National Park Service
U.S. Department of the Interior

Natural Resource Stewardship and Science

Great Basin National Park

Natural Resource Condition Assessment

Natural Resource Report NPS/GRBA/NRR—2016/1105

ON THE COVER
Great Basin National Park, looking south from Wheeler Peak
NPS photo

Great Basin National Park

Natural Resource Condition Assessment

Natural Resource Report NPS/GRBA/NRR—2016/1105

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All manuscripts in the series receive the appropriate level of peer review to ensure that the information is scientifically credible, technically accurate, appropriately written for the intended audience, and designed and published in a professional manner.

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Executive Summary

The Natural Resource Condition Assessment (NRCA) Program aims to provide documentation about current conditions of important park natural resources through a spatially explicit, multi-disciplinary synthesis of existing scientific data and knowledge. For a given NPS unit, NRCAs evaluate conditions for a representative subset of natural resources and resource indicators, reporting where possible on trends in resource condition. They also identify critical information gaps, and characterize a general level of confidence in study findings. The resources and indicators emphasized in a given NRCA project depend on the park's resource setting, status of resource stewardship planning and science in identifying high-priority indicators, and availability of data and expertise to assess current conditions for a variety of potential study resources and indicators.

Great Basin National Park was established as a national park in 1986 providing a high quality and characteristic representation of the basin and range region. Such characteristic features include the gradient of cold desert shrubland to montane forests and woodlands to alpine environments. Ancient bristlecone pine woodland occurs up along the alpine fringe of the park. Given its relatively remote location, high air quality, visibility, and brilliant night skies are also featured. The park encompassed the Lehman Caves National Monument which was created in 1922 to preserve its outstanding cave resources. The NRCA for Great Basin National Park began in 2012 and 16 focal natural resources and ecological stressors were chosen for assessment. These assessments were arranged into four categories including landscape resources, upland resources and ecological integrity, aquatic resources and ecological integrity, and future landscape conditions. This project used a structured ecological integrity assessment framework to evaluate conditions of ecological resources. The framework applies most directly to two of the four thematic resources categories – upland resources and aquatic resources – because these are categories of ecological resources. Primary steps to apply this framework include: identifying the key ecological attributes for each focal resource on which to further focus assessment and subsequent management, identifying indicators for each key attribute for each resource, identifying an expected or reference range of variation for each indicator for each resource, and documenting the status and trends of each focal resource based on indicator data, comparing measured conditions to expected or reference conditions.

Landscape Resources

The landscape resources selected for assessment included air quality, viewsheds, night sky, and rock glaciers. Current conditions for air quality, viewsheds, and night skies at the park are some of the best in the country. Dark night skies and expansive vistas in and around the park draw many visitors annually. Their excellent condition results largely from the park's location in the Great Basin – a region with generally little urban and industrial development and few sources of light or air pollution. Great Basin NP has a well-established, long-term monitoring program in place for air quality; and recent measurements by the Night Sky Program scientists provide excellent baseline data for future monitoring of night sky conditions.

However air quality is of some concern due to the sensitivity of the park's ecosystems to pollutants; in particular nitrogen and sulfur deposition and elevated ozone levels. Regional haze affects long-distance views and has reduced the visual range. Views from the west-side of the park are affected by the Spring Valley Wind Farm, which contrasts with views of the surrounding rural landscape. Rock glaciers are another landscape resource in need of monitoring to detect potential effects of climate change. Increasing ambient temperatures could result in changes to the shape and size of these alpine glacial features.

Upland Resources and Ecological Integrity

Assessed upland resources and indicators included wildfire regime, aspen-mixed conifer forest, sagebrush steppe, and bighorn sheep. Introduced animals and plants, including wild turkey and invasive annual grasses, were also assessed. Upland resources vary in their condition and ecological integrity across the park and surrounding landscape. Current conditions reflect a long history of land use, where past grazing and fire suppression have had lasting effects on upland vegetation, including promoting or allowing the colonization of the park by non-native species. In most native plant communities, late successional vegetation stages are over-represented relative to earlier stages as a result of past suppression of natural wildfire. This condition has many cascading effects, such as limited tree species regeneration in aspen communities, or encroachment of other tree species into sagebrush communities. These effects limit the suitability of habitat for species such as bighorn sheep, likely limiting population viability. Introduced plant species, such as annual cheatgrass, can severely alter vegetation composition and fire regime, especially given the naturally great extent of sagebrush vegetation at lower elevations within and surrounding the park. Wild turkeys, introduced nearby for sport hunting, may be an increasing cause of concern for their effects on park resources. Reintroduction of historically characteristic fire regimes across most park vegetation represents one management response, and can be advanced in places through the safe use of prescribed burning. Challenges to the safe and effective management of fire within the park are many and significant, but taking actions to address the need for a more natural fire regime in the park will remain an important priority into the future.

Aquatic Resources and Ecological Integrity

Aquatic resources vary relatively little in their condition and ecological integrity across the park. The resources and indicators that were assessed included water quality, montane riparian woodlands, Bonneville cutthroat trout, cave and karst processes, and springs. These aquatic resources are all parts of a single hydro-ecological system shaped by the geology and topography of the South Snake Range. The dynamics of this hydro-ecological system are naturally driven by inputs of rain and snow. In turn, these dynamics are shaped by watershed cover and evapotranspiration, surface runoff and groundwater recharge from rainfall and snowmelt, groundwater flow and discharge through the park’s bedrock fracture and karst geology, and the diversity of native terrestrial, riparian, semi-aquatic, and aquatic species that have found their ways into the South Snake Range over many millennia. Changes in precipitation and air temperatures, deposition of atmospheric pollutants, chemical contamination from past land uses, alterations to watershed hydrology through surface development or changes in ground cover, surface water diversions and groundwater pumping, introductions of non-native aquatic species, and visitor traffic through caves all have the potential to alter the park’s natural hydro-ecology both above and below ground.

The assessment found some evidence of changes in hydrologic inputs or in factors that shape watershed hydrologic function that result in altered hydrology within the park. Diversions take place from four springs and from one of the park's streams. A pipeline carries all of Snake Creek's flow past a 3-mile (4.8-km) reach. The pipeline interrupts the natural hydrologic processes of the creek and impacts aquatic resources, including fisheries, riparian vegetation, and karst processes. Groundwater pumping in the surrounding valleys does not presently affect springs and streams within the park, but could in the future. Riparian vegetation is in good condition throughout most of the park but encroachments of woody vegetation – an issue across the park's upland plant communities as well – is a matter of concern.

Atmospheric deposition of nitrogen and sulfur compounds, which can disrupt aquatic chemistry and nutrient cycles, has declined for decades and now meets expectations for natural background deposition. On the other hand, the park continues to experience a high rate of atmospheric deposition of mercury, although there is no evidence that the mercury is bio-accumulating in the aquatic food web to harmful levels. The frequency with which water samples exceed water quality standards for supporting aquatic life has declined over time and the few remaining occurrences may reflect the unique geochemistry of the park rather than any contamination.

Aquatic macroinvertebrate communities in the park's streams appear to be in good condition, showing no evidence of impacts from impaired water quality or physical habitat. And the park has carried out a highly effective program to restore the native Bonneville cutthroat trout along several streams, removing non-native trout from the restored stream sections at the same time.

Finally, the processes that shape cave and karst ecology and geologic formations appear to be intact, except for possible effects from visitors through Lehman Caves. However, additional data are needed to evaluate these possible effects. Cave visitor usage varies over time and can have both direct and indirect effects on cave resource conditions, from direct damage to cave formations to changes in cave air humidity and chemistry that in turn affect cave species and geologic processes.

Future Landscape Conditions

Climate change has a number of potential effects on park resources and values that will require concentrated investment in monitoring over the upcoming decades. Climate projections indicate that in the region surrounding the park, increasing temperatures may also coincide with increasing precipitation. As compared with temperature variables, given inherent variability in precipitation patterns, interpreting past observations and future projections is much less certain. Model projections linking climate to hydrologic models indicate a slight decline in annual flow over upcoming decades. They also suggest shift to earlier snowmelt by up to 30 days, and modest change in snowpack and annual flow by the decade including 2060.

The alpine environment faces high likelihood of significant exposure to climate change effects. Monitoring of alpine vegetation sample plots should assist with detecting trends in alpine plant composition. Phenology indicators, such as rattlesnake emergence and cutthroat trout spawning times, should also provide useful indicators for signaling biological responses to a changing climate.

Results of the NRCA will assist park staff with objectives including prioritzed management actions, Resource Stewardship Strategies and other management plans, support to interpretation of park resources and issues, and engagement in landscape-scaled partnership efforts.

Acknowledgments

We wish to acknowledge the assistance of the National Park Service staff at Great Basin NP and the Pacific West Region including Bryan Hamilton, Margaret Horner, Mark Pepper, Gary Karst, Marsha Davis, Dale Pate, Tod Williams, Deborah Hughson, Dan Duriscoe, Allen McCoy, Jon Reynolds, and Gordon Bell; Chris Crookshanks, Nevada Department of Wildlife; and Scott Miller, U.S. Bureau of Land Management-Utah State University National Aquatic Monitoring Center. We also greatly appreciate review comments provided by Erick Beever, Greg Eckert, Tonnie Cummings, Geoff Moret, Jon Reidel, Kelly Mathis, Larry Don Seale, Mark Meyer, Nita Talent, Rick Kahn, and Stan Kitchen.


Baker Lake, Great Basin NP

1. NRCA Background Information

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

> ***NRCAs Strive to Provide…***
>
> *Credible condition reporting for a subset of important park natural resources and indicators*
>
> *Useful condition summaries by broader resource categories or topics, and by park areas*

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

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

Although the primary objective of NRCAs is to report on current conditions relative to logical forms of reference conditions and values, NRCAs also report on trends, when appropriate (i.e., when the underlying data and methods support such reporting), as well as influences on resource conditions. These influences may include past activities or conditions that provide a helpful context for

[1] The breadth of natural resources and number/type of indicators evaluated will vary by park.

[2] Frameworks help guide a multi-disciplinary selection of indicators and subsequent "roll up" and reporting of data for measures ⇨ conditions for indicators ⇨ condition summaries by broader topics and park areas

[3] NRCAs must consider ecologically-based reference conditions, must also consider applicable legal and regulatory standards, and can consider other management-specified condition objectives or targets; each study indicator can be evaluated against one or more types of logical reference conditions. Reference values can be expressed in qualitative to quantitative terms, as a single value or range of values; they represent desirable resource conditions or, alternatively, condition states that we wish to avoid or that require a follow-up response (e.g., ecological thresholds or management "triggers").

[4] As possible and appropriate, NRCAs describe condition gradients or differences across a park for important natural resources and study indicators through a set of GIS coverages and map products.

[5] In addition to reporting on indicator-level conditions, investigators are asked to take a bigger picture (more holistic) view and summarize overall findings and provide suggestions to managers on an area-by-area basis: 1) by park ecosystem/habitat types or watersheds, and 2) for other park areas as requested.

understanding current conditions, and/or present-day threats and stressors that are best interpreted at park, watershed, or landscape scales (though NRCAs do not report on condition status for land areas and natural resources beyond park boundaries). Intensive cause-and-effect analyses of threats and stressors, and development of detailed treatment options, are outside the scope of NRCAs.
Due to their modest funding, relatively quick timeframe for completion, and reliance on existing data and information, NRCAs are not intended to be exhaustive. Their methodology typically involves an informal synthesis of scientific data and information from multiple and diverse sources. Level of rigor and statistical repeatability will vary by resource or indicator, reflecting differences in existing data and knowledge bases across the varied study components.

The credibility of NRCA results is derived from the data, methods, and reference values used in the project work, which are designed to be appropriate for the stated purpose of the project, as well as adequately documented. For each study indicator for which current condition or trend is reported, we will identify critical data gaps and describe the level of confidence in at least qualitative terms. Involvement of park staff and National Park Service (NPS) subject-matter experts at critical points during the project timeline is also important. These staff will be asked to assist with the selection of study indicators; recommend data sets, methods, and reference conditions and values; and help provide a multi-disciplinary review of draft study findings and products.

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

Important NRCA Success Factors

Obtaining good input from park staff and other NPS subject-matter experts at critical points in the project timeline

Using study frameworks that accommodate meaningful condition reporting at multiple levels (measures ⇨ indicators ⇨ broader resource topics and park areas)

Building credibility by clearly documenting the data and methods used, critical data gaps, and level of confidence for indicator-level condition findings

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

NRCAs also provide a useful complement to rigorous NPS science support programs, such as the NPS Natural Resources Inventory & Monitoring (I&M) Program.[8] For example, NRCAs can provide current condition estimates and help establish reference conditions, or baseline values, for some of a park's vital signs monitoring indicators. They can also draw upon non-NPS data to help evaluate current conditions for those same vital signs. In some cases, I&M data sets are incorporated into NRCA analyses and reporting products.

NRCA Reporting Products…

Provide a credible, snapshot-in-time evaluation for a subset of important park natural resources and indicators, to help park managers:

Direct limited staff and funding resources to park areas and natural resources that represent high need and/or high opportunity situations

(near-term operational planning and management)

Improve understanding and quantification for desired conditions for the park's "fundamental" and "other important" natural resources and values

(longer-term strategic planning)

Communicate succinct messages regarding current resource conditions to government program managers, to Congress, and to the general public

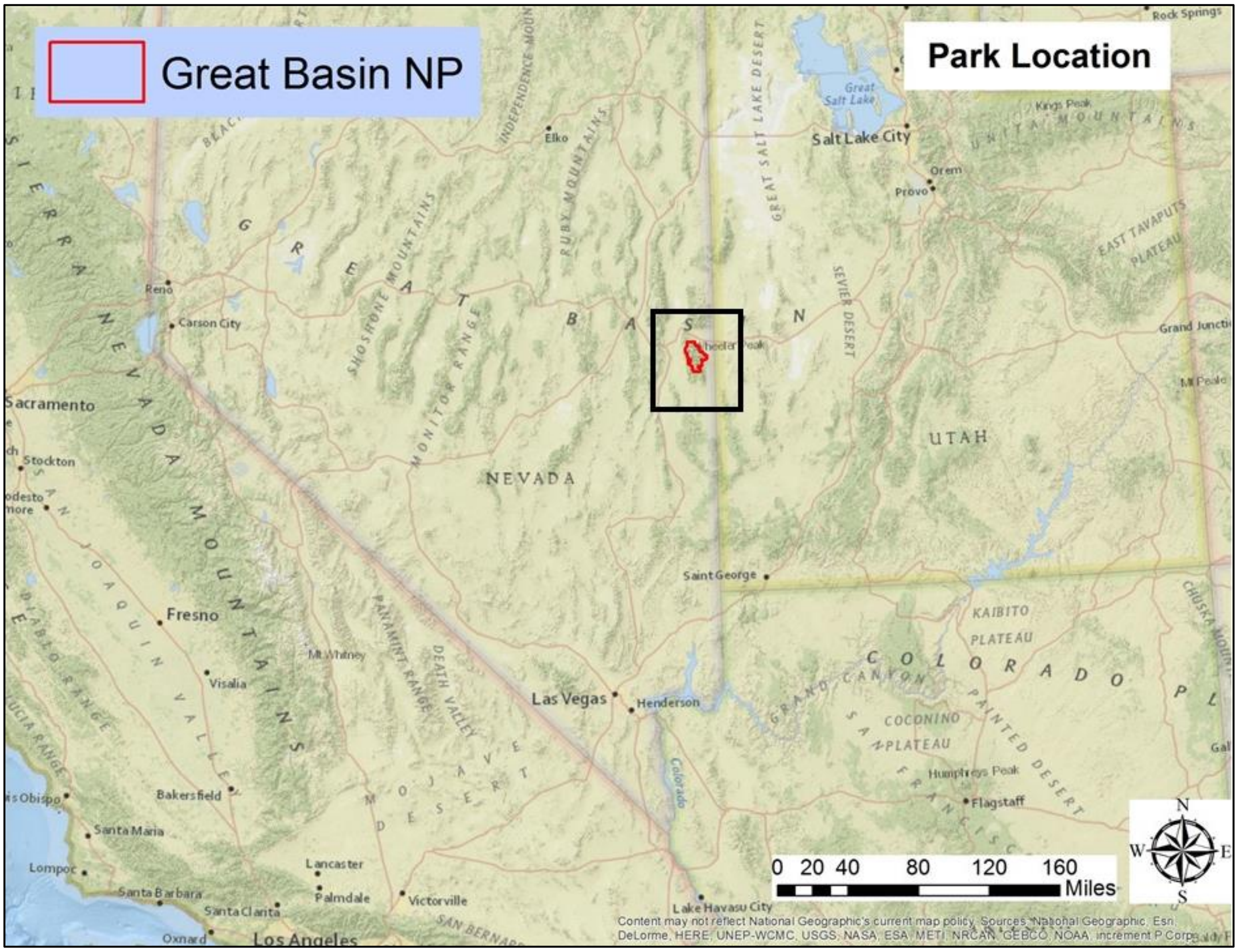
("resource condition status" reporting)

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

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

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

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



Great Basin National Park Location

2. Introduction and Resource Setting

2.1. Introduction

2.1.1. Enabling Legislation

The enabling legislation for the park (Public Law 99-565) states:

> *In order to preserve for the benefit and inspiration of the people a representative segment of the Great Basin of the Western United States possessing outstanding resources and significant geological and scenic values, there is hereby established the Great Basin National Park.*

Great Basin National Park's enabling legislation is based on the Organic Act of 1916, stating that the mission of the National Park Service is to:

> *... conserve the scenery and the natural and historic objects and the wild life therein and to provide for the enjoyment of the same in such manner and by such means as will leave them unimpaired for the enjoyment of future generations.*

2.1.2. Geographic Setting

The hydrologic Great Basin encompasses nearly all of Nevada, parts of western Utah and small portions of California, Oregon and Idaho - roughly 200,000 mi2 (517,998 km2) of arid basins and rugged, isolated mountain ranges. On October 27, 1986, 77,180 acres (312 km2) of this region was set aside as Great Basin National Park (Great Basin NP), enlarging the previous Lehman Caves National Monument of 640 acres (2.6 km2), which had been established in 1922.

Great Basin National Park is located in east central White Pine County, Nevada near the Utah border, and encompasses 77,180 acres (312 km2) of the southern Snake Range1. Wheeler Peak, at 13,063 feet (3,982 m) the centerpiece of Great Basin NP, overlooks two expansive basins – Spring Valley to the west and Snake Valley to the east. However, Great Basin NP includes only 80 acres (32 ha) of the basin environment, and that only as an administrative site. The park is surrounded by Bureau of Land Management (BLM) and private lands.

The park is 300 miles (480 km) north of Las Vegas, 250 miles (400 km) southwest of Salt Lake City, and only a few miles south of U.S. Highway 50. The nearest town is Baker, Nevada where a visitor center is located. Some 65 miles (105 km) to the west, the town of Ely provides major services and Delta, Utah, is 90 miles (145 km) to the east.

Great Basin NP is located within the central Great Basin province of alternating north-south trending mountains and valleys. Extending from a low of 5,287 feet (1,611 m) elevation just north of the town of Baker, to a high of 13,063 feet (3,982 m) elevation at the summit of Wheeler Peak, the park contains a wide variety of natural resources characteristic of the Great Basin. The South Snake Range

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1 Material describing park natural resources was excerpted from the 1999 GRBA Management Plan and then updated.

is the most southeastern of the ranges in the Great Basin with large expanses of terrain above 10,000 feet (3,048 m) and a peak over 13,000 feet (3,962 m) in elevation. The South Snake Range also sits relatively far from the rain shadow of the Sierra Nevada Range and relatively close to humid atmospheric circulation from the Gulf of California.

The topography results from tectonic extensions that created a north-south fault block mountain range and exposed limestones, shales, dolomites, and quartzites. A rock glacier exists at the base of Wheeler Peak, the remnant of what was once one of the largest glaciers in the central Great Basin. There are 13 mountain peaks above 10,000 feet (3,048 m), including seven above 11,000 feet (3,353 m) and four peaks over 12,000 feet (3,658 m). The South Snake Range slopes gradually toward the east and steeply toward the west.

Soil types, climate, and vegetation are all vertically zoned and affected by solar exposure. There is a wide diversity of soil types from alluvium, aridisols to lithosols and tundra soils, controlled as much by bedrock geology and exposure as by elevation. Vegetation type varies from middle latitude desert at 5,000 to 6,500 feet (1,524 to 1,981 m) elevation to alpine tundra at 11,000 to 13,000 feet (3,353 to 3,962 m) elevation. Summer temperatures range from 85 to 105 °F (29 to 41 °C) in the valleys to 55 to 65 °F (13 to 18 °C) on the mountain ridges. The corresponding precipitation ranges from an average annual rainfall of 6 inches (15 cm) in the valleys to 30+ inches (76+ cm) on the mountain ridges. For the park overall, average annual rainfall is 12.9 inches (33 cm). January temperatures at Lehman Caves, 6,825 feet (2,080 m) elevation, may vary from -10 °F to 40+ °F (-23 °C to 4 °C).

2.1.3. Historical Setting

Archeological resources identified at Great Basin National Park include prehistoric artifact scatters, extensive rock art sites, and caves or rockshelters, some with substantial midden deposits. A number of historic period sites have archeological deposits worthy of further investigation. Prehistoric occupation of the park extends from the Paleo-Indian Period (12000 B.C. to 9000 B.C.) through the Great Basin Desert Archaic (9000 B.C. to A.D. 500) and the Fremont (A.D. 500 to 1300) to the Western Shoshone Period (A.D. 1300, to Euro-American cultural expansion). The year 1869 witnessed the beginning of European settlement in Snake and Spring valleys and the establishment of six mining districts in the area of present-day Great Basin National Park. Early ranching and farming in the valley started in the mid-1800s. Absalom Lehman founded his "Cave Ranche" shortly after his discovery of the caves in 1885. He ranched and farmed, providing much needed food and vegetables for the area miners. He started an orchard. A few peach and apricot trees that date back to the 1880s remain and produce fruit to this day. The local communities are still approximately the same size as they were one hundred years ago. Government (county, state, and federal), tourism, ranching, and mining are the primary economic drivers of the area.

2.1.4. Visitation Statistics

Lehman Caves National Monument was created in 1922, and visitor data go back to 1934. Visitation until after World War II was less than 5,000 people per year. Visitation grew steadily in the 1950s and 1960s (Figure 1). In 1987, the year after Great Basin National Park was created, visitation jumped over 23,000 people to 63,532 visitors. The highest number of visitors recorded in one year was 107,526 in 2014 (NPS Public Use Statistics Office 2015).

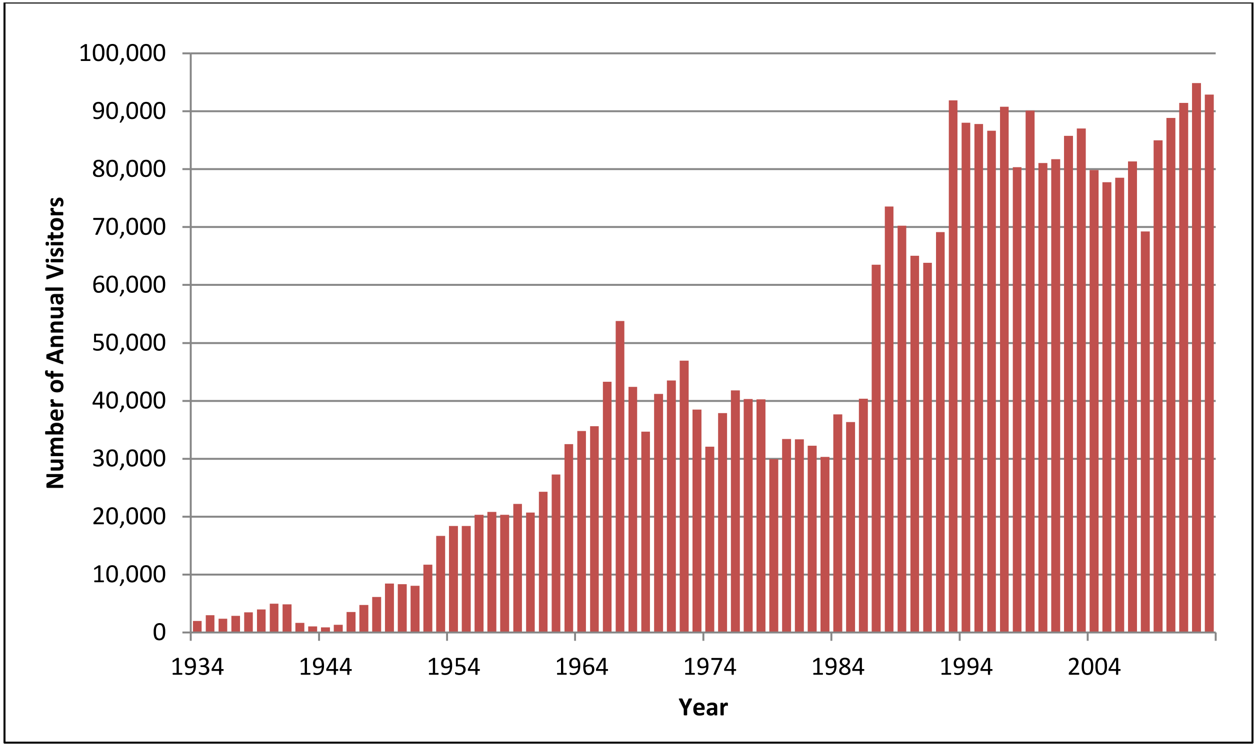

Figure 1. Annual number of recreational visitors to Lehman Caves NM/Great Basin NP, 1934-2013 (NPS Public Use Statistics Office 2014).

Data on visitation by month are tabulated for 1979-2013. In every year during this 34-year period, the number of visitors peaked in June-August. Throughout this time period, 55% of visitors came to the park in summer, just 4% in winter, and the rest split nearly evenly between spring and autumn (Figure 2). Data for just 2013 reflected this trend, with a slight increase in winter visitors to 5%.

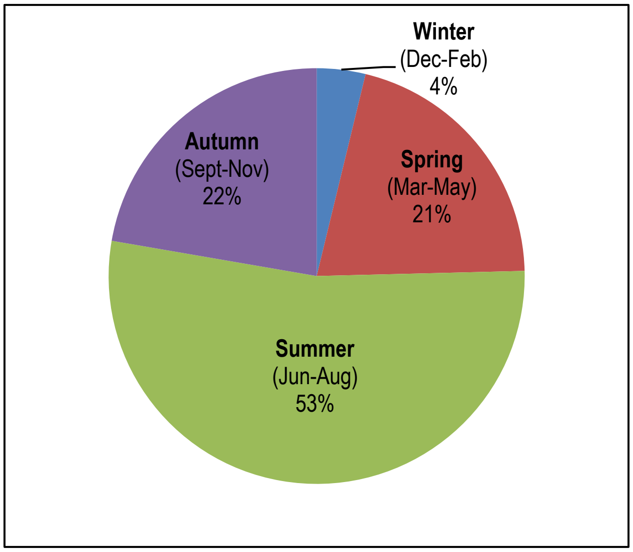

Figure 2. 1979-2013 recreational visitors to Lehman Caves NM/Great Basin NP by season (NPS Public Use Statistics Office 2014).

2.2. Natural Resources

An overview of the park's ecological units is given in Section 2.2.1. A summary of the natural resources at Great Basin NP is presented in Section 2.2.2 representing the information known prior to the completion of this condition assessment. A myriad of data were gathered and compiled throughout this assessment process as a result of the meetings, consultations, and literature reviews pertaining to each natural resource topic. Therefore, some of the information presented in Section 2.2 may have been included in subsequent chapters or omitted depending upon new findings.

2.2.1. Ecological Units, Watersheds, and Management Zones

With just under 8,000 feet (2,438 m) of topographic relief, the park is host to a diverse array of plant communities, wildlife, and aquatic habitats (Figure 3). The vegetation across the lower elevations in the park includes saltbush and sagebrush-grass communities. The foothills and lower montane zones include extensive pinyon-juniper and mountain mahogany woodlands, wet meadows, and woodlands along riparian zones. Still higher are aspen-mixed conifer forests, montane sagebrush steppe, and subalpine spruce forests, extending up to limber pine-bristlecone woodland and alpine tundra.

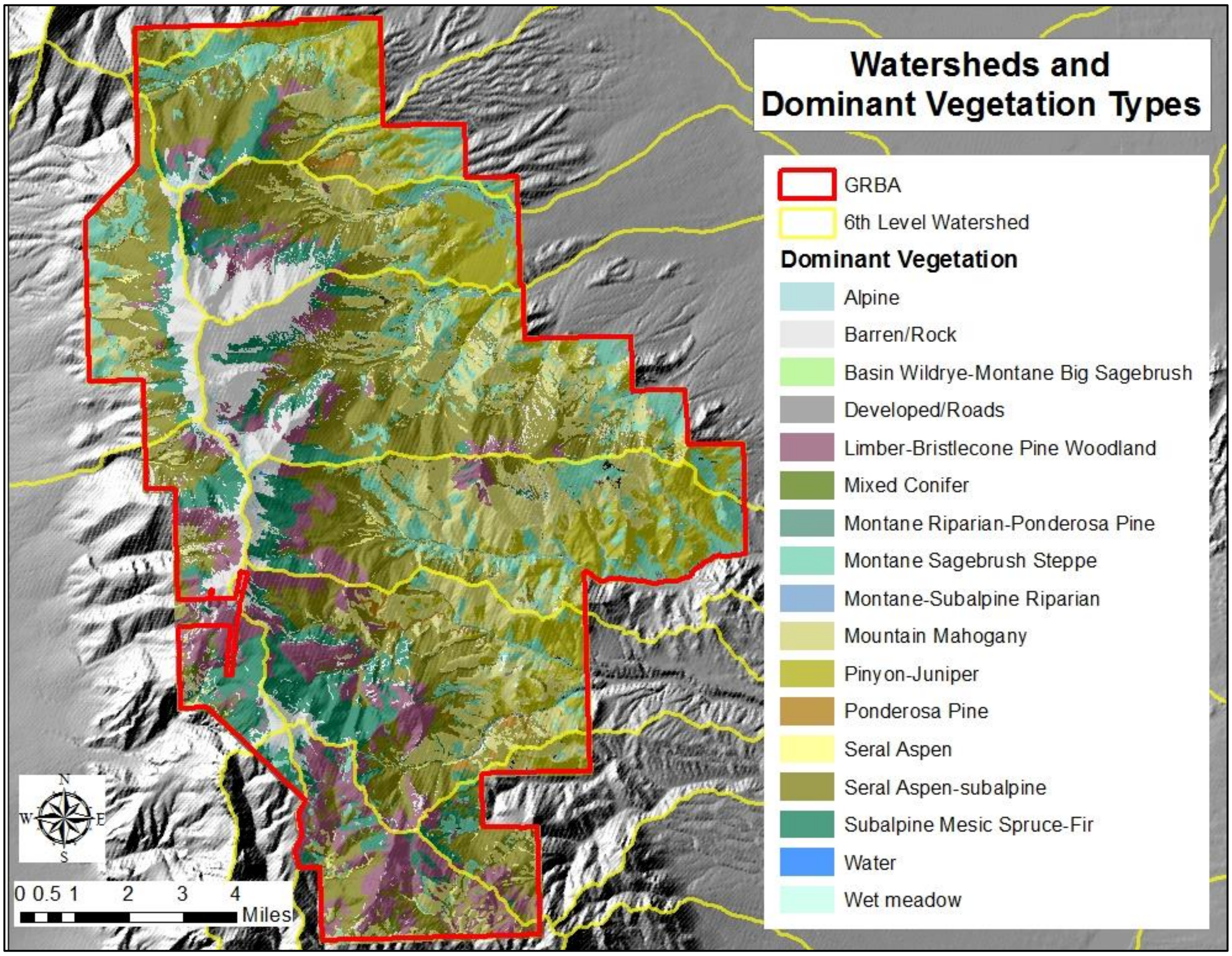

Figure 3. Watersheds and dominant vegetation types of Great Basin National Park (vegetation inventory source: Cogan et al. 2012).

The park has been divided into watersheds based on topography. These are twelve 6th-level watersheds, and are useful for looking at information on a more detailed basis.

The Park's General Management Plan (GMP) divided the park into seven management zones (Figure 4). Each zone has different management actions permitted, as detailed in the GMP. The largest management zone, Primitive, includes nearly half of the park area, and little or no development would occur in this area. Semi-primitive, with more backcountry use and trails, (30%) and Protected

Natural Area, areas with special resource needs and concerns, (12%) encompass the next two largest proportions. Research natural areas include 3.4%; primitive day-use areas include 2.2%; and rural subzone, which provides opportunities for fishing, hiking, and dispersed camping, make up 2% of the park surface. The modern zone, encompassing the Lehman Caves Visitor Center area, along with the Wheeler Peak Scenic Drive and Baker Creek road and adjacent campgrounds and picnic areas, includes just 1.8% of the park.

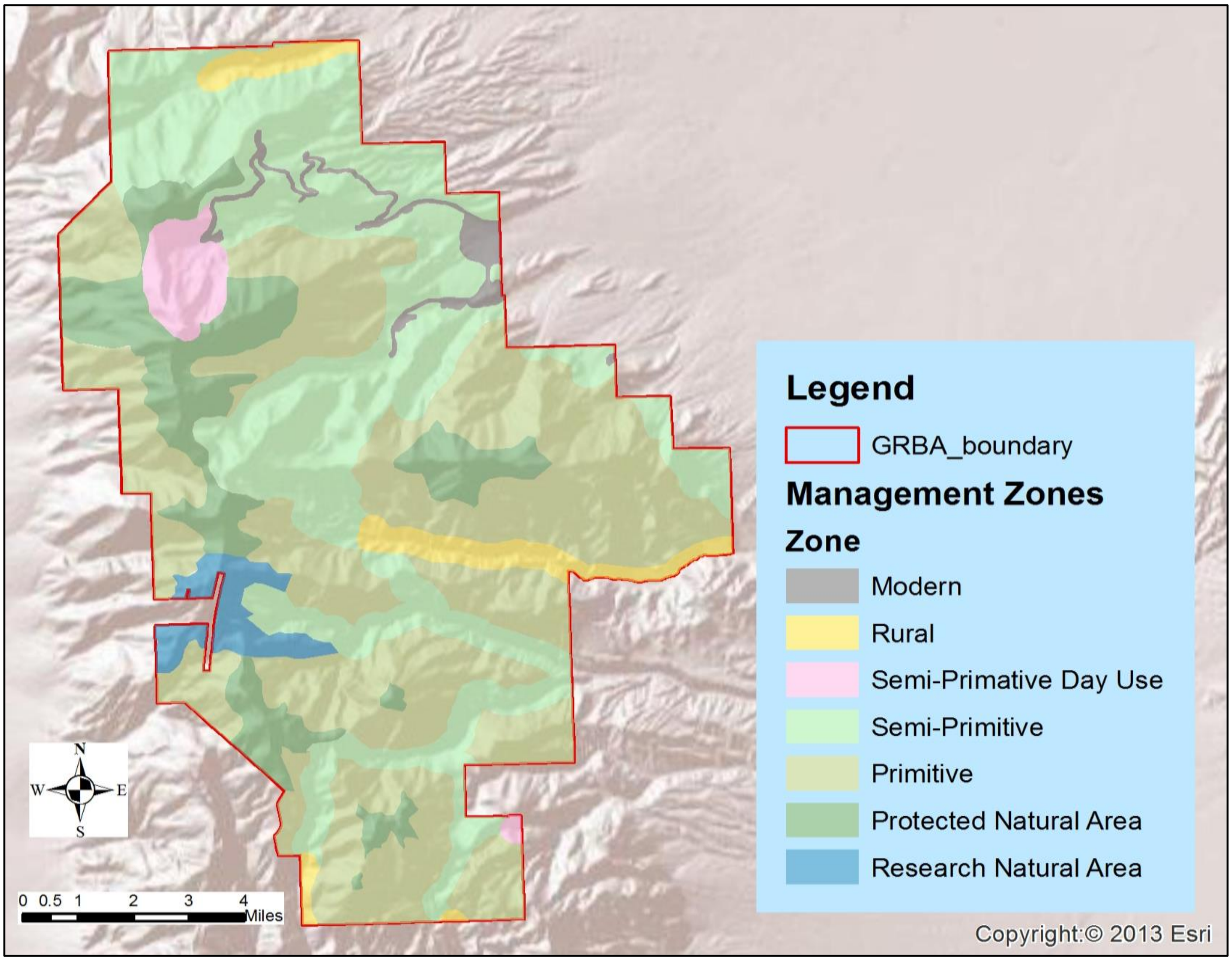

Figure 4. Management zones of Great Basin National Park.

2.2.2. Resource Descriptions

The following resource descriptions are presented in the same order as they are in Chapter 4. Represented below is the basic information known before the natural resource condition assessment was completed. Chapter 4 includes references for the information found.

Landscape Resources

Air Resources (Air Quality, Viewsheds, Night Skies)

Many national parks established prior to the Clean Air Act of 1977 are afforded the greatest air quality protection with Class I airshed designation[2]. Great Basin NP has a Class II airshed designation, yet still enjoys some of the best air quality in the contiguous United States with visibility often extending 120+ miles (193+ km) (mean standard visual range). Scenic vistas are an integral part of interpreting the basin and range landscape, particularly since the enabling legislation allows for the NPS to assume a coordinating role for interagency interpretation of the Great Basin physiographic province.

Visitors to the high elevations of Great Basin NP can enjoy vistas of vast expanses of high desert valleys interspersed with numerous north-south oriented mountain ranges.

The night sky is another example of the importance of excellent air quality to the integrity of the park and visitor experience. The park has recently developed numerous night sky programs and is pursuing the installation of an observatory with the Great Basin National Park Foundation.

Glacier Resources

Great Basin NP contains the partial remnants of one ice glacier, above the Wheeler Peak rock glacier (Osborn and Bevis 2001). This glacier was first identified in 1883 by William Eimbeck, who was installing a heliograph station on Wheeler Peak. The park also has at least seven rock glaciers (Graham 2014). Rock glaciers are ice-masses covered with rock, mostly Prospect Mountain Quartzite falling from the surrounding cirque walls. The rock glaciers may form distinct lobes. The park also contains various glacial features such as cirques and moraines. Despite having many glacial resources, few studies have focused on them, and it is unlikely that the rock glaciers are a significant hydrologic resource.

Upland Resources

Wildfire

Wildfire is a natural part of the ecosystems in the park. However, fire suppression has occurred since the late 1800s. The exclusion of fire in areas has allowed for encroachment of pinyon pine trees in sagebrush areas and white firs in aspen areas. Fire suppression has led to a preponderance of late-successional woody plant communities, which are more susceptible to catastrophic fires and insect outbreaks. The expansion of cheatgrass (*Bromus tectorum*) into the park's lower elevations has the potential of dramatically changing the fire regime in the sagebrush steppe systems possibly resulting in these systems transitioning into annual grasslands.

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[2] The 1977 Clean Air Act amendments designated Class I areas based on these criteria: the following areas that were in existence as of August 7, 1977 - national parks over 6,000 acres (2,428 ha), national wilderness areas and national memorial parks over 5,000 acres (2,023 ha), and international parks.

Aspen-Mixed Conifer Forest
Aspen-mixed conifer forests are found at mid to upper elevations in the park. The mixed conifer component consists primarily of white fir and Douglas-fir, with diverse understories. This habitat currently has an ecological departure of 66 percent, indicating that much of the aspen has disappeared as the mixed conifers have formed a closed-canopy forest (Provencher et al. 2010).

Wild Turkey
Wild turkeys were introduced by NDOW in the early 2000s outside the park. The turkeys quickly entered the park, and their numbers continue to increase and they have spread across multiple park drainages and can be found up to 10,000 feet (3,048 m) in elevation. Their effects on native species in the park have not been studied.

Invasive Annual Grasses
Invasive annual grasses have moved into the park, especially along road corridors. Of particular interest is cheatgrass (*Bromus tectorum*), an invasive exotic annual, which started moving into the park in the mid-1900s. It is now commonly found below 8,000 feet (2,438 m), and sometimes as high as 10,000 feet (3,048 m). Cheatgrass replaces native grasses, decreases food resources for wildlife, and increases the fire frequency of an area.

Bighorn Sheep
The last observation of native bighorn sheep in the South Snake Range was recorded in 1972. The Nevada Department of Wildlife (NDOW) considered bighorn sheep extirpated from the Snake Range by 1975. Twenty Rocky Mountain bighorn sheep from Colorado were reintroduced to the South Snake Range in 1979 and 1980. A bighorn sheep telemetry study was initiated in 2009 by the park and NDOW. A total of 16 bighorn (64% of the estimated population) have been collared in the South Snake Range to determine herd size, disease status, home ranges, survival, lambing range and winter range. Herd size is estimated between 20-25 individuals, similar to the number of bighorn that were originally reintroduced 34 years ago. Disease testing of collared bighorn revealed the South Snake Range population to be the only *Mycoplasma ovipneumoniae*-free herd of Rocky Mountain bighorn sheep in Nevada. GIS modeling suggests that habitat quantity is not a limiting factor in the South Snake Range. Rather, proximity to domestic sheep, mountain lion predation, and habitat quality are the limiting factors to a viable bighorn sheep population.

Sagebrush-Steppe
Sagebrush-steppe includes low sagebrush steppe (420 acres (170 ha)), montane sagebrush steppe-upland (12,710 acres (5,144 ha)), and montane sagebrush steppe-mountain (940 acres (380 ha)). The first two have moderate ecological departure, while the third is only slightly departed from its historical range of variation (Provencher et al. 2010). For all three systems, ecological departure is the result of a paucity of early successional stages, a consequence of changes in the fire regime.

Ten years of small mammal surveys have been completed to determine the effects of sagebrush restoration (through the removal of encroaching conifers) on small mammal density and diversity. Mark-recapture surveys in Lehman Flat began in 2004. Surveys targeting high-value habitat types including sagebrush steppe, riparian, aspen and subalpine grassland habitat were conducted between

2007 and 2012 in thirteen park watersheds. Trapping has documented twenty-three species, including two small mammal species listed as NPS species of management concern.

Aquatic Resources

Water Resources

Ten permanent streams originate in the park between 6,200 and 11,000 feet (1,890 and 3,353 m) elevation and are fed by numerous springs along their courses. The perennial reaches of these streams average 5 miles (8 km) in length. Six streams flow eastward into Snake Valley, and four drain westward into Spring Valley. The largest streams, Strawberry, Lehman, Baker, Snake, South Fork Big Wash, originate from the Baker/Wheeler/Washington Peak areas. Most of the streams gradually percolate into the alluvium and/ or evaporate before reaching the adjacent valleys. Snake Creek contains a 3 mile-long (4.8 km-long) water pipeline diversion system in the park, built to bypass a losing stream reach over karst terrain and deliver water to the town of Garrison. The Park also contains six sub-alpine lakes averaging 3 acres (1.2 ha) in size, of which Baker Lake supports non-native introduced salmonid populations.

Periodic water quality monitoring has taken place since 1999, as part of the Bonneville cutthroat trout reintroduction project and the NPS Inventory and Monitoring protocol for Streams and Lakes. A year-long water quality baseline was conducted in 2007 on a subsample of the park's lakes, streams, springs, and cave water sources (Horner et al. 2009).

Montane Riparian Woodlands

The South Snake Range contains more than 33 watersheds, 25 of which occur mostly within Great Basin NP. Ten of the latter contain streams with one or more perennial reaches that support corridors of riparian vegetation. Headwater elevations for perennial flows range from a low of 7,598 feet (2,316 m) for South Fork Big Wash to a high of 10,213 feet (3,113 m) for Baker Creek. Intermittent stream reaches in other watersheds also support riparian plant communities, including Can Young Canyon and Arch Canyon at the head of the South Fork of Lexington Creek.

The montane riparian plant communities of the park consist of two broad types: the Rocky Mountain Subalpine-Montane Riparian Woodland and Shrubland/Stream; and the Great Basin Lower Montane-Foothill Riparian Woodland and Shrubland/Stream system types. As is typical throughout the Great Basin, riparian communities occupy a very small fraction of the area of the park but contribute greatly to its biological diversity. Cold-air drainage, topographic shading, the presence of running water, and high water tables support distinctive assemblages of plants that tolerate or require moist soils and cooler, more humid microenvironments. Evapotranspiration and shading by the riparian vegetation itself helps maintain these microenvironments. Disturbances caused by irregular pulses of runoff that reshape alluvial soils contribute to the diversity of riparian plant communities.

Bonneville Cutthroat Trout

Among the native aquatic fauna of the park, Bonneville cutthroat trout (BCT) receive the most attention. BCT are native to the Bonneville Basin of eastern Nevada and western Utah. BCT in the State of Nevada have experienced major declines caused by natural and human related changes. This subspecies was once native in the streams of Great Basin NP but was extirpated from most of its assumed historic range in Great Basin NP due to the introduction of non-native salmonids. There were 25+ miles (40+ km) of historical but unoccupied Western BCT stream habitat when Great Basin NP was established. The Park has the potential to provide over 24% of the stream corridor (by length) needed for BCT recovery in Nevada (Baker et al. 2008). In 1999, the park prepared a reintroduction plan and initiated a multi-year process that reestablished Bonneville cutthroat trout in historic habitat within the park, including South Fork Big Wash, Upper Snake Creek, Strawberry Creek, and upper South Fork Baker Creek. BCT are also found in Pine and Ridge Creeks, on the west side of the range, and Mill Creek. Multiple genetic analyses have shown these populations to be pure BCT, as well as all reintroductions to date. Non-salmonids that most likely existed with BCT in many of these creeks included mottled sculpin, speckled dace, and redside shiner, and some reintroduction attempts of those species have been made with varied success.

Fishing is authorized in the enabling legislation in cooperation with the Nevada Department of Wildlife (NDOW). Fish stocking of brook, brown, rainbow, and Lahontan cutthroat trout have historically occurred in Lehman, Strawberry, Baker, and Snake Creeks plus two of the six sub-alpine lakes, Baker and Johnson. NPS policy prohibits the artificial stocking of non-native fishes in natural management zones, thus no stocking of fish has been allowed since the creation of the park in 1986.

Cave/Karst Resources

Lehman Cave displays a wide variety of beautiful formations and is the single-most visited attraction in the park. The cave is formed in Middle Cambrian Pole Canyon Limestone. Lehman Cave is famous throughout the world for its concentration of cave formations, particularly the abundance of cave shields; a rare calcite formation. It is the longest cave in Nevada, at approximately 1.5 miles (2.4 km) long. The cave contains several endemic species, including the Lehman Cave pseudoscorpion (*Microcreagris grandis*), which is only known to the South Snake Range. The cave is regularly used for paleoclimate research as well as other studies. It is believed to have formed from both epigenic (surface water) and hypogenic (deep water) processes (Graham 2014).

In addition to Lehman Caves, there are 45 other known caves in the park. These other caves include the highest elevation and deepest caves in the state of Nevada. Some are small and dusty, while others have maze-like passages and include streams. Physical cave inventories have been conducted in nearly all the caves, while biological cave inventories have been conducted in about half of the caves.

Great Basin NP contains over 30,000 acres (12,100 ha) of karst geology with a high potential for harboring additional cave resources. The karst consists primarily of limestones and dolomites, and is found primarily in the southern section of the park. This area of the park lacks many springs and streams due to the porous rock. A karst area in the Baker Creek watershed contains some of the most highly developed known karst drainage networks in the park (NPS 2006).

Springs

Great Basin NP has over 400 perennial springs, many discovered during a 2003-04 survey. The largest spring is Rowland Spring in the Lehman Creek watershed, with a mean annual discharge of approximately 3.5 cubic feet per second. Some springs may be susceptible to groundwater withdrawal outside the park (Elliot et al. 2006), which could in turn affect the plants and animals that depend on that spring.

Future Landscape Conditions

Climate Change Effects

Climate change in the Great Basin over the past 100 years includes gradually warming temperatures and slightly increased overall precipitation, but decreased snow fall (Chambers et al. 2008). More extreme weather events, such as floods, are expected due to climate change. Plants and animals that require cooler temperatures are expected to disperse upslope or to other cooler portions of the park. Projects in the park that have encompassed climate change components include small mammal surveys, GLORIA mountaintop vegetation and temperature monitoring, and numerous researcher studies.

Additional Wildlife Resources (not specifically covered in Chapter 4)

The wide elevation gradients at Great Basin NP support a diversity of vegetative habitats, which in turn support a wide diversity of wildlife. The Snake Range contains five of the seven Merriam Life Zones of North America. Thus, the list of animal species occurring in and around the park is quite large compared to other mountain ranges in the Great Basin. The species list consists of 72 mammals, 238 birds, 14 reptiles, seven fish, and one amphibian.

Remote camera inventories to document carnivores and NPS species of management concern have been ongoing since 2002. A more intensive sampling protocol was established in 2010 to monitor mesocarnivores. A total of 29 species and four NPS species of management concern have been documented. Remote cameras are also used to monitor trespass livestock and the timing of yellow-bellied marmot emergence.

Rattlesnake telemetry studies were initiated in 2009 when three Great Basin rattlesnakes were implanted with radio transmitters. A total of 37 snakes have been implanted and their movements tracked to document hibernacula locations, life history information, home ranges, effects of short distance translocations, and recidivism rates to capture sites and hibernacula.

The park and Mojave Desert Inventory and Monitoring Network have initiated a long-term macroinvertebrate inventory program and is currently using the information to assess ecosystem health. To date over 100 taxa have been documented and quantified in the lakes, streams, and springs of the park. Surveys for aquatic mollusks were initiated in 1999, with several species identified in the park including the springsnail *Pyrgulopsis kolobensis*. Several insect groups (Coleoptera, Orthoptera, Hymenoptera, Diptera, and Arachnids) have been surveyed during BioBlitzes, adding nearly 200 families to the park's list.

Sensitive, Threatened, and Endangered Species

No federally-listed species are found in the park. However, the park contains some species listed by the state as S1 species. These are species that, within the state of Nevada, are considered critically imperiled and especially vulnerable to extinction or extirpation due to extreme rarity, imminent threats, or other factors. These species are Snake Range whitlowcress (*Draba oreibata* var.

serpentina), Wheeler Peak whitlowcress (*Draba pedicellata* var. *wheelerensis*), Holmgren buckwheat (*Eriogonum holmgrenii*), Mount Moriah beardtongue (*Penstemon moriahensis*), Lehman Cave pseudoscorpion (*Microcreagris grandis*), and Bonneville cutthroat trout (NNHP 2010). The park also maintains a list of Species of Management Concern (Appendix A).

2.2.3. Resource Issues Overview

Great Basin NP has numerous past activities or conditions that influence current park conditions. This section provides a brief introduction to resource condition threats or stressors identified as being "of concern" in terms of potential risk or harm to important park resources. These are explored in more detail in Chapter 4. Some have already been mentioned in Section 2.2.

Air pollutants include sulfates, nitrates, ozone, mercury, and particulates. These could come from vehicles, mines, coal-fired power plants, or other sources, both near to and far from the park. The pollutants can affect air quality, water quality, and health of wildlife, vegetation, and humans.

Development both in and out of the park can affect park resources. Primary development issues at this time are wind farms, groundwater development projects, additional roads, commercial overflights, and additional lights. Effects of development include impacts to visual resources, increased noise and light pollution, more dust and particulates, change in vegetation types to allow greater fire frequency, and disruption of wildlife migratory routes and foraging areas.

Fire suppression over the last 120 years has led to a change in the seral state of many of the habitat types in the park. Aspen stands in particular are often invaded with white fir and have low recruitment rates absent fire. Fire suppression has also allowed a high forest floor fuel load. Little regeneration of ponderosa pines, which depend on fire to release seeds, has been seen in the park.

Water issues are many, given that the park is located in the Great Basin Desert and water is a scarce resource. Primary concerns are water rights, diversions, groundwater pumping adjacent to the park that could affect park water resources, and road maintenance, which may introduce additional gravel or sediment into the stream. These stressors can cause loss of riparian habitat, interruption of groundwater recharge, and increased erosion. More information is provided in Chapter 4.

Non-native animals that live in the park include brook, brown, rainbow and Lahontan cutthroat trout, which were introduced into park streams and displaced native fish species. Non-native turkeys roost outside the visitor center for part of the year, and in the summer can be found in all the park campgrounds. Wild horses are a non-native species found in the surrounding mountain ranges. The Mountain Home Range to the south of the park has a large herd (Sulphur Herd). As the herds expand, it is likely that they will enlarge their territory and come into the park, potentially displacing native species.

Non-native cattle and sheep illegally graze in the park. Livestock have grazed on the South Snake Range since the 1870s. Legal cattle grazing ceased in 1999 and legal sheep grazing in 2008. Effects of both wild and domestic ungulate grazing include decreased bank stability along streams, loss of early seral stages of aspen due to excessive browsing of aspen suckers, and trampling of sensitive species, especially in wetland areas. Domestic sheep can also carry diseases and transmit them to bighorn sheep, as well as decrease forage and water available to native species.

In addition to non-native animals, non-native plants are also found in the park, including the aforementioned cheatgrass. Some of the other 40+ species of non-native plants include highly aggressive species like musk thistle (*Carduus nutans*), spotted knapweed (*Centaurea maculosa*), and bull thistle (*Cirsium arvense*).

Human use of the park may stress some park resources. Lint falls from visitors' clothing during tours of Lehman Cave and may stick to and alter speleothem formation. It also provides an unnatural nutrient source to cave biota. Lights in the cave allow for the growth of lamp flora (algae, mosses, and bacteria), which also can impact cave resources. Visitors may trample invertebrates or cause intentional or accidental physical damage to speleothems. In addition, humans may transmit diseases or pathogens to the cave environment, such as *Pseudogymnoascus destructans*, a fungus which causes white-nose syndrome in bats.

The location of park campgrounds in wetland areas may alter wildlife use of these rare habitats. Social trails can compact soils. Visitors may intentionally or unintentionally introduce non-native species to the park, such as insects or diseases from firewood brought in from other areas, non-native fish or bait, and domestic animals. Road mortality, poaching, and intentional killing are additional threats to park wildlife.

2.3. Resource Stewardship

2.3.1. Management Directives and Planning Guidance

The natural resource management objectives for Great Basin NP identified in the General Management Plan (GMP), 1993, are to:

1) Manage the park to maintain the greatest degree of biological diversity and ecosystem integrity within the provisions of the authorizing legislation.
    a) Eliminate or mitigate any impacts that threaten biological resources.
    b) Determine the extent of plant and animal diversity, monitor changes that are occurring and identify the sources of change; eliminate or mitigate any identified adverse impacts, recognizing that native populations fluctuate naturally.
    c) Monitor and evaluate biological diversity in relation to the influences of major climatic and environmental change, particularly those caused by man.
    d) Protect threatened, endangered, and endemic species and restore them within their natural ranges.
    e) Manage the grazing program to minimize effects on natural process to adhere to the best range management practices with an emphasis on protecting sensitive species.
2) Determine the natural role of wildland fire in the South Snake Range ecosystem, and manage the park to restore and maintain this process.
    a) Develop an action plan for fire management.

3) Maintain the pristine quality of the air, water, geologic and scenic resources in the park.
    a) Establish a baseline to determine resource conditions, monitor changes, and identify sources of change; eliminate or mitigate any human-caused caused impacts that threaten abiotic and scenic park resources.
    b) Restore previously disturbed and abandoned areas (sites of mining activity, undesignated roads and trails, etc.) to natural conditions.
4) Preserve and protect caves and cave systems in the park.
    a) Identify, inventory, and classify caves and cave systems, and eliminate or mitigate impacts on cave resources.
    b) Avoid potentially harmful development in, above, or adjacent to caves unless it can be demonstrated that such development would not significantly affect natural cave conditions.
5) Allow only those recreational activities that contribute to understanding and appreciation of the park's resources and only to the extent that natural, cultural, and scenic values are not impaired.
6) Establish and maintain a broad spectrum of management zones and subzones to avoid limiting visitor use to the extremes of paved and primeval.
7) Develop an interpretive initiative, including facilities, programs, and activities, that makes Great Basin NP the primary area for interpreting the theme of the Great Basin physiographic region.
8) Provide a sense of anticipation for visitors before they reach the park.
9) Locate NPS management facilities outside park boundaries whenever the management functions can be adequately supported from such locations.
10) Work with local communities and assist them in meeting community goals.
11) Work with adjacent communities to help them maximize economic benefits.

2.3.2. Status of Supporting Science

The Mojave Desert Network Inventory and Monitoring Program (MOJN) includes Great Basin NP and currently monitors streams and lakes and integrated upland vegetation and soils. Air quality and climate are also vital signs that are monitored, but funded by separate programs. Additional vital signs that are planned to be developed and implemented in the next ten years are riparian vegetation, riparian birds, invasive plants, fire and fuel dynamics, and landscape dynamics (Chung-MacCoubrey et al. 2008). Protocols have been postponed for the vital signs small mammals, reptile communities, and at-risk populations.

The park also conducts other inventory and monitoring including quarterly sampling of Lehman Cave invertebrates, rattlesnake telemetry, small mammal surveys, remote camera surveys, invasive plant surveys, the GLORIA resurveys on mountain tops, annual BioBlitzes focusing on invertebrates, bighorn sheep telemetry, and Christmas Bird Counts.

Researchers have contributed to the supporting science for the park in many fields, including climate change using lake sediment cores, bristlecone tree rings, stalagmites, and climate stations; botany, including phenology, forest inventories, and characterizing *Castilleja* spp., *Potentilla* spp., *Pinus* spp., and more; geology, including paleontology and characterizing the basin and range formation; hydrology, including water quality and quantity, dye tracing, and impacts of dust; entomology, including looking for the presence of whiteflies, scale insects, gypsy moths, Jerusalem crickets, and characterization of pseudoscorpions and woodboring beetles; cultural resources, including ethnography and dendographs; fire ecology; wildlife biology, including studying flammulated owls and pygmy rabbits.

The Landscape Conservation Forecasting done by The Nature Conservancy for the park (Provencher et al. 2010) provides a baseline and desired future conditions for different park habitats. They mapped 21 biophysical settings and found that nine were slightly departed from natural range of variability (NRV), and ten were moderately departed. However, two were highly departed, basin wildrye and antelope bitterbrush. The major cause for ecological departure across the landscape was an under-representation of early succession classes. They analyzed 10 biophysical settings in greater detail, developing management strategies that determined the role of fire in the South Snake Range.

The data and reports available for each resource topic varied. In addition to the data and reports from the projects listed above, subject matter experts provided information on several topics. Washington level programs including night sky, soundscape, and air quality also provided a wealth of information for this NRCA.

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Stella and Teresa Lakes, Great Basin NP

3. Study Scoping and Design

This NRCA is a collaborative project between Great Basin National Park staff, NPS staff from the Pacific West Region, NatureServe, and Sound Science. NatureServe is a non-profit biodiversity research organization that serves as an umbrella institution for the network of Natural Heritage Programs and Conservation Data Centers located throughout the USA, Canada, and Latin America. NatureServe ecologists work with federal and state agencies and the academic community on biodiversity inventory, ecosystem assessment, and ecological monitoring. Sound Science is an environmental consulting firm focused on ecosystem assessment and monitoring, with extensive experience across the USA.

Project findings will assist park staff with objectives including:

- Developing management priorities for near- and medium- terms
- Conduct park planning, including the Resource Stewardship Strategies and management plans
- Support interpretation of park resources and issues
- Engage in landscape-scaled partnership efforts

The resources selected for this assessment are limited to natural resources, but cultural resources were also taken into consideration within the context of the chosen natural resources. Park staff participated in project development, planning, and writing.

3.1. Preliminary Scoping

A preliminary scoping meeting was held on October 16-17, 2012, at the Great Basin NP headquarters. At this meeting, Great Basin NP and Pacific West Region (PWR) staff met with the NatureServe Principal Investigator (PI) to initiate the NRCA process. The agenda for the meeting included discussing: a) communications amongst the team, b) the resource values of interest for the NRCA, and c) the approach to be used for the assessment. The group agreed that the approach for the NRCA would build upon the Ecological Integrity Assessment Framework (EIAF) outlined in Unnasch et al. (2009). EIAF is described in greater detail in section 3.2.1.

The initial list of possible resources for the NRCA was outlined in the scope of work for the project, and drew upon the collective knowledge and concerns of the Great Basin NP staff and also PWR staff. This list had been prioritized prior to initiation of the project, and at the workshop it was determined to focus further prioritization upon those ranked as “high” in the scope of work. For each of the proposed focal resources, the workshop participants worked with the PI to draft a set of “management questions” (MQs) to articulate the particular management concerns relevant to that resource. Each resource also had listed any known reports or data from within or outside the park, along with individual Park staff and any other persons known to be expert(s) for that resource. Several stressors were also identified as being of particular concern and these ‘focal stressors’ had management questions drafted.

Subsequent to this preliminary scoping meeting, Great Basin NP staff provided to NatureServe many geospatial datasets, tabular data, and report documents relevant to the park’s resource management plans and the values identified during the meeting. NatureServe also compiled geospatial datasets from its own GIS data library, including many resulting from the recently completed Central Basin and Range Rapid Ecoregional Assessment for BLM (Comer et al. 2013), and the Great Basin Energy Assessment project (Unnasch et al. *in prep*).

NatureServe staff then reviewed the park-provided data for each resource or stressor and documented aspects of its usefulness for a NRCA, answering questions such as:

- Is it comprehensive for the park?
- Were metadata or a report available?
- Are there multiple datasets and Great Basin NP staff need to clarify which is most current/relevant?

The management questions were reviewed, and in some cases reframed so as to make them more addressable within the constraints of this NRCA. As relevant for each resource, stressors were listed, and possible ways to measure current conditions were drafted. Lastly, each resource was then ranked high, medium or low for the Great Basin NP NRCA.

NatureServe held two conference calls with the NRCA advisory team to review the list, and the information developed by NatureServe for each resource and stressor. Priority ranking of high, medium, or low was applied and was then reviewed during the second call. A high ranking reflected that data are available, the management question can be answered with reasonable effort, and it is of high importance to Great Basin NP staff.

3.2. Study Design

3.2.1. Indicator Framework, Focal Study Resources, and Indicators

<u>Ecological Integrity Assessment Framework</u>

This assessment has implemented principles and methods of the Ecological Integrity Assessment Framework (EIAF, Unnasch et al. 2009). This framework is a way of organizing, in a hierarchical fashion, bio-geophysical resource topics considered important in park management efforts. Specifically, the EIAF guides the identification of focal resources and stressors, and development of indicators for ecological resource assessment. The methodology incorporates core principles of systematic conservation planning, established and tested by the conservation science community over recent decades (e.g., Margules and Pressey 2000, Parrish et al. 2003, Knight et al. 2006, Sarkar et al. 2006, CMP 2007). This methodology provides a transparent and consistent process to focus resource assessment based on the best available science. It highlights conditions requiring management attention; identifies efficient indicators for management and monitoring; and clarifies critical information gaps, monitoring needs, and hypotheses with implications for adaptive management. The methodology addresses three broad questions:

1) <u>What is important?</u> That is, what resources need to be included in the management process?
2) <u>How is it doing?</u> That is, what is the current condition of each of these resources, as evidenced by indicators for their critical features, drivers, and dynamics?

3) <u>What do we want?</u> That is, what are the desired future conditions for each of these resources, as described by indicators for their critical features, drivers, and dynamics; the desired future conditions of existing and potential stressors; and the critical information gaps that need filling to support adaptive management?

This NRCA addressed only the first two core questions of EIAF methodology (what is important? and how is it doing?). The third question is outside the scope of a NRCA, but output from the NRCA should directly support answering those questions.

Addressing the first of the three EIAF questions involves four steps: (1) identifying the geographic scope of the analysis effort; (2) identifying the suite of biological and ecological resources of potential concern to the park unit; (3) identifying stressors known, suspected, or anticipated to affect these resources; and (4) selecting a sub-set of "focal" ecological resources for management based on the findings from the first three steps. The focal resources are selected based on a "coarse-filter/fine-filter" method (Noss 1987) to ensure that (a) major resources of concern are represented directly or are represented indirectly as a component of a focal resource; and (b) major stressors of concern are represented through their effects on one or more focal resources. The selection process typically involves development of a conceptual ecological model for the affected region as a whole.

Addressing the second of the three EIAF questions also involves four steps: (1) identifying the key ecological attributes for each focal resource, on which to further focus management attention; (2) identifying indicators for each key attribute, for each resource; (3) identifying an expected or reference range of variation for each indicator for each resource; and (4) assessing the status of each focal resource based on indicator data. Key ecological attributes include defining characteristics of a resource, its abundance, and its distribution; and key environmental associations, drivers, and constraints affecting resource characteristics, abundance, and distribution. Indicators may incorporate data using different levels of effort, from remote sensing, to ground-level rapid assessment, or ground-level intensive sampling. Together, the first three steps here result in the development of a conceptual ecological model for each focal resource.

Addressing the third of the three EIAF questions also involves four steps: (1) identifying desired conditions for each focal resource at specific locations based on its key ecological attributes and indicators; (2) identify stressors that affect or threaten to affect these key attributes and indicators in specific locations; (3) setting a timeline for action in specific locations to establish or ensure continuity of desired conditions; and (4) establishing metrics or benchmarks with which to evaluate these actions. Again, addressing this third question is a phase of activity to be undertaken subsequent to this NRCA in the development of Resource Stewardship Strategies.

Each phase of the EIAF also includes a parallel process, to assess the sufficiency of the data and knowledge used to build the conceptual ecological models for the individual focal resources, assess their condition, and address critical hypotheses concerning the resources and their stressors.

Great Basin NP Focal Resources for the NRCA

NPS staff identified resources and stressors for the park during the NRCA scoping process described above. The prioritized list was left as tentative; subject to discovery, review, and evaluation of applicable data sets. The final list of focal resources and stressors is not a comprehensive list of all the resources or stressors in the park. It includes a cross-section of resources and stressors that are characteristic of the park, and/or are of greatest concern or highest management priority in Great Basin NP (Table 1). Several indicators for measuring current conditions for each resource, as well as known or potential stressors, were identified in collaboration with NPS staff. In addition, the assessment area for each resource was discussed and assigned. The "assessment area" includes the complete geography within which a given assessment will take place. This is distinguished from "reporting units" such as a set of watersheds or other more localized spatial units that serve as spatial units for summarizing conditions for a given resource or stressor.

In many cases, the geospatial data were most thematically detailed or had the highest spatial resolution within the park boundaries, while more spatially or thematically coarse data were available for a larger assessment area. Hence some resources were to be addressed by two spatial assessments - one within the park boundaries, the other for a larger area of the landscape.

Table 1 provides the list of focal resources and focal stressors for this NRCA, with the above information developed for each. Ecological "coarse-filter" resources included sagebrush shrublands, aspen-mixed conifer forests, and montane riparian and wetland communities. Ecological "fine-filter" resources included Bonneville cutthroat trout and bighorn sheep. Environmental quality was addressed through focused assessment of water quality/quantity issues, including springs and cave/karst processes; air quality; viewsheds; and assessment of night skies. Fire regime was one primary ecological process to be assessed. Finally, rock glaciers were assessed as one key type of physical feature for Great Basin NP. The focal stressors included potential climate change effects with reference to the interactions with fire regime, and projections relative to selected species and vegetation types. Invasive non-native species were assessed specifically for annual grasses (e.g., cheatgrass) and wild turkey.

The assessment used all available reports and datasets, including historic datasets archived at the park. Data from a small number of recent studies of park surface and groundwater hydrology were not yet available for use in the assessment.

Geographic Scope and Assessment Areas

While the park is a single management unit, it is embedded in a larger landscape where many activities or disturbances may affect resources within the park. Therefore more than one geographic area may be appropriate to effectively support a natural resource condition assessment. As part of the scoping process for focal resources and stressors for the Great Basin NP NRCA, an appropriate assessment area was identified for each (Table 1). The guiding principle for area delineation was the distribution of a given resource or stressor with likely direct effects on the park. Spatial boundaries for each of these were created and reviewed by the Great Basin NP staff and are presented below in Figure 5 through Figure 8. These areas depict the geographic extent within which the focal resource or stressor was mapped and/or otherwise evaluated and documented in the NRCA.

Table 1. Focal resources and stressors identified for the Great Basin NP NRCA. For each, Park and Region staff identified management questions to help focus the assessment. Stressors impinging on each, and possible ways to measure the current condition, are identified. The geographic scope of assessment is listed (see figures in following section) along with the possible sources of data or information relevant to the resource.

Resource	Management Questions	Measures	Stressors	Assessment Area
Biotic Composition				
Ecological Communities				
Sagebrush-steppe	What is the relative ecological integrity of the sagebrush steppe, and are we allocating restoration actions to the right places?	integrity (high-low), Fire regime departure; if possible, show trends over time and by site, restoration sites mapped on top of integrity measures	fire suppression, invasive annual grasses, historical grazing effects, development, climate change	Park & Valleys
Aspen-mixed conifer forest	What is the current ecological integrity of the aspen-mixed conifer stands? Where have nearby fires been? Where have nearby/overlapping insect/disease outbreaks occurred?	integrity (high-low), if possible, map trends over time in events [insect outbreak, wind, fire, disease]	fire suppression, disease, climate change, invasive plants	South Snake Range
Montane Riparian Woodland and Stream	Could groundwater development affect these communities?	land use in groundwater recharge zones (mapped); map areas susceptible to pumping against vegetation map; in-stream habitat conditions addressed via metrics for BCT habitat	Fewer or more extreme flood events due to hydrologic modification, invasive exotic plants, ground or surface water use, grazing (trampling, stream bank erosion), or climate change	South Snake Range
Native Fish				
Bonneville cutthroat trout	Which stream reaches with BCT have the highest ecological integrity? Which watersheds supporting BCT have [altered fire regimes, most development, recent fires, sedimentation, or other impacts on water quality/quantity for BCT]?	land use by watershed; dams (if any) by watershed; fire or Fire Regime Condition Class by watershed; Nevada Division of Wildlife habitat condition metrics; macro-invertebrate community integrity	change in water quality/quantity (sedimentation, diversions, ground/surface water diversions, dams, etc.).	Snake Range

Table 1 (continued). Focal resources and stressors identified for the Great Basin NP NRCA. For each, Park and Region staff identified management questions to help focus the assessment. Stressors impinging on each, and possible ways to measure the current condition, are identified. The geographic scope of assessment is listed (see figures in following section) along with the possible sources of data or information relevant to the resource.

Resource	Management Questions	Measures	Stressors	Assessment Area
Mammals				
Bighorn sheep	Where are recent, nearby fires? Where are domestic sheep being grazed? What is the quality of bighorn habitat?	landscape condition model; fire regime departure for relevant ecological systems that provide habitat;	disease/competition from domestic sheep; loss of forage/water; stress from human activities (recreation); fire; climate change; causes of mortality (mountain lion)	South Snake Range
Environmental Quality				
Water quality/ quantity	What are the trends in water quality/quantity/seasonality in streams, lakes, springs, and caves? What are potential development effects on these aquatic communities and park administrative uses? What are the potential impacts of the pipeline for Snake Creek on aquatic/riparian communities?	map areas susceptible to pumping against streams/rivers/springs locations	ground or surface water use (diversions, pumping), pollutants, climate change	Park & Valleys
Caves/Karst processes	What is the connection between surface/ground water features in/surrounding park and the caves? Are stressors such as visitation or water diversions or climate change affecting invertebrate populations?	narrative interpretation of papers and reports	ground or surface water use (diversions, pumping), pollutants, climate change	Park & Valleys
Springs	What is the status of water quality/quantity of spring productivity for community use?	narrative interpretation of papers and reports	ground or surface water use (diversions, pumping), pollutants, climate change	Park

Table 1 (continued). Focal resources and stressors identified for the Great Basin NP NRCA. For each, Park and Region staff identified management questions to help focus the assessment. Stressors impinging on each, and possible ways to measure the current condition, are identified. The geographic scope of assessment is listed (see figures in following section) along with the possible sources of data or information relevant to the resource.

Resource	Management Questions	Measures	Stressors	Assessment Area
Environmental Quality (continued)				
Air quality	What are trends and potential ecological impacts (esp. thresholds applicable to alpine upland and aquatics) of SOx and NOx and ozone, Mercury, particulates*, visibility? As of 2012	NPS atmospheric measures; for particulates: status of disturbance to sensitive soils in Valleys	pollutants (SOx, NOx and ozone, mercury, particulates)	Park, Valleys & Regional
Viewshed	What are trends in human development relative to viewsheds?	interpretation of mapped development data and viewsheds	Non-natural features (potential for development)	Valleys & Regional
Night skies	What are trends in light pollution and particulate effects on night sky quality?	interpretation of night sky assessment	light pollution, particulate effects	Valleys & Regional
Ecological Processes				
Wildfire	What areas of the park are most impacted by fire suppression (mid elevations, etc?). Which areas of the park would most benefit from prescribed fire? Where have recent fires been?	Fire Regime Condition Class 1-3, for 2 and 3 each, consider additional characteristics: veg type, fuel class, canopy cover	fire suppression or alteration of regime due to historic grazing impacts, invasive species introduction and resultant fine fuel accumulation.	Snake Range
Physical Features				
Rock glaciers	What is their current extent?	map of distribution, including I&M network map	climate change; potential thaw	Park

Table 1 (continued). Focal resources and stressors identified for the Great Basin NP NRCA. For each, Park and Region staff identified management questions to help focus the assessment. Stressors impinging on each, and possible ways to measure the current condition, are identified. The geographic scope of assessment is listed (see figures in following section) along with the possible sources of data or information relevant to the resource.

Resource	Management Questions	Measures	Stressors	Assessment Area
Focal Stressors				
Climate Change				
Climate change	Which focal species (Bighorn, BCT) and habitats (alpine, caves) are most vulnerable during the upcoming 50 years?	Baseline data for future correlations with park observations of climate and hydrology. Projected climate trends and effects on hydrology. Observations on biotic responses to change.	Direct climate stressors (change in temp or precip regimes); Indirect interactions with other (fire, hydrologic change, invasives, phenology)	South Snake Range & Valleys
Invasive Species				
Wild turkeys	What are their ecological effects on other birds, lizards, and snakes? Where are their winter roost sites? Can they be relocated removed?	Narrative review literature re: management of turkeys in the wild	Habitat displacement and population pressure	Snake Range
Invasive Annual Grasses	Where are the areas most susceptible to expansion?	model of potential risk; statistics of overlap with ecological resources of interest	Interactions with fire regime change; and other disturbance such as grazing and human development; climate change	South Snake Range & Valleys

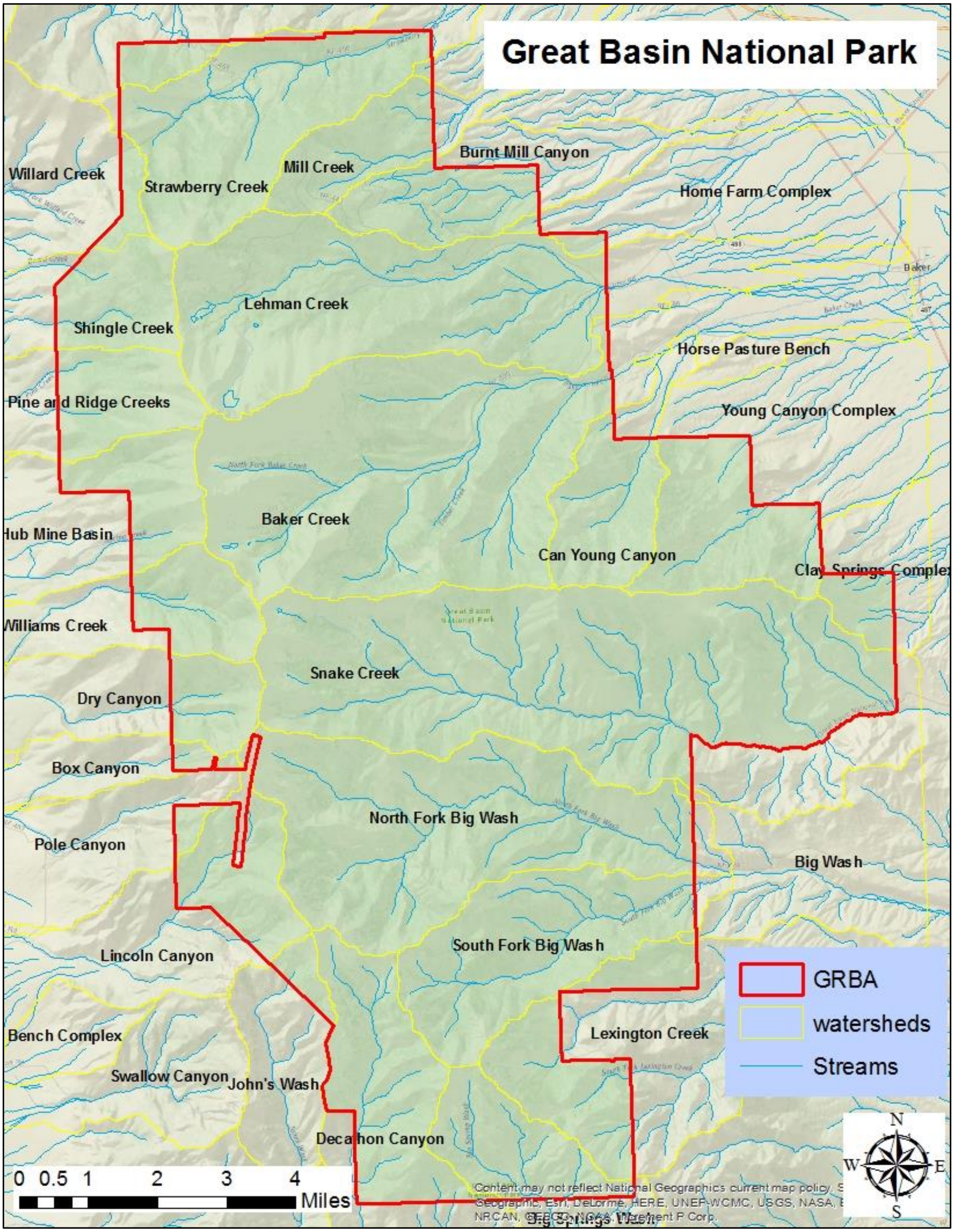

Figure 5. Finest scale assessment area boundary: Great Basin NP.

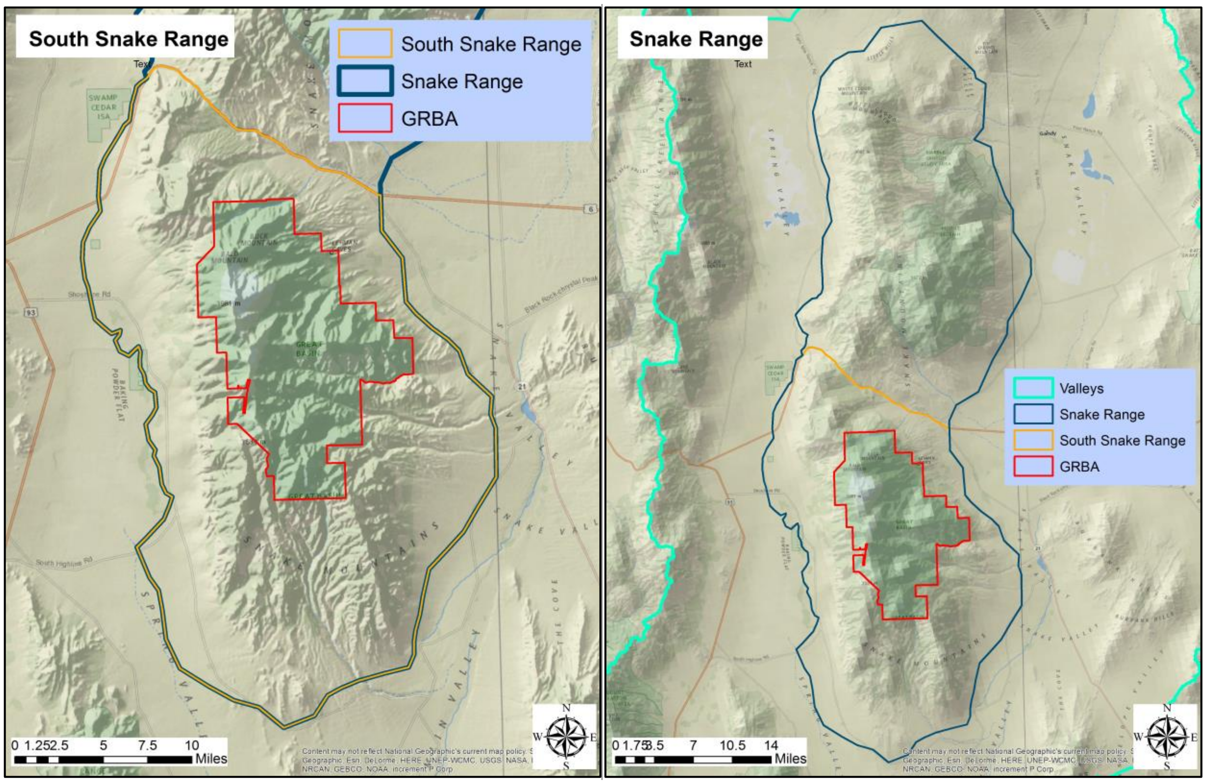

Figure 6. South Snake Range assessment area boundary (left); Snake Range area boundary (right).

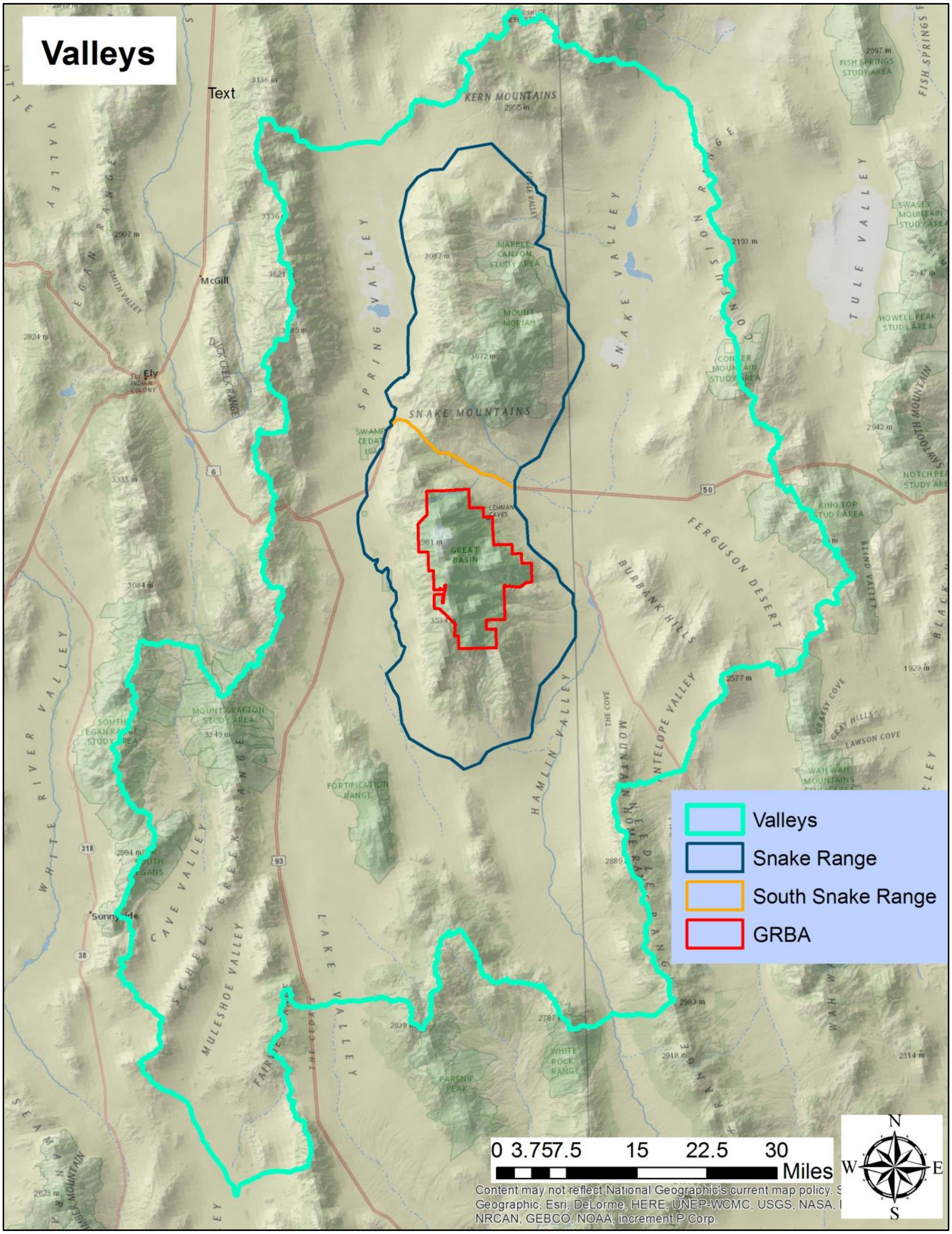

Figure 7. The larger assessment area boundary around Great Basin NP that includes the adjacent valleys.

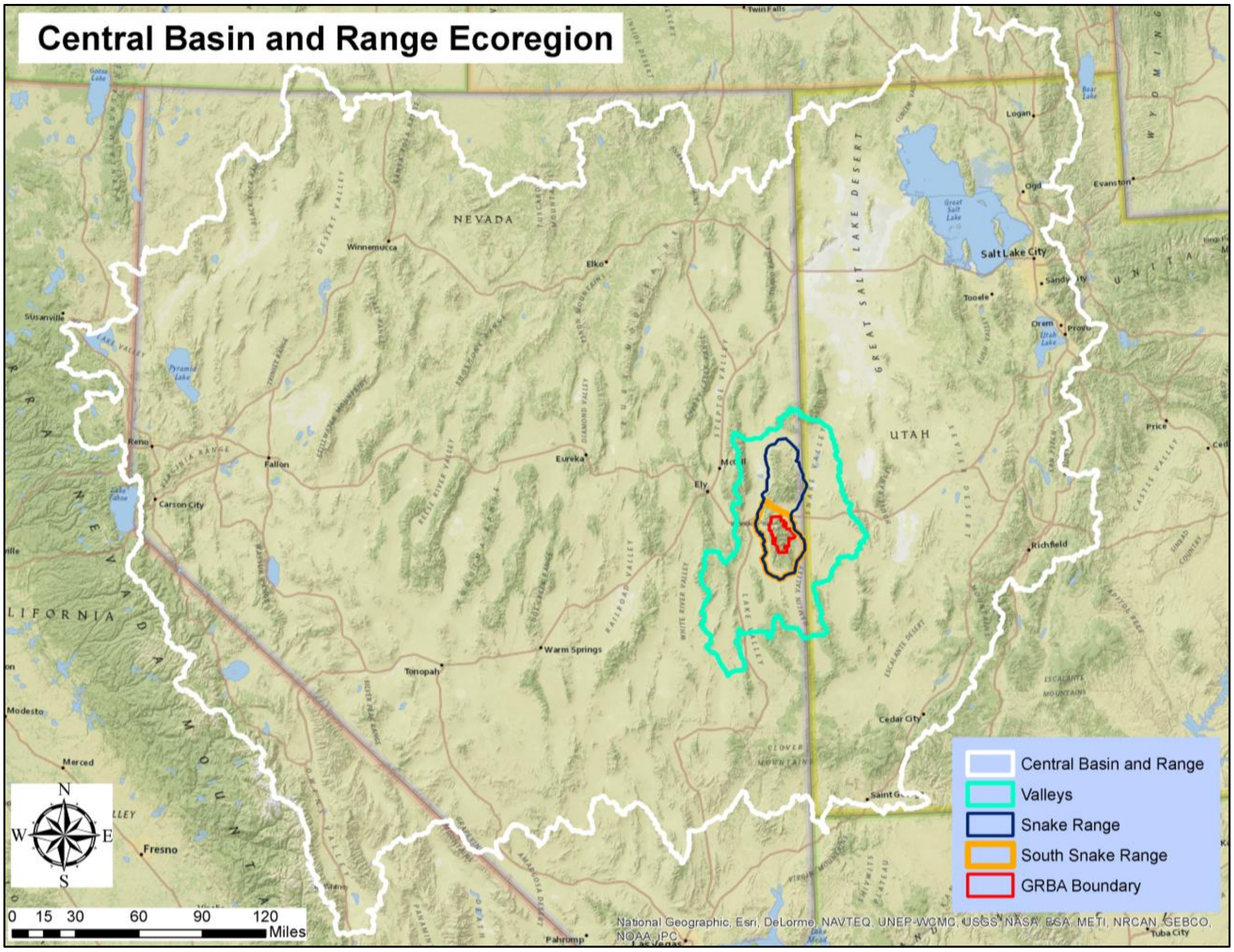

Figure 8. The largest assessment area boundary, the Central Basin and Range ecoregion within which Great Basin NP is located. The other 4 nested assessment boundaries are also shown.

3.2.2. Spatial Reporting Units

The NRCA uses spatial reporting units to report on the condition of each focal resource within the broader assessment area. For example, if one were reporting on the relative ecological condition of stream resources, one might select a set of watershed units of appropriate size to tabulate and document variation in those conditions across the assessment area. For a particular vegetation community type, one might also use watersheds, or some other spatial unit, such as its distribution by mountain range or enclosed basin, or discrete vegetation polygons, as practical spatial units for reporting.

The NRCA utilizes spatial reporting units suitable to each focal resource. Watersheds, beginning at the 5th level (HUC 10) were used for recent regional-scale assessments in this area, and we included HUC 10 and smaller HUC 12 units (6th level watersheds). Additionally, the park has drawn local watersheds boundaries, included in Figure 5, based upon their management needs. These also serve as reporting units for some focal resources.

3.2.3. General Approach and Methods

After identification of both the geographic scope and the focal resources for the NRCA, this study involved further gathering and reviewing of existing literature and data relevant to each of the focal resources. No new field sampling was conducted for this study. However where appropriate, existing data were further processed and analyzed to provide summaries of resource condition or to create new spatial representations.

Data Discovery

The data discovery process began at the initial scoping meeting, at which time Great Basin NP staff provided data and literature in multiple forms, including: NPS reports and monitoring plans, reports from various state and federal agencies, published and unpublished research documents, databases, tabular data, and charts. GIS data were provided by NPS staff. Additional data and literature was acquired through online bibliographic literature searches and inquiries on various state and federal government websites. Data and literature acquired throughout the process were reviewed and evaluated for thoroughness, relevancy, and quality regarding the resources identified during the preliminary scoping.

Data Development and Analysis

Data development and analysis were specific to each resource and their extent depended largely on the amount of information and data available for it. Specific approaches to data development, data quality review, and analysis are found within the respective resource assessment sections, located in Chapter 4 of this report.

The NRCA team developed a conceptual model for the Great Basin NP assessment area from the perspective of upland vs. aquatic resources, and then elaborated on these generalized models as needed for each focal resource or stressor. These conceptual models aimed to characterize current knowledge of characteristic environmental setting and important ecological dynamics. For example, aspen-mixed conifer forests are characterized in terms of their biophysical setting, characteristic fire regime (e.g., fire return interval), vegetation structure, and plant species composition. This generally describes a "reference condition" for comparison with current conditions. In this case, fire return interval for aspen-mixed conifer forests in the Great Basin is expected to fall within a given range, and when it falls outside of that range, we can infer that conditions of these forests will have changed. While direct measurement of fire return interval can be challenging, the relative proportion of vegetation structural stages – resulting from recurring wildfire – might serve as a practical, measureable "indicator" of fire return interval, and in turn, forest resource condition. That is, when wildfire has been suppressed, or occurs more frequently than expected, vegetation structural stages shift from expected proportions. Likewise, environmental quality assessments may characterize an apparently unaltered "reference condition" for comparison with current conditions. Indicators may reflect natural characteristics (e.g., water quality/quantity within some expected range) or target specific "stressors" such as the presence or abundance of non-native species or concentrations of a given pollutant. The NRCA addresses four aquatic focal resources – the montane riparian community; Bonneville cutthroat trout; water quality/quantity; and springs – by a single conceptual ecological model, with sub-models, because these four refer to different parts of a single hydro-ecological system.

Subject Matter Experts

Additional experts were sought to provide specific information was needed. Experts provided advice on data and analysis, and provided review of draft report materials. Assessment of each focal resource from Table 1 proceeded with NatureServe team members assigned according to their specialty. Specific expertise for this assessment was available from among the project team, and NPS staff. Sources of NPS staff expertise included individuals from Great Basin NP, the MOJN, and the PWR. NPS specialists served as resources and reviewers for each focal resource as well. Each specialist subteam made key decisions and drafted the assessment materials. Draft assessment products were made available for broader review by Great Basin NP staff, and formed the focus of workshops via a webinar series.

Scoring Methods and Assessing Condition

Following conceptual modeling and indicator identification, specific ranges of indicator measurement that have been established to indicate "Good" "Moderate Concern" or "Significant Concern" status, relative to reference conditions, were identified. Generally, where sufficiently understood for ecological resources, "Good" measures suggest that the indicator falls within an expected natural range of variation. "Moderate Concern" status results from indicator measures falling outside of that expected range, while "Significant Concern" status results from indicator measures well outside the expected range. Practically, "Moderate Concern" conditions may be feasibly addressed through active management, while "Significant" conditions may require substantial investment and restoration or recovery.

Some indicators were sufficient for reporting in more than three categories (e.g., a 10-point scale of 0.0-1.0), however, for others there was not sufficient knowledge or data to generate categorical assessment results. In these cases, qualitative and descriptive reporting of indicator measures was sufficient for park needs. Once conceptual models were completed and indicators identified, the assessment team worked with Great Basin NP staff to determine appropriate scoring methods for each focal resource and stressor.

Summary Indicator Symbols

Indicators and measures provide a "thumbnail" condition statement or score: a succinct statement or color-coded icon to indicate current condition (and trend, if evaluated). Table 2 includes a visual summary of these indicator symbols and accompanying brief definitions.

Table 2a. Symbols used to indicate condition and trend in this assessment, and their definitions.

Condition Status		Trend in Condition		Confidence in Assessment	
	Resource is in Good Condition		Condition is Improving		High
	Warrants Moderate Concern		Condition is Unchanging		Medium
	Warrants Significant Concern		Condition is Deteriorating		Low

Table 2b. Indicator symbols used to indicate condition, trend, and confidence in the assessment.

Condition Status		Trend in Condition		Confidence in Assessment	
	Resource is in Good Condition		Condition is Improving		High
	Warrants Moderate Concern		Condition is Unchanging		Medium
	Warrants Significant Concern		Condition is Deteriorating		Low

Format of Resource Condition Assessments

With a few modifications, this NRCA report followed the NPS Natural Resource Report outline. All assessments for each resource are presented in a standard format in Chapter 4. The following overview briefly explains the format (including heading format, e.g. 4.X.X.1) and content for each text field and feature for the resource assessments.

4.X.X Resource Name

Condition - Trend

Good –
Unchanging –
Low

Indicators / Measures

- ***Proportional vegetation structural stages***
- ***Abundance of tree regeneration***

<u>Background and Importance</u>

This section provides information regarding the relevance of the resource to the park. This section also explains the characteristics of the resource that help the reader understand subsequent sections of the document.

<u>Data and Methods</u>

Indicators / Measures

- ***Proportional vegetation structural stages***
- ***Abundance of tree regeneration***

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

<u>Reference Conditions</u>

This section explains the reference conditions used to evaluate the current condition, as measured by each indicator. Additionally, explanations of available data and literature that describe the reference conditions are located in this section. Summary boxes referencing indicators are repeated in this section.

<u>Condition and Trend</u>

This section provides a summary of the condition and trend of the indicator/measure at the park based on available literature, data, and expert opinions. This section highlights the key elements used in defining the condition and trend designation, represented by the condition/trend graphic, located at the beginning of each resource topic.

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

Sources of Expertise

Individuals who were consulted for the focal study resources are listed in this section. A short paragraph describing their background can be included.

Literature Cited

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

3.3. Literature Cited

Baker, G., N. Darby, T. Williams, and J. Wullschleger. 2008. Bonneville Cutthroat Trout Restoration Project-Great Basin National Park. Natural Resource Report NPS/NRPC/NRR—2008/055. National Park Service, Fort Collins, Colorado.

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Decathon Canyon, Great Basin NP

4. Natural Resource Conditions

This chapter presents the background, analysis, and condition summaries for the 12 focal resources and 3 focal stressors in the project framework. The following sections are organized in terms of landscape resources, upland resources and ecological integrity, aquatic resources and ecological integrity, and future landscape conditions. Each section discusses the key resources and their measures, stressors, and reference conditions. Sections on landscape and aquatic resources begin with a conceptual model to describe pattern, process, and interactions relevant to the following resource summaries. Each summary is formatted consistently to ease understanding and comparison. Overall findings are discussed in Chapter 5. The following table indicates the report section number and name where each assessment is found; the section numbers or names may be clicked to navigate directly to that section.

Chapter 4 Contents

Page

4.1. Landscape Resources

4.1.1. Conceptual Model of Landscape and Upland Resources

Drawing upon a wealth of existing descriptive information, including conceptual models developed for the National Park Service Inventory and Monitoring programs (Miller 2005, Chung-MacCoubrey et al. 2008); ecoregion descriptions of the NRCS (NRCS 2006) and US Forest Service (McNab et al. 2007); and the Great Basin Ecoregional Blueprint of The Nature Conservancy (Nachlinger et al. 2001), the following conceptual model articulates key assumptions about upland landscape pattern and process to inform this resource assessment.

The pervasive influences of climatic regimes interacting with the basin and range physiography establish overarching biophysical controls that shape the individual ecosystems of Great Basin NP and its surroundings. Between the Sierra Nevada to the west and Wasatch ranges to the east, more than three hundred long, narrow, roughly parallel mountain ranges are separated by broad elongated valleys (Grayson 1993). The structures of mountain ranges are roughly similar, but their compositions are diverse. This pattern is the result of high angle block faulting. As the entire Great Basin was uplifted and stretched, the mountain ranges are uplifted horsts, while grabens fell in to form the basins. While granite, basalt, and rhyolite bedrock occurs throughout the west, south, and central Great Basin, respectively, limestone-rich mountains are concentrated in the east, and included portions of the Snake Range.

Due to its location in the rain shadow of major mountain ranges, the climate of the Great Basin is semiarid. The Sierra Nevada range effectively captures most moisture from east-moving Pacific fronts while the Rocky Mountains intercept most moisture coming from the Gulf of Mexico. The climate regime is continental; with relatively high annual temperature fluctuations due to distance from moderating oceanic climates (Hidy and Klieforth 1990) and high elevation. Temperatures have both daily and seasonal extreme variation while spatial distinctions occur from valley floors to mountaintops. The mountains tend to be cooler and windier than the valleys. Surface air heating during the day yields very high valley temperatures, often accompanied by strong local turbulence that creates dust devils. At night, valleys lose heat rapidly by radiation and cool air pools below warmer air above. Therefore, cold extremes can occur at both high and low elevations, and some plant species least tolerant of coldest temperatures can be found at intermediate elevations. Cold continental cyclones result in spring maximum precipitation in the central and eastern Great Basin. Summer thunderstorms in subtropical air masses from the Gulf of Mexico cause a secondary summer maximum in the southeastern Great Basin, which is often heaviest in the valleys (Adams et al. 1997, Friedman et al. 2002, Sheppard et al. 2002).

Figure 9 illustrates the conceptual model for upland resources of Great Basin NP, acknowledging the driving roles of climate and geophysical setting. Seasonal weather patterns set up recurrent landscape dynamics from snowpack and avalanche, to storm events, lightning strikes, persistent wind shear. The upland systems include natural geophysical dynamics of landslide, soil moisture infiltration, soil and organic matter accumulation, drought, and natural disturbance dynamics such as windthrow, and wildfire. These vary considerably between higher, cooler montane settings and warmer basin settings. All of these natural abiotic drivers interact with biotic responses, such as predator/prey dynamics, herbivory, and insect outbreaks. These are key landscape attributes that support upland focal resources for this NRCA. At highest elevations, glacial and landslide processes produce rock glaciers. Rugged high-elevation slopes provide summer and lambing habitat for Rocky Mountain bighorn sheep. Domestic sheep grazing nearby can cause competition for forage and introduce disease risk to these populations. Wind, insect outbreak and wildfire in montane elevations support aspen mixed-conifer forest. Wildfire suppression and livestock grazing can alter structure and composition of these forests. Wildfire at these and lower elevations with deeper soil development, and at lowest elevation, cryptobiotic soil crust development, is characteristic of big sagebrush shrublands. Grazing of these sites can cause soil compaction and introduce invasive species, such as cheatgrass in these areas.

Just as climate and geophysical setting drives many landscape processes, the relative isolation of Great Basin NP from human population densities and intensive land uses supports key resource values, such as air quality, night sky, and scenic views. Human density is included in the conceptual model as a source of stress on these resources. While there are many positive interactions between human and natural components (e.g., economic development, outdoor recreation, etc.), both dense and dispersed human land uses affect air quality, scenic resources, and night sky. They also affect natural system drivers such as wildfire, and biotic soil crust processes, through grazing regimes, and altered fire regimes in upland systems. Predator/prey dynamics are influenced by human/wildlife conflicts, hunting, domestic sheep, and plant/animal collecting. Land conversion and introduction of invasive plant species closely follow human land use patterns for settlements, energy development (e.g., mining, oil/gas, solar, wind farms, geothermal), irrigated agriculture, or transportation/ communication infrastructure.

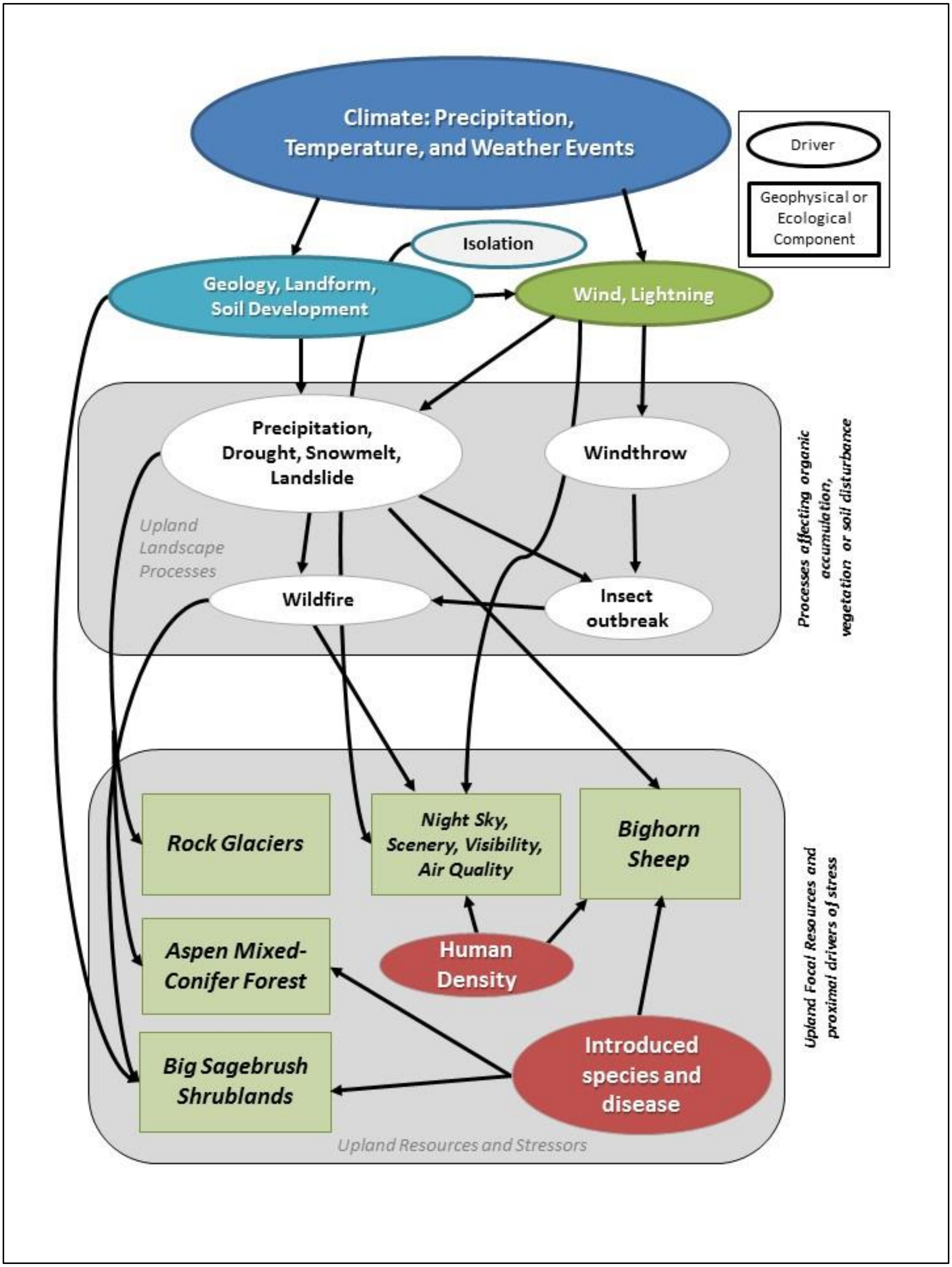


Figure 9. Model components for upland resources of Great Basin NP.

4.1.2. Air Quality

Indicators / Measures

- *Atmospheric Nitrogen and Sulfur deposition*
- *Ozone*
- *Visibility*
- *Mercury*

Condition - Trend

Moderate Concern – Unchanging – High Confidence

<u>Background and Importance</u>

This section describes the air quality and air pollution effects on air quality related values of Great Basin NP. Air quality related values (AQRVs) are those resources sensitive to air pollution and include streams, lakes, soils, vegetation, fish, wildlife and visibility. The primary pollutants affecting AQRVs in Great Basin NP are nitrogen (N) and sulfur (S) compounds (nitrate, ammonium, and sulfate [SO_4^{2-}]); ground-level ozone (O_3); haze-causing particles; and toxic airborne compounds including mercury (Hg).

Great Basin NP is a Class II area, as defined by the Clean Air Act. Under the Organic Act, the NPS manages Great Basin NP to protect air quality and related values from air pollution. Figure 10 shows a map of the NPS Inventory & Monitoring (I&M) Program Mojave Network (MOJN) park boundaries and locations of population centers with more than 10,000 people. There are no population centers larger than 10,000 people near Great Basin NP. Given its location in east central Nevada near the Utah border, the park often enjoys some of the cleanest air in the United States. However, Great Basin NP is occasionally affected by air pollution transported inland from California with the prevailing westerly winds (Edinger et al. 1972, Fenn et al. 2003, Allen et al. 2006). On these days, the park may experiences ozone levels close to or exceeding the primary ozone national ambient air quality standard.

Air Pollution Sources

The main source of S pollution is coal combustion at power plants and industrial facilities. Oxidized N compounds (i.e., nitrogen oxides) result from fuel combustion by vehicles, power plants, and industry. Reduced N compounds (e.g., ammonia and ammonium) are the result of agricultural activities, fires, and other sources. Ozone is formed when nitrogen oxides and volatile organic compounds from vehicles, solvents, industry and vegetation react in the atmosphere in the presence of sunlight, usually during the warm summer months. Persistent bio-accumulative substances include metals and organic compounds, such as pesticides. Coal combustion, incinerators, mining processes, and other industries emit Hg.

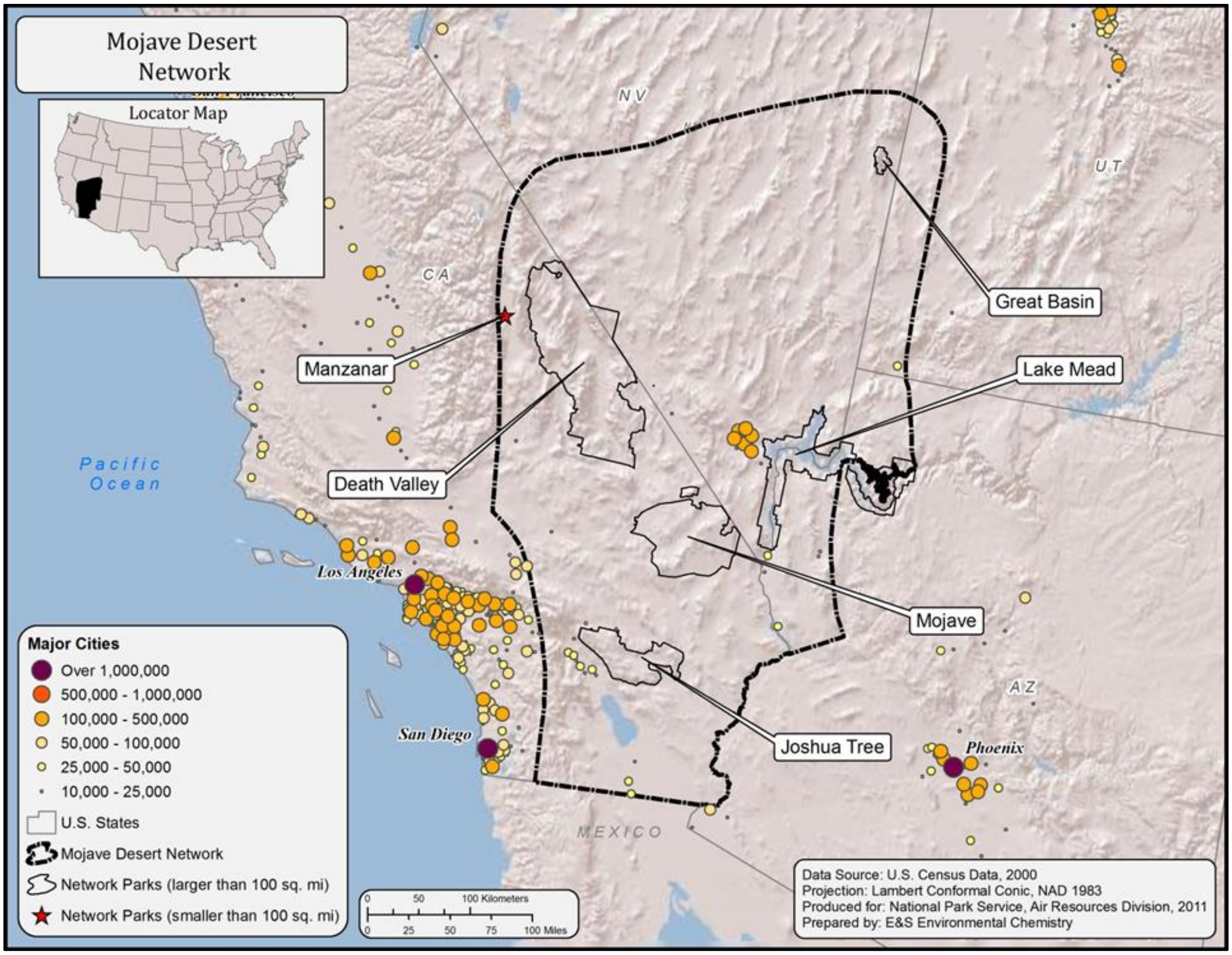


Figure 10. Map of the NPS I&M Program Mojave Network boundaries, with locations of each park in the Mojave Network and population centers with more than 10,000 people around the network.

Air Pollution Effects

Acidification

Atmospheric S and N pollutants reach the Earth's surface through either wet deposition (via rain, snow, clouds, and fog) or dry deposition (via adsorption or impaction). These pollutants change water and soil chemistry, which in turn, affects algae, aquatic invertebrates, soil microorganisms, and root function; and can lead to impacts higher in the food chain (Sullivan et al. 2011b, Greaver et al. 2012). Dry deposition predominates in arid ecosystems, such as are prevalent in Great Basin NP. It is difficult to quantify, however, in large part because the deposition change over time is influenced by many factors, including the mix of air pollutants present, surface characteristics of soil and vegetation, and meteorological conditions (Weathers et al. 2006). Fenn et al. (2009) developed a soil plate sampler for estimating dry deposition fluxes of N to exposed soil in arid ecosystems. This approach could be used to better quantify dry and total N deposition at Great Basin NP.

Nitrogen Nutrient Enrichment

Plant productivity on arid land typically increases with both increasing precipitation (Romney et al. 1978, Bowers 2005) and increasing N availability (Salo et al. 2005, Allen et al. 2009, Rao et al.

2010). In desert ecosystems, the availability of water constrains the abundance of life more than does the availability of N. Brooks (2003) found that plant responses were influenced by specific rainfall events rather than by average annual rainfall, with the annual plants thriving in a year when high rainfall events triggered germination. In the Mojave Desert, the shrub creosote bush (*Larrea tridentata*) showed no increased growth response to experimental N additions (at 10 and 40 kilograms N per hectare per year (kg N/ha/yr) as calcium nitrate, but did respond to increased water (Barker et al. 2006). Conversely, invasive annual grasses showed a greater response to elevated N than did native species. Additionally, elevated levels of N in water bodies, where the availability of water is not a concern, can directly promote the growth of photosynthetic organisms, including algae and aquatic plants, thereby altering the quantity of biomass produced and the structure of the aquatic food web. However, the effects of elevated levels of N in water may be constrained by the availability of other limiting inorganic nutrients, such as phosphorus. Much of the text in this section was obtained from the air quality related values risk assessment report that is being prepared for MOJN parks by Dr. Timothy Sullivan (in press 2015).

Fire risk in desert vegetation communities is largely controlled by interactions among water and N availability, soil texture, and the presence of invasive grasses. Exotic grass litter breaks down slowly, creating a highly flammable continuous fire fuel load during the dry season (Brooks and Minnich 2006). Because of the historical rarity of fire in arid ecosystems, arid land shrubs are typically not fire adapted and experience high mortality and slow re-establishment in response to fire (Brown and Minnich 1986). Slow recovery of shrubs after fire, and fast recovery of grasses contribute to increased fire frequency and a shift from shrub-dominated to exotic grass-dominated vegetation (D'Antonio and Vitousek 1992, Brooks et al. 2004, Steers 2008, Rao et al. 2010). Soil texture also affects fire frequency by modifying soil water holding capacity, infiltration, and hydraulic conductivity (Austin et al. 2004, Schwinning et al. 2004, Rao et al. 2010).

Such changes in terrestrial vegetation and fire risks can have serious management implications. For example, in the agriculturally intensive Snake River Plain and in the Great Basin, extensive cheatgrass (*Bromus tectorum*) invasions contribute to increased fire frequency, that in turn favors even greater cover of cheatgrass (see Section 4.2.1 Wildfire Regime). Loss of native plants adapted to longer fire intervals and the poorer nutritional quality of cheatgrass in turn reduces the carrying capacity of lands (Whisenant 1990).

<u>Ozone</u>
In humans, ozone is a respiratory irritant which can trigger a variety of health problems. Ozone also affects vegetation, causing significant harm to sensitive plant species (USEPA 2013). Ozone enters plants through leaf openings called stomata and oxidizes plant tissue, causing visible injury (e.g., stipple and chlorosis) and growth effects (e.g., premature leaf loss, reduced photosynthesis, and reduced leaf, root, and total size).

<u>Visibility</u>
Fine particles of ammonium sulfate, ammonium nitrate, elemental carbon, and other pollutants in the atmosphere, absorb or scatter light, causing haze and reducing visibility (Hand et al. 2011). Visibility is monitored by the Interagency Monitoring of Protected Visual Environments Network (IMPROVE)

and typically reported using the haze index, the deciview (dv). Deciview is a measurement scale representing perceptible changes in visibility calculated from light extinction measurements.

Mercury (Hg)

After Hg is deposited, it can be transformed by ecosystem processes into a biologically active, toxic form, methylmercury, which biomagnifies in the food chain and can reach harmful levels in fish and other wildlife. The potential biological effects of methylmercury, when it accumulates to high levels in animals, include impacts on reproductive success, growth, behavior, disease susceptibility, and survival (Landers, et al. 2008). Section 4.3.2 (Water Quality/Quantity) discusses the effects of methylmercury further. Not all landscapes equally support the conversion of Hg to methylmercury. Section 4.3.2 below, also discusses the special circumstances required to promote Hg methylation – circumstances that may be relatively uncommon within Great Basin NP.

Data and Methods

Indicators / Measures

- *Atmospheric Nitrogen and Sulfur deposition*
- *Ozone Concentration*
- *Visibility*

Air Quality Monitoring within Great Basin National Park

The approach used for assessing the condition of air quality at Great Basin NP follows the guidance developed by the NPS Air Resources Division (ARD) for use in Natural Resource Condition Assessments (NPS 2010b, c). Interpolated values generated by NPS-ARD, averaged over 5 years, were used to assess condition. NPS-ARD used all available data from NPS, EPA, state, tribal, and local monitors to generate the interpolated values for visibility, ozone and wet N and S deposition for NPS areas across the contiguous U.S.

Figure 11. Weather and air quality monitoring station in Great Basin NP.

Great Basin NP documented visibility conditions from1982-1995 with a 35mm camera. From 1992 to present, the park has been monitoring visibility as part of the IMPROVE network. Precipitation chemistry has been monitored at the park since 1985 as part of the National Atmospheric Deposition Program (NADP)/National Trends Network (NTN). Since 1993, the park has been monitoring ambient ozone concentrations as part of the Clean Air Status and Trends Network (CASTNET). See Appendix B for links to Great Basin NP air quality data and Appendix C for a complete history of air quality monitoring at Great Basin NP.

Table 3 below summarizes the air quality indicators reported here and their definitions.

Table 3. Indicators used for resource assessment of air quality in the park, adjacent valleys and region.

Indicator	Indicator Definition
N and S deposition	Measure of atmospheric wet deposition. The values for wet deposition condition are expressed as the average amount of nitrogen (N) or sulfur (S) in kilograms deposited over a one-hectare area in one year (kg/ha/yr).
Visibility: Deciview	This measure assesses visibility based on the deviation of the current visibility conditions from estimated natural visibility conditions; (i.e., those estimated for a given area in the absence of human-caused visibility impairment).
Ozone	The primary ozone standard is set to protect human health. The standard is 75 parts per billion (ppb) averaged over an eight-hour period. Vegetation response is more directly tied to seasonal, rather than eight-hour, ozone concentrations, so ozone injury can occur even if the primary standard is not exceeded.

National Atmospheric Deposition Program/National Trends Network (NADP/NTN)
The NADP/NTN website (http://nadp.sws.uiuc.edu/) provides a long-term monitoring record of precipitation chemistry at Great Basin NP. The values for wet deposition condition are expressed as the average amount of N or (S in kg/ha/yr (NPS 2013).

Weekly samples are collected and processed following a standard operating procedure established by Dossett and Bowersox (1999). The results of the analyses are then loaded into NADP's database, merged with descriptive information and posted at: http://nadp.sws.uiuc.edu/sites/siteinfo.asp?id=NV05&net=NTN (NADP 2013).

Interagency Monitoring of Protected Visual Environments - IMPROVE
Visibility is monitored by the IMPROVE Program (NPS 2010a). The NPS-ARD assesses visibility based on the deviation of the current Group 50 visibility conditions from estimated Group 50 natural visibility conditions; (i.e., those estimated for a given area in the absence of human-caused visibility impairment (EPA-454/B003-005)). Group 50 is defined as the mean of the visibility observations falling within the range of the 40th through the 60th percentiles as dv. The dv scale scores pristine conditions as a zero and increases as visibility decreases (NPS 2010b). The IMPROVE site provides a long term monitoring record for existing visibility conditions at Great Basin NP. Other methods have also been used to monitor visibility in the park including a camera, transmissometer and nephelometer.

Clean Air Status and Trends Network – CASTNET
The CASTNET site provides a long-term monitoring record of atmospheric N, S, and ozone concentrations at Great Basin NP from 1993 to present.

Mercury
For this assessment, there are two sources of information on mercury. To investigate the transport distances of Hg, Wright et al. (2014) used surrogate surfaces and passive samplers for the measurement of gaseous oxidized mercury (GOM) deposition and concentration. Samplers were deployed from the coast of California to the eastern edge of Nevada (Great Basin NP).

Meteorological data, back trajectory modeling, and ozone concentrations were applied to better understand potential sources of Hg.

Data on mercury in fish muscle tissue samples from Brook trout (*Salvelinus fontinalis*) in Great Basin NP were reported by Eagles-Smith et al. (2014), from samples collected in 2011 from Baker Lake, Lehman Creek, and Snake Creek. The assessment of Water Quality and Quantity (Section 4.3.2) below reports on the results of the Eagles-Smith et al. (2014) study.

Mercury may enter Great Basin NP through both wet and dry deposition. Since significant areas of the western USA are arid, it is hypothesized that dry deposition is an important source of Hg in the park. A primary question is whether sources of Hg are local and thus, relatively easy to address, regional (from within the United States), or global (long range transport), and much more difficult to address. Wright et al. (2014) found dry deposition of mercury to be an important pathway by which it enters ecosystems, and that much of the mercury in Great Basin NP is from regional and global sources. There are currently no reference conditions for ecosystem health related to mercury deposition.

Reference Conditions

The reference conditions against which current air quality indicators are assessed are identified by NPS ARD (2010b) for NRCAs and listed in Table 4.

Table 4. Reference conditions for air quality indicators (Source: NPS 2010b).

Air Quality Indicator	Good	Moderate Concern	Significant Concern
Wet deposition, either sulfur or nitrogen	< 1 kg/ha/yr	1-3 kg/ha/yr	>3 kg/ha/yr
Ozone	≤ 60 ppb	61-75 ppb	≥ 76 ppb
Visibility	< 2 dv	2-8 dv	>8 dv

N and S Deposition

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

Ozone

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

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

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

<u>Condition and Trend</u>

Atmospheric Deposition of Sulfur and Nitrogen

<u>Acidification</u>

Indicators/Measures
Atmospheric Deposition of Sulfur and Nitrogen

An assessment for all NPS I&M networks and parks was conducted for acid pollutant exposure, ecosystem sensitivity to acidification, and park protection to determine the relative risk from acidification. Ecosystem sensitivity to acidification at Great Basin NP was ranked in the highest quintile relative to other I&M parks (Sullivan et al. 2011b). However, Great Basin NP ranked in the lowest quintile for estimated acid pollution exposure. Table 5 provides ecosystem sensitivity to acidification comparisons between all MOJN parks. Great Basin NP's very high sensitivity is due largely to the presence of steep slopes and many low-order and high-elevation streams. Ecosystem sensitivity to acidification rankings take into account land slope, which often influences the degree of acid neutralization provided by soils and bedrock within the watershed. Most watersheds in Great Basin NP have average slopes greater than 40º, with one watershed having average slope greater than 50º.

<u>Indicators and Criteria for Acidification Risk</u>
Great Basin NP has several lakes that are fairly low in acid neutralizing capacity (ANC). These lakes were surveyed in 1986 as part of EPA's National Surface Water Survey. All of the lakes sampled in the park were considered acid-sensitive (ANC less than 200 microequivalents per liter [μeq/L]), according to EPA's classification criteria at that time. The most sensitive lake included in the study was Baker Lake at 10,620 feet (3,238 m), with an ANC of 73 μeq/L. Recent conductivity measurements suggest that the ANC of Baker Lake is, at times, less than 50 μeq/L (Sullivan et al. 2011a, 2011b), a level considered to be very acid-sensitive. Depletion of ANC increases the risk to lakes and streams in the park from episodic or chronic acidification. Baker Lake has a population of Threatened Lahontan cutthroat trout (*Onchorhynchus clarki henshawi*), as well as other fish and invertebrates that could be negatively affected by acidification.

Table 5. Estimated park ranking* for all NPS I&M Mojave Network parks according to risk of acidification impacts on sensitive receptors. (Source: Sullivan et al. 2011a, 2011b)

Park Name	Park Code	Estimated Acid Pollutant Exposure	Estimated Ecosystem Sensitivity to Acidification
Death Valley	DEVA	Very Low	Very High
Great Basin	**GRBA**	**Very Low**	**Very High**
Joshua Tree	JOTR	Moderate	High
Lake Mead	LAKE	Low	High
Manzanar	MANZ	Very Low	Very Low
Mojave	MOJA	Low	High

*Relative park rankings are designated according to quintile ranking, among all I&M Parks, from the lowest quintile (Very Low) to the highest quintile (Very High) risk.

Nitrogen Nutrient Enrichment

Great Basin NP's ranking relative to other I&M parks for nutrient N pollutant exposure is very low and ecosystem sensitivity to nutrient N enrichment was judged by Sullivan et al. (2011d) to be low. Table 6 shows all MOJN parks, with the exception of Great Basin NP, ranked very high to ecosystem sensitivity to N deposition; this is due to the preponderance of desert vegetation at those parks, which is presumed to be highly sensitive to nutrient N enrichment (Sullivan et al. 2011c, 2011d). It should be mentioned here that the rankings are for the park as a whole. Since most of the park is high elevation and contains native species (and non-native species) that are not N sensitive, this seems appropriate. However, the lowest elevations of the park are dominated by desert species and the non-native invasive cheatgrass (*Bromus tectorum*). These low elevation areas are very sensitive to N enrichment with large potentials for complete monocultures after fires, changing the entire ecosystem with fire impacts perpetuating upslope into N insensitive areas.

Table 6. Estimated park rankings* for all NPS I&M Mojave Network parks according to risk of nutrient enrichment impacts on sensitive receptors. (Source: Sullivan et al. 2011d)

Park Name	Park Code	Estimated Nutrient N Pollutant Exposure	Estimated Ecosystem Sensitivity to Nutrient N Enrichment
Death Valley	DEVA	Low	Very High
Great Basin	**GRBA**	**Very Low**	**Low**
Joshua Tree	JOTR	Moderate	Very High
Lake Mead	LAKE	Low	Very High
Manzanar	MANZ	Low	Very High
Mojave	MOJA	Moderate	Very High

*Relative park rankings are designated according to quintile ranking, among all I&M Parks, from the lowest quintile (Very Low) to the highest quintile (Very High) risk.

Indicators and Criteria for Nitrogen Deposition Condition

Pardo et al. (2011) compiled data on empirical critical loads (CL) for protecting sensitive resources in ecoregions across the conterminous United States against nutrient enrichment effects caused by atmospheric N deposition. The critical load represents a threshold (Ellis et al. 2013) below which significant harmful effects to sensitive ecosystems components are not likely to occur. Data on empirical CL for nutrient N deposition in Great Basin NP are limited. Pardo et al. (2011) only reported empirical N CL values in the North American Deserts ecoregion for the protection of lichens and herbaceous plants (Table 7). Note that Pardo et al.'s CL estimates are for total (wet plus dry) N deposition and potential exceedances are based on total N deposition estimates derived from an atmospheric model. The lower end of the reported range was 3 kg N/ha/yr for both lichens and herbaceous plants. Total modeled N deposition was less than 2 kg N/ha/yr at Great Basin NP (Sullivan et al. 2011b). This suggests N critical loads intended to protect lichen and herbaceous plants are not exceeded at Great Basin NP.

Table 7. Empirical critical loads for nitrogen in NPS Mojave I&M Network parks, by ecoregion and receptor from Pardo et al. (2011). Ambient N deposition reported by Pardo et al. (2011) is compared to the lowest critical load for a receptor to identify potential exceedance, indicated by shading. A critical load exceedance suggests that the receptor is at increased risk for harmful effects.

			Critical Load (kg N/ha/yr)	
NPS Unit	**Ecoregion**	**N Deposition (kg N/ha/yr)**	**Lichen**	**Herbaceous Plant**
Death Valley NP	North American Deserts	3.8	3	3 - 8.4
Great Basin NP	**North American Deserts**	**1.8**	3	3 - 8.4
Joshua Tree NP	North American Deserts	7.0	3	3 - 8.4
Lake Mead NRA	North American Deserts	4.8	3	3 - 8.4
Manzanar NHS	North American Deserts	1.7	3	3 - 8.4
Mojave NPres	North American Deserts	4.0	3	3 - 8.4

Ozone

The O_3-sensitive plant species that are known or thought to occur within Great Basin NP are listed in Table 8. Those considered to be bioindicators, because they exhibit very distinctive symptoms when injured by O_3 (e.g., dark stipple), are designated by an asterisk. Great Basin NP contains at least four O_3 bioindicator species.

Indicators/Measures
Ozone

Table 8. Ozone sensitive and bioindicator plant species known or thought to occur in the Great Basin NP. (Data Source: E. Porter, National Park Service, pers. comm., August 30, 2012); lists are periodically updated at https://irma.nps.gov/App/Species/Welcome).

Species	Common Name
Apocynum androsaemifolium*	Spreading dogbane
Apocynum cannabinum	Dogbane, Indian hemp
Artemisia ludoviciana*	Silver wormwood
Pinus ponderosa*	Ponderosa pine
Populus tremuloides*	Quaking aspen
Prunus virginiana	Choke cherry

Two ranking systems were used to determine risk of ozone injury impacts, the NPS ranking system (NPS 2010) and Kohut's system (2007a). The NPS approach is a quick assessment which considers 5-year averages of O_3 conditions. Kohut's O_3 ranking approach constitutes a more rigorous assessment of potential risk to plants by including soil moisture, an important environmental condition. Dry conditions induce stomatal closure in plants, which has the effect of limiting O_3 uptake and injury.

The NPS O_3 risk assessment system uses injury thresholds from the literature (Heck and Cowling 1997) and compares them against five year averages of the W126 or Sum06. W126 is a measure of cumulative O_3 exposure that preferentially weights higher concentrations. The SUM06 is a measure of cumulative exposure that includes only hourly concentrations above 60 ppb over a 3-month period. The W126 was classified as moderate concern at values between 7 and 13 ppm-hr, (as defined by NPS (2010)). Values higher than 13 ppm-hr were classified as High Concern, and values lower than 7 ppm-hr were classified as Low Concern. The SUM06 was classified as Moderate Concern at values between 8 and 15 ppm-hr. Higher and lower values were classified as High Concern and Low Concern, respectively, as defined by NPS (2010).

Kohut (2004, 2007b) examined five individual years of O_3 exposure and soil moisture data in the Mojave Network parks, however exposures have likely changed since the time of his assessment (1995-1999). The exposure levels at three parks (Death Valley, Great Basin, and Joshua Tree; Table 9) were based on in-park monitoring data and the other parks were based on kriging of data from surrounding monitoring sites.

In addition, data for 2000-2004 were analyzed for Great Basin NP (NPS 2013). The SUM06 index generally exceeded the threshold for foliar injury in Great Basin NP during the initial monitoring period (1995-1999) and more definitively exceeded the threshold for the monitoring period 2000-2004.

In recent years (2000-2009), no significant trends in O_3 concentrations have been detected in Great Basin NP (NPS 2013). Although Great Basin NP is designated attainment by EPA because it meets the O_3 standard, it exceeds the 8-hour standard one or two times during the summer ozone season.

EPA has recognized that the 8-hour form for the standard is not appropriate to protect sensitive plants, which respond to longer-term O_3 exposures. In 2010, EPA proposed a new secondary O_3 standard to protect plant health (Federal Register Vol. 75, No. 11, 40 CFR Parts 50 and 58, National Ambient Air Quality Standards for Ozone, Proposed Rules, January 19, 2010, p. 2938). It was based on an index of the total plant O_3 exposure, the W126. For the W126 index, hourly values are weighted according to magnitude and then summed for daylight hours over three months, approximately a growing season. EPA proposed to set the level of the new standard in the range of 7-15 ppm-hr.

Table 9. Ozone assessment risk results* for NPS I&M Mojave Network parks, based on estimated average 3-month W126 and SUM06 ozone exposure indices for the period 2005-2009 and Kohut's (2007a) ozone risk ranking for the period 1995-1999.

Park Name	Park Code	W126 7-13 ppm/hr = Moderate Injury		SUM06 8-15 ppm/hr = Moderate Injury		Kohut O_3 Risk Ranking
		Value (ppm-hr)	Ranking	Value (ppm-hr)	Ranking	
Death Valley	DEVA	28.96	High	40.96	High	Low
Great Basin	**GRBA**	**15.55**	**High**	**21.20**	**High**	**Low**
Joshua Tree	JOTR	29.53	High	39.95	High	High
Lake Mead	LAKE	19.58	High	28.46	High	Low
Manzanar	MANZ	40.46	High	52.46	High	High
Mojave	MOJA	25.92	High	36.49	High	High

*Parks are classified into one of three ranks (Low, Moderate, High), based on comparison with other I&M parks.

Visibility

Natural Background and Existing Visibility Conditions

Indicators/Measures
Visibility

Natural background visibility, the goal of the Clean Air Act, assumes no human-caused pollution, but varies with natural processes such as windblown dust, fire, volcanic activity and biogenic emissions. Estimated natural background "haze" condition was relatively good in the parks in this network (NPS 2010b), compared with other I&M parks (Table 10a and Table 10b).

Table 10a. Estimated natural background visibility in Great Basin NP compared to all NPS I&M Mojave Network parks averaged over the period 2004 through 2008. Reported in deciviews (dv), a measurement scale representing perceptible changes in visibility calculated from light extinction measurements. The deciview scale scores pristine conditions as a zero and increases as visibility decreases (NPS 2010b).

Park Name	Park Code	Site ID	Estimated Natural Background Visibility		
			20% Clearest Days dv	20% Haziest Days dv	Average Days dv
Death Valley	DEVA	DEVA	2.22	7.90	4.68
Great Basin	**GRBA**	**GRBA**	**0.85**	**6.24**	**3.18**
Joshua Tree	JOTR	JOSH	1.68	7.19	4.17
Mojave[2]	MOJA	JOSH	1.68	7.19	4.17

Table 10b. Estimated existing visibility in Great Basin NP compared to all NPS I&M Mojave Network parks averaged over the period 2004 through 2008. Reported in deciviews (dv), a measurement scale representing perceptible changes in visibility calculated from light extinction measurements. The deciview scale scores pristine conditions as a zero and increases as visibility decreases (NPS 2010b).

Park Name	Park Code	Site ID	Existing Visibility 2004 through 2008		
			20% Clearest Days dv	20% Haziest Days dv	Average Days dv
Death Valley	DEVA	DEVA	4.69	15.41	9.63
Great Basin	**GRBA**	**GRBA**	**2.06**	**10.71**	**5.94**
Joshua Tree	JOTR	JOSH	5.51	18.29	11.87
Mojave	MOJA	JOSH	5.51	18.29	11.87

Representative photos of a selected vista under three different visibility conditions at Great Basin NP are shown in Figure 12. Photos were selected to correspond with the clearest 20% of visibility conditions, haziest 20% of visibility conditions, and average visibility conditions at that location.

This series of photos provides a graphic illustration of the visual effect of these differences in haze level on a representative vista in the park.

IMPROVE data allow estimation of visual range (VR). On the best days at the Great Basin NP monitoring site, one can see 199 miles (320 km). Based on the estimated natural conditions compared to existing visibility from 2004-2008, air pollution has reduced average VR from 170 miles to 120 miles (274 km to 193 km). On the haziest days, VR has been reduced from 130 miles to 85 miles (209 km to 137 km). These numbers represent the best in the country, matched only by a few of the nation’s most remote wilderness areas.

Visibility at Great Basin NP

Best Days
Taken: 9:00 am
Haze = 2 dv
VR = 199 mi (320 km)

Worst Days
Taken: 9:00 am
Haze = 10 dv
VR = 93 mi (150 km)

Average Days
Taken: 9:00 am
Haze = 6 dv
VR = 137 mi (220 km)

Figure 12. Three representative photos of the same view in Great Basin NP illustrate the 20% clearest, 20% haziest, and the annual average visibility y. DV is deciview. VR is visual range.

Composition of Visibility Reducing Particulate

Figure 13 shows estimated natural (pre-industrial), baseline (2000-2004), and current (2006-2010) visibility condition and particulate composition for Great Basin NP. The figure illustrates that SO_4^{-2} is the primary component of current haze at Great Basin NP on the 20% clearest days, when human-caused emissions sources are relatively low. On the 20% haziest days, organics contribute the most to haze in Great Basin NP. For the average days organic mass is the largest contributor of visibility impairment in Great Basin NP.

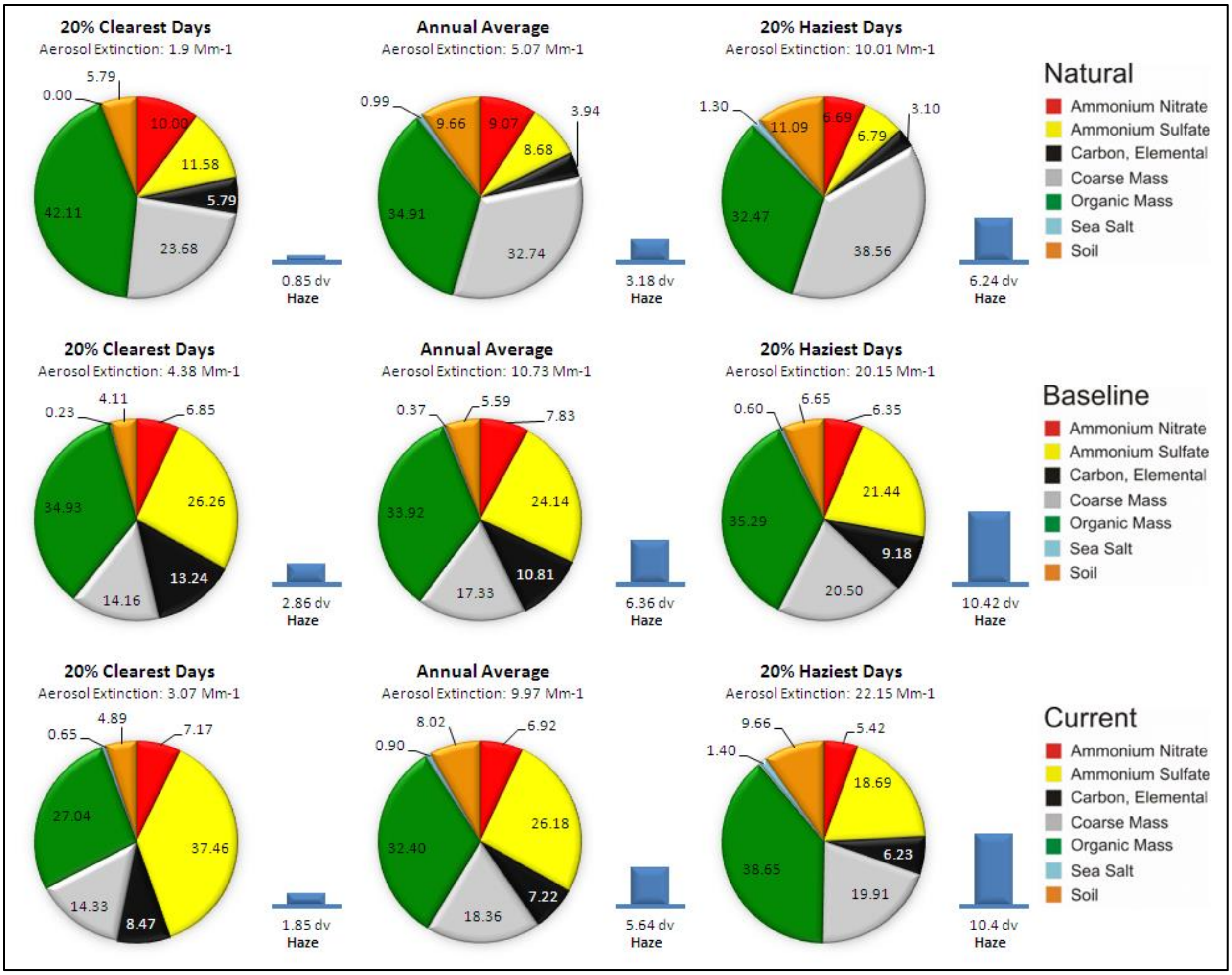


Figure 13. Estimated natural (pre-industrial), baseline (2000-2004), and current (2006-2010) visibility (blue columns) and the particulate composition (pie charts) on the 20% clearest, annual average, and 20% worst visibility days for Great Basin NP. Data Source: http://views.cira.colostate.edu/fed/Tools/RegionalHazeSummary.aspx

Trends in Visibility

NPS (2010) reported long-term trends in visibility on the clearest and haziest 20% of days at monitoring sites in 29 national parks. The average difference between measured visibility and estimated natural visibility condition was 8.3 dv, but several western parks had measured dv on the haziest days well above estimated natural conditions. Such large differences between ambient and estimated natural visibility are reflected in the 2004-2008 monitoring results shown in Table 10. Between 1993 and 2010 Great Basin NP data shows evidence of improvement in visibility in recent years on the 20% clearest and 20% average days. However, the 20% haziest days have remained about the same (Figure 14).

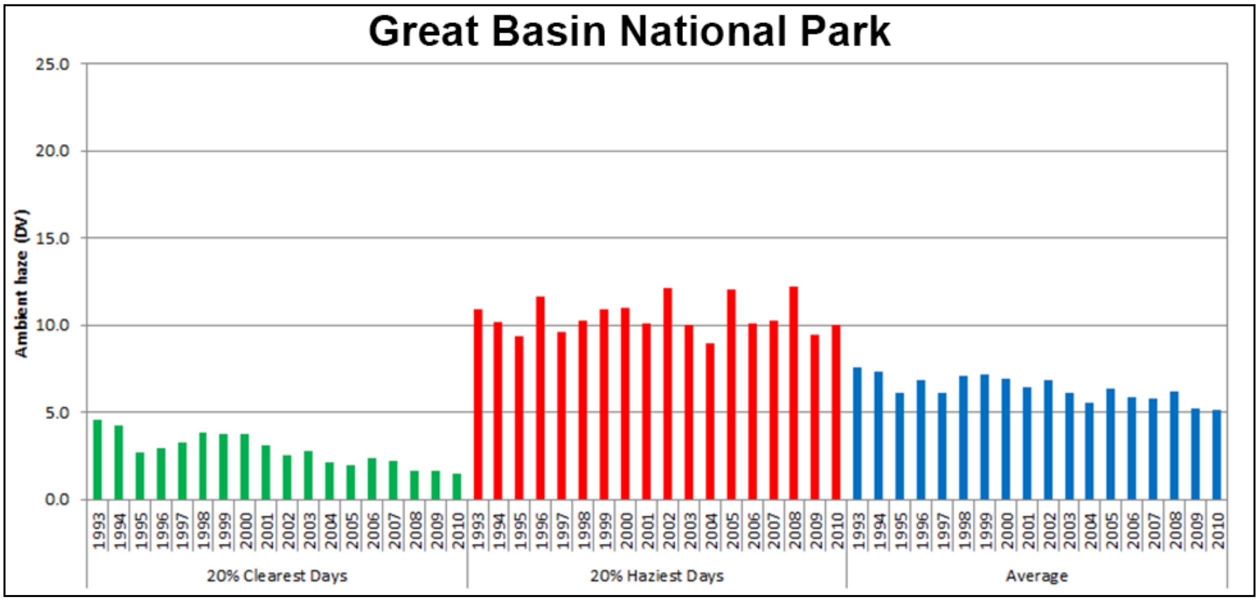


Figure 14. Trends in ambient visibility at Great Basin NP based on IMPROVE measurements on the 20% clearest, 20% haziest, and annual average visibility days over the monitoring period of record. Data Source: http://vista.cira.colostate.edu/improve/Data/IMPROVE/summary_data.htm

According to the 1999 Regional Haze Rule, states and tribes must establish and meet reasonable progress goals for each federal Class I area to improve visibility on the 20% haziest days and to prevent visibility degradation on the 20% clearest days. The national goal is to return visibility in Class I areas to natural background levels in 2064. States must evaluate progress by 2018 (and every 10 years thereafter) based on a baseline period of 2000 to 2004 (Air Resource Specialists 2007). Even though Great Basin NP is a Class II area it should also see visibility improvements as a result of pollution reductions required by the Regional Haze Rule.

The glideslope analyses between current and background visibility (Figure 15) indicate that at the current rate of progress, the haziest days at Great Basin will not meet natural visibility conditions by the 2064 Regional Haze Rule deadline, however, the cleanest days will.

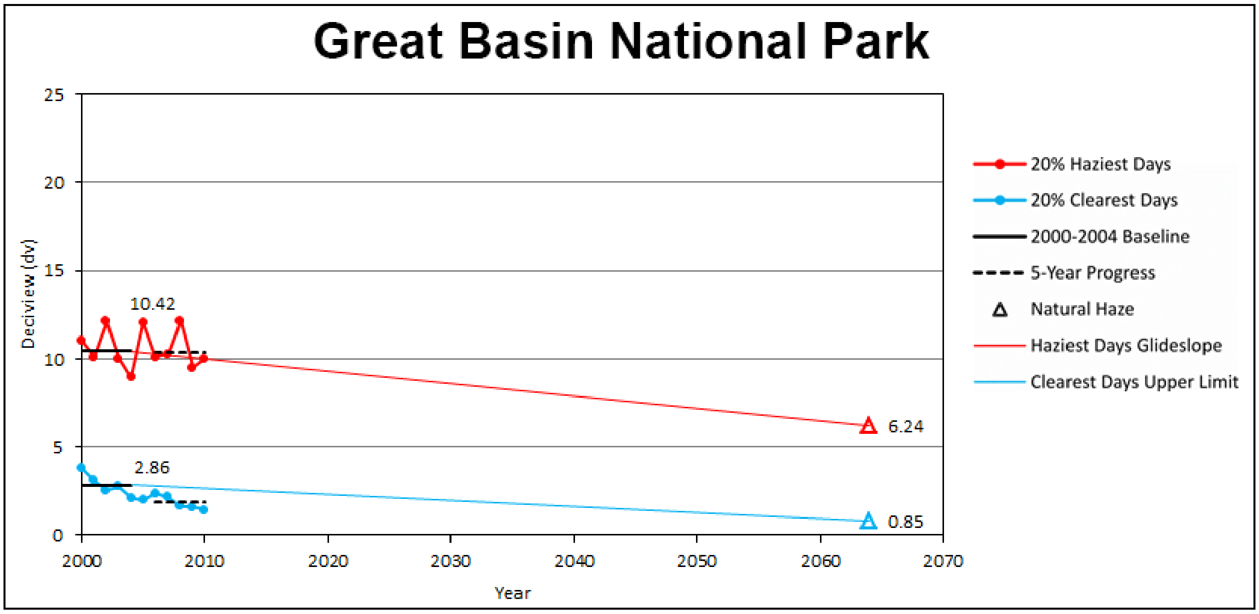


Figure 15. Glideslopes to achieving natural visibility conditions in 2064 for the 20% haziest (red line) and the 20% clearest (blue line) days in Great Basin NP. The regional haze rule requires the clearest days do not get worse than the baseline period. Also shown are measured values during the period 2000 to 2010. Data Source: http://vista.cira.colostate.edu/improve/Data/IMPROVE/summary_data.htm

Mercury

Wright et al. (2014) found the lowest seasonal mean Hg deposition was observed at low elevation (<328 feet (< 100 m)) Pacific Coast sites. Highest values were recorded at Lick Observatory, a high elevation coastal site (4,196 feet (1,279 m)), and Great Basin NP (6,765 feet (2,062 m)). Intermediate values were recorded in Yosemite and Sequoia National Parks. Results indicate that local, regional and global sources of air pollution, specifically oxidants, are contributing to observed deposition. At Great Basin NP, air chemistry was influenced by regional urban and agricultural emissions and free troposphere inputs. Dry deposition contributed ~ 2 times less Hg than wet deposition at the coastal locations, but 3 to 4 times more at the higher elevation sites. Figure 16 provides location of the Environmental Protection Agency's Mercury deposition Network sites and concentration gradients across the United States.

The Section on Water Quality (4.3.2) discusses the effects of mercury deposition on aquatic resources.

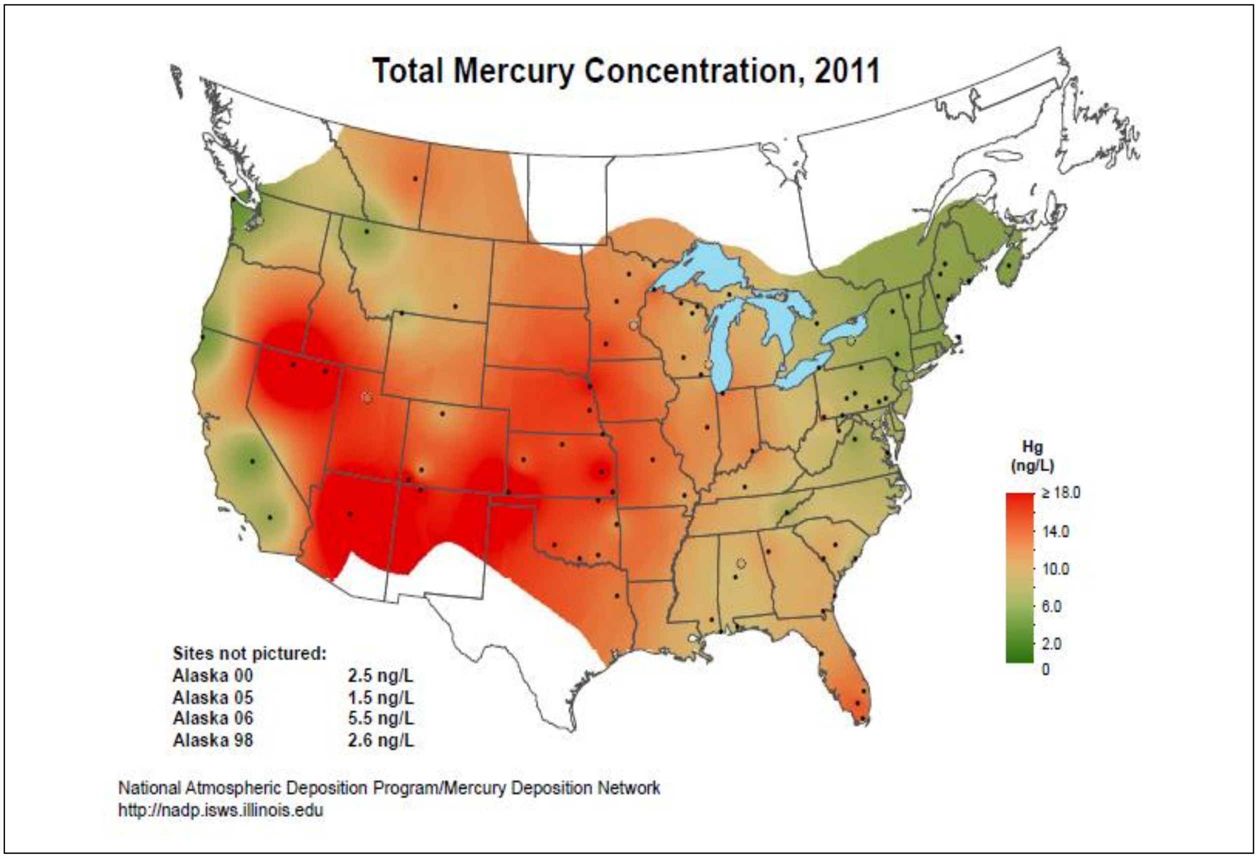
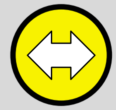
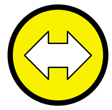
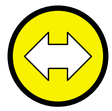
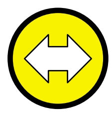
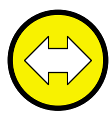
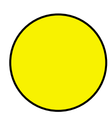


Figure 16. Mercury Deposition Network (MDN) sampling sites in the USA and concentration gradients . From EPA 2011 Toxic Release Inventory.

Summary of Condition and Trend for Air Quality

All of the indicators for air quality fall within the moderate concern ratings of the NPS Air Resources Division (Table 11). Deposition of N and S could be of significant concern because of the high sensitivity of Great Basin NP ecosystems, especially water resources, to acidification. However, the current deposition rate does not warrant significant concern. Mercury deposition is higher than in many other areas of the country and appears to be of regional or even global source; however, bioaccumulation in fish is apparently low (see Section 4.3.2 Water Quality/Quantity for discussion of this).

Table 11. Summary of indicators of condition for air quality at Great Basin NP.

Air Quality			
Indicators of Condition	**Specific Measures**	**Condition Status/Trend**	**Rationale**
Atmospheric Nitrogen Deposition	Measure of atmospheric wet deposition. The values for wet deposition condition are expressed as the average amount of nitrogen (N) in kilograms deposited over a one-hectare area in one year (kg/ha/yr).		Wet nitrogen deposition warrants moderate concern. This condition is based on the 2008–2012 estimated wet nitrogen deposition of 2.9 kilograms per hectare per year (kg/ha/yr). The confidence in the nitrogen condition at Great Basin NP is high because there is an on-site wet deposition monitor.
Atmospheric Sulfur Deposition	Measure of atmospheric wet deposition. The values for wet deposition condition are expressed as the average amount of sulfur (S) in kilograms deposited over a one-hectare area in one year (kg/ha/yr).		Measured value of 1.1 kg/ha/yr is of moderate concern. The confidence in the sulfur condition at Great Basin NP is high because there is an on-site wet deposition monitor.
Ozone	The National Ambient Air Quality Standard (NAAQS) for ozone is set by the EPA, and is based on human health effects.		The monitored ozone concentration from 2008−2012 is at 71.7 ppb, which falls within the moderate concern category. The confidence in the ozone condition at Great Basin NP is high because there is an on-site ozone monitor.
Visibility	This measure assesses visibility based on the deviation of the current visibility conditions from estimated natural visibility conditions; (i.e., those estimated for a given area in the absence of human-caused visibility impairment).		Average visibility at Great Basin NP was 2.4 dv above estimated natural conditions, and is a moderate concern. The degree of confidence in the condition at Great Basin NP is high because there is an on-site visibility monitor.
Mercury	Measure of atmospheric dry deposition of mercury, not the bioaccumulation of mercury or other toxic pollutants.		Atmospheric dry deposition is relatively high, in part due to the park's relatively high elevation. Mercury is rated as a moderate concern at the park. The confidence level in this condition is medium because Great Basin NP has studies from a limited subset of surface waters.

Sources of Expertise

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

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4.1.3. Viewshed

Indicators / Measures

Viewshed Condition Index
Visibility of Spring Valley Wind Farm
Regional Views of SEZs

Condition - Trend

Moderate Concern – Unchanging – Medium Confidence

Background and Importance

The conservation of scenery is established in the NPS Organic Act, ("…to conserve the scenery and the wildlife therein…") and reaffirmed by the General Authorities Act, as amended, Management Policies (Section 1.4.6, and 4.0) (Johnson et al. 2008). The enabling legislation for the park (Public Law 99-565) also establishes scenic values as one of the important resources of the park.

For many parks, scenic views that extend beyond park boundaries are an important component of the visitor experience. The expanse of these views is often inspirational and iconic of the American spirit and often a main reason why people visit parks. Visitors have multiple opportunities to view the surrounding landscape scenery, within and adjacent to the park. Like other isolated ranges in the Basin and Range Province, Great Basin NP is surrounded by basins with the Snake Valley to the east, the Hamlin Valley to the southeast and the Spring Valley to the west. Traveling west from central Utah across the arid flat plains of the Great Basin Desert, the long ridgeline of the South Snake Range stretches across the horizon, with a characteristic rugged landscape, highlighted by snow-covered peaks, steep mountain slopes, rolling foothills, low desert basins and valley floors. An excerpt from the park's General Management Plan (National Park Service 1999) describing the importance of its scenic resources states: "The views across Snake Valley and Spring Valley as visitors approach the park and from various locations within the park greatly enhance experiences and are a significant park resource. Although these valleys are not within the park boundary, they are critical in conveying the theme of the 'Great Basin physiographic region' to visitors. Without the contrasting valley basins, the mountainous lands inside the park can illustrate only a portion of that theme. The loss or visual impairment as a result of major industrial, commercial, or military activity would alter the pastoral scene that adds a critical dimension to the national park."

McGlothlin et al. (2012a) further summarize the value of the scenic characteristics of the park and its environs. They state: "Because of its extensive high relief centered on the Southern Snake Range, it is difficult to avoid substantial impacts to the park's scenic values when developments are sited in the adjacent valleys. The adjacent valley approaches themselves are considered to be components of the visitor experience. Additionally, large areas of the surrounding valleys are visible from the peak of Mt. Wheeler, the prime viewing point within the park. A hiking trail to the peak accommodates approximately 1,200 visitors per year that manage to make the strenuous hike to the top to experience the relatively unspoiled beauty of the surrounding Great Basin."

Viewing these themes within the context and vast scale in which they exist helps to foster the understanding and significance of the park's purpose. This assessment primarily addresses views from within the park boundary of areas outside the park boundary.

Data and Methods

Indicators / Measures

Viewshed Condition Index

Visibility of Spring Valley Wind Farm

Regional Views of SEZs

This assessment of the park's viewshed condition used two categories of indicators and measures (Table 12): one that included a GIS-based indicator (development features combined with an NPS composite viewshed), and two that qualitatively assess visibility of man-made features on the landscape- locally the Spring Valley Wind Farm and regionally two designated Solar Energy Zones (Wah Wah SEZ and the Dry Lake North SEZ).

Table 12. Indicators used for resource assessment of viewshed in Great Basin NP.

Indicator	Indicator Definition
Viewshed Condition Index	GIS-based indicator; using NPS 25-mile & 10-mile (40-km & 16-km) radius composite viewshed combined with a Landscape Condition Index (development based) adjusted for visual impacts
Visibility of Spring Valley wind farm from Wheeler Peak	A narrative interpretation of the report by SWCA consultants to evaluate how accurate the assessment for the Spring Valley Wind Farm was; specifically how visible it really is from Wheeler Peak
Regional Viewshed	A narrative interpretation of a Google Earth assessment of what can be seen from higher elevations of Great Basin NP; specifically looking at two PEIS Solar Energy Zones (Wah Wah SEZ and Dry Lake Valley North SEZ).

GIS-based Indicator: Viewshed Condition Index

Indicators/Measures

Viewshed Condition Index

For the first indicator, Viewshed Condition Index, there were two geospatial inputs: a composite viewshed developed by the NPS (McGlothlin et al. 2012b) for Great Basin NP and a landscape condition index with visual impact and distance weights adjusted to rank features within a view relative to a presumed value associated with "scenic" views. Each of these inputs is described in more detail below, followed by the methods for combining the two into the Viewshed Condition Index. The Valleys assessment area was initially identified for the viewshed analysis, along with Regional; however due to the data constraints of using the below described NPS composite viewshed, the real assessment area for viewshed condition index is a 25-mile (40-km) radius circle around the park, and an inner 10-mile (16-km) radius used to discuss differences between "further" views and "closer" views.

Input 1: Composite Viewshed

In response to development of the BLM Solar Energy Programmatic Environmental Impact Statement (BLM and DOE 2012) (PEIS; http://solareis.anl.gov/documents/fpeis/index.cfm), the NPS developed maps of where utility-scale solar energy development poses a high potential for conflict with natural, cultural, and/or visual resources administered by the NPS for 53 national parks in the western U.S. including Great Basin NP. One of the resources evaluated was viewsheds; the methods are documented in McGlothlin et al. 2012a and 2012b, and provided below and on http://solareis.anl.gov/maps/alternatives/index.cfm.

In order to identify specific scenic views that extend beyond park boundaries, the NPS conducted a geographic information system (GIS)-based viewshed analysis that generated maps using individual park-identified Key Observation Points (KOPs). The KOPs delineated "visible/not visible" areas in an individual park to 25 miles (40 km) beyond park boundaries. The intent of this "line of sight" analysis was to determine 1) which lands outside parks could be seen from these KOPs, and 2) the extent of the acreage of these lands.

The GIS effort used traditional and composite viewshed analyses. Traditional viewshed analyses evaluate the visibility of locations in a binary manner (i.e., Visible/Not Visible) across an area of interest (AOI) from a single, defined observation point (e.g., the KOP). The AOI is the area for which the viewshed analysis is being performed. In order to correspond to the Draft Solar PEIS, the AOI for the NPS analysis consisted of a 25-mile (40-km) area surrounding the park. A sample point is a location within the AOI that could potentially be visible from the KOP. For the purposes of the NPS analysis, the sample point was a potential location of a solar energy facility.

Composite viewshed analyses combine the "seen areas" of multiple viewsheds that may be calculated from more than one KOP. A visible value in a composite viewshed implies that at least one of the sample points is visible from, at minimum, one of the KOPs. In this manner, the number of visible KOPs is recorded on a cell-by-cell basis across the AOI. Composite viewsheds are a quick way to synthesize multiple viewsheds into a single map, thus giving a cursory overview of the land areas visible from a park looking out beyond its boundary. In the case of this analysis, identified areas outside the park were visible from at least one of the KOPs.

For Great Basin NP, 23 KOPs within the park were identified- some were defined by local park personnel, others are named summits from the Geographic Names Information System (GNIS) database that occur within the park boundaries. The KOPs were chosen based on significant points of interest including the visitor center, scenic pullouts on the Wheeler Peak Scenic Drive, peak elevations at or near hiking trails or bristlecone pine groves, within bristlecone pine groves, park campgrounds, and points along the Osceola Ditch. The composite viewshed from the above analysis was selected for use in the Great Basin NP viewshed assessment and is shown below (Figure 17, left). The resultant dataset has a value for the number of KOPs within the park that can "see" any individual cell or pixel; in other words each pixel within the 25-mile (40-km) radius has a count of KOPs that can see the pixel, ranging from 0 to 16 (out of a total of 23).

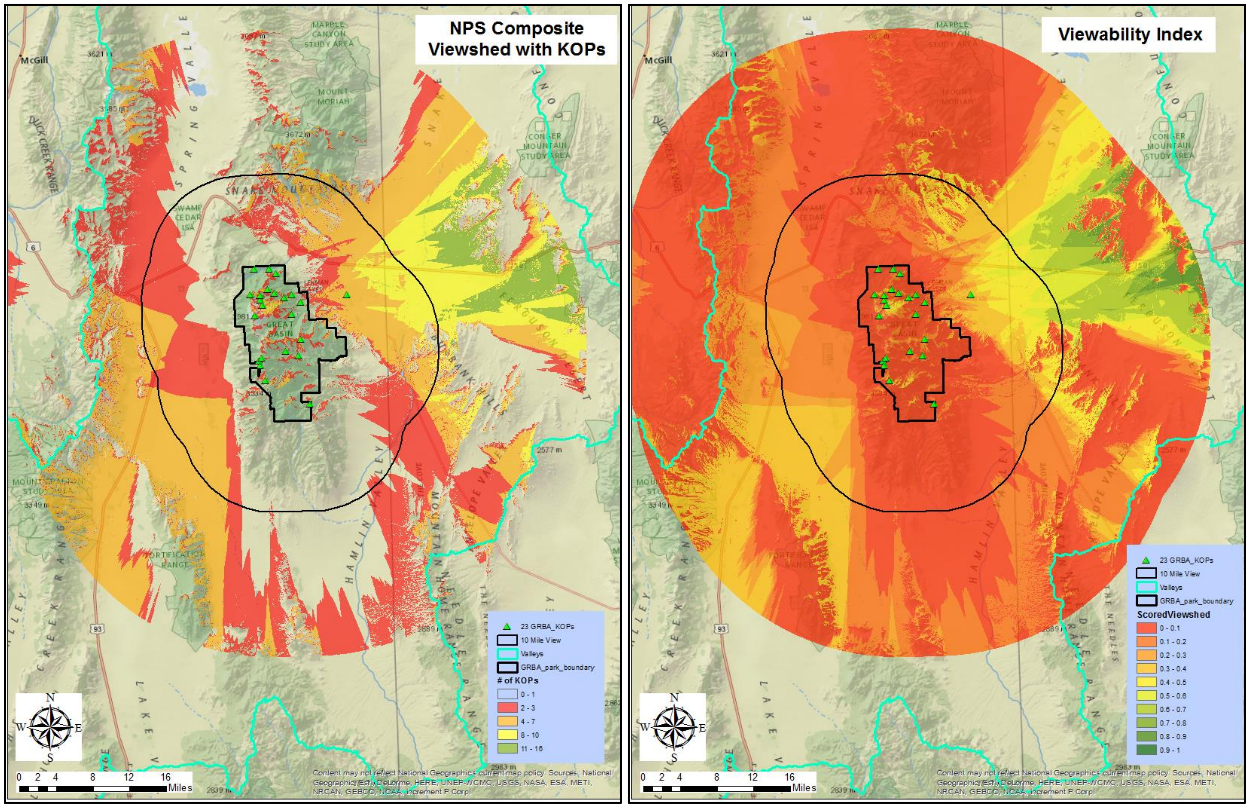


Figure 17. Composite viewshed for Great Basin NP (left) and viewability index (right). Composite viewshed is based on KOPs (small green triangles) entirely within Great Basin NP (n=23); 4 categories of viewshed are displayed, consistent with original source data from NPS; however every pixel does have a value for the number of KOPS. Yellow (7-10 KOPs) and green (10-16 KOPs) are the most visible areas from the KOPs within the park. The viewability index is the result of scoring pixels from 0 to 1 in 10 intervals of 0.1, where 0 = not visible from any KOPs, and 1 = visible from the maximum of 16 KOPs.

For this NRCA analysis, the composite viewshed was further processed to convert the count of KOPs per pixel to a score from 0 to 1; the purpose being to combine this scored composite viewshed with the second input of a landscape condition index (described below). The assumption for the scoring is that the more visible a pixel is (higher number of KOPs) the better it scores, with a score of 1 representing the best and most "visible" pixels (Table 13). Concomitantly, a score of 0 was assigned to all pixels with no KOPs; these are the non-visible locations. In other words, the more places from which one can see that pixel, the better; having a view from the park to its environs is of greater value. This scored composite viewshed is called the **viewability index** (Figure 17, right) in the remainder of this section.

Table 13. Count of key observation points (KOPs) and the viewability scores assigned to pixels with that number of KOPs.

# of KOPs	1	2	3	4	5	6	7	8
Score	0.063	0.125	0.188	0.250	0.313	0.375	0.438	0.500

Table 13 (continued). Count of key observation points (KOPs) and the viewability scores assigned to pixels with that number of KOPs.

# of KOPs	9	10	11	12	13	14	15	16
Score	0.563	0.625	0.688	0.750	0.813	0.875	0.938	1.000

Input 2: Landscape Condition Index

The second input to the Viewshed Condition Index is a model called the Landscape Condition Index (used in other assessments here, see Bighorn Sheep for example). A Landscape Condition Index is a 30-meter resolution map surface that incorporates a land use/land cover intensity rating and a distance decay function, reflecting decreasing ecological impact with distance from the source (Comer and Hak 2009, Comer and Faber-Langendoen 2013).

Visitor perceptions of man-made features vary from person to person, can be highly subjective, and there is no way to be completely objective in how they are defined or measured. Research has shown that there are certain landscape types and characteristics that people tend to prefer over others; most relevant for this assessment is a preference for natural over man-modified landscapes (Zube et al. 1982, Kaplan and Kaplan 1989, Sheppard 2001, Kearney et al. 2008, Han 2010). However, indications are that man-made features seeming to fit with a perceived rural environment (ranch houses, winding dirt roads, etc.), do not evoke the same negative response as commercial or industrial developments, and may even add positively to the perceptions of the landscape (Kearney et al. 2008). Hence the visual impact weights (Table 14) assigned for the index in Figure 18 are ranked from less visually impacting (e.g. pasture) to more so, or even unpleasing (e.g. mines and paved highways).

For purposes of the Great Basin NP viewshed assessment, the intensity and distance decay ratings were set (Table 14) under the following assumptions:

1) Pastoral (agriculture, pastures), rural development (ranch houses), wells and small dirt roads have relatively low impact to scenic views.
2) Mines, paved highways, the wind farm, small or large towns have a stronger impact on views, and are presumed to be more displeasing to most people.
3) There is no "distance effect;" in other words, the feature itself has the impact and increasing distance from it has no effect on the view.

This model incorporates a number of distinct inputs, including roads of varying size and expected traffic volume, land uses from agriculture to urban and industrial (e.g. wind farm) uses. The index scores range from 0 to 1 (in intervals of 0.1), where a score of 1 indicates no development features, and scores ranging from 0.6 to 0 suggesting visually noticeable features (Figure 18) that may be unpleasing to a viewer in the park. For example, the Spring Valley wind farm, to the northwest of the park was ranked a 0.6 in visual impact (Table 14), and in the map shows clearly (blue, rectangular polygon to the northwest of the park). As can be seen in Figure 18, the valleys assessment boundary was used for the landscape condition index.

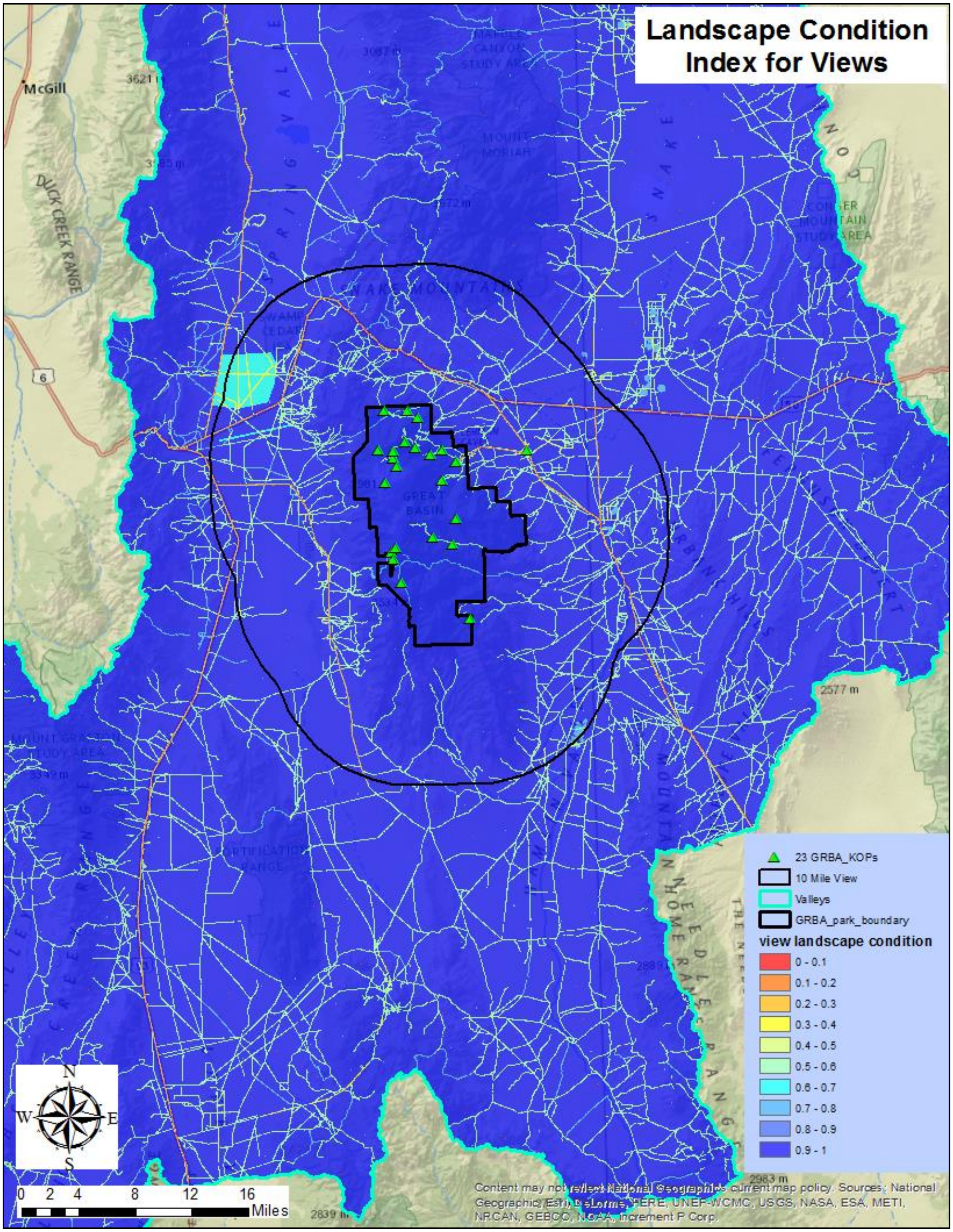


Figure 18. Landscape Condition Index tailored for viewshed analysis.

Table 14. Development features included in the viewshed landscape condition index, with scores for relative visual impact and distance from the feature. A score for impact of 1 suggests little to no visual impact; while those closer to 0 suggest visually unpleasing features. Features are sorted from presumed low visual impact (e.g. pastures at 0.9) to extreme visual impact (mines, 0.05).

Development Theme	Relative Visual Impact	Distance (m)
Pasture	0.9	50
Agriculture	0.7	50
Minor and dirt roads, including 4WD roads	0.7	50
Wells, primarily for stock ponds	0.7	50
Low intensity development	0.6	50
Wind farm	0.6	50
Local, neighborhood and connecting roads	0.5	50
Medium intensity development	0.5	50
Secondary and connecting roads, highways	0.2	50
Mines	0.05	50

Output: Viewshed Condition Index

The above two geospatial inputs, the **viewability index** (scored composite viewshed) and the **landscape condition index** (development features weighted for impact to views) were combined into one model. Each pixel was assigned a score of "viewability" (i.e. can be seen from many places within the park from the viewability index) combined with a relative rank of "visual impact" (i.e. man-made features ranked as visually of low to high impact, from the landscape condition index). The model was created by multiplying the score for each pixel from each of the two inputs (viewability and landscape condition indices). The resultant output is called the **Viewshed Condition Index (**Figure 19**).** In the figure, the boundary of the landscape condition index (valleys) combined with the 25-mile (40-km) radius viewability index resulted in portions of the viewability index not being scored or included in the final viewshed condition index. The 10-mile (16-km) radius boundary is also shown.

For visualization and interpretation of the results, the viewshed condition index was overlaid with a mask that corresponds to a number of key observation points (KOPs). In the first mask, all locations with no or only 1 KOP able to see that location were masked out; hence the result shows the viewshed condition index for all pixels visible from 2 or more KOPs. For comparison, a second mask was done, with the number of KOPs masked being 3 or less; thus the viewshed condition index is seen for all pixels visible by 4 or more KOPs. These maps are presented in the Condition and Trend section below.

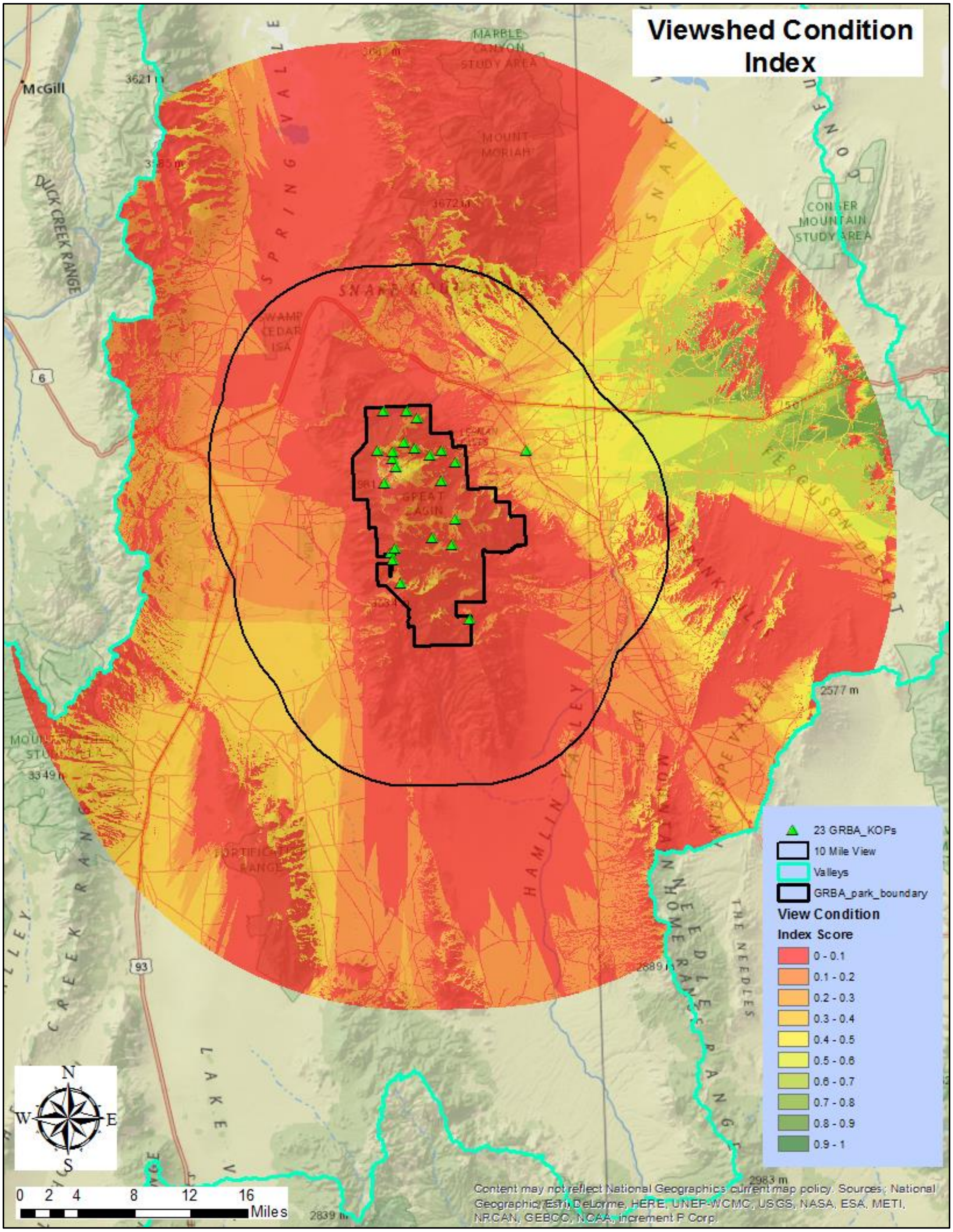


Figure 19. Viewshed condition index for GRBA.This is a combination of the landscape condition index modified for views and the viewability index, a scoring of the NPS composite viewshed.

Qualitative Indicators: Local and Regional Views of Man-made Features

Indicators/Measures

Visibility of Spring Valley Wind Farm

Regional Views of SEZs

For the two narrative indicators (views of Spring Valley Wind Farm, and regional views of SEZs), the purpose is to assess how local views into Spring Valley to the west, from the peak of Mt. Wheeler, have been affected by development of a wind farm with 66 turbine towers. Secondly, from a regional perspective, to assess how visible two Solar Energy Zones (SEZs) will be from the peak, should they be developed.

The methods employed for these are relatively simple: Google Earth (GE) was utilized to simulate the view of the Spring Valley Wind Farm from two peaks within the park: Wheeler Peak and Bald Mountain. GE has good resolution satellite imagery and allows a simulation of looking across a landscape horizontally from a point towards something of interest (in this case the wind farm) and then saving it as an image file. Unfortunately, since GE imagery is from a vertical perspective, the towers and turbines are not visible when the simulation is of standing on Wheeler Peak. This simulation from GE was then compared to the assessment completed in 2009 by SWCA Environmental Consultants (SWCA 2009) prior to the build-out of the Spring Valley Wind Farm. In that assessment, SWCA simulated what the wind farm would look like from Wheeler Peak and compared that to the view without the farm. They also completed a Visual Contrast Rating Worksheet for the Wheeler Peak simulation, which employed standard methods developed by the Bureau of Land Management (BLM 1980, 1986).

For the more regional view, a KMZ file with the locations of the Solar Energy Zones (SEZs) was downloaded from the Solar PEIS website. Two SEZs, as yet undeveloped, were selected for a visual assessment with Google Earth: the Wah Wah SEZ in Utah (southeast of the park), and Dry Lake Valley North (south southwest of the park), in Nevada. Distance, as measured in GE, from Wheeler Peak to the Wah Wah SEZ (Figure 20) is 61.4 miles (98.9 km), and 76.3 miles (122.8 km) to the Dry Lake Valley North SEZ (Figure 21); in both cases the measure was to the approximate center of the SEZ. GE was utilized to generate screenshots from various angles, looking from Wheeler Peak in the park to each SEZ. An elevation profile was also generated by GE showing the terrain between the peak and the SEZ.

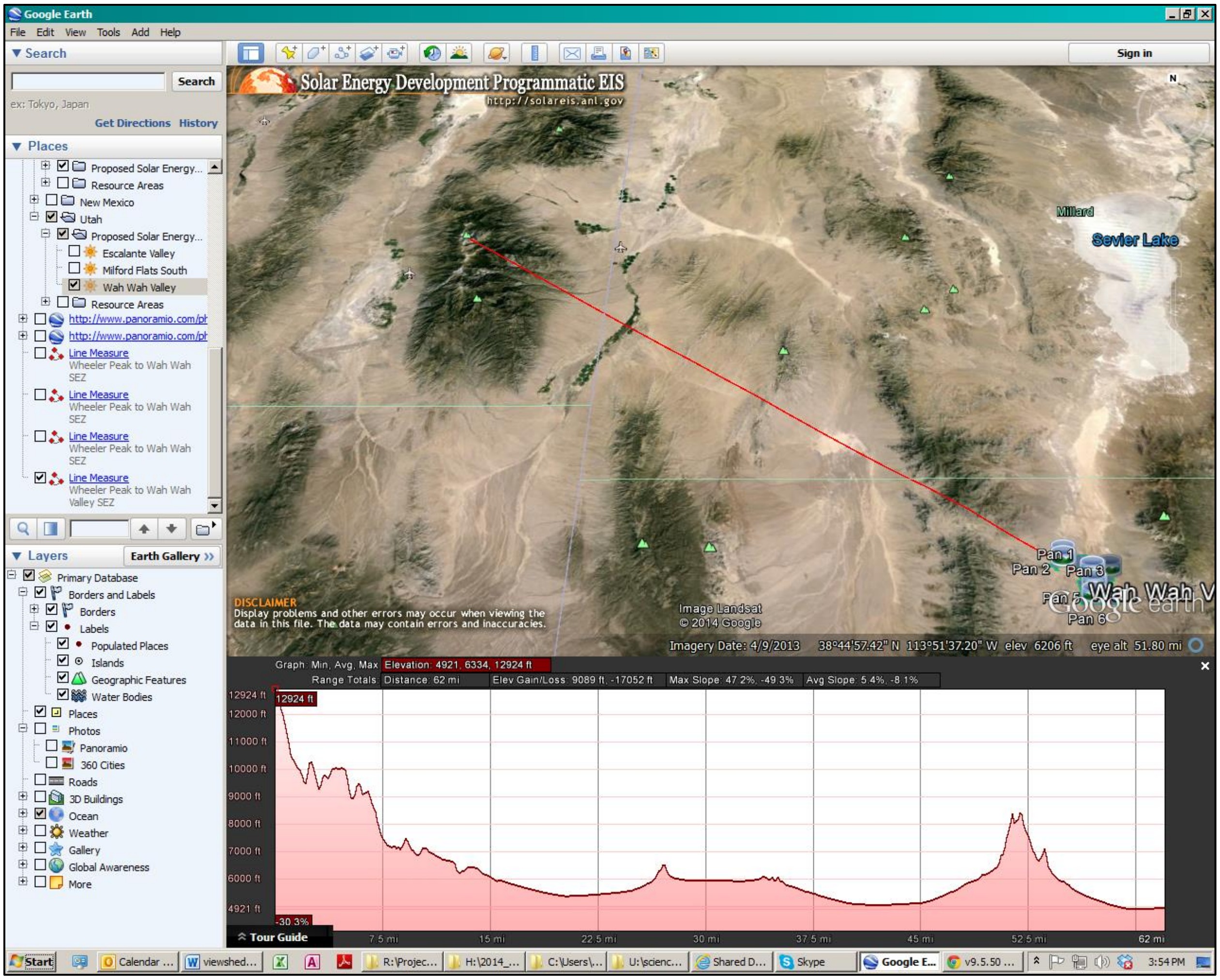


Figure 20. Google Earth screenshot of Wheeler Peak (left center) and a line to the southeast to the Wah Wah SEZ (lower right). Below the image is an elevation profile generated by Google Earth from Wheeler Peak on the left to the SEZ on the right.

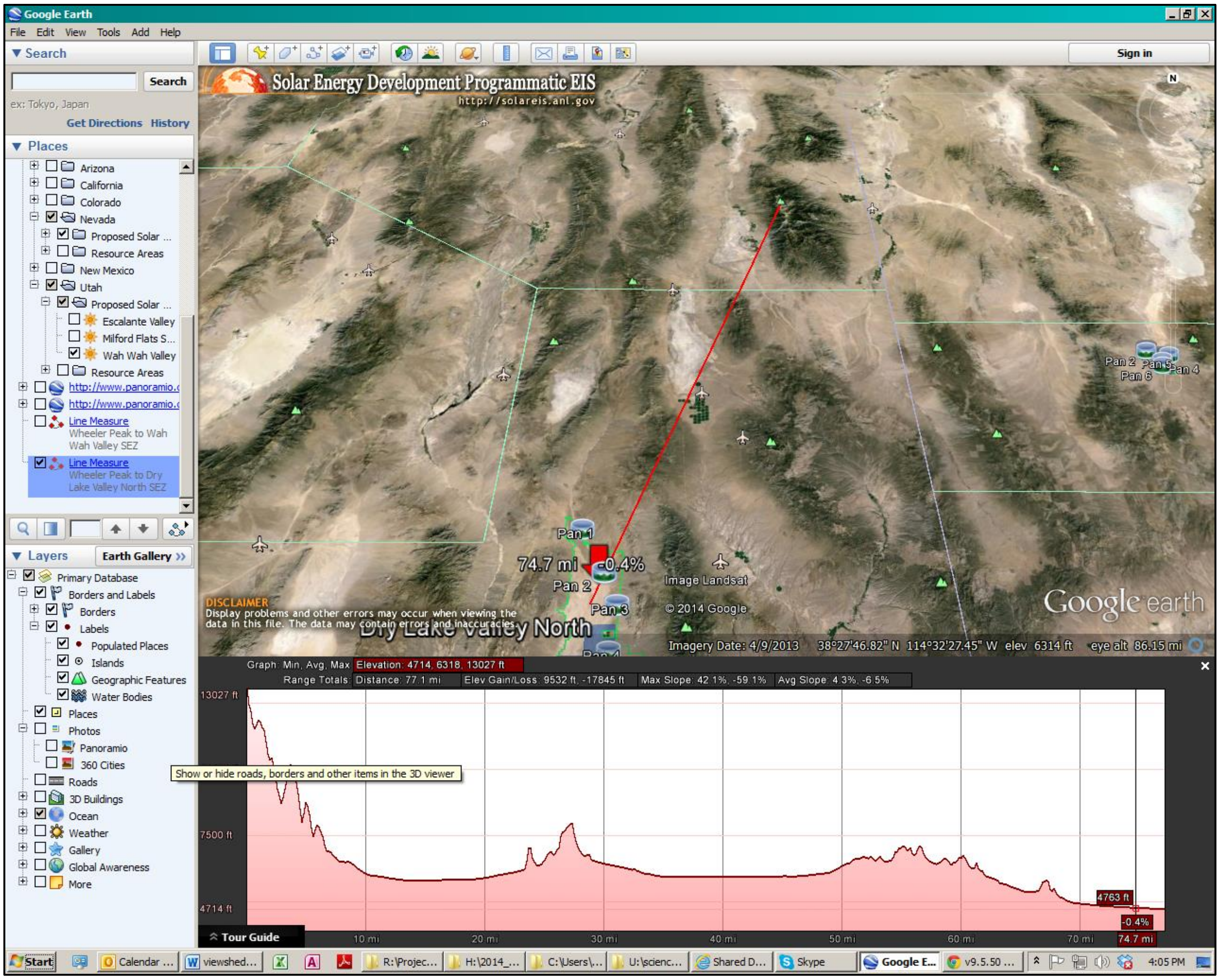


Figure 21. Google Earth screenshot of Wheeler Peak (upper center) and a line to the south-southwest to the Dry Lake Valley North SEZ (lower center). Below the image is an elevation profile generated by Google Earth, from Wheeler Peak on the left to the SEZ on the right.

<u>Reference Conditions</u>

The essence of reference condition is that the park's viewshed has maintained its natural and rural character. A strong foundation of studies has shown that, in general, natural landscapes are preferred by most people over anthropogenic landscapes. When combined with the visibility (here visibility is in the sense of having line-of-sight, not clear air) of something from locations in the park, lack of development can define Good Condition. When visibility allows one to see development features such as roads, wind towers, or buildings, the condition could be considered to be of moderate concern, but if the viewed features are rural in character or provide something pleasing to the eye (green irrigation in a generally tan or brown landscape), then good condition can still be applied.

For the viewshed condition index indicator, the reference condition is that the combined viewshed x development type index is sufficiently low to maintain the rural character of the landscape (Table 15). If housing or development features are of high visual impact and perceived as transitioning to an urban or suburban character, then the perceived quality of the viewshed would likely diminish, as would assessment of the condition.

Table 15. Condition Classes of Viewshed.

Condition	Class	Description
Good	Pristine	No man-made structures or developments are visible within the viewshed.
Good	Minimally Developed	Man-made structures or developments are present, or are of rural character, but the vast majority of the landscape is dominated by natural features.
Moderate	Moderately Developed	Man-made structures or developments occupy a moderate portion of the landscape, or are of high visual impact (straight-line paved highways for example).
Significant Concern	Highly Developed	The vast majority of the landscape is dominated by man-made structures or developments, or there is a significant portion that have high visual impact.

The Visibility of Spring Valley Wind Farm and Regional Viewshed indicators do not support the identification of thresholds to distinguish Good conditions from conditions of either Moderate or Significant Concern. The assessment qualitatively discusses the existing wind farm and its impact on the condition of the views from Wheeler Peak and Bald Peak; and the SEZs and possible impacts on views.

<u>Condition and Trend</u>

Current vistas from Great Basin NP range from nearly pristine to somewhat modified by the existence of roads, agriculture, small towns, utilities, and other development - including a 66 turbine wind farm - visible from some viewpoints. Based on air quality data (see Air Quality Section 4.1.2 above), vistas are often obscured by haze caused by fine particles in the air. Many of the same pollutants that ultimately fall out as nitrogen and sulfur deposition contribute to this haze and visibility impairment. Long range views beyond park boundaries are especially affected by air pollution and haze from dust. Continued general development patterns, where visible, will likely add structures and utilities to existing views, further impacting visual resources.

GIS-based Indicator: Viewshed Condition Index

The viewshed condition index is interesting to interpret. The colors towards the yellow to red end of the spectrum represent areas that are visible from only a few KOPs (Figure 22 and Figure 23), or are scored as having some visual impact that is assumed to be displeasing (i.e. roads, paved highways, towns). When the viewshed condition index is limited to where 4 or more KOPs can see an area (Figure 22), then it is obvious that large portions of the valleys adjacent to Great Basin NP are visible from only a few places within the park (white areas in Figure 22 are not visible to 4 or more KOPs). In the figure, areas with scores from 0.2 to 0.4 (light to darker orange) are places visible to only 4 to 6 KOPs. Many more KOPs have visibility towards the east from the park (the light to dark greens in Figure 22), and also many of the development features with higher visible impacts are within the 10-

mile (16-km) radius (e.g., network of roads around Baker), although Highway 6/50 is a clearly visible feature from east to west in both the near view (within 10 miles (16 km)) and far view (between 10 and 25 miles (16 and 40 km)).

To the west, there is much less that is visible from the KOPs within the park; the orange areas to the southwest are visible from only 4-6 KOPs (Figure 22). In contrast to the east view, there is much less in the way of visual impacts from development; only a few linear roads in the 10-mile (16-km) radius near view and one major highway north-to-south in the far (25-mile (40-km) radius) view.

When the viewshed condition index is masked to visibility from all but one KOP (Figure 23), then many more development features are impacting the condition of views. In the figure areas with scores from 0.1 to 0.4 (light to darker orange) are places visible to only 2 up to 6 KOPs. To the east of the park, in addition to seeing more of Highway 6/50 from more locations within the park, both Highway 487 south from Baker, and Highway 21 south from Garrison are now visible in both the near view (within 10 miles (16 km)) and far view (between 10 and 25 miles (16 and 40 km)).

To the west, while the visible portions of the landscape from the park's KOPs have increased (e.g. more KOPs have a view to the west than in Figure 22), the western view is still less visible from much of the park than the eastern. However, one can now clearly see the visual footprint of the Spring Valley Wind Farm; it is visible from 2 or 3 KOPs, most likely including Wheeler Peak and other high ridge locations on the west ridgeline of the park. Visual impacts from other development features besides the wind farm are limited to roads or highways, particularly in the far (25-mile (40-km) radius) view.

Several photos (Figure 24, Figure 25 and Figure 26) downloaded from Google Earth or provided the Great Basin NP staff illustrate the visibility (line-of-sight) and visual impacts of development features described above.

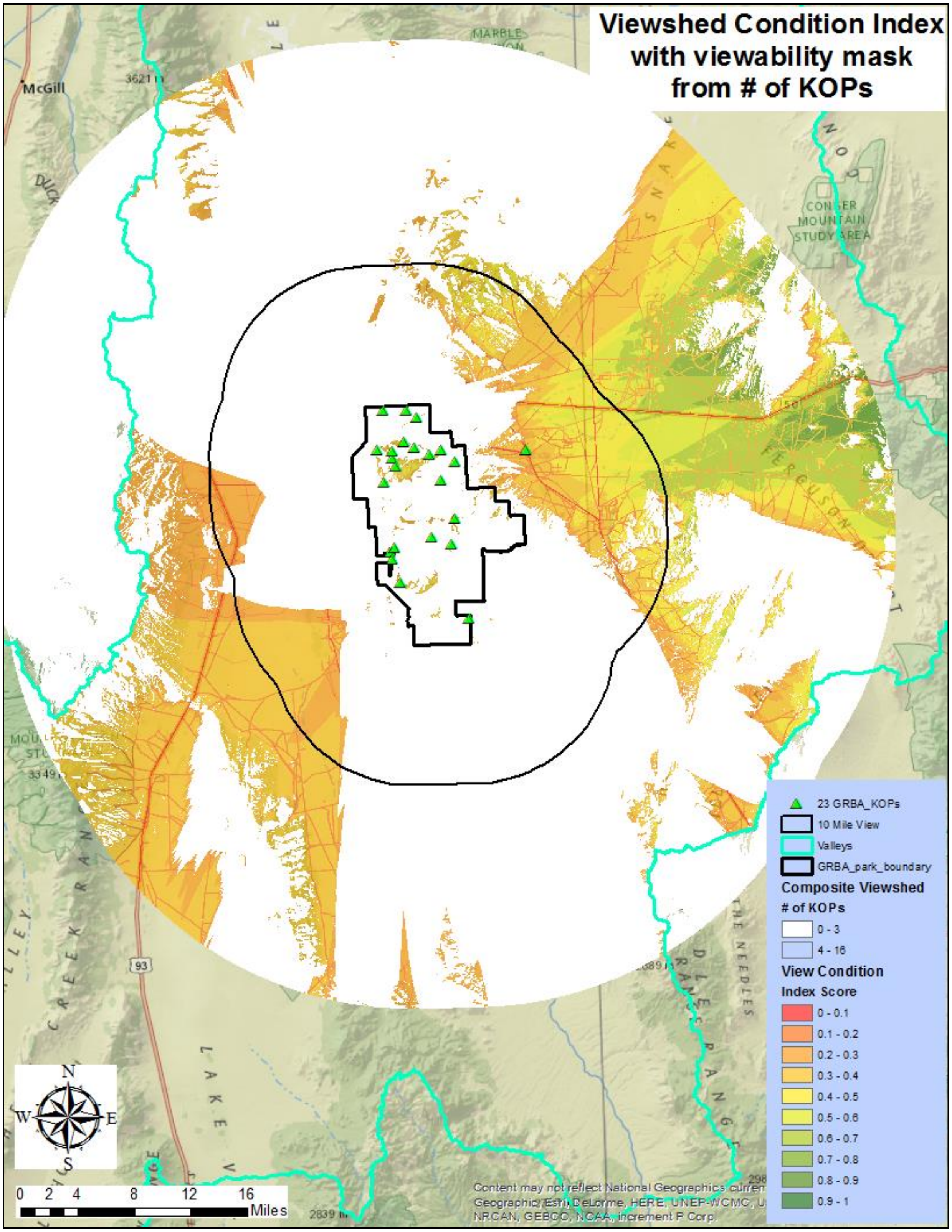


Figure 22. Viewshed condition index masked by areas with 3 or fewer KOPs (white areas). Visible areas of the Index are those where 4 or more KOPs have a view. The outer circle is the 25-mile (40-km) radius of the NPS composite viewshed; the black circle is a 10-mile (16-km) radius.

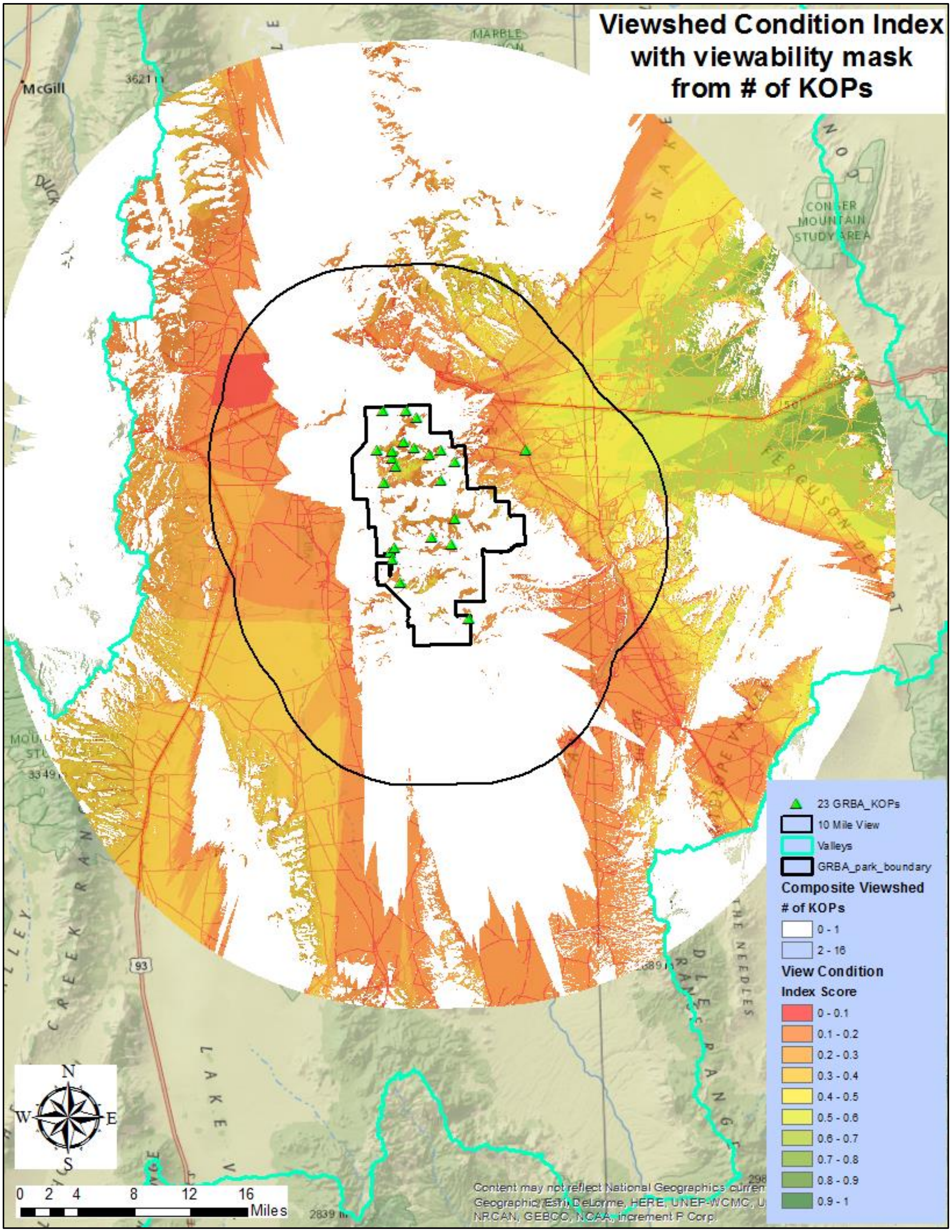


Figure 23. Viewshed condition index masked by areas with 1 or no KOPs (white areas). Visible areas of the Index are those where 2 or more KOPs have a view. The outer circle is the 25-mile (40-km) radius of the NPS composite viewshed; the black circle is a 10-mile (16-km) radius.

Figure 24. Spring Valley to the west of Great Basin NP, from the Wheeler Peak trail. Copied from Google Earth, photo by David E. Smeeth. Areas of irrigated agriculture in the form of center-pivot fields (green circles just right of center of the photo) can be seen, along with linear features of roads. The relatively clear air on this day allows the viewer to glimpse the valley between the two mountain ranges to the west of the park.

Figure 25. Winter view looking east from Great Basin NP, across Baker, NV. Copied from Google Earth, photo by David C. Hryciuk. In winter with snow covering some of the landscape, agriculture and even some roads are less visible. The town of Baker (left center) does not strongly impact the view either.

Figure 26. Photo from summit of Wheeler Peak, looking south. National Park Service photo by Gretchen Baker. Even though Wheeler Peak is the highest point in the park and the South Snake Range, the near view to the south is very limited due to the series of high ridges and peaks. At the furthest distances, regional haze due to dust or air pollutants softens the visual impact of development features such as roads or highways, if they are not blocked by the ridges in the foreground.

Qualitative Indicator: Visibility of Spring Valley Wind Farm from Wheeler Peak

The Spring Valley Wind Farm was completed and put into operations in August 2012. It includes 66 2.3 megawatts (3,100 hp) turbines on 77 acres (31 ha) within the property owned by Pattern Energy which covers 7,673 acres (3,105 ha). The blades on the turbines are 153 feet (46.5 m) long, the hub for the turbines is 262 feet (80 m) above the ground, and the total height of the tower and blades is 415 feet (126.5 m) (information from http://www.aweo.org/windmodels.html; size specifications of common industrial wind turbines).

The assessment completed by SWCA (2009) concluded that the level of change to the landscape as viewed from Wheeler Peak would be "…weak based on the visual resource contrast analysis." Figure 27 is copied from the SWCA report, and represents their simulation of the wind farm as viewed from Wheeler Peak.

While small, the towers and turbines are visible in the simulation and contrast (being a matte gray color) with the background, generally grayish-brown landscape. In addition, they are markedly in linear rows, drawing ones eye to them and are visibly distinct from other linear features in the valley. The visual contrast rating suggests that the wind farm "…makes up only a small portion of the overall panoramic viewshed from the summit. Dominant views from the summit include the jagged mountain range extending to the north and south." (SWCA 2009). While this is technically correct, the contrast of the wind towers and turbines with the surrounding landscape features is such that the farm is distinct and does have a visual impact.

A photo of the current view from Wheeler Peak indicates that the visual impact of the wind farm is more pronounced than the SWCA simulation suggested it would be (Figure 28 and Figure 29). The height and color contrast of the towers and turbines is more visible than in the simulation (Figure 27), where they appear more blurred or fuzzy. Angular, geometric lines occur where access roads were built to each row of towers.

The visibility of the wind farm is even more pronounced (Figure 29) from Bald Mountain, which is in the park, but at a lower elevation and further north than Wheeler Peak (hence closer to the wind farm). The access roads are obvious linear features, and the tower bases appear as small protrusions from those roads. The turbines themselves can be seen, and when moving in the wind, will attract the viewer's eye more strongly. This photo of the actual view from Bald Mountain draws the viewer's eye directly to the wind farm as it is a strong visual contrast to the other features of the landscape.

Figure 27. Simulation of what the Spring Valley Wind Farm would look like from Wheeler Peak by SWCA (2009). Image taken directly from SWCA report. The report was written prior to build-out of the wind farm.

Figure 28. The view from Wheeler Peak towards the Spring Valley Wind Farm. NPS photo by Gretchen Baker. The nearly white vertical towers and the crosshatch of the access roads to the tower bases are clearly visible.

Figure 29. View from Bald Mountain towards the Spring Valley Wind Farm. NPS photo by Gretchen Baker. The crosshatch of the access roads and small square areas of the tower bases is much more visible from Bald Mountain than Wheeler Peak, as the distance from Bald Mountain is shorter.

Qualitative Indicator: Regional Viewshed

Many factors influence the quality of visual resources (e.g. dust, small particulates, wind direction & strength) and the distance a person can see (e.g. an individual's visual acuity, height above the surrounding landscape, intervening features, air quality). While Great Basin NP generally has good air quality, and often crisp, clear views, it does have days where the air quality is poor or hazy (see Air Quality Section 4.1.2 above).

To assess the regional viewshed for Great Basin NP, two formally designated Solar Energy Zones (SEZs) were selected as being close enough to Great Basin NP to be within an approximate 100-mile (161-km) viewshed. These SEZs were designated under the BLMs Programmatic Environmental Impact Statement (PEIS), an analysis conducted by the Bureau of Land Management and the Department of Energy across six southwestern states (BLM and DOE 2012). The two selected SEZs are as yet undeveloped, and are the Wah Wah SEZ in Utah (southeast of the park), and Dry Lake Valley North (south southwest of the park) in Nevada.

The line-of-sight from Wheeler Peak to each of these is somewhat different. For the Utah site, Wah Wah SEZ, while closer to the park there is an intervening ridgeline within the park itself (Figure 30) that blocks much of the more distant view of the valley where the SEZ is delineated. In addition as

Figure 20 shows, there is another ridge close to the SEZ that also blocks the view of the Wah Wah SEZ from all but the highest points in the park. It is unlikely that development of the Wah Wah SEZ would be visible from the park, except from Wheeler Peak and as very small glints of light on the solar panels (which would be oriented to the south, away from the park) and other infrastructure.

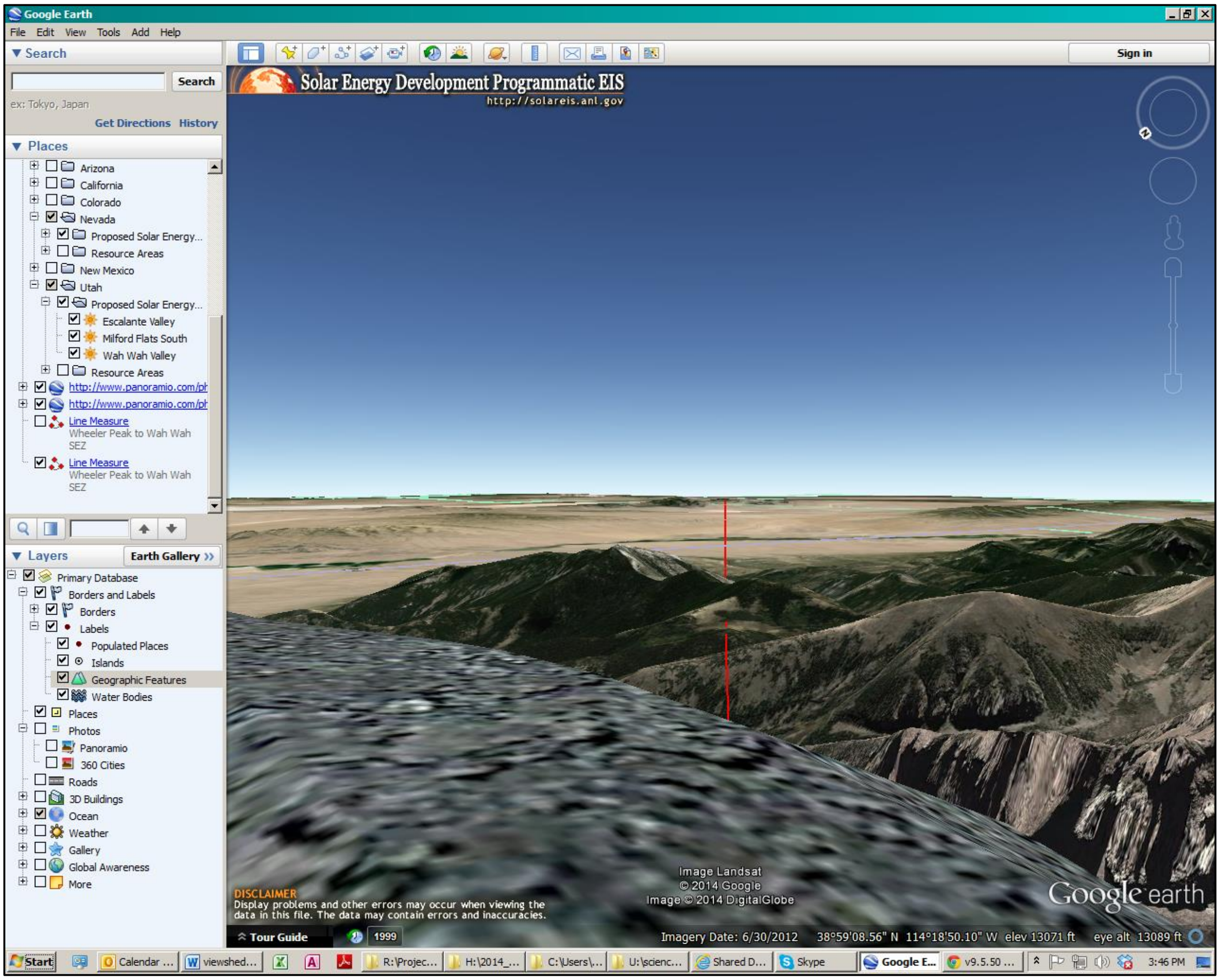


Figure 30. Google Earth simulation of the view from Wheeler Peak southeast towards the Wah Wah SEZ, a distance of ~62 miles (99 km). Where the red line ends on the horizon is the location of the SEZ, but it is on the other side of the small dark ridge.

The view towards Dry Lake Valley North SEZ is somewhat similar (Figure 31); the distance is greater than to Wah Wah (76 miles as opposed to 62 miles (122 km vs. 100 km)), but the intervening topography is lower (Figure 21). The general location of the Dry Lake Valley North SEZ will be visible from more locations within the park than the Wah Wah. However, as with the Wah Wah, it's unlikely the developed infrastructure will be visible except as very small and hazy features.

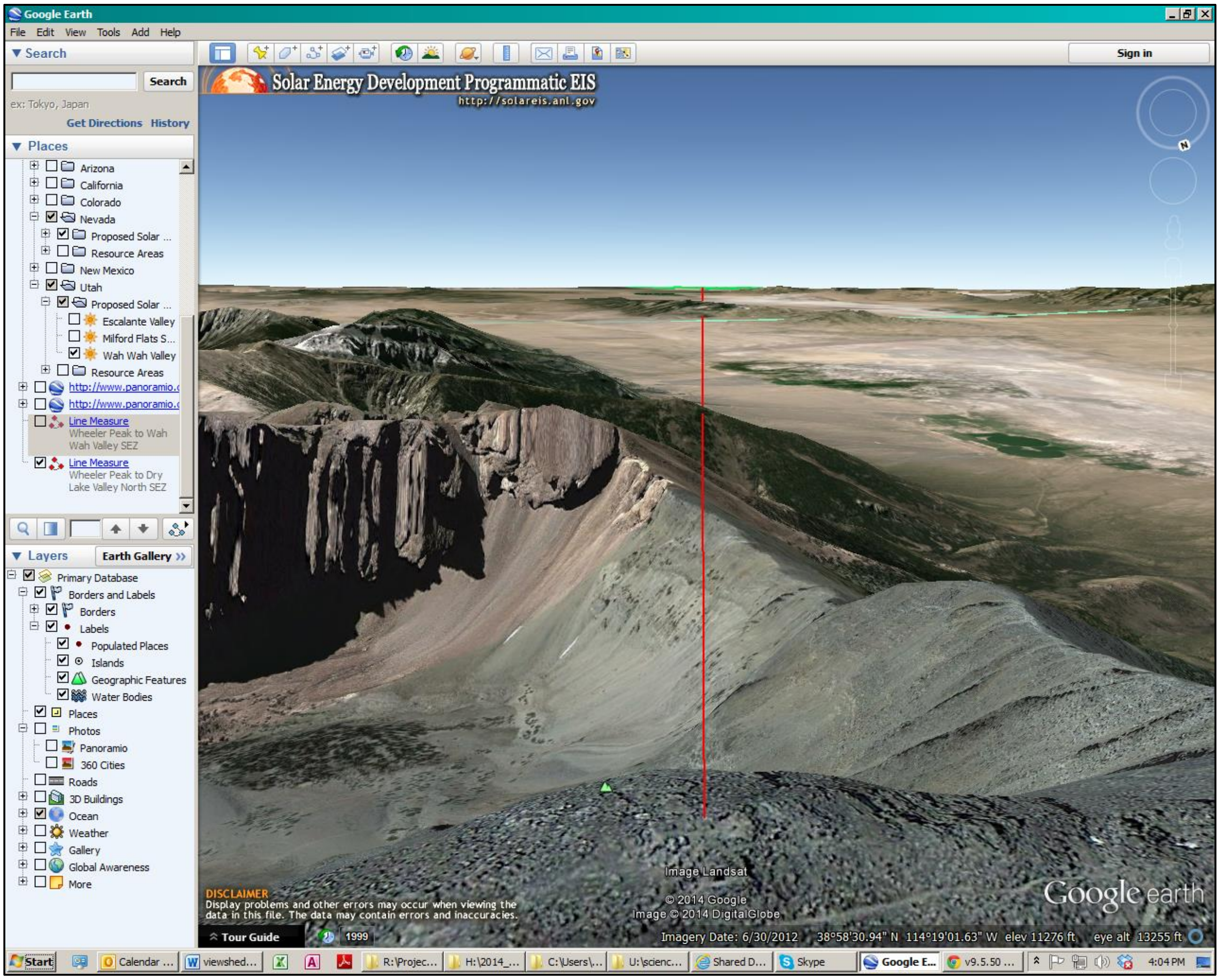


Figure 31. Google Earth simulation of the view from Wheeler Peak south-southwest towards the Dry Lake Valley North SEZ, a distance of ~76 miles (99 km). Where the red line ends on the horizon is the location of the SEZ, where is bounded by the solid green line.

Overall Condition

Depending upon which direction one is looking, and from where in the park, current views from Great Basin NP range from nearly pristine to somewhat modified by development including roads, highways, agriculture, and the Spring Valley Wind Farm. Air quality data suggests haze affects these views on a number of days annually, and is particularly a problem for long-range views. Continued development patterns, when visible from the park, will add structures and utilities, contributing to further impacts on visual resources. Development in upwind areas could disturb soils, and contribute to increased dust and haze.

For assessing the condition of the park's views, one quantitative (viewshed condition index) and two qualitative indicators/measures (views of Spring Valley Wind Farm and regional views of SEZs) were used. The viewshed condition index takes into account the different kinds of developed features in the landscape around Great Basin NP, up to 25 miles from the center of the park, and evaluating the degree to which each type of development feature might be visually displeasing. The two qualitative indicators make use of Google Earth and photos to illustrate how views from within the park might be impacted.

The viewshed condition index suggests that the park viewshed is somewhat different to the east compared to the west. More of the landscape to the east of the park can be seen and in addition it can be seen from more places within the park. While the vast majority of the landscape surrounding Great Basin NP is in a natural, undeveloped state, and much of the development is rural in character, there are distinct features that contrast with this and are highly visible. However, within each of these different viewsheds (east vs west), the amount and types of development are different. Using Table 15, the condition of both viewsheds is rated by this assessment as of Moderate Concern for the viewshed condition index: to the east because of the maze of roads and highways, as well as the town of Baker NV; to the west because of the Spring Valley Wind Farm, as well as roads and highways.

The evaluation of the Spring Valley Wind Farm suggests that, when it is visible from a location within the park, it is highly noticeable. The height and number of the towers and turbines, combined with their linear rows, the color contrast with the surrounding landscape, and turbine movement, draws the viewer's eye. Although the farm is only a small area within the vast views to the west from the peaks of the park, it is in marked contrast to the other features of the landscape, and hence is of Moderate Concern.

Condition Relative to Regional Context

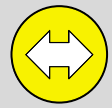
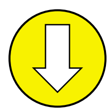
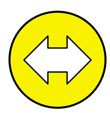
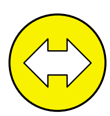
Regionally, the park is within an area with low amounts of development, and certainly compared to other national parks adjacent to larger metropolitan areas, Great Basin NP can be considered to be in good condition, with only minimal amounts of development in its regional context. Although there are ranches, agricultural activities, many small dirt and local roads, and several state or interstate highways, the area is largely undeveloped and "natural" in character (see Figure 18, the Landscape Condition Index, for a visual sense of the development within the valleys surrounding the park). The Google Earth assessment of the two solar energy zones suggests that even were they to be developed, their visibility from the park will be very minor if visible at all.

Beyond a certain distance, the human eye and visual acuity diminishes and even large development features do not impact one's view. The addition of fine particulates from air pollutants or dust further decreases the ability to discern things, be they natural or human built, at long distances such as 50 or 70 miles (80 or 113 km) or more.

Trend

While nothing specific in this resource assessment suggests additional development is likely, there are indications of a recent downward trend for views from the park. First, the air quality assessment indicates that air quality, including particulates of nitrogen, sulfur and dust, is of moderate concern-there are days when particulate-induced haze obscures views. Trends in air quality appear to be stable for now, but in the future the crisp clear views from the park could become less common. Secondly, there are proposals for development of additional wind farms such as the Wilson Creek Wind Farm (which has been rejected and is now location to-be-determined), but it seems entirely possible that one or more additional farms could be developed within the regional viewshed of the park. Thirdly, the Southern Nevada Water Authority is pursuing the development of a ground-water pumping operation in the Spring Valley, and if it moves forward, would develop pumping stations and pipelines to move the water south to Las Vegas. While this is still in the proposal and litigation phase, if it is built it would become another development feature visible from areas within the park. Lastly, to the east of Great Basin NP there is an area proposed by BLM for oil and gas leasing. Should development of this area proceed in the future, it would probably be very visible from much of the eastern side of the park as suggested by the composite viewshed (Figure 17).

Table 16. Summary of indicators of condition for viewshed.

Viewshed			
Indicators of Condition	**Specific Measures**	**Condition Status/Trend**	**Rationale**
Viewshed Condition Index	An index combining the amount & visual impact of development features with the visibility of those features from the park.		Moderate amounts of development are visible both to the east and to the west of the park, especially to the east. Recent construction of the Spring Valley Wind Farm has degraded the views to the northwest. Future structures and utilities would contribute to impacts to the visual resource.
Visibility of Spring Valley Wind Farm	A qualitative evaluation of how visible the wind farm is from the peaks of the park.		The wind farm is highly visible from a few locations within the park. This assessment has high confidence due to actual photos of the farm from points within the park.
Regional Viewshed	A qualitative evaluation of how visible two solar energy zones might be from the peaks of the park.		The SEZs themselves are not likely to be visible from the park, except on the clearest of days and from the highest peaks. However, dust and regional haze degrade scenic vistas regularly, although the air quality data suggests the trend is stable.

Key Uncertainty

The main uncertainty in this assessment is how much and what kinds of development will occur in the future; many factors can affect this that are outside of the park's control.

Sources of Expertise

Dan McGlothlin and Peter Budde of the National Park Serve in Fort Collins, Colorado, conducted the composite viewshed analysis that was used as one of the inputs to the viewshed condition index. Staff of the NPS Air Resources Division have expertise in evaluating visual resources.

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4.1.4. Night Sky

Indicators / Measures

- *Anthropogenic Light Ratio*
- *Sky Brightness:*
  - *Maximum Sky Brightness*
  - *Minimum Sky Brightness*
  - *Integrated Whole Sky*
  - *Integrated Sky Above 20 °*
- *Bortle Dark-Sky Scale*

Condition - Trend

Good Condition– Deteriorating Trend – High Confidence

Background and Importance

A natural lightscape is considered a valued resource by NPS, and natural resource-based parks are mandated to preserve the scenery, which includes protecting a visible (i.e., low artificial light level) night sky (NPS 2006). Great Basin NP has identified its night sky as a fundamental resource and value in their Resource Management Plan (NPS 1999), and on their website (http://www.nps.gov/grba/planyourvisit/great-basin-night-sky.htm).Visitors to national parks also seem to agree that preserving night skies is an important factor for their experience. A 2007 visitor survey conducted throughout Utah national parks found that 86% of visitors thought the quality of park night skies was "somewhat important" or "very important" to their visit (NPS 2010). Additionally, in an estimated 20 national parks, stargazing events are the most popular ranger-led program (NPS 2010).

Figure 32. The Milky Way at night in Great Basin NP. Photo credit: NPS photo.

Natural light/darkness is also an important factor for maintaining health within biological systems; the cycles of day-night (diurnal), lunar and seasonal changes each vary in the natural light intensity and duration. Dark sky is important to ecosystem function, and research demonstrates the multiple adverse impacts of light pollution to community ecology (Longcore and Rich 2004). Animals can experience altered orientation from additional illumination and are attracted to or repulsed by glare, which affects foraging, reproduction, communication, and other critical behaviors (Witherington and Martin 1996, Rich and Longcore 2006). A study of moths and predation by bats, birds, skunks, toads, and spiders found behavior patterns significantly altered by artificial lighting (Frank 1988). The cumulative effects of behavioral changes induced by artificial night lighting on competition and predation have the potential to disrupt key ecosystem functions (Longcore and Rich 2004). Longcore and Rich (2004) predict of light pollution: "the most noticeable effects will occur in those areas where lights are close to natural habitats." Given the effects of light on living organisms, introduction of artificial light into the natural light/darkness regime disrupts the normal routines of many plants and animals (Rich and Longcore 2006), and diminishes stargazing recreational opportunities offered to national park visitors.

As reported in the park's natural resource management plan (NPS 1999) Dr. Roger Lynds and Dr. Jean Goad of the Kitt Peak National Observatory selected Wheeler Peak (13,063 feet (3,982 m), before the Park was created, as their first choice for a new national observatory site. Their 1984 study (Lynds and Goad 1984) of 56 mountain peaks in five western states favored Wheeler Peak, not just because of its immense dark skies, but because of its exceptional astronomical seeing and transparency, critical factors for astrophysics research. These astronomical qualities are a significant part of the Park's natural resources. A night sky inventory was performed recently (NPS 2014) which confirmed that the area surrounding the park, with an average darkness of 21.32 magnitudes per square arc second (msa), is among the few places in the United States where light pollution is almost non-existent.

The park manages dark night sky as a natural resource to provide opportunities for visitor enjoyment. The night skies of Great Basin are sought by park visitors and are one of the key interpretive themes provided by the park. Dark night sky is an important element of the park's scenic qualities as well as an important resource to amateur astronomers, sky watchers, and other visitors. A 2007 survey of 140 visitors to GRBA (Gallaway et al. 2007) found many visitors (45 percent) star gazed or planned to do so, and that almost half of all visitors considered the dark skies as an important or very important consideration when they were making their travel plans to go to the park. Great Basin NP is becoming recognized as a national destination for dark-skies. The park hosts an increasingly popular astronomy festival each summer and holds approximately 100 public astronomical events each year. To meet visitor demand, the park has expanded its public programs to cover a seven month period each year. The park's public programs routinely interact with close 10,000 visitors per year and are placing a priority on dark-sky protection issues by currently undertaking the detailed compliance application to become a certified International Dark Sky Park, one of the few national parks with this designation.

Data and Methods

Indicators / Measures

- ***Anthropogenic Light Ratio***
- ***Sky Brightness:***
    - ***Maximum Sky Brightness***
    - ***Minimum Sky Brightness***
    - ***Integrated Whole Sky***
    - ***Integrated Sky Above 20 °***
- ***Bortle Dark-Sky Scale***

The Natural Sounds & Night Skies Division (NSNSD) of NPS has been developing methodologies for evaluating the night skies across all park units. They define two different aspects of night sky: the *photic environment* which represents the totality of the pattern of light at night at all wavelengths; and the *lightscape* which includes the human perception of the nighttime scene, including both the night sky and the faintly illuminated terrain (NPS 2014). This assessment of park's night sky condition used indicators and measures (Table 17) for both the Great Basin NP photic environment (quantitative measures) and lightscape (qualitative). The quantitative measures have been developed and were collected at Great Basin NP by NPS Night Skies Program scientists and measure night sky brightness derived from charged coupled device (CCD) camera images. The qualitative assessments are commonly used by amateur astronomers to evaluate the potential quality for star gazing.

Table 17. Indicators used for resource assessment of night sky in Great Basin NP.

Indicator	Indicator Definition
Anthropogenic light ratio	This is a quantitative measure that measures total sky brightness averaged across the entire sky and compares that value to natural nighttime light levels
Sky brightness • Maximum sky brightness • Minimum sky brightness • Integrated whole sky • Integrated sky above 20	This is a quantitative measure that assesses the sky brightness using four different parameters, including night light pollution along the horizon.
Bortle dark-sky scale	This is a qualitative measure that uses a scale divided into nine classes. This is a relatively easy measure to use for night sky conditions and requires no special equipment. The scale is based upon how viewable certain features of the night sky, including the Milky Way, constellations, and even the nighttime scene are for astronomers.
Limiting magnitude	This is also a qualitative measure that local astronomers use to assess the brightness of the faintest stars to the naked eye. The limiting magnitude scale closely follows the Bortle Dark-Sky scale.

Quantitative Indicators/Measures

The quantitative indicators and measures used to assess the park's night sky condition are based on methodology developed by NPS Natural Sounds and Night Skies Division scientists using CCD camera images. Detailed descriptions of their methodologies can be found in Duriscoe et al. (2007) and Duriscoe (2013), and at the NPS Natural Lightscape website, along with additional night sky statistics and information for the park and other national parks (http://www.nature.nps.gov/night/index.cfm). The data reported here for the park's quantitative indicator/measures were collected as part of the Night Skies Program. The program's goals of measuring night sky brightness are to describe the quality of the nightscape, quantify how much it deviates from natural conditions, and how it changes with time due to changes in natural conditions, as well as artificial lighting in areas within and outside of the national parks (Duriscoe et al. 2007).

NPS scientists collected night sky data on three occasions at Great Basin NP: October 15, 2004, October 7, 2005, and September 25, 2006. The 2004 data were collected on Buck Mountain (11,008 feet (3,356 m)) in elevation; the 2005 and 2006 data were collected from Mt. Washington, 11,677 feet (3,560 m) in elevation. Two, five, and four sets of night sky brightness data were collected each night, respectively. The data collection procedure used a CCD research grade digital camera, attached to a robotic mount and laptop computer. The computer choreographed the entire system, pointing the camera to pre-determined areas of the sky and captured a series of short exposures. These images were stitched together to form a mosaic of the entire sky that can be displayed in either a panoramic or hemispheric (fish-eye) view. Data were calibrated to stars of known brightness, allowing absolute brightness measures to be extracted from the images. The camera used a green filter, rejecting all other light from the infrared to the ultraviolet. This green or "V-band" filter approximates human night vision sensitivity. Data were displayed in V magnitudes, an astronomical brightness system. The metrics rely on the standard methods of astronomical photometry and its instrumentation, and are quantitative descriptors that may be directly related to both visitor experience and ecosystem function.

For this assessment, two quantitative indicators/measures were derived by NPS from the CCD camera images: the anthropogenic light ratio (ALR), and sky brightness, including maximum sky brightness, minimum sky brightness, and two measures of integrated sky brightness. The ALR is total sky brightness averaged across the entire sky and then compared to natural nighttime light levels (Duriscoe 2013). The maximum sky brightness is typically found in the core of urban light domes (e.g. the semi-circular shaped light along the horizon caused by the scattering of urban light). The minimum sky brightness is typically found at or near the zenith (straight overhead). The integrated night sky brightness is calculated from both the entire celestial hemisphere as well as a measure of the integrated brightness masked below 20° altitude to avoid site-to-site variations introduced by terrain and vegetation blocking.

Brightness values are expressed as astronomical magnitudes per square arc second in the V-band. The astronomical magnitude scale is "upside down" with higher numbers correlating to darker conditions. An arc second is 1/3600th of an angular degree. Both are standard units in the astronomical literature. The measurement process filters out the influence of bright stars, so that the measurement is of the sky background (e.g. the space between the stars). The sky brightness data do not distinguish between natural light sources such as the Milky Way, and artificial light such as urban light scattering.

Qualitative Indicators and Measures

Indicators/Measures
Bortle Dark-Sky Scale
Limiting Magnitude

Two additional qualitative indicators were available for the Great Basin NP lightscape from the 2004-2006 data collected at the park, the Bortle Dark-Sky Scale and Limiting Magnitude. While neither of them provide as quantitative or repeatable of a result as the above-described ALR and Sky Brightness indicators, they are both explained here and results presented.

The Bortle Dark-Sky Scale was proposed by John Bortle (Bortle 2001) based on 50 years of astronomical observations, and has proven to be quite popular with amateur astronomers. Bortle's qualitative approach uses a nine-class scale that requires no special equipment and only a basic knowledge of the night sky (Bortle 2001, Moore 2001) (Figure 33 and Table 18). The Bortle scale uses both stellar and non-stellar objects to distinguish among the different classes. Another advantage of the Bortle scale is that it is suitable for conditions ranging from the darkest skies to the brightest urban areas (Moore 2001). The Bortle scale also uses descriptors that will be more familiar to a broader audience- to which they can better relate to their own aesthetic experience (Moore 2001).

Figure 33. Composite image illustrating the range of night sky conditions based on the Bortle Dark-Sky Scale.

Limiting magnitude (LM) is a qualitative measurement of the brightness of the faintest stars visible to the naked eye (Bortle 2001, Moore 2001). It is also a measure commonly used by amateur astronomers to judge the quality of the night sky because it is simple to measure and requires no special equipment (Bortle 2001). Estimates are made using star counts of 25 sample areas, each containing a field of mapped stars with known brightness values (Moore 2001). In addition to its wide use and simplicity, LM can be expressed in ways that are intuitively easy to understand. For example, increases in night sky brightness (e.g., from light pollution) reduces the contrast between stars and their background; thus reducing an observer’s ability to see fainter stars (Moore 2001). Moore (2001) further expressed this graphically by showing the relationship between LM and the number of stars that are visible to the naked eye (Figure 33). The LM scale is located in Table 18, along with the Bortle Dark-Sky scale.

Table 18. Bortle Dark-Sky and Limiting Magnitude Scales. Limiting magnitudes do not always correspond directly with the Bortle Dark-sky Scale, as a suite of visual observations comprise the determination of the Bortle Class.

Bortle Scale	LM	Milky Way	Astronomical Objects	Zodiacal Light/ Constellations	Airglow and Clouds	Nighttime Scene
Class 1 Excellent Dark Sky-Site	7.6-8.0	MW shows great detail, and Scorpio/ Sagittarius region casts an obvious shadow	Pinwheel galaxy (M33) is an obvious object	Zodiacal light has obvious color, and can stretch across entire sky.	Bluish airglow is visible near the horizon and clouds appear as dark blobs against stars.	Jupiter and Venus annoy night vision, ground objects are barely lit, trees and hills are dark.
Class 2 Typical Truly Dark Site	7.1-7.5	Summer MW shows great detail and has veined appearance	Pinwheel galaxy is visible with direct vision, as are many globular clusters.	Zodiacal light bright enough to cast weak shadows after dusk and has apparent color.	Airglow may be weakly apparent, and clouds still appear as dark voids.	Ground is mostly dark, but object projecting into the sky are discernible.
Class 3 Rural Sky	6.6-7.0	MW still appears complex; dark voids and bright patches and a meandering outline are visible	Brightest globular clusters are distinct, Pinwheel galaxy visible with averted vision.	Zodiacal light is striking in Spring and Autumn, extending 60° above horizon.	Airglow is not visible, and clouds are faintly illuminated except at zenith.	Some light pollution evident along horizon, ground objects are vaguely apparent.
Class 4 Rural/ Suburban Transition	6.1-6.5	Only well above horizon does the MW reveal any structure. Fine details are lost.	Pinwheel galaxy is a difficult object, even with averted vision; Andromeda galaxy very visible.	Zodiacal light is clearly evident, but extends less than 45° after dusk.	Clouds are faintly illuminated except at zenith.	Light pollution domes evident in several directions, sky is noticeably brighter than terrain.
Class 5 Suburban Sky	5.6-6.0	MW appears washed out overhead, and is lost near the horizon	The oval of Andromeda galaxy is detectable, as is the glow in the Orion nebula.	Only hints of zodiacal light in Spring and Autumn.	Clouds are noticeable brighter than sky, even at the zenith.	Light pollution domes are obvious to casual observers, ground objects are partly lit.
Class 6 Bright Suburban Sky	5.1-5.5	MW only apparent overhead, and appears broken as fainter parts are lost to sky glow.	Andromeda galaxy detectable only as a faint smudge, Orion nebula is seldom glimpsed.	Zodiacal light is not visible, Constellations are seen, and not lost against a starry sky.	Clouds anywhere in the sky appear fairly bright as they reflect back light.	Sky from horizon to 35° glows with grayish color, ground is well lit.

Table 18 (continued). Bortle Dark-Sky and Limiting Magnitude Scales. Limiting magnitudes do not always correspond directly with the Bortle Dark-sky Scale, as a suite of visual observations comprise the determination of the Bortle Class.

Bortle Scale	LM	Milky Way	Astronomical Objects	Zodiacal Light/ Constellations	Airglow and Clouds	Nighttime Scene
Class 7 Suburban/ Urban Transition	4.6-5.0	MW is totally invisible or nearly so.	Andromeda galaxy and Beehive cluster are rarely glimpsed.	Zodiacal light is not visible, and constellations are most easily seen.	Clouds are brilliantly lit.	Entire sky background appears washed out, with a grayish or yellowish color.
Class 8 City Sky	4.0-4.5	MW not visible	Pleiades are easily seen, but precious few other objects are visible.	Zodiacal light not visible, and some dimmer constellations lack key stars.	Clouds are brilliantly lit.	Entire sky background has an orangish glow, and it is bright enough to read at night.
Class 9 Inner City Sky	<4.0	MW not visible	Only the Pleiades are visible to all but the most experienced observers.	Only the brightest constellations are discernible.	Clouds are brilliantly lit.	Entire sky background has a bright glow, even at the zenith.

Reference Conditions

The ideal night sky reference condition, regardless of how it's measured, is one devoid of any light pollution from human sources. Night sky quality is principally degraded by light pollution- emissions from outdoor lights that cause direct glare and reduce the contrast of the night sky. Atmospheric clarity also plays a role in the night sky quality; the more clear the atmosphere, the further in distance the impact of a given light source. However, results from night sky data collection throughout 90+ national parks suggest that a pristine night sky is very rare (NPS 2010). The natural brightness of a night sky can be calculated and modeled, and current scientific efforts are addressing the subtraction of natural sky features to evaluate the degree of anthropogenic light pollution (Duriscoe 2013). Modeling, combined with actual data captured from pristine sites, will eventually enable a measure of departure from natural reference conditions.

Anthropogenic Light Ratio

An anthropogenic light ratio of 0.0 would indicate pristine natural conditions, while a ratio of 1.0 would indicate that anthropogenic light was 100% brighter than the natural light from the night sky.

Sky Brightness

Reference conditions for night sky brightness can vary somewhat based on the time of the night, the position of the Milky Way, and the activity of the sun, which can increase "airglow," a kind of faint aurora. For the minimum night sky brightness measure, the darkest part of a natural night sky is generally found near the zenith. A value of 22.0 magnitudes per square arc second (msa) is considered to represent a pristine sky, though it may vary by more than ±0.3 depending on natural conditions. Lower (brighter) values indicate increased light pollution and a departure from natural conditions. The astronomical magnitude scale is logarithmic, so a change of 2.50 magnitudes corresponds to a 10x difference (1000%); thus a 19.5 msa sky would be 10x brighter than natural conditions. Minimum night sky brightness values of 21.5 to 22.0 msa are generally considered to represent natural (unpolluted) conditions (Walker 1970, 1973, as cited in Duriscoe et al. 2007).

The maximum night sky brightness is often found within the Milky Way of a natural sky. A typical measurement from the Sagittarius region of the Milky Way in a natural sky yields 19.2 msa. Other regions of the Milky Way are somewhat dimmer, or around 20.0-21.0 msa. A value brighter than 19.0 msa will result in impairment to human night vision and may be noticeable by casting faint shadows or causing glare. A value lower (brighter) than 17.0 represents a very bright area of the night sky and would significantly impair human night vision and cast obvious shadows. Values for the brightest portion of the sky are of interest to the NPS because they represent unnatural intrusions on the nightscape, will prevent human dark adaptation, and may have effects on wildlife (Duriscoe et al. 2007). Maximum night sky brightness values of 21.0 to 21.5 msa, exclusive of the Milky Way, are generally considered to represent natural (unpolluted) conditions (C. Moore, NPS, pers. comm.).

Integrated brightness of the entire sky background (excluding stars and planets) is an excellent index of sky quality, as it is a quantity that is site-specific and has significant relevance to the human visual experience. As more datasets are gathered by NPS scientists, the integrated brightness values will be placed into qualitative categories representing sky quality (Duriscoe et al. 2007). To allow site-to-site comparison among locations that have varying terrain or vegetation, a measurement can be made to integrate sky brightness only above 20° altitude. Values for integrated sky brightness (whole) of ~ -7.00 represent natural conditions. For integrated sky brightness (above 20°) values of ~ -6.20 represent natural conditions (C. Moore, NPS, pers. comm.).

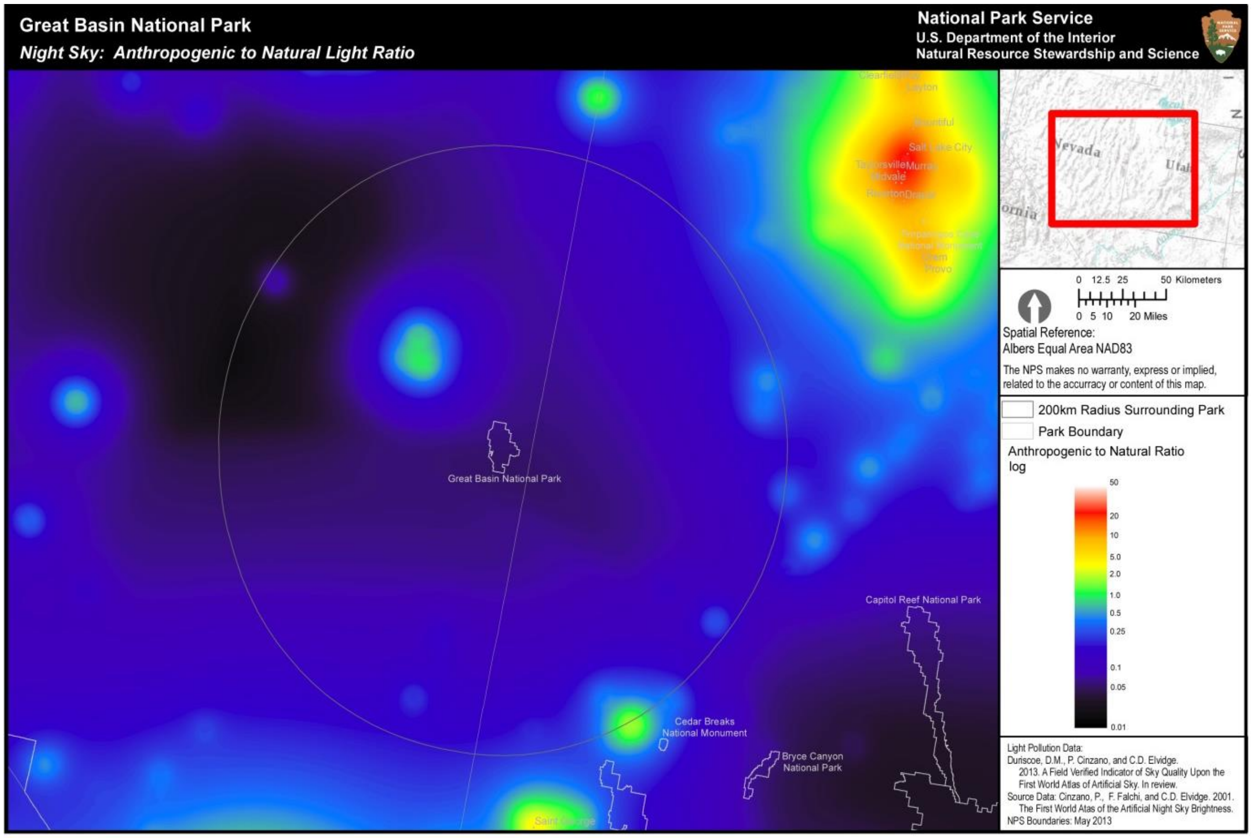
Bortle Dark-Sky Scale and Limiting Magnitude

A night sky with a Bortle Dark-Sky Scale class of 1 (LM > 7.6) is considered an observer's "nirvana" (Bortle 2001); unfortunately, a sky that dark is so rare that few observers have ever witnessed it (Moore 2001). A sky in Bortle's class 2, with a limiting magnitude value between 7.1-7.5 (typical truly dark skies) is considered to be in good condition. Class 3, with a limiting magnitude value between 6.6 and 7.0, is considered to be of a moderate condition. Class 4 and below and a LM of 6.5 have a significantly degraded aesthetic quality and may introduce ecological disruption as well. At Class 4 and worse, many night sky features important to observers are being lost from view due to the reduction in contrast from artificial lights. It is important to note that such degraded conditions can be restored toward a more natural state via improvements in outdoor lighting.

<u>Condition and Trend</u>

Anthropogenic Light Ratio

Ground based observations collected in 2006 from Mt. Washington produced an ALR of 0.05. Compared to other non-urban NPS units, this is extremely good condition. The modeled average ALR value is 0.05 (Figure 34). An anthropogenic light ratio of 0.0 would indicate pristine natural conditions, while a ratio of 1.0 would indicate that anthropogenic light was 100% brighter than the natural light from the night sky. Therefore, at Great Basin NP, the sky is predicted to be just 5% brighter than a natural.



NPS Natural Sounds & Night Skies Division and NPS Inventory and Monitoring Program MAS Group 20140109

Figure 34. Regional anthropogenic light ratio (ALR) near Great Basin NP. Source: NPS Natural Sounds & Night Skies Division. This is modeled ALR and indicates Great Basin NP is in a region with a ratio of 0.05; an anthropogenic light ratio of 0.0 would indicate pristine natural conditions.

Sky Brightness

The night sky brightness values at the park from all three dates of sampling are presented in Table 19. These are consistent with a night sky in good condition, though the data also show the notable impact of light pollution along the horizon. As described above a value of 22.0 magnitudes per square arc second (msa) is considered to represent a pristine sky, though it may vary by more than ±0.3 depending on natural conditions. Lower (brighter) values indicate increased light pollution and a departure from natural conditions. Minimum (darkest region of the sky) night sky brightness values of 21.5 to 22.0 msa are generally considered to represent natural (unpolluted) conditions. Maximum (brightest region) night sky brightness values of 21.0 to 21.5 msa, exclusive of the Milky Way, are generally considered to represent natural (unpolluted) conditions. To allow site-to-site comparison among locations that have varying terrain or vegetation, the integrated sky brightness only above 20° altitude is a useful measurement. Values for integrated sky brightness (whole) of ~ -7.00 represent natural conditions, while for integrated sky brightness (above 20°) values of ~ -6.20 represent natural conditions. For all four measures, lower (brighter) values indicate increased light pollution.

The results in Table 19 for all 3 dates and all datasets indicate Great Basin NP has good to excellent night sky conditions, although there can be seen evidence of light pollution (see Figure 37). The values for the brightest sky datasets are lower than the 21.0 to 21.5 msa considered as representing unpolluted conditions. The values for the darkest are mostly within the 21.5 to 22.0 msa range, while both sets of values for integrated sky are well within the range for excellent conditions.

Table 19. Sky brightness values from Great Basin NP recorded by the NPS Night Skies Program on three dates. Between 2 and 5 datasets were collected during each night, all are shown below. The values are for the darkest area of the sky (near Zenith), brightest area of the sky, and for integrated brightness (whole sky and sky above 20° altitude). Lower (brighter) values indicate increased light pollution and a departure from natural conditions.

Date and Dataset	Darkest (mag/sq arc-sec)	Brightest (mag/sq arc-sec)	Integrated Whole Sky (mag/sq arc-sec)	Integrated Sky above 20° (mag/sq arc-sec)
Oct 2004, #1	21.42	19.91	-7.57	-6.94
Oct 2004, #2	21.45	19.96	-7.63	-7.01
Oct 2005, #1	21.68	20.08	-7.37	-6.76
Oct 2005, #2	21.71	20.01	-7.4	-6.77
Oct 2005, #3	21.72	20.21	-7.39	-6.75
Oct 2005, #4	21.75	20.24	-7.35	-6.71
Oct 2005, #5	21.74	20.32	-7.31	-6.69
Sept 2006, #1	21.97	20.03	-7.10	-6.51
Sept 2006, #2	21.83	20.25	-7.14	-6.56
Sept 2006, #3	21.84	20.40	-7.17	-6.58
Sept 2006, #4	21.89	20.38	-7.14	-6.53

Dark-Sky Scale and Limiting Magnitude

During all three site visits, both the Bortle class and limiting magnitude were estimated (Table 20). Values for each were very similar across all visits with Bortle class of 2 or 3, and limiting magnitude ranging from 6.8 to 7.2. The limiting magnitude values correspond to the low end of Bortle Class 2 and the high end of Bortle Class 3, though there are many factors that confound an exact translation of one system to another. These values represent a dark sky and are considered indicators of good condition.

Table 20. Bortle class and limiting magnitude values for 3 dates at Great Basin NP.

Date	Bortle Class	Limiting Magnitude
Oct 2004	3	6.8
Oct 2005	3	7.2
Sept 2006	2	7.0

Overall Condition

For assessing the condition of the park's night sky, two quantitative (anthropogenic light ratio and sky brightness) and two qualitative indicators/measures (Bortle dark-sky and limiting magnitude scales) were used. These indicators/measures captured different aspects of factors contributing to a night sky, and a summary of them is listed in Table 21. The overall condition of the park's night sky is good and represents a truly dark sky. The combination of clear air (free of aerosols and water vapor that reduce visibility), land with high elevation relative to its surroundings, and a sparse human population in the immediate vicinity of the park results in a view of the night sky that is vulnerable as well as pristine. Photometric measurements taken within the park show that zenith sky condition is virtually unaltered, attaining the theoretical natural darkness of 21.90 magnitudes per square arc-second (Table 19). Although the park's night sky condition is not pristine, it is very good and is among the top 20 darkest night skies measured throughout 80 national parks.

Condition Relative to Regional Context

The NPS Natural Sounds & Night Skies Division has completed modeling of the anthropogenic light ratio across the lower 48 states (Figure 35). The region of the interior western U.S. is generally much less affected by artificial light sources, and northern Nevada and southeastern Oregon have some of the darkest landscapes with few centers of artificial light.

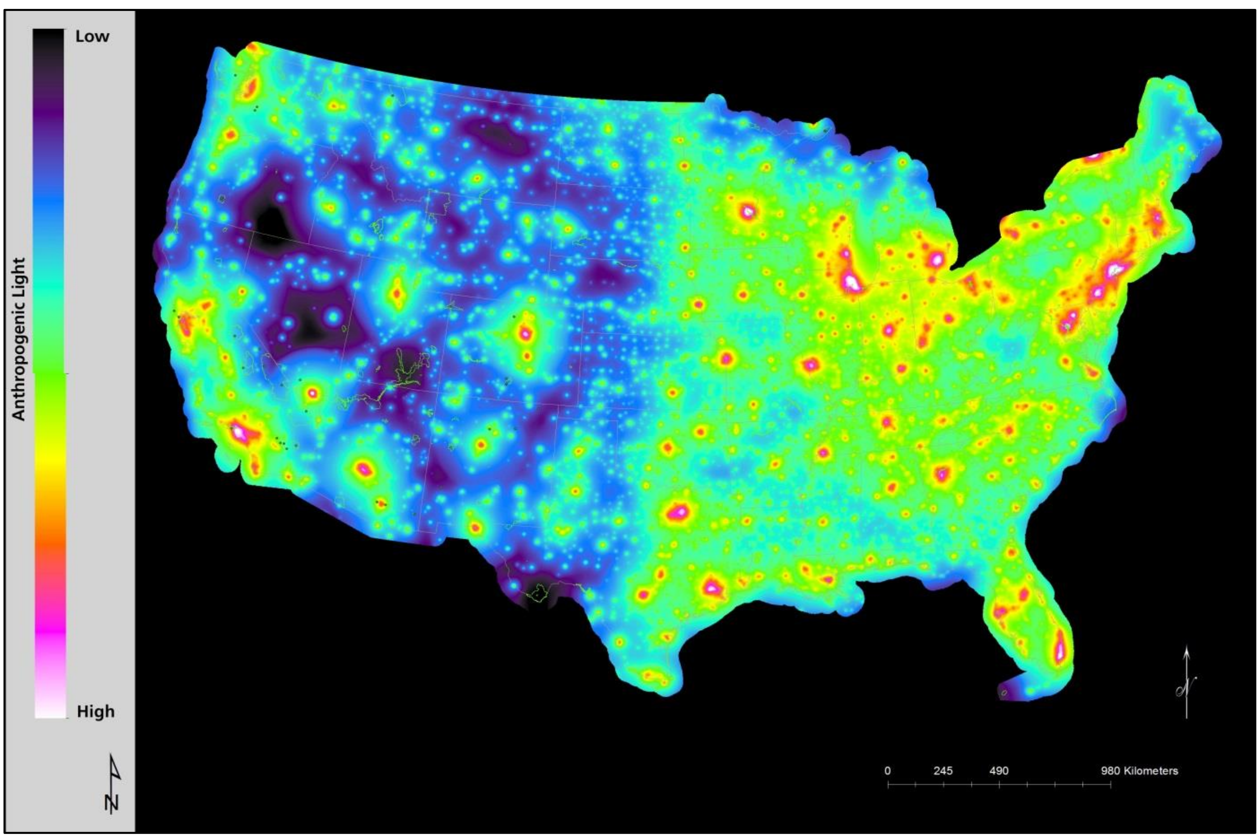


Figure 35. Modeled anthropogenic light ratio (ALR) for the coterminous U.S. Source: NPS Natural Sounds & Night Skies Division, June 2014. Great Basin NP is in one region of the country that is least affected by artificial light sources.

The park is in one of the darkest locations within the “lightshed” that is discerned in Figure 36. However, the park is situated within a relatively dark hole compared to much of the surrounding region (Figure 36). The lack of artificial lighting and dark sky immediately surrounding Great Basin NP provides the darkness necessary for star, planet, and moon visibility during clear nights.

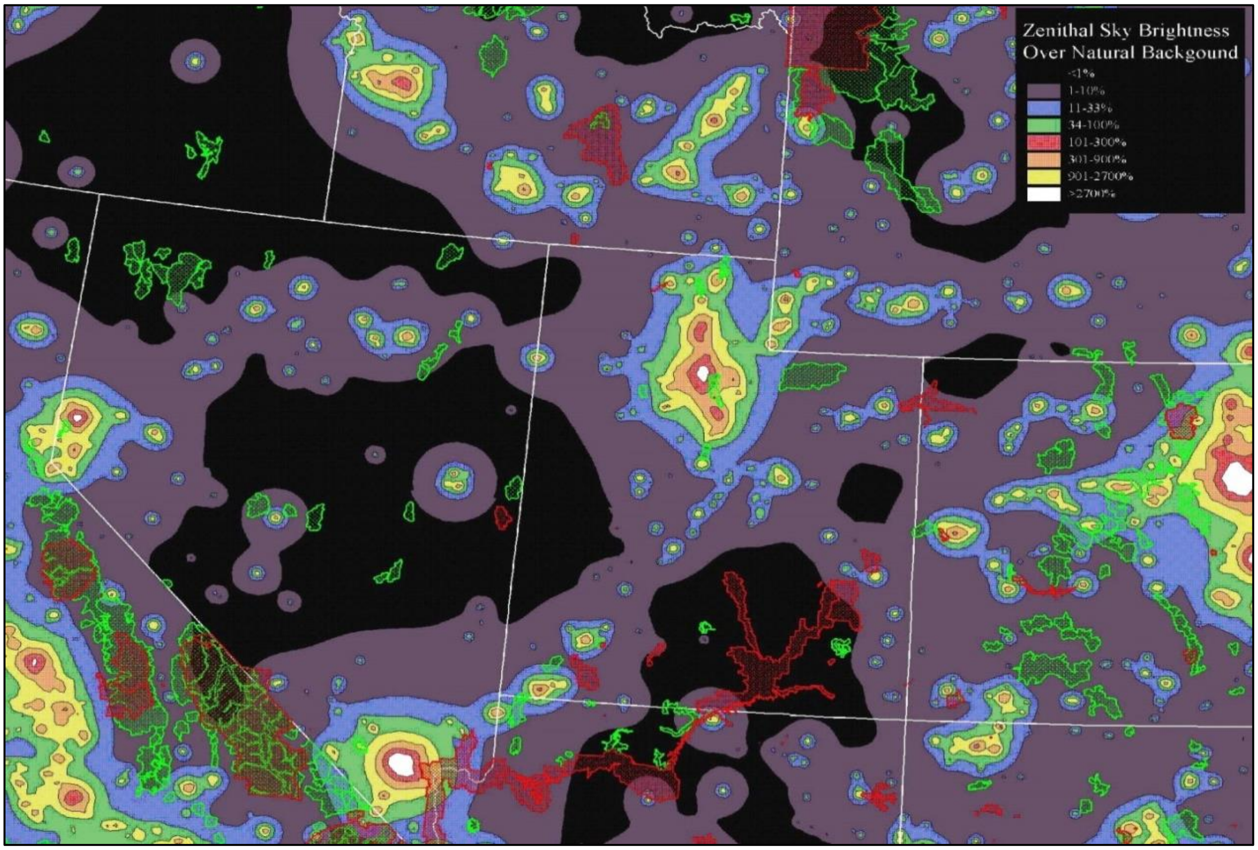


Figure 36. Zenithal sky brightness over natural background. This map shows how dark the night skies are, with black as the darkest and white as the lightest. Great Basin NP is outlined in red and located just left of center on the map, next to the Nevada/Utah state line. Map courtesy of Chad Moore, NPS Night Sky Team. Copied from Winter Midden 2005.

Five artificial light domes are humanly visible from within the park (Figure 37), from left to right: Wasatch Front (Provo, Salt Lake City) (290km), Cedar City, St. George, Las Vegas (311km) and the Ely area (62km). The Ely light dome itself is resolvable into three sources, presumed to be Ely, Ruth, and McGill. The visibility of these light domes is remarkable given their distance and is a testament to the transparency of the air, but they are minor impacts to an otherwise natural sky (Figure 38). A baseline brightness of these light pollution sources has been established and can be monitored over time. Three images below from the park are included (Figure 37 and Figure 38). Data images are shown in false color, with yellow, red, and white corresponding to brighter sky and blue, purple and black corresponding to darker sky.

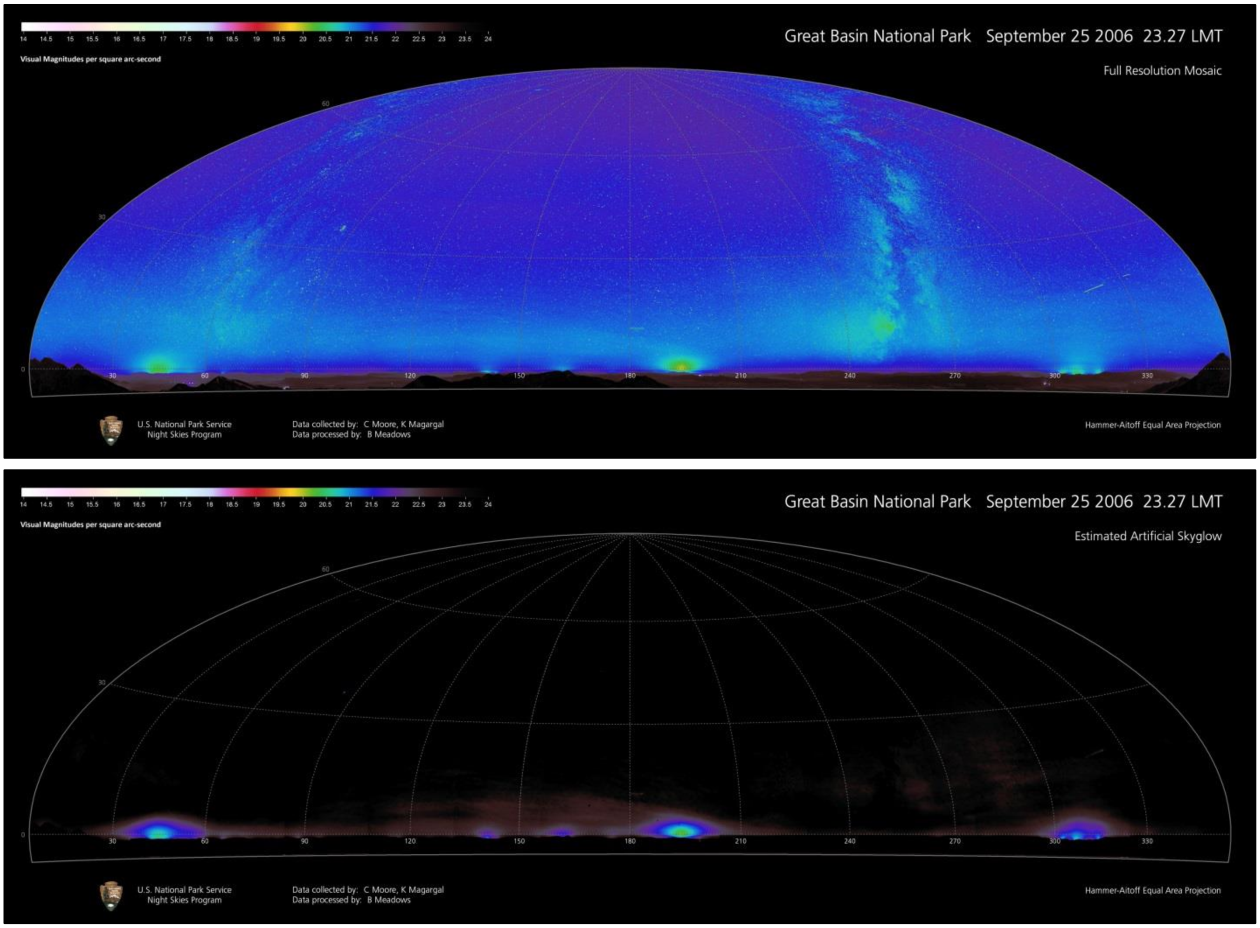


Figure 37. Great Basin NP night sky as measured and photographed on September 25, 2006. Along the horizon, the light glow on the left is from the Wasatch Front (Provo, Salt Lake City) (to the east of the park), the center glow is from Las Vegas to the south, and the right glow (much fainter) is from the nearby Ely/McGill area just to the west of the park. The path of the Milky Way can be seen arcing up and over the dome of the sky in the top figure. In the bottom figure, the natural light glow has been removed via a modeling process, leaving only the glow along the horizon of anthropogenic sources.

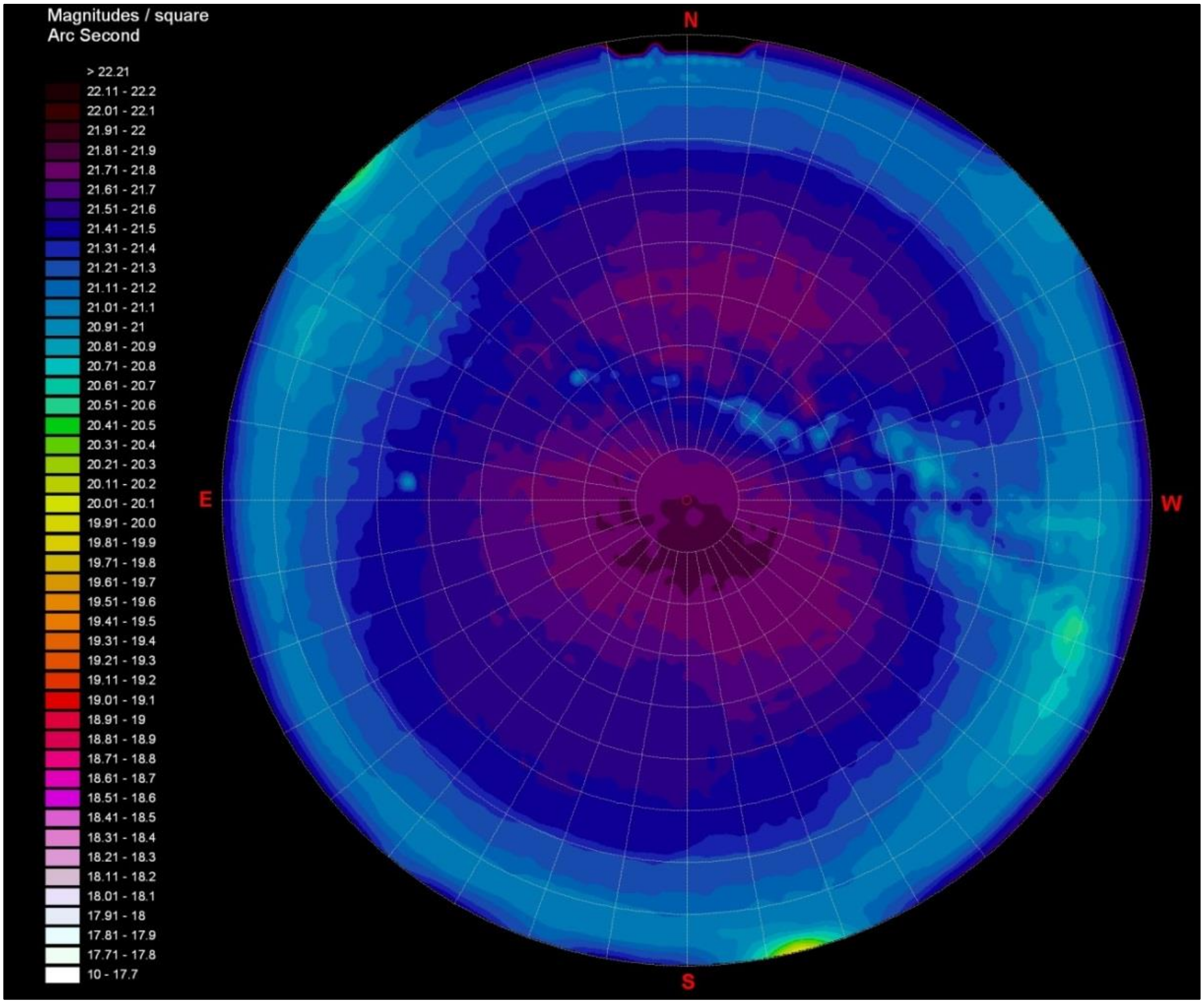


Figure 38. Great Basin NP light dome; view is the full hemisphere (fish-eye view), looking directly up into the overhead sky, as if lying down one's feet are pointing to the south. The artificial light domes on the horizon for Las Vegas (south by southwest), and Wasatch Front (northeast) can be seen on the edges of the fish-eye view. The darkest portions of the image are in the purple to dark purple colors directly overhead, and the Milky Way can be seen in the lighter blues arcing through the purple regions of the sky.

Trend

As can be seen in Figure 36, the park is located on the eastern edge of Nevada and the Great Basin region, which in general has very little light pollution. However, light pollution appears to be a global-scale problem affecting nearly every country of the world. Light pollution in the park's data is visible from cities as far away as Las Vegas, NV (over 185 miles (300 km) away). There is general widespread recognition that a continued degradation of night sky condition occurred over the past several decades (Cinzano 2002), and the night sky appears more seriously endangered than commonly believed (Cinzano et al. 2001). Furthermore, it is not surprising that the overall problem is more severe in the United States, Europe, and Japan, given their developed status. Although problems of light pollution might be perceived as primarily an urban problem, even our most pristine national parks are experiencing or are imminently threatened by light pollution (Duriscoe 2001).

Additionally, Cinzano (2002) examined changes in night sky brightness based on published measurements taken between 1947 and 2000. His analysis indicates a rapid increase in artificial night sky brightness; although he points out this conclusion is based on an overall average that cannot reliably be extrapolated to a specific rate of change at a given location.

It is for this reason that the trend for Great Basin NP is listed as a downward trend in condition – recent decades have seen increased light pollution, new sources of artificial light are being added, and the population centers contributing to anthropogenic light continue to grow. However, it should be recognized that this is within a context of overall global declines in the quality of the night sky. Without landscape-scale conservation efforts and a much higher awareness of the problem of light pollution, night sky degradation is likely to track with (or be in excess of) population growth.

Table 21. Summary of indicators of condition for night sky.

Night Sky			
Indicators of Condition	**Specific Measures**	**Condition Status/Trend**	**Rationale**
Anthropogenic light ratio	This is a quantitative measure that measures total sky brightness averaged across the entire sky and compares that value to natural nighttime light levels		The ALR is among the lowest measured or modeled for any non-urban parks and is considered excellent condition. The trend is downward, as recent development in large population centers to the east and south of the park is occurring and light pollution will become more of an issue in the future.
• Sky brightness • Maximum sky brightness • Minimum sky brightness • Integrated whole sky • Integrated sky above 20	This is a quantitative measure that assesses the sky brightness using four different parameters, including night light pollution along the horizon.		Sky brightness values are among the best measured in any NP in the lower 48, but still indicate some light pollution on the horizon from cities and towns. The trend is downward, as more development is occurring and light pollution will become more of an issue in the future.
Bortle dark-sky scale	Qualitative measure that uses a scale divided into nine classes; based upon how viewable certain features of the night sky are for astronomers, including the Milky Way, constellations, and even the nighttime scene.		Bortle Class 2 indicates a good condition night sky. The trend is unknown, as no measured values for recent years are available. Confidence is medium due to no trend data.

Table 21 (continued). Summary of indicators of condition for night sky.

Night Sky			
Indicators of Condition	**Specific Measures**	**Condition Status/Trend**	**Rationale**
Limiting magnitude	A qualitative measure that local astronomers use to assess the brightness of the faintest stars to the naked eye.		The limiting magnitude value of 7 also indicates a good condition night sky. The trend is unknown, as no measured values for recent years are available. Confidence is medium due to no trend data.

Key Uncertainty

The Bortle Dark-sky Scale and Limiting Magnitude estimations have the principle drawback in that they rely upon human visual observers and have the attendant bias. Differences in visual acuity as well as time and effort expended can influence the estimates of LM (Bortle 2001, Moore 2001). The CCD camera system and photometric measurement of night sky brightness is highly precise, but is nevertheless affected by vagaries in the atmosphere and in fluctuations in natural night sky brightness (Duriscoe et al. 2007, Duriscoe 2013). Research is underway to minimize the influences of these factors upon the quantification of artificial light; and existing data can eventually be post-processed to this new standard (Duriscoe 2013).

Sources of Expertise

Chad Moore, Program Manager for the NPS Natural Resources Program Center, Natural Sounds and Night Skies Division and his colleague Dan Duriscoe provided information pertaining to Great Basin NP's night sky methodology and results. Moore is the program manager for a small team of scientists that measure, restore, and promote the proper management of the night sky resource. He and team member, Dan Duriscoe, have developed an automated all-sky camera capable of precise measurement of light pollution. For the past few years they have been inventorying and monitoring the night sky at several US national parks. Staff of Great Basin NP provided information on current night sky and astronomical programs at the park.

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4.1.5. Rock Glaciers

Indicators / Measures

- *Rock Glacier Size*
- *Rock Glacier Elevation*
- *Rock Glacier Height*
- *Thermokarst Features*

Condition - Trend

Moderate Concern –
No Trend –
Low Confidence

Figure 39. Rock Glacier in Lehman Cirque (photo by John Van Hoesen, 2001).

Background and Importance

Throughout the Pleistocene, glaciers occurred in the South Snake Range. A diverse array of subalpine glacial landforms and features are preserved in Great Basin NP. Maps of glacial features indicate that glaciers flowed down Lehman, Baker, and Snake creeks, and small independent glaciers occurred from Bald Mountain in the north to Granite Peak in the south. Ice during older Pleistocene glacial advances descended to between 8000 and 8300 feet (2440 and 2530 m) in major drainages, and the longest glaciers were approximately 4 miles (6.4 km) long (Osborn and Bevis 2011).

Subalpine glacial lakes, known as tarns, play a significant role in the ecosystem of the park and in the monitoring of climate change. Four tarns fill glacial cirques in the park and include: Stella, Teresa, Baker, and Johnson lakes. Additional glacial features at Great Basin include cirques, moraines, bergschrund, arêtes, horns, and kettles. Glaciers were first described from field observation in the South Snake Range by William Eimbeck of the Coast and Geodetic Survey in August 1883. Subsequent description of glacial features in Lehman Cirque was provided in 1955 by Weldon Heald, Drewes (1958), Whitebread (1969), and (Piegat 1980). The South Snake Range includes the only remaining glacier ice in the Great Basin east of the Sierra Nevada. The Wheeler Peak glacier is the one remaining, albeit quite small, glacier within the park (Olsen and Bevis 2001). As noted by Olsen (1990) the presence of glaciers in the Great Basin, otherwise surrounded at lower elevation by desert, offers a number of potential themes for natural history interpretation, including how and why glaciers have formed and changed over geologic time.

Rock glaciers are rock debris that either bury an ice glacier and/or are frozen in interstitial ice; some would describe them as glaciers covered by talus (Graham 2014). Often in subalpine cirque basins where there are permafrost conditions and glacial ice is slowly receding, rock glaciers can form when rock debris falls from adjacent cliff faces on top of glacial ice. The water source for rock glaciers may be either surface snowmelt or ground water, and so rock glaciers typically form within existing rocky talus. Once sufficient ice has accumulated, weight propels their flow downslope as interstitial ice deforms and creates tongue-shaped bodies. Advancing rock glaciers will typically have a steep sloping front with an angle of repose of 30-40^{o}. Due to a lack of continued input of snow and ice, the lower segment of an ice glacier may stagnate while the upper portion remains active. With insulating properties of the rock debris, rock glaciers may persist, and even advance after clean glaciers have retreated in response to warming temperatures. Rock glaciers that do not move are considered to be “fossil” glaciers. An ice-cemented rock glacier will tend not to change shape once its ice core is gone, but if the ice core is in the process of melting, the rock glacier may deflate and form pitted thermokarst features on its surface, where sinkholes of debris collapse to fill the void left by ice melt. Rock glaciers were included in this assessment because change in their shape and location could indicate substantial change in climate at higher elevations of the park.

There are at least seven identified rock glaciers in the park, covered by rock debris of Prospect Mountain Quartzite (Figure 40). Four of the rock glaciers described in detail are located in Lehman Cirque (red arrow), North Fork Baker Cirque (orange arrow), Teresa Cirque (blue arrow), and on the northwest slope of Jeff Davis Cirque (yellow arrow) (Van Hoesen and Orlendorff 2011).

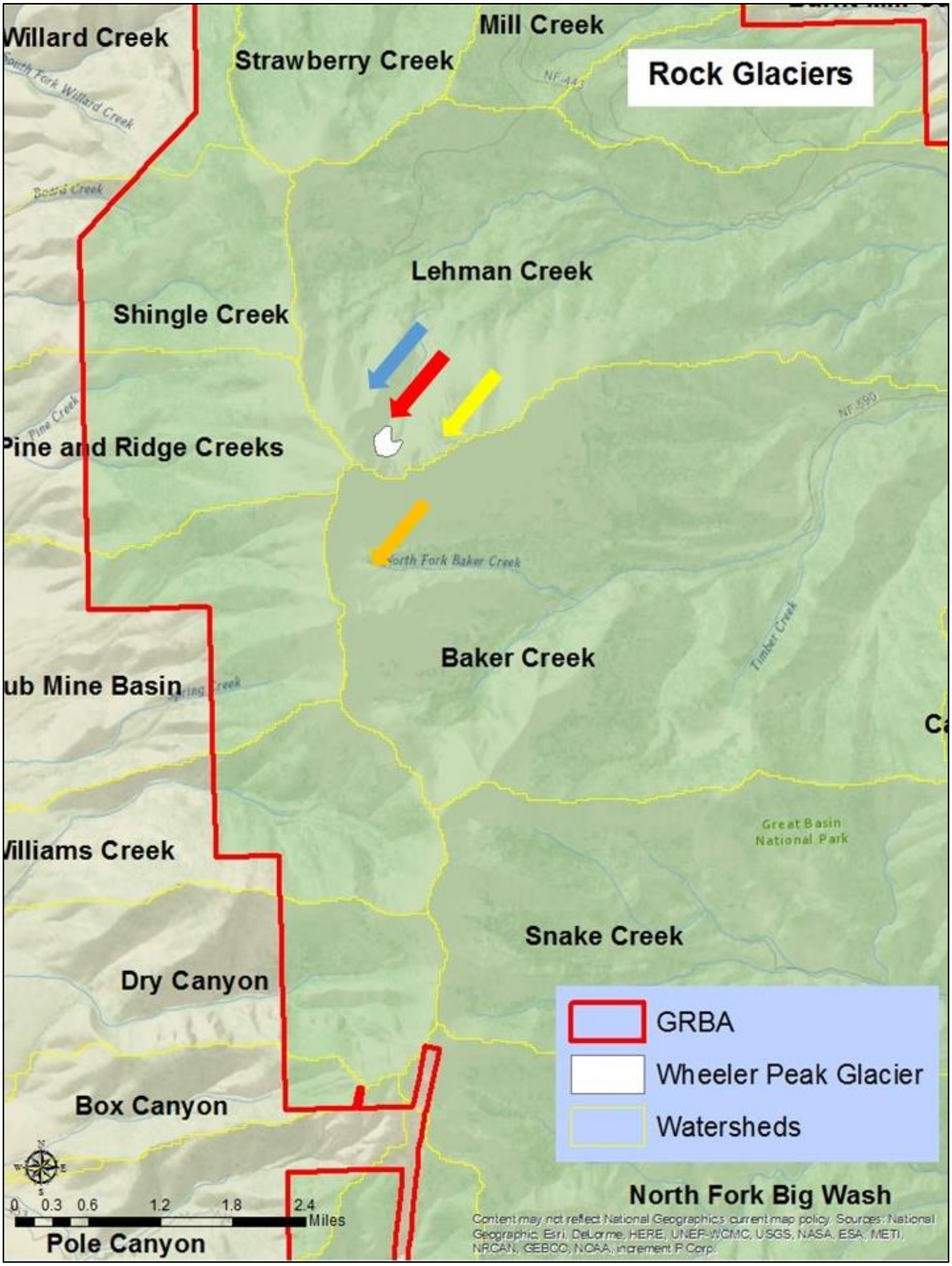

Figure 40. Major rock glaciers within the park.

Data and Methods

Indicators / Measures

- ***Rock Glacier Size***
- ***Rock Glacier Elevation***
- ***Rock Glacier Height***
- ***Thermokarst Features***

Olsen (1990) built on prior work by Piegat (1980) to provide a descriptive synthesis of knowledge for the rock glacier and other glacial features in Lehman Cirque, or as it was referenced there, Wheeler Peak Cirque. Olsen and Bevis (2001) provided addition context, discussing glacial features of the entire Great Basin. Olsen (1990) indicated that available evidence suggests that the Lehman rock glacier was likely formed during the later Holocene. This is evidenced by its placement relative to older glacial moraines and the current annual snowline, and the presence of volcanic ash from the Mono Craters eruption 1200 years ago. Following a common pattern in rock glaciers, the lower portions are oldest, as evidenced by a rounded form (rather than younger, blockier deposits), as well as plant establishment and lichen growth. Olsen (1990) interpreted field observations to indicate that segment to be younger than 1200 years in age. Relative location and lichen cover indicate a much more recent origin for the upper portion, perhaps from the "Little Ice Age" of 1300-1850.

John Van Hoeson completed field observations and mapping in 2000 and 2001 and documented the location and morphology of Lehman, North Fork Baker Creek, and Teresa rock glaciers. Van Hoesen and Orlendorff (2011) completed subsequent mapping and field verification of features of the Snake Range. Using 1-meter resolution aerial imagery from the National Agricultural Imagery Program, they interpreted and digitized periglacial landforms. Morphometric parameters of rock glaciers were calculated from the GIS map data. They also modeled solar radiation at elevations above 9,843 feet (3,000 m). They were able to document that areas of lowest solar exposure, or most consistently found in cooler, shaded conditions, would be most likely to support rock glaciers. This analysis provides a primary source of baseline information to tracking change in rock glacier location and extent with the park.

Reference Conditions

Overall rock glacier size, width, and the elevations of upper rooting and lower terminal points would be expected to change if ice cores and interstitial ice were melting or expanding. Rooting portions of a rock glacier typically occur closest to the upper cirque walls (the common source of rock debris) while terminal points are at the lower end of the glacial lobe. Prior to more substantial effects of melting, a deflation would likely occur, lowering the height of the upper glacier surface and subsequent pitted thermokarst features would likely appear or expand.

Following from descriptions and available measurements, primary indicators of changing conditions among Great Basin NP rock glaciers could therefore include a change in overall area, and elevation of upper rooting and lower terminal locations. Additional measures could include height, and the appearance (or expansion) of pitted thermokarst features. The latter two indicators could be derived through interpretation of repeat photography and field observation.

Table 22 provides baseline morphometry for rock glaciers within the park (Van Hoesen and Orndorff 2011). The Lehman rock glacier was mapped and measured in three lobes (Figure 41). In the figure, dashed lines indicate approximate elevation contours while solid arrowed lines indicate the edge of a rock glacier lobe. The upper lobe descends from the base of Lehman Glacier at about 11,982 feet (3,652 m) elevation for approximately 1,490 feet (454 m). The second lobe extends down slope another 869 feet (265 m) in elevation. The terminal lobe extends an additional 636 feet (194 m) to approximately 10,735 feet (3,272 m) elevation. Total area of these mapped units ranges from 23,450.05 m^2 to 116,938.84 m^2. (5.8 acres to 28.9 acres) All fall within the elevation range of 10,699 to 12,031 feet (3,261 to 3,667 m).

Table 22. Summary of site location characteristics for South Snake Range rock glaciers. Glaciers were characterized in a GIS using meters as the base unit of measurement; therefore, results were provided in meters.

Location *	~ Area (m^2)	~ Rooting elevation (m)	~ Terminal elevation (m)	~ Length (m)	~ Width (m)
NFBC	116,938.84	3,397	3,261	669	100
TC	27,320.00	3,319	3,260	142	280
LUL	81,993.78	3,667	3,374	454	206
LML	49,934.72	3,371	3,329	265	177
LLL	23,459.05	3,326	3,272	194	100
JDS	33,387.59	3,402	3,292	230	119

* NFBC = North Fork Baker Cirque; TC = Teresa Cirque; LUL = Lehman Upper Lobe’ LLL = Lehman Lower Lobe; JDS = Jeff Davis Slope; LML = Lehman Middle Lobe

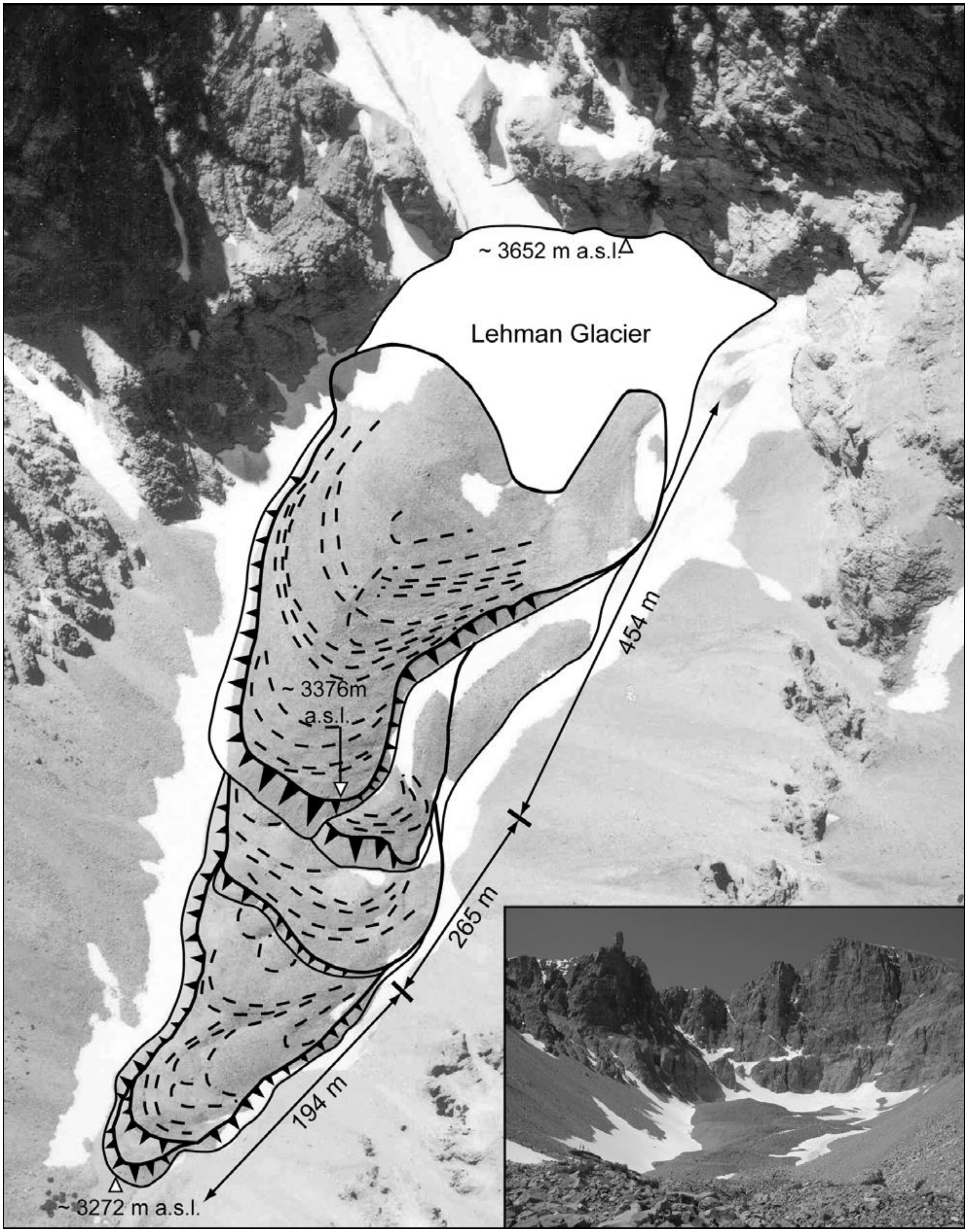

Figure 41. Morphometric map of Lehman rock glacier (from Van Hoesen and Orndorff 2011)

Condition and Trend

Upon review of past descriptions for glacial features in Lehman Cirque, Olsen (1990) concluded that the Lehman Glacier had thinned over the previous 30-40 years. He noted that the upstream limit of moderately thick rock debris cover stood higher than the ice headwall, while downstream ice had maintained its thickness. This interpretation was consistent with other measured trends in glacier recession while adjacent rock glaciers remained stable with warming temperatures. He predicted that, with increasing warming, there would be a deeper depression between the exposed ice headwall and the debris-covered rock glacier. This would be followed by the accumulation of debris from rock fall into that depression.

Van Hoesen (2003) used ground-penetrating radar on the lower parts of the Lehman rock glacier and concluded that it does not include an ice core, and is therefore made up solely of rock with interstitial ice. These observations, plus the detailed mapped inventory of Van Hoesen and Orndorff (2011), provide much baseline information for ongoing assessment. New investment in monitoring existing area and elevation parameters will be required to determine if any significant change is taking place. Additionally, baseline observations of rock glacier height and thermokarst features will be needed to further assess trends in condition into the future. Measurement of the size/volume of Lehman Glacier could also provide useful insight for monitoring condition of the adjacent rock glacier.

Table 23. Summary of indicators of condition for rock glaciers in the park.

Rock Glaciers			
Indicators of Condition	**Specific Measures**	**Condition Status/Trend**	**Rationale**
Rock Glacier Size	Areal estimate in m^2		Baseline measurements in place; no apparent indication of change reported
Rock Glacier Elevation	Rooting and terminal elevations		Baseline measurements in place; no apparent indication of change reported
Rock Glacier Height	Measured from repeat photography		Baseline measurements needed
Appearance of Thermokarst Features	Field interpretation and photography		Baseline inventory and measurements needed

At this time, interpretation of current condition and trends in the park's rock glaciers must remain qualitative, but there is currently little evidence suggesting that substantial change is occurring in the morphology of these rock glaciers. Repeat measurement will be required to detect trends in rock glaciers. As noted above, the input of ice is partially controlled by the size of the adjacent glacier which has been declining and is likely inactive. Given these observed trends in Lehman glacier, and potential climate change effects, moderate concern for these rock glacier features is warranted.

Sources of Expertise

John Van Hoesen, Dept. Environ. Studies, Green Mountain College, VT

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4.2. Upland Resources and Ecological Integrity

Focal resources in the upland landscape of the park include forests, shrublands, and populations of sensitive wildlife, such as bighorn sheep. By assessing the ecological integrity of these resources, one can gain insights into the changing conditions causing ecosystem stress and clarify options for management. Integrity assessment first involves identifying the key ecological attributes for each focal resource. Key ecological attributes include defining characteristics of a resource, its abundance, and its distribution; and key environmental associations, drivers, and constraints affecting the resource. The next step is to identify indicators for each key attribute and characterizing an expected or reference range of variation for each indicator. Once this range is characterized, one can then measure the status of each focal resource based on indicator data. Indicators may incorporate data using different levels of effort, from remote sensing, to ground-level rapid assessment, or ground-level intensive sampling. Below we address upland resources including aspen-mixed conifer forests, sagebrush steppe, along with wildlife regimes that are key ecological attributes of most upland vegetation in the park. We also assess bighorn sheep as an upland species that is sensitive to a range of resource conditions in the park.

In some cases, a direct assessment of common stressors provides an effective means to document status and trends in conditions affecting the integrity of multiple resources. Following a similar approach as applied to focus resource assessment, below we address introduced wild turkeys and invasive annual grasses.

4.2.1. Wildfire Regime

Condition - Trend

Moderate Concern – Deteriorating Trend – High Confidence

Indicators / Measures
- *Fire Extent*
- *Fire Regime Departure*

Background and Importance

Great Basin NP supports a diversity of ecological systems – alpine, forests, woodlands, shrublands, smaller herbaceous meadows, and riparian areas – along the steep elevation gradient of the Snake Range. Prior to the park's creation the southern Snake Range was managed by the U. S. Forest Service under a multiple use mandate. During that time, the fire management was under a total suppression paradigm. In addition to fire suppression, livestock grazing persisted within the park until 2009 (1999 for cattle, 2008 for sheep). As a consequence of these historic management actions, many ecological systems in the park have vegetation and fuels that are degraded compared to pre-settlement or more natural conditions.


Lincoln Canyon, Great Basin NP

Historically, the grasslands, shrublands, and woodlands of the Snake Range were structured primarily by fire driven by precipitation cycles, insect outbreaks, and with native grazing ungulates and Native American burning playing a role of an unknown importance. However, these roles have changed; the history of domestic livestock use and wildfire suppression has resulted in fires occurring at times, frequencies, and intensities that are outside of pre-settlement ranges (Blackburn and Tueller 1970, Brown and McDonald 1995, Schmidt et al. 2002, West et al. 2002, Beever et al. 2003).

While the longer fire-free intervals prevailing through the first half of the last century favored woody species, the regional invasion of cheatgrass (*Bromus tectorum* L.) in the 1950s has shortened fire-free intervals. Cheatgrass, a non-native annual grass, increased dramatically after historic livestock use reduced native bunchgrasses and forbs (Young et al. 1987, Young and Sparks 2002). In the park, annual grasses are mostly found at the lower elevations and up to about 8,000 feet (2,438 m) in elevation. Because native plant species do not survive the frequent fires facilitated by cheatgrass (Young et al. 1987), and have seedlings that do not compete successfully against cheatgrass for soil moisture (Melgoza et al. 1990), systems can move toward a cheatgrass monoculture nearly devoid of biodiversity values.

<u>Data and Methods</u>

Indicators / Measures

- ***Fire Extent***
- ***Fire Regime Departure***

In collaboration with Great Basin NP, The Nature Conservancy (TNC) of Nevada applied Landscape Conservation Forecasting™ to map potential vegetation and current vegetation, determine ecological departure, and define fire regime condition classes. This method was built upon the inter-agency LANDFIRE vegetation mapping and fire regime condition metric, to which was added uncharacteristic vegetation classes and state-and-transition simulation of management models (Low et al. 2010).

TNC modified the Fire Regime Condition methodology (hereafter referred to as ecological departure) developed under the national LANDFIRE program to assess the project area's ecological condition. Ecological departure is an integrated, landscape-level estimate of the ecological condition of terrestrial, riparian, and wetland ecological systems (Provencher et al. 2010). Ecological departure incorporates species composition, vegetation structure, and disturbance regimes to estimate an ecological system's departure from its natural range of variability (NRV). NRV is the percentage of each vegetation succession class that would be expected under a natural disturbance regime. Ecological departure is then measured using a scale of 0 to 100 where higher numbers indicate higher departure from NRV. In addition, since the cost and management urgency to address different uncharacteristic vegetation classes vary greatly, a separate designation and calculation of "high-risk" vegetation classes was also applied. High-risk vegetation classes include invasive species, conversions of vegetation type, or other uncharacteristic vegetation that is very expensive to restore. For condition assessment, the protocol included:

1) Use high-resolution satellite imagery and ground-truth the imagery via field surveys and conduct remote sensing to map current vegetation and succession classes.
2) Map biophysical settings (the dominant vegetation types expected to occur under a natural disturbance regime).
3) Determine the natural range of variation of successional states for each biophysical setting through modeling of pre-European settlement vegetation dynamics.
4) Determine ecological departure from the natural range of variation and percentage of high risk classes of each system.
5) Classify the ecological departure of each biophysical setting into fire regime condition classes (FRCC 1 = low departure at <34%; FRCC 2 = moderate departure from 34-66%; and FRCC 3 = high departure at >66%).

6) Classify the percentage of high risk vegetation as low (0%); medium (1-10%); high (11-30%); and very high (>30%).

Detailed methodologies for each of these steps are found in Provencher and Low (2011) and Provencher et al. (2010). Stands for vegetation types are characterized by similar plant species composition, differentiated from adjacent stands by a discernible boundary that may be abrupt or distinct. Stands are also characterized by structural integrity, with similar horizontal and vertical spacing of plant species. Vegetation type stands were identified using the remote sensing component of Landscape Conservation Forecasting™ applied to all biophysical settings in the park and then separated by watershed.

In order to measure the current (or future) ecological condition of each ecological system, it was first necessary to define the Natural Range of Variation (NRV) per biophysical setting. NRV is the relative amount (percentage) of each vegetation class in a given landscape that would be expected to occur in a biophysical setting under natural disturbance regimes and 20th century climate (Hann and Bunnell 2001, Provencher et al. 2007, Provencher et al. 2008, Rollins 2009). The NRV was calculated with the state-and-transition modeling software Vegetation Dynamics Development Tool (VDDT, ESSA Technologies, Barrett 2001, Beukema et al. 2003). To determine the NRV for each ecological system in the project area, TNC modified models from a TNC Great Basin and Mojave Desert ecoregion library developed in northwestern Utah, eastern Nevada, and California (Forbis et al. 2006, Provencher et al. 2007, Provencher et al. 2008, Provencher et al. 2009, Low et al. 2010). Ecological departure is a broad-scale measure of biophysical setting condition – an integrated, landscape-level estimate of the ecological condition of terrestrial and wet biophysical settings. Ecological departure incorporates species composition, vegetation structure, and disturbance regimes to estimate a biophysical setting's departure from its NRV.

Reference Conditions

Technically, ecological departure is a measure of dissimilarity between the NRV (expected "natural" distribution of vegetation classes) and the current vegetation class distribution. NRV for biophysical settings in Great Basin NP is summarized in Table 24. Ecological departure is scored on a scale of 0% to 100%: Zero percent represents NRV while 100% represents total departure. Further, a coarser-scale metric known as Fire Regime Condition Class (FRCC): FRCC 1 represents biophysical setting with low (<34%) departure; FRCC 2 indicates biophysical setting with moderate (34 to 66%) departure; and FRCC 3 indicates biophysical settings with high (>66%) departure (Hann et al. 2004). The abundance of uncharacteristic states is addressed only through the reduced extent of historical seral stages.

In order to document the relationship between recent disturbance and each vegetation type, mapped perimeters of wildfire were obtained and overlaid on each type distribution.

Table 24. Natural Range of Variation (NRV) expressed as a percentage of each successional class for all Great Basin NP biophysical settings.

Biophysical Setting	NRV					
	A[1]	B	C	D	E	U
Alpine	1	99				
Antelope Bitterbrush	21	44	21	7	7	0
Aspen Woodland	16	41	33	10		0
Aspen-Mixed Conifer	19	43	24	9	5	0
Aspen-Subalpine Conifer	12	33	47	8		0
Basin Wild rye	18	63	19			0
Black Sagebrush	17	47	24	10	2	0
Limber-Bristlecone Pine	9	12	78			0
Limber-Bristlecone Pine-moist	17	47	36			0
Low Sagebrush Steppe	25	56	19			0
Mixed Conifer	11	19	24	23	23	0
Montane Riparian	21	36	43			0
Montane Sagebrush Steppe-mountain	21	44	22	10	3	0
Montane Sagebrush Steppe-upland	21	44	22	10	3	0
Montane-Subalpine Grassland	4	30	66			0
Mountain Mahogany	8	13	15	23	41	0
Mountain Shrub	7	23	41	29		0
Pinyon-Juniper Woodland	2	6	26	65		0
Ponderosa Pine	11	2	29	57	1	0
Riparian Ponderosa Pine	26	9	47	17	1	0
Spruce	18	36	2	43		0
Subalpine Riparian	13	58	29			0
Wet Meadow	5	38	58			0

[1] Standard LANDFIRE coding for the 5-box vegetation model: A = early-development; B = mid-development, closed; C = mid-development, open; D = late-development, open; E = late-development, closed; and U = uncharacteristic.

Fire Regime Conditions

The park's terrestrial biophysical settings exhibit a range of departure from their natural range of variation due to fire exclusion, historic grazing, and other land use practices (Provencher et al. 2010). Table 25 shows the departure values and the percent of each BPS in a high risk class.

Based on an area-weighted calculation for the entire Great Basin NP, the park's terrestrial vegetation was rated as 42% departed or FRCC 2. Additionally, 8% of the park vegetation is in a high risk class. The primary cause of ecological departure was the lack or near absence of early-succession classes and an over-representation of later-succession classes. Uncharacteristic classes negatively influenced ecological departure scores and increased the percentage of high-risk classes. Figure 42 shows the Ecological Departure for the entire park.

Table 25. Ecological Departure and Percent of BPS in High Risk Classes for terrestrial BPSs within the park.

Biophysical Setting	Acres	% of project area	Percent Departure	Percent High Risk
Alpine	1,689	2.30%	0.1 [c]	0 [c]
Antelope Bitterbrush	336	0.50%	74 [a]	28 [b]
Aspen Woodland	567	0.80%	27 [c]	16 [b]
Aspen-Mixed Conifer	8,114	11.10%	66 [b]	6 [c]
Aspen-Subalpine Conifer	11,316	15.40%	60 [b]	7 [c]
Basin Wild rye	268	0.40%	68 [a]	43 [a]
Black Sagebrush	1,877	2.60%	60 [b]	39 [a]
Limber-Bristlecone Pine	1,991	2.70%	16 [c]	0 [c]
Limber-Bristlecone Pine-mesic	4,502	6.10%	48 [b]	0 [c]
Low Sagebrush Steppe	422	0.60%	61 [b]	0 [c]
Mixed Conifer	594	0.80%	32 [c]	0 [c]
Montane Riparian	452	0.60%	26 [c]	3 [c]
Montane Sagebrush Steppe-mountain	943	1.30%	30 [c]	2 [c]
Montane Sagebrush Steppe-upland	12,711	17.30%	56 [b]	21 [b]
Montane-Subalpine Grassland	271	0.40%	16 [c]	0 [c]
Mountain Mahogany	14,053	19.20%	23 [c]	0 [c]
Mountain Shrub	19	0.00%		
Pinyon-Juniper Woodland	6,947	9.50%	11 [c]	10 [b]
Ponderosa Pine	253	0.30%	54 [b]	0 [c]
Riparian Ponderosa Pine	171	0.20%	34 [b]	0 [c]
Spruce	5,768	7.90%	36 [b]	0 [c]
Subalpine Riparian	1	0.00%		- [c]
Wet Meadow	87	0.10%	49 [b]	0 [c]

[a] Rated as being of Signficant Concern (red).

[b] Rated as being of Moderate Concern (yellow).

[c] Rated as being Good (green).

Table 26. Current conditions in Great Basin NP for each BPS including: current acres in each vegetation class, current percent acres in each vegetation class, natural range of variation which represents the desired condition for each biophysical setting, and ecological departure.

BPS	Class [a]	A	B	C	D	E	AG	DP	NAS	SA	SAP	SD	SFE	TA	TE	TE/SA/SAP	Total
Alpine	Acres in Class	13	1,676	-	-	-	-	-	-	-	-	-	-	-	-	-	1,689
	NRV	1	99	0	0	0	0	0	0	0	0	0	0	0	0	0	100
	Current % in Class	1	99	0	0	0	0	0	0	0	0	0	0	0	0	0	100
	Ecological Departure																0
Antelope Bitterbrush	Acres in Class	0	2	36	56	23	-	17	-	-	121	-	-	-	59	22	336
	NRV	21	44	21	7	7	0	0	0	0	0	0	0	0	0	0	100
	Current % in Class	0	1	11	17	7	0	5	0	0	36	0	0	0	17	6	100
	Ecological Departure																75
Aspen Woodland	Acres in Class	39	263	82	91	-	-	92	0	-	-	-	-	-	-	-	567
	NRV	16	41	33	10	0	0	0	0	0	0	0	0	0	0	0	100
	Current % in Class	7	46	15	16	0	0	16	0	0	0	0	0	0	0	0	100
	Ecological Departure																27
Aspen-Mixed Conifer	Acres in Class	133	321	1,149	2,439	3,580	-	-	492	-	-	-	-	-	-	-	8,114
	NRV	19	43	24	9	5	0	0	0	0	0	0	0	0	0	0	100
	Current % in Class	2	4	14	30	44	0	0	6	0	0	0	0	0	0	0	100
	Ecological Departure																66
Aspen-Subalpine Conifer	Acres in Class	1,161	1,207	1,294	6,917	-	-	-	737	-	-	-	-	-	-	-	11,316
	NRV	12	33	47	8	0	0	0	0	0	0	0	0	0	0	0	100
	Current % in Class	10	11	11	61	0	0	0	7	0	0	0	0	0	0	0	100
	Ecological Departure																59

[a] Standard LANDFIRE coding for the 5-box vegetation model: A = early-development; B = mid-development, closed; C = mid-development, open; D = late-development, open; E = late-development, closed; see Provencher et al. (2010) for detailed explanation of type-specific successional stage codes.

Table 26 (continued). Current conditions in Great Basin NP for each BPS including: current acres in each vegetation class, current percent acres in each vegetation class, natural range of variation which represents the desired condition for each biophysical setting, and ecological departure.

BPS	Class [a]	A	B	C	D	E	AG	DP	NAS	SA	SAP	SD	SFE	TA	TE	TE/SA/SAP	Total
Basin Wild rye	Acres in Class	6	30	117	0	0	0	61	-	18	0	0	-	-	35	0	268
	NRV	18	63	19	0	0	0	0	0	0	0	0	0	0	0	0	100
	Current % in Class	2	11	44	0	0	0	23	0	7	0	0	0	0	13	0	100
	Ecological Departure																68
Black Sagebrush	Acres in Class	-	118	715	307	-	-	54	-	332	7	-	-	-	239	105	1,877
	NRV	17	47	24	10	2	0	0	0	0	0	0	0	0	0	0	100
	Current % in Class	0	6	38	16	0	0	3	0	18	0	0	0	0	13	6	100
	Ecological Departure																60
Limber-Bristlecone Pine	Acres in Class	64	61	1,866	-	-	-	-	-	-	-	-	-	-	-	-	1,991
	NRV	9	12	78	0	0	0	0	0	0	0	0	0	0	0	0	100
	Current % in Class	3	3	94	0	0	0	0	0	0	0	0	0	0	0	0	100
	Ecological Departure																16
Limber-Bristlecone Pine-mesic	Acres in Class	425	298	3,778	-	-	-	-	-	-	-	-	-	-	-	-	4,502
	NRV	17	47	36	0	0	0	0	0	0	0	0	0	0	0	0	100
	Current % in Class	9	7	84	0	0	0	0	0	0	0	0	0	0	0	0	100
	Ecological Departure																48
Low Sagebrush Steppe	Acres in Class	0	85	337	-	-	-	-	-	-	-	-	-	-	-	-	422
	NRV	25	56	19	0	0	0	0	0	0	0	0	0	0	0	0	100
	Current % in Class	0	20	80	0	0	0	0	0	0	0	0	0	0	0	0	100
	Ecological Departure																61
Mixed Conifer	Acres in Class	192	49	42	200	110	-	-	-	-	-	-	-	-	-	-	594
	NRV	11	19	24	23	23	0	0	0	0	0	0	0	0	0	0	100
	Current % in Class	32	8	7	34	19	0	0	0	0	0	0	0	0	0	0	100
	Ecological Departure																32

[a] Standard LANDFIRE coding for the 5-box vegetation model: A = early-development; B = mid-development, closed; C = mid-development, open; D = late-development, open; E = late-development, closed; see Provencher et al. (2010) for detailed explanation of type-specific successional stage codes.

Table 26 (continued). Current conditions in Great Basin NP for each BPS including: current acres in each vegetation class, current percent acres in each vegetation class, natural range of variation which represents the desired condition for each biophysical setting, and ecological departure.

BPS	Class [a]	A	B	C	D	E	AG	DP	NAS	SA	SAP	SD	SFE	TA	TE	TE/SA/SAP	Total
Montane Riparian	Class	A	B	C	D	E	AG	DP	DE	SA	SAP	SD	SFE	TA	TE	TE/SA/SAP	Total
	Acres in Class	25	111	298	-	-	1	-	11	-	0	1	4	-	-	-	452
	NRV	21	36	43	0	0	0	0	0	0	0	0	0	0	0	0	100
	Current % in Class	6	25	66	0	0	0	0	2	0	0	0	1	0	0	0	100
	Ecological Departure																27
Montane Sagebrush Steppe-mountain	Acres in Class	9	416	470	27	1	10	-	-	10	-	-	-	-	-	-	943
	NRV	21	44	22	10	3	0	0	0	0	0	0	0	0	0	0	100
	Current % in Class	1	44	50	3	0	1	0	0	1	0	0	0	0	0	0	100
	Ecological Departure																30
Montane Sagebrush Steppe-upland	Acres in Class	66	963	4,857	2,283	840	5	8	-	-	974	26	-	-	2,574	116	12,711
	NRV	21	44	22	10	3	0	0	0	0	0	0	0	0	0	0	100
	Current % in Class	1	8	38	18	7	0	0	0	0	8	0	0	0	20	1	100
	Ecological Departure																57
Montane-Subalpine Grassland	Acres in Class	2	47	221	-	-	-	-	-	-	-	-	-	-	-	-	271
	NRV	4	30	66	0	0	0	0	0	0	0	0	0	0	0	0	100
	Current % in Class	1	17	82	0	0	0	0	0	0	0	0	0	0	0	0	100
	Ecological Departure																16
Mountain Mahogany	Acres in Class	92	686	1,090	3,775	8,409	-	-	-	-	-	-	-	1	-	-	14,053
	NRV	8	13	15	23	41	0	0	0	0	0	0	0	0	0	0	100
	Current % in Class	1	5	8	27	60	0	0	0	0	0	0	0	0	0	0	100
	Ecological Departure																22

[a] Standard LANDFIRE coding for the 5-box vegetation model: A = early-development; B = mid-development, closed; C = mid-development, open; D = late-development, open; E = late-development, closed; see Provencher et al. (2010) for detailed explanation of type-specific successional stage codes.

Table 26 (continued). Current conditions in Great Basin NP for each BPS including: current acres in each vegetation class, current percent acres in each vegetation class, natural range of variation which represents the desired condition for each biophysical setting, and ecological departure.

BPS	Class [a]	A	B	C	D	E	AG	DP	NAS	SA	SAP	SD	SFE	TA	TE	TE/SA/SAP	Total
Mountain Shrub	Acres in Class	0	2	16	0	0	-	-	-	-	-	-	-	-	0	-	19
	NRV	7	23	41	29	0	0	0	0	0	0	0	0	0	0	0	100
	Current % in Class	0	12	85	1	2	0	0	0	0	0	0	0	0	0	0	100
	Ecological Departure																46
Pinyon-Juniper Woodland	Acres in Class	0	15	1,694	4,545	-	0	-	-	-	0	0	-	692	-	-	6,947
	NRV	2	6	26	65	0	0	0	0	0	0	0	0	0	0	0	100
	Current % in Class	0	0	24	65	0	0	0	0	0	0	0	0	10	0	0	100
	Ecological Departure																10
Ponderosa Pine	Acres in Class	1	0	70	40	141	-	-	-	-	-	-	-	-	-	-	253
	NRV	11	2	29	57	1	0	0	0	0	0	0	0	0	0	0	100
	Current % in Class	1	0	28	16	56	0	0	0	0	0	0	0	0	0	0	100
	Ecological Departure																55
Riparian Ponderosa Pine	Acres in Class	27	9	46	37	52	-	-	-	-	-	-	-	-	-	-	171
	NRV	26	9	47	17	1	0	0	0	0	0	0	0	0	0	0	100
	Current % in Class	16	5	27	22	30	0	0	0	0	0	0	0	0	0	0	100
	Ecological Departure																34
Spruce	Acres in Class	1,377	31	123	4,237	-	-	-	-	-	-	-	-	-	-	-	5,768
	NRV	18	36	2	43	0	0	0	0	0	0	0	0	0	0	0	100
	Current % in Class	24	1	2	73	0	0	0	0	0	0	0	0	0	0	0	100
	Ecological Departure																36
Subalpine Riparian	Acres in Class	1	0	0	-	-	-	-	-	-	-	-	-	-	-	-	1
	NRV	13	58	29	0	0	0	0	0	0	0	0	0	0	0	0	100
	Current % in Class	60	29	11	0	0	0	0	0	0	0	0	0	0	0	0	100
	Ecological Departure																48

[a] Standard LANDFIRE coding for the 5-box vegetation model: A = early-development; B = mid-development, closed; C = mid-development, open; D = late-development, open; E = late-development, closed; see Provencher et al. (2010) for detailed explanation of type-specific successional stage codes.

Table 26 (continued). Current conditions in Great Basin NP for each BPS including: current acres in each vegetation class, current percent acres in each vegetation class, natural range of variation which represents the desired condition for each biophysical setting, and ecological departure.

BPS	Class [a]	A	B	C	D	E	AG	DP	NAS	SA	SAP	SD	SFE	TA	TE	TE/SA/SAP	Total
Wet Meadow	Acres in Class	0	76	11	-	-	-	-	-	-	-	-	0	-	0	-	87
	NRV	5	38	58	0	0	0	0	0	0	0	0	0	0	0	0	100
	Current % in Class	0	87	13	0	0	0	0	0	0	0	0	0	0	0	0	100
	Ecological Departure																50

[a] Standard LANDFIRE coding for the 5-box vegetation model: A = early-development; B = mid-development, closed; C = mid-development, open; D = late-development, open; E = late-development, closed; see Provencher et al. (2010) for detailed explanation of type-specific successional stage codes.

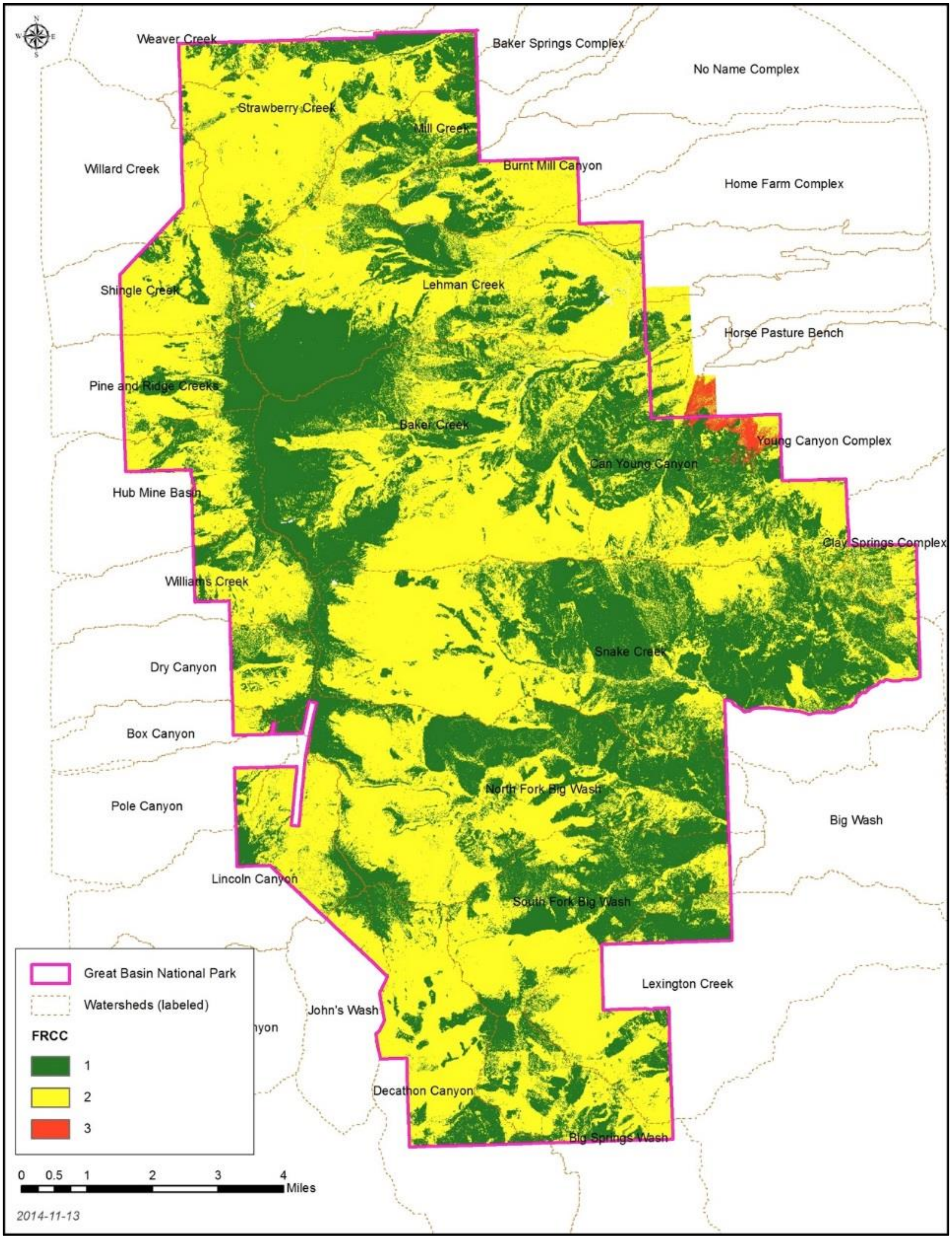


Figure 42. Fire Regime Condition Class as calculated by Provencher et al. (2010).

In general, the ecological departure in all systems was driven by two factors. First, there is an overabundance of the later (older) stages, C&D, and an under abundance of the earlier stages. Provencher et al. (2010) interpret this as a result of historical fire suppression preventing these older, closed stages from being reset to earlier seral states. Similarly, fire suppression has likely allowed for conifer encroachment into Aspen, Sage-steppe and other systems, resulting in a significant area being classified in the TE (tree encroached) state. Finally, cheatgrass has invaded much of the park below 8,000 feet (2,438 m) in elevation resulting in SA (Shrub/Annual Grass) and SAP (Shrub/Annual Grass/Perennial Grass) uncharacteristic states emerging in some BPSs.

Fire History and Extent

There have been 116 fires in or around the park since 1959, with 91 of those occurring inside the current park boundaries. There are fire perimeter data for fires occurring since 1999 (Figure 43). In 1999, the Big Wash fire started in the early fall. The Park allowed this fire to burn for resource benefit and it eventually burned approximately 40 acres (16 ha). In July 2000, the Phillips Ranch Fire burned 2,667 acres (1,079 ha) of mixed conifer, spruce and bristlecone. Approximately 1,704 acres (690 ha) of NPS lands and 963 acres (390 ha) of National Forest Service land were affected. High intensity burn areas included more than half of the total burned acreage. The Horse Heaven fire burned approximately 50 acres (20 ha) of mixed conifer in 2000. The Granite Fire started on August 18, 2001 and burned approximately 614 acres (248 ha) of mixed conifer and ponderosa pine at a high intensity. The fire burned 539 acres (218 ha) in Great Basin NP and 75 acres (30 ha) in the HNF. In addition, there have been two very small fires since 1999. Figure 43 shows the location of fire starts prior to 1999 and the burn perimeters for all fires since that time.

The frequency and extent of wildfire in the park remains what likely occurred under NRV. Since 1999, an average of 0.2% of the park has burned each year. If natural fire return intervals ranged between 50 and 100 years, between 1% and 2% of the park's vegetation should be impacted by fire annually.

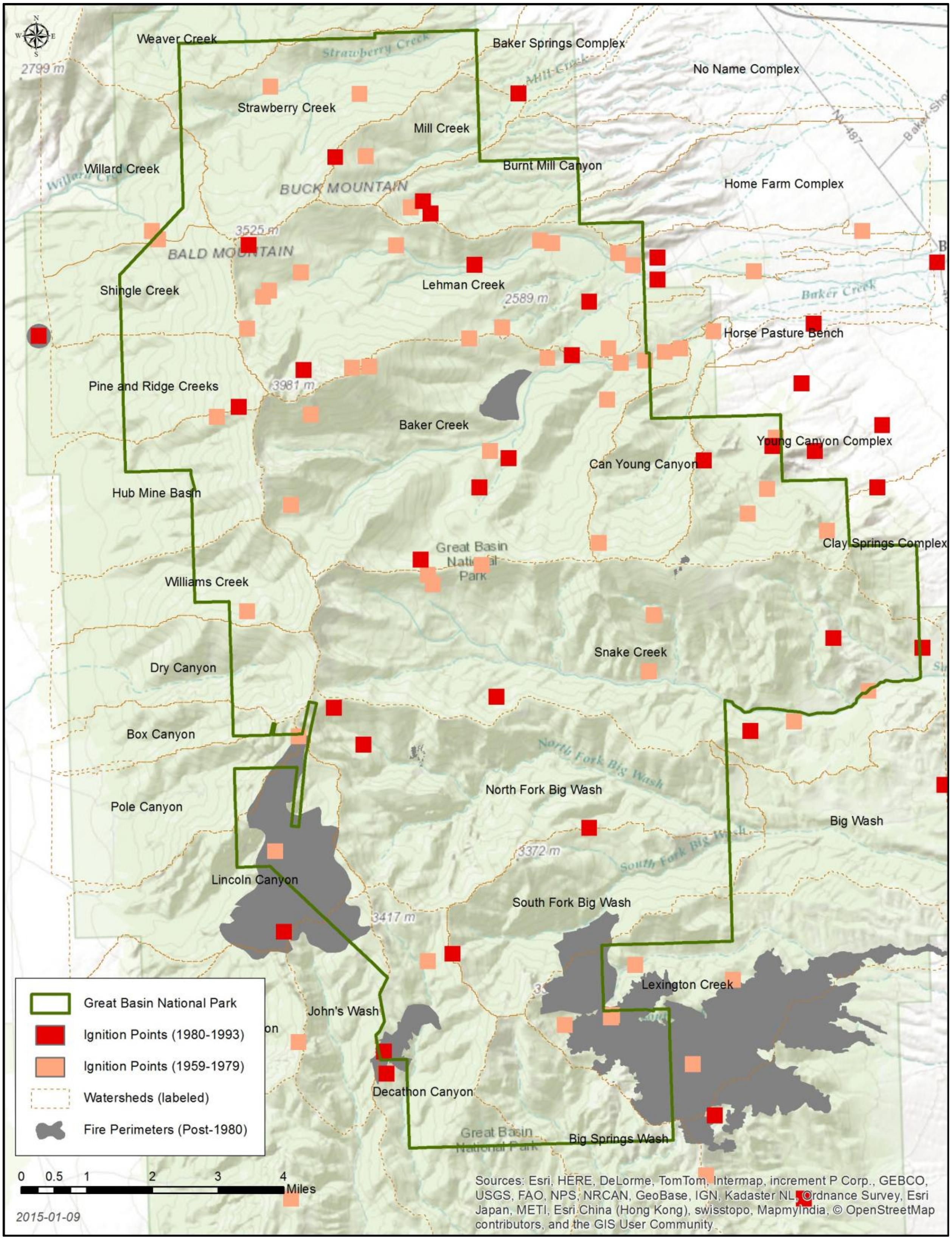


Figure 43. Wildfire ignitions and wildfire perimeters since 1980.

An Assessment of the Potential for Prescribed Fire Management within the Great Basin National Park

The use of prescribed fire to manage vegetation is often the most economical tool for restoring the NRV in western ecosystems. Prescribed fire can, when appropriately applied, mimic natural fire regimes or reduce fuel loadings sufficiently to allow for the return of natural fire regimes. However, the implementation of prescribed fire requires significant training, expertise, and experience. This is especially true in areas with complex topography, heavy fuel loadings, and few natural fire breaks. Great Basin NP has all of these complicating factors.

> *"According to Gruell et al. (1994), fire played a major role as an ecological factor in plant communities over the past several hundred years in Great Basin NP. A complex and variable fire history largely took place prior to 1860. Fire frequencies apparently varied considerably depending on aspect, topography, and ignition source. It appears that fires occurred at close intervals on north slopes, canyon bottoms, and in other localities where light surface fuels were sufficient to carry fire. Quantitative evidence suggests that north slopes in Snake Creek and Strawberry Creek had a burn interval of 20 years. Light surface fires promoted establishment and growth of grasses and other herbaceous fuels. These highly combustible fuels were vulnerable to frequent burning. The absence of fire for a decade or more would have allowed establishment of big sagebrush. These shrubs, along with other flammable vegetation, would have increased the odds of fire carrying into adjacent areas. It is evident that localized sites did not burn cleanly because of fuel discontinuity.*
>
> *Trees have encroached upon what was formerly a savannah, grassland, or shrub steppe. Evidence of this exists in the skeletal remains of shrubs in forest understory. Pinyon-juniper and white-fir encroachment is closely tied to the virtual absence of fire since the later 1800s. The cause of these profound successional changes can also be attributed to unrestricted livestock grazing between the late 1800s and about 1940. Blackburn and Tueller (1970) came to this conclusion after studying black sagebrush communities in the Burnt Mill locality of the Snake Range. Livestock undoubtedly had a major role in triggering changes through reduction of herbaceous vegetation, reduction in fine fire fuels, and disturbance of soils."* (Cristobal and Williams 2007)

In their Landscape Conservation Forecasting assessment for the park, Provencher et al. (2010) identified seven biophysical settings (BPS) that are departed from their natural range of variation as a result of changes in the fire regime. These are:

- aspen mixed conifer
- aspen subalpine conifer
- limber/bristlecone-mesic
- basin wild rye
- montane sagebrush steppe-upland
- black sagebrush
- low sagebrush

Figure 44 shows the location of each of these BPSs within the park. Longstanding nationwide policies to suppress all wildfires has resulted in a deficit in early successional stages and an overabundance of older, closed canopy, stages of all seven these systems. Fire suppression has also resulted in the accumulation of heavy fuel-loads which change fire behavior and more intense fires.

While is it possible to implement prescribed fire in almost any landscape (e.g., using aerial ignitions and limited control), controlled burns within Great Basin NP will likely require relatively small burn units and an emphasis on maintaining significant safety margins.

This assessment of prescribed fire potential was predicated on the need for safety, control, and protection of the resources. Based on a review of various prescribed fire planning documents and discussions with Burn Bosses, we have identified two safety criteria that help identify areas appropriate for implementing prescribed fire:

1) Slope. Fire intensity increases exponentially with slope and changes dramatically once slopes exceed 30% (Weise and Biging 1997). We have thus excluded all slopes >30% from potential prescribed fire as head fires on such slopes are dangerous and very difficult to control. Figure 45 shows all slopes <30% within the park.
2) Distance from a road. Because of the accumulated fuel loads within the park, fire managers will have to construct fuel breaks around each burn unit. Our consultation with Burn Bosses suggests that, depending on fuel type and topography, the difficulty in constructing fuel breaks increases with distance from roads and equipment. A general consensus was that implementing a prescribed fire in areas >0.5 mile (0.8 km) from a road would require significantly greater time and resources. Similarly, as distance from access points increase, the cost and challenge of suppression increases. Thus, we have created 2 buffers, one at 0.5 mile (0.8 km) and the second at 1.0 mile (1.6 km) for the parks roads. We believe that implementing prescribed fire beyond 1.0 mile (1.6 km) from a road would prove to be expensive and potentially dangerous to both fire managers and the resource. Figure 46 shows these 0.5 and 1.0 mile (0.8 and 1.6 km) buffers around the park’s roads.

We merged the shapefiles provided by Provencher et al. (2010) and clipped the result to the Great Basin NP boundary. The result included polygons for all 7 vegetation types. We clipped a 30-meter DEM (Digital Elevation Model) to the park boundary and used the result to create a slope raster. We converted the slope raster to a shapefile and extracted polygons with slope values ≤30%. Then we applied 0.5 mile and 1.0 mile (0.8 km and 1.6 km) buffers to the local roads shapefile provided by the park. Finally, we calculated the union of: 1) areas recommended for treatment with prescribed fire within the park, 2) areas with slopes ≤30%, and 3) areas within 0.5 mile or 1.0 mile (0.8 km and 1.6 km) of local roads.

<u>Condition and Trend</u>

Results for the intersection of all three conditions (Potential Areas) are illustrated in Figure 47 and Figure 48. These figures show that the Aspen Subalpine Conifer and Aspen Mixed Conifer BPSs in the northern part of the park have the greatest potential for implementing prescribed fire management.

There are occurrences of montane sagebrush steppe, low sagebrush, and basin wild rye BPSs that also occur within these buffers and could potentially be managed with prescribed fire. However, these occurrences are at significant risk of cheatgrass (and other exotic annual grass) invasion. In the Great Basin NP Fire Management Plan, Cristobal and Williams (2007) call for full suppression on all natural fires below 8,000 feet (2,438 m) in elevation to prevent cheatgrass from expanding further into the park. They also call for the park to limit prescribed fire below 8,000 feet (2,438 m) to prevent cheatgrass infestation unless vegetative analysis shows minimal risk on site and adjacent to the site.

Figure 49 through Figure 52 show the overlay of cheatgrass risk calculated for the park and the 8,000-foot (2,438 m) contour relative to those areas of potential prescribed fire management.

After accounting for access, risk, and probability of cheatgrass invasion, there are two areas in the park that seem to be appropriate for prescribed fire management: the aspen subalpine conifer occurrence and some associated aspen mixed conifer in the northern reaches of the park and the aspen mixed conifer stands at the headwaters of Snake Creek.

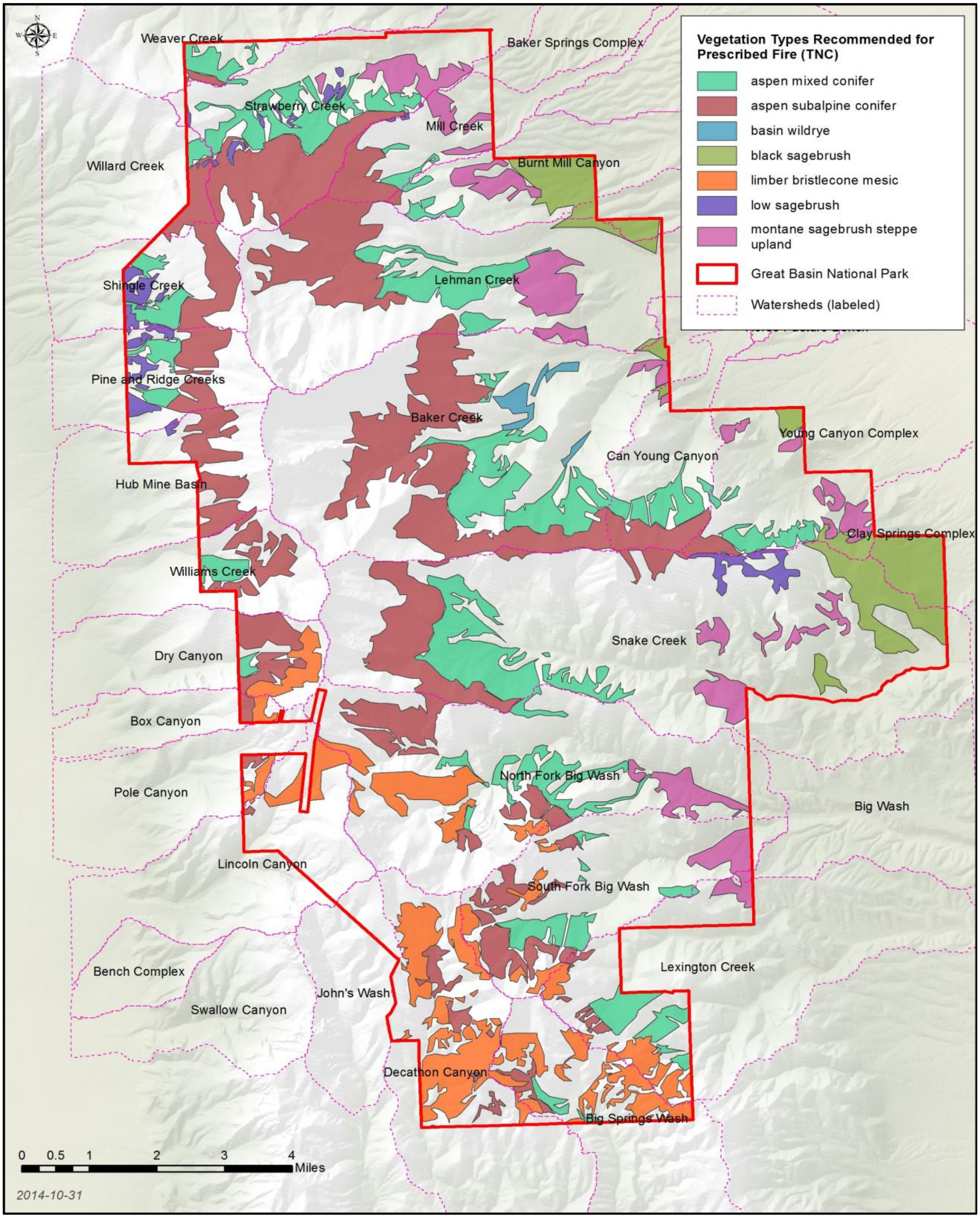


Figure 44. Vegetation types recommended for potential prescribed fire management by Provencher et al. (2010).

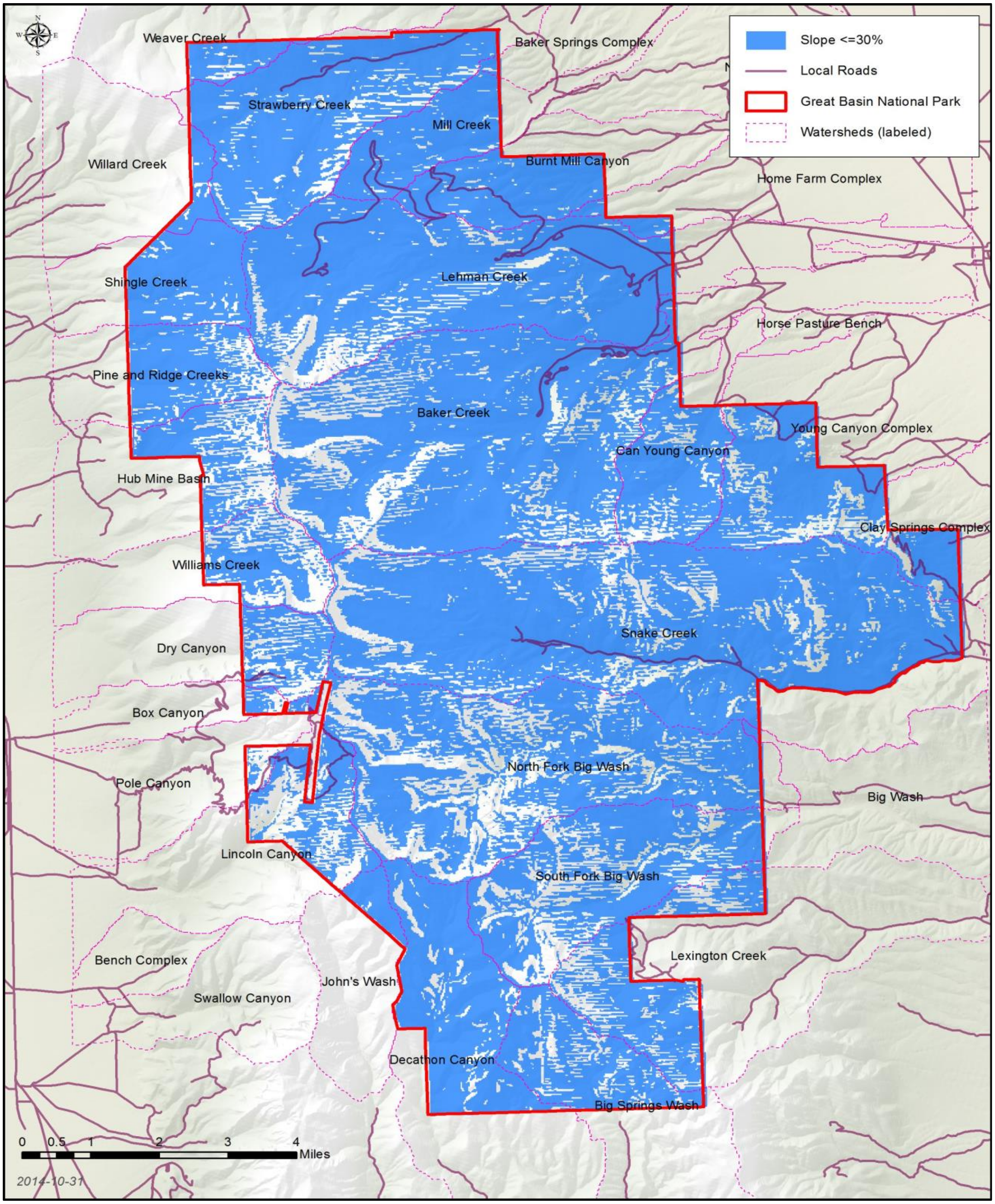


Figure 45. Areas within the park with slopes less than 30%.

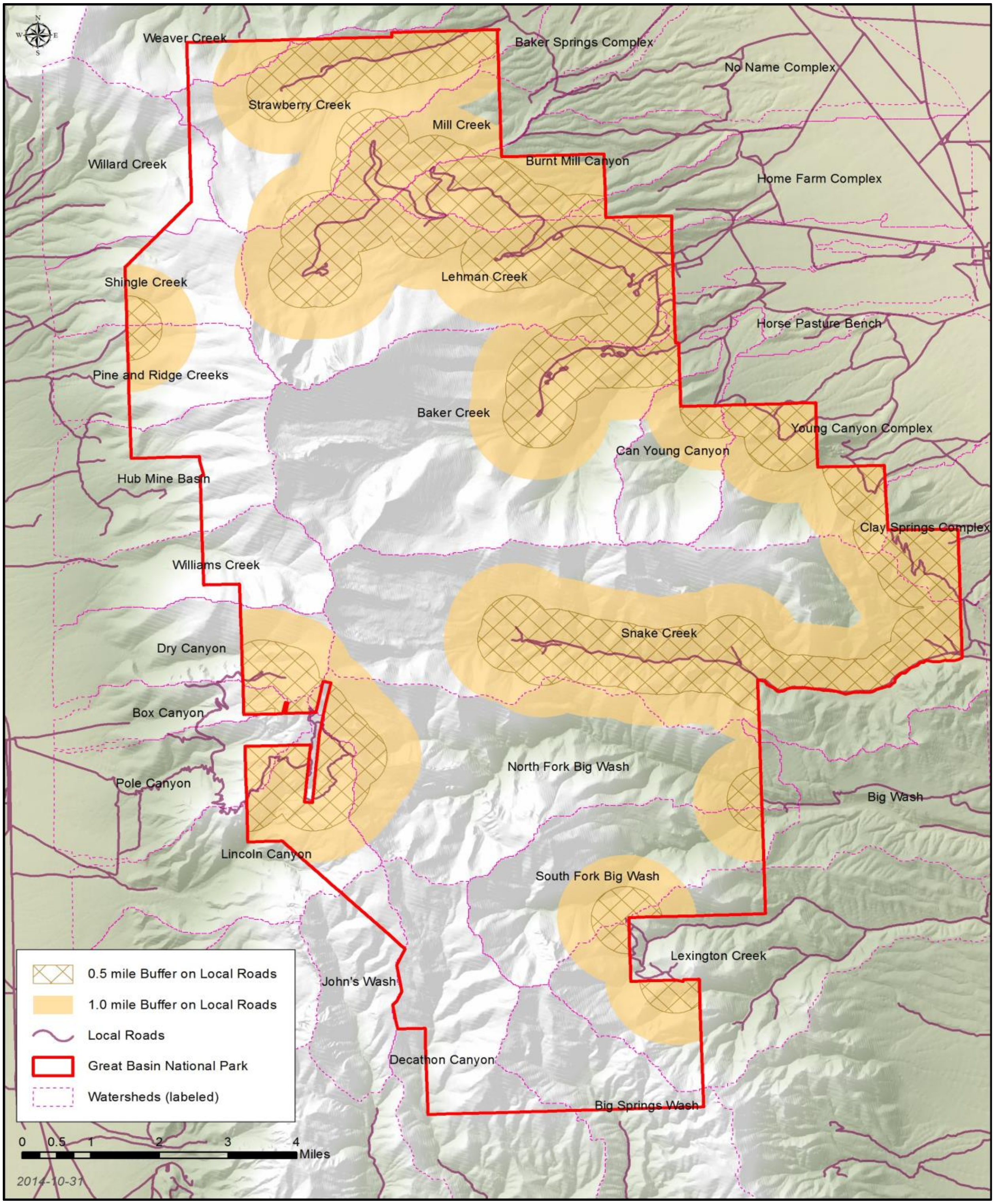


Figure 46. Areas within the park within 0.5 and 1.0 mile (0.8 to 1.6 km) of a road.

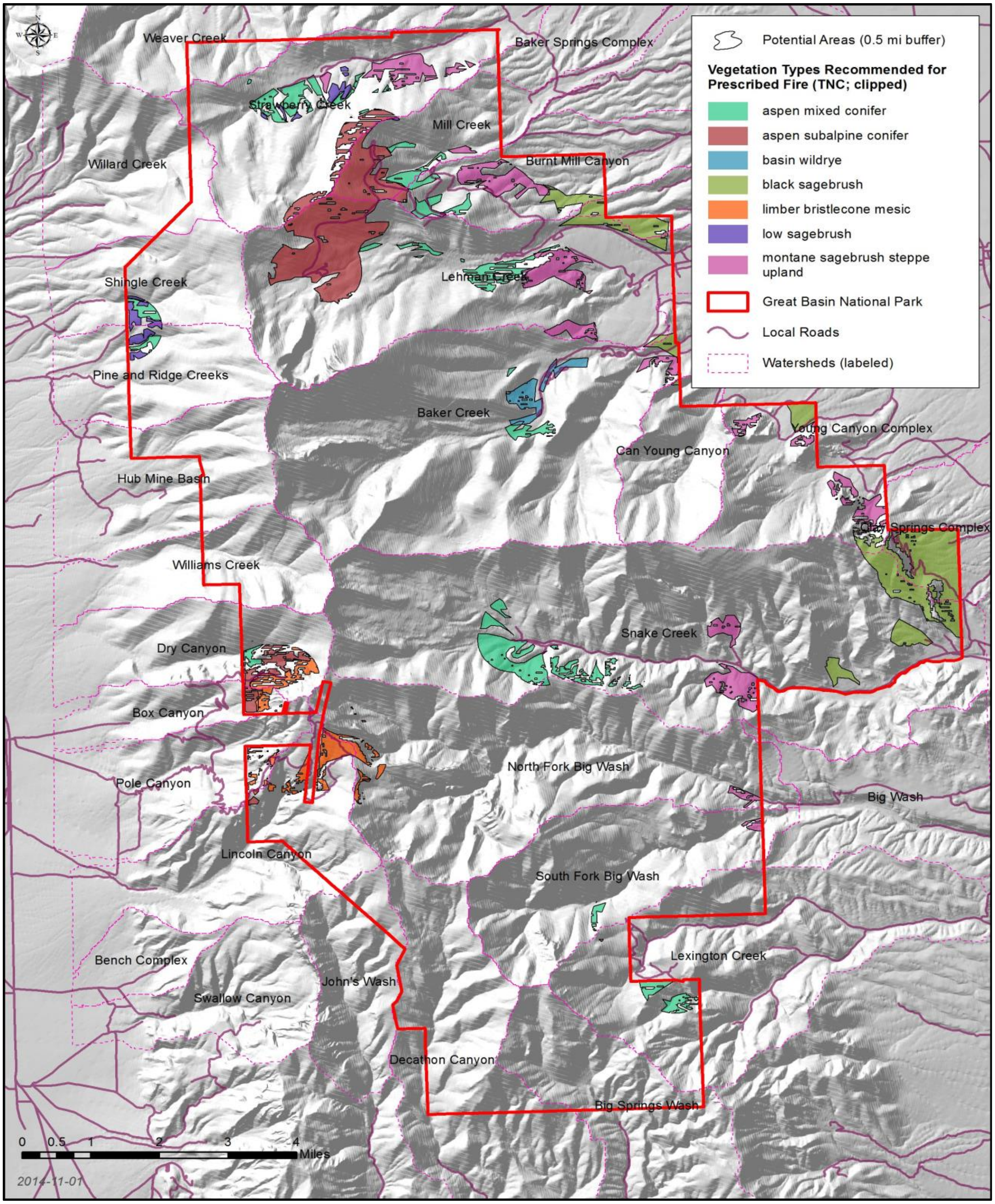


Figure 47. Overlay of areas for potential prescribed fire management, within 0.5 mile (0.8 km) of a road, relative to safety concerns. This figure shows all areas of possible prescribed fire management within 0.5 mile (0.8 km) of a road.

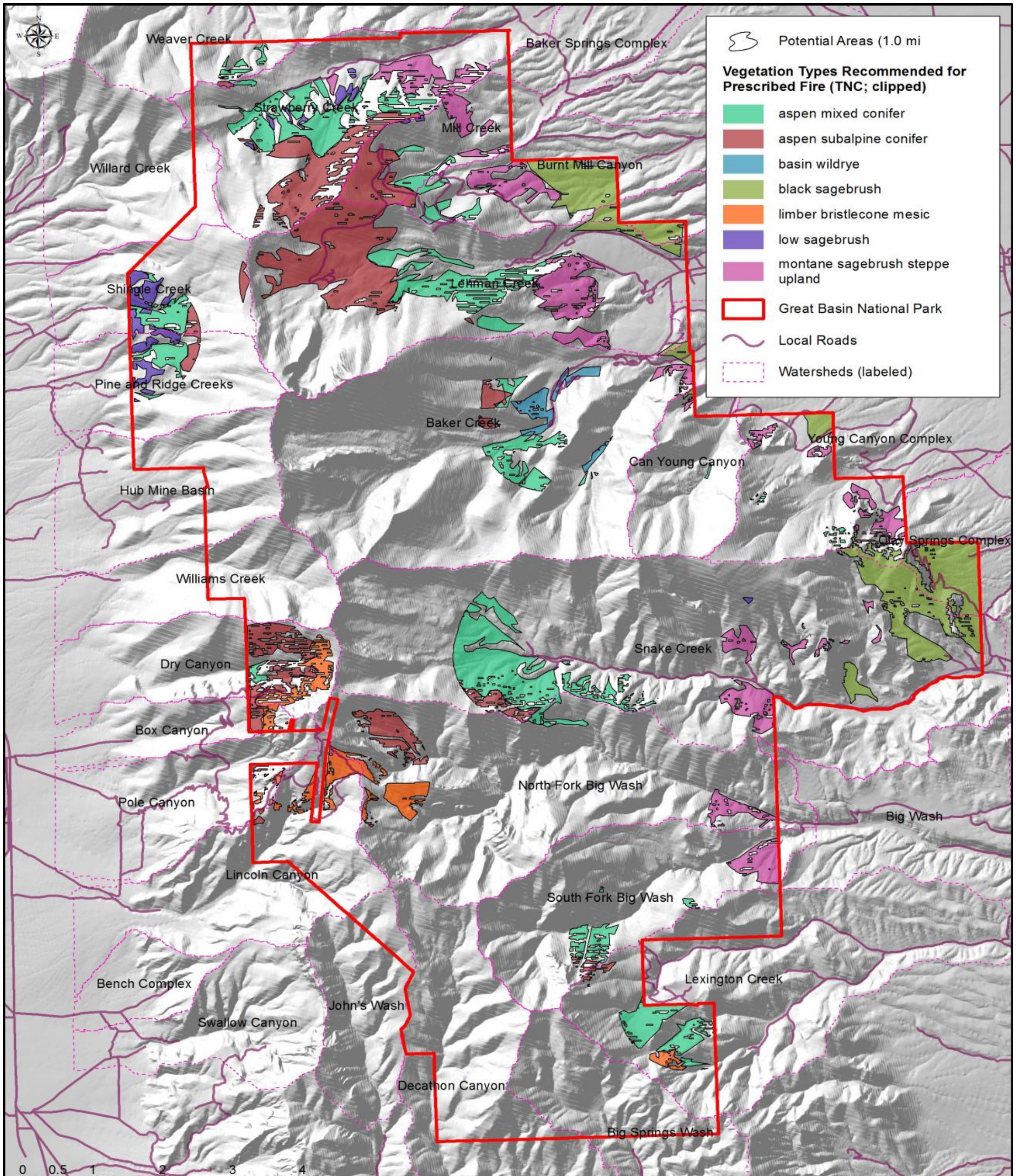


Figure 48. Overlay of areas for potential prescribed fire management, within 1.0 mile (1.6 km) of a road, relative to safety concerns. This figure show all areas of possible prescribed fire management within 1.0 mile (1.6 km) of a road.

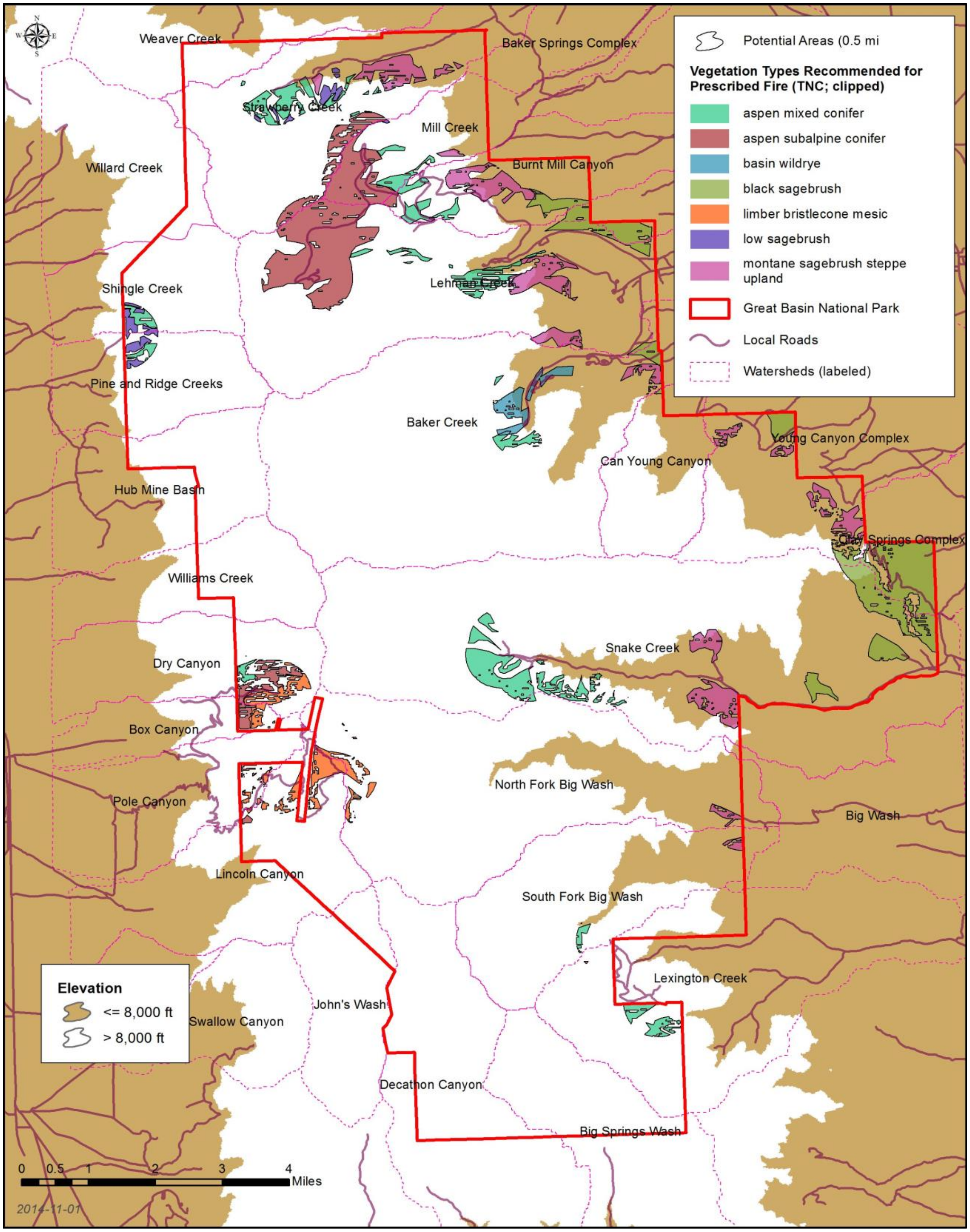


Figure 49. Overlay of areas for potential prescribed fire management within 0.5 mile (0.8 km) of a road with the relative risk of cheatgrass shown by the 8,000-foot (2,438 m) contour.

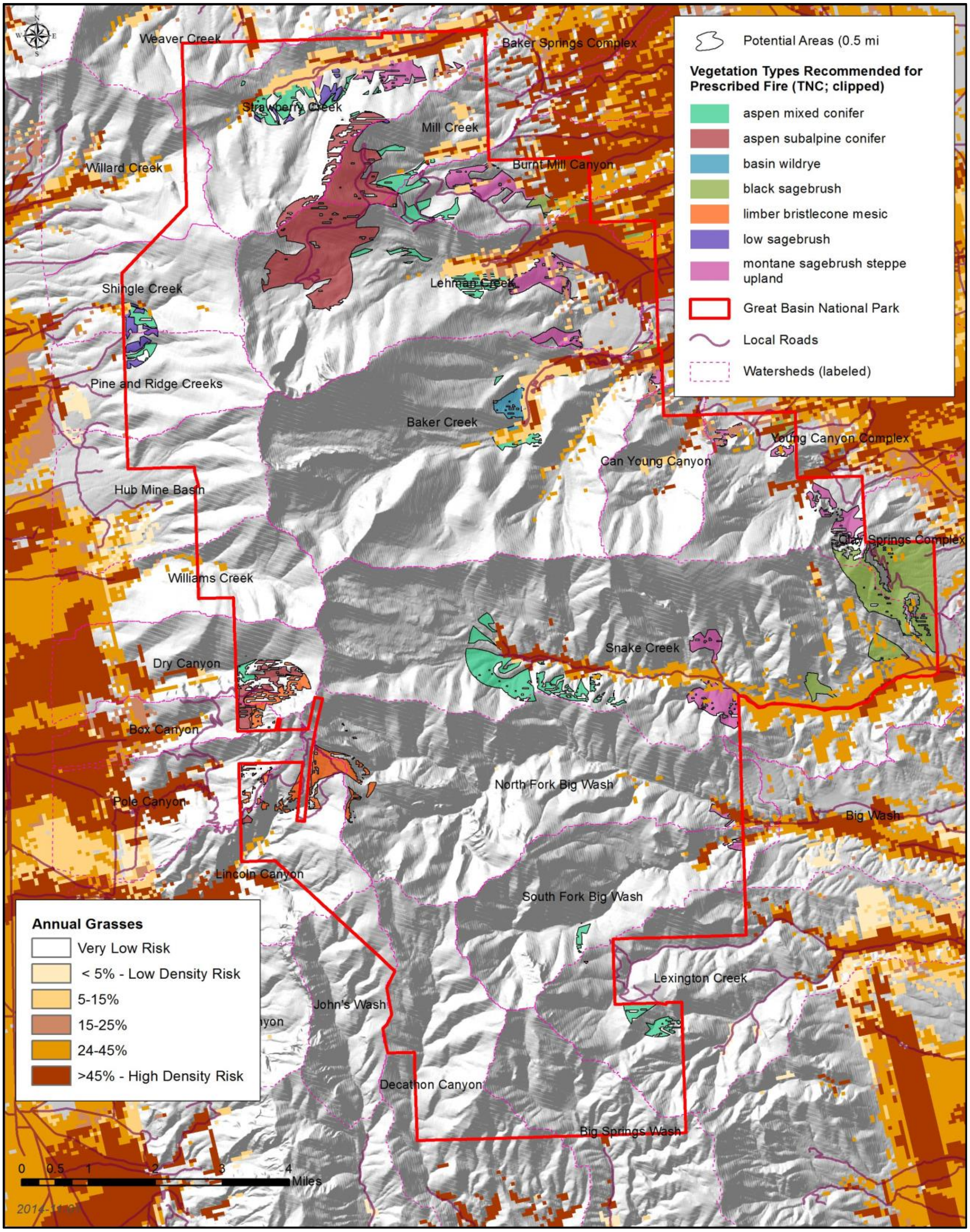


Figure 50. Overlay of areas for potential prescribed fire management within 0.5 mile (0.8 km) of a road with the relative risk of cheatgrass invasion based on the cheatgrass risk assessment.

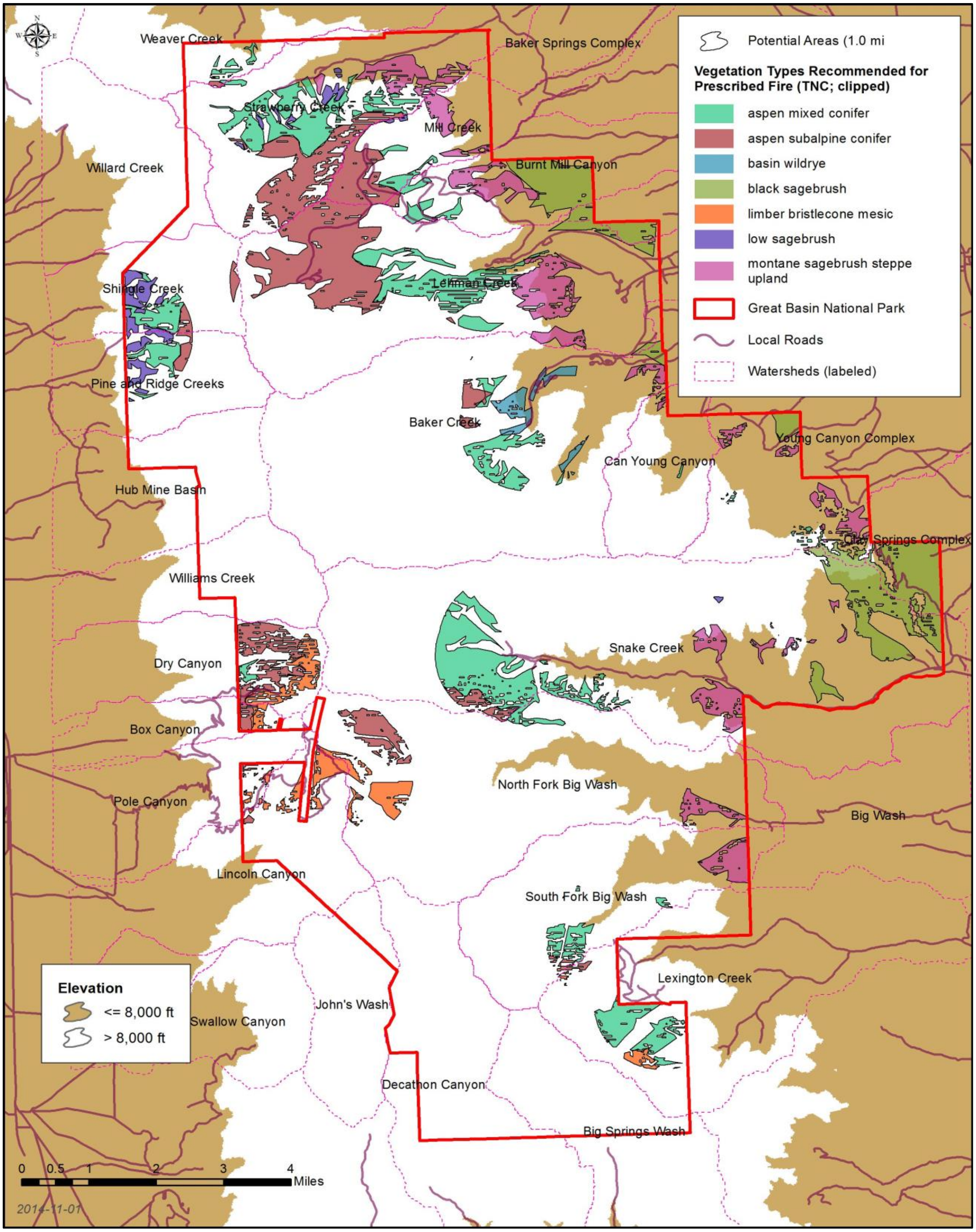


Figure 51. Overlay of areas for potential prescribed fire management within 1.0 mile (1.6 km) of a road with the relative risk of cheatgrass shown by the 8,000-foot (2,438 m) contour.

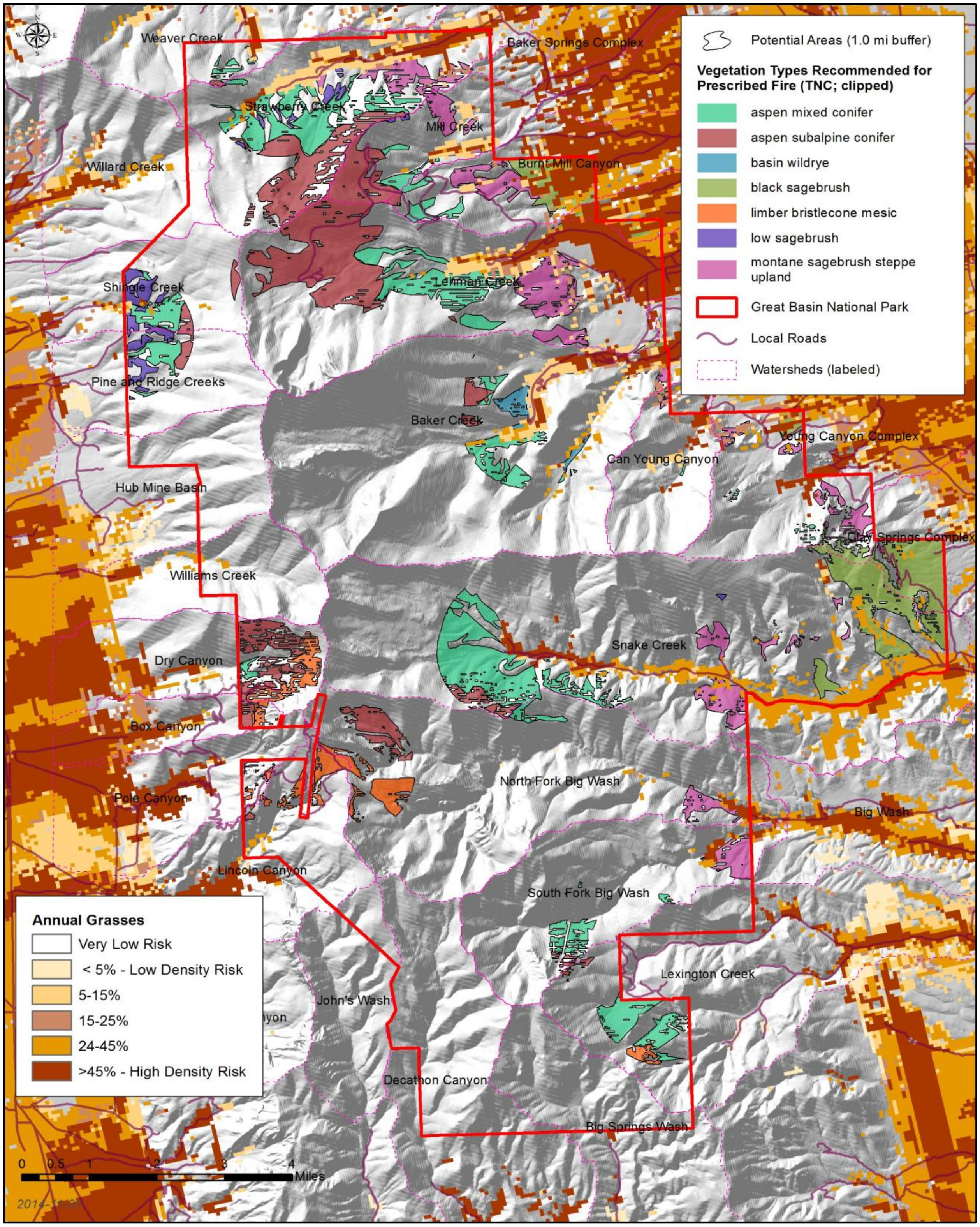
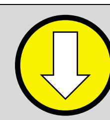
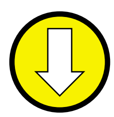
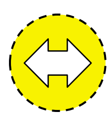


Figure 52. Overlay of areas for potential prescribed fire management within 1.0 mile (1.6 km) of a road with the relative risk of cheatgrass invasion based on the cheatgrass risk assessment.

Summary of Status

- The ecological condition of the park's terrestrial BPSs vary, ranging from 0.1% for Alpine to 74% departed for the Antelope Bitterbrush. On an area-weighted basis, the park's vegetation is 42% departed from NRV, which presents some concern.
- The current condition of most terrestrial systems in the park (i.e., percent departure from NRV) is due to an over representation of late successional classes; under representation of early classes. Two systems, Basin Wild rye and Black Sagebrush have a significant proportion of high risk classes.
- The current condition of the parks terrestrial systems is a result of the interaction of a number of historic stresses including inappropriate livestock grazing, the introduction of cheatgrass and historic fire exclusion.
- Under current management practices, these terrestrial systems will continue to increase their departure from NRV, and some form of disturbance is required to reset older stands back to early seral states.
- The rugged topography, remoteness of the landscape, and the potential for the expansion of cheatgrass limits the potential for using prescribed fire as a tool to restore NRV in many of the park's ecological systems. However, there are large stands of Aspen that could be managed using prescribed fire.

Table 27. Summary of indicators for condition of wildfire regime in Great Basin NP.

Wildfire Regime			
Indicators of Condition	**Specific Measures**	**Condition Status/Trend**	**Rationale**
Fire Regime Condition Class	Proportional extent of FRCC 2-3		Within Great Basin NP the area weighted average departure is 42%
Fire Occurrence	Area of Disturbance caused by wildfire.		Wildfire disturbance since 1980 has been ~3% of Total area of the parks terrestrial systems. This is ~0.25%/year, or approximately $1/5^{th}$ of NRV for the park

<u>Sources of Expertise</u>

This assessment was derived largely from the following sources:

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Jeremy Bailey, Associate Director for Fire Training, The Nature Conservancy and Michael Batcher, Fire Manager, provided guidance on the prescribed fire assessment.

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4.2.2. Aspen-Mixed Conifer Forest

Indicators / Measures

- *Fire Regime Condition Class*
- *Fire Occurrence*
- *Insect/Disease Outbreak*

Condition - Trend

Moderate Concern – Deteriorating Trend – High Confidence

Background and Importance

Material for this assessment was largely derived from the Great Basin NP Aspen Stand Condition Assessment (Horner et al. 2014).

Quaking aspen (*Populus tremuloides*) tends to occur within the park between 7,000 and 10,000 feet (2,133 - 3,048 m) elevation. It is associated with riparian corridors and higher elevation springs and occurs in mixed stands of mid-elevation and subalpine conifers, in avalanche scars and on talus slopes. Pure stands of aspen are rare in the park and typically occur with conifers and/or with sagebrush steppe. The total mapped acreage of all aspen systems in the park is 19,997 acres (8,092 ha), making aspen the largest vegetation type in the park. Three aspen systems include “stable aspen” (aspen woodland) at 567 acres (229 ha), “seral aspen” (aspen-mixed conifer) at 8,114 acres (3,284 ha), and “seral subalpine aspen” (aspen-subalpine conifer) at 11,316 acres (4,579 ha).

Aspen-dominated systems support a high diversity of flora and fauna (Kay 1997, Bartos 2001, Hamilton et al. 2009, Kuhn et al. 2011), and after riparian communities, provide the highest level of species diversity in arid environments (Kay 1997, Kuhn et al. 2011). Aspen communities have minimal species overlap with other vegetation types in the park and exhibit greater heterogeneity in plant composition at the site scale (Kuhn et al. 2011). Elk and deer depend on aspen stands and their productive understories for cover and forage. These communities also support a high abundance and diversity of invertebrates because they contain a higher diversity of understory plants than other forest types. Mature aspen stands provide habitat for breeding birds; and due to their susceptibility to certain diseases (e.g., heart rot), aspen stands provide nesting habitat for primary and secondary avian cavity nesters (Swanson et al. 2010). Aspen stands are also highly valued for their esthetic and recreational value throughout the semiarid West.

Not only do aspen stands support higher species diversity, they also maintain soil moisture, serve as natural fire breaks, and augment water yields. Aspen and other forested uplands are critical to watershed health because they regulate run-off and groundwater recharge (Rogers et al. 2001). Watersheds dominated by aspen release more water into stream channels and water tables than watersheds dominated by conifers and allow greater downstream water availability (Bartos and Campbell 1998, Hamilton et al. 2009). Aspen communities enhance stream bank stability, increased resistance to catastrophic flooding events, increased stream nutrient inputs and provide shade and cover for aquatic species (Swanson et al. 2010).

Quaking aspen is a relatively short-lived species, with individual trees reaching senescence around 100 years (Shepperd et al. 2006, Swanson et al. 2010). Although aspen can reproduce via seed, sexual reproduction is rare. Vegetative reproduction (i.e., cloning) allows aspen to persist during periods unfavorable to seedling establishment (Otting and Lytjen 2003). Aspen benefits from cloning versus seed propagation because new stems have access to stored carbohydrate reserves and an established root system. Being an early seral species, aspens respond well to disturbance (Rogers 2002, Swanson et al. 2010) and are often among the first species to reoccupy a recently disturbed site. Disturbance to roots or mature trees stimulates the production of new stems from underground root buds. Without disturbance, apical dominance (Schier et al. 1985) can also limit regeneration in older, mature aspen stands, and more shade-tolerant conifer species encroach, overtop, and replace aspen.


Aspen Stands

Aspen stands are declining in extent throughout the West. Substantial aspen dieback has been observed over the last fifteen years with recent, large aspen mortality events in southwestern Colorado and Arizona (Worall et al. 2008, Fairweather et al. 2008). Bartos (2001) reported declines in historic aspen ranges between 49% (Colorado) and 96 % (Arizona) and estimated a 60% decline in aspen acreage across all eight western states. These recent and wide-ranging declines in aspen suggest that current management strategies and climate conditions are affecting aspen vigor in many portions of its western range (Guyon and Hoffman 2011). Major factors contributing to aspen decline in western forests include: fire exclusion; competition with and shading by encroaching conifers; excessive browsing of aspen suckers by wild and domestic ungulates; and environmental stressors including drought, insects, and disease.

The greatest anthropogenic impact on aspen health over the last century has been the exclusion of fire and chronic overbrowsing (Bartos and Campbell 1998, Rogers et al. 2001, Kay 1997, Kitchen 2012, Heyerdahl et al. 2011). Historically, conifer encroachment and overtopping of aspen (i.e., successional decline) were balanced by disturbance, primarily fire, but also by insect outbreaks, disease and avalanches (Swanson et al. 2010). Successional decline has resulted in the deterioration and loss of aspen stands in many areas (Bartos 2008) including Great Basin NP where over a century of fire suppression and wild and domestic ungulate grazing has greatly decreased early seral stages of aspen and left park aspen systems vulnerable to conifer encroachment and loss of aspen clones.

Fire regimes changed in the Great Basin with Euro-American settlement when intense grazing and active fire suppression began and Native American burning practices ended (Kay 1995, Griffin 2002, Kitchen 2012). Since about1900, the beneficial effects of fire have been virtually absent from what is now Great Basin NP. Fire histories for one Great Basin NP watershed reveal the last large fire occurring in 1865 (Heyerdahl et al. 2011, Kitchen 2012). Before this time small, frequent fires in mid-elevation plant communities were common (Kitchen 2012) and maintained early seral plant communities and habitat heterogeneity. Fire suppression, along with favorable climate conditions, has shifted vegetation away from a range of seral states and community types and towards a preponderance of late-successional woody plant communities. As a result, conifer species have expanded and crowded out fire dependent species like aspen.

Declines in aspen forests have the potential to reduce local and landscape level plant species diversity and negatively impact other beneficial ecosystem functions aspen provide (Kuhn et al. 2011). Negative impacts include: 1) changes in fire frequency and intensity; 2) net loss in species diversity; 3) loss of soil stability, increased erosion and reduced nutrient cycling; 4) loss of productivity and forage and associated wildlife implications; 5) loss in resistance of aspen communities to non-native weeds, insects, and pathogens; and 6) loss of resiliency of communities to recover from disturbance and perturbations. Efforts by land managers to restore and conserve aspen communities will benefit biodiversity at local and landscape scales providing ecosystem resilience, productivity, nutrient retention and resistance to invasive plants (Kuhn et al. 2011).

In this assessment, we address management concerns regarding the current ecological integrity of aspen-related systems, the location of recent wildfires, the location of disease and insect outbreaks, and current knowledge of aspen regeneration.

Data and Methods

Indicators / Measures

- ***Fire Regime Condition Class***
- ***Fire Occurrence***
- ***Insect/Disease Outbreak***

One key ecological attribute for Aspen Mixed-Conifer Forests is fire regime, driving aspen regeneration and successional dynamics of aspen stands. One practical indicator for this key attribute is fire regime condition class. See 4.2.2.1 and Horner et al. (2014) for an explanation of methods used to measure fire regime condition class for these forests.

In order to document the relationship between recent disturbance and aspen regeneration, mapped perimeters of wildfire, insect, and disease outbreaks were gathered for comparison with 46 vegetation sample plot data located within aspen-related biophysical settings where they might indicate aspen regeneration. Fire event data through 2006 were obtained from the park were evaluated relative to aspen-related biophysical settings. Insect and disease damage maps from the USDA Forest Service Aerial Survey Detection efforts were compiled from 1991-2013. These polygons were merged in temporal groups (1991-2003 vs. 1991-2013). Those from the 1991-2003 period were combined with vegetation samples (largely derived from 2003 field work) in order to quantify the degree to which insect and disease events could have opened forest canopies and effected aspen regeneration.

Reference Conditions

The stable aspen biophysical setting supports woodlands (Figure 53) at middle and upper elevations in the park between 8,000 and 11,200 feet (2,438 - 3,414 m). Stable aspen in the park is often associated with springs, seeps or other riparian features. Soils are usually deep, well-developed and loamy. Stable aspen occurs on gentle to moderate slopes on all aspects, although some patches do occur on steeper slopes. Stable aspen stands typically contain older, more mature aspen stems with diverse understories. Understories include a variety of herbaceous and shrub species. Early-succession stands contain *Ribes* sp. and mountain snowberry with very little sagebrush. Conifers are usually present in this system after 40 years, but successional pathways do not lead to conifer dominance or conversion. Rather, succession leads to conversion from stable aspen to montane sagebrush steppe once mature aspen have reached senescence (~125 years). Without disturbance or some level of regeneration, sagebrush and bitterbrush dominate after 100 years as mature trees die off.

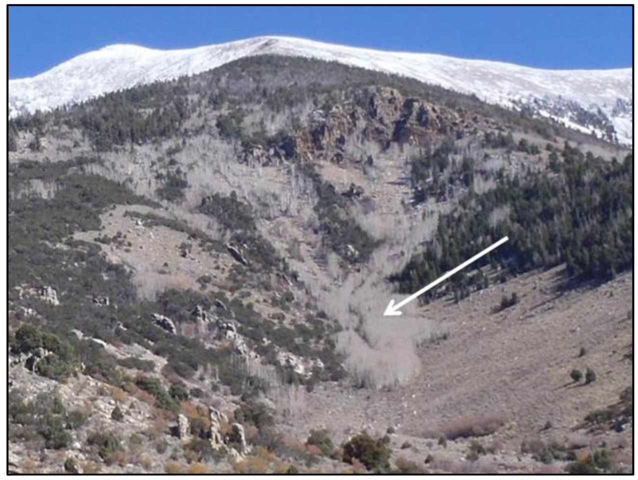

Figure 53. Stable Aspen Biophysical Setting (white arrow identifies aspen clone)

However this interpretation of common successional pathways and natural disturbance is not supported universally. Especially where this type occurs at higher elevations, stable aspen stands may not require severe disturbance events for self-replacement and stand health. Exclosure studies reveal that when protected from herbivory, stable aspen stands produce new shoots at a steady or semi-regular basis. The rate of sucker production increases when the overstory thins but is not comparable in number to the massive synchronized pulse of suckers that often follows a severe fire (20,000-30,000+ shoots per acre is common). The exclosure work confirms that when sufficient numbers of suckers are allowed to recruit into the overstory, the stand remains healthy and sagebrush and other shade intolerant shrub species are not a significant component. Fire is not required and it may be relatively unimportant for these stands. Finally, treatment of these stands (by fire or mechanical) could lead to loss of clones if browse pressure is too high (Kitchen pers. comm.).

Figure 54. Seral Aspen Biophysical Setting.

The Seral Aspen biophysical setting supports aspen-mixed conifer forests (Figure 54) at middle and upper elevations, typically between 7, 500 and 9, 500 feet (2,286 and 2,896 m), and cover 11% of the park (8,114 acres (3,284 ha)). It is the second largest park aspen system. Understories are diverse and include a range of shrubs, forbs and grasses. Common shrubs include *Ribes* sp., and mountain snowberry. Herbaceous cover is diverse and species composition is dependent on soil moisture and canopy cover. Conifers in this system are white fir and Douglas-fir. After 40 years, conifers are present in seral aspen stands. Without disturbance (e.g., fire, insect/disease dieback), conifers are dominant in this system after 100 years, but reach co-dominance after 80 years. Soils are usually deep, well-developed and loamy with seral aspen stands occurring on gentle to steep slopes on all aspects. In the park, seral aspen stands are often associated with riparian corridors. Fifty percent of seral aspen stands in the park are currently dominated by conifer (Provencher et al. 2010).

Table 28. Reference conditions by successional class for stable aspen biophysical settings.

Class Code [a]	Class Abbreviation and Description
A	*Early*; 0-100% cover of aspen <5 m (16 ft) tall; 0-9 yrs.
B	*Mid1-closed*; 40-99% cover of aspen <5-10 m (<16-33 ft); dense herbaceous and non-sagebrush shrub understory and midstory; 10-39 yrs.
C	*Late1-closed*; 40-99% cover of aspen 10-25 m (33-82 ft); few conifers in mid-story; dense herbaceous and non-sagebrush shrub understory and mid-story; >39 yrs.
D	*Late1-open*; 10-39% cover of aspen 10-25 m (33-82 ft); 0-25% conifer cover 10-25 m (33-82 ft); moderately dense herbaceous and non-sagebrush shrub understory and mid-story; >99 yrs.
U	*DP-Open*: 10-39% cover of older aspen 10-25 m (33-82 ft); no or little aspen regeneration; few conifers in mid-story; sparse understory and sagebrush often present
MSu-A to B	*Early & Mid1-Open*: Conversion to Montane Sagebrush Steppe-upland biophysical setting (see 1126u); 0-30% mountain big sagebrush or bitterbrush cover, 10-80% grass and forb cover.
Reference Condition: Natural Range of Variation	16%: A-Early 41%: B-Mid-closed 33%: C-Late-close 10%: D-Late-open 0%: U

[a] Standard LANDFIRE coding for the 5-box vegetation model: A = early-development; B = mid-development, closed; C = mid-development, open; D = late-development, open; E = late-development, closed; U = Uncharacteristic class (DP = depleted); MSu-A to B = conversion to montane sagebrush steppe-upland class A to B; MC-E = conversion to mixed conifer class E; and SP-D = conversion to spruce class D.

Table 29. Reference conditions by successional class for seral aspen biophysical settings.

Class Code [a]	Class Abbreviation and description
A	*Early*; 0-100% cover aspen <5 m (16 ft); mountain snowberry and *Ribes* common; 0-19 yrs.
B	*Mid1-closed*: 40-99% cover aspen <5-10 m (16-33 ft); mountain snowberry and *Ribes* common; 11-39 yrs.
C	*Mid2-closed*: 40-99% cover aspen 10-25 m (33-82 ft); conifer saplings visible in mid-story; mountain snowberry and *Ribes* common; 40-79 yrs.
D	*Late1-open*: 10-39% cover aspen 10-25 m (33-82 ft); 0-25% mixed conifer cover 5-10 m (16-33 ft); mountain snowberry and *Ribes* common; >80 yrs.
E	*Late1-closed*: 40-80% cover of mixed conifer 10-50 m (33-164 ft); <40% cover of aspen 10-25 m (33-82 ft); mountain snowberry and *Ribes* present; >100 yrs.
MC-E	*Closed*: Conversion to Mixed Conifer (1052); 35-90% cover of mixed conifers 10-49 m (33-164 ft); mountain snowberry and *Ribes* present; conifer litter abundant
Reference Condition: Natural Range of Variation	19%: A-Early 43%: B-Mid1-Closed 24%: C-Mid2-closed 9%: D-Late-open 5%: E-Late-closed 0%: U

[a] Standard LANDFIRE coding for the 5-box vegetation model: A = early-development; B = mid-development, closed; C = mid-development, open; D = late-development, open; E = late-development, closed; U = Uncharacteristic class (DP = depleted); MSu-A to B = conversion to montane sagebrush steppe-upland class A to B; MC-E = conversion to mixed conifer class E; and SP-D = conversion to spruce class D.

Figure 55. Seral Aspen-Subalpine Biophysical Setting.

The Seral Aspen-Subalpine biophysical setting supports aspen-conifer forests (Figure 55) at upper elevations in the park, typically above 9,000 feet (2,743 m). Understories of higher elevation stands are typically less productive and less diverse than seral aspen stands, but do include low shrubs, forbs and grasses. Shrub species include common juniper, *Ribes* sp., *Ericameria* sp., and mountain snowberry. The herbaceous understory is sparse, but does contain both grasses and forbs. The dominant conifers in this system are Engelmann spruce or limber pine, and less frequently bristlecone pine. After forty years, conifers are present in this system and without adequate disturbance may become co-dominant after 170 years. Conversion to subalpine conifer (spruce forest) can occur within 130 years (Provencher et al. 2010). Subalpine aspen stands are sometimes associated with upper reaches of riparian systems and occur on moderate to steep slopes on all aspects. Sixty-eight percent of seral subalpine aspen are currently dominated by spruce.

Table 30. Reference conditions by successional class for seral aspen-subalpine settings.

Class Code [a]	Class Abbreviation and description
A	*Early*: 50-100% cover aspen <2m; mountain snowberry and *Ribes* common; 0-9 yrs.
B	*Mid1-closed*: 40-99% cover aspen <5-10m; mountain snowberry and *Ribes* common; 10-39 yrs.
C	*Mid2-open*: 10-30% cover aspen 10-24m; 10% cover of white fir and Engelmann spruce; mountain snowberry and *Ribes* common; 40-169 yrs.
D	*Late1-closed*: 40-50% cover of white fir and Engelmann spruce cover 25-50m; <40% cover of aspen; mountain snowberry and *Ribes* common; >169 yrs.
SP-D	*Late1-Closed*: Conversion to Spruce biophysical setting (1056); 40-100% cover of Engelmann spruce 25-49m; >129 yrs.
Reference Condition: Natural Range of Variation	12% A-Early 33% B-Mid-closed 47% C-Mid-open 8%: D-Late-closed 0%: U

[a] Standard LANDFIRE coding for the 5-box vegetation model: A = early-development; B = mid-development, closed; C = mid-development, open; D = late-development, open; E = late-development, closed; U = Uncharacteristic class (DP = depleted); MSu-A to B = conversion to montane sagebrush steppe-upland class A to B; MC-E = conversion to mixed conifer class E; and SP-D = conversion to spruce class D.

Condition and Trend

Fire Regime Conditions

All three aspen biophysical settings showed departure from their natural range of variation due to fire exclusion, historic grazing, and other land use practices (Table 31, Provencher et al. 2010). Ecological departure was lowest for stable aspen (27%). When calculated for the park landscape as a whole, seral and seral subalpine aspen showed higher levels of departure: seral aspen was 66% departed, and seral subalpine aspen was 60% departed. The primary cause of ecological departure was the lack or near absence of early-succession classes and an over-representation of late-succession classes. Uncharacteristic classes negatively influenced ecological departure scores and increased the percentage of high-risk classes. Seral aspen and seral subalpine aspen stands have already experienced a six and seven percent loss of aspen clones, respectively, a total of 1,229 acres (497 ha) converted to conifer systems. The seral aspen acres already converted to mixed conifer or spruce systems fall within the uncharacteristic, high-risk NAS (no aspen) class which is equivalent to late-succession mixed conifer class E or late-succession spruce class D.

Table 31. Current conditions in Great Basin NP for each aspen system including: current acres in each vegetation class, current percent acres in each vegetation class, natural range of variation (NRV) which represents the desired condition for each biophysical setting, and ecological departure.

Aspen System	**Class** [a]	**A**	**B**	**C**	**D**	**E**	**DP3**	**NAS3**	**Total**
Aspen Woodland (Stable Aspen)	Current Acres in Class	39	263	82	91	-	92	0	567
	Nat. Range Variation (%)	16	41	33	10	0	0	0	100
	Current % in Class	7	46	15	16	0	16	0	100
	Ecological Departure (%)						0	0	**27**
Aspen-Mixed Conifer (Seral Aspen)	Current Acres in Class	133	321	1,149	2,439	3,580	-	492	8,114
	Nat. Range Variation (%)	19	43	24	9	5	0	0	100
	Current % in Class	2	4	14	30	44	0	6	100
	Ecological Departure (%)						0	0	**66**
Aspen-Subalpine Conifer (Seral Aspen-subalpine)	Current Acres in Class	1,161	1,207	1,294	6,917	-	-	737	11,316
	Nat. Range Variation (%)	12	33	47	8	0	0	0	100
	Current % in Class	10	11	11	61	0	0	7	100
	Ecological Departure (%)								**60**

[a] Standard LANDFIRE coding for the 5-box vegetation model: A = early-development; B = mid-development, closed; C = mid-development, open; D = late-development, open; E = late-development, closed. Uncharacteristic classes defined by TNC, but not defined by LANDFIRE: DP = Depleted; NAS = No aspen (conversion to mixed-conifer, MC-D or subalpine conifer, SP-D). For aspen biophysical settings, high risk classes are represented by uncharacteristic classes DP and NAS.

Aspen stand condition was also calculated within each watershed. These results can indicate higher or lower levels of departure when compared with park-wide calculations due to the more constrained portion of the aspen distribution. These scores were relatively homogenous across park watersheds (Table 32, Figure 56). The mean condition and health score was 63.2% departure from NRV with a standard deviation of 11.7%. The relatively homogenous, high ecological departure scores are consistent with the effects of fire exclusion on a landscape scale. Decathon Canyon had the lowest departure score and contains a high percentage of stable aspen (30%), a system defined by an absence of conifer encroachment.

Table 32. Aspen condition and health scores for all watersheds.

Watershed	Acres	% Park	Aspen Acreage	% Aspen	Condition score	FRCC score	Proportion park aspen
Baker	10781	14%	3568.2	33%	62 [b]	2 [b]	18%
Snake	13605	18%	2728.8	20%	58 [b]	2 [b]	14%
Strawberry	5373	7%	2455.3	46%	73 [a]	3 [a]	13%
Lehman	8233	11%	2059.4	25%	60 [b]	2 [b]	10%
NF Big Wash	8306	11%	1480.2	18%	60 [b]	2 [b]	8%
SF Big Wash	4451	6%	1154.5	26%	51 [b]	2 [b]	6%
Shingle	1992	3%	1146.6	58%	72 [a]	3 [a]	6%
Can Young	1999	3%	708.9	35%	74 [a]	3 [a]	4%
Pine Ridge	1722	2%	610.5	35%	79 [a]	3 [a]	3%
Hub	1582	2%	569.6	36%	61 [b]	2 [b]	3%
Lexington	2508	3%	559.5	22%	59 [b]	2 [b]	3%
Williams	1485	2%	539.5	36%	66 [a]	3 [a]	3%
Dry	1289	2%	442.1	34%	60 [b]	2 [b]	2%
Young	2807	4%	436	16%	64 [b]	2 [b]	2%
Mill	1652	2%	404.1	24%	59 [b]	2 [b]	2%
Decathon	3239	4%	390.2	12%	28 [c]	1 [c]	2%
Big Springs	1988	3%	184.3	9%	59 [b]	2 [b]	1%
Burnt Mill	1764	2%	134.6	8%	79 [a]	3 [a]	1%
Lincoln	2251	3%	48.3	2%	74 [a]	3 [a]	0%

[a] Rated as being of Signficant Concern (red).

[b] Rated as being of Moderate Concern (yellow).

[c] Rated as being Good (green

Stable aspen woodlands cover less than one percent of the park (567 acres (229 ha)), but had the highest percentage of high risk classes (16%). Ecological condition was rated as good (27% departure) and fell into FRCC 1, but the high percentage of high risk classes indicates a potential need for management action. Departure in this system was attributed to a low percentage of early and mid-succession classes and a component of a depleted uncharacteristic class. Aspen woodland's natural range of variation requires 70% of this system to fall within mid-succession classes B and C, 16% within class A and no acres in uncharacteristic classes (Table 28). However, given a lack of consensus on the role of disturbance in these stands, there is a need for closer review of conditions to determine the relative priority of taking management actions and what actions might be most appropriate.

Early and mid-successional seral aspen classes A and B are virtually nonexistent and late-succession classes dominated by conifers (class D and E) are over-abundant. This system had an ecological departure of 66%, one percent away from a 'high' departure ranking and fell into FRCC 2. Six percent (492 acres (199 ha)) of the potential area has already converted to mixed-conifer, the high risk class for this system (Table 29). High departure was caused by a lack of natural disturbance which resulted in a large over-abundance of late-succession classes and a subsequent lack of early and mid-succession classes.

Aspen-subalpine conifer is the largest of park aspen systems (11,316 acres (4,579 ha)). Approximately 7,000 acres (2,833 ha) of aspen-subalpine conifer (61%) are in the late-closed succession class D. The target for this class under natural range of variation is only eight percent. Mid-closed and mid-open succession classes B and C are highly underrepresented. Seven percent of the potential area has already converted to subalpine conifer, the uncharacteristic, high risk class for this system. Ecological departure ranked at the high end of fair (60%) missing a FRCC 3 classification by six percent (Table 30 and Table 31). High ecological departure stemmed from a large over-abundance of the late-succession class which is dominated by subalpine conifers, and an underrepresentation of the two mid-succession classes.

Disturbance and Aspen Regeneration

A total of 46 vegetation samples gathered within Great Basin NP during 2003 were located within the mapped biophysical settings of either seral aspen or seral aspen-subalpine (Figure 56). These data include an indication of aspen regeneration through measures of percent cover within the forest canopy. Table 33 provides a summary of findings with samples summarized in terms of high (>15%) cover vs. medium (5-15%) vs. low (1-5%) vs. no regeneration. While almost no fires have occurred since 1980 within these biophysical settings, disturbance from insect and disease have occurred. While vegetation samples from 2003 are limited and not sufficiently representative of the aspen biophysical settings within the park (Figure 57), the coincidence of these disturbances between 1991 and 2003 was limited to just two, and these appear to have had no discernable effect on regeneration by 2003 (Table 33), although anecdotal information from 2011 field observations at the Granite Fire (occurred in 2001) suggest that where the fire was more intense, there appeared to be quite good aspen regeneration (Stan Kitchen pers. comm.). This could be significant given the high densities of deer and elk that use that area.

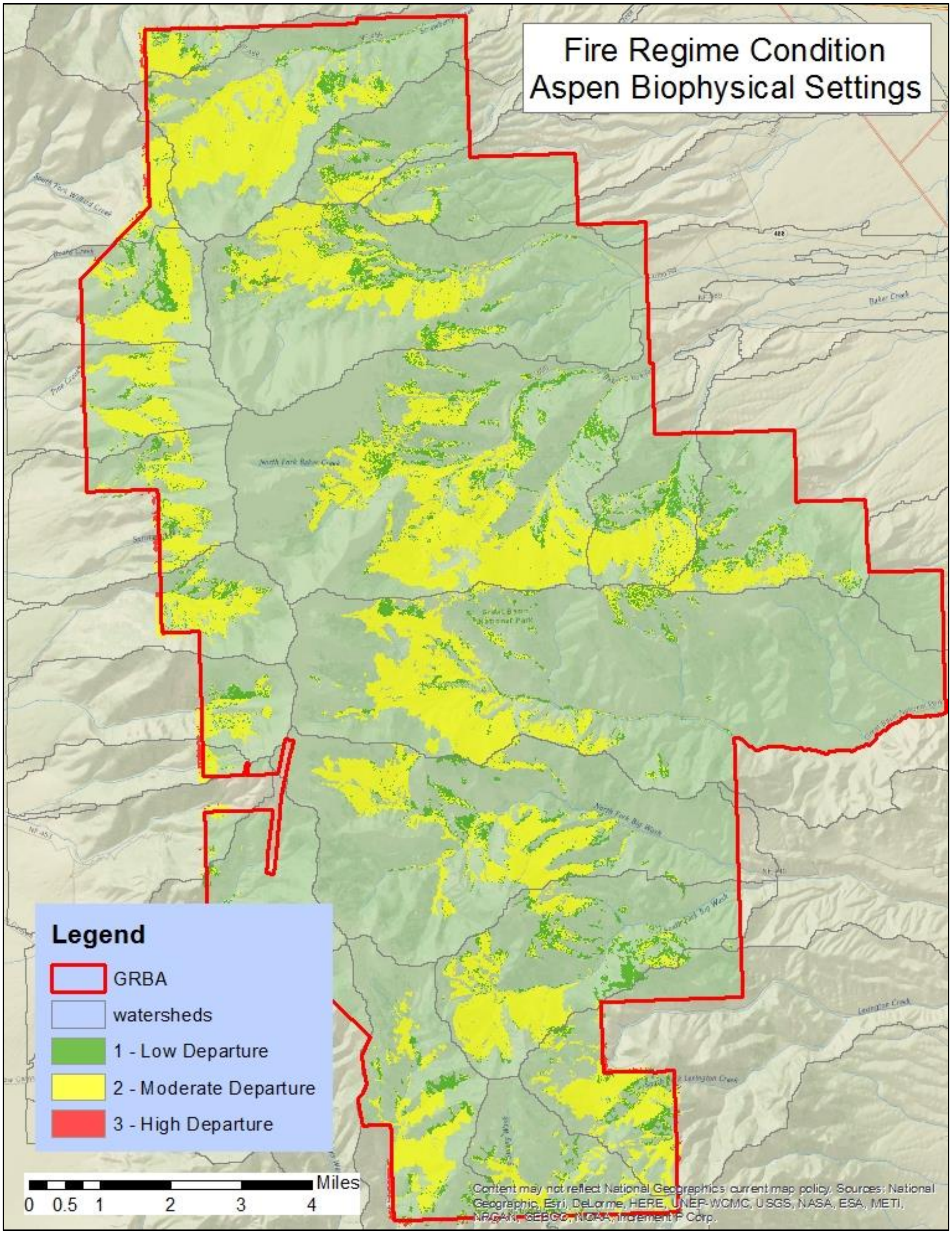

Figure 56. Aspen biophysical settings and FRCC for all of GRBA.

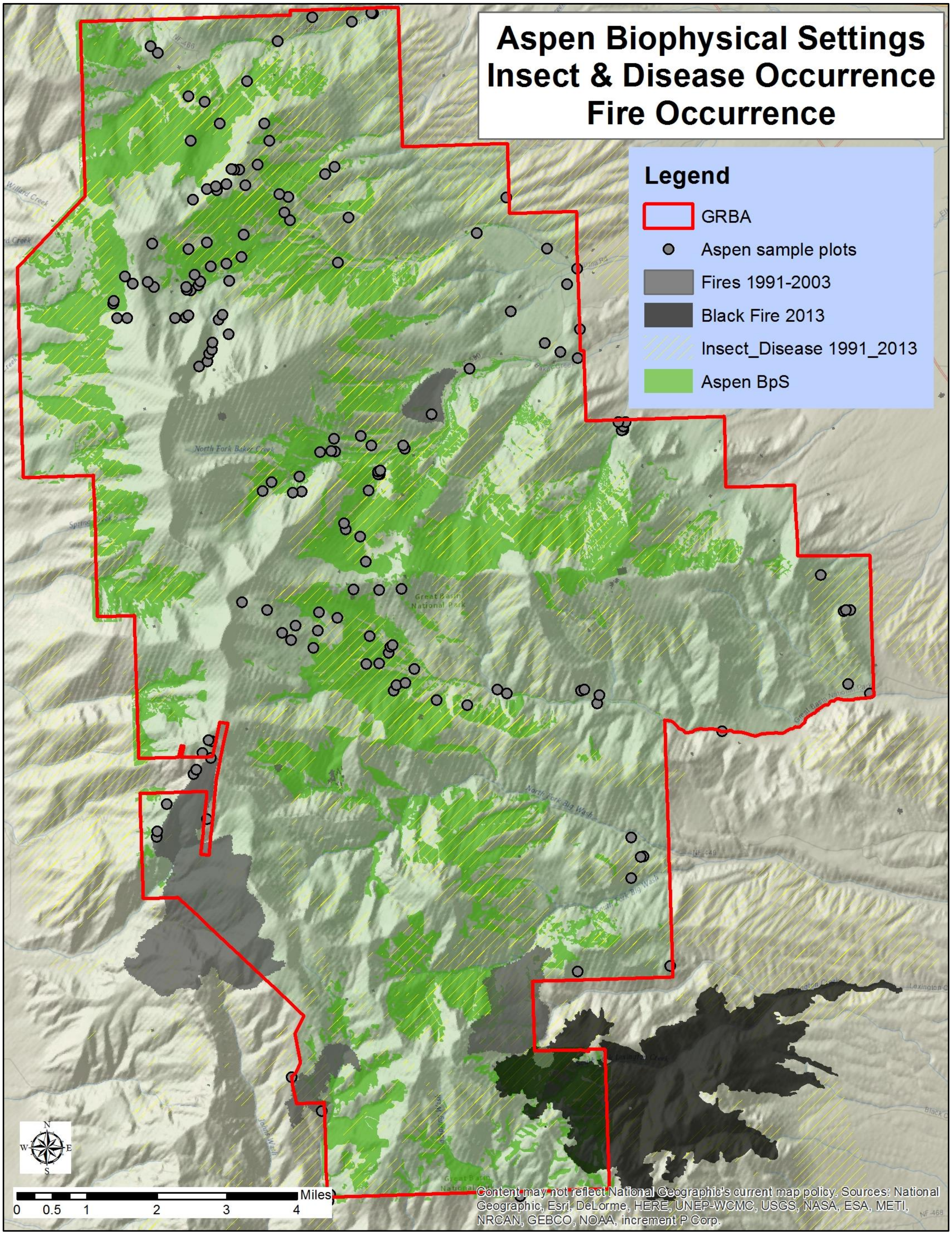

Figure 57. Coincidence of fire and insect or disease occurrence with aspen biophysical settings.

Table 33. Summary scores for aspen regeneration with disturbance in Great Basin NP.

Biophysical Setting	No. samples	No regeneration	Low (1-5% cover)	Moderate (5-15% cover)	High (>15% cover)
Seral Aspen - disturbed	0	0	1	0	0
Seral Aspen – no disturbance	3	0	0	0	0
Seral Aspen-Subalpine - disturbed	2	1	1	0	0
Seral Aspen-Subalpine – no disturbance	41	25	14	2	1

Interestingly, between 2003 and 2013, the number of these sample plots taken in 2003 had subsequent occurrences of insect or disease events by 2013. In that 10-year period, 15 additional samples experienced several subsequent disturbance events.

A total of 12,637 acres (5,114 ha), or 62%, of the aspen-related biophysical settings have experienced some level of disturbance from insect or disease outbreak since 1991.

Monitoring of vegetation sample plots should provide a more definitive indication of trends in aspen regeneration where these provide the source of natural disturbance.

Summary of Status

The ecological condition of park aspen varies: stable aspen stands are 27% departed from natural range of variation, seral aspen are 66% departed, and seral subalpine aspen stands are 60% departed.

- While the current condition of aspen in the park (i.e., percent departure from natural range of variation) varies among the three subtypes, but vegetation departure is most commonly due to an over representation of late successional classes; under representation of early classes; poor aspen regeneration and recruitment; and a loss of aspen clones on 1,229 acres (497 ha).
- The current condition of aspen stands is a direct result of fire exclusion.
- Under current management practices, aspen stands will continue to decline. The conversion of aspen to conifer is predicted to result in permanent loss of aspen from over 10,000 acres (4,047 ha) within 50 years. This would likely constitute impairment under NPS policy.
- Aspen stand condition and health was relatively homogenous across the park. This homogeneity is consistent with the effects of broad scale fire exclusion.
- Decathon Canyon had the best aspen condition assessment score and the Burnt Mill watershed the worst.
- The lack of long-term monitoring data in aspen stands that have experienced fire is an important data gap.

Table 34. Summary of indicators of condition for aspen-mixed conifer forests in Great Basin NP.

Aspen Mixed-Conifer Forest			
Indicators of Condition	**Specific Measures**	**Condition Status/Trend**	**Rationale**
Fire Regime Condition Class Seral Aspen	Proportional extent of FRCC 2-3		Within Great Basin NP 66% fire regime departure = FRCC 3
Fire Regime Condition Class Seral Aspen-Subalpine	Proportional extent of FRCC 2-3		Within Great Basin NP 60% fire regime departure = FRCC 2
Fire Regime Condition Class Stable Aspen	Proportional extent of FRCC 2-3		Within Great Basin NP 27% fire regime departure = FRCC 1
Forest Insect & Disease Overlap	Outbreak patch overlap with aspen – related biophysical settings		Quite extensive, but as of 2003, with little or no measureable effect on aspen regeneration
Wildfire Overlap	Wildfire patch overlap with aspen – related biophysical settings		Very limited sample, no measureable effect on aspen regeneration

<u>Sources of Expertise</u>

This assessment was derived largely from Horner et al. 2014 Natural Resource Report NPS/GRBA/NRR-2014/782

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4.2.3. Wild Turkey

Indicators / Measures

- *Turkey Population Size*
- *Distribution and Extent of Core Usage Areas*

Condition - Trend

Condition Unknown – Possibly Deteriorating - Insufficient Data

<u>Background and Importance</u>

Wild Turkey (*Meleagris gallopavo*) is not native to the Great Basin, but populations have become established within the park. From observations by Park staff, it is clear that there is breeding, nesting and recruitment of wild turkeys within the park. Both the Merriam's turkey (*Meleagris gallopavo merriami*) and the Rio Grande wild turkey (*Meleagris gallopavo intermedia*) have been introduced by Nevada Department of Wildlife (NDOW) for sport hunting to mountain ranges throughout the State of Nevada. Both wild turkey subspecies are known from elsewhere in the southwest United States. In the 18th and 19th centuries the Merriam's turkey range included ponderosa pine forests of Colorado, New Mexico, and northern Arizona, while the Rio Grande turkey ranged from southern Kansas down through Tamaulipas, Mexico (Dickson 1992). The Merriam's subspecies is recognizable from the white coloration of its tail feather tips, distinct from the dark brown tips in more eastern subspecies and tan with the Rio Grande turkey. Merriam's turkey is thought to have originated from turkeys domesticated by Native American cultures, which became feral as those civilizations declined (Rea 1980).

In 2004, 108 Merriam's turkeys were introduced by NDOW from populations in Idaho to White Pine County. Some were introduced to the Hidden Canyon Ranch adjacent to the park in the Big Wash watershed. Others were introduced at Silver Creek Ranch, approximately 10 miles (16 km) north of the park. NDOW permits hunting of male turkeys within Unit 115 of White Pine County. This unit surrounds the park. For the season from March-May 2014, a total of 25 turkey hunting tags were available for Unit 115. This was the largest number of any limited entry hunting unit in the state.

Introduced wild turkey populations to the park could have undesirable effects on Park resources. Based on Park staff observations, where turkeys congregate, their feces can accumulate and affect Park visitor experiences and uses. They can also cause surface disturbance and promote spread of invasive plant species. Additionally, wild turkeys are omnivorous, with a diet including green forage, hard and soft mast, seeds, agricultural crops, insects, and small vertebrates (Dickson 1992, Hurst 1992). It is possible that with expanding wild turkey populations within the park, congregation in trees and aggressive behavior by nesting hens could affect other tree and ground nesting birds or small vertebrate populations. Flocking in riparian zones during winter months could impact vegetation. Others have noted the potential for negative effects from seed foraging by wild turkey on revegetation projects, such as those concentrated in riparian zones (ODFW 2004).

Research and monitoring is therefore warranted to document wild turkey population location, size, habitat usage, and its potential effect on other Park resources. No substantial research of this nature has been conducted within the Great Basin. Morrison (2007), working with introduced populations of wild turkeys on Santa Cruz Island, California, documented explosive population growth following removal of both pig and sheep populations. Morrison hypothesized that vegetation response from removal of the other introduced species enhanced habitat for wild turkey. Given concerns that elevated turkey populations might alter predatory patterns of golden eagle, they elected to remove wild turkeys from the island during winter months when flocking behavior was most common. While conducting research in mainland California, Gillingham (2008) looked at effects of wild turkeys on the California Quail (*Callipepla californica*). She concluded that there was no substantial negative effect. In that instance, while broad habitat characteristics were shared by both species, microhabitat usage varied in part due to the relative size of the individual birds, with the relatively smaller quail more fully utilizing chaparral subcanopy habitat where turkeys would not tend to utilize.

The desire for sport-hunting in surrounding White Pine County has resulted in turkey population introduction and maintenance. This management by NDOW will support population expansion and continued turkey usage in more productive riparian habitats with the park. If impacts to park resources are substantial enough, management options could include hazing, capture and removal, or a fall hunting season targeting females to limit population numbers. This would be consistent with NPS management policies and with common state wildlife management policies, such as those in Oregon, where if it is determined that native species or habitats are being negatively impacted by wild turkeys, appropriate management actions should be taken to protect affected resources.

Data and Methods

Indicators / Measures

- ***Turkey Population Size***
- ***Distribution and Extent of Core Usage Areas***

Estimates of wild turkey population size and core usage areas within the park would enable managers to better monitor and evaluate potential negative effects of wild turkey on other Park resources. Current data are limited to direct field observation or remotely from cameras stationed in different park locations. From 21 distinct observations taken in recent years, a total of 56 individuals were counted in remote camera observations; with observations ranging from 1 to 9 birds. Observations were somewhat evenly split between upland and riparian habitats. Another 96 individuals were observed and recorded in the field. Park staff concluded that wild turkeys likely utilize lower elevations of all park watersheds.

Radio telemetry would be needed to adequately document location and abundance of wild turkeys within the park in order to map core usage zones. Within these core usage areas, concentrated monitoring could aim to determine if and how there are negative effects on other park resources. Once established, estimates of wild turkey population size within these areas could include winter roost counts and or baited trail camera counts taken during a one week period in winter.

Wild turkey population estimates from surrounding White Pine County could be derived from harvest estimates by NDOW. These types of estimates often include indices such as numbers of gobblers heard per day, spring gobbler harvest, or spring gobbler harvest/100 hunter days (Lint et al. 1995), or trap and release of hens each fall.

Reference Conditions

Since the intended management goal for a natural resource park is "unimpaired for the enjoyment of future generations" reference condition would logically be the complete absence of exotic species. However, since wild turkey populations have been introduced and become established into the surrounding region, a practical approach to assessment can focus less on their presence, and more on the abundance of wild turkeys that would cause impairment to native species and other park resources.

In one case from Santa Cruz Island, California, Morrison (2007) documented no direct predatory effects of wild turkey on other native species, but noted concern for altering predatory behavior of golden eagles that prey upon wild turkeys. Golden eagles were not known from the island prior to 1990, and had preyed upon introduced feral pigs. Following investments in feral pig removal, introduced wild turkeys could serve as alternate prey for golden eagles, maintaining their presence and abundance on the island.

While this sort of impairment, applying to other introduced species in the park, has yet to be documented, it would most likely correlate with the size of the flock. Estimates of wild turkey population size, especially within core usage zones, would assist with decision-making by Park managers.

Wild turkeys tend to establish winter roosts in tall trees along deep valley streams (ODFW 2004). Nesting hens with preflight poults roost on the ground, and are vulnerable to predation. As noted above, feeding behavior of Merriam's turkeys in their native range includes a diversity of plants (grasses and mast-producing trees and shrubs), seeds, insects, and snails. Surface water availability is a key limiting factor, so one could expect wild turkey within the park to nest in densely vegetated riparian zones around streams and springs.

Condition and Trend

Data are currently insufficient to quantify the location and abundance of wild turkey populations in core usage areas within the park. Park staff indicated that some park resources may be negatively affected by concentrated wild turkey populations, but these effects have yet to be quantified. The management response may include hazing of the turkey population in selected areas targeted trapping and relocation, and/or targeted reduction of females through NPS approved methods.

Table 35. Summary of indicators for the effects of wild turkey on Park resources.

Wild Turkey			
Indicators of Condition	**Specific Measures**	**Condition Status/Trend**	**Rationale**
Turkey population size	Index models for population estimates from winter roost counts. Harvest data/population estimates from NDOW		Available observation data are too limited to provide a population estimate, observations suggest that some damage to other park resources is occurring.
Distribution and Extent of Core Usage Areas	Location and areal extent of mapped core usage areas		Available observation data are too limited to provide any more than a qualitative statement that they occur and congregate in riparian zones in all drainages throughout the park.

<u>Sources of Expertise</u>

Bryan Hamilton, Wildlife Biologist, Great Basin NP

Meg Horner, Great Basin NP

<u>Literature Cited</u>

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4.2.4. Invasive Annual Grasses

Condition - Trend

Moderate Concern – Trend Unknown – Medium Confidence

Indicators / Measures

% area of vegetation type by annual grass cover risk category

Background and Importance

Globalization of human migration, commerce, transportation, and recreation has introduced invasive exotic species to new areas at an unprecedented rate. Barriers that once restricted the movement of many species have been surpassed with modern technology and are causing a homogenization of Earth's biota. Although only 10% of introduced species become established and just 1% becomes invasive (Williamson 1993, Williamson and Fitter 1996), non-native species have profound impacts worldwide on the environment, economies, and human health.

Invasive species have been directly linked to effects on primary productivity and water availability relative to dominant native species (Tilman1999), changes in ecosystem structure, alteration of nutrient cycles and soil chemistry (Ehrenfeld 2003), shifts in community productivity (Vitousek 1990) and composition (Dornelas et al. 2014), reduced agricultural productivity (D'Antonio and Mahall 1991), and the loss of species (Tabek et al. 2014). The damage to natural resources caused by these species can be irreparable. Invasive species are considered second only to habitat destruction as an immediate threat to wildland biodiversity (Wilcove et al. 1998), and interacting effects of species invasions with climate change are poorly understood (Dukes and Mooney 1999). Consequently, the dynamic relationships among plants, animals, and their environment established over millennia are at risk of being abruptly lost. For the NPS, the consequences of these invasions present a significant challenge to the management of natural resources that are "unimpaired for the enjoyment of future generations." National parks may be located where past land uses in the surrounding landscape have brought invasive species. Once established, NPS units are frequently deluged by new species arriving through predictable (e.g., road, trail, and riparian corridors), sudden (e.g., long-distance dispersal through cargo containers and air freight), and unexpected pathways (e.g., weed seeds in restoration planting mixes).

An estimated 72% of the Great Basin ecoregion is impacted by the annual invasive cheatgrass (*Bromus tectorum*) (Pellant et al. 2004). The alteration of native vegetation by this and other annual grass invasives can alter wildfire regimes and change to hydrologic systems (Brooks et al. 2004, Pierson et al. 2011). Between 2000 and 2009, nearly 16.2 million acres (6.6 million ha) of the Great Basin ecoregion burned, and of these burned areas, some two million acres (809,000 ha) reburned due to an emergence of a cheatgrass fire cycle in degraded rangelands. The magnitude of the invasion and its effects on natural ecosystems makes this possibly the most significant plant invasion in North America (Weltz et al. 2014).

Prevention and early detection are the principal strategies for successful invasive plant management. While there is a need for long-term suppression programs to address high impact species, eradication efforts are most successful for infestations of less than one hectare in size (Rejmanek and Pitcairn 2002). For Great Basin NP, invasive annual grasses are of most immediate concern at lower elevation margins of the park and in the surrounding basins. However, with changing landscape conditions, concern for these species may extend to higher elevations. Therefore, assessment of current and future risks of these invasive species is warranted.

Data and Methods

Invasive annual grasses relevant to Great Basin NP include a number of Eurasian grasses such as bromes (*Bromus* spp.) with *Bromus tectorum* being of primary concern. Chambers et al. (2007) found that in the Great Basin ecoregion, growing season temperature limits cheatgrass distribution at higher elevations, and soil moisture is a primary limitation at lower elevations. Soil moisture, and nitrate availability increase following vegetation removal or fire, assisting with invasibility. Variability in soil moisture and nitrate availability, which tends to be higher at lower elevations, also contributes to cheatgrass invasibility. But where native perennial graminoid species are abundant (i.e., in high quality vegetation condition, and generally at higher elevation locations), cheatgrass invasibility is more limited.

Given this understanding of cheatgrass behavior and prior efforts to model invasive risk (Bradley and Mustard 2006), a spatial model was developed by NatureServe for the region including Great Basin NP in order to indicate the relative risk of annual grass invasion (Comer et al. 2013). This regional model was subsequently updated for this NRCA. Invasive annual grass model aims to indicate the location where biophysical conditions, both natural and cultural, indicate relatively high risk for annual grass presence. It is comprised of five separate continuous spatial models, each representing a risk of supporting invasive annual grasses at different levels of absolute cover. Importantly, it does not predict actual cover abundance of invasive grasses, but does use field observations to develop a predictive risk map.

Field sample observations for model development and validation were acquired from the July 2011 update of the LANDFIRE publicly available vegetation sample points. A total of 2,159 samples, from across the LANDFIRE Map Zone 17, encompassing the eastern Great Basin, were identified as having an invasive annual grass component within the overall species composition of the sample site. A total of 6 species were identified within the sample sites, of which 99% of the total samples were comprised of cheatgrass (*Bromus tectorum*) (Table 36).

The majority of sample points are comprised of a single species of annual grass, but some points contain several species per sample. The final sample total includes 2,155 samples plots, with the majority of the samples in the fourth and fifth levels of percent cover (Table 37).

Table 36. Invasive Annual Grasses present with the combined Great Basin (LANDFIRE MZ 17).

Invasive Grass Species	**Count**
Avena barbata	1
Bromus rubens	20
Bromus tectorum	2,134
Hordeum vulgare	2
Lamarkia aurea	1
Secale cereale	1
Grand Total	**2,159**

Table 37. Sample size per percent cover category.

Invasive Annual Grass Abundance Risk Category	**Sample Count**	**Minimum Cover (%)**	**Maximum Cover (%)**	**Average Cover (%)**
1- less than 5%	60	0.98	4.85	3.25
2 – 5-15%	181	5	14.32	10.38
3 – 15-25%	184	15	24.9	19.12
4 – 25-45%	396	25	44.44	33.26
5 – greater than 45%	1,334	45.45	100	81.76
Grand Total	**2,155**			

Independent spatial layers for inductive modeling using Maxent software consisted of both continuous and categorical feature types. Landforms, surficial lithology, bioclimatic ombrotype and thermotype were derived from existing USGS national data layers (Sayre et al. 2009). All other variables were derived from either soil maps (SSURGO and STATSGO) or 10-meter Digital Elevation Model (rescaled to 30-meter). No new remotely-sensed imagery, which would be required to fully map the current distribution of invasive plants, was used for these models. However, recent fire perimeters (since 2011) were included.

In order to maximize the number of samples applied to the model, a two-part modeling approach was used to determine model performance. In addition to the final models which consist of all available sample points, a separate analysis was performed using a series of 10 replicate models with random withholding of 10% of total samples for model validation. The average AUC score from the receiver operating characteristics (ROC) score was used to determine the model validity. See Peterson et al. (2008) for discussion of strengths and weaknesses associated with this standard approach to model validation. The variable contribution to individual models was constant across the majority of the cover class with bioclimatic thermotype and recent fire patch distance explaining 42-55% of the model variability. Overall model performance was acceptable with ranges in AUC score from 0.77 to 0.86 and with standard deviations ranging from 0.011 to 0.03.

Final models for each density categories were compiled from the five independent models using the threshold where occurrence equal training sensitivity and specificity (0.39-0.47). This value in all model categories was the most restrictive threshold value. The final composite model is comprised of each individual model layered in order of lowest percent coverage to highest percent coverage with each increasing percent cover layer superseding all underlying data values (Figure 58).

Quantifying invasive plant risk to Great Basin NP resources

Invasive annual grass risk to Great Basin NP was calculated by quantifying the area of each abundance risk category within the assessment boundary encompassing the valleys surrounding Great Basin NP. Current invasive annual grass effects on major Great Basin NP vegetation types were assessed within park boundaries using this spatial model. This indicator is measured by combining the mapped area of the biophysical settings (Provencher et al. 2011) and current vegetation types (Cogan et al. 2012) with the composite invasive plant layer and reporting the area (in hectares) per vegetation patch with risk estimated for invasive grasses at abundance categories of >5%, 5-15%, and >15%.

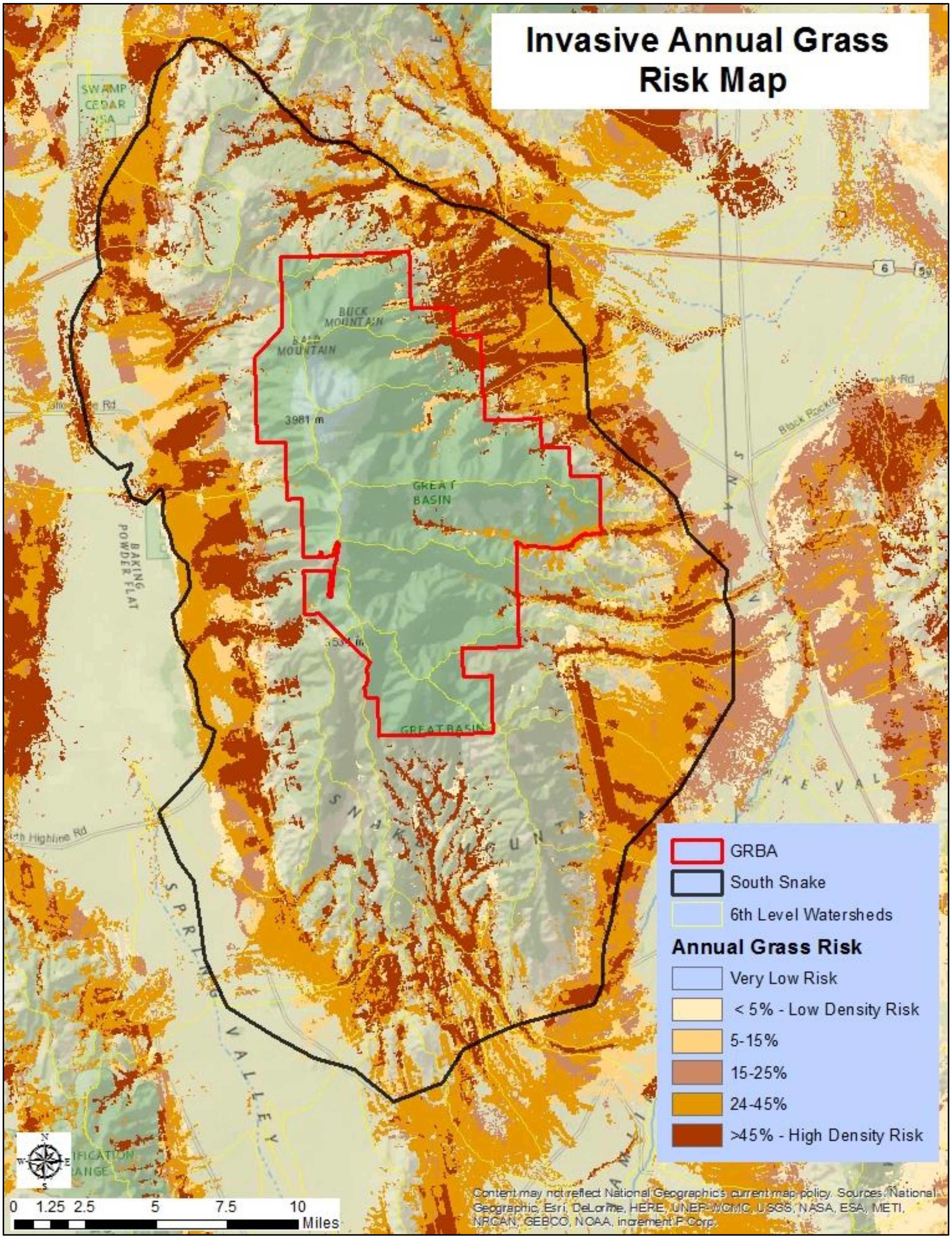

Figure 58. Invasive Annual Grass Risk, South Snake Range, indicating areas of very low risk, plus 5 categories where invasives could occur in low to high levels of abundance.

Reference Conditions

Since the intended management goal for a natural resource park is "unimpaired for the enjoyment of future generations" reference condition would logically be the complete absence of exotic species. However, such a reference condition is unlikely to be feasibly achieved where invasive annual grasses have been established, and where these wind-dispersed species are abundant in the landscape surrounding the park. However, a practical reference condition can be established where the presence of invasive species remains in sufficiently low densities that their potential to displace and extirpate native species is negligible. By this, we mean that the ecological attributes (e.g., species composition, structure, etc.) and natural processes remain within an expected natural variation for a given community type (e.g., mountain sagebrush shrubland). Therefore, the reference condition of "good" is that invasive annual grass species are known to occur regionally or on adjacent lands, but have not yet been confirmed within park, or if species have been confirmed, distribution is limited in extent, and occupies less than 5% cover within any occurrence of a given vegetation community. A "moderate concern" condition is when invasive annual grasses occur with 5-15% cover. Finding and controlling patches might prevent large-scale invasion, and distribution is somewhat limited in extent and may vary in intensity from sparse individuals to dense patches. A condition of significant concern is warranted when exotic plants threaten to alter these primary communities to the point where they no longer maintain these attributes or processes. For example, when exotic species dominate a community where key native species are expected for that community type, then the area would be considered as severely degraded. However, significant concern is also warranted when the trend for a community is clearly toward such a degraded outcome rather than it actually having been realized. Therefore, "significant concern" conditions exist where there is the high potential for >15% invasive annual grass cover.

Condition and Trend

The annual grass risk model indicates a very strong elevation zone where invasive grasses pose the greatest threat, excluding both higher montane elevations and basin bottoms of the landscape including Great Basin NP (Figure 59). The model indicates that 4,408,234 acres (1,783,949 ha; 48% of area) of the "Valleys" assessment area has a risk of invasive grass at abundances >5% cover. The "moderate concern" portion (5-15% abundance risk) encompasses 297,574 acres (120,424 ha; 3%) and the "significant concern" portion encompasses 4,110,660 acres (1,663,525 ha; 45%).

Within and in the immediate surroundings of Great Basin NP, valley bottoms within drainages, especially throughout the east and south sides of the park, show the highest potential for invasive annual grass invasion. Based on the spatial model, of all biophysical settings mapped within Great Basin NP (Provencher et al. 2011), only montane sagebrush steppe was found to include some predicted risk of invasive annual grasses. This biophysical setting encompasses 9,207 acres (3,726 ha) within the park. Existing vegetation with this biophysical setting is either dominated by mountain sagebrush (*Artemisia tridentata* ssp. *vaseyana*), or pinyon and juniper woodland. In fact, some 5,214 acres (2,110 ha; 56%) of this biophysical setting is now dominated by encroaching pinyon and/or juniper woodland.

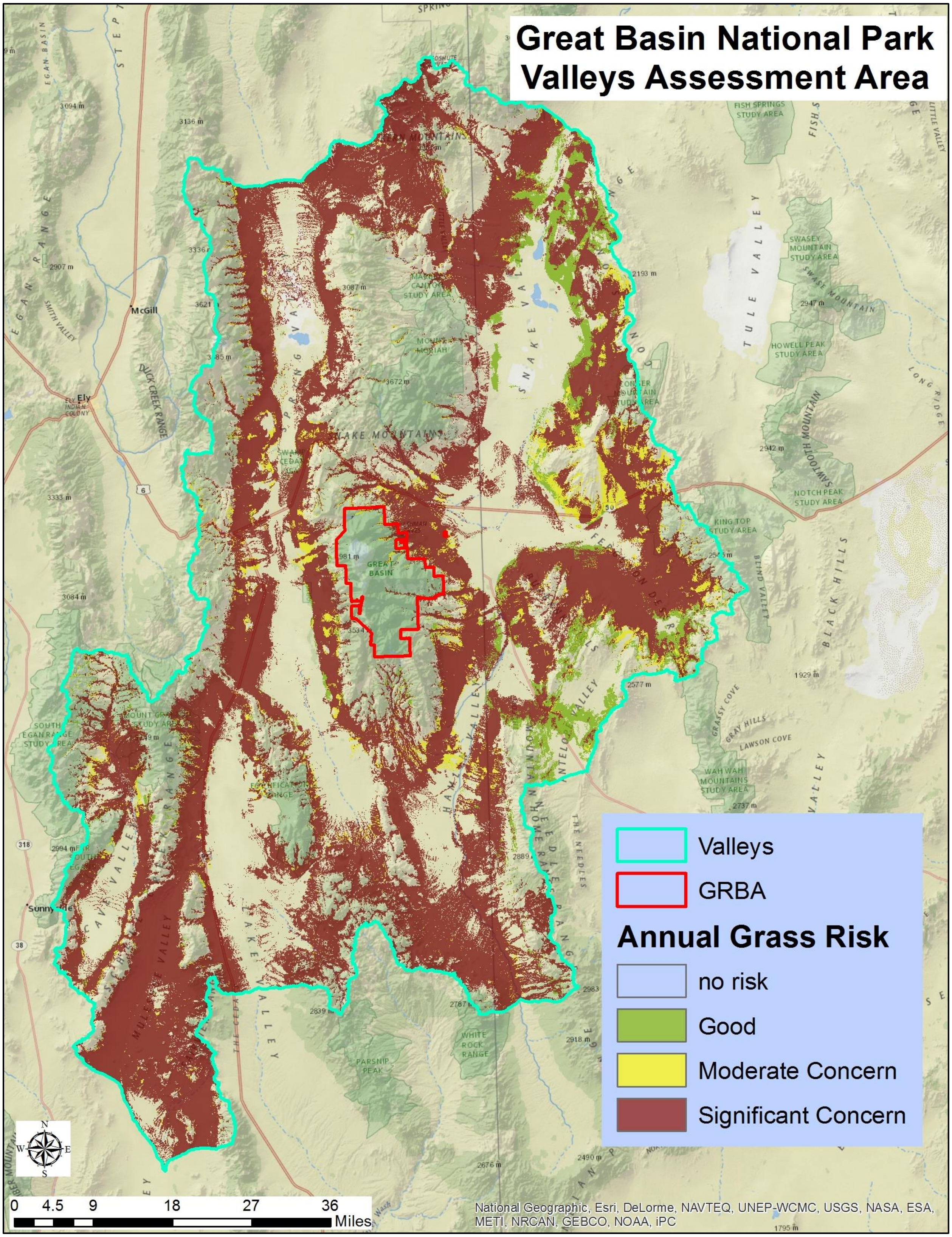

Figure 59. Invasive Annual Grass Risk Model throughout the Valleys assessment area.

For this montane sagebrush steppe biophysical setting, 7,888 acres (3,192 ha) or 85% of its extent falls within "good" reference conditions with regards to invasive annual grasses (i.e., annual grass risk of <5% abundance). Some 292 acres (118 ha), or 3% of the total area, fall within the "moderate concern" category, with an annual grass risk of 5-15% abundance. Some 1,028 acres (416 ha), or 11% of the total extent, falls within the "significant concern" category, with an annual grass risk of >15% abundance (Figure 60).

Considering the potential for expansion from current to higher elevations (Bradley and Mustard 2006), elevation contours between 8,202 and 9,186 feet (2,500 and 2,800 m) were established to document the extent of biophysical settings that, while not currently threatened, might be most vulnerable to invasive grass expansion over the coming decades. This vulnerability could result from effects of climate change and/or further adaptation by cheatgrass and related invasive species. As noted elsewhere, the fire regime conditions within this elevation zone could result in particularly intense wildfire that could predispose sites to invasion (Provencher et al. 2011). Given the documented ecophysiological limitation of growing season temperature and the trends towards warmer temperatures, an upslope trend in cheatgrass invasion might be detected during the upcoming decades. The maps shown in Figure 61 depict current invasive annual grass risk in combination with this 300-meter (984-foot) elevation contour interval and the major biophysical settings occurring there.

Three of the major biophysical settings (*sensu* Provencher et al. 2011) that define the montane upland zone of Great Basin NP fall within this elevation contour interval. These include "seral aspen-subalpine" which encompasses 1,020 acres (413 ha), "mountain mahogany" encompassing 806 acres (325 ha), and "montane sagebrush steppe" encompassing 467 acres (189 ha). Chambers et al. (2007) note the importance of maintaining or restoring high densities in native perennial herbaceous species as a primary strategy to prevent cheatgrass invasion. These three biophysical settings, and the existing vegetation they support, vary in terms of the typical densities of perennial herbaceous species. Within this 8,202 - 9,186 foot (2,500 - 2,800 m) elevation band, the seral aspen-subalpine setting tends to be concentrated in valleys and side slopes adjacent to riparian zones, with much existing vegetation including white fire (*Abies concolor*) with quaking aspen (*Populus tremuloides*). This type of vegetation often supports dense herbaceous ground cover. Similarly, the montane sagebrush steppe occurs mainly on side slopes and tends to support high densities of perennial bunchgrasses; at least where past grazing and/or fire suppression have not had significant impact. Within this elevation band of Great Basin NP, much of the existing vegetation in these settings is a mixture of sagebrush and pinyon-juniper woodland. This suggests a higher likelihood than for the seral aspen-subalpine setting that there may commonly be a relatively sparse understory of perennial herbaceous vegetation. The mountain mahogany biophysical setting within this elevation band tends to be dominated by curly-leaf mountain mahogany (*Cercocarpus ledifolius*) and commonly dominates steep rocky slopes and ridgelines with a sparse herbaceous understory.

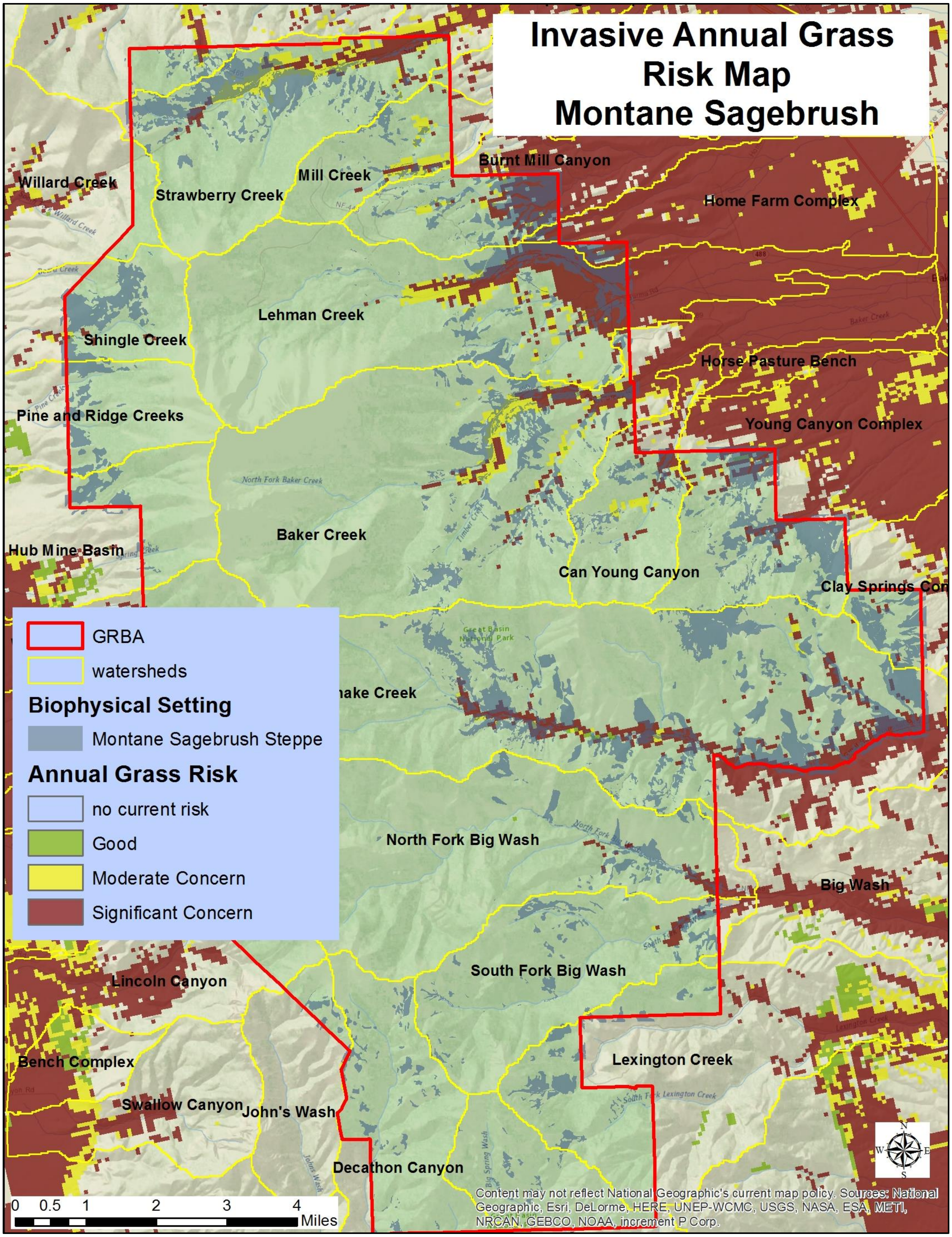

Figure 60. Invasive Annual Grass Risk Model relative to Montane Sagebrush Steppe biophysical setting within GRBA.

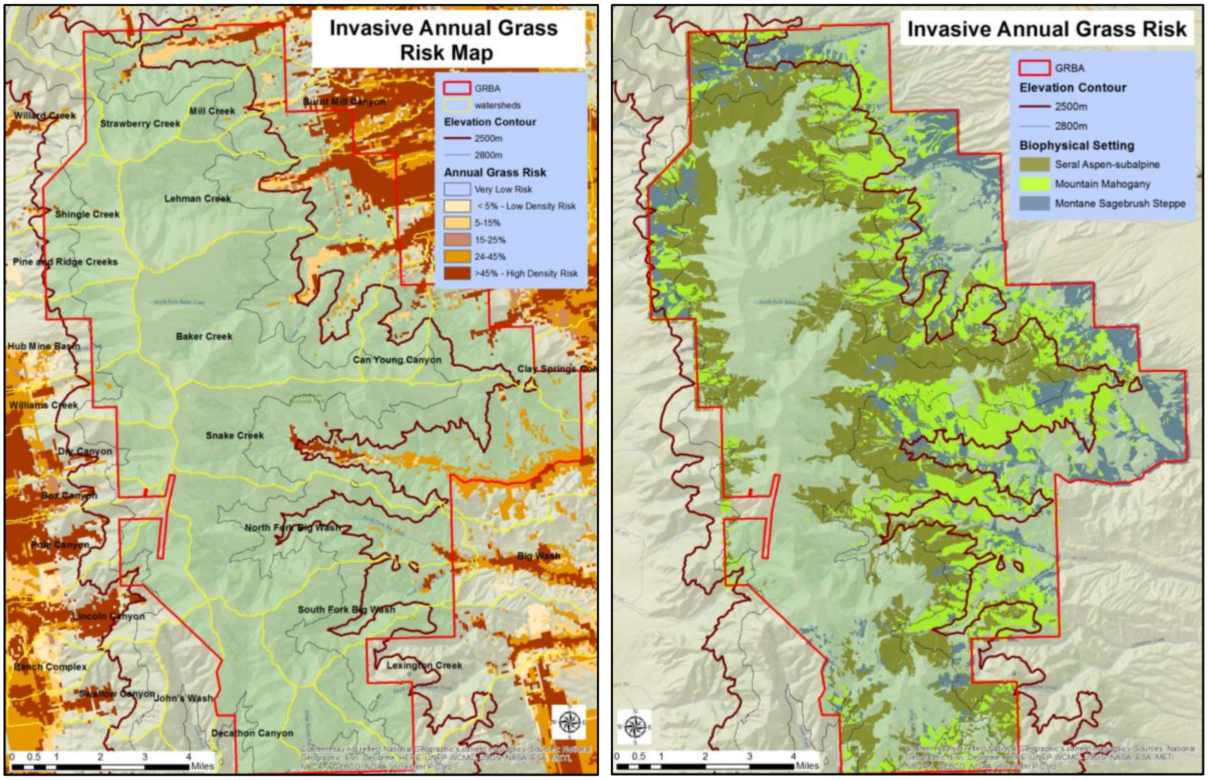

Figure 61. Invasive annual grass risk relative to the 8,202 - 9,186 foot (2,500 - 2,800 m) elevational contour interval (left); and major biophysical settings (right) within Great Basin NP falling in the 8,202 - 9,186 foot (2,500 - 2,800 m) elevational contour interval (right).

Of these three biophysical settings, the montane sagebrush steppe is most likely to occur in conditions making it vulnerable to invasive annual grass invasion. This would especially be the case where surface disturbance and/or intense wildfire occur in close proximity to current patches of these invasive grasses.

With the primary indicator being % area of vegetation type by annual grass cover risk category, there should be significant concern for the conditions immediately surrounding Great Basin NP. With 45% of the “Valleys” assessment area with a risk of invasive grass at abundances >15% cover, this should be an ongoing concern for park management. For the particular biophysical setting of montane sagebrush steppe, within the Great Basin NP boundary nearly 15% falls within the “moderate concern” or “significant concern” categories. Given these estimates, an overall condition rating of “moderate concern” is appropriate. Available data preclude any definitive statement on trends in this indicator, but no strong trend has been observed.

Table 38. Summary of the indicator for invasive annual grasses at Great Basin NP.

Invasive Annual Grasses			
Indicators of Condition	**Specific Measures**	**Condition Status/Trend**	**Rationale**
% area of vegetation type by annual grass cover risk category	Estimated by biophysical setting within Great Basin NP boundaries, with "moderate concern" defined by 5-15% cover of invasive annual grass indicated, and >15% cover indicated for "significant concern"		Estimates based on predictive risk model derived from local field sampling and biophysical features. Risk is high throughout basins surrounding Great Basin NP. Risk model indicates risk throughout lowest elevation margin of the park. Additional area within the park could become vulnerable to invasion.

Among the primary data gaps and uncertainties associated with this assessment includes the reliability of the invasive annual grass risk map. Additional field samples with species and percent cover, within and surrounding Great Basin NP, could provide additional input for further model validation and improvement. Field assessment of invasive annual grass cover and effects on sagebrush vegetation within Great Basin NP would not only assist with model validation, but also provide additional support to management and restoration planning. Further inventory and monitoring of invasive annual grass cover, across major vegetation types, would be important to quantify trends and detect conditions where expansion to higher elevations may be occurring.

Sources of Expertise

Patrick Mingus, Great Basin NP physical science technician provided review and input for this assessment.

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4.2.5. Bighorn Sheep

Indicators / Measures

- *Survival Rate*
- *Trend in Herd Size*
- *Disease Status*
- *Winter Range Forage Quality*
- *Fire Regime Condition Class*
- *Wildfire Overlap*
- *Domestic Sheep in Adjacent Grazing Allotments*
- *Landscape Condition*

Condition – Trend

Significant Concern – Unchanging – High Confidence

Background and Importance

As with other NPS units throughout the western United States, bighorn sheep are emblematic of natural conditions and bring important scenic and educational values (Figure 62). Early explorers noted the presence of mountain sheep surrounding the Snake Range (Simpson 1876). A letter written in 1985 to the Nevada Department of Wildlife (NDOW) recounted a history of local wildlife sightings, including bighorn sheep, elk, antelope, and deer, dating back to the early 20th century from throughout the Snake Range and nearby mountain ranges (Robison 1985). The letter indicated that, while earlier Shoshone Indian colonies from around Baker, Nevada likely persisted on small mammals (jack rabbit, ground squirrel) they undoubtedly also utilized elk, antelope, and mountain sheep. The letter suggested that elk were likely hunted out of the Snake Range by early pioneers, and that mountain sheep had gradually declined, likely due to disease spread from domestic sheep and predation from mountain lions. Extensive and relatively unregulated livestock grazing, including concentrated use by domestic sheep, was common throughout the Snake Range in much of the 20th century. Wildfire suppression during this same period resulted in change to vegetation structure, with expansion of woody vegetation at the expense of more open and forage-rich habitats. These conditions also likely inhibited sheep movement and provided greater opportunity for mountain lion predation. By 1975, NDOW considered bighorn sheep to be effectively extirpated from the Snake Range (Tsukamoto 1975).

Figure 62. Bighorn Sheep in Great Basin NP.

In recent decades, interest in conserving and restoring bighorn sheep populations and habitats has steadily increased among state wildlife agencies and federal land managers throughout the West. In addition to Great Basin NP, bighorn sheep habitat in the South Snake Range is predominantly managed by the Ely District of BLM. The Ely District considers the management of bighorn sheep to be a priority in the Snake Range (BLM 2008). The plan indicates that BLM will "manage habitat for Rocky Mountain bighorn sheep in the Snake Range," and "manage domestic sheep and goats in accordance with current BLM policy when changes to BLM grazing permits are being considered in the Snake Range." The plan also stipulates that "where appropriate, restrict permitted activities within occupied desert bighorn sheep habitat from March 1 through May 31 and from July 1 through August 3," and "consider managing habitat for desert bighorn sheep in unoccupied ranges if and when domestic sheep grazing no longer occurs in the area."

In 1979 and 1980, 20 Rocky Mountain bighorn sheep (*Ovis canadensis canadensis*) were introduced to Great Basin NP from Colorado populations. Today, within the ranges surrounding Great Basin NP, bighorn sheep occur within the Snake Range. Figure 63 depicts suitable bighorn habitat in the South Snake Range, based on habitat suitability models (Darby and Williams 2001) and using protocols from Smith et al. (1991). Habitat suitability parameters for the model included human use density, water availability, non-forest vegetation, and steep slopes. In the figure, green indicates both winter and summer range. Total suitable habitat was estimated at 37,474 acres (15,165 ha). The model suggested that there should be sufficient suitable habitat to support a viable population of over 100 individuals; with population viability being a 95% probability of persistence for 100 years.

An expert panel met in 2003 to discuss bighorn sheep restoration in the South Snake Range. Their recommendations centered on two limiting factors: habitat quality and risk of disease transmission from domestic sheep (Peek et al. 2003). Open, non-forested area of sufficient size and slope is required to support adequate forage and escape distances to limit mountain lion predation. Since recent wildfires had been noted to increase forage quality, use of prescribed fire at high elevations, and within lower-elevation winter range, was recommended.

Regarding the risk of disease transmission, they noted the overlap of domestic sheep grazing allotments with the bighorn range, risking not only disease transmission, but competition for forage. The panel recommended closure of overlapping grazing allotments and disease testing of resident sheep prior to new bighorn introductions to the South Snake Range. All domestic sheep allotments within Great Basin NP were retired in 2008 when grazing permits were transferred as part of a land sale.

Below is an assessment of bighorn sheep population and habitat conditions within the South Snake Range, documenting limiting factors to their viability and persistence. Some key management concerns addressed by this assessment include the locations of nearby domestic sheep grazing allotments, location of nearby wildfires, and inferences about the quality of bighorn sheep habitat, including distance from concentrated human activity and potential for interchange with nearby bighorn populations.

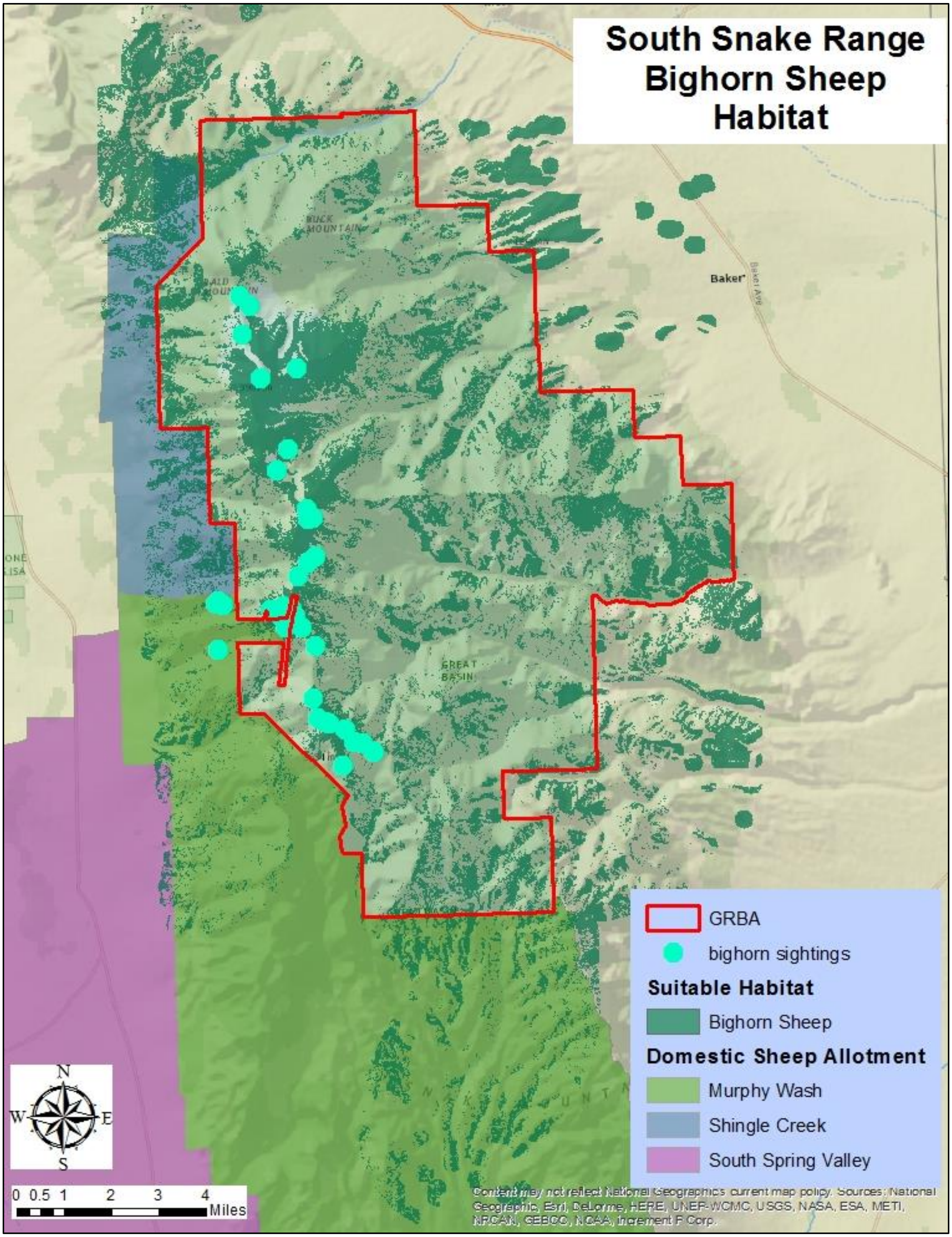

Figure 63. Suitable bighorn sheep habitat and bighorn sightings in the South Snake Range , with Great Basin NP and adjacent domestic sheep grazing allotments.

Data and Methods

Indicators / Measures

- *Survival Rate*
- *Trend in Herd Size*
- *Disease Status*
- *Winter Range Forage Quality*
- *Fire Regime Condition Class*
- *Wildfire Overlap*
- *Domestic Sheep in Adjacent Grazing Allotments*
- *Landscape Condition*

The Ecological Integrity Framework (Unnasch et al. 2009) links conceptual models that describe the relationships between change agents, stress, and response for a given focal resource to field measurements and spatial models that provide practical measures across the assessment area. For bighorn sheep, the assessment area is the South Snake Range. Scientific literature was consulted to refine a conceptual model of bighorn sheep habitat, identifying key ecological attributes and sources of ecological stress and likely responses. Locations of bighorn sheep populations related to the Snake Range exist as generalized polygons (from several sources) and more specialized range from Darby and Williams (2001) (Figure 63). Hamilton (2011) completed helicopter-assisted count and capture/radio-collar studies for 6 individuals in the South Snake Range between 2009 and 2010, providing over 11,000 georeferenced observations for rams (2) and ewes (4) through those seasons. This sample of individuals, albeit small, accounted for 30% of the estimated 20 individuals in Great Basin NP at the time. It provided estimates of home range size and seasonal range, and population survival estimates. Disease testing was also completed for 8 individuals.

Additional spatial data were used to assess conditions affecting bighorn sheep populations within and surrounding the Snake Range. Current grazing allotments from adjacent BLM land were used to document the proximity of domestic sheep grazing to bighorn populations within Great Basin NP. Wildfire locations documented since 1980 were used investigate their association to bighorn habitat. Relative landscape condition, as modeled using NatureServe methods (Comer and Hak 2009), was used to gauge proximity of dense human land uses and dense tree canopy relative to bighorn habitat and determine where potential barriers to movement might occur.

The Ecological Integrity Scorecard documents the primary indicators of each key ecological attribute identified for a given focal resource. For assessment of bighorn sheep, indicators are initially listed and described in Table 39. The following section on reference conditions provides additional background and rationale for selection of key ecological attributes and indicators. The last section on condition and trends summarizes results from the application of these indicators to the South Snake Range assessment area.

Table 39. Indicators used for resource assessment of bighorn sheep in the South Snake Range.

Key Ecological Attribute: Population health and interchange	
Indicator	**Indicator Definition**
Survival Rate	Female survival rate over a 29 month sample period from radio-collar sample of 6 individuals
Trend in Herd Size	Field observation and estimated count of individuals
Disease Status	Presence of *Mycoplasma ovipneumoniae* among bighorn sheep individuals.
Winter Range Forage Quality	Areal extent and forage quality, measured using annual grass risk model
Fire Regime Condition Class	Observed proportions of succession classes relative to expected proportions
% Habitat Area with Wildfire Since 1980	Wildfire patch overlap with summer vs. winter bighorn range, limiting woody vegetation and enhancing forage quality
Proximity to domestic sheep in nearby BLM Grazing Allotments	Presence of domestic sheep within seasons and distances that generate risk of disease transmission
Landscape Condition Index	Intersection of seasonal range distribution map with the landscape condition layer and reporting the average LCI for summer vs. winter range. Landscape Condition Index is a 30-meter resolution map surface that incorporates a land use /land cover intensity rating and a distance decay function, reflecting decreasing ecological impact with distance from the source. This model was customized for bighorn sheep integrating location of forested vs. non-forested vegetation.

Reference Conditions

Individual sheep currently found within Great Basin NP are Rocky Mountain bighorn sheep (*Ovis canadensis canadensis*). Desert bighorn were likely in the Snake Range historically (Hamilton pers. comm.). In any case, due to environmental characteristics and proximity, the characteristics of the Desert bighorn (*Ovis canadensis nelsoni*) provide additional insight for characterizing reference conditions at Great Basin NP, and are referenced here. Bighorn sheep in this region tend to occur in alpine to shrub-steppe in mountains, foothills, or river canyons. Suitable escape terrain (cliffs, talus slopes, etc.) is an important feature of the habitat. In winter, bighorns spend much of their time within 300 feet (91 m) of escape terrain (Oldemayer et al. 1971, Erickson 1972), and usually stay within one half mile (800 m) of escape terrain throughout the year (Pallister 1974). The solar heat on south aspects also reduces cold stress on sheep (Shackleton et al. 1999). While gregarious, for most of the year adult males live apart from females/young (Shackleton et al. 1999, Krausman et al. 1999). Among mature males, older males (up to an age of not more than 10 years) generally dominate younger males during the breeding season; males older than 10 years decline rapidly in condition. Female life spans tend to be 10-14 years. Male annual home ranges are up to 14.3 mi^2 (37 km^2) in Nevada (Leslie and Douglas 1979). Hamilton (2011) estimated home ranges for both rams and ewes in the South Snake Range that averaged 29.7 mi^2 (77 km^2) in size, substantially larger than statewide averages. This could suggest that relatively poor habitat quality results in additional movement across a wider range. Carrying capacity for bighorn can also be reduced through grazing by other ungulates (domestic sheep, cattle, feral horses and burros, etc.). \

Bighorns probably live in groups primarily to reduce predation (Shackleton et al. 1999). Coyotes may be a significant predator on young in some areas, killing up to 80% of the year's lambs. Mountain lions are important predators as well (Krausman et al. 1999), and can have significant impacts on remnant or transplant herds (Krausman et al. 1999). Mountain lions are likely the primary source of predation in the South Snake Range. Direct losses to predation are not generally as important as the fact that threats of predation force females and young to use less productive habitats in and near escape terrain (Festa-Bianchet 1988, Demarchi et al. 1999). Wehausen (in Hamilton 2011) suggested that the mountain lion population in the South Snake Range has likely increased with increasing (or rebounding) deer populations, and when combined with increasing woody vegetation density, the increasing threat from lion predation would inhibit movement by bighorn sheep.

Sheep populations other than those in low deserts, such as those of Great Basin NP, typically migrate between an alpine or montane summer range and a lower elevation winter range (Shackleton et al. 1999). Some groups may occupy as many as five separate ranges during a year (Geist 1971). This vertical migration is likely a response to the increasing abundance of nutritious, new vegetative growth at higher elevations as spring and summer progress (Shackleton et al. 1999). The downward migration is motivated by snow accumulation in the high elevation summer ranges (Shackleton et al. 1999).

Bighorns in southwestern deserts have an extended mating season encompassing several months (Krausman et al. 1999), but the season is relatively later and shorter elsewhere, generally November in the northern part of the range (Shackleton et al. 1999). Litter size is 1, rarely 2 (Geist 1971, Turner and Hansen 1980). Young are weaned in 4-6 months. Females first breed usually in second year in south, third year in north; occasionally in first year in some areas (Krausman et al. 1999, Shackleton et al. 1999); fecundity generally declines only slightly after eight years of age (Caughley 1977).

The key ecological attribute driving the integrity of bighorn sheep populations is the maintenance of interacting healthy individuals. Healthy individuals can reproduce and successfully recruit lambs into the population. Therefore, local access to escape terrain (cliffs, talus slopes, etc.), especially in lambing habitat, and facilitated access to seasonal habitat, are important features to maintain each interacting population. Over multiple generations, the ability for occasional movement to nearby mountain ranges and distinct genetic populations would also be important for long-term viability.

Bighorn sheep experience stress when faced with change agents, such as land development, including mines that directly remove habitat. Roads and other transportation corridors (railroads, power lines), wind farms, or oil/gas platforms, fragment habitat distribution (Debinski and Holt 2001). More dispersed human activities, such as recreation, hunting, logging, or ORV activities result in increases in road densities or disturbance via disrupted breeding, foraging, soil surface disturbance that affects biological soil crusts or uprooting or damage to plants. Any of these stressors can result in responses, such as decreased dispersal success, reproductive success, and increases in direct mortality.

Large historical declines were primarily the result of competition with domestic stock (e.g., cattle, domestic sheep, and burros), diseases and parasites introduced by domestic sheep, overhunting, and habitat loss (Cowan 1940, Buechner 1960, Sugden 1961, Stelfox 1971, Goodson 1982, Boyce et al. 1990, Valdez and Krausman 1999). In some areas, lungworm infections may predispose bighorn to respiratory infection by opportunistic bacteria; lungworm life cycle involves a gastropod intermediate host. Psoroptic scabies from domestic sheep devastated bighorn populations in the first half of the twentieth century (Boyce et al. 1990). Many die offs (greater than 50% mortality over a few months) of herds have been reported over the last century. In 2009 and 2010, bighorn sheep throughout the western United States experienced massive pneumonic epizootic outbreak with subsequent mortality exceeding 50% in some herds. *Mycoplasma ovipneumoniae* is transmitted from nose to nose contact between domestic and bighorn sheep, predisposing sheep to further bacterial infections by *Pasteurella trehalosi, Pasturella multocida* and *Mannheimia haemolytica* (Foreyt 1989, Besser et al. 2008, Dassanayake et al. 2009). The animals subsequently die from acute bronchopneumonia (Ryder et al. 1992, Dunbar 1992, Schwantje 1988). See Bunch et al. (1999) for a general account of diseases and parasites affecting bighorn sheep. These diseases are generally not lethal to domestic sheep (Krausman et al. 1996).

For these reasons, management guidelines include temporal and spatial separation of domestic from bighorn sheep herds (Western Association of Fish and Wildlife Agencies [WAFWA] – Wild Sheep Working Group 2010). Guidelines recommend nine miles (~14 km) of spatial separation between domestic sheep and bighorns. Less than nine miles (~14 km) separation is permissible if specific barriers are in place, such as rivers or major roads.

Habitat Loss and Degradation

Loss and degradation of habitat, especially key winter forage sites, is a key threat (Valdez and Krausman 1999, Shackleton et al. 1999, Krausman et al. 1999). Habitat degradation can occur through overgrazing by domestic stock, competition with exotic ungulates (e.g., Aoudad or Barbary, *Ammotragus lervia*), excessive off-road vehicle use, spread of rangeland weeds, and the usurpation of water sources (Simpson 1980, Valdez and Krausman 1999, Krausman et al. 1999). Fire suppression and resulting vegetation succession (encroachment of tall dense shrubland and forest) have been a major cause of habitat loss in Colorado and British Columbia (Davidson 1991, Cannings et al. 1999, Wakelyn 1987). Fragmentation of habitat reduces or eliminates genetic interchange among populations (Ramey 2000) and reduces the probability of recolonization following local extirpation; both these effects are especially of concern in small populations (fewer than 100 individuals), which are especially vulnerable to extirpation (Berger 1990).

Any of these stressors can result in responses, such as decreased reproductive success, and increases in direct mortality. The Hamilton (2011) radio collar studies provide the basis for several important indicators for bighorn sheep integrity (Table 40). These include herd survival rate, trend in herd size, and disease status. Survival rates are estimated by radio collaring of mature ewes or can be inferred by standardized annual classification counts of ewe/lamb ratios. Trend in herd size may be measured through periodic overall estimates from aerial and field counts. Disease status can be determined by presence of *M. ovipneumonia* or other pneumonia related diseases and also be lamb survival rates. A related indicator is the seasonal overlap of bighorn ranges and domestic sheep in nearby grazing allotments.

Given concerns for the extent and quality of winter forage, the areal extent of winter range located away from surface disturbance and areas likely invaded by exotic grasses and forbs provides one useful indicator. Spatial models of landscape condition, in this case emphasizing surface disturbance from roads and other land uses, along with a spatial model of invasive annual grass potential (see Section 4.2.4) are overlain with winter range maps to make this measurement.

Fire regime condition class (FRCC) measures the departure from expected fire regime as indicated by the observed proportion of vegetation succession classes relative to the expected proportion for a given vegetation type (see Section 4.2.1). FRCC 1 indicates that proportions are within expected ranges. FRCC 2 indicates moderate concern due to regime departure. FRCC 3 indicates substantial regime departure and significant management concern. Similarly, the proportional area of bighorn habitat that has experienced wildfire since 1980 indicates area of habitat recovery from fire regime alteration.

Another indicator of integrity for bighorn sheep populations is the landscape condition model (LCM), which reflects landscape conditions and distance effects of those conditions. This type of model commonly addresses the stressors of habitat removal and habitat disturbance. However, in this application, where treed vegetation with >40% canopy closure occurs, it is included as a condition of the landscape threatening to bighorn sheep (i.e., mountain lion cover). This spatial analysis aims to measure relative quality of winter and summer range, and the limitations on seasonal movement.

Ideally, long-term effects of fragmentation among sheep populations would be addressed through direct measurement of interchange across multiple subpopulations. This could be addressed through direct field measurements of movement (e.g., GPS and radio-collar tracking) and/or through analysis of genetic material among individuals from distinct subpopulations. Genetic measures could address heterozygosity and inbreeding depression. Where feasible, a characterization of the expected range of variation for values from each of these indicators would be desirable. The landscape condition index is a stressor-based measure, and so comparison of current scores (i.e., 0-100 for a given area) are in fact compared against a score of 100 (i.e., the lack of surface disturbance). Summarizing these scores for sheep habitat within each 6th level watershed provides an initial indication for interpretation.

However, for the indicator of population fitness, one could characterize an expected range of variation in rates of dispersal between the South and North Snake Range. However, given the current status of bighorn sheep in the South Snake Range, and the potential for augmenting this herd in restoration efforts, population interchange between the Great Basin NP and adjacent herds could be addressed in the future.

Table 40. Indicators used for resource assessment of bighorn sheep in the South Snake Range.

Indicator	Significant Concern	Moderate Concern	Good
Survival Rate	Female Mortality Greater than Replacement Rate	Female Mortality at Replacement Rate	Female Mortality Less than Replacement Rate
Disease Status	Presence of *Mycoplasma ovipneumoniae* among bighorn sheep individuals		Absence of *Mycoplasma ovipneumoniae* among bighorn sheep individuals
Winter Range Forage Quality	<650 ha with low quality forage	>650 ha with variable forage quality	>650 ha with high quality forage
Trend in Herd Size	Declining herd size	Stable herd size	Increasing herd size
Fire Regime Condition Class	FRCC 3 Severe Departure	FRCC 2 Moderate Departure	FRCC 1 No Departure
% Habitat Area with Wildfire Since 1980	Descriptive interpretation	Descriptive interpretation	Descriptive interpretation
Proximity of domestic sheep in adjacent BLM Grazing Allotments	High potential for domestic sheep and bighorn sheep contact	No domestic sheep in contact during sensitive seasons	No domestic sheep within nine miles (~14 km) of bighorn herds
Landscape Condition Index	Scores generally < 50 - Qualitative interpretation of landscape fragmentation and barriers to long-term movement	Scores between 50 - 80 Qualitative interpretation of landscape fragmentation and barriers to long-term movement	Scores generally > 80 - Qualitative interpretation of landscape fragmentation and barriers to long-term movement

<u>Condition and Trend</u>

Survival rate was addressed through a 29-month period (2009-2011) through radio-collar studies (Hamilton 2011). Survival rates are generally high for adult bighorn sheep (Geist 1971). Over the course of the study, three of four ewes (75%) and none of two rams, died. Cause of mortality for two of the ewes was identified as mountain lion predation. The cause of death of the third ewe could not be determined.

Survival Rate

Indicators/Measures
Survival Rate

zHamilton (2011) modeled survival using known fate models with two time periods per year (summer and winter). Due to a small sample size, the results were equivocal and estimates ranged from very high to very low survival with poor estimates of variability. Ewe survival was consistently estimated at 66% of ram survival. This differs from the common expectation that rams have lower survival than ewes (Jorgenson et al.

1997), although other authors have attributed higher mortality rates to females due to reproductive costs. Overall survival was estimated at 0.97 ± 0.27. This is considered high survival and is consistent with other populations.

Trend in Herd Size

Indicators/Measures
Trend in Herd Size

Capture crews observed 20-25 bighorns in January 2008, and 15-18 on 6 November 2008. Seventeen bighorns were observed on 12 January 2010. Composition high counts were 7 rams, 10 ewes and 3 lambs (Hamilton 2011). This result does not conflict with the survival estimates, and suggests that in recent years, this herd is maintaining stable, albeit low, numbers.

If a viable population is defined as one which has a 95% probability of surviving for 100 years without management intervention (Smith et al. 1991), this population size is generally considered to be 100 – 125 individuals. Berger (1990) suggested that local extinction of bighorn populations of less than 50 individuals is highly probable. One-hundred percent of the fourteen populations examined were locally extinct within 50 years. Food shortages, weather, predation and competition were considered unlikely as causal factors while inbreeding depression and disease from domestic sheep were considered most likely. Currently the South Snake Range bighorn population (20-25 individuals) is not viable. Without management intervention, the extirpation of this population is highly likely.

Disease Status

Indicators/Measures
Disease Status

Between 2009 and 2011, Hamilton (2011) completed disease and mineral testing on eight bighorns (4 ewes and 4 rams). Of particular interest are the culture tests for *Pasteurella trehalosi* and *Mannheimia haemolytica* and the PCR diagnostics for *Mycoplasma ovipneumoniae*. Four rams were cultured for *P. trehalosi* and *M. haemolytica* and PCR tested for *M. ovipneumoniae*. Two lion-killed ewes were PCR tested for *M. ovipneumoniae*. No positive results were found for *M. ovipneumoniae*. Mixed results were found for *P. trehalosi* and *M. haemolytica* (likely non-virulent strains).

Although domestic sheep carry *M. ovipneumoniae*, *P. trehalosi* and *M. haemolytica* with no clinical symptoms, virulent strains cause severe bronchopneumonia and rapid death of bighorn sheep. Pneumonia epidemics are often characterized by decreased lamb survival in the years (in some instances, decades) following high adult mortality events. This research on bighorn pathology and associated mortalities has major implications towards augmentation of the South Snake range bighorn herd. Source herds were greatly reduced in abundance and are known carriers of *Mycoplasma ovipneumoniae*. The South Snake Range bighorn herd is the only known *M. ovipneumoniae*-free herd of Rocky Mountain or California bighorn in Nevada (Peregrine Wolf pers. comm.). This finding elevates the value of this herd considerably and increases the need to restore the herd to a viable population size.

Winter Range Forage Quality

Indicators/Measures
Winter Range Forage Quality

Snow depths exceeding 12 inches (30 cm) are generally avoided by bighorn sheep (Shackleton et al. 1999) and snow cover appeared to dictate habitat utilization of collared individuals during the winter (Hamilton 2011). Winter range was considered as the portions of the home range utilized by bighorns from December 1 – Feb 28. Critical winter habitat occurred in Box Canyon, Lincoln Canyon, and Lincoln Peak. When snow cover was light, bighorns utilized higher elevations up to 11,000 feet (3,353 m). Bighorns also extensively utilized the base of the toe slopes in the southern portion of the range during winter months when heavy snow cover pushed bighorns to lower elevations.

Forage on winter range has been suggested as a limiting factor for bighorns (Shackleton et al. 1999). Smith et al. (1991) suggested that 1,600 acres (650 ha) of winter range are required to support a viable population. Darby and Williams (2001) habitat model indicates just 1,522 acres (616 ha) of winter range (Figure 64) in the South Snake Range. Additionally, the quality of this habitat may be compromised by past land uses and expansion of invasive cheatgrass and other exotic plant species (Chambers et al. 2007), overlay of winter range with cheatgrass risk map (see Section 4.2.4). Currently, 55 acres (22 ha) or 3.5% of mapped winter range appears to fall within areas suggested to be at high risk of cheatgrass invasion (Figure 64).

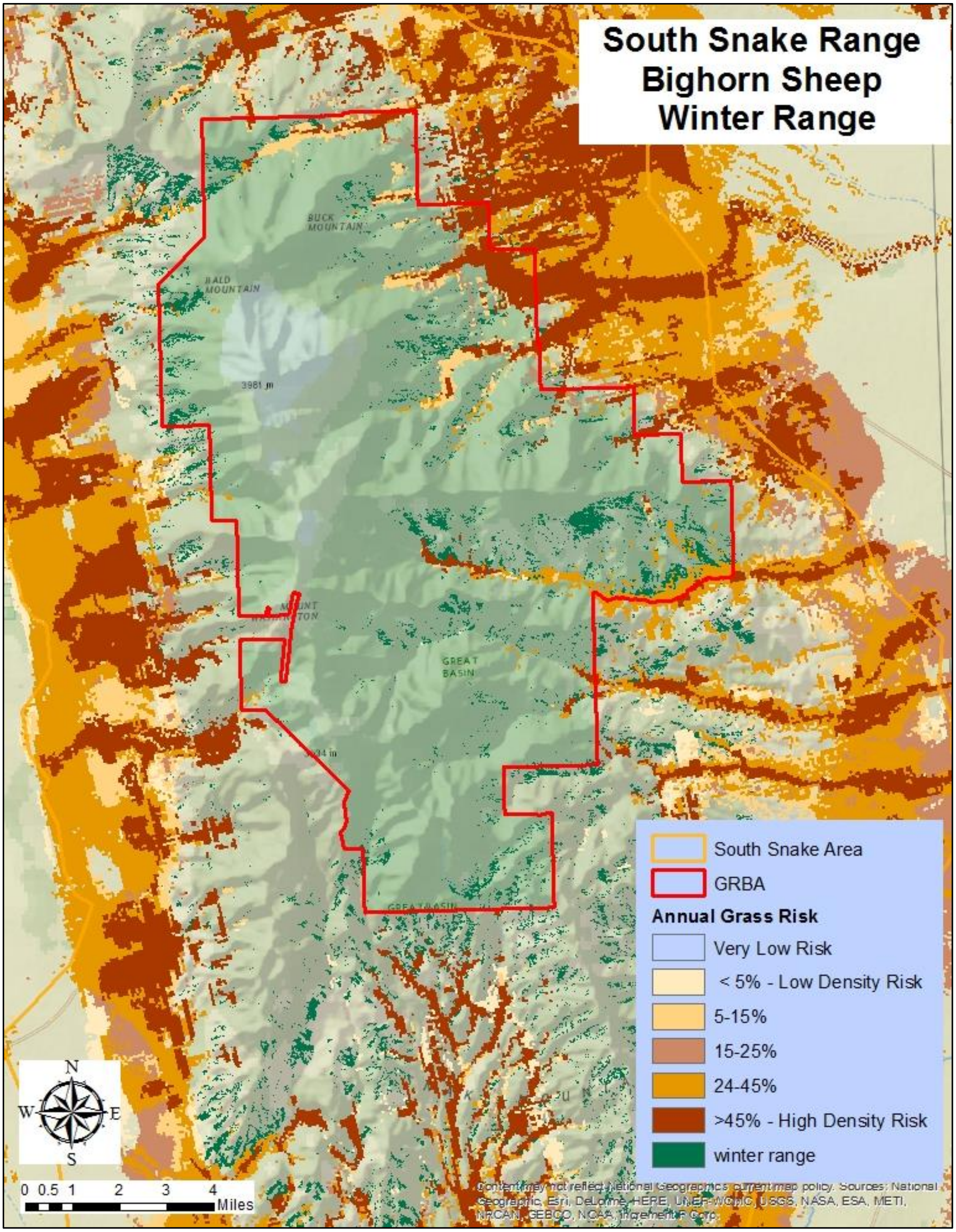

Figure 64. Suitable winter range for bighorn sheep in the South Snake Range, mapped with risk of invasive annual grasses (3.5%).

Fire Regime Condition Class

Indicators/Measures
Fire Regime Condition Class

Fire regime condition class (FRCC) measures the departure from expected fire regime as indicated by the observed proportion of vegetation succession classes relative to the expected proportions for a given vegetation type (See Section 4.2.1). FRCC 1 indicates that proportions are within expected ranges. FRCC 2 indicates moderate concern due to regime departure. FRCC 3 indicates substantial regime departure and significant management concern.

Bighorn sheep summer range includes 1,275 acres (516 ha) (44%) with no fire regime departure, 1,332 acres (539 ha) (46%) in FRCC 2 (moderate departure) and 292 acres (118 ha) (10%) in FRCC 3 (severe departure). Bighorn sheep winter range includes 566 acres (229 ha) (37%) with no fire regime departure, 724 acres (293 ha) (48%) in FRCC 2 (moderate departure) and 227 acres (92 ha) (15%) in FRCC 3 (severe departure) (Figure 65). Fully 56% of summer range and 63% of winter range indicate some level of fire regime departure.

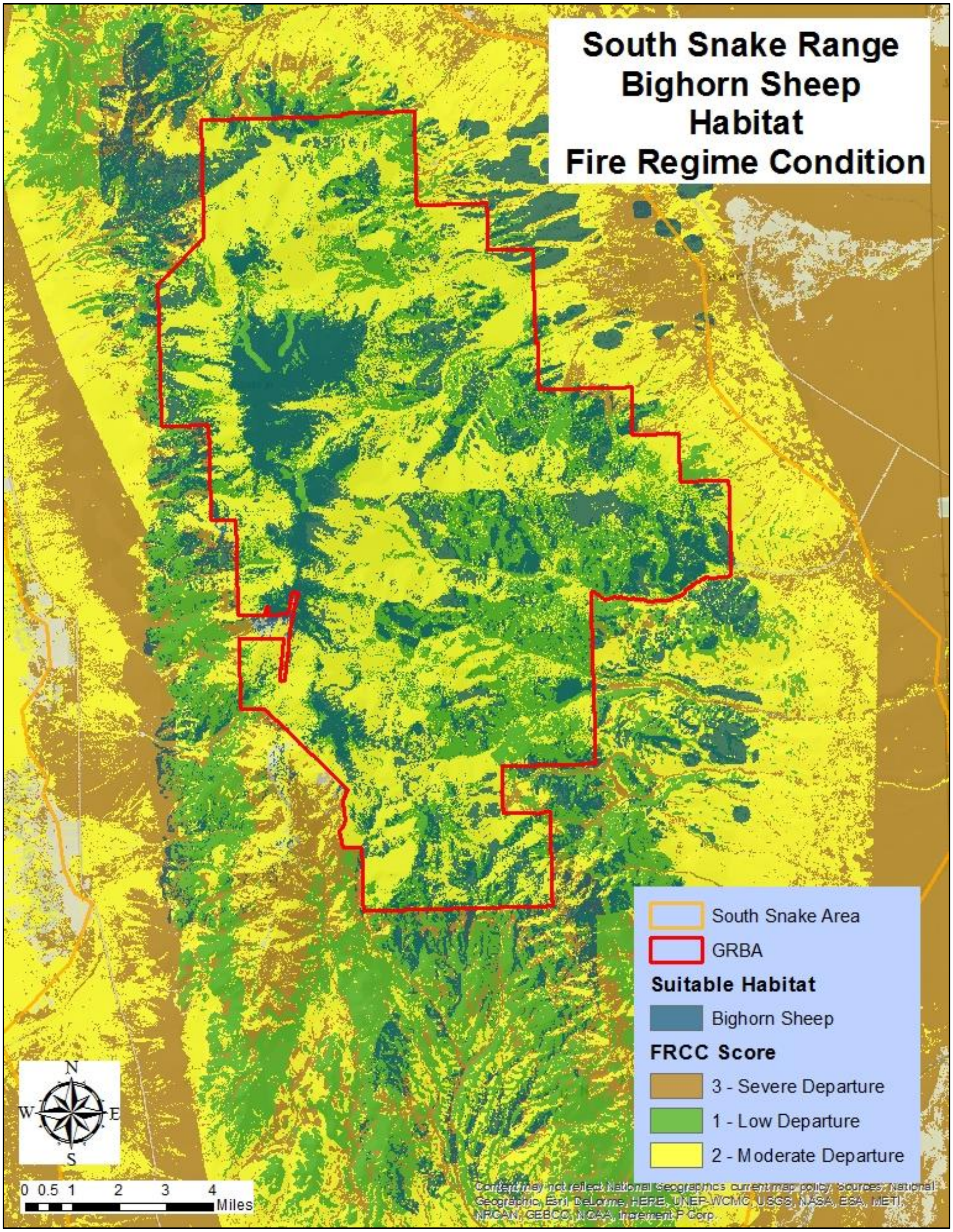

Figure 65. Suitable bighorn sheep habitat in the South Snake Range, with Great Basin NP and fire regime condition classes.

% Habitat Area with Wildfire Since 1980

Indicators/Measures
% Habitat Area with Wildfire Since 1980

The proportional area of bighorn habitat that has experienced wildfire since 1980 indicates area of habitat recovery from fire regime alteration. Using all available fire occurrence data, we determined that approximately 226 acres (90 ha) of Great Basin NP lands burned between 1959 and 1979. Since 1980, nearly 12,600 acres (5,040 ha) of the South Snake Range have burned. However, only about 70 acres (28 ha) of suitable bighorn sheep habitat was affected by those fires. These were concentrated in the Baker Creek prescribed burn (1999), Phillips Ranch (2006), and Border (2006) fires.

These results indicate the urgent need for vegetation treatment due to fire regime alteration.

Proximity of Domestic Sheep in adjacent BLM Grazing Allotments

Indicators/Measures
Proximity of Domestic Sheep in adjacent BLM Grazing Allotments

Three domestic sheep allotments overlap with the home ranges of the South Snake Range bighorn herd (Hamilton 2011):

- Murphy's Wash - season of use is June 5 to September 10 (1550 dry ewes with rams)
- Shingle Creek - season of use is 20 June – 10 September (1550 dry ewes)
- South Spring Valley – season of use is 1 May - 15 June (known number of ewes and lambs)

Spatially, there is greatest overlap between the Murphy's Wash Allotment and bighorn sheep home ranges. Hamilton completed several forms of home range calculations and these resulted in an overlap of between 51-59% with Murphy's Wash Allotment (Figure 63). During the period of domestic sheep use of this allotment, bighorns tend to be at higher elevations and there is apparently little temporal overlap between bighorns and domestic sheep. The Shingle Creek allotment has little spatial overlap (<3% - 8%). Similar to Murphy's Wash, during the period of domestic sheep use of Shingle Creek, bighorns tend to be at higher elevations minimizing temporal overlap. Although only a small portion of the bighorns home ranges overlap the South Spring Valley allotment (<1% - 10%), this allotment has the greatest potential for interaction because both bighorn and domestic sheep utilize similar portions of this allotment at the same time (May).

Separation of domestic sheep and bighorn sheep can occur both spatially and temporally. Although disease testing currently suggests minimum interaction between bighorns and domestic sheep there is still high potential for contact. If bighorn populations increase or are augmented, conflicts between bighorns and domestic sheep will likely escalate. Management guidelines recommend nine airline miles (~14 km) of spatial separation between domestic sheep and bighorns (1998; Western Association of Fish and Wildlife Agencies-Wild Sheep Working Group 2010). In the South Snake range, bighorn home ranges directly overlap with active domestic sheep allotments with the two species separated by less than a mile (1.6 km).

Currently the active domestic sheep grazing allotments in the South Snake Range are held by the Southern Nevada Water Authority (SNWA). Potential mitigation includes fencing, changes in timing of use, and retirement of the domestic sheep allotments. East side allotments could potentially cause concern if the bighorn herd expands to the east side of South Snake Range. Additionally, policies may consider treatment of wandering sheep, preventing those individuals from returning to the herd as another technique to minimize introduction of exotic disease vectors.

Landscape Condition

Indicators/Measures
Landscape Condition

A Landscape Condition Index is a 30-meter resolution map surface that incorporates a land use/land cover intensity rating and a distance decay function, reflecting decreasing ecological impact with distance from the source (Comer and Hak 2009; Comer and Faber-Langendoen 2013). This model included 20 distinct inputs, including roads of varying size and expected traffic volume, land uses from agriculture to urban and industrial uses (Figure 66). The index scores range from 0-100, with relatively high index scores suggesting a greater distance from landscape features that could cause stress to a given focal resource. Typically scores above the range of 80 indicate relatively unaltered landscape condition. At the opposite extreme, scores below 50 indicate a lot of local landscape conversion and fragmentation, and suggest significant concern.

For application to bighorn sheep, this model was customized by integrating location of forested vs. non-forested vegetation. Given the documented effects of mountain lion predation on bighorn herds, and the effect on bighorn behavior when nearby closed-canopy tree cover, this factor expressing as additional important component of landscape condition from the perspective of the Great Basin NP Bighorn sheep herd.

By segmenting this spatial model into three categories and combining it with each map of summer and winter range, this provides another indication of the quality of bighorn sheep habitat. Thresholded LCI scores of < 50 (Significant Concern), 50-80 (Moderate Concern), and > 80 (Good), when assessed for bighorn sheep summer range, 7% of falls within Significant Concern, fully 55% falls within Moderate Concern, and 38% falls within Good. With these same thresholds bighorn winter range scores were 17% of falls within Significant Concern, fully 54% falls within Moderate Concern, and 29% falls within Good.

More qualitatively, the LCI indicates the location of potential barriers to movement between the North and South Snake Range, suggesting some degree of concern for long-term genetic exchange among herds if and when they are fully re-established at Great Basin NP (Figure 66). However, barriers to movement to inhibit genetic flow between herds is now thought of as both good and bad, bad relative to genetic issues but good if one herd becomes compromised from disease. Recent discussions among the WAFWA sheep working group suggest that genetic issues can be mitigated via trap and transplant with appropriate disease testing while encouraging natural movements between herds runs the risk of introducing novel disease vectors. While this appears inconsistent with NPS "naturalness" policies for wildlife management, it may be more secure for bighorn sheep until such time as a vaccine or other means of reducing the disease cycle can be developed and implemented.

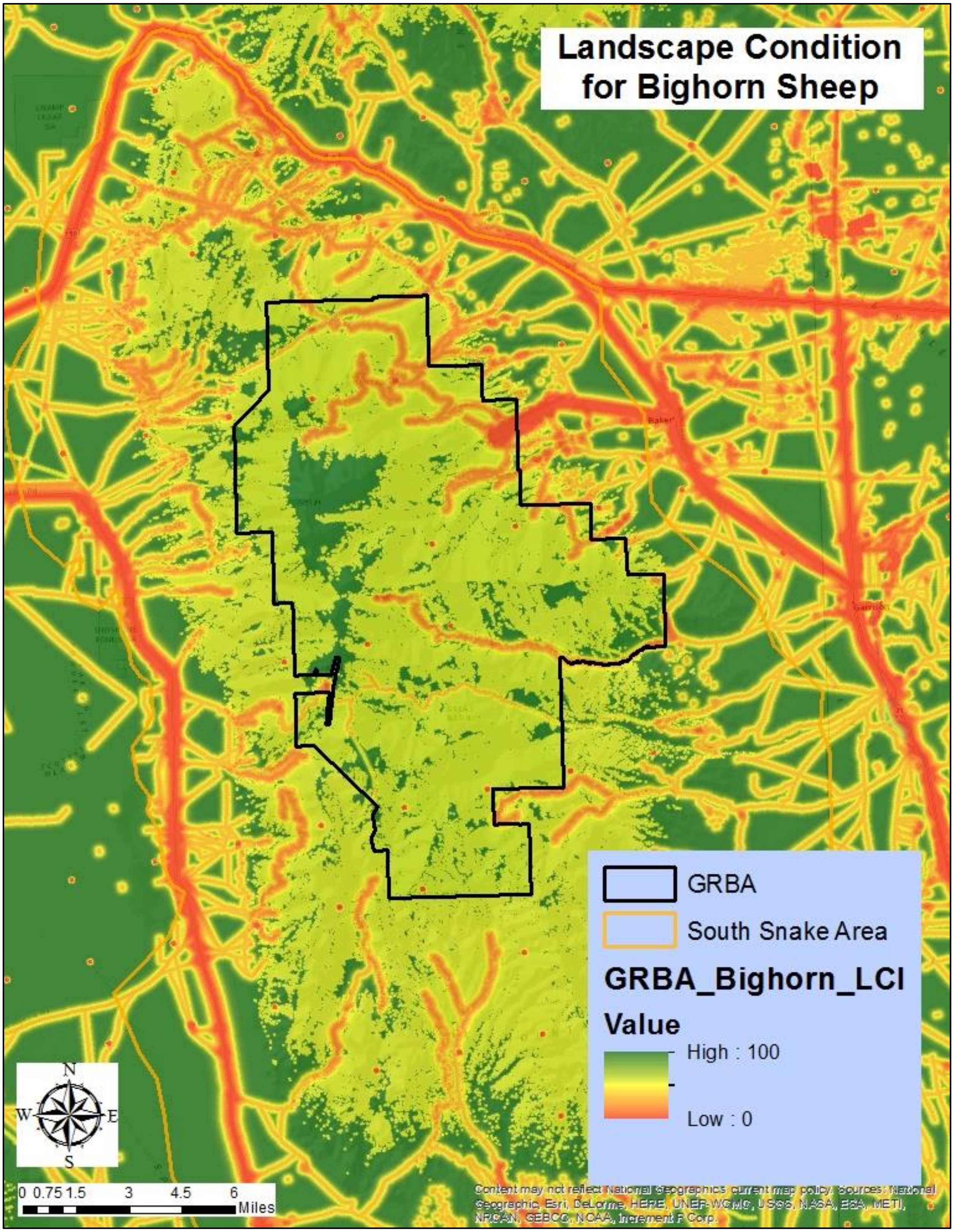

Figure 66. Landscape Condition Index designed for Bighorn Sheep.

Finally, Table 41 includes a summary of the eight condition indicators for bighorn sheep. Two indicators, Trend in Herd Size and Disease Status indicate good condition and no apparent change, with medium confidence. All other indicators suggest significant concern. Survival Rate, Winter Range, Fire Regime Condition, and Landscape Condition all suggest deteriorating condition for bighorn sheep. Indicators of wildfire overlap on sheep range, and Proximity to domestic sheep in nearby grazing allotments both appear to be unchanging. Confidence in these indicators is likely strongest in measures of fire regime condition, wildfire overlap with sheep range, and domestic sheep usage from neighboring allotments. Confidence is low for indicators of survival rate (need larger sample size), quality of winter range, and landscape condition. The latter two would benefit from additional field validation. Overall condition rating was placed at significant concern, relatively stable, and high overall confidence in indicator scores.

Table 41. Summary of indicators of condition for bighorn sheep at Great Basin NP.

Bighorn Sheep			
Indicators of Condition	**Specific Measures**	**Condition Status/Trend**	**Rationale**
Survival Rate	Survival rate and causes of mortality over a two-year sample period from radio-collar sample of 6 individuals		Well below an estimated 50-100 for viability; current survival estimates would benefit from more robust sampling
Trend in Herd Size	Field observation and estimated count of individuals		Based on field counts, a very small, apparently stable herd, but it should be increasing
Disease Status	Presence of *Mycoplasma ovipneumoniae* among bighorn sheep individuals		Based on 30% population sample, appears to be an important disease-free herd
Winter Range	Areal extent and forage quality		<650 ha of winter range, quality varies due to past land use and risk of invasive plants
Fire Regime Condition Class	Proportional extent of FRCC 2-3		>50% of suitable habitat with moderate to severe fire regime departure
Wildfire Overlap	Wildfire patch overlap with bighorn range, limiting woody vegetation		Very limited, but important habitat improvement observed from recent fires

Table 41 (continued). Summary of indicators of condition for bighorn sheep at Great Basin NP.

Bighorn Sheep			
Indicators of Condition	**Specific Measures**	**Condition Status/Trend**	**Rationale**
Proximity of Domestic Sheep in adjacent BLM Grazing Allotments	Presence of domestic sheep within seasons and distances that generate risk of disease transmission		Spatial and temporal overlap currently limited, but still too close given established guidelines; expanded populations would likely escalate potential for disease spread.
Landscape Condition Index	Intersection of habitat distribution map with the LCI layer and reporting the average scores for summer vs. winter range.		Predominantly using intact landscape, but much dense tree cover from mountain lions, and road barrier between South and North Snake ranges could isolate populations over the long term

Sources of Expertise

Bryan Hamilton, Wildlife Biologist, Great Basin NP, provided radio collar data, and assessment review.

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4.2.6. Sagebrush-Steppe

Condition - Trend

Moderate Concern – Deteriorating Trend – High Confidence

Indicators / Measures

- *Fire Regime Condition Class*
- *Fire Regime Departure*
- *Annual Grass Cover*

<u>Background and Importance</u>

Sagebrush (*Artemisia tridentata*) dominated communities are ubiquitous in the Great Basin, and range from the basin floors to over 10,000 feet (3,048 m) in elevation. With increasing elevation gain, basin big sagebrush (*Artemisia tridentata* var. *tridentata*) at 1,969 - 6,890 feet (600 - 2,100 m), Wyoming big sagebrush (*Artemisia tridentata* spp. *wyomingensis*) at 2,625 - 6,890 feet (800 - 2,100 m), and mountain big sagebrush (*Artemisia tridentata* spp. *vaseyana*) at 2,625 - 10,171 feet (800 - 3,100 m), are the dominant shrubs in these communities. Provencher et al. (2010) classify those mid-elevation communities dominated by *Artemisia tridentata* spp. *wyomingensis* as the Montane Sagebrush Steppe – Upland ecotype and the higher elevation, *Artemisia tridentata* spp. *vaseyana* dominated communities as the Montane Sagebrush Steppe – Mountain ecotype. The Basin Big Sagebrush communities (dominated by *Artemisia tridentata* var. *tridentata*) are found in the basin bottoms and thus were not mapped by Provencher et al (2010).

Figure 67. Sagebrush (*Artemisia tridentata*)-dominated communities. Photo: Bob Unnasch.

Higher precipitation and cooler temperatures result in higher soil moisture, greater soil development, and increased plant production in the mid- to upper-elevations of the region's mountain ranges (Alexander et al 1993). Conversely, the lower elevations have minimal precipitation and higher temperatures resulting in lower plant productivity (Smith and Nowak 1990).

The distributional pattern of *Artemisia tridentata* subspecies and plant productivity associated with elevation also drove the historical fire ecology of these shrublands. As a result of the low plant productivity at lower elevations, the basin big sagebrush and lower-elevation Montane Sagebrush Steppe - Upland communities tended to be fuel-limited. As the *Artemisia* shrubs matured, the canopy would eventually close allowing for wildfire to carry. As soon as a fire encountered open canopy and discontinuous fuels, it would not be able to spread. Thus, historically, wildfires tended to be patchy and relatively limited in extent.

Artemisia tridentata is killed by fire and so the historic landscape mosaic in these lower elevations was a patchwork of all seral stages ranging from grass-dominated states to old closed-canopy sagebrush. Provencher et al. (2010) identify the Natural Range of Variability for the Montane Sagebrush Steppe – Upland type as 21% early successional, 66% mid-successional, and 13% late successional reflecting this pattern. Post-fire recovery of these low-dry communities can be very slow and a return to pre-burn conditions can take several decades (Humphrey 1984). *Artemesia* is dependent on recruitment by seed following fire, and thus reinvades from the burn's edges. Daubenmire (1975) reported that *A. tridentata* germination and establishment is tied to years of significant precipitation and that many years can pass between favorable years limiting the rate of reinvasion.

With increasing plant productivity, the mid- and high-elevation Montane Sagebrush Steppe – Upland and Montane Sagebrush Steppe – Mountain ecotypes had greater fuel loadings, and tended to burn more frequently with larger fire extents. However, soil moisture increases with elevation, so seed recruitment, seedling survival and recovery rates were higher than in the basin bottoms (Nelson et al. 2014). In response, *Artemisia tridentata* spp. *vaseyana* dominated communities are more resilient to fire and are able to recover within 25 years following fire (Bushey 1987). Thus, the Montane Sagebrush - Mountain communities had higher fire frequencies (15-35 years), larger fire extents, and shorter recovery times.

In an experimental study in central Nevada, Chambers (2005) demonstrated that the resilience of sage-brush communities to (prescribed) fire increases with elevation (Figure 68). Three years following disturbance the higher sites showed the least change in community composition and structure.

The expansion of *Bromus tectorum* (cheatgrass) throughout the Great Basin has resulted in dramatic changes in Basin Big Sagebrush Steppe and lower elevation Montane Sagebrush Steppe - Upland communities. Cheatgrass is a system-altering species that has transformed the entire Great Basin region (D'Antonio and Vitousek 1992, Pellant 1996). Cheatgrass is a plastic winter annual that germinates with increased soil moisture in the fall, winter, or spring. Its early germination, rapid growth, and ability to usurp early season soil moisture, makes it an effective competitor relative to native shrub, bunchgrass and forb seedlings. Under favorable conditions, cheatgrass is capable of producing continuous fine fuels in the sagebrush steppe herbaceous layer. Cheatgrass is usually dead and dry (i.e., *cured*) by mid-July, in contrast with the native perennial grasses that still contain ~65% moisture at this time. These cured fine fuels promote fire spread, and result in a positive feedback that eliminates native shrubs, forbs and grasses while encouraging continued invasion.

The presence of cheatgrass, in even relatively small amounts constitutes a significant threat to the persistence of native sagebrush steppe communities. Young and Evans (1975) determined that cheatgrass produces between 5,000 and 15,000 seeds per m^2 in sagebrush steppe communities degraded by wildfire or inappropriate grazing practices. Young et al. (1969) documented plant cheatgrass densities of 10,000-13,000 plants per m^2 in Nevada sagebrush steppe. Miller et al. (2014) documented an average of a four-fold increase in the percent cover of cheatgrass and other exotic annual grasses three years following prescribed fire management across 11 sites in the floristic Great Basin.

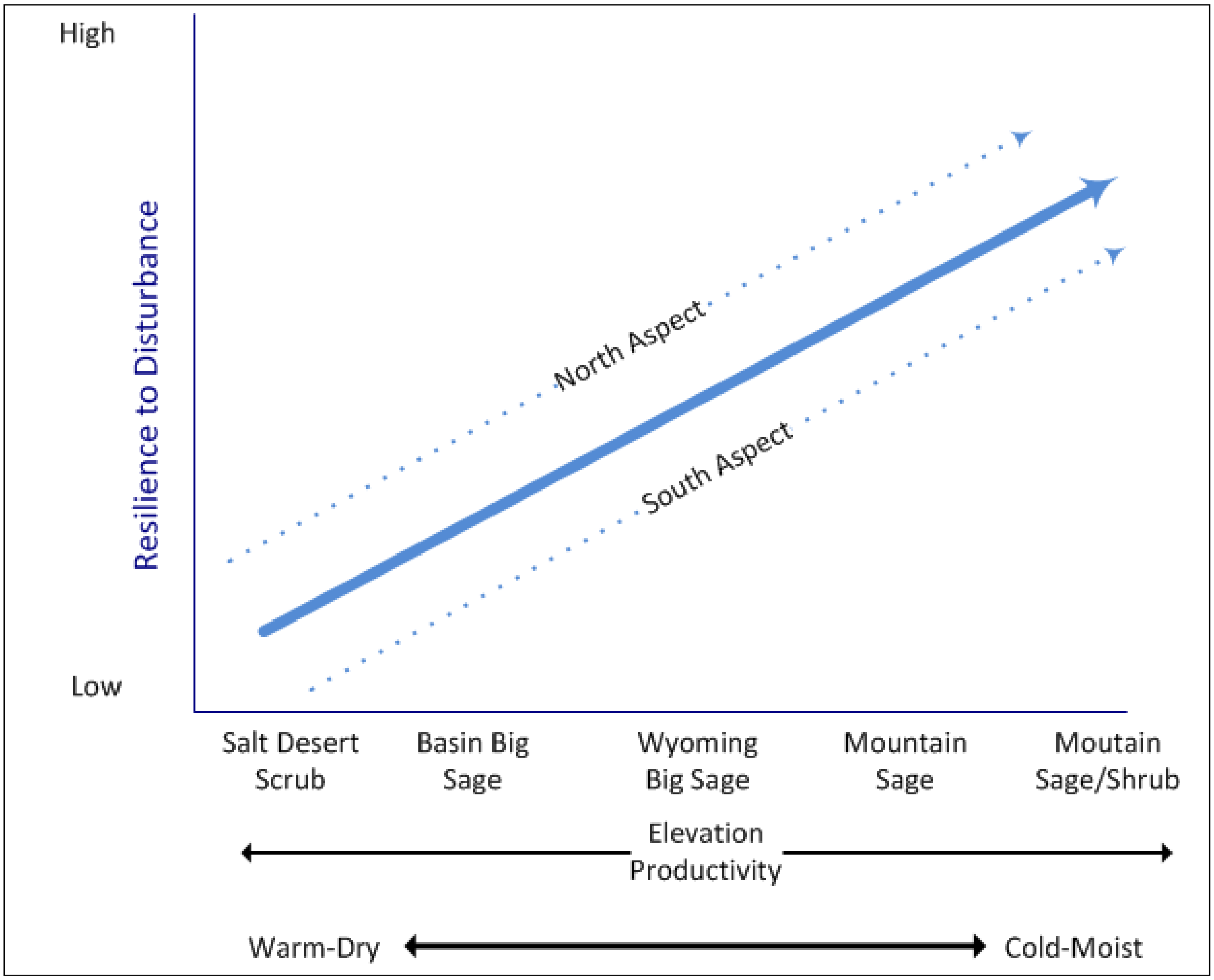


Figure 68. Resilience of sage-brush communities in relation to prescribed fire and elevation (Chambers 2005).

Cheatgrass is adapted to Great Basin communities ranging from 1,500 to >9,000 feet (457 to >2,743 m) in elevation and from 6 to 20 inches (15-51 cm) of precipitation. Germination of cheatgrass is limited by soil temperature, and its spread into higher elevations seems to be limited by winter temperatures. Thus, currently cheatgrass is limited to the lower elevations within the park.

Vegetation Description

The dominant sagebrush community in the park is the Montane Sagebrush Steppe-Upland ecotype which Provencher et al. (2010) report totaling 12,710 acres (5,144 ha) in extent or about 17% of the park. Montane sagebrush steppe occurs above the 14-inch (36-cm) precipitation zone and largely forms the matrix community within this zone, intergrading with other dominant communities within the park, including mountain mahogany (14,053 acres (5,687 ha)) and pinyon-juniper woodland (6,947 acres (2,811 ha)).

A variety of other shrubs can be found throughout the Montane Sagebrush Steppe in the park, but these are seldom dominant, they include *Ericameria watsonii, Chrysothamnus viscidiflorus, Ephedra, Symphoricarpos oreophilus, Purshia tridentata*, *Ribes*, and *Amelanchier utahensis*. The herbaceous layer is usually well represented, but bare ground may be common particularly in the lower, more arid and disturbed occurrences. Graminoids can be abundant and may include *Pseudoroegneria spicata, Poa fendleriana, Hesperostipa comata, Elymus trachycaulus, Elymus elymoides, Leymus, Achnatherum hymenoides, and Poa secunda ssp. secunda*. Forbs are often numerous and an indicator of health. Forb species include several *Astragalus species, Balsamorhiza, Castilleja angustifolia, Crepis spp., Erigeron spp., Eriogonum species, Lupinus argenteus, Phlox gracilis* and *Senecio* spp. (Shaw, undated)

There is a small extent (973 acres (394 ha)) of the Montane Sagebrush Steppe - Mountain ecotype at the highest elevations. As described above, this system has a slightly different fire history than the upland ecotype, and is more resilient to fire. The Mountain ecotype also has a higher diversity of shrubs.

Disturbance Description

Historic mean fire return intervals in and recovery times of mountain big sagebrush are subjects of lively debate (Welch and Criddle 2003) as there is no fire-scar data on which to base estimates; most estimates are based on fire-scar data from adjacent forestlands. *A. tridentata* is killed by fire, and so communities are subject to stand-replacement fires (Britton and Clark 1985). Post fire recovery of *Artemesia* is driven by recruitment by seed. Thus, the rate of recovery is determined by the size of the fire, because seed must disperse from the fire margins, and successful recruitment by seed (Daubenmire 1975).

Provencher et al. (2010) report Fire Return Intervals of 40 – 80 years for the Montane Sagebrush Steppe – Upland, and 50 – 80 years for the Montane Sagebrush – Mountain subtypes in the park.

In contrast, they report FRI ranging between 150 – 250 years for Black Sagebrush. These FRIs are similar to those reported by other authors (Crawford et al. 2004, Johnson 2000, Miller et al. 1994, Burkhardt and Tisdale 1969 and 1976, Houston 1973, Miller and1995, Miller et al. 2000, Baker 2011). Under pre-settlement conditions mosaic burns generally exceeded 75% due to the relatively discontinuous herbaceous layer.

Fire regimes changed in the Great Basin with Euro-American settlement when intense grazing and active fire suppression began and Native American burning practices ended (Kay 1995, Griffin 2002, Kitchen 2012). Since about 1900, the beneficial effects of fire have been virtually absent from what is now Great Basin NP. Fire histories for one Great Basin NP watershed reveal the last large fire occurring in 1865 (Heyerdahl et al. 2011, Kitchen 2012). Before this time small, frequent fires in mid-elevation plant communities were common (Kitchen 2012) and maintained a mosaic structure that included a significant extent of early seral plant communities and habitat heterogeneity. The reduction of fine fuels (as a result of domestic livestock use) and active fire suppression, along with favorable climate conditions, has shifted vegetation away from a range of seral states and community types and towards a preponderance of late-successional woody plant communities. This is reflected in the Ecological Departure scores reported by Provencher et al (2010).

The introduction of cheatgrass has significantly changed the fire regime in the Basin Big Sagebrush and the Montane Sagebrush Steppe - Upland communities that fringe the park's boundaries. These more frequent fires will likely spread into the park as cheatgrass expands upslope and deeper into the park.

In this assessment, we address management concerns regarding the current ecological integrity of sagebrush steppe-related systems, the location of recent wildfires, the location of invasive annual grasses, and current knowledge of sagebrush regeneration.

Data and Methods

Indicators / Measures

- ***Fire Regime Condition Class***
- ***Fire Regime Departure***
- ***Annual Grass Cover***

A key ecological attribute for Sagebrush-Steppe is the fire regime that drives the system's successional dynamics and its conversion to other states. One practical indicator for this key attribute is fire regime condition class. See 4.2.2.1 and Horner et al. (2014) for an explanation of methods used to measure fire regime departure and its assignment into condition class for these systems. The second key ecological attribute is the abundance of annual grasses (i.e., *Bromus tectorum)* that, with sufficient cover can irreversibly transition sagebrush communities into annual grasslands.

In order to measure the current (or future) ecological condition of each ecological system, it was first necessary to define the Natural Range of Variation (NRV) per biophysical setting. NRV is the relative amount (percentage) of each vegetation class in a given landscape that would be expected to occur in a biophysical setting under natural disturbance regimes and 20th century climate (Hann and Bunnell 2001, Provencher et al. 2007, Provencher et al. 2008, Rollins 2009). The NRV was calculated with the state-and-transition modeling software Vegetation Dynamics Development Tool (VDDT, ESSA Technologies, Barrett 2001, Beukema et al. 2003). To determine the NRV for each ecological system in the project area, TNC modified models from a TNC Great Basin and Mojave Desert ecoregion library developed in northwestern Utah, eastern Nevada, and California (Forbis et al. 2006, Provencher et al. 2007, Provencher et al. 2008, Provencher et al. 2009, Low et al. 2010). Ecological departure is a broad-scale measure of biophysical setting condition – an integrated, landscape-level estimate of the ecological condition of terrestrial and wet biophysical settings. Ecological departure incorporates species composition, vegetation structure, and disturbance regimes to estimate a biophysical setting's departure from its NRV.

Reference Conditions

Technically, ecological departure is a measure of dissimilarity between the NRV (expected "natural" distribution of vegetation classes) and the current vegetation class distribution. Ecological departure is scored on a scale of 0% to 100%: Zero percent represents NRV while 100% represents total departure. Further, a coarser-scale metric known as Fire Regime Condition Class (FRCC): FRCC 1 represents biophysical setting with low (<34%) departure; FRCC 2 indicates biophysical setting with moderate (34 to 66%) departure; and FRCC 3 indicates biophysical settings with high (>66%) departure (Hann et al. 2004). The abundance of uncharacteristic states is addressed only through the reduced extent of historical seral stages.

In order to document the relationship between recent disturbance and sagebrush steppe, mapped perimeters of wildfire were obtained and overlaid on the distribution of the sagebrush steppe systems.

This ecological system occurs in many of the Western United States, usually at middle elevations ranging from 3,281 to 8,202 feet (1,000-2,500 m). Within the Great Basin mapping zone, elevation ranges from 4,495 feet (1,370 m) in Idaho to 10,500 feet (3,200 m) in the White Mountains California (Table 42; Winward and Tisdale 1977, Blaisdell et al. 1982, Cronquist et al. 1994, Miller and Eddleman 2000).

Table 42. Reference conditions by successional class for montane sagebrush steppe - upland biophysical settings.

Class Code [a]	Class Abbreviation and Description
A	*Early: 0-12 yrs;* 0-10% canopy of mountain sage/mountain brush; 10-80% grass/forb cover
B	*Mid--open*: 13-38 yrs; 11-30% cover of mountain sage/mountain shrub; >50% herbaceous cover
C	*Mid--closed*; : 38+ yrs; 31-50% cover of mountain sage/mountain brush; 25-50% herbaceous cover, <10% conifer sapling cover
D	*Late-open*: 80-129 yrs; 10-30% cover conifer <5m for PJ and <10m for mixed conifers; 25-40% cover of mountain sage/mountain brush; <30% herbaceous cover
E	*Late-closed*: 130+ yrs; 31-80% conifer cover (lower for PJ, greater for mixed conifers) 10-25m; 6-20% shrub cover; <20% herbaceous cover
U	*ES: Early-Shrub;*20-50% cover rabbitbrush species
U	*TE*: *Tree-Encroached*; 31-80% conifer cover 10-25 m (33-82 ft); <5% shrub cover; <5% herbaceous cover
U	*DP: Depleted*; 20-50% cover of mountain sage/mountain brush; <5% herbaceous cover; <10% conifer sapling cover
U	*SAP: Shrub-Annual-Grass-Perennial-Grass*; 21-50% cover of mountain sage/mountain brush; >5% cover of native grass; 5-10% cheatgrass cover; <10% conifer sapling cover

[a] Standard LANDFIRE coding for the 5-box vegetation model: A = early-development; B = mid-development, closed; C = mid-development, open; D = late-development, open; E = late-development, closed; U = Uncharacteristic class (*DP* = depleted); MSu-A to B = conversion to montane sagebrush steppe-upland class A to B; MC-E = conversion to mixed conifer class E; and SP-D = conversion to spruce class D.

Table 42 (continued). Reference conditions by successional class for montane sagebrush steppe - upland biophysical settings.

Class Code [a]	Class Abbreviation and Description
U	SA: Shrub-Annual-Grass; 21-50% cover of mountain sage/mountain brush; ≤5% cover of native grass; ≥5% cheatgrass cover; <10% conifer sapling cover
U	*AG: Annual-Grass;* 10-30% cover of cheatgrass
Reference Condition: Natural Range of Variation	21%: A-Early 44%: B-Mid-closed 22%: C-Late-close 10%: D-Late-open 03%: E-Late-closed 00%: U

[a] Standard LANDFIRE coding for the 5-box vegetation model: A = early-development; B = mid-development, closed; C = mid-development, open; D = late-development, open; E = late-development, closed; U = Uncharacteristic class (*DP* = depleted); MSu-A to B = conversion to montane sagebrush steppe-upland class A to B; MC-E = conversion to mixed conifer class E; and SP-D = conversion to spruce class D.

Condition and Trend

Fire Regime Conditions

Both sagebrush-steppe biophysical settings exhibit some departure from their natural range of variation due to fire exclusion, historic grazing, and other land use practices (Provencher et al. 2010). However, the ecological departure of the sagebrush steppe – mountain ecotype falls within FRCC 1, indicating that relative to other systems, it requires little management attention.

When calculated for the park landscape as a whole, mountain sagebrush steppe-upland was calculated as 57% departed. In contrast, sagebrush steppe-mountain was calculated as 30% departed. The primary cause of ecological departure was the lack or near absence of early-succession classes and an over-representation of later-succession classes. Uncharacteristic classes negatively influenced ecological departure scores and increased the percentage of high-risk classes. Figure 69 shows the Ecological Departure for the sagebrush-steppe biophysical setting (BPS).

Ecological departure in the Montane Sagebrush Steppe-upland was driven by two factors. First, there is an overabundance of the later (older) stages, C&D and an under abundance of the earlier stages. Provencher et al. (2010) interpret this as a result of historical fire suppression preventing these older, closed stages from being reset to earlier seral states. Similarly, fire suppression has likely allowed for conifer encroachment, resulting in ~20% of the historic Sagebrush-steppe-upland being classified in the TE (tree encroached) state.

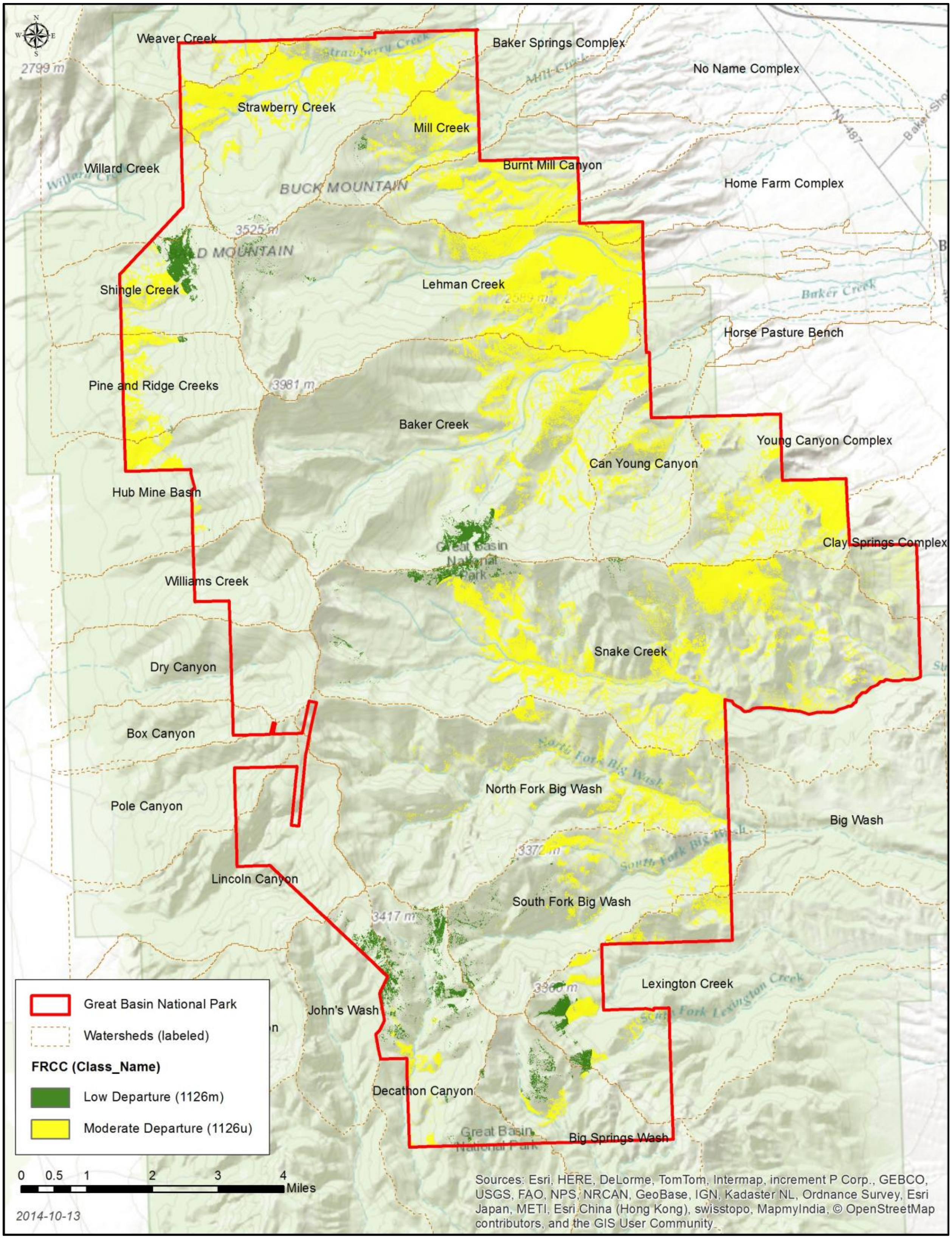


Figure 69. Montane Big Sagebrush biophysical setting and FRCC for all of Great Basin NP.

Table 43. Current conditions in Great Basin NP for each sagebrush-steppe system including: current acres in each vegetation class, current percent acres in each vegetation class, natural range of variation which represents the desired condition for each biophysical setting, and ecological departure.

Sagebrush-Steppe System	Class [a]	A	B	C	D	E	AG	DP	SA	SAP	SD	TE	TE/SA/SAP	Total
Montane sagebrush steppe-upland	Current Acres in Class	66	963	4,857	2,283	840	5	8		974	26	2,574	116	12,711
	Nat. Range Variation (%)	21	44	22	10	3								100
	Current % in Class	1	8	38	18	7				8		20	1	100
	Ecological Departure (%)													57
Montane sagebrush steppe-mountain	Current Acres in Class	9	416	470	840	1	10		10					943
	Nat. Range Variation (%)	21	44	22	3	3								100
	Current % in Class	1	44	50	7	0								100
	Ecological Departure (%)													30
	Current Acres in Class	9	416	470	840	1	10		10					943

[a] Standard LANDFIRE coding for the 5-box vegetation model: A = early-development; B = mid-development, closed; C = mid-development, open; D = late-development, open; E = late-development, closed. Uncharacteristic classes defined by TNC, but not defined by LANDFIRE: AG= Annual Grass; DP = Depleted; SA=Shrub Annual Grass; SAP=Shrub Annual Grass – Perennial Grass; SD=Shrub Depleted; TE=Tree Encroached.

Disturbance and Montane Big Sagebrush
Historically, the most common disturbance structuring the Montane Sagebrush Steppe BPS was fire. Fires both maintained the NRV and limited conifer encroachment.

Starting early in the last century, grazing by domestic livestock reduced the cover of native perennial bunchgrasses which, in turn, reduced the frequency of wildfires allowing for the expansion of conifers into the sagebrush steppe. Then, in the middle of the last century, cheatgrass spread throughout the Great Basin, taking advantage of the reduction of the native bunchgrasses. The current ecological condition of the Montane Sagebrush Steppe-upland BPS reflects all of these stresses.

Passive restoration of the Montane Sagebrush Steppe will involve wildfire management. Allowing wildfires to, within fire management bounds, replace the older closed canopy seral classes with earlier successional classes could bring this system closer to NRV.

Figure 70 shows the location of wildfires within the park since 1980. These fires have burned only about 10% of the area that would have burned under NRV.

Cheatgrass is an ecosystem-changing species that promotes fires, and reduces fire return intervals to less than 10 years thereby eliminating most, if not all native species. Baker (2006), for example, was strident in stating that "If maintaining and restoring habitat for sagebrush-dependent species is the goal, fire should be suppressed where there is a threat of cheatgrass (*Bromus tectorum)*".

Cheatgrass is present in Great Basin NP. Figure 71 shows the estimated current distribution of cheatgrass (and other annual grasses) in relation to the Montane Sagebrush Steppe. This figure illustrates that cheatgrass is ubiquitous in the valley bottoms surrounding Great Basin NP, and it is encroaching into the park.

Cheatgrass is benefited by fire, and will expand rapidly following any burn. This is especially true in those areas that have been degraded by domestic livestock. The best protection from cheatgrass invasion is a healthy perennial bunchgrass community. While cheatgrass is believed to be limited by cold soil temperatures, it has been recorded at 10,000 feet (3,048 m) in Idaho, suggesting that it may be evolving a greater tolerance to cold soils.

Medusahead (*Taeniatherum caput-medusae*) is another exotic cool-season grass that, like cheatgrass, is a pyrogenic system-changing species. Medusahead is more tolerant of cold soil temperatures, and is commonly found at higher elevations in Idaho. Once established, medusahead can thrive in both the montane sagebrush steppe-upland and –mountain communities. This exotic grass is expanding rapidly in Idaho and has been recorded in several counties in Nevada, including Elko County. If established in Great Basin NP, medusahead, in combination with cheatgrass, have the potential of transforming the park's montane sagebrush steppe communities.

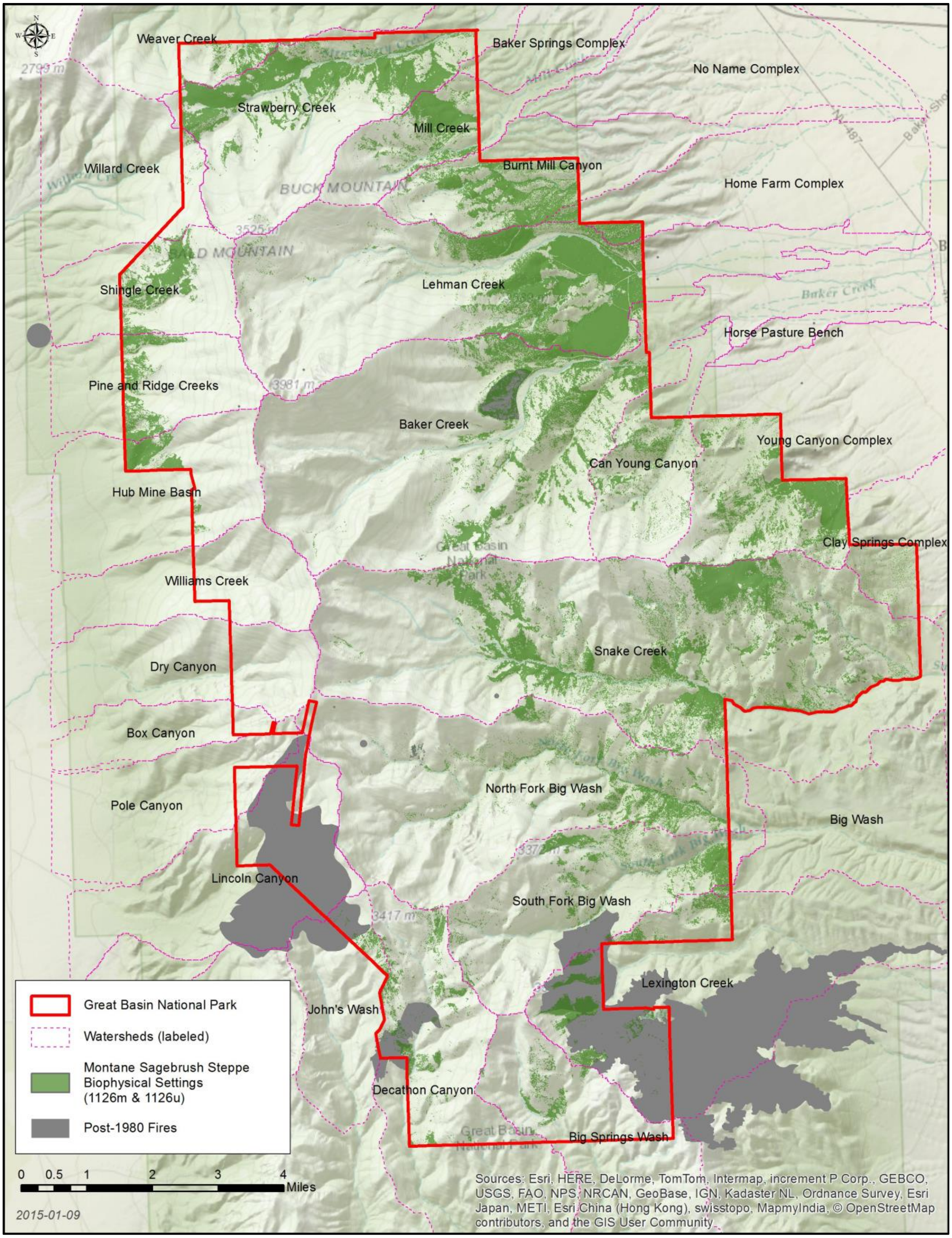


Figure 70. Coincidence of wildfires since 1980 with Big Sagebrush biophysical setting.

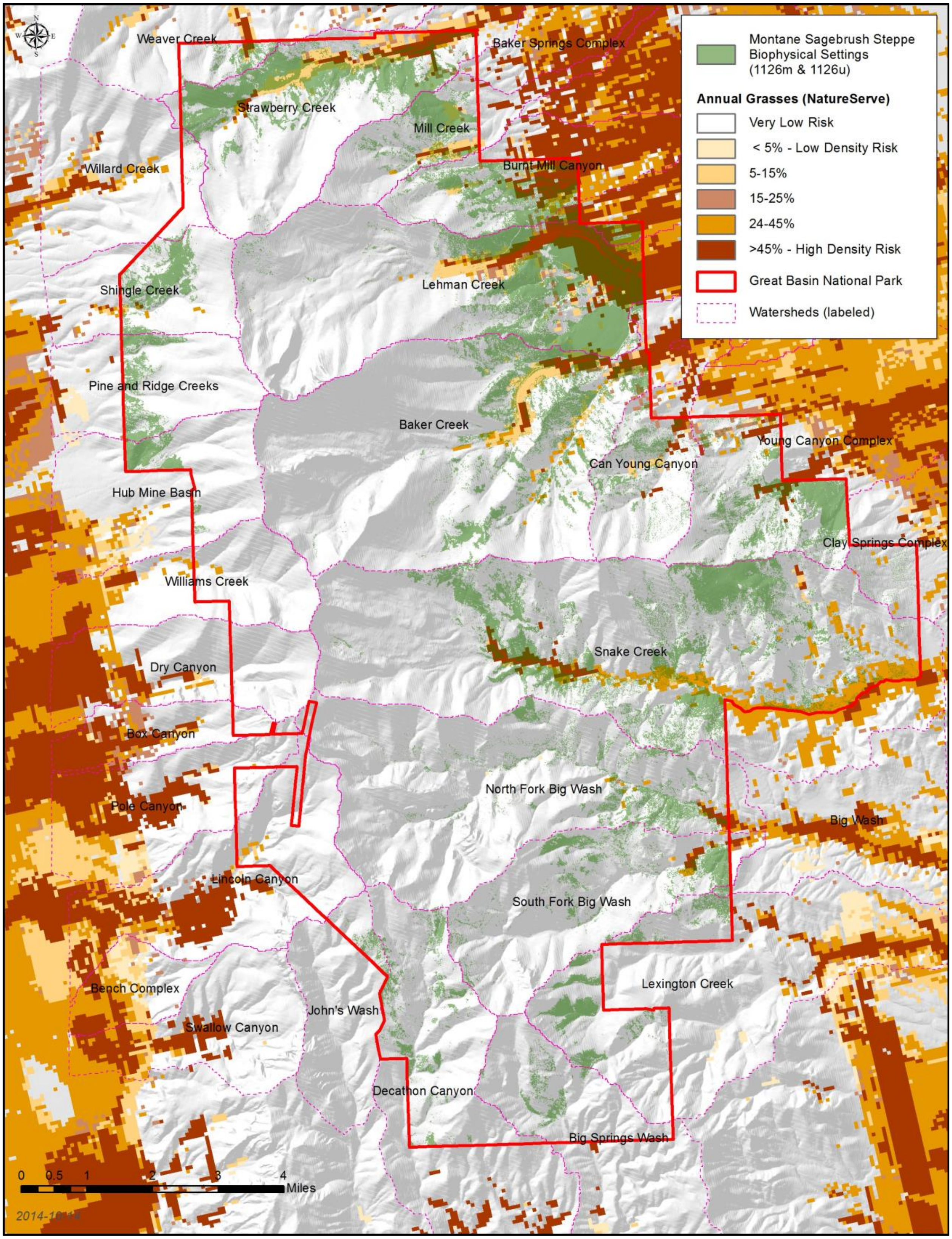


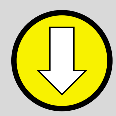
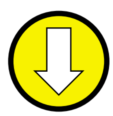
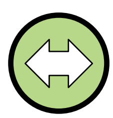
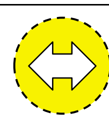
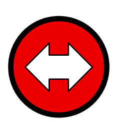
Figure 71. Coincidence of cheatgrass with Big Sagebrush biophysical setting.

Summary of Status

The ecological condition of the park's montane sagebrush steppe varies:

- The upland ecotype are 57% departed from natural range of variation, and the mountain ecotype are 31% departed.
- The current condition of Montane Sagebrush Steppe in the park (i.e., percent departure from NRV) is due to an over representation of late successional classes; under representation of early classes; and encroachment by native conifers and exotic annual grasses.
- The current condition of sagebrush steppe communities is a result of the interaction of a number of historic stresses including inappropriate livestock grazing, the introduction of cheatgrass and historic fire exclusion.
- Under current management practices, the montane sagebrush steppe stands will continue to increase their departure from NRV, and some form of disturbance is required to reset older stands back to early seral states.
- The Montane Sagebrush Steppe communities remain relatively intact and have the potential to recover if the native bunchgrasses are able to rebound from historic grazing impacts.

Table 44. Summary of indicators of condition of Sagebrush-Steppe in Great Basin NP.

Sagebrush-Steppe			
Indicators of Condition	**Specific Measures**	**Condition Status/Trend**	**Rationale**
Fire Regime Condition Class Montane Sagebrush Steppe-Upland	Proportional extent of FRCC 2-3		Within Great Basin NP 56% fire regime departure = FRCC 3
Fire Regime Condition Class Montane Sagebrush Steppe-Mountain	Proportional extent of FRCC 2-3		Within Great Basin NP 31% fire regime departure = FRCC 1
Fire Occurrence	Area of Disturbance caused by wildfire		Wildfire disturbance since 1980 has been ~10% of NRV.
Cover extent of annual grasses	Cheatgrass is abundant in the valley bottoms surrounding the park, and it is encroaching into the park.		Cheatgrass is a system-changing species that has converted much of the Great Basin's Sagebrush Steppe into annual grasslands.

Sources of Expertise

This assessment was derived largely from:

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Chambers et al. 2014. Resilience to stress and disturbance, and resistance to *Bromus tectorum* L. invasion in cold desert shrublands of western North America. Ecosystems 17:360-375.

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4.3. Aquatic Resources and Ecological Integrity

Focal resources in aquatic environments of the park include lakes, streams, riparian zones, and populations of sensitive fish, such as Bonneville cutthroat trout. By assessing the ecological integrity of these resources, one can gain insights into the changing conditions causing ecosystem stress, and clarify options for management. Integrity assessment first involves identifying the key ecological attributes for each focal resource. Key ecological attributes include defining characteristics of a resource, its abundance, and its distribution; and key environmental associations, drivers, and constraints affecting the resource. The next step is to identify indicators for each key attribute and characterizing an expected or reference range of variation for each indicator. Once this range is characterized, one can then measure the status of each focal resource based on indicator data. Indicators may incorporate data using different levels of effort, from remote sensing, to ground-level rapid assessment, or ground-level intensive sampling. Below we address aquatic resources including water quality, montane riparian woodlands, cave/karst processes, springs, and Bonneville cutthroat trout.

4.3.1. Conceptual Model for Aquatic Resources

<u>Conceptual Model Development</u>

The conceptual ecological model for aquatic resources in Great Basin NP, similar to the model for upland resources, draws upon a wealth of existing conceptual models. Most importantly, the model here rests on the "Montane Wet System" model developed for the Central Basin and Range Rapid Ecoregional Assessment (Comer et al. 2013) and the "Wet System" model developed by Miller et al. (2010) to guide integrated landscape monitoring of the Great Basin. The conceptual ecological model for aquatic resources in the park comes in two parts: (1) an overarching "Aquatic Resources" model that addresses all aquatic ecological resources together; and (2) a set of three "sub-system" models that address dynamics specific to individual ecological sub-systems within the larger ecosystem. The overarching Aquatic Resources model for the park is shown in two diagrams, one without the human drivers (Figure 72) and one with these drivers included (Figure 73).

Sub-system conceptual models play three crucial roles in the Ecological Integrity Assessment Framework by helping to identify: (1) the key ecological attributes for each focal resource, on which to further focus management attention; (2) indicators for each key attribute, for each resource; and (3) an ecologically acceptable or reference range of variation for each indicator, for each resource. Key ecological attributes include defining physical, biological, and ecological characteristics of a resource, its abundance, and its distribution; and key environmental associations, drivers, and constraints.

The sub-system models developed for the park concern the "Stream-Riparian," "Spring," and "Cave/Karst" sub-systems of the larger aquatic landscape. Two of the focal resources addressed in the present Natural Resource Condition Assessment – Bonneville Cutthroat Trout and Montane Riparian Woodlands – are aspects of the "Stream-Riparian" sub-system. The resource labeled "Water Quantity/Quality" is an aspect of both the "Stream-Riparian" and "Spring" sub-systems. The resource labeled "Cave/Karst Processes" addresses several aspects of the Cave/Karst sub-system.

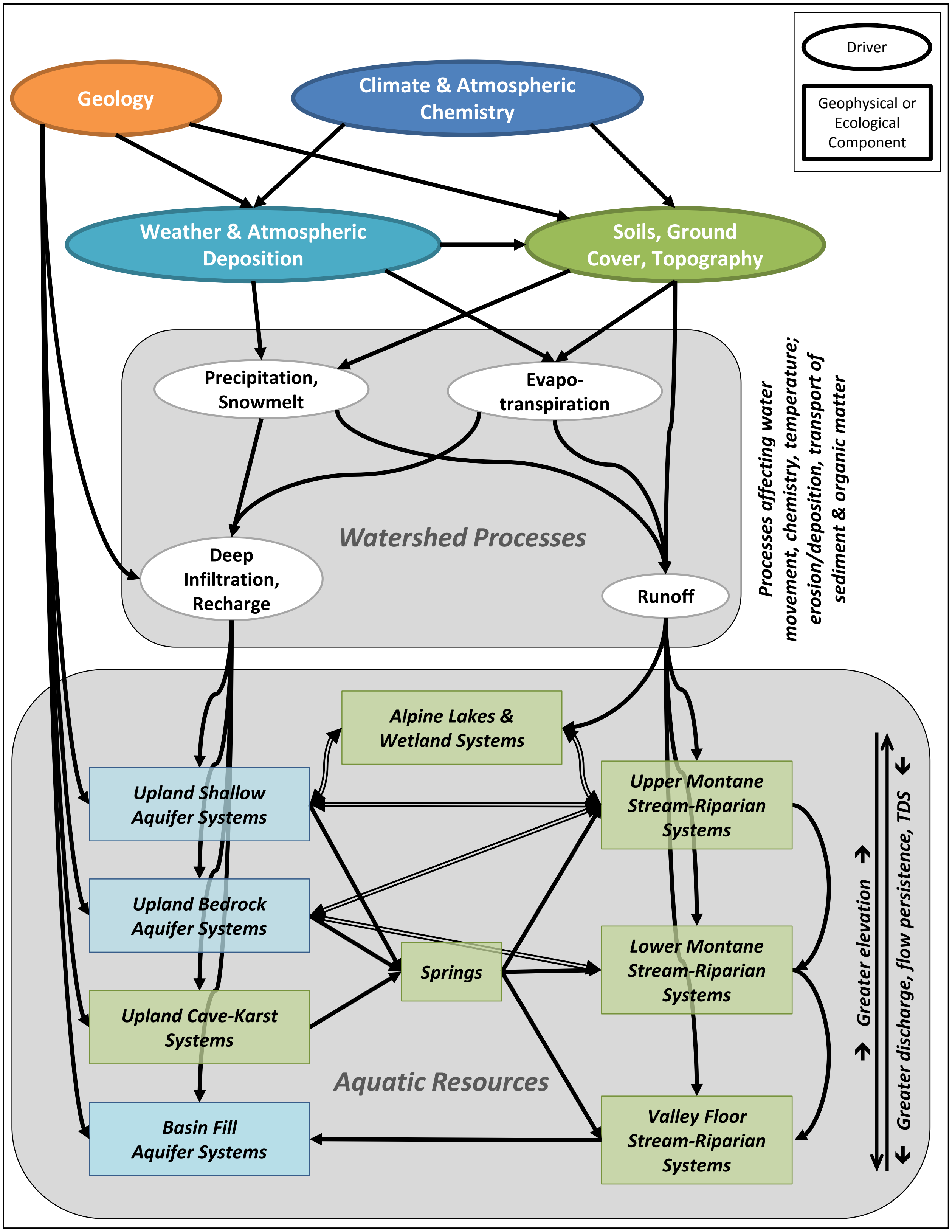

Figure 72. Overarching Aquatic Resources conceptual model for Great Basin NP, showing only natural drivers.

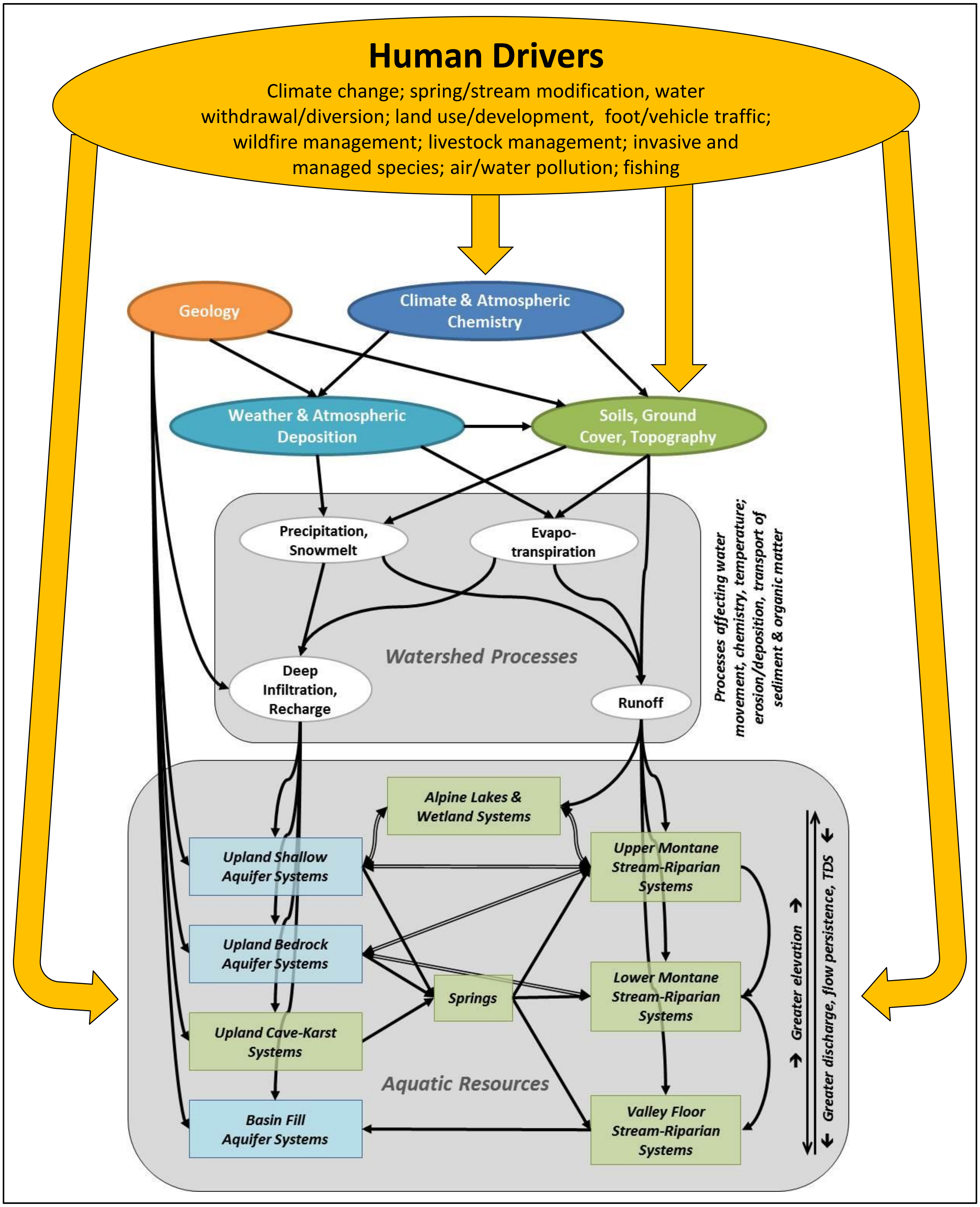

Figure 73. Overarching Aquatic Resources conceptual model for Great Basin NP, including human drivers.

Aquatic Resources Model

The overarching Aquatic Resources model for the park (Figure 72) recognizes a gradation of riparian-stream sub-systems that occur at different elevations, from small, mostly upper montane stream courses, some with intermittent flow; to mid-sized, mostly lower montane stream courses with mostly perennial flow; to stream courses that emerge onto the valley floor, perennial as they emerge but becoming intermittent with distance from the piedmont. Higher losses from evapotranspiration diminish stream flow at lower elevations, as does leakage of stream water into underlying bedrock fractures along some reaches at middle to lower elevations. Stream discharge volume and total concentration of dissolved matter (total dissolved solids, TDS) generally increase with decreasing elevation (Baker 2007). The potential for overbank flooding generally increases with increasing discharge, and also with decreasing elevation because of the increasingly large catchment basins.

The overarching model also recognizes the importance of groundwater flow in shaping the hydrology and chemistry of cave, spring, and stream waters in the park; and recognizes four groundwater flow systems – shallow upland aquifers, upland bedrock aquifers, cave/karst flow systems, and basin fill aquifers. Together with deeper, carbonate aquifer systems (not included in the model for the park), these aquifers comprise the regional aquifer system (Elliott et al. 2006, Heilwell and Brooks 2011). Groundwater discharge to surface waters within the park occurs both at discrete springs and through diffuse seepage along some stream reaches ("gaining" reaches); and stream water also seeps back into the groundwater system along some stream reaches ("losing" reaches). Some springs and groundwater seeps discharge directly into streams; others only into localized wet meadows with no stream outflow (Baker 2007).

The overarching Aquatic Resources model also recognizes alpine aquatic ecological resources, identified in Figure 72 as the "Alpine Lakes & Wetland Systems" sub-system. This sub-system is included for the sake of completeness. However, for the reasons discussed in Chapter 3, the Natural Resource Condition Assessment does not address this particular sub-system.

The Aquatic Resources model (Figure 72) recognizes the importance of several drivers that shape aquatic and wetland ecological dynamics within the aquatic realm: surface water and groundwater movement, chemistry, and temperature; and the erosion, transport, and deposition of sediment and organic matter. The model recognizes that these drivers are shaped in turn by watershed processes affecting precipitation and snowmelt, evapotranspiration, runoff, and shallow versus deep infiltration. At larger scales of time, groundwater and watershed dynamics themselves are shaped by Park geology, climate, and atmospheric chemistry, which affect weather, the chemistry of wet and dry atmospheric deposition, topography, soil development, and watershed vegetation. Aquatic ecological dynamics in the park thus are shaped by a hierarchy of drivers, operating at different scales of time.

Human activities globally, regionally, and locally within the park also act as drivers, shaping aquatic ecological dynamics in the park. Figure 73 illustrates, in general terms, how human actions affect aquatic ecological dynamics in the park, either by altering the dynamics of natural drivers, or by directly altering the aquatic ecological resources themselves. Climate change, for example, alters precipitation and temperature patterns ("weather" in Figure 73), and air pollution alters atmospheric chemistry. These effects then cascade through the natural hierarchy of watershed drivers to affect aquatic ecological dynamics. Invasive aquatic species, on the other hand, directly alter the biological composition and inter-species interactions within the aquatic ecological systems, although they may also affect physical processes such as riparian evapotranspiration or stream bank stability. The sub-system models provided below spell out the interactions of human drivers with the aquatic ecological resources of the park in greater detail.

Stream-Riparian Sub-System Model

Figure 74 shows the conceptual ecological model for the stream-riparian sub-system for the park. This model integrates information from four sources: (1) the Stream and Riparian conceptual model presented in Miller et al. (2010); and the (2) Rocky Mountain Subalpine-Montane Riparian Woodland and Shrubland/Stream, (3) Rocky Mountain Lower Montane-Foothill Riparian Woodland and Shrubland/Stream, and (4) Great Basin Foothill and Lower Montane Riparian Woodland and Shrubland/Stream conceptual models presented in Comer et al. (2013). Unnasch et al. (2014) also summarizes key features of the Great Basin Foothill and Lower Montane Riparian Woodland and Shrubland/Stream conceptual model. These sources provide detailed bibliographies.

The conceptual ecological model for the stream-riparian sub-system shows drivers and system components in greater detail than the overarching Aquatic Resources model. The proximate drivers and system components together comprise the key ecological attributes for the model. System components consist of pivotal physical, biological, and ecological characteristics of a resource, its abundance, and its distribution. The stream-riparian sub-system model specifically identifies the following system components:

- Floodplain Soils. This component addresses the mineralogy, hydrology, hydrochemistry, organic matter content, structure, stability, and biotic composition of the alluvial soils of the riparian zone. These aspects of floodplain soils both affect and are affected by other components, including stream flow, channel morphology, and floodplain flora.
- Stream Flow Quantity & Quality. This component addresses the daily, seasonal, annual, and longer-term variability in water flow, dissolved and suspended matter constituents of the water in the stream, and water temperature and pH. These aspects of stream flow quantity and quality affect aquatic fauna and flora; and both affect and are affected by floodplain soils and channel morphology.
- Channel Morphology. This component addresses the gradient, lateral and longitudinal geometry, longitudinal connectivity, and stability and dynamism of the stream channel; and substrate structure. These aspects of channel morphology affect aquatic fauna and flora; and both affect and are affected by floodplain soils and stream flow dynamics.
- Floodplain Flora. This component addresses the distribution, density, composition, and structure of the floodplain vegetation community. These in turn affect the aquatic biotic community; and both affect and are affected by floodplain soils.
- Aquatic Fauna, Flora. This component addresses the distribution, biomass, composition, and food-web interactions of stream and benthic biota, including algae and emergent vegetation; Bonneville cutthroat trout and other fishes; and macroinvertebrates and zooplankton.

Proximate natural drivers that shape these system components in turn include:

- Aquifer Systems. Streams in the park receive water from the groundwater system in the form of spring discharge and diffuse groundwater seepage, as shown in the Aquatic Resources model. Groundwater-surface water interactions shape stream hydrology, temperature, and chemistry; and are the most crucial process shaping flow persistence along individual stream reaches.
- Runoff. Watershed runoff – both diffuse runoff and ephemeral channel flow – delivers not only precipitation and snowmelt to stream channels but also sediment, particulate organic matter, and dissolved inorganic and organic matter. Runoff is the most crucial driver shaping extreme high-flow events and overbank flooding of the riparian zone, which together strongly shape channel morphology and floodplain soils and their dynamics.

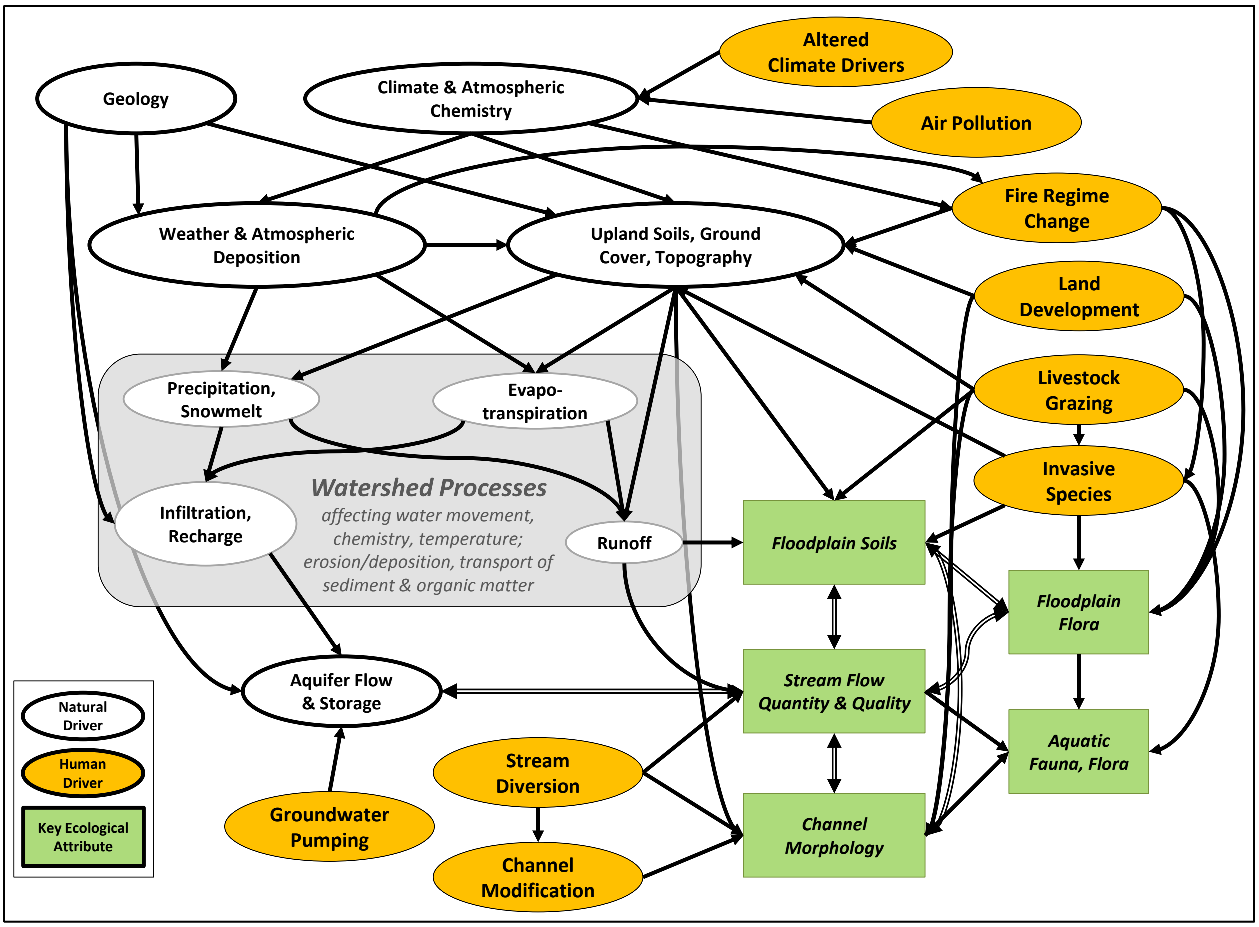

Figure 74. Stream-riparian sub-system conceptual ecological model for Great Basin NP.

- Upland Soils, Ground Cover, Topography. This driver mostly affects the stream-riparian system indirectly, through its effects on watershed processes that shape water movement, chemistry, temperature; watershed soil erosion and deposition; and the transport of sediment and organic matter. However, this driver also can affect the stream-riparian system directly through the spread of upland wildfires into the riparian zone and as habitat for fauna that also use the riparian zone and/or stream waters.

Finally, proximate anthropogenic drivers that shape these system components in turn include:

- Groundwater Pumping, which can alter aquifer system storage and flow gradients in ways that alter groundwater-surface water interactions along affected stream reaches, thereby altering stream flow.
- Stream Diversion, which removes surface water from the stream channel, thereby altering stream flow and channel morphology (e.g., wetted area). The construction of stream diversion structures also results in channel modification.
- Channel Modification, which reshapes channel morphology to better suit human use of the riparian zone, for example to stabilize channel geometry at a road crossing or in areas of intensive recreational activity.
- Invasive Species, which alter the composition of the floodplain and aquatic biotic communities. Invasive species can also alter ecological processes such as herbivory and predation on native species, competition for food and habitat among native aquatic fauna, the structure of the aquatic food web, evapotranspiration, and floodplain soil chemistry and structure. Invasive species also can affect stream-riparian systems indirectly by altering watershed ground cover and soils.
- Livestock Grazing, which can alter floodplain vegetation and soils, and alter channel morphology through trampling. Livestock grazing also can affect the stream-riparian system indirectly through its impacts on upland soils and ground cover, thereby affecting watershed processes; and by serving as a vector for the introduction of invasive plants into a locality.
- Land Development, which includes development and/or maintenance of park facilities, environmental monitoring stations, hiking trails, roads, and historic cultural features. Land development can eliminate or degrade habitat for native plants and animals; alter ground surface infiltration, runoff, and erosion patterns; and concentrate visitor activities and wastes.
- Fire Regime Change, both through wildfire management and through the effects of climate change, can involve changes to the frequency, timing, and severity of wildfires. Such changes can affect floodplain vegetation, both directly through changes in the riparian wildfire regime and indirectly through the effects of upland wildfire on the spread of invasive species. Fire regime changes also affect stream-riparian systems indirectly by altering watershed processes.

The model also recognizes the impacts of climate change and air pollution on the stream-riparian system. These drivers affect stream-riparian ecological condition indirectly, through their effects on weather and atmospheric deposition, and the cascading effects of these changes on upland soils and cover and watershed processes.

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4.3.2. Water Quality/Quantity

Indicators / Measures

- *Watershed Landscape Condition*
- *Riparian Corridor Landscape Condition*
- *Stream Nutrient Enrichment*
- *Exceedance of Water Quality Standards*
- *Mercury in Fish Muscle Tissue*
- *Benthic Macroinvertebrate Assemblage Integrity*
- *Snowpack Condition*
- *In-Park Stream Diversions*

Condition - Trend

Good Condition– Unchanging – High Confidence

Background and Importance

The discussion of water quality and quantity focuses on surface water in Great Basin NP, mostly its streams but with additional reference to lakes and springs where appropriate. The assessment also includes a separate section on Springs. The discussion here concerns current conditions. Section 4.4, Future Landscape Conditions, addresses possible impacts of climate change on water quantity.

Perennial streams are biologically distinct features of the park's high desert landscape. Six of its perennial streams – the eastward-flowing Strawberry, Mill, Lehman, Baker, and Snake Creeks, and South Fork Big Wash – historically supported populations of native Bonneville cutthroat trout (*Oncorhynchus clarki utah*), as discussed below in Section 4.3.4. Three other native fishes also occur in the perennial streams within the park: mottled sculpin (*Cottus bairdi*), speckled dace (*Rhinichthys osculus*), and redside shiner (*Richardsonius balteatus*). Non-native fish species also occur, as discussed below in Section 4.3.4. Native stream-dependent mammals in the park include beaver (*Castor canadensis*), muskrat (*Ondatra zibethica*), and water shrew (*Sorex palustris*). The perennial streams also support diverse communities of aquatic invertebrates (see below), and provide drinking and cooling water for numerous terrestrial species. The integrity of the biological communities that occupy or use the streams in the park depends in part on the integrity of the flow regimes and water chemistry. Alterations to the flow regime (water quantity) and water chemistry (water quality) in streams can lead to changes in the structure and function of their biological communities. Similarly, as discussed below in Section 4.3.3, the integrity of the riparian community – near-stream vegetation and animal life – also depends in part on the integrity of the flow regimes of the park's streams.

The assessment area for surface water quality and quantity consists of the park and adjacent portions of Snake and Spring Valleys. Twenty-five watersheds originate in Great Basin NP (Baker 2007) (Figure 75). Ten of these –_Strawberry, Mill, Lehman, Baker, Snake, Williams, Pine, Ridge, and Shingle Creeks, and South Fork Big Wash – contain one or more perennial stream reaches. Eight watersheds support intermittent flow, and the remaining seven support only ephemeral flow (Baker 2007). Eight other watersheds originate within the assessment area but outside the park boundaries. Table 45 summarizes information on the ten watersheds with perennial flow in the assessment area.

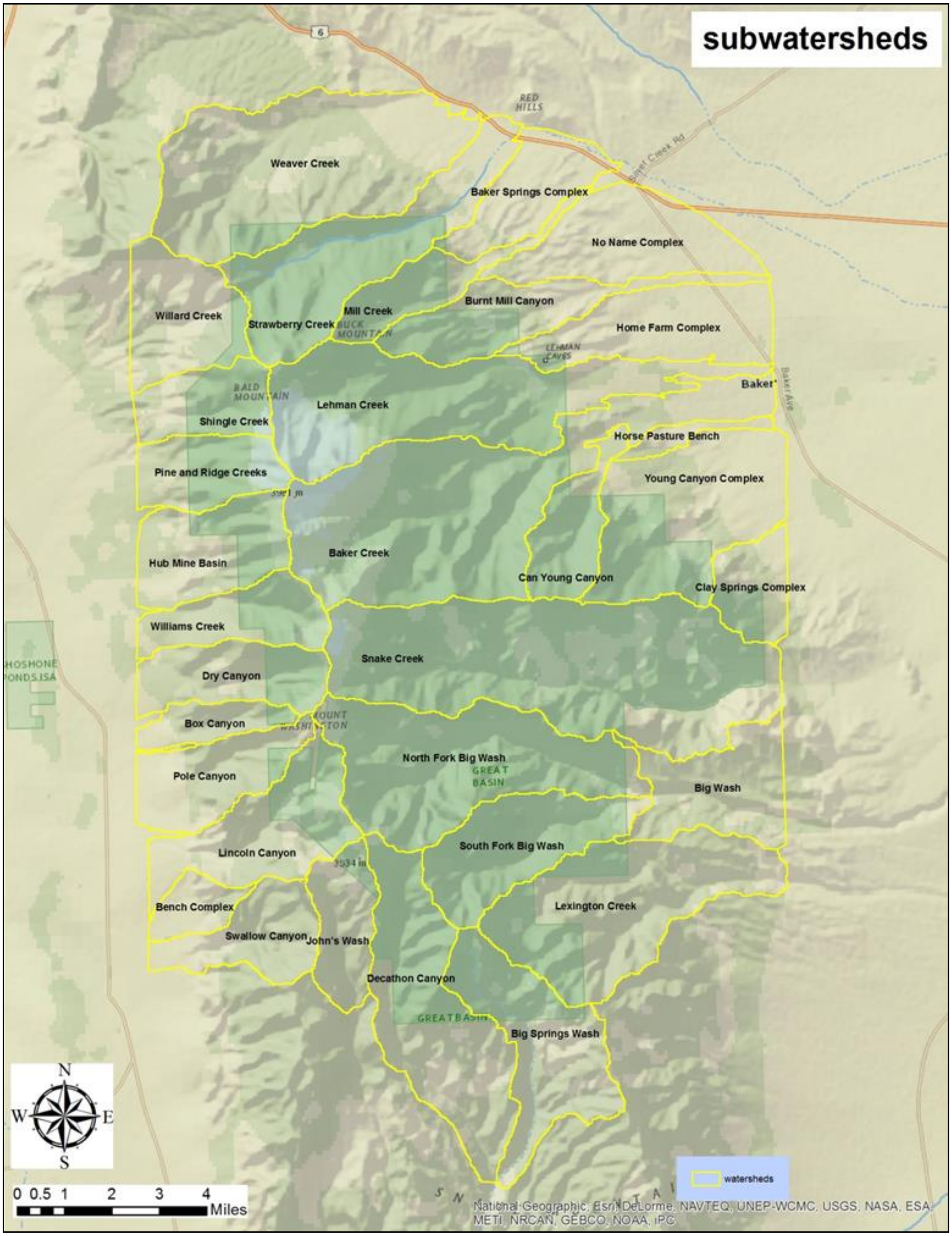


Figure 75. Watersheds delineated by Great Basin NP for management purposes.

Table 45. Summary data for perennial streams within Great Basin NP (from Baker 2007). Original data on length, elevation, and area were provided in metric values and not converted here.

<table>
<tr><th>Watershed</th><th>Stream length in Park (km)</th><th>Source elevation (m)</th><th>Watershed area in Park (km[b])</th><th>N. of springs</th><th>Average annual flow (cfs) [a]</th></tr>
<tr><td>Baker</td><td>15.9</td><td>3,113</td><td>43.7</td><td>148</td><td>9.08</td></tr>
<tr><td>Lehman</td><td>10.5</td><td>3,100</td><td>32.9</td><td>79</td><td>5.13</td></tr>
<tr><td>Mill</td><td>3.1</td><td>2,864</td><td>6.8</td><td>13</td><td>(no data)</td></tr>
<tr><td>Pine</td><td>1.3</td><td>2,773</td><td rowspan="2">6.9</td><td rowspan="2">15</td><td rowspan="2">1.18 [b]</td></tr>
<tr><td>Ridge</td><td>0.3</td><td>2,510</td></tr>
<tr><td>Strawberry</td><td>7.9</td><td>2,591</td><td>19.3</td><td>59</td><td>0.58</td></tr>
<tr><td>Snake above pipeline</td><td rowspan="2">17.9</td><td rowspan="2">2,950</td><td rowspan="2">52.1</td><td>37</td><td>2.70</td></tr>
<tr><td>Snake below pipeline [c]</td><td>2</td><td>1.22</td></tr>
<tr><td>South Fork Big Wash</td><td>3.2</td><td>2,316</td><td>17.9</td><td>12</td><td>0.53</td></tr>
<tr><td>Shingle</td><td>2.2</td><td>2,968</td><td>6.4</td><td>9</td><td>0.84</td></tr>
<tr><td>Williams</td><td>1.0</td><td>2,700</td><td>5.9</td><td>11</td><td>1.13</td></tr>
</table>

[a] All discharge values are from Baker (2007) except where noted.

[b] Discharge per SNWA (2008a).

[c] Discharge measured at Park boundary per Baker (2007).

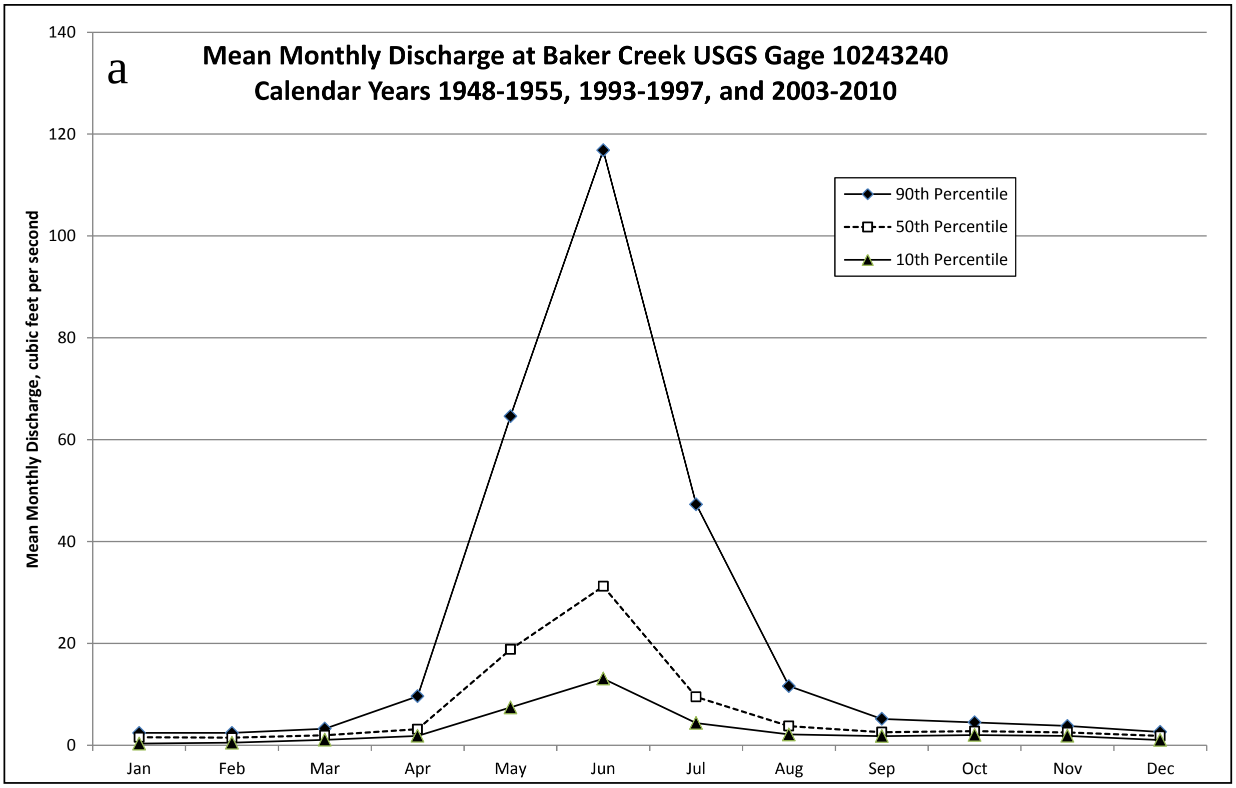
The water flowing in the streams of Great Basin NP comes from a single source: precipitation across the South Snake Range. However, the water from that precipitation reaches the streams through several routes, and these routes strongly influence the hydrology and chemistry of the streams (Elliott et al. 2006, Paul et al. 2014).

Precipitation across the South Snake Range falls as rain or snow from three types of storms, the contributions of which vary greatly from year to year, as summarized by Elliott et al. (2006):

> *Precipitation at the park is from three types of storms… Storms that form as low-pressure systems in the Pacific move across the Sierra Nevada and Cascade Range. Although all of Nevada is in the rain shadow of these mountains, heavy precipitation from these storms can occur. Continental storms, or Great Basin lows … occur when low-pressure systems build over Nevada and Utah. The lows build along cold fronts influenced by polar-air masses brought southward by northerly winds. These storms are most common from April to June, but can produce heavy snowfall during the winter. Convective thunderstorms from moist air that moves into the region from the Gulf of California and the Gulf of Mexico during late summer can produce intense rainfall.*

These storms create three seasons of precipitation, with peaks in March, May, and September; the March and May peaks are roughly equal in magnitude to each other and the September peak slightly higher (Elliott et al. 2006). The precipitation arrives either as rain or, in the colder months, as snow. Some of the snow melts quickly after arrival, but some also accumulates as snowpack at higher elevations, which in turn melts with the return of warmer weather in May-July. Snow rarely remains after June. The water from rain and snowmelt may evaporate, or flow overland directly to streams, or infiltrate into the soil. Water that infiltrates the soil may return to the atmosphere through evaporation and plant transpiration (together called “evapotranspiration”), remain localized in the soil as moisture, percolate to the water table and then flow laterally downhill to emerge at streams, or percolate downward to recharge the deeper groundwater system. Any overland flow that reaches a surface channel before being lost to evapotranspiration, infiltrating the soil, or percolating to the deeper groundwater system becomes stream flow. Evapotranspiration along the riparian corridor also returns some of the stream water back to the atmosphere. Percolating groundwater flows downward under the influence of gravity, recharging deeper bedrock and alluvial aquifers within the South Snake Range or resurfacing into stream channels along seepage zones. The water discharged from aquifers into stream channels is termed stream “baseflow.” As discussed under both Springs and Cave/Karst Processes (see below), some groundwater in the South Snake Range flows into bedrock fracture systems. The water in these fracture systems may re-emerge in caves, discharge at discrete springs at the ground surface, or flow downward further underground to recharge regional aquifers (Elliott et al. 2006, Flint and Flint 2007, Heilweil and Brooks 2011).

The interactions of precipitation, snowmelt, evapotranspiration, runoff, infiltration, and groundwater discharge produce a pattern of stream flow in the park that differs from the pattern of precipitation (see Section 4.3.1). Evapotranspiration is much higher during the warmer months of the year, and also depends on the types and extent of coverage of vegetation across each watershed. Both recharge and runoff – except following localized thunderstorms – arise almost entirely from snowmelt. This produces a consistent annual stream hydrograph with a single, strong peak in June and a period of very low flow from September or October through March or April (Elliott et al. 2006, Baker 2007, Flint and Flint 2007). Figure 76 shows the 90th, 50th (median), and 10th percentiles of mean monthly discharge at the Baker Creek and Lehman Creek stream gages, calculated from their discontinuous records: calendar years 1948-1955, 1993-1997, and 2003-2010 for Baker Creek; and calendar years 1948-1955, 1993-1997, and 2003-2012 for Lehman Creek (see Data and Methods, below).



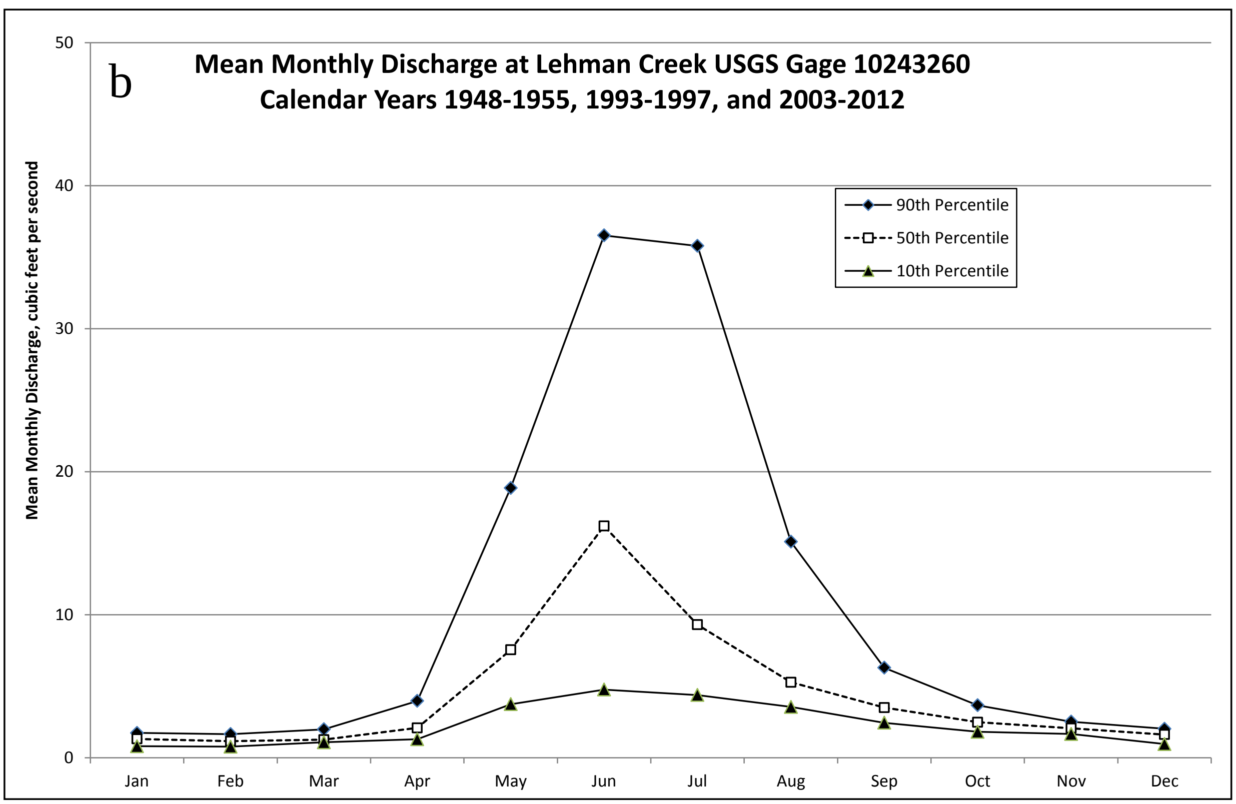


Figure 76. 90th, 50th, and 10th percentiles for mean monthly discharge at two stream gauges in Great Basin NP: (a) USGS gauge 10243240, Baker Creek; and (b) USGS gauge 10243260, Lehman Creek. Vertical scale differs between (a) and (b).

Further, the perennial streams in the park include reaches that gain water (via seepage and spring discharge) from or lose water back to the groundwater system (see Section 4.3.2). Gains from seepage occur along reaches where the adjacent water table stands higher than the elevation of the water in the stream; and losses occur along reaches where the relationship is reversed. The difference in elevation between the water table and the stream along each reach varies seasonally as well as from year to year, depending on the timing and magnitudes of precipitation and evapotranspiration (see above). Elliott et al. (2006) assessed the locations of gaining and losing reaches. Losing reaches within the park occur in four types of settings, where the channel flows (1) directly over highly fractured or karstic bedrock; (2) over alluvial gravel deposits that overlie such fractured bedrock; (3) along alluvial gravel deposits that extend outward from the park onto the valleys; or (4) across the zone of contact between the bedrock of the South Snake Range and the basin fill deposits of the valley floor (Elliott et al. 2006, Paul et al. 2014).

The geology and hydrologic cycle of the South Snake Range together govern the chemistry of stream and spring water in the park (Elliott et al. 2006, Baker 2007, Horner et al. 2009, Prudic and Glancy 2009, Paul et al. 2014) (see Section 4.3.2). The rain and snow naturally arrive with very low concentrations of dissolved solids but high concentrations of dissolved CO_2. The CO_2 and water (H_2O) in clouds react to form carbonic acid, resulting in moderately acidic precipitation. Soil microbes generate additional CO_2 as they consume organic matter in the soil, and this process adds further CO_2 to any water that percolates through the soil, further increasing the acidity of the percolating water. As the soil water percolates further downward, it infiltrates bedrock fractures and pores, and begins reacting with the bedrock. Most of the bedrock across the northern half of the park consists of metamorphic and igneous minerals that do not react quickly with acidic precipitation to neutralize its acidity. The opposite is true across the generally lower-elevation southern half of the park, where carbonate minerals predominate.

The soils that have formed over the different bedrock mineralogies of the park similarly differ in their acid neutralizing capacity. Comparatively, the water that falls across the northern half of the park dissolves mineral matter and loses its acidity relatively more slowly as it runs off or infiltrates the soils; while the water that falls across the southern half does this relatively more quickly. Water that passes through the groundwater system before re-emerging at springs or along seepage zones dissolves mineral matter and loses its acidity along those flow paths. The alluvial gravels of the park also act as components of the groundwater system, through which water flows after entering the gravels via seepage from the stream or from the underlying bedrock. The groundwater in the alluvial gravels flows downhill, and may seep back into the underlying bedrock or back into the stream along downstream reaches. The alluvial gravels impart their own additional chemical signatures on the waters that pass through them.

In general, the longer the water remains in the groundwater system, the more its chemistry changes. As a result, the chemistry of streams and springs in the park varies depending on six broad, interrelated factors (Elliott et al. 2006, Baker 2007, Horner et al. 2009, Prudic and Glancy 2009, Paul et al. 2014): (1) where the precipitation falls; (2) the mineralogy and permeability of the soils and/or bedrock formations over or through which the water flows before becoming stream or spring flow;

(3) the length of time the water spends in contact with soils and bedrock before emerging at a spring and/or flowing into a stream channel; (4) the mineralogy of the stream channel substrate (which depends on the mineralogy of the watershed); (5) the length of time the water spends flowing within the alluvial gravels before emerging at a spring and/or flowing into a stream channel; and (6) the length of time the water spends flowing along a stream channel, mixing with water already in the channel, and interacting with the minerals that make up the channel bed.

The geology and hydrologic cycle of the South Snake Range similarly shape stream and spring water temperatures in the park. Water from winter rainstorms, water from snowmelt, and water that spends a longer portion of its time as groundwater, provide cooler inputs to streams than does runoff from summer storms. Further, temperatures in the aquifers of the park are relatively stable temperatures year-round. Groundwater emerging at springs and seeps and along gaining stream reaches therefore moderates stream temperatures, keeping them warmer in winter and cooler in summer than would be expected from air temperatures alone.

The stream waters of the park accumulate the effects of both past and current human activities across the surrounding landscape, which has a history of mining, timber harvesting, water diversion, recreational use, and, livestock grazing. Cattle grazing within the park ended in 1999; sheep grazing on the west and south sides of the park continued through 2008. One diversion still removes water from perennial stream reaches within the park. The Snake Creek pipeline consists of a 3-mile (5-km) pipe installed in 1961 to bypass a losing section of the stream, between 7,610 and 6,760 feet (2,320 and 2,060 m) elevation, to irrigate agricultural fields around Garrison, UT. However, Snake Creek is frequently dry at the park boundary, especially during late summer and early winter, indicating that the pipeline may have little ultimate utility to downstream water users. Water still flows along the bypassed reach, when flow in upper Snake Creek exceeds the capacity of the pipe intake during spring runoff and after strong thunderstorms. Other vestiges of the history of water diversions within the park include the East-Side Osceola Ditch, which diverted water from Lehman, Mill, and Strawberry Creeks northward to the town of Osceola from 1885 to 1891; and diversions from several springs. The present assessment discusses the latter in the section below on Springs (section 4.3.6).

Proposed large-scale groundwater pumping in the Spring and Snake Valleys also has the potential to affect the amount of water flowing in streams within the park. Groundwater pumping in these valleys would take place at elevations lower than that of the park boundary. At first glance, this might seem to rule out the possibility that this pumping could affect streams or springs in the park. However, groundwater pumping lowers the groundwater level not only at the immediate location of the well but for some surrounding distance, too. The distance outward from a well location, within which the groundwater level will fall, depends on the hydraulic properties of the aquifer(s) tapped by the well. These effects of groundwater pumping spread outward (propagate) especially easily in aquifer materials with high hydraulic conductivity, such as alluvial deposits and bedrock with extensive systems of fractures and cavities such as carbonate formations. Large alluvial deposits occur within the lower reaches of several watersheds in the park, extending outward onto the valley floors; and carbonate bedrock aquifers underlie portions of both the park and its surrounding valleys, particularly the Snake Valley. These alluvial deposits and bedrock aquifer systems present conduits along which the effects of groundwater pumping in the valleys could propagate into the park. Such changes in groundwater dynamics, in turn, could diminish groundwater discharge at some springs and along gaining stream reaches, and/or create or expand losing stream reaches within the park.

The possibility of intensive groundwater pumping in the Spring and Snake Valleys increased significantly in 1989 when the Las Vegas Valley Water District and its later offshoot, the Southern Nevada Water Authority (SNWA), and Vidler Water Company, a private firm, began submitting applications for groundwater rights in the two valleys (Elliott et al. 2006, U.S. BLM 2012). These applications triggered a series of scientific field investigations and groundwater flow modeling studies, 2002-2011, to evaluate the potential impacts such pumping might have on the water resources of the park and surrounding region (Elliott et al. 2006, Welch and Bright 2007, USGS 2008, SNWA 2008b, 2010, Heilweil and Brooks 2011, Halford and Plume 2011, Paul et al. 2014). Elliott et al. (2006; see also Halford and Plume 2011) used the results of the first few years of these field investigations to distinguish areas where surface-water resources are: (a) “likely” susceptible to ground-water withdrawals; or (b) less likely but still “potentially susceptible” to groundwater withdrawals. Figure 77 shows the results of this integrative assessment.

Figure 77 and its associated data indicate that several perennial stream reaches within the park would be either likely or potentially susceptible to the effects of groundwater pumping in the surrounding Spring and Snake Valleys. These streams either (1) flow over permeable rocks or sediments that could be affected by pumping in the valleys or (2) receive water from springs or groundwater seepage from such rocks or sediments (Elliott et al. 2006, Halford and Plume 2011). Figure 77 and its associated data do not identify any intermittent stream reaches inside the park that would be either likely or potentially susceptible to the effects of groundwater pumping in the surrounding Spring and Snake Valleys. Table 46 summarizes the results for streams.

Table 46. Perennial stream reaches within Great Basin NP likely or potential susceptible to groundwater withdrawals in the adjacent valleys (after Elliott et al. 2006).

Zone Type	Susceptible Perennial Reaches
Likely Susceptible	• Lehman Creek, from Park boundary upstream for approx. 2 mi (~3 km) • Baker Creek, from Park boundary upstream for approx. 1.5 mi (~2.5 km) • Pole Canyon, tributary to Baker Creek, approx. lower 1 mi (~ 1.5 km) • Strawberry Creek, possibly immediately at Park boundary • Pine and Ridge Creeks, possibly immediately at Park boundary • Snake Creek, possibly immediately at easternmost point where it coincides with Park boundary
Potentially Susceptible	• Snake Creek where it flows along the eastern Park boundary, from approx. the easternmost point where it coincides with Park boundary upstream for approx. 1.5 mi (~2.5 km) • Snake Creek and un-named tributary, along upper half of reach bypassed by pipeline for approx. 1.5 mi each for creek and tributary (~2.5 km each)

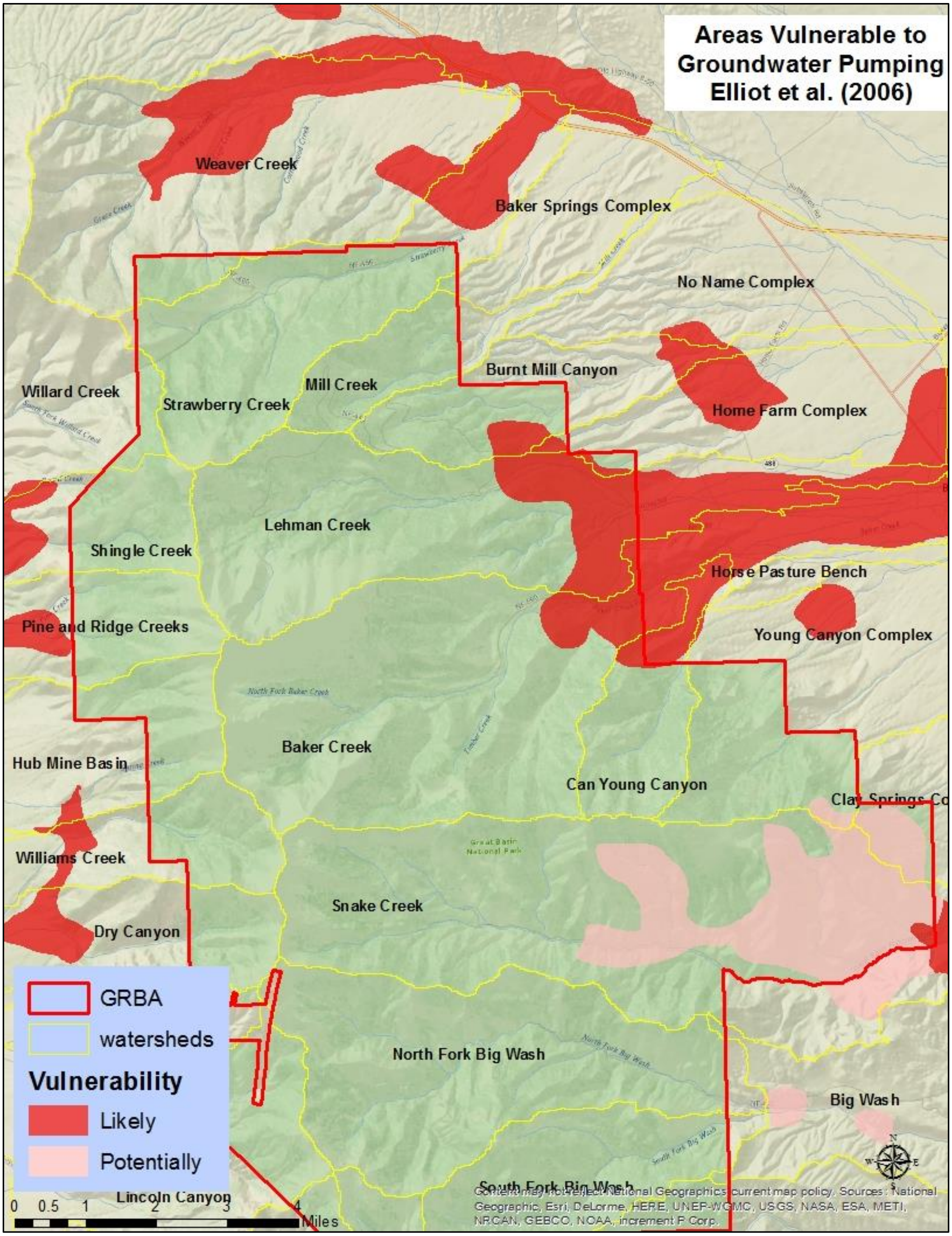


Figure 77. Areas within and around Great Basin NP estimated likely or potentially vulnerable to effects of groundwater pumping in Snake and Spring valleys (after Elliott et al. 2006, Plate I).

The results of the assessment by Elliott et al. (2006) also indicate that 27 springs within the park would be vulnerable to the effects of groundwater pumping specifically in the Snake Valley. These springs receive their groundwater discharges from permeable rocks or sediments that could be affected by pumping in the valleys. Section 4.3.6, below, discusses the potential impacts on springs.

Groundwater flow modeling of the park and its surrounding valleys by SNWA (2010) and Halford and Plume (2011) shows that the actual spatial distribution and magnitude of impacts of groundwater pumping in the adjacent valleys to groundwater in the park would differ depending on how many wells are operated, their locations, the aquifer layer(s) from which they pump, their pumping rates, and the number of years they operate. Permit applications for water withdrawals provide a basis for identifying plausible scenarios for these variables of operation, and groundwater flow modeling can evaluate the potential impacts of these different scenarios (SNWA 2010, Halford and Plume 2011). However, it is not presently possible to know whether any one of these scenarios will ever be implemented. In fact, at the time of the present assessment (2014), most of the applications for groundwater rights in the two valleys remain under review or have been granted by the Nevada State Engineer but are under appeal.

The stream corridors in the park attract numerous recreational activities, including hiking, camping, fishing, and bird watching. All the designated camping and picnic areas within the park boundaries lie alongside stream corridors. Most of the roads, vehicle trails, and designated hiking trails also follow stream corridors for at least some of their distance. Roads and trails not only concentrate visitor traffic and its associated impacts on stream water quality, but concentrate erosion that can affect stream turbidity. Water quality and quantity along streams within the park are also vulnerable to indirect impacts from changes to their surrounding watersheds. Changes in watershed plant cover – including changes that result from fire management – can affect rates of evapotranspiration, infiltration, and runoff, affecting stream hydrology and sediment inputs (Smith et al. 1995, Greene and Mann 1997, Allan 2004, Beever and Pyke 2004, Beever et al. 2005, Baker 2007). Runoff following fires across a watershed can carry pulses of mineral concentrations dissolved from the ash. Deposition of atmospheric pollutants, particularly in precipitation at higher elevations (see Air Quality, above), can alter stream chemistry by introducing additional ions into surface runoff and groundwater that can alter aquatic pH, nutrient balances (nitrate, sulfate); and by introducing contaminants such as mercury (see below).

The hydrology of the streams in Great Basin NP has been a subject of monitoring and scientific investigations since well before the founding of the park. The U.S. Geological Survey (USGS) established a stream gauge on Baker Creek in 1947 (Station 10243240), with official records covering water years 1948-1955, 1993-1997, and 2003-2004, after which the park took over gauge maintenance and operation. The USGS also established a gauge on Lehman Creek in 1947 (Station 10243260), with official records covering water years 1948-1955, 1993-1997, and 2003-2012. The National Park Service reactivated the station in late May, 2014. Hood and Rush (1965) collected data on streamflow at several locations in the Snake Valley watershed as part of a reconnaissance survey of the water resources of the Snake Valley area (NV and UT). The USGS operated gauges on numerous streams in and around the park in 2002-2004, as part of its assessment of the potential impacts of groundwater pumping on surface water resources within the park (Elliott et al. 2006). These gauges were located on Strawberry, Snake, Shingle, Decathon, and Williams Creeks, and South Fork Big Wash; and at Rowland Spring. The Park has continued operating the gauges on Strawberry, Snake, Shingle, and Williams Creeks and South Fork Big Wash since 2004. Additionally, SNWA (2008a) collected single-day flow data for Willard, Board, Shingle, Pine and Ridge, Williams, Weaver, Strawberry, Lehman, Baker, Snake, Lexington, and Chokecherry Creeks, and Big Wash, to help document its applications for groundwater withdrawal permits for the Spring and Snake Valleys.

The water quality of the streams – and also the springs and lakes – in Great Basin NP similarly has been a subject of monitoring and scientific investigations beginning long before the founding of the park. The reconnaissance survey of the water resources of the Snake Valley area in Nevada and Utah by Hood and Rush (1965) produced data not only on streamflow but also on groundwater elevations and the chemistry of water from streams, springs, and wells. Metcalf et al. (1989) collected field data on lake and stream water (February, March, and May) and analyzed samples for a wide range of mostly inorganic chemical parameters. The National Park Service (2000) later reviewed all U.S. Environmental Protection Agency (USEPA) databases for data on surface water quality in Great Basin NP through 1998, including sample locations and the collecting institution. The review located 10,093 observations for 184 separate parameters collected between 1966 and 1998 by the National Park Service, U.S. Geological Survey, U.S. Environmental Protection Agency, Nevada Department of Conservation and Natural Resources, and Utah Department of Environmental Quality at 428 monitoring stations, 293 of which lie within the park boundaries. Most (92%) of the samples are from one-time or one-year sampling efforts between 1968 and 1998. Only three stations yielded longer-term records.

The National Park Service collects samples of stream macroinvertebrates in the park as a tool for assessing water quality (see below, Data and Methods). The samples considered for the present assessment were collected from 2001 to 2012 using standard field methods, and include samples collected by park staff in 2006-2007 for the baseline assessment of water quality (Horner et al. 2009) (see below); and samples collected by National Park Service, Mojave Desert Network Inventory and Monitoring teams since 2009 following the Network's Streams and Lakes Protocol (Moret et al. 2012a, 2012b, 2013). U.S. Geological Survey monitoring of stream gauge stations in 2002-2004 included measurements of water temperature and specific conductance (conductivity), as part of the assessment of surface water-groundwater connectivity (Elliott et al. 2006). The Park Service subsequently assessed water quality in 2006-2007 at six lakes, 35 springs, four caves, and 20 stream sampling locations (Horner et al. 2009). This assessment included field measurements, grab samples for laboratory measurement of inorganic composition, and sampling of stream macroinvertebrates (see above). Prudic and Glancy (2009) analyzed water samples collected in 2007 from Cave and Marmot Springs, tributaries to Lehman Creek, as part of the U.S. Geological Survey assessment of potential impacts of groundwater pumping in Snake Valley. The U.S. Geological Survey collected additional water samples in 2009 from stream reaches, springs, and caves along Baker and Snake Creeks as parts of this same assessment (Paul et al. 2014). In 2011, Park staff collected and Eagles-Smith et al. (2014) subsequently tested Brook trout (*Salvelinus fontinalis*) from Baker Lake, Lehman

Creek, and Snake Creek for mercury (Hg) in muscle tissue samples as part of a national study. The Nevada Department of Wildlife (NDOW) also published health advisories based on mercury concentrations in two other non-native species of trout collected in 2009 from Lehman and Snake Creeks (see below). Bioaccumulation of mercury in animal tissue provides a more accurate indicator of the ecological effects of mercury pollution than analyses of water samples. Finally, National Park Service, Mojave Desert Network Inventory and Monitoring teams also began collecting data on water chemistry in the park in 2009, again following the Network's Streams and Lakes Protocol (Moret et al. 2012a, 2012b, 2013). The data from these latter monitoring efforts include water temperature, dissolved oxygen, pH, and specific conductance; nutrients (Nitrogen and Phosphorus); and major ions. A report by Moret et al. (2013) presents the initial results of these field investigations for 2009 and 2010, including discussions of data quality, and an additional report is in preparation (Moret et al. *in prep*.).

Data and Methods

Indicators / Measures

- ***Watershed Landscape Condition***
- ***Riparian Corridor Landscape Condition***
- ***Stream Nutrient Enrichment***
- ***Exceedance of Water Quality Standards***
- ***Mercury in Fish Muscle Tissue***
- ***Benthic Macroinvertebrate Assemblage Integrity***
- ***Snowpack Condition***
- ***In-Park Stream Diversions***

The scoping study identified three broad topics of concern, regarding surface water quality and quantity in the park: (1) trends in water quality, quantity, and seasonality; (2) potential threats, with particular emphasis on the proposed SNWA groundwater development project in Spring and Snake Valleys; and (3) impacts of existing/ongoing activities, including continuing operation of the Snake Creek diversion.

Stream gauge measurements from the park unfortunately do not presently provide sufficient data, with which to assess possible long-term trends in the condition of the flow regime – i.e., the pattern of variation in stream discharge over time. Ecologically potentially important characteristics of a stream flow regime include the magnitude of seasonal baseflow; the magnitude, timing, and duration of seasonal maxima and minima; the magnitude, frequency, timing, and duration of extreme flow conditions; and the variability (e.g., variance) in these characteristics (e.g., Poff et al. 2010). Stream flow records are subject to significant random variation in stream inputs and outputs; and a single year of daily flow records provides only a small sample of that variation (Kennard et al. 2010). Statistically reliable estimates of all but the most basic characteristics (e.g., average annual discharge) of the flow regime for a single location, for a single time period, typically require three or more decades of continuous records (Henriksen et al. 2006, TNC 2009, Kennard et al. 2010). Reliably identifying statistical trends in characteristics of the flow regime correspondingly requires even more years of data. The two stream gauges with the longest records for Great Basin NP are on Baker and Lehman Creeks. Both gauges have discontinuous histories of operation, as noted above. Their longest periods of record are eight calendar years for Baker Creek (2003-2010) and ten for Lehman Creek (2003-2012). The 1993-1997 and 1948-1955 periods do not individually provide sufficient years of data for statistically characterizing the flow regimes at the two gauges for those two periods, for comparison to the most recent period at these gauges. Additionally, except for very general features of the stream flow regime, such as median annual or monthly discharge (see above), it is not appropriate to combine all years of data from each gauge to represent a single period. Studies of climate change in the Great Basin indicate that the years 1948-1955 fall within a different climate regime than do the past three decades (Comer et al. 2013).

On the other hand, it is possible to evaluate the *likelihood* of trends in surface water quantity and seasonality for the park by looking at factors that critically shape spring and stream discharge and water quality in the park. The conceptual ecological model for aquatic resources in the park (Section 4.3.1) and the discussion of the park hydrogeology, above, identify several such factors, for which data are available: (1) snowpack variation, the dominant variable shaping (a) the magnitude and timing of the annual spring runoff pulse in all perennial streams in the park and (b) the magnitude of annual recharge; (2) in-Park diversions of stream water into ditches or pipes that remove water from its natural courses; (3) the intensity of human activities across the watersheds of the park that can alter key watershed-scale hydrologic functions such as runoff and recharge that affect stream discharge; and (4) the intensity of human activities immediately along the stream corridors of the park that could alter key riparian hydrologic functions such as evapotranspiration that also affect stream discharge. (As noted above, the present assessment addresses diversions from Springs separately, below, section 4.3.6).

Similarly, the existing measurements of surface water chemistry from the park unfortunately also do not provide sufficient data, with which to assess possible long-term trends in water quality. Surface water chemistry conditions naturally vary not only year to year but also season to season and over the course of any single day. They may also vary in interaction with each other. Investigators have measured water chemistry conditions multiple times at only a few locations in the park, and the data from these locations are not yet sufficient to separate out annual, seasonal, and diurnal variation with any statistical reliability.

Nevertheless, some data are available to characterize the overall integrity of water quality in the park, in three ways. First, published data are available from 2009-2010 and preliminary data are available from 2011-2013 on the concentrations of soluble forms of nitrogen and phosphorus in streams in the park. These substances are crucial nutrients in stream ecosystems, supporting the growth of algae and aquatic plants that comprise one of the foundations (aka “primary productivity”) of the entire aquatic food web. Second, it is possible to identify water quality measurements that exceed threshold values recognized as indicating conditions potentially harmful to aquatic life. The incidence of such extreme values provides a rough overall indicator of the extent of threats to water quality in the park. Third, the level(s) of mercury contamination in fish tissue in the park (see above) provides an indication of the overall level of mercury contamination in the aquatic food web. And finally, data on stream macroinvertebrates can be integrated into an indicator of the overall integrity of the stream benthic macroinvertebrate community. Decades of studies across the U.S. (and worldwide) have demonstrated the effectiveness of such indicators in identifying surface waters that are biologically impaired as a result of altered water quality (see below).

Understanding of these direct indicators of water quality can be supplemented with information on factors that critically shape variation in these direct indicators. The conceptual ecological model for aquatic resources in the park (Section 4.3.1) and the discussion of park hydrogeology, above, identify several such factors, for which data are available: (1) atmospheric deposition of nitrate, sulfate, and mercury; (2) the intensity of human activities across the watersheds of the park that could impair water quality by, for example, altering soil erosion or inputs of pollutants that may wash into surface waters; and (3) the intensity of human activities immediately along the stream corridors of the park that could impair water quality by, for example, altering soil erosion or inputs of pollutants immediately along the riparian corridor.

Table 47 identifies the indicators used to assess the status and trends in water quality and quantity in the park, based on the key ecological attributes identified in the conceptual model for the stream-riparian sub-system (see above, Section 4.3.1). The table shows the key ecological attributes assessed, and identifies the type or level of effort represented by each indicator.

Table 47. Indicators used for resource assessment of water quality and quantity in Great Basin NP.

Key Ecological Attribute	Indicator	Level [a]	Indicator Definition
Stream Flow Quality	Watershed Landscape Condition	1	LCI assessed at scale of watersheds, indicating extent of human modifications to landscape that affect critical watershed processes
	Riparian Corridor Landscape Condition	1	LCI assessed at scale of a 200 m buffer along the stream axis within watersheds, indicating extent of direct human modifications to the riparian corridor
	Stream Nutrient Enrichment	2	Concentrations of dissolved inorganic nutrients in water quality samples
	Incidence of Exceedance of Water Quality Standards	3	Frequency with which water quality samples exceed regulatory standards for aquatic life support
	Mercury in Fish Muscle Tissue	3	Frequency of fish samples that exceed toxic threshold values for mercury body load
	Benthic Macroinvertebrate Assemblage Integrity	3	Ratio of observed to expected benthic macroinvertebrate taxa in stream samples
Stream Flow Quantity	Watershed Landscape Condition	1	LCI assessed at scale of watersheds, indicating extent of human modifications to landscape that affect critical watershed processes
	Riparian Corridor Landscape Condition	1	LCI assessed at scale of a 200 m buffer along the stream axis within watersheds, indicating extent of direct human modifications to the riparian corridor
	Area of Vulnerability to Off-Park Groundwater Pumping	2	Narrative assessment of the spatial distribution of areas across which off-Park groundwater pumping could affect surface waters inside the park
	Snowpack Condition	2	Narrative assessment of snowpack variation and trends statistics
	In-Park Stream Diversions	3	Narrative assessment of the possible impacts of in-Park stream diversions

[a] "*Level*" refers to the spatial scale and intensity of the data collection methods, per Chapter 3, Section 3.2.1 Indicator Framework, Focal Study Resources, and Indicators.

Watershed Landscape Condition and Riparian Corridor Landscape Condition

The Watershed Landscape Condition and Riparian Corridor Landscape Condition indicators use the Landscape Condition Index (LCI) methodology (Comer and Hak 2012). The LCI methodology estimates the likely cumulative impact to ecological condition across a landscape resulting from human modifications to that landscape. Many human land uses affect ecological condition, for example, through vegetation removal or alteration, soil disturbance and re-contouring, stream diversion and changes to land-surface permeability, and introductions of invasive species. These actions alter ecological conditions across a landscape both directly through immediate impacts on species and their habitat, and indirectly through impacts on landscape processes. Alterations to landscape processes by human modifications to a watershed can include altered rates of runoff, infiltration, and evapotranspiration; altered rates of soil erosion and sediment transport into surface waters; and introductions of substances that, when washed downslope, can contaminate surface waters. Potential contaminants include human bodily waste and spills of commercial and industrial chemicals, including automotive fluids. In general, the greater the intensity of human development of a watershed, the greater the likelihood of such alterations to the watershed, which in turn will result in alterations to stream hydrology and water quality. Human modifications directly to a riparian corridor, in turn, concentrate the potential for such impacts to stream hydrology and water quality directly along stream reaches. Management actions such as waste containment, runoff containment, erosion control, minimization of impervious surfaces, and the provision of buffer zones between human activities and sensitive resources can all counteract the effects of watershed and riparian corridor development.

The inputs to the LCI methodology consist of mapped data on residential, municipal, and industrial development; infrastructure for transportation and urban and industrial land use; and other modifications to land cover such as for agriculture, pasture, or silviculture. The present assessment uses data current to 2010, mapped by 30-meter pixel. The methodology calculates a "site impact score" for each pixel for twenty categories of land modification, organized under the headings of (a) Transportation, (b) Urban and Industrial Development, and (c) Managed and Modified Land Cover. Site impact score values range from 100, indicating no impact, to 0, indicating complete elimination of all ecological value (e.g., inside an active open-pit mine). The methodology additionally recognizes that ecological impacts take place not only at the immediate site of a given type of land modification but for some surrounding distance. The methodology accomplishes this by assigning a "decay score" for each category of land modification. The decay score indicates the rate at which the ecological impacts of a given type of land modification dissipate with distance from the original site of impact. An algorithm calculates the distance-decayed impact score that each type of impact imposes on the pixels surrounding the original site of impact. Pixels with no land modification receive a default site impact score of 100, indicating that the pixel is 100% intact. The resulting overall LCI value for a pixel consists of the product of the on-site and distance-decayed impact scores for all categories of land modification in the data set.

LCI values estimate the potential magnitude of cumulative impact to ecological conditions in each 30-meter pixel resulting from human modifications to the landscape both in and immediately around that pixel. The index values provide an alternative to direct measurements of ecological condition, such as measurements of faunal and floral community composition and structure; soil structure; recharge; runoff, and channel flow integrity; and soil and water chemistry. Such direct measurements are rarely available at a statistically representative number of sampling locations across any large landscape and waterscape.

The present assessment uses LCI site impact score and decay score values originally developed for the entire western United States, in cooperation with the Western Governors Association, Landscape Connectivity Working Group (J. Pierce, Western Governors Association Landscape Working Group, State of Washington, personal communication, 2012, Comer and Hak 2012). The Central Basin and Range Rapid Ecoregional Assessment (Comer et al. 2013) then applied these score values to that ecoregion alone. The present assessment updates the original results from the Rapid Ecoregional Assessment using finer-scale data on roads, trails, and other infrastructure across the park; and using 30-meter mapping pixels, versus the 90-meter data used in the Rapid Ecoregional Assessment. Otherwise, as with the Western Governors Association and Rapid Ecoregional Assessment applications, the data still represent conditions in 2010 (data sets dated 2006-2010), here taken to represent "current" conditions in and around the park.

The indicator, Watershed Landscape Condition, specifically measures the average LCI value for all pixels within each watershed in the assessment area. The 33 watersheds within the assessment area (Figure 75) were delineated by the park for management purposes (Baker 2007) and do not correspond precisely to 6th-level hydrologic cataloging units delineated by the U.S. Geological Survey (http://water.usgs.gov/GIS/huc.html). The present assessment further subdivides the watersheds into higher- and lower-elevation portions at 8,200-foot (2,500 m) elevation, corresponding to the distinction between the two riparian-stream ecological system types that together comprise the montane riparian woodlands of the park. The Watershed Landscape Condition indicator therefore consists of the watershed average per-pixel LCI value, calculated separately for the watershed area above versus below 8,200 feet (2,500 m).

The indicator, Riparian Corridor Landscape Condition, in turn evaluates the degree to which the riparian corridor in particular remains unaltered by human land modifications. Human activities can directly remove or harm riparian vegetation; and unaltered riparian corridors also support natural flooding and sediment deposition and scour processes crucial to the natural dynamics of the aquatic and riparian biotic communities (Belsky et al. 1999, Allan 2004, Hansen et al. 2005). Specifically, the indicator uses the LCI methodology to measure the degree of modification of the riparian corridor within each watershed. It uses the same watersheds as the previous indicator, Watershed Landscape Condition, again divided into higher- and lower-elevation portions at the 8,200-foot (2,500 m) contour line.

Calculation of the Riparian Corridor Landscape Condition indicator involved five steps:

1) Identify all 30-meter pixels in which a riparian-stream ecological system types occurs, as evaluated for the Central Basin and Range Rapid Ecoregional Assessment (see below, Section 4.3.3, Montane Riparian Woodlands). Riparian pixels are classified both by system type and by

one of the underlying vegetation community types that comprise each system (see Comer et al. 2013).

2) Identify the riparian "corridor," consisting of all 30-meter pixels identified in Step 1, plus all 30-meter pixels that lie within a 100-meter radius of each 30-meter pixel identified in Step 1.
3) Analyze the distribution of riparian corridor pixels identified in Step 2, to identify groups of these pixels that belong to a single vegetation community type and lie immediately adjacent to (share an edge with) each other. Each such group is defined as a riparian corridor "occurrence." Areas where two or more such occurrences overlap are defined as additional distinct riparian corridor occurrences.
4) Calculate the area and average per-pixel LCI value for each riparian corridor occurrence.
5) Calculate the area-weighted average LCI value for all riparian corridor occurrences in each watershed, again divided into higher- and lower-elevation portions at 8,200 feet (2,500 m).

Stream Nutrient Enrichment

Inputs of soluble forms of nitrogen and phosphorus are crucial to aquatic ecosystems. Together with inputs of organic matter (e.g., plant litter) from the surrounding riparian corridors and uplands, inputs of inorganic nutrients such as dissolved nitrate/nitrite, ammonium, and phosphate ions determine the total biomass of aquatic organisms a stream can support. In unaltered watersheds, direct inputs of inorganic nutrients to streams ultimately and overwhelmingly come from the natural chemical weathering of alluvial and upland soils. Weathering rates depend on the mineralogy of the landscape, organic activity in soils across the landscape, air and water temperatures, precipitation rates, and the natural chemistry of the precipitation. Human activities can alter the rates of inputs of inorganic nutrients to streams in several ways, by: (1) discharging wastes onto the ground or directly into the water; (2) changing the vegetation, wildfire regime, and soils across watersheds; or (3) polluting the air upwind of a watershed, leading to atmospheric wet deposition of the pollutants dissolved in precipitation and atmospheric dry deposition of the pollutants as dust.

Dissolved nutrient levels in streams vary with water temperature and time of day, in synchrony with the level of biological activity in the water; with stream discharge rates; and with the timing and intensity of snowmelt and runoff pulses from the watershed. For example, nutrient data collected during a period of low stream flow are not easily compared to data collected during a storm event. Collecting representative data on dissolved nutrient levels in streams therefore requires a sampling program that takes into account these sources of variation. Unfortunately, the history of water quality sampling in the park includes only one sampling program designed to produce such representative data on stream nutrients, maintained by the National Park Service, Mojave Desert Network Inventory and Monitoring program (Moret et al. 2012a, 2012b, 2013). This program has collected nutrient data for streams in Great Basin NP during the late-summer low-flow season in the park (July 31-September 12) since 2009, at the same locations sampled for stream benthic macroinvertebrates. The program is amassing data that eventually will help assess nutrient levels in streams in the park and the ways they may vary with water temperature and time of day; stream discharge rates; and the timing and intensity of snowmelt and runoff pulses from individual watersheds. Preliminary results provide sufficient information for a qualitative evaluation of nutrient concentrations. The present assessment also qualitatively evaluated this indicator indirectly, using information on the aforementioned factors that can alter rates of stream nutrient inputs: watershed condition; fire regime; and atmospheric deposition.

Incidence of Exceedance of Water Quality Standards
Data on the incidence of exceedance of water quality standards among samples from Great Basin NP consist of field measurements and laboratory analyses of water samples that identify concentrations of specific substances that exceed federal criteria for aquatic life support. Data potentially suitable for this kind of analysis are available from two sources:

1) The National Park Service (2000) review of all public databases of water quality analyses from 1966 through 1998, 92% of which date between 1968 and 1998. Great Basin NP maintains an archive of all the data from this study.
2) The results of the 2006-2007 baseline water quality assessment (Horner et al. 2009). Great Basin NP maintains an archive of all the data from this study.

However, the data from the older samples (1966-1998) were collected using a variety of methods for field sample collection and preservation, laboratory handling and chemical analysis, and data quality assessment and control; and the lab methods had differing limits of detection and quantification for different chemical parameters. As a result, with one exception, the data from the older samples (1966-1998) are not readily amenable to comparison with each other or, in aggregate, for comparison to more recent data to look for evidence of trends. The data from the older samples were deemed suitable for broad comparisons only for water pH measured in the field, because the technology for field measurements of pH is relatively simple has been in common use for many decades.

Mercury in Fish Muscle Tissue
Mercury is a constituent of atmospheric deposition across the park, as discussed above (see Air Quality). Although mercury may also occur in wastes from the processing of mining ores, no data are available on whether historic mining in the park involved any use of mercury.

Mercury is poorly soluble in water and does not directly affect organisms in the receiving waters. However, microbes in the anaerobic depths of wetland and aquatic sediments convert molecular mercury to a biologically active form, methyl-mercury through a process called methylation. Organisms that feed on these microbes introduce the methyl-mercury into the food web of the water body, where it bio-accumulates with every successive link in the web. As a result, mercury can become concentrated in the tissues of top aquatic predators such as trout and fish-eating birds such as bald eagles, potentially reaching concentrations sufficient to cause neurological and other damage in these keystone species (e.g., Driscoll et al. 2007). Mercury concentrations in the tissues of aquatic predators therefore provide a clear picture of whether mercury is entering and moving through an aquatic ecosystem at sufficient concentrations to cause ecological harm. In contrast, data on inorganic mercury concentrations in atmospheric deposition do not provide direct evidence of the aquatic ecological impacts of mercury deposition in a watershed. The rate of uptake into the aquatic food web depends on the rate of inorganic input and the rate of methylation; the latter of which depends on the weather, hydrogeology, and soils of the watershed.

The data on mercury in fish muscle tissue samples from Great Basin NP come from two sources:

1) A report by Eagles-Smith et al. (2014) on samples from Brook trout (*Salvelinus fontinalis*) collected in 2011 from Baker Lake, Lehman Creek above the Upper Lehman Creek Campground, and Snake Creek above the pipeline inlet (Jon Reynolds, Great Basin NP, personal communication, January 2015).
2) Nevada Department of Wildlife (NDOW) mercury-based health advisories for human consumption of brown and rainbow trout (*Salmo trutta* and *Oncorhynchus mykiss*, respectively) from Lehman Creek and brown trout from Snake Creek http://www.ndow.org/Fish/Fish_Safety/Mercury/Health_Advisory_Status_of_Eastern_Nevada_waters/). NDOW prepares its health advisories in collaboration with the Nevada Division of Environmental Protection, the Nevada State Health Division, and the U.S. Environmental Protection Agency. The data supporting the health advisories for Great Basin NP are from fish captured by Great Basin NP in 2009 from Lehman Creek between the Upper and Lower Lehman Creek Campgrounds and from Snake Creek below the pipeline outlet (Ben Roberts, Great Basin NP, personal communication, December 2014; Jon Reynolds, Great Basin NP, personal communication, January 2015).

Benthic Macroinvertebrate Assemblage Integrity
The data on benthic macroinvertebrate assemblage integrity come from the National Park Service stream monitoring activities described above. The samples date from 2001 to 2012, and were collected using kick or Surber nets from riffle habitat by several programs: the U.S. EPA National Wadeable Streams Assessment (WSA) (USEPA 2006); Great Basin NP (Horner et al. 2009); and the National Park Service Inventory and Monitoring Program, Mojave Desert Network unit (Moret et al. 2012a, 2012b, 2013). Barbour et al. (1999), Horner et al. (2009), and Moret et al. (2012a, 2012b) describe the field methods. The data are housed at the "BugLab" (http://www.usu.edu/buglab/), officially the National Aquatic Monitoring Center, a partnership of the U.S. Bureau of Land Management (BLM) and Utah State University (USU). Analysis was limited to samples with a sampled area of at least 0.5 m^2, and a minimum count of 150 invertebrate specimens, based on BugLab experience identifying samples with reliable data (Scott Miller, Director, BLM/USU National Aquatic Monitoring Center, personal communication, March 2014). Table 48 identifies the locations of the stream benthic macroinvertebrate samples used in the present assessment, by mountain range, stream, station name, and map coordinates. The table also indicates the years in which samples were collected. The single sample from 2001 was collected on October 11; all samples during 2002-2004 were collected between June 19 and July 15; and all subsequent samples, 2006-2012, were collected between July 31 and September 12.

The use of stream benthic macroinvertebrates as indicators of water quality has a long scientific history (Barbour et al. 1999, Karr and Chu 1999). The abundance and taxonomic and functional composition of the benthic macroinvertebrate assemblage change in response to cumulative changes in water temperature, turbidity, and chemical composition – and also cumulative changes in physical habitat conditions. The changes in taxonomic and functional composition are commonly summarized using one or more indexes that compare observed composition to the composition expected for reference conditions for the same type of stream in the same ecoregion. The use of such indexes has expanded greatly over the past three decades, as the U.S. EPA and states have refined their use in evaluating state compliance with requirements of the federal Clean Water Act, particularly compliance with standards for aquatic life-use support (Barbour et al. 2000, Davies and Jackson 2006).

The present assessment used a type of index of benthic macroinvertebrate assemblage integrity based on the ratio of the observed number of taxa to the number of taxa expected for an unaltered stream reach of the same type, termed an O/E (observed/expected) index. The methodology rests on a predictive model of how the benthic macroinvertebrate taxa in a particular region are naturally distributed in relation to numerous characteristics of the stream and its watershed, termed a River InVertebrate Prediction and Classification System (RIVPACS)-type predictive model. The accuracy of the predictions is greater when the predictive model is based on samples from a smaller region (Carlisle and Hawkins 2008, Hawkins et al. 2010a, Hawkins et al. 2010b) (see also http://www.cnr.usu.edu/wmc/htm/bioassessments/predictive-models-literature).

The present assessment used an O/E index developed by the Western Center for Monitoring & Assessment of Freshwater Ecosystems (http://cnr.usu.edu/wmc/) specifically for use in the Nevada Department of Environmental Protection, Bureau of Water Quality Planning, state-wide Bioassessment Program (http://ndep.nv.gov/bwqp/bioassessment.htm) (Scott Miller, Director, BLM/USU National Aquatic Monitoring Center, personal communication, March 2014). The Nevada O/E model requires that benthic macroinvertebrate taxa be identified to a very high level of specificity, particular for midges, a broad category of small flies, the aquatic larvae of which are highly sensitive to stream water quality (Scott Miller, Director, BLM/USU National Aquatic Monitoring Center, personal communication, March 2014). For this reason, the present assessment only addresses samples with midge specimens classified to a high level of taxonomic detail during laboratory analysis. The statistical analyses were carried out by the BLM/USU National Aquatic Monitoring Center. Figure 78 provides a map of the sample locations across both the South and North Snake Ranges; Figure 79 provides greater detail on the sample locations across the South Snake Range.

Table 48. Names, locations, and dates of stream benthic macroinvertebrate samples from South and North Snake Ranges used in O/E analysis.

Range	Stream Name	Station ID	Latitude N	Longitude W	2001	2002	2004	2006	2007	2009	2010	2011	2012
South Snake Range	Baker Creek	BAKR1	38.9914	114.2055						X			
		BAKR2	38.9599	114.2673							X		
		BAKR3	38.9722	114.2655								X	X
		EPA02-006	38.9752	114.2480		X							
		GBNP-05	38.9904	114.2174					X				
		NV343320	38.9739	114.2536			X						
		SFBaker	38.9694	114.2607									X
	Lehman Creek	EPA02-007	39.0094	114.3080		X							
		LEHMAN-01	39.0119	114.2146						X			
		LHMN2	39.0157	114.2892							X	X	X
	Mill Creek	GBNP-39	39.0375	114.2667						X	X	X	X
	Pine Creek	PNCK-01	38.9969	114.3487						X	X	X	X
	Ridge Creek	RIDGE-01	38.9860	114.3517						X	X	X	X
	Shingle Creek	SHINGLECK-01	39.0047	114.3505						X	X	X	X
	Snake Creek	EPA02-034	38.9265	114.2570		X							
		p-NVW04485-016	38.9160	114.1480				X					
		SNAKBCT7	38.9264	114.2586	X								
		SNAKE-1	38.9301	114.2593						X	X	X	X
	South Fork of Big Wash	BWSHBCT3	38.8819	114.1958						X	X	X	X
	Strawberry Creek	EPA02-035	39.0524	114.3140		X							
		STRAWB-1	39.0597	114.2765						X	X	X	X
	Willard Creek		39.0324	114.3696									X

Table 48 (continued). Names, locations, and dates of stream benthic macroinvertebrate samples from South and North Snake Ranges used in O/E analysis.

Range	Stream Name	Station ID	Latitude N	Longitude W	2001	2002	2004	2006	2007	2009	2010	2011	2012
North Snake Range	Deadmans Creek		39.3235	114.1431									X
	Deep Creek		39.3228	114.1413									X
	Hampton Creek		39.2424	114.0982									X
	Hendrys Creek		39.2109	114.0796									X
	Negro Creek	EPA02-033	39.2759	114.2800		X							
	Silver Creek	EPA02-015	39.1653	114.2190		X							

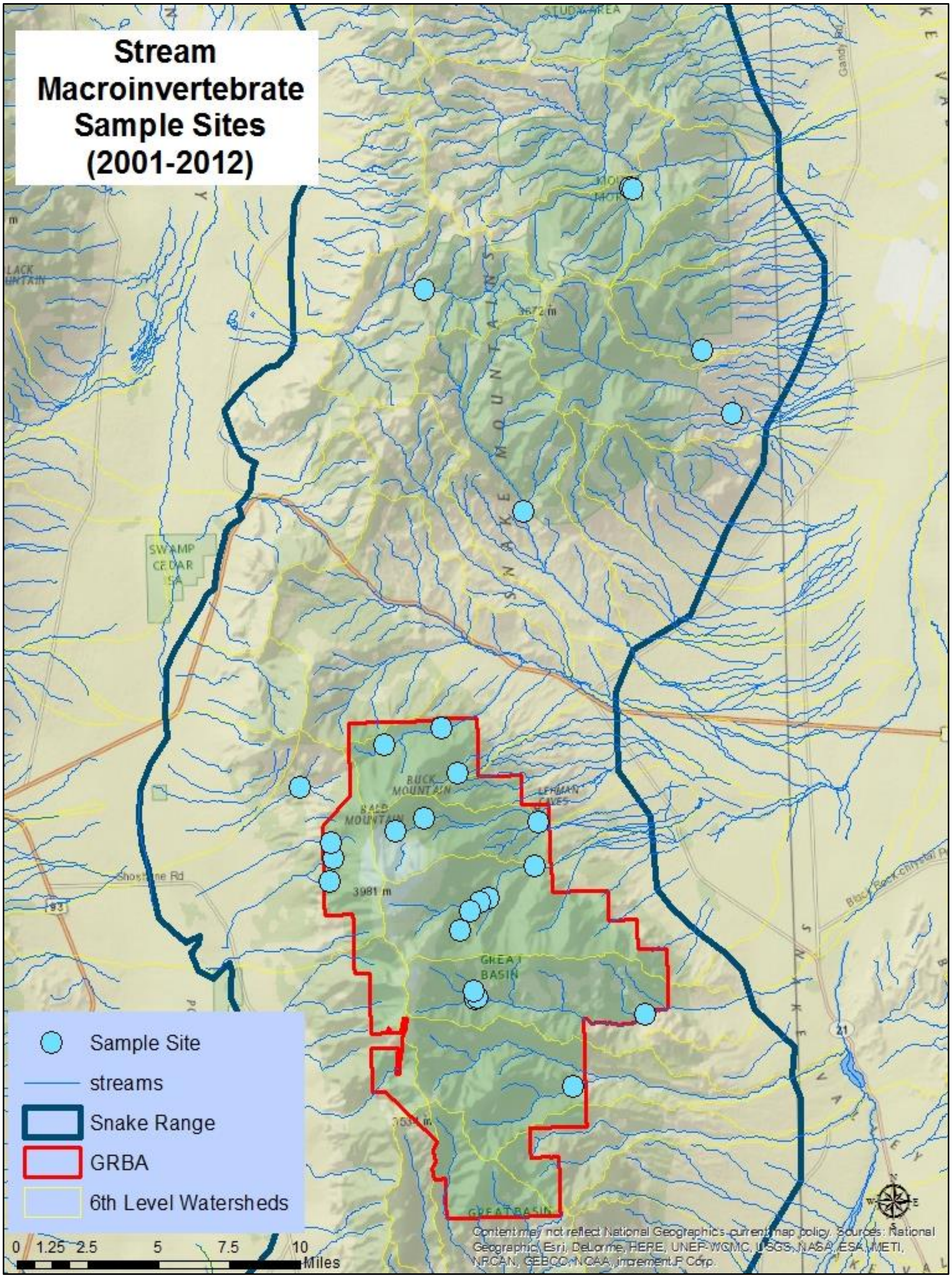


Figure 78. Locations of stream benthic macroinvertebrate samples, 2001-2012, included in O/E analysis for Great Basin NP and vicinity (North and South Snake Ranges).

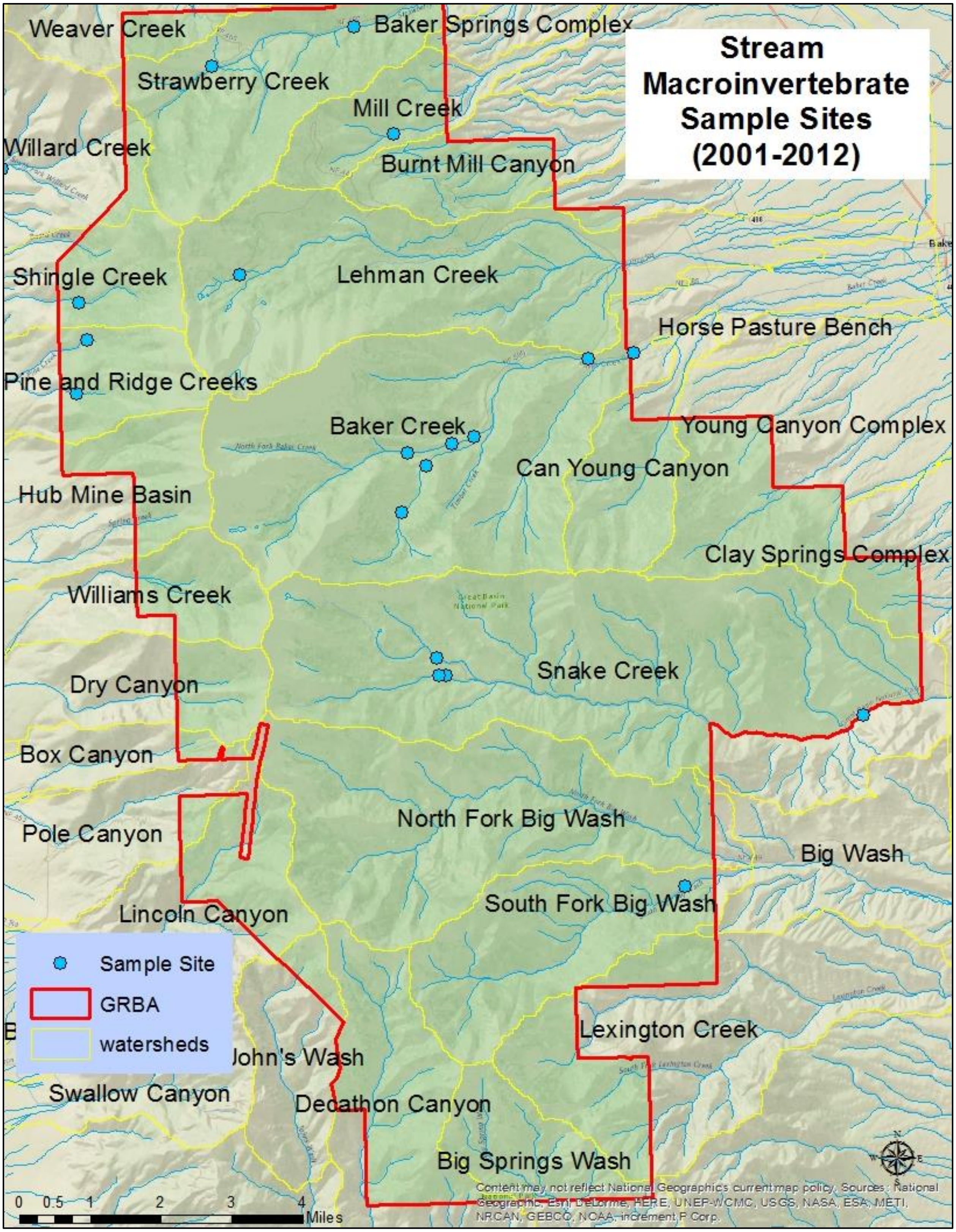


Figure 79. Locations of stream benthic macroinvertebrate samples collected inside Great Basin NP, 2001-2012, included in O/E analysis for Park and vicinity.

Snowpack Condition
The data on snowpack variation come from measurements collected from snow courses at three different elevations in the headwaters of the Baker Creek watershed between 1942 and 2014. These data are maintained by the U.S. Department of Agriculture, Natural Resources Conservation Service, National Water and Climate Center (http://www.wcc.nrcs.usda.gov/nwcc/rgrpt?report=snowcourse&state=NV). Table 49 summarizes basic information on the snow courses in the park.

Table 49. Snow course data summary for Great Basin NP.

Station Name	Station ID	Elevation (ft / m)	Dates*
Baker Creek #1	14L01	7,950 / 2,423	1942-1973, 1975-2014
Baker Creek #2	14L02	8,950 / 2,728	1942-2014
Baker Creek #3	14L03	9,250 / 2,819	1942-1982, 1991-2014
Wheeler Peak	1147	10,120 / 3,085	2009-2014

[a] Other gaps of 1-2 years also occur in the records for individual months at each site.

The present assessment does not include data from a fourth snowpack monitoring station, the Wheeler Peak SNOTEL. This fourth station has a period of record too short for inclusion in the present assessment. As described at the aforementioned National Water and Climate Center website, the Wheeler Peak site is a SNOTEL station, which uses a newer and better methodology than that used at the Baker Creek stations, including collecting measurements continuously rather than manually during a limited number of site visits. Measurement crew visit to Baker Creek #1, #2, and #3 stations on approximately the first day of each March and April each year – and sometimes also to May 1 during years with late-forming and/or late-melting snowpack. Each snow course consists of a permanently marked, 1,000-foot (~ 300 m) transect across a small meadow that is relatively sheltered from wind. The crew measures snow depth at 5-20 locations, at approximately even intervals along the transect using an open-ended, graduated aluminum tube. The crew weighs the tube immediately after removing it from the snow using a scale that automatically converts total sample weight to inches of water, termed the Snow Water Equivalent (SWE). The data are analyzed to produce measures of average snow depth and SWE for each snow course, for each sample date. The present assessment used all sample dates within ±3 days of April 1 to represent snowpack conditions for each year – a well-established predictor of total snowmelt for each winter season in the region (Das et al. 2009, McCabe and Wolock 2009, Brown and Mote 2009, USBR 2011).

Figure 80 shows the relationship between April 1 SWE at the Baker Creek #3 snow course station, and both maximum monthly and total annual discharge at the stream gauge station on Baker Creek at the Narrows, USGS gauge station #10243240. The snow course station is located at 9,250 feet (2,819 m) elevation; the gauge station at 6,750 feet (2,057 m) in the same watershed. The USGS operated the Baker Creek gauging station intermittently from October 1947 to September 2004, after which time the National Park Service assumed responsibility for the station. The graph uses data from 18 years between 1950 and 2010 for which both the Baker Creek #3 snow course station and the Baker Creek gauge station have sufficient data: calendar years 1950-55, 1993-97, and 2004-2010. National Park Service gauge data after September 2010 are not yet digitally available. USGS gauge data are not available for October-December 1955 and October-December 1997. However, these are always months of very low flow. Including these years in the analysis slightly underestimates total annual discharge for those years but does not affect the data on maximum monthly discharge). The graph, using $\log_{10}$ values to reduce the effects of extreme values, shows that April 1 SWE predicts maximum monthly discharge with moderately high reliability (R^2 = 0.754), and predicts total annual discharge with only slightly lower reliability.

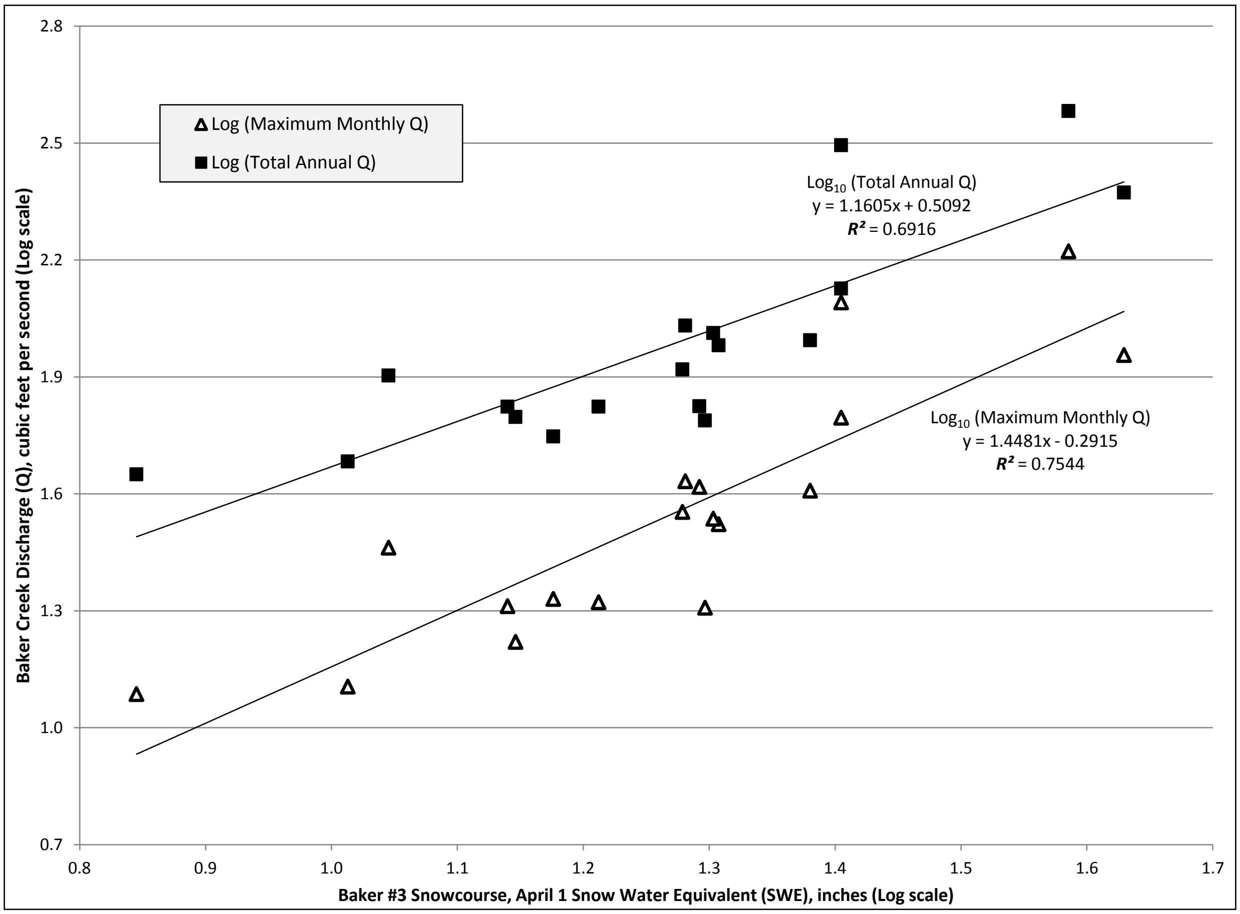


Figure 80. April 1 Snow Water Equivalent (SWE) in the headwaters of Baker Creek versus Baker Creek total annual and maximum monthly discharge (Q) for 18 calendar years between 1950 and 2010, Great Basin NP.

<u>Reference Conditions</u>

The present assessment defined reference conditions for water quality/quantity indicators in various ways.

Watershed Landscape Condition and Riparian Corridor Landscape Condition
A LCI value of 100 for an individual pixel indicates an absence of land modification in and around that pixel. The present assessment for montane riparian woodland recognizes a LCI value > 70 as indicating “Good” condition; a LCI value > 50 but ≤ 70 as indicating “Moderate Concern;” and a LCI value ≤ 50 as indicating “Significant Concern.” This categorization reflects LCI site impact scores determined for the western U.S. in general and for the Central Basin and Range Rapid Ecoregional Assessment in particular (Comer et al. 2013, Comer and Hak 2012): A site impact score of 70 for dirt roads and other four-wheel-drive vehicle trails; and site impact scores of 50 for local and connecting roads, medium density development, and power transmission lines. The present assessment thus assumes that, even in the absence of any other immediate and surrounding impacts, the presence of a dirt road or other four-wheel-drive vehicle trail within a riparian corridor occurrence pixel is sufficient to classify the pixel as falling into the “Moderate Concern” rating category for that resource. A dirt road or other four-wheel-drive vehicle trail not only displaces vegetation but promotes erosion, provides a corridor for incursions by non-native species, and provides a setting for introductions of contaminants. Similarly, the present assessment assumes that, even in the absence of any other immediate and surrounding impacts, the presence of a paved road, medium-density development, or a power line within a riparian corridor occurrence pixel is sufficient to classify the pixel as falling into the “Significant Concern” rating category for that resource. Without intensive management, these types of land modifications can strongly alter local hydrology, strongly promote erosion, encourage or involve significant human activity on the surrounding land surface, provide numerous opportunities for incursions of non-native species, and provide settings for introductions of contaminants.

Stream Nutrient Enrichment
No historic data on nutrient concentrations in the streams of Great Basin NP, or similar streams nearby in the Great Basin, were identified for this assessment that might suggest estimates of reference nutrient concentrations. Moret et al. (2013) note that the State of Nevada sets a water quality standard for total phosphorus for Class A Waters of ≤0.10 mg/L as phosphorus.

Incidence of Exceedance of Water Quality Standards
Water quality standards for aquatic life support provide a useful basis for distinguishing conditions of “Significant Concern” from conditions of only “Moderate Concern,” under National Park Service definitions. The standards applied here consist of U.S. EPA National Water Quality Criteria in use at the time of this assessment (USEPA 2014), for all water quality parameters detected in samples from Great Basin NP, for which a federal criterion exists. These criteria are presented in Table 50, below. As noted in footnote 3 for the table, the criterion for copper (Cu) varies depending on several additional factors of water chemistry. Different species of aquatic fauna also differ in their sensitivity to Cu.

The rating scale for this indicator also must recognize that one or more samples from an individual site may sometimes exceed a water quality standard for an individual parameter because of unusual natural conditions. This occurs most often in springs or streams fed by water from mineralogically distinctive geologic environments. Springs or streams with naturally distinctive chemistries constitute ecological settings with potentially distinctive conservation values. Prudic and Glancy (2009) and Paul et al. (2014) provide data on background chemistry in springs in Great Basin NP for comparison to stream water quality samples. Exceedances of water quality standards only raise concerns for ecological resource conservation when they occur at sites affected by human activities, such as pollution from historic mining or modern wastes.

Table 50. U.S. Environmental Protection Agency, current National Water Quality Criteria (USEPA 2014) for freshwater aquatic life support, for water quality parameters relevant to Great Basin NP.

Parameter Name	Std. Type [a]	Criterion [b]	Units
Arsenic, Dissolved	Fresh Chronic	150	μg/L as Element
Cadmium, Dissolved	Fresh Chronic	0.25	μg/L as Element
Chloride, Dissolved	Fresh Chronic	860	mg/L as Element
Copper, Dissolved [c]	Fresh Chronic	11.5	μg/L as Element
Iron, Dissolved	Fresh Chronic	1000	μg/L as Element
Lead, Dissolved	Fresh Chronic	2.5	μg/L as Element
Mercury, Dissolved	Fresh Chronic	0.77	μg/L as Element
Nickel, Dissolved	Fresh Chronic	52	μg/L as Element
Oxygen, Dissolved, Lower Limit	Fresh Chronic	4	mg/L as Gas
pH, Lower Limit	Fresh Chronic	6.5	Standard Unit
pH, Upper Limit	Fresh Chronic	9	Standard Unit
Selenium, Dissolved	Fresh Chronic	5	μg/L as Element
Silver, Dissolved	Fresh Acute	3.2	μg/L as Element
Zinc, Dissolved	Fresh Chronic	120	μg/L as Element

[a] Indicates whether criterion is for freshwater aquatic life use support for chronic or acute exposure.

[b] Values are for upper limit of acceptable exposure except where noted in Parameter Name.

[c] The criterion for copper varies with several factors, including the species of concern. The value listed here derives from the U.S. EPA (2007) Biotic Ligand Model (BLM) method, using the mean value for acute toxicity determined for Lahontan cutthroat trout (Oncorhynchus clarki henshawi), a close relative of the Bonneville cutthroat trout native to Great Basin NP, and the mean ratio of acute to chronic concentration determined for the genus Oncorhynchus.

Mercury in Fish Muscle Tissue

As noted above, the present assessment uses data on mercury in fish muscle tissue samples from Great Basin NP from the study by Eagles-Smith et al. (2014); and health advisories from the Nevada Department of Wildlife. The data analyzed by Eagles-Smith et al. (2014) are from Brook trout collected from Baker Lake, Lehman Creek, and Snake Creek in 2011. That study reviews the literature on the impacts of different whole-body concentrations of mercury (Hg) on fish health, and identifies two thresholds for biological effects: a no-observed-effects (NOE) concentration of 200 ng

Hg/g (200 nanograms of mercury per gram of fish weight); and a lowest-observed-effects (LOE) concentration of 300 ng Hg/g fish weight. The authors state that the NOE threshold "… identifies the Hg concentration in fish tissues below which fish should not experience deleterious effects of Hg exposure on reproduction, growth, or survival." Similarly, the authors state that the LOE threshold "… indicates the concentration above which sub-lethal endpoints of Hg exposure, including alterations to reproductive health, have been documented in laboratory and field studies of fish." The present assessment applies the fish-based NOE threshold to distinguish Good conditions from conditions of Moderate Concern; and the fish-based LOE threshold to distinguish between conditions of Moderate versus Significant Concern.

The NDOW Health Advisories for trout consumption from the Lehman Creek and Snake Creek in turn rest on a different threshold value for mercury concentration, because the advisories concern impacts to human health rather than fish health. Specifically, NDOW issues health advisories for waters where a fish species has an average methylmercury level above 1.0 ppm (1.0 μg/g). This is equivalent to 930 ng Hg/g. The threshold for a health advisory therefore exceeds the LOE threshold for fish, indicating a condition of Significant Concern.

Benthic Macroinvertebrate Assemblage Integrity

The National Aquatic Monitoring Center (Scott Miller, Center Director, personal communication, August 2014) provided the following statement concerning the methods applied to their O/E analysis of stream macroinvertebrate sample data from the park, to assess sample composition relative to reference conditions:

> *We used the Nevada Department of Environmental Protection observed/expected (O/E) index to assess biological condition of sampled sites (Vander Laan 2012). O/E models compare the macroinvertebrate taxa observed at sites of unknown biological condition (i.e., 'test sites') to the assemblages expected to be found in the absence of anthropogenic stressors (see Hawkins et al. 2000 for details). The Nevada O/E model is based on 165 reference sites grouped into 8 distinct classes based on the similarity of macroinvertebrate assemblage composition among sites following the standard methods of Hawkins et al. (2000) and described in detail by Stoddard et al. (2006). The expected class membership and subsequent reference macroinvertebrate assemblage (E) for comparison to test sites is predicted by linear discriminant function models using maximum temperature, maximum precipitation, slope, average discharge, predicted conductivity, elevation, and watershed area. Prior to computing O/E scores, data for all test sites was standardized to the operational taxonomic units used to derive the Nevada O/E model (Vander Laan 2012) and re-sampled to a 300 fixed-count. Based on model performance, O/E scores were calculated for taxa having a probability of capture ≥ 0 to increase the precision of O/E estimates and subsequent model sensitivity to stressors in isolated, arid regions. Biological condition was subsequently assessed based on established thresholds from interval/equivalence tests, with test sites scoring > 0.686 in "Good" biological condition (i.e., comparable to reference conditions); sites scoring between 0.686 and 0.602 in "Fair" (inconclusive) biological condition; and sites scoring <0.602 in "Poor" biological condition. For the Nevada O/E model,*

the minimum count required for assigning an O/E score and biological condition rating is 200 individuals. Samples with less than 200 individuals were not given a condition rating.

The present assessment equates “Poor” in the terminology of the National Aquatic Monitoring Center to “Significant Concern” in the terminology of the National Park Service; “Fair” with “Moderate Concern;” and “Good” with “Good.”

Snowpack Condition

The purpose of this indicator is to assess whether changes in snowpack condition have taken place in the park that could result in ecologically important alterations to the pattern of stream discharge (water quantity) among the streams in the park. However, the stream gauge data for the park are presently too limited (see above) to support the identification of specific threshold values for the magnitude of April 1 SWE associated with specific ecologically important variation in stream flow variation. Further, because the snow data are collected only on dates on or close to the first of each month (mostly March 1 and April 1), it is not possible to assess other aspects of annual snowpack variation, such as the date or magnitudes of maximum snowpack depth, or the first date of snowpack formation and the last date of snowmelt. As a result, it is not presently possible to identify criteria with which to distinguish Good snowpack conditions from conditions of either Moderate or Significant Concern. The indicator is included to provide information on a key natural driver affecting stream flow quantity (and recharge) in the park, through a test for any long-term trend in April 1 snowpack (SWE) magnitude.

In-Park Stream Diversions

The purpose of this indicator is to assess whether in-Park diversions of surface water are having impacts on stream flows within the park. The assessment addresses diversions from streams separately from diversions of springs (see Springs, below, section 4.3.6). However, data are not presently sufficient to determine the degree to which the sole active in-Park stream diversion – the Snake Creek pipeline – may be affecting ecological conditions along that stream relative to any reference conditions. Consequently, the present assessment can only qualitatively address the existing stream diversion and its likely impacts on stream ecological condition.

Condition and Trend

Watershed Landscape Condition

The *Summary of Status* section, below, presents the results for this indicator, which also applies to the Montane Riparian Woodlands resource. As discussed there, all watershed portions above the 8,200-foot (2,500-m) contour line, and all except one watershed portion below the 8,200-foot (2,500-m) contour line, fall within the “Good” range for watershed condition. These results indicate that watershed conditions likely support natural rates of runoff, infiltration, evapotranspiration, recharge, and sediment erosion. The one exception is the lower-elevation portion of the Lehman Creek watershed, which falls within the “Moderate Concern” range. This watershed portion, the most heavily developed watershed portion in the park, contains sections of the Wheeler Peak Scenic Drive; the Upper and Lower Lehman Creek camping areas; Lehman Caves, the Lehman Caves Visitor Center, and adjacent picnic and RV camping areas; and State Route 488 between the Visitor Center and Baker, NV. Land modifications within this one catchment have the potential to cause moderate changes to watershed hydrology and erosion. Watershed LCI values were not available for previous time periods, against which to compare the recent watershed values for evidence of any trend(s).

Riparian Corridor Landscape Condition

The *Summary of Status* section, below, also presents the results for this indicator, which again also applies to the Montane Riparian Woodlands resource. As discussed there, the majority of riparian corridor occurrences above the 2500 m contour fall within the "Good" range for Riparian Corridor Landscape Condition. The watershed-scale summary for this indicator (see Section 4.3.3, below) identifies only one watershed above 8,200 feet (2,500 m) in which the area-weighted averages indicate a condition of "Moderate Concern": the Burnt Mill Canyon watershed. This departure apparently is associated with the Osceola self-guiding trail (see Montane Riparian Woodlands, below). All other higher-elevation watersheds have average Riparian Corridor LCI values in the "Good" range. In contrast, the area-weighted averages for this indicator (see Section 4.3.3, below) identifies only 19 of 43 occurrences below the 8,200-foot (2,500-m) contour that fall within the "Good" range, 12 that fall within the ranges of "Moderate Concern," and one that falls within the range of "Significant Concern." The thirteen lower-elevation watersheds with ratings of moderate or significant concern for this indicator include some with only small areas within the park; but they also include the lower-elevation portions of the Baker, Lehman, Lexington, Snake, and Strawberry Creek watersheds with substantial areas inside the park. However, the area-weighted average Riparian Corridor LCI score for all lower-elevation watersheds together marginally falls within the range of conditions here classified as "Good." The watersheds with individual area-weighted averages in the "Good" range are slightly larger than those in the other two rating categories. These results indicate that near-stream hydrologic functions (runoff, infiltration, evapotranspiration, and erosion) are most likely unimpaired at higher elevations, but may be moderately impaired in nearly half of all watersheds at lower elevations.

Management actions such as waste containment, runoff containment, erosion control, minimization of impervious surfaces, and the provision of buffer zones between human activities and sensitive resources can all counteract the effects of riparian corridor development. The LCI methodology does address such management responses. LCI values for the riparian corridor were not available for previous time periods, against which to compare the recent values for evidence of any trend(s).

Stream Nutrient Enrichment

Moret et al. (2013; in prep.) tabulate data on stream nutrient concentrations determined by the National Park Service, Mojave Desert Network Inventory and Monitoring program beginning in 2009 (Moret et al. 2012a, 2012b, 2013). As noted above, the data come from water samples collected from Snake, Baker, Lehman, Pine, Ridge, South Fork Big Wash, Mill, Shingle, and Strawberry creeks during the late-summer low-flow season, at the same locations sampled for benthic macroinvertebrates. The data have not yet been processed to take into account the effects of variation in stream discharge and time of day; and the authors report some ongoing but diminishing difficulties with methods to ensure data quality. However, the data provide an initial picture of stream nutrient conditions (Moret et al. 2013; in prep.; Geoff Moret, Hydrologist, National Park Service Inventory and Monitoring Program, Mojave Desert Network, personal communication, April 2015).

The results indicate that total nitrogen (N) does not exceed 0.64 mg/L; total dissolved N does not exceed 0.55 mg/L; nitrate + nitrite does not exceed 0.495 mg/L; total phosphorus (P) does not exceed 0.074 mg/L; and total dissolved P does not exceed 0.020 mg/L in any sample. These results exclude values below the minimum level of quantification or even below the method detection limit (MDL), and exclude values that pointed to problems with equipment or handling. Moret et al. (2013; *in prep*.; Geoff Moret, Hydrologist, National Park Service Inventory and Monitoring Program, Mojave Desert Network, personal communication, April 2015) describe these results as "very low," indicating no causes for concern.

Three sources of information also provide indirect evidence concerning possible trends in stream nutrient enrichment in the park, as noted above. These consist of information on: (1) the likely intensity of human activities across watersheds and near streams that could result in discharges of wastes onto the ground or directly into the water; (2) changes in vegetation, wildfire regime, and soils across watersheds; and (3) atmospheric deposition of nitrogen. The information for the first comes from the assessments of Watershed Landscape Condition and Riparian Corridor Landscape Condition, above; the information for the second comes from the assessment of the Wildfire Regime, above; and the information for the third comes from the assessment of Air Quality, above.

The assessments of Watershed Landscape Condition and Riparian Corridor Landscape Condition, above, indicate that the watershed uplands of the park are mostly in Good condition at all elevations; riparian corridors are mostly in Good condition, but with an increasing density of patches in Moderate condition at lower elevations. There are no data to evaluate for possible trends in these conditions. The assessment of Wildfire Regime points to departures of Moderate Concern consistent with a history of wildfire suppression. Wildfires result in the transport of ash into streams, delivering pulses of non-volatile nutrients such as phosphorus. The great reduction in wildfire frequency and extent therefore has likely altered natural stream nutrient regimes in the park.

Finally, the assessment of Air Quality points to ongoing elevated levels of total nitrogen deposition, warranting a rating of Moderate Concern. These findings suggest indirectly that streams in the park are experiencing perhaps moderately altered patterns of nutrient inputs. However, many factors intervene, between atmospheric deposition of nitrogen and its appearance within stream waters. For example, much of the nitrogen that falls as wet deposition in snow that becomes part of the snowpack or falls as dry deposition onto the snowpack may be carried quickly out of the system during snowmelt. The assessment of Air Quality therefore does not necessarily point to likely conditions of Moderate Concern for nutrients in the streams. However, the findings for Air Quality do suggest that the topic warrants careful study.

Incidence of Exceedance of Water Quality Standards
As noted above, most of the water quality data from Great Basin NP for the period 1966-1998 do not presently allow for a quantitative assessment of exceedances of water quality standards. Only the field-measured data on water pH lend themselves to this kind of quantitative analysis. Table 51

summarizes the pH values recorded during water quality sampling in and immediately around the park for the period 1966-1998 (National Park Service 2000). In turn, Table 52 summarizes the results of the review of all water quality sampling in and immediately around the park for the period 2006-2007 (Horner et al. 2009), for water quality parameters for which national aquatic life support criteria are available (see above).

The older data (Table 51) show that pH measurements between 1966 and 1998 never fell outside the acceptable range (6.5 to 9 standard units) among measurements in caves and only rarely among measurements in streams, fell outside this range among nearly 6% of pH measurements in lakes, and fell outside the acceptable range in more than 23% of the measurements in springs.

In turn, the more recent data (Table 52) show that the values of several water quality parameters from the samples from 2006-2007 sometimes exceeded water quality criteria. Specifically, the samples collected in 2006-2007 frequently exceeded water quality criteria for DO and lead in cave samples and exceeded acceptable values for pH measurements in lakes. Concentrations of copper also exceeded the relevant water quality criterion in nearly 10% of all cave samples. Additionally, concentrations of iron exceeded the relevant water quality criterion for slightly more than 10% of all stream samples.

Table 51. pH observations and criterion exceedances in samples collected 1966-1998 in Great Basin NP (NPS 2000).

	Cave Samples				Lake Samples				Spring Samples				Stream Reach Samples			
Parameter	N. Sites	N. Obs	N. Exc.	% Exc.	N. Sites	N. Obs	N. Exc.	% Exc.	N. Sites	N. Obs	N. Exc.	% Exc.	N. Sites	N. Obs	N. Exc.	% Exc.
pH	4	10	0	0.0%	65	252	14	5.6%	37	259	60	23.2%	52	362	2	0.6%

Table 52. Water quality observations and criterion exceedances in samples collected 2006-2007 in Great Basin NP (Horner et al. 2009).

	Cave Samples				Lake Samples				Spring Samples				Stream Reach Samples			
Parameter	N. Sites	N. Obs	N. Exc.	% Exc.	N. Sites	N. Obs	N. Exc.	% Exc.	N. Sites	N. Obs	N. Exc.	% Exc.	N. Sites	N. Obs	N. Exc.	% Exc.
Arsenic	3	14	0	0.0%	6	24	0	0.0%	8	25	0	0.0%	48	123	0	0.0%
Chloride	3	14	0	0.0%	6	24	0	0.0%	8	25	0	0.0%	48	123	0	0.0%
Copper	3	14	1	7.1%	6	24	0	0.0%	8	25	0	0.0%	48	123	1	0.8%
DO	3	14	4	28.6%	6	24	1	4.2%	7	24	1	4.2%	47	124	5	4.0%
Iron	3	14	0	0.0%	6	24	0	0.0%	8	25	1	4.0%	48	123	13	10.6%
Lead	3	7	3	42.9%	0				4	10	0	0.0%	16	30	0	0.0%
pH	3	28	0	0.0%	6	29	8	27.6%	8	50	0	0.0%	48	249	6	2.4%
Zinc	3	14	0	0.0%	6	24	0	0.0%	8	25	0	0.0%	48	123	0	0.0%
Total	3	119	8	6.7%	6	173	9	5.2%	8	209	2	1.0%	48	1018	25	2.5%

Only the values for pH can be compared between the two time periods (1968-1998 versus 2006-2007). Exceedances of pH in lakes, as a fraction of all pH measurements in lakes by time period, are far more common among the older samples (1966-1998) than among the more recent samples (2006-2007). Conversely, exceedances of pH in springs are far less common among the older samples (1966-1998) than among the more recent samples (2006-2007). Exceedances for pH can occur when the sample pH is higher than the upper criterion or lower than the lower criterion for this parameter. Therefore, it is noteworthy that, among the 76 older water quality samples (1966-1998) that fell outside the acceptable range of values for pH, all the pH exceedances in spring and stream water and 11 (79%) of the 14 pH exceedances in lake water involved readings *below* the national criterion of 6.5 standard units. In contrast, among the 14 recent samples (2006-2007) that fell outside the acceptable range for pH, 7 of the 8 exceedances in lakes (87.5%) fell below the lower threshold (6.5 standard units), while the few (n=6) exceedances in streams (out of a total of 249 observations) fell equally above and below the upper and lower thresholds (9 and 6.5 standard units), respectively. Further, no pH readings from either springs or caves in the recent data fell either above or below the acceptable range at all.

Thus, pH exceedances in lakes in both time periods consistently (but not exclusively) involve readings below 6.5 units. In contrast, pH exceedances in springs occur only in the older dataset, and pH exceedances in streams shift from being common and exclusively below 6.5 units in the older data to uncommon (2.4%) and balanced between high and low readings in the more recent data. These changes in pH possibly could be related to changes in atmospheric deposition of the acidic anions, nitrate and sulfate (see Air Quality, above). Even low levels of nitrate and sulfate deposition can cause acidification in waters with naturally low buffering capacity, such as exist in the lakes across the northern half of the park with its non-carbonate geology (Baron et al. 2000, Porter et al. 2005, McNulty et al. 2007, Burns et al. 2008, Saros et al. 2010, Pardo et al. 2011, Nanus et al. 2012, Ellis et al. 2013, Lovett 2013, Blett et al. 2014). Excess acidification degrades aquatic habitat and, in extreme cases, eliminates most native organisms from an affected water body. The records of atmospheric deposition (1985-2012) at the park (see Air Quality, above) not only span the recent years of water quality monitoring in the park, but also overlap the years covered by the earlier period of water quality sampling in the park (1966-1998). Figure 81 (a and b) shows the status and trends in nitrate and sulfate deposition at the Lehman Caves Visitor Center atmospheric monitoring station (Station ID NADP NV05) for 1985-2012, expressed as kg/ha/yr and eq/ha/yr. Both nitrate and sulfate deposition show downward trends over the period of record, although with much inter-annual variation. The graphs in Figure 81 show the regression lines and $\boldsymbol{R^2}$ values.

Figure 81 shows that the years of overlap of the record of atmospheric deposition with the earlier period of water quality sampling, 1985-1998, experienced higher rates of deposition of the acidifying anions of nitrogen and sulfur than later years. Acid deposition likely was taking place prior to 1985 as well.

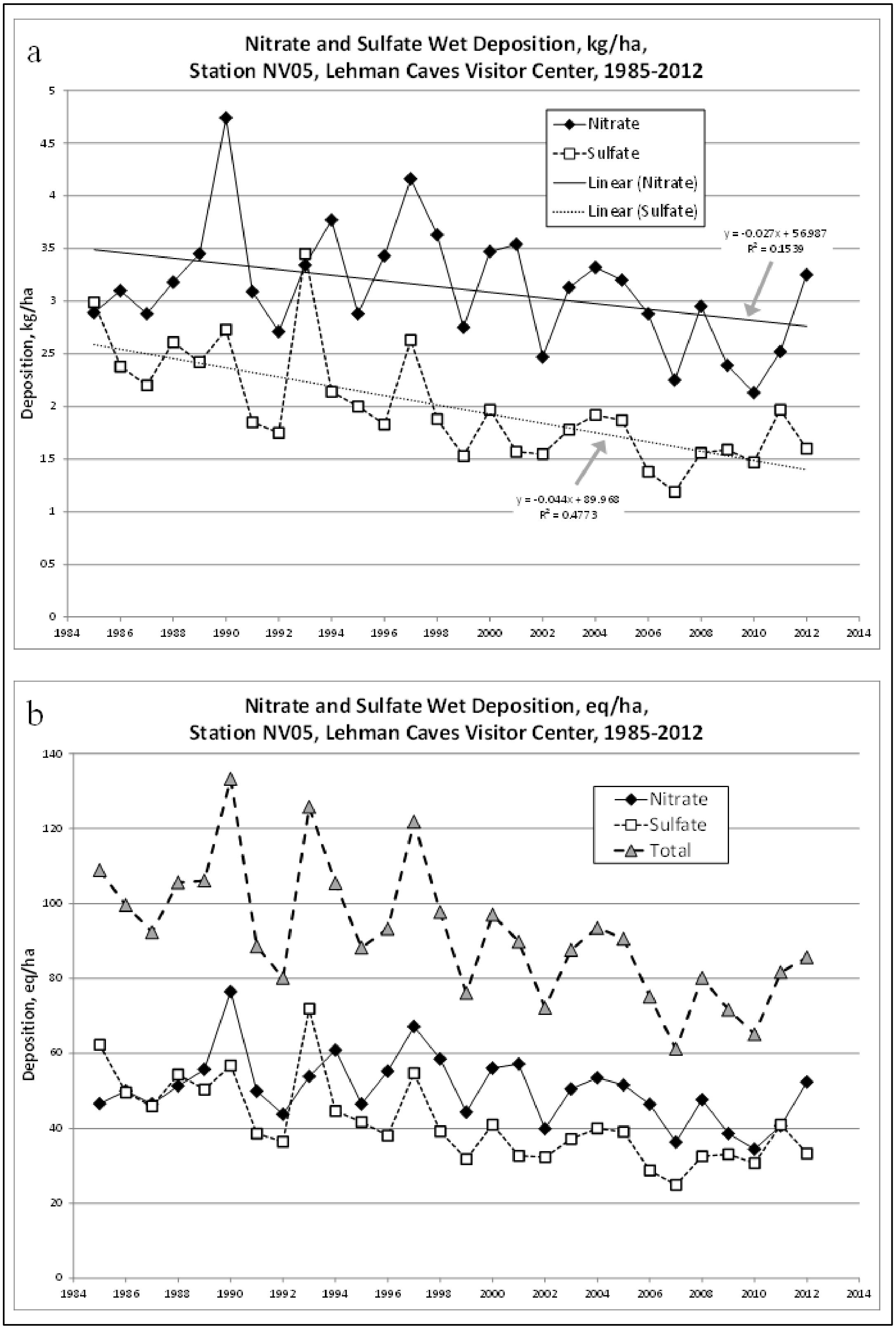


Figure 81. Atmospheric deposition of nitrate and sulfate, Great Basin NP, 1985-2012: (a) kg/ha/yr; (b) eq/ha/yr.

The incidence of exceedances for metals in the samples from 2006-2007 also requires some notice. Prudic and Glancy (2009) and Paul et al. (2014) present data on the concentrations of a range of ions in cave and spring discharges likely to be unaffected by pollution. These data indicate that copper may occur in spring samples at concentrations up to 1.1 μg/L (Paul et al. 2014) and iron up to 0.311 μg/L (Prudic and Glancy 2009). These cations derive from reactions of groundwater with the mineralogy of the South Snake Range. However, neither Prudic and Glancy (2009) nor Paul et al. (2014) report concentrations of either cation in excess of their respective water quality criteria. Their analyses also indicate that cadmium, lead, selenium, and zinc are typically not detectable in unaltered cave and spring discharges; and that low concentrations of dissolved oxygen occur naturally in cave samples. Consequently, other than the unexplained high number of exceedances for lead in samples from caves, the incidence of exceedances in samples from caves in Great Basin NP likely reflects their unusual *natural* chemistry, not any type of pollution.

Mercury in Fish Muscle Tissue
None of the Brook trout samples collected from Great Basin NP in 2011 had a mercury concentration greater than 100 ng Hg/g fish weight, well below the NOE threshold (Eagles-Smith et al. 2014). The results thus indicate consistently Good conditions. The authors state that the results are "…among the lowest measured in the current study [of 21 National Parks in the western U.S.] suggesting that at the time of sampling the ecological risk posed by Hg in these systems is likely low." However (see Air Quality, above), Eagles-Smith et al. (2014) also note that atmospheric dry deposition of Hg in the park was recently found to be among the highest measured in six western national parks (Wright et al. 2014). Conditions in the park therefore may limit methylation, and therefore limit bioaccumulation. For example, wetlands are few and small within the park, especially at higher elevations, limiting the extent of soils in which methylation can take place. However, the NDOW health advisories for consumption of brown and rainbow trout indicate the presence of conditions of Significant Concern for this indicator, at least at lower elevations along Lehman and Snake Creeks from which the fish samples were collected in 2009 for mercury analysis by NDOW (Ben Roberts, Great Basin NP, personal communication, December 2014; Jon Reynolds, Great Basin NP, personal communication, January 2015). The combination of the findings of Eagles-Smith et al. (2014) and the NDOW health advisories suggests that conditions for this indicator are of Moderate Concern. However, the contrast between the findings of the study by Eagles-Smith et al. (2014) and the NDOW health advisories suggests that methyl-mercury may accumulate in stream food webs as one moves from high to low elevation within the park. Further investigations of mercury body loads among fish in the park could help determine if there is in fact a difference in loads between fish at high versus low elevations, and point to the factors potentially responsible for this contrast, such as differences in wetland abundance with elevation.

Benthic Macroinvertebrate Assemblage Integrity
Table 53 shows the O/E values calculated for the 52 samples analyzed for this assessment, color coded to identify the samples rated Significant Concern (red), Moderate Concern (orange), and Good (green).

Table 53. O/E results for stream benthic macroinvertebrates in the South and North Snake Ranges, 2001-2012.

Range	Stream Name	Station ID	2001	2002	2004	2006	2007	2009	2010	2011	2012
North Snake Range	Deadmans Creek										1.0268 [c]
	Deep Creek										1.0269 [c]
	Hampton Creek										1.2267 [c]
	Hendrys Creek										0.9638 [c]
	Negro Creek			1.2911 [c]							
	Silver Creek			0.7720 [c]							
South Snake Range	Baker Creek	BAKR1						1.2340 [c]			
		BAKR2							0.7917 [c]		
		BAKR3								0.7214 [c]	0.8889 [c]
		EPA02-006		0.8455 [c]							
		GBNP-05					1.0894 [c]				
		NV343320			0.8825 [c]						
	Lehman Creek	EPA02-007		0.6606 [b]							
		LEHMAN-01						1.1418 [c]			
		LHMN2							0.6876 [c]	0.6611 [b]	0.7994 [c]
	Mill Creek							1.0153 [c]	1.2454 [c]	1.0185 [c]	1.4774 [c]
	Pine Creek-01							1.1285 [c]	1.2249 [c]	0.7396 [c]	1.2220 [c]
	Ridge Creek							0.9562 [c]	0.9824 [c]	0.9254 [c]	0.8894 [c]

[a]Samples rated as being of Signficant Concern (red).

[b]Samples rated as being of Moderate Concern (yellow).

[c]Samples rated as being Good (green).

Table 53 (continued). O/E results for stream benthic macroinvertebrates in the South and North Snake Ranges, 2001-2012.

Range	Stream Name	Station ID	2001	2002	2004	2006	2007	2009	2010	2011	2012
South Snake Range (continued)	Shingle Creek							1.2005 [c]	1.4390 [c]	0.9153 [c]	1.1675 [c]
	Snake Creek	EPA02-034		1.0343 [c]							
		p-NVW04485-016				1.0276 [c]					
		SNAKBCT7	0.4634 [a]								
		SNAKE-1						1.1741 [c]	1.3521 [c]	1.2403 [c]	1.2757 [c]
	South Fork of Big Wash							0.7892 [c]	0.7980 [c]	0.6241 [b]	0.8763 [c]
	Strawberry Creek	EPA02-034		1.2343 [c]							
		p-NVW04485-016						1.2344 [c]	1.1880 [c]	1.0400 [c]	1.2413 [c]
	Willard Creek										1.0323 [c]

[a]Samples rated as being of Signficant Concern (red).

[b]Samples rated as being of Moderate Concern (yellow).

[c]Samples rated as being Good (green).

The data in Table 53 include samples from multiple locations along Baker, Lehman, Snake, and Strawberry Creeks. However, these stations are located sufficiently far apart that they must be treated as samples from different stream reaches that may experience different stresses. For example, the stations along Baker Creek occur both above and below tributary confluences; and above and below campgrounds. Repeat sampling over multiple years began at several stations in 2009, 2010, or 2011. These are the only stations for which it is possible to assess evidence for trends in conditions; but these stations provide at most only four years of data, depending on the station.

The dataset contains only one sample rated Significant Concern – a sample collected from a station on Snake Creek in 2001. This location was never resampled; consequently, it is not possible to evaluate whether conditions changed at this station in subsequent years. The dataset also contains a sample rated Moderate Concern – collected at a station on Lehman Creek in 2002. This location also was never resampled, so again it is not possible to evaluate whether conditions changed at this station in subsequent years.

Two stations – one on Lehman Creek (LHMN2) and one on South Fork Big Wash – receive ratings of Good for 2010 and 2012 but a rating of Moderate Concern for 2011. This might suggest that conditions at these two stations uniquely declined between 2010 and 2011 and then improved between 2011 and 2012. However, almost all of the stations resampled between 2009 and 2012 show a drop in O/E score in 2011, followed by a recovery in 2012. The worsened conditions in 2011 at the Lehman Creek and South Fork Big Wash stations thus do not indicate unique conditions at those locations in that year. Instead, they merely are examples of a pattern affecting nearly all stations. Give the collecting dates for the samples collected in 2010, 2011, and 2012, the data thus indicate that stream benthic macroinvertebrates in both the North and South Snake Ranges experienced unusually stressful conditions between September 2010 and June 2011. The disturbance was likely due to unusual hydrologic conditions. Specifically, digital stream gauge data are available for this period from the Lehman Creek gauge station (see above). These data show that calendar year 2011 experienced the fourth largest annual discharge recorded across all years of gauge record, exceeding the 85th percentile for annual discharge; and experienced the largest annual discharge recorded during the period spanned by the stream benthic macroinvertebrate samples. Annual discharge was higher in 2005, but the stream benthic invertebrate sample dataset does not include any samples from that year. Further, the months of June and July, 2011, were particularly wet, experiencing monthly discharges exceeding the 84th and 91st percentiles for these two months, respectively, across all years of record, as a result of unusually intense summer storms. June and July 2011 in fact experienced monthly discharges larger than any recorded for those two months during the period spanned by the stream benthic macroinvertebrate samples. Again, June and July discharges were was higher in 2005, but the stream benthic invertebrate sample dataset does not include any samples from that year. Otherwise, the most recent years of data consistently indicate Good conditions among all stations sampled for stream invertebrates.

Snowpack Condition

Figure 82 and Figure 83 show the SWE measured at the three snow courses in the headwaters of Baker Creek on April 1 (± 3 days) between 1942 and 2014. The presence of any trend(s) in the data was assessed using three methods: linear regression on the raw data; linear regression on log-transformed data; and the Mann-Kendall test.

Linear regression on the raw data: Figure 82(a) shows the raw SWE values for snow course #3, elevation 9,250 feet (2,819 m), along with the linear regression line and its associated $\boldsymbol{R^2}$ value. The data appear to show a slight downward trend, but with significant inter-annual variation that results in an almost negligible $\boldsymbol{R^2}$ value. Figure 83 shows the raw SWE values and associated linear regression lines and $\boldsymbol{R^2}$ values for snow courses #2 and #1 at 8,950 feet and 7,950 feet, respectively (2,728 m; 2,423 m). These sites exhibit the same tenuous downward trends, high inter-annual variability, and extremely low $\boldsymbol{R^2}$ values as site #3. SWE values are lower at the lower elevations.

Linear regression on log-transformed data: Precipitation data are typically highly skewed, with a small number of extremely high values that distort means and regression lines. Using a $\log_{10}$ transformation produces a more symmetrical univariate distribution of values. In the present case, $\log_{10}$ transformation – Figure 82(b) – produces a linear regression line for snow course #3 with essentially no slope and an $\boldsymbol{R^2}$ value indistinguishable from 0. This again indicates that there is no statistically reliable evidence for any trend in snowpack at this site.

Mann-Kendall test: The Mann-Kendall test (Helsel and Hirsch 2002, Helsel et al. 2006) is a widely applied non-parametric test for trends in chronological data. It makes fewer assumptions about the underlying distributions of the data, compared to standard linear regression methods. Figure 82(a) and Figure 83 show the *tau* correlation coefficient and p values for the Kendall's *tau* Correlation Test for each snow course, calculated using the U.S. Geological Survey “Kendall” program (Helsel et al. 2006). The results again show that none of the three snow courses has experienced a statistically significant trend in SWE values over time.

These results indicate that, at least for the past 73 years, snowpack formation at high elevation in the park has been highly variable but has experienced no statistically significant trend in April 1 (± 3 days) SWE values.

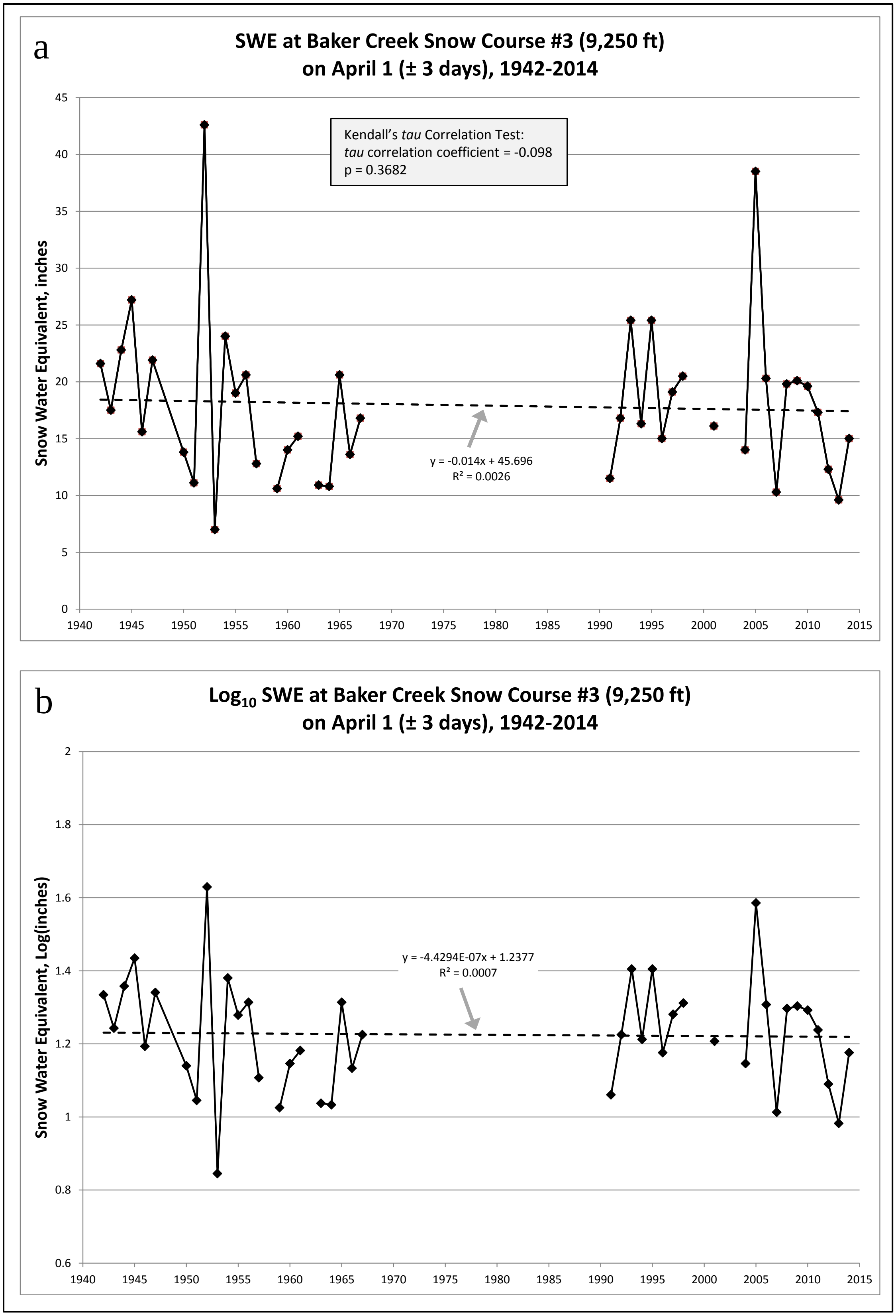


Figure 82. Snow Water Equivalent (SWE) on April 1 ± 3 days, Baker Creek Snow Course #3, Great Basin National Park, 1942-2014: (a) Raw SWE values; (b) Log10 of SWE values.

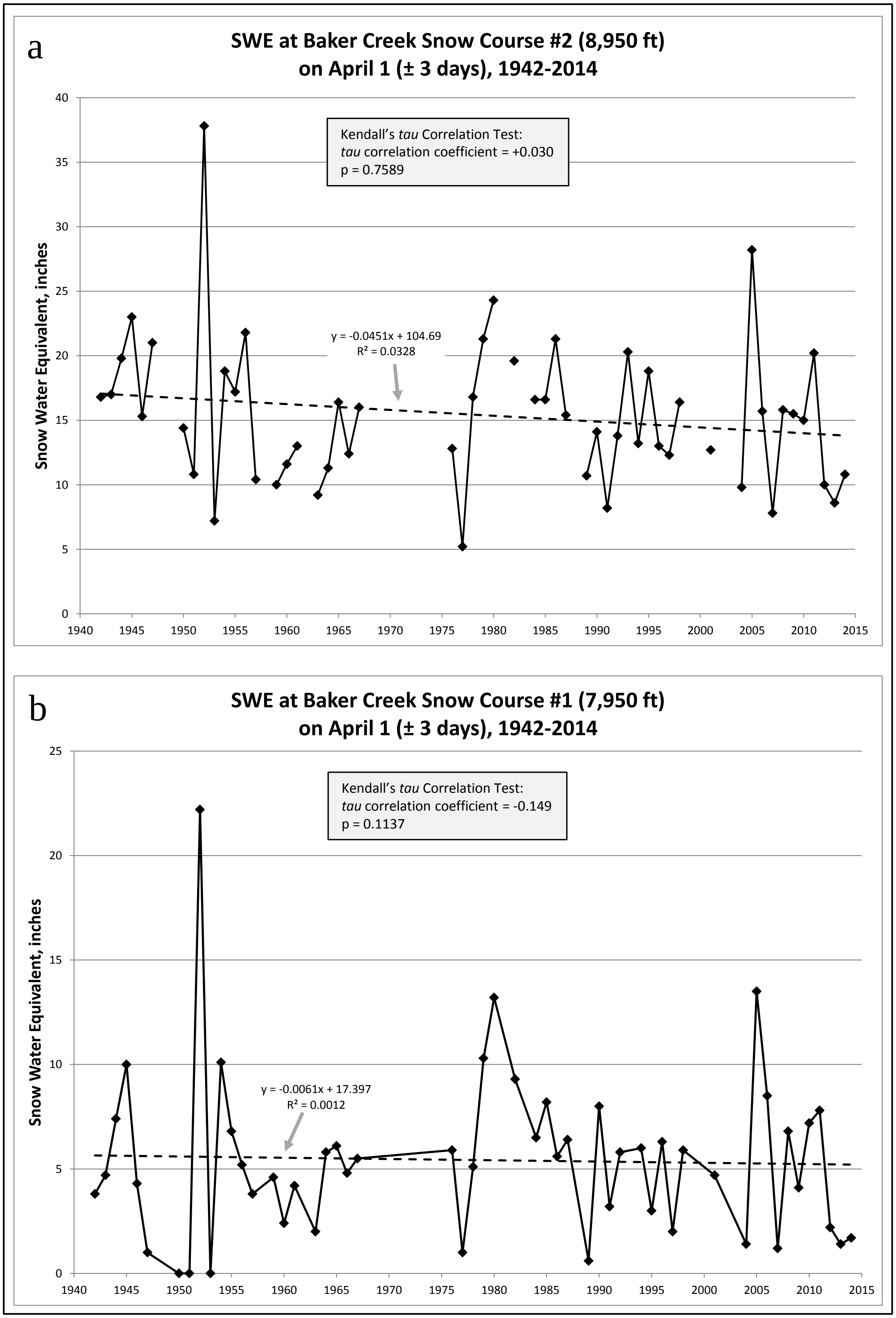


Figure 83. Snow Water Equivalent (SWE) on April 1 ± 3 days, Baker Creek Snow Courses #2 and #1, Great Basin National Park, 1942-2014: (a) Site #2; (b) Site #1.

In-Park Stream Diversions

As discussed earlier, structures divert water at only one location along a perennial stream reach within the park. This consists of the Snake Creek pipe, a 3-mile (5-km) structure installed in 1961 to bypass a losing section of the stream, between 7,610 and 6,760 feet (2,320 - 2,060 m) elevation. The diversion captures all of the water during most of the year. This water would otherwise provide aquatic habitat, sustain riparian vegetation, and allow for natural karst processes along the losing reach..

Snake Creek could have experienced year-round flow within the park during wet or normal years prior to construction of the pipeline diversion. However, it is not possible to ascertain whether or how often such circumstances occurred historically. The bypassed reach today flows only intermittently, during spring runoff and after strong thunderstorms when stream discharge above the pipe intake exceeds the capacity of the intake. Elliott et al. (2006) also reported a loss of 2.6 ft3/s between the top and bottom of the pipeline, a more than 15% loss of water during the time of measurement. The bed and underlying bedrock are clearly highly permeable. This suggests that the pipeline has greatly exaggerated a natural condition of intermittency for the reach that it spans, increasing the frequency and duration of dry conditions. In this interpretation, the riparian phreatophytes along the reach bypassed by the pipeline have likely experienced significant impacts from the diversion, because they depend(ed) on stream water that formerly infiltrated along the reach. Fisheries within the bypassed reach have been completely eliminated due to the current seasonality of water. Even when fish are able to access this reach during wet years, the pipeline inlet becomes a fish barrier to further movement upstream. Quantifying the aquatic and vegetative changes caused by the bypass requires additional information.

The groundwater recharged along the losing reach – minus any losses to evapotranspiration – would have flowed underground to possibly discharge elsewhere. Specifically, at least some of the water formerly recharged along the losing reach sustained seepage and spring discharge further downstream, below the end of the pipeline. Elliott et al. (2006) determined that the water lost along the losing reach recharged (and today still recharges, but at much lower rates) two particular, highly fractured bedrock formations: the Pole Canyon Limestone and the Prospect Mountain Quartzite. The former lies beneath approximately the upper half of the distance spanned by the pipeline, while the latter formation lies beneath the lower half. Water recharged from Snake Creek to the Prospect Mountain Quartzite re-emerges as seepage and springs below the end of the pipe, while Snake Creek water recharged to the Pole Canyon Limestone leaves the watershed – and therefore leaves the park – as groundwater. Elliott et al. (2006) suggest that the groundwater in the Pole Canyon Limestone subsequently discharges either "… [at] Big Springs at the southeast corner of the southern Snake Range, or as ET on the valley floor adjacent to Big Springs and Lake Creeks southeast of the Snake Creek drainage."

The direct impacts of the Snake Creek pipeline within the park are the loss of flow along the bypassed stream reach and the diminished discharge of groundwater from the Prospect Mountain Quartzite to Snake Creek below the end of the pipe. Indirect impacts include the loss of aquatic resources, including fisheries, reduction in riparian vegetation, and loss of karst surface to subsurface hydrological processes.

Summary of Status

Table 54 summarizes the results for the nine indicators used to assess water quality and quantity. Seven of the nine indicators point to present-day Good conditions throughout the park and two point to conditions of Moderate Concern, with varying levels of uncertainty. Only four indicators could be assessed for trends, and all four showed an absence of trends.

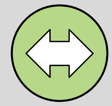
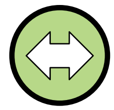
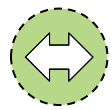
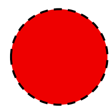
The indicators for water quality assess both the likelihood of impacts from human activities on the landscape (Watershed Landscape Condition; Riparian Corridor Landscape Condition; Stream Nutrient Enrichment), and the evidence for actual degradation of water quality (Stream Nutrient Enrichment; Incidence of Exceedance of Water Quality Standards; Mercury in Fish Muscle Tissue; Benthic Macroinvertebrate Assemblage Integrity). The benthic macroinvertebrate assemblage results include one sample with a rating of Significant Concern for 2001, and another with a rating of Moderate Concern for 2002. However, neither location has been subsequently resampled; consequently, it is not possible to determine whether or how conditions have changed at these two locations. Additionally, most samples collected in 2011 show poorer conditions than samples from the same locations in 2010 or 2012. In two instances, this dip in conditions for 2011 put two stations into the range of Moderate Concern, but both locations recovered in 2012. The consistent, widespread drop and subsequent recovery in benthic macroinvertebrate assemblage condition scores in 2011-2012 point to the effects of a regional driver, most likely the unusually wet weather in June-July, 2011, that resulted in extremely high stream discharge. The Incidence of Exceedance of Water Quality Standards shows a shift from conditions of possibly Moderate Concern for pH among lakes and springs and Good condition for caves and streams for the period 1966-1998; to Moderate Concern for pH in lakes and Good condition in all other water body types for the period 2006-2007. This assessment could not determine possible reasons for the greater incidence of exceedances in the older samples. However, a comparison of the water quality data with the data on atmospheric deposition suggests a hypothesis that higher rates of acid deposition during the earlier period contributed to the differences in pH values in lake and spring water quality between the two periods. Continuing atmospheric deposition of nitrogen also may sustain elevated nitrogen levels in the streams of the park, but the relationship between deposition rates and stream concentrations has not yet been explored in detail. The possibility of this relationship results in a rating of Moderate Concern for this indicator.

All indicators of water quantity point to Good conditions throughout the park. These indicators assess only the likelihood of impacts from human activities on the landscape; the data on surface water quantity (stream flows) in the park are as yet not sufficient to support a statistical analysis of environmental flow components. Only one indicator for water quantity was supported by evidence suitable for an analysis of trends: Snowpack Condition. The data from the upper Baker Creek watershed for SWE on April 1, 1942-2014, indicate that, despite significant inter-annual variation, snowpack formation shows no upward or downward trend over the past 73 years. No data were available with which to assess trends for the other indicators for water quantity.

Table 54. Summary of indicators for condition of water quality and quantity for Great Basin NP.

Water Quality/Quantity			
Indicators of Condition	**Specific Measures**	**Condition Status/Trend**	**Rationale**
Watershed Landscape Condition	LCI assessed at scale of watersheds (addresses both water quality and quantity)		Mostly high LCI scores for watershed condition at all elevations; no evidence to evaluate trend. However, indicator provides only indirect information on condition of resource.
Riparian Corridor Landscape Condition	LCI assessed at scale of a 200 m buffer along stream corridor (addresses both water quality and quantity)		Mostly high LCI scores for riparian corridor condition at higher elevations; mixed for lower elevations; no evidence to evaluate trend. However, indicator provides only indirect information on condition of resource.
Stream Nutrient Enrichment	Concentrations of dissolved inorganic nutrients in water quality samples		Direct evidence suggests no concentrations of concern. Indirect evidence suggests possible departure from natural pattern due to atmospheric deposition but provides no information on possible trends within stream water.
Incidence of Exceedance of Water Quality Standards	Frequency at which water quality samples per site exceed standards for aquatic life support		Consistent evidence of Good current conditions. pH readings show improving trend but no data available on trends in other water quality parameters.
Mercury in Fish Muscle Tissue	Frequency of fish samples that exceed toxic threshold values for mercury body load		Reliable data indicate very low body loads in one study; high in another; no data to evaluate for trends.

Table 54 (continued). Summary of indicators for condition of water quality and quantity for Great Basin NP.

Water Quality/Quantity			
Indicators of Condition	**Specific Measures**	**Condition Status/Trend**	**Rationale**
Benthic Macroinvertebrate Assemblage Integrity	Ratio of observed to expected benthic macroinvertebrate taxa		No trend away from Good conditions for any stream reaches; 2011 scores mostly lower than 2010 and 2012 likely due to unusual weather and stream discharge.
Snowpack Condition	April 1 SWE, 1942-2014; trend only		No trend in April 1 snowpack SWE values. However, SWE alone does not predict recharge and runoff for the park.
In-Park Stream Diversions	Number, types, and impacts of diversions; narrative only		Diversion of 3 miles of stream and associated impacts are significant but lack of data limit trend and overall confidence.

<u>Sources of Expertise</u>

The assessment of this resource rests on previously collected data and maps, except for the new analyses of stream benthic macroinvertebrate sample O/E values provided by the BLM/USU National Aquatic Monitoring Center. The assessment benefited from advice from Scott Miller, Director of the National Aquatic Monitoring Center, to design the analysis of the stream benthic macroinvertebrate samples; and from Geoff Moret, Hydrologist, National Park Service Inventory and Monitoring Program, Mojave Desert Network. The identifications of LCI break-points for distinguishing conditions of "Good," "Moderate Concern," and "Significant Concern" rest on expert input into the LCI methodology itself (see above). The identification of break-points for rating the overall results for water quality also rests on expert judgment. Great Basin NP staff provided crucial advice on park conditions and access to archival data.

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4.3.3. Montane Riparian Woodlands

Indicators / Measures

- ***Watershed Landscape Condition***
- ***Riparian Corridor Landscape Condition***
- ***Riparian Reach Condition***
- ***Fire Regime Departure***

Condition - Trend

Good Condition– Unchanging – Low Confidence

Background and Importance

The South Snake Range contains more than 33 watersheds, 25 of which occur mostly within Great Basin NP (Baker 2007; Figure 75). Ten of the latter contain streams with one or more perennial reaches that support corridors of riparian vegetation: Strawberry Creek, Mill Creek, Lehman Creek, Baker Creek, Snake Creek, South Fork Big Wash, Williams Creek, Pine and Ridge Creeks, and Shingle Creek. Headwater elevations for perennial flow range from a low of 7,598 feet (2,316 m) for South Fork Big Wash to a high of 10,213 feet (3,113 m) for Baker Creek (Baker 2007). Intermittent stream reaches in other watersheds also support riparian plant communities, including Can Young Canyon and Arch Canyon at the head of the South Fork of Lexington Creek (Greene and Mann 1997).

The montane riparian plant communities of the park consist of two broad types: the Rocky Mountain Subalpine-Montane Riparian Woodland and Shrubland/Stream; and the Great Basin Lower Montane-Foothill Riparian Woodland and Shrubland/Stream system types (Comer et al. 2013, Unnasch et al. 2014). As is typical throughout the Great Basin, riparian communities occupy a very small fraction of the area of the park (Figure 84) but contribute greatly to its biological diversity. Cold-air drainage, topographic shading, the presence of running water, and high water tables support distinctive assemblages of plants that tolerate or require moist soils and cooler, more humid microenvironments. Evapotranspiration and shading by the riparian vegetation itself helps maintain these microenvironments. Disturbances caused by irregular pulses of runoff that reshape alluvial soils contribute to the diversity of riparian plant communities.

The montane riparian plant communities of the park are dominated by a limited set of tree and shrub species, as shown in Table 55. The order of dominance varies among the watersheds (Smith et al. 1995, Beever and Pyke 2004, Beever et al. 2005). Table 55 also lists other species that may occur (Beever and Pyke 2004; (http://www.nps.gov/grba/naturescience/plants.htm). Several of the dominant and "other" riparian species may also occur outside of riparian areas.

These distinctive assemblages of plants in turn attract distinct assemblages of ungulates, beaver, bats, birds, amphibians, and insects that shelter, feed, or breed in riparian communities; or use riparian zones as corridors for movement (Beever and Pyke 2004, Beever et al. 2005, Baker 2007). Up to 75% of all montane wildlife species in the Great Basin use riparian areas during some or all of their lives (Beever et al. 2005).

Table 55. Riparian tree and shrub species of Great Basin NP, in order by relative dominance, after Smith et al. 1995, Beever and Pyke 2004, and Beever et al. 2005.

Species Dominance Category	Species (scientific name, common name)
Dominant Tree Species	*Populus tremuloides*, Quaking aspen
	Abies concolor, White fir
	Picea engelmannii, Engelmann spruce
Other Tree Species	*Populus angustifolia*, Narrowleaf cottonwood
	Pinus flexilis, Limber pine
	Pseudotsuga menziesii, Douglas fir
	Acer glabrum, Rocky Mountain maple
	Juniperus scopulorum, Rocky Mountain juniper
Dominant Shrub Species	*Rosa woodsii*, Woods' rose
	Symphoricarpos oreophilus, Mountain snowberry
	Betula occidentalis, Water birch
	Salix spp., willow (six species in Park)
	Amelanchier alnifolia, Western serviceberry
	Mahonia repens, Creeping barberry
	Cornus sericea, Red osier dogwood
Other Shrub Species	*Prunus virginiana*, Western chokecherry
	Sambucus cerulea, Blue elderberry
	Rhus trilobata, Desert sumac

Montane riparian plant communities also strongly influence aquatic ecological conditions along the streams they border. Vegetative litter and dissolved organic materials produced by decomposing riparian plant matter provide nutrients crucial to the stream food web; larger woody debris and overhanging vegetation contribute to the diversity of stream habitats available for invertebrates and fish; and evapotranspiration and shading by the riparian vegetation help maintain cooler stream water temperatures. The viability of native fish populations in the park thus depends in part on the condition of the riparian plant communities in the park.

Riparian corridors in the park receive intensive use by people. Wheeler Peak, Lehman Caves, and the many other caves in the area have long attracted visitors; and the land has a history of mining, timber harvesting, water diversion, and cattle grazing until 1999 and sheep grazing through 2008. The riparian areas in the park attract numerous recreational activities, including hiking, camping, fishing, hunting, and bird watching. All the designated camping and picnic areas within the park boundaries lie in or alongside riparian areas; and most of the designated hiking trails follow riparian corridors for at least some of their distance, as do portions of most roads and vehicle trails. Roads and trails not only channel visitor traffic but displace habitat and concentrate erosion. The intensity of visitation and density of roads and trails also may make riparian corridors particularly vulnerable to introductions of non-native plant species. Further, riparian plant communities in the park may suffer long-term consequences from the historic impacts of mining, timber harvesting, water diversions, and livestock grazing. And riparian plant communities are vulnerable to indirect impacts from changes to their surrounding watersheds. Changes in watershed plant cover – including changes that result from fire management – can affect rates of water infiltration and runoff, affecting the stream hydrology and sediment inputs (Smith et al. 1995, Greene and Mann 1997, Allan 2004, Beever and Pyke 2004, Beever et al. 2005, Baker 2007).

The riparian plant communities of Great Basin NP have been subjects of scientific investigations and management actions since the creation of the park. Smith and others (1994, 1995) collected data on fixed riparian vegetation monitoring plots in 1991-1993 to advance understanding of "the structure and function of riparian ecosystems in the Great Basin" in general. In 2001-2002, Beever and others (Beever and Pyke 2004, Beever et al. 2005) revisited the plots established by Smith and his colleagues to look for evidence of changes in vegetation, and also established 31 new transect sites along Strawberry, Lehman, Baker, and Snake Creeks. They re-established the locational datum points for the previous (Smith et al. 1994, 1995) plots, and installed permanent datum points for the new transects, to enable subsequent revisits. Between these two intensive investigations, Greene and Mann (1997) assessed riparian and wetland conditions along 55 miles (89 km) of stream corridor in the park using the "Proper Functioning Condition" methodology developed by the U.S. Department of the Interior, Bureau of Land Management (Prichard et al. 1998). Baker (2007) then summarized the results of these previous studies and added information from investigations in 2003-2004 on the distribution of springs across the entire Park, including along all stream corridors.

These studies led to a range of management actions to address impacts identified at individual field locations, such as habitat loss, soil erosion and compaction, associated with road encroachment and runoff and with livestock grazing (Baker 2007). Cattle grazing ended in the park in 1999 and sheep grazing in 2008. Identification and removal of invasive plants along riparian corridors began in the mid-1990s and was partially funded through the Southern Nevada Public Land Management Act beginning in 2007 (data on file, Great Basin NP).

Nevada Department of Wildlife (NDOW) and the National Park Service jointly carried out assessments of the condition of riparian vegetation in the park in 2009-2011 along all streams in the South Snake Range included in the Bonneville cutthroat restoration program discussed below (Chris Crookshanks, NDOW, personal communication, April 2014; Jon Reynolds, National Park Service, personal communication, April 2014; data on file, Great Basin NP). These investigations addressed the following streams: Mill Creek, Pine and Ridge Creek, Snake Creek, Baker Creek (South Fork), South Fork Big Wash, and Strawberry Creek. The results of these most recent assessments are presented below. Finally, TNC addressed wildfire regime condition in montane riparian woodlands as part of its larger study of wildfire regime condition across the entire Park, 2010-2011, as discussed in Section 4.2.1, above.

Data and Methods

Indicators / Measures

- ***Watershed Landscape Condition***
- ***Riparian Corridor Landscape Condition***
- ***Riparian Reach Condition***
- ***Fire Regime Departure***

The scoping study identified two critical management questions concerning the montane riparian woodlands of the park: What is the current ecological integrity of the montane riparian woodlands; and could groundwater development affect these communities? The investigative team subsequently determined that the second question applies more properly to the “Water Quantity/Quality” resource, discussed earlier in this chapter. The question concerning the current condition of montane riparian woodlands applies to the South Snake Range assessment area.

The assessment characterized the distribution of montane riparian woodlands in the South Snake Range based on the distribution of several riparian vegetation communities, which the Central Basin and Range Rapid Ecoregional Assessment assigned to two broad ecological system types: the Rocky Mountain Subalpine-Montane Riparian Woodland and Shrubland/Stream system; and the Great Basin Lower Montane-Foothill Riparian Woodland and Shrubland/Stream system (Comer et al. 2013). Unnasch et al. (2014) also characterized the distribution of the Lower Montane-Foothill ecological system specifically for the South Snake Range. These two ecological system types share many characteristics in common. The subalpine-montane system differs from the lower montane-foothill system primarily in the smaller size and greater hydrologic variability of the stream; the smaller extent of its alluvial soils; and a higher proportion of plant and animal species that better tolerate colder weather/water conditions (Comer et al. 2013). The Central Basin and Range Rapid Ecoregional Assessment mapped the distribution of these two system types based on their shared floral characteristics (assessed from satellite data), and used an elevation criterion elevation to distinguish the two types (Comer et al. 2013). The Central Basin and Range Rapid Ecoregional Assessment specifically used a distinguishing elevation criterion of 8,200 feet (2,500 m), which falls roughly in the middle of the range of elevations within which ground-truthed examples of the two types overlap. The present assessment uses the distribution data assembled by the Rapid Ecoregional Assessment (Figure 84).

Table 56 identifies the indicators used to assess the condition of montane riparian woodlands in the park, based on the key ecological attributes identified in the conceptual model for the stream-riparian sub-system (see *Stream-Riparian Sub-System Model* secton above). Table 56 identifies and defines the indicators selected, and the key ecological attribute to which each pertains.

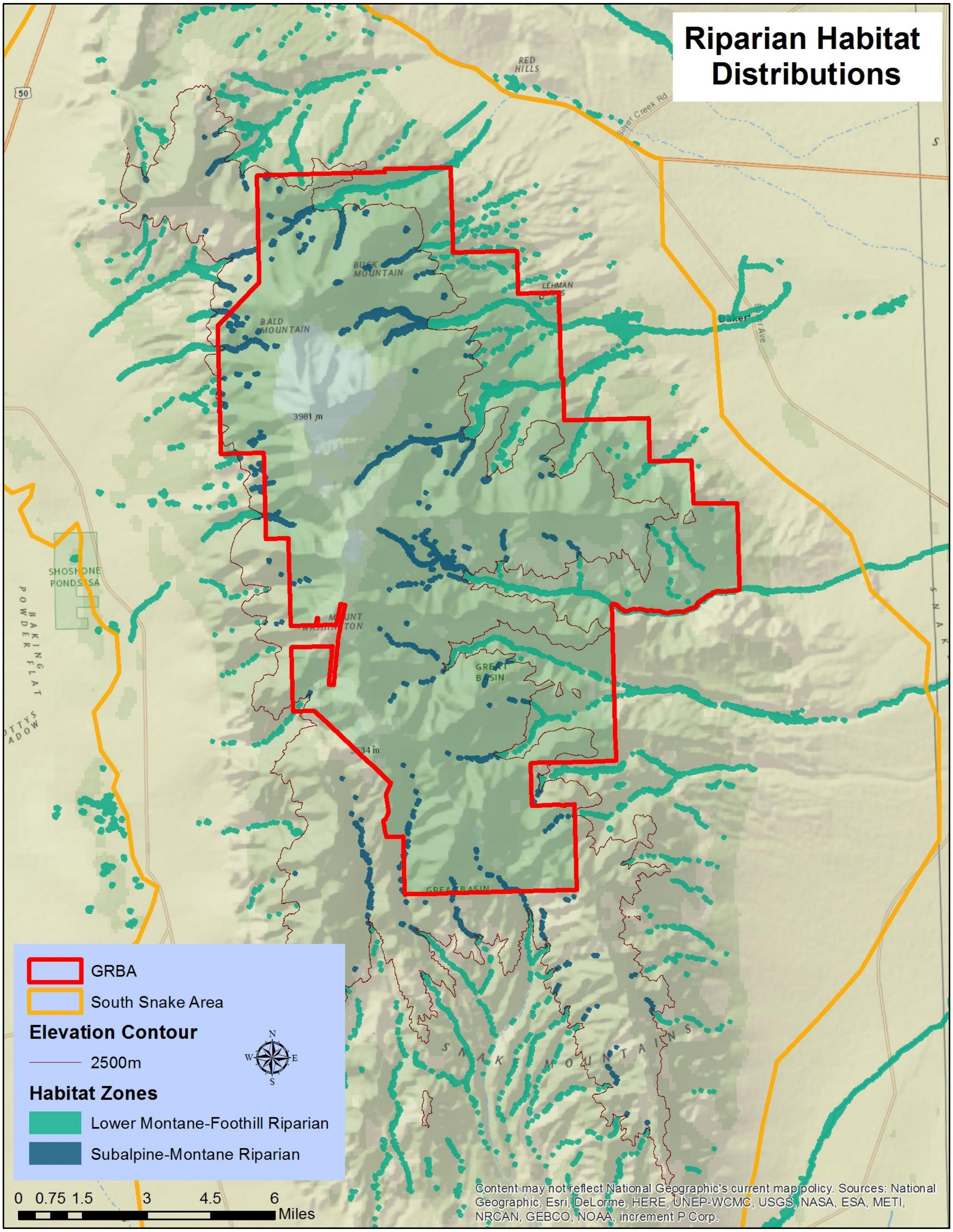


Figure 84. Distribution of the montane riparian woodland resource in and around Great Basin NP.

The assessment team explored the availability of other data, with which to assess the condition of other stream-riparian sub-system key ecological attributes or provide complementary evidence for the condition of the key ecological attributes shown in Table 56. As discussed above (Background and Importance), Beever and others (Beever and Pyke 2004; Beever et al. 2005) in 2001-2002 repeated and expanded on work carried out in 1991-1993 by Smith and others (Smith et al. 1994, Smith et al. 1995) to collect quantitative data on riparian vegetation, morphology, and soils along Strawberry, Lehman, Baker, and Snake creeks. Unfortunately, although designed for periodic repetition, the field investigations by Beever and others in 2001-2002 have not been repeated; and no subsequent studies have used comparable methods. Consequently, the bearing of their findings on current conditions in Great Basin NP is not known, especially in light of changes such as the cessation of sheep grazing (2008) since 2001-2002. Nevertheless, the changes observed between riparian conditions in 1991-1993 and to those observed in 2001-2002 (Beever and Pyke 2004; Beever et al. 2005) provide important background quantitative information to understand the results of the four more indirect and/or qualitative indicators that the present assessment could implement.

The Watershed Landscape Condition and Riparian Corridor Landscape Condition indicators applied to montane riparian condition in Great Basin NP use the Landscape Condition Index (LCI) methodology, described above (Section 4.3.2.2.1) and in Comer and Hak 2012, Comer et al. 2013). The LCI methodology estimates the likely cumulative impact to ecological condition across a landscape resulting from human modifications to that landscape. Section 4.3.2.2.1, above, provides further information on the origins, organization, data sources, and application of the methodology to the watersheds and riparian corridors of the park.

The third indicator applied to montane riparian condition in Great Basin NP, Riparian Reach Condition, derives from the data collected by field teams from the Nevada Department of Wildlife (NDOW) and the National Park Service in 2009-2011 along all streams in the South Snake Range included in the Bonneville cutthroat restoration program (Chris Crookshanks, NDOW, personal communication, April 2014; Jon Reynolds, National Park Service, personal communication, April 2014; data on file, Great Basin NP). The field methodology consisted of a type of rapid visual assessment, the General Aquatic Wildlife Survey (GAWS) (Overton et al. 1997). The version used in Great Basin NP was adapted from the original methodology by NDOW (Chris Crookshanks, NDOW, personal communication, April 2014; field manuals on file, NDOW, Ely, NV). The NDOW field team trained the park Service team in its field methods, to ensure consistency (Jon Reynolds, National Park Service, personal communication, April 2014). Riparian Reach Condition is a summary variable calculated from data recorded under the GAWS methodology.

Table 56. Indicators used for resource assessment of montane riparian woodland condition in the South Snake Range.

Indicator	Indicator Definition	Key Ecological Attributes
Watershed Landscape Condition	Landscape Condition Model assessed at scale of watersheds, indicating extent of human modifications to landscape that affect critical watershed processes.	Floodplain Soils, Stream Flow Quantity & Quality, Channel Morphology
Riparian Corridor Landscape Condition	Landscape Condition Model assessed at scale of a 200 m buffer along the stream axis within watersheds, indicating extent of direct human modifications to the riparian corridor.	Floodplain Flora, Floodplain Soils
Riparian Reach Condition	Field observation of riparian vegetation condition at individual stream reaches, collected as part of the 2009-2011 General Aquatic Wildlife Survey of streams included in the Bonneville cutthroat trout restoration program. These observations can be compared in some respects to the findings of Greene and Mann (1997) concerning riparian and wetland conditions along 55 miles (89 km) of stream corridor in the park assessed using the "Proper Functioning Condition" methodology.	Floodplain Flora
Fire Regime Departure	Index of departure of fire regime from expected natural range of variation (see Section 4.2.1), measured specifically for montane riparian woodlands.	

Riparian Reach Condition evaluates the degree to which the vegetation along individual stream reaches matches expected conditions. Field investigators first determine what seral stage dominates at a site, and then evaluate some or all of nine variables depending on which seral stage dominates: (1) dominance of trees; (2) damage to tree over-story; (3) shrub composition; (4) density of shrubs (crown closure); (5) damage to shrub mid-story; (6) understory composition; (7) ground cover; (8) damage to understory plants; and (9) damage to soil. The investigators score each variable on a scale of 0-4; Table 57 lists the nine variables and their scoring criteria. The "Riparian Score" for an individual reach is the sum of the scores for all rated variables. Because the number of variables rated varies by seral stage, the maximum possible Riparian Score also varies by seral stage.

Table 58 lists the seral stage types recognized, and the variables evaluated and the maximum possible Riparian Score for each seral stage. The indicator, Riparian Reach Condition, consists of the Riparian Score for each individual reach *divided by the maximum possible Riparian Score for the dominant seral stage for that survey location*. It therefore indicates the fraction (calculated as percentage) of the maximum possible score achieved at each survey location.

The fourth indicator applied to montane riparian condition in Great Basin NP, Fire Regime Departure, as an index of departure of fire regime from expected natural range of measured specifically for montane riparian woodlands. Section 4.2.1.2, above, discusses the data and methodology of the Fire Regime Departure index, which was used by TNC to assess the condition of the wildfire regime across 24 biophysical settings in the park, including montane riparian woodlands.

Table 57. Field variables and scoring criteria for Riparian Reach Condition (field manuals on file, NDOW, Ely, NV).

Score	4	3	2	1	0
Dominance of trees	All size classes except in cottonwood; stand regeneration may be lacking; 75% of species present; regeneration vigorous; trees in clusters or continuous with ≥ 50% canopy; no exotics	3 to 4 size classes present; 50% of species present; trees usually in clusters with 40-49% canopy; exotics infrequent	2 to 3 size classes present; seedlings and sprouts show use & some lateral branching; occasional exotics, monocultures common; canopy 25-39%	Seldom more than one size class present; usually decadent tree cover scattered, 10-24%; few seedling or sprouts, and these are heavily browsed or damaged; exotics common	Trees absent or only rare, remnant decadent native trees; seedlings and sprouts severely hedged, damaged, or lacking; exotics may dominate
Damage to tree over-story	Light to no browsing of seedlings and saplings; growth linear in seedlings and saplings	Moderate browsing of seedlings and saplings; growth branching in seedlings and saplings	Heavy browsing of seedlings and saplings; growth clubbed; some small trees damaged by breaking, cutting, or trampling	Most seedlings and saplings destroyed by extensive browsing, trampling, debarking or cutting; some pole sized trees also damaged	All size classes severely damaged or removed
Shrub composition	Decreasers dominant; few increasers present	Decreasers dominant; increasers encroaching	Decreasers and increasers in approx. equal abundance	Increasers dominant; decreasers diminishing	Increasers dominant; few decreasers present
Crown closure	>90%	70-90%	50-70%	30-50%	<30%
Damage to shrub mid-story	Light to no browsing; linear growth	Moderate browsing with some lateral branching	Heavy browsing; growth clubbed; some shrubs damaged by breaking, cutting, or trampling	Growth and regeneration stymied by grazing; most shrubs damaged by breaking, cutting, or trampling	No regeneration; most shrubs dead or removed
Under-story composition	Decreasers dominant; few increasers or invaders present	Decreasers dominant; increasers encroaching	Decreasers slightly more abundant than increasers; invaders present	Increasers dominant; decreasers and invaders about equal in abundance	Increasers or invaders dominant; few decreasers present
Ground cover	>90%	80-90%	70-80%	60-70%	<60%
Damage to understory plants	Plants vigorous with large seed heads; light grazing or trampling	Seed heads common; trampling minimal or light to moderate	Vigor down; some seed heads; trampling evident; grazing moderate	Vigor down; few seed heads; most plants grazed or trampled	Few plants present and all are damaged
Damage to soil	No compaction or erosion present	Some compaction; no erosion present	Some compaction with sheet erosion occurring in isolated patches	Compaction severe; rill erosion occurring	Compaction severe; gully and rill erosion occurring

Table 58. Field variables evaluated for each riparian seral stage or potential natural condition (PNC) step, and maximum possible score (after NDOW).

Seral Stage or PNC Step	Variables Rated	Max Possible Score
Tree PNC	1-9	36
Early to Late Tree Seral Stages	3-9	28
Shrub PNC	3-9	28
Early to Late Shrub Seral Stages	6-9	16
Grass/Forb PNC	6-9	16
Early to Late Grass/Forb Seral Stages	7-9	12

Reference Conditions

Table 59 summarizes the overall assessment framework for the four indicators used to evaluate montane riparian woodland condition. The rationale for this framework is as follows:

A LCI value of 100 for an individual pixel indicates an absence of land modification in and around that pixel, as discussed above, Section 4.3.2.2.1. The present assessment for montane riparian woodland recognizes a LCI value > 70 as indicating "Good" condition; a LCI value > 50 but ≤ 70 as indicating "Moderate Concern;" and a LCI value ≤ 50 as indicating "Significant Concern." This categorization reflects LCI site impact scores determined for the western U.S. in general and for the Central Basin and Range Rapid Ecoregional Assessment in particular (Comer and Hak, in prep., Comer et al. 2013): A site impact score of 70 for dirt roads and other four-wheel-drive vehicle trails; and site impact scores of 50 for local and connecting roads, medium density development, and power transmission lines. The present assessment thus assumes that, even in the absence of any other immediate and surrounding impacts, the presence of a dirt road or other four-wheel-drive vehicle trail within a montane riparian woodland pixel is sufficient to classify the pixel as falling into the "Moderate Concern" rating category for that resource. A dirt road or other four-wheel-drive vehicle trail not only displaces vegetation but promotes erosion and provides a corridor for incursions by non-native species. Similarly, the present assessment assumes that, even in the absence of any other immediate and surrounding impacts, the presence of a paved road, medium-density development, or a power line within a montane riparian woodland pixel is sufficient to classify the pixel as falling into the "Significant Concern" rating category for that resource. Without intensive management, these types of land modifications can strongly alter local hydrology, strongly promote erosion, encourage or involve significant human activity on the surrounding land surface, and provide numerous opportunities for incursions of non-native species.

The NDOW and Park Service data files classify the raw Riparian Score values into a four-part scale, Poor, Fair, Good, and Excellent. NDOW rates all riparian occurrences of the seral stage, "Grass/Forb PNC," as "Fair", equivalent to "Moderate Concern" in the National Park Service methodology. That is, the NDOW methodology classifies all riparian sites in which this seral stage dominates as moderately degraded riparian habitat*. Otherwise, the NDOW* four-part rating scale corresponds directly to specific increments of values for Riparian Reach Condition, the percentage of the maximum possible score achieved at each survey location, as follows:

- For Riparian Reach Condition < 50%, the NDOW rating is "Poor," equivalent to "Significant Concern" in the National Park Service methodology.
- For Riparian Reach Condition ≥ 50% but < 66%, the NDOW rating is "Fair," equivalent to a rating of "Moderate Concern" in the National Park Service methodology.
- For Riparian Reach Condition ≥ 66%, the NDOW rating is either "Good" or "Excellent, equivalent to a rating of "Good" in the National Park Service methodology. An NDOW rating of "Excellent" corresponds to a Riparian Reach Condition value > 97%, indicating reference conditions.

Table 59. Indicator score ranges used for assessment of montane riparian woodlands resource in the South Snake Range.

Indicator	Significant Concern	Moderate Concern	Good
Watershed Landscape Condition	Score ≤ 50	Score > 50 but ≤ 70	Score > 70
Riparian Corridor Landscape Condition	Score ≤ 50	Score > 50 but ≤ 70	Score > 70
Riparian Reach Condition	Score < 50%	PNC = Grass/Forb or Score ≥ 50% but < 66%	Score ≥ 66%
Fire Regime Departure	See Section 4.2.1, Table 24 for scoring criteria.		

Section 4.2.1.2, above, discusses the data and methods used by TNC to estimate references conditions for the wildfire regime across 24 biophysical settings in the park, including montane riparian woodlands. Specifically, Table 24 presents the expected distribution of vegetation condition class by biophysical setting, including montane riparian woodlands.

<u>Condition and Trend</u>

Figure 85 shows the distribution of Watershed Landscape Condition LCI scores by watershed within and immediately around the park, with all watersheds divided into higher- and lower-elevation portions at the 8,200-foot (2,500 m) contour line. All watershed portions above the 8,200-foot (2,500 m) contour line fall within the "Good" range for watershed condition; as do all but one watershed portion below the 8,200-foot (2,500 m) contour line. However, the lower-elevation portion of the Lehman Creek watershed falls within the "Moderate Concern" range for watershed condition. This watershed portion contains sections of the Wheeler Peak Scenic Drive; the Upper and Lower Lehman Creek camping areas; Lehman Caves, the Lehman Caves Visitor Center, and adjacent picnic and RV camping areas; and State Route 488 between the Visitor Center and Baker, NV. It is unquestionably the most heavily developed watershed portion in the park. The

LCI value for this watershed portion indicates that land modifications within the catchment have the potential to cause moderate changes to important ecological processes affecting the montane riparian woodlands resource. As noted above, such changes could include alterations to watershed hydrology and erosion, and greater opportunities for incursions of non-native species. Watershed LCI values were not available for previous time periods, against which to compare the recent watershed values for evidence of any trend(s).

Figure 86 and Figure 87 show the distribution of Riparian Corridor Landscape Condition scores by riparian corridor occurrence within and immediately around the park, for the higher- and lower-elevation portions of all watersheds, respectively. LCI values for the riparian corridor were not available for previous time periods, against which to compare the recent values for evidence of any trend(s).

Across the higher-elevation portions of the watersheds (Figure 86), the majority of riparian corridor occurrences fall within the "Good" range for Riparian Corridor Landscape Condition. The exceptions among higher-elevation portions of the watersheds include:

- One small occurrence each in the upper Strawberry and Mill Creek watersheds immediately at the 8,200-foot (2,500 m) contour line, associated with the Osceola self-guiding trail, that fall in the range of "Significant Concern."
- One occurrence each in the upper Strawberry Creek, Mill Creek, and Burnt Mill Canyon watersheds, apparently associated with the Osceola self-guiding trail and, in the Mill Creek watershed, also with a portion of the Wheeler Peak Scenic Drive where it crosses a stream headwater zone. These all fall in the "Moderate Concern" range.
- A cluster of occurrences near the headwaters of Lehman Creek associated with the terminus of the Wheeler Peak Scenic Drive and the Wheeler Peak camping area, that fall in the "Moderate Concern" range, surrounding a smaller occurrence in the "Significant Concern" range.
- One occurrence along Timber Creek, a tributary to Baker Creek, apparently associated with a trail intersection within the riparian corridor. This occurrence falls in the "Moderate Concern" range.
- A cluster of occurrences in the upper Snake Creek watershed apparently associated with the Shoshone camping area and a major trail section extending uphill from that location to a major trail intersection within the riparian corridor, mostly falling in the "Moderate Concern" range but with one occurrence in the "Significant Concern" range.
- A pair of occurrences in the Lexington Creek watershed just outside the park boundary, associated with a dirt road, falling in the "Moderate Concern" range.

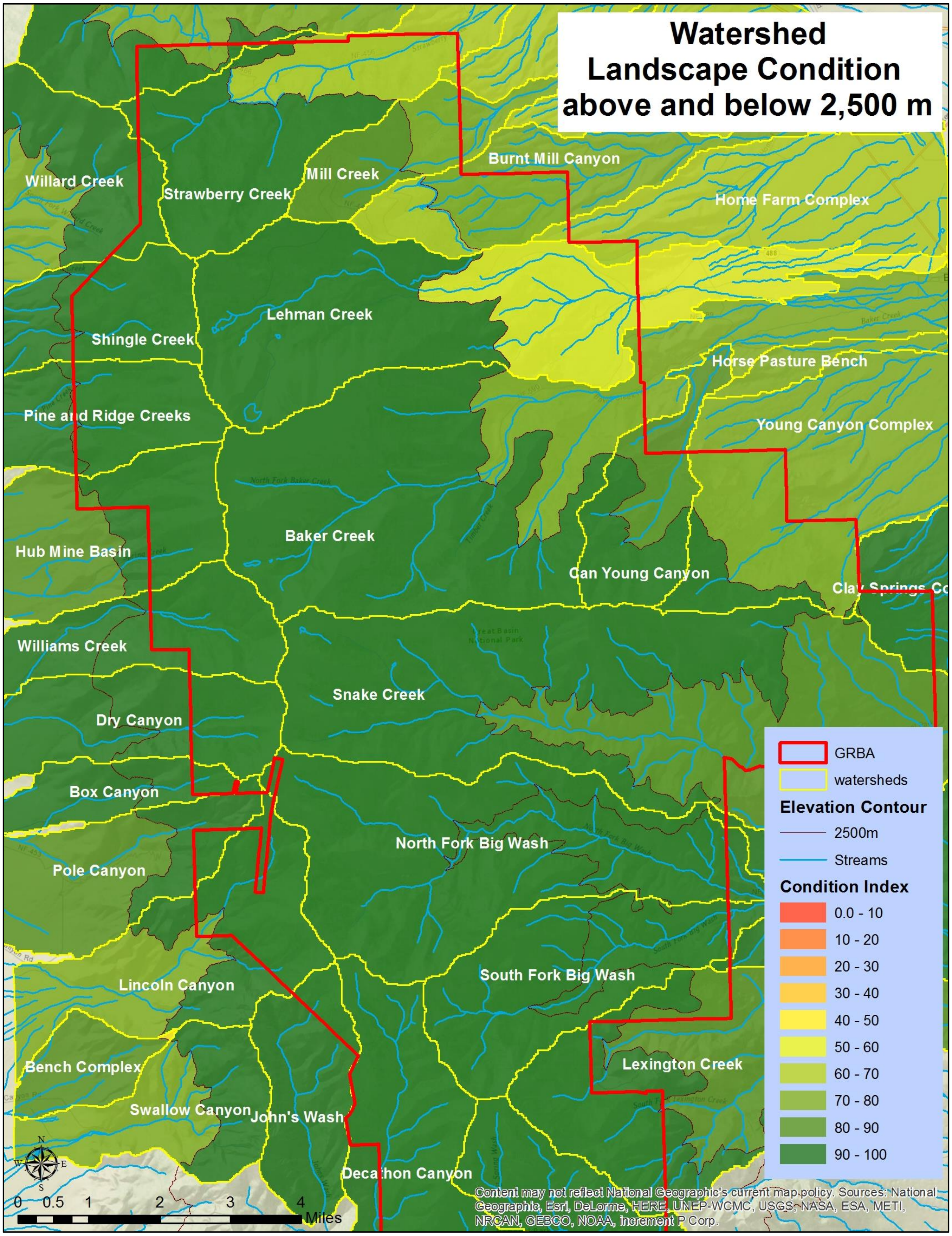


Figure 85. Watershed Landscape Condition scores by watershed in and around Great Basin NP.

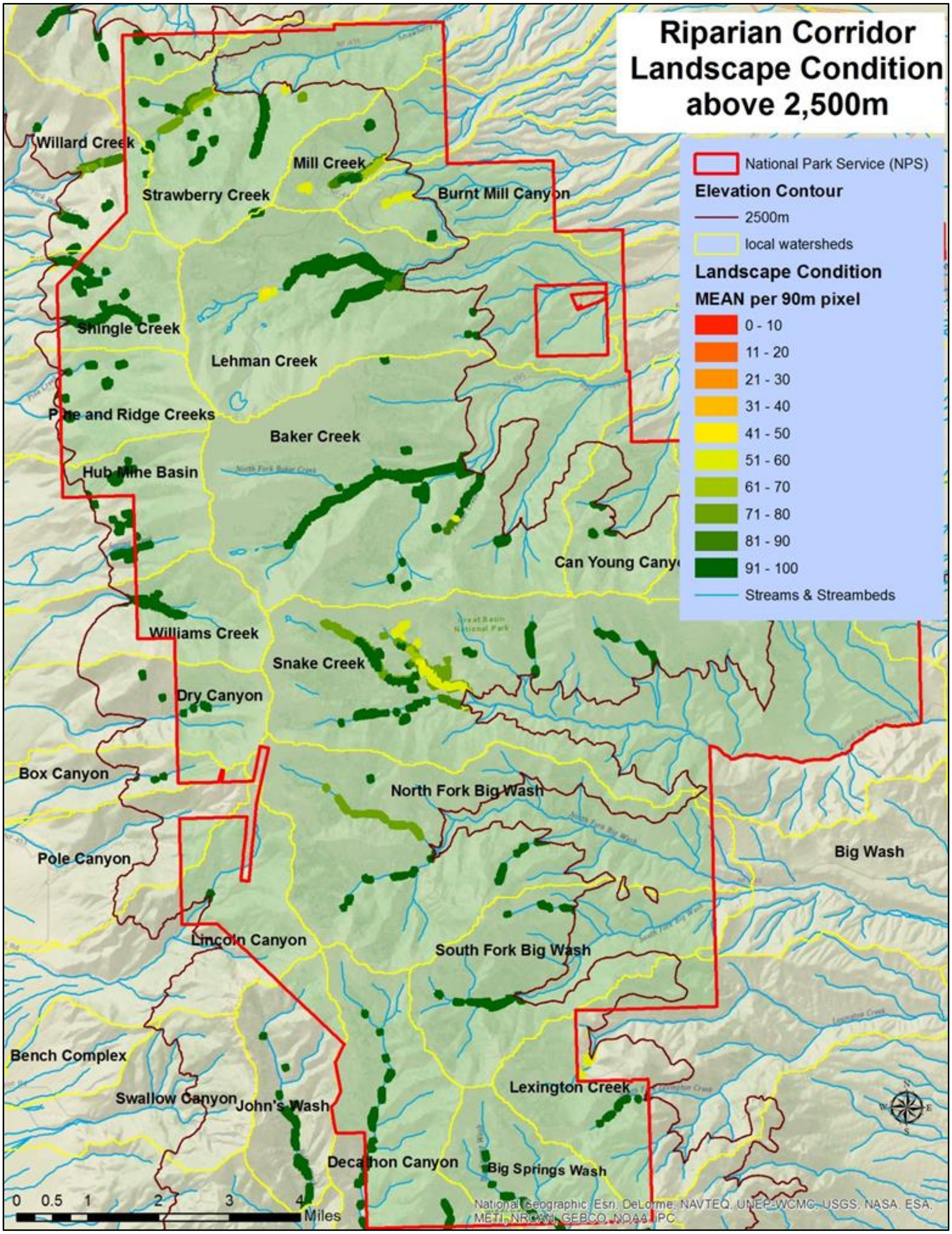


Figure 86. Riparian Corridor Landscape Condition scores by resource occurrence in the higher-elevation portions of watersheds in and around Great Basin NP.

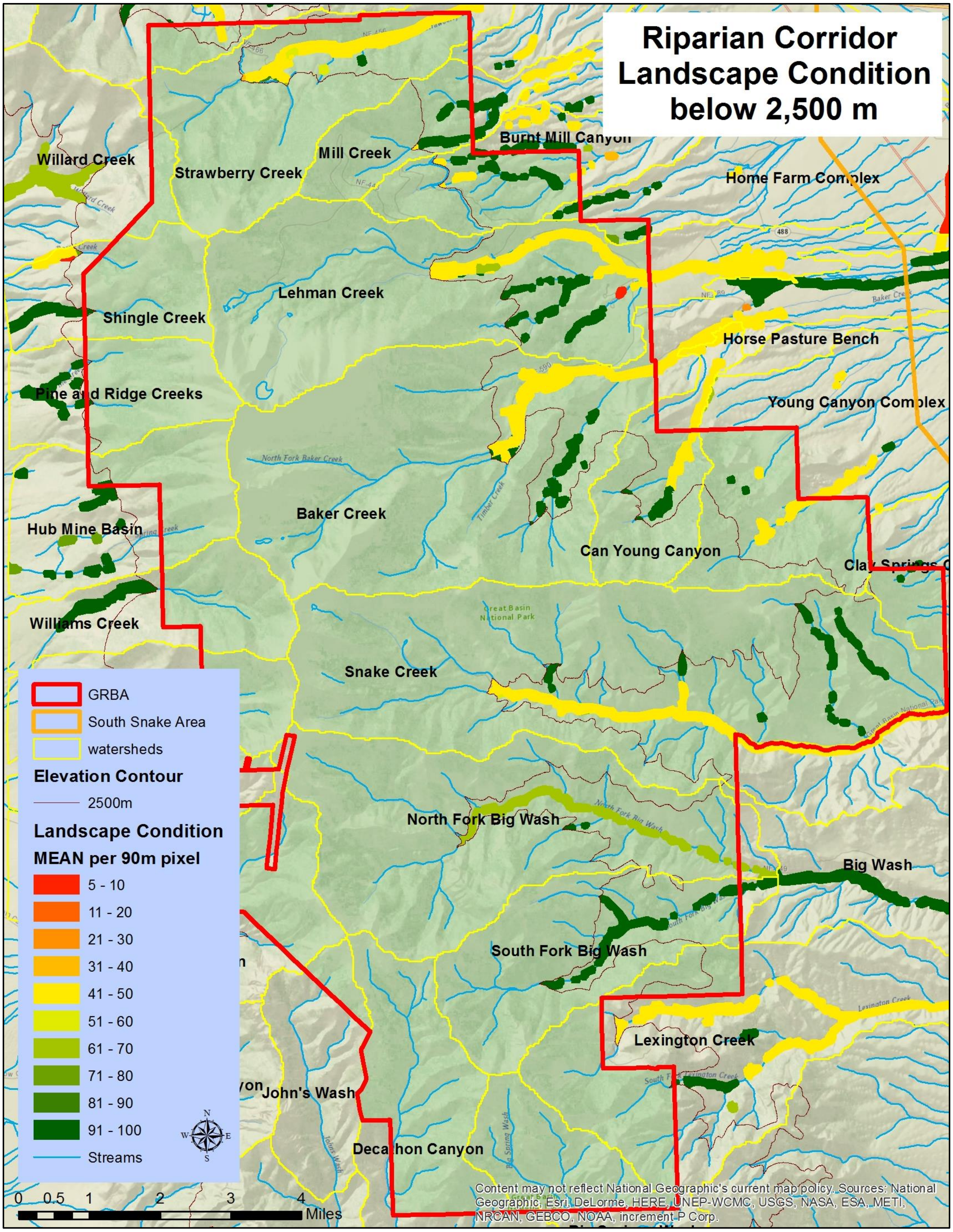


Figure 87. Riparian Corridor Landscape Condition scores by resource occurrence in the lower-elevation portions of watersheds in and around Great Basin NP.

Across the lower-elevation portions of the watersheds (Figure 87, below), a slight majority of riparian corridor occurrences fall within the “Good” range for Riparian Corridor Landscape Condition. However, except for the occurrences along the North and South Forks of Big Wash, these “Good” occurrences are small and scattered. In contrast, numerous occurrences among the lower-elevation portions of the watersheds fall within the ranges of “Moderate” or “Significant Concern.” These latter occurrences include:

- A cluster of occurrences outside the park that fall in the ranges of both the “Moderate” and “Significant Concern” in the southeastern section of the Willard Creek watershed associated with a smaller drainage known as Board Creek, the reasons for which are not immediately apparent.
- A cluster of occurrences in the ranges of both the “Moderate” and “Significant Concern” in the Strawberry Creek watershed inside the park near the 8,200-foot (2,500 m) contour line, associated with the Osceola self-guiding trail and the intersection of National Forest Roads 456 and 466.
- A small cluster of occurrences in the range of “Significant Concern” in the headwaters of the “No Name” drainage complex between the Mill Creek and Burnt Mill Canyon watersheds, of unknown causes.
- A small cluster of occurrences in the range of “Significant Concern” in the Burnt Mill Canyon watershed near the park boundary, of unknown causes.
- A nearly continuous occurrence along the entire length of Lehman Creek inside the park, extending much of the distance downhill toward Baker, NV, along the channelized section of Lehman Creek outside the park boundary, all assessed as falling in the range of “Significant Concern. These impacts are associated with portions of the Wheeler Peak Scenic Drive; the Upper and Lower Lehman Creek camping areas; Lehman Caves, the Lehman Caves Visitor Center, and adjacent picnic and RV camping areas; and State Route 488 between the Visitor Center and Baker, NV.
- A single long occurrence along the former channel of Lehman Creek, here included within the Baker Creek watershed, extending most of the way from Baker, NV, uphill toward the park boundary, falling in the range of “Moderate Concern,” associated with several dirt roads.
- A nearly continuous occurrence along the entire length of Baker Creek inside the park, extending down to and below the confluence of the Can Young Canyon watershed with the Baker Creek watershed, all falling in the range of “Significant Concern,” associated with roads and trails adjacent to the creek, two campgrounds, and a picnic area.
- A small occurrence outside the park, between present-day Baker Creek and the former channel of Lehman Creek, where a dirt road crosses the riparian corridor, falling deeply into the range or “Significant Concern.”
- One small occurrence falling in the range of “Significant Concern” and several larger clusters falling in the range of “Moderate Concern” in the upper elevations of the Young Canyon Complex, associated with dirt roads crossing and running alongside the riparian corridor.

- A small occurrence along Snake Creek near the 8,200-foot (2,500 m) contour line that falls in the range of "Significant Concern" and a long, continuous occurrence extending downhill along Snake Creek from that location both within and far eastward from the park, falling in the range of "Moderate Concern," associated with National Forest Road 448, several National Park camping areas, and the Snake Creek pipeline.
- Occurrences all along mainstem and North and South Forks of Lexington Creek outside the park boundary, mostly within the range of "Moderate Concern" with one small occurrence in the range of "Significant Concern," all associated with Lexington Creek Road and the dirt road that extends from the larger road to the head of the trail to Lexington Arch.

Table 60 summarizes the Riparian Corridor Landscape Condition LCI results in the form of the average of the LCI scores for all riparian corridor occurrences in each watershed weighted according to the area of each occurrence. The weighting is necessary because the occurrences within each watershed vary widely in area.

Table 60. Area-weighted average Riparian Corridor Landscape Condition LCI score by watershed (listed in alphabetical order). Colors indicate condition ratings.

Watershed Name	<8200 ft (2500 m)	>8200 ft (2500 m)
Baker Creek	68.47[b]	96.40[c]
Baker Springs Complex	42.63[a]	
Bench Complex	69.00[b]	
Big Springs Wash	73.38[c]	98.51[c]
Big Wash	97.05[c]	
Box Canyon	100.00[c]	100.00[c]
Burnt Mill Canyon	77.76[c]	66.28[b]
Can Young Canyon	71.81[c]	100.00[c]
Clay Springs Complex	99.81[c]	
Decathon Canyon	81.23[c]	99.97[c]
Dry Canyon	100.00[c]	100.00[c]
Home Farm Complex	67.82[b]	
Horse Pasture Bench	63.00[b]	
Hub Mine Basin	95.66[c]	100.00[c]
John's Wash	100.00[c]	100.00[c]
Lehman Creek	66.70[b]	95.18[c]
Lexington Creek	57.68[b]	85.96[c]

[a]Samples rated as being of Signficant Concern (red).

[b]Samples rated as being of Moderate Concern (yellow).

[c]Samples rated as being Good (green).

Table 60 (continued). Area-weighted average Riparian Corridor Landscape Condition LCI score by watershed (listed in alphabetical order). Colors indicate condition ratings.

Watershed Name	<8200 ft (2500 m)	>8200 ft (2500 m)
Lincoln Canyon	62.51[b]	
Mill Creek	70.17[c]	78.02[c]
No Name Complex	65.56[b]	
North Fork Big Wash	78.88[c]	100.00[c]
Pine and Ridge Creeks	99.37[c]	100.00[c]
Pole Canyon	71.24[c]	
Williams Creek	94.78[c]	99.77[c]
Young Canyon Complex	57.47[b]	
Grand Average	73.62[c]	94.90[c]
Shingle Creek	91.46[c]	99.18[c]
Snake Creek	66.83[b]	91.47[c]
South Fork Big Wash	99.86[c]	100.00[c]
Strawberry Creek	62.63[b]	89.07[c]
Swallow Canyon	62.79[b]	
Weaver Creek	78.10[c]	100.00[c]
Willard Creek	79.46[c]	89.78[c]

[a]Samples rated as being of Signficant Concern (red).

[b]Samples rated as being of Moderate Concern (yellow).

[c]Samples rated as being Good (green).

The summary results in Table 60 identify 12 lower-elevation (below 8,200 feet (2,500 m)) watersheds, in which the area-weighted average Riparian Corridor Landscape Condition LCI results indicate a condition of "Moderate Concern," and one watershed with an area-weighted average in the range of "Significant Concern." Many of these thirteen lower-elevation watersheds of concern include only small areas within the park; but the thirteen also includes the lower-elevation portions of the Baker, Lehman, Lexington, Snake, and Strawberry Creek watersheds with substantial areas inside the park. However, the area-weighted average Riparian Corridor Landscape Condition LCI score for all lower-elevation watersheds still falls (marginally) within the range of conditions here classified as "Good." The summary results in Table 60 also identify only one higher-elevation (above 8,200 feet (2,500 m)) watershed, in which the area-weighted average Riparian Corridor Landscape Condition LCI results indicate a condition of "Moderate Concern": the Burnt Mill Canyon watershed. All other higher-elevation watersheds have average Riparian Corridor Landscape Condition LCI values in the "Good" range.

Figure 88 shows the Riparian Reach Condition ratings for all locations at which field crews assessed riparian condition during the 2009-2011 GAWS surveys. For comparison, the GAWS results are shown superimposed on the Riparian Corridor Landscape Condition results. The results are as follows:

- No survey location within the park or the South Snake Range assessment area received a rating of "Significant Concern."
- Three survey locations received ratings of "Moderate Concern": one on Strawberry Creek just outside the park boundary; one on Ridge Creek just outside the park boundary; and one at the upper end of the South Fork of Baker Creek, inside the park.
- 50 survey locations received a rating of "Good" across the six watersheds surveyed, but four of these lack locational data and so cannot be mapped.
- Two survey locations lack data on riparian condition.

The survey location for Riparian Reach Condition that received a rating of "Moderate Concern" on the South Fork of Baker Creek falls in the middle of a meadow, which the survey protocol automatically classifies as an area of disturbance (see above). If the meadow is a natural feature, however, this classification may be incorrect. The survey location on Strawberry Creek lies adjacent to a road crossing (National Forest Road 456), along a stream reach that extends between a diversion structure and the park boundary. The field crew recorded disturbed vegetation with invasive species, reduced ground cover, and evidence of soil compaction. And the survey location on Ridge Creek lies in an area dominated by grasses and forbs just upstream from the end of a dirt road.

The three locations for Riparian Reach Condition that received a rating of "Moderate Concern" do not lie along stream reaches with Riparian Corridor Landscape Condition scores that received ratings of "Moderate Concern" or worse. Conversely, all of the locations assessed for Riparian Reach Condition along Snake Creek fall within the range of "Good" conditions, but lie along stream reaches with Riparian Corridor Landscape Condition scores of "Moderate Concern." Riparian Corridor Landscape Condition scores thus do not strongly predict Riparian Reach Condition scores or vice versa. Their lack of correlation may simply reflect the difference in spatial scale between the two variables. However, this lack may also reflect the positive impacts of management efforts to minimize potential harm to riparian areas from roads, trails, and camping within the park, particularly along the streams included in the Bonneville cutthroat trout restoration program (on which the GAWS surveys focused).

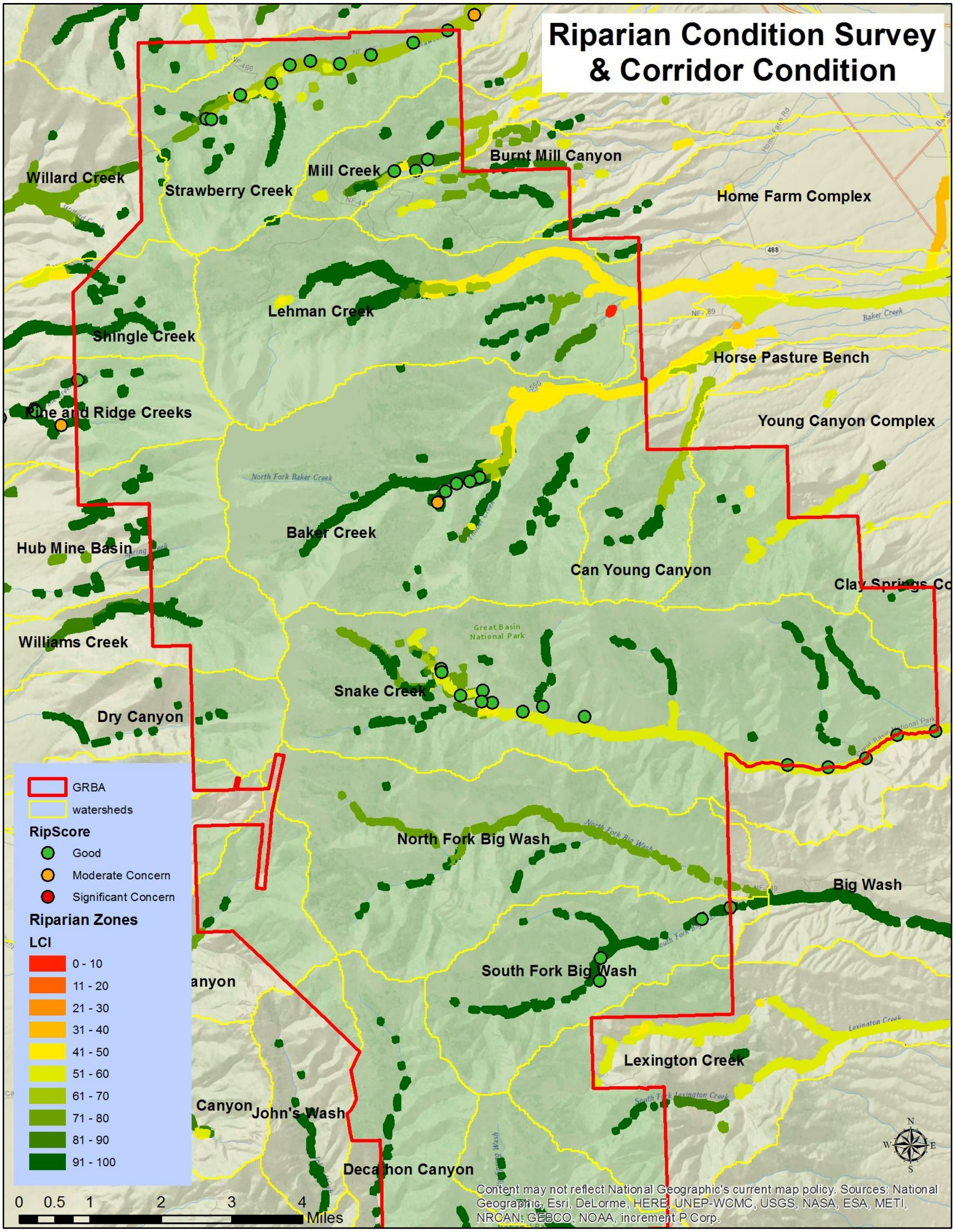


Figure 88. Riparian Reach Condition ratings by 2009-2011 GAWS survey location in and around Great Basin NP, overlaid on Riparian Corridor Landscape Condition scores by resource occurrence.

The results of the Riparian Reach Condition analysis can be compared to the results of the Riparian and Wetland Functional Assessment carried out in 1997 (Greene and Mann 1997), discussed above. This study evaluated 71 riparian areas across 55 valley miles (89 km) within the park. The assessment identified no riparian areas with "Non-Functional" conditions; four with "Functional-At Risk" conditions; and 67 with "Functional" conditions. Table 61 summarizes the results from 1997. The four locations rated "At Risk" were all associated with dirt roads and areas of heavy foot traffic (campgrounds and trails through the riparian area), including along the Osceola self-guiding trail. The survey team also noted trampling by livestock at several sites. No site rated "At Risk" in the 1997 survey received a rating of "Moderate Concern" in the 2009-2011 GAWS surveys. However, the location that received a rating of "Moderate Concern" on Strawberry Creek outside the park boundary in the GAWS survey lies only a short distance downstream from the two sites rated "At Risk" in 1997, both of which lie alongside the same access road (National Forest Road 456).

Table 61. Summary of results from 1997 riparian assessment by watershed (Greene and Mann 1997).

Watershed Name	No. of Locations "At-Risk"	No. of Locations "Functional	Total No. of Locations
Strawberry	2	6	8
Baker	1	22	23
Lehman	0	9	9
Arch Canyon [a]	0	2	2
Lexington	0	1	1
Mill	0	3	3
Snake	1	18	19
Can Young Canyon	0	2	2
South Fork Big Wash	0	2	2
Pine	0	1	1
Shingle	0	1	1

[a] Arch Canyon is a tributary to the South Fork of Lexington Creek)

The assessments of riparian conditions in 1997 versus 2009-2011 thus present a similar picture of conditions in the park, with a majority of survey locations exhibiting "Good" conditions, only a handful exhibiting moderately degraded conditions, and none exhibiting severely degraded conditions. Greene and Mann (1997) also identified the same types of factors at work in 1997 as are suggested by the data from 2009-2011 (summarized above): road encroachment, road erosion, foot traffic, camping, and the impacts of the 3-mile-long (4.8-km-long) water diversion along Snake Creek. They also identified possible impacts from cattle, which were removed from the park in 1999.

As noted earlier, too, Beever and others in 2001-2002 (Beever and Pyke 2004, Beever et al. 2005) resurveyed the riparian vegetation study sites surveyed by Smith and others in 1991-1993 (Smith et al. 1994, 1995), and surveyed numerous riparian transects. The resurvey identified a complex mixture of changes in cover percent and vegetation structure and composition since the original survey, but could not identify any single reason for these changes. The end of cattle grazing two years prior to the resurvey may have permitted an increase in shrubs that Beever et al. (2005) observed in comparing their data to those of Smith and others in 1991-1993. However, natural succession, variation in weather, and channel incision also may have contributed to the complex mix of changes and stasis represented in the differences and similarities between the two survey periods. On the other hand, Beever and Pyke (2004) made special note of one type of change between the two study periods as particularly noteworthy: Engelmann spruce, *Picea engelmannii*, showed a consistent increase of 574-656 feet (175-200 m) in its lower-elevation bounds across all four watersheds (Strawberry, Lehman, Baker, and Snake) between 1991-1993 and 2001-2002. They also noted that narrowleaf cottonwood, *Populus angustifolia*, exhibited a similar elevational shift in its lower-elevation bounds between the two study periods, specifically upward shifts of 656 feet (200 m) along Baker Creek and 2,297 feet (700 m) along Lehman Creek. However, they also note that the apparent shift for the latter species "…may have occurred because sampling in 1991-1993 was not continuous along riparian corridors, but only at regularly spaced sites." Beever (Erik Beever, Research Ecologist, Northern Rocky Mountain Science Center, U.S. Geological Survey, personal communication, March 2015) suggests that the most reliably demonstrated shift, for Engelmann spruce could be a consequence of climate change (see Section 4.4.1, below). A resurvey of the plots and transects last surveyed in 2001-2002 could provide important data on such trends for comparison.

Section 4.2.1, above, presents the results obtained by TNC in its assessment of the condition of the wildfire regime across 24 biophysical settings in the park, including montane riparian woodlands. Specifically, Table 25, above, reports the overall fire regime departure scores for the individual biophysical settings; and Table 26, above, compares the present percentages of cover for individual vegetation condition classes to their expected values. These results indicate that montane riparian woodlands in the park exhibit an average 26% fire regime departure, although with only 3% of the area of this biophysical setting classified as at high risk. The TNC study found that coverage in vegetation condition class "C" stood at 66%, versus an expected 43%; coverage in vegetation class "B" stood at 25% versus an expected 36%; and coverage in vegetation class "A" stood at 6% versus an expected 21%. These results indicate a shift toward later-successional vegetation, that is, they indicate a pattern of woody vegetation encroachment. These results are consistent with the findings of an inventory of springs in the park, in 2003-2004, discussed in the Springs resource summary in Section 4.3.6, below. That inventory recorded evidence of woody encroachment at roughly 23% of springs in the park, all in montane riparian woodlands.

<u>Summary of Status</u>
Table 62 summarizes the results for the four indicators used to assess the condition of montane riparian woodlands in the park.

In summary, the results for the four indicators tell a consistent story:

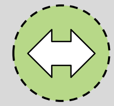
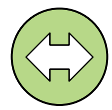
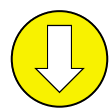
- Modifications to watershed landscape context are minimal above 8,200 feet (2,500 m), but greater below 8,200 feet (2,500 m). The Lehman Creek watershed below 8,200 feet (2,500 m) exhibits the greatest modeled alterations to watershed landscape condition among the lower-elevation watersheds, falling into the “Moderate Concern” range for this indicator.

- Modifications to modeled riparian corridor landscape condition are mostly minimal above 8,200 feet (2,500 m), resulting in “Good” LCI conditions, but with exceptions in areas of high densities of trail, road, or campground activity including the road-trail-campground complex at the top of the Wheeler Peak Scenic Drive in the Lehman Creek watershed.
- Modifications to riparian corridor landscape condition are more substantial below 8,200 feet (2,500 m), including several areas within the park with high densities of road, trail, campground, parking, and visitor activity, particularly in the Lehman, Baker, and Snake Creek watersheds. Lower-elevation watershed portions outside the east side of the park often have conditions of “Moderate Concern” or worse, but lower lower-elevation watershed portions outside the west side of the park mostly have “Good” LCI conditions.
- Riparian reach conditions mostly fall within the “Good” range, but with areas of localized degradation. However, these data cover only six watersheds.
- Fire regime departure conditions fall within the “Moderate Concern” range, as a result of fire suppression and resulting encroachment of later-successional woody vegetation along the montane riparian woodland corridors of the park.

Table 62. Summary of indicators for condition of montane riparian woodlands in Great Basin NP.

Montane Riparian Woodlands			
Indicators of Condition	**Specific Measures**	**Condition Status/Trend**	**Rationale**
Watershed Landscape Condition	LCI assessed at scale of watersheds (addresses both water quality and quantity)		Mostly high LCI scores for watershed condition at all elevations; no evidence to evaluate trend. However, indicator provides only indirect information on condition of resource.
Riparian Corridor Landscape Condition	LCI assessed at scale of a 200 m buffer along stream corridor (addresses both water quality and quantity)		Mostly high LCI scores for riparian corridor condition at higher elevations; mixed for lower elevations; no evidence to evaluate trend. However, indicator provides only indirect information on condition of resource.

Table 62 (continued). Summary of indicators for condition of montane riparian woodlands in Great Basin NP.

Montane Riparian Woodlands			
Indicators of Condition	**Specific Measures**	**Condition Status/Trend**	**Rationale**
Riparian Reach Condition	Index of riparian vegetation seral stage condition at individual stream reaches, GAWS methodology, 2009-2011		Almost all locations scored in the "Good" range, with little change from conditions observed in 1997, although that study used a different methodology. Both studies rely on potentially subjective ratings of field conditions.
Fire Regime Departure	Index of departure of fire regime from expected natural range of variation, measured specifically for montane riparian woodlands (see Section 4.2.1)		Section 4.2.1 indicates 26% ecological departure for montane riparian woodlands, involving shift toward later-successional vegetation (i.e., woody vegetation encroachment) due to fire suppression. 2003-2004 inventory recorded woody encroachment at ~23% of springs in the park, all in montane riparian woodlands.

These results point to an overall rating of "Good" for the condition of the montane riparian woodland resource, but this overall rating depends on the weight given to the results of the assessment of fire regime departure. This particular indicator points to an overall rating of "Moderate Concern," and, while based in part on analyses of remote sensing data, is consistent with field observations. The ending of legal cattle grazing in the park in 1999 and legal sheep grazing in 2008, the ongoing program of management and removal of invasive species from riparian areas, and the absence of management activities that could further reduce watershed and riparian corridor condition suggest a qualitative assessment of "Unchanging," while the effects of fire suppression suggest a qualitative assessment of "Deteriorating" conditions. As a result of these conflicting signals, the overall ratings are assigned a "Low" confidence.

These overall findings rest on reliable data on watershed and riparian corridor landscape condition, and on GAWS field data on riparian condition from 2009-2011. However, the indicators for landscape condition provide only indirect information on riparian condition. Further, the GAWS field data result from a rapid visual assessment of riparian conditions. These types of assessments can be affected by variation in observer training, professional background, and abilities; field conditions;

and protocol repeatability (e.g., Kershner et al. 2004, Heitke et al. 2008, Roper et al. 2010). Finally, the GAWS field data pertain to portions of only six watersheds within the South Snake Range – the six watersheds included in the Bonneville cutthroat trout restoration program (see below). Given their inclusion in this restoration program, the riparian corridors in these six watersheds may not be representative of all riparian corridors in the park. These qualifying concerns suggest a rating of "Medium" for confidence in the assessment. As noted above, these uncertainties in the interpretability of these four indicators point to a need for more quantitative data on the condition(s) of the montane riparian corridors in Great Basin NP, possibly generated through a resurvey of the plots and transects last surveyed by Beever and others in 2001-2002.

Sources of Expertise

The assessment of this resource benefited from input from Chris Crookshanks, NDOW, and Jon Reynolds, National Park Service, concerning the methods of the GAWS surveys in 2009-2011. However, the assessment itself relies entirely on map and field data, and on NDOW protocols for classifying GAWS riparian data by condition class. The identification of LCI break-points for distinguishing conditions of "Good," "Moderate Concern," and "Significant Concern" rests on expert input into the LCI methodology itself (see above). Erik Beever, U.S. Geological Survey, provided helpful suggestions concerning the bearing of the riparian plot and transect survey data from 2001-2002 on the understanding of present conditions in the park.

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4.3.4. Bonneville Cutthroat Trout

Indicators / Measures

- *Bonneville cutthroat trout population density*
- *Miles of occupied habitat*
- *Habitat condition index*
- *Channel stability index*
- *Water quality/quantity condition*
- *Riparian corridor landscape condition*
- *Riparian reach condition*

Condition - Trend

Good Condition – Unchanging – Medium Confidence

<u>Background and Importance</u>

The Bonneville cutthroat trout (*Onchorynchus clarki utah*) is the only salmonid native to Great Basin NP, and in fact the only salmonid native to east-central Nevada in general. It is one of only four fishes native to the South Snake Range. The others are the mottled sculpin (*Cottus bairdi*), speckled dace (*Rhinichthys osculus*), and redside shiner (*Richardsonius balteatus*). The status of the Bonneville cutthroat in the park has been the subject of several reports, most recently by the Nevada Department of Wildlife (NDOW 2006), Baker et al. (2008), Houston et al. (2011, 2013), and Pepper and Reynolds (2012). The following background summary for the species is based on these reports, particularly Baker et al. (2008) and Pepper and Reynolds (2012).

The Bonneville cutthroat trout of the park are remnants of a population that formerly occupied Pleistocene Lake Bonneville and its tributary streams. Lake Bonneville covered most of the western third of what is now the state of Utah, with one arm extending west into the Snake Valley along the east side of the South Snake Range. Beginning ca. 15,000-12,000 years ago, at the end of the Pleistocene epoch, Lake Bonneville shrank away, stranding populations of the species in several tributary watersheds. The Snake Valley population became genetically isolated, and today is considered to be a distinct race of Bonneville cutthroat trout (Baker et al. 2008, Houston et al. 2011, 2013). Other former tributaries to Lake Bonneville also still harbor population remnants.

The Bonneville cutthroat trout is part of the "Aquatic Fauna, Flora" key ecological attribute of the stream-riparian ecological sub-system in the park. It is the top native aquatic predator in the sub-system, dependent on clean, clear, cool flowing water with a suitable mix of pool, riffle, and run habitat; plentiful cover; and a suitable mix of aquatic invertebrates on which to feed. As a result, it is sensitive to alterations in stream hydrology, water temperature and chemistry (water quality), physical habitat, and the structure of the aquatic food web. As noted above (see Section 4.3.2, Water Quality/Quantity), such alterations can arise through changes in climate, atmospheric deposition, watershed and riparian zone development, channel modifications and trampling by livestock, water diversions, and groundwater pumping. Culverts installed at road crossings and dams installed to control water flow may present barriers to fish movement. As a top aquatic predator, Bonneville cutthroat trout is vulnerable to impairment by chemical contaminants that bioaccumulate through the aquatic food web, such as mercury. It is also vulnerable to competition from non-native trout species introduced into the South Snake Range – brook trout (*Salvelinus fontinalis*), rainbow trout (*Oncorhynchus mykiss*), Lahontan cutthroat trout (*Onchorynchus clarki henshawi*), and brown trout (*Salmo trutta*) – and to hybridization with Lahontan cutthroat trout and rainbow trout. As a result, Bonneville cutthroat trout are sensitive, readily-appreciated indicators of the overall ecological integrity of the park (Baker et al. 2008, NPCA 2009).

At the time that Great Basin NP was established, in 1986, Bonneville cutthroat trout had disappeared from an estimated 95% of its historic range. No streams within the park were thought to harbor the species, and the park General Management Plan of 1993 established goals for restoring the species within the park. The Park later joined numerous other agencies and organizations in establishing a range-wide program for species restoration (Williams et al. 1999, Lentsch et al. 2000, NDOW 2006), with goals to restore the species to its entire natural range, including within the park. Subsequently, these goals were modified to exclude Lehman Creek (see below). Restoration within the park was proposed to include the removal of all non-native salmonids from Bonneville cutthroat trout habitat. Non-native salmonids had been unofficially and officially stocked into the streams and lakes of the South Snake Range for many decades (Pepper and Reynolds 2012). In 1999, the nearest streams thought to harbor Bonneville cutthroat trout – and from which stock could be reintroduced into the park – were Hendry's Creek in the North Snake Range; and Pine and Ridge Creeks on the west side of the South Snake Range, outside the historic range. However, subsequent testing identified genetically pure Bonneville cutthroat trout in Mill Creek, inside the park, and this population became the dominant source for reintroducing the species to other streams inside the park (see below). Suspected Bonneville cutthroat trout in Strawberry Creek proved to be Bonneville cutthroat/rainbow hybrids, not suitable for use as a source stock for the restoration program (Baker et al. 2008, Houston et al. 2011, 2013).

The program for restoring Bonneville cutthroat trout to the park had several objectives, originally planned for a ten-year timeline (1999-2008): (1) obtain baseline data on biotic and abiotic conditions along the streams in the park; (2) identify 8 miles (15 km) of stream reaches that, through the maintenance or installation of barriers, could sustain the species in isolation from non-native salmonids; (3) remove non-natives from these targeted reaches, including determining the best methods for this effort; (4) maintain and/or install barriers to ensure the continued isolation of Bonneville cutthroat trout in these reaches from non-native populations entrenched downstream; (5) restore physical habitat conditions where necessary along eroded or artificially modified sections of the targeted reaches; (6) reintroduce genetically pure Bonneville cutthroat trout in sufficient numbers to each targeted reach to support reproduction; and (7) monitor habitat conditions and species numbers and health to assess success, identify emerging problems, and adapt management actions accordingly (Williams et al. 1999, NDOW 2006). The initial list of targeted streams consisted of Mill Creek, Strawberry Creek, Lehman Creek, the South Fork of Baker Creek, and Upper Snake Creek, and the South Fork of Big Wash. The program later dropped consideration of Lehman Creek due to concerns about its use as a source of drinking water outside the park. Chemical removal proved to be the best method for eliminating non-native fishes from Strawberry and Snake Creeks. The South Fork of Baker Creek was cleared by electrofishing. Restoration efforts in the park began in 1999 with surveys of Mill Creek and the South Fork of Big Wash, and genetic testing of the Mill Creek population. After a second round of genetic testing in 2000 confirmed the genetic purity of the Mill Creek population, the park Service removed 56 trout for reintroduction into the upper perennial reach of South Fork Big Wash. The program thereafter expanded to the remaining targeted reaches, with the removal of non-native fishes completed in 2005; and with repeated surveys, habitat restoration, and additional reintroductions continuing through 2012. The Park also experimented in 2002 with streamside incubators along Strawberry Creek to supplement introductions from the hatchery broodstock, but the method failed. All successful reintroductions through the program therefore were from the Mill Creek broodstock, except for two reintroductions from Hendry's Creek into Snake Creek in 2005 and 2008. Reintroduced Bonneville cutthroat trout quickly began reproducing in all restored reaches, and expanded their range even further upstream along the South Fork of Baker Creek (see Condition and Trend, below). The removal of two culverts along Strawberry Creek in 2012 helped promote the expansion in that watershed (Pepper and Reynolds 2012). The success of the Bonneville cutthroat trout restoration project also led the park to begin restoration of the remaining three native fishes to their natural ranges (Baker et al. 2008). Figure 89 reproduces Figure 22 from Baker et al. (2008), showing the streams that today support Bonneville cutthroat trout within the park and the rest of the South Snake Range.

The Bonneville cutthroat trout restoration project suffered only one setback: brook trout were detected in 2009 in the restored reaches along Snake Creek, which all lie upstream from the pipeline. This reappearance led to discussions and proposals for improving a downstream barrier, again purging these reaches of all salmonids, and restarting the restoration efforts there (Pepper and Reynolds 2012, National Park Service 2013). Construction of a barrier is planned for winter 2014-15, with piscicide treatment to follow. An Environmental Assessment is presently in preparation (Mark Pepper, Great Basin NP, personal communication, October 2014).

Several long-term challenges remain for sustaining Bonneville cutthroat trout in the park, as is the case throughout the remaining range of the species and throughout the remaining ranges of all other cutthroat trout subspecies (e.g., Hilderbrand and Kershner 2000a). First, Bonneville cutthroat trout population numbers and lengths of occupied habitat in the park remain low (see below, Condition and Trend), for the populations in individual streams to persist in the face of the natural variability of stream and riparian habitat in the park. Fires, floods, droughts, and disease all have the potential to set back restoration efforts along any reach stream in the park. Second, the risk of non-native salmonids reappearing in restored reaches remains high. Recreational fishers may sometimes unknowingly (albeit illegally) release desired non-native sport fishes into streams they like to visit.

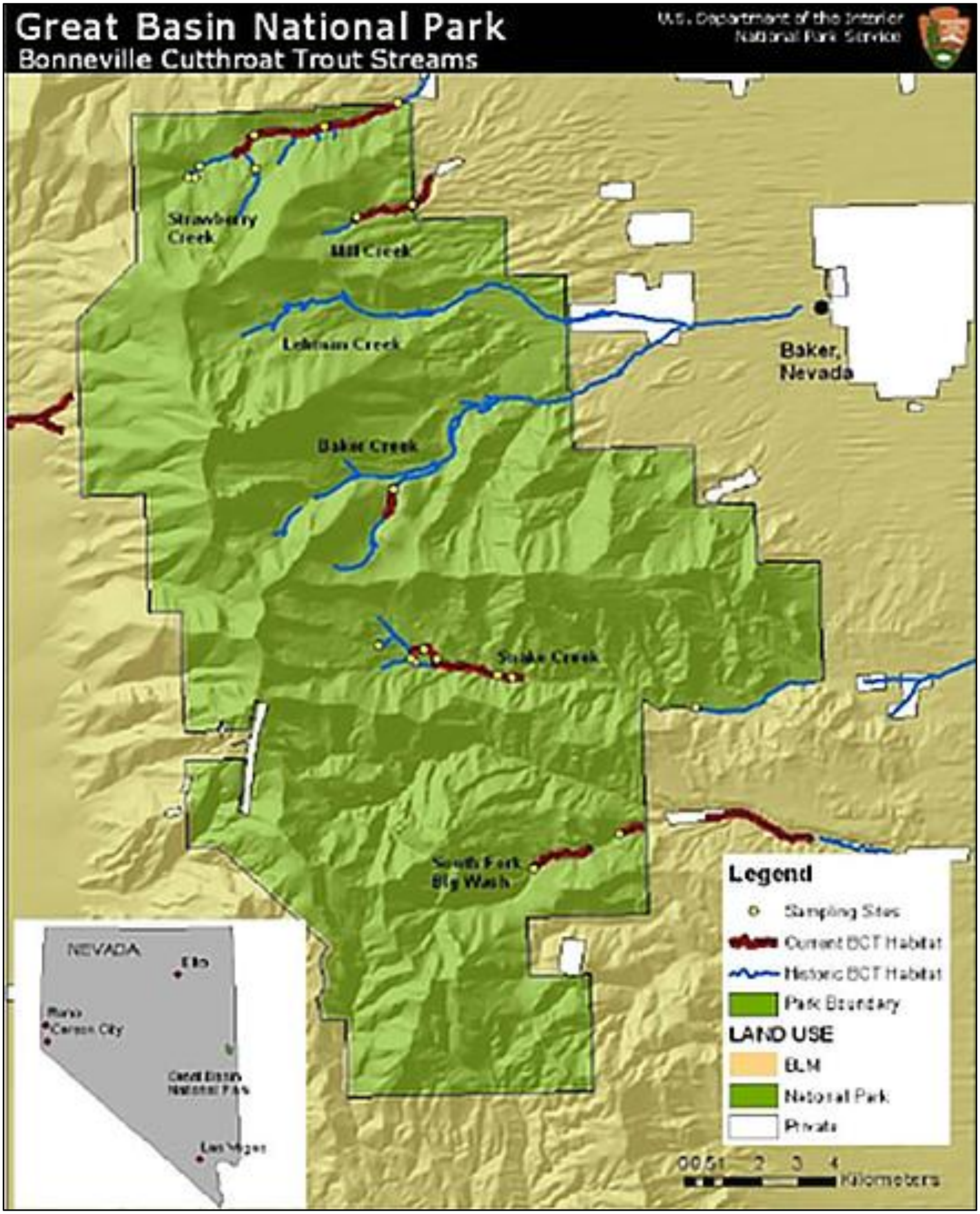

Figure 89. Reproduction of Figure 22 from Baker et al. (2008), showing Bonneville cutthroat trout streams in Great Basin NP and vicinity.

Additionally, the Spring Creek Rearing Station, a Nevada State rearing station raising rainbow trout, is located near the confluence of Snake and Spring Creeks 1.4 miles (2.25 km) downstream of the park boundary. Both rainbow and brown trout occur along Snake Creek between the rearing station and the park boundary (Pepper and Reynolds 2012). A barrier at the park boundary would permit restoration of Bonneville cutthroat trout to the perennial reach of Snake Creek downstream from the pipeline, and further isolate the restored reaches of upper Snake Creek (above the pipeline) as discussed above. Third, inbreeding within the small populations established in each of the restored streams could result in genetic founder effects that impair population viability. Nevertheless, the restoration program faces these challenges only because it has already been so successful.

Data and Methods

Indicators / Measures

- ***Bonneville cutthroat trout population density***
- ***Miles of occupied habitat***
- ***Habitat condition index***
- ***Channel stability index***
- ***Water quality/quantity condition***
- ***Riparian corridor landscape condition***
- ***Riparian reach condition***

The discussion here concerns current conditions for Bonneville cutthroat trout in the park. Section 4.4, Future Landscape Conditions, addresses possible impacts of climate change on the species. The data collected by the monitoring efforts of the Bonneville cutthroat trout restoration project in the park provide data on the density and distribution of the species as well as non-native salmonids in the five targeted watersheds. Additional indicators can provide information on in-stream habitat condition, water quality and quantity, and riparian habitat quality. These latter indicators are measures of stressors that could affect restoration success. The results of the assessments for water quality and quantity in the park (see above, Section 4.3.2) provide the needed information on water quality and quantity. In turn, the results for two indicators of montane riparian woodland condition (see above, Section 4.3.3) provide the needed information on riparian habitat quality: riparian corridor landscape condition, and riparian reach condition.

Finally, data on in-stream habitat condition were collected as part of the General Aquatic Wildlife Survey (GAWS) (Overton et al. 1997) carried out by the Nevada Department of Wildlife (NDOW) and the National Park Service in 2009-2011 in conjunction with the Bonneville cutthroat trout restoration project, as described in Section 4.3.3 above (Pepper and Reynolds 2012, Chris Crookshanks, NDOW, personal communication, April 2014; Jon Reynolds, National Park Service, personal communication, April 2014; data on file, Great Basin NP). The NDOW field team trained the park Service team in its field methods, to ensure consistency (Jon Reynolds, National Park Service, personal communication, April 2014). The GAWS data span the reaches targeted for

Bonneville cutthroat trout restoration along Strawberry Creek, Mill Creek, the South Fork of Baker Creek, Snake Creek above and below the pipeline, and the South Fork of Big Wash. The teams also collected GAWS data along the reaches along Pine and Ridge Creeks already occupied by Bonneville cutthroat trout.

Table 63 identifies the indicators used to assess the condition of Bonneville cutthroat trout in the park, incorporating the results from the assessments of water quality/quantity and the montane riparian woodlands, above (Sections 4.3.2 and 4.3.3, respectively).

Table 63. Indicators used for resource assessment of Bonneville cutthroat trout condition in Great Basin NP.

Indicator	Indicator Definition
Bonneville cutthroat trout population density	Bonneville cutthroat trout per mile of habitat, across all five streams with restored reaches.
Bonneville cutthroat trout miles of occupied habitat	Bonneville cutthroat trout miles of occupied habitat, across all five streams with restored reaches.
Bonneville cutthroat trout habitat HCI	GAWS Habitat Condition Index results, along the five streams with restored reaches.
Bonneville cutthroat trout habitat CSI	GAWS Channel Stability Index results, along the five streams with restored reaches.
Water Quality/Quantity condition	Results of assessment of water quality/quantity based on multiple indicators (see Section 4.3.2).
Riparian corridor landscape condition	Results of assessment of montane riparian woodland landscape condition (see Section 4.3.3).
Riparian reach corridor condition	Results of GAWS assessment of riparian vegetation condition (see Section 4.3.3).

The GAWS data include several metrics of channel geometry and stability assessed along five transects perpendicular to the stream axis at each sampling station. The transect data are then summarized in two indexes of in-stream habitat condition: a Habitat Condition Index (HCI); and a Channel Stability Index (CSI).

The HCI consists of the average of six measures of channel condition, as follows:

- “Pools Measured” assesses the pool to riffle ratio, with the highest score assigned to a pool to riffle ratio of 50:50. The metric is scaled 0-100.
- “Quality Pools” assesses the percentage of the pools measured that are considered to be quality pools (based on the depth, width, and presence of cover), scaled 0-100.
- “Stream Bottom” assesses the percent of the substrate that is rubble and gravel, scaled 0-100.
- “Bank Cover” assesses the percent of the banks (left and right banks combined) with grass, shrub, or tree cover, scaled 0-100.

- “Bank Soil Stability” assesses how susceptible the banks are to erosion along a qualitative scale from 1 (very erodible) to 4 (very stable) and calculates the average. The average rating for the left and right banks together, across all five transects, is rescaled 0-100.
- “Bank Vegetation Stability” assesses the apparent stability of vegetation along the banks, along a qualitative scale from 1 (very erodible) to 4 (very stable) and calculates the average. The average rating for the left and right banks together, across all five transects, is rescaled 0-100.

The CSI consists of the sum of five qualitative ratings of the stability of the soil on the upper banks of the channel, five for the soil on the lower banks, and five for the bottom sediments, each scored on a scale of 1 to >18.

Reference Conditions

The present assessment defined reference conditions for the indicators for Bonneville cutthroat trout condition in various ways. No data on reference conditions are available for Bonneville cutthroat trout population density or miles of occupied habitat in the park. Studies indicate that isolated inland cutthroat trout populations reach higher densities, have greater access to seasonally specific habitats, and are more resilient to disturbances in larger watersheds with greater lengths of connected stream habitat that span wider ranges of altitude (Hilderbrand and Kershner 2000a, 2000b, Harig and Fausch 2002, Fausch et al. 2009). For example, a study of four populations of cutthroat trout, including two Bonneville cutthroat trout sub-species, Hilderbrand and Kershner (2000a) calculated that more than 5 miles (8 km) of stream would be needed to maintain a single population with high fish abundance (0.3 fish/m, approximately 480 fish/mile), and more than 16 miles (25 km) of stream to maintain a single population of low abundance (0.1 fish/m, approximately 160 fish/mile). The authors concluded that isolated cutthroat trout populations with less than these minima may not persist over the long term; and that barriers constructed to protect cutthroat trout from non-native salmonids may provide short-term solutions but entail long-term risks for maintaining viable cutthroat trout population sizes.

Modeling could provide estimates for the minimum lengths of connected stream habitat needed to sustain Bonneville cutthroat trout in Great Basin NP. However, achieving such minima in the park will be constrained by the difficulty of removing and keeping non-native salmonids out of some stream reaches, and the presence of the pipeline along Snake Creek that effectively breaks that stream into two isolated water bodies (Pepper and Reynolds 2012). The goals for restoring Bonneville cutthroat trout in the park (Williams et al. 1999, Lentsch et al. 2000, NDOW 2006) consequently focus on stream reaches along which it would be feasible to restore the species, not on the question of how much stream habitat would be enough for the species to sustain itself in the park. These goals therefore do not constitute ecological reference conditions. The “Conservation Agreement and Conservation Strategy for Bonneville Cutthroat Trout (*Oncorhynchus clarki utah*) in the State of Nevada” (NDOW 2006) in fact suggested that only one stream system in the park, Snake Creek and its tributaries, might be large and complex enough to support a limited metapopulation. On the other hand, the National Park Service has the ability to sustain Bonneville cutthroat trout in Great Basin NP through active management, despite the vulnerability of all restored streams to fires, floods, droughts, disease, and intrusions of non-native salmonids. Nevertheless, Great Basin NP would prefer to see self-sustaining populations in every restored creek, with appropriate distributions of age classes, distributed throughout the restored stream reaches (Gretchen Baker, Great Basin NP, personal communication, December 2014).

The Park rates GAWS HCI values as follows (Pepper and Reynolds 2012): 0-49, Poor, equivalent to the National Park Service rating of "Significant Concern;" 50-55, Fair, equivalent to the National Park Service rating of "Moderate Concern;" and 56+, Good, equivalent to the National Park Service rating of "Good." In turn, the present assessment determined the rating scales applied to the GAWS CSI data based on the values stated in the GAWS data files (data on file, Great Basin NP). The data show that the park rates the CSI values as follows: 77-102, Fair, equivalent to the National Park Service rating of "Moderate Concern;" and 15-76, Good, equivalent to the National Park Service rating of "Good." The GAWS data contain no CSI scores higher than 102, and all scores from 77 to 102 were rated as "Fair." Consequently, it is not possible to determine from the data the range of values that would correspond to a potential rating of "Poor." Finally, Table 47 and Table 56, above, present the definitions for the multiple indicators for Water Quality/Quantity and Montane Riparian Woodland condition.

Section 4.3.2, above, discusses reference conditions for the indicators of water quality and quantity used in the present assessment. In turn, Section 4.3.3.3 discusses reference conditions for the indicators of montane riparian woodland condition.

<u>Condition and Trend</u>
With the exception of Mill Creek, the streams targeted for Bonneville cutthroat trout restoration in the park were purged of all salmonids prior to reintroduction of the target species. The following paragraphs summarize the number of individuals reintroduced, in what years; and the results of surveys conducted in 2009-2011 (see above and Pepper and Reynolds 2012):

- Strawberry Creek. Reintroductions: 34 Bonneville cutthroat trout in 2002; 30 more in 2005. Survey results: 2009, average of 443 Bonneville cutthroat trout per mile along 2.7 miles of restored habitat; 2011, 755 per mile along 3.25 miles (5.23 km) of restored habitat within the park.
- Mill Creek. No reintroductions. Survey results: 1999-2008, estimated densities of 113 to 740 trout per mile; 2009, at new sample stations, average of 354 per mile along 1.09 miles (1.75 km) of occupied habitat.
- South Fork Baker Creek. Reintroductions: 45 trout in 2005. Survey results: 2010, average of 215 trout per mile along 3.0 miles (4.8 km) of restored habitat.
- Snake Creek. Reintroductions: 104 trout in 2005; 100 more in 2008. 2010, average of 117 trout per mile along 2.5 miles (4.0 km) of restored habitat.
- South Fork Big Wash. Reintroductions: 56 trout in 2000; 31 more in 2010. Survey results: 2010 and 2011 surveys combined, average of 748 trout per mile along 1.5 miles (2.4 km) of restored habitat within the park.

The data on reintroductions and from stream surveys show that Bonneville cutthroat trout numbers increased quickly along all restored stream reaches following reintroduction. The clearest data come from Strawberry Creek, into which 64 individuals were introduced between 2002 and 2005, representing a *minimum* density of 24 trout per mile. By 2009 average density had increased to 443 trout per mile; and by 2011 to 755 trout per mile. The South Fork of Baker Creek presents another example, in which the reintroduced trout not only fully occupied the expected habitat but expanded further upstream to occupy additional habitat after introduction of only 45 Bonneville cutthroat trout. The continuing expansions indicate that the restoration program is coming closer every year meeting its goals of having self-sustaining populations in every restored creek, with appropriate distributions of age classes, distributed throughout the restored stream reaches (Gretchen Baker, Great Basin NP, personal communication, December 2014).

Table 64 and Table 65 (see also Figure 90 and Figure 91) summarize show the results from the Habitat Condition and Channel Stability indexes calculated from the GAWS data from 2009-2011 along the streams included in the Bonneville cutthroat trout restoration project.

Table 64. Summary of Habitat Condition Index results for streams in Bonneville cutthroat trout restoration program, Great Basin NP.

Stream	Stations meeting criteria for “Good” condition	Stations meeting criteria for “Moderate Concern”	Stations meeting criteria for “Significant Concern”
Strawberry Creek	9		1
Mill Creek	1	1	2
South Fork Baker Creek	1	3	0
Upper Snake Creek	9	0	1
South Fork Big Wash	1	2	0

Table 65. Summary of Channel Stability Index results for streams in Bonneville cutthroat trout restoration program, Great Basin NP.

Stream	Stations meeting criteria for “Good” condition	Stations meeting criteria for “Moderate Concern”	Stations meeting criteria for “Significant Concern”
Strawberry Creek	5	5	0
Mill Creek	2	2	0
South Fork Baker Creek	3	1	0
Upper Snake Creek	5	4	0
South Fork Big Wash	4	1	0

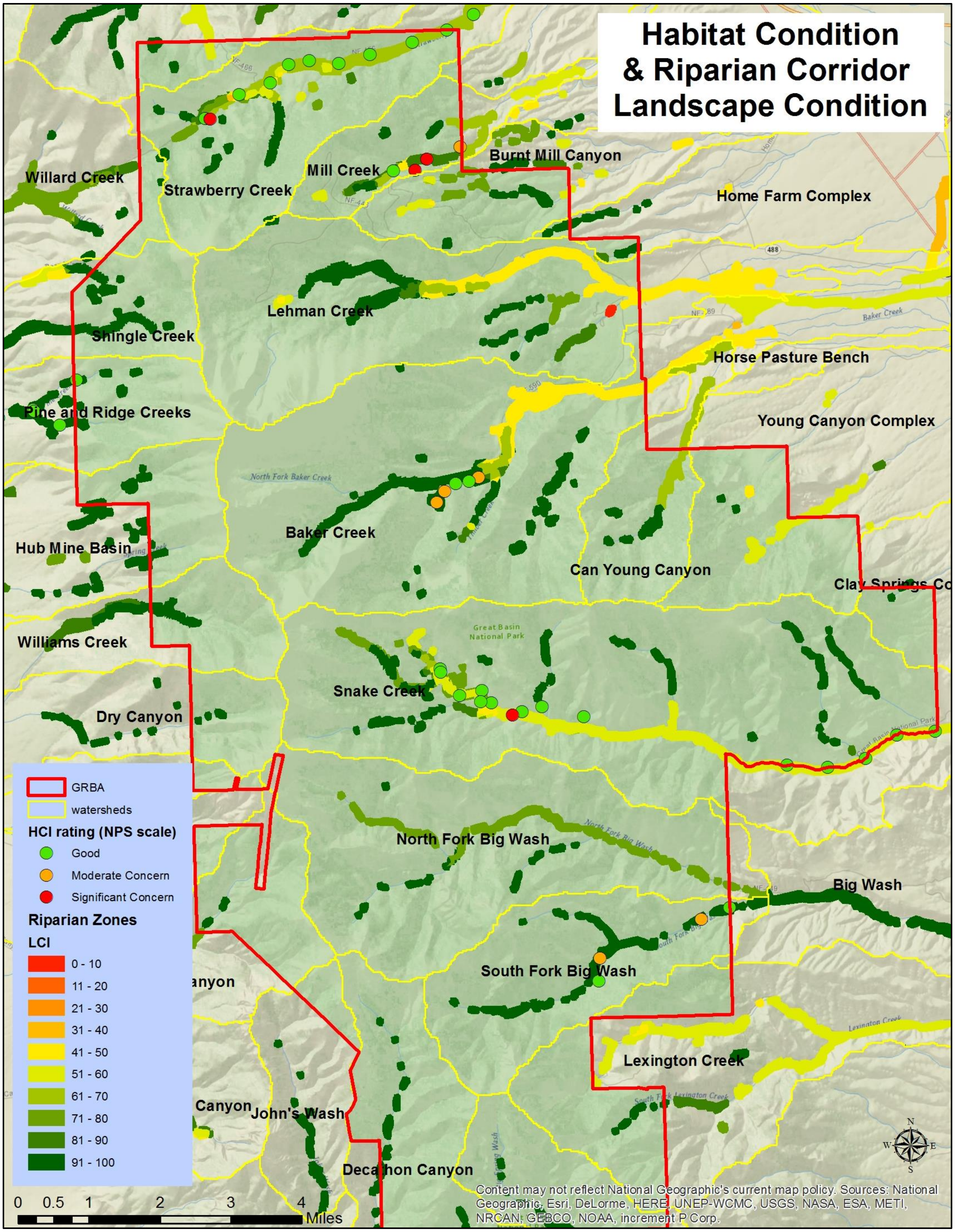

Figure 90. Habitat Condition Index scores and Riparian Corridor Landscape Condition, Great Basin NP.

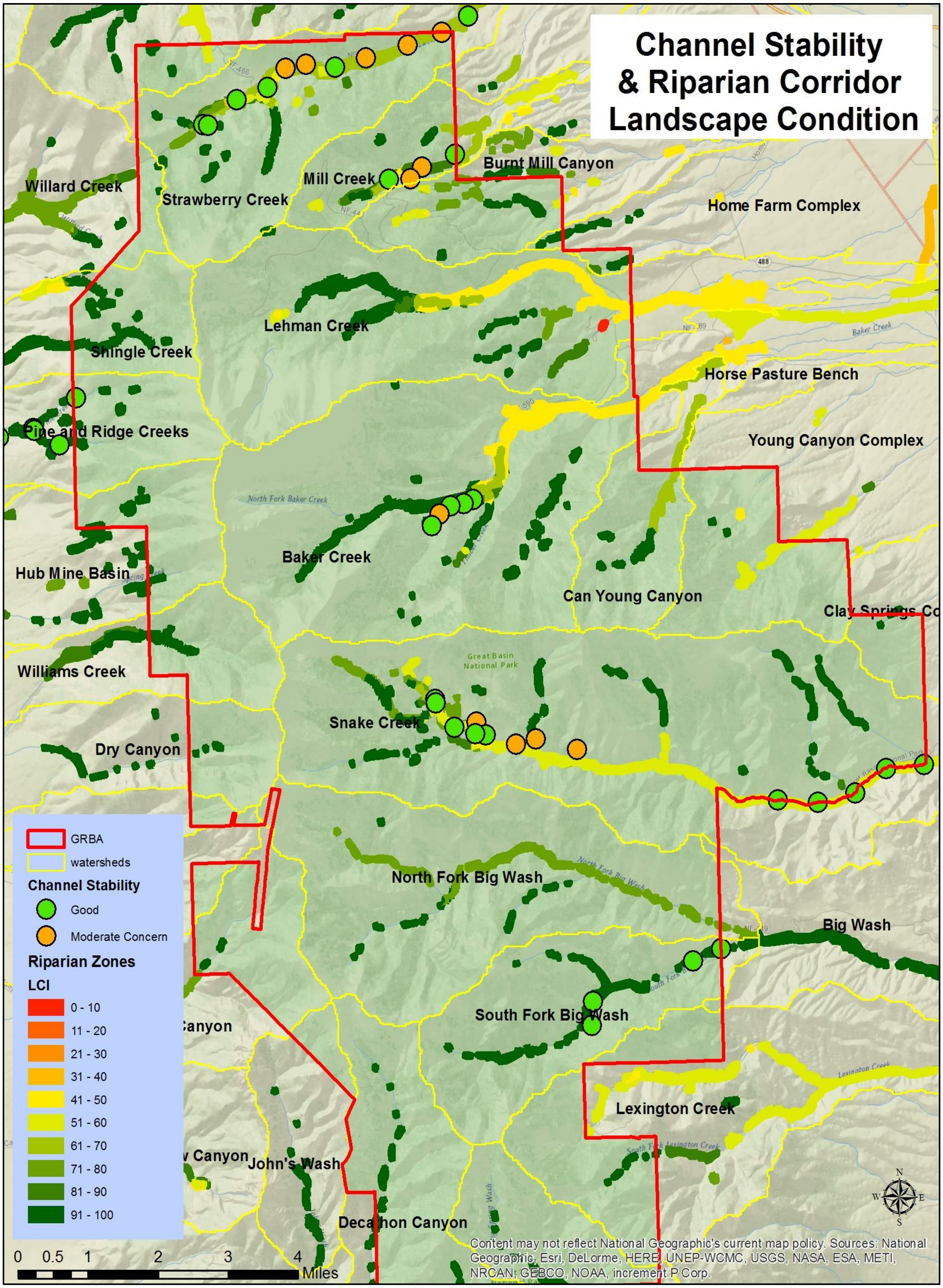

Figure 91. Channel Stability Index scores and Riparian Corridor Landscape Condition, Great Basin NP.

Figure 90 and Figure 91 show the GAWS results superimposed on the results for Riparian Corridor Landscape Condition, calculated for the Water Quality/Quantity and Montane Riparian Woodland assessments, for comparison.

The HCI and CSI results thus suggest that habitat conditions are not consistently good along any of the restored streams, as of 2009-2011. In particular, they suggest sections of every restored stream exhibit at least a moderate degree of channel instability, and excessive simplicity (insufficient complexity) in habitat conditions, based on the translation of the index scores into rating categories.

The results of the park-wide assessment of Water Quality/Quantity condition, presented in Section 4.3.2.4, above, indicate that neither degraded hydrology nor degraded water quality pose a threat to Bonneville cutthroat trout within the park, with two exceptions. First, the lowest extent of the restored reach along upper Snake Creek lies near or within the zone of potential impacts from groundwater pumping in Snake Valley. Second, the Snake Creek pipeline eliminates trout habitat along a large portion of Snake Creek, and reduces flow along the reach below the pipeline that is proposed as a potential restoration site.

The results of the assessment of Montane Riparian Woodland condition, presented in Section 4.3.3.4, above, indicate that Riparian Corridor Landscape Condition scores among the five streams in the Bonneville cutthroat trout restoration project are highest along the South Fork of Baker Creek and along the South Fork of Big Wash; and intermediate along Strawberry Creek, Mill Creek, and upper Snake Creek. However, Riparian Corridor Landscape Condition addresses only the *potential* for ecological impacts from riparian corridor development, and does not distinguish development managed to minimize ecological impacts from less-carefully-managed development. In turn, Riparian Reach Condition, also measured during the GAWS sampling in 2009-2011, scores in the "Good" range at all stations along the reaches included in the trout project, except for a score in the "Moderate Concern" range at the upper-most station along the South Fork of Baker Creek.

Summary of Status
Table 66 summarizes the results for the eight indicators used to assess the condition of Bonneville cutthroat trout in the park.

In summary, the results for the seven indicators tell a mixed story:

- The direct measurements of Bonneville cutthroat trout status indicate that the species has been successfully restored to all five targeted streams in the park, with highly reliable data. The combined information on water quality and quantity similarly reliably indicates that, except for two isolated locations, neither altered water quality nor altered water quantity pose threats to the restored trout. Trout densities and some aspects of water quality may in fact be improving further. On the other hand, unauthorized intrusions of other salmonids into targeted reaches remain a problem, particularly along Snake Creek.
- With varying degrees of reliability, the GAWS data on in-stream habitat condition, channel stability, and riparian reach condition; and the GIS-based data on riparian corridor landscape

condition suggest that stream-riparian habitat conditions vary between “Moderate Concern” and “Good” but with no evidence to assess for trends.

Table 66. Summary of indicators for condition of Bonneville cutthroat trout for Great Basin NP.

Bonneville Cutthroat Trout			
Indicators of Condition	**Specific Measures**	**Condition Status/Trend**	**Rationale**
Bonneville cutthroat trout population density	Bonneville cutthroat trout per mile of restored habitat		The density of Bonneville cutthroat trout has increased in all restored streams across all years of monitoring since reintroduction.
Bonneville cutthroat trout miles of occupied habitat	Miles of occupied habitat		Bonneville cutthroat trout quickly occupied all available habitat along all restored streams following reintroduction, and with only one exception have not expanded further.
Bonneville cutthroat trout habitat HCI	GAWS habitat condition index		Every stream has stations with HCI scores rated both Good and either Moderate or Significant Concern. No data are available on trends.
Bonneville cutthroat trout habitat CSI	GAWS channel stability index		Every stream has stations with HCI scores rated both Good and Moderate Concern, except all stations along South Fork Big Wash are rated Good; and stations rated Good outnumber those rated Moderate Concern overall. No data are available on trends.
Park-Wide Water Quality/Quantity Condition	Composite results of assessment of water quality/quantity based on multiple indicators (see Section 4.3.2).		No evidence of any widespread conditions or trends in water quality or quantity that might threaten Bonneville cutthroat trout, but two localized concerns.

Table 66 (continued). Summary of indicators for condition of Bonneville cutthroat trout for Great Basin NP.

Bonneville Cutthroat Trout			
Indicators of Condition	**Specific Measures**	**Condition Status/Trend**	**Rationale**
Riparian Corridor Landscape Condition	LCI assessed at scale of a 200 m buffer along stream corridor (addresses both water quality and quantity)		Mostly high LCI scores for riparian corridor condition at higher elevations and mixed for lower elevations, but the indicator provides only indirect information on riparian condition. No evidence to evaluate trend.
Riparian Reach Condition	Field observation of riparian vegetation condition at individual stream reaches, collected as part of the 2009-2011 General Aquatic Wildlife Survey of streams included in the Bonneville cutthroat trout restoration project.		Mostly high scores in the "Good" range, but data pertain to portions of only seven watersheds and do not cover highly altered riparian areas along Lehman, Baker, or Snake Creeks. No evidence to evaluate trend.

These results point to an overall rating of "Good" for current conditions, with stable or improving conditions. However, at the same time, several indicators point to problems of "Moderate Concern" due to current impairments to riparian corridor conditions and to in-stream habitat, requiring restoration and management; and due to intrusions of other salmonids into stream reaches from which they need to be excluded.

These overall findings rest on reliable data on trout numbers and distribution; riparian corridor landscape condition; and riparian and stream habitat conditions from the GAWS fieldwork in 2009-2011. However, the indicators for landscape condition provide only indirect information on riparian condition. Further, the GAWS field data result from rapid visual assessments. These types of assessments can be affected by variation in observer training, professional background, and abilities; field conditions; and protocol repeatability (e.g., Kershner et al. 2004, Heitke et al. 2008, Roper et al. 2010).

<u>Sources of Expertise</u>
The assessment of this resource benefited from input from Chris Crookshanks, NDOW, and Jon Reynolds, National Park Service, concerning the methods of the GAWS fieldwork in 2009-2011. Sections 0 and 4.3.3.6, above, discuss the sources of expertise for the indicators of water quality and quantity, and montane riparian woodland condition.

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4.3.5. Cave/Karst Processes

Indicators / Measures

- *Seasonal Visitor Count*
- *Cave Temperature*
- *Cave Humidity*
- *Cave Hydrology*
- *Cave Water Quality*
- *Macroinvertebrate Composition*
- *Packrat Abundance*

Condition - Trend

Good Condition – Unchanging – Low Confidence

Background and Importance

Great Basin NP contains over 30,000 acres of karst geology with a high potential for cave resources. *Karst* is defined as a distinctive topography formed by the dissolution of carbonate rock (e.g., limestone, dolomite, marble) that is typically characterized by sinkholes, caves, and underground drainage. A *karst feature* is defined as a cave, sinkhole, sinking streams, or other solution feature. Karst occurs mostly in the southern 25% of the park (blue shading in Figure 92), with lesser occurrences on the eastern flanks of the park. The southern area of the park lacks many springs and streams due to solution features that tend to enhance infiltration of water into the subsurface. The associated carbonate rock formations are the Pole Canyon Limestone (Middle Cambrian), Lincoln Peak Formation (Middle to Late Cambrian), Notch Peak Limestone (Late Cambrian to Early Ordovician), and the Guilmette Formation (Late Devonian). These formations capture, store, and deliver water to areas in and around the park, and to the regional carbonate rock aquifer flow system. A karst area in the Baker Creek watershed contains some of the most highly developed known karst drainage networks in the park.

Caves are protected by the Federal Cave Resources Protection Act of 1988 (FCRPA), which defines caves as “any naturally occurring void, cavity, recess, or system of interconnected passages which occurs beneath the surface of the earth or within a cliff…which is large enough to permit an individual to enter, whether or not the entrance is naturally formed or manmade. The term shall include any natural pit, sinkhole, or other feature which is an extension of the entrance.” While the FCRPA makes a distinction between significant and insignificant caves, 43 CRF 37.11(d) stipulates that all caves on NPS administered lands are deemed to fall within the definition of “significant cave.”

Cave resources include any material or substance occurring naturally in caves and cave entrances on federal lands including, but not limited to, animal life, plant life, paleontological deposits, sediments, minerals, speleogens, and speleothems. A *Wild Cave* is defined as any cave that has not been developed for human use.

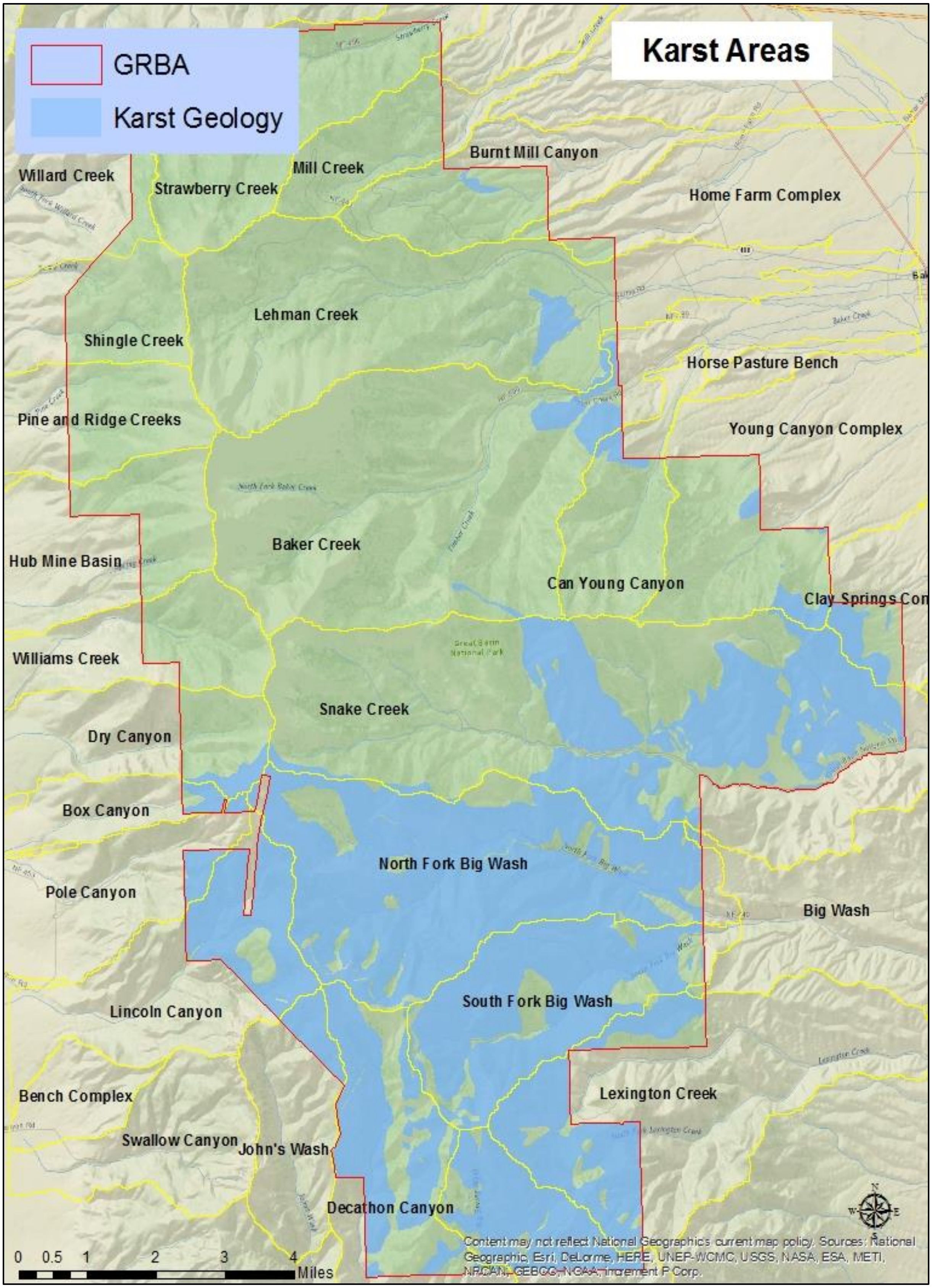

Figure 92. Location of karst geology within Great Basin NP.

Physical cave inventories have been conducted in nearly all the known caves in the park, while biological cave inventories have been conducted in about half the caves. In total, there are 46 known caves in the park preserving spectacular cave formations such as stalactites, stalagmites, cave popcorn, flowstone, shield formations, and at least one significant pictograph site. The Park contains solution caves, fracture systems, ice caves (caves containing ice year-around), and 23 known rock shelters. In addition to Lehman Caves, which is described elsewhere, other caves include highest elevation and deepest caves in the state of Nevada. Some are small and linear, while others have maze-like passages. Many park caves are dry, but some contain underground streams. Four distinctive geographic groupings of caves exist in the park. From north to south, these groups are Lehman Hill Caves, Baker Creek Caves, Snake Creek Caves, and Alpine Caves.

Lehman Caves, Little Muddy Cave, Lehman Annex Cave, and Root Cave make up the Lehman Hill Cave System. The cave passages' proximity and similar passage orientation suggests that these caves may have formed from a single evolving drainage network. Partially open to the public, Lehman Caves includes spectacular formations including 300 rare shield formations. It is the longest cave in Nevada, at approximately 2 miles (3.2 km) long, and is believed to have formed from both epigenic (surface water) and hypogenic (deep water) processes (Graham 2014).

Of the Lehman Cave Hill System, Lehman Annex Cave is the highest in elevation. Lehman Cave and Root Cave occur at around 7,000 feet (2,134 m). Little Muddy Cave is at a lower elevation. A nearby active spring at a lower elevation may be today's representative of the watercourse that formed Lehman Hill Cave System. The spring rises from glacial alluvium and its connection with the karst system above is speculative.

In 1958, Arthur Lange investigated the caves of the Baker Creek area for the Western Speleological Institute and concluded that there was once only one system that cut through the Baker Creek area. Through cave exploration, physical connections among Ice, Crevasse, and Wheelers Deep Caves have been documented. Model and Dynamite Caves have been shown to be connected hydrologically to Ice-Crevasse-Wheeler Deep Caves.

The Snake Creek caves include Snake Creek, Squirrel Springs cave, and Fox Skull cave. Snake Creek Cave was historically the most popular wild cave in Great Basin NP. The cave is known for its spectacular aragonite, anthrodite and frostwork formations. Signatures from Morrison and Roland in 1886 show a long history of the cave's visitation. The Snake Creek Cave entrance is approximately 1,700 feet (518 m) long and comprised of two roughly parallel passages.

Most of the caves found in the Alpine Group (above 9,000 feet (2,743 m) are classified as fracture caves, having formed along fracture planes. High Pit Cave, located above 11,000 feet (3,353 m), is the highest solution cave in Nevada. High Pit is also notable for the old, persistent, compacted snow known as *neve* found just inside the entrance. The bottom of High Pit is plugged with snow. Long Cold Cave is located at an elevation of about 10,000 feet (3,048 m). The cave is the deepest cave in the park (and in Nevada) at a depth of 440 feet (134 m).

The park contains several sensitive and endemic cave species. Most of the caves in the park support populations of sensitive bat species that use the caves for hibernacula, maternity colonies, and transitional roosts. Twelve species of bats have been documented in the park, including seven NPS-Sensitive bat species: long-eared myotis (*Myotis evotis*), long-legged myotis (*Myotis volans*), Townsend's big-eared bat (*Corynorhinus townsendii*), fringed myotis (*Lasiurus cinereus*), silver-haired bat (*Lasionycteris noctivagans*), spotted bat (*Euderma maculatum*), and pallid bat (*Antrosous pallidus*). White nose syndrome,[3] caused by the fungus *Geomyces destructans*, poses a severe threat to bat hibernacula and maternity colonies and has caused mortality of over 5 million bats since 2006 throughout the eastern U.S. Fortunately it is not present in or around Great Basin NP at this time. In order to combat disease spread, cave closures are one widespread and urgent response, limiting potential introduction of fungal materials by individuals who have previously visited contaminated caves.

Because caves bring natural isolation, there is commonly a high degree of endemism in the macroinvertebrate fauna. The relative uniqueness of cave fauna in the park is not fully known, as there is a need for more investigation in caves throughout the surrounding region (Taylor et al. 2008, Waltari and Guralnick 2009). Lehman Cave and several other caves contain a sensitive cave-adapted pseudoscorpion, *Microcreagris grandis* (Muchmore 1962). Several caves in the Baker Creek cave system, and some alpine caves, contain harvestman, *Sclerobunus ungulatus,* originally described by Briggs (1971) from specimens collected by R. de Saussure in 1952, and now thought to be endemic to the South Snake Range (Derkarabetian and Hedin 2014). Eleven endemic and numerous obligate invertebrate species are found in the park, including the Lehman Cave pseudoscorpion (*Microcreagris grandis*), which is only known to the South Snake Range.

The only caves in the park open to the public are Lehman Caves and Little Muddy Cave with entry regulated by permit. All other caves remain closed at this time to combat disease spread and protect bat populations. The permit system is mandated by the FCRPA and helps to protect their fragile ecosystems because human activity may impact biotic communities as well as physical processes.

Cave and karst processes can be affected by larger-scale drivers, such as groundwater movement and geochemistry within the South Snake Range, and processes that shape regional atmospheric temperature, humidity, and gas concentrations (e.g., CO_2). Climate change may be one pervasive stressor affecting cave systems in varying ways across the park, with potential changes in temperature and humidity being most concentrated near cave entrances. Other primary stressors to cave systems in the park include effects of visitor use, such as physical touch; looting and vandalism; inputs of lint and other organic particle debris; impacts to air and water quality from human breath, including impacts to CO_2 concentration; and the physical infrastructure required to support visitation. Changes in the taxonomic composition and abundance of the fauna that visit individual caves (e.g., bats and packrats), can affect cave and karst processes.

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[3] http://www.nwhc.usgs.gov/disease_information/white-nose_syndrome/

Data and Methods

Indicators / Measures

- *Seasonal Visitor Count*
- *Cave Temperature*
- *Cave Humidity*
- *Cave Hydrology*
- *Cave Water Quality*
- *Macroinvertebrate Composition*
- *Packrat Abundance*

A Great Basin NP geologic resources evaluation scoping meeting of December 9, 2003 identified *g*eological resources and issues for the cave and karst systems of the park (NPS 2003). That report identified key stressors, issues and concerns, and inventory needs. It resulted in the Graham (2014) geologic resource inventory report, where data and recommendations were briefly updated. Monitoring questions and specific needs for monitoring were identified, including:

- Are cave invertebrate populations stable?
- Are structural elements of the caves stable?
- Is small mammal use in caves changing?
- Is water input to caves changing?
- Is air quality in caves deteriorating?
- Is the microclimate in caves changing?
- Are soil chemistry and sediment loading within caves changing?
- Are caves used as maternity roosts and hibernacula by bat species in good condition?
- Is the incidence of cave vandalism increasing?

The Park drafted a Cave and Karst Management plan in 2004. That draft plan identifies high priority areas for resource inventory and monitoring. These include photomonitoring of cave condition, bat roost sites, water sources, microclimate, and vegetation at cave entrances, among others. Taylor et al. (2008) conducted cave invertebrate surveys in 15 caves within the park. They developed complete invertebrate composition lists, identified potential threats to invertebrate populations, developed management strategies for documented taxa, and created a database for developing GIS layers for these taxa. They also gathered baseline data on microclimate and investigated visitor use impacts on cave invertebrate composition. Hydrology associated with caves in the park has been partially addressed through studies of the hydrogeochemistry of a small number of caves (Prudic and Glancy 2009, Paul et al. 2014). A dye tracing study is currently in progress to determine if there are hydrologic linkages among caves and with springs within and surrounding the park. From the completed studies, baseline information can be evaluated for its utility in assessing resource condition. However, at this time, limited quantitative information is available to document trends in cave/karst resource condition. Data on the status of various drivers that affect cave and karst processes provide information on the likelihood of alterations.

Reference Conditions

Figure 93 provides a conceptual ecological model for the cave/karst sub-system for the park. This model integrates information from several sources, including: (1) the groundwater conceptual model presented in Miller et al. (2010); (2) the summary report of the Great Basin NP geologic resources evaluation scoping meeting of December 9, 2003 (NPS 2003); (3) the report on the cave biota the park by Taylor et al. (2008); (4) the Great Basin NP geologic resources inventory report (Graham 2014); (5) the Great Basin NP, Cave/Karst Systems website[4], including resources linked therein; and (6) the National Park Service, Cave & Karst Resources website[5]. These sources provide detailed bibliographies and links to additional publications.

The conceptual ecological model for the cave/karst sub-system shows drivers and system components in greater detail than the overarching Aquatic Resources model. The proximate drivers and system components together comprise the key ecological attributes for the model. System components consist of pivotal physical, biological, and ecological characteristics of a resource, its abundance, and its distribution. The model recognizes three types of cave biota: troglobites, species that occur only in caves, where they complete their entire life cycle; trogloxenes, species that may incidentally visit caves, e.g., for shelter, but do not require caves to complete their life cycle; and troglophiles, species that can but do not always complete their life cycle in caves (Taylor et al. 2008).

The cave/karst sub-system model specifically identifies the following sub-system components:

- Cave Pool, Stream Dynamics. This component addresses the daily, seasonal, annual, and longer-term variability in pool volume and cave stream discharge; and the composition and concentration of dissolved and suspended matter, temperature, pH in cave pool and stream water. Streams and seepages are one source of organic material entering the cave. These variables affect and are affected by cave air dynamics and troglobiotic community dynamics (see below).
- Speleothem Dynamics. This component addresses the geometry, mineralogy, and chemistry of speleothem features; and their stability and dynamism. These variables affect and are affected by cave air dynamics (see below).
- Cave Air Dynamics. This component addresses the daily, seasonal, annual, and longer-term variability in cave air temperature, humidity, and chemistry. These variables affect and are affected by cave pool and stream dynamics, and speleothem dynamics through the exchange of gases, including water vapor. Cave air dynamics also affect troglobitic, trogloxenic, and troglophilic community dynamics by shaping the suitability of cave air conditions for different species.

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[4] http://www.nps.gov/grba/naturescience/cave.htm

[5] http://www2.nature.nps.gov/GEOLOGY/caves/index.cfm

- Troglobitic Community Dynamics. This component addresses the composition, density, distribution, and interactions of the troglobitic faunal assemblage, from microbes to macroinvertebrates. These variables both affect and are affected by cave pool and stream dynamics, and trogloxenic community dynamics.
- Trogloxenic/-philic Community Dynamics. This component addresses the composition, density, distribution, interactions, visitation regime of, and matter imported by, the trogloxenic and troglophilic faunal assemblages together. Trogloxenes such as packrats (e.g., *Neotoma* spp.) and troglophiles such as bats are perhaps the most important contributors in this community. Trogloxenic and troglophilic community dynamics strongly affect troglobitic community dynamics, since the organic matter brought into caves provides essential inputs to the troglobitic food web. Trogloxenes and troglophiles in turn may feed on troglobites. Trogloxenic and troglophilic community dynamics also affect cave pool and stream dynamics, specifically water chemistry; and cave air dynamics through trogloxene/troglophile respiration and through degasing from decomposing trogloxene/troglophile wastes.

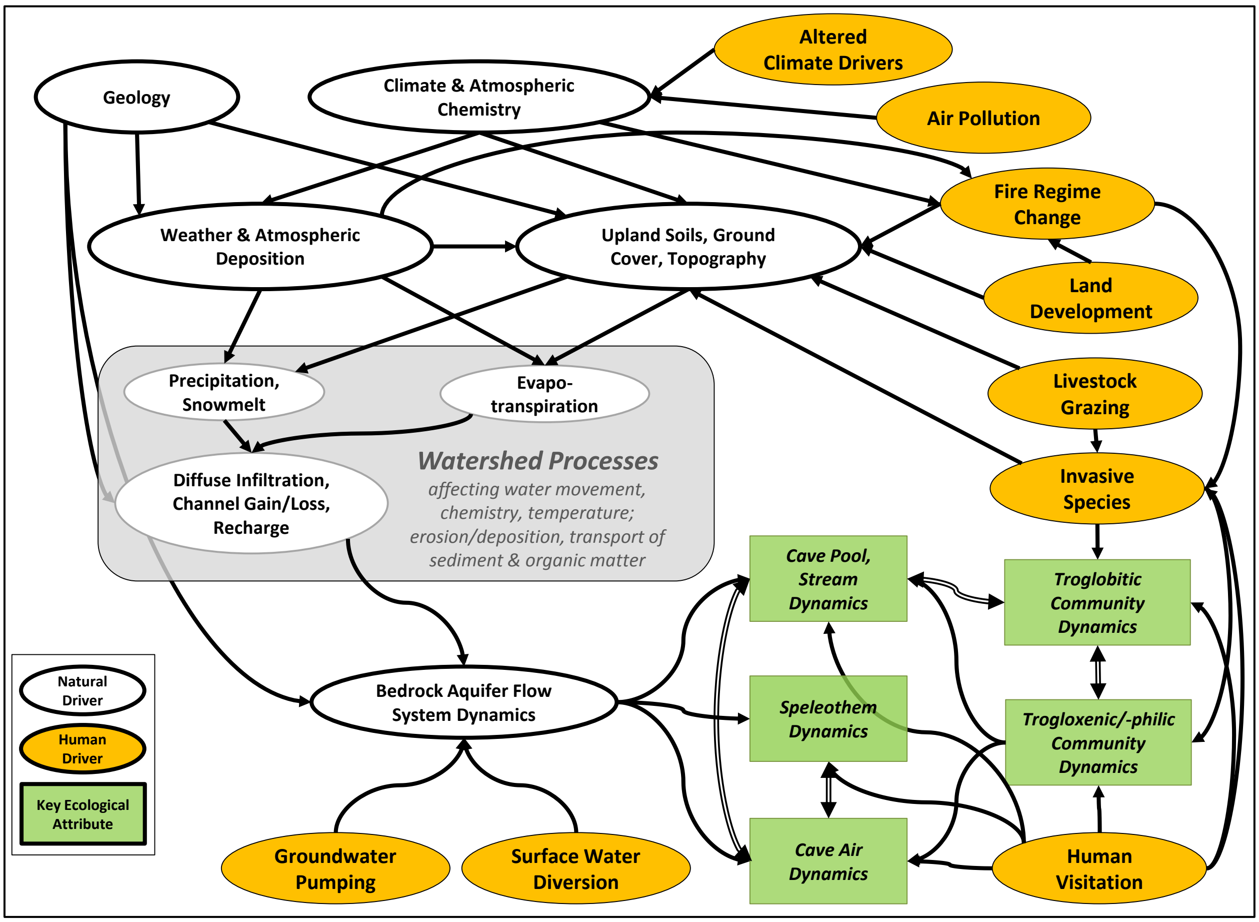


Figure 93. Cave/karst sub-system conceptual ecological model for Great Basin NP.

Proximate natural drivers that shape these system components in turn include:

- Bedrock Aquifer Pore, Micro-fracture, Macro-fracture, and Cavity Flow Systems. This comprises a set of drivers: aquifer storage; flow path geometry and duration; and the hydrogeochemistry of bedrock aquifer pore, micro-fracture, larger fracture (gravity-flow), and cavity flow systems. These affect cave systems in different ways, depending on which aquifers and which flow paths contribute to conditions in an individual cave.
- Diffuse Infiltration, Channel Gain/Loss, Recharge. This label refers to the hydrologic processes that result in water recharging to individual aquifers, all shaped by watershed processes that shape water movement, chemistry, temperature; watershed soil erosion and deposition; and the transport of sediment and organic matter. This model component includes movements of water from streams and alluvial aquifers into bedrock fractures, a form of recharge specific to stream channels. Water from upstream runoff and springs may return to the bedrock aquifer system through this form of recharge, and may contribute to the water flowing through individual caves (Prudic and Glancy 2009, Paul et al. 2014).

Finally, proximate anthropogenic drivers that shape these system components include:

- Groundwater Pumping, which can alter aquifer system storage and flow gradients in ways that alter bedrock aquifer pore, micro-fracture, macro-fracture, and cavity flows, including entirely intercepting individual flow paths (see Water Quality/Quantity, above).
- Surface Water Diversion, which removes surface water from stream channels, thereby potentially altering recharge to aquifer systems, discharges from which may contribute to water flow into and through one or more caves.
- Human Visitation, which consists of Park staff, recreational visitors, scientific investigators, and other cave explorers – a distinct trogloxenic community – and physical modifications of caves by Park management to accommodate visitation (e.g., prepared walkways, lighting). Visitor respiration can change cave air temperature, humidity, and chemistry; and organic matter carried in by visitors can alter the chemistry of cave air, waters, and surfaces. Physical contact of visitors and their belongings with cave features can alter their surface structure and chemistry of these surfaces, through both accidental and intentional contact, including vandalism and littering. Scientific investigations also can remove troglobites; and visitors can introduce non-native biota.
- Invasive Species, which can alter the composition of the trogloxenic and troglophilic communities, and thereby alter the ways in which these communities interact with the cave environment and its troglobitic community. Non-native microbes and inadvertently translocated troglobites can become parts of the troglobitic community and alter the dynamics of that community. Invasive species also can affect cave/karst systems indirectly by altering watershed ground cover and soils. White-nose syndrome has the potential to impact bat populations, which are an important part of the foodweb both in and out of caves
- Livestock Grazing, which affects cave/karst systems indirectly through its impacts on upland soils and ground cover, thereby affecting watershed processes; and by serving as a vector for the introduction of invasive plants into a locality. While livestock grazing is no longer occurring in

the park, past effects across the watersheds that recharge the groundwater associated with caves, past effects near caves, and input from grazing outside the park are possible.

- Land Development, which includes development and/or maintenance of park facilities, environmental monitoring stations, hiking trails, roads, and historic cultural features. Land development can eliminate or degrade habitat for native plants and animals; alter ground surface infiltration, runoff, and erosion patterns; and concentrate visitor activities and wastes both park-wide and immediately around cave entrances.
- Fire Regime Change, both through wildfire management and through the effects of climate change, can involve changes to the frequency, timing, and severity of wildfires. Such changes can affect cave/karst systems indirectly through their effects on the spread of invasive species and on watershed processes. Development within the park (i.e., roads, trails, and campgrounds) may affect wildfire management. Fire response, in consideration of safety and infrastructure, may include fire retardants which persist in the environment and may impact cave biota (Tobin 2015)

The model also recognizes the potential impacts of climate change and air pollution on cave/karst systems. These drivers affect cave/karst ecological conditions indirectly, through their effects on weather and atmospheric deposition, and the cascading effects of these changes on upland soils and cover, watershed processes, and the potential composition of the trogloxenic and troglophilic communities. However, many of the impacts of climate change and air pollution on cave/karst systems may emerge far more slowly than the impacts of these stressors on other ecological resources in the park because of the slow rate at which these impacts can radiate through the groundwater system.

Data on the conditions of the cave/karst sub-system components and their proximate natural and anthropogenic drivers are sparse. However, the conceptual model highlights several direct indicators of cave/karst condition that could serve as effective foci for a full condition assessment, as indicated in the following list of proposed indicators/measures of cave/karst system condition in the park. The list includes an indicator focused on seasonal visitor counts and rates of visitation to different portions of Lehman Caves. Inclusion of this indicator recognizes the possibility that visitor traffic is a source of stress to cave resources, a hypothesis warranting close study. The list of indicators also includes measures of cave temperature, cave humidity, cave hydrology, and cave water quality. The biotic response to environmental factors could be assessed through measurement of packrat abundance and the taxonomic composition, distribution, and density of troglobitic, trogloxenic, and troglophilic macroinvertebrate populations. Indirect indicators of the integrity of cave/karst processes in the park include the indicators of watershed condition and hydrology discussed above (see Water Quality/Quantity). These latter indicators address drivers of cave/karst dynamics and the likelihood of their alteration.

Condition and Trend

As noted previously, data on the conditions of the proposed indicators of cave/karst sub-system component conditions and their proximate natural and anthropogenic drivers are sparse. The following paragraphs summarize the state of knowledge for the proposed indicators.

Seasonal Visitor Count

Taylor et al. (2008) reviewed visitation statistics for Lehman Caves from fiscal years 2001-2007, documenting an average of 30,517 visitors per year. More recent statistics, gathered between 2010 and 2014, indicate an average of 27,503 people visited each year, with highest visitor count in these years of 28,110 in 2010 and lowest of 25,671 in 2014. Monthly visitor numbers peak in the June-August period, with between 4,500 and 6,500 visitors. While trends in visitor numbers are difficult to interpret, any decline in visitation could suggest a decrease of stress and a resulting improvement in condition. However, relationships between visitor number and cave/karst condition have yet to be fully documented for Lehman Caves.

Cave Temperature and Cave Humidity

Taylor et al. (2008) documented baseline values for temperature and humidity for Lehman Caves. Primary patterns in these climate variables are driven by distance from the cave opening, with increasing humidity and temperature with distance from cave opening, and decreasing variability in these measures with distance from cave opening. At distances greater than 200 feet (61 m) from the cave entrance, annual average air temperature falls between 52.7 and 54.5 °F (11.5 and 12.5 °C). Locations that are closer to cave entrances had air temperature averages between 48.6 and 53.6 °F (9.2 and 12 °C). Seasonal variation in air temperature varies from highs of over 53.6 °F (12 °C) in July and lows below 46.4 °F (8 °C) in February. At distances greater than 200 feet (61 m) from the cave entrances, annual averages for relative humidity range between 83% and 87%. Locations that are closer to the cave entrances had relative humidity averages between 72% and 85%. Given the incomplete sample of caves that these data represent, one can expect these ranges to vary with elevation and aspect of cave openings (e.g., warmed temperatures on south-facing slopes). With climate change, one can anticipate the potential for warming temperatures and drying conditions within the cave systems of the park.

Cave Hydrology

Neither of the two water quality studies for the park (NPS 2000, Horner et al. 2009) provides data on flow rates or pool depths for water samples collected from caves in the park. Prudic and Glancy (2009) and Paul et al. (2014) provide data on the likely hydrogeologic flow paths through which water reaches several caves within the park, and the likely ages of the waters that emerge within these caves or at nearby surface springs (durations of the flow paths). Prudic and Glancy (2009) specifically present data and analyses for Cave Springs, Marmot Spring, and Lehman Caves; and Paul et al. (2014) present data and analyses for Model Cave and nearby springs in the Baker Creek drainage and Squirrel Spring Cave and nearby springs in the Snake Creek drainage.

The reports by Prudic and Glancy (2009) and Paul et al. (2014) show that the water emerging in the sampled caves originated largely as upland recharge years to decades earlier. However, the reports provide limited data on cave water flow and/or pool depths at single dates and times, rather than data on the range of variation in cave water discharge and pool depths. Long-term monitoring is needed to establish baseline data on cave hydrology. In general, however, longer groundwater flow paths, and flow paths with multiple branches and tributaries, tend to even out the effects of inter-annual variation in recharge, and so produce more stable discharge rates. Caves that receive water in part from groundwater recharged along streams tend to show greater inter-annual variation.

Cave Water Quality
The two water quality studies for the park (NPS 2000, Horner et al. 2009) do provide data the chemistry of water samples collected from caves in the park, 1966-1998 and 2006-2007. Prudic and Glancy (2009) and Paul et al. (2014) subsequently collected additional data on cave water chemistry. Lehman Caves, Model Cave, and Squirrel Springs Cave are the most commonly sampled caves among these four studies. However, collectively, these reports provide data on cave water quality for very small numbers of samples scattered over time from inconsistent locations within the sampled caves, rather than data on the range of variation in cave water chemistry over time at fixed sampling stations. Long-term monitoring is needed to establish baseline data on cave water quality. In general, however, longer groundwater flow paths tend to even out the effects of inter-annual variation in the water quality of recharge. Long flow paths tend to produce waters in equilibrium with the geochemistry of the aquifer(s) contributing to discharges, and so produce more stable water chemistries at their points of discharge. Caves that receive water in part from groundwater recharged along streams tend to show greater inter-annual variation.

Macroinvertebrate Composition
Taylor et al. (2008) documented 155 macroinvertebrate taxa from 22 caves. The majority of unique taxa were located at a single site. These single site-localities reflect both taxa not normally found in caves, along with narrowly endemic cave taxa. Patterns in taxonomic diversity (2-10 taxa) and number of specimens (20-120 specimens) gathered in samples varied with distance from cave entrances; with lower numbers found with increasing distance into the cave. These patterns resemble those observed for cave temperature and humidity. Higher numbers of specimens (but not taxa) occur during September-January than the May-July period; mostly explained by grey springtails and white springtails. Grey springtails are considered less cave-adapted (troglophiles) are more abundant closer to cave entrances, whereas white springtails are more cave-adapted (troglobites) and found deeper into caves.

Taylor et al. (2008) analyzed the patterns in abundance of specimens relative to visitor trails within Lehman Caves, for selected taxa common to that cave system, but detected no significant trends. Sampling that accounted from distance from trails used by visitors also detected no pattern to indicate an effect by trail usage. These findings contrast with those from a study at Carlsbad Caverns National Park using the same sample design that detected significant differences in biota between high and low usage areas. However, the analysis of the Lehman Caves data identified two taxa important to cave managers – *Microcreagris grandis*, a troglobitic pseudoscorpion; and a white millipede (*Nevadesmus ophimontis*) – were both notably more abundant with greater distance from visitor trails. Taylor et al. (2008) concluded that the age of the trail, low percentage of cave substrate covered by asphalt, combined with well-trained cave tour guides (to minimize off-trail travel, food, and trash) and large seasonal breaks in visitors, contributes to maintaining good resource conditions in Lehman Caves.

Packrat Abundance

Given their significance to troglobite energetics, the introduction of organic material from packrats could form an important focus for measuring ecological condition of caves in the park.

About 20 species of woodrats (genus *Neotoma*), also known as pack rats, cave rats, cliff rats, and other common names, inhabit a wide variety of habitats throughout North America. Many of these species use caves. Woodrats are nest builders, using a variety of plant materials to make nests, called middens. Some of these middens have been important to paleoecologists. Woodrats are generally considered trogloxenes but, like some species of bats, can be troglophilic in certain locations using clifflines, hollow trees, debris piles, and man-made structures as shelter.

The most studied woodrats in NPS caves are Allegheny woodrats (*Neotoma magister*), a native species in the eastern United States. They are primarily nocturnal and territorial species so they are usually solitary, except when mating and raising young. After a mother gives birth, the young stay for two to four months. Then the mother ejects the young, or a youngster may force the mother and other young out of the nest. Generally one or two woodrats may be found around a single cave entrance area. In the East they are found in the woods and often associated with rocky habitat. In the Midwest and Southeast where rocky habitat is scarce, they may be found near fence rows, shrubs, and trees. They can move long distances (2.2 miles (3.5 km)) to look for mates, but they usually forage within 656 feet (200 m) of the entrance to obtain food. Some stay even closer, going less than 164 feet (50 m) to find the food they need. Males tend to have larger home ranges than females. In the last 35 years, there has been a noted decline in the northeastern portion of their range. Several states have listed Allegheny woodrats as threatened or endangered, and the US Fish and Wildlife Service has them listed as species of concern (NatureServe global rank of G3-G4; vulnerable to apparently secure).

Woodrats, a facultative species that come and go, provide a good link between surface and subsurface ecosystems. They use caves primarily as shelter and incidentally supplement the cave environment with an input of organic material. Even one woodrat can greatly add to the organic material in a cave. Woodrats generally do not venture far into the cave, but have been known to travel hundreds of feet from an entrance. Fresh woodrat sign far from any known entrance usually indicates that a woodrat-sized entrance is nearby. Woodrats build a nest (sometimes concealed by a house/den made of sticks or bark) out of vegetative material, such as finely shredded bark or grass. They distribute dried leaves around the nest, possibly so that anything that approaches the nest will make noise. Woodrats often gather bones and shiny objects from outside of caves, which they incorporate into their nests. Woodrats use the nest for sleeping and rearing young. In the West, woodrats sometimes use juniper which may have a repellant effect on some fleas and other organisms. Woodrats tear down and rebuild nests fairly frequently. Their food sources, including nuts, fruits, berries, flowers, fungi, green vegetation, along with any leaf litter and sticks they bring in, provide a food source for cave organisms. Woodrats establish a separate latrine area, and guano deposited there is important. Several cave invertebrate communities have been found utilizing these latrine areas; these guano dependent organisms include: fungus gnats, predatory beetles, bacteria, and more. Occasionally woodrats die in caves and provide a large nutrient input to cave organisms. Woodrats often use the same middens and latrines over many generations. They are able to travel through dark cave passages by following urine trails. These trails can become polished when used for multiple generations.

In addition to the threats facing most terrestrial cave-dwelling creatures, woodrats face some additional ones. These include raccoon roundworm parasite; chestnut blight (at one time American chestnuts made up 25% of canopy in areas); sudden oak decline and gypsy moth leading to a decrease in supply of key food sources (i.e., acorns).

Both direct and indirect methods can be used to survey woodrats. The most common direct technique is to mark/recapture woodrats using live traps. Woodrats can then be ear tagged (although some ear tags may be lost) or have an ear tattooed. While the woodrat is in hand, it can be sexed, weighed, checked for age class, checked for ectoparasites, assessed for overall health and reproductive condition. Woodrats are easily caught in live traps, but it should be noted that due to low density, a large number of traps must be used in order to get meaningful data (Woodman et al. 2007).

Indirect methods for surveying woodrats include:

- Scat monitoring, which is used by the Klamath Network (Krejca et al. *forthcoming*) provides a method for populations surveys. For this protocol, they monitor scat deposition, mostly from rodents but also from other mammals and birds. The timed area searches used to detect scat are fairly simple, requiring minimal training or equipment, and they provide valuable information on the consistency and amount of nutrient inflows that support cave communities.
- UV light for looking at woodrat urine
- Tracking boards to determine if a woodrat is entering a cave
- Trail cameras to photograph woodrat use of a cave

The bushy-tailed woodrat (*Neotoma cinerea*), thought to be historically abundant within Great Basin NP along Baker Creek, were not found in in significant numbers at lower elevations of the park in 2000 (Rickart et al. 2008).

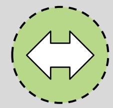
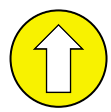
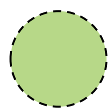
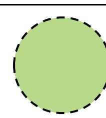
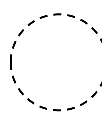
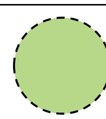
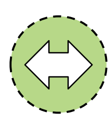
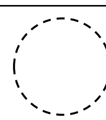
Summary of Status

Table 67 summarizes the results for the indicators used to assess the condition of cave and karst processes in the park.

The indicators assessed for water quality and quantity for the park overall (see above, Water Quality/Quantity) can be used to supplement the limited information on indicators specific to the caves in the park. The indicators for watershed landscape condition, riparian corridor landscape condition, atmospheric deposition, snowpack condition, and in-Park diversions address potential alterations to drivers that affect cave and karst processes, including upland and streamside recharge rates and chemistry. None of these indicators points to less than good, stable conditions for these drivers. Similarly, data on the overall incidence of exceedance of water quality standards point to stable or improving water quality in the park in general since the 1966-1998 study period (NPS 2000). These findings suggest that cave/karst processes in the park are not presently impaired or threatened by trends of impairment to any watershed-scale drivers affecting Park hydrology or water quality overall.

Finally, factors to consider for monitoring of cave condition into the future include: (a) negative impacts from human visitation; (b) changes in energetic inputs caused by changing vegetation, groundwater flow, and/or packrat and bat communities; and (c) changes in cave climate, energy flow, and cave dwellers access due to cave gating.

Table 67. Summary of indicators for condition of cave and karst processes for Great Basin NP.

Cave and Karst Processes			
Indicators of Condition	**Specific Measures**	**Condition Status/Trend**	**Rationale**
Seasonal Visitor Use	Monthly visitor count		Stable or slightly downtrending annual visitor count, with 5-7,000 cave visitors per month from June-August.
Cave Temperature	Data logger measures from locations throughout a subset of caves		Baseline data exist, but trend data are lacking
Cave Humidity	Data logger measures from locations throughout a subset of caves		Baseline data exist, but trend data are lacking
Cave Hydrology	Dye tracing study results and subsequent measures within caves and at connected discharge sites.		Scattered baseline data exist, but trend data are lacking
Cave Water Quality	Ions, turbidity, and other measures from cave pools		Scattered baseline data exist, but trend data are lacking
Macroinvertebrate Composition	Sample records of taxonomic composition, diversity, abundance, and presence of sensitive taxa		Baseline data exist, initial indications are that conditions are good
Packrat Abundance	Measured through organic accumulation in middens		Baseline and trend data are lacking

Sources of Expertise

Dale Pate, NPS National Cave and Karst Coordinator

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Gary Karst, NPS Pacific West Region, Regional Hydrologist

Gretchen Baker, Ecologist, Great Basin NP

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4.3.6. Springs

Indicators / Measures

- *Spring Discharge*
- *Spring Water Quality*
- *Spring Pool Margin Fauna and Flora*
- *Spring Pool Fauna*
- *Spring Modifications and Diversions*
- *Invasive Species*

Condition - Trend

Good – Unchanging – Medium Confidence

Background and Importance

Great Basin NP contains over 425 perennial springs and seeps, based on a survey in 2003-2004. Figure 94 shows the distribution of springs in the park. As discussed in Section 4.3.1, above, individual springs and seeps may be fed by either shallow or deep groundwater sources; and their outflow in turn often contributes significantly to stream flow. Springs may be singular or occur in tight clusters with multiple orifices, termed spring complexes. Springs and seeps may flow only seasonally or year-round; and have an average water temperature of 45 ± 5.5 °F (7.2 ± 3.1 °C). They attract a wide range of land animals: the survey in 2003-2004 found signs of animal visitation at nearly 90% of all springs in the park (Baker 2007). Springs also often provide habitat for distinct assemblages of aquatic organisms, particularly invertebrates. The inventory conducted in 2003-2004 found mollusks in 12% of all springs in the park, including *Pyrgulopsis kolobensis*, a type of springsnail, *Valvata humeralis*, a type of snail, and pea clams, *Pisidium* spp.

The springs in the park have long attracted human activities. The 2003-2004 inventory found human disturbances in the immediate vicinity of nearly 17% of the springs in the park, including roads, trails, and livestock trampling. Nearly half of these springs with human disturbances in their immediate vicinities (7% of all springs in the park) had adjacent cultural features such as water troughs, fencing, or historic cabins; or had evidence of development for water use such as pool enlargements, walls, or diversions.

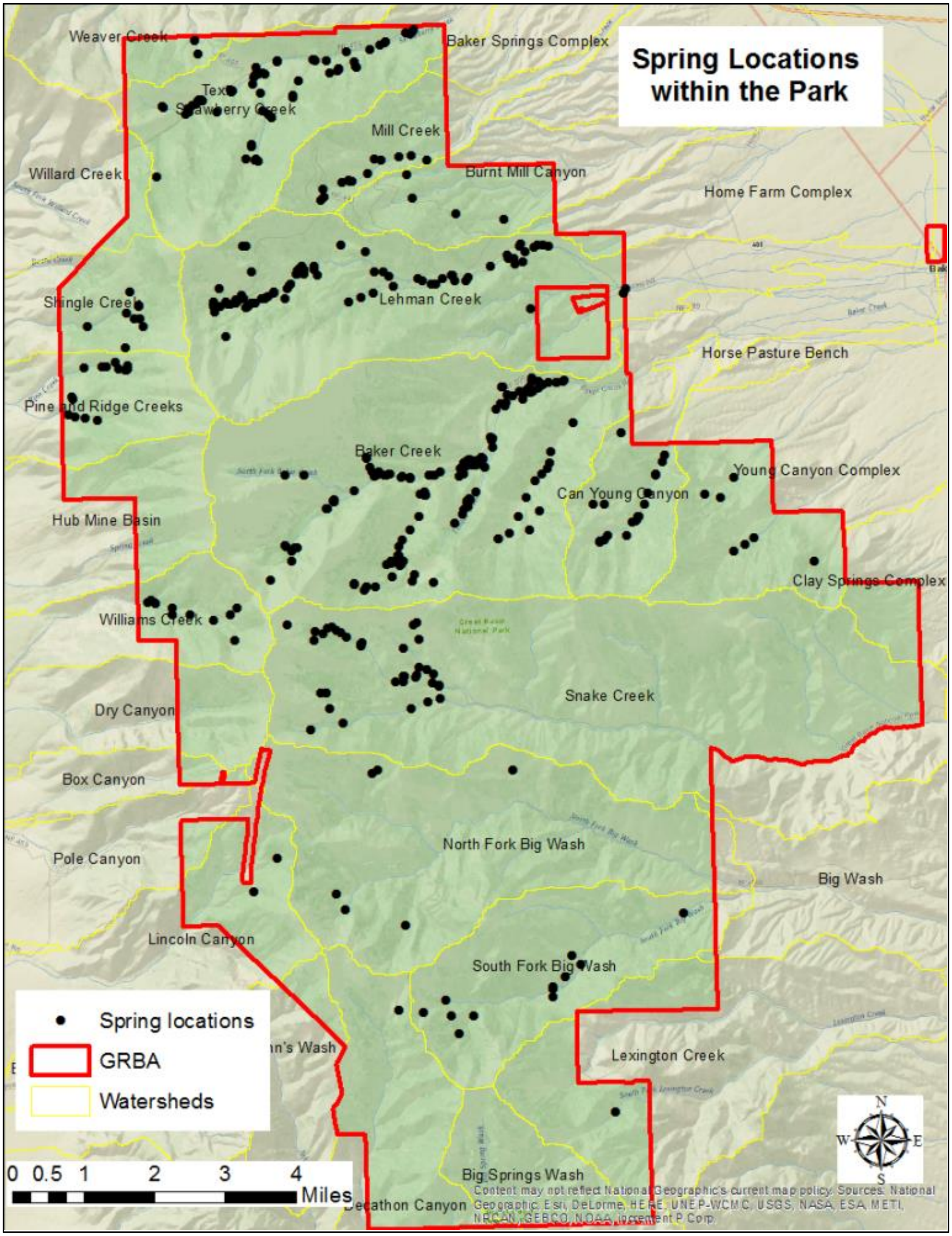


Figure 94. Locations of springs in Great Basin NP.

Data and Methods

Indicators / Measures

- ***Spring Discharge***
- ***Spring Water Quality***
- ***Spring Pool Margin Fauna and Flora***
- ***Spring Pool Fauna***
- ***Spring Modifications and Diversions***
- ***Invasive Species***

Figure 95 shows the conceptual ecological model for the spring sub-system for the park. The model shows natural and human drivers and other sub-system components in greater detail than the overarching Aquatic Resources model. The sub-system components together comprise the key ecological attributes for the sub-system. As discussed in Chapter 3, key ecological attributes include defining characteristics of an ecological resource, its abundance, and its distribution; and key environmental associations, drivers, and constraints that strongly affect the characteristics, abundance, and distribution of the resource. In turn, the key ecological attributes for the sub-system point to the need for indicators, with which to assess the condition of the key ecological attributes.

The spring sub-system model integrates information from two sources: (1) the Spring conceptual model presented in Miller et al. (2010); and (2) the Great Basin Springs and Seeps conceptual model presented in Comer et al. (2013). Unnasch et al. (2014) also summarizes key features of the Great Basin Springs and Seeps conceptual model. These sources provide detailed bibliographies. Following Miller et al. (2010), the model differentiates between spring orifices and pools. Orifices are discrete geologic openings from which water emerges from the groundwater system to the land surface, including submerged locations. Water discharging through spring orifices emerges from groundwater systems, as yet little affected by air and water temperature and pressure at the land surface or by interactions with water from other sources. Pools are surface headwater features within which spring water spends a measurable residence time, fed by discharge from one or more spring orifices and also potentially by diffuse runoff from the surrounding land. Water temperature and chemistry in pools are shaped by the interaction of the discharging groundwater with the open air, and by inputs of dissolved and particulate matter from the surrounding land and vegetation. However, not all springs have pools. Springs may discharge to a stream or into a wetland, which in turn may or may not be connected to a larger stream further downslope. Springs that discharge directly into a stream below the water surface do not form pools; their discharge immediately becomes a part of the stream flow.

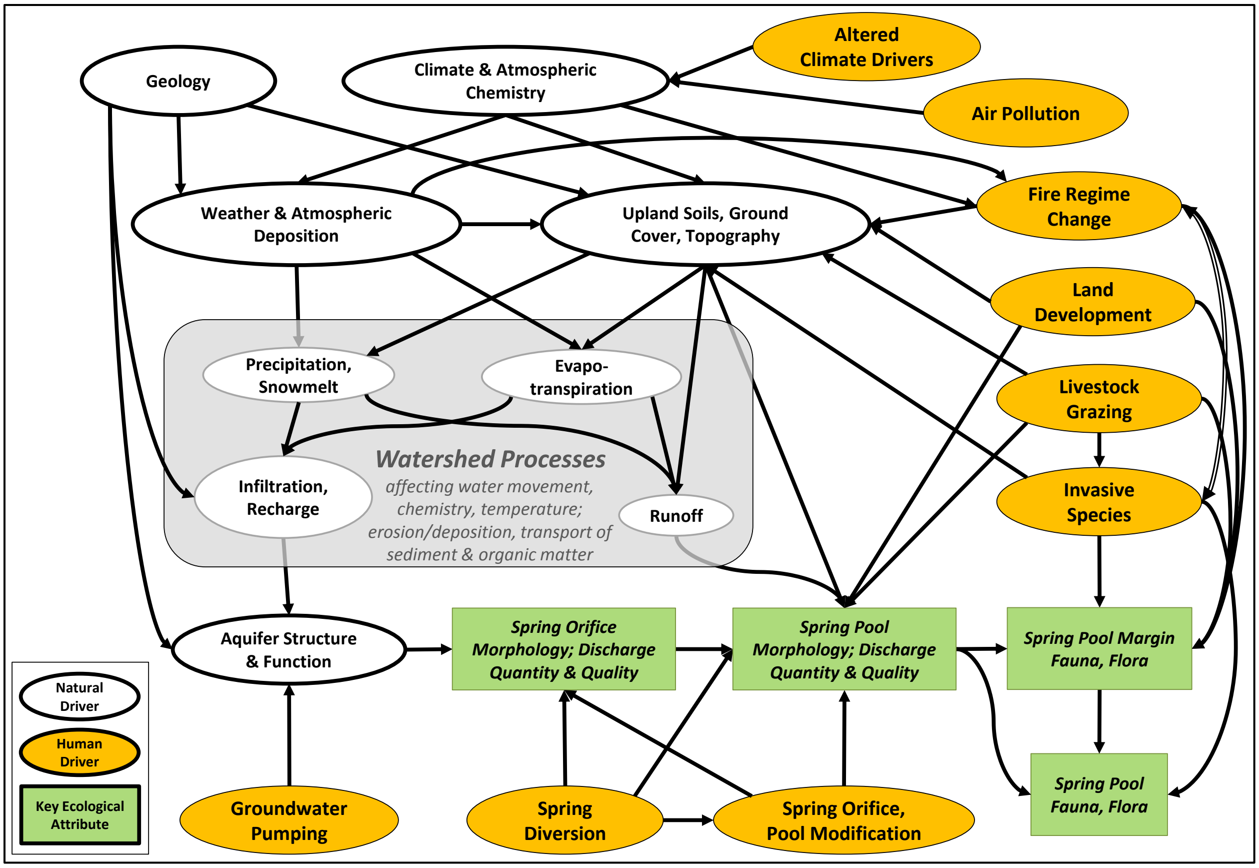


Figure 95. Spring sub-system conceptual ecological model for Great Basin NP

The spring sub-system model specifically identifies the following key ecological attributes:

- Spring Orifice Morphology; Discharge Quantity & Quality. This key ecological attribute concerns the morphology and stability of the spring orifice; and daily, seasonal, annual, and longer-term variability in its discharge, solute composition, temperature, and pH. These variables affect spring pool characteristics.
- Spring Pool Morphology; Discharge Quantity & Quality. This key ecological attribute concerns the morphology and stability of the spring orifice; and daily, seasonal, annual, and longer-term variability in its discharge, solute composition, temperature, and pH. These variables affect each other and also affect the biotic communities of the spring pool and pool margin.
- Spring Pool Margin Fauna, Flora. This key ecological attribute concerns the composition and density of the faunal and floral assemblages around the spring pool margins. These variables are shaped by spring pool volume, discharge quantity, and water quality; and by spring orifice and pool morphology. They are also affected by watershed dynamics including the fire regime, land development and grazing at spring sites, and invasive species.
- Spring Pool Fauna, Flora. This key ecological attribute concerns the distribution, biomass, composition, and interactions of the biota living in spring orifices and pools, including algae and emergent vegetation; fishes; and macroinvertebrates and zooplankton. These variables are shaped

by spring pool volume, discharge quantity and quality; spring orifice and pool morphology; and spring pool margin fauna and flora.

Natural drivers that most directly and strongly shape these key ecological attributes for the sub-system include:

- Aquifer Structure and Function. This driver encompasses several factors: aquifer permeability and storage; and flow path length, duration, and hydrogeochemistry. These several factors together determine spring orifice discharge quantity and water quality.
- Runoff. Watershed runoff – including diffuse runoff and ephemeral channel flow – delivers surface water, sediment, particulate organic matter, and dissolved inorganic and organic matter into spring pools. Runoff into spring pools strongly shapes extreme high-stage events within pools and overbank flooding of the spring pool margin, factors that together help shape pool morphology and the biotic community of the pool margin.
- Upland Soils, Ground Cover, Topography. This driver affects the spring sub-system directly by determining the soil matrix in the vicinity of each spring, and therefore helping shape pool morphology. It also affects the spring sub-system indirectly, through its effects on watershed processes that shape water movement, chemistry, temperature; watershed soil erosion and deposition; and the transport of sediment and organic matter; and through its effects on the spread of upland wildfires into the pool margin.

The human drivers that most directly and strongly shape the key ecological attributes for the sub-system include:

- Groundwater Pumping, which can alter aquifer system storage and flow gradients in ways that alter groundwater discharge to springs, including entirely eliminating such discharges.
- Spring Diversion, which removes water directly from spring orifices and pools, thereby altering the proportion of their discharge available to support ecological processes. Spring diversion also reduces the flow of spring water into stream channels, thereby potentially altering recharge to aquifer systems, groundwater discharges from which might otherwise later emerge at one or more other springs.
- Spring Orifice, Pool Modification, which reshapes orifice and/or pool morphology to better suit human use of the spring zone, for example to make it easier to divert spring water or to stabilize pool geometry and margins in areas of intensive recreational activity.
- Invasive Species, which alter the composition of the spring pool and pool margin biotic communities. Invasive species also can alter ecological processes such as herbivory around pool margins; predation on native pool species; competition for food and habitat among native pool fauna; the structure of the aquatic food web; evapotranspiration; and pool margin soil chemistry and stability. Invasive species also can affect spring systems indirectly by altering watershed ground cover and soils.
- Livestock Grazing, which can alter pool margin vegetation and soils, and alter pool morphology through trampling. Livestock grazing also can affect spring systems indirectly through its impacts

on upland soils and ground cover, thereby affecting watershed processes; and by serving as a vector for the introduction of invasive plants into a locality.

- Land Development, which includes development and/or maintenance of park facilities, environmental monitoring stations, hiking trails, roads, and historic cultural features both park-wide and immediately around individual springs. Land development can eliminate or degrade habitat for native plants and animals; alter ground surface infiltration, runoff, and erosion patterns; and concentrate visitor activities and wastes.
- Fire Regime Change, both through wildfire management and through the effects of climate change, can involve changes to the frequency, timing, and severity of wildfires. Such changes can affect pool margin vegetation, both directly through changes in its wildfire regime and indirectly through the effects of upland wildfire on the spread of invasive species. Fire regime changes also affect spring systems indirectly by altering watershed processes, such as evapotranspiration. The spread of some invasive plant species may alter the fire regime; and changes in fire regime due to wildfire management and the effects of climate change may affect the spread of some invasive plant species as well as succession within natural vegetation communities.

The model also recognizes the indirect impacts of climate change and air pollution on the spring sub-system. These long-term, large-scale human drivers affect spring ecological conditions through their effects on weather and atmospheric deposition, and the cascading effects of these changes on upland soils and cover and watershed processes.

The key ecological attributes and human drivers for the spring sub-system point to the need for indicators of spring discharge and water quality, pool and pool margin fauna and flora, groundwater pumping, spring diversions and other modifications, and invasive species. Changes to the fire regime affecting springs can be assessed through indicators of the fire regime condition class for the riparian corridors of the park, which encompasses all the spring locations in the park. Section 4.3.3, Montane Riparian Woodlands, above, provides this information.

Section 4.3.2, Water Quality/Quantity, above, discusses the hydrogeology of Great Basin NP, the varying sources of the water that emerges at springs in the park, and the history of sampling of water quality at springs in the park (NPS 2000, Elliott et al. 2006, Baker 2007, Flint and Flint 2007, SNWA 2008a, Horner et al. 2009, Prudic and Glancy 2009, Heilweil and Brooks 2011, Paul et al. 2014). As discussed there, the water that emerges at springs within the park consists of water that fell originally as rain or snow across the South Snake Range. Some of that water infiltrates directly into bedrock fracture systems within the Range, and some runs off to become stream flow, from which it subsequently may infiltrate into alluvial gravels along the stream courses. In turn, the water in the bedrock and alluvial aquifers may emerge at springs and seeps at lower elevations within the park, either at the ground surface or within caves. The remainder of the alluvial and bedrock groundwater in the South Snake Range flows further downward to emerge at springs and seeps outside the park, or to recharge regional aquifers (Elliott et al. 2006, Flint and Flint 2007, Heilweil and Brooks 2011).

As also discussed in Section 4.3.2 above, the chemistry and temperature of the water in surface springs in the park varies depending on six broad, interrelated factors: (1) where precipitation falls across the park; (2) the mineralogy and permeability of the upland soils, alluvial soils, and/or bedrock formations into which the resulting surface water infiltrates; (3) the sometimes complicated paths that this infiltrated water follows through these upland soils, alluvial soils, and/or bedrock formations, under the force of gravity, including flows back and forth between surface streams and alluvial aquifers, and between alluvial and bedrock aquifers; and (4) the length of time the water spends in contact with the open air, and in contact with these different soils and bedrock formations, before emerging at a spring or seep. Water that enters the hydrologic system of the park as snowmelt tends to produce or maintain colder temperatures in springs inside the park. Similarly, water that spends a longer portion of its time as groundwater tends to produce more stable spring water temperatures. Additionally, water that spends more time as groundwater before emerging at a spring, and groundwater that flows through bedrock formations with more chemically reactive minerals, tend to produce spring waters with more complex chemistries and higher concentrations of dissolved minerals (Prudic and Glancy 2009, Paul et al. 2014). Each spring in the park discharges water that has followed a unique path through the surface and/or subsurface hydrogeologic systems of the park. Each spring in the park therefore has a unique natural pattern of discharge, temperature, and chemistry.

The 2000 National Park Service review of water quality data from the park from 1966 to 1998 (see Section 4.3.2 above) included several observations of spring water quality, temperature, and discharge (NPS 2000). These data contain 315 observations across 42 spring sampling locations, for water chemistry parameters for which water quality criteria exist for aquatic life use support. The data from 1966-1998 also contain 33 observations of spring discharge, one at each of 33 spring locations scattered across the entire 33 years of data; and 345 observations of spring water temperature across 61 spring locations. Most (N=216) of the observations of spring water temperature, 1966-1998, are from a single site, Cave Springs, with an average of roughly two observations per spring among the remaining 60 springs. As also discussed in Section 4.3.2, however, with the exception of field-measured pH, it is difficult to compare the data from 1966-1998 to more recent data on water chemistry in springs in the park due to differences in field and laboratory methods.

Elliott et al. (2006) collected a continuous record of discharge at Rowland Spring, a tributary to Lehman Creek, from 09/2002 to 09/2004 (http://waterdata.usgs.gov/nwis/dv/?site_no=10243265&agency_cd=USGS&referred_module=sw); and conducted synoptic surveys of discharge from the spring on 07/22 and 10/07 of 2003. The NPS teams that inventoried the springs in the park in 2003-2004 measured spring discharge and collected basic water quality field measurements at every spring where physically feasible (Baker 2005, 2007). In turn, the subsequent baseline water quality study of the park in 2006 and 2007 collected water samples from 34 springs for laboratory analysis (Horner et al. 2009). Section 4.3.2.2, above, discusses the data and methods used to analyze these water quality measurements, specifically to assess the incidence of exceedances of water quality criteria for aquatic life-use support.

Section 4.3.2.2, above, also discusses the data requirements for analyzing continuous time-series data from streams, with which to assess basic patterns of daily, seasonal, and annual variation in flow regimes; and for comparing these patterns between different periods. As noted above, statistically reliable estimates of all but the most basic characteristics (e.g., average annual discharge) of the flow regime for a single location, for a single time period, typically require three or more decades of continuous records (Henriksen et al. 2006, TNC 2009, Kennard et al. 2010). Reliably identifying statistical trends in characteristics of the flow regime correspondingly requires even more years of data. These same considerations apply to the analysis of discharge data from springs; and to the analysis of temperature data from both streams and springs. Additionally, the park contains a wide diversity of springs, with differing hydrogeologic sources. Against these standards, the data on discharge collected between 1966 and 1998; by Elliott et al. (2006); by the NPS inventory teams in 2003-2004; and by the NPS in 2006-2007 inventory do not yet comprise a sufficient body of data with which to assess basic patterns of daily, seasonal, and annual variation in flow regimes, let alone trends in flow characteristics, for any single spring within the park – let alone for the different kinds of springs present in the park.

However, several of the indicators addressed in the Water Quality/Quantity resource assessment, in Section 4.3.2 above, address the likelihood of alterations to the overall hydrology of the park – alterations that potentially could affect discharge at springs across the park. These indicators address Snowpack Condition, a major driver of both groundwater recharge and stream flow across the South Park Range; and aspects of Watershed Landscape Condition, which could affect watershed hydrology, including the relative rates of infiltration versus runoff versus evapotranspiration.

The 2003-2004 inventory teams recorded very limited information on fauna and flora in the spring pools and around their margins. This information consisted of observations of vegetative community type; dominant trees, shrubs, and herbs/forbs; and the presence/absence of mollusks (Baker 2007; G. Baker, Great Basin NP, personal communication October 2014). The project also submitted mollusk samples from five springs for formal identification. In turn, monitoring teams for the subsequent baseline water quality study of the park collected representative samples of aquatic macroinvertebrates from seven springs in 2007 (Horner et al. 2009). Following taxonomic identification of the aquatic macroinvertebrate samples, the results were converted to simple indexes of taxonomic richness and diversity. Such indexes are common tools for assessing impacts of human disturbance on water bodies, comparing sample richness and diversity to index values obtained from reference sites. Unfortunately, insufficient data exist with which to characterize reference conditions for aquatic vegetation or macroinvertebrates in springs in the park. The park archives contain data on macroinvertebrates sampled from Rowland Spring in the 1990s and in 2007 (Gretchen Baker, Great Basin NP, personal communication, December 2014). However, these data concern only a single spring among hundreds with widely varying hydrology and chemistry; and the earlier Rowland Spring sample does not necessarily represent reference conditions.

The macroinvertebrate data from 2003-2004 also do not include detailed macroinvertebrate taxonomic identifications for most springs; and the macroinvertebrate data from the 2007 samples represent only seven springs in a single year. The park sent snails from 2003-2004, from springs in the Baker Creek and Snake Creek watersheds, to a malacologist for identification. The samples were reported to consist of two native species: *Valvata humeralis* (glossy valvata) in both watersheds, and *Pyrgulopsis kolobensis* (Toquerville springsnail) in the Snake Creek watershed. However, the specimens sent for identification do not constitute representative samples of mollusks from springs in the park; other spring mollusks recorded during the 2003-2004 inventory include pea clams, *Pisidium* spp. Consequently, it is not yet possible to assess the condition of the aquatic flora or fauna of the spring pools in the park. The monitoring data from the park similarly do not yet support an assessment of the abundance, distribution, taxonomy, or impacts of invasive species in the springs of the park.

Section 4.3.2, above, includes a review of the threats to streams and springs inside the park posed by potential groundwater pumping outside the park. These data can be used to identify springs that lie within areas likely or potentially vulnerable to hydrologic alteration by groundwater pumping in Spring and Snake valleys (Elliott et al. 2006, Baker 2007). The 2003-2004 inventory also identified springs affected by diversions or dams. Finally, the indicator of fire regime condition class for the montane riparian woodlands in the park, presented in Section 4.3.3, above, provides information on changes in vegetation structure along the riparian corridors of the park, in which the vast majority of springs occur.

<u>Reference Conditions</u>

As noted above, the springs in the park emerge from a great diversity of geologic settings. As a result, they naturally differ in their hydrology and chemistry. The identification of reference conditions for water quality and quantity among the springs in the park must take into account this natural variability. Data do not yet exist to classify the springs in the park into types based on their patterns of discharge, temperature, and chemistry, let alone to estimate reference conditions for these types. Water quality criteria for aquatic life-use support provide a “one size fits all” basis for identifying reference conditions. However, the U.S. EPA National Water Quality Criteria were developed largely with reference to stream and lake ecosystems (USEPA 2014). Their interpretation for springs must be qualified, because springs with consistently distinct water chemistries may develop distinct aquatic biota adapted to their unique chemistries. Similarly, as noted above, sufficient data do not yet exist with which to estimate reference conditions for the taxonomic composition and abundance of aquatic fauna or flora in the springs of the park, including the identification and abundance of invasive species.

On the other hand, Section 4.3.2, above, discusses indicators for assessing potential threats to spring discharge and chemistry in the park arising from either: (a) changes in snowpack condition, watershed condition, atmospheric deposition, and groundwater pumping outside the park boundaries; or (b) the presence of dams and diversions at springs. Reference conditions for these threat-based indicators simply consist of an absence of evidence for the relevant threats and/or modifications. Section 4.3.3, above, discusses the definition of reference conditions for fire regime condition class for montane riparian woodlands in the park. Finally, merely the presence of any non-native (invasive) species in springs in the park is here considered sufficient to warrant a rating of Moderate Concern, since such species can spread easily.

Condition and Trend

In the absence of sufficient data to directly assess spring discharge conditions across the park, threat-based indicators for park-wide hydrologic conditions (see Section 4.3.2, above) provide a basis for assessing this indicator. As discussed in Section 4.3.2.4, there is no evidence for changes in Snowpack Condition or Watershed Landscape Condition that would point to changes in Park hydrology – specifically to changes in watershed-scale groundwater recharge.

The data on water quality exceedances, presented in Section 4.3.2.4, (Table 51) show that pH measurements between 1966 and 1998 fell outside the acceptable range in more than 23% of the measurements in springs, and all these exceedances fell below the minimum acceptable threshold of 6.5 standard units. In turn, the more recent data (Table 52) show that pH measurements did not fall outside the acceptable range of variation in any of the 50 samples taken during 2006-2007. These results indicate a rating of Good for water quality at spring sites for this time period.

Additionally (see Table 52, Section 4.3.2.4), the samples collected in 2006-2007 exceeded water quality criteria only for DO and Lead, and did so in only 4% of all spring samples. These results indicate a consistent rating of "Good" for water quality at spring sampling locations for this more recent time period.

Further information on water quality in springs comes from studies by Prudic and Glancy (2009) and Paul et al. (2014), as also discussed in Section 4.3.2.4, above. These studies present data on water chemistry in spring discharges likely to be unaffected by pollution, indicating that copper may occur naturally in spring samples at concentrations up to 1.1 μg/L (Paul et al. 2014) and iron up to 0.311 μg/L (Prudic and Glancy 2009). These cations derive from reactions of groundwater with the mineralogy of the South Snake Range. Neither Prudic and Glancy (2009) nor Paul et al. (2014) recorded any samples with concentrations of copper or lead that exceeded their respective water quality criteria; and neither recorded many samples with even detectable concentrations of cadmium, lead, selenium, or zinc. They also sometimes observed low concentrations of dissolved oxygen in waters emerging at springs in caves.

As noted in Section 4.3.2.4, above, the areas identified by Elliott et al. (2006) as likely vulnerable to the effects of groundwater pumping in Snake Valley include large portions of lower Lehman Creek, Baker Creek, and Can Young Canyon, and Snake Creek immediately at the park boundary. In addition, one area identified by Elliott et al. (2006) as potentially vulnerable to the effects of groundwater pumping in Snake Valley extends up Snake Creek nearly to the pipeline inlet. As shown in Figure 96, 27 springs occur in these areas of likely or potential vulnerability, including 15 along lower Lehman Creek (one directly at the park boundary), 11 along lower Baker Creek and its tributaries, and one along Can Young Canyon.

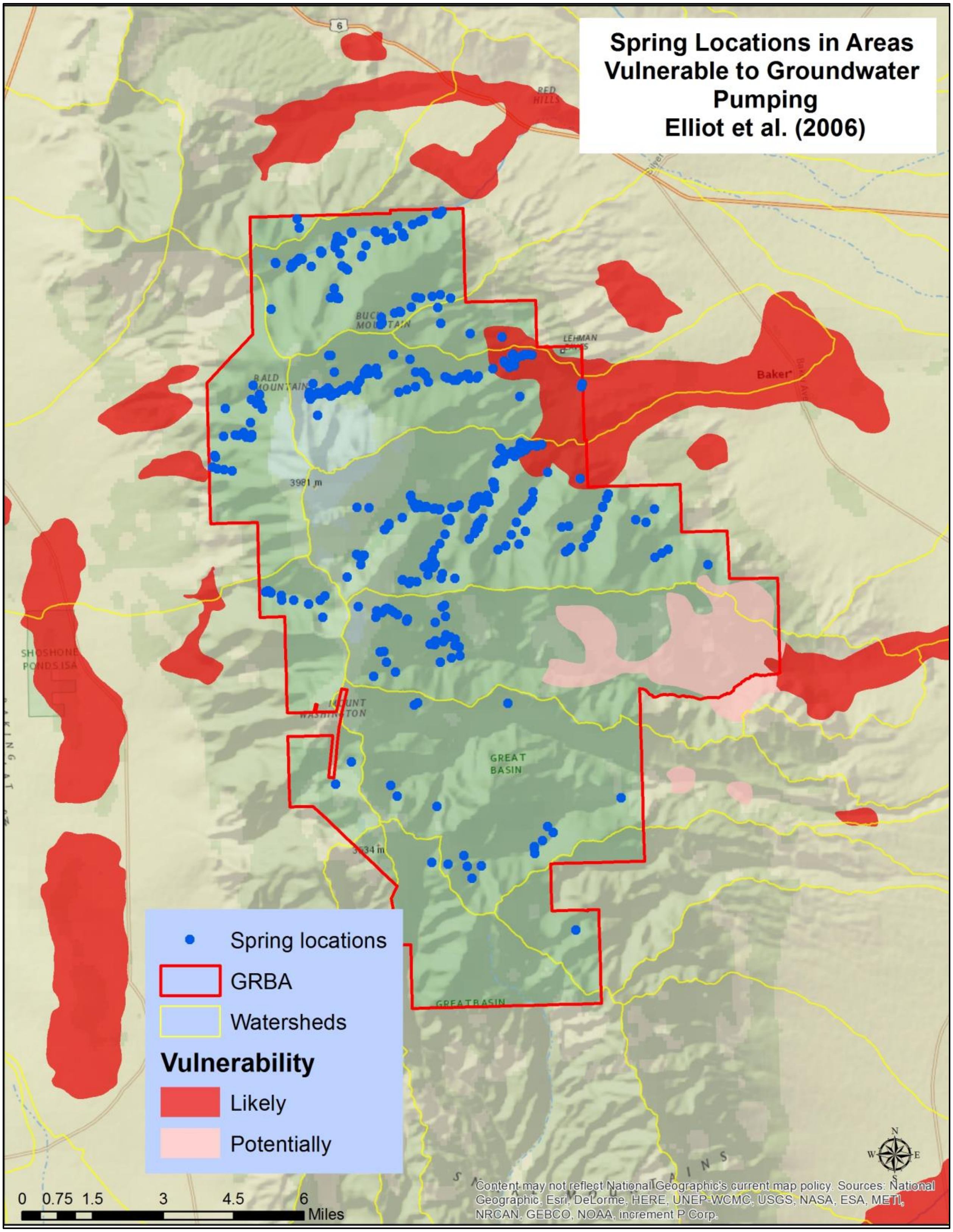


Figure 96. Spring locations in Great Basin NP in relation to areas likely or potentially susceptible to groundwater pumping.

The Snake Creek pipeline prevents Snake Creek from recharging groundwater along its entire length. As noted in Section 4.3.2.4, at least some of the water that formerly infiltrated along the reach spanned by the pipeline recharged groundwater in the Prospect Mountain Quartzite bedrock formation. In turn, some of the Snake Creek water recharged to this formation formerly re-emerged as seepage and springs within the park below the end of the pipe (Elliott et al. 2006). The inventory in 2003-2004 identified only two springs in this lower reach. However, the pipeline has operated since 1961 and evidence of former springs may no longer have been visible by 2003-2004. Given the evidence assembled by Elliott et al. (2006), it can be hypothesized that infiltration along the reach now spanned by the Snake Creek pipeline supported additional springs – or additional flow at the two known springs – along lower Snake Creek below the location where the pipeline terminates today. However, the available data do not permit a detailed evaluation of this hypothesis.

The 2003-2004 inventory also identified diversions at six springs along Lehman Creek, six along Baker Creek, one along the North Fork of Big Wash, and two along Young Canyon. Since that time, spring diversions have been removed at all but four locations. This represents less than 1% of the springs in the park, but it is not known whether the remaining four springs are ecologically or geologically significant - or hydrologically connected-, or whether their modifications impair their ecological or geologic condition. Consequently, conditions are likely to be at least stable at all the modified springs.

The Fire Regime Condition Class (FRCC) assessment for the montane riparian woodland communities in the park as a whole (see above, Section 4.3.3.4) indicates a fire regime departure of 26%. The springs in the park overwhelmingly occur within the montane riparian woodland zone of the park, and the FRCC results point to alterations to the fire regime for the vegetation surrounding the springs of the park. The FRCC results specifically suggest that fire suppression has caused a shift toward under-representation of early and mid-succession vegetation classes relative to late-succession classes along the riparian corridors in the park. Baker (2005, 2007) specifically notes that wildfire suppression since about 1880 has allowed woody vegetation to encroach on many springs in the park. Approximately 23% of the springs inventoried in 2003-2004 were found to be experiencing vegetation encroachment, involving a shift in the dominant vegetative community either from aspen to white fir or from sagebrush to pinyon/juniper (Baker 2005). Such encroachment could increase evapotranspiration in the vicinity of the affected springs, potentially reducing spring discharge. However, no data are yet available to test the hypothesis that encroachment affects (or will affect) spring hydrology. Further, it is not possible to determine if the shifts in vegetation represent a trend of continuing degradation or simply a change to an alternative state.

The reports on the inventory of 2003-2004 recommend removing encroaching vegetation from affected springs (Baker 2005, 2007) and evaluating whether these efforts affected spring discharge. As noted in Section 4.3.3, above, continuing fire suppression will otherwise promote further encroachment. As of the date of the present assessment, however, the park has not yet begun a program of removal of encroaching woody vegetation around its springs (G. Baker, Great Basin NP, personal communication, October 2014).

Finally, the inventory of 2003-2004 recorded a non-native plant species, watercress (*Rorippa nasturtium-aquaticum*) in the pools of 16.9% of all springs and spring complexes in the park. However, the survey found no evidence of non-native mollusks or other non-native spring fauna.

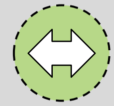
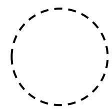
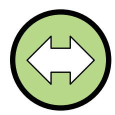
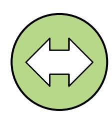
Summary of Status

Table 68 summarizes the results for the indicators used to assess the condition of springs in the park.

Table 68. Summary of indicators for condition of springs in Great Basin NP.

Springs			
Indicators of Condition	**Specific Measures**	**Condition Status/ Trend**	**Rationale**
Spring Discharge	Flow characteristics calculated from continuous discharge data representing all spring types in Park.		Baseline data as yet exist only for a small number of springs, for a few years. However, data on Snowpack Condition and Watershed Landscape Condition (see Sections 4.3.2.4.7 and 4.3.2.4.1) indirectly indicate that no changes in watershed processes are taking place across the park that could affect the sources of spring discharge relative to reference conditions. Encroachment of woody vegetation around springs (see below) could affect spring hydrology via its effects on evapotranspiration, but no data are available to test the hypothesis.
Spring Water Quality	Water quality characteristics calculated via repeated sampling of a representative sample of spring types in Park.		Baseline data as yet exist only for a small number of springs, for a few years. However, data from springs on exceedances of water quality criteria for pH aquatic life indicate that such exceedances were far less frequent in samples from 2006-2007 compared to 1966-1998.
Spring Pool Margin Fauna and Flora	Abundance and composition of pool margin fauna and flora by spring type.		Some baseline data exist from 2006-07, but not enough to establish estimates of baseline conditions for specific types of springs. Data on fire regime condition class for montane riparian woodlands across the park in general point to a shift toward later-successional vegetation (i.e., woody vegetation encroachment) resulting from fire suppression; and the 2003-2004 inventory recorded woody encroachment at only ~23% of springs in the park. However, it is not possible to determine if the shifts in vegetation represent a trend of continuing degradation or simply a change to an alternative state.

Table 68 (continued). Summary of indicators for condition of springs in Great Basin NP.

Springs			
Indicators of Condition	**Specific Measures**	**Condition Status/ Trend**	**Rationale**
Spring Pool Fauna	Abundance and composition of pool macroinvertebrates by spring type.		Baseline data as yet exist only for a small number of springs, for a few years. No indirect data are available to guide an estimate of condition or trend.
Spring Modifications and Diversions	Systematic inventory of dams and diversions.		Four diversions at springs as of 2015, some still active, but representing less than 1% of the springs in the park. Snake Creek pipeline has potentially reduced or eliminated groundwater discharge to springs along lower Snake Creek (Elliott et al, 2006) . Modeling of the possible impacts of groundwater pumping outside the park boundaries indicate that 27 springs within the park could be affected by such pumping. However, such pumping is not taking place and remains hypothetical while permit applications remain in intense legal dispute.
Invasive Species	Systematic inventory of invasive species in pool margins and pools.		Baseline data as yet exist only for a small number of springs, for a few years. Observations in 2003-2004 recorded watercress (*Rorippa nasturtium-aquaticum*) in the pools of 16.9% of all springs and spring complexes in the park, a cause for concern, but recorded no evidence of non-native mollusks or other non-native spring fauna.

Viewed together, the results for the six indicators of spring condition tell a mixed story. No data provide direct evidence concerning the integrity of spring discharge regimes in the park. However, indirect evidence suggests that discharge quantities are neither impaired by past stresses nor under present threat. No direct evidence is available on the integrity of spring water chemistry regimes in the park. However, indirect evidence from exceedances of water quality criteria in springs indicates a significant decline in such exceedances (i.e., a significant improvement in spring water quality) between samples from 1966-1998 versus samples from 2006-2007. No direct evidence is available on baseline conditions for spring pool margin fauna and flora. However, data point to a pattern of encroachment of woody vegetation around ~23% of the springs in the park, likely as a result of fire suppression in the montane riparian woodlands of the park in general. The encroachment is of Moderate Concern, but it is not possible to determine if it is part of an ongoing trend of degradation or simply a change to an alternative state. The evidence concerning spring modifications and diversions indicate that such alterations presently affect less than 1% of the springs in the park; and the Snake Creek pipeline has potentially reduced or eliminated groundwater discharge to springs along lower Snake Creek. Finally, data from 2003-2004 indicate a moderate presence of a non-native plant species, watercress (*Rorippa nasturtium-aquaticum*), in spring pools in the park, but no data are available with which to assess condition for other spring pool fauna or flora, native or non-native, let alone trends for any.

These results suggest an overall rating of "Good" for current conditions, with stable conditions overall on balance. Nevertheless, springs do appear to face risks resulting from fire suppression in the park and introductions of non-native plant species. Additionally, the rating warrants an average but borderline rating of "Low" for confidence, given the indirect nature of much of the evidence available.

<u>Sources of Expertise</u>

The assessment of this resource rests on previously collected data and maps. See Sections 0 and 4.3.3.6 for information on the sources of expertise for the park-wide assessments of water quality/quantity and montane riparian woodland condition. Gretchen Baker and Ben Roberts, Great Basin NP, provided additional guidance.

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4.4. Future Landscape Conditions

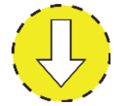
Pervasive environmental changes pose risks to all focal resources in the park. Climate change, air pollution, and changing water- and land-use patterns surrounding the park could have profound effects on park resources during the 21st century. For this reason, the present assessment considers future trends in the environment including the park in order to place the present conditions and trends in the park's resource in a broader context. Specific resource assessments – e.g., for Air Quality and for Water Quantity/Quality – consider threats posed by long-term trends in atmospheric deposition and proposed groundwater mining in the adjacent valleys. Unnasch et al. (2014) examine the possible impacts of energy resource development in the adjacent valleys. Here we provide an assessment of the possible impacts of climate change on the park landscape.

4.4.1. Climate Change Effects

Indicators / Measures

- *Change in mean annual temperature*
- *Change in mean annual precipitation*
- *Change in season and amount of streamflow*
- *Change in snowpack*
- *Change in species composition in alpine vegetation*
- *Change in phenology of key plant species*
- *Change in phenology of key animal species*

Condition - Trend



Moderate Concern – Deteriorating Trend – Low Confidence

<u>Background and Importance</u>

Global climate change and its possible effects on climate patterns throughout the Great Basin are matters of increasing concern for resource management at Great Basin NP. Temperature and precipitation drive ecosystem productivity and natural dynamics, such as the rate of plant growth, the frequency of wildfires, the seasonal flow of streams, and patterns of groundwater recharge with long-term consequences for spring discharge and stream baseflow. Paleoecological studies show that past episodes of climate change triggered ecosystem change at regional and local scales with varying speed and intensity (Wells 1983, Betencourt et al. 1990). As the rate of change increases, resource managers can expect profound shifts in key ecological processes to cascade through natural systems, resulting in altered productivity, changes to species composition, local extinctions, and instances of ecological degradation or collapse (IPCC 2013, IPCC 2014).

The modern scientific study of ecosystems dates back over a century, but understanding of the many linkages between key climate variables and ecosystem dynamics across diverse landscapes remains inadequate. Nor is there sufficient understanding of the ways in which climate change may interact with other stressors, such as those tied to land and water use, that have already effected the integrity of many ecosystems. One certain conclusion that we can draw is that *ecosystems will not simply 'move'* as climate changes, *but will instead transform* in unprecedented ways because of the controlling link between climate and many ecosystem processes (Fagre et al. 2009); including the individualistic responses of species (Finch 2012). The challenge posed by climate change in the coming decades is to clarify strategies that strengthen ecosystem resilience and minimize ecological degradation or collapse due to a loss of ecological integrity, and then to facilitate the natural transformation of ecosystems in ways that maximize retention of ecosystem processes. This is why the NPS Climate Change Response Strategy (National Park Service 2010) and subsequent NPS science advisory board report indicated the urgency to steward NPS resources for *"continuous change that is not yet fully understood, in order to preserve ecological integrity"* (Colwell et al. 2012).

Resource managers at any given NPS unit need to better understand and assess the relative vulnerability of focal resources in the unit to the specific climate-induced stressors most likely to affect the unit. NPS units throughout the southwest may become vulnerable to increasing fire frequencies (Moritz et al. 2012), drought and beetle infestation (Breshears et al. 2005, van Mantgem et al. 2009), reduced snowpack (Garfin et al. 2013), and loss of pika populations in alpine environments (Beever et al. 2011). In their national assessment of exposure to land use and climate change, Hansen et al. (2014) scored Great Basin NP relatively high among 57 NPS units for vulnerability to effects of climate change. The present section of the Great Basin NP assessment summarizes and discusses current understanding of climate trends and their potential effects on selected focal resources. Indicators for this assessment aim to gauge trends in climate itself, trends in the geophysical effects of changing climate, and possible biological responses to climate change.

Data and Methods

Indicators / Measures

- ***Change in mean annual temperature***
- ***Change in mean annual precipitation***
- ***Change in season and amount of streamflow***
- ***Change in snowpack***
- ***Change in species composition in alpine vegetation***
- ***Change in phenology of key plant species***
- ***Change in phenology of key animal species***

Data sets pertaining to climate change and its effects on the park vary from broad scale spatial models of climate to local scale sampling aimed at monitoring resource response. Data from climate stations throughout the Great Basin are used to document 20th century trends in temperature and precipitation. Chambers (2008) provided a summary of climate trends and projections for the Great Basin region as a whole.

The Intergovernmental Panel on Climate Change (IPCC) releases periodic reports that summarize the state of climate change science. These provide global to subcontinental-scale synthesis of current climate models and projections. Climate projections vary depending on the particular global models used, methods for translating global models to a given region, and assumptions within each model regarding trends in human production of greenhouse gases. Current projections for temperature are considered to be more reliable than those for precipitation. No current models adequately address shorter-term or extreme events, such as drought of one or a few years. Models produce different projections of future climate trends, and differences widen with each decade into the future. Therefore, given the current state of climate science, results from model ensembles, or groups of climate projections, are most commonly used, and one can be most confident in ensemble projections for the upcoming decades.

Gonzalez (2014) provided a summary of climate trends since 1950 and future projections to 2100 with specific application to the park within the larger region. Hansen et al. (2014) provided estimates of historical trends between 1895 and 2007 for the landscape surrounding the park. They also provided a moisture index, combining measures for temperature and precipitation, and one measure of biome shifts (Rehfeldt et al. 2012).

Several existing data sets and research efforts pertain to individual park resources. The BLM Rapid Ecoregional Assessment for the Central Basin and Range ecoregion analyzed differences between 20th century climate and climate projections to 2060 (Comer et al. 2013). These regional analyses have a spatial resolution of 4 km^2 (1.5 mi^2), and identify the monthly variables (maximum temperature, minimum temperature, and total precipitation) that are projected to depart more than two standard deviations from mean values observed from the 20^{th} century. The result enables further detail as to the seasonal character of climate projections where statistically significant change is predicted.

The park includes alpine sample sites for the Global Observation Research Initiative in Alpine Environments (GLORIA). Sample plots are used to quantify plant species richness, species composition, vegetation cover, soil temperature, and length of snow cover period. In order to facilitate detection of trends, samples are arrayed along both vertical and horizontal gradients (Baker and Horner 2009). Annual patterns in tree growth, as expressed in tree rings from bristlecone pine (*Pinus longaeva*), provide one long-term record of environmental change. Salzer et al. (2010) measured historical trends in tree growth in three sites from across the Great Basin region.

Aquatic resources have been the focus of two recent studies. The first was from Reinemann et al. (2011) where they recovered sediment cores from Stella Lake and Baker Lake that enabled analysis of changing aquatic conditions over the past 7,000 years. Segments of each sediment core were dated using lead-210 measures of mineral material and carbon-14 measures of wood and conifer needle fragments. By examining subfossil remains of midges along dated portions of each sediment core, midge composition was compared with other reference sites to describe environmental conditions as they were at a given historical period. That effort also established an additional sensor network throughout the park for gauging air temperature and humidity.

A second analysis looked at potential effects of changing climate on snowpack and stream flow in the Lehman and Baker Creek watersheds (Volk 2014). A precipitation-runoff model was developed for these drainages and used to evaluate climate effects. This model did not include groundwater interactions with surface flows. A 30-year record of observed precipitation was repeated three times in model simulations for a future 90-year period. Results of the 90 year simulation were then segmented back to 30 year intervals (2009-2038, 2039-2068, and 2069-2098) and compared against four global model results. The global models were each based on differing assumptions of greenhouse gas concentrations (called representative concentration pathways, or RCPs). This allowed for differences in project streamflow to be related directly to different model projections of temperature over the upcoming 90 years. For this assessment, results from the 2039-2068 time period is emphasized, given higher confidence that one can place on model results from that intermediate time period, relative to the later time period.

Reference Conditions

Since the intended management goal for a natural resource park is "unimpaired for the enjoyment of future generations" reference condition would logically be the complete absence of climate change and its effects beyond what would be expected without measureable human influence. However, such a reference condition is unlikely to be feasibly achieved where measureable climate change is already occurring and is likely to occur over upcoming decades.

A practical reference condition can be established where the values in climate variables remains within one to two standard deviations of the 20th century mean. This provides one measure of statistical variation expressed in climate observation or model projections. By gauging where and when a given climate variable extends beyond that range provides a clear signal that effects on focal resources may occur. Where there is a direct linkage between climate variables and specific resource indicators, such as a hydrologic model tied directly to precipitation data, specific inferences of climate change effects can be made. In many cases, however, that translation must be an interpretation, combining knowledge of the ecology of a given resource with the climate projection.

Here we use an assumption that if a given climate variable falls within one standard deviation of the 20th century mean value, climate change effects are likely to be negligible. By this, we mean that the ecological attributes (e.g., species composition, structure, etc.) and natural processes remain within an expected natural variation for a given focal resource. Therefore, the measured condition relative to reference condition is "good." We use two standard deviations from 20th century mean values to indicate that "significant concern" is warranted. This leaves circumstances where climate variables fall between one and two standard deviations from the 20th century mean to indicate "moderate concern." Further interpretation is required to translate that change in climate to other measurable features of a given focal resource.

Using this as a basis for interpretation, the following indicators were targeted in our review of available data sets pertaining to the park; including a series of indicators directly related to climate, and a second set being response indicators of selected focal resources.

Condition and Trend

The primary questions for which we seek answers are these:

- Over the past several decades, has the mean annual temperature changed?
- Over this same time period, has the mean annual precipitation (totals or patterns) changed?
- Over the upcoming decades, are mean annual temperatures and precipitation projected to change to a significantly?
- Over this same time period, will seasonal snowpack and streamflow change significantly?
- Which focal resources might be most vulnerable to climate change in the upcoming decades?

Across the Great Basin region, warming of 0.6 to 1.0 °F (0.3 - 0.6 °C) has occurred over the past 100 years (Wagner et al. 2003, Chambers 2008). Using similar data and analysis (Haas 2010), Hansen et al. (2014) estimated a 1.3 °F (0.7 °C) increase in mean annual temperature for the landscape encompassing the park. Gonzalez (2014) provided a graphical summary of temperature trends for the period from 1895 – 2010, with an estimate of 1.0 °F (0.6 °C) per century trend persisting since 1950, although this trend was not statistically significant (Figure 97).

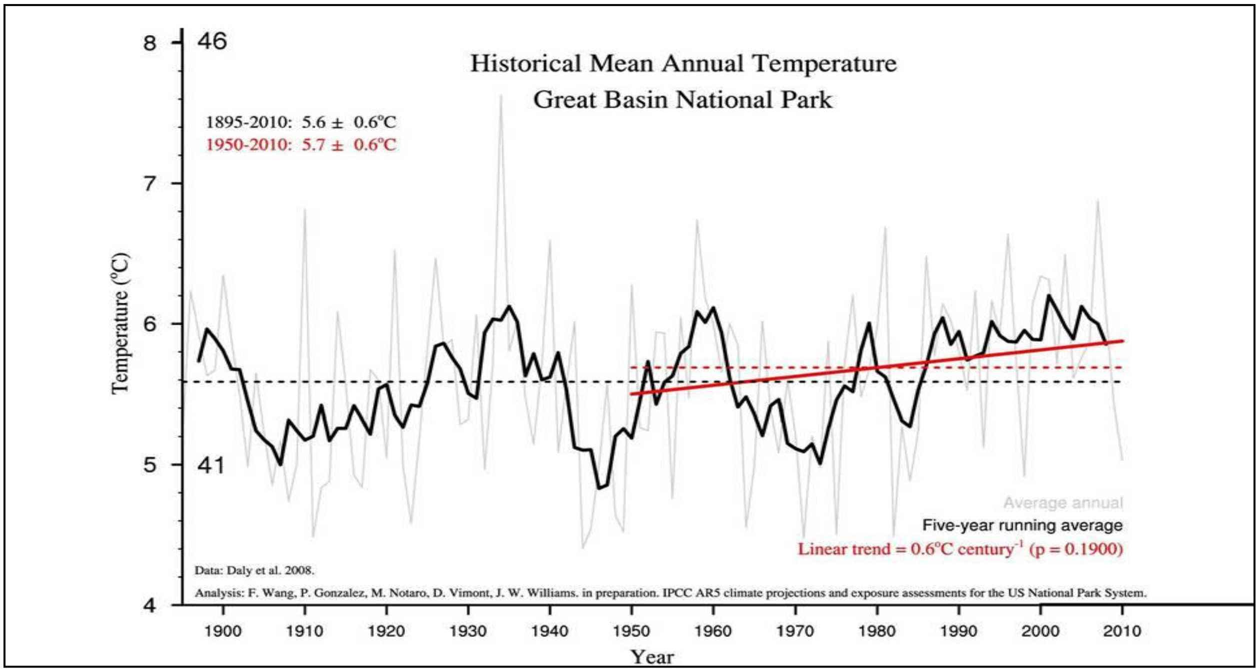


Figure 97. Historical temperature trends for Great Basin NP (from Gonzalez 2014).

Regional tree ring analyses of bristlecone pines correlated strongly with these historical trends in temperature. Measures of radial growth for the second half of the 20th century were greater than any 50-year period of the last 3,700 years (Salzer et al. 2010). Because the strongest trends in growth were consistently limited to within 492 vertical feet (150 m) of treeline, researchers were able to isolate temperature as the driving cause, distinct from CO_2 fertilization, precipitation or other factors.

These findings are further corroborated by analysis results from lake sediment cores from Stella and Baker lakes. In their reconstructed paleoclimate for the region, Reinemann et al. (2011) concluded that there were significant temperature shifts across the central Great Basin over the Holocene Epoch, and that peak temperatures occurred approximately 5,300 years ago. The lake core analysis indicates that these lakes experienced increased July temperatures starting around 1980, and current temperatures are as high as have been recorded over the past 1,000 years. Fortunately, the sediment cores also indicate that, while the park likely experienced wide swings in temperature and aridity throughout the Holocene, Stella Lake never dried out completely, and appears to have maintained a diverse aquatic ecosystem throughout the last 7,000 years. In any case, given trends in July temperatures, a condition of moderate concern is appropriate.

Gonzalez (2014) also provided estimated trends in mean annual precipitation for the 1895-2010 timeframe. These data indicate linear trend increase of 36% based on precipitation averages between 1950 and 2010. However, the variability found within each of these two 30-year periods (1950-1980 vs. 1980-2010) is quite high, so their statistical significance is low, and no firm conclusions can be drawn at this time. While increasing temperatures during the growing season tend to result in higher evapotranspiration rates, thus offsetting some increased precipitation, this analysis does suggest a need for close monitoring of precipitation (amount, seasonality, proportions represented as snow) over upcoming decades. The assessment of Water Quality and Quantity, above, includes an analysis of evidence for trends in the April 1 snow water content of the snowpack in the headwaters of Baker Creek, using snowpack data from 1942 to 2014 (Figure 82, and Figure 83). The analysis found no evidence of any trend(s) over this span of time.

Future projections of climate variables for the Great Basin region indicate substantial increases in temperature over the upcoming decades. Gonzalez (2014) estimated 2000-2100 changes in temperature and precipitation under low, high, and highest greenhouse gas emission scenarios, as compared to a baseline period of 1971-2000. Under the low emission scenario, a temperature increase of 2.8 ^{o}C (5 ^{o}F) is projected, along with a 1% increase in average annual precipitation. Under the high emission scenario, a temperature increase of 3.2 ^{o}C (6 ^{o}F) is projected, along with a 2% *decrease* in average annual precipitation. Under the highest emission scenario, a temperature increase of 5 ^{o}C (9 ^{o}F) is projected, along with a 1% *decrease* in average annual precipitation. A clear increasing trend in temperature is suggested by all climate projections, while the degree of change in precipitation remains difficult to interpret, especially when using model projections that extend out 100 years.

Climate projections applied to the BLM rapid ecoregional assessment aimed to characterize the difference between 2060 projections and the entire 20th century baseline (Comer et al. 2013). These models used a 20 year period from the climate projection (2040-2060) and compared that variability to the historical range of variation measured from 1895 through 1980. Again, this regional analysis has a spatial resolution of 4 km^2 (1.5 mi^2) and identifies the monthly variables (maximum temperature, minimum temperature, and total precipitation) that are projected to depart more than two standard deviations from mean values observed from the 20th century. Figure 98 provides one form of visualizing results of the analysis for the Valleys study area encompassing the park. For each 4-km^2 grid cell, it depicts the number of monthly variables projected to be at least two standard deviations from the 1895-1980 mean value. It indicates that at least 4 of 36 monthly variables are projected to deviate significantly throughout the study area. A maximum of 9 of 36 monthly variables are projected to be >2 stdv from the 20th century mean value within the park. This provides one initial measure of climate change to occur across the Valleys study area over the next 50 years.

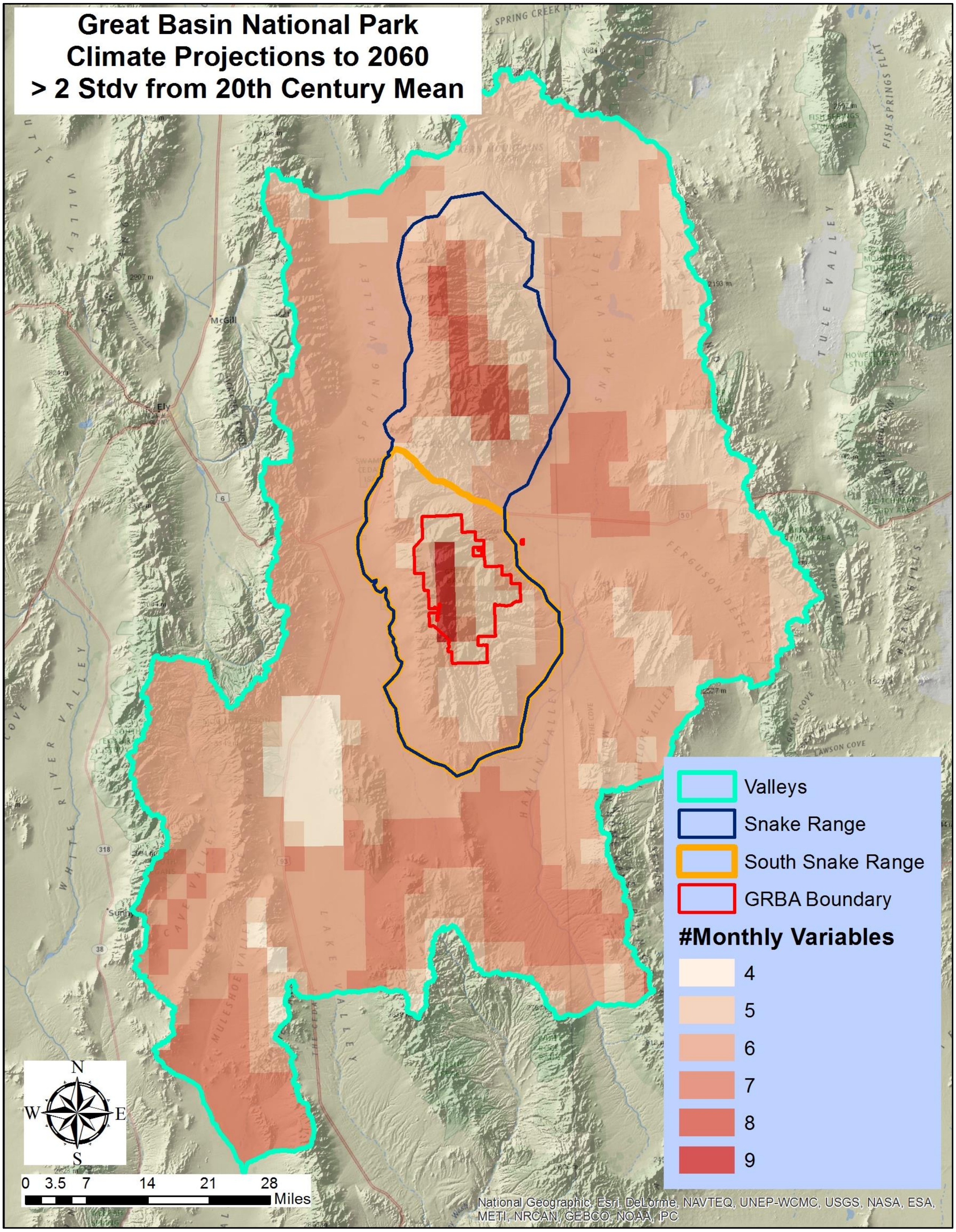


Figure 98. Climate projections compared against 20th century climate means: numbers of 36 monthly climate variables projected to be >2 stdv from baseline mean.

Table 69 provides detail to better understand the significance of this visualization. It provides a summary of the particular monthly variables, their proportions extent, and projected values for the valleys study area. This summary indicates that projections for precipitation do not deviate by at least two standard deviations anywhere within the study area. However, both monthly maximum (daytime) and minimum (nighttime) temperature are projected to be beyond two standard deviations throughout the study area. These elevated average temperatures are projected to be pervasive throughout the months of July and August. For the months of June, September, and October, just the minimum temperature is projected to be most elevated. Increasing mean temperatures vary from 4.5 ^{o}F to 7.4 ^{o}F with a relatively narrow expected range.

Table 69. Summary of climate projections for monthly variables, selected for those with >2 stdv from 20th century baseline values.

Variable (Month, 2060 forecast)	% of Area with Value >2 stdev departure from 20th century mean	Departure from Baseline (degrees F, for 4-km^2 grid cells with > 2 Stdev departure by 2060			
		Mean	Min	Max	stdev
January Min Temp	0.3%	7.4	7.5	7.4	0.1
June Min Temp	17.6%	4.5	4.9	4.3	0.1
June Max Temp	0.3%	6.1	6.3	5.8	0.3
July Min Temp	99.4%	5.6	6.3	4.8	0.3
July Max Temp	100%	5.5	6.1	4.8	0.3
August Min Temp	100%	6.3	7.0	5.6	0.2
August Max Temp	100%	6.1	6.9	5.5	0.4
September Min Temp	96.2%	6.5	7.1	5.6	0.3
September Max Temp	4.0%	5.6	6.0	5.1	0.2
October Min Temp	69.7%	5.3	6.0	4.3	0.3
October Max Temp	1.8%	6.7	7.1	6.2	0.3

Again, these data suggest that the primary consideration of climate change for the park, over the upcoming decades, should be related to effects of elevated growing season temperatures, with numerous potential effects on vegetation growth, susceptibility to wildfire, disease, and drought stress.

Finally, Volk (2014) analyzed the potential effects of changing climate on snowpack and stream flow in the Lehman and Baker Creek watersheds. The precipitation-runoff model used in this analysis was validated against historical data and resulted in an error rate of less than 12%. Future simulations included four representative assumptions of greenhouse gas concentrations, and were summarized by three 30-year periods over the next 90 years (2009-2038, 2039-2068, and 2069-2098). For the mid-century period of 2039-2068, results of future simulations did not differ significantly among the four representative greenhouse gas emission scenarios.

Overall results for this time period from Volk (2014) suggest:

1) Limited change in mean annual precipitation and mean annual streamflow.
2) Slight shifts towards earlier snowmelt by one to several weeks. These shifts should be more pronounced in watersheds with more substantial south-facing slope area.
3) Peak snow-water equivalence date may shift earlier by one to several days.
4) Sublimation, evaporation, and transpiration may increase from October through April, and decrease from June through August, especially with warmer greenhouse gas scenarios.
5) Streamflow volume relative to precipitation volume decreases with increasing temperature; but this effect may be more pronounced at middle elevations where evapotranspiration is highest. That is, higher elevation alpine environments have inherently less vegetation, and mixed conifer forests at higher and cooler elevations transpire less than vegetation at lower-elevations.

Phenology, or phenological events, such as flowering, migration, or breeding behavior, offers another avenue for detecting ecological effects of a changing climate. The National Phenology Network is helping to establish protocols, data sets, and citizen-science efforts to monitor phenology throughout the United States (Schwartz et al. 2012). Ideally, a small subset of easily measured phenomena should be selected to provide a robust and sensitive measurement of changing conditions within the park. With phenological trends established and change detected, new insights for other forms of climate change monitoring may be identified. For this assessment, initial steps were taken to identify potential indicators for phenology monitoring with the park. Two animal taxa were tentatively selected for this purpose. The spring emergence of Great Basin rattlesnakes (*Crotalus viridis lutosus*) may be monitored to indicate shifts in spring temperatures, while spawning times for Bonneville cutthroat trout (*Oncorhynchus clarki utah*) may indicate shifts in stream water temperature, including the timing of temperature cues for spawning in relation to stream discharge.

Denny et al. (2014) provide a compilation of methods suitable for selection and measurement of phenology for plant and animal taxa. This reference, combined with established plant lists for the park, will be used to select tree and/or shrub species suitable for monitoring plant phenology.

Table 70 provides summary indicator scores for climate change effects at the park. Some indicators, such as those based on observed climate, tree ring, and sediment core records, have a strong basis for making inferences of resource condition. Other data sets, such as measures for plant species composition in alpine environments, have established baseline data collected, but will require repeat measurement in order to begin to measure trends. Climate projections, and hydrologic models building from climate projections, should be viewed with caution, as climate science in this area is rapidly expanding, so these indicators should be periodically revisited with current models. Other indicators for phenology of selected biological resources are identified here, although baseline data for them are not available.

Table 70. Summary indicator scores for climate change effects at Great Basin NP.

Climate Change Effects			
Indicators of Condition	**Specific Measures**	**Condition Status/ Trend**	**Rationale**
Observed Change in Mean Annual Temperature	Observed climate, tree ring data		Moderate confidence in measurable trends in 20th century observations, indicating moderate concern for increasing temperature trends extending beyond 1 standard deviation of 20th century baseline.
Projected Future Change in Mean Annual Temperature	Model projections		Moderate confidence in model projections to 2060, suggesting potential departure beyond 2 standard deviations of 20th century baseline.
Observed Change in Mean Annual Precipitation	Observed climate		High confidence in 20th century observations, falling within 1 standard deviation of 20th century baseline.
Projected Future Change in Mean Annual Precipitation	Model projections		Low confidence in conflicting model projections to 2060, but few indicate change greater than 1 standard deviation of 20th century baseline.
Observed Change in composition of aquatic communities	Observed midge composition from lake sediments		Temperature trends and effects on lake drawdown raise some concern. However, a 7,000 year record indicates that lakes never dried down completely and maintained diverse aquatic fauna throughout Holocene.
Observed Change in season and amount of streamflow	Observed timing of snowmelt, Average annual flow		Observations indicate no significant departure from 20th century baseline.
Projected Future Change in season and amount of streamflow	Model projections of timing of snowmelt, Average annual flow		Model projections show a slight decline in annual flow, and suggest shift to earlier snowmelt by up to 30 days, and modest change in annual flow by 2060.
Change in snowpack	Projected change in snowpack		Model projections suggest modest change in overall snowpack by 2060, but including changes in the magnitude and timing of snowmelt which strongly affect stream flow.
Change in species composition in alpine vegetation	Change in plant species presence, abundance, and composition.		Alpine environment faces high likelihood of significant climate exposure. Remeasurement of GLORIA plots is needed to detect trends.

Table 70 (continued). Summary indicator scores for climate change effects at Great Basin NP.

Climate Change Effects			
Indicators of Condition	**Specific Measures**	**Condition Status/ Trend**	**Rationale**
Change in median emergence time of rattlesnakes	To be determined based on appropriate field sample technique		This indicator could offer one terrestrial vertebrate response to air temperature change.
Change in water temperature and spawning time for Bonneville cutthroat trout	To be determined based on appropriate field sample technique		This indicator could offer one aquatic vertebrate response to stream water temperature change. Some baseline data from 22 April-27 June 2002 exist for GRBA.
Tree or shrub phenology	To be determined based on appropriate field sample technique		This indicator could offer one or more plant responses to temperature and/or precipitation change.

Sources of Expertise

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Snake Range, Great Basin NP

5. Discussion

5.1. Applying an Ecological Integrity Framework to Natural Resource Assessment

This resource condition assessment is intended to provide natural resource information to Great Basin National Park staff that can be used to prioritize management action, prepare Resource Stewardship Strategies and specific resource management plans, interpret natural resource values, and engage with neighboring managers on natural resources issues. This chapter summarizes the results of the assessment in two ways. First, the chapter summarizes the key findings of the assessment, focusing on four thematic resource categories: landscape resources, upland resources and ecological integrity, aquatic resources and ecological integrity, and future landscape conditions. Second, the chapter summarizes background information and findings for each individual resource in the form of a resource brief.

This assessment incorporated use of an ecological integrity framework (Unnasch et al. 2009) to assess the conditions of ecological resources. The framework applies most directly to two of the four thematic resources categories – upland resources, and aquatic resources – because these are categories of ecological resources. Steps in the framework include: (1) identifying the key ecological attributes for each focal resource, on which to further focus assessment and subsequent management; (2) identifying indicators for each key attribute, for each resource; (3) identifying an expected or reference range of variation for each indicator for each resource; and (4) assessing the status of each focal resource based on indicator data, comparing present conditions to expected or reference conditions. Key ecological attributes include defining characteristics of a resource, its abundance, and its distribution; and key environmental associations, drivers, and constraints affecting resource characteristics, abundance, and distribution. Indicators may incorporate data using different levels of effort, from remote sensing, to ground-level rapid assessment, to ground-level intensive sampling. Together, the first three steps in the framework result in the development of a conceptual ecological model for each focal resource.

Subsequent steps in the ecological integrity framework include: (5) identifying desired conditions for each focal resource at specific locations based on its key ecological attributes and indicators; (6) identify stressors that affect or threaten to affect these key attributes and indicators in specific locations; (7) setting a timeline for action in specific locations to establish or ensure continuity of desired conditions; and (8) establishing metrics or benchmarks with which to evaluate these actions. Ordinarily, these additional steps would be undertaken subsequent to a NRCA, to guide the development of Resource Stewardship Strategies. However, indicators used in this assessment should relate strongly to metrics and benchmarks selected for use in planning and evaluating management actions. Therefore, these measures should form a link between stewardship actions and periodic NRCA updates. Further, the present assessment did identify two major stressors that affect or threaten to affect key attributes across multiple resources in the park: invasive plants and animals and climate change. To better meet NRCA needs and requirements, the assessment treated these two major stressors as separate topics for evaluation, because they potentially could have widespread effects on multiple biological and non-biological resources.

5.2. Overall Condition Summary and Implications

The following paragraphs summarize the key findings of the assessment for four thematic resource categories: (1) landscape resources; (2) upland resources and ecological integrity; (3) aquatic resources and ecological integrity; and (4) future landscape conditions. Table 71, following these narrative summaries, provides a more detailed, tabular summary.

5.2.1. Landscape Resources

Landscape resources including air quality, viewsheds, and night skies are important features of the park. Dark night skies and expansive vistas from and within the park draw many visitors annually. Current conditions for air quality, viewsheds, and night skies at the park are some of the best in the country. Their relative excellent condition results from the park's location in the Great Basin – a region with generally little development and few sources of light or air pollution. The park has well-established, long-term monitoring programs in place for air quality; and recent measurements by the Night Sky Program scientists provide excellent baseline data for future monitoring of night sky conditions. However air quality is of some concern due to the sensitivity of the park's ecosystems to pollutants, in particular nitrogen and sulfur deposition. In addition, while the park is currently in attainment for ozone, concentrations of ozone regularly exceed the EPA standard one or two times during the summer ozone season. Views from the west-side of the park are affected by the Spring Valley Wind Farm, which contrasts greatly with views of the surrounding rural landscape. Regional haze affects long-distance views and has reduced the visual range somewhat. Some areas adjacent to the park were identified as not having high visibility from within the park. Theoretically, these non-visible places represent areas where some development could occur without impacting the park's viewshed. Rock glaciers are one landscape resource deserving of increased monitoring to detect potential effects of climate change.

5.2.2. Upland Resources

Upland resources and indicators assessed included wildfire regime, aspen-mixed conifer forest, sagebrush steppe, and bighorn sheep. Introduced animals and plants, including wild turkey and invasive annual grasses, were also assessed. Upland resources vary in their condition and ecological integrity across the park and surrounding landscape. Current conditions reflect a long history of land use, where past grazing and fire suppression have had lasting effects on upland vegetation, including promoting or allowing the colonization of the park by non-native species. In most native plant communities, late successional vegetation stages are over-represented relative to earlier stages as a result of past suppression of natural wildfire. This condition has many cascading effects, such as limited tree species regeneration in aspen communities, or encroachment of other tree species into sagebrush communities. These effects limit the suitability of habitat for species such as bighorn sheep, likely limiting population viability. Introduced plant species, such as annual cheatgrass, can severely alter vegetation composition and fire regime, especially given the naturally great extent of sagebrush vegetation at lower elevations within and surrounding the park. Wild turkeys, introduced nearby for sport hunting, may be an increasing cause of concern for their effects on park resources.

Reintroduction of historically characteristic fire regimes across most park vegetation represents one important management response to address upland resource conditions, and can be advanced in places through the safe use of prescribed burning. Challenges to the safe and effective management of fire within the park are many and significant, but taking actions to address the need for a more natural fire regime in the park will remain an important priority into the future.

5.2.3. Aquatic Resources

Aquatic resources vary relatively little in their condition and ecological integrity across the park. The five aquatic resources addressed in the present assessment, including water quality and quantity, montane riparian woodlands, Bonneville cutthroat trout, cave and karst processes, and springs. These five resources are all parts of a single hydro-ecological system shaped by the geology, topography, weather, and vegetation of the South Snake Range. The dynamics of this hydro-ecological system are naturally driven by inputs of rain and snow. In turn, these dynamics are shaped by watershed cover and evapotranspiration, surface runoff and groundwater recharge from rainfall and snowmelt; groundwater flow and discharge through the park's bedrock fracture and karst geology; and the diversity of native terrestrial, riparian, semi-aquatic, and aquatic species that have found homes in the South Snake Range over many millennia. Changes in precipitation and air temperatures, deposition of atmospheric pollutants, chemical contamination from past land uses, legacy impacts of grazing, alterations to watershed hydrology through surface development or changes in ground cover, surface water diversions and groundwater pumping, introductions of non-native aquatic species, and visitor traffic through caves all have the potential to alter the park's natural hydro-ecology both above and below ground.

The assessment found little evidence of changes in hydrologic inputs or in factors that shape watershed hydrologic function that could result in altered hydrology within the park. Diversions take place from only four springs and from one of the park's streams. A pipeline carries all of Snake Creek's flow past a 3-mile (4.8-km) reach. The pipeline interrupts the natural hydrologic processes of the creek and impacts aquatic resources, including fisheries, riparian vegetation, and karst processes. Groundwater pumping in the surrounding valleys does not presently affect springs and streams within the park, but could in the future. Riparian vegetation is in good condition throughout the park, except in a few highly developed locations, but encroachments of woody vegetation – an issue across the park's upland plant communities as well – is a matter of concern. Atmospheric deposition of nitrogen and sulfur, which can disrupt aquatic chemistry and nutrient cycles, has declined for decades but has been stable more recently. In turn, the park experiences a relatively high rate of atmospheric deposition of mercury, and mercury has accumulated in some trout in the park to concentrations potentially harmful to both trout and humans who may eat such trout. However, other trout show very low levels of accumulation of mercury, suggesting that conditions other than deposition rate also shape the likelihood of mercury bio-accumulation in the park's aquatic food webs, possibly including watershed characteristics that influence the rate of mercury methylation. The frequency with which water samples exceed water quality standards for supporting aquatic life has declined over time, and the few remaining occurrences may reflect the unique geochemistry of the park rather than any contamination. Aquatic macroinvertebrate communities in the park's streams appear to be in good condition, showing no evidence of impacts from impaired water quality or physical habitat. And the park has carried out a highly effective program to restore the native Bonneville cutthroat trout along several streams, removing non-native trout from the restored stream sections at the same time. Finally, the processes that shape cave and karst ecology and geologic formations appear to be intact, except for possible effects from visitors through Lehman Caves. However, additional data are needed to evaluate these possible effects. Cave visitor usage varies over time and can have both direct and indirect effects on cave resource conditions, from direct damage to cave formations to changes in cave air humidity and chemistry that in turn affect cave species and geologic processes.

5.2.4. Climate Change

Climate change has a number of potential effects on park resources and values that will require concentrated investment in monitoring over the upcoming decades. Increasing temperatures may also coincide with increasing precipitation. As compared with temperature variables, given inherent variability in precipitation patterns, interpreting past observations and future projections is much less certain. Model projections linking climate to hydrologic models indicate a slight decline in annual flow over upcoming decades. They also suggest shift to earlier snowmelt by up to 30 days, and modest change in snowpack and annual flow by 2060.

Dead Lake, Great Basin National Park

The alpine environment faces high likelihood of significant climate exposure. Remeasurement of alpine vegetation sample plots over time should assist with detecting trends in plant composition. Phenology indicators, such as rattlesnake emergence and cutthroat trout spawning times, should also provide useful indicators for signaling biological responses to a changing climate.

Table 71. Summary of findings from the Great Basin NP natural resource assessment.

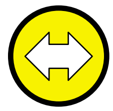
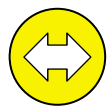
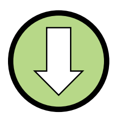
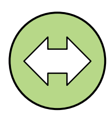
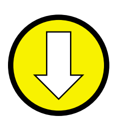
Resource or Stressor Name	Indicator of Condition	Overall Condition Status/Trend	Rationale and Uncertainties
Landscape Resources			
Air Quality	• *Atmospheric Nitrogen and Sulfur deposition* • *Level of ozone* • *Visibility haze index* • *Mercury Deposition*		The condition of total N and total S deposition is rated moderate and the sensitivity of the park's aquatic ecosystems to acidification effects is of concern. In addition, ozone, haze and mercury deposition are all of moderate concern. Recent trends are improving in some cases, but stable in others.
Viewsheds	• *Viewshed Condition Index* • *Visibility of Spring Valley Wind Farm* • *Regional Views of SEZs*		Vistas from the park into adjacent valleys and across them to other mountain ranges are of moderate concern. The park sits in a generally rural & undeveloped landscape, but there are many small roads, a couple of major highways, and the Spring Valley Wind Farm, all of which impinge on the viewshed. Regional haze impedes the long-distance views for which the interior west is known and valued.
Night Skies	• *Anthropogenic Light Ratio* • *Sky Brightness:* • *Maximum Sky Brightness* • *Minimum Sky Brightness* • *Integrated Whole Sky* • *Integrated Sky Above 20 °* • *Bortle Dark-Sky Scale*		Currently night sky condition is among the best found in national parks of the lower 48. Still, there are artificial light domes visible from the park. While downward trend in recent years can be inferred, no measurements are available to substantiate that.
Rock Glaciers	• *Rock Glacier Size* • *Rock Glacier Elevation* • *Rock Glacier Height* • *Thermokarst Features*		Steady decrease in Lehman Glacier causes moderate concern and suggests monitoring for change in remaining rock glaciers to detect effects of climate change. No apparent change has been observed, but additional baseline and trend data are needed for verification.
Upland Resources and Ecological Integrity			
Fire Regime	• *Fire Extent* • *Fire Regime Departure*		Historic grazing impacts and a policy of fire exclusion has resulted in an excess of late seral and a paucity of early seral stages. This trend is anticipated to continue unless fire (either prescribed or managed wildfire) frequency increases. Three major concerns are the lack of fire in aspen dominated systems, encroachment into montane big sagebrush by pinyon and juniper trees, and the potential transition at lower park elevations of montane big sagebrush steppe-upland to a cheatgrass dominated system.

Table 71 (continued). Summary of findings from the Great Basin NP natural resource assessment.

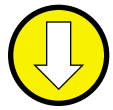
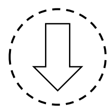
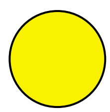
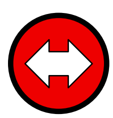
Resource or Stressor Name	Indicator of Condition	Overall Condition Status/Trend	Rationale and Uncertainties
Upland Resources and Ecological Integrity (continued)			
Aspen-mixed conifer forest	• *Fire Regime Condition Class* • *Fire Occurrence* • *Insect/Disease Outbreak*		Moderate concern is indicated due to fire regime alteration that has resulted from decades of fire suppression. Altered fire regimes are most pronounced in seral aspen communities. Extensive insect outbreaks have affected conifer forest canopies, but responses in aspen regeneration are limited; but additional data are needed to verify this finding.
Wild Turkeys	• *Turkey Population Size* • *Distribution and Extent of Core Usage Areas*		Observations so far indicate potential for concern for damaging effects of introduced wild turkeys on Park resources. Monitoring of population size and the distribution of high-usage areas is needed.
Invasive Annual Grasses	• *% area of vegetation type by annual grass cover risk category*		Moderate concern is indicated. Based on a spatial model, risk is high throughout basins surrounding the park, and throughout the lower elevation margin of the park. Additional area above 8,000 feet (2,438 m) elevation could become vulnerable to invasion as species adapt, new species are introduced, and as a result of climate change.
Bighorn Sheep	• *Survival Rate* • *Trend in Herd Size* • *Disease Status* • *Winter Range Forage Quality* • *Fire Regime Condition Class* • *Wildfire Overlap* • *Domestic Sheep in Adjacent Grazing Allotments* • *Landscape Condition*		High concern is indicated. The current bighorn sheep herd appears to be stable, but is considered far too small for long-term viability. Current survival estimates would benefit from more robust sample. Based on current population samples, the park supports an important disease-free herd. Spatial and temporal overlap with domestic sheep allotments is currently limited, but still too close given established guidelines; expanded bighorn populations would likely escalate potential for disease spread. Habitat quality, in both winter and summer range, appears to be the primary limitation of herd expansion. Addressing fire regime alteration, and in winter range, limiting/restoring degrading effects of past land use, are likely needed to secure long-term viability.

Table 71 (continued). Summary of findings from the Great Basin NP natural resource assessment.

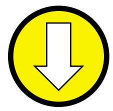
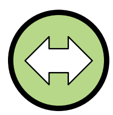
Resource or Stressor Name	Indicator of Condition	Overall Condition Status/Trend	Rationale and Uncertainties
Upland Resources and Ecological Integrity (continued)			
Sagebrush Steppe	• *Fire Regime Condition Class* • *Fire Regime Departure* • *Annual Grass Cover*		Moderate concern is indicated. Fire Regime Departure is a consequence of excess of late seral stages, reflecting the lack of fire disturbance. However, this is of less concern than the encroachment of cheatgrass into the low elevation occurrences of the upland subtype. Active restoration of this system, by opening closed canopy stands is appropriate and necessary to halt this trend in increasing departure. Mechanical or herbicide treatments are recommended as these would minimize the possibility of cheatgrass expansion.
Aquatic Resources and Ecological Integrity			
Water Quality/ Quantity	• *Watershed Landscape Condition* • *Riparian Corridor Landscape Condition* • *Stream Nutrient Enrichment* • *Incidence of Exceedance of Water Quality Standards* • *Mercury in Fish Muscle Tissue Benthic Macroinvertebrate Assemblage Integrity* • *Snowpack Condition* • *In-Park Diversions*		Park water quality and quantity appear to be in good, stable condition, although potential threats exist from climate change; atmospheric deposition of nitrogen, sulfur, and mercury; and groundwater pumping in the adjacent valleys. The park has active gauges on four streams in the park, and will eventually have continuous records long enough to support detailed assessments of streamflow variability. The gauge records, along with the continuing measurements of snowpack in the park, provide crucial data for assessing the potential effects of climate change. The continuing monitoring of atmospheric deposition in the park also provides a crucial record of this potential external source of water pollution that affects the park as a whole.

Table 71 (continued). Summary of findings from the Great Basin NP natural resource assessment.

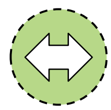
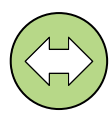
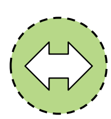
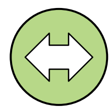
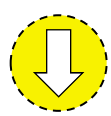
Resource or Stressor Name	Indicator of Condition	Overall Condition Status/Trend	Rationale and Uncertainties
Aquatic Resources and Ecological Integrity (continued)			
Montane Riparian Woodland	• *Watershed Landscape Condition* • *Riparian Corridor Landscape Condition* • *Riparian Reach Condition* • *Fire Regime Departure*		The evidence points to overall good conditions for montane riparian woodlands. However, this overall rating weights the evidence of fire regime departure equally with the other indicators. By itself, this latter indicator suggests an overall rating of “moderate concern” with a “deteriorating” trend. As a result of these apparently conflicting findings, the overall rating warrants a rating of “low” confidence. Further, there is a lack of recent ground-based, quantitative data on riparian vegetation collected representatively across the park. Such data are needed to more accurately guide management planning and action to sustain the integrity of these resources.
Bonneville Cutthroat Trout (BCT)	• *Bonneville cutthroat trout population density* • *Miles of occupied habitat* • *Habitat condition index* • *Channel stability index* • *Water quality/quantity condition* • *Riparian corridor landscape condition* • *Riparian reach condition*		The park has successfully restored Bonneville cutthroat trout to Strawberry Creek, South Fork Baker Creek, Snake Creek, and South Fork Big Wash. Good water quality, stream flow, stream macroinvertebrate assemblage, and riparian woodland conditions all support BCT viability in the park. However, the restored streams face risks of severe fires that could affect their riparian vegetation; intrusions of non-native trout; altered hydrology due to the Snake Creek pipeline and off-Park groundwater pumping; and inconsistent channel habitat quality. Ongoing monitoring will help the park keep its eye on these issues. Climate change and genetic isolation may also pose threats.
Cave/Karst Processes	• *Seasonal Visitor Count* • *Cave Temperature* • *Cave Humidity* • *Cave Hydrology* • *Cave Water Quality* • *Macroinvertebrate Composition* • *Packrat Abundance*		The evidence points to overall good conditions, but additional data are needed on the potential impacts of cave visitation by people and use by wildlife. Visitor usage varies over time and can have direct effects on cave resource conditions. Baseline data exist for key environmental variables of temperature, humidity and hydrology, but trend data are lacking. Macroinvertebrate composition also indicates good baseline conditions, but trend data are needed. Baseline data on additional environmental (water quality) and biological data (e.g., packrat, bat) are needed.

Table 71 (continued). Summary of findings from the Great Basin NP natural resource assessment.

Resource or Stressor Name	Indicator of Condition	Overall Condition Status/Trend	Rationale and Uncertainties
Aquatic Resources and Ecological Integrity (continued)			
Springs	• *Spring Discharge* • *Spring Water Quality* • *Spring Pool Margin Fauna and Flora* • *Spring Pool Fauna* • *Spring Modifications and Diversions* • *Invasive Species*		All indicators point to overall good conditions for the seeps, springs, and spring complexes in the park. However, the evidence for overall stable hydrology is indirect. Diversions affect only 15 springs/spring complexes in the park, but presumably alter their ecology. No intrusions of exotic spring fauna are known but could occur all too easily. Encroachments by native woody vegetation and exotic aquatic plants affect moderate fractions of the springs in the park, it is not clear how much harm is yet involved. These issues and the lack of long-term hydrologic data point to a need for improved long-term monitoring.
Future Landscape Conditions			
Climate Change Effects	• *Change in mean annual temperature* • *Change in mean annual precipitation* • *Change in season and amount of streamflow* • *Change in snowpack* • *Change in species composition in alpine vegetation*		Moderate concern for climate change effects on park resources is indicated by 20th century observations and by climate model projections of temperature over upcoming decades. As compared with temperature variables, given inherent variability in precipitation patterns, interpreting past observations and future projections is much less certain. Model projections connecting climate change to hydrology indicate a slight decline in annual flow, and suggest shift to earlier snowmelt by up to 30 days, and modest change in snowpack and annual flow by 2060. Alpine environment faces high likelihood of significant climate exposure. Remeasurement of alpine vegetation sample plots is needed to detect trends. Phenology indicators, such as rattlesnake emergence and cutthroat trout spawning times, should provide useful indicators for signaling biological responses.

5.3. Natural Resource Condition Assessment: Resource Briefs

Appendix D presents “resource briefs” for the individual resources and stressors addressed in the present assessment. Each brief summarizes information on the importance of the resource or stressor, and on the findings of the assessment (status and trends). Each brief then concludes with a discussion of the findings and their implications for management and/or monitoring.

Appendix A: Great Basin National Park: Listing of Species of Management Concern

Great Basin National Park
Species of Management Concern
(SOMC)

As mandated by NPS 77, Natural Resources Management Guidelines:

> "The National Park Service will identify and promote the conservation of all federally listed threatened, endangered, or candidate species within park boundaries and their critical habitats…The National Park Service also will identify all state and locally listed threatened, endangered, rare, declining, sensitive, or candidate species that are native to and present in the parks, and their critical habitats…All management actions for protection and perpetuation of special status species will be determined through the park's resource management plan."

> "Management of these species should be determined at the park level in consultation with concerned and knowledgeable parties. Although specific recovery actions may not be indicated, their identification as rare or sensitive species should warrant heightened management concern."

In addition, the Park's primary objective as stated in the General Management Plan is:

1) Manage the park to maintain the greatest degree of biological diversity and ecosystem integrity within the provisions of the authorizing legislation.

National Park Service Management Policies (2006) provide broad authority to manage for sensitive and rare species.

> "Management (should)… protect rare, threatened, or endangered species"

> "The National Park Service will inventory, monitor, and manage state and locally listed species in a manner similar to its treatment of federally listed species to the greatest extent possible. In addition, the Service will inventory other native species that are of special management concern to parks (such as rare, declining, sensitive, or unique species and their habitats) and will manage them to maintain their natural distribution and abundance."

Based upon these statements, the park is mandated to identify all rare and sensitive species and their habitats within the park and to manage for their continuity.

Based upon literature reviews, fieldwork, and historical information, Resource Management staff have identified 71 species as sensitive (Table 1) based on their current status in the park as meeting one or more factors listed below as defined by NPS 77 Natural Resources Management Guidelines. These factors include:

1) Local rarity of native species.

2) Whether or not the species is endemic to the park or local vicinity.

3) Importance of the species to the park (as identified in park management objectives).

4) Whether the species is the subject of political concern or unusual public interest.

5) The usefulness of the species as an indicator species.

6) The vulnerability of the species to local population declines.

7) Whether the species or its habitat is subject to human disturbance during critical portions of its life cycle.

Table A-1. List of species of management concern known to occur in or near Great Basin National Park. The last six species listed have not been documented in GRBA or vicinity, but their presence is likely.

Common Name	Species	Added 2014
Merriam's shrew	*Sorex merriami*	
Water shrew	*Sorex palustris*	
Inyo shrew	*Sorex tennellus*	
Pallid bat	*Antrozous pallidus*	
Townsend's big-eared bat	*Corynorhinus townsendii*	
Spotted bat	*Euderma maculatum*	
Silver-haired bat	*Lasionycteris noctivagans*	
Hoary bat	*Lasiurus cinereus*	
Fringed myotis	*Myotis thysanodes*	
Long-eared myotis	*Myotis evotis*	
Long-legged myotis	*Myotis volans*	
Ermine	*Mustela erminea*	
Bighorn sheep	*Ovis canadensis*	
Beaver	*Castor canadensis*	
Sagebrush vole	*Lemmiscus curtatus*	
Porcupine	*Erethizon dorsatum*	
Yellow-bellied marmot	*Marmota flaviventris*	
Pygmy rabbit	*Brachylagus idahoensis*	
Greater sage grouse	*Centrocercus urophasianus*	
Northern goshawk	*Accipiter gentilis*	
Swainson's hawk	*Buteo swainsoni*	
Ferruginous hawk	*Buteo regalis*	
Peregine falcon	*Falco peregrinus*	
Three-toed woodpecker	*Picoides tridactylus*	
Lewis's woodpecker	*Melanerpes lewis*	
Flammulated owl	*Otus flammeolus*	
Short-eared owl	*Asio flammeus*	
Brewer's sparrow	*Spizella breweri*	
Sage sparrow	*Amphispiza belli*	√
Sage thrasher	*Oreoscoptes montanus*	√
Pinyon jay	*Gymnorhinus cyanocephalus*	
MacGillivray's warbler	*Oporornis tolmiei*	
yellow warbler	*Dendroica petechia*	
Black rosy-finch	*Leucosticte atrata*	
Sonoran mountain kingsnake	*Lampropeltis pyromelana*	
Great Basin whiptail	*Aspidoscelis tigris*	
Desert horned lizard	*Phrynosoma platyrhinos*	√

Table A-1 (continued). List of species of management concern known to occur in or near Great Basin National Park. The last six species listed have not been documented in GRBA or vicinity, but their presence is likely.

Common Name	Species	Added 2014
Great Basin spadefoot	*Spea intermontana*	
Bonneville cutthroat trout	*Oncorhynchus clarki utah*	
Lahontan cutthroat trout	*Oncorhynchus clarki henshawi*	√
Mottled sculpin	*Cottus bairdi*	
Nokomis fritillary	*Speyeria nokomis*	√
Toquerville springsnail	*Pyrgulopsis kolobensis*	
Great Basin cave psuedoscorpion	*Microcreagris grandis*	
Snake Range millipede	*Nevadesmus ophimonus*	√
Great Basin cave millipede	*Idagona lehmanensis*	√
Model Cave harvestman	*Sclerobunus ungulatus*	√
Model Cave amphipod	*Stygobromus albapinus*	√
Scalloped moonwort	*Botrychium crenulatum*	√
Holmgren's buckwheat	*Eriogonum holmgrenii*	
Nevada catchfly	*Silene nachlingerae*	
Waxflower	*Jamesia tetrapetala*	
Wheeler Peak draba	*Draba pedicellata* var. *wheelerensis*	√
Snake Range draba	*Draba serpentina*	
Nevada primrose	*Primula cusickiana* var. *nevadensis*	
Holmgren's cinquefoil	*Potentilla holmgrenii*	√
Wooly head clover	*Trifolium eriocephalum*var. *villeferum*	√
Tunnel Springs beardtongue	*Penstemon concinnus*	
Wheeler Peak beardtongue	*Penstemon leiophyllus* var. *francisci-pennellii*	
Mt Moriah penstemon	*Penstemon moriahensis*	√
Wheeler Peak sandwort	*Eremogone congesta* var. *wheelerensis*	
Snowline springparsley	*Cymopterus nivalis*	
Watson's goldenbush	*Ericameria watsonii*	
Bristlecone pine	*Pinus longaeva*	√
Ponderosa pine	*Pinus ponderosa*	√
Ringneck snake	*Diadophis punctatus*	
Short-horned lizard	*Phrynosoma hernandesii*	
Intermountain wavewing	*Cymopterus basalticus*	
Pennell's whitlowgrass	*Draba pennellii*	
Rayless tansyaster	*Machaerantha grindelioides* var. *depressa*	
Great Basin fishhook cactus	*Sclerocactus pubispinus*	

Extensive inventory efforts have been directed at mammals, reptiles, amphibians, fish, mollusks, cave invertebrates, and plants. Despite such efforts, truly rare species often remain undetected by traditional taxon-based inventory methods. Future inventories should focus on specialized survey methods such as remote cameras, direct trapping, mist-netting, pitfall trapping, owl surveys, drift fences, and acoustic detection in an occupancy framework for small mammals, shrews, birds, and bats.

Great Basin National Park species of management concern generally fall into three categories. 1) Species perceived as rare due to a fossorial, nocturnal, or secretive nature. Inventory efforts may reveal these species as common when appropriate detection methods are used. 2) Species imperiled due to habitat conversion, such as riparian, alpine, and sagebrush obligate species. 3) Truly rare species that are patchily distributed (e.g. cave invertebrates) and/or present in low densities.

The following list contains species currently recognized by federal or state agencies. Several species are not listed at federal or state levels, but their unique status or declining population trends warrant their listing as a NPS species of management concern under the criteria listed above. Thirteen species were removed from the list for the 2014 update. Species were removed because GRBA does not contain the species' preferred habitat; the park boundary lies outside their current range (long-billed curlew, California quail, western burrowing owl, fox sparrow, loggerhead shrike, speckled dace and redside shiner); or surveys revealed these species to be more common than previously known (ringtail, long-tailed weasel, striped skunk, spotted skunk and side-blotched lizard). Sixteen species were added to the list including four newly described species of endemic cave invertebrates and several alpine plant species (Table 1).

Maps with historic and recent observations for most species can be found in Appendix A. Maps were not included for several plant species, fringed myotis and Lewis's woodpecker because of limited or no locality data for the park or vicinity. To view locality maps, click on the underlined 'Map' at the end of each species description. Photo credit can be found in Appendix B.

MAMMALS

MERRIAM'S SHREW (*SOREX MERRIAMI*) – Three records exist for Merriam's shrew near the park – two in Strawberry Creek and one near the town of Baker (latter from Rickart and Robson 2007). This species is widespread but uncommon in the West (Armstrong 1999). As with other shrew species, the Merriam's shrew is an insectivore feeding on a wide variety of arthropods. It can be found in riparian habitat but seems to prefer dryer herbaceous sites in sagebrush, grassland, pinyon-juniper and montane forest habitat (Armstrong 1999). It is active throughout the year. Threats are poorly understood, but may include habitat conversion to annual grasslands or rabbitbrush and conifer encroachment (NDOW 2012). Surveys are needed to determine occurrence and occupied habitat. Map

WATER SHREW (*SOREX PALUSTRIS*) – The water shrew is the largest shrew in the region weighing eight to 18 grams. Water shrews are broadly distributed throughout the northern portions of North America and can occupy a wide elevation range from 7, 500 to 11,000 feet. Water shrews are restricted to riparian habitat along perennial streams, and their diet reflects this. They feed mostly on aquatic insects and sometimes small, aquatic vertebrates (Beneski and Stinson 1987). Only a few records exist in the park for water shrews (Rickart and Robson 2005). Locality data is not available for all records. Threats include water diversions, development and habitat loss. Directed surveys are needed to determine occurrence and distribution in the park. Map

INYO SHREW (*SOREX TENNELLUS*) – The Inyo shrew is the smallest shrew species found in the park. It occurs in California and Nevada, but there is only one park record, from Lehman Creek (9,900 feet). This specimen was collected in rocky, streamside habitat (Rickart et al. 2004) and extended the known range for this species by 300 km (NDOW 2012). Inyo shrews are a montane species and can occur in rocky areas from pinyon-juniper to alpine habitats, oftentimes associated with talus. Inyo shrews are active year-round. Very little is known about the behavior or food habits of the Inyo shrew (Hoffman and Owen 1980). This species is listed as imperiled in Nevada by NatureServe, and could be affected by water diversions, development and loss of riparian habitat. Surveys are needed to determine occurrence and habitat needs. Map

PALLID BAT (*ANTROZOUS PALLIDUS*) – The pallid bat is a colonial species that occurs in a variety of habitats and over a wide elevation range. They are common in lower elevation deserts but also occur in sagebrush steppe, low to mid elevation woodlands and subalpine forests (NV Natural Heritage Program; Rickart and Robson 2005). Preferred roost sites are also diverse. The park region represents the northern distribution limit for this species in the central Great Basin (Ports and Bradley 1996; Rickart and Robson 2005). Park records exist from Snake Creek Cave and the Baker Creek cave system. The pallid bat is listed as vulnerable in Nevada by NatureServe. Roost sites include rock crevices or buildings, and less often caves, tree hollows or mines. Hibernation typically occurs in caves. As with other bat species, the spread of white-nose syndrome, recreational caving, permanent closures of mine and cave entrances that exclude bats, and habitat loss are potential threats. More extensive sampling at potential roost sites and in foraging habitat is needed. Map

TOWNSEND'S BIG-EARED BAT (*CORYNORHINUS TOWNSENDII*) – Townsend's big-eared bats occur over a wide elevation range and a variety of habitat types (Ports and Bradley 1996). They feed mainly on moths and are dependent on caves and mines for roosting. In the spring, females form large maternity colonies of more than 100 individuals (Rickart et al. 2008); males tend to roost singly. Townsend's big-eared bats forage in wooded habitat types near streams (NV Natural Heritage Program) and can travel long distances to forage (NDOW 2012). Park records exist for Lehman Caves, the Baker Creek cave system, Snake Creek and Lincoln Canyon along with records from several high elevation caves. Townsend's big-eared bats are declining throughout Nevada (NDOW 2012) and are listed as imperiled in the state by NatureServe. This species is highly susceptible to disturbance (Sherwin et al. 2000). Hibernation and roosting occurs out in the open in caves or mines, so big-eared bats can be easily disturbed, especially females in maternity colonies. They are heavily dependent on caves and mines and have not demonstrated flexibility in their choice of roosting sites. White-nose syndrome, recreational caving, complete and permanent closures of mine and cave entrances that exclude bats, and loss of riparian habitat are the primary threats (NDOW 2012). Continued monitoring is needed to determine foraging habitat and shifts or abandonment of hibernacula, maternity colonies and roost sites. Map

SPOTTED BAT (*EUDERMA MACULATUM*) – The spotted bat is a truly rare species in Nevada. Extensive mist-netting at cave entrances and mines has failed to document this species in the park. Two unconfirmed reports exist from Lehman Cave (1958) and Model Cave (1966), but the spotted bat is easily distinguishable from other bat species by its unique black and white color pattern. Records also exist for spotted bat from Pine Valley, UT (Jason Williams, pers. comm.). The spotted bat occurs over a broad elevation range and utilizes a variety of habitat types. It feeds on flying insects and roosts in crevices, often found in or around cliffs or rock outcrops (Rickart and Robson 2005). This species can be hard to sample, flying high enough to avoid mist nets and exhibiting sensitivity to noise and light (NV Natural Heritage Program). Acoustic sampling at caves, mines, and potential foraging habitat is recommended to document species. Map

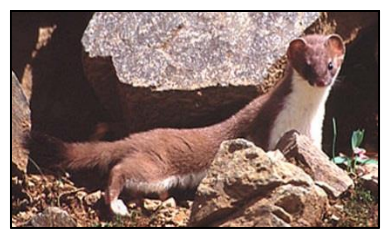
SILVER-HAIRED BAT (*LASIONYCTERIS NOCTIVAGANS*) – The silver-haired bat is an uncommon but regular, seasonal migrant in the park region (Rickart and Robson 2005; Rickart et al. 2008). It has been listed as vulnerable in Nevada (NatureServe). Park records exist for Snake Creek and Lincoln Canyon. Silver-haired bats prefer forested habitat and tend to roost singly or in small groups in trees. Occasionally, they will roost in caves or buildings. They utilize a variety of forested and woodland habitat types (pinyon-juniper, aspen, mixed-conifer, cottonwood and limber pine), but are most commonly found in mature forests. Roosting habitat may be a limiting factor for this species. Silver-haired bats have been shown to migrate long distances to access foraging sites. The silver-haired bat is vulnerable to alternative energy development, logging, and removal of clusters of large snags (NDOW 2012). Surveys are needed to determine roosting sites and preferred foraging habitat. Map

HOARY BAT (*LASIURUS CINEREUS*) – The hoary bat is a tree roosting species reliant on forested or riparian habitat. Records occur near Lincoln Peak and in Spring Valley (Shoshone Ponds). The hoary bat is a migratory species that is widespread throughout North America and can utilize a wide range of elevations and habitat types. Roosting sites are typically in the foliage of trees (Rickart and Robson 2005). The status of hoary bats in Nevada is unknown. It can be a difficult species to sample and has a patchy distribution in the state. The hoary bat has already been impacted by renewable energy projects. It is the most common bat mortality found at wind farms (NDOW 2012). This species is not known to be affected by white-nose syndrome (NatureServe). Acoustic surveys are needed to determine roosting and foraging sites. Map

FRINGED MYOTIS (*MYOTIS THYSANODES*) – The fringed myotis is a rare species not commonly captured during surveys (NDOW 2012). There are no park records for fringed myotis, although suitable habitat exists. The fringed myotis is a forest species common in mid to high elevation forests (Jason Williams, pers. comm.). It is widespread in the western U.S., but its distribution in Nevada is patchy (NDOW 2012) and abundance is apparently low (NatureServe). Crevices or trees are its preferred roosting site. Hibernation occurs in mines and caves. This species is highly susceptible to human disturbance at roost sites and hibernaculum (Western Bat Working Group 2005, NDOW 2012). Fringed myotis is listed as imperiled in Nevada by NatureServe and may be vulnerable to White-nose syndrome. Threats include human disturbance of roost sites, maternity colonies, and hibernacula; recreational caving; barricades or gating of mine and cave entrances that exclude bats; and loss of habitat (NatureServe). Because of low-intensity echolocation and the tendency for fringed myotis to forage above normal mist-net height, acoustic surveys are recommended to increase probability of detection. Surveys should focus in forested habitat near forest edges or water (Western Bat Working Group 2005) and at caves or mines during emergence.

LONG-EARED MYOTIS (*MYOTIS EVOTIS*) – There are numerous park records for long-eared myotis from the Baker Creek cave system, Snake Creek and Lincoln Canyon. This species has a broad distribution and can be found throughout the state, but is considered uncommon in Nevada (NDOW 2012). Long-eared myotis are typically found in mid to high elevation forests (Rickart and Robson 2005) and are capable of foraging in dense vegetation. This species can use a variety of roosting sites, but tends to select trees, roosting under bark or in tree hollows. Females have a low reproductive rate. They form small maternity colonies in the summer where they can be vulnerable to disturbance (NV Natural Heritage Program). Long-eared myotis are believed to hibernate in Nevada, but data on winter habits are unknown. This species may be vulnerable to white-nose syndrome (NDOW 2012). Surveys are needed to determine foraging and roosting habitat in the park. Restoration projects in forested habitat types my affect this species. Map

LONG-LEGGED MYOTIS (*MYOTIS VOLANS*) – The long-legged myotis has the broadest distribution among the bats that occur in the park region (Rickart and Robson 2005). They can utilize a wide range of elevations and habitat types. Numerous park records exist for this species. Long-legged myotis is considered a forest species despite its demonstrated flexibility in seasonal habitat selection. This species forages in and around the forest canopy and uses riparian zones (NV Natural Heritage Program). Long-legged myotis hibernate in caves and mines, but their vulnerability to white-nose syndrome is unknown (NatureServe). Roosting sites are varied and may include tree hollows, cliff crevices, mines and caves. Visitation and closures of mine and cave entrances that exclude bats are threats. Restoration projects in forested habitat types may affect long-legged myotis. Surveys are needed to determine foraging and roosting habitat in areas other than mine or cave locations. Map



ERMINE (*MUSTELA ERMINEA*) - Ermine are restricted to mid and high elevation forests (Rickart et al. 2008). Several historic park records, wildlife observations and remote camera inventories suggest that ermine are widespread in the park. Ermine are predicted to go extinct from the Snake Range due to climate related declines in habitat quantity and quality (McDonald and Brown 1992). Easily confused with the more common and widespread long-tailed weasel, unambiguous identification requires direct measurement or photographs that allow measurement of relative tail length (Hall 1946). Trapping and remote camera inventories are recommended to document species occurrence, habitat preferences and occupancy patterns. Maintenance of mid to high elevation forest health and alpine areas are important management considerations. Map

BIGHORN SHEEP (*OVIS CANADENSIS*) - The South Snake Range currently supports a small herd of approximately 30 bighorn. Bighorns were extirpated from GRBA by the 1970s and reintroduced by NDOW in 1979. Domestic sheep, mountain lion predation and winter habitat quality are currently limiting bighorn population growth (Peek et al. 2003). Although recent fires have improved habitat dramatically, the current population is not viable, and without management intervention, the extirpation of this population is highly likely (Berger 1990). Bighorns are currently being monitored with satellite linked GPS collars, and a project is currently examining the conservation genetics of the population. Management should focus on maintaining separation between domestic sheep and bighorns, improving habitat via fires, and augmenting the population (Hamilton 2009). Map

BEAVER (*CASTOR CANADENSIS*) - Beaver are riparian obligates and play an important role in wetland and riparian hydrology (Rickart et al. 2008). Although there is abundant historic sign (gnawed stumps and terraces) in most perennial park streams, legitimate questions persist over the nativity of beaver to the area (Hall 1946, 1981).Grayson pers. comm. Populations currently occur at lower elevations in Weaver and Strawberry Creeks outside the park. Montane riparian areas may not be able to support beaver without connectivity to lower elevation, low gradient streams. Most park habitat is too high gradient (4-10%) to support beaver (Baker and Hill 2003, Hay 2010). Management should focus on maintaining high quality riparian habitat, protecting established populations, and carbon dating of tree stumps to determine the nativity of this species. A habitat suitability model could be used to evaluate the ability of habitat in the park to support viable beaver populations. Map

SAGEBRUSH VOLE (*LEMMISCUS CURTATUS*) - Sagebrush voles are shrub steppe obligates declining due to loss of sagebrush habitat (Rickart et al. 2008). Sagebrush voles occur over a wide elevational gradient in multiple habitats in the park, including annual grasslands (Hamilton 2003a). Population eruptions are well documented in this species (Carroll and Genoways 1980). Such variability in abundance makes monitoring and trend assessment difficult. Inventories should focus on intensive trapping during good precipitation years. Management actions should focus on the maintenance of high quality sagebrush habitat, increasing patch size and increasing connectivity of sagebrush habitat. Map

PORCUPINE (*ERETHIZON DORSATUM*) - Porcupines were formerly widely distributed and abundant in the park (Hall 1946) but populations have precipitously declined (Rickart et al. 2008). Although porcupine populations are inherently cyclical (Spencer 1964), declines in the Great Basin are linked to mountain lion predation (Sweitzer et al. 1997). Riparian habitat forms an important part of porcupine habitats in the Great Basin. Management should focus on maintaining healthy forests, riparian areas, and shrublands. Speed enforcement is an important consideration to minimize road mortality. Inventories should continue to document and monitor populations and habitat utilization should be documented with radio telemetry. Map

YELLOW-BELLIED MARMOT (*MARMOTA FLAVIVENTRIS*) – Yellow-bellied marmots are sagebrush obligates that exhibit high fidelity to their burrow sites. They are a colonial species with a long hibernation period, typically July to March (Barash 1989). Threats include conifer encroachment into sagebrush steppe habitat. Floyd (2004)documented several potential extirpations from four isolated Great Basin mountain ranges, but targeted surveys and general wildlife observations have shown that colonies are widespread in the park (Hamilton and Horner 2010). Habitat restoration projects in sagebrush steppe have been completed or are underway. Maintenance of open sagebrush steppe with an herbaceous understory, adequate soils for burrows, and rock outcrops for basking and lookouts are important for this species. Pre-treatment surveys are recommended within restoration project boundaries to document marmots and mark burrows. Other mitigation measures include avoiding fire or mechanical treatments when marmots are most active and foraging, March to July. Speed enforcement is an important consideration to minimize road mortality. Floyd also found connectivity between ranges suggesting that the species is not as isolated as had been presupposed by Brown (1971). Map

PYGMY RABBIT (*BRACHYLAGUS IDAHOENSIS*) **–** The pygmy rabbit is a sagebrush obligate dependent on mature big sagebrush for cover, forage, breeding and burrowing (Green and Flinders 1980). Burrow sites are typically in deep, friable soils to enable burrow excavation (NV Natural Heritage Program). Pygmy rabbits are endemic to the Great Basin with a very limited distribution outside of the physiographic region. They are listed as vulnerable in Nevada (NatureServe). Threats include loss of habitat and habitat connectivity to conifer encroachment, cheatgrass invasion, development and fire (NDOW 2012). One historic record exists from Baker Creek; extant populations exist in Spring Valley. Extensive inventories were completed in the park. Only five records of pygmy rabbit sign were documented (scat or burrow); no pygmy rabbits or active burrows were encountered. A recent observation in the park occurred in Lehman Creek. The park's higher elevation and rocky soils may limit use or available habitat for pygmy rabbits. The maximum known elevation for pygmy rabbits is 2,450 m (8,038 feet) (NV Natural Heritage Program). An apparent upward elevation shift for this species has been attributed to climate change (USFWS 2010; NDOW 2012), so dispersal into the park may be possible. Maintaining mature stands of basin, Wyoming and mountain big sagebrush as well as maintaining connectivity between upper and lower elevation stands could facilitate this. Map

BIRDS

GREATER SAGE GROUSE (*CENTROCERCUS UROPHASIANUS*) – Greater sage grouse are a US Fish and Wildlife Service candidate species and a sagebrush obligate, heavily dependent on sagebrush steppe during critical portions of its life (Connelly et al. 2011). Threats include habitat loss and fragmentation, grazing, fire, energy development and predation (Great Basin Bird Observatory 2010). Sage grouse were present in the park historically, including breeding records, but only anecdotal observations have been made recently. Active leks (breeding grounds) occur outside the park in Snake and Spring Valleys. Telemetry surveys in Snake Valley, in conjunction with NDOW, documented lekking grounds near Kious Basin and use of agricultural lands. Annual lek surveys are ongoing. Suitable summer habitat (wet meadow, riparian and sagebrush steppe) is available in the park. Habitat restoration projects have been completed or are underway including conifer removal and spring restoration. Continued lek surveys are recommended as well as cross-jurisdictional restoration efforts to improve habitat condition and connectivity. Surveys in potential summer habitat are also recommended. Map

NORTHERN GOSHAWK (*ACCIPITER GENTILIS*) – The Northern goshawk is a forest raptor whose nesting habitat is limited to mature aspen stands and coniferous forest. The Nevada population is estimated at 700 and has been listed as imperiled due to restricted and/or degraded aspen habitat (NatureServe 2014). The Snake Range is recognized as a key conservation area (Great Basin Bird Observatory 2010). Maintenance and restoration of park aspen stands is critical for this species. Aspen stands in the park are in extremely poor condition. Broadcast surveys have documented nesting in Can Young Canyon and South Fork Big Wash. Incidental sightings have been reported in Snake Creek, Strawberry Creek, Baker Creek and Mill Creek. Continued broadcast surveys in potential habitat are needed. Pre-treatment monitoring is recommended for prescribed fire or thinning projects in aspen, mixed-conifer or spruce habitat. Map

SWAINSON'S HAWK (*BUTEO SWAINSONI*) – Swainson's hawks are rarely recorded in the park despite suitable habitat (Hartley and Gubanich 2004). Records occur from low elevation shadscale survey plots outside park boundaries and one high elevation bristlecone pine site (Woodyard et al. 2003). Swainson's hawks are long-distance migrants that winter in Argentina. This species usually occurs close to riparian or other wet habitat types and has adapted to using agricultural landscapes in Nevada. It prefers agricultural, lowland riparian and sagebrush habitat types, and avoids densely forested areas. It typically nests in large trees with overhead cover or in cliffs. Historic and recent declines have been attributed to loss of riparian habitat, pesticide use, human development, and decreases in prey populations. Species will benefit from maintenance of open riparian woodlands and open shrublands (GBBO 2010). There is a general need to document breeding birds, particularly raptors in the park. Map

FERRUGINOUS HAWK (*BUTEO REGALIS*) – The ferruginous hawk is a year-round resident in Nevada and the largest buteo in North America. Records from the park and vicinity include sites in bristlecone pine, piñon-juniper, and shadescale (Medin et al. 2000, Woodyard et al. 2003). Christmas bird count surveys often record this species adjacent to park boundaries (NPSpecies). Preferred breeding habitat for ferruginous hawks includes open sagebrush adjacent to piñon-juniper edges. Prey consists mostly of lagomorphs. Population declines in the 1980s spurred a petition for listing in 1991 that was not fulfilled (Great Basin Bird Observatory 2010). The densest breeding populations occur in eastern and central Nevada. This species avoids densely wooded areas; but prefers lone or peripheral tress for nesting (NDOW 2012). Management actions should maintain or improve suitable nest sites and protect active nests from disturbance (GBBO 2010), including fire and livestock (NDOW 2012). Some annual fluctuations in numbers of ferruginous hawks can be attributed to prey abundance, so improving habitat for prey is also important along with limiting human disturbance and keeping native vegetation intact (GBBO 2010). Potential conflicts exist with renewable energy development (NDOW 2012). Map

PEREGRINE FALCON (*FALCO PEREGRINUS*) – Peregrine falcons were delisted by the US Fish and Wildlife Service in 1999, but are still listed as imperiled in Nevada by NatureServe. Reintroduction efforts by state agencies reestablished peregrine falcons on the west side of the park. Occasional sightings have been reported in the park at higher elevations near Wheeler Peak, Mt. Washington and Lincoln Canyon. White Pine County is one of only three counties in the state where breeding has been confirmed since 1960 (NDOW 2012). This species uses varied habitat types, but appears to favor open environments and nests in cliffs. Primary prey is other birds. The state population is small with estimates of 140-180 individuals. Energy development may impact foraging areas and migration corridors (NDOW 2012). Management actions should include maintaining habitat for avian prey species near cliffs or potential nesting sites; preventing disturbance near known nesting sites and adjacent foraging habitat; and implementing seasonal closures of climbing routes near known nest locations (NDOW 2012). Surveys are needed to determine if birds are still established and successfully nesting in the park and if there are newly occupied territories. Map

THREE-TOED WOODPECKER (*PICOIDES TRIDACTYLUS*) (Synonym: *P. DORSALIS*) – GRBA may represent the only records for three-toed woodpecker in Nevada (Sibley 2003, Hartley and Gubanich 2004). It prefers coniferous forest, primarily spruce, or recently burned areas. It is listed as imperiled in the state (NatureServe 2014). There have been three recent records reported from the park: 2004, 2011 and 2012. Hartley and Gubanich (2004) reported two vouchers for this species, but location information was not given. Surveys in higher elevation coniferous forest, especially spruce, are needed. Map

LEWIS'S WOODPECKER (*MELANERPES LEWIS*) – The Lewis's woodpecker is a rare, year-round resident in northern Nevada. There is only one literature record indicating its presence in park (Hartley and Gubanich 2004). No recent records or observations have been reported. Habitat for this species includes vulnerable vegetation types including aspen, cottonwood and Ponderosa pine (NDOW 2012). This species is listed as sensitive or vulnerable because of historic range contractions and population declines. The Nevada population is estimated at 13,000. It is a weak excavator reliant on large, dead snags with natural cavities or abandoned holes for nesting (GBBO 2010). Surveys are needed in riparian habitat, aspen and ponderosa pine habitats.

FLAMMULATED OWL (*OTUS FLAMMEOLUS*) – Flammulated owls are documented from the Snake Range (Great Basin Bird Observatory 2010). White-fir encroachment into Ponderosa pine and aspen may be degrading suitable habitat. Flammulated owls have slow reproductive rates, are insectivorous and are cavity nesters, often using flicker holes. Management should focus on improving limited Ponderosa pine woodlands with mechanical thinning and prescribed fire. Inventory methods should be owl specific and allow positive identification to species. Map

SHORT-EARED OWL (*ASIO FLAMMEUS*) – Short-eared owls are uncommon in Nevada. They are known from only a few locations outside the park, although suitable habitat exists within park boundaries. Short-eared owls are vole specialists, and habitat needs for this species correspond with prey choice. Short-eared owl populations tend to track fluctuations in vole abundance, which can undergo considerable variation. Habitat associations include wet meadow, sagebrush steppe with a robust herbaceous component, and grasslands (Great Basin Bird Observatory 2010). Species specific inventories in the park are needed. Diurnal surveys may prove most productive. Management should focus on improving or maintaining sagebrush steppe, wet meadow and grassland habitat types to maintain or improve prey abundance. Map

BREWER'S SPARROW (*SPIZELLA BREWERI*) – Brewer's sparrows occur in the park and have declined on average by 2% per year since 1968. They are included on the Audubon Watchlist. Populations have declined since the 1960's, with larger declines since the 1980's due to loss of sagebrush habitat (Hartley and Gubanich 2004). Management should focus on maintaining and improving sagebrush steppe habitat. Brewer's sparrows are the most successful of the sagebrush obligates at utilizing montane sagebrush habitat which is available in the park. Map

SAGE SPARROW (*AMPHISPIZA BELLI*) - Sage sparrows are a conservation priority species that require large patch sizes of sagebrush habitat. The species has suffered historic and recent population declines and their habitat is threatened by conifer encroachment and annual grasses (Great Basin Bird Observatory 2010). Monitoring should focus on documenting populations and breeding bird surveys. Management should focus on protection of habitat and restoration of sagebrush. Map

SAGE THRASHER (*OREOSCOPTES MONTANUS*) - Sage thrashers are a stewardship species in Nevada. Sage thrashers are not declining to the same extent as other sagebrush obligate bird species but are still declining. They are a priority species and short distance migrant that require large patch sizes of sagebrush habitat. This species has suffered historic and recent population declines and their habitat is threatened by conifer encroachment and annual grasses (Great Basin Bird Observatory 2010). Monitoring should focus on documenting populations and breeding bird surveys. Management should focus on protection of habitat and restoration of sagebrush. Map

PINYON JAY (*GYMNORHINUS CYANOCEPHALUS*) – Pinyon jays utilize both pinyon-juniper woodland and sagebrush habitat, and appear to prefer transition zones between the two or sagebrush openings within pinyon stands. Telemetry studies in White Pine County (2007-2009) revealed limited use in dense woodland habitat (Great Basin Bird Observatory 2010). This species is commonly encountered during annual bird surveys, but is experiencing range-wide declines. Threats include habitat loss through infilling of sagebrush patches, and loss of understory and mixed age classes within pinyon stands. Maintaining understory vegetation and sagebrush patches within pinyon stands will be important. Map

MACGILLIVRAY'S WARBLER (*OPORORNIS TOLMIEI*) **(**Synonym: *Geothlypis tolmiei*) – MacGillivray's warbler is a migrant and an indicator of riparian health. It utilizes a variety of habitat types, but seems to prefer dense shrub cover, willows and wet habitats in parts of its range. This species is listed as apparently secure in Nevada (NatureServe), but may be vulnerable to loss or degradation of riparian habitat. Breeding bird surveys have documented this species in several park watersheds with perennial streams. Maintenance of riparian and wet meadow habitat within the park will benefit this species. Map

YELLOW WARBLER (*DENDROICA PETECHIA*) – Yellow warblers are restricted to wet, brushy riparian habitat. This species is a migrant and an indicator for riparian health. The Nevada population is listed as vulnerable by NatureServe. Breeding bird surveys have confirmed their presence in the park in several perennial watersheds: Baker, Lehman and Strawberry Creeks. Maintenance of riparian and wet meadow habitat will benefit this species. Map

BLACK ROSY-FINCH (*LEUCOSTICTE ATRATA*) – The black rosy-finch is a known breeder in the Snake Range and is dependent on open alpine habitat, making it vulnerable to climate change. This species has a small global population (est. 20,000) and restricted summer and winter habitat. Critical winter roost sites are located in caves, mine entrances or rock fissures in lower elevation pinyon-juniper and sagebrush habitat (Audobon 2007; GBBO 2010). During the summer months, the black rosy-finch utilizes alpine habitat on Wheeler Peak, Bald Mountain and vicinity (Medin 1987, Medin et al. 2000, Woodyard et al. 2003). Protection of alpine habitat and critical winter roost sites, including appropriate gating of cave and mine entrances, is an important management consideration (NDOW 2012). Breeding bird surveys in alpine habitat should be conducted to verify continued breeding within the park, survey alpine habitat for additional populations, and monitor this species' response to changing climatic conditions. Map

REPTILES

SONORAN MOUNTAIN KINGSNAKE (*LAMPROPELTIS PYROMELANA*) –Sonoran Mountain kingsnakes are only documented from the park in Lincoln Canyon (two anecdotal records exist from the east side of the park). This species occurs widely in other areas of the Snake Range, and its apparent absence from the east side of GRBA is puzzling. Kingsnakes are highly secretive but occur across a wide elevation and habitat gradient (Hubbs 2004). Inventory efforts should include pitfall trapping, drift fence arrays, road surveys, visual encounter surveys and radio telemetry. The species is popular in the pet trade and collection is prohibited in Nevada and regulated in Utah. Map

GREAT BASIN WHIPTAIL (*ASPIDOSCELIS TIGRIS*) – Whiptails occur in low elevation habitats across the Great Basin (Setser et al. 2002). Only one park record occurs outside the Baker Administrative site in lower Lehman Creek. Management should focus on protecting the park's most suitable habitat, the Baker Administrative Site and documenting this species at higher elevations. Map

DESERT HORNED LIZARD (*PHRYNOSOMA PLATYRHINOS*) – Although widespread across the Great Basin (Setser et al. 2002, Stebbins 2003), desert horned lizards are found in the park only at the Baker Administrative Site. This species prefers low elevation, shrub habitat and are nearly entirely myrmeciphagous in their diet (Stebbins 2003). Horned lizards are collected commercially in Nevada. Management should focus on protecting low elevation habitat on the Baker Administrative site. Map

AMPHIBIANS

GREAT BASIN SPADEFOOT (*SPEA INTERMONTANA*) – Although widely distributed regionally (Linsdale 1940, Setser et al. 2002, Stebbins 2003), the Great Basin Spadefoot is the only amphibian species occurring in the park (Hamilton 2003b). The only suitable habitat is the Baker Administrative site. They likely breed and metamorphose outside the park. Management should focus on avoiding disturbance to the Baker Administrative site. Radio telemetry could be used to locate breeding habitat and subsequently protect it. Map

FISH

BONNEVILLE CUTTHROAT TROUT (*ONCORHYNCHUS CLARKI UTAH*) – Bonneville cutthroat trout (BCT) are the only salmonid native to eastern Nevada and Great Basin National Park. BCT were presumed extirpated from the park (Williams et al. 1999), but several populations were later discovered. Seven populations occur in the park, five of which were reintroduced by park staff. The park's small, isolated populations of BCT occur in headwater streams making them susceptible to stochastic events such as large floods and forest fires and vulnerable to environmental effects associated with climate change (Heino et al. 2009). BCT are susceptible to competition and predation with non-native brook trout and brown trout, as well as introgression with rainbow trout. Proper barrier installations are needed to isolate and protect native trout populations from non-native fish, and future augmentations may be required to sustain existing populations. The pristine conditions of headwater streams need to be maintained. Infrastructure maintenance and improvements are needed to prevent negative impacts from roads and trails to BCT streams. Map

LAHONTAN CUTTHROAT TROUT (*ONCORHYNCHUS CLARKI HENSHAWI*) – Lahontan cutthroat trout (LCT) are listed as Threatened under the Endangered Species Act wherever they may occur. LCT is the largest of the cutthroat species and is native to the Lahontan Basin. A small, self-sustaining population has occupied Baker Lake (10,600 ft.) since 1986 when the park was created. Fin clips collected in 2011 from Baker Lake identified the population as pure Lahontan with no evidence of rainbow trout or other cutthroat species (Shirizowa 2012). Although they have cohabitated for many years, the LCT population is threatened by a population of non-native brook trout in the lake. Both competition and predation are likely mechanisms that may work in concert with the natural history traits of brook trout to mature at younger ages and have greater size-specific fecundity than cutthroat trout (Kennedy et al. 2003). At this time, we recommend that the purity of this Lahontan cutthroat trout population be recognized. While it is an introduced population, it may have conservation use for populations in the Lahontan Basin (Shirizowa 2012). Management considerations include suppressing brook trout in Baker Lake using fine mesh gill net techniques or rod and reel. Map

MOTTLED SCULPIN (*COTTUS BAIRDI*) – Mottled sculpin are broadly distributed across the United States and native to the Upper Snake River Basin and isolated populations in endorheic basins in Nevada (Page and Burr 1991). Mottled sculpin were reintroduced to Strawberry Creek and South Fork Big Wash. The Strawberry Creek population was augmented several times without success; only a few individuals have been captured in subsequent sampling attempts. No mottled sculpin were caught after augmentations in South Fork Big Wash. Barriers to successful reintroduction are most likely due to predation from Bonneville cutthroat trout. Future reintroduction efforts should first introduce sculpin, to establish a sustaining population before adding predatory species. Relevant references: Haskins (1991); Andersen & Deacon (1996), Sigler and Sigler (1987). Map

INVERTEBRATES

NOKOMIS FRITILLARY (*SPEYERIA NOKOMIS*) – This medium-sized butterfly (6.3-7.9 cm wing span) is in the brush-foot family and lives throughout the west. Males patrol for receptive females who walk on the ground to lay single eggs near host plants. Unfed, first-stage caterpillars hibernate; in the spring they feed on leaves of their host plant, *Viola nephrophylla*. Their habitat includes moist meadows, seeps, marshes and other riparian areas. Threats include draining of habitat and human development. This species is considered secure globally, though it might be quite rare in parts of its range, especially at the periphery. Management recommendations include habitat protection and management. Moderate grazing is compatible with this species and may be necessary. Map

TOQUERVILLE SPRINGSNAIL (*PYRGULOPSIS KOLOBENSIS*) – Springsnails (family Hydrobiidae), are small (1-8 mm), sexually reproducing aquatic mollusks. They are oviparous, with reproduction occurring several times a year. They feed on algae (Sada 2001). Springsnails are most abundant near spring sources, with species from the genus *Pyrgulopsis* especially abundant in areas with watercress (Sada 2001). The Toquerville springsnail is only found in springs near Snake Creek. This species is wide-ranging as currently taxonomically defined. The main threats to springsnails are habitat alteration from surface water diversion, livestock grazing, groundwater depletion, and non-native macroinvertebrates. Recommendations include protecting park water sources, education and outreach about aquatic invasive species and proper cleaning techniques, and periodic monitoring. Map

Cave Biota

GREAT BASIN CAVE PSEUDOSCORPION (*MICROCREAGRIS GRANDIS* MUCHMORE) – This pseudoscorpion is 15-20 mm long, with tan to reddish coloring. It was first collected in Lehman Caves in the late 1930s, and since then has been found in several park caves: Pictograph, Little Muddy, Crevasse, Cave 24, Fox Skull, Lehman Annex, Model, Root, Squirrel Spring, Systems Key, Water Trough, and Broken Cave. It is endemic to Great Basin National Park. Recommendations are to limit entry into caves containing this species as well as conduct periodic monitoring. Since this species is endemic to the park and found in Lehman Caves, it is a good species to highlight to help the public understand the cave ecosystem. Map

SNAKE RANGE MILLIPEDE (*NEVADESMUS OPHIMONIS* SHEAR) – This small, white millipede, only about 10 mm long, is a cave invertebrate often found in moist areas on soil or bedrock. It has been found in Lehman, Little Muddy, Model, Snake Creek, and Wheeler's Deep caves, along with one cave outside the park. It is endemic to the South Snake Range. Threats include climate change and over-visitation. Recommendations are to limit entry into caves containing this species (e.g., Model Cave) and conduct periodic monitoring. Map

GREAT BASIN CAVE MILLIPEDE (*IDAGONA LEHMANENSIS* SHEAR) – This white to yellow millipede is about 10-20 mm long with a cylindrical body. It has been found in caves with water present like Model, Water Trough and Squirrel Springs along with several alpine caves (Bristlecone Cave, Cave 24, Lincoln Canyon Mine and Pine Cone Cave). In addition, the Great Basin cave millipede is also found in Ice Cave, Systems Key Cave, and Wheeler's Deep. It was found in 2006 and described as a new species in 2007. It is endemic to Great Basin National Park. Threats include climate change and over-visitation. Recommendations include periodic monitoring and limiting entry into caves containing this species. Map

MODEL CAVE HARVESTMAN (*SCLEROBUNUS UNGULATUS* DERKARABETIAN) – The harvestman is a predator generally found on moist surfaces in caves. It was first found in Model Cave and described in 1971 by Briggs as *Cyptobunus ungulatus ungulatus*; since then it has been found in several other park caves: Crevasse, Halliday's Deep, Ice, Upper Pictograph, Wheeler's Deep, Systems Key, and Cave 24. In 2014, it was elevated to the species level and moved to a different genus (*Sclerobunus*). It is endemic to GRBA. Threats include climate change and over-visitation. Recommendations are to limit cave access and conduct periodic monitoring. Map

MODEL CAVE AMPHIPOD (*STYGOBROMUS ALBAPINUS*) – This amphipod species was discovered in November 2008 and described as a new species in 2011. Thus far, it has only been found in Model Cave, in water. This species seems to prefer warmer, more conductive groundwater than cooler and less conductive surface water. Threats include water withdrawals that may lower the water table and pollutants from upstream in Baker Creek (e.g. fire retardant and oil spills). Recommendations include periodic biological monitoring, protecting park water resources, especially groundwater, managing wildfires in the Baker drainage with as little fire retardant as possible, and swift response to any spills near Baker Creek. Map

PLANTS

Thirteen species of rare and/or sensitive plant species occur within Great Basin National Park. An additional four species occur locally but remain undocumented in the park. Six species are former Category 2 candidates for listing under the Endangered Species Act and are now designated by the US Fish and Wildlife Service as species of concern.

In 2004 and 2005, a survey was completed to assess the location, distribution and relative abundance of five species including Holmgren's buckwheat (*Eriogonum holmgrenii*), Wheeler Peak penstemon (*Penstemon leiophyllus* var. *francisci-pennellii*), Nevada primrose (*Primula cusickiana* var. *nevadensis*), Nevada catchfly (*Silene nachlingerae*) and snowline (Elko) springparsley (*Cymopterus nivalis*).

SCALLOPED MOONWORT (*BOTRYCHIUM CRENULATUM*) – OPHIOGLOSSACEAE – Presence is confirmed in the park in Snake Creek near Johnson Lake. Scalloped moonwort, also known as dainty moonwort, is a diminutive species native to the western United States, but it is an aquatic or wetland dependent in Nevada. This species is limited to higher elevation, wet meadows in the park. It is listed as a species of concern by the US Fish and Wildlife Service, BLM and the US Forest Service. It is also included on the Nevada Natural Heritage Program At-Risk list and NV Native Plant Society list. Management should focus on restoration and maintenance of mid to high elevation wetlands, wet meadows and springs. Relevant references: Morefield (2001), NNHP (2012), Clifton (2012), USDA (2015).

HOLMGREN'S BUCKWHEAT (*ERIOGONUM HOLMGRENII*) – POLYGONACEAE – Holmgren's buckwheat, or Snake Range buckwheat, is endemic to the South Snake Range and is estimated to occur on 387 acres of park lands. It occurs on quartzite and limestone talus in alpine and subalpine areas. Populations in GRBA have been extensively mapped, but demography, natural history and ecology are largely unknown. It is listed by several federal and state agencies as a species of concern (US Fish and Wildlife Service, US Forest Service, NV Natural Heritage Program, and NV Native Plant Society). Threats include recreational use of alpine and subalpine areas. Management should focus on protecting alpine areas from disturbance and documenting additional localities. Relevant references: Morefield (2001), Clifton (2012), USDA (2015). Map

NEVADA CATCHFLY (*SILENE NACHLINGERAE*) – CARYOPHYLLACEAE – Nevada catchfly, also Nachlinger's catchfly, is endemic to central Great Basin ranges (e.g. Snake, Quinn, Ruby). This species is rare and is estimated to occur on 129 acres in the park. Nevada catchfly is a US Fish and Wildlife Service species of concern; a US Forest Service, Region 4 sensitive species; designated a NV Special Status Species by the BLM; and is listed on the At-Risk species list by the NV Natural Heritage Program. Like many Great Basin endemics, Nevada catchfly is found primarily in isolated alpine areas on limestone substrates. Populations in the park have been extensively mapped and occur primarily in the Lincoln Peak and Mount Washington areas. Threats include illegal OHV use and recreational use of alpine and subalpine areas. Management should focus on protecting alpine areas from disturbance and documenting additional localities. Relevant references: Morefield (2001), Clifton (2012), USDA (2015). Map

WAXFLOWER (*JAMESIA TETRAPETALA*) – HYDRANGEACEAE – Waxflower is a rare and local central Great Basin limestone endemic. It is listed as a US Fish and Wildlife Service species of concern; US Forest Service, Region 4 sensitive species; designated a NV Special Status Species by the BLM; listed as an At-Risk species by the Nevada Natural Heritage Program; and on the NV Native Plant Society watch-list. Waxflower occurs primarily on limestone cliffs, talus, and canyons in alpine and subalpine environments. Several locations and collections have been documented in GRBA, mostly in the Mount Washington and Lincoln Canyon areas. Threats include illegal OHV use and recreational use of alpine and subalpine areas. Management should focus on protecting alpine areas from disturbance and documenting additional localities. Relevant references: Morefield (2001), Clifton (2012), USDA (2015). Map

WHEELER PEAK DRABA (*DRABA PEDICELLATA* VAR. *WHEELERENSIS*) – BRASSICACEAE – Presence in the park is confirmed. It is also called Wheeler Peak whitlowcress. This species is a Nevada endemic. It is on the Nevada Natural Heritage Program At-Risk-List and on the NV Native Plant Society watch list. It occurs on a range of soils, including limestone within the park. This species is limited to the highest areas of the South Snake Range on rocky slopes and crevices of cliffs near Wheeler Peak, Mt Washington and along Highland Ridge (Clifton 2012). Threats include domestic sheep grazing, illegal OHV use and recreational use of alpine and subalpine areas. Management should focus on protecting alpine areas from disturbance and documenting additional localities.

SNAKE RANGE DRABA (*DRABA SERPENTINA*) – BRASSICACEAE - Presence in the park is confirmed. It is also called Snake Range whitlowcress or serpentine draba. This species is a Nevada endemic. It is listed as sensitive by the US Fish and Wildlife Service and US Forest Service. It is listed as threatened by the NV Native Plant Society and included on the At-Risk List for the NV Natural Heritage Program. It occurs in rocky alpine and subalpine areas often associated with limestone. Threats include domestic sheep grazing, illegal OHV use and recreational use of alpine and subalpine areas. Management should focus on protecting alpine areas from disturbance and documenting additional localities. Synonymous with *D. oreibata* var. *serpentina*. Relevant references: Morefield (2001), Clifton (2012), USDA (2015). Map

Nevada Primrose (*Primula cusickiana* var. *nevadensis*) – Primulaceae –Nevada primrose occurs on 316 acres of alpine and subalpine limestone and is endemic to east-central Nevada. The US Fish and Wildlife Service ranks Nevada primrose as a species of concern as does Region 4 of the US Forest Service, the Nevada Natural Heritage Program and the Nevada Native Plant Society. It occurs in limited habitat and is therefore susceptible to disturbance. Threats include illegal OHV use and recreational use of alpine and subalpine areas. Management should focus on protecting alpine areas from disturbance and documenting additional localities. Relevant references: Morefield (2001), Clifton (2012), USDA (2015). Map

Holmgren's Cinquefoil (*Potentilla holmgrenii*) – Rosaceae – Presence in the park is confirmed. This is a high elevation species found on rocky slopes, ridge tops and alpine turf, typically above 10,000 feet. It is listed as at-risk by the Nevada Natural Heritage Program and on the Nevada Native Plant Society watch-list. Management should focus on protecting alpine areas from disturbance and continued monitoring through GLORIA protocols. [*P. nivea* L., misapplied.] Relevant references: NNHP (2012) and Clifton (2012).

Wooly Head Clover (*Trifolium eriocephalum* var. *villeferum*) – Fabaceae – Presence in the park is confirmed; also known as woolly clover. This is a very limited, lower elevation species known only from a small campsite in Snake Creek. It is a wetland species, typically found in wet meadows and shaded, riparian habitat. This species is included on the Nevada Natural Heritage Program's At-Risk List and a watch list species for the NV Native Plant Society. Inventories are needed to document additional localities. Management should focus on maintenance of low elevation riparian habitat and strict mitigation measures for restoration or capital improvement projects within riparian areas where this species occurs, especially in Snake Creek. Relevant references: NNHP (2012), Clifton (2012), USDA (2015).

Tunnel Springs Beardtongue (*Penstemon concinnus*) – Scrophulariaceae – Presence in the park is confirmed; also known as elegant penstemon. It is a rare, local species endemic to the central Great Basin. The US Fish and Wildlife Service, US Forest Service, NV Natural Heritage Program and NV Native Plant Society all list it as a species of concern. Tunnel Springs beardtongue can be found on gravelly, mid-elevation alluvial slopes with sagebrush and pinyon-juniper. Threats include grazing, transportation and facility development, pinyon-juniper encroachment, and exotic plants. Management should focus on protecting known populations and potential habitat from disturbance and documenting additional localities. Relevant references: Morefield (2001), Clifton (2012), USDA (2015). Map

Wheeler Peak Penstemon (*Penstemon leiophyllus* var. *francisci-pennellii*) – Scrophulariaceae – Subspecies *francisci-pennellii* is an east-central Nevada endemic. It is listed as sensitive by the BLM, the NV Natural Heritage Program and the NV Native Plant Society. It occurs on dry, rocky alpine and subalpine slopes, in alpine meadows, and in forest openings at mid to high elevations. Management should focus on protecting alpine areas from disturbance and documenting additional localities. Other common names are Pennell's or smoothleaf beardtongue. Synonymous with *P. francisci-pennellii*. Relevant references: Morefield (2001), Clifton (2012), USDA (2015). Map

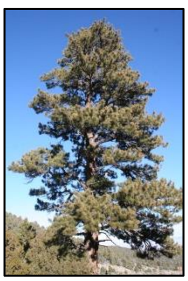
Mt. Moriah Beardtongue (*Penstemon moriahensis*) – Scrophulariaceae – Presence in the park is confirmed (Pole Canyon). Species also occurs in the North Snake Range. This is a rare, local, native species endemic to very few ranges in the central Great Basin (North and South Snake, Kern). It is listed as a US Forest Service and Nevada Natural Heritage Program sensitive species and included on the Nevada Native Plant Society watch-list. It occurs in scrubby woodlands at 7,000-9,000 feet. Inventories should be conducted in suitable habitat to document additional localities for this species. Relevant references: Morefield (2001), Clifton (2012), USDA (2015).

Wheeler Peak Sandwort (*Eremogone congesta* var. *wheelerensis*) – Caryophyllaceae -Presence is confirmed in the park, although GRBA herbarium collections contain no subspecific taxonomy and only a few locations in the park have been documented. Endemic subspecies *wheelerensis* is critically rare in Nevada, occurring only in the Snake Range and Ruby Mountains. Wheeler's sandwort is on the NV Natural Heritage Program's watch-list but was removed from the NV Native Plant Society's watch-list. It occurs in alpine and subalpine environments. Threats include domestic sheep grazing and recreational use of alpine and subalpine areas. Management should focus on protecting alpine areas from disturbance and documenting additional localities. Synonomous with *Arenaria congesta* var. *wheelerensis*. Relevant references: Morefield (2001), Clifton (2012), USDA (2015). Map

Snowline (Elko) Springparsley (*Cymopterus nivalis*) – Apiaceae – Snowline springparsley, also called snow wavewing, occurs on 718 acres of park land. A globally secure native species, snowline springparsley is considered rare in Nevada. It is included on the Nevada Natural Heritage Program's watch-list. It occurs on dry alpine and subalpine slopes and ridges, frequently on limestone, but it is not a true limestone endemic. Threats include illegal OHV use and recreational use of alpine and subalpine areas. Management should focus on protecting alpine areas from disturbance and documenting additional localities. Relevant references: Clifton (2012), USDA (2015). Map

WATSON'S GOLDENBUSH (*ERICAMERIA WATSONII*) – ASTERACEAE – Presence is confirmed in the park. Globally secure native species, but relatively rare in east-central Nevada. It has been delisted by the NV Native Plant Society, but is included on the NV Natural Heritage Program's watch-list. Watson's goldenbush occurs on cliffs, rock outcrops, generally on dry sites across a wide elevation range. Threats include domestic sheep grazing, illegal OHV use and recreational use of alpine and subalpine areas. Management should focus on protecting alpine areas from disturbance and documenting additional localities. Synonymous with *Haplopappus watsonii*. Relevant references: Morefield (2001), Clifton (2012), USDA (2015). Map

BRISTLECONE PINE (*PINUS LONGAEVA*) – Bristlecone pines are one of the longest-lived organisms on Earth. This five-needle pine occurs fairly frequently between 8,000 and 11,000 feet (Clifton 2015). Although stable over its entire range, this species is vulnerable to climate change, white pine blister rust and possible mountain pine beetle outbreaks. Management should focus on monitoring and preventing impacts to high elevation stands of 'ancient' trees by limiting dispersed recreation in those areas, illegal wood harvest, and loss of high value stands by fire or insect outbreaks. Map



PONDEROSA PINE (*PINUS PONDEROSA*) – The distribution of Ponderosa pine is limited in the park due to historic logging and a century of fire exclusion. Fire is the dominant process in maintaining Ponderosa pine stands (Provencher et al. 2010). With an intact seed bank, it is an early colonizer after fire. Some stands in the park are limited to riparian corridors. It is vulnerable to mountain pine beetle outbreaks and encroachment by white fir and pinyon pine. Management actions should focus on reintroduction of fire and preventing infestations of mountain pine beetle with the use of pheromone patches (e.g. Verbenone). Map

Plants and animals not known in GRBA but presence possible

RINGNECK SNAKE (*DIADOPHIS PUNCTATUS*) – Ringneck snakes are undocumented from the park (Hamilton 2003a), but museum records and observations from Snake Valley and nearby mountain ranges suggest the species occurs in suitable habitat (Bosworth et al. 2004). Ringneck snakes are highly secretive and patchily distributed in the Great Basin (Linsdale 1940, Stebbins 2003). Inventory efforts should include pitfall trapping, drift fence arrays, road surveys and visual encounter surveys.

SHORT-HORNED LIZARD (PHRYNOSOMA HERNANDESII) – Short-horned lizards are not documented in the park (Hamilton 2003a) but suitable habitat exists. Short-horned lizards have different habitat requirements than desert horned lizards, differ in diet, and are far less common and more patchily distributed in the Great Basin than desert horned lizard (Stebbins 2003). Short horned lizards prefer sagebrush habitat but also occur sympatric with desert horned lizards in some areas in greasewood habitat. Although short-horned lizards use montane areas in some states, they do not use this habitat in the Great Basin. Horned lizards are collected commercially in Nevada. Inventories should attempt to locate this species in suitable habitat with visual encounter surveys. A photograph voucher is necessary to document relative horn length.

INTERMOUNTAIN WAVEWING (*CYMOPTERUS BASALTICUS*) – APIACEAE – Presence in the park is unconfirmed, but possible. Intermountain wavewing is a rare native species endemic to areas in western Utah and White Pine County, NV, including the North Snake Range. It is listed as a sensitive species by the Nevada Natural Heritage Program and included on the Nevada Native Plant Society's watch-list. It is also listed in the park's General Management Plan as a sensitive species. Intermountain wavewing is found in low and mid-elevation sagebrush and piñon-juniper communities. Inventories are needed in suitable habitat to document this species. Relevant references: Morefield (2001), Clifton (2012), USDA (2015).

PENNELL'S WHITLOWGRASS (*DRABA PENNELLII*) – BRASSICACEAE – Presence in the park is unconfirmed, but possible. This is a rare species endemic to White Pine County, Nevada, specifically the Schell Creek Range. It is listed as a sensitive species by the US Forest Service and the Nevada Natural Heritage Program. It has been de-listed by the Nevada Native Plant Society. It occurs in cracks, crevices, rocky slopes and ledges, possibly associated with limestone, over a wide elevation range. Inventories should focus on suitable habitat to document this specie sin the park. Relevant references: Morefield (2001), Clifton (2012), USDA (2015).

RAYLESS TANSYASTER (*MACHAERANTHA GRINDELIOIDES* VAR. *DEPRESSA*) – ASTERACEAE – Presence in the South Snake Range is confirmed but not within GRBA. It is an intermountain species, but variety *depressa* is relatively rare in Nevada. This species is on the watch-list for the Nevada Natural Heritage Program, but has been de-listed by the Nevada Native Plant Society. It is a low elevation species that occurs on dry, barren places with alkaline soils. Inventories are needed to document this species within park boundaries. Synonymous with *Eriocarpum grindelioides* var. *depressa* and

Haplopappus nutallii var. *depressus*. Relevant references: Morefield (2001), Clifton (2012), USDA (2015).

GREAT BASIN FISHHOOK CACTUS (*SCLEROCACTUS PUBISPINUS*) – CACTACEAE – Presence in the park is unconfirmed, but this species occurs at lower elevations below park boundary. The Great Basin fishhook cactus is a globally secure native species, but in Nevada it is limited to the Baker area in White Pine County. This species is protected in Nevada. It occurs on rocky flats and hillsides with saltbush, sagebrush and pinyon-juniper, generally below 7,000 feet. Surveys are needed within the Baker Administrative Site to document this species and prevent illegal commercial collection. Relevant references: Clifton (2012), USDA (2015).

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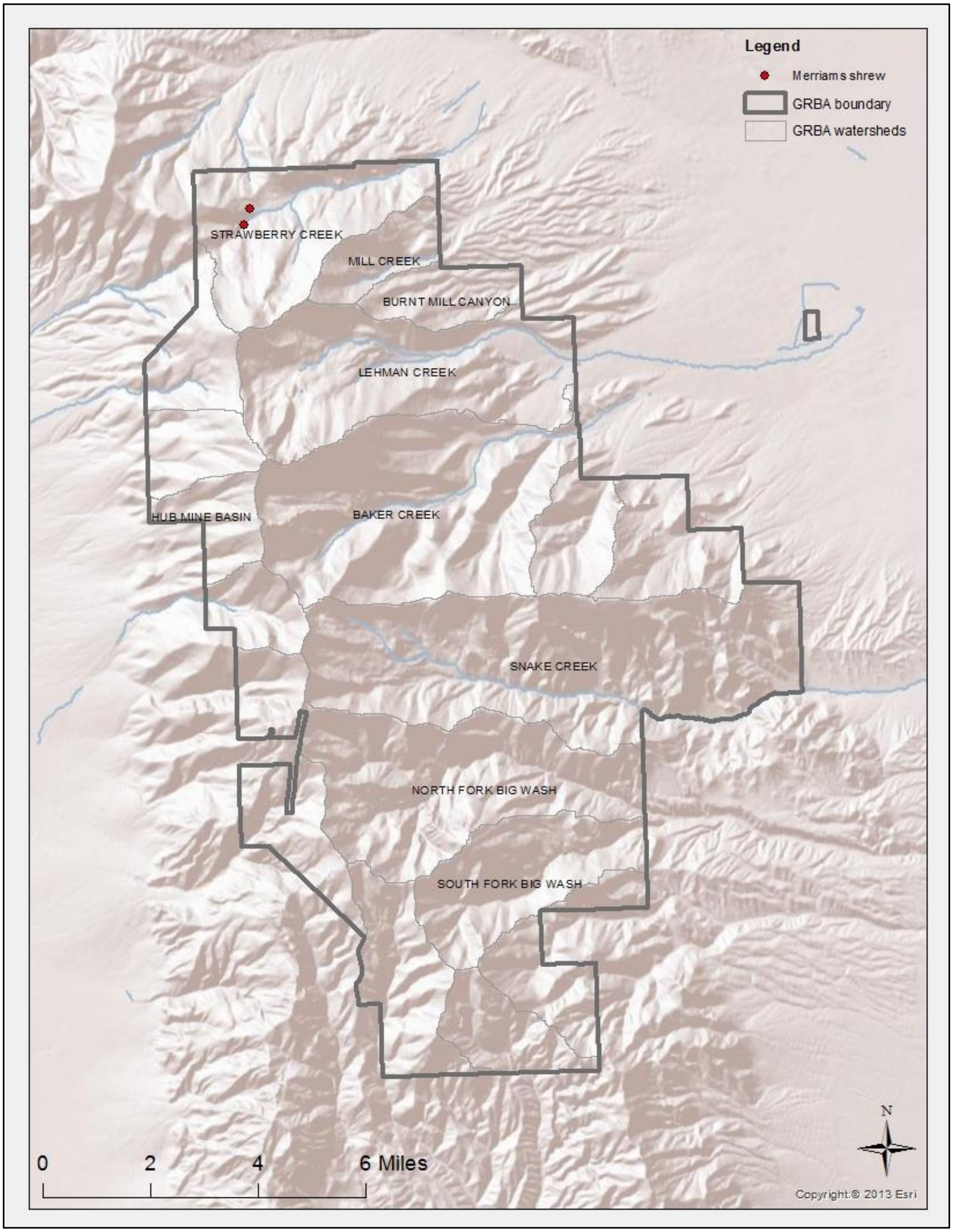
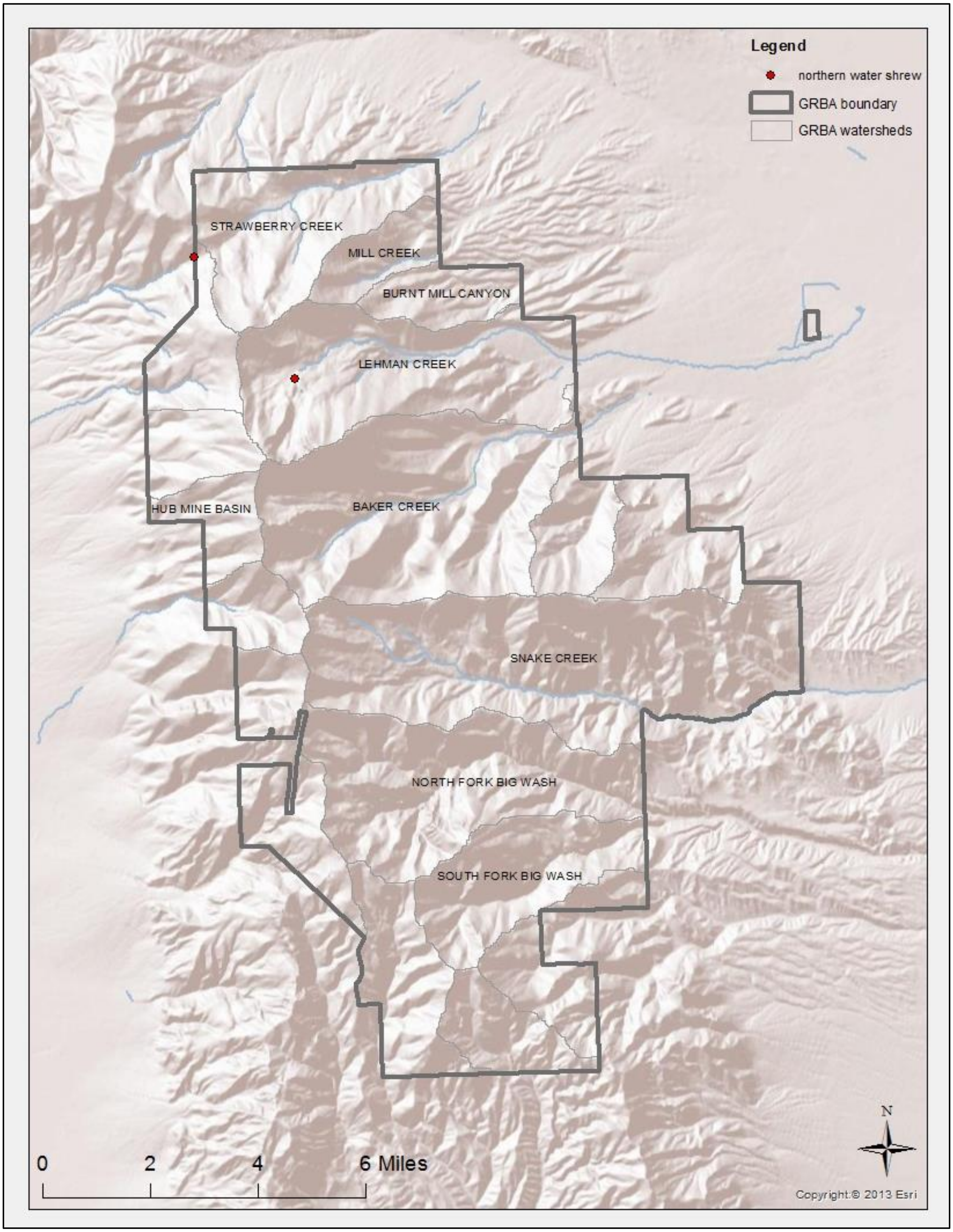
Zeppelini, D., S.J. Taylor, and M.E. Slay. 2009. Cave *Pygmarrhopalites* Vargovitsch, 2009. (Collembola, Symphypleona, Arrhopalitidae) in United States. Zootaxa 2204:1-18

APPENDIX A. Species of management concern locality maps

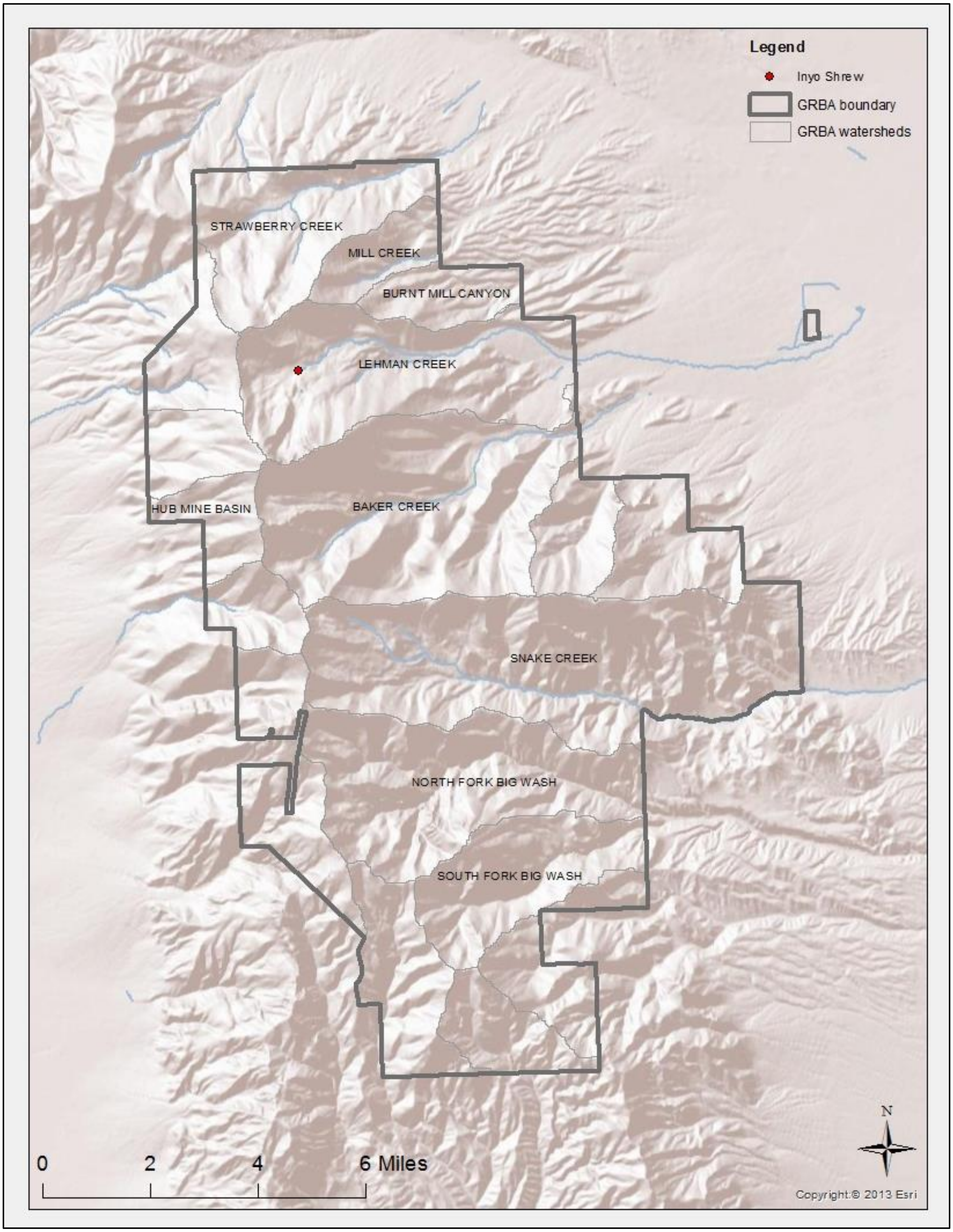
Merriam's Shrew (*Sorex merriami*)



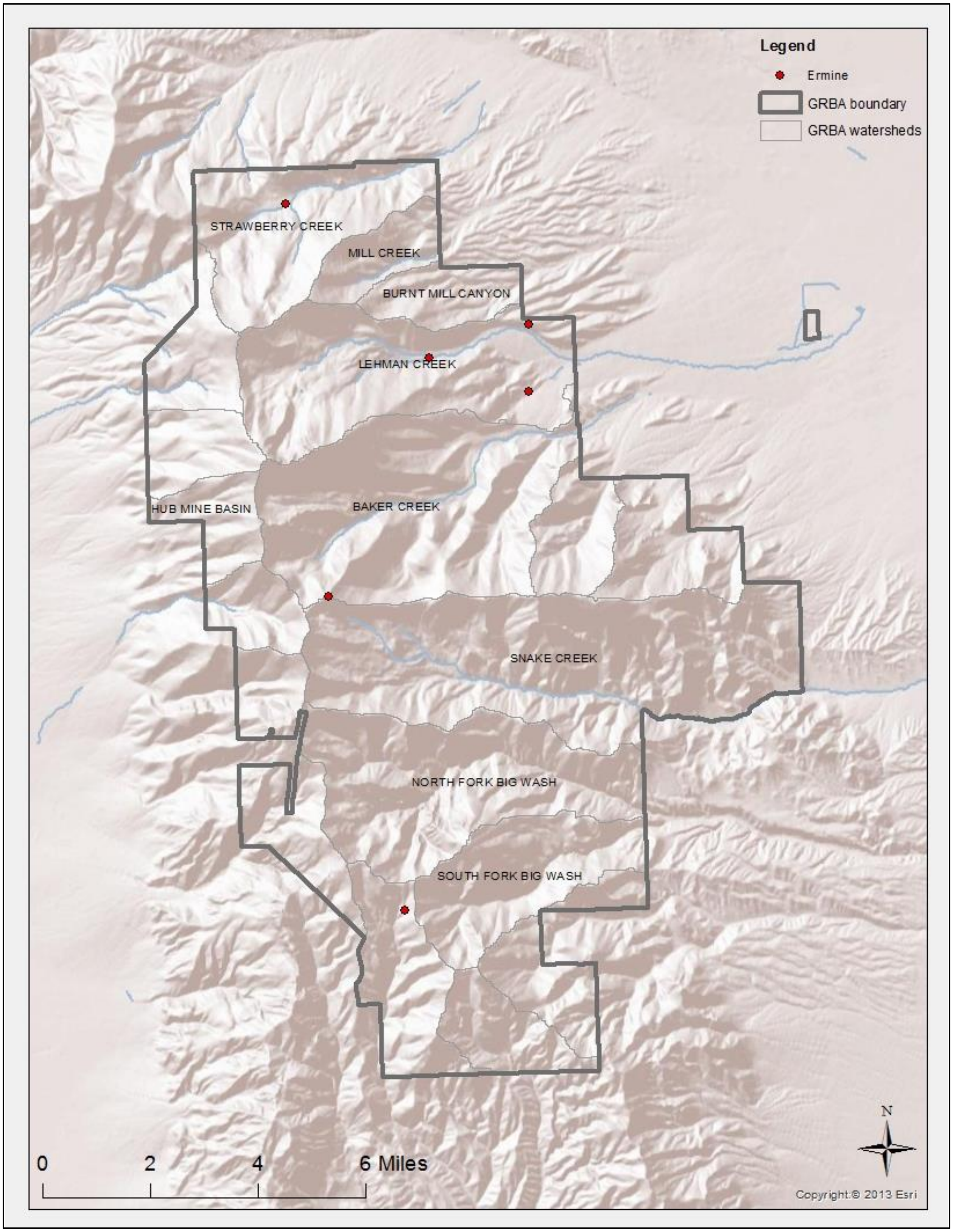
Water Shrew (*Sorex palustris*)



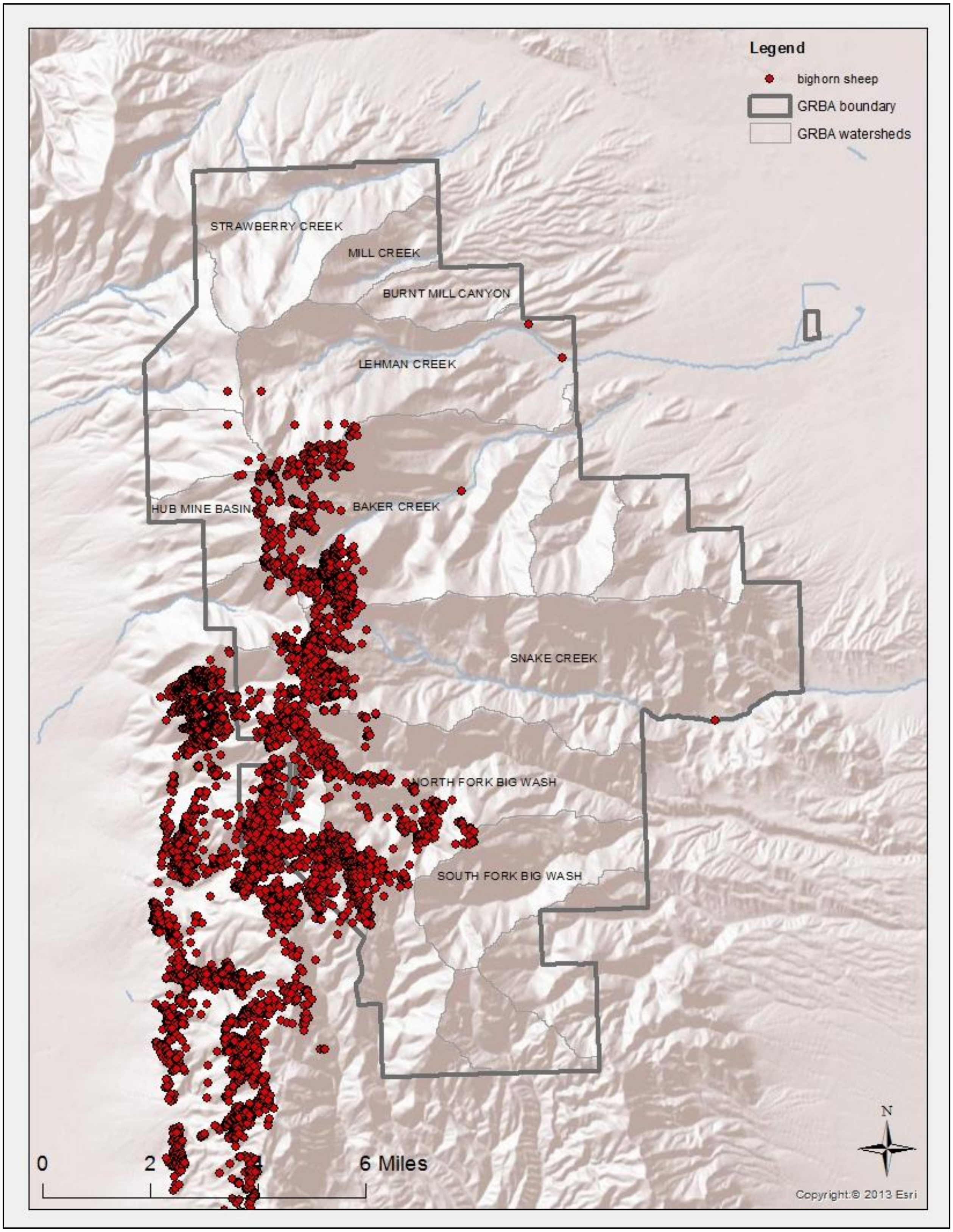
Inyo Shrew (*Sorex tennellus*)



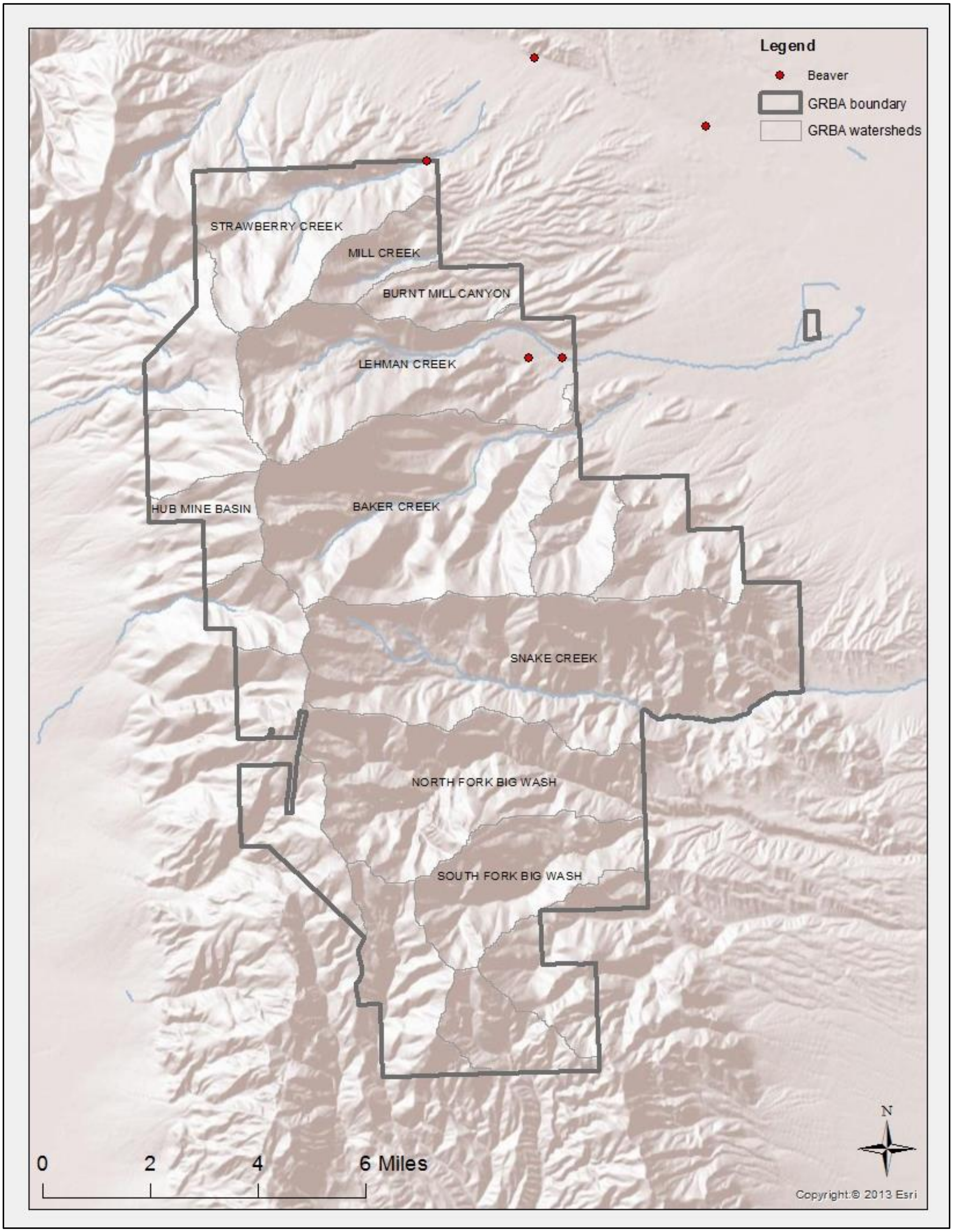
Ermine (*Mustela erminea*)



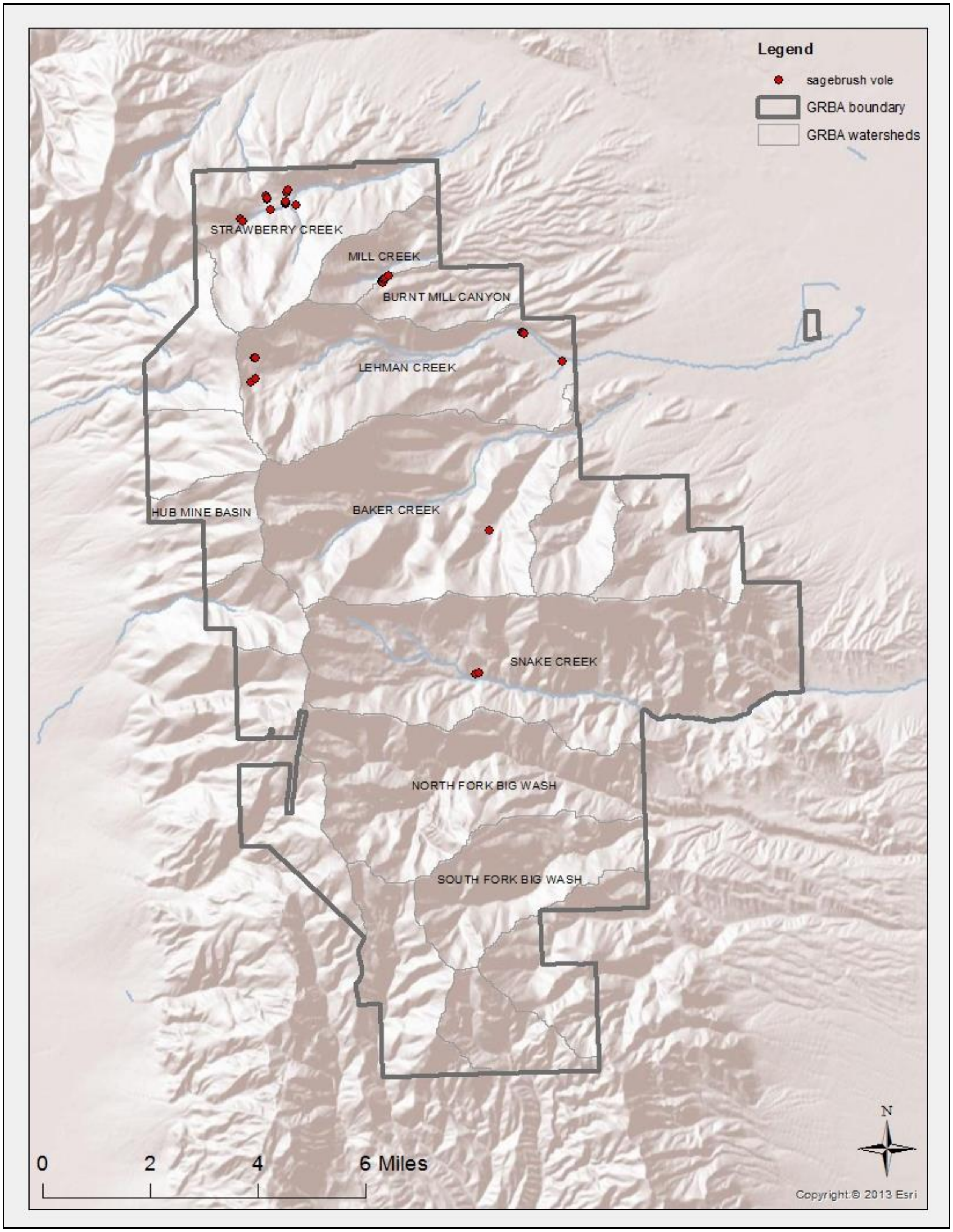
Bighorn Sheep (*Ovis canadensis*)



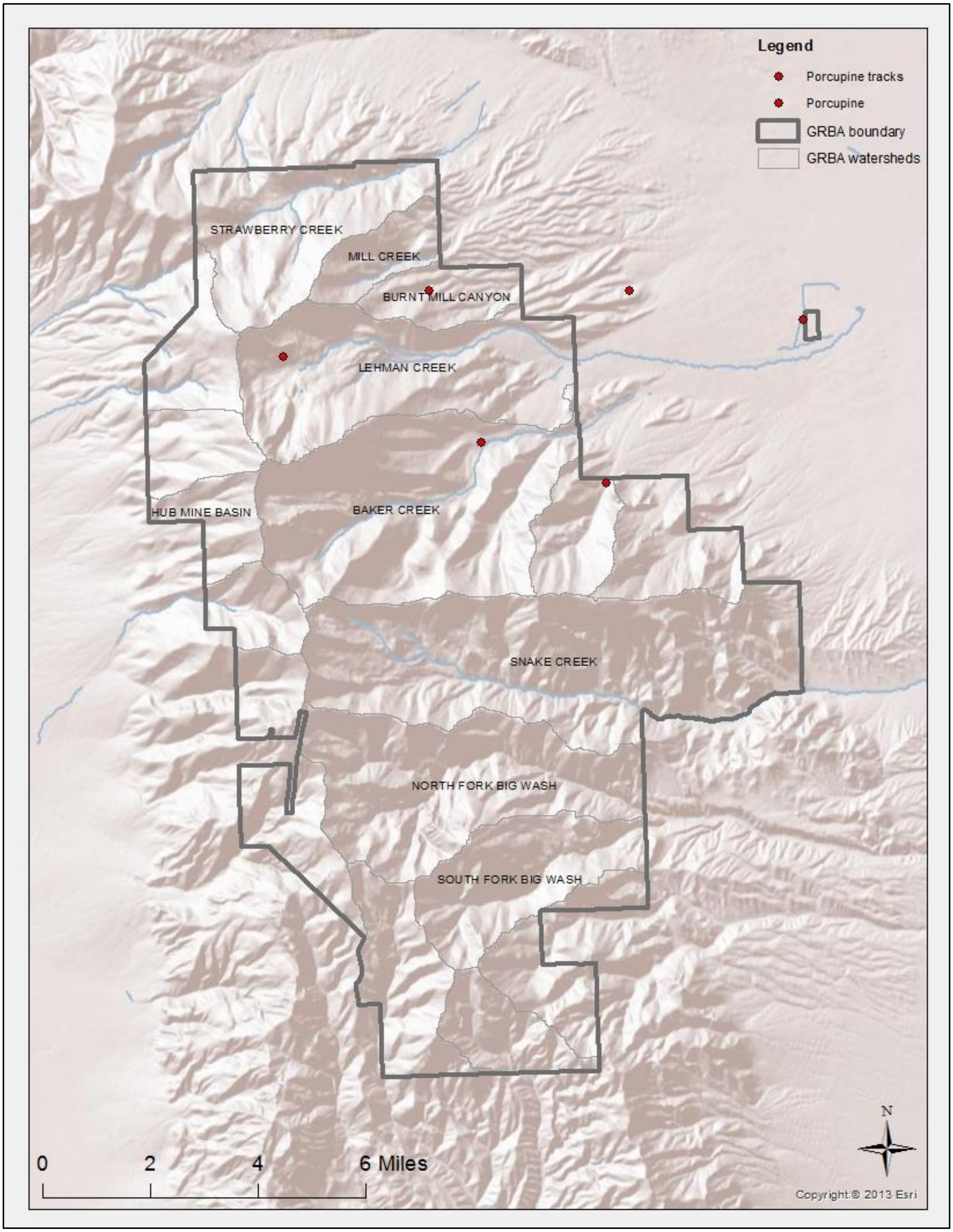
Beaver (*Castor canadensis*)



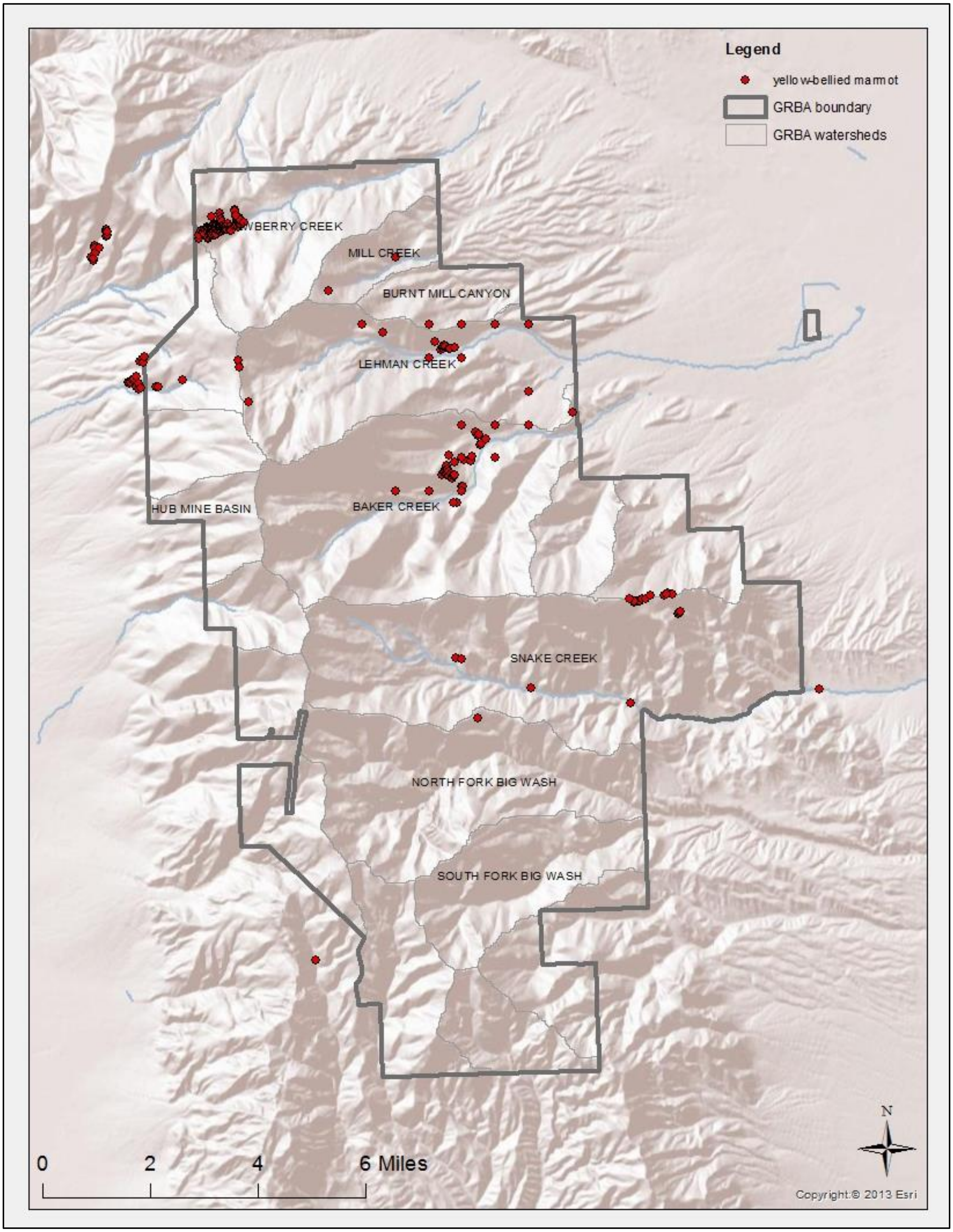
Sagebrush Vole (*Lemmiscus curtatus*)



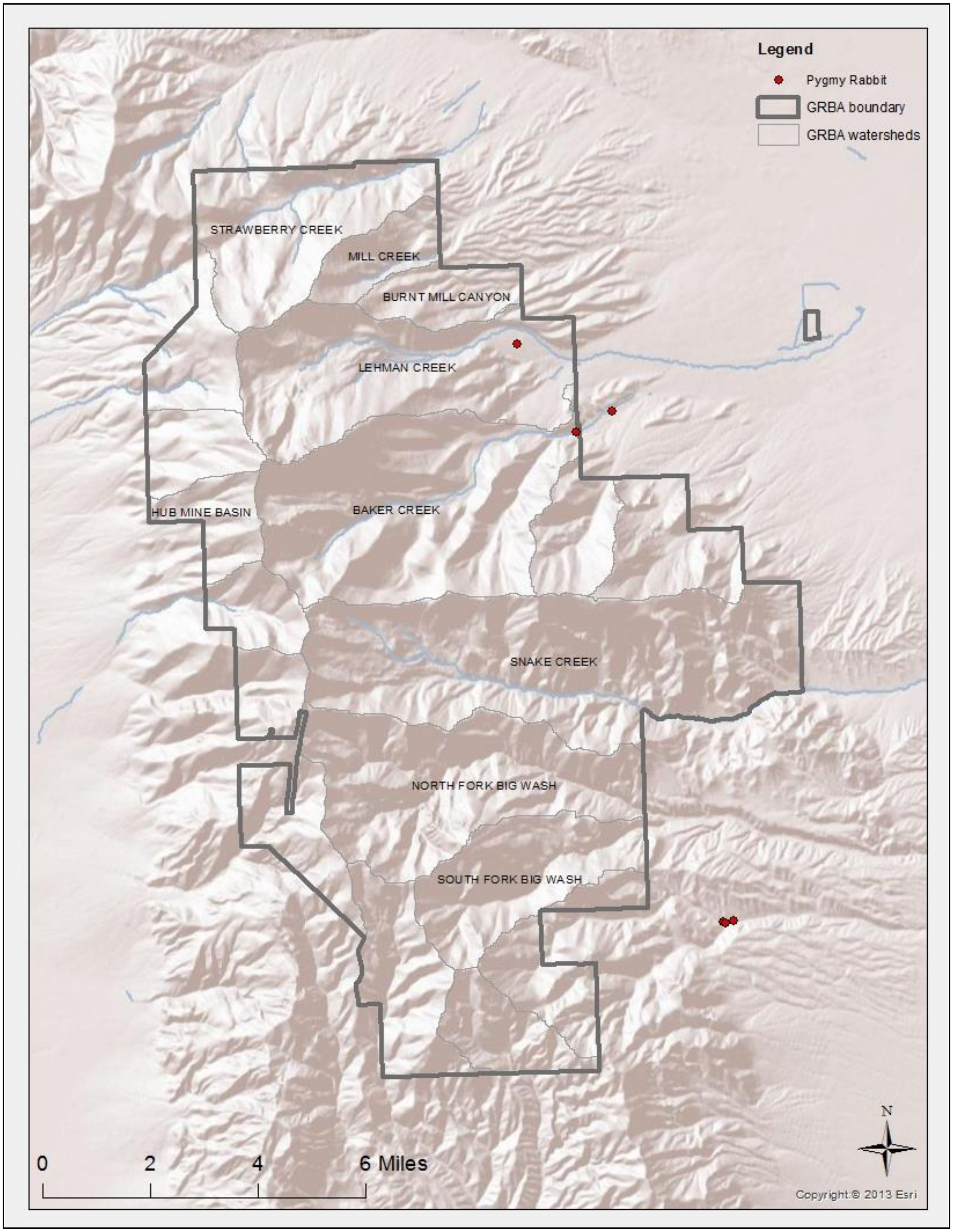
Porcupine (*Erethizon dorsatum*)



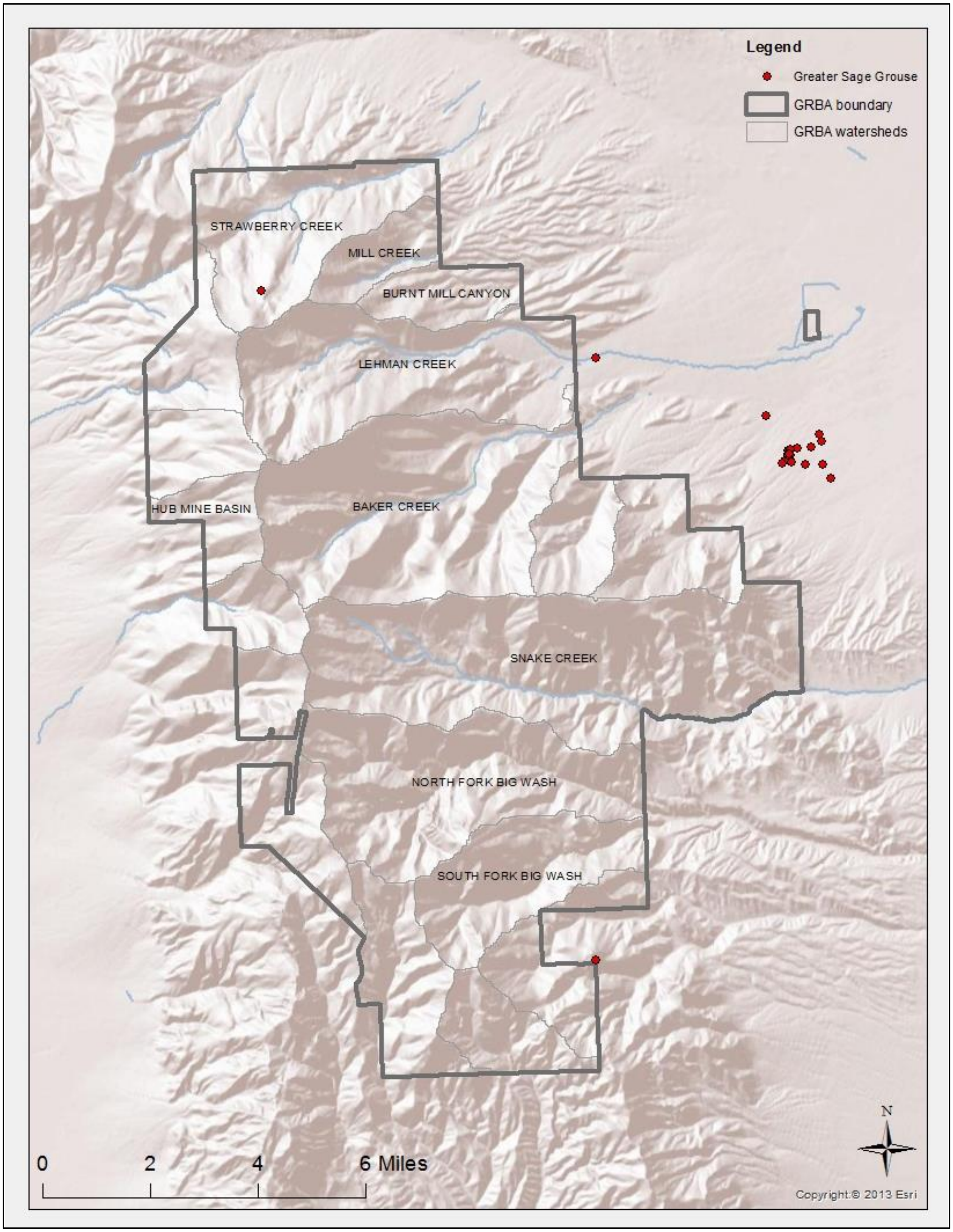
Yellow-bellied Marmot (*Marmota flaviventris*)



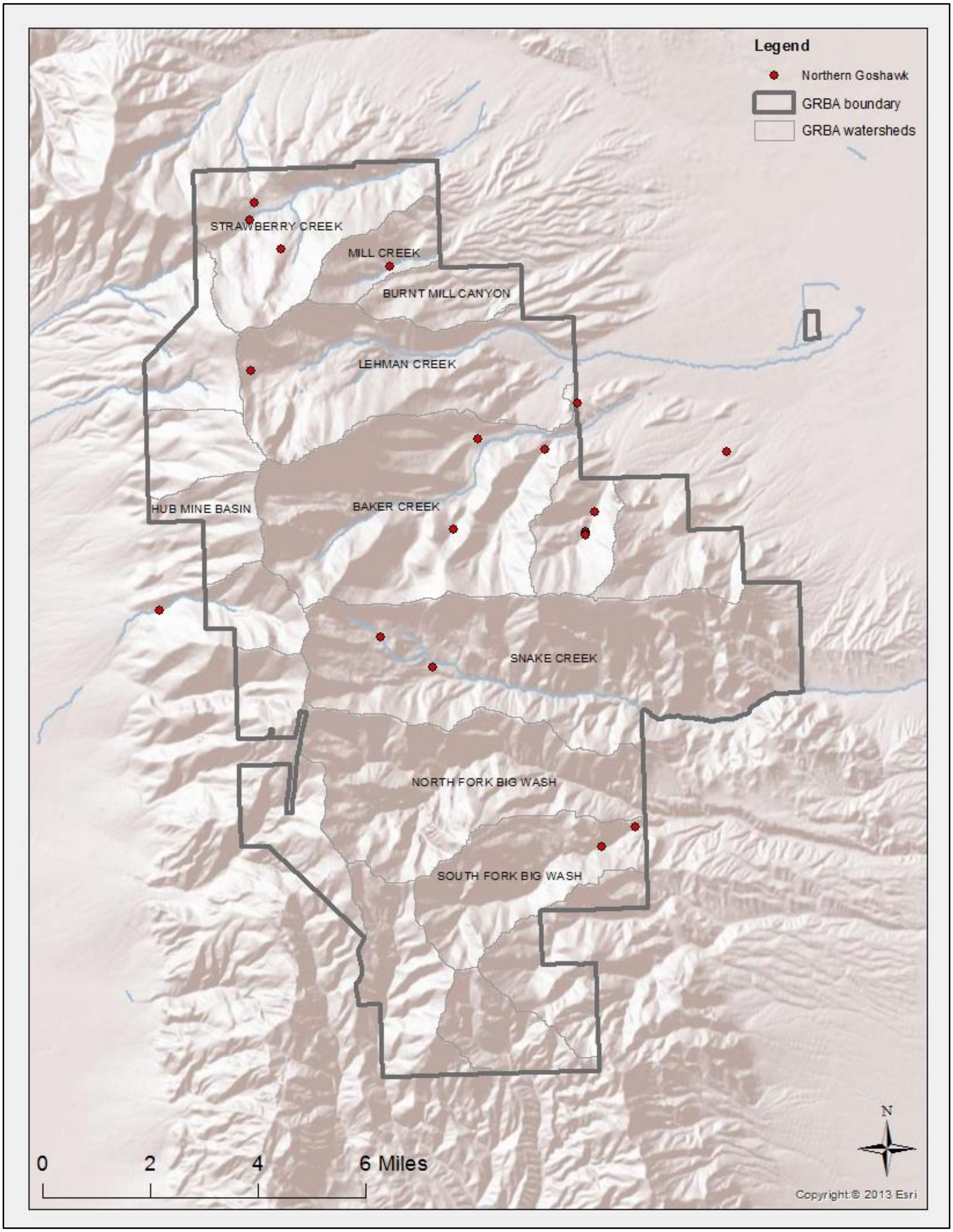
Pygmy Rabbit (*Brachylagus idahoensis*)



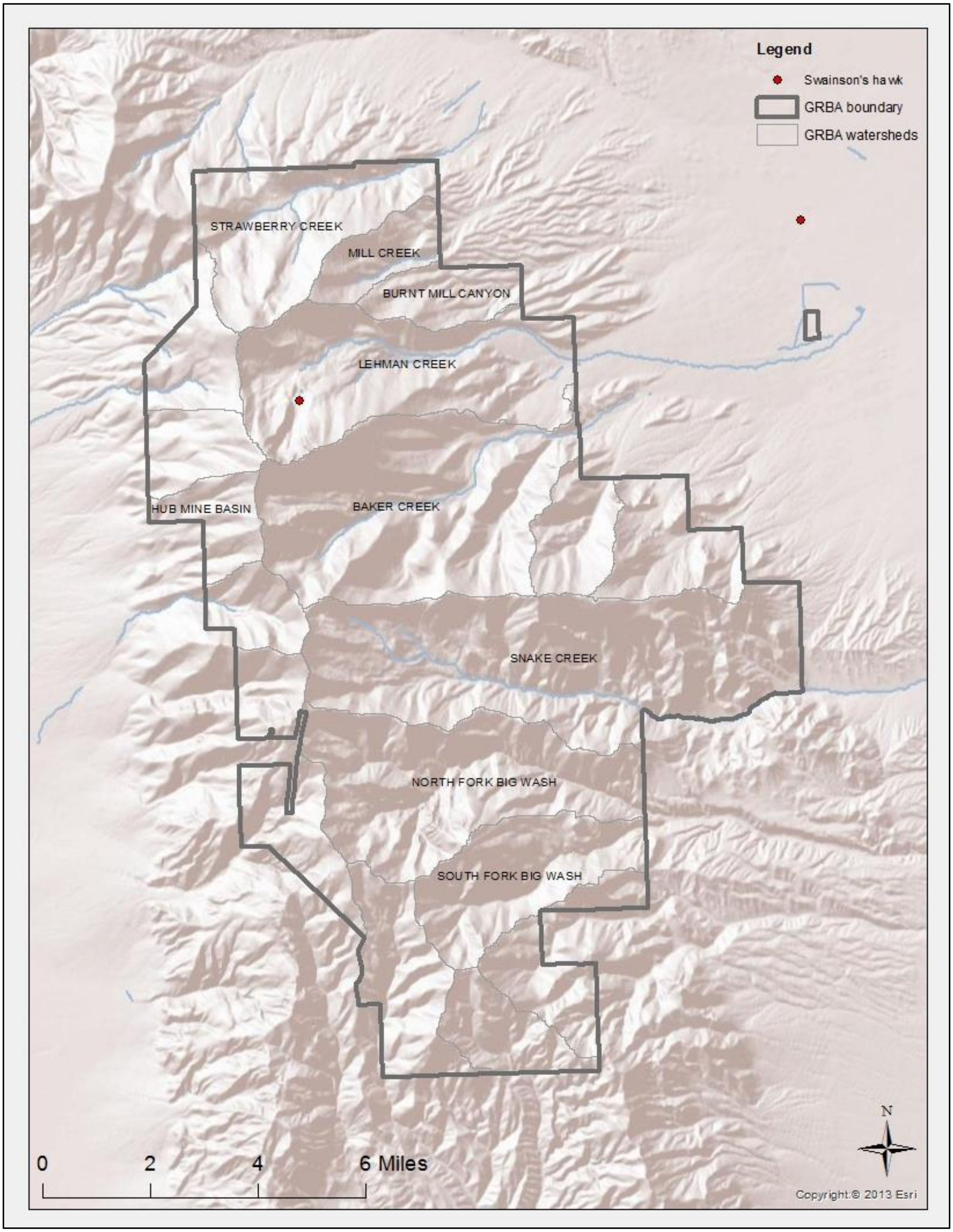
Greater Sage Grouse (*Centrocercus urophasianus*)



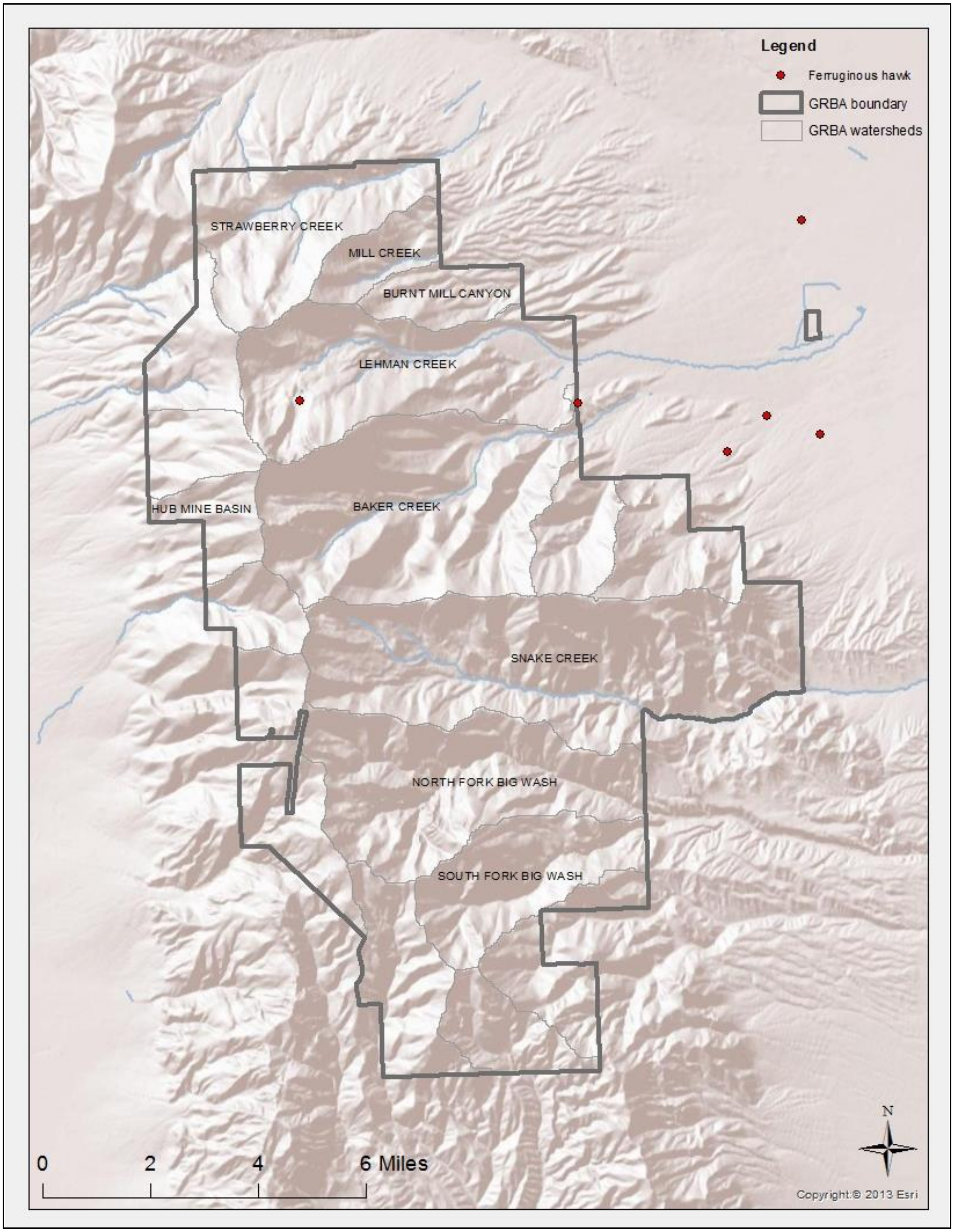
Northern Goshawk (*Accipiter gentilis*)



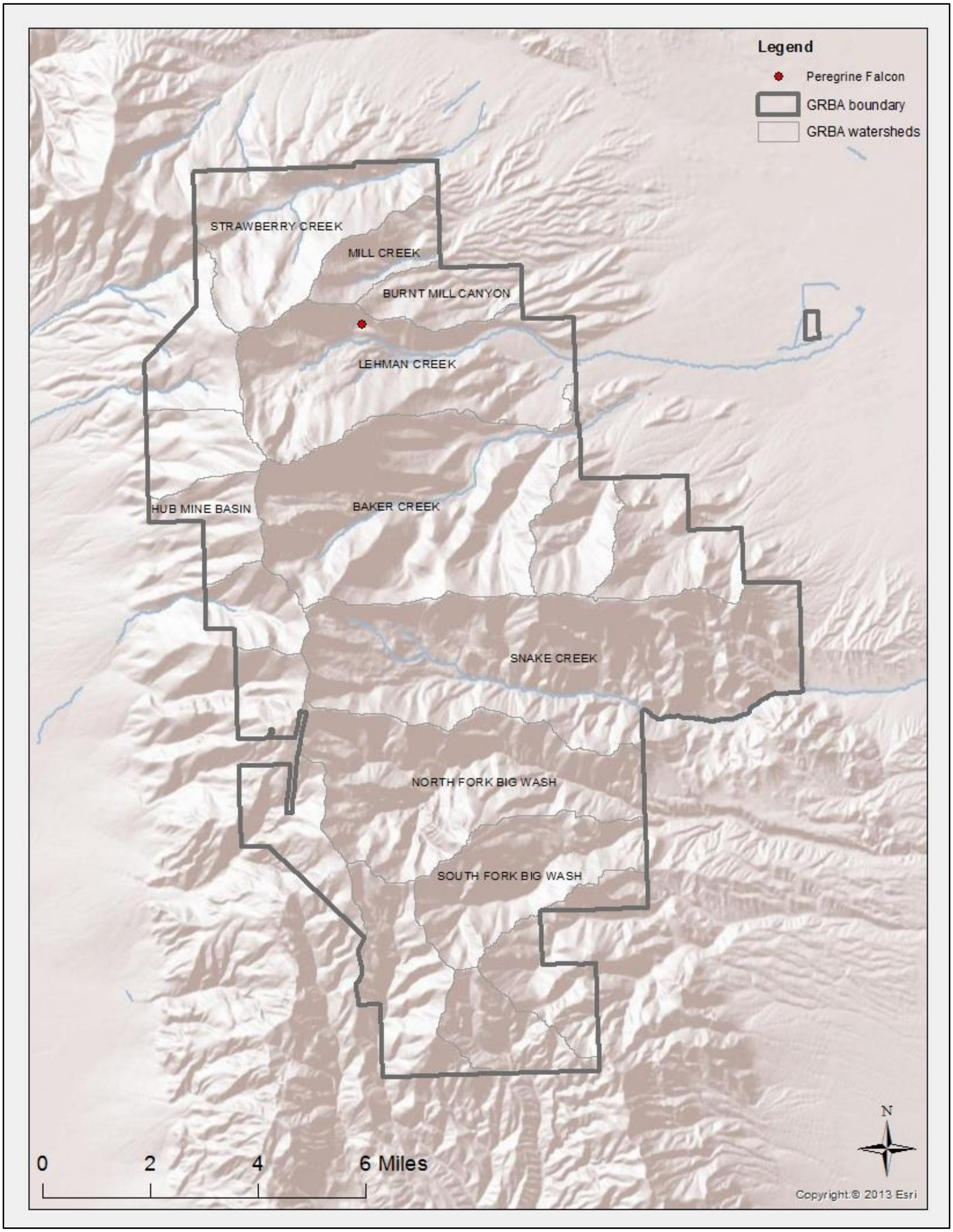
Swainson's Hawk (*Buteo swainsoni*)



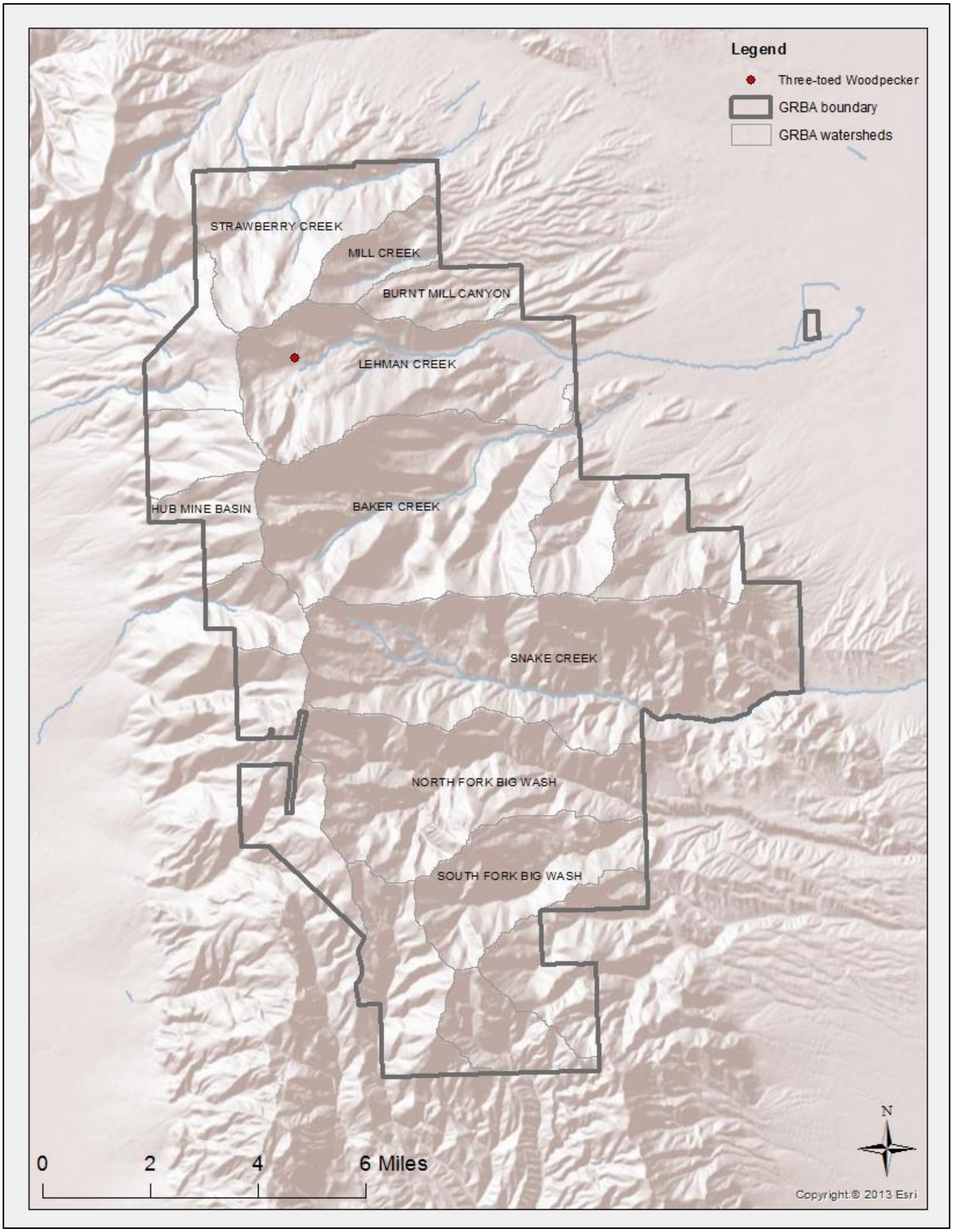
Ferruginous Hawk (*Buteo regalis*)



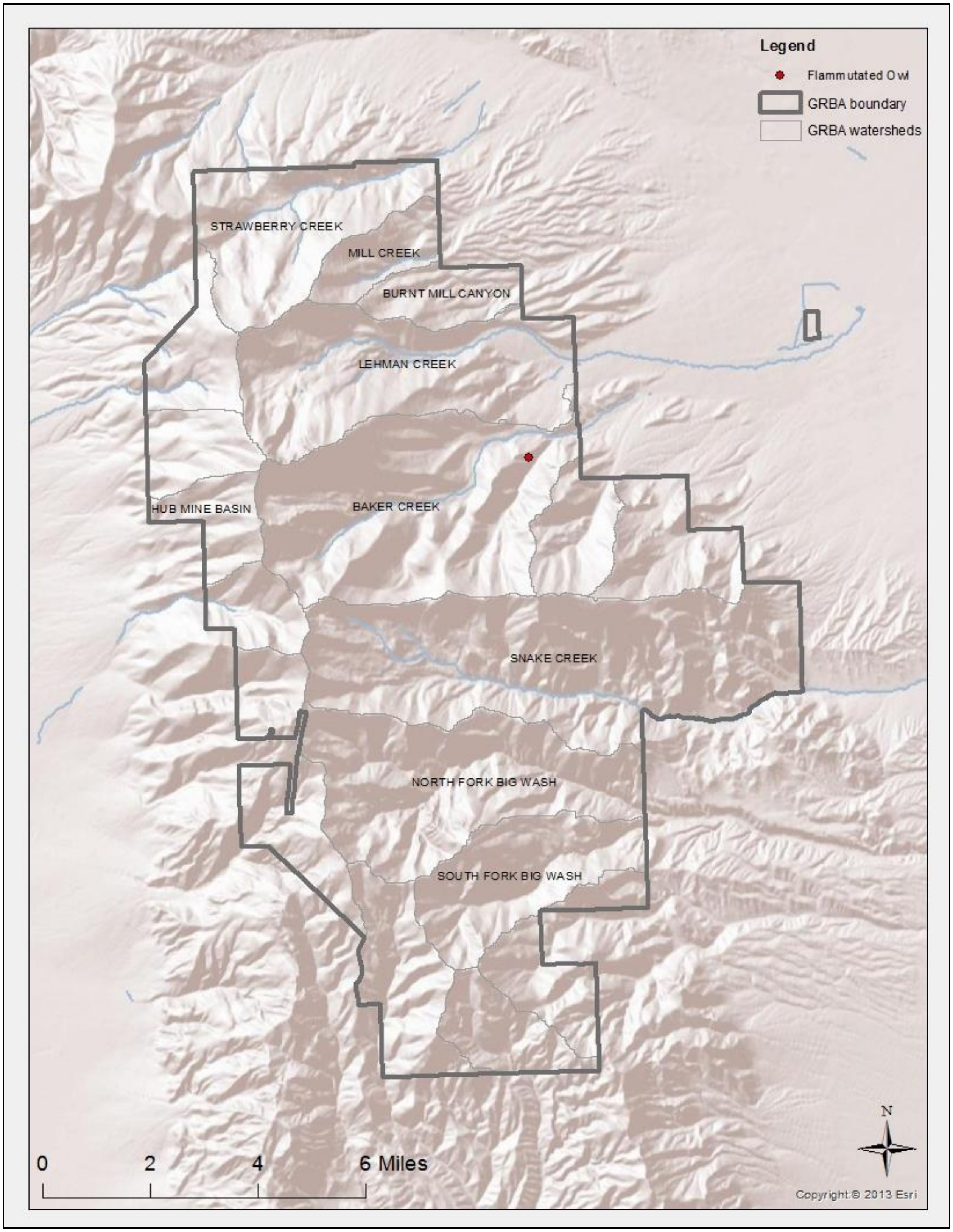
Peregrine Falcon (*Falco peregrinus*)



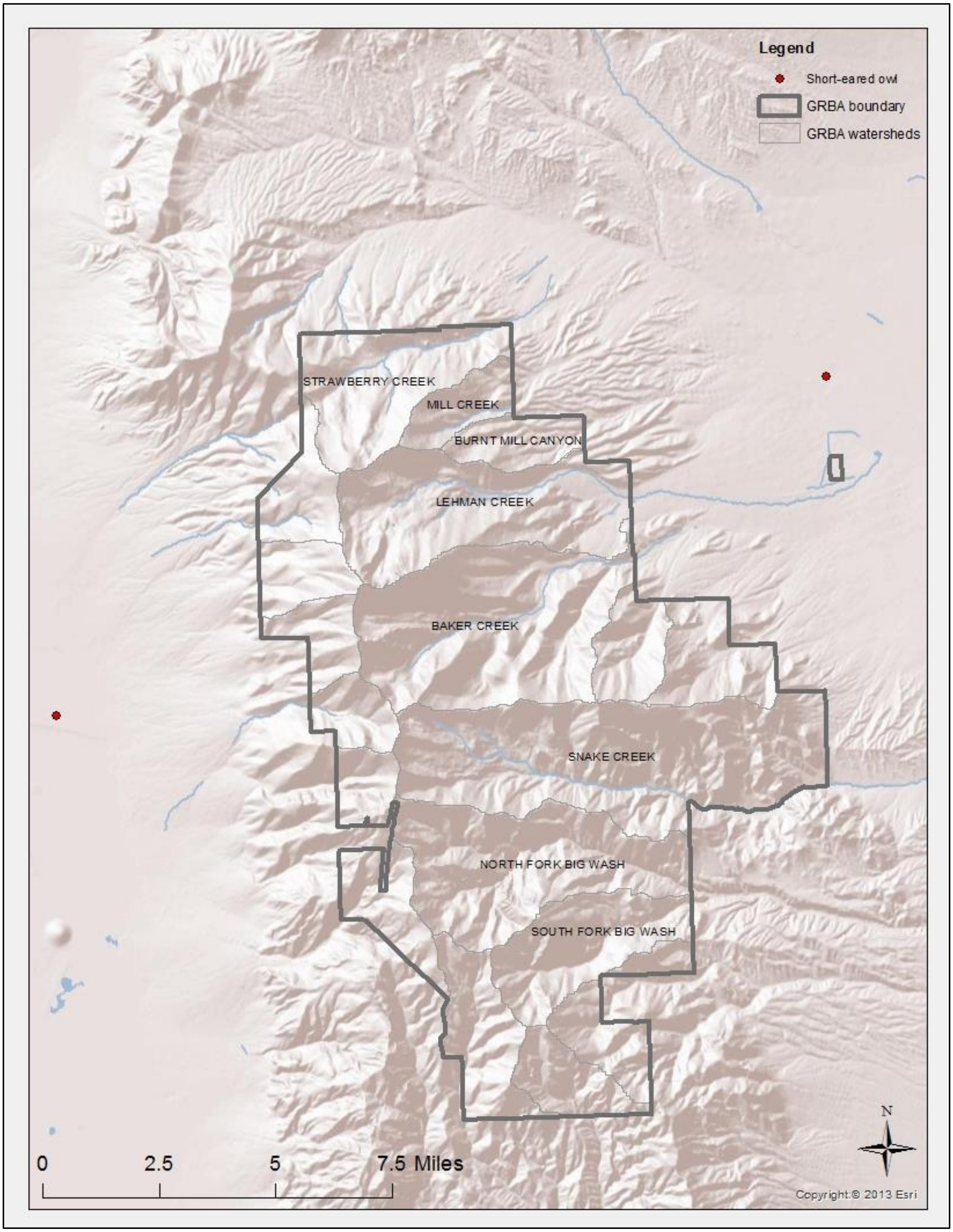
Three-toed Woodpecker (*Picoides tridactylus*)



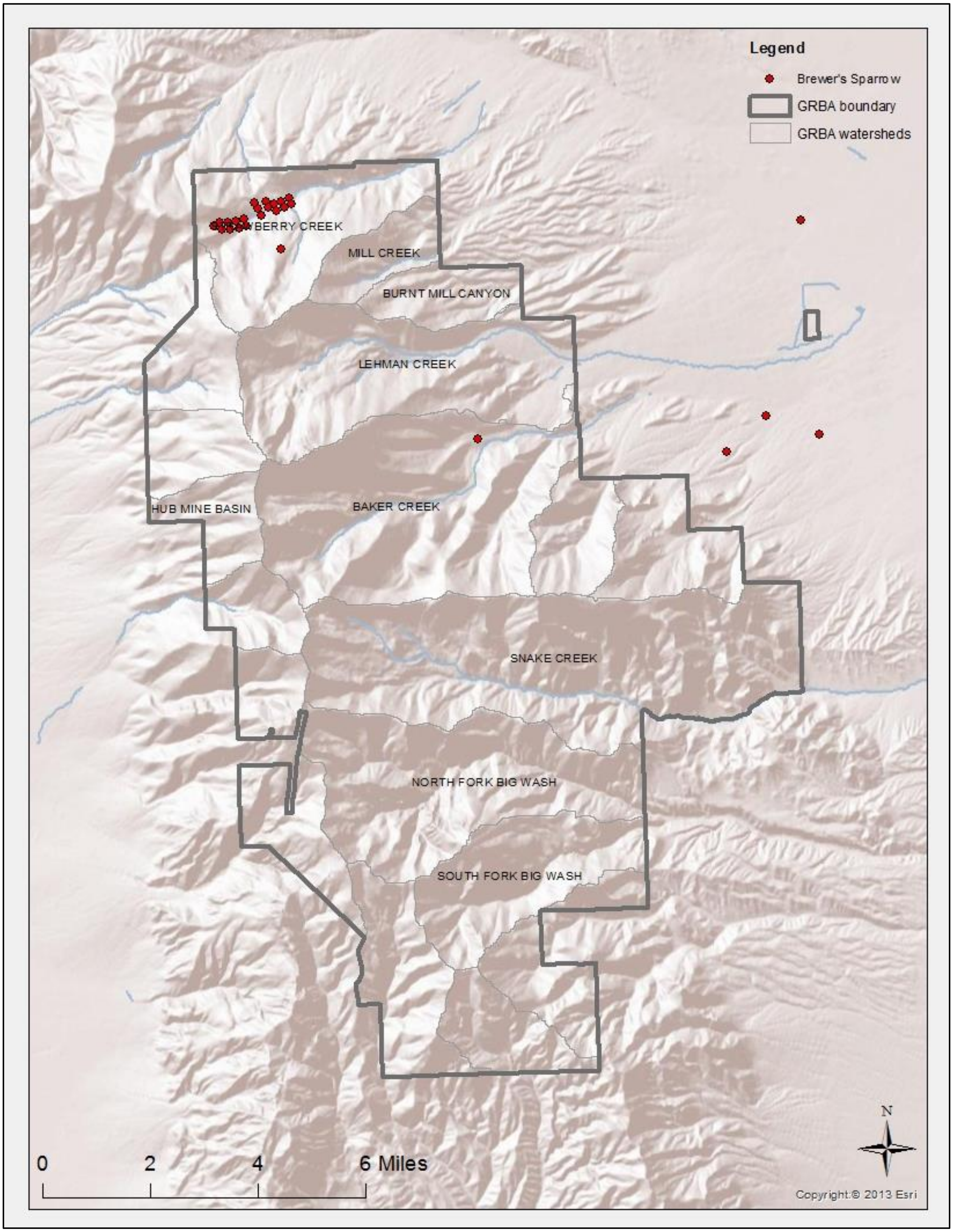
Flammulated Owl (*Otus flammeolus*)



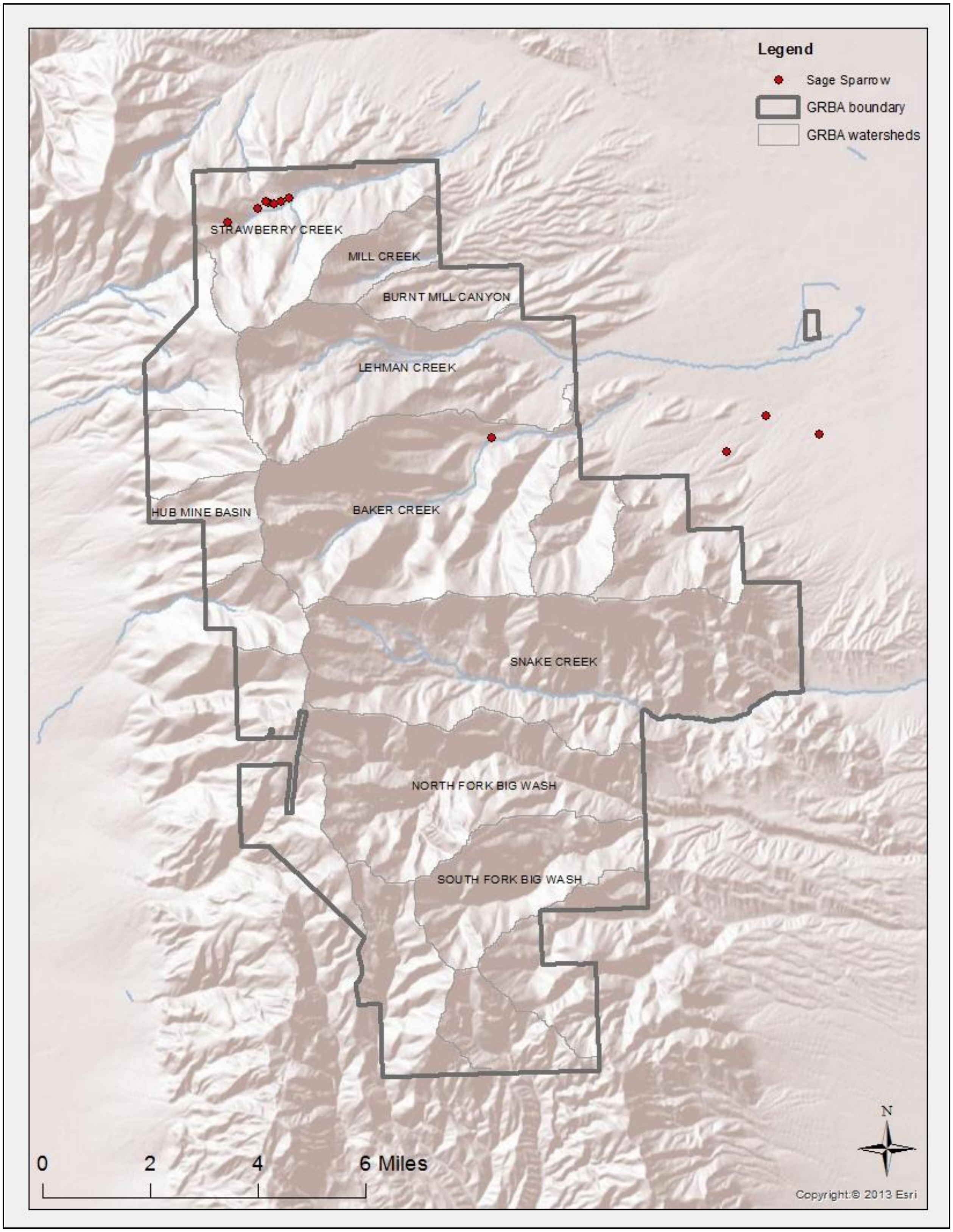
Short-eared Owl (*Asio flammeus*)



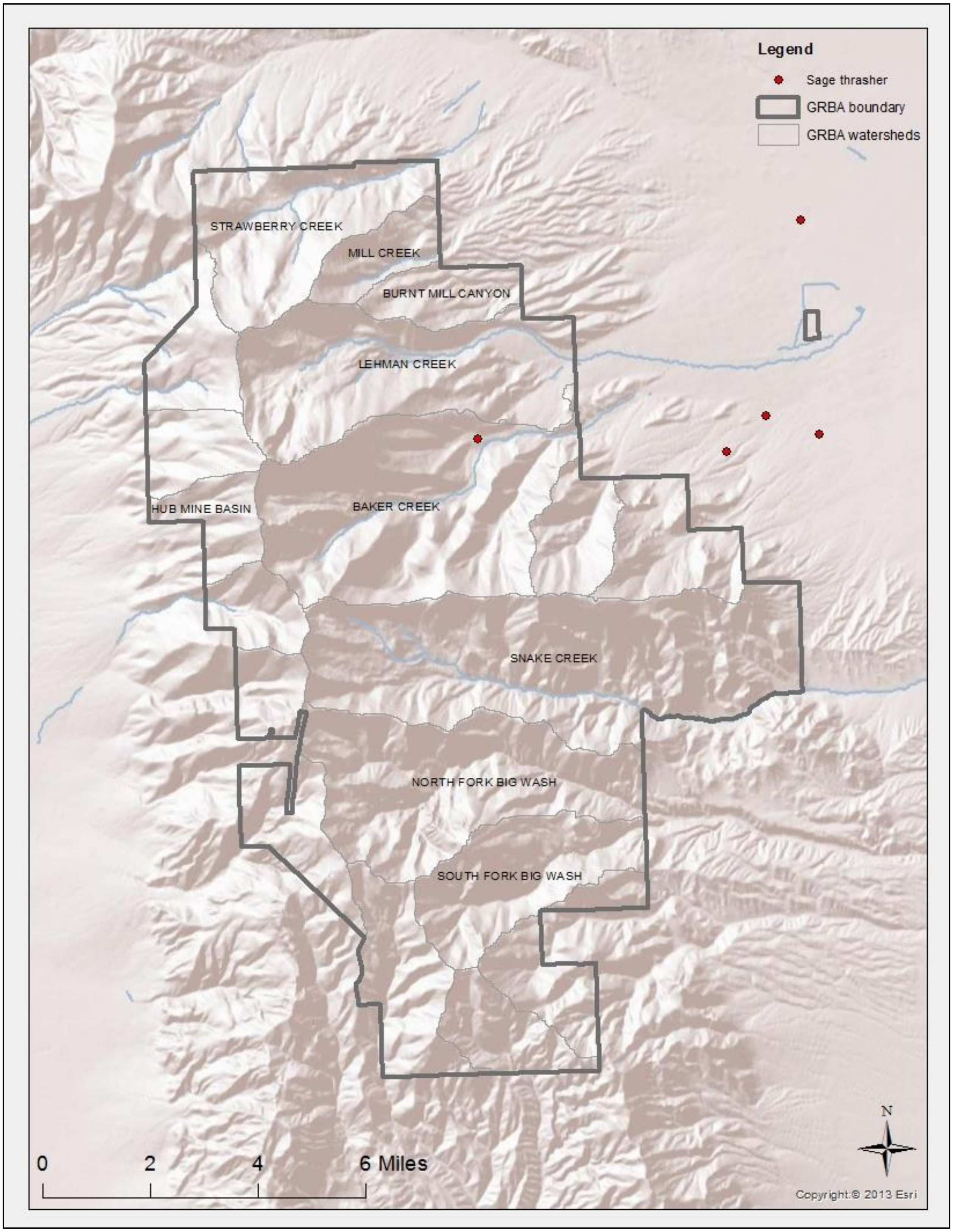
Brewer's Sparrow (*Spizella breweri*)



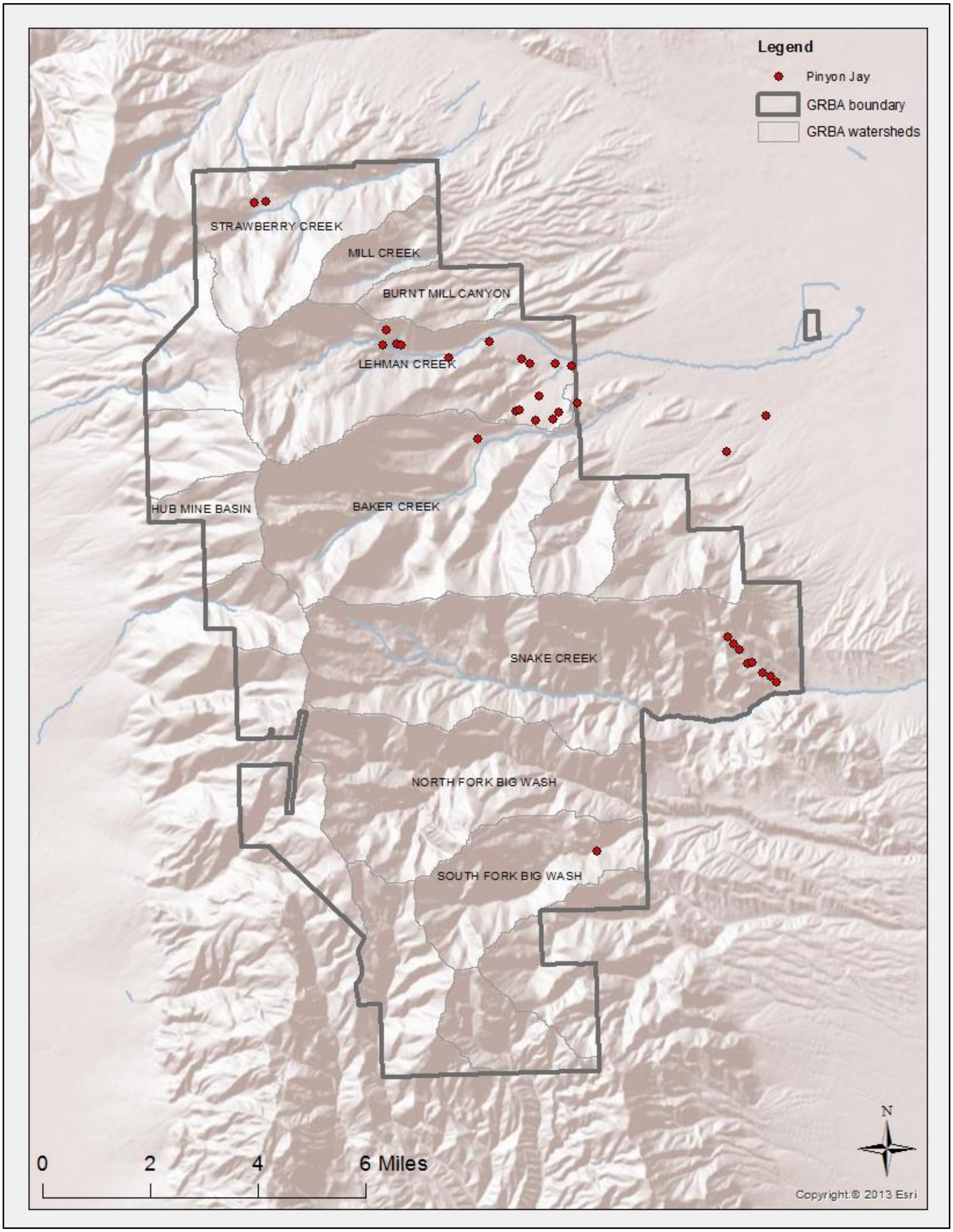
Sage Sparrow (*Amphispiza belli*)



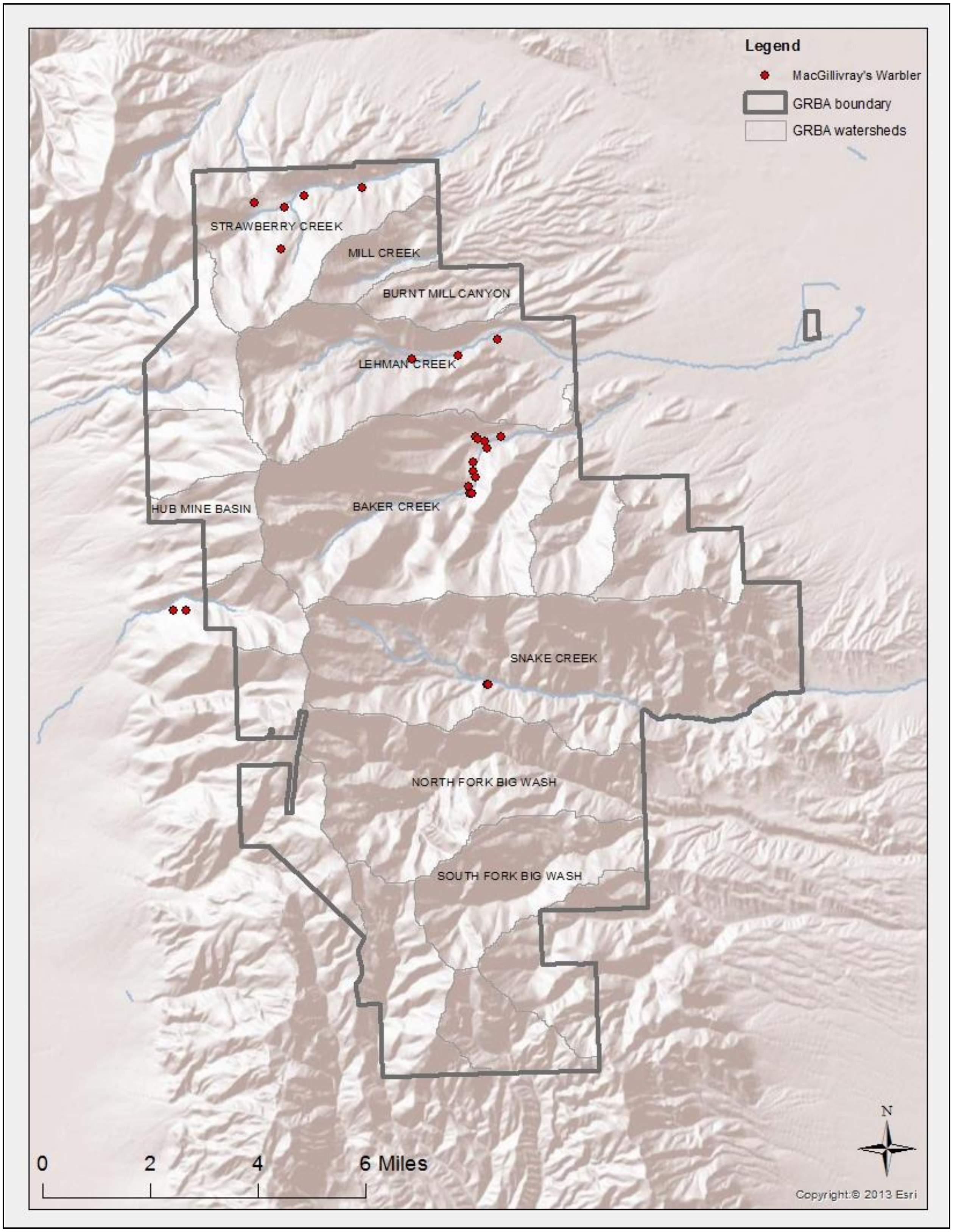
Sage Thrasher (*Oreoscoptes montanus*)



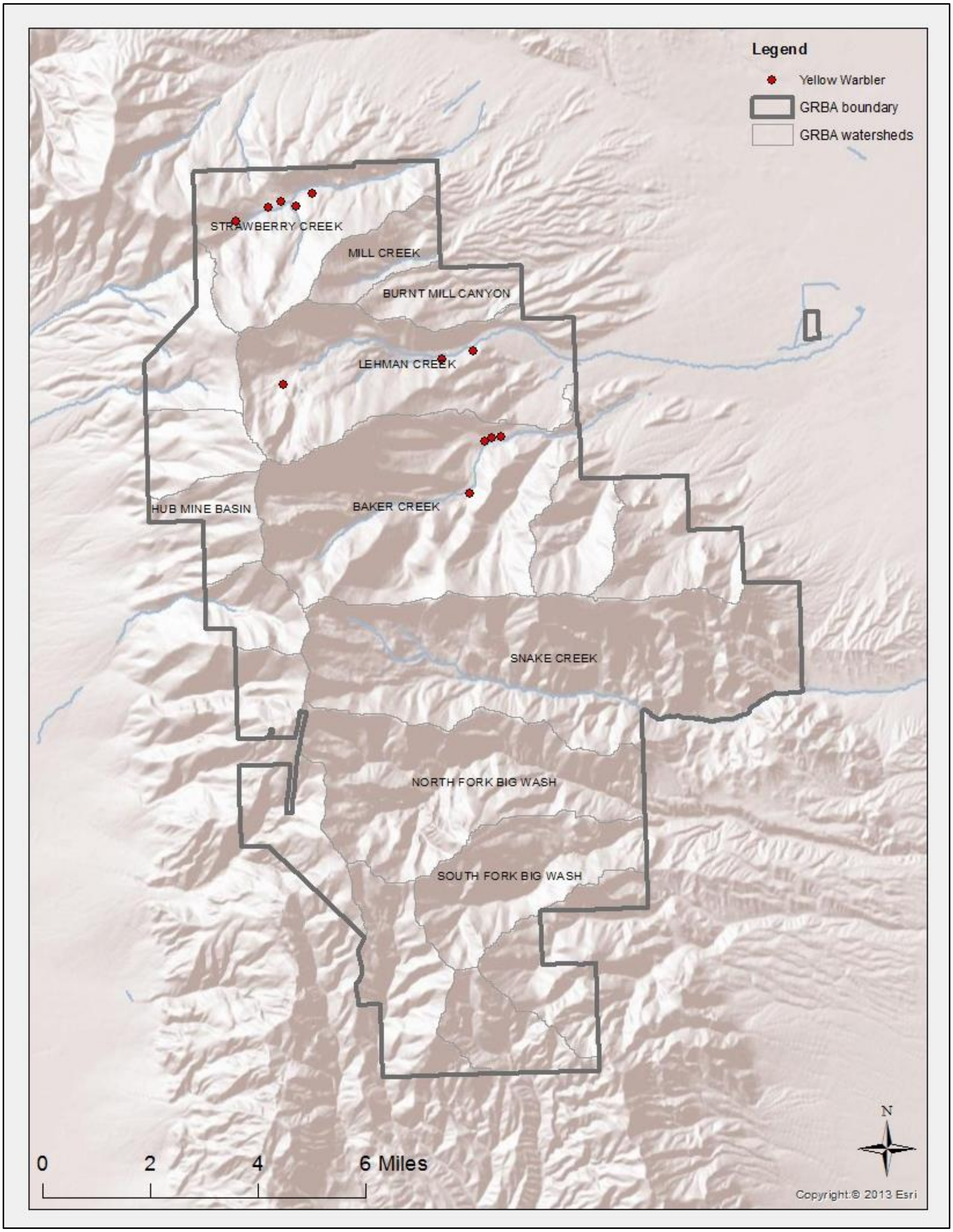
Pinyon Jay (*Gymnorhinus cyanocephalus*)



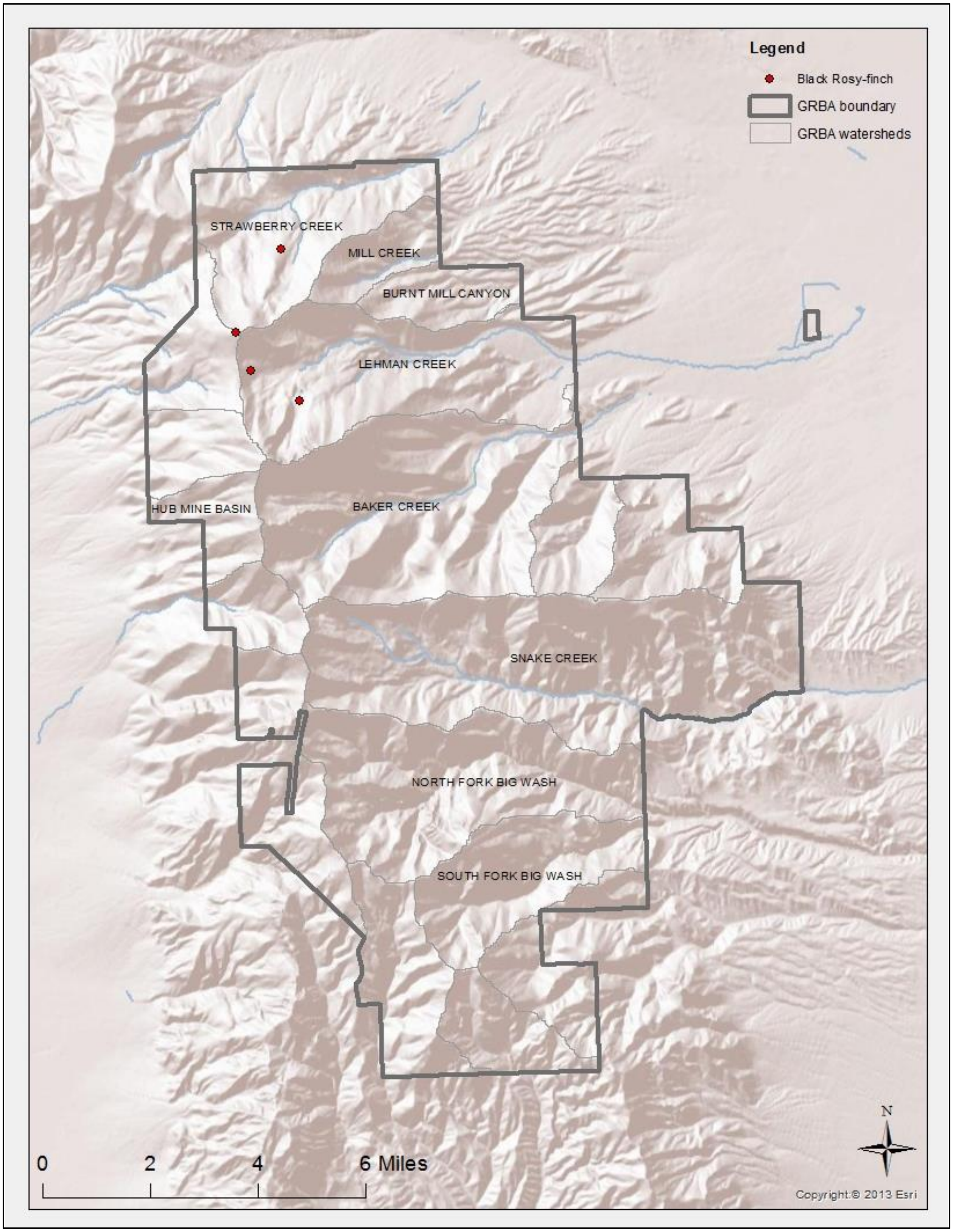
MacGillivray's Warbler (*Oporornis tolmiei*)



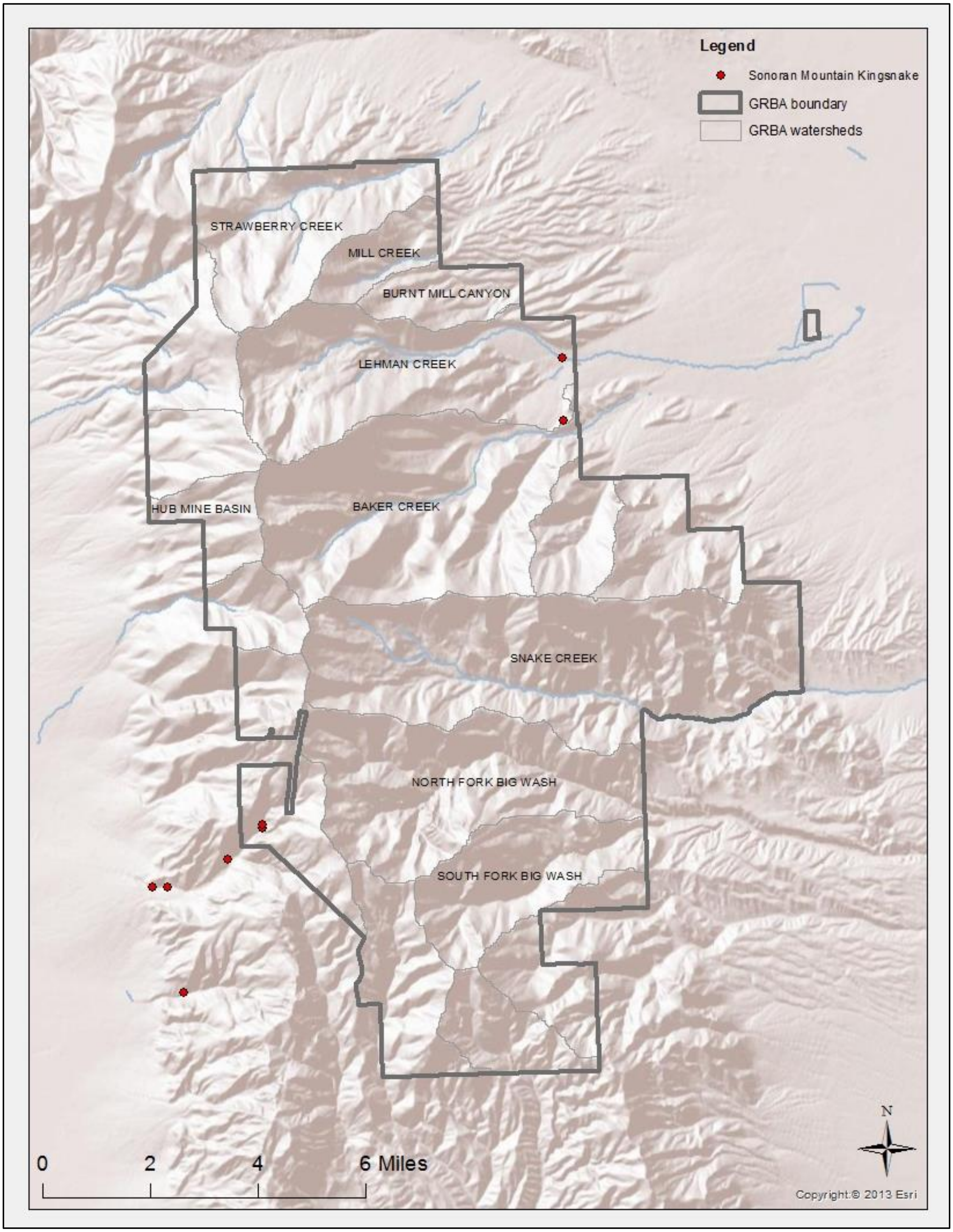
Yellow Warbler (*Dendroica petechia*)



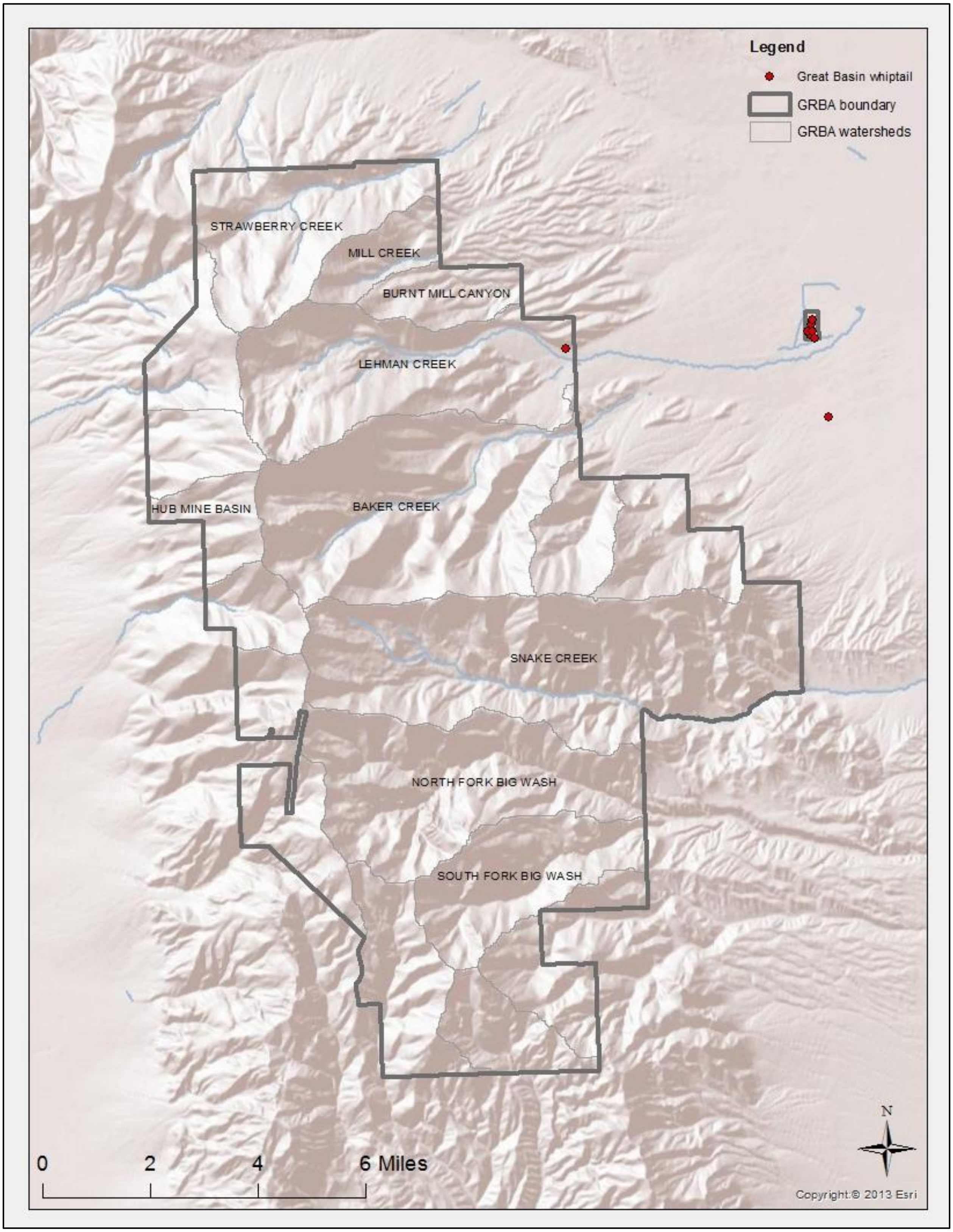
Black Rosy-Finch (*Leucosticte atrata*)



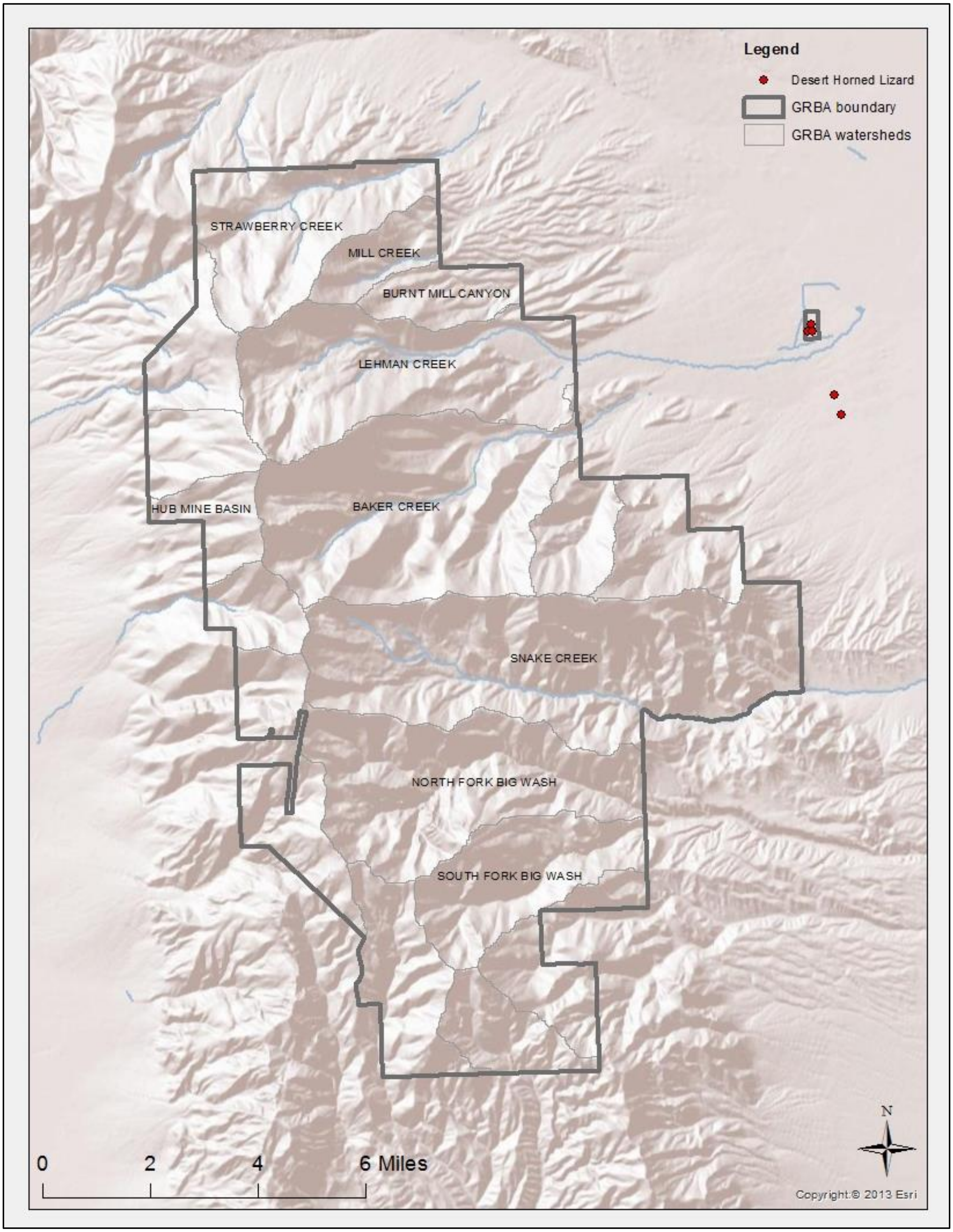
Sonoran Mountain Kingsnake (*Lampropeltis pyromelana*)



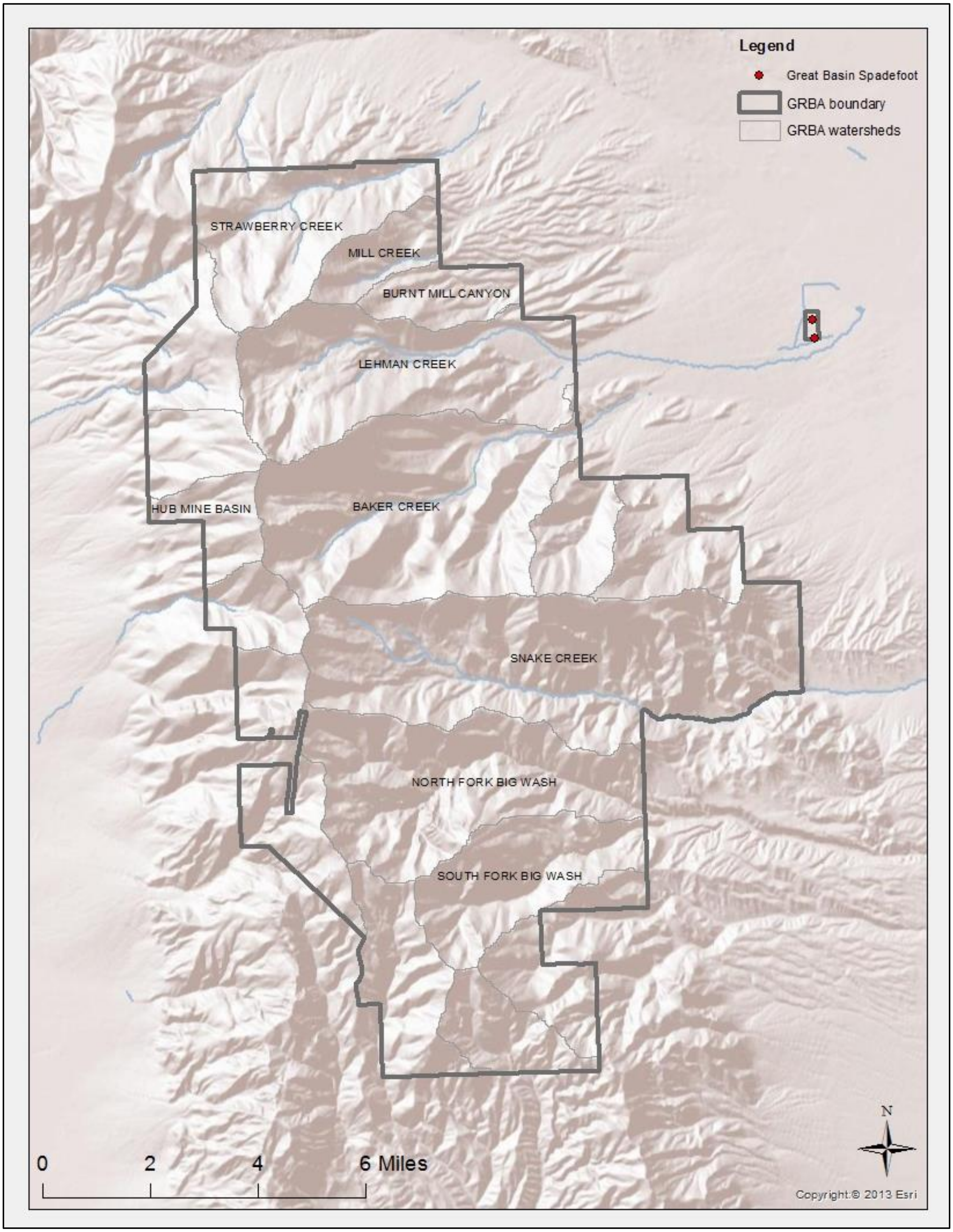
Great Basin Whiptail (*Aspidoscelis tigris*)



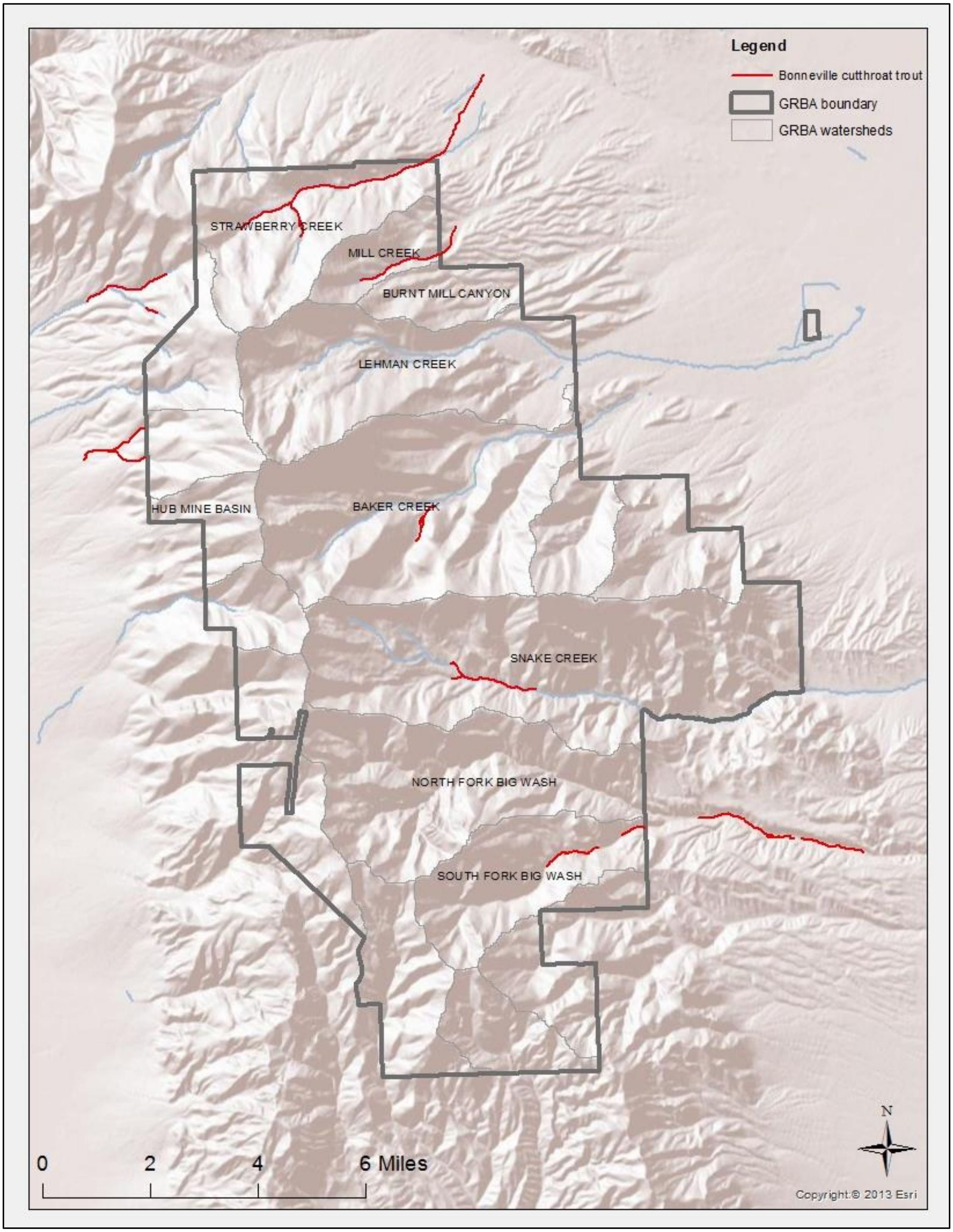
Desert Horned Lizard (*Phrynosoma platyrhinos*)



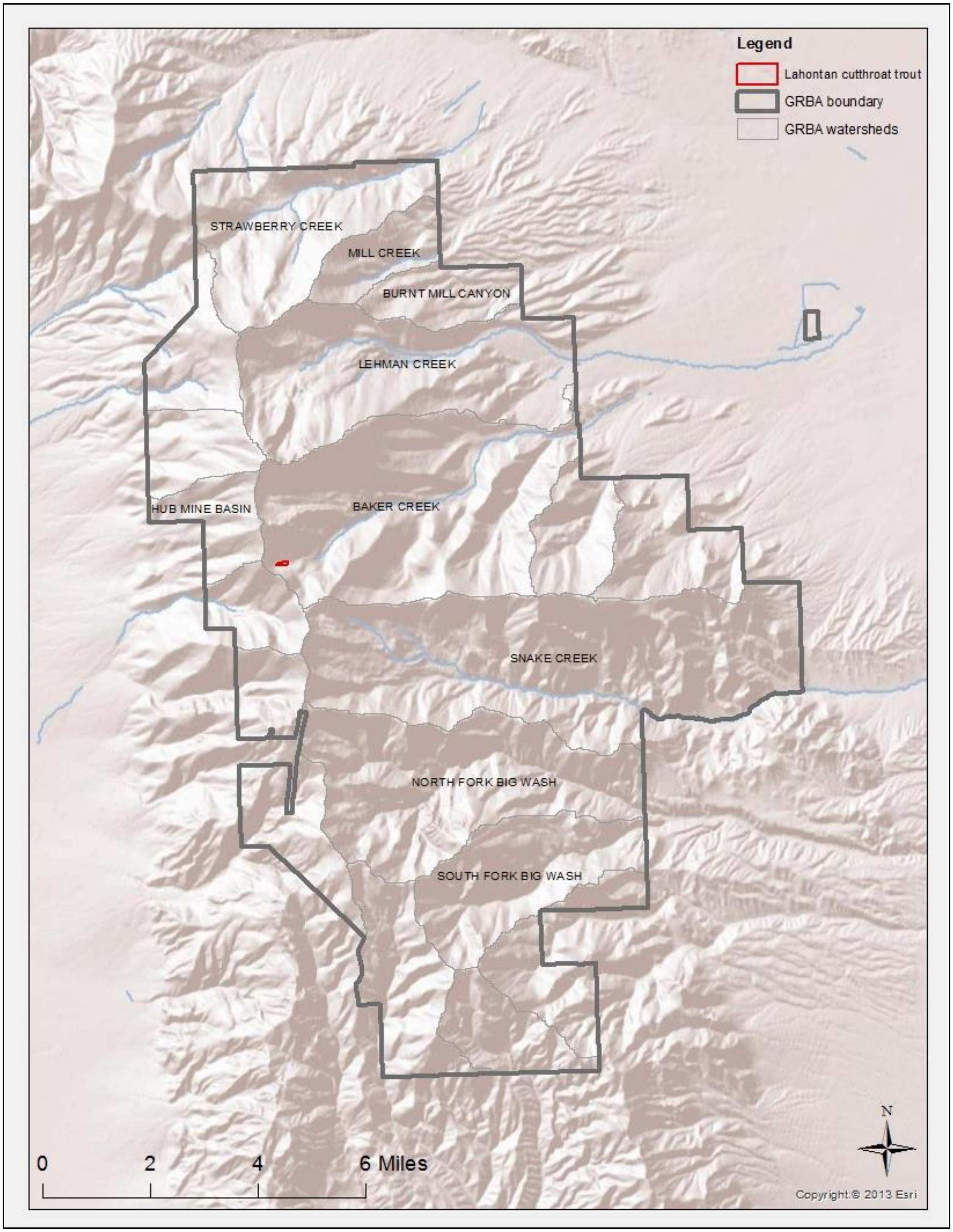
Great Basin Spadefoot (*Spea intermontana*)



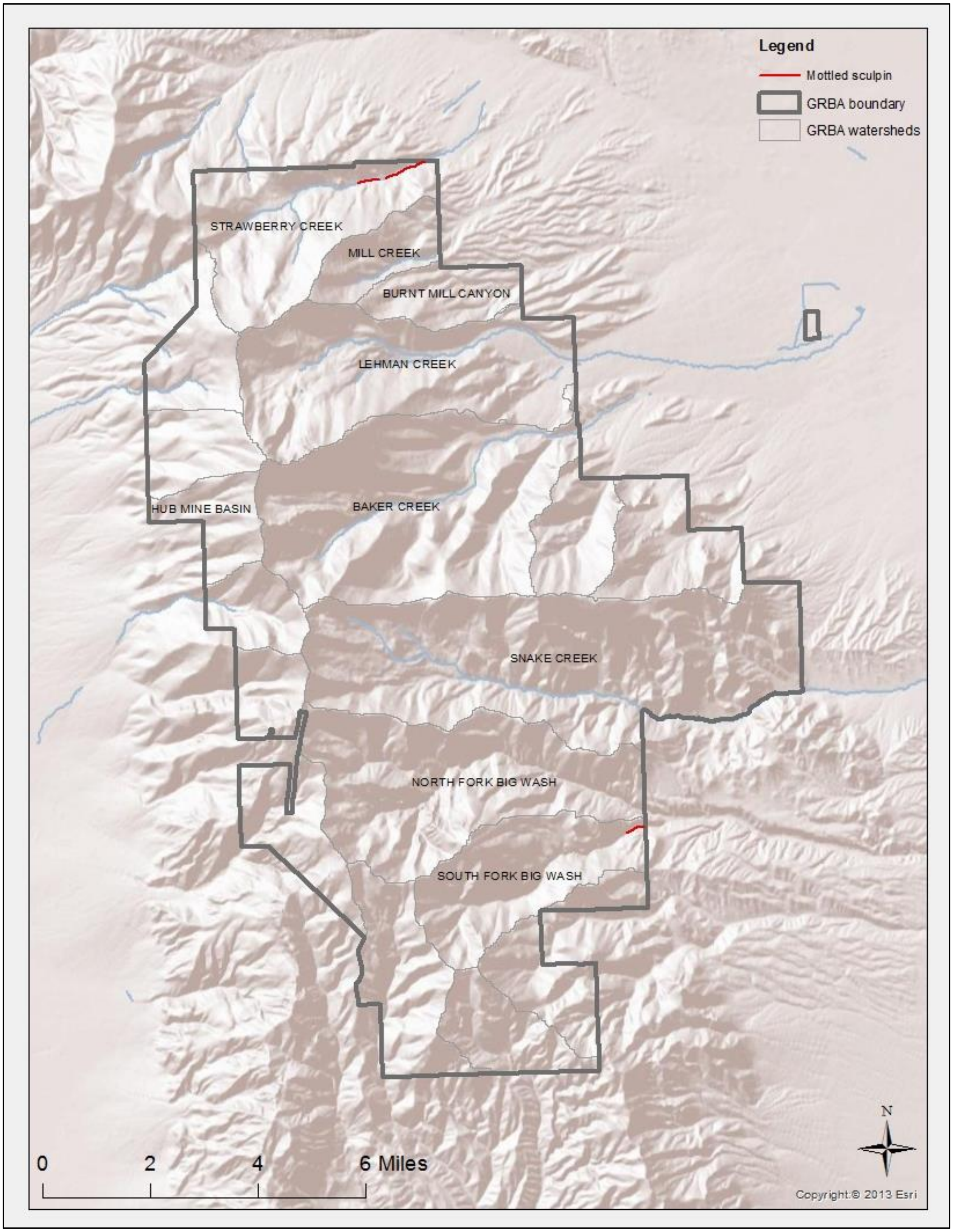
Bonneville Cutthroat Trout (*Oncorhynchus clarki utah*)



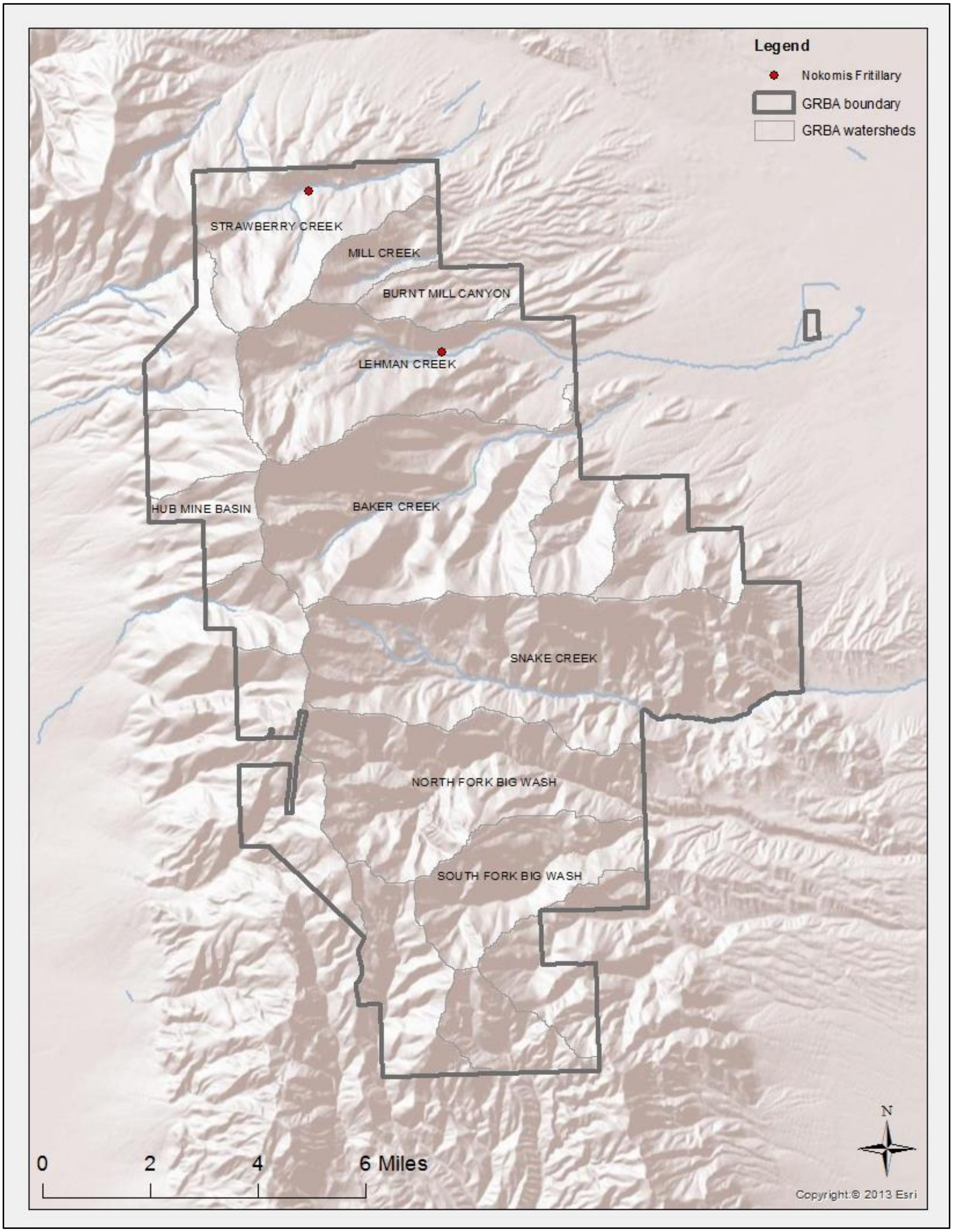
Lahontan Cutthroat Trout (*Oncorhynchus clarki henshawi*)



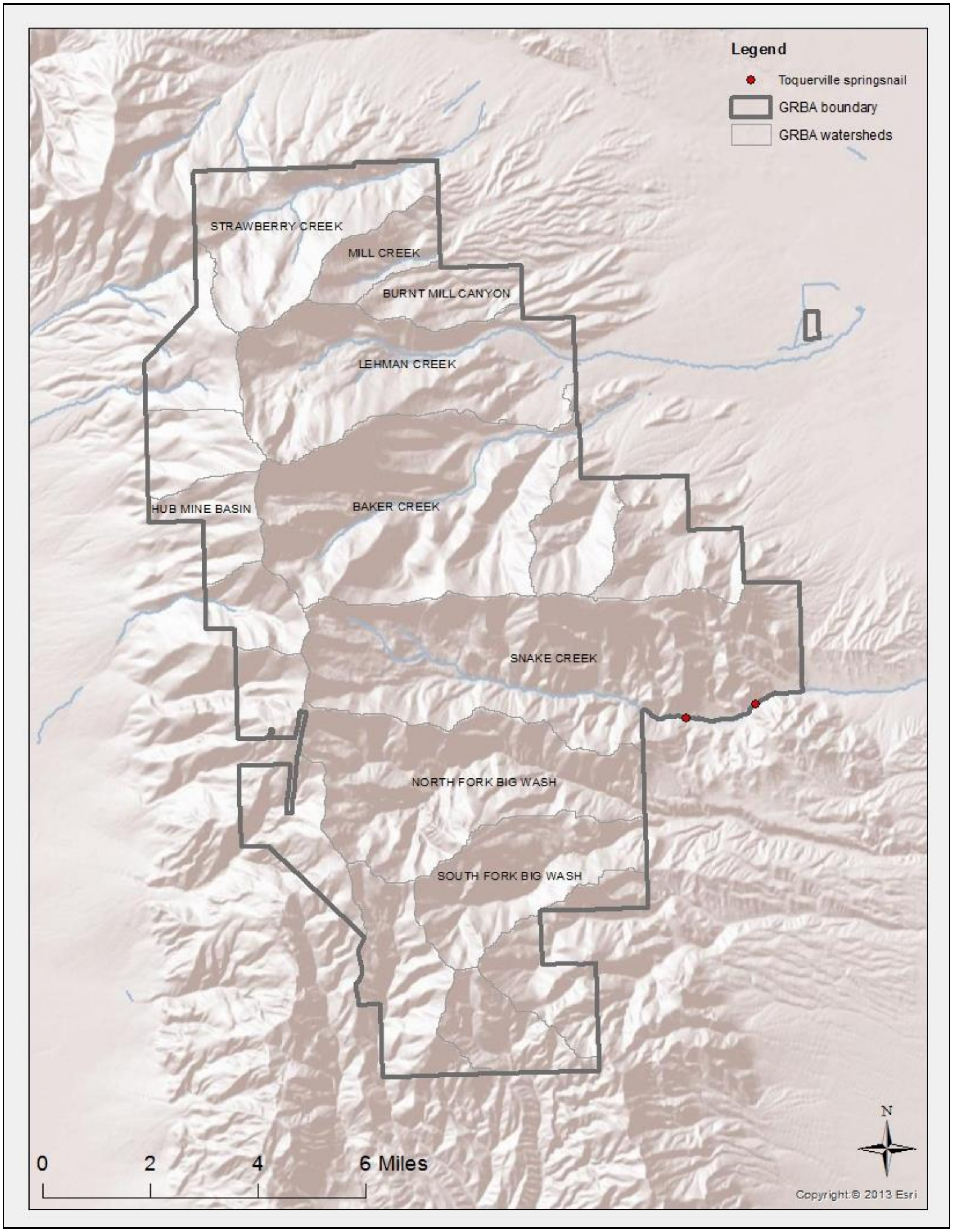
Mottled Sculpin (*Cottus bairdi*)



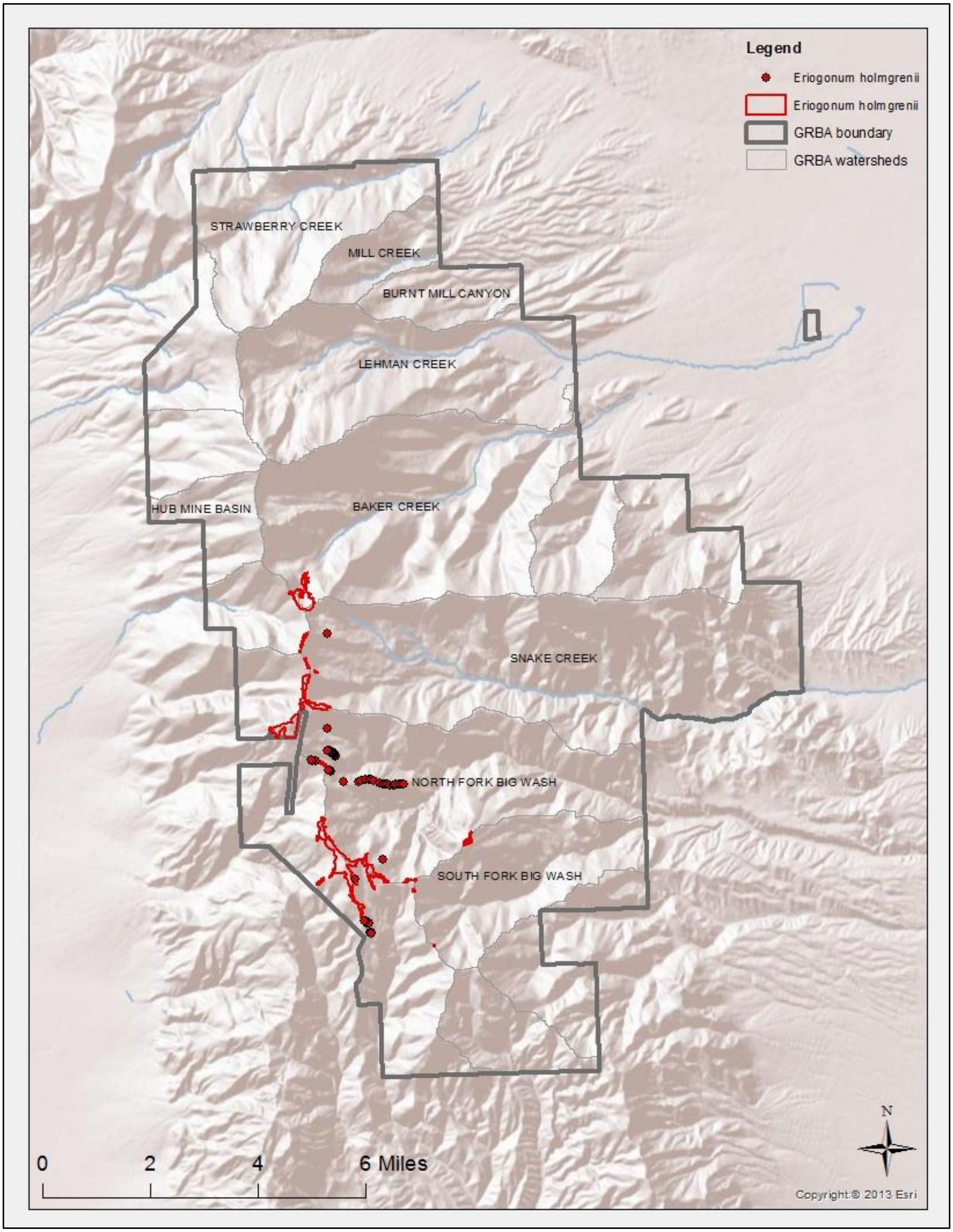
Nokomis Fritillary (*Speyeria nokomis*)



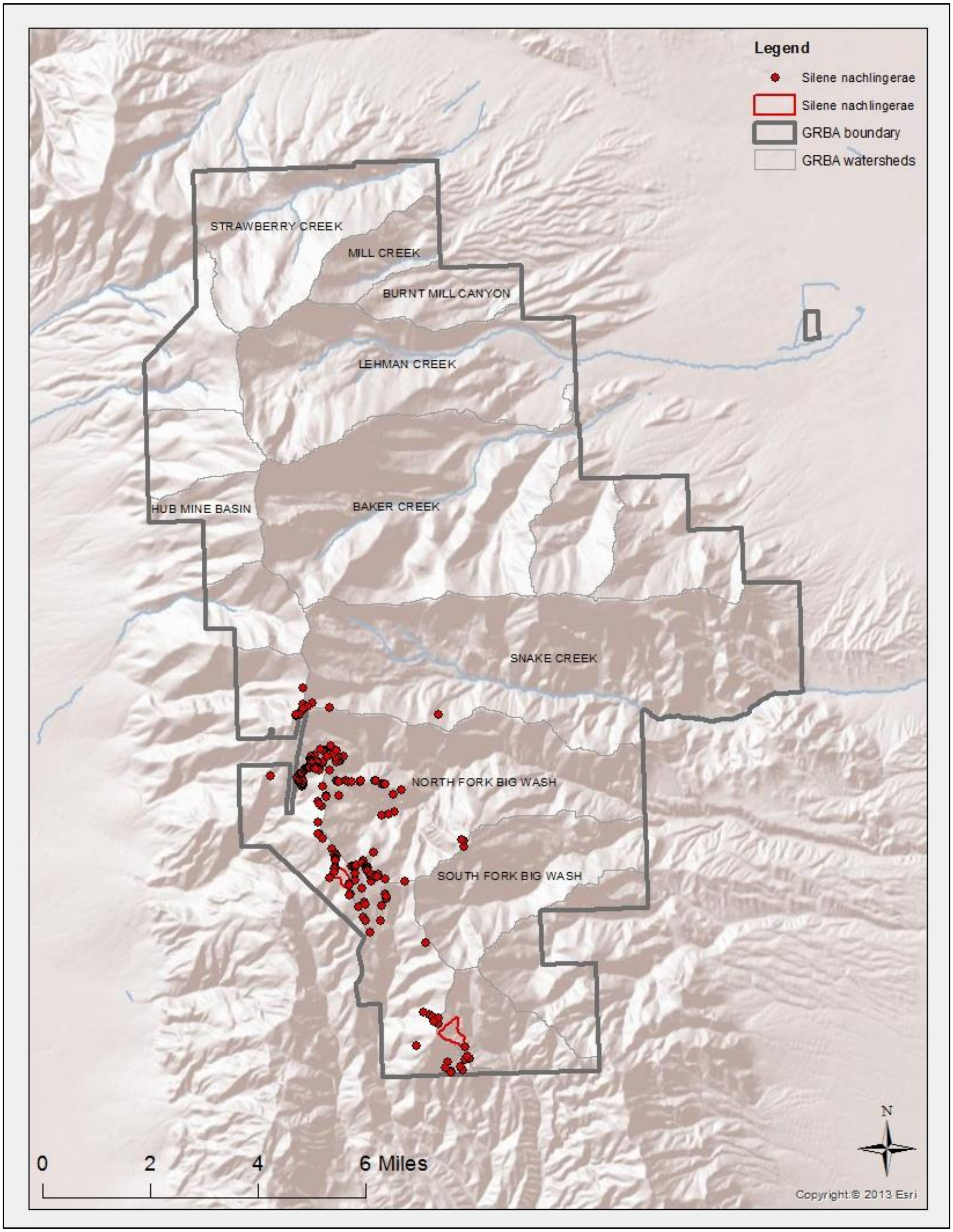
Toquerville Springsnail (*Pyrgulopsis kolobensis*)



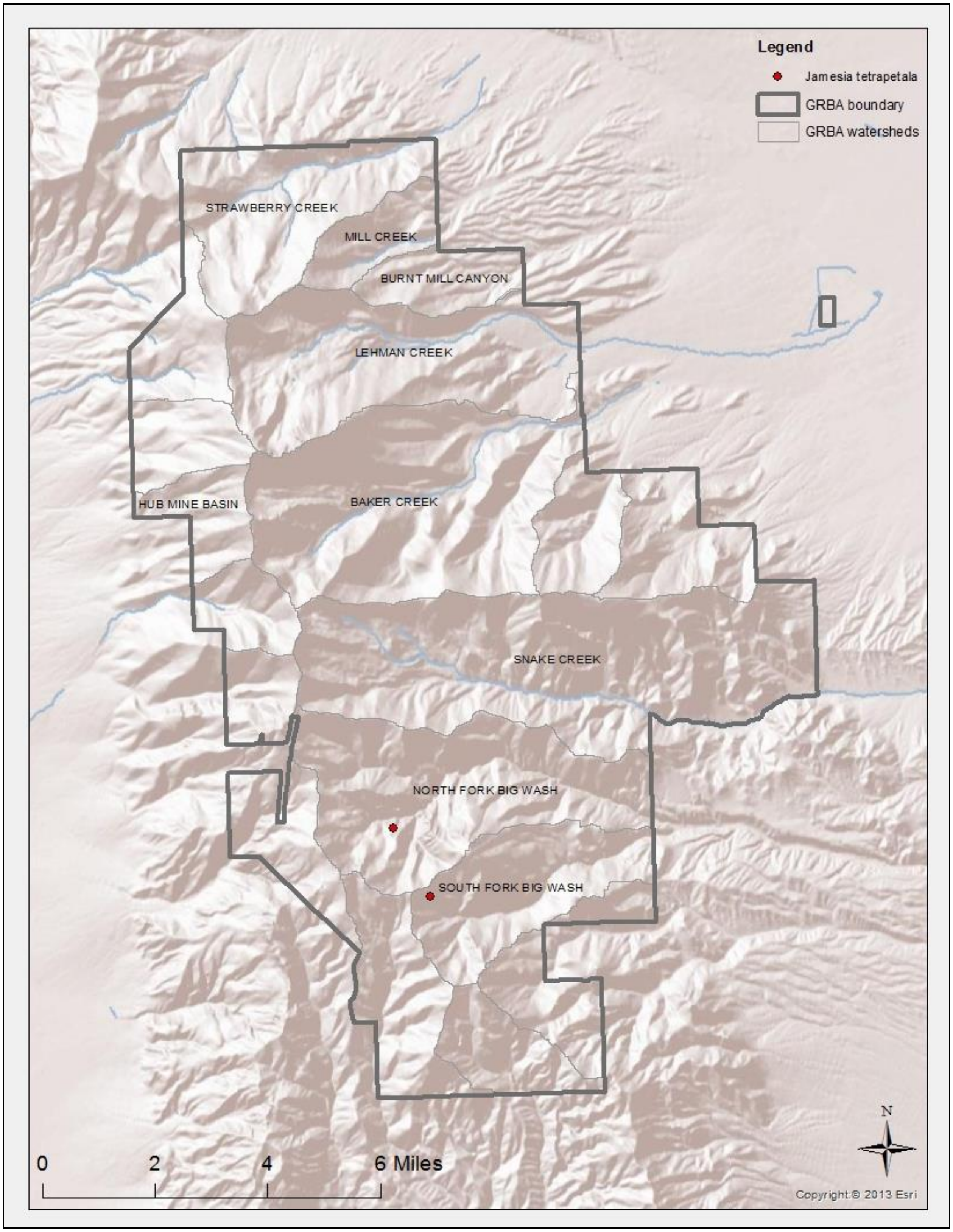
Holmgren's Buckwheat (*Eriogonum holmgrenii*)



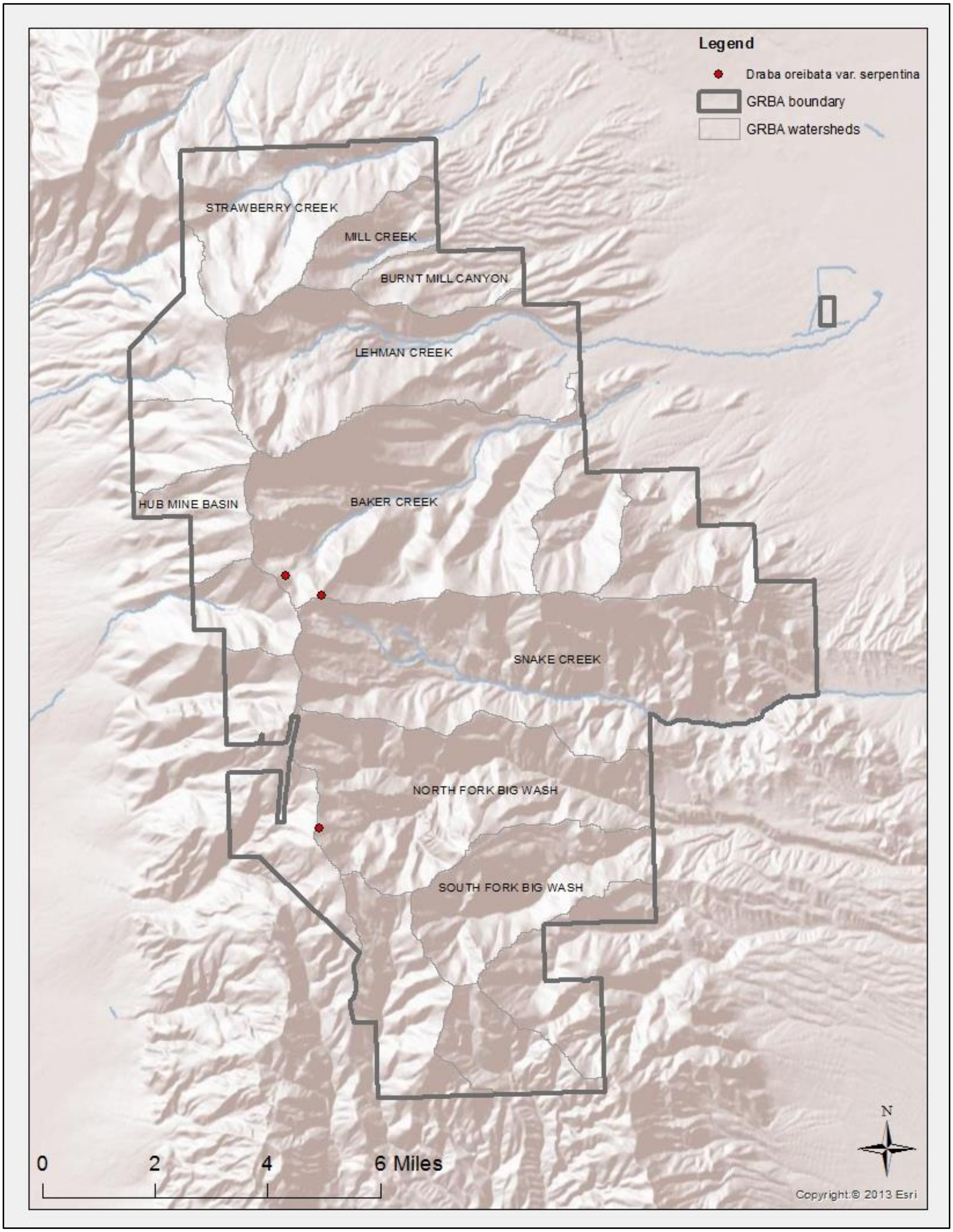
Nevada Catchfly (*Silene nachlingerae*)



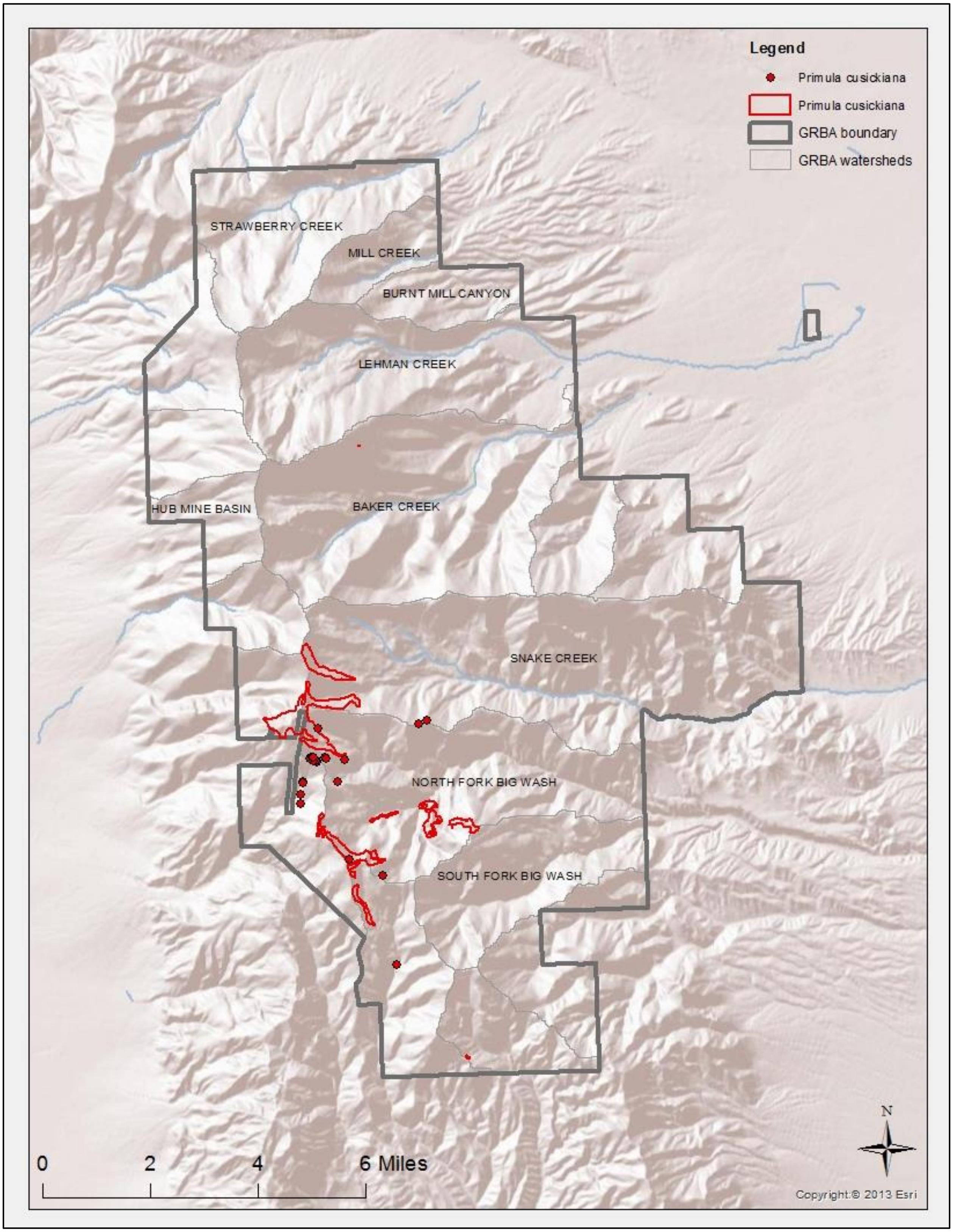
Waxflower (*Jamesia tetrapetala*)



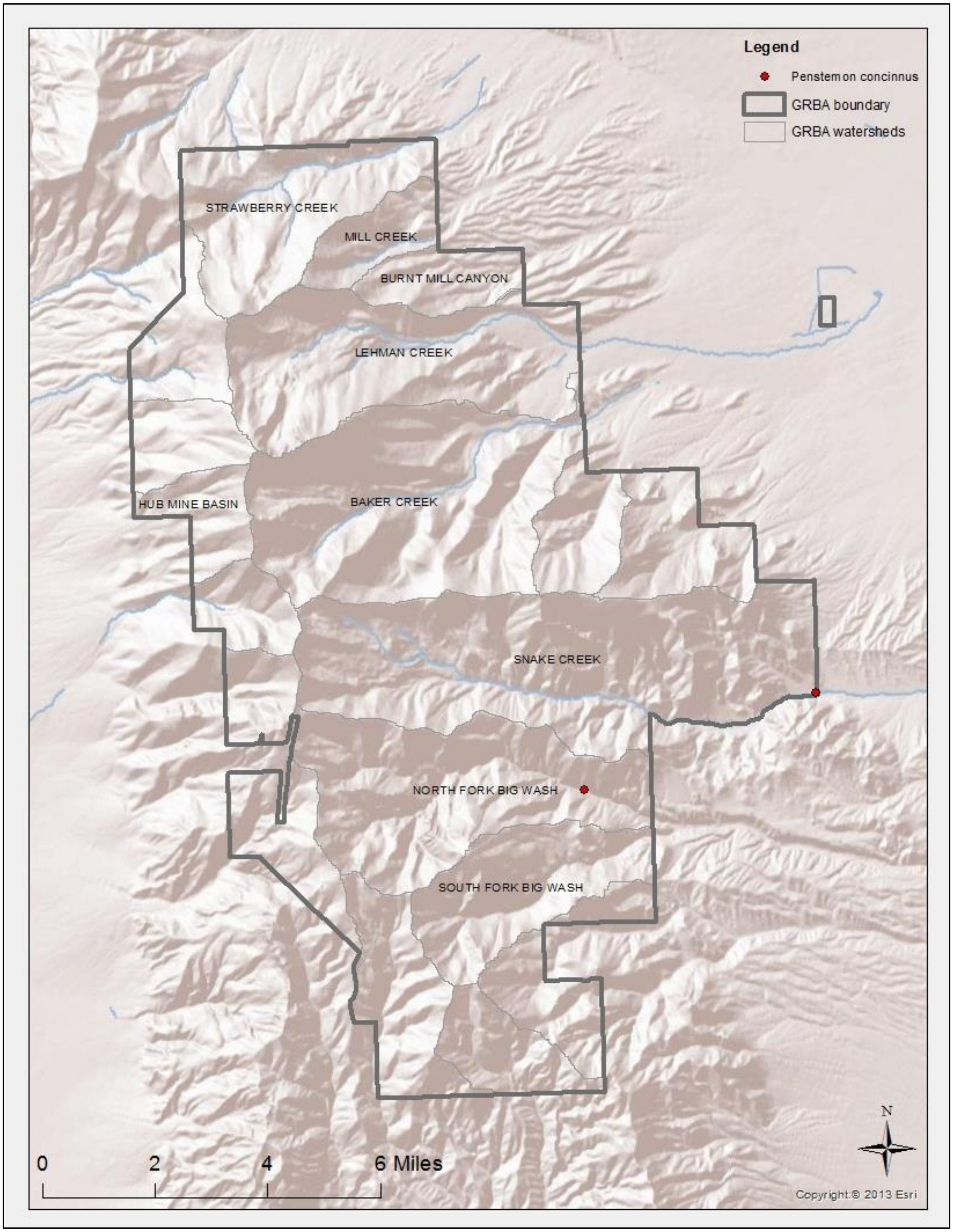
Snake Range Draba (*Draba oreibata var. serpentina*)



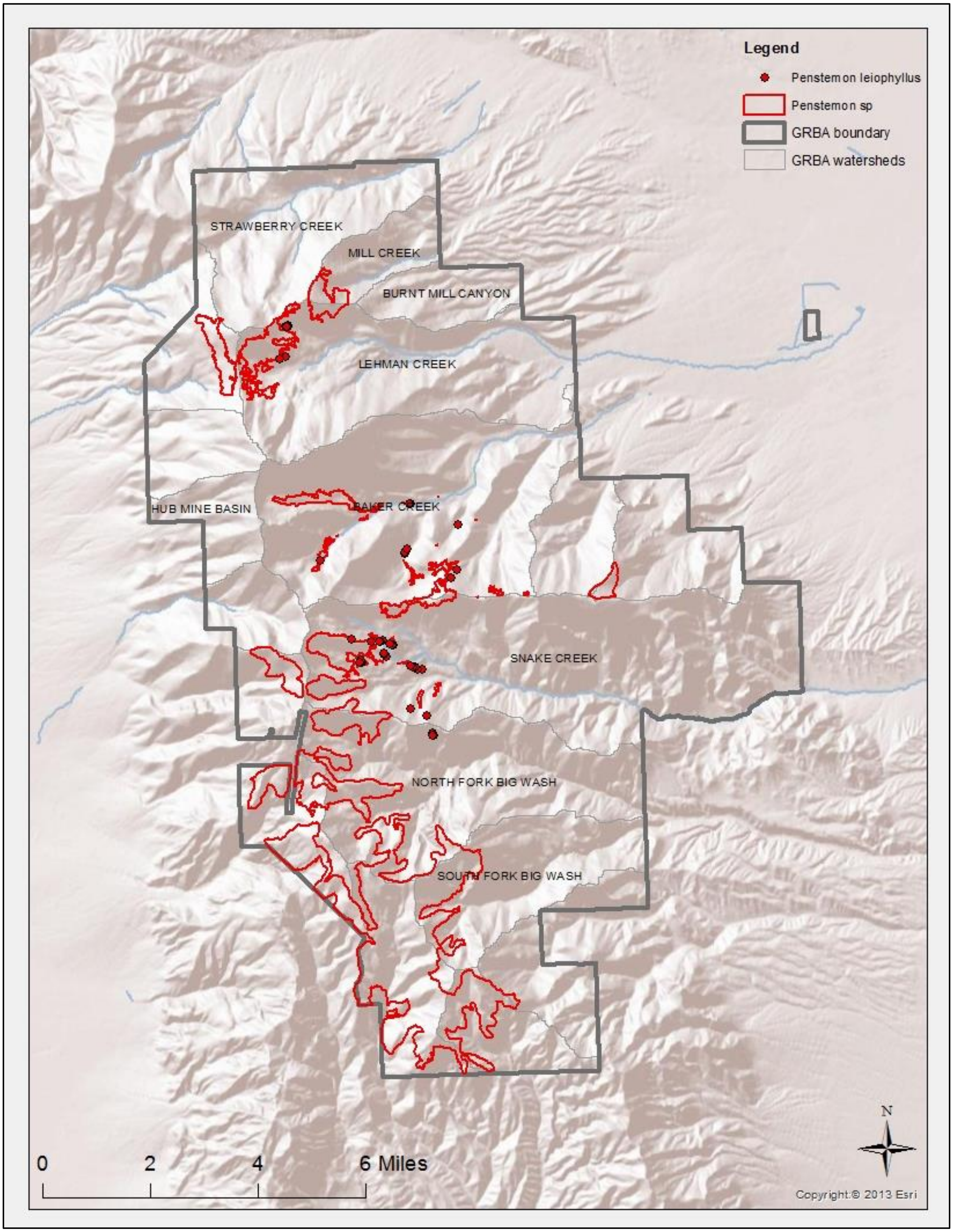
Nevada Primrose (*Primula cusickiana var. nevadensis*)



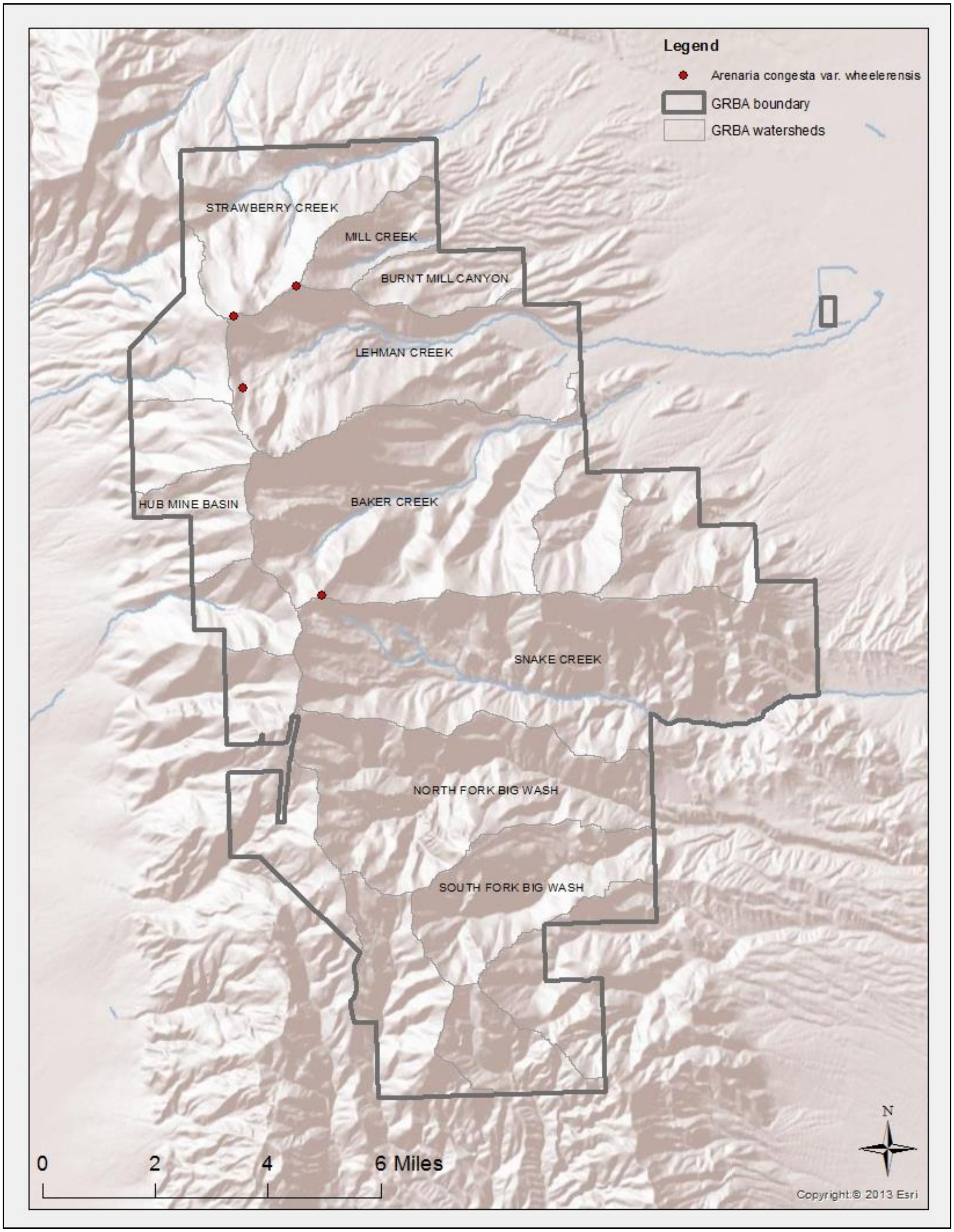
Tunnel Springs Beardtongue (*Penstemon concinnus*)



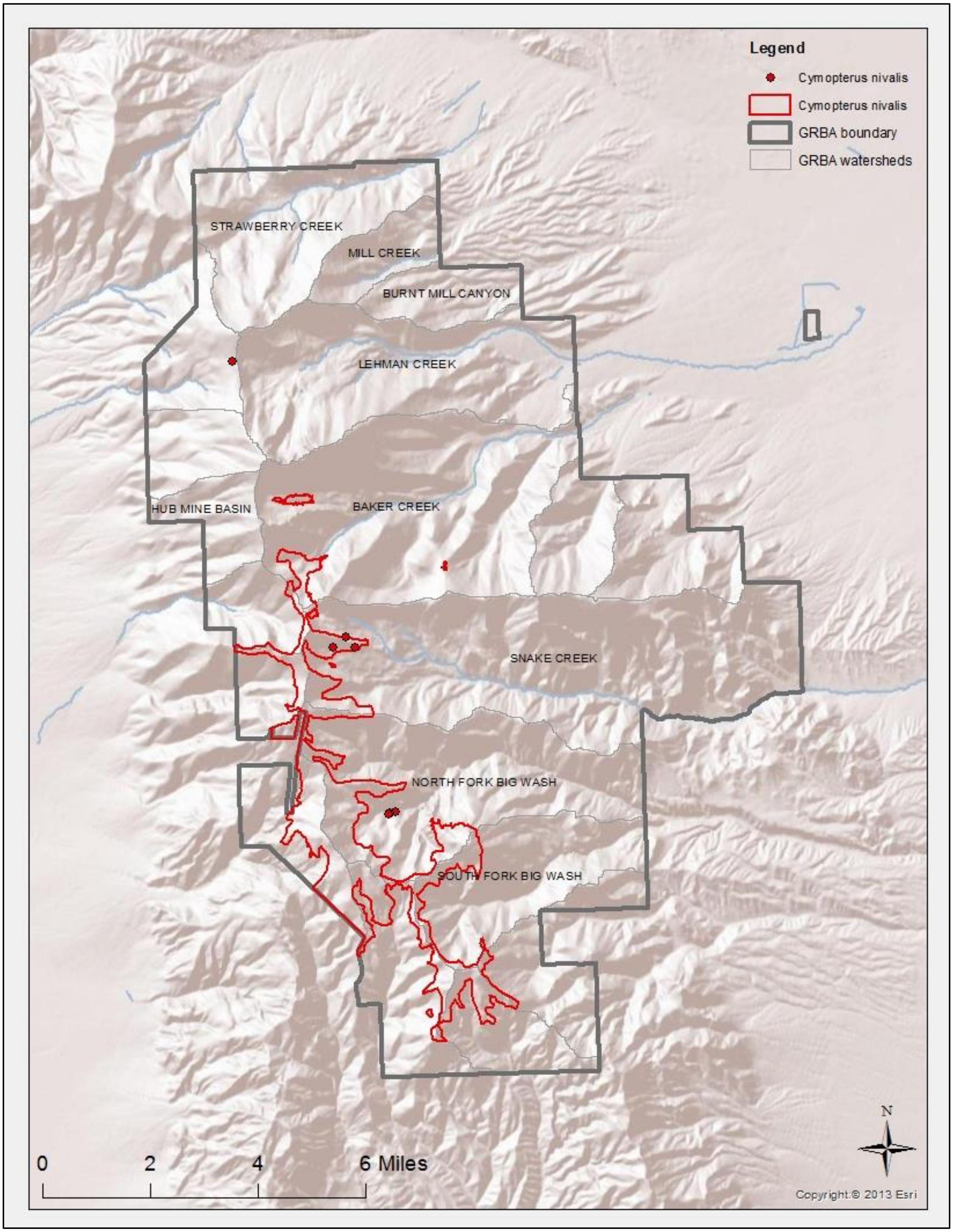
Wheeler Peak Penstemon (*Penstemon leiophyllus var. francisci-pennellii*)



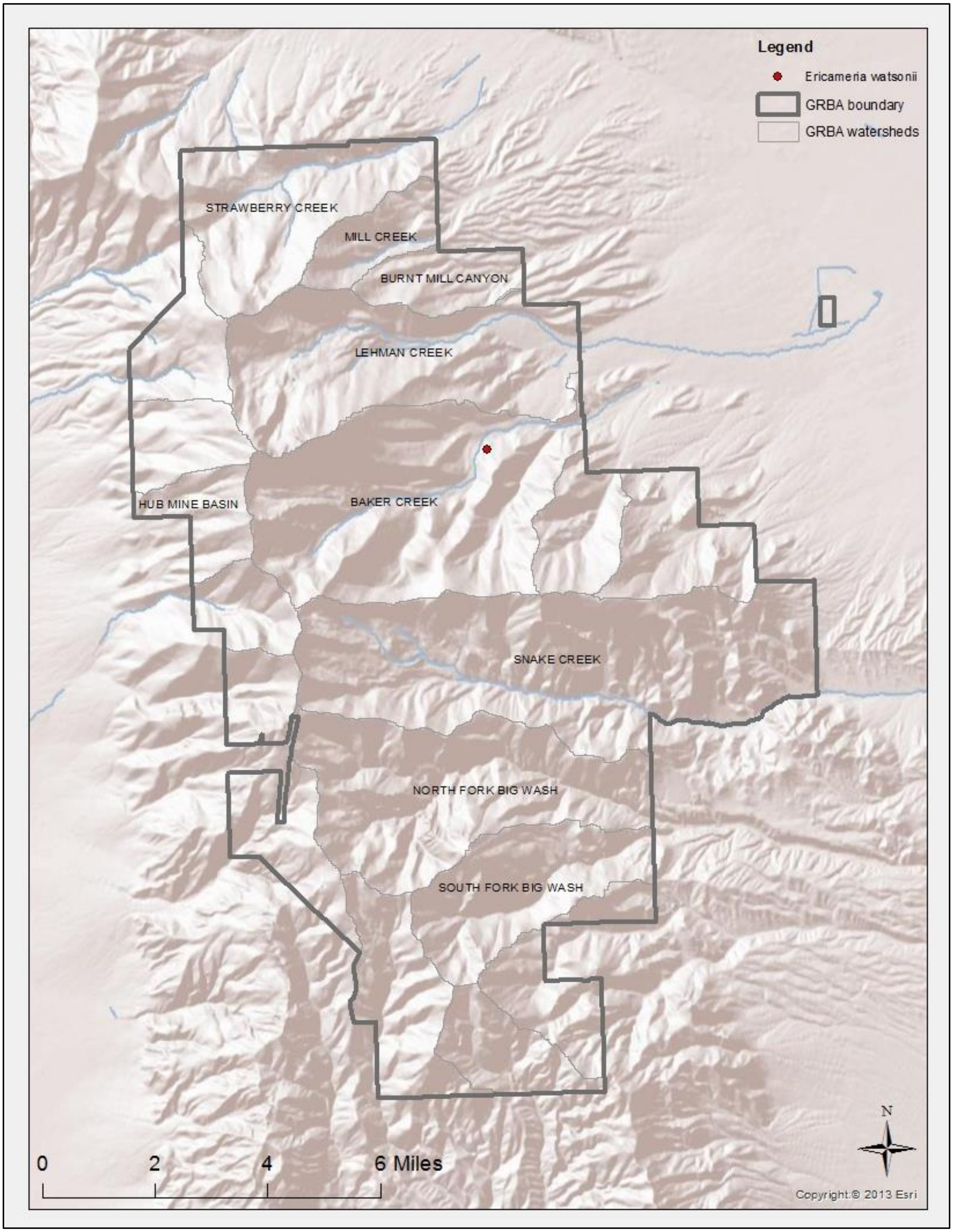
Wheeler Peak Sandwort (*Eremogone congesta var. wheelerensis*)



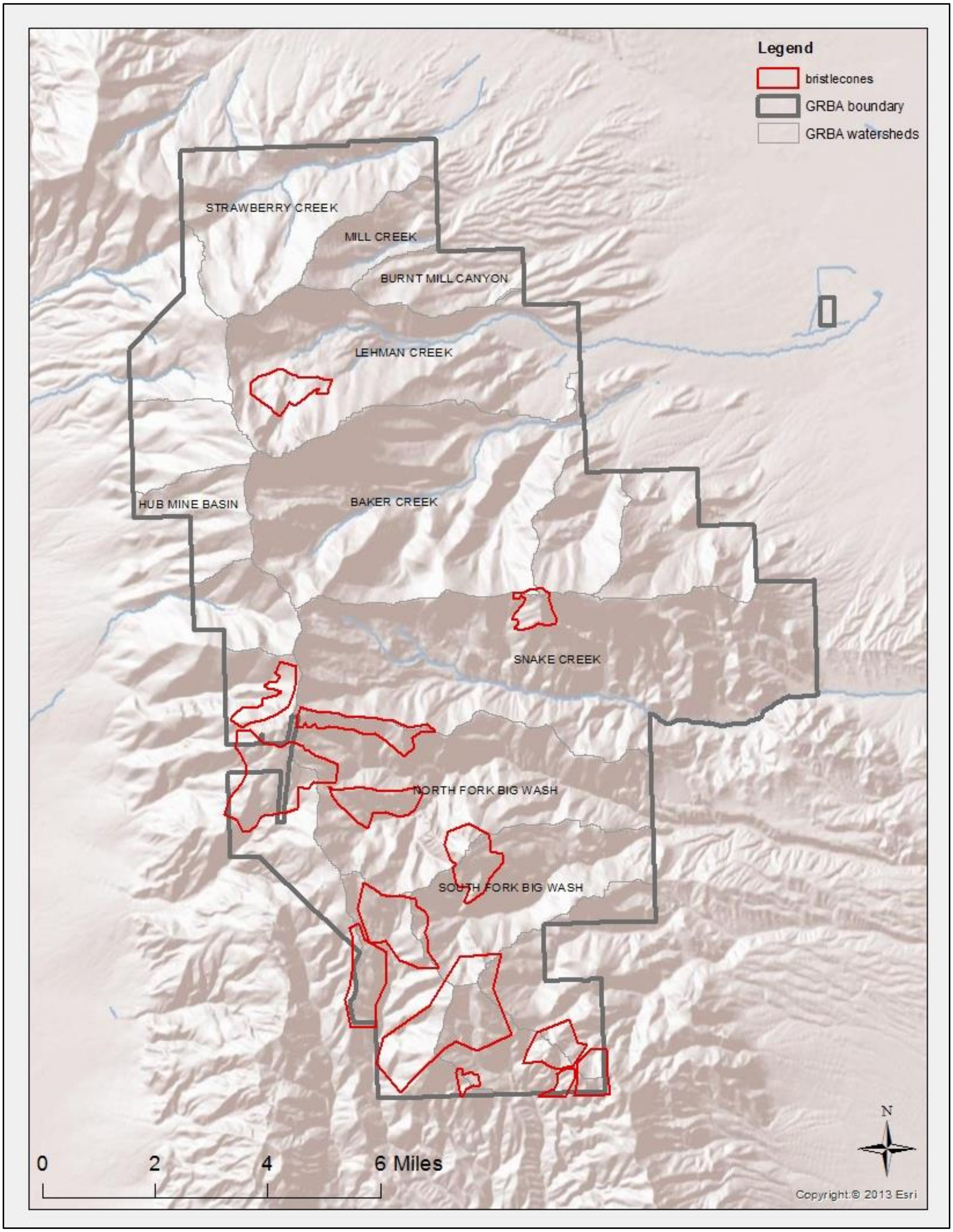
Snowline Springparsley (*Cymopterus nivalis*)



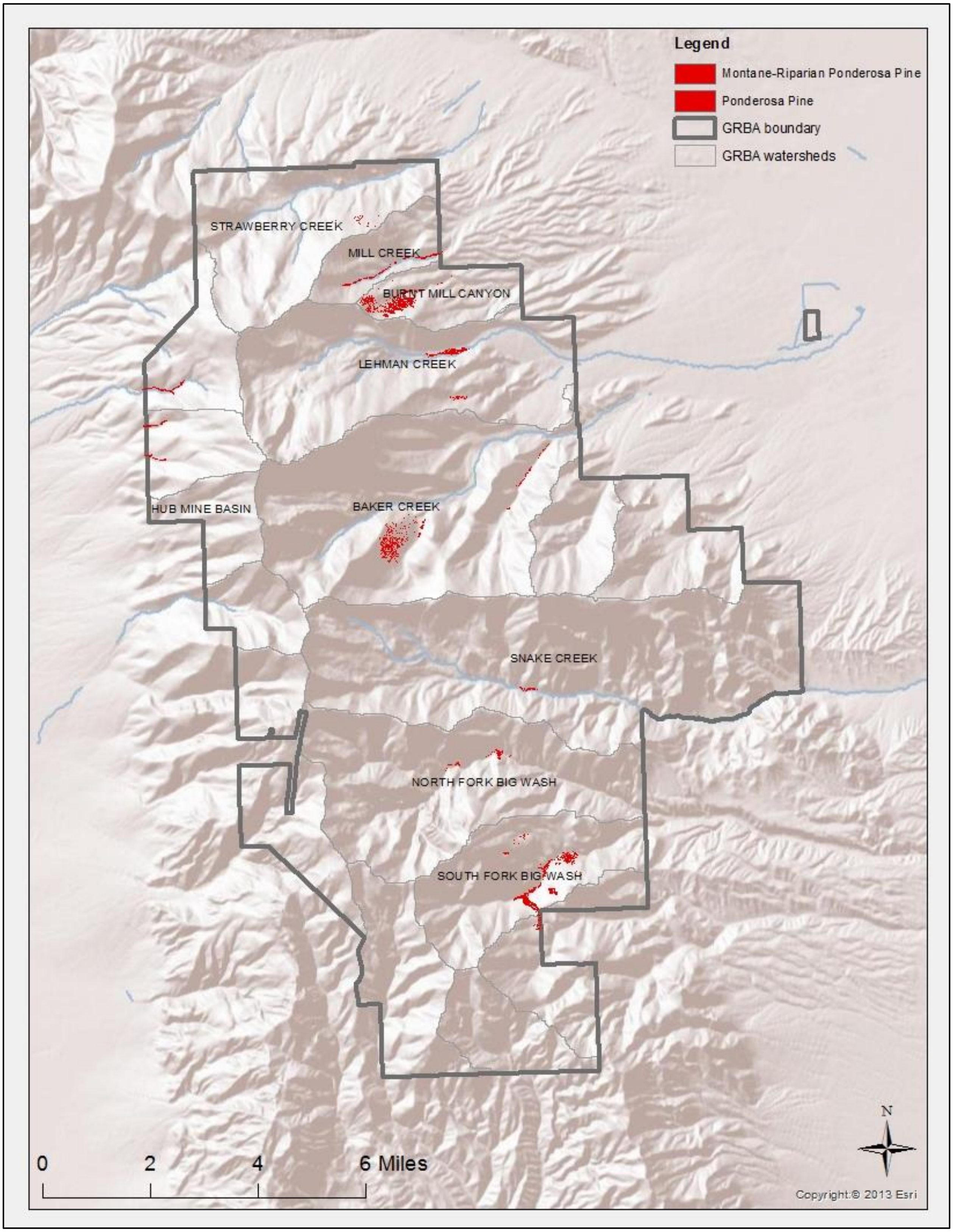
Watson's Goldenbush (*Ericameria watsonii*)



Bristlecone Pine (*Pinus longaeva*)



Ponderosa Pine (*Pinus ponderosa*)



APPENDIX A. Photo credit

L. Arnold

- *Marmota flaviventris*

Roger W. Barbour:

- *Sorex palustris*
- *Antrozous pallidus*
- *Lasionycteris noctivagans*
- *Myotis volans*

Glenn Bartley (birds.audobon.org)

- *Oporornis tolmei*

John Cang

- *Mustela erminea*

Mark. A. Chappell

- *Lemmiscus curtatus*

Glenn Clifton

- *Botrychium crenulatum*
- *Draba pedicellata var. wheelerensis*
- *Draba serpentina*
- *Jamesia tetrapetala*
- *Potentilla concinnus*
- *Potentilla moriahensis*
- *Silene nachlingerae*
- *Trifolium eriocephalum var. villiferum*

Gerald and Buff Corsi

- *Erethizon dorsatum*

Coburn Currier

- *Brachylagus idahoensis*

David Hunter

- *Microcreagris grandis Muchmore*
- *Nevadesmus ophimonis Shear*
- *Idagona lehmanensis Shear*
- *Sclerobunus ungulatus Derkarabetian*

Jukka Jantunen (birds.audobon.org)

- *Picoides tridactylus*

Christy Klinger

- *Falco pereginus*

Jacque Lowery

- *Spizella breweri*
- *Amphispiza belli*

J. Lutz

- *Buteo regalis*

Karl Maslowski

- *Castor canadensis*

Tim Mullican

- *Sorex merriami*

Martin Myers

- *Accipter gentilis*
- *Melanerpes lewis*
- *Oreoscoptes montanus*
- *Gymnorhinus cyanocephalus*

Larry Neel

- *Buteo swainsoni*
- *Asio flammeus*

Paul A. Opler

- *Speyeria nokomis*

B. Moose Peterson

- *Myotis evotis*

Fred Peterson

- *Otus flammeolus*

Eric A. Rickart

- *Sorex tenellus*

Greg Scyphers

- *Leucosticte atrata*

Steven J. Taylor

- *Stygobromus albapinus*

Steve Ting

- *Centrocercus urophasianus*

Merlin D. Tuttle

- *Euderma maculatum*

Margaret Williams (NV Native Plant Society)

- *Primula cusickiana var. nevadensis*
- *Penstemon leiophyllus var. francisci-pennellii*
- *Cymopterus nivalis*
- *Ericameria watsonii*

Public Domain

- *Corynorhinus townsendii (BLM)*
- *Myotis thysanodes (USGS)*

National Park Service Photo

- *Lasiurus cinereus*
- *Ovis canadensis*
- *Lampropelits pyromelana*
- *Diadophis punctatus*
- *Aspidoscelis tigris*
- *Phrynosoma platyrhinos*
- *Phrynosoma hernandesii*
- *Spea intermontana*
- *Oncorhynchus clarki utah*
- *Oncorhynchus clarki henshawi*
- *Cottus bairdi*
- *Pyrgulopsis kolobensis*
- *Eriogonum holmgrenii*
- *Arenaria congesta var. wheelerensis*
- *Pinus longaeva*
- *Pinus ponderosa*

Appendix B: Links to Air Quality Monitoring Networks

Acid Deposition (wet & dry deposition data, precipitation and maps):

- http://nadp.sws.uiuc.edu/
- http://www.epa.gov/castnet/

Mercury Deposition (data and maps):

- http://nadp.sws.uiuc.edu/

Visibility (data and maps):

- http://vista.cira.colostate.edu/improve/
- http://vista.cira.colostate.edu/views/

Ozone & Meteorology:

- http://ard-request.air-resource.com/

Meteorology:

- NWS Data: http://www.ncdc.noaa.gov/oa/ncdc.html

Ozone Mapping and Forecasting of Western U.S.:

- http://airnow.gov/

Appendix C: Great Basin National Park
Air Quality Monitoring History

Active and Inactive Monitoring Sites as of January 2014

Table C-1. Air quality monitoring at Great Basin. Latitude: 38.0053 deg N, Longitude: 114.2161 deg W, Elevation: 2,139 m (7,017 ft) (From: http://www.nature.nps.gov/air/).

Parameter	Start	End	Years	Seasons	Period	Interval	Instrument	Operating Agency	Network
Sulfur Dioxide	04/28/1993	07/15/1995	2.2	-	year-round	24-hour average	Sampler	NPS	IMPROVE
Ambient Temperature (non-aspirated)	08/20/1992	09/30/2006	14.1	-	year-round	1-hour average	Sensor	NPS	IMPROVE
Relative Humidity	08/20/1992	09/30/2006	14.1	-	year-round	1-hour average	Sensor	NPS	IMPROVE
Relative Humidity	01/23/2008	present	6.0	-	year-round	1-hour average	Sensor	NPS	IMPROVE
Ambient Temperature (aspirated)	01/23/2008	present	6.0	-	year-round	1-hour average	Sensor	NPS	IMPROVE
35MM Camera Slide	06/01/1982	04/01/1995	12.8	-	year-round	1 or more/day	Camera	NPS	NPS-VIS
Extinction coefficient	08/20/1992	09/30/2006	14.1	-	year-round	1-hour average	Transmissometer	NPS	IMPROVE
IMPROVE Sampler Module A	05/27/1992	03/01/2000	7.8	-	year-round	24-hour average	Sampler	NPS	IMPROVE
IMPROVE Sampler Module A	03/01/2000	present	13.9	-	year-round	24-hour average	Sampler - VII	NPS	IMPROVE
IMPROVE Sampler Module B	05/27/1992	03/01/2000	7.8	-	year-round	24-hour average	Sampler	NPS	IMPROVE
IMPROVE Sampler Module B	03/01/2000	present	13.9	-	year-round	24-hour average	Sampler - VII	NPS	IMPROVE

Parameter	Start	End	Years	Seasons	Period	Interval	Instrument	Operating Agency	Network
IMPROVE Sampler Module C	05/27/1992	03/01/2000	7.8	-	year-round	24-hour average	Sampler	NPS	IMPROVE
IMPROVE Sampler Module C	03/01/2000	present	13.9	-	year-round	24-hour average	Sampler - VII	NPS	IMPROVE
IMPROVE Sampler Module D	05/27/1992	03/01/2000	7.8	-	year-round	24-hour average	Sampler	NPS	IMPROVE
IMPROVE Sampler Module D	03/01/2000	present	13.9	-	year-round	24-hour average	Sampler - VII	NPS	IMPROVE
Standard Visual Range	02/01/1986	11/01/1987	1.7	-	year-round	1 or more/day	Camera	NPS	NPS-VIS
Scattering coefficient	01/23/2008	present	6.0	-	year-round	1-hour average	Nephelometer	NPS	IMPROVE

Table C-2. Air quality monitoring at Lehman Caves | Latitude: 39.0053 deg N, Longitude: 114.2169 deg W, Elevation: 2,066 m (6,778 ft) (From: http://www.nature.nps.gov/air/).

Parameter	Start	End	Years	Seasons	Period	Interval	Instrument	Operating Agency	Network
Precip. vol. & ions	01/15/1985	present	29.1	-	year-round	Weekly	Sampler	NPS	NADP/NTN

Table C-3. Air quality monitoring at Maintenance Yard. AQS Site: 32-033-0101 | Latitude: 39.0053 deg N, Longitude: 114.2158 deg W, Elevation: 2,060 m (6,759 ft) (From: http://www.nature.nps.gov/air/).

Parameter	Start	End	Years	Seasons	Period	Interval	Instrument	Operating Agency	Network
Stacked Filter Pack	05/16/1995	present	18.7	-	year-round	Weekly	Sampler	NPS	CASTNET
Ozone	08/24/1993	present	20.4	-	year-round	1-hour average	Analyzer	NPS	CASTNET
Dew Point	08/24/1993	03/31/1995	1.6	-	year-	1-hour average	Sensor	NPS	NPS-

Parameter	Start	End	Years	Seasons	Period	Interval	Instrument	Operating Agency	Network
					round				GPMP
Delta Temperature	04/01/1995	12/31/2010	15.8	-	year-round	1-hour average	Sensor	NPS	CASTNET
Relative Humidity	09/01/1993	present	20.4	-	year-round	1-hour average	Sensor	NPS	CASTNET
Precipitation	08/24/1993	present	20.4	-	year-round	1-hour average	Sensor	NPS	CASTNET
Standard Deviation for Wind Direction	04/01/1995	present	18.8	-	year-round	1-hour average	Sensor	NPS	CASTNET
Solar Radiation	08/24/1993	present	20.4	-	year-round	1-hour average	Sensor	NPS	CASTNET
Scalar Wind Speed	08/24/1993	present	20.4	-	year-round	1-hour average	Sensor	NPS	CASTNET
Ambient Temperature (aspirated)	08/24/1993	present	20.4	-	year-round	1-hour average	Sensor	NPS	CASTNET
Vector Wind Direction	08/24/1993	present	20.4	-	year-round	1-hour average	Sensor	NPS	CASTNET
Vector Wind Speed	08/24/1993	present	20.4	-	year-round	1-hour average	Sensor	NPS	CASTNET
Wetness Sensor	04/01/1995	12/31/2010	15.8	-	year-round	1-hour average	Sensor	NPS	CASTNET
Stacked Filter Unit	10/12/1982	06/29/1986	3.7	-	year-round	72-hour average	Sampler	NPS	NPS-VIS
Standard Visual Range	06/01/1982	02/28/1986	3.7	-	year-round	1 or more/day	Teleradiometer	NPS	NPS-VIS

Appendix D: Resource Briefs

The briefs in the appendix are for the individual resources and stressors addressed in the present assessment. Each brief summarizes information on the importance of the resource or stressor, and on the findings of the assessment (status and trends). Each brief then concludes with a discussion of the findings and their implications for management and/or monitoring.

Air Quality at Great Basin National Park

Natural Resource Condition Assessment

Importance

Most human activities, including manufacturing and industrial processes, agricultural practices, land disturbance, and fossil fuel combustion, produce air pollution. Great Basin National Park is located in White Pine County in east central Nevada near the Utah border and is isolated from any sizeable city or major point sources of air pollution. Great Basin NP enjoys some of the cleanest air in the United States due to its location, but occasionally experiences ozone levels that near the primary standard for human health. In very clean air however, it takes only a small amount of air pollution to have an adverse effect on visibility.

Atmospheric sulfur and nitrogen pollutants can cause acidification of streams, lakes, and soils. Mobile source and other fossil fuel combustion emissions in and near urban areas are the largest contributors of sulfur and nitrogen pollution in the Great Basin region. Lakes in Great Basin NP are considered to be somewhat acid-sensitive because of their position on metamorphic and granitic rocks and the park's steep terrain, which allows limited opportunity for incoming acidic deposition to be buffered by base cations in rocks and soils.

Nitrogen deposition can also cause undesirable enrichment of natural ecosystems, leading to changes in plant species diversity and soil nutrient cycling.

Ozone pollution can harm human health, reduce plant growth, and cause visible injury to foliage. Great Basin NP is located in an ozone attainment area because ozone concentrations meet the national ozone standards to protect human health. Risk to plants is assessed using metrics for exposure over three or five months. Risk to plants in Great Basin NP from ozone was low in an assessment conducted for all parks nationwide.

Particulate pollution can cause haze, reducing visibility. Visibility affects how well (acuity) and how far (visual range) one can see, but air pollution can degrade visibility. Both particulate matter (e.g. soot and dust) and certain gases and particles in the atmosphere, such as sulfate and nitrate particles, can create haze and reduce visibility. Haze in Great Basin NP is primarily caused by sulfate, nitrate, organics, and coarse mass.

Photo showing average visibility conditions at Great Basin NP

Visibility can be subjective and value-based (e.g., a visitor's reaction viewing a scenic vista), or it can be measured objectively by determining the size and composition of particles in the atmosphere that interfere with a person's ability to see landscape features.

Airborne toxics, including mercury (Hg) and other heavy metals, can accumulate in food webs, reaching toxic levels in top predators. Effects have been documented in some areas, including parts of California, in piscivorous fish and wildlife.

Status and Trends

Great Basin NP is considered to have low sensitivity to nitrogen nutrient enrichment and is at low risk because of the type of vegetation in the park and the distance to major urban areas. However, the park's ecosystems are considered to be highly sensitive to acidification from sulfur deposition, although the exposure to sulfur is low.

Overall findings of this assessment include:

- Current wet deposition rates of total nitrogen or sulfur are above the Air Resources Division recommended benchmark for good condition, and are rated of moderate concern.

- Recent trends in their deposition show no change.
- The park currently does not meet the Air Resource Division's recommended benchmark level for ozone. The monitored ozone concentration from 2008–2012 is at 71.7 ppb, which falls within the moderate concern category. In addition, the park regularly exceeds the 8 hour standard on several days during the summer ozone season.
- Haze conditions in and around Great Basin NP are some of the best in the country. However, when comparing the estimated natural haze conditions to existing visibility from 2004-2008, air pollution has reduced average visual range from 170 miles to 120 miles (274 km to 193 km). On the haziest days, visual range has been reduced from 130 miles to 85 miles (209 km to 137 km).
- Mercury deposition is higher than many other areas of the country, and was found to be the highest at higher elevations across the region.

Discussion

The air quality at Great Basin NP is currently of moderate concern. While in the case of either sulfur or nitrogen, rates of deposition are only slightly above the benchmark for good condition and trends appear stable, the park's ecosystems are highly sensitive to the effects of these pollutants. The park has well established air quality monitoring in place, which provided a solid baseline for the air quality assessment.

The impacts of air pollutants on the park's terrestrial and aquatic ecosystems is of concern as they are sensitive, especially the aquatic systems. Those are addressed in the water quality and quantity assessment.

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Natural Resource Condition Assessments Web Page:
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Viewshed at Great Basin National Park

Natural Resource Condition Assessment

Importance

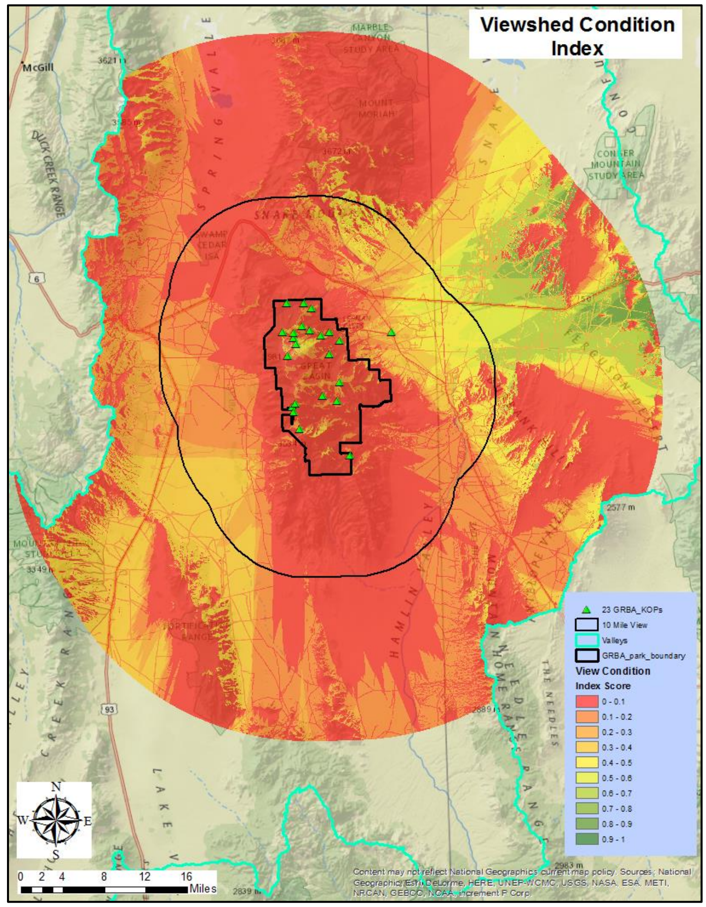
The conservation of scenery is established in the NPS Organic Act, ("…to conserve the scenery and the wildlife therein…") and reaffirmed by the General Authorities Act.

For many parks, scenic views that extend beyond park boundaries are an important component of the visitor experience. The expanse of these views is often inspirational and iconic of the American spirit and often a main reason why people visit parks. Visitors have multiple opportunities to view the surrounding landscape scenery, within and adjacent to the park. Like other isolated ranges in the Basin and Range Province, Great Basin NP is surrounded by basins. Traveling west from central Utah across the arid flat plains of the Great Basin Desert, the long ridgeline of the South Snake Range stretches across the horizon, with a characteristic rugged landscape, highlighted by snow-covered peaks, steep mountain slopes, rolling foothills, low desert basins and valley floors.

An excerpt from the park's General Management Plan describes the importance of its scenic resources: "The views across Snake Valley and Spring Valley as visitors approach the park and from various locations within the park greatly enhance experiences and are a significant park resource. Although these valleys are not within the park boundary, they are critical in conveying the theme of the 'Great Basin physiographic region' to visitors. Without the contrasting valley basins, the mountainous lands inside the park can illustrate only a portion of that theme. The loss or visual impairment as a result of major industrial, commercial, or military activity would alter the pastoral scene that adds a critical dimension to the national park."

Status and Trends

Current vistas from Great Basin National Park range from nearly pristine to somewhat modified by the existence of roads, agriculture, small towns, utilities, and other development - including a 66 turbine wind farm - visible from some viewpoints. Based on air



Viewshed condition index for GRBA.This is a combination of the landscape condition index modified for views and the viewability index, a scoring of the NPS composite viewshed

quality data, vistas are often obscured by haze caused by fine particles in the air. Many of the same pollutants that ultimately fall out as nitrogen and sulfur deposition contribute to this haze and visibility impairment. Long range views beyond park boundaries are especially affected by air pollution and haze from dust.

A Viewshed Condition Index, below, was developed, which reveals the patterns of how visible the landscape surrounding the park is from within the park. It also scores the impact to the view of development features such as roads, highways, towns, and the wind farm. It assumes having a view from many areas within the park is desirable (greens to yellows in the figure below), while some development features (e.g., the wind farm) are not desirable within the view (reds and oranges).

Overall findings of this assessment include:

- Large portions of the valleys adjacent to Great Basin NP are visible from only a few places within the park.
- Snake Valley to the east of the park is highly visible from many locations within the park itself; and is also an area with a small town (Baker), a number of roads and a major highway, especially within the 10-mile (16-km) radius from the park.
- The view to the west is also impacted by development features, but is visible from fewer locations within the park.
- The Spring Valley Wind Farm is noticeable from the higher peaks on the western side of the park and contrasts markedly with the surrounding rural and natural landscape.
- Continued general development patterns, where visible, will likely add structures and utilities to existing views, further impacting visual resources.

Discussion

Currently the vistas from the park are good; however some development activities in the adjacent valleys are noticeable and are likely to be displeasing to some visitors. Haze in the air from dust and pollutants decreases the long-distance vistas for which this region of the west is known. Additional development in the future will impact the views.

The viewshed condition index provides a useful way to evaluate which areas outside of the park could be developed with minor impacts to views from within the park. Given the viewshed condition index is predicated on a composite viewshed based on key observation points in the park and 'line-of-sight' assumptions, the features of the development, such as size, height, contrast, and shape, will also need to be considered, not just whether the location is within one of the less-visible areas.

The NPS should continue to work with other agencies and private land owners to assess the visual impacts of various new development projects in the vicinity of the park and to encourage them to consider the valuable visual resource as they design and implement new projects.

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Resource Brief

National Park Service
U.S. Department of the Interior

Natural Resource Stewardship & Science
Water Resources Division

Night Sky at Great Basin National Park

Natural Resource Condition Assessment

Importance

A natural lightscape is considered a valued resource by the National Park Service, and natural resource-based parks are mandated to preserve the scenery, which includes protecting a visible (i.e., low artificial light level) night sky. Great Basin NP has identified its night sky as a fundamental resource and value in their Resource Management Plan and on the park's website. The park manages dark night sky as a natural resource to provide opportunities for visitor enjoyment. The night skies of Great Basin are sought by park visitors and are one of the key interpretive themes provided by the park. Dark night sky is an important element of the park's scenic qualities as well as an important resource to amateur astronomers, sky watchers, and other visitors. A 2007 survey of 140 visitors to Great Basin NP found some 45% of visitors star gazed or planned to do so, and that almost half of all visitors considered the dark skies as an important or very important consideration when they were making their travel plans to go to Great Basin NP. About 20 percent brought equipment such as a telescope, binoculars, or a camera for observing the night sky.

Natural light/darkness is an important factor for maintaining health within biological systems; the cycles of day-night (diurnal), lunar and seasonal changes each vary in the natural light intensity and duration. Dark sky is important to ecosystem function, and research demonstrates the multiple adverse impacts of light pollution to community ecology. Animals can experience altered orientation from additional illumination and are attracted to or repulsed by glare, which affects foraging, reproduction, communication, and other critical behaviors.

Night sky quality is principally degraded by light pollution- emissions from outdoor lights that cause direct glare and reduce the contrast of the night sky. Atmospheric clarity also plays a role in the night sky quality; the clearer the atmosphere, the further in distance the impact of a given light source. However, results from night sky data collection throughout 90+ national parks suggest that a pristine night sky is very rare.

The Milky Way at night in Great Basin NP (Photo credit: NPS photo)

Status and Trends

The overall condition of the park's night sky is very good and represents a truly dark sky. The combination of clear air (free of aerosols and water vapor that reduce visibility), land with high elevation relative to its surroundings, and a sparse human population in the immediate vicinity of the park results in a view of the night sky that is vulnerable as well as nearly pristine.

Photometric measurements taken within the park show that zenith sky condition is virtually unaltered, attaining the theoretical natural darkness of 21.90 magnitudes per square arc-second. Although the park's night sky condition is not pristine due to artificial light domes on the horizon, it is very good and is among the top 20 darkest night skies measured throughout 80 national parks.

Overall findings of this assessment include:

- Five artificial light domes are visible from within the park: Wasatch Front (Provo, Salt Lake City) (290km), Cedar City, St. George, Las Vegas (311km) and the Ely area (62km), which is resolvable into three distinct light domes.
- The park is in one of the darkest locations within the regional "lightshed" on the eastern edge of Nevada and the Great Basin region, which in general has very little light pollution.

- The lack of artificial lighting and dark sky immediately surrounding Great Basin NP provides the darkness necessary for star, planet, and moon visibility during clear nights.
- There is general widespread recognition that a continued degradation of night sky condition globally has occurred over the past several decades, and the night sky appears more seriously endangered than commonly believed.

Discussion

The night sky conditions at the park are currently very good, and within the park itself efforts have been made to minimize light pollution from the visitor center and other park facilities. However, the park has little influence over the effects on its dark skies from continued population growth in the Great Basin or larger western US, such as in Ely, Salt Lake City or Las Vegas.

Education and outreach by NPS and scientists is an important goal, and the night sky and astronomical programs at the park should continue to contribute to the education of the general public

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Rock Glaciers at Great Basin National Park

Natural Resource Condition Assessment

Importance

A number of subalpine glacial features are preserved in the park. Maps of these features indicate that in the past, glaciers flowed down Lehman, Baker, and Snake creeks, and small independent glaciers occurred from Bald Mountain in the north to Granite Peak in the south. Ice during older Pleistocene glacial advances descended to between 8,000 and 8,300 feet (2,440 and 2,530 m) in major drainages, and the longest glaciers were about 4 miles (6.4 km) long. Glacial lakes, known as tarns, play a significant role in the ecosystem of the park and in the monitoring of climate change. Four tarns fill glacial cirques in the park and include Stella, Teresa, Baker, and Johnson lakes. The Wheeler Peak glacier is the one remaining, albeit quite small, glacier within the park. The presence of glaciers in the Great Basin, otherwise surrounded at lower elevation by desert, offers a number of potential themes for natural history interpretation, including how and why glaciers have formed and changed over geologic time.

Rock glaciers are rock debris that either bury an ice glacier and/or are frozen in interstitial ice; some would describe them as glaciers covered by rocky talus. There are currently seven identified rock glaciers in the park, all covered by rock debris of Prospect Mountain Quartzite. Often, rock glaciers can form when rock debris falls from adjacent cliff faces on top of glacial ice, and some have a solid ice core. The water source for rock glaciers may be either surface snowmelt or ground water, and they typically form within existing rocky talus. Once sufficient ice has accumulated, weight propels their flow downslope as interstitial ice deforms and creates tongue-shaped bodies. Due to a lack of continued input of snow and ice, the lower segment of an ice glacier may stagnate while the upper portion remains active. With insulating properties of the rock debris, rock glaciers may persist, and even advance after ice glaciers have retreated in response to warming temperatures.

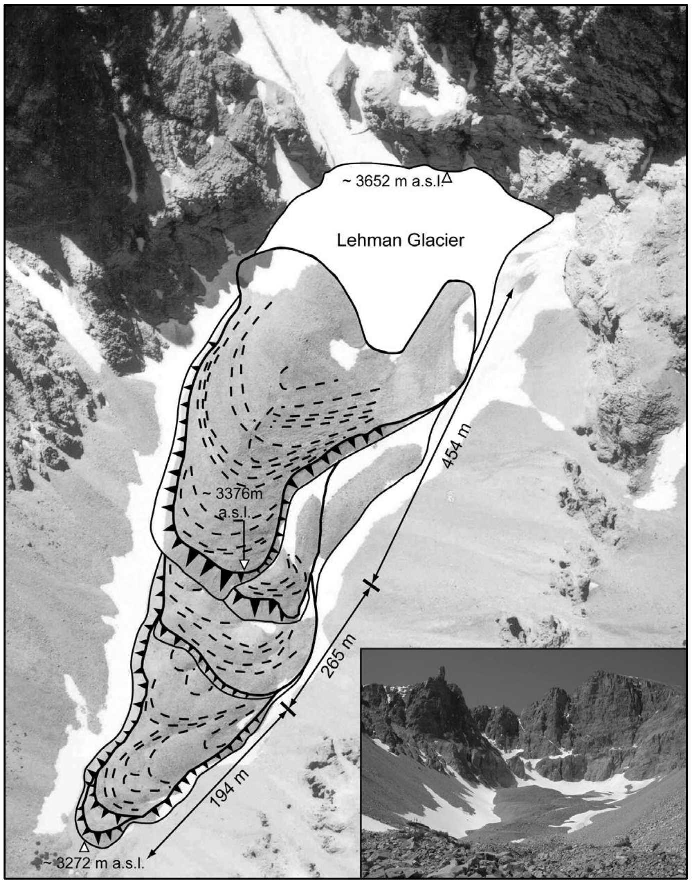
Rock glaciers that do not move are considered to be "fossil" glaciers. An ice-cemented rock glacier will tend not to change shape once its ice core is gone, but if the ice core is in the process of melting, the rock glacier may deflate and form pitted thermokarst features on its surface, where sinkholes of debris collapse to fill the void left by ice melt. Rock glaciers were included in this assessment because change in their shape and location could indicate substantial change in climate at higher elevations of the park.

Rock Glacier in Lehman Cirque (photo by John Van Hoesen, 2001)

Status and Trends

Overall rock glacier size, width, and the elevations of upper rooting and lower terminal points would be expected to change if ice cores and interstitial ice were melting or expanding. Rooting portions of a rock glacier typically occur closest to the upper cirque walls (the common source of rock debris), while terminal points are at the lower end of the glacial lobe. Prior to more substantial effects of melting, a deflation would likely occur, lowering the height of the upper glacier surface and subsequent pitted thermokarst features would likely appear or expand.

Following from descriptions and available measurements, primary indicators of changing conditions among the park's rock glaciers could therefore include a change in overall area and elevation of upper rooting and lower terminal locations. Additional measures could include height and the appearance (or expansion) of pitted thermokarst features. The latter two indicators could



Morphometric map of Lehman rock glacier (from Van Hoesen and Orndorff 2011)

be derived through interpretation of repeat photography and field observation.

Upon review of past descriptions for glacial features in Lehman Cirque, researchers concluded that the Lehman Glacier had thinned over the previous 30-40 years. The upstream limit of moderately thick rock debris cover stood higher than the ice headwall, while downstream ice had maintained its thickness. This interpretation was consistent with other measured trends in glacier recession while adjacent rock glaciers remained stable with warming temperatures. It is predicted that, with increasing warming, there would be a deeper depression between the exposed ice headwall and the debris-covered rock glacier. This would be followed by the accumulation of debris from rockfall into that depression.

Ground-penetrating radar was used on part of the Lehman rock glacier and it was determined that it does not include an ice core, and is therefore made up solely of rock with interstitial ice. These observations, plus the detailed mapped inventory completed in 2011 provide much baseline information for ongoing assessment.

Discussion

At this time, interpretation of current condition and trends in Great Basin NP rock glaciers must remain qualitative, but there is currently little evidence suggesting that substantial change is occurring in the morphology of these rock glaciers. However, given observed trends in Lehman glacier, moderate concern for these rock glacier features is warranted.

New investment in monitoring existing area and elevation parameters will be required to determine if any significant change is taking place. Additionally, baseline observations of rock glacier height and thermokarst features will be needed to further assess trends in condition into the future.

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Resource Brief

National Park Service
U.S. Department of the Interior

Natural Resource Stewardship & Science
Water Resources Division

Wildfire Regime at Great Basin National Park

Natural Resource Condition Assessment

Importance

Wildfire has historically been a key factor structuring the ecological systems of the Basin and Range. Fires removed accumulated fuels, released nutrients, and "reset" the vegetation back to early successional stages. This resulted in the Snake Range having a complex mosaic of ecological communities, each comprised of a diversity of structural stages. This structural diversity formed the foundation of the biological diversity found within the region.

The historic fire regime within the Snake Range and surrounding basins was driven in large part by the productivity of the vegetation. Thus, the fire regime changed with elevation, and was ultimately a result of soil moisture. In the basins, the Basin Big Sagebrush steppe had a very long fire return interval (i.e., the span of time between fire events at a specific place). These systems were "fuel limited" and it took 150 to 350 years for sufficient fuels to accumulate to carry a fire. This paucity of fuels also caused the fires to be limited in extent – each fire was likely only tens or hundreds of acres in size. However, any fire was of high severity resulting in the death of all the shrubs, resetting the patch to its earliest seral state. The resulting vegetation structure was a complex mosaic of small patches of different ages, ranging from bunchgrass dominated patches to patches with closed canopies of Basin Big Sagebrush.

In contrast to the basin bottoms, the mid-elevation communities including aspen were more mesic, and thus more productive. These more productive systems accumulated fuels more rapidly and thus experienced more frequent fires. Yet, because these are more mesic systems, the fire behavior was driven by moisture. Thus fires, while larger in extent were generally of mixed intensity with only some canopy loss. Aspen in particular is dependent on these mixed intensity fires to restore the clones' health. Fires remove the old, decadent, and diseased stems and stimulate the clone to put out new suckers. These fires also tend to kill any conifers or other species that have invaded the clone. Without these rejuvenating fires, aspen clones tend to become diseased and begin to die out.

Wildfire in progress at Great Basin NP

The fire regimes of the Snake Range have changed dramatically over the past century. In the more mesic middle elevations, a policy of fire suppression over the past 75 years has largely eliminated the rejuvenatative mixed-intensity fires and has promoted an accumulation of fuels. In the basins and foothills, domestic livestock consumed the grasses and forbs that contributed to the fine fuels resulting in fewer fires and contributing to the dominance of woody vegetation and the encroachment of conifers into the sagebrush steppe. Season-long use of these systems by livestock resulted in the decline and loss of the native bunchgrasses providing an opportunity for cheatgrass and other annual weeds to invade. Cheatgrass is a cool season annual grass that germinates in the autumn, grows through the spring and sets seed and dies by early summer. This leaves a standing crop of fine fuels throughout the fire season. Because it is an annual species, cheatgrass thrives on disturbance, and if present on a site, becomes abundant following fire. This can result in the conversion of sagebrush steppe into an annual grassland. This conversion is a permanent transition, and the changed fire regime prevents the return of the native species.

Status and Trend

There should be moderate concern for fire regime conditions overall in the park. Under a natural fire regime an ecological system has a fairly stable distribution of seral stages. Natural succession pushes patches to later seral stages, while fire disturbance resets these to an earlier stage. A change in the fire regime results in a change in the relative abundance of each seral stage.

Fire Regime Departure is a measure of the change in the landscape mosaic resulting from a change in the fire regime. Departure ranges from zero to 100%, where a zero percent departure indicates that the current mosaic is within the Natural Range of Variation. Among the park's ecological systems, Departure ranges from 0.1% (alpine) to 74% (Antelope Bitterbrush). On an area-weighted basis, the park's vegetation communities are 42% departed from their Natural Range of Variation, which is considered to be moderately departed.

By and large, this departure is the result of an overabundance of later seral stages and a paucity of early stages, reflecting historical grazing impacts and the past decades policy of fire suppression.

Discussion

Fire is far less common in the park than it was historically. The total extent of wildfire in the park since 1980 is about 10% of what it would have been under the Natural Range of Variation. There are many consequences to this lack of fire. The park's aspen communities are in decline as a result of encroaching conifers, disease and decadence. These systems require periodic fire and have not had that rejuvenation for close to a century. If fire is not reintroduced to these systems, the park will see a significant loss of aspen and its associated wildlife. An assessment of the potential for prescribed fire management within the park suggests that the Aspen woodland and Aspen-Mixed Conifer systems could be safely and effectively managed with prescribed fire.

In contrast, the Montane Sagebrush Steppe-Upland system is also significantly departed, but would not benefit from prescribed fire management. This system predominantly occurs below 8,000 feet (2,438 m) in elevation and thus likely has cheatgrass present in most areas. Prescribed fire will likely benefit the cheatgrass at the expense of the native bunchgrasses and forbs. Mechanical or herbicide treatments, if possible, would be a possible management option to open areas of dense, closed canopy stands of sagebrush.

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National Park Service
U.S. Department of the Interior

Natural Resource Stewardship & Science
Water Resources Division

Aspen-Mixed Conifer Forest at Great Basin National Park

Natural Resource Condition Assessment

Importance

Quaking aspen (*Populus tremuloides*) tends to occur within the park between 7,000 and 10,000 feet (2,134 and 3,048 m) elevation. The total mapped acreage of all aspen systems in the park is 19,997 acres (8,092 ha), making aspen the largest vegetation type in the park. Three aspen systems are distinguishable as subtypes, including "stable aspen" (aspen woodland) at 567 acres (229 ha), "seral aspen" (aspen-mixed conifer) at 8,114 acres (3,284 ha), and "seral subalpine aspen" (aspen-subalpine conifer) at 11,316 acres (4,579 ha).

Aspen-dominated systems support a high diversity of plants and animals, and after riparian communities, provide the highest level of species diversity in arid environments. Mature aspen stands provide habitat for breeding birds; and due to their susceptibility to diseases, aspen trees provide nesting habitat for cavity nesters. Aspen stands are also highly valued for their esthetic and recreational value throughout the semiarid West. Aspen and other forested uplands are critical to watershed health because they regulate run-off and groundwater recharge. Watersheds dominated by aspen release more water into stream channels and water tables than watersheds dominated by conifers and allow greater downstream water availability. Aspen communities enhance stream bank stability, increase resistance to catastrophic flooding events, increase stream nutrient inputs and provide shade and cover for aquatic species.

Substantial aspen dieback has been observed over the last fifteen years with recent, large aspen mortality events in southwestern Colorado and Arizona. Reported declines in historic aspen ranges between 49% (Colorado) and 96 % (Arizona) and there is an estimated 60% decline in aspen acreage across all eight western states. These recent and wide-ranging declines in aspen suggest that current management strategies and climate conditions are affecting aspen vigor in many portions of its western range.

Status and Trends

The greatest human impact on aspen health over the last century has been the exclusion of fire and chronic

Aspen stands at Great Basin National Park

overbrowsing. Historically, conifer encroachment and overtopping of aspen were balanced by disturbance, primarily fire, but also by insect outbreaks, disease and avalanches.

Fire regimes changed in the late 1800s when intense grazing and active fire suppression began and Native American burning practices ended, and the beneficial effects of fire have been virtually absent. Fire histories for one Park watershed reveal the last large fire occurring in 1865. Before this time small, frequent fires in mid-elevation plant communities were common and maintained early seral plant communities and habitat heterogeneity. Fire suppression, along with favorable climate conditions, has shifted vegetation away from a range of seral states and community types and towards a preponderance of late-successional woody plant communities.

Overall findings of this assessment include:

- The ecological condition of park aspen varies: stable aspen stands are 27% departed from natural range of variation, seral aspen are 66% departed, and seral subalpine aspen stands are 60% departed. Overall, there should be moderate concern for the condition of these forests within the park.
- While the current condition of aspen in the park (i.e., percent departure from natural range of

- variation) varies among the three subtypes, but vegetation departure is most commonly due to an over representation of late successional classes; under representation of early classes; poor aspen regeneration and recruitment; and a loss of aspen clones on 1,229 acres (497 ha).
- The current condition of aspen stands is a direct result of fire exclusion.
- Aspen stand condition and health was relatively homogenous across the park. This homogeneity is consistent with the effects of broad scale fire exclusion.
- Decathon Canyon had the best aspen condition assessment score and the Burnt Mill watershed the worst.
- A total of 12,636 acres (5,114 ha) or 62%, of the aspen-related biophysical settings have experienced some level of disturbance from insect or disease outbreak since 1991.

Discussion

Under current management practices, aspen stands will continue to decline. The conversion of aspen to conifer is predicted to result in permanent loss of aspen from over 10,000 acres (4,047 ha) within 50 years. This would likely constitute impairment under NPS policy.

Efforts by land managers to restore and conserve aspen communities will benefit biodiversity at local and landscape scales providing ecosystem resilience, productivity, nutrient retention and resistance to invasive plants.

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Wild Turkeys at Great Basin National Park

Natural Resource Condition Assessment

Importance

Wild Turkey (*Meleagris gallopavo*) is not native to the Great Basin, but populations have become established within the park. From observations by Park staff, it is clear that there is breeding, nesting, and recruitment of wild turkeys within the park. Both the Merriam's turkey (*Meleagris gallopavo merriami*) and the Rio Grande wild turkey (*Meleagris gallopavo intermedia*) have been introduced by Nevada Department of Wildlife (NDOW) for sport hunting to mountain ranges throughout the state. The Merriam's subspecies is recognizable from the white coloration of its tail feather tips, distinct from the dark brown tips in more eastern subspecies and tan in the Rio Grande turkey. Merriam's turkey is thought to have originated from turkeys domesticated by Native American cultures, which became feral as those civilizations declined.

In 2004, 108 Merriam's turkeys were introduced from populations in Idaho to White Pine County. Some were introduced to the Hidden Canyon Ranch adjacent to the park in the Big Wash watershed. Others were introduced at Silver Creek Ranch, approximately 10 miles (16 km) north of the park. NDOW permits hunting of male turkeys within Unit 115 of White Pine County. This unit surrounds the park. For the season from March-May 2014, a total of 25 turkey hunting tags were available for Unit 115. This was the largest number of any limited entry hunting unit in the state.

Introduced wild turkey populations to the park could have undesirable effects on Park resources. Where turkeys congregate, their feces can accumulate and affect Park visitor experiences and uses. They can also cause surface disturbance and promote spread of invasive plant species. Additionally, wild turkeys are omnivorous, with a diet including green forage, hard and soft mast, seeds, agricultural crops, insects, and small vertebrates. It is possible that with expanding wild turkey populations within the park, congregation in trees and aggressive behavior by nesting hens could affect other tree and ground nesting birds or small vertebrate populations. Flocking in riparian zones during winter months could impact vegetation. There is also potential for negative effects from seed foraging by wild turkey on revegetation projects, such as those concentrated in riparian zones.

Wild turey (*Meleagris gallopavo*)

Status and Trends

Research and monitoring is warranted to document wild turkey population location, size, habitat usage, and its potential effect on other Park resources. No substantial research of this nature has been conducted within the Great Basin. Researchers working with introduced populations of wild turkeys on Santa Cruz Island, California documented explosive population growth following removal of both pig and sheep populations. It was hypothesized that vegetation response from removal of the other introduced species enhanced habitat for wild turkey. Other research from California looked at effects of wild turkeys on the California quail (*Callipepla californica*), and concluded that there was no substantial negative effect. In that instance, while broad habitat characteristics were shared by both species, microhabitat usage varied in part due to the relatively size of the individual birds, with the relatively smaller quail more fully utilizing subcanopy habitat.

Discussion

The desire for sport-hunting in surrounding White Pine County has resulted in turkey population introduction and maintenance. This management will support population expansion and continued turkey usage in more productive riparian habitats with the park. If impacts to park resources are substantial enough, management options could include hazing, capture and removal, or a fall hunting season targeting females to limit population numbers. This would be consistent with NPS policies and with common state wildlife management policies. If it is determined that native species or habitats are being negatively impacted by wild turkeys, appropriate management actions should be taken to protect affected resources.

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Invasive Grasses at Great Basin National Park

Natural Resource Condition Assessment

Importance

Globalization of human migration, commerce, transportation, and recreation has introduced invasive exotic species to new areas at an unprecedented rate. Although only 10% of introduced species become established, and just 1% are invasive, non-native species have profound impacts worldwide on the environment, economies, and human health.

Invasive species have been directly linked to effects on primary productivity and water availability relative to dominant native species, changes in ecosystem structure, alteration of nutrient cycles and soil chemistry, shifts in community productivity and composition, reduced agricultural productivity, and the loss of native species. The damage to natural resources caused by these species can be irreparable. Invasive species are considered second only to habitat destruction as an immediate threat to wildland biodiversity, and interacting effects of species invasions with climate change are poorly understood. Consequently, the dynamic relationships among plants, animals, and their environment established over millennia are at risk of being abruptly lost.

An estimated 72% of the Great Basin ecoregion is impacted by the annual invasive cheatgrass (*Bromus tectorum*). The alteration of native vegetation by this and other annual grass invasives can alter wildfire regimes and impact hydrologic systems. Between 2000 and 2009, nearly 16.2 million acres (6.6 million ha) of the Great Basin ecoregion burned, and of these burned areas, some two million acres (809,000 ha) reburned due to an emergence of a cheatgrass fire cycle in degraded rangelands. The magnitude of the invasion and its effects on natural ecosystems makes this possibly the most significant plant invasion in North America.

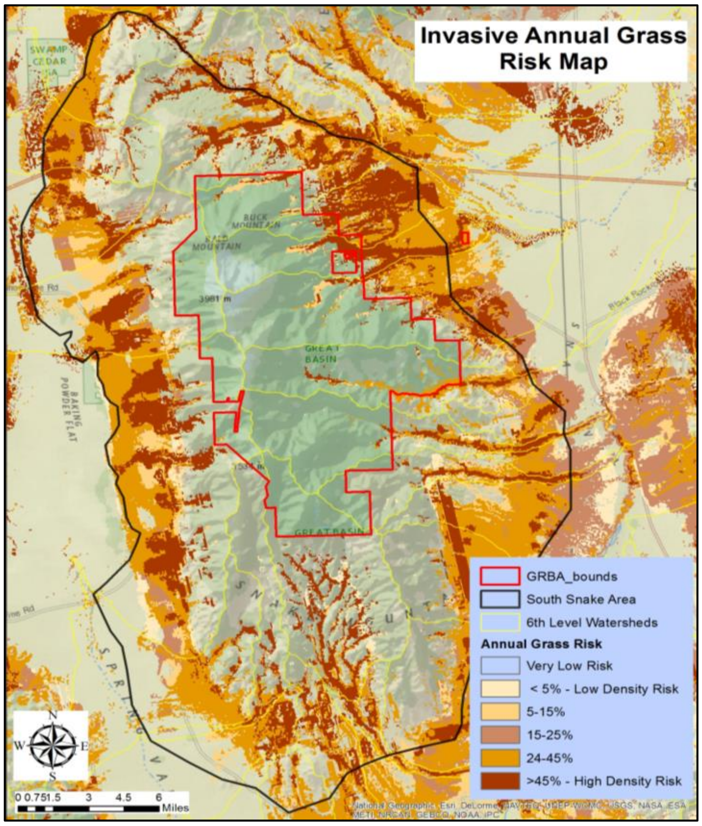
Researchers have found that in the Great Basin ecoregion, growing season temperature limits cheatgrass distribution at higher elevations, and soil moisture is a primary limitation at lower elevations. Soil moisture, and nitrate availability, each increase following vegetation removal or fire, assisting with invasion. But where native perennial grass species are abundant (i.e., in high quality vegetation condition, and generally at higher elevation locations), cheatgrass invasibility is more limited.

Cheatgrass (*Bromus tectorum*

Status and Trends

A spatial model was developed for the Great Basin region and used for this assessment to document potential risk of invasion within and surrounding the park. It depicts areas with a risk of supporting invasive grasses at different levels of abundance, or percent cover. Valley bottoms within drainages, especially throughout the east and south sides of the park, show the highest potential for annual grass invasion. But of all biophysical settings mapped within Great Basin NP, only montane sagebrush steppe was found to include some predicted risk of invasive annual grasses. This biophysical setting encompasses 9,200 acres (3,726 ha) within the park. Existing vegetation with this biophysical setting is either dominated by mountain sagebrush (*Artemisia tridentata ssp. vaseyana*), or pinyon and juniper woodland. In fact, some 56% of this biophysical setting is now dominated by encroaching pinyon and/or juniper woodland.

For this montane sagebrush steppe biophysical setting, 85% of its extent falls within “good” reference conditions with regards to invasive annual grasses (i.e.,



Invasive Annual Grass Risk, South Snake Range, indicating areas of very low risk, plus 5 categories where invasives could occur in low to high levels of abundance

annual grass risk of <5% abundance). About 3% of the total area falls within the "moderate concern" category, with an annual grass risk of 5-15% abundance. About 11% of the total extent falls within the "significant concern" category, with an annual grass risk of >15% abundance.

Considering the potential for expansion from current to higher elevations, elevation contours between 8,200 and 9,190 feet (2,500 and 2,800 m) were established to document the extent of biophysical settings that, while not currently threatened, might be most vulnerable to invasive grass expansion over the coming decades. This vulnerability could result from effects of climate change and/or further adaptation by cheatgrass and related invasive species. There are also other invasive plant species, such as Medusahead (*Taeniatherum caput-medusae*) and North African grass (*Venenata dubia*), that are adapted to colder climates and are increasing in abundance in the Great Basin. As noted elsewhere, the fire regime conditions within this elevation zone could result in particularly intense wildfire that could predispose sites to invasion. Given the documented ecophysiological limitation of growing season temperature and the trends towards warmer temperatures, an upslope trend in invasive plants might be detected during the upcoming decades.

Of the major biophysical settings in this elevation zone, montane sagebrush steppe is most likely to occur in conditions making it vulnerable to invasive annual grass invasion. This would especially be the case where surface disturbance and/or intense wildfire occur in close proximity to current patches of these invasive grasses.

There should be significant concern for the conditions of invasive annual grasses in areas immediately surrounding the park. With 45% of the surrounding valleys with a risk of invasive grass at abundances >15% cover, the risk to park resources, especially at lower elevations, should be an ongoing concern for park management. For the particular biophysical setting of montane sagebrush steppe, within the park boundary nearly 15% falls within the "moderate concern" or "significant concern" categories. Given these estimates, an overall condition rating of "moderate concern" is appropriate. Available data preclude any definitive statement on trends in this indicator, but no strong trend has been observed.

Discussion

Prevention and early detection are the principal strategies for successful invasive plant management. While there is a need for long-term suppression programs to address high impact species, eradication efforts are most successful for infestations of very limited size. For Great Basin NP, invasive annual grasses are of most immediate concern at lower elevation margins of the park, and in the surrounding basins. However, with changing landscape conditions, concern for these species may extend to higher elevations. Therefore, assessment of current and future risks of these invasive species is warranted.

Among the primary data gaps associated with this assessment includes the reliability of the invasive annual grass risk map. Additional field samples with species and percent cover, within and surrounding the park, could provide input for further model validation and improvement. Field assessment of invasive annual grass cover and effects on sagebrush vegetation within the park would not only assist with model validation, but also provide additional support to management and restoration planning. Further inventory and monitoring of invasive annual grass cover across major vegetation types would be important to quantify trends and detect conditions where expansion to higher elevations may be occurring.

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Resource Brief

National Park Service
U.S. Department of the Interior

Natural Resource Stewardship & Science
Water Resources Division

Bighorn Sheep at Great Basin National Park

Natural Resource Condition Assessment

Importance

As with other NPS units throughout the western United States, bighorn sheep (*Ovis canadensis*) are emblematic of natural conditions and hold important scenic and educational values. Early explorers noted the presence of mountain sheep surrounding the Snake Range. A letter written in 1985 to the Nevada Department of Wildlife (NDOW) recounted a history of local wildlife sightings, and suggested that elk were likely hunted out of the Snake Range by early pioneers, and that mountain sheep had gradually declined, likely due to disease spread from domestic sheep and predation from mountain lions. Extensive and relatively unregulated livestock grazing, including concentrated use by domestic sheep, was common throughout the Snake Range in the 20th century. Fire suppression during this same period resulted in change to vegetation structure, with expansion of woody vegetation at the expense of more open and forage-rich habitats. These conditions also likely inhibited sheep movement and provided greater opportunity for mountain lion predation. By 1975, NDOW considered bighorn sheep to be effectively extirpated from the Snake Range.

Interest in conserving and restoring bighorn sheep populations and habitats has steadily increased among state wildlife agencies and federal land managers throughout the West. In 1979 and 1980, 20 Rocky Mountain bighorn sheep (*Ovis canadensis canadensis*) were introduced to the park from Colorado populations.

Concern for the successful restoration of this herd led to the convening of an expert panel in 2003. Their recommendations centered on two limiting factors; habitat quality and risk of disease transmission from domestic sheep. On the latter issue, in 2009 and 2010, bighorn sheep throughout the western United States experienced massive pneumonic epizootic outbreak with subsequent mortality exceeding 50% in some herds. Mycoplasma ovipneumoniae is transmitted from nose to nose contact between domestic and bighorn sheep, predisposing sheep to further bacterial infections by Pasteurella trehalosi, Pasteurella

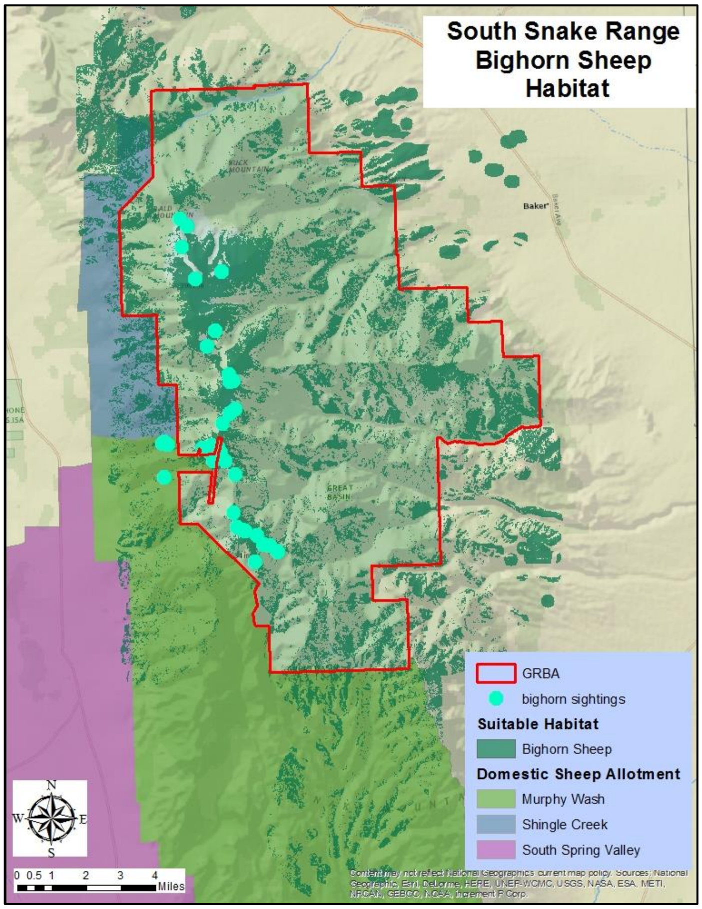
Bighorn Sheep (*Ovis canadensis*)

multocida multocida and Mannheimia haemolytica.

Regarding the risk of disease transmission, they noted the overlap of domestic sheep grazing allotments with the bighorn range, risking not only disease transmission, but competition for forage. The panel recommended closure of overlapping grazing allotments and disease testing of resident sheep prior to new bighorn introductions to the South Snake Range. All domestic sheep allotments within the park were retired in 2008 when grazing permits were transferred as part of a land sale, and the park's bighorn herd remains disease free.

Additionally, non-forested area of sufficient size is required to support adequate forage and escape distances to limit mountain lion predation. Since recent wildfires had been noted to increase forage quality, use of prescribed fire at high elevations, and within lower-elevation winter range, was recommended.

Outside the park, the South Snake Range is predominantly managed by the Ely District of Bureau of Land Management (BLM). The Ely District considers the management of bighorn sheep to be a priority in the Snake Range. Their plan stipulates that "where appropriate, restrict permitted activities within occupied desert bighorn sheep habitat from March 1 through May 31 and from July 1 through August 3," and "consider managing habitat for desert bighorn



Suitable bighorn sheep habitat and bighorn sightings in the South Snake Range, with Great Basin NP and adjacent domestic sheep grazing allotments

sheep in unoccupied ranges if and when domestic sheep grazing no longer occurs in the area."

Status and Trend

The key attribute supporting the integrity of bighorn sheep populations is the maintenance of interacting healthy individuals. Healthy individuals can reproduce and successfully recruit lambs into the population. Therefore, local access to escape terrain (cliffs, talus slopes, etc.), especially in lambing habitat, and facilitated access to seasonal habitat, are important features to maintain each interacting population. Over multiple generations, the ability for occasional movement to nearby mountain ranges and distinct genetic populations would also be important for long-term viability.

Researchers modeling bighorn sheep habitat suitability include parameters for human use density, water availability, non-forest vegetation, and steep slopes. Total suitable habitat was estimated at 37,474 acres (15,165 ha). The model for the South Snake Range suggests that there should be sufficient suitable habitat to support a viable population of over 100 individuals.

For this assessment a series of indicators for bighorn sheep condition included female survival rate, trends in herd size, disease status in herd, quality of winter range forage, wildfire regime condition class, proportion of habitat burnt since 1980, proximity to domestic sheep in adjacent grazing allotments, and an index of landscape condition customized to habitat requirements of the sheep.

Two indicators, trend in herd size and disease status indicate good condition and no apparent change. The relatively small population within the park does not appear to be decreasing to a measurable degree, and there is currently no incidence of disease among the herd.

All other indicators suggest significant concern. Survival rate, winter range, fire regime condition, and landscape condition all suggest deteriorating condition for bighorn sheep within the park. For survival rate, the current herd of 20-25 individuals is well below the 50-100 individual range considered necessary for a minimum viable population. As mapped, less than 650 acres (263 ha) of suitable winter range habitat exists, and much has been affected by past land uses. Indicators of fire overlap on sheep range, and proximity of domestic sheep in nearby grazing allotments both appear to be unchanging.

Discussion

The overall condition rating was placed at significant concern, apparently unchanging, and high confidence in indicator scores.

Confidence in these indicators is likely strongest in measures of fire regime condition, wildfire overlap with sheep range, and domestic sheep usage from neighboring allotments. Confidence is low for indicators of survival rate, in that there is a need for a larger population sample, and for quality of winter range, and landscape condition. The latter two would benefit from additional field validation.

This assessment suggests the need for concentrated effort to restore habitat conditions in winter and summer ranges, take steps to maintain a disease free herd, and make continued investments in closely monitoring the bighorn sheep population of the South Snake Range.

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Sagebrush Steppe at Great Basin National Park

Natural Resource Condition Assessment

Importance

Within the Basin and Range region, sagebrush steppe was historically the dominant ecological system, largely covering the valley bottoms and sweeping up into the foothills in the lower to mid elevations. Within Great Basin NP there are two subtypes, the montane big sagebrush-upland (12,710 acres [5,144 ha]), and montane big sagebrush-mountain (943 acres (382 ha)). Together, these cover approximately 17% of the park. The montane big sagebrush-upland forms the matrix community in the park's lower elevations and supports a diversity of wildlife. Sagebrush (*Artemisia tridentata*) is ubiquitous, ranging from the valley bottoms to 10,000 feet (3,048 m) in elevation and is the iconic species within the Great Basin.

Status and Trends

The park's sagebrush steppe is currently moderately departed for historic conditions, causing moderate concern. The upland subtype has been rated as 57% departed and the mountain subtype as 30% departed. This departure is the result of three interrelated factors, past inappropriate domestic livestock use, invasive annual grasses, and fire suppression. The introduction of domestic livestock in the late 1800s resulted in the loss of the native bunchgrasses and forbs. This loss of fine fuels resulted in a reduced fire frequency, allowing for the expansion of sagebrush as well as encroachment of conifers into these shrublands. These two historical factors, in combination with decades of active fire suppression, have resulted in the abundance of late-seral sagebrush steppe (e.g., dense and tall sagebrush and/or conifer trees with substantial overall woody vegetation cover) and a paucity of early seral stages currently in the park.

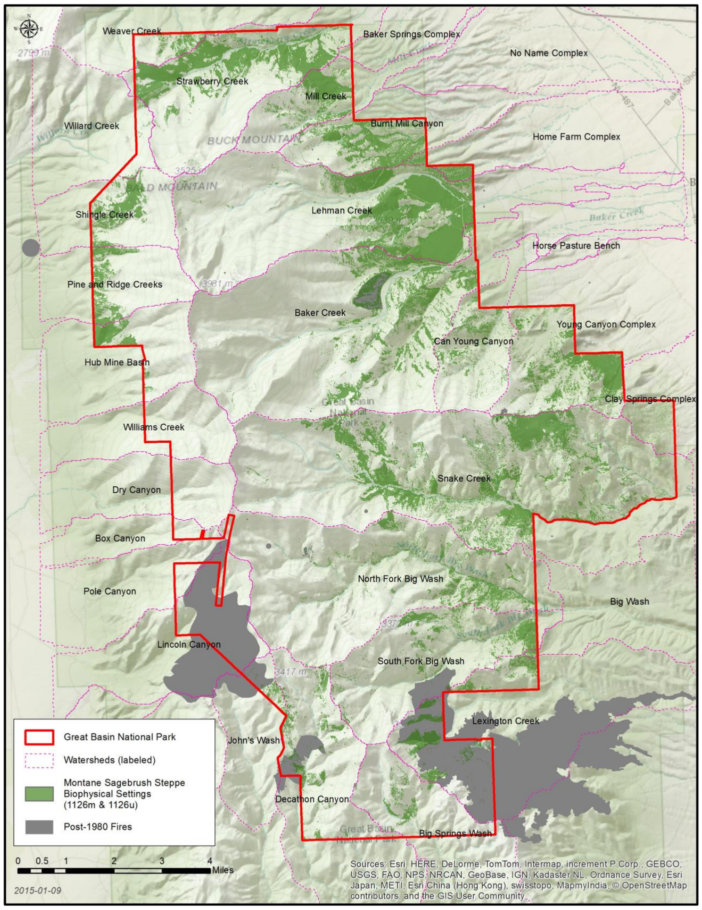
The loss of the native bunchgrasses allowed for the invasion and expansion of cheatgrass (*Bromus tectorum*) in the middle of the last century. Where cheatgrass is abundant, the accumulated fine fuels result in frequent fires that displace the native species, resulting in a conversion to annual grassland. While there is little evidence of such conversion in the park, the majority of the upland

Sagebrush (Artemisia tridentata)-dominated communities. Photo: Bob Unnasch

subtype is currently at risk of conversion, either to invasive annual grass with intense fire and or surface disturbance, or with fire exclusion, through conifer tree encroachment.

Overall findings of this assessment include:

- The upland ecotype are 57% departed from natural range of variation, and the mountain ecotype are 31% departed.
- The current condition of all sagebrush steppe communities in the park is due to an over representation of late successional classes (conifer trees and dense shrubs) and a paucity of early classes.
- The current condition of the park's sagebrush steppe communities are the result of a changed fire regime.
- The sagebrush steppe-upland type is currently threatened by encroachment of conifer trees, and by the expansion of annual grasses, most importantly, cheatgrass (*Bromus tectorum*).



Coincidence of wildfires since 1980 with Big Sagebrush biophysical setting

- Medusahead (*Taeniatherum caput-medusae*) and Ventenata (*Ventenata dubia*) are both annual grasses that have system-changing impacts similar to cheatgrass, but have been documented to occur in areas that are unsuitable for *B. tectorum*. Both species occur in counties close to the park. Thus, the park should be vigilant in surveying and controlling both.

Discussion

Under current management, the sagebrush steppe systems in the park will continue to exhibit departure from historic conditions. The current departure is a reflection of the change in the relative abundance of the system's seral stages; there is an overabundance of late-seral and a paucity of early seral stages. Conifer tree encroachment will continue throughout much of the sagebrush distribution in the park. Additionally, much of the sagebrush steppe-upland at lower elevations is currently at risk of conversion to annual grassland as a result of the expansion of cheatgrass. This could result especially following intense wildfire events or soil disturbance. Thus, the management of the sagebrush steppe-upland is confounded by the presence and expansion of cheatgrass. The reintroduction of fire, either through prescribed or managed wildfire, could result in the further expansion of cheatgrass and other annual grasses resulting in a wholesale conversion to annual grasslands. The restoration of sage-steppe to conditions closer to the Natural Range of Variation will depend on the reduction of sagebrush cover and creation of open patches. Alternatives to fire disturbance include mechanical treatments and seeding after treatments or fire.

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Water Quality/Quantity at Great Basin National Park

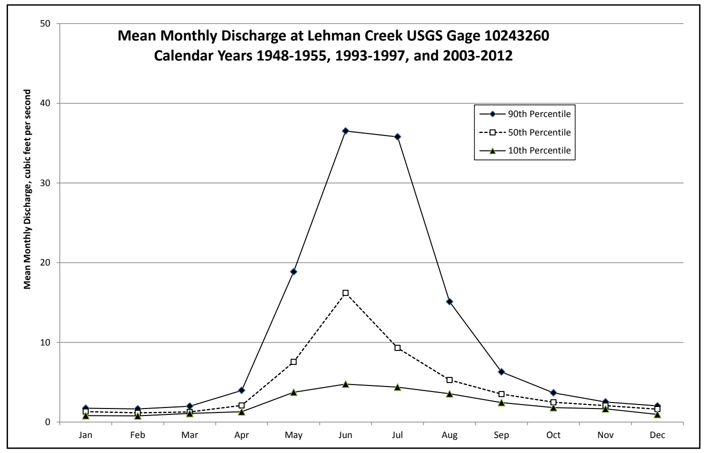
Natural Resource Condition Assessment

Importance

The surface streams, springs, and lakes of Great Basin National Park are among the biologically most distinct features of its high desert landscape. Six of its perennial streams – Strawberry, Mill, Lehman, Baker, and Snake Creeks, and South Fork Big Wash – historically supported native Bonneville cutthroat trout (*Oncorhynchus clarki utah*) and three other native fishes: mottled sculpin (*Cottus bairdi*), speckled dace (*Rhinichthys osculus*), and redside shiner (*Richardsonius balteatus*). Bonneville cutthroat trout have recently been returned to all but Lehman Creek. The Park's surface waters also support native stream-dependent mammals such as beaver (*Castor canadensis*) and water shrew (*Sorex palustris*); provide drinking and cooling water for numerous terrestrial animals; and support unique riparian plant communities. Changes to the quality and quantity of surface water in the park can adversely affect the structure and function of the park's aquatic biological communities, near-water vegetation, and animal life naturally attracted to these waters.

Status and Trends

Several indirect indicators point to an intact, stable hydrologic regime in the park. Snowpack water content on April 1 of each year provides a reliable predictor of both annual total and peak monthly discharge for streams in the park; and measurements since 1942 show no trend in April 1 snowpack water content. There is also no evidence of changes in watershed condition that would affect the relative rates of infiltration and runoff from precipitation and snowmelt. A pipe built along Snake Creek in 1961 diverts all normal flows (except following storms and during peak snow melt) for 3 miles (5 km). The pipe bypasses a section of channel, along which the stream water sank into the fractures of an underlying bedrock aquifer. The pipe empties back into the creek below the bypass. No groundwater pumping presently affects the park, but proposed future pumping in Snake and Spring Valleys, outside the park, could change this picture, pulling water out of the lower elevations of



90th, 50th, and 10th percentiles for mean monthly discharge at USGS gauge 10243260, Lehman Creek

some valleys inside the park.

Direct and indirect evidence suggests that nutrient levels in streams are not artificially elevated in the park. However, alternatively, it is also possible that nitrogen levels in the streams are elevated due to continuing atmospheric deposition of nitrogen (see Air Quality). Measurements of surface water quality at numerous locations show a decrease in the incidence of low pH readings in springs and streams in the park between 1966-98 and 2006-07.

Overall atmospheric deposition of nitrogen and sulfur has remained relatively stable in recent years but remains a matter of concern. On the other hand, the park has experienced a long-term decline in atmospheric deposition of acidic nitrate and sulfate ions. This may have affected surface water in the park by lowering the frequency of conditions with pH values below 6.5. The park experiences high levels of atmospheric deposition of mercury, but not all trout sampled in the park contain high levels of bio-accumulated mercury in their tissues. Other factors, potentially including the distribution of wetlands (a key factor in whether deposited mercury in watersheds gets converted into biologically active methyl-mercury), thus determine whether the mercury deposition has ecological impacts on the aquatic food web in the park. Finally, stream macroinvertebrates from numerous sampling locations in and immediately around the park – highly sensitive to disturbances to water quality – show an almost complete absence of such disturbances. Locations sampled for three years in a row, 2010-2012, showed a dip in condition in 2011, likely due to unusually wet weather and extreme rates of stream discharge in June and July, 2011.

Discussion

Park water quality and quantity appear to be in good, stable condition, although potential threats exist from climate change, atmospheric deposition, and groundwater pumping in the adjacent valleys. The Park has active gauges on four streams in the park, and eventually will have continuous records long enough to support detailed assessments of streamflow variability. The gauge records, along with the continuing measurements of snowpack in the park, provide crucial data for assessing the potential effects of climate change. The continuing monitoring of atmospheric deposition in the park also provides a crucial record of this potential external source of water pollution that affects the park as a whole; and ongoing monitoring by the National Park Service, Mojave Desert Network Inventory and Monitoring team will greatly expand knowledge of water chemistry and its ecological effects in the park.

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Natural Resource Condition Assessments Web Page:
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Montane Riparian Woodlands at Great Basin National Park

Natural Resource Condition Assessment

Importance

Great Basin National Park contains 25 watersheds. Ten of these – the Strawberry, Mill, Lehman, Baker, Snake, Williams, Pine and Ridge, and Shingle Creeks and South Fork Big Wash watersheds – contain streams that flow perennially along at least parts of their valleys. Streams flow intermittently in other parts of these same watersheds, as well as in other watersheds, including Can Young Canyon and Arch Canyon. Riparian woodlands occur along all these perennial and intermittent stream reaches.

Riparian woodlands cover only a small fraction of the park but contribute greatly to its biological diversity. Cold-air drainage, topographic shading, the presence of at least intermittently running water and high water tables support distinctive assemblages of plants that tolerate or require moist soils and cooler, more humid microenvironments. Such settings are rare in the arid Great Basin in general, and in the park in particular. Tree species that occur exclusively or frequently in the riparian woodlands of the park include *Populus tremuloides*, Quaking aspen; *Abies concolor*, White fir; *Picea engelmannii*, Engelmann spruce; *Populus angustifolia*, Narrowleaf cottonwood; *Pinus flexilis*, Limber pine; *Pseudotsuga menziesii*, Douglas fir; *Acer glabrum*, Rocky Mountain maple; and *Juniperus scopulorum*, Rocky Mountain juniper. Shrub species that occur exclusively or frequently in the riparian woodlands of the park include *Rosa woodsii*, Woods' rose; *Symphoricarpos oreophilus*, Mountain snowberry; *Betula occidentalis*, Water birch; *Salix spp.*, six species of willow; *Amelanchier alnifolia*, Western serviceberry; *Mahonia repens*, Creeping barberry; *Cornus sericea*, Red osier dogwood; *Prunus virginiana*, Western chokecherry; *Sambucus cerulea*, Blue elderberry; and *Rhus trilobata*, Desert sumac.

Evapotranspiration and shading by these plants helps maintain the unique microenvironments of the riparian zones in the park, contributing to their usefulness as habitat for many terrestrial and aquatic species (see also discussion for Water Quality and Quantity). Plant litter and riparian insect larvae contribute to the habitat complexity and food web of the streams. And ungulates, beaver, bats, birds, amphibians, and insects

Montain riparian woodland

find passage or shelter, feed, or breed in the park's riparian woodlands. In fact, up to 75% of all montane wildlife species in the Great Basin use riparian areas during some or all of their lives. Occasional wildfires, and floods caused by occasional storms, help maintain the diversity of plant species in these woodlands.

Status and Trends

Several indicators directly or indirectly point to intact, relatively stable conditions in the riparian woodlands of the park. As noted in the assessment of water quality and quantity in the park, there is no evidence of changes to the park that would result in changes to the hydrology or sediment loads along its streams. Further, only a few riparian areas in the park have been substantially altered by development, e.g., for parking, picnics, camping, or hiking. However, a minority has experienced significant alteration, with roads and trails paralleling major perennial stream reaches. And qualitative surveys of riparian vegetation condition at individual stream reaches in 1997 and again in 2009-2011 both found a majority of survey locations exhibiting "Good" conditions for riparian vegetation condition and succession. Only a handful of locations surveyed in each period exhibited moderately degraded conditions, and none exhibited severely degraded conditions. The same types of factors appear responsible for the scattered degraded conditions in each study period: road encroachment, road erosion, foot traffic, camping, and water diversions. Legacy impacts of the history of land use across the South Snake Range – livestock grazing, mining and its encampments, etc. – were not evident in either survey.

However, the assessment of wildfire across the park (see above) indicates that 26% of the area of montane riparian woodlands in the park has experienced a shift toward later-successional vegetation (i.e., woody vegetation encroachment) due to fire suppression. Additionally, a 2003-2004 survey recorded woody encroachment at ~23% of all springs in the park, all in montane riparian woodlands, almost all of which occur in the park's riparian zones.

Discussion

The several indicators examined point to an overall rating of "Good" for the condition of the montane riparian woodland resource. However, this overall rating depends on the weight given to the evidence of fire regime departure. By itself this latter evidence would suggest an overall rating of "Moderate Concern" with a "Deteriorating" trend. On the other hand, the removal of livestock from the park, the ongoing program of management and removal of invasive species from riparian areas, and the absence of management activities that could further reduce watershed and riparian corridor condition alternatively suggest an overall rating of "Good" with no trend at all. As a result of these apparently conflicting findings, the overall rating warrants a rating of "Low" confidence.

Indeed, most of these findings rest on indirect or qualitative evidence and/or analyses of remote sensing data, all of which have important weaknesses as sources of evidence. The methods of rapid visual assessment applied in the 1997 and 2009-2011 surveys, for example, can be affected by variation in observer training, professional background, and abilities; field conditions; and protocol. Further, the 2009-2011 survey addressed only portions of only six watersheds within the South Snake Range – the six watersheds included in the Bonneville cutthroat trout restoration program. Given their inclusion in this restoration program, the riparian corridors in these six watersheds may not be representative of all riparian corridors in the park. These limitations in the available data on riparian woodland condition in the park suggest a need for additional, more systematic and quantitative monitoring. In fact, a study in 1991-1993 collected quantitative data on riparian vegetation at several fixed monitoring plots. Another research team revisited these same plot locations in 2001-2002 to look for evidence of changes in vegetation. This second study team also re-established the locational datum points for the previous plots, established 31 new riparian transects, and installed permanent datum points for these new transects, to enable subsequent revisits. A repeat study of these plots and transects could provide invaluable direct, longer-term evidence of riparian woodland condition and trends to help guide management.

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Bonneville Cutthroat Trout at Great Basin National Park

Natural Resource Condition Assessment

Importance

The Bonneville cutthroat trout *(Onchorynchus clarki utah)* (BCT) is the only salmonid native to Great Basin National Park, and in fact the only salmonid native to east-central Nevada. BCT once occupied numerous tributaries to Pleistocene Lake Bonneville, which covered most of western Utah, with one arm extending west into Snake Valley. Lake Bonneville disappeared at the end of the Pleistocene, stranding populations of BCT in several tributaries, including the perennial streams along the east sides of the North and South Snake Ranges. Other former tributaries to Lake Bonneville also harbor remnant, genetically distinct population of the species. BCT is the top native aquatic predator in the perennial streams of the park, and requires clean, clear, cool flowing water with a suitable mix of pool, riffle, and run habitat; plentiful cover; and a suitable mix of aquatic invertebrates on which to feed. As a result, it is sensitive to changes in stream flow, water temperature, water quality, physical habitat quality, and the aquatic food web. Introduced non-native trout, such as rainbow trout, also compete and may interbreed with BCT.

Bonneville cutthroat trout (*Onchorynchus clarki utah*)

Status and Trends

Bonneville cutthroat trout were thought to have disappeared from the South Snake Range – and indeed across 95% of its historic range – by the time Great Basin NP was established in 1986. In 1999, the park joined numerous other agencies and organizations in launching a range-wide program for species restoration that included restoration within the park. The discovery of a genetically intact population of BCT in Mill Creek helped energize the park's restoration program. The program includes eliminating non-native trout from selected streams sections, restoring stream habitat, reintroducing BCT, and monitoring fish and habitat conditions and BCT genetics. The Park now supports healthy densities of BCT along more than 11 miles (18 km) of Strawberry Creek, Mill Creek, South Fork Baker Creek, Snake Creek, and South Fork Big Wash. Water quality and stream flow are both in good condition, as are stream macroinvertebrate assemblages (see Water Quality/Quantity). Ecological conditions along the riparian zones provide shade and inputs of plant litter and insects crucial to the stream food web (see Montane Riparian Woodlands).

Some issues remain, however. Surveys of physical habitat conditions along the restored streams, 2009-2011, indicate that some sections of every restored stream depart from desired conditions of channel stability and complexity. The surveys did not indicate the causes of these departures. Further (see Water Quality/Quantity), a pipe built along Snake Creek in 1961 diverts all normal flows for 3 miles (5 km), preventing BCT from moving freely between upper and lower Snake Creek but also preventing non-native trout from moving upstream into upper Snake Creek. Lower Snake Creek experiences intrusions of non-native trout from a Nevada State rearing station downstream from the park. Planning is underway to remove non-native trout from lower Snake Creek within the park and install a barrier to prevent future intrusions. Riparian vegetation along the restored streams is changing, apparently as a consequence of the history of fire suppression across the park (see Montane Riparian Woodlands), in ways that could increase the potential for severe wildfires that could damage the streams. And proposed groundwater pumping in Snake Valley could alter the hydrology of some restored reaches at lower elevations along Strawberry, Baker, and Snake Creeks.

Discussion

The Park has successfully restored Bonneville cutthroat trout to Strawberry Creek, South Fork Baker Creek, Snake Creek, and South Fork Big Wash; and enhanced habitat quality for BCT along Mill Creek. Good water quality, stream flow, stream macroinvertebrate assemblage, and riparian woodland conditions all support BCT viability in the park. Threats remain, however, in the form of risks of severe fires that could affect the restored streams and their riparian vegetation; intrusions of non-native trout; altered hydrology due to the Snake Creek pipeline and off-Park groundwater pumping; and inconsistent channel habitat quality. Climate change and genetic isolation may also pose threats.

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Resource Brief

National Park Service
U.S. Department of the Interior

Natural Resource Stewardship & Science
Water Resources Division

Cave/Karst Processes at Great Basin National Park

Natural Resource Condition Assessment

Importance

Great Basin National Park contains over 30,000 acres of karst geology. *Karst* is a distinctive topography formed by the dissolution of carbonate bedrock, such as limestone, that may include sinkholes, caves, and underground drainage. A karst area in the Baker Creek watershed contains some of the most highly developed known karst drainage networks in the park. There are 46 known caves in the park, preserving spectacular formations such as stalactites, stalagmites, cave popcorn, flowstone, and shield formations, and at least one significant pictograph site. The Park also contains fracture systems, ice caves, tectonic caves, and 23 known rock shelters.

Lehman Caves, Little Muddy Cave, Lehman Annex Cave, and Root Cave make up the Lehman Hill Cave System. Partially open to the public, Lehman Caves includes spectacular formations including 300 rare shield formations. It is the longest known cave in Nevada, at approximately 1.5 miles (2.4 km) long, and is believed to have formed from both surface and deep water processes. Most other caves are closed to the public, to protect their fragile ecosystems.

Most caves in the park support populations of sensitive bat species that use the caves for hibernacula, maternity colonies, and transitional roosts. White-nose syndrome, a deadly illness currently sweeping through the bat populations of the eastern U.S., is not present in or around the park at this time.

Caves in arid regions tend to be biologically isolated from each other, and species may evolve unique adaptations to the cave environment. The Park is home to eleven endemic, cave-adapted invertebrate and numerous obligate cave-dwelling invertebrate species, including the Lehman Cave pseudoscorpion, *Microcreagris grandis*, and a harvestman, *Sclerobunus ungulatus*, thought to be endemic to the South Snake Range. However, the relative uniqueness of cave species in the park is not fully understood because caves in the surrounding region are not as well studied.

Status and Trends

The unique formations and biota of the caves in the park are sensitive to effects from visitor use, such as physical touch; looting and vandalism; inputs of lint and other organic particle debris; impacts to air and water quality

Lehman Caves at Great Basin NP

from human breath, including impacts to CO_2 concentration; and the construction and maintenance of physical infrastructure to support visitation. Changes in the composition and abundance of the species that move between the caves and outside habitats, such as bats and packrats, also can affect cave and karst processes. Additionally, cave and karst processes can be affected by changes in groundwater movement and geochemistry; and in atmospheric temperature, humidity, and gas concentrations.

Lehman Caves visitation statistics from fiscal years 2001-2007 indicate an average of 30,517 visitors per year. Between 2010 and 2014, an average of 27,503 people visited the caves each year, peaking in the June-August period, with between 4,500 and 6,500 monthly visitors. While trends in visitor numbers are difficult to interpret, any decline in visitation could suggest a decrease of stress and a resulting improvement in condition. However, relationships between visitor number and cave/karst condition have yet to be fully documented for Lehman Caves.

Within Lehman Caves, humidity and temperature increase and also become less variable with distance from the cave openings. Annual average air temperatures vary between

Great Basin Cave pseudoscorpion (*microcreagris grandis muchmore*)

52.7 and 54.5 °F (11.5 and 12.5 °C) in locations greater than 200 feet (61 m) from the cave entrances, but vary between 48.6 and 53.6 °F (9.2 and 12 °C) closer to the cave entrances. Monthly average air temperature at distances greater than 200 feet (61 m) from the cave entrances vary between 53.6 °F (12 °C) in July and 46.4 °F (8 °C) in February. Similarly, annual average relative humidity varies between 83% and 87% in locations beyond 200 feet (61 m) from the cave entrances, versus 72%-85% at locations closer to the entrances. Data on reference conditions and/or trends in cave temperature and humidity are not available.

Cave Hydrology and Water Quality

Data on cave hydrology and water quality in the park are available for only a small number of caves, from brief and/or scattered study periods. Chemical analyses indicate that the waters in the sampled caves originated largely as upland recharge at higher elevations in the South Snake Range years to decades earlier. However, the data also indicate that these cave waters consist of mixtures of water recharged at different times that moved through the intervening bedrock along multiple flow paths. This mixing tends to even out the effects of inter-annual variation in recharge, producing more stable discharge rates. A few caves also receive water that leaks out of nearby streams as they pass over bedrock fractures, imparting on these caves a pattern of greater variability in their discharge.

Longer, inter-mixing groundwater flow paths tend to even out the effects of inter-annual variation in the chemistry of the water recharged across the South Snake Range, and variation in the geochemistry of the aquifers through which the groundwater flows. As a result, most cave waters in the park have stable water chemistries. However, caves that receive water in part from nearby streams tend to show greater inter-annual variation. Data from long-term, continuous and periodic monitoring are needed to look for evidence of changes in cave hydrology and water chemistry, and how these may relate to variation in cave visitation, upland recharge, and other potential factors.

Cave Macroinvertebrates

Investigators have found fewer numbers and species of macroinvertebrates in Lehman Caves with increasing distance from the cave entrances. The investigators also found that two species – *Microcreagris grandis*, the Lehman Cave pseudoscorpion, and *Nevadesmus ophimontis*, the Snake Range white millipede – were both notably more abundant with greater distance from visitor trails. The age of a trail; the percentage of cave substrate covered by asphalt; training of cave tour guides to minimize off-trail travel, food, and trash; and seasonal breaks in visitorship along individual trails also appear to affect macroinvertebrate numbers and species diversity near the trails in Lehman Caves. Data on reference conditions and/or trends in cave macroinvertebrates are not available.

Discussion

The quality and quantity of water available on the land surface in the park should strongly affect the quality and quantity of the water that reaches the park's caves and karst formations through upland and along-stream recharge. As discussed above (see water quality and quantity), none of the indicators for surface water quality and quantity for the park point to less than good, stable or improving conditions for these drivers. These findings suggest that cave/karst processes in the park are not presently impaired or threatened by trends of impairment in these key drivers. On the other hand, air exchange and visitation of caves through their surface openings may be sources of ongoing or future impacts to cave geochemistry and ecology. Bat guano and packrat middens could, with development of suitable methods, provide data on visitation by these species and the types, quantities, and chemical composition of the organic matter that they deposit. More generally, given the potentially high sensitivity of cave geochemistry and ecology to changes in outside air chemistry and human and wildlife visitation, the park faces a need for long-term monitoring of cave air, macroinvertebrate numbers and species diversity, human and wildlife visitation and the materials they bring in. Changes in near-cave surface vegetation and gating of cave entrances could also affect in-cave conditions, as well.

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Springs at Great Basin National Park

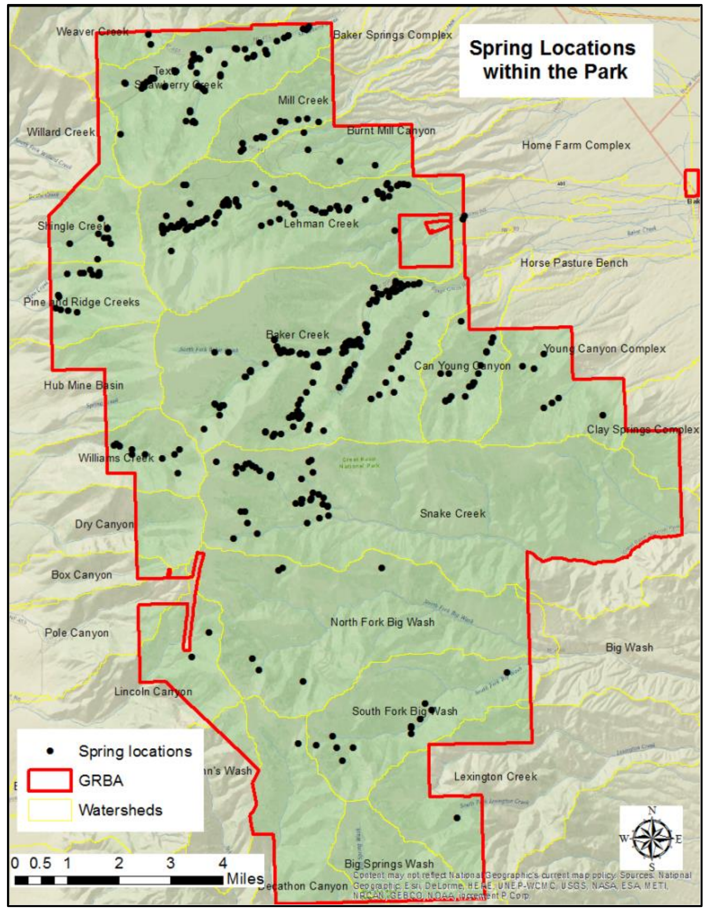
Natural Resource Condition Assessment

Importance

Great Basin National Park contains over 425 perennial seeps, springs, and spring complexes along the riparian zones in almost all of the park's 25 watersheds. Most of these watersheds contain at least one spring, while several, e.g., the Strawberry, Lehman, and Baker Creek watersheds, contain dozens. Some springs are isolated; others occur in tight clusters, *aka* spring complexes. The springs and seeps may flow only seasonally or year-round, depending on whether they are fed by shallow or deep groundwater sources. Their waters often flow directly into streams, contributing to stream flow. An inventory of the park's springs in 2003-2004 found that 12% contained native mollusks, including *Pyrgulopsis kolobensis*, a type of springsnail, *Valvata humeralis*, a type of snail, and pea clams, *Pisidium spp*. The springs also attract terrestrial wildlife: the inventory in 2003-2004 found signs of animal visitation at nearly 90% of all springs in the park. Finally, the park's seeps and springs harbor a unique spectrum of mosses, algae, sedges, rushes, and other plants adapted to their uniquely cool, wet settings. Park spring temperatures average 45 ± 5.5 °F (7.2 ± 3.1 C°). The park's springs also have long attracted human activity, both as water sources and as settings for encampments and residences. The inventory of 2003-2004 found evidence of active and/or historic diversions at fifteen springs/spring complexes including Cave Springs, which supply the water for the Lehman Caves Visitor Center. Since that time, spring diversions have been removed at all but four locations. This represents less than 1% of the springs in the park.

Status and Trends

Numerous investigators have measured spring discharge since 1966, the date of the first record, including studies by the U.S. Geological Survey in 2002-2004 and by the National Park Service in 2003-2004, 2006-2007, and currently. However, the resulting data do not yet comprise a sufficient record with which to assess basic patterns of daily, seasonal, and annual variation in flow regimes, let alone trends in flow characteristics, for any single spring within the park – let alone for the different kinds of springs present in



Locations of springs in Great Basin NP

the park. However (see Water Quality/Quantity), there is no evidence of changes to the hydrology of the park's watersheds and groundwater systems that would result in changes to the hydrology of its springs. Active diversions affect only a handful of the park's springs (e.g., Cave Springs).

Data on water quality in the park's springs from 1966-1998 compared to 2006-2007, were included in the overall assessment of water quantity and quality in the park (see above). Nearly 25% of all measurements of pH from 1966-1998 fell below 6.5 standard units, the lower limit of acceptable conditions. In contrast, none of the measurements of pH from 2006-2007 fell outside the range of acceptable values at all. In general, water quality conditions in springs in 2006-2007 consistently fall within the "Good" condition range.

The 2003-2004 inventory recorded a non-native plant species, watercress (*Rorippa nasturtium-aquaticum*) in the pools of 16.9% of all springs and spring complexes in the park, but found no evidence of non-native mollusks or other non-native spring fauna. At the same time, the inventory recorded evidence of encroachments of woody vegetation at ~23% of springs in the park. As noted above (see Montane Riparian Woodlands), this evidence for woody encroachment is consistent with evidence of an altered fire regime along the park's riparian corridors.

Discussion

The several indicators examined point to an overall rating of "Good" for the hydrology and water quality of the seeps, springs, and spring complexes in the park. However, evidence for overall stable spring hydrology is indirect. Closing this data gap requires long-term monitoring of a sample of springs. Diversions affect a very small fraction of the springs in the park, but presumably alter the ecology of the where they do occur. Introductions of exotic spring fauna pose an ongoing threat due to the ease with which they accidentally can occur. And encroachments by native woody vegetation and an exotic aquatic plant species also pose ongoing threats, warranting long-term monitoring of at least a sample of springs.

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Climate Change Effects at Great Basin National Park

Natural Resource Condition Assessment

Importance

Global warming, and its effects on climate patterns throughout the Great Basin, causes increasing concern for resource management at the park. Temperature and precipitation drive ecosystem productivity and natural dynamics, such as the rate of plant growth, the frequency of wildfires, and the seasonal flow of streams. As the rate of change increases, resource managers can expect profound shifts in key ecological processes to cascade through natural systems, resulting in altered productivity, changes to species composition, local extinctions, and instances of ecological degradation or collapse. The challenge posed by climate change in the coming decades is to clarify strategies that strengthen ecosystem resilience and minimize ecological degradation or collapse due to a loss of ecological integrity, and then to facilitate the natural transformation of ecosystems in ways that maximize retention of ecosystem processes.

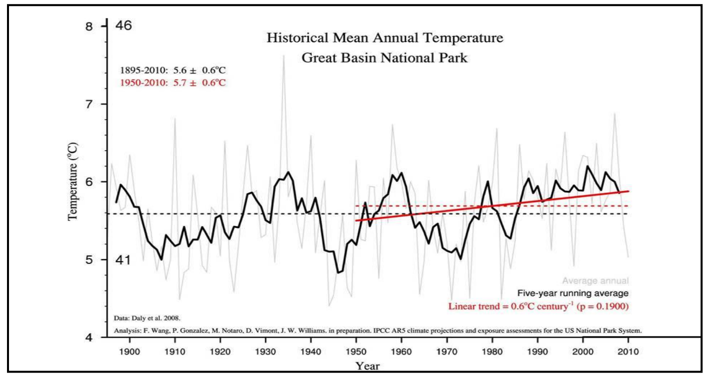
Parks throughout the southwest may become vulnerable to increasing fire frequencies, drought and beetle infestation, reduced snowpack, and loss of pika populations in alpine environments. Indicators for this assessment aim to gauge trends in climate itself, trends in the geophysical effects of changing climate, and the biological responses to change climate.

Status and Trends

Across the Great Basin region, warming of 0.6 to 1.0 °F (0.3 - 0.6 °C) has occurred over the past 100 years. Others have estimated a 1.26 °F (0.7 °C) increase in mean annual temperature for the landscape encompassing the park.

Regional tree ring analyses of bristlecone pines correlated strongly with these historical trends in temperature. Measures of radial tree growth for the second half of the 20th century were greater than any 50-year period of the last 3,700 years.

These findings are further corroborated by analysis results from lake sediment cores from Stella and Baker lakes. The lake core analysis indicates that these lakes experienced increased July temperatures starting



Historical temperature trends for Great Basin NP (from Gonzalez 2014)

around 1980, and current temperatures are as high as have been recorded over the past 1,000 years. Fortunately, the sediment cores also indicate that, while the park likely experienced wide swings in temperature and aridity throughout the Holocene, Stella Lake never dried out completely, and appears to have maintained a diverse aquatic ecosystem throughout the last 7,000 years. In any case, given trends in July temperatures, a condition of moderate concern is appropriate.

Analysis of mean annual precipitation for the 1895-2010 timeframe indicate an increasing trend of 36% per century between 1950 and 2010, but high variability in these data mean that this projected trend is of limited statistical significance. Increasing temperatures during the growing season tend to result in higher evapotranspiration rates, thus offsetting some increases effects of greater precipitation, so this finding does suggest that there may be significant effects to be closely monitored.

Climate projections applied to the ecoregion encompassing the park aimed to characterize the difference between 2060 projections and the entire 20th century. Monthly variables (maximum temperature, minimum temperature, and total precipitation) are projected to depart more than two standard deviations from mean values observed from the 20th century. This analysis indicates that projections for precipitation do not deviate by at least two standard deviations anywhere within the landscapes including the park. However, both monthly maximum (daytime) and minimum (nighttime) temperature are projected to be beyond two standard deviations throughout the area. These elevated average temperatures are projected to be pervasive throughout the months of July and August. For the months of June, September, and October, just the minimum temperature is projected to be most elevated. Increasing mean temperatures vary from 4.5 ^{o}F to 7.4 ^{o}F.

Again, these data suggest that the primary consideration of climate change for the park over the upcoming decades should be related to effects of elevated growing season temperatures, with numerous potential effects on vegetation growth, susceptibility to wildfire, disease, and drought stress.

Finally, the potential effects of changing climate on snowpack and stream flow were analyzed for the Lehman and Baker Creek watersheds. Future simulations were summarized by three 30-year periods over the next 90 years (2009-2038, 2039-2068, and 2069-2098).

Overall results for this time period suggest:

- Limited change in mean annual precipitation and mean annual streamflow.
- Slight shifts towards earlier snowmelt by one to several weeks. These shifts should be more pronounced in watersheds with more substantial south-facing slope area.
- Peak snow-water equivalence date may shift earlier by one to several days.
- Sublimation, evaporation, and transpiration may increase from October through April, and decrease from June through August, especially with warmer greenhouse gas scenarios.
- Streamflow volume relative to precipitation volume decreases with increasing temperature; but this effect may be more pronounced at middle elevations where evapotranspiration is highest. That is, higher elevation alpine environments have inherently less vegetation, and mixed conifer forests at higher and cooler elevations transpire less than vegetation at lower-elevations.

Discussion

Management responses to changing climate need to be based upon an expanding understanding of its effects on key park resources. Analysis of climate observations, model projections of future trends, and consistent monitoring of geophysical and biological responses to change all contribute to this understanding.

Current results of climate projections, and hydrologic models built from climate projections, should be viewed with caution, as climate science in this area is rapidly advancing, so these indicators should be periodically revisited with updated models.

Other indicators, such as those based on observed climate, tree ring, and sediment core records, have a strong basis for making inferences of resource condition.

Still other data sets, such as measures for plant species composition in alpine environments, have established baseline data collected, but will require repeat measurement in order to begin to measure trends.

Monitoring of phenology offers an additional set of indicators to detect biological responses to changing climate. Additional indicators, such as the spring emergence of rattlesnakes, spawning time for Bonneville cutthroat trout, and seasonal phenology in trees and shrubs, all offer important opportunities to deepen knowledge about the effects of climate change in the park.

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