2025

WUPATKI PUEBLO

PRESERVATION MANAGEMENT PLAN

Wupatki National Monument, Flagstaff, AZ

WUPATKI PUEBLO

PRESERVATION MANAGEMENT PLAN

Acknowledgments

This report is made possible with support from the J. Paul Getty Trust.

We gratefully acknowledge the diverse, distinct, and vibrant Native peoples since time immemorial whose direct descendants continue to celebrate the ancestral homelands and make their home at Wupatki National Monument today. This acknowledgment honors the unbroken ties between Indigenous Peoples and their traditional lands.

In undertaking the 3-year research for this project, we acknowledge the support of National Park Service staff from the Flagstaff Area National Monuments: Amy Horn, Kelsey Vaughan-Wiltsee, and Shayna Marks. We thank Gwenn Gallenstein for generously contributing time and effort for assisting in archival research at the Museum of Northern Arizona. We are grateful to Ian Hough and Evan Oskierko-Jeznacki at Vanishing Treasures for continued support throughout the project.

The research and assessment of Wupatki Pueblo was informed by the knowledge and research of Laura Gambilongo, Paulo Lourenço, Alberto Barontini, Rui Silva, and Rafael Ramírez Álvarez de Lara from the Department of Civil Engineering at the University of Minho, Portugal.

Finally, graduate students at the Center for Architectural Conservation at the Weitzman School of Design, University of Pennsylvania greatly contributed to carrying out many aspects of this report.

All graphics, images, and photographs are credited to the CAC, unless otherwise noted.

Prepared by: Ha Leem Ro, Frank G. Matero

PD#: 10079513 / Reference #: ORG-202148418

THE CENTER FOR ARCHITECTURAL CONSERVATION   Weitzman SCHOOL OF DESIGN UNIVERSITY of PENNSYLVANIA   NATIONAL PARK SERVICE   Getty

Table of Contents

INTRODUCTION TO THE PRESERVATION MANAGEMENT PLAN

1

1 Introduction to the Preservation Management Plan

1.1. Background

Wupatki Pueblo (WUPA 2676) is located approximately 45 miles from Flagstaff, Arizona built upon a natural sandstone outcropping forming the southern boundary of Wupatki Basin. Nine hundred years ago, it was the largest trading center for 50 miles; now, the 100-room pueblo is the largest free-standing pre-contact structure in Northern Arizona. Its scale reflects the influx of diverse Indigenous communities from across the Southwest, evinced by the variety of architectural styles, ceramics, and burial practices present at the site. A total of thirteen federally recognized tribes are associated with Wupatki National Monument (WUPA NM) today.

Although these communities migrated from the area in the late 13th century, the Pueblo continues to hold deep spiritual meaning for the Native communities who believe the people who lived and died here remain as spiritual guardians. As such, Wupatki Pueblo embodies the histories of the ancestors who built and occupied it as well as those who continue to help care for it for future generations.

Since the excavation of its standing architecture in the 1930s, Wupatki Pueblo has been preserved and interpreted under the stewardship of the National Park Service (NPS). As at many historic sites, preservation of the Pueblo has been limited by available funding and resources.

Given the realities of managing a 35,254-acre national monument and also within the context of changing environmental conditions, it is critical to update existing preservation and management strategies to prioritize resources and funding, and more importantly, to continue to move from reactive to proactive/preventive conservation and care.

The Wupatki Pueblo Preservation Management Plan (PMP) will be a critical tool for informing and shaping that strategy as NPS works to implement a long-term resource management program. The PMP offers a unique opportunity for the NPS to assess the escalating climate risks to the standing architecture of Wupatki Pueblo, develop resilience and adaptation guidelines, and advance a strategic plan for implementation.

The Center for Architectural Conservation (CAC) at the Weitzman School of Design, University of Pennsylvania completed this work in partnership with the University of Minho (UM), Portugal through funding from the Getty Foundation.

Like many ancestral sites with substantial standing architecture, Wupatki has deferred capital needs, existing obsolescent treatments, and limited operating resources whose vulnerability is now compounded by climate-related risks.

Through this project the team developed a risk and vulnerability assessment for readily-deployable tools to enable NPS to consider new preservation and management strategies to help mitigate climate change and related vulnerabilities and to provide capacity building in site preservation training to local tribal community partners.

1.2. Plan Objectives

This PMP for Wupatki Pueblo was developed as part of the 3-year project seeking to address the following objectives:

1) Develop methods and standards for archiving and accessing legacy data (e.g., past stabilization/treatment records, historic photos, etc.);
2) Update site documentation methods and systems;
3) Develop multi-scalar conditions recording and assessment;
4) Update treatment methods, materials, and evaluation standards, and;
5) Renew stakeholder consultations and professional training including a program for preparing Native American youth for careers in cultural resource management.

The PMP therefore offers a set of guidelines and methodologies that can be used to inform future planning, preservation, and maintenance of the stone masonry at Wupatki Pueblo.

The purpose of this document is to provide park management staff with the background data needed for the physical preservation of the park's standing architecture. It should also serve as the component of planning and management that guides the daily and long-term site preservation activities within the park. While the preservation and management strategies and guidelines provided in this document are applicable and transferable to other similar sites in WUPA NM, this document is specifically tailored for Wupatki Pueblo.

▲ *Panoramic view of Wupatki Pueblo.*

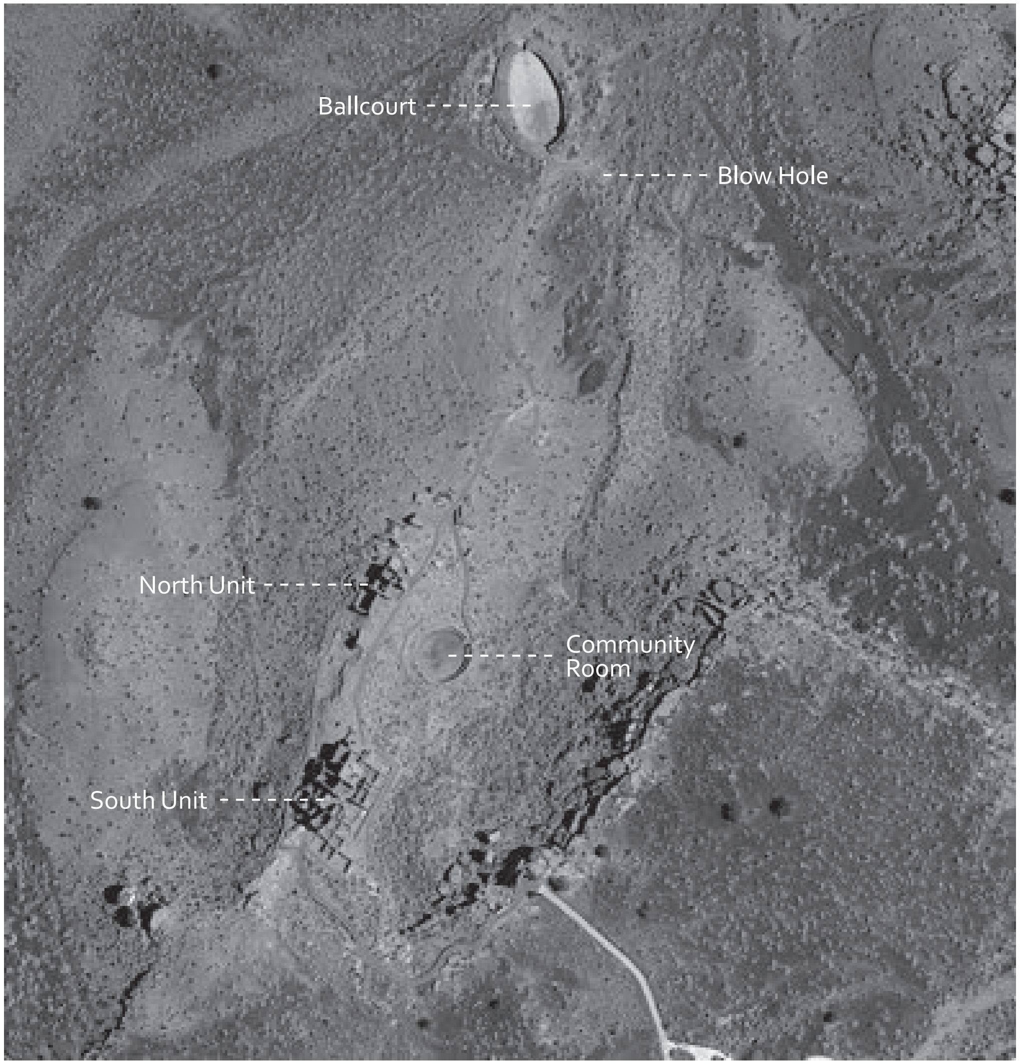
1.3. Wupatki Pueblo Site

Wupatki Pueblo is located at within Wupatki National Monument, which was initially established in 1924 as a much smaller area focused around Wupatki and Citadel Pueblos.

As one of the first units incorporated into the monument in 1924, it is now situated within the 35,253 acres of monument boundaries.

This PMP addresses the constructed elements of Wupatki Pueblo. For the purposes of this document, "Wupatki Pueblo" refers to the site as a whole, consisting of five distinct architectural units including the South Unit, North Unit, Ballcourt, Community Room, and the Blow Hole.

These terms are used throughout the PMP and identified on the Base Site Map. These names are based on historical documents and existing terms used by cultural resource and site management.



▸ *Area Scope of Wupatki Pueblo PMP (Source: Google Earth).*

1.4. Ownership and Heritage Status

Wupatki Pueblo is currently under the stewardship of the NPS, specifically as part of the Flagstaff Area National Monuments (FLAG NM). Because of historical circumstances, the federal government has a unique set of legal obligations and mandates in place for Native American tribal entities. These efforts include preserving and helping to perpetuate traditional cultural values and allowing continued access to traditional sacred sites.

WUPA NM is traditionally associated with the following Tribes:

- Fort McDowell Yavapai Nation, AZ
- Havasupai Tribe of the Havasupai Reservation, AZ
- Hopi Tribe of AZ
- Hualapai Tribe of the Hualapai Indian Reservation, AZ
- Kaibab Band of Paiute Indians of the Kaibab Indian Reservation, AZ
- Navajo Nation, AZ, NM, UT
- San Carlos Apache Tribe of the San Carlos Reservation, AZ
- San Juan Southern Paiute Tribe of AZ
- Tonto Apache Tribe of AZ
- White Mountain Apache Tribe of the Fort Apache Reservation, AZ
- Yavapai-Apache Nation of the Camp Verde Indian Reservation, AZ
- Yavapai-Prescott Indian Tribe, AZ
- Zuni Tribe of the Zuni Reservation, NM

Consultation efforts with these tribal affiliates are ongoing at WUPA NM.

Wupatki was established as a National Monument in 1924 and listed on the National Register of Historic Places (NRHP) on October 15th, 1966. All of the archeological sites within its boundaries, including Wupatki Pueblo are determined to be eligible for the National Register of Historic Places by the Arizona State Historic Preservation Office (SHPO).

▸ *Tribal members at Wupatki Pueblo, 2023.*

1.5. Preservation Management Plan Methodology

A Preservation Management Plan is a document that outlines the significance and values of a place, followed by policies and guidelines that help managers to retain that significance into the future. It aims to provide long-term consistency in the methodologies employed for the conservation and management of the place by evaluating current philosophies of approach, and establishing discrete modules of activities that define contemporary "best practices" in the recording, documentation, monitoring, treatment, and information management of the park's primary cultural resources.

A significant part of this particular project focused on creating a critical conservation history of Wupatki Pueblo by assembling and assessing all available archival records into a relational database that allows cultural resource managers to make better informed decisions by easily identifying past actions and prioritizing areas of specific interests or need.

This was followed by updating baseline documentation of the site including site maps and an identification system of architectural features in order to improve on digital data coordination and management.

In August of 2022, the CAC carried out the first iteration of the Rapid Assessment Survey (RAS) developed to identify high-risk areas. A more detailed conditions survey followed for those resources identified as high priority. Vulnerabilities and risks, both at the material and management levels, were identified throughout the process by reviewing previous research and with additional research by the Department of Civil Engineering at the University of Minho.

Analysis and synthesis of the data collected informed the identification of existing conditions, vulnerabilities, and conservation and management policies and treatment options outlined in this PMP.

1.6. Organization of the Preservation Management Plan

The PMP is organized into two volumes: Volume 1, the main plan for Wupatki Pueblo, and Volume 2, the Historic Preservation Guide (HPG), which includes practical "manuals" and appendices to support the proposed preservation management program. It also contains relevant appendices for additional context and resources. PMP chapters address the project background, methodology, site history (with emphasis on past preservation efforts), current conditions, vulnerabilities and risks, conservation policies, operational guidelines, and future recommendations. The HPG consists of modules outlining "best practices" for recording, documentation, monitoring, and data management across various stages in site preservation and management.

To enhance usability, the document includes cross-references in blue and red to guide readers to relevant HPG manuals in implementing the preservation program and supplementary materials in the Appendices respectively.

1.7. Limitations

This PMP specifically addresses Wupatki Pueblo, which consists of five discrete units: South Unit, North Unit, Community Room, Ballcourt, and Blowhole. However, as the preservation and management framework outlined in this document was intended to be incorporated into the existing preservation and management program at WUPA NM, many of the guiding philosophies and tools provided may be applicable to other, but not all, maintained archeological sites in the monument, particularly relevant to other frontcountry sites in the Extended Learning Zones. In other words, the preservation philosophies, guidelines, and policies discussed in this document may not be suitable for other sites within monument boundaries categorized as other management/visitor experience zones.

The PMP is a management tool and a reference document; it does not include specifications for work, detailed cost estimates, or work plans.

The PMP was sent to 13 associated tribes for their review in November 2024. No comments were received.

1.8. Acronyms

Acronyms used in the PMP are listed below in alphabetical order:

- ACHP: Advisory Council on Historic Preservation
- ALCC: Ancestral Lands Conservation Corps
- CAC: The Center for Architectural Conservation at Weitzman School of Design, University of Pennsylvania
- CCC: Civilian Conservation Corps
- CWA: Civil Works Administration
- FLAG NM: Flagstaff Area National Monuments
- HPG: Historic Preservation Guide
- IPCC: Intergovernmental Panel on Climate Change
- MNA: Museum of Northern Arizona
- NAGPRA: Native American Graves Protection and Repatriation Act
- NAU: Northern Arizona University
- NEPA: National Environmental Policy Act of 1969
- NHPA: National Historic Preservation Act of 1966
- NOAA: National Oceanic and Atmospheric Administration
- NPS: National Park Service
- NRHP: National Register of Historic Places
- PMP: Preservation Management Plan
- RAS: Rapid Assessment Survey
- SOI: Secretary of the Interior
- SOW: Scope of Work
- USGS: U.S. Geological Survey
- VT: NPS Vanishing Treasures Program
- WPA: Works Progress Administration
- WRCC: Western Regional Climate Center
- WUPA 2676: Wupatki Pueblo
- WUPA NM: Wupatki National Monument
- WX: Weather

Front & Chapter Cover: Wupatki Pueblo & CAC crew at Wupatki Pueblo, 2022 (Credit: Ha Leem Ro, Colin Cohan).

SITE PRESERVATION HISTORY 2

2 Site Preservation History

2.1. Overview

Today, Wupatki Pueblo contains approximately 80 rooms arranged in tiers up to three stories high. The Pueblo is divided into two spatially separated room blocks called the North and South Units. The open area between these two units remains unexcavated and lacks remnant prehistoric standing walls, although a historic dry-laid wall connects the two areas. The two units were originally linked by additional rooms and a plaza. In addition to the size and visual prominence of the Pueblo itself, the architecture of Wupatki is notable for the associated masonry-lined Ballcourt located a short distance northwest of the Pueblo and a large, unroofed circular "Community Room" immediately east of the Pueblo, which has been variously referred to as an "amphitheater", "dance plaza", or "great kiva".

The Pueblo is built around and on top of a prominent outcrop of Moenkopi Sandstone near the base of Woodhouse Mesa, a basalt lava flow that forms the southern boundary of Wupatki Basin. Situated within the Basin, this area is one of the lowest, warmest, and driest major landforms on the Colorado Plateau. It lies outside of the Grand Canyon, Glen Canyon, and other major canyon settings. The Pueblo's surrounding climate features generally hot summers and cold winters. Weather records collected for WUPA NM beginning in the later half of the 20th century show average temperatures ranging from 35.2°F in January to 79.9+°F in July, with maximum temperatures occasionally exceeding 110°F, and with winds typically flowing out of the west or southwest. Further analysis of weather data in conjunction with the data collected from the new Onset® HOBO®weather station installed in summer of 2022 reveals that the average temperature has risen by 3°F, from 55.7°F in 1940 to 58.2°F in 2023. Maximum temperatures plateaued around 72°F and minimum temperatures increased from 43.5°F to 46°F. This is indicative of increasingly mild winters and consistent summer conditions. As for wind patterns, prevailing winds are predominantly coming from the southwest, followed by the northwest, averaging around 10 mph.

In the context of a changing climate, it can be expected that these trends may continue to change in the upcoming years (See Chapter 5, "Assessing Vulnerability: Adapting to Climate Change" for a detailed discussion on climate-related issues surrounding Wupatki Pueblo).

The Pueblo is constructed mostly of semi-shaped Moenkopi sandstone, basalt cobbles, and earthen mortar made from clay-rich deposits procured from Wupatki Basin and nearby volcanic mesas.

Scholars have also noted that wooden features (e.g., vigas) made of high elevation tree species like ponderosa pine, spruce, and fir, as well as certain cultural artifacts (e.g., obsidian and non-local pigments; remains of parrot species from tropical regions) found in the structure were sourced from distant areas. Wupatki Pueblo has therefore been described as a regional trade center and a cultural nexus, where people of many prehistoric cultures of northern Arizona exchanged goods, traditions, and ideas.

2.2. Site Evolution

Wupatki Pueblo was constructed between the late 1000s and early- to mid-1200s. Occupying an area of approximately 3,700 square meters, it is estimated to have contained about 100 rooms at its maximum build-out phase. The rooms served a variety of residential, storage, and ceremonial functions, reflected in varying room sizes, construction details, floor features, and associated artifacts. Although never more than four stories tall, the Pueblo's construction around and on top of the sloping base of the Moenkopi Sandstone outcrop created the appearance of a five-story dwelling. During the late 12th century, the peak period of its occupation, Wupatki Pueblo was the largest dwelling in the Sinagua region and probably in northern Arizona generally. An estimated 120 people lived in the village during its maximum period of occupation, ca. CE 1130-1200.

The North and South Units are believed to be have been occupied at the same time with the growth of the Pueblo understood to be outward and upward from the core rooms built against the rock outcrops.

Tree-ring records indicate that significant building stopped by CE 1215. Archeological excavations showed that other rooms and walls surrounding them created a definite enclosed plaza or courtyard spaces with an especially noteworthy construction of a very high retaining wall on the west side of the Pueblo. This was most likely built for trash and earth fill, providing an elevated flat surface adjacent to the room blocks.

There were no exterior ground floor doorways that opened to the outside of the Pueblo; entry to rooms on the outer perimeter of the Pueblo was exclusively through roof openings.

Left unoccupied by the early 13th century, the Pueblo was first documented in 1851 during a U.S. Army exploring expedition led by Brevet Captain Lorenzo Sitgreaves.

▲ *Sketch by R.H. Kern on the U.S. Army Exploration Expedition led by Lorenzo Sitgreaves in 1851 of the North and South Pueblo Units. The report describes the Pueblo "covered with the lava deteritus, and all the prominent points occupied by the ruins of stone houses in considerable size, and in some instances of three stories in height....evidently the remains of a large town..." in Lorenzo Sitgreaves, Report of an expedition down the Zuni and Colorado Rivers §, 69 (1853). p. 9. Much of the current masonry remains the same.*

Archaeological excursions followed throughout the early 20th century, eventually leading to the Pueblo's incorporation into Wupatki National Monument, established by Presidential Proclamation on December 9, 1924. Jesse Walter Fewkes was the first to map and set up a classification scheme for the different units in the Pueblo (i.e., Section A for South Unit and Section B for North Unit) after his visit in 1900. 30 years later, the first authorized excavation project was conducted by Harold S. Colton with the Museum of Northern Arizona (MNA) and the Civil Works Administration (CWA), when the name "Wupatki", meaning "tall or long cut house"in Hopi, and the site number NA 405 was officially assigned to the Pueblo. Much of the effort expended during this period also consisted of clearing and reconstructing rooms to their envisioned prehistoric appearance as well as addition of features for visitor access.

Under the NPS's stewardship, the nature of works carried out at WUPA 2676 shifted towards stabilization for visitation, shaping the site to its current configuration.

▲ *One of the earliest photographs taken of Wupatki Pueblo in 1904; view looking west (Credit: Earle R. Forrest; Museum of Northern Arizona)*

By the 1950s, all the 1930s reconstructions were removed and the structure comprehensively stabilized. The last recorded archaeological excavation at WUPA 2676 occurred in 1965, focusing on the Ballcourt and Blow Hole, followed by their reconstruction.

Today, WUPA 2676 is a heavily developed archaeological site with a paved parking lot, concrete sidewalks, a 1938 staff residence, a modern Mission 66 visitors' center, a paved walkway with steel handrails, an overlook with a concrete retaining wall, rooms and walls that have been stabilized with cement, and many other modern improvements. Despite these additions, the Pueblo largely retains its integrity with a vast majority of its wall stones in their original place and appearance, except for areas stabilized with cement mortars and relaid (i.e., capstones). The NPS continues to focus on stabilizing the structure to maintain the original form and the outline of the Pueblo, although the ways in which they have approached preservation have also changed over time as discussed in the following section.

2.3. Preservation History

Preservation activities have occurred almost every year at Wupatki Pueblo since its excavation in 1933 (with the exception of longer gaps between 1943 and 1952; between 1953 and 1960; and 1964 and 1978), with the activities performed summarized in "annual" reports. The following discussion of past preservation efforts at WUPA 2676 is therefore organized by decade.

Discussions for works pertaining up through the year 2000 are derived largely from Brennan and Downum's Report of Findings Prestabilization Documentation for Wupatki Pueblo (NA 405) Wupatki National Monument (2001). Summary of work completed post-2000 is based on annual preservation reports drafted by the WUPA NM. For more information on various stabilization activities and projects discussed here, refer to the bibliography provided in this chapter.

1930s

Wupatki Pueblo was the first site in the Monument to be stabilized. Much of the earlier preservation efforts focused on addressing issues surrounding the disturbances and reconstructions by the MNA) and CWA. Harold S. Colton began detailed mapping and excavation of WUPA 2676 in the late 1920s. An extensive excavation project was initiated by MNA in 1933, utilizing Works Progress Administration (WPA) workers and later, the Civilian Conservation Corps (CCC). Colton's work at WUPA 2676 was initially designed to excavate and stabilize portions of the Pueblo in order to make the resource available for public visitation.

During the 1933 excavations, which focused on part of the South Unit, restoration of Rooms 35, 36, and 44 was completed, and the walls of the excavated Community Room were capped. With the continuation of the excavation in 1934 as a CWA project, Rooms 1, 2, and 4 were restored and reconstructed. Wall restoration was also completed in Rooms 41, 60, 62, 63, and 68; in addition, a large number of walls in both the North and South Units were capped. At this time additional stabilization was necessary in the northwest corner of Room 35.

By March 1934, it was also necessary to repoint the walls in Room 4. Following the dissolution of the CWA project in April 1934, Wupatki was without a custodian in residence until James W. Brewer became the ranger in August 1934.

During Brewer's tenure, several projects were completed at WUPA 2676. Rooms 36 and 63 were reconstructed as living quarters for Brewer and his wife, Sallie.

▲ *The debris surrounding Wupatki Pueblo would be gradually removed throughout the early 20th century. Through the works of MNA and CWA, parts of the structure were rebuilt, restored and repurposed at various times and with different technical approaches (1934; Credit: Arizona State Library).*

This conversion necessitated rather extensive interior work, including plastering the walls and repairing the restored roofs. Room 41B was dismantled and rebuilt as part of the ranger quarters during this time period, though records of this change are missing. Brewer also installed a drain in Room 49 at Wupatki and dug a drainage channel in Room 7 from the ventilator to the outside of the room. By the summer of 1935, issues with the initial CWA work began to surface; the wall and roof reconstructions in Room 35 were removed and replaced, and minor repairs were needed in Rooms 1 and 4. Wupatki also served as a testing ground for various chemical stabilization methods during the 1930s. In April 1935, preservatives were applied to Room 41 and to exposed floors and firepits in Room 28. In early 1936, drainage improvements were made to Room 72, and roof work in Room 63 was completed, requiring additional work in August.

During August and September of 1937, further repairs were necessary on the restored roof of Room 1 at WUPA 2676. In November 1938, David P. Jones, the newly appointed custodian of Wupatki,

▲ *David Jones putting a roof on the refrigerator room at Wupatki Pueblo in 1938 (Credit: Ted Nichols,* Letters From Wupatki*).*

restored part of Room 51's south wall, removed CWA capping in Rooms 49, 50, and 51, and recapped them. By the following summer, leakage in several of the restored rooms had become serious, prompting Jones and two CCC workers to slope the roofs during July to improve drainage.

Soil cement (five parts soil to one part cement) was used as early as 1933-34 and perhaps into the 1940s. Tinted and untinted cements from this period were used until the 1980s.

1940s

Stabilization projects throughout 1940s continued to revolve around repairing the reconstructed rooms. Wupatki, like other Southwest National Monuments, suffered from severe understaffing, leading to significant neglect by 1940. In response, Custodian Jones, Collaborator A. E. Buchenberg and Engineer E. F. Preece undertook several emergency stabilization projects including the stabilization of the east wall of Room 41 in the later half of 1941 with the installation of an iron beam support.

Some of the stabilization works were experimental in nature, particularly that of Buchenberg's chemical preservation testing and repointing and capping of walls at WUPA 2676 with various mortar mixtures during 1941.

Methods for shifting to a more regular maintenance program were also introduced at this time. Between October and December 1941, Albert H. Schroeder surveyed a number of major sites, including WUPA 2676, at the Monument to assess stabilization needs.

Shroeder's project marked a shift in the cultural resource management strategy by incorporating survey forms and photo documentation to delineate previous stabilization materials from original fabric and record concurrent stabilization work. Documentation of subsequent stabilization projects has followed the same format, incorporating stabilization surveys and photographs into a larger narrative report describing the work conducted.

▲ *Room 41 after excavation in 1941; the east wall is later stabilized with a steel turn buckle and iron beam support (Credit: MNA).*

▲ *A. E. Buchenberg testing soil samples mixed with varying amounts of preservative in 1940 (Credit: MNA).*

1950s

In 1952, the first full-scale stabilization was undertaken at WUPA 2676 since the original excavation. The 1952 project was the result of a change in NPS policy stressing preservation rather than restoration. In conjunction with the Wupatki stabilization, 18 rooms were excavated. These 18 rooms, along with the 37 rooms excavated in 1933-34, were all stabilized in 1952; the amount of stabilization necessary in each room was highly varied. All of the restorations completed in 1933- 34 were removed; this work included returning Rooms 36, 41B, and 63 to an approximation of their pre-1933 condition. The modern roof in Room 63 had been removed sometime prior to 1952, but there is no record of this project.

In 1953, NPS completed an extensive drainage installation project throughout the Pueblo. Prehistoric features such as ventilators were sometimes converted into drains, and modern drainages were built in both the North and South Units, though work in the South Unit was primarily restricted to the east side of the Pueblo.

A major change occurred in materials with the introduction of Portland cement at this time, viewed as a "magic bullet" for preservation workers for its durability and versatility. With an increasing workload to meet the demands of increasing visitation to the site, stabilization projects quickly became dependent on the material to "harden" the site. Often tinted to match the original mortar or at least to approximate a uniform appearance, the cement was tempered with either sand varying from fine-grained to large inclusions as well as cinders. These practices continued until the 1970s, marking the evolving preservation methods and formulations over time.

◄ *Reconstructed parts of Wupatki Pueblo were "turned back" to their earlier appearance following NPS's shift to preservation in 1950s. Reconstructed portion of the south wall of Room 44 (left) is removed in 1952 (right) (Credit: NPS).*

1960s

The NPS completed another large-scale stabilization project at WUPA 2676 in 1964 under the direction of Charles Voll and Martin Mayer. Capstones were reset, mortar joints repointed, and floors were backfilled and graded for drainage in almost all rooms of the Pueblo.

It was apparently during this project that two dry-laid walls were built between the North and South Units in an attempt to keep visitors from crossing over unexcavated rooms into the Room 12 area.

In 1965, the Wupatki Ballcourt was excavated and reconstructed under the direction of Alexander Lindsay and George Gumerman from MNA. The Blow Hole located near the Ballcourt was also opened, and a masonry block was built around the opening of the Blow Hole.

1970-80s

Numerous small-scale stabilization projects were carried out at Wupatki Pueblo during this time. It was during this period when cyclical maintenance stabilization became more of a regular program at WUPA NM. Most of the work included assessing every room for stabilization needs, resetting loose capstones, and repairing eroded walls (e.g., repointing, grouting).

NPS began to shift away from "hardening" sites and logically the material of choice for stabilization changed from cement to an acrylic emulsion amended soil mortar. Introduced in the 1980s, Rhoplex™ E-330 continued to be used as a mortar amendment until 2021.

▲ *Excavation of the Ballcourt in 1965 (Credit: NPS).*

▲ *Masonry wall being constructed around the Blow Hole in 1965 (Credit: NPS).*

1990-2000s

Routine cyclical maintenance stabilization projects continued throughout this period. In 1997 and 1998, preservation activities focused on needs of the North Unit of the Pueblo (Rooms 1-5,7-10,12, and 15), plus the resetting of a loose lintel in Room 4 and the addition of a rubble buttress on the exterior of Room 5. The modern step that provided access to Room 3 was removed and the gap was filled with several courses of stone set in Rhoplex amended mortar. Also, a dry laid wall was constructed near the entrance to Room 35 to keep visitors from wandering off-trail in that area.

Although not a preservation project per se, intensive architectural documentation of WUPA 2676 was initiated in 1996 and continued through 2000; the project was carried out by both NPS employees and Northern Arizona University (NAU) graduate students working together under an NPS-NAU cooperative agreement. The resulting deliverable was the Report of Findings Prestabilization Documentation for Wupatki Pueblo (NA 405) Wupatki National Monument (2001), the most extensive study to date detailing the Pueblo's excavation, stabilization, and maintenance history up to the year 2000. In 2001, the NPS published the "Ruins Preservation Plan and Implementation Guidelines for Wupatki National Monument," outlining the preservation program and guidelines and standards for its implementation.

2010-2020s

Since the adoption of the 2001 Preservation Program, individual units in the Pueblo have been assessed and treated on a rotating schedule. Data recording forms and documentation requirements also became more standardized by the end of the 20th century. By far the most advantageous development during this period is the increased use of documentation as a preservation tool. Stabilization efforts continue to focus on comprehensive recording of the existing features as well as the works performed.

The preservation approach by NPS has drastically shifted from heavy to minimal physical intervention to maintain what remains of the original fabric while providing public safety; stabilization efforts continue to focus on resetting capstones, repointing mortar joints, and adding/removing fill for water control.

The most recent change in the mortar amendments has been the shift from Rhoplex™ to ParexUSA® Adacryl (chemically similar products) as the mortar amendment; the material was tested in the field in 2021 at WUPA 2676 and the Park fully transitioned to Adacryl in 2022, given its availability in smaller quantities, making it easier to purchase and store.

In the summer of 2022, the project to develop an integrated site conservation and management plan for WUPA 2676 was initiated. The project was carried out by the CAC with partnerships with the NPS and the structural engineers from the UM, Portugal. This document is the direct product of the project updating the existing preservation plan for WUPA 2676 in the context of changing environmental conditions and threats.

Wupatki Pueblo Change Over Time in Photographs

The 1930s was a time of big change for Wupatki Pueblo. Following archeological excavations as well as the site's incorporation into a national monument, the Pueblo was partially restored, most likely prompted by the disrupted stability of the site and increased public visitation.

1933-34

▸ *1934 excavation and restoration in progress for Rooms 62, 63, 35 in the South Unit (Credit: NPS).*

2022

◂ *Same view of the South Unit with all the reconstruction removed. Also note the widened crack in the boulder.*

1933-34

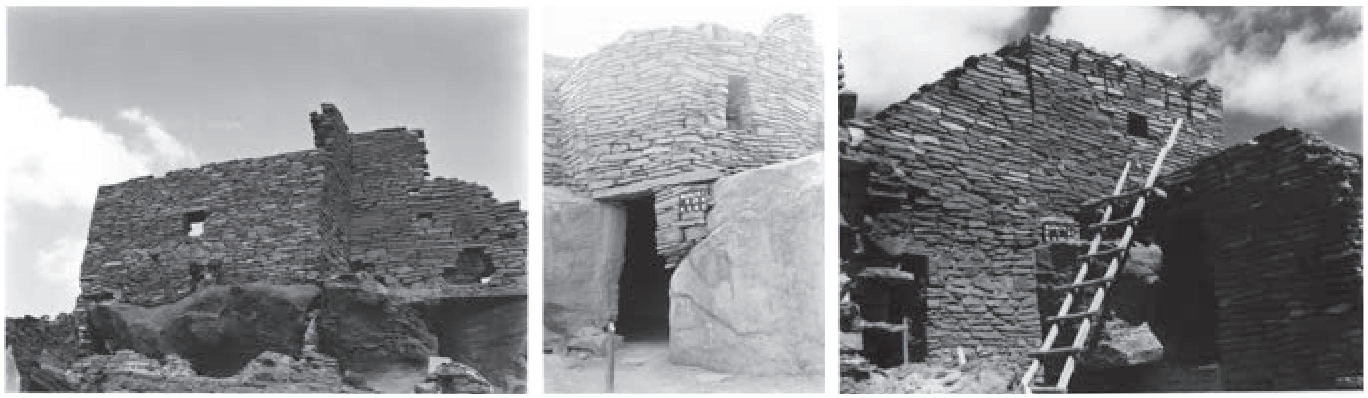
▸ *1934 excavation and restoration in progress for Rooms 60 and 62 in the South Unit (Credit: NPS)*

2022

◂ *Same view of the South Unit with all reconstruction removed.*

With changing NPS policies towards preservation in the mid-20th century, reconstructed parts were removed, gradually shaping WUPA 2676 into what we now see today. Modern but incompatible materials (e.g., Portland cement, rebar) were also introduced at this time for stabilization purposes. With another shift in NPS approaches, stabilization at WUPA NM now focuses on using in-kind materials and techniques.

1952



◀ *1930s reconstructions in both the South (left, center) and North Units (right) were removed in 1950s in response to changing NPS policies towards preservation (Credit: NPS).*

2022

◀ *Stabilization at Wupatki Pueblo now focuses on retaining the original standing architectural form using compatible materials and techniques.*

References

The bibliography provided here has been built from Ellen Brennan and Christian Downum's "Report Of Findings Prestabilization Documentation For Wupatki Pueblo (NA 405) Wupatki National Monument," and the "Ruins Preservation Plan and Implementation Guidelines: Wupatki National Monument, Arizona" published by the NPS.

The list has been organized into decades; entries are listed by year of stabilization work, not necessarily by date of publication.

Up to 1930s

"Southwest Monuments Monthly Report, April, 1926 to June, 1941." 1926.

Colton, Harold S., L.l. Hargrave, J.W. Brewer, Jr., Ten Broeck Williams, Richard Van Valkenburgh, and J.C. Fisher Motz. "Scientific Report on the Excavation of Wupatki: F-68 C.W.A. Work Project No. 10, Wupatki National Monument." Report on file, National Park Service, Wupatki National Monument, Flagstaff, 1933-34.

Reed, Erik K. and James W. Brewer. "The Excavation of Room 7, Wupatki." Southwestern Monuments Special Report No. 13., 1937.

1940s

Buchenberg, A.E. "Preliminary Report on Ruin Stabilization Southwestern National Monuments." 1941.

Schroeder, Albert H. "Albert Schroeder Field Notes 1941." 1941.

Van Cleave, Philip, and David Jones. "Jones and Van Cleave Field Notes 1941." 1941.

"Report on the Ruins Stabilization Project at Wupatki National Monument October 13 - December, 1941." January 12, 1942.

King, Dale S. "Nalakihu: Excavations at a Pueblo III Site on Wupatki National Monument, Arizona." Museum of Northern Arizona Bulletin, No. 23, 1949.

1950s

Richert, Roland. "Roland Richert Field Notes 1952." 1952.

Vivian, Gordon, and Roland Richert. "Comprehensive Stabilization of Wupatki Ruin 1952." Globe, Arizona: Ruins Stabilization Unit Southwestern Monuments, n.d.

"Stabilization Report Wupatki National Monument Drainage Project 1953." Southwestern National Monuments, November 1953.

Vivian, Gordon. "Gordon Vivian Field Notes 1953." September 1953.

1960s

Shiner, Joel L. "Stabilization of Ten Ruins in Wupatki National Monument." Globe, Arizona: National Park Service Ruins Stabilization Unit, January 1961.

Voll, Charles B., and Martin T. Mayer. "Stabilization Report 1964 Wupatki Ruin, NA 405." Globe, Arizona: Ruins Stabilization Unit Southwest Archaeological Center, October 1964.

Mayer, Martin T. "1965 Stabilization Report of Wupatki Blow Hole." Globe, Arizona: Ruins Stabilization Unit Southwest Archaeological Center, June 1965.

Mayer, Martin T "Stabilization Report on the Wupatki Ball Court (NA 405)." Globe, Arizona: Ruins Stabilization Unit Southwest Archaeological Center, June 1965.

1970s

Chambers, George J. "Wupatki National Monument Sites NA-407, NA-404 & NA-2922 Stabilization Report." Tucson, Arizona: Ruins Stabilization Unit Western Archaeological Unit, September 1976.

1980s

Trott, James J. "Maintenance Stabilization of Wupatki Pueblo." New Mexico: Chaco Culture National Historical Park, February 1981.

Adams, Stephen E. "Wupatki: Special Projects, 1982." Farmington, New Mexico: National Park Service, October 1982.

Healy, Michael G. "Stabilization Records Wupatki Ruin NA 405: May, 1982." Wupatki National Monument, October 1982.

Davis, Anthony. "Stabilization Report 1984 Wupatki Ruin, NA 405." Wupatki National Monument, 1984.

Protiva, J.D. "Maintenance Stabilization Completion Report of Summer 1985." Wupatki National Monument: National Park Service, 1985.

Welton, Robert. "Wall Investigation: East Wall of Room 41. Wupatki Ruin, Wupatki/Sunset Crater National Monument." Denver: Denver Service Center National Park Service, November 1986.

Protiva, J.D. "Stabilization Report 1986 Wukoki Ruin NA 203 Wupatki Ruin NA 405." Wupatki National Monument, November 1986.

"Scope of Work: Preservation Work at Wupatki Pueblo." Wupatki National Monument: National Park Service, August 10, 1987.

"Wupatki Ruin Stabilization - 1987 - NA 405." January 12, 1988.

Trott, James J., and Barry Sulam. "Scope of Work at Wupatki Pueblo." Wupatki National Monument, April 10, 1988.

Cinnamon, Steven K. "Scope of Work Cyclic Maintenance Stabilization August, 1988." Wupatki National Monument, 1988

"Stabilization Completion Report: Wupatki Ruin (NA405), Nalakihu (NA358), and NA2765B." Wupatki National Monument, 1989.

1990s

"Wupatki National Monument Scope of Work for the 1991 Stabilization Project." Santa Fe, New Mexico: National Park Service Southwest Region, 1991.

"1993 Scope of Work." 1993.

"Scope of Work Ruins Preservation Maintenance Flagstaff Areas Calendar Year 1995." National Park Service, 1995.

Pfost, Lisa A. "1995 Ruins Preservation Database Project Flagstaff Area National Monuments." Northern Arizona University, January 1996.

Glassco, Greg. "1996 Preservation Activities at Wupatki National Monument (WUPA). Scope of Work, Cyclic Maintenance of Wupatki, Nalakihu and Citadel Pueblos." Flagstaff, Arizona: Flagstaff Area National Monuments National Park Service, October 1997.

Balenquah, Lyle, Lloyd Masayumptewa, Al Remley, J. Nicoli, and Bernard Natesway. "1998 Maintenance Stabilization Records." Wupatki National Monument, 1998.

Downum, Christian E., Ellen Brennan, and James P. Holmund, "An Architectural Study of Wupatki Pueblo (NA 405)." Flagstaff, AZ: Northern Arizona University, February 1999.

Natesway, Bernard. "Report on Ruins Preservation Activities Flagstaff Area National Parks June - October 1998." National Park Service Flagstaff Area National Parks Technical Series No.1. Flagstaff, Arizona: Flagstaff Area National Monuments National Park Service, May 1999.

2000s

Balenquah, Lyle, Jeriy DeYoung, Helen Fairley, Ian Hough, Lloyd Masayumptewa, Todd R. Metzger, and Al Remley. "Ruins Preservation Plan and Implementation Guidelines Wupatki National Monument." *Flagstaff Area National Monuments CRM Technical Series*, No. 1 (2001)

Brennan, Ellen, and Christian Downum. "Report Of Findings Prestabilization Documentation For Wupatki Pueblo (NA 405) Wupatki National Monument." Flagstaff, Arizona: Northern Arizona University, June 2001.

Masayumptewa, Lloyd. "Summary Of Cyclic Ruins Preservation Activities At Wupatki National Monument Summer 2001." *National Park Service Flagstaff Area National Parks Technical Series* No. 2. Wupatki National Monument: Flagstaff Area National Monuments National Park Service, March 2002.

Balenquah, Lyle. "2002 Ruins Preservation Final Report: Wupatki, Nalakihu and Citadel Pueblos. Scope of Work, Cyclic Maintenance of Wupatki, Nalakihu and Citadel Pueblos," Wupatki National Monument: Flagstaff Area National Monuments National Park Service, 2002

Balenquah, Lyle, and Amanda Johnson. "Wupatki Pueblo 2005 Ruins Preservation Final Report. Scope of Work, Cyclic Maintenance of Wupatki, Nalakihu and Citadel Pueblos," Wupatki National Monument: Flagstaff Area National Monuments National Park Service, July 2006.

Webber, Charles. "Report On Ruins Preservation Activities Flagstaff Area National Monuments June-September 2007." *National Park Service Flagstaff Area National Parks Ruins Preservation Program Technical Series*. Wupatki National Monument: Flagstaff Area National Monuments National Park Service, January 2009.

Dorr, Roger. "Report on Ruins Preservation Activities Flagstaff Area National Monuments June-September 2008." *National Park Service Flagstaff Area National Monuments Ruins Preservation Program Technical Series*. Wupatki National Monument: Flagstaff Area National Monuments National Park Service, May 7, 2009.

2010S

Baldwin, Lisa. "2009-2010 Preservation Activities at Wupatki National Monument (WUPA). Scope of Work, Cyclic Maintenance of Wupatki, Nalakihu and Citadel Pueblos." Wupatki National Monument: Flagstaff Area National Monuments National Park Service, January 16, 2015.

Rucker, Daniel. "Archeological Preservation Report 2012 Wupatki National Monument Scope of Work, Cyclic Maintenance of Wupatki, Nalakihu and Citadel Pueblos." Wupatki National Monument: Flagstaff Area National Monuments National Park Service, January 2013.

Fisher, Preston. "Trip Report: Observations and Recommendations for Wupatki Ruin, WS-2676, and Citadel Ruin, WS-2671." Santa Fe: Vanishing Treasures Program National Park Service, May 21, 2013.

Baldwin, Lisa, and Brian Yaquinto. "2013 Preservation Activities at Wupatki National Monument (WUPA). Scope of Work, Cyclic Maintenance of Wupatki, Nalakihu and Citadel Pueblos." Wupatki National Monument: Flagstaff Area National Monuments National Park Service, March 19, 2015.

Neumann, Alex. "(2014) Preservation Activities at Wupatki National Monument (WUPA). Scope of Work, Cyclic Maintenance of Wupatki, Nalakihu and Citadel Pueblos." Wupatki National Monument: Flagstaff Area National Monuments National Park Service, April 6, 2015.

Huffer, Donelle. "2015 Preservation Activities at Wupatki National Monument (WUPA). Scope of Work, Cyclic Maintenance of Wupatki, Nalakihu and Citadel Pueblos." Wupatki National Monument: Flagstaff Area National Monuments National Park Service, October 27, 2016.

Brown, Dana, and Erin Gearty. "2016 Preservation Activities at Wupatki National Monument (WUPA). Scope of Work, Cyclic Maintenance of Wupatki, Nalakihu and Citadel Pueblos." Wupatki National Monument: Flagstaff Area National Monuments National Park Service, August 1, 2017.

Brown, Dana. "2017 Preservation Activities at Wupatki National Monument (WUPA). Scope of Work, Cyclic Maintenance of Wupatki, Nalakihu and Citadel Pueblos." Wupatki National Monument: Flagstaff Area National Monuments National Park Service, November 15, 2018.

Brown, Dana, and Alex Neumann. "2018 Preservation Activities at Wupatki National Monument (WUPA).Scope of Work, Cyclic Maintenance of Wupatki, Nalakihu and Citadel Pueblos." Wupatki National Monument: Flagstaff Area National Monuments National Park Service, June 20, 2019.

Brown, Dana, and Shayna Marks. "2019 Preservation Activities at Wupatki National Monument (WUPA). Scope of Work, Cyclic Maintenance of Wupatki, Nalakihu and Citadel Pueblos." Wupatki National Monument: Flagstaff Area National Monuments National Park Service, January 30, 2020.

2020S

Anderson, Kirk C. "Wupatki Pueblo Geoarcheology Landscape Assessment," Flagstaff, Museum of Northern Arizona, August 5, 2021.

Ro, Ha Leem. "Integrated Site Conservation Management Plan: Wupatki National Monument, AZ. Phase I Interim Report." Philadelphia: The Center for Architectural Conservation, January 2022.

Gambilongo, Laura, Alberto Barontini, and Paulo B. Lourenço. "Wupatki National Monument, Arizona (US): Inspection and Recommendations," Portugal: University of Minho, May 2022.

Ro, Ha Leem. "Integrated Site Conservation Management Plan: Wupatki National Monument, AZ. Phase II Interim Report." Philadelphia: The Center for Architectural Conservation, January 2023.

Anderson, Kirk C. "Wupatki National Monument: Erosion Mitigation Study - WUPA 2676." Flagstaff: Museum of Northern Arizona, February 22, 2023.

Silva, Rui A., Laura Gambilongo, Alberto Barontini, and Paulo B. Lourenço. "Wupatki National Monument Implementation of Grout Injection Trial Zone." Portugal: University of Minho, April 2023.

Gambilongo, Laura, Rafael Ramirez Alvarez de Lara, Alberto Barontini, and Paulo B. Lourenço. "Wupatki National Monument: Damage Survey Update and Additional On-Site Testing." Portugal: University of Minho, December 2023.

Gambilongo, Laura, Nicola Chieffo, and Paulo B. Lourenço. "Wupatki National Monument: Preliminary Seismic Assessment Using Vulnerability Index Methods," Portugal: University of Minho, December 2023.

Ro, Ha Leem. "Integrated Site Conservation Management Plan: Wupatki National Monument, AZ. Phase III Interim Report." Philadelphia: The Center for Architectural Conservation, January 2024.

Boerger, Caroline, and Kelsey Vaughan-Wiltsee. "2023 Preservation Activities at Wupatki National Monument (WUPA).Report on Preservation Activities at: Middle Mesa (WUPA 833), Antelope House (WUPA 355), WUPA 1736, WUPA 1742, WUPA 1744, and Wupatki Pueblo Ballcourt and Amphitheater/ Community Room (WUPA 2676)." Wupatki National Monument: Flagstaff Area National Monuments National Park Service, February 5, 2024.

Ramirez, Rafael, and Paulo B. Lourenço. "Wupatki National Monument Structural Modeling and Assessment." University of Minho, November 2024.

Chapter Cover: Excavation at an Ancestral Pueblo archaeological site by the CWA in Coconino County (Credit: Arizona Memory Project, https://azmemory.azlibrary.gov/nodes/view/238998).

3 HERITAGE VALUES AND SIGNIFICANCE

3 Heritage Values and Significance

3.1. Introduction

This chapter outlines the heritage values that make Wupatki Pueblo significant, discussing them within the broader context of the values pertaining to the entire monument.[1] The unique sets of values identified through historical research, evaluation of physical integrity, and stakeholder discussions informed the significance, policies, and recommendations outlined in this PMP.

It is incumbent upon Wupatki Pueblo's preservation program to ensure that all sites are adequately protected to preserve their value to the scientific community, traditionally associated communities, and the general public. A brief discussion of these values to be preserved follows below.

3.1.1. Traditionally Associated Native American Values

Wupatki National Monument was created in 1924 to preserve and protect Native American archeological remains "built by ancestors of a most picturesque tribe."[2] Attitudes and federal policies towards the rights of Native American Indian communities to have input into the preservation of ancestral sites on federal land have changed significantly in the last half century, and now require parks to strengthen the role of Indigenous members in federal land management through co-stewardship policies.[3]

The Pueblo is part of a larger interconnected sacred landscape linked to ancestral history and clan migrations. This landscape includes significant sites and artifacts, natural features, plants, animals, and water sources that continue to play an essential role in the cultural identity and ongoing traditional practices of these communities. There are currently 13 Native American Tribes identified by the NPS as culturally associated with Wupatki National Monument. Government-to-government consultation efforts are ongoing, and as information and input is received, this section will be updated. The Associated Native American Tribes include:

* Fort McDowell Yavapai Nation
* Havasupai Tribe
* Hopi Tribe
* Hualapai Indian Tribe
* Kaibab Band of Paiute Indians
* Navajo Nation
* San Carlos Apache Tribe
* San Juan Southern Paiute Tribe
* Tonto Apache Tribe
* White Mountain Apache Tribe
* Yavapai-Apache Nation
* Yavapai-Prescott Indian Tribe
* Zuni Tribe

The Hopi Tribe has provided the following information concerning the values that they deem important to places such as Wupatki[4]:

Although current archeological interpretations attribute the prehistoric builders of these structures to cultures they term "Anasazi" (a Navajo word) and "Sinagua" (a Spanish word), the recognized descendants of these prehistoric people, the modern Pueblos (Hopi, Zuni, Acoma, etc.), have their own identities of the people who once lived within Wupatki National Monument. The Hopi call them the Hisatsinom (People of Long Ago) and continue to have strong connections to the sites and standing architecture within and surrounding Wupatki National Monument.

Sites such as Wupatki and Wukoki are known in Hopi history to be the ancestral villages of many clans that presently make up Hopi culture. Each of these clans fulfilled a spiritual and predestined obligation to migrate upon the earth, only to end these journeys once they had traveled to the four corners of the earth. Only then, could they return to the spiritual "Earth Center," the geographic location being the Hopi Mesas. Certain Hopi clans recognize the remaining sites within and surrounding Wupatki National Monument as being among the final "resting spots" that were established before ending their epic migrations at Hopi. In Hopi culture, the time and space that separates the prehistoric and historic is relatively short, and therefore the occupation of ruins such as Wupatki and Wukoki is almost considered a recent event in their history. These events include the continuation and establishment of much of present day Hopi culture.

During these migrations the various clans were instructed to leave their "footprints" upon the land to show that they had indeed traveled far and wide. These "footprints" are the material evidence archeologists term ruins, burials, shrines, trails, rock art, sherds, textiles, and lithics. Therefore, there are specific Hopi clans that have a recognized history into this area, and have also invested a great deal of thought and labor in establishing the places that would later constitute Wupatki National Monument. As such, these sites continue to serve as physical and spiritual connections to the cultural past of the Hopi people.

As stewards of a cultural heritage site, the NPS has a unique set of responsibilities to each associated Native American tribe including an obligation to preserve traditional cultural values and allow continued respectful access to traditional ancestral sites. Through the partnerships such as cooperative agreements with Conservation Legacy's Ancestral Lands Conservation Corps (ALCC) and through the Tribal consultation process, the Monument seeks to learn from tribal partners and engage specialized knowledge and skills needed to appropriately preserve pre-contact masonry architecture and landscape.

▲ *Tribal members visiting WUPA 2676 during a consultation meeting in 2023.*

▲ *ALCC crew members working on WUPA 2676 (Credit: ALCC, CAC).*

3.1.2. Public Value

Public value refers to the direct and indirect ways in which society benefits from studying and preserving cultural resources.[5] These benefits include acquiring knowledge about humankind's past and using of that knowledge to inform and educate the public; the preservation objects, sites, structures, landscapes, etc. for public appreciation and learning; and practical applications of scientific findings acquired through archeological investigations.

Currently, Wupatki Pueblo's main function is as an open-air interpretive site for educating the public about the cultures, communities, and families that made their homes for thousands of years in the landscape surrounding the San Francisco Peaks. Each year, more than 200,000 visitors to Wupatki National Monument are educated through interpretive waysides, exhibits, brochures, and other informational resources.

▲ *NPS Rangers lead public programming for children at WUPA NM (Credit: NPS).*

3.1.3. Scientific Value

Scientific value is defined as the potential for using cultural resources to establish reliable interpretations about human behavior, interaction, cultural variability, and culture change.[6] Scientific data includes analysis of artifacts, architecture, settlements and settlement systems, food remains, resource exploitation, and evidence of past environments. Scientific significance depends on the degree to which cultural resources within the monument contain data appropriate for answering various substantive technical, methodological, or theoretical questions. The value of this data can only be determined in the regional context and in relationship to archaeologically important problems and questions using the framework of the monument's research design.

Thus, it is relevant to preserve sites that have been identified as containing important information based on the following:

1) Research questions and resulting interpretations as defined by regional research designs, state plans, and previous archeological work. Research plans continuously evolve and are modified as new information becomes available. A site may increase or decrease in scientific value as knowledge about certain site types and cultural groups increases. Cultural resources with definable research problems may be more valuable for scientific study in the future than they are today. Preservation activities should conserve a site's scientific value for future generations of researchers.
2) New methods and techniques for studying cultural resources will undoubtedly be developed. These techniques should allow data to be collected more cost effectively, increasing the scientific value of preserved resources.

Although past and current approaches have concentrated mainly on the maintenance of form and outline of previously stabilized sites, the value and obligation to ensure the protection and preservation of any identifiable original fabric—which has inherent scientific value—must also be addressed.

▲ *CAC Laser scanning (top) and installing the weather station with NPS Vanishing Treasures (bottom) at WUPA 2676.*

The significant architectural elements and attributes consist predominantly of the materials used by the original builders (e.g., stone, earthen mortar, and wood) and how these materials were assembled to construct walls, structures (architectural form, function, and patterning), and features within the landscape.

Working within this general framework, the FLAG NM preservation program has three basic areas of concern: (1) the preservation of traditional cultural values, (2) the preservation of scientific values, and (3) the preservation of general heritage and interpretive values. It is important to recognize that there is overlap in the preservation objectives for these different values. Moreover, many sites contain variables and attributes that are of value to the scientific community, traditionally associated communities, and the general public, but the preservation of these differing values may dictate different approaches that are not necessarily compatible with one another. In these cases, the relative importance of the different values must be weighed relative to each other in order to determine the most appropriate preservation strategy.

▸ *Researchers from University of Minho and ALCC crew members grouting at the North Unit.*

◂ *NPS staff and CAC investigating Wupatki Pueblo.*

3.2. Statements of Significance

3.2.1. Historical Significance

The sites within WUPA NM represent specific expressions of pre-contact Native American architecture and community organization, and tangible manifestations of Native American oral history and traditions dating primarily to the mid-late Pueblo II and early-mid Pueblo III periods, ca. CE 1070-1220.

The monument is also significant for providing a microcosmic view of the major events and trends in Navajo history through the experiences of the members of a Navajo family headed by Peshlakai Etsidi. After centuries of sporadic use, Peshlakai Etsidi reoccupied WUPA NM in the late 1860s returning from the Long Walk, which forcibly removed them from their homelands and re-established them near Fort Sumner in New Mexico. Even after their return to Wupatki, the Navajo were further impoverished by the removal of their agricultural lands by the railroad and the Federal Stock Reduction Program in the mid-1930s.

Anglo-Navajo relations were not all acrimonious; during the 1930s, a series of Christmas parties held at WUPA NM were attended by local Navajos fostering a spirit of goodwill between monument personnel and the Navajo. In 1936 the Navajo Craftsman Exhibition was held by the NPS with the co-operation of Harold S. Colton of the Museum of Northern Arizona. The monument exhibited Navajo crafts to Anglos who came from miles around and encouraged the revival of traditional Navajo craftwork. This event presaged the Navajo Show still held each year by the Museum of Northern Arizona.

▲ *The Peshlakai family on Christmas Day, 1935 at Wupatki (top); Sally (left) and Clyde Peshlakai (right) (Credit: NAU; Jones,* Letters from Wupatki*).*

Beginning about 1940, the NPS began to reconsider the Navajo presence at WUPA NM. An eventual agreement permitted one family, the granddaughter of Peshlakai Etsidi, to remain at the monument. This arrangement stipulated that the agreement would terminate with the death of the "head of household" and could not be transferred to other family members. These events are representative of the experiences of many Navajo of the period and reflect the evolving relationship between Native Americans and the U.S. government from the mid-19th to the early 20th centuries. They are significant for providing a historical guidemap to navigate future relations between the two groups.

As part of the monument, Wupatki Pueblo shares this broader historical context but also hold its own significance for its connection to various historic cultures of northern Arizona such as the Sinagua, Cohonina, Kayenta, and Hohokam.[7] Its unique architecture reflects these diverse influences. Historically recognized for its extraordinary size for its time and place, Wupatki village served as a hub for cultural exchange and adaptation, demonstrating how these communities thrived in the harsh desert climate of the Wupatki Basin by skillfully utilizing local resources for construction and trade. The diverse connection continues today, with 13 culturally associated Native American Tribes, who continue to view the Pueblo as an integral part of their heritage.

As the largest pueblo within the monument, Wupatki has been central to NPS preservation efforts since the 1930s. Its preservation history reflects evolving NPS approaches, offering valuable insights into best practices for maintaining these historical and cultural resources. More recent efforts involve ongoing collaboration with Native American communities, like those spearheaded by the ALCC,ensuring Wupatki's protection as both a sacred site and a testament to the renewed relationship between the NPS and Indigenous peoples. In this aspect, Wupatki Pueblo's historical significance extends beyond its architectural and archaeological features, embodying a rich legacy of cultural resilience, adaptation, and ongoing significance to Indigenous communities today.

▲ *ALCC crew members and NPS staff at Wupatki Pueblo conducting condition assessments.*

3.2.2. Cultural and Spiritual Significance

Natural and cultural resources within the Monument hold significant traditional cultural importance to a number of contemporary Native American tribes for their associations with specific clans, traditional stories and ceremonies, as well as with tribal history. More generally, the sites within the monument serve as tangible reminders of the long-standing connection between Pueblo people and this region. The bond of certain Navajo families, specifically those descended from or related through marriage to Peshlakai Etsidi, is likewise strong and continues to be maintained through the standing architecture, livestock facilities, and other tangible reminders of their tenure on this land.

These cultural remnants (i.e., ceramics, textiles, lithic material, architecture) are considered by the Native American tribes as "footprints" left behind by their ancestors "who lived, died, and were buried at these places, purposely [remaining] as spiritual stewards of the land continuing to watch over their ancient homes long after their physical presence is gone."[8]

3.2.3. Aesthetic and Natural Significance

The clean air and environment of Wupatki National Monument provide exceedingly rare opportunities to experience uninterrupted vistas, stunning night skies, and natural sounds in a wilderness environment.

Wupatki National Monument harbors one of the largest protected areas of juniper savanna, grassland, and desert shrubland within the southern Colorado Plateau region. It provides habitat for native species sensitive to human land use and habitat fragmentation impacts and serves as a critical scientific research area for pronghorn (*Antilocapra americana*) and regional environmental change.

▲ *Pecked petroglyph panel showing clan migration at Wupatki Pueblo.*

▲ *South Unit of Wupatki Pueblo at sunset.*

3.2.4. Architectural and Archaeological Significance

Wupatki National Monument protects one of the most densely populated archeological landscapes of the Southwest, where multiple cultural groups coexisted and interacted in the wake of the eruption of Sunset Crater Volcano.

Cultural resources at Wupatki Pueblo are well maintained and the potential for scientific investigation and interpretation is enormous. Although pothunting occurred at some sites before the area attained status as a National Monument and surface material has been removed or disturbed in the years since, substantial subsurface materials remain undisturbed. Even those areas that have been excavated provide a wealth of information about the prehistoric occupation of the area. Excavations have confirmed the presence of artifactual and botanical remains, chronometric data, faunal assemblages, mortuary remains, and stratified deposits in rooms and extramural areas. The unexcavated areas of the Pueblo hold potential for significant scientific discoveries.

Architecture of Wupatki Pueblo also represents several cultural styles, exhibiting a number of unusual features, with some areas showing a unique blending of architectural traits from several cultures. Significance also derives from the number of architectural styles represented in a relatively small area, a situation unique in the prehistoric Southwest.

▲ *Architectural features such as the Chacoan basalt stone courses and chinker stones in mortars joints showcase the diversity of cultures that built and called Wupatki Pueblo home.*

3.3. Issues of Integrity

According to the National Register of Historic Places (NRHP) guidelines, in order for a site to be considered eligible for the NRHP, it must not only be significant in terms of meeting the NRHP criteria, but it must also retain integrity. Integrity is defined as "the ability of a property to convey its significance." Individually, the sites in WUPA NM retain many elements of integrity that are essential for NRHP significance. Each of these elements are discussed individually below:

3.3.1. Location

Except for a few outstanding isolated artifacts that were given individual site designations during the Wupatki Inventory Survey[9] and then collected, all sites in WUPA NM retain their locational integrity. The ancestral Puebloan sites' location within the landscape—their specific location relative to each other and their general location on the northern periphery of the Sinagua culture area, eastern boundary of Cohonina territory, and southwestern frontier of the Ancestral Puebloan culture area—are integral to their significance. The Navajo sites' location at the southeastern limit of historic Navajo territory is likewise important to their significance.

3.3.2. Setting

The setting of the sites in WUPA NM has not been significantly modified by the addition of modern roads and facilities. A single paved road, a visitor center, a small maintenance and employee housing area, some paved trails and scattered wayside signs are the only visual intrusions on the prehistoric setting, and these occur in a few, very localized settings within the 35,253-acre park. With the possible exception of Wupatki Pueblo, almost all the sites retain their original ambiance in terms of the surrounding natural environment and soundscape.

3.3.3. Design

At the most heavily visited frontcountry sites, the original external design of structures has been largely retained through stabilization of their mass, form, and outline. Many other elements of architectural design, such as the layout of interior benches, bins, and hearths, have been lost at the most heavily visited sites due to past stabilization treatments as well as human and natural agents of deterioration. What remains of the original structures serves to illustrate both the simplicity and practicality of Sinaguan and Ancestral Puebloan architectural design. At most of the less heavily visited sites in backcountry settings, stabilization treatments have not been performed at all or have been performed at a very minimal level, and in these instances, natural agents of deterioration have been the principal causes of design loss. Many of these unstabilized or minimally stabilized sites retain their mass, form, and outline, as well as more specific design elements such as wall abutment patterns, absence of ground-floor entryways, and many other specific features.

3.3.4. Workmanship

Although heavily stabilized, all of the frontcountry sites at WUPA NM still retain original architectural fabric which reveals aspects of the original ancestral building techniques. Many backcountry sites retain even more aspects of workmanship, due to the fact that original construction techniques have not been obscured by subsequent stabilization efforts.

3.3.5. Materials

The majority of structural sites at WUPA NM retain a high percentage of their original wall stones, as well as original interior mortar. As noted above, the frontcountry sites at WUPA NM, although heavily stabilized, still retain a considerable amount of original fabric, including original stones and interior mortar. Nevertheless, walls have been compromised by past stabilization efforts, due to the introduction of modern materials such as tinted cement and ferrous reinforcements. The current preservation program is attempting to reverse some of the intrusive effects of past stabilization efforts by removing cement mortar as it erodes and replacing it with amended clay mortars that more closely match the prehistoric materials.

3.3.6. Association

The sites in WUPA NM are primarily associated with the ancestral Puebloan cultures referred to by archeologists as Sinagua, Cohonina, and Kayenta. This is reflected in their architectural characteristics, the artifact assemblages that have been or are still associated with the sites, their location on the geographic frontier of these three prehistoric cultural areas, as well as their associations in Native American oral histories.

3.3.7. Feeling

The element of feeling is fully retained by most Wupatki sites as reflected by the sites' ability to evoke a deep, sometimes even emotional response from visitors. The combination of a largely unmodified natural setting and intact architecture that retains elements of original design, materials and workmanship successfully conveys a tangible sense of the past. Due to the ability of these sites to evoke strong responses from visitors, the NPS managers continue to accommodate direct visitor access to some of the sites in order to promote this sense of direct connection with the past.

Notes

1 The values and significance of Wupatki Pueblo discussed in this chapter have been adapted from Lyle Balenquah et al., “Ruins Preservation Plan and Implementation Guidelines Wupatki National Monument,” *Flagstaff Area National Monuments CRM Technical Series*, No. 1 (2001), Section 4-3 to 4-8. A detailed discussion on values and significance pertaining to the entire monument can be found in "Wupatki National Monument Foundational Document," NPS, Wupatki National Monument, Arizona, 2015.

2 U.S. President, Proclamation, “Establishing the Wupatki National Monument, Arizona, Proclamation 1721 of December 9th, 1924,” https://coolidgefoundation.org/resources/proclamation-december-9-1924/.

3 Secretary's Order No. 3403 of November 15, 2021," Joint Secretarial Order on Fulfilling the Trust Responsibility to Indian Tribes in the Stewardship of Federal Lands and Waters," U.S. Department of Agriculture and Department of Interior, https://www.doi.gov/sites/doi.gov/files/elips/documents/so-3403-joint-secretarial-order-on-fulfilling-the-trust-responsibility-to-indian-tribes-in-the-stewardship-of-federal-lands-and-waters.pdf; NPS Director Chuck Sams to National Leadership Council Superintendents, September 13, 2022,"Policy Memorandum 22-03: Fulfilling the National Park Service Trust Responsibility to Indian Tribes, Alaska", U.S. Department of Interior, https://www.nps.gov/subjects/policy/upload/PM_22-03.pdf. These two recent policy implementation establishes standards for federal agencies in fulfilling their obligations to federally recognized Indigenous Tribes.

4 Lyle Balenquah et al., “Ruins Preservation Plan and Implementation Guidelines Wupatki National Monument,” *Flagstaff Area National Monuments CRM Technical Series*, No. 1 (2001), Section 4-5.

5 Charles R. McGimsey and Hester A. Davis, *The Management of Archeological Resources : The Airlie House Report* (Washington D.C.: Society for American Archaeology, 1977).

6 Ibid.

7 Christian E. Downum, Ellen Brennan, and James P. Holmund, “An Architectural Study of Wupatki Pueblo (NA 405)” (Flagstaff, AZ: Northern Arizona University, February 1999).

8 Lyle J. Balenquah, “Beyond Stone and Mortar,” *Heritage Management* 1, no. 2 (2008): 142–62, https://doi.org/10.1179/hma.2008.1.2.145, 155.

9 Bruce A. Anderson, “Wupatki Archeological Inventory Survey Project: Final Report,” *Southwest Cultural Resources Center Professional Paper* 35 (1990).

Chapter Cover: Courtney and Modesta Dixon (sister of Sally and Catherine Peshlakai) sewing on "the porch" (Credit: Tad Nichols; In *Letters from Wupatki* by Courtney Reeder Jones. Tucson, AZ: University of Arizona Press, 1995).

SITE ASSESSMENT 4

4

Site Assessment

4.1. Introduction

Understanding the current conditions and the causal factors that affect a historic structure is imperative in order to anticipate and plan for appropriate conservation and preservation needs. This chapter is intended to provide an overall summary of masonry conditions at Wupatki Pueblo based on numerous investigative studies within the past five years as well as site inspections that were carried out by the CAC and by the Civil Engineering Department at UM, Portugal as part of this PMP project.

The on-site assessments for this project were limited to evaluating visible above-ground architectural features. Given the higher presence of original material in the two larger South and North Units of Wupatki Pueblo, assessment efforts were primarily focused on those areas. The other three units are subject to the same governing legislation, regulations, and preservation policies and program outlined in this PMP (Chapters 6 to 8); however, because these units are largely reconstructed, they were not prioritized for assessment within the project timeframe.

Based on the evaluation of the South and North Units, which have more original masonry, it was assumed that the findings regarding conditions are representative of the site and the factors of deterioration discussed in this chapter apply equally to all rubble masonry features across the Pueblo.

On-site assessments of buried features and natural resources were not carried out as part of this PMP project but findings from other relevant reports published for Wupatki Pueblo have been synthesized in this chapter. The studies consulted have been cited as endnotes and other relevant sources are also listed in the References section at the end of this chapter.

▲ *The CAC conducting Rapid Assessment Survey (RAS) at Wupatki Pueblo, 2022.*

4.2. Factors Affecting Masonry Condition

The major factors that potentially affect the deterioration of any site and its structures can be grouped into the following three categories:

1) Inherent Construction Inadequacies Resulting from Original Building Techniques and Materials

The original builders' choice of materials and techniques significantly impacts site stability, directly related to the longevity of the structure and its ability to withstand deterioration from natural- and human-induced impacts.

Construction materials with lower durability, such as easily eroding stone, mortar with minimal clay content or a high organic content, and wood beams used as wall footings, can accelerate deterioration. Likewise, construction on soft fill or unstable talus slopes, floodplains, or in the vicinity of seeps or runoffs; unplumbed walls; poor bonding in wall wythes, or excessive mortar use; and walls thicker at the top than the base can contribute to structural decay.

While these construction styles were perfectly adequate for the original inhabitants, they are highly susceptible to deterioration when left unattended, especially for wet-laid structures in exposed locations like Wupatki Pueblo—preserved in a half-built state, without roofs and constant maintenance. Wet-laid stones are easily displaced as mortar erodes, and walls with rubble cores invite moisture penetration, subjecting the structure to a host of natural factors of deterioration. In contrast, dry-laid or dry-laid/mudded structures are much more resistant to deterioration as they transmit the load from stone to stone without relying on mortar.

Subterranean or semi-subterranean structures, like wet-laid structures, also deteriorate rapidly without maintenance; moisture can begin to pool on the floor causing salt deposition and basal undercutting. Saturated mortar from runoff disintegrate from wet/dry, freeze/thaw, and salt cycling, resulting in walls that bulge and begin to collapse in response to dead load differential and hydrostatic pressures.

▲ *The original builder's choice of materials, building techniques as well as early prehistoric repairs can impact the site greatly as seen in the North Unit. Retention of them is critical to an understanding of the Pueblo's early history.*

2) Environmental Factors

Archeological sites are not static; they are dynamic and continually seek an equilibrium with their environment. Simply put, environmental factors erode building fabric, forcing "natural weathering," deterioration, and subsequent accumulation of debris in sufficient quantity to negate further collapse. Lack of continuous upkeep exposes the stone, mortar, and other structural fabric to environmental factors, leading to deterioration and imminent collapse. The resultant debris accumulates around the remnants of the standing elements until the remains become buried in their own deposition.

Various environmental agents, including water, salt crystallization, acid precipitation, thermal fatigue, vegetation, wind, lightning, and animals, all contribute to deterioration; deterioration is seldom a result of any one factor working independently. However, water plays a central role, directly or indirectly impacting more types of deterioration than any other factor. Its effects include abrasion, dispersion, dissolution, and the transportation and conversion of corrosive aerosols and gases, commonly known as "acid rain".

Salt crystallization and hydration can particularly damage stone, mortar, and adobe. Soluble salts can infiltrate walls through capillary action, or airborne particles, or stabilization cements and herbicides. Other environmental agents that are dependent on the presence of moisture include the growth of bacteria, algae, fungi, lichens, and plants, which chemically and mechanically (i.e., root systems) deteriorate building materials.

In the desert Southwest, intense sunlight and temperature fluctuations cause thermal stresses. Wind abrasion from sand grains and deposition of wind-borne material can cause differential fill/pressure and ultimately collapse, or contribute to archaeological site damage overtime. Damage to archaeological sites from lightning has also been known to occur. Animal activity, particularly rodents, insects, birds, and livestock, also pose significant threats.

▲ *Severe salt crystallization (i.e., efflorescence) observed at Wupatki Pueblo after a heavy rain event (Credit: NPS).*

▲ *Animal burrowing at Wupatki Pueblo. Animal activity in and around masonry walls can undermine the structural integrity of the walls and allow for water infiltration.*

3) Human Factors

Anthropogenic causes of deterioration to archaeological sites can be separated into three distinctive categories:

i. Intentional impacts, including vandalism, graffiti, and looting;

ii. Unintentional impacts that stem from ignorance or carelessness; and,

iii. Deferred maintenance.

Vandalism is the deliberate destruction of any structural remains or cultural features, while looting involves the theft of artifacts or features (e.g., rock imagery panels), often undermining wall bases and damaging structures. Although some surface artifact collection (i.e., collectors' piles) may be an unintentional, most visitors are aware that such activities are illegal on public lands.

Unintentional visitor impacts usually stem from a lack of awareness of the fragility of prehistoric sites, or unrecognized features, like middens. The likelihood of unintentional impacts is directly correlated to accessibility. Sites like Wupatki Pueblo, close to roads and trails, exhibit higher rates of visitation and higher frequencies of unintentional damage from visitors occasionally walking or sitting on walls, dislodging stones and loosening capstones along the trails.

Archeologists and preservation crews may also unintentionally impact sites. Excavation is inherently disruptive of the archaeological record, and often damaging to the structural remains; past preservation practices have also caused adverse effects through the use of incompatible modern materials and construction of new architectural features.

Deferred maintenance does not necessarily stem from ignorance or negligence but primarily from lack of resources and insufficient preservation planning. For example, the lack of fall protection for workers at Wupatki Pueblo has delayed much work on higher areas at the site. Delayed repairs are detrimental to the longevity of archeological sites as it can lead to increased long-term costs, safety risks, and more catastrophic failures.

▲ *Graffiti on masonry at Wupatki Pueblo (Credit: NPS)*

▲ *Loose capstones near the trail caused by foot traffic.*

▲ *Deferred maintenance of structures in higher areas can cause greater issues in the long term.*

4.3. Understanding the Walls of Wupatki Pueblo: Rubble Masonry

Understanding a building's construction method is crucial, as it dictates deterioration mechanisms. This section examines the shared properties of rubble masonry construction (system components, properties, and functions), followed by an analysis of rubble masonry mechanics, including load distribution and stability under different conditions.

4.3.1. Rubble Masonry Components

4.3.1.1. Stone and Mortar

Rubble masonry walls, whether dry-built or wet-laid, are complex systems employing stones chosen for their size, shape, coursing patterns, wythe bonding, and foundation presence. Wet-laid walls, as seen at Wupatki Pueblo, use both stone and mortar with larger stones at the base and smaller stones and mortar filling the gaps and core for increased surface contact of the main walls.

Typical rubble masonry uses natural stones, usually sourced locally, which vary in shape and size, along with mortar —a binder like clay or lime mixed with water and aggregates that connects the stones. Local geography and geology dictate the materials for the masonry system, ultimately defining its properties. Given the wide diversity of materials and complexity, this section elaborates on the materials and typologies similar to those observed at Wupatki Pueblo.

Stones and mortars are generally brittle materials, breaking easily under tension but withstanding compression better. Due to the low resistance of both of these materials to tensile forces, interaction between them—stone arrangement, and stone-to-mortar ratio—is vital for the proper load distribution in the wall. Concentrated loads can lead to stress points, cracks, and collapse.

The term "rubble" implies variability—stone of variable size and shape—as in the case of Wupatki Pueblo’s masonry units that vary in thickness and regularity. Optimal performance is typically expected when the majority of the wall consists of medium to large regular-shaped stone blocks with even bearing surfaces and a homogeneous load distribution through coursing.

Rubble masonry, especially when involving irregular stone units, typically requires more mortar to fill gaps and provide flexibility and bonding strength essential for structural support. Failure to achieve this balance can lead to concentrated loads, leading to stress, cracks, collapse, and accelerated deterioration.

Wupatki Pueblo's unique rubble masonry, primarily made of tabular Moenkopi sandstone[1], requires less mortar as bedding planes form the bed joints. The tabular stones may improve load distribution, while their arrangement in horizontal (i.e., coursing) and vertical (i.e., wythe bonding) orientations impact the wall system's overall performance.

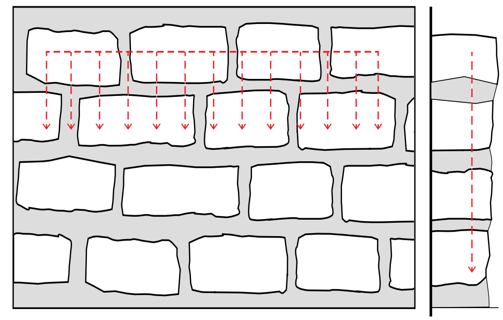
▲ *Moenkopi sandstones used at Wupatki Pueblo are typically tabular with offset head joints.*

4.3.1.2. Bonding Courses

There are two sub-types of rubble masonry defined by the horizontal placement (i.e., coursing) of stones:

1) Coursed Rubble Masonry

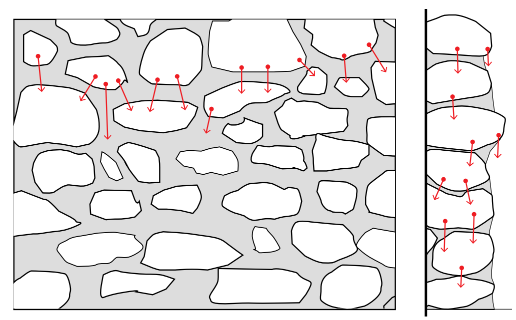
In equal courses of uniform-height stone, mechanical performance improves due to even horizontal load distribution. This applies to vertically aligned stones on wall faces, ensuring a direct vertical load path without interruptions, enhancing structural integrity.



▲ *"Coursed Rubble Masonry" consists of stones organized into uniform courses of equal height. In elevation, red dashed lines illustrate the even distribution of horizontal loads. The vertical alignment of stones facilitates a direct vertical load path.*

2) Uncoursed or Random Rubble Masonry

In contrast to the uniform arrangement of coursed rubble masonry, randomly placed rubble stones of varying height lack regularity, leading to imbalanced loads and localized stress concentrations. In uncoursed random rubble masonry, load distribution relies on the mortar between stones to alleviate stress.



▲ *"Uncoursed or Random Rubble Masonry" comprises randomly arranged rubble stones of varying heights. In walls lacking clear coursing, the irregularity of the stones leads to imbalanced loads and localized differential load distributions.*

4.3.1.3. Wythe Bonding.

While the type and amount of mortar plays a large role in the structural performance of the system, the way that the stones interlock, both in the coursing of elevation(s) and across the thickness of the wall (the wythes) will also impact the total wall performance. In the case of walls built with small stones that do not overlap, the mortar should be able to provide balance by transferring the loads in the transverse direction.

The arrangement of stones in perpendicular direction, where the connection occurs across the thickness of the wall (two opposite adjacent wythes), will aid the transverse interlock and secure the wall to prevent vertical separation. Interlocking wythes are not always present and different types of masonry constructions will behave differently.

Four different cross-sectional bonding types have been identified at Wupatki Pueblo based on the number of wythes and the way they interlock. The structural stability of each type of wall is dependent on the load distributions and stone relationships across their wythes. The distribution of loads will depend on the geometry of each wythe, how the elements connect, if they connect, and the mechanical and geometric properties of the stones. Consequently, deterioration and structural failure will vary depending on how the loads are distributed.

1) Not-Interlocked Double Wythes

In a wall with not-interlocked double wythes, two stacks of stones make up the thickness of the wall and stand parallel to each other with no apparent cross wall interlocking connections.

▲ *Not-Interlocked Double Wythe wall*

2) Interlocked Double Wythes

In a wall with interlocked double wythes, two layers of stones make up the thickness of the wall and are interlocked with each other in a zig-zag bond.

▲ *Interlocked Double Wythe wall*

3) Triple Wythes or Compound Wall

A triple wythes wall has three layers of stones that make up the thickness of the wall. Triple wythe walls are either well or partially interlocked at Wupatki and are typically consistent in width.

▲ *Triple Wythe wall*

4) Multi-Wythes

A multi-wythes wall has varying numbers of stone wythes that make up the thickness of a single wall. Multi-wythe walls are either well or partially interlocked at Wupatki and usually taper in width towards the top of the wall.

▲ *Multi-Wythe wall*

4.4. Agents of Rubble Masonry Deterioration

Deterioration may occur in different ways for rubble masonry construction; it can be specific to a material (i.e., the stone itself), or it can extend to the whole wall system. External factors, especially when moisture-related, induce intrinsic stresses that can cause irreversible damage. Porous materials, like most stones and mortar used in masonry construction, absorb moisture, leading to micro-structural damage, frost, and thermal expansion. Macro forces like wind, vegetation, fill, and visitor traffic can easily disrupt the masonry according to the origin and direction of the load, the wall construction, and its condition. Intrinsic stresses to the masonry system depend on the chemical and mechanical properties of its materials. Water infiltration through absorption (i.e., rising damp) or direct contact (i.e., precipitation) triggers decay processes, weakening stones and mortar and leading to cracking and disintegration. Once water infiltrates the masonry system, smaller pores within the stones and mortar reach full capacity, weakening their strength and rendering them more vulnerable to damage. Subsequently, if temperatures plummet below freezing, the water-filled pores freeze, generating internal pressure that can lead to cracking, flaking, and overall disintegration. If salts are present, the damage is worse. All of the above are particularly problematic for soil mortars where excessive moisture can cause clay mortar dissociation and loss.

4.5. Rubble Masonry Deterioration Scenarios

4.5.1. Moisture Infiltration

Direct environmental factors like precipitation, wind, and sun radiation directly affect the wall and are also intertwined with indirect factors, such as water runoff or surface splash, which result from direct deterioration.

Among these, precipitation moisture is a primary driver of deterioration in historic structures. Rain and melting snow can find numerous entry points into the masonry wall system, seeping through any opening in the wall caps, via water runoff, splashing against the wall surface, or even through surface capillarity.

In the case where water intrusion occurs through openings or cracks in the wall caps, water can enter the interior of the wall unseen causing irreparable damage to the interior structure. As water infiltrates and descends through the core of the wall, it dislodges and transports fine materials from the mortar downwards, creating substantial voids in the upper sections of the wall's interior. These voids facilitate the detachment and redistribution of larger materials within the wall, eventually leading to internal pressure and the separation of wythes. Eventually this can result in bulging, leaning, and collapse.

Furthermore, water from precipitation can infiltrate the system upon contact with damp soil. Moisture permeates vertically and horizontally through the pores via capillarity, saturating the materials. As moisture rises through different materials, varying rates of expansion and contraction occur during saturation and drying phases, inducing movement. Depending on the composition and properties of the materials, this can lead to expansion, displacement, or erosion of materials. This is especially noticeable in walls with multiple repair campaigns of different mortar formulations.

This process may also trigger efflorescence due to the crystallization of dissolved salts from the stones, mortar, or soil. Particularly troublesome are large reserves of water, such as snow, which pose challenges as both rising and falling damp, capable of overwhelming earthen mortar or adobe systems, causing large scale deformation and collapse.

Water accumulation can also attract biological agents, which can have some impact in material deterioration. In certain instances, roots may accelerate masonry decay. Additionally, vegetation in proximity to structures often indicates high moisture levels

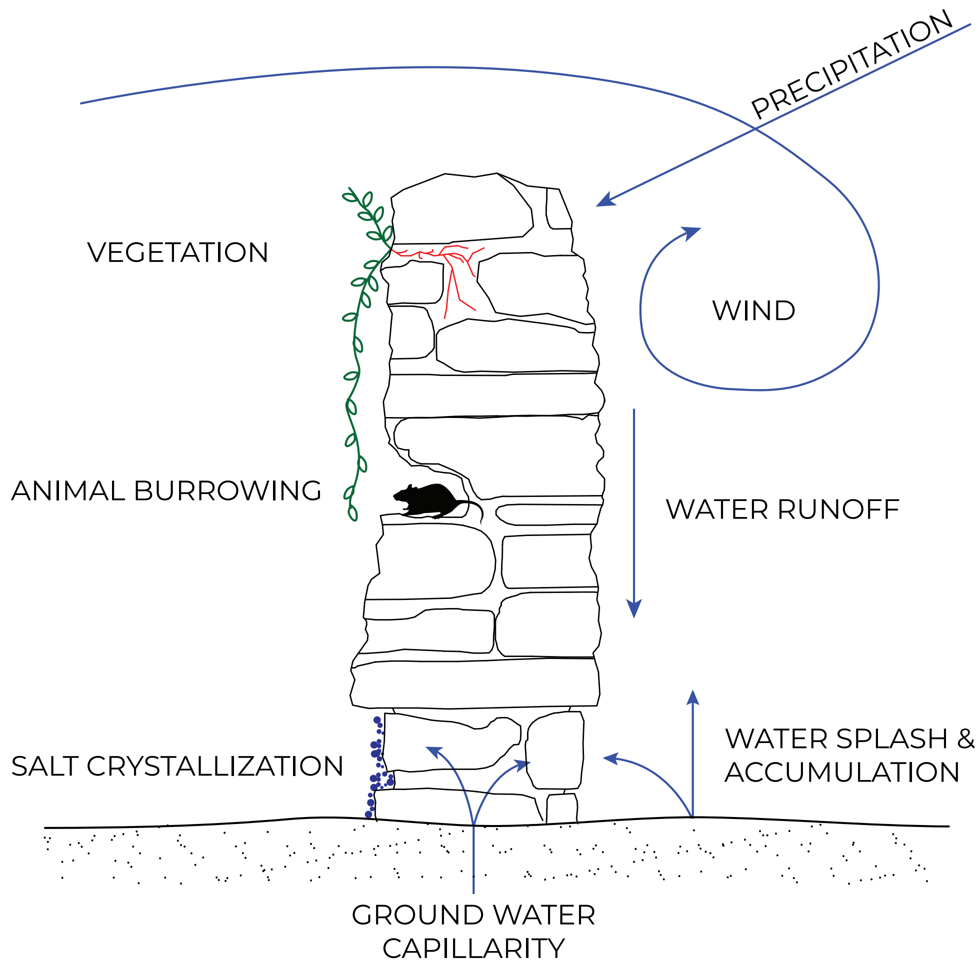
4.5.2. Wind and Thermal Variations

Wind pressure can aid in the infiltration of rainwater into the system, pushing it against the wall surface where it is absorbed. Variations in wind direction can lead to uneven water absorption, resulting in differential movement on opposing sides of the wall. Additionally, wind can contribute to material erosion by abrading wall surfaces and inducing dynamic loading on structures, causing them to flex and vibrate.

The loss of mortar or stone surface can affect the even distribution of loads, leading to concentrated stresses in specific locations. Differential thermal exposure can also cause differential expansion, resulting in cracking and deformation of the wall.

4.5.3. Presence of Organic Activity

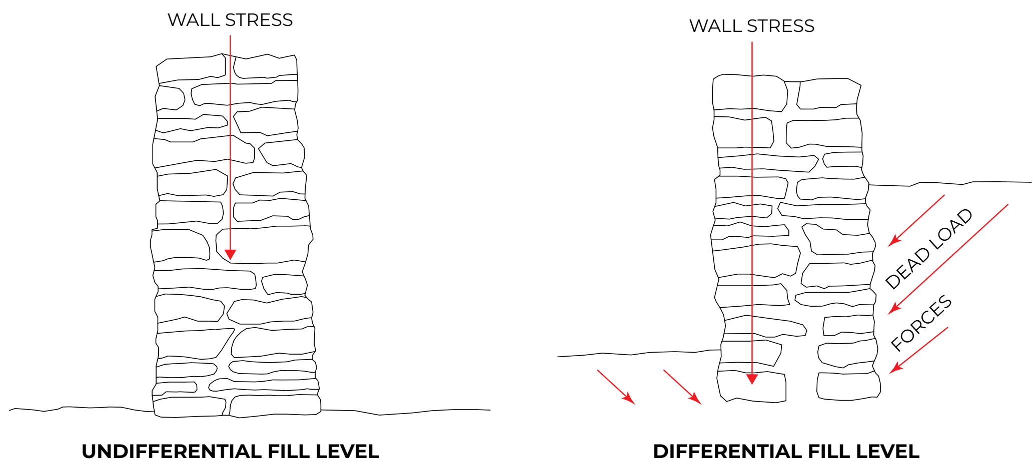
Organic activity, from both plants and animals, can pose a significant threat to masonry wall integrity. Animals dig burrows, loosening mortar and dislodging wall materials, while plants extend roots through mortar joints. As previously discussed, mortar provides a surface to distribute the concentrated loads caused by the irregular shape of the stones. The lack of bonding surface can lead to water intrusion and localized stresses, increasing the risk of cracking, instability, and collapse, particularly as burrowing and root systems deepen.



▸ *Basic schematic diagram of the agents of deterioration of rubble masonry walls. It is important to recognize that the causes of deterioration rarely occur in isolation. Depending on the broader site context, such as geography, climate, and extent of previous interventions, certain factors may play a more significant role in the erosion of the rubble masonry structure, but multiple forces are always interacting and contributing to the deterioration (Adapted from U.S. Department of Interior, Preservation Brief No. 5, 1978).*

4.5.4. Differential Fill

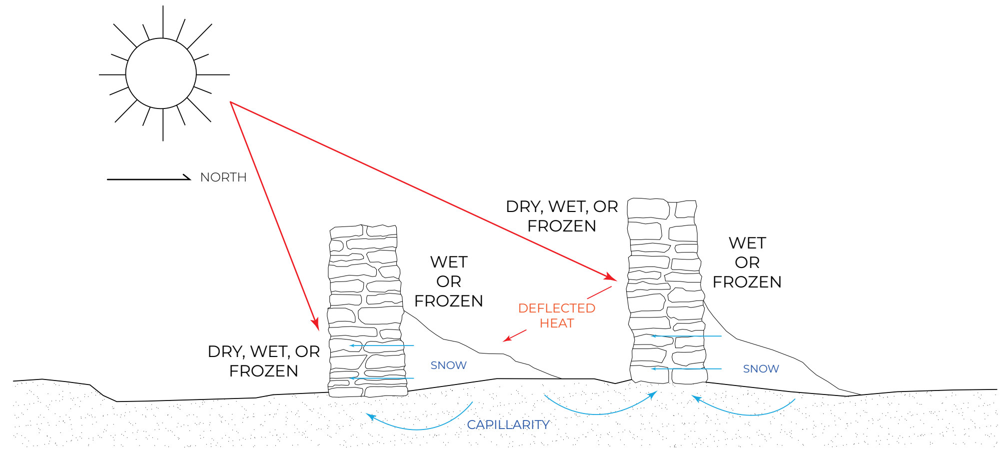
Undifferential and differential soil fill levels around walls result in different dead (permanent) loads and wall stresses that cause the walls to deform or collapse. For above-grade, free-standing walls without fill, the absence of differential lateral loads exerted upon them helps maintain balance. However, in structures with differential fill levels, increased loading from the fill pushes the wall toward the side lacking fill to provide resistance. This differential fill can also retain and transmit moisture, causing additional damage. Such imbalance results in instability, deformation, and eventual collapse. As previously discussed, rubble masonry is composed of non-uniform stones, and unintended loads introduced during early stabilization efforts may disrupt the system, causing cracking due to differential movement.

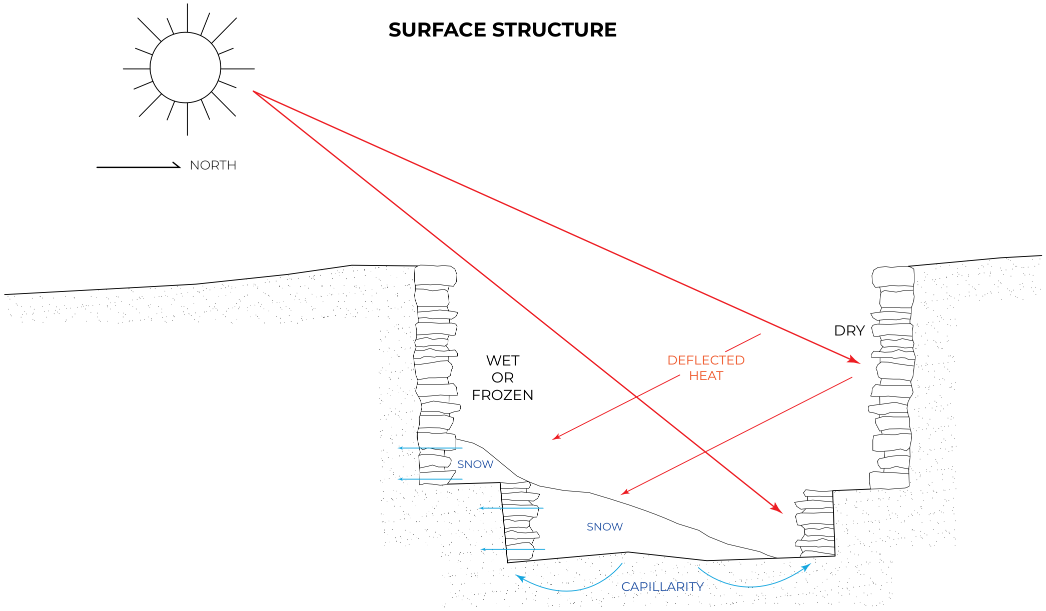


▲ *Wall stress is evenly distributed in walls with undifferential fill levels (left), whereas walls with differential fill levels experience unevenly distributed wall stress due to higher dead load forces exerted on one side of the wall (right).*

4.5.5. Deterioration Schemes for Surface / Subterranean Structures

Despite being exposed to the same weathering elements (e.g., rain, snow, wind and sun), walls experience deterioration differently depending on whether they are above or below grade. Above-grade structures, by nature of consisting of free-standing walls, may be more prone to wind load and atmospheric moisture, whereas subsurface structures may experience more applied load from grade and ground moisture. Also, depending on the orientation of the wall, the wall may experience more (typically if south or west facing) deterioration from higher thermal expansion or from snow accumulation (typically if north or east facing).





▶ *Structural deterioration related to aspect; south-facing walls experience greater temperature fluctuations, but north-facing walls typically suffer more severe deterioration due to prolonged saturation and freezing. (Adapted from U.S. Department of Interior, Preservation Brief No. 5, 1978).*

4.6. Current Condition of Wupatki Pueblo

4.6.1. General Observations

The construction materials of Wupatki Pueblo were all obtained from immediate and nearby locales. Moenkopi sandstone, soil, and wood comprise the major construction system of one- to three-wythe rubble masonry walls laid in earthen (soil) mortar, sometimes with openings and remnants of wooden log beams (vigas) and lintels. Today the walls are fragmentary, standing on shallow or unknown foundations and occasional living rock outcroppings and boulders.

Despite continuously being subjected to deterioration from material, environmental, and anthropogenic factors, the Pueblo walls retain much of their original physical fabric and character, owing to continued cyclical maintenance carried out at the site.

Signs of deterioration observed at Wupatki Pueblo include (in no particular order): eroded mortar joints, efflorescence, loose capstones, and wall deformation—issues mostly manageable by in-house personnel. Less common were through-wall cracks, and severe deformation (to the point of requiring bracing), indicating overall structural stability. Severe damage was observed in localized areas, specifically in areas at the confluence of drainage or areas with difficult access, highlighting the need to identify and understand factors that affect the site to prioritize vulnerable areas for focused preservation efforts.

Structural issues, particularly in regards to the bedrock supporting the two larger units of WUPA2676, are also attributed to underlying geological and hydrological factors, underscoring the need for comprehensive site-wide assessment to reduce erosion risk, rather than simply treating architectural features.

Decades of preservation efforts are made evident through the variety of stabilization mortars[2] visible at Wupatki Pueblo, including more intrusive forms of stabilization, such as steel bracing in the upper rooms of the South Unit and cement mortars, which have become more or less permanent parts of the site.
The following sections examine the current condition of Wupatki Pueblo, organized into two categories, progressing from the structural overview to specific material conditions.

4.6.2. Structural Stability

All built structures are inevitably affected by their surrounding environment, including climate, landscapes, and geologic processes. In particular, the structural performance of buildings is closely tied to the dynamics of underlying geological features (e.g., landforms, seismic, volcanic framework). The damaging effects caused by these factors can be compounded by climatic and hydrological systems—also inevitably shaped by broader natural contexts—and by the inherent construction inadequacies of historic structures. Wupatki Pueblo's structural health has been, and continues to be, dependent on the geomorphology and the human responses which created the Pueblo structures.

Wupatki Pueblo is built directly on top of and around a narrow ridge of highly eroded Moenkopi sandstone and siltstone outcrop formation. This elevated positioning of the main units of the Pueblo reduces the risk of damage to the structures from landslides, rockfalls, flood, and debris flow from the nearby Woodhouse Mesa.

▸ *WUPA 2676 sits on and around a heavily eroded Moenkopi Formation.*

It is believed that water movement through the structures has potentially eroded the Pueblo's bedrock drainages approximately 10-20 centimeters in the past 1,000 years, since the Sinagua left the area.[3] Under extreme summer heat, with high evaporation rates and heavy precipitation, the Moenkopi Formation is likely to undergo accelerated salt weathering over time. Additionally, underlying tectonic fracture patterns that cut through the bedrock have created structurally vulnerable areas, particularly as the rooms are oriented to conform to those pre-existing breaks.[4]

The following have been observed by Kirk C. Anderson as recorded in the 2022 geoarcheology landscape assessment regarding the condition of boulders present at Wupatki Pueblo:[5]

- Currently, the majority of the Moenkopi blocks embedded in the South Units are in a stable position.
- The bedrock block visible on the north end of the South Unit is no longer *in situ*; the tilted bedrock block and the walls on top are slowly slipping downslope due to gravity (creeping).
- In the South Unit, a number of gaps between stable and moving blocks, as well as in between the boulders and their interface, has been filled with loose material, creating weak points where rainfall and runoff seep in and saturate the material causing swelling and subsequent structural movement. Freezing and thawing of this sediment also contributes to the gradual movement of the blocks away from their original positions.

▲ *The tilted bedrock and the walls atop at the north end of the South Unit is creeping downslope (Source: Anderson, "WUPA Geoarcheology Landscape Assessment," p. 54).*

▲ *The close-up image of the same tilted bedrock at the north end of the South Unit. In an inherently unstable position, debris accumulation and precipitation flowing through the gap can cause gradual movement of the boulder. This process, called "creep," driven by shrinking and swelling due to wetting, drying, freezing, and thawing, further contribute to its instability. Note the sediment that has dispersed out from the gap; cracks in rock formations can also add to the deterioration of masonry features directly underneath.*

- The boulder on the north end of the North Unit is tilted approximately 30° causing the wall to separate.

  Note: this crack was treated with injection grouting by UM in the summer of 2023. The performance evaluation of the grout after injection showed adequate filling of the voids, suggesting improved continuity of the masonry.[6]

▲ *The boulder at north end of the North Unit is actively tilting about 30°, causing walls to separate (Source: Anderson, "WUPA Geoarcheology Landscape Assessment,"53).*

Structural engineers from UM made similar observations that cracks, mainly appearing on only one elevation of the walls, are present where the connections are weak between the natural formations and masonry walls as well as between adjacent walls. While in some cases with significant width, none of them were noted to be undergoing a sudden or rapid movement.[7]

Some boulders are deteriorating (e.g., erosion from water runoff and undercutting foundations) which could eventually threaten both their stability and the masonry on them, especially as precipitation events increase in intensity.

▲ *The Moenkopi formation supporting the northernmost wall of the North Unit is severely eroded, and can threaten the structural stability in the long term if untreated (Credit: UM).*

The main cause can be attributed to inadequate drainage throughout the Pueblo; the relatively inefficient nature of how the terraced structures are able to shed water as well as the inadequate performance of the installed drainage system both contribute to the detrimental accumulation and undesirable movement of water through the masonry structures.

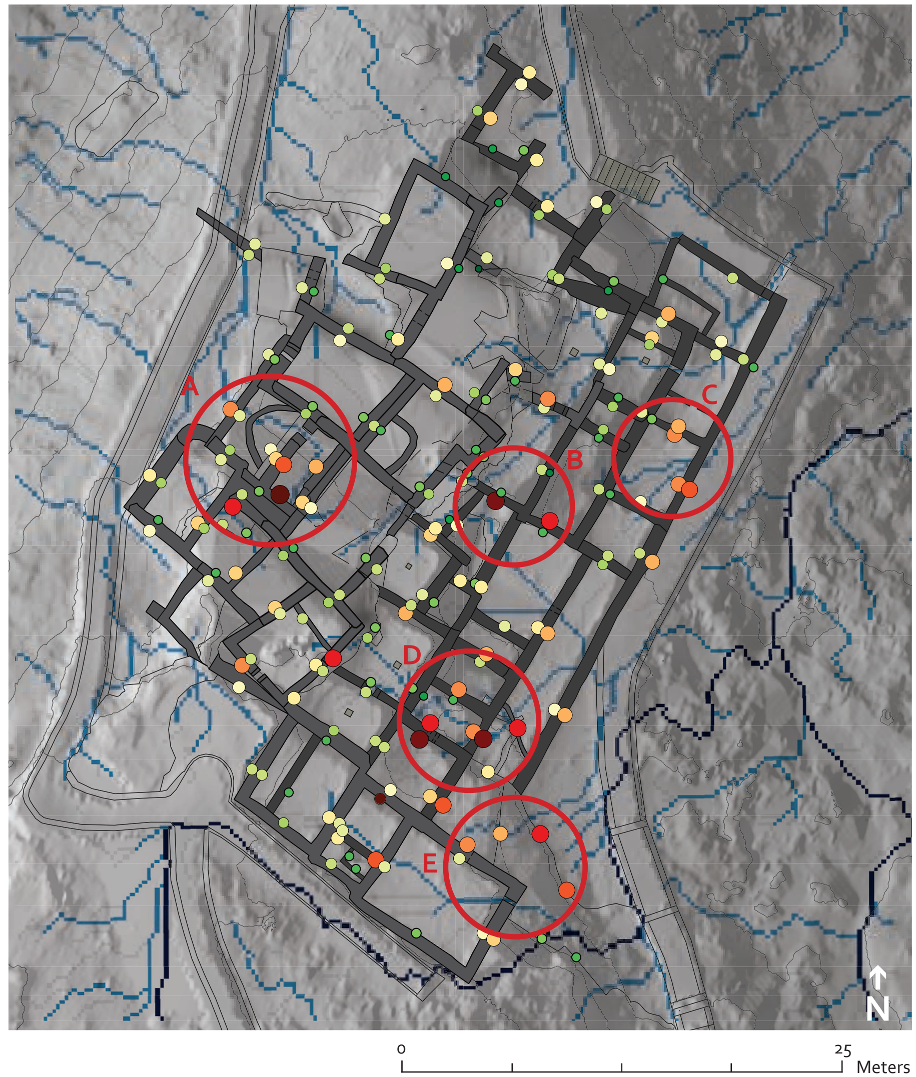
Additionally, floor erosion caused by water runoff from recent high intensity rain events has been flagged as a potential risk to the structural stability of Wupatki Pueblo.

▲ *Example of an eroding boulder on the west elevation of the South Unit. Water runoff is eroding both the boulder and the abutting masonry, particularly in their adjoining interface.*

How is Water Movement Affecting Wupatki Pueblo?

The image on the right shows surface deterioration data for the South Unit from the CAC's 2022 Rapid Assessment Survey (RAS). The data points illustrate the extent of basal erosion, masonry and mortar deterioration, as well as damage caused by pests and fill slope (higher scores = higher deterioration level).

Higher scores were typically observed in lower areas of the pueblo, particularly walls situated near or directly within the drainage paths and confluence points, such as drainage outlets. This underscores the need to thoroughly understand water movement as well as factors that affect it throughout the Pueblo to minimize its negative effects and to implement effective, proactive management strategies.

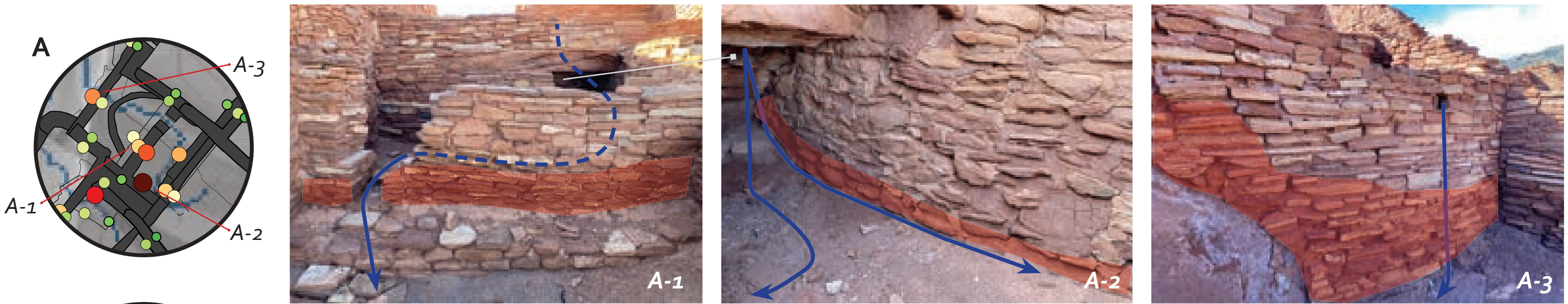


<u>Legend</u>

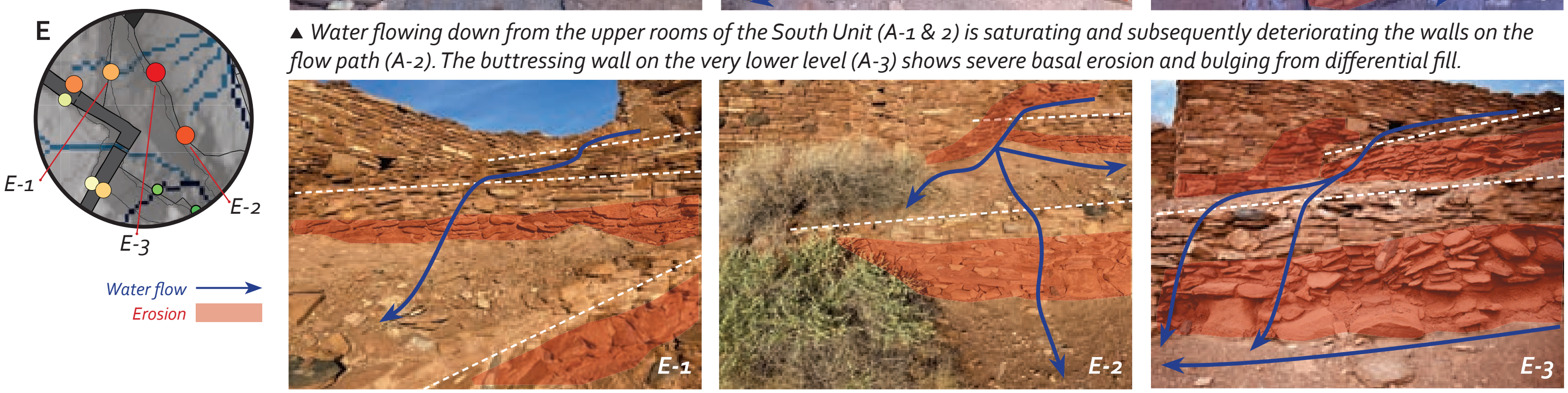
RAS Surface Deterioration Score:
High ● ● ● ● ● ● ● ● ● ● ● ● ● ● Low

Stream Accumulation:
High Moderate Low

Elevation:
250m 20m



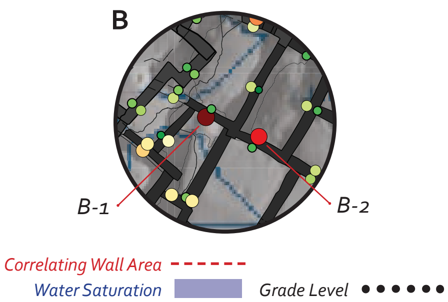
▲ *Water flowing down from the upper rooms of the South Unit (A-1 & 2) is saturating and subsequently deteriorating the walls on the flow path (A-2). The buttressing wall on the very lower level (A-3) shows severe basal erosion and bulging from differential fill.*



▲ *Water flow across varying grade levels (E-1; dashed lines) is saturating the walls and shedding debris to lower areas (E-2 &3) of the South Unit. With rainfall, the debris-laden water can cause further damage to the masonry through abrasion and impact.*

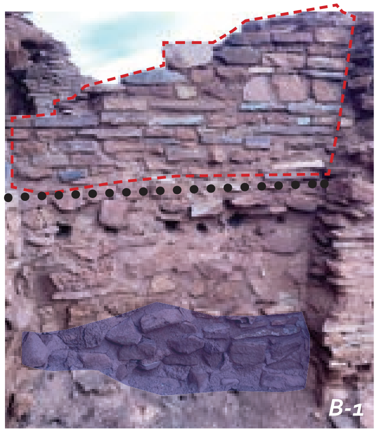
Downward Water Movement through Multiple Structures and Fill Levels

The terraced design of Wupatki Pueblo inevitably directs water to flow downward across multiple levels of rooms and through a series of walls. If the ground surfaces and fill remain saturated for extended periods, moisture can saturate the floor and the surrounding masonry. In colder seasons, the absorbed water can freeze and thaw, expanding and contracting within the materials causing them to deteriorate and break apart. During intense precipitation events, large volumes of water passing through the layers of fill and walls can exert pressure on the structures, further damaging them as debris is carried along with the flow.

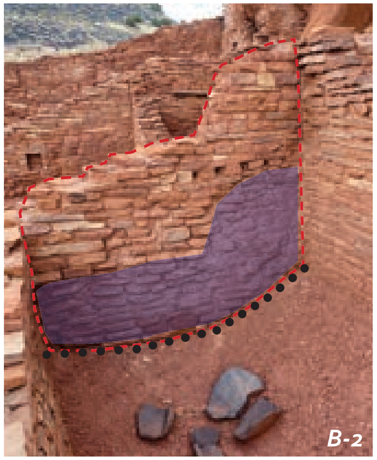


Water Transmission Between Different Fill Levels

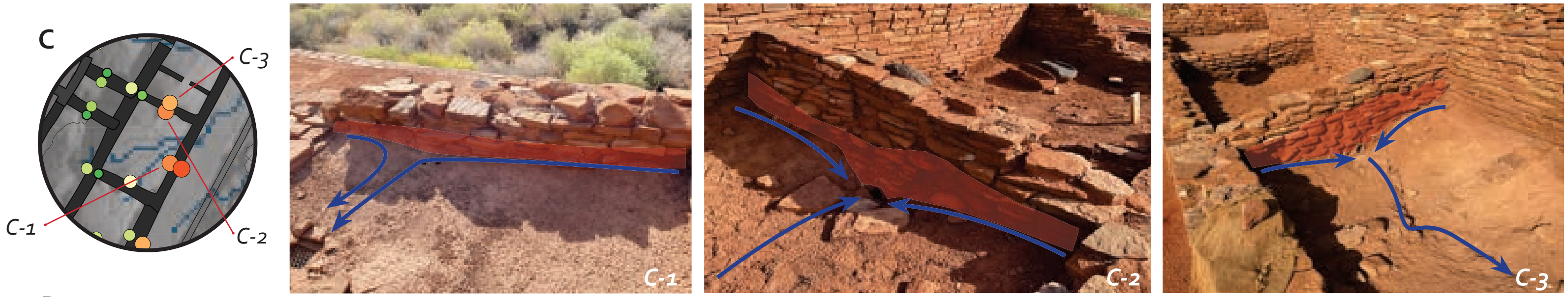
Different grade levels on either side of a masonry wall create significant risks for water infiltration, moisture buildup, and structural damage, especially without adequate drainage and waterproofing measures. Water will typically travel from the higher grade to the lower, saturating the wall, if without proper drainage, and causing damage like spalling from salt crystallization and freeze-thaw cycling. If one side of the wall is consistently more saturated than the other, it may experience differential expansion and contraction due to moisture, leading to cracks or structural strain over time.



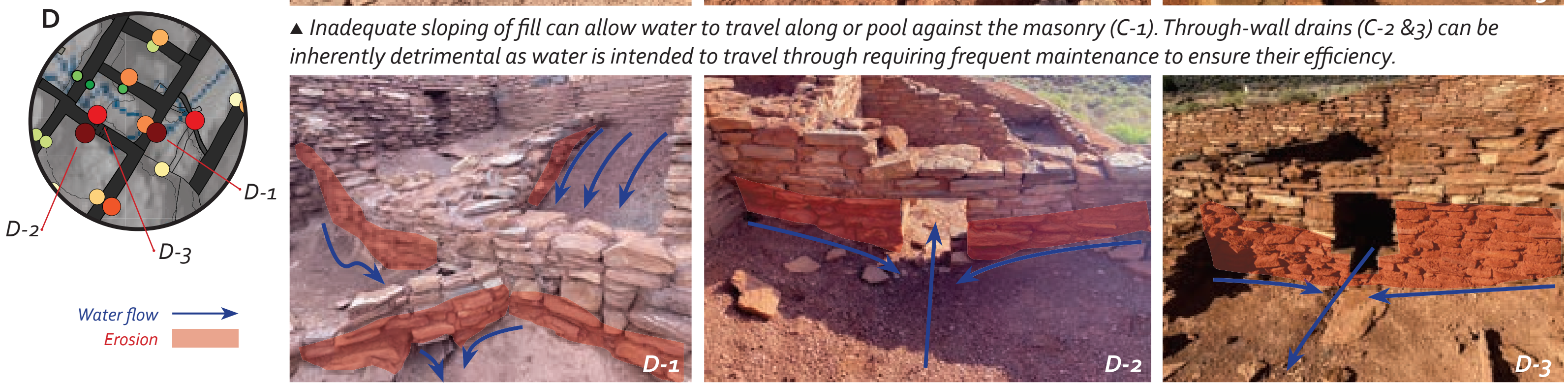
▲ *Water from the higher grade can seep through the wall into the lower side (B-1), leading to moisture buildup and deterioration of the more exposed elevation from subsequent thermal and moisture expansion (i.e., different evaporation rate, salt crystallization, freeze-thaw damage).*



▲ *Without appropriate drainage on the higher grade, water may accumulate on the base of the wall leading to rising damp (B-2). Presence of harder mortars on the opposite side of the may exacerbate differential water movement through the wall.*



▲ *Inadequate sloping of fill can allow water to travel along or pool against the masonry (C-1). Through-wall drains (C-2 &3) can be inherently detrimental as water is intended to travel through requiring frequent maintenance to ensure their efficiency.*



▲ *Steeper slopes (D-1) intended to quickly shed water can be problematic if there are not enough outlets, especially when drainage uses exiting structures (D-2 &3), inevitably directing water towards the original masonry features, which gradually saturates and erodes building materials.*

Insufficient Water Drainage throughout the Pueblo

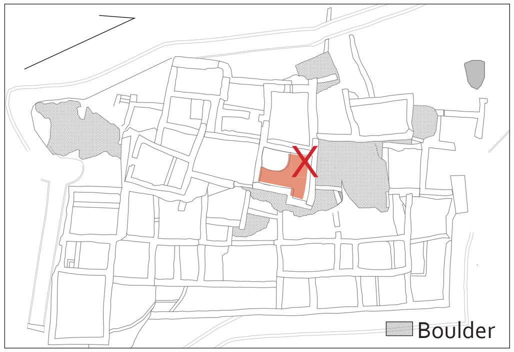
Given Wupatki Pueblo's characteristics (e.g., multi-story construction, prevalence of differential fill), effective drainage is crucial for water control and minimizing the risk of moisture-induced damage originally controlled by drainage. Many of the drains were installed in the 1950s through the masonry, at times utilizing existing openings (e.g., ventilators, doorways). Water drainage, therefore, when not properly maintained, can harm original structures. The drains in the lower areas bear the brunt of pressure, and the increasing intensity of precipitation events may exceed the capacity of Wupatki Pueblo's current drainage system.

One notable structural issue is the failing floor in Room 38 of Wupatki Pueblo, where a large void was observed by the CAC and UM in the summer of 2023. Initially an area noted for severe structural cracking, poor drainage (insufficient capacity) seems to have been a critical cause in worsening the floor's condition.

Inadequate water control in upper areas built on the Moenkopi formation (such as the area in question) can be particularly damaging to the overall structure. Accumulated water can seep into cracks and voids, gradually eroding the boulder and surrounding structures over time. Poor drainage may cause water to pool or concentrate in specific areas, exerting more pressure on weak points like the through-wall drainage pipe, which serves as an inherent structural risk.

Additionally, water damage in upper rooms on a boulder may be harder to detect and repair, allowing deterioration to progress unchecked. The height and inaccessibility can delay necessary interventions, leading to more extensive damage over time.

▸ *Locator map of the South Unit, showing the location of the failing northwest corner (Red 'X') in Room 38 (light red). Also note that the area in question is on top of the boulder.*



▾ *The northwest corner of Room 38 of Wupatki Pueblo observed in 2022 (left) and in 2023 (right). Step cracking, typically considered as a sign of settling foundations, is prominent on the north wall (1.73.1) and requires further monitoring to assess the extent of ongoing movement.*

Recent installation and monitoring of crack monitors have confirmed movement. Any potential shift in the boulder supporting the wall may have contributed to and may continue to accelerate deterioration, allowing weathering elements to further exploit weakened areas.

The structural vulnerability of masonry walls at Wupatki Pueblo, built directly on the soil or boulders without visible foundations, is intensified by their design. The walls lack tie stones (i.e., key masonry units that span the entire wall's width to provide structural cohesion) and proper corner connections between orthogonal walls, making them susceptible to horizontal loads or soil settlements. The absence of stabilizing horizontal elements, such as floors or roofs, further compounds this weakness, increasing the Pueblo's risk during seismic events. In 2023, UM assessed the seismic vulnerability of most structures at Wupatki Pueblo as ranging from medium to high.[8] Although the likelihood of a catastrophic earthquake is low based on historical records,[9] the risks were evaluated higher due to its inherent disposition to incur damage and the value of the cultural resource at risk. Certain sections of the Pueblo were observed to exhibit a higher risk of failure under severe seismic events; slender walls (i.e., taller and thinner walls), although making up less than 10% of the Pueblo, exhibit higher risks of failure.[10] A number of walls tilting beyond 4°, notably the east wall of Room 41 and the north wall of Room 44, also show the highest vulnerability.

Fortunately, the masonry at Wupatki Pueblo is considered to be "of reasonable quality and in overall good condition, without internal voids or disaggregation,"[11] and site erosion is largely under control due to the trail system surrounding the Pueblo.[12]

The trail provides an erosion-resistant path and barrier, preventing rain-induced rills from reaching the rooms, though minor rilling has begun in some areas. While natural hazards (e.g., the Pueblo's location on bedrock, precipitation, and earthquakes) cannot be controlled, identifying the most vulnerable areas to those factors can be crucial in mitigating potentially catastrophic events. Also, considering the presence of more severe issues in localized sites, prioritization of most vulnerable areas for treatment based on the factors discussed is recommended (e.g., RAS). Ongoing stabilization and monitoring efforts have preserved the structural integrity of Wupatki Pueblo, but a targeted approach will allow for a more focused and efficient stabilization process, ensuring that resources are strategically allocated to address the root causes of deterioration, potentially preventing further damage, rather than merely applying temporary fixes.

◄ *Minor rilling has begun at the trail's base on the east side of the South Unit; placing local stones on flow paths can help control this erosion (Source: Anderson, "WUPA Geoarcheology Landscape Assessment," 60).*

Structural Health of Wupatki Pueblo

The image on the right shows structural integrity data from the CAC's 2022 RAS. It highlights wall deformation, structural cracking, and the condition of openings (if present), while also accounting for the wall's inherent vulnerability given its height and differential fill levels.

Severe structural issues were limited to specific areas and, similarly, the prevalence of yellow to green points across the South Unit indicates its overall soundness. Taller walls and those with greater differential fill generally scored higher, as did walls scoring higher for surface deterioration (e.g., severe basal erosion). Walls in the upper rooms also had higher scores, suggesting that deferring maintenance in these areas can be detrimental in preserving the structural integrity of the site.

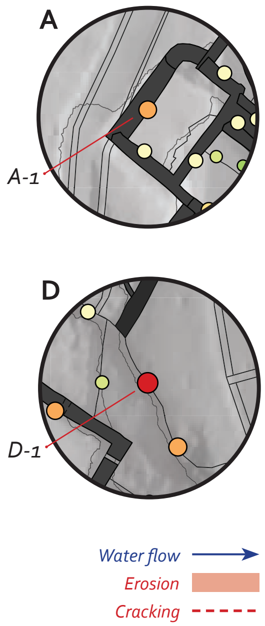
Legend

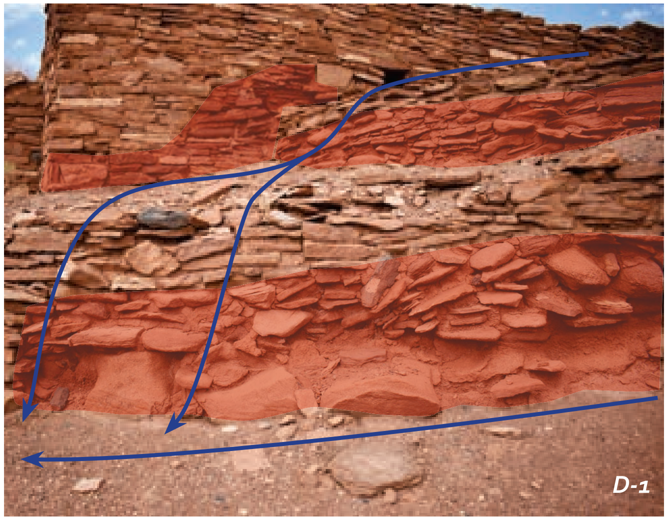
RAS Structural Deterioration Score:

High ● ● ● ● ● ● ● ● ● ● ● ● ● ● Low

Elevation:

250m 20m





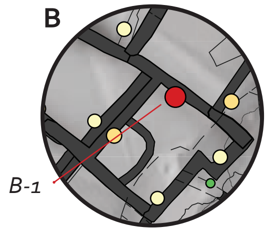
▶ *Water movement directed by the construction design of Wupatki Pueblo (e.g., terracing, differential fill, drainage placement) affects the condition of building materials and can gradually undermine the structural stability of masonry walls.*

Correlation Between Surface Deterioration and Structural Integrity

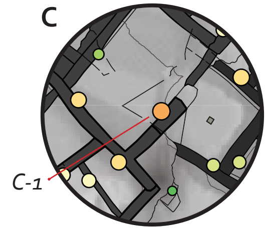
Material and structural stability are intricately connected and cannot be considered separately. Severe erosion of stones and mortar can weaken masonry walls, while structural movement can accelerate the rate of material disintegration.

At Wupatki Pueblo, water movement throughout the structures can erode the masonry wall, particularly at wall bases, leading to a weakening of structural support. Walls with greater differential fill can experience different loads, causing weakened walls to further deform and collapse. Buttressing walls in the lower areas of the Pueblo, therefore, appear to be most at risk of erosion and deformation, requiring ongoing attention going beyond regular repointing treatment. This may entail dry stacking rocks and other bracing measures to provide structural support or relieving the differential loading.

B



C



▸ *Deterioration symptoms of masonry walls and other features in the upper areas of Wupatki Pueblo can go unnoticed for extended periods of time given the difficult access to these areas. The key to preserving these structures lies in proactive care, understanding the structure's unique vulnerabilities, and careful and strategic planning to ensure regular monitoring of all aspects of the Pueblo.*

B-1

C-1

Difficult Access and Deferred Maintenance

Upper rooms in the South Unit, located on top of the Moenkopi Formation, are likely to be more structurally vulnerable due to their height, lack of foundation, and increased exposure to wind loads. Inaccessibility to these areas poses a significant threat to structural integrity; deferred maintenance, albeit unintended, can cause unnoticed conditions to worsen over time, resulting in more extensive damage.

Additionally, even the well-intentioned interventions can inadvertently harm the structure; for instance, steel braces in masonry walls can corrode, ultimately causing significant damage and potentially catastrophic failures. Developing safe and efficient ways to access upper rooms (e.g., temporary scaffolding to allow for regular inspections and timely repairs) can prevent minor wear from escalating into severe damage.

4.6.3. Material Stability

As an open-air archeological site, all of Wupatki Pueblo's building materials—stone, earthen mortars, wood, and steel—are constantly exposed to weathering, each responding differently depending on its properties and role within the construction system.

Stone and earthen mortars, due to their porous nature, are particularly vulnerable to moisture, whereas wood and steel exhibit better resistance. However, soil-based construction systems (e.g., rubble masonry), provided they are well-connected, can demonstrate greater resilience against mechanical forces like earthquakes, while horizontal features (e.g., stone, wood, steel lintels or beams) are more prone to deformation and fracturing under excessive stress.

Fortunately, Wupatki's dry climate and the historically infrequent major seismic events (as discussed previously) have been advantageous for Wupatki Pueblo, allowing it to maintain relatively good material integrity. Deterioration is nonetheless present at varying degrees throughout the Pueblo.

For example, building stones sourced from the Moenkopi Formation show varying levels of delamination, friability, and efflorescence, although grayish units appear to be more sensitive to moisture. Stones in the lower three to five courses of the walls show the most significant deterioration; complete loss of stone units is most commonly observed in these basal areas. This erosion pattern indicates that poor water drainage and the resulting water accumulation are key factors contributing to the deterioration of Wupatki Pueblo's walls.

Unit displacement, such as spalling, appears to be uncommon, likely due to the tabular shape of the masonry units, which are laid horizontally (i.e., in their natural bed), allowing for greater contact with the mortar, enhancing stability. Loose stones are most frequently observed on wall caps, most likely caused by human interaction, freeze-thaw cycling, and thermal movement.

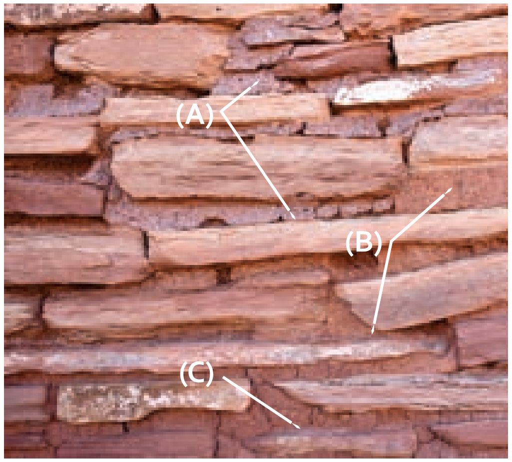
Cracking of individual stone units is also a less frequently observed issue at Wupatki Pueblo.

▲ *Basal erosion is a frequently observed problem at Wupatki Pueblo, resulting in the loss of stone units and mortar. Primary causes include water flow along the base, rising damp from accumulated moisture, and water movement due to differential fill levels.*

Even within the same material category, deterioration can occur in different forms and at varying rates. For example, numerous types of repointing (stabilization) mortars used at Wupatki Pueblo show varying levels of strength and durability. Mechanical property characterization tests performed by UM in 2022 confirmed varying levels of compressive strength and durability for seven different amendment mortars tested (six of them were amended soil mortars and the last was a cement mortar).[13]

While all of the amended mortars were ultimately confirmed to have acceptable strength and durability, recurrent operations of repointing without the removal of previous phases of mortar can present negative ramifications in the long term for the rubble masonry walls. There are, in fact, many instances in which several iterations of stabilization mortars are visible in a single elevation, each layer of different mortar campaigns showing varying levels of adherence to the substrate as well as varying thicknesses, often very superficial (up to several millimeters in depth).[14]

Different types of mortars on a single wall can be problematic, as each responds differently to moisture in terms of shrinkage, permeability, and resistance. These varying behaviors create inconsistencies within the wall, making it harder to predict how the materials will interact and deteriorate over time, especially with water. Incompatible mortars can lead to uneven moisture retention, weakening some areas while leaving others more stable, ultimately compromising the wall's overall integrity.



▲ *Masonry wall showing three different types of amendment mortar at Wupatki Pueblo; one of soil cement (A), cinder aggregates (B), and finer soil binder with more shrinkage (C).*

Cement mortars, while seemingly durable due to their hardness, can be highly detrimental. The increased density and impermeability of cement mortars trap moisture—both in liquid and vapor forms—within the stone, original mortar, and the masonry system. This leads to the reduced wet strength of both stone and mortar, and can cause indirect damage from freeze-thaw cycles and salt crystallization. Additionally, removal of these mortars is often difficult and potentially damaging.

▲ *Cement mortars found across Wupatki Pueblo are often incompatible with the original masonry in terms of performance and appearance (often grey or white in color).*

Hard dense mortars, whether amended earthen or cement-based, can damage the softer masonry units by directing water to softer sandstones, causing erosion and leading to a condition known as "honey-combing". While fairly uncommon at Wupatki Pueblo, the continued layering of amended mortars with higher impermeability increases the risk of stone deterioration across the site. Deteriorating mortars, similarly with stone units, are most commonly observed in basal areas where water movement is concentrated.

▲ *Honey-combing occurs due to different hardness of adjacent materials. At Wupatki Pueblo, acrylic-amended or soil-cement mortars, which are more impervious to moisture, can cause the more porous, water-absorbent sandstone units deteriorate at an accelerated rate.*

Wooden features such as remnants of vigas, floor beams, and lintels are uncommon at the Pueblo but exhibit signs of decay. The most visible original wooden beam, spanning Rooms 74 and 75, is splitting and supported by two protruding rebars, while other wooden elements, though deteriorating at different rates, appear stable. Given their less visible nature and scarcity at the site, practicing good documentation and record-keeping will be imperative to ensure their continued monitoring.

▸ *Images showing original wooden beam in Rooms 74 and 75 (top); viga stubs in Room 24 (middle); and wooden beams visible under Room 41 (bottom). Though less prominent than other materials, wooden features at Wupatki Pueblo are key to understanding original construction techniques. They exhibit varying degrees of deterioration, ranging from splitting (top, middle) to slight fracturing (bottom). There is no historical record indicating that these wooden components have received treatment (e.g., sprayed with preservatives), though most appear to have been stabilized along with the surrounding masonry.*
Given their historical significance and vulnerability, it is essential to continue monitoring and treating these wooden features to ensure their preservation, as they offer insight into the site's architectural and cultural history.

Similar to wooden elements, there are few steel features visible at Wupatki Pueblo; they all were introduced to the site in the mid-20th century as interventive measures to provide structural support to deforming walls. The most prominent steel element visible to the public is the plate on the exterior of the east wall of Room 44 (1.56.1.E), which UM observed to be moderately corroded and loose, rendering it ineffective. While its removal is recommended in the long term, obvious interventions as such could contribute to the broader narrative of preservation and evolving approaches, provided their continued presence does not compromise the structural integrity or overall significance of Wupatki Pueblo.

Other less visible steel elements, such as the steel beam supporting the east wall of Room 41 and the tie anchor between Room 41 and 41B1, were also noted to be in fair condition, showing minor signs of corrosion. A more pressing concern is the uncertainty about the exact locations of other steel interventions throughout the Pueblo.

A few steel elements have been observed in inconspicuous locations during the project; the lack of historical records detailing their locations and installation dates makes it difficult, if not impossible, to assess their current conditions, which could lead to unintended deferred maintenance. Unmonitored steel elements, especially those embedded in masonry, can cause severe problems if they come into contact with moisture, leading to rust and expansion that could disrupt the masonry structure. Given the projected increase in precipitation intensity due to climate change, it is crucial to locate, document, and monitor these steel elements to prevent future complications.

Although the stability of Wupatki Pueblo is discussed in separate categories, structural and material stability are interconnected. Eroding materials contribute to structural failure, and structural movement accelerates material deterioration.

This underscores the importance of identifying all factors affecting a historic structure, as well as the need for regular maintenance to address issues early. Additionally, good record-keeping is essential to track the condition of all features within the system, as even the most visible elements—such as rubble masonry walls—can be impacted by hidden components.

▸ *Steel plate on 1.56.1.E (top) is moderately corroded and loose. A rebar is partially visible in 1.69.0 (bottom); locating steel interventions will be crucial to assess their current conditions.*

4.7. Short-and Long-Term Assessment Needs at Wupatki Pueblo

Site assessment needs at Wupatki Pueblo, prioritized from short-term (1-5 years) to long-term (5-10 years), include but are not limited to the following:

4.7.1. Short-Term Assessment Needs

- Drainage Assessment

  Evaluating and addressing drainage issues throughout Wupatki Pueblo is a priority, considering that water-induced material degradation is a crucial factor affecting both the material and structural health of the site.

- Routine Site Assessment and Monitoring

  Although already a regular part of the site maintenance program at WUPA 2676, site assessment and monitoring should incorporate assessing both material deterioration and structural movement of walls. In the short term, this can involve identifying high-priority walls showing both material (e.g., erosion) and structural issues (e.g., cracking) through the SOW survey (WUPA 2676 SOW Survey Manual) to treat and monitor those walls. Structural monitoring in the short term can be as simple as installing a crack monitor to track structural movement of the Pueblo or involve targeted laser scanning to track movement.

- Metal and Steel Element Survey

  As mentioned throughout this chapter, the extent of interventions using steel and metal elements throughout the Pueblo is unclear. Locating these interventions in the upcoming years will be beneficial to understanding and preventing damage within the masonry.

- Wood Survey

  Likewise with metal elements, keeping track of the location and condition of wooden elements in the Pueblo will be important in preserving those features.

4.7.2. Long-Term Assessment Needs

- Continued Site Assessment and Monitoring

  Long-term site assessment will involve conducting the RAS annually for at least 5 years to identify deterioration patterns at Wupatki Pueblo, which will aid in proactive intervention (see WUPA 2676 RAS Manual for detailed discussion on understanding survey data). In terms of the structural stability of the Pueblo, additional laser scans of those areas identified as structurally vulnerable can be done for comparative purposes.

- Advanced studies considering three-dimensional behavior of walls at Wupatki Pueblo will help in understanding how to strengthen slender and tilted walls in preparing for potential seismic events.

References

The bibliography provided here lists all the investigative studies and reports consulted for this chapter as well as other helpful resources regarding cultural resource conditions at Wupatki Pueblo.

Wupatki Specific

Anderson, Kirk C. "Wupatki National Monument" Erosion Mitigation Study - WUPA 2676." PDF. February 23rd, 2023.

—. "Wupatki Pueblo Geoarcheology Landscape Assessment." Flagstaff, AZ: Museum of Northern Arizona, August 5th, 2021.

Dickensheets, Caroline, "A Performance Evaluation of Amended Stabilization Mortars at Wupatki National Monument, Arizona." M.S. Thesis, University of Pennsylvania, 2019. https://repository.upenn.edu/hp_theses/680

Dickensheets, Caroline, and Frank G. Matero. "Performance Testing of Acrylic-Amended Earthen Mortars at Wupatki National Monument in Arizona." *APT Bulletin: The Journal of Preservation Technology* 52, no. 1 (2021). https://www.jstor.org/stable/27018181.

Flatté, Naftalia, "A Site Vulnerability Study for Wupatki Pueblo, Wupatki National Monument." M.S. Thesis, University of Pennsylvania, 2021. https://repository.upenn.edu/hp_theses/712

Gambilongo, Laura, Alberto Barontini, and Paulo Lourenço. "Wupatki National Monument, Arizona (US): Inspection and Recommendations." Guimarães, Portugal: University of Minho, May 2022.

Gambilongo, Laura, Nicola Chieffo, and Paulo Lourenço. "Wupatki National Monument Preliminary Seismic Assessment Using Vulnerability Index Methods." University of Minho, December 2023.

Purcell, David E. "An Intensive Cultural Resources Survey Around Wupatki Pueblo (WS2676) Wupatki National Monument, Arizona." Flagstaff, AZ: Museum of Northern Arizona, February 17th, 2020.

Ramirez, Rafael, and Paulo B. Lourenço. "Wupatki National Monument Structural Modeling and Assessment." University of Minho, November 2024.

Silva, Rui A., Laura Gambilongo, Alberto Barontini, and Paulo Lourenço. "Wupatki National Monument Implementation of Grout Injection Trial Zones." Guimarães, Portugal: University of Minho, April 2023.

Other Useful Resources

Ashurst, John. *Conservation of Ruins*. Routledge eBooks, 2007. https://doi.org/10.4324/9780080466910.

Lim, Alex. "Soft Capping of Archaeological Masonry Walls: Far View House, Mesa Verde National Park." M.S. Thesis, University of Pennsylvania, 2009. https://repository.upenn.edu/handle/20.500.14332/36620.

Sponholtz, Craig, Jr., Avery Anderson, Watershed Artisans, and Quivira Coalition. "Erosion Control Field Guide." 2010. https://quiviracoalition.org/wp-content/uploads/2018/03/Erosion-Control-Field-Guide.pdf.

Wood, Chris, Alan Cathersides, and Heather Viles. "Soft Capping on Ruined Masonry Walls." Historic England, April 2, 2019. https://historicengland.org.uk/research/results/reports/7547/SoftCappingonRuinedMasonryWalls.

Notes

1 The Moenkopi sandstones at Wupatki Pueblo were sourced from the eroded Triassic Moenkopi Formation in the Wupatki Basin, consisting of thin layers of reddish-brown mudstone, sandstone, and siltstones that were deposited on broad tidal flats, in slow-flowing rivers, and floodplains of a broad coastal plain. For more detailed information on the petrology of Moenkopi sandstones, see Robert A. Cardigan, "Petrology of the Triassic Moenkopi Formation and Related Strata in the Colorado Plateau Region," *Geological Survey Professional Paper* 692 (Washington D.C.: U.S. Government Printing Office, 1971), https://pubs.usgs.gov/pp/0692/report.pdf.

2 In Ellen Brennan et al.'s 2001 report, 17 different types of mortars were listed, whereas in the University of Minho's 2022 report, eight types of mortars were identified. This is most likely due to continued stabilization efforts at Wupatki Pueblo, during which repointing has become one of the most predominantly used preservation methods. This means that older stabilization mortars, as well as the original, may be hidden below more recent mortar work. See Ellen Brennan et al., *Report of Findings: Prestabilization Documentation for Wupatki Pueblo (NA 405) Wupatki National Monument (*Flagstaff, AZ: Northern Arizona University, 2001), 81-82; and Laura Gambilongo, Alberto Barontini, and Paulo B. Lourenço, "Wupatki National Monument, Arizona (US): Inspection and Recommendations" (Guimarães, Portugal: University of Minho, May 2022), 16.

3 Kirk C. Anderson, "Wupatki Pueblo Geoarcheology Landscape Assessment," submitted to Flagstaff Area National Monuments, August 5th, 2021, 9.

4 Ibid., 48.

5 Ibid., 20-21.

6 Rui Silva et al., "Wupatki National Monument Implementation of Grout Injection Trial Zones" (Guimarães, Portugal: University of Minho, 2023).

7 Gambilongo, Barontini, and Lourenço, "Wupatki National Monument, Arizona (US): Inspection", 46.

8 Laura Gambilongo, Nicola Chieffo, and Paulo Lourenço, "Wupatki National Monument Preliminary Seismic Assessment Using Vulnerability Index Methods" (University of Minho, December 2023), 17.

9 In Anderson, "Wupatki Pueblo Geoarcheology Landscape Assessment," pg. 9, it is noted that between 1830 and 2011, the Coconino County area experienced hundreds of earthquakes, majority of which had a magnitude (Mw) of 3.0 or less. A handful of earthquakes were of moderate magnitude (between 3.0 and 5.0), and only three exceeded a magnitude of 6.0.

10 Rafael Ramirez and Paulo B. Lourenço. "Wupatki National Monument Structural Modeling and Assessment."Guimarães, Portugal: University of Minho, November 2024), 14

11 Gambilongo, Barontini, and Lourenço, "Wupatki National Monument, Arizona (US): Inspection", 3.

12 Anderson, "Wupatki Pueblo Geoarcheology Landscape Assessment," 56.

13 Gambilongo, Barontini, and Lourenço, "Wupatki National Monument, Arizona (US): Inspection", 31-37.

14 Ibid., 26.

Chapter Cover: T-shaped doorway at Wupatki Pueblo, 2022 (Credit: Ha Leem Ro).

ASSESSING VULNERABILITY: ADAPTING TO CLIMATE CHANGE 5

5 Assessing Vulnerability: Adapting to Climate Change

5.1. Introduction

Cultural resource management has long since moved beyond the question of whether the climate is changing and is now focused on defining the next course of action to mitigate and adapt to potential adverse effects. To understand and address the dynamic and complex challenges brought on by a changing climate, vulnerability assessments have become the dominant approach capable of providing a multi-faceted evaluation of many variables and uncertainties involved.[1]

Assessing climate vulnerability, defined as "the degree to which a cultural resource is susceptible to effect of climate change, variability, and extremes,"requires understanding the exposure, sensitivity, and adaptive capacity of the identified cultural heritage.[2] This chapter's primary goal is to outline those elements for Wupatki Pueblo by understanding its vulnerabilities posed by its physical context in the context of climate change and associated anthropogenic factors. With the premise that Wupatki Pueblo has high exposure as an open-air archeological site and high sensitivity due to its rubble stone masonry construction, planning for adaptation through the vulnerability assessment is crucial in safeguarding Wupatki Pueblo's resources, assets, and values in their current form or context over the long term.

Exposure (E)
the nature and the degree to which a cultural resource is exposed to climatic variations and their related impacts; it is dependent on its physical context such as geo-location and setting.

Sensitivity (S)
the degree to which a cultural resource is affected by, either beneficially or adversely, to climate-related stimuli; it is dependent on the intrinsic trait of the resource (i.e., its material composition and mechanical construction).

Adaptive Capacity (AC)
the ability of a cultural resource to adjust in order to expand its to coping range under existing and/or future climate variability and conditions.

Vulnerability (V)
the degree to which a cultural resource is susceptible to effects of climate change, variability and extremes. It is a function of exposure (E), sensitivity (S), and adaptive capacity (AC).

5.2. Vulnerability Assessment Framework

The vulnerability assessment framework for this PMP has been adapted from multiple scholarly sources (see bibliography) as well as the NPS Adaptation Planning Process.[3]

While vulnerability assessments may vary in design, many of them generally include these four steps as integral to the process: (1) define scope of heritage (resources, assets, values) to be assessed, (2) understand and assess exposure, sensitivity, and adaptive capacity over time, (3) develop indicators for elements of vulnerability, and (4) assess and quantify vulnerability.

The contents of this chapter have been organized following the four steps listed above. The first two steps are related to Chapter 3, "Heritage Values and Significance" and Chapter 4, "Site Assessment"; refer to these chapters for more detailed information on heritage values and the physical characteristics of Wupatki Pueblo.

▲ *Four-step vulnerability assessment framework adapted for Wupatki Pueblo.*

Step 1: Define Scope of Heritage to be Assessed

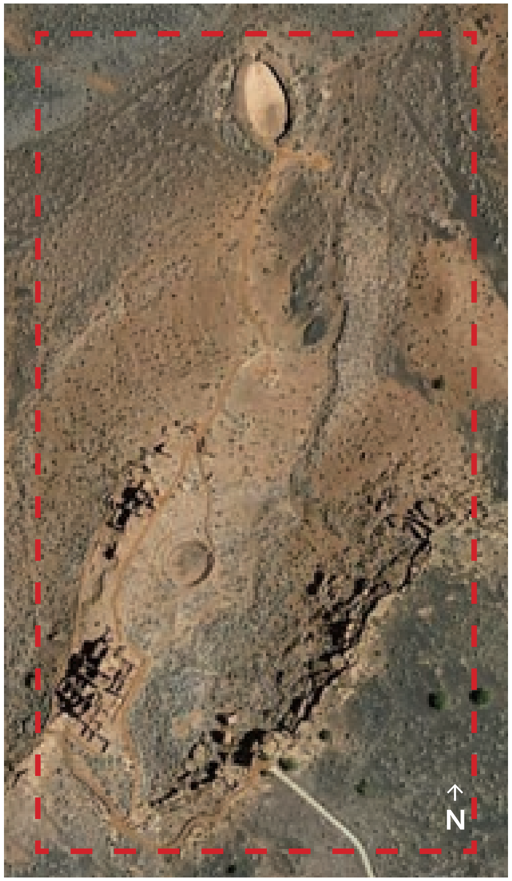
Establishing a clearly defined scope of what cultural resources and assets will be assessed is essential to produce meaningful results. This step requires understanding what is considered significant for the site as well as the spatial boundary in which the identified resources are included. The term "heritage" as used in this process can encompass both the physical fabric and immaterial (i.e., intangible) characteristics and values of the site.

For this PMP, emphasis was placed on assessing the vulnerability of the four distinct architectural units (North and South Pueblo, Community Room, and Ballcourt) of Wupatki Pueblo and the natural setting immediately surrounding them. The architectural structures occupy an area of approximately 3,700m² within the 44,130m² boundary.

Heritage resources, assets, and values (also see Chapter 3) to be assessed within those boundaries have been summarized in Table 5.1. It must be noted that the list is not meant to be comprehensive and is subject to modification as new or different assets or values requiring attention may be revealed.

Wupatki Pueblo Resource / Asset	Associated Values
Free-Standing Structures & Archeological Features	Ancestral associations Traditional building techniques Preservation history
Other Archeological Features and Artifacts	Ancestral associations Cultural diversity
Natural Setting	Uninterrupted vistas Wilderness Native grasslands

Table 5.1. Wupatki Pueblo heritage resource, assets, and values identified for vulnerability assessment.



▲ *Spatial boundary (red dashed line) as defined for the purposes of the vulnerability assessment of Wupatki Pueblo (Source: Google Earth).*

Step 2: Understand and Assess Exposure, Sensitivity, and Adaptive Capacity

Vulnerability (V) is a function of exposure (E), sensitivity (S), and adaptive capacity (AC) as represented by:

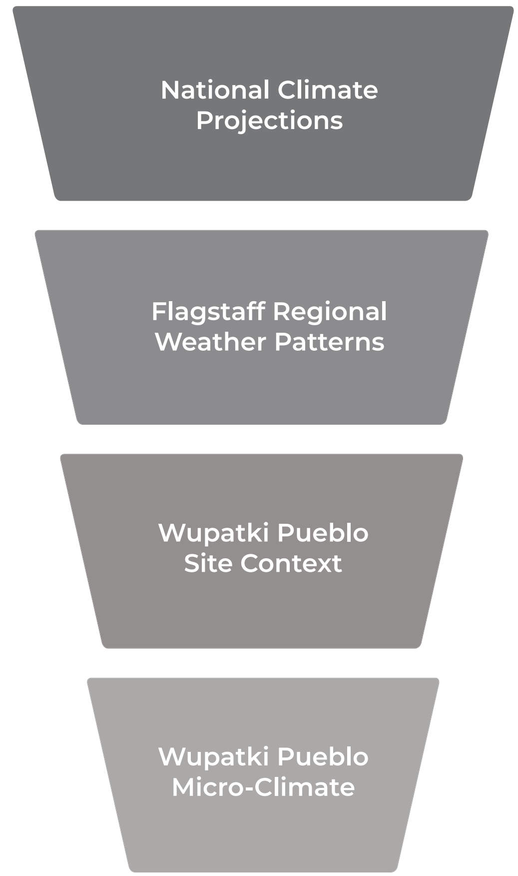
$$V = (E + S) - AC$$

Higher exposure and higher sensitivity will result in higher vulnerability, while higher adaptive capacity will result in lower vulnerability.

Understanding these factors, however, first requires the identification of climate drivers and a range of possible future climatic conditions. In other words, this step involves understanding how different climatic parameters (e.g., precipitation, temperature) impact the degree to which the cultural resource is exposed to and affected by the implicated hazards (exposure and sensitivity), and the ability of the resource to resist change (adaptive capacity).

The CAC analyzed four different levels of climate and weather data to get a comprehensive overview of changing climatic trends. The hierarchy spans from national climate models forecasting future conditions under various scenarios, to regional/local data from Flagstaff and the Pueblo's surrounding context, down to micro-level data from the Pueblo's on-site weather (WX) station and moisture sensors in the South Unit.

Key findings for Wupatki Pueblo reveal a clear trend of rising temperatures, with all future projections exceeding the recent historical average (1979–2012). Temperature increases and precipitation changes exhibit significant variability, with average temperature projections ranging from +2.1°F to +8°F and annual precipitation changes spanning from a decrease of 1.1 inches to an increase of 2.5 inches by 2050.[4] High-intensity winds predominantly come from the northwest, west, and southwest, posing structural risks. In addition, projections suggest a rise in severe and extreme drought days, as reflected in the drought index.[5]

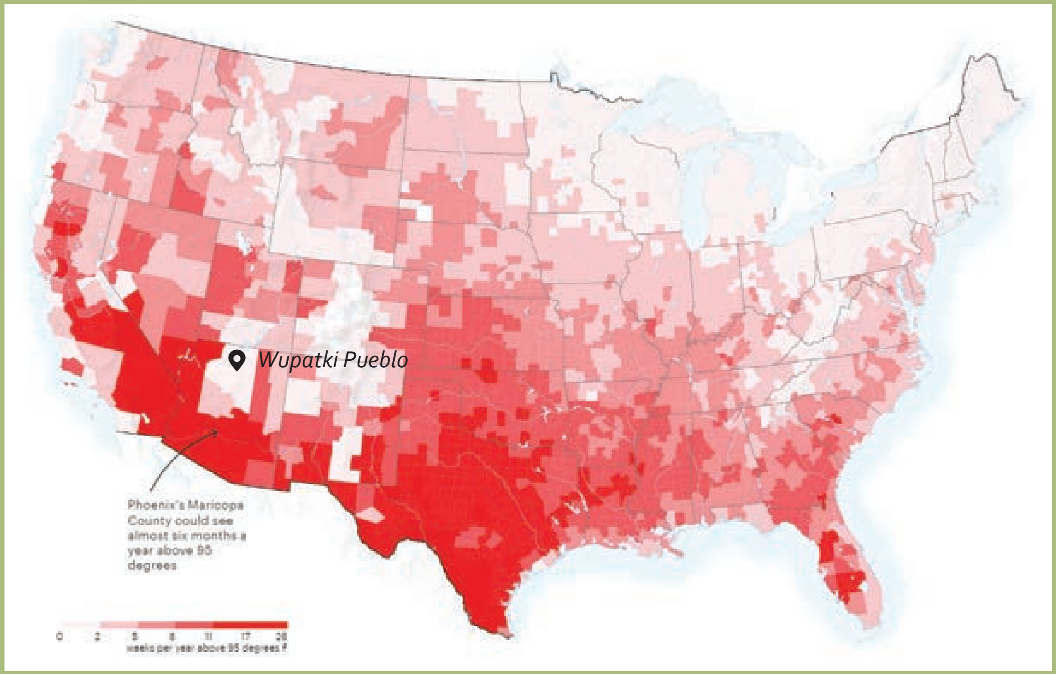


▲ *Four different levels of climate/weather data assessed to identify climate drivers.*

U.S. National Climate Projections

By 2100, the average U.S. temperature is projected to increase about 3°F to 12°F depending on emission levels and climate models. With the increase in average temperature, the number of days with high temperatures above 90°F is also expected to increase throughout the U.S., implying more frequent and intense extreme heat events and/or heat waves.[6]

Precipitation projections across the U.S. differ by region; northern parts of the country are expected to become wetter, particularly in the winter and spring, whereas southern areas, especially the Southwest, are projected to become drier. Heavy precipitation events are expected to be more frequent across the country, however.[7]



▲ *Extreme heat scenario (i.e., number of weeks/year above 95°F) between 2040-2060 for the U.S. modeled by Rhodium Group/Climate Impact Lab. Note the concentration of darker red in the Southwest region (Source: "New Climate Maps Show a Transformed United States," https://projects.propublica.org/climate-migration/).*

Regional Climate Trends

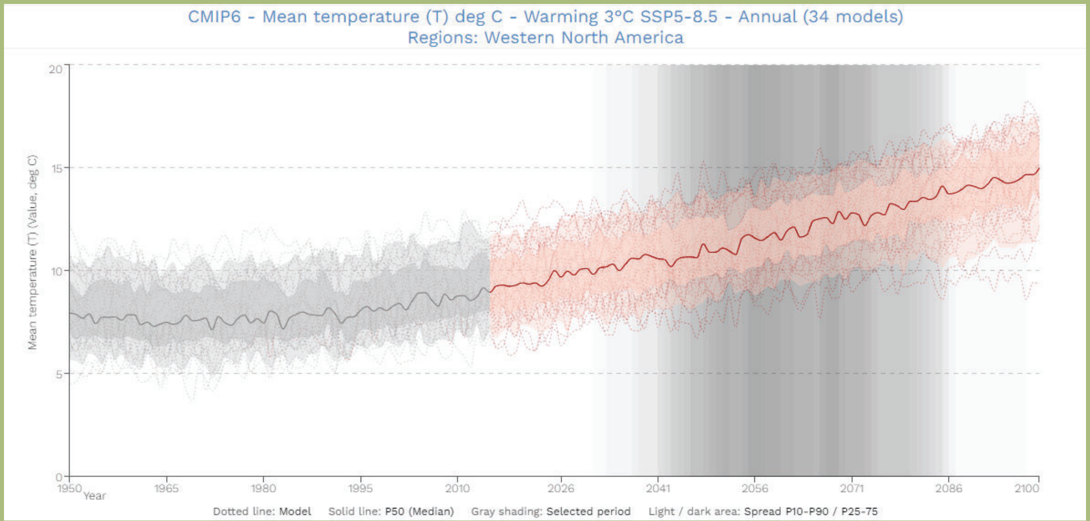
U.S. Southwest Region Projections

According to the IPCC, the U.S. Southwest is expected to experience a warming trend across all seasons, with annual mean temperatures rising as high as 9°F by 2100 in a high-emission scenario.[8] The region is also projected to remain susceptible to year-to-year and decade-long variations, such as unusually wet spells and drought episodes.[9] The observed variability in mean precipitation in the Southwest is noted to be greater than that of other U.S. regions signifying a greater unpredictability and thus greater difficulty in planning for adaptation. The southern portion of the region, however, will receive less precipitation while the northern portion is projected to receive the same or increase in precipitation.

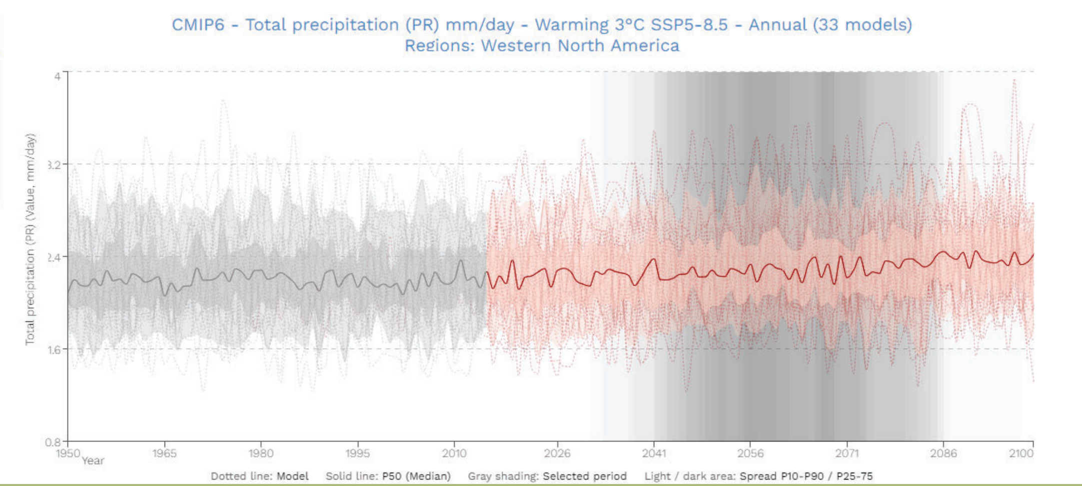
Seasonal differences are projected as well, with winter precipitation projected to increase and the other three seasons (especially spring) showing the greatest precipitation reductions.

Freeze-thaw (or freeze-free) season, however, is projected to increase across the region with the entire region exhibiting an increase of at least 17 additional freeze-thaw days. The interior far West is expected to experience an increase of more than 38 days.[10] This increase is likely to contribute to the increased vulnerability of historic structures, especially masonry sites.

With an escalating warming trend coupled with a tendency in parts of the region toward annual precipitation decreases, lower spring snow-pack is also forecasted. A marked reduction in snow accumulation in mountain watersheds across the Southwest regions is expected to result in lower soil moisture by early summers, that is, resulting in increased risks of drought and wildfires.[11]



◀ *The mean annual temperature (°C) projection graph for the U.S. Southwest in a high emission scenario from 1950 to 2100 (Source: "IPCC WGI Interactive Atlas," https://interactive-atlas.ipcc.ch/).*

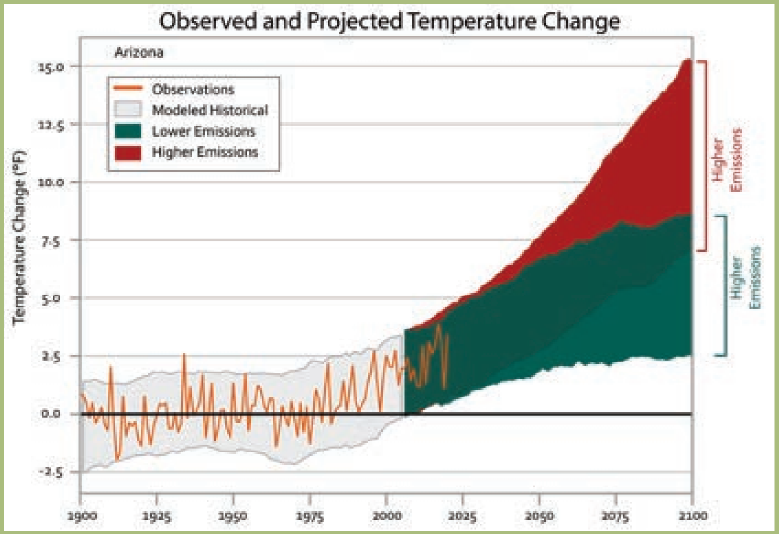


◀ *The total precipitation (mm) per day projection graph for the U.S. Southwest in a high emission scenario from 1950 to 2100 (Source: "IPCC WGI Interactive Atlas," https://interactive-atlas.ipcc.ch/).*

Arizona and Flagstaff

According to the National Oceanic and Atmospheric Administration (NOAA) State Climate Summaries, temperatures in Arizona have risen approximately 2.5°F since the beginning of the 20th century.[12] Historically unprecedented increases in annual average temperatures are projected for the remainder of this century with a notable increasing trend in both daytime high and nighttime low summer temperatures, implying intensifying future heat waves for a state that already experiences extremely hot conditions.

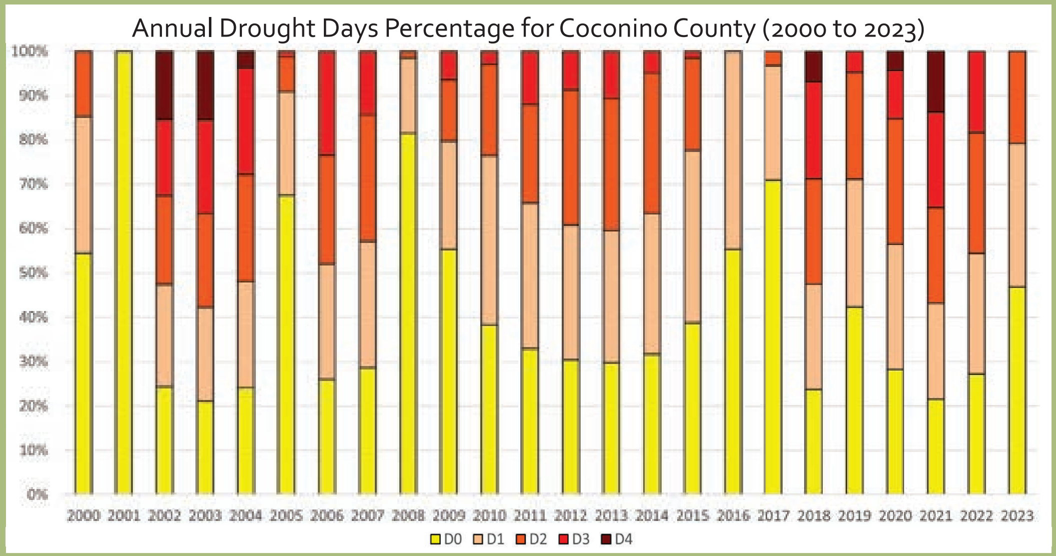
Despite being in the higher terrain of the Colorado Plateau with typically cold winters and mild summers, Flagstaff (in Coconino County) is also projected to experience a warming trend, with average temperatures having risen notably in the last 30 years. Climate profiles developed by University of Arizona[13] and the data set from the NOAA's WX station at Flagstaff Airport suggest an average temperature increase of 5°F by 2050 and more than 10°F by 2100 from the current average of 52.3°F.



▲ *Observed and projected temperature change for Arizona (Source: NOAA State Climate Summaries).*

The increase in average temperature is expected to result in fewer cold days and more hot days in a given year. Specifically, Flagstaff is likely to see a substantial increase in the number of days above 90°F, projected to reach up to 80 days per year by the end of the century, a significant spike from the current average of two days per year. Minimum temperatures are also rising, leading to fewer days with temperatures dropping below freezing, potentially impacting precipitation trends and ultimately influencing moisture-related issues within cultural resources and assets. Precipitation patterns in Coconino County have been historically variable, and this variability is expected to continue with no clear changes in average precipitation trends. However, rising temperatures will increase evaporation and transpiration rates, leading to drier soils and contributing to more frequent and severe droughts. Additionally, rising low temperatures indicate a shift from snow to rain during the colder months of the year, which could potentially lead to more intense rainfall and an increased risk of flooding for the region.

According to the U.S. Drought Monitor (USDM) program, drought conditions for Coconino County typically begin in February, persisting throughout spring season and peaking during summer. While it is difficult to identify a clear long-term trend from the USDM data from 2000 to 2023, Severe (D2) and Extreme Drought (D3) conditions have been prevalent since 2017, with sporadic instances of Exceptional Drought (D4) days.[14] With projected temperature increases, drought days should be expected to increase contributing to a more arid climate for the region.



▲ *Annual drought days percentage for Coconino County (2000-2023) using the USDM drought category system. The five categories are: Abnormally Dry or D0, (a precursor to drought, not actually drought), and Moderate (D1), Severe (D2), Extreme (D3) and Exceptional (D4) Drought (Source: USDM, https://www.drought.gov/data-maps-tools/us-drought-monitor).*

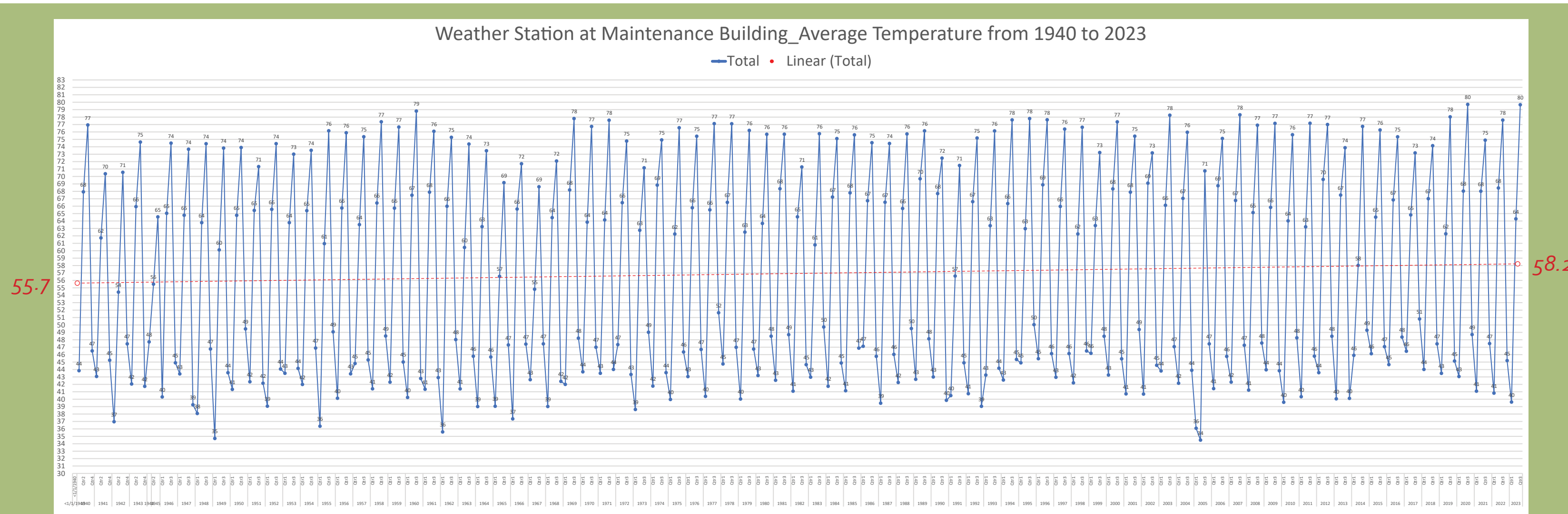
Wupatki Pueblo Site Context: Historical Conditions (1940-2023)

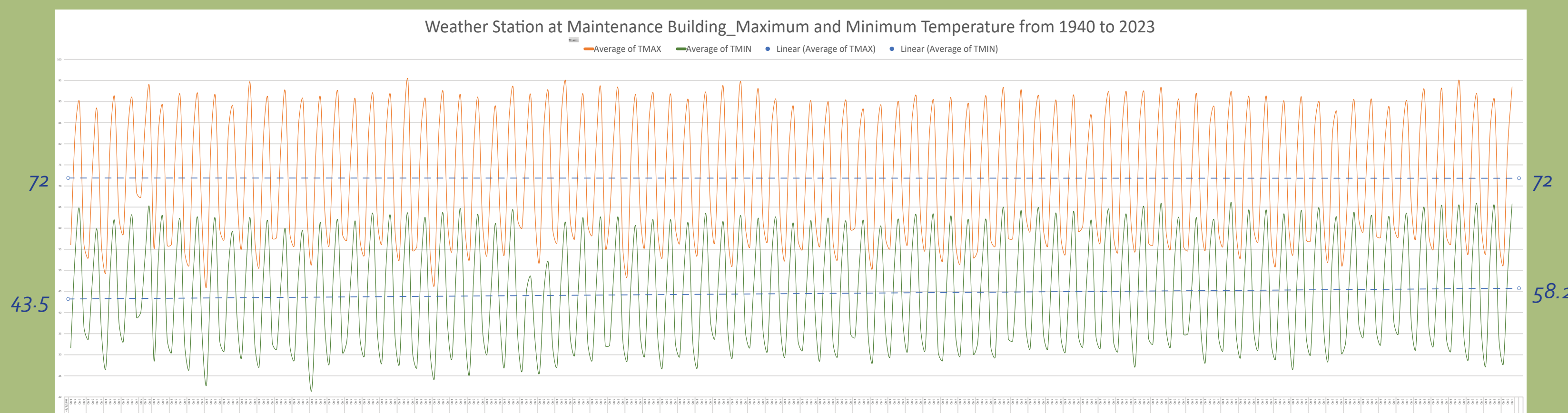
Site-level climate trends for Wupatki Pueblo were analyzed using the data recorded by NOAA's WX station at Wupatki National Monument's Maintenance Building, operational since 1940. Over 83 years, the data reveal a median annual temperature increase of 3°F, rising from 55.7°F in 1940 to 58.2°F in 2023. While maximum annual temperatures have remained steady around 72°F, minimum annual temperatures have risen from 43.5°F to 46°F, indicating increasingly mild winters. Since 1970, daily minimum (night time) temperatures have increased more rapidly than daily maximum (daytime) temperatures, reducing the diurnal temperature range and indicating warmer nights.[15]

Precipitation trends at Wupatki appear to be influenced by larger forces (e.g., El Niño and La Niña events), with annual precipitation data indicating a generally upward trend but variability year-to-year. Quarterly data highlight that most precipitation has occurred during the third quarter (July to September), aligning with the Northern Arizona monsoon season, which traditionally spans June to late September. However, since 1970, Wupatki's monsoon season has shifted slightly, starting in mid-July and ending in early September. Rainfall has also become more frequent and intense, particularly from mid-July to late August, suggesting a potential intensification in both volume and intensity of rainfall within a slightly shortened monsoon season.

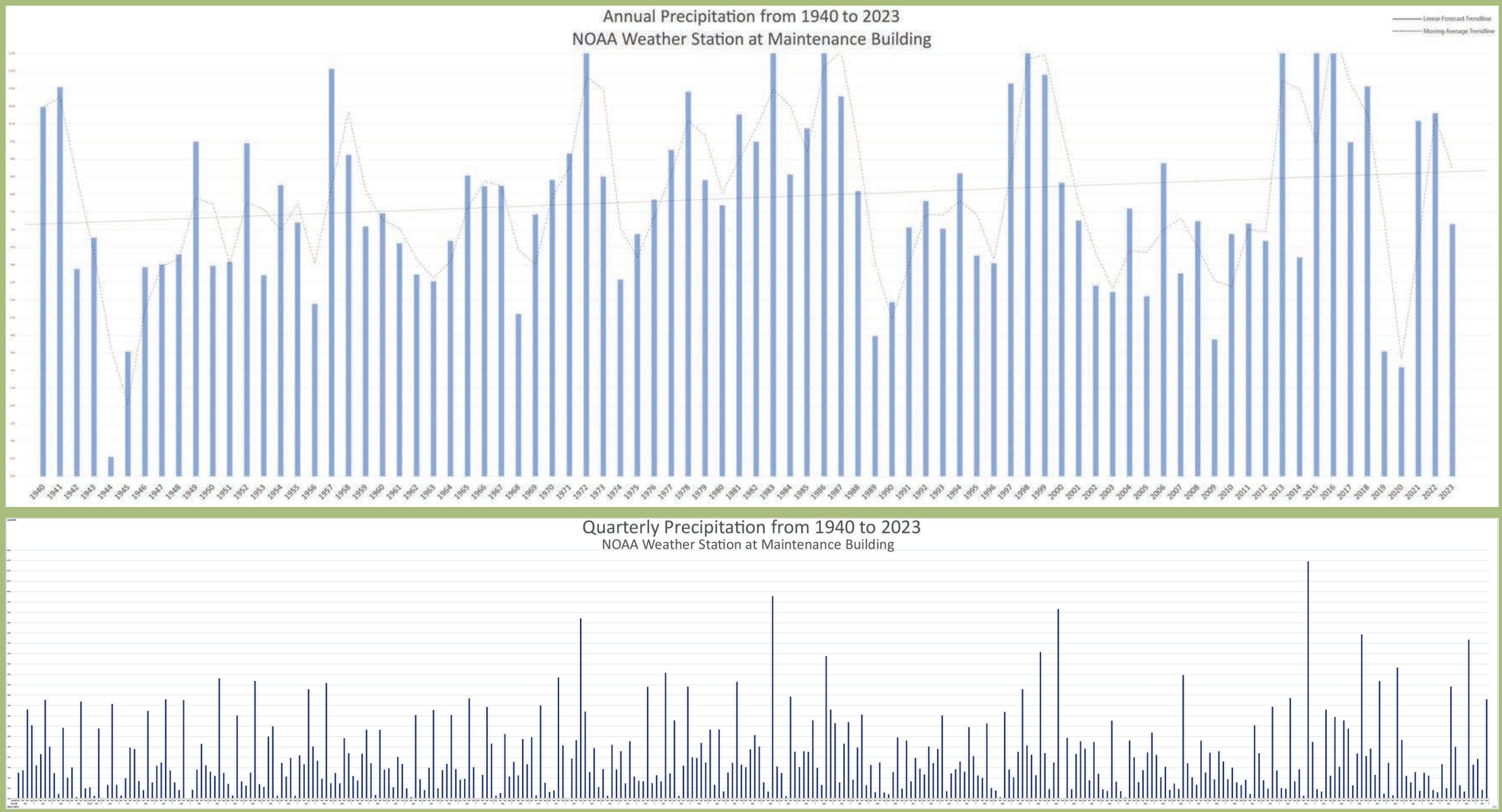
Wupatki is also experiencing changes in extreme precipitation events. Since 1958, there has been a 17% increase in rainfall during heavy storms, driven by warmer air holding more moisture, leading to more intense precipitation events. Winter precipitation trends also reflect notable changes.[16] The typical precipitation season in the region, extending from November to April, peaks during December, January, and February. Data show a clear increase in winter precipitation during these months, particularly in January, which has experienced a sharp rise in both frequency and intensity of rain events. December and January have seen more frequent heavy precipitation, while March shows increased variability and more extreme events.

These trends suggest that warming temperatures are transforming winter precipitation patterns, with rain and rainstorms becoming more prevalent in what were historically snow-dominated months. These evolving precipitation dynamics highlight the need for adaptive strategies to address heightened risks of severe weather, hydrological changes, and potential flooding events.





▲ *The NOAA weather station at the Maintenance Building recorded variations in mean (top); and maximum and minimum (bottom) temperatures (°F) from 1940 to 2023. The minimum temperature increased by approximately 3°F, signaling warmer winters at the site.*



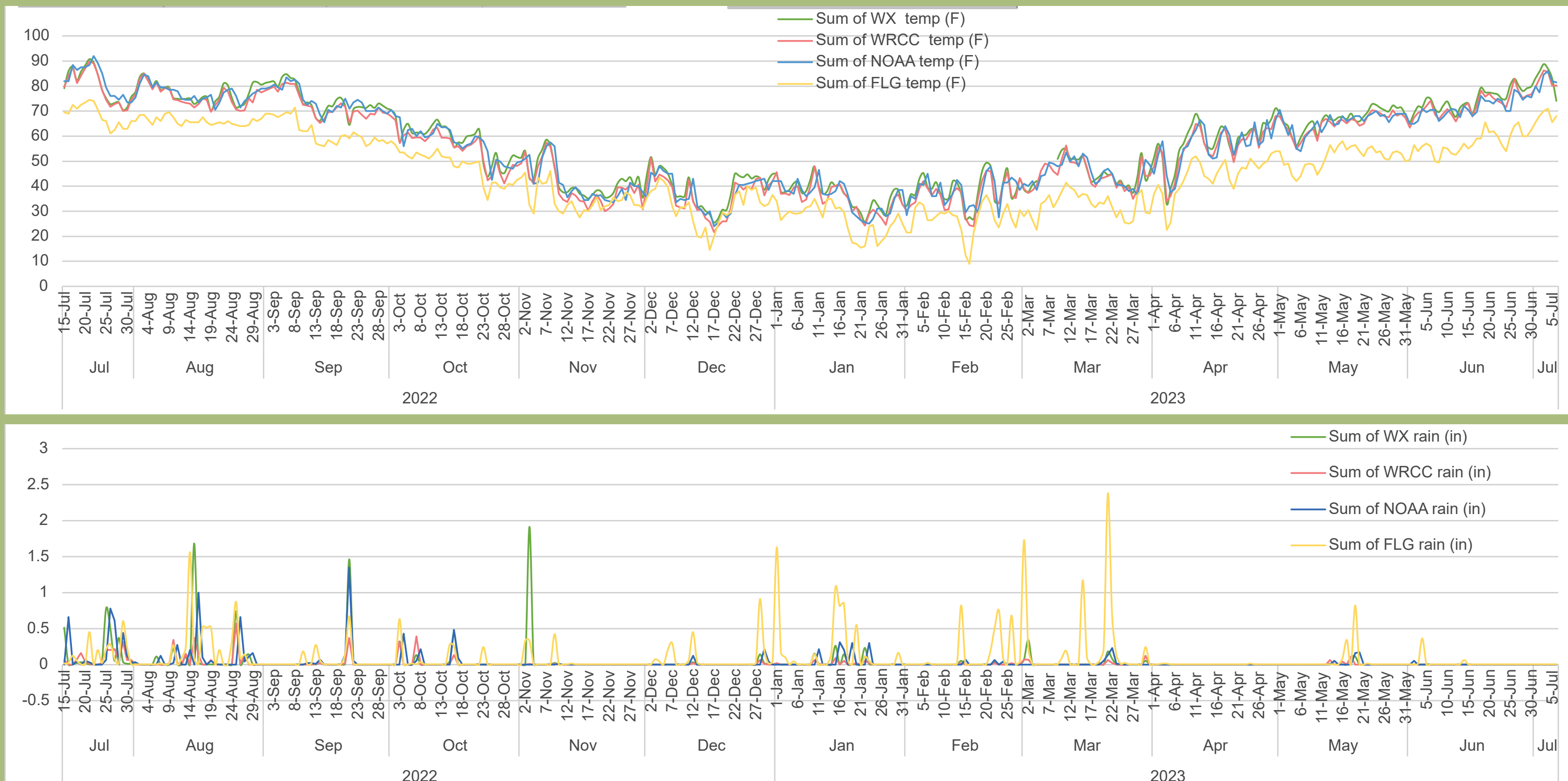
▲ *Annual (top) and quarterly (bottom) precipitation data from the NOAA WX station at the Maintenance Building. While the moving average trendline suggests an unpredictable annual pattern, the linear trendline suggests a constant rate of change in annual precipitation from 1940 to 2023. Although the overall amount of precipitation has not changed much over time, the instances of steep hikes for precipitation in the third quarter suggest an intensification of precipitation events.*

Wupatki Pueblo Micro-Climate

A new WX station was installed at Wupatki Pueblo with the assistance of the Vanishing Treasures (VT) program in the summer of 2022 to better understand weather trends specific to the Pueblo. Data from this new station were compared with three other stations near and far (NOAA WX station at the Maintenance Building, Western Regional Climate Center (WRCC) WX station on Woodhouse Mesa, and Flagstaff Airport WX station) to identify any similarities and/or idiosyncrasies between micro, meso, and macro-level climate trends.

Comparing a year's worth (July 2022–July 2023) of weather data from the four different stations, it was revealed that the new WX station, located closest to the Pueblo, consistently recorded higher temperatures and occasionally reported greater precipitation volumes on certain days. These isolated differences are not enough to identify truly unique micro-climatic patterns surrounding Wupatki Pueblo, however. The tendency for the newest WX station to record higher temperatures may be potentially due to its more advanced sensors and/or its location within a desert basin, where ground surface heat reflection is more pronounced. This contrasts with the NOAA and WRCC stations situated at a higher elevation, and the Flagstaff Airport WX station located in a distinctly different climate. Similarly, the higher precipitation volumes reported by the new station could be attributed to its rapid 5-minute recording intervals, which may capture short-duration rainfall events more effectively. The limited timeframe of data collection is insufficient to identify definitive, unique climatic patterns at Wupatki Pueblo. Continued monitoring over a longer period will be essential to better understand localized weather dynamics and distinguish them from broader regional trends.

▲ *WX station installed south of the South Unit at Wupatki Pueblo in July 2022 (Credit: NPS).*

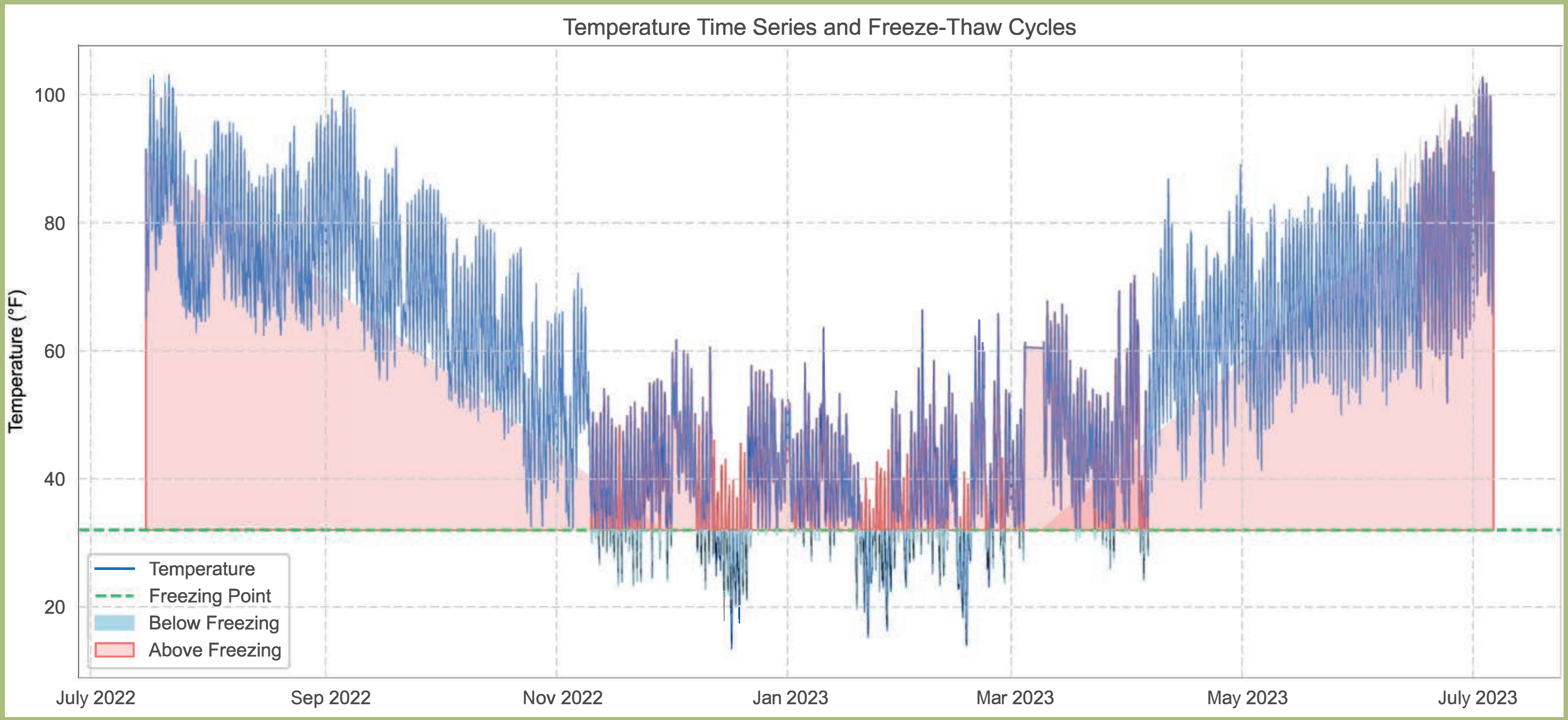


▲ *Temperature variations (top) and precipitation data (bottom) in 5-day increments from July 2022 to July 2023, as recorded by WX station at Wupatki Pueblo (WX), Mesa (WRCC), Maintenance Building (NOAA), and Flagstaff Airport (FLG). Overlaying these data sets reveals that the airport experiences lower overall temperatures and reacts earliest to temperature fluctuations. Pueblo records higher peak temperatures compared to Mesa, suggesting micro-climate differences at the Pueblo site while showing synchronous precipitation events across all locations. However, Flagstaff Airport records the most pronounced peaks in precipitation, while the Pueblo (WX) station captures greater volume compared to the other two nearby stations.*

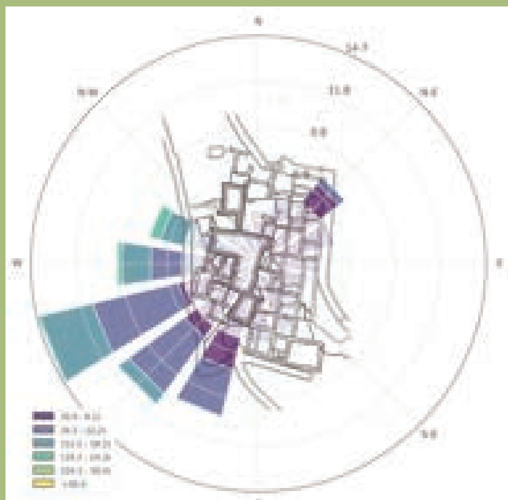
Wupatki Pueblo Micro-Climate Cont'd

Other important climatic parameters to consider in the context of understanding decay mechanisms for Wupatki Pueblo are the freeze-thaw cycle and prevailing wind directions. A freeze-thaw cycle (FTC) is defined as the occurrence when air temperature drops low enough to freeze water (32°F) and then increases enough for it to thaw again with both freezing and thawing periods lasting over 30 minutes.[17] These cycles most commonly occur during the wintertime but can happen at any time of the year. The WX station at the Pueblo recorded the freeze-thaw season for July 2022 to July 2023 as lasting approximately 147 days with an estimated 71 freeze-thaw cycles occurring. The impact of these cycles on masonry depends on their frequency as well as their timing and duration within the season. Critically, when temperature fluctuations align with increased moisture availability—from sources like rain in addition to snow-melt—the potential for water damage is significantly amplified. Furthermore, a notable shift of the freeze-thaw season to later in the year, aligning with a wetter season, exacerbates the exposure of structures to water damage. This shift intensifies the risks, as structures are subjected to an increased amount of water during the freeze-thaw periods, thus heightening the vulnerability of masonry to weather-induced stress and decay.

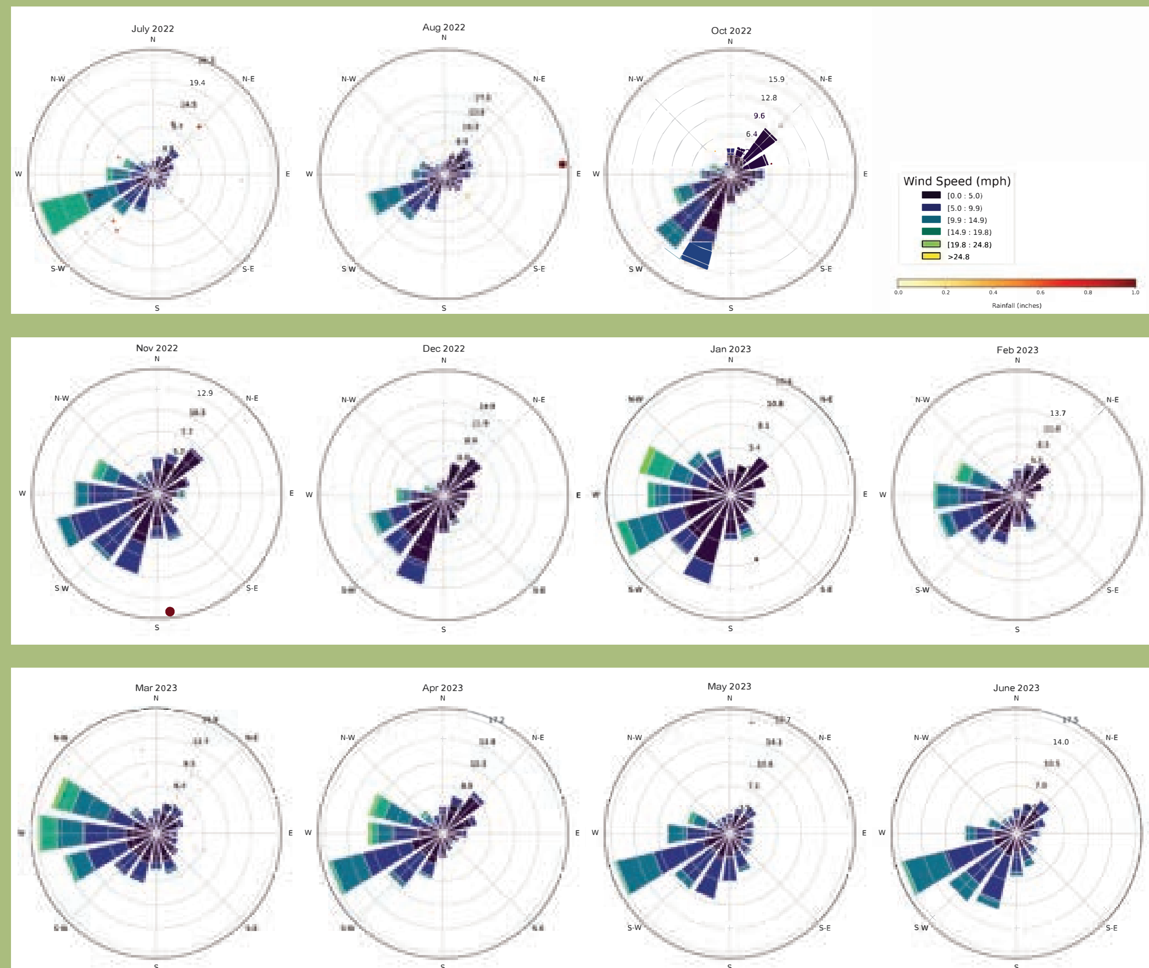
The weather data at the Pueblo provides valuable insights into wind patterns, including direction, speed, and precipitation levels from July 2022 to July 2023. Aggregated monthly and visualized in wind roses, along with annual wind intensity and precipitation trends, the data indicate that winds predominantly originate from the southwest, followed by the northwest, while northern winds are less frequent and weaker. Regarding wind speed, the highest values are primarily concentrated in the west and southwest, averaging around 10 mph. The northwest also experiences high-speed winds, though less frequently. When analyzed alongside rainfall events, these wind characteristics suggest an increased risk to Pueblo structures and features facing northwest, west, and southwest. This indicates that these areas may be more vulnerable to weather-induced damage, highlighting them as critical priorities for future conservation and resilience planning.



▲ *Analysis of freeze-thaw cycles using temperature data from Wupatki Pueblo's WX station. The green line denotes the freezing point at 32°F. The areas shaded in blue and red indicate temperatures below and above the freezing threshold, respectively.*



▲ *Wind rose graph showing annual wind intensity and direction (July 2022 to July 2023) overlaid with the floor plan of the South Unit.*

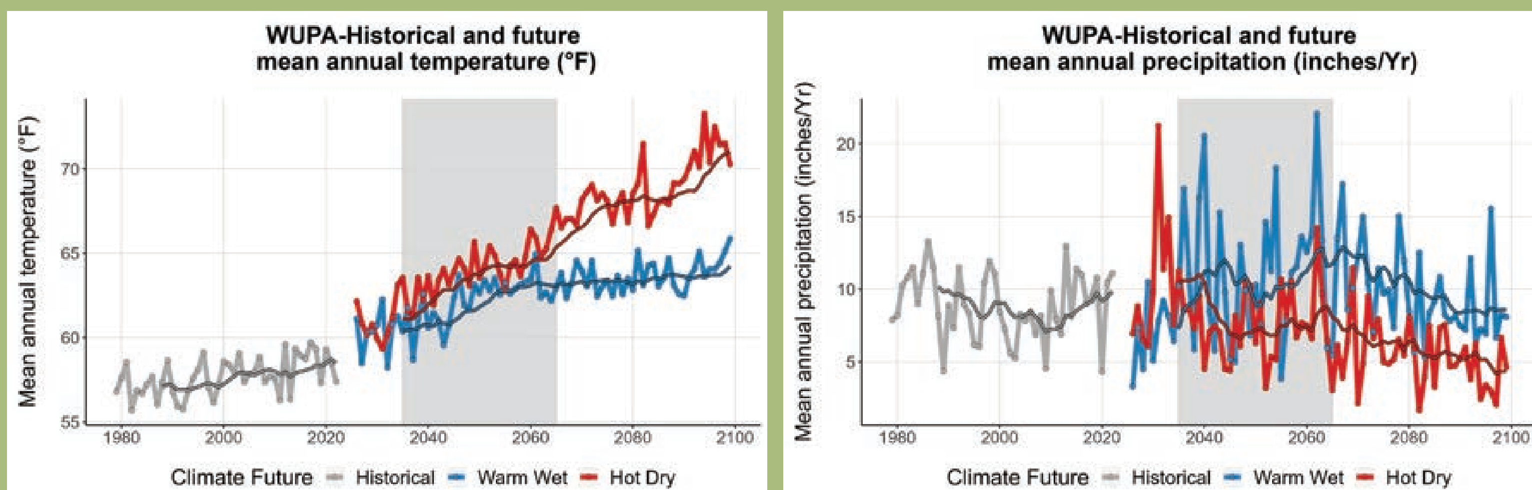


▸ *Monthly wind intensity overlaid with real-time precipitation, captured as scatter points, from July 2022 to July 2023. For Wupatki Pueblo prevailing winds originate from the West and Southwest, exhibiting higher speeds.*

So What Does This Mean For Wupatki Pueblo?

While an overall warming trend is expected for Wupatki Pueblo, climate models vary in the extent to which annual temperatures will rise depending on greenhouse gas emission scenarios. Along with the variability in precipitation projections, two different climate futures entailing different climate impacts can be considered for Wupatki Pueblo: "Warm Wet" and "Hot Dry" conditions through 2050.[18] It must be noted, however, that the two climate scenarios are relative to each other, not the past; the Warm Wet climate future might be more arid than what the site experienced historically but the name refers to wetter conditions projected than the Hot Dry climate future.[19]

The two different climate scenarios will impact the exposure, sensitivity, and the adaptive capacity in different degrees for Wupatki Pueblo. The following sections of this chapter outline the three elements of vulnerability in each of the two identified climate futures.



▲ *Observed data from 1979-2002 (gray line) and projected annual temperature (left) and precipitation (right) for Warm Wet (blue line) and Hot Dry (red line) climate futures. The smooth line represents a decade-average for those periods, while the gray-shaded area (2035-2065) indicates the period averaged to project conditions for 2050 (Source: Wupatki National Monument Climate Futures Summary, NPS Climate Change Response Program, 2024).*

Step 2 Cont'd: Understand and Assess Exposure, Sensitivity, and Adaptive Capacity

Exposure

By identifying climate future projections, it becomes possible to describe the exposure of cultural resources to the identified climatic parameters as well as human factors and their associated impacts (Table 5.2). Exposure of earthen structures and earthen mortared masonry, especially excavated structures like Wupatki Pueblo, presents even more serious problems given the rapid changes that always ensue, often immediately after exposure.

<table>
<tr><th colspan="2">Climatic / Anthropogenic Parameters by Climate Future (by 2050)</th><th colspan="2">Impact by Climate Future (by 2050)</th></tr>
<tr><th>WARM WET</th><th>HOT DRY</th><th>WARM WET</th><th>HOT DRY</th></tr>
<tr><td>Moderate Annual Temperature Rise: + 3.6 °F</td><td>Extreme Annual Temperature Rise: + 5.8 °F</td><td rowspan="2">Water retention in masonry structures and ground surface</td><td rowspan="2">Continued drought and rapid evaporation rate may exacerbate material failure, structural performance (e.g., shrinkage, cracking) and salt accumulation</td></tr>
<tr><td>Annual Precipitation Rise: +0.9"</td><td>Annual Precipitation Drop:- 0.9"</td></tr>
<tr><td>Extreme Precipitation Rise: +3.4"</td><td>Extreme Precipitation Rise: +1.5"</td><td colspan="2">Increased risks of flash flooding, land/mudslides, increased pressure on infrastructure (i.e., drainage) and wall collapse</td></tr>
<tr><td colspan="2">Prevailing Winds</td><td>Erosion from wind-driven rain</td><td>Erosion from sediment laden winds, increased evaporation rates</td></tr>
<tr><td colspan="2">Seismic Activity</td><td colspan="2">Risk of structural failure, collapse</td></tr>
<tr><td colspan="2">Visitor Disturbance</td><td colspan="2">Physical damage (e.g., mechanical damage, graffiti), loss of physical integrity</td></tr>
<tr><td colspan="2">Preservation Activity</td><td colspan="2">Potential for insufficient treatment, human error</td></tr>
</table>

Table 5.2. Evaluation of Wupatki Pueblo's exposure to climate and anthropogenic factors and their associated impacts.

Sensitivity

The sensitivity of a site is dependent on the aspects of its physical composition (i.e., material and construction system) and its current condition that affect the performance and durability. Evaluating sensitivities therefore requires understanding deterioration mechanisms particular to the building material and the construction typology, with the assumption that worse conditions lead to an expedited deterioration process (Table 5.3). See Chapter 4, "Site Assessment" for a detailed discussion on current condition and agents of deterioration for Wupatki Pueblo.

<table>
<tr><th rowspan="2">Wupatki Pueblo Resource / Asset / Value</th><th colspan="2">Summary of Impacts by Climate Future (by 2050)</th><th colspan="2">Mechanism</th></tr>
<tr><th>WARM WET</th><th>HOT DRY</th><th>WARM WET</th><th>HOT DRY</th></tr>
<tr><td>Pueblo Features: Rubble Masonry, Moenkopi Sandstone, Earthen Mortar, Cementitious Preservation Mortar</td><td rowspan="3">• Water retention in structures and ground surface
• Increased risks of flooding, land/mudslides pressuring drainage systems
• Erosion from precipitation events
• Structural damage from both natural and anthropogenic factors</td><td rowspan="3">• Extended drought periods affecting material
• Erosion from sediment laden winds, increased evaporation rates</td><td>Moenkopi sandstone and earthen mortar is prone to erosion from moisture. Hard cementitious material may affect moisture movement within structures.</td><td>Different evaporation rates of original and preservation material may cause faster decay of earthen materials.</td></tr>
<tr><td>Other Archaeological Features & Artifacts</td><td>Soil erosion from precipitation events can reveal and disturb buried deposits. Water retention in soil can affect buried deposits.</td><td>Increase in evaporation rates can affect site stability, increasing threats from wind erosion and fire.</td></tr>
<tr><td>Natural Setting</td><td>Heavy rain can erode soil increasing flood risks and debris flow.</td><td>Extended drought conditions increases wild fire risks, contributing to severe soil erosion post-precipitation events.</td></tr>
</table>

Table 5.3. Evaluation of Wupatki Pueblo's sensitivity to impacts from climate change.

Adaptive Capacity

As finite, immovable, and non-renewable resources, the adaptive capacity of cultural heritage sites effectively depends on cultural resource management. This doesn't only refer to the day-to-day site management efforts such as regular maintenance (i.e., preservation treatment) and upkeep of control systems (e.g., drainage systems), but also includes broader factors, such as larger administration policies and programs that govern the site. In that context, it is important to consider the different scales at which adaptive capacity can be affected (Table 5.4).

Adaptive Capacity Area Categories	Wupatki Pueblo	Comment(s)
Policies and Programs	• Eligible for listing on the National Register of Historic Places (1966) • Near Wupatki Visitor Center Complex Historic District (2006) • NPS Stewardship and Management (see Chapter 6, "Conservation Goals, Policies and Guidelines" for a detailed listing of all relevant federal laws and regulations as well as management structures) • Tribal Co-Stewardship (2022)	Numerous federal laws as well as NPS policies provide strong legislative backing for continued stabilization and risk mitigation efforts
Information and Knowledge	• NPS and institutional partners • Tribal Engagement and Indigenous Knowledge	Continued partnerships can expand knowledge about the site and preservation methods further contributing to its preservation
Implementation	• Annual preservation and maintenance cycle	Frequent preservation maintenance efforts contribute to the improving the adaptive capacity of the site
Monitoring		

Table 5.4. Evaluation of adaptive capacity areas for Wupatki Pueblo.

Step 3: Develop Indicators for Elements of Vulnerability

Indicators are measurable factors used as proxies for the three elements of vulnerability in quantifying them (Tables 5.2, 5.3, 5.4). Once vulnerability "scores" are calculated using the $V = (E + S) - AC$ formula, these scores can aid cultural resource managers prioritize areas for attention and develop strategies for risk mitigation and preparedness.

In this assessment, indicators were selected with a focus on evaluating Wupatki Pueblo as a whole, rather than analyzing individual units or specific walls. However, it is important to note that vulnerability can vary depending on the scale of observation and monitoring. For example, while all units and areas of Wupatki Pueblo may be equally exposed to climatic hazards, the South Unit may be more sensitive—and therefore more vulnerable—due its location on bedrock, the presence of taller structures, as well as the prevalence of original architecture. In contrast, the Ballcourt, which has been fully reconstructed with cement mortars, may have lower sensitivity and therefore lower vulnerability. Even within a single unit, different levels of vulnerability can exist. For instance, structures/features that are in higher areas of the pueblo may be more vulnerable given the height of the walls (higher sensitivity) and reduced maintenance access (lower adaptive capacity). While these nuances are noted in this assessment, a more detailed, wall-level analysis could provide deeper insights in the future.

A key characteristic of many indicators, particularly those related to exposure and adaptive capacity, is that they highlight aspects of the site that can be managed to reduce risks. For instance, increased exposure to visitor impact could be mitigated through stricter supervision or by reducing unsupervised hours. This aspect of the vulnerability assessment process provides valuable insights into short- and long-term opportunities for improving cultural resource management.

The criteria for scoring were based on site-specific knowledge gained throughout the project as well as understanding patterns of deterioration for archeological sites and earthen structures. This step was also supported by the Cultural Resources Environmental Vulnerability Assessment Toolbox (CREVAT) developed for National Park Service sites.[20]

Indicator (Proxy for Exposure)	Score Criteria		
	1	2	3
Change in Annual Temperature (°F)	< 2.7 °F	= 2.7 °F	*> 2.7 °F*
Change in Extreme Precipitation (inches/day)	< 1 inch	= 1 inch	*> 1 inch*
Seismic Hazard Zone Category	Zone A, B	*Zone C, D, D1*	Zone D2, E
Presence of Protective System/Surface (e.g., shelter, sacrificial coating)	Sheltered	-	*Open-Air Site/No Protective Systems*
Length of Visiting Season	Limited Visitation	Seasonal Opening	*All Year-Round*
Proximity to Visitor Trails / Ease of Visitor Access	No Direct Trails/ Difficult Access	Limited/Guided Access	*Full Visitor Access via Trail*

Table 5.5. Indicators and scoring criteria for Exposure for Wupatki Pueblo. Score criteria applicable to the Pueblo are noted in GREEN.

Comments on Exposure Indicators and Score Criteria

The exposure indicators selected for this exercise were based on widely accepted natural and human causes contributing to resource degradation. The list provided is not exhaustive and can be expanded to included additional indicators, such as changes in freeze-thaw frequency, wildfire hazard potential, and more refined scoring criteria, like the proximity of trails to structures with specific distances or the slope surrounding a feature separated by actual degree measure. The provided indicators for exposure are derived from understanding Wupatki Pueblo's locational and physical context. As an open-air archaeological site accessible to visitors year-round, Wupatki Pueblo is particularly vulnerable to the impacts of the changing climate as well as impacts from human activity.

Score criteria for the listed indicators were based on well-established thresholds; 2.7 °F is considered the climate benchmark for global warming and 1" of rain within a 24-hour period is also generally accepted as a threshold for defining extreme precipitation.[33] According to the Earthquake Hazard Map published by the Federal Emergency Management Agency (FEMA), Flagstaff is categorized as likely to experience strong shaking that can cause negligible to considerate damage in built structures depending on seismic preparedness.[34] Historical seismic records, however, show that major earthquake events have been infrequent for Wupatki Pueblo, although the inherent value of the site puts it at a higher risk to any seismic activity (see Chapter. 4, "Site Assessment" for more information).

Indicator (Proxy for Sensitivity)	Score Criteria		
	1	2	3
Type of Material	Dense / Non-Porous	***Mixed***	Porous
Type of Construction	Complex	Mixed	***Simple***
Presence of Incompatible Treatment Materials (i.e., materials that are not in-kind)	Low	***Moderate***	High
Extent of Past Intervention (i.e., reconstruction)	High	***Moderate***	Low
Current Condition of Structure & Materials	Good	***Fair***	Poor

*Table 5.6. Indicators and scoring criteria for Sensitivity for Wupatki Pueblo. Score criteria applicable to the pueblo are noted in **GREEN**.*

Comments on Sensitivity Indicators and Scoring Criteria

The sensitivity indicators were selected based on an understanding Wupatki Pueblo's material composition and structural characteristics. The Pueblo's primary construction system consists of one- to three-wythe rubble masonry (simple construction), mostly built from Moenkopi sandstone laid in earthen mortar. These materials, being hygroscopic (water-absorbing) and the relatively weak connection between walls make the Pueblo particularly sensitive to environmental impacts. Ongoing stabilization efforts have helped preserve the site's material health, keeping its overall sensitivity at a moderate level (see Chapter. 4, "Site Assessment" for more detailed discussions on the current conditions of Wupatki Pueblo).

Likewise with the exposure indicators, the list of sensitivity indicators is not exhaustive and can be expanded to include more detailed criteria, such as the porosity and clay content (with laboratory analyses) that influence the erosion of building materials. The scoring criteria used here are adapted from CREVAT, a geospatial toolset developed by the NPS to assess the vulnerability of different building systems to climate change in the NPS Intermountain Region[35].

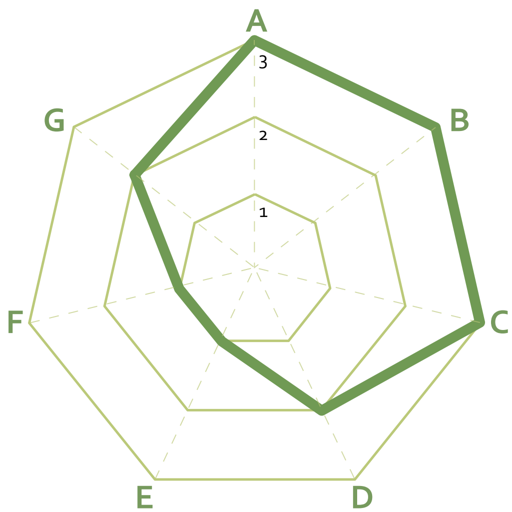


Chart 5.7. Indicators, scores and scoring criteria for each indicator (bullet points) for Adaptive Capacity for Wupatki Pueblo.

Comments on Adaptive Capacity Indicators and Scoring Criteria

The adaptive capacity indicators and scoring criteria for Wupatki Pueblo were adapted from Marvin Ravan's 2023 vulnerability assessment framework for cultural heritage sites.[36] Adaptive capacity was analyzed with the help of FLAG NM Cultural Resource Management team.

(A) Legal Framework & Multi-Sectoral Cooperation

- Legal framework for cultural heritage protection
- Cooperation among disaster management, heritage, and civil organizations for risk preparedness and emergency response

(B) Socioeconomic Factors Related to Risk Management

- Insurance and/or financial resources for risk management (mitigation and recovery)
- Local community support

(C) Risk Awareness

- Staff awareness of sudden- and slow-onset hazards and climate change threats to cultural heritage

(D) Information & Communication System

- Heritage, Hazard and Risk info system (e.g., inventory of heritage assets, hazards, vulnerabilities in GIS)
- Emergency contacts directory (including heritage and disaster specialists)
- Access to early warning and evacuation data/info

(E) Risk Preparedness Plan/Activities

- Emergency response services/plan (e.g., equipment and supplies for emergency evacuation of movable objects, damage assessment, security, and stabilization)
- Disaster drills and site exercises
- Early warning systems (e.g., fire alarms, storm alerts)
- Skilled human resources

(F) Risk Mitigation Plan/Activities

- Hazard prevention/mitigation (e.g., flood levees)
- Risk mitigation for decorative/movable objects, and structures (e.g., seismic fixing techniques for collections, seismic structural retrofitting)

(G) Monitoring & Maintenance Plans/Procedures

- Regular monitoring & maintenance of structures/materials, control systems (e.g., drainage systems), and climate parameters (e.g., precipitation)

Step 4: Quantify and Assess Vulnerability

With the indicators and score criteria established, vulnerability of Wupatki Pueblo can be measured. The sum of the exposure, sensitivity, and adaptive capacity scores is divided by the number of indicators in each category to ensure equal weighting, allowing for consistent comparisons on a standardized 1-3 scale.[21] The final calculated vulnerability score for Wupatki Pueblo is ***2.89*** *out of a possible* ***3***.

Exposure Indicator	Score
Change in Annual Temperature	3
Change in Extreme Precipitation	3
Seismic Hazard Zone Category	2
Presence of Protective System/Surface	3
Length of Visiting Season	3
Proximity to Visitor Trails/ Ease of Visitor Access	3
Number of Indicators: 6	**17**

Adaptive Capacity Indicator	Score
Legal Framework & Cooperation	3
Socioeconomic Factors	3
Risk Awareness	3
Info & Communication System	2
Risk Preparedness Plan	1
Risk Mitigation Plan	1
Monitoring & Maintenance	2
Number of Indicators: 7	**15**

Sensitivity Indicator	Score
Type of Material	2
Type of Construction	3
Presence of Incompatible Treatment Materials	2
Extent of Past Intervention	2
Current Condition	2
Number of Indicators: 5	**11**

Vulnerability = Exposure + Sensitivity - Adaptive Capacity	
Exposure	17 / 6 = **2.83**
Sensitivity	11 / 5 = **2.2**
Adaptive Capacity	15 / 7 = **2.14**

Vulnerability of Wupatki Pueblo = 2.89

Step 4 Cont'd: Quantify and Assess Vulnerability

The vulnerability of Wupatki Pueblo is considered moderately high under both Hot Dry and Warm Wet climate scenarios. These conditions are expected to accelerate material decay and structural deterioration due to rising temperatures and changing precipitation patterns. Hygroscopic (water-absorbing) materials, such as Moenkopi sandstone and earthen mortars, are particularly susceptible, as they expand and contract with changes in moisture levels.

These effects can be compounded by increased corrosion rates for metal interventions, which are prone to deterioration when relative humidity levels exceed 55%. Although such high humidity levels are less likely at Wupatki Pueblo, pollutants and salts can nonetheless trigger material deterioration even at lower humidity levels.

As a publicly open archeological site, Wupatki Pueblo is exposed to natural forces (gravity, wind, seismic activity), environmental factors (fire, precipitation, UV radiation, pests), and human-induced risks like visitor impact.

While the likelihood for custodial neglect and deferred maintenance is very low for Wupatki Pueblo, unpredictable weather events may render existing treatments ineffective or even harmful to the original structures. Similarly, current control systems such as drainage may be insufficient to manage sudden-onset hazards (e.g., flash flooding) despite routine monitoring of Wupatki Pueblo is by FLAG NM cultural resources staff.

Despite these challenges, Wupatki Pueblo demonstrates strong adaptive capacity due to robust institutional and legal protections, supported by key federal laws such as the National Historic Preservation Act (NHPA) and the Archaeological Resources Protection Act (ARPA), and NPS policies.[22] The government's self-insurance for repair and disaster response costs (though funding can be influenced by shifting national priorities), along with emergency response agreements with nearby parks (e.g., Grand Canyon National Park and Coconino National Forest) form a solid foundation, while strong support from national advocates of the NPS, and within the Flagstaff community, ensures ongoing efforts to preserve and protect the site.

FLAG NM's Fire Management Plan, Emergency Operations Plan, and support from national response teams like Burned Area Emergency Rehabilitation (BAER), along with Everbridge notification systems, enhance Wupatki's adaptive capacity. Additionally, FLAG NM staff are trained to handle natural hazards including wildfires, floods, and landslides, with cultural resources staff in particular have specialized training in geomorphology to better assess site impacts.

Wupatki's heritage resources are well-documented, with about 99% of its archeological sites recorded in a Geographic Information System (GIS). However, gaps remain in hazard-related data; GIS risk maps for archeological sites for wildland fire hazard exist but erosional risks have only undergone preliminary assessments and are yet to be fully mapped.[23]

Recent climate change studies, like the Wupatki Climate Futures Summary, have raised awareness within the NPS about long-term threats to the site, though challenges remain in preparedness and mitigation efforts. The Adaptive Capacity assessment shows a lack of definitive plans for addressing disaster impacts on the site. While an evacuation plan exists for museum objects, no specific plans are in place for damage assessment or response following natural disasters. Additionally, no drills or training exercises have been conducted to prepare staff for such events. Emergency response resources at FLAG NM are limited, with much of the capacity to address natural disasters relying on partnerships with local emergency services and support from NPS regional and national offices. Wupatki's law enforcement officers and archaeologists are trained to respond quickly during emergencies; the latter group in particular, plays a critical role in assessing and mitigating impacts on cultural resources during such events. Continued research and monitoring and leveraging the on-site weather station are crucial for understanding climate changes. Implementing climate adaptation strategies is essential for the monument to document and address the impacts of climate change.

Summary of Hazards for Wupatki Pueblo

Wupatki Pueblo is vulnerable to various potential hazardous factors, including but not limited to:

Site Erosion	*Wupatki Pueblo is highly susceptible to moisture-induced erosion. With the projected increase in extreme temperatures and intense precipitation events, the rubble masonry walls may experience sudden moisture influxes leading to various forms of moisture-related deterioration (e.g., basal erosion, mechanical damage from freeze-thaw cycles). Additionally, overall site erosion can also destabilize the original masonry structures leading to more catastrophic failures.*
Insufficient Preservation Approaches	*While stabilization efforts at Wupatki Pueblo have kept the site in good condition, the unpredictability and increasing intensity of climate change impacts require a shift from reactive to proactive preservation. This approach should be guided by a deep understanding of the various factors affecting the site's condition, prioritizing the most vulnerable areas to enable more targeted and effective preservation strategies.*
Lack of Risk Mitigation & Preparedness Planning	*Adaptive capacity of Wupatki Pueblo can be further improved by addressing the gaps in mitigation planning and preparedness for both sudden- and slow-onset hazards. The effectiveness of mitigation, response, and recovery plans depends heavily on the quality of resource and disaster documentation; this effort may involve expanding the current vulnerability assessment framework, climate change scenario planning, developing/improving a geospatial risk information system, as well as capacity building through educational and training programs for all stakeholders.*

5.3. Climate Change Adaptation and Adaptive Management Strategies

Climate change adaptation involves intentional actions to mitigate harm or take advantage of opportunities created by changing conditions. However, the inherent uncertainty of future conditions makes it difficult for adaptation efforts to rely solely on static plans or one-off predictions. This is where adaptive management becomes essential, offering a dynamic framework that embraces uncertainty, promotes learning, and supports flexibility in decision-making.[24]

Adaptive management recognizes that our understanding of climate change will continue to change over time. It emphasizes continuous monitoring and iterative adjustments, allowing cultural resource management goals and strategies to adapt in response to observed outcomes and new scientific insights.[25] This process ensures that adaptation efforts remain relevant and effective as conditions change.

For Wupatki Pueblo, adapting to climate change may involve seemingly simple adjustments, such as shifting fieldwork to cooler seasons to avoid extreme temperatures. However, adaptive management requires fully integrating climate change considerations into every aspect of preservation management planning, treating climate change impacts as central to the process rather than as afterthoughts.

Adaptive management, in essence, calls for a fundamental rethinking of preservation strategies to address the continually evolving and unprecedented environmental condition moving beyond traditional approaches or past precedents for stabilization to adopt creative and proactive strategies.

The following section outlines adaptive management strategies for Wupatki Pueblo.

Adaptive Management Strategy 1: Keep Up-to-Date on Climate Change Information

Obtaining high-quality climate information and understanding the potential effects of climate impacts on park resources, facilities, and operations is foundational to the climate adaptation process. A wide range of resources, both external and internal to the NPS, are available to provide climate-related data. These resources include, but are not limited to:

- NOAA's Climate.gov
- U.S. Global Research Program's U.S. Climate Resilience Toolkit
- USGS's Strategic Hazard Identification and Risk Assessment (SHIRA) Mapper
- NPS Intermountain Region Cultural Resources Environmental Vulnerability Assessment Toolbox (CREVAT)
- University of California Merced Climatology Lab's Climate Toolbox

Familiarity with these tools, and the ability to effectively use them, is a key element of a successful climate adaptation and management strategy.

Similarly, as climate resources become more widely available, the rapid proliferation of climate information, driven by the uncertainty and variability of climate change, can pose significant challenges for decision makers due to the sheer volume and complexity of the data.

To navigate the vast amount of information available to park resource managers, a more focused approach is needed to identify which aspects of the cultural resources are more vulnerable to specific stressors. In this process, close collaboration among scientists, subject matter experts, Indigenous partners, and other stakeholders is essential for gaining deeper insight into the cultural resource. This collaboration can also help expand the creative mitigation options; for example, Indigenous knowledge of traditional stewardship practices can enrich adaptation strategies.

The NPS has made considerable progress in understanding the risks that climate change poses to park resources, and Wupatki Pueblo is no exception. FLAG NM staff are well-aware of threats and have begun actively monitoring micro-climate data for the Pueblo with the on-site weather station.

Adaptive Management Strategy 2: Focus on Understanding Vulnerability

The vulnerability assessment presented in this chapter serves as a foundational component of adaptive management. By identifying and prioritizing the most probable and impactful threats from climate change, the assessment grounds adaptation efforts in a clear understanding of current and potential risks. However, given the unpredictable nature of climate change, these assessments must be iterative, updated regularly with new data and insights to reflect evolving conditions.

Cultural resource managers can also build upon the vulnerability assessment provided as part of this PMP, a generalized study of the Pueblo as a whole, by examining each unit at different scales, such as micro (material), meso (building systems), and macro (landscape) to allow for more targeted decision making. Further research can also enhance information regarding the site's sensitivity, especially by investigating the mechanical properties of the rubble masonry, and the composition of the original earthen mortar, when possible.

To better prioritize resources, similar vulnerability assessments can be carried out for other structures within the Frontcountry Zones (i.e., Overview and Extended Leading Zones) which include Wukoki, and the Citadel allowing for a site-by-site analysis. This ongoing refinement will ensure that strategies remain relevant and effective, aligning closely with the principles of adaptive management.

Adaptive Management Strategy 3: Shift to Data-Driven Management

One key way to address the uncertainties in cultural resource management is by focusing on the measurable, cumulative effects of weathering on the resources. These effects represent the visible symptoms of long-term stressors on a site—essentially, the tangible signs of deterioration. Understanding these cumulative effects is crucial, as it allows resource managers to develop more informed conservation strategies, making decisions that better support the long-term preservation of a site.

Effective management goes beyond merely observing current conditions; it requires tracking the impact of preservation interventions over time. Evaluation criteria must be based on the physical properties and behaviors of the materials involved, ensuring that assessments are grounded in observed conditions. This includes defining what constitutes a 'good' or 'bad' condition, ensuring that treated areas show measurable improvement or, at the very least, do not degrade further.

This adaptive management approach is central to the stabilization workflow proposed in this PMP, specifically in terms of utilizing the RAS for evaluating physical deterioration symptoms and leveraging the legacy stabilization data to evaluate the efficacy of past treatments to ultimately inform prioritization of stabilization resources for Wupatki Pueblo. This approach aims to make the site more self-sustaining, with minimal ongoing maintenance and cost-effective measures.

Adaptive Management Strategy 4: Use Climate Change Scenario Planning

The success of adaptive management relies on explicitly linking preservation strategies to specific climate risks, ensuring that management actions are intentional and strategic rather than reactive.[26] In that aspect, climate change scenario planning provides a valuable framework for addressing climate uncertainties by exploring a range of plausible future conditions.[27] Using the best available climate information, scenario planning helps managers consider diverse and relevant possibilities that challenge established practices and assumptions.

By exploring likely scenarios, managers can evaluate the sustainability of current practices, pinpoint critical uncertainties that require further research or monitoring, and develop goals or actions that are resilient in an unpredictable future. The primary goal is to generate insights that guide decision-making and help managers take informed actions to protect cultural resources more effectively. Collaboration with stakeholders, including Indigenous partners, academics, and experts, is crucial for gaining deeper insights and expanding mitigation options for the cultural resource.

Adaptation strategies for the identified scenarios do not always require new approaches. They can range from efforts to maintain or restore the resource to its historical or acceptable current conditions (resist), to accepting changes without intervention (accept), or guiding the resource in a new direction (direct) (RAD framework).[28]

For many national parks, including WUPA NM, the primary response has been to resist change, prioritizing the preservation of the original forms and materials. At Wupatki Pueblo, current preservation goals focus on maintaining the architectural integrity (see Chapter 6," Preservation Goals, Policies, and Guidelines"). However, as rapid environmental changes continue,the long-term feasibility of resisting climate impacts will become increasingly difficult and costly.

This emphasizes the need for preservation goals to evolve in response to ever-changing future climate conditions. The climate crisis demands proactive management that embraces inherent uncertainties, challenging long-standing assumptions and creating adaptive strategies to a wide range of future outcomes.

5.4. Next Steps for Wupatki Pueblo

This section provides recommendations for adaptive preservation management at Wupatki Pueblo following the strategies outlined above.

- Continue collaborating with both internal and external partners, as well as associated tribes, to expand and address gaps in climate-related and site knowledge and associated risks.
- Maintain ongoing efforts to collect and monitor weather data to track climate trends and adapt management strategies as needed (Basics of Weather Stations and Analyzing Weather Data in HOBOware and Excel).
    - Short-term (1 month–1 year): Collecting data for a few months to a year can help observe seasonal changes, understand daily variations, and capture specific weather events. This can highlight preliminary trends or factors contributing to deterioration mechanisms like temperature, humidity, and precipitation.
    - Medium-term (1–5 years): Extending data collection over one to five years provides a more comprehensive understanding by accounting for year-to-year variability for all weather parameters. This creates a reliable baseline and reveals how fluctuations in environmental conditions might stress a resource over time.
    - Long-term (10+ years): To track climate-related changes and understand potential long-term impacts on preservation, data collection over a decade or more is ideal. This allows for the identification of gradual shifts in climate, such as warming trends or changing precipitation patterns, which could significantly affect a site over time.
- Broaden and update vulnerability assessments by incorporating a wider range of climate change indicators, and adopt a more targeted approach to assess vulnerabilities on a unit-by-unit or site-specific basis.
- Monitor and Adjust Preservation Goals
    - Continuously reassess and adjust preservation goals in line with changing climate conditions through monitoring.
    - Acknowledge that maintaining original form and outline of Wupatki Pueblo may become unsustainable in the longterm, and prioritize proactive, flexible preservation strategies.
- Focus on Cumulative Effects of Weathering
    - Tracking the long-term, cumulative effects of weathering and climate-related stressors on cultural resources through consistent monitoring and documentation of physical deterioration symptoms (e.g., using the RAS) will help resource managers shift towards a data-driven approach to make more informed preservation decisions through any given climate conditions.

- Evaluate and Adjust Preservation Interventions
  - » The efficacy of existing stabilization methods cannot be guaranteed under changing climate conditions and, therefore, a regular assessment of preservation intervention is necessary.
  - » This effort also involves using legacy stabilization data (e.g., WUPA 2676 Legacy Database), assessing what worked and what did not, to refine preservation intervention methods.
- Develop Strategies/Plans to Specific Risks
  - » For addressing climate risks, the following strategies are recommended for Wupatki Pueblo, but should not be limited to:
    - * Upgrade Drainage Systems: Evaluate and enhance the Pueblo's drainage systems based on real-time moisture sensor data to address trapped moisture and prevent water-induced erosion, particularly during monsoon seasons.
    - * Regular Structural Integrity Assessments: Implement routine checks of the Pueblo's structural integrity, ensuring early detection of vulnerabilities and adapting to changes as needed.
    - * Develop action plans for risk preparedness and mitigation: Develop and execute preemptive action plans tied to extreme weather events as well as natural disasters to minimize impact on the site's preservation.
    - * Continuous Monitoring Systems: Invest in advanced monitoring systems to track environmental conditions, such as moisture levels, erosion rates, and structural deterioration, allowing for timely and data-driven responses.
    - * Soil and Structural Analysis: Conduct detailed studies of soil and rock properties and their behavior under heavy rainfall, linking this data to the Pueblo's structural deterioration to inform more resilient maintenance practices.
    - * Micro-Topography and Water Flow Management: Perform micro-topography and flow analysis to identify the most effective room fill/ground surface contours for reducing mechanical abrasion and managing water flow, improving the Pueblo's resilience to erosion.
    - * Fire Risk Mitigation: Reduce wildfire risks by reducing fuel loads around the Pueblo and developing a preparedness plan, especially given the increasing threat of wildfires due to rising temperatures and prolonged droughts.
  - » For addressing anthropogenic risks, the following planning need is identified, but should not be limited to:
    - * Visitor Use Management Plan (VUMP): Climate change brings challenges to visitor experience at Wupatki Pueblo, such as increased uncertainty due to extreme weather events making certain areas inaccessible or unsafe. At the same time, visitors

themselves can contribute to the degradation of the site's resources. A VUMP is essential to address these challenges by assessing climate-driven effects on visitor access and safety, while also evaluating current visitors, their expectations, and ways to attract future visitors. The plan should set specific goals for both resource protection and visitor experience, ensuring Wupatki remains relevant and resilient for future generations in a changing climate.

- Engage Stakeholders and Experts
  - » The specific strategies described above must actively involve Indigenous partners, academics, and other resource experts in discussions on cultural resource management in the context of climate change. Integrating traditional knowledge will expand preservation approaches and enable culturally sensitive mitigation strategies, ensuring a more inclusive and effective response to climate change.
- Implement Climate Change Scenario Planning and the RAD Framework[29]
  - » The RAD (Resist-Accept-Direct) framework is a decision making model developed to guide cultural resource management in the face of rapid environmental change. It recognizes three potential management responses to transformational change:[30]
    - * Resist: strategies focused on helping a park resource, asset, or value withstand the impacts of climate change to remain within current acceptable conditions
    - * Accept: approaches involving purposefully taking no specific action to alter the trajectory of climate change effects on resources, assets, and values
    - * Direct: strategies that intentionally plan for and actively work to guide the trajectory of change, with a goal of achieving desired future conditions
  - » Two plausible climate scenarios have been identified for Wupatki: Hot Dry and Warm Wet.[31] Based on these, cultural resource managers can plan for climate change impacts within practical constraints (e.g., budget limitations, public support, or political feasibility).[32] Depending on the desired goals or specific needs of the park, managers should develop a diverse set of adaptation responses (RAD), clearly defining the objectives of each action. Multiple strategies can be applied across different park areas, with approaches evolving over time (e.g., from resistance to acceptance) as climate impacts progress. This suggests that scenario planning cannot be a one-time exercise; continuous scenario planning and environmental monitoring will be essential to allow managers to update strategies as conditions change and new information emerges.

Climate Scenario	Cultural Resource	Climate Impact	Desired / Achievable Future Condition	Strategy	Actions
WARM WET	Wupatki Pueblo and the Immediate Surrounding Landscape	Increased intensity of precipitation events leads to greater risk of material erosion/ damage/loss	Persistence of the structure at/in its current site and condition	**Resist**: Minimize site erosion	• Upgrade and install additional drainage systems • Use engineered erosion controls like geotextiles, retaining walls, vegetative capping to stabilize soil and reduce impact on masonry • Redesign wall caps • Test more resilient mortar formulations
			Remains intact as long as possible but acknowledge potential for damage or loss	**Accept**: Allow for autonomous change, including loss of the original fabric	• Implement a monitoring program to document natural changes occurring in the surrounding environment • Allow natural vegetation growth around the walls, accepting that this may lead to changes in the ecosystem while providing some erosion control, and balancing with fire threat • Document and interpret historical changes to visitors and staff
			Surrounding landscape takes brunt of impact	**Direct**: Redirect water from walls by redesigning the site	• Design shelters to protect most exposed structures • Modify landscape around the walls to create terraces or steps to slow down water flow and reduce impact on masonry
HOT DRY		Higher temperature & extended drought periods lead to increased risk of mechanical erosion of masonry	Exposed structures and site remain in its current state	**Resist**: Minimize masonry erosion	• Increase frequency of stabilization treatment to annual, moving the stabilization fieldwork season to cooler seasons • Continue using amended earthen mortar, considering transition to biodegradable amendments
			Remains intact as long as possible but acknowledge potential for damage or loss	**Accept**: Allow for autonomous change, including loss of the original fabric	• Allow natural degradation, accepting some damage • Focus on monitoring walls and selectively treating and reinforcing severely damaged sections • Document and interpret historical changes to visitors and staff
			Conversion of the site to pre-Euroamerican contact landscape	**Direct**: Actively rebury exposed structures to create a new cultural landscape	• Document resource to acknowledge its historical presence before reburial to protect structures • Allow natural vegetation growth and supplement with fire-resistant vegetation to thrive in projected conditions • Interpret and communicate change to visitors and staff

Table 5.8. Example of climate adaptation strategies and actions based on climate scenarios for Wupatki Pueblo. While the RAD framework may be less effective for non-living resources, this example is provided to help broaden thinking about adaptation strategies going forward.[37]

Notes

1 Cathy Daly, "A Framework for Assessing the Vulnerability of Archaeological Sites to Climate Change: Theory, Development, and Application," *Conservation and Management of Archaeological Sites* 16, no. 3 (August 2014): 268–82, https://doi.org/10.1179/135050331 5Z.00000000086.
2 Ibid.
3 NPS, "Planning for a Changing Climate: Climate-Smart Planning and Management in the National Park Service" (Fort Collins, CO: NPS Climate Change Response Program, 2021), https://irma.nps.gov/DataStore/Reference/Profile/2279647.
4 NPS, "Wupatki National Monument Climate Futures Summary" (Fort Collins, CO: NPS Climate Change Response Program,2024).
5 "Coconino County Conditions | Drought.gov," Drought.gov, n.d., https://www.drought.gov/states/arizona/county/coconino.
6 "Climate Change Science: Future of Climate Change," US EPA: Climate Change, n.d., https://climatechange.chicago.gov/climate-change-science/future-climate-change.
7 Ibid.
8 Jeffrey A. Hicke et al., "North America," In *Climate Change 2022 – Impacts, Adaptation and Vulnerability*, 1929–2042 (Cambridge: Cambrige Univeristy Press, June 22, 2023), https://doi.org/10.1017/9781009325844.016; in this report the Southwest is referred to as Western North America (WNA).
9 Daniel R. Cayan et al., "06: Future Climate: Projected Average," in Assessment of Climate Change in the Southwest United States: A Report Prepared for the National Climate Assessment (Washington, DC: Island Press, n.d.), 101–25.
10 Linda O. Mearns et al., "A Regional Climate Change Assessment Program for North America," *Eos, Transactions American Geophysical Union* 90, no. 36 (September 8, 2009): 311–311, https://doi.org/10.1029/2009e0360002.
11 Cayan et al., "06: Future Climate: Projected Average," 109.
12 Rebecca Frankson et al., "State Climate Summary 2022: Arizona," in NOAA Technical Report NESDIS 150-AZ (Silver Spring, MD: NOAA/NESDIS, 2022), https://statesummaries.ncics.org/downloads/Arizona-StateClimateSummary2022.pdf.
13 Alison M. Meadow et al., *Climate Profile for the City of Flagstaff, Arizona* (Tucson, AZ: University of Arizona, 2018), https://doi.org/10.13140/RG.2.2.20826.70083; and data from the airport weather station are available from the NOAA National Centers for Environmental Information (NCEI) Daily Observational Data Map: https://gis.ncdc.noaa.gov/maps/ncei/cdo/daily.
14 "Coconino County Conditions | Drought.gov."
15 NPS, "WUPA NM Climate Futures Summary,"2.
16 Ibid.,2.
17 A standard way to define FTCs is as the total number of times temperature readings cross the 32°F (or freezing) threshold during a given time period, divided by two. This calculation reflects the frequency of conditions alternating between freezing and thawing, impacting various environmental and infrastructural aspects; see GLISA, "Freeze-Thaw Cycles," n.d., https://glisa.umich.edu/resources-tools/climate-impacts/freeze-thaw-cycles/#:~:text=station%20to%20station.-,Definition%20of%20Freeze%2DThaw%20Cycles,at%20any%20time%20of%20year.
18 NPS, "WUPA NM Climate Futures Summary."
19 Ibid.
20 "CREVAT TOOLBOX." Cultural Resources Environmental Vulnerability Assessment Toolbox (CREVAT), n.d. https://experience.arcgis.com/experience/bf35fe50fcb2468b9809970eba750139/.
21 Various formulas exist for quantifying the three major factors of vulnerability. For this particular project, methodologies from Anne E. Miller, Nicholas Steele, and Benjamin W. Tobin, "Vulnerability and Fragility Risk Indices for Non-Renewable Resources," *Environmental Monitoring and Assessment* 190, no. 7 (June 2, 2018), https://doi.org/10.1007/s10661-018-6749-5 was used. Other studies consulted include: Marvin Ravan et al., "A Vulnerability Assessment Framework for Cultural Heritage Sites: The Case of the Roman Ruins of Tróia," *International Journal of Disaster Risk Science* 14, no. 1 (February 1, 2023): 26–40, https://doi.org/10.1007/s13753-023-00463-4; and Daly, "A Framework for Assessing the Vulnerability of Archaeological Sites to Climate Change."
22 Such policies include the Organic Act, 16 U.S.C. §1 (1916); the Organic Act established the National Park Service within the Department of Interior to regulate and promote the use of national parks in alignment with the fundamental purpose to " conserve the scenery and the natural and to provide for their enjoyment in such manner and by such means as will leave them unimpaired for the enjoyment of future generations."

23 Colorado State University completed a preliminary assessment of erosion hazard of sites in Wupatki Wash, but otherwise non-wildland fire climate change-related hazards are not well-identified or mapped.

24 NPS, “National Park Service Climate Change Response Strategy 2023 Update” (Washington, D.C.: Department of the Interior, 2023), https://www.nps.gov/subjects/climatechange/upload/NPSClimateChangeResponseStrategy2023.pdf.

25 Ibid.

26 Ibid.

27 Climate Change Scenario Planning has been address as a planning need for Wupatki National Monument in the 2015 Foundation Document. For more information on climate scenario planning see: “Scenario-Based Climate Change Adaptation Showcase - Climate Change (U.S. National Park Service),” n.d., https://www.nps.gov/subjects/climatechange/scenarioplanning.htm.

28 Gregor Schuurman et al., “Resist-accept-direct (RAD)—a Framework for the 21st-century Natural Resource Manager,” December 22, 2020, https://doi.org/10.36967/nrr-2283597; also see “Resist-Accept-Direct Framework - Climate Change (U.S. National Park Service),” n.d., https://www.nps.gov/subjects/climatechange/resistacceptdirect.htm.

29 Ibid.

30 NPS, “Planning for a Changing Climate," 53-55.

31 NPS, “WUPA NM Climate Futures Summary.”

32 NPS, “Using Scenarios to Explore Climate Change: A Handbook for Practitioners” (Fort Collins, CO: NPS Climate Change Response Program, January 2013), https://irma.nps.gov/DataStore/DownloadFile/485697.

33 Intergovernmental Panel on Climate Change (IPCC). “Global Warming of 1.5°C: An IPCC Special Report on the impacts of global warming of 1.5°C above pre-industrial levels and related global greenhouse gas emission pathways, in the context of strengthening the global response to the threat of climate change, sustainable development, and efforts to eradicate poverty.” Cambridge, UK and New York, NY, USA: Cambridge University Press, 2018. https://www.ipcc.ch/site/assets/uploads/sites/2/2022/06/SR15_Full_Report_LR.pdf.; and “Days of Precipitation Over 1 Inch | U.S. Climate Resilience Toolkit,” U.S. Climate Resilience Toolkit, n.d., https://origin-climate-toolkit.woc.noaa.gov/dashboard-days-precipitation-over-1-inch.

34 "Earthquake Hazard Maps," FEMA.gov, Department of Homeland Security. Last modified August 3, 2020. https://www.fema.gov/emergency-managers/risk-management/earthquake/hazard-maps

35 “CREVAT TOOLBOX.”

36 Ravan et al., “A Vulnerability Assessment Framework for Cultural Heritage Sites."

37 This exercise has been adapted from NPS, “Planning for a Changing Climate," 40-43. Readers are encouraged to refer to this document for a comprehensive adaptation planning framework that incorporates climate projections and scenarios, providing guidance on integrating climate change considerations into all aspects of NPS planning.

Chapter Cover: Weather Station at Wupatki Pueblo, 2022 (Credit: Ha Leem Ro).

6 PRESERVATION GOALS, POLICIES, AND GUIDELINES

6 Preservation Goals, Policies, and Guidelines

6.1. Introduction

The purpose of preservation policies is to provide a framework for decision making about the future use, care, preservation, and interpretation of Wupatki Pueblo. The policies are a guide for how particular actions should be approached based on goals set for Wupatki Pueblo as well as guiding principles and recognized heritage values of the place.

The contents presented in this chapter have been adapted from two major preservation guides published by the NPS applicable to WUPA 2676: "Ruins Preservation Plan and Implementation Guidelines WUPA NM (2001)"[1] and "Preservation and Management Guidelines for Vanishing Treasures Resources (2009)"[2].

6.2. Preservation Goals

The primary goals of the preservation program at Wupatki Pueblo are to[3]:

1) Preserve what remains of the original architectural fabric and,
2) Maintain the form and outline of the standing architecture previously treated in the past.

The original architecture provides insights into original builders and occupants. Although some structures have been heavily stabilized and, in places, substantially reconstructed, the Pueblo still retains much of its material and locational integrity. These features reveal important information about the original form and outline that still conveys important information about household and community organization while the remaining architecture's construction materials and techniques convey historic episodes of remodeling and repairs.

As such, preservation at Wupatki Pueblo aims to satisfy the following interpretive themes as outlined in the Foundation Document:[4]

- Human Occupation, Lifeways, and Environmental Change
- Cultural Diversity and Interaction among Pueblo Ancestors
- Ancestral Homelands and Cultural Traditions
- Cultural Resource Integrity
- Habitat Preservation
- Scenic Views and Soundscape

6.3. Current Management and Preservation Approach

6.3.1. Management Structure

Management zones have been established for the park to facilitate the preservation and protection of the park's cultural resources and to ensure that the existing resources are appropriately used and made available for visitor experience, while honoring tribal preferences and values.

Currently, WUPA 2676 is considered to be in the "Overview Zone," an area intended and designed to provide visitors with a broad understanding of park purpose and significance. Resources in this zone are preserved to appear natural, where paving or other management actions will be taken as necessary to protect resources. Visitors can interact with resources only to the extent possible without undue impact to those resources; they are able to get an overview of park resources and significance in a short time frame and with minimal physical exertion.

Resources in the Overview Zone are monitored incrementally throughout the year. Currently, WUPA 2676 is monitored twice a year for disturbances and threats to the overall site and each of the Pueblo units is assessed every three years for necessary preservation repair and maintenance. Normally, in the late winter or early spring, a more thorough conditions survey and assessment of the standing architecture and features is performed to establish priorities for the coming field season. Information is documented using specifically designed recording forms (i.e., Pre-Preservation SOW Table Form). This information is then used to establish a list of priorities for preservation treatment. The monitoring is usually performed by the permanent employees on the Cultural Resources team.

At the time of this report, preservation projects at WUPA 2676 are supported by NPS cyclical maintenance funding and fees collected from visitors. All projects submitted are ranked and prioritized based upon the individual judging criteria for each funding source.

Funding for the park's preservation efforts comes from various sources including: (1) Cultural Resources Cyclic Maintenance funds; (2) Federal Lands Recreation Enhancement Act (FLREA) funds; and (3) emergency sources. The park's base operations account currently funds three Cultural Resource crew members for six months per year, with project funding covering for the remaining six months and additional seasonal staff for six months. Park-generated funding packages support the completion of projects identified and programmed in the park's Resources Management Plan.

6.3.2. Preservation Approach

The following objectives currently guide the preservation approach for Wupatki Pueblo designated as the Overview Zone:

- Ensure all identifiable original fabric is protected from further deterioration and preserved to maintain the inherent construction style and pattern;
- Complete all physical treatments in a manner that continues the existing appearance of the architectural remains;
- Ensure that the mass, scale and proportions of the existing architectural remains are maintained;
- Ensure that the existing physical layout is maintained; and
- Ensure that all materials used in the treatment process will be visually and structurally compatible with the original architecture in terms of color, texture, and construction style.

These approaches are accomplished by both direct and indirect measures:

- Direct: physical treatments employed to prevent, or reduce deterioration or divert the sources of natural or human-caused impacts, including placing silicon beads above alcoves and rock shelters, adding fill to divert drainage, resetting loose capstones, repointing, grout injections, and installing physical barriers to control site access.
- Indirect: all nonphysical means, including public education, documentation, ranger surveillance, and long-term planning of facilities.

6.4. Legislative and Regulatory Provisions

Cultural resources in WUPA NM are managed according to various historic preservation and environmental laws, proclamations, Executive orders, and regulations, granting the park authority and responsibility to preserve and protect its cultural resources for future generations. These legislative and regulatory measures include:

- NHPA of 1966, as amended, establishes a framework of procedural protections that promote the identification and protection of historic resources, including archaeological sites, at the federal level, while also influencing efforts at the state and local levels.[5]
- Section 106 of the NHPA and its implementing regulations subjects all activities within the monument that have the potential to affect cultural resources and provides a reviewing process for identifying and mitigating adverse effects to historic properties.[6]
- Section 110 of the NHPA mandates federal agencies to establish historic preservation programs to identify, evaluate, and protect historic properties under their jurisdiction.[7]
- Policy Memorandum 22-03[8] provides guidelines to implement Secretary's Order No. 3403, Joint Secretarial Order on Fulfilling the Trust Responsibility to Indian Tribes in the Stewardship of Federal Lands and Waters.[9] It outlines how the Department of the Interior and the Department of Agriculture will collaborate with Native Tribes in co-stewarding federal lands and waters through consultation, capacity building, and other means consistent with applicable authorities.
- The Native American Graves Protection and Repatriation Act (NAGPRA) requires halting all work and consulting regional cultural resource professionals and relevant ethnic groups at the time of inadvertent discovery of resources or items of cultural significance or sensitivity (e.g., human remains or burials) during preservation activities.[10] If removal of such items is necessary and approved, it must follow NPS-28[8] and ACHP guidelines[11] on the treatment of human remains and burial goods.

6.5. Preservation Standards and Guidelines

Standards set the expected quality to be achieved and maintained in both applying principles for archeological and historic preservation practices. Guidelines and management tools provide directions or outline procedures for compliance and ensuring that established standards are fulfilled.

- Secretary of the Interior (SOI)'s Standards and Guidelines for Archeology and Historic Preservation provide technical advice on archeological and historic preservation activities and methods.[12]
- The SOI's Standards and Guidelines for the Treatment of Historic Properties addresses four different types of treatments (Preservation, Rehabilitation, Restoration, Reconstruction) to be applied to a wide variety of resource types (e.g., buildings, sites, structures, objects, and districts).[13]

- » The SOI's Standards for the Treatment of Historic Properties are regulatory only for projects receiving Historic Preservation Fund grant assistance and other federally-assisted projects. Otherwise, these guidelines are intended to provide general guidance for work on any historic building or site.
- » Based on current preservation goals at WUPA NM, "Preservation" will be the primary and most appropriate treatment, defined as "the act or process of applying measures necessary to sustain the existing form, integrity, and materials of historic property."[14]

- The Cultural Resources Management Guideline (NPS-28[15], Director's Order 28[16], and Director's Order 28A: Archeology[17])includes guidance appropriate for management of archeological and historic structure resources.

6.6. General Management Policies

The policies are organized in a scalar manner beginning with broader, park-wide relevant policies narrowing down to site-specific preservation guidelines.

Policy 1: Manage in Accordance with National Federal Heritage Legislations, Standards, and Guidelines (see above)

Policy 2: Adoption of the PMP

This PMP is the primary working document guiding conservation and management for WUPA 2676. Adoption of the PMP includes reviewing its content and updating it on a regular basis (every 5 years) as well as its dissemination to all interested parties including the public, stakeholders, and professionals.

Policy 3: Significance Guides Preservation and Planning

Preservation and planning should always be significance-driven, the processes responding to the significance embodied by the site and the values held by the stakeholders. Establish whether there is sufficient information to understand the impact of potential modifications and consider the effects of any intervention or change on the cultural significance of the place prior to beginning work.

Policy 4: Seek Professional and Cultural Advice

Consult experienced conservation professionals, practitioners, and tribal partners on the development of proposals for the site. Consider internal assets (e.g., VT) and external expertise (e.g., Cooperative Ecosystem Studies Unit (CESU)) partnerships with universities and museums) as well as Tribal consultations to coordinate and implement a holistic approach to preservation, prioritization of projects, and addressing both immediate and long-term preservation needs and goals for WUPA 2676.

Policy 5: Practice Good Record Keeping and Documentation

Recording and documentation are crucial at all stages of historic site preservation and management. Using standardized forms and methods customized for WUPA 2676 ensures that relevant data is recorded consistently from year to year, while minimizing redundancy.

Managing archival data is equally important; a database of past preservation records (e.g., archeological and preservation reports, photographs, etc.) should be kept and continually updated at the conclusion of projects. All relevant manuals, standards and guidelines (e.g., SOPs, HPG booklets) for using recording forms and managing records must also be maintained to ensure consistent data collection and protect data integrity.

6.7. Preservation Policies

Policy 1: Prioritize Areas for Stabilization and Treatment

The use of the SOW Survey as well as the RAS data in the long-term is recommended to approach preservation planning in a methodical and strategic manner that recognizes needs and priorities across the site, with a focus on maximizing available resources and prioritizing preventive action.

Policy 2: Understand the Cause(s) of Deterioration

A variety of causes or factors can be responsible for deterioration at a site. Most of these can be ascribed to natural or human induced causes, or to inherent architectural flaws as a result of the materials and techniques employed by the original builders or past preservation treatments. It is important to have an adequate understanding of the causes of deterioration, not only to ensure that appropriate and effective preservation strategies are implemented, but more importantly, to go beyond mere remediation to deceleration, or prevention of deterioration.

In many cases, the removal of the factors of deterioration may be sufficient to bring the site to a state of relative stability. In other cases, repair of the structural fabric will be necessary to prevent further damage. Refer to Chapter 4, "Site Assessment" for a more detailed discussion on factors affecting resource conditions.

Policy 3 : Use Architecturally Appropriate/Compatible Materials and Treatment Methods

Best conservation practices follow these three principles: (1) compatibility, (2) retreatability, and (3) reversibility, where possible. Treatments should allow for future interventions without damaging the original fabric.

Preserving as much original material as possible ensures a site's integrity and authenticity, while introduction of new materials may at times be inevitable. When new materials must be introduced, they should be compatible with original materials and construction systems and not compromise their performance. Replacement of original fabric should ideally be made using compatible materials and good craftsmanship, unless solid scientific evidence supports an alternative.

Selecting appropriate and compatible treatment materials and methods requires careful review and modification of selected materials and techniques prior to application. This includes knowing the availability, material characteristics, and performance of the materials that will be used and will interact with the original material. Specialized tests should be conducted on any and all materials that are proposed to ensure that they will be effective and not have adverse effects to the original fabric as well as the environment or the public. Tests also need to be repeated when soil sources change to confirm suitability.

Policy 4: Use of Culturally Appropriate Materials and Treatment Methods

All interventions including to "not intervene" should be in compliance with agreed upon cultural norms established through consultation. Concerning how the standing architecture is viewed and how it should be protected and preserved, the Hopi Tribe submitted the following considerations for the 2001 WUPA NM Preservation Plan:[18]

> ***The Hopi people do not consider these ruins to be abandoned. Hopi belief states that these places were purposely left for a much larger reason, one that involves fulfillment of traditional prophecy and obligations to uphold the responsibilities as "caretakers" of the land occupied by present-day Hopi people and their ancestors.***
>
> ***The Hopi believe that these ruins continue to be occupied by their ancestors, who lived, died, and were buried at these places. These ancestors purposely remain as spiritual stewards of the land, continuing to "watch over" these ruins long after their physical presence is gone.***
>
> ***Traditional Hopi belief holds a much different perspective on how these ruins should be maintained, and to what degree. Traditional belief is one of allowing nature to take its course, and therefore, these ruins should be allowed to degrade, and return to a natural state. This of course goes against the very idea of ruins preservation, and remains as one objection to the ruins preservation process. But it does not mean that there cannot be found suitable alternatives.***
>
> ***The discontinued use of intrusive methods (reconstruction) and materials (Portland Cement) at Wupatki National Monument, and the limiting of preservation activities to only those ruins currently open to the general public are positive alternatives. Written and photographic documentation are also suitable alternatives to the ruins preservation process. As illustrated here, these sites hold different meanings and are viewed from a different perspective than that of the non-Native person. The Hopi people believe that these sites are evidence that they have traveled upon and occupied the southwestern area since time immemorial. They serve as tangible reminders for Hopi people that they have a vested interest in the protection, preservation and interpretation of these places.***

Policy 5 : Using Qualified Personnel

All activities affecting cultural resources will be performed by qualified personnel. Trained park staff and volunteers may assist if they receive proper training and are supervised by a qualified cultural resource specialist. Qualification standards for various cultural resources positions within the park are presented below.

- Cultural Resource Management Specialist / Archeologist

A bachelor's degree in anthropology is required for entry-level (GS-5) positions; additional education and experience are needed for GS-7 and above. Additional standards to be followed by the NPS are contained in the SOI's Standards and Guidelines for Archaeology and Historic Preservation.[19] The minimum professional qualifications for a full-performance archeologist are 1) a graduate degree in archaeology, anthropology, or a closely related field, or demonstrated equivalence; 2) at least one year full-time professional experience or equivalent specialized training in archaeology, archaeological research, administration, and management; 3) at least four months of supervised field and analytical experience in general North American archaeology; and 4) demonstrated ability to carry research to a completion.

- Cultural Resource Management Specialist / Historic Architect

A degree in architecture; a state license to practice architecture; at least one year of graduate study in architectural preservation, American architectural history, preservation planning; and at least one year of full-time professional experience on preservation and restoration projects, which must include detailed investigations of historic structures, preparation of historic structures research projects, and preparation of construction documents for preservation projects.

- Preservation Specialist (Exhibit Specialist, GS-1010)

A preservation specialist shall be recommended by the regional historical architect or appropriate center supervisor, reviewed by the regional or center historic preservation skills review board, and certified by the regional director or center chief, based upon criteria established by the associate regional director, cultural resources, Washington Office. Factors include: 1) the ability to demonstrate journeyman level skills in two building crafts; 2) the knowledge and ability to act as a project supervisor; 3) exposure to historic preservation methods and philosophy; or 4) the ability to demonstrate master-level skills in one craft with the ability to train others; and, 5) exposure to historic preservation method and philosophy.

- Historic Craftsperson / Maintenance Person (Masonry Worker)

A masonry worker shall be recommended by the superintendent, reviewed by the regional historic preservation skills review board, and certified by the regional director, based upon criteria established by the associate director, cultural resources, Washington Office. Factors may include: 1) the ability to demonstrate journeyman level skills in one building craft; and 2) exposure to historic preservation method and philosophy.

Policy 6 : Follow Logistical / Safety Requirements

The logistical requirements at the site must be investigated to identify difficulties involved in transporting personnel, equipment, and materials to a particular work location. The investigation should: (1) develop mechanical aids and safety devices for ensuring the safest and most effective means of completing the proposed work, and (2) develop most effective means to minimize impact upon the site and the surrounding topography.

Work conditions will follow Occupational Safety and Health Administration (OSHA) guidelines for safety standards and existing NPS rules and regulations (NPS-50B) for the protection of personnel, property, and the environment.[20] All personnel involved in the treatment process will be expected to wear personal protective equipment (PPE), including safety glasses, hard hats, gloves, and kneepads. All hazardous materials will be utilized in accordance with the appropriate Material Safety Data Sheets (MSDS) and with OSHA's "right-to-know" requirements. All scaffold and ladders will be utilized according to OSHA standards. All work areas located in the proximity of the existing visitor trails shall be roped off and signed " Area Closed" to prevent visitor entry. All crew members will receive an orientation in work safety. Any unsafe situations will be promptly corrected by the project director.

Policy 7: Follow Stabilization Etiquette

All tools, work and storage areas, and vehicles will be kept clean and maintained in good order. All tools, excess mortar, and stone spalls will be gathered and removed from the site daily. Trash will be deposited at the local landfill or other approved public trash depot. Following the completion of the project, all evidence of the stabilization activities will be obliterated and the site returned to a prestabilization appearance to the extent possible.

6.8. Challenges and Considerations

PMP policies and recommendations are designed to address these current management and preservation challenges at Wupatki Pueblo:

- Historical Approaches Continue to be Implemented

The current preservation goal is oriented towards preserving the original architecture, rather than focusing on preventing or inhibiting further deterioration. While the approach to preserve the original fabric is still a valid one for protecting the values inherent to the site, continued use of generic repair styles (e.g., cyclical mortar repointing, backfilling, etc.) without understanding the pathologies and addressing actual causes of deterioration will always put cultural resource managers in a reactive position to varying and unpredictable changes.

Stabilization should also be viewed as not simply a technical exercise, but as an important component of archeological inquiry, collecting and analyzing detailed architectural information in regards to understanding the intent of the original builders. This type of information can aid the stabilization process by ensuring that any repairs made will be structurally and aesthetically compatible with the original construction.

- Lack of Guidance and Training

Not all NPS personnel have a materials conservation background and/or have had training in pre-contact masonry preservation and repair. In many cases, stabilization work is carried out without any formalized training, accompanied by written "how-to" manuals and/or standards or guidelines. Without established guidelines, tremendous efforts are needed to bring new crew members up to date, not to mention the possibility of losing the accumulated stabilization knowledge during personnel changes (e.g., change in seasonal crew, management staff etc.). Maintaining a collection of manuals, standards and guidelines is crucial to a consistent preservation program ensuring the legacy of Wupatki's stewardship to proceed into the future.

It is also important to remember and incorporate the invaluable Indigenous knowledge of associated tribes going beyond traditional consultations. Through increased and collaborative engagement with the Indigenous partners and communities, better management and preservation decisions can be made as well as better interpretation of the history of ancestral homelands.

- Inadequately Assessing Priorities

Although NPS staff are familiar with the site and its changing conditions, using qualitative evaluations—such as assigning priorities based on informal surveying and monitoring of sites using subjective qualifiers (e.g., High, Moderate, Low)—may lead to inconsistencies over time with different personnel as well as to an insufficient understanding of the site as a whole.

Assessment of priorities should be based on objective comparative values from evaluating areas or features with standardized parameters and questions across the site. Given the current management structure and limited resources at the park, the recommended approach for evaluating priorities is to conduct the SOW Survey at the unit that has been designated for cyclical maintenance, rather than across the entire site (see Chapter 7, "Strategies for Preservation and Operational Guidelines" for more detailed discussion on the SOW Survey).

This is to state the limitations of the suggested SOW Survey methodology in that while it may aid in prioritizing work within a single unit, it can result in incorrect identification of priority areas across the whole site; for example, the park staff may be required to assess priority areas in the South Unit as it is due for cyclical maintenance in a given fiscal year even when the North Unit or other areas may require preservation attention, that is, of a higher priority.

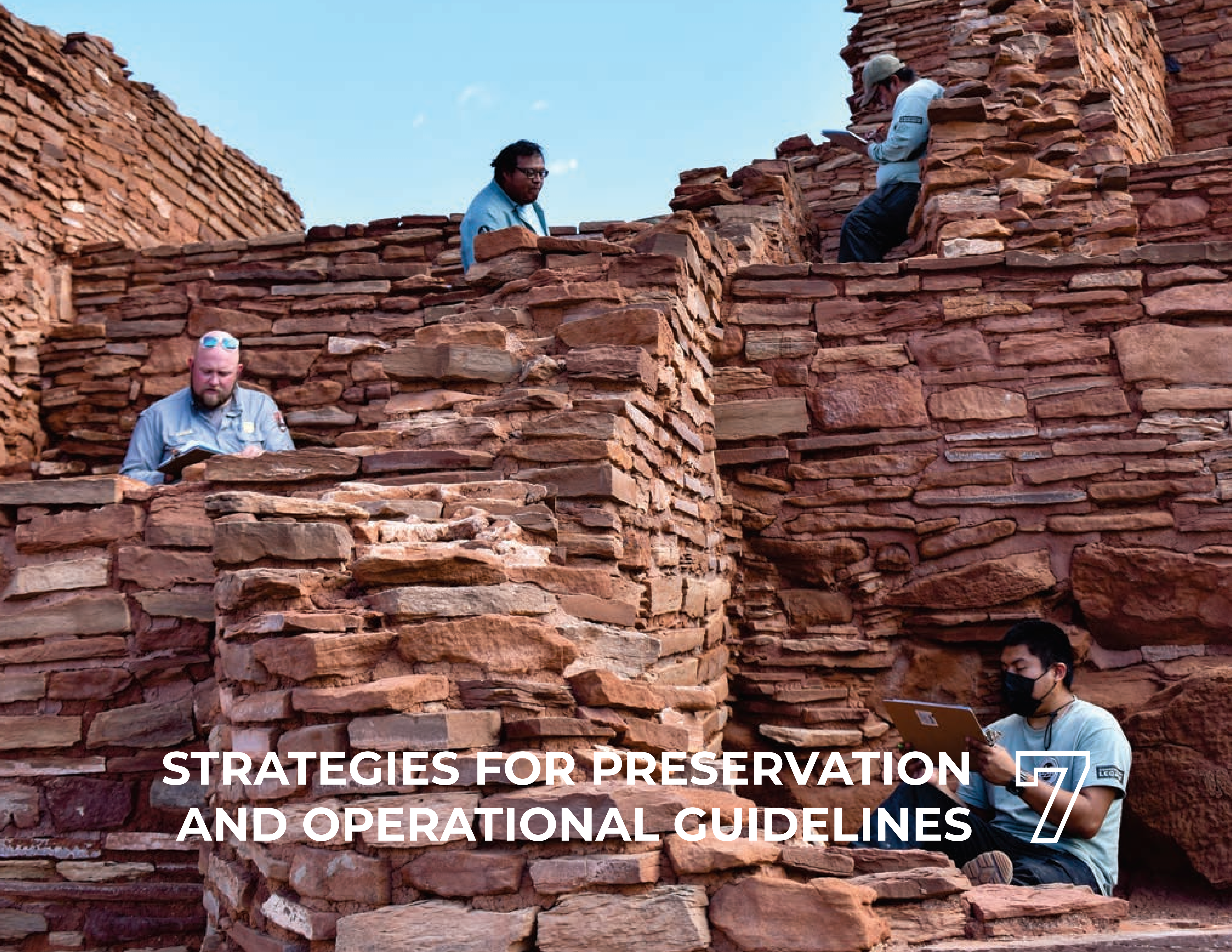
While it would be ideal to assess the entire site, given the staffing level, it will be important to consider long-term data collected from the Rapid Assessment Survey (RAS) that examines representative features of Wupatki Pueblo to determine areas of priority outside the scope of what is designated for cyclical maintenance cycle (see Chapter 7, "Strategies for Preservation and Operational Guidelines" for more detailed discussion on the RAS).

Notes

1 Lyle Balenquah et al., "Ruins Preservation Plan and Implementation Guidelines Wupatki National Monument," *Flagstaff Area National Monuments CRM Technical Series*, No. 1 (2001).
2 John M. Barrow et al., "Preservation and Management Guidelines for Vanishing Treasures Resources," *Intermountain Cultural Resource Management Professional Paper*, No. 75 (2009).
3 Goals cited from Lyle Balenquah et al., "Ruins Preservation Plan."
4 "Foundation Document Wupatki National Monument, Arizona," United States Department of the Interior, National Park Service, Wupatki National Monument, 8.
5 The National Historic Preservation Act (NHPA). 54 U.S.C. § 300101 et seq. October 15, 1966. https://www.achp.gov/sites/default/files/2018-06/nhpa.pdf.
6 Section 106 of NHPA: Protection of historic Properties. 54 U.S.C. 306108. 36 CFR 800, as revised in 2004, https://www.achp.gov/sites/default/files/regulations/2017-02/regs-rev04.pdf.
7 Section 110 of NHPA: The Secretary of the Interior's Standards and Guidelines for Federal Agency Historic Preservation Programs Pursuant to the National Historic Preservation Act. 16 U.S.C. 470a. https://www.govinfo.gov/content/pkg/FR-1998-04-24/pdf/98-10972.pdf; guidance can be found in the Standards and Guidelines for Federal Agency Historic Preservation Programs Pursuant to the NHPA (63 FR 20496).
8 NPS, Policy Memorandum 22-03: Implementing the Federal Lands Recreation Enhancement Act. Washington, DC: U.S. Department of the Interior, September 13, 2022. https://www.nps.gov/subjects/policy/upload/PM_22-03.pdf.
9 U.S. Department of the Interior and U.S. Department of Agriculture, Joint Secretarial Order 3403: Fulfilling the Trust Responsibility to Indian Tribes in the Stewardship of Federal Lands and Waters. SO 3403 A1. Washington, DC, November, 15 2021. https://www.doi.gov/sites/doi.gov/files/elips/documents/so-3403-joint-secretarial-order-on-fulfilling-the-trust-responsibility-to-indian-tribes-in-the-stewardship-of-federal-lands-and-waters.pdf.
10 The Native American Graves Protection and Repatriation Act (NAGPRA) of 1990. 25 U.S.C. 3001 et seq. November 16, 1990 https://www.ecfr.gov/current/title-43/subtitle-A/part-10.
11 Advisory Council on Historic Preservation, "Policy Statement Regarding Treatment of Burial Sites, Human Remains and Funerary Objects," Washington, DC, February 23, 2007. PDF. https://www.achp.gov/sites/default/files/policies/2018-06ACHPPolicyStatementRegardingTreatmentofBurialSitesHumanRemainsandFuneraryObjects0207.pdf.
12 NPS, Archeology and Historic Preservation; Secretary of the Interior's Standards and Guidelines. FR 48:44716-40. Washington, DC: U.S. Department of the Interior September 29, 1983. https://www.nps.gov/subjects/historicpreservation/upload/standards-guidelines-archeology-historic-preservation.pdf.
13 NPS, Secretary of Interior's Standards for the Treatment of Historic Properties. 36 CFR Part 68, Washington, DC: U.S. Department of the Interior, July 12, 1995. https://www.govinfo.gov/content/pkg/FR-1995-07-12/pdf/95-16953.pdf
14 For detailed standards and guidelines regarding Preservation, see Anne E. Grimmer, ed., "The Secretary of the Interior's Standards for the Treatment of Historic Properties with Guidelines for Preserving, Rehabilitating, Restoring & Reconstructing Historic Buildings" (Washington, D.C.: U.S. Department of the Interior National Park Service Technical Preservation Services, 2017), https://www.nps.gov/orgs/1739/upload/treatment-guidelines-2017-part1-preservation-rehabilitation.pdf.
15 NPS, NPS-28: Cultural Resources Management Guideline. Washington, DC: U.S. Department of the Interior, June 11, 1998. https://www.nps.gov/parkhistory/online_books/nps28/28intro.htm.; Refer to Technical Supplement, Chapter 7:8-9 for NAGPRA concerns.
16 NPS, Director's Order 28: Cultural Resource Management. Washington, DC: U.S. Department of the Interior, June 11, 2002. https://www.nps.gov/subjects/policy/upload/DO_28_6-11-2002.pdf.
17 NPS, Director's Order 28A: Archeology. Washington, DC: U.S. Department of the Interior, October 12, 2004. https://www.nps.gov/subjects/policy/upload/DO_28A_10-12-2004.pdf.

18 Balenquah et al., "Ruins Preservation Plan and Implementation Guidelines", Section 4-6.
19 NPS, Notice, "Secretary of Interior's Standards and Guidelines for Archaeology and Historic Preservation," *Federal Register* 48, No. 190, (September 29, 1983). https://www.nps.gov/subjects/historicpreservation/upload/standards-guidelines-archeology-historic-preservation.pdf.
20 NPS, Director's Order 50B: Occupational Safety and Health Program. Washington, DC: U.S. Department of the Interior, September 3, 2008. https://www.nps.gov/subjects/policy/upload/DO_50B_9-3-2008.pdf; also see NPS, Reference Manual 50B: Occupational Safety and Health Program that provides information, guidance, and direction for carrying out the policy and program objectives found in Order 50B. https://www.nps.gov/subjects/policy/upload/RM-50B_Contents.pdf.

Chapter Cover: ALCC and NPS staff at Wupatki Pueblo, 2023 (Credit: Ha Leem Ro).



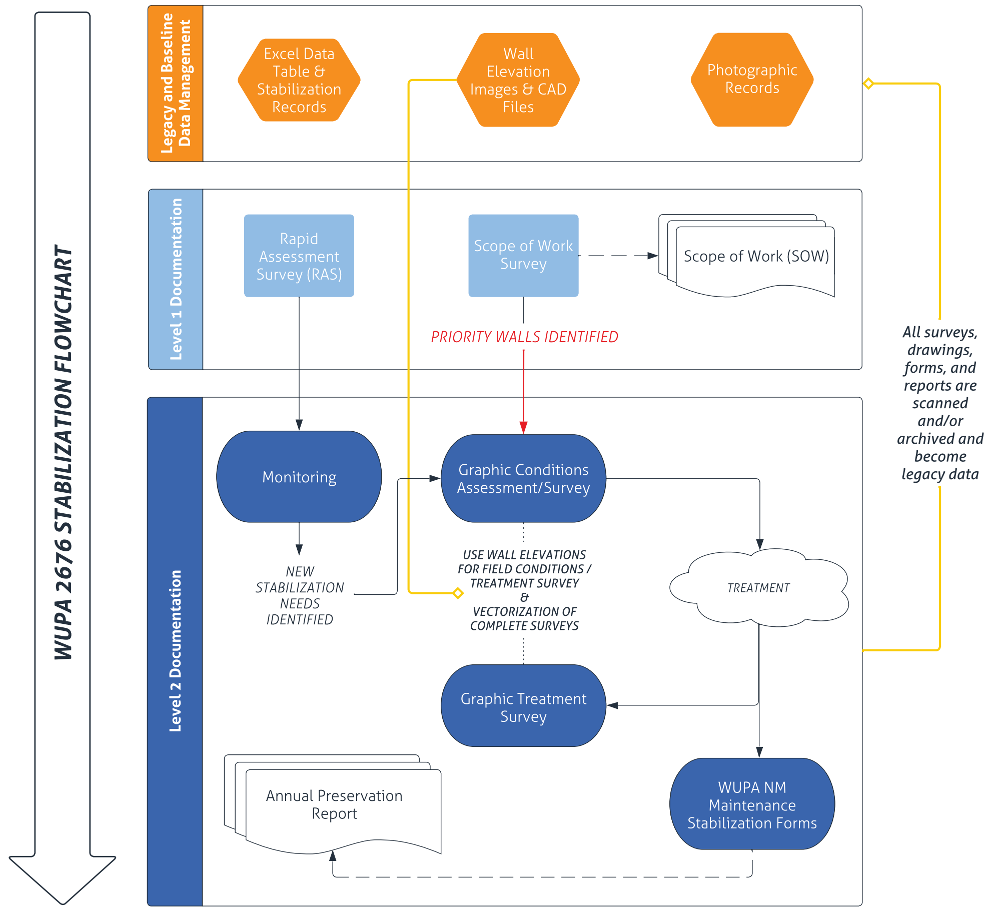
7 STRATEGIES FOR PRESERVATION AND OPERATIONAL GUIDELINES

7 Strategies for Preservation and Operational Guidelines

7.1. Introduction

This chapter outlines a recommended workflow for preservation activities at Wupatki Pueblo, broadly categorized into 3 phases. The sub-sections in this chapter are noted with color icons that correspond to each of the phases in the flowchart. The purpose of this chapter is to establish standards and guidelines for implementing a refined site preservation program. Detailed description of the processes, forms, and manuals required in each of the phases are noted in blue text within the body of the sections referring to documents that can be found in Volume 2: HPG and red text for supplementing items in the Appendices.

The newly developed methods presented in this PMP, however, are not meant to replace existing management protocols and/or processes. Rather, they are intended to be incorporated into the current NPS preservation framework at WUPA 2676 to improve the consistency and efficiency of data collection and management.



▲ *WUPA 2676 Stabilization Flowchart outlines the preservation program specifically tailored for Wupatki Pueblo currently in the Overview Zone. The guiding principles and methodologies may therefore be applicable to those other sites categorized as Overview and may be expanded for the sites in the Extended Learning Zone.*

7.2. Workflow Design

This workflow provides tools for identifying and prioritizing the most vulnerable areas and features of Wupatki Pueblo, particularly in the face of climate change and limited resources, to address the site's numerous preservation needs.

Effective resource prioritization and management is in large part accomplished through following these guidelines:[1]

- Planning informed by archival research (Legacy Data)
- Documenting and analyzing structures/features
- Implementing treatment and conducting post-treatment monitoring, maintenance, and management

The recommended preservation framework therefore takes a three-phased approach following the above-mentioned guidelines.

Although presented as three distinct phases, they are interrelated; many of the products from each of the phases are not intended to be standalone deliverables but rather preparatory materials to be utilized in other stages of the program. The data generated throughout the preservation process in turn become additional data contributing to the cyclical conservation and management processes as well as future legacy data. In essence, the WUPA 2676 stabilization program is designed to be an iterative cycle for addressing preservation needs at WUPA 2676 most efficiently and consistently.

7.3. Preservation Workflow for Wupatki Pueblo

This section provides a more detailed description of all processes and products necessary to carry out preservation activities on standing architecture at WUPA 2676. Also refer to *Volume II: Historic Preservation Guide for Wupatki Pueblo* as delineated by the blue text within the specific segments.

Phase 1 : Legacy and Baseline Data Management

This phase outlines data and forms required at the most basic level (baseline data, e.g., site map, elevation/profile maps) for all preservation activities and management policies and guidelines for the standing architecture. It also discusses the significance of utilizing legacy data throughout the preservation planning process. Legacy data, as used in this document, refers to all past records that pertain to preservation activities at historic sites. It includes the following types of information but not limited to:

- Archaeological/excavation records,
- Stabilization/treatment records and,
- Photographs

Understanding physical changes to the site, especially in the standing masonry due to excavation and stabilization efforts over the years, is critical to proper cultural resource management with the following advantages:

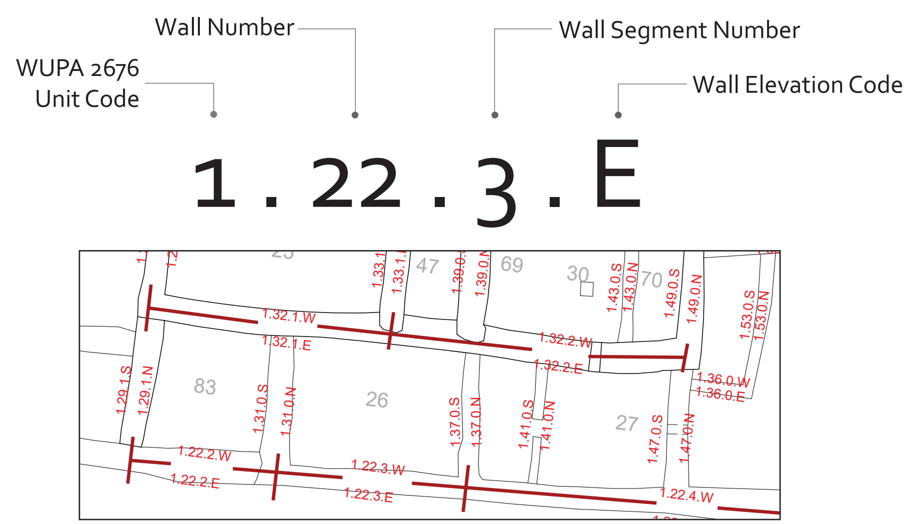
- Identification of areas with chronic, acute, and/or nascent deterioration symptoms;
- Identification of the nature and extent of past preservation treatments (where, when, why, and with what type of materials);
- Identification of the compatibility of the preservation work performed with the original architecture, aesthetically and structurally;
- Long-term monitoring through analyzing change over time; and
- Identification of any presence and/or absence of original features that may have been obscured or altered by past preservation treatments.

It is crucial for cultural resource managers to collect high-quality and consistent data to secure these benefits long-term. This is accomplished through utilizing consolidated sets of baseline data and a standardized system that allows for consistency in both data entry/collection and recall.

Wupatki Pueblo Base Site Map

An accurately scaled and geo-referenced site plan/map depicting features, structures, and/or rooms is crucial for efficient site management. As crucial as the plan-view map itself is the identification system (i.e., room and wall numbers) that allows coordination of all related data and ease of surveying as well as recording and visualizing information by location in GIS (Basics of Baseline Site Maps; How to Work with AutoCAD and ArcGIS Pro).

Wupatki Pueblo has had multiple versions of site maps and varying numbering systems for identifying features since the 1930s. To prevent future confusion, the CAC has produced a baseline site map with conservation identifiers (CIDs) for all standing walls at Wupatki Pueblo (WUPA 2676 Base Site Map).



▲ *The CID code sequence is represented on the top, while the bottom shows examples as represented in the WUPA 2676 Base Site Map. Red numbers are CIDs, while gray numbers refer to existing room numbers.*

WUPA 2676 CID System:

- Each wall identification is broken into four distinct parts, each separated by a decimal.
- The first number is the Pueblo unit code; four separate units of WUPA 2676 are numbered 1 through 4 (1 = South Unit, 2 = North Unit, 3 = Community Room, 4 = Ball Court).
- The second number is the wall number; east- and west-facing walls have even values while north- and south-facing walls have odd values.
- The third number is the segment number. Larger/longer walls have been subdivided into smaller multiple segments (roughly 10ft) in an effort to define physical units of approximately equal length for the purposes of comparing survey data. Walls that have not been subdivided are numbered with a zero (0) for the segment number.
- The fourth number is the wall elevation code, identified by a letter code based on the cardinal direction (N/S/E/W) the elevation is facing.
- In cases where wall tops (caps) are identified, replace the cardinal direction code with "C" for cap; "F" to denote features within a wall (e.g., openings) and; "T" to denote wall ends with significant surface area that require surveying.

Guidelines:

1) All printed site maps shall be produced from the main control AutoCAD file.
2) Any newly identified features and/or future modifications shall be updated in the AutoCAD drawing accordingly; appropriate CIDs will be given to those features according to the numbering system provided.
3) The CIDs identified in the base site map shall be used for denoting walls throughout all preservation activities at WUPA 2676 including the Scope of Work (SOW) survey, Rapid Assessment Survey (RAS), pre- and post-treatment documentation processes as well as for any documentation or recording purposes.

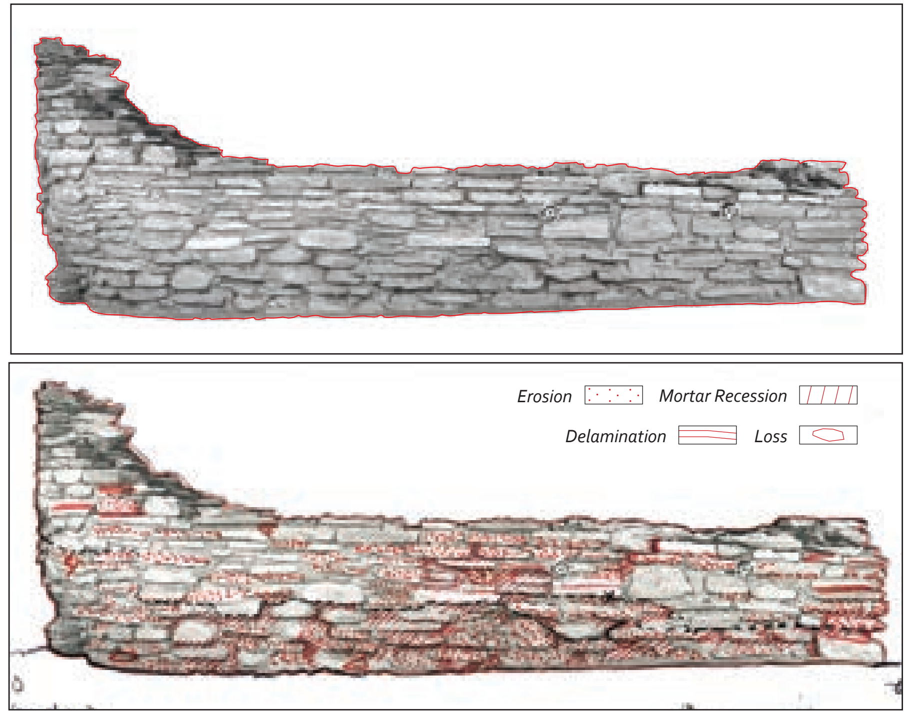
Rectified Photo Wall Elevation and CAD Drawings

Wall elevation drawings, combined with rectified photography, are significant additions to the arsenal of documentation enabling easy and accurate recording of the standing architecture and its condition and treatment (i.e., pre- and post-treatment documentation). Rectified wall images can be created using common photo manipulation softwares such as Adobe Photoshop (Basics of Rectified Photography, Basics of Photographic Modification in Photoshop) or photogrammetry softwares (Basics of Reality Capture). The image is then traced and scaled in AutoCAD to produce wall elevation drawings that can be used for recording purposes (Step-By-Step Rectified Wall Elevations).

High resolution images can capture subjects in great detail, but photographs nonetheless only document what the camera is able to capture. Therefore, the rectified wall elevation images are only useful if taken back into the field to annotate the details of the architecture and conditions being recorded.

The rectified photo wall elevations ultimately should serve as a 'map' that guides the viewer for recording anything of interest (How to Do Graphic Conditions Survey).

While the field annotations may be sufficient in many cases, digitizing (vectorizing) the information in a graphics program that provides scaling tools such as AutoCAD may be beneficial in analyzing the information collected both qualitatively and quantitatively. The methodology developed by the CAC allows for generating a series of overlays for analyzing condition and treatment correlations over multiple preservation seasons as well as tracking and monitoring conditions over a longer period of time (Vectorizing Multi-Year Conditions Assessments in AutoCAD). It is important to note that wall elevation images, whether hand drawn or created from photography, and the recording forms augment each other. They cannot be used to substitute for one another.



▲ *Rectified photo wall elevation image of 1.74.0.W (top) and scanned field conditions assessment using the same rectified photo wall elevation drawing (bottom).*

__Guidelines:__

1) Wall elevation drawings shall be prepared using photogrammetry or rectified photography methods and AutoCAD.
2) Wall elevation drawings shall be prepared for all standing walls prior to any preservation activities (NOTE: Most of the wall elevation drawings have been prepared by the CAC).
3) The wall elevation images and drawings shall be updated in the case of notable changes in the profiles of walls/features (e.g., catastrophic collapse).
4) The prepared drawings shall be used for any documentation activities relevant to the subject wall/feature.

Photograph Collection

Photographs, both historic and contemporary, are invaluable resources for sites, providing insights into the past and current conditions.

The NPS retains a hefty photographic collection on Wupatki Pueblo extending back to the early 20th century and will continue to expand the collection as preservation activities are required to be documented photographically.

Maintaining a collection of that extent is no easy task. Contrary to what we would assume, managing a digitized collection can be as complex as managing a physical one; if files are not properly named and organized, data recall and recovery can be troublesome.

The CAC recommends using Adobe Bridge, an open-source digital asset management software, for managing all photographic records for WUPA 2676 (Basics of Adobe Bridge). It allows using a standardized set of keywords/tags to embed (i.e., metadata) in the photographs which prevents keystroke error, a critical factor that can cause data recall to fail (Basics of Metadata).

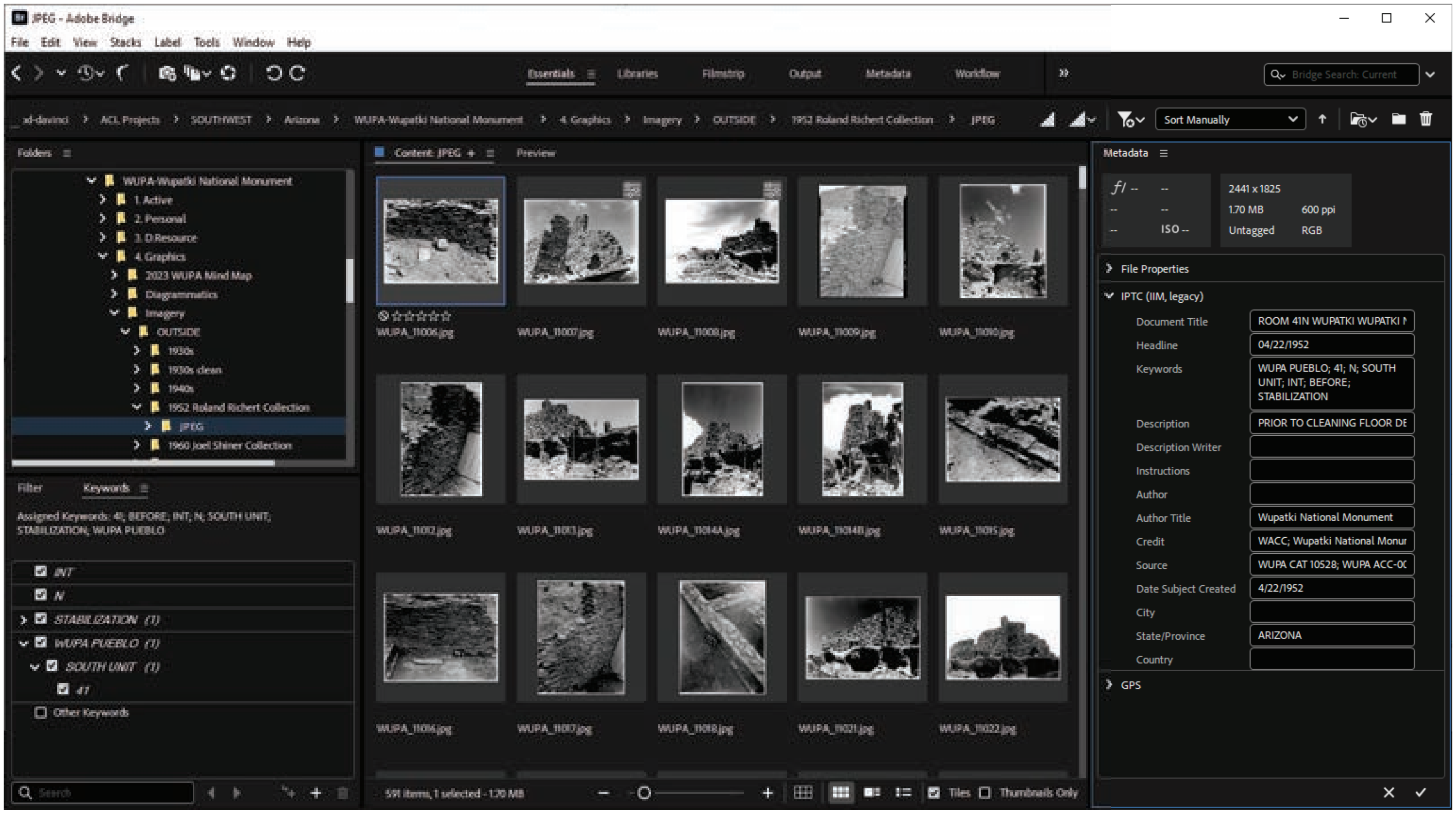
The CAC has also developed a preliminary controlled vocabulary keyword catalog (WUPA 2676 CVKC) for organizing historic photographs. The list, as stated, is only preliminary and should be updated according to the park's needs. The CVKC does not replace the existing file naming and organizational protocols at WUPA NM but general recommendations are made below. The guidelines below also do not discuss policies for transferring photos to shared servers park-wide and to monument-wide databases (e.g., FLAGCRIS/ARCH).

Guidelines:

1) All preservation activities shall be photographed before, during (action photos), and after work is performed.
2) All photographs on the park's server shall be organized using Adobe Bridge using the CVKC. All park staff should use the same CVKC. The list is flexible and should be updated depending on park needs.
3) The following is recommended for file naming and organization to establish a streamlined preservation program:
   - Create a designated folder to store preservation-related photos and label it to reflect the fiscal year of the project, the type of project (preservation), the batch number, and the site.
     - » For example, the folder labeled 'D22_P03_WUPA 2676'

       = Digital photos for 2022 (D22), preservation (P), photo batch 03 in the FLAGARCH database (03), site number (WUPA 2676)
   - All photos stored in the folder should be batch renamed containing the name of the folder itself followed by an underscore (_) and a number in parentheses (added automatically when batch renaming files in a folder).
     - » For example, photos in the folder labeled 'D22_P03_WUPA 2676'

       = D22_P03_WUPA 2676 (1), D22_P03_WUPA 2676(2) .....
4) Note that all the above information can be entered as metadata in Bridge as well as what area/feature (i.e., room, wall segment) and when the photo was taken (i.e., before, during, and after).



▲ *Managing a digital photographic collection can be as difficult as managing a physical one. A digital image management and organization software, like Adobe Bridge, can provide an efficient means for quickly categorizing and recalling images based on assigned metadata. Using metadata can also prevent unnecessarily long file naming conventions as the metadata can contain more information about the content of the photographic files rather that in the file names themselves.*

Wupatki Pueblo Legacy Database

The Wupatki Pueblo Legacy Database, is a flat data table (i.e., Excel spreadsheet) containing stabilization and conservation references from archival documents, reports, and forms up to FY2022. This database achieves two functions: 1) organizing and storing stabilization chronologies for Wupatki Pueblo up to FY2022 and 2) allowing researchers and resource managers to customize queries for data recall.

The Legacy Database was initially designed in a relational database software (i.e., Microsoft Access) in an effort to better organize and compile complex and extensive sets of conservation data spanning over almost over 80 years. To be able to assemble information from various types of sources with varying formats, the data entry form had to be constricted to focus on the most basic, but crucial, pieces of information pertaining to the stabilization event such as the start date and duration, area(s) affected, description, and the source record in which the reference was made.

Over time, documentation requirements at WUPA NM have evolved, expanding beyond simple narrative descriptions to include more quantitative data (e.g., amount of materials added or removed). The increased level of detail in more recent stabilization records allows for more comprehensive analyses but incorporating this detailed information into the initial, more generic relational database would have inevitably resulted in the loss of some nuanced insights.

For that reason, as well as the relative ease of using spreadsheet software (e.g., Microsoft Excel) requiring a shallow learning curve for data management, and analyses, the decision was made to extract all data compiled into a single data table.

This data table is intended to solely contain stabilization data up to FY2022, and should *NOT* be expanded through data entry. Stabilization data post-2022 will be collected using the Maintenance Stabilization Forms (as discussed in the following section) which allows for consistent data collection and aggregation also in the spreadsheet software.

While this necessitates the management of two data table files (i.e., one for pre- and the other post-FY2022 data) pertaining to stabilization records for WUPA 2676, it is recommended to keep both files separately to preserve the integrity of older records while ensuring the full scope of the newer quantitative information is consistently captured. Future decisions regarding data integration can be made as database methods improve, allowing for a seamless merge that minimizes the risk of data loss.

The Legacy Database should be a key resource for extracting relevant information from past documentation —up to FY2022—regarding architectural information (e.g., materials used, individual wall attributes, and construction features etc.); condition (e.g., the types and patterns of deterioration that have affected the site in the past); and preservation efforts (e.g., past stabilization methods, treatment materials and techniques). This historical data should in turn guide future preservation strategies and treatment methods based on evaluating the effectiveness of past approaches.

Guidelines:

1) The Wupatki Pueblo Legacy Database shall be consulted, in conjunction with the Maintenance Stabilization data table file (see following section), to compile all readily accessible archaeological, preservation stabilization and maintenance records (up to FY2022) for the structures and features targeted for treatment. This task should be completed before any field documentation or treatment is initiated.
2) The WUPA 2676 Legacy Database shall *NOT* be updated through data entry to preserve the integrity of the data compiled. The use of the legacy database is strictly to view, extract, and analyze historic stabilization information up to FY2022.
3) A designated database manager shall be responsible for proper data extraction and management according to the guidelines and the codebook provided (WUPA 2676 Database Codebook; also see How to Filter and Summarize Data Tables in Excel).

	A	B	C	D	E	F	G
7	LEGACYID	EVENTID	STRDATE	ENDDATE	ROOMNO	CID	DESCRPT
8	2778	2003	7/27/2022	7/27/2022	56	56G	Interior: The problem area includes the basal course of the west side of the Entry. Disturbances were likely caused by insect activity and visitation.
9	1518	1988	7/27/2022	7/27/2022	50	1.8.0.C	Capstones: Problem area included 2 capstones. Old mortar was removed and new mortar was added. Disturbances were likely caused by water erosion and visitation.
10	1518	1988	7/27/2022	7/27/2022	51	1.8.0.C	Capstones: Problem area included 2 capstones. Old mortar was removed and new mortar was added. Disturbances were likely caused by water erosion and visitation.
11	1759	2015	7/27/2022	7/29/2022	28	1.49.0.C	Capstones The problem area was the capstones. Old mortar was removed and new mortar was added to add 1 capstone and reset 11 capstones. Disturbances were likely caused by water erosion.
12	1759	2015	7/27/2022	7/29/2022	70	1.49.0.C	Capstones The problem area was the capstones. Old mortar was removed and new mortar was added to add 1 capstone and reset 11 capstones. Disturbances were likely caused by water erosion.
13	2777	2003	7/27/2022	7/27/2022	46	1.18.2.E	Interior: The problem area includes the basal course of the west side of the Entry. Disturbances were likely caused by insect activity and visitation.
14	2777	2003	7/27/2022	7/27/2022	56	1.18.2.E	Interior: The problem area includes the basal course of the west side of the Entry. Disturbances were likely caused by insect activity and visitation.
15	2777	2003	7/27/2022	7/27/2022	57	1.18.2.E	Interior: The problem area includes the basal course of the west side of the Entry. Disturbances were likely caused by insect activity and visitation.
16	2776	2003	7/27/2022	7/27/2022	56	1.17.0.S	Interior: The problem area includes the basal course of the west side of the Entry. Disturbances were likely caused by insect activity and visitation.
17	2776	2003	7/27/2022	7/27/2022	57	1.17.0.S	Interior: The problem area includes the basal course of the west side of the Entry. Disturbances were likely caused by insect activity and visitation.
18	2775	2003	7/27/2022	7/27/2022	56	1.16.2.W	Interior: The problem area includes the basal course of the west side of the Entry. Disturbances were likely caused by insect activity and visitation.

▲ *Stabilization data in the Wupatki Pueblo Legacy Database can be filtered by date of the event as well as by room (ROOMNO) and wall identifiers (CID).*

Maintenance Stabilization Forms

Recording forms and documentation packages (e.g., preservation reports) contain narrative information on the architectural features and preservation activities performed that are otherwise difficult to capture graphically.

Although completed post-treatment for all sites in FLAG NM, the Maintenance Stabilization Form is discussed as part of Phase 1 of the stabilization program as they serve as one of the primary legacy data sources. This section is primarily concerned with preparing, managing, and collecting data using the Maintenance Stabilization Form. While the form preparation and organizational standards and guidelines stated here are specific to the post-treatment form, many are applicable to all recording/survey forms at WUPA NM.

Currently, digital PDF forms are used to collect post-treatment information at WUPA 2676. There are two different types of maintenance stabilization forms filled out after each year, FLAG NM Maintenance Stabilization *Wall* and *Room* Forms.

The *Wall* Form is the smallest scale of data collection, collecting all relevant data about wall conditions and treatments for a given year. *Wall* Forms are filled out for every wall that received treatment that year.

The *Room* Forms provide the cumulative information for a given room, populated from the data collected on individual *Wall* Forms for a given room. When only one wall is stabilized in a given room, however, only the *Room* Form is filled out for that wall.

To ensure efficient and consistent data collection and management, the following is recommended:

<u>*Guidelines:*</u>

1) Consider discontinuing *Room* Forms for WUPA 2676

   It is recommended that only *Wall* Forms continue to be filled out to record post-treatment information to prevent redundancy and to ensure consistency of the data collected for long-term monitoring (See Interim Report II submitted in January 2023 for a detailed evaluation of stabilization forms used at WUPA).

   The adoption of this PMP requires that the standard unit for preservation work and recording be done at the wall level, that is, looking at individual wall segments as a single entity; hence, the CIDs. Using *Wall* Forms with CIDs for identification will ensure continuity and consistency in recording information on a wall-by-wall basis.

2) Continue using digital platforms for data collection

   The CAC has recreated the *Wall* Form in Survey123 to streamline in-field data collection and report generation (Basics of Survey123, How to Create Survey Forms using Survey123). In the case that the form cannot be filled out in the field, the CAC also has provided a formatted digital PDF form as an alternative (FLAG NM Maintenance Stabilization Form in Survey123 and Fillable PDF Manual). Fillable PDFs are easier to complete and useful for data analysis as recorded data can be exported as FDF files and merged in Excel (How to Use Acrobat for Paper and Digital Forms).

3) Consider data collected from the Maintenance Stabilization Forms as legacy data

The data table created from exporting data from Survey123 or fillable PDF forms should serve as another legacy database containing stabilization data post-FY2022. This Maintenance Stabilization data table, along with the WUPA 2676 Legacy Database (see previous section), shall be consulted to compile all readily accessible archaeological, preservation stabilization and maintenance records for the structures and features targeted for treatment. This task should be completed before any field documentation or treatment is initiated.

While using a single platform for data entry simplifies merging data to create the data table, in the case that both platforms were used, instructions for merging separate data tables have been provided in FLAG NM Maintenance Stabilization Form in Survey123 and Fillable PDF Manual.

4) Practice good upkeep for the Maintenance Stabilization data table

The table should be promptly updated at the completion of any stabilization project to prevent backlog in data management and subsequent data loss. A designated database manager shall be responsible for proper data extraction and overall data management.

This effort also includes transferring data from paper forms, if used, into the digital data table to prevent data loss as well as establishing and a consistent protocol for naming and organizing stabilization records on the shared server.

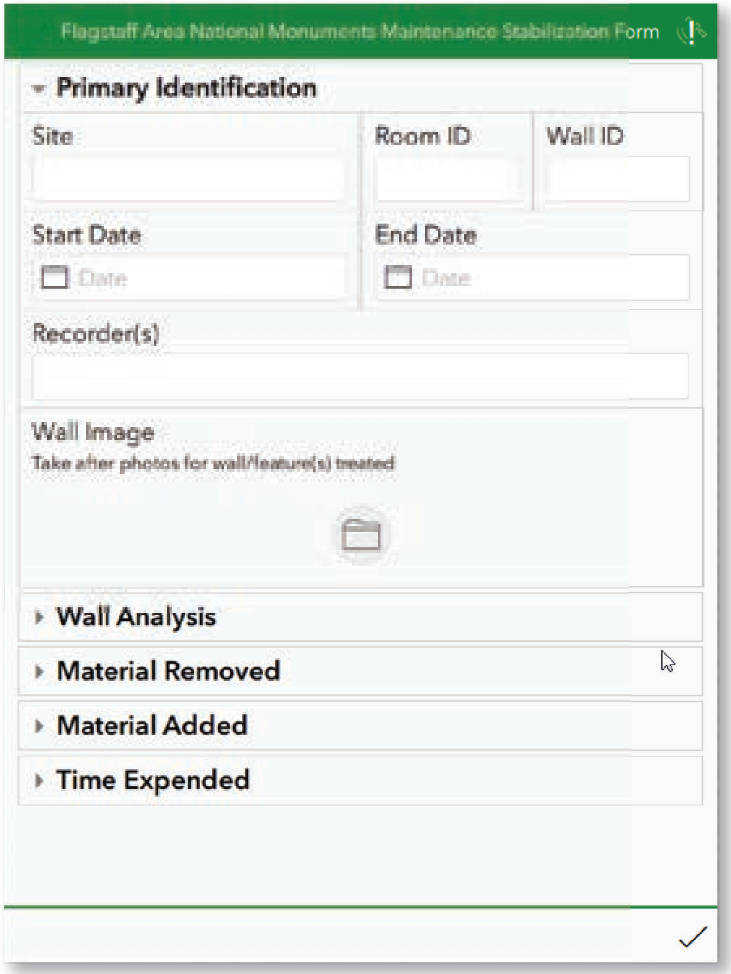
5) Refrain from modifying already-established forms

A prerequisite for time-series analysis is collecting data with the same parameters at consistent intervals.

Stabilization record forms that have been used for WUPA 2676 have largely remained unchanged since 2017, suggesting a large set of data already present that can inform both conservation and management decisions.

If and when modifications to the forms are necessary, it is important to make sure that digital forms are set up according to the protocols provided (FLAG NM Maintenance Stabilization Form in Survey123 and Fillable PDF Manual) to guarantee the collection of consistent sets of information for cumulative analysis.

6) The completed digital forms should be archived at the MNA. It is also recommended that the digital forms be printed on archival quality paper to be incorporated into a physical archive.



Flagstaff Area National Monuments Maintenance Stabilization Form

Primary Identification

Site

Room ID

Wall ID

Start Date

Date

End Date

Date

Recorder(s)

Wall Image

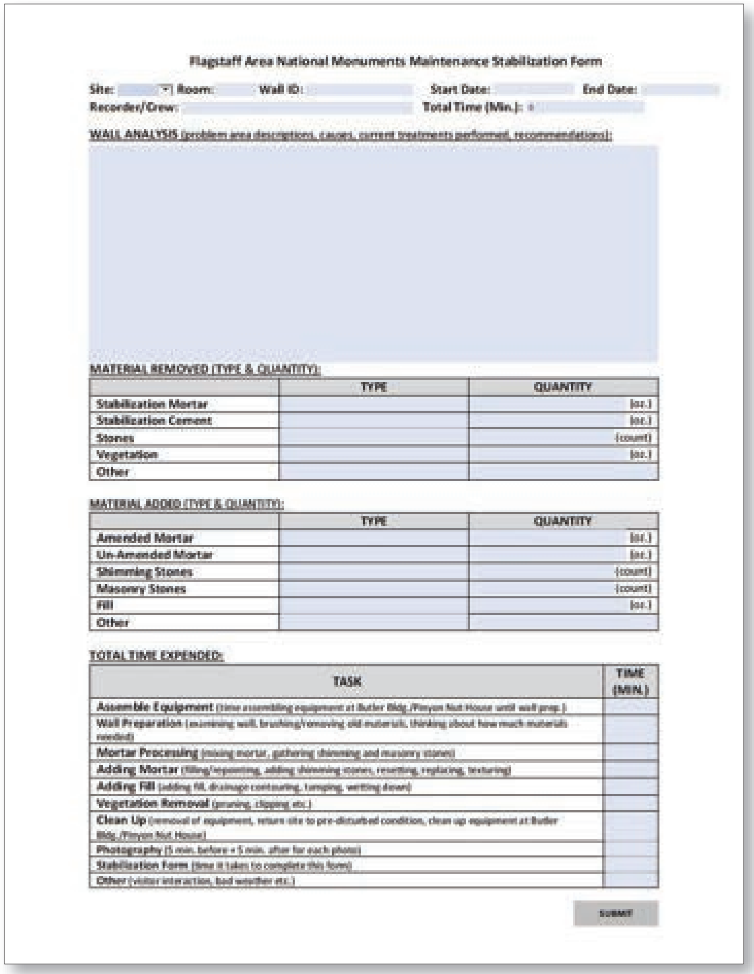
Take after photos for wall/feature(s) treated

Wall Analysis

Material Removed

Material Added

Time Expended



Flagstaff Area National Monuments Maintenance Stabilization Form

Site: Room: Wall ID: Start Date: End Date:

Recorder/Crew: Total Time (Min.): 0

WALL ANALYSIS (problem area descriptions, causes, current treatments performed, recommendations):

MATERIAL REMOVED (TYPE & QUANTITY):

	TYPE	QUANTITY
Stabilization Mortar		(oz.)
Stabilization Cement		(oz.)
Stones		(count)
Vegetation		(oz.)
Other		

MATERIAL ADDED (TYPE & QUANTITY):

	TYPE	QUANTITY
Amended Mortar		(oz.)
Un-Amended Mortar		(oz.)
Shimming Stones		(count)
Masonry Stones		(count)
Fill		(oz.)
Other		

TOTAL TIME EXPENDED:

TASK	TIME (MIN.)
Assemble Equipment (time assembling equipment at Butler Bldg./Pinyon Nut House until wall prep.)	
Wall Preparation (examining wall, brushing/removing old materials, thinking about how much materials needed)	
Mortar Processing (mixing mortar, gathering shimming and masonry stones)	
Adding Mortar (filling/repointing, adding shimming stones, resetting, replacing, texturing)	
Adding Fill (adding fill, drainage contouring, tamping, wetting down)	
Vegetation Removal (pruning, clipping etc.)	
Clean Up (removal of equipment, return site to pre-disturbed condition, clean up equipment at Butler Bldg./Pinyon Nut House)	
Photography (5 min. before + 5 min. after for each photo)	
Stabilization Form (time it takes to complete this form)	
Other (visitor interaction, bad weather etc.)	

SUBMIT

▲ *CAC recreated the Flagstaff Area National Monuments Maintenance Stabilization Form in Survey123 (left) and reformatted the existing fillable PDF form (right) to ensure consistency in data collection. While the digital platforms may provide an easier entry mode, it is important to note that paper forms may be inevitable in some cases. If paper forms are used, remember to always transfer the data back into the digital file following established protocols to prevent data loss.*

Phase 2 : Priority-Based Planning

The second phase pertains to prioritizing areas at WUPA 2676 for treatment. Successful preservation planning and implementation is largely dependent on resource prioritization given the extent of the site and limited resources of the park; some areas may require immediate stabilization efforts even when they fall outside the predetermined maintenance cycle, others may warrant limited efforts, and still others may merit no immediate preservation action whatsoever.

To identify high-priority areas for treatment based on deterioration symptoms rather than on arbitrary and subjective evaluations, the CAC recommends a modified Scope of Work Survey (SOW) in conjunction with the Rapid Assessment Survey (RAS) intended for long-term monitoring.

The following section provides guidelines for preparing and implementing both surveys at WUPA 2676.

Rapid Assessment Survey (RAS)

The Rapid Assessment Survey (RAS) is a framework for a cyclical unit-wide conditions assessment intended to identify feature vulnerabilities and to inform and substantiate emergency conditions and their stabilization as well as further monitoring (Basics of Rapid Assessment Survey (RAS)). An important aspect of the RAS is to identify features and areas based on observed conditions that prioritize their examination to the next level of graphic recording and treatment (Phase 3).

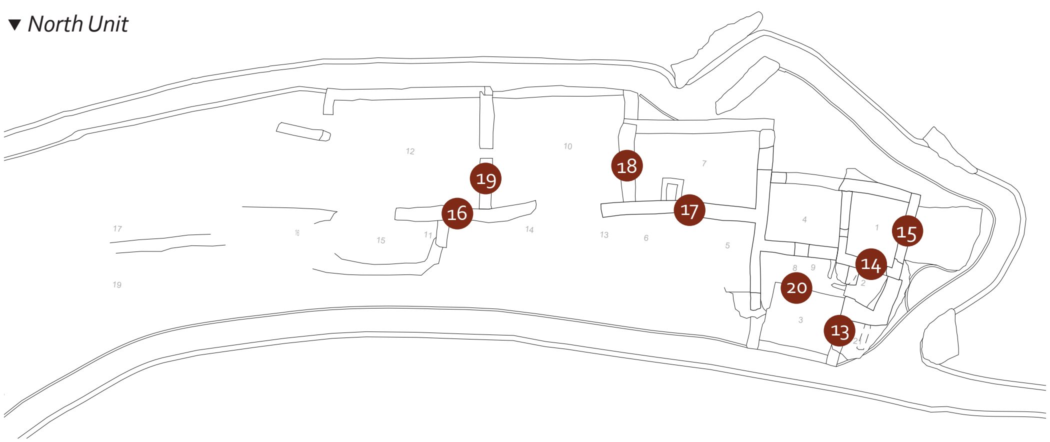
Ideally designed to be conducted annually across the entire site of interest, the RAS is intended to encourage a data-driven prioritization process aiding in the allocation of resources in the maintenance cycle. As data are collected on a regular basis, this methodology is also intended as a form of monitoring to help the NPS understand deterioration trends ultimately shifting site management to a more proactive/preventive mode of conservation.

During this PMP project, in discussion with cultural resource managers, it became apparent that the frequency and the extent for which the RAS needed to be conducted for a site as extensive as Wupatki Pueblo was not practical. To ensure that the benefits of the RAS methodology could still be achieved, the project team decided on continuing the RAS annually on a selected group of 20 pilot walls rather than all walls at Wupatki Pueblo (WUPA 2676 RAS Manual). Chosen for representing variable characteristics and features found at WUPA 2676, the data collected are intended to serve as a representative dataset for understanding deterioration trends at Wupatki Pueblo.

The RAS can be conducted digitally using Survey123 , which is the recommended format for its ease of use and data extraction capabilities. The survey, however, can be done on paper if necessary in which case the collected data must be transferred to the final data table according to the protocols provided.

▼ *South Unit*

▼ *North Unit*



List of WUPA 2676 Pilot RAS Walls

1	1.11.1	11	1.81.1
2	1.11.3	12	1.9.3
3	1.22.1	13	2.11.0
4	1.26.0	14	2.14.2
5	1.27.0	15	2.17.0
6	1.32.2	16	2.2.3
7	1.42.0	17	2.2.4
8	1.49.0	18	2.25.0
9	1.59.0	19	2.27.1
10	1.80.0	20	2.8.0

NOTE:
The numbers do not indicate the order in which surveys need to be conducted nor the severity of conditions.

▲ *The WUPA 2676 RAS walls were selected based on different physical attributes found at WUPA 2676 that can affect a wall's performance and its vulnerability. The walls selected are of different widths, heights, orientation, and show varying levels of differential fill. While other walls may be included, it is recommended that the above list is maintained. This is so that datasets compiled over multiple years will begin to display what factor and/or combination of factors contribute to the deterioration of rubble masonry walls at WUPA 2676 informing preservation and management decisions. Note that walls were selected only in the South and North Units given their higher physical integrity compared to the Community Room and the Ballcourt that were reconstructed in 1965. For more detailed information on the selection process and the implementation guidelines, refer to the Basics of RAS and WUPA 2676 RAS Manual.*

Guidelines:

1) The RAS shall be conducted on the selected 20 walls following the guidelines provided on an annual basis regardless of scheduled preservation and maintenance treatment for those walls (WUPA 2676 RAS Manual).
2) This information shall be collected as part of a regularly scheduled monitoring program independent of other archaeological surveys conducted in the park.
3) The RAS shall be conducted by designated staff members who have been trained in site preservation and have been familiarized with the WUPA 2676 RAS procedure and supporting documents (WUPA 2676 RAS Illustrated Glossary).
4) The data collected shall be analyzed to discern deterioration trends and patterns at WUPA 2676 informing future decisions on treatment and management interventions (WUPA 2676 RAS Manual; How To Filter And Summarize Data Tables In Excel).

Scope of Work (SOW)

A Scope-of-Work (SOW) is currently required to be prepared in advance for all sites scheduled for preservation and maintenance treatment, except in the case of critical emergency stabilization. Also known as the Preservation Treatment Work Plan, the SOW delineates what treatment work will be done, when, where, and how based on walk-through assessments on site. While a necessary product to allow preservation treatment personnel to complete the project from beginning to end, the current assessment process inevitably puts emphasis on remediation, overlooking the importance of monitoring conditions to target causes of decay, rather than merely treating symptoms.

Again, to assist the park to transition from a subjective evaluation approach to a data-centric prioritization system, the CAC recommends modifying the SOW process incorporating the SOW Survey to allow cultural resource managers to focus on evaluating visible conditions to determine the appropriate level of treatment.

The SOW Survey (once again in Survey123) is essentially a simplified version of the RAS that includes questions on overall surface and structural conditions of the feature being surveyed while also maintaining aspects of the existing SOW process in regards to identifying necessary treatment types and all relevant information (WUPA 2676 SOW Survey Manual). At the end of the process, areas/features needing treatment will be prioritized by the severity of conditions identified, scored, and calculated numerically.

Guidelines:

1) The SOW Survey shall be completed for ALL features identified in the unit scheduled for preservation and maintenance treatment, except in the case of emergency stabilization.

   At WUPA 2676, every unit receives cyclical maintenance treatment every 3 years. This means that the SOW Survey will also be completed every 3 years for each unit.
2) Pre-existing conditions shall be photographed during the SOW Survey.

3) Once the SOW Survey is complete, a priority feature list shall be developed. Priorities will be assigned through data analysis (WUPA 2676 SOW Survey Manual; How To Filter And Summarize Data Tables In Excel) as well as according to types of preservation work required, logistics, and costs. The listing shall consist of three categories:

   » High Priority: Areas requiring immediate/emergency treatment including temporary protection;

   » Moderate Priority: Areas in urgent need of preservation, without which will fail within one year;

   » Low Priority: Areas in need of no work beyond cyclical maintenance and/or further monitoring and eventual preservation but for which work can be delayed for at least one year or more.

4) This information will be used to determine the appropriate level of monitoring and preservation treatment proposed:

   » High to Moderate Priority areas will be subjected to additional conditions survey (How To Do Graphic Conditions Surveys). The conditions survey will provide detailed information regarding what treatment options will be selected and where it will be applied.

   » Low Priority areas will not require immediate assessment or treatment interventions but will be monitored until eventual preservation needs are identified.

5) The List of Proposed Treatments Table shall be informed by the data collected and analyzed. The table shall be included in the final SOW document to be submitted for in-house, tribal, and SHPO reviews and any other compliance requirements. The final SOW document at a minimum should consist of the following:[2]

   » A description of preservation techniques and materials that will be used;

   » A description, on a location-by-location basis, of the areas where work is to be done, including quantitative measurements as necessary;

   » A description of logistical requirements, including the transportation of personnel and equipment as well as material sourcing, and specialized tools or techniques that will be used;

   » A listing of the number of personnel that will be required to complete the work and the necessary experience of these individuals;

   » The requirements for documenting the work that will be completed (e.g., stabilization or maintenance data forms, before and after photography, daily or weekly report, project completion report, etc.);

   » A description of additional archaeological/architectural documentation or data recovery needs (e.g., surface collections or excavations, etc.);

- » The expected costs for completing the project; and
- » A proposed scheduling time frame.

6) The plan should be prepared within an adequate time frame to allow for both in-house review as well as to satisfy compliance requirements.

7) All raw data, manuscripts, and reports acquired or produced as part of the Pretreatment Documentation phase must in archived accordance with previously accepted standards and guidelines.

8) A minimum of 5 final copies with original photographs should be produced. Individual copies should be retained for the park files and library, the regional files and library for archival purposes.

Phase 3 : Treatment and Documentation

The last phase of the WUPA preservation workflow is treatment implementation and all related documentation processes.

Graphic Conditions Survey

The conditions assessment process is primarily concerned with gathering information on current threats and active deterioration. The purpose is to identify what factors are causing damage, to what extent, and what preservation strategies could be implemented to treat the structure. As primarily an investigative exercise, the level of detail for the data collected will eventually aid in the development of possible explanations regarding the standing architecture answering some of the following questions (How to Do Graphic Conditions Survey):

- How were the walls built?
- What features are present and what is their function? Do they represent a functional component of the structure? Was the original use modified or discontinued?
- What was the order of construction?
- Is there evidence of additions, renovations, or modification to the overall design?
- Is there evidence of structural maintenance?
- Are there stylistic variations that can be seen on a wall-by-wall basis?
- How does the construction of this structure relate to adjacent structures?
- What portions of the structure remain intact?
- What are the processes of erosion affecting the structure?
- What is the rate and intensity of the erosion? Are portions of the structure currently threatened?
- Has the deterioration had an effect on the integrity of the structure?

To answer some of these questions it is necessary to consult legacy data (i.e., previous stabilization records) and historic photographs. This will result in a more comprehensive understanding of changes on the site and remaining structures, leading to better informed preservation decisions going forward.

Guidelines:

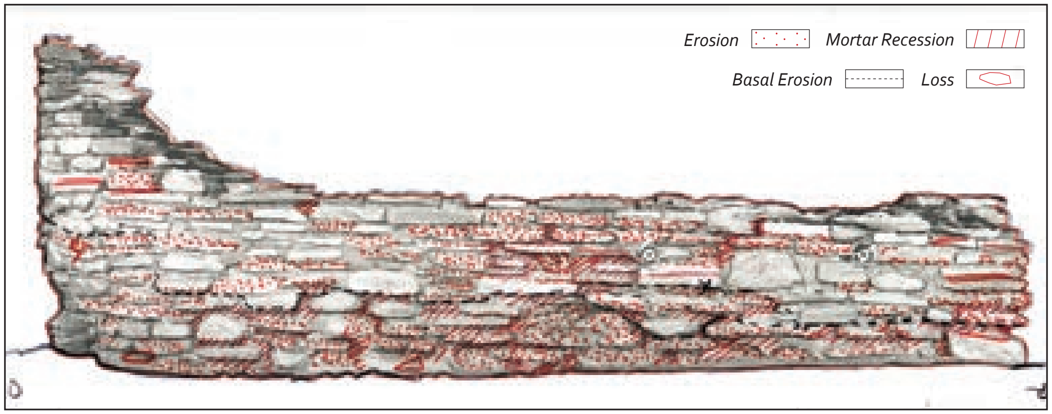
1) A graphic condition survey will be completed on all areas/features identified in the SOW Survey as High to Moderate Priority, requiring further monitoring and/or preservation treatment (How To Do Graphic Conditions Surveys).

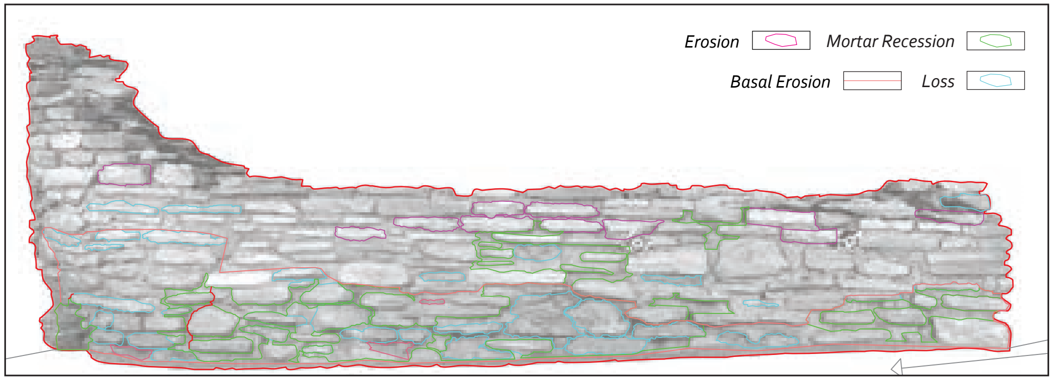
2) All surveys should utilize graphic notations but also should contain narrative text description wherever necessary for clear and detailed data collection.

3) All field surveys should be conducted using rectified photo wall elevations generated in Phase 1.

4) Graphic conditions assessment should always be conducted together with legacy data analysis and historic photographs relevant to the subject wall/feature.

5) All completed field assessments shall be transferred in AutoCAD following provided guidelines and protocols to enable multi-year data analysis (Vectorizing Multi-Year Condition Assessments in AutoCAD).





▲ *Field and digital graphic condition survey examples of wall 1.74.0.W at WUPA 2676. While field condition assessments can be sufficient in some cases, digitizing and vectorizing them can provide additional benefits such as creating multi-year overlays to track and monitor changes over time. Also note that the scanned field conditions assessment and the vectorized drawing utilizes the same rectified photo wall elevation created in Phase 1 of the WUPA 2676 stabilization workflow. As such, the WUPA 2676 stabilization program is designed to provide a streamlined and iterative process for utilizing baseline data sets throughout the assessment, treatment,and analysis stages.*

Treatment Implementation[3]

Walls identified as High- to Moderate-Priority will receive treatment during the annual maintenance cycle, primarily involving the stabilization of architectural fabric including, but not limited to, repointing eroded mortar joints, replacing deteriorated and missing stone masonry, grouting, and newlaying stone as caps or in cavities of varying sizes. Depending on the observed needs from monitoring the site, treatments can also consist of implementing protective measures such as site burial, water diversion, vegetation or rodent control, and the construction of temporary shelters. The treatment process will be photographed, including documenting work in progress.

Given the variety of treatment options applicable at Wupatki Pueblo, detailed descriptions for each treatment method have been outlined in Chapter 8, "Treatment Options and Implementation Guidelines." The overarching guidelines, policies and requirements for implementing preservation treatment at WUPA 2676 have also been outlined in more detail in Chapter 6, "Conservation Goals, Policies, and Guidelines."

Treatments Documentation

Much like the graphic conditions survey, a graphic treatments survey is a documentary exercise that will eventually allow cultural resource managers to analyze the extent and the efficacy of treatments performed over time.

Upon the completion of all treatment work, the location and types of interventions performed will be graphically annotated using the rectified photo wall elevations. The completed field surveys will then be digitally scanned and transferred in AutoCAD to allow for time-series analysis.

Guidelines:

1) A graphic treatments survey will be completed on all areas/features that have received preservation treatment.
2) All surveys should utilize graphic notations but also should contain narrative text description wherever necessary for clear and detailed data collection.
3) All field surveys should be conducted using rectified photo wall elevations generated in Phase 1.
4) Photographs will be taken of all walls that are treated, after the work is completed. Repair area will be photographed in a "wet" state to distinguish between the new materials and the original.
5) All completed field surveys shall be transferred in AutoCAD following provided guidelines and protocols to enable multi-year data analysis.

Post-Fieldwork Data Management

Upon completion of the fieldwork the collected data—architectural, conditions assessments, treatment surveys and supporting data forms, photographs, etc.—should be digitized, appropriately named, and transferred to appropriate locations in the park server. The collected data and relevant forms will become legacy data feeding the iterative WUPA 2676 stabilization workflow cycle. The material should also be readied to be printed on archival quality paper to be both archived and incorporated into required final reports.

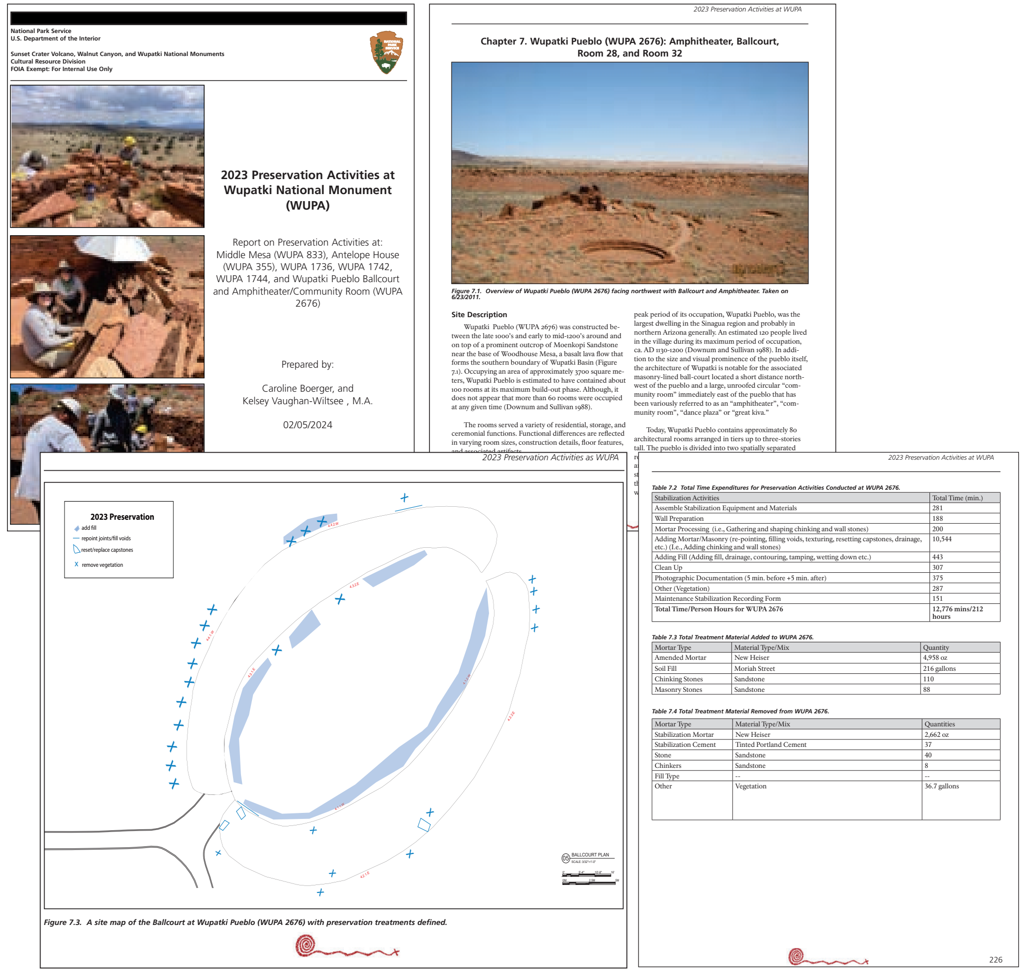
Guidelines:

1) A stabilization treatment report (annual preservation report) is produced to document completed treatment activities for all sites treated within WUPA NM during the cyclical annual preservation schedule. One chapter is dedicated to whichever unit has been treated at WUPA 2676 that year. It is important that the report be complete and detailed. At a minimum, the treatment report should contain the following:
   - » An introduction describing the project including:
     - * Name and identification number of the units, rooms and/or walls worked on;
     - * How many people were used to complete the work and who they were;
     - * When the work was done;
     - * How much money was spent and the source of funding; and,
     - * Any problems encountered.
   - » A description of the methods and materials used for stabilization including the total quantity of materials used and where they were acquired, and any specialized analysis performed (e.g., laboratory analysis on original and stabilization mortars).
   - » A brief summary or listing on a structure-by-structure, wall-by-wall basis of the treatment repairs that were completed.
   - » A brief summary or listing of areas/features designated for monitoring and future preservation treatment recommendations.
   - » A brief description or reference to any archaeological documentation or data recovery.
   - » A bibliography of references that were consulted.
   - » A series of appendices that include:
     - * Graphic conditions assessments documenting the condition of each structure/feature;
     - * Graphic treatments survey documenting the work performed on a structure-by-structure basis;
     - * A minimum of one before and after photograph of each area stabilized;
     - * A plan view map or other appropriate maps showing the location of the repairs on a structure-by-structure basis, the location of deterioration and the types, and other relevant information such as location of sediment sources, etc.; and
     - * Complete Maintenance Stabilization Forms for each structure/feature treated containing both narrative and tabular data sheets.
2) Distribution of copies of the final report will be consistent with the data recovery report. The final report should be submitted within 9 months following completion of the fieldwork.

3) Protected from Public Disclosure

While not applicable to WUPA 2676 and other frontcountry sites, cultural resource information for backcountry sites in the annual preservation report is protected from public disclosure under 16 U.S.C. Section 470w-3, of the National Historic Preservation Act of 1966[4], as amended, and 16 U.S.C. Section 470 xx of the Archaeological Resources Protection Act of 1979.[5] Unless a separate report is created for WUPA 2676, the annual report, when including protected sites, will be protected from public disclosure.

The reports shall be shared with institutional partners at the discretion of the cultural resource manager.



▸ *Preservation Treatment Reports (Annual Preservation Reports) produced following the annual cyclical maintenance treatment should contain comprehensive information regarding work completed serving as significant sources of legacy data for future cultural resource managers.*

Monitoring and Maintenance

Regular monitoring, followed by the maintenance of any problems observed, is essential for keeping the site stable and reducing future preservation costs. This involves revisiting the site regularly after treatment applications, examining the sites, duplicating photographic images of sites for long-term comparative purposes (Basics of Time Sequence Photography), and identifying potential deterioration agents. Currently, monitoring at WUPA 2676 occurs twice a year.

The main goals are to document changes from both natural and anthropogenic causes (e.g., graffiti, etc.), evaluate deterioration factors and agents, assess efficacy of past treatments, and ensure sites continue to exist in a stable, non-threatened condition.

Any observed changes or new preservation needs should be documented and treated following the same protocols and guidelines defined in the WUPA 2676 Stabilization Workflow. The RAS may also be conducted during the scheduled monitoring session.

Guidelines:

1) Monitoring assessment shall be conducted twice a year at WUPA 2676.
2) Monitoring personnel need not be stabilization personnel, but all personnel will be familiarized with the process and forms required prior to the fieldwork (see FLAG NM Archeological Site Monitoring Instruction Manual and Data Dictionary and Form).
3) The monitoring inspections should look for:
    - Signs of general erosion and deterioration;
    - Loose or displaced fabric;
    - Structural strain or failure;
    - Damage from insect and rodent activity;
    - Obtrusive vegetation; and,
    - Damage resulting from visitation.
4) The monitoring of a site should inspect the foundation, mortar joints, wall, stone, and wood members. Specific areas include:
    - Masonry: inspecting all mortared joints, top courses, midsections, and basal foundations for eroding or missing mortar. The stone masonry should be inspected for signs of deterioration or displacement that might cause or contribute to structural stability.
    - Wood members: inspecting all wood members in roofs, doorways, and walls for signs of damage, strain, or failure.
    - Midden and intact cultural deposits: inspecting remains to identify loose or damaged sections and areas of impact.
    - Surrounding fill and interior floor areas: inspecting for evidence of water channeling, rodent burrowing, pot-hunting, or displacement of sediments which might have an undermining effect on the architecture.

7.4. Limitations

The WUPA 2676 Stabilization Workflow discussed above focuses primarily on work that is to be done in regards to the standing architecture of WUPA.

Appropriate protocols and legal compliance requirements (e.g., NAGPRA concerns[6]) should be met for any archeological artifacts recovered on site.[7] However, many of the guidelines and best practices for preserving built heritage are applicable to archeological resources; proper documentation, data compilation and management will allow for rapid retrieval, correlation, and tabulation of information gathered ensuring continued care of recovered artifacts.

For additional guidelines for handling archeological materials and potential excavations at WUPA 2676, refer to Sections 7-17 and 7-18 in the "Ruins Preservation Plans and Implementation Guidelines WUPA NM" (2001).[8]

7.5. Conclusion

The WUPA 2676 Stabilization Workflow should be viewed as one road map that provides a route among many to achieve preservation goals. Each phase and step involved is critical to maintaining an orderly process for long-term preservation. Consistency is the key underlying principle throughout this process. Consistency in data collection, management, and dissemination ensures that the information gathered over time, as well as the high quality of expert knowledge and workmanship necessary to preserve the built heritage, is continued into the future.

Consistency, however, should not be mistaken for inflexibility. It is essential to evaluate the effectiveness of the work performed and procedures followed and it is incumbent on cultural resource managers to seek improved methods for bettering preservation approaches. In that notion, the methods and processes discussed in this chapter are open to modification, and it is expected that the workflow - along with this entire PMP, will be continuously updated and refined as perceptions, knowledge, and needs evolve over time.

Notes

1 Adapted from John M. Barrow et al., "Preservation and Management Guidelines for Vanishing Treasures Resources," *Intermountain Cultural Resource Management Professional Paper*, No. 75 (2009).

2 This section has been adopted from Lyle Balenquah et al., "Ruins Preservation Plan and Implementation Guidelines Wupatki National Monument," *Flagstaff Area National Monuments CRM Technical Series*, No. 1 (2001), Section 7.

3 This section has been adapted from and updates treatment guidelines presented in Balenquah et al., "Ruins Preservation Plan" (2001), Section 4.

4 Section 304 of The National Historic Preservation Act. 54 U.S.C. 300310. https://www.gsa.gov/system/files/NHPA.pdf

5 Section 470hh of The Archeological Resources Protection Act of 1979: Confidentiality of Information Concerning Nature and Location of Archaeological Resources. 16 U.S.C. §470hh. https://www.govinfo.gov/content/pkg/USCODE-2013-title16/html/USCODE-2013-title16-chap1B.htm.

6 The Native American Graves Protection and Repatriation Act (NAGPRA) of 1990. 25 U.S.C. 3001 et seq. https://www.ecfr.gov/current/title-43/subtitle-A/part-10

7 Handling and documentation of recovered artifacts/archaeological materials will be processed in accordance with the existing regional guidelines as well as the Secretary of the Interior's Standards and Guidelines for Archeology and Historic Preservation, https://www.nps.gov/articles/sec_stds_intro.htm

8 Lyle Balenquah et al., "Ruins Preservation Plan and Implementation Guidelines Wupatki National Monument," *Flagstaff Area National Monuments CRM Technical Series*, No. 1 (2001).

Chapter Cover: ALCC and NPS staff at Wupatki Pueblo, 2022 (Credit: Ha Leem Ro).

TREATMENT OPTIONS AND IMPLEMENTATION GUIDELINES 8

8 Treatment Options and Implementation Guidelines

8.1. Introduction

This chapter outlines treatment options for the masonry and site of Wupatki Pueblo and details implementation strategies for each. The preservation strategies presented should be considered as a descriptive guide to the various alternatives that are available to address present and future problems. The previous two chapters that explain guiding principles and policies for conservation treatment guide all understanding of goals for preservation activities at Wupatki Pueblo.

It is also important to remember that while many archeological sites share common features, each one is unique. The idiosyncratic nature of each feature and site dictates that the uniqueness of each needs to be considered in determining appropriate preservation strategies. Likewise, to implement appropriate and effective preservation treatment on the features of a site that are actively deteriorating, agents of deterioration must be understood to target causes, not just to remediate symptoms.

Refer to Chapter 4, Section 4.2. "Factors Affecting Masonry Architecture Condition" to understand underlying factors that are present at Wupatki Pueblo.

8.2. Categories of Treatments

There are three major categories of treatments:

1) Protection

Site protection methods are primarily concerned with preserving site attributes exclusive of the standing architecture. The ultimate goal is to implement a strategy that will curtail degenerative forces operating on the location upon which a site is situated, including all associated cultural deposits and artifactual materials.

In some instances this includes addressing eroding surfaces in and around standing architectural remains. In general, protection methods will be implemented to mitigate surface erosion or deflation, stream bank erosion, or eliminating or controlling vegetation or animals.[1]

2) Stabilization

Structural stabilization is often the primary method for preserving standing architectural remains by reinforcing missing and deteriorated structural components. The goal is to provide stability to deteriorating structural fabric while preserving the materials, elements, features, styles, and the overall form representative of the past cultures at Wupatki.

Structural repairs generally involve materials that duplicate or are compatible with the original fabric and architectural style, ensuring that they do not impact the overall appearance of the walls, features, or structures that are being repaired. For future researchers and the general public, distinctions between the original and the newly added repair materials are made by thorough written and photographic documentation. Occasionally, in situ methods may be used to distinguish new work from old, such as the use of marked stones, micro-tags in the mortar, or the use of polypropylene screen in mortar joints to discern new rebuilt masonry work from old.

3) Monitoring

Monitoring techniques typically involve recording information at longer intervals, the datasets of which are also set aside for longer periods before actual analyses. While the effect and value of these methods may not be perceived immediately, monitoring is crucial in preservation processes for identifying changes and their causes as well as trends (e.g., moisture movement, structural deformation, etc.) to inform future preservation decisions.

In most instances, monitoring can be done through manual data observation (i.e., field surveys) but it can also involve automated data collection equipment that require expertise in installation. Even in these cases, data collection, and sometimes the analyses of the information collected, can be done with minimal training.

All monitoring techniques, however, require establishing baseline data that can be compared with data collected at a later date.

8.3. Implementation Guidelines

Implementation guidelines for treatment options in each category are provided below. The following recommendations are generally prescriptive to the conditions at Wupatki Pueblo. In many cases, follow-up studies may be required to determine exact formulations, procedures, and assessment protocols.

8.3.1. Protective Treatments

8.3.1.1. Shelters

The construction of temporary or permanent shelters is an alternative protection strategy that has not been widely used in the region; however, there are selected cases throughout the Southwest where shelters have been constructed over sites (e.g., Casa Grande Ruins National Monuments, Anniversary Site at Walnut Canyon National Monument) and the overall benefits have been positive. Currently, the park does not see the need for shelters at Wupatki Pueblo. In the future, impending climate change may require this method to be revisited.

8.3.1.2. Floor and Ground Surface Protection

Floor and ground surface protection methods include applying a thin soil layer over surface features to delay surface erosion or deflation, backfilling exposed subsurface site attributes, and using riprap to stabilize slopes and cut-banks exposed by streams or arroyos. Properly installed floor protection systems can mitigate damage to already damaged basal masonry courses by protecting them from weathering.

At Wupatki, ground protection typically involves adding small lifts of sediment to protect floors, ground surfaces, and wall bases. This approach facilitates drainage contouring, shields exposed cultural deposits, and reduces foot traffic damage. Using stones in this process can reduce the amount of sediment needed and brace the fill, providing additional support. When incorporating stones, they should resemble rubble or naturally occurring formations, and all sediment layers must be manually compacted in six- to ten-inch lifts, separated from the original matrix by vapor permeable filter fabric. Markers should indicate the center and corners of filled rooms.

Backfilling, which involves adding substantial fill to alter room depth, serves multiple purposes: equalizing differential fill levels, supporting walls, and protecting exposed areas. The process requires careful material selection and design, often incorporating layered materials to balance drainage with compaction. At present, no backfilling of rooms at Wupatki is planned pending further structural investigations of differential fill. Conversely, in some cases, differential fill removal may be required to address wall deformation, where other remedial means are not possible. Any such removal must undergo review for archaeological sensitivity and comply with park regulations.

Riprapping options include rock berms, gabions, geowebbing, sandbags, and bulkheads. Prior to any intervention, the present ground surface should be marked with filter fabric, and labeled and dated with aluminum markers. Regardless of the method chosen, the process should be carefully planned to ensure that the equipment and materials used do not damage the site.

8.3.1.3. Vegetation Control

Methods for dealing with damage caused by vegetation generally involve cutting down or cutting back vegetation that has a potential for causing above-ground or subsurface damage to site attributes. Removal and eradication of vegetation also contributes to reducing wildland fuels, hence reducing wildfire risks.[2] Native grasses should be encouraged to grow, since they provide stability to surface deposits. Large shrubs and trees growing in or immediately adjacent to site features, however, should be cut off at the ground surface. The roots should only be extracted if the process does not disturb the surrounding fill or cause damage to subsurface features. For buried rubble construction, earthen mortar and plaster provide a desirable context for root growth. Burning is also an effective means for dealing with unwanted vegetation, but it is not recommended on archeological sites, due to the likelihood of introducing modern carbon in the deposits and the potential for wild fires. There are currently no herbicides recommended for use.

8.3.1.4. Pest Control

Most methods for dealing with animals are somewhat problematic. Insects can be effectively eliminated, at least in terms of wood elements, by the application of a wood preservative. However, strategies for addressing insect damage to mortar, and damage caused by rodents, bats, and birds to various other aspects of a site remain underdeveloped. Current efforts at Wupatki prioritize exclusion over removal as animals often return and repopulate. While removal can provide short-term relief, it often creates a void that nearby animals quickly fill. Exclusion methods, such as installing hardware cloth to prevent woodrats from nesting in ventilators, offer more sustainable solutions. Pesticides are generally not recommended for use at due to potential harm to the environment and cultural materials.

8.3.1.5. Water Control

Preserving sites and structures requires effective water management, as direct precipitation, pooling, and runoff are major causes of deterioration.

Techniques including retaining walls, bedrock drainage channels, and artificial driplines (e.g., lead, zinc, or silicone "lips") have long been used at Southwest sites to redirect water away from sensitive areas. A reversible artificial dripline at alcove openings, for instance, can also prevent runoff from damaging cultural remains, though such methods may alter site environments.

In 1953, an extensive drainage installation project was completed throughout Wupatki Pueblo, involving the conversion of some prehistoric features such as ventilators into drains, and the installation of modern drainages in both the North and South Units. Regularly inspecting and managing these drainage systems are crucial for water control. Redirecting some existing systems is recommended to relieve pressure on the primary drainage outlet, particularly through the Pueblo's lower east side, which handles 58.2% of the watershed. Anderson's 2023 erosion study suggests adding another outlet below Room 81 to redistribute watershed and reduce strain on nearby masonry walls.[3]

Another method for managing water runoff is installing subsurface systems that can serve as catchment basins in the floors of structures, and plumbing pipes can be used to drain water away from wall bases. At a minimum, and as a less costly option, recontouring room fill to direct water away from walls can help manage runoff.[4] Placing *media luna* structures in room fills can also assist in redirecting and slowing down water flow to reduce erosion.[5] Alternate methods of water control such as ground cover water retention should also be explored (e.g., similar to soft capping). With proper sediments and geotextiles, this method can be extremely effective in hot dry climates, allowing water to evaporate before affecting the walls.

▸ *Management of existing systems(e.g., clearing blocked drains) (top, middle) as well as the installation of new drainage systems (e.g., media luna) (bottom) are equally important measures for preventing and redirecting water flow in historic sites.*

8.3.1.6. Other Related Protection Methods

Other indirect site protection methods include:

» Closing a site to visitor use;

» Increasing authoritative presence to monitor visitor movement within a site;

» Implementing visitor education programs to increase visitors' awareness of site significance and fragility; and,

» Installing signs or barriers to enhance visitors' awareness or restrict visitor movement within a site;

The NPS, however, has a responsibility to provide the public with opportunities to experience and learn from both the tangible and intangible remnants of the past. It is therefore imperative that a find a balance at Wupatki Pueblo, allowing visitor access in a controlled manner while ensuring the adequate protection and preservation of the resources that make the site significant.

8.3.2. Stabilization Treatments

Two stabilization approaches guide treatment depending on whether walls contain original or replacement materials based on archival and historical records. The defined approaches are as follows:

- Original fabric repairs: Preserve original fabric in terms of the materials, elements, architectural style, and mass and form minimizing impact on visual and structural integrity.
- Replacement fabric repairs: Ensure visual consistency with original materials focusing on color and texture without reconstructing original styles. Aim for 100% removal of detrimental and incompatible materials like previous soil-cement, colored mortars and Portland cement wherever possible without compromising the existing fabric. For walls needing over 50% mortar joint replacement, remove all old repair mortar and apply new mortar uniformly.

All stabilization repairs should blend with or match the known original fabric without altering the original architectural style or appearance, ensuring that no features, element, or components are obliterated. Only minimal repairs necessary for structural and visual consistency should be undertaken, keeping in mind that each stabilization repair has an impact upon the integrity of the site.

All stabilization techniques discussed in this section require that the features to be treated be "prepared" first; all areas to be repaired must be clean of soil and debris, and all loose or out of place stone and mortar removed to create a firm, clean surface. If a footing is required, loose debris and fill should be removed until a relatively compact surface is reached. Ideally, repairs should be made without reorienting or moving structural components, and original materials should only be reset into position if structural stability is uncompromised. All proposed disturbance of original fabric and intact and in situ cultural deposits shall be investigated by the project archaeological technician before repairs are initiated.

8.3.2.1. Repointing

Repointing is the process of repairing deteriorated mortar joints where cracking, separation, or loss of mortar has weakened the structural support of the overlying walls. It should be carried out only to the extent necessary to ensure structural stability. It is important to note that most stabilization techniques discussed in this chapter involve repointing or working with mortar in general, which requires the following procedures:

1) Remove deteriorated mortar to a depth of 2-2.5 times the width of the joint or deeper until sound original mortar is located. Old soil-stabilized mortars should be removed by hand chisel; harder cement mortars may require specialized power grinders to be used by trained practitioners so as not to damage the masonry;
2) Remove dust and debris, and dampen joints with water to prevent surrounding masonry or mortar from absorbing excessive moisture from the stabilization mortar causing it to dry out prematurely and crack;
3) Pack the mortar tightly into the joint, filling it slightly recessed. Use true, leveler, and false spalls as needed to match the appearance of the original fabric present. Mortar joints should be compressed, not slicked smooth, when applying.
4) When the newly added mortar is thumbprint hard, texture the joints to create a rough, natural appearance, avoiding smoothing or over-texturing to prevent an overly curated appearance. When dry, use a damp sponge to create a weathered appearance by exposing the aggregate in the soil mix; never texture by dimpling the surface with the end of a whisk broom on wet mortar.
5) Wet cure newly added mortar to slow moisture evaporation and prevent shrinkage cracks; wet curing is extremely important when temperatures are above 80°F or when newly repaired walls are in direct sunlight. This can be done by misting or draping soaked burlap over the wall, during and after completion, for at least 24 hours.

8.3.2.2. New-laying, Re-laying, and Resetting on Stone Masonry Walls

These stabilization tasks should be used to correct problems caused by masonry loss, looseness, and displacement. The general procedure for new-laying, re-laying, and resetting stone depends on the presence of mortar.

For *Wet-Laid* stone masonry walls:

1) Prepare a stable textured surface for the stone;
2) Dampen the area with water and apply a mortar bed. For larger re-lay areas, install a polypropylene mesh on top of the fresh mortar before laying the stone to indicate rebuilt sections such as wall caps.
3) Dampen the stone and set lightly on the mortar bed, allowing about 2 cm of the exterior face to extend outward. Gently slide the stone into position until flush with surrounding units, using a rubber mallet to secure as needed. Use true, leveler, and false spalls to minimize mortar use, level or support the stone, and create decorative patterns where appropriate.

For *Dry-Laid / Mudded* stone masonry walls:

1) Prepare a clean surface to provide a solid contact area for the stone;
2) Place the stone within the void, flush with the adjacent wall surface; and,
3) Tap the stone into place or wedge with leveler spalls to secure it; minimizing joint size and overlapping stones will provide the maximum amount of stability.

▲ *Example of wedging dry-laid stone masonry (highlighted in red) courses to reinstate structural stability to a masonry wall with severe basal erosion at Wupatki Pueblo.*

8.3.2.3. Wall Caps

At exposed archeological sites, broken masonry walls are typically preserved using either hard or soft capping. Hard capping involves applying lime, cement, and/or modified soil mortars, or adding additional masonry courses on exposed wall tops. It has long been a common practice in many archeological sites including Wupatki Pueblo, where it is assumed that the upper two to three courses of all walls contain capstones placed as part of stabilization activities since the 1930s.[6] Soft capping uses native grass or soft herbaceous and perennial plants to cover wall tops, providing less intrusive protection and integrating with the landscape, as seen at archeological sites globally.[7]

Regardless of the type, effective wall cap design should:

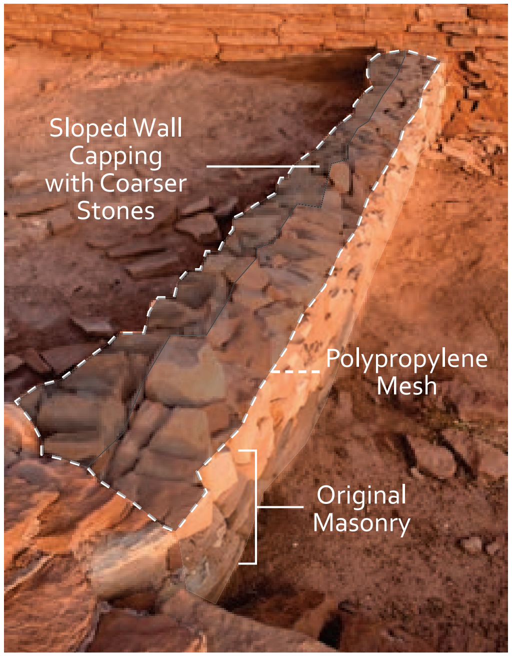
- Minimize water infiltration into the original masonry;
- Provide cohesive strength to the wall tops without stressing the original structure;
- Reduce thermal movement;
- Be distinguishable from the original structure, without diminishing the original character of the historic site;
- Be easily installed and removed, if necessary; and,
- Be maintained using local materials.

Hard wall caps act as sacrificial layers, protecting the original structure from environmental weathering. However, at sites like Wupatki Pueblo, where visitors can interact with the resource in close proximity, wall caps are also susceptible to disturbances from human activities such as walking, sitting, or climbing. Therefore, wall cap designs must consider ways in which capstones can deter both environmental and human impacts effectively. A key consideration is to avoid creating wall caps with flat surfaces as they can trap moisture, leading to water pooling and infiltration through the original structures. Additionally, flatter surfaces are also more inviting for human interaction, further increasing the risk of damage. An alternative wall cap design for Wupatki Pueblo may feature a slight peak incorporating coarser, angular stones to shed precipitation as well as to discourage human interaction. Newly laid capstone courses should be placed on top of a polypropylene mesh to demarcate any original masonry beneath. If and when the two to three existing capstone courses above the original masonry at Wupatki Pueblo are rearranged to this design, or even when resetting loose capstones, the same guidelines for resetting stones outlined in section 8.3.2.2 should be followed. When arranging capstones to form a peak, care must be taken to avoid excessive slopes that could may cause rapid water runoff down the wall faces and to prevent overloading historic masonry.

Before applying modified repair earthen mortars, all cement mortars should be removed, where possible. Capstone mortars are typically higher in amendment for durability. When old caps are removed, wall interiors should be inspected for voids and gaps and filled with stones and mortar.

Despite their apparent durability, hard capping may not be a sustainable long-term solution due to the labor required for continued maintenance. Capstones are frequently reset as part of the regular maintenance cycle at Wupatki Pueblo, with assessments of higher, less accessible capstones often postponed. Ideally, maintenance should only be deferred because of the soundness or the secondary importance of features, such as wall caps that are essentially reconstructed features, allowing more resources to be allocated to preserving the original fabric and addressing urgent needs. Soft capping can therefore be a low-maintenance and cost-effective alternative for protecting exposed walls at Wupatki Pueblo.

▲ *Example of a wall cap at Wupatki Pueblo showing the exposed mortar bed where water can pool (noted in blue) encouraging moisture infiltration through the original masonry wall.*



▲ *A rendered example of the same wall cap showing angular stones arranged to form a slight water shed slope with a layer of polypropylene mesh beneath the capstones.*

Wall segments with sound cement stabilized wall caps can be used as the base for supporting one to two new courses to hold the vegetative capping. Soft capping should be prioritized for areas that are most prone to deterioration from unintended deferred maintenance (e.g., taller walls and/or higher areas) and lower walls more susceptible to visitor impact. Walls at least two wythes thick (approximately 3 feet wide) are suitable for soft capping, as they provide sufficient surface area to support the soil that will ultimately retain moisture for evaporation and anchor root systems securely.

Soft caps can also contribute to the larger preservation philosophy of representing the structures as part of the broader landscape as well as preventing the creation of a false impression of the site's original character. The existing wall caps (2-3 masonry courses) at Wupatki Pueblo can be misleading to visitors who might perceive them as parts of the original structure. Although soft capping may alter the site's appearance, it can provide a more naturalized way to distinguish between original and reconstructed elements.

▲ *An example of soft capping at Far View House in Mesa Verde National Park using locally available grass. The geo-fabric protruding on the left serves as a barrier to prevent the roots and water affecting the original masonry wall (Credit: Alex Lim).*

8.3.2.4. Injection Grouting

Injection grouting is a technique that involves injecting grout—a fluid-like mixture of water, binding materials (e.g., lime, soil etc.), and inert fillers (e.g., ceramic microspheres)—to fill cracks, open joints, voids, or honeycombs in masonry. The grout should function as a flowable "mortar" and ideally have negligible shrinkage to fill voids and should remain stable without cracking or crumbling. The selection of the type of grout for the particular type of masonry repair work should be based on the compatibility of the grout with the original masonry system. No grouts should be used on site without prior laboratory testing by a qualified conservator.

An earthen grout mixture (Sieved Soil: Limestone Powder: Sodium Hexametaphosphate = 60:40:0.4 wt%) has been developed by the Civil Engineering Department at the University of Minho (UM), Portugal in 2023. Any injection grouting at WUPA 2676 will be carried out in accordance with the guidelines presented in the documents submitted by UM (see Appendix).

8.3.2.5. Stone Replacement and Consolidation

Individual stone deterioration at Wupatki Pueblo is rare, except in basal courses using clay-rich, grey colored Moenkopi sandstones, which exhibit greater erosion (i.e., flaking and disaggregation). These stones should be monitored for surface loss, and where they jeopardize the stability of the wall should be considered for replacement with a more robust sandstone. The use of stone consolidants is not recommended at this time.

8.3.2.6. Wood Repairs and Preservatives

Repairs to wooden features will typically involve adhering or consolidating fractured or deteriorating members, an approach preferred over replacements to retain original wood members. Both carpenter wood glues and epoxies have been used successfully in the past.[8]

Additionally, a non-staining wood preservative can be applied to wood members exposed to weathering, particularly those in contact with soil or embedded within masonry to prevent deterioration from moisture contact and burrowing insects. Typical preservatives that will be used will be a combination of linseed oil, paraffin wax, and mineral spirits. Current NPS policies favor the use of Bora-Care, a borate-based product that provides prevention and control of termites, carpenter ants, powderpost beetles, and decay fungi.

A conservation specialist should be contacted to determine the most appropriate preservatives to use.

8.3.2.7. Structural Reinforcement

Non-corrosive materials like reinforcing bars, wire clips, cramps, anchors, and mesh are used for integral structural support and stiffening for various wall construction types as well as in roofs. They are typically used to provide lateral support to unbuttressed multi-story walls and reinforce roof beams compromised by excessive weight. These materials should be used and integrated into the structure discreetly when other stabilization methods aren't feasible. In some sites, wooden vigas were left or inserted to provide structural support for opposing walls. Dry or friction-dependent reinforcements are preferred over adhesive-set repairs; however, in most cases, consulting a structural engineer is recommended for significant wall reinforcement issues.

Additionally, plywood and other milled lumber, such as 2 x 4s and 2 x 6s, can be used as temporary braces to support collapsed or leaning walls. Plywood can be used to protect severely degraded original roofs but this method is recommended when other stabilization methods are not possible.

Walls deemed most at risk for seismic activity should be studied for possible reinforcement methods including the reinsertion of wooden vigas for lateral support.

8.3.3. Treatment Material Guidelines

8.3.3.1. Soil Sources

Current FLAG NM policy permits collection of in-park soil sources where soil is being removed for some other purposes. Soil "extracted" during that time can be used for stabilization processes. For several years, the primary source for soil for treating all WUPA NM sites has been the Moenkopi Formation, exposed in cutbanks within the park's New Heiser maintenance area. The soil was sourced from slope wash caused by weathering interbedded siltstone deposits within the formation, eroding from a three-meter-high cut face surrounding the south and west sides of the maintenance area enclosure created during the yard's construction. The slope wash is occasionally cleared by the maintenance crew to keep the base of the fence clear of debris. There is, however, concern with the long-term availability of this soil source.

Consequently, staff have acquired soil for future stabilization from “off-park” sources. In instances where external sources are unavailable, it may be necessary to acquire soil from undisturbed areas within the boundaries of the park to perform stabilization treatment. Use of these areas will require evaluation in accordance with NPS policy, National Environmental Policy Act (NEPA), and National Historic Preservation Act (NHPA).

Use of such locations will be approved only if: (1) the proposed soil is the only available source that will match the original materials at the proposed treatment site, (2) less than ¼ ton of soil will be extracted, (3) follow-up extraction needs will be minimal, (4) the source is away from known archaeological sites and free of archaeological material, (5) an archeologist will monitor the extraction, and (6) excavation depth does not exceed 25 centimeters, with the area reclaimed to prevent creating new erosional patterns.[9]

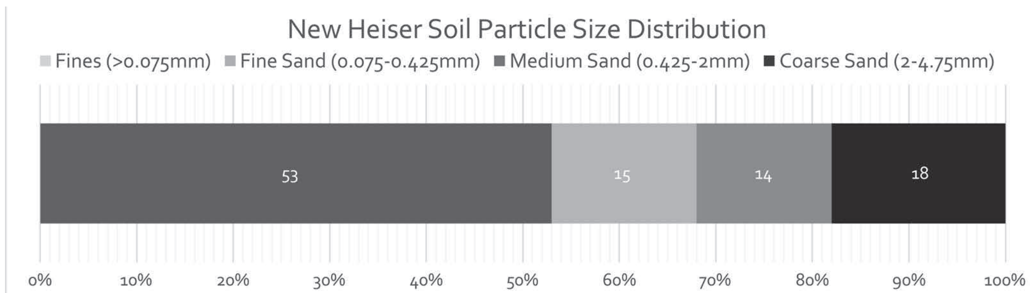
Any materials from new suppliers being considered or new locations within the park must be tested for compatibility before being used on the site.

8.3.3.2. Mortar Sediments

Before any stabilization repairs, a stabilization mortar mix will be developed as part of the pretreatment documentation phase of a project for each site targeted for treatment. At Wupatki Pueblo, current stabilization assumes acrylic-amended earthen mortars are compatible with existing masonry.[10] However, original mortar should be analyzed when possible to confirm compatibility and guide mortar development.

Proposed mortars will be informed by a soils testing kit to determine texture and particle size. Soil characterization tests (2022) by UM identified the New Heiser soil, currently used for repointing, as sandy lean clay with over 50% fines.[11] Research suggests sandy soils (60-65% coarse sand, 10-15% clay) work best with acrylic amendments; thus, additional sand or sandy soil is recommended to lower clay content.[12] It is therefore recommended that sand or sandy soil be added to reduce the clay content.

Lab analysis will verify compatibility with the masonry whenever soil sources change. Basic tests include particle size distribution, shrinkage, cohesion, salt content, and Munsell color notation, with optional tests for expansive clays, calcium carbonate, and organic content.



▲ *New Heiser soil particle gradation graph created from soil characterization performed by UM in 2022. Based on previous research, soils with at least 60-65% of coarse sand with 10-15% of clay is considered to be ideal for acrylic amended mortars. It is therefore recommended that sand be added to New Heiser soil when mixing with acrylic amendments (Data Source: UM, 2022 / Graph Adaptation by CAC).*

The finalized mortar mix, completed well before stabilization begins, will specify sediment proportions and types to closely match the original mortars in color, and texture, ensuring adequate structural and aesthetic compatibility between the old and new materials. Replacement mortars will be subtly distinguishable from original materials and previous repairs.

Soils will be screened through a 1/4-inch wire mesh to remove unwanted material and stored on tarps to prevent contamination or moisture, which could affect water-amendment ratios. Soil source areas may serve as mortar processing sites.

8.3.3.3. Floor and Ground Sediments

Floor and ground protection materials should match the site's original soil composition (in percentages of sand, silt, and clay or that roughly equate to a sandy loam). High-clay or high-silt sediments should be avoided due to moisture retention, while high-sand sediments may be used with precautions to prevent displacement by wind or by foot traffic. The use of geo-textiles, stone, or sand must be contextually appropriate.

8.3.3.4. Mortar Amendments

At Wupatki Pueblo, Rhoplex E-330 was used successfully as the designated mortar amendment until 2022, when it was replaced by Adacryl.[13] The preferred solution mixture is 4 parts water to 1 part Adacryl, which was determined through field testing. This mixture is used for wall joints, whereas, 2 parts water to 1 part Adacryl is used for resetting capstones.

After mixing it with water, the Adacryl solution needs to be stored in an airtight container to prevent evaporation and setting. Once the amendment has been mixed with soil, it should not be exposed to air or direct sunlight for extended periods of time. A two-hour time frame can be used as an acceptable rule-of-thumb; once this time frame has passed, the amended mortar should be discarded. Hardened amended mortar cannot be retempered or regenerated for use, as the long-term effects of doing this are unknown. Mixing of small batches is recommended to follow these guidelines.

Although acrylic emulsions have been long used, biodegradable organic options such as psyllium are under study and should be considered.

8.3.3.5. Water

Water for structural treatments must be sourced from park maintenance areas and regularly tested to ensure purity and transported to the work area in containers. In-field tests should be conducted to ensure the water is potable and free of carbonates, which can cause efflorescence and staining, leading to structural degradation and eventual collapse. As a general rule, water free of organic debris and without an unpleasant odor or taste is likely acceptable for use. Semi-quantitative salt indicator strips can also be used to determine purity.

8.3.3.6. Stone Masonry

Sources for stone masonry should be investigated to ensure an adequate and compatible supply for required repairs. Stones from within the structure being repaired can be reused, provided no archeological context remains. If on-site sources are depleted, alternative off-monument sources should be used. All stones selected must be durable and modifiable to match the surrounding masonry being repaired.

8.3.4. Monitoring

Monitoring techniques involve tracking physical conditions (e.g., cracks, leaning, bulging walls etc.) that may be indicators for active deterioration and/or any variables (e.g., surface recession, moisture movement) to identify causal trends for deterioration in a structure.

As previously stated, monitoring typically involves recording data at longer intervals over a period of time and requires establishing a starting datum point. This also necessitates establishing a monitoring schedule. While more severe conditions will require more frequent monitoring, the monitoring frequency will not only depend on the severity of threats to features within the site but also the ease of accessibility to the site/area as well as the availability of personnel to conduct the monitoring.

The most crucial aspect of monitoring is keeping clear and consistent documentation of monitoring locations to ensure continuity in revisits preventing data loss.

8.3.4.1. Monitoring Cracks

Masonry structures are always moving, typically resulting in small and minimal cracks. While it is common for walls and cracks to fluctuate with daily and seasonal temperature changes, it is important to recognize that cracks can signal potential severe problems emerging within the structure or the ground on which they are built.

Cracks will often appear in inherently weak points in a structure's design or construction but can also arise from various issues, such as damaged internal or nearby drains, faulty water pipes, and subsequent loss of ground support. Additional factors may include deteriorated internal timber (e.g., original flooring or roofing), corroded metal supports (e.g., steel bracing), soil subsidence or shrinkage, tree roots, unstable neighboring walls, and eroded or damaged foundations.

A rapid increase in crack movement, such as faster widening, often will signal a heightened risk of structural collapse. To prevent catastrophic events, it is important to identify the rate of movement through routine measurements, either taken manually with a caliper or tape measure, or tracked using commercial crack monitors.

Refer to VT's "Preservation and Management Guidelines for VT Resources (2009)"[14] and "Guidelines for Crack Monitoring (2024)" prepared by UM (see Appendix) for detailed instructions on manually measuring cracks and using crack monitors.

▲ *Example of cracking in a structurally vulnerable area (drain opening) with a crack monitor installed to track movement at Wupatki Pueblo.*

8.3.4.2. Weather (WX) Stations

As complex and varied as material systems, deterioration, and maintenance practices may be, all are affected by environmental exposure. Given the realities of climate change, tracking baseline environmental parameters over time has become essential for understanding how they impact cultural resources. Distinguishing which environmental factors may be affecting or exacerbating certain material and system performance can help isolate underlying root causes that may be hidden during other types of assessment.

Minimum requirements for a WX station to gather baseline environmental data typically include: temperature, relative humidity, wind speed and direction, solar gain, and precipitation. The ideal setup location is far away from potential obstructions such as trees, buildings, extreme terrain. A general rule of thumb is five times the height of the nearest/ tallest object. Any object that may cast a shadow from either a solar or aerodynamic perspective should be avoided to ensure proper data collection.

The installation location should also be close enough to the resource so that the station can capture the average exposure conditions, but far away enough that the readings are not influenced by the structure. Other factors that may influence the location include the presence of archeological resources (e.g., burials) and visitor access and impact. The decision to determine the best location should ultimately be made in consultation with park staff and experts.

Most data loggers for WX stations can continue to operate and record data for extended periods of time with minimal maintenance. Nonetheless, installed equipment should regularly be monitored for potential damage from visitors or animals.

When analyzing the data collected, comparing micro-climate data specific to individual resources against regional or national climate projections can help refine confidence in projected outcomes by aligning key environmental variables across both data sets (Basics of Weather Stations).

▲ *A weather station installed at Wupatki Pueblo in the summer of 2022 to collect and monitor micro-climate data for the site. This particular installation is an Onset product that has wind speed, wind direction, precipitation, ambient temperature, relative humidity, and solar radiation sensors. This is a self-contained, weatherproof system with its own solar panel and battery capable of operating for up to a year at 15-minute logging intervals before data offload is required. Also note the zip-ties placed on the horizontal bar to deter birds, as well as the weights placed on the tripod to secure its position in high-wind events.*

An Onset™ weather station was installed at Wupatki Pueblo in the summer of 2022 to collect and monitor micro-climate data for the site. This particular WX station is equipped with HOBO® sensors for wind speed, wind direction, precipitation, temperature, humidity, and solar radiation. This station runs autonomously with a solar panel and battery, capable of operating for up to a year with 15-minute logging intervals before data offload is required. The WX station is currently positioned about 100 feet south of the South Unit's southernmost wall, away from the main trail and path, with enough access for both the staff and wandering visitors. A temporary interpretive wayside has been placed to inform visitors about the station and access, but the relative accessibility warrants regular checks for tampering or damage.

Routine maintenance is key; staff should monitor the station at least monthly to ensure equipment stability and functionality. This includes checking the tripod currently secured with weights from high-wind events, and removing animal droppings, especially from the solar panel. Deterrents for birds placed on horizontal perching surfaces, such as UV resistant zip-ties, should also be replaced seasonally. Cables should be inspected to ensure they follow manufacturer guidelines with drip loops for moisture protection; in areas with rodents, additional rodent-proof tubing may be needed. Any exposed wires visible to the public can be camouflaged by applying unamended mortar to blend with and/or attached to the masonry, though this also requires frequent inspection as mortar can degrade or become conspicuous. The data logger should also be checked monthly to confirm logging status, which can be verified through the blinking status LED, reading data outputs, or connecting a computer to assess the current logging state, battery level, and potential errors. If relocation of the station or equipment replacement is required, consult manufacturer guidelines as well as with experts (e.g., VT) and ensure compliance for grounding rods and stakes.

Full seasonal data, ideally over one year, is recommended to capture comprehensive environmental exposure, though interval snapshots also offer valuable insights. Staff are therefore encouraged to offload data monthly, or at least once every three months, allowing for both frequent equipment check-up and timely collection of seasonal data. Using a shuttle (a portable data reader) is recommended at Wupatki Pueblo given the site's challenging conditions for computer use.

Data files directly offloaded from Onset devices are in a proprietary .dtf format, which can be opened in HOBOware (available in free or paid options) and can be exported into a variety of different formats. HOBOware also allows data to be exported as vendor-neutral file formats (e.g., TXT and CSV) that can be read in softwares like Excel, which can be more optimal for data filtering and statistical analysis.

Weather data analyses for cultural resource management will typically involve both understanding changes in individual climatic parameters (e.g., precipitation, relative humidity, wind patterns, and temperature) and examining how different climatic parameters relate to each other.

Analyzing precipitation and temperature data together, for instance, can reveal moisture-related risks like erosion, freeze-thaw cycles, and material saturation. Similarly, examining relative humidity alongside temperature as well as dew point data helps managers evaluate risks of material cracking and condensation, which contribute to freeze-thaw damage and biological growth that accelerate surface wear. Wind patterns, especially in arid environments like Wupatki, further indicate erosion-prone areas and potential abrasion from wind-driven particles, with the intensity and direction of winds affecting exposed surfaces. Temperature fluctuations combined with solar radiation data highlight UV-induced material degradation and thermal stress, as prolonged exposure may cause materials to become brittle.

Together, these data insights offer a nuanced view of environmental factors driving potential deterioration and necessitate specific preservation strategies.

A constructive weather data analysis requires extended and consistent data collection. Most experts recommend collecting weather data for at least 30 years to calculate a region's climate average,[15] and this can be achieved in the long term for Wupatki Pueblo. In the meantime, data analysis every year is recommended to anticipate environmental impacts at the site to inform preservation decisions.

At a minimum, it is recommended that precipitation and temperature data be analyzed to anticipate extreme weather events, which may require immediate responses from cultural resources staff, such as flash flooding mitigation, as well as to track freeze-thaw cycles that impact structural stability.

Establishing a localized environmental baseline is critical but should also be contextualized within broader climate patterns. Following guidance from Chapter 5, "Assessing Vulnerability," comparing Wupatki's micro climate with national and regional climate data can provide valuable insights into potential changes. Data analysis performed should be utilized to modify and update vulnerability assessment for Wupatki Pueblo as necessary; this approach will ensure the vulnerability assessment for the Pueblo remains relevant as broader climate trends evolve.

For further guidance on setting up and using weather stations, including how to offload data, refer to Basics of Weather Stations. Basic information regarding analyzing weather data can be found in Analyzing Weather Data in HOBOware and Excel. For more information on how to leverage Excel for data analysis, refer to How to Filter and Summarize Data Tables in Excel.

Additionally, internal resources are available to assist parks for a broader understanding of weather data and climate studies: consult with the Climate Change Response Program responsible for generating climate future scenarios for national parks, as well as VT and the Climate Resilience Evaluation and Awareness Tool (CREVAT) for analyzing vulnerabilities across parks in the NPS Intermountain Region.

8.3.4.3. Physical Sensors

Unlike WX stations, certain environmental sensors must be in direct contact with cultural resources for measuring variables. For cultural sites, this typically involves embedding moisture and temperature sensors into the soil or masonry joints to monitor water movement and temperature differentials across the site or the structure. Data gathered from these sensors can help assess how structures respond to weather events when compared with WX station data.

The advantage of using embedded sensors is their ability to collect long-term with minimal maintenance. As a more intrusive monitoring method, however, careful consideration is needed before installation to assess potential impacts on both cultural resources and visitor experience. When sensors are installed for extended periods, they should be routinely checked for potential damage caused by visitors or animals. Digital moisture meters offer a less intrusive alternative, but they are less suitable for long-term data collection as they require frequent site visits to gather measurements.

The frequency of maintenance, for both the WX stations and physical sensors, will often depend on the type of data logging system used; networked systems using cellular or Wi-Fi connections offer remote access, alarms, and notifications, but may be impractical at sites with limited connectivity, like Wupatki Pueblo. They can also come with recurring costs to secure internet plans. Standalone systems lack remote access, requiring manual data offloading, but are more affordable upfront. They can operate for longer periods, but require periodic inspections to check for malfunctions.

The number of sensors needed depends on several factors to determine what is considered "representative" of a specific context, feature, or material. For example, in assessing the severely eroded masonry wall supporting the three terraced rooms—"stepped rooms" characteristic of Wupatki Pueblo's terraced structure—eight moisture sensors were installed strategically through out the earthen floors. This number was based on the size of the area as well as the existing knowledge of chronic moisture issues present in rubble masonry structures with varying levels of differential fill.

▲ *This data logger placed in Room 41 at Wupatki Pueblo collects data from the eight moisture sensors installed to monitor moisture movement across the three terraced rooms. This particular model (Onset HOBO Data logger) was placed in the highest room to maximize exposure to the sun while also minimizing disruption from visitors. It is important to note that factors like ease of access, feasibility of installation (i.e., whether the sensors can actually be embedded in the material/structure), and visibility to the public can affect the final location of sensors and data loggers.*

8.4. Emergency Stabilization[16]

Emergency situations can pose serious risks of damage to or loss of cultural resources that may warrant immediate intervention. An emergency is defined as a situation in which material failure or collapse is occurring or about to occur. There are three levels of emergency response: the highest priority is life and human safety, followed by the imminent loss of historic material without safety concerns, and finally, the potential loss of non-historic repair material, which may require further management input. Normally, this loss is not considered to be an emergency with regard to VT resources.[17]

In such cases, conservation professionals should take all reasonable measures for preservation, recognizing that strict adherence to the SOI's standards and guidelines for the treatment of historic properties and best practices for conservation may not be feasible. According to Chapter IX of the Programmatic Agreement between the NPS, the ACHP, and the National Conference of SHPOs (2008), these guidelines should still be followed as closely as possible.[18]

When public health and safety is at risk, immediate action must be taken to prevent collapse, particularly in publicly accessible areas. Safety is of the highest importance and resources may be closed off due to hazards. If the Superintendent deems a situation an emergency requiring urgent action, time can be very critical; there may not be time for standard Section 106 procedure. In such cases, notification to the SHPO and other consulting parties is essential, ideally within 24 hours, with appropriate follow-up.

Any remedial action taken must be reversible and safely executed, ensuring the protection of the structure's integrity. If feasible, conservation professionals should develop a treatment plan before any intervention, outlining objectives, risks, and alternative approaches. This plan should be submitted to the relevant parties, such as the owner or custodian, when necessary.

Remedial actions should avoid damaging the structure's integrity. These actions usually involve trail closure, wall braces, temporary frames, sand bagging, and temporary covers.

Employees should not take actions that endanger themselves; trained professionals should be contacted to handle emergency procedures if needed and if employee safety is a concern. Once the remedy has been taken and the wall or structure is reasonably secure, the project should return to normal processes, including Section 106 procedure and tribal consultations, as soon as possible. In the case of inadvertent discovery of buried ancestors, consult FLAG NM's Comprehensive Agreement regarding NAGPRA inadvertent discovery plan (2021)[19].

During treatment, the conservation professional should maintain dated documentation that includes a record or description of techniques or procedures involved, materials used and their composition, the nature and extent of all alterations, and any additional information revealed or otherwise ascertained. A summary report prepared based on this information should also provide, as necessary, recommendations for subsequent care.

8.5. Future Studies and Treatment Recommendations for Wupatki Pueblo

- Original Mortar Analysis

  If and when possible, original mortar should be analyzed to confirm compatible treatment mortar formulations as well as structural performance of the masonry walls.

- Transition to Green (Soft) Capping

  Soft capping can play a key role as cultural resource management as WUPA NM transitions to a more sustainable model. See 8.3.2.3 earlier in the chapter for recommendations specific to Wupatki Pueblo.

- Nontraditional Treatment Options

  While the current management goal of preserving the original architecture and form may necessitate traditional treatment methods (e.g., repointing, resetting capstones) in the short-term, challenges posed by climate change may necessitate exploring non-conventional approaches to preserving Wupatki Pueblo.

These alternative methods include selective deconstruction[20] and curated ruination[21] (intentional decay). Both approaches require careful consideration of the role of the original fabric and how changes to the material integrity might affect the meaning (i.e., value and significance) of the cultural resource.

Adopting these methods should involve extensive discussion with preservation professionals and tribal communities to determine whether the loss of structural integrity necessarily equates to a loss of meaning. Discussions should explore the idea that decay and disintegration can hold cultural, as well as economic value, offering alternative ways to understand and honor material change. The premise that meaning is derived not only from the preservation and persistence of structures, but also from their processes of decay, must be fully embraced before implementing these strategies.

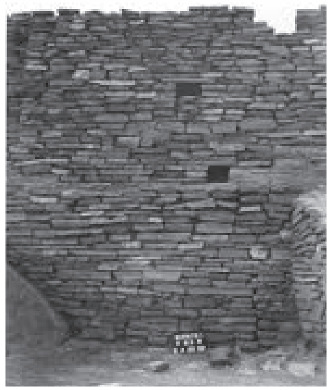
It is essential to distinguish these intentional methods from neglect or disinvestment. Clear and thorough documentation of the site before implementing such approaches is critical, as is transparent communication about the management decisions and the ways in which heritage values will continue to be preserved. If deconstruction is followed by reconstruction, whether at the same location or elsewhere, reconstructed elements must be distinguishable from the original fabric, and this distinction should be clearly conveyed to all stakeholders.

8.6. Model Intervention Strategies

This section outlines model intervention strategies for rubble masonry at Wupatki Pueblo, focusing on walls identified as most at risk through the 2022 Rapid Assessment Survey (RAS). While common symptoms exist, the scenarios addressed are not universal, as conditions vary across the site.

Historic Photos

1933-1934

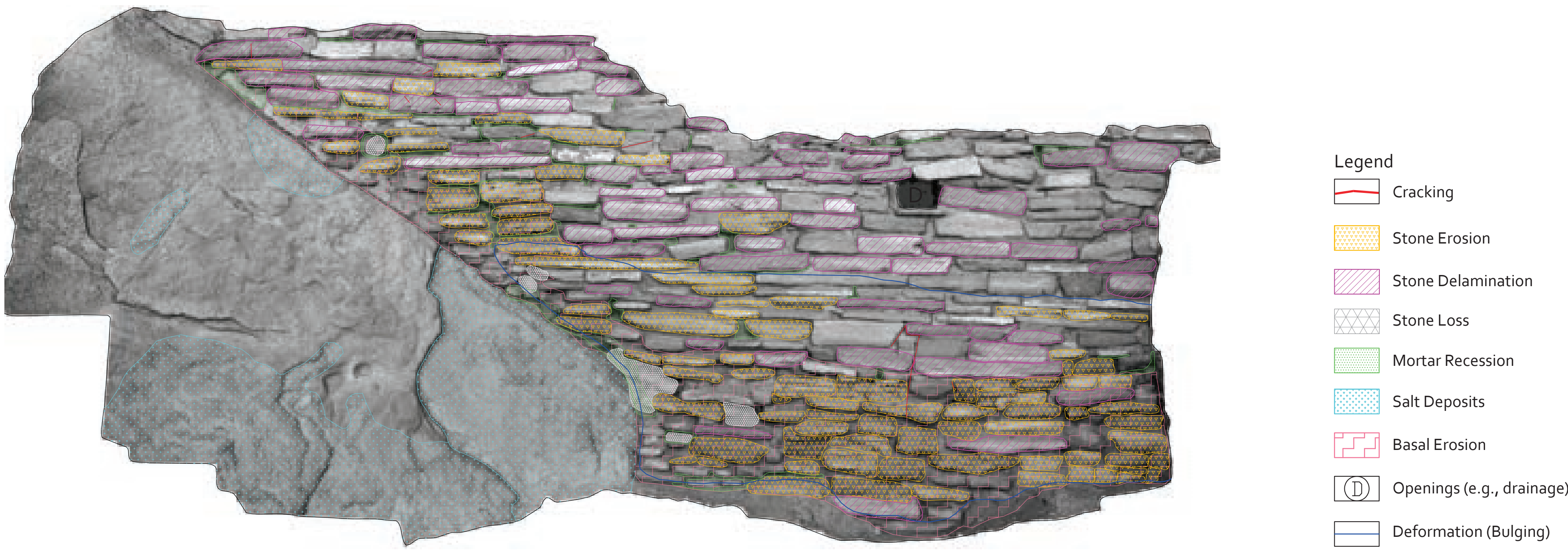


04/20/1952

06/12/1952

1989

Conditions Assessment



Wall 1.72.0.W / Room 63

Wall 1.72.0 was rebuilt by the CWA between 1933 and 1934 to stabilize the South Unit, and was further modified throughout the following decades to support rebuilt ranger's quarters (including Room 63) and to support drainage systems. The upper reconstructed part of the wall was later removed and Room 63 was backfilled in 1988, which the wall currently now supports.

Historical photos suggest that this backfilling has caused water transmission issues through the west elevation (1.72.0.W); compounded by poor drainage, the water appears to be seeping in through the fill and out the masonry wall, specifically through the basal areas, saturating the structure in the process.

1.72.0.W is bulging more significantly than observed in the 1989 image, again due to the saturated differential fill that is exerting force on the wall, pushing the wall outward. Structural cracks are visible at the center of the bulge.

The adjacent bedrock to the left of 1.72.0.W is also showing moderate levels of erosion, although the rate is less significant than the masonry wall itself.

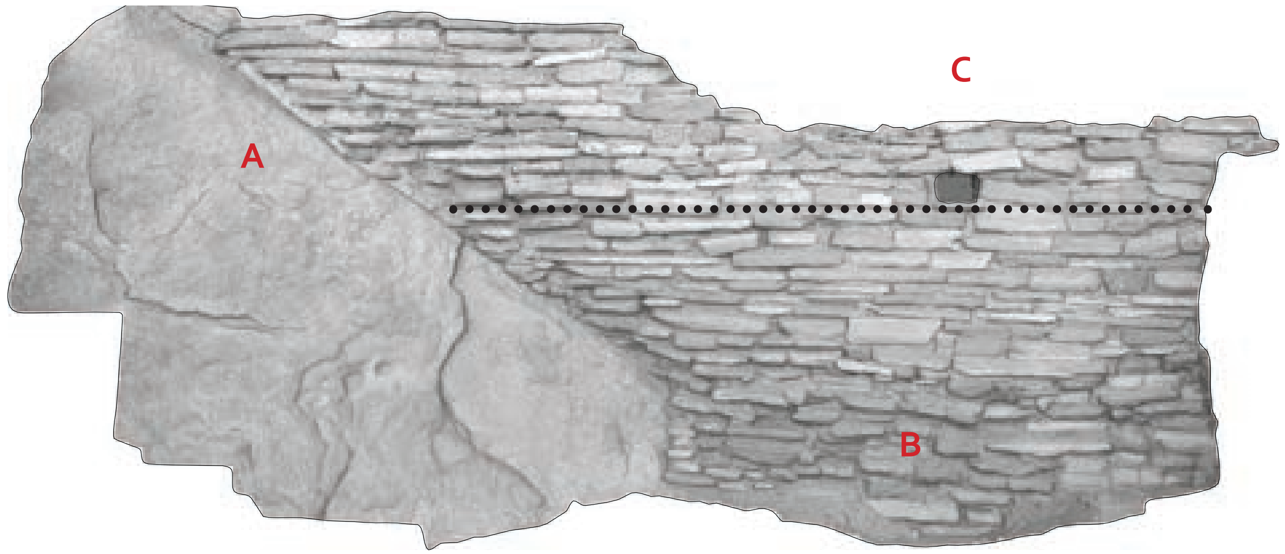
Wall 1.72.0.W / Rm 63

Locator Map

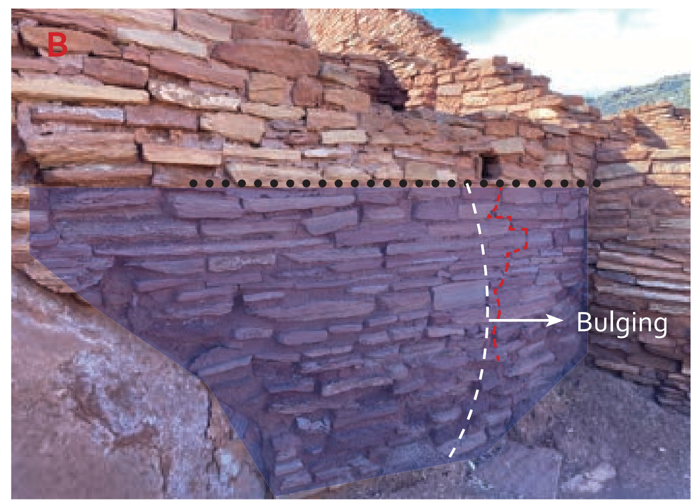
Summary of Conditions / Issues

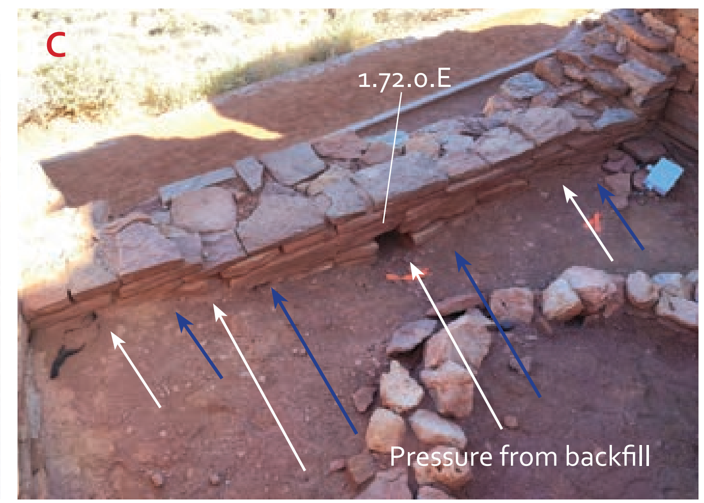
- Severe basal erosion
- Bulging from differential fill
- Erosion of masonry units along bedrock
- Poor water drainage

Recommended Treatment(s)



Water flow *Water Saturation* *Erosion* *Cracking* *Grade Level*





A: Consolidation may be considered for eroded stones above the bedrock and a preventive flashing installed at the interface.

B: Repair/replace basal stones and grout cracks. Test for salts; if tested as chlorides, nitrates/nitrites, or sulfates, poultice cleaning should be performed.

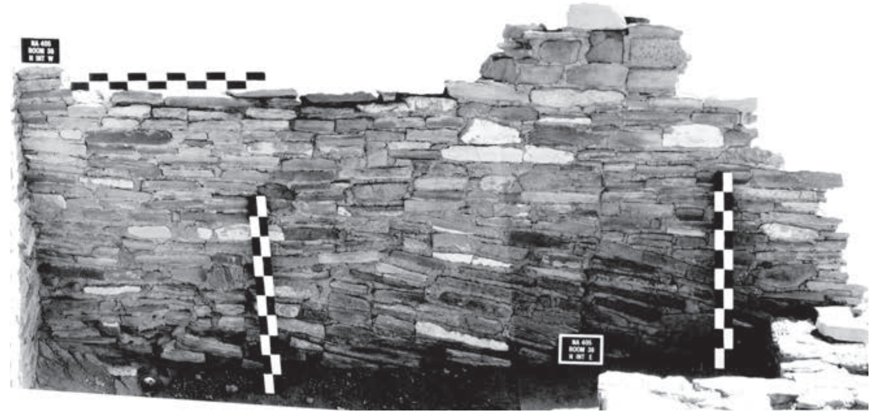
C: Excavating Room 63 is recommended to relieve backfill pressure causing the wall to deform. Wall bulging and subsequent cracking will need be stabilized by a range of possible treatments including, but not limited to, grouting and repointing. If backfilling the room, the wall will need to be waterproofed on the back side and a light-weight engineered soil installed with proper drainage. To reduce/remove pressure on the wall, a second retaining wall could be built behind to hold back the fill. Soft capping should be considered for the wall top and basal drainage installed.

Wall 1.73.1.S / Room 38

Historic Photos

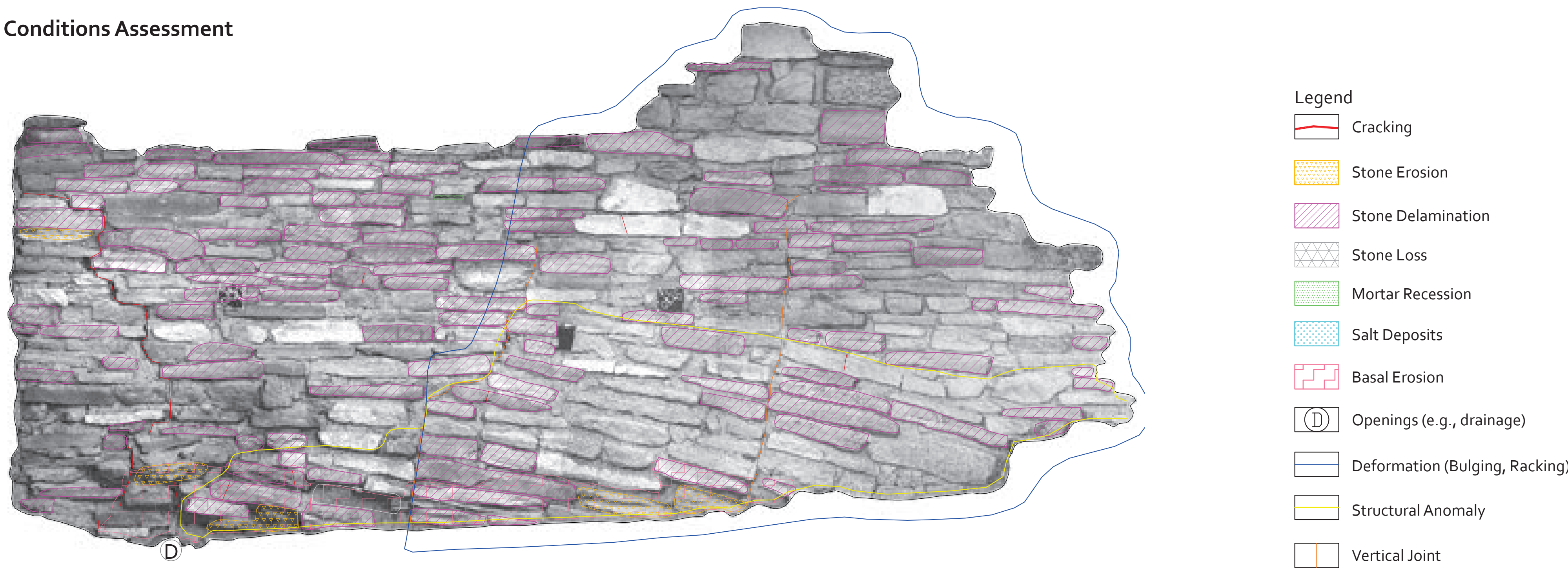
04/22/1952

07/07/1952



2001

Conditions Assessment



Maintenance efforts for Wall 1.73.1.S have focused on basal, surface, and cap stabilization, including resetting stones, filling voids, and repointing mortar (1952, 1988, 2001, 2008, 2016). Key interventions also include the removal and relaying of concrete mortar with two reinforced integral members through the center to tie the east and west halves together in 1952; and the installation of a 4"clay pipe drain at the northwest corner of 1.73.1.S leveling out to Room 34 on bedrock.

Water control has been a persistent issue in Room 38, impacting the masonry condition of 1.73.1.S. Erosion control measures, such as mortar and stone paving (2008) and the construction of an evaporation pond (2016), have been implemented to slow water flow.

Persistent structural issues, such as cracking at the western end and slumping at the eastern end due to bedrock movement, have been observed since 2016. The crack has become severe, exacerbated by high water flow near the drain, with a large void observed above the drain in 2022.

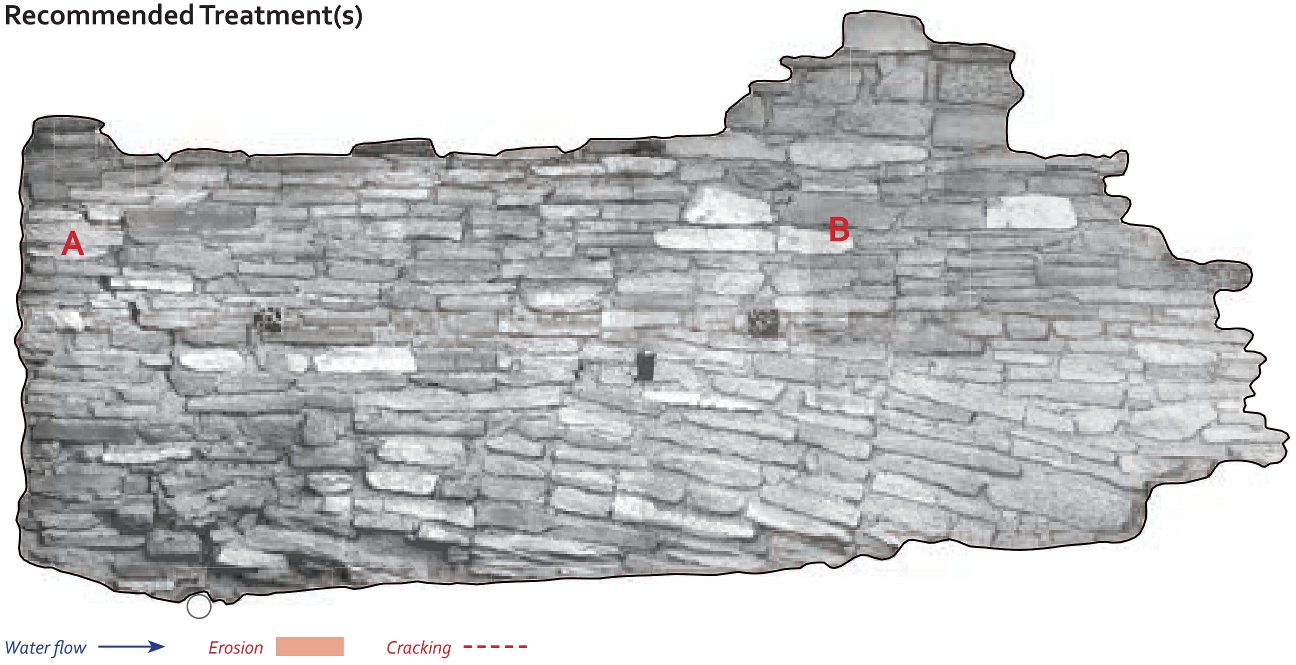
Wall 1.73.1.S / Rm 38

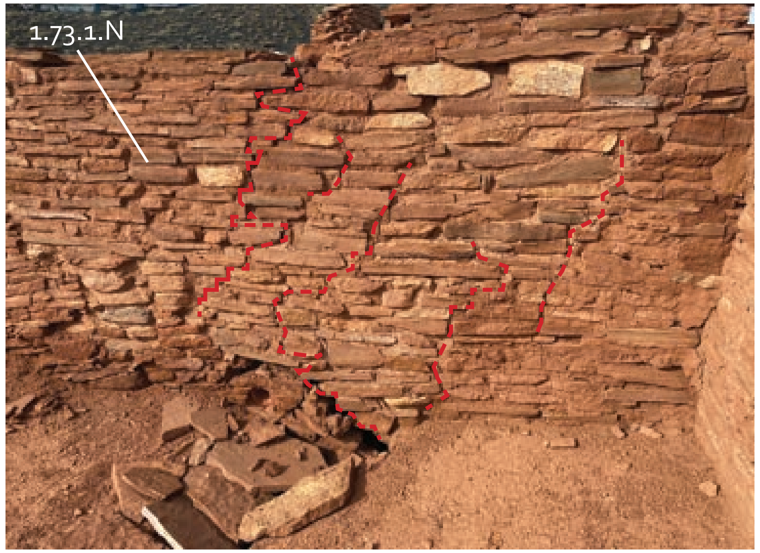
Locator Map

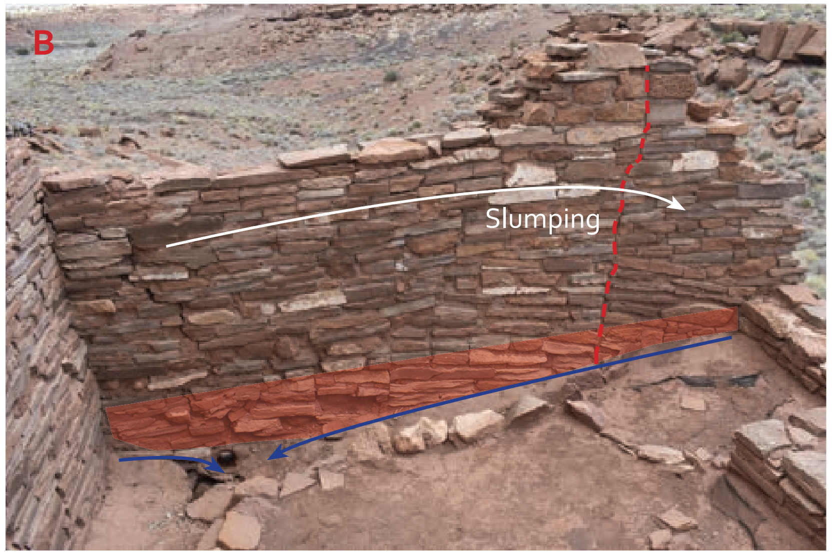
Summary of Conditions / Issues

- Severe structural cracking
- Slumping
- Floor failure near drain
- Poor water drainage

Recommended Treatment(s)







A: Water drainage in Room 38 has caused significant wall destabilization. Structural cracks should be grouted, and joints repointed on both wall elevations. The breached floor should be carefully opened and inspected, with alternative drainage options explored to enhance capacity beyond the 4" clay pipe outlet. The structural crack, monitored since October 2024, should continue to be observed.

B: Most wall deformation should be left as is and only individual stones repaired. Basal stones need to be repaired/replaced and cracked stones grouted. Salts identified as chlorides, nitrates/nitrites, or sulfates should be treated with poultice cleaning. Consolidation may be considered for the eroded stones. Soft capping should be considered for the wall top to provide additional stability for the wall and protection for the wall caps.

Historic Photos

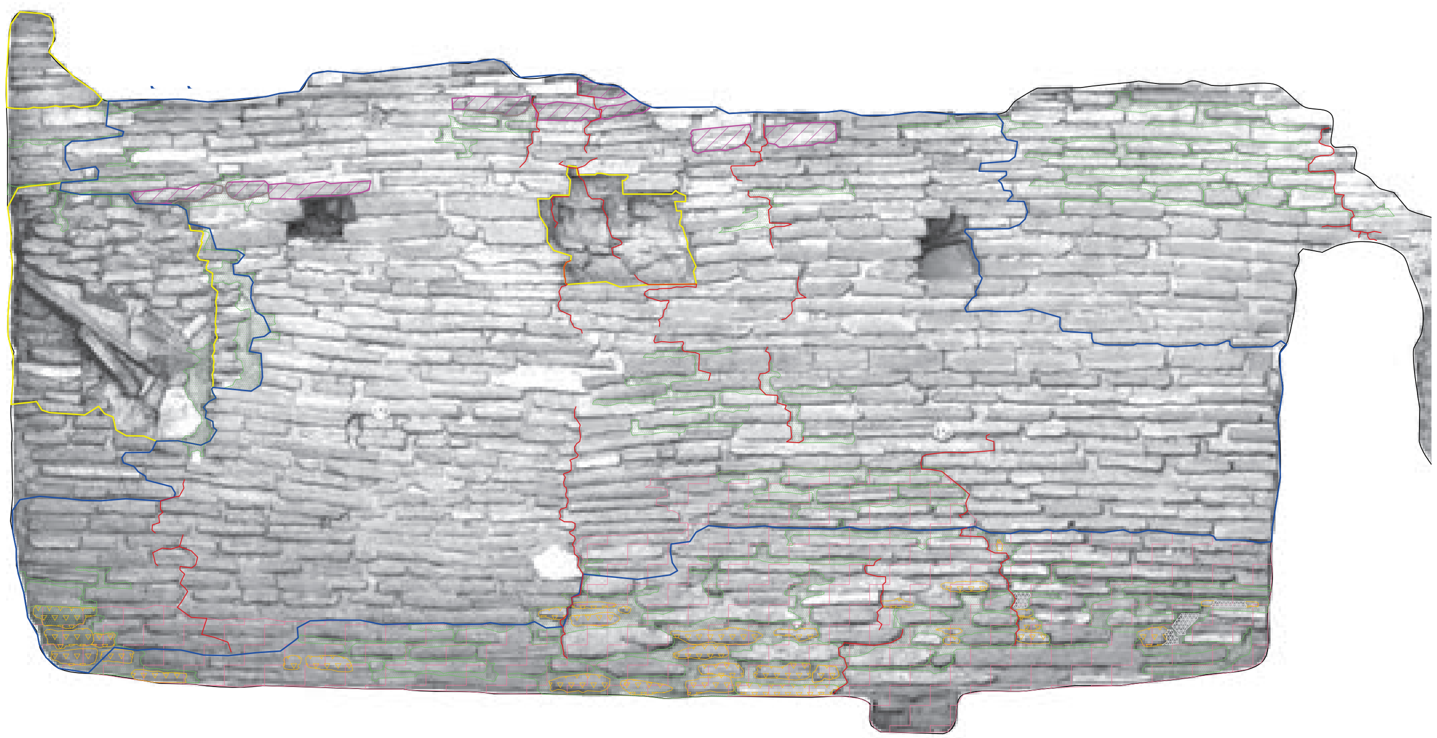

October 1936


06/23/1952

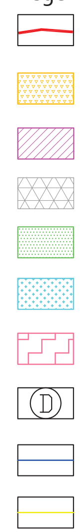

June 1964


2001

Conditions Assessment



Legend



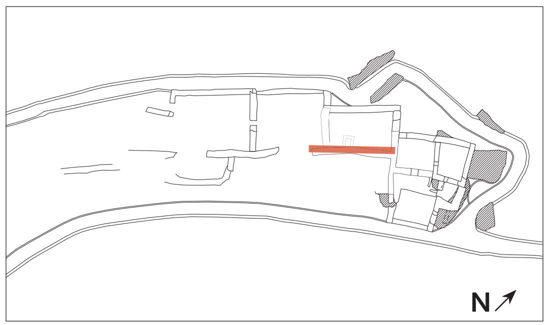
Wall 2.2.4.W / Room 7

Wall 2.2.4 has undergone extensive stabilization and repair efforts since 1933, including excavation, mortar capping, grouting, repointing, and structural reinforcements. Significant interventions include the addition of reinforced concrete and masonry above a broken doorway in 2.2.4.W (1952), application of various mortar types such as Portland cement (1930s–1950s), Rhoplex E-330 (1985), and Nissan Red mortar (2017), and recent work addressing voids, cracks, and capstones (2021). The wall has a mix of historic and modern masonry, with notable bulging and chronic cracks observed since the 1930s, particularly at subfloor pits and near a cross wall.

The wall has differential filling due to collapsed rubble on the east elevation (2.2.4.E), and moisture movement appears to influence mortar recession and basal erosion on the west elevation (2.2.4.W). Stone erosion is more prominent in the upper portions, with limited deterioration at the doorway. Chronic structural issues, such as visible cracks and bulging, persist and require ongoing monitoring.

Wall 2.2.4.W / Rm 7

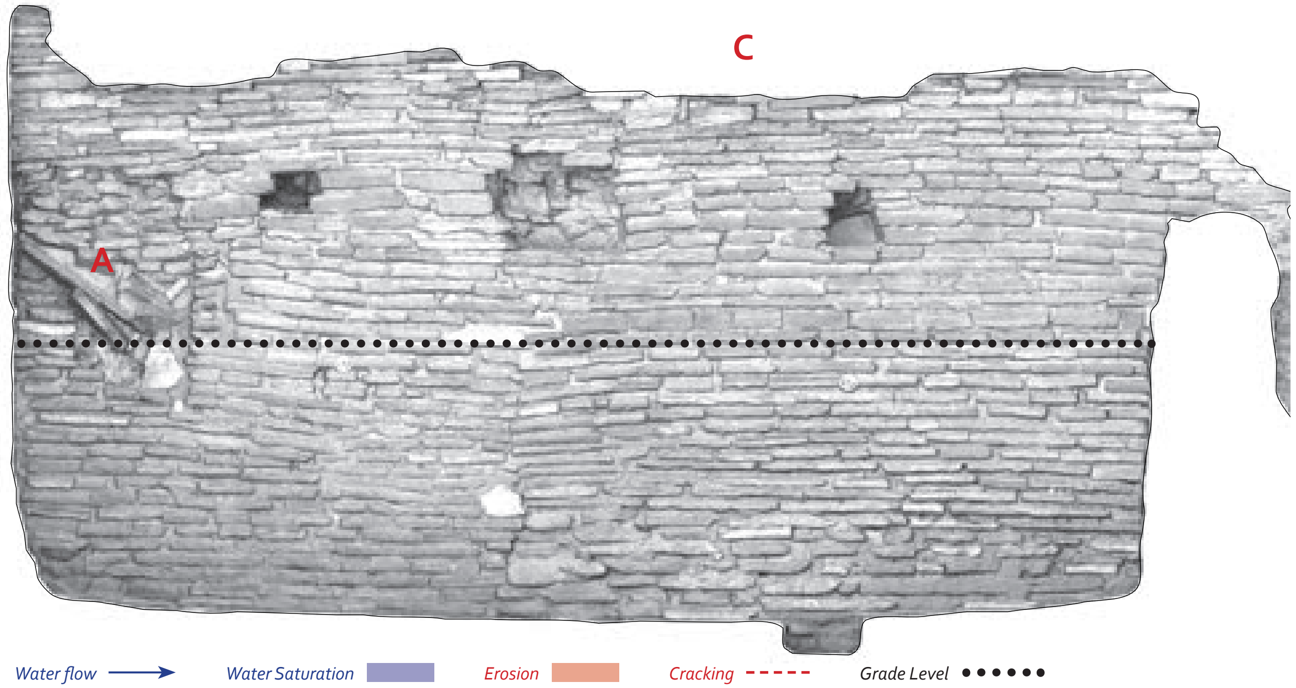
Locator Map



Summary of Conditions / Issues

- Basal erosion
- Bulging and racking from differential loading
- Separation from cross-wall on north

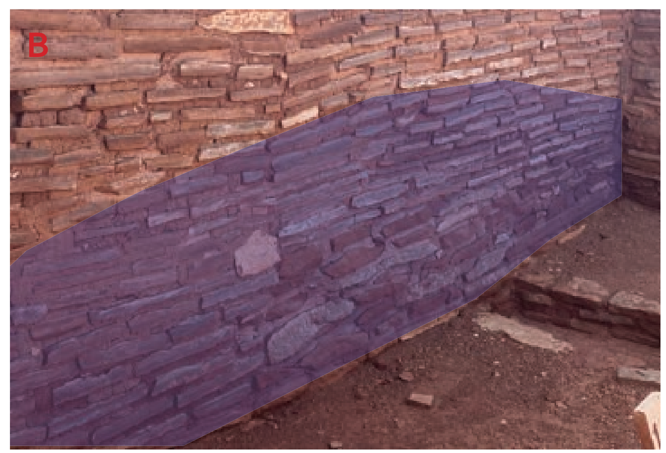
Recommended Treatment(s)

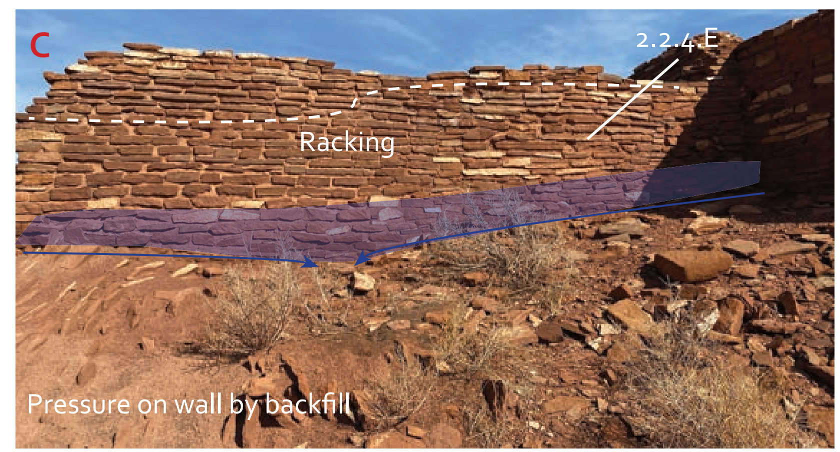


A: Irregular stone masonry should be monitored and repointed. All structural cracks should be grouted.

B: Basal stones need to be repaired/replaced and cracked stones grouted. If salts test as chlorides, nitrates/nitrites, or sulfates, poultice cleaning should be performed. Consolidation may be considered for the eroded stones.

C: In order to relieve the active outward forces of the backfill and moisture transfer on the east face, debris should be removed down to grade. Most wall deformation should be left as-is and only individual stones repaired. Soft capping should be considered for the wall top and basal drainage installed.





Notes

1 The reader is also referred to Robert M. Thorne, Patricia M. Fay and James J. Hester, *Archaeological Site Preservation Techniques: A Preliminary Review*, Technical Report E-87-3 (Vickburg, MS: U.S. Army Engineer Waterways Experiment Station, May 1987) for more detailed discussions regarding non-architectural methods for site preservation. NPS-77, Natural Resource Management Guidelines should also be consulted before any project is initiated that may have an effect on the soils and vegetation of the park.

2 For guidance on fire management guidelines and policies currently in place at Wupatki Pueblo see: NPS, "Flagstaff Area National Monuments Fire Management Plan: Environmental Assessment/Assessment of Effect" (August, 2005).

3 Kirk C. Anderson, "Wupatki National Monument: Erosion Mitigation Study –WUPA2676," February 22, 2023; see Recommendation 3, pg. 23-24.

4 It is recommed that a thin layer of gravel can limit floor erosion vulnerability. A size of gravel between 2-3cm diameter will prevent floor erosion during sustained runoff flow events of 1cm deep on floor slopes up to 25°; gravel of 3-4cm diameter for between 35°and 40°. It is suggested to cover all floor surfaces with slopes of 5° or greater with gravel 2-3cm gravel, provided the size of the rooms are manageable, to ensure heightened erosion protection (In Taylor Joyal, "Wupatki Erosion Risk Analysis of Rooms 36, 41, 41a, and 63 in the South Pueblo, Wupatki National Monument," Appendix A to "Wupatki Pueblo Geoarcheological Landscape Assessment," ed. Kirk C. Anderson).

5 For more information regarding soil erosion methods, including using media lunas, see Craig Sponholtz and Avery C. Anderson, "Erosion Control Field Guide," PDF File. March 2016. https://www.watershedartisans.com/wp-content/uploads/2016/03/Erosion-Control-Field-Guide.pdf.

6 Ellen Brennan et al., *Report of Findings: Prestabilization Documentation for Wupatki Pueblo (NA 405) Wupatki National Monument*. Flagstaff, AZ: Northern Arizona University, 2001, p.24,.

7 For more guidelines and benefits of soft capping, see Chris Wood, Alan Cathersides, and Heather Viles, "Soft Capping on Ruined Masonry Walls" (Historic England, April 2, 2019), https://historicengland.org.uk/research/results/reports/7547/SoftCappingonRuinedMasonryWalls; and, Alex Lim, "Soft Capping of Archaeological Masonry Walls: Far View House, Mesa Verde National Park" (M.S. Thesis, University of Pennsylvania, 2009), https://repository.upenn.edu/handle/20.500.14332/36620.

8 Conservation Services, in Kinnelon, New Jersey, currently produces the widest variety of epoxies that have been proven successful for gluing and repairing deteriorated beams.

9 Lyle Balenquah et al., "Ruins Preservation Plan and Implementation Guidelines Wupatki National Monument" (Flagstaff Area National Monuments National Park Service, June 2001), Section 6-15.

10 Caroline Dickensheets and Frank G. Matero, "Performance Testing of Acrylic-Amended Earthen Mortars at Wupatki National Monument in Arizona," *APT Bulletin: The Journal of Preservation Technology* 52, no. 1 (2021): 5–14. https://www.jstor.org/stable/27018181.

11 Laura Gambilongo, Alberto Barontini, and Paulo Lourenço, "Wupatki National Monument, Arizona (US): Inspection and Recommendations" (Guimarães, Portugal: University of Minho, May 2022), 38-43.

12 Caroline Dickensheets, "A Performance Evaluation of Amended Stabilization Mortars at Wupatki National Monument, Arizona" (MS Thesis, University of Pennsylvania, 2019), https://repository.upenn.edu/hp_theses/680; this study tested the previous soil source used at Wupakti Pueblo and its performance with Rhoplex E-330. While is is assumed that Rholplex and Adacryl, as acrylic emulsions, have similar behaviors when in contact with earthen mortars, future studies like this thesis are recommended to test the durability, performance, and compatibility at with the masonry at Wupatki Pueblo.

13 The preferred solution mixture has been 2 1/2 parts water to one part Rhoplex E-330, with the recommended temperatures range for using Rhoplex being between 110° and 50°F.

14 Specifically refer to Pg. 54-58 in John M. Barrow, "Preservation and Management Guidelines for Vanishing Treasures Resources," *Intermountain Cultural Resource Management Professional Paper*, No. 75 (2009).

15 "Climate," World Meteorological Organization, March 20, 2024, https://wmo.int/topics/climate.
16 This section has been adapted from Barrow, "Preservation and Management Guidelines for Vanishing Treasures Resources," p.147.
17 Barrow, "Preservation and Management Guidelines."
18 NPS, ACHP, and National Conference of State Historic Preservation Officers, *Programmatic Agreement for Compliance with Section 106 of the National Historic Preservation Act*., Washington, DC: NPS, 2008
19 NPS, "Comprehensive Agreement Regarding Inadvertent Discoveries and Intentional Excavations Between the NPS and The Hopi Tribe, The Hualapai Tribe, and The Navajo Nation," Flagstaff, AZ: FLAG, 2021.
20 Historic England, "Historic England's Approach to the Reconstruction of Heritage Assets | Historic England," n.d., https://historicengland.org.uk/advice/planning/the-reconstruction-of-heritage-assets/historic-englands-approach/#Section2Text.
21 Caitlin DeSilvey, *Curated Decay: Heritage Beyond Saving*, 2017, https://muse.jhu.edu/book/49665.
22 ProSoCo Inc., in Kansas City, Kansas currently provides a variety of stone consolidants that might have good potential for Wupatki Pueblo.

Chapter Cover Credit: Ha Leem Ro, NPS staff at Wupatki Pueblo, 2022.