2000

Cultural Resource Management Using Computer Applications: A Case Study from Kotyiti, New Mexico

Nicholas L. Stapp
University of Pennsylvania

Follow this and additional works at: http://repository.upenn.edu/hp_theses

Part of the Historic Preservation and Conservation Commons

http://repository.upenn.edu/hp_theses/468

Copyright note: Penn School of Design permits distribution and display of this student work by University of Pennsylvania Libraries.
Suggested Citation:
University of Pennsylvania, Philadelphia, PA.

This paper is posted at ScholarlyCommons. http://repository.upenn.edu/hp_theses/468
For more information, please contact libraryrepository@pobox.upenn.edu.
Cultural Resource Management Using Computer Applications: A Case Study from Kotyiti, New Mexico

Disciplines
Historic Preservation and Conservation

Comments
Copyright note: Penn School of Design permits distribution and display of this student work by University of Pennsylvania Libraries.

Suggested Citation:

This thesis or dissertation is available at ScholarlyCommons: http://repository.upenn.edu/hp_theses/468
CULTURAL RESOURCE MANAGEMENT USING COMPUTER APPLICATIONS, A CASE STUDY FROM KOTYITI, NEW MEXICO

Nicholas L. Stapp

A THESIS

in

Historic Preservation

Presented to the Faculties of the University of Pennsylvania in Partial Fulfillment of the Requirements for the Degree of

MASTER OF SCIENCE

2000

Robert W. Preucel
Supervisor
Dr. Robert Preucel
Associate Professor of Anthropology

Gustavo Araoz
Reader
Lecturer, Graduate Program in Historic Preservation

Frank Materne
Graduate Group Chair
Associate Professor of Architecture
ACKNOWLEDGEMENTS

Firstly, I would like to thank Dr. Robert Preucel for his help in collecting, interpreting and preparing the data for this thesis. Without Dr. Preucel's encouragement, this thesis and its preceding report would never have been accomplished. I would also like to thank Gustavo Araoz for encouraging me to examine CRM from a global perspective, Dr. Dana Tomlin for guidance through the use of GIS and its theoretical ramifications to CRM, Frank Matero, the Pueblo of Cochiti, Santa Fe National Forest, Dr. David Romano, Jill Family, Loa Traxler and Mike Wilcox whose support was invaluable. Further, I would like to thank Richard Pirtle of the USGS for his assistance in converting and correcting the surveyed and raster data, which is the backbone of this thesis. Finally, I would like to thank several corporate sponsors, who either granted or dramatically reduced costs of products and services necessary for this thesis. These companies include: Earthsat, ERDAS, ESRI, RGIS at the University of New Mexico and Centennial Blueprint of Philadelphia.
## TABLE OF CONTENTS

<table>
<thead>
<tr>
<th>Section</th>
<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
<td>Introduction</td>
<td>1</td>
</tr>
<tr>
<td>1.0 Chapter 1 – Background and Intent</td>
<td>7</td>
</tr>
<tr>
<td>1.1 Statement of Need</td>
<td>7</td>
</tr>
<tr>
<td>1.2 Cultural Resource Management and GIS</td>
<td>8</td>
</tr>
<tr>
<td>1.3 History of GIS</td>
<td>11</td>
</tr>
<tr>
<td>1.3.1 Precomputer GIS</td>
<td>11</td>
</tr>
<tr>
<td>1.3.2 GIS and computers</td>
<td>12</td>
</tr>
<tr>
<td>1.4 GIS in Archaeology</td>
<td>14</td>
</tr>
<tr>
<td>1.5 National Park Service and GIS</td>
<td>19</td>
</tr>
<tr>
<td>1.5.1 GIS in the American Southwest</td>
<td>20</td>
</tr>
<tr>
<td>1.6 Brief History of Kotyiti</td>
<td>24</td>
</tr>
<tr>
<td>1.6.1 Cultural Heritage</td>
<td>24</td>
</tr>
<tr>
<td>1.6.2 Ethnohistoric Data</td>
<td>27</td>
</tr>
<tr>
<td>1.6.3 The Pueblo Revolts (1680 &amp; 1696)</td>
<td>29</td>
</tr>
<tr>
<td>1.6.4 The Archaeological Phase</td>
<td>32</td>
</tr>
<tr>
<td>2.0 Chapter 2 – Data Collection and Preparation</td>
<td>38</td>
</tr>
<tr>
<td>2.1 Data Collection</td>
<td>38</td>
</tr>
<tr>
<td>2.2 Stage One – Paper Data</td>
<td>40</td>
</tr>
<tr>
<td>2.3 Stage Two – Digital Data</td>
<td>44</td>
</tr>
<tr>
<td>2.4 Geology, Vegetation and Climate</td>
<td>51</td>
</tr>
</tbody>
</table>
**LIST OF ILLUSTRATIONS**

<table>
<thead>
<tr>
<th>Figure</th>
<th>Description</th>
<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.1</td>
<td>Location map of ancestral and contemporary Keresan pueblos.</td>
<td>4</td>
</tr>
<tr>
<td>1.1</td>
<td>Flow chart of the history of GIS.</td>
<td>13</td>
</tr>
<tr>
<td>1.2</td>
<td>Fold out restored plan of LA 295.</td>
<td>25</td>
</tr>
<tr>
<td>1.3</td>
<td>Photograph of the architecture at LA 295.</td>
<td>28</td>
</tr>
<tr>
<td>1.4</td>
<td>Bandelier plan of LA 295.</td>
<td>33</td>
</tr>
<tr>
<td>1.5</td>
<td>Nelson plan of LA 295.</td>
<td>35</td>
</tr>
<tr>
<td>1.6</td>
<td>Dougherty plan of LA 295 and LA 84.</td>
<td>36</td>
</tr>
<tr>
<td>2.1</td>
<td>DEM of Horn Mesa.</td>
<td>48</td>
</tr>
<tr>
<td>2.2</td>
<td>Photograph of Horn Mesa.</td>
<td>52</td>
</tr>
<tr>
<td>2.3</td>
<td>Aerial photograph of LA 84 and the vegetation of Horn Mesa.</td>
<td>55</td>
</tr>
<tr>
<td>3.1</td>
<td>Fold out plan of the topography of Horn Mesa, including LA 295 and LA 84.</td>
<td>66</td>
</tr>
<tr>
<td>3.2</td>
<td>Schematic explaining the layering system of GIS.</td>
<td>67</td>
</tr>
<tr>
<td>3.3</td>
<td>Fold out plan of an aerial photograph draped over a DEM of Horn Mesa.</td>
<td>70</td>
</tr>
<tr>
<td>3.4</td>
<td>Fold out plan of the topography of Horn Mesa, including political boundaries and LA 295, LA 84.</td>
<td>71</td>
</tr>
<tr>
<td>3.5</td>
<td>Fold out detail of Roomblock I and part of Roomblock II of LA 295.</td>
<td>73</td>
</tr>
</tbody>
</table>
INTRODUCTION

The management of cultural resources is a complex and politically charged issue both in the United States and abroad. The United States has led the way in pioneering standards for cultural resource management (CRM). United States standards for CRM are predominantly site based. This site based approach normally examines specific components of a site at a single scale of interpretation. The limitations of this approach are numerous and ultimately negative for site preservation. This one-dimensional approach makes it difficult for related or future characteristics to be included into the site management plan.

A different, all inclusive, multi scalar approach has been adopted for this thesis, which documents and examines the relations between sites and features at multiple interpretation levels. This versatile approach uses computer applications, specifically geographic information systems (GIS), to interpret and manage a historical site and its associated landscape. This layered, cake-like approach operates in a cyclical fashion, allowing current, related and future site characteristics to be incorporated into the site management plan. This multi scalar approach is the result of research conducted from September 1998 until

1 Many mainstream GIS software packages were evaluated during the research phase of this thesis. Based upon this evaluation an informed decision was made as to what software to use to analyze the digital data. The mainstream off the shelf computer applications used for this study includes Adobe Photoshop by Adobe, ArcView by ESRI and AutoCAD by Autodesk.
December 1999 for a master’s thesis in the Graduate Program in Historic Preservation at the University of Pennsylvania.

**Purpose of research**

This thesis provides a descriptive outline of how and why computer applications and GIS should be used in order to identify, interpret and render archaeological, topographical, photographic and historical data, land use and other categories of data that may surface in the future. There are several analytical tools that will ease a discussion of the role of GIS in interpreting and managing a historical site. The first is to simplify and standardize as many relevant computerized methods as possible within the time frame of the thesis. Another is to explain what type of digital data and why digital data was used to identify and map the resources of a site. This thesis also explains, in layperson terms, how the digital data is used. Using these tools, a standardized methodology was roughed out to form the framework for the research. Although this framework is similar in design to those commonly used for research, this framework streamlines the processes, making a more efficient and accurate management plan.

The framework contains four main categories: data collection; data preparation; interpretation of the data and recommendations for the management of the data. By applying this framework to a historical site, a clear plan of the layers of information pertaining to the site can be created. This plan will allow
recommendations for the management of the site and its cultural landscape to be made based upon these methodological approaches.

A case study was chosen to test the framework and to create a cultural resource management plan. Although there were many opportunities for research, a set of criteria needed to be met to choose a case study. These criteria included:

1. Research on the site needed to be conducted by someone from the University of Pennsylvania;
2. The site had to be historically significant;
3. The site needed to either be associated to or a part of the landscape around the site;
4. The site needed to be accessible if a visit was necessary;
5. A level of data needed to exist for the site, for example;
   a) Topographic maps.
   b) Aerial photographs.
   c) Archaeological data.
   d) Oral or published historical data.

Many sites were considered for this research project. However, one site in particular stood out as a significant cultural landscape and rich archaeological site in need of digital documentation and a resource management plan. The site is a Native American site called Kotyiti Pueblo, located in Santa Fe National Forest (SFNF) in New Mexico (see figure 0.1). This site was selected due to its
Figure 0.1  Location map of the ancestral and contemporary Keresan pueblos (from Snead and Preucel 1999: figure 8.1).
extraordinary ethno-historical documentation, its unusual above and below ground preservation and its connection to a contemporary pueblo village.\(^2\)

Additionally, the site is significant to the region, as it was one of the focal points for the Pueblo Revolt of 1680 and the Spanish Reconquest.

In 1995, Professor Robert Preucel of the Department of Anthropology at the University of Pennsylvania initiated the Kotyiti Research Project (KRP) in collaboration with the Pueblo of Cochiti.\(^3\) This project has had successive field seasons producing a survey of the structures and topographic features of the community. One of the goals of the project is to document the architectural stone for stone construction of the community, which consists of two separate yet probably contemporary villages. Another goal is conditions assessment, interpreting what processes contribute to site degradation and what steps can be taken to control these processes.

Much of the data collected by the KRP is the framework for this thesis. The task here was to collect and manipulate the data into a common digital format. Additional data was collected or created by the author where holes existed. This thesis has produced a well-rounded plan of the site, complete with examples of what has been done and what can be done for a site in need of an accurate, controllable resource management plan. With such a plan, site preservation can be simulated, visualized and implemented. Upon completion of

\(^2\) The descendants of Kotyiti are the current inhabitants of the modern pueblo of Cochiti. The site is presently used for ceremonial visits before tribal hunting trips, for outdoor education for the children of Cochiti Pueblo and as a symbol of the strength and honor of their ancestors.

\(^3\) Preucel 1998:1.
this thesis, all of the data will be provided to Cochiti Pueblo. This action will empower the residents of the pueblo to manage the destiny of Kotyiti.
1.1 Statement of need

Of the many issues that presently concern the preservation and interpretation of archaeological communities, the identification and the management of site resources are of central importance. These resources could include archaeological, historical and architectural sites, districts, towns, objects, traditional lifeways, cultures and human activities. Historically, sites have been systematically identified by means of a series of specialized maps, each featuring particular resources. Although this is an effective means to interpret a site, it is costly, laborious and sometimes incomplete. A new tool, incorporating computer science, has allowed researchers to effectively collect and integrate data on a site dynamically, using a GIS. By using a GIS on a culturally significant site, site managers can identify, interpret and manage the cultural resources of any given site.

It is important for a resource manager to have a clear understanding of the commonly accepted guidelines for cultural resource management before producing a GIS plan for any given site. Once this has been achieved, then exploration into the uses of a GIS on a site can lead to a more effective resource management plan.
1.2 Cultural Resource Management and GIS

CRM is a basic tool for the preservation of tangible and intangible heritage. CRM not only provides a resource management plan but also strategies to effectively implement management plans. The National Park Service (NPS) defines cultural resource management as

"an umbrella term for activities affecting cultural resources; includes the preservation, use, protection, selective investigation of, or decision not to preserve, prehistoric and historic remains, including legislation and actions, to safeguard extant evidences or to preserve records of the past."\(^4\)

In other words, CRM is the synthesis of various conservation treatments, an establishment of policies and an effective stewardship of heritage. The NPS definition for culture is another important definition that is setting the standards for understanding the cultural significance of a site or landscape.

"Culture (is) a system of behaviors, values, ideologies, and social arrangements. These features, in addition to tools and expressive elements such as graphic arts, help humans interpret their universe as well as deal with features of their environments, natural and social. Culture is learned, transmitted in a social context, and modifiable. Synonyms for culture include ‘lifeways,’ ‘customs,’ ‘traditions,’ ‘social practices,’ and ‘folkways.’ The terms ‘folk culture’ and ‘folklife’ might be used to describe aspects of the system that are unwritten, learned without formal\(^4\)

\(^4\) NPS 1981: 7. Franz Boas’s, famed American ethnographer, originally defined this term in the early 20\(^{th}\) century.
...
instruction, and deal with expressive elements such as dance, song, music and graphic arts as well as storytelling.”

With this framework of definitions, CRM puts preservation in a larger perspective of planning. The objective of a cultural resource management plan is to preserve and protect heritage for future generations against any adverse changes due to natural decay and deterioration, development pressure, use or visitation. CRM involves research, documentation and evaluation of all contributing cultural and natural resources; determination of its significance and values; establishment of conservation policies and strategies as well as analysis and evaluation of the resources to develop various alternatives to preserve the resources and to protect its values it against adverse development. The fundamental policy of the NPS on CRM is to

"locate, identify, evaluate, preserve, manage, and interpret qualified cultural resources in every park in such a way that they may be handed on to the future generations unimpaired... Consistent with the requirements of law, resource managers and professionals at all levels shall take positive action to perpetuate unimpaired the cultural resources of the National Park System; to prevent adverse effects on these resources by development, visitor use, or resource management activities; and to prohibit vandalism or unauthorized excavation, collection, or appropriation of cultural resources.”

Cultural resource managers must document and preserve the resource base and prevent adverse effects or impacts that could result from development, visitor use or problematic management strategies. In recent years, NPS as well as other preservation agencies' emphasis has generally shifted from extensive preservation development to one of preservation maintenance.\(^7\) Thus, CRM is a permanent proactive and preventive conservation process rather than an occasional, reactive and remedial solution.

Portions of the site of Kotyiti are under the jurisdiction of the United States Forest Service (USFS) and administered by the Santa Fe National Forest (SFNF). Therefore, SFNF has the responsibility and authority to identify, document, preserve and manage the cultural resources within the Santa Fe National Forest. It is also responsible for reviewing any project that might have potential influence on these resources. The USFS follows the Secretary of Interior's (SOI) guidelines for the preservation, rehabilitation, restoration and reconstruction of historic buildings.\(^8\) SFNF also seeks advice from expert consultants for various preservation issues and treatments and routinely consults with affiliated Pueblo groups.

Other parts of Kotyiti are under the jurisdiction of the state of New Mexico and are managed by the University of New Mexico.

---

\(^7\) Ibid. This is parallel to developments in the field of movable artifact collections that are now focused on preventive conservation rather than individual artifact treatment.

1.3 History of GIS

1.3.1 Precomputer GIS

Tracing GIS ultimately leads to the first use of the thematic map, which graphically depicts one spatial aspect of the real world. Professionals such as landscape architects, planners and engineers conducted the early stages of GIS. Cutting a feature from certain thematic maps and adding them to others turned out to be a very useful concept, and was employed as early as 1913 by Warren Manning, a landscape architect. In 1936, John K. Wright, an environmental planner, created a "dasymetric" map of Cape Cod, which illustrates a precomputer demand for numerical management of multiple spatial distributions. In 1951, Jacqueline Tyrwhitt at the University of Toronto, combined four layers of data; elevation, surface geology, hydrology and farmland into a single map overlay. This process is one of the first examples within an academic setting of thematic mapping and is essential for GIS operations today. Another early pioneer, Ian McHarg of the University of Pennsylvania, revolutionized map overlay techniques by initiating intellectual discussion on layered spatial analysis. McHarg's development incorporated environmental and social constraints into thematic maps, allowing further factors to be incorporated

---


10 Wright also is the creator of areal interpolation, which is a precalculated table, which allows his technique to be applied to any site. Chrisman 1998: 34.

into the overlay, this is further illustrated in the flowchart, which maps out the history of GIS (see figure 1.1).\(^{12}\)

1.3.2 GIS with Computers

Thus far, map overlay was a manual task that involved physically cutting, scaling, aligning and superimposing map layers. The computer revolutionized cartography by automating these tasks. As early as 1959, a graduate student named Waldo Tobler at the University of Washington introduced a computer technique that could digitally superimpose maps.\(^ {13}\) His techniques consisted of three stages, which he called MIMO (map in-map out): map input, map manipulation and map output.\(^ {14}\) This was to be the first of the many computer-mapping programs that took advantage of the advent of modular programming languages.

Early GIS software packages were not very powerful in terms of map analysis, but they did simplify the map overlay process. This was crucial because it led to the introduction of digital spatial data to government agencies. More digital data necessitated the creation of more powerful systems to analyze

---

\(^{12}\) Foresman 1998: Foreward.

\(^{13}\) Tobler 1959: 526-534.

\(^{14}\) Ibid.
Figure 1.1 Flow chart illustrating the history of GIS (from Foresman, 1998: figure 1.2)
it. One of the first fully developed GIS programs was The Canada Geographical Information System (CGIS), which debuted in 1964.\textsuperscript{15}

In the 1980’s, as computer hardware and data storage became more affordable, GIS systems made the transition from the mainframe to the minicomputer and finally from the workstation to the personal computer.\textsuperscript{16} Academically, GIS classes have been incorporated in curricula and commercially it is a multibillion-dollar business.\textsuperscript{17} Today GIS is a complex, computerized decision support system that integrates spatially referenced data. These systems capture, store, retrieve, analyze and display spatial data. This data is presented in an highly organized assemblage of computer hardware, software, spatial data and operating instructions designed for capturing, storing, updating, manipulating, analyzing and displaying all forms of geographically referenced information (see figure 1.1).\textsuperscript{18}

\textbf{1.4 GIS in Archaeology}

Archaeology has used many data recovery and manipulation technologies. Remote sensing is one such technology. Remote sensing is identified as

\textsuperscript{15} Foresman 1998: 23-25.
\textsuperscript{16} Foresman 1998: 80-82.
\textsuperscript{17} Foresman 1988: 370-371.
\textsuperscript{18} Hanna and Culpepper 1998: 198.
"using a recording device not in physical contact with the surface being analyzed, including: 1) Using sensors sensitive to various bands of the electromagnetic spectrum 2) Assessing its spectral image without having the sensor in direct contact with the surface 3) Interpreting environmental conditions at, below, and above the surface of the earth, typically by processing images from an aircraft (i.e. aerial photography), satellite imaging, or radar.”

As early as 1922, remotely sensed data was collected from archaeological sites that were photographed using World War I surplus planes. Remote sensing is now common in the discipline. Remote sensing can be combined with GIS for even more powerful analyses.

Remote sensing techniques brought many benefits to archaeology. It is the most efficient way to survey large areas of land for subterranean features or changes in vegetation and terrain possibly caused by human behavior. It is also the fastest way to survey unsafe terrain or sites where archaeologists are not permitted entrance for political or other reasons.

Similarly, GIS brings many benefits to archaeology. Data updates and corrections, compared to the old format, which was slow and costly, can be conducted quickly and efficiently. Using GIS, measurements can be completed

---

19 Ibid.
in a matter of seconds. Building complex simulations only limited by imagination becomes possible in a reasonable amount of time.

The first regular use of the word GIS in archaeology started between 1983 and 1985. The application that is credited with making GIS a mainstream tool in the field of archaeology is predictive modeling. During the 1970’s, cultural resource managers were eager for tools that would help survey the vast amount of federally controlled land. In addition, as archaeology shifted its focus from the site to the landscape, data was more readily available for immediate analysis and there was a demand for automated predictive modeling. Computers became a favorite tool to create the statistical models that are now conventional in archaeology and resource management.

Since predictive modeling was such an influential factor in the development of GIS in archaeology, it is appropriate to define "modeling" and explain its role in archaeology and resource management.

Voorips defines archaeological models as "Partial representations of a theory and are formulated in a manner which enables the archaeologists to test the theory by means of empirical data." Warren describes predictions as being

---

22 Ibid: 25.
24 Kvamme 1990: 112-126.
25 Ibid.
26 Warren 1990: 201-205.
28 Voorips 1986.
crucial to the scientific method.\textsuperscript{29} When new patterns are found in a certain context, hypotheses are formed to explain them and models are built in other contexts to test the hypothesis.\textsuperscript{30}

The statistical models used in archaeological predictive modeling are a variation of regression analysis and its many categories. Bivariate linear regression looks at the relationship between two variables; an independent variable, such as proximity to rivers and a dependent variable, such as the presence of an archaeological site.\textsuperscript{31} Multiple regression studies the relationship between one dependent variable (archaeological site, e.g.) and one or more independent variables (proximity to a river and a hill, e.g.) allowing the independent variable to be within proximity to a river as well as a hill.\textsuperscript{32} Logistical regression models, on the other hand, trace relationships among multiple independent and dependent variables.\textsuperscript{33} In this case, the dependent variables could be the presence as well as absence of archaeological sites. The independent variables can include as many parameters as the archaeologist deems important to the archaeological site location.\textsuperscript{34} For this reason, this technique of using independent variables is best suited to archaeological applications, and is the one that is used the most. Stepwise logistic regression is

\textsuperscript{29} Warren 1990: 97-99.

\textsuperscript{30} Ibid: 102-105.

\textsuperscript{31} Ibid.

\textsuperscript{32} Ibid.

\textsuperscript{33} Ibid.

\textsuperscript{34} Savage 1990: 332.
an extension of a standard logistical regression and is different only in that it uses pre-selected significance levels at which variables are either added or deleted.\textsuperscript{35}

Predictive modeling seeks to establish a causal relationship between certain environmental parameters and known archaeological site locations, to build a statistical model based on that relationship and to apply the model to unsurveyed data taken from the landscape. The time and labor saved by using predictive modeling and GIS made it the most capable tool for the task because it was cost effective and allowed the location of sites to be identified without actual site visits.\textsuperscript{36} Predictive modeling gained tremendous popularity during the latter half of the 1980’s, as statistical methods improved and computer hardware and software became more powerful and affordable.

GIS use expanded not only in the archaeological community, but in the social sciences as well. Unlike many technologies, GIS was seen as more than a tool. Many considered it a revolution in spatial thinking and a catalyst for change in the way human spatial behavior is studied.\textsuperscript{37} In many ways, the technology has been equated to the advent of relational databases. As opposed to the other types of databases, network and hierarchical, when relational databases were introduced to archaeology, they affected the discipline by

\textsuperscript{35} Christopherson et al 1996.

\textsuperscript{36} Ibid.

\textsuperscript{37} Marble 1990: 10-11.
changing the way data was collected, the nature of questions asked about it and
the overall conceptual design of the archaeological excavation.\textsuperscript{38}

1.5 National Park Service and GIS

The NPS was involved in several project oriented GIS endeavors in the
mid to late 1970's, including testing programs with NASA-Earth Resources
Laboratory, the NPS Denver Service Center, the EPA Environmental Monitoring
Systems Laboratory and the USGS EROS Data Center.\textsuperscript{39} These testing
programs were established to evaluate the utility of remote sensing and GIS
technologies for NPS planning and resource management applications.

In the early 1980's, the NPS Denver Service Center developed an
integrated approach to remote sensing and GIS using computer technology. The
project used vector and raster based data to conduct small scale, single project
remote sensing. These activities were based upon individual project funding and
lacked the financial continuity necessary to have enduring value and NPS wide
impact.\textsuperscript{40}

By 1985, higher level management officials at the NPS recognized the
potential of remote sensing and GIS for NPS use. The result of this admission of
need was the reorganization of the Denver Service Center into a Washington

\textsuperscript{38} Harris and Lock 1996: 352.

\textsuperscript{39} Foresman 1998: 195.

\textsuperscript{40} Ibid.
Office GIS Division with base funding to supplement project activities. The formation of this office created greater remote sensing and GIS activity within the NPS and also attempted to establish guidelines for hardware, software and data use within the NPS system.\(^{41}\)

The later half of the 1980’s led to the co-development of many public domain software suites predominately based on Unix machines. These software packages include; Geographical Resources Analysis Support System (GRASS), System Applications Group Information System (SAGIS) and Earth Resources Laboratory Applications Systems (ELAS).\(^{42}\) These software packages allowed a combination of raster and vector data to be combined, processed and manipulated to conduct geospatial analysis.

With the advent of cheaper, more powerful microcomputers and more versatile cross platform software, GIS and NPS have developed into one of the standard setters for GIS and resource management in the 1990’s. Presently, many of the National Park staff are minimally trained and either have access to digital data or the equipment to produce a general site map.

1.5.1 GIS in the American Southwest

The historical American Southwest was the location for academic and scientific research since the late nineteenth century and continues to be an area

\(^{41}\) Ibid: 196.

\(^{42}\) Ibid.
where major bodies of research are conducted. Initial interest included numerous field visits around northern and central New Mexico by famed ethno historian/archaeologist Adolph Bandelier in 1880. What Bandelier discovered and published captured America’s imagination. In 1912 a trained archaeologist named Nels Nelson, a representative of the American Museum of Natural History, developed stratigraphic excavation at the site of San Cristobal in the Galisteo Basin. Nelson’s research enhanced an understanding of the antiquity of Native peoples from the “Four Corners” region.

Researchers throughout the region adopted the mapping methods that were employed and developed by these two archaeological pioneers of the American Southwest. These techniques became the standard for archaeological research within this region until the introduction and development of computer applications. Remote sensing and photogrammetry are the early techniques that foreshadowed the use of GIS in the American Southwest.

One of these techniques, remote sensing, uses aerial photographs for visual interpretation and overall site mapping. Charles Lindbergh practiced this technique as early as the 1920’s in the American Southwest. Although many of his photographs were taken from oblique angles, these images yielded

---

43 Bandelier was one of the pioneers for ethno historical research; he introduced the American Southwest and its inhabitants to the rest of the United States.

44 “Four Corners” refers to the area where the corners of the states of Arizona, Utah, Colorado, and New Mexico meet.

45 Drager 1983.
information about the southwestern archaeological community never seen before.\textsuperscript{46}

It was not until after World War II that the American archaeological community appreciated the full benefits of using aerial imagery to interpret a site. Post war U.S. intelligence proved that varying types of information could be extracted from low and high altitude photographs, including subterranean, building and transportation data.\textsuperscript{47} This data was extracted using false color filters and stereo pair interpretation.\textsuperscript{48} The archaeological community applied these techniques to sites of historical interest.

Another early technique that arose out of remote sensing was photogrammetry. This technique allows a map or plans to be made from a series of overlapping photographs.\textsuperscript{49} Although these techniques were refined over the years after World War II, they essentially remained a new modern archaeological technique in America until the advent of the personal computer in the late 1970's.\textsuperscript{50}

During this period of computational evolution, many software companies saw a niche in the corporate market where there was no software specifically designed for the specific professions, i.e. architecture, engineering and

\textsuperscript{46}This information included overall site plan, road and trail patterns and topographic relief.

\textsuperscript{47}Star 1997.

\textsuperscript{48}Ibid.

\textsuperscript{49}Ibid.

\textsuperscript{50}Foresman 1998: 80-82.
mechanical design. Unbeknownst to software developers, many of the early computer drafting and image manipulation programs could be modified for archaeological use. In its simplest format, digital remote sensing evolved, allowing the user to view the aerial image on a screen and digitize or draw on top of it. This incorporation of new technology into archaeological research became popular with many academics studying in the American Southwest. Although the process was visually attractive, it was laborious and the equipment was very expensive.

In the 1980’s, a technological revolution allowed popular use of less expensive computers, while universities and government agencies adopted computer applications into the workplace. The NPS, eager to try new techniques, tested the use of remote sensing and digital image manipulation. Paralleling this to the development of computerized GIS, it was only a matter of time before archaeological GIS was routinely used in the American Southwest.

Although the techniques of GIS have existed for twenty years, archaeological GIS is still in its infancy in the American Southwest. Most of the scholarly examples of GIS in the American Southwest come from governmental and academic case studies that occurred in the 1990’s. The area of Chaco Canyon, New Mexico has been the testing platform for many of the modern computerized techniques in the southwest. This area has been remotely sensed and three-dimensionally rendered. Also, GIS has been applied to the many sites

---

51 Drager 1983.
that fall within the Chaco Canyon region.\textsuperscript{52} Other examples of GIS in the American Southwest come from amateurs wishing to expand their knowledge of the prehistory and history of the American Southwest.\textsuperscript{53}

\section*{1.6 Brief History of Kotyiti}

\subsection*{1.6.1 Cultural Heritage}

The site of Kotyiti is located in Santa Fe National Forest, located in Sandoval County, New Mexico (see figure 0.1). Kotyiti is well known as one of the centers of resistance during the Pueblo Revolt and Reconquest Periods (1680-94).\textsuperscript{54} The total known site area consists of three main cultural and archaeological zones. The first, which is the core of the site, is the pueblo (LA 295) (see figure 1.2).\textsuperscript{55} The pueblo or main village is quite large, with over one hundred and thirty-seven rooms, some are thought to have been multistoried. These rooms are clustered together into six roomblocks organized into a parallelogram. Additionally, there are two plazas, one (Plaza A) measuring

\begin{footnotesize}
\begin{enumerate}
\item This region was the testing area for early remote sensing. NASA later revisited it, in conjunction with UC Berkley looking for road networks. One recent example of a comprehensive GIS study of this region comes John Kantner’s paper presented to Society for American Archaeology (SAA). Kanter 1997: 49-62.
\item Examples of archaeological amateurs are Paul Logsdon (his work includes documenting many sites in the Four Corners area from the air), Joseph Courtney White (his work includes documenting many sites by ground survey in the Four Corners area) and Tom Baker (whose work is mainly for profit and includes taking aerial photographs of sites in the Southwest).
\item Snead & Preucel 1999: 187.
\item The LA refers to numbers that the Laboratory of Anthropology has assigned to prehistoric and historic sites in New Mexico that have been recorded and processed.
\end{enumerate}
\end{footnotesize}
Figure 1.2 Restored plan of LA 295
approximately 3,806 m$^2$ and another (Plaza B) measuring approximately 2323 m$^2$. There are two kivas, which are situated close to the center of each plaza, both measuring approximately 8.5 m in diameter. The entire pueblo covers approximately 8,936 m$^2$ and is architecturally constructed predominantly of shaped tuff blocks with mortar and irregular tuff chinking (see figure 1.3). It is important to explain the many names of LA295. The following chart illustrates the Spanish, Anglicized and Pueblo versions of the site name and the topography where the site is located.

<table>
<thead>
<tr>
<th>Spanish</th>
<th>Anglicized</th>
<th>Cochiti</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cachiti Pueblo</td>
<td>Cochiti</td>
<td>Hanut Kot-yi-ti</td>
</tr>
<tr>
<td>Cochiti Pueblo</td>
<td>Old Cochiti</td>
<td>Cochiti above</td>
</tr>
<tr>
<td>La Cieneguilla de Cochiti</td>
<td>LA 295</td>
<td>Kotyiti</td>
</tr>
<tr>
<td><em>The little marsh of Cochiti</em></td>
<td>Plaza pueblo</td>
<td>Cochiti</td>
</tr>
<tr>
<td>Pueblo Viejo</td>
<td>LA 84</td>
<td>Kot-yi-ti shoma</td>
</tr>
<tr>
<td><em>Old Pueblo</em></td>
<td><em>Outlier village</em></td>
<td><em>Old Cochiti</em></td>
</tr>
<tr>
<td>La Cieneguilla</td>
<td>Horn Mesa</td>
<td><em>Kot-yi-ti Kamatse shoma</em></td>
</tr>
<tr>
<td><em>The little marsh</em></td>
<td></td>
<td><em>Old Cochiti settlement</em></td>
</tr>
<tr>
<td>La Mesa de la Cieneguilla de Cochiti</td>
<td></td>
<td>K’otyiti haarctic</td>
</tr>
<tr>
<td><em>Mesa of the little marsh of Cochiti</em></td>
<td></td>
<td><em>Cochiti houses</em></td>
</tr>
<tr>
<td>Potrero de las Casas</td>
<td>Horn Mesa</td>
<td>Hanut Katruque</td>
</tr>
<tr>
<td><em>Potrero of the houses</em></td>
<td></td>
<td><em>Houses above</em></td>
</tr>
</tbody>
</table>


57 Ibid: 3.
The known history of Kotyiti is taken from a combination of data sources, namely ethnographic and archaeological literature. In order to understand how Kotyiti's post conquest history evolved, it is necessary to construct a timeline of the published accounts and literature. There are two distinctive sources of collected data for scientific analysis, the ethnohistoric data and the archaeological data.

1.6.2 Ethnohistoric Data

The ethnohistoric data covers approximately one hundred and fifty six years, from 1540 to 1696.\textsuperscript{58} Cochiti, along with many other tribes along the northern Rio Grande, became exposed to Spanish culture as a result of Spanish colonization. This European exposure influenced many tribes within the region to submit to the influence of a member of the New Mexican government, Don Juan

\textsuperscript{58} It is important to note that during the time of the Spanish entradas (1540-1598) the first documented visit to Cochiti was in the fall of 1581 by the Rodriguez-Chamuscao expedition. The following year, the Antonio de Espejo stopped at Cochiti to barter for food in 1582. During this period, the people of Cochiti may have lived in a pueblo called Kuapa (LA 3443 and 3444), which is where the modern Cochiti Keres migrated.
Figure 1.3   Photograph of the architecture of LA 295 (from Nels Nelson's visit to Kotyiti 1912).
de Oñate at Santo Domingo. In July 1598, rods of office were given throughout the region and missionaries were assigned parishes among the pueblos. Cochiti was one of these parishes. In 1614, Cochiti was made a visita of Santo Domingo and assigned its own priest in 1637. Sometime during this period, Cochiti Pueblo had a mission called San Buenaventura de Cochiti constructed within the limits of the pueblo. This event was probably one of the last major events to occur before the Pueblo Revolt.

1.6.3 The Pueblo Revolts (1680 & 1696)

On August 10, 1680, the Pueblo Indians of Northern New Mexico staged a revolt after several decades of Spanish assaults on their way of life. Causes of Pueblo discontent that led to the rebellion included Spanish exploitation of the Pueblo Indians as laborers, the church/state rivalry, disease, droughts, Indians raiding towns, poor harvests and the zealous attempts of Franciscans to stamp out Pueblo religious practices. The instigators of the revolt were from the Pueblo tribes of the Tewa, Tiwa and the Keres. One of the key leaders in the

---

59 Santo Domingo is a Keres pueblo that was colonized by the Spanish. This site became the center for the regions Mexican government. Espinosa: 1988, p. 17-18.

60 Ibid: 5-9.

61 The priest was named Fray Justo de Miranda. Preucel 1998:9.

62 Although an exact construction date is not known for the mission at Cochiti, it can be assumed that it was constructed either slightly before or during the early tenure of Fray Justo de Miranda. Ibid.

revolt was Popé, a Tewa medicine man from the village of San Juan. Popé, along with the other Puebloan leaders such as Alonzo Catiti, the supreme leader of the Keres, convened numerous war councils, discussing their anger and aggression towards the Spanish. 64

A synchronized attack was planned to take place on August 11, 1681. The rebellious Puebloans discovered that the Spanish knew of their attack and carried out an attack one day earlier to surprise the Spanish. The Pueblo Indians went on a rampage throughout New Mexico, killing Spanish men, women and children and destroying all vestiges of Spanish authority. 65 Spanish survivors fled to Santa Fe, which was put under siege. On August 21, 1680 the governor of Santa Fe, Antonio de Otermín ordered survivors to evacuate the city and flee south to El Paso. 66

In 1681, Otermín attempted to forcibly reclaim the territory lost in the revolt. He assigned his maestro de campo, Juan Dominguez de Mendoza, to investigate the state of the northern pueblos. 67 During this same time, Horn (Cochiti) Mesa and the village of Kotyiti was hosting a pan-Puebloan meeting to discuss how to react to the Spanish attempts to reconquer New Mexico. 68 On his way north, Mendoza passed through many pueblos, which were all abandoned.

64 Although Popé played a key role in leading the revolt, leaders from other villages played just as an important role as Popé. These would include El Ollita, Francisco Tanjete, Saca and Alonso Catiti, Antonio Malacate. Ibid: 34.


66 Ibid.

67 Ibid.

Sometime after December 13, 1681, Mendoza and his men arrived at Cochiti Pueblo. They heard about the war council meeting at Kotyiti. Mendoza and his party, fearing attack, fortified themselves within the confines of Cochiti Pueblo, which had been abandoned. After being warned of an impending attack, Mendoza began a retreat to Otermín's plaza de armas located just north of Isleta Pueblo. Although Don Luis of Picuris and other rebels pursued them, Mendoza and his army arrived on December 18. Ultimately, Otermín's reconquest attempt failed and the region was free of Spanish rule until 1692.

General Diego de Vargas visited Kotyiti three times from the years of 1692-1694. During his first visit in 1692, Vargas learned that Keres from Cochiti, San Felipe and San Marcos Pueblos inhabited Kotyiti. Vargas unsuccessfully attempted to bring the occupants down from the mesa. During his second visit in 1693, Vargas again was unsuccessful in bringing the inhabitants down from the mesa. In 1694, at the request of Zia, a christianized pueblo, Vargas attacked Kotyiti on April 17, 1694. Vargas took 342 women and

---

69 Ibid.
70 Ibid.
71 Ibid.
72 Ibid.
73 Ibid: 12-14.
75 Ibid: 15.
76 Zia requested intervention by Vargas because the rebels were raiding the pueblo on numerous occasions and they feared for their safety. Ibid: 16.
children as prisoners while most of the men fled. As a final blow, Vargas burned the village of Kotyiti. That was probably the last time the site was occupied as a village.\textsuperscript{77} The site was completely abandoned after it was burned in 1694 and is presently used for ceremonial purposes by the Pueblo of Cochiti.\textsuperscript{78}

1.6.4 The Archaeological Phase

This phase is important in understanding the historical, physical and social significance of Kotyiti. Kotyiti was first described in anthropological literature by famed anthropologist Adolph F. Bandelier in 1880. Bandelier was particularly interested in the site because it was referenced in both the Spanish ethnohistoric documents and Cochiti oral history accounts. Bandelier mapped the site during his first visit October 8, 1880 (see figure 1.4).\textsuperscript{79} This map was created by taking measurements of every room. Bandelier also gathered a considerable amount of Cochiti oral history relevant to the ancestral use of Kotyiti in order to interpret the events that occurred at the site. During his brief association with the American Museum of Natural History from 1903-1906, Bandelier seems to have mentioned the research potential of Kotyiti to the Curator of Anthropology, Clark Wissler.\textsuperscript{80}

In 1912, Nels Nelson, an archaeologist from the American Museum of Natural History was excavating at San Cristobal New Mexico, in the Galisteo

\textsuperscript{77} Ibid: 19.

\textsuperscript{78} Ibid.

\textsuperscript{79} Lange and Riley 1966: 139.

\textsuperscript{80} Preucel 1998: 19.
Figure 1.4  Bandelier's plan of LA 295 (from *Histoire* 1887-8: Plate XXI).
Basin. After an unsuccessful first season, Nelson was instructed to move on to Kotyiti by Wissler. During Nelson's visit, he surveyed and completely excavated Kotyiti. Nelson created two maps of Kotyiti and its environs, including topography, site locations and the location of base camp. One of those is a full layout plan of LA 295, including kivas, roomblocks and plazas (see figure 1.5).

The next research related visit to the site was in 1979. Julia Dougherty, of the SFNF, surveyed and remapped Kotyiti and its environs. Dougherty's goal was to map out the entire site, consisting of two contemporary settlements, and to resolve the outstanding questions about legal boundaries and custodial rights (see figure 1.6). This research provided a plan of the site and some theories on how Kotyiti was constructed. Based on this new plan, Dougherty concluded that the two villages fall within the jurisdiction of the SFNF.

During the years of 1991, 1993 and 1995 representatives from the SFNF documented vandalism, looting and the physical conditions of the site. It is important to note that the federal government mandated the activity by the SFNF representatives occurring from 1979 to 1995.
Figure 1.6 Dougherty's plan of LA 295 and LA 84 (from Preucel 1998: figure 3.5).
This activity was conducted in compliance with the Archaeological Resources Protection Act (ARPA) of 1979 and the 1980 and 1992 amendments to the National Historic Preservation Act (NHPA) of 1966.\footnote{Archaeological Resources Protection Act (ARPA) gives stringent protection to sites on federal lands and provides fines and prison terms for removing archaeological materials from federal lands without a permit. Amendments include conducting archaeological surveys of all lands, development of uniform provisions, and requiring federal land managers to develop public awareness programs. National Historic Preservation Act (NHPA) is a complex act requiring the federal government to establish a nationwide system for identification, protection and rehabilitation of "historic places." It uses appropriated funds to conduct surveys and planning in each state. This act set up a national framework for historic preservation. The amendments to NHPA included better definitions of terms and regulations. It also increases penalties for violations of the original 1966 Act and created a comprehensive federal policy for historic preservation. ARPA of 1979 and the 1980 and 1992 amendments to the NHPA of 1966.}
CHAPTER TWO: Data Collection and Preparation

2.1 Data Collection

This chapter outlines the methods that were used to compile and compute data for interpreting Kotyiti. Although a significant amount of the general site information was taken from published sources, the framework for which this research project was based came from the data that was collected by Dr. Robert Preucel and the Kotyiti Research Project.

Dr. Preucel describes the KRP's focus as "to identify and understand the social processes surrounding the founding and occupation of Kotyiti." The KRP data was collected by Dr. Preucel and field assistants from four consecutive field seasons and has yielded a large amount of physical information about the site. This information includes a surveyed plan, consisting of building footprints and topography, a stone for stone documentation for every known structure on the site, a basic structural conditions assessment documenting existing and burned plaster, and graffiti and extant architecture. Additionally, the KRP team identified a small amount of faunal and flora activity and general site deterioration due to unmonitored site visitation by hikers, campers and vandals.

---

83 Ibid: 75-76.
One of the tasks at hand was to collect and categorize all of the available types of data that exist for the site, not only from the KRP but also from any other available source. This was an especially difficult task due to the lack of availability of data and a lack of standardization in data collection. Additionally, many data sources were not readily apparent, so a large amount of time was spent locating the sources either through bibliographic references or over the Internet. Another part of the data collection process included making contacts in the public and private sectors, including convincing sympathetic professionals to assist or donate their time or products for this thesis. Although these beginning steps may seem daunting, it is important to note that persistence paid off in the form of data, advise, software and services.

An assessment of the available types of data was necessary. This process of evaluation was achieved by talking to Dr. Preucel, pursuing bibliographic references, contacting relevant professionals and browsing the Internet. The first stage of this evaluation was to collect all of the paper products that exist for the site; this included historic and modern topographic maps at varying scales, site locating maps, plans of the site, field journals from the KRP, global positioning system (GPS) data, environmental data, ground level photographs, aerial photographs and satellite images. The second stage consisted of collecting all available digital products, these included topographic maps at varying scales, digital elevation models (DEM) of the topography around the site, computerized GIS files of Sandoval county, surveyed data of Kotyiti and digitized plans of the site and the area around the site. The third stage involved
collecting oral histories and relevant literature, either from published sources or
directly from Dr. Preucel.

The following outlines offer a detailed list of every form of data that was
collected for this study. Although some of this data was not used for the study, it
was important to collect all available data for future research to be conducted by
Dr. Preucel or Cochiti Pueblo.

2.2 Stage One - Paper Data

The majority of the data in Stage One was either collected over the
Internet or by telephone communication from the United States Geological
Survey (USGS) or it was provided by Dr. Preucel.

It became apparent that familiarity with USGS nomenclature was
necessary for successful data collection. It is essential to know specific types of
information in order to conduct a search through the USGS, this would include:

1. Country (U.S.A.)
2. State (New Mexico)
3. County (Sandoval)
4. District/Region (Santa Fe National Forest, Cochiti Land Grant & Cochiti
   Dam)
5. Name of the USGS Quadrangle covering research zones (Cañada &
   Cochiti Dam)
6. Approximate coordinates for the site (E. 373831.342065 + N.
   3951786.440720)
7. UTM zone that the site falls within (Zone 13)

If all of this information is known, the data collection process should be straightforward. If, however, this information is not known, the process will be time consuming and possibly unsuccessful.

The data that was available from the USGS came in two formats, paper and digital. One of the goals of this research project is to provide a copy of all the data from the thesis to Cochiti Pueblo. With this in mind, it was important to archive all forms of data for future use by the Cochiti Environmental Protection Office (CEPO). All paper data collected is listed below. The paper data that was collected from the USGS includes sections 1(a), 1(b), 1(c), 1(d) and sections 8(c) and 8(d). With the exception of section 6(c) and all of section 9, the rest of the data was provided by Dr. Preucel. The data in section 6(c) came from the Los Alamos National Laboratory (LANL). Earthsat Imaging Company provided the data in section 9(a) and the Resource Geographic Information System Program (RGIS) at the University of New Mexico provided the data in section 9(b). Once all of this data was collected, it was organized and categorized (Table 2.1).

Table 2.2 Stage I Paper Data

1. Topographic Maps
   a. 1/24,000 USGS Quadrangle “Cañada,” 1993
   b. 1/24,000 USGS Quadrangle “Cochiti Dam,” 1993
   c. 1/100,000 USGS Quadrangle “Los Alamos,” 1978
   d. 1/250,000 USGS Quadrangle “Albuquerque,” 1983
2. Site Locating Maps
   a. Lange’s 1/1,267,200 regional map, (after 1990)
   b. Bandelier’s map of Potrero Viejo, 1880
   c. Habichte-Mauche’s 1/1,500,000 regional map, (after 1993)

3. Plans of the Site
   a. Bandelier’s plan of the mesa top sites and trails, 1880
   b. Bandelier’s plan of LA 295, 1887/8
   c. Nelson’s plan of LA 295, 1912
   d. Dougherty’s plans of LA 295 and LA 84, 1979
   e. Kotyiti Research Project plan of LA 295, 1996

4. Field Journals
   a. 6 Metric Transit Books used by the Kotyiti Research Project containing a stone for stone hand drawing for every known room in LA 295, 1996-1998

5. GPS Data
   a. In 1996, 11 points were collected in a GPS survey conducted by the Director of the NPS Pecos Survey, Genevive Head. 10 of these points are for LA 295 and 1 is for LA 84
   b. In 1999, Dr. Preucel and Cochiti Pueblo collected 4 points, to field check these data
6. Environmental Data
   a. Vegetation data recorded by Dr. Preucel, 1996
   b. Animal activity recorded by Dr. Preucel, 1996
   c. Climatic conditions for the region, published by LANL, 1991
   d. Geological information for the region, published by USGS, 1991

7. Ground Level Photographs
   a. 8 photographs taken by Nels Nelson, 1912
   b. 3 photographs taken by Dr. Preucel, 1996
   c. 5 photographs taken by Charles Lange, 1950's

8. Aerial Photographs
   a. 1 photograph taken by Lange, 1950's
   b. 4 photographs taken by Tom Baker, 1990's
   c. 1/24,000 low level photograph from the National Aerial Photography Program (NAPP), 1996
      Ref. # 9630-149
   d. 1/24,000 low level photograph from the NAPP, 1996
      Ref. # 9627-222

9. Satellite Images
   a. Landsat scene covering the region, taken in 1980
   b. Landsat scene covering the region, captured in 1986
2.3 Stage Two – Digital Data

As with stage one, the majority of the data in stage two was either collected from the USGS or from Dr. Preucel, with the exclusion of sections 3 and sections 5(c), 5(d), 5(e), and 5(f) which was provided by RGIS and created during the research phase of this thesis. All of the digital data collected is listed below. The USGS data came in many digital formats, this proved to be challenging because the data had to be converted into a standardized format for viewing on the software used for this research project. The data was digitally compressed into a smaller manageable file size, which made it easier to transfer over the Internet from the USGS public data warehouse. The process of collecting the digital data was either directly through the USGS website or through the USGS file transfer protocol (FTP) site. Either method, dependent upon the speed of the Internet connection, was as simple as transferring a file from a floppy disk to a computer. A third option was to contact the USGS directly and have them collect the data for a fee.

All of these options are useful for data collection, however, it is important to know that the data cannot be used immediately; it comes in either a raw or a processed format. The “raw” format means that it has not been “cleaned up” or geo-rectified. The “processed” format comes in two versions, the first is

\[^84\] http://edcwww.cr.usgs.gov/, the ftp site address is provided by a USGS representative when something is purchased or when data cannot be found on the USGS web page.

\[^85\] “Cleaned up” refers to the process of removing unwanted visual noise or residue that is on the image. “Geo-rectified” refers to the process of taking a scanned image and assigning geographic
cleaned up and geo-rectified to a low standard. This low standard means that the data has been scanned and generally rectified to small scale data sets. The level of accuracy for rectification is 15-30 meters. The second version is cleaned up and has been geo-rectified to the highest standard that the USGS makes available to the public. This high standard means that the scanned data has been processed for visual scanned noise and rectified to a larger scale, with an accuracy level of 2-5 meters. The data that was collected for this case study was a mixture of raw and processed data.

The topographic maps (stage II, sections 1(a)-(d)) are all scanned versions of the paper products. The USGS provides these maps geo-rectified to the exact Universal Transverse Mercator (UTM) coordinates that represent the UTM zone that New Mexico falls within. Generally, the accuracy level for the USGS geo-rectification varies, however it is especially high for the study area, which is 2 meter resolution. The advantage of having this data was the maps were scanned in one piece and geo-rectified to the highest level of accuracy that the USGS makes available to the public.

The conventional approach in scanning large maps is to use a flatbed scanner, which has a scan dimension of 11 x 17 scannable inches. This method produces multiple scans, which are then digitally stitched together using a photographic editing software package. This process takes multiple scans and forms one plan. This method however, introduces a large amount of error and

coordinates (longitude/latitude or universal transverse mercator UTM) to the image virtually through specific software, e.g. ArcView GIS or AutoCAD.
possible loss of data due to a poor overlap and incompatible scale between each scan. Therefore, whenever possible a large format scanner should be used. One of the advantages of scanning on a large format scanner is that the scan is in one piece. Additionally, there are no seams and the process is generally less labor intensive.

A second more important form of data that was collected for the study was the DEM data for the region. A DEM consists of geo-rectified contour lines taken directly from the USGS topographic maps. The DEM’s are composed of contour lines that have an elevation value assigned to them. The USGS rendered this contour data into a three-dimensional format and had a false skin or terrain applied to the topographic skeleton or wire frame (see figure 2.1). These cartographic models are especially useful when a site has a landscape associated with it. The DEM adds a dimension of mass and space to the study area. The DEM can also be used to analyze the site and how it is situated within its landscape. Additionally, this data can be modified for specific levels of research using off the shelf software such as ArcView GIS or AutoCAD. All of section 2 was acquired from the USGS with the exception of 2(d), which was created for this thesis.

All of section 3 was prepared by RGIS. This data consists of 6 types of GIS coverages that contain the entire county of Sandoval. Although it is good to have as much data as possible for any site, only sections 3(a), 3(b), and 3(e) were used for this study. Not all of the data provided by the RGIS was geo-
rectified, so a decision was made to only spend time converting the GIS data that was essential for the study.

Stage II section 4 is arguably one of the most important types of data for a site. If a site is amenable to the collecting electronic total station surveyed data
3D Horn Mesa
Elevation Range
- 6804.444 - 6920
- 6688.889 - 6804.444
- 6573.333 - 6688.889
- 6457.778 - 6573.333
- 6342.222 - 6457.778
- 6226.667 - 6342.222
- 6111.111 - 6226.667
- 5995.556 - 6111.111
- 5880 - 5995.556

Figure 2.1 DEM of Horn Mesa depicting elevation in a three-dimensional perspective, with LA 295 and LA 84 in black
at best or GPS data at worse, then the site researchers can produce a highly accurate map of the site. The electronic total station surveys are commonly considered to have a higher degree of accuracy than those using the GPS unit. With the advent of technological innovations, GPS units are being refined and should soon become nearly as accurate as an electronic total station survey. By having this type of surveyed data, an archaeologist can produce a network of structural footprints with their exact dimension and orientation information represented in the footprint. This is important for Kotyiti because it is possible that the pueblo was oriented in specific cardinal directions for symbolic and possibly for defensive purposes. This is also important because it allows maps and plans that have been digitized to be scaled, rotated and fitted to the surveyed evidence. Section 5 lists a series of digitized plans that have been scaled, rotated and fitted to the surveyed evidence. This incorporation of information types (surveyed and digitized data) is invaluable, not only because it provides an area for accurate analysis of the site by distance, angles, layers, themes and the third dimension but also because it allows for future research. Future research could consist of a full GPS survey of the structures and topography of LA 295 and LA 84. This coordinate data could then be added to the existing surveyed and digitized data, modifying the existing resource management plan of Kotyiti (Table 2.2).

Table 2.3 Stage II Digital Data

1. Topographic Maps
   a. 1/24,000 USGS Quadrangle “Cañada,” 1993
b. 1/24,000 USGS Quadrangle “Cochiti Dam,” 1993

c. 1/100,000 USGS Quadrangle “Los Alamos,” 1978

d. 1/250,000 USGS Quadrangle “Albuquerque,” 1983

2. DEM

a. 1/24,000 USGS Quadrangle “Cañada,” 1993

b. 1/24,000 USGS Quadrangle “Cochiti Dam,” 1993

c. 1/24,000 USGS Quadrangle taken from “Cañada,” focusing on Horn Mesa, 1999

d. 1/200,000 USGS Quadrangle “Los Alamos,” 1993

3. County GIS Data (all 1996)

a. Political boundaries

b. Hydrological information

c. Manmade Features

d. Transportation information

e. Overall topography at 20 meter interval

f. Vegetation coverage

4. Surveyed Data

a. Total station survey comprising of over 10,000 points\textsuperscript{86}, 1996-1997

5. Digitized Plans (all 1999)

\textsuperscript{86} Loa Traxler, who at the time worked for Museum Applied Science Center for Archaeology (MASCA) at the University of Pennsylvania Museum, shot this surveyed data on an electronic total station from 1996 & 1997. The level of accuracy provided by MASCA is +/- 2mm +2ppm and 3 seconds of arc. However, this survey was never keyed into New Mexico’s geodetic system, it was conducted under a floating grid which was situated on Horn Mesa. Additionally, the data was projected on a system that is not standard to USGS conventions, which are: Datum UTM 1927, Spheroid Clark 1866. After lengthy discussion with Dr. Richard Pirtle, a USGS veteran for 40 years, the data was keyed into the state grid system and properly projected. The corrected data resulted in an accuracy level of +/- 5 meters.
a. Plan of all the surveyed data, including points and topographic lines
b. Plan of the surveyed data tracing the footprint of LA 295
c. Restored plan of LA 295
d. Contour map at 20 meter intervals for all of Horn Mesa
e. Restored plan of LA 84
f. Stone for stone rendering for Roomblock I and part of Roomblock II (rooms 1-34)

2.4 Geology, Vegetation and Climate

Additional data that was collected for the study area includes how the region was geologically formed, vegetation coverage and general climatic conditions for the region. This type of information is specifically important to understand because it not only illustrates how and why the physical attributes of the site were formed but it can also be used to anticipate natural occurrences affecting the site.

Kotyiti is located on the southeasterly finger of Horn Mesa, ranging in elevation from 5880 to 6920 meters (see figure 2.2). The site is located approximately seven miles northwest of the modern Pueblo of Cochiti. Horn Mesa is part of the southernmost edge of the Jemez or Pajarito Plateau.\footnote{Hewett 1906.} The Jemez Plateau terrain is comprised of many narrow mesas or prominent fingers of land surrounded by deep canyons. These landforms branch out from the Jemez Mountains down to the Rio Grande. This rugged topography was formed
Figure 2.2  Photograph of Horn Mesa (from Preucel 1996).
by the erosion of the foundation of the plateau of deep volcanic ash deposits.\textsuperscript{88} The dominant rock of Horn Mesa is the Tshirege member of Upper Bandelier tuff. This rock, produced by the eruption of the Valles volcano approximately 1.12 million years ago is defined as follows:

"Upper Bandelier Tuff (Tshirege Member) – White to tan to pink welded rhyolitic ash-flow containing abundant phenocrysts of sanidine and quartz and trace clinopyroxene, hypersthene, and fayalite. Sanidine typically displays a blue iridescence; consists of several flow units in a compound cooling unit; locally contains a thin (.05m) nonwelded laminated ash-fall deposit at base unit that contains roughly 1\% hornblend latite pumice (Baily et al 1969); locally may contain abundant rock fragments from nearby volcanic sources; Qbt (map symbol) forms conspicuous pink cliffs throughout the Pajarito Plateau; originated from catastrophic eruptions that formed the Valles Caldera; K-Ar age 1.12+\-0.03 Ma; maximum observed thickness about 120 m.\textsuperscript{89}"

Beneath this material lies the Otowi member of lower Bandelier tuff that was produced by the eruption of Toledo volcano approximately 1.45 million years ago.\textsuperscript{90} This rock forms the base of Horn Mesa. Although these two rocks formed during different geological sequences, Lower Bandelier tuff is very difficult to distinguish from upper Bandelier tuff by hand observation.\textsuperscript{91}

\textsuperscript{88} Goff et al. 1990.

\textsuperscript{89} Ibid.

\textsuperscript{90} Preucel 1998:p. 2.

\textsuperscript{91} Goff et al 1990.
Dr. Preucel has produced the most recent survey of vegetation of LA 295 and LA 84, his observations are printed below (see figure 2.3):

"Horn Mesa encompasses the transition between the Pinon-Juniper woodland and the Ponderosa Pine-Oak Forest. There is a Riparian community below along Cochiti and Bland Canyons to the north and south. LA 295 is located at the upper end of the Pinon-Juniper woodland. There is a old alligator juniper (Juniperus deppeana) in the northeastern corner of Plaza A. Other plants on site include mountain mahogany (Cercocarpus), Gambel oak (Quercus gambelii), chamisa (Chrysothamnus nauseosus), snakeweed (Gutierrezia sarothrae), saltbush (Atriplex sp), narrowleaf yucca (Yucca angustissima), cholla (Opuntia imbricata), prickley pear cactus (Opuntia sp).

Plant succession has proceeded at a fairly rapid pace since the turn of the century. The major factors in this process have been the abandonment of the Hispanic community of La Cañada and the end of sheep grazing."\(^{92}\)

The Pajarito Plateau experiences a semiarid continental climate with varied and unpredictable weather. Spring is defined by strong winds and varied temperatures that often fall below freezing and brief but violent snowstorms can occur in March and April. Summer temperatures rise above 90° F with violent thunderstorms occurring on a regular basis. Fall is sunny with daytime temperatures between ranging 70-80° F and frequently freezing at night.\(^{93}\)

---

\(^{92}\) Preucel 1996: p. 67.

\(^{93}\) This type of climatic information can be incorporated into a GIS study measuring, for example, past erosion and predicting future erosion. See chapter 3, section 3.2.4 for more discussion.
Figure 2.3  Aerial photograph of LA 84 and the vegetation of Horn Mesa (from Tom Baker 1996).
temperature variations occur through the winter ranging from 0-60° F, often accompanied by heavy snowfalls (see figure 2.3).

2.5 Data Preparation

There were three general categories of data that were prepared in order to conduct an overall examination of the study area. These categories included, new paper data, new digital data and digital data that has already been processed for the site.

2.5.1 Paper Data

As described above, the first step of using paper data is to scan it into a digital format. This can be done three different ways, firstly, by using a flatbed scanner, secondly, by using a large format scanner or thirdly, by using a high resolution digital camera.

A flatbed scanner is the most common peripheral that is used by the general consumer. Flatbed scanners are commercially available, inexpensive and relatively easy to use. The draw back of using this device is that it has a limited scanning area, usually 8.5 x 11 or 11 x 17 inches. If the paper data is

Website providing a brief climatic description of the Los Alamos region New Mexico, http://www.lib.utexas.edu/Libs/PCL/Map_collection/united_states/Los_Alabos_Guide98.pdf
larger than these areas, then the data has to be scanned in multiple parts. This can lead to scaling issues and to a general low level of accuracy.

A more successful alternative is to use a large format scanner, which can scan a piece of paper up to 34 inches wide, with a limitless length. This technology, which was originally created for commercial use, is available to the academic community through private vendors. Although this process is a fee-based service, it is worthwhile. The final product is a single scan that is seamless, time efficient and instantly ready for use.

The third option, the digital camera, is recommended for large volume digital reproduction. Although a digital camera produces a photograph, if taken under the correct conditions, the digital photograph can be utilized in the same manner as a scanned image. For example, the KRP provided 6 field survey books with over 200 pages of data that had to be digitally documented. Each of these pages documented the stone for stone plan of every room in Kotyiti Pueblo. Although the task was large, the data from these field books needed to be scanned for future digitization and for archival purposes. All of these pages were photographed in 3 hours on a copy stand, under a controlled environment. The photographed data was downloaded in 10 minutes onto a computer and the process was complete. All of these formats were used for this research project.

95 The right conditions would include, good lighting, a steady base for the camera and a familiarity with the functionality of the camera.
2.5.2 Digital Data

This dataset or type of data can be created in two ways, the first is by using numerical data and the second is by digitizing or tracing data from a scanned image. The first way can be a very complicated technique. It is dependent upon a certain amount of numerical data that references points in a space on an X, Y and Z plane. This information can come in the form of surveyed or GPS data or more generally from distance or elevation sources. The product that is produced from this type of data is usually a crude point or line map.

The second format is best utilized with scanned data. This procedure allows for exact renderings to be digitized or drawn on the computer screen from the original scan. This process is called “heads-up” digitizing and is simply a matter of opening a scanned image in the background of a computer session, and then the scanned image is traced on top of it. Many software packages, including Autodesk’s AutoCAD and Adobe Photoshop allow a scanned image to be opened, manipulated and traced. These software packages work in a system of layers, each representing a different identifying feature within the digitized drawing. When a scanned image is brought into the AutoCAD or Photoshop environment, it is treated as a layer that can be turned on and off, rotated, scaled, cropped and stretched. An unlimited series of layers can be set up within the workspace that identifies the features from the scanned image. For example, the restored plan for Kotyiti consists of actual evidence, hypothesized evidence,
existing plaster, doorways and vents. Each one of these categories from the restored plan has a layer assigned to it. Once a plan is in a digitized format it can be easily edited because the new data is composed of several separate yet related entities or polygonal lines.

An additional benefit of using a digitized drawing over just using a scanned plan is that AutoCAD allows the polygonal line entities to have independent Z or elevation values assigned to it, in order to render an entity three dimensional. This process is especially valuable when producing a contour map of a site.

2.5.3 Existing Digital Data

This last category of data preparation is the most challenging to master. It is very difficult to grasp what type of data is needed for a study and even more perplexing as to the forms it comes in. For example, this research project was a GIS based project that started from ground zero. In the beginning stages of this project, an exhaustive search had to be conducted for all the available software that is used by GIS practioners and related disciplines. A general understanding of how the software functioned, the types of data the software produced and why everyone in the GIS community uses different types of software to achieve the same goal. For instance, the NPS generally uses ArcView for a GIS study while the USGS uses ArcInfo, both products are made by ESRI however; ArcView is a
simpler GIS package while ArcInfo is a highly technical or "high end" GIS software package.

A clear understanding of the inter connectivity between software platforms was necessary for a successful exchange of research related data. The data that was collected for this thesis came from various sources, mainly from the NPS, the USGS, the USFS, the RGIS and the KRP. All of this data came in different formats and had to be converted into a few standardized formats that were usable by the software from this research project. These formats are outlined in the following table as original file type to converted file type.

The source data usually came compressed, either from a Unix workstation or from a pc. Since the two of these operating systems work on different coded language systems, they do not easily communicate with each other. So any data prepared on a Unix machine needs to be converted to a standardized pc format. This was achieved by either using extraction or decompressing software applications or by simply knowing which file extension to type at the end of the raw file (Table 2.4.4).

**Table 2.5.4 File extensions for data compression**

1. (SDTS) The Spatial Data Transfer Standard is a format standard for GIS data. The purpose of SDTS is to permit static transfers of spatial data between dissimilar computer systems. SDTS is a transfer format, not a processing format; it does not replace any internal formats of any GIS. For a more detailed discussion visit the USGS site at http://edcwww.cr.usgs.gov/glis/hyper/guide/usgs_dlg
2. (GZ) also known as Gzip (short for GNU Zip) utility on UNIX systems. Files in this format usually have a .gz or .z extension.
3. (TAR) The name `tar' comes from this use; it stands for tape archiver. Despite the utility's name, tar can direct its output to available devices, files, or other programs. See the description for number 4 for extraction.
4. (TAR.GZ) *.gz compression is generally used when there are multiple "."s in the file name like somefile.tar.gz. When this file is downloaded to a PC, an internet browser commonly replaces the internal "."s with ".". If these underscores are replaced with periods within Winzip – it should be possible to unzip the file.
5. (ZIP) A popular DOS and Windows file compression format. Files in this format typically have a .zip extension.

Once the data was decompressed and had the correct file extension assigned to it, the data had to be viewed. For the most part, ArcView was the main GIS tool used for this thesis. However, a limited license of ERDAS Imagine, a "high-end" GIS software package, was granted for this research and was used for to supplement some of the GIS functionality. Additionally, it could be argued that AutoCAD produces a product similar to that of ArcView, with raster, vector, polygonal and database functionality. Therefore AutoCAD could be considered a GIS tool. Early on in the research process, a decision was made to use ArcView and AutoCAD to allow more universal access, as the main software tools for the research, which meant that all of the data had to be made viewable in the software. A number of different file extensions can be opened in ArcView and AutoCAD (Table 2.4.5).
Table 2.5.5 File extensions ArcView accepts

1. (DEM) Digital Elevation Models from the USGS
2. (COV) ArcInfo Coverage file
3. (DWG) Drawing file from AutoCAD
4. (DXF) Drawing Exchange File from AutoCAD
5. (SHP) Shape file
6. (DBF) Data Base File
7. (GRD) Grid file
8. (TIN) Triangulated Irregular Network
9. (DOQ) Digital Ortho Quads from the USGS
10. (DRG) Digital Raster Graphic from the USGS
11. (DLG) Digital Line Graphic from the USGS

File extensions AutoCAD accepts:

1. (DWG) Drawing file
2. (DXF) Drawing Exchange File

The purpose of this thesis was to establish a foundation of useful data for current and future study by collecting and creating as much data as possible within the time frame of this thesis. Another goal of this thesis was to convert all of the collected data into a standardized format that could be utilized by anyone with the recommended off the shelf software (ArcView and AutoCAD). The final goal of this thesis was to make suggestions on the management of the data and to recommend a basic resource management plan for Kotyiti and its environs using a combination of preservation guidelines. This will be done in several
ways, by identifying the relevant resources discovered in the research, by adopting a mixture of standards for preservation from various resource management charters and codes and by using modern conservation strategies for the stabilization of the historical fabric of the site.
CHAPTER THREE: Recommendations for Management

This chapter is dedicated to explaining the results of the application of the data to a historically and archaeologically significant site. This chapter will also propose management recommendations based upon the collected data outlined in Chapter Two. It will also explain how and why the data was used to produce a management plan for the resources identified at Kotyiti. With an understanding of this process, this chapter will reveal the categories of data used for research and show how these categories were employed to form a basic resource management plan at Kotyiti.

Chapter Two outlined the types of data that were collected and their final converted format necessary to render all of it viewable on related software platforms, for example, ArcView and AutoCAD. The following section will explain the results of the process of overlaying several categories of data to produce a resource management plan for Kotyiti. This section will also explain how a resource management plan was synthesized out of the combined spatial data and will show the results of the analyzed layers.

3.1 Evaluation and Application of the Data

3.1.1 Evaluating the Data
In order to evaluate the resources of a site, a cultural resource manager needs to have a clear understanding of the relationships between the different spatial components of a site. Cultural landscapes are composed of a collection of features, which are organized into spatial components. These spatial components could include small scale features such as shrines or caches, and larger scale features such as patterns of fields and forest which define the spatial character of the landscape. Individual features in the landscape should never be viewed in isolation, but in relationship to the landscape as a whole. Generally, it is the arrangement and the interrelationship of these character-defining features, as they existed during the period of significance that is most critical before considering applying preservation practices.

Kotyiti, for example, is composed of many interrelated spatial components, both cultural and natural. These include the spatial organization and construction of LA 295 and LA 84, vegetation information including juniper and cacti, topography and visitor circulation including historic and modern trails (see figure 3.1). Although most of this spatial information is specific to the site, it is also directly related to the more general landscape resources, in a cause and effect relationship. These two bodies of information have to be linked in the resource management plan because they are spatially and physically related (see figure 3.2). This spatial information has been managed digitally using GIS. GIS has allowed these spatial components to be viewed, arranged, manipulated and linked in a controlled environment. This controlled environment allowed specific research questions to be asked: where exactly are LA 295 and LA 84 located?
Figure 3.1 Plan of the topography of Horn Mesa, including LA 295 and LA 84.
Figure 3.2  Schematic showing the relation between layered information using a GIS (from Foresman 1998: figure 7.6, p. 104).
What are the spatial relations between LA 295 and LA 84? Where do the boundaries for the SFNF and the Cañada de Cochiti Land Grant fall?

3.1.2 Applying the Data

A series of steps have been conducted while artificially combining the data using GIS as a spatial management tool. These steps included identification, retention and preservation of existing spatial components, unique to Kotyiti and Horn Mesa. With all of these features identified, it is possible to define their relationship by using GIS. These relationships are dependent upon the accuracy of Kotyiti and Horn Mesa’s spatial components and the skill of the GIS user. Specific resources have to be singled out of the overall resource management plan in order to render the spatial components into a useful and manageable site preservation tool.

The most important non-site spatial component produced for the resource management plan was a topographic map of the study area (see figure 3.1). This map had to be accurate, including coordinate and elevation information assigned to internal and external points on the map. The topographic map provided a large amount of general landscape information in and around the site. For example, the topographic map could include roads; paths; contours; boundaries for public and private land; quarries; mines and site locations. This type of landscape information is important because it may directly relate to and affect the site. Another example would be how a low level aerial photograph can
be incorporated into the research by “draping” it on top of a DEM. This combination of data renders a two dimensional aerial photograph into the third dimension (see figure 3.3).

Topographic maps are particularly useful in addressing legal boundaries. Kotyiti, for example, has been the subject of a boundary dispute between the SFNF and the University of New Mexico. Currently the main site (LA 295) falls within the jurisdiction of the USFS. It was very important to accurately position the topography, boundary and site information to determine the exact location of the sites for the boundary analysis. This analysis resulted in the discovery that at least half of LA84, which is probably contemporary with LA 295, is located on Cañada de Cochiti Land Grant and thus falls within the jurisdiction of the University of New Mexico (see figure 3.4).

The next important spatial component that is site specific was the surveyed data. The surveyed data needs to have coordinates and when possible elevation information assigned to the point and line surveyed information. This layer of information is crucial to place the site accurately within the topographic layer, thus linking it digitally and geographically. This information is crucial to the accurate placement, scale and orientation of any site or structure plan.

Another important site specific spatial component is the plan of the site. The site plan will need to have coordinate and elevation information assigned to elements included within the site plan. The site plan will also need to be prepared by a professionally trained surveyor or draughts person.\footnote{Many disciplines fall within this category, e.g. archaeologists, architects and engineers.} This plan
Figure 3.3 An aerial photograph of Horn Mesa draped over a DEM of Horn Mesa, rendering the photograph three-dimensional.
Plan of the topography of Horn Mesa, including political boundaries and LA 295, LA 84.
should be based upon an actual survey of the site, including exact thickness of walls, locations of doorways and hearths. An accurate scale and north arrow should also always be included in any plan.

All other data to be included in the study can be digitally linked together; using these three important base layers of information. Any additional data can be created from all of the source fitted data. For instance, one of the branches of research for this thesis was to produce a sample of a stone for stone plan of LA 295. Dr. Preucel documented the original room plans in the field by hand. These journals include a stone for stone rendering of each room in LA 295, including intact walls, fallen walls, existing plaster, topography inside the rooms, locations of doors, hearths and vents, artifacts in-situ and biological activity. Using the digitized geo-referenced restored plan of LA 295 as a rectification guide, all of the rooms of Roomblock I and part of Roomblock II were fitted into their exact location (see figure 3.5). Measurements of the newly fitted data were made in AutoCAD and compared to those from the field journals. This allowed all of the information documented in the field to be geo-rectified to +/- 5 meters. This process allows for small scale accuracy at 1/24000 and large scale data at 1/10 to be used.97

---

97 The unit of measurement is of a ratio where 1 inch on the map will equal 24,000 feet of the earth's surface.
Figure 3.5  Detail of Roomblock I and part of Roomblock II of LA 295
73
3.2 Recommendations

The purpose of this section is to suggest recommendations for future implementation at Kotyiti. This section is comprised of suggestions that do not incorporate needed discussions with the USFS and Cochiti Pueblo and is therefore not an absolute remedy to preservation issues at Kotyiti. Although some of these ideas are proactive, they should be treated as suggestions and would therefore require further consideration by all parties before implementation. In order to better manage and preserve Kotyiti, a series of current and future plans of action need to be considered. These plans have been organized into two categories: management of data and management of the site.

3.2.1 Management of Data

The management of the compiled data from this thesis should be a priority for the future custodians of this site. The management strategy should include understanding how to preserve different types of data for archival purposes. Different types of data call for varying levels of data management and preservation. For example, in an ideal situation, the paper data that was collected for this thesis will need to be protected from extensive handling and inappropriate storage. This would mean that a custodian should be present
when the paper products are handled. This would also mean the paper products should be stored in a dry, low to no light drawer, large enough to hold oversized maps and if possible printed or mounted on acid free paper.

The digital data should be archived biannually on a large capacity type of media, for example, a compact disc or a backup tape and stored in two separate locations, in case an accident occurs at one of the archival locations. The backup media has a shelf life of 100 years.\textsuperscript{98} Additionally, this digital data should be stored on a research dedicated computer that allows 24 hour restricted access. Other suggestions would include:

1. A full archive at Cochiti Pueblo including correct storage for paper and photographic documentation, digital archives, historic and ethnohistoric literature, archaeological information, regional information including faunal, floral and physical data.

2. A room could be set aside to house a resource management laboratory, possibly incorporated into CEPO. This laboratory could include a few networked computers, outfitted with the appropriate hardware and software and could act as a model for other Native American sites. The suggested hardware could include adequate hard drive space, a high speed processor, and a compact disc burner for digital archiving. The suggested software could include the latest editions of ArcView, AutoCAD and Microsoft Office Professional. Additional recommendations would include a color plotter or printer, a scanner and a high speed internet connection.

\textsuperscript{98} Although the shelf life of the backup media is long, the digital data may become obsolete. Additionally, as years pass, it may become increasingly difficult to retrieve archived data as computer systems evolve.
3. A web page for the site should be created. This site could be housed either through Cochiti Pueblo or directly through an affiliated academic institution. This web site could include the past, current and future research by Cochiti Pueblo and affiliated researchers. This web page would also act as an education tool and would help to preserve Kotyiti by educating the public on the significance and fragility of the site without disclosing sensitive site location information.

3.2.2 Management of the Site

The resource management plan for Kotyiti was developed out of an equation created for this thesis, which consists of a number of resource variables. These variables were put together after a specific problem was identified. This equation allows factors affecting the site (e.g. natural, cultural and manmade resources) to be selectively grouped together to solve an identified problem. This combination produces a solution affecting or involving the factors of the equation. For example, high level visitation could be deteriorating a site through measurable trail erosion, vandalism and looting. An equation could be created combining transportation information, archaeological zones, records of site visitation and topography revealing that an inappropriately placed road or trail could be adversely affecting an archaeological zone. A series of solutions could be derived based upon the equation, for example:
ISSUE: Deterioration of a Site = Trail Erosion, Vandalism and Looting

EQUATION: \( \text{Transportation Info} + \text{Archaeological Zones} + \text{Visitation Records} + \text{Topography} = \)

SOLUTIONS: 1) Reroute or close trails or roads on or near the site.
2) Tone down the publicity for the archaeological zone.
3) Display appropriate signage discouraging visitation.

The variables of this equation will need to be accurate, as outlined in Chapter Two, in digital format. The equation can then be computed and analyzed, using ArcView as a resource management calculator, producing multiple solutions for the site. The solutions can be further researched, eventually leaving one realistic solution to the problem, which can be applied to the management plan for the site.

The management of these various types of data can be very complicated. It is necessary to link all of the data sets not only through a computerized environment but also visually, in order to produce a fully interactive site management plan. An interactive plan would allow a resource manager to add and subtract data when necessary, this process would always keep the resource management plan up to date and would be the best solution to protecting a site.

The management for Kotyiti can be organized into several categories, management strategies, site stabilization, the inclusion of signage, vegetation management and the management of publicity.
3.2.3 Management Strategies

If the site is to remain in the shared hands of the USFS and the University of New Mexico, it should adhere to the current NPS standards of site preservation, outlined in chapter one. The current antiquated approach of site management that is practiced at Kotyiti is passive and pays little or no attention to the structural condition of the site. A possible alternative to the current management strategy would be to share the responsibilities with the Pueblo of Cochiti. This could include direct involvement in the documentation, stabilization and general vegetation maintenance of the site. A more official alternative would be for the SFNF to send interested representatives from the Pueblo of Cochiti to be trained by the NPS about managing a culturally sensitive site.

3.2.4 Site Stabilization

Physical features within the cultural landscape may need to be stabilized or protected through preliminary measures until additional work can be undertaken. Structural reinforcement of many of the walls of the Pueblo is required for the village to survive better the dramatic climatic changes in the region. Cycles of freezing and thawing have eroded the mortar in the bottom 3-4 courses of most of the walls. Additionally, any existing plaster should be documented and consolidated for future interpretation. This work should be
conducted in such a manner that it detracts as little as possible from the sites appearance. Any trenches near the architectural features on site should be filled in, to stop any future walls from falling. Animal activity, including waste and burrows, should be monitored and any infestations should be managed.

3.2.5 Inclusion of Signage

There is a need for minimal signage at Kotyiti. Signage is necessary to advise and warn visitors about the fragility of the site and its connection to the Pueblo of Cochiti. If there is to be signage, it should be near the subject of interpretation. More information about the site could possibility be found either on a co-operatively designed brochure or on a web site sponsored by the SFNF or the University of New Mexico.

3.2.6 Vegetation Management

The groundcover on Horn Mesa is generally thick and severely affects the interpretation and integrity of the overall site. Since this vegetation is not currently managed, it is probable that root systems and foliage could be damaging subterranean features, extant architecture, general site layout and artifacts in-situ. One management strategy would be to remove or cut back the herbaceous vegetation, this action would reduce these damaging activities. Another option would be to conduct seasonal controlled burns, such as are used
in Bandelier National Monument. Any solution should be devised in consultation between the SFNF and Cochiti Pueblo.

3.2.7 Management of Publicity

Kotyiti is the victim of the popularity of Horn Mesa as a hiking destination. Horn Mesa is one of the more prominent rocky protrusions in the area. This has led to Horn Mesa becoming popular with regional rock climbers, hikers and campers. These weekend adventurers inevitably discover Kotyiti and either go pottery hunting, pitch camp, litter or vandalize the site. This type of activity needs to be managed either by the SFNF, the University of New Mexico or by the county. It needs to be publicly known that the area is historically and culturally sensitive, and therefore should be treated with respect.

3.3 Future Recommendations

The bulk of this thesis has addressed the physical spatial components of Kotyiti. It has also examined the interrelationship between these components. All future recommendations of this thesis focus on the site, using the tools established and outlined in this thesis. GIS could act as the vehicle to steer Kotyiti towards a higher level of preservation and interpretation. The following recommendations should be considered during future research on Kotyiti:
1. Oral History – Previously documented and newly gathered oral traditions of Cochiti should be documented and mapped out in a similar manner to the methods in this thesis. Sites such as Pueblo of the Stone Lions and Kuapa could be investigated. This type of research would document migration routes, economic routes and political boundaries.

2. Ethnohistoric History – All of the ethnohistoric data should be mapped out, showing routes of trade, conquest and warfare. For example, Vargas’s attack could be plotted on the landscape.

3. Artifacts – All documented artifacts should be keyed in to the site plan, showing the location of the find. This could also prove invaluable for mapping out household activities.

4. Ethnography – Some of the data collected by Charles Lange could be keyed into a database and mapped out. This would permit a closer examination of the relationship between Modern Cochiti and Kotyiti. Both continuities and discontinuities in cultural practices would be revealed.

5. GIS – A higher level of GIS could be conducted for the entire area of the Cañada and Cochiti Dam Quads. More maps and a relational database could be created for future study. Additionally, Kotyiti could be monitored and managed in the future using the GIS that was created for this thesis.
BIBLIOGRAPHY


U.S. Department of Interior "The Section 110 Guidelines, Annotated Guidelines for Federal Agency Responsibilities under Section 110 of the National Historic Preservation Act," Working with Section 106, jointly issued by


### APPENDICES

#### Acronyms used in thesis:

<table>
<thead>
<tr>
<th>Acronym</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>ARPA</td>
<td>Archaeological Resources Protection Act</td>
</tr>
<tr>
<td>CEPO</td>
<td>Cochiti Environmental Protection Office</td>
</tr>
<tr>
<td>CGIS</td>
<td>Canada Geographical Information System</td>
</tr>
<tr>
<td>CRM</td>
<td>Cultural Resource Management</td>
</tr>
<tr>
<td>DEM</td>
<td>Digital Elevation Model</td>
</tr>
<tr>
<td>ELAS</td>
<td>Earth Resources Laboratory Applications Systems</td>
</tr>
<tr>
<td>EPA</td>
<td>Environmental Protection Agency</td>
</tr>
<tr>
<td>FTP</td>
<td>File Transfer Protocol</td>
</tr>
<tr>
<td>GIS</td>
<td>Geographic Information Systems</td>
</tr>
<tr>
<td>GPS</td>
<td>Global Positioning System</td>
</tr>
<tr>
<td>GRASS</td>
<td>Geographical Resources Analysis Support System</td>
</tr>
<tr>
<td>KRP</td>
<td>Kotyiti Research Project</td>
</tr>
<tr>
<td>LA</td>
<td>Laboratory of Anthropology</td>
</tr>
<tr>
<td>LANL</td>
<td>Los Alamos National Laboratory</td>
</tr>
<tr>
<td>NHPA</td>
<td>National Historic Preservation Act</td>
</tr>
<tr>
<td>NPS</td>
<td>National Park Service</td>
</tr>
<tr>
<td>MIMO</td>
<td>Map in-map out</td>
</tr>
<tr>
<td>RGIS</td>
<td>Resource Geographic Information System Program</td>
</tr>
<tr>
<td>SAGIS</td>
<td>System Applications Group Information System</td>
</tr>
<tr>
<td>SFNF</td>
<td>Santa Fe National Forest</td>
</tr>
<tr>
<td>SOI</td>
<td>Secretary of Interior</td>
</tr>
<tr>
<td>USFS</td>
<td>United States Forest Service</td>
</tr>
<tr>
<td>USGS</td>
<td>United States Geological Survey</td>
</tr>
<tr>
<td>UTM</td>
<td>Universal Transverse Mercator</td>
</tr>
</tbody>
</table>
HTML links used in thesis:

Sites specifically about New Mexico:

http://npi.org/ag-ctech.html
http://www.pbs.org/weta/thewest/wpages/wpgs000/w010_001.htm
http://www.ghcc.msfc.nasa.gov/archeology/chaco.html
http://www.portup.com/~gws/gws97.html
http://museums.state.nm.us/hpd/
http://www.nmia.com/~quasho/
http://www.ghcc.msfc.nasa.gov/archeology/chaco.html
http://sipapu.ucsb.edu/roads/SAA96.pdf
http://geology.cr.usgs.gov/
http://swanet.org/nm.html
http://www.trail.com/~melliott/paja/pajahist.html
http://www.nativemaps.org/StoriesNewsReviews/stories.html
http://www.mapsofnewmexico.com/
http://www.swanet.org/
http://www.trail.com/~melliott/
http://www.landuse.com/
http://www.ci.santa-fe.nm.us/sfpl/nmmlink.html
http://www.swanet.org/
http://www.nps.gov/band/
http://www.golfnewmexico.com/cho.html
http://www.lib.utexas.edu/Libs/PCL/Map_collection/united_states/Los_Alanos_Guide98.pdf
GIS specific sites:

http://edcwww.cr.usgs.gov/
http://edac.unm.edu/
http://www.bubl.ac.uk/link/l/remote sensing.htm
http://edcwww.cr.usgs.gov/programs/NSLRSDA.html
http://plasma.nationalgeographic.com/mapmachine/ax/atlas_mapframe.html
http://www.ngdc.noaa.gov/mgg/geology/tar_info.html
http://www.spaceimaging.com/level2/prodhigh.htm
http://www.spin-2.com/
http://www.pci.on.ca/
http://www.cast.uark.edu/
http://www.utexas.edu/depts/grg/gcraft/notes/remote/remote_f.html
http://terraserver.microsoft.com/
http://edcwww.cr.usgs.gov/webglis
http://www.sciam.com/
http://www.nps.gov/gis/
http://164.214.2.59/sandi/arch/
http://mcmcweb.er.usgs.gov/drg/
http://www.ghcc.msfc.nasa.gov/archeology/
http://www.nima.mil/
http://data.geocomm.com/
http://www.gjc.org/
http://www.nr.usu.edu/Geography-Department/rsgis/tutor.html
http://rst.gsfc.nasa.gov/ToF/C/Coverpage.html
<table>
<thead>
<tr>
<th>INDEX</th>
<th>Pages</th>
</tr>
</thead>
<tbody>
<tr>
<td>ACAD</td>
<td>1, 45, 46, 58, 59, 61, 62, 64, 72, 75</td>
</tr>
<tr>
<td>Arcview</td>
<td>1, 45, 46, 59, 61, 62, 64, 75, 77</td>
</tr>
<tr>
<td>Bandelier, A.</td>
<td>21, 32, 33, 42</td>
</tr>
<tr>
<td>Bandelier National Monument</td>
<td>80</td>
</tr>
<tr>
<td>Bandelier Tuff</td>
<td>53</td>
</tr>
<tr>
<td>Cañada</td>
<td>40, 41, 49, 50, 54, 68, 69, 81</td>
</tr>
<tr>
<td>Cañada de Cochiti Land Grant</td>
<td>68, 69</td>
</tr>
<tr>
<td>Cochiti Dam</td>
<td>40, 41, 50, 81</td>
</tr>
<tr>
<td>Cochiti Pueblo</td>
<td>5, 6, 26, 29, 31, 40, 41, 42, 74-76, 80</td>
</tr>
<tr>
<td>Conservation</td>
<td>8, 9, 10, 63</td>
</tr>
<tr>
<td>CRM</td>
<td>1, 8, 9, 10</td>
</tr>
<tr>
<td>DEM</td>
<td>39, 46, 48, 50, 62, 70, 92</td>
</tr>
<tr>
<td>Dougherty, J.</td>
<td>34, 36, 42</td>
</tr>
<tr>
<td>GIS</td>
<td>1, 2, 7, 8, 11-24, 39, 44, 46, 47, 49, 50, 59-61, 65, 68, 80, 81, 92</td>
</tr>
<tr>
<td>Kotyiti</td>
<td>3, 5, 6, 10, 24, 26-28, 30-34, 38, 39, 42, 51, 57, 58, 62, 64, 65, 68, 69, 74, 76-81</td>
</tr>
<tr>
<td>KRP</td>
<td>5, 38, 39, 57, 60, 92</td>
</tr>
<tr>
<td>LA 84</td>
<td>26, 36, 42, 48, 49, 51, 54, 55, 65, 66, 68, 71</td>
</tr>
<tr>
<td>LA 295</td>
<td>24, 25, 26, 28, 33-36, 42, 48, 49, 51, 54, 65, 66, 68, 69, 71, 72, 73</td>
</tr>
<tr>
<td>Nelson, N.</td>
<td>21, 28, 32, 34, 42, 43</td>
</tr>
<tr>
<td>NPS</td>
<td>8-10, 19, 20, 42, 59, 60, 78, 92</td>
</tr>
<tr>
<td>Preservation</td>
<td>1, 2, 5, 7-10, 37, 62, 63, 65, 68, 74, 78, 80</td>
</tr>
<tr>
<td></td>
<td></td>
</tr>
<tr>
<td>---</td>
<td>---</td>
</tr>
<tr>
<td>SFNF</td>
<td>3, 10, 34, 68, 69, 78, 79, 80, 92</td>
</tr>
<tr>
<td>USGS</td>
<td>19, 40, 41, 43, 44, 45, 46, 49, 50, 59, 60, 62, 92</td>
</tr>
</tbody>
</table>
Please return this book as soon as you have finished with it. It must be returned by the latest date stamped below.