organism morphology (e.g., deformities). Non-point source threats to the periphyton community include fine inorganic sediment. Increased levels of fine sediment negatively impact primary and secondary production and nutrient cycling by increasing turbidity (Relyea et al. 2000). Turbidity reduces or blocks the sunlight needed by many periphyton for photosynthesis.

Excess nutrients, particularly nitrogen and phosphorus, are a cause of concern for periphyton in GRKO. According to McGuire (2010), the Clark Fork is susceptible to nutrient pollution in the Deer Lodge Valley and has been observed to be impaired in past years. Nitrogen and phosphorus generate algae growth (McGuire 1990). According to Schweiger et al. (2014), filamentous algal cover in the Clark Fork at GRKO was at 75% in 2008, which is over 35 times the mean ecoregion value (2%). While algae create habitat and cover for fish and macroinvertebrates, an excess of nutrients can cause algal blooms, which can be detrimental to stream health (Smith and Schindler 2009, Schweiger et al. 2014). Due to excess nutrients and lower stream flows in GRKO, algal blooms have occurred in the park from the 1970s through 2011 (Suplee et al. 2012, Schweiger et al. 2014). Three blue-green algae species that occur in Montana are capable of producing toxins when blooming that can be harmful to livestock and wildlife (Surber 2009).

Dewatering is another threat to periphyton in GRKO. Dewatering may impact periphyton by altering streamflow. Water may also be lost from the system at the Warm Springs settling ponds upstream of GRKO, where the surface area of the water is increased and flow is slowed, allowing for increased evaporation (Smith, written communication, 5 September 2014). Decreases in species richness have occurred as a result of low or fluctuating flow rates (Benenatti et al. 1998, as cited in Poff et al. 2012). Low flow rate also decreases water quality by increasing heavy metal concentrations, which in turn can negatively affect periphyton (Watson 1985).

Climate change is a growing concern for periphyton in GRKO. Increasing water temperatures and low flow rates are often attributed to climate change (Isaak et al. 2012, Leppi et al. 2012). Temperature can impact periphyton growth, with high temperatures and low flows resulting in an explosion of periphyton growth, which can impact water quality (Shilling 2007). Studies in Arctic lakes have shown dramatic shifts in diatom communities over the past two centuries that seem to parallel climate warming (Douglas et al. 1994, Smol et al. 2005).

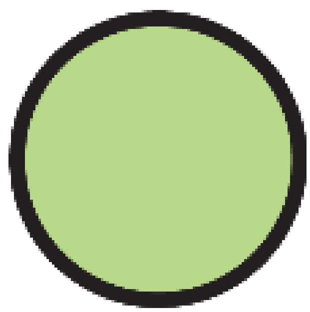
Data Needs/Gaps

There are no historical or long-term data from the sediment increaser model, making it impossible to identify any trends in the periphyton community over time based on this metric alone. The most recent data for GRKO and the surrounding area are from 2008 and 2009 (Schweiger et al. 2014) and 2011 (Atkins et al. 2012). The ROMN collected additional data from 2011-2013, but it was not yet ready for publication at the time this NRCA was written. Continued yearly monitoring efforts will aid in future assessments of the Clark Fork River periphyton community in GRKO. With Superfund remediation activities occurring along the Clark Fork in GRKO in the coming years, an opportunity exists to study how periphyton are impacted by the initial disturbance and by the subsequent “improved” (e.g., less contaminated) conditions.

<u>Overall Condition</u>

Sediment Increaser Model
The *Significance Level* for the sediment increaser model was assigned a 3. Schweiger et al. (2014) found PRA and probability of impairment to be below MT DEQ thresholds in 2008 and 2009. Atkins et al. (2012) documented a lower PRA and probability of impairment in 2011, also below the MT DEQ thresholds. Both studies found little evidence of impairment due to metal contamination, but taxa suggestive of nutrient enrichment were common (Atkins et al. 2012, Schweiger et al. 2014). Given that all sediment increaser model metrics available for GRKO and Deer Lodge met MT DEQ standards, the *Condition Level* for this measure was assigned a 1, or low concern.

Weighted Condition Score (WCS)
The *WCS* for periphyton in GRKO is 0.33. This suggests that the periphyton community in the park is currently in good condition. However, this score is at the very top of the good condition range, and any small decline in the community could shift it into the moderate concern range. There are not enough data available at this time to assign a trend.

Periphyton			
Measures	Significance Level	Condition Level	**WCS = 0.33**
Sediment Increaser Model	3	1	

4.6.6 Sources of Expertise
Billy Schweiger, Rocky Mountain Network Ecologist

4.6.7 Literature Cited

Atkins, Rhithron Associates, Inc., and Montana Fish, Wildlife and Parks. 2012. Monitoring report for 2011: Clark Fork River Operable Unit. Montana Department of Environmental Quality and Montana Department of Justice, Helena, Montana.

Bahls, L. L. 1993. Periphyton bioassessment methods for Montana streams. Water Quality Bureau, Montana Department of Health and Environmental Sciences, Helena, Montana.

Benenatti, P. L., J. P. Shannon, and D. W. Blinn. 1998. Desiccation and recolonization of phytobenthos in a regulated desert river: Colorado River at Lees Ferry, Arizona, USA. Regulated Rivers: Research Management 14:519-532.

Douglas, M. S. V., J. P. Smol, and W. Blake Jr. 1994. Marked post-18th century environmental change in high-Arctic ecosystems. Science 266(5184):416-419.

Fore, L. S., and C. Grafe. 2002. Using diatoms to assess the biological condition of large rivers in Idaho (U.S.A). Freshwater Biology 47:2015-2037.

Isaak, D. J., S. Wollrab, D. Horan, and G. Chandler. 2012. Climate change effects on stream and river temperatures across the northwest U.S. from 1980-2009 and implications for salmonid fishes. Climatic Change 133:499-524.

Leppi, J. C., T. H. De Luca, S. W. Harrar, S. W. Running. 2012. Impacts of climate change on August stream discharge in the Central-Rocky Mountains. Climatic Change 112:997-1014.

McGuire, D. L. 1990. Aquatic macroinvertebrate surveys in the Clark Fork River, 1986 to 1988. Clark Fork Symposium. University of Montana, Missoula, Montana.

McGuire, D. L. 2010. Clark Fork River biomonitoring: Macroinvertebrate community assessments in 2009. U.S. Environmental Protection Agency, Region 8, Denver, Colorado.

Medley, C. N., and W. H. Clements. 1998. Responses of diatom communities to heavy metals in streams: the influence of longitudinal variation. Ecological Applications 8(3):631-644.

Montana Department of Environmental Quality (MT DEQ). 2011. Periphyton standard operating procedure. Montana Department of Environmental Quality, Helena, Montana.

Montana Department of Environmental Quality (MT DEQ). 2012. Water quality planning bureau field procedures manual for water quality assessment monitoring. Version 3.0. Montana Department of Environmental Quality, Helena, Montana.

Poff, B., K. A. Koestner, D. G. Neary, and D. Merritt. 2012. Threats to western United States riparian ecosystems: A bibliography. General Technical Report RMRS-GTR-269. Department of Agriculture, Forest Service, Rocky Mountain Research Station, Fort Collins, Colorado.

Relyea, C. D., G. W. Minshall, R. J. Danehy. 2000. Stream insects as bioindicators of fine sediment. Watershed Management 2000 Conference. Stream Ecology Center, Department of Biological Sciences, Idaho State University, Pocatello, Idaho.

Schweiger, E. W., L. O'Gan, D. Shorrock, and M. Britten. 2014. Stream ecological integrity at Grant-Kohrs Ranch National Historic Site: Rocky Mountain Inventory & Monitoring Network 2008-2010 stream monitoring report. Natural Resource Technical Report NPS/ ROMN/NRTR—2014/881. National Park Service, Fort Collins, Colorado.

Shilling, F. 2007. Periphyton (attached algae and aquatic plants) as indicators of watershed condition. Chapter 4 *in* The California Watershed Assessment Manual. California Natural Resources Agency, Sacramento, California.

Smith, J. D., J. H. Lambing, D. A. Nimick, C. Parrett, M. Ramey, and W. Schafer. 1998. Geomorphology, flood-plain tailings, and metal transport in the Upper Clark Fork Valley, Montana. Water-Resources Investigations Report 98-4170. U.S. Geological Survey, Helena, Montana.

Smith, V. H., and D. W. Schindler. 2009. Eutrophication science: Where do we go from here? Trends in Ecology and Evolution 24(4):201-207.

Smol, J. P., A. P. Wolfe, H. J. Birks, M. S. V. Douglas, V. J. Jones, A. Korhola, R. Pienitz, K. Ruhland, S. Sorvari, D. Antoniades, and others. 2005. Climate-driven regime shifts in the biological communities of Arctic lakes. Proceedings of the National Academy of Sciences 102(12):4397-4402.

Spaulding, S. A., D. J. Lubinski, and M. Potapova. 2010. Diatoms of the United States. http://westerndiatoms.colorado.edu (accessed 25 September 2014).

Stevenson, R. J., and L. L. Bahls. 2012. Chapter 6: periphyton protocols. Pages 6-2 – 6-23 *in* Barbour, M. T., J. Gerritsen, B. D. Snyder, and J. B. Stribling (eds). 2012. Rapid bioassessment protocols for use in streams and wadeable rivers: periphyton, benthic macroinvertebrates, and fish – second edition. U.S. Environmental Protection Agency, Washington, D.C.

Stoddard, J. L., D. V. Peck, S. G. Paulsen, J. Van Sickle, C. P. Hawkins, A. T. Herlihy, R. M. Hughes, P. R. Kaufmann, D. P. Larsen, G. Lomnicky, and others. 2005. An ecological assessment of western streams and rivers. U.S. Environmental Protection Agency, Washington, D.C.

Suplee, M. W., V. Watson, W. K. Dodds, and C. Shirley. 2012. Response of algal biomass to large-scale nutrient controls in the Clark Fork River, Montana, United States. Journal of the American Water Resources Association 48(5):1008-1021.

Surber, G. 2009. Toxic algae: Potential in drought limited water supplies. Montana State University Extension Service, Bozeman, Montana.

Teply, M., and L. Bahls. 2005. Diatom biocriteria for Montana streams. Montana Department of Environmental Quality, Helena, Montana.

Teply, M. 2010a. Diatom biocriteria for Montana streams. Montana Department of Environmental Quality, Helena, Montana.

Teply, M. 2010b. Interpretation of periphyton samples from Montana streams. Montana Department of Environmental Quality, Helena, Montana.

van Dam, H., A. Mertens, and J. Sinkeldam. 1994. A coded checklist and ecological indicator values of freshwater diatoms from The Netherlands. Netherlands Journal of Aquatic Ecology 28(1):117-133.

Watson, V. J. 1985. A synthesis of water quality problems in the Clark Fork River Basin. *In* Proceedings of the Clark Fork River symposium. Montana College of Mineral Science and Technology, Butte, Montana.

4.7 Aquatic Macroinvertebrates

4.7.1 Description

Macroinvertebrates are often used as biological indicators in assessing overall aquatic ecosystem health (EPA 2012). Their absence may reflect disturbances, such as metal contamination, that can affect higher trophic levels (EPA 2012). In the Clark Fork River, macroinvertebrates are an important food source for birds, fish, and other wildlife (EPA 2012). Stream communities, which include macroinvertebrates, are one of the ROMN's Vital Signs, chosen to represent the overall condition of the park's water resources (Schweiger et al. 2014). Macroinvertebrate indicator species can range from sensitive species, such as many stoneflies (order Plecoptera), caddisflies (order Trichoptera; Photo 25), and mayflies (order Ephemeroptera) to the much more tolerant midge (Diptera) and aquatic worm (Oligochaeta) species.

Photo 25. Caddisfly species (*Hydropsych*e sp.) that is common in the Clark Fork River at GRKO (NOAA photo by Dr. Dwayne Meadows).

The Upper Clark Fork River is the main body of water that runs through the park. The Clark Fork has been impacted by human disturbance for over 100 years, particularly mining activities which are responsible for contaminating the river with both metal and organic pollutants (McGuire 1990). Elevated concentrations of metals have been documented in the river's water, sediments, and aquatic organisms (insects and fish) (Smith et al. 1998). Estimates of the Clark Fork aquatic macroinvertebrate community's biointegrity in the Deer Lodge area from the mid-1980s to mid-2000s suggested it was slightly to moderately impaired, but showing some improvement in the late 2000s (McGuire 2010).

4.7.2 Measures

- RIVPACS modeling (observed to expected [O:E] and Bray Curtis metrics)
- Multimetric indices (MMI)

4.7.3 Reference Conditions/Values

The reference conditions for this assessment are those used by Schweiger et al. (2014), selected largely following Montana DEQ guidance (MT DEQ 2012a, b, c) with a few from other agencies or that were found in the literature. Schweiger et al. (2014) also developed ecoregion thresholds for select metrics using reference sites in the Middle Rockies Ecoregion (see Schweiger et al. [2014] for details on how thresholds were established). Reference assessment points were taken from multiple sources to aid in evaluating the condition of macroinvertebrates in the Clark Fork River in GRKO. A subset of metrics and assessment points were selected from Schweiger et al. (2014) and are shown in Table 42.

Table 42. Macroinvertebrate metrics with ecoregion thresholds (Schweiger et al. 2014) and reference condition assessment points.

Macroinvertebrate Metrics	Ecoregion Threshold[1]	Reference Assessment Points
RIVPACS O:E[2]	>1.0	>0.8
RIVPACS Bray Curtis[1]	<0.30	--
Low Valley Multimetric Index[2]	>60.1	>48
Valley/Foothill Prairies Multimetric Index[3]	--	>75
Karr Benthic Index of Biotic Integrity[4]	--	>46
Hilsenhoff Biotic Index (Nutrients)[5]	--	<3
Fine Sediment Biotic Index[6]	--	>8
Temperature Index	--	--
Metal Tolerance Index[7]	--	<4

[1] Note that these thresholds and/or metrics are NOT used by the MT DEQ and have no regulatory significance.
[2] RIVPACS O:E and MMI metrics were used by the MT DEQ through 2011 (MT DEQ 2012c); values above or equal to a criterion are in reference while values less than a criterion are in non-reference.
[3] Used by MT DEQ prior to the current MMI model (Bukantis 1998); described in Bollman (1998).
[4] Has never been used by the MT DEQ; described in Karr (1998).
[5] Can be used by the MT DEQ in support of other nutrient data; described in Hilsenhoff (1988).
[6] Has never been used by the MT DEQ; described in Relyea et al. (2000).
[7] This index is specific to the Clark Fork (McGuire 1987, 1989; Ingman and Kerr 1989) and may be used by the MT DEQ.

4.7.4 Data and Methods

Schweiger et al. (2014) presents results from several years of monitoring the ecological integrity of the Clark Fork River at GRKO, including 2 years of macroinvertebrate data (2008 and 2009). Biological samples were collected from 11 transects systematically spread along a 500-m (1,640 ft) sample reach (Figure 40) using methods largely derived from the EPA Environmental Monitoring and Assessment Program (EMAP) (Stoddard et al. 2005) and the Montana DEQ (MT DEQ 2012a). All biological data were collected at base flow. The two primary aquatic macroinvertebrate bioassessment methods utilized in this NRCA are the Montana Low Valley Multimetric Index (MMI) (Jessup et al.

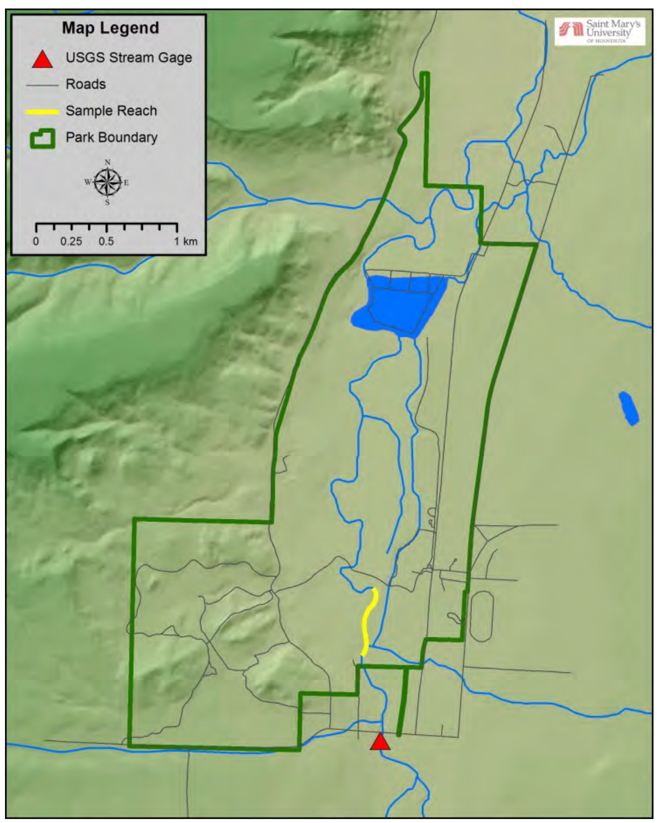


Figure 40. The location of the sample reach (yellow) in relation to the USGS stream gage (outside the park) (Schweiger et al. 2014).

2006, MT DEQ 2012c) and the River Invertebrate Prediction and Classification (RIVPACS) model (Hawkins et al. 2000, Van Sickle 2008, MT DEQ 2012c). The MMI incorporates five component metrics (i.e., macroinvertebrate community characteristics): percent EPT (Ephemeroptera, Plecoptera, and Trichoptera), percent Chironomidae, percent Crustacea and Mollusca, percent shredder taxa, and percent predators (Jessup et al. 2006). RIVPACS models use macroinvertebrate observations from high quality streams in the region to create a reference (i.e., expected taxa) for similar streams (Jessup et al. 2006, Van Sickle 2008). This assessment will focus on two particular components from RIVPACS recommended by the MT DEQ (2012c): the observed:expected (O:E) and Bray Curtis dissimilarity metrics.

Atkins et al. (2012) prepared a monitoring report for the Clark Fork River Operable Unit in 2011. Several stations along the Clark Fork River were sampled; however, only one station (USGS gaging station at Deer Lodge) is used in this NRCA because of its proximity to the park. Four samples were collected from the station, one each in April, June, September, and December of 2011. The aquatic macroinvertebrate bioassessment methods utilized in Atkins et al. (2012) include the Low Valley MMI (Jessup et al. 2006, MT DEQ 2012c), Montana Valleys/ Foothill Prairies (MVFP) (Bollman 1998), and RIVPACS (Hawkins 2005, Jessup et al. 2006).

4.7.5 Current Condition and Trend

RIVPACS

Schweiger et al. (2014) presents two RIVPACS model-derived metrics from 2008 and 2009. The ratio of observed to expected taxa (O:E) was above the MT DEQ threshold (0.8) and met the ecoregion threshold (>1.0) for both sample events (Table 43). This indicates that a high proportion of the macroinvertebrate taxa observed at GRKO were characteristic of those expected from a reference stream in Montana. The Bray Curtis dissimilarity metrics for 2008 and 2009 showed similar results, with both values falling within the ecoregion threshold (< 0.30) developed by Schweiger et al. (2014) (Note that the ecoregion thresholds developed by Schweiger et al. [2014] are not used by the MT DEQ and have no regulatory significance). This suggests there is little dissimilarity between the macroinvertebrate community in a regional reference stream and that observed at GRKO (Schweiger et al. 2014).

Table 43. The RIVPACS metrics from the Clark Fork River at GRKO during the summers of 2008 and 2009 (Schweiger et al. 2014).

Metric	Base Flow Summer 2008	Base Flow Summer 2009
RIVPACS O:E (P>0.5)	>1.0	>1.0
RIVPACS Bray Curtis dissimilarity (P>0.5)	0.22	0.20

Atkins et al. (2012) calculated a RIVPACS value from sampling on the Clark Fork River at Deer Lodge in 2011. The mean value for the RIVPACS O:E metric was 0.78, which is just below the MT DEQ impairment threshold (0.8). The minimum and maximum values at this station ranged from approximately 0.7 to 1.0 (Atkins et al. 2012). These RIVPACS values indicate some impairment of the macroinvertebrate community in the Clark Fork River at Deer Lodge in 2011.

Multimetric Indices (MMI)

Schweiger et al. (2014) presents 2008 and 2009 results from GRKO for three MMI metrics, several stressor specific metrics, and the component metrics for the most current MMI. The Low Valley MMI was above the MT DEQ threshold of 48 in both years (Table 44). This indicates that MT DEQ would have likely considered the GRKO macroinvertebrate community characteristic of a reference condition macroinvertebrate assemblage. When compared to the more conservative ecoregion threshold of 60 developed by Schweiger et al. (2014), GRKO values are above this point in 2008 and slightly below in 2009. The Valley/Foothill Prairies MMI was slightly below the reference point in both years (Table 44). This MMI was developed for lower-order streams (i.e., further upstream in a watershed) and may actually be a more useful index for sites where sediment is an important stressor, like the Clark Fork (Schweiger et al. 2014). The Karr Benthic Index of Biotic Integrity was also below the reference point, suggesting a slightly more impaired condition than the other MMIs. However, this index was originally calibrated for the Pacific Northwest and may not be well suited for the specific disturbance regime in the Clark Fork at GRKO (Schweiger et al. 2014). All stressor specific metrics with established reference assessment points (see Table 42 footnotes) suggest that nutrients, sediment, and metal concentrations were causing some impairment of the macroinvertebrate community in 2008 and 2009 (Table 44).

Table 44. Core macroinvertebrate metrics for the Clark Fork River in GRKO during the summers of 2008 and 2009 (Schweiger et al. 2014).

Metric	Base Flow Summer 2008	Base Flow Summer 2009	Reference Assessment Points
Mulimetric Indices (MMI)			
Low Valley Multimetric Index	65	58.7	>48
Valley/Foothill Prairies Multimetric Index	61	56	>75
Karr Benthic Index of Biotic Integrity	30	36	>46
Stressor Specific Metrics			
Hilsenhoff Biotic Index (Nutrients)	4.83	5.03	<3
Fine Sediment Biotic Index	4.21	4.47	>8
Temperature Index	15.85	15.91	--
Metal Tolerance Index	4.21	5.07	<4
Components of the above MMIs			
Percent EPT[1]	35.1	16.5	
Percent Chironomidae[1]	37.8	27.1	
Percent Crustacea and Mollusca[2]	0.1	0.7	
Shredder Taxa Richness[2]	3	3	
Percent Predator[1]	9.8	15.4	

[1]typically decreases with increased stress, [2] increases with increased stress

In terms of the component metrics within the MMIs, the percent Chironomidae was relatively high in both years and percent EPT was high in 2008, which contributed to the high MMI scores (Table 44). The very low percent Crustacea and Mollusca and shredder taxa richness also likely drove up the MMI scores. The percent predator taxa was relatively high as well, suggesting a more intact aquatic insect food web (Schweiger et al. 2014).

Atkins et al. (2012) documented mean MMI and MVFP values from the Clark Fork River at Deer Lodge in 2011. The MMI mean value was 59.6, which was above the MT DEQ reference assessment point (>48); however, the MMI value was just below the ecoregion threshold developed by Schweiger et al. (2014) (>60.1). The MVFP mean value was 47.2, which was low compared to the MT DEQ reference assessment point (>75). The MVFP indicates moderate impairment in the Clark Fork River at Deer Lodge in 2011 (Table 45).

Table 45. MMI and MVFP metric values and impairment class recorded at the Deer Lodge Station in 2011 (Atkins et al. 2012).

Metric	Score	Impairment Class
MMI	59.6	Not impaired
MVFP	47.22	Moderate impairment

Threats and Stressor Factors

NPS staff identified several threats to macroinvertebrates in the park. Most of the threats involve point source and non-point anthropogenic disturbances, including metals contamination, excess nutrients, sedimentation, riparian habitat modification, dewatering, and shifts in temperature and precipitation due to climate change.

Point sources of contamination in the Clark Fork watershed that threaten macroinvertebrates include historic mining and smelting operations. Those point sources leaking or running off into the Upper Clark Fork River resulted in the Superfund site designation. Mining contamination includes high concentrations of metals, dissolved solids, and salts, all of which can impact and reduce populations of aquatic organisms, especially macroinvertebrates (Cain et al. 2004). Elevated metal levels can be found in the water, sediment, and aquatic organisms of the Clark Fork (Smith et al. 1998). Non-point sources include fine inorganic sediment. Increased levels of fine inorganic sediment negatively impact macroinvertebrates, fish, primary and secondary production, and nutrient cycling by increasing turbidity (Relyea et al. 2000). Increased turbidity leads to lower primary production which in turn leads to habitat reduction for macroinvertebrates. Available food sources can also be buried under the increased inorganic sediment (Relyea et al. 2000).

Excess nutrients are a cause of concern for macroinvertebrates in GRKO. Nitrogen and phosphorus generate algae growth, which in turn may cause significant changes in macroinvertebrate abundance and composition (McGuire 1990). Macroinvertebrate densities may initially increase due to nutrient enrichment. However, once nutrient levels become too high, they become toxic and cause macroinvertebrate densities to decline (McGuire 1990). Taxa composition also changes with higher levels of nutrients. Numbers of tolerant species increase while sensitive species decline in numbers (McGuire 1990). McGuire (2007) showed that nutrient/organic pollution was a concern in the Clark Fork near GRKO (Deer Lodge Station) in 2006. This site was one of 11 sites along the Clark Fork that were considered to have significant biological impairment (McGuire 2007). According to McGuire (2010), the Clark Fork is susceptible to nutrient pollution in the Deer Lodge Valley and has been observed to be impaired in past years.

Dewatering is another threat to macroinvertebrates in GRKO. Water withdrawal for irrigational operations is the main type of dewatering affecting macroinvertebrates in the Clark Fork basin

(Watson 1985). Water may also be lost from the system at the Warm Springs settling ponds upstream of GRKO, where the surface area of the water is increased and flow is slowed, allowing for increased evaporation (Smith, written communication, 5 September 2014). These water losses may impact macroinvertebrates by altering streamflow, which in turn may decrease water quality, especially by increasing heavy metal concentrations (Watson 1985). Dewatering has resulted in decreased aquatic macroinvertebrate abundance, richness, and evenness (Muehlbauer et al. 2011).

Climate change is a growing concern and threat to macroinvertebrates in GRKO. Increasing water temperatures and low flow rates are often attributed to climate change (Isaak et al. 2012, Leppi et al. 2012). Increasing water temperatures cause dissolved oxygen (DO) levels to decrease. When DO levels are low, respiration becomes more difficult for aquatic life (e.g., fish and macroinvertebrates) (USGS 2014). Low flow rates and droughts may result in a skewed macroinvertebrate community (Boulton 2003), favoring smaller organisms as well as organisms more tolerant of drought. Climate change has also been known to change sediment type, which can be either beneficial or problematic for aquatic macroinvertebrates. When fine sediment increases as a result of climate change, pools can fill and cause habitat degradation, which is detrimental to aquatic life especially macroinvertebrates (Goode et al. 2012). In addition, climate change may impact invertebrate phenology. Harper and Peckarsky (2006) suggest that warmer water temperatures and lower flow rates could cause temporal shifts in mayfly metamorphosis.

Data Needs/Gaps

There are no historical or long-term RIVPACS or MMI data for aquatic macroinvertebrates in GRKO, making it impossible to identify any trends in the community over time based on these metrics alone. The most recent data available for macroinvertebrate communities in or near GRKO are from a 2011 study (Atkins et al. 2012). The ROMN collected additional data from 2011-2013, but it was not yet ready for publication at the time this NRCA was written. Future monitoring of macroinvertebrates in the Upper Clark Fork River at GRKO will be needed to better assess the current condition and possible trends. With Superfund remediation activities occurring along the Clark Fork in GRKO in the coming years, an opportunity exists to study how aquatic macroinvertebrates are impacted by the initial disturbance and by the subsequent “improved” (e.g., less contaminated) conditions.

Overall Condition

RIVPACS

The *Significance Level* for RIVPACS was assigned a 3. Schweiger et al. (2014) presented two RIVPACS metrics for each year during the study. The O:E RIVPACS metrics in both years met the ecoregion threshold (1.0) developed by Schweiger et al. (2014) and were also above the reference assessment point of 0.8 utilized by the MT DEQ, meaning the state would deem the community “not impaired”. The Bray Curtis dissimilarity metrics for 2008 and 2009 were both within the ecoregion threshold (<0.30) developed by Schweiger et al. (2014). Atkins et al. (2012) presented a RIVPACS value of 0.78 at Deer Lodge in 2011, which suggests some impairment. The *Condition Level* for this measure is a 1, or low concern.

Multimetric Indices (MMI)
The *Significance Level* for MMI was assigned a 3. Schweiger et al. (2014) calculated results for three MMI metrics, several stressor specific metrics, and the component metrics for the most current MMI for macroinvertebrates in GRKO during 2008 and 2009. The Low Valley MMI was above the MT DEQ threshold of 48 in both years, indicating that the agency would likely consider the macroinvertebrate community characteristic of a reference condition macroinvertebrate assemblage. When compared to the ecoregion threshold of 60 developed by Schweiger et al. (2014), GRKO values are above this point in 2008 and slightly below in 2009. Several other biotic indices calculated by Schweiger et al. (2014) did not meet reference points established in the literature, which may be of concern. However, it is important to note that these additional indices are not currently used by the MT DEQ and have no regulatory significance. Atkins et al. (2012) documented MMI and MVFP values in 2011 on the Clark Fork River at the Deer Lodge station. The MMI mean value was 59.6, which was above the MT DEQ reference assessment point (> 48); however, this value was just below the ecoregion threshold developed by Schweiger et al. (2014) (>60.1). The MVFP mean value was 47.2, which was low compared to the MT DEQ reference assessment point (>75). The MVFP suggests impairment, although the metric is not currently used by the MT DEQ. Because the results from GRKO meet the reference assessment points for the MMI currently used by the MT DEQ, the *Condition Level* for this measure is a 1, or of low concern.

Weighted Condition Score (WCS)
The *WCS* for aquatic macroinvertebrates in GRKO was 0.33. This indicates that the aquatic macroninvertebrate community in the park is in good condition. However, this score is at the very top of the good condition range, and any small decline in the community could shift it into the moderate concern range. A trend could not be assessed due to the lack of historical and long-term data for the selected measures.

Aquatic Macroinvertebrates			
Measures	Significance Level	Condition Level	**WCS = 0.33**
RIVPACS	3	1	
MMI	3	1	

4.7.6 Sources of Expertise
Billy Schweiger, Rocky Mountain Network Ecologist

4.7.7 Literature Cited

Atkins, Rhithron Associates, Inc., and Montana Fish, Wildlife and Parks. 2012. Monitoring report for 2011: Clark Fork River Operable Unit. Montana Department of Environmental Quality and Montana Department of Justice, Helena, Montana.

Bollman, W. 1998. Improving stream bioassessment methods for the Montana Valley and Foothill Prairies Ecoregion. Thesis. University of Montana, Missoula, Montana.

Boulton, A. J. 2003. Parallels and contrasts in the effects of drought on stream macroinvertebrate assemblages. Freshwater Biology 48:1173-1185.

Bukantis, R. 1998. Rapid bioassessment macroinvertebrate protocols: Sampling and sample analysis SOPs. Montana Department of Environmental Quality, Planning and Prevention and Assistance Division, Helena, Montana.

Cain, D. J., S. N. Luoma, and W. G. Wallace. 2004. Linking metal bioaccumulation of aquatic insects to their distribution patterns in a mining-impacted river. Environmental Toxicology and Chemistry 23(6):1463-1473.

Environmental Protection Agency (EPA). 2012. Macroinvertebrates and habitat. U.S. Environmental Protection Agency. http://water.epa.gov/type/rsl/monitoring/vms40.cfm (accessed 21 July 2014).

Goode, J. R., C. H. Luce, and J. M. Buffington. 2012. Enhanced sediment delivery in a changing climate in semi-arid mountain basins: implications for water resource management and aquatic habitat in the Northern Rocky Mountains. Geomorphology 139-140:1-15.

Harper, M. P., and B. L. Peckarsky. 2006. Emergence cues of a mayfly in a high-altitude stream ecosystem: potential response to climate change. Ecological Applications 16(2):612-621.

Hawkins, C. P., R. H. Norris, J. N. Hogue, and J. W. Feminella. 2000. Development and evaluation of predictive models for measuring the biological integrity of streams. Ecological Applications 10:1456-1477.

Hawkins, C. P. 2005. Development of a RIVPACS (O:E) Model for assessing the biological integrity of Montana streams. The Western Center for Monitoring and Assessment of Freshwater Ecosystems, Utah State University, Logan, Utah.

Hilsenhoff, W. L. 1988. Rapid field assessment of organic pollution with a family-level biotic index. Journal of the North American Benthological Society 7:65-68.

Ingman, G. L., and M. A. Kerr. 1989. Water quality in the Clark Fork River basin Montana: state fiscal years 1988-1989. Montana Department of Health and Environmental Sciences, Water Quality Bureau. Helena, Montana.

Isaak, D. J., S. Wollrab, D. Horan, and G. Chandler. 2012. Climate change effects on stream and river temperatures across the northwest U.S. from 1980-2009 and implications for salmonid fishes. Climatic Change 133:499-524.

Jessup, B., C. Hawkins, and J. Stribling. 2006. Biological indicators of stream condition in Montana using benthic macroinvertebrates. Prepared for the Montana department of Environmental Quality by TetraTech, Inc., Owing Mills, MD, and the Western Center for Monitoring and Assessment of Freshwater Ecosystems, Utah State University, Logan, Utah.

Karr, J. R. 1998. Rivers as sentinels: Using the biology of rivers to guide landscape management. Pages 502-528 *in* R. J. Naiman and R. E. Bilby (eds.). River ecology and management: Lessons from Pacific coastal ecosystems. Springer Publishing, New York, New York.

Leppi, J. C., T. H. De Luca, S. W. Harrar, S. W. Running. 2012. Impacts of climate change on August stream discharge in the Central-Rocky Mountains. Climatic Change 112:997-1014.

McGuire, D. L. 1987. Clark Fork River macroinvertebrates study, 1986. Technical report prepared for the Montana Governor's office and Montana Water Quality Bureau. Helena, Montana.

McGuire, D. L. 1989. Clark Fork River aquatic macroinvertebrate survey, August, 1987. Technical report prepared for the Montana Department of Health and Environmental Sciences/Water Quality Bureau. Helena, Montana.

McGuire, D. L. 1990. Aquatic macroinvertebrate surveys in the Clark Fork River, 1986 to 1988. Clark Fork Symposium. University of Montana, Missoula, Montana.

McGuire, D. L. 2007. Clark Fork River biomonitoring: macroinvertebrate community assessments, 2006. United States Environmental Protection Agency, Region 8, Denver, Colorado.

McGuire, D. L. 2010. Clark Fork River biomonitoring: Macroinvertebrate community assessments in 2009. U.S. Environmental Protection Agency, Region 8, Denver, Colorado.

Montana Department of Environmental Quality (MT DEQ). 2012a. Water quality planning bureau field procedures manual for water quality assessment monitoring. Version 3.0. Montana Department of Environmental Quality, Helena, Montana.

Montana Department of Environmental Quality (MT DEQ). 2012b. Montana 2012 Final Water Quality Integrated Report. Montana Department of Environmental Quality, Helena, Montana.

Montana Department of Environmental Quality (MT DEQ). 2012c. Sample collection, sorting, taxonomic identification, and analysis of benthic macroinvertebrate communities standard operating procedure. Montana Department of Environmental Quality, Helena, Montana.

Muehlbauer, J. D., M. W. Doyle, and E. S. Bernhardt. 2011. Macroinvertebrate community responses to a dewatering disturbance gradient in a restored stream. Hydrology Earth System Sciences 15:1771-1783.

Relyea, C. D., G. W. Minshall, R. J. Danehy. 2000. Stream insects as bioindicators of fine sediment. Watershed Management 2000 Conference. Stream Ecology Center, Department of Biological Sciences, Idaho State University, Pocatello, Idaho.

Schweiger, E. W., L. O'Gan, D. Shorrock, and M. Britten. 2014. Stream ecological integrity at Grant-Kohrs Ranch National Historic Site: Rocky Mountain Inventory & Monitoring Network 2008-2010 stream monitoring report. Natural Resource Technical Report NPS/ ROMN/NRTR—2014/881. National Park Service, Fort Collins, Colorado.

Smith, J. D., J. H. Lambing, D. A. Nimick, C. Parrett, M. Ramey, and W. Schafer. 1998. Geomorphology, flood-plain tailings, and metal transport in the Upper Clark Fork Valley, Montana.

Stoddard, J. L., D. V. Peck, S. G. Paulsen, J. Van Sickle, C. P. Hawkins, A. T. Herlihy, R. M. Hughes, P. R. Kaufmann, D. P. Larsen, G. Lomnicky, and others. 2005. An ecological assessment of western streams and rivers. U.S. Environmental Protection Agency, Washington, D.C.

U.S. Geological Survey (USGS). 2014. Water properties and measurements. http://ga.water.usgs.gov/edu/characteristics.html (accessed 17 September 2014).

Van Sickle, J. 2008. An index of compositional dissimilarity between ovserved and expected assemblages. Journal of the North American Benthological Society 27:227-235.

Watson, V. J. 1985. A synthesis of water quality problems in the Clark Fork River Basin. University of Montana, Missoula, Montana. http://cas.umt.edu/clarkfork/Past_Proceedings/1985_proceedings/Watson/Watson.htm (accessed 3 July 2014).

4.8 Air Quality

4.8.1 Description

Air pollution can significantly affect natural resources and their associated ecological processes, and the health of park visitors. Consequently, air quality in parks and wilderness areas is protected and regulated through the 1916 Organic Act and the Clean Air Act of 1977 (CAA) and the CAA's subsequent amendments. The Clean Air Act defines two distinct categories of protection for natural areas, Class I and Class II airsheds. Class I airsheds receive the highest level of air quality protection as offered through the CAA; only a small amount of additional air pollution is permitted in the airshed above baseline levels. For Class II airsheds, the increment ceilings for additional air pollution above baseline levels are slightly greater than for Class I areas and allows for moderate development (EPA 2013a). GRKO is designated as a Class II airshed.

Photo 26. View from Grant Kohrs Ranch on a clear, high visibility day (NPS photo).

Parks designated as Class I and II airsheds typically use the EPA's National Ambient Air Quality Standards (NAAQS) for criteria air pollutants as the ceiling standards for allowable levels of air pollution. The EPA believes these standards, if not exceeded, protect human health and the health of natural resources (EPA 2013a). The CAA also establishes that current visibility impairment in these areas must be remedied and future impairment prevented (EPA 2013a). However, the EPA acknowledges that the current NAAQS are not necessarily protective of ecosystems and is currently developing secondary NAAQS for ozone, nitrogen, and sulfur compounds to protect sensitive plants, lakes, streams, and soils (EPA 2010, EPA 2011a). To comply with CAA and NPS Organic Act mandates, the NPS established a monitoring program that measures air quality trends in many park units for key air quality indicators, including atmospheric deposition, ozone, and visibility (NPS 2008).

GRKO is located in semirural western Montana, which has allowed it to be relatively unaffected by industrial air pollution; however, some air pollution does occur (NPS 1993). Agricultural burning, sawmill activity, timber slash, road dust, and residential fuelwood burning have all been observed and may be contributing to pollution in the area (NPS 1993). Poor visibility is an issue caused by air pollution; visibility issues are mostly attributed to regional forest fires and regional prescribed burns (Smith, written communication, 16 September, 2014).

4.8.2 Measures

- Sulfate deposition
- Nitrogen deposition

- Ozone
- Particulate matter ($PM_{2.5}$)
- Visibility

Atmospheric Deposition of Sulfur and Nitrogen

Sulfur and nitrogen oxides are emitted into the atmosphere primarily through the burning of fossil fuels, industrial processes, and agricultural activities (EPA 2012a). While in the atmosphere, these emissions form compounds that may be transported long distances and settle out of the atmosphere in the form of pollutants such as particulate matter (e.g., sulfates, nitrates, ammonium) or gases (e.g., nitrogen dioxide, sulfur dioxide, nitric acid, ammonia) (EPA 2012a, NPS 2008). Atmospheric deposition can be in wet (i.e., pollutants dissolved in atmospheric moisture and deposited in rain, snow, low clouds, or fog) or dry (i.e., particles or gases that settle on dry surfaces as with windblown dusts) form (EPA 2012a). Deposition of sulfur and nitrogen can have significant effects on ecosystems including acidification of water and soils, excess fertilization or increased eutrophication, changes in the chemical and physical characteristics of water and soils, and accumulation of toxins in soils, water and vegetation (NPS 2008, reviewed in Sullivan et al. 2011a and 2011b).

Ozone

Ozone occurs naturally in the earth's atmosphere where, in the upper atmosphere, it protects the earth's surface against ultraviolet radiation (EPA 2012a). However, it also occurs at the ground level (i.e., ground-level ozone) where it is created by a chemical reaction between nitrogen oxides and volatile organic compounds (VOCs) in the presence of heat and sunlight (NPS 2008). Ozone is also one of the most widespread pollutants affecting vegetation in the U.S. (NPS 2008). Considered phytotoxic, ozone can cause significant foliar injury and growth effects for sensitive plants in natural ecosystems (NPS 2008, EPA 2012c). Specific effects include reduced photosynthesis, premature leaf loss, and reduced biomass; prolonged exposure can increase vulnerability to insects and diseases or other environmental stresses (NPS 2008). At high concentrations, ozone can aggravate respiratory and cardiovascular diseases, reduce lung function, cause acute respiratory problems, and increase susceptibility to respiratory infections (EPA 2012a, EPA 2012d, EPA 2013b); this would be a concern for visitors and staff engaging in aerobic activities in the park, such as hiking.

Particulate Matter (PM) and Visibility

Particulate matter (PM) is a complex mixture of extremely small particles and liquid droplets that become suspended in the atmosphere. Particulate matter largely consists of acids (such as nitrates and sulfates), organic chemicals, metals, and soil or dust particles (EPA 2013c, EPA 2014b). Fine particles are a major cause of reduced visibility (haze) in many national parks and wildernesses (EPA 2012a). $PM_{2.5}$ can be directly emitted from sources such as forest fires or they can form when gases emitted from power plants, industry and/or vehicles react with air (EPA 2013c, EPA 2014b). Particulate matter either absorbs or scatters light. As a result, the clarity, color, and distance seen by humans, decreases, especially during humid conditions when additional moisture is present in the air (EPA 2012a, EPA 2013c). $PM_{2.5}$ is also a concern for human health as these particles can easily pass through the throat and nose and enter the lungs (EPA 2012a, EPA 2013c, EPA 2014b). Short-term exposure to these particles can cause shortness of breath, fatigue, and lung irritation (EPA 2012a, EPA 2013c).

4.8.3 Reference Conditions/Values

The NPS Air Resources Division (ARD) developed an approach for rating air quality conditions in national parks, based on the current NAAQS, ecosystem thresholds, and visibility improvement goals (Table 46) (NPS 2011). Assessment of current condition of nitrogen and sulfur atmospheric deposition is based on wet (rain and snow) deposition. Ozone condition is based on the NAAQS standard of 75 parts per billion (ppb) (an annual fourth-highest daily maximum 8-hr concentration, averaged over 3 years). The NAAQS standard for $PM_{2.5}$ is a weighted annual mean of 15.0 µg/m^3 or 35 µg/m^3 in a 24-hour period over an average of 3 years (EPA 2011a). Visibility conditions are assessed in terms of a Haze Index, a measure of visibility (termed deciviews) that is derived from calculated light extinction and represents the minimal perceptible change in visibility to the human eye (NPS 2011). Finally, NPS ARD recommends the following values for determining air quality condition (Table 46). The "good condition" metrics may be considered the reference condition for GRKO.

Table 46. National Park Service Air Resources Division air quality index values (NPS 2011).

Condition	Ozone Concentration (ppb)	Wet Deposition of N or S (kg/ha/yr)	Visibility (dv*)
Significant Concern	≥76	>3	>8
Moderate Condition	61-75	1-3	2-8
Good Condition	≤60	<1	<2

*a unit of visibility proportional to the logarithm of the atmospheric extinction; one deciview represents the minimal perceptible change in visibility to the human eye.

4.8.4 Data and Methods

<u>Monitoring in the Park</u>
There is no active on-site monitoring of air quality parameters in Deer Lodge or within GRKO. The closest monitoring locations are in Butte, Clancy, Helena, and Missoula, Montana. Figure 41 displays the locations of the air quality monitoring stations nearest to GRKO.

<u>NPS Data Resources</u>
Although data on air quality parameters are not actively collected within park boundaries,

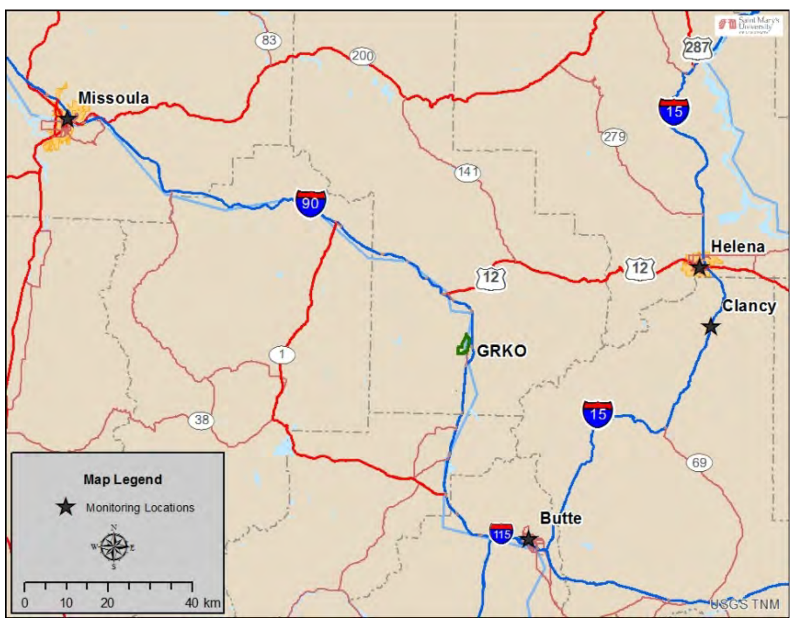


Figure 41. Locations of the air quality monitoring stations nearest to GRKO.

data collected at several regional monitoring stations for various parameters can be used to estimate air quality conditions in GRKO. NPS ARD provides estimates of ozone, wet deposition of nitrogen and sulfur, and visibility that are based on interpolations of data from all air quality monitoring stations operated by NPS, EPA, various states, and other entities, averaged over the most recent 5 years (2008 - 2012). These estimates are available from the Explore Air website (NPS 2014) and are used to evaluate air quality conditions. On-site or nearby data are needed for a statistically valid trends analysis, while a 5-year average interpolated estimate is preferred for the condition assessment. NPS (2010) describes air quality conditions and trends in an annual report for over 200 park units, including GRKO.

Other Air Quality Data Resources

The EPA Air Trends Database provides annual average summary data for ozone concentrations near GRKO (EPA 2014a). Ozone concentrations are collected at a monitor in Missoula, MT (site ID 30-063-0024), located approximately 137 km (85 mi) from GRKO. The site is operated by the MT DEQ Air Quality Division and has collected data from June 2010 through January 2014 (EPA 2014a). Since 2014 data are not complete at the time of assessment, data through December 2013 are used for assessment. The nearest monitors collecting data on particulate matter concentrations ($PM_{2.5}$) are located at Butte (Site ID: 30-093-0005), Helena (Site ID: 30-049-0026), and Missoula (site ID 30-063-0024), Montana. The Butte monitoring station is approximately 48 km (30 mi) from GRKO; this monitor has collected data from March 2008 through January 2014. The Helena monitoring station is 72 km (45 mi) from the park and has collected data from August 2008 through January 2014. The Missoula site (ID 30-063-0024), which is the same monitor location as ozone, has collected particulate matter data from November 2008 through January 2014. All three monitors are currently active in data collection and are operated by the MT DEQ Air Quality Division. Results from monitors located within 16 km (10 mi) from parks are generally considered to be representative of park conditions. Data recorded at monitors beyond this distance from parks may represent regional conditions, but may not be representative of actual park conditions, and caution exhibited in drawing conclusions about park condition (Ellen Porter, NPS Air Resources Division Air Quality Specialist, phone communication, 25 October 2012).

The National Atmospheric Deposition Program–National Trends Network (NADP) database provides annual average summary data for nitrogen and sulfur concentration and deposition across Montana (NADP 2014). The nearest NADP monitoring site is located at Clancy, MT (site ID: MT07), approximately 109 km (68 mi) east of GRKO. This site has collected deposition data for the region since 1984 and is currently active in monitoring (NADP 2014). The proximity of this monitor to GRKO, as well as access to the monitor data summaries, is viewable on the NPS Air Atlas – Estimated Atmospheric Deposition website (NPS 2013b).

The Interagency Monitoring of Protected Visual Environments Program (IMPROVE) actively monitors visibility conditions in Class I airsheds across the U.S. The IMPROVE monitoring site nearest to GRKO is located northeast of Helena, MT, in the Gates of the Mountains Wilderness (monitor ID GAMO1), approximately 97 km (60 mi) from the park. The Visibility Information Exchange Web System (VIEWS) database provides average annual visibility monitoring data (in deciviews) and trend graphics for the GAMO1 monitoring site from 2000-2008 for the clearest and haziest 20% of days for the region (VIEWS 2010). Due to its distance from GRKO, data from this monitor are likely representative of conditions in the area overall, but may not accurately represent conditions at the park specifically; thus, data are interpreted with care.

Special Air Quality Studies

Sullivan et al. (2011a) assessed the relative sensitivity of national parks to the potential effects of acidification caused by acidic atmospheric deposition from nitrogen and sulfur compounds. The relative risk for each park was assessed by examining three variables: the level of exposure to emissions and deposition of nitrogen and sulfur; inherent sensitivity of park ecosystems to acidifying compounds (N and/or S) from deposition; and level of mandated park protection against air pollution degradation (i.e., Wilderness and Class I). The outcome was an overall risk assessment that estimates the relative risk of acidification impacts to park resources from atmospheric deposition of nitrogen and sulfur (Sullivan et al. 2011a). Using the same approach, Sullivan et al. (2011b) assessed the sensitivity of national parks to the effects of nutrient enrichment by atmospheric deposition of nitrogen. The outcome was an overall risk assessment that estimates the relative risk to park resources of nutrient enrichment from increased nitrogen deposition.

4.8.5 Current Condition and Trend

Atmospheric Deposition of Nitrogen and Sulfur

Five-year interpolated averages of total nitrogen (from nitrate and ammonium) wet deposition and total sulfur (from sulfate) wet deposition are used to estimate condition for deposition; using a five-year average smoothes out annual variations in precipitation, such as heavy precipitation one year versus drought conditions in another (NPS 2014). The current 5-year average (2008 - 2012) estimates deposition of total nitrogen in GRKO at 0.6 kg/ha/yr, while total deposition of sulfur is 0.2 kg/ha/yr (NPS 2014). Five-year averages for wet deposition of ammonium (NH_4) is estimated at 0.4 kg/ha/yr , and estimates for deposition of sulfate (SO_4) and nitrate (NO_3) are 0.7 kg/ha/yr and 1.1 kg/ha/yr, respectively (NPS 2014). Relative to the NPS ratings for air quality conditions (see Table 46 for ratings values), atmospheric deposition of both nitrogen and sulfur falls into the *Good Condition category*.

Concentrations (mg/L) of nitrogen, sulfur, and ammonium compounds in wet deposition can be used to evaluate trends in deposition of total nitrogen and sulfur. Since atmospheric wet deposition can vary greatly depending on the amount of precipitation that falls in any given year, it can be useful to examine concentrations of pollutants, which factor out the variation introduced by precipitation. Annual averages from 1984-2012 indicate that sulfate concentrations in GRKO have decreased overall, while ammonium has increased slightly, and nitrate has fluctuated substantially across the near 30 year period of record (NADP 2014). Figure 42 shows the annual concentration of nitrate, sulfate, and ammonium recorded at the nearest NADP monitor, located in Clancy, Montana (approximately 109 km [68 mi] north of the park).

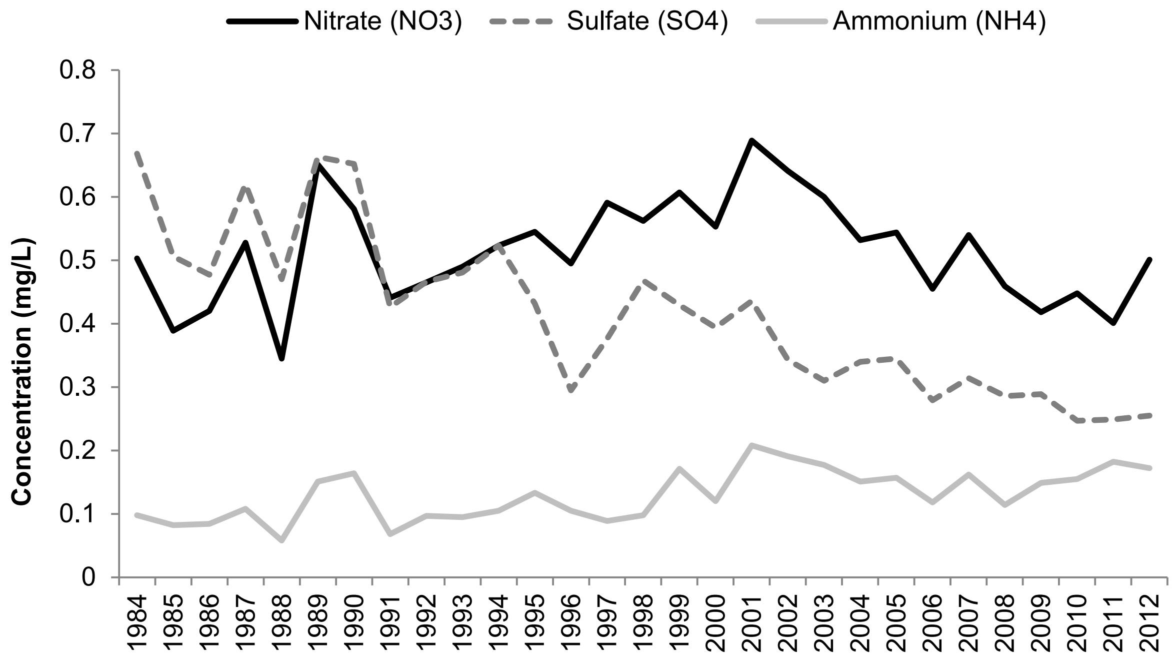


Figure 42. Annual average concentrations of sulfate (SO_4), nitrate (NO_3), and ammonium (NH_4) (mg/L) in precipitation in GRKO, 1984-2012 (NADP monitoring site MT07) (Source: NADP 2014). Note: Ammonium (NH_4) is included because it adds significantly to total nitrogen deposition.

Relative risk of acidification and nutrient enrichment of ecosystems was assessed by examining exposure to nitrogen deposition and acidification, inherent sensitivity of park ecosystems, and mandates for park protection. Sullivan et al. (2011c) ranked GRKO as having very low exposure to acidifying (nitrogen and sulfur) pollutants, very low ecosystem sensitivity to acidification, and moderate park protection due to its Class II airshed status. The ranking of overall risk from acidification due to acid deposition was very low relative to other parks (Sullivan et al. 2011c). In a separate examination, Sullivan et al. (2011d) used the same approach to assess the sensitivity of national parks to nutrient enrichment effects from atmospheric nitrogen deposition relative to other parks. GRKO was ranked as having very low risk for nitrogen pollutant exposure, high ecosystem sensitivity, and moderate park protection mandates (Class II airshed). The ranking of overall risk of effects from nutrient enrichment from atmospheric nitrogen deposition was very low relative to other parks (Sullivan et al. 2011d).

<u>Ozone</u>
The NAAQS standard for ground-level ozone is the benchmark for assessing current ozone conditions within park units. In 2008, the standard was strengthened from 80 ppb to 75 ppb, based on the annual fourth highest daily maximum 8-hour concentration, averaged over 3 years (EPA 2012b). The condition of ozone in NPS units is determined by calculating the 5-year average of the fourth-highest daily maximum of 8-hour average ozone concentrations measured at each monitor within an area over each year (NPS 2011). The current 5-year average (from 2008 - 2012) for GRKO indicates

an average ground-level ozone concentration of 61.2 ppb (NPS 2014), which falls under the *Moderate Condition* category based on NPS guidelines (NPS 2013a).

Long-term data that characterize ozone concentrations within the park do not exist. However, ozone concentrations are monitored daily by MT DEQ at the Sieben Flatts monitoring site near Helena, MT, approximately 80.5 km (50 mi) east of GRKO. Although results from this monitor may not be representative of ozone concentrations within GRKO, they are considered to represent concentrations in the general region of the park. Figure 43 illustrates the trend in annual fourth-highest daily maximum 8-hour values from 2011 to 2014; these are presented with revised national standards to provide perspective on acceptable versus potentially harmful ozone conditions in the region. Concentrations range from 46.0 to 57.0 ppb (EPA 2014b); all measurements are well within the standards considered protective of human health.

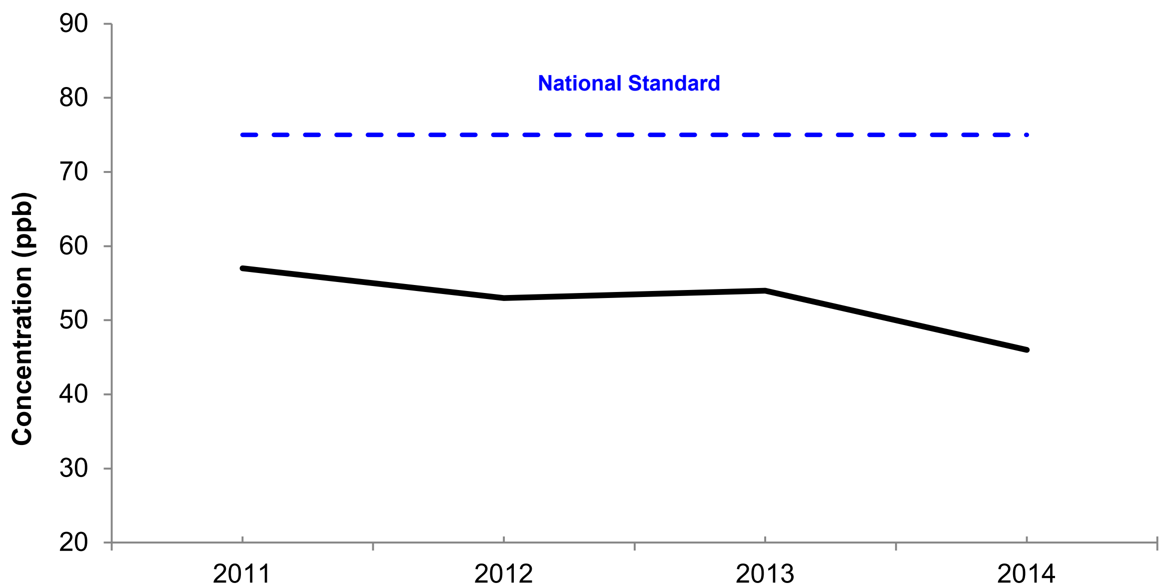


Figure 43. Annual 4th highest 8-hour maximum ozone (O_3) concentrations (ppb) in the GRKO region, 2011-2014 (Source: EPA 2014b). Note: Seiben Flatts, MT monitoring site 30-049-0004 is located approximately 80.5 km (50 mi) east of GRKO.

Kohut (2004) assessed ozone concentrations in ROMN and the risk of injury to plant species that are sensitive to sustained ozone exposure. Estimations by kriging indicate that, from 1995-1999, ambient ozone concentrations around GRKO frequently exceeded 60 ppb and only occasionally exceeded 80 ppb (less than 20 hours each year); concentrations exceeded 100 ppb very rarely (total of 6 hours across 5 years of monitoring) (Kohut 2004). Sensitive plant species begin to experience foliar injury when exposed to ozone concentrations of 80-120 ppb/hour for extended periods of time (8 hours or more), and drier soil conditions can decrease the ability of plants to absorb ozone; thus increasing ambient ozone concentrations. However, the infrequent incidence of concentrations higher than 80 ppb in GRKO and rare or mild drought conditions make the risk of foliar injury from ozone low

(Kohut 2004). If the level of risk increases in the future, ozone foliar damage may be assessed using quaking aspen (Populus tremuloides) as an indicator species (Kohut 2004).

Particulate Matter ($PM_{2.5}$)

The NAAQS standard for $PM_{2.5}$ is a weighted annual mean of 15.0 µg/m^3 or 35 µg/m^3 in a 24-hour period over an average of 3 years (EPA 2012b). Particulate matter concentrations collected at monitors in Helena, Missoula, and Butte, Montana are available from 2008 through 2013. Weighted annual average $PM_{2.5}$ concentrations in the GRKO region during the time of data collection appear to be relatively stable in recent years, fluctuating slightly between 7 and 11 µg/m^3 (Figure 44)(EPA 2014a). All measurements were well within the EPA standards for levels that are protective of human health at the time of active data collection.

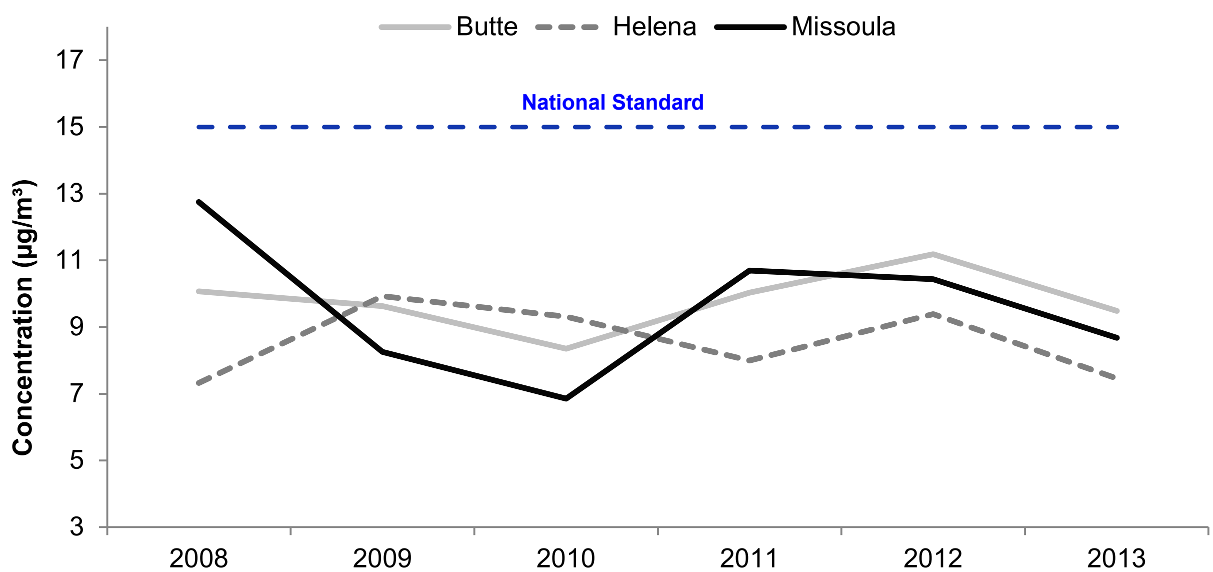


Figure 44. Annual particulate matter ($PM_{2.5}$) concentrations (weighted annual mean) near GRKO, 2008-2013 (EPA 2014a). Note: Monitoring stations are located in Butte, Helena, and Missoula, MT.

Visibility

Visibility impairment occurs when airborne particles and gases scatter and absorb light; the net effect is called "light extinction," which is a reduction in the amount of light from a view that is returned to an observer (EPA 2003). In response to the mandates of the CAA of 1977, federal and regional organizations established IMPROVE in 1985 to aid in monitoring of visibility conditions in Class I airsheds. The goals of the program are to 1) establish current visibility conditions in Class I airsheds; 2) identify pollutants and emission sources causing the existing visibility problems; and 3) document long-term trends in visibility (NPS 2010, NPS 2013a).

The most current 5-year average (2008 - 2012) estimates average visibility in GRKO to be 3.1 dv above average natural visibility conditions (NPS 2014). This estimate falls into the *Moderate Condition* category based on NPS criteria for air quality assessment.

The clearest and haziest 20% of days each year are also examined for parks (NPS 2014), as these are the measures used by states and EPA to assess progress towards meeting the national visibility goal. Conditions measured near 0 dv are clear and provide excellent visibility, and as dv measurements increase, visibility conditions become hazier. The most current 5-year average (2008 - 2012) estimates visibility at GRKO at 2.7 dv on the 20% clearest days and 14.2 dv on the 20% haziest days (NPS 2014). These estimates fall into the *Moderate* Condition and *Significant Concern* categories, respectively. Figure 45 displays visibility data (in dv) collected at Gates of the Mountains wilderness area (monitor ID GAMO1), approximately 97 km northeast of GRKO; data represented show the average visibility on the clearest and haziest 20% of days each year for the region (VIEWS 2010).

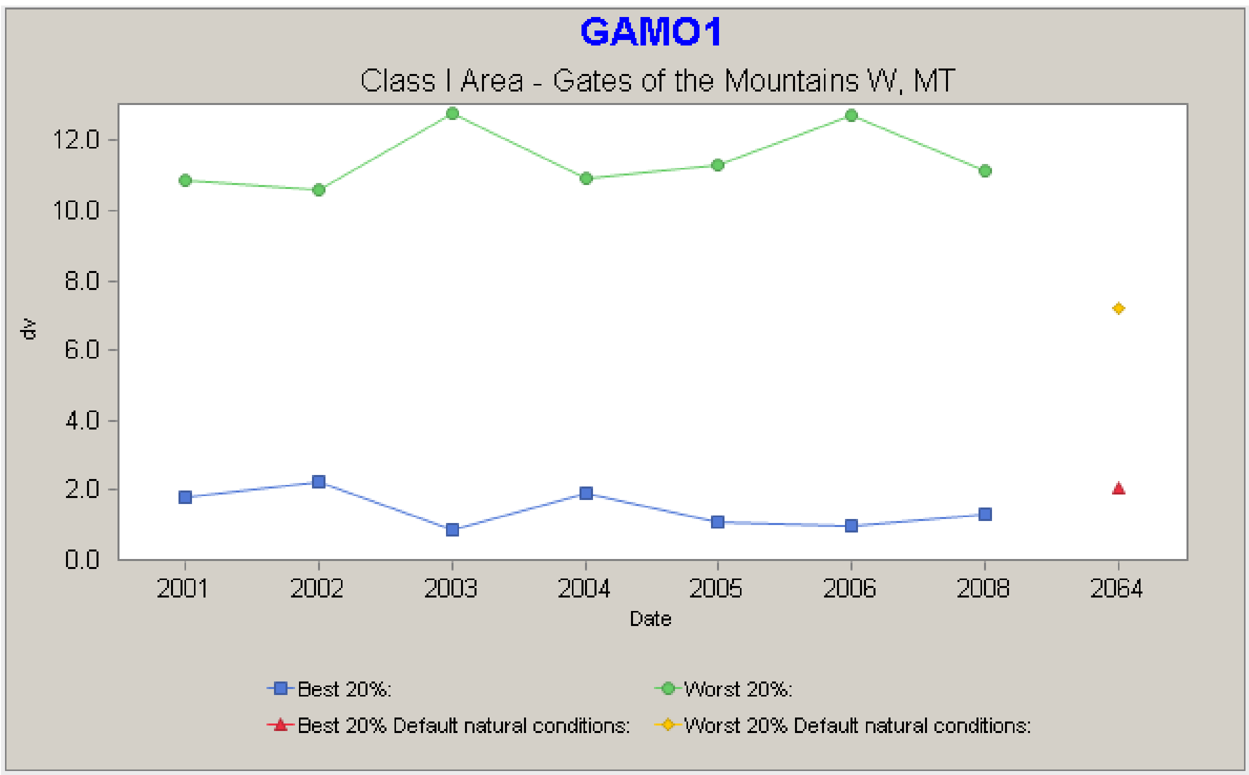


Figure 45. Annual average visibility in the GRKO region, 2001-2008 (VIEWS 2010). The Gates of the Mountains (GAMO1) monitor is located northwest of Helena, MT, approximately 97 km (60 mi) from GRKO. Values shown indicate average visibility during the 20% clearest and 20% haziest days each year. Values at 2064 are the natural background visibility conditions, set by EPA Regional Haze Rule, to which all Class I areas are required to restore visibility conditions by 2064.

Threats and Stressor Factors

The GRKO park staff identified two potential threats to air quality in the park. These threats to the air quality in the park include agricultural and riparian burning. Pollution, affecting historical buildings, is a potential threat that could result from poor air quality. Agricultural burning occurs on an annual basis in GRKO, while riparian burning has been a more recent effort to restore the riparian corridor inside the park. According to Jimenez (2002), agricultural burning can impact air quality. Increased $PM_{2,5}$ concentrations are one characteristic of impacted air quality from agricultural burning (Jimenez 2002). Air pollution is another threat because it adversely affects the historic buildings and structures located in GRKO. Atmospheric corrosion may occur on the historic buildings as a result of dry and wet deposition of pollutants (Kucera and Fitz 1995).

According to the EPA and the Intergovernmental Panel on Climate Change (IPCC), global climate change is expected to negatively affect air quality (EPA 2011b). Both ozone and particulate pollution are heavily influenced by weather shifts. The EPA projects that climate change could increase summertime average ground-level ozone concentrations in many areas by 2-8 ppb. It could also cause particulate pollution to increase in some regions and decrease in others (EPA 2011b).

Data Needs/Gaps

There are no air quality monitors within the acceptable distance (16 km [10 mi]) to accurately represent conditions in the park. The closest monitors are located more than 56 km (35 mi) away. Monitors in Helena and Butte provide particulate matter and ozone concentration data as both daily and annual average summaries. The nearest active NADP monitor that provides annual averages for nitrogen and sulfur deposition is located in Clancy, Montana, approximately 109 km (68 mi) west of GRKO. The nearest IMPROVE site, which monitors visibility, is located in Glacier National Park, over 333 km (207 mi) northwest of GRKO. Periodic or consistent monitoring of nitrogen and sulfur deposition, ozone, particulate matter, and visibility would help managers better understand the local air quality conditions in and around GRKO and how they may affect other park resources.

Overall Condition

Sulfate Deposition

The *Significance Level* for sulfate deposition was also defined as a 3. Current NPS interpolated averages for nitrogen deposition are considered to be in Good Condition, based on NPS criteria for rating air quality (NPS 2014). Sullivan et al. (2011a, 2011c) rate GRKO as having very low exposure to acidifying (nitrogen and sulfur) pollutants, very low ecosystem sensitivity to acidification, and moderate park protection due to its Class II airshed status, with a very low overall risk from acidification due to acid deposition relative to other parks. NADP (2014) data show relatively stable concentrations of sulfate over the past 10 years, all measuring less than 1 mg/L. As a result, sulfate deposition was assigned a *Condition Level* of 0, or no concern/good condition.

Nitrogen Deposition

The *Significance Level* for nitrogen deposition was also defined as a 3. Current NPS interpolated averages for nitrogen deposition are considered to be in Good Condition, based on NPS criteria for rating air quality (NPS 2014). Likewise, Sullivan et al. (2011b, 2011d) rate GRKO as having very low risk for nitrogen pollutant exposure, high ecosystem sensitivity, and moderate park protection mandates (Class II airshed), with a very low overall risk of effects from nitrogen deposition of relative to other parks. NADP (2014) data show relatively stable concentrations of nitrate and ammonium over the past 10 years, all measuring less than 1 mg/L. As a result, nitrogen deposition was assigned a *Condition Level* of 0, or no concern/good condition.

Ozone Concentration
The *Significance Level* for ozone was also defined as a 3. Current average ground-level ozone concentrations fall into the moderate condition category based on NPS criteria for rating air quality condition. Annual 4th highest 8-hour maximum concentrations (2011 through 2014) show relatively stable concentrations for the short period of record; this is not a long enough record of data to assess a trend. All measurements are well within EPA standards protective of human health. Kohut (2004) suggests the risk of foliar injury from ozone is low for the park. Therefore, the *Condition Level* for ozone concentration is a 0, of no concern/good condition.

Particulate Matter
The *Significance Level* for particulate matter was also defined as a 3. Weighted annual average $PM_{2.5}$ concentrations in the GRKO region appear to be relatively stable in recent years (2009-2013), fluctuating only slightly (EPA 2014a). All measurements were well within the EPA standards for levels that are protective of human health. As a result of this, the *Condition Level* for particulate matter was assigned a 0, or no concern/good condition.

Visibility
The *Significance Level* for visibility was also defined as a 3. Current interpolated average visibility estimates fall into the moderate concern category based on NPS criteria. Visibility on the 20% clearest days also falls into the moderate concern category (though just barely), while visibility on the 205 haziest days falls into the significant concern category. The *Condition Level* for visibility was assigned a 2, indicating visibility is of moderate concern.

Weighted Condition Score
The *Weighted Condition Score* for the component is 0.13, indicating air quality is in good condition overall, warranting no concern. Available data and estimates imply the trend for all assessed air quality parameters is stable, as indicated by the horizontal double arrow in the graphic. This condition designation is assigned with a moderate level of confidence based on the available data from multiple agencies and estimates provided by the NPS Air Resources Division. Air quality is considered a vital sign for GRKO and, although it is not monitored directly in the park, air quality information is interpolated from regional air monitors and basic parameters are estimated for the park on a yearly basis.

Air Quality			
Measures	Significance Level	Condition Level	WCS = 0.13
Nitrogen Deposition	3	0	
Sulfur Deposition	3	0	
Ozone Concentration	3	0	
Particulate Matter	3	0	
Visibility	3	2	

4.8.6 Sources of Expertise

Ellen Porter, Biologist, NPS Air Resources Division

4.8.7 Literature Cited

Environmental Protection Agency (EPA). 2003. Guidance for estimating natural visibility conditions under the Regional Haze Rule. EPA-454/B-03-005. Office of Air Quality Planning and Standards. Emissions, Monitoring and Analysis Division, Research Triangle Park, North Carolina.

Environmental Protection Agency (EPA). 2010. Policy assessment for the review of the Secondary National Ambient Air Quality Standards for NOx and SOx: Second external review draft. EPA452/P-10-008. Office of Air Quality Planning and Standards Health and Environmental Impacts Division. Research Triangle Park, North Carolina.

Environmental Protection Agency (EPA). 2011a. Policy assessment for the review of the secondary national ambient air quality standards for oxides of nitrogen and oxides of sulfur. EPA-452/R-11-005a. Office of Air Quality Planning and Standards Health and Environmental Impacts Division. Research Triangle Park, North Carolina.

Environmental Protection Agency (EPA). 2011b. Climate change and air quality. http://www.epa.gov/airquality/airtrends/2011/report/climatechange.pdf (accessed 22 July 2014).

Environmental Protection Agency (EPA). 2012a. Our nation's air: Status and trends through 2010. EPA-454/R-12-001. Office of Air Quality Planning and Standards, Air Quality Assessment Division, Research Triangle Park, North Carolina.

Environmental Protection Agency (EPA). 2012b. Air & radiation: National Ambient Air Quality Standards (NAAQS). http://www.epa.gov/air/criteria.html (accessed 30 May 2014).

Environmental Protection Agency (EPA). 2012c. Ground level ozone: ecosystem effects. http://www.epa.gov/airquality/ozonepollution/ecosystem.html (accessed 2 June 2014).

Environmental Protection Agency (EPA). 2012d. Ground level ozone: health effects. http://www.epa.gov/airquality/ozonepollution/health.html (accessed 2 June 2014).

Environmental Protection Agency (EPA). 2013a. Air and radiation: Clean Air Act Title I. http://epa.gov/oar/caa/title1.html#ic (accessed 4 April 2014).

Environmental Protection Agency (EPA). 2013b. Ground-level ozone standards designations. http://www.epa.gov/ozonedesignations/ (accessed 4 April 2014).

Environmental Protection Agency (EPA). 2013c. Particulate matter (PM). http://www.epa.gov/airquality/particlepollution/ (accessed 2 June 2014).

Environmental Protection Agency (EPA). 2014a. Air data. http://www.epa.gov/airdata/ad_maps.html (accessed 4 April 2014).

Environmental Protection Agency (EPA). 2014b. Air quality index: A guide to air quality and your health. EPA-456/F-14-002. Office of Air Quality Planning and Standards, Outreach and Information Division. Research Triangle Park, North Carolina. http://www.epa.gov/airnow/aqi_brochure_02_14.pdf (accessed 4 April 2014).

Jimenez, J. R. 2002. Air quality from agricultural field burning in eastern Washington. Thesis. Washington State University, Pullman, Washington

Kohut, R. J. 2004. Ozone risk assessment for Rocky Mountain Network. NPS/NRPC/ARD/NRTR—2004. National Park Service, Fort Collins, Colorado.

Kucera, V., and S. Fitz. 1995. Direct and indirect air pollution effects on materials including cultural monuments. Water, Air, and Soil Pollution 85:153-165.

National Atmospheric Deposition Program (NADP). 2014. National Atmospheric Deposition Program – National Trends Network Monitoring location MT07 (Clancy, Montana). http://nadp.sws.uiuc.edu/sites/siteinfo.asp?id=MT07&net=NTN (accessed 3 April 2014).

National Park Service (NPS). 1993. Grant-Kohrs Ranch National Historic Site environmental impact statement for a general management plan and development concept plan. National Park Service, Rocky Mountain Region, Fort Collins, Colorado.

National Park Service (NPS). 2008. Air Atlas summary tables for I & M parks. http://www.nature.nps.gov/air/permits/ARIS/networks/docs/SummariesAirAtlasRevised11072003.pdf (accessed 4 April 2014).

National Park Service (NPS). 2010. Air quality in national parks: 2009 annual performance and progress report. Natural Resource Report NPS/NRPC/ARD/NRR—2010/266. National Park Service, Denver, Colorado.

National Park Service (NPS). 2011. Rating air quality conditions. Air Resources Division, Natural Resources Program Center. National Park Service, Denver, Colorado. http://nature.nps.gov/air/planning/docs/20111122_Rating-AQ-Conditions.pdf (accessed 4 April 2014).

National Park Service (NPS). 2013a. Air quality in national parks: trends (2000-2009) and conditions (2005-2009). Natural Resources Report NPS/NRSS/ARD/NRR—2013/683. National Park Service, Denver, Colorado.

National Park Service (NPS). 2013b. Air Atlas – Estimated atmospheric deposition. http://www.nature.nps.gov/air/Maps/AirAtlas/deposition.cfm (accessed 3 June 2014).

National Park Service (NPS). 2014. NPS air quality estimates: ozone, wet deposition, and visibility. http://www.nature.nps.gov/air/Maps/AirAtlas/IM_materials.cfm (accessed 4 May 2014).

Sullivan, T. J., G. T. McPherson, T. C. McDonnell, S. D. Mackey, and D. Moore. 2011a. Evaluation of the sensitivity of inventory and monitoring national parks to acidification effects from atmospheric sulfur and nitrogen deposition: main report. Natural Resource Report NPS/NRPC/ARD/NRR—2011/349. National Park Service, Denver, Colorado.

Sullivan, T. J., T. C. McDonnell, G. T. McPherson, S. D. Mackey, and D. Moore. 2011b. Evaluation of the sensitivity of inventory and monitoring national parks to nutrient enrichment effects from atmospheric nitrogen deposition: main report. Natural Resource Report NPS/NRPC/ARD/NRR—2011/313. National Park Service, Denver, Colorado.

Sullivan, T. J., G. T. McPherson, T. C. McDonnell, S. D. Mackey, and D. Moore. 2011c. Evaluation of the sensitivity of inventory and monitoring national parks to acidification effects from atmospheric sulfur and nitrogen deposition: Rocky Mountain Network (ROMN). Natural Resource Report NPS/NRPC/ARD/NRR—2011/371. National Park Service, Denver, Colorado.

Sullivan, T. J., G. T. McPherson, T. C. McDonnell, S. D. Mackey, and D. Moore. 2011d. Evaluation of the sensitivity of inventory and monitoring national parks to nutrient enrichment effects from atmospheric nitrogen deposition: Rocky Mountain Network (ROMN). Natural Resource Report NPS/NRPC/ARD/NRR—2011/324. National Park Service, Denver, Colorado.

Visibility Information Exchange Web System (VIEWS). 2010. Air quality data, tools, and resources: Trends analysis – Gates of the Mountains (GAMO1) monitor. http://views.cira.colostate.edu/web/Trends/ (accessed 2 July 2014).

4.9 Water Quality

4.9.1 Description

A healthy ecosystem requires good quality ground and surface water. Water quality affects species abundance and distribution for both plant and aquatic species, as well as the overall health of the natural ecosystem and the human inhabitants of an area. Water chemistry has been identified as a Vital Sign for parks in the ROMN, including GRKO (Britten et al. 2007). Water temperature, specific conductance, pH, total suspended sediment, dissolved oxygen, coliform bacteria, nutrients, and metals are the core water quality measures of concern identified by the park.

The Clark Fork River (Photo 27) drains a large portion of western Montana, beginning at the confluence of Silver Bow Creek and Warm Springs Creek near Butte, MT, and ultimately emptying into the Columbia River in Washington (Thornberry-Ehrlich 2007). Approximately 5.5 km (3.4 mi) of the Upper Clark Fork River run through the center of the GRKO property (Figure 46). This portion of the river is directly downstream of the city of Deer Lodge, MT, with the northern section of the park containing the municipal waste water treatment facility for the city. GRKO lies between Cottonwood Creek on the upstream (south) end and Fred Burr Creek on the downstream (north) end. Most of the park's surface water is contained in the Clark Fork River; however, numerous springs and creeks that feed into the Clark Fork also contribute to the total surface waters in GRKO. Several shallow level aquifers also contribute to the flow of the river throughout the park (Thornberry-Ehrlich 2007).

Photo 27. Upper Clark Fork River at GRKO (photo by Sarah Gardner, SMUMN GSS 2013).

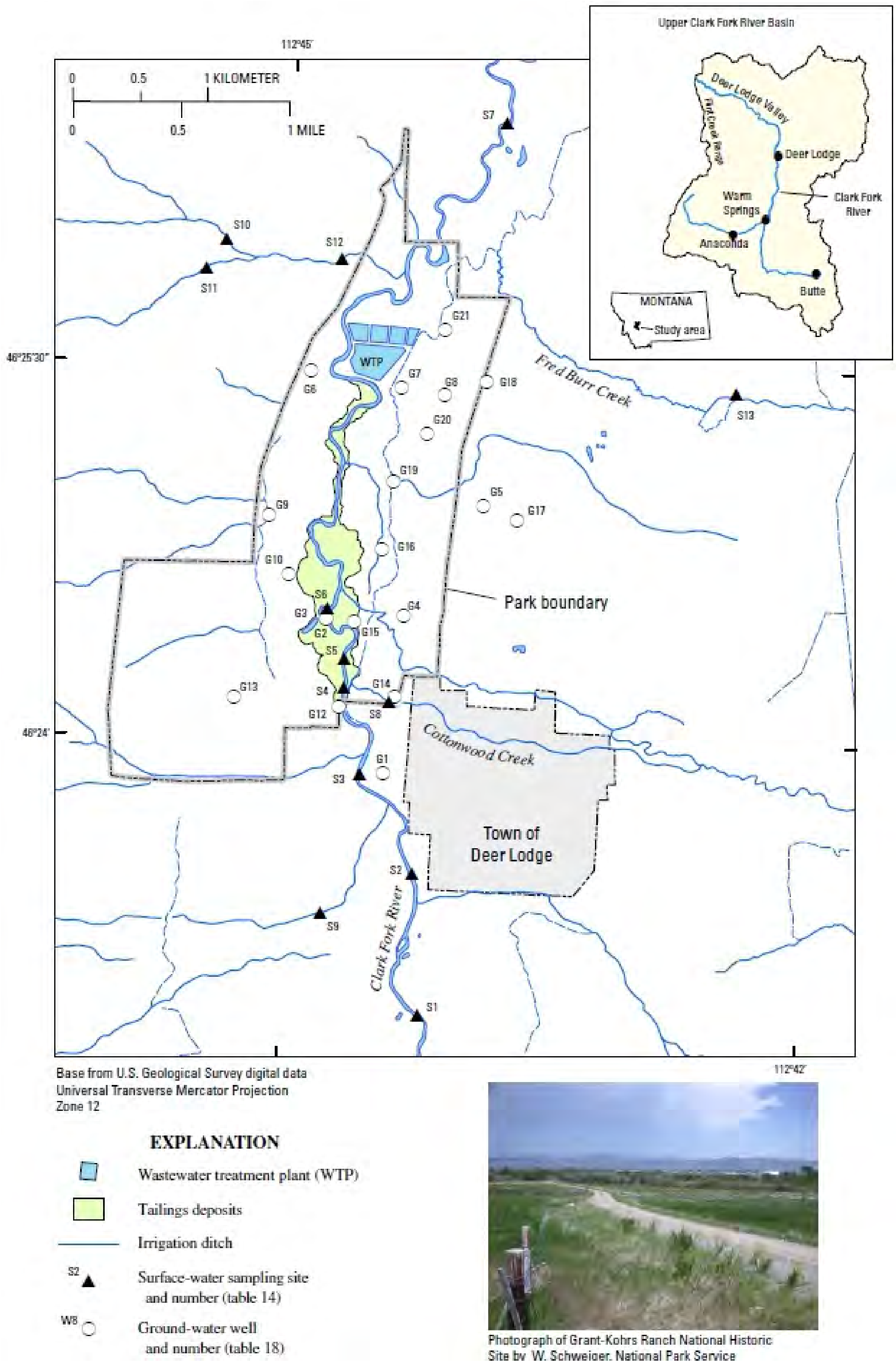


Figure 46. Grant-Kohrs location map with water quality sampling locations (reproduced from Mast 2007).

The Clark Fork River at GRKO is downstream from historic mining activity that has significantly impacted the area. Mining began in the Deer Lodge Valley in 1864 when gold was discovered (Horstman 1984). Gold mining transitioned to silver mining and then to copper mining by the late 1800s. The arrival of the railroad in 1883 allowed heavy mining equipment to be transported into the valley (Horstman 1984). Metals processing, as well as hydraulic mining, resulted in large quantities of minerals and waste products accumulating in the flood plain. Record flooding in the late 1800s and early 1900s (particularly in spring 1908) distributed these wastes throughout the 193 km (120 mi) of the Upper Clark Fork River, eventually causing the Deer Lodge Valley to be designated as a Superfund site. Sediments deposited during these floods raised the level of the valley's floodplain by a meter or more (Ramsey et al. 2005). High levels of mining contaminants including arsenic, cadmium, copper, magnesium, lead, zinc and iron are now embedded in the floodplain soils (Thornberry-Ehrlich 2007). Erosion continues to expose and re-distribute contaminated sediments, exposing the ecosystem to these toxic metals repeatedly. Superfund remediation activities will begin within the GRKO riparian corridor in late 2015 (Johnson, written communication, 10 February 2015). Remediation will completely alter the riparian area, removing vegetation along with contaminated soils. The area will be replanted with grasses, shrubs and trees to restore its natural setting, but full recovery is expected to take more than 10 years (Johnson, written communication, 10 February 2015).

4.9.2 Measures

- Water temperature
- Specific conductance
- pH
- Total suspended sediment
- Dissolved oxygen
- Coliform bacteria
- Nutrients
- Metals

<u>Water Temperature</u>

Water temperature greatly influences water chemistry and can strongly affect aquatic organisms. Not only can temperature affect the ability of water to hold oxygen, but water temperature also affects biological activity within water systems (Allan 1995). All aquatic organisms, from fish to insects to zoo- and phytoplankton, have a preferred or ideal temperature range (Allan 1995). As temperature increases or decreases too far past this range, the number of individuals and species able to live there eventually decreases. In addition, higher temperatures allow some compounds or pollutants to dissolve more easily in water and can be more toxic to aquatic life (USGS 2014).

Specific Conductance

Specific conductance is a measure of the ability of water to conduct electrical current, which depends largely on the amount of dissolved ions in the water (Allan 1995). Water with low amounts of dissolved ions (such as purified or distilled water) will have a low specific conductance, while water with high amounts of dissolved solids (such as salty sea water) will have a higher specific conductance (Allan 1995). Specific conductance is an important water quality parameter to monitor because high levels can indicate that water is unsuitable for drinking or aquatic life (USGS 2014).

Photo 28. Water clarity in a tributary to Clark Fork within GRKO (photo by Sarah Gardner, SMUMN GSS 2013).

pH

pH is a measure of the level of acidity or alkalinity of water and is measured on a scale from 0 to 14, with 7 being neutral (Allan 1995). Water with a pH of less than 7.0 indicates acidity, whereas water with a pH greater than 7.0 indicates alkalinity. Aquatic organisms have a preferred pH range that is ideal for growth and survival (USGS 2014). Chemicals in water can change the pH and harm animals and plants living in the water; thus, monitoring pH can be useful for detecting natural and human-caused changes in water chemistry (USGS 2014).

Total Suspended Sediment (TSS)

Total suspended sediments (TSS) are inorganic and organic particles (e.g., sand, silt, algae) suspended within a water body. Suspended sediment is often measured by the dry weight of sediment collected in the water column (Robertson et al. 2006). TSS can also be measured indirectly through turbidity, which measures the extent of light scattered in water. Erosion along river banks increases the total suspended sediments in the river (Thornberry-Ehrlich 2007), and is currently a management concern in GRKO. Because much of the floodplain within the Deer Lodge Valley contains mining contaminants, an increase in suspended sediment in the water due to river bank erosion can raise the concentrations of toxic chemicals and metals in the river (Thornberry-Ehrlich 2007).

Dissolved Oxygen

Dissolved oxygen (DO) is critical for organisms that live in water. Fish and zooplankton filter out or "breathe" dissolved oxygen from the water to survive (USGS 2014). Oxygen enters water from the air when atmospheric oxygen mixes with water at turbulent, shallow riffles in a waterway, or when released by aquatic plants as a byproduct of photosynthesis. As the amount of DO drops, it becomes more difficult for aquatic organisms to survive (USGS 2014). The concentration of DO in a water body is closely related to water temperature (cold water holds more DO than does warm water), altitude, salinity, and steam structure (turbulent, rapid waterways integrate more DO than slow-moving, stagnant waterways) (Allan 1995). Thus, DO concentrations are subject to seasonal fluctuations as low temperatures in the winter and spring allow water to hold more oxygen, and warmer temperatures in the summer and fall cause water to hold less oxygen (USGS 2014).

Coliform Bacteria

Total coliform is a measure used to assess the level of disease-causing microorganisms present in the water (EPA 1997). Coliform contamination can originate from point source urban discharge as well as from non-point source runoff. Fecal coliform is the most commonly used indicator of coliform bacteria in water (EPA 1997).

Nutrients

Nutrients are chemical elements which are essential for plant and animal survival, but can become contaminants at higher concentrations in water (Mueller and Helsel 2013). Nitrates and phosphorus are two common nutrient contaminants in water bodies (Mueller and Helsel 2013). While nitrogen and phosphorus occur naturally in soils and thus in surface waters, they are increased by human inputs such as sewage, fertilizers, and livestock waste (Muir 2012). These nutrients can cause a host of water quality related problems when present in high concentrations, such as excessive plant and algae growth which depletes dissolved oxygen available to aquatic organisms, a process known as eutrophication (EPA 1997, 2012). Sources of nutrients entering the Clark Fork River include urban inputs (e.g., the Butte municipal wastewater treatment plant) and runoff as well as non-point source agricultural runoff (Mast 2007).

Metals

Heavy metals have been present in elevated concentrations in the Clark Fork River sediment and water for many years (Smith et al 1998). Cadmium, copper, lead, zinc, and arsenic are some of the heavy metals found in the water and surrounding soils (Photo 29). While trace amounts of these metals occur naturally in the soils, the elevated levels in the Clark Fork floodplain are a result of historic mining and smelting processes upstream of the park (Thornberry-Ehrlich 2007). Toxic metals can accumulate in the food chain, causing damage to organisms (Besser and Leib 2007, EPA 2013). Mercury contamination is caused by airborne deposition originating from coal combustion, waste incineration, mining, and natural sources (EPA 2014). In water, mercury is converted to methylmercury, a neurotoxin that is biomagnified in the aquatic food web (EPA 2014).

Photo 29. Metal tailings buried feet under the riparian top soil (photo by Sarah Gardner, SMUMN GSS 2013)

4.9.3 Reference Conditions/Values

As noted in Schweiger et al. (2014, p. 8), the primary motivation of the NPS when monitoring stream health (including water quality) at GRKO is “to understand and document the long-term ecological condition of GRKO’s aquatic resources in order to better protect and manage them.” The NPS does not have any regulatory authority over waters in the park. Therefore, NPS water quality monitoring and analysis uses criteria that are deemed most useful for an ecological interpretation (Schweiger et al. 2014). These may include current state criteria, older criteria no longer in use, criteria still in development, or reference points newly developed by the NPS from ecological reference sites.

For this assessment, the reference conditions for surface water quality in GRKO are primarily the MT DEQ water quality standards for aquatic life, or applicable EPA standards. Not all of the measures in this assessment have applicable state or federal (EPA) water quality standards. When measures are compared to other study results, or to suggested standards that do not carry the weight of law, it has been noted.

Some measures have a relative standard, such as water temperature (Table 47, Table 48). Montana surface water temperature standards are based on the naturally occurring temperature in each water body and an acceptable variance from that. Other standards vary by classification or characteristics of the water body, such as hardness, pH, or season. The Clark Fork in the Deer Lodge Valley is classified as a C-1 surface water body, meaning it is “suitable for bathing, swimming, and recreation; growth and propagation of salmonid fishes and associated aquatic life, waterfowl, and furbearers; and agricultural and industrial water supply” (Mohr 2012, p. 7).

Table 47. Applicable reference standards for selected parameters of surface water at GRKO.

Parameter	Surface Water Standard
Temperature	No state-wide standard; variation allowed depends on natural water temperature range in each water body (MT DEQ 2006).
Specific Conductance	No standard set for Clark Fork River. A 500 µs/cm standard recommended for Tongue River in eastern Montana (EPA 2007). This number was used as an informal reference condition for GRKO by Schweiger et al. (2014).
pH	Induced variation in pH within the range of 6.5-8.5 must be less than 0.5 (MT DEQ 2006). Natural pH outside this range must be maintained without change. Natural pH above 7.0 must be maintained above 7.0 (MT DEQ 2002).
Total Suspended Sediment	N/A
Dissolved Oxygen	Early life stages: 9.5 mg/L (7-day mean) or 8.0 mg/L (1-day min) Other Life Stages: 6.5 mg/L (30-day mean) or 4.0 mg/L (1-day min) (MT DEQ 2012)
Coliform Bacteria	1 April - 31 October:<126 colony forming units (cfu) per 100 ml, and 10% of the total samples may not exceed 252 cfu per 100 ml during any 30-day period. 1 November - 31 March: <630 cfu per 100 ml and 10% of the samples may not exceed 1,260 cfu per 100 ml during any 30-day period (MT DEQ 2006)
Total Phosphorus	21 June -21 September : 30 µg/L (Suplee and Watson 2013)
Total Nitrogen	21 June21 - 21 September : 300 µg/L (Suplee and Watson 2013)

Table 48. Applicable reference points for selected metals in surface water at GRKO (MT DEQ 2012). Note that these are not adjusted for hardness; given the water chemistry of the Clark Fork, reference points for cadmium, copper, and lead would be higher within GRKO (Schweiger et al.2014).

Parameter	Acute	Chronic
Arsenic	340 µg/L	150 µg/L
Cadmium	0.52 µg/L	0.097 µg/L
Copper	3.79 µg/L	2.85 µg/L
Lead	13.98 µg/L	0.545 µg/L
Zinc	37 µg/L	37 µg/L

4.9.4 Data and Methods

At present, the EPA's Storage and Retrieval water quality database management system (STORET) has more than 2,200 sampling event entries dating back to 1969 within 1 km (0.6 mi) of the park's boundary. These sampling events include both surface and ground water, with a variety of parameters reported. Most of these data have been incorporated and interpreted into the following three reports.

Mast (2007) summarized surface and groundwater water quality monitoring for GRKO over 20 years (through 2004). The majority of this data was obtained from STORET or the USGS's National Water Information System (NWIS). Parameters discussed include water temperature, DO, pH, specific conductance, nutrients, and metals.

Schweiger et al. (2014) investigated the stream ecological integrity (SEI) in GRKO using data collected between May and mid-November from 2008-2010. NPS staff sampled a reach of the Clark Fork River that extended from the main bridge to the southern border of the park. Additional water temperature data from May 2001 through April 2010 were also obtained from the USGS water monitoring station in Deer Lodge. Sample data from this study summarized in this NRCA include water temperature, nutrients, and water column and sediment metal concentration.

Atkins et al. (2012) collected water quality measurements on a quarterly basis (April, June, September, and December) from the USGS gaging station on the Clark Fork at Deer Lodge (just upstream of GRKO) in 2011. Parameters monitored included water temperature, pH, DO, specific (electrical) conductance, nutrients.

4.9.5 Current Condition and Trend

Water Temperature

Mast (2007) identified the median surface water temperature for the Clark Fork in or near GRKO as 9.6°C (49.3°F). The minimum recorded was 0.0°C (32°F), and the maximum recorded temperature was 26.5°C (79.9°F). The data analyzed for this report were collected over a 24-year period from 1980-2004, and included 637 sample results. Sampling locations are presented in Figure 46.

Groundwater temperatures were sampled 79 times from 20 different wells (Figure 46; Mast 2007); all 20 wells were in or near GRKO. The median temperature recorded was 11.6°C (52.9°F), the minimum recorded temperature was 7.6°C (45.7°F), and the maximum recorded temperature was 17.4°C (63.3°F). The data analyzed for this report were collected over a 20 year period from 1980-2000 and included 52 sample results (Mast 2007).

Schweiger et al. (2014) also documented minimum, median, and maximum water temperatures for surface water in GRKO. Between 2008 and 2010, the median temperature was 5.5°C (41.9°F), the minimum temperature was 4.8°C (40.6°F), and the maximum temperature was 19.1°C (66.4°F). The variations in sampling timing and methodologies between Mast (2007) and Schweiger et al. (2014) may account for the differences in temperature ranges observed.

Using data collected from the USGS gauging station at Deer Lodge, Schweiger et al. (2014) summarized the 7-day mean maximum temperatures from 2001-2010. These data were compared to the summer maximum temperature threshold of 15 °C for optimal bull trout (*Salvelinus confluentus*) rearing (USFWS 1998; Figure 47). Approximately 86% of summer temperatures during this period were above the maximum temperature threshold. When Schweiger et al. (2014) applied a flow and seasonally adjusted trend model (ESTREND; Schertz et al. 1991, Slack and Lorenz 2003) to these temperature data, a slight (but insignificant) positive trend in minimum water temperatures was seen, suggesting stream temperatures may have increased slightly over time.

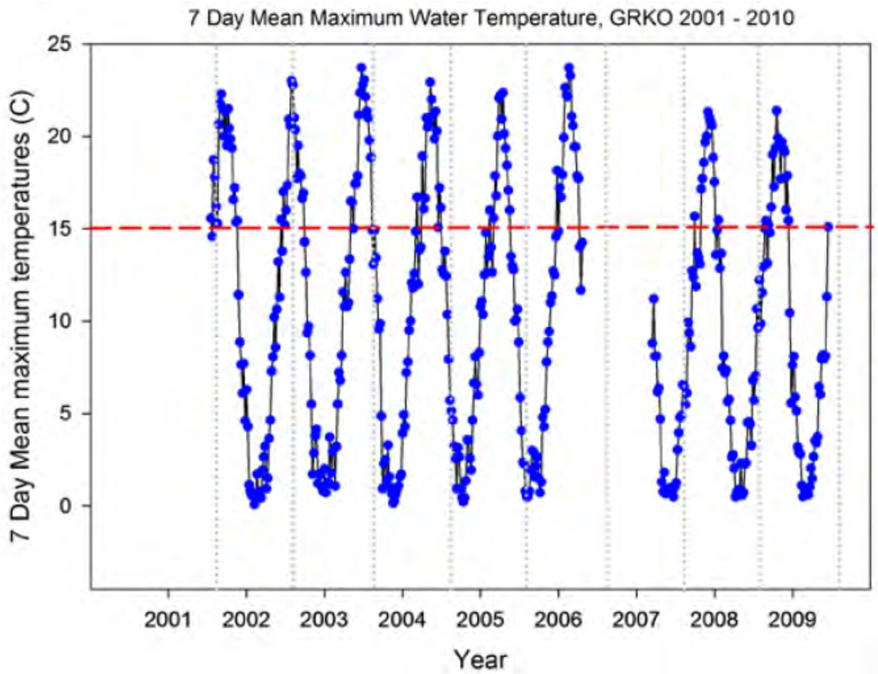


Figure 47. Mean 7-day maximum water temperature for water years, 2001-2010 at Deer Lodge USGS gauge. Horizontal red line depicts maximum summer temperature threshold (USFWS 1998) for optimal bull trout rearing. Dotted vertical gray lines delineate water year boundaries (Reproduced from Schweiger et al. 2014).

Atkins et al. (2012) recorded water temperatures in the Clark Fork at Deer Lodge ranging from just above 0°C (32°F) in December to 10.9°C (51.6°F) in September (Table 49). All values fell within a similar range as Mast (2007) and Schweiger et al. (2014).

Table 49. Water temperatures (°C) in the Clark Fork at Deer Lodge, 2011 (Atkins et al. 2012).

	April	June	September	December
Water Temperature (°C)	6.1	9.9	10.9	0.1

Specific Conductance

Mast (2007) reported the median value for specific conductance of surface waters in GRKO from 1980-2004 at 524 µS/cm, while the minimum recorded value was 208 µS/cm and the maximum was 1,890 µS/cm. There were 534 sample results that measured specific conductance over this time period. Figure 48 below illustrates the specific conductance and its seasonal variance from a single sampling location (S3) over the course of 12 months.

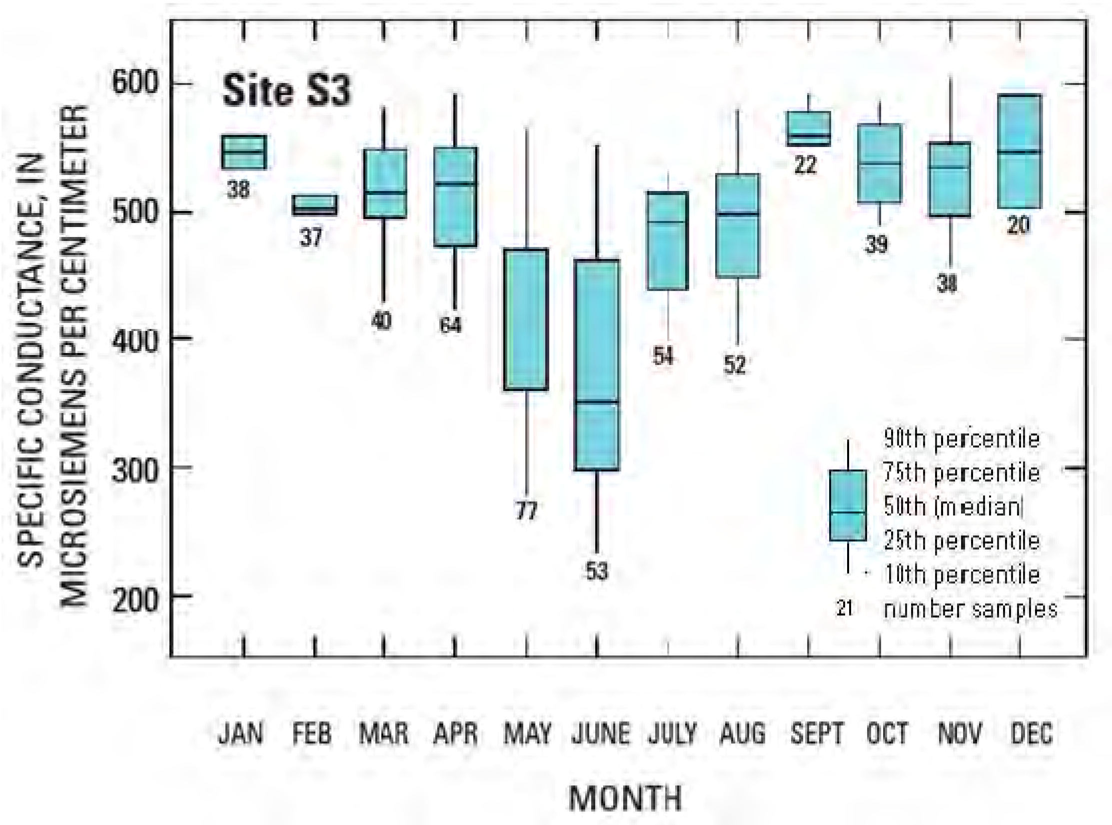


Figure 48. Seasonal variation in specific conductance at a GRKO sampling site, 1982-2004 (reproduced from Mast 2007).

Mast (2007) reported that the specific conductance of GRKO's groundwater had a median value of 457 µS/cm, while the minimum recorded was 242 µS/cm and the maximum recorded was 799 µS/cm. The data analyzed for this report were collected over a 20-year period from 1980 - 2000 and included 53 sample results.

Schweiger et al. (2014) also documented minimum, median, and maximum specific conductance values of surface water at GRKO between 2008 and 2010. The median specific conductance value was 428.3 µS/cm, while the minimum specific conductance value was 266 µS/cm, and the maximum specific conductance value was 480.9 µS/cm. Montana has no formal state-wide reference condition for specific conductance, but the EPA (2007) developed criteria for the Tongue River tributaries in eastern Montana that suggested 500 µS/cm as a reference threshold. This criterion was used as an informal reference for GRKO by Schweiger et al. (2014) but has no regulatory significance; all measurements during the 2008-2010 study period met this suggested threshold. Schweiger et al. (2014) found a fairly large decreasing trend in conductivity (-3.5 µmhos/yr) at the nearby USGS gauging station over 15 years. This likely suggests an improving trend in water chemistry, as specific conductance is a useful general indicator of overall water quality (Billy Schweiger, ROMN Ecologist, written communication, 26 November 2014).

Atkins et al. (2012) recorded a median specific conductance of 267.5 µS/cm with a range of 211.8 to 370.0 µS/cm (Table 50). None of the measurements exceeded the informal reference condition of 500 µS/cm, and all fell within a similar range as Mast (2007) and Schweiger et al. (2014).

Table 50. Specific conductance (µS/cm) in the Clark Fork at Deer Lodge, 2011 (Atkins et al. 2012).

	April	June	September	December
Specific conductance	290.0	211.8	370.0	245.0

pH

Mast (2007) reported the median value for pH of surface water from 1980-2004 as 8.27. The minimum recorded pH value was 6.70 and the maximum recorded pH value was 8.91 (Mast 2007). Flow and seasonally adjusted trend models suggested an upward trend in pH from 1989 to 2004. Groundwater pH had a median value of 7.31 with a minimum of 6.45 and a maximum of 7.68 over a 20-year period from 1980-2000 (Mast 2007).

Schweiger et al. (2014) documented minimum, median, and maximum pH values of surface water in GRKO between 2008 and 2010. The median pH was 8.5; the minimum pH was 8.1, and the maximum pH was 8.6. According to Schweiger et al. (2014), there is no evidence that these pH values were outside the "natural" range of variation for the Clark Fork. pH is likely naturally somewhat basic (i.e., above 7.0) because of the geological source materials (e.g., rocks and minerals) in the watershed. Schweiger et al. (2014) also states that a more basic pH may be beneficial for GRKO as heavy metals are more soluble and bioavailable, and therefore more toxic, in acidic waters.

Atkins et al. (2012) recorded pH values between 7.74 and 8.17, with a median of 8.15 (Table 51). All values fell within a similar range as Mast (2007) and Schweiger et al. (2014).

Table 51. pH values for the Clark Fork at Deer Lodge, 2011 (Atkins et al. 2012).

	April	June	September	December
pH	7.74	8.13	8.17	8.01

Total Suspended Sediment (TSS)

While Mast (2007) did not analyze data regarding TSS, the report mentioned that TSS often exceeds 50 mg/L during the spring runoff at GRKO. This elevated amount of suspended sediment is partially caused by erosion of the mine tailings that have been deposited throughout the Clark Fork floodplain (Mast 2007).

No TSS values were reported for groundwater in either Mast (2007) or Schweiger et al. (2014).

Schweiger et al. (2014) documented minimum, median, and maximum for TSS in surface water in GRKO between 2008 and 2010. The median TSS was recorded as 13.1 mg/L; the minimum TSS was 6.4 mg/L, and the maximum TSS reading was 42.4 mg/L. There is no applicable state of Montana standard regarding TSS in the Clark Fork.

Dissolved Oxygen

The State of Montana established the minimum instantaneous DO concentration standard for surface waters at 8 mg/L for early life stages of fish, and 4 mg/L for other life stages in class C-1 Rivers like the Clark-Fork (MT DEQ 2002). The median value for DO in GRKO's surface waters from 1980-2004 was reported at 10.4 mg/L; the minimum recorded value was 6.2 mg/L, and the maximum was 12.4 mg/L (Mast 2007). There were 94 sample results that measured dissolved oxygen over this time period. While the median value met the MT DEQ standard, the minimum fell below the standard of 8 mg/L for early life stages of fish.

Dissolved oxygen in groundwater had a median value of 5.6 mg/L; the minimum recorded was 4.6 mg/L, and the maximum recorded was 6.4 mg/L (Mast 2007). The data analyzed by Mast (2007) were collected over a 20 year period from 1980-2000 but included just three sample results.

Schweiger et al. (2014) documented minimum, median, and maximum DO values of surface water in GRKO between 2008 and 2010. The median DO was 9.3 mg/L, the minimum DO was 8.2 mg/L, and the maximum DO was 12.2 mg/L.

Atkins et al. (2012) recorded DO measurements between 9.90 mg/L and 12.08 mg/L with a median of 10.16 mg/L (Table 52).

Table 52. Dissolved oxygen measurements (mg/L) for the Clark Fork at Deer Lodge, 2011 (Atkins et al. 2012).

	April	June	September	December
Dissolved Oxygen	10.42	9.90	8.98	12.08

Dissolved oxygen levels in Schweiger et al. (2014) and Atkins et al. (2012) were above the MT DEQ minimum standard during all sampling events. There is no specific DO standard that applies to groundwater.

Nutrients

Mast (2007) presents results for ammonia, nitrate, and orthophosphate from 1987 to 1995 (Table 53). Overall, nutrient levels were generally low, although concentrations of nitrogen were up to five times higher in the winter months compared to the summer months (Mast 2007). While median values met the state standards that were in effect at the time, some maximum values did exceed those standards.

Table 53. Nutrient levels (mg/L) of surface waters in GRKO (Mast 2007).

Nutrients (mg/L)	Number of Analyses	Minimum Value	Median Value	Maximum Value	State Standard[1]
Ammonia, dissolved	90	0 mg/L	0.01 mg/L	0.23 mg/L	≤ 2.14 mg/L
Nitrate, total	185	0.02 mg/L	0.18 mg/L	0.94 mg/L	Total N ≤ 0.3 mg/L (21 June – 21 Sept.)
Orthophosphate	89	0.001 mg/L	0.006 mg/L	0.024 mg/L	Total P ≤ 0.03 mg/L (21 June – 21 Sept.)

[1] Ammonia state standard from MT DEQ (2012), for a pH of 8.5 and assuming fish are present; Total N and P standards from Suplee and Watson (2013).

Mast (2007) also used three components to analyze the nutrient levels of groundwater in GRKO. Orthophosphate, phosphorus, and nitrate measurements were analyzed from groundwater from 1980 to 2000 and are presented in Table 54 below.

Table 54. Nutrient levels (mg/L) in groundwater at GRKO (Mast 2007).

Nutrients (mg/L)	Number of Analyses	Minimum Value	Median Value	Maximum Value
Nitrate, dissolved	19	<0.01	0.5	2.2
Orthophosphate, total	4	<0.1	<0.1	0.2
Phosphorus, total	18	<0.01	0.05	0.16

Schweiger et al. (2014) present data for several nutrients including total nitrogen, total phosphorus, and nitrites plus nitrates in the Clark Fork River at GRKO between 2008 and 2010. In general, nutrients increased as flow rates increased, but rarely exceeded Montana water quality standards. Although nutrient levels did marginally exceed standards in some sample events, there were not enough data to complete the full MT DEQ nutrient assessment protocol (Suplee and Sada de Suplee 2011). Nutrient levels have historically been higher in this area (Dodds et al. 1997, Suplee et al. 2012); the recent lower nutrient levels may be an indicator of improved water quality due to remediation efforts. Table 55 displays the nutrient level data from the Clark Fork River in GRKO between 2008 and 2010.

Table 55. Nutrient levels (mg/L) in surface waters at GRKO, 2008-2010 (as reported in Schweiger et al. 2014). Except as indicated, assessment points are state of MT chronic aquatic-life criteria with human-health values in parentheses.

Nutrients (mg/L)	Number of Analyses	Minimum Value	Median Value	Maximum Value	Standard
Nitrite + Nitrate, dissolved (mg/L as N)	7	0.004	0.02	0.11	0.1(10) [1]
Nitrogen, total (mg/L as N)	8	0.16	0.26	0.31	0.3[2]
Phosphorous, total (mg/L as P)	8	0.007	0.02	0.03	0.03[2]

[1] The nitrite + nitrate standard is informal and is for a base flow in the Middle Rockies Ecoregion (Suplee et al. 2008); the human health standard in parenthesis is from MT DEQ (2012).

[2] Also for base flow in the Middle Rockies ecoregion (Suplee and Watson 2013).

Atkins et al. (2012) recorded nitrites plus nitrates, total nitrogen, and total phosphorus at the Deer Lodge station in 2011. However, there also were not enough data to complete the full MT DEQ nutrient assessment protocol. It is important to note that MT DEQ standards for these nutrients only apply from 21 June to 21 September. While September nutrient levels met state standards, total nitrogen and phosphorus measurements exceeded these standards in June (Table 56). Atkins et al. (2012) suggests this is likely due to peak spring runoff conditions. Total suspended sediment is high during runoff conditions and total phosphorus levels are often correlated with TSS, as phosphorus readily adheres to sediment particles in surface water. Nitrogen can also increase during this time due to increased agricultural nonpoint source runoff (Atkins et al. 2012).

Table 56. Nutrient levels (mg/L) in the Clark Fork at Deer Lodge, 2011 (Atkins et al. 2012).

Nutrients (mg/L)	April	June	September	December	Median
Nitrite + Nitrate, dissolved	0.15	0.09	0.08	0.27	0.12
Total Nitrogen	0.65	0.57	0.25	0.39	0.48
Total Phosphorus	0.027	0.176	0.017	0.013	0.022

Metals

Due to the impact of historic mining practices, the presence of metals is a primary concern in the surface waters of the Clark Fork within GRKO. Arsenic, cadmium, copper, iron, lead, manganese, and zinc are all associated with mine tailings and have been detected in both surface and ground water samples, as well as soils (Lambing 1991). Metals enter the river by direct erosion of mine tailings that have been deposited in the floodplain over years of flooding, as well as leaching from soil directly into water (Smith et al. 1998). Table 57 presents summary statistics of trace element measurements that were collected from 1980-2004 and summarized in Mast (2007).

Table 57. Dissolved and total trace elements (µg/L) in surface water at GRKO (Mast 2007). Except as indicated, standards are state of MT chronic aquatic-life criteria with human-health values in parentheses.

Constituent (µg/L)	No. Analyses (no. censored)	Minimum Value	Median Value	Maximum Value	Aquatic-Life (human-health) standard
Arsenic, dissolved	146	6	13	39	150* (10)
Cadmium, dissolved	144 (108)	0.02[2]	0.1	5	0.46* (5)
Copper, dissolved	251	3	8	120	3.6* (1,300)
Iron, dissolved	247 (25)	3[2]	13	190	(300)[3]
Lead, dissolved	148 (108)	0.04[2]	0.6	50	0.9* (15)
Manganese, dissolved	243	1	50	400	(50)[3]
Zinc, dissolved	247	0.9	11	230	36.5* (2,000)
Aluminum, total	122	18	100	1,129	87[4]
Arsenic, total	321	2	4	240	150 (18*)
Cadmium, total	287 (89)	0.06[2]	1	8	0.52*
Copper, total	442	2	25	1,500	3.8*
Iron, total	434	27	310	29,000	1,000
Lead, total	291 (8)	0.5[2]	6	200	0.55*
Manganese, total	417	8	120	4,600	50*
Zinc, total	444 (2)	5[2]	40	1,700	37*

* Standard taken from Schweiger et al. (2014), calculated using a median hardness of 186 mg/L as $CaCO_3$.

[1] Table value standard calculated for hardness of 250 mg/L.

[2] Minimum reported value less than minimum censored value.

[3] Secondary standard based on aesthetic properties such as taste, odor, and staining.

[4] Dissolved concentration.

Mast (2007) also compiled summary data on trace metals in groundwater. These data were collected from 1980–2000 and are presented in Table 58 below. The data that Mast (2007) summarized for groundwater included 10 trace elements; however, only six of the elements were frequently found in groundwater samples. Aluminum (48% of samples), arsenic (32% of samples), copper (32% of samples), iron (97% of samples), and zinc (100% of samples) were the most frequently detected trace elements. The most probable source for the arsenic, copper, and zinc is the mine tailings that have been deposited in the floodplain (Mast 2007).

Table 58. Trace elements (µg/L) in groundwater at GRKO (reproduced from Mast 2007).

Constituent (µg/L)	No. Sites	No. Analyses (no. censored)	Minimum Value	Median Value	Maximum Value	Human-Health Standard
Aluminum, dissolved	18	75 (39)	<10	<10	280	--
Arsenic, dissolved	18	75 (51)	3[1]	<5	39	10
Cadmium, dissolved	18	75 (72)	<1	<1	5	5
Chromium, dissolved	18	75 (71)	<2	<5	5	100
Copper, dissolved	18	75 (51)	<2	<3	7	1,300
Iron, dissolved	17	72 (2)	<2.0	36	707	300[2]
Lead, dissolved	17	73 (70)	<10	<10	<40	15
Manganese, dissolved	17	72 (2)	<1	13	605	502
Zinc, dissolved	18	75	1	3	120	2,000

[1] Minimum reported value less than minimum censored value.

[2] Secondary standard based on aesthetic properties such as taste, odor, and staining

While the wells tested are not used for human consumption, Mast (2007) used the human health standards applicable in Montana for a frame of reference. The only element to exceed the human health standard was arsenic, with its current standard set at 10 µg/L (changed from 50 µg/L in 2001). Arsenic levels that exceeded the standard were found in a total of 12 samples in four wells. The samples that exceeded the standard ranged from 11 µg/L to 39 µg/L (Mast 2007).

Mercury is another trace element of concern for GRKO that is associated with mining. Schweiger et al. (2014) reported that the median value for total mercury in the sediment surrounding the Clark Fork River on GRKO was 0.337 mg/kg. The minimum reported value for mercury in sediment was 0.146 mg/kg, and the maximum was 0.594 mg/kg (Schweiger et al. 2014). It is important to note that total mercury values represent inorganic mercury compounds and do not measure organic forms like methylmercury, which are highly toxic and easily absorbed by aquatic organisms (Schweiger et al. 2014).

Neither Montana nor federal thresholds or standards exist for levels of total mercury in sediment, but MacDonald et al. (2000) suggested thresholds that could be used as guidelines in freshwater ecosystems. MacDonald et al. (2000) reports a range of values for 28 different contaminants, each bounded by a “threshold effect concentration” (TEC) on the low end and a “probable effect concentration” (PEC) on the high end. The TEC is intended to represent a lower limit below which no toxicity to sediment dwelling organisms should occur, and the PEC is intended to provide an upper limit at which toxicity to sediment dwelling organisms is highly probable to occur (MacDonald et al. 2000).

A TEC of 0.18 mg/kg (dry weight) and a PEC of 1.06 mg/kg (dry weight) were suggested by MacDonald et al. (2000) as the threshold for mercury in sediment. In subsequent tests, MacDonald et al. (2000) determined that the TEC was only 34% accurate (i.e., of the 35 samples predicted to be non-toxic, only 12 actually were non-toxic). This suggests that the TEC for mercury is likely lower than 0.18 mg/km. Only four samples above the PEC were available for testing, which is insufficient for drawing conclusions, but 100% of those samples were toxic, as predicted. The median mercury level from Schweiger et al. (2014) of 0.337 mg/kg is above MacDonald et al.'s (2000) initially proposed TEC, meaning mercury could be negatively affecting sediment dwelling organisms within GRKO.

Schweiger et al. (2014) reported both dissolved and total metal concentrations for surface water samples from 2008-2010 (Table 59). The State of Montana requires total metals as a reporting criteria, but because it is primarily the dissolved form of the metals that causes aquatic toxicity, the EPA (1996) recommended reporting dissolved concentrations as well. In comparing 2008-2010 data to historic data from the nearby USGS gauge using a flow and seasonally adjusted trend model (ESTREND; Schertz et al. 1991, Slack and Lorenz 2003), Schweiger et al. (2014) found that the 2008-2010 data show decreases (i.e., improvements) in the levels of several metals, particularly cadmium, copper, lead, and zinc.

Table 59. Summary of water physiochemistry for the Clark Fork River in Grant-Kohrs Ranch National Historic Site, 2008-2010. Except as indicated, assessment points are state of MT chronic aquatic-life criteria with human-health values in parentheses. For additional clarifications on table content, see notes below (Modified from Schweiger et al. 2014).

Constituent or property (µg/L)	No. Analyses	Minimum Value	Median Value	Maximum Value	Criteria or Assessment Point
Metals in water, total recoverable					
Aluminum, total	7	52.8**	210**	865	--
Arsenic, total	8	9.3	14.5**	22	150(18)[3]
Barium, total	4	43	49	52.7	(1000)
Beryllium, total^	4	--	--	--	(4)
Cadmium, total	3	0.3**	0.3**	0.3**	0.52(5)[3]
Chromium, total^	4	--	--	--	(100)
Copper, total	8	6	21.8	74	3.8(1300)[3]
Iron, total	8	50.9	283.5**	1190	1000(300)[2]
Lead, total	7	0.7**	2.6**	13	0.55(15)[3]
Manganese, total	8	35**	75.4**	120	50[2]
Selenium, total^	8	--	--	--	5(50)
Zinc, total^	3	--	--	--	37(2000)[3]
Metals in water, dissolved					
Aluminum, dissolved^	8	--	--	--	87
Arsenic, dissolved	7	5.6*	10.3*	19.9	150(10)[1]
Barium, dissolved	3	30.9	46 1	46 3	--
Beryllium, dissolved^	4	--	--	--	--
Cadmium, dissolved^	3	--	--	--	0.46(4.41)[1]
Chromium, dissolved^	3	--	--	--	(86)[1]
Copper, dissolved	7	5	9*	12	3.6(1248)[1]
Iron, dissolved^	7	--	--	--	--
Lead, dissolved	7	77.8	186	216	0.9(10.5)[1]
Manganese, dissolved	7	0.008*	0.30*	25.2	--
Selenium, dissolved^	7	--	--	--	5(50)[1]
Zinc, dissolved^	4	--	--	--	36.5(1972)[1]

[1] Values for dissolved trace elements are derived from the State of Montana water quality numeric criteria using formulas from EPA (2009) and a median hardness of 186 mg/L as $CaCO_3$

[2] Human health value is a secondary standard based on aesthetic properties such as taste, odor, and staining and is more conservative than chronic standards. MT DEQ does not assess iron secondary standards that apply to taste and odor to water-dwelling organisms are expected, whereas PECs are the concentrations at which negative effects on sediment dwelling organisms are judged more likely to occur than not

[3] Derived from criteria in Record of Decision (EPA 2004) using formulas from EPA (2009) and a median hardness of 186 mg/L as $CaCO_3$; may differ from statewide standards

* Value or median contains predicted results from regression on order statistics (ROS) model

** >80% of results at Detection Limit(s), results tenuous

^ All results were at detection limits (i.e., very low), no analysis possible

Many metals have a strong diurnal and/or seasonal concentration pattern in the Clark Fork River. Figure 49 represents the copper concentration at GRKO over a 12-month period. The highest concentration of metals generally coincided with peak flow. This may be due to the greater amounts of suspended sediment in the river during high flow conditions such as spring snowmelt (Lambing 1991, Mast 2007). This is also demonstrated by the seasonal variation in arsenic concentration illustrated in Figure 50.

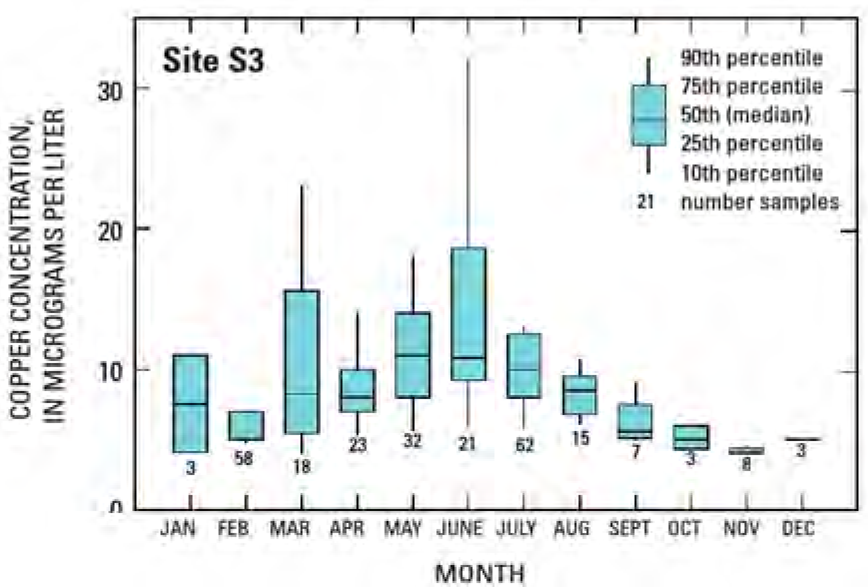


Figure 49. Seasonal variation in copper concentration, 1982-2004 (reproduced from Mast 2007).

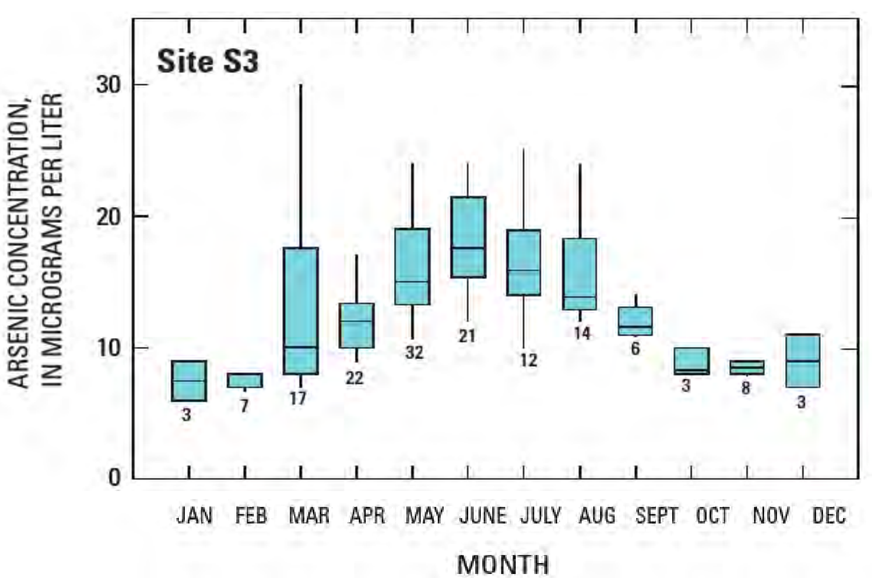


Figure 50. Seasonal variation in arsenic concentration, 1982-2004 (reproduced from Mast 2007).

Threats and Stressor Factors

GRKO staff identified several potential threats and stressors to the water quality in the park. While most of the threats are anthropogenic (mining contamination, nutrient enrichment, point and nonpoint source discharge, and dewatering), one is naturally occurring (drought).

The impact of historical mining to the area is a significant threat to water quality at GRKO. Mining contamination from tailings includes high concentrations of metals, dissolved solids, and salts that have been distributed throughout the floodplain. All of these contaminants can impact and reduce populations of aquatic organisms, especially ecological indicator species (e.g., macroinvertebrates, fish). Mine tailings can adversely affect water quality over a long period of time. According to the Safe Drinking Water Foundation (SDWF 2009), mine tailings can cause pollution that requires remediation anywhere from decades to centuries. Sudden influxes of residual metals due to heavy rain events are also known to cause fish kills (Lipton et al. 1995).

Nutrient enrichment (e.g., from fertilizer) is another threat to water quality in GRKO. Fertilizers can enter the water after a rain event causing an influx of nutrients (e.g., phosphorous, nitrogen) into the Clark Fork. An excess of nutrients can result in eutrophication, which affects several water quality parameters such as dissolved oxygen, water temperature, and pH (Suplee et al. 2008). To minimize nutrient enrichment from fertilizer, park management has the soil analyzed to determine the exact amount of nutrients the plants will utilize for that growing season. Best Management Practices utilized to prevent runoff include maintaining buffer strips along waterways and fertilizing when the plants are actively growing and will uptake the fertilizer (Smith, written communication, 27 January 2015).

Concerns for point source pollution include the wastewater treatment site for the municipality of Butte (population approximately 34,000) and other smaller cities (e.g., Anaconda) as well as numerous individual septic systems upstream from GRKO. Non-point source pollution concerns include cattle/animal wastes entering the stream as well as runoff due to agricultural irrigation (Mast 2007).

Dewatering is another potential stressor for water quality at GRKO. During the summer months, irrigation ditches divert water from tributaries as well as the main stem of the Clark Fork for crops. Poff et al. (1997) states that when river waters are diverted for human use (e.g., irrigation) the resulting changes in hydrology can affect the survival, reproduction, and migration of biota. For example, dewatering may contribute to the fact that flow in the Clark Fork in August and September is often less than adequate for maintaining a salmonid fishery (USFWS 1998). The effects of dewatering also cause groundwater to become a major source of flow for the Clark Fork during the summer months. Specific conductance in the river increases during this time, as groundwater introduces more dissolved solids into the stream. This effect is due to the groundwater's longer interaction time with rock/soil (Pilgrim et al. 1979).

Drought, which is a natural occurrence that can be exacerbated by human activity, was identified by park staff as a concern. As illustrated by Figure 51, the Palmer Hydrologic Index for the state of Montana shows that Montana experienced severe and extreme drought between 10% and 20% of the time over the last 100 years (MDES 2013). Drought can result in low water levels, which increases metal concentration, influences pH and temperature, and can cause larger amounts of sediment to be released into the river during rain events.

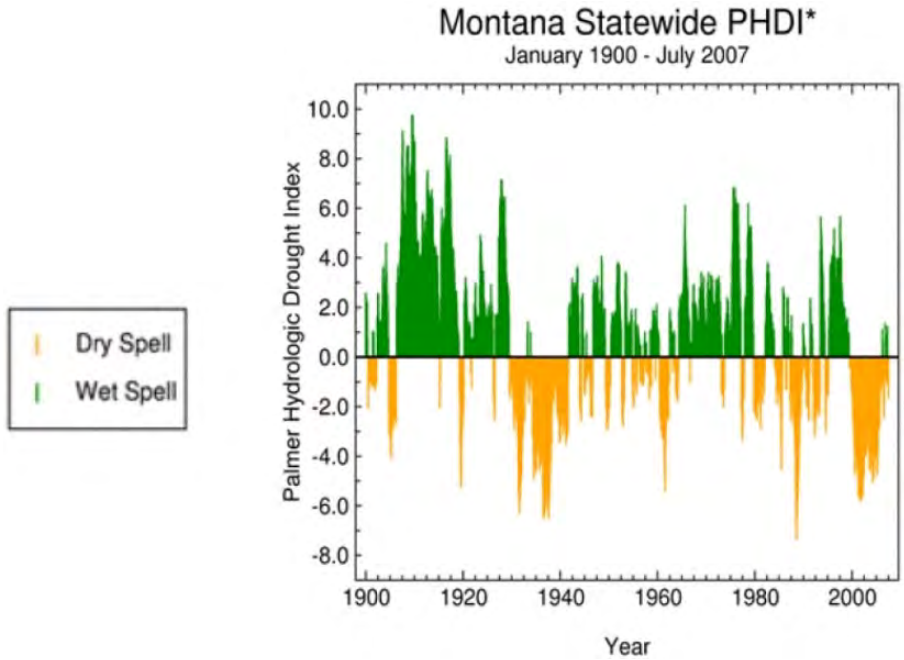


Figure 51. Palmer Hydrologic Drought Index 1997-2007 (reproduced from MDES 2013).

Data Needs/Gaps

Because of the historic impacts of mining and Superfund status of the Clark Fork River area, there are many documents available addressing surface water quality issues around GRKO. However, much less data are available for groundwater quality than for surface water quality, particularly within the last 6-8 years. Data are also limited for TSS and no data could be found for coliform bacteria in GRKO's surface waters.

In the coming years, Superfund remediation activities will be occurring along the Clark Fork riparian zone in GRKO. This will involve the removal of contaminated sediments and soil from the 100-year channel migration zone, followed by backfilling with clean soil and revegetation with native species (Johnson, written communication, 10 February 2015). This will provide an opportunity to study how such efforts impact water quality parameters in both the short and long-term.

Overall Condition

Water Temperature

The project team defined the *Significance Level* for water temperature as a 3. Schweiger et al. (2014) examined existing data as well as collecting new data on water temperature. The authors concluded that the stream temperature was within an acceptable range, but the data suggested temperatures may be on the rise. The authors acknowledge that the length of the sampled data (2001-2010) was short and that more data are needed to increase the confidence level in their conclusion. Therefore, water temperature is presently of low concern (*Condition Level* = 1) but warrants careful monitoring and analysis in the future.

Specific Conductance

The project team defined the *Significance Level* for specific conductance as a 3. The median measurement of specific conductance from 1980-2004 (524 µS/cm) was slightly above the suggested informal threshold of 500 µS/cm (EPA 2007, Schweiger et al. 2014). Over the last 15 years, a trend of decreasing conductivity has been noted at the nearby USGS gauging station (Schweiger et al. 2014). From 2008-2010, the median specific conductance within GRKO, as measured by Schweiger et al. (2014), was 428.3 µS/cm. As a result, specific conductance is of low concern (*Condition Level* = 1).

pH

The project team defined the *Significance Level* for pH as a 3. The pH level of a stream has a profound influence on the biota that inhabit the water. At GRKO, pH appears to be within a natural range of variation. Therefore, pH is of low concern (*Condition Level* = 1).

Total Suspended Sediment

The project team defined the *Significance Level* for total suspended sediment (TSS) as a 3. Montana's administrative rules prohibit any increase in sediment that would be harmful, detrimental, or injurious to public health and welfare, recreation, safety, livestock, or wildlife (MT DEQ 2006). Since no numeric standards exist within the state of Montana and limited data are available for GRKO, a *Condition Level* for TSS was not assigned at this time.

Dissolved Oxygen

The project team defined the *Significance Level* for DO as a 3. The State of Montana established the minimum instantaneous DO concentration for surface waters at 8 mg/L for early life stages of fish, and 4 mg/L for other life stages in class C-1 rivers like the Clark Fork (MT DEQ 2012). Dissolved oxygen in Schweiger et al. (2014) and Atkins et al. (2012) met this reference condition during all sampling events. At present, there is no evidence indicating a cause for concern regarding DO levels (*Condition Level* = 0).

Coliform Bacteria

The project team defined the *Significance Level* for coliform bacteria as a 1. Measures with a *Significance Level* of 1 are not discussed in the current condition section of the text, rather they are briefly summarized in the Overall Condition section. Data regarding coliform bacteria in the park are limited. No measurements for coliform bacteria in GRKO's surface waters could be found. Moore and Woessner (2001) detected coliform bacteria in several groundwater monitoring wells. While most measurements were <1 CFU/100 ml, two records exceeded 500 CFU/100ml. However, given the lack of data, a *Condition Level* for coliform bacteria cannot be assigned at this time.

Nutrients

The project team defined the *Significance Level* for nutrients as a 3. While the majority of median nutrient levels recorded by Schweiger et al. (2014) fell within MT DEQ standards, some maximum values exceeded these standards, and Atkins et al. (2012) documented exceedances for nitrogen and phosphorus at the Deer Lodge station in June 2011. While high nutrient levels have historically been an issue on the Clark Fork, recent work suggests that they are not a major concern at this time (Schweiger et al. 2014). Because of this, nutrients are currently of low concern (*Condition Level* = 1).

Metals
The project team defined the *Significance Level* for metals as a 3. Because of the historic mining activity in the area, as well as the continued presence of metals and trace elements associated with mining, metals continue to be a concern for GRKO. Metals detected in water samples at GRKO include arsenic, cadmium, copper, iron, lead, manganese, and zinc. Because of these continued concerns, metals are of high concern (*Condition Level* = 3).

Weighted Condition Score
The *Weighted Condition Score* for water quality in GRKO is 0.39, meaning the current condition is of moderate concern. The trend in water quality for many parameters appears to be improving slightly over time.

Water Quality			
Measures	Significance Level	Condition Level	**WCS = 0.39**
Water Temperature	3	1	
Specific Conductance	3	1	
pH	3	1	
Total Suspended Sediment	3	n/a	
Dissolved Oxygen	3	0	
Coliform Bacteria	1	n/a	
Nutrients	3	1	
Metals	3	3	

4.9.6 Sources of Expertise
Billy Schweiger, ROMN Ecologist

Jason Smith, GRKO Natural Resource Specialist

Jeff Johnson, GRKO CERCLA Project Manager

4.9.7 Literature Cited

Allan, J. D. 1995. Stream ecology: structure and function of running waters. Chapman and Hall, London, England.

Atkins, Rhithron Associates, Inc., and Montana Fish, Wildlife and Parks. 2012. Monitoring report for 2011: Clark Fork River Operable Unit. Montana Department of Environmental Quality and Montana Department of Justice, Helena, Montana.

Besser, J. M., and K. J. Leib. 2007. Toxicity of metals in water and sediment to aquatic biota. Pages 839-849 *in* Integrated investigations of environmental effects of historical mining in the Animas River Watershed, San Juan County, Colorado. Church, S. E., P. von Guerard, and S. E. Finger (eds.). U.S. Geological Survey, Reston, Virginia.

Britten, M., E. W. Schweiger, B. Frakes, D. Manier, and D. Pillmore. 2007. Rocky Mountain Network Vital Signs monitoring plan. Natural Resource Report NPS/ROMN/ NRR-2007/010. National Park Service, Fort Collins, Colorado.

Dodds, W. K., V. H. Smith, and B. Zander. 1997. Developing nutrient targets to control benthic chlorophyll levels in streams: A case study of the Clark Fork River. Water Research 31(7):1738-1750.

Environmental Protection Agency (EPA). 1996. Sampling ambient water for trace metals at EPA water quality criteria levels. U.S Environmental Protection Agency, Office of Water, Washington, D.C.

Environmental Protection Agency (EPA). 1997. Fecal bacteria: What are fecal bacteria and why are they important? *In* Volunteer stream monitoring: A methods manual. U.S. Environmental Protection Agency, Washington, D.C.

Environmental Protection Agency (EPA). 2004. Clark Fork River Operable Unit of the Milltown Reservoir/Clark Fork River Superfund Site, Record of Decision Part 1: Declaration. U.S. EPA BOI032130003.DOC/KM. U.S. Environmental Protection Agency, Washington, D.C.

Environmental Protection Agency (EPA). 2007. National rivers and streams assessment: Field operations manual. EPA-841-B-07-009. U.S. Environmental Protection Agency, Washington, D.C.

Environmental Protection Agency (EPA). 2009. National recommended water quality criteria. U.S. Environmental Protection Agency, Office of Science and Technology, Washington, D.C.

Environmental Protection Agency (EPA). 2012. Phosphorus. http://www.epa.gov/agriculture/ag101/impactphosphorus.html (accessed 12 June 2014).

Environmental Protection Agency (EPA). 2013. Secondary drinking water regulations: Guidance for nuisance chemicals. http://water.epa.gov/drink/contaminants/secondarystandards.cfm (accessed 12 June 2014).

Environmental Protection Agency (EPA). 2014. Mercury: basic information. http://www.epa.gov/mercury/about.htm (accessed 12 June 2014).

Horstman, M. C. 1984. Historical events associated with the Upper Clark Fork drainage. Montana Department of Fish, Wildlife, and Parks, Helena, Montana.

Lambing, J. H. 1991. Water quality and transport characteristics of suspended sediment and trace elements in streamflow of the Upper Clark Fork Basin from Galena to Missoula, Montana, 1985-90. U.S. Geological Survey, Helena, Montana.

Lipton, J., H. Bergman, D. Chapman, T. Hillman, M. Kerr, J. Moore, and D. Woodward. 1995. Aquatic resources injury assessment report, Upper Clark Fork River Basin. State of Montana, Natural Resource Damage Litigation Program, Helena, Montana.

MacDonald, D. D., C. G. Ingersoll, and T. A. Berger. 2000. Development and evaluation of consensus-based sediment quality guidelines for freshwater ecosystems. Archives of Environmental Contamination and Toxicology 39:20-31.

Mast, M. A. 2007. Assessment of historical water-quality data for National Park units in the Rocky Mountain Network, Colorado and Montana through 2004. U.S. Geological Survey Scientific Investigations Report 2007-5147. U.S. Geological Survey, Reston, Virginia

Mohr, J. 2012. A guide to Montana water quality regulation. Environmental Quality Council, Legislative Environmental Policy Office, Helena, Montana.

Montana Department of Environmental Quality (MT DEQ). 2002. Water-use classifications: Administrative Rules of Montana 17.30.607 to 17.30.611. Montana Department of Environmental Quality, Helena, Montana.

Montana Department of Environmental Quality (MT DEQ). 2006. Surface water quality standards and procedures. Chapter 30, subchapter 6 *in* Administrative rules of Montana: Environmental quality. Montana Department of Environmental Quality, Helena, Montana.

Montana Department of Environmental Quality (MT DEQ). 2012. Montana numeric water quality standards. Circular DEQ-7. Montana Department of Environmental Quality, Water Quality Planning Bureau, Helena, Montana.

Montana Disaster and Emergency Services (MDES). 2013 State of Montana multi-hazard mitigation plan and statewide hazard assessment: 2013 update. http://letsmitigatemontana.com/draft-pdm-plan/ (accessed 20 August 2014).

Moore, J. N., and W. W. Woessner. 2001. Geologic, soil water, and groundwater report - 2000: Grant-Kohrs Ranch National Historic Site. National Park Service, Deer Lodge, Montana.

Mueller, D. K., and D. R. Helsel. 1996. Nutrients in the nation's waters—too much of a good thing? U.S. Geological Survey, Reston, Virginia.

Muir, P. 2012. Oregon State University Online: Eutrophication. http://people.oregonstate.edu/~muirp/eutrophi.htm (accessed 12 June 2014).

Pilgrim, D. H., D. D. Huff, and T. D. Steele. 1979. Use of specific conductance and contact time relations foe separating flow components in storm runoff. Water Resources Research 15(2):329-339.

Poff, N. L., J. D. Allan, M. B. Bain, J. R. Karr, K. L. Prestegaard, B. D. Richter, R. E. Sparks, and J. C. Stromberg. 1997. The natural flow regime. Bioscience 47(11):769-784.

Ramsey, P. W., M. C. Rillig, K. P. Feris, J. N. Moore, and J. E. Gannon. 2005. Mine waste contamination limits soil respiration rates: A case study using quantile regression. Soil Biology and Biochemistry 37:1177-1183.

Robertson, M. J., D. A. Scruton, R. S. Gregory, and K. D. Clarke 2006. Effect of suspended sediment on freshwater fish and fish habitat. Canadian Technical Report of Fisheries and Aquatic Sciences 2644. Fisheries and Oceans Canada, St. John's, Newfoundland and Labrador.

Safe Drinking Water Foundation (SDWF). 2009. Mining and water pollution. http://www.safewater.org/PDFS/resourcesknowthefacts/Mining+and+Water+Pollution.pdf (accessed 4 August 2014).

Schertz, T. L., R. B. Alexander, and D. J. Ohe. 1991. The computer program EStimate TREND (ESTREND): A system for the detection of trends in water-quality data. U.S. Geological Survey Water-Resources Investigations Report, Reston, Virginia.

Schweiger, E. W., L. O'Gan, D. Shorrock, and M. Britten. 2014. Stream ecological integrity at Grant-Kohrs Ranch National Historic Site: Rocky Mountain Inventory & Monitoring Network 2008-2010 stream monitoring report. Natural Resource Technical Report NPS/ ROMN/NRTR—2014/881. National Park Service, Fort Collins, Colorado.

Slack, J. R., and D. L. Lorenz. 2003. USGS library for S-PLUS for Windows, Release 2: U.S. Geological Survey Open-File Report 2003–357. http://pubs.er.usgs.gov/usgspubs/ofr/ofr03357 (accessed 29 December 20014).

Smith, J. D., J. H. Lambing, D. A. Nimick, C. Parrett, M. Ramey, and W. Schafer. 1998. Geomorphology, flood-plain tailings, and metal transport in the Upper Clark Fork Valley, Montana.

Suplee, M. W., V. Watson, A. Varghese, and J. Cleland. 2008. Scientific and technical basis of the numeric nutrient criteria for Montana's wadeable streams and rivers, and addendums. Montana Department of Environmental Quality, Helena, Montana.

Suplee, M. W., and R. Sada de Suplee. 2011. Assessment methodology for determining wadeable stream impairment due to excess nitrogen and phosphorus levels. Montana Department of Environmental Quality, Helena, Montana.

Suplee, M. W., V. Watson, W. K. Dodds, and C. Shirley. 2012. Response of algal biomass to large-scale nutrient controls in the Clark Fork River, Montana, United States.

Suplee, M. W., and V. Watson. 2013. Scientific and technical basis of the numeric nutrient criteria for Montana’s wadeable streams and rivers - Update 1. Montana Department of Environmental Quality, Helena, Montana.

Thornberry-Ehrlich, T. 2007. Grant- Kohrs Ranch National Historic Site: Geologic resource evaluation report, Natural Resource Report NPS/NRPC/GRD/NRR—2007/004. National Park Service, Fort Collins, Colorado.

U.S. Fish and Wildlife Service (USFWS). 1998. A framework to assist in making Endangered Species Act determinations of effect for individual or grouped actions at the bull trout subpopulation watershed scale. U.S. Fish and Wildlife Service, Washington, D.C.

U.S. Geological Survey (USGS). 2014. Water properties and measurements http://water.usgs.gov/edu/characteristics.html (accessed 12 June 2014).

4.10 Soundscape

4.10.1 *Description*

The NPS's mission is to preserve natural resources, including natural soundscapes, associated with the national park units. The definition of soundscape in a national park is the total ambient sound environment of the park, which is comprised of both natural ambient sound and human-made sounds (NPS 2000). Intrusive sounds are of concern to park visitors, as they detract from their natural and cultural resource experiences (NPS 2000). These sounds can also disturb wildlife or livestock, possibly altering their behavior (NPS 2012a). In addition, traffic or other human-caused noises may interrupt interpretive programs being held within a park. According to a survey conducted by the NPS, many visitors come to national parks to enjoy, equally, the natural soundscape and natural scenery (NPS 1994).

Photo 30. Sound monitoring equipment in the field at GRKO (NPS photo).

GRKO has a very unique cultural soundscape, as the soundscape of the park is that of a working ranch (NPS 2012b). The sounds of working ranch hands, whinnying horses, crowing roosters, and cattle activity are essential to GRKO's soundscape.

4.10.2 Measures

- Characteristics of sounds (sound type, sound level)

4.10.3 Reference Conditions/Values

Sound monitoring at GRKO from 2009-2010 (NPS 2012b) established a baseline characterization of the soundscape at the ranch that could be used for comparison in the future. However, this report did not identify any reference or "target" levels for sound characteristics (e.g., type of sound, loudness, duration). Given the mission of the park, sounds will be judged differently depending on their cultural significance; certain sounds are expected on a historic ranch while others are not (e.g., airplanes, semi traffic, motorized construction). Reference conditions for soundscape should determine acceptable and unacceptable levels for these unexpected or "non-contributing" sounds. Regarding sound level (i.e., loudness), the EPA (1974) determined that sounds above 60 dBA interfere with outdoor conversation, and would likely interrupt interpretive programs at the park. For the purpose of this assessment, 60 dBA will be used as a reference condition for sound level for non-contributing sounds. For types of sound, the reference will be to keep the percentage of new sounds (using NPS 2012b as a baseline) that are non-contributing to the cultural landscape and visitor experience below 10% (Christine Ford, GRKO Integrated Resource Program Manager, email communication, 20 August 2014).

4.10.4 Data and Methods

NPS (2012b) conducted baseline sound monitoring for GRKO from March 2009 to March 2010. GRKO staff, Montana State University, and the NPS Natural Sounds and Night Skies Division (NSNSD) worked together to assess seasonal as well as diurnal soundscape characteristics at a site 200 m (656 ft) south and west of the ranch house (Figure 52). Several acoustic instruments were used, including a Larson Davis 831 sound level meter, a calibrated digital audio recorder, a HOBO anemometer, and digital data logging system. Sound pressure levels were graphed for all 12 months during the survey. Montana State University also created a website where samples from the audio recordings can be heard: http://www.coe.montana.edu/ee/rmaher/audio_monitor/grko.htm.

Figure 52. The location of the sampling site in relation to the Ranch House and GRKO Visitor Center (reproduced from NPS 2012b).

4.10.5 Current Condition and Trend

Characteristics of Sounds

Types of Sounds

NPS (2012b) documented both natural and anthropogenic sounds within the ranch. Natural sounds can be divided into biologic and geologic categories. Biologic sounds include horses, cattle, birds, coyotes (*Canis latrans*), frogs, and insects. The ranch has several working horses (draft, quarter) that are used daily to perform chores throughout the ranch. Some geologic sounds included flowing water, rustling grass, wind, and storms. Common anthropogenic sounds at GRKO included highway traffic from I-90, which occurred almost all the time, railroad traffic, and ranching activity (trucks and tractors, cowboys performing their daily activities, etc.). Most of the railroad traffic during monitoring was for remediation purposes, and was transporting contaminated soil from a nearby portion of the Clark Fork Superfund site (NPS 2012b). Currently, typical railroad traffic consists of two trains through the ranch per day (Johnson, written communication, 17 October 2014). Other anthropogenic sounds that could be heard on the ranch were airplanes, sirens from the city, car horns honking, and the back-up warning beeps from vehicles (park and public). Some of these anthropogenic sounds are expected and contribute to the cultural experience, while others are non-contributing. Non-contributing sounds are those that would not have occurred during the ranching era (i.e., late 19th and early 20th centuries).

NPS (2012b) also documented diurnal and seasonal tendencies in sounds. Higher activity and sound levels from dawn until dusk were caused by animals on the farm, wildlife, and an increase in anthropogenic sounds, such as the cowboys, cars, trains, and planes. Low activity was seen after dusk, with some geologic sounds still occurring such as wind, water, and storms, as well as the occasional car, plane, and train.

Sound Level (Loudness)

NPS (2012b) documented monthly sound levels including minimum, average, and maximum sound pressure levels (1 sec Leq[dBA]) from March 2009 to March 2010 (Figure 2). Average sound levels varied throughout the seasons; two examples of sound level graphs from different seasons are shown below (Figure 53). During the winter, the average sound level tended to remain below 40 dBA, whereas in summer months the average sound level regularly surpassed 40 dBA. Maximum sound levels rarely exceeded 80 dBA during most of the year; however, during the summer months they occasionally approached 90 dBA. Sound levels, on average, were higher in late summer (July, August). The loudest sound (95 dBA) came from a natural occurrence (thunder clap) in the month of July (Figure 53).

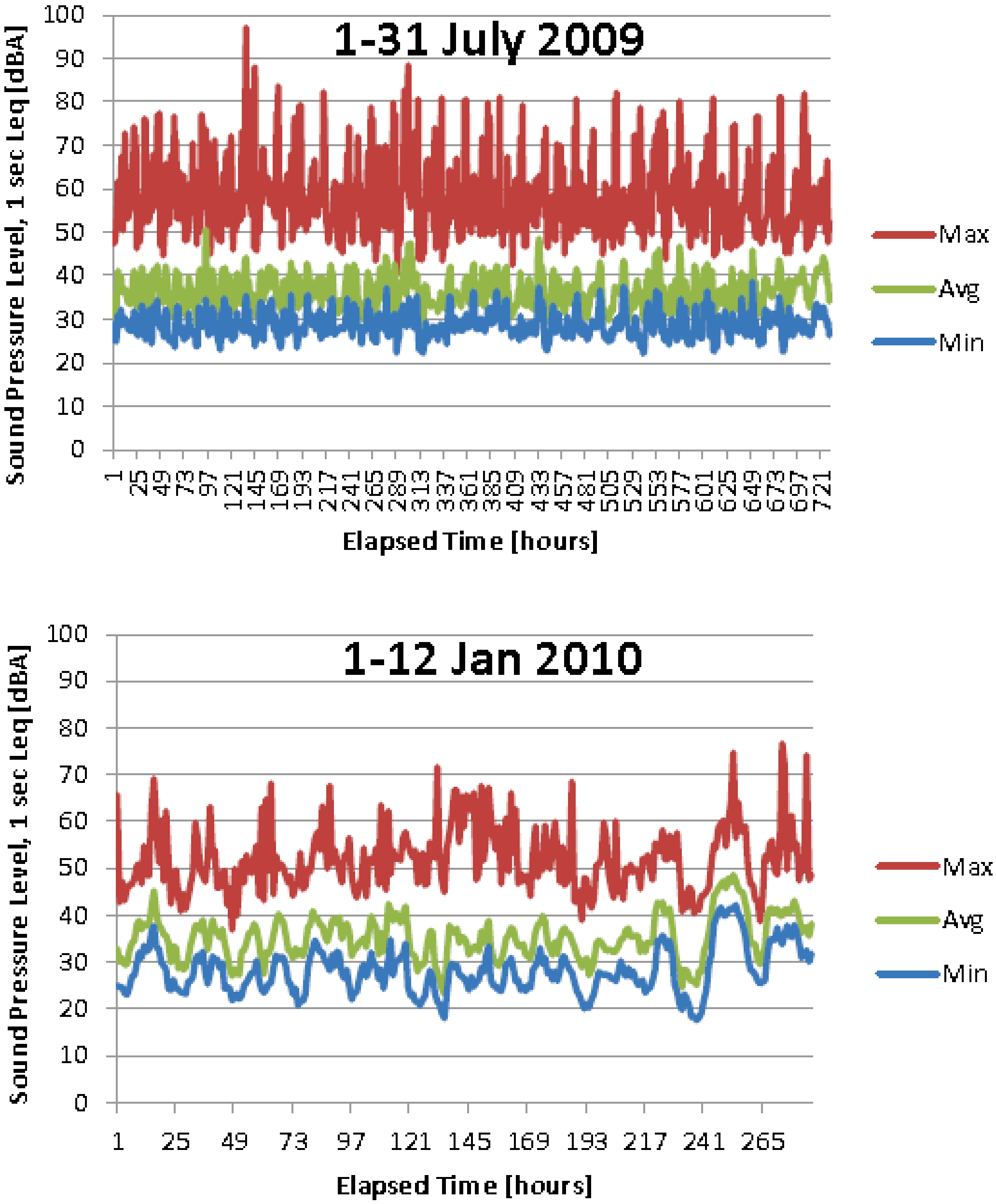


Figure 53. Sound pressure level graphs from the months of July and January at GRKO (from NPS 2012b).

<u>Threats and Stressor Factors</u>

GRKO park staff identified several threats to the ranch's cultural soundscape. The threats include increased airport traffic, increased train traffic, increased interstate traffic (semis), Superfund remediation activities, ranch construction activities, and increased development outside of the park. The Deer Lodge-City-County airport is a major threat to GRKO soundscape. The airport is less than 1.6 km (1 mi) away from the southern border of the ranch (Figure 54). According to AirNav (2014), there was an average of 78 aircraft operations a week in 2013. Local general aviation was the most common operation, occurring 43% of the time; approximately 37%, 12%, and 7% of operations were transient general aviation, air taxi, and military operations, respectively. In 2012, there was a proposal to establish the Deer Lodge-City-County airport as Class E (controlled) airspace (DOT 2012). The expansion of the airport may cause an increased number of annual aircraft operations that cause natural and cultural sounds to be drowned out or even decrease (NPS 2008, 2012b). In addition, individuals with private jets and helicopters have purchased land near GRKO that was once a large ranch (NPS 2012b). This may increase air travel over the ranch.

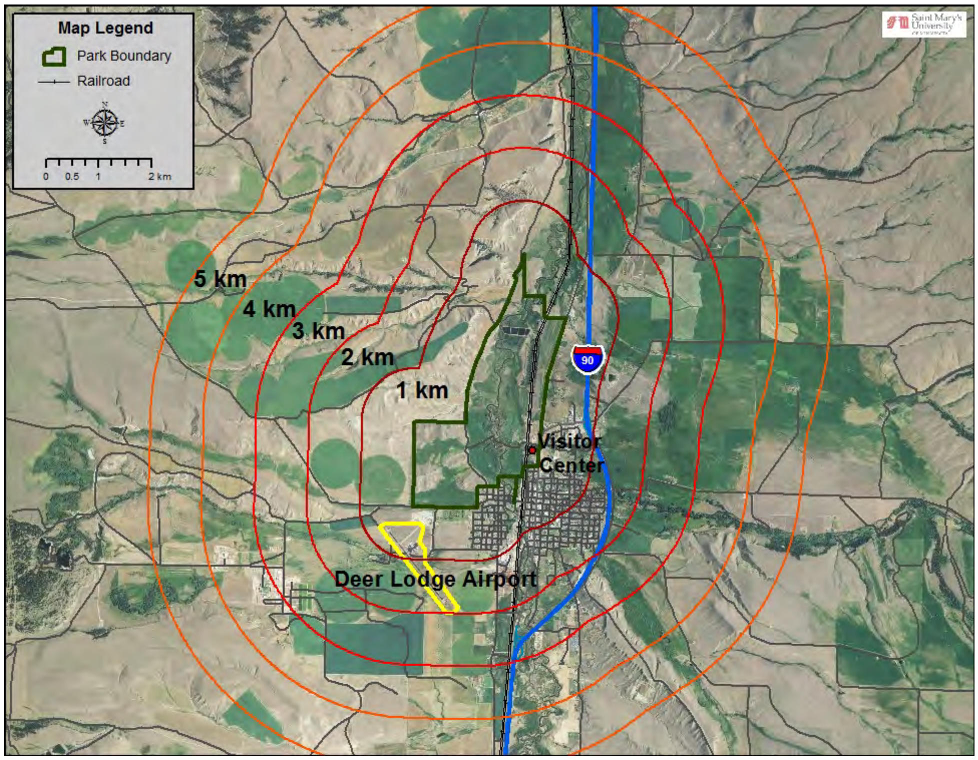


Figure 54. Location of the airport, railroad, and interstate in relation to GRKO.

Increased traffic, both train and interstate, is another threat to the soundscape in GRKO. Train tracks run through the eastern portion of the park, while the interstate runs near the eastern border (Figure 54). Train traffic has increased considerably due to the transportation of contaminated soil from the Milltown Dam remediation site (NPS 2012b). In the next 2 years, Superfund remediation activities will be taking place along the Clark Fork within GRKO. Anthropogenic sounds will increase during this time, as the cleanup will involve heavy construction equipment and trucks. This increased activity is estimated to last approximately 18 months (Johnson, written communication, 17 October 2014).

Increased development near the park is another threat to soundscape. In the past 10-20 years, commercial and residential development has occurred just east of the ranch, particularly around the I-90 exit ramp. This contributes to the increase in traffic and general anthropogenic sounds, as well as noise from machinery during construction.

Data Needs/Gaps

There are no long-term soundscape data for GRKO. NPS (2012b) conducted a baseline monitoring report for the park from March 2009 to March 2010. The continuation of annual measurements of sound levels and sound recordings is essential in the management of GRKOs cultural soundscape. An additional focus on the frequency and duration of non-contributing sounds or the percent of time they are audible would also be useful.

It may be helpful for GRKO to create a soundscape management plan or integrate soundscape into other planning documents. This would clearly outline contributing and non-contributing sounds, and set acceptable levels for the loudness, frequency, and duration of non-contributing sounds. Separate targets could be set for day and nighttime hours and for different seasons. Several parks in the NPS have completed these plans or written soundscape sections in other management plans and could be used as models (Denali National Park and Preserve [NPS 2006], Guadalupe Mountains National Park [NPS 2009], Zion National Park [NPS 2010]).

<u>Overall Condition</u>

Characteristics of Sounds
The project team defined the *Significance Level* for characteristics of sounds as a 3. Many of the sounds heard at GRKO contribute to the cultural experience expected on a ranch, such as livestock, ranch hands working, bird song, and wind rustling in the grass. Other sounds, including airplanes and interstate traffic, would not be expected in a ranch setting. Interstate traffic is audible at almost all hours at the ranch. NPS (2012b) data indicated the average sound level is often below 40 dBA in the winter months and frequently above 40 dBA in the summer months. Occasional levels exceeding 90 dBA are common in the summer months. While maximum sound levels regularly exceeded the 60 dBA reference condition, average sound levels only rarely passed this threshold; NPS (2012b) did not indicate whether these louder sounds were from contributing or non-contributing sources. Based on the data that is currently available, this measure is assigned a *Condition Level* of 1.

Weighted Condition Score
A *Weighted Condition Score* of 0.33 was assigned to GRKO soundscape, which is on the boundary between good condition and moderate concern. Given the serious concern over increases in unnatural anthropogenic sounds such as airplanes and increased traffic on the railroad and interstate, the overall condition of soundscape at GRKO is considered of moderate concern with a declining trend.

Soundscape			
Measures	Significance Level	Condition Level	**WCS = 0.33**
Characteristics of Sounds (Sound Level, Sound Type)	3	1	

4.10.6 Sources of Expertise

Christine Ford, GRKO Integrated Resources Program Manager

4.10.7 Literature Cited

AirNav LLC (2014). FAA information effective 03 April 2014. Deer Lodge-City_County Airport. http://www.airnav.com/airport/38S (accessed 30 July 2014).

Department of Transportation (DOT). 2012. Proposed rules. Federal Register 77(137):41939-41940. http://www.gpo.gov/fdsys/pkg/FR-2012-07-17/pdf/2012-17282.pdf (accessed 30 July 2014).

Environmental Protection Agency (EPA). 1974. Information on levels of environmental noise requisite to protect public health and welfare with an adequate margin of safety. Environmental Protection Agency, Office of Noise Abatement and Control, Washington, D.C.

National Park Service (NPS). 1994. Report on effects of aircraft overflights on the National Park System. National Park Service, Fort Collins, Colorado.

National Park Service (NPS). 2000. Directors order #47: Soundscape preservation and noise management. http://www.nps.gov/policy/DOrders/DOrder47.html (accessed 7 April 2014).

National Park Service (NPS). 2006. Denali National Park and Preserve: Final backcountry management plan. National Park Service, Denali Park, Alaska.

National Park Service (NPS). 2008. Grant-Kohrs Ranch National Historic Site: Foundation for planning and management. National Park Service, Deer Lodge, Montana.

National Park Service (NPS). 2009. Resource stewardship strategy: Guadalupe Mountains National Park. National Park Service, Guadalupe Mountains National Park, Texas.

National Park Service (NPS). 2010. Soundscape management plan: Zion National Park. http://www.nps.gov/zion/parkmgmt/upload/ZNP-Soundscape-Plan_Sep_2010.pdf (accessed 7 August 2014)

National Park Service (NPS). 2012a. Effects of noise. http://www.nature.nps.gov/sound/effects.cfm (accessed 27 August 2014).

National Park Service (NPS). 2012b. Baseline sound monitoring at Grant Kohrs Ranch NHS. Final Report. Montana State University, Bozeman, Montana.

4.11 Viewscape

4.11.1 Description

For this assessment, viewscape refers to the visible natural and cultural features on the landscape in GRKO. A viewshed is the area that is visible from a particular location or set of locations, often developed using GIS analysis tools. Two datasets are required to calculate a viewshed using GIS: a digital elevation model (DEM) and point or polyline data defining points from which a person would be viewing a landscape. With the defined data, GIS software determines visibility to and from a particular cell or set of cells in a DEM, resulting in a viewshed layer. This viewshed layer is a raster that defines the visible area on the landscape from the point or set of points contained within an outline of a polygon. Analyzing layers that identify areas of undesirable impacts on the landscape within viewsheds creates a quantitative description of visual stress on a viewshed; repeating this process for multiple viewshed layers in a pre-defined landscape, such as a national park, provides a quantitative description of stress across the viewscape in the area.

Photo 31. Westward view of the mountains from a trail on the southeast side of GRKO (Photo by Sarah Gardner, SMUMN GSS 2013).

Multiple studies indicate that people prefer natural compared to developed landscapes (Sheppard 2001, Kearney et al. 2008, Han 2010). The National Park Service Organic Act (16 U.S.C. l) implies the need to protect the viewscapes of national parks, monuments, and reservations. At GRKO, cultural landscape viewing is a primary visitor activity. GRKO natural vistas include open fields with foothills and mountains in the distance (John Milner Associates et al. 2004). Cultural views include complexes of historical structures and equipment, corrals, and ranching operations (John Milner Associates et al. 2004).

4.11.2 Measures

- Change in land use cover type inside the park (internal viewscape)
- Change in land use cover type outside the park (external viewscape)
- Change at selected photo points

4.11.3 Reference Conditions/Values

The reference condition for viewscape is the condition of views and vistas contributing to cultural landscape significance, as documented in the GRKO cultural landscape report (John Milner Associates et al. 2004).

4.11.4 Data and Methods

GRKO park staff provided historic aerial photos of GRKO from 6 different years over time. These photos were from 1947, 1960, 1972, 1979, 1983, and 2001. All of the aerial photos cover only a portion of the park and its surroundings, but do not all cover the same area with the exception of the 2013 NAIP imagery (retrieved from the NRCS Geospatial Data Gateway), which covers the entire United States (NRCS GDG 2014). As a result, only 3 years (1947, 1972, 2013) were used to display any changes in development in and surrounding GRKO over time. Aerial photos from before (1947), during (1972), and after (2013) park establishment were used to illustrate historic conditions and post-park establishment conditions. There were three areas (A, B, C) south and east of the park that were analyzed (Figure 55).

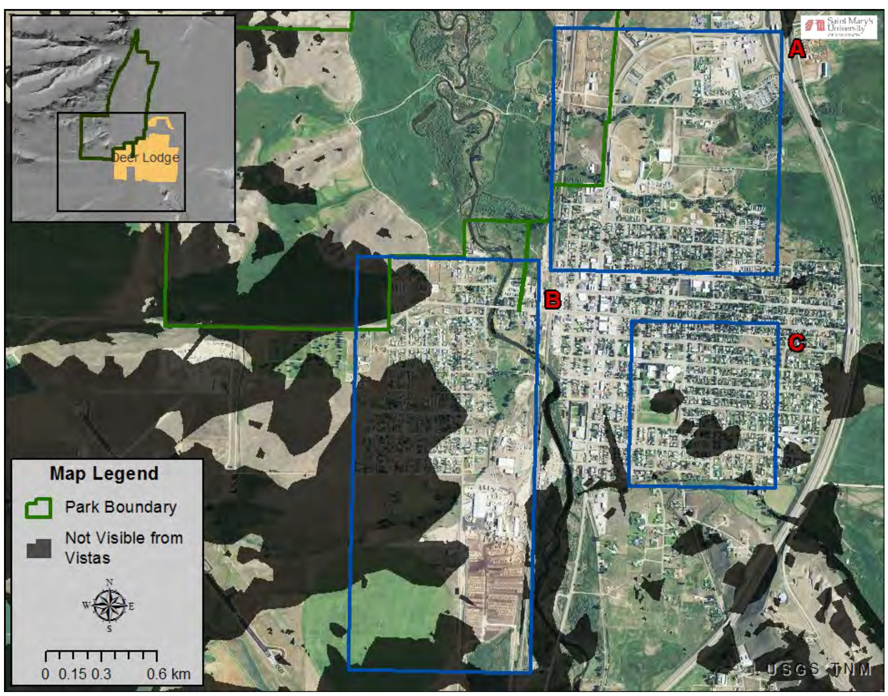


Figure 55. Locations of the three areas (A, B, C) with the most visible change in development between 1947 and 2013.

Historic photos from the early 1900s were provided by GRKO, to compare with photos from similar vantage points taken in 2002 and 2014. The photos from 2002 were obtained from GRKO's cultural landscape report (John Milner Associates et al. 2004). Photos from 2014 were taken by park staff to aid in this assessment.

John Milner Associates et al. (2004) prepared a cultural landscape report (CLR) for GRKO. The report includes a landscape history and description of existing conditions. There are nine landscapes described in this report, each with a vista representing that landscape. The landscapes include the home ranch complex, east feed lot/Warren Hereford Ranch, Grant-Kohrs Residence, Warren Residence, pasture and hayfields, upland pasture, riparian woodland, railroad corridor, and development zone. Descriptions of each landscape are also included. Photo points were added to the report and were coupled with two photos (one from the late 1800s to early 1900s and another from 2002) to compare change over time.

Park staff identified six observation points and four trails of interest within the park for analysis in this NRCA: four comparative points from the CLR (12, 13, 22, and 36), the Ranch House back porch, the River Bridge, Outer Loop Road, Bridge Road, Ridge Road, and the old County Road (Figure 56). For each of these points or lines, a viewshed was calculated using ESRI's Spatial Analyst Viewshed Tool in ArcGIS 10.2, which requires point or polyline GIS data (representing the viewing location) and a DEM. For each of the observation points, a point shapefile was created for use with the Viewshed Tool. For line features, a polyline was created; the Viewshed Tool uses each vertex in the line to determine the viewshed of the feature as a whole. The DEM used was the 1/3-arc second National Elevation Dataset (NED) DEM. A 1.7 m (5.5 ft) offset was applied to each observation point shapefile to account for average human height. The result of the operation is a theoretical viewshed layer that represents the visible area from a point without correcting for visibility factors (e.g, vegetation, smoke, humidity, heat shimmer, or curvature of the earth).

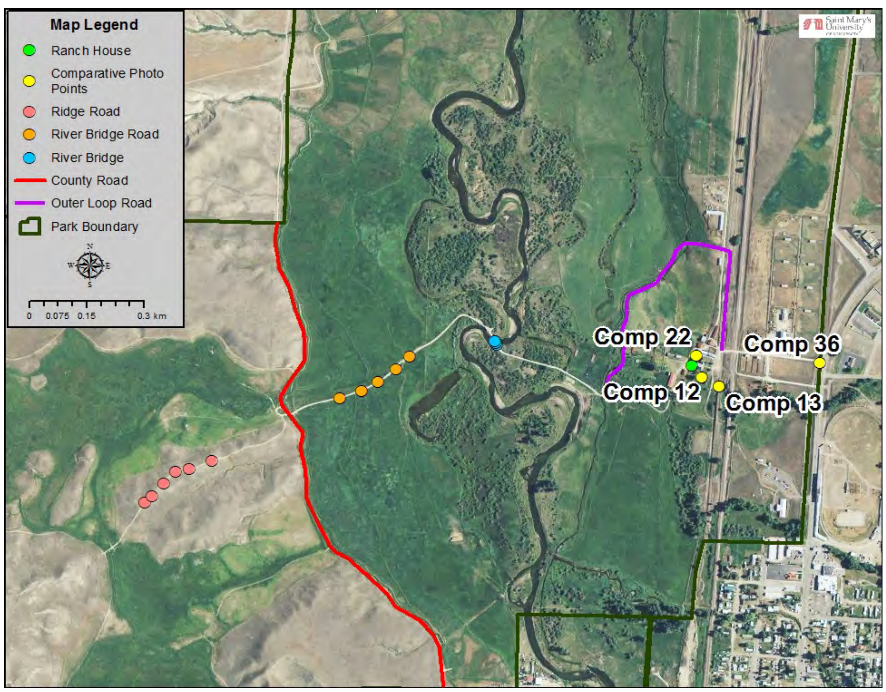


Figure 56. Locations of the 10 selected viewing areas in GRKO.

In summary, two raster layers were developed for this analysis: an internal viewshed layer and an external viewshed layer. The internal viewshed layer represents the area of the park visible from the 10 selected viewing areas in the park. The external viewshed layer represents the areas outside the park boundary that are visible from high-use viewing areas inside the park.

4.11.5 Current Condition and Trend

A composite viewshed was created by combining the 10 high-use viewing areas in the park in an effort to define the most viewable areas of the study region. This analysis was combined with a 10-m DEM used in the viewshed analysis to produce an output defining the most viewable areas of the region (Figure 57). However, the viewable area is limited, as some of the viewsheds would have returned viewable areas beyond the extent of the DEM. Figure 57 displays the composite viewshed, which displays which areas in and around the park cannot be seen, areas that can only be viewed from one vista, and areas that can be seen from multiple vistas.

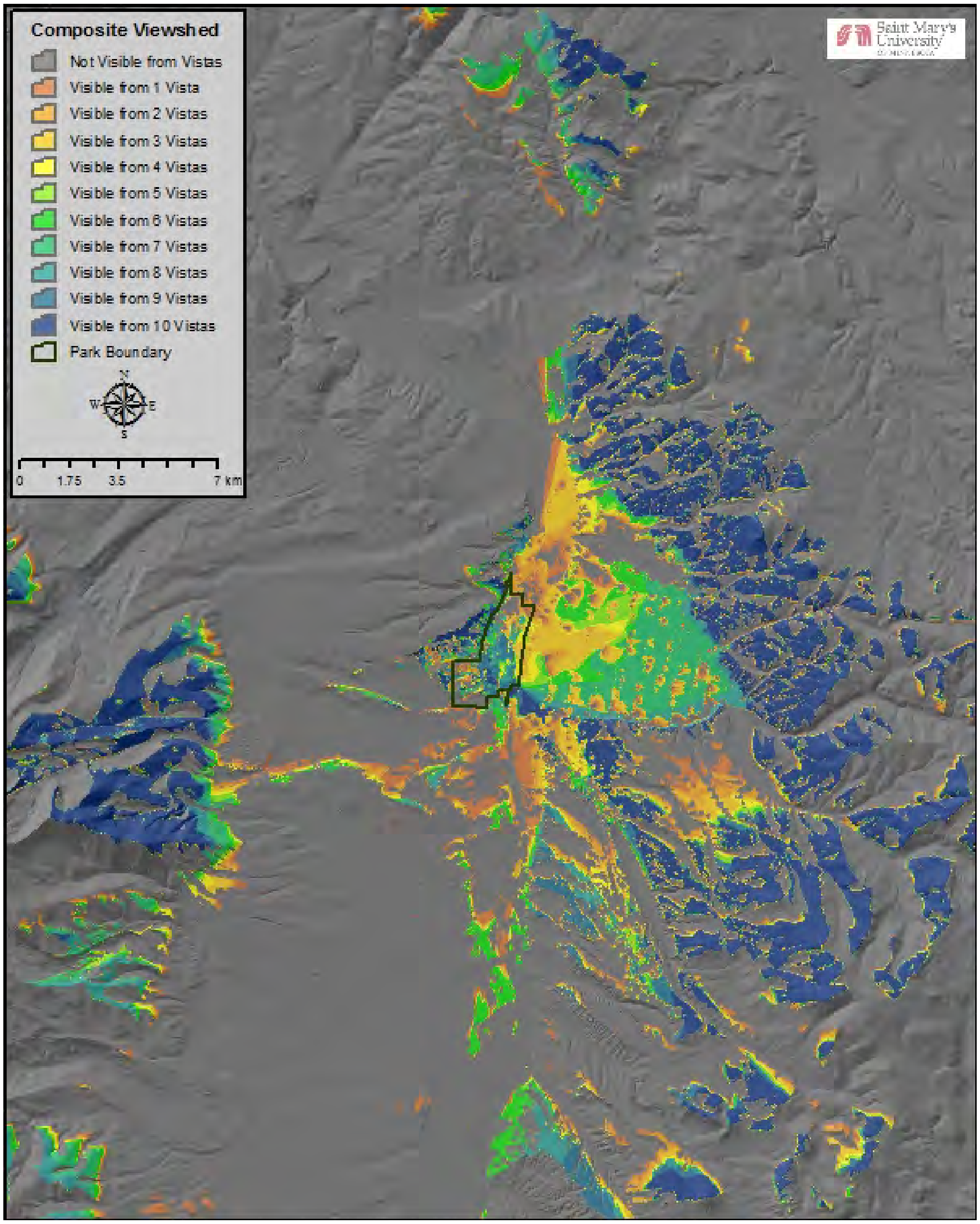


Figure 57. Composite viewshed using vistas in GRKO.

<u>Change in Land Use Cover Type Inside the Park (Internal Viewscape)</u>

Ten observation points were used to determine the internal viewshed of GRKO. The resulting total visible area from the observation points was 495 ha (1,223 ac), about 78% of the park's total area. Most of the area not visible from these points is near the southwest border and in the northern portion of the park.

The primary 2011 National Landcover Database (NLCD) landcover classes viewable within GRKO are Pasture/Hay and Grassland/Herbaceous, at 25% each (Table 60; Jin et al. 2013). The Pasture/Hay class is dominated by grasses, legumes, and grass-legume mixtures. Grazing and production of hay crops are the uses for the Pasture/Hay classification (MRLC 2014). Graminoids dominate the Grassland/Herbaceous class. This herbaceous vegetation accounts for approximately 80% of the total vegetation in the landcover class. These areas "are not subject to intensive management such as tilling, but can be utilized for grazing" (MRLC 2014, p. 1). Figure 58 displays the visible land cover classifications in and around GRKO.

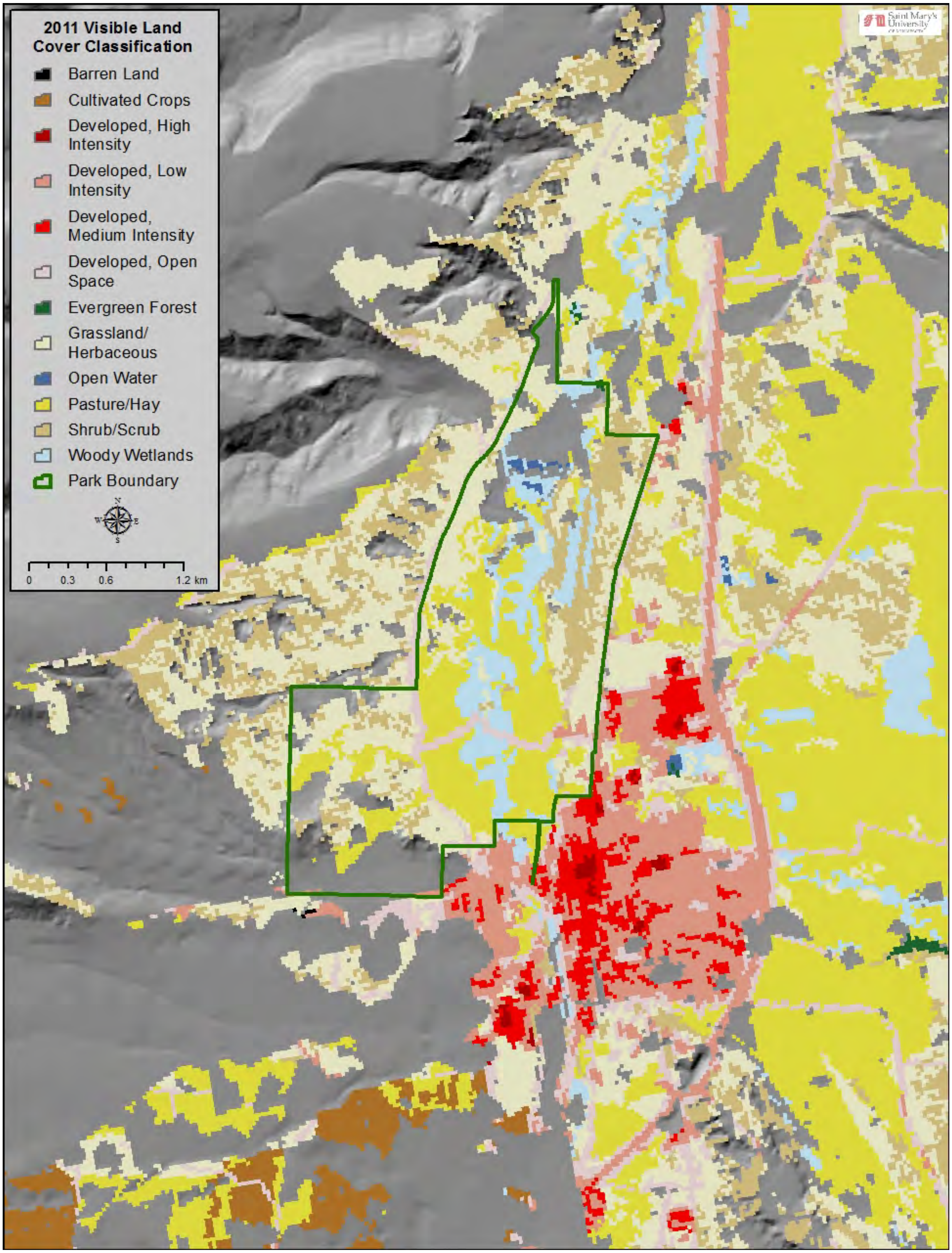


Figure 58. Landcover classification of visible areas in and around GRKO (Jin et al. 2013).

Table 60. 2011 NLCD viewable landcover composition in GRKO (Jin et al. 2013).

Landcover Classification	Hectares	Percent Land Cover
Pasture/Hay	165.7	25
Grassland/Herbaceous	159.39	25
Not Visible	143.1	22
Woody Wetlands	86.8	13
Shrub/Scrub	71.7	11
Developed, Open Space	24.8	4
Developed, Low Intensity	3.9	<1
Open Water	2.61	<1
Evergreen Forest	0.3	<1

Analysis of NLCD change data indicates very little change within the internal viewshed from 2001 to 2011; approximately 32 ha (79 ac) changed over that time (about 6% of total visible area from the observation points) (Table 61). Only three land cover classifications changed in the park between 2001 and 2011 (Pasture/Hay, Shrub/Scrub, Woody Wetlands). The largest area of change occurred near the western border, changing from the Pasture/Hay classification to Grasslands/Herbaceous classification. All areas that changed in the park were converted to the Grasslands/Herbaceous classification. Figure 59 displays the changes in the park's internal landcover between 2001 and 2011.

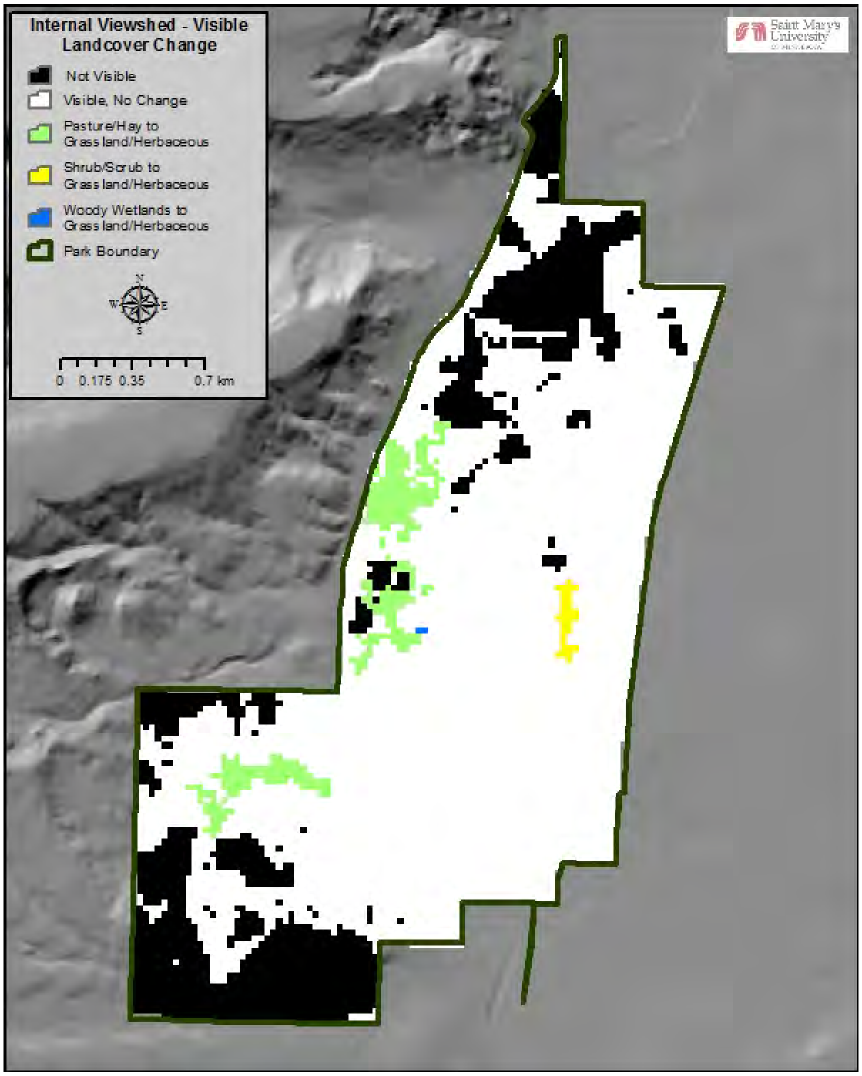


Figure 59. Internal viewshed analysis. Visible landcover change in GRKO between 2001 and 2011 (Jin et al. 2013).

Table 61. NLCD landcover change in GRKO between 2001 and 2011 (Jin et al. 2013).

Landcover Change Type	Hectares	Percent Visible Areas
Visible, but No Change	484	94
Pasture/Hay to Grassland/Herbaceous	28	6
Shrub/Scrub to Grassland/Herbaceous	3	<1
Woody Wetlands to Grassland/Herbaceous	<1	<1

Change in Land Use Cover Type Outside the Park (External Viewscape)

Similar to the internal viewshed, the external viewshed changed little between 2001 and 2011 according to the NLCD change product. Within 25 km (15.5 mi) of the park, 43,137 ha (106,593 ac) were identified as visible from the viewpoints established for the park; of these, approximately 730 ha (1,804 ac) experienced a change in landcover classification (about 2%). A majority of this change (419 ha [1,035 ac]) was from Evergreen Forest to Shrub/Scrub (Figure 60). The Shrub Scrub landcover class includes, "areas dominated by shrubs; less than 5 meters tall with shrub canopy typically greater than 20% of total vegetation. This class includes true shrubs, young trees in an early successional stage, or trees stunted from environmental conditions" (MRLC 2014, p. 1). About 116 ha (287 ac) of area changed to Grassland/Herbaceous landcover within 24 km (62 mi) of the park boundary. Approximately 17 ha (42 ac) of the visible area changed to developed area, with much of this developed area being the High Intensity designation (i.e., areas where people reside or work in high numbers, more than 80% impervious surfaces [MRLC 2014]). Unlike the internal viewshed of the park, the primary NLCD cover class in the external viewshed is the Evergreen Forest designation. Appendix L provides a complete listing of designation changes between 2001 and 2011.

Aerial photos were used to display the change in development in and around GRKO. The three areas that were used displayed the most change in development between 1947 and 2013 (Figure 55).

Area A

Over the last 65 years, development occurred in and around the eastern border of the park. The changes that occurred inside the park between 1947 and 1972 included the addition of the Warren Hereford complex (square corrals, Warren barn, sales barn, bull corral, and office building) (Figure 61). Between 1972 and 2013 the visitor center and walking path from the visitor center to the ranch house complex was created. The major change that occurred outside the park was the expansion of North Main Street, looping east toward Interstate 90, between 1972 and 2013. Residential and commercial buildings were developed after the addition of this road. More residential development occurred south and east of Little Joe E-70 Park.

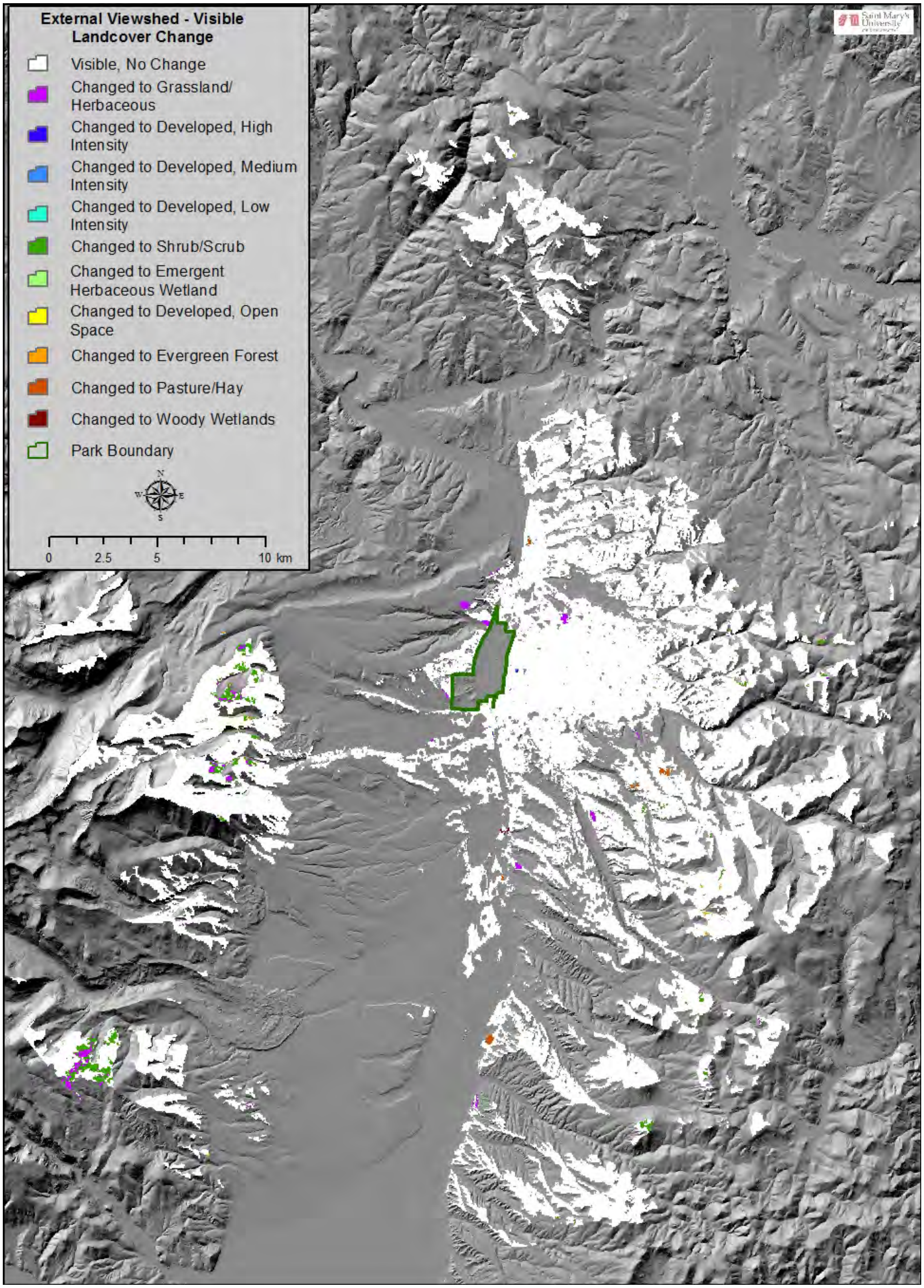


Figure 60. External viewshed analysis. Visible land cover change in areas surrounding GRKO between 2001 and 2011 (Jin et al. 2013).

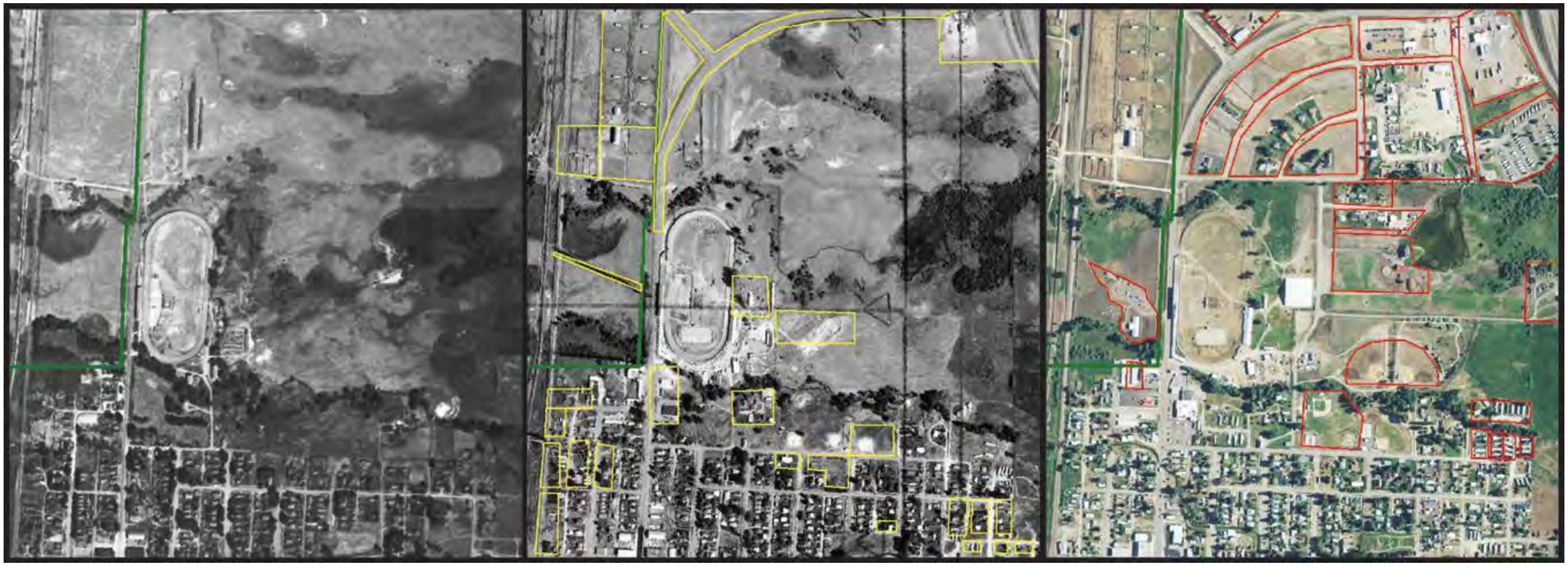


Figure 61. Aerial photos of Area A in 1947 (left), 1972 (middle), and 2013 (right). The yellow and red polygons represent areas within Area A that changed from 1947 to 1972 and from 1972 to 2013, respectively.

Area B

Development occurred around the southern border of the park. Most of the changes in development between 1947 and 1972 were residential expansion. Residential areas continued to expand throughout the northern portion of Area B between 1972 and 2013. A lumber yard (located in the southern portion of Area B) may have been present in 1947; however, it is more prevalent in the 1972 photo and has expanded greatly by 2013. Figure 62 displays the changes in development in Area B in 1947 (left), 1972, (middle), and 2013 (right).

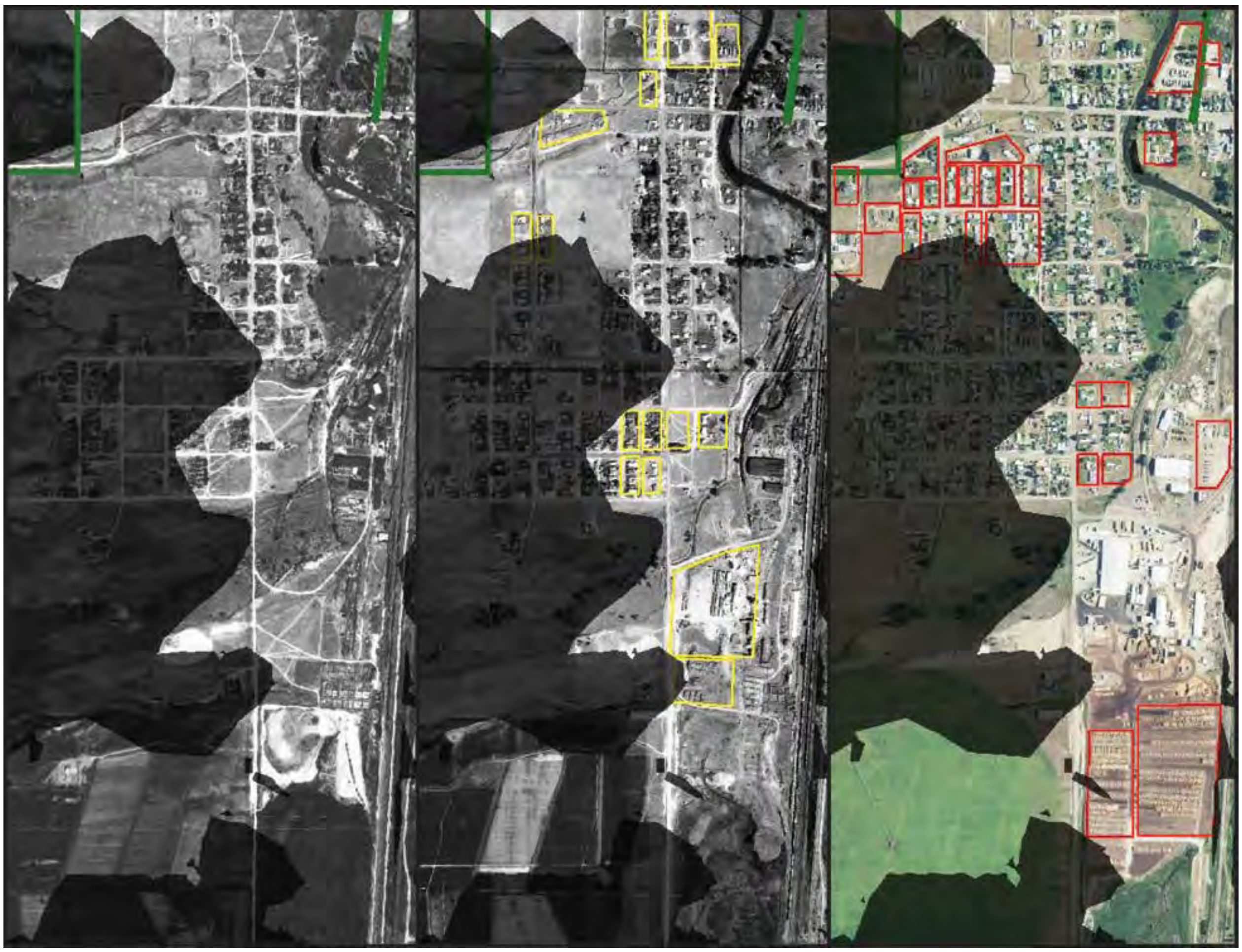


Figure 62. Aerial photos of Area B in 1947 (left), 1972 (middle), and 2013 (right). The yellow and red polygons represent areas within Area B that changed from 1947 to 1972 and from 1972 to 2013, respectively. The dark gray shaded areas are not visible from the selected viewpoints

Area C

Development also occurred to the southeast of the park. In 1947, this area was relatively open with patches of residential areas. By 1972, most of the open fields were filled in with residential homes. Cottonwood City Park, an elementary school, and a junior high school were also built (located just north of the park's track). By 2013, barely any open fields remained due to the construction of more residential homes. Figure 63 displays the changes in development in Area C in 1947 (left), 1972, (middle), and 2013 (right).

Figure 63. Aerial photos of Area C in 1947 (left), 1972 (middle), and 2013 (right). The yellow and red polygons represent areas within Area C that changed from 1947 to 1972 and from 1972 to 2013, respectively. The dark gray shaded areas are not visible from the selected viewpoints.

Change at Selected Photo Points

Comparative Point 12

This vista consists of the south side of the ranch house and thoroughbred barn. Photo 32 displays the view from comparative point 12 in the early 1900s (top left), 2002 (top right), and 2014 (bottom). There have been several changes in viewscape at comparative point 12 from 1900 to 2014. Between the early 1900s and 2002, the vegetation blocking the view of the fence in the foreground and white building in the background thinned out considerably. Cottonwood trees seem to dominate the vegetation in the background in 2002 and are still present in 2014. Shrubs seen in the field in 2002 have grown several feet by 2014. All historic structures remained constant throughout the time period with the exception of changes made to the fence by 2014. Figure 64 displays the location of each selected photo point and the direction that photo is facing.

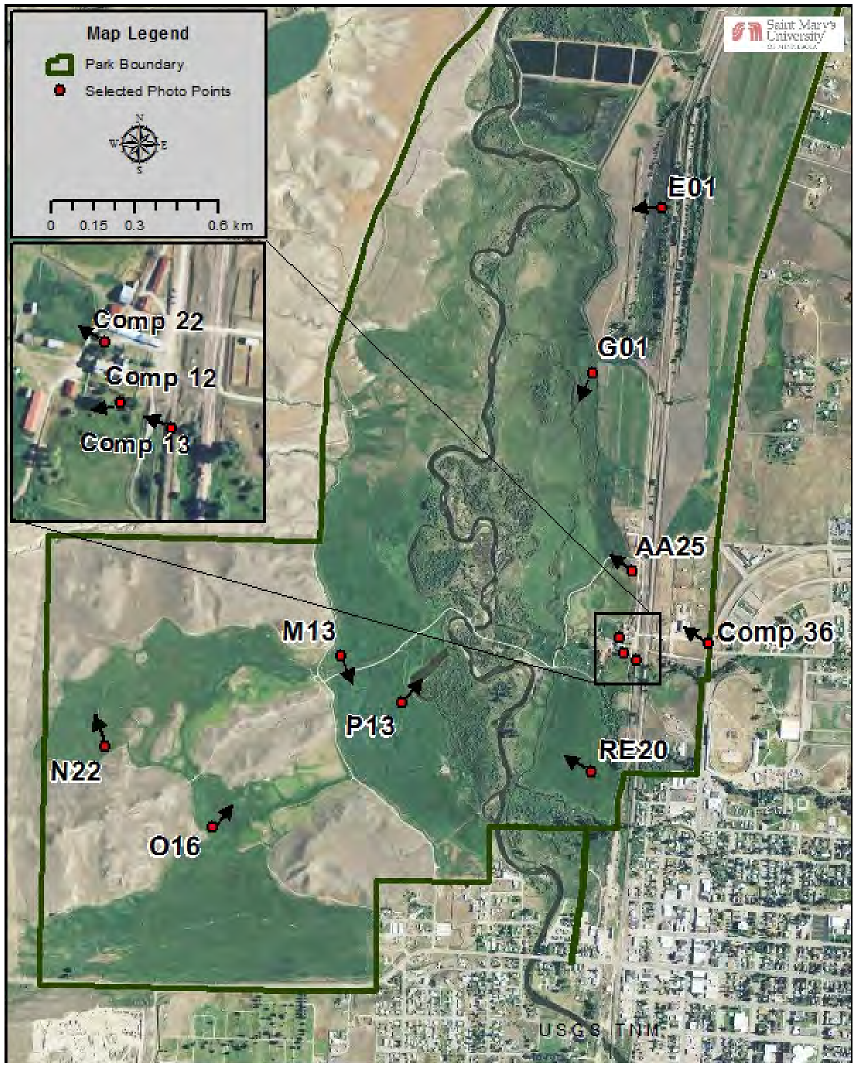


Figure 64. The location of each selected photo point in GRKO, and the direction each photo is facing.

Photo 32. The view from comparative point 12 in the early 1900s (top left), 2002 (top right), and 2014 (bottom) (NPS photos).

Comparative Point 13

This vista contains the general view of the ranch. There have been several changes in viewscape at comparative point 13 from 1900 to 2014 (Photo 33). A visible footpath was present in the early 1900s, but that path was no longer distinguishable by 2002. This cultural viewscape was not compromised by power lines in the early 1900s. In 2002, the power lines in front of the ranch house are blocked by trees; however, the vegetation blocking the power lines from view were removed by 2014. Several power lines are visible from this vista. Vegetation in the field seems to have only changed by natural succession between 2002 and 2014.

Photo 33. The view from comparative point 13 in the early 1900s (top left), 2002 (top right), and 2014 (bottom) (NPS photos).

Comparative Point 22

This vista looks west toward the Lower Yards. There has been little change in viewscape at this vista. Throughout the years the road has become more pronounced. In the early 1900s, the road seemed to be more of a dirt trail. By 2002, gravel was put down to make the trail more permanent and easily accessible to motorized vehicles as well as horses. The cultural structures have remained constant between the early 1900s and 2014. There are no pronounced changes in vegetation at this vista. Photo 34 displays the view from comparative point 22 in the early 1900s (top left), 2002 (top right), and 2014 (bottom).

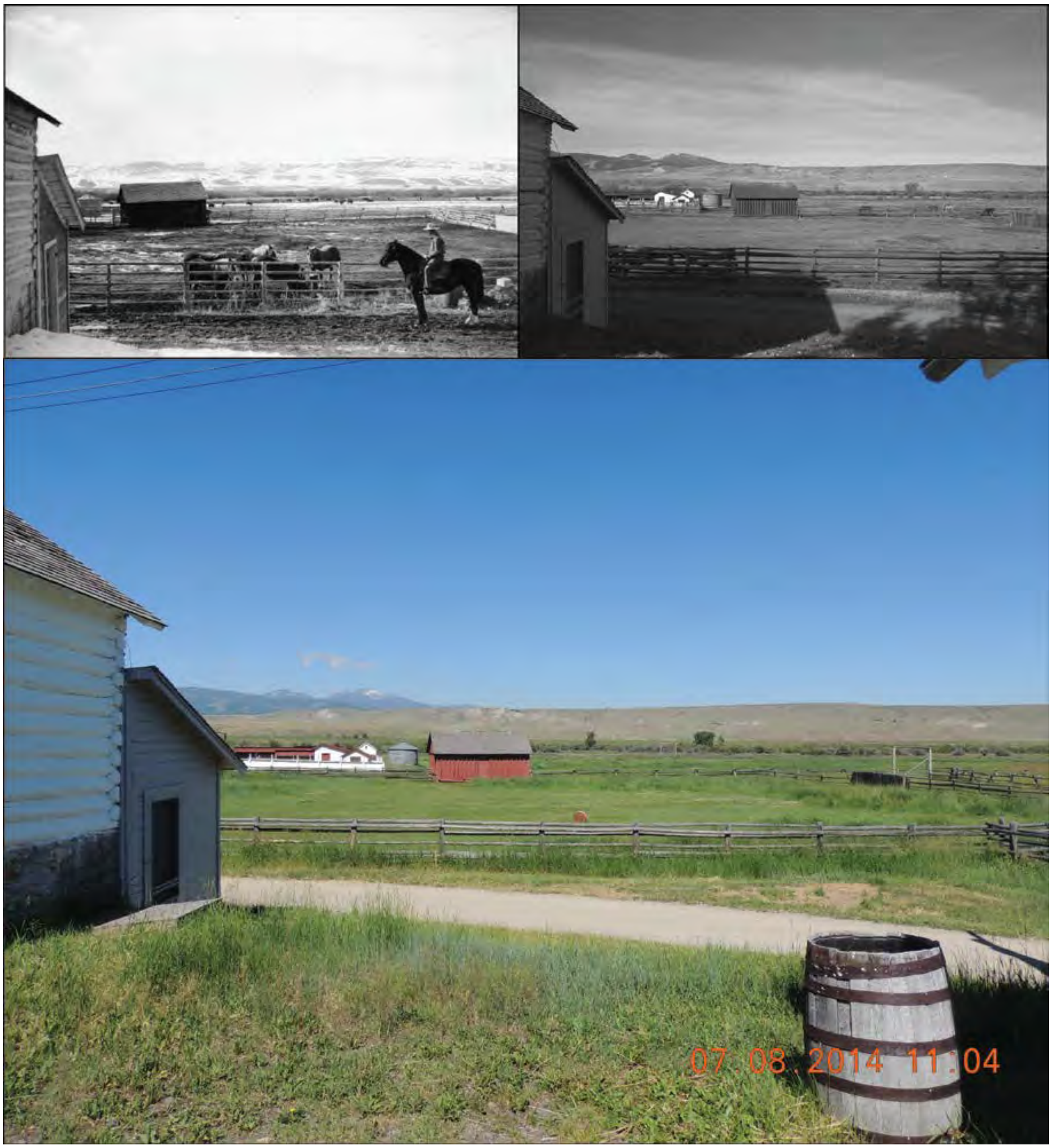


Photo 34. The view from comparative point 22 in the early 1900s (top left), 2002 (top right), and 2014 (bottom) (NPS photos).

Comparative Point 36

This vista is of the Warren Hereford Ranch sign and barn from the administrative entrance. Photo 35 displays the view from comparative point 36 in the early 1900s (top left), 2002 (top right), and 2014 (bottom).There were a few changes in viewscape at this vista. Throughout the years, additions were made to the entrance and fence line, which do not appear to adversely affect the cultural viewscape. There seems to be little change to the vegetation, but two trees were removed between the 1900s and 2002. Power lines can easily be seen in the 2002 and 2014 photos. The presence of cars and the parking lot may also take away from cultural view in the 2014 photo.

Photo 35. The view from comparative point 12 in the early 1900s (top left), 2002 (top right), and 2014 (bottom) (NPS photos).

RE 20

This vista is a westward-facing view of Stuart Field. The vista has not changed much between 2002 and 2014. A photo from the early 1900s was not available for comparison at this vista. The top posts on the fence gates are the only noticeable change in the structure between 2002 and 2014. The path that worked its way through Stuart Field in 2002 is not visible in 2014. The vegetation has not changed much between 2002 and 2014. This vista does not seem to have been adversely affected by development. Photo 36 displays the view from vista RE 20 in 2002 (left) and 2014 (right).

Photo 36. The view from vista RE 20 in 2002 (left) and 2014 (right) (NPS photos).

G 01

This vista is a view of the North Meadows. There was little to no change in cultural viewscape at this vista. The fence has had no visible change between 2002 and 2014. The vegetation throughout the photo has not changed. The vegetation to the left of the fence seems to be denser in 2014, but this could be due to the time of year the photo was taken. Overall, the viewscape from this vista looks unaffected by noncontributing features. Photo 37 displays the view from vista G 01 in 2002 (left) and 2014 (right).

Photo 37. The view from vista G 01 in 2002 (left) and 2014 (right) (NPS photos).

M 13
This vista is of Kohrs Ditch Road. There was little to no change in cultural viewscape at this vista. The road has become more pronounced and filled in with gravel since 2002. The tree line to the left of the road seems to have filled in since 2002. Overall, the viewscape from this vista looks unaffected by noncontributing features. Photo 38 displays the view from vista M 13 in 2002 (left) and 2014 (right).

Photo 38. The view from vista M 13 in 2002 (left) and 2014 (right) (NPS photos).

O 16
This vista is the view from Little Gulch Field looking east towards the ranch complex. Vegetation composition and height seem to be the main change at this vista. The taller vegetation in the 2014 picture may be a result of the time of year the photo was taken. Developed areas were visible in 2002 and remain visible in 2014. The developed area has not noticeably expanded during the time difference. Overall, the viewscape from this vista looks unaffected by newly-developed, noncontributing features. Photo 39 displays the view from vista O 16 in 2002 (left) and 2014 (right).

Photo 39. The view from vista O 16 in 2002 (left) and 2014 (right) (NPS photos).

N 22
This vista is of the Upland Pasture area. The unpaved trail that was present in 2002 remains unpaved in 2014. The vegetation seems to be similar (in height and density) in 2002 and 2014. There are no noncontributing features visible from this vista. Overall, the viewscape from this vista has experienced little change. Photo 40 displays the view from vista N22 in 2002 (left) and 2014 (right).

Photo 40. The view from vista N 22 in 2002 (left) and 2014 (right) (NPS photos).

P 13
This vista is of a 91 m (300 ft) long slough (fed by three natural springs) located to the west of the river. Developed areas to the east of the park can be seen in both years. There does not seem to be a visible change in development. Riparian vegetation conceals a large portion of development from this vista. Aquatic and terrestrial vegetation has not changed much from 2002 to 2014. Overall, this vista does not seem to have changed much over the last 12 years. Photo 41 displays the view from vista P 13 in 2002 (left) and 2014 (right).

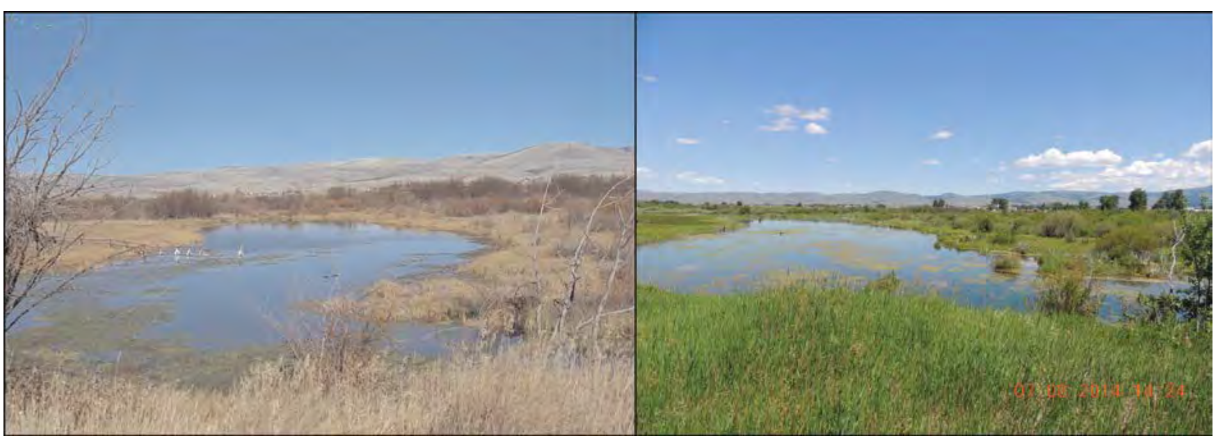


Photo 41. The view from vista P 13 in 2002 (left) and 2014 (right) (NPS photos).

E 01

This is a view of the barrow pits wetland in the park. A power line was the only non-contributing feature at this vista, and it has been there since 2002. The body of water seems to have widened between 2002 and 2014 (Photo 42), although this may be natural variation. The vegetation in the area has not changed much in height or distribution. The beaver lodge in the 2002 photo cannot be seen in the 2014 photo because these are similar vantage points of the same vista, not the exact same location. Overall, the vista has not been altered nor has it been affected by additional non-contributing features since 2002.

Photo 42. The view from vista E 01 in 2002 (left) and 2014 (right) (NPS photo).

<u>Threats and Stressor Factors</u>

GRKO park staff identified several threats that impact the park's cultural and natural viewscape. Those threats include gravel mining located south of the park, invasive species, Superfund remediation activities, development, and the conspicuousness of non-contributing features.

Development is a major concern to viewscape in GRKO. According to McChristian (1977), modern development occurring on the west slope of the valley is a major threat to the cultural viewscape. The park is located just west of the city of Deer Lodge. It is difficult not to see noncontributing features from within the park, and the city continues to develop, as seen in the external viewshed analysis using NLCD data.

The conspicuousness of non-contributing features is another threat to the GRKO viewscape. Noncontributing features include any manmade structure that might detract from the cultural structures in the park. Non-contributing features inside the park include power lines and poles established within the last 25 years, blue watering troughs, the gravel parking area, the parking area by the visitor center, and the asphalt side walk leading from the visitor's center to the home ranch complex (John Milner Associates et al. 2004). Noncontributing features that can be seen from the park include the city structures, such as the arches associated with McDonald's fast food restaurant (less than a mile away). Most development is occurring to the south and east of the park. A scenic easement in the northern section of the park protects the cultural viewscape to the north (John Milner Associates et al. 2004). There is another easement (Five Valleys Trust Easement) to the west of the park, located on the Rock Creek Ranch, which was established in 2006 (Smith, written communication, 14 November 2014).

Gravel mining occurring to the south of the park is a threat to the viewscape at GRKO. There is an active gravel mine located south of Taylor Field within the Deer Lodge airport (Smith, written communication, 14 November 2014). Sand and gravel mining degrade the aesthetic feel of viewscapes (Ayenagbo et al. 2011). Abandoned mines may have mounds of aggregate left over, making the viewscape look unnatural and disturbed. Some abandoned mines do naturalize but vegetation succession takes time and there is no guarantee that natural plant communities will grow back (TOARC 2014). Mining can also degrade air quality by generating particulates (i.e., dust), which may decrease the visibility of the viewscape (Blodgett 2004).

Invasive plant species are a threat to the GRKO viewscape. Invasive species, not intentionally planted, are considered noncontributing features that adversely affect the historical and cultural vegetative composition (John Milner Associates et al. 2004). These species can produce different colors and textures on the landscape than the native plants and intentionally cultivated grasses.

Superfund remediation activities will impact the GRKO viewscape starting in late 2015. Remediation will completely alter the riparian corridor, removing vegetation along with contaminated soils. The taller vegetation in this area blocks a majority of the developed city areas from view at the vistas located on the west side of the river. Large, unvegetated areas may be visible for months at a time due to this removal. The heavy equipment used in these activities will also likely be visible from portions of the ranch. The restored area will be replanted with a variety of grasses, shrubs, and trees to restore it to a natural setting. The estimated duration for the remediated area to fully recover is greater than 10 years (Johnson, written communication, 14 November 2014).

Data Needs/Gaps

The data gap that exists is the lack of historic photos. Only four of the 12 selected photo points have historic photos from the early 1900s. Unfortunately, these may be difficult or impossible to obtain at this stage. Additional historic aerial photos (e.g., from the 1990s or mid-2000s) could be helpful in documenting development just outside the park that has impacted its viewscape.

Overall Condition

Change in Land Use Cover Type Inside the Park (Internal Viewscape)

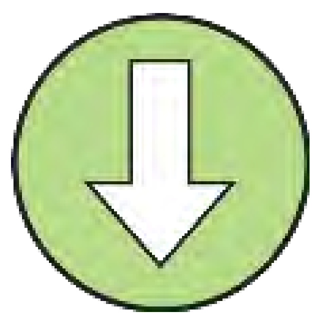
The *Significance Level* for change in land use cover type inside the park was defined as a 3. The internal viewscape analysis using NLCD data indicated very little change within the internal viewshed from 2001 to 2011. Approximately 32 ha (79 ac) changed over that time, which accounts for 6% of total visible area from the selected observation points. There were only three land cover classifications that changed in the park between 2001 and 2011 (Pasture/Hay, Shrub/Scrub, Woody Wetlands). All areas that changed in the park shifted to the Grasslands/Herbaceous classification. As a result, the *Condition Level* of this measure is 0, indicating no concern.

Change in Land Use Cover Type Outside the Park (External Viewscape)

The *Significance Level* for change in land use cover type outside the park was also defined as a 3. Similar to the internal viewshed, the external viewshed changed little between 2001 and 2011. Of the 43,137 ha (106,593 ac) visible from selected viewpoints within 25 km of the park, approximately 730 ha (1,804 ac) experienced a change in classification (about 2%). Some of the visible area directly west of the park that experienced change was converted to low intensity developed area. As a result, the *Condition Level* of this measure is 1, indicating low concern.

Change at Selected Photo Points
The *Significance Level* for change at selected photo points was also defined as a 3. Most of the selected photo points displayed little change over time. Those points with photos that date back to the early 1900s, however, documented the addition of noncontributing features. Those features include power lines and poles, gravel parking lots, cars, and more developed roads. As a result, the *Condition Level* of this measure is 1, indicating low concern.

Weighted Condition Score
The *Weighted Condition Score* for the component is 0.22, indicating viewscape is in good condition overall. The external viewscape and aerial photos display a growing city of Deer Lodge. This increase in development surrounding GRKO suggests a declining trend for viewscape.

Viewscape			
Measures	Significance Level	Condition Level	**WCS = 0.22**
Change in Land Use Cover Type Inside the Park (Internal Viewscape)	3	0	
Change in Land Use Cover Type Outside the Park (External Viewscape)	3	1	
Change at Selected Photo Points	3	1	

4.11.6 Sources of Expertise
Jason Smith, GRKO Natural Resource Specialist

4.11.7 Literature Cited

Ayenagbo, K., J. N. Kimatu, J. Gondwe, and W. Rongcheng. 2011. The transportation and marketing implications of sand and gravel and its environmental impact in Lome-Togo. Journal of Economics and International Finance 3(3):125-138.

Blodgett, S. 2004. Environmental impacts of aggregate and stone mining. Center for Science in Public Participation. http://www.csp2.org/files/reports/Environmental%20Impacts%20of%20Sand%20and%20Gravel%20Operations%20in%20New%20Mexico.doc.pdf (accessed 25 June 2014).

Han, K-T. 2010. An exploration of relationships among responses to natural scenes. Scenic beauty, preference and restoration. Environment and Behavior 42(2):243–270.

Jin, S., L. Yang, P. Danielson, C. Homer, J. Fry, and G. Xian. 2013. A comprehensive change detection method for updating the National Land Cover Database to circa 2011. Remote Sensing of Environment 132:159 – 175.

John Milner Associates, Rivanna Archaeological Consulting, Susan Maxman and Partners Architects. 2004. Cultural landscape report. Grant-Kohrs Ranch National Historic Site, Deer Lodge, Montana.

Kearney, A. R., G. A. Bradley, C. H. Petrich, R. Kaplan, S. Kaplan, and D. Simpson-Colebank. 2008. Public perception as support for scenic quality regulation in a nationally treasured landscape. Landscape and Urban Planning 87:117–128.

McChristian, D. C. 1977. Ranchers to rangers: An administrative history of Grant-Kohrs Ranch National Historic Site. Rocky Mountain Cluster, National Park Service. http://www.nps.gov/history/history/online_books/grko/adhi/adhi7b.htm (accessed 21 August 2014).

Multi-Resolution Land Characteristics Consortium (MRLC). 2014. National Land Cover Database 2006 product legend. http://www.mrlc.gov/nlcd06_leg.php (accessed 21 August 2014).

Natural Resource Conservation Services (NRCS), Geospatial Data Gateway (GDG). 2014. 2013 NAIP imagery. United States Department of Agriculture. http://datagateway.nrcs.usda.gov/ (accessed 15 September 2014).

Sheppard, S. R. J. 2001. Beyond visual resource management: emerging theories of an ecological aesthetic and visible stewardship. Pages 149-172 *in* Sheppard, S. R. J., and H. W. Harshaw (eds.). Forests and landscapes: Linking ecology, sustainability and aesthetics. CABI Publishing, New York, New York.

The Ontario Aggregate Resource Corporation (TOARC). 2014. Management of abandoned aggregate properties program (MAAP). http://www.toarc.com/maap-1/about-maap.html (accessed 25 June 2014).

4.12 Hydrology

4.12.1 Description

The Clark Fork River is an important resource for GRKO. The river and its hydrogeologic system is a primary resource at GRKO and it also protects a small portion of the upper Clark Fork River drainage (Thornberry-Ehrlich 2007). The river is integral to many of the on-going ecological processes within the ranch, as well as playing an important role in current ranching operations (Schweiger et al. 2014). GRKO also holds multiple water-right claims to use surface water from the river and its tributaries for flood irrigation (John Milner Associates et al. 2004).

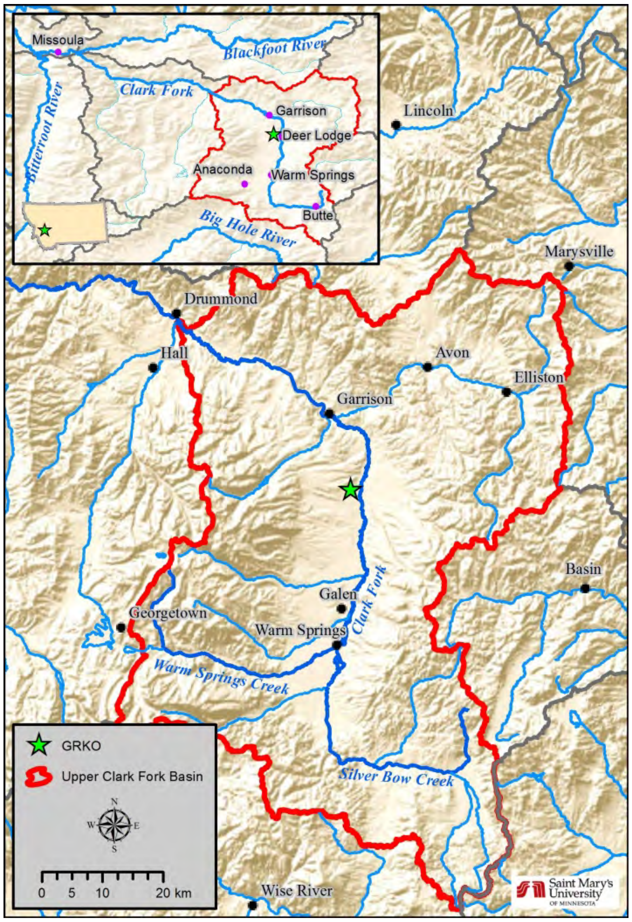


Figure 65. Location of Clark Fork River in western Montana.

The Clark Fork River near the Idaho border is the largest stream in Montana (MT DNRC 2004). Its headwaters are located in west-central Montana at the confluence of Silver Bow and Warm Spring Creeks (Figure 65). GRKO is located along a 238 km (148 mi) reach of the Clark Fork that stretches from its headwaters near Butte, Montana to the former headwaters of the Milltown Reservoir near Bonner, Montana just upstream from Missoula, Montana (Dodge et al. 1996). This reach drains a watershed (Upper Clark Fork) of approximately 4,856 km² (875 mi²) (Hornberger et al. 1997). From its headwaters, the Clark Fork flows generally northward through the wide and meandering floodplain of the Deer Lodge Valley with an average gradient of 3.8 m/km [0.7 ft/mi] (Schweiger et al. 2014). Primary surface water use within the watershed includes irrigation, stock watering, light industry, hydroelectric power generation, and habitat for trout fisheries. Land use within the watershed consists primarily of cattle production, logging, mining and recreation (Dodge et al. 1996). Large-scale mining and smelting had historically been a major land use, but are now largely discontinued (Dodge et al. 1996).

GRKO is located along a 5.5 km (3.4 mi) section of the Clark Fork River within the Upper Clark Fork watershed (Figure 66). The Ranch is located downstream from the town of Deer Lodge between Cottonwood Creek to the south and Fred Burr Creek to the north (Figure 66). Within the boundaries of GRKO there are six small tributary creeks and nine natural springs that feed into the Clark Fork River (John Milner Associates et al. 2004). The Clark Fork bisects GRKO north to south. The

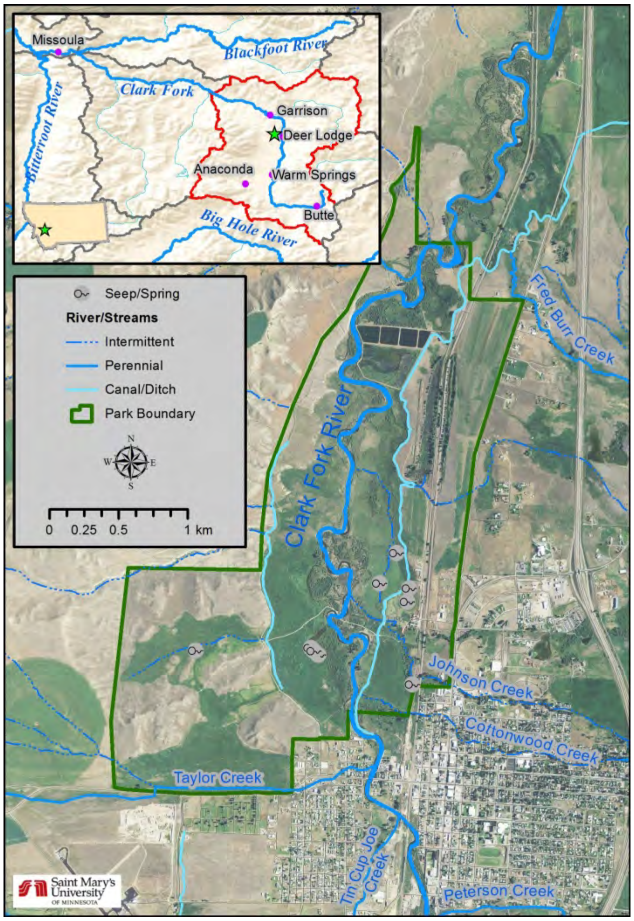


Figure 66. Location of Clark Fork River at GRKO.

domestic buildings and buildings associated with cattle ranching operations are located to the east while the west side of the river consists of pastures and hayfields.

GRKO is located along a reach of the Clark Fork River that has been given a beneficial use classification of C-1 (MT DEQ 2012). This is defined as suitable for the following uses: primary contact recreational use (bathing, swimming, and recreation); growth and propagation of salmonid fishes and their associated aquatic life, waterfowl, and furbearers; and agricultural and industrial water supply (MT DEQ 2006). This reach is also on the 303(d) list for the State of Montana (MT DEQ 2012). It is designated as not supporting for aquatic life, cold water fishery, and primary contact recreational use. This is primarily the result of impairment from mine tailings, causing elevated copper, lead, and zinc concentrations, and agriculture and municipal point-source discharge, which have resulted in elevated nitrogen, phosphorus, and sediment concentrations (MT DEQ 2014a).

4.12.2 Measures

- Stream discharge
- Irrigation flow inputs
- Timing and amount of precipitation
- Depth to groundwater

4.12.3 Reference Conditions/Values

The reference condition for stream discharge is defined as the average hydrograph conditions that were derived for the period of 1980-2012 by Schweiger et al. (2014). The reference condition for precipitation is the historic record from a cooperative weather station located near Deer Lodge, MT. The reference condition for depth to groundwater is based on a report on water resources conditions at GRKO by Woessner and Johnson (2001). A reference condition could not be established for irrigation flow inputs.

4.12.4 Data and Methods

The information for this assessment was gathered primarily from hydrologic data developed by several prior studies on the contamination to the surface water and ground water from the Clark Fork Superfund Site (e.g., Hornberger et al. 1997, Schweiger et al. 2014). Stream discharge information for stream gauge 12324200, located in the Clark Fork River near Deer Lodge, Montana was obtained from the USGS Water Information System website (http://waterdata.usgs.gov/mt/nwis/inventory?search_site_no=12324200). This station has a continuous record of discharge data from water year 1979 to the present. Precipitation data was obtained from the Western Regional Climate Center website (http://www.ncdc.noaa.gov/oa/ncdc.html) for the Deer Lodge 3W station. Historic data was also available for another station at Deer Lodge, Montana that was incorporated to analyze the period of record.

4.12.5 Current Condition and Trend

Stream Discharge

Discharge monitoring data is available from a USGS stream gage station located in the Clark Fork River near Deer Lodge, MT (Station Number 12324200). A continuous discharge record is available from water year 1979 to the present. A hydrograph based on mean monthly discharge over this period is shown in Figure 67. The hydrograph for the gauging station reflects the general conditions found in the Clark Fork River above Missoula, Montana. Stream discharge remains relatively stable from fall to early winter (October - January) with little variation in monthly discharge during the period of record for these months (Hornberger et al. 1997). During the months of February and March, stream flow begins to increase as a result of increased runoff from snow melt in the lower elevations (Hornberger et al. 1997). The months of April and May mark a transitional period between winter and summer. Precipitation can be in the form of rain or snow, but it tends to contribute little to overall stream flow, as the ground is generally thawed and the water can infiltrate (Hornberger et al. 1997). Stream flow increases during this period as a result of snow melt in the mid-elevations and can be augmented by some high-elevation snow melt (Hornberger et al. 1997). Peak flow can occur during this period, if temperatures are warmer than normal and the snow pack melts earlier than normal (Hornberger et al. 1997). Peak flow generally occurs in late May or early June, as a result of rainfall and snow melt in the high-elevations. Stream discharge declines during July and August as a result of warmer daily temperatures and less frequent and less intense precipitation events, and also because of irrigation withdrawals (Hornberger et al. 1997). The combination of the end of the irrigation season and late summer precipitation events result in increased discharge levels in September (Hornberger et al. 1997).

Schweiger et al. (2014) created a 30-year normal (1980 - 2010) discharge dataset for the gaging station at Deer Lodge. This data, and data for every water year on record, are summarized in Table 62. Mean annual discharge during the 30-year period averaged 2,507 cubic meters per second (cms) (88,538 cubic feet per second [cfs]). Minimum daily mean discharge was 1.7 cms (61 cfs) with a maximum daily discharge of 67.7 cms (2,390 cfs). The highest peak flow on record (67.7 cms [2,390 cfs]) occurred on 23 May 1981 (USGS 2014b). The lowest peak flow recorded was 0.6 cms (22 cfs) this occurred on two occasions, 22 April 1988 and 8 June 1991 (USGS 2014b). Figure 68 is a graph of the daily flows for the period of record. There is a slightly negative trend (i.e., a decrease in flow) over the historical record. A previous study (Schweiger et al. 2014) calculated this as a marginal ($p = 0.13$) negative trend of 0.05 cms/year (1.72 cfs/year).

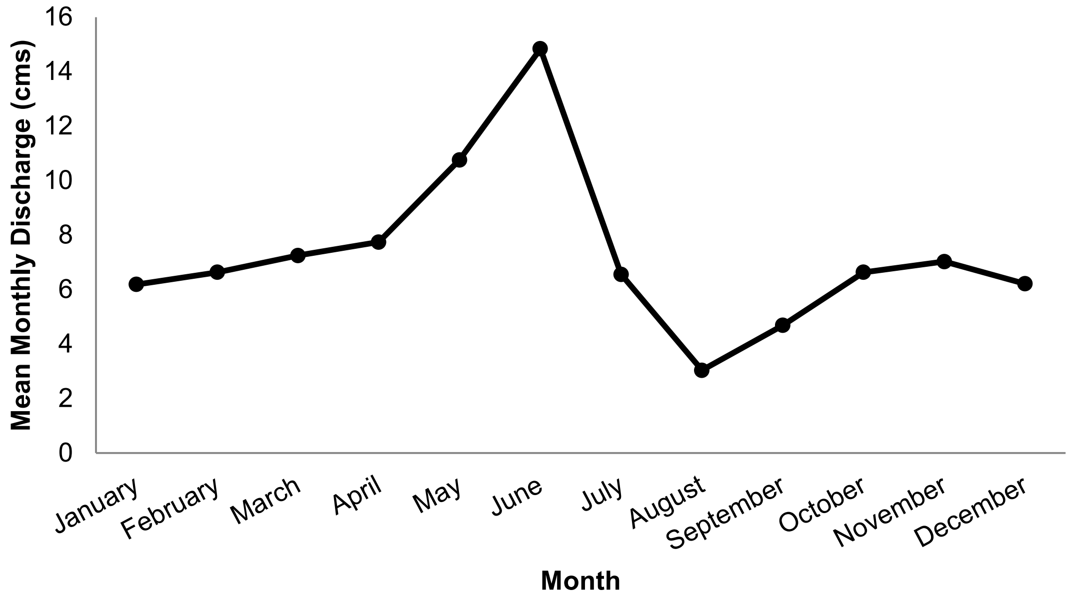


Figure 67. Hydrograph of mean monthly discharge rates of the Clark River from USGS Gage Station 12324200 located near Deer Lodge, MT.

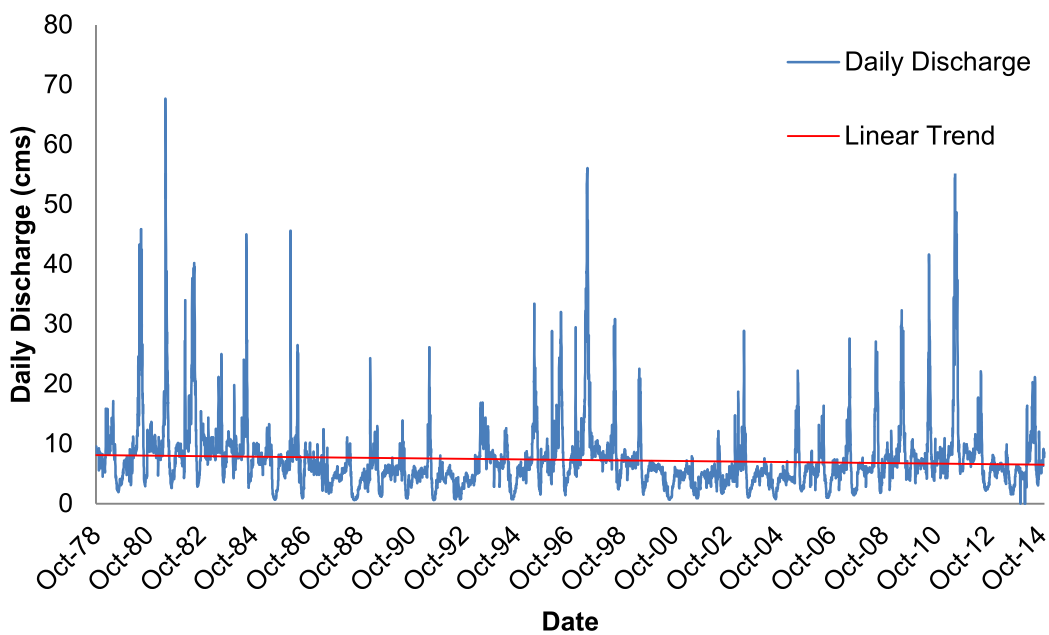


Figure 68. Daily discharge rates (Oct 1978 - present) of the Clark River from USGS Gage Station 12324200 located near Deer Lodge, MT.

Table 62. Discharge data from the Clark Fork River (Deer Lodge USGS station 12324200) near GRKO (USGS 2014b). All results are in cms with cfs equivalents in parenthesis.

Water Year	Total Discharge	Minimum Discharge	Maximum Discharge	Date of Maximum Discharge	Median	Standard Deviation
1979	2735 (96572)	1.9 (68)	17.1 (605)	May 25	8.1 (287)	114
1980	3942 (139200)	2.9 (104)	45.9 (1620)	June 16	7.4 (263)	300
1981	4144 (146360)	2.6 (92)	67.7 (2390)	May 23	9.1 (320)	321
1982	4513 (159370)	2.8 (100)	40.2 (1420)	June 25	9.5 (334)	297
1983	3525 (124500)	3.6 (126)	25 (884)	July 11	9.7 (344)	99
1984	3577 (126331)	2.7 (94)	45 (1590)	June 22	8.9 (315.5)	185
1985	2428 (85730)	0.7 (25)	13.3 (469)	May 4	7.4 (260)	110
1986	2824 (99712)	0.9 (32)	45.6 (1610)	February 25	7.2 (256)	175
1987	2036 (71887)	1.7 (60)	12.5 (440)	May 28	5.9 (210)	74
1988	1604 (56637)	0.6 (22)	11.1 (391)	April 22	4.6 (161.5)	84
1989	1898 (67027)	1.2 (42)	24.3 (858)	March 10	4.6 (161)	104
1990	1893 (66834)	0.8 (29)	13.9 (490)	May 31	5.5 (195)	70
1991	1914 (67576)	0.6 (22)	26.2 (924)	June 8	5 (177)	125
1992	1352 (47758)	0.7 (26)	8 (284)	November 6	4 (142)	58
1993	2559 (90383)	2.5 (88)	16.9 (596)	June 18	5.7 (203)	123
1994	2144 (75714)	0.7 (26)	12.6 (445)	May 13	6.6 (233)	101
1995	2833 (100037)	1.6 (55)	33.4 (1180)	June 7	6.2 (220)	172
1996	3389 (119680)	1.4 (50)	32 (1130)	June 11	7.7 (272.5)	217
1997	4801 (169550)	4.5 (160)	56.1 (1980)	June 14	8.8 (312)	377
1998	3197 (112899)	2.4 (85)	30.9 (1090)	July 4	8.1 (287)	157
1999	2604 (91976)	1.5 (52)	22.5 (796)	June 4	7 (246)	128
2000	1612 (56928)	0.7 (24)	7.1 (251)	November 26	5.6 (196.5)	72
2001	1563 (55183)	0.9 (31)	7.9 (279)	June 4	4.8 (170)	54
2002	1662 (58692)	1.7 (59)	12.1 (429)	June 10	4.7 (165)	57
2003	2177 (76884)	1 (36)	28.9 (1020)	June 1	5.4 (189)	143
2004	1499 (52932)	0.8 (27)	7.6 (267)	March 9	4.4 (156)	53
2005	2034 (71818)	2.1 (73)	22.2 (785)	June 18	4.5 (158)	126
2006	2016 (71187)	1 (35)	16.4 (578)	June 11	5.5 (194)	98
2007	2160 (76273)	1.4 (50)	27.6 (974)	June 7	5.7 (200)	130
2008	2648 (93499)	1.8 (64)	27.1 (957)	June 5	5.8 (206)	165
2009	3343 (118055)	2.3 (80)	32.3 (1140)	June 1	7.5 (264)	208
2010	3198 (112943)	3.4 (120)	41.6 (1470)	June 17	6.9 (245)	203
2011	4655 (164388)	4.2 (150)	55.5 (1960)	June 14	8 (283)	431
2012	2848 (100563)	2.2 (78)	22.1 (781)	June 6	8.2 (288)	123
2013	1876 (66241)	1.6 (55)	9.9 (349)	May 30	5.7 (200)	63
2014	2917 (103023)	2.7 (96)	21.2 (748)	June 28	6.2 (219)	133
Historic (1980-2010)	2507 (88,538)	1.7 (61)	67.7 (2,390)	May 28	6.4 (226)	140

A study was conducted in 2009 (KirK 2010) where discharge (among several other parameters) was measured for Cottonwood Creek. A total of 15 flow monitoring sites were established for this study, with four sites along Cottonwood Creek (KirK 2010). The location of the four sites is shown in Figure 69. Flow measurements were taken between 21 April and 19 October 2009 and the results for the four stations on Cottonwood Creek are shown in Table 63. As can be seen in Table 63 and in Figure 70, flows where highest in April, peaking in May and dropping to less than 0.5 cms in June.

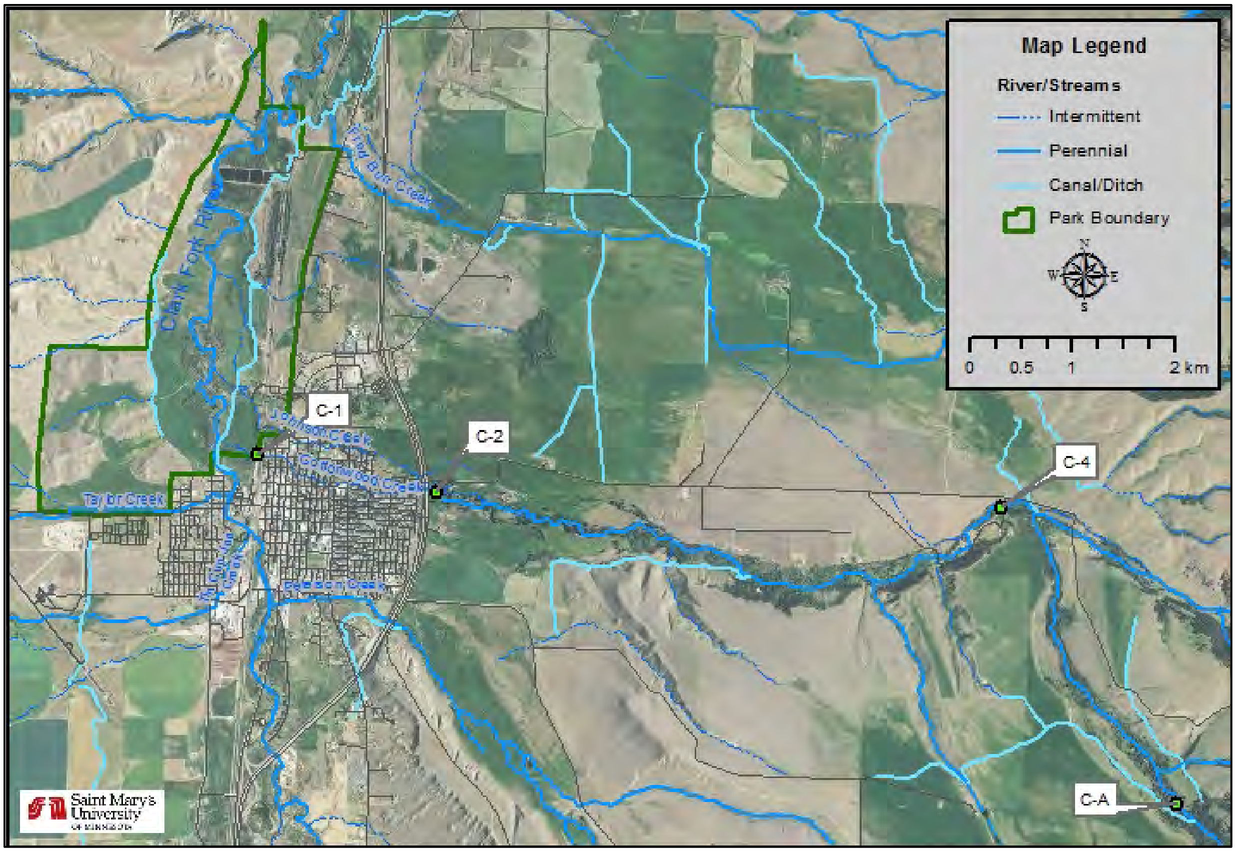


Figure 69. Flow monitoring points along Cottonwood Creek (KirK 2010).

Table 63. Stream flow in Cottonwood Creek. All results are in cms with cfs equivalents in parenthesis (KirK 2010).

Date	C-1	C-2	C-4	C-A
21-Apr-09		0.64 (22.53)		
22-Apr-09	0.92 (32.51)		1.37 (48.27)	
8-May-09	0.49 (17.42)	0.45 (15.96)	0.56 (19.94)	0.51 (17.94)
21-May-09	1.92 (67.81)	1.79 (63.31)		
22-May-09			1.91 (67.3)	1.99 (70.22)
22-May-09				
28-May-09	3.85 (136.02)	3.72 (131.29)	4.28 (151.08)	
29-May-09				4.7 (166.02)
29-Jun-09	0.16 (5.71)	0.17 (5.94)	0.16 (5.6)	0.76 (26.98)
5-Aug-09	0.08 (2.77)	0.06 (2.28)	0.17 (5.95)	0.26 (9.03)
19-Oct-09	0.09 (3.05)	0.08 (2.88)	0.03 (1.09)	0.07 (2.64)

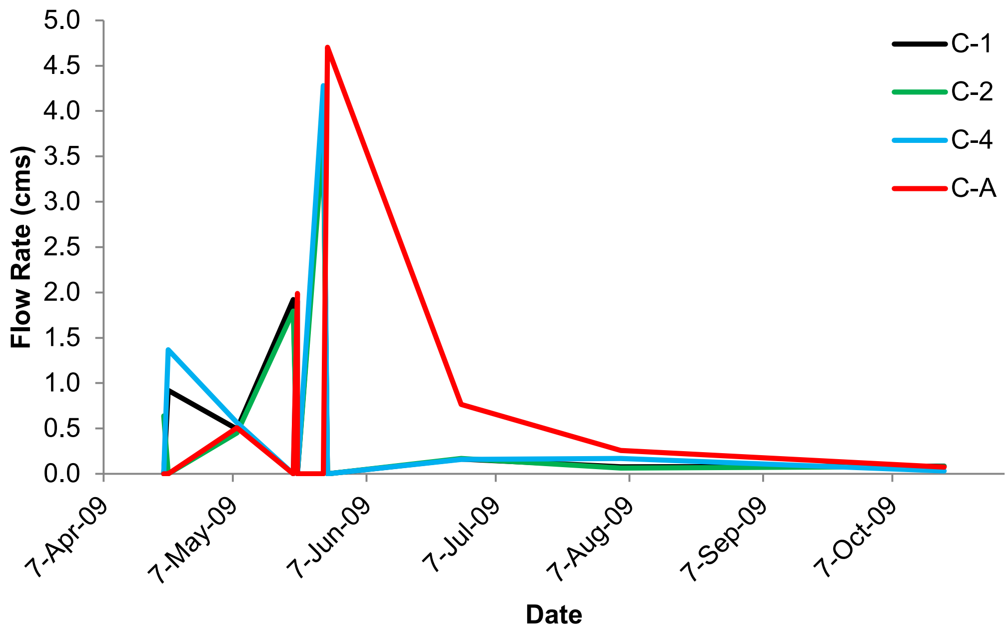


Figure 70. Flow rates for Cottonwood Creek (21 April through 19 October 2009 [KirK 2010]).

Irrigation Flow Inputs

Irrigation is the largest consumer of water in Montana, accounting for 97% of the total water withdrawals and 94% of the total water consumed (MT DEQ 2014b). Several geographic, climatic and agricultural factors affect when irrigation occurs, but in general the irrigation season starts in mid- April and continues through mid-September (MT DNRC 2004). Natural flow patterns in the Clark Fork are affected by the cumulative impacts of upstream water uses (MT DNRC 2004). In the Upper Clark Fork, tributaries and the main stem of the Clark Fork exhibit reduced flows in the summer months. This can be attributed to the combination of irrigation diversions and natural factors (MT DNRC 2004). On the other hand, depending on water use practices and local physical features, return flow, especially from flood irrigation can augment late season natural streamflow (MT DNRC 2004). Nimick (1993) reported that stream flow data indicated that ground-water inflow to the Clark Fork is significant, primarily in the reach between Racetrack and Garrison, and that irrigation-return flow is probably the main source of this water. GRKO holds several water rights claims for diverting

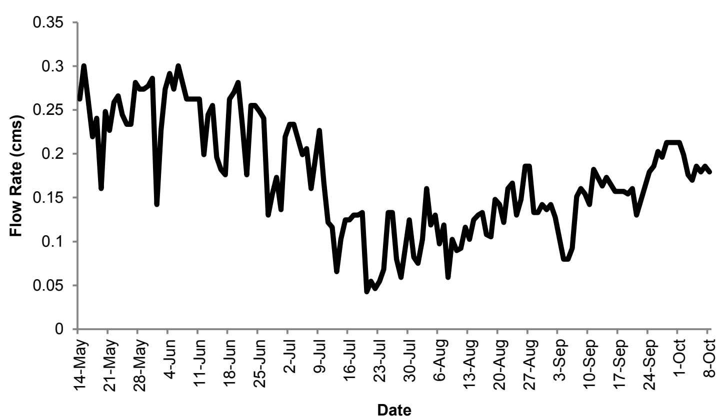


Figure 71. Flow rate in the Westside Ditch 2 ft. parshall flume within GRKO for the 2012 season.

water for irrigation use from the Clark Fork River, Cottonwood Creek, Johnson Creek and Taylor Creek (MT WRB 2014). It also holds additional ground water and surface water rights for domestic and stock watering use (MT WRB 2014).

Figure 71 shows the flow rates for the Westside Ditch for the 2012 irrigation season. Accurate flow rates were not available for all irrigation sources. Average flow for this period was 0.17 cms (6.1 cfs). Peak flow of 0.3 cms (10.6 cfs) occurred on two occasions, 15 May and 6 June (NPS 2012).

Timing and Amount of Precipitation

The climate in the Clark Fork River basin results from influences of moist air masses stemming from the Pacific Ocean (MT DNRC 2004). Compared to the rest of Montana, GRKO experiences patterns of relatively abundant precipitation and mild winters, with the occasional extended cold periods, and hot, dry periods in summer (MT DNRC 2004). Table 64 summarizes the 30-year normal temperature and precipitation values for the station located near Deer Lodge, MT. Over this period, annual precipitation averaged 27 cm (10.62 in) (NCDC 2014). Mean monthly precipitation was highest in May and June and declined through late summer into fall (Figure 72). Total monthly precipitation is shown in Figure 73. Missing data periods in the graph correlate to months where five or more days of precipitation data were missing. These months were not used in the analysis. Over the period of record the total monthly precipitation has remained relatively stable, yet slightly increasing as is indicated by the trend line on the graph. In terms of total annual precipitation, analysis of data from 1950 through 2010 shows a positive linear trend of 13% per century (Gonzalez 2014).

Table 64. 1980-2010 normals for Deer Lodge 3W (NCDC 2014).

Mean Temperature °C (°F)	5.1 (41.2)
Mean Maximum Temperature °C (°F)	13.3 (56)
Mean Minimum Temperature °C (°F)	-3.1 (26.5)
Mean Total Precipitation cm (in)	27 (10.62)

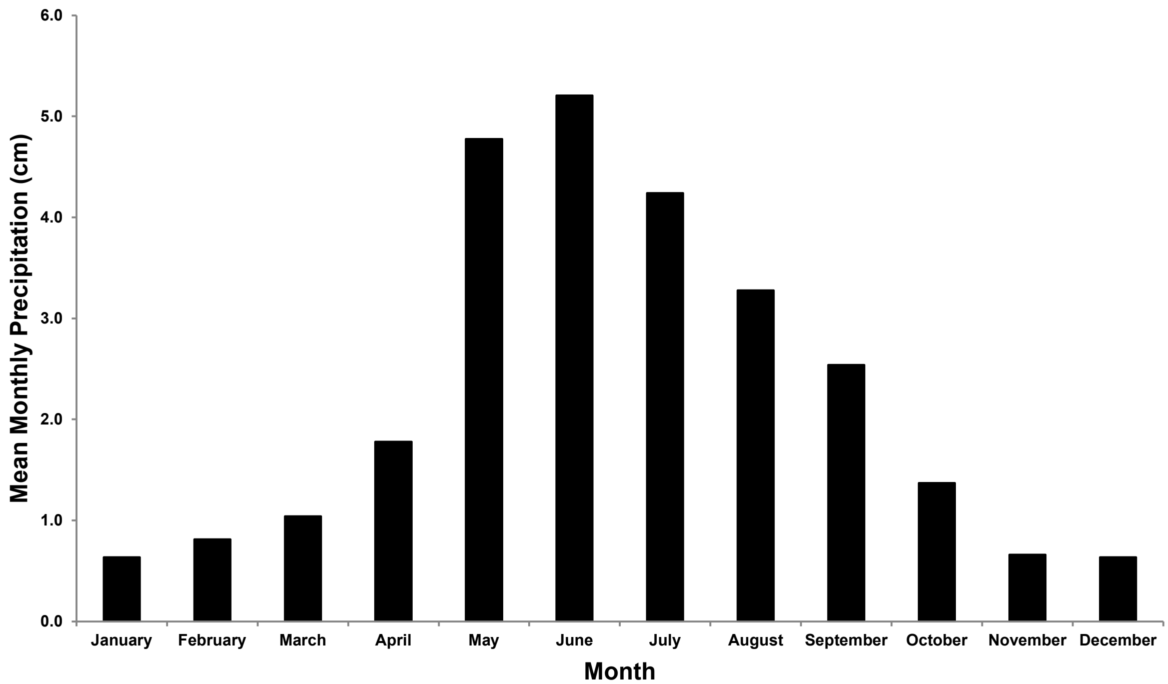


Figure 72. 1980-2010 normal precipitation for Deer Lodge, MT (Cooperative Weather Station Deer Lodge 3W) (NCDC 2014).

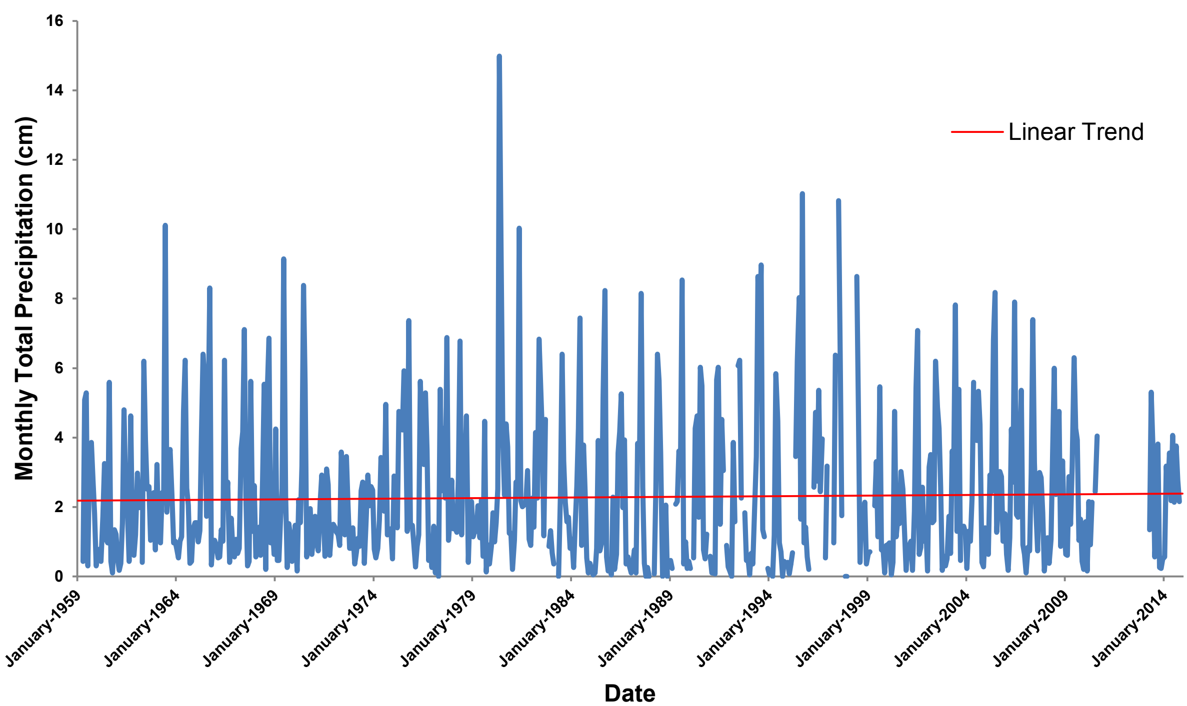


Figure 73. Monthly total precipitation for the period of record for Cooperative Weather Station Deer Lodge 3W. Months with more than five days missing were not used in analysis.

Depth to Groundwater

Groundwater supplies in the Clark Fork basin are found in two basic types; basin fill aquifers or fractured bedrock aquifers (MT DNRC 2004). GRKO is located within a basin fill aquifer (MT DNRC 2004). These can be either shallow and unconfined or deep and confined and can range from several hundred to several thousand feet thick (MT DNRC 2004). Specifically, GRKO is located within the Northern Rocky Mountains Intermontane Basins aquifer system, which is an unconsolidated sand and gravel aquifer (USGS 2014a). Basin fill aquifers can range from being limited in extent and productivity to highly productive and dependable (MT DNRC 2004). Recharge in these aquifers can come from sources such as the infiltration of water from precipitation or snowmelt or excess irrigation water (MT DNRC 2004). These types of aquifers can be diminished by discharge to streams, evaporation, and withdrawals from pumping (MT DNRC 2004).

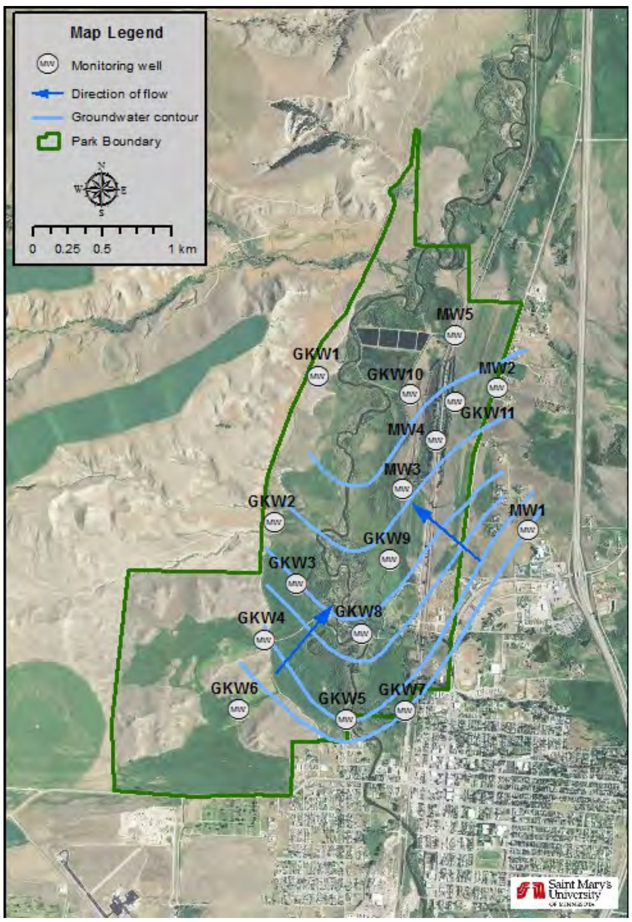


Figure 74. Groundwater dynamics at GRKO (GRKO GIS 2007).

At GRKO, groundwater occurs near the ground surface (Moore and Woessner 2001, Woessner and Johnson 2001). Previous studies at GRKO, using monitoring well and piezometer data, have found that the water table within the floodplain portion is within about 1.5 m (5 ft) of the ground surface. Under the gravel terraces to the east, the water table is generally 3 - 6 m (10 - 20 ft) below the surface, and can be up to 9 m (30 ft) or more below the surface for the upper portions of the west side fields (Moore and Woessner 2001, Woessner and Johnson 2001). The city sewer line runs underneath a portion of GRKO. In order to limit groundwater infiltration into the line, the City of Deer Lodge has recently slip-lined the sewer line and sealed the manholes. It is unknown what, if any affect this could have on the depth to groundwater (Johnson, written communication 8 December 2014). Figure 74 shows the location of select monitoring wells, and general direction of groundwater flow. This flow is generally from the uplands areas towards the floodplain area. On the west side of the river the groundwater flow is towards the northeast and on the east side of the river the groundwater flows in a northwesterly direction (Woessner and Johnson 2001).

For the Upper Clark Fork, when not affected by irrigation, groundwater levels are generally highest during the spring runoff and then gradually decline until the next spring (Nimick 1993). Groundwater will also show short-term rises in response to rainfall or snowmelt events (Nimick 1993). This general pattern can be seen at GRKO in Figure 75.

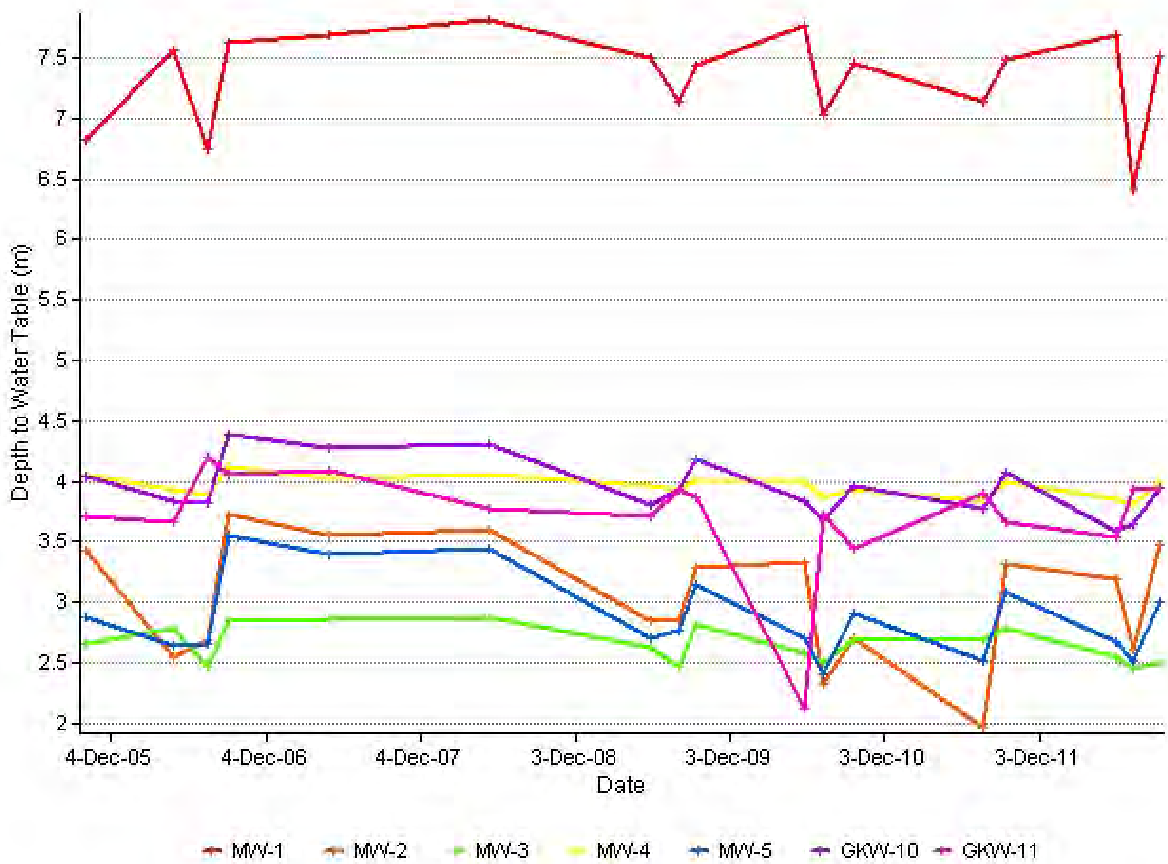


Figure 75. Depth to groundwater for selected monitoring wells at GRKO (Reproduced from WET 2012).

<u>Threats and Stressor Factors</u>
GRKO staff identified several potential threats and stressors to the surface water and groundwater resources in the park. These include human alteration to the river, dewatering, climate change, and drought.

Climate change is a growing concern and threat to steam hydrology at GRKO as well as across the western United States. Changes to stream hydrology in the western United States have been well documented and these changes are expected to continue (Barnett et al. 2008). Projected increases in temperature will cause earlier snow melt in the upper elevations, resulting in earlier peak flows and reduced summer flows (Dettinger et al. 2004).

Periods of drought can threaten the supplies of water for irrigated crops and community drinking water supplies (MT DES 2013). Rangeland and irrigated agricultural lands do not exhibit the effects of drought as quickly as non-irrigated cultivated cropland (MT DES 2013). Drought conditions diminish groundwater resources which can lead to reduced pumping capacity, dry wells and degraded water quality (MT DES 2013). A rare spring drought occurred in 1992 and, coupled with early irrigation withdrawals, resulted in a rapid decrease in stream discharge and some of the lowest flows on record for the months of May and June (Hornberger et al. 1997).

The Palmer Hydrological Drought Index (PHDI) can be used to show hydrological (long-term cumulative) drought and wet conditions, as it more accurately reflects groundwater conditions and surface water conditions (NCDC 2013). Figure 76 shows the PHDI for the state of Montana. The state has experienced severe and extreme drought between 10% and 20% of the time over the last 100 years (MT DES 2013). Drought conditions can result in low water levels, causing changes in water quality, temperature and sediment loading.

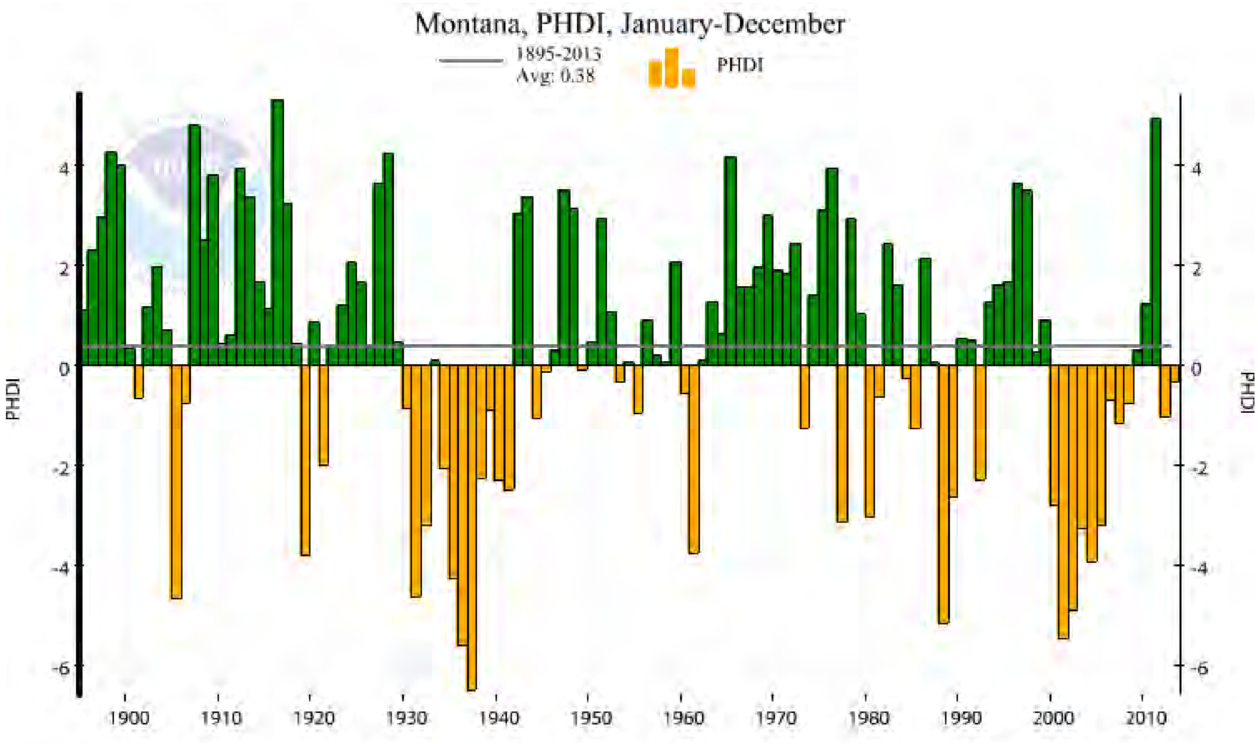


Figure 76. Palmer Hydrologic Drought Index (PHDI) for Montana. Graph was created and downloaded from time series data from the National Climatic Data Center (Reproduced from NCDC 2014).

The supply of ground and surface water can be affected by several factors. These include evaporation of surface water, timing and degree of precipitation events, ground water discharge to streams, and from withdrawals from pumping (MT DNRC 2004). The largest consumer of groundwater within the Upper Clark Fork basin is public water supply and irrigation. However, the bulk of water used in irrigation comes from surface water diversions (MT DNRC 2004). Groundwater is growing in importance as the source of a potable water supply. One study showed that the municipal and residential population grew in the Upper Clark Fork basin on the average about 1% a year during a ten-year period prior to 2004 (MT DNRC 2004). At this rate, the Upper Clark Fork will have a population of almost 68,000 by the year 2020. At the water use rates exhibited during 2004, this would translate into a daily groundwater flow rate of approximately 0.1 cms (5 cfs) (MT DNRC

2004). Currently, the basin contains approximately 48,970 irrigated ha (121,000 ac) and the projected demand for future water use by irrigation depends on two factors (MT DNRC 2004). The first being the amount of irrigable lands remaining in the basin and secondly the ability to store surface supplies or to find hydrologically unconnected groundwater (MT DNRC 2004).

Alterations in flow will affect the rate of channel migration and stream bank erosion in a dynamic system like the Clark Fork River (Moore et al. 2002, Parmar 2008). Studies conducted at GRKO have shown that the erosion and deposition rates are approximately balanced, resulting in no net measurable loss of land (Moore et al. 2002). Increased flow rates due to anthropogenic disturbances (or precipitation) upstream of GRKO have the potential to disrupt this balance (Moore et al. 2002). Efforts are in place to minimize anthropogenic impacts to river flow (EPA 2004). Powell County regulates the land use and building activities within the 100 year floodplain (EPA 2004). Construction and land use changes within the floodplain can result in increased river flow from runoff. Also the stream bank and riparian re-vegetation components of the Clark Fork Superfund Site remediation plan address the erosional concerns associated with the slickens deposits (EPA 2004). The remediation/restoration efforts for the Clark Fork Superfund Site started in 2012, with the portion within GRKO slated to begin in 2015 (Johnson, written communication, 8 December 2014).

Data Needs/Gaps

Data or studies describing groundwater resources in the Upper Clark Fork basin are available for only select locations (MT DNRC 2004). When it does exist, it tends to have limited information on sustainable yields, flow patterns, influences by existing users and other information that would aid in the development of planning and management programs (MT DNRC 2004). More scientific research is needed to understand the interaction between surface water and groundwater in order to evaluate water availability for new wells and the potential impacts of improving irrigation efficiency (MT DNRC 2004). Currently there is a study being conducted by Montana Tech to determine surface and groundwater flow connections in the area of GRKO's historic buildings (Smith, written communication, 5 January 2014). Also, it is unclear whether climate change is having a measurable impact on the Clark Fork in GRKO (Schweiger et al. 2014). In general in the northern and central Rockies, streamflow has shifted toward earlier peak runoff, which has been attributed to more precipitation falling as rain rather than snow and earlier snowmelt (Mote et al. 2005, Knowles et al. 2006). The midpoint of annual discharge and the date of highest flows at GRKO are trending later in the year than during the historic period of record (Schweiger et al. 2014). This would suggest that the hydrograph is shifting forward in time due to delayed runoff. There is also a suggestion that the GRKO hydrograph is becoming more variable. More data is needed in order to determine if this shift is due to climate change (Schweiger et al. 2014). Additional data on the other sources of irrigation inputs would be necessary to accurately determine a condition level for the irrigation input measure.

Overall Condition

Stream Discharge
The measure of stream discharge was assigned a *Significance Level* of 3, as it is a fundamental hydrologic variable which has significant influence on many river conditions. The timing and amount of stream flow, coupled with its interaction with other elements of river habitat, is a critical component and determinant of the condition of rivers (Schweiger et al. 2014). Data from the USGS gaging station at Deer Lodge shows that over the period of record there has been a slight decline in discharge. Also, the timing of peak flow has tended to be later in the year than the historic average. Due to these factors, a *Condition Level* of 1 was assigned.

Irrigation Flow Inputs
Irrigation flow input was assigned a *Significance Level* of 3. GRKO has multiple water-right claims to divert surface water from the Clark Fork River and its tributaries for flood irrigation (John Milner Associates et al. 2004). Accurate flow records were not available for all these sources of diversion. Due to this, a *Condition Level* was not assigned.

Timing and Amount of Precipitation
The *Significance Level* for the precipitation measure was a 3. No significant trends can be seen in the data from the weather station near the park. The *Condition Level* for this measure is 0, indicating no concern.

Depth to Groundwater
The *Significance Level* for depth to groundwater was a 3. Limited data is available on the depth to groundwater at GRKO. There is also limited data on what constitutes a sustainable yield for groundwater (MT DNRC 2004). Due to these factors, a *Condition Level* was not assigned.

Weighted Condition Score
A *Weighted Condition Score* was not calculated for hydrology at GRKO, since condition could not be assigned for two of the four measures. It is not appropriate to assign trends in the overall condition of the hydrologic regime of the Clark Fork River at GRKO based solely on the one available data source. The only measure that exhibited any trend was total stream discharge.

Hydrology			
Measures	Significance Level	Condition Level	WCS = N/A
Stream Discharge	3	1	
Irrigation Flow Inputs	3	n/a	
Timing and Amount of Precipitation	3	0	
Depth to Groundwater	3	n/a	

4.12.6 Sources of Expertise

Jeffery Johnson, GRKO CERCLA Project Manager

Jason Smith, GRKO Natural Resource Specialist

4.12.7 Literature Cited

Barnett, T. P., D. W. Pierce, H. G. Hidalgo, C. Bonfils, B. D. Santer, T. Das, G. Bala, A. W. Wood, T. Nozawa, A. A. Mirin, and others. 2008. Human-induced changes in the hydrology of the western United States. Science 319:1080-1083.

Dettinger, M., K. Redmond, and D. Cayan. 2004. Winter orographic precipitation ratios in the Sierra Nevada large-scale atmospheric circulations and hydrologic consequences. Journal of Hydrometeorology 5:1102-1116.

Dodge, K. A., M. I. Hornberger, and E. V. Axtmann. 1996. Water-quality, bed-sediment, and biological data (October 1994 through September 1995) and statistical summaries of data for streams in the Upper Clark Fork Basin, Montana. USGS Open-File Report 96-432. U.S. Geological Survey, Helena, Montana.

Environmental Protection Agency (EPA). 2004. Clark Fork River Operable Unit of the Milltown Reservoir/Clark Fork Superfund Site, Record of Decision Part 2: Decision summary. U.S. Environmental Protection Agency, Helena, Montana.

Grant-Kohrs Ranch NHS GIS Program (GRKO GIS). 2007. Groundwater monitoring wells at Grant-Kohrs Ranch National Historic Site, Montana. National Park Service, Deer Lodge, Montana.

Gonzalez, P. 2014. Climate trends, Grant-Kohrs Ranch National Historic Site, Montana. Climate change trends. Published Report-2217692. National Park Service Climate Change Response Program, Washington, D.C.

Hornberger, M. I., J. H. Lambing, S. N. Luoma, and E. V. Axtmann. 1997. Spatial and temporal trends of trace metals in surface water, bed sediment, and biota of the Upper Clark Fork Basin, Montana, 1985-95. USGS Open-File Report 97-669. U.S. Geological Survey, Menlo Park, California.

KirK Engineering and Natural Resources, Inc. 2010. Cottonwood Creek flow monitoring and fish barrier study. Watershed Restoration Coalition of the Upper Clark Fork, Deer Lodge, Montana.

Knowles, N., M. D. Dettinger, and D. R. Cayan. 2006. Trends in snowfall versus rainfall in the western United States. Journal of Climate 19:4545-4559.

Montana Disaster and Emergency Services (MT DES). 2013 State of Montana multi-hazard mitigation plan and statewide hazard assessment: 2013 update. http://letsmitigatemontana.com/draft-pdm-plan/ (accessed 10 November 2014).

Montana Department of Environmental Quality (MT DEQ). 2006. Surface water quality standards and procedures. Chapter 30, subchapter 6 *in* Administrative rules of Montana: Environmental quality. Montana Department of Environmental Quality, Helena, Montana.

Montana Department of Environmental Quality (MT DEQ). 2012. Montana 2012 final water quality integrated report. Montana Department of Environmental Quality, Helena, Montana.

Montana Department of Environmental Quality (MT DEQ). 2014a. 2014 water quality information: Clark Fork River, Powell County. https://svc.mt.gov/deq/dst/#/app/cwaic/report/cycle/2014/auid/MT76G001_030 (accessed 23 February 2015).

Montana Department of Environmental Quality (MT DEQ). 2014b. Climate change and water. http://deq.mt.gov/ClimateChange/NaturalResources/Water/WaterUses.mcpx (accessed 8 November 2014).

Montana Department of Natural Resources and Conservation, Water Resources Division (MT DNRC). 2004. Clark Fork River Basin water management plan. http://dnrc.mt.gov/wrd/water_mgmt/clarkforkbasin_taskforce/water_mgmt_plan.asp (accessed 12 November 2014).

Montana Department of Natural Resources and Conservation, Water Rights Bureau (MT WRB). 2014. Water rights query system. http://nris.mt.gov/dnrc/waterrights/default.aspx (accessed 8 November 2014).

Moore, J. N., and W. W. Woessner. 2001. Geologic, soil water and groundwater report - 2000 Grant Kohrs Ranch National Historic Site. National Park Service, Deer Lodge, Montana.

Moore, J. N., B. Swanson, and C. Wheeler. 2002. Geochemistry and fluvial geomorphology report - A draft report to the Grant-Kohrs Ranch National Historic Site. National Park Service, Deer Lodge, Montana.

Mote, P. W., A. F. Hamlet, M. P. Clark, and D. P. Lettenmaier. 2005. Declining mountain snowpack in western North America. Bulletin of the American Meteorological Society 86:39-49.

National Climatic Data Center (NCDC). 2013. U.S. Palmer Drought Indices. http://www.ncdc.noaa.gov/oa/climate/research/prelim/drought/palmer.html (accessed 4 December 2014).

National Climatic Data Center (NCDC). 2014. Statistical weather and climate information. http://www.ncdc.noaa.gov/oa/ncdc.html (accessed 10 November 2014).

National Park Service (NPS). 2012. 2012 GRKO Westside ditch 2 ft parshall flume measurements. Unpublished data received from Jason Smith, 19 September 2014.

Nimick, D. A. 1993 Hydrology and water chemistry of shallow aquifers along the Upper Clark Fork, Western Montana. USGS Water Resources Investigations Report 93-4052. Montana Bureau of Mines and Geology, Helena, Montana.

Parmar, N. 2008. Bank erosion and channel migration of the Clark Fork River at Grant-Kohrs Ranch N.H.S., Western Montana. Thesis. University of Montana, Missoula, Montana.

Schweiger, E. W., L. O'Gan, D. Shorrock, and M. Britten. 2014. Stream ecological integrity at Grant-Kohrs National Historic Site: Rocky Mountain Inventory and Monitoring Network 2008-2010 stream monitoring report. Natural Resources Technical Report NPS/ROMN/NRTR - 2014/881. National Park Service, Fort Collins, Colorado.

Thornberry- Ehrlich, T. 2007. Grant- Kohrs Ranch National Historic Site geologic resource evaluation report. Natural Resource Report NPS/NRPC/GRD/NRR—2007/004. National Park Service, Denver, Colorado.

United States Geological Survey (USGS). 2014a. The National Map small-scale collection. http://nationalmap.gov/small_scale/ (accessed 10 November 2014).

U.S. Geological Survey (USGS). 2014b. National Water Information System: Web Interface – USGS 12324200 Clark Fork at Deer Lodge MT. http://waterdata.usgs.gov/mt/nwis/inventory?search_site_no=12324200 (accessed 12 November 2014).

Water and Environmental Technologies (WET). 2012. Groundwater monitoring report - Deer Lodge effluent irrigation project, 2012 irrigation season. Water and Environmental Technologies, Butte, Montana.

Woessner, W. W., and M. M. Johnson. 2001. Water resources characterization report 2000 and 2001 field seasons - Grant-Kohrs Ranch National Historic Site. National Park Service, Deer Lodge, Montana.

4.13 Soils

4.13.1 Description

Soils are a vital part of the ecosystem, supporting plant growth, cycling nutrients, providing habitat for a variety of micro- and macro-organisms, and influencing water retention, percolation, and purification (NPS 2010). Soil conditions can provide insight into ecosystem processes and productivity and can determine vegetative composition and structure; as a result, the ROMN recognized surface soils as an indicator of terrestrial ecosystem integrity (Manier et al. 2011). Soils are particularly important in a ranch setting, as they provide the nutrients required by crops and forage plants.

The soils at GRKO are derived from alluvium (loose sediments deposited by water flow) and range from deep, coarse loams along the Clark Fork River, to shallow, poorly developed soils in the upland grasslands (NPS 2013a, Rice et al. 2012). For over a century, the ranch's riparian area has been subjected to metal contaminants washing downstream from the historic mining districts around Anaconda and Butte, MT. Many of these wastes were washed downstream along the Clark Fork River floodplain by large floods in the early 1900s (Kapustka 2002, Ramsey et al. 2005a). Sediments deposited during these floods raised the level of the floodplain by a meter or more (Ramsey et al. 2005a). Mining wastes were unevenly distributed and further agitated by subsequent floods and channel migration, leading to extensive spatial variation in contaminant concentration within the soils (Ramsey et al. 2005a). Small patches in the GRKO riparian area, called "slickens" (Figure 77), are so contaminated that they are devoid of vegetation and contain surface accumulations of heavy metal salts (Ramsey et al. 2005a; Photo 43). The primary soil contaminants from mining waste include arsenic, cadmium, copper, lead, and zinc (Kapustka 2002).

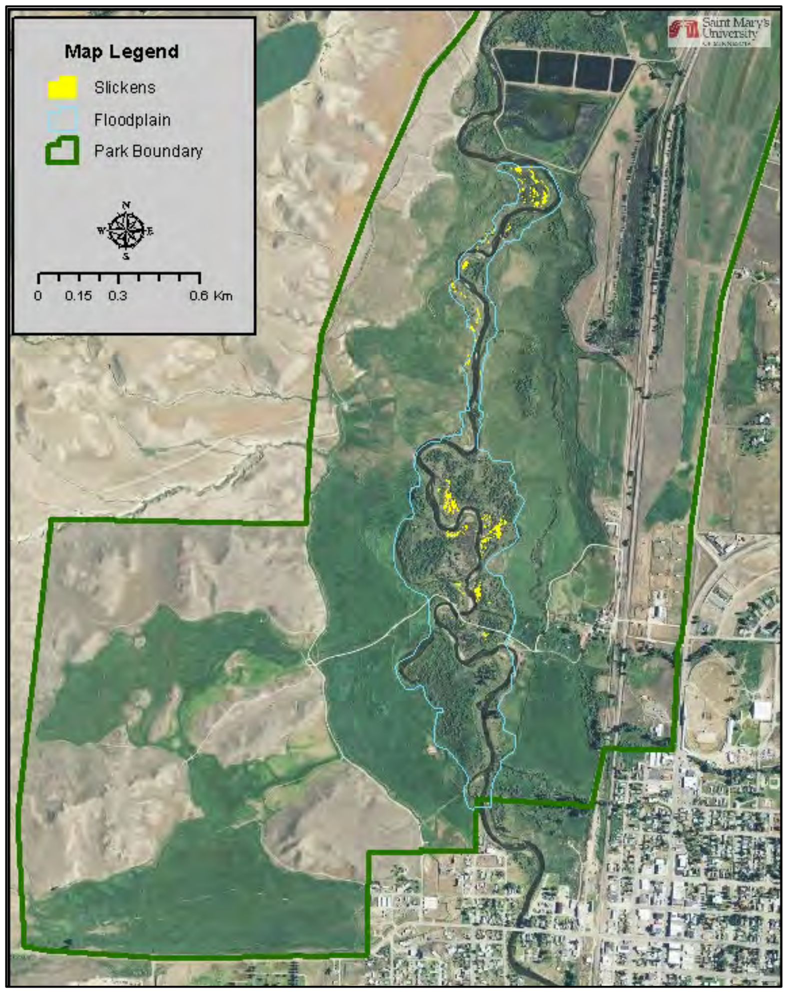


Figure 77. The Clark Fork floodplain and slickens areas at GRKO.

Photo 43. An unvegetated slickens area along the Clark Fork in GRKO; note the white crust of heavy metals salts (Photo by Sarah Gardner, SMUMN GSS 2013).

4.13.2 Measures

- Soil chemistry
- Soil aggregate stability
- Bulk density
- Soil microbial composition and respiration

Soil Chemistry

Measures of soil chemistry that will be used in this assessment are pH, organic matter content, and nutrient levels. Soil pH influences the availability of nutrients to plant life. A pH below 7 indicates acidity; acidic soils can limit nutrient availability (Manier et al. 2011). Conversely, low pH levels can make toxic metals more available for plant uptake (Ramsey et al. 2005a). Soil organic matter is the percent of the soil that consists of dead plant and animal tissues in varying stages of decomposition (Manier et al. 2011). Organic matter content affects nutrient availability, soil structure (e.g., stability), pH, and water holding capacity (Sollins et al. 1999). High levels of organic matter, in combination with a near-neutral pH, can also reduce the bioavailability of toxic metals, reducing harmful effects to plants (Ramsey et al. 2005a).

Nutrient levels in the soil are directly linked to productivity (e.g., plant biomass) and can be an indicator of ecosystem processes such as nutrient cycling and decomposition (Manier et al. 2011). Three of the most important nutrients, particularly in an agricultural setting, are nitrogen (N), phosphorous (P), and potassium (K). These nutrients are critical for plant growth, such as crop and forage production. Nutrient levels can be maintained in the soil by incorporating animal manure, “green manure” (plant material intentionally grown to be returned to and enrich the soil), or other organic wastes (e.g., straw, crop residue, wood ash) (Olson and Leinard 2013). Legumes such as alfalfa and clover fix atmospheric nitrogen, converting it to a form that is usable by other plants. While most Montana soils are naturally high in potassium (with the exception of sandy soils and those high in organic matter), they are typically low in available phosphorous (Olson and Leinard 2013).

Soil Aggregate Stability

Soil aggregate stability estimates soil integrity, in terms of its ability to bind into cohesive units (Shorrock et al. 2010). More stable or cohesive soils are generally more resistant to erosion (Manier et al. 2011). However, if stability is extremely high, it may indicate soil compaction, which can negatively impact water infiltration and plant growth. Soil stability is strongly influenced by organic matter, which binds the soil particles and also varies with soil texture (Shorrock et al. 2010). As a result, only soils of similar textures (i.e., similar ratios of sand, silt, and clay) can be compared for stability. At GRKO, all soils are similar enough in texture that stability estimates are comparable throughout the park (Shorrock et al. 2010).

Bulk Density

Bulk density, a measure of soil mass per volume, is an indicator of soil structure or strength (Manier et al. 2011). Bulk densities are influenced by soil texture and organic matter content, and range from 0.6 to 1.8 g/cc (Manier et al. 2011). Soils with high silt and clay content (i.e., smaller particles) typically show higher densities than coarser textured soils. High densities often suggest soil compaction, which impacts plant growth and reduces the porosity required for the transport of water and gases (e.g., oxygen). In finer-textured soils, a bulk density above 1.4 g/cc may limit root penetration and water storage (NPS 2013a).

Soil Microbial Composition and Respiration

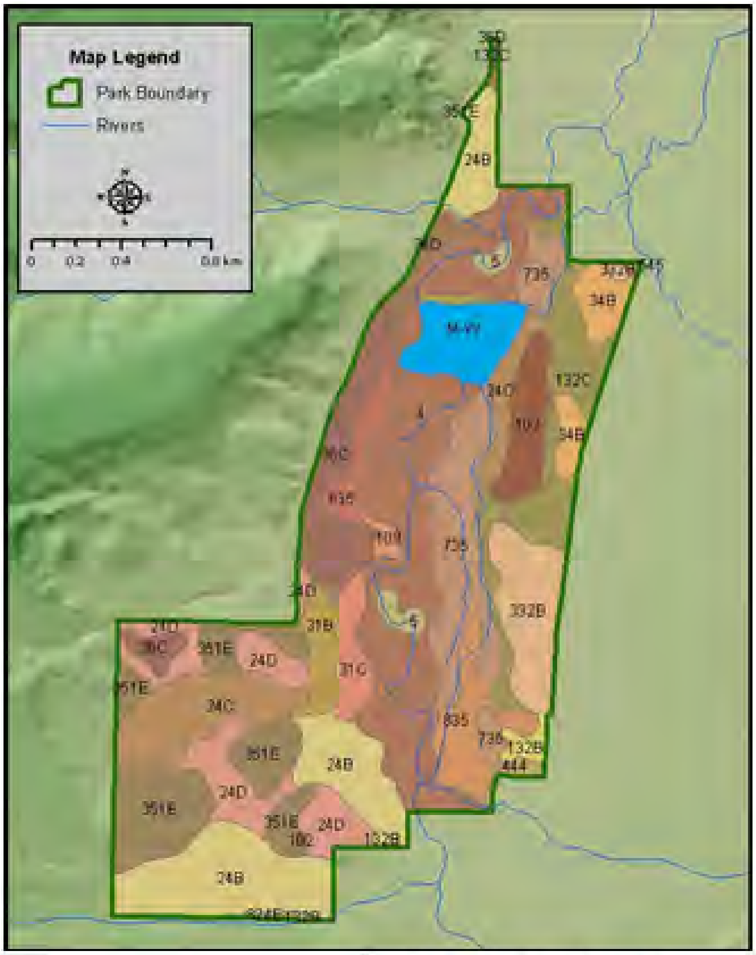
Soil microbes play an important role in ecological processes such as organic matter decomposition and nutrient cycling (e.g., nitrogen and carbon) (Menta 2012). Soil respiration is a measure of CO_2 production by these microorganisms during their normal activities and can indicate soil health (Ramsey et al. 2005a). Soil activity plays a key role in nutrient availability, which in turn influences plant growth and overall productivity (Gannon and Rillig 2002). When soil microbe communities are altered and/or respiration is low, nutrients may accumulate in forms that are unavailable to plant life. Soil microbial respiration is influenced by moisture, temperature, nutrient availability, and heavy metal contamination (Gannon and Rillig 2002, Ramsey et al. 2005a).

4.13.3 Reference Conditions/Values

Reference conditions for soils can vary depending on the desired use of the land (e.g., crop production, grazing, recreation, etc.). Since GRKO is a working ranch, the NRCA project team looked for values recommended for agriculture or crop production, if available. In the case of pH, the suitable range for most crops is between 6 and 7.5 (Dinkins and Jones 2013). For organic matter content, 2% is considered normal for Montana soils (Dinkins and Jones 2013). With regard to nutrients, recommended nitrogen levels vary with crop yield goals. Most hayfields at GRKO have a yield goal of 2 tons/acre (4.5 metric tons/ha). With a primary crop of grass, the recommended nitrogen level for this yield is 25 mg/kg (50 lbs/ac) (Jacobsen et al. 2005). Phosphorus and potassium recommendations are not dependent on yield goals; optimal levels are above 16 ppm (1 ppm = 1 mg/kg) for phosphorus, and above 250 ppm for potassium (although levels above 800 ppm can be toxic) (Dinkins and Jones 2013). For soil aggregate stability, the reference condition will be a stability class range of 4.5-5.5 (see current condition section for explanation of stability classes). Suitable bulk densities vary by soil texture, with finer soils experiencing negative impacts at lower densities. Since very little soil at GRKO is finer than a silty clay loam (NPS 2013a), the reference condition for bulk density will be <1.5 g/cm^3, which is considered the density at which root restriction would occur in silty clay loams (NRCS 2001). No reference conditions have been established for soil microbial composition and respiration.

4.13.4 Data and Methods

A soil survey and map for the park were completed by the NRCS from 1989-1991 (NPS 2013a, b; Figure 78). Data gathered included soil pH, organic matter content, and moist bulk density.



Map symbol	Map unit name	Map symbol	Map unit name
4	Aquents-Slickens complex, 0 to 2% slopes, occasionally flooded	132B	Beaverell cobbly loam, 0 to 4% slopes
5	Slickens-Aquents complex, 0 to 2% slopes, occasionally flooded	132C	Beaverell cobbly loam, 4 to 8% slopes
24B	Con loam, 0 to 4% slopes	332B	Beaverell loam, 0 to 4% slopes
24C	Con loam, 4 to 8% slopes	351E	Roy-Shawmut-Danvers complex, 15 to 35% slopes
24D	Con loam, 8 to 15% slopes	444	Gregson loam, 0 to 4% slopes, rarely flooded
31B	Varney clay loam, 0 to 4% slopes	545	Saypo loam, 0 to 4% slopes
31C	Varney clay loam, 4 to 8% slopes	635	Tetonview loam, 0 to 4% slopes
34B	Cetrack loam, 0 to 4% slopes	735	Tetonview-Blossberg loams, 0 to 4% slopes, rarely flooded
36C	Varney-Con loams, 4 to 8% slopes	824E	Con-Sixbeacon cobbly loams, 15 to 35% slopes
36D	Varney-Con loams, 8 to 15% slopes	835	Tetonview loam, 0 to 4% slopes, rarely flooded
102	Pits, gravel	M-W	Miscellaneous water
109	Bohnly silt loam, 0 to 2% slopes		

Figure 78. GRKO soil map (above) and description of soil map units (NPS 2013b).

The ROMN started gathering soils data at GRKO in 2006 as part of their vegetation and soils monitoring program (Manier et al. 2011). The goals of this program, regarding soils, are to

> Determine the status and trend in soil condition in grassland, shrubland, and woodlands of each park based on measures of 1) dynamic properties such as soil stability, extent of non-vegetated soils, and erosion and 2) inherent properties including physical texture, composition and soil chemistry (Manier et al. 2011, p. 11).

Data gathered includes chemical properties (e.g., pH, nutrients, organic matter) and physical properties such as bulk density and soil aggregate stability (Manier et al. 2011). Twenty-centimeter-deep soil samples collected in the field were sent to a lab for analysis of all parameters with the exception of soil aggregate stability, which was measured in the field according to methods outlined by Herrick et al. (2005). This test involves placing a fragment of soil (ped) into a sieve and submerging it in water for a period of time to determine how long it holds its structure. Units that remain intact for longer periods of time are considered more stable and are assigned to a higher stability class (Manier et al. 2011). Stability classes and descriptions are described in Table 65 below. Sampling and analysis protocols for other parameters are described in further detail in Shorrock et al. (2010) and Manier et al. (2011). Data from 2006-2012 (ROMN 2006-2012) were downloaded from the NPS Integrated Resource Management Applications (IRMA) portal at https://irma.nps.gov/App/.

Table 65. Soil stability classes according to methods described by Herrick et al. (2005) (adapted from Manier et al. 2011).

Stability class	Criteria for classification
1	50% of structure lost within 5 seconds of immersion (melts and falls through sieve)
2	50% of structural integrity lost 5-30 seconds after immersion
3	50% of structural integrity lost 30 seconds – 5 minutes after immersion, or <10% of soil remains after 5 dipping cycles
4	10-25% of soil remains after 5 dipping cycles
5	25-75% of soil remains after 5 dipping cycles
6	75-100% of soil remains after 5 dipping cycles

Additional information on soil chemistry was obtained from soil test reports; tests were conducted by Agvise Laboratories of North Dakota on soil samples collected by GRKO staff from various hayfields on the ranch (Agvise 2008, 2010, 2013). Samples were submitted from eight fields in 2008, one field in 2010, and nine fields in 2013. Parameters analyzed include nutrients (nitrate, phosphorus, and potassium), organic matter content, and pH.

Soil microbial composition and respiration were studied at GRKO in 2000 and 2001 by Gannon and Rillig (2002). Fifteen sites were sampled in 2000 and 30 in 2001, although three sites had to be excluded in 2001 due to flooding during part or all of the study season (Gannon and Rillig 2002). Differences in microbial composition were estimated using phospholipid fatty acid (PLFA) analysis. PLFA structure varies between groups of prokaryote and eukaryote microorganisms; a component analysis of fatty acid concentrations in a soil sample can detect changes in relative abundance within the microbial community (Ramsey et al. 2005b). Additional analyses of these data were conducted by Ramsey et al. (2005a, b). Rice and Ray (1984) focused primarily on metal contamination of soils but briefly addressed soil microbe activity.

4.13.5 Current Condition and Trend

Soil Chemistry

pH and Organic Matter

Soils in western Montana tend to be neutral to slightly acidic (Dinkins and Jones 2013). Over the past decade, studies at GRKO have found soil pH values ranging from 4.2 to 8.8 (Table 66). Lower values, indicating more acidic soils, are typically from highly contaminated sites where heavy metals have influenced pH (Gannon and Rillig 2002). Tetratech (2012) obtained two samples with a pH below 4, both from depths of more than 45 cm (18 in). Over the 4 years of data collection by ROMN, mean soil pH has been 6.9, which is nearly neutral and falls within the reference range of 6.0-7.5 chosen for this assessment.

Table 66. pH measurements from GRKO.

	# of samples	Range	Mean
Moore and Woessner (2001)	141	4.3-8.8	--
Gannon and Rillig (2002)	40	4.2-8.3	6.7
Hayfield soil tests (Agvise 2008, 2010, 2013)	18	6.6-8	7.4
Tetratech (2012)	--	3.3-9.2	--
NPS (2013)	--	4.5-8.4*	--
ROMN 2009	24	5.6-8.1	6.9
ROMN 2010	18	5.7-7.7	6.6
ROMN 2011	24	6.3-7.7	6.9
ROMN 2012	24	6.5-7.9	7.2
ROMN Overall	**90**	**5.6-8.1**	**6.9**

*This range is for only the top horizon of each soil type, typically 15-23 cm (6-9 in).

Moore and Woessner (2001) found that lower pH readings are more common in the riparian area, where higher levels of metal contamination from mine wastes are present (Figure 79).

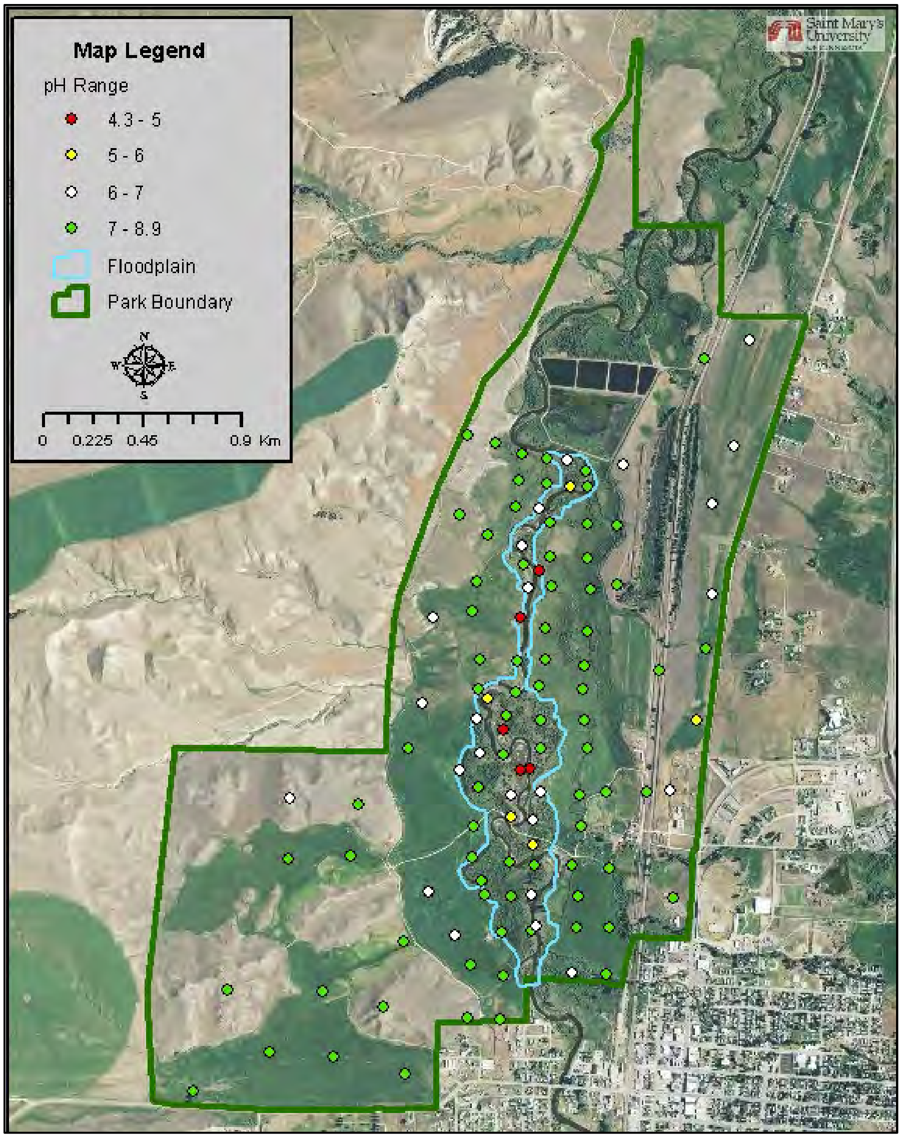


Figure 79. Map of soil pH in 2000 by sampling location (data from Moore and Woessner 2001).

Organic matter content of soils in GRKO is generally above the 2% that is considered average for Montana. Over 4 years of sampling by the ROMN, organic matter content has ranged from 0.9%-23.8%, with a mean of 7.6% (Table 67). According to the soil survey (NPS 2013a), the surface layer of two soil types found in the park (Bohnly in map unit 109 and Gregson in map unit 444) contains 28-70% organic matter.

Table 67. Organic matter content measurements from GRKO.

	# of samples	Range	Mean
Gannon and Rillig (2002)	55	0.9-17.7%	6.6%
Hayfield soil tests (Agvise 2008, 2010, 2013)	17	4.9-17.2%	8.8%
NPS (2013)*	--	1-70%	--
ROMN 2009	24	2.6-21.9%	8.2%
ROMN 2010	18	1.5-14.5%	5.6%
ROMN 2011	24	3.1-18.7%	6.8%
ROMN 2012	24	0.9-23.8%	9.7%
ROMN Overall	**90**	**0.9-23.8%**	**7.6%**

*This range is for only the top horizon of each soil type, typically 15-23 cm (6-9 in).

Nutrients (N, P, K)

Soil nutrient levels are highly variable throughout GRKO. Samples from several of the park's hayfields (Figure 80) showed considerable variation, both between fields and over time (Figure 81). West fields 3 and 4, near the Clark Fork, generally yielded the highest nutrient levels while upland fields tended to have lower nutrient levels.

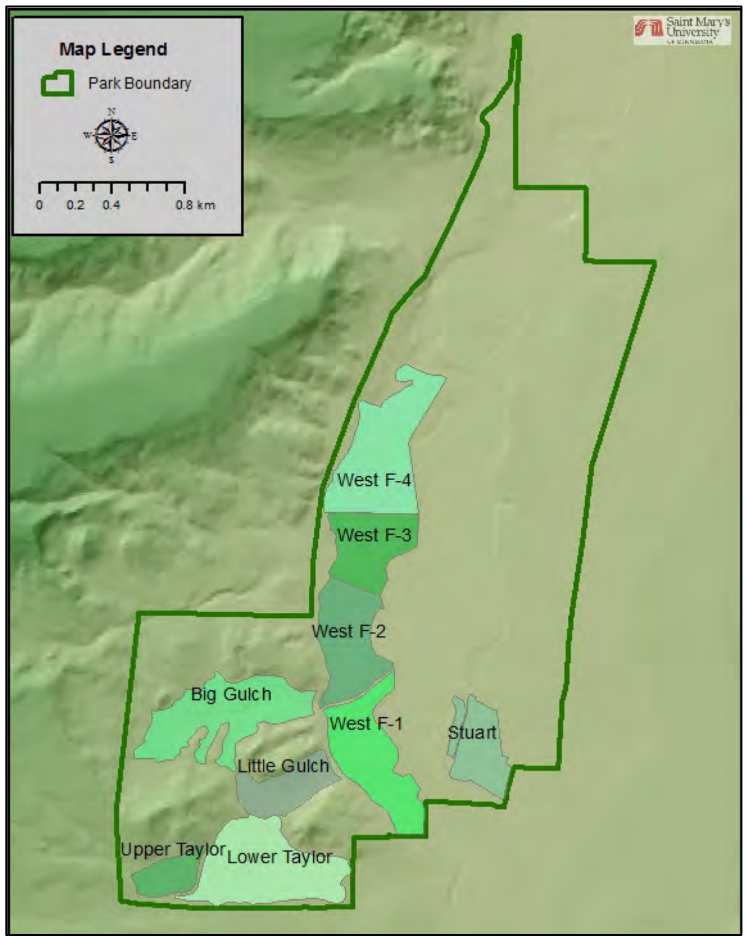


Figure 80. GRKO hayfields with soil sample test results.

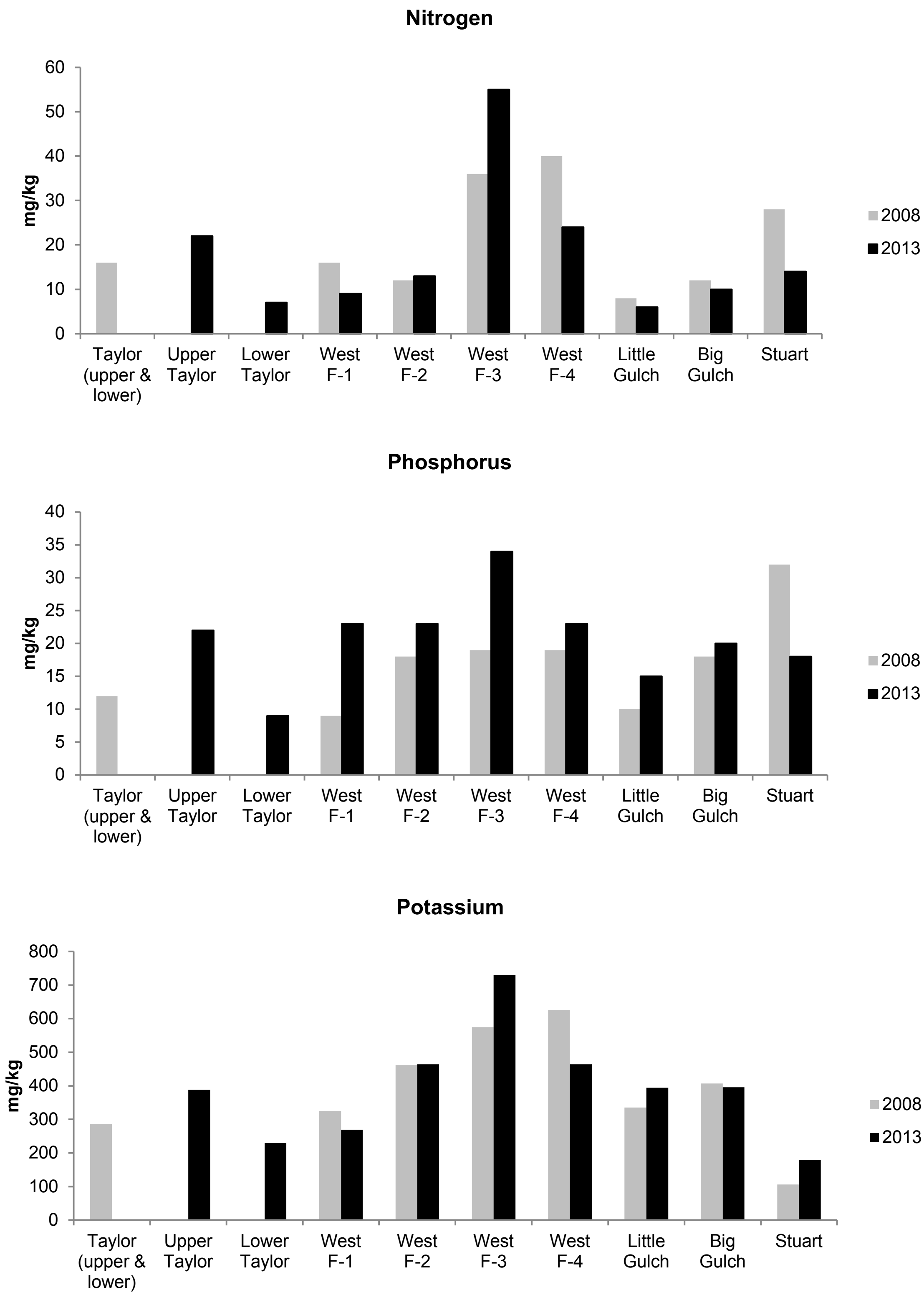


Figure 81. Soil nutrient levels from sampled GRKO hayfields in 2008 and 2013 (Agvise 2008, 2013). All samples were taken from the top 15 cm (6 in) of the soil. Note that Upper and Lower Taylor were sampled as one unit in 2008 and separately in 2013.

During ROMN sampling, which occurred throughout the park, nitrogen ranged from 1.2- 286.8 mg/kg, with a mean of 44.6 mg/kg (Table 68). The range within just the sampled hayfields was smaller at 2.5-27.5 mg/kg with a mean of 9.3 mg/kg. The recommended nitrogen level, given GRKO's crop yield goals, is 25 mg/kg. However, lower levels may be acceptable in areas that are not managed for crops. As with most Montana soils, GRKO samples were low in phosphorus and high in potassium. Mean annual phosphorus levels were variable, with 2 years above the recommended 16 mg/kg (or ppm) and 2 years below; the mean over all 4 years of sampling was below 16 mg/kg (Table 68). Mean potassium levels were above the recommended 250 mg/kg in all but one year of ROMN sampling.

Table 68. Nutrient measurements from GRKO. Unless otherwise listed, measurements are in mg/kg.

	Nitrogen as NO_3 (mg/kg)		**Phosphorus (mg/kg)**		**Potassium(mg/kg)**	
	Range	Mean	Range	Mean	Range	Mean
Hayfield soil tests (Agvise 2008, 2010, 2013)	5-55 lb/ac (~2.5-27.5 mg/kg)	18.5 lb/ac (~9.3 mg/kg)	8-34	18.4	106-730	382.6
ROMN 2009	3.3-148.2	46.2	0.07-1.28	0.30	224.6-874.8	452.1
ROMN 2010	16.4-286.8	99.8	8.6-32.4	16.7	204.4-636.4	411.8
ROMN 2011	1.2-100.4	14.4	3.7-16.2	8.9	110.1-807.0	380.2
ROMN 2012	2.3-55.6	18.1	6.0-60.0	20.1	63.8-706.5	226.2
ROMN Overall	**1.2-286.8**	**44.6**	**0.07-60**	**11.5**	**63.8-874.8**	**367.6**

Shorrock et al. (2010) noted that nutrient levels were considerably higher at two plots in the GRKO riparian area. Floodplain soils are often nutrient rich due to their location in a depositional environmental (i.e., river flooding can deposit new, nutrient rich sediments and organic matter) (Shorrock et al. 2010).

Soil Aggregate Stability

The ROMN protocol samples soil aggregate stability at two depths: surface (top 1 cm) and subsurface (2 cm deep) (Manier et al. 2011). Most soils at GRKO are fairly stable and not particularly vulnerable to erosion (Shorrock et al. 2010). Over 7 years of sampling, mean surface stability ranged from 3.9 to 5.3 with a mean of 4.7 (Table 69). Subsurface stability was slightly lower with a range of 3.3 to 4.9 and a mean of 4.3. The surface stability mean falls within the selected reference condition range of 4.5-5.5, while the subsurface score is just below this range. Given that subsurface soils are less exposed and therefore less vulnerable to erosion, this lower value is not a particular concern.

Table 69. Soil aggregate stability measurements from GRKO.

	# of samples	Mean - Surface	Mean - Subsurface
ROMN 2006	191	4.1	3.6
ROMN 2007	91	4.6	4.9
ROMN 2008	45	3.9	3.3
ROMN 2009	91	4.6	4.9
ROMN 2010	150	5.3	4.6
ROMN 2011	150	5.0	4.2
ROMN 2012	180	5.1	4.6
Overall	**898**	**4.7**	**4.3**

The ROMN has also noticed differences in soil stability depending on ground cover (vegetated vs. bare ground) (Shorrock et al. 2010). In 2009, surface soil stability at sites with canopy cover was one point higher than at sites with no canopy cover. Subsurface soil stability was more than 1.5 points higher at sites with canopy cover (Shorrock et al. 2010).

Bulk Density

ROMN sampling has not indicated that any soils at GRKO are compacted to the point of negatively impacting the vegetation community (Shorrock et al. 2010). During 4 years of study, bulk densities have ranged from 0.68 to 1.66 g/cm^3 with a mean of 1.1 g/cm^3 (Table 70). All annual means were within the selected reference condition of <1.5 g/cm^3.

Table 70. Bulk density measurements (g/cm^3) from GRKO.

	# of samples	Range (g/cm^3)	Mean (g/cm^3)
NPS (2013)*		1.1-1.55	--
ROMN 2009	24	0.79-1.66	1.15
ROMN 2010	17	0.94-1.43	1.13
ROMN 2011	24	1.01-1.42	1.21
ROMN 2012	24	0.68-1.27	1.01
ROMN Overall	**89**	**0.68-1.66**	**1.1**

*This range is for only the top horizon of each soil type, typically 15-23 cm (6-9 in).

Soil Microbial Composition and Respiration

The earliest study to explore soil microbe activity at GRKO was Ray and Rice (1984). Bioassays were performed on three soil samples from a slickens area and three samples from an adjacent vegetated area. Tests showed that soil microbial enzyme activity was reduced by 85% in the slickens areas, suggesting that heavy metal contamination depressed soil microbial activity (Rice and Ray 1984).

Gannon and Rillig (2002) conducted a more thorough study of soil microbial composition and respiration at GRKO in 2000-2001. Measured in micromoles (µM) of CO_2 per square meter per second, respiration over the 2 years ranged from 0.15 to 12.27 µM/m^2/s with a mean of 3.28 µM/m^2/s (Table 71). Respiration rates declined from September to November in 2000, demonstrating that temperature influences microbial activity.

Table 71. Microbial respiration measurements (μM/m^2/s) from plots at GRKO (Gannon and Rillig 2002).

Date	Sample plots	Range	Mean
2000	15		
14 September		0.30-12.27	5.23
26 September		0.20-5.94	2.32
10 October		0.15-4.09	1.97
2 November		0.20-2.54	0.81
2001	22		
7 June		0.32-8.41	3.43
22 June		1.60-9.21	4.57
2 July		1.00-10.28	4.67
24 September		0.36-7.89	3.27
Overall		**0.15-12.27**	**3.28**

Gannon and Rillig (2002) found connections between microbial respiration and pH, organic matter, soil moisture, and metal contamination. Sites with the highest respiration typically had high organic matter content and low heavy metal levels (Gannon and Rillig 2002). Heavy metal contamination often lowers soil pH levels, and as a result, respiration generally declines with lower pH (i.e., more acidic soils). However, the relationship between metal contamination and respiration was not linear; rather, heavy metals appeared to limit the maximum level of respiration that could be achieved. In other words,

> While at every metal concentration a number of environmental factors are acting upon respiration rates as measured in the field, the potential to achieve a high rate clearly decreases with increased metal index. This means that with increasing metal concentration, metals become a more and more dominant effect with respect to determining respiration (Gannon and Rillig 2002, p. 26).

Gannon and Rillig (2002) also determined, through PLFA analysis, that soil microbial community composition is significantly altered by heavy metal contamination.

Ramsey et al. (2005b) further analyzed Gannon and Rillig's (2002) microbial community composition data from September-October 2000. In September, microbial PLFAs ranged from 50-362 nmol/g with a mean of 156 362 nmol/g. October PLFAs yielded a mean of 141 nmol/g with a range of 60-226 nmol/g (Ramsey et al. 2005b). Data showed that high metal contamination levels caused a decline in both microbial biomass and microbial community richness (as estimated by PLFA peak number) (Figure 82). As metal levels increased, the microbial community appeared to shift from primarily Gram-negative bacteria and Actinomycetes to Gram-positive bacteria and fungi. However, these microbial declines may not be a direct effect of metal contamination, but rather due to low plant productivity and, therefore, low organic material inputs in contaminated areas (Ramsey et al. 2005b).

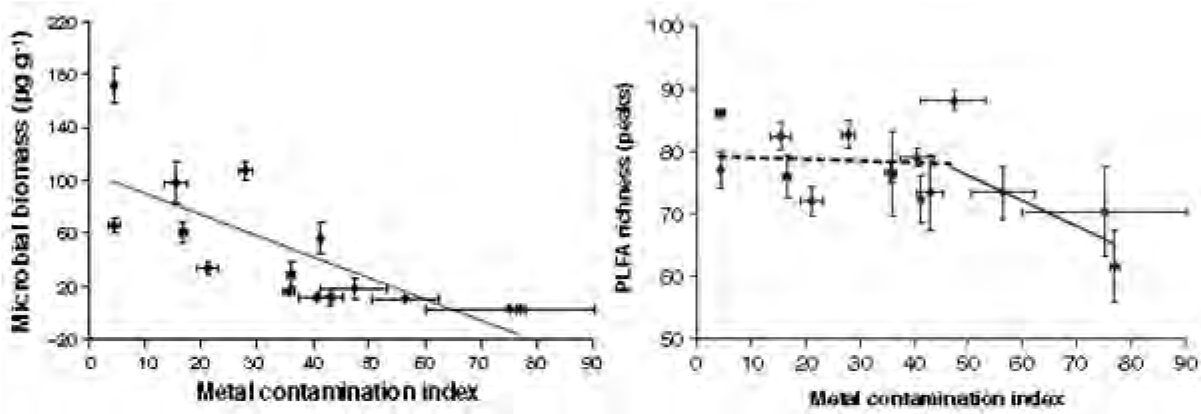


Figure 82. Soil microbial biomass (left) and community richness (right) at GRKO both decline as metal contamination increases (from Ramsey et al. 2005b).

<u>Threats and Stressor Factors</u>
Threats to the soils of GRKO include erosion, contamination from historic mining activity, remediation activities, improper grazing and /or irrigation, and removal of vegetation (e.g., haying). The mining wastes that triggered the Superfund designation in the Upper Clark Fork region are a serious concern at GRKO, particularly the heavy metal contamination and associated increases in acidity (Thornberry-Ehrlich 2007). Heavy metal contamination not only has the potential to affect the health of humans and animals, it also can impact plant health and productivity as well as soil microbial community structure and respiration (i.e., nutrient cycling) (Gannon and Rillig 2002, Kapustka 2002, Ford and Beyer 2014). Ford and Beyer (2014) established heavy metal criteria levels for soils at mining sites to protect wildlife and livestock from adverse exposure (Table 72). Above these levels, animals may experience toxic effects.

Table 72. Wildlife soil criteria for selected wildlife and livestock; metal levels are given in mg/kg (Ford and Beyer 2014).

	Arsenic	Cadmium	Copper	Lead	Zinc
deer mouse	583	18	601	191	1,437
white-tailed deer	517	15	279	1,627	1,238
mourning dove	134	9	689	133	634
mallard	646	25	1,008	637	1,896
cattle	355	20	281	1,127	1,600
horse	431	21	2,013	142	1,674

Several studies have explored soil metal contamination at GRKO over the past three decades and have collected samples with metal levels above the criteria recommended in Table 72. The earliest report is Rice and Ray (1984), who sampled soils in the early 1980s. This study found mean arsenic levels in the riparian area that exceeded criteria for the mourning dove and mean copper levels that exceeded criteria for all species listed above except horses (Table 73). Rice and Ray (1984) also illustrates that metal contamination is highest in the riparian area (nearest to the river, which is the source of most contaminants), moderate in the pastures/hayfields, and low in the uplands. Moore and Woessner (2001) found mean levels of four metals (arsenic, copper, lead, and zinc) that exceeded criteria for at least one of the species in Table 72. However, only mean copper levels exceeded criteria in the surface soils, where most animals are likely to come in contact with metals (Table 73). According to Moore and Woessner (2001), the concentrations of all five metals sampled were greater than five times the baseline levels they established for the ranch (see Moore and Woessner 2001 for details on baseline calculation). They also found, in agreement with Rice and Ray (1984), that contamination levels were highest in the riparian area (see Figure 83), and that the total volume of contaminated soil ranged from 293,000 m^3 to 1,660,000 m^3 (72.4-410.2 ac) (Moore and Woessner 2001).

Table 73. Mean metal contaminant levels in GRKO soils in mg/kg (or ppm, since 1 mg/kg = 1ppm). Ranges are listed in parentheses, when available. Numbers in red exceed one or more of the criteria in Table 72 while numbers in bold exceed criteria for cattle.

	Arsenic	Cadmium	Copper	Lead	Zinc
Rice and Ray (1984)					
Riparian	176	5.0	**1,630**		
Meadow (Pastures)	49	2.2	184		
Benches (Uplands)	30	1.6	75		
Moore & Woessner (2001)					
Soil profiles	190 (10-**1,600**)	4.0 (1.0-20)	**1,300** (3.0-**15,000**)	200 (8.0-**1,600**)	820 (14-**4,500**)
Surface soils	46 (13-**940**)	2.4 (1.0-12)	**420** (29-**8,400**)	77 (16-920)	610 (43-**3,200**)
Kapustka (2002)	315 (26-**880**)		**2,343** (120-**7,100**)		1,487 (109-**2,900**)

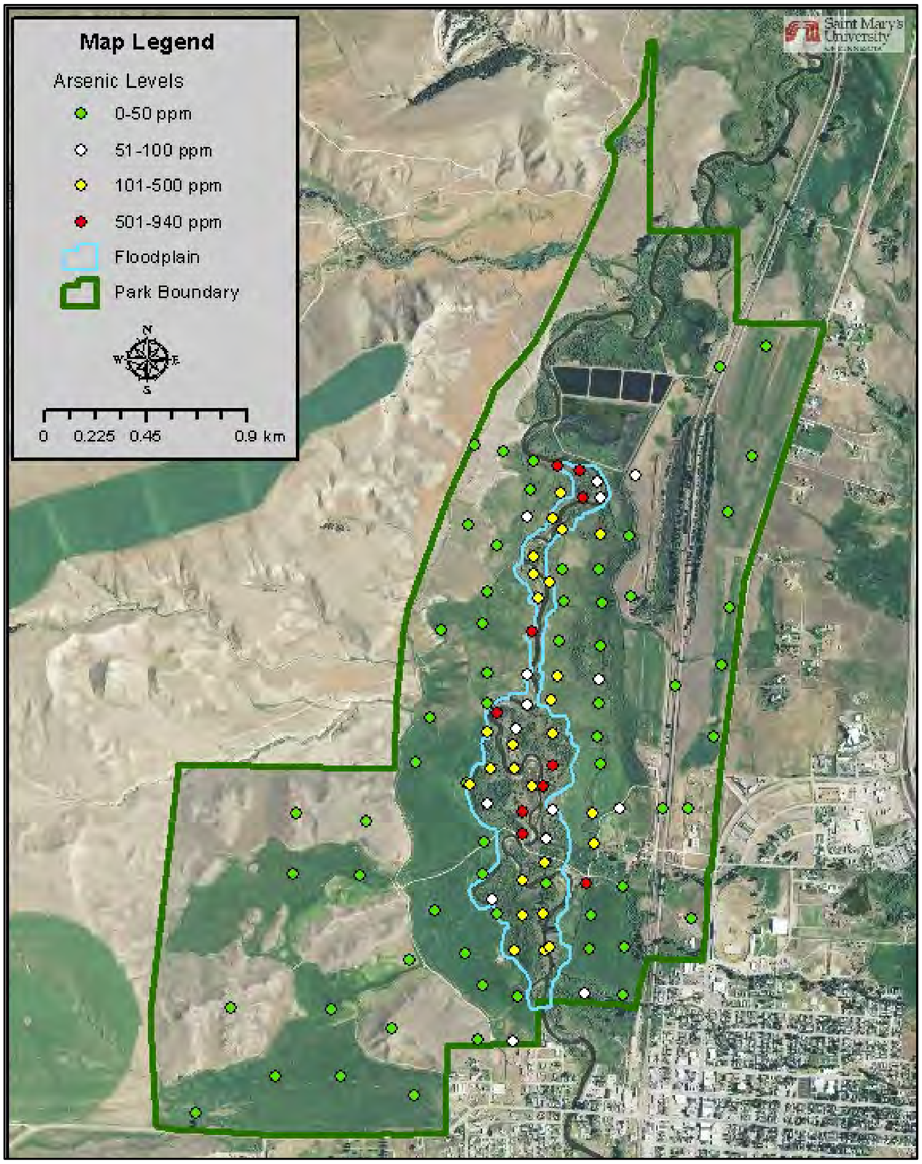


Figure 83. Map of soil arsenic concentrations in 2000 by sampling location (data from Moore and Woessner 2001). Note that 1 ppm = 1 mg/kg.

Kapustka (2002) found that GRKO soils were toxic to plants (i.e., phytotoxic), in both field plots and laboratory studies. As the metal concentrations in the soils increased, total plant biomass and root biomass both decreased, with plant mortality occurring in some cases. According to a phytotoxicity scoring system established by Kapustka (2002), seven soil samples from GRKO were classified as severely phytotoxic, 12 as highly phytotoxic, 24 as moderately or mildly phytotoxic, and only two samples as non-phytotoxic.

More recently, Tetratech (2012) sampled 576 soil pits within GRKO to determine the extent of metal contamination (Figure 84). For their purposes, any sample with total contaminants of concern (As, Ca, Cu, Pb, Zn) levels above 800 mg/kg were considered contaminated. Tetratech (2012) found that approximately 400 of the 576 soil pits contained soils above the 800 mg/kg level. Nearly 150 pits contained soils with arsenic levels above the criteria for cattle, while just over 250 pits had lead levels above the criteria for mourning doves (*Zenaida macroura*), deer mice (*Peromyscus* spp.), and horses (Tetratech 2012).

In the coming years, a massive remediation effort will take place along the Clark Fork within GRKO boundaries in an effort to remove much of this mining contamination from the site. Areas targeted will be those within the 100-year channel migration zone where the cumulative contaminants of concern exceed 800 mg/kg and the depth of contamination is 61 cm (24 in) or greater. This will involve removing approximately 296,110 m^3 (387,297 yd^3) of soil to an average depth of 0.7 m (2.3 ft) (Johnson, written communication, 17 October 2014). These areas will be backfilled with clean soil and "uncontaminated rooting medium" to support native plant revegetation and return the flood plain to a 2-year flood level (NPS 2007, p. 3-2). While the removal of this contamination will benefit GRKO in the long run, it will cause a temporary disturbance that will heavily impact the park's soils within the remediation zone.

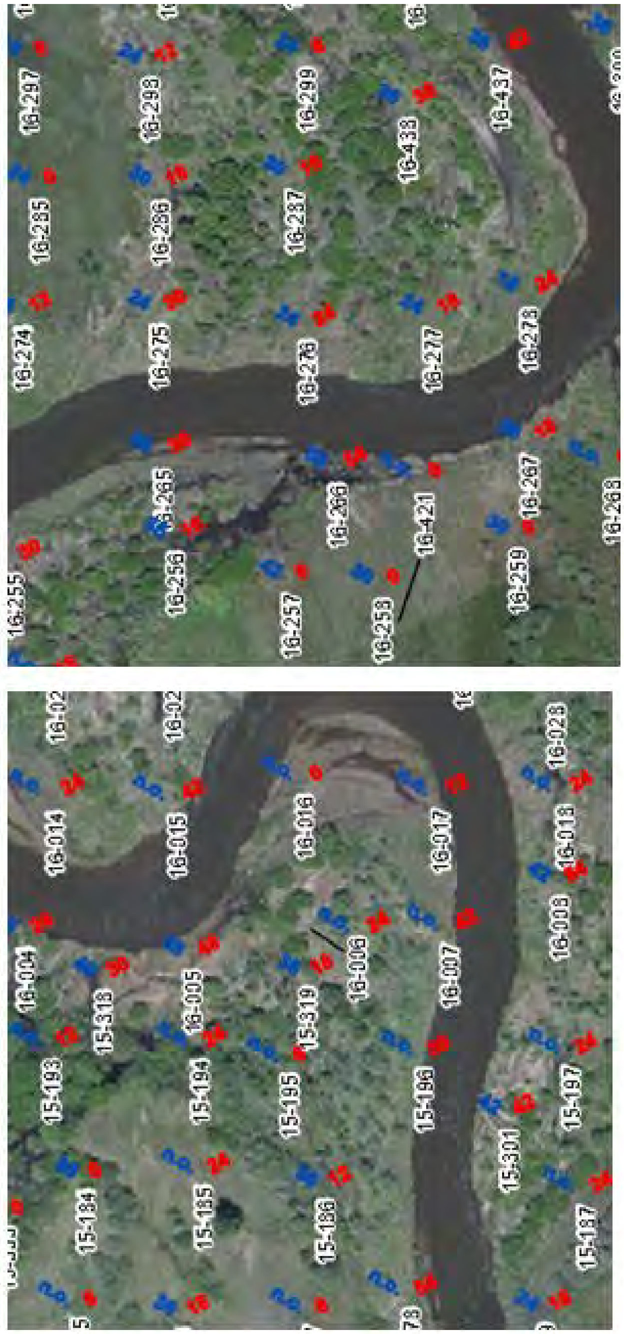


Figure 84. Tetratech (2012) soil pit locations (left). Above are close-up images of two areas (highlighted in orange boxes on larger map) showing the depth (in inches - red numbers) to which contamination exceeds the 800 mg/kg level (Tetratech 2012).

Overgrazing can cause soil compaction and the loss of vegetation that protects soils from erosion (da Silva et al. 2003, EPA 2003). Soil compaction can also destroy soil microbial biota and degrade their habitat (Menta 2012). Trampling along streambanks accelerates bank erosion, which can alter stream morphology and increase sedimentation, negatively impacting water quality (Armour et al. 1991). The removal of vegetation through hay harvest can negatively impact soils by removing carbon and nitrogen from the nutrient pools (Franzluebbers et al. 2000).

Data Needs/Gaps

Further information is needed on soil microbial community composition and respiration in GRKO in order to assess this measure's condition and any trends over time. Additional research into how the soil microbial community and its condition influence other park resources, particularly vegetation, would also be useful. Park managers are also interested in how grazing (high intensity, short duration grazing, specifically) impacts soil microbes (Smith, written communication, 5 May 2015). Continued ROMN monitoring of soil properties will help identify any changes in condition over time that are a cause for concern.

Overall Condition

Soil Chemistry

The soil chemistry measure was assigned a *Significance Level* of 3. Most soils within GRKO have pH levels within the 6-7.5 range considered suitable for crops. However, some soils in the riparian areas that have been contaminated with mining waste show pH readings below 4.5, which can inhibit plant growth. Additionally, heavy metal contaminant concentrations exceed levels known to impact plants and animals. Soil organic matter levels are above the 2% considered normal for Montana, averaging 7.6% over 4 years of ROMN sampling. Soil nutrient levels (N, P, K) are highly variable over the ranch. According to ROMN sampling, mean nitrogen levels were well above the recommended 25 mg/kg during 2 years of sampling (2009, 2010), but below that level in the remaining 2 years (2011, 2012). Several hayfield soil tests also showed nitrogen below the recommended level. Typical of Montana soils, some GRKO soils showed phosphorous levels below the recommended 16 mg/kg. Potassium levels were more consistently above the recommended 250 mg/kg, with only one annual mean from ROMN sampling just below this level. In summary, much of the soil sampling at GRKO has shown soil chemistry measurements that meet reference conditions. However, some areas are cause for concern (e.g., low pH in riparian/slickens areas, low nutrients in hayfields). As a result, this measure is assigned a *Condition Level* of 2, indicating moderate concern.

Soil Aggregate Stability

This measure was assigned a *Significance Level* of 3. Most soils at GRKO are considered fairly stable (Shorrock et al. 2010). While the overall mean surface soil stability from 7 years of ROMN sampling (4.7) falls within the reference condition range of 4.5-5.5, two annual means (2006, 2008) and the overall mean for subsurface soil samples (4.3) are below this range. Therefore, soil aggregate stability is assigned a *Condition Level* of 1 (low concern).

Bulk Density

Bulk density was assigned a *Significance Level* of 3. Since all annual means and nearly all sample ranges from ROMN monitoring over 4 years are within the selected reference condition of <1.5 g/cm^3, this measure received a *Condition Level* of 0, indicating no concern.

Soil Microbial Composition and Respiration
This measure was also assigned a *Significance Level* of 3. While some data exists regarding the soil microbial community at GRKO, not enough is known to assess its current condition. A *Condition Level* could not be assigned.

Weighted Condition Score
The *Weighted Condition Score* for soils at GRKO is 0.33. This is on the border between the low concern and moderate concern ranges. Given that isolated areas of soil are so highly contaminated with mining wastes and are clearly impacting soil chemistry and microbial activity, this resource is considered of moderate concern.

Soils			
Measures	Significance Level	Condition Level	**WCS = 0.33**
Soil Chemistry	3	2	
Soil Aggregate Stability	3	1	
Bulk Density	3	0	
Microbial Composition and Respiration	3	n/a	

4.13.6 Sources of Expertise
Jason Smith, GRKO Natural Resource Specialist

Jeff Johnson, GRKO CERCLA Project Manager

4.13.7 Literature Cited

Agvise Laboratories. 2008. Soil test reports: Grant-Kohrs Ranch. Agvise Laboratories, Northwood, North Dakota.

Agvise Laboratories. 2010. Soil test report: Grant-Kohrs Ranch. Agvise Laboratories, Northwood, North Dakota.

Agvise Laboratories. 2013. Soil test reports: Grant-Kohrs Ranch. Agvise Laboratories, Northwood, North Dakota.

Armour, C. L., D. A. Duff, and W. Elmore. 1991. The effects of livestock grazing on riparian and stream ecosystems. Fisheries 16(1):7-11.

da Silva, A. P., S. Imhoff, and M. Corsi. 2003. Evaluation of soil compaction in an irrigated short-duration grazing system. Soil and Tillage Research 70:83-90.

Dinkins, C. P., and C. Jones. 2013. Interpretation of soil test reports for agriculture (MT200702AG). Montana State University Extension, Bozeman, Montana.

Environmental Protection Agency (EPA). 2003. National management measures to control nonpoint source pollution from agriculture. EPA 841-B-03-004. Environmental Protection Agency, Washington, D.C.

Ford, K. L., and W. N. Beyer. 2014. Soil criteria to protect terrestrial wildlife and open-range livestock from metal toxicity at mining sites. Environmental Monitoring and Assessment 186:1899-1905.

Franzluebbers, A. J., J. A. Stuedemann, H. H. Schomberg, and S. R. Wilkinson. 2000. Soil organic C and N pools under long-term pasture management in the southern Piedmont U.S.A. Soil Biology and Biochemistry 32:459-478.

Gannon, J. E., and M. Rillig. 2002. Relationship of heavy metal contamination to soil respiration. National Park Service, Deer Lodge, Montana.

Herrick, J. E., J. W. Van Zee, K. M. Havstad, L. M Burkett and W. G. Whitford. 2005. Monitoring manual for grassland, shrubland and savanna ecosystems. USDA-ARS Jornada Experimental Range, Las Cruces, New Mexico, and University of Arizona Press, Tucson, Arizona.

Jacobsen, J., G. Jackson, and C. Jones. 2005. Fertilizer guidelines for Montana crops. Montana State University Extension, Bozeman, Montana.

Kapustka, L. A. 2002. Phytotoxicity tests on soils from the Grant-Kohrs Ranch National Historic Site, Deer Lodge, Montana. National Park Service, Deer Lodge, Montana.

Manier, D., D. Shorrock, E. W. Schweiger, I. Ashton, B. Frakes, M. Britten, D. Pillmore, and J. Burke. 2011. Rocky Mountain Network vegetation composition structure and soils monitoring protocol: Small park grasslands, shrublands, and woodlands; Version 1.0. Natural Resource Report NPS/ROMN/NRR-2011/383. National Park Service, Fort Collins, Colorado.

Menta, C. 2012. Soil fauna diversity – function, soil degradation, biological indices, soil restoration. Pages 59-94 *in* Biodiversity conservation and utilization in a diverse world. G. A. Lameed (ed.). http://www.intechopen.com/books/biodiversity-conservation-and-utilization-in-a-diverse-world (accessed 15 July 2014).

Moore, J. N., and W. W. Woessner. 2001. Geologic, soil water and groundwater report - 2000 Grant Kohrs Ranch National Historic Site. National Park Service, Deer Lodge, Montana.

National Park Service (NPS). 2007. Federal restoration plan for Grant-Kohrs Ranch National Historic Site. National Park Service, Deer Lodge, Montana.

National Park Service (NPS). 2010. Vegetation composition, structure, and soils: Small parks. Resource brief. National Park Service, Rocky Mountain Network, Fort Collins, Colorado.

National Park Service (NPS). 2013a. Grant-Kohrs Ranch National Historic Site, Montana: Soil survey – DRAFT. National Park Service, Fort Collins, Colorado.

National Park Service (NPS). 2013b. Soil map unit distribution of Grant-Kohrs Ranch National Historic Site, Montana. National Park Service, Fort Collins, Colorado.

Natural Resources Conservation Service (NRCS). 2001. Rangeland soil quality – compaction. http://www.nrcs.usda.gov/Internet/FSE_DOCUMENTS/nrcs142p2_051912.pdf (accessed 15 July 2014).

Olson, B., and B. Leinard. 2013. BMP Report: Grant-Kohrs Ranch National Historic Site. National Park Service, Deer Lodge, Montana.

Ramsey, P. W., M. C. Rillig, K. P. Feris, J. N. Moore, and J. E. Gannon. 2005a. Mine waste contamination limits soil respiration rates: A case study using quantile regression. Soil Biology and Biochemistry 37:1177-1183.

Ramsey, P. W., M. C. Rillig, K. P. Feris, N. S. Gordon, J. N. Moore, W. E. Holben, and J. E. Gannon. 2005b. Relationship between communities and processes; new insights from a field study of a contaminated ecosystem. Ecology Letters 8:1201-1210.

Rice, P. M., and P. C. Ray. 1984. Floral and faunal survey and toxic metal contamination study of the Grant-Kohrs Ranch National Historic Site. National Park Service, Deer Lodge, Montana.

Rice, P. M., E. W. Schweiger, W. Gustafson, C. Lea, D. Manier, D. Shorrock, B. Frakes, and L. O'Gan. 2012. Vegetation classification and mapping project report, Grant-Kohrs Ranch National Historic Site. Natural Resource Report NPS/ROMN/NRR—2012/589. National Park Service, Fort Collins, Colorado.

Rocky Mountain Inventory and Monitoring Network (ROMN). 2006. Vegetation composition, structure, and soils (VCSS) yearly master database - 2006. Microsoft Access database. Obtained from https://irma.nps.gov/App/ (accessed 16 July 2014).

Rocky Mountain Inventory and Monitoring Network (ROMN). 2007. Vegetation composition, structure, and soils (VCSS) yearly master database - 2007. Microsoft Access database. Obtained from https://irma.nps.gov/App/ (accessed 16 July 2014).

Rocky Mountain Inventory and Monitoring Network (ROMN). 2008. Vegetation composition, structure, and soils (VCSS) yearly master database - 2008. Microsoft Access database. Obtained from https://irma.nps.gov/App/ (accessed 16 July 2014).

Rocky Mountain Inventory and Monitoring Network (ROMN). 2009. Vegetation composition, structure, and soils (VCSS) yearly master database - 2009. Microsoft Access database. Obtained from https://irma.nps.gov/App/ (accessed 16 July 2014).

Rocky Mountain Inventory and Monitoring Network (ROMN). 2010. Vegetation composition, structure, and soils (VCSS) yearly master database - 2010. Microsoft Access database. Obtained from https://irma.nps.gov/App/ (accessed 16 July 2014).

Rocky Mountain Inventory and Monitoring Network (ROMN). 2011. Vegetation composition, structure, and soils (VCSS) yearly master database - 2011. Microsoft Access database. Obtained from https://irma.nps.gov/App/ (accessed 16 July 2014).

Rocky Mountain Inventory and Monitoring Network (ROMN). 2012. Vegetation composition, structure, and soils (VCSS) yearly master database - 2012. Microsoft Access database. Obtained from https://irma.nps.gov/App/ (accessed 16 July 2014).

Shorrock, D. E., I. Ashton, M. Britten, J. Burke, D. Pillmore, and E. W. Schweiger. 2010. Vegetation composition structure and soils monitoring at Grant-Kohrs Ranch National Historic Site: 2009 annual data report. Natural Resource Data Series NPS/ROMN/NRDS—2010/087. National Park Service, Fort Collins, Colorado.

Sollins, P., C. Glassman, E. A. Paul, C. Swanston, K. Lajtha, J. W. Heil, and E. T. Elliott. 1999. Soil carbon and nitrogen: pools and fractions. Pages 89-105 *in* Standard soil methods for long-term ecological research. G. P. Robertson (ed). Oxford University Press, Cary, North Carolina.

TetraTech. 2012. Clark Fork site data summary report: Reach A, phases 15 and 16. Montana Department of Environmental Quality, Remediation Division, Helena, Montana.

Thornberry- Ehrlich, T. 2007. Grant- Kohrs Ranch National Historic Site geologic resource evaluation report. Natural Resource Report NPS/NRPC/GRD/NRR—2007/004. National Park

Chapter 5 Discussion

Chapter 5 provides an opportunity to summarize assessment findings and discuss the overarching themes or common threads that have emerged for the featured components. The data gaps and needs identified for each component are summarized and the role these play in the designation of current condition is discussed. Also addressed is how condition analysis relates to the overall natural resource management issues of the park.

5.1 Component Data Gaps

The identification of key data and information gaps is an important objective of NRCAs. Data gaps or needs are those pieces of information that are currently unavailable, but are needed to help inform the status or overall condition of a key resource component in the park. Data gaps exist for most key resource components assessed in this NRCA. Table 74 provides a detailed list of the key data gaps by component. Each data gap or need is discussed in further detail in the individual component assessments (Chapter 4).

Table 74. Identified data gaps or needs for the featured components.

Component	Data Gaps/Needs
Grazing	➢ Full Rangeland Health Assessments ➢ Future repetition of range condition assessments and similarity indices
Riparian Area	➢ Repetition of vegetation surveys/research following Superfund remediation (including ecological effect size, NRCS Riparian Health Assessments, and Greenline Assessments) ➢ Update of National Wetland Inventory data using more recent aerial imagery
Pastures/Hayfields	➢ Utilize a “nutrient budget” to track all nutrients applied to hayfields and pastures ➢ Establish a plan for managing “Effluent Fields” since the city’s effluent water is no longer available for irrigation
Uplands (grasslands, non-irrigated)	➢ Additional community surveys in order to calculate ecological effects sizes (will be aided by development of NRCS Ecological Site Descriptions) ➢ Full Rangeland Health Assessments ➢ Future repetition of range condition assessments and similarity indices
Birds	➢ Establishment of an annual survey with increased yearly sampling (>1 survey/year) and a spatially balanced bird protocol would allow for density and occupancy estimates ➢ More winter bird surveys, in addition to Christmas Bird Counts
Periphyton	➢ Continued yearly monitoring efforts to accumulate long-term data for the sediment increaser model ➢ Study how periphyton are impacted by the initial disturbance of Superfund remediation and by the subsequent “improved” (e.g., less contaminated) conditions

Table 74. Identified data gaps or needs for the featured components. (continued)

Component	Data Gaps/Needs
Aquatic Macroinvertebrates	➢ Continued yearly monitoring efforts to accumulate long-term data for the RIVPACS model and MMI ➢ Study how aquatic macroinvertebrates are impacted by the initial disturbance of Superfund remediation and by the subsequent "improved" (e.g., less contaminated) conditions
Air Quality	➢ No air quality monitors within the distance (16 km [10 mi]) necessary to accurately represent conditions in the park
Water Quality	➢ Limited data for groundwater quality ➢ Limited data for total suspended sediment (TSS) of surface waters and no data for coliform bacteria specific to park surface waters ➢ Study how Superfund remediation efforts impact water quality parameters in both the short and long-term
Soundscape	➢ Regular measurements (annual or biennial) of sound levels and sound recordings ➢ Additional focus on the frequency and duration of non-contributing sounds or the percent of time they are audible ➢ Create a soundscape management plan or integrate soundscape into other planning documents
Viewscape	➢ Additional analysis of historic aerial photos (e.g., from the 1990s or mid-2000s) to further document development just outside the park that has impacted its viewscape
Hydrology	➢ Limited information on irrigation flow inputs and groundwater resources (e.g., depth to groundwater, flow patterns, sustainable yields) ➢ Research into the interaction between surface water and groundwater and the influence of irrigation ➢ Additional study to determine if and how climate change is affecting GRKO hydrology
Soils	➢ Further information on soil microbial community composition and respiration, as well as research into how the soil microbial community and its condition influence other park resources, particularly vegetation ➢ Research into the impacts of grazing (high intensity, short duration) on soils and soil microbes ➢ Continued ROMN monitoring of soil properties to help identify any changes in condition

Several of the park's data needs involve continuing recently established monitoring programs, to accumulate sufficient data for identifying any trends over time (e.g., periphyton, aquatic macroinvertebrates, soils, soundscape). Other components, such as birds, would benefit from more consistent sampling efforts (both timing and methodology), as funding allows.

5.2 Component Condition Designations

Table 75 displays the conditions assigned to each resource component presented in Chapter 4 (definitions of condition graphics are located in Table 76 following Table 75). It is important to remember that the graphics represented are simple symbols for the overall condition and trend assigned to each component. Because the assigned condition of a component (as represented by the symbols in Table 75) is based on a number of factors and an assessment of multiple literature and data sources, it is strongly recommended that the reader refer back to each specific component assessment in Chapter 4 for a detailed explanation and justification of the assigned condition. Condition designations for some components are supported by existing datasets and monitoring information and/or the expertise of NPS staff, while other components lack historical data, a clear understanding of reference condition (i.e., what is considered desirable or natural) for some measures, or even current information. Condition could not be determined for three of the 13 selected components: grazing, uplands, and hydrology.

For featured components with available data and fewer information gaps, assigned conditions varied. Six components are considered in good condition: pastures and hayfields, birds, periphyton, aquatic macroinvertebrates, air quality, and viewscape. However, periphyton and aquatic macroinvertebrates scores were at the edge of the good condition range, and any small decline in the community could shift them into the moderate concern range. Four components (riparian area, water quality, soundscape, and soils) were of moderate concern, and no components were considered to be of significant concern.

Table 75. Summary of current condition and condition trend for featured NRCA components.

Component	WCS	Condition
Ecosystem Extent and Function		
Disturbance Regimes		
Grazing	N/A	
Biological Composition		
Ecological Communities		
Riparian Area	0.54	
Pastures/Hayfields	0.33	
Uplands (Grasslands, non-irrigated)	N/A	

Table 75. Summary of current condition and condition trend for featured NRCA components. (continued)

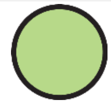
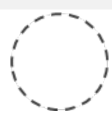
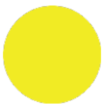
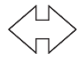
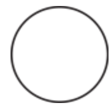
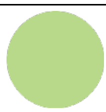
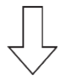
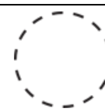
Component	WCS	Condition
Birds		
Birds	0.22	
Freshwater Biota		
Periphyton	0.33	
Aquatic Macroinvertebrates	0.33	
Environmental Quality		
Air quality	0.13	
Water quality	0.39	
Soundscape	0.33	
Viewscape	0.22	
Physical Characteristics		
Geologic & Hydrologic		
Hydrology (Surface and Groundwater Dynamics)	N/A	
Soils	0.33	

Table 76. Description of symbology used for individual component assessments.

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 *(explanation is required if a trend symbol or a medium/high confidence band is shown)*				

Examples of how the symbols should be interpreted:

Resource is in good condition, its condition is improving, high confidence in the assessment.

Condition of resource warrants moderate concern; condition is unchanging; medium confidence in the assessment.

Condition of resource warrants significant concern; trend in condition is unknown or not applicable; low confidence in the assessment.

Current condition is unknown or indeterminate due to inadequate data, lack of reference value(s) for comparative purposes, and/or insufficient expert knowledge to reach a more specific condition determination; trend in condition is unknown or not applicable; low confidence in the assessment.

5.3 Park-wide Condition Observations

Vegetation Communities/Grazing
The vegetation communities of GRKO are vital resources for the park, particularly given their integral role in providing grass and hay for livestock on the working ranch and as a backdrop of the cultural landscape. The park's pastures and hayfields are in good condition and stable, while the riparian area is of moderate concern. A trend could not be determined for the riparian area, as some measures seemed stable but others did not have enough data to detect any change over time (e.g., Greenline Assessment, NRCS Riparian Health Assessment). The riparian area will be heavily impacted by Superfund remediation activities, with extensive soil removal and re-vegetation in the near future. The condition of GRKO's upland grasslands could not be determined due to a scarcity of data for the selected measures. Invasive plants are a serious threat to the uplands, but there is currently no evidence that upland grassland conditions are of significant concern.

The condition of grazing is largely dependent on the condition of the vegetation communities utilized. Two methods commonly used to assess grazed lands were selected as measures for this component: Range Condition/Similarity Index and Rangeland Health (Pellant et al. 2005). Recently calculated Range Condition scores and similarity indices, which focus on vegetative composition, suggest that GRKO's grazing areas are in good condition. Full Rangeland Health Assessments, which take into account other ecosystem characteristics (e.g., soil condition, ecological processes), have not been completed for GRKO's lands. As a result an overall condition was not determined for the grazing component. Ecological Site Descriptions, which are in the initial stages of development by the NRCS, will aid in assessing grazing land conditions in the future (NRCS 2015).

Other Biotics
Other biotic components included in the NRCA were birds, periphyton, and aquatic macroinvertebrates. Birds were considered in good condition with a stable trend. This is a good sign for the park overall, as bird populations often serve as indicators of an ecosystem's health (Morrison 1986, Hutto 1998, NABCI 2009). Periphyton and aquatic macroinvertebrates also received a "good condition" designation but, as mentioned above, were on the border of the moderate concern range. Consistent monitoring of these communities was recently initiated and continuation of those efforts will allow for more accurate assessment of their condition.

Environmental Quality
Environmental quality is important in maintaining healthy functioning ecosystems. The health of terrestrial and aquatic organisms in parks can be affected substantially by the condition of air and water quality. GRKO's air quality appears to be in good condition; however, the nearest monitoring stations are outside the range of what the NPS ARD considers representative of park conditions (16 km [10 mi]). Monitoring stations closer to GRKO would be needed to confirm that interpolated and estimated data used in this NRCA accurately reflects conditions in the park.

Clark Fork water quality, including within GRKO, has been heavily impacted by historic mining contamination from upstream. Metals in the water and sediment of the park have been a significant concern for management. The current condition of water quality is of moderate concern but with an improving trend. Upcoming Superfund remediation efforts along the Clark Fork within GRKO will remove much of the historic contamination, which will likely further improve condition. However, the disturbance from these remediation activities may cause a temporary decrease in water quality.

The park's viewscape is currently in good condition, with little change occurring inside the park but noticeable development outside park boundaries to the south and east. Soundscape is of moderate concern due to increased air, train, and road traffic around the park. This increased traffic suggests a deteriorating trend for the component.

Physical Characteristics
An overall condition could not be assigned for GRKO's hydrology, primarily due to limited information on irrigation flow inputs (i.e., how much water is diverted from the river for irrigation) and depth to groundwater. For those measures with enough data for analysis (stream discharge, annual precipitation), concern was low. This suggests there is currently no significant cause for concern regarding hydrology at the park.

The park's soils are currently of moderate concern, largely due to the lingering effects of historic mining contamination in the riparian area. Although soil physical properties (bulk density, aggregate stability) and organic matter content are of no or low concern, heavy metal contaminant concentrations in some areas exceeded levels known to impact plants and animals (Moore and Woessner 2001, Kaputska 2002, TetraTech 2012). This contamination appears to have negatively impacted pH levels and soil microbial activity (Gannon and Rillig 2002). As with water quality, upcoming Superfund remediation efforts will improve soil conditions in the riparian area in the long-term but may first cause a short-term disturbance and decline in conditions.

Park-wide Threats and Stressors
Several threats and stressors influence the condition of multiple resources within GRKO. These include invasive plant species, mining contamination, and the related Superfund remediation activities. Many non-native plant species that occur in the park were introduced as hay species and pasture grasses and are now considered "contributing features" on the cultural landscape, as they represent the history of ranching in the area (John Milner Associates et al. 2004). However, other non-natives are considered invasive and are a significant concern at GRKO. Invasive species can alter plant community composition and ecological processes (e.g., water and nutrient cycling) and contribute to biodiversity and habitat losses (Lacey et al. 1989, NPS 2008). They also threaten the cultural landscape the park was set aside to protect and can reduce forage quality (Manier et al. 2011). Recent efforts to reduce invasive species at GRKO have been largely effective, particularly in the riparian area (see Appendix E), but further work and continued vigilance will be necessary to minimize their impact.

Mining contamination has affected many park resources, including vegetation communities, soils, and water quality. Some "slickens" patches in the riparian area are so contaminated that they are completely devoid of vegetation (Rice and Hardin 2002). This contamination is what led to the designation of the Upper Clark Fork as a Superfund site in 1992 (NPS 2007). Remediation efforts to remove much of this contamination have been occurring in stages upstream (south) of GRKO for several years. Remediation activities are scheduled to begin soon in GRKO and will involve the removal of nearly 300,000 m^3 of contaminated soil from the Clark Fork riparian area. These areas will be backfilled with clean soil to support native plant revegetation and return the floodplain to a 2-year flood level (NPS 2007). While this will help restore the health of the riparian area in the long-term, the removal and initial restoration efforts will cause disturbance that will temporarily impact nearly every resource in the park, including vegetation, wildlife, water quality, soils, and even soundscape and viewscape.

Overall Conclusions

As outlined in Chapter 2, GRKO's management objectives include providing opportunities for visitors to understand the cattle industry and its evolution, and managing natural resources in a way that complements the historical context of the ranch and cattle ranching operations (NPS 1993). GRKO also strives towards sustainable ranching, which "maintains and improves grassland and riparian health, supports vigorous livestock and wildlife populations that result in economic success, educational opportunity and community benefit beyond a single generation" (NPS 2011). Balancing these objectives, which sometimes may conflict, can be a challenge. This NRCA found that six of the 13 selected components (resources) are currently in good condition and none are of significant concern. Components that are of moderate concern are primarily influenced by threats and stressors outside the control of park managers. These results suggest that GRKO is successfully meeting its sustainable ranching and natural resource management goals.

5.4 Literature Cited

Gannon, J. E., and M. Rillig. 2002. Relationship of heavy metal contamination to soil respiration. National Park Service, Deer Lodge, Montana.

Hutto, R. L. 1998. Using landbirds as an indicator species group. Pages 75-92 *in* Avian conservation: Research and management. Island Press, Washington, D.C.

John Milner Associates, Rivanna Archaeological Consulting, Susan Maxman and Partners Architects. 2004. Cultural landscape report. National Park Service, Deer Lodge, Montana.

Kaputska, L. A. 2002. Phytotoxicity tests on soils from the Grant-Kohrs Ranch National Historic Site, Deer Lodge, Montana. National Park Service, Deer Lodge, Montana.

Lacey, J. R., C. B. Marlow, and J. R. Lane. 1989. Influence of spotted knapweed (*Centaurea maculosa*) on surface runoff and sediment yield. Weed Technology 3(4):627-631.

Manier, D., D. Shorrock, E. W. Schweiger, I. Ashton, B. Frakes, M. Britten, D. Pillmore, and J. Burke. 2011. Rocky Mountain Network vegetation composition structure and soils monitoring protocol: Small park grasslands, shrublands, and woodlands; Version 1.0. Natural Resource Report NPS/ROMN/NRR-2011/383. National Park Service, Fort Collins, Colorado.

Moore, J. N., and W. W. Woessner. 2001. Geologic, soil water and groundwater report - 2000 Grant Kohrs Ranch National Historic Site. National Park Service, Deer Lodge, Montana.

Morrison, M. L. 1986. Bird populations as indicators of environmental change. Current Ornithology 3:429-451.

National Park Service (NPS). 1993. Grant-Kohrs Ranch National Historic Site: Environmental impact statement for a general management plan and development concept plan. National Park Service, Deer Lodge, Montana.

National Park Service (NPS). 2007. Federal restoration plan for Grant-Kohrs Ranch National Historic Site. National Park Service, Deer Lodge, Montana.

National Park Service (NPS). 2008. Exotic plant management team: 2008 annual report. National Park Service, Biological Resources Management Division, Fort Collins, Colorado.

National Park Service (NPS) 2011. Grant-Kohrs Ranch: Sustainable ranching. http://www.nps.gov/grko/learn/management/upload/Sustainable-Ranching-2-28-11.pdf (accessed 17 February 2015).

Natural Resources Conservation Service (NRCS). 2015. Ecological Site Descriptions. http://www.nrcs.usda.gov/wps/portal/nrcs/main/national/technical/ecoscience/desc/ (accessed 6 May 2015).

North American Bird Conservation Initiative, U.S. Committee (NABCI). 2009. The State of the Birds, United States of America, 2009. U.S. Department of the Interior, Washington, D.C.

Pellant, M., P. Shaver, D. A. Pyke, and J. E. Herrick. 2005. Interpreting indicators of Rangeland Health, version 4. Technical Reference 1734-6. U.S. Department of the Interior, Bureau of Land Management, National Science and Technology Center, Denver, Colorado.

Rice, P. M., and J. Hardin. 2002. Riparian plant community structure at Grant-Kohrs Ranch. National Park Service, Deer Lodge, Montana.

TetraTech. 2012. Clark Fork site data summary report: Reach A, phases 15 and 16. Montana Department of Environmental Quality, Remediation Division, Helena, Montana.

Appendices

Appendix A. Non-native plants species documented in GRKO (NPS 2014). Note that not all non-native species are invasive. Species in bold have been designated as “contributing features” of the cultural landscape (John Milner Associates et al. 2004).

Scientific Name	Common Name	Scientific Name	Common Name
Achillea ptarmica	sneezeweed	*Polygonum convolvulus*	black bindweed
*Rhaponticum repens**^	Russian knapweed	*Polygonum persicaria*	ladysthumb
Artemisia biennis	biennial wormwood	*Rumex acetosella*	sheep sorrel
Carduus nutans	musk thistle	*Rumex crispus*	curly dock
*Centaurea stoebe**^	spotted knapweed	*Rumex obtusifolius*	bitter dock
*Cirsium arvense**^	Canada thistle	*Lonicera x bella*	Bell's honeysuckle
Cirsium vulgare	bull thistle	*Medicago lupulina*	black medick
Hieracium umbellatum	narrowleaf hawkweed	*Medicago sativa*	alfalfa
Lactuca sativa	garden lettuce	*Melilotus officinalis*	sweetclover
Lactuca serriola	prickly lettuce	*Onobrychis viciifolia*	sainfoin
Sonchus arvensis	field sowthistle	***Trifolium pratense***	**red clover**
Sonchus arvensis ssp. *uliginosus*	moist sowthistle	*Trifolium repens*	white clover
*Tanacetum vulgare**^	common tansy	*Vicia cracca*	bird vetch
Taraxacum officinale	dandelion	*Betula pendula*	European white birch
Tragopogon dubius	yellow salsify	*Galeopsis tetrahit*	hemp nettle
Tragopogon pratensis	meadow salsify	*Glechoma hederacea*	ground ivy
Callitriche stagnalis	pond water-starwort	*Syringa vulgaris*	common lilac
*Cynoglossum officinale**^	houndstongue	*Campanula rapunculoides*	creeping bellflower
Myosotis scorpioides	forget-me-not	*Linaria vulgaris**^	yellow toadflax
Alyssum alyssoides	pale madwort	*Plantago major*	common plantain
Alyssum desertorum	desert madwort	*Verbascum thapsus*	common mullein
Barbarea vulgaris	yellowrocket	*Euphorbia esula**^	leafy spurge
Camelina microcarpa	littlepod falseflax	***Agropyron cristatum***	**crested wheatgrass**
Capsella bursa-pastoris	shepherd's purse	***Agrostis stolonifera***	**redtop**
Lepidium chalapensis	lenspod hoarycress	*Alopecurus pratensis*	meadow foxtail
*Lepidium draba**^	whitetop; hoary cress	***Bromus inermis***	**smooth brome**
Lepidium appelianum	hairy whitetop	*Bromus arvensis*	field brome
Descurainia sophia	herb sophia; flixweed	*Bromus tectorum**	cheatgrass
Hesperis matronalis	dames rocket	*Dactylis glomerata*	orchard grass
*Lepidium latifolium**^	perennial pepperweed	*Echinochloa crus-galli*	barnyard grass
Lepidium perfoliatum	clasping pepperweed	*Elymus repens*	quackgrass
Cerastium fontanum ssp. *vulgare*	common mouse-ear chickweed	*Elymus trachycaulus* ssp. *trachycaulus*	slender wheatgrass
Rorippa sylvestris	creeping yellowcress	*Lolium pratense*	meadow fescue
Sisymbrium altissimum	tall tumblemustard	*Phalaris arundinacea*	reed canarygrass
Sisymbrium loeselii	tumblemustard	***Phleum pratense***	**timothy**
Thlaspi arvense	field pennycress	*Poa compressa*	Canada bluegrass
Amaranthus blitoides	mat amaranth	***Poa pratensis***	**Kentucky bluegrass**
Chenopodium album	lambsquarters	*Setaria viridis*	green bristlegrass
Chenopodium glaucum	oakleaf goosefoot	*Nasturtium officinale*	watercress
*Bassia scoparia**	kochia; burningbush	*Ranunculus repens*	creeping buttercup
Salsola paulsenii	barbwire Russian thistle	*Ranunculus acris**^	tall buttercup
Salsola tragus	prickly Russian thistle	*Malus* sp.	apple
*Gypsophila paniculata**	baby's breath	*Potentilla recta**^	sulfur cinquefoil

Scientific Name	Common Name	Scientific Name	Common Name
Thinopyrum intermedium	**intermediate wheatgrass**	*Convolvulus arvensis**^	field bindweed
Silene latifolia ssp. *alba*	bladder campion	*Hyoscyamus niger*	black henbane
Silene vulgaris	maidenstears	*Solanum dulcamara*	climbing nightshade
Polygonum arenastrum	oval-leaf knotweed		

* - Northern Rocky Mountains EPMT priority species for GRKO (NPS 2011b)

^ - State of Montana noxious weed

Appendix B. Ecological Effect Size Examples

by Peter Rice, University of Montana Research Ecologist

Ecological effect size (A) is a whole community level parameter that quantifies the deviation of current in-situ Grant-Kohrs plant communities from the desired Potential Natural Community (PNC). The Montana Riparian Wetland Association (MRWA) developed a riparian & wetlands plant community classification system (Hansen et al. 1995) which provides the reference standard data for the PNCs expected on the Grant-Kohrs Ranch. Ecological effect size (A) is derived from ocular canopy cover estimates for every individual species in the sample plots. In our application, the calculated A ranges from 0 to 1; the larger the value of A, the greater the deviation of the species composition of the sample plot from the PNC.

Toxic metal contamination of the Grant-Kohrs riparian soils caused the plant species composition to be altered from the PNC as a function of differential toxic metal susceptibility and tolerance among the plant species. In the examples in Table B-1, we see that the ecological effect size (A) for the deviation of the GRKO Geyer Willow community type from the MRWA PNC reference condition is 0.088 and 0.143 for the Water Birch community type (Table B-1). Both example cases are very highly statistically significant ($p<0.001$). Moreover plant ecologists consider ecological effect sizes of 0.1 to 0.3+ calculated from numerous plots to be ecologically important. Vegetation ecological effect sizes greater than 0.4 are rare in natural systems, unless there are disturbance forces that remove and replace large portions of the in-situ vegetation.

Table B-1. Ecological effect size (A) deviation of two Grant-Kohrs riparian plant communities from the desired Potential Natural Community (MRWA PNC; Hansen et al. 1995).

Community Type	Common Name	Number of Plots		Ecological Effect Size	
		MRWA PNC	GK	A	P<X
SALGEY	GEYER WILLOW	67	43	0.088	<0.001
BETOCC	WATER BIRCH	20	28	0.143	<0.001

The extent of the ecological effect size or deviation from PNC can be portrayed graphically by ordination techniques (Figure B-1 and Figure B-2). In the graphic portrayal we contrast the GRKO plots with their respective PNC reference plots. Only plant species present in at least 20% of sampled plots (i.e., constancy ≥20%) were included in this ordination. Each point represents a single plot. The point or plot position in the ordination coordinate system, like ecological effect size, is also determined by the ocular canopy cover estimates for every individual species in that sample plot. Plots that are closer together are more similar in overall species composition. Plots that are increasingly separated in the coordinate system are increasingly dissimilar in species composition. As a group, the Grant Kohrs plant community plots are clearly different from the desired PNC group. Stress values of 20 or less suggest that the graphic can be visually interpreted with confidence. (Note that ordinations are actually three-dimensional and the full degree of separation between plots is not visible in the two-dimensional graphs below.)

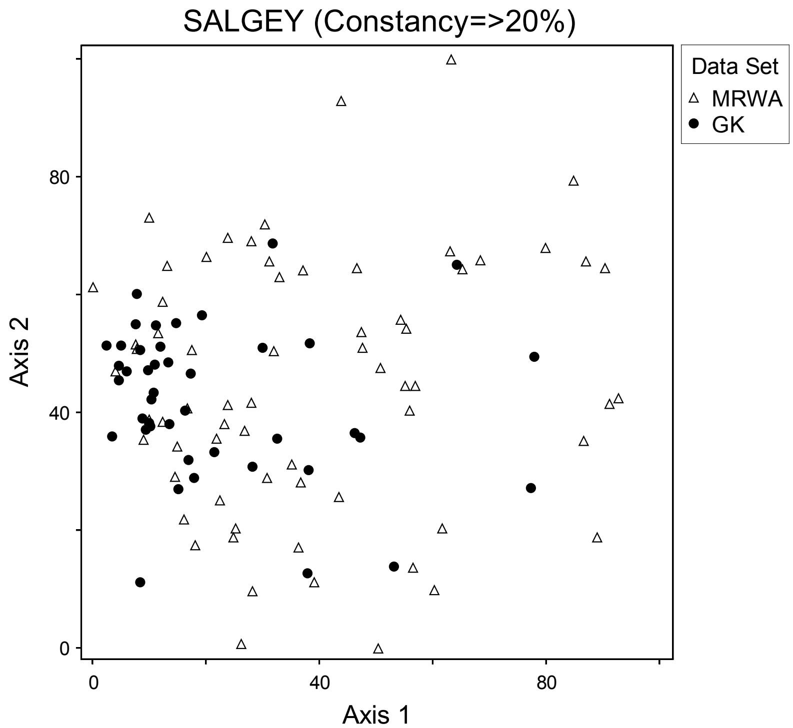


Figure B-1. NMS ordinations of Geyer Willow (SALGEY) plots on the Grant-Kohrs Ranch contrasted with the Potential Natural Community as defined by the Montana Riparian and Wetland Association standard reference plots (Three-Dimensional Ordination, Stress 18.4).

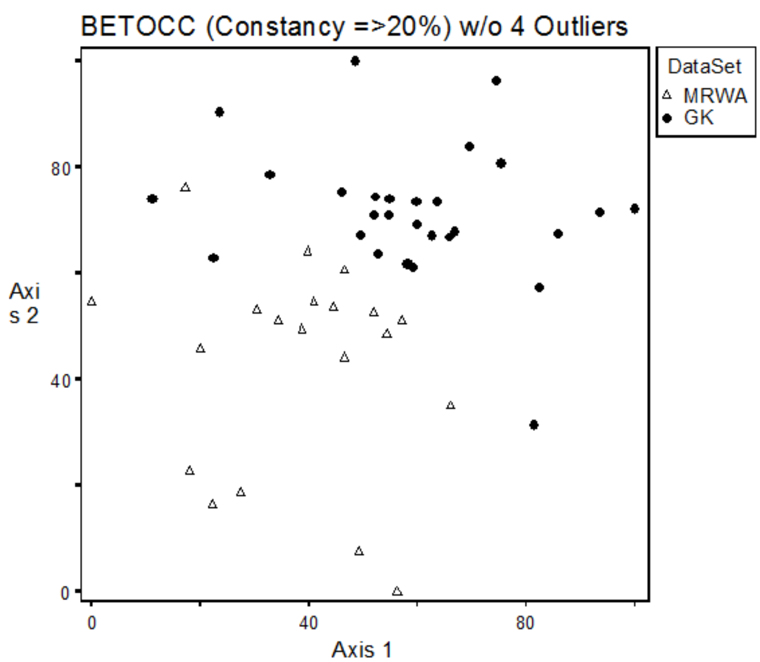


Figure B-2. NMS ordinations of riparian Water Birch (BETOCC) plots on the Grant-Kohrs Ranch contrasted with the Potential Natural Community as defined by the Montana Riparian and Wetland Association standard reference plots (Three-Dimensional Ordination, Stress 12.5).

By re-grading the riparian flood plain topographic elevations, replacing contaminated soils, and replanting as part of Superfund remediation efforts, the NPS is acting to restore the metal impacted plant communities on the Ranch to a more natural condition. The various MRWA PNC reference plots provide an all species numerical standard for that goal and calculation of ecological effect size provides a quantitative measure of progress towards the natural restoration goal.

Appendix C. Plant species documented throughout Montana in the 19 riparian community types that occur within GRKO (see Table 11) by Hansen et al. (1995), in GRKO riparian areas by Rice and Hardin (2002) or Rice and Smith (2011). The final column indicates all species documented by Hansen et al. (1995) that have been confirmed within GRKO (NPS 2014c), both in and outside the riparian zone. Columns under Hansen et al. (1995) indicate if a species was found in riparian community types dominated by (or named for) trees and shrubs or community types dominated by herbaceous vegetation.

Scientific name	Common name	Hansen et al. (1995)		Rice & Hardin (2002)	NPS (2014c)
		Tree/shrub	Herbaceous	Riparian	in GRKO
Trees					
Abies lasiocarpa	subalpine fir	x	x		
Acer negundo	boxelder	x			
Betula papyrifera	paper birch	x			
*Elaeagnus angustifolia**	Russian olive	x			
Fraxinus pennsylvanica	green ash	x			x
Juniperus scopulorum	Rocky Mountain juniper	x		x	x
Larix occidentalis	western larch	x			
Picea sp.	spruce sp.	x	x		
Pinus contorta	lodgepole pine	x	x		
Pinus flexilis	limber pine	x			
Pinus ponderosa	ponderosa pine	x			
Populus angustifolia	narrowleaf cottonwood	x			
Populus deltoides	Great Plains cottonwood		x		
Populus tremuloides	quaking aspen	x	x		x
Populus balsamifera ssp. *trichocarpa*	black cottonwood	x	x	x	x
Pseudotsuga menziesii	Douglas fir	x			
Salix alba	golden willow	x			
Salix amygdaloides	peach-leaf willow	x			
Thuja plicata	western redcedar	x			
Shrubs					
Acer glabrum	Rocky Mountain maple	x			
Alnus incana	mountain alder	x		x	x
Amelanchier alnifolia	western serviceberry	x		x[1]	x
Arctostaphylos uva-ursi	kinnikinnick	x			
Artemisia cana	silver sagebrush	x			
Artemisia frigida	fringed sagebrush	x			x
Artemisia tridentata	big sagebrush	x			
Betula glandulosa	bog birch	x	x		
Betula occidentalis	water birch	x		x	x
Celastrus scandens	American bittersweet	x			
Chrysothamnus viscidiflorus	green rabbitbrush			x	x
Clematis ligusticifolia	western virgin's bower	x			

Scientific name	Common name	Hansen et al. (1995)		Rice & Hardin (2002)	NPS (2014c)
		Tree/shrub	Herbaceous	Riparian	in GRKO
Clematis occidentalis	Columbia clematis	x			
Cornus canadensis	bunchberry	x			
Cornus sericea	red-osier dogwood	x	x	x	x
Crataegus douglasii	black hawthorn	x			
Crataegus succulenta	succulent hawthorn	x			
Dasiphora fruticosa	shrubby cinquefoil	x	x	x	x
Dryas drummondii	yellow mountain-avens	x			
Elaeagnus commutata	silverberry	x			
Ericameria nauseosa	gray rabbitbrush			x	x
Gutierrezia sarothrae	broom snakeweed			x	x
Juniperus communis	common juniper	x			
Juniperus horizontalis	creeping juniper	x			
Kalmia microphylla	small-leaved laurel		x		
Ledum glandulosum	Labrador tea	x	x		
Linnaea borealis	twinflower	x			
Lonicera involucrata	twinberry honeysuckle	x	x		
Lonicera utahensis	Utah honeysuckle	x			x
Mahonia repens	creeping Oregongrape	x	x		
Parthenocissus quinquefolia	Virginia creeper	x			
Parthenocissus vitacea	woodbine	x			
Philadelphus lewisii	mock orange	x			
Prunus americana	wild plum	x			
Prunus virginiana	common chokecherry	x		x	x
Rhamnus alnifolia	alder buckthorn	x			
Rhus aromatica	fragrant sumac	x			
Ribes americanum	black currant	x			
Ribes aureum	golden currant			x	x
Ribes cereum	wax currant	x			
Ribes sp.	currant sp.	x	x	x	x
Ribes hudsonianum	stinking currant	x			
Ribes inerme	whitestem gooseberry	x			
Ribes lacustre	swamp currant	x			
Ribes missouriense	Missouri gooseberry	x			
Ribes odoratum	buffalo currant	x			
Ribes oxyacanthoides	Canadian gooseberry	x		x	x
Ribes viscosissimum	sticky currant	x			
Rosa acicularis	prickly rose	x	x		
Rosa arkansana	prairie rose	x			
Rosa woodsii	woods rose	x	x	x	x
Rubus idaeus	wild raspberry	x		x	x

Scientific name	Common name	Hansen et al. (1995)		Rice & Hardin (2002)	NPS (2014c)
		Tree/shrub	Herbaceous	Riparian	in GRKO
Rubus parviflorus	thimbleberry	x			
Salix bebbiana	Bebb willow	x	x	x	x
Salix boothii	Booth willow	x	x	x	x
Salix brachycarpa	short-fruited willow	x			
Salix candida	hoary willow	x	x		
Salix commutata	undergreen willow	x			
Salix drummondiana	Drummond willow	x	x	x	x
Salix eriocephala	diamond willow	x			
Salix exigua	sandbar willow	x	x	x	x
Salix sp.	willow	x			
Salix farriae	Farr willow	x			
Salix geyeriana	Geyer willow	x	x	x	x
Salix lucida ssp. *lasiandra*	Pacific willow	x	x	x	x
Salix lutea	yellow willow	x	x	x	x
Salix planifolia	planeleaf willow	x	x		
Salix pseudomonticola	mountain willow	x			
Salix wolfii	Wolf's willow	x	x		
Sambucus sp.	elderberry sp.	x			
Shepherdia argentea	thorny buffaloberry	x			
Shepherdia canadensis	Canada buffaloberry	x			
*Solanum dulcamara**	climbing nightshade	x			x
Sorbus scopulina	Cascade mountain-ash	x			
Spiraea betulifolia	shiny-leaf spiraea	x			
Spiraea douglasii	Douglas's spiraea	x			
Symphoricarpos albus	common snowberry	x			
Symphoricarpos occidentalis	western snowberry	x		x	x
*Tamarix chinensis**	salt cedar	x			
Toxicodendron rydbergii	western poison ivy	x			
Vaccinium membranaceum	thin-leaf huckleberry		x		
Vaccinium occidentale	western blueberry	x			
Vaccinium scoparium	whortleberry	x			
Viburnum edule	low-bush cranberry	x			
Vitis riparia	river-bank grape	x			
Graminoids					
Achnatherum occidentale	western needlegrass	x	x		
Achnatherum richardsonii	Richardson's needlegrass	x	x		
*Agropyron cristatum**	crested wheatgrass	x			x
Agrostis pallens	dune bentgrass		x		
Agrostis exarata	spike bentgrass	x	x		
Agrostis humilis	alpine bentgrass	x	x		

Scientific name	Common name	Hansen et al. (1995)		Rice & Hardin (2002)	NPS (2014c)
		Tree/shrub	Herbaceous	Riparian	in GRKO
Agrostis idahoensis	Idaho bentgrass	x		x[1]	x
Agrostis scabra	rough bentgrass	x	x		
*Agrostis stolonifera**	redtop	x	x	x	x
*Agrostis capillaris**	colonial bentgrass	x			
Alopecurus aequalis	short-awned foxtail		x	x	x
Alopecurus magellanicus	alpine foxtail	x	x		
*Alopecurus geniculatus**	water foxtail		x		
*Alopecurus pratensis**	meadow foxtail	x	x	x	x
Andropogon gerardii	big bluestem	x			
Aristida purpurea var. *longiseta*	red threeawn	x			x
Beckmannia syzigachne	slough grass	x	x	x	x
Bouteloua gracilis	blue grama	x			x
Bromus anomalus	nodding brome	x			
Bromus marginatus	mountain brome	x	x		
Bromus ciliatus	fringed brome	x	x		
*Bromus inermis**	smooth brome	x	x	x	x
*Bromus arvensis**	field brome	x			x
*Bromus hordeaceus**	soft brome	x			
*Bromus tectorum**	cheatgrass	x			x
Calamagrostis canadensis	bluejoint reedgrass	x	x	x[1]	x
Calamovilfa longifolia	prairie sandreed	x			
Calamagrostis purpurascens	purple reedgrass	x			
Calamagrostis stricta	narrow-spiked reedgrass	x	x		x
Calamagrostis stricta ssp. *inexpansa*	northern reedgrass			x	
Carex amplifolia	bigleaf sedge		x		
Carex aperta	Columbia sedge		x		
Carex aquatilis	water sedge	x	x	x	x
Carex atherodes	awned sedge	x	x	x	x
Carex athrostachya	slender-beaked sedge	x	x		
Carex aurea	golden sedge	x	x		
Carex bebbii	Bebb's sedge	x			x
Carex buxbaumii	Buxbaum's sedge	x	x		
Carex canescens	gray sedge	x	x		
Carex capillaris	hair sedge	x	x		
Carex concinnoides	northwestern sedge	x			
Carex crawei	Craw's sedge	x	x		
Carex cusickii	Cusick's sedge	x	x		
Carex deweyana	Dewey's sedge	x			

Scientific name	Common name	Hansen et al. (1995)		Rice & Hardin (2002)	NPS (2014c)
		Tree/shrub	Herbaceous	Riparian	in GRKO
Carex diandra	lesser-panicled sedge		x		
Carex disperma	soft-leaved sedge	x			
Carex douglasii	Douglas' sedge	x	x	x	x
Carex sp.	sedge sp.	x	x	x	x
Carex filifolia	threadleaf sedge	x			
Carex flava	yellow sedge		x		
Carex haydeniana	Hayden's sedge		x		
Carex inops	sun sedge	x			
Carex hoodia	Hood's sedge	x			
Carex idahoa	Idaho sedge		x		
Carex illiota	sheep sedge		x		
Carex interior	inland sedge	x	x		
Carex lasiocarpa	slender sedge	x	x		
Carex lenticularis	lentil-fruit sedge	x	x		
Carex leptalea	bristle-stalked sedge	x	x		
Carex limosa	mud sedge	x	x		
Carex livida	pale sedge		x		
Carex microptera	small-winged sedge	x	x	x	x
Carex multicostata	manyrib sedge	x			
Carex nebrascensis	Nebraska sedge	x	x	x	x
Carex viridula	green sedge	x	x		
Carex pachystachya	thick-headed sedge	x	x		
Carex parryana	Parry's sedge		x		
Carex magellanica	poor sedge		x		
Carex pellita (formerly *lanuginosa*)	woolly sedge	x	x	x	x
Carex praegracilis	clustered field sedge	x	x	x	x
Carex praticola	meadow sedge	x	x		
Carex raynoldsii	Raynold's sedge	x			
Carex retrorsa	retrorse sedge	x			
Carex rostrata	beaked sedge	x	x	x	x
Carex saxatilis	russet sedge		x		
Carex sartwellii	Sartwell's sedge		x		
Carex scirpoidea	single-spike sedge		x	x	x
Carex scopulorum	Holm's Rocky Mountain sedge	x	x		
Carex simulata	short-beaked sedge	x	x		x
Carex sprengelii	Sprengel's sedge	x			
Carex stipata	sawbeak sedge	x	x	x	x
Carex vesicaria	inflated sedge	x	x		
Catabrosa aquatica	brook grass			x	x
Cinna latifolia	drooping woodreed	x			

Scientific name	Common name	Hansen et al. (1995)		Rice & Hardin (2002)	NPS (2014c)
		Tree/shrub	Herbaceous	Riparian	in GRKO
*Dactylis glomerata**	orchard grass	x	x		x
Danthonia californica	California oatgrass		x		
Danthonia intermedia	timber oatgrass	x			
Deschampsia cespitosa	tufted hairgrass	x	x	x	x
Dichanthelium acuminatum	Pacific panicgrass	x			
Dulichium arundinaceum	three-way sedge		x		
Echinochloa crus-galli *	barnyard grass	x			x
Eleocharis acicularis	needle spike-rush		x		
Eleocharis compressa	flatstem spikerush	x			
Eleocharis palustris	common spikesedge	x	x	x	x
Eleocharis pauciflora	few-flowered spike-rush		x		
Elymus canadensis	Canada wildrye	x			x
*Elymus caninus**	bearded wheatgrass	x	x		x
Elymus glaucus	blue wildrye	x	x		
Elymus lanceolatus ssp. *lanceolatus*	thickspike wheatgrass	x	x		
*Elymus repens**	quackgrass	x	x	x	x
Elymus virginicus	Virginia wildrye	x			
Eriophorum chamissonis	chamisso's cotton-grass		x		
Eriophorum angustifolium	many-spiked cotton-grass		x		
Festuca idahoensis	Idaho fescue	x	x		
Festuca occidentalis	western fescue	x		x	x
Festuca rubra	red fescue	x			
Festuca subulata	bearded fescue	x			
Glyceria borealis	northern mannagrass	x	x		
Glyceria elata	tall mannagrass	x			
Glyceria grandis	American mannagrass	x	x	x	x
Glyceria striata	fowl mannagrass	x	x		
Hesperostipa comata	needle-and-thread	x			x
Hierochloe odorata	sweetgrass	x		x	x
Hordeum brachyantherum	meadow barley	x	x		
Hordeum jubatum	foxtail barley	x	x	x	x
Juncus alpinoarticulatus	northern rush		x		
Juncus articulatus	jointed rush	x	x		
Juncus balticus	Baltic rush	x	x	x	x
Juncus bufonius	toad rush	x	x		
Juncus effusus	common rush			x	x
Juncus ensifolius	dagger-leaf rush	x	x		
Juncus filiformis	thread rush			x	x
Juncus hallii	Hall's rush	x	x		

Scientific name	Common name	Hansen et al. (1995)		Rice & Hardin (2002)	NPS (2014c)
		Tree/shrub	Herbaceous	Riparian	in GRKO
Juncus interior	inland rush		x		
Juncus longistylis	long-styled rush	x	x		
Juncus nevadensis	Sierra rush		x		
Juncus nodosus	knotted rush		x	x	x
Juncus regelii	Regel's rush		x		
Juncus tenuis	slender rush	x	x		
Juncus torreyi	Torrey's rush	x			
Koeleria macrantha	prairie junegrass	x	x		x
Leymus cinereus	basin wildrye	x			x
*Lolium pratense**	meadow fescue	x	x		x
*Luzula campestris**	field woodrush	x			
Luzula parviflora	small-flowered woodrush	x	x		
Muhlenbergia andina	foxtail muhly	x	x		
Muhlenbergia asperifolia	alkali muhly	x	x		x
Muhlenbergia filiformis	pullup muhly	x	x		
Muhlenbergia racemosa	marsh muhly	x			
Nassella viridula	green needlegrass	x			x
Oryzopsis micrantha	littleseed ricegrass	x			
Pascopyrum smithii	western wheatgrass	x	x	x	x
*Phalaris aquatica**	bulbuous canarygrass		x		
*Phalaris arundinacea**	reed canarygrass	x	x	x	x
Phleum alpinum	alpine timothy	x	x		
Phleum pratense *	common timothy	x	x	x	x
Phragmites australis	common reed	x			
*Poa compressa**	Canada bluegrass	x	x	x	x
Poa cusickii	Cusick's bluegrass	x	x		x
Poa interior	inland bluegrass		x		
Poa palustris	fowl bluegrass	x	x		
*Poa pratensis**	Kentucky bluegrass	x	x	x	x
Poa secunda	Sandberg bluegrass	x		x	x
*Polypogon monspeliensis**	annual rabbitsfoot grass		x		
Pseudoroegneria spicata	bluebunch wheatgrass	x	x		x
Puccinellia nuttalliana	Nuttall alkaligrass		x		
*Schedonorus pratensis**	meadow fescue			x	x
Schoenoplectus acutus	hardstem bulrush	x	x		
Schoenoplectus americanus	American bulrush	x	x		
Schoenoplectus fluviatilis	river bulrush	x			
Schoenoplectus maritimus	cosmopolitan bulrush	x	x		
Scirpus microcarpus	small-fruited bulrush	x		x	x
Scirpus pallidus	pale bulrush	x	x		

Scientific name	Common name	Hansen et al. (1995)		Rice & Hardin (2002)	NPS (2014c)
		Tree/shrub	Herbaceous	Riparian	in GRKO
Schoenoplectus pungens	sharp bulrush	x	x		
Schoenoplectus tabernaemontani	softstem bulrush		x	x	x
*Scolochloa festucacea**	common rivergrass		x		
Setaria viridis	green bristlegrass	x			x
Spartina gracilis	alkali cordgrass	x		x	x
Spartina pectinata	prairie cordgrass	x	x		
*Thinopyrum intermedium**	intermediate wheatgrass	x			x
Trisetum wolfii	Wolf's trisetum	x	x		
Forbs					
Achillea millefolium	common yarrow	x	x	x	x
Aconitum columbianum	Columbian monkshood	x	x		
Actaea rubra	red baneberry	x	x		
Agastache urticifolia	nettle-leaf giant-hyssop	x			
Agoseris glauca	pale agoseris	x	x		x
Agrimonia striata	striate agrimony	x			
*Alisma plantago-aquatica**	American waterplantain		x		
Allium brevistylum	short-style onion	x			
Allium cernuum	nodding onion	x			x
Allium geyeri	Geyer's onion		x		
Allium schoenoprasum	wild chives	x	x	x	x
Ambrosia psilostachya	western ragweed	x			
Ambrosia trifida	giant ragweed	x			
Anaphalis margaritacea	pearly everlasting	x			
Androsace spp.	fairy-candelabra	x			x
Anemone cylindrica	candle anemone	x			
Anemone multifida	cliff anemone	x	x		
Angelica arguta	sharptooth angelica	x	x		
Antennaria anaphaloides	tall pussytoes	x	x		
Antennaria corymbosa	meadow pussytoes	x	x		
Antennaria parlinii	plainleaf pussytoes	x			
Antennaria umbrinella	pussytoes	x	x	x	x
Antennaria microphylla	littleleaf pussytoes	x			x
Apocynum androsaemifolium	spreading dogbane	x			
Apocynum cannabinum	Indianhemp	x	x		
Arabis sp.	rockcress	x			x
Arabis glabra	tower mustard	x			
Aralia nudicaulis	wild sarsaparilla	x			
*Arctium lappa**	great burrdock	x			
*Arctium minus**	lesser burdock	x			
*Arenaria serpyllifolia**	thyme-leaf sandwort	x			

Scientific name	Common name	Hansen et al. (1995)		Rice & Hardin (2002)	NPS (2014c)
		Tree/shrub	Herbaceous	Riparian	in GRKO
Argentina anserina	silverweed cinquefoil			x[1]	x
Arnica amplexicaulis	clasping arnica	x			
Arnica chamissonis	meadow arnica	x	x		
Arnica fulgens	orange arnica	x			
Arnica latifolia	broadleaf arnica	x			
Arnica rydbergii	Rydberg's arnica		x		
Artemisia campestris	green sagewort	x			x
Artemisia dracunculus	wild tarragon	x			
Artemisia ludoviciana	cudweed sagewort, white sagebrush	x		x	x
Asarum caudatum	wild ginger	x			
Asclepias speciosa	showy milkweed	x	x		x
Asclepias verticillata	whorled milkweed	x			
Asclepias viridiflora	green milkweed	x			
*Asparagus officinalis**	asparagus	x			
*Asperugo procumbens**	madwort	x			
Astragalus agrestis	field milk-vetch	x			
Astragalus alpinus	alpine milk-vetch	x			
Astragalus canadensis	Canada milk-vetch		x		
Astragalus miser	weedy milk-vetch		x		
*Atriplex patula**	spreading orache			x	x
Barbarea orthoceras	American wintercress	x			
*Bassia scoparia**	kochia	x			x
*Berteroa incana**	hoary alyssum	x			
Bidens cernua	nodding beggartick		x	x	x
*Butomus umbellatus**	flowering-rush		x		
Callitriche hermaphroditica	autumnal water-starwort		x		
Caltha leptosepala	elkslip marshmarigold		x		
Calystegia sepium	hedge bindweed	x			
Camelina microcarpa	smallseed falseflax	x			x
Camassia quamash	common camas	x			
Camissonia breviflora	short-flowered evening-primrose		x		
Campanula rapunculoides	creeping bellflower			x	x
Campanula rotundifolia	bluebell	x			x
Canadenthus modestus	new world aster	x			
*Capsella bursa-pastoris**	shepherd's purse	x	x		x
Cardamine breweri	Brewer's bittercress		x		
*Carum carvi**	caraway	x			
*Carduus nutans**	musk thistle	x		x	x

Scientific name	Common name	Hansen et al. (1995)		Rice & Hardin (2002)	NPS (2014c)
		Tree/shrub	Herbaceous	Riparian	in GRKO
Cardamine pensylvanica	Pennsylvania bittercress	x	x		
Castilleja miniata	scarlet paintbrush	x			
Castilleja sulphurea	sulphur paintbrush		x		
Centaurea stoebe ssp. *micranthos**	spotted knapweed	x	x	x	x
Cerastium arvense	field chickweed	x	x		
Cerastium fontanum ssp. *vulgare**	common mouse-ear chickweed	x			x
Chamerion angustifolium	fireweed	x	x	x	x
Chamerion latifolium	alpine fireweed	x			
Chenopodium album	lambsquarters	x		x	x
*Chenopodium glaucum**	oakleaf goosefoot	x		x	x
Chenopodium rubrum	red goosefoot	x			
Cicuta douglasii	western water hemlock			x	x
Cicuta maculata	spotted water-hemlock	x	x		
Circaea alpina	enchanter's nightshade	x			
*Cirsium arvense**	Canada thistle	x	x	x	x
Cirsium canescens	platte thistle	x	x		
Cirsium flodmanii	Flodman's thistle	x			x
Cirsium scariosum	meadow thistle	x	x		
Cirsium undulatum	wavyleaf thistle			x	x
*Cirsium vulgare**	bull thistle	x	x	x	x
Cleome serrulata	Rocky Mountain beeplant			x	x
Collomia linearis	narrow-leaf collomia	x		x	x
*Convolvulus arvensis**	field bindweed	x			x
Conyza canadensis	Canadian horseweed	x			
Coptis occidentalis	western goldthread	x			
Corydalis aurea	golden smoke		x		
Coreopsis tinctoria	plains coreopsis	x			
Crepis runcinata	meadow hawksbeard	x	x	x	x
*Cynoglossum officinale**	houndstonge	x		x	x
Delphinium sp.	larkspur sp.	x			x
Descurainia pinnata	pinnate tansymustard	x			
Descurainia incana	mountain tansymustard	x		x[1]	x
*Descurainia sophia**	flixweed	x			x
*Dianthus armeria**	deptford pink	x			
Dodecatheon jeffreyi	tall mountain shooting star		x		
Dodecatheon pulchellum	dark-throat shootingstar	x	x	x	x
Draba stenloba	slender draba		x		
Drosera anglica	great sundew		x		

Scientific name	Common name	Hansen et al. (1995)		Rice & Hardin (2002)	NPS (2014c)
		Tree/shrub	Herbaceous	Riparian	in GRKO
Drosera linearis	linear-leaved sundew		x		
Drymocallis glandulosa	sticky cinquefoil	x			
Echinocystis lobata	wild cucmber	x			
Elodea canadensis	broad waterweed		x		x
Elodea nuttallii	Nuttall's waterweed		x		
Epilobium ciliatum	fringed willowherb	x	x	x	x
Epilobium glaberrimum	smooth willow-herb	x	x		
Epilobium minutum	chaparral willowherb	x		x	x
Epilobium palustre	marsh willowherb	x	x		x
Epilobium brachycarpum	autumn willow-herb	x			
Erigeron acris	bitter fleabane		x		
Erigeron lonchophyllus	spearleaf fleabane			x	x
Erigeron peregrinus	subalpine daisy	x	x		
Erigeron speciosus	showy fleabane	x			
Eriogonum umbellatum	sulfur buckwheat	x			x
Erysimum cheiranthoides	wormseed wallflower	x	x		
Erysimum repandum	treacle mustard	x			
Eucephalus engelmannii	Engelmann's aster	x			
*Euphorbia esula**	leafy spurge	x		x	x
Eurybia conspicua	showy aster	x			
Eurybia integrifolia	thickstem aster			x	x
Eurybia sibirica	Arctic aster		x		
Euthamia occidentalis	western goldenrod	x	x		
*Filago arvensis**	field filago	x			
Floerkea proserpinacoides	false mermaid	x	x		
Fragaria vesca	woodland strawberry	x	x		
Fragaria virginiana	Virginia strawberry	x	x		
Gaillardia aristata	common gaillardia	x			x
Galium aparine	cleavers	x	x		
Galeopsis tetrahit	hemp nettle			x	x
Galium boreale	northern bedstraw	x	x	x	x
Galium trifidum	small bedstraw	x	x	x	x
Galium triflorum	sweetscented bedstraw	x	x		
Gentiana affinis	prairie gentian	x	x		
Gentiana calycosa	explorer's gentian		x		
Gentianopsis detonsa	smaller fringed gentian	x	x		
Geranium richardsonii	white geranium	x			
Geranium viscosissimum	sticky geranium	x	x		
Geum aleppicum	yellow avens	x			
Geum macrophyllum	large-leaved avens	x	x	x	x
Geum rivale	purple avens	x	x		
Geum triflorum	old man's whiskers	x			x

Scientific name	Common name	Hansen et al. (1995)		Rice & Hardin (2002)	NPS (2014c)
		Tree/shrub	Herbaceous	Riparian	in GRKO
Glycyrrhiza lepidota	American licorice	x		x	x
Grindelia squarrosa	curly-cup gumweed	x		x	x
Hackelia deflexa	nodding stickseed	x			
Hackelia floribunda	showy stickseed	x			
Helenium autumnale	common sneezeweed	x	x		
Helianthus nuttallii	Nuttall's sunflower	x	x	x	x
Helianthus petiolaris	prairie sunflower	x			
Helianthus pauciflorus	stiff sunflower	x			
Heracleum lanatum	cow-parsnip	x	x	x	x
Heterotheca villosa	hairy golden aster			x	x
Hippuris vulgaris	common mare's-tail		x		x
Humulus lupulus	common hop	x			
Hydrophyllum spp.	waterleaf spp.	x			x
*Hypericum perforatum**	St. John's wort	x	x		
*Hyoscyamus niger**	black henbane			x	x
Impatiens aurella	orange balsam	x	x		
Iris missouriensis	Rocky Mountain iris	x	x	x	x
*Iris pseudacorus**	paleyellow iris	x			
Lactuca biennis	tall blue lettuce	x			
*Lactuca serriola**	prickly lettuce	x	x	x[1]	x
Lactuca tatarica var. *pulchella*	blue lettuce			x	x
Lathyrus ochroleucus	cream-flowered peavine	x			
Lemna minor	duckweed	x	x	x	x
Lepidium appelianum *	globepod hoarycress			x	x
*Lepidium draba**	whitetop			x	x
*Lepidium latifolium**	perennial pepperweed			x	x
*Lepidium perfoliatum**	clasping pepperweed			x	x
Lepidium virginicum	tall pepperweed		x		
*Leucanthemum vulgare**	oxeye daisy	x	x		
Ligusticum canbyi	Canby's licorice-root	x			
Ligusticum tenuifolium	slender-leafed licorice-root	x	x		
*Linaria dalmatica**	dalmation toadflax	x			
*Linum perenne**	blue flax	x	x	x	x
Linum rigidum	yellow flax	x			
*Linaria vulgaris**	yellow toadflax, butter and eggs	x		x	x
Lithospermum ruderale	western gromwell	x			
*Lobularia maritima**	sweet alyssum	x			
Lupinus argenteus	silvery lupine	x			
Lupinus sericeus	silky lupine	x	x		x
Lycopus americanus	cut-leaved water horehound	x			

Scientific name	Common name	Hansen et al. (1995)		Rice & Hardin (2002)	NPS (2014c)
		Tree/shrub	Herbaceous	Riparian	in GRKO
Lycopus asper	rough bugleweed	x			
Lygodesmia juncea	skeletonweed	x			x
Lysimachia ciliata	fringed loosestrife	x	x		
Lysimachia thyrsiflora	yellow loosestrife			x	x
Maianthemum racemosum	feathery false lily of the valley	x			
Maianthemum stellatum	starry false Solomon's seal	x	x	x	x
*Medicago lupulina**	black medick	x		x	x
*Medicago sativa**	alfalfa	x		x	x
*Melilotus officinalis**	sweet-clover	x	x	x	x
Mentha arvensis	wild mint	x	x	x	x
Menyanthes trifoliata	buckbean	x	x		
Mertensia ciliata	mountain bluebell	x	x		
Mimulus guttatus	common monkeyflower	x			x
Minuartia nuttallii	Nuttall's sandwort		x		
Mirabilis albida	white four-o'clock	x			
Mitella breweri	Brewer's miterwort		x		
Mitella stauropetala	side-flowered miterwort	x			
Moehringia lateriflora	bluntleaf sandwort	x			
Moehringia macrophylla	bigleaf sandwort	x	x		
Monarda fistulosa	horsemint	x			
*Myosotis arvensis**	field forget-me-not	x			
Myosotis laxa	small-flowered forget-me-not	x	x		
*Myosotis scorpioides**	common forget-me-not	x	x	x	x
*Myriophyllum spicatum**	Eurasian water milfoil		x		
*Nasturtium officinale**	watercress	x	x		x
*Nepeta cataria**	catnip	x			
Nuphar polysepala	spatter-dock		x		
Oenothera villosa	hairy evening primrose	x		x	x
Opuntia polyacantha	plains pricklypear	x			x
Orthocarpus luteus	yellow owl-clover	x			
Osmorhiza berteroi	mountain sweet-cicely	x		x[1]	x
Osmorhiza depauperata	blunt-fruit sweet-cicely	x			
Osmorhiza occidentalis	western sweet-cicely	x			
Osmorhiza purpurea	purple sweet-cicely	x			
Oxytropis spp.	locoweed spp.	x			x
Packera cana	woolly groundsel	x			x
Packera pauciflora	alpine groundsel	x	x		
Packera pseudaurea var. *pseudaurea*	streambank groundsel	x			
Packera subnuda	few-leaved or Buek's groundsel		x		

Scientific name	Common name	Hansen et al. (1995)		Rice & Hardin (2002)	NPS (2014c)
		Tree/shrub	Herbaceous	Riparian	in GRKO
Parnassia fimbriata	fringed grass-of-parnassus		x		
Parnassia palustris	northern grass-of-parnassus	x	x		
Parietaria pensylvanica	Pennsylvania pellitory	x			
Pedicularis groenlandica	elephant's head	x	x		
Penstemon confertus	yellow penstemon	x			
Penstemon procerus var. procerus	pincushion beardtongue	x	x		x
Penstemon rydbergii	Rydberg's penstemon		x		
Perideridia gairdneri	Gardner's yampah	x	x		
Petasites sagittatus	arrowleaf sweet coltsfoot	x			x
Phacelia hastata	silverleaf phacelia	x			
Phacelia procera	tall phacelia	x			
Physalis heterophylla	clammy groundcherry	x			
Physostegia parviflora	purple dragonhead	x	x		
Plantago eriopoda	saline plantain	x	x		x
*Plantago major**	common plantain	x	x	x	x
Platanthera dilatata	white bog orchid	x	x	x	x
Platanthera hyperborean	northern green bog orchid		x		
Polygonum amphibium	water smartweed	x	x	x	x
Polygonum austiniae	Austin's knotweed		x		
*Polygonum aviculare**	prostrate knotweed	x	x	x	x
Polygonum bistortoides	American bistort	x	x		
*Polygonum convolvulus**	black bindweed			x	x
*Polygonum hydropiper**	marshpepper smartweed		x		
Polygonum lapathifolium	curlytop knotweed	x	x	x	x
Polemonium occidentale	western polemonium	x	x		
*Polygonum persicaria**	ladysthumb			x	x
Polemonium pulcherrimum	skunk-leaved polemonium	x	x		
Polygonum douglasii ssp. *johnstonii*	Johnston's knotweed	x			
Potentilla anserina	common silverweed	x	x	x	x
*Potentilla argentea**	silvery cinquefoil	x			
Potamogeton diversifolius	diverse-leaved pondweed	x			
Potentilla diversifolia	diverse-leaved cinquefoil	x	x		
Potentilla gracilis	slender cinquefoil	x	x	x	x
Potamogeton gramineus	grass-leaved pondweed		x		
Potentilla norvegica	Norwegian cinquefoil	x			
Potentilla palustris	purple cinquefoil	x	x		

Scientific name	Common name	Hansen et al. (1995)		Rice & Hardin (2002)	NPS (2014c)
		Tree/shrub	Herbaceous	Riparian	in GRKO
Potentilla paradoxa	bushy cinquefoil	x			
Potamogeton pectinatus	fennel-leafed pondweed		x		
Potamogeton pusillus	baby pondweed		x		
Potamogeton richardsonii	Richardson's pondweed		x		
Potentilla rivalis	brook cinquefoil		x		
Prosartes trachycarpa	wartberry fairy-bell	x			
Prunella vulgaris	heal all	x	x		
Pediomelum esculentum	Indian breadroot	x			
Pyrrocoma integrifolia	entire-leaved goldenweed			x	x
Pyrola asarifolia	pink wintergreen	x			x
Pyrola elliptica	white wintergreen	x			
Ranunculus sp.	buttercup	x		x	x
Ranunculus acriformis	sharpleaf buttercup		x	x	x
Ranunculus aquatilis	water buttercup		x	x	x
Ranunculus cymbalaria	alkali buttercup		x	x	x
Ranunculus flammula	creeping buttercup		x		
Ranunculus gmelinii	lesser yellow water buttercup		x	x	x
Ranunculus macounii	Macoun's buttercup	x	x		
Ranunculus hyperboreus	Arctic buttercup	x	x		
Ranunculus pensylvanicus	Pennsylvania buttercup			x	x
*Ranunculus repens**	creeping buttercup	x	x		x
Ranunculus sceleratus	celery-leaved buttercup		x	x	x
Ranunculus longirostris	longbeak buttercup		x		x
Ratibida columnifera	prairie coneflower	x			
*Rhaponticum repens**	Russian knapweed			x	x
Rorippa calycina	persistent yellowcress		x		
Rorippa curvisiliqua	western yellowcress	x			x
Rorippa curvipes	blunt-leaf yellowcress		x		x
Rorippa palustris	marsh yellowcress	x	x		
*Rorippa sylvestris**	creeping yellowcress	x	x	x	x
Rubus pubescens	dwarf red blackberry	x			
Rudbeckia laciniata	tall coneflower	x			
Rudbeckia occidentalis	western coneflower	x			
*Rumex acetosella**	sheep sorrel	x		x	x
*Rumex crispus**	curly dock	x	x	x	x
Rumex maritimus	golden dock	x	x	x	x
*Rumex obtusifolius**	bitter dock			x	x
Rumex aquaticus var. fenestratus	western dock	x	x		
Rumex salicifolius var. mexicanus	willow dock	x	x		x
Sagittaria cuneata	arumleaf arrowhead		x		

Scientific name	Common name	Hansen et al. (1995)		Rice & Hardin (2002)	NPS (2014c)
		Tree/shrub	Herbaceous	Riparian	in GRKO
Sagittaria latifolia	broadleaf arrowhead		x		
*Salsola tragus**	prickly Russian thistle	x			x
Sanicula marilandica	Maryland sanicle	x			
Saxifraga odontoloma	brook saxifrage	x			
Saxifraga oregana	Oregon saxifrage	x			
Scutellaria galericulata	marsh skullcap	x	x	x	x
Sedum lanceolatum	lance-leaved stonecrop	x			
Senecio hydrophiloides	tall groundsel	x	x		
Senecio hydrophilus	water ragwort	x	x		
Senecio integerrimus	lambstongue groundsel	x	x		x
Senecio serra	tall ragwort	x	x		
Senecio sphaerocephalus	ballhead ragwort	x			
Senecio triangularis	arrowleaf groundsel	x	x		
*Silene csereii**	bladder campion	x			
Silene douglasii	Douglas's catchfly	x			
Silene latifolia ssp. *alba**	bladder campion	x		x	x
Silene menziesii	Menzies' campion	x			
*Sisymbrium altissimum**	tall tumblemustard	x		x[1]	x
Sisyrinchium idahoense	blue-eyed grass	x	x	x	x
*Sisymbrium loeslii**	tumblemustard	x		x	x
Sium suave	hemlock waterparsnip	x	x	x	x
Solidago canadensis	Canada goldenrod	x	x	x	x
Solidago gigantea	giant goldenrod	x	x		
Solidago missouriensis	Missouri goldenrod	x		x	x
Solanum rostratum	buffalobur nightshade	x			
*Sonchus arvensis**	perennial or field sowthistle	x	x	x	x
*Sonchus asper**	prickly sowthistle	x			
*Sonchus oleraceus**	common sowthistle	x			
Sparganium angustifolium	narrowleaf bur-reed		x		
Spirodela polyrhiza	common duckmeat		x		
Spiranthes romanzoffiana	hooded ladies tresses		x		
Stachys palustris	swamp hedge-nettle	x	x	x[1]	x
Stellaria americana	American chickweed	x			
Stellaria calycantha	northern starwort	x			
Stellaria longipes	longstalk starwort	x	x	x	x
Stellaria umbellata	umbrella starwort	x	x		
Stenotus lanuginosus	wooly mock goldenweed	x	x		
Streptopus amplexifolius	clasping-leaved twisted stalk	x			
Swertia perennis	felwort	x	x		
Symphyotrichum campestre	western meadow aster			x	x

Scientific name	Common name	Hansen et al. (1995)		Rice & Hardin (2002)	NPS (2014c)
		Tree/shrub	Herbaceous	Riparian	in GRKO
Symphyotrichum chilense	Pacific aster	x	x	x[1]	x
Symphyotrichum ciliolatum	Lindley's aster	x			
Symphyotrichum eatonii	Eaton's aster	x			
Symphyotrichum falcatum	white prairie aster	x		x	x
Symphyotrichum foliaceum	leafy aster	x	x		
Symphyotrichum lanceolatum ssp. *hesperium*	white panicle aster	x	x	x	x
Symphyotrichum boreale	northern bog aster	x	x		
Symphyotrichum laeve	smooth blue aster	x	x		x
Symphyotrichum oblongifolium	aromatic aster	x			
Symphyotrichum spathulatum	western mountain aster	x	x	x	x
Symphyotrichum ericoides var. *pansum*	white heath aster	x	x	x	x
*Tanacetum vulgare**	common tansy	x		x	x
*Taraxacum laevigatum**	rock dandelion	x			
*Taraxacum officinale**	common dandelion	x	x	x	x
Thalictrum alpinum	alpine meadowrue	x			
Thalictrum dasycarpum	Purple meadowrue	x		x	x
Thalictrum fendleri	Fendler's meadowrue	x	x		
Thalictrum occidentale	western meadowrue	x		x	x
Thalictrum sparsiflorum	fewflower meadowrue		x		
Thalictrum venulosum	veiny meadowrue	x			
Thermopsis montana	mountain goldenbanner	x			
Thermopsis rhombifolia	prairie thermopsis	x			
*Thlaspi arvense**	field pennycress	x	x		x
Triantha glutinosa	sticky tofieldia		x		
*Tragopogon dubius**	western salsify	x	x	x	x
Tragopogon pratensis	meadow salsify			x	x
*Trifolium aureum**	hop clover	x	x		
Trifolium longipes	longstalk clover	x	x	x	x
Triglochin maritimum	seaside arrow-grass	x	x	x	x
Triglochin palustris	marsh arrow-grass		x		
*Trifolium pratense**	red clover	x	x	x	x
*Trifolium repens**	white clover	x	x	x	x
Typha angustifolia	narrow-leaved cattail		x		
Typha latifolia	broadleaf cattail	x	x	x	x
Urtica dioica	stinging nettle	x	x	x	x
Utricularia minor	lesser bladderwort		x		
Utricularia macrorhiza	common bladderwort		x		x
*Vaccaria hispanica**	cow herb	x			
Valeriana dioica	northern valerian	x			

Scientific name	Common name	Hansen et al. (1995)		Rice & Hardin (2002)	NPS (2014c)
		Tree/shrub	Herbaceous	Riparian	in GRKO
Valeriana edulis	tobacco root	x	x	x	x
Veronica americana	American speedwell	x	x		
Veronica anagallis-aquatica	water speedwell	x	x	x	x
*Verbascum blattaria**	moth mullein	x			
Veratrum californicum	California false hellebore	x			
Veronica catenata	chain speedwell	x	x		
Verbena hastata	blue verbena	x			
*Veronica officinalis**	common speedwell	x			
Veronica peregrina	purslane speedwell		x		
Veronica scutellata	marsh speedwell	x	x		
Verbena stricta	hoary verbena		x		
*Verbascum thapsus**	common mullein	x		x	x
Veronica wormskjoldii	American alpine speedwell	x			
Vicia americana	American vetch	x	x	x	x
Viola canadensis	Canada violet	x			
Viola sp.	violet sp.	x	x		
Viola macloskeyi	small white violet	x			
Viola nephrophylla	northern bog violet	x	x		
Viola nuttallii	Nuttall's violet	x			
Viola orbiculata	round-leaved violet	x			
Viola palustris	marsh violet	x			
Xanthium strumarium	common or rough cocklebur	x			
Zigadenus elegans	mountain death camas	x		x	x
Zizia aptera	heart-leaved alexanders	x		x	x
Zizia aurea	golden alexanders	x			
Ferns & allies					
Athyrium filix-femina	common ladyfern	x			
Equisetum arvense	field horsetail	x	x	x	x
Equisetum fluviatile	swamp horsetail	x	x	x	x
Equisetum hyemale	scouringrush horsetail	x	x	x	x
Equisetum laevigatum	smooth scouring-rush	x	x	x	x
Equisetum palustre	marsh horsetail	x			
Equisetum pratense	meadow horsetail	x	x		
Equisetum sylvaticum	woodland horsetail	x			
Equisetum variegatum	variegated horsetail	x	x		
Lycopodium spp.	club-moss		x		
Pteridium aquilinum	western brackenfern	x			

* Non-native species

[1] Species documented in the riparian area by Rice and Smith (2011) but not Rice and Hardin (2002).

Appendix D. NRCS riparian health assessment worksheets for GRKO.

RIPARIAN ASSESSMENT WORKSHEET--continued

NAME OF STREAM: No Name Creek REACH ID: ________ DATE: 6/25/2014

Question 3. The Stream is in Balance with the Water and Sediment Supplied by the Watershed

6 = The width to depth ratio appears to be appropriate for the stream type and its geomorphic setting. There is no evidence of excess sediment removal or deposition. There are no indications that the stream is widening or getting shallower. There may be some well-washed gravel and cobble bars present. Pools are common. Rosgen "B" and naturally occurring "D" channel types are exceptions.

4 = The stream has widened and/or has become shallower due to disturbances that have caused the banks to become unstable or from dewatering which reduces the amount of water and energy needed to effectively move the sediment through the channel. *(Note: Sediment sources may also be from offsite sources.)* Point bars are often enlarged by gravel with silt and sand common, and new bars are forming. Pools are common, but may be shallow. Rosgen "B" and naturally occurring "D" channel types are exceptions.

2 = The width to depth ratio exceeds what is appropriate for the stream type. Point bars are enlarged by gravel with abundant sand and silt, and new bars are forming that often force lateral movement of the stream. Mid channel bars are often present. For prairie streams there is often a deep layer of sediment on top of the gravel substrate. The frequency of pools is low. Rosgen "B" and naturally occurring "D" channel types are exceptions.

0 = The stream has poor sediment transport capability which is reflected by poor channel definition. The channel is often braided having at least 3 active channels. Naturally occurring Rosgen "D" channels types are exceptions. Pools are filled with sediment or are not existent.

SCORE: Potential 6 **Actual** 6

Please clarify the rationale for your score, including comments regarding *potential* and *capability* and document with photograph if appropriate.

Comments: Width to depth is believed to appropriate, as there is very little excess sediment removal or deposition. The stream does widen for about a 1/4 mile, but this is within a standing water wetland reach of this stream.

Vegetative Considerations

Question 4. Streambank with Vegetation (Kind) having a Deep, Binding Root Mass

Note: For stream types where riparian vegetation is not required for sustainability, this question can be skipped and given an N/A, with an explanatory note or comment. Be sure to adjust the potential score if this question is skipped. (See Appendix I for stability ratings for most riparian, and other, species.) Presence generally means more than one or two, healthy individuals of a species in the reach.

6 = The streambank vegetative communities are comprised of at least four plant species with deep, binding root masses.

4 = The streambank vegetative communities are comprised of at least three plant species with deep, binding root masses.

2 = The streambank vegetative communities are comprised of two plant species with deep, binding root masses.

0 = The streambank vegetative communities are comprised of one or no plant species with deep, binding root masses.

SCORE: Potential 6 **Actual** 6

Please clarify the rationale for your score, including comments regarding *potential* and *capability* and document with photograph if appropriate.

Comments: Very good species composition of high binding root mass ratings. General Carex utriculata dominantes with small populations of Carex nebrascensis, Carex aqualis, Juncus Balticus, and Salix spp. intermixed. When stream exists into Clark Fork portions of the stream bank does begin to shift to introduced pasture grasses and spp. composition decreases with high root binding ratings.

Question 5. Riparian/Wetland Vegetative Cover (Amount) in the Riparian/Flood plain Area

Note: For stream types where riparian vegetation is not required for sustainability, this question can be skipped and given an N/A, with an explanatory note or comment. Be sure to adjust the potential score if this question is skipped.

6 = More than 85% of the riparian/wetland canopy cover has a stability rating ≥ 6

4 =75%-85% of the riparian/wetland canopy cover has a stability rating ≥ 6

2 =65%-75% of the riparian/wetland canopy cover has a stability rating ≥ 6

0 = Less than 65% of the riparian/wetland canopy cover has a stability rating ≥ 6

NOTE: A low score for this item may be enough to keep the stream reach from being rated Sustainable

SCORE: Potential 6 **Actual** 4

RIPARIAN ASSESSMENT WORKSHEET--continued

NAME OF STREAM: No Name Creek **REACH ID:** ______ **DATE:** 6/25/2014

Question 5--continued

Please clarify the rationale for your score, including comments regarding *potential* and *capability* and document with photograph if appropriate.

Comments: Except when entering into the Clark Fork, No Name Creek has approxiamately 85-75% cover of riparian species with deep binding root mass ratings along the majority of the stream reaches. Poa pratensis and Alopecurus pratensis may present future problems if invasion continues into the current stream bank.

Question 6. Noxious Weeds in the Riparian Area

3 = None of the riparian area has noxious weeds present.

2 = Up to 5% of the riparian area has noxious weeds (a few are present).

1 = Up to 10% of the riparian area has noxious weeds present (abundant).

0 = Over 10% of the riparian area has noxious weeds (very apparent and extensive distribution).

SCORE: Potential 3 **Actual** 2

Please clarify the rationale for your score, including comments regarding *potential* and *capability* and document with photograph if appropriate.

Comments (NOTE--List all noxious weed species): Cirsium arvense, Euphorbia esula, and Cardaria draba are present on the reach, with the greatest concentration near the Clark Fork River.

Question 7. Disturbance-Caused Undesirable Plants in the Riparian Area

3 = 5% or less of the riparian area with undesirable plants (very few present).

2 = 5-10% of the riparian area with undesirable plants (few are present).

1 = 10-15% of the riparian area with undesirable plants (commonly distributed).

0 = Over 15% of the riparian area with undesirable plants (abundant over much of the area).

SCORE: Potential 3 **Actual** 3

Please clarify the rationale for your score, including comments regarding *potential* and *capability* and document with photograph if appropriate.

Comments (NOTE--List all nuisance weeds and undesirable plants): Cirsium arvense, Euphorbia esula, and Cardaria draba are few along the majority of No Name except when nearing the Clark Fork. Particularly Euphorbia esula and Cardaria draba increase in this reach. Cirsium arvense is present along the stream and wetland throughout the reach of the stream, but in low cover (<5%) to none.

Question 8. Woody Species Establishment and Regeneration

Note: For stream types where riparian vegetation is not required for sustainability, this question can be skipped and given an N/A, with an explanatory note or comment. Be sure to adjust the potential score if this question is skipped. At least 10 individuals in a class should be present in the reach to count. Count only 1+ years of age. Do not count seedlings of the year as mortality is very high the first year.

8 = All age classes of desirable woody riparian species present (see Table 3).

6 = One age class of desirable woody riparian species is clearly absent, all others well represented. Often, it will be the middle age group(s) absent. For sites with potential for both trees and shrubs there may be one age class of each absent. Having mature individuals and at least one younger age class present indicates the potential for recovery.

4 = Two age classes (seedlings and saplings) of native riparian shrubs and/or two age classes of native riparian trees are clearly absent, or the stand is comprised of mainly mature species. Other age classes well represented.

2 = Disturbance induced, (i.e. facultative, facultative upland species such as rose, or snowberry) or non-riparian species dominate. Woody species present consist of decadent/dying individuals. (Refer back to Question 1 if this is the situation. The channel may have incised.)

0 = A few woody species are present (<10% canopy cover), but herbaceous species dominate (at this point, the site potential should be re-evaluated to ensure that it has potential for woody vegetation); or, the site has at ≥ 5% canopy cover of Russian olive and/or salt cedar. On sites with long-term manipulation or disturbance, woody species potential is easily underestimated.

RIPARIAN ASSESSMENT WORKSHEET--continued

NAME OF STREAM: No Name Creek **REACH ID:** ________ **DATE:** 6/25/2014

Question 8. Woody Species Establishment and Regeneration--continued

SCORE: Potential 8 **Actual** 0

Please clarify the rationale for your score, including comments regarding *potential* and *capability* and document with photograph if appropriate.

Comments: Willows are present along the reach but are less than 10% canopy cover and are comprised mainly of older mature to decadent individuals. Willow cover increases significantly near the Clark Fork river. Few to no saplings, suckers, or mature woody species are present for the majority of the reach.

Functional Considerations

Question 9. Utilization of Trees and Shrubs

Note: For stream types where riparian vegetation is not required for sustainability, this question can be skipped and given an N/A, with an explanatory note or comment. Be sure to adjust the potential score if this question is skipped.

4 = 0-5% of the available second year and older stems are browsed.

3 = 5%-25% of the available second year and older stems are browsed (lightly).

2 = 25%-50% of the available second year and older stems are browsed (moderately..

1 = More than 50% of the available second year and older stems are browsed (heavily). Many of the shrubs have either a "clubbed" growth form, or they are high-lined or umbrella shaped.

0 = There is noticeable use (10% or more) of unpalatable and normally unused woody species

SCORE: Potential 4 **Actual** 3

Please clarify the rationale for your score, including comments regarding *potential* and *capability* and document with photograph if appropriate.

Comments: Browsing is present and is assumed to be largely from moose browse. Browse pressure is light on the few woody species present and does not appear to be a limiting factor.

Question 10. Flood plain Characteristics for Dissipating Energy and Capturing Sediment

8 = Active flood or overflow channels exist in the flood plain. Large rock, woody debris, and/or riparian vegetation appropriate for the setting are sufficient to adequately dissipate stream energy and trap sediment on the flood plain. There is little evidence of excessive erosion or disturbance that reduces energy dissipation and sediment capture on the flood plain. There are no headcuts where either overland flow and/or flood channel flows return to the main channel.

6 = The flood plain meets the characteristics of the description in Question 8 above, but demonstrates slight limitations in the kind and amount of large rock, woody debris, and/or riparian vegetation present. Riparian vegetation structure is below that required to dissipate energy. There may be occasional evidence of surface erosion and disturbance, but generally not extensive enough to have affected channel development.

4 = Large rock, woody debris, and/or riparian vegetation is present, but generally insufficient (quality or quantity) to fully dissipate stream energy. Some sediment may be captured, but greater evidence of incipient erosion and/or headcuts is readily present.

2 = Inadequate Large rock, woody debris, and/or riparian vegetation is available for dissipation of energy or sediment capture. There is very little evidence of sediment capture. There is some streambank erosion due to human disturbance or alterations, and occasional headcuts where overland flows or flood channel flows return to the main channel.

0 = Flood plain area reflects the following conditions: 1) The flood plain area is very limited or not present and is inadequate to dissipate energy; 2) flood or overflow channels do not exist; and 3) large rock, woody debris, and/or riparian vegetation is not adequate to dissipate stream energy and trap sediment on the flood plain. Streambank and/or flood plain erosion and/or evidence of human alteration are common. "G"- and "F"-type channels (Rosgen) typically reflect these conditions.

SCORE: Potential 8 **Actual** 8

Please clarify the rationale for your score, including comments regarding *potential* and *capability* and document with photograph if appropriate.

Comments: The stream has a healthy appearance with little to no erosion and excess sediment erosion. Large structures to dissipate energy are present in the form of wood debris, with the bulk of stream energy dissipation and sediment deposition resulting when the flood plain is accessed. No headcuts were observed.

NAME OF STREAM:____________________ REACH ID:____________________ DATE:____________

SUMMARY

		SCORE POTENTIAL	SCORE ACTUAL	POSSIBLE
QUESTION 1:	Stream Incisement	8	8	0, 2, 4, 6, 8
QUESTION 2:	Lateral Cutting	8	8	0, 3, 5, 8
QUESTION 3:	Stream Balance	6	6	0, 2, 4, 6
QUESTION 4:	Deep, Binding Rootmass	6	6	N/A, 0, 2, 4, 6
QUESTION 5:	Riparian/Wetland Vegetative Cover *	6	4	N/A, 0, 2, 4, 6
QUESTION 6:	Noxious Weeds	3	2	0, 1, 2, 3
QUESTION 7:	Undesirable Plants	3	3	0, 1, 2, 3
QUESTION 8:	Woody Species Establishment	8	0	N/A, 0, 2, 4, 6, 8
QUESTION 9:	Browse Utilization	4	3	N/A, 0, 1, 2, 3, 4
QUESTION 10:	Riparian Area/Flood plain Characteristics *	8	8	N/A, 0, 2, 4, 6, 8
	TOTAL	60	48	(60 total possible)

(POTENTIAL SCORE FOR MOST BEDROCK OR BOULDER STREAMS) (36)
(questions 1, 2, 3, 6, 7, 10)

(POTENTIAL SCORE FOR MOST LOW ENERGY "E" STREAMS) (48)
(questions 1 – 7, 10)

RATING: = $\frac{\text{Actual Score}}{\text{Potential Score}}$ X 100 = % rating

80-100% = SUSTAINABLE
50-80% = AT RISK
LESS THAN 50% = NOT SUSTAINABLE

* Only in certain, specific situations can both of these receive an "N/A".

Please clarify the rationale for your rating, including comments regarding potential. Can the limitations be addressed by the decision maker?

NOTES The stream appears to be sustainable, but in the near future the stream is possibly threatened by the continued invasion of introduced pasture grasses and low willow recruitment, this stream will enter the At Risk category. Noxious weeds also pose a threat to the stream integrity in the near future if disturbances increase with a no management approach taken. This stream appears to have a strong potential of a larger willow community as observed in the stream stretches near the Clark Fork. Willow species do exist along the stream, but do not have a sufficient population of recruitment suckers to replenish the remaining old mature and decadent individuals in the upper portions of the stream.

TREND: Does the reach appear to be improving or declining? Explain.

The stream appears to be slightly improving as there is some indications that willows are beginning to colonize portions further away from the Clark Fork (increase in young saplings and young mature individuals greatest in those stretches). Introduced grasses have only colonized in areas that have pasture influences or some small disturbances and may be removed by the native Carex spp. with time. Woody material and flood plain function are sufficient as is, but if willows and other woody debris enter the reach the stream should have improved structure content to reduce stream energy and increase sedimentation entrapment.

RIPARIAN ASSESSMENT WORKSHEET

NAME OF STREAM: No Name Creek **REACH LOC OR ID:** ______

DATE: 6/25/2014 **ID TEAM/OBSERVERS:** Jarrett Payne

LENGTH OF REACH: 1.25 Mile (Approx) **LAT/LONG - BEGIN/END:** ______

MAP OR QUAD NAME: ______ **PHOTO #S:** ______ **PRIMARY LAND USE:** Pasture

PLANT COMMUNITY: Grass/Grasslike **ROSGEN CHANNEL TYPE:** E **BFDEPTH:** 1.5 **BFWIDTH:** 15.7

WIDTH/DEPTH RATIO: 10.4 : 1 **CHANNEL SUBSTRATE :** Silty over gravel/cobble

Geomorphic Considerations

Question 1. Stream Incisement (Downcutting)

8 = Channel stable, no active downcutting occurring; or, old downcutting apparent but a new, stable riparian area has formed within the incised channel. There is perennial riparian vegetation well established in the riparian area (Stage 1 and 5, Schumm's Model Figure 2).

6 = Channel has evidence of old downcutting that has begun stabilizing, vegetation is beginning to establish, even at the base of the falling banks, soil disturbance evident (Stage 4, Schumm's Model Figure 2).

4 = Small headcut, in early stage, is present. Immediate action may prevent further degradation (Early Stage 2, Schumm's Model Figure 2).

2 = Unstable, channel incised, actively widening, limited new riparian area/flood plain, flood plain not well vegetated. The vegetation that is present is mainly pioneer species. Bank failure is common (Stage 3, Schumm's Model Figure 2).

0 = Channel deeply incised, resembling a gully, little or no riparian area, active downcutting is clearly occurring. Only occasional or rare flood events access the flood plain. Tributaries will also exhibit downcutting or signs of downcutting (Stage 2, Schumm's Model Figure 2).

The presence of active headcuts should nearly always keep the stream reach from being rated Sustainable.

SCORE: Potential 8 **Actual** 8

Please clarify the rationale for your score, including comments regarding *potential* and *capability* and document with photograph if appropriate.

Comments: Almost no downcutting was present along the stream reach except when entering the Clark Fork, which was assumed to have been caused by the Clark Fork flood waters rising and cutting portions of the bank.

Question 2. Streambanks with Active Lateral Cutting (inspect banks on both sides of the stream)

8 = Lateral bank erosion is in balance with the stream and its setting.

5 = There is a minimal amount of human-induced, active lateral bank erosion occurring, primarily limited to outside banks.

3= There is a moderate amount of human-induced active lateral bank erosion occurring on either or both outside and inside banks.

0 = There is extensive human-induced lateral bank erosion occurring on outside and inside banks and straight sections.

SCORE: Potential 8 **Actual** 8

Please clarify the rationale for your score, including comments regarding *potential* and *capability* and document with photograph if appropriate.

Comments: Almost none to little lateral cutting and is assumed to be within the natural tolerances of this stream.

RIPARIAN ASSESSMENT WORKSHEET--continued

NAME OF STREAM: N and S Fork Johnson Creek **REACH ID:** ____________ **DATE:** 6/6/2014

Question 3. The Stream is in Balance with the Water and Sediment Supplied by the Watershed

6 = The width to depth ratio appears to be appropriate for the stream type and its geomorphic setting. There is no evidence of excess sediment removal or deposition. There are no indications that the stream is widening or getting shallower. There may be some well-washed gravel and cobble bars present. Pools are common. Rosgen "B" and naturally occurring "D" channel types are exceptions.

4 = The stream has widened and/or has become shallower due to disturbances that have caused the banks to become unstable or from dewatering which reduces the amount of water and energy needed to effectively move the sediment through the channel. *(Note: Sediment sources may also be from offsite sources.)* Point bars are often enlarged by gravel with silt and sand common, and new bars are forming. Pools are common, but may be shallow. Rosgen "B" and naturally occurring "D" channel types are exceptions.

2 = The width to depth ratio exceeds what is appropriate for the stream type. Point bars are enlarged by gravel with abundant sand and silt, and new bars are forming that often force lateral movement of the stream. Mid channel bars are often present. For prairie streams there is often a deep layer of sediment on top of the gravel substrate. The frequency of pools is low. Rosgen "B" and naturally occurring "D" channel types are exceptions.

0 = The stream has poor sediment transport capability which is reflected by poor channel definition. The channel is often braided having at least 3 active channels. Naturally occurring Rosgen "D" channels types are exceptions. Pools are filled with sediment or are not existent.

SCORE: **Potential** 6 **Actual** 6

Please clarify the rationale for your score, including comments regarding *potential* and *capability* and document with photograph if appropriate.

Comments: Near the active rail road boundary the stream is unable to access a sufficient floodplain. When stream enters some culverts, down cutting is apparent, but minimal.

Vegetative Considerations

Question 4. Streambank with Vegetation (Kind) having a Deep, Binding Root Mass

Note: For stream types where riparian vegetation is not required for sustainability, this question can be skipped and given an N/A, with an explanatory note or comment. Be sure to adjust the potential score if this question is skipped. (See Appendix I for stability ratings for most riparian, and other, species.) Presence generally means more than one or two, healthy individuals of a species in the reach.

6 = The streambank vegetative communities are comprised of at least four plant species with deep, binding root masses.

4 = The streambank vegetative communities are comprised of at least three plant species with deep, binding root masses.

2 = The streambank vegetative communities are comprised of two plant species with deep, binding root masses.

0 = The streambank vegetative communities are comprised of one or no plant species with deep, binding root masses.

SCORE: **Potential** 6 **Actual** 4

Please clarify the rationale for your score, including comments regarding *potential* and *capability* and document with photograph if appropriate.

Comments: Vegetation kinds usually consisted of Juncus balticus, Carex utriculata, Carex nebrascensis, Carex spp., Phalaris arundinacea Scirpus spp., Salix spp., Alnus spp., and Populus spp., but in majority of sites only three species were present.

Question 5. Riparian/Wetland Vegetative Cover (Amount) in the Riparian/Flood plain Area

Note: For stream types where riparian vegetation is not required for sustainability, this question can be skipped and given an N/A, with an explanatory note or comment. Be sure to adjust the potential score if this question is skipped.

6 = More than 85% of the riparian/wetland canopy cover has a stability rating ≥ 6

4 =75%-85% of the riparian/wetland canopy cover has a stability rating ≥ 6

2 =65%-75% of the riparian/wetland canopy cover has a stability rating ≥ 6

0 = Less than 65% of the riparian/wetland canopy cover has a stability rating ≥ 6

NOTE: A low score for this item may be enough to keep the stream reach from being rated Sustainable

SCORE: **Potential** 6 **Actual** 2

RIPARIAN ASSESSMENT WORKSHEET--continued

NAME OF STREAM: N and S Fork Johnson Creek REACH ID: DATE: 6/6/2014

Question 5--continued

Please clarify the rationale for your score, including comments regarding *potential* and *capability* and document with photograph if appropriate.

Comments: Portions of the stream reach in both forks before converging have high amounts of introduced pasture grasses: Alopecurus pratensis, Poa pratensis, and Bromus inermis that have low binding root mass. After Johnson Creek exists Johnson Creek Feedlot does native vegetation cover begin to increase to expected historic communities with expected higher binding root mass ratings.

Question 6. Noxious Weeds in the Riparian Area

3 = None of the riparian area has noxious weeds present.

2 = Up to 5% of the riparian area has noxious weeds (a few are present).

1 = Up to 10% of the riparian area has noxious weeds present (abundant).

0 = Over 10% of the riparian area has noxious weeds (very apparent and extensive distribution).

SCORE: **Potential** 3 **Actual** 2

Please clarify the rationale for your score, including comments regarding *potential* and *capability* and document with photograph if appropriate.

Comments (NOTE--List all noxious weed species): Euphorbia esula, Centaurea steobe, and Cynoglossum officinale are present along the stream reach, but in low cover amounts (<5%). These Species are more prevalent along the active rail road bordering the N and S forks banks.

Question 7. Disturbance-Caused Undesirable Plants in the Riparian Area

3 = 5% or less of the riparian area with undesirable plants (very few present).

2 = 5-10% of the riparian area with undesirable plants (few are present).

1 = 10-15% of the riparian area with undesirable plants (commonly distributed).

0 = Over 15% of the riparian area with undesirable plants (abundant over much of the area).

SCORE: **Potential** 3 **Actual** 3

Please clarify the rationale for your score, including comments regarding *potential* and *capability* and document with photograph if appropriate.

Comments (NOTE--List all nuisance weeds and undesirable plants): Low cover amounts throughout stretch, but Centaurea steobe may become an issue in the near future if no management action is taken.

Question 8. Woody Species Establishment and Regeneration

Note: For stream types where riparian vegetation is not required for sustainability, this question can be skipped and given an N/A, with an explanatory note or comment. Be sure to adjust the potential score if this question is skipped. At least 10 individuals in a class should be present in the reach to count. Count only 1+ years of age. Do not count seedlings of the year as mortality is very high the first year.

8 = All age classes of desirable woody riparian species present (see Table 3).

6 = One age class of desirable woody riparian species is clearly absent, all others well represented. Often, it will be the middle age group(s) absent. For sites with potential for both trees and shrubs there may be one age class of each absent. Having mature individuals and at least one younger age class present indicates the potential for recovery.

4 = Two age classes (seedlings and saplings) of native riparian shrubs and/or two age classes of native riparian trees are clearly absent, or the stand is comprised of mainly mature species. Other age classes well represented.

2 = Disturbance induced, (i.e. facultative, facultative upland species such as rose, or snowberry) or non-riparian species dominate. Woody species present consist of decadent/dying individuals. (Refer back to Question 1 if this is the situation. The channel may have incised.)

0 = A few woody species are present (<10% canopy cover), but herbaceous species dominate (at this point, the site potential should be re-evaluated to ensure that it has potential for woody vegetation); or, the site has at ≥ 5% canopy cover of Russian olive and/or salt cedar. On sites with long-term manipulation or disturbance, woody species potential is easily underestimated.

RIPARIAN ASSESSMENT WORKSHEET--continued

NAME OF STREAM: N and S Fork Johnson Creek **REACH ID:** ________ **DATE:** 6/6/2014

Question 8. Woody Species Establishment and Regeneration--continued

SCORE: **Potential** 8 **Actual** 4

Please clarify the rationale for your score, including comments regarding *potential* and *capability* and document with photograph if appropriate.

Comments: A rating of 4 was selected, however, there is limited amounts of disturbance most likely due to livestock disturbance and competition from introduced pasture grasses in both N and S Forks and thought the Johnson Creek Feed Lot Pasture that is limiting new recruitment (lots of decadent trees). All classes present after Johnson Creek Feed Lot Pasture.

Functional Considerations

Question 9. Utilization of Trees and Shrubs

Note: For stream types where riparian vegetation is not required for sustainability, this question can be skipped and given an N/A, with an explanatory note or comment. Be sure to adjust the potential score if this question is skipped.

4 = 0-5% of the available second year and older stems are browsed.

3 = 5%-25% of the available second year and older stems are browsed (lightly).

2 = 25%-50% of the available second year and older stems are browsed (moderately.

1 = More than 50% of the available second year and older stems are browsed (heavily). Many of the shrubs have either a "clubbed" growth form, or they are high-lined or umbrella shaped.

0 = There is noticeable use (10% or more) of unpalatable and normally unused woody species

SCORE: **Potential** 4 **Actual** 3

Please clarify the rationale for your score, including comments regarding *potential* and *capability* and document with photograph if appropriate.

Comments: Light browse levels overall, but young willows may be influenced negatively in some stretches near Johnson Creek Feedlot Pasture.

Question 10. Flood plain Characteristics for Dissipating Energy and Capturing Sediment

8 = Active flood or overflow channels exist in the flood plain. Large rock, woody debris, and/or riparian vegetation appropriate for the setting are sufficient to adequately dissipate stream energy and trap sediment on the flood plain. There is little evidence of excessive erosion or disturbance that reduces energy dissipation and sediment capture on the flood plain. There are no headcuts where either overland flow and/or flood channel flows return to the main channel.

6 = The flood plain meets the characteristics of the description in Question 8 above, but demonstrates slight limitations in the kind and amount of large rock, woody debris, and/or riparian vegetation present. Riparian vegetation structure is below that required to dissipate energy. There may be occasional evidence of surface erosion and disturbance, but generally not extensive enough to have affected channel development.

4 = Large rock, woody debris, and/or riparian vegetation is present, but generally insufficient (quality or quantity) to fully dissipate stream energy. Some sediment may be captured, but greater evidence of incipient erosion and/or headcuts is readily present.

2 = Inadequate Large rock, woody debris, and/or riparian vegetation is available for dissipation of energy or sediment capture. There is very little evidence of sediment capture. There is some streambank erosion due to human disturbance or alterations, and occasional headcuts where overland flows or flood channel flows return to the main channel.

0 = Flood plain area reflects the following conditions: 1) The flood plain area is very limited or not present and is inadequate to dissipate energy; 2) flood or overflow channels do not exist; and 3) large rock, woody debris, and/or riparian vegetation is not adequate to dissipate stream energy and trap sediment on the flood plain. Streambank and/or flood plain erosion and/or evidence of human alteration are common. "G"- and "F"-type channels (Rosgen) typically reflect these conditions.

SCORE: **Potential** 8 **Actual** 6

Please clarify the rationale for your score, including comments regarding *potential* and *capability* and document with photograph if appropriate.

Comments: There is fair amounts of woody material, but more woody material would improve stream dissipation. Rocks appear to be sufficient in some stream sections, but near wetland areas disappear and are replace by high amounts of silt and Organic Material. Overall there appears to be enough structures to dissipate flow energy and capturing sediment, but may be lacking especially in wetland and active Rail Road boundary.

NAME OF STREAM:______ REACH ID:______ DATE:______

SUMMARY

		SCORE POTENTIAL	SCORE ACTUAL	POSSIBLE
QUESTION 1:	Stream Incisement	8	6	0, 2, 4, 6, 8
QUESTION 2:	Lateral Cutting	8	8	0, 3, 5, 8
QUESTION 3:	Stream Balance	6	6	0, 2, 4, 6
QUESTION 4:	Deep, Binding Rootmass	6	4	N/A, 0, 2, 4, 6
QUESTION 5:	Riparian/Wetland Vegetative Cover *	6	2	N/A, 0, 2, 4, 6
QUESTION 6:	Noxious Weeds	3	2	0, 1, 2, 3
QUESTION 7:	Undesirable Plants	3	3	0, 1, 2, 3
QUESTION 8:	Woody Species Establishment	8	4	N/A, 0, 2, 4, 6, 8
QUESTION 9:	Browse Utilization	4	3	N/A, 0, 1, 2, 3, 4
QUESTION 10:	Riparian Area/Flood plain Characteristics *	8	6	N/A, 0, 2, 4, 6, 8
	TOTAL	60	44	(60 total possible)

(POTENTIAL SCORE FOR MOST BEDROCK OR BOULDER STREAMS) (36)
(questions 1, 2, 3, 6, 7, 10)

(POTENTIAL SCORE FOR MOST LOW ENERGY "E" STREAMS) (48)
(questions 1 – 7, 10)

RATING: = $\frac{\text{Actual Score}}{\text{Potential Score}}$ X 100 = % rating

80-100% = SUSTAINABLE
50-80% = AT RISK
LESS THAN 50% = NOT SUSTAINABLE

* Only in certain, specific situations can both of these receive an "N/A".

Please clarify the rationale for your rating, including comments regarding potential. Can the limitations be addressed by the decision maker?

NOTES Evidence of stream down cutting near active Rail Road and Culverts, low amounts of mature and sapling woody species, presence of noxious weeds, high cover amounts of introduced pasture grasses on banks, and stretches of the stream has insufficient structures (wood debris and rock) to dissipate stream energy and entrap sediment. Where the rail road intersects the stream boundary both forks may be unable to reach floodplain during flood events. These are the major criteria in deciding this stream category.

TREND: Does the reach appear to be improving or declining? Explain.

The stream appears to be improving in stream dissipation and in some cases incesment near older water culverts. Browsing does not appear to be limiting the wood species, but woody species are declining most likely due to high amounts of introduced grass species. Other than stretches near the railroad banks appear to be stable and should imporve with more time and pasture rest to allow native grasses with high root binding ratings to increase. With active managment for noxious weeds current levels should be able to eliminated for the most part. These noxious weeds do not appear to be rapidly colonizing suggesting stable pasture conditions and low disturbances. Active management in planting woody species is suggested or using prescribed fire to stimulate suckering to improve the current decadent woody species populations.

RIPARIAN ASSESSMENT WORKSHEET

NAME OF STREAM: North and South Fork Johnson Creek **REACH LOC OR ID:** ______

DATE: 6/6/2014 **ID TEAM/OBSERVERS:** Jarrett Payne

LENGTH OF REACH: .5 miles (approx) **LAT/LONG - BEGIN/END:** ______

MAP OR QUAD NAME: ______ **PHOTO #S:** ______ **PRIMARY LAND USE:** Pasture

PLANT COMMUNITY: Grass/Grasslike **ROSGEN CHANNEL TYPE:** E **BFDEPTH:** 1.5 **BFWIDTH:** 8.0

WIDTH/DEPTH RATIO: 5.3:1 **CHANNEL SUBSTRATE :** Silty over Sandy Cobbles

Geomorphic Considerations

Question 1. Stream Incisement (Downcutting)

8 = Channel stable, no active downcutting occurring; or, old downcutting apparent but a new, stable riparian area has formed within the incised channel. There is perennial riparian vegetation well established in the riparian area (Stage 1 and 5, Schumm's Model Figure 2).

6 = Channel has evidence of old downcutting that has begun stabilizing, vegetation is beginning to establish, even at the base of the failing banks, soil disturbance evident (Stage 4, Schumm's Model Figure 2).

4 = Small headcut, in early stage, is present. Immediate action may prevent further degradation (Early Stage 2, Schumm's Model Figure 2).

2 = Unstable, channel incised, actively widening, limited new riparian area/flood plain, flood plain not well vegetated. The vegetation that is present is mainly pioneer species. Bank failure is common (Stage 3, Schumm's Model Figure 2).

0 = Channel deeply incised, resembling a gully, little or no riparian area, active downcutting is clearly occurring. Only occasional or rare flood events access the flood plain. Tributaries will also exhibit downcutting or signs of downcutting (Stage 2, Schumm's Model Figure 2).

The presence of active headcuts should nearly always keep the stream reach from being rated Sustainable.

SCORE: **Potential** 8 **Actual** 6

Please clarify the rationale for your score, including comments regarding *potential* and *capability* and document with photograph if appropriate.

Comments: Near culverts and railroad boundary the stream incisement appears to be stabilizing in certain reaches and increasing slightly around the railroad boundary. The stream may have difficulty in accessing a suitable floodplain to dissipate flow energy and release sediment load.

Question 2. Streambanks with Active Lateral Cutting (inspect banks on both sides of the stream)

8 = Lateral bank erosion is in balance with the stream and its setting.

5 = There is a minimal amount of human-induced, active lateral bank erosion occurring, primarily limited to outside banks.

3= There is a moderate amount of human-induced active lateral bank erosion occurring on either or both outside and inside banks.

0 = There is extensive human-induced lateral bank erosion occurring on outside and inside banks and straight sections.

SCORE: **Potential** 8 **Actual** 8

Please clarify the rationale for your score, including comments regarding *potential* and *capability* and document with photograph if appropriate.

Comments: Lateral cutting is within the assumed natural tolerance of this stream. Some lateral cutting is occurring around old decadent trees/shrubs and around railroad boundary.

RIPARIAN ASSESSMENT WORKSHEET--continued

NAME OF STREAM: Cottonwood Creek **REACH ID:** ______ **DATE:** 6/26/2014

Question 8. Woody Species Establishment and Regeneration--continued

SCORE: **Potential** 8 **Actual** 6

Please clarify the rationale for your score, including comments regarding *potential* and *capability* and document with photograph if appropriate.

Comments: Fair Cottonwood and Willow cover with most age classes represented except for young mature cottonwoods and willow species. Recruitment noted throughout for willow, but not as high for Black Cottonwood.

Functional Considerations

Question 9. Utilization of Trees and Shrubs

Note: For stream types where riparian vegetation is not required for sustainability, this question can be skipped and given an N/A, with an explanatory note or comment. Be sure to adjust the potential score if this question is skipped.

4 = 0-5% of the available second year and older stems are browsed.

3 = 5%-25% of the available second year and older stems are browsed (lightly).

2 = 25%-50% of the available second year and older stems are browsed (moderately..

1 = More than 50% of the available second year and older stems are browsed (heavily). Many of the shrubs have either a "clubbed" growth form, or they are high-lined or umbrella shaped.

0 = There is noticeable use (10% or more) of unpalatable and normally unused woody species

SCORE: **Potential** 4 **Actual** 3

Please clarify the rationale for your score, including comments regarding *potential* and *capability* and document with photograph if appropriate.

Comments: Light browsing noted to almost none for the entire reach surveyed. Does not appear to be limiting the woody riparian species success for stand replacement.

Question 10. Flood plain Characteristics for Dissipating Energy and Capturing Sediment

8 = Active flood or overflow channels exist in the flood plain. Large rock, woody debris, and/or riparian vegetation appropriate for the setting are sufficient to adequately dissipate stream energy and trap sediment on the flood plain. There is little evidence of excessive erosion or disturbance that reduces energy dissipation and sediment capture on the flood plain. There are no headcuts where either overland flow and/or flood channel flows return to the main channel.

6 = The flood plain meets the characteristics of the description in Question 8 above, but demonstrates slight limitations in the kind and amount of large rock, woody debris, and/or riparian vegetation present. Riparian vegetation structure is below that required to dissipate energy. There may be occasional evidence of surface erosion and disturbance, but generally not extensive enough to have affected channel development.

4 = Large rock, woody debris, and/or riparian vegetation is present, but generally insufficient (quality or quantity) to fully dissipate stream energy. Some sediment may be captured, but greater evidence of incipient erosion and/or headcuts is readily present.

2 = Inadequate Large rock, woody debris, and/or riparian vegetation is available for dissipation of energy or sediment capture. There is very little evidence of sediment capture. There is some streambank erosion due to human disturbance or alterations, and occasional headcuts where overland flows or flood channel flows return to the main channel.

0 = Flood plain area reflects the following conditions: 1) The flood plain area is very limited or not present and is inadequate to dissipate energy; 2) flood or overflow channels do not exist; and 3) large rock, woody debris, and/or riparian vegetation is not adequate to dissipate stream energy and trap sediment on the flood plain. Streambank and/or flood plain erosion and/or evidence of human alteration are common. "G"- and "F"-type channels (Rosgen) typically reflect these conditions.

SCORE: **Potential** 8 **Actual** 6

Please clarify the rationale for your score, including comments regarding *potential* and *capability* and document with photograph if appropriate.

Comments: Good amounts of debris such as beaver dams to dissipate stream energy, but flood plain characteristics in the lower portions of the stream limit the stream in ability to access a suitable floodplain without some lateral erosion. Erosion is noticeable but is stabilizing. Channel development does not appear to be influenced by these factors.

NAME OF STREAM:______ REACH ID:______ DATE:______

SUMMARY

		SCORE POTENTIAL	SCORE ACTUAL	POSSIBLE
QUESTION 1:	Stream Incisement	8	8	0, 2, 4, 6, 8
QUESTION 2:	Lateral Cutting	8	5	0, 3, 5, 8
QUESTION 3:	Stream Balance	6	6	0, 2, 4, 6
QUESTION 4:	Deep, Binding Rootmass	6	6	N/A, 0, 2, 4, 6
QUESTION 5:	Riparian/Wetland Vegetative Cover *	6	2	N/A, 0, 2, 4, 6
QUESTION 6:	Noxious Weeds	3	2	0, 1, 2, 3
QUESTION 7:	Undesirable Plants	3	3	0, 1, 2, 3
QUESTION 8:	Woody Species Establishment	8	6	N/A, 0, 2, 4, 6, 8
QUESTION 9:	Browse Utilization	4	3	N/A, 0, 1, 2, 3, 4
QUESTION 10:	Riparian Area/Flood plain Characteristics *	8	6	N/A, 0, 2, 4, 6, 8
	TOTAL	60	47	(60 total possible)

(POTENTIAL SCORE FOR MOST BEDROCK OR BOULDER STREAMS) (36)
(questions 1, 2, 3, 6, 7, 10)

(POTENTIAL SCORE FOR MOST LOW ENERGY "E" STREAMS) (48)
(questions 1 – 7, 10)

RATING: = Actual Score / Potential Score X 100 = % rating

80-100% = SUSTAINABLE
50-80% = AT RISK
LESS THAN 50% = NOT SUSTAINABLE

* Only in certain, specific situations can both of these receive an "N/A".

Please clarify the rationale for your rating, including comments regarding potential. Can the limitations be addressed by the decision maker?

NOTES Lateral cutting is evident and puts the stream at risk in the lower portions before entering into the Clark Fork. Lateral cutting may be influenced by the amount of introduced grass species colonizing the riparian banks the reduces capabilities to prevent further erosion. Riparian wetland cover is not ideal in the lower stretches which places this stream in an AT RISK category. Further more Cottonwood and Willow recruitment is desirable to improve this stream stretch. The stream is limited as the banks in the lower portions of this stream where built and is assumed to prevent flooding into the neighboring pasture prevents the stream from accessing the a suitable floodplain in some location to release sediment load and flow energy.

TREND: Does the reach appear to be improving or declining? Explain.

Cottonwood Creek appears to be improving as there is evidence of willow recruitment, bank stabilization, and beaver activity within the lower and upper reaches of Cottonwood. Vegetation communities in the upper portion of Cottonwood Creek are stable and proved sufficient cover for binding the banks together. Riparian vegetation communities may be improving slowly or are stable in the lower portions of Cottonwood Creek. Management may be needed to remove some of the introduced grasses to prevent current and further erosion if more native riparian species with high root binding ratings are not colonizing those banks. The presence of beaver suggests that Cottonwood Creek has suffiencent structures to dissipate water flow energy from further eroding some of the lower portions of the banks. Sediment appears to be building in those areas with beaver, and may bring the river height up to access a suitable flood plain.

RIPARIAN ASSESSMENT WORKSHEET

NAME OF STREAM: Cottonwood Creek REACH LOC OR ID: ____

DATE: 6/26/2014 ID TEAM/OBSERVERS: Jarrett Payne

LENGTH OF REACH: .25 mile LAT/LONG - BEGIN/END: ____

MAP OR QUAD NAME: ____ PHOTO #S: ____ PRIMARY LAND USE: Animal and Hay Pasture

PLANT COMMUNITY: Cottonwood and Willow converging into Grass ROSGEN CHANNEL TYPE: E BFDEPTH: 3.1 BFWIDTH: 20.9

WIDTH/DEPTH RATIO: 9.3 : 1 CHANNEL SUBSTRATE : Gravel/Cobble Mix

Geomorphic Considerations

Question 1. Stream Incisement (Downcutting)

8 = Channel stable, no active downcutting occurring; or, old downcutting apparent but a new, stable riparian area has formed within the incised channel. There is perennial riparian vegetation well established in the riparian area (Stage 1 and 5, Schumm's Model Figure 2).

6 = Channel has evidence of old downcutting that has begun stabilizing, vegetation is beginning to establish, even at the base of the falling banks, soil disturbance evident (Stage 4, Schumm's Model Figure 2).

4 = Small headcut, in early stage, is present. Immediate action may prevent further degradation (Early Stage 2, Schumm's Model Figure 2).

2 = Unstable, channel incised, actively widening, limited new riparian area/flood plain, flood plain not well vegetated. The vegetation that is present is mainly pioneer species. Bank failure is common (Stage 3, Schumm's Model Figure 2).

0 = Channel deeply incised, resembling a gully, little or no riparian area, active downcutting is clearly occurring. Only occasional or rare flood events access the flood plain. Tributaries will also exhibit downcutting or signs of downcutting (Stage 2, Schumm's Model Figure 2).

The presence of active headcuts should nearly always keep the stream reach from being rated Sustainable.

SCORE: Potential 8 Actual 8

Please clarify the rationale for your score, including comments regarding *potential* and *capability* and document with photograph if appropriate.

Comments: Bank erosion is noticeable near Clark Fork River. River banks were built up (40+ years ago), but does not show signs of recent down cutting.

Question 2. Streambanks with Active Lateral Cutting (Inspect banks on both sides of the stream)

8 = Lateral bank erosion is in balance with the stream and its setting.

5 = There is a minimal amount of human-induced, active lateral bank erosion occurring, primarily limited to outside banks.

3= There is a moderate amount of human-induced active lateral bank erosion occurring on either or both outside and inside banks.

0 = There is extensive human-induced lateral bank erosion occurring on outside and inside banks and straight sections.

SCORE: Potential 8 Actual 5

Please clarify the rationale for your score, including comments regarding *potential* and *capability* and document with photograph if appropriate.

Comments: Lateral bank erosion is noticeable around bends were banks have been built in the lower portions of the stream on the outside portions of the stream banks.

RIPARIAN ASSESSMENT WORKSHEET--continued

NAME OF STREAM: Cottonwood Creek **REACH ID:** ________ **DATE:** 6/26/2014

Question 3. The Stream is in Balance with the Water and Sediment Supplied by the Watershed

6 = The width to depth ratio appears to be appropriate for the stream type and its geomorphic setting. There is no evidence of excess sediment removal or deposition. There are no indications that the stream is widening or getting shallower. There may be some well-washed gravel and cobble bars present. Pools are common. Rosgen "B" and naturally occurring "D" channel types are exceptions.

4 = The stream has widened and/or has become shallower due to disturbances that have caused the banks to become unstable or from dewatering which reduces the amount of water and energy needed to effectively move the sediment through the channel. *(Note: Sediment sources may also be from offsite sources.)* Point bars are often enlarged by gravel with silt and sand common, and new bars are forming. Pools are common, but may be shallow. Rosgen "B" and naturally occurring "D" channel types are exceptions.

2 = The width to depth ratio exceeds what is appropriate for the stream type. Point bars are enlarged by gravel with abundant sand and silt, and new bars are forming that often force lateral movement of the stream. Mid channel bars are often present. For prairie streams there is often a deep layer of sediment on top of the gravel substrate. The frequency of pools is low. Rosgen "B" and naturally occurring "D" channel types are exceptions.

0 = The stream has poor sediment transport capability which is reflected by poor channel definition. The channel is often braided having at least 3 active channels. Naturally occurring Rosgen "D" channels types are exceptions. Pools are filled with sediment or are not existent.

SCORE: Potential 6 Actual 6

Please clarify the rationale for your score, including comments regarding *potential* and *capability* and document with photograph if appropriate.

Comments: The stream appears to have to widen in some locations where the ditch has been built up in the lower portion of this survey. However, it appears the banks are beginning to stablize and there is a large presence of beaver dams in this reach to reduce rive flows and deposit sediment.

Vegetative Considerations

Question 4. Streambank with Vegetation (Kind) having a Deep, Binding Root Mass

Note: For stream types where riparian vegetation is not required for sustainability, this question can be skipped and given an N/A, with an explanatory note or comment. Be sure to adjust the potential score if this question is skipped. (See Appendix I for stability ratings for most riparian, and other, species.) Presence generally means more than one or two, healthy individuals of a species in the reach.

6 = The streambank vegetative communities are comprised of at least four plant species with deep, binding root masses.

4 = The streambank vegetative communities are comprised of at least three plant species with deep, binding root masses.

2 = The streambank vegetative communities are comprised of two plant species with deep, binding root masses.

0 = The streambank vegetative communities are comprised of one or no plant species with deep, binding root masses.

SCORE: Potential 6 Actual 6

Please clarify the rationale for your score, including comments regarding *potential* and *capability* and document with photograph if appropriate.

Comments: The majority of the vegetative communities have 4 native riparian species with deep binding root mass ratings. Species include Carex utriculata, Carex nebrascensis, Juncus Balticus, Scirpus spp., Populus trichocarpa, Salix spp. and Phalaris arundinacea. Vegetative community diversity decreases near Clark Fork where banks have been built up, which borders a hay pasture.

Question 5. Riparian/Wetland Vegetative Cover (Amount) in the Riparian/Flood plain Area

Note: For stream types where riparian vegetation is not required for sustainability, this question can be skipped and given an N/A, with an explanatory note or comment. Be sure to adjust the potential score if this question is skipped.

6 = More than 85% of the riparian/wetland canopy cover has a stability rating ≥ 6

4 =75%-85% of the riparian/wetland canopy cover has a stability rating ≥ 6

2 =65%-75% of the riparian/wetland canopy cover has a stability rating ≥ 6

0 = Less than 65% of the riparian/wetland canopy cover has a stability rating ≥ 6

NOTE: A low score for this item may be enough to keep the stream reach from being rated Sustainable

SCORE: Potential 6 Actual 2

RIPARIAN ASSESSMENT WORKSHEET--continued

NAME OF STREAM: Cottonwood Creek **REACH ID:** ________ **DATE:** 6/26/2014

Question 5--continued

Please clarify the rationale for your score, including comments regarding *potential* and *capability* and document with photograph if appropriate.

Comments: Introduced pasture species Alopecurus pratensis, Bromus inermis, Elymus repens, and Poa pratensis have reduced overall cover density of riparian banks with high root mass binding riparian species in much of the reach to about 65% total cover throughout the river.

Question 6. Noxious Weeds in the Riparian Area

3 = None of the riparian area has noxious weeds present.

2 = Up to 5% of the riparian area has noxious weeds (a few are present).

1 = Up to 10% of the riparian area has noxious weeds present (abundant).

0 = Over 10% of the riparian area has noxious weeds (very apparent and extensive distribution).

SCORE: **Potential** 3 **Actual** 2

Please clarify the rationale for your score, including comments regarding *potential* and *capability* and document with photograph if appropriate.

Comments (NOTE–List all noxious weed species): Cirsium arvense present in low to no cover along banks. No other species sighted.

Question 7. Disturbance-Caused Undesirable Plants in the Riparian Area

3 = 5% or less of the riparian area with undesirable plants (very few present).

2 = 5-10% of the riparian area with undesirable plants (few are present).

1 = 10-15% of the riparian area with undesirable plants (commonly distributed).

0 = Over 15% of the riparian area with undesirable plants (abundant over much of the area).

SCORE: **Potential** 3 **Actual** 3

Please clarify the rationale for your score, including comments regarding *potential* and *capability* and document with photograph if appropriate.

Comments (NOTE–List all nuisance weeds and undesirable plants): Cirsium arvense in low cover amounts near and around disturbance areas and on stable banks.

Question 8. Woody Species Establishment and Regeneration

Note: For stream types where riparian vegetation is not required for sustainability, this question can be skipped and given an N/A, with an explanatory note or comment. Be sure to adjust the potential score if this question is skipped. At least 10 individuals in a class should be present in the reach to count. Count only 1+ years of age. Do not count seedlings of the year as mortality is very high the first year.

8 = All age classes of desirable woody riparian species present (see Table 3).

6 = One age class of desirable woody riparian species is clearly absent, all others well represented. Often, it will be the middle age group(s) absent. For sites with potential for both trees and shrubs there may be one age class of each absent. Having mature individuals and at least one younger age class present indicates the potential for recovery.

4 = Two age classes (seedlings and saplings) of native riparian shrubs and/or two age classes of native riparian trees are clearly absent, or the stand is comprised of mainly mature species. Other age classes well represented.

2 = Disturbance induced, (i.e. facultative, facultative upland species such as rose, or snowberry) or non-riparian species dominate. Woody species present consist of decadent/dying individuals. (Refer back to Question 1 if this is the situation. The channel may have incised.)

0 = A few woody species are present (<10% canopy cover), but herbaceous species dominate (at this point, the site potential should be re-evaluated to ensure that it has potential for woody vegetation); or, the site has at ≥ 5% canopy cover of Russian olive and/or salt cedar. On sites with long-term manipulation or disturbance, woody species potential is easily underestimated.

Appendix E. Invasive Species Monitoring

Introduction

This report compares the results of non-native invasive plant surveys performed at GRKO in 2003, 2012, and 2013. Their purpose was to identify and map the distribution of non-native plant species that were of concern to park resource managers or were known to be invasive in other areas (Wood and Rew 2005). The 2003 survey was part of a larger inventory and mapping project initiated by the Intermountain Region (IMR) of the NPS (Wood and Rew 2005). The goals of the IMR project are to develop a database to assist resource managers with invasive plant management and control, to provide a baseline dataset for long term monitoring efforts, and to facilitate data sharing within the NPS and with external agencies (Wood and Rew 2005). The goals of the resource managers at GRKO were to develop maps of the location of non-native invasive plant species to assist with their management and restoration actions, to prioritize mapping in those habitats with an increased risk of invasion, particularly the upland ranges and the Clark Fork River riparian area, and to search for potential new invaders (Wood and Rew 2005). Several years after the 2003 survey, the Northern Rocky Mountains Exotic Plant Management Team (NRM EPMT) initiated control efforts to reduce invasive plant infestations within GRKO (NPS 2011). Thus, an additional goal of the 2012 and 2013 surveys was to document the effects of invasive species control efforts.

Site Description

Grant-Kohrs Ranch is located in Deer Lodge, Montana and occupies 607 ha (1,500 ac) of irrigated pasture, upland rangelands, and riparian area along the Clark Fork River. The NPS manages GRKO as an active cattle ranch and an interpretive site open to the public (Wood and Rew 2005). The ranch has a number of buildings and corrals, along with several roads, irrigation ditches, and fenced areas (Wood and Rew 2005).

Disturbance History

Currently the ranch is comprised of relatively intact upland grasslands along with irrigated mesic pastures that are managed for hay production and/or grazing (Wood and Rew 2005). A rail line and right-of-way area operated and managed by Burlington Northern/Santa Fe Railroad runs through the ranch. A borrow pit created from the excavations used to build the railroad grade is located at the north end of the ranch, and functions as a wetland (Wood and Rew 2005). GRKO is bisected by the Clark Fork River with approximately 51 ha (126 ac) of fenced riparian area located along the river (Wood and Rew 2005). The reach of the Clark Fork flowing through GRKO is part of the Clark Fork River Operable Unit of the Milltown Reservoir Sediments National Priority Superfund Site. Natural and anthropogenic hydrological processes have resulted in the deposition of high levels of heavy metals in the riparian area from upstream mining and smelting operations (Wood and Rew 2005).

Justification for Action

The NPS considers the invasion of non-native plant species (exotics, non-indigenous species, invasive species, or weeds) as one of the most serious threats that faces the lands they manage (NPS 2009). These non-native invasive species are considered the second greatest threat to biodiversity after habitat destruction (Randall 1996). Because these species have characteristics that allow them to rapidly invade new areas and out-compete existing native plant communities, they are often referred to as invasive species (Westerbrooks 1998).

Invasive species are not necessarily noxious weeds. A noxious weed can be defined as any plant species that has been designated by a federal, state or county government as injurious to public health, agriculture, recreation, wildlife or property (Sheley et al. 1999). The State of Montana, in its County Weed Control Act (CNWCA), defines a noxious weed as a "...plant of foreign origin that can directly or indirectly injure agriculture, navigation, fish or wildlife, or public health" (Montana Weed Control Association 2009). Their control is required by the CNWCA (7-22-2101 MCA) and is usually administered within county districts. The CNCWA also requires weed management plans to incorporate all appropriate methods, including education, prevention, mechanical methods, biological controls, cultural methods, and general land management practices (MDA 2013). Currently there are 32 plant species on the Montana state noxious weed list (Montana Weed Control Association 2009). A summary of the noxious weed status and applicable priority status for each of the non-native species found during the three GRKO surveys is listed in Table E-1.

Table E-1. Noxious weed status of species identified in field surveys (Wood and Rew 2005, NPS 2012, Krogstad and Kamerman 2013, MSU 2014).

Scientific Name	Common Name	MT Noxious Weed List	MT Priority Status
Bromus tectorum	cheatgrass		3
Centaurea stoebe	spotted knapweed	x	2B
Cirsium arvense	Canada thistle	x	2B
Convolvulus arvensis	field bindweed	x	2B
Cynoglossum officinale	houndstongue	x	2B
Euphorbia esula	leafy spurge	x	2B
Gypsophila paniculata	babysbreath		
Lepidium draba	whitetop	x	2B
Lepidium latifolium	perennial pepperweed	x	2A
Linaria dalmatica	Dalmatian toadflax	x	2B
Linaria vulgaris	yellow toadflax	x	2B
Potentilla recta	sulfur cinquefoil	x	2B
Ranunculus acris	tall buttercup	x	2A
Rhaponticum repens	Russian knapweed	x	2B
Tanacetum vulgare	common tansy	x	2B
Thlaspi arvense	field pennycress		

Priority 1A - These species have a very limited presence or are not present in the state. When detected management criteria requires prevention, education, and eradication. No Priority 1A species were identified in the field inventories.

Priority 1B - These species have a limited presence in the state. When present management criteria requires eradication or containment, with prevention and education elsewhere. No Priority 1B species were identified in the field inventories.

Priority 2A - These species are commonly found in isolated areas of the state. Management criteria requires containment and suppression where common; and eradication, prevention, and education where less abundant.

Priority 2B - These species are abundant in the state, and widespread in many counties. Management criteria requires containment and suppression where abundant and widespread; and eradication, prevention and education where less abundant.

Priority 3 - These species are not identified as noxious weeds, but as regulated plants that have the potential to have significant negative impacts. Research, education, prevention, and control programs, where appropriate, are recommended to minimize the spread of these weeds. Control of these species is not mandated.

Vegetation Community Survey History

Prior to the IMR non-native survey conducted in 2003, several studies had addressed the vegetation community and the presence of non-native plants in GRKO (Wood and Rew 2005). In 1983, the University of Montana (UM) performed an inventory of vascular plant species in GRKO (Rice and Ray 1984). This study included a checklist of native and non-native plants, but did not address species location or frequency. This inventory was also part of a larger assessment of toxic metal contamination of the soil and biota of the Clark Fork River riparian area (Rice et al. 1984). During the years 2000-2002, researchers from the UM updated the earlier plant inventory and also classified the species found as either native or non-native (Rice and Hardin 2002b). In 2002, Rice and Hardin (2002a) also conducted a survey of the riparian vegetation along the Clark Fork River within the ranch. This study compared the riparian communities in the Superfund site to similar uncontaminated riparian communities in Western Montana. Riparian communities were classified and mapped and data were collected on the riparian community structure and species composition. However, non-native species were not specifically identified (Rice and Hardin 2002a).

IMR Non-native Invasive Plant Survey

Non-native invasive plant surveys were conducted in GRKO in 2003, 2012 and 2013. These surveys were designed and conducted as part of the IMR non-native species project and also to address the GRKO resource managers' management concerns and goals (Wood and Rew 2005). The 2003 survey was conducted by Montana State University (MSU) during the period of 30 June – 7 July and 9-10 September (Wood and Rew 2005). In 2012, surveys were conducted between 3 July and 2 August (NPS 2012). The 2013 survey was conducted between 6 June and 8 August (Krogstad and Kamerman 2013). To address the specific concerns of GRKO, a methodology was created that used three different sampling protocols (Wood and Rew 2005). The specific protocol is discussed in Wood and Rew (2005), but in general surveys were conducted along transects within the GRKO management units. The locations of these units are shown in Figure E-1. The primary protocol was to collect data along transects, using Global Positioning System (GPS) receivers to record the occurrences of non-native invasive species (Wood and Rew 2005). The second protocol involved the delineation of transects in areas that were too topographically difficult to sample intensively. In these cases, the transects followed the landscape or geographical features (Wood and Rew 2005). A third method was used in the areas of least interest to GRKO resource managers or in areas where the invasive plant density throughout the survey unit made it difficult to accurately delineate them into distinct populations (Wood and Rew 2005). In these instances, the area was sampled by one of two methods. If possible, the area was sampled by one of the two methods described above, or by visual observations (Wood and Rew 2005).

For all methods, whenever a non-native invasive species infestation was observed, it was delineated as either a point, polygon, or gross area (polygon) feature (Wood and Rew 2005). Small patches were generally mapped as point features and the length and width of the patch was recorded. The larger patches of infestation were mapped as either a polygon or gross area polygon. The difference being polygon features encompassed a distinct plant population and the gross area polygon feature mapped the general occurrence of the invasive species and a percent distribution within that area was recorded for use in calculating area (Wood and Rew 2005).

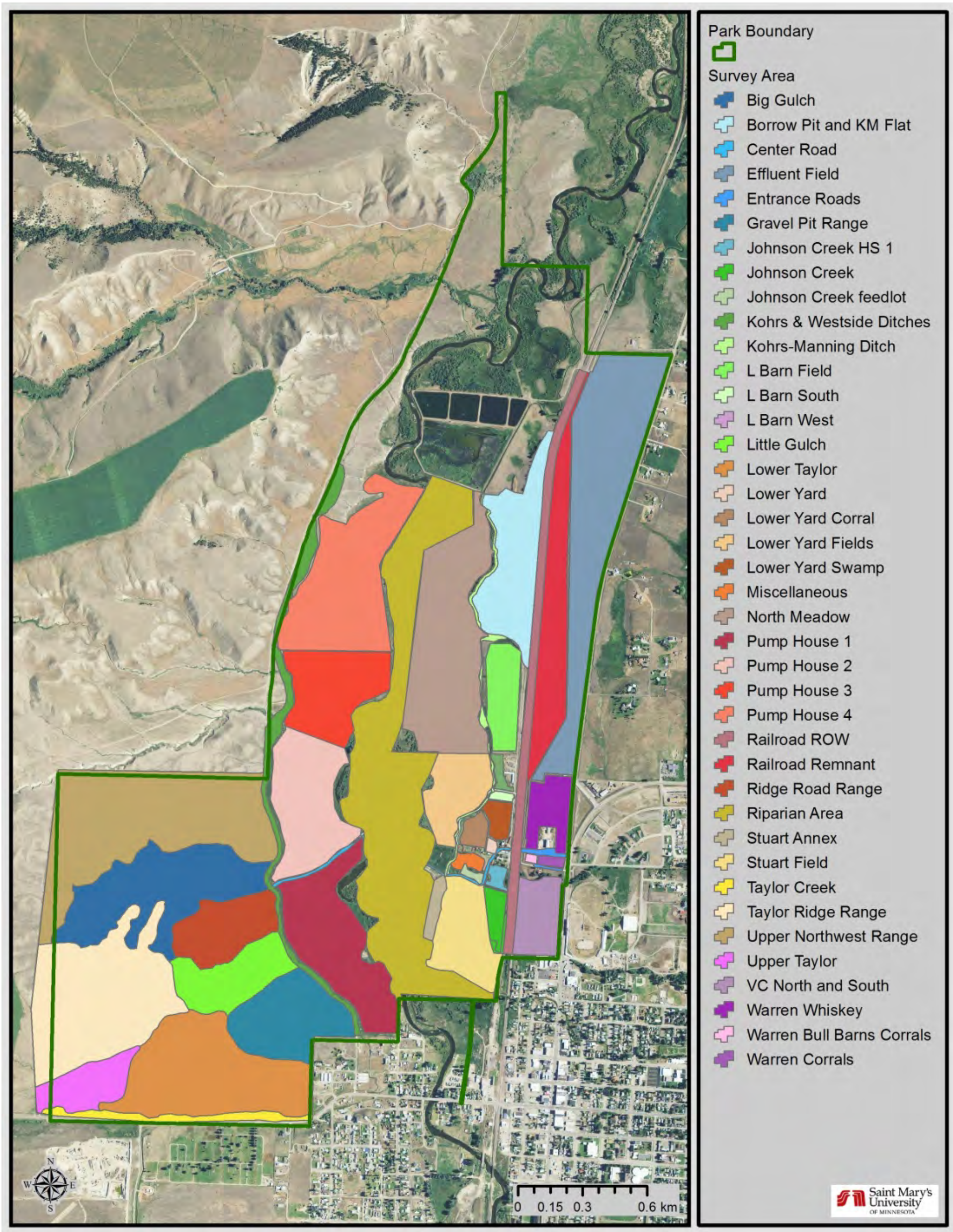


Figure E-1. Management Units (or field names) at GRKO as of 2003.

Area Infested with Non-native Invasive Plant Species

The surveys conducted in 2003, 2012 and 2013 covered approximately 343 ha (849 ac). A comparative summary of the 2003 and 2012 surveys, including cumulative infested area and total infested area, is shown in Table E-2 and graphically in Figure E-2. Due to differences in methodology, it may be inaccurate to directly compare results from the 2013 survey. The cumulative infested area includes any overlaps where a number of species might occupy portions of the same mapped patch or point, but each is considered as a unique infestation (Wood and Rew 2005). The total area infested was calculated by removing the overlapping areas in the calculation, so that even if a number of species infests the same physical space, the area infested is counted only once (Wood and Rew 2005). The results of the 2003 and 2012 surveys show that overall there has been a significant reduction in the area of the infestations on the ranch. As shown in Table E-2 and Figure E-2, the cumulative area decreased from approximately 256 ha (632 ac) in 2003 to only 119 ha (293 ac) in 2012. The total infested area dropped from 223 ha (550 ac) to 106 ha (261 ac).

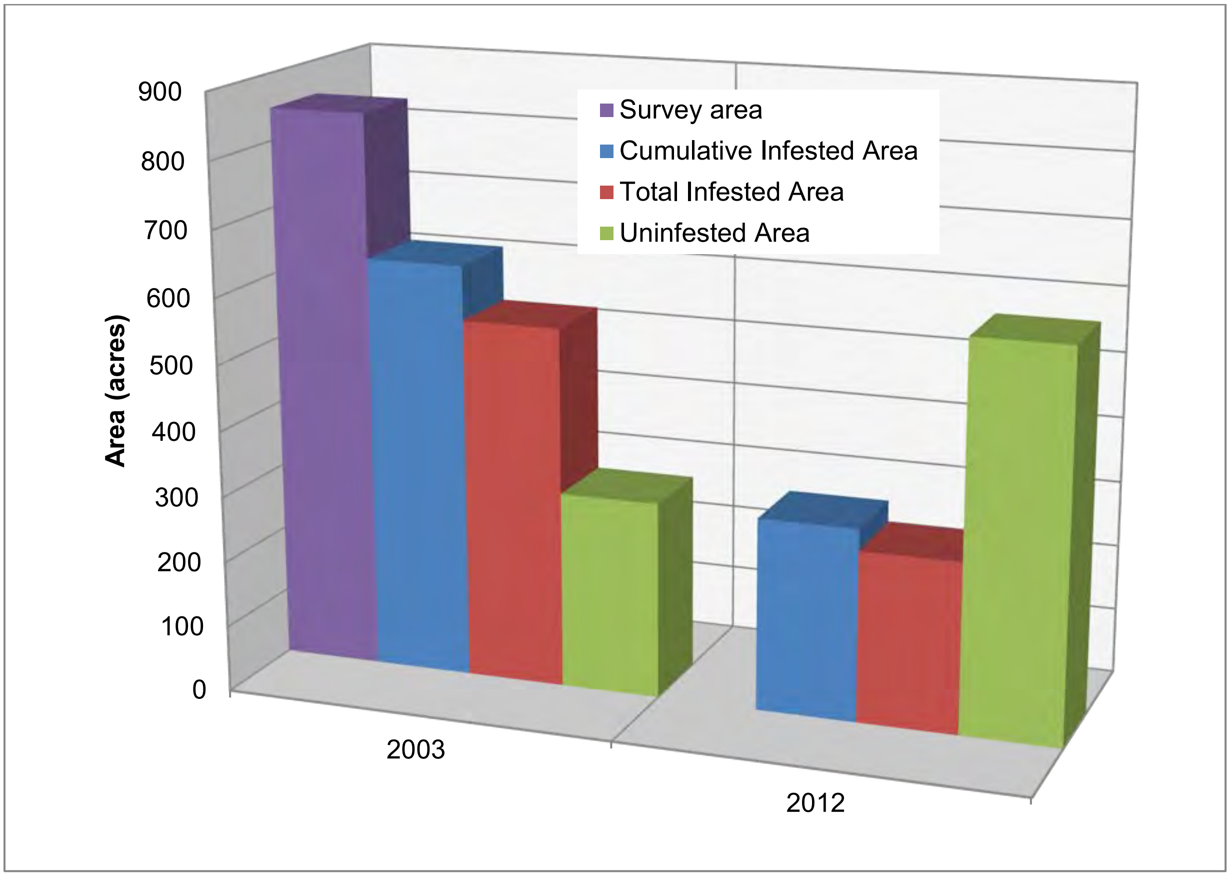


Figure E-2. Comparison of the 2003 and 2012 field surveys in terms of area surveyed, cumulative infested area, total infested area and uninfested area (Wood and Rew 2005, NPS 2012). Results from the 2013 survey are not included because direct comparisons may be inaccurate due to differences in methodology.

Table E-2. Summary of non-native invasive species field inventory results (Wood and Rew 2005, NPS 2012).

	Hectares (acres)	
	2003	**2012**
Survey Area	343.5 (848.9)	~340 (~840)[1]
Cumulative Infested Area	255.7 (631.8)	118.7 (293.2)
Total Infested Area	222.4 (549.5)	105.5 (260.6)
Uninfested Area	121.1 (299.3)	238.1 (588.3)

[1] Total area surveyed in 2012 was similar to 2003 but likely not exact.

Non-native Invasive Plant Species Composition at GRKO

A total of 16 non-native invasive plant species were recorded in GRKO during the 2003 and 2012 surveys (Figure E-3) and their infestation levels are provided in Table E-3. Of these, only cheatgrass, babysbreath (*Gypsophila paniculata*), and field pennycress are not on the noxious weed lists for the State of Montana (Table E-1). Cheatgrass is a regulated Priority 3 species in Montana, and babysbreath is listed as a noxious weed in nearby counties in Montana (Deerlodge and Silver Bow). The area infested declined from the 2003 levels for the majority of species; however, four species were recorded in 2012 that had not been documented in 2003. Again, due to differences in methodology, it may be inaccurate to directly compare results from the 2013 survey to the 2003 and 2012 results. However, 2013 results are summarized separately in Table E-5. A summary of all three surveys' findings for each species is provided in the remainder of this appendix.

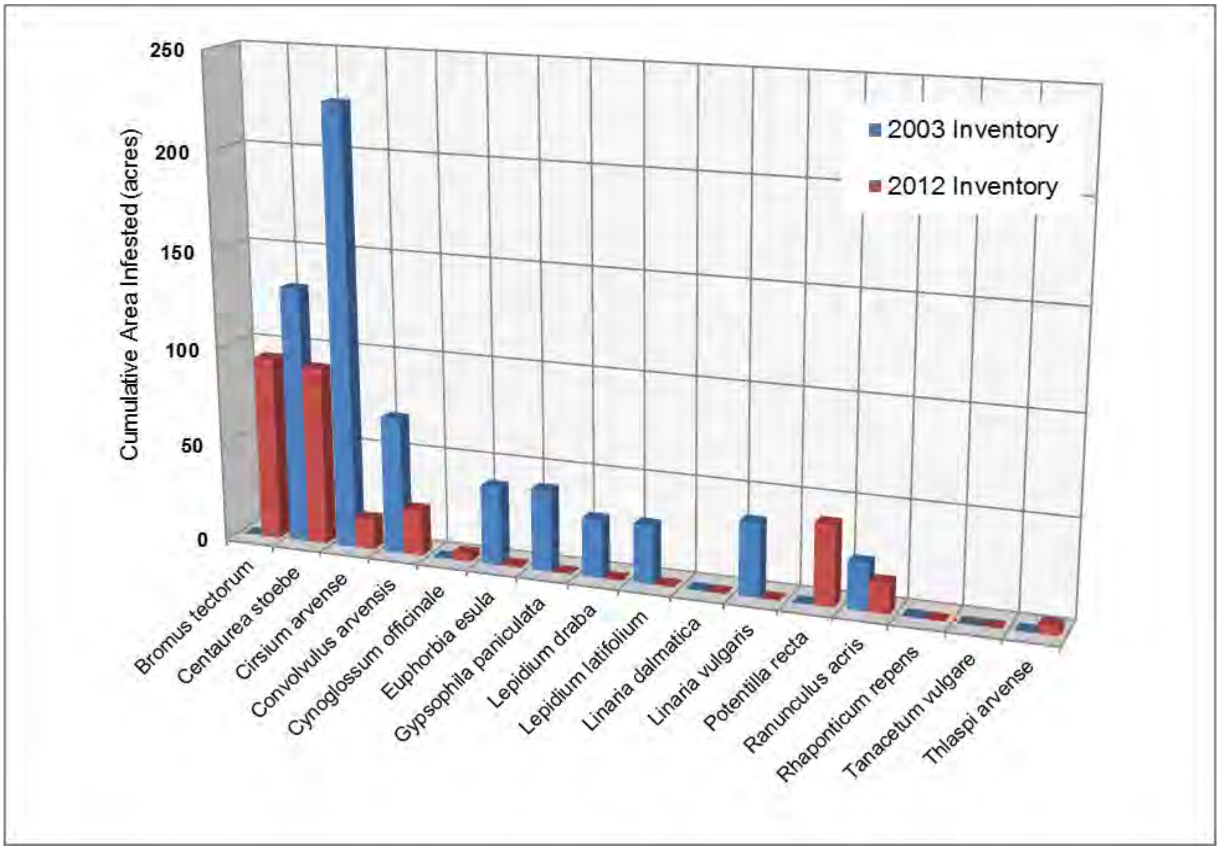


Figure E-3. Comparison of cumulative areas for non-native invasive species identified during field surveys (Wood and Rew 2005, NPS 2012, Krogstad and Kamerman 2013). Results from the 2013 survey are not included because direct comparisons may be inaccurate due to differences in methodology.

Table E-3. Composition of non-native invasive plant species identified during 2003 and 2012 field inventories (Wood and Rew 2005, NPS 2012).

	Cumulative Area Infested hectares (acres)		Number of Observed Infestations	
Species	**2003**	**2012**	**2003**	**2012**
Bromus tectorum	--	38.31 (94.67)	--	49
Centaurea stoebe	53.37 (131.87)	37.12 (91.72)	219	71
Cirsium arvense	91.54 (226.19)	6.45 (15.93)	100	78
Convolvulus arvensis	28.34 (70.04)	9.60 (23.73)	34	15
Cynoglossum officinale	0.08 (0.19)	1.58 (3.90)	16	5
Euphorbia esula	16.35 (40.40)	0.33 (0.82)	26	31
Gypsophila paniculata	16.88 (41.71)	0.05 (0.12)	70	5
Lepidium draba	12.02 (29.69)	0.12 (0.30)	60	61
Lepidium latifolium	12.14 (30.00)	0.18 (0.44)	56	48
Linaria dalmatica	--	< 0.005 (<0.01)	--	1
Linaria vulgaris	15.21 (37.58)	0.06 (0.14)	38	18
Potentilla recta	--	16.66 (41.18)	--	19
Ranunculus acris	9.68 (23.93)	6.26 (15.46)	5	7
Rhaponticum repens	0.06 (0.16)	0.02 (0.04)	4	1
Tanacetum vulgare	0.01 (0.03)	< 0.005 (<0.01)	8	3
Thlaspi arvense	--	1.92 (4.75)	--	65
Totals	**255.68 (631.79)**	**118.66 (293.21)**	**636**	**477**

Table E-4. Distribution of non-native invasive species identified during 2003 and 2012 field inventories (Wood and Rew 2005, NPS 2012).

	Percent Cumulative Area Infested		Percent Observed Infestations	
Species	**2003**	**2012**	**2003**	**2012**
Bromus tectorum	--	32.3%	--	10.3%
Centaurea stoebe	20.9%	31.3%	34.4	14.9%
Cirsium arvense	35.8%	5.4%	15.7	16.4%
Convolvulus arvensis	11.1%	8.1%	5.3%	3.1%
Cynoglossum officinale	< 0.1%	1.3%	2.5%	1.0%
Euphorbia esula	6.4%	0.3%	4.1%	6.5%
Gypsophila paniculata	6.6%	< 0.1%	11.0	1.0%
Lepidium draba	4.7%	0.1%	9.4%	12.8%
Lepidium latifolium	4.7%	0.1%	8.8%	10.1%
Linaria dalmatica	--	< 0.1%	--	0.2%
Linaria vulgaris	5.9%	< 0.1%	6.0%	3.8%
Potentilla recta	--	14.0%	--	4.0%
Ranunculus acris	3.8%	5.3%	0.8%	1.5%
Rhaponticum repens	< 0.1%	< 0.1%	0.6%	0.2%
Tanacetum vulgare	< 0.1%	< 0.1%	1.3%	0.6%
Thlaspi arvense	--	1.6%	--	13.6%
2013 Totals	**~340 (~840)**	**18.7 (46.3)**	**4.6**	**338.9 (837.5)**

Table E-5. Summary of 2013 non-native invasive plant survey results (Krogstad and Kamerman 2013).

Species	Cumulative Area Infested hectares (acres)	Number of Observed Infestations	Percent Cumulative Area Infested	Percent Observed Infestations
Centaurea stoebe	2.08 (5.13)	129	11.1%	11.8%
Cirsium arvense	2.24 (5.53)	129	11.9%	11.8%
Convolvulus arvensis	1.72 (4.25)	24	9.2%	2.2%
Cynoglossum officinale	< 0.005 (<0.01)	4	< 0.1%	0.4%
Euphorbia esula	5.74 (14.18)	154	30.6%	14.1%
Gypsophila paniculata	0.67 (1.66)	46	3.6%	4.2%
Lepidium draba	2.57 (6.34)	242	13.7%	22.1%
Lepidium latifolium	1.48 (3.66)	175	7.9%	16.0%
Linaria vulgaris	0.49 (1.22)	76	2.6%	6.9%
Potentilla recta	< 0.005 (<0.01)	1	< 0.1%	< 0.1%
Ranunculus acris	1.76 (4.35)	114	9.4%	10.4%
Totals	**18.75 (46.32)**	**1094**	**---**	**---**

Cheatgrass (*Bromus tectorum*)

Montana does not list cheatgrass as a noxious weed, but the state has identified it as a Priority 3, regulated plant (MSU 2014). Plants with this designation have the potential to have significant negative impacts. While control of these species is not mandated, research, education, prevention, and control programs are recommended to minimize spread (MSU 2014).

Cheatgrass plants range from 15 to 61 cm (6 to 24 in) tall (Menalled et al. 2012). In early growth stages, leaves are brownish-green while at maturity the plant is red-brown in color and has erect, slender stems (Menalled et al. 2012). Leaf sheaths are flat, twisted blades with long, narrow leaves, and small soft hairs cover the entire plant (Menalled et al. 2012, Montana Weed Control Association 2014). At maturity, cheatgrass has purple colored branched clusters of seed heads and slender extensions (awns) on the seeds (Montana Weed Control Association 2014). The awns stick to clothing and the hair and fur of animals, one of the vectors the plant utilizes for seed dispersal (Menalled et al. 2012). Cheatgrass is a prolific seed producer, with seeds remaining viable for two to three years (Menalled et al. 2012). Cheatgrass is extremely adaptable and can be found growing on all exposures and all types of topography (Montana Weed Control Association 2014). It infests heavily grazed rangeland, roadsides, burned areas and other disturbed areas quickly (Montana Weed Control Association 2014). It can also invade undisturbed areas and out-compete native vegetation (Montana Weed Control Association 2014).

The field survey conducted by Wood and Rew (2005) in 2003 did not include cheatgrass as a target species and therefore no occurrences of the species were mapped. During the 2012 survey it accounted for nearly a third of the cumulative infested area mapped (NPS 2012). Forty-nine patches of cheatgrass covering nearly 38 ha (95 ac) were mapped (Table E-3). The majority of the infestations were found west of the Clark Fork River (Figure E-4). Seven patches were 0.4 ha (1 ac) or larger (NPS 2012). The largest of these patches, approximately 10.5 ha (26 ac), was located in pastureland (Upper Northwest Range). Another patch of approximately 6.5 ha (16 ac) was also located in this pasture. A large infestation, covering approximately 10 ha (25 ac) was also found in the railroad remnant area. The remaining large patches were located in pastureland; a 4.3 ha (10.6 ac) patch in River Ridge Road, 5.5 ha (13.5 ac) and 0.6 ha (1.5 ac) patches in Gravel Pit Range, a 0.4 ha (1 ac) patch in Taylor Ridge Range and 1,214 m^2 (0.3 ac) and 1,618 m^2 (0.4 ac) patches in VC North and South (NPS 2012). The remaining 40 patches were mapped as point infestations, and with the exception of one (along west side road), all were less than 405 m^2 (0.1 ac). This patch in the upland area along the west side road was measured at just over 405 m^2 (0.1 ac) (NPS 2012). The other patches were found in a mixture of pasture and hayland, and one was found along Taylor Creek (NPS 2012). The 2013 field efforts did not survey for cheatgrass, so no infestations were mapped (Krogstad and Kamerman 2013).

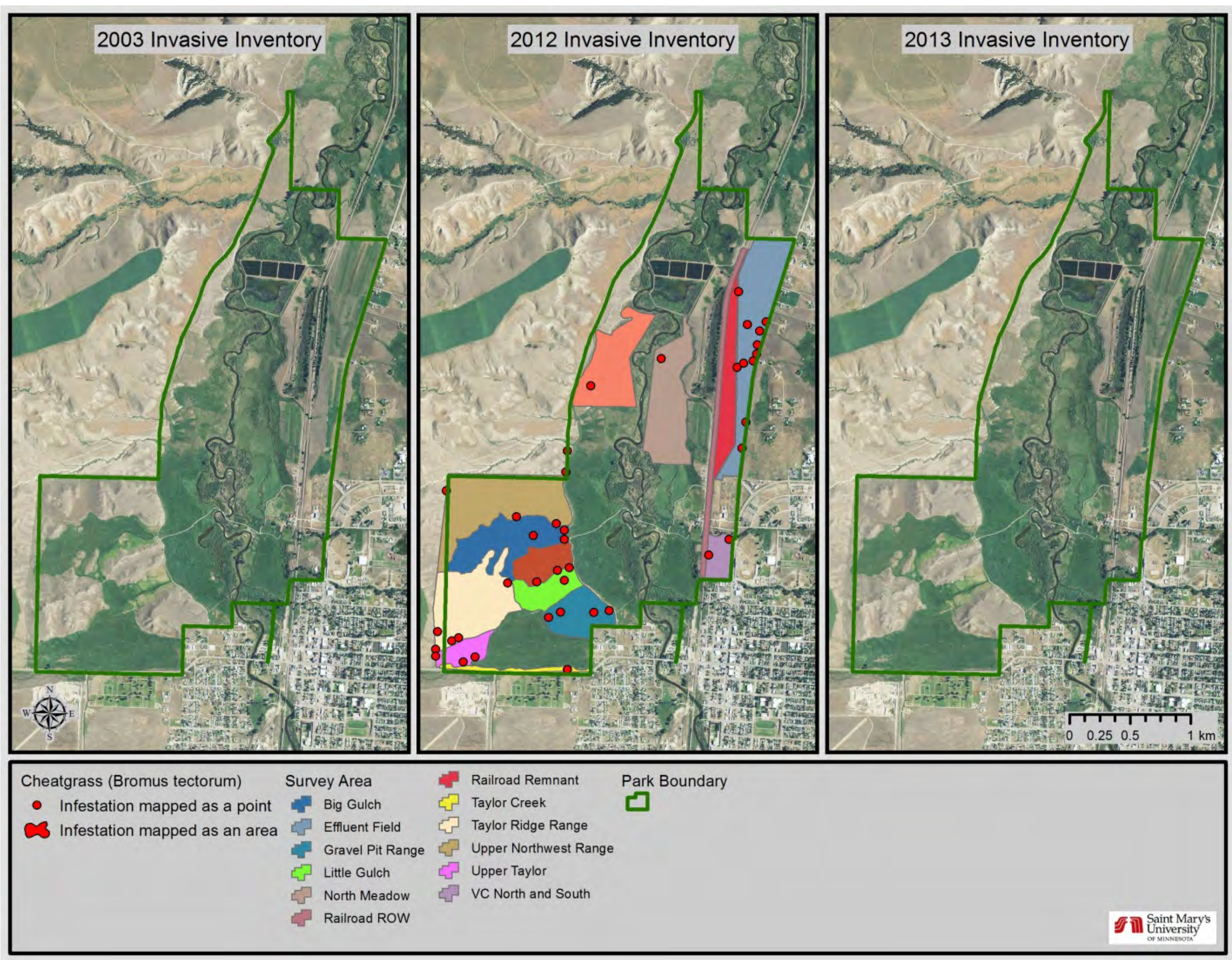


Figure E-4. Location of cheatgrass infestations found during the three field surveys. Note that the 2013 field efforts did not survey for cheatgrass, so no infestations were mapped.

<u>Spotted knapweed (*Centaurea stoebe*)</u>

Montana classifies spotted knapweed as a noxious weed (MDA 2013). The state has designated it as a Priority 2B species (MDA 2013). Control of 2B species requires eradication or containment of existing infestations coupled with education and prevention measures (MSU 2014).

Spotted knapweed is a short-lived perennial species that can grow as tall as 1.2 m (4 ft) in height (Montana Weed Control Association 2014). It has slender, many-branched stems with a single flower at the end of each branch (Duncan et al. 2011). Stems and leaves are normally blue-green in color (Montana Weed Control Association 2014). The flowers are normally a pinkish-purple, but can also be light purple or white. The flower heads are surround by bracts (small leaf-like structures) that give a "spotted" appearance to the flower head (Duncan et al. 2011). Spotted knapweed is a prolific seed producer, with one plant producing up to 300 flower heads and up to 140,000 seeds (Montana Weed Control Association 2014). Spotted knapweed prefers disturbed areas with sunny arid conditions in coarse soils. It is most often found in sunny areas with well drained or gravel/sandy soils (Montana Weed Control Association 2014). It is highly adaptable and shade tolerant, allowing it to grow in both moist and dry conditions (Montana Weed Control Association 2014).

Spotted knapweed was one of the most abundant non-native invasive plants mapped at GRKO during all three field surveys (Table E-4). In the 2003 survey, only Canada thistle was mapped in greater numbers or cumulative area (Table E-3). A total of 219 instances were mapped in 2003 (Figure 5). Of this total, the vast majority were mapped as point features (201) ranging in size from a single plant to 0.6 ha (1.5 ac) (Wood and Rew 2005). Eighteen instances were mapped as polygon features, all but two being less than 2.8 ha (7 ac) (Wood and Rew 2005). The Burlington Northern railroad and right-of-way was infested through the length of the ranch, covering nearly 14.9 ha (36.8 ac) (Wood and Rew 2005). The other large area, totaling 8.6 ha (21.2 ac), was located in the Railroad Remnant and KM Flats (Wood and Rew 2005). Due to their particularly dense nature, some of the areas in the Railroad Remnant and KM Flats area were also mapped as point features. Other areas with significant numbers of small infestations mapped as point features included the Gravel Pit Range, Ridge Road Range, Taylor Ridge Range, Upper Northwest Range, Upper Taylor Field, and the VC North and South Fields. A number of infestations were found in the riparian area, generally close to the river along gravel bars (Wood and Rew 2005).

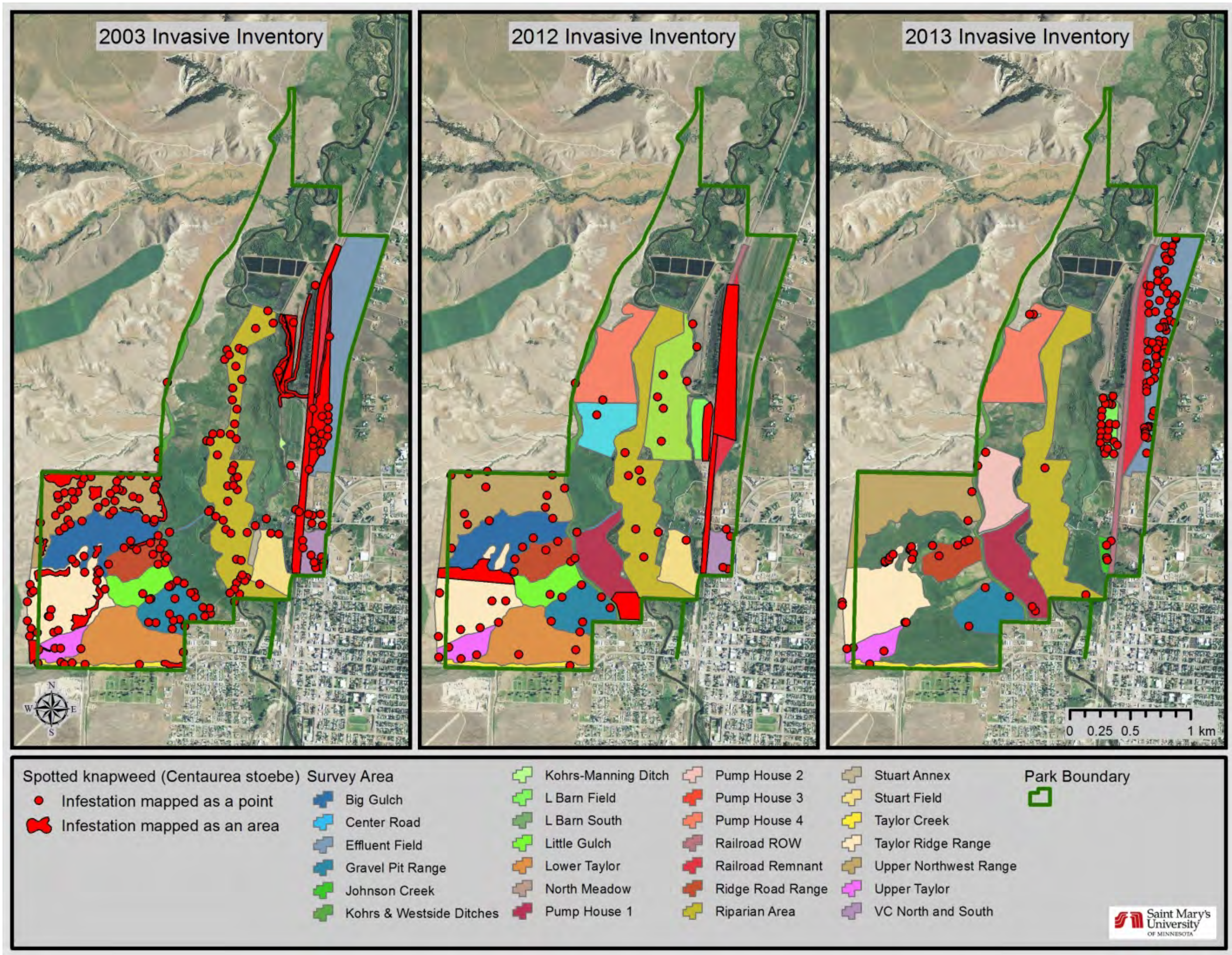


Figure E-5. Location of spotted knapweed infestations found during the three field surveys.

Results of the 2012 survey showed significant declines in both the number of spotted knapweed infestations mapped and in cumulative area infested (Table E-3). As was the case in 2003, it was still the second most abundant invasive plant mapped. A total of 71 infestations were mapped during the 2012 survey (NPS 2012). The majority of these were small patches mapped as point features (66), all of which were less than 405 m^2 (0.1 ac) with one exception, a 1,618 m^2 (0.4 ac) infestation on a hillside in the Taylor Ridge Range (NPS 2012). As can been seen in Figure E-5, the point infestations mapped in 2012 were basically in the same locations as in 2003, but the number of infestations had been reduced. However, a few new infestations were found, mostly in the North Meadows Field (NPS 2012). The large KM Flat infestation found in 2003 had been reduced to three smaller point infestations (Figure E-5). The railroad and railroad right-of-way remained infested throughout the ranch. While the overall cumulative area infested in this area remained relatively unchanged from the 2003 survey, the denser patches that had been separately delineated as points in 2003 had been reduced enough by 2012 to not warrant a separate point delineation (NPS 2012). The infestations in the northern portion of the Taylor Ridge Range (Figure E-5) that were mapped as a 1.4 ha (3.4 ac) polygon along with a few small point infestations in 2003, was mapped as a single polygon infestation of approximately 6.7 ha (16.5 ac) (NPS 2012). Additionally, two new polygon infestations were mapped in the Pump House 1 (4.6 ha [11.4 ac]) and L Barn Field 93.1 ha [7.7 ac]), areas that were not present in 2003 (NPS 2012).

In the 2013 field survey, spotted knapweed was still one of the more abundant invasive species found (Table E-5). The number of infestations increased from 2012 levels (perhaps due to a longer survey period) but the cumulative area infested was reduced (Krogstad and Kamerman 2013). The large infestations that had been previously mapped as polygons were reduced to only a few infestations that were mapped as points. The railroad and railroad right-of-way showed no signs of spotted knapweed (Figure E-5). The increase in the number of point infestations mainly was the result of new detections in the Effluent Fields and the fact that the polygon infestation in the L Barn Field had been replaced by a large number of point infestations (Krogstad and Kamerman 2013).

Canada thistle (*Cirsium arvense*)

Montana lists Canada thistle as a noxious weed (MDA 2013). The state has designated it as a Priority 2B species (MDA 2013), requiring eradication or containment of existing infestations coupled with education and prevention measures (MSU 2014).

Canada thistle can grow up to 1.2 m (4 ft) tall and develops a deep and extensive root system. Leaves are lance-shaped and deeply loped, with yellowish spines on the edges. Its flowers resemble spotted knapweed in that they are pink to purple in color. Plants produce both male and female flowers, with the male flower heads resembling globes while the female flowers are flask-shaped. Each female flower produces a single seed with a papery cover that is easily dispersed by wind. Both male and female flowers must be present for the plant to go to seed. A single plant can produce over 3,000 seeds annually. Canada thistle reproduces by seed dispersal, but spreads primarily through horizontal roots (Montana Weed Control Association 2014). Canada thistle is generally found in open areas with moderate moisture. It often invades areas where water levels fluctuate, such as stream banks or irrigation ditches. It is also commonly found in fallow fields, abandoned lots, pastures, road ditches and right-of-ways, railway embankments and right-of-ways, and abandoned gravel pits (Montana Weed Control Association 2014).

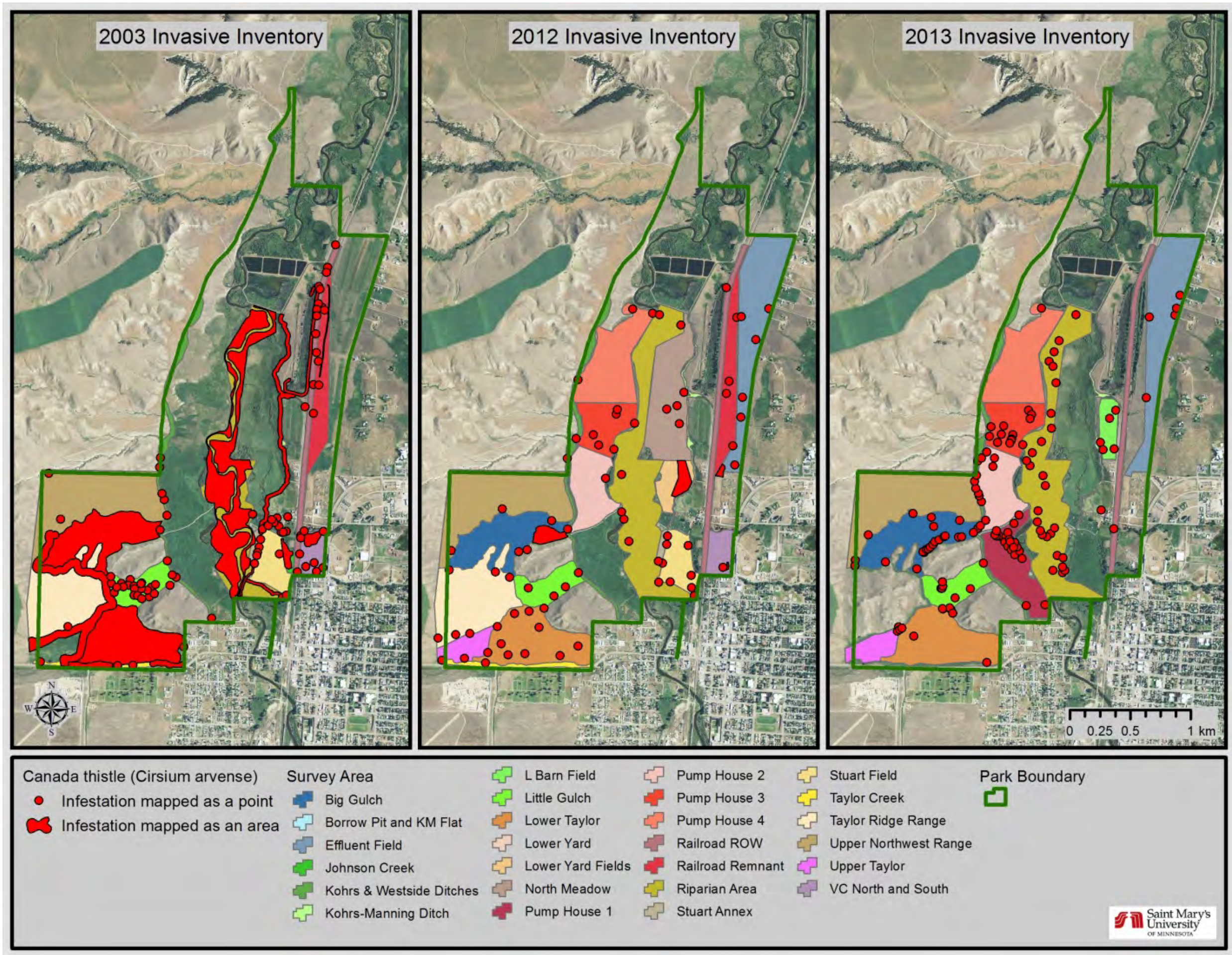


Figure E-6. Location of Canada thistle infestations found during the three field surveys.

Canada thistle was the most abundant non-native invasive plant mapped at GRKO in 2003, both in cumulative area and number of mapped infestations (Wood and Rew 2005). In terms of infested area, it was nearly double the area infested by spotted knapweed with less than half the number of mapped infestations (Table E-3). It was found along irrigation ditches, creeks, and around the borrow pit wetland (Figure E-6). In all, 100 infestations were mapped covering 91.5 ha (226 ac) (Table E-3). The majority of these were mapped as point infestations, with 14 being large enough to be mapped as polygon features (Wood and Rew 2005). These larger infestations ranged in size from 0.4 – 23.5 ha (1 - 58 ac) (Wood and Rew 2005). The largest of these were located in the Lower Taylor Field (23.5 ha [58 ac]), the riparian area (20 ha [49.5 ac]), and along the Westside and Hartz irrigation ditches (15.9 ha [39.4 ac]) (Wood and Rew 2005). Other large infestations were found in Big Gulch (13.4 ha [33.2 ac]) and the Kohrs-Manning Ditch (9.7 ha [23.9 ac]) (Wood and Rew 2005). The infestations mapped as point features were primarily found along the Westside and Kohrs-Manning Ditches, the railroad right-of-way and railroad remnant area, Little Gulch, and VC North and South (Wood and Rew 2005).

The results of the 2012 field survey showed that while Canada thistle was still the most abundant invasive species in terms of number of infestations, it only accounted for approximately 5.5% of the total cumulative infested area (Table E-3; NPS 2012). This was a significant decline from infestations representing 36% of the total in the 2003 field survey (Table E-4). A total of 78 infestations were mapped in 2012, only four of which were mapped as polygon features, ranging in size from 0.12 ha – 2.8 ha (0.3 ac - 7 ac) (NPS 2012). The large infestations in Lower Taylor and the riparian areas had been reduced to a few point infestations (Figure E-6). The large infestation in Big Gulch had been reduced in size to a patch of 2.8 ha (7 ac) and a few point features (NPS 2012). One new infestation was mapped in the Lower Yards Field covering just under 2.8 ha (7 ac) (NPS 2012). The infestation along the Westside Ditch had been reduced to a few point infestation (NPS 2012). For the remaining infestations mapped as point features, reductions were seen in most areas, including the Kohrs-Manning Ditch, Little Gulch, VC North and South, the railroad and railroad right-of-way and the railroad remnant area. A few new infestations were mapped in 2012, primarily in the North Meadows, Pump House 3 and Effluent Field areas (Figure E-6).

During the 2013 field survey, all 129 infestations of Canada thistle were mapped as point features (Figure E-6). Canada thistle was still one of the more abundant invasive species mapped, comprising approximately 12% of both the cumulative area infested and number of infestations identified during the 2013 field survey (Table E-5). Only 20 of the mapped infestation were larger than 405 m^2 (0.1 ac). They ranged in size from 405 m^2 – 809 m^2 (0.1 ac - 0.2 ac) (Krogstad and Kamerman 2013). The infestations in the North Meadows, Lower Yards Fields, and VC North and South were not present in 2013. The number of infestations in Lower Taylor, Railroad Remnant, Stuart Field and Effluent Field were reduced. The 2013 survey also found an increase in the number of mapped observations in Big Gulch, Pump House 1, 2 and 3, L Barn Field and Westside Ditches (Krogstad and Kamerman 2013).

Field bindweed (*Convolvulus arvensis*)

Montana lists field bindweed as a noxious weed and has designated it as a Priority 2B species (MDA 2013). Control of 2B species requires eradication or containment of existing infestations coupled with education and prevention measures (MSU 2014).

Field bindweed is a perennial vine with an extensive root system that grows both laterally and vertically, creating a dense mat system beneath the soil surface. It grows along the ground until it encounters an obstacle to climb, where it will climb and form dense infestations. Its roots are cord-like and white and produce buds which form new shoots. Field bindweed has dark green smooth arrow-shaped leaves. Flowers are white and pink in color, bell-shaped and about 2.5 cm (1 in) in diameter. Field bindweed produces pear-shaped seeds, but reproduces primarily through its root system (Montana Weed Control Association 2014). Field bindweed can be found in most disturbed areas or disturbed habitats. It prefers sunny areas and uses its vine system to move into sunlight (Montana Weed Control Association 2014).

The 2003 field inventory identified 34 field bindweed infestations (Table E-3). This accounted for roughly 5% of the total number of infestations and 11% of the cumulative infested area (Table E-4). Thirty of these infestations were comprised of point features that were under 0.4 ha (1 ac) in size (Wood and Rew 2005). Only seven of these point infestations were greater than 405 m^2 (0.1 ac), ranging in size from 405 m^2 – 3,237 m^2 (0.1 ac - 0.8 ac) (Wood and Rew 2005). Four infestations were mapped as polygon features, ranging in size from 1.6 ha to 14.6 ha (4 ac to 36 ac) (Wood and

Rew 2005). Large areas of field bindweed infestation were found along the Westside Ditch (9.1 ha [22.5 ac]), Lower Taylor Field (14.7 ha [36.2 ac]) and Little Gulch (3.5 ha [8.6 ac]) (Figure 7). The smaller infestations mapped as point features were found in several areas, the majority being in the Kohrs and Westside Ditches, Upper Taylor Range, and Taylor Ridge Range areas (Wood and Rew 2005).

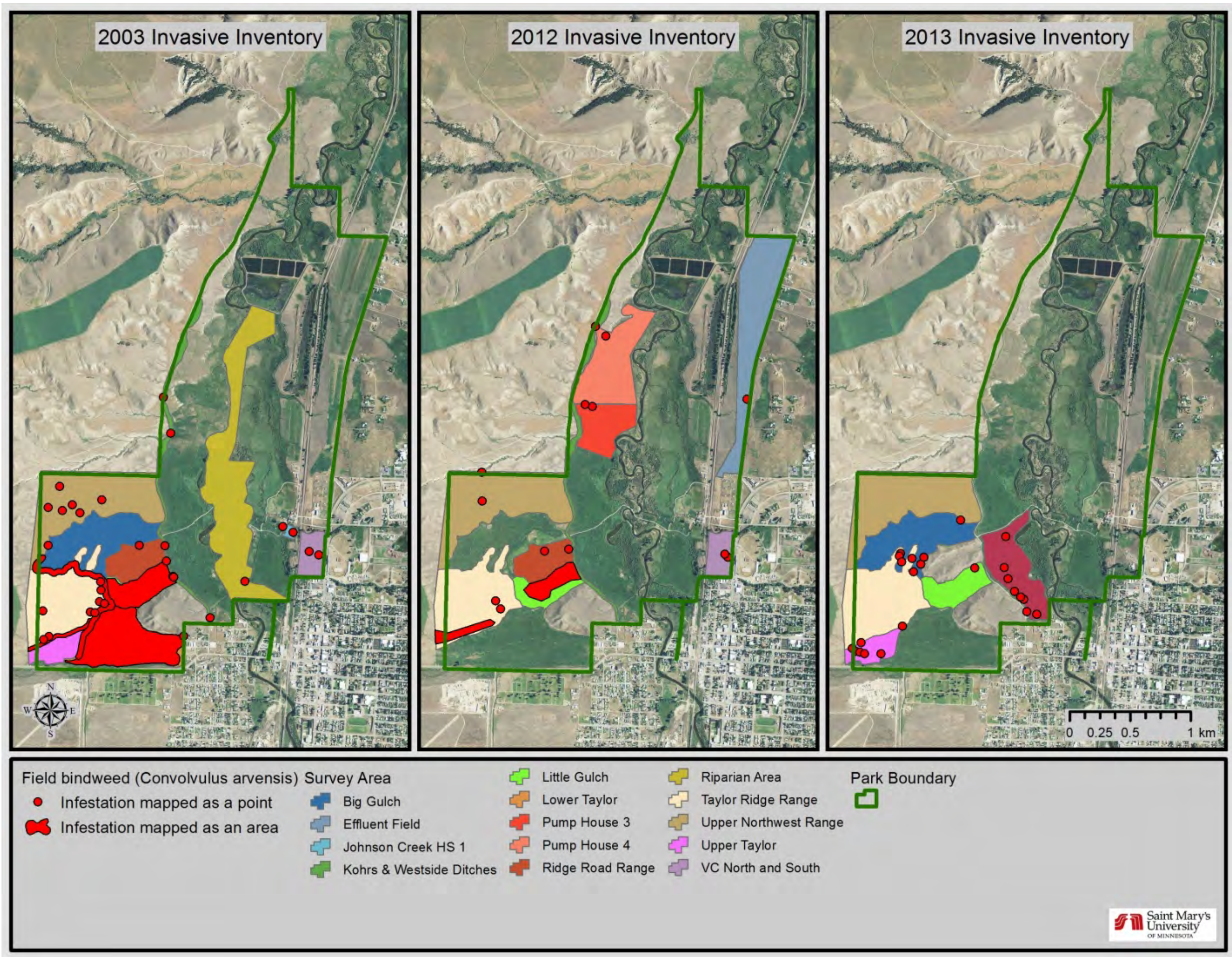


Figure E-7. Location of field bindweed infestations found during the three field surveys.

The results of the 2012 field survey showed a decline in both the number of infestations and the cumulative area infested (Table E-3). In 2012, field bindweed accounted for only 3% of the total number of infestations and 8% of the cumulative area infested on the ranch (Table E-4). Thirty-four infestations were identified with only two being large and dense enough to map as a polygon feature. One of the polygon infestations was in Little Gulch, where the 3.5 ha (8.6 ac) patch mapped in 2003 had expanded to 6.2 ha (15.4 ac) (NPS 2012). The other was a 3.3 ha (8.1 ac) patch in Taylor Ridge Range (NPS 2012). The infestation along the Westside Ditch was not present, nor was the large infestation in Lower Taylor (Figure E-7). All of the infestations mapped as point features, except one, were less than 40 m^2 (0.01 ac) (NPS 2012). The one larger point feature was 525 m^2 (0.13 ac) in size and located in the Taylor Ridge Range (NPS 2012). The location of the infestations mapped during 2012 was similar to 2003. New infestations were found in Pump House 3 and 4 and the Effluent Field (NPS 2012).

The 2013 survey showed a continued decline in the cumulative infested area but a slight increase in the number of infestations mapped. While field bindweed was on the lower end of the scale in terms of number of occurrences, it still was one of the more abundant non-native invasive species in terms of cumulative area infested (Table E-5). Twenty-four infestations were mapped in 2013, all as point features, ranging in size from 405 m^2 – 809 m^2 (0.1 ac - 0.2 ac) (Krogstad and Kamerman 2013). The point infestations mapped in 2012 in Ridge Road Range, Pump House 3 and 4, VC North and South, and Effluent Field were not present (Figure E-7). The large infestation in Little Gulch was reduced to a small patch of approximately 809 m^2 (0.2 ac) (Krogstad and Kamerman 2013). The 2013 inventory also identified infestations in Upper Taylor and Pump House 1, which were not present in the 2003 survey (Krogstad and Kamerman 2013).

Houndstongue (*Cynoglossum officinale*)

Montana has classified houndstongue as a noxious weed (MDA 2013). The state has designated it as a Priority 2B species (MDA 2013). Houndstongue is a biennial forb with a deep tap-root (Montana Weed Control Association 2014). In its first year it forms a basal rosette with broad oblong leaves up to 25.4 cm (1 ft) in length and 7.6 cm (3 in) wide. It forms stems in its second year and can grow up to 101 cm (4 ft) in height. It produces five-petaled reddish-purple flowers with four triangular rounded seeds. These seeds easily attach to animals, humans and vehicles (Montana Weed Control Association 2014). Houndstongue prefers well-drained, relatively sandy/gravelly soils. It is often found in disturbed areas such as trails, roadsides and abandoned cropland, rangeland, pastureland and riparian areas (Kedzie-Webb and Sheley 2009).

The 2003 field survey mapped 16 patches covering approximately 809 m^2 (0.2 ac) (Table E-3). It accounted for 2.5% of the total number of observations and less than 0.1% of the cumulative infested area (Table E-4). The majority of the houndstongue infestations were found close to the railroad right-of-way, railroad remnant area or Johnson Creek areas (Figure E-8). All houndstongue infestations were less than 405 m^2 (0.1 ac) (Wood and Rew 2005).

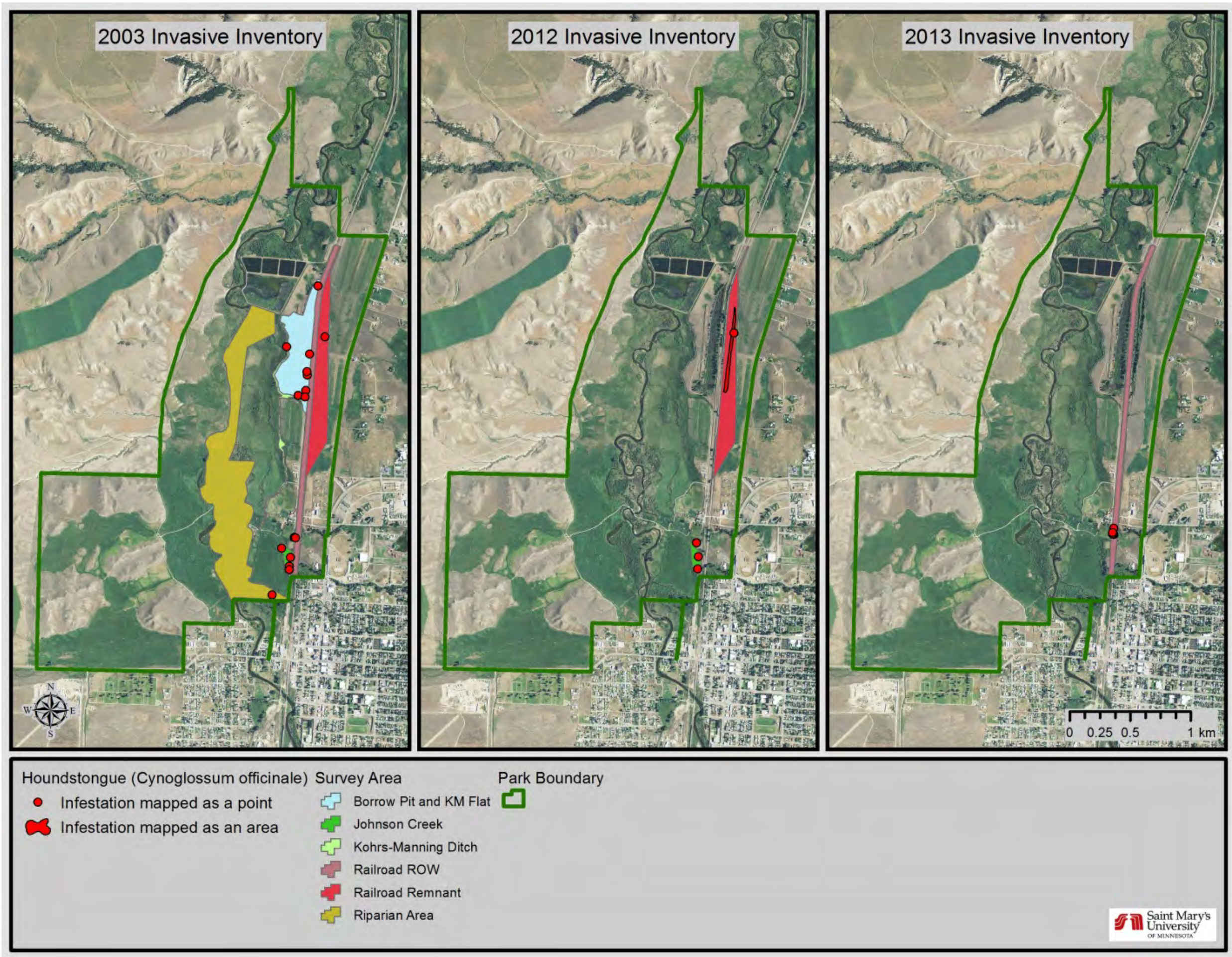


Figure E-8. Location of houndstongue infestations found during the three field surveys.

The 2012 field survey found only five infestations; however, the cumulative infested area increased from the 2003 level (Table E-3). This was due to the mapping of one large infestation of almost 1.6 ha (4 ac) in the railroad remnant area (NPS 2012). Four smaller patch infestations were mapped in the Johnson Creek area. All were less than 40 m^2 (0.01 ac) (Wood and Rew 2005). Of the locations where infestations were mapped in 2003, only those in the Johnson Creek and railroad remnant areas remained (Wood and Rew 2005).

The 2013 survey identified only four small infestations covering less than 40 m^2 (0.01 ac) (Table E-5). They were all located within the railroad right-of-way area (Figure E-8) and were not present in the 2012 survey (Krogstad and Kamerman 2013).

Leafy spurge (*Euphorbia esula*)

Montana lists leafy spurge as a noxious weed and has designated it as a Priority 2B species (MDA 2013), requiring eradication or containment of existing infestations coupled with education and prevention measures (MSU 2014).

Leafy spurge is a deep-rooted perennial that can grow up to 0.91 m (3 ft) in height (Montana Weed Control Association 2014). The leaves and stems of leafy spurge are bluish green and produce a yellow-green flower arranged in clusters of seven to ten. The roots have pink buds which develop into new shoots. The plant also produces seed capsules containing grayish-brown oblong seeds (Montana Weed Control Association 2014). Leafy spurge is a highly adaptable plant that grows in a variety of dry and moist habitats and in a variety of soil conditions (Goodwin et al. 2001, Montana Weed Control Association 2014). It is commonly found in abandoned cropland, pasture, rangeland, or along waterways or irrigation ditches (Goodwin et al. 2001, Montana Weed Control Association 2014).

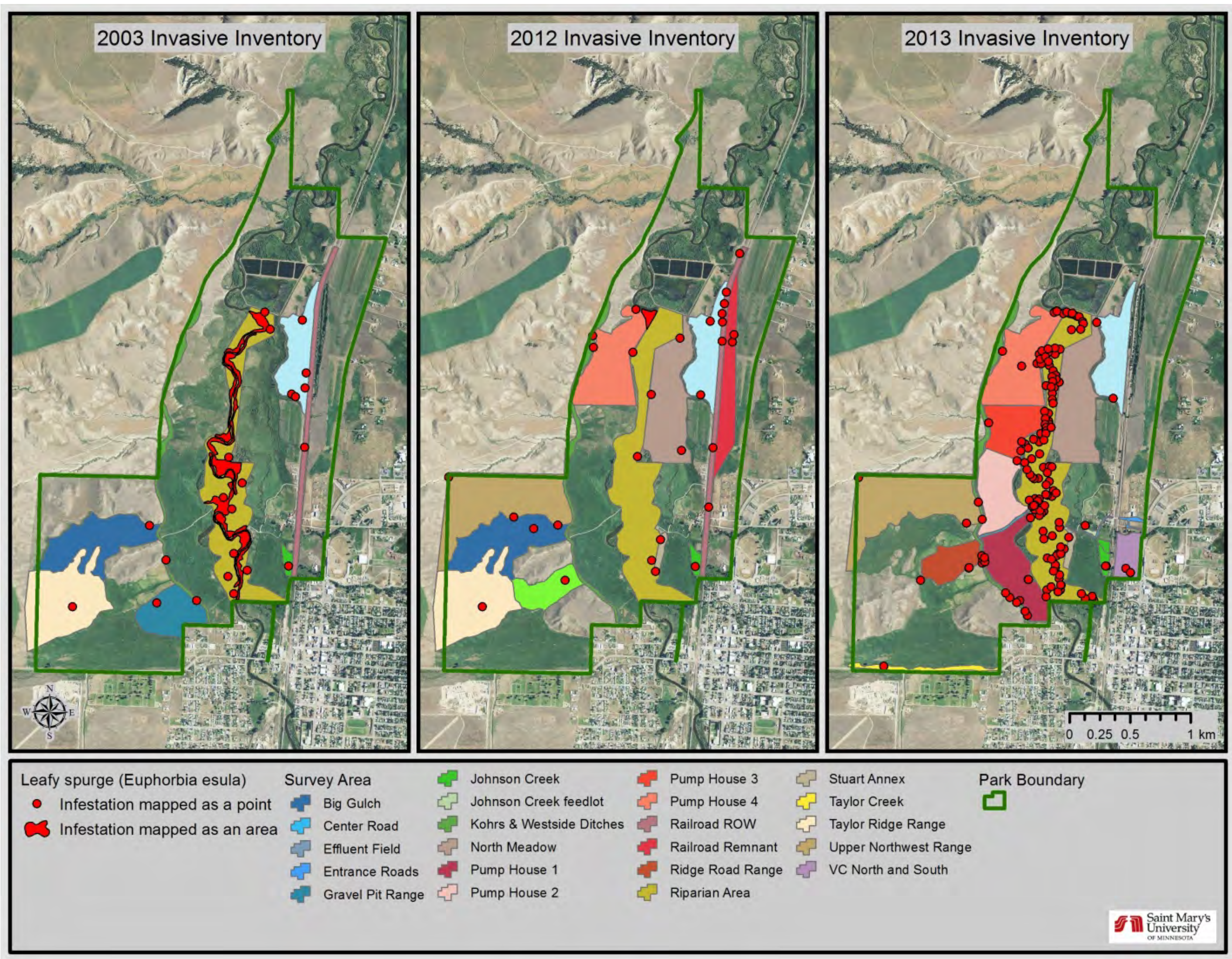


Figure E-9. Location of leafy spurge infestations found during the three field surveys.

During the 2003 field inventory, leafy spurge was abundant in the riparian area (Figure E-9). Four nearly contiguous polygons totaling just over 15.8 ha (39 ac) were mapped along the Clark Fork River (Wood and Rew 2005). Another ten infestations, totaling just under 0.4 ha (1 ac) were also mapped as small point features in this area (Wood and Rew 2005). In all, 99% of the 16.3 ha (40.4 ac) infested were found in the riparian area (Table E-3). Other leafy spurge infestations were mainly confined to the borrow pit, Johnson Creek, Gravel Pit Range, Taylor Ridge Range, Big Gulch and along the Westside road (Wood and Rew 2005). Five infestations, all under 40 m^2 (0.01 ac), were mapped in the borrow pit area (Wood and Rew 2005). Single infestations, also under 40 m^2 (0.01 ac), were mapped in the Johnson Creek, Gravel Pit Range, and Big Gulch (Figure E-9). Two slightly larger patches of 243 m^2 and 162 m^2 (0.06 ac and 0.04 ac) were mapped along the Westside road (Wood and Rew 2005). Another slightly larger infestation (607 m^2 [0.15 ac]) was located in the Taylor Ridge Range (Wood and Rew 2005).

The inventory conducted in 2012 showed a marked reduction in the area infested by leafy spurge, although the number of mapped infestations increased slightly (Table E-3). The inventory found less than 0.4 ha (1 ac) of GRKO infested with leafy spurge (NPS 2012). The infestation in the riparian area had been reduced to four small point infestations covering less than 60 m^2 (0.015 ac) (NPS 2012). The number of infestations in the borrow pit area had also been reduced from five to two small infestations (NPS 2012). The number of infestations in the Gravel Pit Range also had decreased from 2003 levels (NPS 2012). Figure E-9 shows that infestations were found in other areas of the ranch in 2012 where they were not present in 2003. In addition, some of the areas infested in 2003 showed an increase in number of infestations. In Big Gulch, the number of infestations increased from one to three, but the total area infested remained relatively unchanged at <40 m^2 (0.01 ac) (NPS 2012). The number of infestations also increased along the railroad tracks and in the railroad remnant area. This area went from having only one mapped instance in 2003 (<40m^2 [< 0.01 ac]) to ten infestations covering 202 m^2 (0.05 ac) in 2012 (NPS 2012). New infestations were mapped in the Upper Northwest Range, Little Gulch, North Meadows, Stuart Annex and Pump House 4 fields. The infestations in the Pump House 4 field included the only infestation mapped as a polygon in 2012, a 0.3 ha (0.7 ac) patch in the northeast corner of the field (NPS 2012).

The results of the 2013 survey found a greater number of infestations and a greater total area infested than in 2012 (Table 5). This was primarily from the increased number of infestations found in the riparian area. Although the 2013 survey mapped only point infestations, the pattern of infestation in the riparian area was very similar to that found during the 2003 survey (Figure E-9). Of the 154 infestations mapped in 2013, 72% (111) were in the riparian area. These infestations ranged in size from <40 m^2 to 809 m^2 (<0.01 ac to 0.2 ac) with 82 of these being greater than 40 m^2 (0.01 ac) (Krogstad and Kamerman 2013). Of the infestations greater than 40 m^2, 87% of those were between 405 m^2 and 809 m^2 (0.1 ac and 0.2 ac) (Krogstad and Kamerman 2013). Other significant changes included an increase in the number of infestations found in the Westside Ditch and in the Pump House 1, 2, and 3 fields (Krogstad and Kamerman 2013). A few areas showed a decrease in the number of infestations, including areas along the railroad tracks, and in North Meadows, Taylor Ridge Range, and Little Gulch. The 2013 survey also found infestations in VC North and South, Taylor Creek, Johnson Creek and Johnson Creek feedlot areas that had not been present in either of the previous surveys (Krogstad and Kamerman 2013).

Babysbreath (*Gypsophila paniculata*)

Although the State of Montana does not classify babysbreath as a noxious weed, it is on county noxious weed lists for neighboring Deer Lodge and Silver Bow counties (Wood and Rew 2005). It was included in the survey as ranch managers were concerned about its spread on the ranch from a potential downwind source in the Deer Lodge cemetery, located south of the ranch (Wood and Rew 2005).

Babysbreath is a perennial herb with a deep penetrating root system. It has a smooth stem, with linear leaves that are opposite one another. Babysbreath has many branches and grows to almost 0.91 m (3 ft) in height. The plant develops flower buds in its third year, and then produces clusters of white flowers; it spreads primarily through seed production. Babysbreath is found in a variety of habitats, including roadsides, ditches, pasture and rangeland areas (British Columbia Ministry of Agriculture 2014).

The 2003 survey found babysbreath predominantly infesting the upland range sites (Figure E-10). Overall, nearly 17 ha (42 ac) were infested (Table E-3). The largest density of infestation was found in the Gravel Pit Range (Wood and Rew 2005). This density made it difficult to map unique patches, so the entire unit was mapped as a gross area and unique patches were mapped within this area when they had a higher than average canopy cover (Wood and Rew 2005). Within the gross area, one polygon with 30% canopy cover was mapped along the road at the south end of the range and extended up into the old gravel pit (Figure E-10). Seven additional infestations were mapped in the Gravel Pit Range, all but one 93,642 m^2 [0.9 ac]) were less than 80 m^2 (0.02 ac) (Wood and Rew 2005). The total area infested in the Gravel Pit Range was 4.4 ha (10.9 ac) (Wood and Rew 2005). The next largest infestation was found in the Taylor Ridge Range. Two large patches and 17 smaller point patches were mapped. The total area infested was approximately 10.9 ha (27 ac), with the two large patches accounting for 10.5 ha (26 ac) (Wood and Rew 2005). Additional smaller patch infestations were found in the Upper Northwest Range (1,214 m^2 [0.3 ac]), Ridge Road Range (0.4 ha [1 ac]) and Little Gulch (162 m^2 [0.04 ac]) (Wood and Rew 2005). Other infestations, comprised mainly of isolated individual plants, were found in the Taylor Creek, Lower Taylor, and Big Gulch areas, Westside Ditches, on a gravel bar in the riparian area, and two large plants next to the walkway from the Visitor Center to the Kohrs House (Wood and Rew 2005).

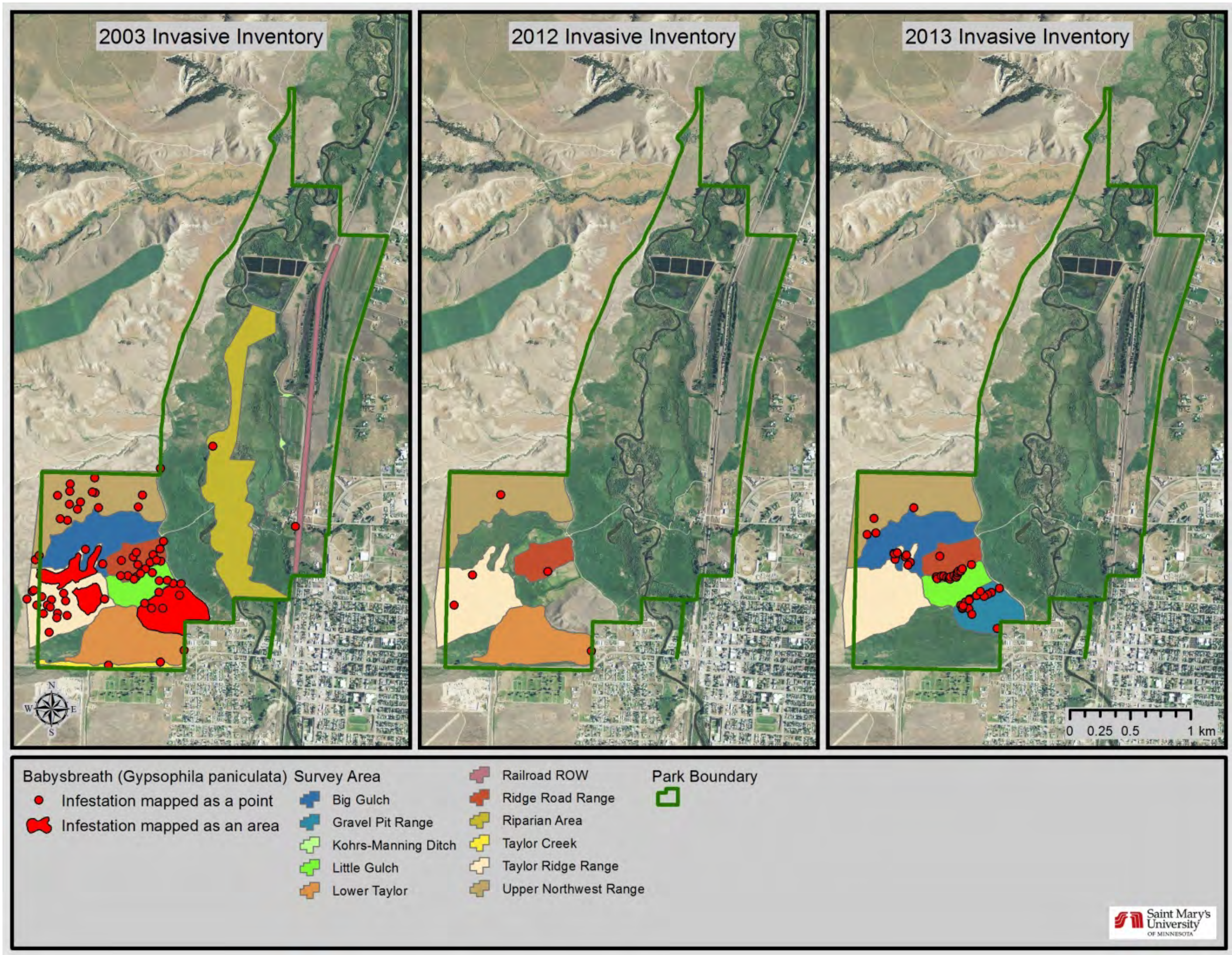


Figure E-10. Location of babysbreath infestations found during the three field surveys.

The survey conducted in 2012 showed a decline in the infestations of babysbreath in terms of numbers and total area (Table E-3). None of the large infestations found in 2003 were evident in the 2012 survey (Figure E-10). Five small patches were mapped, two in the Taylor Ridge Range, and one each in the Lower Taylor, Ridge Road Range and Upper Northwest Range (NPS 2012).

The 2013 survey showed both an increase in the number and total area of infestations from 2012 (Table E-5). However, it still was significantly below the original findings in 2003. The majority of the sightings (63%) were found in the Ridge Road Range and Gravel Pit Range (Krogstad and Kamerman 2013). The number of infestations had increased from one (<40 m^2 [0.01 ac]) to 13 (0.4 ha [1 ac]) in the Ridge Road Range. Sixteen new infestations, totaling 2,023 m^2 (0.5 ac), were found once again in the Gravel Pit Range (Krogstad and Kamerman 2013). The remaining infestations were found in Little Gulch, Upper Northwest Range, Big Gulch and Taylor Ridge Range and, with the exception of Little Gulch (809 m^2 [0.2 ac]), all were under 40 m^2 (0.01 ac) in area (Krogstad and Kamerman 2013).

Whitetop (*Lepidium draba*; formerly *Cardaria draba*)
The state of Montana lists whitetop as a noxious weed and has designated it as a Priority 2B species (MDA 2013). Whitetop is a perennial that can grow up to 0.6 m (2 ft) in height and has an extensive root system that deeply penetrates both laterally and vertically (Montana Weed Control Association 2014). It has basal and stem leaves covered with soft white hairs (Graves-Medeley et al. 2011). Flowers are white with four petals and form in clumps at the end of the stems. They have a flat-topped appearance and tend to turn cream colored as the plant matures. Seed capsules are flat, heart-shaped and contain two reddish-brown seeds in a pod. Whitetop can produce around 3,000 seeds annually, and reproduces by seed or by shoots from its roots (Montana Weed Control Association 2014). Whitetop prefers open unshaded areas with moist soils or areas of moderate rainfall (Montana Weed Control Association 2014). This tendency results in it being found in habitats such as irrigated cropland and pastures, ditches, or the edges of riparian areas. Undisturbed habitats, including excessively grazed areas, waste areas and open grasslands are also preferred habitats (Montana Weed Control Association 2014).

In the 2003 survey, most whitetop infestations were mapped in or near irrigated pastures or in developed/disturbed areas (Figure E-11). A total of 60 infestations covering approximately 12.1 ha (30 ac) (Table E-3) were identified during the field survey (Wood and Rew 2005). All but one of these patches were mapped as point features, and were less than 809 m^2 (0.2 ac) in size (Wood and Rew 2005). One large patch (11.3 ha [28 acres]) of whitetop was mapped along the southern edge of Lower Taylor Field (Wood and Rew 2005).

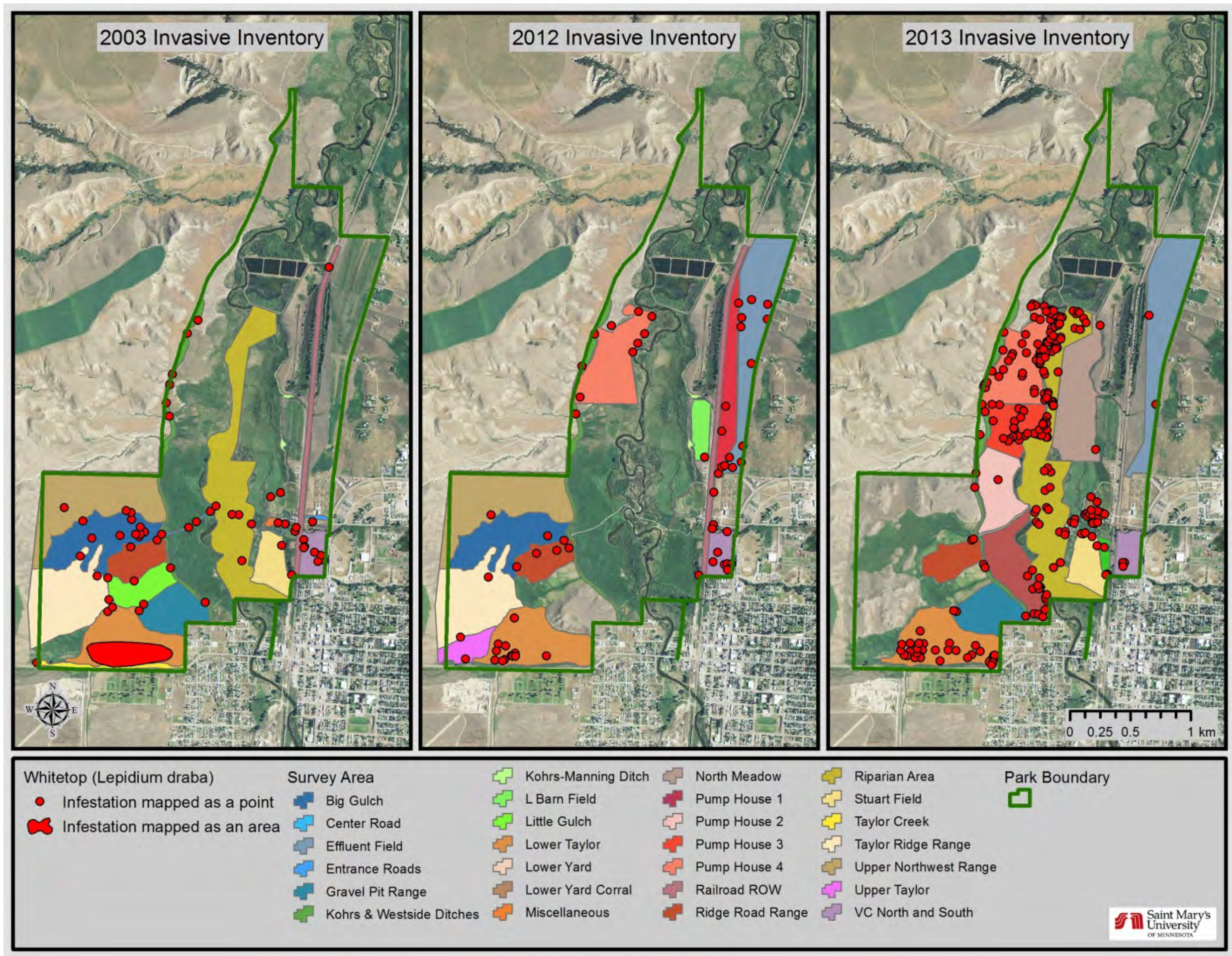


Figure E-11. Location of whitetop infestations found during the three field surveys.

The results of the 2012 field survey (Table E-3) show the number of mapped infestations remained basically the same as in 2003, but the area infested was reduced (NPS 2012). As was the case in 2003, the majority of the infestations were found in irrigated areas. The large patch found in Lower Taylor Field in 2003 was reduced to 10 small patches covering a total area of less than 405 m^2 (0.1 ac) (NPS 2012). The number of patches in Big Gulch and Little Gulch was reduced, but slightly increased in the Ridge Road Range (Figure E-11). Other notable changes in whitetop distribution were a decline in the number of infestations in the riparian area, and an increase in the number of patches in the Pump House 4 and Effluent Field areas.

The number of infestations mapped in 2013 was much higher than those observed in 2012. This is possibly due to the difference in the sampling protocol used in the 2013 survey. Whitetop was the most abundant non-native invasive species found, comprising 22% of all infestations, but only comprised 14% of the cumulative infested area (Table E-5). Only about a third of the infestations mapped in 2013 were larger than 405 m^2 (0.1 ac) (Krogstad and Kamerman 2013). The largest of these was approximately 3,238 m^2 (0.8 ac) while the rest ranged from 405 m^2 to 809 m^2 (0.1 to 0.2 ac) (Krogstad and Kamerman 2013). The cumulative area infested was also greater than in 2012, as would be expected due to the larger number of infestation mapped. The 2013 survey did show a reduction in the number of infestations in the Big Gulch, Little Gulch, Ridge Road Range, Taylor Ridge Range and Upper Northwest Range, Effluent Field and VC North and South area (Figure E-11). However, there was an increase in the number of infestations found in irrigated areas (Lower Taylor Field Pump House 1, 2, 3, and 4 Fields) and the riparian and Westside Ditch areas (Krogstad and Kamerman 2013).

Perennial pepperweed (*Lepidium latifolium*)

Montana classifies perennial pepperweed as a noxious weed (MDA 2013). The state has designated it as a Priority 2A species (MDA 2013). Control of 2A species requires eradication or containment of existing infestations where less abundant, with the management actions prioritized by local weed districts (MSU 2014).

Perennial pepperweed is a perennial that has multiple branching brittle stems and generally grows to 0.3 m - 0.9 m (1 - 3 ft) high but can reach heights of up to 2.4 m (8 ft) (Montana Weed Control Association 2014). The leaves of the plant are bright green to grayish-green in color, serrated and can be up to 0.3 m (1 ft) in length and 7.6 cm (3 in) wide, although the leaves tend to be less serrated as they extend from the stem (Montana Weed Control Association 2014). The plant produces small, white four-petaled flowers in dense clusters. Seeds are found in small flattened pods that contain two seeds each that are dropped at irregular intervals (Montana Weed Control Association 2014). The plant mainly spreads from its extensive brittle root systems, but also spreads as stems break off and scatter seeds (Montana Weed Control Association 2014). Perennial pepperweed prefers wet and sunny conditions, but is also adaptable to drier conditions (Montana Weed Control Association 2014). This flexibility allows it to occur in seasonally inundated areas, riparian areas, and stream and river banks as well as along roadsides, railroads. It is also commonly found in pastures and croplands (Montana Weed Control Association 2014).

The 2003 survey mapped 12 ha (30 ac) that were infested with perennial pepperweed (Table E-3). This included three large infestations that were located in the riparian area and along the Kohrs-Manning Ditch (Figure E-12). The two large infestations in the riparian area were approximately 3.6 ha (9 ac) and 1.8 ha (4.4 ac) in size (Wood and Rew 2005). An additional 24 point infestations were mapped covering 2,833 m^2 (0.7 ac) (Wood and Rew 2005). The third large infestation was found in the Kohrs-Manning Ditch and covered approximately 4.96 ha (12.25 ac) (Wood and Rew 2005). Also mapped in this area was one point infestation that covered approximately 1,011 m^2 (0.25 ac) (Wood and Rew 2005). These infestations comprised nearly 90% (10.8 ha) (26.7 ac) of the total area infested with perennial pepperweed (Wood and Rew 2005). Seven point infestations were found in the railroad right-of-way and railroad remnant areas, totaling just under 2,023 m^2 (0.5 ac) and six small patches were found in the borrow pit wetland, totaling 2,428 m^2 (0.6 ac) (Wood and Rew 2005). The remaining perennial pepperweed occurrences were found along Center Road, where approximately 0.5 ha (1.25 ac) were infested, and in the VC North and South area (1,214 m^2 [0.3 ac]) (Wood and Rew 2005). Perennial pepperweed was also found in Big Gulch, Stuart Field, Lower Yard Corral and Swamp, but these were very small infestations (less than 40 m^2 [0.01 ac]) (Wood and Rew 2005).

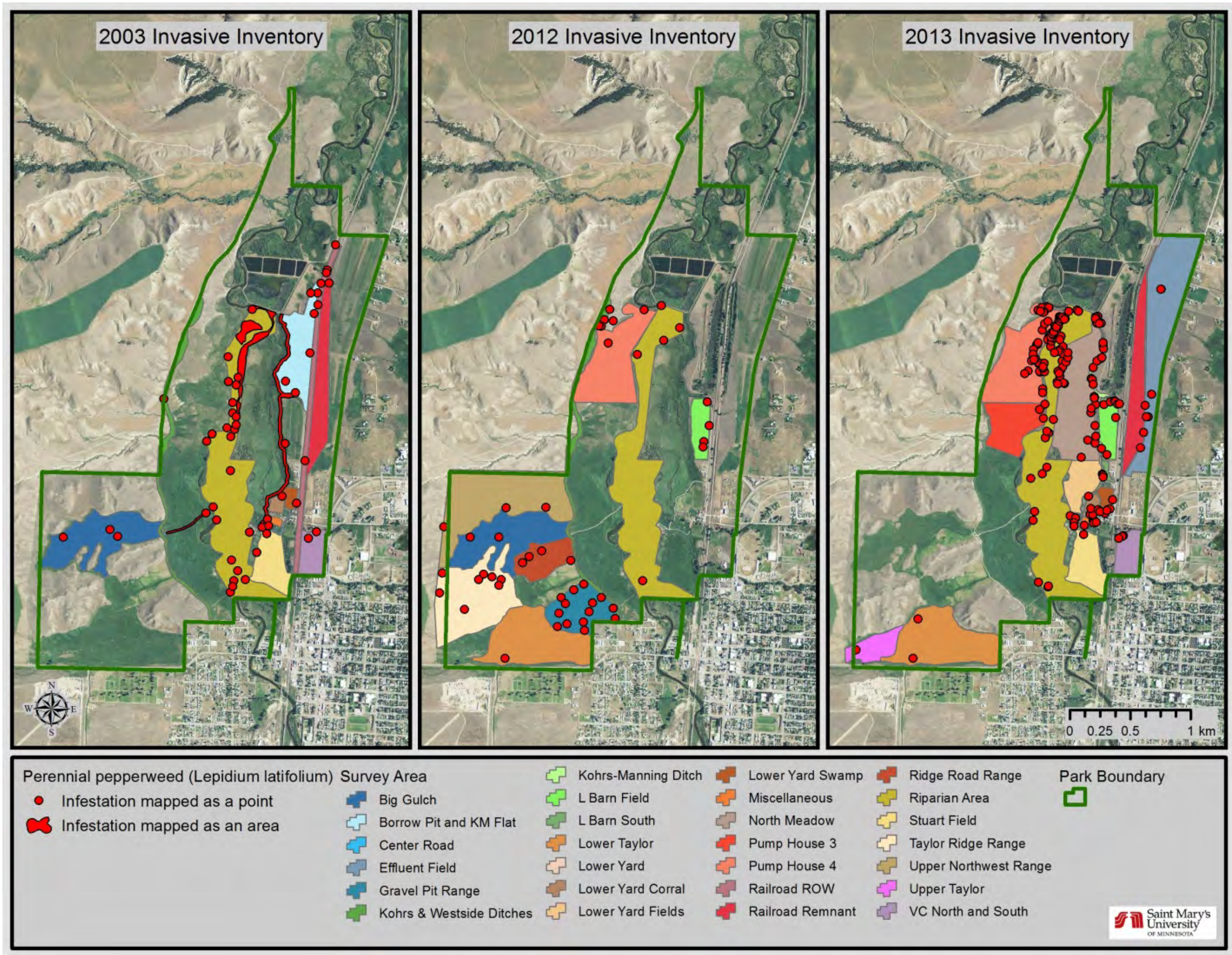


Figure E-12. Location of perennial pepperweed infestations found during the three field surveys.

The 2012 survey showed a small decrease in the number of mapped instances but the total area infested was considerably lower (Table E-3). The infestation in the riparian area had been reduced to only five small infestations covering >405 m^2 (0.1 ac) (NPS 2012). The infestations found in the Kohrs-Manning Ditch, Borrow Pit, railroad right-of-way and remnant areas, Stuart Field, Center Road, VC North and South, Lower Yard Corral and Lower Yard Swamp areas were not present in the 2012 survey (Figure E-12). One less infestation was found in Big Gulch than in 2003, but the total area infested was still less than 405 m^2 (0.1 ac) (NPS 2012). Most notable were infestations found in the Upper Northwest Range, Taylor Ridge Range, Ridge Road Range, Gravel Pit Range, Lower Taylor, Pump House 4, and L Barn Field areas that were not present in the 2003 survey (Figure E-12). Within Taylor Ridge Range, eight infestations were found covering approximately 809 m^2 (0.2 ac) (NPS 2012). Fourteen instances were mapped in the Gravel Pit Range covering 526 m^2 (0.13 ac), and the four instances found in the L Barn Field covered 405 m^2 (0.1 ac) (NPS 2012). All the other instances were very small (less than 40 m^2 [0.01 ac]) (NPS 2012).

The 2013 survey showed an increase in the number of infestations from 2012 (Table E-5). The area infested also rose slightly, but on average, it increased only about 40 m^2 (0.01 ac) per infestation. The majority of the infestations were found in the northern half of the ranch, similar to the 2003 survey (Figure E-12). The riparian area, North Meadows, and Pump House 4 had the majority of the infestations. Over 70%, or 1.1 ha (2.6 ac), of the total area infested was in these three areas (Krogstad and Kamerman 2013). The riparian area had 47 infestations covering 2,023 m^2 (0.5 ac), North Meadow had 21 covering 0.45 ha (1.1 ac), and Pump House 4 had 30 patches covering just over 0.44 ha (1 ac) (Krogstad and Kamerman 2013). The remaining infestations were primarily located in and around the L Barn Field, Lower Yard Corral and Swamp, VC North and South, and the Effluent Field.

Dalmatian toadflax (*Linaria dalmatica*)

Montana lists Dalmatian toadflax as a noxious weed and has designated it as a Priority 2B species (MDA 2013). Dalmatian toadflax is a short-live perennial herb that produces snapdragon-like yellow flowers (Jacobs and Sing 2006, Montana Weed Control Association 2014). It has a deep tap root, but also produces lateral roots that can extend out 3 m - 3.7 m (10 ft -12 ft) (Montana Weed Control Association 2014). It has a woody stem that can grow up to a height of 1.2 m (4 ft) (Montana Weed Control Association 2014). Seeds are produced in small capsules that contain small dark seeds with “papery” wings (Montana Weed Control Association 2014). Dalmatian toadflax spreads by both root and seeds, with the seeds being viable for up to ten years (Montana Weed Control Association 2014). It prefers full sunlight on coarse-textured well-drained soils, and is typically found in areas such as along roadsides, transitional forest-grassland areas, pastures and rangelands (Montana Weed Control Association 2014).

Dalmatian toadflax was not found during either the 2003 (not on the target species list) or 2013 field surveys, only in the 2012 survey (Figure E-13). The 2012 survey found one isolated plant in the Effluent Field (NPS 2012).

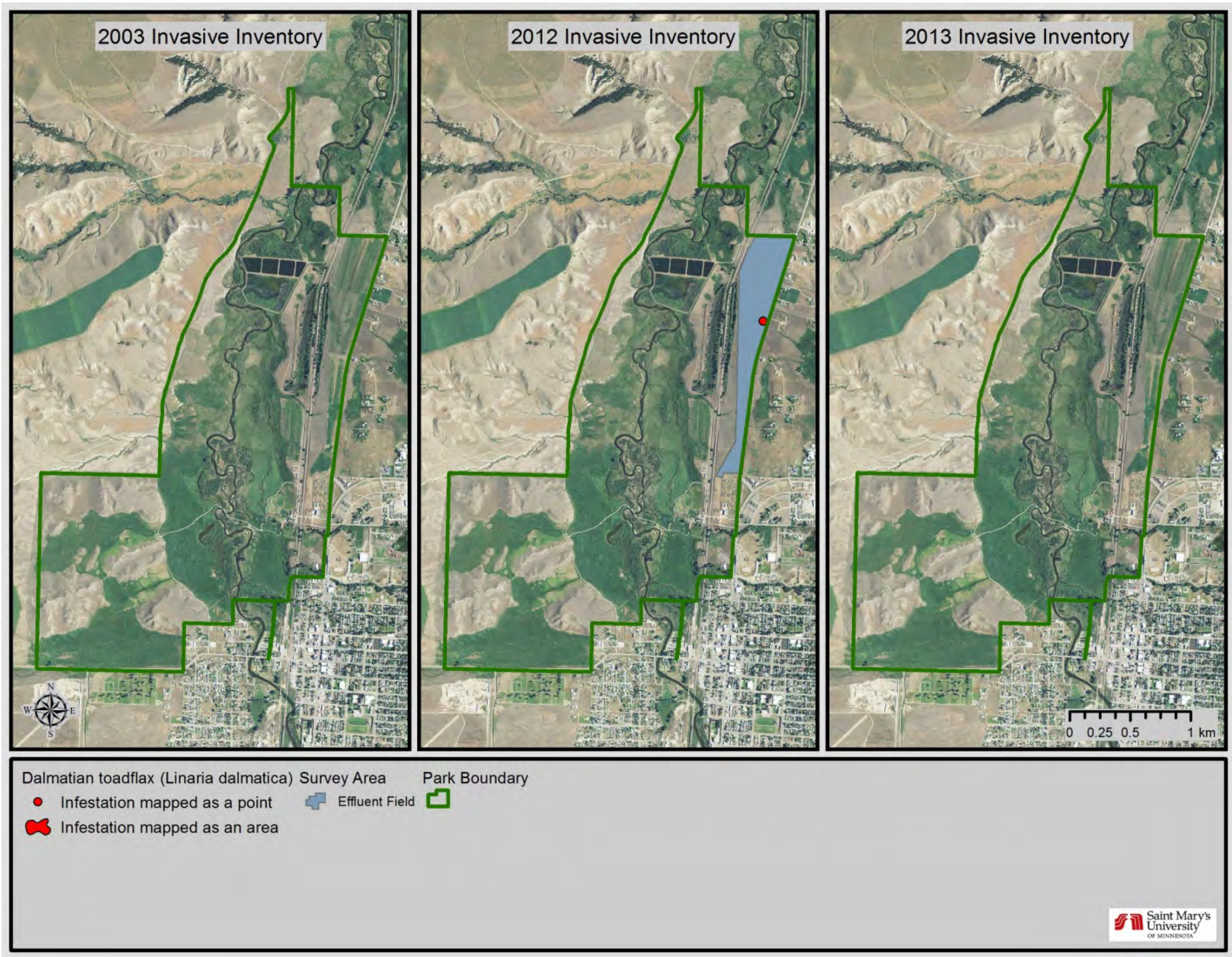


Figure E-13. Location of Dalmatian toadflax infestations found during the three field surveys. Note that Dalmation toadflax was not on the target species list for the 2003 survey.

Yellow toadflax (*Linaria vulgaris*)

The state of Montana classifies yellow toadflax as a noxious weed and has designated it as a Priority 2B species (MDA 2013), requiring eradication or containment of existing infestations coupled with education and prevention measures (MSU 2014).

Yellow toadflax is a perennial plant with an extensive horizontal root system, multiple stems and grows to a height of 0.3 m - 0.6 m (1ft - 2 ft) (Montana Weed Control Association 2014). Seedlings resemble leafy spurge, but do not produce the milky sap when broken (Montana Weed Control Association 2014). Yellow toadflax has numerous pale green to gray-green leaves, which are pointed at both ends, but have smooth margins (Montana Weed Control Association 2014). It produces snap-dragon like flowers in dense clusters of 15-20. These flowers are pale to bright yellow with a downward pointing yellow spur (Montana Weed Control Association 2014). It produces brown, oval seed capsules that are winged and contain several seeds. It can produce up to 30,000 seeds annually and reproduces by seed or through its root system (Montana Weed Control Association 2014). Yellow toadflax prefers well-drained sandy or gravel soils that remain somewhat moist (Montana

Weed Control Association 2014). It is commonly found in a variety of areas including rangeland and pastureland (Montana Weed Control Association 2014).

The 2003 survey found yellow toadflax mainly in the moister areas of the ranch, but was predominantly found in the riparian area (Figure E-14). In total, 38 infestations covering approximately 15.4 ha (38 ac) were mapped (Table E-3). Of these, 31 of them were found in the riparian area (Wood and Rew 2005). This included nine large clumped infestations, ranging from 0.4 ha - 4.5 ha (1 ac - 11 ac) in size (Wood and Rew 2005). This accounted for 98% of the total infested area (Wood and Rew 2005). The remaining occurrences were found in the borrow pit (4), railroad right-of-way (2) and VC North and South (1) (Wood and Rew 2005).

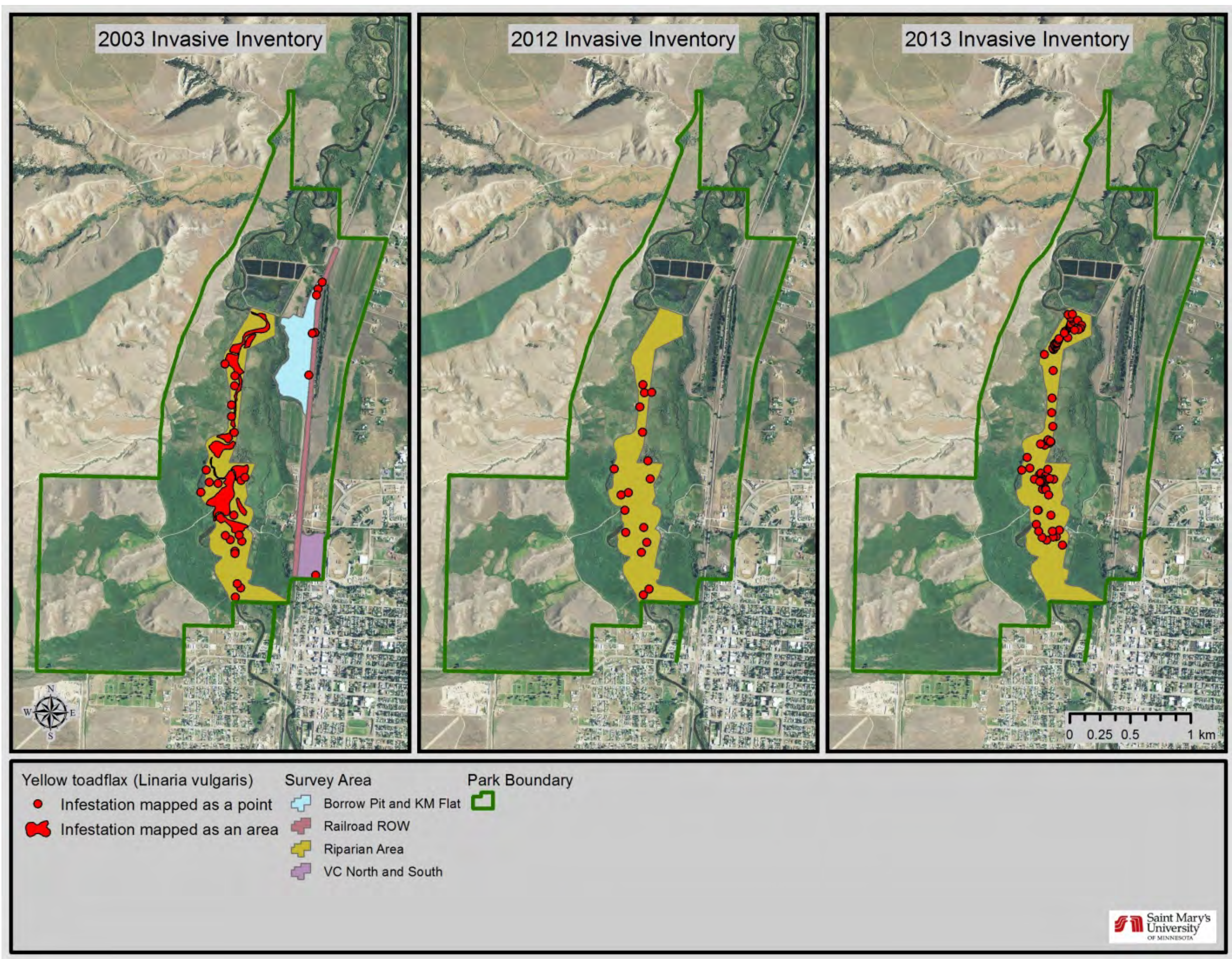


Figure E-14. Location of yellow toadflax infestations found during the three field surveys.

In 2012, the area infested with yellow toadflax was reduced to almost 405 m^2 (0.1 ac), although there were still quite a few instances found during the survey (Table E-3). All of the occurrences were found in the riparian area, but none of the large clumped infestations mapped in 2003 were present (Figure E-14). All the infestations were mapped as small patches and were less than 161.9 m^2 (0.04 ac) in size. Of the 18 infestations mapped, all but three were less than 40.5 m^2 (0.01 ac) in size (NPS 2012).

In 2013, the number of infestations and the total area infested both increased (Table E-5). As was the case in 2012, all the infestations were found in the riparian area (Figure E-14). There was considerable increase in the number of infestations mapped. These infestations were all quite small, but it still did show an increase in the total area infested (Krogstad and Kamerman 2013). Only four of the infestations mapped were larger than 405 m^2 (0.1 ac) (Krogstad and Kamerman 2013).

Sulphur cinquefoil (*Potentilla recta*)

Montana lists sulphur cinquefoil as a noxious weed and has designated it as a Priority 2B species (MDA 2013). Sulphur cinquefoil is a perennial forb with a single woody taproot, that grows up to 0.9 m (3 ft) in height (Montana Weed Control Association 2014). Its leaves are palmate with five to seven toothed leaflets (Montana Weed Control Association 2014). The leaves are 5 cm -10 cm (2 in - 4 in) long and are more numerous at the base of the plant (Montana Weed Control Association 2014). Its flowers have five yellow petals with notched tips and a darker yellow center (Montana Weed Control Association 2014). Sulphur cinquefoil produces comma-shaped dark brown seeds with narrow winged edges. It can spread either by seed or by its root system (Montana Weed Control Association 2014). It prefers full sunlight and has adapted to a wide variety of soil conditions. It is commonly found in grasslands and roadsides (Montana Weed Control Association 2014).

The original survey in 2003 did not identify any sulphur cinquefoil; however, it was found in both the 2012 and 2013 surveys (Table E-3). All of the infestations mapped in 2012 were less than 405 m^2 (0.1 ac) except for one large infestation in Lower Taylor (Figure E-15). This one infestation was approximately 16.6 ha (41 ac) in size, accounting for almost all of the total infested area (NPS 2012). Nine small infestations were found in the Lower Yard Fields. One occurrence was 40.5 m^2 (0.01 ac) in size and all the others were less than 40.5 m^2 (0.01 ac) (NPS 2012). Three instances were mapped in Pump House 4; two were less than 40.5 m^2 (0.01 ac) and the third was 121.4 m^2 (0.03 ac) in size (NPS 2012). Two instances were found in North Meadows, 364 m^2 and 202 m^2 (0.09 ac and 0.05 ac) in size respectively (NPS 2012). One instance each was found in the Effluent Fields, Stuart Field, Pump House 3 and the riparian area. All of these were less than 40.5 m^2 (0.01 ac) in size, except for the infestation found in Pump House 3, which was 81 m^2 (0.02 ac) in size (NPS 2012).

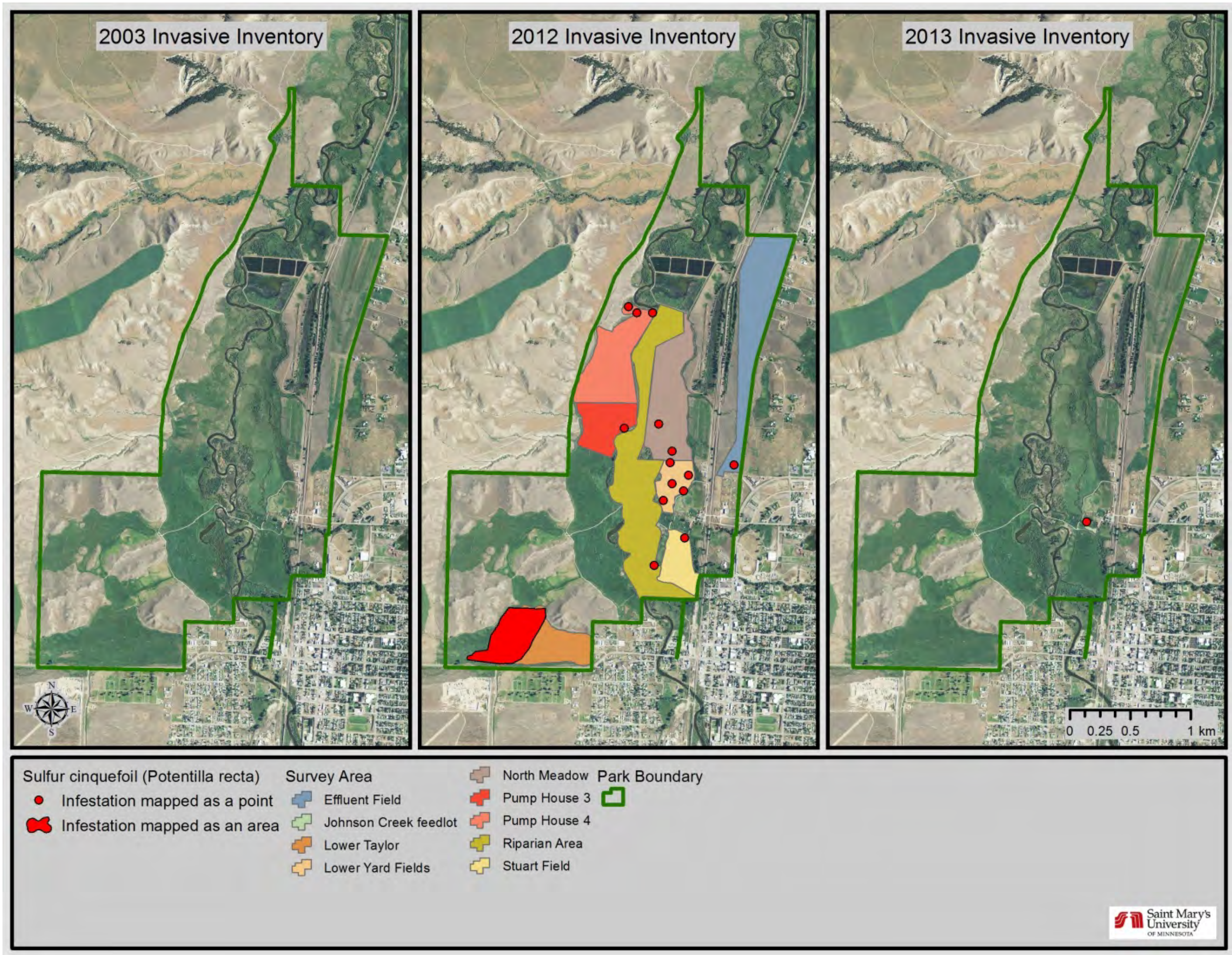


Figure E-15. Location of sulphur cinquefoil infestations found during the three field surveys.

The 2013 survey did not find and of the infestations mapped in 2012 (Figure E-15). Only one small occurrence (> 40.5 m^2) (> 0.01 ac) near the Johnson Creek feedlot was mapped during the survey (Krogstad and Kamerman 2013).

Tall buttercup (*Ranunculus acris*)

The state of Montana lists tall buttercup as a noxious weed (MDA 2013). It has been designated as a Priority 2A species (MDA 2013). Control of 2A species requires eradication or containment of existing infestations where less abundant with the management actions prioritized by local weed districts (MSU 2014).

Tall buttercup is a perennial with 0.3-0.9 m (1-3 ft) stems (Montana Weed Control Association 2014). These stems are hollow and often branch near the top of the plant. Leaves are palmately divided; the lower leaves have long petioles with hairy surfaces, while the upper leaves are smaller and usually three-lobed (Montana Weed Control Association 2014). The plant has a five-petaled yellow flower, each producing yellowish egg-shaped, flat seeds (Montana Weed Control Association 2014). Tall buttercup is adapted to a variety of habitats, but prefers moist soils such as wet lowlands and woodlands (Montana Weed Control Association 2014). It is commonly found in pastures, open areas and along roadsides (Montana Weed Control Association 2014). Infestations will decrease in dry years, but rebound and expand during wet years (Montana Weed Control Association 2014).

During the 2003 survey tall buttercup was found in Stuart Field (Figure E-16). This was the first recorded instance of tall buttercup on the ranch (Wood and Rew 2005). A total of five instances of tall buttercup were identified during the 2003 survey (Table E-3). The largest infestation occurred in Stuart Field (8.9 ha [22 ac]) and a 0.8 ha (2 ac) infestation was also mapped in the Stuart Field Annex (Wood and Rew 2005). The remaining three infestations were small patches (less than 121 m^2 [0.03 ac]) located to the south of the main infestation near Cottonwood Creek (Wood and Rew 2005).

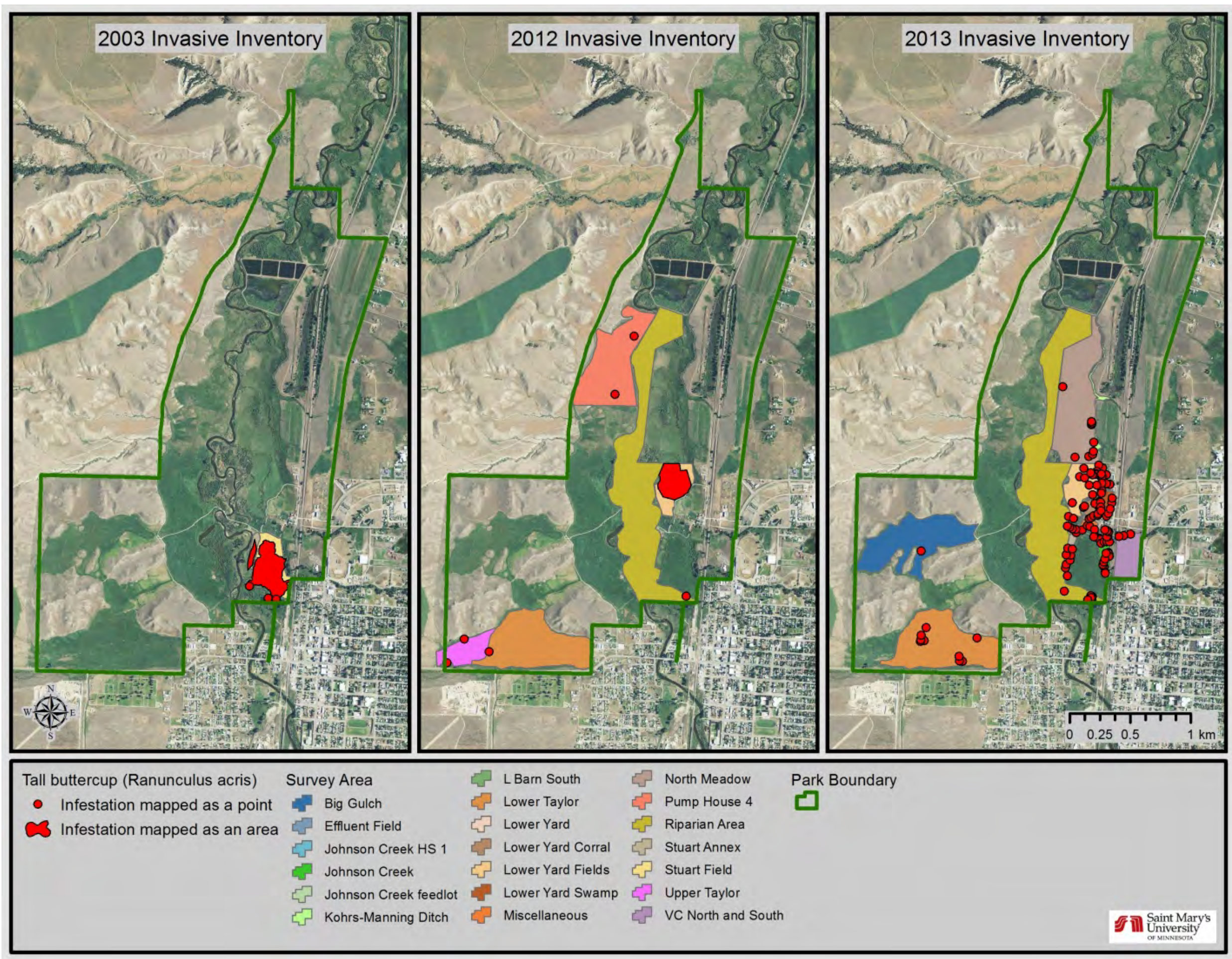


Figure E-16. Location of tall buttercup infestations found during the three field surveys.

The survey conducted in 2012 showed a slight decrease in the total area infested, but a slight increase in the number of infestations as compared to the 2003 results (Table E-3). The infestations found during 2003 were not present in 2012 but new infestations were found (Figure E-16). The largest infestation was a 6.1 ha (15 ac) patch found in the Lower Yards Field (NPS 2012). The remaining occurrences were smaller patches found in Lower Taylor, Upper Taylor, riparian area and Pump House 4. These were under 40 m^2 (0.01 ac) in size, except for the two patches in Pump House 4 (NPS 2012). These covered 283 m^2 (0.07 ac) and 162 m^2 (0.04 ac) respectively (NPS 2012).

The 2013 survey showed an increase in the number of observations of tall buttercup infestation, but they were very small, so the total area infested was lower (Table E-5). As can be seen in Figure E-16, the majority of these occurrences were centrally located around the Lower Yard Field, Lower Yards Swamp, Lower Yards Corral, Stuart Field, Johnson Creek and North Meadows areas. This area accounted for nearly 80% of the total occurrences and nearly 95% of the area infested (Krogstad and Kamerman 2013). The largest infestations in terms of numbers and area were found in Johnson Creek and Lower Yards Field. In Lower Yards Field a total of 16 patches were found and in Johnson Creek a total of 19 patches were found (Krogstad and Kamerman 2013). Nine patches each were found in North Meadows, Lower Taylor, and the riparian area. The infestation in the riparian area was approximately 809 m^2 (0.2 ac) in size, while the other two were less than 405 m^2 (0.1 ac) (Krogstad and Kamerman 2013). The other infestation in Stuart Field Annex consisted of seven patches covering 2,833 m^2 (0.7 ac) (Krogstad and Kamerman 2013).

Russian knapweed (*Rhaponticum repens*; formerly *Acroptilon repens*)
Montana classifies Russian knapweed as a noxious weed and has designated it as a Priority 2B species (MDA 2013). Russian knapweed is a rhizomatous, deep-rooted perennial forb that grows to about 61 cm (2 ft) tall. It has thin, stiff stems covered with soft, short hairs. Flowers are light pink to purple in color. Two characteristics distinguish Russian knapweed from other knapweed species. First, the flower head bracts have light thin hairs, a papery, translucent tip and are green at the base. Second, it has a rhizomatous root system instead of a taproot. The leaves of the rosettes are narrow at the base and widen towards the tip (Duncan et al. 2011). Seed production for Russian knapweed is highly variable, but in general less than other knapweeds. Optimal conditions can result in up to 1,200 seeds per plant (Duncan et al. 2011). Russian knapweed relies on vector distribution for seed dispersal. Vehicles, contaminated crop seed, hay, gravel, road fill, wildlife and domestic livestock are common vectors of dispersal (Duncan et al. 2011). Seeds can also be spread by rivers and other waterways. Seed longevity is in the range of two to nine years, and once established, patches normally spread by rhizomatous growth (Duncan et al. 2011). Mature plants can spread rapidly, covering as much as 7 m (23 ft) over two growing seasons (Duncan et al. 2011). Russian knapweed typically invades disturbed areas and not healthy natural habitats (Montana Weed Control Association 2014). It is adapted to a wide range of habitats including pastureland, cropland, rangeland, and roadsides (Duncan et al. 2011, Montana Weed Control Association 2014). It has a tolerance for poorly drained, saline, alkaline soils that extends its range to irrigation ditches, flood plains and river corridors (Duncan et al. 2011).

During the 2003 field inventory, four small infestations of Russian knapweed were mapped, all on the west side of the Clark Fork River (Figure E-17). The cumulative area infested with Russian knapweed (Table E-3) was approximately 647 m^2 (0.16 ac), with the majority of this area represented by one patch located in the Taylor Ridge Range. Another patch, slightly less than 162 m^2 (0.04 ac), was located in pastureland (Big Gulch). The remaining two infestations, both less than 40 m^2 (0.01 ac), were located in upland range habitat along the westside road and in the riparian area. Overall, infestations of Russian knapweed comprised less than 0.1% of the cumulative infested area (Table E-4) identified during the 2003 survey (Wood and Rew 2005).

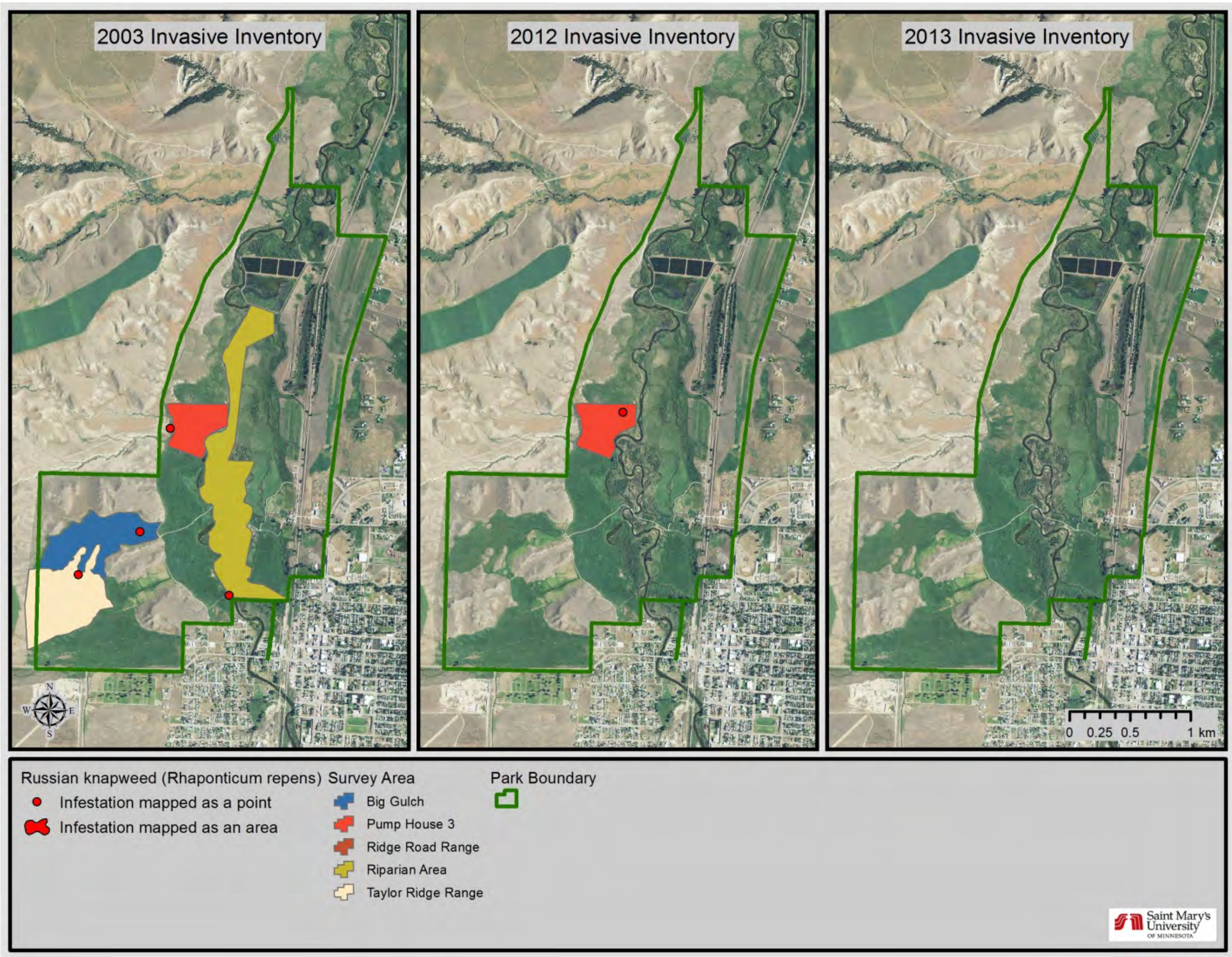


Figure E-17. Location of Russian knapweed infestations found during the three field surveys.

In 2012, only one infestation of Russian knapweed was mapped by the survey (Figure E-17). This infestation was located in pastureland (Pump House 3) and was relatively small, measuring just 162 m^2 (0.04 ac) (Table E-3). Table E-4 shows that the 2012 results are similar to the 2003 results, with Russian knapweed comprising less than 0.01% of the cumulative infested area (NPS 2012). The number of infestations and the cumulative area infested was reduced by 75% from 2003 to 2012. Field surveys conducted in 2013 did not identify any Russian knapweed infestations (Krogstad and Kamerman 2013). However, NPS staff did observe the species in the park during 2014 (Smith, written communication, February 2015).

Common tansy (*Tanacetum vulgare*)

Montana lists common tansy as a noxious weed (MDA 2013). Montana has designated it as a Priority 2A species (MDA 2013). Control of 2A species requires eradication or containment of existing infestations where less abundant with the management actions prioritized by local weed districts (MSU 2014).

Common tansy is a perennial forb with an extensive root system that can grow to a height of 1.5 m (5 ft) (Montana Weed Control Association 2014). It has dark green leaves that can be 25 cm (10 in) long and up to 7.6 cm (3 in) wide (Montana Weed Control Association 2014). Common tansy has yellow to yellow-orange flowers that form in dense flat clusters. It produces a grayish tan ribbed seed. It spreads through seed dispersal and by its root system (Montana Weed Control Association 2014). Common tansy prefers moist soils, and can be commonly found along roadsides and railroad right-of-ways, stream banks, rangeland and irrigated pasture (Montana Weed Control Association 2014).

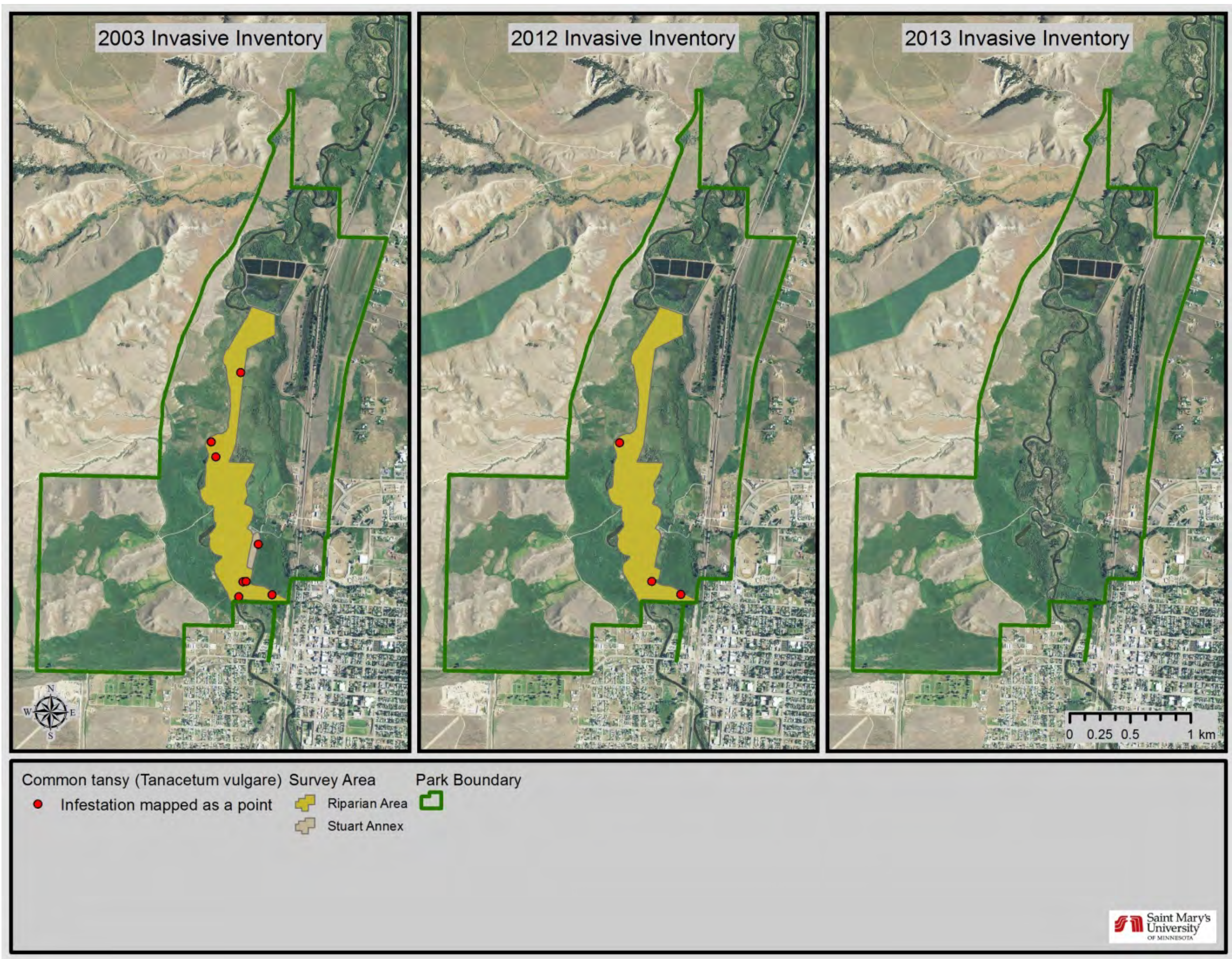


Figure E-18. Location of common tansy infestations found during the three field surveys.

The 2003 survey mapped eight infestations of common tansy (Figure E-18). All the patches were small, measuring less than 40 m^2 (0.01 ac) (Wood and Rew 2005). Seven infestations were located in the riparian area with a total infested area of approximately 81 cm^2 (0.02 ac) (Wood and Rew 2005). The remaining infestation was found in Stuart Annex.

The survey conducted in 2012 mapped only three occurrences of common tansy, all located in the riparian area (Figure E-18). As was the case in 2003, these were very small infestations; however, they were smaller in 2012, with none larger than 4 m^2 (43 ft^2) in size (NPS 2012). No instances of common tansy were noted during the 2013 survey (Krogstad and Kamerman 2013). However, the species was observed in the park during 2014 (Smith, written communication, February 2015).

Field pennycress (*Thlaspi arvense*)

Field pennycress is not listed as a noxious weed by the state of Montana (MDA 2013) and it is also not listed as a noxious species by any county in Montana (MSU 2014).

Field pennycress is an annual that can grow up to 61 cm (24 in) in height (Koundinya and Hansen 2012). It has both a slender taproot and a fibrous lateral root system (Alaska Natural Heritage Progam 2010). Its leaves are stalkless, up to 3.8 cm (1.5 in) long and 1.3 cm (0.5 in) wide, with an ear-like lobe at the base and large-toothed to wavy margins (Alaska Natural Heritage Progam 2010). It produces small white four-petaled flowers in clusters at the end of stalks (Koundinya and Hansen 2012). It can be commonly found in areas such as open disturbed areas, roadsides, railroads and riparian areas (Koundinya and Hansen 2012).

Field pennycress was only mapped on the ranch during the 2012 survey (Figure E-19). It was not on the list of dominant species that was used during the 2003 survey (Wood and Rew 2005) and was not surveyed for in 2013 due to its low management priority (Smith, written communication, February 2015). The 2012 survey mapped 1.92 ha (4.75 ac) of field pennycress (Table 3). This was made up of mostly small patches, but two larger patches were mapped in the Westside Ditch and Effluent Field (NPS 2012). The largest of these (1.5 ha [3.6 ac]) was located in the Westside Ditch and a 3,237 m^2 (0.8 ac) patch was mapped in the Effluent Field (NPS 2012). The remaining infestations were all very small, less than 405 m^2 (0.1 ac) in size (NPS 2012).

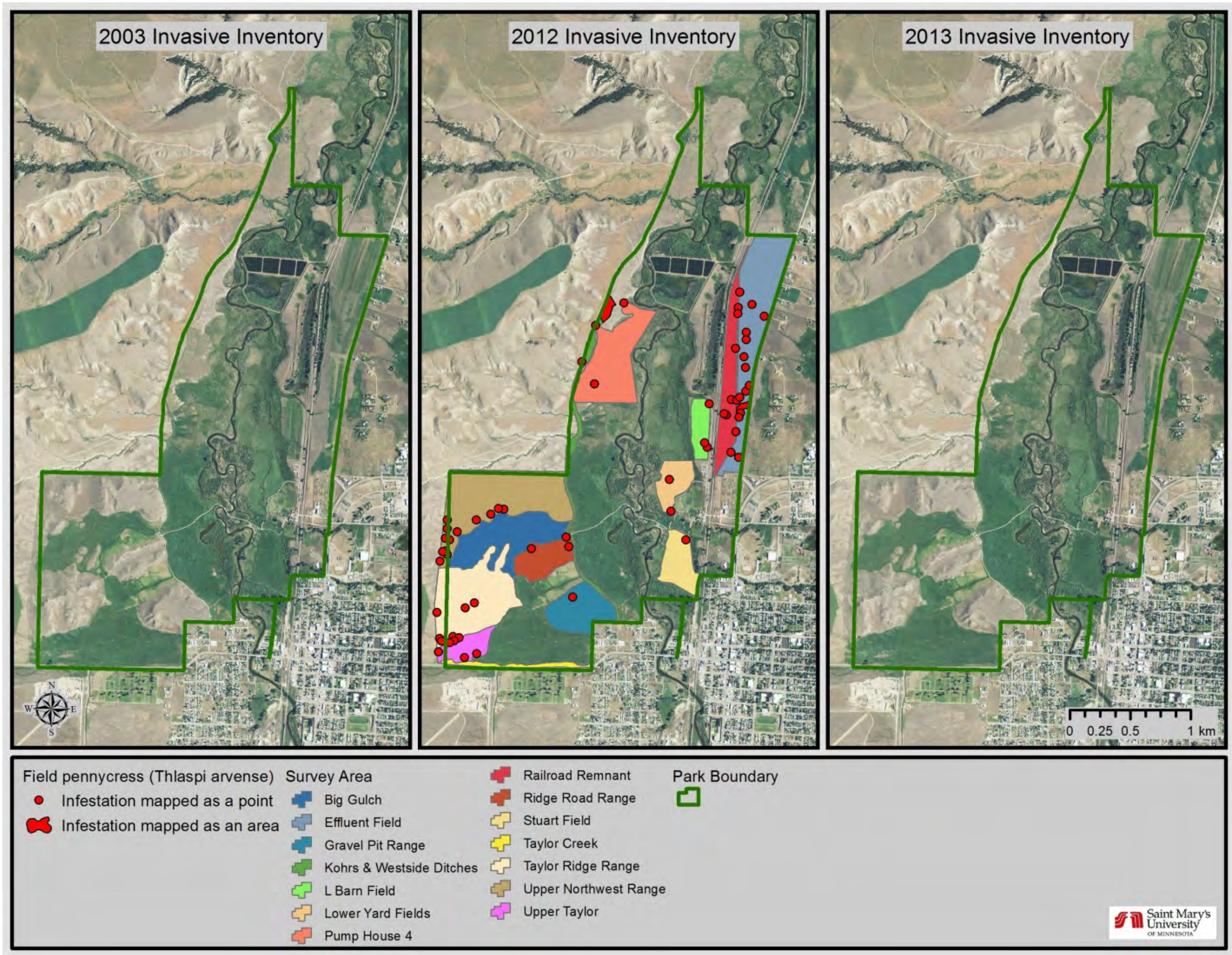


Figure E-19. Location of field pennycress infestations found during the three field surveys. Note that the 2003 and 2013 field efforts did not survey for this species, so no infestations were mapped.

Literature Cited

Alaska Natural Heritage Progam. 2010. Field pennycress. University of Alaska - Anchorage, Anchorage, Alaska.

British Columbia Ministry of Agriculture. 2014. Baby's breath. http://www.agf.gov.bc.ca/cropprot/babysbreath.htm (accessed 31 December 2014).

Duncan, C., J. Story, R. Sheley, H. Parkinson, J. Mangold. 2011. Biology, ecology, and management of Montana knapweeds. Montana State University Extension, Bozeman, Montana.

Goodwin, K., R. Sheley, R. Nowierski, and R. Lym. 2001. Leafy spurge: Biology, ecology and management. USDA Agricultural Research Service, Sidney, Montana.

Graves-Medeley, M., J. Mangold, and K. Goodwin. 2011. Biology, ecology, and management of whitetop. Montana State University Extension, Bozeman, Montana.

Jacobs, J., and S. Sing. 2006. Ecology and management of Dalmatian toadflax. Invasive Species Technical Note No. MT-3. Montana State University Extension, Bozeman, Montana.

Kedzie-Webb, S., and R. L. Sheley. 2009. Houndstongue: Identification, biology and integrated management. Montana State University Extension, Bozeman, Montana.

Koundinya, V., and R. Hansen. 2012. Pennycress. http://www.agmrc.org/commodities__products/grains__oilseeds/pennycress/ (accessed 31 December 2014).

Krogstad, L., and R. Kamerman. 2013. 2013 Non-native plant survey at Grant-Kohrs Ranch National Historic Site. Montana State University, Bozeman, Montana.

Menalled, F., J. Mangold, and E. Davis. 2012. Cheatgrass : Identification, biology and integrated management. Montana State University Extension, Bozeman, Montana.

Montana Department of Agriculture (MDA). 2013. Montana noxious weed list. Montana Department of Agriculture, Helena, Montana.

Montana State University (MSU). 2014. Montana noxious weed information. http://www.msuextension.org/invasiveplantsMangold/noxioussub.html (accessed 31 December 2014).

Montana Weed Control Association. 2009. Weed control and management. http://www.mtweed.org/weed-control-management/ (accessed 31 December 2014).

Montana Weed Control Association. 2014. Weed ID. http://www.mtweed.org/weed-identification/ (accessed 31 December 2014).

National Park Service (NPS). 2009. Invasive species…..What are they and why are they a problem? http://www.nature.nps.gov/biology/invasivespecies/ (accessed 31 December 2014).

National Park Service (NPS). 2011. Northern Rocky Mountains invasive plant management plan. National Park Service, Fort Collins, Colorado.

National Park Service (NPS). 2012. 2012 Non-native plant survey at Grant-Kohrs Ranch National Historic Site. National Park Service, Deer Lodge, Montana.

Randall, J. A. 1996. Weed control for preservation of biological diversity. Weed Technology 10:370-383.

Rice, P. M., G. J. Ray, J. J. Bromenshenk, and P .C. Tourangeau. 1984. Floral and faunal survey and toxic metal contamination study of the Grant-Kohrs Ranch National Historic Site. Report for National Park Service. University of Montana, Missoula, Montana.

Rice, P. M., and G. J. Ray. 1984. Baseline plant inventory of the Grant-Kohrs Ranch. Report for National Park Service. University of Montana, Missoula, Montana.

Rice, P. M., and J. Hardin. 2002a. Riparian plant community structure at Grant-Kohrs Ranch. Report for National Park Service. University of Montana, Missoula, Montana.

Rice, P. M., and J. Hardin. 2002b. Vascular plant survey of Grant-Kohrs Ranch National Historic Site. Report for National Park Service. University of Montana, Missoula, Montana.

Sheley, R. L., J. K. Petroff, and M. M. Borman. 1999. Introduction. Pages 1-3 *in* R. L. Sheley and J. K. Petroff, editors. Biology and Management of Noxious Rangeland Weeds. Oregon State University Press, Corvallis, Oregon.

Westbrooks, R. 1998. Invasive plants, changing the landscape of America: Fact book. Federal Interagency Committee for the Management of Noxious and Exotic Weeds (FICMNEW), Washington, D.C.

Wood, S. D., and D. L. J. Rew. 2005. Non-native plant survey at Grant-Kohrs Ranch National Historic Site. Montana State University, Bozeman, Montana.

Appendix F. Species of conservation concern that have been identified in GRKO.

Common Name	Global Rank	State Rank	Federal Status	MT PIF Status	CFWCS Status
alder flycatcher	G5	S3B			II-I
American dipper				III	
American white pelican	G4	S3B		III	III
bald eagle	G5	S3	USFWS - DM	II	I-III
Barrow's goldeneye				II	
black rosy-finch				II	
black tern				II	
black-billed cuckoo	G5	S3B		II	II-I
black-crowned night-heron	G5	S3B		III	II-I
black-necked stilt	G5	S3B		III	III-II
bobolink	G5	S3B		III	III
Brewer's blackbird				III	
Brewer's sparrow	G5	S3B	BLM	II	II-III
brown creeper	G5	S3		I	II
burrowing owl	G4	S3B	USFS, BLM	I	I-III
calliope hummingbird				II	
Caspian tern				II	
Cassin's finch	G5	S3		III	II-III
Cassin's vireo				III	
chipping sparrow				III	
Clark's nutcracker	G5	S3		III	III
clay-colored sparrow				III	
common loon	G5	S3B	USFS, BLM	I	I-III
common tern				II	
cordilleran flycatcher				II	
downy woodpecker				III	
ferruginous hawk	G4	S3B	BLM	II	II-III
Franklin's gull	G4 G5	S3B	BLM	II	II

Common Name	Global Rank	State Rank	Federal Status	MT PIF Status	CFWCS Status
golden-crowned kinglet				III	
gray catbird				III	
gray-crowned rosy-finch	G5	S2B, S5N			II
great blue heron	G5	S3			III
green-tailed towhee				III	
Hammond's flycatcher				II	
harlequin duck	G4	S2B	USFS, BLM	I	I-III
hooded merganser				II	
horned grebe	G5	S3B		II	II
killdeer				III	
lark bunting				II	
lark sparrow				III	
lazuli bunting				II	
least flycatcher				III	
Lewis's woodpecker	G4	S2B		II	II
long-billed curlew	G5	S3B	BLM	II	I-II
MacGillivray's warbler				III	
marbled godwit				II	
northern goshawk	G5	S3	USFS, BLM	II	II-I
northern harrier				III	
olive-sided flycatcher				I	
peregrine falcon	G4	S3	USFWS - DM, USFS, BLM	II	II-III
pinyon jay	G5	S3			II-III
red crossbill				III	
red-headed woodpecker	G5	S3B		II	II
red-naped sapsucker				II	
red-winged blackbird				III	
rufous hummingbird				III	

Common Name	Global Rank	State Rank	Federal Status	MT PIF Status	CFWCS Status
sharp-shinned hawk				III	
short-eared owl				III	
song sparrow				III	
Swainson's hawk				III	
Townsend's solitaire				III	
Townsend's warbler				III	
trumpeter swan	G4	S3	BLM	II	I-III
varied thrush				III	
veery	G5	S3B		III	II-III
warbling vireo				III	
white-faced ibis	G5	S3B	BLM	II	II-I
willet				III	
Williamson's sapsucker				II	
willow flycatcher				II	
Wilson's phalarope				III	
winter wren	G5	S3		II	II-III
yellow-headed blackbird				III	

(G) = Global

(S) = State

(B) = State rank modifier indicating breeding for a migratory species.

(N) = A state rank modifier referring to a non-breeding population of the species.

G5/S5 = Common, widespread, and abundant (although it may be rare in parts of its range). Not vulnerable in most of its range.

G4/S4 = Uncommon but not rare (although it may be rare in parts of its range), and usually widespread. Apparently not vulnerable in most of its range, but possibly cause for long-term concern.

G3/S3 = Potentially at risk because of limited and/or declining numbers, range, and/or habitat, even though it may be abundant in some areas.

G2/S2 = At risk because of very limited and/or declining numbers, range, and/or habitat, making it vulnerable to global extinction or extirpation in the state.

BLM = Bureau of Land Management Sensitive Species.

USFWS (DM) = Recovered, delisted, and monitored species under the Endangered Species Act of 1973 as defined by the U.S. Fish and Wildlife Service.

USFS = U.S. Forest Service Sensitive Species or Species of Concern.

Appendix G. Bird species identified as present or probably present in GRKO.

Common Name	NPS (2014)	Rice and Ray (1984)	Giroir and Beason (2005)	Larson (2011)	Atkinson and Smucker (2013)	CBC (2006-2012)
alder flycatcher				X		
American avocet	X					
American coot	X					X
American crow	X	X	X	X		X
American dipper	X					X
American goldfinch	X	X	X			X
American kestrel	X	X	X	X		
American pipit	X					
American robin	X	X	X	X	X	
American tree sparrow	X					X
American white pelican	X					
American wigeon	X					X
American bittern	X					
Anna's hummingbird	X					
ash-throated flycatcher	X					
Baird's sandpiper	X					
bald eagle	X					X
band-tailed pigeon	X	X				
bank swallow	X	X	X			
barn swallow	X	X		X	X	
Barrow's goldeneye	X					X
belted kingfisher	X	X				X
black rosy-finch	X					
black tern	X					
black-bellied plover	X					
black-billed cuckoo	X	X				
black-billed magpie	X		X	X	X	X
black-capped chickadee	X	X	X	X	X	X
black-crowned night-heron	X					
black-headed grosbeak	X		X		X	
black-necked stilt	X					
blue jay	X					
blue-winged teal	X	X			X	
bobolink	X	X	X	X	X	
Bohemian waxwing	X					X
Bonaparte's gull	X					
Brewer's blackbird	X		X	X		X
Brewer's sparrow	X					

Common Name	NPS (2014)	Rice and Ray (1984)	Giroir and Beason (2005)	Larson (2011)	Atkinson and Smucker (2013)	CBC (2006-2012)
brown creeper	X					X
brown-headed cowbird	X		X	X	X	
bufflehead	X					
Bullock's oriole	X		X			
burrowing owl	X					
California gull	X				X	
calliope hummingbird	X					
Canada goose	X		X	X		X
canvasback	X					
Caspian tern	X					
Cassin's finch	X					
Cassin's vireo	X					
cedar waxwing	X	X	X			X
chipping sparrow	X			X		
cinnamon teal	X					
Clark's nutcracker	X					X
clay-colored sparrow	X		X			
cliff swallow	X	X	X			
common goldeneye	X					X
common grackle	X		X	X	X	
common loon	X					
common merganser	X					X
common nighthawk	X				X	
common raven	X		X	X	X	X
common redpoll	X					X
common tern	X					
common yellowthroat	X		X	X	X	
Cooper's hawk	X					X
cordilleran flycatcher	X					
dark-eyed junco	X			X		X
double-crested cormorant	X				X	
downy woodpecker	X		X			X
dusky flycatcher	X					
eared grebe	X					
eastern kingbird	X		X	X	X	
herring gull	X					
Eurasian collared-dove						X
European starling	X		X	X	X	X
evening grosbeak	X					X

Common Name	NPS (2014)	Rice and Ray (1984)	Giroir and Beason (2005)	Larson (2011)	Atkinson and Smucker (2013)	CBC (2006-2012)
ferruginous hawk	X					
Franklin's gull	X					
gadwall	X		X			
golden eagle	X					X
golden-crowned kinglet	X					
gray catbird	X		X			
gray jay	X					X
gray partridge	X					X
gray-crowned rosy-finch	X					X
great blue heron	X	X			X	X
great egret	X					
great horned owl	X	X				
greater scaup	X					
greater white-fronted goose	X					
greater yellowlegs	X					
green-tailed towhee	X					
green-winged teal	X					X
gyrfalcon	X					
hairy woodpecker	X					X
Hammond's flycatcher	X					
harlequin duck	X					
Harris's sparrow	X					
hermit thrush	X					
hoary redpoll	X					
hooded merganser	X					
horned grebe	X					
horned lark	X		X	X	X	X
house finch	X			X		X
house sparrow	X			X		X
house wren	X		X	X		
killdeer	X	X	X	X	X	X
lapland longspur	X					X
lark bunting	X					
lark sparrow	X			X		
lazuli bunting	X					
least flycatcher	X		X			
least sandpiper	X					
lesser scaup	X				X	
lesser yellowlegs	X					

Common Name	NPS (2014)	Rice and Ray (1984)	Giroir and Beason (2005)	Larson (2011)	Atkinson and Smucker (2013)	CBC (2006-2012)
Lewis's woodpecker	X					
Lincoln's sparrow	X					
long-billed curlew	X		X		X	
long-billed dowitcher	X					
long-eared owl	X					
long-tailed duck	X					
MacGillivray's warbler	X				X	
mallard	X	X	X	X	X	X
marbled godwit	X					
marsh wren	X		X			
merlin	X					X
mountain bluebird	X				X	
mountain chickadee	X				X	X
mourning dove	X	X	X		X	X
northern flicker	X	X	X	X	X	X
northern goshawk	X					X
northern harrier	X	X		X	X	X
northern mockingbird	X					
northern pintail	X					
northern pygmy-owl	X					X
northern rough-winged swallow	X		X	X	X	
northern saw-whet owl	X					
northern shoveler	X					X
northern shrike						X
northern waterthrush	X		X			
olive-sided flycatcher	X					
orange-crowned warbler	X					
osprey	X		X	X		
pectoral sandpiper	X					
peregrine falcon	X					
pied-billed grebe	X					X
pine grosbeak	X					X
pine siskin	X					X
pinyon jay	X					
prairie falcon	X					X
red crossbill	X					X
red-breasted merganser	X					X
red-breasted nuthatch	X					
redhead	X					

Common Name	NPS (2014)	Rice and Ray (1984)	Giroir and Beason (2005)	Larson (2011)	Atkinson and Smucker (2013)	CBC (2006-2012)
red-headed woodpecker	X					
red-naped sapsucker	X		X			
red-necked grebe	X					
red-necked phalarope	X					
red-tailed hawk	X	X	X	X	X	X
red-winged blackbird	X	X	X	X	X	X
ring-billed gull	X					
ring-necked duck	X					
ring-necked pheasant	X					
rock pigeon	X			X		X
rock wren	X					
Ross's goose	X					
rough-legged hawk	X					
rough-winged hawk						X
ruby-crowned kinglet	X					
ruddy duck	X		X			
rufous hummingbird	X					
rusty blackbird	X					
Sabine's gull	X					
sanderling	X					
sandhill crane	X			X	X	
savannah sparrow	X		X	X	X	
Say's phoebe	X					
scarlet tanager	X					
semipalmated plover	X					
semipalmated sandpiper	X					
sharp-shinned hawk	X					X
short-eared owl	X					
snow bunting	X					X
snow goose	X					
snowy egret	X					
solitary sandpiper	X					
song sparrow	X	X	X	X	X	X
sora	X		X			
spotted sandpiper	X		X		X	
spotted towhee	X					
Steller's jay	X					
stilt sandpiper	X					
Swainson's hawk	X			X		

Common Name	NPS (2014)	Rice and Ray (1984)	Giroir and Beason (2005)	Larson (2011)	Atkinson and Smucker (2013)	CBC (2006-2012)
Swainson's thrush	X					
swamp sparrow	X					
Townsend's solitaire	X					X
Townsend's warbler	X					
tree swallow	X	X	X	X	X	
trumpeter swan	X					
tundra swan	X					X
turkey vulture	X					
varied thrush	X					
veery	X					
vesper sparrow	X		X	X	X	
violet-green swallow	X					
Virginia rail	X					
warbling vireo	X					
western bluebird				X		
western grebe	X					
western kingbird	X		X	X		
western meadowlark	X		X	X	X	
western sandpiper	X					
western tanager	X					
western wood-pewee	X		X	X	X	
whimbrel	X					
white-breasted nuthatch	X					
white-crowned sparrow	X			X		
white-faced ibis	X					
white-throated sparrow	X					
white-throated swift	X					
white-winged crossbill	X					
wild turkey	X					
willet	X					
Williamson's sapsucker	X					
willow flycatcher	X		X	X	X	
Wilson's phalarope	X					
Wilson's snipe	X	X	X	X	X	
Wilson's warbler	X					
winter wren	X					
wood duck	X		X			
yellow warbler	X		X	X	X	
yellow-breasted chat	X					

Common Name	NPS (2014)	Rice and Ray (1984)	Giroir and Beason (2005)	Larson (2011)	Atkinson and Smucker (2013)	CBC (2006-2012)
yellow-headed blackbird	X	X	X			
yellow-rumped warbler	X					

Appendix H. Species observed in GRKO based on each survey method during Atkinson and Smucker (2013).

Species	Point Count	Nest Found	Mist Net	Area Search
American avocet				X
American crow		X		X
American goldfinch			X	X
American kestrel				X
American robin	X	X	X	X
American white pelican				X
American wigeon				X
bald eagle				X
bank swallow		X		X
barn swallow	X			X
belted kingfisher				X
black-billed magpie	X	X	X	X
black-capped chickadee	X	X	X	X
black-headed grosbeak	X			X
blue-winged teal	X			
bobolink	X			X
Brewer's blackbird				X
brown-headed cowbird	X		X	X
Bullock's oriole			X	X
California gull	X			X
calliope hummingbird			X	X
Canada goose				X
canvasback				X
Cassin's vireo			X	X
cedar waxwing			X	X
chipping sparrow			X	X
cinnamon teal				X
clay-colored sparrow			X	X
common grackle	X		X	X
common merganser				X
common nighthawk	X			X
common raven	X			X
common yellowthroat	X	X	X	X
cordilleran flycatcher			X	X
dark-eyed junco				X
double-crested cormorant	X			X
downy woodpecker			X	X
dusky flycatcher			X	X
eastern kingbird	X		X	X

Species	Point Count	Nest Found	Mist Net	Area Search
Eurasian collared-dove				X
European starling	X			X
evening grosbeak				X
fox sparrow				X
gadwall				X
gray catbird			X	X
gray partridge				X
great blue heron	X			X
great horned owl				X
greater yellowlegs				X
hairy woodpecker				X
Hammond's flycatcher			X	X
hermit thrush			X	X
horned lark	X			X
house finch			X	X
house wren			X	X
killdeer	X			X
lazuli bunting			X	X
least flycatcher			X	X
lesser scaup	X			
Lincoln's sparrow			X	X
long-billed curlew	X			X
Macgillivray's warbler	X		X	X
mallard	X			X
marsh wren			X	X
merlin				X
mountain bluebird	X			
mountain chickadee	X		X	X
mourning dove	X			X
northern flicker	X	X	X	X
northern harrier	X			X
northern rough-winged swallow	X		X	X
northern shoveler				X
northern waterthrush			X	X
orange-crowned warbler			X	X
osprey				X
pine siskin			X	X
red-breasted nuthatch			X	X
red-eyed vireo			X	X
red-naped sapsucker			X	X
red-tailed hawk	X			X

Species	Point Count	Nest Found	Mist Net	Area Search
red-winged blackbird	X	X		X
ring-billed gull				X
ruby-crowned kinglet			X	X
rufous hummingbird			X	X
sandhill crane	X			X
savannah sparrow	X	X	X	X
song sparrow	X		X	X
sora				X
spotted sandpiper	X			X
Swainson's thrush			X	X
Tennessee warbler			X	X
Townsend's warbler			X	X
tree swallow	X			X
veery			X	X
vesper sparrow	X		X	X
violet-green swallow				X
warbling vireo				X
western meadowlark	X			X
western tanager			X	X
western wood-pewee	X		X	X
willow flycatcher	X		X	X
Wilson's snipe	X			X
Wilson's warbler			X	X
wood duck				X
yellow warbler	X	X	X	X
yellow-headed blackbird				X
yellow-rumped warbler			X	X

Appendix I. Species distribution and abundance during the Giroir and Beason (2005) survey in GRKO.

Species	Grassland	Riparian	Total
Canada goose		1	1
wood duck		4	4
gadwall		1	1
mallard		1	1
ruddy duck		1	1
osprey		1	1
red-tailed hawk		1	1
American kestrel	1	1	2
sora		1	1
killdeer	3	8	11
spotted sandpiper		8	8
long-billed curlew	7		7
Wilson's snipe		14	14
mourning dove	2	9	11
red-naped sapsucker		2	2
downy woodpecker		1	1
northern flicker		7	7
western wood-pewee		3	3
willow flycatcher	1	20	21
least flycatcher		1	1
western kingbird		1	1
eastern kingbird		5	5
black-billed magpie		18	18
American crow	3	16	19
common raven	2		2
horned lark	19		19
tree swallow		1	1
northern rough-winged swallow	4	1	5
bank swallow		7	7
cliff swallow	1		1
black-capped chickadee		2	2
house wren		10	10
marsh wren		11	11
American robin		4	4
gray catbird		10	10
European starling		20	20
cedar waxwing		1	1
yellow warbler		25	25
northern waterthrush		6	6
common yellowthroat	1	14	15

Species	Grassland	Riparian	Total
clay-colored sparrow		1	1
vesper sparrow	27	1	28
savannah sparrow	30	46	76
song sparrow		18	18
black-headed grosbeak		3	3
bobolink	3	8	11
red-winged blackbird	1	22	23
western meadowlark	29	21	50
yellow-headed blackbird		10	10
Brewer's blackbird	9		9
common grackle	1	8	9
brown-headed cowbird	1	31	32
Bullock's oriole		4	4
American goldfinch		2	2
Total # of Individuals	**145**	**412**	**557**

Appendix J. Species abundance during the Larson (2011) survey of the grassland/agricultural habitats in GRKO.

Species	# of Individuals	% of Observations
savannah sparrow	156	31
bobolink	57	11
western meadowlark	43	9
brown-headed cowbird	29	6
red-winged blackbird	28	6
vesper sparrow	28	6
American robin	14	3
Wilson's snipe	14	3
American crow	12	2
killdeer	12	2
black-billed magpie	11	2
song sparrow	9	2
European starling	6	1
tree swallow	5	1
eastern kingbird	4	< 1
sandhill crane	4	< 1
chipping sparrow	3	< 1
common grackle	3	< 1
dark-eyed junco	3	< 1
horned lark	3	< 1
northern rough-winged swallow	3	< 1
red-tailed hawk	3	< 1
western wood-pewee	3	< 1
willow flycatcher	3	< 1
yellow warbler	3	< 1
alder flycatcher	2	< 1
American kestrel	2	< 1
barn swallow	2	< 1
black-capped chickadee	2	< 1
house wren	2	< 1
northern flicker	2	< 1
rock dove	2	< 1
Swainson's hawk	2	< 1
western bluebird	2	< 1
Brewer's blackbird	1	< 1
Canada goose	1	< 1
common raven	1	< 1
common yellowthroat	1	< 1
house finch	1	< 1
house sparrow	1	< 1

Species	**# of Individuals**	**% of Observations**
lark sparrow	1	< 1
mallard	1	< 1
northern harrier	1	< 1
osprey	1	< 1
white-crowned sparrow	1	< 1
western kingbird	1	< 1
unidentified bird	*2*	*< 1*
unidentified swallow	*2*	*< 1*
unidentified Empid. Flycatcher	*1*	*< 1*
unidentified falcon	*1*	*< 1*
unidentified gull	*1*	*< 1*
Total	**489**	**100**

Appendix K. Species distribution and abundance during the Atkinson and Smucker (2013) survey in GRKO.

Species	Grassland/Agriculture	Riparian/Wetland	Total
double-crested cormorant		1	1
great blue heron		2	2
mallard	3	1	4
blue-winged teal	1		1
lesser scaup	1		1
northern harrier	1		1
red-tailed hawk	1		1
sandhill crane	1		1
killdeer		1	1
spotted sandpiper		2	2
long-billed curlew	2	1	3
Wilson's snipe	4	7	11
California gull	1	1	2
mourning dove		1	1
common nighthawk	2		2
northern flicker	1	2	3
western wood-pewee	2		2
willow flycatcher	1	1	2
eastern kingbird	1	1	2
black-billed magpie	10	21	31
common raven	5	1	6
horned lark	1		1
tree swallow	7	1	8
northern rough-winged swallow	3	10	13
barn swallow	2	3	5
black-capped chickadee	2	2	4
mountain chickadee	1		1
mountain bluebird	2		2
American robin	1		1
European starling	2	1	3
yellow warbler	6	10	16
MacGillivray's warbler		2	2
common yellowthroat	2	5	7
vesper sparrow	14		14
savannah sparrow	46	26	72
song sparrow		4	4
black-headed grosbeak	1	3	4
bobolink	4	1	5
red-winged blackbird	25	15	40
western meadowlark	15	11	26

Species	Grassland/Agriculture	Riparian/Wetland	Total
common grackle	1		1
brown-headed cowbird	3	9	12
Total # of Individuals	**175**	**146**	**321**

Appendix L. NLCD landcover class composition and change (2001-2011) within GRKO external viewshed (gray indicates class with actual change).

Landcover Class	Hectares	Percent Visible Cover
Evergreen Forest to Evergreen Forest	17227	40
Shrub/Scrub to Shrub/Scrub	12217	28
Grassland/Herbaceous to Grassland/Herbaceous	7514	17
Pasture/Hay to Pasture/Hay	3572	8
Developed, Open Space to Developed, Open Space	623	1
Evergreen Forest to Shrub/Scrub	419	1
Cultivated Crops to Cultivated Crops	404	1
Developed, Low Intensity to Developed, Low Intensity	403	1
Woody Wetlands to Woody Wetlands	214	<1
Evergreen Forest to Grassland/Herbaceous	116	<1
Barren Land to Barren Land	114	<1
Developed, Med Intensity to Developed, Medium Intensity	102	<1
Pasture/Hay to Grassland/Herbaceous	43	<1
Shrub/Scrub to Evergreen Forest	32	<1
Grassland/Herbaceous to Pasture/Hay	29	<1
Grassland/Herbaceous to Shrub/Scrub	20	<1
Cultivated Crops to Grassland/Herbaceous	19	<1
Shrub/Scrub to Grassland/Herbaceous	17	<1
Grassland/Herbaceous to Evergreen Forest	11	<1
Developed, High Intensity to Developed, High Intensity	10	<1
Woody Wetlands to Pasture/Hay	7	<1
Shrub/Scrub to Pasture/Hay	5	<1
Open Water to Open Water	4	<1
Pasture/Hay to Woody Wetlands	3	<1
Deciduous Forest to Deciduous Forest	2	<1
Developed, Low Intensity to Developed, High Intensity	1	<1
Grassland/Herbaceous to Woody Wetlands	1	<1
Developed, Open to Developed, Medium Intensity	1	<1
Barren Land to Grassland/Herbaceous	1	<1
Developed, Open Space to Developed, Low Intensity	1	<1
Developed, Low Intensity to Developed, Medium Intensity	1	<1
Grassland/Herb to Developed, Medium Intensity	1	<1
Grassland/Herb to Developed, High Intensity	1	<1
Developed, Open Space to Developed, High Intensity	<1	<1
Grassland/Herbaceous to Developed, Open Space	<1	<1
Developed, Med Intensity to Developed, High Intensity	<1	<1
Woody Wetlands to Grassland/Herbaceous	<1	<1
Grassland/Herb to Emergent Herb Wetlands	<1	<1

NPS 451/130317, October 2015

National Park Service
U.S. Department of the Interior

Natural Resource Stewardship and Science
1201 Oakridge Drive, Suite 150
Fort Collins, CO 80525

www.nature.nps.gov