National Park Service
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Natural Resource Stewardship and Science

Grand Canyon Wilderness Character Narrative and Baseline Monitoring Assessment

Building Blocks for Wilderness Stewardship

Natural Resource Report NPS/GRCA/NRR—2019/2003

"I hope the United States of America is not so rich that she can afford to let these wildernesses pass by, or so poor she cannot afford to keep them."

– *Margaret Murie*

ON THIS PAGE
California condor
(NPS/MICHAEL QUINN)

ON THE COVER
Sunset over the Grand Canyon wilderness observed from the Grandview Trail
(NPS/TOBIAS NICKEL)

Grand Canyon Wilderness Character Narrative and Baseline Monitoring Assessment

Building Blocks for Wilderness Stewardship

Natural Resource Report NPS/GRCA/NRR—2019/2003

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U.S. Department of the Interior
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Dedication

This publication is dedicated to all past, present, and future defenders of wilderness. Your efforts safeguard the Earth's wild treasures from our species' most destructive tendencies and demonstrate that humility and restraint are possible in an age of overconsumption and unfettered development.

I also dedicate it to all those who venture responsibly into the Grand Canyon wilderness – may you find the inspiration, solitude, and tranquility that you seek.

"Thousands of tired, nerve-shaken, over-civilized people are beginning to find out that going to the mountains is going home; that wildness is a necessity; and that mountain parks and reservations are useful not only as fountains of timber and irrigating rivers, but as fountains of life."

– John Muir, *Our National Parks*

"Wilderness preservation is a gesture of planetary modesty and a badly needed exercise of restraint on the part of a species notorious for its excesses."

– Roderick Frazier Nash, *Wilderness and the American Mind*

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Executive Summary

The central legislative mandate of the Wilderness Act of 1964 is to preserve the wilderness character of protected areas included in the National Wilderness Preservation System. This mandate has been affirmed in National Park Service policy, which also extends this level of protection to areas that have been proposed for wilderness designation until the legislative process has been completed. Administrative boundaries alone are insufficient to protect wilderness character. The only way to know whether the wilderness character of an area is preserved is to systematically monitor it.

This report is the baseline assessment of wilderness character for the Grand Canyon proposed and proposed potential wilderness. The intent of this assessment is to develop an understanding of the key features of wilderness character at Grand Canyon National Park and to provide a framework to understand how wilderness character changes over time. This assessment contains two principal aspects: 1) a qualitative *Wilderness Character Narrative*, which describes the unique and often-intangible values of the Grand Canyon wilderness, and 2) a quantitative *Baseline Monitoring Assessment*, which offers specific data-based measures of wilderness character and establishes a protocol that will be used to monitor change in wilderness character at Grand Canyon National Park far into the future. Together, the Wilderness Character Narrative and Baseline Monitoring Assessment form the *Building Blocks for Wilderness Stewardship*. They provide a holistic understanding of wilderness character in the Grand Canyon wilderness and demonstrate what sets this special place apart from other public lands and wilderness areas across the nation.

This report fulfills two parts of the directive in NPS Director's Order 41 which states 1) "wilderness parks should develop a wilderness character narrative which describes what is unique and special about a specific wilderness" and 2) "wilderness parks will conduct a wilderness character assessment, which includes identifying what should be measured, establishing baseline data, and conducting ongoing monitoring of trends." Additionally, this document is intended to fulfill the *Keeping It Wild in the National Park Service* (2014) recommendation that encourages every park with wilderness resources "to identify any immediate concerns in wilderness, and to inform managers and the public about the current status of wilderness character."

This report is intended to serve as a standalone document that outlines a framework and monitoring protocol for ongoing wilderness character monitoring at Grand Canyon National Park, which should occur every five years. This report is also intended to serve as a foundation document to support the process of developing a Wilderness Stewardship Plan at Grand Canyon National Park. Finally, this report seeks to empower land managers with the knowledge needed to make carefully-weighted wilderness stewardship decisions that respect and preserve the wilderness character of Grand Canyon for generations to come.

Acknowledgments

I stand on the shoulders of previous and current wilderness managers, scientists, and other staff at Grand Canyon National Park, who, over the decades, have produced a wealth of knowledge, datasets, and documents that form the foundation for this report. Many subject matter experts provided insightful input, shared their data, and assisted me in the planning, drafting, and editing phases of this report. I want to extend a special thank you to Mike Kearsley, who served as a supportive mentor and supervisor throughout the development of this report. I also want to acknowledge Claire Rozdilski, who provided valuable feedback and direction during the final stretch of this project. I also thank Roger Semler, Erin Drake, and Tim Devine for organizing an outstanding Preservation of Wilderness Character Training at the Tumbling River Ranch in Grant, Colorado.

I want to recognize several cohorts of previous wilderness fellows, who, since 2010, have paved the way and completed wilderness character assessments for many wilderness areas across the National Wilderness Preservation System. Through their professionalism, hard work, and dedication they build the reputation of this program, demonstrating that young professionals are taking on and can be trusted with such a multi-faceted, large-scale, and intellectually challenging project. In particular, I would like to recognize Laiken Jordahl, who completed multiple wilderness fellowships in the Southwest and shared valuable advice with me.

My appreciation also goes to the National Park Service Wilderness Stewardship Division and the American Conservation Experience for making this wonderful experience possible, allowing me to turn my passion for wilderness preservation into a viable professional opportunity. My hope is that this excellent Wilderness Fellowship Program will endure long into the future, harnessing the idealism and energy of young professionals, while providing them with an invaluable career experience in the field of wilderness stewardship.

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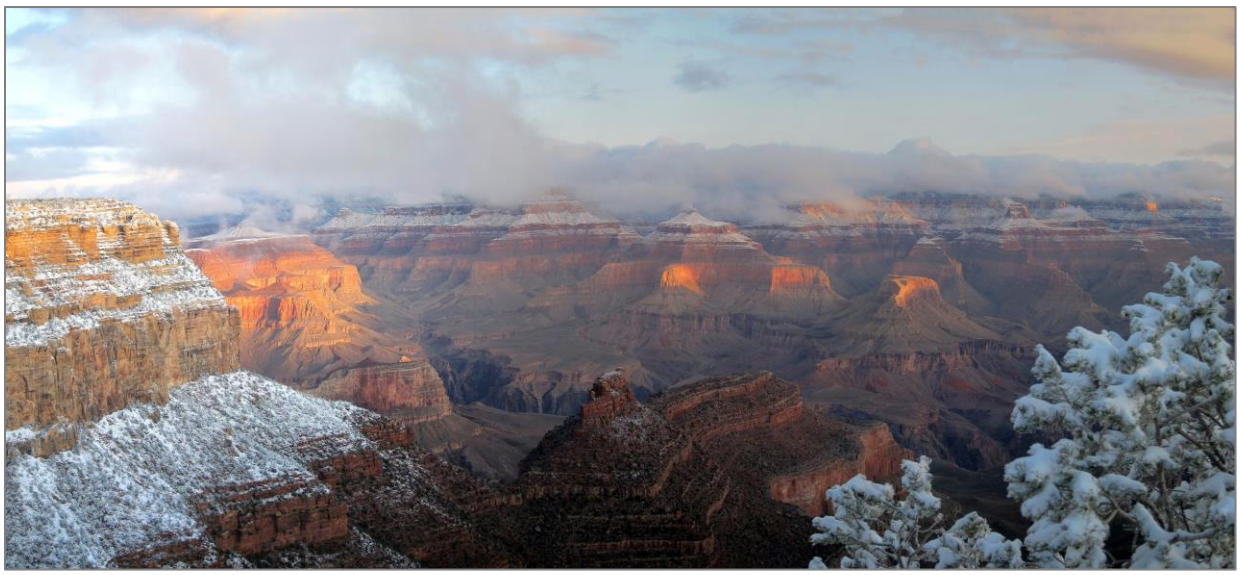
Defining Wilderness Character

The Wilderness Act of 1964 (16 U.S.C. § 1131-1136) was passed by a nearly unanimous vote in the United States Congress to protect natural lands from the seemingly endless threats of "expanding settlement and growing mechanization." The primary mandate of the Wilderness Act is given in Section 4(b) and states that "each agency administering any area designated as wilderness shall be responsible for *preserving the wilderness character of the area*" [emphasis added]. In order to establish a common understanding of this directive, wilderness character was formally defined by an interagency monitoring team representing the United States Forest Service (USFS) (Department of Agriculture), as well as the United States Fish and Wildlife Service (USFWS), National Park Service (NPS), and Bureau of Land Management (BLM) (Department of the Interior (DOI)) as follows:

> "Wilderness character is a holistic concept based on the interaction of (1) biophysical environments primarily free from modern human manipulation and impact, (2) personal experiences in natural environments relatively free from the encumbrances and signs of modern society, and (3) symbolic meanings of humility, restraint, and interdependence that inspire human connection with nature. Taken together, these tangible and intangible values define wilderness character and distinguish wilderness from all other lands." (Landres et al. 2015, p. 7)

Wilderness character encompasses the five qualities that are described in the definition of wilderness from Section 2(c) of the Wilderness Act. Together, these five qualities are used to monitor how management actions, impacts from visitor use, and external factors affect wilderness character over time. The five qualities apply nationally to all wilderness areas – regardless of their size, location, administering federal agency, or other unique place-specific attributes – because they are rooted in the legal definition of wilderness.



Sunrise over Grand Canyon in winter (NPS/MICHAEL QUINN).

Untrammeled

Wilderness is ". . . an area where the earth and its community of life are untrammeled by man"

- Wilderness ecological systems are essentially unhindered and free from the intentional actions of modern human control or manipulation when the Untrammeled Quality is preserved.

Natural

Wilderness ". . . is protected and managed so as to preserve its natural conditions"

- Wilderness ecological systems are substantially free from the effects of modern civilization when the Natural Quality is preserved.

Undeveloped

Wilderness is ". . . an area of undeveloped Federal land . . . without permanent improvements or human habitation"

- Wilderness retains its primeval character and influence and is essentially without permanent improvement or modern human occupation when the Undeveloped Quality is preserved.

Solitude or Primitive and Unconfined Recreation

Wilderness ". . . has outstanding opportunities for solitude or a primitive and unconfined type of recreation"

- Wilderness provides opportunities for visitors to find solitude and to challenge themselves with a primitive and unconfined type of recreation when the Solitude or Primitive and Unconfined Recreation Quality is preserved.

Other Features of Value

Wilderness ". . . may also contain ecological, geologic, or other features of scientific, educational, scenic, or historical value"

- Other tangible features of scientific, educational, scenic, or historical value in wilderness add to wilderness character when they are preserved.

In addition to these qualities of wilderness character, wilderness also has important intangible aspects that are difficult or impossible to quantify or monitor. These intangible aspects arise from the interactions humans have with the biophysical elements of wilderness. They can include the scenic beauty, spiritual value, immensity of an area, and opportunities for self-discovery, self-reliance, and challenge that come from wilderness settings. These intangible aspects of wilderness are best addressed qualitatively and are discussed in the Wilderness Narrative section of this assessment.

Wilderness character may change over time and may be improved or diminished by the actions or inaction of managers. The challenge of wilderness stewardship is that decisions and management actions taken to protect one quality of wilderness character can often degrade another quality. In addition, the cumulative result of seemingly small decisions and actions may cause a significant gain or loss of wilderness character over time. Because of this complexity, preserving wilderness

character requires that agency staff document the management decisions made for wilderness and monitor the impacts of those decisions.

Wilderness Stewardship in the National Park Service

The NPS plays a vital role in preserving wilderness character across the National Wilderness Preservation System (NWPS), administering approximately 40% (almost 44 million acres) of all designated wilderness in the country (NPS 2009a). More than 85% of all NPS lands have been designated as wilderness or are formally eligible, proposed, recommended, or potential wilderness – more total acres and a greater proportion of land than any other wilderness management agency.

NPS policy affirms the mandate of the Wilderness Act to preserve wilderness character. The NPS Management Policies (2006a) on Wilderness Preservation and Management (Chapter 6) single out preservation of wilderness character and mandate consideration of wilderness character in actions spanning resource management, environmental compliance, analysis of minimum requirements, cultural resource protection, management of facilities and signs, and interpretation and education.

NPS Director's Order 41: Wilderness Stewardship (NPS 2013a), provides specific direction for the preservation of wilderness character, mandating that each wilderness park:

- "will integrate the concept of wilderness character into park planning, management, and monitoring"
- "should develop a wilderness character narrative which describes what is unique and special about a specific wilderness"
- "will conduct a wilderness character assessment, which includes identifying what should be measured, establishing baseline data, and conducting ongoing monitoring of trends"

NPS Director's Order 41 also references the five qualities of wilderness character in *Keeping It Wild 2* (Landres et al. 2015) and steers managers to *NPS Reference Manual 41* (NPS 2013b) to inform the implementation of these wilderness mandates. *NPS Reference Manual 41* is the primary level 3 guidance for wilderness stewardship for the NPS. It includes both *Keeping it Wild in the National Park Service* (NPS 2014) and the *Wilderness Stewardship Plan Handbook* (NPS 2014a). Both documents provide insights on how to integrate wilderness character into park planning, management, and monitoring.

This assessment of wilderness character for the Grand Canyon wilderness is intended to fulfill two parts of the directive in NPS Director's Order 41 through: 1) the development of a Wilderness Character Narrative and 2) the completion of a Wilderness Character Monitoring Baseline Assessment. Additionally, this document is intended to fulfill the recommendation that encourages every park with wilderness resources "to identify any immediate concerns in wilderness, and to inform managers and the public about the current status of wilderness character" (NPS 2014). Figure 1 depicts how this assessment fits into the overall wilderness stewardship planning framework and supports the process of developing a Wilderness Stewardship Plan at Grand Canyon National Park.

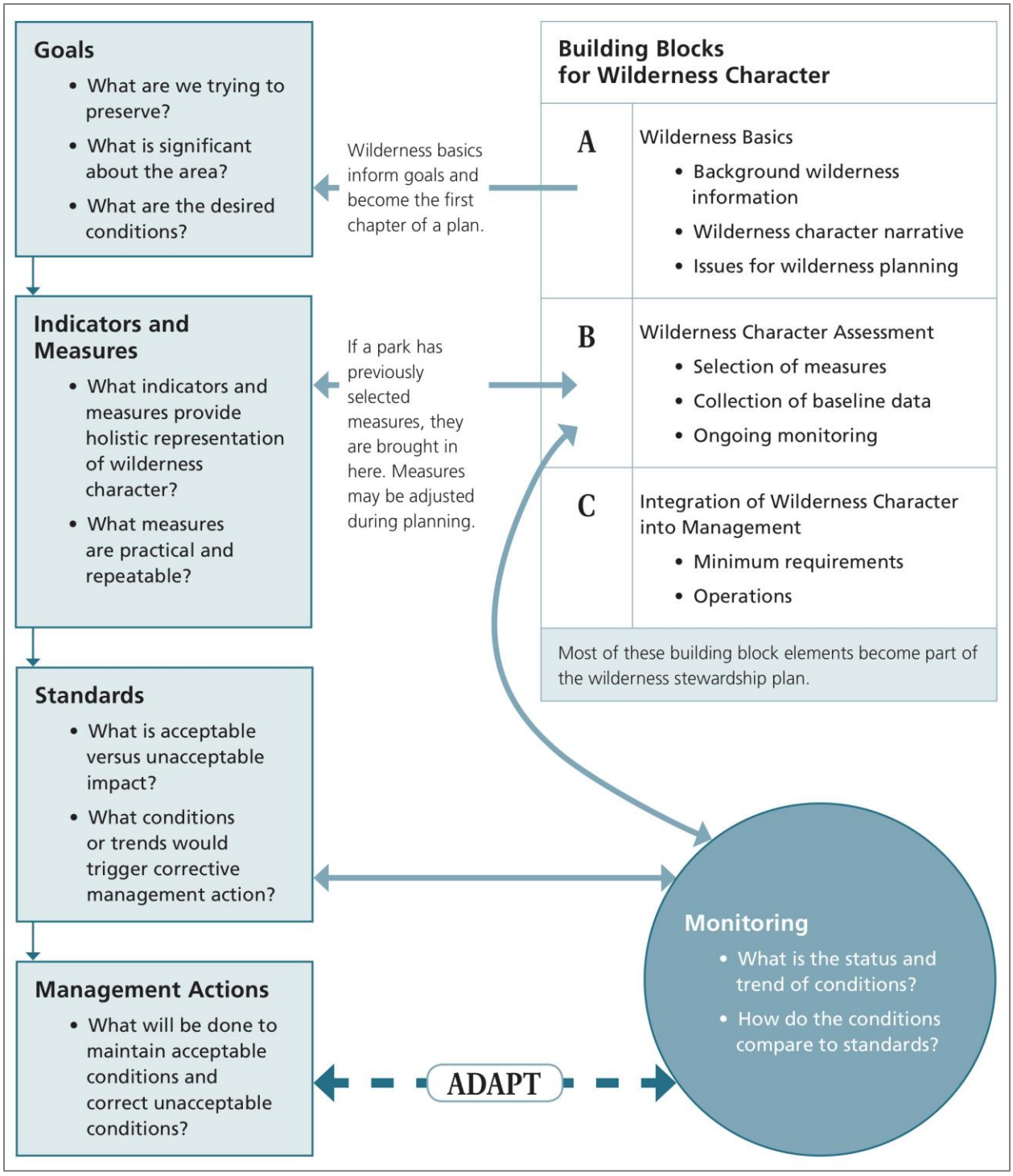


Figure 1. Wilderness Stewardship Planning Framework (NPS 2014a).

Introduction to the Grand Canyon Wilderness

Ninety-four percent of Grand Canyon National Park is managed as wilderness (Figure 2). This assessment considers all 1,149,773 acres of proposed and proposed potential wilderness identified in the 2010 Wilderness Recommendation (NPS 2010). For the purposes of this report, these lands are together referred to as the "Grand Canyon wilderness."

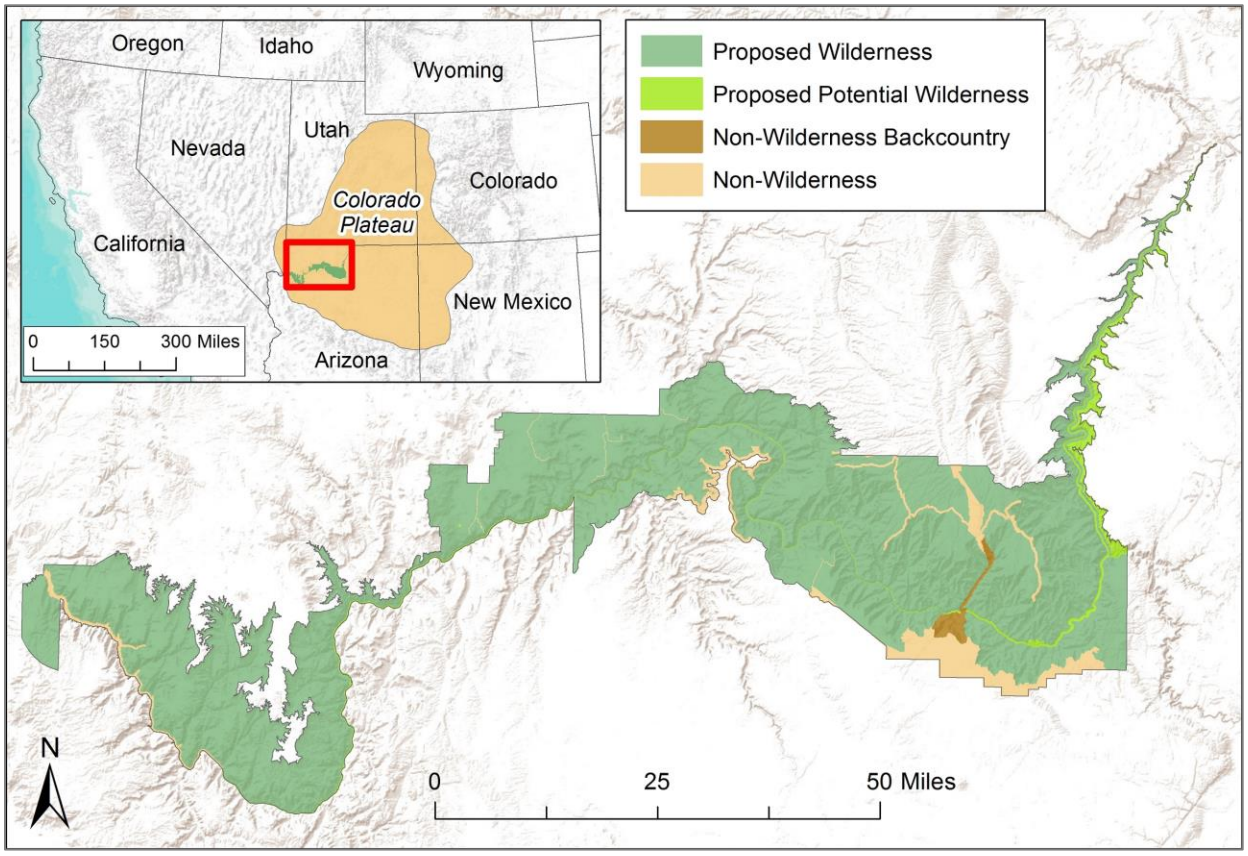


Figure 2. Map of the Grand Canyon proposed and proposed potential wilderness.

The Grand Canyon wilderness lies on the southern end of the Colorado Plateau in northern Arizona. The Colorado Plateau, a region characterized by mostly flat-lying sedimentary rocks that have been raised thousands of feet above sea level, is a vast semiarid land of color and canyons that is largely drained by the Colorado River and its tributaries. The forces of erosion have cut deeply into the land, sculpting numerous steep-walled canyons. The higher elevations of the plateau are forested, while the lower elevations are a series of desert basins.

The Grand Canyon wilderness is dominated by its namesake, a twisting 277-mile-long gorge with miles of side canyons formed during six million years of geologic activity and erosion by the Colorado River and its tributaries (Ranney 2005). Exposed geologic strata rising for more than a mile above the river represent one of the most complete geologic records seen anywhere on Earth. Mostly

intact ecosystems range from the lower canyon's Sonoran Desert to the North Rim's coniferous forest, contributing to the wilderness' outstanding biological diversity.

Historical and Administrative Setting of the Grand Canyon Wilderness

John Wesley Powell's exploration of the Colorado River brought the Grand Canyon to public attention in the 1860s and 1870s. Shortly thereafter, concern for the preservation of the Grand Canyon's unique resources began to grow as more people visited the canyon or settled there. U.S. Senator Benjamin Harrison of Indiana introduced legislation that would have granted formal protection for the Grand Canyon as a public park in Congress in 1882, 1883, and 1886 – well before Arizona became a state in 1912. Harrison served as president of the United States from 1889 to 1893, and in the last year of his term, he set aside the Grand Canyon as a forest reserve under the Forest Reserve Act of 1891 (16 U.S.C. § 471 et seq.). Tourism development on the canyon's rim was not affected, and grazing, lumbering, and mining were still allowed with permits.

President Theodore Roosevelt visited the canyon in 1903, expressing his wish that it remain unspoiled for future generations. On November 28, 1906, he enhanced the canyon's protective status by declaring portions to be a federal game preserve. The first real measure of protection, however, did not arrive until January 11, 1908, when Roosevelt, under the authority of the Antiquities Act of 1906 (16 U.S.C. § 431-433), issued a proclamation setting aside 818,560 acres as Grand Canyon National Monument. In Proclamation No. 794 (35 Stat. 2175), Roosevelt stated that the Grand Canyon is "an object of unusual scientific interest, being the greatest eroded canyon within the United States, and it appears that the public interests would be promoted by reserving it as a National Monument with such other land as is necessary for its proper protection." The USFS retained its administrative responsibility for the newly created monument.

On February 26, 1919, Woodrow Wilson signed into law the Grand Canyon National Park Establishment Act (16 U.S.C. § 221-227), making Grand Canyon the nation's seventeenth national park. Later that year Congress appropriated funds for administrative responsibilities to be transferred to the NPS. The NPS had only been established three years earlier by the National Park Service Organic Act of 1916 (54 U.S.C. § 100101(a)), providing the agency with its mission, which is "to conserve the scenery and the natural and historic objects and the wildlife 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."

In 1927, the park was enlarged, and in 1931 the park was closed to new mineral entry claims. On December 22, 1932, President Herbert Hoover established a second Grand Canyon National Monument for protection of parts of the Grand Canyon downstream from the park. On January 20, 1969, Lyndon B. Johnson established Marble Canyon National Monument for protection of parts of the Grand Canyon upstream from the park.

In 1975, Congress passed the Grand Canyon National Park Enlargement Act (16 U.S.C. § 228), which added the two national monuments, parts of Glen Canyon and Lake Mead National Recreational Areas (NRAs), and other federal and state lands to the existing Grand Canyon National Park. In the Act, Congress stated that its object was to: ". . . provide for the recognition by Congress

that the entire Grand Canyon, from the mouth of the Paria River to the Grand Wash Cliffs, including the tributary side canyons and surrounding plateaus, is a natural feature of national and international significance. Congress therefore recognizes the need for the further protection and interpretation of the Grand Canyon in accordance with its true significance." As a testimony to the canyon's spectacular scenery and natural grandeur, visitation to the park reached an all-time high of 6.28 million people in 2017. In fact, Grand Canyon is second only to Great Smoky Mountains National Park in visitation to national parks (National Geographic 2018).

Grand Canyon's international significance was further enshrined when the United Nations Educational, Scientific and Cultural Organization (UNESCO) designated the park as a World Heritage Site on October 26, 1979 for its natural beauty and powerful landscapes, exceptional example of biological environments, and diverse topography. As a World Heritage Site, the Grand Canyon is recognized as a place of universal value containing superlative natural features that should be preserved as part of the heritage of all the world's peoples. The UNESCO Statement of Significance reads:

> "The Grand Canyon is among the earth's greatest ongoing geologic spectacles. Its vastness is stunning; the evidence it reveals about the earth's history invaluable. The 0.9 mile-deep gorge ranges in width from 0.3 mile to 18.6 miles. The Canyon twists and turns 276.5 miles, and was formed during six million years of geologic activity and erosion by the Colorado River on the earth's upraised crust. The Canyon's buttes, spires, mesas, and temples appear as mountains when viewed from the rims. Horizontal strata exposed in the canyon retrace geologic history over two billion years and represent the four major geologic eras." (UNESCO 2018)

Yaki Point sunset (NPS/MICHAEL QUINN).

The World Heritage Site designation also recognized the cultural importance of the park. Eleven Traditionally Associated Tribes have inhabited the region for over 12,000 years and their histories and cultures are inextricably linked to the canyon. Government-to-government consultation provides opportunities for integration of tribal perspectives into NPS management and for rebuilding relationships that have been historically negative. In accordance with NPS policy, resource managers

make an effort to involve tribes in project planning, field activities, data analysis, and interpretation to better understand their relationships with Grand Canyon and to identify and protect resources and places of tribal importance in the park.

History of Wilderness Planning and Management at Grand Canyon

The Wilderness Act of 1964 (16 U.S.C. § 1131-1136), Section 3(c), instructed the Secretary of the Interior to review all roadless areas of at least 5,000 acres in the NPS and to submit a report regarding the suitability of these areas for wilderness classification. The act provided a ten-year review period and timetable.

In 1970, the NPS released for public review its Preliminary Wilderness Study for Grand Canyon National Park, Marble Canyon National Monument, and Grand Canyon National Monument. The study recommended phasing out motorized use on the Colorado River, and closing the network of primitive roads on the North Rim to qualify these areas for wilderness designation. The total wilderness area identified was 569,200 acres, or 63% of the 900,000-acre park. Absent from the study were any South Rim lands except the Palisades of the Desert area (NPS 1970).

The draft Wilderness Recommendation (NPS 1971) included 508,500 acres. Deleted from the recommendation were the river corridor due to continued motor boat use, areas of the North Rim where fire hazard reduction required motorized transport, and a one-eighth of a mile buffer zone around the entire park. The final Wilderness Recommendation (NPS 1972a), added areas of the North Rim, where fuel buildup was not a concern, the Grand Canyon National Monument where grazing had been eliminated, and the entire buffer zone. A Final Environmental Impact Statement (FEIS) for the Proposed Wilderness Classification (NPS 1973) was released in the following year.

No action had been taken on the Wilderness Recommendation by 1975, when the Grand Canyon National Park Enlargement Act (16 U.S.C. § 228) added Marble Canyon National Monument, Grand Canyon National Monument, and adjacent portions of Glen Canyon and Lake Mead NRAs, Kaibab National Forest, and some BLM lands into Grand Canyon National Park. The act, as amended in August of 1975, required the submission of a new Wilderness Recommendation reflecting an enlarged Grand Canyon National Park within two years.

The revised Preliminary Wilderness Proposal (NPS 1976) found 992,046 acres of the enlarged park suitable for wilderness. An additional 120,965 acres, including the river corridor, were identified as potential wilderness, for a total of 1,113,011 acres. The Draft Environmental Impact Statement (DEIS) (NPS 1976a), was released for public comment, resulting in 509 letters and written statements. The Final Wilderness Recommendation (NPS 1977), signed by the Director of the NPS, proposed 1,004,066 acres (including the river corridor and most of the North Rim) for immediate wilderness designation. An additional 108,945 was classified as potential wilderness. The NPS sent this recommendation to the DOI Legislative Counsel in 1977, where it was held in abeyance pending completion of the Colorado River Management Plan.

Upon completion of the Colorado River Management Plan (NPS 1980), the NPS Director sent the 1980 Wilderness Recommendation (NPS 1980a) to the DOI Assistant Secretary for Fish, Wildlife

and Parks, proposing 980,088 acres for immediate wilderness designation and an additional 131,814 acres as potential wilderness. The revised recommendation eliminated the 1,109-acre area between the South Kaibab and the Bright Angel trails and recommended the river corridor as potential wilderness until the planned phase-out of motors in 1985. However, an amendment to the 1981 DOI Appropriations Bill (94 Stat. § 2957, 2972) prevented the use of appropriated funds to implement a management plan for the Colorado River which "reduces the number of user days or passenger launches for commercial motorized watercraft excursions . . . below that which was authorized for the same period in calendar year 1978." This amendment resulted in the abandonment of the 1980 Colorado River Management Plan and its wilderness emphasis. A new river plan was written (NPS 1981), motor use on the river continued, and consideration of the 1980 Wilderness Recommendation was suspended.

In the following decade, several mining, grazing, and other leases within the park that had been excluded from recommendation were either retired or acquired. These were included in a review and update to the 1980 Wilderness Recommendation, along with a re-examination of the 1969 Field Solicitor's Opinion regarding the western boundary of the Navajo Nation (NPS 1993). Some changes in acreage resulted from the use of more accurate mapping technologies, but all modifications were consistent with the letter or intent of the 1980 Recommendation. This updated Wilderness Recommendation was transmitted by the Superintendent to the Director of the NPS (NPS 1993a). However, the Director never signed the recommendation, nor forwarded it to the Secretary of the Interior, and it remained in an indeterminate state.

A General Management Plan (NPS 1995) replaced a 1976 Master Plan, provided guidance for wilderness management, and called for the development of a Wilderness Management Plan. The resulting Wilderness Management Plan DEIS (NPS 1998) coincided with public scoping for the update to the Colorado River Management Plan. Confusion over how the wilderness plan related to the river plan led the NPS to suspend work on the Wilderness Management Plan in 2000.

In 2010, another update to the 1980 Wilderness Recommendation was drafted (NPS 2010), which incorporated clarifications and corrections to the wilderness boundary descriptions outlined in the 1980 and 1993 Wilderness Recommendations. The document proposed that 1,143,918 acres within the park be designated by an act of Congress. Of this total, 1,117,457 acres are identified for immediate designation, and 26,461 acres are identified as potential wilderness pending resolution of boundary and motorized river issues. While the 1980 map (Figure 3) remains the official Wilderness Recommendation map for the park, modern mapping tools have been used to refine, correct, and update wilderness boundaries (Figure 2). The 2010 Wilderness Recommendation remains in draft form and was never forwarded to the Director of the NPS.

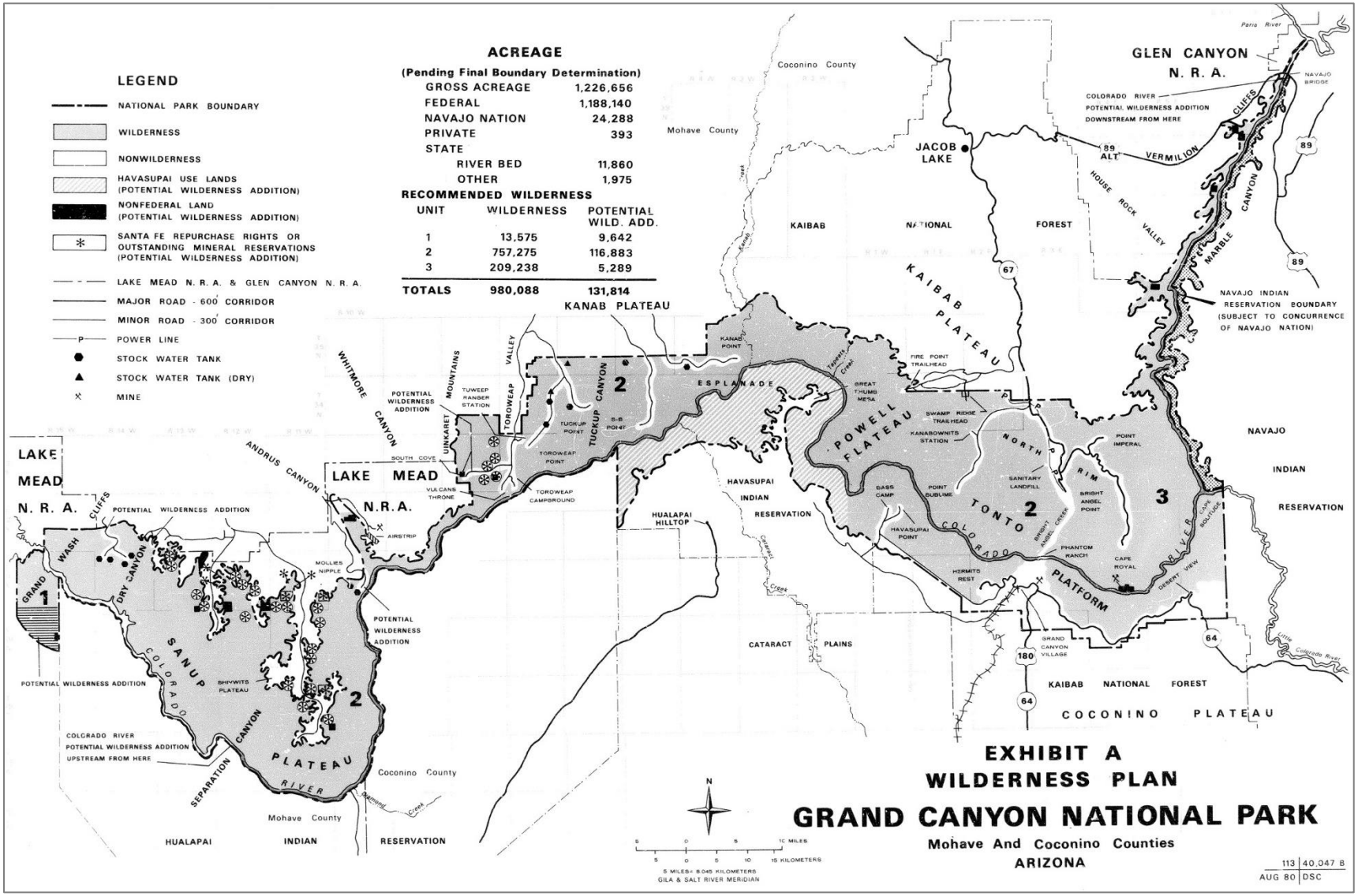


Figure 3. Official map from the 1980 Final Wilderness Recommendation.

As of publication of this report, designation of the Grand Canyon wilderness is still pending. In accordance with NPS Management Policies (2006a), the park manages its proposed and proposed potential wilderness in the same manner as designated wilderness. The NPS will take no action to diminish wilderness suitability while awaiting the legislative process, and management decisions affecting wilderness are made in expectation of eventual designation.

> **Note:** While not identical, wilderness and backcountry planning and management at Grand Canyon National Park are interrelated. A "History of Backcountry Planning and Management at Grand Canyon" is available in Appendix A.

Grand Canyon Wilderness Units

The Grand Canyon wilderness (1,149,773 acres) consists of four units (NPS 2010; Table 1; Figure 4). The Grand Wash Cliffs Unit on the western edge of the park is divided from the rest of the park by a non-wilderness section of the Colorado River. The Western Park and Eastern Park units are divided by the non-wilderness backcountry area of the cross-canyon corridor and developed areas of the North and South Rims. The Navajo Indian Properties Unit lies east of the Colorado River and north of the Little Colorado River.

Table 1. Grand Canyon proposed wilderness units.*

Wilderness unit	Gross acreage	Wilderness (combined)	Proposed wilderness	Proposed potential wilderness	Non-wilderness
Grand Wash Cliffs	22,815	22,815	22,815	0	0
Western Park	886,149	868,635	861,922	6,713	17,514
Eastern Park	236,382	234,489	229,812	4,677	1,893
Navajo Indian Properties	23,834	23,834	8,681	15,153	0
Total	**1,169,180**	**1,149,773**	**1,123,230**	**26,543**	**19,407**

* Acreages are based on the most recent Geographical Information System (GIS) analysis of both the 2010 Wilderness Update (NPS 2010) and revised boundary data filed with the NPS Land Resources Division. Therefore, acreages vary slightly from those provided in the 2010 Wilderness Recommendation.

Unit 1, Grand Wash Cliffs

The Grand Wash Cliffs Unit is located in the extreme western portion of the park. It is bounded on the north by Lake Mead reservoir, and on the west, south, and east by Lake Mead NRA, BLM lands, and the Hualapai Indian Reservation, respectively. This area contains the Grand Wash Cliffs escarpment on the south side of the Colorado River. The entire area (22,815 acres) is proposed for immediate designation.

> **Note:** The Grand Wash Cliffs Unit is not to be confused with the designated Grand Wash Cliffs Wilderness managed by the BLM and located about 20 miles to the north of the park in the Grand Canyon-Parashant National Monument.

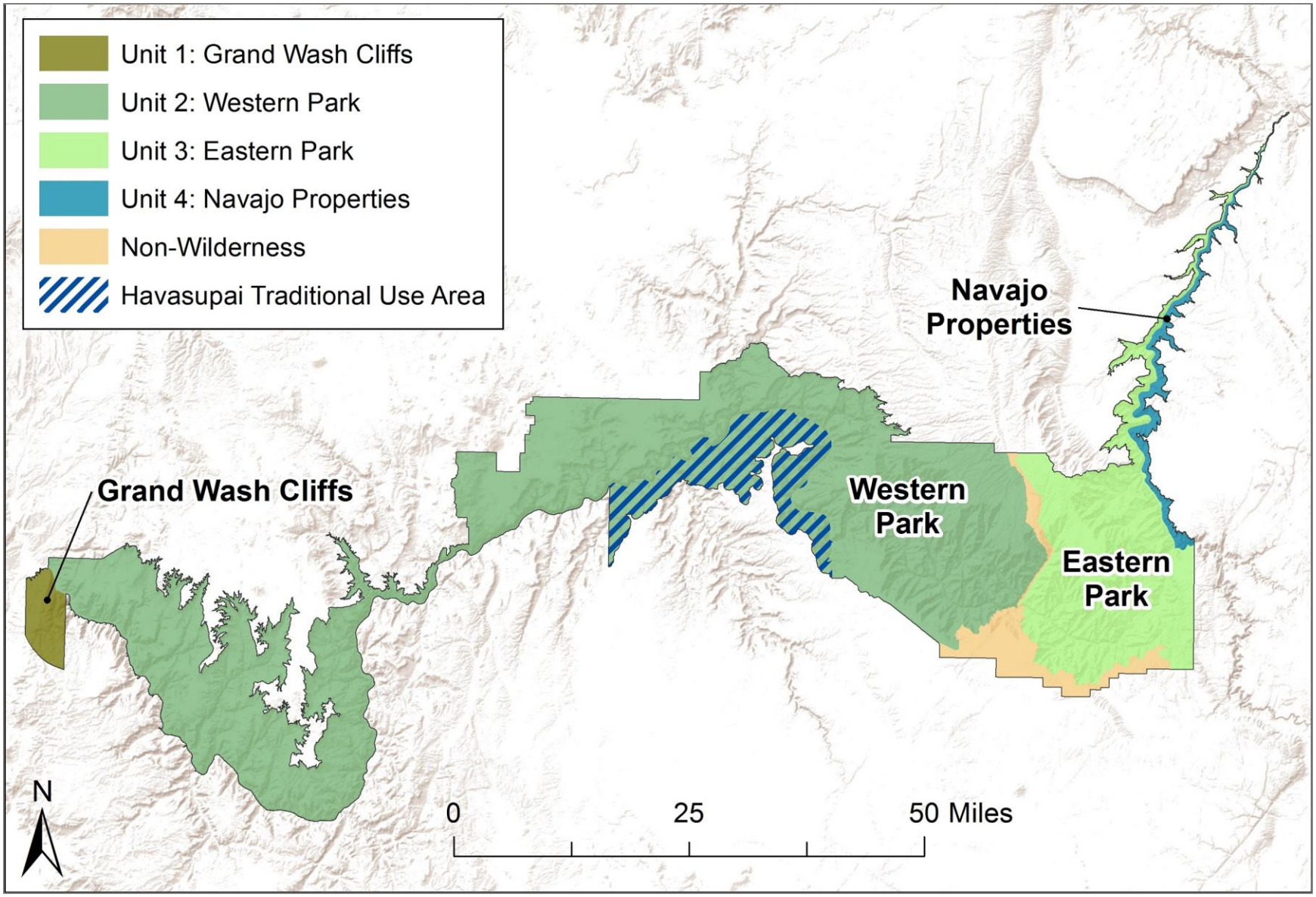


Figure 4. Map of Grand Canyon proposed wilderness units.

Unit 2, Western Park

This large unit comprises 868,635 acres west of the North and South rims developed areas. Many of the natural and geographic wonders of the Grand Canyon are represented here. Within it, the Curtis-Lee Tracts (67 acres) and 6,646 acres / 151.2 miles of the Colorado River corridor from 0.1 mile below Silver Bridge (River Mile (RM) 88.6) to Separation Canyon (RM 239.8) are identified as proposed potential wilderness. Primitive access roads for trailheads and other attractions in Toroweap Valley (9.5 miles), the Kanab Plateau (20.3 miles), the Kaibab Plateau (36.1 miles), and the Coconino Plateau (27.7 miles) include 300-feet non-wilderness corridors. Proposed wilderness in the Western Park Unit also includes the Havasupai Traditional Use Lands. Excluded from the wilderness proposal are nearly 8,500 acres south of Pasture Wash and around the Great Thumb to allow tribal members mechanized access to reservation lands and to allow access to the 140-mile Trailhead.

Havasupai Traditional Use Lands

The 1975 Grand Canyon Enlargement Act (16 U.S.C. § 228) required the return of 83,800 acres of NPS land to the Havasupai Tribe, increasing the size of the tribe's reservation to approximately 185,000 acres. The act also provided for an additional 95,700 acres as "Havasupai Traditional Use Lands" within the park to be used by members of the tribe for "traditional purposes, including religious purposes and the gathering of, or hunting for, wild or native foods, materials for paints and medicines . . . for agricultural and grazing purposes, subject to the ability of such lands to sustain such use as determined by the Secretary." Congressional intent to include these lands within the Wilderness Recommendation was explicit. Section 10(b) states: "The lands hereby transferred to the tribe shall remain forever wild and no uses shall be permitted under the plan which detract from the existing scenic and natural values of such lands." The 1980 Wilderness Recommendation proposed the 95,700-acre Havasupai Traditional Use Lands as a potential wilderness addition, pending the outcome of a range capacity and terrestrial ecosystem study. That study was completed in 1982 and concluded that grazing by livestock would be damaging to the environment. Subsequent Wilderness Recommendations have identified these lands as proposed wilderness (NPS 1993 and 2010).

Unit 3, Eastern Park

The Eastern Park Unit includes Marble Canyon, the North Rim east of Highway 67, and the inner canyon east of the crosscanyon corridor. Within this unit are the numerous plateaus, summits, and other colorful features that add to the beauty of Grand Canyon seen by most visitors from the rim. Also included are the Palisades of the Desert and adjacent rim lands. Potential wilderness additions to this unit consist of the 325-acre Hearst Inholding above Sockdologer Rapid, as well as 4,352 acres / 82.1 miles of the Colorado River corridor from 0.1 mile below Navajo Bridge (RM 4.6) to 0.5 mile upstream of the confluence with Bright Angel Creek (RM 87.7). Areas excluded from proposed wilderness include: 280 acres upstream of Navajo Bridge and paved road corridors (600-feet wide) to Point Imperial and Cape Royal (22.3 miles).

Unit 4, Navajo Indian Properties

This area comprises the eastern side of Marble Canyon and is a narrow strip of land between the Colorado River and the park boundary, north of the Little Colorado River. These lands include a 15,153-acre inholding, consisting of all lands generally west of the Marble Canyon Rim (the legal

boundary of the park as specified by the 1975 Enlargement Act) and east of the authorized NPS boundary located one-quarter mile from the east bank of the river.

The Eastern Park Unit as seen from Desert View (NPS/MICHAEL QUINN).

Wilderness Character Narrative

A Wilderness Character Narrative is a qualitative and holistic description of what makes a particular wilderness unique and special (Landres et al. 2015). It is a foundational document intended to identify fundamental wilderness resources, determine wilderness threats, and acknowledge important intangible values associated with the wilderness. A well-crafted Wilderness Character Narrative complements and enhances the quantitative Wilderness Character Monitoring Baseline Assessment.

Introduction

> "The wonders of the Grand Canyon cannot be adequately represented in symbols of speech, nor by speech itself. The resources of the graphic art are taxed beyond their powers in attempting to portray its features. Language and illustration combined must fail. The elements that unite to make the Grand Canyon the most sublime spectacle in nature are multifarious and exceedingly diverse." – John Wesley Powell, *The Exploration of the Colorado River and its Canyons*

Grand Canyon, a wild treasure of the American West, is one of the planet's most iconic landscapes. During the last six million years, water and wind have carved Grand Canyon (Ranney 2005); these same erosional and tectonic processes shape the canyon today. Grand Canyon's exposed geologic layers span nearly half of Earth's history and record environments from erupting volcanoes to quiet seas. Grand Canyon, with its immense size, dramatic and colorful geologic record exposures, and complex geologic history, is one of world's most scenic and scientifically valued landscapes.

Being one of the largest undeveloped areas in the United States, the Grand Canyon wilderness is a sanctuary for life that contains a remarkable array of natural communities. Much of this diversity can be attributed to the park's dramatic topography. Extremes of elevation provide microhabitats for natural processes supporting rare and endemic species. Water in hundreds of springs, ephemeral pools, unaltered creeks, and the Colorado River provides life with the opportunity to flourish in this otherwise arid environment. Local snowmelt, moving on the surface or via contorted underground channels, creates sustaining pockets supporting unique species assemblages. The canyon is a living laboratory for scientific research in numerous fields that contribute greatly to understanding the relationship between biotic communities and their abiotic environments.

Human cultures and the canyon have been shaping each other for over 12,000 years. The canyon is an important homeland for native peoples and a place of historic Euro-American exploration and discovery. Today those relationships continue. The cultures of American Indian tribes are intermingled with the landscapes, and outdoor recreationists from around the world seek out the challenges, inspirations, and life-altering experiences that the Grand Canyon wilderness provides.

This narrative is intended to capture these feelings, experiences, and relationships. The narrative is organized around the five qualities of wilderness character, grounding it in the statutory language of the 1964 Wilderness Act. Subsequent sections describe the self-willed elements that are free from human control, ecological processes that have shaped the landscape, visitor experiences that may not be available elsewhere, the undeveloped character and rugged topography, and notable scientific, educational, scenic, and cultural values of the Grand Canyon wilderness.

Untrammeled Quality

Wilderness is essentially unhindered and free from modern human actions that control or manipulate the community of life.

Weathered mesas, lofty plateaus, majestic temples, craggy peaks – the persistent and unstoppable forces of erosion are ubiquitous in the Grand Canyon wilderness. From the howling spring winds to the serene winter silence, the Grand Canyon wilderness is a landscape of variation and volatility. Summer monsoons materialize rapidly and unpredictably, unleashing torrents of rain that saturate vegetation and biological soil crust in minutes. Flash floods send earthen brown water careening through arroyos and cutting channels ever-deeper into the alluvial slope. With graceful power, water is the incontestable architect of this arid landscape. The canyon itself, a twisting 277-mile-long gorge, was carved out of the rock during six million years of erosion by the Colorado River and its tributaries (Ranney 2005).

Human hands have also played a role in sculpting the Grand Canyon landscape, though one far more subtle. Throughout the modern-day wilderness, a patient study of the archaeological record reveals a 12,000 year-old relationship between humans and the Grand Canyon. Sizeable portions of the modern-day wilderness were farmed and lived in, and the effects of native peoples on the landscape can still be seen in abandoned water diversion features for agricultural fields and small-scale erosion-control (Fairley et al. 1994; Davis et al. 2000). While ancient peoples altered the landscape and its natural processes in several ways, these manipulations are difficult to discern today, and do not seem to significantly impact modern-day natural processes or plants and animals.

European exploration of the region began in the 16th century and expanded in the 18th century with visits by Spanish missionaries. In the decades after the Mexican-American War, federal explorers and military in the Southwest located transportation routes and identified natural resources. It was during this time that pioneers, following new east-west wagon roads, approached the rim of the Grand Canyon. The Atlantic & Pacific Railroad's arrival in the Southwest accelerated this settlement, opening the region to entrepreneurs who initially invested in traditional economic ventures, such as mining, logging, and ranching. However, the canyon itself produced nothing but headaches for cowboys, shepherds, and miners, prompting some of them to turn to tourism as a commercial enterprise. The early 20th century saw an increase in tourism, which led to growing awareness of the significance of the Grand Canyon's resources, as well as a movement to protect them.

Unfavorable reports of explorations in and around Grand Canyon, along with difficulties of transport, native peoples' persistence, and the absence of a regional labor pool, accounted for the reluctance of eastern entrepreneurs to penetrate the region, thus leaving vast swaths of land in an undeveloped state. It also bought time for early preservations to rally in support of protecting this natural wonder. Towering stands of ponderosa pine on both rims were withdrawn from logging in 1893, when President Harrison set aside the Grand Canyon Forest Reserve. The expansion of the reserve by President Roosevelt in 1905 ended settlement and most logging in the area that would become the park. The creation of Grand Canyon National Park 14 years later completely halted all timber harvests, preserving until this day one of the nation's largest and best examples of a ponderosa pine climax community.

The government also took steps to ensure that the park was protected from future mineral extraction. By 1931, with the passage of 46 Stat. 1043, the park was closed to new mineral entry claims (Billingsley et al. 1997; Anderson et al. 1998). Previously established claims both within the park and on public lands outside the park remained active. Orphan Mine, where mining activity ceased in 1969, was the last mine to close within the wilderness. Since then, no mines have been actively worked on within the modern boundaries of the park. Abandoned adits, shafts, and weathered tailings piles exist in a few areas in the wilderness, preserving the history of mining in Grand Canyon.

In the 20th century, expanding settlement and cultivation of the arid West made it apparent that the most precious resource in this region is neither lumber nor gold nor uranium, but water. The Colorado River in particular is a remarkable and life-nurturing feature in a land of so little water, and thus quickly attracted the attention of settlers, politicians, engineers, and preservationists alike. To solve the growing water shortage, dams were proposed to create reservoirs. Immediately upstream on the Colorado from Grand Canyon, Glen Canyon was a lesser-known region of incredible beauty and wildness extending over a hundred miles. In 1956, the Colorado River Storage Project approved the Glen Canyon Dam, inundating one of the wild treasures of the American West over the next decade.

The Grand Canyon wilderness would have suffered a similar fate had it not been for strong public opposition. The proposed Bridge Canyon and Marble Canyon dams would have flooded sizeable portions of Grand Canyon and 90% of the Colorado River would have been diverted from its normal course. A 20-year struggle ensued over whether to build dams in the Grand Canyon, with preservationists ultimately coming out victorious. The Colorado River Basin Project Act of 1968 (82 Stat. 890) specifically prohibited dams on the Colorado River between the Hoover and Glen Canyon dams. On January 3, 1975, Congress enlarged Grand Canyon National Park, including within its boundaries 277 miles of free-flowing river.

In addition to protecting the longest undammed stretch of the Colorado River, the Grand Canyon wilderness also contains some of the least trammeled tributaries and springs in the entire Southwest (Zaimes et al. 2007; Barnes 2013). In fact, the Colorado River and selected tributaries in the park potentially meet the criteria for designation under the Wild and Scenic Rivers Act (16 U.S.C. 1271 et seq.; NPS 1995; Barnes et al. 2005). Inclusion in the National Wild and Scenic River System would further protect the free-flowing character of the Colorado River and its tributaries in the Grand Canyon and further highlight their outstanding natural, cultural, and recreational values.

Modern-day, NPS authorized trammeling actions sometimes occur within the Grand Canyon wilderness and are predominantly carried out with the intention of improving the Natural Quality. For example, to return populations of the endangered humpback chub, the park has removed exotic predatory fish from Bright Angel, Havasu, and Shinumo creeks and translocated chub to Havasu and Shinumo creeks. Similarly, critically endangered California Condors are released in Vermilion Cliffs National Monument adjacent to the park and treated for lead poisoning in efforts to stabilize the sensitive population. Research projects aimed at protecting sensitive species sometimes involve collaring, tagging, and/or blood sampling wildlife, such as bighorn sheep, mountain lions, and bats.

Crystal Rapid (NPS/KRISTEN MCALDON).

Under the Grand Canyon Protection Act of 1992 (42 U.S.C. § 4321 et seq.), managers have conducted high-flow experimental releases from Glen Canyon Dam to mimic natural, pre-dam fluctuation in river flow and offset detrimental effects from dam operations. These controlled floods seek to restore downstream resources by rebuilding eroded beaches and creating new backwaters for native fish (Schmidt et al. 2001; Gloss et al. 2005; Melis 2011). To disadvantage the non-native tamarisk in riparian habitats, resource managers have also carried out several restoration projects, removing tamarisk trees and outplanting native species along the banks of the Colorado River and its tributaries (NPS 2009; Belote et al. 2010).

To reintroduce fire as an ecological process and mimic natural fire events, prescribed fires are implemented in forested areas above the rim. Over a century of wildland fire suppression has altered the natural fire regime in these woodland communities. Vegetation changes caused by past fire suppression have generally increased live and dead fuel loading, creating potentially hazardous arrangement of close standing, burnable vegetation, or ladder fuel. Ladder fuel helps fires ascend taller forest trees, increasing risk of higher intensity crown fires. If subjected to crown fire, large forest landscapes may be converted to shrub communities, watershed and soil processes can be impacted, and other ecosystem values altered.

The current Fire Management Plan (NPS 2012) recognizes wilderness character as part of the policy guiding fire management activities. Operational guidance directs the completion of the minimum

requirement analysis (MRA) process to ensure management actions chosen to have the least possible impact. Fire management also is based on the best currently available science, recognizing the ecological benefits of naturally occurring fires to Grand Canyon's fire-adapted plant communities. Ponderosa pine forests, for example, require regular, low intensity fires in order to thrive (Huffman et al. 2008). Over the past four decades, fire managers have been able to increase the opportunities to manage naturally ignited wildfires without suppressing them. Managers also use prescribed fire to restore the fire regime to a state that natural fire would be allowed to exist on the landscape without detrimental effects. Some suppression efforts will have to continue into the future until these prescribed fire treatments have met fuel reduction objectives. The overall goal of the fire management plan is to eventually allow fire to play its natural role with little human intervention, thus benefiting the Untrammeled Quality in the years to come.

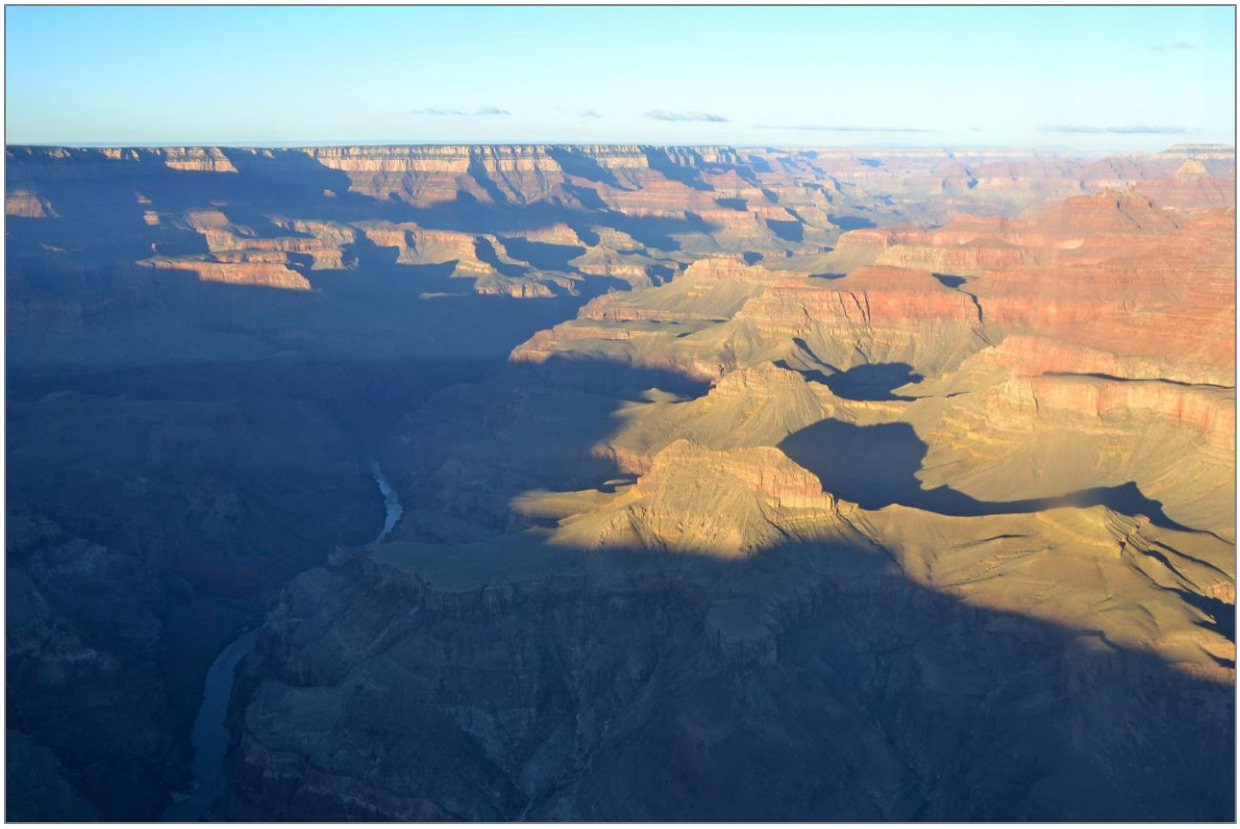
Unauthorized trammeling actions are few and far between, though they could be more common than documented, as park staff cannot be aware of all actions taking place in a wilderness as vast as Grand Canyon. One notable example includes the release of the tamarisk leaf beetle as a biological control agent in a limited area of the western U.S. in 2001 to help manage invasive tamarisk infestations. It was not approved for release within 200 miles of endangered southwestern willow flycatcher habitat, but it migrated further than anticipated, and spread to Grand Canyon (Tamarisk Coalition 2018).

Trespass livestock and bison from adjacent public and tribal lands also create unauthorized trammeling impacts. Cattle enter the park when fences go down and degrade vegetation, soil, and water resources. Hybrid bison from a State of Arizona herd entered the North Rim when Arizona managers curtailed feeding and fence maintenance and hunting pressure caused them to move. The high meadow and wooded habitats cannot support their grazing, and fragile cultural resource sites are rapidly degraded by trampling and wallowing (NPS 2015a). NPS is planning to reduce the size of the herd to fewer than 200 through capture and relocation and lethal culling over the next three to five years (NPS 2017a). Reducing the herd size will protect the Natural Quality of the Grand Canyon wilderness but is an authorized trammeling action because mangers will intentionally manipulate the community of life. This scenario highlights the dilemma wilderness managers are regularly confronted with when balancing the need for natural resource protection with the guiding principle that wilderness should be primarily affected by the forces of nature. It is also an example demonstrating that unauthorized trammeling may at times necessitate authorized trammeling in order to preserve the integrity of a wilderness area, thus making it all the more important to prevent unauthorized trammeling as much as possible.

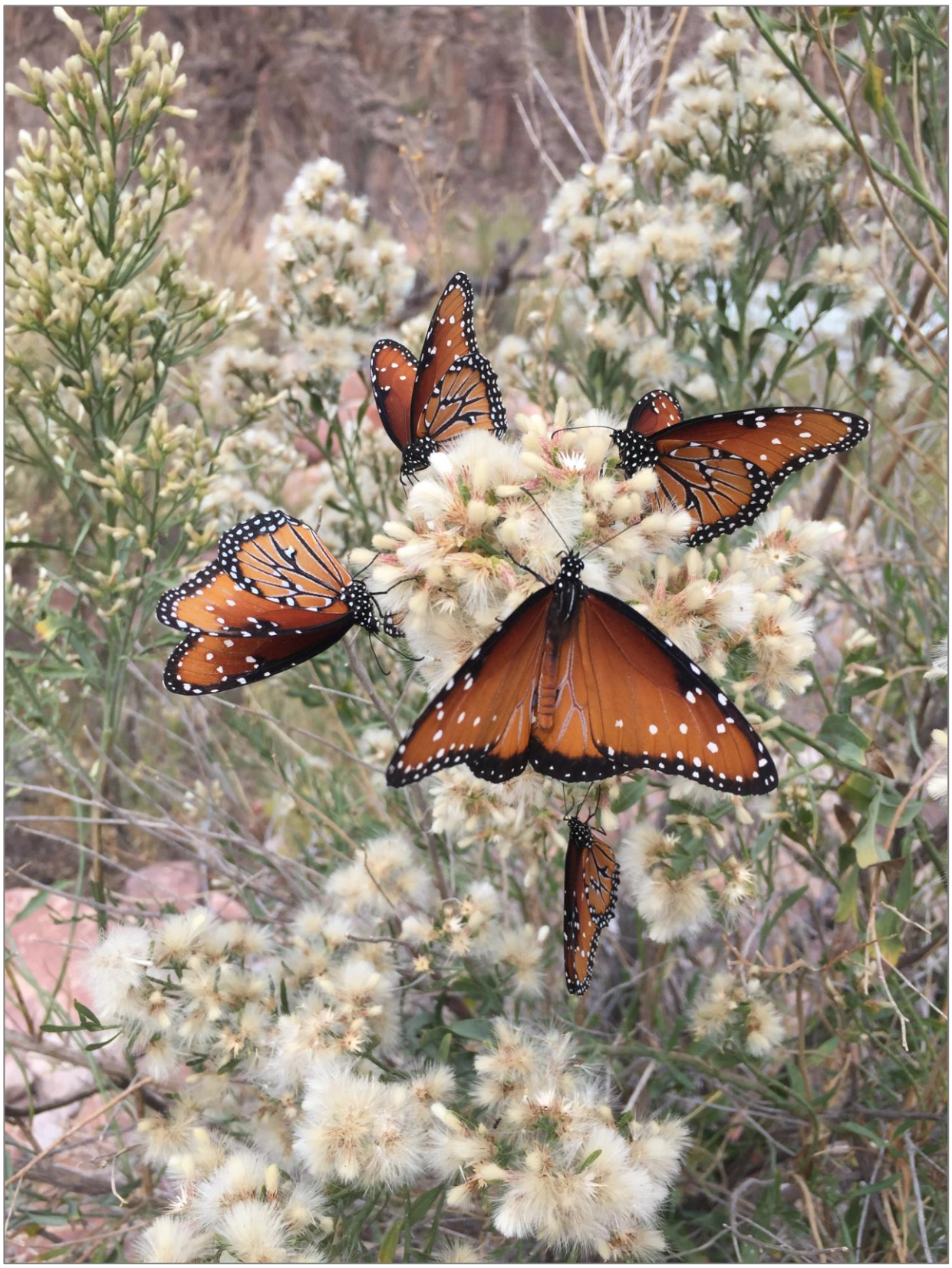
In summary, the Grand Canyon wilderness remains one of the most self-willed, untrammeled landscapes in the continental United States. Ruggedness, inaccessibility, and exposure to the elements rendered many early mining, grazing, and logging attempts unprofitable. Due to its vastness and remoteness, the Grand Canyon wilderness constitutes a sanctuary for life, containing remnants of dwindling ecosystems such as boreal forest and desert riparian communities, and a multitude of plants, animals, and fish – some of which are found nowhere else on Earth. In this ecological refuge, there is a wedding of geology and life forms that, on a human time scale, appear solid, stable, and unchanging. Yet, this sense of permanence is far from reality. Continuous change sculpts the physical

environment – uplift and erosion, volcanism, and the interaction of climate with the varied topography. The Grand Canyon wilderness is a clear testament to the raw and untamable power held by Mother Nature. It is a humbling and majestic landscape. It also a landscape that must be protected.

As vast as it is, the Grand Canyon wilderness is part of the larger landscape of the southwestern United States, a mosaic of state and federal lands, rural communities, tribal lands, and metropolitan areas. As such, the seemingly well protected incised canyons downstream or downwind remain vulnerable to activities that occur on the surrounding landscape, including livestock grazing, uranium mining, power generation, air pollution from vehicle emissions and distant cities, and river regulation and groundwater development. As climate change progresses, ecological processes are expected to further deviate from ranges of natural variation. These changing environmental conditions emphasize that "restraint is the core of the new valuation of wilderness as a moral resource. When we protect wilderness we deliberately withhold our power to change the landscape" (Nash 2004). Therefore, the MRA process should continue to be employed to evaluate each NPS-management decision impacting wilderness. If the Untrammeled Quality is diminished, benefits to other aspects of wilderness character should clearly outweigh costs of trammeling. Restraint and humility are key principles that truly set wilderness apart from all other public lands. As succinctly stated by Howard Zahniser (1992), "We must remember always that the essential quality of the wilderness is its wildness."



Aerial photograph of the Colorado River and Solomon Temple (NPS).



Queen butterflies pollinating arrow weed near Granite Rapid (NPS/TOBIAS NICKEL).

Natural Quality

Wilderness maintains ecological systems that are substantially free from the effects of modern civilization.

The park's diverse natural resources begin with the Grand Canyon itself, a geologic wonder of astounding natural beauty. Over the last six million years, the Colorado River sculpted the Colorado Plateau's southern edge creating Grand Canyon and revealing rock layers in beautiful sequence that serve as windows into time (Ranney 2005). Rocks exposed in Grand Canyon range from 1,840 to 270 million years in age, encompassing three eras of geologic time (Paleozoic, Mesozoic, and Cenozoic) and the Precambrian. The Grand Canyon wilderness also preserves a superb fossil record. Algal mats and bacterial spores over 1,200 million years old and soft-tissue subfossils from late Pleistocene fauna (about 11,000 years old) testify to a broad range of ancient landscapes. Studying the fossils and rock formations of Grand Canyon offers the unique opportunity to read the biography of the planet and marvel at the forces of nature that have shaped the terrain. Contemplating the history recorded in these rocks sparks an undeniable sense of humility and smallness in the observer, but perhaps also generates a feeling of liberation and transcendence.

Besides being a geologic wonder, the Grand Canyon wilderness possesses outstanding biological diversity that includes the flora and fauna of all four North American major deserts (the Great Basin, Sonoran, Mojave, and Chihuahuan; Stortz et al. *in review*). Extreme changes in elevation, exposure, and climate in Grand Canyon support a wide range of habitats in unusual proximity. Traversing from rim to river, one not only retraces the planet's history recorded in the stratified rock but encounters five of Merriam's seven life zones (the Lower Sonoran, Upper Sonoran, Transition, Canadian, and Hudsonian life zones), the ecological equivalent of traveling from Mexico to Canada (NPS 2017).

The vegetation of Grand Canyon consists largely of intact, functioning native plant communities that vary from cool, moist subalpine forests and meadows between 8,000 and 9,000 feet to hot, dry deserts at elevations as low as 1,200 feet (Kearsley et al. 2015). The wilderness contains six vegetation zones: riparian, desert shrub, pinyon-juniper woodland, ponderosa pine forest, spruce/fir forest, and mountain meadows in the sub-alpine zone (NPS 2017). A wide range of microhabitats are known to support at least 1,732 vascular plant species, 64 moss species, 195 lichen species, and 167 fungi species (NPS 2018f). There are several plant species that are endemic to the wilderness, while only about 11% of the flora is exotic (NPS 2009). The diversity and beauty of the canyon's vegetation is astounding, from the sparse desert plants that defy a seemingly inhospitable, arid climate to lush flora and hanging gardens near springs and riparian areas along the Colorado River and its tributaries, and all the way to the high-elevation forests and subalpine grasslands.

Extensive portions of the canyon are covered by biological soil crusts, which create a more favorable environment for vascular plants to germinate under arid conditions (Darby et al. 2010). Biological soil crusts are communities of living organisms composed of cyanobacteria, fungi, lichens, mosses, and algae in varying proportions (Belnap and Lange 2001). These soils play important roles in reducing soil erosion, increasing water conservation and in promoting nitrogen fixation (Darby et al. 2010). However, they are highly fragile and vulnerable to the impacts of recreational use and air pollution. Due to the relatively clean air and remote and rugged nature of most of the park, soils

remain in generally good condition. In areas with high human use, impacts on biological soil crusts are significant, as these crusts are highly susceptible to trampling and require long time periods to recover composition and function (Cole 1990).

The Grand Canyon wilderness also serves as a valuable wildlife refuge due to the immense primitive areas, the topographic character, and the relatively unfragmented landscape. The park provides important habitat for at least 91 mammals, including mule deer, desert bighorn sheep, mountain lion, coyote, bobcat, and 22 species of bats, as well as 58 reptile and amphibian species, over two dozen fish species, and thousands of different invertebrates (NPS 2018f). With over 350 bird species and its riparian habitat valuable to avifauna, the entire Grand Canyon National Park has been designated as a Globally Important Bird Area (National Audubon Society 2018). Additionally, there are numerous endemic animal species known only to exist in the park (NPS 2017), and there are likely many more – particularly endemic cave-adapted species – yet to be identified.

Mountain Lion (NPS).

While some species are yet to be discovered, some of the canyon's biodiversity is imperiled by human activity. Currently, the Grand Canyon wilderness provides an ecological refuge for several species listed under the federal Endangered Species Act (16 U.S.C. § 1531 et seq.) including, but not limited to, the Mexican spotted owl, southwestern willow flycatcher, razorback sucker, and humpback chub (NPS 2017). Other species recognized as sensitive/special status species include nine species of bats, desert bighorn sheep, northern goshawk, peregrine falcon, flannelmouth sucker, bluehead sucker, and bald and golden eagles. While human disturbance, transportation infrastructure, and development threaten these species on surrounding lands, the Grand Canyon wilderness provides

high-quality habitat, allowing these species to thrive and survive. Prior to the protections granted by wilderness status, at least nine wildlife species were extirpated from the region, including the grizzly bear, gray wolf, black-footed ferret, jaguar, Colorado pikeminnow, bonytail, roundtail chub, northern leopard frog, and southwestern river otter (NPS 2017). These local extinctions remind land managers to practice restraint and respect the community of life.

Efforts to be better stewards of the environment have protected the California condor. Extinction loomed for this species when its total population had dwindled to just 22 birds in 1982 (The Peregrine Fund 2018). Since 1996, condors raised in captivity are released annually into Vermilion Cliffs National Monument adjacent to the park. California condors have been successfully nesting within the park and have once again become much-appreciated inhabitants of the Grand Canyon wilderness. Although California condor recovery has come a far way, these animals still face significant ongoing human-caused threats and remain a conservation-dependent species. Lead poisoning through ingestion of spent lead bullets continues to be the leading cause of mortality of these scavengers in the wild (Walters et al. 2010; Johnson et al. 2013).

Much of the astounding biological diversity depends on Grand Canyon's tributaries and springs, which represent some of the least altered water resources in the Southwest (Zaimes et al. 2007; Barnes 2013). These waters support rare desert riparian ecosystems, which have disproportionately high value for their limited spatial extent and nurture a high percentage of the park's plants and animals (Webb et al. 2007; Zaimes et al. 2007; Barnes 2013). Riparian areas represent roughly 1% of the park's total area, but they support more than 20% of native plant species and provide habitat for more than 80% of wildlife species recorded in the park (Stevens et al. 1999; Kearsley et al. 2015). In light of the fact that 90% of riparian areas in Arizona have been degraded or destroyed, Grand Canyon's largely intact riparian areas are especially valuable (Zaimes et al. 2007; Barnes 2013). Inclusion in the National Wild and Scenic River System would further protect these tributaries and highlight their outstanding natural, cultural, and recreational values.

Feeding these surface waters is the second largest area of karst limestone bedrock of any national park unit (Weary and Doctor 2014). Contained in this dissolved bedrock is a complex groundwater system. Water travels through fractures in the rocks, sometimes emerging at the surface in the form of springs and streams that nurture life in the canyon. Based on isotope analysis, some of the water discharging at these springs has been determined to be over 3,000 years old (Monroe et al. 2005). The groundwater protected underneath the Grand Canyon wilderness is a scarce and critical, but often unseen, resource in the surrounding desert landscape. It is also imperiled. As the area becomes even warmer and drier (IPCC 2013; Kunkel et al. 2013), precipitation and subsequent aquifer recharge will likely decline. At the same time, population in the region is projected to increase, leading to unmet water demands before 2050 (USBR 2012). If regional groundwater withdrawal exceeds recharge for an extended period of time, groundwater depletion will result in declining water tables and dried out aquifers, threatening the stream and spring habitats so important to life in the canyon (Galloway et al. 1998; Konikow and Kendy 2005).

Modred Creek (NPS).

Grand Canyon's water resources remain intact partially due to the fact that no new mineral claims have been permitted in the park in over 80 years. Despite its spectacular display of geologic riches,

the true worth of these minerals lies in their scenic, scientific, and educational values. Leaving these deposits in the ground not only ensures that they may be marveled at by future generations, it also prevents the environmental impacts that accompany resource extraction. Because surrounding lands are not subject to the same laws and policies as wilderness lands, water resources inside the Grand Canyon wilderness are potentially threatened by regional mining activity. Thousands of uranium and other claims on public lands around the park (NPCA 2010, Stortz et al. *in review*) may cause degradation of water quality through elevation of heavy metal concentrations beyond natural background levels (Beisner et al. 2017). Many claims are clustered above aquifers that feed tributaries and springs inside the wilderness, and mobilization of toxic metals from weathering of tailings piles could threaten aquatic life and human health. The current 20-year ban on new uranium claims on public lands adjacent to the park (BLM 2011) remains controversial and may be lifted.

The Grand Canyon wilderness contains some of the nation's cleanest air, protected as a Class 1 Airshed by the Clean Air Act (42 U.S.C. § 7401 et seq.). Clean air allows for expansive vistas that are an important component of the Grand Canyon wilderness. Visitors to the South Rim can see across the 12 miles to the Walhalla Plateau and Walla Valley and as far as the Painted Desert. It is also not unusual to be able to see from the North Rim to the San Francisco Peaks 60 miles to the south. The grandeur, however is marred when haze from copper smelters, urban development, dust, vehicle exhaust, and agriculture travel over long distances from industrial and metropolitan sources hundreds of miles away (Eatough et al. 1997; Green 1999; Eatough et al. 2001). The average natural visual range at Grand Canyon has been reduced from about 170 miles (without the effects of pollution) to about 144 miles (IMPROVE 2016). On high pollution days, the visual range has been reduced from 120 miles to below 95 miles. The Navajo and Four Corners coal-fired power plants are major regional sources of nitrogen oxides and fine particulate matter that contribute to the haze (NPCA 2010; Arizona State University 2012). The Navajo plant is scheduled for decommissioning in 2019 (Frisch 2017), which may improve regional air quality in the future.

Climate change will impact nearly every aspect of natural systems in the Grand Canyon wilderness. By 2050, temperatures in the Southwest are predicted to rise as much as 3°C, and extreme temperatures may be more severe and more frequent (Seager et al. 2007; IPCC 2013; Kunkel et al. 2013). Predicted higher temperatures, reduced snowpack, and longer droughts are expected to increase wildfire potential (Fisichelli 2013). Greater variability in rainfall is expected to lead to increased flash flooding, hill slope erosion, and debris flow initiation (Griffiths et al. 2004). Upward shifts of species distributions will allow invasive exotic species to proliferate (Ikeda et al. 2014) and lead to unpredictable shifts in native communities (Walther et al. 2002). Arid environments like the Grand Canyon wilderness are particularly sensitive to climate change and drought, as many species in these regions already live at the natural limits of their range (Monahan and Fisichelli 2014). Even subtle changes in these environments can cause catastrophic alterations in the abundance, distribution, and composition of biotic communities (Loehman 2010). Some species and habitats may even become extirpated from the wilderness (Rehfeldt et al. 2012).

The issue of climate change makes it apparent that the act of drawing boundaries alone is insufficient to protect wilderness character. The Grand Canyon wilderness does not exist in a vacuum. Its

stunning natural beauty and biological diversity is interconnected with the expanding settlement and growing mechanization of the civilization that surrounds it. Therefore, an earnest attempt to safeguard these wilderness areas for future generations begins long before and continues long after setting foot in wilderness.

Beavertail Cactus (NPS/MICHAEL QUINN).

Undeveloped Quality

Wilderness retains its primeval character and influence, and is essentially without permanent improvements or modern human occupation.

The landscape of the Grand Canyon wilderness flows continuously, responding to stratigraphic, volcanic, and erosional forces. There are few straight lines and right angles symptomatic of the human touch. Climate and topography have repeatedly compelled miners and other developers to shift from extracting resources in mines to extracting dollars from tourist pockets. As a result, the Grand Canyon wilderness is in many ways as primeval as it was in ancient times. When combined with adjacent public and tribal lands, this area comprises one of the largest undeveloped areas in the contiguous United States.

Nearly all of the structures, signs, roads, and other developments in the park are concentrated in the 6% of the park outside of proposed wilderness. Remnants of historic mining attempts are few and far between in the wilderness, telling stories of early pioneer life and of efforts to carve a living from the canyon walls. Metal gates have been installed at the entrance of several abandoned mineshafts and caves for resource protection and visitor safety. A few historic fire towers and cabins are also present in wilderness, preserving the legacy of early federal administration. Overall, this is a landscape where nature reigns supreme, where the land has retained its primeval character, and where the imprint of modern civilization is substantially unnoticeable.

Modern-day, NPS-authorized installations in wilderness areas are primarily scientific monitoring equipment, wildlife cameras and collars, trail counters, and other instruments. Because NPS policy dictates that any development in wilderness be subject to an MRA, they are mostly subtle, temporary and placed in such a way as to blend in with the surrounding environment. Researchers and managers comply, for the most part, and these items are usually removed when their projects end.

The river at the heart of the Grand Canyon wilderness affords a remarkable 277-mile experience of unmechanized solitude for six months of the year. This unbroken stretch of river remains free of impoundments and is accessible only by trail in some places, with its shorelines for the most part as primitive and rugged as in the days of John Wesley Powell. Rafting down the river is an exceptional wilderness experience, combining thrilling whitewater adventure and magnificent vistas of a remarkable geologic landscape including remote and intimate side canyons. Following in the footsteps of early explorers like Powell, a human-powered raft trip down the Colorado River of the Grand Canyon encapsulates the great promise made to the American people by the Wilderness Act of 1964. The compromise struck over motorized river travel also represents the ability of the American political system to accommodate seemingly conflicting ideas concerning wilderness and its uses, lighting a way for wilderness and civilization to co-exist.

The remoteness and topography of Grand Canyon have made roads rare. Since the first wilderness study, over two hundred miles of road have been abandoned (NPS 2010). At the present time, non-wilderness corridors surround 14 primitive and three paved roads passing through wilderness. The presence of road corridors is associated with environmental issues, such as habitat fragmentation, invasive species proliferation, looting of cultural resources, and illegal hunting.

The lack of roads and rugged topography sometimes necessitate the use of aircraft for administratively approved purposes, such as search and rescue (SAR), scientific study, fire- and resource management, and facility maintenance. Each administrative flight into wilderness, except for SAR and emergency, is subject to an MRA. As a result, landings and take-offs of helicopters are a rare occurrence, especially considering the vastness of the Grand Canyon wilderness.

The lack of inholdings within the wilderness boundaries is also remarkable. Currently, only three inholdings remain within Grand Canyon National Park, totaling just over 1% (15,545 acres) of the park's area (see pp. 88-89). The Navajo inholding, however, is of concern from a wilderness preservation standpoint. Confluence Partners LLC proposed the development of a "Grand Canyon Escalade" above the confluence of the Colorado and Little Colorado rivers. A 1.4-mile tramway

would shuttle 10,000 visitors a day to the bottom of Grand Canyon and feature an elevated walkway and amphitheater below the rim, as well as a hotel, restaurant, RV center, and other resort attractions above the rim (Grand Canyon Trust 2018). The NPS and several Traditionally Associated Tribes have opposed the project. Legislation to approve the master agreement for the project was rejected by the Navajo Nation Council on October 31, 2017. The looming possibility of a similar type development highlights the threat that inholdings can pose to wilderness areas.

Historic Signal Hill Fire Tower (NPS).

Solitude or Primitive and Unconfined Recreation Quality

Wilderness provides outstanding opportunities for solitude or primitive and unconfined recreation.

Grand Canyon's expansive wilderness provides outstanding opportunities for experiencing solitude in remote areas of the park. These unspoiled reaches of wilderness provide an arena where wilderness purists can find tranquility and escape reminders of mechanized society, and where individuals can be truly alone in the enormity of the natural world. The scale of the Grand Canyon sparks an undeniable sense of self-reflection and wonder – immeasurable but fundamental aspects of wilderness character that simply cannot be quantified. There is little question – the Grand Canyon landscape speaks to something elemental and timeless in the human spirit. Immersed in this vast landscape, visitors begin to exist as something beyond their everyday cares and worries.

The night sky over Grand Canyon reveals a cascade of luminous stars and planets. These ancient constellations have shaped the arts, sciences, and ideas across the millennia. Gazing at the Milky Way from camp, thoughts of human scale, purpose, and spirituality seem compulsory. The night sky is inspiring. It is primordial. It is also imperiled. One-third of the world's population - including 80% of Americans - can no longer see the Milky Way (Falchi et al. 2016). Grand Canyon National Park is one of the remaining places in the United States where one can experience a star-filled night sky. Natural factors of high elevation and dry air, combined with the Grand Canyon's isolation from major population centers, allow the night sky to shine with uninhibited glory largely free from light pollution. As a result, the park received provisional Dark Sky Park status in June 2016 from the International Dark Sky Association. To obtain full Dark Sky Park status, the park is changing up to 60% of its light fixtures to minimize light pollution and provide a pristine viewing experience of the Milky Way. However, the main threats to night sky quality originate from outside the park due to growth of surrounding communities and light domes from distant cities (Duriscoe et al. 2015).

In addition to dark night skies, natural sounds and natural quiet have long been regarded as critical to wilderness character. During one of the most daring expeditions in pioneer history, John Wesley Powell attempted to sum up his feelings about the Grand Canyon natural soundscape in his journal:

> "It is the land of music. The river thunders in perpetual roar, swelling in floods of music when the storm Gods play upon the rocks, and fading away in soft and low murmurs when the infinite blue of heaven is unveiled. With the melody of the great tide rising and falling, swelling and vanishing forever, other melodies are heard in the gorges of the lateral canyons, while the waters plunge in the rapids among the rocks or leap in great cataracts. Thus the Grand Canyon is a land of song. Mountains of music swell in the rivers, hills of music billow in the creeks and meadows of music murmur in the rills that ripples over the rocks. Altogether it is a symphony of multitudinous melodies. All this is the music of waters. The adamant foundations of the Earth have been wrought into a sublime harp, upon which the clouds of the heavens play with mighty tempests or with gentle showers." (Powell 2003)

Unfortunately, today's visitors of the Grand Canyon wilderness will find that the natural soundscape is frequently interrupted and drowned out by human-caused, mechanically produced sounds. The presence of aircraft overflights threatens visitor opportunities for solitude. Sounds of aircraft, originating from commercial air tours, are often audible, even in in the most remote areas of the wilderness. Although tour flights provide an alternative visitor experience, they have a disproportionately broad geographic impact on wilderness. Administrative uses of aircraft and helicopters for SAR operations, scientific study, fire monitoring, trail maintenance, and other purposes also impact natural soundscapes, but are a relatively rare occurrence in wilderness.

The ability to experience and view a landscape unmarred with human presence also cultivates a sense of remoteness and solitude. Grand Canyon is internationally recognized for its scenic value and expansive vistas enabling visitors to marvel at the vastness of the landscape. Conversely, these same views also enable visitors to see human developments outside of wilderness that can temporarily shatter the feeling of remoteness and wildness. Some developments that can be seen from vantage points within wilderness include: the Grand Canyon Skywalk, Desert View Watchtower, the Mt.

Emma radio repeater, and wind turbines on the Coconino Plateau. At night, lights from developed areas on South and North Rims are visible in some parts of the wilderness (Duriscoe et al. 2015).

Grand Canyon offers world-class opportunities for adventure and primitive recreation. The Colorado River in Grand Canyon provides a unique combination of thrilling whitewater adventure and magnificent vistas of a remarkable wilderness landscape. A river trip through Grand Canyon is one of the most sought-after wilderness experiences in the world, offering a 277-mile mix of placid smooth water and turbulent whitewater. The Colorado River Management Plan (NPS 2006) preserves the true wilderness experience and solitary adventure of a human-powered raft trip in the six-months non-motorized season. In the summer with higher traffic and motorized rafts, isolation and solitude are exchanged for increased access.

Boaters running Lava Falls Rapid on the Colorado River (NPS/MARK LELLOUCH).

Other recreational opportunities in the Grand Canyon wilderness include backpacking, day hiking, climbing, and canyoneering. Relatively few maintained trails are present, leaving the majority of the expanse open to the truly primitive navigational methods of off-trail travel and route-finding. With a harsh climate and rugged physical environment, recreation here demands a high degree of self-sufficiency and endurance. Users must accept certain risks that comprise a wilderness experience and primitive methods of travel, and those who are ill-prepared may well be humbled by the landscape. Adventure in the Grand Canyon wilderness largely requires visitors to meet the environment on its own terms, with few modern facilities provided for their comfort or convenience.

Use-limits have been employed for backcountry overnights since the 1970s, and backcountry overnight use is relatively stable due to a well-established permit system. The appeal of backcountry

permits is clearly visible in the fact that demand for them often exceeds their availability. The Backcountry Management Plan (NPS 1988) emphasizes the difference in experience opportunities through zoning (Appendix B). Areas that are accessed by maintained trails starting near the developed areas are the most popular. These "Threshold" zone use areas are managed to allow relatively heavy use while protecting resources through designated campsites and composting toilets. Use areas in "Primitive" and "Wild" zones are managed for progressively more self-reliant visitors who seek greater levels of solitude. These areas generally do not have wayfinding signs, and permit only a few groups per night to minimize the frequency of seeing others. This zoning approach to visitor management leaves vast swaths of the Grand Canyon wilderness unscathed and uncrowded for those who seek solitude and a truly remote wilderness experience.

A group of hikers in the eastern portion of the wilderness (NPS).

> "You cannot see the Grand Canyon in one view, as if it were a changeless spectacle from which a curtain might be lifted, but to see it, you have to toil from month to month through its labyrinths." – John Wesley Powell, *The Exploration of the Colorado River and its Canyons*

Other Features of Value Quality

Wilderness may also contain other features of scientific, educational, scenic, or historical value.

Cultural Resources

The Grand Canyon wilderness is not just a biophysical entity; it is a cultural landscape that embodies a 12,000 year old relationship between humans and the Grand Canyon (NPS 2017). As of February 2018, 3,222 archaeological sites have been documented in the Grand Canyon wilderness. Ninety-four percent of the park has not been formally inventoried, and an estimated 50,000-60,000 sites may still await discovery (NPS 2016). There is a significant diversity in the types of archaeological resources present, including rock art, projectile points, stone tools, pottery, split-twig figurines (i.e. animal

figures fashioned from a single twig), masonry pueblos, cliff dwellings, and kivas (2017c). This vast archaeological record is a fundamental aspect of the Grand Canyon wilderness and the protection and stewardship of this resource is critical to preserving its wilderness character.

Nankoweap Granaries in Marble Canyon (NPS/MARK LELLOUCH).

The great significance of Grand Canyon's cultural heritage lies in its classic example of human adaptation to a semiarid climate. Native people found sustainable ways to thrive in an environment that most modern-day westerners would consider harsh or even inhospitable. Unique cultural adaptations made by diverse native peoples over millennia – such as establishing travel routes from river to rim, farming at 8,000 feet, and using varied microenvironments seasonally across the region – nurtured life in this rugged and arid region (NPS 2017).

These same adaptive strategies are found in neighboring tribes' historic and present-day land use, and today Grand Canyon remains an important part of the traditional homeland for the following Traditionally Associated Tribes: the Havasupai Tribe, Hopi Tribe, Hualapai Tribe, Navajo Nation, Kaibab Band of Paiute Indians, Paiute Indian Tribe of Utah, Las Vegas Tribe of Paiute Indians, Moapa Band of Paiute Indians, San Juan Southern Paiute Tribe, Yavapai-Apache Nation, and the Zuni Tribe (Figure 5). All of these groups have ancestral and spiritual ties to the canyon and recognize certain tangible and intangible properties as important to their histories. In fact, the entire canyon has been recognized as a Traditional Cultural Property (TCP) by the above-mentioned Traditionally Associated Tribes. This means the canyon is associated with the cultural practices and

beliefs of living communities, is rooted in the history of these communities, and is important to the continued cultural identity of these tribes (Parker and King 1998). In the powerful words of Leigh Kuwanwisiwma, a member of the Hopi Tribe:

> "Ancestral villages that have fallen into ruin are not dead places whose only meaning comes from scientific values. The Hopi ancestors who lived in these villages still spiritually occupy these places, and these ancestors play an integral role in the contemporary Hopi ceremonies that bring rain, fertility, and other blessings for the Hopi people and their neighbors throughout the world. *Itaakuku* –footprints – are thus part of the living legacy of the ancestors, and they play a vital role in the religious activities essential to the perpetuation of Hopi society. Shrines are places where ritual deposits are made, and because their ancestors and sacred objects were buried in ancestral villages, the Hopi people care for these places as shrines. Hopi people visiting an ancestral village feel a deep reverence for both the place and the surrounding landscape." (Kuwanwisiwma and Ferguson 2004)

To many native peoples, the Grand Canyon represents their place of origin into this world. To some, it also represents the place where their spirits come to rest after death. And for others, archaeological remains in the Canyon provide evidence for their migration from their place of origin to their present homes. In *A Zuni Corridor of Memory*, Jim Enote writes:

> "The Grand Canyon or *Chimik'yana'kya* is a place of emergence where ancestral Zunis spent time adjusting to the surface world after emerging from a place beneath the canyon. After some time at the canyon our people began a search for the middle place, which we eventually found near our present day Zuni village in Western New Mexico. If you followed the Little Colorado River upstream from its confluence at the larger Colorado River you would eventually find yourself precisely at modern day Zuni." (Enote 2009)

All Traditionally Associated Tribes believe they have been entrusted to care for the canyon and the river. As a result, these tribes have a vested interest in management of park resources as preservation of their cultural heritage. Government-to-government consultation with the Traditionally Associated Tribes provides opportunities for integration of tribal perspectives into NPS management. In accordance with NPS policy (2006a), park resource managers make an effort to involve tribes in project planning, field activities, data analysis, and interpretation to better understand their histories and relationships with Grand Canyon and to identify and protect resources and places of tribal importance in the park.

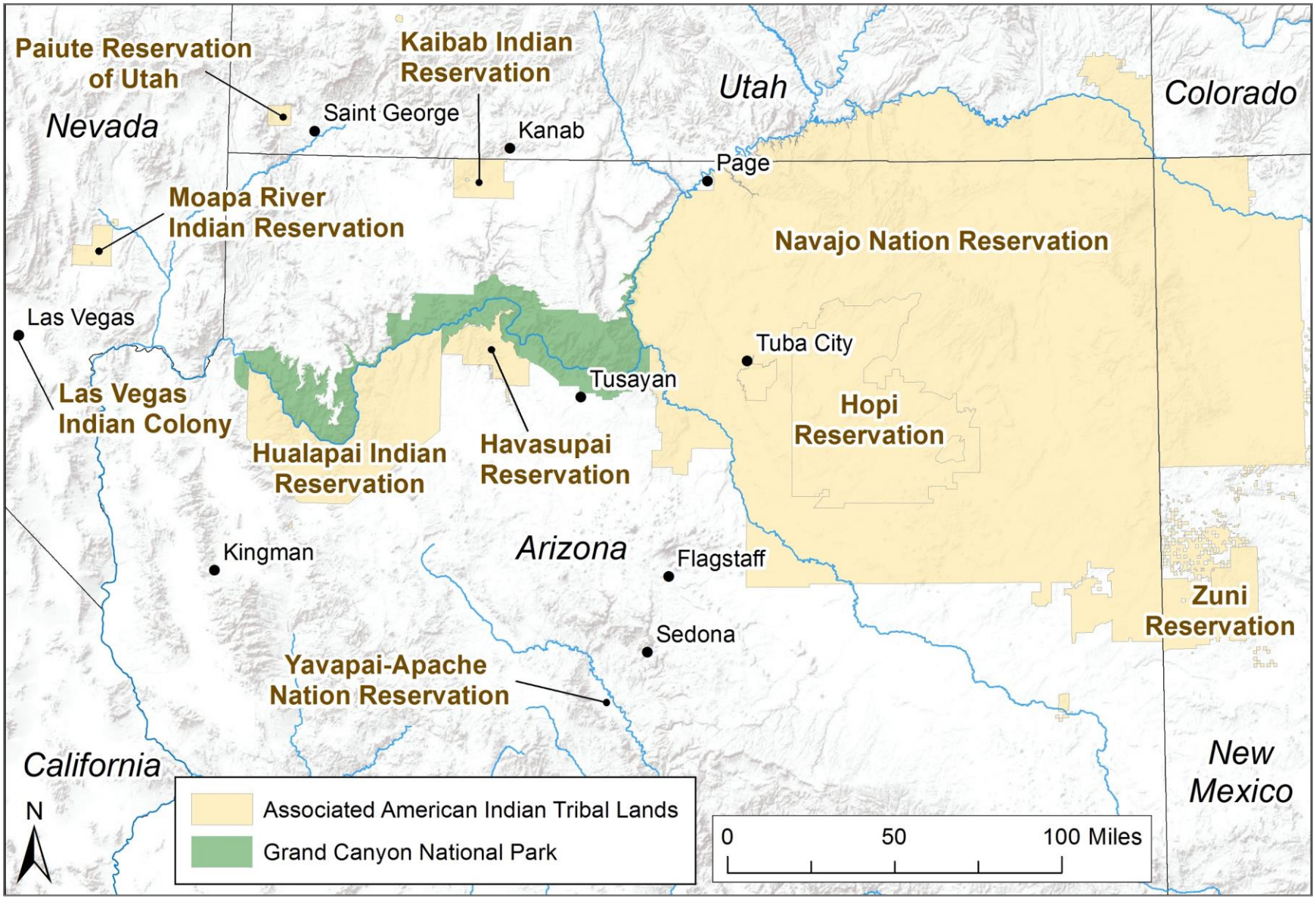


Figure 5. Map of Traditionally Associated Tribes.

Today, native peoples return to Grand Canyon to collect culturally important resources and make personally significant connections. Ethnographic resources in the park include numerous plants, animals, and insects, as well as archaeological resources and specific places in the landscape (NPS 2016). Moreover, it is unlikely that the total number of ethnographic resources in the park will ever be known, nor their full meaning due to the sensitive and confidential nature of such information.

Recent settlers have also left their own archaeological legacy, which is best summarized by the history of exploration, exploitation, pioneer settlement, railroad development, and federal administration (Anderson 2000). Physical remains of their endeavors from the earliest explorers through development of the national park are represented in the archaeological record, which includes evidence of early exploration by John Wesley Powell and Robert Brewster Stanton, mineral exploitation by Ralph Cameron, Pete Berry, William Wallace Bass, Louis Boucher, and John Hance among others, and the remains of early tourist enterprises and livestock ranching.

Threats to cultural resources are manifold. Climate change poses a danger to Grand Canyon's cultural resources, altering landscape geomorphology and threatening site stability. As storms increase in intensity due to climate change (Seager et al. 2007), archaeological resources will face amplified levels of erosion. Although many sites have endured weathering for centuries, they are not immune to further deterioration. In addition, visitor use often has a negative effect on archaeological site condition. Technological advances, such as GPS devices and social media, enable visitors to share precise archaeological site locations and characteristics, resulting in increased visitation and adverse effects on cultural resources. Emerging recreational pursuits, such as canyoneering and pack rafting, also have the potential to expose previously inaccessible cultural resources to the effects of increased visitation and associated human disturbances. To mitigate these impacts, Grand Canyon National park engages in programs of visitor education, cultural resource monitoring, and archaeological site and ruins preservation.

Left: black on white bowl, 1100-1275 common era; right: gold watch and watch key which belonged to John Wesley Powell (NPS).

Cave Resources

Millions of people visit Grand Canyon National Park each year, and very few of them have any idea that an entirely different type of geologic wonder is hidden beneath their feet. Grand Canyon National Park protects the second largest area of karst limestone bedrock of any national park unit (Weary and Doctor 2014). The limestone of the Grand Canyon National Park contains about 350 known caves and likely harbors hundreds more (B. Tobin, personal communication, 2017). These caves are mostly associated with the Redwall-Muav limestone formations and vary in length from 80 feet to tens of miles. Grand Canyon National Park currently protects the 12th longest cave (36.7 miles) in the United States. With exploration and documentation still in early stages, the caves and karst resources of the Grand Canyon are truly exceptional and rank among the park units created for these types of resources, such as Mammoth Cave, Carlsbad Caverns, Jewel Cave, and Wind Cave.

These caves feature a wide array of important resources. The area's dry climate and the inherent sheltered nature of caves make them the ideal environment for preservation of natural and cultural resources, often resulting in very rich and rare deposits. The general inaccessibility of the caves further protects artifacts from human disturbance. The combination of concentrated resources and exceptional preservation truly makes the caves of the Grand Canyon area some of the world's most critical and valuable environments.

Paleontological resources that have been found in Grand Canyon caves include rare soft-tissue subfossils, dung, and packrat middens (Santucci et al. 2001). The only specimen of soft-tissue remnants of the extinct Harrington's mountain goat and keratinous hornsheaths have been found in Grand Canyon caves (Mead et al. 1986). In some caves, bones, pollen, and plant fragments in packrat middens have been built up for thousands of years producing a nearly record of species presence for much of the Quaternary period and revealing long-term climate trends in the park (Wells 1976; Cole 1990a). Plant parts in Shasta ground sloth dung in Rampart Cave date back as far as 40,000 years, containing a wealth of plant and pollen data.

Although the presence of speleothems (cave formations) and their aesthetic value are well known, their delicacy, diversity, and scientific importance are often overlooked. Gypsum hair and cave pearls found in the park are rare elsewhere. Other speleothems play an essential role in reconstructing local paleoclimates because their growth rate is dependent on water availability and soil carbon dioxide levels. By studying the annual growth layers of these deposits, scientists can tease out hundreds of thousands of years of information about past climates (Gascoyne 1992; Lauritzen and Lundberg 1999; Linge et al. 2001).

Caves also provide important habitat for dozens of species in the park. For example, 22 different species of bats are known to exist in the canyon (NPS 2018f), many of which use caves for maternity or hibernation roosts (Kunz 1982; Hill and Smith 1984). Invertebrates, whose isolation within caves leads to endemism, are some of the most important and vulnerable species in cave ecosystems. Ongoing research is revealing the contents and geographical distribution of cave macroinvertebrates in the park and adding new species to fauna lists (Krejca et al. *in review*).

Human activities comprise the biggest stressor on cave resources. As cave visitation increases, so do impacts on speleothems, bat populations, and macroinvertebrate communities. The most significant known damage to cave resources in the park occurred at Rampart Cave in 1976 when a visitor started a fire in the cave that caught the dung deposit on fire and burned for more than six months (Santucci et al. 2001). This destroyed not only half of the dung, but also many other resources in the cave (packrat middens, sloth bones). While the Rampart Cave incident is a dramatic example, things as simple as tracking mud onto flowstone or depositing skin oils on minerals can cause damage (Horrocks 2013). Visitors can also spread white-nose syndrome via contaminated clothing (Shelley et al. 2013). While the epidemic has not yet reached Grand Canyon, this fungal disease has the potential to decimate the park's highly diverse bat population (Cryan et al. 2010; Chung-MacCoubrey 2013).

To protect fragile and precious cave resources, locations of caves are kept confidential, and (except for Cave of the Domes) cave entry and exploration in the park is only permitted for research purposes (NPS 2018b). Some resources, however, are so sensitive that even well-educated visitors can cause negative impacts, which is why researchers are resorting to innovative, low-impact methods to inventory cave resources (Henderek et al. 2015). As a last resort, the park has installed metal gates at the entrances of Rampart and Stanton's Cave to protect them from disturbance. This case illustrates how restrictions and installations in wilderness are sometimes necessary for resource protection, even if these measures detract from the Undeveloped and Unconfined Recreation Qualities.

Pallid Bat (NPS/ERIC HOPE).

Scientific Value

Grand Canyon has intrigued scientists at least since geologist John Strong Newberry laid his eyes on the canyon walls in 1858. Grand Canyon is a scientific laboratory for investigations studying development of highly incised landscapes in uplifted terrain in a tectonically active region. It was the work of geologists that changed public opinion of the Grand Canyon from that of "a worthless locale" (Ives 1861) to "the most sublime of earthly spectacles" (Dutton 1882). After nearly 150 years, geologists are still not finished studying Grand Canyon, whose origin and evolution remain a dynamic field. Much of the geologic research that takes place here receives international interest, and Grand Canyon continues to play an important role in geoscience education and geoscience literacy efforts. Almost every high school earth science and college level geology textbook discusses the geology of Grand Canyon. The canyon represents an outstanding classroom and research facility for researchers and educators worldwide.

Grand Canyon has long been an important setting for research on archaeology, ecology, geomorphology, recreation and visitor experience, soundscapes, air quality, and hydrology, among others. Being such a vast and undeveloped landscape, Grand Canyon presents the rare opportunity to study ecosystems mostly free from modern human influences. Grand Canyon's diverse array of habitats and rich cultural history provide opportunities for scientific study. For example, to better understand the relationship between desert riparian systems and underground aquifers, NPS scientists in cooperation with academic institutions have begun researching the highly complex karst system and groundwater flow regime of the Grand Canyon (Jones et al. 2017; Tobin et al. 2017). Furthermore, the Colorado River in Grand Canyon is one of the most studied river systems in the world. Studies here have international significance for understanding impacts of dam operations on downstream environments.

In recognition of Grand Canyon's scientific value, six research natural areas totaling 8,845 acres were officially designated in the park in the 1970s. Research natural areas are established in a typical example of an ecological community type, preferably one that has been little disturbed in the past and where natural processes are minimally impacted by human activity. These areas are set aside permanently and managed exclusively for approved nonmanipulative research, that is, research that measures but does not alter existing conditions. Numerous institutions, representing a wide range of disciplines, contribute to the understanding of park resources. At any given time, approximately 60 active studies are occurring in Grand Canyon National Park.

One much-studied inhabitant of the Grand Canyon wilderness is the Kaibab squirrel, a rare subspecies that can only be found on the Kaibab Plateau (Hall 1981). In recognition of the species' scientific significance, a large segment of Kaibab squirrel habitat, straddling the border between the park and the Kaibab National Forest, was designated as a National Natural Landmark (NNL) by the Secretary of the Interior in 1965. The area illustrates an important principle of biological evolution: allotropic speciation or genetic differentiation in geographically isolated populations. The Kaibab squirrel's closest relative, the Abert's squirrel, is found in similar habitat on Grand Canyon's South Rim, but not on the North Rim. Biologists believe these two subspecies once shared a common

ancestor, but the Grand Canyon's geographic barrier isolated the northern population and over time it developed unique characteristics sufficient to be a separate subspecies (Hall 1981).

Because the park has such a wide diversity of plants and animals, the Grand Canyon can serve as a natural laboratory for documenting changes in vegetation and wildlife and provide important scientific information on the impacts of climate change. The response of vegetation and wildlife within Grand Canyon National Park will also provide a natural comparison for other U.S. public lands. Those public lands are often used for mining, grazing, and resource extraction, activities that also change the landscape, but it is often unclear how much of that change is due to direct human activity versus the effects of a changing climate. Measuring the impacts of climate change on the Grand Canyon wilderness, which has largely been spared direct human impacts, may offer insight on the potential effects of climate change in places where causes cannot be easily identified and isolated.

Hand in hand with the research that goes toward understanding the impacts of climate change is a unique opportunity to share that information with the public. Grand Canyon National Park received 6.28 million visitors in 2017, a fact that positions the park to serve as a leader in educating a wide audience about the effects of climate change, using the Grand Canyon as a case study. Interpreting climate change research for millions of people who visit the canyon could quickly disseminate important information on the topic of climate change, its impacts, and effective solutions.

The enabling legislation of Grand Canyon National Park repeatedly emphasizes the park's scientific value, and the NPS "has a responsibility to support appropriate scientific activities in wilderness and to use science to improve wilderness management" (2006a). A high-quality park research program is critical for meeting park goals and objectives. As demonstrated by John Wesley Powell, effective stewardship of natural resources must be grounded in evidence and driven by scientific inquiry.

Left: excavation of the Palisades kiva; right: Museum of Northern Arizona staff examines a large potsherd recovered during an archaeology project (NPS).

Conclusion

In the midst of increasing human populations and a rapidly mechanizing world, places like the Grand Canyon wilderness only become more valuable. As public lands in the Southwest fall under threat of resource extraction, energy and urban development, and privatization, it is wilderness areas like these that can, with thoughtful and forward-thinking management, provide a refuge for plants, animals, and humans alike for centuries to come. In spite of its vastness, the Grand Canyon wilderness does not exist in a vacuum. Water extraction, dam operations, grazing, mining, development, climate change, and air pollution all threaten the seemingly protected canyon wilderness downstream or downwind. In the face of these ecological challenges, evidence-based and dedicated stewardship of this irreplaceable wilderness resource will become ever more important.

Wilderness stewardship is complicated by the competing qualities of wilderness character, as highlighted throughout this Wilderness Character Narrative. Decisions benefiting one quality may often degrade another. Therefore, wilderness managers must carefully weigh the benefits and drawbacks and choose the course of action (or inaction) that overall most respects and preserves wilderness character. This report provides managers with a tool to approach wilderness stewardship with humility, respect and a deeper understanding, ultimately helping them to preserve wilderness character as a whole.

A hiker pausing to take in the Monument Creek Pinnacle (NPS).

Wilderness Character Baseline Monitoring Assessment

This Wilderness Character Assessment discusses the measures selected for monitoring wilderness character at Grand Canyon National Park and establishes a quantitative baseline data value for each measure to which future data will be compared. Measure selection was informed by the integral wilderness resources and threats to those resources identified in the Wilderness Character Narrative. The measures selected, and the corresponding data compiled and analyzed for each, establish a foundation for continued monitoring of the Grand Canyon wilderness, which should occur every five years. The purpose of this monitoring is to improve wilderness stewardship by informing managers how wilderness character is changing over time and why changes may have occurred.

The wilderness character monitoring strategy described in this document is outlined in *Keeping It Wild 2: An Updated Interagency Strategy to Monitor Trends in Wilderness Character Across the National Wilderness Preservation System* (Landres et al. 2015). Wilderness character monitoring is based on the five qualities and organized around a hierarchical framework (Figure 6). Each quality is divided into a set of monitoring questions, indicators, and measures to assess trends in wilderness character over time. Monitoring questions frame wilderness character monitoring to answer particular management questions; indicators are distinct and important elements within each monitoring question; and measures are a specific aspect of wilderness on which data are collected to assess trend in an indicator. While the qualities, monitoring questions, and indicators are nationally consistent, measures are specific to individual wilderness areas to ensure local relevancy.

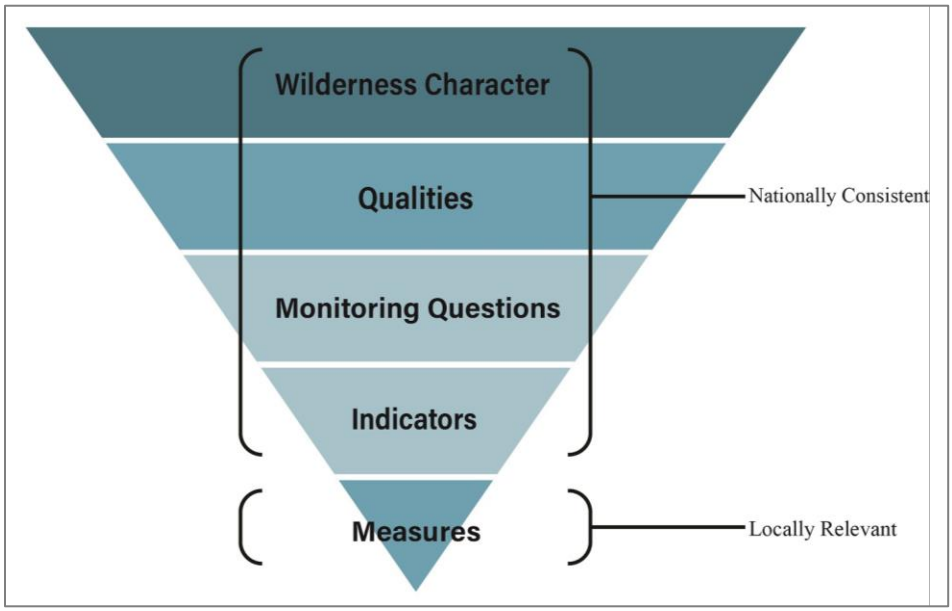


Figure 6. *Keeping It Wild 2* hierarchical framework (Landres et al. 2015).

An online Interagency Wilderness Character Monitoring Database accompanies this document and serves as the central portal for data entry, storage, analysis, and reporting for all four wilderness

managing agencies (Adams et al. 2012). All measures and baseline data specific to the Grand Canyon wilderness have been entered.

Wilderness Character Monitoring Measures

These measures constitute the baseline assessment of the Grand Canyon wilderness; they describe the conditions in the first year in which all measures report data and when consistent monitoring protocols are established. For each measure, this report includes the following information.

2018 Baseline Data Value—specifies the data value entered into the Interagency Wilderness Character Monitoring Database for 2018, the baseline year for wilderness character monitoring at Grand Canyon.

Year(s) of Data Collection—specifies the year(s) the data for a measure's data value was/were collected. For example, if data pulled from a national website were only available to the public two years after data collection, the 2018 data value has a date year of 2016. Measures use calendar years unless stated otherwise.

Background and Context—defines the context and relevance for the measure as related to specific issues at the Grand Canyon wilderness and addresses why the measure was selected.

Measure Description and Collection Protocol—defines what is being measured and how, including the process through which data is compiled or gathered. "Collection protocol" is included in this document to describe the process by which data are gathered from existing sources; in-the-field data collection instructions are not included.

Data Source—defines where baseline information for the measure can be found in the future. All named individuals are employed by Grand Canyon National Park, unless stated otherwise.

Data Adequacy—defines the reliability of the data in terms of being able to assess trends in the measure. Data adequacy is based on both data quantity and data quality. Data quantity refers to the level of confidence that all appropriate data records have been gathered. Data quality refers to the level of confidence about the source(s) of data and whether the data are of sufficient quality to reliably identify trends in the measure. As outlined in the *Forest Service Technical Guide* (Landres et al. 2009, p. 26), these two aspects of data adequacy are subjectively evaluated and scored using the framework provided in Table 2 and 3.

Significant Change—defines how much the data must change from the baseline data value to indicate an upward or downward trend in the measure. "Significant change" here is neither intended to mean significant change in a statistical sense nor imply use of an Environmental Impact Statement (EIS) under the National Environmental Policy Act (NEPA). Instead, significant, or meaningful, change in each measure is based on nationally or locally determined thresholds, indicating when a degradation or improvement of wilderness character has occurred. In most cases, thresholds were identified by the Wilderness Fellow based on interviews with subject-matter experts.

Together, these subsections provide a comprehensive overview of each measure, provide transparency into wilderness character monitoring measures selected, and form the basis of the wilderness character monitoring strategy of the Grand Canyon wilderness.

Table 2. Data quantity and quality definitions.

Category	Term	Definition
Data Quantity	Complete	There is a high degree of confidence that all data records have been gathered. For example, to assess the occurrence of nonindigenous invasive plants, a complete inventory of the wilderness was conducted, or all likely sites were visited.
	Partial	Some data is available, but the data are generally considered incomplete. For example, to assess the occurrence of nonindigenous invasive plants, a partial inventory was conducted, or a sampling of sites was conducted where these plants are likely to occur.
	Insufficient	Even fewer data records have been gathered, or perhaps this measure is not dependent on actual field data. For example, no inventory for nonindigenous invasive plants has been conducted.
Data Quality	High	There is a high degree of confidence that the quality of the data can reliably assess trends in the measure. For example, data on the occurrence of nonindigenous invasive plants are from ground-based inventories conducted by qualified personnel.
	Moderate	There is a moderate degree of confidence about the quality of the data. For example, data on invasive plants could come from national or regional databases; for visitor use, data could come from direct visitor contacts.
	Low	There is a low degree of confidence about the quality of the data. For example, data on invasive plants and visitor use could come from estimates rather than hard data.

Table 3. Data adequacy scoring.

Data Quantity	+	Data Quality	=	Data Adequacy
Complete (3)	+	High (3)	=	High (6)
Partial (2)	+	Moderate (2)	=	Medium (4-5)
Insufficient (1)	+	Low (1)	=	Low (≤3)

Tapeats Creek (NPS).

Process Used for Identifying Measures

Three key words guided measure selection for wilderness character monitoring at Grand Canyon National Park: useful, simple, practical. In accordance with *Keeping It Wild 2* (Landres et al. 2015) and to reduce the workload of future monitoring, the number of measures was deliberately kept to the minimum deemed necessary to credibly capture future changes in wilderness character. To keep it practical, measure selection was largely driven by availability of preexisting data from national, regional, or local monitoring programs, or cost-effectiveness if new data collection was needed. All actions were carried out by the Wilderness Fellow unless otherwise specified.

1. **Gather information**—Background information was gathered to understand the wilderness, including its history, ecosystems, and potential future threats. This information was gathered by reading park planning documents, reviewing scientific literature, interviewing park staff, and visiting the wilderness.
2. **Create list of possible measures**—Preliminary measures were identified and compiled for all indicators based on the information gathered and interviews with park staff. Several measures were based on measures described in wilderness character monitoring documents or measures developed for other wilderness areas and adapted to suit the Grand Canyon wilderness.
3. **Refine measures**—Measures were prioritized and refined through discussions and meetings with relevant staff, evaluating the significance, feasibility, vulnerability, and reliability of

measures. Availability of scientific information currently and into the future was also considered.

4. **Approval of measures**—The final list of measures was developed and submitted to Wilderness and Visitor Use Management staff.
5. **Locate and synthesize data**—Available data for each measure were collected by contacting relevant individuals and pulling information from national databases, shared drives, the GRCA GIS Database Library, or paper files. Data were processed and analyzed as necessary.
6. **Write report**—Background information, collection protocol, data adequacy, data source, and significant change were described for each measure.
7. **Peer review**—Subject-matter experts who were not directly involved in the collection, analysis, or reporting of the data, critically evaluated the report for its scientific merit, provided constructive comments and recommended revisions.
8. **Incorporate comments**—Changes, edits, and feedback from park staff and independent peer reviewers were received by the Wilderness Fellow. Edits were incorporated into the final draft.
9. **Approval of final report**—Report was reviewed, finalized, and approved by relevant staff, including the Superintendent.
10. **Enter data**—Data were entered into the Interagency Wilderness Character Monitoring Database.

Overview of Wilderness Character Monitoring Measures

Table 4 provides a basic overview of the 28 monitoring measures selected for the Grand Canyon wilderness. Each measure is described in detail in its respective section later in the report.

Table 4. Overview of Grand Canyon wilderness character monitoring measures.

Quality	Indicator	Measure
Untrammeled	Actions authorized by the federal land manager that intentionally manipulate the biophysical environment	1-1: Plant species manipulated 1-2: Animal species manipulated 1-3: Prescribed fires 1-4: Wildfire suppression
	Actions not authorized by the federal land manager that intentionally manipulate the biophysical environment	1-5: Unauthorized trammeling actions
Natural	Plants	2-1: Exotic plant species
	Animals	2-2: Exotic animal species

Table 4 (continued). Overview of Grand Canyon wilderness character monitoring measures.

Quality	Indicator	Measure
Natural (continued)	Air and water	2-3: Haze index 2-4: Ground-level ozone 2-5: Nitrogen in wet deposition 2-6: Sulfur in wet deposition 2-7: Discharge-precipitation ratio (Kanab Creek) 2-8: Discharge-precipitation ratio (Havasu Creek) 2-9: Discharge-precipitation ratio (Little Colorado)
	Ecological processes	2-10: Fire regime 2-11: Landscape connectivity
Undeveloped	Presence of non-recreational structures, installations, and developments	3-1: Index of authorized non-recreational developments 3-2: Primitive road corridors
	Presence of inholdings	3-3: Inholdings
	Use of motor vehicles, motorized equipment, or mechanical transport	3-4: Administrative flight hours 3-5: Motorized river trip launches
Solitude Or Primitive And Unconfined Recreation	Remoteness from sights and sounds of human activity *inside* wilderness	4-1: User nights
	Remoteness from sights and sounds of human activity *outside* of wilderness	4-2: Night sky quality 4-3: Intrusions on natural soundscapes
	Facilities that decrease self-reliant recreation	4-4: Facilities that decrease self-reliant recreation 4-5: Trails index
	Management restrictions on visitor behavior	4-6: Camping restrictions
Other Features	Deterioration or loss of integral cultural features	5-1: Condition of archaeological sites

Untrammeled Quality

Wilderness is essentially unhindered and free from modern human control or manipulation.

Measures for the Untrammeled Quality monitor human actions in wilderness that intentionally manipulate the biophysical environment. Actions that intentionally manipulate or control ecological systems inside wilderness degrade the Untrammeled Quality regardless of what instigated the action or if benefits to other qualities of wilderness character are gained by the action. Withholding action is a key concept for understanding this quality; management of wilderness, in contrast to management of other types of land, should be approached with restraint and humility. When monitoring the Untrammeled Quality, the NPS can track either the decision to manipulate the biophysical environment, or the opportunity for humans to let natural processes occur without intervention. Table

5 shows all measures used to monitor the Untrammeled Quality in the Grand Canyon wilderness. See Appendix C for detailed guidance about what counts as a trammeling action.

Table 5. Measures selected for the Untrammeled Quality.

Indicator	Measure	Data Adequacy	Significant Change	Baseline Data Value
Actions authorized by the federal land manager that intentionally manipulate the biophysical environment	Plant species manipulated	High (6)	≥ 10%	45 species
	Animal species manipulated	High (6)	≥ 10%	40 species
	Prescribed fires	High (6)	Any	4 prescribed fires
	Wildfire suppression	High (6)	≥ 10%	45 fires suppressed
Actions not authorized by the federal land manager that intentionally manipulate the biophysical environment	Unauthorized trammeling actions	Low (3)	Any	0 actions

Tapeats sandstone at Salt Creek observed from the Tonto Trail (NPS/MICHAEL QUINN).

1.1 Plant Species Manipulated

Untrammeled Quality • Actions authorized by the federal land manager that intentionally manipulate the biophysical environment

2018 Baseline Data Value: 45 plant species manipulated

Year(s) of Data Collection: 2013-2017

Background and Context: Proliferation of invasive plant species is one of the greatest threats to the Natural Quality of wilderness. Exotic plants can outcompete native plants, take over vegetative composition, impact wildlife habitat, and alter fire regimes. Because it is a goal of the NPS to protect plants native to park ecosystems (NPS 2006a), the control of exotic species and restoration of native species is often necessary. In spite of these good intentions and benefits to the Natural Quality, actions taken to manipulate the biophysical environment are considered trammeling.

Over the years, resource managers at Grand Canyon have removed upwards of 250,000 tamarisk trees from riparian areas along the Colorado River and tributaries using manual and chemical treatment. In addition, the Colorado River Management Plan (NPS 2006) mandates vegetation monitoring and restoration at beach campsites throughout the river corridor. In 2013-2014, tamarisk removal took place at Nankoweap and Crystal, Flint, Hance, Shinumo, and Clear creeks. Since then, restoration work has slowed down significantly due to reduced funding and staffing and concerns that tamarisk removal may impact potential habitat for the endangered southwestern willow flycatcher. The threat posed by tamarisk infestations has also decreased, as the tamarisk leaf beetle – introduced as a biological control agent for tamarisk in parts of the West in 2001 – has defoliated tamarisk stands in the park.

In recent years, NPS-authorized projects that manipulate vegetation in the Grand Canyon wilderness have been rare. There is one ongoing restoration project at Granite Camp (RM 93.8) within the Monument Creek watershed that started back in 2011. The goal of this project is to rehabilitate degraded native riparian plant communities and wildlife habitat. Vegetation crews carry out restoration work at the site bi-annually. Project components include manual and chemical treatment of invasive species (primarily tamarisk) and revegetation with native species. Temporary exclusion cages have been installed around some outplanted native species to protect them from herbivory by beavers and other wildlife. Similar type projects are currently underway at Cardenas Camp (RM 71.7) and Grand Canyon Youth Camp (RM 274). The park is also planning to revegetate disturbed areas at the abandoned Orphan Mine site in the future. Trammeling impacts from these projects will be captured during the next round of monitoring.

Between 2013-2017, park staff manipulated a total of 45 plant species in wilderness (Table 6). Restoration crews manually and chemically treated 28 of an estimated 208 exotic species that have become established in the park (Appendix D). To help native species repopulate areas where invasives have been removed, crews also outplanted 17 native species. In the face of a changing climate and the likely arrival of new exotic species, the potential for future trammeling actions in wilderness may increase. Any authorization of future trammeling will involve the completion of an MRA and include careful consideration for the Untrammeled Quality of wilderness. Wilderness management priorities differ from those of other federal lands in that natural resource managers are legally mandated to approach wilderness lands with utmost humility and restraint, allowing nature to unfurl in a self-willed condition. This respect for natural processes is a core concept of wilderness.

Table 6. Plant species manipulated: 2013-2017.

Scientific Name	Common Name	Status
Acer negundo	box elder	Native
Agave utahensis	Utah agave	Native
Alhagi maurorum	camelthorn	Exotic
Bebbia juncea	sweetbush	Native
Brassica tournefortii	Sahara mustard	Exotic
Bromus diandrus	ripgut brome	Exotic
Bromus rubens	red brome	Exotic
Bromus tectorum	cheatgrass	Exotic
Carduus nutans	musk thistle	Exotic
Celtis laevigata	sugarberry	Native
Centaurea biebersteinii	spotted knapweed	Exotic
Cirsium vulgare	bull thistle	Exotic
Conyza canadensis	horseweed	Exotic
Cortaderia selloana	Pampas grass	Exotic
Datura wrightii	Western Jimson weed	Native
Descurainia sophia	flixweed	Exotic
Elaeagnus angustifolia	Russian olive	Exotic
Encelia farinosa	brittlebush	Native
Ephedra funerea	Mormon tea	Native
Hordeum marinum	Barley	Exotic
Imperata brevifolia	California satintail	Native
Juncus articulatus	jointleaf rush	Native
Lepidium latifolium	perennial pepperweed	Exotic
Lycium andersonii	Anderson boxthorn	Native
Malcolmia africana	African mustard	Exotic
Marrubium vulgare	horehound	Exotic
Melilotus officinalis	yellow sweetclover	Exotic
Muhlenbergia asperifolia	alkali muhly	Native
Onopordum acanthium	Scotch thistle	Exotic
Populus fremontii	Fremont's cottonwood	Native
Porophyllum gracile	slender poreleaf	Native
Prosopis glandulosa	honey mesquite	Native
Rubus discolor	Himalaya blackberry	Exotic
Rumex crispus	curly dock	Exotic
Saccharum ravennae	Ravenna grass	Exotic
Salix exigua	narrowleaf willow	Native

Table 6 (continued). Plant species manipulated: 2013-2017.

Scientific Name	Common Name	Status
Salix gooddingii	Goodding's willow	Native
Salsola tragus	Russian thistle	Exotic
Senegalia greggii	catclaw acacia	Native
Sisymbrium altissimum	tumble mustard	Exotic
Sisymbrium irio	London rocket	Exotic
Solanum elaeagnifolium	silverleaf nightshade	Exotic
Sonchus asper	spiny sowthistle	Exotic
Sonchus oleraceus	common sowthistle	Exotic
Tamarix ramosissima	tamarisk, salt cedar	Exotic

Measure Description and Collection Protocol: Data value is the total number of plant species, both native and non-native, manipulated as part of NPS-authorized restoration efforts during a five-year monitoring period. An exotic species is considered "manipulated" when it is targeted for chemical or manual control in wilderness. Conversely, a native species is considered "manipulated" if it is outplanted from a nursery to a restoration site in wilderness. Spreading fertilizer, repeated watering, and spreading seed to rehabilitate disturbed areas in wilderness is also counted as manipulation of targeted species. For future monitoring, consult with vegetation program staff to develop a count of the number of plant species manipulated in wilderness. A decrease in the number of plant species manipulated would contribute to an upward trend for this indicator of the Untrammeled Quality.

Data Source: Cam Prophet, *Invasive Plant Crew Lead*; Ahsa Jensen, *Nursery Manager and Crew Lead*; Daniel Boughter, *Restoration Biologist*.

Data Adequacy: High (6) – Data quantity is complete because all vegetation management actions taken are well documented and new actions typically require an MRA. Data quality is high for the same reasons.

Significant Change: Any change of 10% or more from the baseline is considered significant.

Fencing protecting an outplanted tree from herbivory (NPS/TOBIAS NICKEL).

1.2 Animal Species Manipulated

Untrammeled Quality • Actions authorized by the federal land manager that intentionally manipulate the biophysical environment

2018 Baseline Data Value: 40 animal species manipulated

Year(s) of Data Collection: 2013-2017

Background and Context: Authorizations of trammeling related to wildlife are sometimes justified to remove exotic animals, aid protected species, or conduct scientific studies that help wilderness managers better understand complex ecosystem relationships. Nonetheless, actions like these are manipulations of the natural world and degrade the Untrammeled Quality. Several wildlife-related trammeling actions have occurred within the Grand Canyon wilderness in recent years (Table 7).

California Condors—Since 1996, condors raised in captivity are released annually into Vermilion Cliffs National Monument adjacent to the park. Although these releases occur outside the wilderness, Landres et al. (2015) explicitly states that actions affecting a population whose range extends into the wilderness should be counted. Once released, Condors remain a conservation-dependent species and are monitored, tagged, and treated for lead poisoning.

Bison—Wildlife biologists sedated and collared 11 hybrid bison between 2013 and 2017. Over the next three to five years, the park is planning to reduce the size of the herd to fewer than 200 through a combination of relocation and lethal culling (NPS 2017a).

Mountain Lions—Between 2003 and 2014, park wildlife biologists sedated and collared 32 mountain lions. The captures mostly occurred in non-wilderness, but impacted a species whose range extends into wilderness.

Bighorn Sheep—Twenty-five bighorn sheep were sedated and collared between 2010 and 2016. In addition, five animals suffering from respiratory disease were euthanized by park biologists.

Bats—In the face of white-nose syndrome spreading rapidly across North America, wildlife biologists have been studying the park's diverse bat population to gather baseline data in the event that the epidemic reaches Grand Canyon. White-nose syndrome is a fungal disease that is highly contagious among bat colonies and boasts mortality rates over 90% (Cryan et al. 2010; Chung-MacCoubrey 2013). Of the 22 bat species known to exist in the park, 18 species have been captured during mist-net surveys between 2015 and 2017. The netting setup allows bats to be caught live and released unharmed near the point of capture. Physiological characteristics are recorded to quantify bat health using minimally invasive methods.

Fish—NPS fishery crews have removed exotic rainbow and brown trout from Bright Angel, Havasu, and Shinumo creeks using electricity to temporarily stun fish so they can be captured and euthanized. Native fish also captured during the removal efforts include speckled dace, bluehead sucker, and flannelmouth sucker. Speckled dace are measured and released, as are the suckers, but when large enough, suckers also have Passive Integrated Transponder (PIT) tags injected into the abdominal cavity. To restore populations of endangered humpback chub, the park has PIT tagged and translocated this species to Havasu and Shinumo creeks. Endangered razorback suckers have been captured as larvae in Lake Mead, grown to size in a hatchery, surgically implanted with sonic tags, and released in the main channel of the Colorado River near Bright Angel Creek. In cooperation with the NPS, Arizona Game and Fish Department (AZGFD), U.S. Geological Survey (USGS), and USFWS have been conducting electrofishing and hoop net sampling in the main channel of the Colorado River. Several native and non-native fish species are captured during these surveys. Common carp, bluehead and flannelmouth suckers, and humpback chub are PIT tagged, while all brown trout captured during these surveys are euthanized.

Table 7. Animal species manipulated: 2013-2017.

Group	Scientific Name	Common Name	Type of manipulation
Bird	*Gymnogyps californianus*	California condor	Reintroduction, lead poison treatment
Fish	*Ameiurus melas*	Black bullhead	Electrofishing and hoop net surveys
Fish	*Ameiurus natalis*	Yellow bullhead	Electrofishing and hoop net surveys
Fish	*Catostomus discobolus*	Bluehead sucker	Electrofishing and hoop net surveys (PIT)
Fish	*Catostomus latipinnis*	Flannelmouth sucker	Electrofishing and hoop net surveys (PIT)
Fish	*Cyprinus carpio*	Common carp	Electrofishing and hoop net surveys (PIT)

Table 7 (continued). Animal species manipulated: 2013-2017.

Group	Scientific Name	Common Name	Type of manipulation
Fish	*Cyprinella lutrensis*	Red shiner	Electrofishing and hoop net surveys
Fish	*Dorosoma cepedianum*	Gizzard shad	Electrofishing and hoop net surveys
Fish	*Fundulus zebrinus*	Plains killifish	Electrofishing and hoop net surveys
Fish	*Gambusia affinis*	Western mosquitofish	Electrofishing and hoop net surveys
Fish	*Gila cypha*	Humpback chub	Translocation, surveys (PIT)
Fish	*Ictalurus punctatus*	Channel catfish	Angling
Fish	*Lepomis cyanellus*	Green Sunfish	Electrofishing and hoop net surveys
Fish	*Morone saxatilis*	Striped bass	Electrofishing and hoop net surveys
Fish	*Oncorhynchus mykiss*	Rainbow trout	Euthanization
Fish	*Pimephales promelas*	Fathead minnow	Electrofishing and hoop net surveys
Fish	*Rhinichthys osculus*	Speckled dace	Electrofishing and hoop net surveys
Fish	*Salmo trutta*	Brown trout	Euthanization
Fish	*Xyrauchen texanus*	Razorback sucker	Reintroduction, surveys
Mammal	*Antrozous pallidus*	Pallid bat	Mist-net surveys
Mammal	*Bison bison*	Bison	Sedation, collaring
Mammal	*Corynorhinus townsendii*	Townsend's big-eared bat	Mist-net surveys
Mammal	*Eptesicus fuscus*	Big brown bat	Mist-net surveys
Mammal	*Euderma maculatum*	Spotted bat	Mist-net surveys
Mammal	*Idionycteris phyllotis*	Allen's big-eared bat	Mist-net surveys
Mammal	*Lasionycteris noctivagans*	Silver-haired bat	Mist-net surveys
Mammal	*Lasiurus blossevillii*	Western red bat	Mist-net surveys
Mammal	*Lasiurus cinereus*	Hoary bat	Mist-net surveys
Mammal	*Myotis californicus*	California myotis	Mist-net surveys
Mammal	*Myotis ciliolabrum*	Small-footed myotis	Mist-net surveys
Mammal	*Myotis evotis*	Long-eared myotis	Mist-net surveys
Mammal	*Myotis occultus*	Arizona myotis	Mist-net surveys
Mammal	*Myotis thysanodes*	Fringed myotis	Mist-net surveys
Mammal	*Myotis velifer*	Cave myotis	Mist-net surveys
Mammal	*Myotis volans*	Long-legged myotis	Mist-net surveys
Mammal	*Myotis yumanensis*	Yuma myotis	Mist-net surveys

Table 7 (continued). Animal species manipulated: 2013-2017.

Group	Scientific Name	Common Name	Type of manipulation
Mammal	*Ovis canadensis*	bighorn sheep	Sedation, collaring, euthanization (if sick)
Mammal	*Parastrellus hesperus*	Canyon bat	Mist-net survey
Mammal	*Puma concolor*	Mountain lion	Sedation, collaring
Mammal	*Tadarida brasiliensis*	Mexican free-tailed bat	Mist-net surveys

Measure Description and Collection Protocol: Data value is the total number of animal species manipulated as part of administrative actions or NPS-authorized research projects during a five-year monitoring period. Any action to intentionally manipulate, hinder, restrict, or control the biophysical environment is considered a trammeling action. Captures resulting in the collaring, banding, tagging, or blood sampling of wildlife would be considered trammeling actions and counted under this measure. Releasing and translocating species, electrofishing, euthanizing, treating lead poisoning, supplying food or water sources to wildlife within wilderness would also be counted under this measure. For future monitoring, consult with wildlife and fisheries biologists, as well as the park's Research Coordinator to develop a count of the number of animal species manipulated in wilderness. Monitoring reports published by AZGFD and USGS also provide critical information on fish species captured during electrofishing and hoop net sampling trips. NEPA documents, MRAs, and research permitting records may further aid in developing a comprehensive list of wildlife-related trammeling actions. Over time, a decrease in the number of animal species manipulated would contribute to an upward trend for this indicator of the Untrammeled Quality.

Data Source: Greg Holm, *Wildlife Program Manager*; Brian Healy, *Fisheries Program Manager*; Robert Schelly, *Fisheries Biologist*; Brandon Holton, *Wildlife Biologist*; Miranda Terwilliger, *Wildlife Biologist*; Ronda Newton, *Research Coordinator*; MRAs, NEPA documents; AZGFD and USGS fish monitoring reports (Rogowski et al. 2016; Persons et al. 2017).

Data Adequacy: High (6) - Data quantity is complete because authorized wildlife-related trammeling actions are well documented by park managers and typically require the completion of an NPS research permit or MRA. Data quality is high for the same reasons.

Significant Change: Any change of 10% or more from the baseline is considered significant.

Electrofishing in Shinumo Creek (NPS).

Bison herd on the North Rim (NPS).

1.3 Prescribed Fires

Untrammeled Quality • Actions authorized by the federal land manager that intentionally manipulate the biophysical environment

2018 Baseline Data Value: 4 prescribed fires in wilderness

Year(s) of Data Collection: 2013-2017

Background and Context: Fires in the Grand Canyon wilderness were mostly suppressed between the 1870s and late 20th century. Vegetation changes caused by past fire suppression have generally increased live and dead fuel loading in forested communities. This has resulted in potentially hazardous arrangements of close-standing vegetation, which increases the risk of higher-intensity crown fires. If subjected to crown fire, forested vegetation may be converted to shrub communities, watershed and soil processes may be impacted, and ecosystem values altered.

To restore ecosystem function, fire managers increasingly look to prescribed fires as a management tool. Prescribed fires are management-ignited fires intentionally lit to reintroduce fire as an ecological process and mimic natural fire events. Prescribed burn units often require multiple entries to meet management objectives. The first prescribed burn typically reduces understory and mid-story vegetation and consumes ground fuels. A second burn consumes dead and down fuel from the first fire and thins new plants sprouted. Subsequent burns (typically every seven to 15 years) maintain a fire-influenced forest and reduce fuel accumulations since the last fire (NPS 2012). Today, prescribed fire is a well-established and accepted practice used by land managers to improve forest health and maintain ecosystems. While prescribed fire is used to improve the Natural Quality in areas where the natural fire regime has been altered, it is also a rationally planned human intervention in the biophysical environment, and therefore affects the Untrammeled Quality.

Between 1980 and 2017, more than 208,000 park acres have burned. Of these, 43% (89,665 acres) were treated with prescribed fire and 46% (96,468 acres) were naturally ignited fires managed for multiple objectives. Wildfires managed with only suppression objectives accounted for 11% (21,853 acres) of the total. After almost four decades of proactive fire management, progress toward restoring natural fire regimes to the park is measurable, but far from fully achieved. This amount of managed fire has been insufficient to remedy decades of landscape-scale fire exclusion. In many areas, multiple fire treatments will be needed to restore desired ecological conditions (NPS 2012).

During the baseline monitoring period (2013-2017), NPS staff managed four prescribed fires within the Grand Canyon wilderness, burning a total of 8,754 wilderness acres (Figure 7; Table 8). As the park achieves its objective of restoring the natural fire regime, reducing the number of prescribed fires conducted in wilderness would benefit the Untrammeled Quality in the years to come.

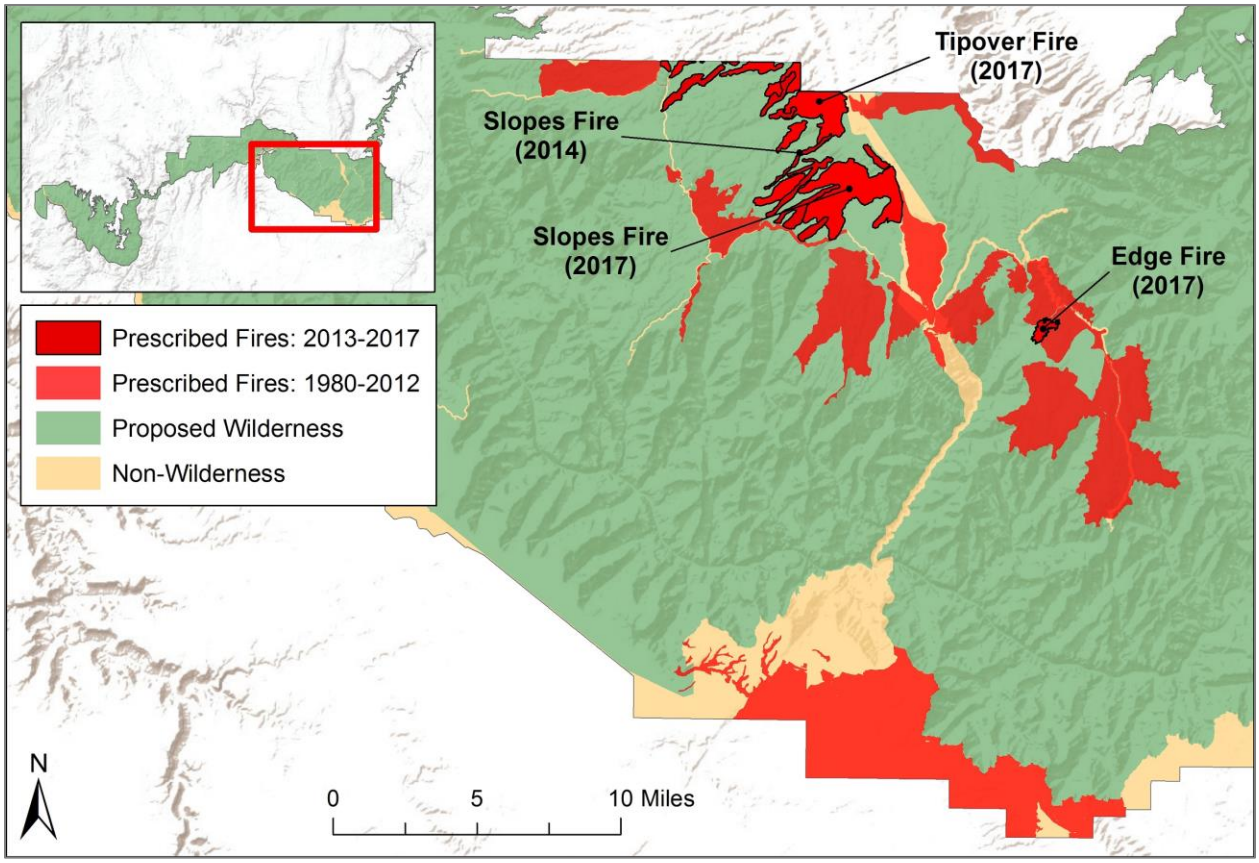


Figure 7. Map of prescribed fires at Grand Canyon National Park: 1980-2017.

Table 8. Prescribed fires in wilderness: 2013-2017.

Year	Fire Name	Wilderness Acres Burned*
2014	Slopes	2,214
2017	Tipover	2,206
2017	Edge	238
2017	Slopes	4,096
Total	**4 Prescribed Fires**	**8,754**

*Acreage listed here may differ from total area burned, as many fire perimeters spanned both wilderness and non-wilderness.

Measure Description and Collection Protocol: Data value is the total number of prescribed fires that occurred within the Grand Canyon wilderness on the Kaibab Plateau over the course of a five-year monitoring period. Data were obtained from a fire perimeter GIS-layer maintained by Grand Canyon National Park. The dataset was queried by year and type ("Rx" only). For data collection purposes, each prescribed fire was counted as a single data value, regardless of its magnitude, as each prescribed burn is a missed opportunity for constraint (Landres et al. 2015). Prescribed fires that have multiple polygons associated with them in the same year (e.g. Slopes fire) are counted as a single data point, as they are all part of a single project occurring at the same time. However, if fires with

the same name occurred in different years (e.g. Slopes Fire), they should be counted as two separate incidents. Fires, which almost exclusively (>90% of total acres) occurred in non-wilderness and only minimally intersected the wilderness boundary, were not included in this measure. Wilderness acres burned by these fires are insubstantial, and intersection with wilderness boundaries may even be the result of slight inaccuracies in the way fire perimeters and wilderness boundaries are digitized. Furthermore, only prescribed fires that were managed in wilderness areas on the Kaibab Plateau should be included in this measure. While prescribed burns are also carried out on the South Rim, these management activities are primarily confined to non-wilderness areas. During the 2013-2017 monitoring period, the Shoshone and Horsethief prescribed burns, which occurred on the South rim and only minimally intersected wilderness boundaries, were excluded from the data value based on this reasoning. Over time, a decrease in the number of prescribed fires would contribute to an upward trend for this indicator of the Untrammeled Quality.

Data Source: Jay Lusher, *Chief of Fire and Aviation*; Chris Marks, *Deputy Fire Management Officer*; David Robinson, *Fuels Specialist*; Fire geodatabase (GRCA GIS Database Library).

Data Adequacy: High (6) – Data quantity is complete because all prescribed fires are well documented by fire management and ecologists. Data quality is high for the same reason.

Significant Change: Any change from the baseline data value is considered significant.

Prescribed burn (NPS).

1.4 Wildfire Suppression

Untrammeled Quality • Actions authorized by the federal land manager that intentionally manipulate the biophysical environment

2018 Baseline Data Value: 45 naturally ignited fires suppressed

Year(s) of Data Collection: 2013-2017

Background and Context: Wildfire is a naturally occurring and essential part of wilderness ecosystems that often serves as a beneficial disturbance regime and provides a host of ecosystem services. Allowing fires to burn in wilderness is ecologically desirable. However, unsuppressed wildfires can easily escape to non-wilderness areas and pose threats to existing infrastructure, cultural resources, and public safety. Fires in wilderness areas are often suppressed, and this suppression allowed explicitly by the Wilderness Act Section 4(d)(1) and subsequent wilderness policy (NPS 2006a). Nonetheless, fire suppression is a manipulation of a natural biophysical process, and a clear trammeling action.

Under the current Fire Management Plan (NPS 2012), fire managers are required to develop and implement a response to each wildfire detected. Suppression responses include, but are not limited to, extinguishing, confining, containing, monitoring the fire, or a mix of these responses. Fire management activities are assessed on a programmatic basis under the minimum requirement decision process to reduce wilderness impacts to the extent possible.

Over the last four decades, fire managers have been able to increase the opportunities to manage naturally ignited fires for multiple objectives. Objectives can include sustaining native vegetation communities and restoring the natural fire regime. Reflecting these changing approaches to fire management, only 18% (21,852 acres) of naturally ignited wildfires between 1980 and 2017 were managed exclusively for suppression objectives. Conversely, 82% (96,468 acres) of naturally ignited fires were managed for multiple objectives. While fires managed for multiple objectives still involve suppression activities (and thus trammeling actions), this approach seeks to balance trammeling impacts with other management objectives, often allowing fire to play its natural role in the ecosystem under an established set of conditions. During the baseline five-year monitoring period (2013-2017), 49 naturally ignited fires burned in the Grand Canyon wilderness (Figure 8; Table 9,). Of these, four were extinguished by natural causes with no fire suppression action taken, 28 received a limited suppression response, and 17 received a full suppression response.

Fire managers at Grand Canyon are working to restore the natural fire regime and reduce fuel accumulation through the use of prescribed fire to a state were natural fire would be allowed to exist on the landscape without detrimental effects. However, suppression efforts will continue into the future until prescribed fire treatments have met fuel reduction objectives. The overall goal is to eventually allow fire to play its natural role with little human intervention, a fire management approach that would significantly benefit the Untrammeled Quality.

Measure Description and Collection Protocol: Data value is the total number of naturally ignited (begun by lightning) wildfires in wilderness that were suppressed over the course of a five-year monitoring period (Table 9). Data were obtained through the Wildland Fire Management Information (WFMI) database, which is housed by National Interagency Fire Center (NIFC). Fire management staff are required to enter a report for every fire under their jurisdiction into the WFMI database.

New users must request access to the database to view and download records to calculate the value for this measure. Coordinates of ignition points and other pertinent information were obtained for each fire and exported to ArcGIS. Fires were spatially selected based on ignition points intersecting wilderness areas. To ensure accuracy and also include fires that started outside of, but moved into wilderness, the data was cross-referenced with a fire perimeter GIS-layer maintained by Grand Canyon National Park. Human-caused fires were excluded from the analysis, as they would not be considered natural processes.

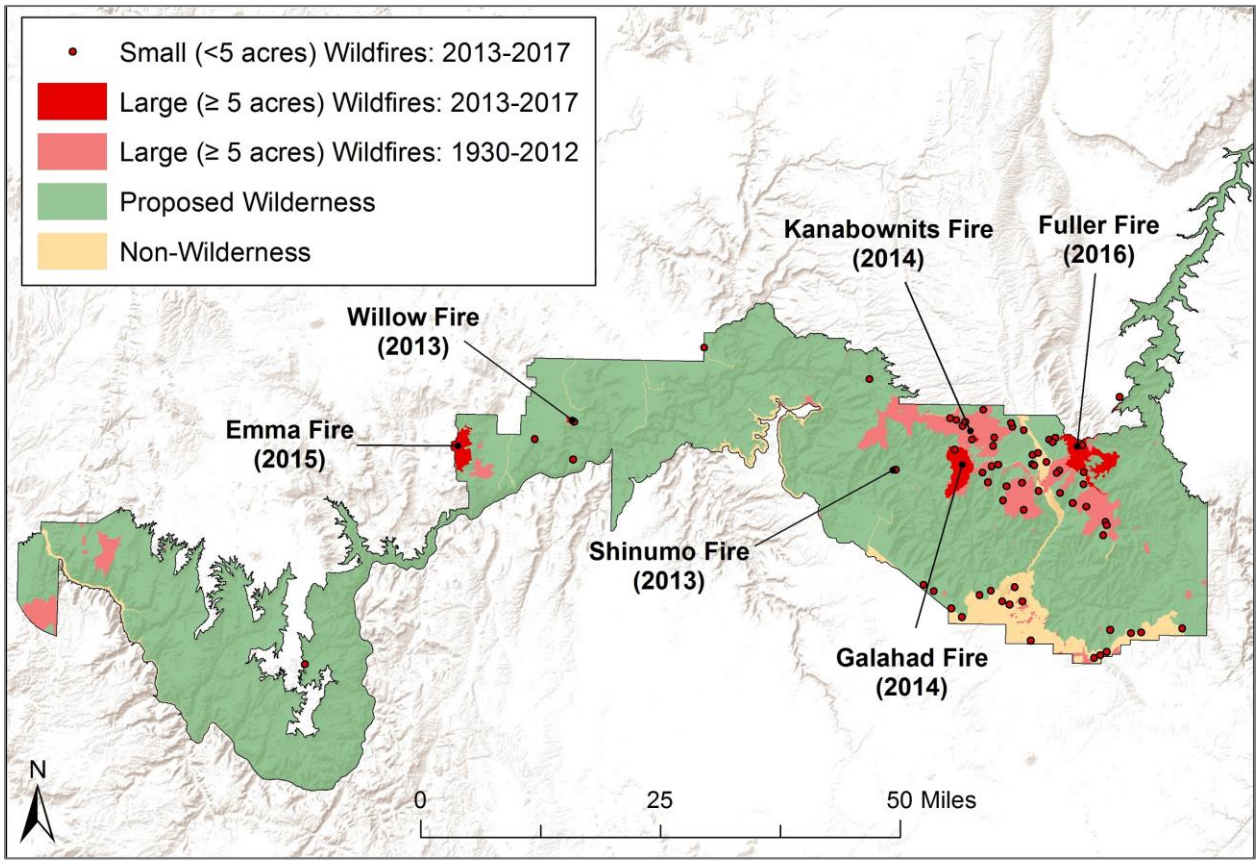


Figure 8. Map of wildfires at Grand Canyon National Park: 1930-2017.

Table 9. Naturally-ignited fires and suppression responses: 2013-2017.

Year	Fire Name	Acres Burned	Fire Protection Type
2013	Upper	0.1	11
2013	Willow	223.0	14
2013	Walhalla	0.1	11
2013	Tuckup	0.1	14
2013	Meadow	0.5	14
2013	Hades	0.2	14

Table 9 (continued). Naturally-ignited fires and suppression responses: 2013-2017.

Year	Fire Name	Acres Burned	Fire Protection Type
2013	Cheyava	0.1	14
2013	Shinumo	22.0	14
2013	Dripping	0.1	21
2013	Hades Lake	0.1	14
2013	Robbers	0.1	14
2013	Thompson	0.1	14
2013	Lindberg	0.1	14
2013	Hill	0.1	14
2013	Outlet	0.1	14
2013	Fuller 2	0.1	14
2014	Jim	0.3	11
2014	Dragon	0.5	11
2014	Galahad	6,137.0	14
2014	Coffee	0.1	14
2014	Creek	0.1	14
2014	Stairway	0.1	14
2014	Little	0.2	11
2014	Bright	0.3	11
2014	Jug	0.1	14
2014	Lancelot	0.1	11
2014	Modred	0.1	11
2014	Kanabownits	287.0	14
2014	Crystal	0.1	11
2014	Marble Flats	0.1	11
2014	Mimbreno	0.1	21
2014	Tower	0.1	14
2015	Blue	0.3	14
2015	Crescent	0.1	14
2015	Moran	0.1	21
2015	Dragon	0.1	14
2015	Emma	3,848.0	14
2015	Kanab	0.1	14
2015	Cape	0.1	11
2015	Plateau	0.1	11
2016	Lancelot	1.8	11

Table 9 (continued). Naturally-ignited fires and suppression responses: 2013-2017.

Year	Fire Name	Acres Burned	Fire Protection Type
2016	Milk	0.1	14
2016	Sinkhole	0.1	11
2016	Fork	1.5	11
2016	Fuller	8,458.0	14
2016	Dripping	0.3	21
2016	Uncle Jim	0.1	14
2016	Greenland	0.1	11
2016	Tiyo	0.1	11

Suppression responses were evaluated based on the Fire Protection Type assigned to each fire. The most common codes assigned to naturally ignited fires in the Grand Canyon wilderness are 11, 14, and 21. Fire Protection Type 11 indicates a full suppression response, while 14 indicates a limited suppression response, where the management goal is other than full suppression, or where conditions prevent full suppression. For purposes of this measure, fires assigned types 11 and 14 are considered "suppressed." Fire Protection Type 21 describes wildfires that are discovered after they have already been extinguished by natural causes (NIFC 2007). Each naturally ignited fire that receives a suppression response, regardless of the magnitude of the fire or of the suppression, is counted as a single trammeling action toward the data value. Over time, a decrease in the number of naturally ignited fires receiving a suppression response would contribute to an upward trend for this indicator of the Untrammeled Quality.

Wildfires (NPS).

Data Source: Jay Lusher, *Chief of Fire and Aviation*; Chris Marks, *Deputy Fire Management Officer*; David Robinson, *Fuels Specialist*; Fire geodatabase (GRCA GIS Database Library); WFMI database (NIFC 2018).

Data Adequacy: High (6) – Data quantity is complete because all fires and fire suppression actions are well documented by fire management and ecologists. Data quality is high for the same reason.

Significant Change: Any change of 10% or more from the baseline is considered significant.

1.5 Unauthorized Trammeling Actions

Untrammeled Quality • Actions not authorized by the federal land manager that intentionally manipulate the biophysical environment

2018 Baseline Data Value: 0 actions

Year(s) of Data Collection: 2013-2017

Background and Context: Unauthorized trammeling actions are fundamentally different from authorized trammeling actions because the effects of these actions are not fully considered or weighed by resource managers. Unauthorized manipulations are often undertaken with little to no consideration for the ecosystem and can have a large impact on wilderness character. Some unauthorized actions that have been reported at Grand Canyon and that might be considered trammeling are discussed below. Unauthorized trammeling actions could be more common than documented, as park staff cannot be aware of all actions that take place in wilderness at all times.

Trespassing of domestic livestock: Trespass livestock and bison from adjacent public and tribal lands create unauthorized trammeling impacts, degrading vegetation, soil, archaeological sites, and water resources (NPS 2015a). No comprehensive data tallying trespass livestock in wilderness is available.

Fish Stockings: Under the current Fisheries Management Plan (NPS 2013), the NPS only authorizes stocking rainbow trout in the Glen Canyon NRA when their population drops to a low level. Although no stockings have impacted the Grand Canyon wilderness in recent years, AZGFD is planning to stock exotic trout near Lees Ferry in 2018. If such an action were to occur, it could threaten native fish species and alter fish community composition in wilderness. NPS staff spend significant amount of time and resources removing exotic fish and translocating native fish – efforts that could be undermined by stocking exotic fish upstream of the park. Future stocking events carried out without NPS approval should each be counted as an unauthorized trammeling action.

Release of biological control agents: The tamarisk leaf beetle was released as a biological control agent in a limited area of the western U.S. in 2001 to help manage invasive tamarisk infestations. It was not approved for release within 200 miles of endangered southwestern willow flycatcher habitat, but it migrated further than anticipated, and spread to Grand Canyon (Tamarisk Coalition 2018). While tamarisk leaf beetles continue to affect riparian habitats in the Grand Canyon wilderness today, the release occurred prior to 2013. Therefore, this action was not included in the baseline value. In the future, any unauthorized and intentional releases of biological control agents should be counted under this measure as one action per species released.

Poaching: Illegal hunting outside the park affects wildlife inside the Grand Canyon wilderness, especially its mountain lion population. Even though the Grand Canyon serves as an unhunted

protected refuge, almost 60% of known mortalities to mountain lions collared in the canyon can be attributed to sport hunting outside of the park (unpublished NPS report, Holton). Moreover, several collared mountain lions abruptly disappeared while ranging outside the park's boundary, and unreported harvesting of some of these animals is suspected. Because mountain lions are apex predators, the trammeling effects of legally and illegally hunting these animals outside the park are likely felt throughout the ecological community. At this time, however, poaching has not been documented systematically enough to warrant its inclusion under this measure. Should there be a spike in poaching incidences, or should non-NPS government agencies actively pursue a predator control program without the park's approval, then this should be counted as a single unauthorized trammeling action per wildlife species that is affected.

Off-road Vehicle Use: Off-road vehicle travel in sensitive desert or alpine meadow environments can scar the landscape in ways that takes decades to heal. Impacts from off-road vehicle can affect both cultural and natural resources, alter surface hydrology, cause soil compaction, and fragment the natural habitat. Off-road vehicle tracks have been observed in a few areas, but no systematic data has been collected. It is unclear whether the intention behind the actions is to manipulate the biophysical environment, and therefore it is also unclear whether this is a trammeling action.

Vandalism of cultural sites: Vandalism and graffiti have occurred at cultural sites in wilderness. While these actions are illegal and destructive, the intent of these acts is not to manipulate the biophysical environment. Therefore, these occurrences are not counted as trammeling actions.

Measure Description and Collection Protocol: Data value is the sum total of unauthorized trammeling actions that take place within wilderness over a five-year period. Actions that would be counted under this measure include any unauthorized action by another agency, a citizen group, or an individual citizen that *intentionally* manipulates the biophysical environment. Unintentional actions such as an escaped campfire resulting in a forest fire in wilderness are not trammeling actions because there is no intent behind the action to manipulate the biophysical environment. Examples of actions that would be counted under this measure include the unauthorized use of herbicides or mechanical means to eradicate any plant species, unauthorized seeding or planting of any plant species, arson with the intent of resource damage, widespread collection or significant harm of wildlife and plants, and intentional release of a native or exotic wildlife species, among others. Individual instances of illegal hunting or poaching would not be considered trammeling unless these actions had measurable effects altering the abundance, distribution or predator-prey relationships of species. Illegal motor vehicle incursions would not be counted as trammeling unless the intent of the action was to manipulate the biophysical environment and impacts were widespread.

For future monitoring, consult with park rangers and science and resource managers to determine whether widespread and/or significant illegal activity has occurred within wilderness that would qualify as a trammeling action. Whether a particular action is counted toward the data value should be based on the professional judgment of park staff. Please also see Appendix C for detailed information about how to count trammeling actions. Over time, an increase in unauthorized trammeling actions would contribute to a downward trend in the Untrammeled Quality.

Data Source: Grand Canyon National Park records and staff.

Data Adequacy: Low (3) – Data quantity is partial because events may occur in wilderness that are not detected. Data quality is low because fewer incidents are reported to NPS than likely occur.

Significant Change: Any change from the baseline data value is considered significant.

Natural Quality

Wilderness ecological systems are substantially free from the effects of modern civilization.

The Natural Quality assesses the integrity of local ecosystems and their freedom to change and develop without human manipulation. The Natural Quality tracks the *effects* of human actions and modern civilization on natural ecosystems (in contrast to the Untrammeled Quality, which tracks the actions themselves). Ecosystems include all living and non-living things in an area, as well as the interactions between them. Within wilderness, changes to the Natural Quality can be caused directly or indirectly, and intentionally or unintentionally. While some aspects of the Natural Quality may be under the control of wilderness managers, other aspects (such as air quality or the effects of climate change) may not be. Monitoring ecosystem changes inside wilderness is critical to understanding the unique character of each wilderness area and how it is impacted by human actions. Table 10 shows all measures used to monitor the Natural Quality in the Grand Canyon wilderness.

Greenland Lake on the Walhalla Plateau (NPS/MICHAEL QUINN).

Table 10. Measures selected for the Natural Quality.

Indicator	Measure	Data Adequacy	Significant Change	Baseline Data Value
Plants	Exotic plant species	Medium (5)	≥ 5%	208 species
Animals	Exotic animal species	Medium (5)	≥ 5%	33 species
Air and water	Haze index	High (6)	≥ 1.0 dv	4.5 dv
	Ground-level ozone	High (6)	≥ 2.0 ppm-hrs	17.5 ppm-hrs
	Nitrogen in wet deposition	High (6)	≥ 0.5 kg/ha/yr	2.8 kg/ha/yr
	Sulfur in wet deposition	High (6)	≥ 0.5 kg/ha/yr	1.0 kg/ha/yr
	Kanab Creek	Medium (5)	≥ 2 stdev	0.00444 discharge-precipitation ratio
	Havasu Creek	Medium (5)	≥ 2 stdev	0.02208 discharge-precipitation ratio
	Little Colorado River	Medium (5)	≥ 2 stdev	0.01929 discharge-precipitation ratio
Ecological processes	Fire regime	Medium (5)	Categorical	54.6 mean vegetation departure
	Landscape connectivity	High (6)	Any	498 miles of protected boundary

2.1 Exotic Plant Species

Natural Quality • Plants

2018 Baseline Data Value: 208 exotic plant species

Year(s) of Data Collection: 2018

Background and Context: Exotic plant species can alter ecosystems and threaten biodiversity by outcompeting native plant species (Vitousek et al. 1996; Cronk and Fuller 2001). Without the natural competitors or pre

dators that would be present in their native ranges, invasive plants can proliferate in landscapes where they have been introduced free from the processes that have evolved to regulate growth within their native ranges. Invasive species can affect vegetation composition, which, in turn, affects wildlife habitat, with the potential to cause cascading impacts through the ecosystem. Both plant and animal biodiversity, as well as healthy fire regimes and other ecological processes are in danger of being altered as invasive plants proliferate. Over the last few centuries, the number and abundance of exotic species have increased drastically worldwide. Exotic species are considered among the greatest threats to national parks (NPS 2006a), and it is estimated that more than 2.6 million acres (3-5 %) of NPS lands are dominated by exotic plant species (Beard and App 2012).

Historical plant surveys in Grand Canyon reveal a steady increase in exotic plant species found in the park (Mead 1930; Hawbecker 1936; McDougall 1947; NPS 2009). Some of the first exotic plants introduced to Grand Canyon were planted by early settlers to provide forage, grasses, and herbs for domestic livestock. Other exotics were introduced intentionally for erosion control or for aesthetic purposes. Creation of roads, trails, campgrounds, visitor centers, and picnic areas further contributed to establishment of exotic plant species as seeds were carried in and transported on machinery, in gravel, or contaminated seed mixes. Visitors have also unknowingly introduced and transported seeds on vehicles, mules, hiking boots, and by other means. People, machinery, vehicles, livestock, wildlife, fire, wind, and water have all contributed to exotic plant species establishment and spread.

As of 2018, 208 exotic plant species have been found within park boundaries with more expected in the future. It is estimated that roughly half the park's total acreage currently contains exotic plant species, and the entire park is considered at risk (NPS 2009). Forty-two plant species are of particular concern to park managers, because they are considered highly invasive and occur in limited and thereby manageable populations. Examples of highly invasive species in the Grand Canyon wilderness include: tamarisk, camelthorn, Russian olive, tree of heaven, knapweeds, cheatgrass, and Himalaya blackberry. For a complete list of exotic plant species, please see Appendix D. Vegetation management staff actively treat exotic plant species throughout the park. While treatment of exotic plants and restoration of native habitat should benefit this and other measures of the Natural Quality, these actions are also counted under the "Plant Species Manipulated" measure under the Untrammeled Quality.

Tamarisk along the shore of the Colorado River (NPS).

Measure Description and Collection Protocol: Data value is the total number of exotic plant species known to exist in the park. Vegetation management staff keep a list of all verified exotic plants. Please note that this list does not include exotic aquatic plants, as little information currently exists on aquatic flora in the park. While not all of these exotic plant species necessarily occur in wilderness, they are all a potential threat to the Natural Quality of wilderness character. Species that solely occur in developed areas of the park may become established in wilderness over time and should be actively monitored. For future monitoring, consult with vegetation management staff to obtain the most recent list of exotic plant species known to exist in the park. Over time, an increase in the number of exotic plants species would contribute to a downward trend for this indicator of the Natural Quality.

Data Source: Cam Prophet, *Invasive Plant Crew Lead*; Ahsa Jensen, *Nursery Manager and Crew Lead*; Daniel Boughter, *Restoration Biologist*; NPSpecies Database (NPS 2018f).

Data Adequacy: Medium (5) – Data Quantity is partial, because many remote areas of the vast Grand Canyon wilderness have not been surveyed for exotic plants. Data quality is high, because vegetation management staff keep accurate records of exotic plant locations, treatment, and proliferation and are generally aware of large-scale infestations.

Significant Change: Any change of 5% or more from the baseline is considered significant.

2.2 Exotic Animal Species

Natural Quality • Animals

2018 Baseline Data Value: 33 exotic animal species

Year(s) of Data Collection: 2018

Background and Context: Within the past two centuries, the human-mediated dispersal of species into new regions of the world has greatly increased in scale and magnitude, and is expected to intensify in future years due to climate change and the increasing globalization of travel and commerce (Baskin 2002). Some of these introduced species become naturalized in their new locations, expand their ranges, and have dramatic effects on natural systems (Cox 1999). Because exotic species did not evolve in concert with native species, their arrival can be disruptive to natural ecological processes. The consequences of exotic species invasion can include displacement of native species, alteration of food webs, and reduction in habitat value (Tempel et al. 2004).

As of 2018, there are 33 exotic animal species known to exist in the park, including four bird, four mammal, five invertebrate, and 20 fish species (NPS 2018; USGS 2018a; Table 11). Introduced fish species, such as brown and rainbow trout, have arguably had the most negative impacts on the natural ecosystem and local biodiversity. The Colorado River and tributaries were historically home to eight native fish species, of which six are endemic to the Colorado River Basin (NPS 2013). Exotic fish introductions have contributed to the extirpation of the Colorado pikeminnow and bonytail and the roundtail chub. Two other native fish species, humpback chub and razorback sucker, are currently listed as endangered. As climate change progresses, range shifts will likely allow exotic species to further proliferate (Ikeda et al. 2014). In light of these changes, park managers will be faced with difficult decisions regarding the treatment and removal of exotic species.

Table 11. Exotic animal species list.

Group	Scientific Name	Common Name
Bird	*Alectoris chukar*	Chukar Partridge
Bird	*Molothrus ater*	Brown-headed Cowbird
Bird	*Streptopelia decaocto*	Eurasian Collared-Dove
Bird	*Sturnus vulgaris*	European Starling
Fish	*Ameiurus melas*	Black bullhead
Fish	*Ameiurus natalis*	Yellow bullhead
Fish	*Cyprinus carpio*	Common carp
Fish	*Cyprinella lutrensis*	Red shiner
Fish	*Dorosoma cepedianum*	Gizzard shad
Fish	*Dorosoma petenense*	Threadfin shad

[a] No official decision has been made yet as to whether Bison are native to the park. Given current plans to control the bison population, this species was listed as exotic under this measure until a decision is reached.

[b] Gammarus was introduced in the Lees Ferry reach as trout food. It has not been taxonomically identified at the species level. For the purpose of this measure, Gammarus is counted as a single species.

Table 11 (continued). Exotic animal species list.

Group	Scientific Name	Common Name
Fish	*Fundulus zebrinus*	Plains killifish
Fish	*Gambusia affinis*	Western mosquitofish
Fish	*Ictalurus punctatus*	Channel catfish
Fish	*Lepomis cyanellus*	Green Sunfish
Fish	*Lepomis macrochirus*	Bluegill
Fish	*Micropterus dolomieu*	Smallmouth bass
Fish	*Micropterus salmoides*	Largemouth bass
Fish	*Morone saxatilis*	Striped bass
Fish	*Notemigonus crysoleucas*	Golden shiner
Fish	*Oncorhynchus mykiss*	Rainbow trout
Fish	*Pimephales promelas*	Fathead minnow
Fish	*Pomoxis nigromaculatus*	Black crappie
Fish	*Salmo trutta*	Brown trout
Fish	*Sander vitreus*	Walleye
Insect	*Pieris rapae rapae*	Cabbage White
Mammal	*Bison bison*	Bison[a]
Mammal	*Cervus elaphus*	Elk
Mammal	*Equus asinus*	Feral burro
Mammal	*Pecari tajacu*	Javelina
Other Non-vertebrates	*Didymosphenia geminata*	Rock snot
Other Non-vertebrates	*Dreissena bugensis*	Quagga mussel
Other Non-vertebrates	*Gammarus sp.*	Amphipod crustacean[b]
Other Non-vertebrates	*Potamopyrgus antipodarum*	New Zealand mud snail

[a] No official decision has been made yet as to whether Bison are native to the park. Given current plans to control the bison population, this species was listed as exotic under this measure until a decision is reached.

[b] Gammarus was introduced in the Lees Ferry reach as trout food. It has not been taxonomically identified at the species level. For the purpose of this measure, Gammarus is counted as a single species.

Measure Description and Collection Protocol: Data value is the total number of exotic animal species known to exist in the park. The NPSpecies and Nonindigenous Aquatic Species databases were used as primary sources to gather this information, which was then verified by park wildlife and fisheries biologists. Please note that this list is not comprehensive with respect to invertebrates (e.g., insects), as it is impractical to monitor them all. Instead, the intent of this measure is to monitor exotic species that are of concern to local resource specialists and provide a best available count of

exotics known to exist in the park. Over time, an increase in the total number of exotic animal species would contribute to a downward trend for this indicator of the Natural Quality.

Data Source: Greg Holm, *Wildlife Program Manager*; Brian Healy, *Fisheries Program Manager*; Miranda Terwilliger, *Wildlife Biologist*; Robert Schelly, *Fisheries Biologist*; NPSpecies and Nonindigenous Aquatic Species Databases (NPS 2018f; USGS 2018a).

Data Adequacy: Medium (5) – Data quantity is partial because some exotic animal species, especially invertebrate and small bodied fish species, may not be accounted for. Data quality is high, because the species included have been verified by park wildlife and fisheries biologists.

Significant Change: Any change of 5% or more from the baseline is considered significant.

2.3-6 Air Quality Measures

Natural Quality • Air and Water

2018 Baseline Data Values: Table 12 shows baseline data values for measures selected to monitor air quality in the Grand Canyon wilderness.

Table 12. Air quality measures: baseline data values.

Air quality measure	Baseline data value	Condition status
Haze index	4.5 dv	moderate concern
Ground-level ozone	17.5 ppm-hrs	significant concern
Nitrogen in wet deposition	2.8 kg/ha/yr	significant concern
Sulfur in wet deposition	1.0 kg/ha/yr	significant concern

Year(s) of Data Collection: 2011-2015

Background and Context: Grand Canyon National Park is designated a Class I Airshed under the Clean Air Act Amendments of 1977 (42 U.S.C. § 7401 et seq.), which provide special protection for air quality, sensitive ecosystems, and clean, clear views. Despite these protections and its relative remoteness, the vistas at Grand Canyon are sometimes obscured by haze caused by fine particles in the air. Visibility currently warrants “moderate concern” at Grand Canyon National Park. This status is based on the NPS Air Resources Division (ARD) benchmarks (Table 13) and the 2011–2015 estimated visibility on mid-range days of 7.4 deciviews (dv), which is 4.5 dv above estimated natural visibility conditions of 2.9 dv (NPS 2018a). The average natural visual range at Grand Canyon has been reduced from about 170 miles (without the effects of pollution) to about 144 miles (IMPROVE 2016). On high pollution days, the visual range has been reduced from 120 miles to below 95 miles. Coal-burning power plants, distant large urban areas and even international emissions are all contributors to haze in the park (Eatough et al. 1997; Green 1999; Eatough et al. 2001).

Table 13. ARD benchmarks for visibility, ozone, nitrogen, and sulfur (Taylor 2017).

Condition status	Haze Index (dv)	W126 (ppm-hrs)	Wet deposition (kg/ha/yr)
Resource in good condition	< 2	< 7	< 1
Warrants moderate concern	2 - 8	7 - 13	1 - 3
Warrants significant concern	> 8	> 13	> 3

These same sources also contribute to high ozone levels in the Four Corners region. Increased ozone in the lower atmosphere is a major constituent in smog. It is created when ultraviolet light interacts with volatile organic compounds and nitrogen oxides. Ground-level ozone can damage respiratory systems of humans and animals as well as plant tissues. Ecologically valuable riparian areas are especially vulnerable to ozone damage due to the presence of moisture during periods of high ozone levels. Vegetation health risks from ground-level ozone warrant "significant concern" at Grand Canyon. This status is based on the ARD benchmarks and the 2011–2015 estimated W126 metric of 17.5 parts per million-hours (ppm-hrs) (NPS 2018a). A risk assessment concluded that 19 plant species at Grand Canyon have high sensitivity to ozone concentrations (NPS 2018g).

In addition, there are 12 acid sensitive plant species known to exist in the park (NPS 2018). Deposition of nitrogen and sulfur can cause acidification, excess fertilization (eutrophication), and changes in soil and water chemistry that can affect community composition and alter biodiversity (Fenn et al. 2003). Preliminary testing has also suggested that archaeological sites are vulnerable to deterioration from acidic deposition (Sullivan 2016). Between 2011 and 2015, estimated wet nitrogen deposition was 2.8 kilograms per hectare per year (kg/ha/yr) and estimated wet sulfur deposition was 1.0 kg/ha/yr (NPS 2018a). Both levels normally warrant "moderate concern" based on the ARD benchmarks. However, vegetation communities at Grand Canyon have evolved under low nitrogen and sulfur conditions and are ranked as having "very high sensitivity" to nitrogen-enrichment and sulfuric acidification effects (Sullivan et al. 2011 and 2011a). As a result, the ARD has elevated the park's status for both nitrogen and sulfur wet deposition to "significant concern."

Past and future closures of power plants in the region may benefit air quality in the Grand Canyon wilderness. The Mojave Power Plant in Nevada was closed in 2005, and the Navajo Generating Station is scheduled for decommissioning in 2019 (Frisch 2017). The Navajo station is one of the nation's largest coal-fired power plants and less than 12 miles from Grand Canyon. Even though it has been retrofitted with pollution-scrubbing technologies, the power plant still emits high levels of sulfur and nitrogen each year (Arizona State University 2012). The Four Corners Generating Station in New Mexico, 200 miles east of Grand Canyon, also has some of the highest annual emission of nitrogen of any plant in the nation (NPCA 2010). As cheaper and cleaner energy alternatives become more viable, air quality at Grand Canyon may improve in the future.

Measure Description and Collection Protocol: Although counted as four separate measures for wilderness character trend analysis, the collection protocols for these measures are nearly identical and, therefore, described collectively in this section. In all cases, data value is an estimated 5-year

average for Grand Canyon National Park, reported from the NPS Air Quality Conditions and Trends database (NPS 2018a). Annual values are averaged over a 5-year period at each monitoring site and then interpolated across all monitoring locations using an inverse distance weighting method. The estimated 5-year average for individual parks is the maximum value within park boundaries derived from this national analysis.

Visibility is monitored throughout the U.S. in the Interagency Monitoring of Protected Visual Environments (IMPROVE) network. Currently 24-hour particulate samples are collected every third day and analyzed for chemical composition. These data are used to calculate the haze index in deciview (dv). The haze index is designed so that uniform changes in haziness correspond to uniform incremental changes in visual perception. Visibility worsens as the haze index value increases. The haze index on mid-range days (40th to 60th percentile) was used, rather than 20% haziest or clearest days (as used for Clean Air Act visibility goals), because the goal of this monitoring is to evaluate trends in the natural environment from human-caused change. Mid-range days capture overall trends in human-caused changes to visibility, while eliminating episodic natural events such as wildfires and dust events, both of which can greatly influence visibility on the 20% haziest days.

Ozone is monitored across the U.S. through air quality monitoring networks operated by the NPS, Environmental Protection Agency, states, and others. The W126 metric in ppm-hrs is a biologically relevant measure that focuses on plant response to ozone exposure. The W126 metric equation preferentially weighs the higher ozone concentrations that are more likely to cause plant damage and sums all of the weighted concentrations during daylight hours.

Atmospheric wet deposition is monitored across the U.S. as part of the National Atmospheric Deposition Program/National Trends Network (NADP/NTN). While ecosystems respond to total (wet and dry) deposition, wet deposition is used as a surrogate for total deposition, because wet deposition is the most widely available monitored source of nitrogen and sulfur deposition data. Wet deposition in kg/ha/yr was calculated by multiplying measured nitrogen and sulfur concentrations in precipitation from monitoring sites by a 30-year normalized precipitation.

Note that the estimated values reported here differ from the measured 5-year averages collected at the air quality monitoring stations in the park. It is advantageous to report an estimated value based on interpolation of data from many different monitoring stations, because data collected at a single monitoring site may not be representative of air distribution in large park expanses, such as the Grand Canyon wilderness.

Due to the time involved in processing the data, the 2018 value reported here represents the 5-year average between 2011 and 2015. For future monitoring, the most recent rolling 5-year average available should be used. Over time, a significant decrease in deciviews and ozone, nitrogen, and sulfur concentrations would result an upward trend in these measures. Please note that each air quality variable is its own measure, meaning that the trend in each will contribute separately toward the “Air and Water” indicator under the Natural Quality.

Data Source: Ksienya Taylor, *Natural Resource Specialist, ARD*; NPS Air Quality Conditions and Trends database (NPS 2018a).

Data Adequacy: High (6) – Data quantity is complete because air quality data were recorded regularly during and prior to the 5-year reporting span. Data quality is high, because there are air quality monitoring stations measuring visibility, ozone, and wet deposition within park boundaries.

Significant Change: Table 14 shows significant change thresholds for air quality measures selected. These thresholds were developed by the NPS-ARD.

Table 14. Air quality measures: significant change thresholds.

Air quality measure	Threshold
Haze index	≥ 1.0 dv
Ground-level ozone	≥ 2.0 ppm-hrs
Nitrogen in wet deposition	≥ 0.5 kg/ha/yr
Sulfur in wet deposition	≥ 0.5 kg/ha/yr

2.7-9 Discharge-Precipitation Ratios at Selected Streams

Natural Quality • Air and Water

2018 Baseline Data Value: 0.00444 (Kanab); 0.02208 (Havasu); 0.01929 (Little Colorado)

Year(s) of Data Collection: 2013-2017 (water years; October through September)

Background and Context: Much of the park's ecological diversity depends on Grand Canyon's streams, which represent some of the least altered water resources in the Southwest (Zaimes et al. 2007; Barnes 2013). These streams support rare desert riparian ecosystems and their contribution to regional biodiversity is immense (Webb et al. 2007; Zaimes et al. 2007; Barnes 2013). Feeding these surface waters, in addition to precipitation and snowmelt, is the second largest area of karst limestone bedrock of any national park unit (Weary and Doctor 2014). Contained in this dissolved bedrock is a complex groundwater system. Water travels through fractures in the rocks, sometimes emerging at the surface in the form of springs and streams that nurture life in the canyon.

A major concern for groundwater in the area is that the combination of climate change and water supply development will lead to declining water tables and dried out aquifers, threatening the stream and spring habitats so important to life in the canyon (Galloway et al. 1998; Konikow and Kendy 2005; Stortz et al. *in review*). A predicted drying of the climate in the Southwest (IPCC 2013; Kunkel et al. 2013) will lead to a decline in aquifer recharge. At the same time, population in the region is projected to increase, leading to unmet water demands before 2050 (USBR 2012). Therefore, potential increases of groundwater withdrawal pose a substantial threat to ecologically valuable water systems in the Grand Canyon wilderness.

Measure Description and Collection Protocol: Although counted as three separate measures for wilderness character trend analysis, the collection protocol for these measures is identical and, therefore, described collectively in this section. The data value for each measure is the mean annual ratio of stream flow (discharge) data and precipitation data for a selected stream drainage area over a five-year monitoring period. This ratio is used as a proxy to measure declining water tables and potential impacts from water supply developments. The underlying assumption is that the water budget for any given drainage area corresponds to the following equation:

$$\text{Precipitation} = \text{Evapotranspiration} + \text{Discharge}$$

Assuming that evapotranspiration stays relatively constant, any significant decrease in the annual discharge to precipitation ratio can be attributed to some other external factor, such as ground water withdrawal, unbalancing the above equation.

Three separate tributaries to the Colorado River (one per measure) in the Grand Canyon wilderness were selected for this analysis.

> *Kanab Creek* originates in Kane County, Utah and is fed by springs coming off of the Kaibab Plateau before entering the Colorado River 125 miles to the south. Average monthly discharge rates are heavily dependent on seasonal rainfall and snowmelt, ranging from 3 cubic feet per second (cfs) to over 50 cfs during the baseline five-year monitoring period, with a peak streamflow during this time of 9,860 cfs in August of 2013 (USGS 2018).
>
> *Havasu Creek* flows intermittently above the southern canyon wall during times of heavy snowmelt or monsoons. It meanders above the rim for about 50 miles until it enters Havasu Canyon. It then reaches Havasu Springs, where an underground source feeds the creek, resulting in steady average monthly discharge rates between 70-80 cfs year-round. Between 2013 and 2017, stream flow peaked at 11,100 cfs in August of 2013 (USGS 2013). Havasu Creek is well known for its blue-green color, distinctive travertine formations, and breathtaking water falls.
>
> The *Little Colorado River* stretches almost 340 miles from its headwaters in the White Mountains in Apache County, Arizona, to the confluence with the Colorado River near Desert View in Grand Canyon National Park. However, only the upper reaches of the river above St. Johns, and the lowermost stretch below Cameron, flow year-round; the middle section only flows during the wet seasons. Monthly average flows recorded at the USGS stream gauge near Desert View average several hundred cfs year-round, with peak stream flows often exceeding 2,000 cfs in late summer and late winter (USGS 2018).

While not a comprehensive account of waterways in the Grand Canyon wilderness, this sample provides for an initial assessment of changes in water quantity in the respective drainage areas. It also allows for the identification of potential differences between water tables on North and South Rims. To repeat this analysis in the future, please follow the steps outlined below:

1. Access stream flow data from the Water Information Systems database (USGS 2018):

   a. Kanab Creek (USGS site number: 09403850): https://waterdata.usgs.gov/nwis/uv?site_no=09403850
   b. Havasu Creek (USGS site number: 09404115): https://waterdata.usgs.gov/nwis/uv?site_no=09404115
   c. The Little Colorado River (USGS site number: 09402300): https://waterdata.usgs.gov/nwis/uv?site_no=09402300
2. Select "Time-series: Daily data"
3. Select the following parameters: "00060 Discharge (Mean)," "Tab-separated," and the dates for the water year in question. A water year is defined as the 12-month period from October 1, for any given year through September 30, of the following year. The water year is designated by the calendar year in which it ends, and which includes 9 of the 12 months.
4. Copy values into Excel and use the "text to column" function.
5. Multiply each daily mean discharge value in cfs by 86,400 (number of seconds in a day) to calculate the daily total volume. Sum these values to get the total discharge volume in cubic feet (ft^3) for the given water year
6. Access precipitation data from the Remote Automated Weather Stations (RAWS) Climate Archive (Western Regional Climate Center 2018). The corresponding monitoring stations for each stream are:
   a. Kanab Creek (RAWS: Gunsight Arizona): https://raws.dri.edu/cgi-bin/rawMAIN.pl?azAGUN
   b. Havasu Creek (RAWS: Tusayan): https://raws.dri.edu/cgi-bin/rawMAIN.pl?azATUS
   c. Little Colorado River (RAWS: Hopi Arizona): https://raws.dri.edu/cgi-bin/rawMAIN.pl?azAHPI
7. Select "Monthly Summary Time Series"
8. Select the following parameters: "Precipitation" and the months of the water year (October through September). Copy data into the excel sheet.
9. Calculate the total inches of precipitation per 12 months to get the annual total. Convert this total from inches to feet.
10. Multiply annual total precipitation in feet by the stream's total drainage area in square feet (ft^2) to arrive at the total precipitation volume in cubic feet for the drainage area of the selected stream for a given water year.
    a. Kanab Creek drainage area: 2,367 $miles^2$ (65,988,172,800 ft^2)
    b. Havasu Creek drainage area: 3,020 $miles^2$ (84,192,768,000 ft^2)
    c. Little Colorado River drainage area: 26,972 $miles^2$ (751,936,000,000 ft^2)
11. Divide total stream discharge volume (ft^3) by the total precipitation volume (ft^3) of its drainage area to calculate the annual discharge-precipitation ratio for a given water year.

12. Repeat these steps for each water during the monitoring period. The baseline data value was derived for water years 2013-2017. During future rounds of monitoring, the most recent five-year average will be compared to the 2013-2017 baseline data. For example, for the next monitoring round in 2023, data for water years 2018-2022 will be analyzed.
13. Calculate the mean annual discharge-precipitation ratio for the five-year monitoring period.
14. Subtract the baseline value from the mean annual discharge-precipitation ratio calculated for the most recent monitoring period. If the difference is equal to or greater than two standard deviations (Table 15), this change would be considered significant. For example, if the mean annual discharge-precipitation ratio recorded for Kanab Creek for water years 2018-2022 were 0.00411, the calculation would be as follows: 0.00411 - 0.00444 = -0.00033, which is a decline of less than two standard deviations. In this case, change would not be considered significant and may be attributed to natural variability.
15. Repeat this analysis for each of the three stream drainage areas.

Over time, declining mean discharge-precipitation ratios smaller than the baseline value by a magnitude of two or more standard deviations would contribute to a downward trend in the measure. Please note that each selected stream drainage area is its own measure, meaning that the trend in each will contribute separately toward the "Air and Water" indicator.

Table 15. Discharge-precipitation ratios for selected streams 2013-2017.

Water year	Kanab Creek	Havasu Creek	Little Colorado River
2013	0.00562	0.02409	0.02454
2014	0.00395	0.02705	0.01968
2015	0.00420	0.02010	0.01538
2016	0.00348	0.01754	0.02091
2017	0.00493	0.02162	0.01594
Five-year average	**0.00444**	**0.02208**	**0.01929**
Standard deviation	**0.00084**	**0.00366**	**0.00377**
Significant change	**≥ 0.00168**	**≥ 0.00732**	**≥ 0.00754**

Data Source: Ben Tobin, *Hydrologist / Cave Resource Specialist*; USGS Water Information Systems (USGS 2018); Western Regional Climate Center (2018).

Data Adequacy: Medium (5) – Data quantity is complete because streamflow and precipitation data were recorded daily during and prior to the 5-year reporting span. Data quality is partial because the precipitation data is collected at a single location and then extrapolated across the entire drainage basin. In reality, precipitation levels can vary substantially across such an area.

Significant Change: A change of two or more standard deviations is significant (Table 15).

Havasu Creek (NPS/ERIN WHITTAKER).

2.10 Fire Regime

Natural Quality • Ecological Processes

2018 Baseline Data Value: 54.6 mean vegetation departure value (moderate to high departure)

Year(s) of Data Collection: 2014

Background and Context: A fire regime describes fire frequency, intensity, timing, and distribution for a particular vegetation type. The heterogeneity in ecosystem composition and distribution across

the Grand Canyon wilderness contributes to the complex and variable role of fire as a natural disturbance factor. Wide variability in topography and vegetation communities creates stark differences in levels of fire adaptation across the landscape. Fires in the Grand Canyon wilderness were mostly suppressed between the 1870s and late 20th century, which has altered the natural fire regime in some vegetation types. Suppression has had the greatest negative effects in forested communities that once experienced frequent and low-severity fires, such as ponderosa pine forests (Huffman et al. 2008). Impacts caused by past fire suppression activity include changes to plant density, species composition, biomass distribution, nutrient cycling, forest floor shading, and other aspects of ecosystem structure and function (Fulé et al. 1997; Fulé et al. 2004).

As discussed under the Untrammeled Quality, land managers at Grand Canyon have used prescribed fires to restore fire as a natural disturbance process in forested areas above the rims. After more than 30 years of proactive fire management, progress toward restoring natural fire regimes is measurable, but far from fully achieved. The amount of managed fire has been insufficient to remedy over a century of landscape-scale fire exclusion. In many areas, multiple fire treatments will be needed to restore desired ecological conditions. As the park achieves its fire treatment objectives, the fire regime will resemble pre-suppression conditions more closely, thus benefiting the Natural Quality.

Measure Description and Collection Protocol: Data value is the average vegetation departure value calculated for selected Fire Management Units (FMUs). The FMUs selected for this analysis include Plateau, Kaibab Summit, and portions of Peninsulas, all of which are located on the Kaibab Plateau. These FMUs were chosen because prescribed fires have and will continue to take place in these units and because these units cover a large wilderness area (83,304 acres) above the rim that is mostly forested. The most recent (2014) Vegetation Departure GIS-layer was obtained from LANDFIRE. This layer depicts the amount that current vegetation has departed from simulated historical (pre-suppression era) vegetation reference conditions using a range from 0 to 100, with 100 representing maximum departure from historical conditions (Barrett et al. 2010). The reference conditions are derived from quantitative vegetation and disturbance dynamics models (Beukema et al. 2003). Current vegetation conditions are derived from LANDFIRE layers of existing vegetation type, cover, and height. Comparison of reference conditions and current vegetation conditions for the study area indicates that forested wilderness areas on the Kaibab Plateau show moderate to high departure from historical conditions, with a mean vegetation departure value of 54.6 (Figure 9; Table 16). Over time, a decrease in the average vegetation departure value would result in an upward trend in this measure and would benefit the Natural Quality.

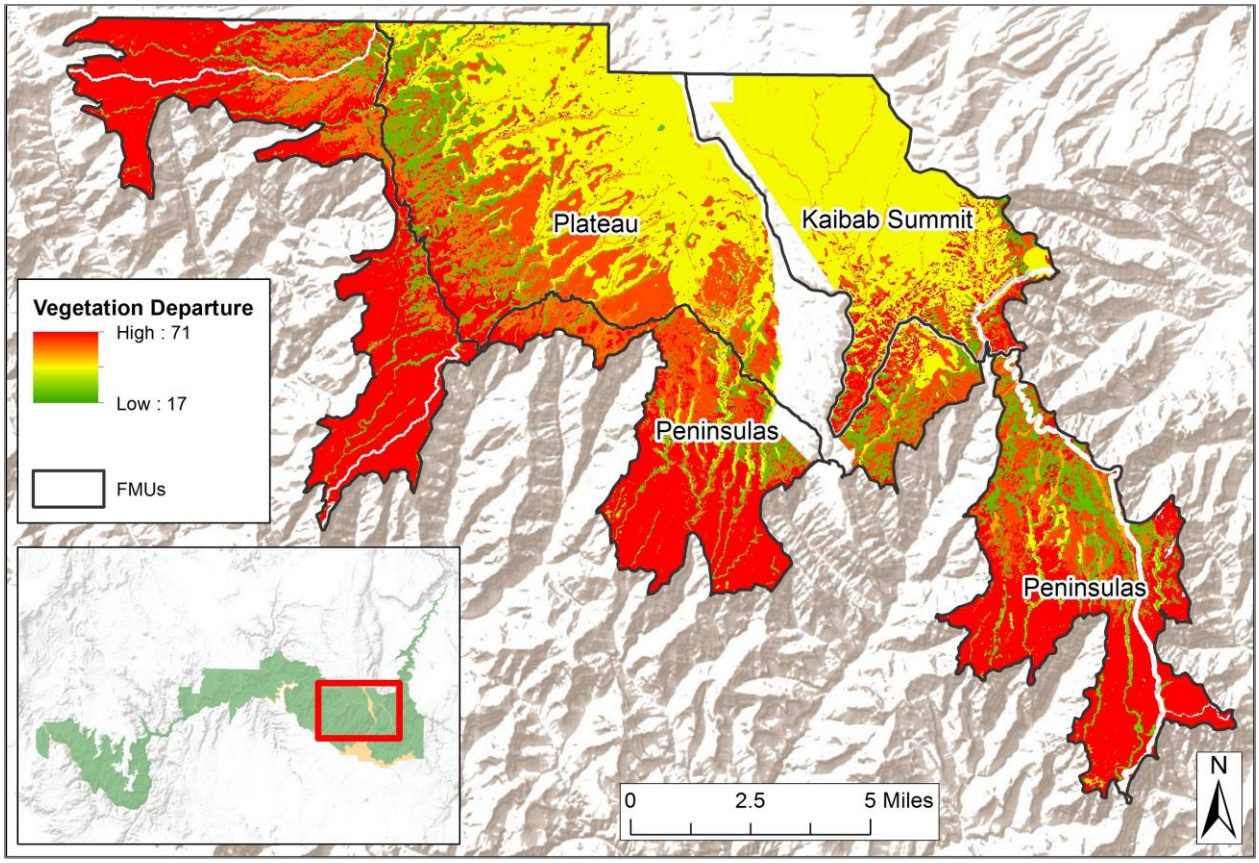


Figure 9. Map of vegetation departure from historic conditions on the Kaibab Plateau.

Table 16. Vegetation Condition Classes (LANDFIRE 2018).

Vegetation Condition Class	Departure Value
1a: Very low departure	0 - 16
1b: Low departure	17 - 33
2a: Moderate to low departure	34 - 50
2b: Moderate to high departure	51 - 66
3a: High departure	67 - 83
3b: Very high departure	84 - 100

Data Source: Jay Lusher, *Chief of Fire and Aviation*; Chris Marks, *Deputy Fire Management Officer*; David Robinson, *Fuels Specialist*; LANDFIRE database (LANDFIRE 2018).

Data Adequacy: Medium (5) – Data quantity is complete because LANDFIRE modeling used remote sensing data, providing total coverage of the study area. Data quality is moderate because there is a moderate level of uncertainty with the modeled data. A more accurate fire regime analysis would require a synthesis of multiple sources of historical fire data for comparison with modern records and observations. Such an analysis extends beyond the scope of this monitoring.

Significant Change: Change from one Vegetation Condition Class to another is significant.

2.11 Landscape Connectivity

Natural Quality • Ecological Processes

2018 Baseline Data Value: 498 miles of wilderness boundary shared with protected areas

Year(s) of Data Collection: 2018

Background and Context: Landscape connectivity is an expression of the degree to which species are able to maintain their natural range and migration patterns. When populations become isolated, they lose genetic diversity and become vulnerable to local extinction. Connectivity may also facilitate the ability of species to adapt to climate change with mechanisms such as range shifts. Connectivity is diminished by human development and activity such as roads, buildings, agriculture, mining, and other changes to the natural condition of the land. Tracking change in connectivity provides insight into the impacts and pressures outside developments have on wilderness ecosystems.

The Grand Canyon wilderness is almost entirely surrounded by other federal and tribal lands. The park is bounded in the north by the Kaibab National Forest and the Arizona Strip District of the BLM (which includes Grand Canyon-Parashant National Monument and Vermilion Cliffs National Monument), on the east by the Navajo Reservation and Glen Canyon National NRA, on the south by the Kaibab National Forest and Hualapai and Havasupai reservations, and on the west by Lake Mead NRA (Figure 10). While these surrounding lands offer a buffer of environmental protection, they are not all subject to the same laws and policies as wilderness. BLM and USFS lands are managed under the multiple-use concept, which permits grazing, hunting, logging, mining, and other forms of resource extraction. The U.S. Bureau of Reclamation (USBR) has a mission focused on managing water resources, including dams, powerplants, and canals. Activities and developments on American Indian reservations take place at the discretion of tribal governments.

Ten additional wilderness areas comprise the Greater Grand Canyon wilderness complex (Figure 10; Table 17). In fact, the Grand Canyon wilderness forms the core of 1.5 million acres of *de facto* wilderness consisting of designated and proposed wilderness units. Three designated wilderness units are contiguous to the park: Saddle Mountain Wilderness (USFS), Mt. Logan Wilderness (BLM), and Kanab Creek Wilderness (BLM/USFS). The Grand Canyon wilderness also adjoins seven proposed wilderness units in the Grand Canyon-Parashant National Monument: Shivwits Plateau, Andrus Point, Lava, Whitmore Point, Balanced Rock, Cockscomb, and Azure Ridge. Additionally, the Kaibab Squirrel NNL extends beyond the park, protecting 223,106 acres of the Kaibab National Forest.

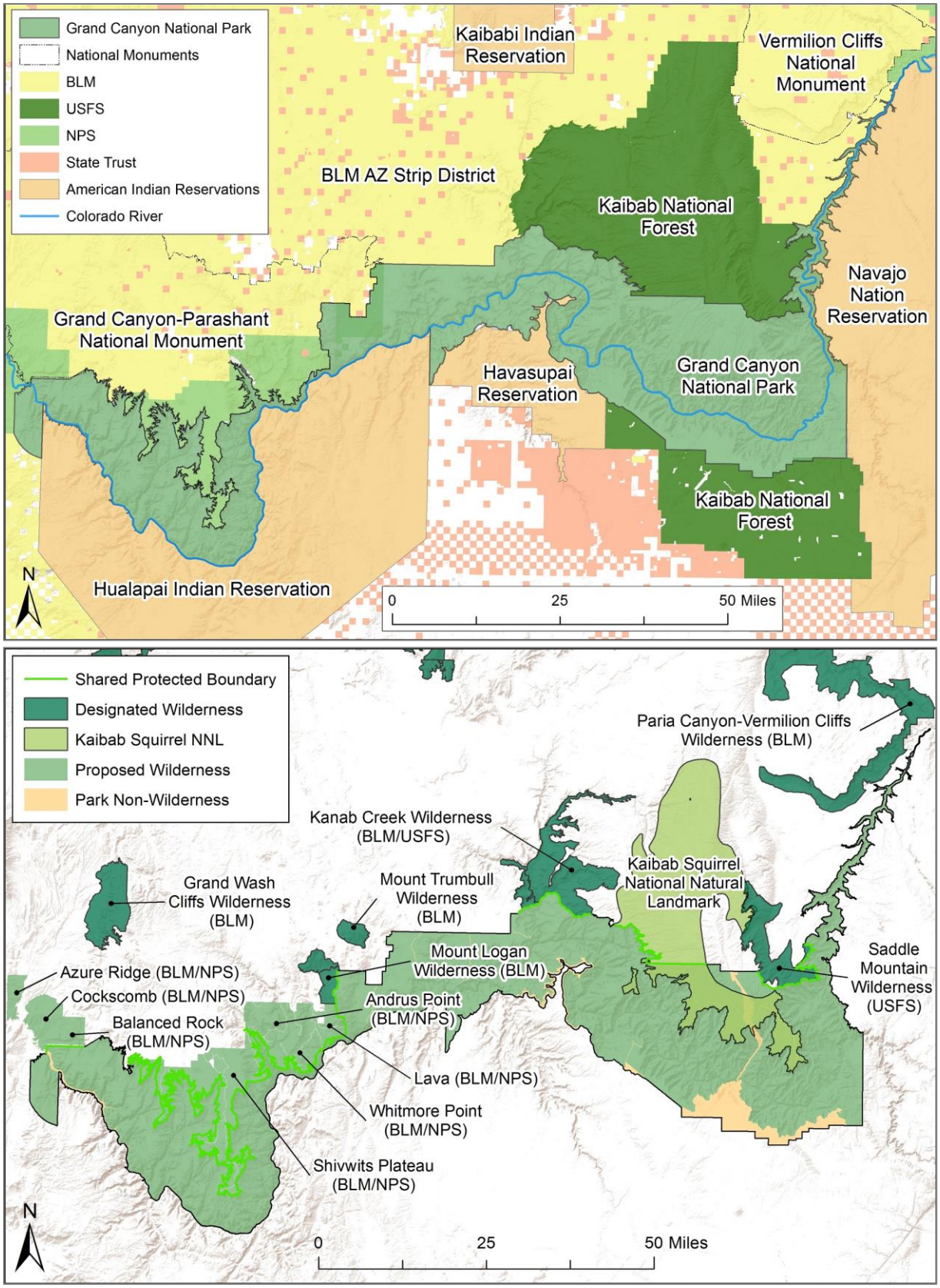


Figure 10. Maps of wilderness areas and landownership in the Grand Canyon region.

Table 17. Wilderness areas adjoining the Grand Canyon wilderness.

Wilderness	Agency	Status	Acres
Andrus Point	BLM/NPS	Proposed	16,149
Azure Ridge	BLM/NPS	Proposed	8,602
Balanced Rock	BLM/NPS	Proposed	14,709
Cockscomb	BLM/NPS	Proposed	16,799
Kanab Creek	BLM/USFS	Designated	68,412
Lava	BLM/NPS	Proposed	11,650
Mt. Logan	BLM	Designated	14,733
Saddle Mountain	USFS	Designated	41,118
Shivwits Plateau	BLM/NPS	Proposed	84,882
Whitmore Point	BLM/NPS	Proposed	37,708
Total	**–**	**–**	**314,762**

In total, the Grand Canyon wilderness shares 54 miles of boundary with other designated wilderness areas, 406 miles with proposed areas that are managed as wilderness, and 38 miles with the Kaibab Squirrel NNL. This means that 498 miles (44%) of the park's total 1,126-mile circumference intersect with other public lands that are managed primarily for conservation purposes. It is safe to say that the Grand Canyon *de facto* wilderness complex forms one of the largest undeveloped areas in the continental United States that is protected from the habitat destruction and fragmentation threatening biodiversity in many other places around the world.

Measure Description and Collection Protocol: Data value is the total mileage of wilderness boundary that intersects other protected areas. For purposes of this measure, "protected areas" include lands that are managed as wilderness or are set aside primarily for conservation purposes. Protected areas include all categories of wilderness, including eligible, proposed, and recommended, because they are currently all managed in the same manner as designated wilderness while awaiting the legislative process. The Kaibab Squirrel NNL was also included, because this landmark is managed for its outstanding biological diversity, illustrative character, rarity, and value to science and education. GIS analysis was used to calculate the miles of border shared between the Grand Canyon wilderness and adjoining protected areas. Over time, an increase in this mileage would indicate an upward trend for this measure.

Data Source: SouthwestWilderness and PARA_Proposed Wilderness_2008 GIS-layers (Wilderness.gdb, GRCA GIS Database Library); KaibabSquirrel_NNL GIS-layer (Wildlife,gdb., GRCA GIS Database Library).

Data Adequacy: High (6) – Data quantity is complete, because land use data is available for all lands adjoining the Grand Canyon wilderness. Data quality is high, because protection status for these lands is well documented.

Significant Change: Any change from the baseline data value is considered significant.

Undeveloped Quality

Wilderness retains its primeval character and influence, and is essentially without permanent improvement or modern human occupation.

The Undeveloped Quality is the most familiar and recognizable quality of wilderness for many people. Without buildings, roads, or improvements on the landscape, the Undeveloped Quality demonstrates the idea that humans are visitors that do not remain. Motor vehicles, motorized equipment, and mechanical transport also affect how humans interact with wilderness landscapes. These uses likewise diminish the primeval character and influence of wilderness and are correspondingly monitored within the Undeveloped Quality of wilderness character. The Wilderness Act of 1964 makes the following allusions to the Undeveloped Quality of wilderness character:

- The National Wilderness Preservation System was created "in order to assure that an increasing population, accompanied by expanding settlement and growing mechanization, does not occupy all areas within the United States" (2a);
- Wilderness is "in contrast with those areas where man and his own works dominate the landscape" (2c);
- Wilderness should be managed in such a way that "the imprint of man's work is substantially unnoticeable" (2c);
- And that "there shall be no permanent road within any Wilderness area…no temporary road, no use of motor vehicles, motorized equipment or motorboats, no landing of aircraft, no other form of mechanical transport, and no structure or installations within any such area" (4c).

Table 18 shows measures used to monitor the Undeveloped Quality in the Grand Canyon wilderness.

Table 18. Measures selected for the Undeveloped Quality.

Indicator	Measure	Data Adequacy	Significant Change	Baseline Data Value
Presence of non-recreational structures, installations, and developments	Index of authorized non-recreational developments	Medium (4)	≥ 5%	642.8 weighted development score
	Primitive road corridors	High (6)	Any	78.6 miles
Presence of inholdings	Inholdings	High (6)	Any	3 inholdings
Use of motor vehicles, motorized equipment, or mechanical transport	Administrative flight hours	Medium (4)	≥ 5%	595 flight hours / year
	Motorized river travel	Medium (5)	≥ 2 stdev	481 motorized trip launches / year

3.1 Index of Authorized Non-Recreational Developments

Undeveloped Quality • Presence of non-recreational structures, installations, and developments

2018 Baseline Data Value: 642.8 total weighted development score

Year(s) of Data Collection: 2018

Background and Context: Modern structures, installations, and developments are signs of human presence and impact the Undeveloped Quality of wilderness character. Developments in wilderness vary in sizes from hardly-noticeable wildlife cameras to larger, more obvious infrastructure like radio repeaters and fire towers. Table 19 is the best available inventory of current non-recreational structures, installations, and developments present in the Grand Canyon wilderness. Due to the vastness and remoteness of the Grand Canyon wilderness, some developments that are present in wilderness may not be included in this inventory. For example, non-functioning installations from past research projects may be unaccounted for.

Measure Description and Collection Protocol: Data value is a weighted score that reflects the extent of all non-recreational physical developments in wilderness. Many structures counted in this measure support the preservation of other wilderness qualities, but any modern development in wilderness negatively affects the Undeveloped Quality. Currently functioning and defunct administrative and scientific installations, as well as historical structures are included. Pre-modern (prior to European settlement) archaeological sites, such as cliff dwelling and kivas, are excluded from this measure. Developments that exist primarily for recreation purposes like backcountry toilets are not counted in this measure; they are monitored as facilities that decrease self-reliant recreation under the Solitude or Primitive and Unconfined Recreation Quality.

"Weight of development" values of structures were derived loosely from the "BLM Development Index" (BLM 2012, pp. 25-26). The final data value is the aggregate of all developments multiplied by their respective "weight of development" value. Over time, a decrease in this aggregate would contribute to an upward trend for this indicator. If something is added during future rounds of monitoring not because it was built or installed in that time, but because it was overlooked, not yet discovered, forgotten, and not inventoried in this assessment, it should not count against the Undeveloped Quality. It should be noted, documented, and added to the baseline data value.

Data Source: Mark Nebel, *GIS Program Manager*; Ronda Newton, *Research Coordinator*; park records and staff; Structures, Stocktanks, and Utilities geodatabases (GRCA GIS Database Library).

Data Adequacy: Medium (4) – Data quantity is partial because some developments present in wilderness may not be accounted for. Data quality is moderate because some numbers have been estimated using best judgments.

Significant Change: Any change of 5% or more from the baseline is considered significant.

Table 19. Index of non-recreational developments.

Category	Development	Descriptions and Comments	Number	Weight of Development	Development Score
Administrative structures (score: 121)	Radio repeaters	Mt. Emma repeater	1	15	15
	Bison exclosures	Fencing for protection of water resources	6	3	18
	Metal gates	Last Chance mine, Rampart, Domes, Stanton's Caves	4	1	4
	Cave registers	Ammo cans	75	0.2	15
	Trail counters	Hermit and Grandview trails	2	0.1	0.2
	Vegetation fencing	Protect outplanted vegetation from herbivory at restoration sites at Cardenas (54) and Granite Camp (172)	226	0.3	67.8
	Caches	Large aluminum river box (1), 5-gallon buckets (10), ammo can (1) each at Cardenas and Granite Camp	2	0.5	1
Historic structures (score: 439)	Cabins	Muave Saddle, Basin, Historic Salt, and Kanabownits cabins, Pasture Wash ranger station, Pasture Wash barn	6	7	42
	Fire towers	Kanabownits and Signal Hill fire towers	2	10	20
	Water infrastructure	Pasture Wash water catchment and cistern	1	5	5
	Stock tanks	Earthen ponds constructed for livestock	34	3	102
	Cable crossings	Lees Ferry, LCR, Diamond Creek	3	5	15
	Mines	Last Chance, Bass copper, Bass asbestos, Tanner-McCormack, Point Sublime Copper, Copper Grant, Marshall Lazune Group, Boucher, Hance, Orphan, and 11 mines that have no official name	21	10	210
	Tram towers	Bat Cave Tram Towers	3	15	45
Research Installations (score: 82.8)	Wildlife cameras	Monitor bison, javelina, hognose skunks, etc.	49	0.1	4.9
	Wildlife collars	Bighorn sheep (2) and bison (8)	10	0.2	2
	Acoustics recorders	Bat study, soundscapes, overflights	7	0.2	1.4
	Tree metal tags	Mark goshawk nest trees	35	0.2	7

Table 19 (continued). Index of non-recreational developments.

Category	Development	Descriptions and Comments	Number	Weight of Development	Development Score
Research Installations (score: 82.8) (continued)	Rebar plot markers	Vegetation study	51	0.2	10.2
	Control points	Geodetic control network	442	0.1	44.2
	Ultrasonic Receivers	Passive telemetry to listen for fish with implanted sonic tags	18	0.1	1.8
	Cave temp. loggers	Cave monitoring	10	0.1	1
	Cave visit counters	Cave of the Domes and confidential locations	5	0.1	0.5
	Weather stations	Includes 5' pole on tripod, camera, solar panel	5	1	5
	Beach cameras	Monitoring of beach erosion	48	0.1	4.8

Top left: Salt Cabin; top right: stock tank; middle left: Last Chance Mine cookhouse; middle right: winch at Last Chance Mine; bottom left: wildlife camera; bottom right: trail counter (NPS).

3.2 Primitive Road Corridors

Undeveloped Quality • Presence of non-recreational structures, installations, and developments

2018 Baseline Data Value: 78.7 miles

Year(s) of Data Collection: 2018

Background and Context: The 1964 Wilderness Act explicitly states that there shall be no permanent roads in wilderness "except as necessary to meet minimum requirements for the administration of the area" (4c). In fact, only roadless "islands" of at least 5,000 contiguous acres were initially reviewed for wilderness suitability. NPS Management Policy (2006a) prohibits operating any motorized vehicle within wilderness, on or off-road, except as provided for in specific legislation. Roads in wilderness pose a significant and direct impact to wilderness character and are clear signs of human development. Additionally, roads enable motorized use and increased traffic in wilderness areas, impacting many qualities of wilderness character.

As a result of the 1980 and subsequent Wilderness Recommendations, over one hundred primitive roads (combined over 200 miles) in wilderness have been closed over the last decades (Figure 11). While some of these roads are still distinguishable, many of them have been revegetated and returned to a natural state or have been converted to trails. These management actions have improved wilderness character and are representative of changing attitudes among park managers away from road-building and toward wilderness preservation.

The only roads located within wilderness are exclusively for administrative purposes and include: Cedar Mountain (7.4 miles) and E-15 (3.0 miles) roads near desert view and Kanabownits Cabin and Tower roads (combined 0.4 miles), minor off-shoots of Kanabownits Road leading to said administrative features. In addition, USFS road FS268 (1.0 mile) is open to the public and briefly forms the park/wilderness boundary with the Kaibab National Forest near Swamp Ridge.

In addition, there are 78.6 miles of primitive roads that bisect wilderness areas, but are located in 300-ft wide non-wilderness corridors staked out by the Wilderness Recommendation (NPS 2010; Figure 11; Table 20). Even though these roads are not strictly in wilderness and occupy a small fraction of the landscape in terms of total area, their influence extends beyond their immediate boundaries. Roads precipitate habitat fragmentation by splitting otherwise large patches into smaller ones, and thus creating edge habitat. Road access is also correlated with hunting pressure, poaching, and harassment, especially of large mammals (Ruth et al. 2011), as well as increased vandalism to cultural resources (NPS 1998). In addition, vehicular traffic directly destroys biological resources by crushing vegetation and biological soils, and retards revegetation through soil compaction (NPS 1998). Disturbed surfaces in turn provide ideal habitat and avenues for invasive species proliferation (NPS 2009). While these roads facilitate access to major trailheads and scenic viewpoints, they are clear signs of development and impact wilderness character.

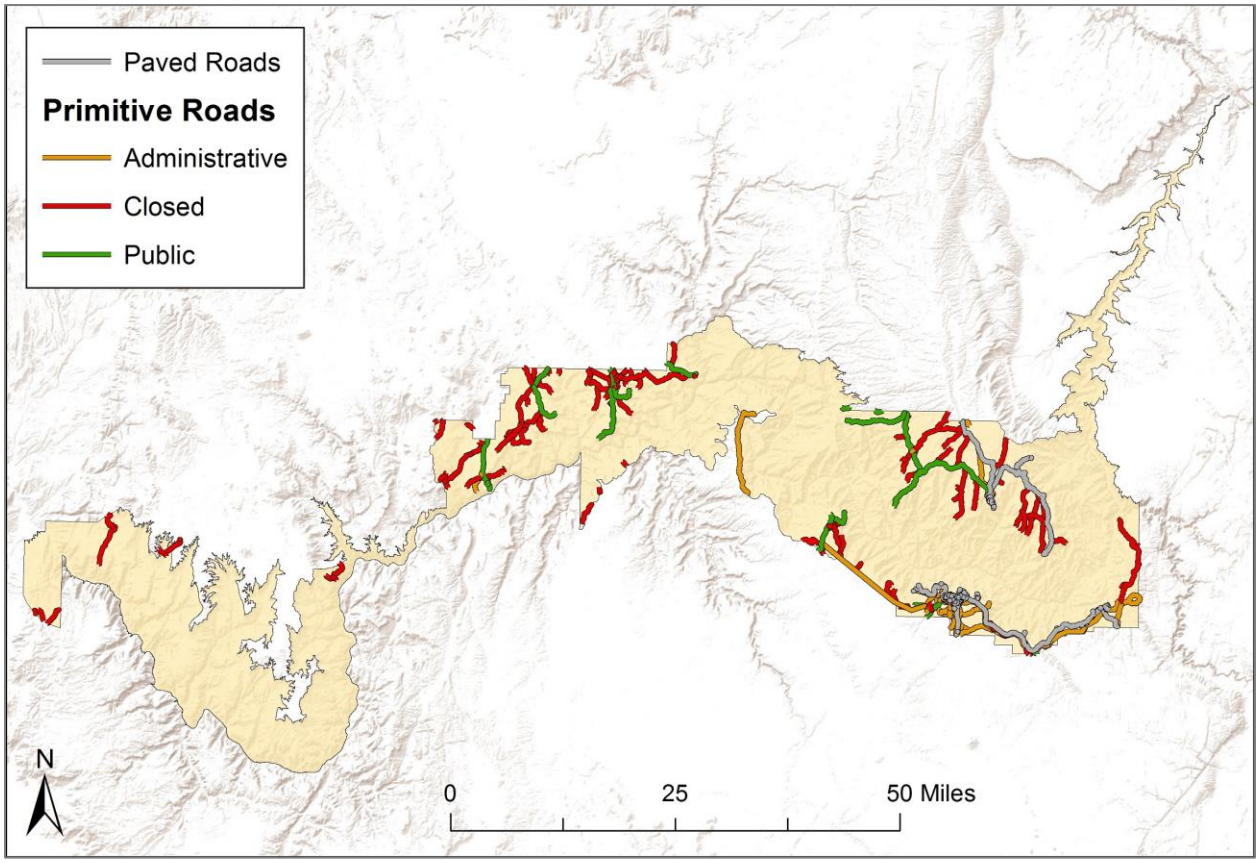


Figure 11. Map of roads within park boundaries.

Table 20. List of primitive road corridors bisecting wilderness.

Road name	Miles
150 Mile Canyon Road	5.9
Fire Point Road	1.0
FS268 Road	1.0
Havasupai Point	3.0
K-10 Road	2.7
Kanab Point Road	4.3
Kanabownits Road	8.6
Point Sublime Road	17.2
SB Point Road	7.9
Schmutz	5.4
South Bass Trailhead	4.6
Swamp Point Road	7.9
Toroweap Valley Road	6.8
Vulcans Throne Road	2.4
Total miles of road	**78.7**

Measure Description and Collection Protocol: Data value is the total miles of primitive road corridors that bisect wilderness. Both public and administrative roads were counted under this measure. Roads that are officially considered closed are not counted, although their contour may in some cases still be readily apparent in the landscape. The park's GIS Program Manager was consulted to determine an accurate mileage count of all roads in the park. In the case of a few roads, their status (closed, public, or administrative) was unclear, with conflicting management guidelines outlined by different park documents. The Superintendent's Compendium (NPS 2018b) was used as the main authority to determine road status. The Wilderness Recommendation (NPS 2010) and park staff familiar with the matter were also consulted. In a few cases, *de facto* road conditions encountered on the ground were inconsistent with management guidelines.

The Backcountry Management Plan DEIS (NPS 2015) proposes to clarify the status of several primitive roads in the park. A future Wilderness Stewardship Plan and other park documents may also reassess the existence and extent of primitive roads. Therefore, a change in this data value is possible. For future monitoring, the park's GIS Program Manager, the current Superintendent's Compendium, recent park planning documents, and the Roads GIS-layer should be consulted to determine if any roads listed in Table 20 have been closed in recent years. In the unlikely event that future road-building in the Grand Canyon wilderness is authorized by the NPS, such development would significantly degrade wilderness character. By contrast, if additional roads are closed, revegetated, or converted to trails, a decrease in total miles of primitive road corridors bisecting wilderness would contribute to an upward trend for this indicator of the Undeveloped Quality.

Data Source: Mark Nebel, *GIS Program Manager*; Roads GIS-layer (Transportation.gdb, GRCA GIS Database Library); Superintendent's Compendium (NPS 2018b); Wilderness Recommendation (NPS 2010).

Data Adequacy: High (6) – Data quantity is complete because park managers are aware of and maintain accurate GIS data on all roads in wilderness. Data quality is high for the same reason.

Significant Change: Any change from the baseline data value is considered significant.

Primitive road on the North Rim (NPS).

3.3 Inholdings

Undeveloped Quality • Presence of inholdings

2018 Baseline Data Value: 3 inholdings

Year(s) of Data Collection: 2018

Background and Context: Inholdings in wilderness are not subject to the same laws and policies as wilderness lands. They can pose problems for wilderness managers, as the activities and developments that take place within them are at the discretion of the landowner and have the potential to impact wilderness character. The presence of inholdings may encourage future developments or mechanized use in the wilderness, because the Wilderness Act specifically allows mechanical use and road-building for accessing "existing claims or rights" (4c). Currently, three inholdings exist within the Grand Canyon wilderness, totaling 15,545 acres.

Hearst Inholding

These privately owned lands comprise 325 acres in the southeast portion of the park. Mining for asbestos last occurred in this area in the late 1950s. Access to the tract is by river or helicopter. The Land Protection Plan recommends fee acquisition, with donation or exchange as the preferred acquisition method (NPS 1989). The inholding is currently proposed as potential wilderness (NPS 2010). The intention of the inholding owner is unknown.

Curtis-Lee Tracts:

These tracts consist of 67 acres located in Toroweap Valley. They are currently proposed as potential wilderness (NPS 2010). These tracts are identified for fee acquisition in the event donation is not possible (NPS 1989). The intentions of the inholding owners are unknown.

Navajo Inholding

These lands comprise an approximately 15,153-acre inholding within the legal boundary of Grand Canyon National Park as defined by the 1975 Enlargement Act (16 U.S.C. § 228). The Navajo inholding consists of all lands between one-quarter mile from the east bank of the Colorado River and Marble Canyon rim. Although the 1975 Enlargement Act included this area within the park's legal boundaries, the area is also included within the lands of the Navajo Nation Reservation. In recognition of this, the act states in Section 5: "no land or interest in land, which is held in trust for any Indian tribe or nation, may be transferred to the United States under this Act or for purpose of this Act except after approval by the governing body of the respective Indian tribe or nation." The 1975 Enlargement Act was passed with the intention of meeting Navajo concurrence, but concurrence was never formally requested. The 15,153-acre inholding is identified as proposed potential wilderness until concurrence is reached with the Navajo Nation (NPS 2010).

Other unresolved land ownership issues and boundary disputes are described below.

Navajo Boundary Dispute

The Navajo Nation claims ownership of the entire 23,834-acre area from the Colorado River to the east rim of Marble Canyon. Based upon a Field Solicitor Opinion (Manges 1969), the NPS maintains

that parklands extend one-quarter mile east of the bank of the Colorado River. The one-quarter-mile-wide ownership dispute area (8,681 acres) is included within the administrative boundary of the park and has been classified as proposed wilderness (as opposed to proposed potential wilderness, as is the case with the Navajo inholding).

Hualapai Boundary Dispute

The Hualapai Reservation was established in 1883, three decades before the establishment of Grand Canyon National Park. The executive order establishing the reservation indicated that its northern boundary is the southern shore of the Colorado River (RM 165.2 to RM 273.9). To the Hualapai, the Colorado River is the backbone or *hakatai'a* of their lifeline, and they believe the center of the river is the boundary of their lands. A solicitor's opinion (Leshy 1997) places the boundary at the historic high-water mark on the south bank of the river. In early 2000, the NPS and the Hualapai signed a memorandum of understanding formalizing a government-to-government partnership, acknowledging different interpretations of the boundary, but agreeing to cooperatively address the area of dispute, now identified as an "Area of Cooperation."

State Ownership: Colorado Riverbed

The State of Arizona holds fee title to the bed of the Colorado River. The Land Protection Plan (NPS 1989) identifies acquisition of these tracts through exchange as a priority. State ownership of the riverbed does not preclude wilderness designation (NPS 2010).

Measure Description and Collection Protocol: Data value is the number of inholdings located within the boundaries of the Grand Canyon wilderness. An inholding is defined as land owned or managed by an entity other than the NPS that is within wilderness boundaries (NPS 2013b). This measure does not include development on adjacent lands unless a parcel is included within the wilderness boundary. The Curtis-Lee Tracts are counted as a single inholding. It is highly unlikely that any new inholdings in wilderness would be established. At this point, it is also considered unlikely that the three current inholdings would be transferred to NPS any time soon. A decrease in inholdings would contribute to an upward trend in the Undeveloped Quality.

Data Source: Mark Nebel, *GIS Program Manager*; Inholdings GIS-layer (GRCA_Boundary.gdb, GRCA GIS Database Library).

Data Adequacy: High (6) – Data quantity is high because of the formal documentation process by which inholdings are acquired and ownership transferred. Data quality is high for the same reason.

Significant Change: Any change from the baseline data value is considered significant.

3.4 Administrative Flight Hours

Undeveloped Quality • Use of motor vehicles, motorized equipment, or mechanical transport

2018 Baseline Data Value: 595 flight hours / year (helicopter & fixed-wing)

Year(s) of Data Collection: 2013-2017

Background and Context: Mechanical transport is prohibited by the Wilderness Act, except when "necessary to meet minimum requirements of the administration of the area for the purpose of this Act" (4c). While permitted if necessary, the use and landing of helicopters and aircraft – like all motorized use in wilderness – diminishes the Undeveloped Quality of wilderness character. Aircraft use can also disturb wildlife, disrupt natural quiet, and hamper visitor solitude impacting both the Natural and Solitude or Primitive and Unconfined Recreation Qualities.

The remoteness and rugged topography of the Grand Canyon wilderness makes administrative aircraft use a critical and sometimes life-saving tool. The park has a large aviation workload, and aircraft are involved in many projects, including construction and maintenance of facilities and infrastructure, basic transportation of persons and cargo for managerial and administrative purpose, SAR operations, medical response and evacuation, law enforcement, and wildland fire detection, management, and suppression.

As a result, the park has long been concerned about the effects of its own air operations on the natural soundscape and has implemented one of the most strictly regulated aviation programs within the NPS and the DOI. The park's first Internal Aviation Management Plan (NPS 1986) established a stringent internal policy to review and reduce park flights. Today, each flight request is reviewed to ensure that it is the most efficient, economical, and effective method of performing the required task consistent with park objectives. These objectives include the protection of natural soundscapes.

To further mitigate impacts to soundscapes caused by air operations, the park has also led the way in incorporating "quiet aircraft technology." As of this writing, the primary helicopter model (Boeing / McDonnell Douglas MD900 Explorer) used for administrative missions continues to be among the quietest helicopters in operation, demonstrating the park's commitment to achieving the goal of substantially restoring the natural quiet in the park.

Figure 12 and Table 21 show the major users of the park's aviation program between 2013 and 2017. 2017 was an unusual year with several significant incidents and projects such as the North Rim pipeline break and the Merrell Search, which added flight time that was above average. During the next five-year monitoring period (2018-2022), it is predicted that the park's aviation program will continue to operate above average due to major upcoming projects requiring aviation support, including the transcanyon pipeline project. While necessary for the administration of the park, flight operations have a clear impact on wilderness character. Monitoring patterns of administrative flight operations will enable managers to be aware of trends in aircraft use and make well-informed decisions regarding the necessity of authorizing motorized use in wilderness.

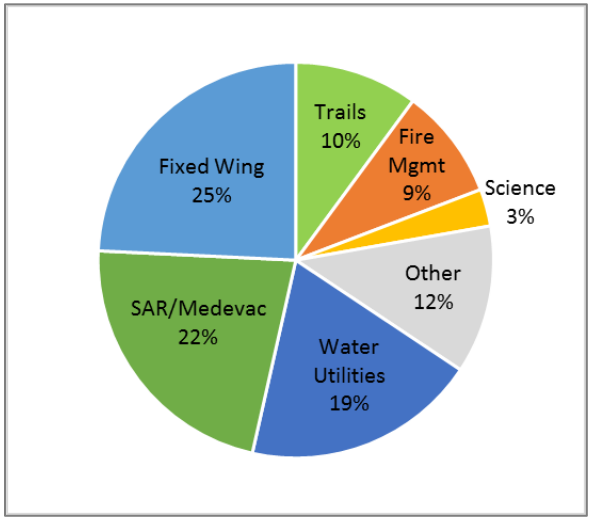


Figure 12. Pie chart showing distribution of administrative flight time by major users.

Table 21. Administrative flight hours: 2013-2017.

Year	Trails	Water Utilities	SAR/ Medevac	Fire Mgmt	Science	Other	Total (Helicopter)	Fixed-Wing	Total (Combined)
2013	88	115	130	26	18	78	455	–	–
2014	18	93	107	83	17	38	356	–	–
2015	58	83	138	14	16	89	398	–	–
2016	71	112	137	69	23	64	475	–	–
2017	77	171	142	72	25	91	578	–	–
2013-17	312	574	654	264	99	360	2,262	712	2,974
Average	**62**	**115**	**131**	**53**	**20**	**72**	**452**	**142**	**595**

Measure Description and Collection Protocol: Data value is the mean annual number of administrative flight hours within Grand Canyon National Park. The park's aviation management staff annually prepare an "Air Operations Summary," in which the data for this monitoring is made available. Please note that the summary statistics include SAR and wildland fire missions flown out of park to support the interagency community. These flight hours are subtracted and excluded from this monitoring. Further, "guarantee time" is omitted, as these hours are not flown in the park. Over time, a decrease in the mean annual number of administrative flight hours would contribute to an upward trend in this indicator.

Parkwide (opposed to wilderness-specific) data was used for this measure for several reasons. Given the park's large aviation work load, it would have been impractical to analyze each flight description to determine if a given flight entered wilderness. Furthermore, administrative flights are routed away from developed areas for noise abatement and to reduce risks to visitors, residents, facilities, and park resources including listed National Register historic buildings and districts (NPS 2011). Therefore, it is safe to assume that almost all administrative flights pass over wilderness, even if their destination is in non-wilderness. For example, a helicopter delivering steel pipe for pipeline replacement in the non-wilderness crosscanyon corridor still has the potential to impact wilderness character. Locations of helicopter landings, except for SAR operations, are also not documented in the park's aviation database. This makes it difficult to determine if and when helicopters land in wilderness. An attribute field could be added to the database, indicating the location of the landing and/or whether the landing took place in wilderness. The need for such record keeping was identified in the "Opportunities for Future Wilderness Planning" section at the end of this report.

Furthermore, fixed-wing use is currently much more difficult to track than helicopter use. Fixed-wing hours flown in the park are combined in the "Annual Air Operations Summary" with flight operations assisting the interagency community. More detailed reporting and statistics on fixed-wing flights for NPS missions occurring within the park could be made available.

Lastly, in 2015, Grand Canyon National Park began operating the first unmanned aircraft systems (UAS) program within the NPS. The goal of the program is to reduce risk to personnel, resources, and visitors and to develop best practices for future UAS integration at other NPS units. In 2017, the park safely conducted thirteen UAS missions for a total of over 24 hours of flight time. If the UAS program becomes firmly established as part of park aviation operations, it should be included during future monitoring.

Data Source: Matthew Walls, *Assistant Helicopter Program Manager*; Brandon Torres, *Chief of Emergency Services*; Eric Graff, *Helicopter Program Manager/Paramedic*; Galen Howell, *Airplane Pilot*; Annual GRCA Aviation Reports (2013-2017).

Data Adequacy: Medium (4) – Data Quantity is partial, because UAS are unaccounted for. Data quality is medium, because it is unknown how many administrative flights within the park actually entered wilderness. Confidence in the accuracy of the fixed-wing data is also moderate.

Significant Change: Any change of 5% or more from the baseline is considered significant.

NPS helicopter landing next to the Colorado River (NPS).

3.5 Motorized River Travel

Undeveloped Quality • Use of motor vehicles, motorized equipment, or mechanical transport

2018 Baseline Data Value: 481 motorized trip launches / year

Year(s) of Data Collection: 2013-2017

Background and Context: The Grand Canyon Wilderness Recommendation (NPS 2010) identifies 233.3 miles (10,998 acres) of the Colorado River corridor as proposed potential wilderness, meaning that these lands possess wilderness characteristics which would normally qualify them for designation, but contain temporary non-conforming uses, which prevent their being immediately designated as wilderness. In the case of the Colorado River, motor boats have been used for exploring the river since 1949. The NPS has moved to phase out motorized river use several times (NPS 1972 and 1980) to conform with mandates from its policies (NPS 2006a), but plans have been met with strong opposition. The continued operation of motorboats on the Colorado River impacts the Undeveloped Quality of the area and is inconsistent with the value and purpose of wilderness.

Today, commercial outfitters under contract with the NPS take visitors down the river in motorized rafts between April 1 and September 16 (NPS 2006). Boats are powered by 25- to 40-horsepower, four-stroke engines, and each boat typically carries 8 to 23 people. Permits for noncommercial river trips are distributed through a weighted lottery system. Most self-guided trips are conducted via non-motorized vessels (e.g. rafts, dories, and kayaks), but permit holders are allowed to travel down the river via motorized craft during the mixed-use season with their maximum trip length reduced to 12 days. Finally, administrative river use includes missions that focus on resource management, scientific research, education, visitor protection, and tribal issues. Administrative river missions are

not included in the use allocations and are scheduled in consideration of recreational-use launch patterns. Some administrative river missions involve motorized watercraft.

Of the total motorized launches between 2013 and 2017, commercial trips accounted for 89%, self-guided trips for 5%, and administrative missions for 6% (Table 22). River use is well documented and regulated by park management and has been relatively stable in recent years, reaching established launch limits most days of the year. However, because mechanical transport is a non-conforming use prohibited under Section (4c) of the Wilderness Act, it is still important to establish a baseline and monitor such use over time.

Table 22. Motorized river trip launches: 2013-2017.

Year	Commercial	Noncommercial	Administrative	Total
2013	418	29	31	478
2014	433	28	40	501
2015	430	21	30	481
2016	430	22	25	477
2017	425	16	27	468
Average	**427**	**23**	**31**	**481**
Standard Deviation	**6**	**5**	**6**	**12**

Measure Description and Collection Protocol: Data value is the mean annual number of motorized river trip launches over the course of a five-year monitoring period. Each river trip that launches from Lees Ferry (RM 0) and involves at least one motorized watercraft is counted as a single data value, regardless if one or more motorized vessels are used as part of the same trip. This means that motor-supported trips (also known as hybrid trips) using at least one motorized vessel to carry gear are counted under this measure. Human-powered raft trips (using oars or paddles) are not counted, as they are not classified as mechanical transport (NPS 2013b). Trips that launch from Diamond Creek (RM 226) are not counted, because the Colorado River below Separation Canyon (RM 239.8) has not been proposed as potential wilderness (NPS 2010), and because data of river operations in the Lower Gorge are not easily available. Lees Ferry (RM 0), Diamond Creek (RM 226), and Pearce Ferry (RM 280) are the only places within the river corridor where boats (except for non-motorized packrafts) can be launched, de-rigged, or transported out of the steep-walled canyon.

Commercial trip data was obtained from the park's Concessions Management Specialist, and the park's Backcountry Permits Program Manager shared data on self-guided motor trips. Administrative river missions are authorized at the discretion of the Superintendent and tracked by the Backcountry Information Center. The park's Research Coordinator also provides permits for all administrative trips with a focus on scientific research, and a "Research Launch Calendar" exists on the park's shared drive. However, no centralized database was made available that documents all administrative river missions and that is searchable by motorized vs. non-motorized use. The need for such a database was identified in the "Opportunities for Future Wilderness Planning" section at the end of

this report. For the baseline, administrative river use data was assembled from various sources and some motorized launches may be unaccounted for. Over time, a decrease in the mean annual number of motorized river trip launches would contribute to an upward trend in this indicator.

Data Source: Laura Shearin, Concessions Management Specialist; Steve Sullivan, Backcountry Permits Program Manager; Ronda Newton, Research Coordinator.

Data Adequacy: Medium (5) – Data quantity is partial because some administrative river trip missions may not be accounted for. Data quality is high because a rigorous permit system exists, and Lees Ferry Rangers oversee river trip launch operations year-round.

Significant Change: Any change of two or more standard deviations is considered significant.

Motorized river travel (NPS).

Solitude or Primitive and Unconfined Recreation Quality

Wilderness provides outstanding opportunities for solitude or primitive and unconfined recreation.

Amidst the continued mechanization and technological advancements of society, wilderness provides opportunities for solitude and experiences that are not available in many other places. *Keeping It Wild 2* (Landres et al. 2015) suggests that solitude "encapsulates a range of experiences, including privacy, being away from civilization, inspiration, self-paced activities, and a sense of connection with times past." Wilderness is unique in that its managers are mandated to provide opportunities for primitive, unconfined, and self-reliant recreational experience. Although managers cannot guarantee or require that visitors experience solitude or primitive and unconfined recreation, they must protect and uphold the opportunity to have those experiences. The Solitude or Primitive and Unconfined Recreation Quality focuses on the tangible aspects of the setting that affect the visitor experience, and not on the subjective nature of the visitor experience itself. Many intangible aspects of wilderness recreation (challenge, self-reliance, self-discovery, etc.) are not monitored under this quality, but are still integral to the wilderness experience. Table 23 shows measures used to monitor the Solitude or Primitive and Unconfined Recreation Quality in the Grand Canyon wilderness.

Table 23. Measures selected for the Solitude or Primitive and Unconfined Recreation Quality.

Indicator	Measure	Data Adequacy	Significant Change	Baseline Data Value
Remoteness from sights and sounds of human activity *inside* of wilderness	User nights	High (6)	≥ 2 stdev	38,663 user nights / year
Remoteness from sights and sounds of human activity *outside* of wilderness	Night sky quality	Medium (5)	Categorical	99.46% of wilderness area < 0.33 ALR
	Intrusions on natural soundscapes	Medium (5)	≥ 5%	44,144 commercial air-tour overflights / year
Facilities that decrease self-reliant recreation	Facilities that decrease self-reliant recreation	High (6)	≥ 10%	23 facilities
	Trails index	High (6)	≥ 10%	586 weighted trail score
Management restrictions on visitor behavior	Camping restrictions	High (6)	Any	95.5% of wilderness open to at-large camping

The Grand Canyon wilderness in winter (NPS).

4.1 User Nights

Solitude or Primitive and Unconfined Recreation Quality • Remoteness from sights and sounds of human activity inside of wilderness

2018 Baseline Data Value: 38,663 user nights / year

Year(s) of Data Collection: 2013-2017

Background and Context: The Grand Canyon wilderness is distinguished for its exceptional backpacking opportunities. The ability to spend multiple days away from roads and mechanization in the wilderness enables visitors to truly experience solitude, remoteness, and self-reflection. To preserve this experience, backcountry permitting and use limits have been employed by the park since the 1970s. The Backcountry Use and Operations Plan (NPS 1974) first established use limits for trailheads outside the corridor. The trailhead quota system was replaced by management zones, which were further divided into backcountry use areas with prescribed limits (Appendix B). Each use

area has an overnight capacity based upon the size of the area, the number of suitable campsites, its ecological sensitivity, its management zoning, and its use history. Overnight backcountry visitation is well documented by park management and has been relatively stable in recent years, reaching a practical use capacity for popular months and use areas. However, it is still important to establish a baseline in order to monitor how many visitors are using the wilderness resource and understand how visitors respond to permitting policy changes over time. Between 2013 and 2017, visitors to the Grand Canyon wilderness enjoyed an average of 38,663 backcountry user-nights per year (Table 24). In addition, opportunities for solitude vary significantly between management zones and use areas (Figure 13). In 2017, 18% of total overnight backcountry use occurred in the Threshold Zone, another 20% occurred in the Primitive Zone, and only 2% occurred in the Wild Zone. By contrast, the mostly non-wilderness Corridor Zone supported 57% of total overnight backcountry use in 2017.

Table 24. User nights by management zone: 2013-2017.

Year	Threshold	Primitive	Wild	Total
2013	15,502	18,789	2,703	36,994
2014	16,440	19,936	2,383	38,759
2015	16,287	21,077	2,327	39,691
2016	15,884	20,435	2,362	38,681
2017	17,122	19,934	2,134	39,190
Average	**16,247**	**20,034**	**2,382**	**38,663**
Standard Deviation	**611**	**839**	**205**	**1,016**

Measure Description and Collection Protocol: Data value is the average number of user nights that visitors spent annually in the Threshold, Primitive, and Wild Management Zones over the course of a five-year monitoring period. Management zones and wilderness boundaries do not always align. Including visitation data for these three management zones, however, represents an excellent estimate of the total number of user nights spent in the Grand Canyon wilderness. A user night is defined as one hiker in the backcountry for one night. The Backcountry Information Center keeps count of all overnight permits granted. Backcountry permits are provided per group, specifying the number of hikers to camp overnight in a use area. For overnight use in the wilderness, groups can either be small (1-6 people) or large (7-11 people). Number of user nights, opposed to number of permits, was chosen as the unit of analysis for this monitoring, because it more accurately captures impacts on opportunities for solitude and visitor's perception of crowdedness and remoteness.

Data was obtained from the park's Backcountry Permits Program Manager, who compiles visitor use statistics into an annual report. Commercially guided backpacking trips, which in 2017 enjoyed 11.6% of user nights spent in wilderness, are included in this data. Administrative users, which accounted for 1.1% of all user nights spent in wilderness in 2017, also obtain overnight backcountry permits, with the exception of law enforcement patrols and some resource management activities for conditions that need immediate attention. Note that this measure does not include river user nights. Motorized river trip launches are monitored separately under the Undeveloped Quality, indirectly

capturing opportunities for solitude as experienced by river runners. Over time, an increase in number of backcountry overnight stays would contribute to a downward trend in this indicator.

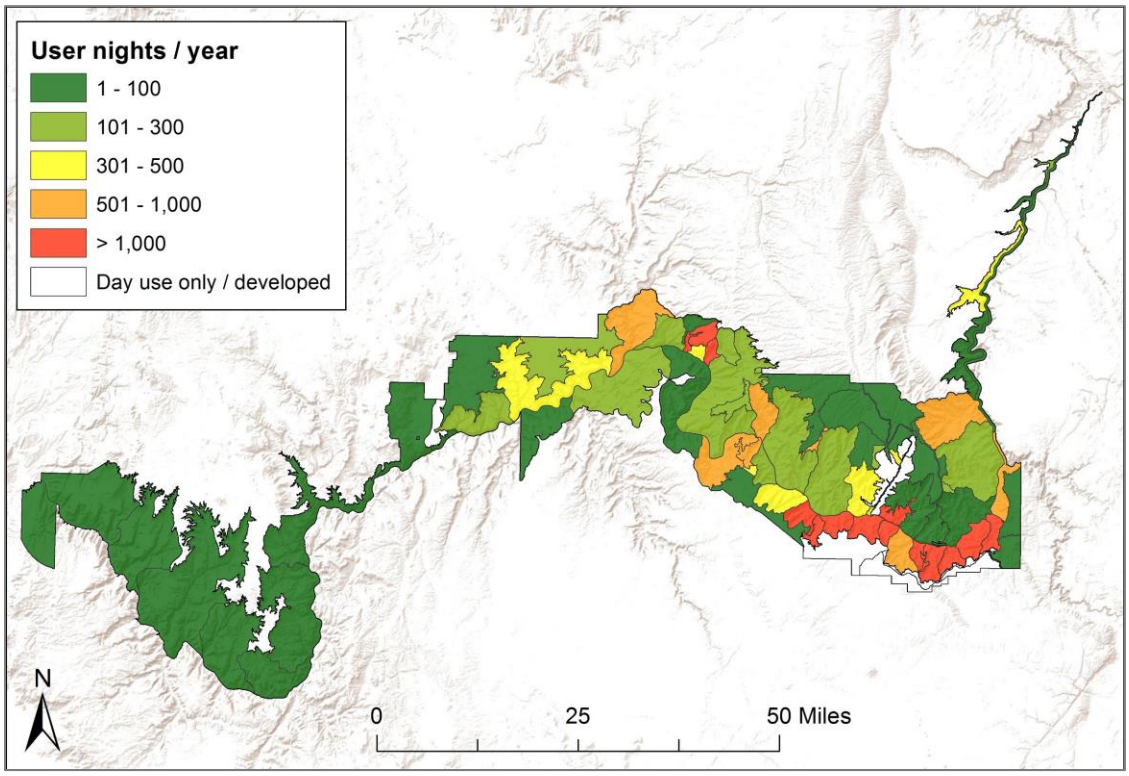


Figure 13. Map showing distribution of overnight backcountry use by use area.

Data Source: Steve Sullivan, Backcountry Permits Program Manager.

Data Adequacy: High (6) - Data quantity is complete because all overnight visitors are required to file a backcountry permit. While unpermitted camping does occur, rangers estimate the number of illegal overnights to have a negligible impact on overall data accuracy.

Significant Change: Any change of two or more standard deviations is considered significant.

4.2 Night Sky Quality

Solitude or Primitive and Unconfined Recreation Quality • Remoteness from sights and sounds of human activity outside of wilderness

2018 Baseline Data Value: 99.46% of wilderness area < 0.33 ALR

Year(s) of Data Collection: 2015

Background and Context: Natural night skies are fundamental to wilderness character, providing a visible sense of remoteness, inspiration, and wonder. Light pollution can detract from the ability to experience the natural world free from visual reminders of modern civilization (Duriscoe 2001). In addition, the photic environment is a critical habitat component for nocturnal species and important

to ecosystem function (Longcore and Rich 2004; Rich and Longcore 2006; Holker et al. 2010; Kyba and Holker 2013). Night skies are also a significant element of cultural heritage, driving cosmology, stories, and the tracking of time and season throughout history (Rogers and Sovick 2001).

The Grand Canyon wilderness is a fantastic place for stargazing with the natural night sky similar to that which historic and prehistoric stargazers would have enjoyed in generations past. Dry air, high altitude, relative remoteness from urban centers, and infrequent cloud cover combine as factors that allow for incredibly dark skies where the Milky Way is bright and zodiacal light is visible. In recognition of its exceptional night sky quality, Grand Canyon received provisional Dark Sky Park status from the International Dark Sky Association in 2016. The park is currently working on changes that would result in full Dark Sky Park status.

Threats to dark night skies observed from the Grand Canyon wilderness mainly originate from developed areas outside the park boundaries. The Las Vegas light dome has significant effects on the westernmost portion of the Grand Canyon wilderness. Planned development and population increases in gateway communities may also degrade the quality of night skies. The impact of light trespass upon wilderness character from within the park is also of concern. Outdoor lights in developed areas on North and South rims, as well as at Phantom Ranch, are visible from locations within the wilderness for many miles (Duriscoe et al. 2015).

Measure Description and Collection Protocol: Data value is the geographic extent of the Grand Canyon wilderness that exhibits an all-sky light pollution ratio (ALR) below 0.33. This ratio is calculated by removing natural night sky components from the total observed sky brightness (Duriscoe 2013; Moore et al. 2013). A natural night sky has an average brightness across the entire sky of 78 nL (nanolamberts, a measure of luminance), and includes components such as the Milky Way, zodiacal light, airglow, and other starlight. ALR is expressed as a ratio of anthropogenic to natural light and ranges from a theoretical value of 0.0 (unaffected conditions) to over 80 (80 times more light than occurs naturally). ALR is derived from a GIS-based model using satellite data. A neighborhood analysis was performed by the Natural Sounds and Night Skies Division (NSNSD) to estimate brightness over the entire sky (Duriscoe 2013; Moore et al. 2013). The modeled anthropogenic light over the entire sky is the basis for the map of ALR values (Figure 14).

Further spatial analysis of Figure 14 indicates that 99.46% of the Grand Canyon wilderness has an ALR value below 0.33. The NSNSD considers ALR values below 0.33 (i.e. 1/3rd brighter than natural conditions) as “good” (Table 25). Moreover, 78.19% of the Grand Canyon wilderness has an ALR value below 0.1, meaning that night sky quality in those parts of the wilderness is “outstanding.” The mean ALR value for the Grand Canyon wilderness is 0.069, indicating that on average the night sky above the Grand Canyon wilderness is 6.9% brighter than it would be if only natural conditions were present. In other words, night sky quality in most areas of the Grand Canyon wilderness closely resembles natural conditions. However, variation within the Grand Canyon wilderness is significant, ranging from “outstanding” to “moderate” ratings. ALR values for parts of western Grand Canyon are greater than 0.33, indicating that the wilderness experience for visitors in those areas is impacted by light pollution.

For future monitoring, staff working with the NSNSD should be consulted. As new satellite imagery becomes available, updated spatial models of ALR will be developed and used for wilderness character monitoring. Over time, a decrease in the percentage of the Grand Canyon wilderness exhibiting ALR values below 0.33 would contribute to an upward trend in the Solitude or Primitive and Unconfined Recreation Quality.

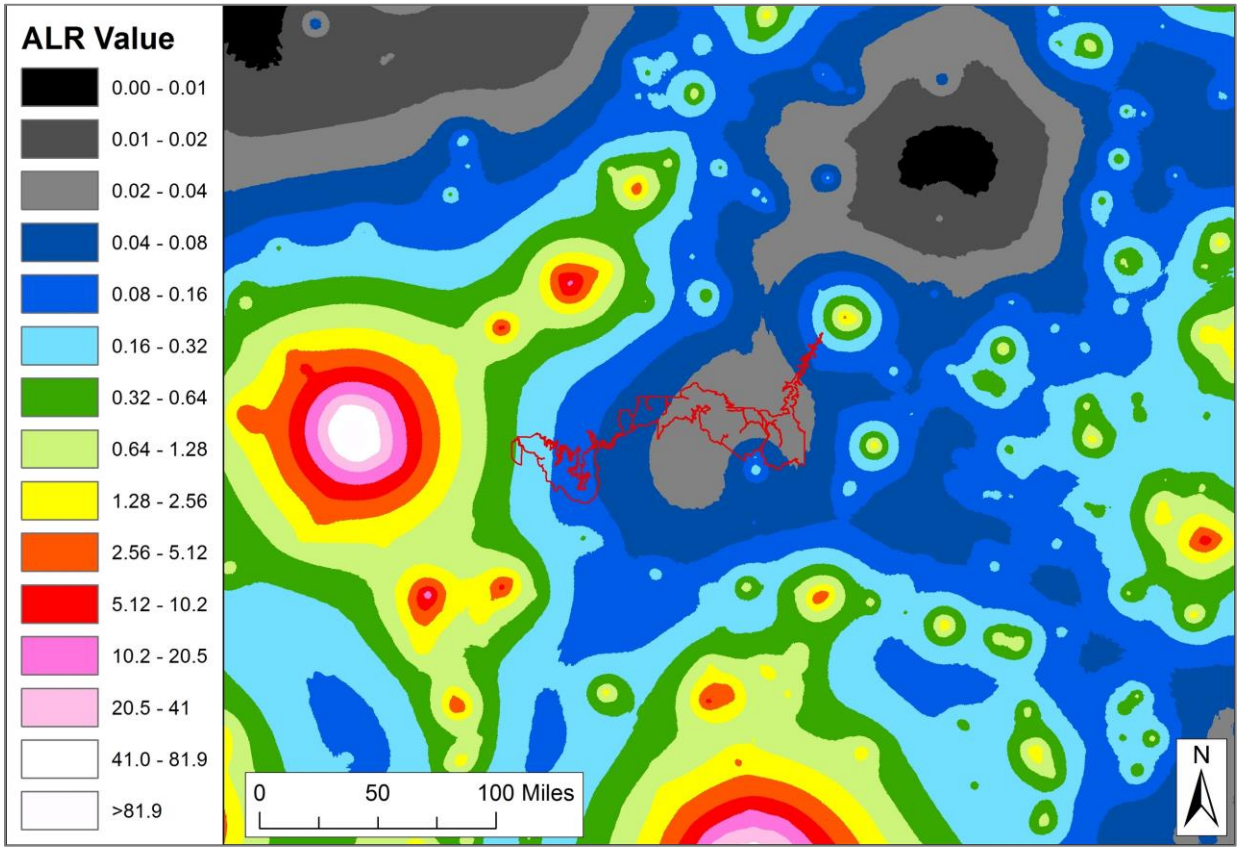


Figure 14. Map showing predicted impact of artificial sky glow.

Table 25. Anthropogenic Light Ratio (ALR) condition categories (Moore et al. 2013).

Threshold Category	ALR
Outstanding	< 0.1
Good	0.1 - 0.33
Moderate	0.33 - 2.00
Concern	> 2.00

Data Source: Sharolyn Anderson, *Physical Scientist, NSNSD*.

Data Adequacy: Medium (5) – Data quantity is complete because ALR modeling used satellite imagery, providing total geographic coverage of the Grand Canyon wilderness. Data quality is moderate because there is a moderate level of uncertainty with the modeled data.

Significant Change: If the geographic extent of the Grand Canyon wilderness that exhibits ALR values below 0.33 were to fall below 90%, such a change would be considered significant. This threshold is based on an interim guidance document issued by the NSNSD (Moore et al. 2013).

The night sky as observed over Grand Canyon (NPS).

4.3 Intrusions on Natural Soundscapes

Solitude or Primitive and Unconfined Recreation Quality • Remoteness from sights and sounds of human activity outside of wilderness

2018 Baseline Data Value: 44,144 commercial air-tour overflights / year

Year(s) of Data Collection: 2016

Background and Context: The ability to enjoy the sounds of nature separate from anthropogenic noise is a vital component of wilderness character. Human-caused noise can affect many of the intangible values of wilderness that visitors seek. Natural sounds also play an important role in the ecosystem, allowing animals to communicate, find mates, sense danger, and hunt effectively.

Human-caused noise can alter sensitive ecological processes and affect wildlife stress levels, movement, and habitat utilization.

Recognizing that human-caused noise can adversely affect park resources, NPS Management Policies (2006a) and NPS Director's Order 47 (2000) "require, to the fullest extent practicable, the protection, maintenance, or restoration of the natural soundscape resource in a condition unimpaired by inappropriate or excessive noise sources." The order further states that in planning for soundscape preservation and noise management, park managers "must use the best science available to determine the impact of existing or proposed noise sources on the soundscape, wildlife, cultural resources, and the visitor experience, as appropriate."

Within the Grand Canyon wilderness, the most significant intrusion on natural soundscapes arguably results from air-tour overflights. Airplane and helicopter noise is often audible in the central areas of both rim and inner canyon wilderness (Figure 15). As far back as 1975, the Grand Canyon National Park Enlargement Act (16 U.S.C. § 228) required studies on the adverse effects of aircraft overflights. In 1987, the National Parks Overflights Act (49 U.S.C. § 40128) mandated substantial restoration of natural quiet in Grand Canyon National Park, which was defined as 50% or more of the park achieving natural quiet (i.e., no aircraft audible) for 75% to 100% of the day, each day. In 2000, Congress passed the National Parks Air Tour Management Act (49 U.S.C. § 40128), which reaffirmed the legal mandate to restore natural quiet to Grand Canyon. The act also called for the Federal Aviation Administration (FAA), in consultation with the NPS, to create incentives for commercial air-tour operators in the park to integrate "quiet aircraft technology." During this time, the park conducted several acoustic studies to determine natural ambient sound levels (Falzarano 2005; Ambrose 2006; Levy and Falzarano 2007, 2007a, 2007b, 2008). Data from these studies were used in aircraft noise modeling and informed the Special Flight Rules Area in the Vicinity of Grand Canyon National Park DEIS (NPS 2011a). However, the EIS was never finalized, and the soundscape program at the park was discontinued.

Intrusions on natural soundscapes are also noticeable in parts of western Grand Canyon, where air-tour companies operate flights from Las Vegas to the Hualapai Reservation. In 2000, the federal government granted the Hualapai Tribe an exemption from commercial air-tour allocations based on general trust-responsibility concepts and the tribe's economic dependence on commercial air tourism. The exemption allows air-tour operators with a tribal contract to take-off and land at the reservation's airport without adherence to the annual allocation on total commercial air-tour operations. Unlimited flights have essentially meant unlimited impacts to wilderness character in areas of western Grand Canyon under or near air-tour flight paths, where the sound of helicopter blades serves as a frequent reminder of mechanized society.

Although the NPS does not have jurisdiction over the airspace above its lands, air-tour operations have a clear impact on wilderness character. Measuring levels of anthropogenic noise sheds light on the frequency and degree of human-caused disturbance in wilderness. Therefore, it is still important to establish a baseline and monitor these impacts over time.

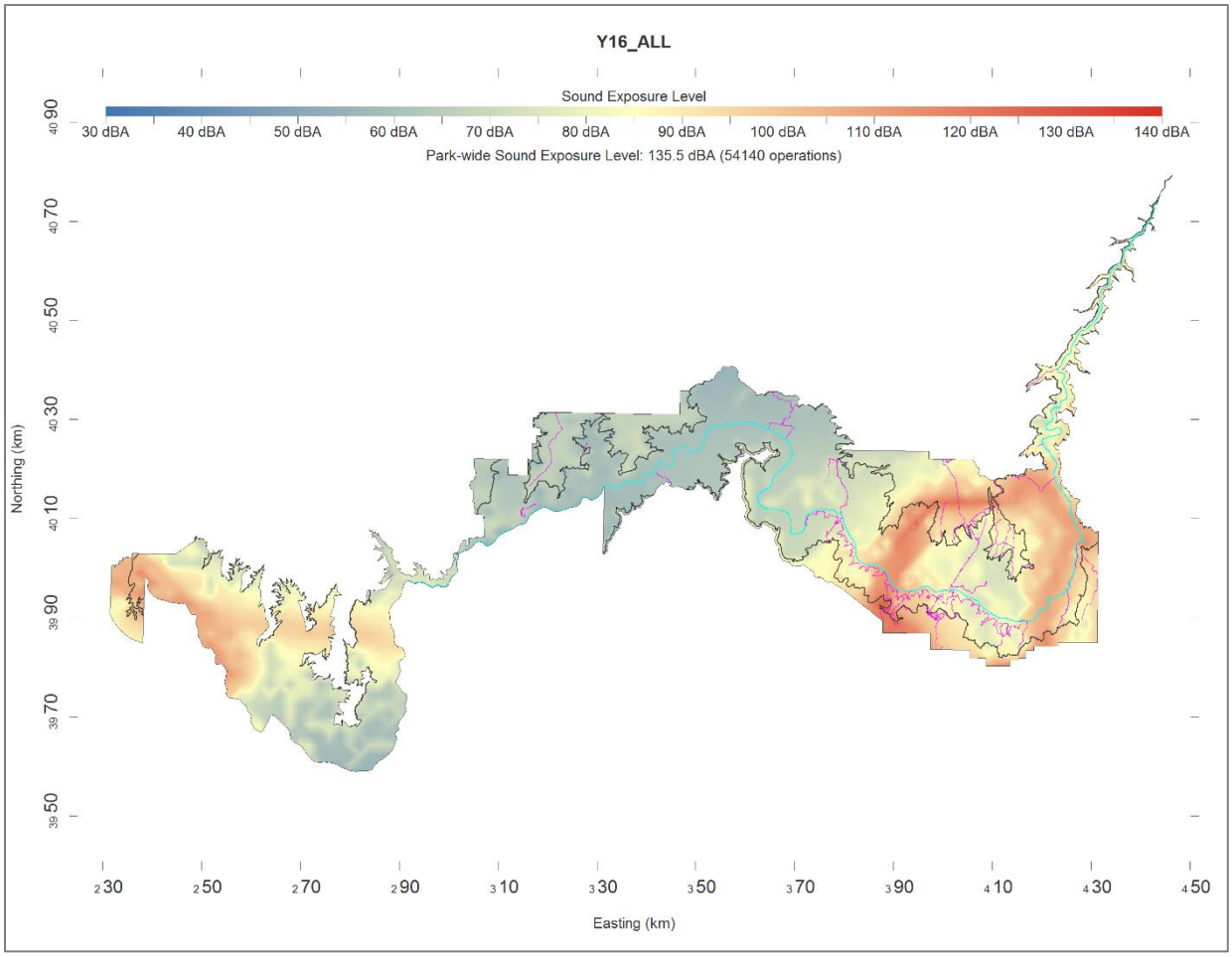


Figure 15. Map showing sound exposure levels from air-tour operations (NSNSD).

Measure Description and Collection Protocol: Data value should be the mean annual number of commercial air-tours flown under NPS contract over the course of a five-year monitoring period. Air-tour operators are required to report flights, and annual summary statistics are available to GRCA Planning, Environment, and Projects. Because data for years 2012-2015 was not made available at this time, the baseline data value is solely based on the number of commercial air-tours flown in 2016 (Table 26). For future monitoring, the most recent rolling 5-year average for which data is available should be used. Over time, a decrease in the number of commercial air-tour overflights would contribute to an upward trend in this indicator.

Data Source: Robin Martin, *Division Chief, Planning, Environment, and Projects*; Elly Boerke, *Environmental Protection Specialist*; Emma Brown, *Acoustical Resource Specialist (NSNSD)*; Damon Joyce, *Physical Scientist (NSNSD)*.

Data Adequacy: Medium (5) – Data quantity is partial because flights operated by air-tour companies with a tribal contract are not included. Data quality is high, because air-tour operators under contract with the NPS are required to report flight numbers every year.

Table 26. Commercial air-tour overflights under contract with NPS: 2012-2016.

Year	Air-tour overflights
2012	n/a
2013	n/a
2014	n/a
2015	n/a
2016	44,144
Average	**44,144**
Standard Deviation	**n/a**

Significant Change: Any change of 5% or more from the baseline is considered significant.

4.4 Facilities that Decrease Self-Reliant Recreation

Solitude or Primitive and Unconfined Recreation Quality • Facilities that decrease self-reliant recreation

2018 Baseline Data Value: 23 facilities

Year(s) of Data Collection: 2018

Background and Context: The primitive, self-reliant, and unconfined nature of wilderness recreation should allow for a sense of adventure, discovery, and challenge. Visitors must accept certain risks that comprise a wilderness experience and primitive methods of travel, with few modern "amenities" provided for their comfort or convenience. Adventure in the Grand Canyon wilderness largely requires visitors to meet the environment on its own terms. Vast swaths of the Grand Canyon wilderness are free from trails and development, open to the truly primitive navigational methods of off-trail travel and route-finding. With a harsh climate and rugged physical environment, recreation in these areas demands a high degree of self-sufficiency and endurance.

In high-use areas of the wilderness, the park has placed several recreation-related facilities to protect natural and cultural resources and reduce visitor impacts. These include trail signs, designated campsites, and composting toilets. Of these, toilets have the largest impact on wilderness values. Waste is removed from composting toilets via helicopter about once or twice yearly depending upon use levels at designated campsites. Maintenance activities including general upkeep and stirring of compost, which is generally done on hiking patrols. Composting toilets are placed as a last resort measure to address human-waste problems, following the completion of an MRA. Designated campsites and composting toilets currently exist in heavily visited areas within the Threshold and Primitive Zones (Figure 16). While these facilities are intrusions in wilderness, they are also critical to reducing adverse effects on natural or cultural resources.

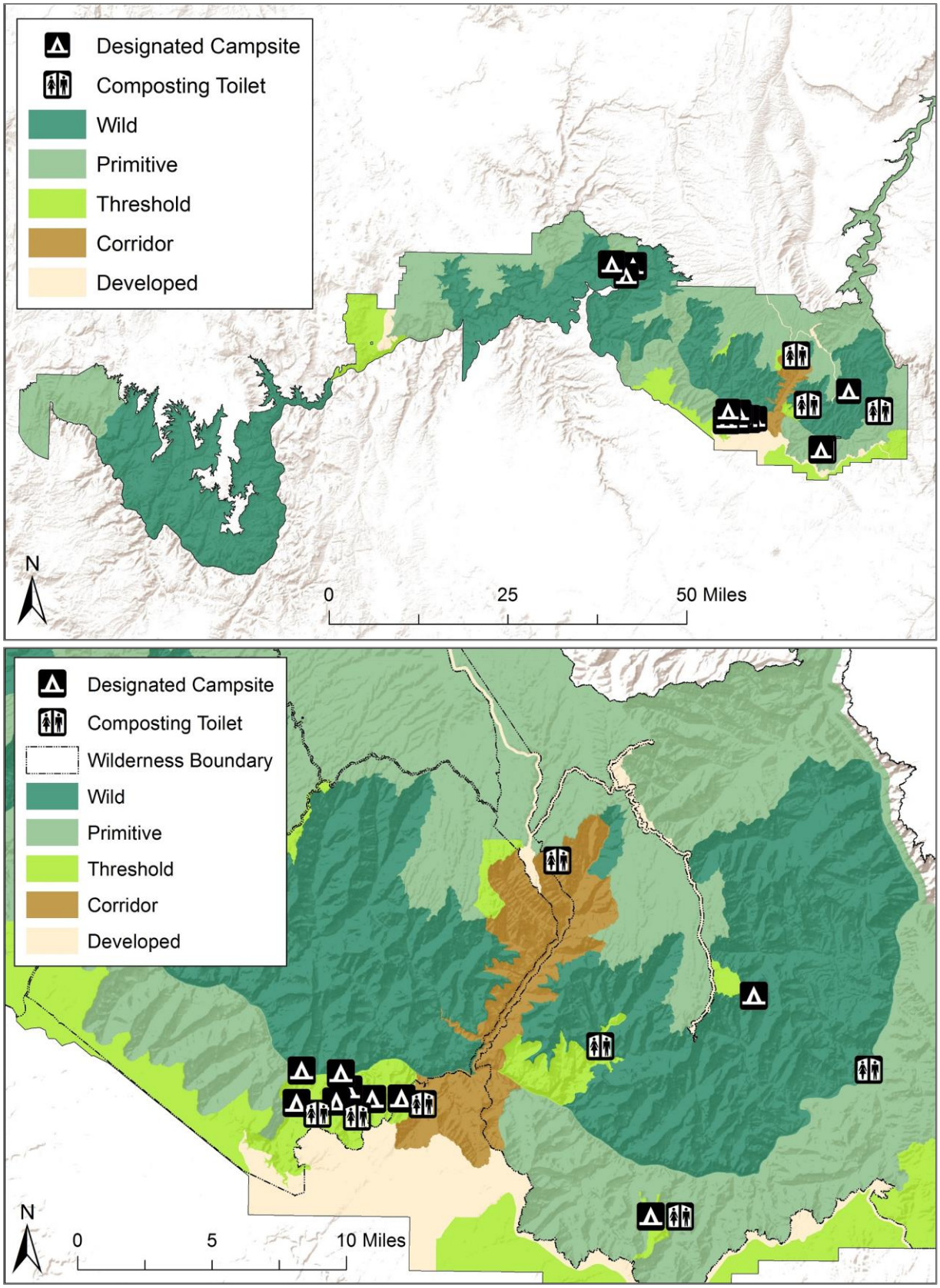


Figure 16. Maps of designated campsites and composting toilets in wilderness.

Left: composting toilet on Horseshoe Mesa; right: trail sign along the Hermit Trail (NPS/TOBIAS NICKEL).

Measure Description and Collection Protocol: Data value is the number of permanent facilities authorized by the NPS that decrease self-reliant recreation in wilderness. Data was obtained from GIS-layers showing locations of designated campsites and composting toilets. The park's Wilderness Coordinator, GIS Program Manager, Backcountry Permits Program Manager, and Trail Crew Supervisor were also consulted to verify location, maintenance, and potential removal of facilities.

When counting facilities, the following guidelines must be observed to ensure consistent future monitoring and trend assessment:

- Each facility is weighted equally.
- Facilities that should be counted under this measure include shelters, toilets, developed water sources, designated campsites, ranger stations, and other amenities that make the wilderness experience more comfortable and/or reduce primitive and self-reliant recreation.
- Any facility that has been placed in the wilderness with the intention of staying there for at least six months is considered "permanent" for purposes of this monitoring protocol.
- Different types of facilities within 300-feet of each other are counted separately, but multiple facilities of the same type in the same area are counted as a single unit. For example, on Horseshoe Mesa, there are currently three composting toilets and multiple designated campsites in close proximity to each other. The three toilets are counted as one facility and the campsites are counted as one facility, totaling two units for this area.
- Recreational facilities that are eligible for or listed on the National Register of Historic Places are included in this measure, under the condition that they still serve a recreational purpose and are actively being used. For example, the Santa Maria shelter on the Hermit Trail is counted under this measure, but the Pasture Wash Ranger station is not.
- Unauthorized recreational facilities are removed as soon as they are noticed and, therefore, not included under this measure.
- Trails in wilderness are monitored separately in the next section and not included under this measure. Similarly, trail features (e.g. water bars, erosion checks, etc.) are also not counted.

- Several facilities are located immediately adjacent to or just within wilderness boundaries (as digitized for the 2015 Backcountry Management Plan DEIS). To ensure consistency during future monitoring, these facilities and rationales for their in- or exclusion are listed here.
    - *Horn Creek designated campsite and toilet*: The GIS points for these facilities are currently located approximately 10 m outside of the official wilderness boundary. However, they are located within a backcountry use area that is mostly within wilderness. Therefore, these facilities were included in this measure.
    - *Toroweap Viewpoint toilet*: The GIS point for this facility is located outside a non-wilderness road corridor, just within wilderness boundaries. However, because visitors can drive to this facility, it was excluded from the data value.
    - *Designated campsites at trailheads (Point Sublime, Swamp Point, Ruby Point, Signal Hill, and Fire Point)*: These campsites are located at trailheads accessible via non-wilderness road corridors. GPS points for these facilities place them either just inside or just outside of wilderness. Because these facilities are accessible via motor vehicle, they were all categorically excluded from this measure.
    - *Point Sublime toilet*: This facility was excluded for the same reason as the designated campsite in the same location.

Table 27 provides an inventory of all 23 recreational facilities currently known to be present in the Grand Canyon wilderness. For future monitoring, consult with the park's GIS Program Manager, Backcountry Permits Program Manager, Trail Crew Supervisor and/or Backcountry Information Center to obtain information about new facilities or removals. A decrease in the number authorized recreation facilities would result in an upward trend in this measure.

Table 27. Facilities that decrease self-reliant recreation.

Category	Location(s)	Number
Designated campsites	Cape Final, Cedar Springs, Deer Creek, Granite Rapids, Hermit Creek, Hermit Rapids, Horn Creek, Horseshoe Mesa, Lower Tapeats, Monument Creek, Salt Creek, Upper Tapeats	12
Composting toilets	Clear Creek, Deer Creek, Hermit Creek, Horn Creek, Horseshoe Mesa, Monument Creek, Salt Creek, Tanner Delta, Uncle Jim Point, Upper Tapeats	10
Shelters	Hermit Trail (Santa Maria Springs)	1
Total	**–**	**23**

Data Source: Campsite and Backcountry Toilets GIS-layers (BackcountryManagementPlan.gdb, GRCA GIS Database Library); Mark Nebel, *GIS Program Manager*; Steve Sullivan, *Backcountry Permits Program Manager*; Chris Brothers, *Trail Crew Supervisor*; Backcountry Information Center.

Data Adequacy: High (6) – Data quantity is complete because park managers are aware of and maintain accurate GIS data on NPS-authorized recreational facilities present in wilderness. Data quality is high for the same reasons.

Significant Change: Any change of 10% or more from the baseline is considered significant.

4.5 Trails Index

Solitude or Primitive and Unconfined Recreation Quality • Facilities that decrease self-reliant recreation

2018 Baseline Data Value: 586 total weighted trail score

Year(s) of Data Collection: 2018

Background and Context: Maintained and developed trails in wilderness help confine visitor use impacts to isolated areas in wilderness and allow recreation managers to direct the movement of backcountry travel. These trails reduce the potential formation of social trails, prevent erosion, ensure visitor safety, and often reduce the total area impacted. They also allow less experienced recreationists to venture into the wilderness with little risk of getting lost and guide visitors to points of interest. While maintained developed trails provide a host of clear benefits to both wilderness users and managers, these benefits come at the expense of the visitor's ability to experience primitive and unconfined recreation. Trails that are wide, smooth, and easy to follow reduce the feeling of primitiveness, the need to practice skills such as wayfinding, and the benefits and inspiration derived from physical and mental challenge.

Grand Canyon National Park has 473 miles of trail, with 310 miles being located in wilderness. Most of the highly developed trails are located within the crosscanyon corridor, which is classified as "non-wilderness backcountry" and receives over 50% of total backcountry visitation (NPS 2015). By contrast, the 316 miles of trail traversing the Grand Canyon wilderness are only minimally maintained and receive far less visitation. For an area its size, there are very few trails present in the Grand Canyon wilderness (Figure 17).

Measure Description & Collection Protocol: Data value is a weighted score that reflects the mileage and Trail Class of official trails within the wilderness. Trail Classes reflect trail development scale and management standards arranged along a continuum from one to five, with five being most developed (FGDC 2017). The number of miles of each trail in wilderness is multiplied by the respective Trail Class. The final Trail Index value is the sum of the weighted scores for all trails (Table 28). For future monitoring, consult with the GIS Program Manager, Backcountry Information Center, and/or Trail Crew Supervisor to determine any changes in the official trails network. Over time, a decrease in the Trail Index would contribute to an upward trend for this indicator.

Data Source: Mark Nebel, *GIS Program Manager*; Trails GIS-layer (Transportation.gdb, GRCA GIS Database Library); Chris Brothers, *Trail Crew Supervisor*; Backcountry Information Center.

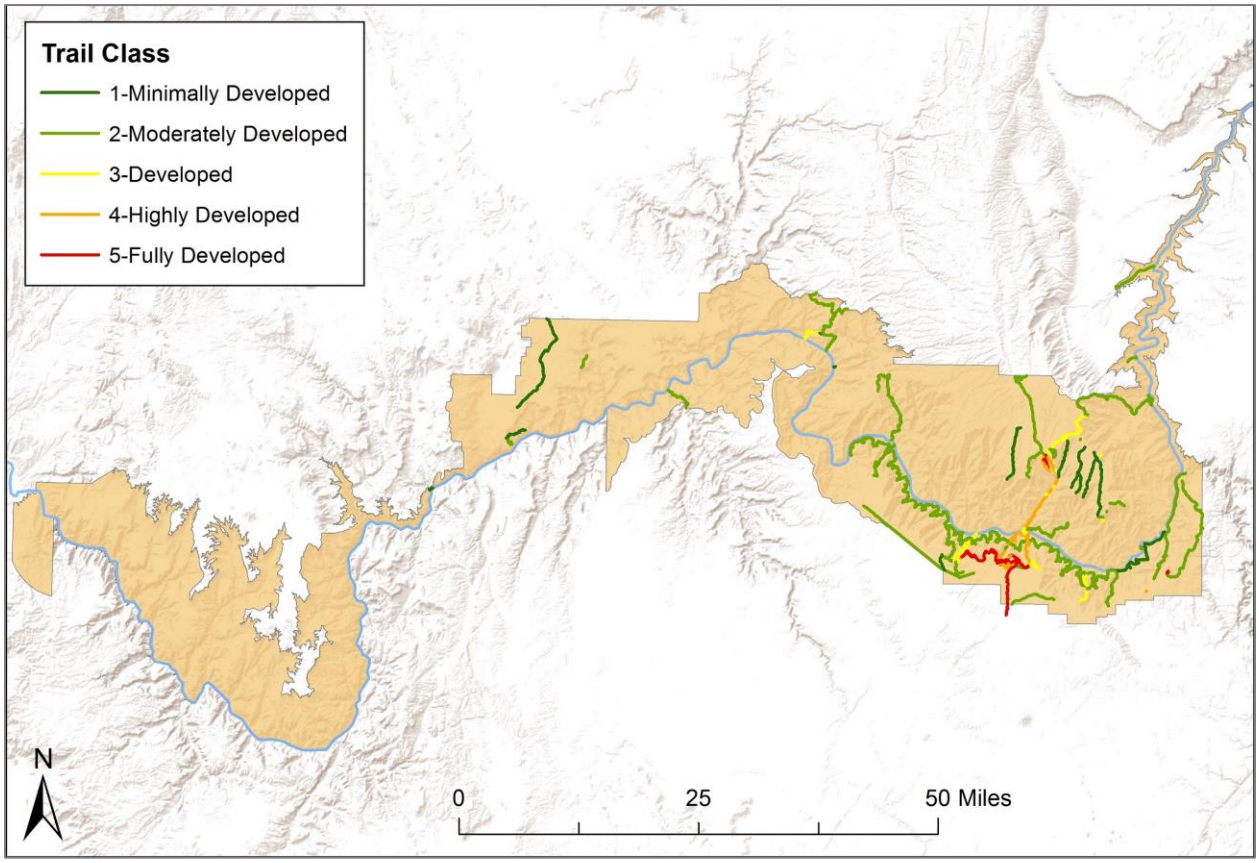


Figure 17. Map of the park's official trails network.

Table 28. Trails index

Trail Name	Miles	Trail Class	Trail Score
Tuckup Alternate	1.2	2	2.4
Monument Creek	1.3	3	3.8
Saddle Canyon	1.4	2	2.7
Hance Creek	1.5	2	2.9
Hermit Creek	1.6	2	3.2
Dripping Springs	1.6	2	3.3
Schmutz Spring	1.7	2	3.4
Cottonwood Creek	1.8	2	3.5
Dripping Springs Access	1.8	1	1.8
Cape Final	2.0	2	4.0
Bill Hall	2.0	2	4.1
Point Imperial	2.4	2	4.7
Tapeats Creek	2.4	2	4.8
Nankoweap Delta	2.5	2	4.9

Table 28 (continued). Trails index

Trail Name	Miles	Trail Class	Trail Score
Uncle Jim	2.5	2	5.0
Ariel Point	2.7	1	2.7
Waldron	2.8	2	5.6
Tuckup	2.9	1	2.9
Powell Plateau	3.2	2	6.5
Deer Creek	3.3	3	9.8
Havasu Canyon	3.6	2	7.1
Widforss Point	4.4	2	8.7
Francois Matthes	4.7	1	4.7
Old Bright Angel	4.7	1	4.7
Grandview	4.7	3	14.2
Komo Point	5.0	1	5.0
Boucher	5.8	2	11.5
South Canyon	5.9	2	11.9
New Hance	6.2	2	12.3
Tiyo Point	6.3	1	6.3
Hermit	6.4	3	19.3
South Bass	7.0	2	14.0
Walhalla Glades	7.3	1	7.3
Tanner	7.7	2	15.4
Clear Creek	8.3	2	16.5
Ken Patrick	8.4	3	25.2
Nankoweap	9.9	2	19.8
Beamer	10.0	2	19.9
Escalante	11.4	1	11.4
North Bass	12.1	2	24.1
Brady Hollow	12.1	1	12.1
Thunder River	12.5	2	25.0
Cape Solitude	14.4	2	28.9
East Tonto	30.8	2	61.6
West Tonto	58.5	2	117.0
Total	**310.3**		**586**

Data Adequacy: High (6) – Data quantity is complete because park managers are aware of and maintain accurate GIS data on the miles and Trail Class of designated trails present in wilderness. Data quality is high for the same reasons.

Significant Change: Any change of 10% or more from the baseline is considered significant.

Civilian Conservation Corps building Clear Creek Trail in the 1930s (NPS).

Hiker on the Tonto Trail (NPS/TOBIAS NICKEL).

4.6 Camping Restrictions

Solitude or Primitive and Unconfined Recreation Quality • Management restrictions on visitor behavior

2018 Baseline Data Value: 95.5% of wilderness is open to at-large camping

Year(s) of Data Collection: 2018

Background & Context: Opportunities for solitude or primitive and unconfined recreation are key components of any wilderness experience. However, at times, providing for visitor use can compromise other wilderness resources and values. The Natural Quality can be impacted by visitor disturbances to wildlife and opportunities for solitude can be reduced as visitor numbers increase. Use restrictions are an important tool used by park managers to achieve a balance between the sometimes conflicting qualities inherent to wilderness management.

Unconfined recreation is greatest when visitors have the most freedom over their actions and decisions. While restrictions on visitor behavior are generally intended to protect the Natural Quality or improve outstanding opportunities for solitude, they also degrade the visitor opportunity for unconfined recreation. Historically high recreation visitation to the Grand Canyon wilderness has necessitated the employment of visitor-use regulations and limitations for decades. A backcountry permit system and limits on group sizes protect the visitor's opportunity for solitude. A river trip through Grand Canyon is one of the most sought-after wilderness experiences in the world, which has necessitated a lottery system to regulate river use. Prohibition of campfires prevents fire damage and preserves sparse wood sources. Prohibition of pack stock, pets, and hunting also protect the Natural Quality of wilderness.

Restrictions on campsite selection are effective to manage visitor use impact patterns. While at-large (or dispersed) camping is generally associated with unconfined recreation and the experience of traversing wilderness, such practices can also lead to widespread social trailing, soil erosion, and vegetation damage, especially in heavily visited wilderness areas. Conversely, designated campsites restrict the freedom to camp anywhere, but concentrate visitor use and reduce overall impacts on natural and cultural resources.

Currently, 95.5% of total wilderness area is open to at-large camping. In 24 of 96 backcountry use areas (primarily in the heavily visited Corridor and Threshold Zones; Figure 18), visitors are required to camp in designated sites. An additional seven backcountry use areas are managed for day use only. Temporary closures of specific areas are rare in the Grand Canyon wilderness, but are sometimes necessary to facilitate fire and resource management activities and/or ensure visitor safety.

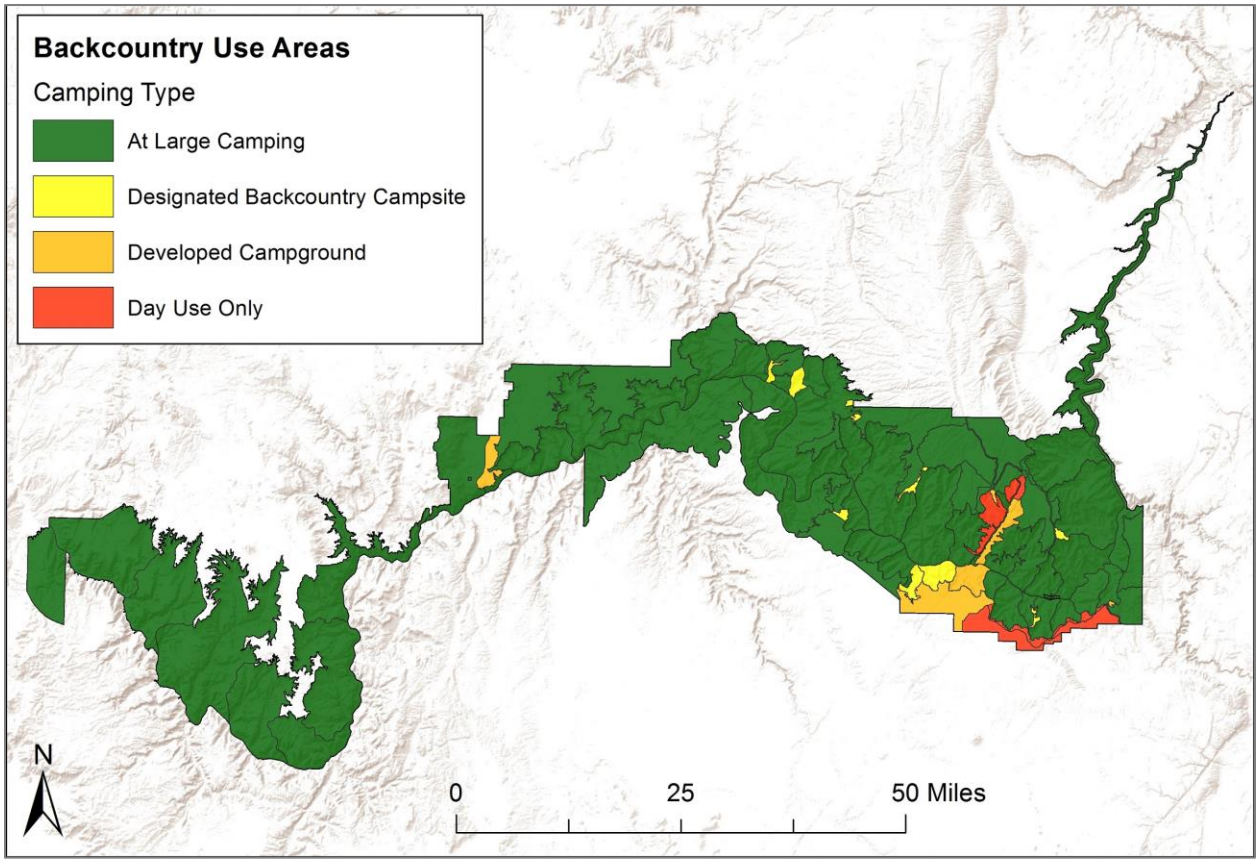


Figure 18. Map showing camping restrictions by backcountry use area.

As the number and nature of wilderness visits changes, continued reassessment of the effectiveness, relevance, and ability to enforce camping restrictions will be important as park management strives to balance the inherent value of unconfined recreation with other wilderness qualities. The park is currently in the process of revising its Backcountry Management Plan, which may revisit existing regulations to protect park resources from rising visitation and recreation impacts.

Measure Description & Collection Protocol: Data value is the percentage of total wilderness area open to at-large camping, meaning that visitors can camp anywhere (in accordance with general regulations and Superintendent's Compendium restrictions). By contrast, where designated camping exists, visitors may not select other campsites or establish new ones. A GIS analysis was performed to determine the total wilderness acreage where at-large camping is allowed relative to overall wilderness area. Currently, 1,097,975 of 1,149,773 wilderness acres (95.5%) are open to at-large camping. As camping restrictions change from at-large camping to designated sites or vice versa, the data value should be updated accordingly. Over time, an increase in the percentage of wilderness area open to at-large camping would contribute to an upward trend for this measure.

Data Source: Steve Sullivan, *Backcountry Permits Program Manager*; Backcountry Management Plan DEIS (NPS 2015); Superintendent's Compendium (NPS 2018b); BackcountryManagementPlan geodatabase (GRCA GIS Database Library).

Data Adequacy: High (6) – Data quantity is complete because visitor use restrictions are clearly defined in park policy for all backcountry use areas. Data quality is high for the same reason.

Significant Change: Any change is considered significant for this measure.

Other Features of Value Quality

Wilderness may also contain other tangible features of scientific, educational, scenic, or historical value.

Wilderness areas may possess tangible, site-specific features that are integral to wilderness character and whose presence adds value to the wilderness resource. These features may:

- Be specifically identified in the enabling legislation for the wilderness, be on the National Register of Historic Places, on a State Register, or part of a National Historic Trail, or be identified as a Priority Heritage Asset;
- Contribute to making the area's meaning and significance clear and distinct, or help define how people think about and value an area;
- Help tell a broader story of a distinctive human relationship with the land;
- Contain additional educational, scientific, or scenic value.

The Other Features of Value Quality is different from the other four qualities in that it may not be relevant for all wilderness areas. Even if a feature fits in one or more of the above categories, it may not necessarily be considered under this quality. Ultimately, it is up to local resource specialists and wilderness managers to determine if any other features of value are present and should be included in wilderness character monitoring. Features included in this quality are also counted under other qualities if relevant. For example, a building that is on the National Register of Historic Places could add value to wilderness character under the Other Features of Value Quality for its historic or cultural significance, but as a structure in wilderness it would also be counted under the Undeveloped Quality. Table 29 shows the measure used to monitor the Other Features of Value Quality in the Grand Canyon wilderness.

Table 29. Measures selected for the Other Features of Value Quality.

Indicator	Measure	Data Adequacy	Significant Change	Baseline Data Value
Deterioration or loss of integral cultural features	Condition of archaeological sites	Medium (5)	≥ 0.1	2.63

Left: fossilized animal tracks; right: fossilized fern (NPS/MICHAEL QUINN).

5.1 Condition of Archaeological Sites

Other Features of Value Quality • Deterioration or loss of integral cultural features

2018 Baseline Data Value: 2.63

Year(s) of Data Collection: 2006-2017

Background and Context: Archaeological sites within the Grand Canyon wilderness reveal evidence of nearly 12,000 years of human occupation and use of Grand Canyon lands. Grand Canyon has eleven Traditionally Associated Tribes whose histories and cultures are inextricably linked to the canyon. Well-preserved archaeological sites continue to shed light on how past peoples lived and interacted with lands now considered wilderness. Archaeological resources range from an isolated artifact to an entire community of habitation rooms and agricultural features. As of February 2018, there are 3,222 known archaeological sites within the Grand Canyon wilderness. However, only a small percentage of the wilderness has been inventoried for cultural resources, and the number of archaeological sites will continue to grow as new sites are discovered and documented. These sites are important sources of information about the past, and are an irreplaceable wilderness resource adding value and depth to Grand Canyon's wilderness character.

Archaeological site conditions degrade when a site is damaged or destroyed by environmental or human factors. Factors that contribute to site degradation include natural processes related to erosion, wildfire, flooding, animals, vegetation, and structural deterioration, as well as intentional and unintentional human disturbances such as camping, social trailing, theft or looting, vandalism, and waste or trash disposal. Climate change also poses a threat to Grand Canyon's archaeological sites, as intensified storms and more extreme weather events are likely to amplify existing erosional impacts (Seager et al. 2007). Although most of these sites have endured weathering for centuries, they are not immune to further deterioration. Losing even a single artifact can erase a piece from the puzzle, limiting the ability to understand past cultures. Protecting archaeological resources in wilderness ultimately benefits the cultural values component of wilderness character. By preserving evidence of 12,000 years of human history with the Grand Canyon, it helps maintain the historical and contemporary relationships that Traditionally Associated Tribes have with parklands and resources as well as provide for continued study of past peoples' connections to the landscape.

Measure Description and Collection Protocol: Data Value is the average site condition of a sample of archaeological sites within the Grand Canyon wilderness (Table 30). For purposes of this monitoring, the park's Cultural Resource Program Manager selected 351 archaeological sites that are in wilderness and have been monitored in the last 11 years. The majority of these sites are located in the Colorado River Corridor, with the remaining sites situated in the following backcountry areas: Hermit to Indian Garden (Hermit Trail to Tonto Trail junction and across to Indian Garden), South Kaibab to Grandview (across the Tonto), Grandview to Tanner (Escalante Route), Clear Creek, and Tapeats-Surprise Valley-Deer Creek. The sample is heavily tilted toward river sites, because these sites are easier to access, and an established and well-funded archaeological river monitoring program exists. Sites in the backcountry are currently monitored as opportunities present themselves. However, park archaeologists are planning to establish a monitoring program for backcountry sites that is as robust as the one in the river corridor (NPS 2015). The goal is to monitor archaeological sites every five years. Some sites (attraction sites that get a lot of visitation) are monitored every 1 or 2 years, while sites that are stable and show no disturbance by environmental or human effects might be monitored on a longer cycle (10 years or more).

Table 30. Archaeological site conditions.

Site Condition	Condition Score	Number of Sites	Total Condition Value
Good	3	242	726
Fair	2	88	176
Poor	1	21	21
Destroyed	0	0	0
Total	**–**	**351**	**923**

A list of archaeological site identification numbers for sites included in this monitoring is available in Appendix E. For consistency, these same sites should be selected for future monitoring. The sensitive nature of cultural resource data requires this analysis to be completed by cultural resource staff with access to the GRCA Archaeological Site Database. An increase in the average condition value of archaeological sites would contribute to an upward trend in this indicator of the Other Features of Value Quality.

Data Source: Ellen Brennan, *Cultural Resources Program Manager*; Donelle Huffer, *Vanishing Treasures Archaeologist*; GRCA Archaeological Site Database.

Data Adequacy: Medium (5) – Data Quantity is partial, because analysis is based on a sample of archaeological sites. Data quality is high, because experienced archaeologists regularly monitor these sites using standardized protocols.

Significant Change: Any change greater than one tenth of a point from the baseline data value is considered significant. In other words, if data value were to drop below 2.53 or rise above 2.73 change would be considered significant.

Measures Suggested for Future Use

The measures in this section were determined to be highly significant to wilderness character. The measures were not included, however, because no data was available at the time the baseline was established. If data becomes available for any of these measures, it is recommended that they be incorporated into the monitoring framework.

Average Campsite Condition

Solitude or Primitive and Unconfined Recreation Quality • Remoteness from sights and sounds of human activity inside of wilderness

At Grand Canyon National Park, several backcountry campsite inventory programs have been instituted (NPS 1988, 1998, and 2006; Foti et al. 2006; Kaplinski et al. 2014). The revised Colorado River Management Plan (NPS 2006) also mandates monitoring of beach campsites. The goal of current monitoring efforts is to combine backcountry campsite monitoring, both river- and land based, into a single program. Because that has not happened yet, a measure of "average campsite condition" was not included for wilderness character monitoring. When that process is complete, campsite condition data should be incorporated in the future.

Trail Signs

Solitude or Primitive and Unconfined Recreation Quality • Facilities that decrease self-reliant recreation

The park is currently compiling a trail sign inventory. When that process is complete, the number of trail signs in wilderness should be incorporated in the future.

Paleontological Site Conditions

Other Features of Value Quality • Deterioration or loss of other integral site-specific features of value

Inventorying of paleontological resources within the Grand Canyon wilderness is still in its infancy and no currently usable dataset was available for this measure. If a systematic survey of paleontological sites within the Grand Canyon wilderness is conducted and useful baseline data is generated, this measure should be incorporated.

Human Disturbance of Cave Resources

Other Features of Value Quality • Deterioration or loss of other integral site-specific features of value

Human activities comprise the biggest stressor on cave resources. Except for Cave of the Domes on Horseshoe Mesa, cave entry and exploration in the park is only permitted for research purposes (NPS 2018b). Nevertheless, unauthorized cave visitation and resulting impacts on cave resources is a concern (B. Tobin, personal communication, 2017). To better monitor cave visitation, park staff have

installed trail counters at the entrances of several caves. A future Cave and Karst Resources Plan may also implement a monitoring program of cave disturbance. As this data becomes available, this measure should be incorporated into wilderness character monitoring.

Measures Not Used for Wilderness Character Monitoring

The measures described below were considered for wilderness character monitoring, but were ultimately not used. Descriptions of each measure and rationales for exclusion are included. To reduce the workload of future monitoring, the number of measures was deliberately kept to the minimum deemed necessary to capture future changes in wilderness character.

Actions that Manipulate Hydrology

Several high-flow experimental releases from Glen Canyon Dam have been conducted over the last 20 years to mitigate dam impacts on downstream resources. The controlled floods are intended to mimic natural, pre-dam fluctuation in river flow, improve native fish habitats, and slow the continued loss of sandbars. Because flows from Glen Canyon Dam are modified at all times, these periodic high-flow experimental releases were not counted as separate trammeling actions.

Actions that Manipulate Soils

Due to the remoteness of much of the Grand Canyon wilderness, biological soils are generally in good condition, with impacts being localized in areas of concentrated visitor use. Evidence of soil disturbing actions is mostly anecdotal and not well monitored. The intention to trammel is also absent in most cases of soil disturbance, which usually result from a lack of awareness.

Plant Species of Concern

Sentry milk-vetch is currently the only listed endangered plant species in the park. There are also several plant species of special concern, including California bearpoppy, Arizona prickly poppy, Grand Canyon suncup, Kaibab suncup, Grand Canyon campion, and Tusayan flameflower. Although this measure was identified as important by park staff, measuring the success or failure of native plants poses problems in wilderness character monitoring and is difficult to do without assuming an ecological target state (Landres et al. 2015).

Native Animal Species Extirpated

Nine wildlife species have been extirpated from Grand Canyon: grizzly bear, gray wolf, black-footed ferret, jaguar, Colorado pikeminnow, bonytail, roundtail chub, northern leopard frog, and southwestern river otter. Conversely, California Condors and humpback chub are being reintroduced to Grand Canyon. While extirpation and reintroduction of native species is discussed in the Wilderness Character Narrative, counting native species does not necessarily monitor human-caused threats nor can a trend be assigned without assuming an ecological target state (Landres et al. 2015).

Animals Killed or Infected by Pathogens

Transmission of respiratory disease from domestic sheep has contributed to the decline of desert bighorn sheep in North America (George et al. 2008; Wehausen et al. 2011). Cavers can also spread white-nose syndrome, a deadly disease that affects North American bats (Cryan et al. 2010; Shelley et al. 2013; Chung-MacCoubrey 2013). This measure was not included due to data infeasibility.

Miles of River Dominated by Non-Native Fish

Non-native fish have contributed to extirpation of three native fish species and the listing of two others as endangered. Although monitoring fish community composition was identified as important by park staff, this analysis would have exceeded the scope of wilderness character monitoring.

Impaired Waters on the Clean Water Act Section 303(d) List

The park's hydrologist and fishery biologists raised concerns that certain "pollutants" identified by the Arizona Department of Environment Quality (ADEQ) are problematic. For example, the Colorado River and its tributaries are listed as impaired due to suspended sediment (ADEQ 2017). However, these waters are naturally turbid, and native fish have evolved under these conditions (Schmidt et al. 1998).

Regional Road Density

Tracking change in regional road density would provide insight into the pressures outside developments have within wilderness ecosystems. However, the U.S. Census Bureau's TIGER/Line® Shapefiles were deemed inadequate for this analysis, and the park's own regional transportation dataset varies significantly in quality and quantity for different jurisdictions.

Measures Related to Climate Change

Climate change research extends beyond the scope of wilderness monitoring. Established climatology programs exist and this science is conducted by specialists at a higher level than is possible for an individual wilderness. Further, the Natural Quality should not be used to maintain a particular ecological status quo (Landres et al. 2015).

Miles of Pipeline

The 15-mile transcanyon pipeline is located in the non-wilderness crosscanyon corridor. While construction work related to pipeline maintenance or replacement can have an impact on wilderness character (e.g. using helicopters to fly in steel pipe), these impacts are captured elsewhere.

Extent of Cell-Phone Reception

The ability to call, text, or browse the web from inside the wilderness can impact opportunities for solitude and diminish the need for primitive and self-reliant skills. Cell reception is present in a few areas within the Grand Canyon wilderness, but no usable data was available.

Involvement of Traditionally Associated Tribes

After deliberation with the park's tribal liaison, it was decided not to include this measure, because confining tribal values to a single quantitative measure would trivialize the relationship between native peoples and their homeland. Instead, the intangible values represented by ongoing cultural connections between native peoples and the canyon are discussed in the Wilderness Character Narrative. Due to laws and agreements, tribal consultation is already entrenched in park operations.

Viewshed Impacts

Expansive vistas are a valuable component of the Grand Canyon wilderness. As part of "Enjoy the View" (NPS 2018c), Grand Canyon National Park completed a visual resource inventory in 2016

(Meyer et al. *in review*). However, continued data collection is uncertain, and the sites selected for the initial inventory are in developed areas and may not reflect wilderness viewsheds.

Future Monitoring

With official wilderness designation still pending, preserving the wilderness character of the Grand Canyon wilderness should be at the forefront of park policy. The careful preservation of Grand Canyon wilderness character will serve as a clear testament to the area's natural and cultural significance and iconic stature – worthy of official designation.

The completion of this assessment does not automatically ensure the preservation of wilderness character or the longevity of wilderness character monitoring. Wilderness monitoring is an ongoing, long-term undertaking. Preserving wilderness character is also the principal legal mandate of the Wilderness Act (16 U.S.C. § 1131-1136), which has been reaffirmed by NPS policy (NPS 2006a). From a practical perspective, the most important reason for tracking change in wilderness character is to provide solid information that can be used to inform management decisions and improve on-the-ground wilderness stewardship. As succinctly stated by Schindler and Hilborn (2015), "Without monitoring and assessment, we have no way to determine when changes to management are needed."

As mandated by NPS Director's Order 41 (NPS 2013a), the park's Wilderness Coordinator, with guidance and support offered by the NPS Wilderness Stewardship Division, will be responsible for continuing wilderness character monitoring efforts and updating data values in the Interagency Wilderness Character Monitoring Database at: https://wc.Wilderness.net/ (new users must request access to the database). With data sources and collection protocols described under each measure in this report, continuing wilderness character monitoring at Grand Canyon should be a straightforward task that is expected to take the park's Wilderness Coordinator no more than two pay periods (160 hours) once every five years. As stated repeatedly throughout this report, wilderness character monitoring heavily relies on existing data collection efforts conducted at park, regional, and national levels. The resources required to keep up these efforts are not included here, because these activities are already integrated into agency operations and budgeted for separately. The next round of monitoring of the Grand Canyon wilderness will take place in 2023.

At the end of each five-year monitoring cycle, the Wilderness Coordinator will also prepare a brief report (3-5 pages) presenting trends in Grand Canyon wilderness character. This report will be shared with an audience of decision-makers and resource managers at Grand Canyon, as well as interested citizens. It will also be used for upward reporting in the agency. It is recommended that the standardized icons (Table 31 and 32; available at: nature.nps.gov/publications/NRPM) designed and approved for use with the Natural Resource Condition Assessment and State of the Parks programs be used to indicate wilderness resource condition and trends. For future determining of trends in wilderness character, please consult *Keeping It Wild 2* (Landres et al. 2015, pp. 24-31).

Monitoring by itself cannot mitigate impacts to wilderness values. Monitoring is not an end product; it is a method for tracking and evaluating resource conditions, so managers can develop appropriate actions for protection. The next section will discuss some of these actions that were identified during the development of this report.

Table 31. Indicator symbols used to indicate condition, trend, and data adequacy.

Condition Status		Trend in Condition		Confidence in Assessment	
Condition Icon	**Condition Icon Definition**	**Trend Icon**	**Trend Icon Definition**	**Confidence Icon**	**Confidence Icon Definition**
	Resource is in Good Condition		Condition is Improving		High
	Resource warrants Moderate Concern		Condition is Unchanging		Medium
	Resource warrants Significant Concern		Condition is Deteriorating		Low

* Condition status definitions are extracted from *Wilderness Character Assessment: Workshop Participant Guide* (NPS 2017b).

Table 32. Example indicator symbols with verbal descriptions.

Symbol Example	Verbal Description
	Resource is in good condition; its condition is improving; high confidence in the assessment.
	Condition of resource warrants moderate concern; condition is unchanging; medium confidence in the assessment.
	Condition of resource warrants significant concern; trend in condition is unknown or not applicable; low confidence in the assessment.
	Current condition is unknown or indeterminate due to inadequate data, lack of reference value(s) for comparative purposes, and/or insufficient expert knowledge to reach a more specific condition determination; trend in condition is unknown or not applicable; low confidence in the assessment.

Opportunities for Future Wilderness Planning

The following section describes management opportunities that were identified during the development of this report. Addressing these opportunities would improve stewardship of the Grand Canyon wilderness in the future.

Wilderness Designation: Many visitors may be surprised to find out that in this vast and majestic park and world heritage site, there are no designated wilderness areas. As the proposed wilderness is currently managed as wilderness per NPS policy, there would be minimal changes to land use, park operations, and funding needs should Congress move forward with designating these lands as wilderness. Official wilderness designation would create a certainty about the future, ensuring that tomorrow's management will look essentially like today's management. If there are no roads or permanent developments now, there will be none in the future. The current temporary management as *de facto* wilderness is just that – temporary. The logical next step toward pursuing designation of the Grand Canyon wilderness is to update the 2010 Wilderness Recommendation based on revised park boundaries in GIS and other changes that may have occurred and provide this updated recommendation to the Director of the NPS. However, without widespread public support, designation of the Grand Canyon wilderness is unlikely to pass. Therefore, connecting citizens to their wilderness heritage and nurturing life-long connections between people of diverse cultures and wilderness should be a key component of any future Wilderness Stewardship Plan.

Wild and Scenic River Designation: The National Rivers Inventory (NPS 2018e) identifies 17 stream and river segments (395 miles) within Grand Canyon National Park with potential for inclusion in the National Wild and Scenic River System. All of these segments are within or adjacent to proposed wilderness. Designation under the Wild and Scenic Rivers Act of 1968 (16 U.S.C. 1271 et seq.) would provide an additional layer of protection and preserve the free-flowing character of these waterways. Section 5(d)(1) of the Wild and Scenic Rivers Act directs federal agencies to identify potential additions to the national system through their respective resource and management plans. The park's General Management Plan (NPS 1995) acknowledges that the Colorado River and selected tributaries potentially meet the criteria for Wild and Scenic River designation. Prior to designation, a wild and scenic river study must be conducted to determine eligibility, suitability, and classification of the waterways in question. Under a cooperative agreement with Prescott College, the eligibility study for the tributaries and main stem of the Colorado River has been completed (Barnes et al. 2005). With the NPS celebrating the 50th Anniversary of the Wild and Scenic Rivers Act, the park could review the findings of this study, identify additional information needs, and outline next steps toward pursuing designation.

Backcountry Management Plan: While not identical, wilderness and backcountry planning and management at Grand Canyon National Park are interrelated. The park's 1988 Backcountry Management Plan (NPS 1988) was intended for review after three years but is still in use today. This plan is no longer consistent with NPS wilderness policy. Recognizing the need for an updated plan, the park released a new Backcountry Management Plan / DEIS (NPS 2015) for public review and comment in 2015. The park is currently reviewing public comments and revising the EIS. Publication

of the Backcountry Management Plan FEIS and issuing a Record of Decision would address issues concerning visitor experience and resource protection in the park's backcountry including commercial backcountry services, emerging recreational uses, group size limits and use levels, primitive road closures, commercial filming, and degradation of wilderness character in some use areas, among others. The park's Foundation Document (NPS 2017) also identifies a revised Backcountry Management Plan as a high priority need.

Wilderness Working Group: A parkwide interdisciplinary working group (canyon rangers, resource specialists, planners, trail specialists, interpreters, and permits staff) is being developed and could meet at least quarterly to discuss wilderness planning, compliance, and management challenges, as well as identify information needs. Building and maintaining social capital through informed discourse and a shared sense of purpose would be a powerful way to build support for ambitious management actions and preservation of wilderness character at Grand Canyon.

Wilderness Stewardship Plan: A Wilderness Stewardship Plan guides the management actions to preserve wilderness character. It identifies future conditions, establishes indicators, standards, conditions and thresholds beyond which management should take action to reduce human impacts on wilderness resources. NPS Management Policies (2006a) require each park containing wilderness resources to develop and maintain a Wilderness Stewardship Plan or equivalent document. The development of a Wilderness Stewardship Plan would entail preparation of an EIS and require a significant amount of agency personnel and funding. A Wilderness Stewardship Plan was identified as a planning need in the Foundation Document (NPS 2017).

Data Needs: The following data collection efforts and improvements of existing efforts would increase the efficiency of wilderness character reporting, improve the accuracy of wilderness character data, and more effectively capture important aspects of wilderness character. Most of these data needs are also identified in the Foundation Document (NPS 2017).

Campsite Condition Monitoring—Integrating river and backcountry campsite monitoring programs into a single database would enable park staff to better assess visitor use impacts and monitor this measure under the Solitude or Primitive and Unconfined Recreation Quality.

Paleontological Resource Inventory—A systematic survey of paleontological sites within Grand Canyon is currently underway. Such a survey will establish useful baseline data and will allow for monitoring of this important resource under the Other Features of Value Quality.

Cave Visitation Data—Park staff have already installed trail counters at the entrances of several caves. Collecting this data consistently into the future would enable managers to quantify human impacts on cave resources and include this measure under the Other Features of Value Quality.

Trail Sign Inventory—The park is currently in the process of developing a trail sign inventory. Accounting for all signs will allow park staff to quantify impacts on primitive recreation and the need for route-finding to navigate the Grand Canyon wilderness. Such an inventory could also guide the future need for placement, removal, and maintenance of such signs.

Administrative Flight Data Collection—Detailed statistics are currently published on administrative helicopter use at Grand Canyon National Park in an annual aviation report. However, fixed-wing flight hours flown in the park are combined with hours flown for the USFS and the BLM. More detailed reporting and statistics on administrative fixed-wing flights could be made available in the park's annual aviation report. Locations of helicopter landings, except for SAR operations, are also not documented in the park's aviation database. This makes it difficult to determine if and when helicopters land in wilderness. An attribute field could be added to the database, indicating the location of the landing and whether the landing took place in wilderness.

Administrative Motorized River Use Data Collection—Information about administrative river-based missions utilizing motorized boats is currently dispersed among many different programs and divisions. A centralized database and approval process for all river-based missions carried out by NPS, USGS, AZGFD, USBR, and other agencies would improve the accuracy and efficiency of monitoring this type of use.

MRDG Database—In order to allow wilderness management staff to efficiently track, search for, follow up on, and compile information about Minimum Requirement Decision Guides (MRDGs) and associated activities in wilderness, all approved MRDGs could be entered into a spreadsheet and listed by year, type (programmatic vs. project-specific), user group, prohibited uses exempted, qualities impacted, etc. Improvements in PEPC could also result in improved tracking of actions that are approved in wilderness, particularly those with prohibited tools.

End-of-year Reviews of Programmatic MRAs—Programmatic MRAs risk providing blanket exemptions for prohibitions identified in Section 4(c) of the Wilderness Act. Currently programmatic MRAs are reviewed and approved at the beginning of the year. This makes it difficult to quantify and collect data on the activities that were categorically permitted. For example, the exact amount of chainsaw use (hours or days per person) is largely unrecorded. To improve this, a process could be established under which programs that were granted a programmatic MRA report back at the end of the year on their activities.

Installations Geodatabase—Any wilderness inventorying effort is currently complicated by the fact that no long-term centralized data repository exists in which installations placed in wilderness are recorded. The NPS Alaska Region developed a consistent approach that standardizes the storage and management of installations. A template geodatabase, together with a user guide and data collection forms, can be found at http://165.83.62.205/rgr/akgis/index.cfm?action=dsp&topic=status&item=installations. Such a database would strengthen wilderness stewardship, cumulative effect analyses, and research permitting at Grand Canyon.

Conclusion

As mandated by NPS Director's Order 41 (NPS 2013a), this document provides Grand Canyon National Park with an official Wilderness Character Narrative, the establishment of baseline wilderness character measures and data, and a framework for continuing this monitoring to assess changes in wilderness character far into the future. In providing these building blocks for wilderness stewardship, this report also serves as a foundation document to support the process of developing a Wilderness Stewardship Plan at Grand Canyon National Park. Beyond fulfilling these policy requirements, this report seeks to empower park managers to make carefully-weighed wilderness stewardship decisions with the ultimate goal of facilitating the preservation of wilderness character.

The measures selected for wilderness character monitoring by this assessment are not all-inclusive or comprehensive. Future monitoring should continue to revisit the adequacy of these measures and their data sources, and new measures should be incorporated if new issues become relevant to wilderness character or new data become available. To fully realize the investment in this monitoring program and ensure its credibility, any future changes must be carefully documented and should only be made if necessary or if having a demonstrable positive long-term effect on this program.

Significant wilderness-related datasets were generated through this project, including an inventory of physical developments and installations in wilderness, a count of trammeling actions and environmental manipulations that have occurred within wilderness in recent years, an inventory of motorized use and mechanized transport that has been authorized within wilderness, and the aggregation of wilderness-specific datasets from local, regional, and national sources. The information generated by this assessment has applications beyond wilderness character monitoring, and should serve as a resource for future park planning.

Point Imperial, the highest point on the North Rim at 8,803 feet, overlooks the Painted Desert and the eastern portion of the Grand Canyon wilderness (NPS/MICHAEL QUINN).

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List of Acronyms and Abbreviations

ADEQ: Arizona Department of Environmental Quality

ALR: All-sky Light Pollution Ratio

ARD: Air Resources Division

AZGFD: Arizona Game and Fish Department

BLM: Bureau of Land Management

CFS: Cubic feet per second

DEIS: Draft Environmental Impact Statement

DOI: United States Department of the Interior

EIS: Environmental Impact Statement

FAA: Federal Aviation Administration

FEIS: Final Environmental Impact Statement

FGDC: Federal Geographic Data Committee

GIS: Geographical Information System

GRCA: Grand Canyon National Park

IMPROVE: Interagency Monitoring of Protected Visual Environments

IPCC: Intergovernmental Panel on Climate Change

MRA: Minimum Requirement Analysis

MRDG: Minimum Requirement Decision Guide

NADP/NTN: National Atmospheric Deposition Program/National Trends Network

NEPA: National Environmental Policy Act

NIFC: National Interagency Fire Center

NNL: National Natural Landmark

NPCA: National Parks Conservation Association

NPS: National Park Service

NRA: National Recreation Area

NSNSD: Natural Sounds and Night Skies Division

NWPS: National Wilderness Preservation System

PIT: Passive Integrated Transponder

RM: River Mile

SAR: Search and rescue

UAS: Unmanned aircraft systems

UNESCO: United Nations Educational, Scientific, and Cultural Organization

USBR: United States Bureau of Reclamation

USFWS: United States Fish and Wildlife Service

USFS: United States Forest Service

USGS: United States Geological Survey

WFMI: Wildland Fire Management Information

Glossary

Assessment of the Grand Canyon wilderness requires the use of technical terms. Some of the most important are defined in this section. Terms in ***bold italics*** are defined separately in this glossary.

All-sky light pollution ratio (ALR): measure of anthropogenic sky luminance relative to natural conditions. (Moore et al. 2003)

Archaeological site: Physical remains of past human activity that are at least 50 years old. Sites are significant based on their identity, age, location, and context. Sites must also retain information about the past. Sites may be historic or prehistoric in age, above ground or subsurface, including in ***caves*** and under water. (NPS 2016)

At-large camping: In ***use areas*** without ***designated camping***, individuals or groups can camp anywhere in accordance with normal regulations and Compendium restrictions (NPS 2015).

Backcountry: The term backcountry generally refers to "primitive and undeveloped portions of parks. Usually these areas limit development to trails, unpaved roads, and administrative facilities" (NPS 2006a). Grand Canyon's backcountry consists of over 1.1 million acres of primitive, undeveloped area, most of which is proposed for ***wilderness*** designation. For planning purposes, the backcountry also includes the ***Crosscanyon Corridor*** and Tuweep. Backcountry is not the same as wilderness. Rather, backcountry refers to a general condition of land, whereas wilderness is a federal designation. Management of park wilderness portions requires different administrative practices than backcountry because the Wilderness Act and NPS Management Policies impose additional conditions and constraints. NPS policy requires wilderness awaiting designation be treated as wilderness until Congress acts. (NPS 2015)

Biological control: using the natural enemies of a pest or ***invasive plant species*** to reduce the population to acceptable levels. (NPS 2009)

Cave: The Federal Cave Resources Protection Act of 1988 defines the term cave as:

> "Any naturally occurring void, cavity, recess, or system of interconnected passages beneath the surface of the earth or within a cliff or ledge, including any cave resource therein, and which is large enough to permit a person to enter, whether the entrance is excavated or naturally formed. Such term shall include any natural pit, sinkhole, or other feature that is an extension of a cave entrance or which is an integral part of the cave."

Grand Canyon has adapted this definition to include any dissolution or erosional feature 50 feet or longer where the entrance (drip line) is not wider than the cave is long. For example, by this definition, Redwall Cavern on the Colorado River is not a cave but an alcove.

Concessioner: A commercial venture operating under a concession contract with the National Park Service. The term of a concession contact is generally 10 years. (NPS 2015)

Crosscanyon Corridor (Corridor Management Zone): Includes Bright Angel, South Kaibab, and North Kaibab Trails and their associated facilities (Indian Garden, Bright Angel, and Cottonwood Campgrounds); Phantom Ranch tourist lodging, ranger stations, and sewage and water treatment facilities. Overnight use by backcountry ***permit***. (NPS 2015)

Designated camping: Required when necessary to restrict intensive use to previously disturbed areas and limit the impact. Designated campgrounds (composed of several adjacent sites) are found in the ***Corridor Management Zone***. Separate designated campsites are located in use areas outside of the Corridor Management Zone with sites located according to aesthetic, environmental, and sociological criteria. Where designated camping exists, backcountry users may not select other campsites. (NPS 2015)

Desired conditions: Describe an ideal condition of ***wilderness character***. This is both a holistic condition, as well as the desired condition for each ***quality*** of wilderness character. (NPS 2017b)

Electro-fishing: A scientific fish-sampling technique that uses electricity to temporarily stun fish, so they can be captured. Electro-fishing is a common scientific survey method to sample fish populations for abundance, density, and species composition. When performed correctly, electro-fishing results in no permanent harm to fish, which return to their natural state shortly after being affected by electro-fishing equipment. (NPS 2013)

Exotic species: A species that occupies or could occupy parklands directly or indirectly as the result of deliberate or accidental human activities. Because an exotic species did not evolve in concert with species native to the place, the exotic species is not a natural component of the natural ecosystem at that place. Exotic species are also commonly referred to as weeds (in the case of plant species), non-native, alien, or ***invasive species***. (NPS 2006a)

Extirpated: Local extinction, in which a species ceases to exist in a specific geographic area, though it still exists elsewhere. (NPS 2013)

Fire Management Unit: A land management area defined by objectives, management constraints, topographic features, access, values to be protected, political boundaries, fuel types, and major ***fire regime*** groups, etc., that set it apart from an adjacent FMU. (NPS 2012)

Fire regime: Fire frequency, ***intensity***, timing, and distribution for a particular vegetation type. Historic fire regimes refer to past fire patterns. Historic fire frequency and timing can be inferred from fire scars on old trees, especially ponderosa. (NPS 2012)

Group night: A group night is one group in the backcountry for one night. For overnight use in the backcountry, groups can either be small (1-6 people) or large (7-11 people). (NPS 2015)

Haze index: the unit of measurement of visibility derived from light extinction that is designed so that incremental changes correspond to uniform incremental changes in visual perception, across the entire range of conditions from pristine to highly impaired. Haze index is measured in deciviews. (Taylor 2017)

Indicator: Indicators are distinct and important elements under each ***monitoring question***. In nearly all cases, there is more than one indicator under a monitoring question. Each wilderness and agency would be responsible for reporting the ***trend*** in all indicators. The same set of indicators applies nationwide to all ***wilderness areas*** managed by all agencies. (Landres et al. 2015)

Inholding: Land owned or managed by an entity other than the National Park Service that is within the ***designated***, ***recommended***, ***proposed***, or ***eligible wilderness*** boundary. (NPS 2013b)

Installation: Anything made by humans that is not intended for human occupation and is left unattended or left behind when the installer leaves the wilderness. (NPS 2013b)

Invasive species: A species known to displace ***native species*** in otherwise intact communities. Not all ***exotic species*** are invasive. (NPS 2006a)

Karst: Landforms and hydrologic systems created by the dissolution of soluble rocks such as limestone, dolomite, and gypsum and characterized by underground drainage systems with sinkholes and caves. (NPS 2017a)

Light pollution: Brightening of the night sky that inhibits the observation of stars and planets, caused by anthropogenic sources such as streetlights.

Lower Gorge: The fifty-one miles of river from below Diamond Creek (RM 226) to the river's entry into Lake Mead (RM 277) is called the Lower Gorge.

Management zone: Geographic area defined by resource, managerial, and social conditions/settings. For example, the ***Corridor Zone*** has ranger stations, designated campsites, toilets, running water, and a lodge with cabins at Phantom Ranch. The Corridor Zone is managed for high visitation levels. The Primitive Zone is, by comparison, managed for lower use levels, does not generally have designated camping or toilets, and one can expect to see five or fewer backpacking groups per day; providing increased opportunities for solitude. Management zones help guide backcountry management actions and help provide opportunities for diverse experiences. They are comprised of smaller geographic units called ***use areas***. A more detailed discussion of management zones and use areas is included in Appendix B. (NPS 2015)

Measures: Measures are the specific elements under each ***indicator*** on which data are collected to assess ***trend*** in an indicator. One or more specific measures are used to quantify or qualitatively evaluate the condition of an indicator. (NPS 2017b)

Mechanical transport: Any contrivance for moving people or material in or over land, water, snow or air which has moving parts and is powered by a living or non-living power source. This includes (but is not limited to) wheeled vehicles such as bicycles, game carriers, carts and wagons. Mechanical transport does not include wheelchairs when used as necessary medical appliances, nor does it include skis, snowshoes, sleds, travois, non-motorized river craft including drift boats, rafts, or canoes, or similar primitive devices. (NPS 2013b)

Minimum requirement analysis (MRA): The minimum requirement analysis is a two-step process that documents 1) the determination as to whether or not a proposed management action is appropriate and necessary for the administration of the area as ***wilderness***, and does not pose a significant impact to the wilderness resources and character; and, 2) the selection of the ***minimum tool*** that causes the least amount of impact to ***wilderness character***. (NPS 2013b)

Minimum Requirements Decision Guide (MRDG): The Minimum Requirements Decision Guide is a process that was developed by the Arthur Carhart National Wilderness Training Center to assist wilderness managers with completing a ***Minimum Requirements Analysis*** for wilderness projects and making defensible management decisions that comply with the Wilderness Act.

Minimum tool: A use or activity determined to be necessary to accomplish an essential task that makes use of the least intrusive tool, equipment, device, force, regulation, or practice that will achieve the management objective. (NPS 2013b)

Monitoring: Monitoring is the collection and analysis of repeated observations or measurements to evaluate changes in condition and progress toward meeting a management objective. As used in this document, it is synonymous with tracking change in ***wilderness character***. (NPS 2017b)

Monitoring questions: For each ***quality***, monitoring questions capture essential components that address particular management questions and goals. The same set of monitoring questions applies nationwide to all ***wilderness areas***, although some agencies do not use these questions and instead go directly from qualities to ***indicators***. (Landres et al. 2015)

Motorized equipment: Any machine activated by a motor, engine, or other non-living power source. This includes chain saws, power drills, generators, windmills and snow blowers. Motorized equipment does not include shavers, wrist watches, clocks, flashlights, cameras, camping stoves, solar panels, batteries, explosives, cellular telephones, radio receivers or transmitters, or GPS units. (NPS 2013b)

National Wilderness Preservation System (NWPS): The NWPS is the sum total of all ***wilderness areas*** designated under the Wilderness Act of 1964 and subsequent legislation. The NPS, BLM, USFS, and USFWS are the federal agencies that share the responsibility of managing the nation's ***wilderness***. As of 2018, there are 765 wilderness areas in the NWPS, protecting about 5% (109,982,783 acres) of the entire United States. Alaska contains just over half of America's wilderness, leaving 2.7% of the contiguous United States designated as wilderness. (wilderness.net)

Native species: All species that have occurred or now occur as a result of natural processes on lands designated as units of the National Park System. Native species in a place are evolving in concert with each other. A goal of the NPS is to perpetuate native species as part of the natural ecosystem. (NPS 2006a)

Natural visibility conditions: estimated to exist in a given area in the absence of human-caused visibility impairment. (Taylor 2017)

Non-conforming uses: Human land uses and activities taking place in ***wilderness*** that are prohibited under Section (4c) of the Wilderness Act. These include: temporary roads, use of motor vehicles, ***motorized equipment*** or motorboats, landing of aircraft, any other form of ***mechanical transport***, and ***structures*** or ***installations*** within a ***wilderness area***.

Permit: A backcountry use permit provides permission for a ***group*** of a specified number of hikers to camp overnight in a specified ***use area***. (NPS 2015)

Photic environment: the totality of the pattern of light at night at all wavelengths. Though not all wavelengths are perceived by the human eye, the photic environment affects a broad range of species and is integral to ecosystems. (Moore et al. 2013)

Prescribed fire: Any fire ignited by management actions to meet specific objectives. A written, approved prescribed fire plan must exist prior to ignition. (NPS 2012)

Qualities: Qualities are the primary elements of wilderness character that link directly to the statutory language of the 1964 Wilderness Act. The same set of qualities applies nationwide to all ***wilderness areas*** managed by all agencies. In this framework, the Untrammeled, Natural, Undeveloped, and Solitude or Primitive and Unconfined Recreation Qualities are all necessary to assess ***trend*** in ***wilderness character*** and each wilderness would report the trend in each of these qualities. Where other features of value exist in and are integral to a wilderness, the Other Features of Value Quality would also be reported. (Landres et al. 2015)

Riparian: Pertaining to banks of a river or wetland. Plants in this area are usually dependent on or influenced by the water table connected to the adjacent surface water body (lake, wetland, or stream). (NPS 2013)

River Miles (RM): Distance along the Colorado River corridor is measured in river miles (RM), beginning near the park's eastern boundary at Lees Ferry with RM 0 and ending near the park's western boundary at the Grand Wash Cliffs with RM 277. Most river trips begin at Lees Ferry, approximately one mile upstream from the park boundary, in Glen Canyon NRA. Most trips end at the only place within the 277-mile river corridor where boats can be de-rigged and transported out of the steep-walled canyon: Diamond Creek at RM 226. (NPS 2006)

Soundscape (natural): The aggregate of all the natural, nonhuman-caused sounds that occur in parks, together with the physical capacity for transmitting natural sounds. (2006a)

Structure: Anything made by humans that is intended for human occupation, or their possessions, and is left behind when the builder leaves the wilderness. (NPS 2013b)

Traditionally Associated Tribes: American Indian tribes that remain attached to a park area despite having relocated. Tribes are traditionally associated when (1) the tribe regards park resources as essential to its development as a culturally distinct people; (2) the association has endured for at least two generations (40 years); and (3) the association began prior to establishment of the park. Grand Canyon's Traditionally Associated Tribes include the Havasupai, Hopi, Hualapai, Kaibab Band of

Paiute Indians, Las Vegas Band of Paiute Indians, Moapa Band of Paiute Indians, Navajo Nation, Paiute Indian Tribe of Utah, San Juan Southern Paiute Tribe, Yavapai-Apache Nation, and The Pueblo of the Zuni. (NPS 2015)

Trail Class: Trail Classes are categories arranged along a continuum from one to five, with five being most developed. The Trail Class identified for a trail prescribes its development scale, representing its intended design and management standards. (FGDC 2017)

Trend: A directional change measured in resources and visitor experiences by ***monitoring*** their condition over time. Trends describe if the ***wilderness qualities*** and overall ***character*** are improving, stable, or worsening. (NPS 2017b)

Use Area: Grand Canyon's ***backcountry*** is divided into 96 distinct use areas defined, to the extent possible, according to identifiable topographic features such as ridge tops and drainages that allocate use by geographic area. They may vary in size from several hundred to several thousand acres. Backcountry ***permits*** specify allowable use areas. Each area is identified by a three-digit code referencing location and camping opportunities. Each Use Area is classified in one of four ***management zones***: Corridor, Threshold, Primitive, or Wild (Map 1.2). Classification of use areas into management zones is associated with how the park manages resources given the level of visitor use and types of activities. A more detailed discussion of management zones and use areas is included in Appendix B. (NPS 2015)

User night: A user night is one hiker in the ***backcountry*** for one night. (NPS 2015)

Valid existing rights: Those property rights, in existence on the date of ***wilderness designation*** or on such date as provided for in the particular Act that designated an area as wilderness, that were created by a legally binding conveyance, lease, deed, contract, or other document; or as otherwise provided by Federal law. (NPS 2013b)

Water year: A water year is defined as the 12-month period from October 1 of any given year through September 30 of the following year. The water year is designated by the calendar year in which it ends, and which includes 9 of the 12 months. (USGS 2018)

Wilderness: When applying NPS policies, wilderness includes eligible, proposed, recommended, and designated wilderness. Potential wilderness may be a subset of any of these categories. (NPS 2013b)

> **Designated wilderness**: Federal land designated by Congress as wilderness and a component of the ***NWPS*** where the NPS is required to manage the land according to the Wilderness Act of 1964. (NPS 2013b)
>
> **Eligible wilderness**: An area that possesses the ***qualities*** and ***character***, as identified within the Wilderness Act, which would qualify it for designation within the ***NWPS***. An area where, based upon a wilderness eligibility assessment, the NPS Director has approved the managerial

determination of eligibility for wilderness designation, and has published notice of eligibility in the Federal Register. (NPS 2013b)

Potential wilderness: Lands which possess wilderness characteristics which would normally qualify them for designation within the ***NWPS*** but contain temporary nonconforming or incompatible conditions (such as structures or roads) or uses (such as ***inholdings***, valid mining claims or operations) which prevent their being immediately designated as wilderness. These lands may be identified as "potential wilderness" in NPS wilderness proposals, wilderness recommendations, and by Congress in legislation designating other portions of a park as wilderness. Once the ***non-conforming uses*** have been extinguished by publishing a notice in the Federal Register, designated potential wilderness should be converted to designated wilderness (NPS 2013b)

Proposed wilderness: The findings and conclusions of a formal wilderness study that have been submitted as a proposal by the NPS Director to the DOI, but have not been approved by the Secretary of the Interior. (NPS 2013b)

Recommended wilderness: An eligible wilderness area that has been studied and proposed by the NPS, recommended for wilderness designation by the Secretary of the Interior to the President, and then transmitted by the President to Congress as his or her recommendation for wilderness designation. (NPS 2013b)

Wilderness area: Federal land designated by Congress as a component of the ***National Wilderness Preservation System***. (NPS 2013b)

Wilderness character: Wilderness character is a holistic concept based on the interaction of (1) biophysical environments primarily free from modern human manipulation and impact, (2) personal experiences in natural environments relatively free from the encumbrances and signs of modern society, and (3) symbolic meanings of humility, restraint, and interdependence that inspire human connection with nature. Taken together, these tangible and intangible values define wilderness character and distinguish wilderness from all other lands. (Landres et al. 2015)

Wilderness study: A formal study that evaluates the acreage that has been determined to be eligible for wilderness designation through the completion of a wilderness eligibility assessment. The purpose of the wilderness study is to provide a detailed review necessary to develop official proposals and recommendations for wilderness designation to the NPS Director, the Secretary of the Interior, the President, and Congress. (NPS 2013b)

Appendix A - History of Backcountry Planning and Management at Grand Canyon

The need for visitation management and restrictions at Grand Canyon National Park became apparent over Easter weekend of 1970, when 800 individuals camped at Phantom Ranch's Bright Angel Campground. The resulting overcrowding, unsanitary conditions, clogged toilets, vegetation damage, and litter led to use limits for crosscanyon corridor trailheads in 1971 (NPS 2015). To further address these types of impacts, the first visitor-use management plan for the park's backcountry areas was approved in 1974. The Backcountry Use and Operations Plan (NPS 1974) established a permit system and use limits for trailheads outside the corridor and set a maximum group size of 16.

A new Backcountry Management Plan was adopted in 1983. The plan delineated four management zones (Corridor, Threshold, Primitive, and Wild) to provide opportunities for a wide variety of backcountry experiences (see Appendix B). Management zones were further divided into use areas with prescribed use limits, replacing the trailhead quota system. The plan also required Special Use Permits for backcountry commercial guiding.

Over the next five years, the 1983 Backcountry Management Plan was reviewed, and a revised plan was implemented (NPS 1988). Changes from the previous plan included commercial use policy, private stock use, trail and road standards, management objectives, and a reservation and permit system. The plan also set use limits for Corridor and Wilderness Use Areas; set management objectives for signs, structures, stock use, and primitive roads; described trail classifications and maintenance standards; and set standards for visitor experience and campsite condition. Although the 1988 Backcountry Management Plan was intended for review after three years, it is still in use today.

In 1995, the General Management Plan was approved, directing the park to update its Backcountry Management Plan to be consistent with the park's management objectives and NPS wilderness policy. However, efforts to update the Backcountry Management Plan were redirected to draft a Wilderness Management Plan, which was ultimately suspended in early 2000.

Beginning in 2002, an interdisciplinary Backcountry Task Group was formed, including park rangers, resource managers, planners, trail specialists, interpreters, and permits staff. Over the next decade, the Task Group identified information needs, remedied immediate backcountry issues, coordinated campsite monitoring and visitor experience research, conducted fieldwork to mitigate campsite impacts, and coordinated parkwide workshops on wilderness and research programs.

In 2011, the park conducted public scoping for a new Backcountry Management Plan and subsequently released a DEIS for public review and comment (NPS 2015). The plan addresses commercial backcountry services, emerging recreational uses, group size limits, and degradation of wilderness character, among other issues. The park is currently reviewing public comments and revising the EIS.

Appendix B - Backcountry Management Zones and Use Areas

The 1988 Backcountry Management Plan defines four management zones to better guide management actions and provide opportunities for a variety of recreational experiences (Figure B-1). Management zones are divided into use areas based on established use patterns and resource management considerations. Most use area boundaries are defined according to identifiable topographic features such as ridge tops and drainages. Each use area has been given overnight capacity based on area size, number of suitable and available campsites, and management zoning. There are currently 96 use areas identified in the park's backcountry.

Corridor Zone: Includes Bright Angel and North and South Kaibab trails, developed campgrounds, Phantom Ranch, ranger stations, and sewage and water treatment facilities. The Corridor Zone provides a transition from developed rim areas to inner canyon backcountry. Corridor Zone trails receive high day use levels including hikers, mules, horses, and long-distance runners. The park manages trails and facilities to accommodate high visitation levels. Smallest of backcountry management zones, the Corridor Zone supported 57% of total overnight backcountry use in 2017.

Threshold Zone: Includes use areas managed for moderate to high use and provides opportunity to transition from a developed backcountry experience (Corridor Zone or rim) to wilderness. The landscape is largely undisturbed except in destination areas where use is concentrated. The park limits camping to designated areas, many with composting toilets. Trail encounter rate is moderate, and there is a high probability of camping within sight or sound of other groups. Trails into Threshold Use Areas are generally in close proximity to rim and inner-canyon developed areas. Several inner-canyon trails provide access to this zone including Hermit, Tonto, Grandview, and Clear Creek. Popular day hiking destinations include Santa Maria Springs, Drippings Springs, Horseshoe Mesa, Widforss Point, and Cape Final. In 2017, 18% of total overnight backcountry use occurred in the Threshold Zone.

Primitive Zone: Is managed for low to moderate use and provides opportunities for experiencing wild lands and solitude. The landscape is largely undisturbed, and human-use impacts are most evident near water sources, attraction sites, and along trails. Camping is at-large, although camp areas are defined to address resource impacts. Composting toilets are placed as a last-resort measure to address human waste problems. Trail encounter rate is low-to-moderate, and there is low probability of camping within sight or sound of others in some use areas. Compared to the Corridor and Threshold Zone Use Areas, trails (Tanner, Nankoweap, and Bass) into Primitive Zone Use Areas are more distant from developed areas. In 2017, approximately 20% of total overnight backcountry use occurred in the Primitive Zone.

Wild Zone: Provides outstanding opportunities for solitude and requires the highest level of self-reliance. The landscape is largely undisturbed and natural processes dominate. Wild Zone Use Areas are very large and remote. Camping is at-large and hikers rarely encounter other groups. Trails are unimproved, and route-finding is frequently required. Access to Wild Zones is typically through Threshold and Primitive Zones; remote trailheads are located on other federal and tribal lands. In 2017, approximately 2% of total overnight backcountry use occurred in the Wild Zone.

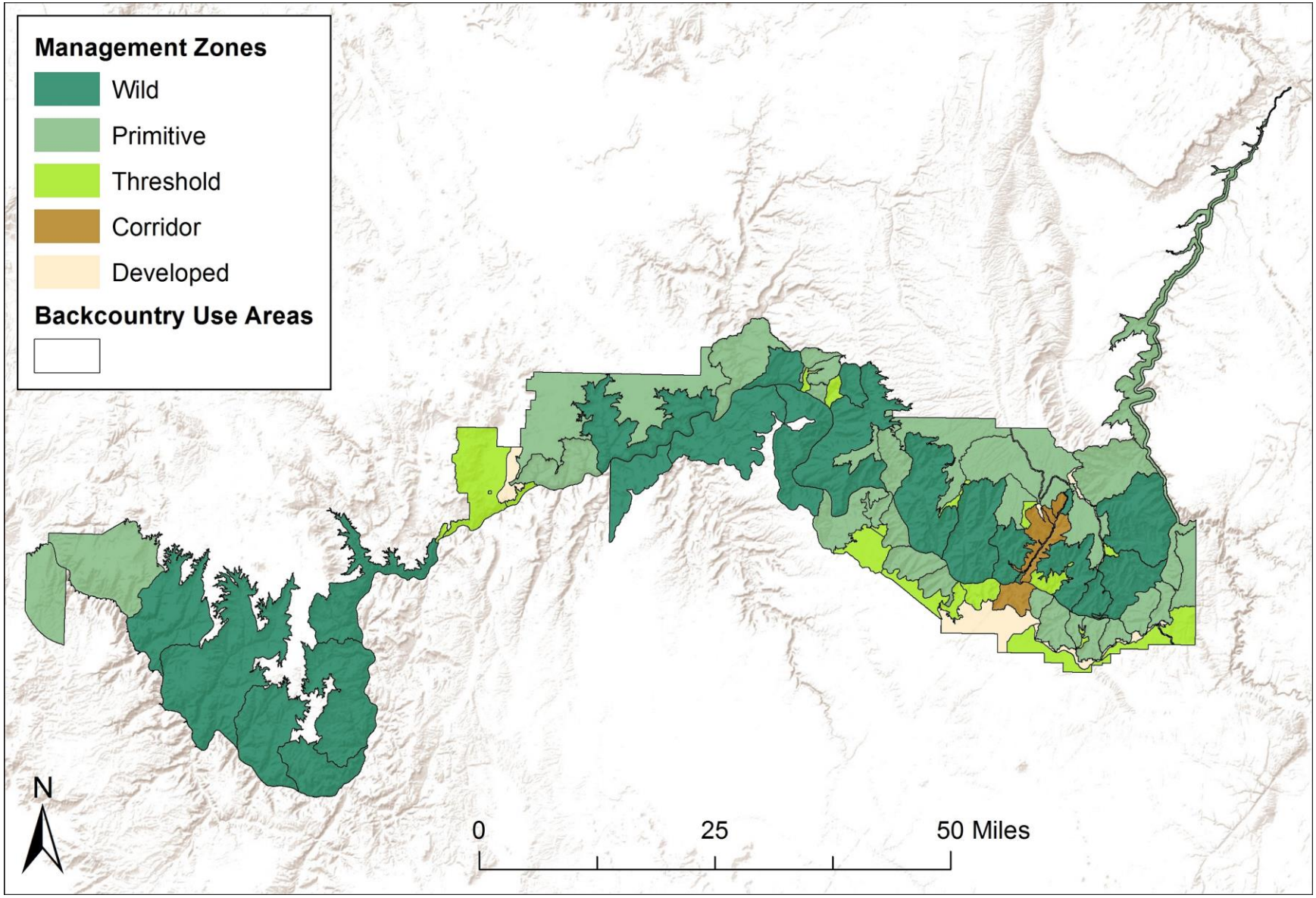

Figure B-1. Map of management zones and backcountry use areas.

Appendix C - What is a Trammeling Action?

An excerpt from *Keeping It Wild 2* (Landres et al. 2015, pp. 101-106).

This appendix provides guidelines and examples to clarify what is and is not a trammeling action. These are intended to capture about 90% of the cases and provide sufficient guidance for local staff to figure out the novel and rarer cases as they occur. A trammeling action is defined as an action that intentionally manipulates "the earth and its community of life" inside a designated wilderness or inside an area that by agency policy is managed as wilderness.

The following terms and phrases clarify this definition above:

- Intentional: done on purpose; deliberate; willful.
- Manipulation: an action that alters, hinders, restricts, controls, or manipulates "the earth and its community of life" including the type, amount, or distribution of plants, animals, or physical resources.
- Intentional manipulation: an action that purposefully alters, hinders, restricts, controls, or manipulates "the earth and its community of life."

Two concepts are crucial for understanding what is and is not a trammeling action: restraint and intention. Restraining our power to manipulate or control the earth and its community of life is at the core of the Untrammeled Quality of wilderness character. Trammeling actions occur when opportunities for restraint are ignored or bypassed; when there is no opportunity for restraint, there is no opportunity to trammel. Wilderness legislation and policies mandate that managers exercise restraint when authorizing actions that interfere with or control wilderness ecological systems. While other agencies, organizations, and the public are not beholden to these same restrictions, activities that have not been authorized by the federal land manager and that manipulate the wilderness environment are counted as trammeling actions.

The second concept central to the idea of trammeling is intentionality. Actions that deliberately interfere with, manage, or control an aspect of wilderness ecological systems are intentional and clear instances of trammeling. As explained in the chapter on the Untrammeled Quality, intentional actions are counted as a trammeling regardless of the magnitude of their effects (including areal extent, intensity, frequency, and duration). For pragmatic reasons, however, some actions are not monitored if they fall below a minimum practical threshold of scale and scope (for example, hand pulling a few individual noxious plants). Much more complex and nuanced is determining whether to include actions whose purpose is not to manipulate the earth and its community of life, but some manipulation of the environment is required to produce the desired outcome. These types of actions can be confusing because the biophysical environment is intentionally manipulated even though it is not the purpose behind the action. In general, when such actions have substantial and foreseeable effects on the wilderness ecosystem, they are counted as a trammeling.

The following sections describe three types of activities: those that are trammeling actions, those that are not trammeling actions, and those that may be trammeling actions. Following these sections, a flowchart provides general guidance for making these determinations.

Activities That Are Trammeling Actions

There are two broad classes of trammeling actions: those that are authorized by the federal wilderness manager, and those that are not. Three subclasses under each of these reflect whether the action is taken on a biological resource, on a physical resource, or on a resource outside the wilderness with the intent to manipulate biophysical resources within the wilderness.

Agency authorized trammeling actions. These are actions that are authorized by the federal wilderness manager as well as actions by other agencies, organizations, or individuals that have been approved or permitted by the federal land manager.

1. Actions taken inside the wilderness on a *biological* resource to intentionally affect "the earth and its community of life." Examples include:
    a. Removing or killing indigenous or non-indigenous vegetation or fish and wildlife.
    b. Adding or restoring indigenous or non-indigenous vegetation or fish and wildlife.
    c. Using chemicals or biocontrol agents to control indigenous or non-indigenous vegetation or fish and wildlife.
    d. Collecting, capturing, or releasing plants and animals under a research permit.
    e. Enclosing or excluding fish and wildlife from an area.
2. Actions taken inside the wilderness on a *physical* resource or natural process to intentionally affect "the earth and its community of life." Examples include:
    a. Suppressing naturally-ignited fire.
    b. Lighting fire (under management prescription) for any purpose.
    c. Constructing or maintaining a dam, water diversion, guzzler, or other persistent installation intended to continuously alter wilderness hydrology; each agency will need to determine their counting rules for monitoring such installations.
    d. Adding acid-buffering limestone to water to neutralize the effects of acid deposition.
3. Actions taken *outside* the wilderness on a physical or biological resource or process to intentionally affect "the earth and its community of life" inside a wilderness. Examples include:
    a. Cloud seeding to intentionally increase precipitation inside the wilderness.
    b. Damming a river outside a wilderness to intentionally alter the hydrology inside the wilderness.
    c. Killing fish and wildlife outside the wilderness, or planting or stocking fish or wildlife outside the wilderness, to intentionally affect the population or distribution of this species inside the wilderness.

Unauthorized trammeling actions. These are citable or other actions taken by other agencies, organizations, or individuals that have not been authorized, approved, or permitted by the federal wilderness land manager.

1. Actions taken inside the wilderness on a *biological* resource to intentionally affect "the earth and its community of life." Examples include:

   a. Adding or removing plants or fish and wildlife.
   b. Other direct manipulation of plants or fish and wildlife.
   c. Indirect manipulation of fish and wildlife, such as changing hunting regulations with the goal of decreasing predator populations within the wilderness.
2. Actions taken inside the wilderness on a *physical* resource or natural process to intentionally affect "the earth and its community of life." Examples include:
   a. Setting arson fire.
   b. Modifying water resources to provide water for wildlife, or otherwise store water or alter the timing of water flow.
3. Actions taken *outside* the wilderness on a physical or biological resource to intentionally affect "the earth and its community of life" inside a wilderness. Examples include:
   a. Releasing or killing species outside of the wilderness with the intention to affect populations whose ranges expand into the wilderness.

In some situations, staff may assume that they do not have the opportunity for restraint because an action is required to comply with other laws or agency policies, or to protect human life or property. Examples of such situations include restoring habitat for a listed endangered species, spraying herbicides to eradicate an invasive non-indigenous plant that is degrading wildlife habitat, transplanting an extirpated species back into the wilderness, or suppressing a naturally-ignited fire. These are still considered trammeling actions because even in these situations staff are deciding to take action as well as deciding the type and intensity of action.

Activities That Are Not Trammeling Actions

Actions for which there is no opportunity for managerial or individual restraint are not considered a trammeling. For example, climate change, air pollutants wafting into a wilderness, and the presence of non-indigenous species that naturally dispersed into a wilderness are not intentional decisions or actions, and therefore do not provide an opportunity for management restraint. Accidental unauthorized actions, such as escaped campfires and oil spills, similarly lack an opportunity to restrain our power over the landscape. Past actions that manipulated the biophysical environment before the area was designated as wilderness are not considered a trammeling because the provisions of the 1964 Wilderness Act did not apply to the area prior to designation.

Another group of examples that are not a trammeling encompass those small-scale actions with no intent to manipulate the earth and its community of life, such as installing meteorological or other science instrumentation, landing a helicopter for SAR operations, and removing trash. Camping violations, unauthorized motorized incursions, and other illegal activities that are not intended to manipulate the biophysical environment are also not counted as trammeling actions; legality is irrelevant in determining whether an action is a trammeling.

Hunting, for sport or subsistence, has provoked an enormous amount of discussion about whether it degrades the Untrammeled Quality. The consensus from the Lessons Learned Workshop was that hunting is generally not a trammeling action because individual hunters are taking individual animals

without the intention to manipulate the wildlife population. However, if a state wildlife agency manipulates hunting quotas (or takes other management action) to alter the predator/prey relationship in order to maximize certain hunting opportunities, this manipulation of the "community of life" would degrade the Untrammeled Quality (see above).

Activities That May Be Trammeling Actions

There are two types of actions that may or may not be considered trammeling actions. The first includes intentional manipulations that interfere with or control an aspect of wilderness ecosystems but are too small in scale or scope to be practically monitored. The second type encompasses those nuanced cases where the primary purpose of the action is not to manipulate the ecosystem but a foreseeable and substantial effect on the earth and its community is required to achieve this purpose. As shown in Table C-1, several hypothetical situations illustrate how an action may or may not be a trammeling depending on the extent of the action and its effects. Each bullet in the table presents a situation where the action being taken likely would, or would not, be considered a trammeling.

Table C-1. Examples of trammeling and non-trammeling actions.

Action	Likely Not a Trammeling	Likely a Trammeling
Treating non-indigenous invasive plants	▪ Hand pulling a small area of non-indigenous invasive plants	▪ Spraying herbicide
Permitting scientific activities	▪ Installing research plot monumentation, such as rebar stakes or nails ▪ Installing most scientific instrumentation ▪ Collecting a limited number of voucher specimens with no impact on species distribution or abundance	▪ Installing enclosures or exclosures ▪ Installing instrumentation that disrupts the movement or behavior of plants, or fish and wildlife ▪ Capturing, collaring, and releasing wildlife
Building system trail	▪ Routing a trail around a rock slide ▪ Building a bridge across a stream to prevent stream bank erosion ▪ Installing a small section of corduroy across a wet area ▪ Installing in waterbars or building rock-cribbing	▪ Routing a trail through an area of sensitive alpine butterfly habitat ▪ Building a large amount of trail to go around a section of river or cliff ▪ Building a trail that requires extensive earth movement or tree cutting
Obliterating non-system trail	▪ Piling vegetation or rocks at the beginning and end of trail sections that cut a switchback	▪ Obliterating a large section of non-system trail that requires extensive earth movement
Restoring campsites	▪ Restoring a single, isolated campsite ▪ Restoring a number of campsites that don't require disrupting the soil or vegetation in the surrounding area	▪ Restoring a number of campsites that requires moving a significant amount of soil or number of plants in the surrounding area
Removing hazard trees	▪ Removing one or a few hazard trees that threaten designated campsites or that are along a trail	▪ Removing all of the hazard trees over a large area

Flowchart

The flowchart (Figure C-1) below is intended to provide general guidelines to help agency staff determine when an action should be considered a trammeling. The first question asks if there is an opportunity for restraint, and is placed first to help avoid confusing those actions that are beyond the scope of management control, or are unauthorized accidents, from actions that managers or others do have an opportunity to influence. Political considerations are not a factor in determining whether or not there is an opportunity for restraint. The second question examines the intentionality of the action and whether the purpose is to manipulate the earth and its community of life. If there is a clear intent to manipulate, then the action is counted as a trammeling unless it does not meet a minimum threshold for practicable monitoring. If the purpose of the activity is not to manipulate the ecological system, the action is nonetheless considered a trammeling if it results in foreseeable and substantial effects to the wilderness ecosystem.

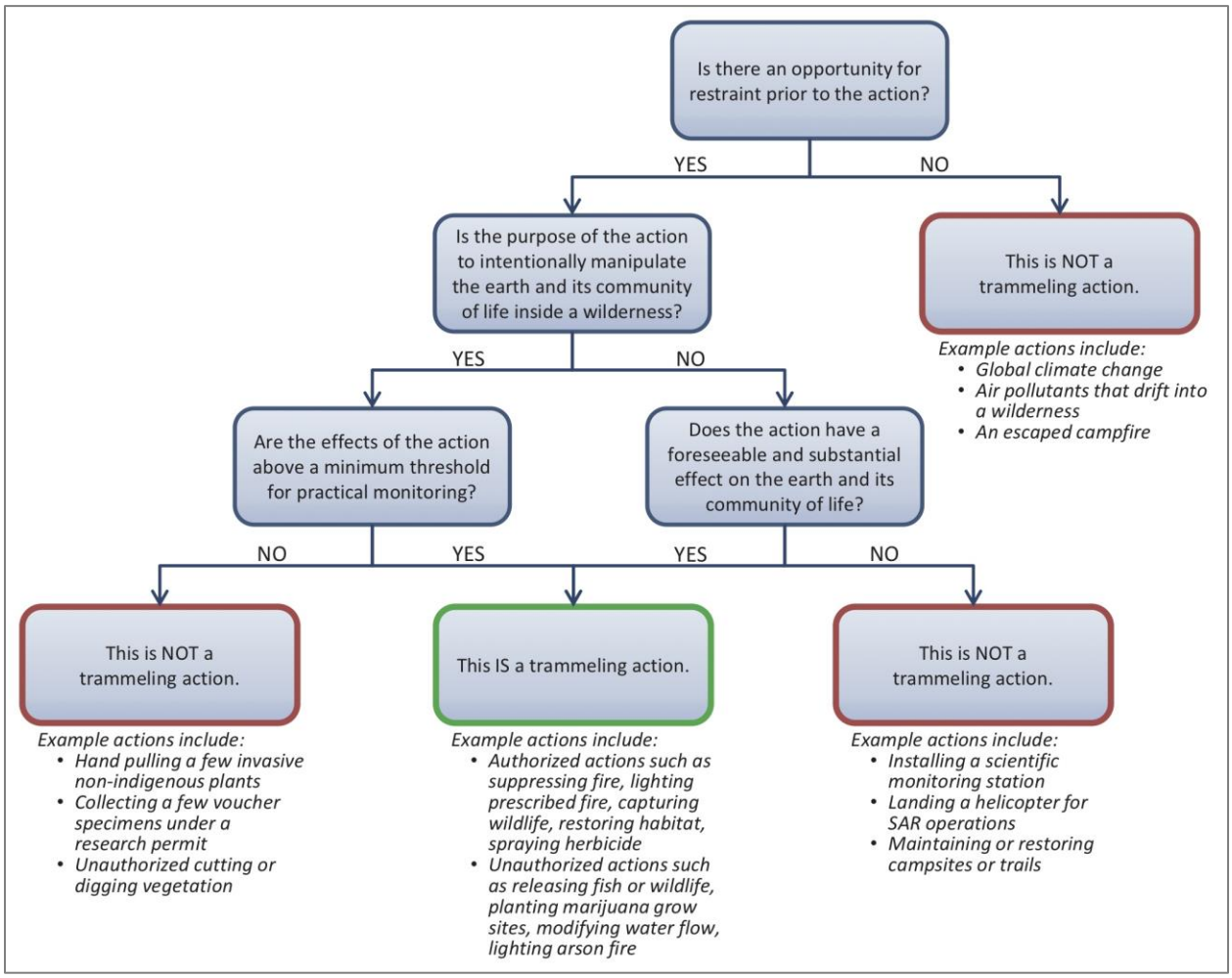

Figure C-1. Flowchart to determine when an action should be considered trammeling.

Appendix D - Exotic Plant Species List

TableD-1. Exotic plant species list.

ID	Scientific Name	Common Name
1	*Acer saccharinum*	silver maple
2	*Acroptilon repens*	Russian knapweed
3	*Aegilops cylindrica*	jointed goatgrass
4	*Agropyron desertorum*	desert wheatgrass
5	*Agrostis stolonifera*	redtop
6	*Ailanthus altissima*	tree of heaven
7	*Alcea rosea*	hollyhock
8	*Alhagi maurorum*	camelthorn
9	*Alopecurus geniculatus*	marsh meadow-foxtail
10	*Alyssum minus*	alyssum
11	*Amaranthus albus*	tumble pigweed
12	*Amaranthus retroflexus*	pigweed
13	*Anthemis cotula*	mayweed
14	*Apium graveolens*	common celery
15	*Arundo donax*	giant reed
16	*Atriplex rosea*	redscale saltbush
17	*Avena fatua*	wild oat
18	*Bassia hyssopifolia*	smother weed
19	*Bothriochloa ischaemum*	yellow bluestem
20	*Brassica tournefortii*	Sahara mustard
21	*Bromus arvensis*	Field brome
22	*Bromus berterianus*	Chilean brome
23	*Bromus catharticus*	rescue grass
24	*Bromus diandrus*	ripgut brome
25	*Bromus hordeaceus ssp. Hordeaceus*	soft chess
26	*Bromus inermis*	smooth brome
27	*Bromus japonicus*	Japanese brome
28	*Bromus madritensis*	compact brome
29	*Bromus rubens*	red brome
30	*Bromus secalinus*	chess
31	*Bromus sterilis*	sterile brome
32	*Bromus tectorum*	cheatgrass
33	*Bupleurum rotundifolium*	hare's ear
34	*Camelina microcarpa*	littlepod false flax

* Lemon balm (*Melissa officinalis*) is pending identification by park biologists.

TableD-1. Exotic plant species list.

ID	Scientific Name	Common Name
35	*Cannabis sativa*	marijuana
36	*Capsella bursa-pastoris*	shepardspurse
37	*Carduus nutans*	musk thistle
38	*Cenchrus spinifex*	coastal sandbur
39	*Centaurea biebersteinii*	spotted knapweed
40	*Centaurea diffusa*	diffuse knapweed
41	*Centaurea melitensis*	Maltese starthistle
42	*Ceratocephala testiculata*	Bur buttercup
43	*Chenopodium album*	lambsquarters
44	*Chenopodium ambrosioides*	Spanish or Mexican tea
45	*Chenopodium murale*	nettle-leaf goosefoot
46	*Chenopodium rubrum*	red goosefoot
47	*Chondrilla juncea*	rush skeletonweed
48	*Chorispora tenella*	blue mustard
49	*Cichorium intybus*	chicory
50	*Cirsium arvense*	Canada thistle
51	*Cirsium vulgare*	bull thistle
52	*Colutea arborescense*	bladder senna
53	*Conioselinum scopulorum*	Rocky Mountain hemlock parsley
54	*Conium maculatum*	poison hemlock
55	*Conringia orientalis*	hare's ear mustard
56	*Convolvulus arvensis*	field bindweed
57	*Conyza canadensis*	horseweed
58	*Corispermum hyssipifolium*	corispermum
59	*Corispermum nitidum*	shiny bugseed
60	*Cortaderia selloana*	pampas grass
61	*Crepis capillaris*	smooth hawksbeard
62	*Cynodon dactylon*	Bermudagrass
63	*Cynoglossum officinale*	houndstongue
64	*Dactylis glomerata*	orchardgrass
65	*Datura stramonium*	jimsonweed
66	*Descurainia sophia*	flixweed
67	*Digitaria sanguinalis*	large crabgrass
68	*Echinochloa crus-galli*	barnyardgrass
69	*Elaeagnus angustifolia*	Russian olive
70	*Elymus repens*	quackgrass

* Lemon balm (*Melissa officinalis*) is pending identification by park biologists.

TableD-1. Exotic plant species list.

ID	Scientific Name	Common Name
71	*Eragrostis cilianensis*	stinkgrass
72	*Eragrostis curvula*	weeping lovegrass
73	*Erodium cicutarium*	filaree
74	*Erysimum repandum*	repand wallflower
75	*Festuca trachyphylla*	hard fescue
76	*Ficus carica*	common fig
77	*Foeniculum vulgare*	fennel
78	*Galium aparine*	bedstraw
79	*Hedera helix*	English ivy
80	*Hieracium aurantiacum*	orange hawkweed
81	*Hordeum jubatum*	foxtail barley
82	*Hordeum marinum*	seaside barley
83	*Hordeum marinum ssp. Gussonianum*	Mediterranean barley
84	*Hordeum murinum*	bulbous barley
85	*Hordeum murinum ssp. Glaucum*	smooth barley
86	*Hordeum murinum ssp. Leporinum*	lepor barley
87	*Hutchinsia procumbens*	prostrate hutchinsia
88	*Iva frutescens*	Jesuit's-bark
89	*Kochia scoparia*	common kochia
90	*Lactuca serriola*	prickly lettuce
91	*Lamium amplexicaule*	henbit
92	*Lathyrus latifolius*	perennial pea
93	*Lepidium draba*	whitetop, hoary cress
94	*Lepidium latifolium*	perennial pepperweed
95	*Lepidium perfoliatum*	clasping pepperweed
96	*Leucanthemum vulgare*	oxeye daisy
97	*Linaria dalmatica*	Dalmatian toadflax
98	*Lolium arundinaceum*	tall fescue
99	*Lolium perenne*	perennial ryegrass
100	*Lolium perenne ssp. Multiflorum*	annual ryegrass
101	*Lolium pratense*	meadow fescue
102	*Lotus corniculatus*	birdfoot deervetch
103	*Macroptilium gibbosifolium*	variableleaf bushbean
104	*Mahonia aquifolium*	hollyleaved barberry
105	*Malcolmia africana*	African mustard
106	*Malus sylvestris*	European crabapple

* Lemon balm (*Melissa officinalis*) is pending identification by park biologists.

TableD-1. Exotic plant species list.

ID	Scientific Name	Common Name
107	*Malva neglecta*	cheeseweed
108	*Malva parviflora*	cheeseweed mallow
109	*Marrubium vulgare*	horehound
110	*Matricaria discoidea*	disc mayweed
111	*Medicago lupulina*	black medic
112	*Medicago polymorpha*	bur clover
113	*Medicago sativa*	alfalfa
114	*Melilotus alba*	white sweetclover
115	*Melilotus indicus*	annual yellow sweetclover
116	*Melilotus officinalis*	yellow sweetclover
117	*Melissa officinalis**	lemon balm
118	*Mentha spicata*	spearmint
119	*Mollugo cerviana*	thread-stem carpetweed
120	*Nepeta cataria*	catnip
121	*Nicotiana glauca*	tree tobacco
122	*Olea europaea*	olive
123	*Onopordum acanthium*	Scotch thistle
124	*Papaver rhoeas*	corn poppy
125	*Paspalum dilatatum*	dallisgrass
126	*Pennisetum glaucum*	yellow foxtail
127	*Phleum pratense*	common timothy
128	*Phoenix dactylifera*	date palm
129	*Piptatherum miliaceum*	smilo grass
130	*Plantago lanceolata*	buckhorn plantain
131	*Plantago major*	common plantain
132	*Platanus wrightii*	Arizona sycamore
133	*Poa annua*	annual bluegrass
134	*Poa bulbosa*	bulbous bluegrass
135	*Poa compressa*	Canada bluegrass
136	*Poa pratensis*	Kentucky bluegrass
137	*Polygonum argyrocoleon*	silversheath knotweed
138	*Polygonum aviculare*	prostrate knotweed
139	*Polygonum convolvulus*	black bindweed
140	*Polygonum persicaria*	lady's thumb
141	*Polypogon interruptus*	ditch polypogon
142	*Polypogon monspeliensis*	rabbitfoot grass

* Lemon balm (*Melissa officinalis*) is pending identification by park biologists.

TableD-1. Exotic plant species list.

ID	Scientific Name	Common Name
143	*Polypogon viridis*	beardless rabbitsfoot grass
144	*Populus canadensis*	Carolina poplar
145	*Portulaca oleracea*	little hogweed
146	*Potamogeton crispus*	curly pondweed
147	*Prunella vulgaris*	healall
148	*Prunus persica*	peach
149	*Pseudognaphalium luteoalbum*	Jersey cudweed
150	*Puccinellia distans*	European alkali grass
151	*Punica granatum*	pomegranate
152	*Ranunculus sceleratus*	celeryleaf buttercup
153	*Rorippa nasturtium-aquaticum*	water cress
154	*Rosmarinus officinalis*	rosemary
155	*Rubus discolor*	Himalaya blackberry
156	*Rumex acetosella*	sheep sorrel
157	*Rumex crispus*	curly dock
158	*Rumex dentatus*	toothed dock
159	*Rumex obtusifolius*	bitter dock
160	*Saccharum ravennae*	Ravenna grass
161	*Salsola tragus*	Russian thistle
162	*Salvia aethiopis*	Mediterranean sage
163	*Schedonorus arundinaceus*	tall fescue
164	*Schismus arabicus*	Arabian schismus
165	*Schismus barbatus*	Mediterranean grass
166	*Scorzonera laciniata*	cutleaf vipergrass
167	*Secale cereale*	cereal rye
168	*Senecio vulgaris*	common groundsel
169	*Setaria pumila*	yellow bristlegrass
170	*Setaria verticillata*	bur bristlegrass
171	*Setaria viridis*	green foxtail
172	*Silene noctiflora*	nightflowering silene
173	*Sisymbrium altissimum*	tumble mustard
174	*Sisymbrium irio*	London rocket
175	*Solanum elaeagnifolium*	silverleaf nightshade
176	*Solanum lycopersicum var. lycopersicum*	garden tomato
177	*Solanum nigrum*	black nightshade
178	*Solanum physalifolium*	hairy nightshade

* Lemon balm (*Melissa officinalis*) is pending identification by park biologists.

TableD-1. Exotic plant species list.

ID	Scientific Name	Common Name
179	*Sonchus asper*	spiny sowthistle
180	*Sonchus oleraceus*	common sowthistle
181	*Sophora japonica*	Japanese pagoda tree
182	*Sorghum halepense*	Johnsongrass
183	*Spergularia salina*	salt sandspurry
184	*Spiraea X vanhouttei*	Van Houtt's spirea
185	*Stellaria media*	common chickweed
186	*Tamarix aphylla*	athel
187	*Tamarix chinensis*	salt cedar
188	*Tamarix ramosissima*	salt cedar
189	*Tanacetum vulgare*	common tansy
190	*Taraxacum laevigatum*	rock dandelion
191	*Taraxacum officinale*	common dandelion
192	*Thinopyrum intermedium*	intermediate wheatgrass
193	*Thlaspi arvense*	field pennycress
194	*Torilis arvensis*	purple field hedge parsley
195	*Tragopogon dubius*	yellow salsify, goatsbeard
196	*Tragopogon porrifolius*	purple salsify
197	*Tribulus terrestris*	puncturevine
198	*Trifolium hybridum*	alsike clover
199	*Trifolium repens*	white clover
200	*Triticum aestivum*	wheat
201	*Typha angustifolia*	narrowleaf cattail
202	*Ulmus pumila*	Siberian elm
203	*Verbascum thapsus*	common mullein
204	*Veronica anagallis-aquatica*	blue water speedwell
205	*Veronica arvensis*	common speedwell
206	*Viburnum opulus*	viburnum
207	*Vinca major*	bigleaf periwinkle
208	*Vinca minor*	common periwinkle

* Lemon balm (*Melissa officinalis*) is pending identification by park biologists.

Appendix E - Archaeological Site Identification Numbers

This appendix provides a list of identification numbers for all 351 archaeological sites included in the "Condition of Archaeological Sites" measure under the Other Features of Value Quality (pp. 115-116) (Table D-1). For consistency, these same sites should be selected for future monitoring.

Table D-1. List of archaeological site identification numbers.

ID	Condition	ID	Condition	ID	Condition	ID	Condition
A:15:0025	Fair	B:11:0273	Good	B:15:0126	Good	B:16:0257	Good
A:15:0029	Poor	B:11:0275	Good	B:15:0127	Good	B:16:0258	Fair
A:15:0031	Fair	B:11:0276	Good	B:15:0128	Good	B:16:0259	Fair
A:15:0033	Fair	B:11:0277	Good	B:15:0132	Good	B:16:0261	Good
A:15:0035	Fair	B:11:0278	Fair	B:15:0133	Good	B:16:0289	Fair
A:15:0038	Fair	B:11:0279	Good	B:15:0134	Good	B:16:0290	Good
A:16:0004	Fair	B:11:0280	Good	B:15:0135	Good	B:16:0308	Good
A:16:0148	Poor	B:11:0281	Good	B:15:0138	Good	B:16:0364	Good
A:16:0159	Fair	B:11:0282	Good	B:15:0139	Good	B:16:0365	Good
A:16:0164	Fair	B:11:0283	Good	B:15:0143	Good	B:16:0911	Good
A:16:0169	Fair	B:11:0284	Good	B:16:0001	Good	B:16:1074	Good
A:16:0180	Poor	B:11:0286	Good	B:16:0003	Good	B:16:1089	Good
B:09:0314	Fair	B:11:0291	Good	B:16:0004	Fair	B:16:1090	Good
B:09:0316	Fair	B:11:0359	Good	B:16:0005	Good	B:16:1092	Good
B:10:0001	Fair	B:11:0374	Good	B:16:0006	Good	B:16:1093	Fair
B:10:0002	Fair	B:11:0375	Poor	B:16:0015	Good	B:16:1094	Good
B:10:0004	Fair	B:11:0486	Good	B:16:0016	Good	C:02:0092	Poor
B:10:0229	Fair	B:13:0001	Good	B:16:0018	Fair	C:02:0094	Fair
B:10:0264	Fair	B:13:0002	Fair	B:16:0019	Fair	C:02:0096	Poor
B:10:0325	Fair	B:14:0093	Good	B:16:0020	Fair	C:02:0097	Fair
B:11:0039	Good	B:14:0094	Good	B:16:0021	Poor	C:02:0098	Poor
B:11:0046	Good	B:14:0095	Good	B:16:0022	Fair	C:02:0101	Good
B:11:0047	Good	B:14:0105	Good	B:16:0088	Fair	C:05:0004	Good
B:11:0048	Good	B:14:0107	Good	B:16:0089	Good	C:05:0005	Good
B:11:0049	Good	B:14:0108	Good	B:16:0090	Fair	C:05:0009	Good
B:11:0078	Good	B:15:0001	Good	B:16:0091	Good	C:05:0031	Good
B:11:0080	Fair	B:15:0073	Good	B:16:0100	Good	C:05:0033	Good
B:11:0081	Good	B:15:0096	Fair	B:16:0129	Good	C:05:0037	Good
B:11:0093	Good	B:15:0097	Good	B:16:0170	Good	C:05:0039	Good
B:11:0227	Good	B:15:0118	Fair	B:16:0218	Fair	C:06:0002	Good
B:11:0228	Fair	B:15:0119	Fair	B:16:0221	Poor	C:06:0003	Good

Table D-1 (continued). List of archaeological site identification numbers.

ID	Condition	ID	Condition	ID	Condition	ID	Condition
B:11:0230	Good	B:15:0123	Good	B:16:0222	Good	C:06:0004	Good
B:11:0271	Good	B:15:0124	Good	B:16:0223	Good	C:06:0005	Good
B:11:0272	Good	B:15:0125	Good	B:16:0224	Good	C:06:0008	Good
C:06:0010	Good	C:09:0187	Good	C:13:0326	Good	C:13:0372	Good
C:09:0001	Good	C:09:0188	Good	C:13:0327	Fair	C:13:0373	Poor
C:09:0004	Good	C:09:0189	Good	C:13:0329	Good	C:13:0374	Poor
C:09:0005	Good	C:13:0001	Fair	C:13:0331	Fair	C:13:0375	Good
C:09:0030	Good	C:13:0002	Fair	C:13:0332	Good	C:13:0376	Good
C:09:0031	Good	C:13:0003	Good	C:13:0333	Good	C:13:0377	Good
C:09:0032	Good	C:13:0005	Good	C:13:0334	Good	C:13:0379	Poor
C:09:0033	Good	C:13:0005	Good	C:13:0335	Good	C:13:0380	Good
C:09:0034	Fair	C:13:0006	Good	C:13:0336	Good	C:13:0381	Good
C:09:0050	Good	C:13:0007	Fair	C:13:0337	Good	C:13:0382	Good
C:09:0051	Good	C:13:0008	Fair	C:13:0338	Fair	C:13:0383	Good
C:09:0052	Good	C:13:0008	Fair	C:13:0339	Fair	C:13:0384	Poor
C:09:0053	Good	C:13:0009	Fair	C:13:0340	Good	C:13:0385	Good
C:09:0054	Fair	C:13:0010	Fair	C:13:0341	Fair	C:13:0386	Fair
C:09:0056	Fair	C:13:0033	Good	C:13:0342	Good	C:13:0387	Good
C:09:0058	Good	C:13:0052	Good	C:13:0343	Fair	C:13:0389	Good
C:09:0059	Good	C:13:0053	Good	C:13:0344	Good	C:13:0390	Good
C:09:0060	Good	C:13:0069	Good	C:13:0345	Good	C:13:0391	Good
C:09:0061	Good	C:13:0070	Good	C:13:0346	Good	C:13:0392	Good
C:09:0062	Good	C:13:0082	Fair	C:13:0347	Good	C:13:0393	Good
C:09:0064	Good	C:13:0083	Good	C:13:0348	Good	C:13:0427	Fair
C:09:0065	Good	C:13:0084	Good	C:13:0349	Fair	C:13:0459	Fair
C:09:0067	Good	C:13:0092	Fair	C:13:0350	Fair	C:13:0486	Good
C:09:0068	Good	C:13:0098	Good	C:13:0351	Good	C:13:0689	Good
C:09:0069	Good	C:13:0099	Good	C:13:0352	Good	C:13:0713	Good
C:09:0070	Good	C:13:0100	Good	C:13:0353	Fair	C:13:0744	Good
C:09:0071	Good	C:13:0101	Good	C:13:0354	Poor	C:13:0770	Fair
C:09:0072	Good	C:13:0122	Good	C:13:0355	Good	C:13:0771	Poor
C:09:0073	Good	C:13:0131	Fair	C:13:0356	Poor	C:13:0776	Fair
C:09:0074	Good	C:13:0152	Fair	C:13:0357	Fair	C:13:0779	Good
C:09:0075	Good	C:13:0233	Good	C:13:0358	Poor	C:13:0780	Fair
C:09:0076	Good	C:13:0236	Fair	C:13:0359	Good	C:13:0786	Good
C:09:0080	Good	C:13:0272	Good	C:13:0360	Fair	C:13:0787	Good

Table D-1 (continued). List of archaeological site identification numbers.

ID	Condition	ID	Condition	ID	Condition	ID	Condition
C:09:0082	Good	C:13:0273	Fair	C:13:0361	Good	C:13:0788	Poor
C:09:0083	Fair	C:13:0274	Good	C:13:0362	Good	C:13:0790	Good
C:09:0084	Good	C:13:0291	Good	C:13:0363	Fair	G:02:0100	Good
C:09:0085	Fair	C:13:0321	Good	C:13:0364	Good	G:02:0101	Good
C:09:0088	Fair	C:13:0322	Good	C:13:0365	Good	G:02:0102	Good
C:09:0184	Good	C:13:0323	Good	C:13:0368	Good	G:02:0105	Good
C:09:0185	Fair	C:13:0324	Fair	C:13:0370	Good	G:02:0106	Fair
C:09:0186	Good	C:13:0325	Good	C:13:0371	Good	G:03:0002	Good
G:03:0003	Fair	G:03:0036	Good	G:03:0053	Good	G:03:0066	Good
G:03:0004	Good	G:03:0037	Good	G:03:0054	Good	G:03:0067	Fair
G:03:0006	Good	G:03:0038	Poor	G:03:0055	Good	G:03:0071	Good
G:03:0020	Good	G:03:0040	Good	G:03:0056	Fair	G:03:0072	Good
G:03:0023	Good	G:03:0041	Good	G:03:0057	Good	G:03:0073	Good
G:03:0024	Good	G:03:0042	Good	G:03:0058	Good	G:03:0076	Fair
G:03:0025	Good	G:03:0043	Fair	G:03:0059	Good	G:03:0077	Good
G:03:0026	Good	G:03:0044	Fair	G:03:0060	Good	G:03:0080	Fair
G:03:0028	Good	G:03:0045	Good	G:03:0061	Good	G:03:0081	Poor
G:03:0029	Good	G:03:0046	Fair	G:03:0062	Good	G:03:0082	Good
G:03:0030	Good	G:03:0048	Good	G:03:0063	Fair	G:03:0083	Good
G:03:0032	Good	G:03:0049	Fair	G:03:0064	Poor	G:03:0085	Good
G:03:0034	Good	G:03:0052	Good	G:03:0065	Good		

Boating down the Colorado River (NPS/MARK LELLOUCH).

"We have an unknown distance yet to run, an unknown river to explore. What falls there are, we know not; what rocks beset the channel, we know not; what walls ride over the river, we know not. Ah, well! We may conjecture many things."

– John Wesley Powell, *The Exploration of the Colorado River and its Canyons*

The Department of the Interior protects and manages the nation's natural resources and cultural heritage; provides scientific and other information about those resources; and honors its special responsibilities to American Indians, Alaska Natives, and affiliated Island Communities.

NPS 113/163190, September 2019

National Park Service
U.S. Department of the Interior

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Desert bighorn sheep (NPS).

The Promise

The 1964 Wilderness Act promised citizens of this country they can forever find special places of solitude and refuge from sights and sounds of civilization, places where ecosystems remain undeveloped and intact and natural processes unfold without direct human intervention.

– 2020 Vision, Interagency stewardship priorities for America's National Wilderness Preservation System