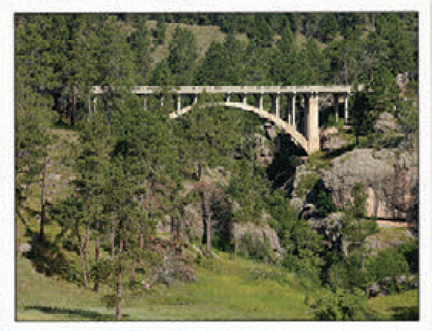
NATIONAL PARK SERVICE • U.S. DEPARTMENT OF THE INTERIOR

RESOURCE STEWARDSHIP STRATEGY SUMMARY

WIND CAVE NATIONAL PARK

SOUTH DAKOTA



JANUARY 2021

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INTRODUCTION

PURPOSE OF A RESOURCE STEWARDSHIP STRATEGY

A resource stewardship strategy (RSS) is a strategic plan, intended to help park managers achieve and maintain desired resource conditions over time (see NPS *Management Policies 2006* [§2.3.2]). As part of a park's planning portfolio, a resource stewardship strategy serves as a bridge between the park's foundation document, other plans, and everyday management of its natural and cultural resources.

More specifically, a resource stewardship strategy is a dynamic planning tool used to set stewardship goals and track progress in achieving and maintaining desired natural and cultural resource conditions. All resource stewardship goals and activities should be based on science, law, NPS management policies, and the long-term public interest.

Essentially, a resource stewardship strategy establishes a framework and a coordinated process for

1. evaluating and summarizing existing information about priority park resources (including key issues, stressors, and threats),
2. using science and scholarship to establish stewardship goals for priority resources,
3. integrating natural and cultural resource management to achieve stewardship goals, and
4. determining what stewardship activities are needed to get us "from where we are to where we want to be."

This information provides a basis for making informed resource management decisions for specific project proposals and for developing and revising annual work plans over time.

A resource stewardship strategy is not a static document or one-time effort. Rather, it is a dynamic framework that should be routinely updated as conditions change; new issues, stressors, or threats are identified; and activities are accomplished. A resource stewardship strategy is reviewed by NPS subject-matter experts and decision makers; however, it is not a publicly reviewed decision document.

The RSS process also provides an opportunity for a park to take an integrated approach to resource management by capitalizing on overlapping opportunities among and within disciplines, identifying stewardship activities that benefit multiple resources, or addressing larger parkwide issues. Taking an integrated approach can result in more effective stewardship for resources through the use of science, scholarship, research, policy, interpretation, and direct management.

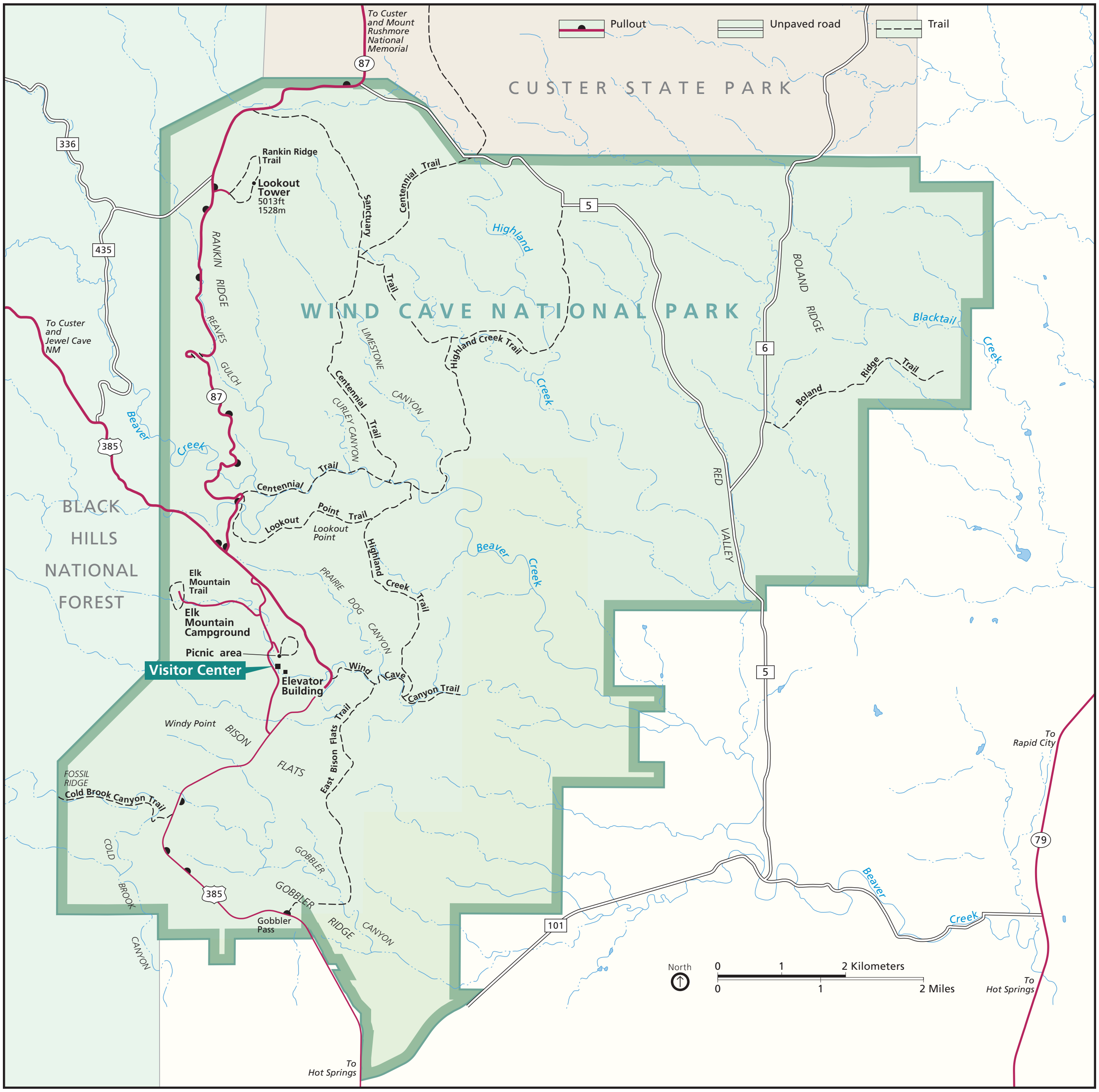
INTENT OF THIS SUMMARY DOCUMENT

This summary document is intended to provide readers with a snapshot of the resource stewardship strategy for Wind Cave National Park. For the sake of simplification and abbreviation, this unit of the national park system will also be referred to as "the park" or WICA in this document. The document serves as a communication tool that complements the dynamic and evolving RSS desktop application that is actively used for resource management. This summary is not intended to describe all of the elements in the resource stewardship strategy, but instead focuses on those components of the strategy that are essential for communicating information about the park's plan to address key management issues and seize opportunities for those resources identified as priority natural and cultural resources.

This document includes a summary of key issues, stressors, and threats affecting park resources; brief descriptions of the park's priority resources and their components; stewardship goals for priority resources and stewardship activities determined to be high priorities for the next three to five years. In addition, this document describes how climate change scenario planning (CCSP) was integrated into the resource stewardship strategy development process for Wind Cave National Park. The document concludes with a brief description of future RSS implementation.

It is important to remember that implementation of the resource stewardship strategy is an ongoing process, with necessary updates and revisions occurring as resource and management conditions change and stewardship activities are carried out.

Figure 1. Map of Wind Cave National Park



Not shown: Detached unit within the adjacent Black Hills National Forest west of the main unit of the park.

BRIEF DESCRIPTION OF WIND CAVE NATIONAL PARK

Wind Cave National Park, the eighth national park, was established with the Wind Cave National Park Enabling Act of January 9, 1903 (32 Stat. 765). The park is located in the southwest corner of South Dakota at the southern edge of the Black Hills, a mountain range in western South Dakota and northeastern Wyoming roughly 120 miles long and 60 miles wide. The Black Hills have been home to American Indians for thousands of years, serving as a spiritually and culturally significant area and providing resources for tools, food, and other materials. The region also became a destination for early explorers, miners, and homesteaders during the 19th and 20th centuries.

The park boundary is approximately six miles north of Hot Springs, South Dakota, and is bounded by Custer State Park on the north, Black Hills National Forest on the west, and by private property on the south and east. The park encompasses 33,918 acres of prairie ecosystem underlain by extensive karst deposits, with Wind Cave being one of the world's longest caves. The cave is well known for its outstanding display of boxwork, an unusual cave feature composed of thin blades of calcite that resemble honeycombs. In addition, the park has more than 40 other, smaller backcountry caves.

Oral traditions reveal that Wind Cave is one of the most sacred and culturally significant areas in the Black Hills for the Lakota and Cheyenne. The Lakota have long identified Wind Cave as a site of genesis where the first humans emerged from the subterranean depths of the cave. The park land above the cave also has long been a place of important cultural connection for the Lakota, who believe that the site is the home of the buffalo nation and carries cosmological traditions about the relationships between the cave, bison, regeneration, and the wind. The Lakota, Cheyenne and many other tribes continue to hold important cultural relationships between humans, animals, and topographical features in the Black Hills, including Wind Cave.

The surface features of the park include expanses of mixed-grass prairie, ponderosa pine, and riparian ecosystems. The gently rolling landscape of the park is a transition zone between eastern and western biomes and supports a great diversity of plant and animal species. The park is well known for its resident bison herd, as well as its opportunities to view mule deer, white-tailed deer, pronghorn, elk, prairie dogs, wild turkey, and a variety of other small mammals.

The cultural resources of the park include archeological evidence of pre-contact and Plains Indian cultures, records of early cave exploration, historic ranching and tourism, and Civilian Conservation Corps (CCC) structures. The National Register of Historic Places (NRHP) includes the Wind Cave National Park Administrative and Utility Area Historic District along with several related historic properties. Other national register-eligible properties are scattered throughout the park. South Dakota Highway 87 within the park may meet the criteria for national register eligibility as a cultural landscape. No national register-eligible traditional cultural properties have been formally defined for the park.

Today, Wind Cave National Park exists as a testament to the long-range visions and collective efforts of many local, state, and national advocates to protect and restore the important resources, setting, and natural systems within this area of the Southern Black Hills as a public resource to be enjoyed by all in perpetuity. Approximately 500,000 people visit the park annually for recreation, including 120,000 touring Wind Cave. Other popular visitor activities include wildlife viewing, camping, hiking, and otherwise enjoying the area for its natural values.

DEVELOPMENT OF THE RESOURCE STEWARDSHIP STRATEGY FOR WIND CAVE NATIONAL PARK

This resource stewardship strategy represents the collaborative efforts of National Park Service (NPS) personnel from the park; the NPS Regional Office for Interior Regions 3, 4, and 5; the NPS Cultural Resources, Partnerships and Science Directorate; the NPS Natural Resource Stewardship and Science Directorate (NRSS), including the Climate Change Response Program (CCRP) and Northern Great Plains (NGPN) Inventory & Monitoring (I&M) Network; the U.S. Geological Survey (USGS); the North Central Climate Adaptation Science Center (NC CASC); and the NPS Denver Service Center, Planning Division (collectively referred to as "the RSS project team" hereafter). It is based on information about park resources that was available at the time of RSS development and on the experience and professional judgment of resource specialists.

In developing the resource stewardship strategy, the RSS project team followed a five-step process established by a national NPS working group that formed to provide direction and oversight for RSS efforts nationwide. This standard RSS process was modified, in consultation with CCRP, USGS, and NC CASC team members, to incorporate additional steps for climate change scenario planning for Wind Cave National Park (figure 2). This integrated process is described below.

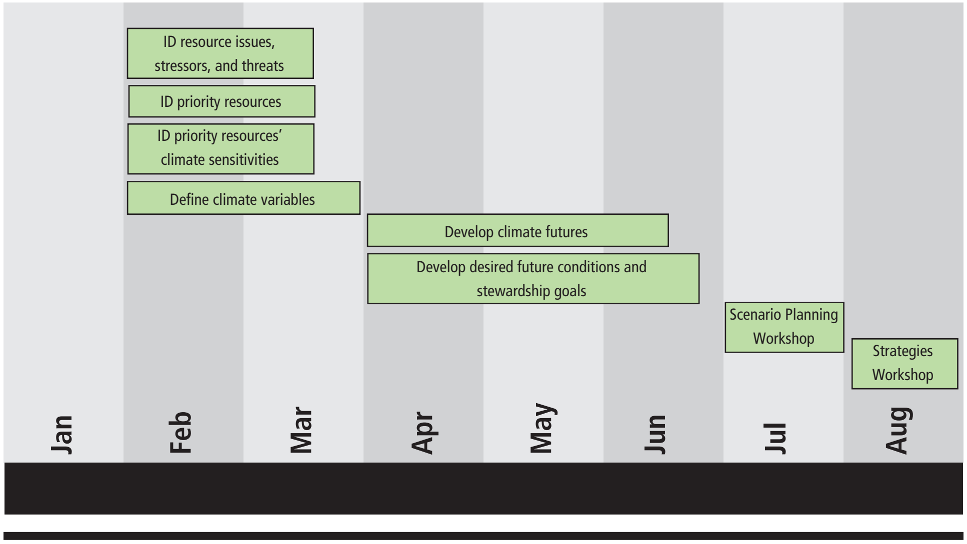


Figure 2. WICA RSS-CCSP Process

Background

Ongoing anthropogenic climate change is evident across the National Park System. These changes, in turn, affect all aspects of park management—from natural and cultural resource management to facilities, operations, and visitor experience.

Relevant scientific information about climate change and its effects is increasingly abundant, but considerable uncertainty regarding future climate changes, the rates of those changes, and the responses of the cultural and natural resources to those changes still exists (figure 3). Forward-looking resource stewardship in an era of continuous change requires effective approaches for understanding and working with consequential and irreducible uncertainty.

The National Park Service and partners have developed and refined a scenario planning approach that works with uncertainty and is based on expert knowledge and synthesis of existing science (NPS 2013, Fisichelli et al. 2016a, Fisichelli et al. 2016b, Star et al. 2016). To help resource managers plan and respond effectively to climate change-related key issues, stressors, and threats, representatives from the National Park Service, the U.S. Geological Survey, and the North Central Climate Adaptation Science Center have developed pilot projects that dovetail the RSS process with the climate change scenario planning process. Climate scientists, adaptation specialists, natural and cultural resource specialists, and planners worked with managers and subject-matter experts at the park to integrate climate change scenario planning into the development of this resource stewardship strategy for WICA. This supplemental project was funded by the North Central Climate Adaptation Science Center.

The WICA RSS project team used scenario planning to identify key climate sensitivities in resources and management concerns, examine a range of plausible future conditions, and explore management options that will be appropriate and effective across that range of potential futures. A more detailed description of the scenario planning process can be found in appendix B.

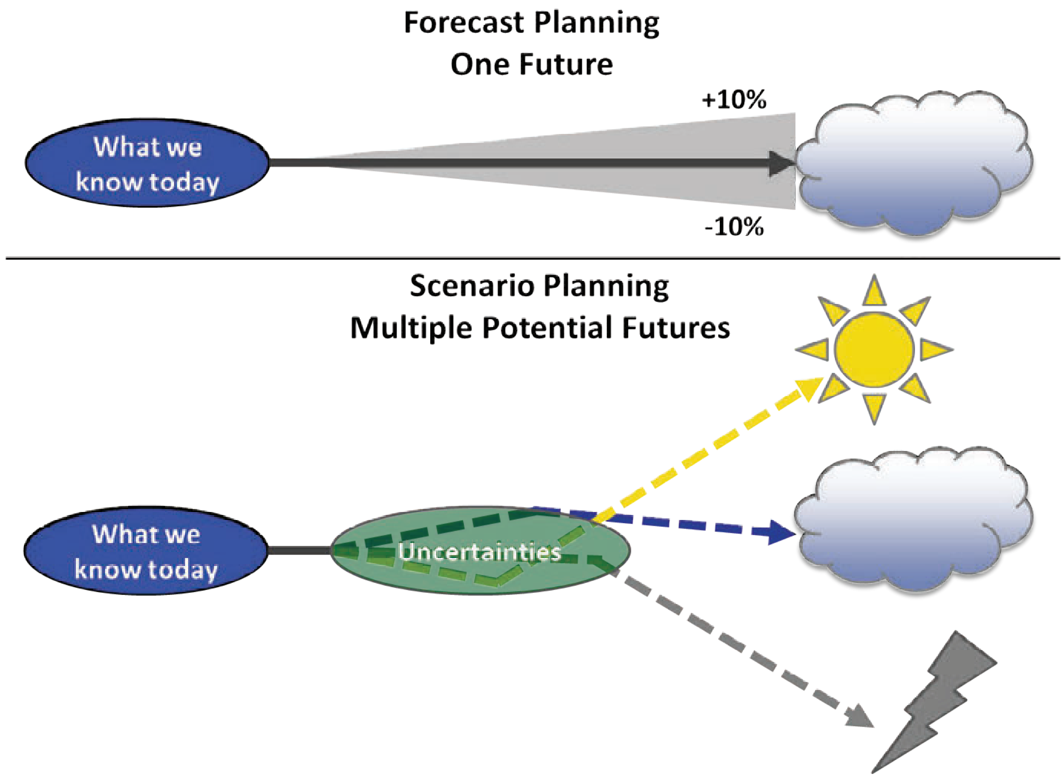


Figure 3. Forecast-based approaches to planning (top panel) use predictions of a single future within a (typically relatively narrow) range of probability (gray shading). Scenarios (bottom panel) characterize a (typically wide) range of distinct future conditions that are all plausible (dashed lines) and provide a framework to support decision making under conditions that are uncertain and uncontrollable. Graphics adapted from Global Business Network.

Summary of the Integrated RSS-CCSP Process for Wind Cave National Park

First, the RSS project team gathered and evaluated existing information about park resources to determine the current condition of resources and the status of information. Next, the team identified the RSS priority resources and their components and preliminary stewardship goals for those priority resources. The team's climate scientists and adaptation specialists then developed four robust climate futures. This involved working with the broader RSS project team to identify the climate sensitivities of the park's priority resources, selecting a set of four climate projections according to those sensitivities, and summarizing relevant climate data for each of those climate projections. These four divergent climate futures encompass the range of ways the park's climate could shift in the coming decades. Finally, the RSS project team developed each climate future into a climate-resource scenario. This step included applying each climate future to each priority resource to identify the resource and management implications under each of the four climate futures. Both the climate and non-climate implications of the key issues, stressors, and threats were then taken into consideration in refining stewardship goals for each priority resource.

Finally, the RSS project team identified stewardship activities aimed at achieving those goals and prioritized activities to implement within the next three to five years. The organization of this summary document parallels this RSS development process, which is described in more detail in internal NPS documents, including the *RSS Development Guide* and the *Supplemental Guidance: Integration of Climate Change Scenario Planning into the Resource Stewardship Strategy Process*. Some key terms that are used throughout this summary document are defined below.

DEFINITIONS OF KEY TERMS

Priority Resource: A cultural or natural resource or value that the National Park Service manages or monitors to maintain a park unit's purpose and significance, to address policy/law mandates, or to address scholarly and scientific research needs or findings.

Priority Resource Component: An aspect or attributing resource that is integral to the functionality, importance, or condition of a priority resource and can be managed or monitored practically over the next five-year horizon. A priority resource component is included, or nested, under the associated priority resources.

Stewardship Activity: One or more initiatives that lead to the achievement of a short-term stewardship goal. On its own, a stewardship activity should produce a specific deliverable or outcome. Activities may include assessments, documentation, identification, maintenance, operations, resource protection, thematic studies, cataloging, evaluation, interpretation, planning, training, data recovery, education, inventory, monitoring, research, survey, treatment, restoration, or other types of management.

Stewardship Goal: A description of what resource condition or information that managers are working to achieve for a particular priority resource or component. Stewardship goals guide the National Park Service in its aim to enhance information; improve or maintain resource conditions; address issues, stressors, or threats; or achieve other park stewardship needs related to the priority resource such as increasing collaboration with partners or expanding education, interpretation, and other programming

Strategy: A tactical path forward defined through achievable actions that maintain or improve aspects of a priority resource / component. Strategies start with a stewardship goal and include a comprehensive set of activities to achieve that goal. Strategies are logically organized, science/scholarship-based, well documented, and reviewed by subject-matter experts. The typical timeframe for executing a strategy is short term typically three to five years, depending on a park's needs.

KEY PARK ISSUES, STRESSORS, AND THREATS

Wind Cave National Park faces a variety of issues, stressors, and threats that affect park resources or may potentially affect park resources in the future. These include factors that are related to climate change and those that are unrelated. Key issues are management concerns that directly relate to park resources and their conditions. Stressors are factors that exacerbate change in resource conditions, while threats are immediate or potential factors that may negatively impact park resources in the future but do not currently affect park resources. The identification of key issues, stressors, and threats helped drive the selection of priority resources for this resource stewardship strategy. Furthermore, the National Park Service considered key issues, stressors, and threats when setting stewardship goals for priority resources and when developing and prioritizing stewardship activities that respond to those goals.

The key issues, stressors, threats that do not directly involve climate change (non-climate) and their implications on the priority resources were identified and analyzed below in table 1.

Table 1. Key Issues, Stressors, and Threats, Potential Implications, and Affected Resources

ISSUE, STRESSOR, OR THREAT	POTENTIAL IMPLICATIONS	RESOURCE TYPES AFFECTED
OVERPOPULATION OF ELK AND BISON	Historical overpopulation of bison and elk has led to grazing pressure on native plants. High levels of bison and elk grazing/browsing can adversely impact the health of those plant communities throughout the park through loss of species diversity, erosion of soils, reduced regeneration, and increases in exotic plant species.	Native vegetation, wildlife, soils, water quality, archeological resources
DISEASE	Diseases such as chronic wasting disease (elk), sylvatic plague (prairie dogs and black-footed ferrets), and white-nose syndrome (bats) can have minor to devastating impacts on wildlife populations. The presence of disease in wildlife populations at the park and state can lead to limitations on what management strategies park staff can use to manage wildlife populations.	Wildlife
INVASIVE PLANTS	Invasive species threaten structure, function, composition, and diversity of native communities; displace species; alter water availability, nutrient cycles, and disturbance regimes; and affect visitor experience.	Native vegetation, soils, ethnographic resources,

Table 1. Key Issues, Stressors, and Threats, Potential Implications, and Affected Resources (continued)

ISSUE, STRESSOR, OR THREAT	POTENTIAL IMPLICATIONS	RESOURCE TYPES AFFECTED
WILDLAND FIRE MANAGEMENT	Fire suppression and significant alterations to the landscape in the region have disrupted natural fire processes that are integral to the health of native ecosystems. As climate change continues, the effects of this suppression on natural systems could be compounded. Population growth and increasing visitation may lead to greater frequency of human-started fires.	Vegetation, soils, water quality, wildlife, ethnographic resources
WATER POLLUTION	Ongoing land uses in the watershed threaten the quality of surface waters. Animal waste, the application of agricultural fertilizer, and discharge from septic systems and other sewage treatment contribute to elevated nitrogen and phosphorus loading in park waters. Likewise, other agricultural practices, industrial land uses, and road runoff in the surrounding area introduce other pollutants to the park's waters.	Water quality, vegetation
WATER WITHDRAWALS	Impoundments on creeks upstream of WICA increase evaporation and reduce surface flow in the park, leaving little surface water available for aquatic organisms, riparian vegetation, and wildlife. Streamflow declines also affect groundwater recharge and cave geologic processes. Subterranean lake water levels could be affected by groundwater withdrawals in the Madison Aquifer. Increases in mean temperature and reductions in precipitation could also reduce groundwater recharge for the karst system.	Hydrology, vegetation, wildlife, soils, cave lakes, cave geologic processes
AIR POLLUTION	Without the effects of pollution, visual range is between 115 and 200 miles. However, views are diminished by pollution-caused haze, reducing visual range to between 65 and 170 miles. At night, particulates also scatter artificial light, increasing the impact of light pollution to the night skies. Total nitrogen deposition is above the minimum ecosystem critical loads for some park vegetation communities, suggesting that lichen, herbaceous, and forest vegetation are at risk for harmful effects. The nutrient enrichment effects can help invasive plant species grow faster (including cheatgrass) and out-compete native vegetation adapted to lower nitrogen conditions. Airborne toxics, including mercury, can deposit and accumulate in organisms, including insect, bird, bat, amphibian, and reptile species, leading to reduced foraging efficiency, survival, and reproductive success.	Air quality, scenic views, wildlife, native vegetation, water resources

Table 1. Key Issues, Stressors, and Threats, Potential Implications, and Affected Resources (continued)

ISSUE, STRESSOR, OR THREAT	POTENTIAL IMPLICATIONS	RESOURCE TYPES AFFECTED
CATALOGING BACKLOG	Without cataloging, the collection is threatened by inappropriate storage and remains of minimal utility. Park staff and outside researchers are unable to know the extent of the records in the park's collections.	Museum collections
LACK OF MUSEUM COLLECTION STORAGE SPACE	Current museum collection storage space is small and limits the park's ability to accept items. Lack of storage space can lead to deterioration of museum objects and archives and an inadequate representation of the park's resources.	Museum collections
REGIONAL DEVELOPMENT AND SURROUNDING LAND USE	Increasing population growth and development (e.g., adjacent communities, energy development) in the region is impacting park resources. With development, the park is witnessing increasing light and noise pollution and obstructions to views. Increasing demand for water use may affect water levels of the Madison Aquifer, impacting cave lakes.	Views, air quality, dark night skies, water resources
LACK OF BASELINE ARCHEOLOGICAL RESOURCE INFORMATION AND ACCESS TO IT	Lack of baseline information regarding archeological resources limits detection of deteriorating resource conditions and promotes inadequate or misguided decisions.	Archeological resources

Understanding the climate change-related key issues, stressors, and threats and their specific implications for the priority resources is an important step in integrating climate change into the RSS process; this information will become the basis for developing or refining appropriate and meaningful RSS goals and activities that respond to those issues, stressors, and threats. Although climate change implications are already often considered as one type of stressor or threat to park resources in the standard RSS process, climate-resource scenario integration in this RSS process included an additional step for organizing the implications of these climate stressors and threats under each plausible climate future.

Relevant scientific information about climate change and its effects is increasingly abundant, but considerable uncertainty regarding future climate changes, the rates of those changes, and the responses of the cultural and natural resources to those changes still exists. Therefore, the RSS project team developed a set of four divergent climate futures that encompass the range of ways the park's climate could shift in the coming decades. A full description of the process of developing divergent climate futures and climate-resource scenarios (the implications of each climate future on the park's priority resources) is found in appendix B. Table 2 summarizes changes in climate metrics for each of the climate futures developed for the scenario planning process.

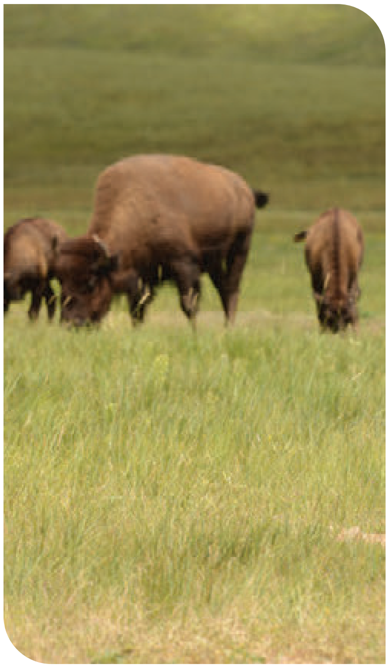
Table 2. Changes in Climate Metrics in Four Divergent Climate Futures for WICA

Metric	CLIMATE FUTURE 1	CLIMATE FUTURE 2	CLIMATE FUTURE 3	CLIMATE FUTURE 4
Warming	Large increase in mean annual temperature (+4.3 °F). Largest increase in fall; much smaller increase in spring. Large loss of winter with high variability of winter metrics. Average winter 32 days shorter, with large increases in daily maximum and minimum temperatures. Large increases in hot days (+17 > 97 °f and +24 with high heat index).	Modest temperature increase (avg +2.1 °F) across all seasons with little variability. Little loss of winter. 9 Fewer days < 32 °f and 20 fewer days of winter. Moderate increase in hot days (+5 > 97 °f and +16 with high heat index).	Largest increase in mean annual temperatures (+5.4 °F) with a moderate degree of inter-annual variability. High warming across all seasons except spring. Largest loss of winter but with less variability. Average winter 40 days shorter, with 31 fewer days < 32 °F. High increase in hot days (+20 > 97 °F and +31 with high heat index) with high inter-annual variability	Consistent, large increase in mean annual temperatures (+4.6 °F). Highest increases in summer months; moderate increases in fall / winter. Moderate loss of winter. 18 fewer days < 32 °F and 12 fewer days of winter. Largest increase in hot days with consistency across years (+22 > 97 °F and +34 with high heat index).
Precipitation	Increasing but highly variable inter-annual precipitation (+7% / year). Largest increases in winter and spring precipitation with increase in spring moisture availability. Increase in most extreme precipitation metrics but—due to variability—minimums also lower than historical minimums.	Slight decline in annual precipitation (-7% / year). Slightly increasing spring and summer precipitation but decline in spring moisture availability. Slight decline in extreme precipitation metrics.	Little change in annual precipitation (+1.7%) but moderately variable between years. Large increase in spring precipitation with slight increases in winter and fall. Slight increase in spring moisture availability. Increase in most extreme precipitation metrics; but due to variability, minimums are also lower than historical minimums	Consistent, significant declines in annual precipitation (-12% / year). Large decrease in summer and moderate decrease in spring precipitation resulting in decline in spring moisture availability. Little change in extreme precipitation metrics, slight decline.
Drought	Similar to historical drought regime in duration and frequency but more intense and slightly longer.	Similar to historical drought regime. Perhaps slightly more frequent droughts due to climate being slightly warmer and drier.	Flash droughts. Infrequent and short but intense droughts. Drought similar to the 2012 drought occurs twice per decade.	Extended droughts. More frequent and longer droughts but of moderate intensity. Drought similar to 2000s drought occurs 40% of the time.

The following changes in climate metrics occur across all four climate futures:

- Increasing average annual temperatures
- Increase in T_{max} and T_{min} in all seasons
- Loss of winter (increasing average winter temps, significant drop in days < 32 °F and days < 0 °F, and shorter winters)
- Fewer freeze-thaw cycles
- Longer growing seasons
- Two to three more late-spring frost events per year
- Increase in days with temperatures greater than historically hot temperatures
- Significant increase in days with high heat index
- Modest increase in winter precipitation
- Increase in the proportion of years that are part of a multi-year drought
- Fewer years between droughts
- More intense droughts

PRIORITY RESOURCES AND COMPONENTS



Priority resources drive the entire RSS process by focusing attention on those park resources that are critical and could most benefit from management direction within the next three to five years. Typically, the priority resources for a resource stewardship strategy may include those that are defined in a foundation document as fundamental or other important resources, as well as additional resources that park staff believes are necessary to maintain the park's purpose and significance, address policy or legal mandates, or address scholarly and scientific research needs. Certain priority resources are standalone, while others may be subdivided into one or more components. The identification of priority resources and components guides the development of stewardship goals and activities in subsequent steps of RSS development. Parsing out the components of each priority resource may help resource managers tailor these goals and activities to more directly target the resource condition or understanding of its constituent parts. Collectively, this component-level stewardship works to improve the condition or understanding of the broader, "umbrella" priority resource.

Table 3 includes a list of priority resources and their components for the WICA resource stewardship strategy. Each priority resource is described in a summary narrative that follows the table.

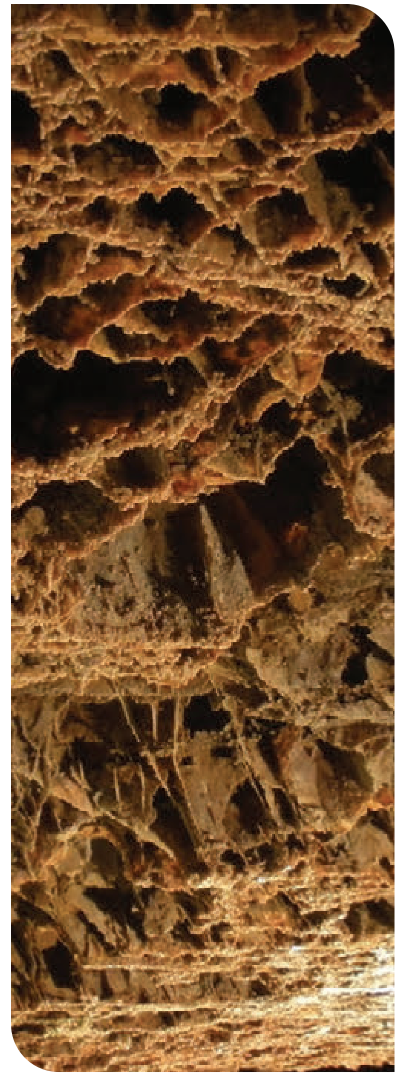
Table 3. Priority Resources and Their Components

PRIORITY RESOURCE	COMPONENT(S)
WIND CAVE*	- *No components identified*
NATIVE WILDLIFE*	- Bison - Elk - Black-tailed Prairie Dog - Black-footed Ferret - Bats
NATIVE VEGETATION*	- Across Park - Prairie/Forest Complex - Riparian - Rare Plant Species
WATER RESOURCES*	- *No components identified*
AIR QUALITY*	- *No components identified*
VIEWS	- *No components identified*
DARK NIGHT SKIES	- *No components identified*
SOUNDSCAPES	- *No components identified*
ARCHEOLOGY*	- *No components identified*
MUSEUM COLLECTIONS*	- *No components identified*
HISTORIC STRUCTURES AND CULTURAL LANDSCAPES*	- *Sanson Ranch* - *CCC-era buildings* - *Mission 66-era buildings*
ETHNOGRAPHIC RESOURCES*	- N/A

*These priority resources were determined to be climate-sensitive by the RSS project team.

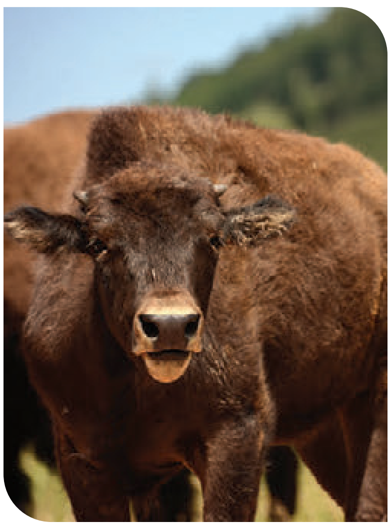
PRIORITY RESOURCE SUMMARIES

These brief descriptions of the park's priority resources were adapted from the park's 2011 Natural Resource Condition Assessment, draft Cultural Resource Stewardship Assessment, 2015 Zoning Management Plan, Natural Resource Reports, and other park reports.



WIND CAVE

Wind Cave is the world's best known example of a multi-level rectilinear maze cave, with anywhere from one to eight interconnecting levels at any given point. More than 154 miles of passages have been explored and mapped to date, making Wind Cave one of the longest cave surveys in the world (currently seventh). Studies of the airflow for which the cave is named suggest that only a tiny fraction of the cave's potential extent has been surveyed. Wind Cave's age, length, and passage density are enough to list it in the ranks of world-class caves, but the cave is significant for many other reasons; the best known of these is boxwork. Boxwork is rarely found in other caves but is found in Wind Cave in quantities and qualities that are unparalleled in all of the world's known caves. The cave is known for its rare and unusual variety of minerals and speleothems, which include helictite bushes, quartz formations, large clusters of frostwork, and fragile growths of gypsum. The ongoing survey project continually makes new discoveries of unusual features in the cave. Several formation types were first identified, described, and named from Wind Cave, including boxwork, frostwork, and helictite bushes. The cave has a simple, but highly specialized ecosystem that operates independently of photosynthesis. More than 200 microbe species have been identified to date, 60 of which are new to science. Finally, the lakes in Wind Cave are the best known access point for humans to interact with the Madison aquifer, which stretches across five states. Cave hydrology and physical processes are greatly influenced by surface water and groundwater, which are addressed separately under the priority resource 'Water Resources.'



NATIVE WILDLIFE

Wind Cave National Park supports one of the most intact prairie wildlife communities in North America, with pronghorn, mule deer, white-tailed deer, elk, prairie dogs, mountain lions, endangered black-footed ferrets, and genetically diverse and brucellosis-free American bison. The mixture of prairie and forest ecotones provides habitat for numerous eastern and western birds as well as small mammals. In total, approximately 200 bird, 48 mammal, 11 reptile, and 6 amphibian species have been recorded at the park.

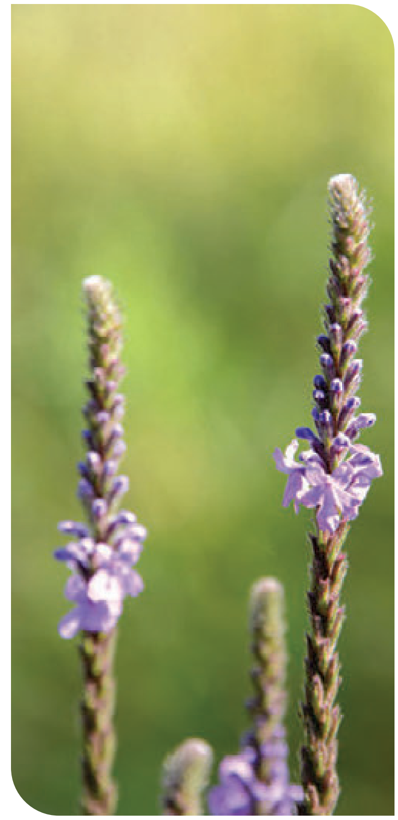
The park is maintaining elk and bison herds at conservative levels to prevent overgrazing. The bison herd is managed to keep the population around 400 animals, while the elk population is maintained to be between 232 and 475 animals. Populations are managed according to the park's bison and elk management plans.

The prairie dog is an integral part of the park's ecosystem and it is an important prey species for park predators such as black-footed ferrets, coyotes, badgers, and hawks. Prairie dogs have a symbiotic relationship with bison, pronghorn antelope, and the burrowing owl. There is an ongoing program to monitor and control prairie dog populations, especially along park boundaries where they might expand onto state or private lands.

The black-footed ferret is currently classified as an endangered species at both the state and federal level. In 2007, black-footed ferrets were reintroduced into the park as an endangered species. In the fall of 2019, Wind Cave released 29 ferrets on nine prairie dog colonies distributed throughout the park to augment their estimated population of 18 to 20 ferrets. This addition will boost population numbers and provide additional genetic diversity.

Twelve species of bats have been confirmed present at the park. Wind Cave and other small caves in the park do not appear to be hibernacula (winter homes) or roosting sites for large numbers of bats, probably because of unsuitable cave climate. The limestone cliffs and forests on the park likely provide good bat roosting habitat.

NATIVE VEGETATION



Native plant communities are a significant resource in WICA; along with water, they form the ecological foundation for wildlife and many of the natural processes occurring within the park. WICA represents a unique ecotone between the Northern Great Plains and southern Black Hills vegetation. According to a Black Hills Community Inventory (based on U.S. National Vegetation Classifications), the park contains 22 plant community types, nine of which are considered rare (i.e., NatureServe Global ranks of G1 to G3). Two-thirds of the park is covered by mixed-grass prairie, consisting primarily of blue grama, western wheatgrass, little bluestem, and threadleaf sedge. Ponderosa pine dominates the forest cover, and, in some areas, ponderosa pine is found in conjunction with Rocky Mountain juniper. Deciduous tree species in the park include paper birch, plains cottonwood, quaking aspen, bur oak, and American elm, among others. Wooded draws and riparian vegetation represent a small proportion of the park landscape but are integral to the ecosystem.

The state of South Dakota Natural Heritage Program (SDNHP) has a process of evaluation to establish plant species of concern based on a state-wide context. There are currently 223 plant species on the SDNHP state list of tracked rare plant species. Seventeen of these occur or have been reported to occur in the park. Also, WICA recognizes plant species that are uncommon in a park-wide context. The 17 state-tracked species and 48 species of limited occurrence are the object of inventory, monitoring, and protection relative to park management activities at WICA.

WATER RESOURCES

Wind Cave National Park lies within the Cheyenne River Basin, which is part of the greater Missouri River watershed. Three perennial streams form sub-watersheds in the park: Beaver Creek, Highland Creek, and Cold Springs Creek, with Beaver Creek being the major drainage of the park. The headwaters of Beaver Creek originate outside of the park near the city of Custer, South Dakota. After entering the park, the entire flow from Beaver Creek often infiltrates the streambed as it flows over the Madison Limestone formation, contributing to recharge in this aquifer. Surface hydrology can change greatly in the park depending on the amount of precipitation that occurs annually. There are 97 springs documented within the park that provide beneficial uses to wildlife. The springflow largely depends on precipitation, and most of the springs do not discharge during dry periods. Of the 97 springs, nine currently are developed (spring boxes and water tanks) to provide water for animals.

Groundwater is held in several aquifers, with the primary aquifers being the Deadwood, Madison, and Minnelusa. A large portion of groundwater recharge is provided by stream flow infiltration as the water intersects karstic limestone outcrops, and groundwater levels respond quickly to significant recharge events in the area. Portions of Wind Cave intersect the water table of the Madison Aquifer and form a series of groundwater lakes within the cave.

AIR QUALITY

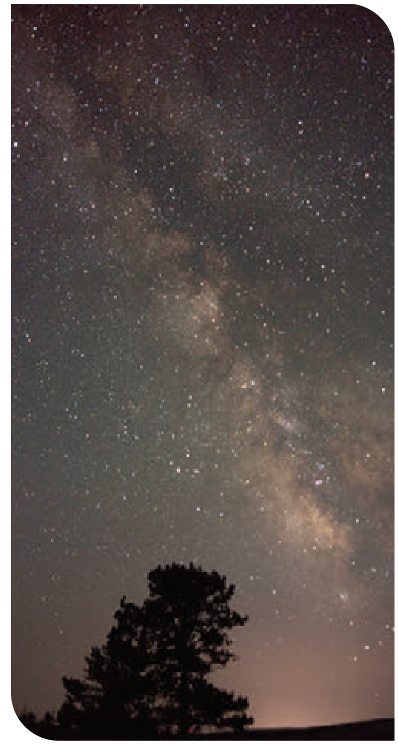
Wind Cave National Park is a Clean Air Act Class I area. This designation provides special protection for air quality, sensitive ecosystems, and clean, clear views. Clean air enhances the color and contrast of the park's landscape features; allows visitors to see great distances; enhances views of the wide open expanses and naturally dark night skies; and contributes directly to ecosystem, visitor, and staff health. According to NPS Air Resources Division methods, overall air quality is in fair condition and is relatively unchanged from 2008 through 2017, the most recent 10-year period analyzed. The overall condition and trend is a combination of air quality indicators for visibility, particulate matter, ozone human health, ozone vegetation health, and pollutant deposition, including nitrogen, sulfur, and mercury. For 2008-2017, trends were relatively unchanged for visibility, ozone, and wet nitrogen deposition, while wet sulfur deposition improved. Sources of air pollution in the park include coal-fired power plants, oil and gas production, mining, agriculture, fires, and vehicle exhaust. Since 2000, emissions from power plants in the region have decreased by over 50% for the protection of class I areas, including Wind Cave National Park. However, emissions from extensive oil and gas development in the nearby Powder River Basin and Denver Basin are likely to increase in the future.

VIEWS

Wind Cave National Park provides some of the most expansive, unobstructed natural vistas in the Black Hills region. These vistas provide a backdrop for viewing the extraordinary abundance of native animal species. From them, a visitor can visualize the park as it might have appeared before the advent of modern development. Views offered at Wind Cave include both natural and cultural resources within and beyond the park, including Buffalo Gap, the badlands and grasslands to the east and south, the Seven Sisters Range, and Black Elk Peak. Expansive views of the park's open, rolling mixed-grass prairies can be seen from higher elevation areas along South Dakota State Highway 87 or NPS 5. The portion of Hwy 87 that is located within Wind Cave has been maintained by the National Park Service as a scenic road in a manner that has largely preserved the original roadway design and natural setting. The overall condition and quality of park scenery is remarkable with regard to the desired condition of a "natural appearing landscape," although in several locations, views have deteriorated because of increasing levels of development on lands outside the park.

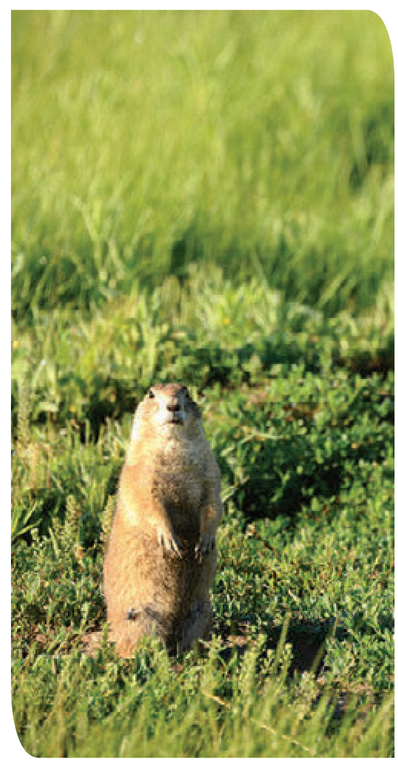
DARK NIGHT SKIES

The National Park Service strives to preserve dark sky views for the enjoyment of park visitors and the well-being of wildlife and habitat. Dark skies provide refuge for wildlife and allow natural processes and rhythms to evolve unimpeded. Wildlife often depend upon the dark sky for survival, using natural patterns of light and dark to navigate, reproduce, hunt, and hide from predators. Wind Cave National Park's rural location creates enjoyable, relatively undisturbed night skies for stargazers. At night, the Milky Way typically stretches from horizon to horizon and displays a lot of detail. Most observers would feel they are in a natural environment, and there would be negligible impact to dark adaptation of eyesight. However, because of the park's relatively close proximity to residential sites, the quality of WICA's night skies is influenced by anthropogenic light sources, including light domes from Custer, Hot Springs, Rapid City, and Mount Rushmore National Memorial.



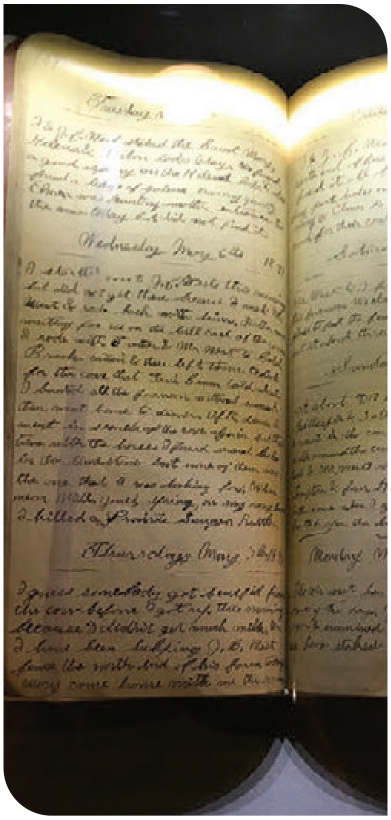
SOUNDSCAPES

The soundscape at Wind Cave National Park varies across the landscape, with a variety of audible natural sounds depending on the location. Natural sounds serve a critical ecological role, while enhancing the visitor experience. Sounds from native wildlife include the occasional elk bugling in September, coyote howling during the day or night, or prairie dogs barking during the day. Breezes rustle through the tree leaves and grasses in the prairie. Summer brings thunderstorms and the sounds of insects during warm afternoons. The sound of wind gusting through trees in the fall portends the upcoming winter season with both its winter snowstorms and impressive silent nights. Animals depend on hearing natural sounds in the environment for a range of activities, including communication, establishing territories, courting and mating, raising families, finding food, and avoiding predators. Currently, the park is one of the least impacted acoustic environments in the Midwest because it has relatively low ambient sound levels. Anthropogenic sounds (cars, park maintenance, etc.) most likely to occur at WICA can be heard near the park office or near roads within the park.



ARCHEOLOGY

Wind Cave National Park contains 276 recorded archeological sites, including one of the oldest archeological rock shelter sites, dating back nearly 7,000 years, in the Black Hills. Both pre-contact and historic sites are found at the park, and include features such as rock art, rock shelters, tipi rings, village sites, rock cairns, kill sites, quarries, lithic scatters, lithic reduction sites, historic homestead sites, and dump sites or middens. One site, the Beaver Creek Rock Shelter, has been listed in the National Register of Historic Places. 29 additional sites are recommended to be potentially eligible for listing. Four sites have been determined to not be eligible, with an additional 14 sites recommended as not eligible. As of January 2020, the remaining 232 sites have not been evaluated.



MUSEUM COLLECTIONS

WICA's museum collections consist of archival materials, cultural resources that include archeological materials recovered from within the park, and natural history specimens. The collections are small in size, numbering approximately 64,000 items in total as reported in the 2018 Collection Management Report. As of fiscal year 2019, 72% of the collections have been cataloged. This number does not reflect a potential accession backlog of resource management records, scientific specimens and associated archives, and other potential archival materials. The collections are assessed to be in good condition.

HISTORIC STRUCTURES AND CULTURAL LANDSCAPES

WICA has 29 structures listed in the National Register of Historic Places. The majority of these structures, including the park's visitor center, were constructed by the Civilian Conservation Corps in the 1930s. These CCC-era structures now comprise the Wind Cave Administrative and Utility Area Historic District. Twenty-seven of the twenty-nine structures are listed as being in good condition per the List of Classified Structures.

In 2011, the park expanded by 5,556 acres. Included in this new acreage was the 160-acre Sanson Family Ranch, one of the earliest homesteads in Custer County. The Sanson Ranch has been determined eligible for inclusion on the National Register of Historic Places, but, as of fiscal year 2019, has not yet been nominated.

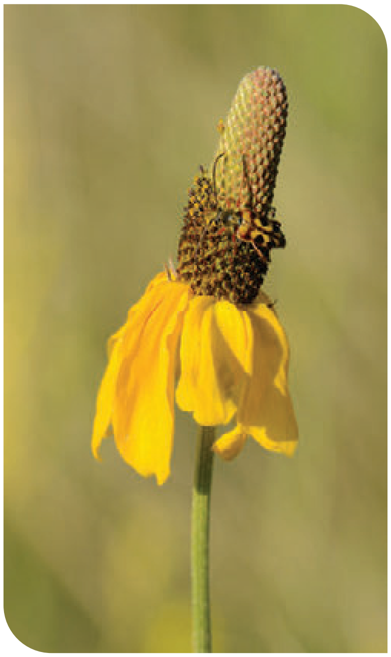
In addition to the individual structures, the park has three documented cultural landscapes. Both the Wind Cave National Park Historic District, an expansion of the Wind Cave Administrative and Utility Area District, and the South Dakota 87 Historic District have up-to-date cultural landscape inventory (CLI) and cultural landscape report (CLR) information. The landscape of the Sanson Ranch was identified in a draft 2014 cultural landscape inventory, though that report remains incomplete.

ETHNOGRAPHIC RESOURCES

Over the past 300 years, American Indian tribes of many different origins have had varying degrees of affiliation, historical as well as cultural, with areas of the Black Hills in and around Wind Cave National Park. Only some of them, notably the Lakota, the Cheyenne, and possibly the Arapaho, have retained an ongoing association with the area that conforms to the definition of a traditional cultural property.

The park and its surrounding environments are resource-rich areas for animals, plants, waters, minerals, and soils used in traditional culture contexts. Many of these resources continue to play a role in contemporary religious observances. Other ethnographic resources of special importance within the park include springs, bluffs, rocky outcroppings, ridges, and burial sites. A good ethnographic overview and assessment is available to park staff, and a current ethnobotany study is being developed as of 2019. Although this documentation is helpful, it is important to note that the locations of places of many religious observances within the park may never be known to park managers.

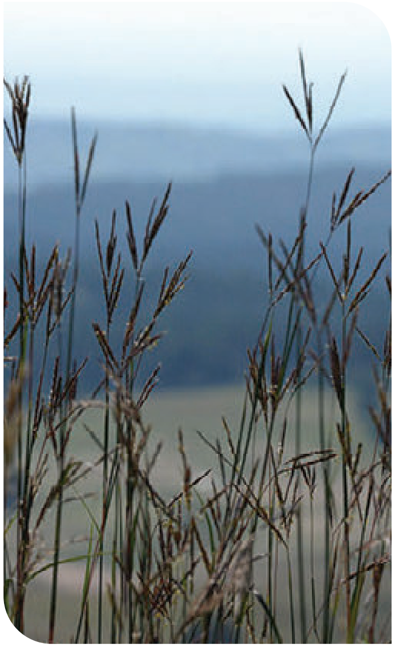
STEWARDSHIP GOALS



Stewardship goals are essential to the RSS process because they articulate what managers are working to achieve for a park's natural and cultural resources and provide both the framework to structure activities later in the RSS process and the time frame needed to reach them. Long-term goals are defined as those that park staff wish to accomplish in a 10- to 20-year time frame. Short-term goals are those that are attainable in a three- to five-year time frame.

Stewardship goals focus on

1. improving quality and/or completeness of current resource information and documentation of one or multiple priority resources;
2. improving or maintaining the conditions of one or multiple priority resources;
3. reducing issues, stressors, or threats that are adversely affecting priority resources; or
4. addressing other management needs for resource stewardship, such as increasing collaboration with partners or expanding education and interpretation related to the park's priority resources.



An important consideration in establishing goals is to determine the appropriate level of knowledge and information and the desired condition for each priority resource and component. Long-term stewardship goals typically bear a strong relationship to broad, qualitative direction for resource management that are set forth in legal mandates, NPS mandates, or established park management documents. Short-term goals tier off long-term goals and set more specific targets for resource management. Short-term goals help drive the development of stewardship activities. Both long-term and short-term goals should be feasible under each of the plausible climate futures developed as part of the climate change scenario planning process. As part of the scenario planning process, the RSS project team examined and refined current management goals for park resources in light of the resource implications under each climate-resource scenario; the results of those assessments are described in detail in appendix B.

The RSS project team identified a wide array of stewardship goals, based upon the current and desired status of information and resource conditions, as well as key issues, stressors, and threats, climate change scenarios, and other management considerations. Long-term and short-term goals are also included in the RSS desktop application, in addition to this summary document (tables 4a - 4l).

Table 4a. Long-Term and Short-Term Stewardship Goals for Wind Cave

COMPONENT	LONG-TERM GOALS	SHORT-TERM GOALS
N/A	Minimize human-caused impacts to the cave, its climate, hydrology, and biological resources.	- To inform management decisions, WICA will continue monitoring airflow patterns, cave climate, CO_2 levels, and mitigation of dust and lint accumulations, and support exploration of the cave. - Reduce unnatural airflow through Walk-In Entrance and the elevator shaft. - Reduce dust deposition along tour routes and off-trail travel routes. - Ensure that infrastructure has minimal impact on cave resources. - Determine the significance of historic artifacts within the cave and decide what goes and what stays.

Table 4b. Long-Term and Short-Term Stewardship Goals for Native Wildlife

COMPONENT	LONG-TERM GOALS	SHORT-TERM GOALS
BISON	The park has a viable population of bison within the target range set by existing management plans (400-650) unless changes to available forage and/or water sources require revising population targets.	- To provide alternative water sources to wildlife during droughts, WICA will improve and maintain developed springs. - Manage bison in accordance with park and regional bison stewardship strategies. - Expand bison range onto the Casey property.
ELK	The park has a viable population of elk within the target range set by existing management plans (232-475) unless new research provides an updated management population target.	- Reduce chronic wasting disease (CWD) prevalence in elk population from 2017 levels.
BLACK-TAILED PRAIRIE DOG	WICA has a viable population of black-tailed prairie dogs across up to 3,300 acres of prairie dog colonies.	- Maintain prairie dogs within population management target, and minimize the risk of plague epizootic over the next five years using best management practices. - WICA contributes to research that promotes plague-management tools.
BLACK-FOOTED FERRET	WICA has a viable population of black-footed ferrets on all suitable habitat by 2040.	- WICA maintains an active ferret management program.
BATS	WICA will reduce threats to bat populations from white-nose syndrome (WNS) and disturbance of hibernating bats.	- To inform management decisions, WICA will have statistically valid estimates of current bat population sizes and activity levels, with sufficient precision and accuracy, by 2025. - To protect bat populations, WICA will minimize human-caused spread of WNS and disturbance of hibernating bats through monitoring, research, and management, by 2025.

Table 4c. Long-Term and Short-Term Stewardship Goals for Native Vegetation

COMPONENT	LONG-TERM GOALS	SHORT-TERM GOALS
ACROSS PARK	Compared to 2019 levels, maintain or increase the abundance and diversity of native plant species across the park and maintain or decrease the abundance proportion of exotic plants and area infested by noxious weeds across the park.	- WICA will reduce exotic and invasive plant cover below 2017 levels.
ACROSS PARK	WICA will increase hardwood density across all size classes by 2030, while preparing for potential longer-term, climate change driven changes that may be difficult or impossible to resist.	- Achieve an increase in hardwood seedlings that show regeneration.
PRAIRIE/ FOREST COMPLEX	WICA will maintain ponderosa pine (PIPO) woodland to achieve fuel loads of 2-10 tons/ acre in those woodlands, through 2040, while preparing for potential longer-term, climate change driven changes that may be difficult or impossible to resist.	- Prescribed fires are completed in high-priority burn units in the following priority order: HQ East & West2, Lookout Flats-Prairie Dog Canyon, Dry Creek-Highland Creek, Beaver, and American Elk-Tower.
RIPARIAN	WICA will maintain riparian and wetland vegetation at current conditions within the park, while preparing for potential longer-term, climate change driven changes that may be difficult or impossible to resist.	- By 2025, vegetation condition based on Multiple Indicator Monitoring is on an increasing trend. - A baseline extent of true riparian vegetation currently in the park is established.
RARE PLANT SPECIES	WICA will minimize negative impacts to rare plant species from park management activities.	- Rare plant species' population locations, sizes, and dynamics are better known and documented.

Table 4d. Long-Term and Short-Term Stewardship Goals for Water Resources

COMPONENT	LONG-TERM GOALS	SHORT-TERM GOALS
N/A	Minimize construction of impoundments upstream of the park that change flow conditions through the park, and limit the withdrawal and diversion of surface and groundwater flowing through the park.	- WICA will maintain ongoing monitoring to increase knowledge about and to detect changes in water quality, spring- and streamflow, and groundwater level that would require active engagement with outside entities. - WICA will continue to minimize the park's water use through implementation of best management practices. - Surface and groundwater conditions meet and/or exceed water quality parameter standards set by the United States Environmental Protection Agency (USEPA) and the state of South Dakota.

Table 4e. Long-Term and Short-Term Stewardship Goals for Air Quality

COMPONENT	LONG-TERM GOALS	SHORT-TERM GOALS
N/A	Improve understanding of air pollution impacts and maintain the long-term air quality data record through continued in-park monitoring of visibility, particulate matter, ozone, and pollutant deposition.	- Improve understanding of air quality through continued monitoring, compiling existing information, identifying sensitive resources, assessing future research needs, and educating park staff about impacts to park resources. - Provide information about air pollution impacts to NPS management, air regulatory agencies, the public, the scientific community, and other stakeholders
N/A	Seek to perpetuate the best possible air quality condition for the protection of resources affected by air pollution, reducing pollutant deposition to below ecosystem critical loads, eliminating human-caused visibility impairment by the year 2064 (where the average visibility is < 2 deciviews above natural conditions), and remaining in attainment for the USEPA National Ambient Air Quality Standards (NAAQS) and in good ozone (W126 index) condition.	- Be an environmental leader by reducing park air pollutant emissions; improving park sustainability and environmental management; and demonstrating the park's commitment to do its part for air/water quality, night sky, and climate change. - Collaborate with other federal, state, regional and local planning organizations, and stakeholders to reduce air quality impacts in the park from external sources of air pollution.

Table 4f. Long-Term and Short-Term Stewardship Goals for Views

COMPONENT	LONG-TERM GOALS	SHORT-TERM GOALS
N/A	Protect, improve, and monitor the condition of views important for natural scenery and cultural resources both within and across park boundaries to maintain or improve visual character and an undeveloped and natural park experience.	- Inventory and assess park views over time to monitor changes in condition. - Minimize changes, visual contrast, and intrusions to views to the extent possible within the park. - Collaborate with adjacent landowners, municipalities, developers, and other stakeholders to promote cooperative conservation of views across park boundaries. - Provide enhanced opportunities for visitors to access and understand the importance of park views.

Table 4g. Long-Term and Short-Term Stewardship Goals for Dark Night Skies

COMPONENT	LONG-TERM GOALS	SHORT-TERM GOALS
N/A	To inform resource management, WICA will quantify and document the condition and trends of the nocturnal environment from artificial light.	- Improve understanding of conditions and trends of the nocturnal environment.
N/A	WICA will improve the night sky resource by reducing light at night within the park boundary.	- Improve the nighttime environment by assessing how the park can improve employee and visitor nighttime scenery within the park boundary.
N/A	WICA will increase outreach and foster investment from the community and nearby partners in the shared night skies.	- Reduce threats to the nocturnal environment and nighttime scenery from outside park boundaries by engaging with the nearby community and raising awareness about the value of the resource and astrotourism, and engage regional partners. - WICA will enhance visitor and student awareness and appreciation of the night sky and its features.

Table 4h. Long-Term and Short-Term Stewardship Goals for Soundscapes

COMPONENT	LONG-TERM GOALS	SHORT-TERM GOALS
N/A	To inform resource management, WICA will characterize the baseline acoustic environment and its relationship and value to other resources.	- Determine the condition and trends of the acoustic resource in the park. - Reduce non-natural and inappropriate noise from park and external activities.

Table 4i. Long-Term and Short-Term Stewardship Goals for Archeology

COMPONENT	LONG-TERM GOALS	SHORT-TERM GOALS
N/A	WICA will have the necessary knowledge to protect significant archeological sites through documentation, monitoring, protection, and mitigation, and maintain integrity in all significant archeological sites, considering climate change and other factors beyond the park's control.	- Monitor and protect an increased number of archeological sites in an undisturbed condition . - Increased information provides guidance for archeology work and identifies the park's high-priority sites, while accounting for climate change vulnerabilities (e.g., changes in precipitation, increased temperature, etc.). - Increase archeological areas surveyed by 5% over the next five years.

Table 4j. Long-Term and Short-Term Stewardship Goals for Museum Collections

COMPONENT	LONG-TERM GOALS	SHORT-TERM GOALS
N/A	WICA museum collections will be fully cataloged within 20 years in accordance with NPS museum management policy. All historical objects and non-paleo natural history objects will be digitized and be made available on the park's website to improve visitor understanding of park history and its natural resources. All historical objects and non-paleo natural history objects will be maintained in good condition in an environment conducive to their long-term safekeeping.	- The park scope of collection statement is up to date and reflects park priorities for accession/deaccessions that support future collection management. - The park addresses overcrowding in museum collections storage. - Increase the number of natural history resource management records that are cataloged over five years. - Increase the number of digitized specimens and historical objects over five years.

Table 4k. Long-Term and Short-Term Stewardship Goals for Historic Structures and Cultural Landscapes

COMPONENT	LONG-TERM GOALS	SHORT-TERM GOALS
SANSON RANCH	WICA will use up-to-date documentation to ensure existing historic structures and documented cultural landscapes retain integrity and NRHP status over the next 20 years	- Restore character-defining features of the Sanson Ranch structures to support future access and interpretation.
CCC-ERA BUILDINGS / MISSION 66 BUILDINGS	WICA will use up-to-date documentation to ensure existing historic structures and documented cultural landscapes retain integrity and NRHP status over the next 20 years	- Assess documentation needs for non-Sanson Ranch historic structures (e.g. the visitor center, the elevator building, the powerhouse, the maintenance yard, and any unevaluated Mission 66 structures) and upload high-priority needs into the Project Management Information System (PMIS).
(ALL)	WICA will use up-to-date documentation to ensure existing historic structures and documented cultural landscapes retain integrity and NRHP status over the next 20 years.	- Maintain cultural landscapes in their national register-eligible condition.

Table 4l. Long-Term and Short-Term Stewardship Goals for Ethnographic Resources

COMPONENT	LONG-TERM GOALS	SHORT-TERM GOALS
N/A	WICA works with tribes through consultation to identify ethnographic resources and the protections they may need in accordance with appropriate laws and regulations.	- Acquire information on ethnographic resources through collaboration with tribes and research.

HIGH-PRIORITY STEWARDSHIP ACTIVITIES

Stewardship activities represent the primary product of the RSS development process, providing the park with a roadmap for investing both human and financial resources in the stewardship of natural and cultural resources. They are logically organized, based on science and/or scholarship, well documented and reviewed by subject-matter experts. Activities are aimed at achieving short-term goals and may also strive to reduce stressors on priority resources and components.

The RSS project team identified a wide array of management activities to consider over the next three- to five-year horizon. Whenever possible, activities were designed with integrated resource stewardship in mind, both in terms of their potential to improve the condition or understanding of multiple resources and/or their potential for efficient deployment through the integrated efforts of multiple staff. For example, fire management at the park benefits many resources. Prescribed fires may be used to restore cultural landscapes, reduce invasive plants, or limit encroachment of ponderosa pine forest into mixed-grass prairie. Still, fire management requires integrated stewardship to protect natural and cultural resources from damage from fire as well as fire management activities. In addition, many of the activities developed involve partnerships or coordination with regional NPS staff. The park made an effort to consider and document integrated resource management efforts within these activities and will seek to carry them out as described.

While the RSS desktop application includes all of the activities identified for each priority resource component, the following table presents only those activities that park staff determined to be high priority in the next three to five years, along with associated short-term goals. The team considered a variety of factors when determining priorities, including feasibility and impact of the management activity, urgency, potential funding opportunities, and sequencing in relation to other activities. Medium and low priority activities are still valuable approaches for achieving resource objectives, but they are generally less urgent or represent secondary approaches. Many of the medium and low priority activities may rise to the level of high priority in the coming years, as stewardship activities are implemented, stewardship goals are achieved, and resource conditions change over time. The full list of activities can be found in Appendix A.

During the climate change scenario planning process, the RSS project team also identified activities that the park may eventually need to implement to achieve resource management goals, depending on future climate conditions. The full list of these activities can be found in appendix B. Only those activities that were identified as a priority for being implemented in the next three to five years appear in this summary document and the desktop application (tables 5a – 5l).

Table 5a. High-Priority Stewardship Activities for Wind Cave

COMPONENT	SHORT-TERM STEWARDSHIP GOAL	HIGH-PRIORITY STEWARDSHIP ACTIVITIES
N/A	To inform management decisions, WICA will continue monitoring airflow patterns, cave climate, CO_2 levels, and mitigation of dust and lint accumulations, and support exploration of the cave.	- Continue vacuuming the cave every other year to remove human-introduced debris.
N/A	Reduce unnatural airflow through the Walk-In Entrance and the elevator shaft.	- *No high-priority activities identified.*
N/A	Reduce dust deposition along tour routes and off-trail travel routes.	- *No high-priority activities identified.*
N/A	Ensure that infrastructure has minimal impact on cave resources.	- *No high-priority activities identified.*
N/A	Determine the significance of historic artifacts within the cave and decide what goes and what stays.	- *No high-priority activities identified.*

Table 5b. High-Priority Stewardship Activities for Native Wildlife

COMPONENT	SHORT-TERM STEWARDSHIP GOAL	HIGH-PRIORITY STEWARDSHIP ACTIVITIES
BISON	To provide alternative water sources to wildlife during droughts, WICA will improve and maintain developed springs.	- Improve or repair four developed springs.
BISON	Manage bison in accordance with park and regional bison stewardship strategies.	- Collaborate with regional office in completing the Draft Decision Framework for the National Park Service Interior Region 5 Bison Stewardship Strategy (in development). - Build a new bison facility. - Continue park bison active management, as informed by the regional bison stewardship strategy (in development). - Continue bison management activities, including continuing to participate in and further develop the Bison Leadership Team and continue to contribute to bison stewardship efforts outside of region (e.g., Grand Canyon) and outside of the National Park Service (e.g., US Fish and Wildlife Service (USFWS), The Nature Conservancy (TNC), etc.).
BISON	Expand bison range onto the Casey property.	- Fence off the water infrastructure (e.g., solar panels, etc.). - Open old boundary fence to allow bison to roam.
ELK	Reduce CWD prevalence in elk population from 2017 levels.	- Continue elk reduction activities to maintain elk at low end of population targets. - Support CWD research. - Continue removing elk carcasses. - Continue to avoid/minimize park activities/practices that congregate wildlife (e.g., salt licks).

Table 5b. High-Priority Stewardship Activities for Native Wildlife (continued)

COMPONENT	SHORT-TERM STEWARDSHIP GOAL	HIGH-PRIORITY STEWARDSHIP ACTIVITIES
BLACK-TAILED PRAIRIE DOG	Maintain prairie dogs within population management target and minimize the risk of plague epizootic over the next five years using best management practices.	- Create sustainable funding to minimize plague risk to prairie dogs. - Use existing disease-management tools (e.g., dusting) as well as new techniques (e.g., oral plague vaccine) and monitor the efficacy of those tools, especially under variable and changing climate conditions.
BLACK-TAILED PRAIRIE DOG	WICA contributes to research that promotes plague-management tools.	- Actively seek funding opportunities from partners to support research in plague management.
BLACK-FOOTED FERRET	WICA maintains an active ferret management program.	- Continue releasing black-footed ferrets and relocating ferrets within the park. - Continue monitoring black-footed ferret populations.
BATS	To inform management decisions, WICA will have statistically valid estimates of current bat population sizes and activity levels, with sufficient precision and accuracy, by 2025.	- Continue annual monitoring of bat usage of Wind Cave at the natural entrance. - Continue to conduct bat surveys at other caves within the park.
BATS	To protect bat populations, WICA will minimize human-caused spread of WNS and disturbance of hibernating bats through monitoring, research, and management, by 2025.	- Maintain the decontamination stations at the entrance and exit to the cave. - Provide information to interpretive staff about wildlife diseases (including WNS) that can be incorporated into interpretive materials and public education. - Continue collecting soil samples from cave to test for WNS. - Continue collaboration with NRSS Biological Resources Division to stay informed on current decontamination protocols/techniques.

Table 5c. High-Priority Stewardship Activities for Native Vegetation

COMPONENT	SHORT-TERM STEWARDSHIP GOAL	HIGH-PRIORITY STEWARDSHIP ACTIVITIES
ACROSS PARK	WICA will reduce exotic and invasive plant cover below 2017 levels.	- Determine strategy for Annual Brome Adaptive Management (ABAM) treatment priorities and assign priorities to burn/ management units accordingly. - Continue to practice Early Detection/ Rapid Response. - Maintain exotic plant mapping, treatment, and monitoring at or above 2018 levels. - Complete seed storage facility. - Create a vegetation management strategy.
ACROSS PARK	Achieve an increase in hardwood seedlings that show regeneration.	- *No high-priority activities identified.*
PRAIRIE/ FOREST COMPLEX	Prescribed fires are completed in high-priority burn units in the following priority order: HQ East & West2, Lookout Flats-Prairie Dog Canyon, Dry Creek-Highland Creek, Beaver, and American Elk-Tower.	- Ensure that Fire Management Office has completed prescribed burn plans and compliance at least three months ahead of burn window. - Conduct yearly coordination meeting between park resource staff and fire ecologist; when feasible coordinate fire planning with archeological specialists. - Maintain support for Northern Great Plains Network (NGPN) and Northern Great Plains (NGP) fire effects monitoring to support resource management. - Support park staff getting trained to support fire program to accommodate expanding shoulder season and wildfire season due to climate change.
RIPARIAN	By 2025, vegetation condition based on Multiple Indicator Monitoring is on an increasing trend.	- Analyze Multiple Indicator Monitoring data and provide recommendations to the park for future management.
RIPARIAN	A baseline extent of true riparian vegetation currently in the park is established.	- *No high-priority activities identified.*
RARE PLANT SPECIES	Rare plant species' population locations, sizes, and dynamics are better known and documented.	- *No high-priority activities identified.*

Table 5d. High-Priority Stewardship Activities for Water Resources

COMPONENT	SHORT-TERM STEWARDSHIP GOAL	HIGH-PRIORITY STEWARDSHIP ACTIVITIES
N/A	WICA will maintain ongoing monitoring to increase knowledge about and to detect changes in water quality, spring- and streamflow, and groundwater level that would require active engagement with outside entities.	- Develop a protocol for surface water quality monitoring; use Technical Assistance Request (TAR). - Collect water samples according to the surface water quality monitoring protocol. - Submit a TAR to the Water Resources Division (WRD) every year for groundwater monitoring (i.e., water levels) and water rights application tracking. - Support I&M cave monitoring by collecting cave lake water samples.
N/A	WICA will continue to minimize the park's water use through implementation of best management practices.	- *No high-priority activities identified.*
N/A	Surface and ground water conditions meet and/or exceed water quality parameter standards set by the USEPA and the state of South Dakota.	- *No high-priority activities identified.*

Table 5e. High-Priority Stewardship Activities for Air Quality

COMPONENT	SHORT-TERM STEWARDSHIP GOAL	HIGH-PRIORITY STEWARDSHIP ACTIVITIES
N/A	Improve understanding of air quality through continued monitoring, compiling existing information, identifying sensitive resources, assessing future research needs, and educating park staff about impacts to park resources.	- Continue to support the NPS air quality monitoring programs and special studies, including IMPROVE, CASTNET, NADP, NPS-GPMP monitoring stations, including site operator staff and training.
N/A	Provide information about air pollution impacts to NPS management, air regulatory agencies, the public, the scientific community, and other stakeholders.	- Provide an air quality section on the park website with content and links to park air quality condition, trends, and implications.
N/A	Be an environmental leader by reducing park air pollutant emissions; improving park sustainability and environmental management; and demonstrating the park's commitment to do its part for air/water quality, night sky, and climate change.	- *No high-priority activities identified.*
N/A	Collaborate with other federal, state, regional and local planning organizations, and stakeholders to reduce air quality impacts in the park from external sources of air pollution.	- Continue to collaborate with nearby NPS units (e.g., DETO, BADL) and park air quality specialists to reduce air quality impacts from sources of pollution.

Table 5f. High-Priority Stewardship Activities for Views

COMPONENT	SHORT-TERM STEWARDSHIP GOAL	HIGH-PRIORITY STEWARDSHIP ACTIVITIES
N/A	Inventory and assess park views over time to monitor changes in condition.	- *No high-priority activities identified..*
N/A	Minimize changes, visual contrast, and intrusions to views to the extent possible within the park.	- Explore options for drought-resistant vegetation screening of maintenance and fire cache area. - Install drought-resistant vegetation screening around Southern Black Hills Water building/fence and/or investigate avenues to encourage removal of the building from the site.
N/A	Collaborate with adjacent landowners, municipalities, developers, and other stakeholders to promote cooperative conservation of views across park boundaries.	- *No high-priority activities identified..*
N/A	Provide enhanced opportunities for visitors to access and understand the importance of park views.	- Establish park webcam(s) to enhance the virtual experience of park scenery.

Table 5g. High-Priority Stewardship Activities for Dark Night Skies

COMPONENT	SHORT-TERM STEWARDSHIP GOAL	HIGH-PRIORITY STEWARDSHIP ACTIVITIES
N/A	Improve understanding of conditions and trends of the nocturnal environment.	- Obtain a baseline night sky data from NRSS Natural Sounds and Night Skies Division (NSNSD) and replicate over time to monitor the night sky for improvements or deterioration.
N/A	Improve the nighttime environment by assessing how the park can improve employee and visitor nighttime scenery within the park boundary.	- Review current lighting within the park and establish a lighting management plan. - Retrofit lighting that is not night sky friendly, using fully sustainable night sky lighting practices. - Remove lights in the park that are unnecessary. - Incorporate night sky-friendly lighting into cattle guard at the south entrance to the park.
N/A	Reduce threats to the nocturnal environment and nighttime scenery from outside park boundaries by engaging with the nearby community and raising awareness about the value of the resource and astrotourism, and engage regional partners.	- *No high-priority activities identified.*
N/A	WICA will enhance visitor and student awareness and appreciation of the night sky and its features.	- *No high-priority activities identified.*

Table 5h. High-Priority Stewardship Activities for Soundscapes

COMPONENT	SHORT-TERM STEWARDSHIP GOAL	HIGH-PRIORITY STEWARDSHIP ACTIVITIES
N/A	Determine the condition and trends of the acoustic resource in the park.	- *No high-priority activities identified.*
N/A	Reduce non-natural and inappropriate noise from park and external activities.	- Explore options for reducing noise from the visitor center generator; for example, replacing the muffler and/or planting trees. - Explore options for retrofitting ATVs and UTVs with new mufflers. - Explore option for replacing cattle guards with quieter designs.

Table 5i. High-Priority Stewardship Activities for Archeology

COMPONENT	SHORT-TERM STEWARDSHIP GOAL	HIGH-PRIORITY STEWARDSHIP ACTIVITIES
N/A	Monitor and protect an increased number of archeological sites in an undisturbed condition.	- *No high-priority activities identified.*
N/A	Increased information provides guidance for archeology work and identifies the park's high-priority sites, while accounting for climate change vulnerabilities (e.g., changes in precipitation, increased temperature, etc.).	- Develop an Archeological Overview and Assessment to summarize existing archeological knowledge, identify relevant research questions, and identify significant gaps in knowledge at WICA related to those questions .
N/A	Increase archeological areas surveyed by 5% over the next five years.	- Meet with MWAC to help determine how they can assist the park. - Write a PMIS statement to increase inventory. - Develop strategy to access archeological expertise onsite for routine and frequent management needs. - Support the increase of areas surveyed throughout the park. - Develop strategy for quick response to conduct post-wildfire archeological inventories. Include Regional Fire, other programs, tribes, WICA, MWAC in discussion.

Table 5j. High-Priority Stewardship Activities for Museum Collections

COMPONENT	SHORT-TERM STEWARDSHIP GOAL	HIGH-PRIORITY STEWARDSHIP ACTIVITIES
N/A	The park scope of collection statement is up to date and reflects park priorities for accession/deaccessions that support future collection management.	- *No high-priority activities identified.*
N/A	The park addresses overcrowding in museum collections storage.	- Explore options for other collections storage locations with reduced fire risk (e.g., off-site.
N/A	Increase the number of natural history resource management records that are cataloged over five years.	- Increase museum staffing. - Explore possibilities of volunteers assisting with cataloging.
N/A	Increase the number of digitized specimens and historical objects over five years.	- *No high-priority activities identified.*

Table 5k. High-Priority Stewardship Activities for Historic Structures and Cultural Landscapes

COMPONENT	SHORT-TERM STEWARDSHIP GOAL	HIGH-PRIORITY STEWARDSHIP ACTIVITIES
SANSON RANCH	Restore character-defining features of the Sanson Ranch structures to support future access and interpretation.	- Prioritize Sanson Ranch restoration projects. - Acquire adequate funding with a PMIS proposal to restore features of Sanson Ranch. - Incorporate wildfire protection issues into Sanson Ranch development.
CCC-ERA / MISSION 66-ERA BUILDINGS	Assess documentation needs for non-Sanson Ranch historic structures (e.g., the visitor center, the elevator building, the powerhouse, the maintenance yard, and any unevaluated Mission 66 structures) and upload high-priority needs into PMIS.	- Develop historic structure reports (HSRs) for structures that need them. - Follow cultural landscape report (CLR) recommendations on vegetation when restoring character-defining features.
(ALL)	Maintain cultural landscapes in their national register-eligible condition.	- Input cultural landscape features into Facility Management Software System (FMSS) Assets for future maintenance/ cyclic needs.

Table 5l. High-Priority Stewardship Activities for Ethnographic Resources

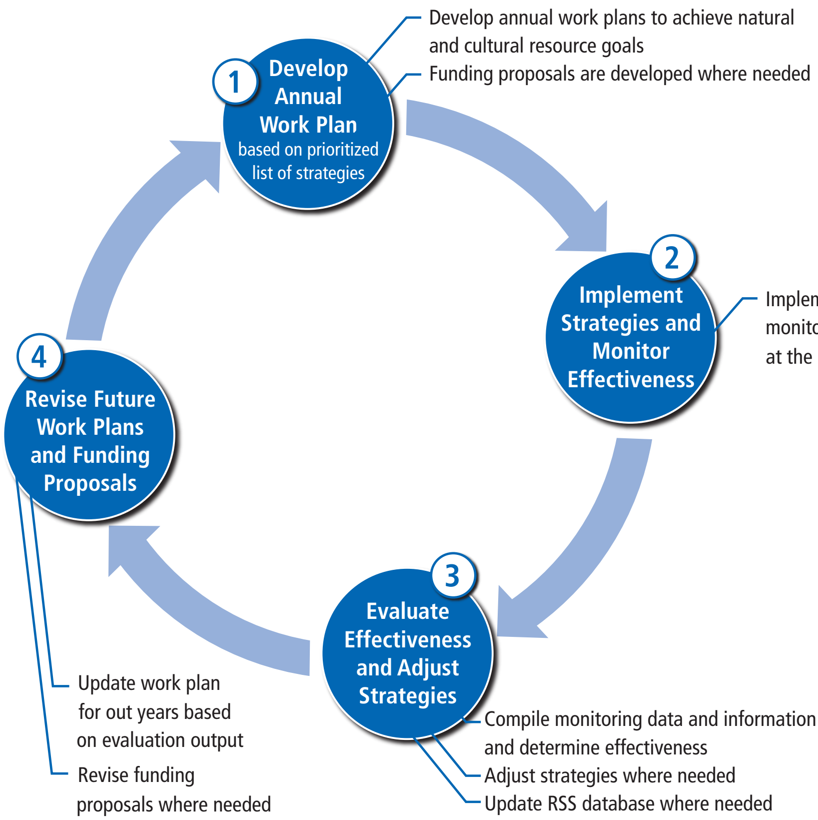
COMPONENT	SHORT-TERM STEWARDSHIP GOAL	HIGH-PRIORITY STEWARDSHIP ACTIVITIES
N/A	Acquire information on ethnographic resources through collaboration with tribes and research.	- Start dialogue with tribes on potential impacts of climate change on ethnographic resources.

ONGOING IMPLEMENTATION OF THE RESOURCE STEWARDSHIP STRATEGY

The stewardship goals, activities, and other pertinent information of the resource stewardship strategy is managed and updated regularly using the RSS desktop application. This information will assist resource managers in determining what, how, when, and where resource management occurs in the park and will assist the parks' resource management staff in developing annual work plans. These work plans will be an important planning tool for park staff to determine what they will be able to realistically tackle over the coming years.

Long-term implementation of the resource stewardship strategy includes park managers monitoring resource information and conditions in order to evaluate the effectiveness of resource stewardship strategies over time. Regular monitoring of RSS progress will provide park managers an opportunity to evaluate whether the stewardship activities are making progress towards identified goals and consider whether adjustments are needed. See figure 4 for more information on the cyclical nature of this process. In addition, routine communication with the public is another important aspect of the implementation process. These outreach efforts are intended to improve public awareness about the science and strategies used to protect the park's diverse resources and values over time.

Figure 4. RSS Implementation Process



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APPENDIX A: WIND CAVE NATIONAL PARK COMPREHENSIVE LIST OF STEWARDSHIP STRATEGIES AND RESPECTIVE PRIORITIES

PRIORITY RESOURCE	LONG-TERM GOAL	SHORT-TERM GOAL	STEWARDSHIP ACTIVITIES
WIND CAVE	Minimize human-caused impacts to the cave, its climate, hydrology, and biological resources.	To inform management decisions, WICA will continue monitoring airflow patterns, cave climate, CO2 levels, and mitigation of dust and lint accumulations, and support exploration of the cave.	- Conduct a carrying capacity study to ensure the proper size and daily number for each tour route and some off-trail routes. (Low) - Monitor biotic communities (bats, packrats, vertebrates, invertebrates, and microbial) in the cave for any changes due to infrastructure or human activities. (Medium) - Update Geologic Resources Inventory. (Low) - Determine drivers for temperature within the cave, including the relative influence of outside air temperatures and geothermal activity, to better understand potential climate change impacts. (Low) - Monitor potential climate change effects on cave lakes. (Medium) - Continue vacuuming the cave every other year to remove human-introduced debris. (High) - Explore how other parks monitor conditions at their caves. (Medium) - Continue to survey/resurvey the cave to update accuracy of cave location and extent. (Medium)
WIND CAVE	Minimize human-caused impacts to the cave, its climate, hydrology, and biological resources.	Reduce unnatural airflow through the Walk-In Entrance and elevator shaft.	- Determine unnatural air leaks and develop a mitigation plan. (Medium)
WIND CAVE	Minimize human-caused impacts to the cave, its climate, hydrology, and biological resources.	Reduce dust deposition along tour routes and off-trail travel routes.	- Develop best management practices on how to reduce dust. (Medium) - Install a walking surface/ stepping stones to reduce dust at the Moon Milk area. (Medium)
WIND CAVE	Minimize human-caused impacts to the cave, its climate, hydrology, and biological resources.	Ensure that infrastructure has minimal impact on cave resources.	- Secure funding to test whether sewer lines and parking lot drain systems are properly working. (Low)

PRIORITY RESOURCE	LONG-TERM GOAL	SHORT-TERM GOAL	STEWARDSHIP ACTIVITIES
WIND CAVE	Minimize human-caused impacts to the cave, its climate, hydrology, and biological resources.	Determine the significance of historic artifacts within the cave and decide what goes and what stays.	- Contact regional curator for technical assistance with the cave's historic archeology as needed. (Low) - Put in STAR request for a Paleontological Inventory Report for Wind Cave (and potentially Persistence Cave). (Medium)
NATIVE WILDLIFE— Bison	The park has a viable population of bison within the target range set by existing management plans (400-650) unless changes to available forage and/or water sources require revising population targets.	To provide alternative water sources to wildlife during droughts, WICA will improve and maintain developed springs.	- Improve or repair four developed springs. (High) - Monitor use of developed springs by bison and elk, and evaluate effectiveness in drawing pressure off natural surface water features. (Medium) - Develop plan for maintaining/ restoring the CCC dam on Bison Flats. (Low)
NATIVE WILDLIFE— Bison	The park has a viable population of bison within the target range set by existing management plans (400-650) unless changes to available forage and/or water sources require revising population targets.	Manage bison in accordance with park and regional bison stewardship strategies.	- Collaborate with regional office in completing the Draft Decision Framework for the National Park Service Interior Region 5 Bison Stewardship Strategy (in development). (High) - Build a new bison facility. (High) - Continue park bison active management, as informed by the regional bison stewardship strategy (in development). (High) - Continue bison management activities, including continuing to participate in and further develop the Bison Leadership Team and continue to contribute to bison stewardship efforts outside of region (e.g., Grand Canyon) and outside of the National Park Service (USFWS, TNC, etc.). (High) - Remove the old bison facility. (Medium) - Collaborate on regional bison stewardship compliance activities. (Medium)
NATIVE WILDLIFE— Bison	The park has a viable population of bison within the target range set by existing management plans (400-650) unless changes to available forage and/or water sources require revising population targets.	Expand bison range onto the Casey property.	- Install new gate for interior fence on Casey property. (Medium) - Fence off the water infrastructure (solar panels, etc.). (High) - Open old boundary fence to allow bison to roam. (High) - Monitor and document bison use of Casey property once made accessible to them (e.g., vegetation impacts). (Medium)

PRIORITY RESOURCE	LONG-TERM GOAL	SHORT-TERM GOAL	STEWARDSHIP ACTIVITIES
NATIVE WILDLIFE— Elk	The park has a viable population of elk within the target range set by existing management plans (232-475) unless new research provides an updated management population target.	Reduce CWD prevalence in elk population from 2017 levels.	- Continue elk reduction activities to maintain elk at low end of population targets. (High) - Support CWD research. (High) - Continue removing elk carcasses. (High) - Continue to avoid/minimize park activities/practices that congregate wildlife (e.g., salt licks). (High)
NATIVE WILDLIFE— Black-tailed Prairie Dog	WICA has a viable population of black-tailed prairie dogs across up to 3,300 acres of prairie dog colonies.	Maintain prairie dogs within population management target and minimize the risk of plague epizootic over the next five years using best management practices.	- Create sustainable funding to minimize plague risk to prairie dogs. (High) - Regularly update map and inventory prairie dog colonies to determine changes in distribution. (Medium) - Use existing disease-management tools (e.g., dusting) as well as new techniques (e.g., oral plague vaccine) and monitor the efficacy of those tools, especially under variable and changing climate conditions. (High)
NATIVE WILDLIFE— Black-tailed Prairie Dog	WICA has a viable population of black-tailed prairie dogs across up to 3,300 acres of prairie dog colonies.	WICA contributes to research that promotes plague-management tools.	- Actively seek funding opportunities from partners to support research in plague management. (High)
NATIVE WILDLIFE— Black-footed Ferret	WICA has a viable population of black-footed ferrets on all suitable habitat by 2040.	WICA maintains an active ferret management program.	- Participate in national black-footed ferret subcommittee meeting to stay current on research. (Medium) - Continue releasing black-footed ferrets and relocating ferrets within the park. (High) - Continue monitoring black-footed ferret populations. (High)
NATIVE WILDLIFE— Bats	WICA will reduce threats to bat populations from white-nose syndrome (WNS) and disturbance of hibernating bats.	To inform management decisions, WICA will have statistically valid estimates of current bat population sizes and activity levels, with sufficient precision and accuracy, by 2025.	- Support research that improves understanding of bat habitat needs (e.g., temperature, humidity, structures) and whether they will still exist at WICA in near- and longer-term future. (Medium) - Continue WICA fine-scale acoustic monitoring of bats. (Medium) - Submit a request for a focused condition assessment on park's existing bat data. (Medium) - Continue annual monitoring of bat usage of Wind Cave at the natural entrance. (High) - Continue to conduct bat surveys at other caves within the park. (High)

PRIORITY RESOURCE	LONG-TERM GOAL	SHORT-TERM GOAL	STEWARDSHIP ACTIVITIES
NATIVE WILDLIFE— Bats	WICA will reduce threats to bat populations from WNS and disturbance of hibernating bats.	To protect bat populations, WICA will minimize human-caused spread of WNS and disturbance of hibernating bats through monitoring, research, and management, by 2025.	- Maintain the decontamination stations at the entrance and exit to the cave. (High) - Provide information to interpretive staff about wildlife diseases (including WNS) that can be incorporated into interpretive materials and public education. (High) - Continue collecting soil samples from cave to test for WNS. (High) - Continue collaboration with Biological Resources Division to stay informed on current decontamination protocols/ techniques. (High)
NATIVE VEGETATION— Across Park	Compared to 2019 levels, maintain or increase the abundance and diversity of native plant species across the park and maintain or decrease the abundance proportion of exotic plants and area infested by noxious weeds across the park.	Reduce exotic and invasive plant cover below 2017 levels.	- Integrate fire, exotic plant treatment, and vegetation monitoring using the ABAM model and framework. (Medium) - Determine strategy for ABAM treatment priorities and assign priorities to burn/management units accordingly. (High) - Continue to practice early detection and rapid response. (High) - Maintain exotic plant mapping, treatment, and monitoring at or above 2018 levels. (High) - Complete seed storage facility. (High) - Develop and begin implementing a seed collection and increase plan (including hardwoods). (Medium) - Continue to support exotic plant management team aerial application contract. (Medium) - Stay current on emerging information on climate change implications for regional exotic plant species abundance and distribution. (Medium) - Create a vegetation management strategy. (High)
NATIVE VEGETATION— Across Park	WICA will increase hardwood density across all size classes by 2030, while preparing for potential longer-term, climate change driven changes that may be difficult or impossible to resist.	Achieve an increase in hardwood seedlings that shows regeneration.	- Identify areas where hardwood recruitment, establishment, and survival are most likely to be successful under current and future climate conditions. (Low) - Restore and maintain existing hardwood exclosures. (Low) - Determine whether existing monitoring is adequate for evaluating hardwood recruitment and distribution extent trends. (Medium)

PRIORITY RESOURCE	LONG-TERM GOAL	SHORT-TERM GOAL	STEWARDSHIP ACTIVITIES
NATIVE VEGETATION— Prairie/ Forest Complex	WICA will maintain PIPO woodland to achieve fuel loads of 2-10 tons/ acre in those woodlands, through 2040, while preparing for potential longer-term, climate change driven changes that may be difficult or impossible to resist.	Prescribed fires are completed in high-priority burn units in the following priority order: HQ East & West2, Lookout Flats-Prairie Dog Canyon, Dry Creek-Highland Creek, Beaver, and American Elk-Tower. American Elk-Tower.	- Ensure that Fire Management Office has completed prescribed burn plans and compliance at least three months ahead of burn window. (High) - Develop and implement a protocol for consistently monitoring herbaceous vegetation production and utilization in the park. (Low) - Conduct yearly coordination meeting between park resource staff and fire ecologist; when feasible coordinate fire planning with archeological specialists. (High) - Maintain support for NGPN and NGP fire effects monitoring to support resource management. (High) - Support park staff getting trained to support fire program to accommodate expanding shoulder season and wildfire season due to climate change. (High) - Request an updated park vegetation GIS layer from I&M. (Medium)
NATIVE VEGETATION— Riparian	WICA will maintain riparian and wetland vegetation at current conditions within the park, while preparing for potential longer-term, climate change driven changes that may be difficult or impossible to resist.	By 2025, vegetation condition based on Multiple Indicator Monitoring is on an increasing trend.	- Analyze Multiple Indicator Monitoring data and provide recommendations to the park for future management. (High) - Prioritize areas for active riparian and wetland restoration and protection in a climate-change-smart framework. (Medium)
NATIVE VEGETATION— Riparian	WICA will maintain riparian and wetland vegetation at current conditions within the park, while preparing for potential longer-term, climate change driven changes that may be difficult or impossible to resist.	A baseline extent of true riparian vegetation currently in the park is established.	- Map existing riparian and wetland (streams and springs) plant community distribution, including areas with the potential to support these communities, and assess their condition. (Medium)
NATIVE VEGETATION— Rare Plant Species	Minimize negative impacts to rare plant species from park management activities.	Rare plant species' population locations, sizes, and dynamics are better known and documented.	- Complete a park-wide rare plant survey. (Medium) - Develop a rare plant monitoring plan. (Medium) - Determine information gaps regarding rare plant response to management activities and decisions (e.g., wildlife population sizes) and climate change. (Low)

PRIORITY RESOURCE	LONG-TERM GOAL	SHORT-TERM GOAL	STEWARDSHIP ACTIVITIES
WATER RESOURCES	Minimize construction of impoundments upstream of the park that change flow conditions through the park, and limit the withdrawal and diversion of surface and groundwater flowing through the park.	WICA will maintain ongoing monitoring to increase knowledge about, and to detect changes in, water quality, spring- and streamflow, and groundwater level that would require active engagement with outside entities.	- Develop a protocol for surface water quality monitoring (use TAR). (High) - Collect water samples according to the surface water quality monitoring protocol. (High) - Submit a TAR to WRD every year for ground water monitoring (i.e., water levels) and water rights application tracking. (High) - Support completion of the USGS water study for Black Hills. (Medium) - Support I&M cave monitoring by collecting cave lake water samples. (High) - Use historical data of cave water levels to characterize natural variability. (Medium)
WATER RESOURCES	Minimize construction of impoundments upstream of the park that change flow conditions through the park, and limit the withdrawal and diversion of surface and groundwater flowing through the park.	WICA will continue to minimize the park's water use throughim-plementation of best management practices. Mamanagement prac-tices.	- Replace bluegrass lawns around upper housing with species requiring less water. (Low) - Evaluate potential to abandon or plug front lawn sprinkler system. (Medium) - Work with facilities staff to retrofit park facilities to low flow fixtures. (Medium) - Assess current park water usage and explore greater efficiencies. (Medium)
WATER RESOURCES	Minimize construction of impoundments upstream of the park that change flow conditions through the park, and limit the withdrawal and diversion of surface and groundwater flowing through the park.	Surface and ground water conditions meet and/or exceed water quality parameter standards set by the USEPA and the state of South Dakota.	- Work with upstream landowners to implement BMPs to reduce impacts to park water quality/quantity. (Low) - Develop an understanding of existing impoundments in the watershed and trends over time. (Low)

PRIORITY RESOURCE	LONG-TERM GOAL	SHORT-TERM GOAL	STEWARDSHIP ACTIVITIES
AIR QUALITY	Improve understanding of air pollution impacts and maintain the long-term air quality data record, through continued in-park monitoring of visibility, particulate matter, ozone, and pollutant deposition.	Improve understanding of air quality through continued monitoring, compiling existing information, identifying sensitive resources, assessing future research needs, and educating park staff about impacts to park resources.	- Become familiar with existing online park air quality information provided by the Air Resources Division (ARD), including park conditions and trends, regional conditions and trends, WICA air profile, park sensitive species, park ozone exceedances, and nearby sources of air pollution. (Medium) - Develop park air quality summary, including compilation of existing data, condition, threats, sensitive resources, and research. (Medium) - Include air quality summary information into staff training. (Medium) - Continue to support the NPS air quality monitoring programs and special studies including IMPROVE, CASTNET, NADP, NPS-GPMP monitoring stations, including site operator staff and training. (High) - Document and investigate future needs in air quality research and ecosystem responses to identify and improve understanding of impacts to sensitive resources. (Medium) - Submit a TAR to ARD to survey for foliar injury of ozone-sensitive plant species. (Low) - Continue participation in the national dragonfly mercury project coordinated by ARD. (Medium) - Acquire sampling design from ARD for monitoring airborne toxic contaminants in park biota. (Low) - Develop air quality threat summary including oil, gas, and dust. (Medium) - Develop and implement a park Air Resources Strategy. (Low)

PRIORITY RESOURCE	LONG-TERM GOAL	SHORT-TERM GOAL	STEWARDSHIP ACTIVITIES
AIR QUALITY	Improve understanding of air pollution impacts and maintain the long-term air quality data record, through continued in-park monitoring of visibility, particulate matter, ozone, and pollutant deposition.	Provide information about air pollution impacts to NPS management, air regulatory agencies, the public, the scientific community, and other stakeholders.	- Provide information to interpretive staff that communicates connections between air quality/pollution, biodiversity, scenic views, night sky, recreation, human health, climate change, and other associated resources. (Medium) - Provide an air quality section on the park website with content and links to park air quality condition, trends, and implications. (High) - Investigate opportunity to create and use an ozone garden with the park's ozone-sensitive and bioindicator plant species for a tangible connection with park resources. (Low)
AIR QUALITY	Seek to perpetuate the best possible air quality condition for the protection of resources affected by air pollution, reducing pollutant deposition to below ecosystem critical loads, eliminating human caused visibility impairment by the year 2064 (where the average visibility is < 2 deciviews above natural conditions), and remaining in attainment for the USEPA NAAQS and in good ozone (W126 index) condition.	Be an environmental leader by reducing park air pollutant emissions, improving park sustainability and environmental management, and demonstrating the park's commitment to do its part for air/water quality, night sky, and climate change.	- Complete the park's NPS Climate Friendly Park action plan. (Medium) - Develop park energy, waste, and water use reduction guidelines. (Medium)
AIR QUALITY	Seek to perpetuate the best possible air quality condition for the protection of resources affected by air pollution, reducing pollutant deposition to below ecosystem critical loads, eliminating human caused visibility impairment by the year 2064 (where the average visibility is < 2 deciviews above natural conditions), and remaining in attainment for the USEPA NAAQS and in good ozone (W126 index) condition.	Collaborate with other federal, state, regional and local planning organizations, and stakeholders to reduce air quality impacts in the park from external sources of air pollution.	- Continue to collaborate with nearby NPS units (e.g., DETO, BADL) and park air quality specialists to reduce air quality impacts from sources of pollution. (High) - Work with county to do dust abatement activities on 7-11 road. (Medium)

PRIORITY RESOURCE	LONG-TERM GOAL	SHORT-TERM GOAL	STEWARDSHIP ACTIVITIES
VIEWS	Protect, improve, and monitor the condition of views important for natural scenery and cultural resources both within and across park boundaries to maintain or improve visual character and an undeveloped and natural park experience.	Inventory and assess park views over time to monitor changes in condition.	- Conduct a visual resource inventory using the NPS ARD process that builds upon the zoning management plan's 2013 scenery conservation analysis. (Medium) - Work with NRSS and NGPN to repeat visual resource inventory every 5-10 years or as landscape changes are observed, to monitor changes in condition. (Medium)
VIEWS	Protect, improve, and monitor the condition of views important for natural scenery and cultural resources both within and across park boundaries to maintain or improve visual character and an undeveloped and natural park experience.	Minimize changes, visual contrast, and intrusions to views to the extent possible within the park.	- Remove unnecessary structures at the Job property. (Medium) - Explore options for drought-resistant vegetation screening of maintenance and fire cache area. (High) - Install drought-resistant vegetation screening around Southern Black Hills Water building/fence and/or investigate avenues to encourage removal of the building from the site. (High)
VIEWS	Protect, improve, and monitor the condition of views important for natural scenery and cultural resources both within and across park boundaries to maintain or improve visual character and an undeveloped and natural park experience.	Collaborate with adjacent landowners, municipalities, developers, and other stakeholders to promote cooperative conservation of views across park boundaries.	- In partnership with stakeholders, establish best practices and/or design guidelines for adjacent landowners and stakeholders. (Medium) - Investigate easement opportunities with land trusts to protect views. (Medium) - Develop relationships with partners that can advocate for limiting development. (Medium)
VIEWS	Protect, improve, and monitor the condition of views important for natural scenery and cultural resources both within and across park boundaries to maintain or improve visual character and an undeveloped and natural park experience.	Provide enhanced opportunities for visitors to access and understand the importance of park views.	- Expand scenic photo gallery on the park's website with the important views chosen for the visual resource inventory (including 360 degree photos of aboveground and cave views and night sky photos). (Medium) - Establish park webcam(s) to enhance the virtual experience of park scenery. (High) - Explore opportunities for a temporary wayside exhibit to interpret impact of wildfire and dust on views. (Medium) - Explore opportunities to incorporate the importance/role of park views into interpretive messaging. (Medium)
DARK NIGHT SKIES	To inform resource management, WICA will quantify and document the condition and trends of the nocturnal environment from artificial light.	Improve understanding of conditions and trends of the nocturnal environment.	- Promote night sky friendly lighting in nearby communities and other parks. (Medium) - Work towards certification as an International Dark Sky Park. (Medium)

PRIORITY RESOURCE	LONG-TERM GOAL	SHORT-TERM GOAL	STEWARDSHIP ACTIVITIES
DARK NIGHT SKIES	WICA will improve the night sky resource by reducing light at night within the park boundary.	Improve the nighttime environment by assessing how the park can improve employee and visitor nighttime scenery within the park boundary.	- Work with nearby schools on curriculum-based school programs focused on night skies. (Medium)
DARK NIGHT SKIES	WICA will increase outreach and foster investment from the community and nearby partners in the shared night skies.	Reduce threats to the nocturnal environment and nighttime scenery from outside park boundaries by engaging with the nearby community and raising awareness about the value of the resource and astrotourism, and engage regional partners.	- Promote night sky friendly lighting in nearby communities and other parks. (Medium) - Work towards certification as an International Dark Sky Park. (Medium)
DARK NIGHT SKIES	WICA will increase outreach and foster investment from the community and nearby partners in the shared night skies.	WICA will enhance visitor and student awareness and appreciation of the night sky and its features.	- Work with nearby schools on curriculum-based school programs focused on night skies. (Medium)
SOUNDSCAPES	To inform resource management, WICA will characterize baseline acoustic environment and its relationship and value to other resources.	Determine the condition and trends of the acoustic resource in the park.	- Submit a TAR to NSNSD to collect Baseline Ambient Acoustic Data. (Medium) - Get a copy of updated acoustic modeling of park unit from NSNSD and share with staff. (Low)
SOUNDSCAPES	WICA will reduce non-natural and inappropriate noise in the park environment.	Reduce non-natural and inappropriate noise from park and external activities.	- As equipment is replaced, explore opportunities to use quieter models of mechanical equipment (e.g., lawn mowers, chain saws, etc.). (Medium) - Explore the feasibility of establishing a recurring "Natural Sounds Day" where limited mechanical equipment is used except in the case of emergency. (Low) - Explore options for reducing noise from the visitor center generator, for example replacing the muffler and/or planting trees. (High) - Explore options for retrofitting ATVs and UTVs with new mufflers. (High) - Explore option for replacing cattle guards with quieter designs. (High) - Explore feasibility of establishing a No-Fly Zone around the park. (Medium)

PRIORITY RESOURCE	LONG-TERM GOAL	SHORT-TERM GOAL	STEWARDSHIP ACTIVITIES
ARCHEOLOGY	WICA will have the necessary knowledge to protect significant archeological sites through documentation, monitoring, protection, and mitigation, and the park will maintain integrity at all significant archeological sites where feasible, considering the effects of climate change and other factors beyond the park's control..	Monitor and protect an increased number of archeological sites in an undisturbed condition .	- Prioritize known archeology sites for protection. (Medium) - Draft a proposal to fund the development and implementation of a climate change-informed vulnerability assessment process to monitor sites and protect them. (Medium) - Draft a proposal to fund increased efforts related to archeological inventory. (Low) - Finish programmatic agreement with state historic preservation office. (Low) - Work with Regional Office staff and area parks to share an archeologist position based in Western South Dakota. (Medium)
ARCHEOLOGY	WICA will have the necessary knowledge to protect significant archeological sites through documentation, monitoring, protection, and mitigation, and the park will maintain integrity in all significant archeological sites, considering climate change and other factors beyond the park's control.	Increased information provides guidance for archeology work and identifies the park's high-priority sites, while accounting for climate change vulnerabilities (e.g., changes in precipitation, increased temperature, etc.).	- Develop an Archeological Overview and Assessment to summarize existing archeological knowledge, identify relevant research questions, and identify significant gaps in knowledge at WICA related to those questions. (High) - Identify sites most susceptible to extreme climate change events (e.g., heavy precipitation) and prioritize efforts to inventory and protect them. (Medium)
ARCHEOLOGY	WICA will have the necessary knowledge to protect significant archeological sites through documentation, monitoring, protection, and mitigation, and the park will maintain integrity in all significant archeological sites, considering climate change and other factors beyond the park's control.	Increase archeological areas surveyed by 5% over the next five years.	- Meet with MWAC to help determine how they can assist the park. (High) - Write a PMIS statement to increase inventory. (High) - Develop a strategy to access archeological expertise onsite for routine and frequent management needs. (High) - Support the increase of areas surveyed throughout the park.. (High) - Develop a strategy for quick response to conduct post-wildfire archeological inventories. Include Regional Fire, other programs, tribes, WICA, and MWAC in discussion. (High)

PRIORITY RESOURCE	LONG-TERM GOAL	SHORT-TERM GOAL	STEWARDSHIP ACTIVITIES
MUSEUM COLLECTIONS	WICA museum collections will be fully cataloged within 20 years in accordance with NPS museum management policy. All historical objects and non-paleo natural history objects will be digitized and be made available on the park's website to improve visitor understanding of park history and its natural resources. All historical objects and non-paleo natural history objects will be maintained in good condition in an environment conducive to their long-term safekeeping.	The park scope of collection statement is up to date and reflects park priorities for accession/ deaccessions that support future collection management.	- Revisit the scope of collection statement every two years or as staff changes. (Medium) - Regularly review integrated pest management plan and update as needed. (Medium)
MUSEUM COLLECTIONS	WICA museum collections will be fully cataloged within 20 years in accordance with NPS museum management policy. All historical objects and non-paleo natural history objects will be digitized and be made available on the park's website to improve visitor understanding of park history and its natural resources. All historical objects and non-paleo natural history objects will be maintained in good condition in an environment conducive to their long-term safekeeping.	The park addresses overcrowding in museum collections storage.	- An interdisciplinary team reviews current collection management plan including climate change issues. (Low) - Monitor the efficacy of the current HVAC and climate control systems and upgrade as needed. (Medium) - Explore options for other collections storage locations with reduced fire risk (e.g., off-site). (High)

PRIORITY RESOURCE	LONG-TERM GOAL	SHORT-TERM GOAL	STEWARDSHIP ACTIVITIES
MUSEUM COLLECTIONS	WICA museum collections will be fully cataloged within 20 years in accordance with NPS museum management policy. All historical objects and non-paleo natural history objects will be digitized and be made available on the park's website to improve visitor understanding of park history and its natural resources. All historical objects and non-paleo natural history objects will be maintained in good condition in an environment conducive to their long-term safekeeping.	Increase the number of natural history resource management records that are cataloged over five years.	- Increase museum staffing. (High) - Explore possibilities of volunteers assisting with cataloging. (High)
MUSEUM COLLECTIONS	WICA museum collections will be fully cataloged within 20 years in accordance with NPS museum management policy. All historical objects and non-paleo natural history objects will be digitized and be made available on the park's website to improve visitor understanding of park history and its natural resources. All historical objects and non-paleo natural history objects will be maintained in good condition in an environment conducive to their long-term safekeeping.	Increase the number of digitized specimens and historical objects over five years.	- Prioritize scanning of museum objects and specimens. (Low) - Explore possibilities of volunteers assisting with digitizing. (Medium)

PRIORITY RESOURCE	LONG-TERM GOAL	SHORT-TERM GOAL	STEWARDSHIP ACTIVITIES
HISTORIC STRUCTURES AND CULTURAL LANDSCAPES— Sanson Ranch	WICA will use up-to-date documentation to ensure existing historic structures and documented cultural landscapes retain integrity and NRHP status over the next 20 years.	Restore character-defining features of the Sanson Ranch structures to support future access and interpretation.	- Prioritize Sanson Ranch restoration projects. (High) - Acquire adequate funding with a PMIS proposal to restore features of Sanson Ranch. (High) - Define key characteristics of Sanson Ranch; assess characteristics; establish restoration plan; implement road improvements. (Medium) - Restore the historic Sanson Ranch home to the degree necessary to make it usable by park staff and accessible by visitors. (Medium) - Incorporate wildfire protection issues into Sanson Ranch development and management. (High) - Make a determination on where to place the Sanson Ranch parking lot. (Medium) - Following consultation with tribes, install wayside signs that interpret the history of Sanson Ranch. (Medium)
HISTORIC STRUCTURES AND CULTURAL LANDSCAPES— CCC-Era and Mission 66-Era Buildings	WICA will use up-to-date documentation to ensure existing historic structures and documented cultural landscapes retain integrity and NRHP status over the next 20 years.	Assess documentation needs for non-Sanson Ranch historic structures (e.g. the visitor center, the elevator building, the powerhouse, the maintenance yard, and any unevaluated Mission 66 structures) and upload high-priority needs into PMIS.	- Develop HSRs for structures that need them. (High) - Prioritize which structures to preserve and which structures to restore. (Medium) - Use documentation to guide maintenance treatments. (Medium) - Increase vegetation clearing and thinning around historic structures to reduce fire risk. (Medium) - Follow CLR recommendations on vegetation when restoring character-defining features. (High) - Enter PMIS proposal for Mission 66 national register nominations. (Low) - Enter PMIS proposal for other buildings needing national register nominations. (Low)

PRIORITY RESOURCE	LONG-TERM GOAL	SHORT-TERM GOAL	STEWARDSHIP ACTIVITIES
HISTORIC STRUCTURES AND CULTURAL LANDSCAPES—All	WICA will use up-to-date documentation to ensure existing historic structures and documented cultural landscapes retain integrity and NRHP status over the next 20 years.	Maintain cultural landscapes in their national register-eligible condition.	- Input cultural landscape features into FMSS Assets for future maintenance/ cyclic needs. (High) - Overlay cultural landscape on vegetation maps and integrate management activities of both. (Medium) - Replace non-native plants with native plants that are consistent with CLR recommendations and adapted to projected climate conditions. (Medium) - Work with cultural landscape inventory (CLI) program staff in the region to assess the Game Ranch and Alvin McDonald's grave site to determine if they are cultural landscapes or features/components of an existing landscape. (Medium)
ETHNOGRAPHIC RESOURCES	WICA works with tribes through consultation to identify ethnographic resources and the protections they may need in accordance with appropriate laws and regulations.	Acquire information on ethnographic resources through collaboration with tribes and research.	- Assess interest and desire of culturally associated tribes to work with park to identify resources of significance. (Medium) - Start dialogue with tribes on potential impacts of climate change on ethnographic resources. (High) - Submit a funding proposal to initiate documentation and identification of ethnographic resources. (Medium) - Document and identify ethnographic resources. Coordinate with archeological specialists to identify cross-walks between TCPs, TEKs, and archeology (Medium) - Assess extent and abundance of identified ethnographic species within the park. (Medium) - Assess climate (short- and long-term) sensitivities of ethnographic resources and monitor those resources. (Medium) - Determine which plant species are abundant enough to harvest and what a sustainable harvest looks like. (Medium) - Determine whether management activities are affecting ethnographic resources and develop strategies for mitigation. (Medium) - Explore feasibility of holding periodic consultation meetings with tribes about upcoming park projects. (Medium)

APPENDIX B: CLIMATE CHANGE SCENARIO PLANNING FOR RESOURCE STEWARDSHIP AT WIND CAVE NATIONAL PARK

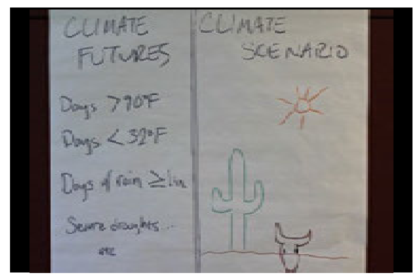
National Park Service
U.S. Department of the Interior

Natural Resource Stewardship and Science

Climate Change Scenario Planning for Resource Stewardship at Wind Cave National Park

Climate Change Scenario Planning Summary

Natural Resource Report



Climate Change Scenario Planning for Resource Stewardship at Wind Cave National Park

Natural Resource Report

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Natural Resource Stewardship and Science

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.

Views, statements, findings, conclusions, recommendations, and data in this report do not necessarily reflect views and policies of the National Park Service, U.S. Department of the Interior. Mention of trade names or commercial products does not constitute endorsement or recommendation for use by the U.S. Government.

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Abstract

This report explains scenario planning as a climate change adaptation tool in general, then describes how it was applied to Wind Cave National Park as the second part of a pilot project to dovetail climate change scenario planning with National Park Service (NPS) Resource Stewardship Strategy development.

In the orientation phase, Park and regional NPS staff, other subject-matter experts, natural and cultural resource planners, and the climate change core team who led the scenario planning project identified priority resource management topics and associated climate sensitivities. Next, the climate change core team used this information to create a set of four divergent climate futures—summaries of relevant climate data from individual climate projections—to encompass the range of ways climate could change in coming decades in the park. Participants in the scenario planning workshop then developed climate futures into robust climate-resource scenarios that considered expert-elicited resource impacts and identified potential management responses. Finally, the scenario-based resource responses identified by park staff and subject matter experts were used to integrate climate-informed adaptations into resource stewardship goals and activities for the park's Resource Stewardship Strategy. This process of engaging resource managers in climate change scenario planning ensures that their management and planning decisions are informed by assessments of critical future climate uncertainties.

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Introduction

Ongoing anthropogenic climate change is evident across the National Park System. Annual mean temperatures in most parks, for example, are already extreme compared to the recent historical record (1901–2012; Monahan and Fisichelli 2014). Climate change is causing widespread physical changes in the environment that directly impact organisms, resources, assets, and values, and generate powerful indirect effects by driving ecological changes (e.g., Stewart et al. 2005, Wang et al. 2014, Mallakpour and Villarini 2015, O'Neel et al. 2015, Lara et al. 2016, Hayhoe et al. 2018, Markon et al. 2018). Despite observed and potential changes, many consider anticipatory management for climate change daunting because plausible projections of climate change and its impacts span a range of outcomes. Forward-looking resource stewardship in an era of continuous change, therefore, requires effective approaches for understanding and working with consequential and irreducible uncertainty.

This challenge has increased awareness of uncontrollable (i.e., irreducible) uncertainty's influence in decision-making (Peterson et al. 2003, Rowland et al. 2014). However, such uncertainties are inherent to planning around complex environmental issues (Gregory et al. 2012) and are addressed by resource managers in a variety of ways. Scenario planning is a structured approach to work with consequential uncertainties and is increasingly being used by resource managers (Rowland et al. 2014, Star et al. 2016). It is a flexible tool that is useful for understanding potential climate change implications and uncertainties in a way that is relevant to resource and landscape management (IPBES 2016). Scenario planning facilitates decision making by providing a structured process for building and thinking about a range of possible futures that managers may face, in order to consider, not what is thought to be most likely, but instead the full range of what is plausible, relevant, and highly consequential (NPS 2013).

The National Park Service (NPS) and partners have developed and refined a climate change scenario planning approach focused on expert opinion and synthesis of pre-existing science (NPS 2013, Star et al. 2016, Runyon et al. 2020), as well as comprehensive guidance for its incorporation into the NPS Resource Stewardship Strategy (RSS) development process (NPS 2019). The RSS development process for Wind Cave National Park (WICA) was the second part of a pilot effort to incorporate a full set of climate-resource scenarios into an RSS, building upon an initial effort with Devils Tower National Monument (Schuurman et al. 2019). We used this approach to lead the development of a set of plausible, expert-elicited climate-resource scenarios for WICA built around the park's priority natural and cultural resources. The scenarios were then used to inform and refine the park's subsequent RSS development. Climate-resource scenario development for WICA was a process of iterative engagement through most of 2019 with WICA and regional NPS staff, climatologists, natural and cultural resource planners, and other subject-matter experts. Much of the scenario development occurred in a scenario planning workshop held at WICA in July 2019.

This report is not a full vulnerability assessment of all resources at WICA and does not explore all aspects of each resource component. Rather, this report focuses on documenting the development of WICA climate-resource scenarios for those resources identified through the RSS process, and describing how those scenarios affected resource stewardship goals in the park's RSS. The full set of goals and activities (which integrates non-climate considerations as well) is captured in the park's RSS summary document and desktop application.

Current and historical climate

Projections of future climate are made relevant to managers by comparing them to historical climate, then the consequences of plausible future climates for resources are determined in the context of other stressors. WICA experiences a mid-latitude, continental climate, with warm summers and cold winters. Climate is generally semi-arid with a spring-early summer precipitation peak and strong diurnal and seasonal temperature variability. Interannual variation in precipitation is high (Figure 1).

Based on historical (1895–2017) gridded data for the park from the PRISM (Parameter-elevation Relationships on Independent Slopes Model; from PRISM Climate Group) dataset (http://prism.oregonstate.edu/; 800m LT81m), average annual temperature ranged from 43 to 51 °F, with a mean of 46 °F, and annual precipitation varied from about 11 to 31 inches, with a mean of 18 inches (Figure 1). Annual mean daily minimum temperature rose significantly (probability value [p]<0.001) from 1895 to 2017, increasing at an estimated +1.9 °F/100 years[1]. From just 1970 to 2017, the estimated increase was +5.5 °F/100 years ($p<0.001$). Annual mean daily maximum temperature showed a weak trend for 1895–2017 ($p=0.06$) and no trend for 1970–2017 ($p=0.27$). Annual mean daily temperature also significantly increased for the full historical period (+1.4 °F/100 years; $p<0.001$) and from 1970 to 2017 (+3.7 °F/100 years; $p<0.05$). Annual mean daily precipitation showed no trend, either for the full or more recent historical period ($p=0.18$ and 0.12, respectively).

[1] We used standard linear regressions (using the R base package) to evaluate trends, and an alpha value of 0.05 as the criterion for statistical significance, throughout the report.

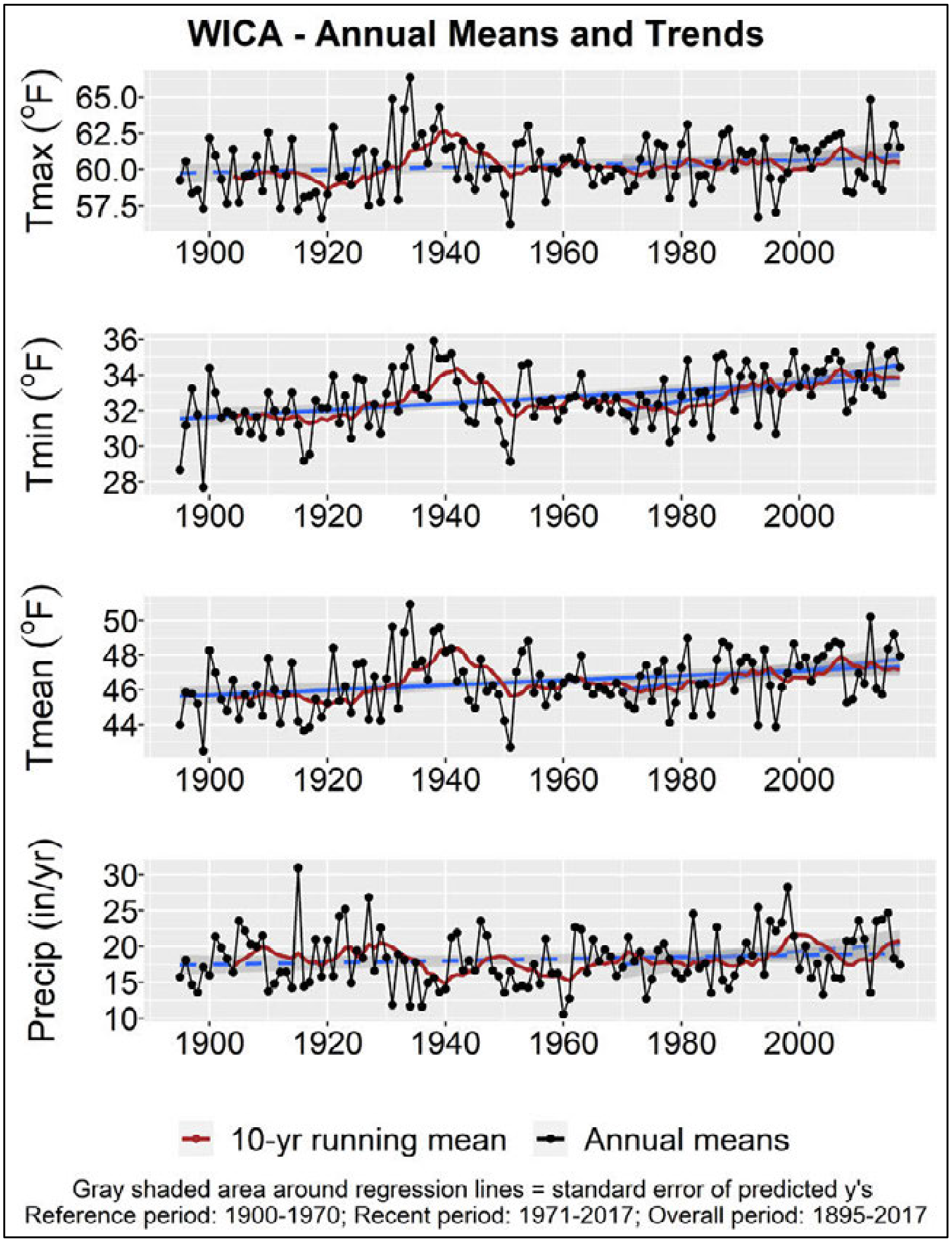

Figure 1. Historical WICA annual mean daily maximum, mean daily minimum, and mean daily temperature (top 3 panels) and mean daily precipitation (lower panel) from 1895–2017. Black points and lines show annual values, and red lines are 10-year running averages. Each graph includes two blue linear regression lines—one for the entire period and another for 1971–2017. Statistically significant regression lines (i.e., p<0.05) are solid, and non-significant lines are dashed. Gray-shaded areas around the regression lines represent point-wise confidence intervals of y values. Data from the PRISM historical gridded dataset (http://prism.oregonstate.edu/).

Resource climate sensitivities

The first step in developing climate-resource scenarios for WICA was to identify the climate sensitivities of the priority natural and cultural resources (those to be addressed in the RSS process) and their specific components. To do this, key park staff and regional partners were led through discussions to list all WICA priority cultural and natural resources with potential climate sensitivities (Table 1 columns; see WICA RSS Summary Document for detailed descriptions) and describe the aspects of climate to which each resource is sensitive[2]. Through this consultation, we developed quantitative climate metrics for each aspect of climate described as important to at least one resource (Table 1 rows). Then park staff and resource experts qualitatively identified the degree to which each resource was sensitive to each climate metric (body of Table 1).

The next step narrowed the climate sensitivities to just those that "pose the greatest risk for achieving one's agreed-upon conservation goals and objectives" (Stein et al. 2014) and identified corresponding climate metrics, resulting in five key climate metrics. Soil moisture availability in the growing season (April, May, and June (AMJ)) influences plant production. Extreme precipitation events have erosion-related effects on archeological, paleontological, and cultural resources, including built structures, and effects on surface water flow and groundwater recharge. Accumulated potential evapotranspiration (PET) in summer and fall was used as a proxy for prairie fire risk, which impacts forage availability for wildlife. Drought—specifically drought duration— (e.g., consecutive drought years) effects plant production, water sources, and wildlife (see Appendix 2 for detail on drought characteristic calculations). Finally, average winter temperature influences cave temperature and plant species composition. We used this set of key, "Tier-1" climate metrics (Table 1) to select a set of relevant and divergent climate futures. When assigning tiers to climate metrics, the aim was not necessarily to reflect the relative vulnerability of resources, but instead to identify climate metrics that relate to the most resource sensitivities, represent an especially strong driver of one or more resources, or are relevant to a particularly important resource.

[2] Table only characterizes climate sensitivities of priority resources, as identified by the RSS team for use in the RSS process. It is not a full characterization of WICA resources or their vulnerabilities, which are outside of the scope of this report

Table 1. Priority resource components and their climate sensitivities. The climate driver is identified on the left, followed by the specific metric used to measure the driver. A resource's sensitivity to the metric is denoted by 'H' for highly sensitive, 'm' for moderate sensitivity, and dash for little to no sensitivity. Climate metrics identified as most critical in terms of posing the greatest threat across the most resource sensitivities, or being particularly important or strong drivers of resource sensitivities, are identified as Tier 1 (column one); all others are Tier 2.

Tier	Climate driver subclass	Specific climate metric	Water: Ground water	Water: Surface water	Veg: Prairie	Veg: Riparian vegetation	Veg: Forest complex	Veg: Rare plant species	Veg: Plants of Tribal collection interest	Cultural: Archeological resources	Cultural: Museum collections	Cultural: Sanson ranch structures	Cultural: CCC-era structures	Cultural: Mission 66 structures	Wildlife: Bison	Wildlife: BFF & BTPD	Wildlife: Elk	Wildlife: Bats	Other: Air quality	Other: Cave (micro-climate)
1	Winter temp	Winter (DJF) temps - average	m	m	m	m	m	m	--	--	--	--	--	--	--	--	--	H	--	H
2	Winter temp	Frequency/duration of temps below threshold	--	--	--	--	--	--	--	--	--	--	--	--	H	--	H	H	--	--
2	Winter temp	Winter length	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	H	--	--
2	Freeze-thaw	# days/year where Tmax > 34 °F & Tmin < 28 °F	--	--	--	--	--	--	--	m	--	H	H	H	--	--	--	--	--	--
2	Freeze events	Late spring frost events	--	--	--	--	--	--	m	--	--	--	--	--	--	--	--	H	--	--
2	Growing season	Growing season start date	--	--	H	--	H	--	--	--	--	--	--	--	--	--	--	--	--	--
2	Growing season	Growing season end date	--	--	H	--	H	--	--	--	--	--	--	--	--	--	--	--	--	--
2	Annual temp	Annual mean temp or Monthly mean temp	m	m	--	H	m	--	--	--	--	--	--	--	--	--	--	--	--	--
1	Extreme precip	# days/yr that precip exceeds 99th-percentile event (for 1950- 1999 historical period)	H	H	--	H	--	--	--	m	--	--	H	--	--	--	--	m	--	--
2	Extreme precip	Size of extreme precipitation events	m	m	--	H	--	--	--	m	--	--	H	--	--	--	--	--	--	--
2	Precip timing	Rain on frozen soil	H	H	--	H	--	--	--	--	--	--	H	--	--	--	--	--	--	--
2	Precip timing	Rain on saturated soil	H	H	--	H	--	--	--	--	--	--	H	--	--	--	--	--	--	--
2	Precip timing	Proportion of annual precip falling in fall & winter	H	H	H	m	m	--	--	--	--	--	--	--	--	--	--	--	--	--
2	Precip timing	Periods of consecutive wet/dry days	m	H	H	m	H	m	--	H	--	--	--	--	m	m	m	m	--	--
2	Snow	Number of snow-covered days per year	--	--	--	--	H	--	--	--	--	--	--	--	--	--	--	--	--	--
1	Soil moisture	Apr-Jun Soil Moisture	H	H	H	H	H	H	m		--	--	--	--	m	H	m	m	--	--
2	Drought	Drought frequency	m	H	H	H	H	H	m	H	--	--	--	--	H	H	H	H	H	--
1	Drought	Drought length (# multi-year droughts in 30- yr period)	m	H	H	H	H	H	m	H	--	--	--	--	H	H	H	H	H	--
2	Drought	Drought intensity	--	H	H	H	H	H	m	H	--	--	--	--	m	m	m	m	H	--
2	Growing season	Growing season end date	--		H	m	H	--	--	--	--	--	--	--	--	--	--	--	--	--
2	Fire risk -- forest	See drought metrics	--	m	m	H	H	m	m	H	H		H	H	--	--	m	H	H	--
1	Fire risk -- prairie	Summer-Fall (Jun-Nov) Accumulated PET	--	--	H	m	--	m	--	m	--	H	H	m	H	H	H		H	--
2	Humidity	Avg monthly relative humidity	--	--	--	--	--	--	--	--	--	m	m	m	--	--	--	--	--	--

*Civilian Conservation Corps (CCC)

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WICA climate futures

The goal of climate change scenario planning is understanding and planning around the plausible range of future values of critical climate metrics. Climate scientists use complex models to project future climate. Because our understanding of Earth's climate is incomplete, each of these models is unique in the way it represents the many physical and biological forces that influence global climate patterns. Consequently, each global climate model (GCM) produces a different view of future climate. Moreover, future climate also depends on societal decisions regarding the future emissions and absorption of climate-influencing gases. Multiple projections of future atmospheric greenhouse gas concentrations have been developed, known as representative concentration pathways (RCPs). Each GCM has been run using each RCP to create a range of scientifically plausible projected climate futures.

Although the projected futures provide resource managers a realistic representation of the uncertainties about future climate, the volume of information can be daunting to incorporate into planning. Average future climate projections for the Northern Great Plains indicate continued warming, more frequent drought and heat waves, and increased winter and spring precipitation (Conant et al. 2018). However, projections specific to WICA vary among individual models and RCPs. To explore this variation and to select a set of climate futures specifically for WICA's scenario planning, we used downscaled climate projection data for the park's location (from MACA [Multivariate Adaptive Constructed Analogs; Abatzoglou and Brown 2012], Schuurman et al. 2019) and considered two projections from each of 18 GCMs: one using a moderate (RCP 4.5), and the other a high (RCP 8.5), greenhouse gas concentration pathway. See Schuurman et al. 2019 for additional methodological details.

The climate projections spanned a range of warming in average annual daily mean temperature from +1.7 °F to +5.7 °F, and a range of change in average annual daily mean precipitation from -1.3 inches (-8%) to +3.7 inches (+19%), for WICA compared to historical (1950-1999) values. Seasonal shifts in precipitation patterns (type, frequency, and intensity) and growing season conditions (onset, duration, and soil moisture levels) varied among the projections. Given this range of future climates, planning for a single future will not prepare a manager for what will actually transpire in the coming decades.

Climate futures, the foundation of climate-resource scenarios, are developed by adding associated resource implications (often referred to as vulnerabilities[3]) to these projections. The wide range of plausible future climate conditions was captured by selecting the four projections that provided maximal divergence in resource implications from among the 28 projections considered (Figure 2):

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[3] Potential resource responses to projected climate conditions are generally described as "vulnerabilities" (e.g., Dawson et al. 2011). However, the resource response could in some cases be positive from the perspective of stewardship goals. For this reason, and for consistency with RSS terminology, we refer to these potential responses with the neutral "implications."

Climate Future 1 (HadGEM2-CC365 RCP 4.5 [Met Office Hadley Centre, UK: Hadley Global Environment Model 2 – Carbon Cycle]); **Climate Future 2** (MRI-CGCM3 RCP 4.5 [Meteorological Research Institute, Japan]) **Climate Future 3** (IPSL-CM5A-MR RCP 8.5 [Institut Pierre Simon Laplace, France: mid-resolution atmospheric model]), and **Climate Future 4** (CSIRO-Mk3-6-0 RCP 4.5 [Commonwealth Scientific and Industrial Research Organization/Queensland Climate Change Centre of Excellence, Australia]). Experience has shown that three or four futures are adequate to capture this divergence and that more are overwhelming. Through consultation with a climatologist, we intentionally avoided selection of models that perform poorly in representing observed, large-scale atmospheric conditions in the WICA region (Rupp et al. 2017, Joyce and Coulson 2020), thereby enhancing plausibility.

We then more fully developed the four climate futures by characterizing associated changes in both the tier-1 and tier-2 climate metrics (see Table 1). Scenario planning participants were provided climate future descriptions—including text, figures (Figures 3-25), and a table (Table 2); see next section. These descriptions are presented as change relative to late-20th-century (1950-1999) conditions and are generally expressed as mean conditions for the time period, but substantial variation occurs around these means.

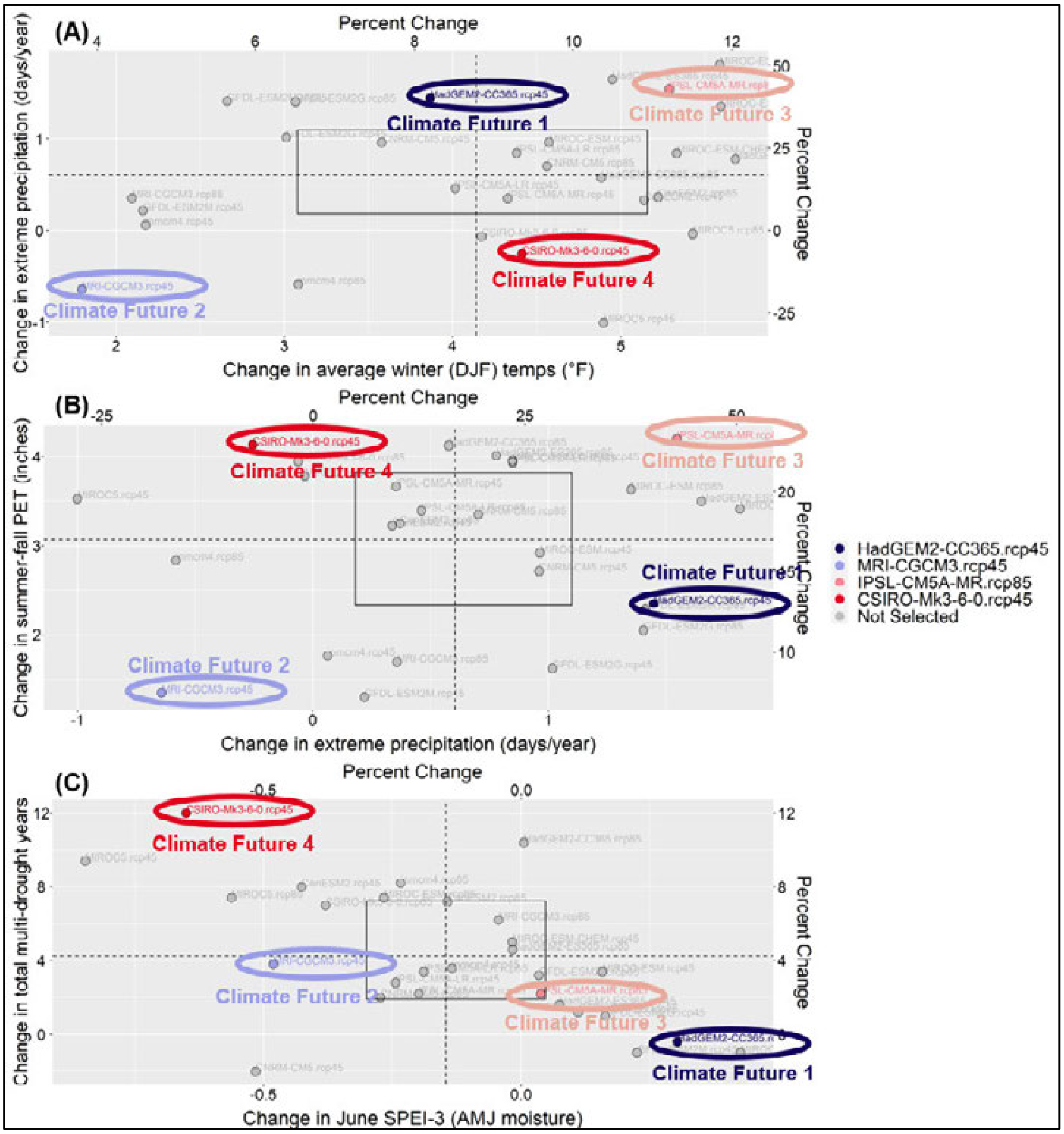

Figure 2. Projected changes in key climate metrics for WICA, including change in average winter (Dec-Feb) temperature and number of days in a year with precipitation >0.7 inch (panel A), change in number of days in a year with precipitation >0.7 inch and summer-fall accumulated PET (panel B), and change in June SPEI-3 (Standardized Precipitation Evapotranspiration Index; details in Appendix) and total multi-drought years (panel C). Points represent differences between average values for the 3-decade period 2025–2055 and 1950–1999 for each GCM. Circled GCM/RCP combinations are projections selected for climate futures. Circle color corresponds with the color of the climate futures and scenarios used throughout this document. Dashed lines indicate the mean value for each axis, and the box around the intersection of the dashed lines defines the central tendency of all projections (models inside the 25th and 75th percentiles for both axes). Left and bottom axes are absolute units of change relative to the historical period and top and right axes represent percent change. Values for Tier-1 metrics for the selected climate futures are provided in Table 4.

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General Summary

Table 2. WICA climate futures (average for 3-decade period 2025–2055), expressed in terms of change relative to the historical period (1950–1999), with negative values indicating declines. W: winter (Dec-Feb); Sp: spring (Mar-May); Su: summer (Jun-Aug); Fa: fall (Sep-Nov). The "Historical" column represents the 1950-1999 average value for each metric.

Climate metric	Season	Climate Future 1	Climate Future 2	Climate Future 3	Climate Future 4	Historical
Annual average temperature (°F)	--	4.3	2.1	5.4	4.6	47.0
Seasonal daily max. temperature (°F)	W	4.4	1.2	5.4	3.2	41.4
Seasonal daily max. temperature (°F)	Sp	2.6	2.3	3.1	4.1	64.9
Seasonal daily max. temperature (°F)	Su	4.2	2.6	6.2	6.9	83.6
Seasonal daily max. temperature (°F)	F	6.1	1.1	5.6	4.2	53.6
Seasonal daily min. temperature (°F)	W	4.9	1.7	5.5	3.4	15.7
Seasonal daily min. temperature (°F)	Sp	2.8	1.9	3.6	3.3	37.8
Seasonal daily min. temperature (°F)	Su	2.6	2.5	6.5	5.7	53.8
Seasonal daily min. temperature (°F)	F	4.8	1.5	5.5	3.7	26.7
Total annual precipitation (in)	--	1.3 (7%)	-1.3 (-7%)	0.3 (2%)	-2.3 (-12%)	19.6
Total seasonal precipitation (in)	W	0.7 (45%)	0.3 (18%)	0.2 (11%)	0.4 (22%)	1.6
Total seasonal precipitation (in)	Sp	1.7 (21%)	-0.4 (-5%)	1.4 (18%)	-0.4 (-4%)	8.0
Total seasonal precipitation (in)	Su	-0.4 (-6%)	0.1 (1%)	-0.5 (-8%)	-1.3 (-22%)	6.5
Total seasonal precipitation (in)	F	0.2 (8%)	-0.3 (-12%)	0.3 (11%)	0.0	2.5
Average seasonal daily relative humidity (%)	W	-0.7	2.4	-4.2	-0.9	54.4
Average seasonal daily relative humidity (%)	Sp	2.9	0.1	-0.7	-1.0	55.0
Average seasonal daily relative humidity (%)	Su	1.6	-0.4	-4.5	-7.9	52.4
Average seasonal daily relative humidity (%)	F	-0.9	0.3	-2.9	-1.6	50.9

Climate Future Comparison

Table 3a. Warming differences among the climate futures.

Climate Future 1	Climate Future 2	Climate Future 3	Climate Future 4
• Large—but seasonally variable—increase in mean annual temperature (avg +4.3 °F). Largest increase in fall; much smaller increase in spring • Large loss of winter conditions with high variability of winter metrics. 32 fewer non-growing-season days and large increases in daily max and min temps • Large increases in hot days (+17 > 97 °F & +24 high heat index)	• Modest temperature increase (avg +2.1 °F) across all seasons with little variability • Little loss of winter conditions. 9 fewer days with tmin < 32 °F and 20 fewer non-growing-season days • Moderate increase in hot days (+5 > 97 °F & +16 high heat index)	• Largest increase in mean annual temperatures (+5.4 °F) with a moderate degree of inter-annual variability. Large warming across all seasons except spring • Largest loss of winter conditions, but with less variability of winter metrics. Average growing-season is 40 days longer with 31 fewer days with tmin < 32 °F • Large increase in hot days (+20 > 97 °F & +31 high heat index) with high degree of inter-annual variability	• Consistent, large increase in mean annual temperatures (+4.6 °F) with highest increases in summer months, but moderate increases in fall / winter • Moderate loss of winter conditions. 18 fewer days with tmin < 32 °F and 12 fewer non-growing season days • Largest increase in hot days with consistency across years (+22 > 97 °F & +34 high heat index)

<u>Warming Common Across Scenarios</u>

- Increase in average annual temperature
- Increase in Tmax and Tmin in all seasons
- Loss of winter conditions (increasing average winter temps, fewer days with Tmin < 32 °F and days with Tmin < 0 °F, and shorter winters[4])
- Fewer freeze-thaw cycles

[4] Average length of winters, calculated as the non-growing season, as defined by the CLIMDEX (https://www.climdex.org/) definition of growing season: the number of days between the start of the first spell of warm days in the first half of the year, and the start of the first spell of cold days in the second half of the year. Spells of warm days are defined as six or more days with mean temperature >41 °F; spells of cold days are defined as six or more days with a mean temperature <41 °F.

- Longer growing seasons
- 2-3 more late-spring frost events/year
- Increase in days that exceed historically hot temperatures
- Substantial increase in days with high heat index

Table 3b. Precipitation differences among the climate futures. The only commonality across scenarios was modest increase in winter precipitation.

Climate Future 1	Climate Future 2	Climate Future 3	Climate Future 4
• Slightly increased (+7%) and highly variable annual precip • Largest increases in winter and spring precip with increase in spring soil moisture availability • Increase in most extreme precip metrics but—due to variability—minima are also lower than historical minima	• Slight decline in annual precip (-7%) • Slightly increasing spring and summer precip but decline in spring soil moisture availability • Slight decline in extreme precip metrics	• Little change in annual precip (+2%) but moderately variable between years • Large increase in spring precip with slight increases in winter and fall. Slight increase in spring soil moisture availability • Increase in extreme precip metrics but—due to variability—minima are also lower than historical minima	• Consistent, large declines in annual precip (-12% / year) • Large decrease in summer and moderate decrease in spring precip resulting in decline in spring soil moisture availability • Little change in extreme precipitation metrics, slight decline

Table 3c. Drought differences among the climate futures.

Climate Future 1	Climate Future 2	Climate Future 3	Climate Future 4
Similar to historical drought regime in duration and frequency but more intense and slightly longer.	Similar to historical drought regime, but droughts slightly more frequent	Flash droughts. Infrequent, and short but intense droughts. Drought similar to the 2012 drought occurs twice per decade	Extended droughts. More frequent and longer droughts but of moderate intensity. Drought regime similar to the 2000s, where drought occurs 40% of the time with little recovery between events

<u>Drought Common Across Scenarios</u>

- Increase in proportion of years that are part of multi-year drought
- Fewer years between droughts (i.e., shorter drought return interval)
- More intense droughts (due to higher temperatures)

Resource-specific climate sensitivity metrics

Table 4. Projected changes in WICA's tier 1 climate metrics (corresponding to priority resource climate sensitivities). Each value is the difference between the climate metric's future-period (2025-2055) average and the historical–period (1950-1999) average. Resource relevance is indicated via shading in the five columns on the right.

Tier	Climate Metric	Climate Future 1	Climate Future 2	Climate Future 3	Climate Future 4	Historical	Water	Vegetation	Cultural	Wildlife	Other
1	AMJ moisture availability (June SPEI-3 values)	0.1	-0.7	0.02	-0.6	0.3					
1	Average winter temperatures (°F)	4.3 (9%)	2.1 (5%)	5.4 (12%)	4.6 (10%)	47.0					
1	Days with precipitation >0.7 inches (99th-perc. event, 1950-1999)	1.0 (27%)	-0.8 (-21%)	1.3 (32%)	-0.4 (-12%)	3.9					
1	Summer-Fall (JJASON) PET (inches)	2.5 (14%)	1.4 (8%)	4.1 (23%)	4.0 (22%)	18.3					
1	Percentage of 30-year period in multi-year drought	9.7 (138%)	9.7 (138%)	6.3 (90%)	33 (471%)	7					
2	T2Days/year with min temperature <32 °F	-29.0	-8.7	-31.4	-17.8	173.4					
2	Days/year with min temperature <0 °F	-6.5	-3.8	-9.2	-6.2	14.0					

Tier	Climate Metric	Climate Future 1	Climate Future 2	Climate Future 3	Climate Future 4	Historical	Water	Vegetation	Cultural	Wildlife	Other
2	Winter length (non-growing-season days/year)	-35.9 (-28%)	-19.5 (-15%)	-39.6 (-31%)	-12.1 (-9%)	128.8					
2	Freeze-thaw cycles (days/year)	-19.5 (-18%)	-3.0 (-3%)	-17.6 (-16%)	-4.0 (-4%)	111.2					
2	Green-up date (days earlier)	Mar-7 (32)	Mar-25 (13)	Mar-10 (29)	Mar-27 (12)	Apr-8					
2	Spring frost events (days/year)	2.2 (14%)	2.5 (16%)	2.7 (16%)	3.0 (18%)	16.3					
2	Days/year >97 °F	16.7	5.4	20.3	21.6	2.9					
2	Average consecutive days/year >97 °F	6.0	1.9	7.0	5.3	1.4					
2	Size of 2-day extreme precipitation event (inches)	0.2 (19%)	-0.2 (-15%)	0.1 (9%)	-0.1 (-9%)	1.2					
2	Precipitation on saturated soil (days/year)	1.9 (95%)	-1.0 (-52%)	1.1 (58)	-0.6 (-33%)	2.0					
2	Annual precipitation occurring in winter (%)	5.2 (25%)	2.5 (12%)	0.9 (4%)	6.7 (32%)	21.1					
2	Days/year with 'extreme caution' heat index[1]	24.1	15.8	31.0	34.9	10.2					
2	Frequency (years between drought events)[2]	-3.0 (-60%)	-3.3 (-65%)	-2.6 (-52%)	-3.8 (-75%)	5.0					
2	Intensity (drought minimum SPEI-6 values)[2,3]	-0.3 (-28%)	-0.2 (-21%)	-0.5 (-44%)	-0.2 (-21%)	-1.1					
2	Duration (average drought length [years])[2]	0.2 (17%)	-0.1 (-4%)	0.3 (20%)	0.9 (68%)	1.4					
2	Severity (intensity x duration)[2,3]	-0.5 (-40%)	-0.1 (-10%)	-0.9 (-69%)	-1.2 (-89%)	-1.4					

[1] This climate metric applies to human wellbeing and is relevant for both visitor and staff management.

[2] Tier 2 drought metrics (See Appendix 2 for details).

[3] Negative values indicate more severe drought conditions in this metric.

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Climate future figures

All figures below, except Figure 21, were presented to workshop participants for their consideration when developing climate-resource scenarios and are included here for reference.

<u>Fundamental climate</u>

These measures of basic climate characteristics visually depict the range of plausible future climate. Resource sensitivity to the metric shown in figure is depicted by color highlighting.

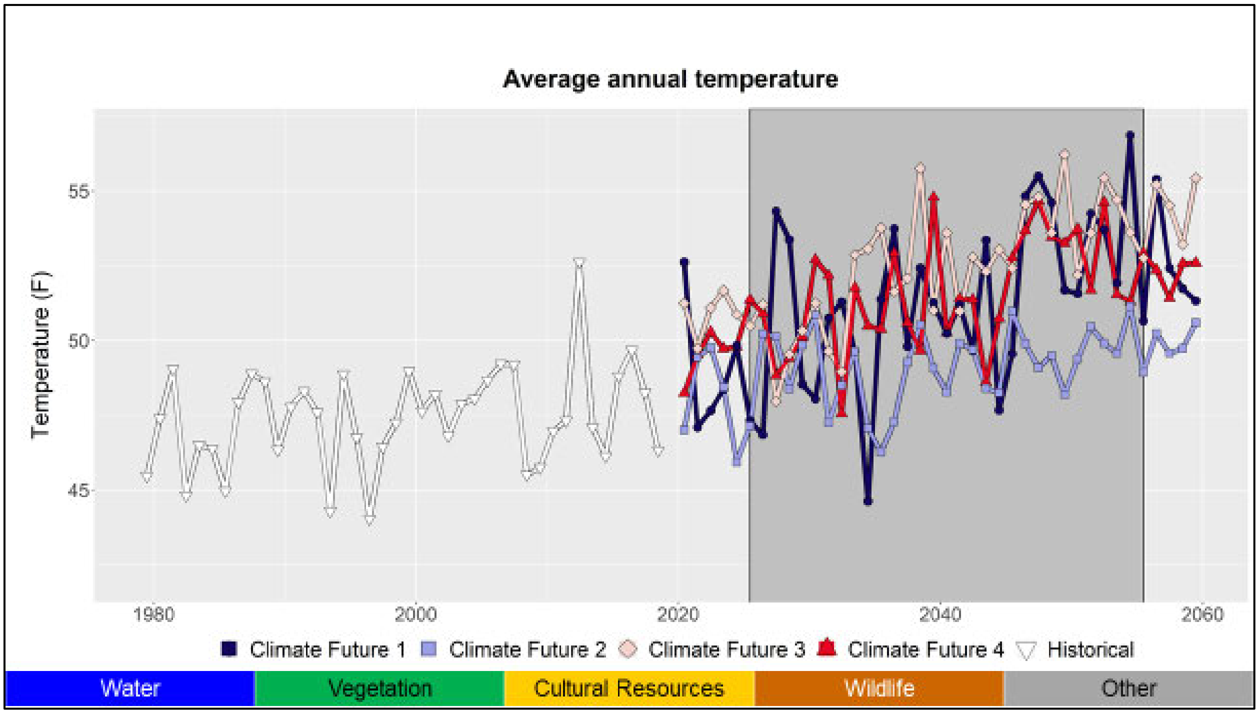

Figure 3. Average annual temperature observed from 1980-2018 and projected through 2060 for selected climate futures. The period of interest for this study (2025-2055) is highlighted in gray. Historical data are the gridded, observed data (gridMET [Abatzoglou, 2013; http://www.climatologylab.org/gridmet.html]) used to train the projections.

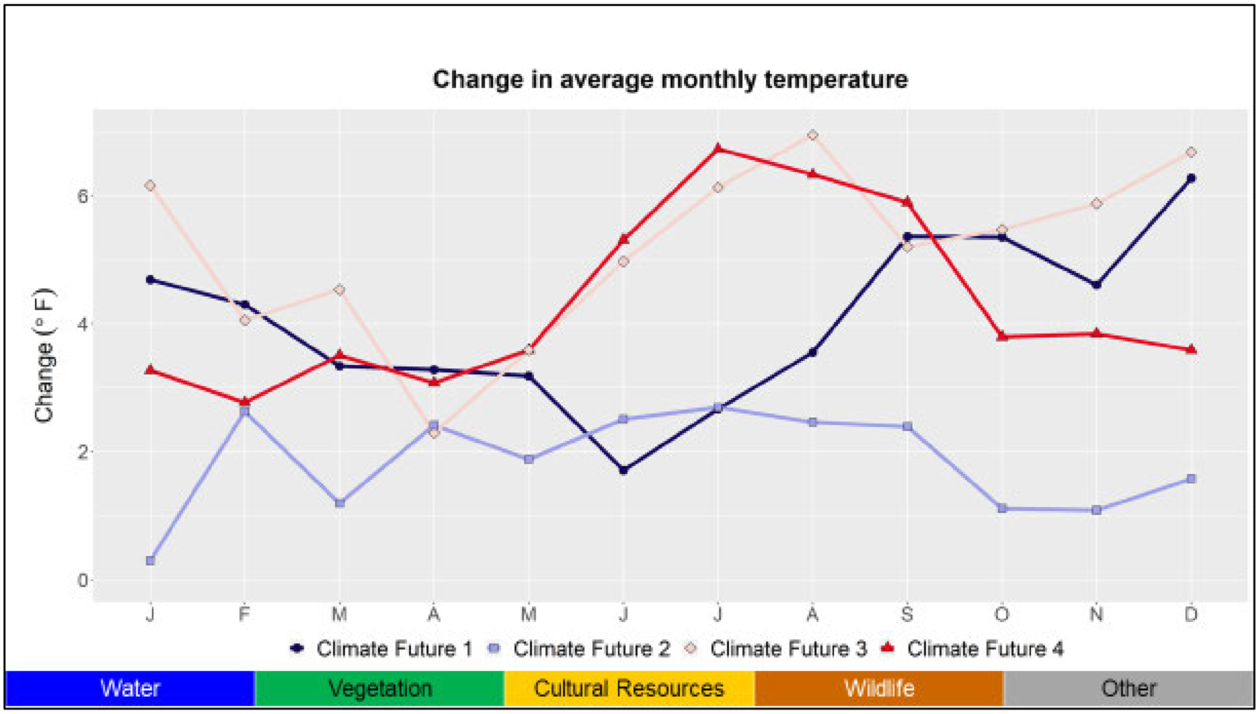

Figure 4. Change in average monthly temperature, 2025-2055 compared to 1950-1999.

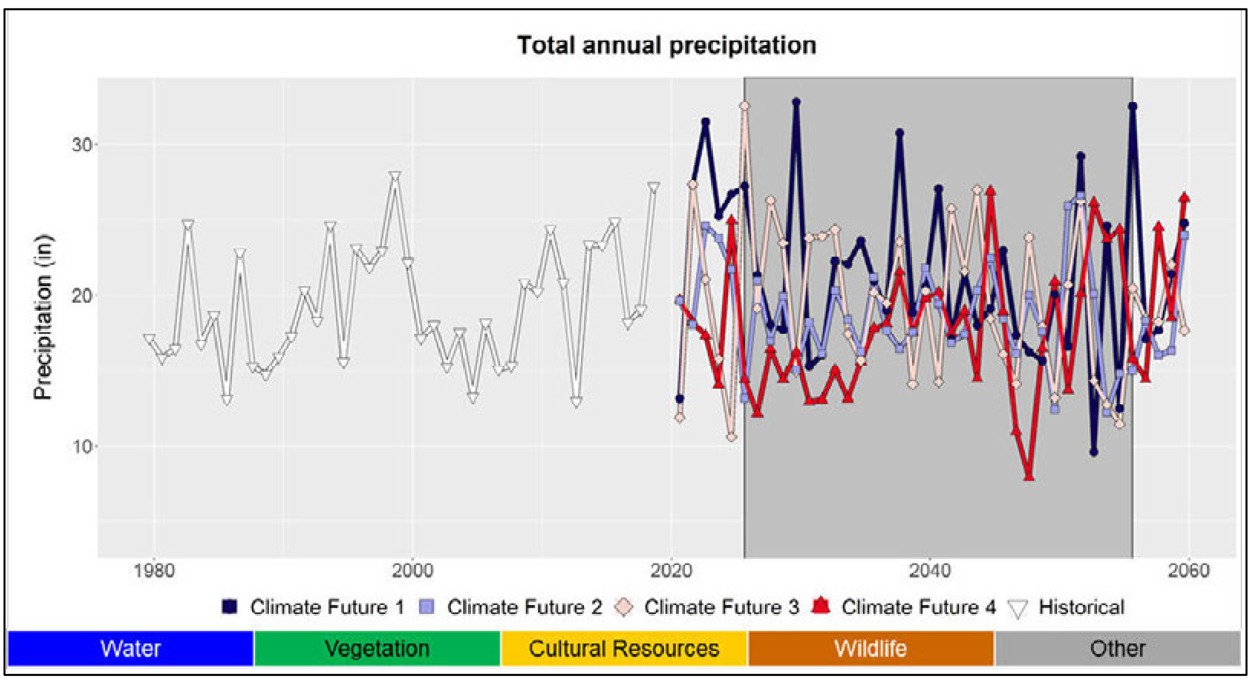

Figure 5. Total annual precipitation observed from 1980-2018 and projected through 2060 for selected climate futures. The period of interest for this study (2025-2055) is highlighted in gray. Historical data in this plot are the gridded, observed data (gridMET) used to train the projections.

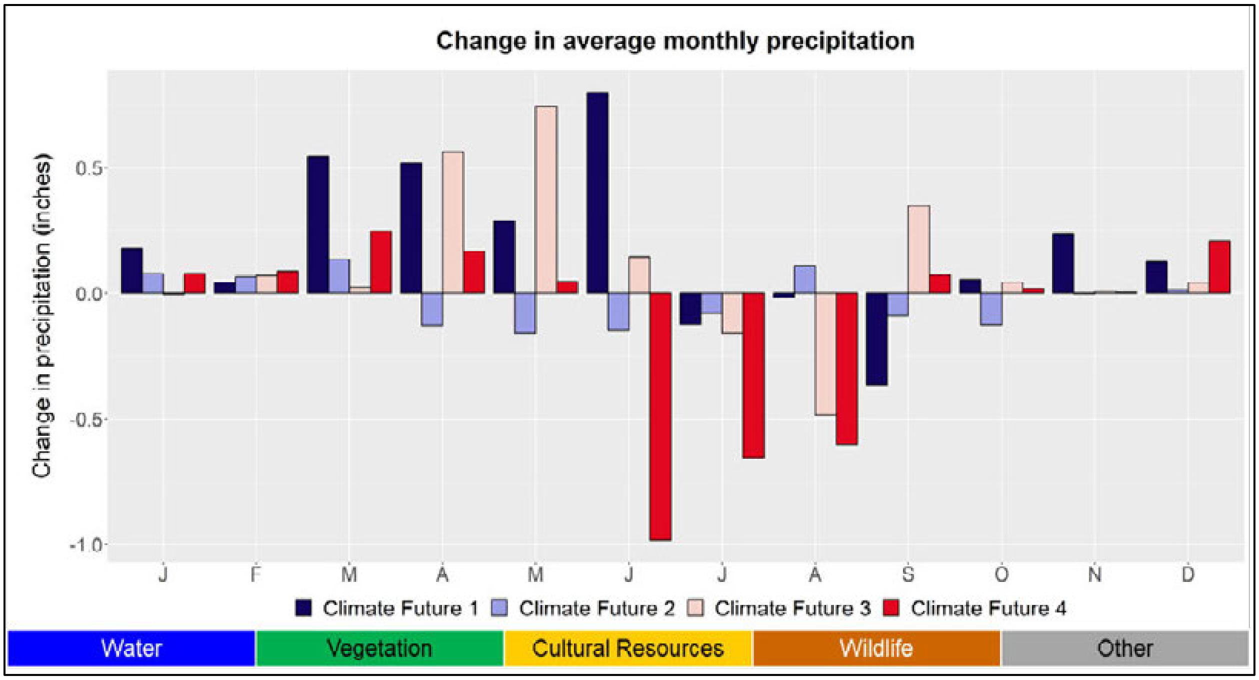

Figure 6. Change in average monthly precipitation, 2025-2055, compared to 1950-1999.

<u>Tier-1 climate metrics</u>

For each tier-1 metric, the distribution of annual values of the metric are shown and summarized using a boxplot. For each climate future, values are projections from each year, 2025-2055. For the historical period (1950-1999), values shown are a sample of values from the modeled past conditions for each of the four projections that were used to create the climate futures. The upper and lower ends of the boxes correspond to the first and third quartiles (25th and 75th percentiles) of the points, the horizontal line in each box indicates the median value and the vertical lines extend to the maximum and minimum values, excluding outliers (i.e., points >1.5 times the quartile), which are plotted individually as small black circles. Note that points are scattered horizontally within columns to avoid overlap. Resource sensitivity to the metric shown in figure is depicted by color highlighting.

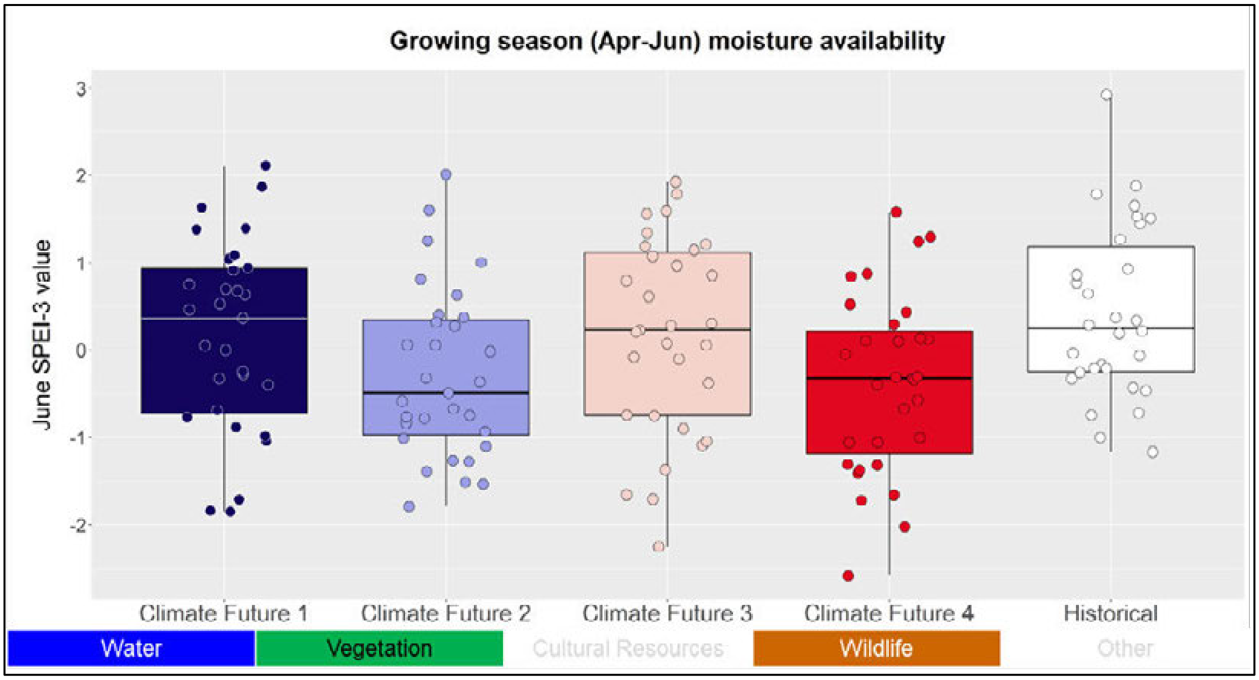

Figure 7. Moisture availability during growing season months, April–June, calculated as the 3-month SPEI (see Appendix 2) at the end of June.

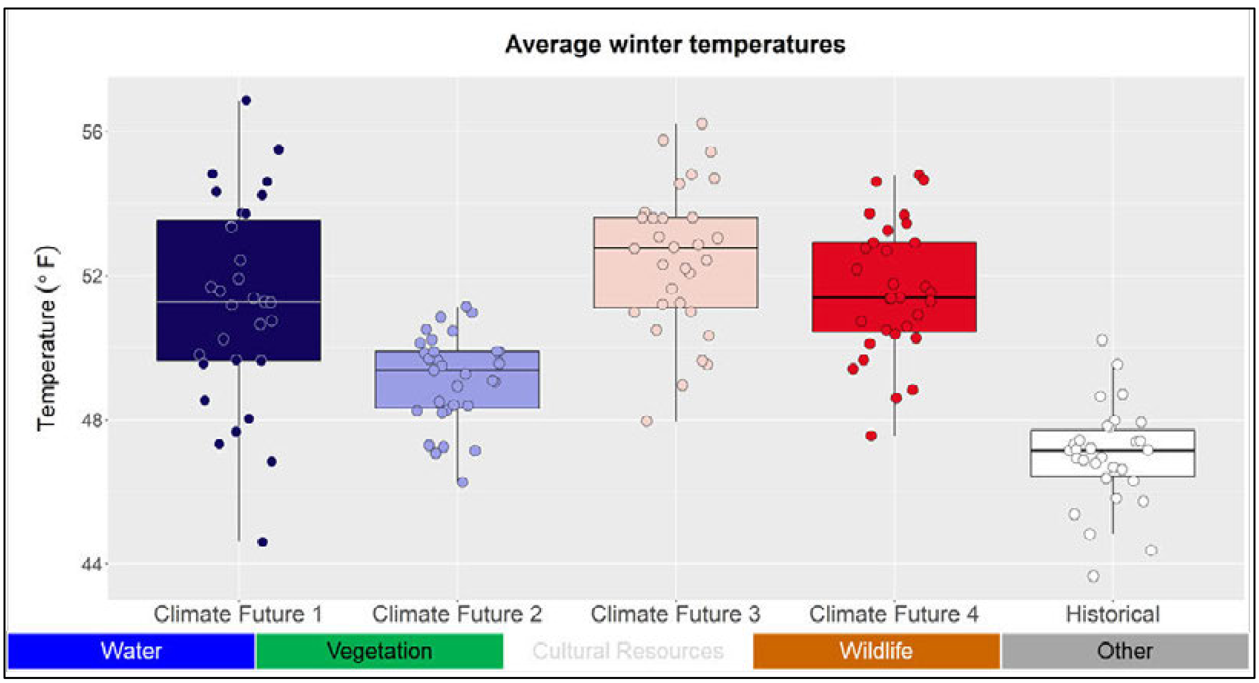

Figure 8. Average winter (Dec-Feb) temperatures.

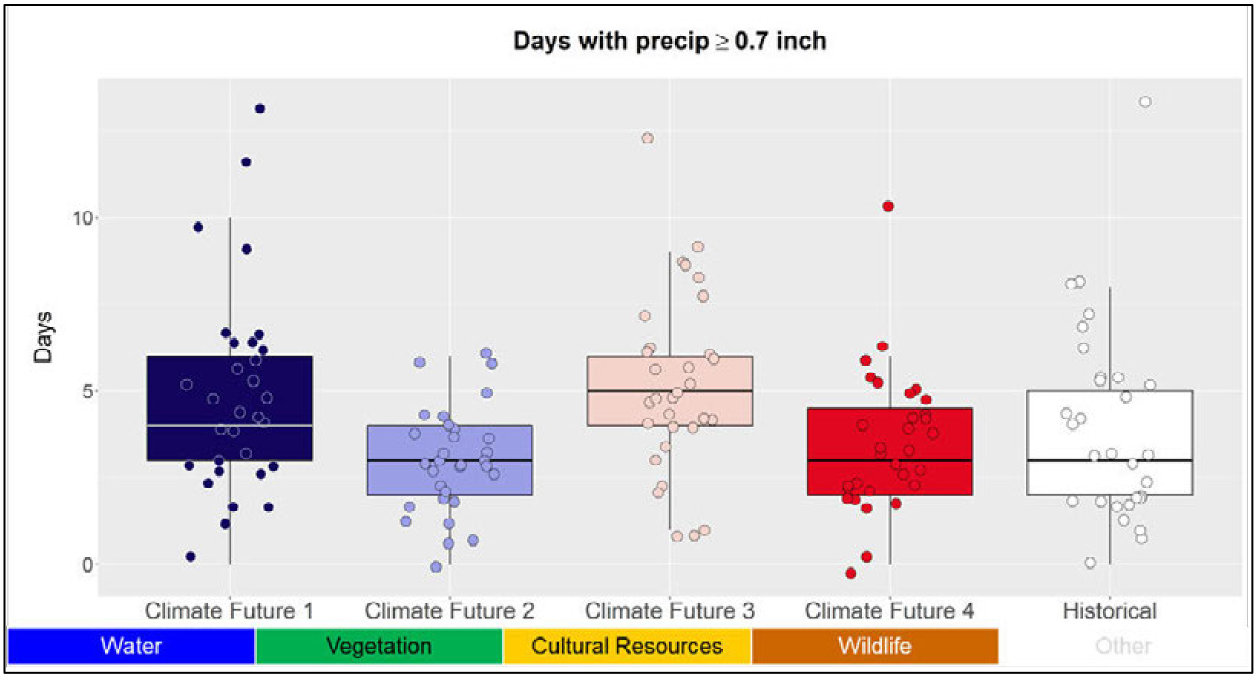

Figure 9. Number of days per year that receive ≥ 0.7 inch total, the historical 99th-percentile event.

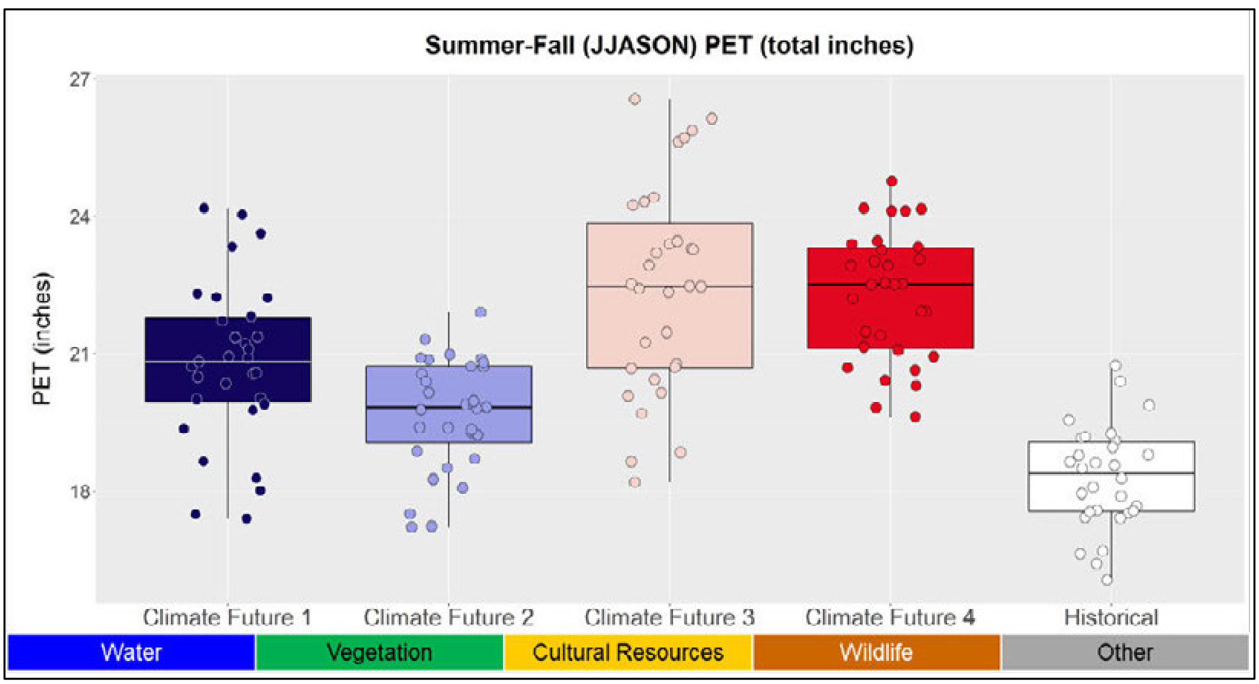

Figure 10. Accumulated monthly potential evapotranspiration (PET) for the growing season (estimated using Thornwaithe equation), a proxy for fire risk.

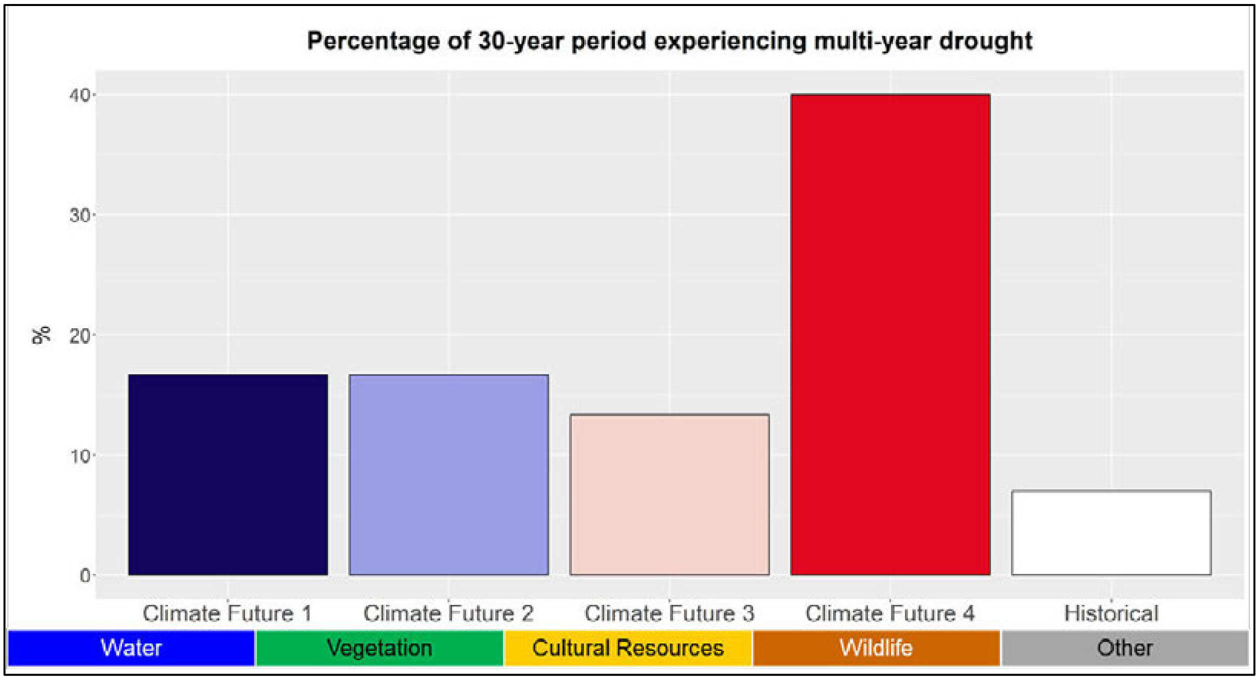

Figure 11. Percentage of years in the 30-year period experiencing multi-year droughts; see Appendix 2 for details.

Tier-2 climate metrics

For each tier-2 metric, the distribution of annual values of the metric are shown and summarized using a boxplot. For each climate future, values are projections from each year, 2025-2055. For the historical period (1950-1999), values shown are a sample of values from the modeled past conditions for each of the four projections that were used to create the climate futures. The upper and lower ends of the boxes correspond to the first and third quartiles (25th and 75th percentiles) of the points, the horizontal line in each box indicates the median value and the vertical lines extend to the maximum and minimum values, excluding outliers (i.e., points >1.5 times the quartile), which are plotted individually as small black circles. Note that points are scattered horizontally within columns to avoid overlap. Resource sensitivity to the metric shown in figure is depicted by color highlighting.

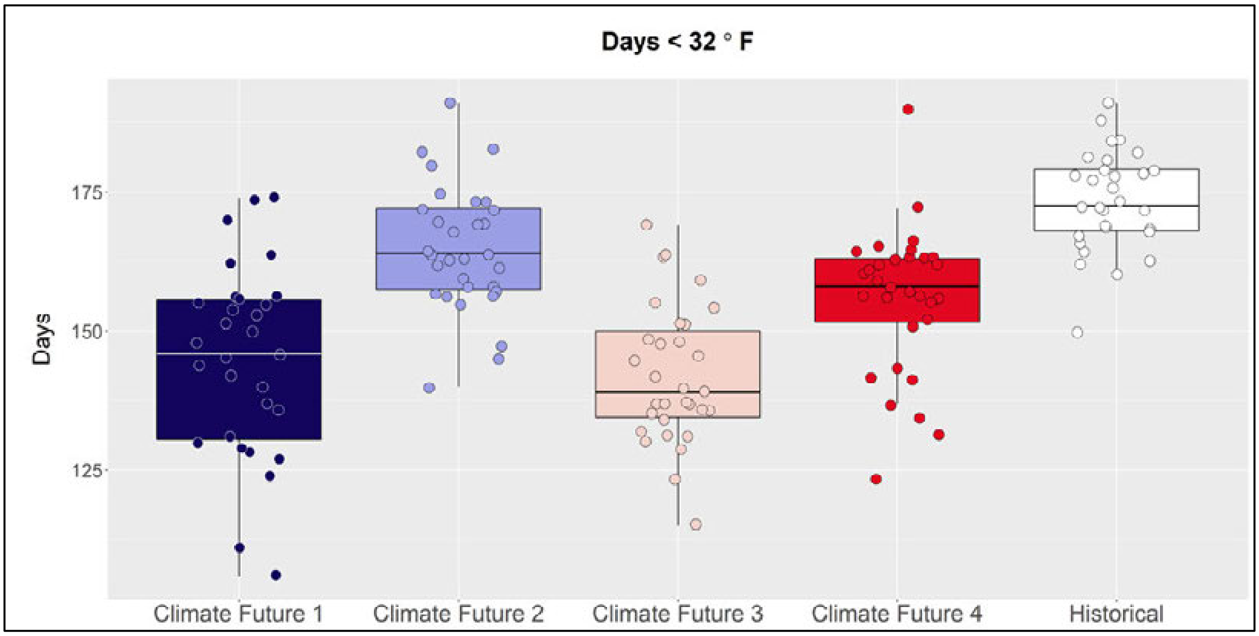

Figure 12. Number of days per year when the minimum temperature <32 °F.

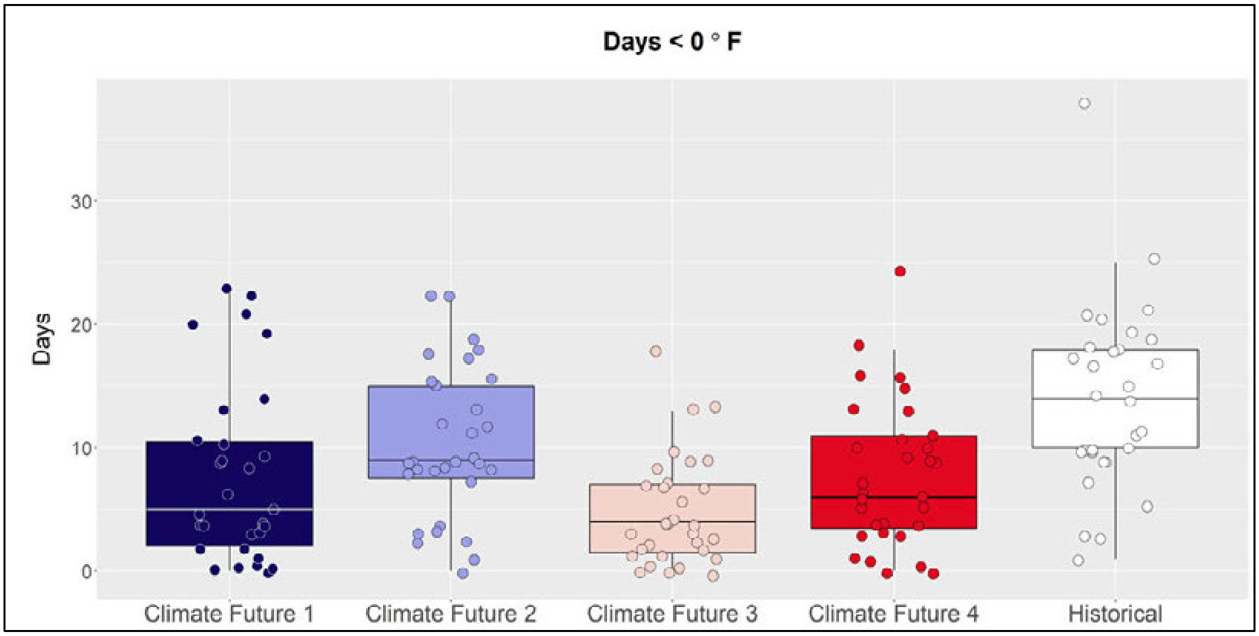

Figure 13. Number of days per year when the minimum temperature <0 °F.

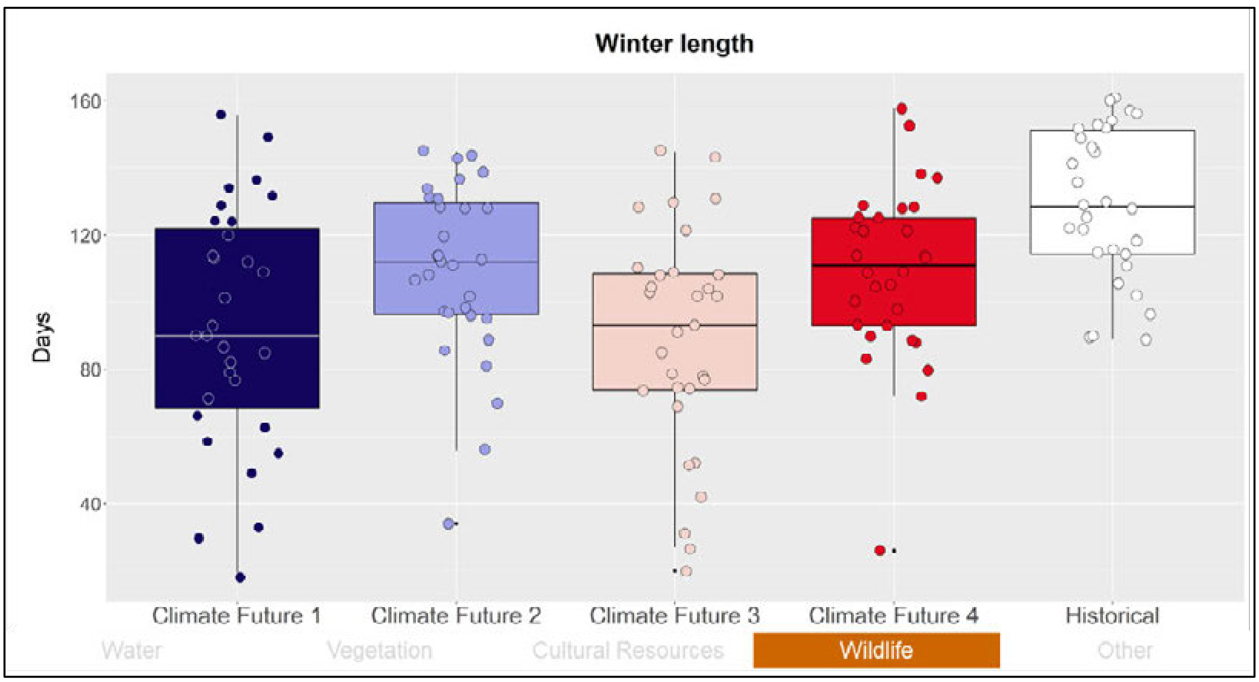

Figure 14. Length of winters, calculated as the non-growing season. The growing season was calculated using the CLIMDEX definition: the number of days between the start of the first spell of warm days in the first half of the year, and the start of the first spell of cold days in the second half of the year. Spells of warm days are defined as six or more days with mean temperature >41 °F; spells of cold days are defined as six or more days with a mean temperature <41 °F.

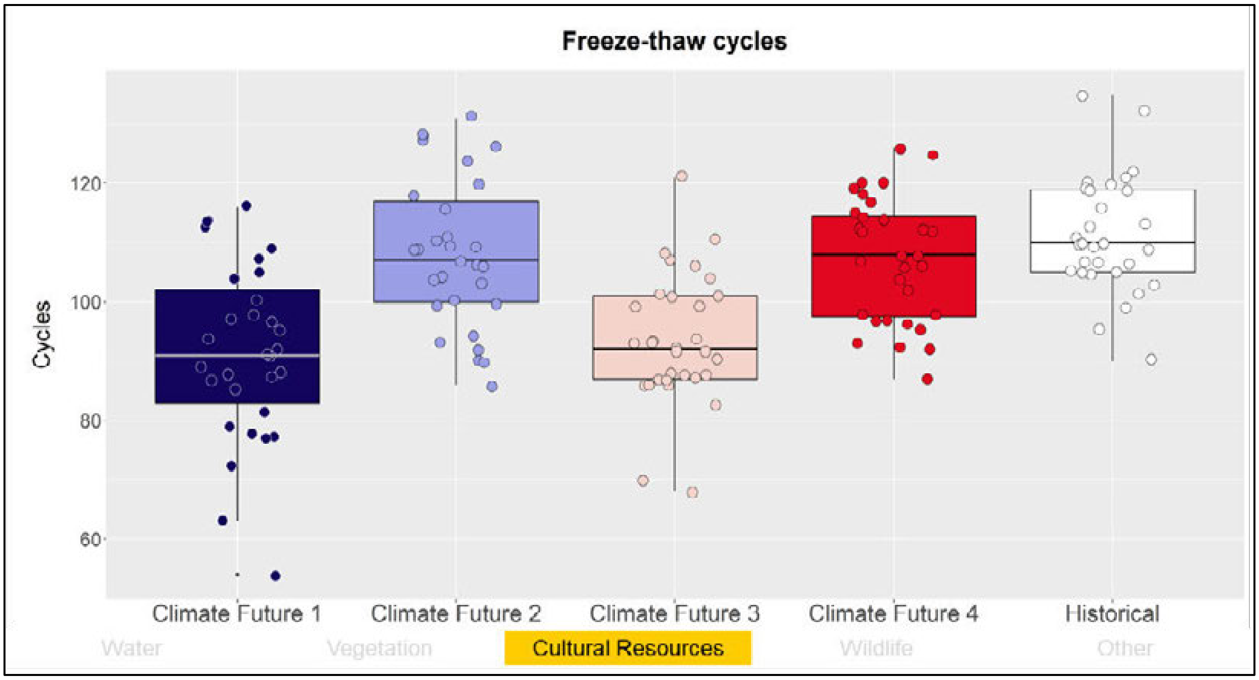

Figure 15. Number of freeze-thaw cycles per year, calculated as days when the maximum temperature >34 °F and the minimum temperature <28 °F.

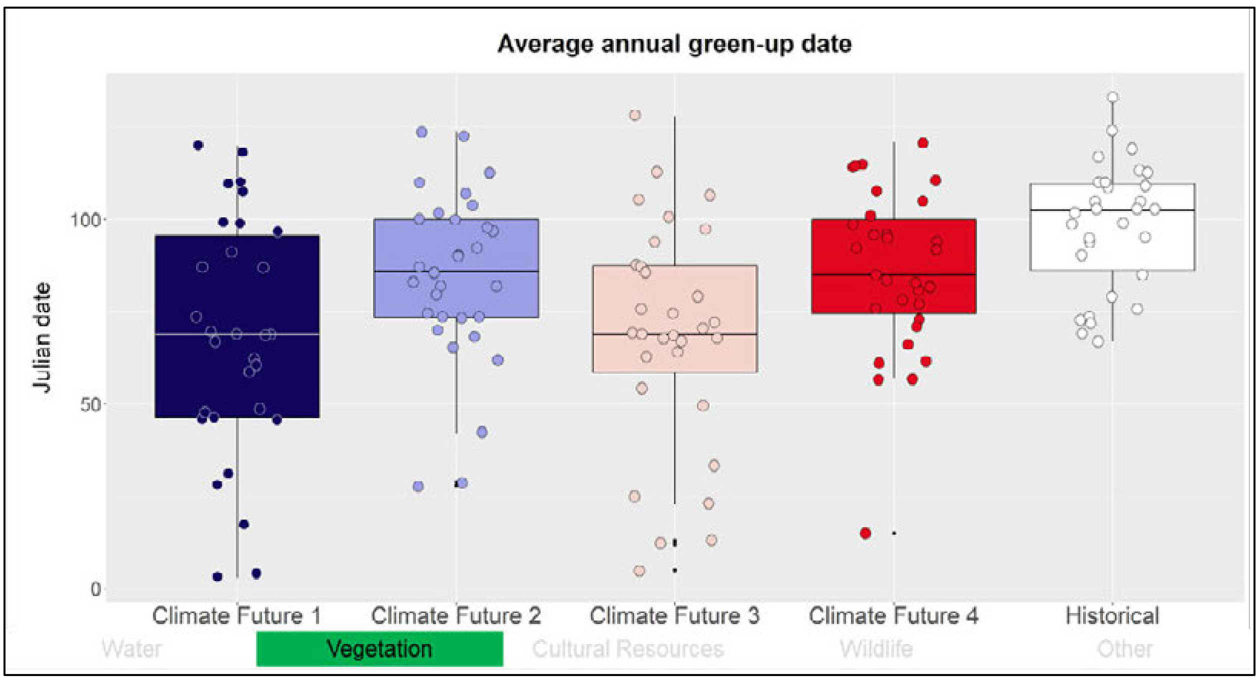

Figure 16. Annual green-up date (expressed as Julian date), calculated as the start of the first spell of warm days in the first half of the year, as described in Figure 14. See Table 4 for dates.

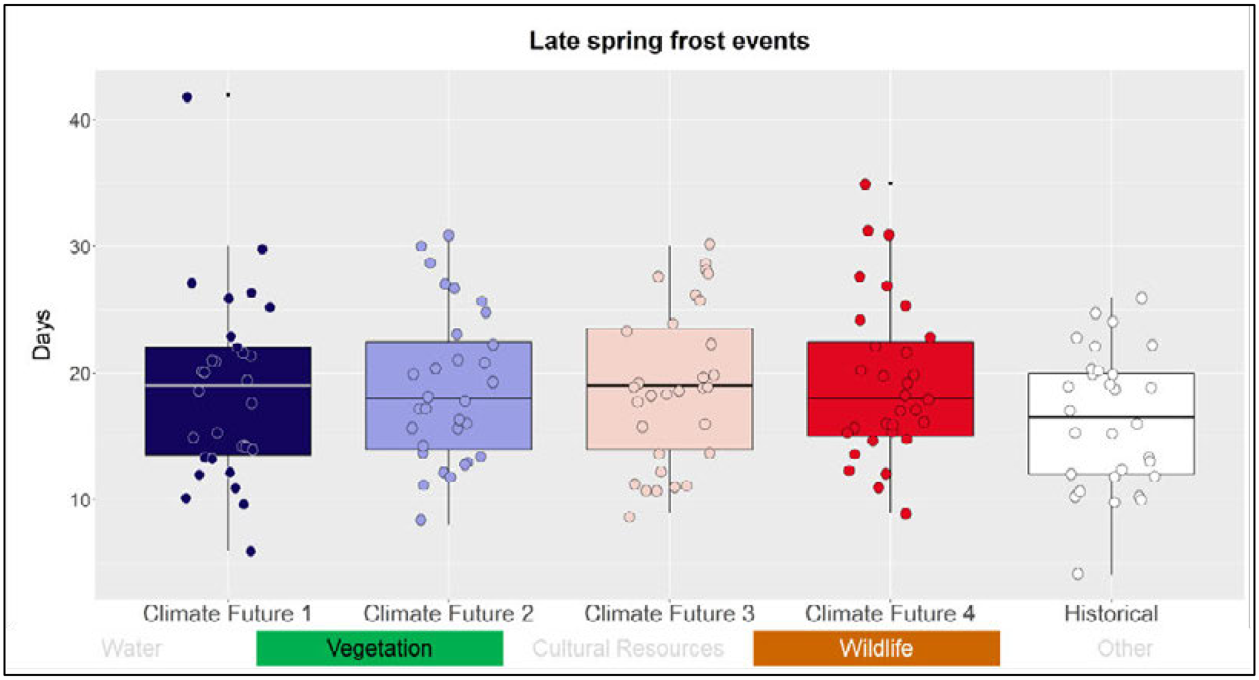

Figure 17. Late spring frost events, calculated as days with minimum temperatures ≤32 °F after the green-up date (see Figure 16 definition), but before the summer solstice.

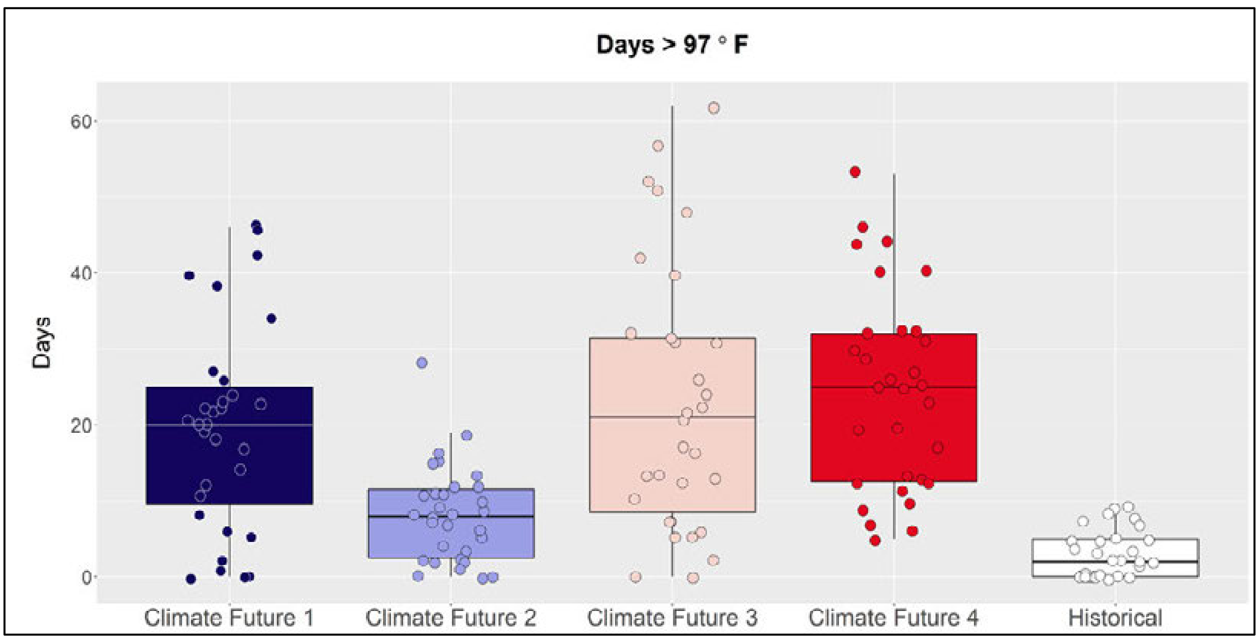

Figure 18. Number of days per year when the maximum temperature >97 °F. Historically, a day that exceeds 97 °F is a 99th-percentile event at WICA.

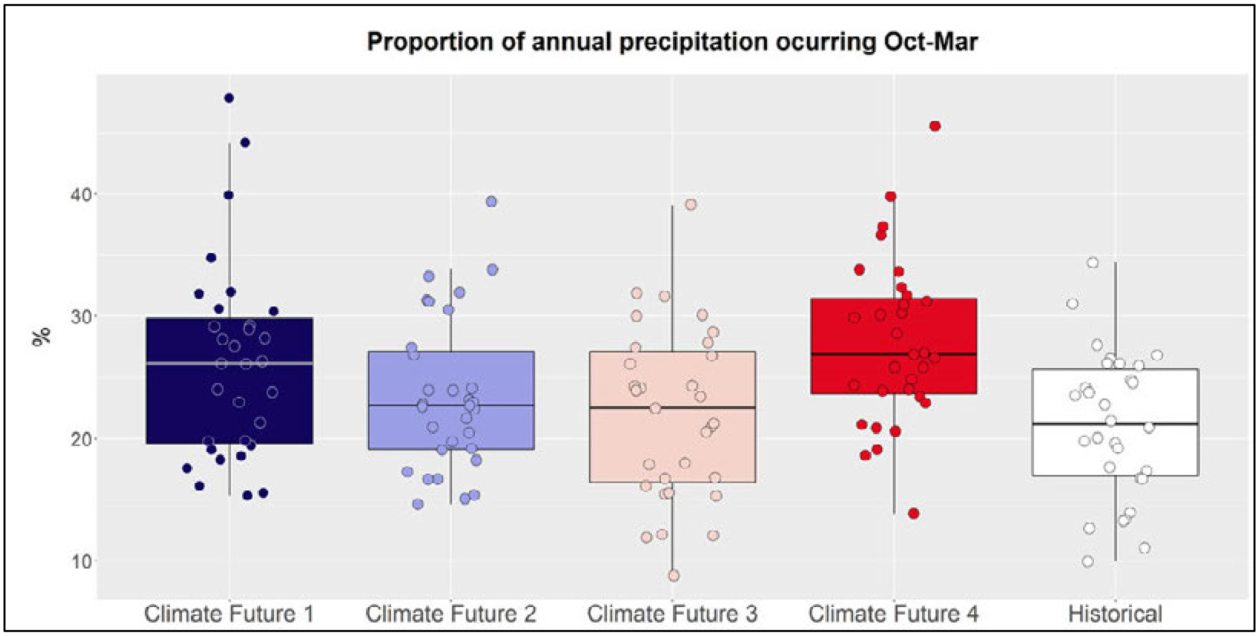

Figure 19. Proportion of total annual precipitation occurring in fall and winter months (Oct-Mar).

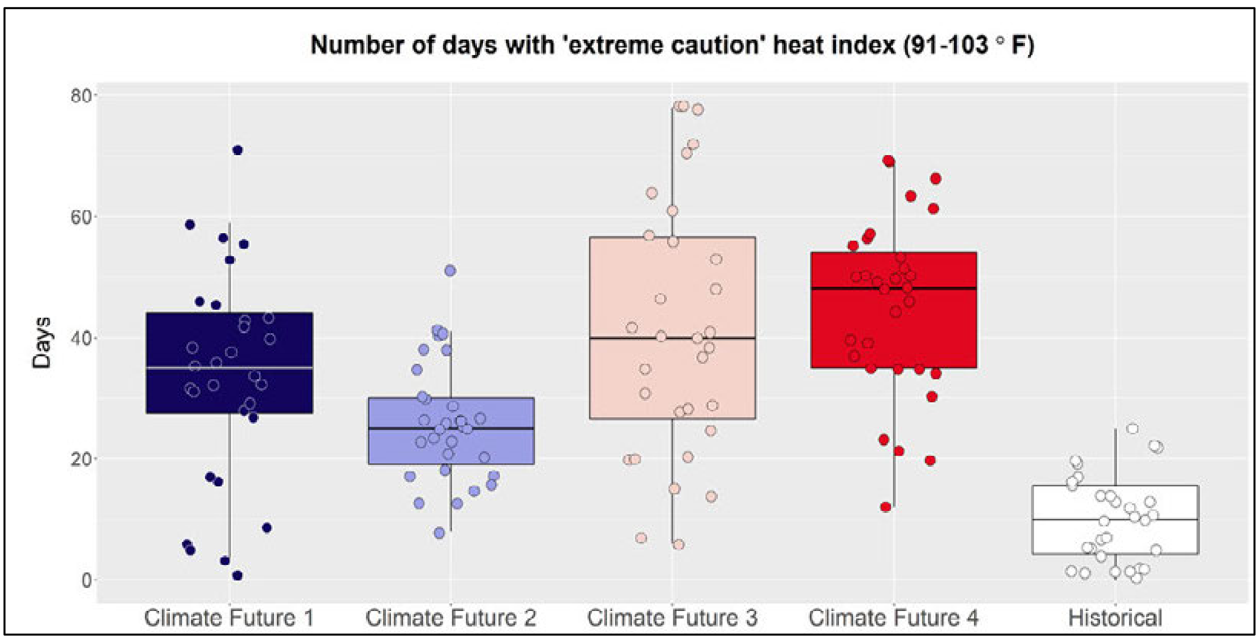

Figure 20. Number of days per year when heat index reaches "extreme caution" levels (91-103 °F). The heat index is an equation used by the National Weather Service to measure the discomfort felt as a result of the combined effects of air temperature and humidity.

Tier-2 Drought Metric Summarizations

The following metrics summarizing climate futures correspond with period signified by the grey shaded area. For details on drought calculations, see Appendix 2.

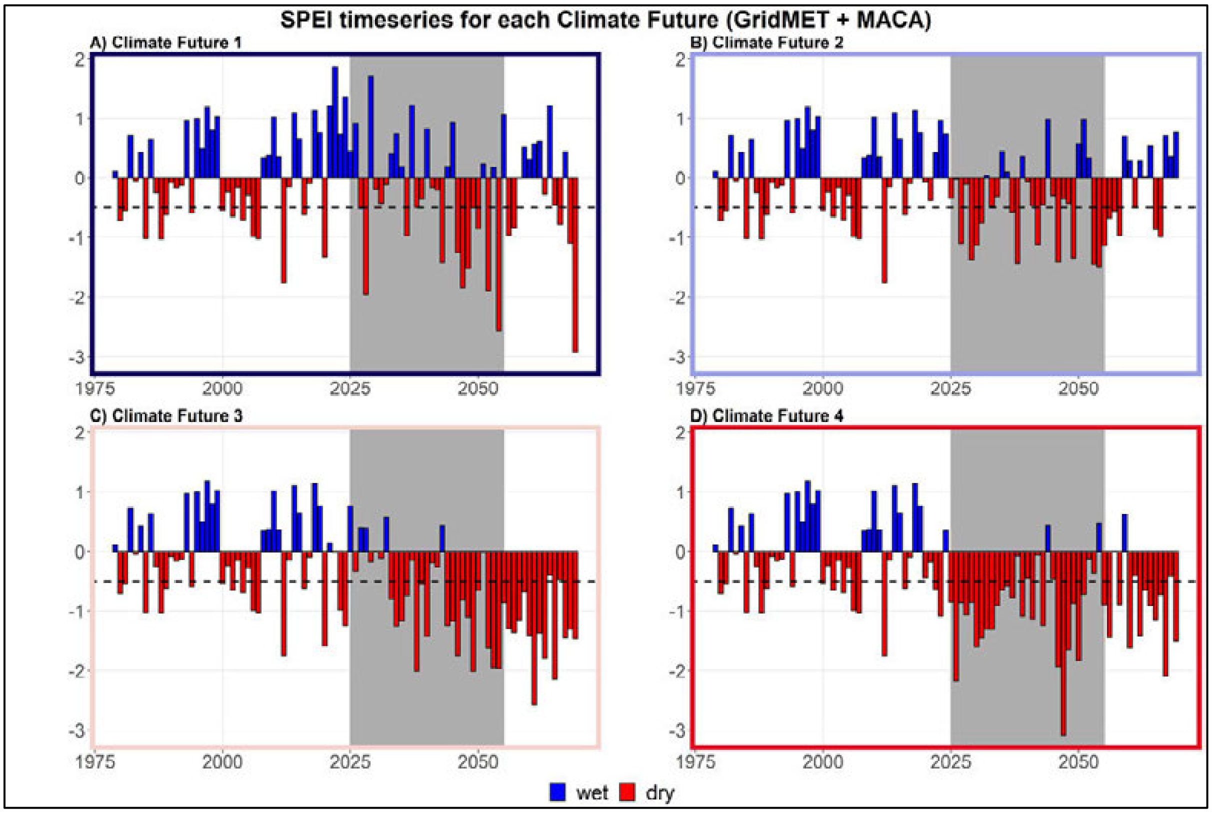

Figure 21. Drought index (SPEI) timeseries for each climate future. Data for the period prior to 2018 is GridMet (Abatzoglou 2013) and after is MACA (Abatzoglou and Brown 2012).

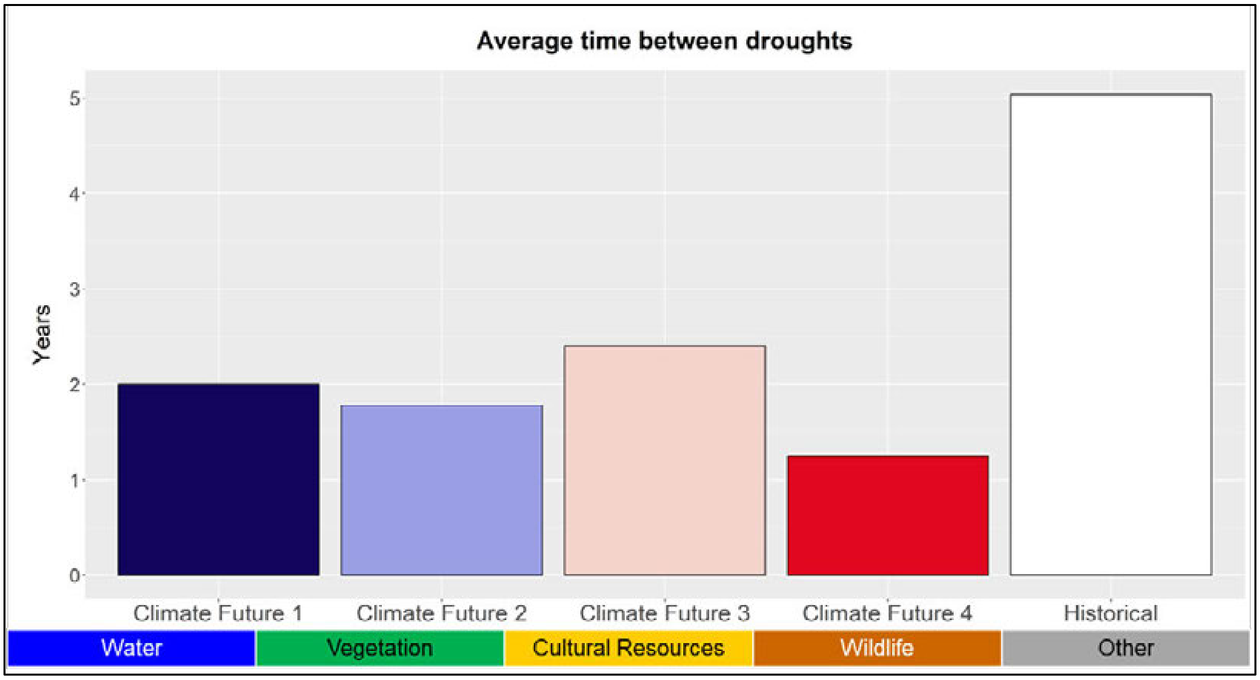

Figure 22. Average drought return interval, or number of years between the end of one drought event and the start of the next drought event.

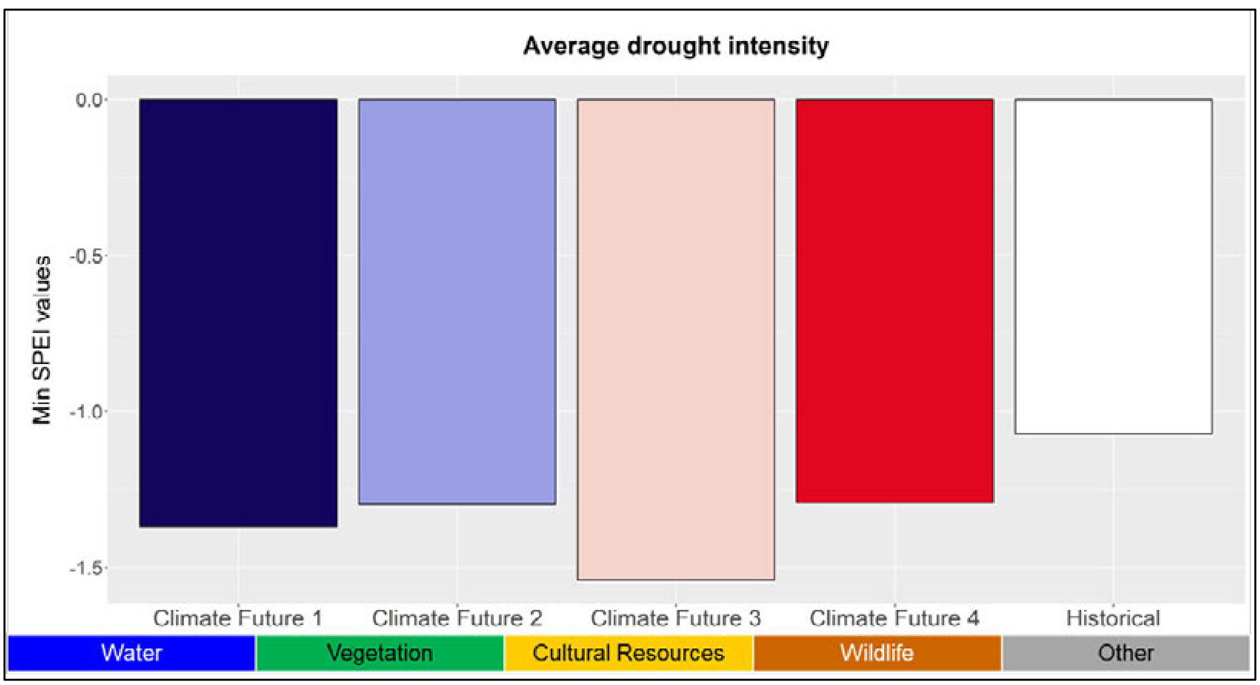

Figure 23. Average minimum SPEI aggregated in 6-month intervals (SPEI-6) values for drought events. Lower values indicate more severe drought conditions.

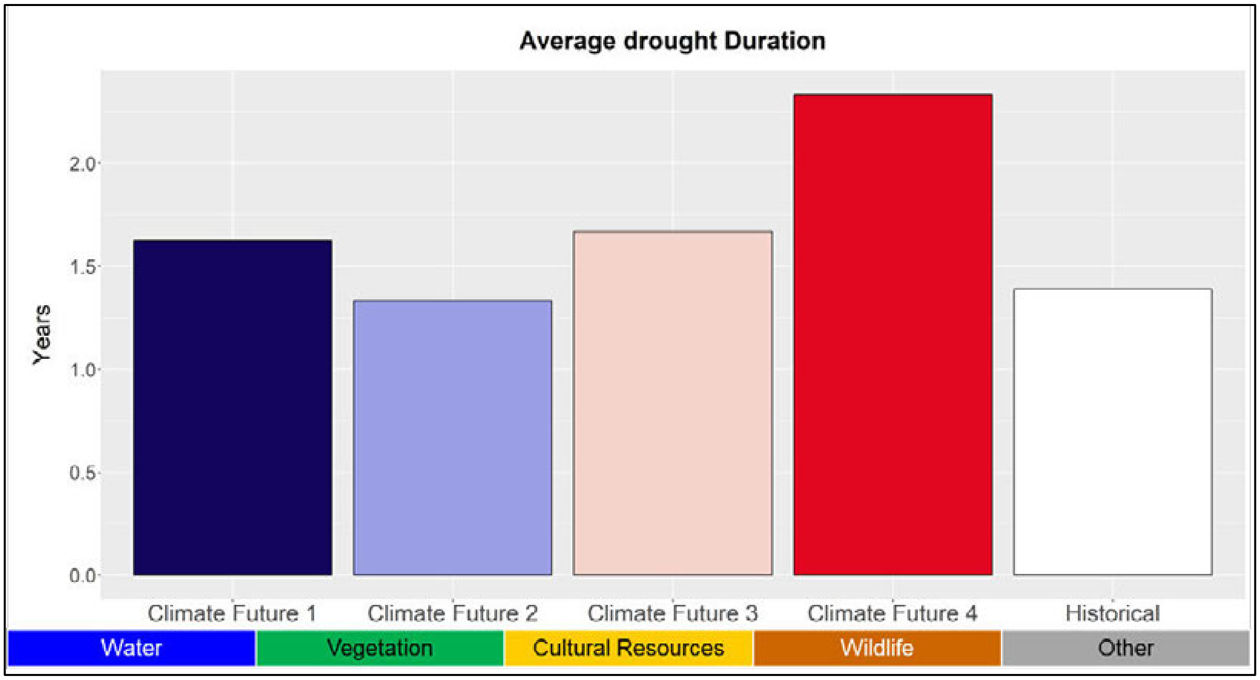

Figure 24. Average drought duration, defined as the average number of years drought events last.

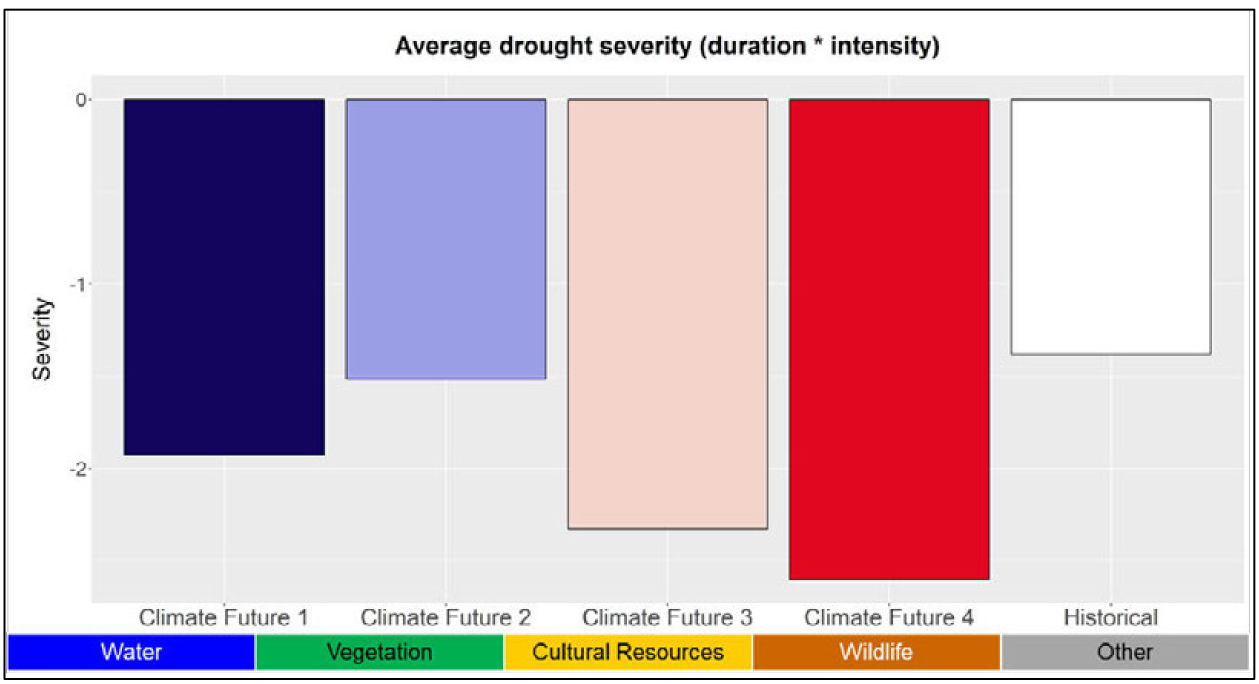

Figure 25. Average 'severity' of drought events, calculated as the duration multiplied by the intensity for the extent of the drought event. Lower values indicate more severe drought conditions.

Climate-resource scenario development and implications

During the July 2019 scenario planning workshop (see WICA RSS Summary, Table 2), participants developed four scenarios from the climate futures then examined current stewardship goals and activities in terms of feasibility and effectiveness, respectively, under each scenario.

Scenario development

Constructing scenarios from the climate futures took two consecutive working sessions; in the first participants worked in either the aquatics/hydrology or vegetation resource subgroup; in the second they worked in either the wildlife, cultural, or air resources subgroup for the second working session. During these sessions, the subgroups determined (ideally) the response of each resource component under each characterized climate future. The resource subjects were sequenced so that climate future implications for base resources (water and vegetation) could inform the second set of resources. Later, participants named the scenarios so they could be more easily identified by their distinguishing characteristics (Table 5).

Table 5. Climate-resource scenarios and their distinguishing characteristics. See Table 3 (a-c) for more complete descriptions of climate futures.

Climate Future	Climate-resource scenario	Features
Climate Future 1	**Log Ride**	Captured the occasional very wet years ("splashes" in an amusement-park water roller coaster)
Climate Future 2	**Hourglass**	Indicated the most gradual and subtle change in climate through time of all the futures
Climate Future 3	**Jenga**	An initial period of little change followed by a strong switch to a consistently drier climate reminded participants of the game in which blocks in a tower are removed until a sudden collapse
Climate Future 4	**Convection Oven**	Simply the hottest and driest of the scenarios

Due to the limited time in the workshop to develop the scenarios, post-workshop discussions and work resulted in additions, modifications, and clarifications to the scenarios. The scenario descriptions in Table 6 are the final versions. The descriptions should not be considered vetted research statements of responses to the climate futures, but rather as insights and examinations of possible futures based on a combination of available science, local expert knowledge, and management experience.

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Table 6. Scenario planning workgroup-envisioned developments and resource implications (vulnerabilities) for WICA climate futures for each priority resource and resource component. Bold text signifies "red flag" events, i.e., impactful outcomes unique to a single scenario (NPS 2020). All references to shifts refer to status under historical conditions.

Priority	Resource component	Log Ride	Hourglass	Jenga	Convection Oven	Common across all/most scenarios
Water	Groundwater (GW)	• More winter precip and higher winter temps lead to earlier and more snow melt, adding to GW recharge • Annual, spring, and winter precip increases likely increase GW levels • Warmer late summers increase GW use by humans which may affect the GW; impacts on GW availability unknown	• Slow decline of GW availability • GW levels in cave lakes decline over time	• GW levels about the same as historical because very little change in annual precip and GW loss has low climate sensitivity	• Decrease in GW levels—faster than the other scenarios • Rate of GW decline dependent on external uses—greatest potential for more GW use outside of the park	--
Water	Surface water (SW)	• Decrease in SW availability in summer • More extreme precip events increase stormflow runoff; potential erosion issues • Variability in SW flow from variability in interannual precip; higher flows levels at times due to more frequent high-precip events; more very low to no-flow days due to drought intensity and length increases • Higher temp creates more evapotranspiration, decreasing summer SW availability; could be negated by late-spring precip increases; it is likely that late summer SW flows will decline	• More low flows throughout the years • Flow regime most similar to historical (out of the four futures) since there is the least amount of departure. • Warmer, longer season could potentially lead to more evapotranspiration (ET), which would negatively impact SW • Scarce SW during more frequent droughts	• Decrease in SW in the late summer; won't take long for a creek to dry up • Increase in SW flows during spring	• **SW will be lower and could dry up**	--

Priority	Resource component	Log Ride	Hourglass	Jenga	Convection Oven	Common across all/most scenarios
Water	Other	• Potentially greatest impacts to SW are existing and new dams upstream from the park. Park may have to depend solely on precip within its boundaries • Potential access issues to certain areas of the park due to flooding • Upward trend for springs and seeps in this future • Potential surrounding land use change (converting private prairie lands into farmland) would increase demand for water outside of park • Water quality declines with large floods due to sedimentation and surface runoff from upstream lands	• Less water availability • Decreased number of springs (both natural and developed) and lower spring flow at times due to decrease in soil moisture • Greatest SW impacts are due to existing and new upstream dams withholding water. Park may have to depend solely on precip within its boundaries	• Slight decrease in number of springs and seeps; they may flow longer into the summer due to greater precip in springtime • Cave lakes would be affected similarly to GW • Water quality depends on land use changes surrounding the park • Greatest impacts to the SW are due to existing and new dams upstream withholding water. Park may have to depend solely on precip within its boundaries	• Spring and seep flow will be lower and dry up faster • Greatest SW impacts are due to existing and new upstream dams withholding water. Park may have to depend solely on precip within its boundaries	• Greatest SW impacts are due to existing and new upstream dams withholding water. Park may have to depend solely on what precip falls within its boundaries
Vegetation	Prairie	• Exotic species: Much warmer winters allow establishment of new exotics (some potentially invasive) • Perennial exotic cool-season grasses (Kentucky bluegrass and smooth brome) and Canada thistle experience boom years but suffering in drought years may balance out to no trend • Exotic species: Moisture-loving annuals/ biennials (sweetclover, mullein, annual bromes -- annual bromes especially benefit from greater proportion of precip in	• Exotic species: Little change or decreasing trend in current problem exotics, which tend to do well with higher (especially spring) moisture. Conditions neither more nor less favorable for new exotics • Productivity: Consistently lower productivity; warm-season grasses decline less than cool-season grasses due to large decrease in early growing season moisture availability but only moderate summer-fall PET increase	• Exotic species: Reduced vigor of many perennial species, creating opportunities for short-lived, drought-tolerant weeds like Russian thistle and kochia, as well as drought-tolerant perennials like white horehound and others not yet in the park (i.e., from further south or west) • Productivity: First half of future-period (2025-2040) productivity may be similar to historical productivity, but productivity **in second half of future period (2040-2055) drops sharply due**	• Exotic species: Most of the current problem exotics (cool-season perennial grasses, mullein, sweetclover, Canada thistle) decline but annual bromes and other exotic annual grasses not yet in the park increase. Horehound and other (some new) drought-tolerant exotics increase • **Productivity: Overall grass production, both warm- and cool-season, decreases by up to 50%**. Deeply rooted shrubs such as rabbit brush and	• Exotic species: Opportunities for new exotics to establish (3 of 4 scenarios) • Productivity: Lower productivity • Prescribed fire: Shifted timing for prescribed fires, or less opportunity • Wildfire: Increased fire risk and fire season length

Priority	Resource component	Log Ride	Hourglass	Jenga	Convection Oven	Common across all/most scenarios
		winter) boom in wet years but persist in seed bank through dry years to create overall increasing trend • Productivity: Drought indices indicate that productivity will usually be somewhat lower, but occasional very wet years punctuate this trend with some very-high-productivity years that favor cool-season grasses • Prescribed fire: Very wet years have limited prescribed fire opportunities in spring and possibly fall, but burns can still be accomplished in other years. Much earlier spring green-up means timing of burns would have to be earlier. Much warmer winters allow more prescribed fire in winter, but higher summer-fall fire danger reduces opportunities for fall prescribed fire • Wildfire: Higher summer-fall fire danger overall, plus warmer winters, lengthens wildfire season into time when fire-fighting resources are scant, leading to larger fires. High fuel buildup in very wet years increases flame lengths if fire occurs in those years or soon after	• Prescribed fire: Lower spring moisture increases opportunities for spring prescribed fire, with season starting moderately earlier than now and some more opportunities in winter. Moderately higher summer-fall fire danger moderately decreases opportunities for prescribed fire in fall • Wildfire: A slight increase in fire risk and length of fire season (increased summer-fall PET) is accompanied by lower intensity (shorter flame lengths) due to consistently lower productivity	**to sharply increased temperatures and some very dry years.** Warm-season grasses decline more than cool-season grasses • Prescribed fire: Shifted prescribed fire opportunities to winter (December-March) • Wildfire: Much warmer winters and higher summer-fall PET increase fire risk, length of fire season, and size of fires in the second half of the future period, but fire intensity (flame length) is lower because of less fuel	sagebrush (if they migrate to the park), as well as drought tolerant succulents, benefit from less grass competition and the shift to higher percentage of precipitation falling in winter. They still remain a minor component of the ecosystem because the winter precip shift is moderate • All grasses decline – including Kentucky bluegrass. • Cheatgrass thrives due to increased winter precipitation • Prescribed fire: Reduced fuel build-up from lower overall production, combined with reduced vigor of exotic cool-season grasses, reduces the ability and desire to conduct fires as frequently as is now desired • Wildfire: More frequent, fire season extends through much of the year, stressing fire-fighting resources and leading to larger fires, but intensity (flame length) is lower because of lower productivity	

Priority	Resource component	Log Ride	Hourglass	Jenga	Convection Oven	Common across all/most scenarios
Vegetation	Riparian	• Warmer temperatures reduce climate suitability for birch (*Betula*) and aspen (*Populus*) • Higher GW tables (as long as withdrawal doesn't increase more) sustain riparian trees through drought periods (those reaching the GW). Decreased SW availability in the summer puts areas at risk of wildlife trampling, which, when combined with flooding from flashier precipitation, decreases bank stability and therefore habitat for wetland herbaceous species	• Moderate increase in temperatures only slightly decreases climate suitability for birch and aspen, so they decline only slightly if at all • Riparian areas contract gradually as GW and SW both decline. Tree species already at the low end of their precip tolerance (hackberry, green ash, ironwood, bur oak, elms) decline or disappear	• Much higher temperatures, especially in latter half of future period, push birch and aspen out of their range of climate suitability, leading to their decline • More frequent, more intense, and more multi-year droughts, especially in second half of future period, reduce vigor of riparian trees and lead to severe concentration of wildlife around what remains of water sources, further damaging riparian vegetation	• Hot and dry conditions are not suitable for birch and aspen, leading to their extirpation • Perpetual drought conditions (compared to historical) leads to severe contraction or extirpation of riparian trees and shrubs	• Reduced suitability for birch and aspen Contraction of riparian area from drought (3 of 4 scenarios)
Vegetation	Forest	• Potential for episodes of high pine recruitment (seedling crops) in wet years • Prescribed fire: same as prairie • Wildfire: same as prairie, though high-recruitment episodes increase ladder fuels, and therefore fire severity • If potential increase in recruitment balances increased mortality, forest will persist largely as is now or could even increase in extent if prescribed fire does not keep up with expansion into grasslands	• Prescribed fire: same as prairie • Wildfire: same as prairie • Minor, if any, decrease in ponderosa pine forest, or potentially even increase if prescribed fire does not keep up with expansion into grasslands	• Prescribed fire: same as prairie • Wildfire: same as prairie, except fire severity higher because of lower moisture conditions in heavy fuels • Increased fire risk and greater mortality from other causes, combined with lower regeneration, causes slow (or very fast, if catastrophic fire) decline in forest extent and density	• Prescribed fire: same as prairie • Wildfire: Occurs more frequently and through much of the year, stressing fire-fighting resources and leading to larger fires that are higher in severity because of lower moisture conditions in heavy fuels • Increased fire risk and greater mortality from other causes, combined with lower regeneration, causes slow (or very fast, if catastrophic fire) decline in forest extent and density	• Increased wildfire risk and season length Shifted timing for prescribed fires, or less opportunity

Priority	Resource component	Log Ride	Hourglass	Jenga	Convection Oven	Common across all/most scenarios
Vegetation	Rare plant species[5]	• Orchids hang on because of occasional years with high spring soil moisture availability	• Orchids decline due to strong decrease in spring soil moisture availability	• Orchids decline sharply in second half of future period when droughts become more common and severe	• Orchids decline precipitously or disappear from the park	Orchids decline (3 of 4 scenarios)
Vegetation	Plants of tribal collection interest[6]	• Boom years for fruit production occasionally punctuate a gradual decline in "eastern" shrubs due to more frequent and intense droughts. Early-season prairie forbs, if long-lived, are sustained by these occasional wet years, and late-season prairie forbs decline moderately	• Fruit-producing shrubs decline gradually due to more frequent and more intense droughts, though not as much as in Climate Future 1. Early-season prairie forbs (including breadroot) decline much more than later season forbs (such as sage)	• Fruit production, and the shrubs themselves, decline sharply in the latter half of the future period, as do later-season forbs. Early season forbs fare better than late-season forbs	• Ethnographic species not associated with hotter, drier areas consistently and strongly decline	Decline in fruit-producing shrubs from more frequent/intense drought
Cultural	Archaeological	• Potential Black-tailed prairie dog town reduction creates less impacts on sites • Increased vegetation could make sites more difficult to locate in the field • Sites near creeks more susceptible to flooding	• Increase in fire, but not a large concern because sites have been burned over many times in the past	• Erosion variability (moderate increase) • Droughts increase impacts from black-tailed prairie dog town expansions	• More extreme than Hourglass—more exposed dirt and more risk to exposure of sites • Increased potential for theft or vandalism • Increased fire-fighting efforts could cause more damage to sites	--
Cultural	Museum collections	• Increased risk for bugs damaging collections • HVAC not an issue due to generator under current conditions but something to look out for in the future	• Potential for more items to intake due to increased research activity (due to milder conditions)	• Potential for more damage to collections by bugs due to fewer hard freezes	• More stress on HVAC system	--

[5] Orchids were used as the stand-in for "rare plants" because the orchid on the rare plant list (*Cypripedium parviflorum*) was the only one for which the subject-matter experts could find any climate-sensitivity information.

[6] Given the breadth of species of tribal collection interest, we chose to focus on a small subset of species for which climate sensitivity was known—fruit-bearing shrubs.

Priority	Resource component	Log Ride	Hourglass	Jenga	Convection Oven	Common across all/most scenarios
Cultural	Historic structures (incl. Sanson ranch, CCC-era, and Mission 66 structures)	• Increased mold/mildew risk—especially Sanson ranch buildings since they aren't regularly occupied • Potential for fire via lightning strikes in the VC areas (CCC-era structures) • Officer quarters already in poor condition so more at risk until projects start • Potential stress on ponderosa pines could negatively impact cultural landscapes in the WICA administration historic district	• Moderate increase in risk for fire • Sanson ranch doesn't have a water source nor is it regularly occupied • Drought stress could increase pine bark beetle, which could cause tree fall hazard • Increased visitation due to milder conditions could be detrimental to campgrounds (Mission 66 era) • Drought stress could increase pine bark beetle, which could disturb cultural landscapes	• Increased fire risk • Increased risk of damage from bugs due to fewer hard freezes in winter • Less severe weathering • Fewer freeze-thaw events is better for structures • Vegetation changes compromise the cultural landscape • More drought could expand prairie dog towns and alter cultural landscapes and cause tree-fall hazards due to increased pine bark beetles	• Fire risk increase for all structures, particularly Sanson ranch buildings • Tree fall increase • Structures may dry out too much • Increased maintenance need for structures • Milder winter season means prolonged visitation which could lead to more campground use (and subsequent degradation) (Mission 66 era) • Increased exotic plant species would disturb the cultural landscapes • More drought could expand prairie dog towns and alter cultural landscapes and cause tree-fall hazards due to increased pine bark beetles	• Increased fire risk to structures in prairie habitats • Drought stress could alter cultural landscapes

Priority	Resource component	Log Ride	Hourglass	Jenga	Convection Oven	Common across all/most scenarios
Wildlife	Bison	• More food availability in some years but slightly less in most • Less pressure on riparian areas because more streams available for longer • High tick numbers	• Decrease in productivity of prairie, but because grazing is currently below capacity it won't impact bison numbers • Greater pressure on riparian areas due to lower SW availability • If increase in winter moisture (Dec, Jan, Feb, Mar) is snow, more salting of roads, attracting bison to roads and more vehicle collisions • Potentially less ticks, because of less moisture in spring	• Decrease in growing season moisture availability -> decreased productivity of prairie, but because grazing is currently below capacity it won't impact bison numbers, at least early on • Water availability might be a constraining factor • Late-summer decrease in precipitation, so potential fire that decreases forage • High tick numbers • Warmer winter -> potential for new diseases coming up from the south that wouldn't normally survive here. For example, Bluetongue	• Looking at vegetation, could be able to maintain current population of bison, although there will be more pressure from grazing on prairie vegetation • Potential loss of forage with fire risk going up • High tick numbers • Water availability might be constraining factor • During periods of more severe drought, might see decreased reproductive rates for bison • During severe droughts, slight potential for bison to try to leave park for water sources • Potential for more vehicle hits during expanded pre-/post-winter shoulder season (when bison may be attracted to roads), but projected trends in snow during these periods is unclear	• Drought years (periodic in Scenario 1) result in lower forage and/or water availability • Tick numbers increase (3 of 4 scenarios)
Wildlife	Black-footed ferret (BFF) & Black-tailed prairie dog (BTPD)	• BTPD: Increase in fleas in wet years so colonies more likely to contract plague in very wet years but could rebound in intervening years • BFF: Potential increase in flea species (two flea species that peak in different times) may increase plague risk to BTPD which could indirectly impact BFF obligate prey base of BTPD and reduce BFF populations	• BTPD: Expansion of prairie dog colonies and potential slight decrease in plague due to fewer fleas in drier years • BFF: Potential decrease in plague in BTPD due to fewer fleas in drier years could increase prey availability of BTPD to black-footed ferrets leads to slight increase in ferrets	• BTPD: Slightly positive effects, at least in first half—potentially higher forage while with pups; then dries out so colonies can expand. Can take advantage of late season green-ups • BFF: Expansion of BTPD colonies leads to potentially slightly more ferrets, but BTPD habitat limited to 3300 acres, that will support an estimated maximum of ~30 ferrets	• BTPD: Colony area expands and density will decrease. Inconclusive as to what happens to disease rates, although initial thoughts are less chance of disease transmission? • BTPD: Might see drops in pup production after severe droughts • BFF: Drier conditions thought to be less likely for plague due to fewer fleas leads to potential increase in BFF populations	• BTPD: Prairie dog populations maintained within target colony acreage • BTPD: Colonies will have potential to expand because of drier conditions (3 of 4 scenarios) • BFF: Ferret populations maintained within targets

Priority	Resource component	Log Ride	Hourglass	Jenga	Convection Oven	Common across all/most scenarios
Wildlife	Elk	• More food in some years but slightly less in most • Potentially higher reproductive rates in some years because of better forage in some years • High tick numbers • Slight potential, if elk are more spread out when better forage is available, that there is less transmission of chronic wasting disease (CWD)	• Slight decrease in productivity of prairie, but because grazing is below capacity it won't impact elk numbers • Elk slightly more concentrated, particularly around water resources when drier, with more potential for transmission of CWD • Potentially fewer ticks, because of less moisture in spring	• Decrease in growing season moisture availability leads to decreased productivity of prairie, but because grazing is below capacity it won't impact elk numbers • Late summer decrease in precipitation, with increased fire risk that could decrease forage • Animals may be more concentrated in the late summer; might be a short season of being concentrated in riparian areas. Concentration leads to higher possibility for CWD transmission • High tick numbers • Unknown if novel diseases such as Bluetongue may arrive in WICA with implications for elk	• May have increase in CWD transmission because they will be concentrated on limited water resource • Vegetation should be adequate for current (2019) population of elk, although there will be more pressure from grazing on prairie vegetation • Potential loss of forage with fire risk going up may lead to constraint on numbers of elk • Higher tick numbers • Water might be a constraining factor. During severe droughts, slight potential for elk to try to leave park for water sources	• Lower forage quantity and possibly quality (due to increase in exotics, increased fire risk) in drought years (periodic in Scenario 1) may impact elk • Higher potential for CWD transmission (3 of 4 scenarios) • Tick numbers increase (3 of 4 scenarios)
Wildlife	Bats	• More insects for bats during wet years. Potentially the highest positive effect on bats with the most water available. Distance to water is less; food availability is greater • Might have issues with forest fire in dry years	• Potential slight decrease in bat populations, although not as much as under Scenario 4 • Decreasing bat populations from loss of water sources, and increased distance required to travel for water • Drier conditions reduce insect populations, decreasing food availability and fitness, resulting in fewer bats	• Able to reproduce. Good foraging in the spring because of high moisture; counteracted by dry August. If there's a wet September, they might be able to recover • When pups are young, there will be good forage. Tough month in August, but there could be a bump in September if we get more precip	• Worst scenario for bats • Decreasing bat populations from loss of water sources and increased distance required to travel for water • Forest fire leads to potential loss of forest and less roosting habitat, decreasing bat numbers • Drier conditions reduce insect populations, decreasing food availability and fitness, resulting in fewer bats	• Drought years result in (periodic in Scenario 1) lower water availability and/or insects during those periods • Might have issues with forest fire in dry years leading to loss of roosting habitat • Uncertainty about how white nose syndrome may affect bats in light of climate change

Priority	Resource component	Log Ride	Hourglass	Jenga	Convection Oven	Common across all/most scenarios
Other	Air quality	• Visibility: moderate impacts to visibility from increased wildland fire activity and dust (from drought) • Deposition: moderate increase in nitrogen deposition due to increase in precipitation, thus impacting native plant species • Ozone: ozone levels will likely increase as allowed by the increase in biogenic VOC (volatile organic compound) emissions from increased plant production	• Visibility: moderate impacts to visibility from increased wildland fire activity and dust (from drought) • Deposition: unknown impacts • Ozone: possible reduction due to reduced biogenic VOC emissions depending on available NO_x	• Visibility: major impacts to visibility from increased wildfire activity and dust (from drought) • Deposition: minor increase to nitrogen deposition due to increase in precipitation, thus impacting native plant species • Ozone: possible reduction in ozone due to reduced biogenic VOC emissions depending on available NO_x	• Visibility: major impacts to visibility from increased wildfire activity and dust (from drought) • Deposition: unknown impacts • Ozone: possible reduction in ozone due to reduced biogenic VOC emissions depending on available NO_x	• Moderate to major impacts to visibility from increased wildland fire activity and dust from drought • Ozone reduction (3 of 4 scenarios)
	Cave (micro-climate)*	--	--	--	--	--

* After review of climate futures, workshop participants determined that the cave microclimate will not be affected by changes in the climate futures.

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Scenario implications: testing goals and actions

Climate change and other global change stressors challenge land managers' abilities to protect natural areas and demand that we re-think conservation concepts, goals, and actions (activities) for a continuously changing world (Hobbs et al. 2010, NPS AB 2012, Fisichelli et al. 2016). Climate change adaptation means adjusting to changing conditions. More formally, it is "adjustment in natural or human systems in response to actual or expected climatic stimuli or their effects, which moderates harm or exploits beneficial opportunities" (IPCC 2007).

In the context of climate change adaptation, scenarios provide the setting for examining the efficacy of a range of management responses across a range of plausible climate futures. In conditions under which existing plans and options fall short, scenarios can be used to help revise current options and develop new ones. Scenarios provide a platform for strategic conversations about aligning goals and actions in the context of change and uncertainty. Most commonly, scenarios help teams generate ideas about what they might do or change under a new set of conditions, as well as identify indicators to monitor, to detect changing conditions, and adjust actions. The result is sets of options for each scenario and resource, some of which will be common to all futures, whereas others will be unique to the particular conditions of a given scenario or subset.

Adaptation frameworks help operationalize scenarios by structuring thinking, incorporating climate change into decisions, and ensuring that the full spectrum of adaptation options is considered. One such adaptation framework involves assessing and possibly re-aligning goals and actions with climate change (Figure 26; adapted from Stein et al. 2014). This "climate smart" framework has three categories: business as usual, climate retrofit, and climate rebuild. In "business as usual," current goals and actions are deemed appropriate and effective based on climate change implication/vulnerability assessments and timeframe of the project. In "climate retrofit," current goals remain viable, but require different actions due to changing conditions. Finally, under "climate rebuild," neither current goals nor actions are tenable, and both require revision.

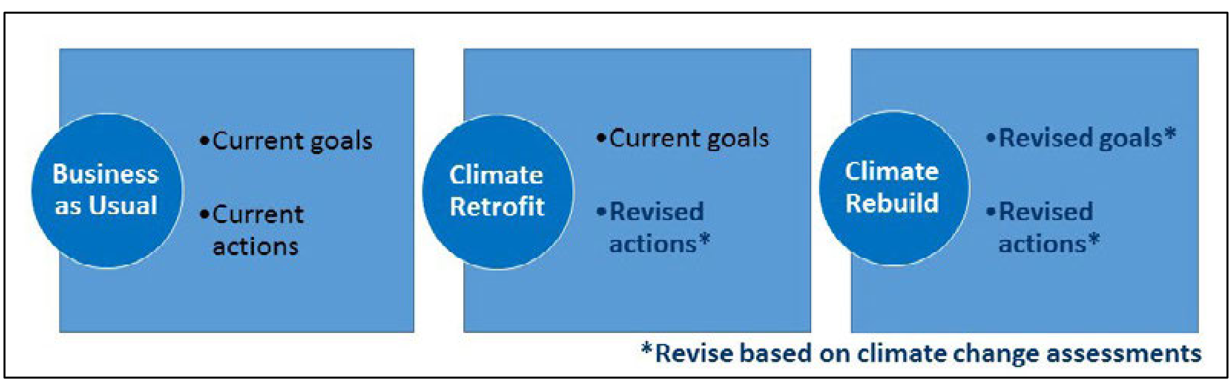

Figure 26. Aligning goals and actions in climate change adaptation. Depending on climate change impacts and vulnerabilities/implications, adaptation will vary from keeping current goals and actions to revising both goals and actions. Figure adapted from Stein et al. (2014).

As natural resource stewardship goals and actions are evaluated and updated consider if management tactics will need to resist, accept, or direct change (adapted from Fisichelli et al. 2016; see also Thompson et al. 2019, Millar et al. 2007, Stein et al. 2014). This helps clarify intended outcomes of a particular management action or program. A resist-change strategy aims for persistence by maintaining current or past conditions. A direct-change strategy actively manages a trajectory of resource change towards new, specific desired conditions. In an "accept change" strategy, the resource responds to climate change and management does not seek to influence the resource-response trajectory. There is no single adaptation option that is appropriate in all situations; rather, the appropriate strategy will vary across resources, space, and time. For example, many persistence-oriented strategies are suitable in the near term but are likely to become increasingly ineffective, risky, and costly as time goes on (Millar et al. 2007). Management response to climate change therefore needs to be continuous and continually reassessed. Scenario planning can generate a portfolio of options, where the investment in specific options is anticipated to shift over time as the future plays out.

After discussion of "climate smart" considerations (Stein et al. 2014) and adaptation frameworks (Figure 26), participants worked in resource subgroups (Appendix 1). Each subgroup examined current stewardship strategies and goals for each component of that resource in light of each climate-resource scenario (resource implications detailed in Table 6). While participants were instructed to avoid detailing activities necessary under each climate-resource scenario, notes were made where activities may be necessary under particular scenarios[7]. The results are described below and summarized in Table 7; additional details are in Appendix 4. After the workshop, stewardship goals were further refined by participants and the project team. Stewardship activities were established and refined during a later RSS workshop, which was informed by this scenario planning work (see following section for details).

[7] The project team learned this assessment is more effective if goals are clearly defined prior to the workshop and there is a structured approach to harvest candidate activities during this review of goals. More detail provided in USGS Final Report: https://www.sciencebase.gov/catalog/item/5ed03fba82ce2832f042d3e2

Table 7. Appropriateness of current goals and actions in light of mid-century scenarios (see Appendix 4 for details). The adaptation responses shown in the table below include "Business as Usual" (current goals and actions), "Climate Retrofit" (current goals and revised actions), and "Climate Rebuild" (revised goals and actions) (Figure 26). Rows with more than one entry (e.g., "BAU, Rebuild") for a given scenario indicate short- and long-term responses. Each resource's current and revised goals and actions are detailed in the following text and Appendix 4.

Goals	Log Ride	Hourglass	Jenga	Convection
Water: Ground- and surface water—maintain existing hydrology	Business as Usual	Business as Usual / Retrofit	Business as Usual / Retrofit	Business as Usual / Rebuild
Veg: Park-wide: maintain or increase native and maintain or decrease exotic species abundance	Retrofit	Business as Usual	Retrofit	Retrofit
Veg: Park-wide: increase hardwood regeneration	Retrofit	Retrofit	Rebuild	Rebuild
Veg: Prairie/Forest Complex: acceptable fuel loads and prairie-forest balance	Retrofit	Retrofit	Rebuild	Rebuild
Veg: Riparian: condition improved and extent maintained	Retrofit	Retrofit	Retrofit	Rebuild
Veg: Rare plant species*—minimize negative impacts to rare plant species	--	--	--	--
Veg: Plants of tribal collection interest*—Consult to ensure protection of ethnographic resources	--	--	--	--
Cultural: Archeological—maintain integrity	Business as Usual	Business as Usual	Business as Usual / Retrofit	Business as Usual
Cultural: Museum collections—Full catalogued	Business as Usual	Business as Usual	Business as Usual / Retrofit	Business as Usual / Retrofit
Cultural: All historic structures—Retain integrity	Business as Usual / Retrofit	Business as Usual	Business as Usual / Retrofit	Business as Usual / Retrofit
Wildlife: Bison—Viable population	Business as Usual	Business as Usual	Business as Usual	Business as Usual / Retrofit-Rebuild
Wildlife: BFF & BTPD—Viable population	Business as Usual	Business as Usual	Business as Usual	Business as Usual
Wildlife: Elk—Viable population	Business as Usual	Business as Usual	Rebuild	Rebuild
Wildlife: Bats*—Reduce WNS threat	--	--	--	--
Other: Air quality—Perpetuate best conditions	Business as Usual	Business as Usual	Business as Usual	Business as Usual
Other: Cave*	--	--	--	--

* Long-term goal is not climate sensitive.

Water Resources

Water resource goals were revised to reflect potential changes to the use and availability of groundwater and surface water. The original long-term goal was to minimize construction of impoundments upstream of the park that change flow conditions through the park and limit the withdrawal and diversion of surface and groundwater flowing through the park. For the goals-review process, short-term goals focused on activities under WICA management control to maintain ideal hydrological conditions–maintaining monitoring, continuation of best management practices, and meeting (or exceeding) water quality standards. The subgroup deemed the long-term goal feasible under the Log Ride, Hourglass, and Jenga scenarios. However, longer droughts under the Jenga scenario (Figure 24 – Drought Duration) require a revised action to improve or revive existing dams to impound water in support of wildlife (this would not be necessary if wildlife numbers decreased). The long-term goal was infeasible under Convection Oven because extreme drought conditions increase private, upstream water use. Under this scenario, the long-term goal was revised to accept the new hydrology and adjust other resource management practices to reflect new conditions.

Vegetation

In examining vegetation goals against the climate-resource scenarios, the vegetation subgroup realized that some goals established in preparation for the workshop did not fully and/or clearly describe the vegetation conditions and trends. Those goals were revised before completing the assessment shown in Table 7 and Appendix 4. Further refinement occurred after the workshop and focused on using available data and information to assign realistic quantities to some of the goals (such as fuel loads). While such quantities are expected in an RSS, they were not necessary for identifying vulnerabilities of some vegetation goals under the scenarios. The goal of maintaining or reducing exotic plant species abundance across the park, while maintaining or increasing native species, was achievable with current practices only under Hourglass. The goal was considered achievable under the other scenarios due to a new, under development, structured adaptive management approach to prescribed fire and herbicide application activities (Symstad et al. in review) would make it possible to achieve this goal in the other scenarios. The goal was made climate-flexible by not being specific about the composition of the native and exotic plant communities.

The current management activities were not sufficient to achieve park goals regarding riparian areas, upland deciduous tree species, prairie-ponderosa pine forest balance, and fuel loads in the current or any future climate. More frequent prescribed fires and mechanical thinning in pine forest, and more exclosures to protect riparian and hardwood forest areas from large herbivores, were expected to make those goals feasible under the Log Ride and Hourglass scenarios. However, under the Jenga and Convection Oven scenarios, the goals would need to be revised to include the caveat of "while preparing for potential longer-term, climate change-driven changes that may be difficult or impossible to resist."; e.g., conversion of forested areas (upland and riparian) to prairie.

Cultural Resources

All long-term goals for cultural resources were considered appropriate, although some required modified actions. Increased fire risk due to more severe droughts in the Jenga and Convection Oven scenarios may result in impacts due to fire-fighting activities and require more emphasis on monitoring activities to maintain integrity of archaeological resources. However, lower vegetation production in the Convection Oven scenario may also provide an opportunity to survey more archaeological resources. Increased fire risk in these scenarios may also necessitate exploration of substitute storage options for museum collections offsite and clearing of vegetation or blacklining around historic structures to reduce fire risk. Maintaining the integrity of historic structures would require more frequent monitoring of unoccupied buildings in the Log Ride scenario to ensure flooding issues are addressed promptly.

Wildlife

Goals for bison and elk were modified for the Jenga and Convection Oven scenarios, acknowledging that the long-term viable population targets for both species may not be feasible considering potential interacting effects of drought and interspecific competition for available forage and water. Bison and elk numbers likely wouldn't be affected early on under the Jenga scenario given that their combined grazing pressure is currently below capacity. But as drought impacts intensify in this scenario (Figures 21-25), the elk population size identified in the original long-term goal for elk pop size may need to be reduced to minimize competition with bison. By reducing elk numbers, the long-term population target for bison was considered feasible in the Jenga scenario. However, more extreme drought conditions in the Convection Oven scenario likely would prompt managers to reduce long-term bison population size as well, although it was unclear what might trigger managers to adjust the long-term goal (e.g., changes in vegetation productivity or rangeland health, or changes in bison mortality or reproductive rates).

Disease was a major wildcard for assessing wildlife goals. Reducing elk numbers in the Jenga and Convection Oven scenarios could support the short-term goal of reducing chronic wasting disease (CWD) prevalence given lower densities of elk that could reduce CWD transmission. Yet even a reduced population of elk may still congregate in higher densities (e.g., to access limited available water in the drier scenarios) where the risk of transmission of CWD may increase. It is unclear how white-nose syndrome and plague (respectively) may be affected by climate and thus the appropriateness of goals for to maintaining viable populations of bats, as well as the intertwined black-footed ferret and black-tailed prairie dog populations across the scenarios is unknown.

Other

Two additional priority resources were air quality and the cave itself. The cave was included in the initial set of climate-sensitive priority resources because cave temperature and wind were thought to be related to atmospheric temperature and pressure outside the cave. However, these relationships are not well understood, and cave conditions may be heavily influenced by geothermal activity. As such, the goal of minimizing human-caused impacts to the cave was treated as not climate-sensitive (given available information), but participants did identify information-related activities to 1) determine drivers for temperature within the cave, including the relative influence of outside air temperatures and geothermal activity, to better understand potential climate change impacts; and 2) monitor potential climate change effects on cave lakes. Additional considerations regarding cave hydrology were captured in the “Water Resources” goals and activities.

The overarching air quality goal that is climate-sensitive is to perpetuate the best possible air quality for the protection of resources affected by air pollution, reducing pollutant deposition to below ecosystem critical loads, eliminating human caused visibility impairment by the year 2064, and remaining in compliance with the EPA National Ambient Air Quality Standards, including ozone condition. This goal was deemed achievable under all scenarios with current activities. Climate change implications for air resources focused on expected impacts from dust and wildfire smoke on visibility, quantity of annual precipitation levels on pollutant deposition (particularly ecological impacts of excess nitrogen deposition), and biogenic volatile organic compound (VOC) emission (plant production) contribution to ozone. The visibility goal was considered achievable, understanding that temporary dust impacts from drought and smoke impacts from wildfire, prescribed fire, and pile burns (winter pile burns around WICA from thinning/logging operations) will remain, regardless of scenario. Although nitrogen deposition and ozone levels may be affected by a changing climate, the magnitude of this effect was considered relatively low and highly uncertain. A much greater concern is the influence of new emission sources and regulations, which were not considered as part of the scenario planning exercise.

Operationalizing climate change scenario planning outcomes

The next step in the climate change adaptation process is operationalizing insights derived from scenario planning into climate-informed management planning and implementation. In the case of WICA, the RSS climate change team engaged with natural and cultural resource planners and resource managers in developing an RSS for the park (Summary Doc). The scenario planning workshop occurred in the middle of the overall RSS process and was followed less than two months later by the RSS workshop, where resource stewardship goals were updated and finalized in the RSS and supporting activities were adopted and prioritized. Materials and insights for the scenario planning process, including all climate summaries and a table used to summarize resource implications across climate futures (Table 6), directly informed multiple steps of the RSS process, including identifying key threats and stressors and developing stewardship goals and activities. Incorporation of scenario planning-derived insights into the RSS workshop also included opportunity for participants to verify or update results presented here.

Examples of climate-smart resource stewardship goals that resulted from this process include:

- WICA has a viable population of bison within the target range set by existing management plans (400-650) unless changes to available forage and/or water sources require revising population targets.
- WICA will maintain ponderosa pine woodlands to achieve fuel loads of 2-10 tons/acre in those woodlands through 2040, while preparing for potential longer-term, climate change driven changes that may be difficult or impossible to resist.
- WICA will have the necessary knowledge to protect significant archaeology sites through documentation, monitoring, protection, and mitigation. The park will maintain integrity in all significant archeological sites over 20 years considering climate change and other factors beyond the park’s control.

High-level goals that acknowledged climate change may have been more likely to foster climate-smart activities. For example, the updated archeology goal (see above) explicitly acknowledges and characterizes climate change, but it is the associated activity of identifying, inventorying, and protecting archeological sites most susceptible to extreme climate change events that shows how this high-level phrasing can foster climate-smart resource management (see list of ultimately-adopted climate smart activities below).

Although workshop participants were instructed to focus on goal achievability and refrain from developing activities until the RSS workshop, scenario planning participants did sometimes discuss necessary activities under one or more scenarios; these ideas were captured in notes and are summarized in Appendix 5. Some of activities were retained in the RSS. For example, a potential management activity in the RSS to support the goal of improving riparian communities is using fencing to protect riparian vegetation from herbivory. This tactic may provide enduring effectiveness if the wetter Log Ride scenario plays out. But as workshop participants discussed, reduced water availability in the hotter and drier scenarios may limit riparian vegetation growth and regeneration, regardless of fencing to reduce herbivory, potentially rendering the long-term goal unachievable. As noted earlier, workshop participants opted to maintain that goal, with the added caveat of "while preparing for potential longer-term, climate change-driven changes that may be difficult or impossible to resist." To accommodate this added caveat, two suggestions were offered for consideration if the hotter and drier futures play out. First, install water monitoring equipment to track trends in seasonal and annual available water in riparian areas (e.g., piezometers; see Cooper and Merritt 2012 for detailed methods and examples). Monitoring trends in available water could inform a threshold where the goal of improving riparian habitat may need to be reassessed, or a management trigger point to adopt other measures to offset the impacts of less water on riparian health. Second, incorporate low-tech, pro-active riparian restoration techniques such as beaver dam analogs (simple rock and wood structures to retain water and raise the water table) to counteract the effects of drought in order to help reach the goal of improving riparian vegetation health in hotter and drier conditions (e.g., see Silverman et al. 2019). While these activities were not adopted in the RSS process, they remain options for the future, if the park maintains this goal in the face of hotter and drier future conditions.

Examples of climate-smart activities adopted by WICA to support stewardship goals include:

- Support bat research that improves understanding of bat habitat needs (e.g., temperature, humidity, structures) and whether they will still exist at WICA in near- and longer-term future.
- Stay current on emerging information on climate change implications for regional exotic plant species abundance and distribution.
- Identify areas where hardwood recruitment, establishment, and survival are most likely to be successful under current and future climate conditions.
- Support park staff getting trained to support fire program to accommodate expanding shoulder season and wildfire season due to climate change
- Identify archeological sites most susceptible to extreme climate change events (e.g., heavy precipitation) and prioritize efforts to inventory and protect them.
- Replace bluegrass lawns around upper housing with species requiring less water.

Organizing potential actions into a management strategy requires consideration of risks, risk tolerance, available resources (e.g., funding and staff), and priorities (e.g., NPS 2013, Maier et al. 2016, Rowland et al. 2014). Some potential actions may be relevant across all scenarios and can collectively form a robust strategy. Or, it may be appropriate to "hedge bets" against multiple scenarios by investing in diverse actions that are each beneficial under a particular climate future. For example, WICA may increase defensible space around buildings to address elevated wildfire risks under the hotter and drier scenarios while also monitoring for possible increase in exotics under the wetter Log Ride scenario. Or, a park may hedge its bets while emphasizing response under a specific scenario (a "core/satellite" strategy). Or, it may "bet the farm" on one particular scenario by investing in actions that are relevant only under one expected scenario. Effective, scenario-based management responses also often require organizing actions temporally. Some actions, for example, are "contingent," such that they would only be useful in addressing a subset of scenarios; these actions—although important to identify and prepare for now—would only be applied in response to specific conditions expressed in that subset. On the other hand, some actions may be robust to all scenarios but cannot be applied today because "bridging" or "transition" actions must be carried out first. An approach that explicitly considers temporal sequencing and complementarity is important for revealing activities that need to be completed in advance (e.g., permitting), or identify decision points where indicators of high-impact changes in climate or other conditions might warrant shifting actions.

Scenarios provide accessible storylines that lend themselves to outreach and communication about the risks and challenges linked with management decisions in the face of very different potential future climate and socio-economic conditions. Sharing such descriptions with expanded stakeholder groups can be an important precursor, particularly for public agencies, to implementing the changes that some future trajectories might require.

Conclusion

This project's goal was to engage resource managers and scientists in climate change scenario planning so that their management and planning decisions will be informed by critical assessment of future climate-related uncertainties. Specifically, we tested and refined an approach for including robust climate-resource scenarios in a comprehensive NPS planning process—development of a park's Resource Stewardship Strategy (RSS). As documented here: we (1) synthesized climate projection information for the park into four plausible, relevant, and divergent potential futures; (2) built on these climate futures to develop climate-resource scenarios through a participatory scenario planning process; and (3) brought these climate-resource scenarios into the RSS process for current and future resource management considerations.

This effort had several outcomes. First the park's robust climate-resource scenarios may continue to inform natural and cultural resource management at WICA through the park's ongoing annual assessments of their RSS goals and activities. Park staff's enhanced understanding of climate change may carry this through to other plans and actions. Second, these scenarios can inform WICA management and planning beyond natural and cultural resources, including facilities, operations, and the visitor experience. More broadly, NPS planners and project team members drew from this project (the second in a series of pilot projects) to develop guidance for incorporating climate change scenario planning into the RSS development process (NPS 2020). This well-documented effort to link climate change scenario planning with natural and cultural resource management planning and action in a major Federal land management agency can serve as a model for others to apply and build upon. Ultimately, this integrated approach offers a unique lens to envision how management activities may play out in light of future uncertainties, enabling the development of nimble and responsive strategies for managing resources as conditions change.

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Appendix 1. Scenario Planning Participants

Participant titles, affiliations, and resource-specialty subgroup.

Name	**Position**	**Organization**	**Scenario planning workshop resource-specialty subgroup**
Vidal Davila	Superintendent	WICA	Water, Cultural
Greg Schroeder	Chief of Resource Management	WICA	Water, Vegetation, Air, Wildlife
Timm Richardson	Botanist	WICA	Vegetation, Wildlife
Marc Ohms	Physical Scientist	WICA	Water, Air
Angela Jarding	Wildlife Biologist	WICA	Vegetation, Wildlife
Tom Farrell	Chief of Interpretation/Cultural Resources	WICA	Water, Cultural
Tanya Shenk	RSS (NR)/CESU Research Coordinator;	MWRO	Vegetation, Wildlife
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Max Joseph	Observer	CU-Boulder, NC CASC	Vegetation, Wildlife
Morgan Elmer	Project Mgr.	DSC	Water, Cultural
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Pricilla Hare	NR Intern	DSC	Vegetation, Air

Appendix 2: Drought characterizations

Drought indices have been developed to integrate precipitation, temperature, and other measures that capture meteorological drought characteristics for use in decision-making (Hayes et al. 2007). Many indices exist, and each has its own merits and limitations. In this project, the Standardized Precipitation–Evapotranspiration Index (SPEI) was used to capture characteristics of drought periods.

SPEI is a multi-scalar drought index, based on precipitation and potential evapotranspiration (PET), that is used to identify wet and dry periods in a given location (Vicente-Serrano et al. 2010). The inclusion of temperature (through its influence on PET) makes SPEI particularly well suited for evaluating combined effects of climatic changes in warming and precipitation. Index values are derived by calculating a climatic water balance, or the accumulation of water deficit/surplus, at various timescales (Vicente-Serrano et al. 2010). SPEI values are summarized across an ecologically relevant timescale. For example, the relationship between prairie grass production and SPEI is often strongest for SPEI values aggregated over three months (Li, 2019), while drought effects on forested systems are more strongly associated with SPEI accumulated over 24-48 months.

SPEI identifies both dry and wet periods: a zero value indicates average moisture balance, positive values signify above-average wetness, and negative values represent drier than average conditions. Because SPEI uses a probabilistic approach (comparison to long-term average), long-term precipitation and temperature records, typically at least 30 years, are required (Vicente-Serrano et al. 2010).

SPEI is calculated from the monthly difference (D) between precipitation (P) and PET:

$$Di = Pi - PETi$$

providing a simple measure of the water surplus or deficit for the month i (Li et al. 2015). Although many methods exist to calculate PET (e.g. Penman-Monteith, Thornthwaithe, Hargreaves, Hamon, etc.), we used the Thornthwaite equation (Thornthwaite 1948, Buytaert and Bievre 2012) since the necessary predictors are available from the downscaled climate data used for developing climate futures.

SPEI is standardized to a specific location so that mean values are 0 (Vicente-Serrano et al. 2010, Vicente-Serrano and National Center for Atmospheric Research Staff 2015). For this analysis, both PET and SPEI were calculated using the R package *SPEI*, which was developed by SPEI's creators (Beguería and Vicente-Serrano 2017).

Describing drought characteristics in historical and future climates

Based on the "theory of runs" (Yevjevich 1967), there are three characteristics of a drought event: duration, severity, and intensity (see Figure A2-1). An SPEI value below -0.5 indicates a "drought", signifying drier than average conditions (Shiau and Shen 2001). A drought event begins when SPEI falls below the threshold and lasts until SPEI returns above the threshold (Figure A2-1). For this analysis, park staff determined that a threshold of -0.5 adequately indicated a drought and that the highest association between SPEI and historical droughts at WICA was for SPEI-6 (SPEI averaged over the preceding 6-month period).

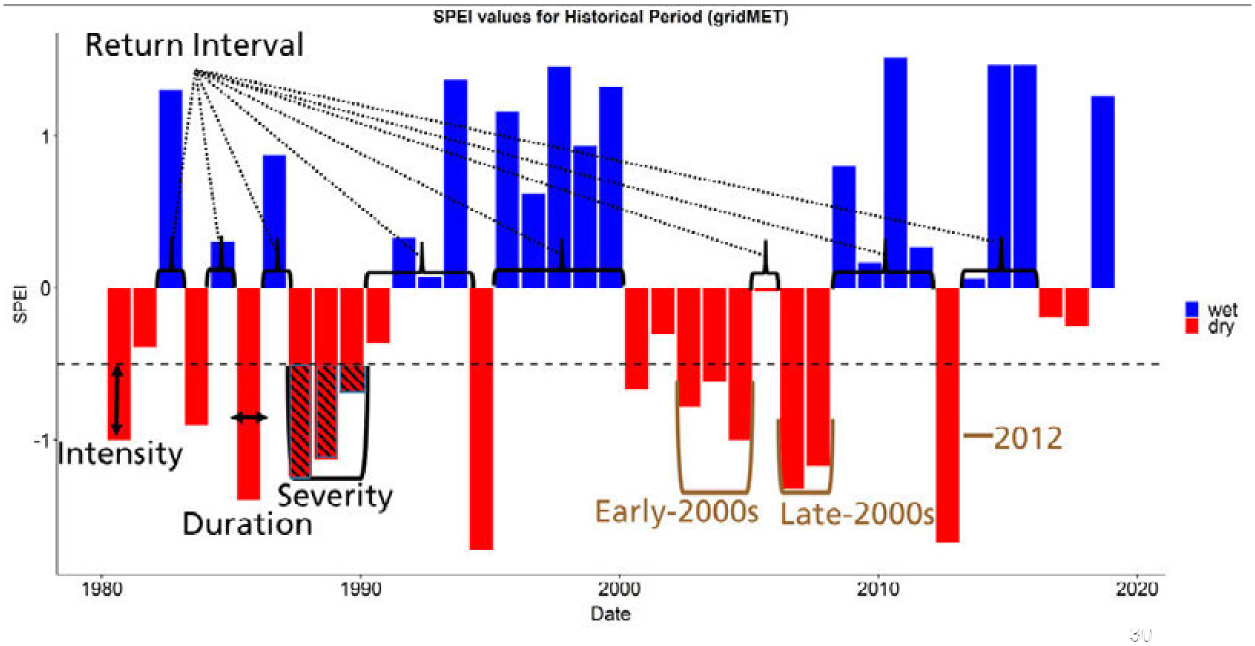

Fig A2-1. Four drought characteristics were calculated based on discrete drought events. Drought events were defined as years when SPEI-6 fell below a threshold of -0.5. For each period (historical or future), drought events were defined then return interval, intensity, duration, and severity were averaged for each climate future. These characteristics are illustrated using observed, historical climate data at WICA (gridMET; Abatzoglou 2013).

We calculated four drought characteristics. Drought duration is the number of consecutive years a drought event lasts. Intensity is the minimum SPEI value during a drought event (e.g., maximum drought level), and severity is the cumulative SPEI value for the duration of the drought event. The frequency of drought events, or return interval, is the length of time (in years) between the end of one drought and the start of the next (Yevjevich 1967, Shiau and Shen 2001, Yang et al. 2009).

We calculated these drought characteristics for each period (historical or future) and climate by calculating each characteristic for each event, then averaging over the period. The "historical" characteristics in Figures 3-25 use the modeled data (MACA; Abatzoglou and Brown 2012) for each GCM represented by our four climate futures over the period of 1950-1999. The tier 2 drought metrics are these averages. The tier 1 drought metric—percentage of 30-year period experiencing multi-year drought—integrated drought frequency and duration.

Characteristics of recent droughts at WICA (Table A2-1) were calculated using gridMET data (Abatzoglou 2013) and used as reference for explaining drought conditions in the four climate futures in Table 3c.

Table A2-1. Drought characteristics for recent droughts observed at WICA (gridMET data).

Time period	Intensity	Duration	Severity
Early 2000s	-1	3	-2.4
Late 2000s	-1.3	2	-2.5
2012	-1.7	1	-1.7

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Appendix 3. Building on climate futures to create robust climate-resource scenarios

Scenario planning workshop participants summarized conditions within each climate future and then worked out implications for WICA resources. Groups named their scenarios as follows: **Log Ride** (Climate Future 1, HadGEM2-CC365 RCP 4.5); **Hourglass** (Climate Future 2, MRI-CGCM3 RCP 4.5), **Jenga** (Climate Future 3, IPSL-CM5A-MR RCP 8.5), and **Convection Oven** (Climate Future 4, CSIRO-Mk3-6-0 RCP 4.5). This appendix is a transcription of those climate-resource scenarios and is provided so that workshop participants can review results of their work in detail and to provide ideas for others wishing to use scenario planning. Implications in red text are "red flags" events, i.e., impactful outcomes unique to a single scenario (NPS 2020). A distilled version of this appendix is in Table 6.

Climate Future 1: 2025–2055 Log Ride

In this scenario:

Key Climate Features:

- Moderate warming
- WET
- Increased (frequency of) large precipitation events
- More humid

What happens to:

Priority resource: Resource component	Implications
Water: Groundwater (GW)	• More winter precip and higher winter temps mean earlier and more snow melt, adding to GW recharge • Annual, spring, and winter precip increases likely increase GW levels • However, warmer late summers increase GW use by humans which may affect the GW; direction of GW available in WICA unknown
Water: Surface water (SW)	• Decrease in SW availability in summer • More extreme events increase stormflow runoff; erosion issues to consider • Variability in SW flow from variability in interannual precip. Higher flows than historical levels at times due to more frequent high-precip events. Also more very low to no-flow days due to increases in drought intensity and length • Higher temp creates more evapotranspiration, decreasing summer SW availability. While this could be negated by late-spring precip increases, it is likely that late summer SW flows will decline from historical flows
Water: Other	• Potentially greatest impacts to SW are existing and new dams upstream from the park. Park may have to depend solely on what precip falls within its boundaries • Potential access issues to certain areas of the park due to flooding • Upward trend for springs and seeps in this future • Potential surrounding land use change (converting private prairie lands into farmland) would increase demand for water outside of park

Priority resource: Resource component	Implications
	• Water quality declines with large floods due to sedimentation and surface runoff from upstream lands
Vegetation: Prairie	• Exotic species: Much warmer winters allow new exotics (some potentially invasive) to establish • Perennial exotic cool-season grasses (Kentucky bluegrass and smooth brome) and Canada thistle experience boom years but suffering in drought years may, balance out to no trend • Exotic species: Moisture-loving annuals/ biennials (sweetclover, mullein, annual bromes -- annual bromes especially benefit from greater proportion of precip in winter) boom in wet years but persist in seed bank through dry years to create overall increasing trend • Productivity: Drought indices indicate that productivity will usually be somewhat lower than historically, but occasional very wet years punctuate this trend with some very-high-productivity years that favor cool-season grasses • Prescribed fire: Very wet years have limited prescribed fire opportunities in spring and possibly fall, but burns can still be accomplished in other years. However, much earlier spring green-up means timing of burns would have to be earlier than historically. Much warmer winters allow more prescribed fire in winter, but higher summer-fall fire danger reduces opportunities for fall prescribed fire • Wildfire: Higher summer-fall fire danger overall, plus warmer winters, lengthens wildfire season into time when fire-fighting resources are scant, leading to larger fires. High fuel buildup in very wet years increases flame lengths if fire occurs in those years or soon after
Vegetation: Riparian	• Warmer temperatures reduce climate suitability for birch (*Betula*) and aspen (*Populus*) • Higher GW tables (as long as withdrawal doesn't increase more) would sustain riparian trees through drought periods if they are reaching the GW. However, decreased SW availability in the summer puts areas at risk of wildlife trampling, which, when combined with flooding from flashier precipitation, decreases bank stability and therefore habitat for wetland herbaceous species
Vegetation: Forest	• Potential for episodes of high pine recruitment (seedling crops) in wet years • Prescribed fire: same as prairie • Wildfire: same as prairie, though high-recruitment episodes increase ladder fuels, and therefore fire severity • If potential increase in recruitment balances increased mortality, forest will persist largely as is now or could even increase in extent if prescribed fire does not keep up with expansion into grasslands
Vegetation: Rare plant species	• Orchids hang on because of occasional years with high spring soil moisture availability

Priority resource: Resource component	Implications
Vegetation: Plants of tribal collection interest	• Boom years for fruit production occasionally punctuate a gradual decline in "eastern" shrubs due to more frequent and intense droughts. Early-season prairie forbs, if long-lived, are sustained by these occasional wet years, and late-season prairie forbs decline moderately
Cultural: Archaeological	• Potential Black-tailed prairie dog town reduction creates less impacts for arch sites • Increased vegetation could make arch sites more difficult to locate in the field • Arch sites near creeks more susceptible to flooding
Cultural: Museum collections	• Increased risk for bugs damaging collections • HVAC not an issue due to generator under current conditions but something to look out for in the future
Cultural: Historic structures	• Increased mold/mildew risk—especially Sanson ranch buildings since they aren't regularly occupied • Potential for fire via lightning strikes in the VC areas (CCC-era structures) • Officer quarters already in poor condition so more at risk until projects start • Potential stress on ponderosa pines could negatively impact cultural landscapes in the WICA administration historic district
Wildlife: Bison	• More food availability in some years but slightly less in most • Less pressure on riparian areas because more streams available for longer • High tick numbers
Wildlife: Black-footed ferret & Black-tailed prairie dog	• BTPD: Increase in fleas in wet years so colonies more likely to contract plague in very wet years but could rebound in intervening years • BFF: Potential increase in flea species (two flea species that peak in different times) may increase plague risk to BTPD which could indirectly impact BFF obligate prey base of BTPD and reduce BFF populations
Wildlife: Elk	• More food in some years but slightly less in most • Potentially higher reproductive rates in some years • High tick numbers • Slight potential, if elk are more spread out when better forage is available, that there is less transmission of chronic wasting disease (CWD)
Wildlife: Bats	• More insects for bats under this scenario during wet years. Potentially the highest positive effect on bats with the most water available. Distance to water is less; food availability is greater • Might have issues with forest fire in dry years
--	• Visibility: moderate impacts to visibility from increased wildland fire activity and dust (from drought) • Deposition: moderate increase in nitrogen deposition due to increase in precipitation, thus impacting native plant species • Ozone: ozone levels will likely increase as allowed by the increase in biogenic VOC (volatile organic compound) emissions from increased plant production

Climate Future 2: 2025–2055 Hourglass

In this scenario:

Key Climate Features:

- Least change in almost every category
- Gradual temperature increase
- Slight decline in precipitation metrics

What happens to:

Priority resource: Resource component	Implications
Water: Groundwater	• Slow decline of GW availability • GW levels in cave lakes decline over time
Water: Surface water	• More low flows throughout the years • Flow regime most similar to historical (of the four scenarios) since there is the least amount of departure from the historical values. • Warmer, longer season could potentially lead to more evapotranspiration (ET), which would negatively impact SW • Scarce SW during more frequent droughts
Water: Other	• Less water availability all around • Decreased number of springs (both natural and developed) and lower spring flow at times due to decrease in soil moisture • Greatest SW impacts are due to existing and new upstream dams withholding water. Park may have to depend solely on what precip falls within its boundaries
Vegetation: Prairie	• Exotic species: Little change or decreasing trend in current problem exotics, which tend to do well with higher (especially spring) moisture. Conditions neither more nor less favorable for new exotics than historically • Productivity: Consistently lower productivity and warm-season grasses decline less than cool-season grasses due to large decrease in early growing season moisture availability but only moderate summer-fall PET increase • Prescribed fire: Lower spring moisture increases opportunities for spring prescribed fire, with season starting moderately earlier than now and some more opportunities in winter. Moderately higher summer-fall fire danger than historically moderately decreases opportunities for prescribed fire in fall • Wildfire: A slight increase in fire risk and length of fire season (increased summer-fall PET) is accompanied by lower intensity (shorter flame lengths) due to consistently lower productivity
Vegetation: Riparian	• Moderate increase in temperatures only slightly decreases climate suitability for birch and aspen, so they decline only slightly if at all • Riparian areas contract gradually as GW and SW both decline. Tree species already at the low end of their precip tolerance (hackberry, green ash, ironwood, bur oak, elms) decline or disappear

Priority resource: Resource component	Implications
Vegetation: Forest	• Prescribed fire: same as prairie • Wildfire: same as prairie • Minor, if any, decrease in ponderosa pine forest, or potentially even increase if prescribed fire does not keep up with expansion into grasslands
Vegetation: Rare plant species	• Orchids decline due to strong decrease in spring soil moisture availability
Vegetation: Plants of tribal collection interest	• Fruit-producing shrubs decline gradually due to more frequent and more intense droughts, though not as much as in Climate Future 1. Early-season prairie forbs (including breadroot) decline much more than later season forbs (such as sage)
Cultural: Archaeological	• Increase in fire, but not a large concern because sites have been burned over many times in the past
Cultural: Museum collections	• Potential for more items to intake due to increased research activity (due to milder conditions)
Cultural: Historic structures	• Moderate increase in risk for fire • Sanson ranch doesn't have a water source nor is it regularly occupied • Drought stress could increase pine bark beetle, which could cause tree fall hazard • Increased visitation due to milder conditions could be detrimental to campgrounds (Mission 66 era) • Drought stress could increase pine bark beetle, which could disturb cultural landscapes
Wildlife: Bison	• Decrease in productivity of prairie, but because grazing is currently below capacity it won't impact bison numbers • Greater pressure on riparian areas due to lower SW availability • If increase in winter moisture (Dec, Jan, Feb, Mar) is snow, more salting of roads, attracting bison to roads and more vehicle collisions • Potentially less ticks, because of less moisture in spring
Wildlife: Black-footed ferret & Black-tailed prairie dog	• BTPD: Expansion of prairie dog colonies and potential slight decrease in plague due to fewer fleas in drier years • BFF: Potential decrease in plague in BTPD due to fewer fleas in drier years could increase prey availability of BTPD to black-footed ferrets leads to slight increase in ferrets
Wildlife: Elk	• Slight decrease in productivity of prairie, but because grazing is below capacity it won't impact elk numbers • Elk slightly more concentrated, particularly around water resources when drier, with more potential for transmission of CWD • Potentially fewer ticks, because of less moisture in spring
Wildlife: Bats	• Potential slight decrease in bat populations, although not as much as under Scenario 4 • Decreasing bat populations from loss of water sources, and increased distance required to travel for water • Drier conditions reduce insect populations, decreasing food availability and fitness, resulting in fewer bats
--	• Visibility: moderate impacts to visibility from increased wildland fire activity and dust (from drought) • Deposition: unknown impacts

Priority resource: Resource component	Implications
	• Ozone: possible reduction due to reduced biogenic VOC emissions depending on available NO_x

Climate Future 3: 2025–2055 Jenga

In this scenario:

Key Climate Features:

- Hottest of all climate futures
- Largest loss of winter
- Little change in precipitation
- Short, intense flash droughts periodically
- Gradual change is most extreme by mid-century

What happens to:

Priority resource: Resource component	Implications
Water: Groundwater	• GW levels about the same as historical because very little change in annual precip and GW loss has low climate sensitivity
Water: Surface water	• Decrease in SW in the late summer; won't take long for a creek to dry up • Increase in SW flows during spring
Water: Other	• Slight decrease in number of springs and seeps. They may flow longer into the summer due to greater precip in springtime • Cave lakes would be affected similarly to GW • Water quality in this future depends on land use changes surrounding the park • Greatest impacts to the SW are due to existing and new dams upstream withholding water. Park may have to depend solely on what precip falls within its boundaries
Vegetation: Prairie	• Exotic species: Reduced vigor of many perennial species, creating opportunities for short-lived, drought-tolerant weeds like Russian thistle and kochia, as well as drought-tolerant perennials like white horehound and others not yet in the park (i.e., from further south or west) • Productivity: First half of future-period productivity may be similar to historical productivity, but productivity **in second half of future period drops sharply due to sharply increased temperatures and some very dry years.** Warm-season grasses decline more than cool-season grasses • Prescribed fire: Shifted prescribed fire opportunities to winter (December-March) • Wildfire: Much warmer winters and higher summer-fall PET increase fire risk, length of fire season, and size of fires in the second half of the future period, but fire intensity (flame length) is lower because of less fuel

Priority resource: Resource component	Implications
Vegetation: Riparian	• Much higher temperatures, especially in latter half of future period, push birch and aspen out of their range of climate suitability, leading to their decline • More frequent, more intense, and more multi-year droughts, especially in second half of future period, reduce vigor of riparian trees and lead to severe concentration of wildlife around what remains of water sources, further damaging riparian vegetation
Vegetation: Forest	• Prescribed fire: same as prairie • Wildfire: same as prairie, except fire severity higher because of lower moisture conditions in heavy fuels • Increased fire risk and greater mortality from other causes, combined with lower regeneration, causes slow (or very fast, if catastrophic fire) decline in forest extent and density
Vegetation: Rare plant species	• Orchids decline sharply in second half of future period when droughts become more common and severe
Vegetation: Plants of tribal collection interest	• Fruit production, and the shrubs themselves, decline sharply in the latter half of the future period, as do later-season forbs. Early season forbs fare better than late-season forbs
Cultural: Archaeological	• Erosion variability (moderate increase) • Droughts increase impacts from black-tailed prairie dog town expansions
Cultural: Museum collections	• Potential for more damage to collections by bugs due to fewer hard freezes
Cultural: Historic structures	• Increased fire risk • Increased risk of damage from bugs due to fewer hard freezes in winter • Less severe weathering • Fewer freeze-thaw events is better for structures • Vegetation changes compromise the cultural landscape • More drought could expand prairie dog towns and alter cultural landscapes and cause tree-fall hazards due to increased pine bark beetles
Wildlife: Bison	• Decrease in growing season moisture availability -> decreased productivity of prairie, but because grazing is currently below capacity it won't impact bison numbers, at least early on • Water availability might be a constraining factor • Late-summer decrease in precipitation, so potential fire that decreases forage • High tick numbers • Warmer winter -> potential for new diseases coming up from the south that wouldn't normally survive here. For example, Bluetongue
Wildlife: Black-footed ferret & Black-tailed prairie dog	• BTPD: Slightly positive effects, at least in first half—potentially higher forage while with pups; then dries out so colonies can expand. Can take advantage of late season green-ups • BFF: Expansion of BTPD colonies leads to potentially slightly more ferrets, but BTPD habitat limited to 3300 acres, that will support an estimated maximum of ~30 ferrets

Priority resource: Resource component	Implications
Wildlife: Elk	• Decrease in growing season moisture availability leads to decreased productivity of prairie, but because grazing is below capacity it won't impact elk numbers • Late summer decrease in precipitation, with increased fire risk that could decrease forage • Animals may be more concentrated in the late summer; might be a short season of being concentrated in riparian areas. Concentration leads to higher possibility for CWD transmission • High tick numbers • Unknown if novel diseases such as Bluetongue may arrive in WICA with implications for elk
Wildlife: Bats	• Able to reproduce. Good foraging in the spring because of high moisture. However, counteracted by dry August. If there's a wet September, they might be able to recover • When pups are young, there will be good forage. Tough month in August, but there could be a bump in September if we get more precip
--	• Visibility: major impacts to visibility from increased wildfire activity and dust (from drought) • Deposition: minor increase to nitrogen deposition due to increase in precipitation, thus impacting native plant species • Ozone: possible reduction in ozone due to reduced biogenic VOC emissions depending on available NO_x

Climate Future 4: 2025–2055 Convection Oven

In this scenario:

Key Climate Features:

- Consistent, large increase in mean annual temperatures
- Hot, dry summers with largest increase in hot days
- Driest: decreased precipitation throughout and decreased soil moisture
- Extended droughts with little recovery between

What happens to:

Priority resource: Resource component	Implications
Water: Groundwater	• Decrease in GW levels—faster than the other scenarios • Rate of GW decline dependent on external uses—greatest potential for more GW use outside of the park
Water: Surface water	• **SW will be lower and could dry up**
Water: Other	• Spring and seep flow will be lower and dry up faster

Priority resource: Resource component	Implications
	• Greatest SW impacts are due to existing and new upstream dams withholding water. Park may have to depend solely on what precip falls within its boundaries
Vegetation: Prairie	• Exotic species: Most of the current problem exotics (cool-season perennial grasses, mullein, sweetclover, Canada thistle) decline but annual bromes and other exotic annual grasses not yet in the park increase. Horehound and other (some new) drought-tolerant exotics increase • **Productivity: Overall grass production, both warm- and cool-season, decreases by up to 50%.** Deeply rooted shrubs such as rabbit brush and sagebrush (if they migrate to the park), as well as drought tolerant succulents, benefit from less grass competition and shift to higher percentage of precipitation falling in winter than historically. However, they still remain a minor component of the ecosystem because the winter precip shift is moderate • All grasses will decline – including Kentucky bluegrass. • Cheatgrass will thrive due to increased winter precipitation • Prescribed fire: Reduced fuel build-up from lower overall production, combined with reduced vigor of exotic cool-season grasses, reduces the ability and desire to conduct fires as frequently as is now desired • Wildfire: Occurs more frequently and through much of the year, stressing fire-fighting resources and leading to larger fires, but intensity (flame length) is lower because of lower productivity
Vegetation: Riparian	• Hot and dry conditions are not suitable for birch and aspen, leading to their extirpation • Perpetual drought conditions (compared to historical) leads to severe contraction or extirpation of riparian trees and shrubs
Vegetation: Forest	• Prescribed fire: same as prairie • Wildfire: Occurs more frequently and through much of the year, stressing fire-fighting resources and leading to larger fires that are higher in severity because of lower moisture conditions in heavy fuels • Increased fire risk and greater mortality from other causes, combined with lower regeneration, causes slow (or very fast, if catastrophic fire) decline in forest extent and density
Vegetation: Rare plant species	• Orchids decline precipitously or disappear from the park
Vegetation: Plants of tribal collection interest	• Ethnographic species not associated with hotter, drier areas consistently and strongly decline
Cultural: Archaeological	• More extreme than Hourglass—more exposed dirt and more risk to exposure of sites • Increased potential for theft or vandalism • Increased fire-fighting efforts could cause more damage to sites
Cultural: Museum collections	• More stress on HVAC system
Cultural: Historic structures	• Fire risk increase for all structures, particularly Sanson ranch buildings • Tree fall increase

Priority resource: Resource component	Implications
	• Structures may dry out too much • Increased maintenance need for structures • Milder winter season means prolonged visitation which could lead to more campground use (and subsequent degradation) (Mission 66 era) • Increased exotic plant species would disturb the cultural landscapes • More drought could expand prairie dog towns and alter cultural landscapes and cause tree-fall hazards due to increased pine bark beetles
Wildlife: Bison	• Looking at vegetation, could be able to maintain current population of bison, although there will be more pressure from grazing on prairie vegetation • Potential loss of forage with fire risk going up • High tick numbers • Water availability might be constraining factor • During periods of more severe drought, might see decreased reproductive rates for bison • During severe droughts, slight potential for bison to try to leave park for water sources • Potential for more vehicle hits during expanded pre-/post-winter shoulder season (when bison may be attracted to roads), but projected trends in snow during these periods is unclear
Wildlife: Black-footed ferret & Black-tailed prairie dog	• BTPD: Colony area expands and density will decrease. Inconclusive as to what happens to disease rates, although initial thoughts are less chance of disease transmission? • BTPD: Might see drops in pup production after severe droughts • BFF: Drier conditions thought to be less likely for plague due to fewer fleas leads to potential increase in BFF populations
Wildlife: Elk	• May have increase in CWD transmission because they will be concentrated on limited water resource • Vegetation should be adequate for current (2019) population of elk, although there will be more pressure from grazing on prairie vegetation • Potential loss of forage with fire risk going up may lead to constraint on numbers of elk • Higher tick numbers • Water might be a constraining factor. During severe droughts, slight potential for elk to try to leave park for water sources
Wildlife: Bats	• Worst scenario for bats • Decreasing bat populations from loss of water sources and increased distance required to travel for water • Forest fire leads to potential loss of forest and less roosting habitat, decreasing bat numbers • Drier conditions reduce insect populations, decreasing food availability and fitness, resulting in fewer bats
--	• Visibility: major impacts to visibility from increased wildfire activity and dust (from drought) • Deposition: unknown impacts

Priority resource: Resource component	Implications
	• Ozone: possible reduction in ozone due to reduced biogenic VOC emissions depending on available NO_x

Appendix 4. Testing goals worksheet

Scenario planning workshop participants examined current goals and assessed whether they would be achievable with current actions, and if not, what revisions to actions and/or goals would be needed to be successful under the conditions of each scenario. Participants focused on evaluating goals; however, where the goals were attainable, actions needed to attain the goals were noted. The goals and actions below reflect the outcomes of the scenario planning workshop, which were further refined by park and regional staff between the scenario planning and RSS workshop and at the final RSS workshop. Not all goals or actions identified below were incorporated into the RSS; instead, participants continued to work with these ideas in the park's RSS process, including thinking across scenarios to identify goals and actions robust across scenarios or address highly consequential potential resource implications under a subset of scenarios.

The groundwater short- and long-term goals were:
Short-term goal(s):

1. Maintain ongoing monitoring
2. Continue to minimize the park's water use through implementation of best management practices
3. Groundwater conditions meet and/or exceed water quality parameter standards set by the Environmental Protection Agency and the state of South Dakota

Long-term goal(s):
Maintain existing hydrology

Table A4-1. Resource/Management Concern: Groundwater.

Scenario	Achievable in short-term? Long-term?	Current goals: Revised actions	Revised goals: Revised actions	Insights, Tradeoffs?
Log ride	Short-term goal(s): 1. Yes 2. Yes 3. Yes Long-term goal(s): Yes	--	--	--
Hourglass	Short-term goal(s): 1. Yes 2. Yes 3. Yes Long-term goal(s): Yes	--	--	--

Scenario	Achievable in short-term? Long-term?	Current goals: Revised actions	Revised goals: Revised actions	Insights, Tradeoffs?
Jenga	Short-term goal(s): 1. Yes 2. Yes 3. Yes Long-term goal(s): No	Long-term goal(s): Yes – With more monitoring of the water levels of the aquifers (especially the Menilusa)	--	Concerns in the long term of the Menilusa aquifer (current park water source) drying out How susceptible to needing to bring in water from another source?
Convection Oven	Short-term goal(s): 1. Yes (with increases) 2. Yes 3. Yes Long-term goal(s): No	Long-term goal(s): No	Long-term goal(s): Accept new hydrology and adjust other resource management practices	In this scenario, external water uses will be a major factor (private water use outside/upstream of the park) May have to see an evolution of water rights policies in order to better assist the park Wildlife support has the potential to shift from surface water to groundwater sources

The surface water short- and long-term goals were:
Short-term goal(s):

1. Maintain ongoing monitoring
2. Continue to minimize the park's water use through implementation of best management practices
3. Surface water conditions meet and/or exceed water quality parameter standards set by the Environmental Protection Agency and the state of South Dakota

Long-term goal(s):
Maintain existing hydrology

Table A4-2. Resource/Management Concern: Surface Water.

Scenario	Achievable in short-term? Long-term?	Current goals: Revised actions	Revised goals: Revised actions	Insights, Tradeoffs?
Log ride	Short-term goal(s): 1. Yes 2. Yes 3. Yes – understanding that the park will/may fail Long-term goal(s):	--	--	This recognizes that conditions will change but the overall intention is to limit increases in regulated flows Park will be vigilant to water use outside the park

Scenario	Achievable in short-term? Long-term?	Current goals: Revised actions	Revised goals: Revised actions	Insights, Tradeoffs?
	Yes – while limiting the amount of regulation (i.e., infrastructure)			Park could potentially participate more in upstream zoning activities
Hourglass	Short-term goal(s): 1. Yes 2. Yes 3. Yes Long-term goal(s): Yes	Would have to consider alterations (add dams, improve springs, etc.) to maintain water sources for wildlife	--	--
Jenga	Short-term goal(s): 1. Yes 2. Yes 3. Yes Long-term goal(s): No	Long-term goal(s): Yes – maintenance will be needed to improve (revive) existing dams	--	Drought duration is more impactful than intensity in this case May not need to do maintenance if bison herd is decreased
Convection Oven	Short-term goal(s): 1. Yes 2. Yes 3. Yes Long-term goal(s): No	--	Long-term goal(s): Accept new hydrology and adjust other resource management practices	Park knows that external factors will be very impactful under this scenario

The prairie short- and long-term goals were:

Short-term goal(s):

1. Prescribed fire and mechanical thinning completed in [X][8] units
2. Exotic/invasive plants below 2017 levels

Long-term goal(s):

1. a. Exotic plant abundance <10% of whole in 25% of park
1. b. Noxious weeds kept to acceptable levels throughout the park
2. 2-10 ton/acre fuel load in prairie

[8] Unit intentionally left blank, to be revisited in RSS workshop

Table A4-3. Resource/Management Concern: Prairie *(Note: did not discuss short-term goals)*.

Scenario	Achievable in short-term? Long-term?	Current goals: Revised actions	Revised goals: Revised actions	Insights, Tradeoffs?
Log ride	Long-term goal(s): 1a: No 1b: Yes 2: No	Long-term goal(s): 1a. Yes – with implementation of the Annual Brome Adaptive Management project (ABAM) Revised action(s): 2. More bison and/or shorter fire return interval	--	--
Hourglass	Long-term goal(s): 1a. Yes (optimistic) 1b. Yes 2. Yes	--	--	--
Jenga	Long-term goal(s): 1a. No 1b. Yes 2. Maybe	Long-term goal(s): 1a. Maybe – with implementation of ABAM	--	2. Maybe achievable only if Rx fire not shut down b/c of elevated preparedness level (i.e., fire resources have been diverted elsewhere)
Convection Oven	Long-term goal(s): 1a. No 1b. Yes 2. Maybe	Long-term goal(s): 1a. Maybe – with implementation of ABAM.	--	2. Fuel might be cheatgrass. Need more info on what 2 ton/acre is to figure out if might drop below it

The riparian vegetation water short- and long-term goals were:

Short-term goal(s):
Riparian vegetation condition is improving

Long-term goal(s):
Riparian vegetation condition is improved

Table A4-4. Resource/Management Concern: Riparian Vegetation.

Scenario	Achievable in short-term? Long-term?	Current goals: Revised actions	Revised goals: Revised actions	Insights, Tradeoffs?
Log ride	Long-term goal(s): No	Long-term goal(s): Yes Revised actions: More fencing/exclosures around riparian areas	--	Trade-offs with wildlife?

Scenario	Achievable in short-term? Long-term?	Current goals: Revised actions	Revised goals: Revised actions	Insights, Tradeoffs?
Hourglass	Long-term goal(s): No	Long-term goal(s): Maybe Revised action(s): More fencing/enclosures around riparian areas	--	Trade-offs with wildlife?
Jenga	Long-term goal(s): No	Long-term goal(s): Maybe Revised action(s): --Piping/pumping from ground --More fencing/exclosures around riparian areas	--	Herbaceous hydric species more at risk than deeper-rooted woody species.
Convection Oven	Long-term goal(s): No	Long-term goal(s): No	Long-term goal(s): Manage for conversion to upland vegetation	Could riparian areas be maintained w/ intensive mgmt.? E.g., beaver, beaver mimicry, piping water, planting, other riparian species (e.g. cottonwood)? What about bird habitat?

The forest complex short- and long-term goals were:

Short-term goal(s):

1. Prescribed fire and mechanical thinning completed in [X][9] units
2. Hardwood seedling density increasing

Long-term goal(s):

1. 2-10 ton/acre fuel load in forest
2. Increasing trend in hardwood density across all size classes
3. Maintain PIPO woodland in 5-20% of park

[9] Unit intentionally left blank, to be revisited in RSS workshop

Table A4-5. Resource/Management Concern: Forest Complex.

Scenario	Achievable in short-term? Long-term?	Current goals: Revised actions	Revised goals: Revised actions	Insights, Tradeoffs?
Log ride	Long-term goal(s): 1. No 2. No 3. Maybe not (Potential catastrophic fire requires management action)	Long-term goal(s): 1. Yes 2. Yes 3. Yes Revised action(s): 1. More mechanical thinning 2. Fence natural water sources 3. Planting trees	--	Uncertainty about whether planting would work. Could investigate literature for better idea?
Hourglass	Long-term goal(s): 1. Yes 2. No 3. Maybe not (Potential catastrophic fire requires mgmt. action)	Long-term goal(s): 1. Yes 2. Yes 3. Yes Revised action(s): 1. More mechanical thinning 2. Fence natural water sources 3. Planting trees	--	--
Jenga	Long-term goal(s): 1. Maybe – same as prairie 2. No 3. No	Long-term goal(s): 2. No 3. Maybe not	Long-term goal(s): 2. Maintain current density of hardwoods in areas where they currently exist 3. Manage for conversion of forest to prairie/shrubland	3. Worried about PIPO regeneration, especially in long-term. Regeneration may not be sufficient
Convection Oven	Long-term goal(s): 1. Maybe – same as fire 2. No 3. Unlikely	Long-term goal(s): 2. No 3. Unlikely	Long-term goal(s): 2. Manage for conversion of forest to prairie/shrubland 3. Manage for conversion of hardwood trees to shrubs	3. Fire risk much higher; expect stand-replacing fires.

The archeological resources short- and long-term goals were:

Short-term goal(s):

1. An increased number of archeological sites are monitored and protected in an undisturbed condition
2. The park will increase archeological area by 5% over the next five years
3. Park will mitigate damage at high priority archeology sites that are being degraded

Long-term goal(s):
WICA will have the necessary knowledge to protect significant archeology sites through documentation, monitoring, protection, and mitigation. The park will maintain integrity in all significant archeological sites over 20 years considering climate change

Table A4-6. Resource/Management Concern: Archeological Resources.

Scenario	Achievable in short-term? Long-term?	Current goals: Revised actions	Revised goals: Revised actions	Insights, Tradeoffs?
Log ride	Short-term goal(s): 1. Yes 2. Yes 3. No Long-term goal(s): Yes	Revised action(s): Yes – need to be more assertive and increase monitoring	--	Mitigating archeology sites, in general, is more on a 10-year span than 5-year. (Overall) Having consecutive wet years would cause staff to consider acting sooner, meaning more assertive/aggressive monitoring for at-risk sites, i.e. sites near creeks
Hourglass	Short-term goal(s): 1. Yes 2. Yes 3. Yes Long-term goal(s): Yes	--	--	--
Jenga	Short-term goal(s): 1. Yes 2. Yes 3. Yes Long-term goal(s): No	Long-term goal(s): Yes – With more emphasis on monitoring activities	--	Potential for more impacts due to fire-fighting activities
Convection Oven	Short-term goal(s): 1. Yes 2. Yes 3. No Long-term goal(s): Yes	Revised action(s): Yes – change management to be more assertive on the prairie dog town expansion threat	--	May be more opportunity to survey more because of the lower veg productivity and more potential for wildland fires Potential for more impacts due to fire-fighting activities, so an avoidance layer could be created to provide to fire-sighting staff and better protect resources

The museum collections short- and long-term goals were:

Short-term goals(s):

1. The park scope of collection statement is up-to-date and reflects park priorities for accessions/deaccessions that support future collection management
2. To address overcrowding in the museum collection room, the park will develop a plan for additional storage within the next 5 years
3. Increase the number of natural history resource management records that are catalogued over 5 years
4. Increase the number of digitized specimens and historical objects over 5 years.

Long-term goal(s):
WICA museum collections will be fully catalogued within 20 years in accordance with NPS museum management policy. All historical objects and non-paleo natural history objects will be digitized and be made available on the park's website to improve visitor understanding of park history and its natural resources. All historical objects and non-paleo natural history objects will be maintained in good condition in an environment conductive to their long-term safekeeping

Table A4-7. Resource/Management Concern: Museum Collections.

Scenario	Achievable in short-term? Long-term?	Current goals: Revised actions	Revised goals: Revised actions	Insights, Tradeoffs?
Log ride	Short-term goal(s): 1. Yes 2. Yes 3. Yes 4. Yes Long-term goal(s): Yes	--	--	Are there any scenarios/future conditions that would increase the amount of specimens being collected (from increased research activities in the park)? 10/300 sites in danger would prioritize but not change the activities.
Hourglass	Short-term goal(s): 1. Yes 2. Yes 3. Yes 4. Yes Long-term goal(s): Yes	--	--	--
Jenga	Short-term goal(s): 1. Yes 2. Yes 3. Yes 4. Yes	Long-term goal(s): Yes - Explore options for other collections storage that is of a reduced fire risk (e.g. off-site)	--	--

Scenario	Achievable in short-term? Long-term?	Current goals: Revised actions	Revised goals: Revised actions	Insights, Tradeoffs?
	Long-term goal(s): No			
Convection Oven	Short-term goal(s): 1. Yes 2. Yes 3. Yes 4. Yes Long-term goal(s): No	Long-term goal(s): Yes	--	--

The historic structures short- and long-term goals were:

Short-term goal(s):
1. Character-defining features of the Sanson Ranch historic buildings are restored to support future access and interpretation.
2. Documentation needs for the historic structures are assessed and national register status for Mission 66 and fire tower in 10 years

Long-term goal(s):
WICA will utilize up-to-date documentation to ensure existing historic structures retain integrity and National Register of Historic Places status over the next 20 years.

Table A4-8. Resource/Management Concern: Historic Structures.

Scenario	Achievable in short-term? Long-term?	Current goals: Revised actions	Revised goals: Revised actions	Insights, Tradeoffs?
Log ride	Short-term goal(s): 1. Yes 2. Yes Long-term goal(s): No	Long-term goal(s): Yes – Would increase frequency of monitoring for unoccupied buildings and ensure responses to issues happen quickly	--	The concept of reduced access to certain resources of this type due to high waters (i.e., the Sanson Ranch) was discussed but, since that area will soon have more road improvements and new culverts installed, the staff don’t see this being as much of a problem in the future
Hourglass	Short-term goal(s):	--	--	--

Scenario	Achievable in short-term? Long-term?	Current goals: Revised actions	Revised goals: Revised actions	Insights, Tradeoffs?
	1. Yes 2. Yes Long-term goal(s): Yes			
Jenga	Short-term goal(s): 1. Yes 2. Yes Long-term goal(s): Yes	Long-term goal(s): Yes – More vegetation clearing around historic structures to reduce fire risk Black-lining historic structures for fire-fighting efforts More aggressive hazard tree removal around historic structures	--	--
Convection Oven	Short-term goal(s): 1. Yes 2. Yes Long-term goal(s): Yes	Long-term goal(s): Yes – More aggressive hazard tree removal around historic structures	--	--

The ethnographic resources short- and long-term goals were:

Short-term goal(s):

1. Consultation practices take place as needed to assist park staff in developing plans and projects
2. Plant gathering agreements are developed and approved and have monitoring protocols as needed
3. Begin to identify and document park-specific tangible and intangible ethnographic resources through consultation process

Long-term goal(s):

WICA will consult with the tribes to ensure the protection of ethnographic resources valued by these traditional cultures in accordance with appropriate laws and regulations

Table A4-9. Resource/Management Concern: Ethnographic Resources.

Scenario	**Achievable in short-term? Long-term?**	**Current goals: Revised actions**	**Revised goals: Revised actions**	**Insights, Tradeoffs?**
Log ride	Short-term goal(s): 1. Yes 2. Yes 3. Yes Long-term goal(s): Yes	--	--	It must be noted that the goals and activity changes for the natural resources under climate change scenarios will affect ethnographic resources (e.g., access)
Hourglass	Short-term goal(s): 1. Yes 2. Yes 3. Yes Long-term goal(s): Yes	--	--	--
Jenga	Short-term goal(s): 1. Yes 2. Yes 3. Yes Long-term goal(s): Yes	--	--	--
Convection Oven	Short-term goal(s): 1. Yes 2. Yes 3. Yes Long-term goal(s): Yes	--	--	--

The bison short- and long-term goals were:

Short-term goal(s):

1. To provide alternative water sources for wildlife during droughts, WICA will improve and maintain developed springs.
2. Complete a Midwest Region Bison Plan
3. Expand bison range onto the Casey property.

Note: The second and third short-term goals were deemed not sensitive to climate.

Long-term goal(s):
The park has a viable population of bison within the target range of 400-650 and balanced with the vegetative base.

Table A4-10. Resource/Management Concern: Bison (*Note: long-term goals for bison were considered in conjunction with long-term goals for elk)*.

Scenario	Achievable in short-term? Long-term?	Current goals: Revised actions	Revised goals: Revised actions	Insights, Tradeoffs?
Log ride	Short-term goal(s): 1. Yes Long-term goal(s): Yes	--	--	Potential trade-off with riparian goals/actions of fencing riparian areas
Hourglass	Short-term goal(s): 1. Yes Long-term goal(s): Yes	--	--	Potential trade-off with riparian goals/actions of fencing riparian areas
Jenga	Short-term goal(s): 1. Yes (concerns about catastrophic fire) Long-term goal(s): 1. Yes	--	--	Potential trade-off with riparian goals/actions of fencing riparian areas --Supplemental feeding is a current management option
Convection Oven	Short-term goal(s): 1. Yes Long-term goal(s): 1. No	Long-term goal(s): 1. Yes and No (depending on priority of bison over other resources and wildlife). Revised action(s): If yes: --Treat WICA as a micro-herd, then bring in more animals when conditions improve --Reduce elk numbers below current management plan --Increase supplemental feeding beyond current levels. If no: --Could reduce bison in long-term to 200 or 300?	--	--What is the 'trigger' for needing to eventually change the goal (i.e., the desired population range)? Changes in vegetation productivity, bison mortality, bison reproductive rates, other? --If forest converted to grassland w/o total invasive takeover, that could offset drying and forage reduction

The black-tailed prairie dogs short- and long-term goals were:

Short-term goal(s):

1. Maintain BTPD within population management target and minimize the risk of plague epizootic over the next 5 years using best management practices
2. WICA contributes to research that promotes plague-management tools. (Note – not climate-sensitive)

Long-term goal(s):
Park has a viable population of BTPD across up to 3300 acres of prairie dog colonies.

Table A4-11. Resource/Management Concern: Black-Tailed Prairie Dogs (BTPD).

Scenario	Achievable in short-term? Long-term?	Current goals: Revised actions	Revised goals: Revised actions	Insights, Tradeoffs?
Log ride	Long-term goal(s): 1. Yes	--	--	Current mgmt.: --Plague dusting
Hourglass	Long-term goal(s): 1. Yes	--	--	--
Jenga	Long-term goal(s): Yes	--	--	PDs resistant to drought; fire. Can go into torpor if need be but can forage longer in shorter winter seasons. WICA can bring BTPDs into national park.
Convection Oven	Long-term goal(s): Yes (No? See notes)	Long-term goal(s): Yes? (see note)	--	--May need to remove BTPDs near park boundaries to prevent expansion onto neighboring properties. Have done so in past but may need more – revised action?

The black-footed ferrets short- and long-term goals were:

Short-term goal(s):
WICA has BFF on 100% of suitable habitat by 2025. *(Note – not climate-sensitive in the short-term)*

Long-term goal(s):
Park has a viable population of BFF on all suitable habitat by 2040.

Table A4-12. Resource/Management Concern: Black-Footed Ferrets (BFF) *(Note: long-term and short-term goals are not climate-sensitive).*

Scenario	Achievable in short-term? Long-term?	Current goals: Revised actions	Revised goals: Revised actions	Insights, Tradeoffs?
Log ride	Long-term goal(s): Yes	--	--	Current mgmt. actions include: --bringing more BFF into the park to supplement current population.
Hourglass	Long-term goal(s):	--	--	--

Scenario	Achievable in short-term? Long-term?	Current goals: Revised actions	Revised goals: Revised actions	Insights, Tradeoffs?
	Yes			
Jenga	Long-term goal(s): Yes	--	--	--
Convection Oven	Long-term goal(s): Yes	--	--	--

The elk short- and long-term goals were:

Short-term goal(s):
Reduce CWD prevalence in elk population from 2017 (Not climate sensitive)

Long-term goal(s):
The park has a viable population of elk within the target range of 232-475 animals

Table A4-13. Resource/Management Concern: Elk (*Note: long-term goals for elk were considered in conjunction with long-term goals for bison)*.

Scenario	Achievable in short-term? Long-term?	Current goals: Revised actions	Revised goals: Revised actions	Insights, Tradeoffs?
Log ride	Long-term goal(s): 1. Yes	--	--	--
Hourglass	Long-term goal(s): 1. Yes	--	--	--
Jenga	Long-term goal(s): 1. No	Long-term goal(s): 1. No	Long-term goal(s): Reduce elk herds at numbers in WICA to less than 230 Action(s): --Revise elk management plan with lower target population range.	Prefer to bias grazing alterations more to bison than elk
Convection Oven	Long-term goal(s): 1. No	Long-term goal(s): 1. No	Long-term goal(s): Reduce elk numbers in WICA to less than 230 Action(s): --Revise elk management plan with lower target population range.	--

The bats short- and long-term goals were:

Short-term goal(s):

1. To inform management decisions, WICA will have statistically valid estimates of historic and current bat population sizes and activity levels, with sufficient precision and accuracy, by 2025.
2. To protect bat populations, WICA will minimize human-caused spread of white-nose syndrome and disturbance of hibernating bats through monitoring, research, and management by 2025.

(Note – not climate-sensitive in the short-term)

Long-term goal(s):

Reduce threats to bat populations from white-nose syndrome (Note – not climate sensitive. Staff did indicate uncertainty about this climate sensitivity and if new information about climate change changes this goal, supporting activities should be reassessed)

Table A4-14. Resource/Management Concern: Bats *(Note: long-term and short-term goals are not climate-sensitive).*

Scenario	Achievable in short-term? Long-term?	Current goals: Revised actions	Revised goals: Revised actions	Insights, Tradeoffs?
Log ride	Long-term goal(s): Yes	--	--	--Bats need water and insects
Hourglass	Long-term goal(s): Yes	--	--	--
Jenga	Long-term goal(s): Yes	--	--	--
Convection Oven	Long-term goal(s): Yes	--	--	--

The air resources short- and long-term goals were:
Short-term goal(s):[10]

1. 1.Air quality: nitrogen deposition effects on vegetation
2. Visibility: The visibility is related to smoke and humidity
3. Remain in attainment for the EPA NAAQS standard for human health or more stringent standard developed by ARD, and good condition of W126 for the protection of ozone sensitive plant species

Long-term goal(s):

1. Seek to perpetuate the best possible air quality condition for the protection of resources affected by air pollution and to reduce pollutant deposition to below ecosystem-critical loads
2. Eliminating human-caused visibility impairment by the year 2064 (the average visibility is <2 deciviews [measurement of haze] above natural conditions)
3. Remain in attainment for the EPA NAAQS for the protection of human health, and good condition of W126 for the protection of ozone sensitive plant species

Table A4-15. Resource/Management Concern: Air Resources.

Scenario	Achievable in short-term? Long-term?	Achievable with revised actions (current goal retained)?	Revised goals & actions	Insights, Tradeoffs
Log ride	Short-term goal(s): 1. Yes 2. Yes 3. Yes Long-term goal(s): 1. Yes 2. Yes 3. Yes	--	--	Burning piles in wintertime creates a lot of smoke because there are no regulations on air quality for these like there are for prescribed smoke dispersion.
Hourglass	Short-term goal(s): 1. Yes 2. Yes 3. Yes Long-term goal(s): 1. Yes 2. Yes 3. Yes	--	--	--
Jenga	Short-term goal(s): 1. Yes 2. Yes 3. Yes Long-term goal(s): 1. Yes	--	--	If continue using fossil fuels as major energy source, nitrogen deposition effect in hotter climate could increase because of increased energy demand for cooling.

[10] Reflect goals revised between CCSP and RSS workshops, due to indecipherability of original goals

Scenario	Achievable in short-term? Long-term?	Achievable with revised actions (current goal retained)?	Revised goals & actions	Insights, Tradeoffs
	2. Yes 3. Yes			
Convection Oven	Short-term goal(s): 1. Yes 2. Yes 3. Yes Long-term goal(s): 1. Yes 2. Yes 3. Yes	--	--	--

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Appendix 5: Activity comparison between climate change scenario planning (CCSP) and Resource Stewardship Strategy (RSS) workshops

Activities identified in the scenario planning workshop and final RSS activities that evolved from the full RSS process.

Priority Resource	CCSP Activities	RSS Activities
Water	• Participate in upstream zoning activities • Maintenance to improve (revive) existing dams and springs (for supporting wildlife) • Monitoring of water levels of the aquifers (especially Minnelusa)	• Develop a protocol for surface water quality monitoring (use Technical Assistance Request) • Collect water samples according to the surface water quality monitoring protocol • Submit a TAR to WRD every year for ground water monitoring (i.e., water levels) and water rights application tracking • Support completion of USGS water study for Black Hills • Support I&M cave monitoring by collecting cave lake water samples. • Use historical data of cave water levels to characterize natural variability. • Replace bluegrass lawns around upper housing with species requiring less water • Evaluate potential to abandon or plug front lawn sprinkler system • Work with facilities staff to retrofit park facilities to low flow fixtures • Assess current park water usage and explore greater efficiencies. • Work with upstream landowners to implement best management practices to reduce impacts to park water quality/quantity • Develop an understanding of existing impoundments in the watershed and trends over time.
Vegetation: Prairie	• Active supplementation of more drought-tolerant cool-season grasses (currently characteristic of further west) • Close attention to grazing utilization will be required to ensure grazer numbers are not too high for reduced production • Increased bison numbers or more frequent prescribed fires (to achieve fuel load goal)	• Ensure that Fire Management Office has completed prescribed burn plans and compliance at least 3 months ahead of burn window. • Develop and implement a protocol for consistently monitoring herbaceous vegetation production and utilization in the park • Conduct yearly coordination meeting between park resource staff and fire ecologist • Maintain support for NGPN and NGP fire effects monitoring to support resource management • Support park staff getting trained to support fire program to accommodate expanding shoulder season and wildfire season due to climate change • Request an updated park vegetation GIS layer from I&M

Priority Resource	CCSP Activities	RSS Activities
Vegetation: Riparian	• Additional fencing/exclosures around riparian areas to protect vegetation from browsing • Maintain riparian areas at or slightly below current density by planting more heat/drought tolerant hardwood species and/or construct beaver dam analogs to hold water • Manage for conversion to upland vegetation	• Analyze Multiple Indicator Monitoring data and provide recommendations to the park for future management. • Prioritize areas for active riparian and wetland restoration and protection in a climate-change-smart framework. • Map existing riparian and wetland (streams and springs) plant community distribution, including areas with the potential to support these communities, and assess their condition.
Vegetation: Forest	• More mechanical thinning and/or prescribed fire • Planting of PIPO seeds or seedlings • Manage for conversion of forest to prairie/shrubland, i.e., change to prairie goals and actions, and maintain pockets of PIPO as examples of what was lost.	
Vegetation: All	• Strong implementation of integrated vegetation management (currently known as ABAM (Annual Brome Adaptive Management project)) • Large exclosures around existing or new aspen/birch are installed and maintained	• Integrate fire, exotic plant treatment, and vegetation monitoring using the ABAM model and framework • Determine strategy for ABAM treatment priorities and assign priorities to burn/management units accordingly • Continue to practice invasive plant early detection and rapid response (EDRR) • Maintain exotic plant mapping, treatment, and monitoring at or above 2018 levels. • Complete seed storage facility • Develop and begin implementing a seed collection and increase plan (including hardwoods) • Continue to support Exotic Plant Management Team aerial application contract • Stay current on emerging information on climate change implications for regional exotic plant species abundance and distribution. • Create a vegetation management strategy.

Priority Resource	CCSP Activities	RSS Activities
		• Identify areas where hardwood recruitment, establishment, and survival are most likely to be successful under current and future climate conditions. • Restore and maintain existing hardwood exclosures • Determine whether existing monitoring is adequate for evaluating hardwood recruitment and distribution extent trends.
Cultural: Archeology	• Assertive/aggressive monitoring for at-risk sites, i.e., sites near creeks • Active management to mitigate threat from prairie dog expansion	• Prioritize known archeology resources for protection. • Draft a proposal to fund the development and implementation of a vulnerability assessment process to monitor sites and project them. • Draft proposal to fund increased efforts related to archeological inventory. • Finish programmatic agreement with State Historic Preservation Officer. • Work with Regional Office staff and area parks to share an archeologist position based in Western South Dakota. • Work with Midwest Archeological Center to develop an archaeological Overview and Assessment and an Archeological Management Plan that include mitigation strategies at high priority archeology sites. • Identify sites most susceptible to extreme climate change events (e.g., heavy precipitation) and prioritize efforts to inventory and protect them. • Meet with MWAC to help determine how they can assist the park. • Develop long-term funding strategy for annual MWAC visits, or station an MWAC employee at park for regional work. • Support the increase of areas surveyed throughout the park. Allow broad use of various management practices. • Work with MWAC to increase the number of surveys conducted after fires and flooding.
Cultural: Museum	• Explore options for other collections storage that is of a reduced fire risk (e.g., off-site)	• Revisit the scope of collection statement every 2 years or as staff changes. • Regularly review integrated pest management and update as needed. • An interdisciplinary team reviews current collection management plan including climate change issues • Monitor the efficacy of the current HVAC and climate control systems and upgrade as needed. • Explore options for other collections storage locations with reduced fire risk (e.g., off-site) • Increase museum staffing. • Explore possibilities of volunteers assisting with cataloging.

Priority Resource	CCSP Activities	RSS Activities
		• Prioritize scanning of museum objects and specimens. • Explore possibilities of volunteers assisting with digitizing.
Cultural: Historic Structures	• Increase frequency of monitoring for unoccupied buildings and ensure responses to issues happen quickly • Increased vegetation clearing around historic structures to reduce fire risk • Black-lining historic structures for fire-fighting efforts • More aggressive hazard tree removal around historic structures	• Prioritize Sanson Ranch restoration projects. • Acquire adequate funding with a Project Management Information System proposal to restore features of Sanson Ranch. • Define key characteristics of Sanson Ranch; assess characteristics; establish restoration plan; implement road improvements. • Restore the historic Sanson Ranch home to the degree necessary to make it usable by park staff and accessible by visitors. • Incorporate wildfire protection issues into Sanson Ranch development and management. • Make a determination on where to place the Sanson Ranch parking lot. • Following consultation with tribes, install wayside signs that interpret the history of Sanson Ranch. • Develop Historic Structure Reports (HSRs) of structures that need them. • Prioritize which structures to preserve and which structures to restore. • Use documentation to guide maintenance treatments. • Increase vegetation clearing and thinning around historic structures to reduce fire risk. • Follow Cultural Landscape Report recommendations on vegetation when restoring character-defining features. • Enter PMIS proposal for Mission 66 National Register nominations. • Enter PMIS proposal for other buildings needing National Register nominations. • Input cultural landscape features into Facility Management Software System Assets for future maintenance/cyclic needs. • Overlay cultural landscape on vegetation maps and integrate management activities of both. • Replace non-native plants with native plants that are consistent with CLR recommendations and adapted to projected climate conditions. • Work with Cultural Landscapes Inventory program staff in the region to assess the Game Ranch and Alvin McDonald’s grave site to determine if they are cultural landscapes or features/components of an existing landscape.
Cultural: Ethnography		• Assess interest and desire of culturally associated tribes to work with park to identify resources of significance.

Priority Resource	CCSP Activities	RSS Activities
		• Start dialogue with tribes on potential impacts of climate change on ethnographic resources. • Submit a funding proposal to initiate documentation and identification of ethnographic resources. • Document and identify ethnographic resources. • Assess extent and abundance of identified ethnographic species within the park. • Assess climate (short- and long-term) sensitivities of ethnographic resources and monitor those resources. • Determine which plant species are abundant enough to harvest and what a sustainable harvest looks like. • Determine whether management activities are affecting ethnographic resources and develop strategies for mitigation. • Explore feasibility of holding periodic consultation meetings with tribes about upcoming park projects
Wildlife: Bison	• Take numbers below current management plan • Increase emergency supplemental feeding beyond current levels • Reduce forest to increase forage • Establish satellite herds, such that not all WICA bison are in the park at once	• Improve or repair four developed springs. • Monitor use of developed springs by bison and elk and evaluate effectiveness in drawing pressure off natural surface water features. • Develop plan for maintaining/restoring the CCC dam on Bison Flats • Collaborate with MWRO in completing a Midwest Regional Bison Stewardship Strategy. • Build a new bison facility • Continue park bison active management, as informed by the MWR Bison Stewardship Strategy (in development). • Continue bison management activities, including continuing to participate in and further develop the Bison Leadership Team and continue to contribute to bison stewardship efforts outside of MWR (e.g., IMR - Grand Canyon) and outside NPS (e.g., FWS, TNC, etc.). • [Activity deleted by park staff during review] • Remove the old bison facility. • Collaborate on MWR Bison Stewardship compliance activities. • Install new gate for interior fence on Casey property • Fence off the water infrastructure (solar panels, etc) • Open old boundary fence to allow bison to roam

Priority Resource	CCSP Activities	RSS Activities
		• Monitor and document bison use of Casey property once made accessible to them (e.g., vegetation impacts).
Wildlife: BTPD / BFF	• Remove BTPD near park boundaries to prevent expansion onto neighboring properties • Additional plague dusting	• BTPD • Create sustainable funding to minimize plague risk to BTPD • Regularly update map prairie dog colonies to determine changes in distribution • Use existing disease-management tools (e.g., dusting) as well as new techniques (e.g., oral plague vaccine) and monitor the efficacy of those tools, especially under variable and changing climate conditions. • Actively seek funding opportunities from partners to support research in plague management • BFF • Participate in national BFF subcommittee meeting to stay current on research • Continue releasing BFF and relocating ferrets within the park. • Continue monitoring BFF populations
Wildlife: Elk	• Revise elk management plan with lower target and population range • Maintain elk populations at lower numbers through sharp shooting	• Continue elk reduction activities to maintain elk at low end of population targets • Support CWD research • Continue removing elk carcasses • Continue to avoid/minimize park activities/practices that congregate wildlife (e.g., salt licks)

CONTACT INFORMATION

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RSS

RESOURCE STEWARDSHIP STRATEGIES

NATIONAL PARK SERVICE

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