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I, Ryan M Washam, hereby submit this original work as part of the requirements for the degree of Master of Arts in Anthropology.

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Archaeology in Distress: Federal Land Management and Archaeological Vulnerability

Student’s name: Ryan M Washam

This work and its defense approved by:

Committee chair: Alan Sullivan, Ph.D.

Committee member: Daniel Murphy, Ph.D.
Archaeology in Distress: Federal Land Management and Archaeological Vulnerability

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Ryan Washam
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Committee:
Alan P. Sullivan, III, Ph.D., Chair
Daniel Murphy, Ph.D.
Abstract

The Upper Basin of the south rim of the Grand Canyon presents an excellent cross-section of different federal agencies’ (Grand Canyon National Park and Kaibab National Forest) approaches to land management. Though the environment and cultural landscape are relatively similar between the two jurisdictions, different priorities lead to dissimilar land management practices. Evidence shows that divergent land management practices between agencies have profound effects on the level of disturbance across the archaeological landscape.

In order to inform the discussion of disturbances across the Upper Basin, this thesis presents a vulnerability study that identifies areas of disruption in the archaeological record and the stressors that ultimately caused this damage. The study uses vulnerability theory, satellite remote sensing data, and GPS data, to analyze trends in ground disturbance and forest use that directly influence cases of inadvertent vandalism to archaeological sites. As a result of this analysis, a disturbance framework for the Upper Basin is presented that draws heavily from current ideas in vulnerability theory. Using this framework, conclusions can be drawn about the influence of federal land managers on archaeological disturbance. The results of this study not only provide evidence for differential preservation in the Upper Basin, but also highlight the use of GIS as a low-cost tool for federal employees to solve complex management issues. In addition, they show the utility of borrowing from human ecology and other fields to structure approaches to archaeological issues.
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Chapter 1: Introduction

“I have done the best I could to show forth the beauty, grandeur, and all-embracing usefulness of our wild mountain forest reservations and parks, with a view to inciting the people to come and enjoy them and get them into their hearts, that so at length their preservation and right use might be made sure.”

- John Muir, 1901

Archaeological Resource Protection and Federal Management

The protection of archaeological resources on federal land is a multifaceted endeavor, mandated by laws such as the Antiquities Act of 1906, the Reservoir Salvage Act of 1960, the Wilderness Act of 1964, the National Historic Preservation Act of 1966, the Department of Transportation Act of 1966, the National Environmental Policy Act of 1969, the Archaeological and Historic Preservation Act of 1974, and the 1979 Archaeological Resources Protection Act (Wildesen 1982). The resource protection effort has proven to be a critical component of the roles and responsibilities entrusted to federal land managers (Fowler 1982: 2-9). Cultural resource law enforcement requires an approach specifically designed to overcome the problems that are associated with the characteristics of individual archaeological landscapes. Due to the current economic climate, protection and assessment of archaeological resources can be economically and logistically taxing to those charged with this duty (Christensen et al. 1988; National Trust for Historic Preservation 2008). Differences between agencies regarding resource protection only exacerbate the difficulties faced by resource managers in providing adequate protection for the many archaeological sites located on national land.

This research provides tools with which managers and law enforcement personnel can focus their cultural resource preservation efforts to provide management that is direct and
In addition, conclusions are drawn about the role of agency policies and practices in contributing to archaeological resource vulnerability. Previous research, using satellite remote sensing in the Upper Basin region of Grand Canyon National Park (GRCA) and Kaibab National Forest (KNF), indicates that, despite their geographical proximity and ecological similarity, there are striking differences between the two federal jurisdictions in the level of archaeological and ecological disturbance (Magee 2007; Sullivan et al. 2012). These differences have been attributed to the diverse management strategies employed by both units of the federal government (Magee 2007: 44-45). Chapter 2 explores the vast differences in land management policy and practice of the USDI National Park Service versus the USDA Forest Service. It also explores the disconnect between policy and actual practice for each agency. This chapter will set the stage for linking land management practice to impacts on the archaeological landscape.

**Study Area and Occupational History**

The Upper Basin Archaeological Research Project (UBARP) has conducted archaeological research in the region since the late 1980s. Of particular interest to the project has been causes of disturbances to the archaeological record of the Upper Basin (Figure 1.1) (Roos 2000; Sullivan 2002b; Uphus et al. 2006). Some anthropogenic factors that impact and change the pinyon-juniper environment across the Southwest include livestock grazing, woodcutting, fire management, climate change, invasive species competition, recreation, and other land uses (Vankat 2013). The study area is a 140 mi² tract of land east of Tusayan, Arizona and south of the Grand Canyon, near the Desert View Watchtower. Elevation varies from 2,256 m (7400 ft) at the Desert View Watchtower to 1860 m (6100 ft) at the basin’s southern terminus, Lee Canyon. The area is dominated in higher elevations by pinyon-juniper woodland with small pockets of
sagebrush and grass. In the south, at lower elevations, the woodland thins and sagebrush and grass become much more dominant. The average annual precipitation for this area has been calculated to be 15.3 inches (389mm) (Sullivan et al. 2002a: 51).

![Map of the Grand Canyon region](image)

**Figure 1.1.** The Upper Basin in Northern Arizona.

Human use of the Grand Canyon region began around 9500 B.C., during the Paleo-Indian period, and continues into the present (Veremeer et al. 2008: 11). The Upper Basin was not occupied until the early Archaic time period (around 2000 B.C.) (Effland et al. 1981; Schwartz 1990). There is relatively little known about the Archaic in the Grand Canyon (Euler 1974) most of our knowledge of the time period in Grand Canyon results from investigations of the split twig figurines at Stanton’s Cave (Euler 1984); the most well-known of prehistoric time periods are the Pueblo I, II, and III periods (A.D. 700 - 1250) (Schwartz 1990). The South Rim of the Grand Canyon has been a melting pot for different cultures throughout time. Around A.D. 700, the
Cohonina people first came to the area, probably from the west. One hundred years later, the Upper Basin became home to a new group of inhabitants from the east, the Kayenta Anasazi, also known as Ancestral Puebloans. This group interacted with and eventually out-populated the Cohonina by the early 12th century (Schwartz 1990).

The two groups are distinguished by differences in material culture, especially ceramics. Cohonina peoples are associated with San Francisco Mountain Gray Wares, while Kayenta Anasazi are associated with Tusayan White and Gray wares (Schwartz 1990). Near the end of Puebloan occupation, around A.D. 1300, ancestral Pai and Southern Paiute people moved into the region from the west (Jones 1986:9). They would occupy the area, with frequent incursions by Hopi and Navajo, up to and during contact with the Spanish in 1540 (Euler 1984). The Spanish would next visit both the North and South rims in 1776. By the late 1800s, the explosion of use by Navajo sheep herders, historic miners, trappers, explorers, missionaries, and tourists had all but decimated traditional indigenous use of the area (Jones 1986: 9-10).

**Vulnerability Theory**

Vulnerability theory, the study of systemic risk in human-ecological interactions, provides a framework for evaluating the relative susceptibility of different potions of the archaeological landscape within the Upper Basin to the disturbances and impacts identified above. Earlier investigations in the area have established that inadvertent forms of vandalism, such as vehicle traffic, woodcutting, camping, and hunting, are the most destructive to the environment and the archaeology of the Upper Basin (Roos 2000; Sullivan et al. 2002b; Uphus et al. 2006). The primary and secondary effects of these disruptions in a concentrated area can lead to massive impacts on the archaeological landscape. These categories of inadvertent vandalism
will be discussed in greater depth in Chapter 3, but the end results of these activities include erosion, soil compaction, soil turbation, removal of matrix, removal of archaeological material, increased rodent activity, and various other impacts (Wilcox 1994; Wildesen 1982). Vulnerability theory takes into account the interaction of several different components of systems under duress. These components consist of the hazard(s), the exposure to this hazard, the sensitivity of a system to this hazard, and the capacity of the system to respond to and adapt to the hazard (Adger 2006; Gallopin 2006; Turner et al. 2003). It combines differential components of vulnerability, and can lead managers to a targeted response that deals with one aspect or another of disturbance. Vulnerability theory and the framework developed in this study will be discussed more in Chapter 3. In addition, Chapter 4 will discuss the data and methods used in applying the framework to the archaeological landscape.

**Geographic Data and Analysis**

In order to assess the utility of vulnerability theory as a framework for modeling archaeological disturbances, or the potential for disturbances to occur, it will be tested with archaeological and environmental data collected from ground survey and satellite imagery. Previous research in this region has found that GIS analysis and satellite-based image interpretation are excellent tools for establishing environmental health and archaeological vulnerability (Magee 2007; Roos 2000; Sullivan et al. 2012; Uphus et al. 2006). In the past, research was focused on impacts to individual sites over time (Roos 2000), or relative vulnerability to the landscape (Magee 2007; Uphus et al. 2006). These studies have proven to be extremely useful in establishing and displaying areas that either exhibit impacts already, or are at risk of sustaining damage.
Data gathered up to five years after these initial studies show that environmental impact and archaeological site degradation has become reality for much the landscape of the Upper Basin. The geographic portion of this study (Chapter 4) focuses on linking digital visual analyses of vulnerability, such as GIS and Satellite Remote Sensing, to the vulnerability framework and the federal management strategies discussed in other chapters. This approach allows for visualization of levels of vulnerability across the landscape, and can inform targeted responses to inadvertent vandalism for specific locations in the Upper Basin.

The last chapter of this thesis provides a synthesis of geographic and satellite data for the Upper Basin and the vulnerability analysis framework developed in Chapter 3. Conclusions will be drawn about the links between land management practice and the vulnerability of the archaeological landscape. Included will be a discussion of areas that may benefit from a targeted response by federal resource managers, as identified using the geographic analysis proposed above. In addition to identifying areas of vulnerability, this chapter will establish recommended courses of action for treatment of vulnerable regions in the Upper Basin and in other federal landholdings where similar regions of archaeological landscape are subject to outside stressors.
Chapter 2: Federal Land Management and Archaeology

Federal land managers face many challenges. Because of differences in goals and missions of various federal agencies, strategies for how best to meet these challenges while achieving the objectives of each agency vary. The Upper Basin provides an excellent example with which to study the effects of different strategies used by land management officials to meet the goals of the USDI National Park Service (Grand Canyon National Park) and the USDA Forest Service (Kaibab National Forest). The implementation of these strategies results in drastic differences on the landscape administered by each agency.

Grand Canyon National Park

Background

Grand Canyon National Park (GRCA) consists of 1,217,403.3 acres of land, with both recreational and protected areas (National Park Service 2012a). More than 4.3 million individuals passed through the South Rim entrance stations in 2011. This figure has risen by several million from when the statistic first began to be calculated in 1974 (National Park Service 2005). With this high amount of visitation, the National Park Service has placed into effect certain guidelines and standards to manage their resources and the visitor experience to ensure that the needs of both are met.

Beginning in the mid-1800s, there were many who sought to exploit Grand Canyon for its mineral and timber resources (Anderson 2000; Morehouse 1996). Early explorers and preservationists, such as John Wesley Powell and John Muir, published reports on the importance of Grand Canyon and its surrounding areas, and advocated to preserve the area as a national park or forest reserve (Anderson 2000; Morehouse 1996; Muir 1901: 34-36; Powell
1895). There were also early attempts by Indiana Senator Benjamin Harrison to set aside the canyon as a public park but these failed (Anderson 2000). In 1893, the area around the canyon was finally established as a Forest Reserve and then named Grand Canyon National Forest in 1907 (Anderson 2000:8). President Theodore Roosevelt further protected the area in 1908 with directions to reserve it as a national monument, and in 1919, with the introduction of a bill by Senator Henry Ashurst of Arizona, the area was converted into a national park at last by President Woodrow Wilson (Anderson 2000: 8-10; Morehouse 1996; National Park Service 1995). The current foundation statement for GRCA identifies the park purpose to, “Preserve and protect Grand Canyon’s unique geologic, paleontologic, and other natural and cultural features for the benefit and enjoyment of the visiting public [and to] protect and interpret Grand Canyon’s extraordinary scientific and natural values” (National Park Service 2010). This statement illustrates the two main components of land management for the Grand Canyon - preservation/protection of the resources and public recreation.

Policies

According to the General Management Plan for Grand Canyon National Park, protection of resources is a core aspect of the overall strategy for management of the South Rim, which includes the Upper Basin. The plan states that protection of the natural, scenic, and cultural resources of the park are of utmost importance when considering management objectives for the park (National Park Service 1995). Protection of resources is to be accomplished by managing visitor use, park development, and support services, as well as by managing and enforcing the park boundary. In addition, inventories of park resources are to be maintained and used to better manage park assets (National Park Service 1995).
Visitor use is to be managed in such a way that it maximizes the visitor’s experience of the solitude, natural conditions, primitiveness, remoteness, and inspirational value of the Grand Canyon, while still maintaining a visitor presence and distribution that is appropriate to the landscape unit and resources available (National Park Service 1995:9). The GMP also states that interpretive programs are to encourage visitors to preserve and protect natural and cultural resources in and out of the park. Management on the corridor trails, and on much of the South Rim, relies heavily on park employee presence in the region to enhance safety and resource protection (National Park Service 1995:10). To minimize crowding, visitor use is limited in certain areas based upon the need to mitigate resource impacts, and the need to provide adequate visitor experiences (National Park Service 1995:13). In order to effectively limit visitor use, a monitoring system is in place to signal peak activity times and resource impacts. In addition, the GMP stipulates that GRCA should provide for an easy to use and environmentally friendly transportation system for visitors, and emphasize the use of non-motorized travel. These are important issues for the park, as the GMP stipulates that the South Rim should be the focus of most visitors’ experiences at the park (National Park Service 1995:10).

In undeveloped portions of the park, which include some sections of the South Rim, management goals include maintaining the visitor experience of a pristine wilderness, while also protecting and preserving the scenic, natural, and cultural resources of the area (National Park Service 1995:12). The park requires investigation of these aspects of undeveloped areas, and resource managers must take action if park goals are not being met (National Park Service 1995:12-14). Access to portions of the park is made more or less available consistent with the need to protect park resources, and the suitability of similar recreation experiences outside of and
in other areas of the park. In portions of GRCA that do contain roads, these should be minimally maintained. All roads that are no longer needed should be re-vegetated, or converted into trails.

Grand Canyon National Park is not only concerned with visitor interaction with the resource, but the park also recognizes the increased need for development along the South Rim. The General Management Plan stipulates that, “all decisions - from initial concept, through design, construction, and operation - must be evaluated in light of principles for natural and cultural resource conservation” (National Park Service 1995:42). Development should maintain the rural meandering character of East and West Rim drives, the two major scenic roads through the park. In addition, there are large undeveloped areas along these two drives that are to remain undeveloped (National Park Service 1995:15). The development plan for this area also states that future directions will be towards the creation of trails, bike paths, and public transportation to minimize the impact of motorized travel in the area.

The NPS Management Policy of 1988 stipulates that parks must create zones for management within the park that cater to the specific needs of each area (National Park Service 1995:19). The delineation of management zones is based on an evaluation of the congressionally established purposes of the park; the nature of the park's natural and cultural resources; all past, existing, and anticipated uses; and park management objectives. For Grand Canyon National Park these zones consist of Natural zones, Cultural zones, and Developed zones.

The Natural zone includes lands and waters that are managed to conserve natural resources and provides for their use and enjoyment by the public in ways that do not adversely negatively affect the resource contained within (National Park Service 1995:19). These areas limit development to dispersed recreational and management facilities that have no adverse effect on scenic quality and natural processes and that are essential for park operations, use, and
appreciation of natural resources. The undeveloped regions of the South Rim, including the Upper Basin, fall in this Natural zone.

Cultural zones include units that will be preserved for the protection, preservation, and interpretation of historical resources (National Park Service 1995:19). These zones are smaller in comparison to others in the park. They include areas such as Tusayan Ruin, the Desert View Watchtower, the Historic El Tovar Hotel, and other historic and prehistoric sites. Many of these areas are closed to the public by special order of the superintendent (National Park Service 2012b).

Development zones include areas for the placement of facilities used by both park managers and park visitors (National Park Service 1995:19). Vegetation loss and loss of historic character are the primary concerns when considering new development or management of old development. In areas where natural or cultural resources are impacted by this development, mitigation efforts will take place. The size of development zones is supposed to be kept to a bare minimum.

Cultural Resource Management at GRCA is based on the guiding principle that cultural resources are to be preserved and protected. As such, the GMP states that the primary purposes of the Cultural Resources program at Grand Canyon National Park is to, “identify, document, and protect these resources” (National Park Service 1995:25). This program is designed to meet the requirements for archaeological protection stipulated in the Archaeological Resources Protection Act, the National Historic Preservation Act, the American Indian Freedom of Religion Act, and the Native American Graves Protection and Repatriation Act. In addition, the GMP states that the program should run active programs for public stewardship, ruins stabilization,
and National Register of Historic Places listing, where appropriate (National Park Service 1995: 24-26).

**Practice**

The National Park Service has developed stringent guidelines for land management in Grand Canyon National Park. Several factors contribute to the successful, or unsuccessful, implementation of these guidelines. Within the park, location plays a large part in deciding which archaeological resources are subject to visitation, as well as which sites receive more management. Backcountry areas, in 2011, received 93,178 user nights (calculated by multiplying persons in the backcountry by nights they stayed) (National Park Service 2012a). While this number is seemingly high, it does not account for visitors staying on the South Rim, who may have made multiple trips below the rim or in the Day Use Areas surrounding the rim. The total number of visitors for the park in 2011 was more than 4.3 million (National Park Service 2012a). Because of the disparity in visitation, and the size and remoteness of much of Grand Canyon National Park, most management and law enforcement activities must take place on the rim, in day use areas where visitation is the greatest.

Funding is also a critical issue for all federal land managers, and one that is of increasing importance due to recent financial cutbacks (Christensen et al. 1988; National Parks Conservation Association 2011; National Trust for Historic Preservation 2008). In a recent study, the National Parks Conservation Association (NPCA) (2011) found that many parks that were not specifically created for archaeological or historical preservation, e.g. Grand Canyon National Park, have issues when trying to implement effective cultural resource protection measures. The NPCA states that the main problems influencing cultural resources are lack of professional
expertise, lack of oversight and monitoring, incomplete research, documentation, and planning, lack of maintenance and preservation work, and lack of integration of resource information into interpretive programming. These issues are due, in large part, to the funding problems experienced by the park service since the mid-1960s (National Parks Conservation Association 2011:46). In a dwindling economic situation, managers must make do with what they have.

**Kaibab National Forest**

*Background*

Kaibab National Forest (KNF) consists of three physically separate ranger districts (RDs) Williams RD, Tusayan RD, and North Kaibab RD. The Tusayan RD includes about 43,377 acres of the Upper Basin and is directly adjacent to and south of Grand Canyon National Park (United States Department of Agriculture, Forest Service 2010:59). The Tusayan Ranger District’s proximity to the South Rim of the Grand Canyon makes it one of the most visited areas in the forest. The Kaibab National Forest in general was visited by more than 456,000 people in 2010 (United States Forest Service 2012a). The guiding document for policy within Kaibab National Forest is the KNF Land Management Plan (United States Department of Agriculture, Forest Service 2010). Archaeologically, the KNF Land Management plan recognizes the Upper Basin as a dense and rich resource for cultural heritage, but acknowledges that Forest Service archaeologists have not surveyed much of the area and much of its archaeology has not been documented by the Forest Service (United States Department of Agriculture, Forest Service 2010: 59).

The Forest Service uses several guiding principles for land management but chief among them is to provide for, “integrated multiple use and sustained yield of goods and services from
the Forest in a way that maximizes net public benefits in an environmentally sound manner” (United States Department of Agriculture, Forest Service 2010:1). The Forest Service was not created with any specific mandate to protect archaeological resources (National Trust for Historic Preservation 2008); however, the KNF Plan recognizes that preservation of the natural and cultural resources in the forest is a priority, and that cooperation with other federal and local land management agencies in the area is appropriate to fulfill its goals (United States Department of Agriculture, Forest Service 2010:1, 12).

Policy

The KNF Land Management Plan includes 12 specific areas of interest when considering land management issues including commercial timber, fuelwood, range, watershed, developed recreation, dispersed recreation, transportation systems, wildlife habitats, heritage resources, wilderness and special areas, land ownership adjustments, and minerals management (United States Department of Agriculture, Forest Service 2010). Fuelwood is of special interest to the Upper Basin region because the area hosts several large tracts where fuelwood is allowed to be harvested (Figures 2.1 and 2.2).
The KNF plan designates the pinyon-juniper woodland as a habitat that should be concentrated on for fuelwood collecting (United States Department of Agriculture, Forest Service 2010:19). The plan states that it provides for more fuelwood than is currently required by
the public, and, if the occasion should arise, commercial timber residue is available to meet the needs of the public should fuelwood availability become a problem.

Recreation is also a major factor of concern for the archaeology of the Upper Basin. Because of the popularity of the Grand Canyon, many overflow visitors (those who cannot be accommodated by recreation facilities in GRCA) camp in this portion of the Tusayan Ranger District (Sullivan et al. 2002b). This is also a popular area for hunting and off road vehicle (ORV) use. Under the current plan, dispersed recreation areas, including the Upper Basin, are supposed to be monitored and inspected routinely to ensure that impacts to these areas are consistent with forest goals and guidelines (United States Department of Agriculture, Forest Service 2010:59-61). Several pamphlets are designed to instruct visitor’s use of and travel in dispersed areas, and signage is to be used to indicate open and closed roads (Forest Service pamphlets in Appendix A). Travel corridors are based on the Environmental Assessment of the Tusayan Ranger District Travel Management Project, which uses the multiple-use concerns of the Forest Service regarding the environment, cultural resources, recreation, and forest product yields to inform travel guidelines and restrictions on 566 miles of road, as well as many miles of administratively closed roads (United States Department of Agriculture, Forest Service 2011). The environmental assessment states that cultural resources will be protected by closing and obliterating roads in close proximity to archaeological sites, and by conducting archaeological survey in those regions where new changes will be made to the existing road system. While the camping corridor along roads in the Upper Basin is 300 ft. from the road, the off-road driving corridor is less than 30 ft., and visitors are encouraged to parallel park next to the road (United States Department of Agriculture, Forest Service 2012b). Though early in the plan it states that the Upper Basin is not well known, the plan also states that the areas surrounding changes to the
road system were surveyed by forest archaeologists, and it was found that less than 2% of dispersed campsites have archaeological sites, and, contrary to the findings presented later in this publication, a finding of no significant impact was determined (United States Department of Agriculture, Forest Service 2011:147).

While there are several developed campgrounds in Grand Canyon National Park and Kaibab National Forest, overflow from these campgrounds is often shuffled into the dispersed camping area of the Upper Basin (Sullivan et al. 2002b). This area is free from any fees and provides a more rustic experience for visitors, with no amenities and fewer regulations than developed areas (United States Department of Agriculture, Forest Service 2012b). Camping is regulated under the Kaibab Forest Plan and the Tusayan Ranger District Travel Management Plan (United States Department of Agriculture, Forest Service 2010; United States Department of Agriculture, Forest Service 2011). The plan designates 16 miles of designated camping corridors, 300 feet wide, along open forest service roads. In addition, policy stipulates that visitors may be in one spot for no more than 14 days, and are encouraged to use already existing campsites. “Leave no trace” principles are to be followed, including packing out trash, depositing human waste in cat holes away from water, trails, and camps, using existing campfire rings, and bringing wood from outside the area if no dead and down is available for a campfire (United States Department of Agriculture, Forest Service 2012b).

Large-game hunting (mostly mule deer and elk) is a common activity in the Upper Basin. It provides $12 million in annual revenue for Coconino County (United States Department of Agriculture, Forest Service 2011: 44). The US Fish and Wildlife Service predicts increases in this activity in years to come (United States Fish and Wildlife Service 2011:6-7) and, as such, the KNF plan makes provision for expanding wildlife habitat with a variety of methods (United
States Department of Agriculture, Forest Service 2010:12). These methods include prescribed burning, seeding with wildlife attracting plants, water development, and the creation of wildlife openings in forested areas. The Travel Management Plan (TMP) also establishes some rules for hunters in the Tusayan Ranger District (Figure 2.3) to help conserve natural and cultural resources (United States Department of Agriculture, Forest Service 2011). The TMP restricts hunters to motorized vehicle use, when retrieving downed game, to within a mile of established and approved roads.

**Figure 2.3.** Forest Service map of all the areas within Tusayan Ranger District that allow hunting (Kaibab National Forest, 2013).

Forest archaeologists conducted a study of actual land impacted by an estimated 414 kills annually, and decided that this would not be a significant impact on archaeological resources. Though archaeologists determined that hunting activities would have no or little effect on archaeological resources, the relatively small amount of land surveyed by the Forest Service in the Upper Basin makes it difficult for them to make this claim with any degree of certainty.
While ground disturbing activity is regulated for hunting, regulation is lacking for ground disturbance during fuelwood operations and many other activities. Geologic and mineral operations, however, are heavily regulated with regard to ground disturbance (United States Department of Agriculture, Forest Service 2011). The TMP proposes to prevent all mineral and geologic prospecting in close proximity to cultural resources that are listed on the National Register of Historic Places.

Heritage resource management is only one of many concerns for the Tusayan Ranger District. However, the KNF plan does require managers to adhere to all major national laws regarding cultural heritage protection (ARPA, NAGPRA, NRHP, etc.; see Chapter 1 for more details). In addition, the plan requires a determination of “no effect” or “no adverse effect,” on cultural resources, for any activity to gain approval (United States Department of Agriculture, Forest Service 2010). Forest archaeologists may suggest revision to any portion of a plan that does not meet forest guidelines. Archaeologists can use signing, fencing, administrative closure, increased patrolling, investigations, interpretive programs, stabilization and data recovery, as appropriate to protect archaeological sites.

Practice

The National Trust for Historic Preservation (2008:24; Figure 2.4) lists several inadequacies of the Forest Service’s heritage resource management program including insufficient funding and staffing, lack of clear mandates to protect cultural resources, conflicting political realities, rise in the use of off road vehicles (ORVs), and increasing mining activity on federal lands.
Figure 2.4. Funding of USDA Forest Service heritage management from 1990-2000 (from National Trust for Historic Preservation 2008: 24).

Added to lack of funding is the focus on timber and watershed management that prevails throughout the USDA Forest Service often to the exclusion of other concerns. In addition, because of funding cuts and the rural nature of the Tusayan Ranger District, the forest relies on local, state, and neighboring entities, along with forest protection officers and law enforcement rangers, to help enforce laws inside the forest (Neil Wientraub, personal communication 2012). While this cross-boundary cooperation is admirable, these agencies have their own jurisdictions to police and the forest will take on a secondary priority in the face of issues elsewhere. Because of the lack of effective funding for law enforcement and other management activities, many of the rules and guidelines meant to protect cultural resources go unheeded. Because the visitor experience is less structured, fewer individuals are able to take advantage of informational material regarding cultural resources. Despite numerous guidelines, cultural resources in the National Forests, including Kaibab National Forest, face many threats.
Chapter 3: Impacts to an Archaeological Landscape

The Upper Basin of Grand Canyon National Park and Kaibab National Forest is a landscape under constant pressure from multiple influences. Not only is this landscape subjected to the administrative actions of two federal agencies, it also is subjected to multiple activities by hundreds of thousands of visitors every year. Far from being a pristine wilderness, this area is fundamentally changed and molded every year by contact with visitors and land managers. As discussed in Chapter 2, there are certain regulations that each agency must take to protect the land, water, ecology, and archaeology of the region. When successful, these measures may protect the cultural resources within the Upper Basin. This chapter aims to create a framework to determine the vulnerability of archaeological sites to anthropogenic forces, based on actual conditions on the ground. It takes into account the strengths and weaknesses of current land management strategies used by both the USDA Forest Service and the USDI National Park Service.

Vulnerability

Vulnerability, as a theoretical concept, has traditionally been the domain of studies focusing on ecology, human ecology, socio-ecological-systems, food availability, risk hazard research, and natural disaster preparedness (Adger 2006; Gallopin 2005; Turner et al. 2003). Turner and colleagues (2003: 8074) note that vulnerability studies, as an arm of “sustainability science,” deal with the tenuous nature of the relationship between human society and the environment. On a more general level, Adger (2006: 268) posits, “Vulnerability is the state of susceptibility to harm from exposure to stresses associated with environmental and social change and from the absence of capacity to adapt.” In its most basic configuration, vulnerability consists
of a hazard, or multiple hazards, exposure of a system to that hazard, the sensitivity of the system to the hazard, and the capacity of that system to adapt or respond (Turner et al. 2003; Figure 3.1).

![Figure 3.1. Traditional model of vulnerability.](image)

While the human-environment interaction is the most common focus for vulnerability scientists, archaeology and heritage protection are relevant topics in the discussion of vulnerability, especially for those who wish to study and model not only actual destruction, but also the potential for future destruction. The model put forth here highlights the factors that make a particular archaeological site or region vulnerable to the effects of direct and indirect human action on a landscape (Figure 3.2).
Figure 3.2. Model of the contributing factors to archaeological vulnerability in the Upper Basin of Grand Canyon National Park and Kaibab National Forest.

**Threats to the Landscape**

Within the Upper Basin, there are multiple activities that pose direct hazards to archaeological landscapes. In addition, some activities do not directly impact the built landscape, but lead to degradation of the archaeological record through indirect means. Direct hazards are those activities that involve immediate damage to archaeological sites. These hazards can include displacement of artifacts due to mechanical means, such as off-road vehicle use, or, even more damaging, the removal of whole features through digging or woodcutting. Indirect hazards result in delayed damage to archaeological sites over time. These include increased erosion due to woodcutting, increased compaction due to frequent travel, and other hazards that are not directly caused by the original action(s). Whether direct or indirect, almost all hazards result in ground disturbance that takes one or more forms including, but not limited to, sediment removal, sediment displacement, and sediment compaction. The movement of sediment in an archaeological site irrevocably damages the context of archaeological resources (artifacts and
features) and thus reduces the information able to be gained from each site. In addition, some of these movements may directly damage artifacts such as ceramics, lithics, prehistoric and historic timbers, masonry, and historic metals.

**Visitor Impact**

While some of the threats to the archaeological record result from natural forces, many threats originate from modern human activity. Some of the activity is the result of the management policies and practices discussed in Chapter 2. Other activity is the result of transient visitors to the Upper Basin. These individuals may be hunters, campers, woodcutters, backpackers, or sightseers. Each activity that takes place on this landscape has some kind of impact on the Upper Basin. This impact may be a minor compaction of soil along the path of a hiker, or something much greater, such as the deforestation of whole hillsides. Some of these activities are more harmful to the ancient landscape than others. Below is a discussion of the most destructive activities that take place on this landscape.

**Vehicle Traffic (On and Off Road)**

Vehicle traffic is by far one of the worst sources of direct disturbance across the landscape of the Upper Basin. As any vehicle moves through a pinyon-juniper woodland, vehicles compact and displace large amounts of sediment (Lei 2004, Figure 3.1).
Table 3.1. Representation of the changes in bulk density, compaction, and pore space after successive passes over a control plot with various vehicles (from Lei 2004).

<table>
<thead>
<tr>
<th>Disturbance type</th>
<th>Number of passes</th>
<th>Bulk density (g·cm⁻²)</th>
<th>Compaction (kg·cm⁻²)</th>
<th>Pore space (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Human foot</td>
<td>0</td>
<td>1.30 ± 0.07</td>
<td>6.0 ± 0.3</td>
<td>50.9 ± 2.9</td>
</tr>
<tr>
<td></td>
<td>1</td>
<td>1.33 ± 0.06</td>
<td>6.1 ± 0.2</td>
<td>49.8 ± 2.9</td>
</tr>
<tr>
<td></td>
<td>10</td>
<td>1.39 ± 0.06</td>
<td>6.4 ± 0.2</td>
<td>47.5 ± 2.8</td>
</tr>
<tr>
<td></td>
<td>100</td>
<td>1.51 ± 0.05</td>
<td>7.0 ± 0.2</td>
<td>43.0 ± 2.7</td>
</tr>
<tr>
<td></td>
<td>200</td>
<td>1.55 ± 0.05</td>
<td>7.3 ± 0.1</td>
<td>41.5 ± 1.9</td>
</tr>
<tr>
<td>Mountain bike</td>
<td>0</td>
<td>1.31 ± 0.07</td>
<td>6.0 ± 0.3</td>
<td>50.6 ± 3.2</td>
</tr>
<tr>
<td></td>
<td>1</td>
<td>1.35 ± 0.08</td>
<td>6.2 ± 0.2</td>
<td>49.9 ± 2.9</td>
</tr>
<tr>
<td></td>
<td>10</td>
<td>1.43 ± 0.06</td>
<td>6.6 ± 0.2</td>
<td>46.0 ± 2.7</td>
</tr>
<tr>
<td></td>
<td>100</td>
<td>1.55 ± 0.06</td>
<td>7.2 ± 0.1</td>
<td>41.5 ± 2.2</td>
</tr>
<tr>
<td></td>
<td>200</td>
<td>1.58 ± 0.06</td>
<td>7.3 ± 0.1</td>
<td>40.4 ± 2.3</td>
</tr>
<tr>
<td>Motorcycle</td>
<td>0</td>
<td>1.33 ± 0.07</td>
<td>6.1 ± 0.2</td>
<td>50.2 ± 3.3</td>
</tr>
<tr>
<td></td>
<td>1</td>
<td>1.38 ± 0.07</td>
<td>6.4 ± 0.3</td>
<td>47.9 ± 2.9</td>
</tr>
<tr>
<td></td>
<td>10</td>
<td>1.46 ± 0.06</td>
<td>6.8 ± 0.2</td>
<td>44.9 ± 2.7</td>
</tr>
<tr>
<td></td>
<td>100</td>
<td>1.57 ± 0.05</td>
<td>7.4 ± 0.1</td>
<td>40.8 ± 2.7</td>
</tr>
<tr>
<td></td>
<td>200</td>
<td>1.59 ± 0.06</td>
<td>7.4 ± 0.1</td>
<td>40.4 ± 2.7</td>
</tr>
<tr>
<td>Vehicle</td>
<td>0</td>
<td>1.30 ± 0.09</td>
<td>6.0 ± 0.3</td>
<td>50.9 ± 3.3</td>
</tr>
<tr>
<td></td>
<td>1</td>
<td>1.39 ± 0.07</td>
<td>6.4 ± 0.2</td>
<td>47.5 ± 2.7</td>
</tr>
<tr>
<td></td>
<td>10</td>
<td>1.51 ± 0.06</td>
<td>7.0 ± 0.2</td>
<td>43.0 ± 2.8</td>
</tr>
<tr>
<td></td>
<td>100</td>
<td>1.62 ± 0.06</td>
<td>7.5 ± 0.1</td>
<td>38.9 ± 2.5</td>
</tr>
<tr>
<td></td>
<td>200</td>
<td>1.63 ± 0.06</td>
<td>7.5 ± 0.1</td>
<td>38.5 ± 2.4</td>
</tr>
</tbody>
</table>

The amount of disturbance is a result of the instrument of disturbance, frequency of visits, and conditions of the soil during the travel (Adams et al. 1982; Lei 2009). Experiments show that soil compacts and displaces at much greater scales when wet rather than dry (Wilson and Seney 1994). This effect can be much greater during the wet seasons following the winter as snow pack melts (Scholl 1989). Lei notes that the structure of sediments also contributes to compaction/disturbance (2004). He notes that fine-grained soils, such as clay or silt, are much less subject to the forces of vehicle traffic than the larger grained soils, such as those found across much of the pinyon-juniper environment of the Upper Basin (Vankat 2013: 277).

The frequency of vehicle visits to an area also contributes to the amount of compression and disturbance of sediment in the Upper Basin. As might be expected, more frequent visits will result in greater amounts of soil compression and disturbance. Lei (2009) notes, however, that, at a certain point, compression, but not disturbance, diminishes in impacted areas. This is to be expected, because, without recharge of loose sediments, there is nothing to compact. Adams and
colleagues note that frequency of impact will also vary the size of the impacted area (1982). In their study of soil compaction in the Mohave Desert, these researches found differences of 20-40 cm (horizontal space) of compacted soil between single impacts and successive impacts (Adams et al 1982: 169).

The method of travel over an area has a great influence on the severity of soil disturbance. As noted in most modern studies of soil disturbance it seems that larger modes of travel create greater magnitudes of disturbance on a single pass (Adams et al. 1982; Lei 2004, 2009; Taylor and Gill 1984). Hiking impacts on the bulk density of soil are about 10 times less severe than those of a full-sized truck. This change in the composition of soil seems to have the most effect between the surface and a depth of 60 milimeters (Lei 2009: 44). On slopes, these effects can be greatly increased (Weaver and Dale 1978).

Areas that have been heavily impacted by vehicle traffic are also prone to heavy amounts of erosion. Research on OHV (off-highway vehicle) traffic shows that erosion is greatly increased in areas of heavy soil compaction, regardless of the mechanism of compaction (Brooks and Lair 2005; Muckel 2004; Wilcox 1994). This increase in erosion creates uneven patterns of water flow across the landscape and results in major changes to the physical composition and disposition of the soils within and near the trail or road (Wallin and Harden 1996). Similar to soil disturbance, these effects can be increased by slopes. The effects of erosion due to vehicle traffic can become more pronounced as traffic increases and the ground becomes less permeable to rainfall (Brooks and Lair 2005). There has also been some research to suggest that reductions in vegetation, due to compaction via vehicle and other traffic, are greatly responsible for increased erosion (Wilson and Seney 1994).
Camping

Previous research in the Upper Basin area has focused on the impacts of camping on or near archaeological sites (Magee 2007; Roos 2000; Sullivan et al. 2002b; Uphus et al. 2006). Many of the effects from camping activities can be considered direct hazards to the landscape and its past record; however, some activities, while not immediately harmful, produce secondary conditions (indirect effects) that negatively impact the landscape.

Some of the impacts associated with camping are similar to those of vehicle traffic. In cases of camping, the longer someone occupies one spot, the more that site is subjected to the forces of compaction and disturbance by foot traffic, vehicle traffic, possibly ORV use, and compaction or disturbance by other means, such as the use of tents, chairs, tables and other camping accessories. While these actions are seemingly innocuous, research into the effects of prolonged use of wilderness areas by people engaged in sedentary or semi-sedentary activity(s) shows marked degradation of the soil and the soil structure in and around the area being used (Cakir et al. 2010; Sullivan et al. 2002b). These changes include sediment compaction and sediment displacement, as well as changes in the chemical and biological makeup of the soil.

Erosion is also a problem in areas that are heavily impacted by camping. As Sullivan et al. (2002b) note, camping, or activities associated with camping, often involve the building of semi-permanent rock structures at the camp site. The removal of rocks from the soil matrix exacerbates erosion (Pickering 2008). If removed material happens to be on or near an archaeological site, erosion can become a major disturbance problem (Figure 3.3).
Because of the effort involved in selecting suitable rocks and placing them in the correct manner, this activity is usually done opportunistically with materials adjacent to the campsite. Depending on the location of the campsite, building materials may consist of naturally occurring Kaibab limestone, Kaibab limestone masonry from archaeological sites, or sandstones that, given the geology of the area, are almost always archaeological in nature. The nature of the archaeological record in the Upper Basin, however, makes it difficult to distinguish the origin of rock outcrops, whether cultural or natural (Roos 2000). As demonstrated above (Figure 3.3), in cases where a campsite is near or on an archaeological site, ancient structures often become subject to scavenging for suitable building material for a fire ring or other makeshift structure (Sullivan et al. 2002b).

Not only is the construction of these modern fire rings harmful, but the fires lit within them can be just as harmful to the archaeological record. As noted in the Forest Service guide to the effects of fire on cultural resources and archaeology, any fire can have some effect on
heritage resources (Table 3.2). The severity of damage depends on location, temperature, duration, and material being affected, among other factors (Ryan et al. 2012).

Table 3.2. List of fire effects to cultural resources and their descriptions (modified from Ryan et al. 2012).

<table>
<thead>
<tr>
<th>Fire Effect</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Combustive Residue</td>
<td>The presence of tar deposits on the surface of a specimen formed as a by-product of the pyrolysis and combustion of organic materials.</td>
</tr>
<tr>
<td>Color Change/Oxidation</td>
<td>An overall darkening or reddening of a specimen from its original color.</td>
</tr>
<tr>
<td>Paint Oxidation</td>
<td>The oxidation of pigment (organic or mineral) on decorated ceramic specimens.</td>
</tr>
<tr>
<td>Color Change</td>
<td>(lithic specimens only) An observable color change of a specimen from original, pre-fire, color.</td>
</tr>
<tr>
<td>Crazing</td>
<td>The presence of fine, non-linear or latticed cracks on the surface of a specimen.</td>
</tr>
<tr>
<td>Spalling</td>
<td>The exfoliation of a portion of the original surface of exposed rock or a specimen due to differential heating and pressure release.</td>
</tr>
<tr>
<td>Spall Scars</td>
<td>The presence of concave depressions on the surface of a specimen where it is evident that a portion of the surface was exfoliated due to spalling.</td>
</tr>
<tr>
<td>Pot-lid Fracturing</td>
<td>Similar to spalling, but specific to lithic artifacts manufactured from cryptocrystalline silicate rocks such as chert.</td>
</tr>
<tr>
<td>Fracturing</td>
<td>The fracturing of a specimen into multiple pieces, and/or the presence of fractures or fissures that penetrate deeply into a specimen.</td>
</tr>
<tr>
<td>Weathered Fracturing</td>
<td>The fracturing of a thermally altered architectural block over time due to mechanical weathering.</td>
</tr>
</tbody>
</table>

In addition, camping activities inhibit the growth of new vegetation, of all types (moss, grass, sedge, forb, shrub, trees, and other woody vegetation), within the confines of the campsite (Taylor 1997). This effect is notably greater as visits increase and visitors expand the campsite beyond its original boundaries (Cole et al. 2008), thereby increasing erosion (Pickering 2008; Wilcox 1994).
Woodcutting

Woodcutting presents several threats to the archaeology of the Upper Basin. On a very basic level, woodcutters impact the landscape in some of the same ways mentioned above. They use heavy vehicles which compress and disturb soil, suppress vegetation, and displace large rocks in the area they work. Woodcutting operations also come with their own unique challenges. In particular, under-monitored and under-regulated woodcutting can result in the removal of historic stumps and wooden structures from their original context (Figure 3.4).

![Figure 3.4. Photograph of the waste products (slash) left from woodcutting activities in the Upper Basin.](image)

The removal of much of the major vegetation on the landscape dramatically increases erosion and the likelihood of disturbance to those sites that have been denuded (Hartley and Vawser 2004). In addition, the increased “dead and down” vegetation biomass can increase the severity of fire effects in the case of wildfires and prescribed burns.

Not only does woodcutting directly affect the archeology of the Upper Basin through soil compaction, erosion, and vegetation loss, but it also affects faunal communities in the region.
These changes in animal behavior can have disastrous effects on the archaeological landscape. Woodcutting provides an ideal environment for many species of rodent, including the packrat. As Turkowski and Reynolds (1970) note, the number and variety of rodents dramatically increases, as pinyon-juniper woodland is cut down. Rodent populations are one of the most destructive forces to archaeological sites (Bocek 1986). Rodent burrowing activities displace artifacts and associated soil, and bring materials not original to a site into close proximity with in-situ remains. Rodents can also damage skeletal remains on archaeological sites through gnawing and scratching (Milner et al. 2000).

![Image](image.jpg)

**Figure 3.5.** Off-road vehicle tracks with a metate fragment and other small artifacts in the foreground.

Woodcutting in pinyon-juniper woodlands creates clearings that are attractive to a wide variety of animals, including large game such as mule deer and elk (Gottfried and Severson 1994; United States Department of Agriculture, Forest Service 2010). While initially the influx of large game animals to a cut area may not produce a great impact to archaeological sites, the availability of large animals, and the ease of access by way of woodcutter’s roads means that
these areas attract hunters searching for elk and deer. Hunting activities include the use of off-road vehicles (ORVs), and 4X4 trucks (Figure 3.5). Temporary camps may be set up near hunting areas and often result in many of the same disturbances displayed in heavy camping areas.

**Exposure to Threats**

While each of the above threats is a factor in the Upper Basin, they are present to different degrees and in different areas. Some threats impact very specific areas, while others are dispersed throughout the landscape. The relative exposure of the archaeological landscape to these impacts is a crucial part of ascertaining relative vulnerability of archaeological sites in the Upper Basin.

*Vehicle Traffic Exposure*

Archaeological sites are most vulnerable to vehicle traffic when they fall in close proximity to roads that are, officially or otherwise, open to public traffic (Brooks and Lair 2005; Hedquist and Ellison 2010; Sullivan et al. 2002b). Adding to this issue is the establishment and use of multiple unofficial roads by visitors to the Upper Basin. The greater the traffic along such roads, the greater the potential for impact to an archaeological site. In addition, service roads and Forest Service roads adjacent to and intersecting high-traffic roads, such as SR-64 leading into Grand Canyon National Park, are more likely to be a point of entry for quick stop-overs and impromptu visitor use of the area. The structure of the pinyon-juniper woodland also plays a part in the landscape’s exposure to impacts. Though density of vegetation varies throughout the Upper Basin, in general, the pinyon-juniper woodland is well spaced providing lots of area for ORV use (Darling 1967). In addition to the density of vegetation, the archaeological landscape of
the Upper Basin is very dense (Figure 3.6). The density of archaeological sites is such that unregulated or unguided recreation will most likely result in contact between archaeological sites and visitors. Other activities, such as camping, woodcutting, hunting, and recreational ORV use, will also expose the landscape to vehicles.

Figure 3.6. Map of MU (mapping unit) density throughout the UBARP project area.
Camping Exposure

Campers use the Upper Basin as a place to recreate to varying degrees, depending on location and season. Areas of opportunity and easy access, especially those places near an established road or route, are more likely to be subject to camping activities. Any place where camping activities are concentrated has the potential to contribute to the relative vulnerability of archaeological sites. Archaeological sites are often located on the flat or near flat ground in the Upper Basin (Sullivan et al. 2002b). Campers also prefer to use flat ground as a matter of convenience. This intersection of preferred space for both archaeological sites and modern campsites often brings archaeology into conflict with recreation.

Woodcutting Exposure

Legal woodcutting in the Upper Basin is designated to certain zones set aside by the USDA Forest Service for use by private woodcutters (United States Department of Agriculture, Forest Service 2010 (Figures 2.1 and 2.2). Administratively, these zones are meant to have inflexible borders within which woodcutting may take place. In reality, the zones are flexible and generally expanding. Areas where woodcutting is present, including those areas between the actual cut and the highway (SR-64), experience increased levels of vehicle traffic, camping, and hunting due to the open nature of such cuts. All of these activities increase the vulnerability of the archaeological landscape of the region.
Inherent Sensitivity of Archaeological Sites

While many disturbances to the archaeological landscape are a direct result of visitor interactions, archaeological sites are also inherently vulnerable due to the physical and ecological conditions on the ground. Conditions on individual sites may make the resource more vulnerable to inadvertent vandalism. Many sites lie on or just below the surface (Hedquist and Ellison 2010). This puts the archaeological resource in direct contact with many of the threats mentioned above. Masonry structures and FCR piles may be even more sensitive because they present easy purchase for the wheels of ORVs and easy construction material for campfire builders (Hartley and Vawser 2004; Hedquist and Ellison 2010; Figure 3.7). Sites without much vegetation are more likely to succumb to the negative effects of visitation than those that are covered with sagebrush, grasses, and other vegetation (Hartley and Vawser 2004). Denuded areas are also much more likely to experience greater erosion via wind, water, visitor, or other means.

Figure 3.7. Photograph of visitor-created masonry fire ring. All of these cobbles are likely sourced from the adjacent masonry structure.
Individual geographic regions are subject to their own issues of sensitivity when subjected to varying patterns of modern visitor behavior. An examination of the severity of recorded impacts in the Upper Basin can shed light on this region’s particular sensitivities.

Figure 3.8. Histogram showing severity of impact as a percent of total impacts.

Figure 3.8 illustrates the differential sensitivity of various site types to impacts from visitor behavior. Specifically it shows the percent of aggregated severity or degree of impacts (recorded severity of camping, vehicle traffic, woodcutting, vandalism, and erosion) for each type of site present within the Upper Basin. What the above figure illustrates is that there is a clear hierarchy in the sensitivity of mapping units based on their type. The dominance of scatters (lithic and/or ceramic) may be explained by the predominance of the site type on the landscape, though these sites are exposed to tremendous pressures from visitation. While displaying nowhere near the impact value of scatters, masonry structures and fire cracked rock piles clearly dominate the rest of the site types evaluated for severity of impact. The intensity of impacts at these sites may be due to their visibility on the landscape, in addition to the available material they provide for making and maintaining modern campfire rings. Brush structures, alignments, and rock piles
exhibit a slightly less severe degree of impacts. The lessened severity of impacts at these sites may be due to in part to their diminished presence on the landscape, but are also a result of their placement on the landscape. In particular, the placement of alignments, mostly away from roads, sometimes in drainages, and the majority falling within the national park, makes them less likely to be exposed to impacts and, therefore, they display less sensitivity. Rock piles, like alignments, are mostly situated in the park and away from roads which means that they present as less sensitive. The lesser severity of impacts at brush structures is harder to explain. These wooden structures may gain some amount of protection from the fact that many are connected to living trees and are better shielded from erosion and other impacts. In addition, they generally do not provide materials for modern use, such as masonry, except in areas designated for woodcutting. The rest of the feature types (cists, quarries, rock art, etc.) display a relatively low severity of impacts and, thus, a low sensitivity. These features are not as exposed to impact as others, and, in the case of most of these site types, they are not useful as a source of raw material for modern construction.

Capacity to Respond to a Threat

Normally, discussions of vulnerability include a discussion of adaptability, or the capacity of a group or system (i.e., the archaeological landscape) to respond to an outside threat. In order to adapt to these threats, effective protective measures by land managers are crucial. Federal land managers have many tools available to stem the flow of disturbances to individual sites. In many cases, contact and action by either a Ranger or Law Enforcement Officer can encourage good practices or prevent illegal action (Chavez and Tynon 2008; Hoots 1976; Williams 1976).
Other land managers have found that public education programs can also be particularly effective. When the public has knowledge of the landscape, the resources, and the consequences of violating them, they’re much more likely to protect and preserve those resources (Chavez and Tynon 2008; Hoots 1976; Sullivan et al. 2002b; Williams 1976). Traditionally education programs have focused on preservation of the spectacular and unique, while leaving many sites deemed “unimportant” out of the discussion with the public and archaeologists (Sullivan et al. 2002; Tainter and Bagley 2005). Education programs often inadequately inform the public of phenomena that, while less spectacular, are just as important to the prehistoric record. However, with proper focus, education can lead to a sense of public ownership and stewardship of our cultural and natural resources (Hardin 1968).

Finally, as discussed in Chapter 2, there are many administrative actions that managers can take when attempting to protect resources. Archaeological survey and monitoring of ground disturbance activities are provided for in a multitude of federal laws, as well as the management plans of all federal lands (Fowler 1982; National Park Service 1995; United States Department of Agriculture Forest Service 2010; United States Department of Agriculture, Forest Service 2011; Wildesen 1982). These activities are important, but they are only one line of defense. The federal government can take other administrative actions to protect cultural resources. These include administrative closure of an area, administrative closure of roads, designation of wildernesses, designation of special use areas, signage placement, fencing, or data recovery (National Park Service 1995; National Park Service 2012b; United States Department of Agriculture Forest Service 2010; United States Department of Agriculture, Forest Service 2011).
How Do these Issues Fit into the Model?

Hunting, camping, and woodcutting present the greatest threats to archaeological sites in the Upper Basin. These potential disturbances are regulated by exposure, or how often these threats will actually impact the archaeology of a specific area within the landscape. The contributions of management (Federal Land Managers) provide some measure of adaptation to respond to these threats. For a variety of reasons, discussed in Chapter 2, the policies of land managers do not always align with what they practice in terms of protective measures for the landscape and archaeology. On-site context is a result of the inherent sensitivity of archaeological sites, but also the secondary effects of visitor impacts, such as erosion or increased rodent activity. Together, these aspects of visitor impact, exposure to a threat, management contributions, and on-site context of archaeology contribute to a site, or an area’s, overall vulnerability.
Chapter 4: Calculating a Vulnerability Index for the Archaeological Landscape

The previous chapter presents the elements of a model for vulnerability of archaeological sites within the Upper Basin of Grand Canyon National Park (GRCA) and Kaibab National Forest (KNF). In this chapter I expand on the use of GIS and Satellite Remote Sensing technology in environmental monitoring and heritage management. In addition, I provide descriptions of the data used to construct a vulnerability index for the Upper Basin and discuss the process for calculating this index. Finally, I discuss the vulnerability index and the resulting datasets.

Geographic Information Systems and Satellite Remote Sensing in Archaeology

Geographic Information Systems (GIS) have become a crucial aspect of archaeological applications in heritage management (Conolly and Lake 2006; Farmer 2008). Most all archaeological information has a spatial component, and a geographic representation of the data provides information that is crucial to the protection and research of cultural resources (Kvamme 1989). Collection of geographic data ensures that archaeological inventories and surveys can be utilized quickly and effectively, while keeping costs low. GIS prepares and packages information about the archaeological record that is easily shared with and used by researchers (Snow et al. 2006). In addition, federal guidelines on how agencies must supervise their resources practically require the use of GIS for managers to be effective (National Park Service 1997, 1998; United States Department of Agriculture, Forest Service 2008).

While the use of GIS has become virtually inseparable from the management of cultural resources, a large majority of this research focuses on predicting the likelihood of archaeological
sites to help narrow down which areas may need survey and mitigation efforts (Kvamme 1999; Reid 2008). While these efforts are important, some recent research in the field has indicated that efforts focused on modeling modern activities and their potential to impact the archaeological record could be equally effective (Dore and Wandsnider 2006). Research in using GIS for heritage management abounds. In particular, several projects have focused on recreation and the management plans meant to deal with recreation and public interaction with the archaeological record. Of some note is the Living with Heritage research project at Angkor, Cambodia. Similar to the Upper Basin, Angkor receives many visitors over the course of a day, via neighboring settlements and tourism programs. Growing demands on the environment and cultural landscape of Angkor have caused the area to deteriorate at an alarming rate. The Living with Heritage research project provided methods for using GIS data and Satellite Remote Sensing to model land use change, manage sustainable tourism and development, and preserve cultural resources (Fletcher et al. 2007).

In the American Southwest, several studies have developed in response to changing management strategies and environmental conditions. In 2003, the National Park Service’s Midwest Archaeological Center undertook a survey project on the banks of the McPhee reservoir in the San Juan National Forest. The purpose of this project was to assess whether site location and type corresponded to level of modern disturbance. In addition, the project aimed to establish the vulnerability of particular sites to visitor use and disturbance (Hartley and Vawser 2004). The study used GIS modeling and qualitative data to conclude that location and site make-up were incredibly important variables in deciding which sites were disturbed. They used these data to identify vulnerable sites and direct management. A similar study conducted by the Colorado Plateau Archaeological Alliance used both GIS and photographic information to assess patterns
of vandalism of the archaeological record in Range Creek Canyon, Utah (Spangler et al. 2006). The information collected was used to make cultural resource management recommendations for Range Creek. In 2010, the Center for Desert Archaeology completed a study on the Tonto National Forest. This study focused on analyzing site disturbances along the roads of the newly minted Tonto National Forest Travel Management Plan (Hedquist and Ellison 2010). Results show that distance between roads and archaeological sites is a highly important factor in determining which sites would be negatively impacted by recreation activities.

Within the Upper Basin there has been a wealth of GIS and Satellite Remote Sensing research focused on management and vulnerability issues. In particular, inadvertent vandalism has been identified as the number 1 culprit in archaeological disturbance (Sullivan et al. 2002b). Attempts have also been made at modeling inadvertent vandalism of the cultural landscape to disturbances from modern sources using both GIS analysis and Satellite Remote Sensing (Magee 2007; Roos 2000; Uphus et al. 2006). The following model uses a combined analysis of vector data from the UBARP GIS database and raster data from a variety of sources to create an approximation of landscape vulnerability.

**GIS and Satellite Remote Sensing Data**

The research presented here uses data from a variety of sources (Table 4.1). Data for the UBARP GIS Database were collected with a Trimble GPS unit or converted to digital data from paper records. The Forest Service Motor Vehicle Use Map road shapefile depicts roads that are open to travel on the Tusayan Ranger District of Kaibab National Forest. This shapefile fails to show all roads available for travel and was supplemented with the Grand Canyon National Park (GRCA) roads shapefile. Both the DEM files and the NDVI files have a 30 meter resolution. The
scale of these data dictates that the calculated vulnerability cells also display a 30 meter resolution. All maps are projected in NAD 1927 UTM Zone 12N. Some datasets have original projections other than NAD 27. These datasets were transformed using the ESRI projection transformation tool.

<table>
<thead>
<tr>
<th>Data Used</th>
<th>Data Class</th>
<th>Data Source</th>
</tr>
</thead>
<tbody>
<tr>
<td>UBARP Mapping Units</td>
<td>Vector (Point)</td>
<td>UBARP GIS Database</td>
</tr>
<tr>
<td>Human Impacts</td>
<td>Vector (Point)</td>
<td>UBARP GIS Database</td>
</tr>
<tr>
<td>USFS Woodcutting Boundary</td>
<td>Vector (Polygon)</td>
<td>UBARP GIS Database</td>
</tr>
<tr>
<td>UBARP Boundary</td>
<td>Vector (Polygon)</td>
<td>UBARP GIS Database</td>
</tr>
<tr>
<td>Federal and Tribal Boundaries</td>
<td>Vector (Polygon)</td>
<td>NPS Data Store</td>
</tr>
<tr>
<td>Grand Canyon Roads</td>
<td>Vector (Line)</td>
<td>NPS Data Store</td>
</tr>
<tr>
<td>MVUM Roads</td>
<td>Vector (Line)</td>
<td>USFS Kaibab National Forest</td>
</tr>
<tr>
<td>30 m DEM (Arizona)</td>
<td>Raster</td>
<td>Arizona Land Resource Information Service</td>
</tr>
<tr>
<td>30 m NDVI</td>
<td>Raster</td>
<td>Web-enabled Landsat Data (WELD) - USGS</td>
</tr>
<tr>
<td>USFS Topo Maps (DRG)</td>
<td>Raster</td>
<td>USFS Kaibab National Forest</td>
</tr>
<tr>
<td>Color Topo Map (DRG)</td>
<td>Raster</td>
<td>National Geographic Society Topo!</td>
</tr>
</tbody>
</table>

**Variables of a Vulnerability Index**

In calculating a vulnerability index for the archaeological landscape of the Upper Basin it is prudent to include several different variables that account for the natural environment, the built environment, the past environment, and modern human behavior. Some of these variables represent sensitivity of the landscape (e.g., vegetation and slope), and some represent exposure to a threat (e.g., roads). The realization of vulnerability resulting from these variables is different across the landscape based on the different activities (camping, woodcutting, and hunting) that result in impacts to the archaeological landscape. It is important to remember that all of these
aspects of vulnerability and the activities that modify them are framed by the actions of the land managers employed by the USDA Forest Service and the National Park Service.

In order to provide a basis for analyzing vulnerability and risk to the archaeological landscape from specific activities, a general exposure model for the cultural landscape of the Upper Basin was conducted. This research incorporates aspects of the natural and built environments, as attributes that contribute to exposure, as well as sensitivity data about certain sites themselves. The general model incorporates information from three more targeted models of exposure to the varying impacts of different activities (camping, woodcutting, and hunting) and as well as a site sensitivity model to modify our understanding of the vulnerability of the area.

To account for these variables different analyses have been conducted. First, all of the models created with these variables are tested against a record of previous impacts. These include data on hearths and trash left behind by visitors. This provides evidence for or against these models as accurate representations of actual modern human behavior and the associated impact. Second, to account for actual placement of archaeological sites and their sensitivities to impact, a sensitivity map of the archaeology of the Upper Basin is overlain onto the overall exposure maps to show areas where both sensitivity and exposure are high, thus highlighting highly vulnerable areas.

**The Natural Environment**

There are two aspects of the natural environment of the Upper Basin that I identified as important to exposure of the archaeological record to impact. The first variable is the relative density of vegetation on the landscape. The second variable I discuss is the slope of the
landscape. While I refer to this landscape as “natural,” years of intervention by park and forest managers in the Upper Basin results in a landscape that is anything but natural. Previous and more recent woodcutting has dramatically changed the forest of the Upper Basin by creating new open areas. Fire suppression and then prescribed fires have dramatically altered the structure of forested areas. In addition, years of recreation have resulted in massive damage to utilized areas.

NDVI and Vegetation Exposure

Previous chapters have emphasized that the density of vegetation is an important factor in determining exposure of archaeological sites to disturbance. A NDVI (Normalized Difference Vegetation Index) image derived from the Landsat series of satellites allows researchers to ascertain relative density of vegetation by analyzing tree cover in the visible red band and the near-infrared bands (Parcak 2009). Higher values of the NDVI image will correspond to greater biomass, or density of vegetation. As stated previously the NDVI images used for this study were pre-prepared via the Web-enabled Landsat Data (WELD) website (Roy et al. 2010). The pixels for this image were reclassified with values from 1 to 10 (Figure 4.1). Values of 1 correspond to the areas that display the most biomass / highest density, while values of 10 correspond to areas that display the least biomass / low density.
Figure 4.1. NDVI values across the Upper Basin.

Figure 4.2. Histogram of all 30m² cells in the Upper Basin in specific NDVI levels.
A histogram of vegetation levels of the Upper Basin shows a curve slightly skewed towards lower levels of exposure potential (Figure 4.2). By separating the units into park or forest we can gain a better understanding of which jurisdiction contributes at certain levels to the vulnerability index (Figure 4.3 and 4.4). This analysis is confounded by the larger area of Forest Service land that has been surveyed by UBARP in contrast to the smaller amount of land surveyed in the National Park by UBARP. Overall the Kaibab National forest covers 84% of the Upper Basin Archaeological Research Project whereas Grand Canyon National park only consists of 16% of surveyed area. In order to control for this issue the following figures display the percent of cells present only within each jurisdiction and not within UBARP as a whole.

![Histogram of NDVI levels present within Grand Canyon National Park.](image)

**Figure 4.3.** Histogram of NDVI levels present within Grand Canyon National Park.
Figure 4.4. Histogram of NDVI levels present within Kaibab National Forest.

Visual analysis of these graphs reveals small but important differences in NDVI between Grand Canyon National Park (GRCA) and Kaibab National Forest (KNF). Grand Canyon has more of its vegetation cells to the left of center (more dense) and Kaibab NF has more land to the right of center (less dense) than GRCA.

Slope Map and Slope Exposure

Another previously identified variable of some importance to site exposure is ground slope in the area of an archaeological site. In general, archaeological sites fall on ground with little to no slope (Grady 1980). Just as past groups did not prefer to place their settlements on uneven surfaces, contemporary campers also put a premium on flat ground for their campsites. This condition often puts visitors into close contact with cultural resources. A slope map was calculated using the spatial analyst extension of ArcGIS (Figure 4.5). This information was reclassified into 10 discrete exposure levels (Table 4.2). The areas with the highest exposure
(low slope) were classified as level 10, while areas of low exposure (high slope) were classified as level 1. Figure 4.6 depicts the number of cells within the UBARP study area with values at specified vulnerability levels.

**Table 4.2.** Conversion table from exposure level to degree of slope.

<table>
<thead>
<tr>
<th>Exposure Level</th>
<th>Slope Degree</th>
</tr>
</thead>
<tbody>
<tr>
<td>10</td>
<td>0 - 3°</td>
</tr>
<tr>
<td>9</td>
<td>4 - 7°</td>
</tr>
<tr>
<td>8</td>
<td>8 - 14°</td>
</tr>
<tr>
<td>7</td>
<td>15 - 18°</td>
</tr>
<tr>
<td>6</td>
<td>19 - 25°</td>
</tr>
<tr>
<td>5</td>
<td>26 - 31°</td>
</tr>
<tr>
<td>4</td>
<td>32 - 38°</td>
</tr>
<tr>
<td>3</td>
<td>39 - 47°</td>
</tr>
<tr>
<td>2</td>
<td>48 - 58°</td>
</tr>
<tr>
<td>1</td>
<td>59 - 90°</td>
</tr>
</tbody>
</table>

**Figure 4.5.** Map of slope across the Upper Basin.
Figure 4.6. Histogram of slope (by level) in the Upper Basin.

The histogram of slope exposure shows that, based on slope alone, the Upper Basin is relatively flat and vulnerable to visitor interaction with the archaeological record (Figure 4.6). This study separates these numbers further into park and forest graphs to facilitate meaningful comparisons (Figures 4.7 and 4.8). Similar to the previous graphs, the following figures only present percentages out of their respective jurisdiction and not of UBARP as a whole.

The area surveyed in Grand Canyon has more than 50% of its surface area with slopes from 0-3°, whereas the area surveyed within Kaibab National Forest displays around 45% land with the same slope range. Kaibab does display some steeper slopes (with lower exposure levels) due to the presence of several dry washes and small cliffs in the area.
Figure 4.7. Histogram of slope (by level) present within Grand Canyon National Park.

Figure 4.8. Histogram of slope (by level) present within Kaibab National Forest.

The Built Environment

Another aspect of the exposure to a threat that has yet to be discussed is how the built environment, in this case roads, affects behavior and shapes the concentration of visitation to
archaeological sites on the landscape. Previous research has indicated a correlation between disturbance occurrence and proximity to State Route 64 (Roos 2000). This correlation generally remains true; however, the research presented here bolsters previous research (Uphus et al. 2006) by identifying that areas near any road in the Upper Basin will attract relatively more disturbances than those areas without roads.

Road Proximity and Exposure

In order to identify areas near to one or more roads within the Upper Basin a layer was created that consisted of several shapefiles of all roads from within both the USDA Forest Service and the USDI National Park Service. This layer was then buffered at set distances that are relevant to current policies of both GRCA and KNF (Figure 4.9). These data were reclassified to represent 10 discrete exposure levels (Table 4.3). The areas with the highest exposure (close to roads) were classified as level 10, while areas of low exposure (far from roads) were classified as level 1.

The histogram of road distance in the Upper Basin shows that the area falls incredibly close to and is penetrated by multiple roads (Figure 4.10). This study separates these numbers further into park and forest graphs to facilitate meaningful comparisons (Figures 4.11 and 4.12). Similar to previous graphs, the following figures only represent percentages of the respective jurisdiction and not of UBARP as a whole.

As these histograms show, Grand Canyon displays a high percentage of lower-level exposure and a low percentage of high-level exposure (Figure 4.11). While Kaibab National Forest displays a similar trend to the National Park, its high-level exposure percentages are greater than those of the park (Figure 4.12). This trend is most likely due to the greater number of roads that cut through Kaibab National Forest (Figure 4.9).
Figure 4.9. Map of distances from a road within the Upper Basin.

Table 4.3. Conversion table from exposure level to distance from a road.

<table>
<thead>
<tr>
<th>Exposure Level</th>
<th>Distance from a Road</th>
</tr>
</thead>
<tbody>
<tr>
<td>10</td>
<td>0-10 m</td>
</tr>
<tr>
<td>9</td>
<td>11-100 m</td>
</tr>
<tr>
<td>8</td>
<td>101-300 m</td>
</tr>
<tr>
<td>7</td>
<td>301-900 m</td>
</tr>
<tr>
<td>6</td>
<td>901-1600 m</td>
</tr>
<tr>
<td>5</td>
<td>1601-2700 m</td>
</tr>
<tr>
<td>4</td>
<td>2701-4200 m</td>
</tr>
<tr>
<td>3</td>
<td>4201-6300 m</td>
</tr>
<tr>
<td>2</td>
<td>6301-9000 m</td>
</tr>
<tr>
<td>1</td>
<td>9001-20000 m</td>
</tr>
</tbody>
</table>
Figure 4.10. Histogram of road distance exposure levels in the Upper Basin.

Figure 4.11. Histogram of road distance (by level) within Grand Canyon National Park.
Figure 4.12. Histogram of road distance (by level) within Kaibab National Forest.

Proximity to SR 64 and Exposure

Another important factor in human presence on the landscape (Roos 2000) that varies slightly from the road distance variable is the proximity to SR 64. The shapefile for Arizona State Route 64 was buffered at set distances to produce 10 distinct vulnerability levels (Table 4.4, Figure 4.13). The areas with the highest exposure (close to SR-64) were classified as level 10, while areas of low exposure (far from SR-64) were classified as level 1.
Figure 4.13. Map of distances from SR 64 within the Upper Basin.

Table 4.4. Conversion table from exposure level to distance from SR 64.

<table>
<thead>
<tr>
<th>Exposure Level</th>
<th>Distance from SR 64</th>
</tr>
</thead>
<tbody>
<tr>
<td>10</td>
<td>0-250 m</td>
</tr>
<tr>
<td>9</td>
<td>251-800 m</td>
</tr>
<tr>
<td>8</td>
<td>801-1500 m</td>
</tr>
<tr>
<td>7</td>
<td>1501-2000 m</td>
</tr>
<tr>
<td>6</td>
<td>2001-2500 m</td>
</tr>
<tr>
<td>5</td>
<td>2501-3000 m</td>
</tr>
<tr>
<td>4</td>
<td>3001-4500 m</td>
</tr>
<tr>
<td>3</td>
<td>4501-5500 m</td>
</tr>
<tr>
<td>2</td>
<td>5501-6500 m</td>
</tr>
<tr>
<td>1</td>
<td>6501-12000 m</td>
</tr>
</tbody>
</table>
Figure 4.14. Histogram of distance from SR 64 (by level) within the Upper Basin.

The histogram of distance from SR 64 in the Upper Basin shows a general trend of more area farther away from the road (exposure level 1) than towards (exposure level 10; Figure 4.14). This study separates these numbers further into park and forest graphs to facilitate meaningful comparisons (Figures 4.15 and 4.16). As with previous graphs, these figures only represent percentages of the respective jurisdiction and not of UBARP as a whole.

As is evident from the histograms (Figure 4.15 and 4.16), Grand Canyon National Park has a much greater land mass close to SR 64 than Kaibab National Forest. One reason for this discrepancy is the fact that SR 64 takes a major turn within GRCA and, therefore, much of the landmass of the park is in close proximity to the two sections of the road. In addition, the landscape of GRCA is somewhat constricted by the proximity of both the Grand Canyon and Kaibab National Forest. This constriction means that distances to SR 64 within GRCA will always be very low (high exposure).
Calculating Potential Exposure across the Landscape using Fuzzy Logic

In order to calculate a potential exposure model for the Upper Basin, some of the above variables were used in ArcGIS to calculate a fuzzy logic raster. A fuzzy logic raster is an image,
composed of pixels calculated by running a number of relevant variables through the fuzzy logic tool of ArcGIS. Specifically, NDVI, slope, on the ground distance from a road, and on the ground distance from SR 64 were identified as the most relevant variables of interest. Fuzzy logic was chosen as a method of calculating potential exposure to impact because of the somewhat non-linear relationship between several of these variables and the degree of exposure they indicate. Fuzzy logic allows for looser predictions than true or false, thus cases may be positive or negative to a degree (Hatzinikolaou 2006). Using fuzzy logic, variables can be assigned a number between 0 and 1 that expresses the degree to which an individual case fits together with all other cases (Zadeh 1965).

**The Application of Fuzzy Logic**

The research presented here uses a three step process in ArcGIS that results in a fuzzy logic exposure raster. First, each variable is assigned membership in a fuzzy logic raster based on how well each cell fits a desired condition. For example, when calculating exposure, cells closer to roads are assigned a higher exposure score, and thus they are assigned higher membership in the fuzzy logic raster. The next step is to combine fuzzy rasters together with a fuzzy overlay tool. Again, this tool assigns membership based on how well each variable fits the group and subscribes to the desired conditions. The final step is to symbolize and reclassify the results to provide a meaningful image for resource managers.

**Camping**

The first of the above mentioned fuzzy analysis surfaces attempts to model camping behavior in the Upper Basin, and thus classify which areas may be vulnerable to interaction with
this user group. This model of camping behavior values certain environmental conditions over others. In the case of camping, Vegetation Health/Density (NDVI), Slope, Distance to a Road, and Distance to SR 64 were identified as important to the model. Specifically areas that have a low NDVI value, and thus low vegetation density, a low slope (with a higher chance of camping placement), are close to a backcountry road, and close to SR 64 were prioritized over others. These areas were identified as areas of least-cost for visitors hoping to camp in the area. Least-cost is based upon the idea that an individual, in this case a camper or group of campers, will travel along the path of least resistance to come to their preferred destination (Rossmo 2000). The least-cost principle is often used in geographic analyses of recreational behavior to describe possible avenues of travel for visitors to an area (Lynch 2002). These variables were given fuzzy membership and then combined using the fuzzy sum and product functions of the fuzzy overlay tool, in ArcGIS, to produce the final fuzzy exposure raster (Figure 4.17). The fuzzy raster was reclassified to provide meaningful exposure categories for analysis. The resulting exposure surface predicts 88% of previously identified human impact events to fall within exposed (level 4) and highly exposed (level 5) areas.
Woodcutting

The next group of interest in predicting exposure across the Upper Basin is woodcutters. The fuzzy model of woodcutting activity uses the same variables as the camping model, but weights these variables differently to show differences in behavior between the user groups. Specifically, areas that have a high NDVI value, and thus high woodcutting availability, a low slope, with a higher chance of available wood, are close to a backcountry road, and far from the main SR 64 were prioritized over others. This model chooses areas that are farther from SR 64 for two reasons: 1) sanctioned woodcutting areas are often located far from the main road so as to preserve the scenic nature of the area, and 2) unsanctioned woodcutting often takes place far from the main road in areas where it would be difficult for government employees and law
enforcement officials to monitor these activities (Alan P. Sullivan, III, personal communication 2013). The identified variables were given fuzzy membership and then combined using the fuzzy sum and product functions of the fuzzy overlay tool, in ArcGIS, to produce the final fuzzy exposure raster (Figure 4.18). The fuzzy raster was reclassified to provide meaningful exposure categories for analysis. The resulting vulnerability surface predicts 75% of previously identified human impact events to fall within exposed and highly exposed areas.

![Figure 4.18. Map of exposure to woodcutting activities within the Upper Basin.](image)

**Hunting**

The last group of interest within the Upper Basin is hunters. Again, the variables being used to model hunting behavior are the same as to model camping and woodcutting, and, again, these variables have been weighted differently to reflect the different pattern of behavior.
exhibited by hunters. Specifically, areas that have a low NDVI value, a low slope, are close to a backcountry road, and far from the main SR 64 were prioritized over others. The only variable that is coded differently between woodcutting behavior and hunting behavior is NDVI. Hunting values open areas where hunters have the opportunity to observe their prey grazing, usually along the edge of an open area within forest (Adams 2001). In addition, while low slopes and backcountry roads help hunters to traverse the landscape, proximity to SR 64 is not as beneficial to hunters as it is to campers. Hunters will prefer areas further from SR 64 for two reasons: 1) for seclusion from other visitors participating in other activities, and 2) it is un-lawful, and un-safe, for anyone to discharge a firearm across SR 64 (36 C.F.R. 261.10 (7/1/2010 Edition)). The identified variables were given fuzzy membership and then combined using the fuzzy sum and product functions of the fuzzy overlay tool, in ArcGIS, to produce the final fuzzy exposure raster (Figure 4.19). The fuzzy raster was reclassified to provide meaningful exposure categories for analysis. The resulting vulnerability surface predicts 77% of previously identified human impact events to fall within vulnerable and highly vulnerable areas.
How do the models fit together?

In order to simplify interpretation of these exposure maps, this analysis also presents an overall exposure map that consists of an amalgamation of all three user-based exposure maps presented above. This map will be combined later with the sensitivity map to produce an overall vulnerability map. The first step in combining these maps was to use a weighting system to calculate weights for each of the user-groups. The weighting system assigns each user-group a weight from 1 to 3 for each disturbance category, as well as an area factor that describes the on-the-ground extent of any disturbance. The weighting helps reflect differences in contributions to the vulnerability of the archaeological record from among these user groups due to their different activity patterns (Table 4.7).
Table 4.5. Weighting vulnerability contributions among user-groups.

<table>
<thead>
<tr>
<th>User Group</th>
<th>Camping Impact Potential</th>
<th>Woodcutting Impact Potential</th>
<th>Hunting Impact Potential</th>
<th>ORV Impact Potential</th>
<th>Area Factor</th>
<th>Weight</th>
</tr>
</thead>
<tbody>
<tr>
<td>Campers</td>
<td>3</td>
<td>1</td>
<td>0</td>
<td>1</td>
<td>1</td>
<td>6</td>
</tr>
<tr>
<td>Woodcutters</td>
<td>0</td>
<td>3</td>
<td>0</td>
<td>3</td>
<td>3</td>
<td>9</td>
</tr>
<tr>
<td>Hunters</td>
<td>1</td>
<td>0</td>
<td>1</td>
<td>2</td>
<td>1</td>
<td>5</td>
</tr>
</tbody>
</table>

As can be seen from Table 4.5, woodcutters receive a high score for contributions to vulnerability, because their potential to impact the area is great for woodcutting, and ORV use. In addition, woodcutters can affect large patches of forest very quickly, which gives them a high area factor and contributes to their high overall weight. Campers receive a much smaller weight because the majority of their impact potential is tied down in camping. They do relatively little woodcutting and use ORV sparingly. They also received a low area factor, because they produce little impact beyond the confines of the area in which they camp. Hunters, by far, received the lowest score contributions to vulnerability. Their impact potential is minimal, and the greatest potential problem among hunters is ORV use. However, because hunters have a relatively smaller footprint on the landscape than woodcutters, they receive both a smaller score for area and a smaller score for ORV use. Hunters are therefore weighted much lower.

These weights were applied to the above mentioned vulnerability raster images calculated with fuzzy logic. The resulting images were averaged to provide an overall view of vulnerability across the Upper Basin (Figure 4.20). After sampling the resulting image at the sites of previously recorded impacts (hearths and trash) to the landscape, this model predicts 77% of previously identified human impact events to fall within vulnerable and highly vulnerable areas.
Figure 4.20. Map of potential exposure to impacts (previous impacts in black) within the Upper Basin.

The Archaeological Record and Sensitivity

The disposition of the archaeological record is itself a factor (sensitivity) in the establishment of vulnerability of the ancient landscape and the sites within. In an area where off-road vehicle traffic is difficult to manage, the density of archaeological sites becomes an important issue. Where sites are the most dense, unrestricted travel stands a greater chance of impacting archaeological sites. The use of these dense areas in concert with the discussion of most sensitive site types (Chapter 3) will inform our discussion of sensitivity.
Archaeological Site Density

In order to explore the relationship between modern human behavior and site density in the Upper Basin, a GIS layer, which included every mapping unit recorded by the Upper Basin Archaeological Research Project, was used to create an archaeological density map (Figure 3.6.). The data were reclassified to represent 10 discrete sensitivity levels (Table 4.6). The areas with the highest sensitivity (high density of mapping units) were classified as level 10, while areas of low sensitivity (low density of mapping units) were classified as level 1. Figure 4.17 depicts the number of cells within the UBARP study area with values at specified sensitivity levels.

Table 4.6. Conversion table from sensitivity level to Density of Mapping Units.

<table>
<thead>
<tr>
<th>Sensitivity Level</th>
<th>Density of Mapping Units per Square Kilometer</th>
</tr>
</thead>
<tbody>
<tr>
<td>10</td>
<td>241-270</td>
</tr>
<tr>
<td>9</td>
<td>211-240</td>
</tr>
<tr>
<td>8</td>
<td>191-210</td>
</tr>
<tr>
<td>7</td>
<td>161-190</td>
</tr>
<tr>
<td>6</td>
<td>131-160</td>
</tr>
<tr>
<td>5</td>
<td>111-130</td>
</tr>
<tr>
<td>4</td>
<td>81-110</td>
</tr>
<tr>
<td>3</td>
<td>51-80</td>
</tr>
<tr>
<td>2</td>
<td>31-50</td>
</tr>
<tr>
<td>1</td>
<td>0-30</td>
</tr>
</tbody>
</table>
The histogram of archaeological density vulnerability levels shows that the surveyed area of the Upper Basin contains a large amount of land that is low in density sensitivity (Figure 4.21). However, this is somewhat misleading, as the area is still fairly dense (the lowest category is 0 – 30 mapping units per square kilometer). This study separates these numbers further into park and forest graphs to facilitate meaningful comparisons (Figures 4.22 and 4.23). Similar to previous graphs, the following figures only represent percentages of the respective jurisdiction and not of the Upper Basin as a whole.
The above figures (Figure 4.22 and Figure 4.23) show that Grand Canyon National Park has more area with high densities of archaeological remains than Kaibab National Forest. While
these figures are instructive for the calculation of the vulnerability model(s), they don’t provide easily interpretable results.

<table>
<thead>
<tr>
<th>Jurisdiction</th>
<th># of Units</th>
<th>Total Land (Km²)</th>
<th>Total MUs</th>
<th>Density</th>
</tr>
</thead>
<tbody>
<tr>
<td>GRCA</td>
<td>5</td>
<td>2.37</td>
<td>595</td>
<td>251/Km²</td>
</tr>
<tr>
<td>KNF</td>
<td>3</td>
<td>12.43</td>
<td>1699</td>
<td>137/Km²</td>
</tr>
</tbody>
</table>

As can be seen in the above table (Table 4.7), Grand Canyon National Park has a much greater density of archaeological remains than Kaibab National Forest. This trend is indicative of the general disposition of archaeological phenomena in the Upper Basin. Sites are usually more concentrated toward the rim of the canyon, located in Grand Canyon NP, and are much more sparsely placed as one moves south and into Kaibab National Forest.

Archaeological Site Sensitivity

While density is definitely a major concern in the archaeologically rich Upper Basin, adding to the discussion of vulnerability is the inherent sensitivity of sites on the landscape. As discussed earlier in Chapter 3, certain attributes of sites may make them more sensitive to the activities of visitors. These sensitivities were established with a graph of the severity of impacts found at each site type (Figure 3.8). To recap, scatters displayed the greatest severity of impacts; masonry structures and FCR piles came next; brush structures, alignments, and rock piles third, and then all other site types.

In order to visualize this information on the landscape these site types were given a number from 1 to 4, with 1 as all other site types (low sensitivity), 2 as brush structures, alignments and rock piles (somewhat low sensitivity), 3 as masonry structures and FCR piles (somewhat high sensitivity), and 4 as scatters (high sensitivity). These sites were then plugged
into the kernel density tool in ArcGIS to establish places where sites were both densely distributed and highly sensitive (Figure 4.24).

Figure 4.24. Density of sensitive archaeological resources in the Upper Basin with 1 being least density of high sensitivity and 5 being highest density and highest sensitivity.

As is shown in the above figure 4.24, sensitive resources are often concentrated near the SR 64 and also within the Kaibab National Forest. It is important to remember that there are sensitive sites throughout the Upper Basin, but, because sensitivity was only measured within the project bounds it can only be reliably visualized within the UBARP survey boundary.
Vulnerability

As previously discussed, vulnerability consists of multiple factors including exposure, sensitivity, and capacity to respond to threats. Combining the previously featured exposure map (Figure 4.20) and archaeological sensitivity map (Figure 4.24) of the Upper Basin into an overall vulnerability map (Figure 4.25) via raster math in ArcGIS helps to identify vulnerable areas that need more attention. This map presents vulnerability on a scale of 1 to 5, where 1 is very low vulnerability and 5 is very high vulnerability.

**Figure 4.25.** Distribution of archaeologically vulnerable areas within the UBARP survey boundaries.
Chapter 5: Conclusions

Previous chapters have identified issues facing federal land and resource managers, particularly those responsible for the Upper Basin of the Grand Canyon, when ensuring the preservation of archaeological resources. These managers need tools to economically and quickly assess resources for vulnerability, so that actions can be targeted towards specific areas that are most at risk. As this thesis has shown, there is great utility and flexibility in the use of GIS modeling as a method to quickly provide data to managers who need to take actions that are both small in scale, but have large impacts. In order to accomplish these goals, GIS models were successfully completed for the Upper Basin (Figures 4.17, 4.18, 4.19, 4.20, and 4.24). These models were also combined (Figure 4.25) to provide an overall vulnerability map for the Upper Basin.

Discussion of GIS Maps and Results

The overall utility of GIS in modeling risk to or vulnerability of archaeological resources is great. GIS provides a dynamic and flexible environment that can be easily modified based on the ever-changing conditions on the ground. It also provides an economical solution, where most cost is associated with the purchase of the program, and data are either generated by managers themselves or easily downloadable via the internet. The models generated here were each constructed using mostly free and field-collected materials (with the exception of the optional National Geographic TOPO! topographic maps and the time it took to gather UBARP archaeological database files). The results of this analysis are encouraging and prove insightful for management purposes.
Behavior Models

The generated models successfully accounted for a majority of previous impacts for all identified user-groups in the Upper Basin. These previous impacts may be continued areas of exposure to visitation for the archaeological record; however, the models presented above allow researchers, managers, and law enforcement personnel to focus on areas that have yet to be negatively modified by users of the landscape, in addition to managing already impacted areas. Separating the exposure of the area out by individual users also allows for targeted enforcement among certain user groups.

As determined by the maps generated in this analysis, each user group presents a different picture of exposure to impact. Based on Figure 4.17, exposure to camping is concentrated near SR 64. Though there are some slightly exposed areas along backcountry roads, the preference of camping groups for easy access to the major highway means that most of their activities will be concentrated near SR 64. Also, this map displays that exposure is high or very high near the road in both the forest and the park, though, in the case of the forest, the corridor of highly exposed and exposed areas extends much further than that of the park.

The preferences of woodcutters for areas further from the main road and for areas that have high tree density have created an exposure map (Figure 4.18) that displays highest potential for woodcutting towards the west and north of the Upper Basin. The western portion of the Upper Basin is susceptible because of its distance from major roads as well as high tree density. In the north, however, even though most national park lands are close to the major road, there are areas of great potential exposure due to the high density of the pinyon-juniper woodland. There
are also some small portions of the eastern Upper Basin that still show high exposure potential, most likely due to pockets of dense pinyon-juniper woodland.

The final behavior modeled, hunting, is also concentrated in the interior of the Upper Basin, this time towards the south-west, an area dominated by National Forest lands (Figure 4.19). This concentration is due to the area’s distance from SR 64, as well as the proximity of several clearings in the dense pinyon-juniper woodland that would attract large game animals such as elk and mule deer. Smaller portions of the eastern Upper Basin present higher potential exposure due to such clearings, as well as the presence of multiple back-country roads.

**Overall Exposure Model**

Where the results of the individual exposure models are encouraging, the results of the overall model are even more encouraging. This model consists of a combination of information from all three individual behavior models and shows similarities with all three of the individual behavior models (Figure 4.20). The resulting map provides a more refined view of exposure to visitor use in the Upper Basin. Like the camping model, this map shows high exposure potential in areas near to SR 64. Similar to the woodcutting and hunting models, there are also areas of high exposure potential corresponding to areas of high vegetation density and low vegetation density respectively.

**Overall Sensitivity Model**

The second portion of analysis involved identifying portions of the archaeological landscape that were highly sensitive to damage via visitor interaction. As previously identified in Chapter 3, scatters (lithic and/or ceramic) are most sensitive, followed by masonry structures and
FCR piles, then alignments, brush structures, and rock piles, and, finally, all other site types. These site types were given a weight based on their relative sensitivity. These were then used to create a weighted density model that shows both highly dense, but also highly sensitive, resources (Figure 4.24). The resulting map shows that sensitive resources are found throughout the project area in large and small concentrations. As mentioned before, this analysis cannot yet be extended throughout the whole of the Upper Basin due to lack of survey data throughout the area. However, if these concentrations are representative of the Upper Basin as a whole, there is great cause to consider much of the area sensitive to visitation.

How do these models relate to the vulnerability of archaeological resources in the Upper Basin?

This model provides generalizations that are intended for management use and not for pinpoint analysis. With that in mind the overall vulnerability model (Figure 4.25) shows that highly vulnerable areas are situated along SR 64 and near the main Forest Service entrance to the Upper Basin (FS road 682); a determination that supports previous UBARP research (Uphus et al. 2006). There are also areas of high vulnerability along the road in Grand Canyon National Park. These are areas that are highly exposed as well as having highly sensitive archaeological resources. This map can also show areas of low vulnerability, due either to low exposure or low sensitivity, such as in the far Northwest corner of the largest survey block, or the farthest Eastern portion of the same. It should be remembered that even areas that register as having low sensitivity or very low sensitivity may contain items that are highly sensitive.

Knowledge of the areas highlighted in Figure 4.25 enables resource managers to more effectively prioritize the protection and management of archaeological sites. This approach offers a flexible way to integrate archaeological site data and human behavior data to enhance
understanding of archaeologically sensitive areas. The study here does not make generalizations about the sensitive nature of archaeological sites, but provides specific geographic areas that are in need of more attention. The data here can be easily integrated with site forms and National Register of Historic Places information for even greater prioritization of archaeological monitoring. This approach is also easily changed over time, or for different situations, to be relevant to many different management concerns.

*Questions from the model?*

Like all scientific endeavors, these models not only provide answers, they also inspire questions. One of the major questions that arise from a close examination of the maps is that, while there are significant differences between the two jurisdictions, Grand Canyon seems to have a much higher percentage of vulnerable areas than might be expected (Figure 4.25). Confounding this issue is the fact that, while the maps may show the area as similarly vulnerable, Grand Canyon National Park has many fewer recorded impacts than Kaibab National Forest (Figure 5.1).

![Figure 5.1. Bar graph of impacts per square kilometer in the Upper Basin](image)
The above figure’s confounding effects can be explained as follows. First, Grand Canyon National Park and Kaibab National Forest display similar archaeological vulnerability because these areas are essentially part of the same environment. They would have the same types of usage by similar groups of visitors all other factors being equal. However, the single defining factor in why there are almost ten times as many impacts in Kaibab National Forest as in Grand Canyon National Park is management. As discussed in Chapter 2, the very goals of the National Park Service and the National Forest Service differ when it comes to recreation management, land-use, and archaeology. While for the National Park, the Upper Basin has been designated a day use only area, the National Forest manages this area with its current multiple-use management strategy. In theory, this strategy should allow for use of the area without significant impacts. However, huge numbers of visitors in concert with shrinking budgets, lack of effective enforcement, and lack of visitor education have made the resource preservation goals of multiple-use management untenable in the Upper Basin.

**Suggestions on Improving Management for Archaeological Resources in the Upper Basin**

*Visitor Education, Enforcement, and Monitoring*

A simple way to negate many of the impacts to archaeological sites in the Upper Basin is to improve visitor education (Chavez and Tynon 2008; Hoots 1976; Sullivan et al. 2002; Williams 1976). Many of the discussed impacts to the archaeological resources of the area are inadvertent. Visitors may be able to better avoid archaeology if they have more accurate knowledge about what to avoid.

In concert with greater visitor education, there also needs to be more enforcement. As mentioned in Chapter 3, enforcement has proven effective in many other jurisdictions to reduce
impacts to natural and cultural resources (Chavez and Tynon 2008; Hoots 1976; Williams 1976). This is, again, a difficult task when faced with the high cost of fielding many law enforcement personnel. Another alternative that is already being used to step up enforcement is the use of Forest Protection Officers. Though they are without arrest powers, these individuals can be of great service by educating visitors and issuing violations to offenders.

Going hand in hand with education and enforcement is monitoring. Monitoring is a constant necessity for resource management professionals. Without frequently updating the conditions of a site, degradation cannot be effectively tracked, new developments cannot be identified, and site information becomes ineffective at assisting the management process. Site stewards are an effective way to boost an agency’s monitoring ability while also educating local stakeholders about cultural resources and their vulnerabilities (Kelly 2007).

Alternatives to Current Use Policies

While this may be the least popular solution, changing current usage of the Upper Basin may be the only way to properly protect the archaeological resources within. One option is to establish more permanent accommodations in the form of a campground and/or ranger station in the Upper Basin on the side of the Kaibab National Forest. These facilities would help to focus the attentions of visitors away from sensitive resources, while also allowing them to enjoy and use the landscape.

Another way to garner interaction between visitors and trained personnel, and increase resource protection, is to require keyed entry into certain areas (Uphus et al. 2006). The requirement of a key or passcode to get into the area would force visitors to visit a ranger station or other similar facility to gain access. This would allow rangers to inform visitors of dos and
don’ts in the Upper Basin, and it would provide an opportunity for more education on the
archaeology of the area. The requirement of a passkey would also allow rangers to effectively set
limits and monitor visitation.

Another even less popular option would be to completely restrict access to the area and
end recreation in the Kaibab National Forest Portion of the Upper Basin. While this would be
extremely unpopular with the public, continued use of the Upper Basin without real changes to
management will result in even greater loss to archaeological resources of the area.

Suggestions for Further Research

Additions or changes to the Current Model

The beauty of this method and the vulnerability framing used here is that both are
endlessly customizable and able to be applied to many situations. One way in which this research
can be expanded upon is to use similar methods (i.e., fuzzy membership analysis) but change the
list of variables. Some variables that may be of interest and that were not discussed in this study,
include detailed range data of preferred hunting species, detailed range data on preferred
woodcutting species, and sensitive and erodible soil data.

While data on preferred species ranges may provide more detailed analysis in the way in
which hunters move across the landscape, for the purposes of this study, it was thought that
species ranges would be too coarse in scale to be of much use. However, species data may be
used to greater effect in situations where this approach was applied on a much larger extent.

NDVI proved to be an effective use of satellite remote sensing data displayed to help
solve real world management issues. It provided an excellent source of information about
vegetation, but it only displayed information about overall vegetation and not specific species
that may be preferred for woodcutting. Whether mapped with GPS or calculated via satellite remote sensing software, specific vegetation species data may provide a much more detailed viewpoint of where woodcutting is likely to take place in small and large scale models.

While it was initially a candidate for inclusion in this study, soil data are unavailable in GIS format for the Kaibab National Forest. Soils can provide information about erosion potentials due to activities such as camping, woodcutting, or off-road vehicle use. These data, similar to the archaeological density data, would help to identify not just where people were most likely to impact, but where impacts would be the most harmful (i.e. cause greater erosion).

Involving Stakeholders

The models presented here use environmental data, government policies/practices, and locations of previous visits to calculate areas where visitors to the Upper Basin are most likely to go. Another approach to modeling that has been used recently is to poll a group of stakeholders (experts or not) on where they predict an action or item to occur. In one example, a group of archaeologists were asked where there was the highest potential for sites on the landscape (Mink et al. 2009). This information was then used to build a prediction model based on the responses of these professionals. In a similar manner, this study may benefit from the input of both users and managers who have greater insight and experience with the repeated use of the Upper Basin.

Expansion of the Survey

Continued survey and expansion throughout any project is important. Without a representative sample of human behavior throughout the entire Upper Basin, trends in modern behavior will be difficult to fully understand. In addition, areas already surveyed may be subject
to varying trends throughout time. Repeated visitation to areas already surveyed is necessary to allow for monitoring diachronic changes in behavior patterns.

Conclusions

The utility of GIS in identifying issues of risk to archaeological sites cannot be overstated, especially in light of the results of this study. The flexibility of such a system is virtually endless, and is only limited by the ability to either produce or obtain, through third parties, a dataset. The datasets used are endlessly modifiable to cater to the specific situations of particular landscapes that require different parameters to be emphasized. The datasets created here are also easily changed to reflect changes in management or preservation.

Vulnerability theory plays an important role in the execution of this study. It not only allows for the framing of thoughts about the components of at risk archaeological sites and landscapes, it also provided the basic framework for the functions performed during the GIS analysis of vulnerability. The basic process of creating sensitivity maps and exposure maps then combining them to form a vulnerability map is an actualized form of the conceptual theory of vulnerability. It is also an excellent example of how archaeology can use information from other disciplines, such as human ecology, to solve unique and complex problems.

This thesis also highlights certain inequities of archaeological preservation between management agencies on the South rim of the Grand Canyon. Even within the same, or similar, environments these differences remain. While some of the variance can be attributed to fundamental differences in the way that the two managing agencies were created, funding, and management practice play large roles in how the archaeological preservation of this landscape is realized. The National Park Service has been, at its core, an organization focused on preservation.
of resources for the sake of preservation and recreation. The Forest Service is an organization focused on use of land as a resource for recreation, business, energy, timber, and a host of other activities. This is not to say that the Forest Service is not focused on or dedicated to preservation, but this is not structured as the highest priority. Regardless, the Forest Service has a mission to protect archaeological, and other, resources while also providing for the use of the forest by the public.

On the South rim of Grand Canyon, the potential for impacts to the archaeological landscape is strikingly similar on both National Park Service and US Forest Service parcels. Dissimilarities begin to appear when one considers the actual number of impacts to archaeological sites. The Forest Service’s mission of protecting archaeological resources has come at odds with its mission to provide for the many uses it allows in this area. Archaeological resources within the Kaibab National Forest are suffering as a result.

Funding can certainly be blamed as a major factor in the difficulty of preservation. With frequent budget cuts, and the subsequent shifting of funds, archaeologists need innovative strategies and alternative methods to integrate visitor use, environmental, and archaeological site information in a way that helps to prioritize areas where archaeology will be impacted the most. This thesis provides visual interpretations of areas with high risk for archaeological impacts, as well as providing information about areas with low potential impact. While the data presented here provides information across only a small portion of the Upper Basin, this type of approach can be used on a larger scale to provide prioritization information about entire Ranger Districts or Forests.
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Lei, Simon


Lynch, J.

Magee, Kevin S.

Milner, George R., Clark Spencer Larsen, Dale L. Hutchinson, Matthew A. Williamson and Dorothy A. Humpf

Mink, Phillip B., John Ripy, Keiron Bailey, and Ted Grosshardt

Morehouse, Barbara J.

Muckel, Gary B. (editor)

Muir, John

National Parks Conservation Association

National Park Service


National Trust for Historic Preservation

Parcak, Sarah H.

Pickering, Catherine Marina

Powell, John Wesley

Reid, Basil A.

Roos, Christopher I.

Rossmo, D. K.


Tainter, Joseph A. and Bonnie Bagley

Taylor, J. H. and W. R. Gill

Taylor, James Y.

Turkowski, Frank J. and Hudson G. Reynolds

Turner, B. L., II, Roger E. Kasperson, Pamela A. Matson, James J. McCarthy, Robert W. Corell, Lindsey Christensen, Noelle Eckley, Jeanne X. Kasperson, Amy Luers, Marybeth L. Martello, Colin Polsky, Alexander Pulsipher and Andrew Schiller

United States Department of Agriculture, Forest Service


United States Department of the Interior, Fish and Wildlife Service
Uphus, Patrick M., Alan P. Sullivan III, Philip B. Mink II.  

Vankat, J. L.  


Wallin, Thomas R., and Carol P. Harden  

Weaver, T. and D. Dale  

Wilcox, Bradford P  

Wildesen, Leslie E  

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Zadeh, L. A.  