The Impact of Digital Data Ecosystems on Our Understanding of the Greater Chacoan Cultural Landscape

Assessing Geospatial Information, Remote Sensing, and Aggregating Roads Data

Carrie C. Heitman and Sean Field

Watch the video version of this chapter, recorded at Crow Canyon Archaeological Center on August 14, 2017.
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Our contribution to this volume on the Greater Chaco Landscape (GCL) is both retrospective and prospective, covering where we have been with regard to specific forms of geospatial, remote sensing and prehispanic roads data and where we might go in light of current work. As anthropologists, we would also like to place these efforts in a broader frame as there are a number of “big picture” issues that emerge from the projects discussed here. We begin with some broad observations and cautionary notes about how cultural resource information is accessed and used for making land management decisions. In light of the threats to the GCL, we take a closer look at how New Mexico site data is recorded, managed, updated, and shared. We then review three recent data aggregation efforts and provide insights on the lessons learned and the ongoing needs demonstrated thereby. These projects include a reconciled Geographic Information System (GIS) database on Chacoan great house locations, a NASA collaboration to identify sites at risk using remote sensing technologies, and aggregated data on Chacoan roads.

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IMPACTS OF DATA SEGREGATION

When land management agencies, such as the Bureau of Land Management (BLM), make oil and gas leasing decisions, they depend upon digital data ecosystems such as a Geographic Information System (GIS). Their GIS in turn relies on other digital data ecosystems (e.g., the New Mexico Cultural Resource Information System, or NMCRIS) to gather and import archaeological site location data into their GIS to help inform their land management plans. In short, data-driven decision making currently requires mediation between various digital data platforms or ecosystems. And while this is a perfectly reasonable workflow to help inform land management decisions, there are inherent weaknesses in these systems that have real-world (and sometimes compounding) consequences for land managers, archaeologists, researchers, and landowners.

In this era of digital data and quick-access expectations, nondigital data, such as paper maps or printed data tables that survive outside of these digital data ecosystems, effectively do not exist. The intermediation between separate data ecosystems is further confounded by incomplete digitization efforts given that older archaeological records (also known as legacy data) do not necessarily exist in digital form. In such cases, even bad digital data that is easily accessible can supersede good, analog data that is more difficult to track down. What’s more, data segregation (Balkanized in separate digital data ecosystems such as those maintained by state or federal agencies, tribes, or separate scholarly networks), has hampered our collective ability to manage and preserve the Greater Chaco Landscape due to inaccurate locations or incomplete site information within some of these bureaucratically authoritative systems.

From a research perspective, such Balkanized practices have resulted in inefficient, duplicated efforts to refine those data. No singular entity or agency has the authority or sufficient resources to continually gather and reconcile both older, legacy (historic) data from the last 125 years and new archaeological data (e.g., raw or processed LiDAR data) about the Greater Chaco Landscape. Hence, relying on one set of site location data (e.g., NMCRIS) can lead to land management decisions based on incomplete or perhaps even inaccurate data. Academic and applied cultural resource specialists are not fully integrated within any one of these data ecosystems. As a result, we cannot always effectively share new findings and learn from one another. Academic archaeologists working outside of the cultural resource management sector, for instance, do not routinely review or contribute their research findings to state databases such as NMCRIS. The converse is also true whereby new work conducted by cultural resource management (CRM) professionals does not
always (or efficiently) reach academics. New observations and interpretations may therefore proceed on separate, albeit parallel, tracks. Similarly, the Chaco Culture National Historical Park unit of the National Park Service (NPS) does not routinely share federal archaeological site data with NMCRIS. The ramifications of incomplete and Balkanized data for the successful management and protection of cultural landscapes should concern cultural heritage specialists of all stripes. And yet, the challenges are bigger still.

**Constraints of Information Architecture**

We must also look closely at what these separate digital data ecosystems both enable and constrain by virtue of their internal information architectures: how the fields, values, and data table relationships were constructed when the systems were designed. Databases engineer data values to enable specific kinds of queries and bring order to human observations. This might be as simple as restricting date input formats (e.g., DD/MM/YYYY) or as complicated as providing an authoritative controlled vocabulary for archaeological site type designations. And while the observations of a particular field archaeologist may not fit a proscribed database category, analysts are often constrained by systems that were designed with specific end-goals in mind. We refer to this process as the technocratic tyranny of digital data ecosystems, or what Athina Karatzogianni and Jacob Matthews (2017) have (somewhat tongue-in-cheek) referred to as “evil intermediation platforms.”

These challenges are well documented and have been the object of vibrant discussion within the digital humanities (e.g., Bailey 2011; McPherson 2012; http://transformdh.org/) and anthropological discourse (e.g., Kelty 2017). “Much of the work in the digital humanities,” McPherson points out, “proceeded as if technologies from XML to databases were neutral tools” (McPherson 2012:142). In order to push back against the systems that constrain and enable certain kinds of knowledge production, McPherson argues we need to critically engage with these systems and expand the pool of practitioners: “We need database literacies, algorithmic literacies, computational literacies, interface literacies. We need new hybrid practitioners: artist-theorists, programming humanists, activist-scholars; theoretical archivists, critical race coders. We need new forms of graduate and undergraduate education that hone both critical and digital literacies” (McPherson 2012:154). The tools and the information architectures we build, McPherson argues, are products of our human biases and engineered to suit the goals of the developers.
At the same time, digital information architectures are often hampered by technological limitations. Chacoan roads provide a vivid example. In earlier versions of NMCRIS, the information system was not able to accommodate linear archaeological features. All sites, including roads, were recorded as centroids or circles (think “dots a map”). The larger the recorded site area, the bigger the circle diameter on the NMCRIS map. And so for linear features such as prehispanic roads, the only way to previously display them within NMCRIS was for the linear extent to display as the diameter of a circle. The map would display a circle that was as big as the road was long. This is a case of a data system that was engineered to display a specific kind of information being stretched beyond its original design constraints. And yet, the real world is always messier than the systems we devise to record information about the world. What happens, for instance, when a land management agency decides to apply a circular buffer zone of 10 m or 100 m to a GIS data point for a Chacoan Great house community that does not conform to the centroid or circular datapoint expectations (Van Dyke et al. 2016) born out of such data ecosystems?

The prior example is not only a potent reminder of how technical limitations can hamper our ability to represent archaeological features, but it also reminds us that these digital viewing platforms (e.g., GIS environments, Google Earth, Google Maps, etc.) both enable expansive perceptions of landscapes over time while simultaneously removing us from the human scale and embodied experience of space and place (see Van Dyke et al., chapter 11 in this volume). So for those of us accustomed to apprehending, interpreting, and managing landscapes through these computer-mediated interfaces, we must recognize how these visualization platforms remove us from the real-world experiences and embodied impacts for the human occupants and stewards who live in these places.

There can be no doubt that tools such as GIS provide us with a robust toolkit for archaeological recording and analysis. Our goal here is not to reject these tools but rather to shed light on their strengths as well as their limitations in light of current Chacoan research and preservation efforts. Not all of the management, preservation, and research challenges facing the greater Chacoan landscape can currently be addressed through technical solutions, nor can we expect future technical advancement to entirely remediate those challenges; therefore, we cannot uniformly succumb to the siren song of technocratic solutionism. In theory, we might all agree with the principles of data-driven management and governance as well as promise of expansive digital futures. But what happens when we have bad data? Or when our information architectures
are inadequate for the needs at hand? What happens when the expansive purview of landscape recording infrastructures infringe on the sovereignty of Native lands? Geospatial viewers provide unfettered access to global locations. If we take the 27,413 sq. mi. Navajo Nation as but one example, under what conditions can or should data about cultural resources on Navajo Nation lands circulate, be considered, or represented by academics and land managers?

Causes for Optimism

While there are a number of challenges for effectively protecting the greater Chacoan cultural landscape, there are also a number of reasons we are optimistic for the future. In the remainder of this chapter, we will highlight and review various recent cases of productive data sharing. As a result of such efforts, we are learning from one another and learning to make better use of historical or legacy data. What’s more, this volume and the working conferences that led to its creation are very tangible signs of success as archaeologists and cultural heritage specialists endeavor to collaborate for the protection and preservation of greater Chaco.

GEOSPATIAL DATA

As a sister agency to the BLM, the NPS has an active interest in the land management decisions that impact the Greater Chacoan cultural landscape. In 2013, Tom Lincoln (NPS) and Steve Lekson of the University of Colorado, Boulder, began developing a Rocky Mountain Cooperative Ecosystems Study Unit (CESU) Task Agreement that would outline the research and preservation needs for the Chaco landscape. In collaboration with Dr. Ruth Van Dyke and myself, we developed a proposal for a series of activities that would help address these needs (see chapter 1, this volume).

In 2013, prior to the CESU agreement, Dr. Van Dyke and Dr. Heitman had started talking about the separate but parallel GIS developments that were focusing on Chacoan great house locations and descriptions. Between the two of us, we knew of at least three or four such efforts that had started with the same data but had then gone on to refine and augment those data for their own research purposes. In light of the management challenges for the greater Chaco landscape, we saw a real need to bring these efforts back together (see figure 14.1).

During our early meetings with then–assistant director of cultural resources, Tom Lincoln (see chapter 17, this volume), we identified a number of needs or gaps in Chacoan Landscape research data. The planned activities included
an initial stakeholders meeting, a GIS reconciliation project, the publication of a white paper (Van Dyke et al. 2016), a subsequent conference with video recorded presentations, and this resulting publication. The senior author’s home institution, the University of Nebraska–Lincoln, took the lead on the GIS reconciliation project.

In 1999, ten archaeologists worked together to assemble a comprehensive database reflecting what was known about great houses and the communities in which they were built. Each archaeologist focused their attention on the region of the Southwest that they knew best, reviewing records for every great house in that area. A standardized set of variables was collected, and each participant also added annotated information and references for each great house. The resulting database served as a focus for discussions when twenty-two archaeologists met at Arizona State University to consider issues related to Chacoan patterns outside of Chaco Canyon. This meeting, called the Chaco World Conference, was sponsored by the NPS, University of Colorado, and Arizona State University. It was one of several such seminars that took place around the Southwest as part of the final stage capstone for The Chaco

**Figure 14.1.** GIF animation (for web) / static figure (for print) showing the ongoing process of the geospatial Chaco Great House data’s disaggregation and reaggregation. Image by Carrie Heitman.
Center research project, which investigated Chaco Canyon during the 1970s and 1980s.

In 2001 the National Center for Preservation Training and Technology awarded a grant to build a complete online spatial database using the results of the 1999 Chaco World Conference. This spatial database, titled The Chaco World Database, was built and maintained by John Kantner from 2001 to 2007 and hosted at Georgia State University. The Chaco Canyon Outlier Database was built by Dr. Kantner and generously donated to the Chaco Research Archive (CRA) in 2011. In 2012 the Chaco World data were supplemented with contributions from various researchers.  

The CRA wanted to responsibly use this GIS to publicly share general information about the extent and organization of the greater Chacoan world. This meant coming up with creative solutions to obscure UTM locations of Chacoan site locations within the outlier great-house database (http://www.chacoarchive.org/bibl_database/greathouses/map). We had limited resources available to address this challenge, and so our senior developer, Robert Bingler, came up with a creative process and low-cost solution to dynamically re-project those site locations elsewhere in the world each time the Google Maps API loads. We also had to use a deliberately low-resolution background satellite image so that modern roads and access routes would be less visible to the user relative to archaeological site locations. This process is invisible to the user, who sees the same satellite imagery and observes the sites in their correct locations relative to the image and to one another. But for those looking to access site locations from the page’s HTML source code, that information has been deliberately altered. The senior author has referred to this elsewhere as “moderated openness” (Heitman 2019). Why not just omit information about the great house locations altogether? We felt it was important to give CRA users a sense of the full geographic extent of the Chaco World, and we needed a map to be able to do that effectively. One might also ask why we should even bother to go through such machinations to obscure site locations given the public accessibility of high-resolution satellite imagery via Google. The answer is that we have a responsibility to not be the purveyors of any information that can be used by looters to do harm to these cultural resources.

In the intervening years after the Chaco World Database was published via the Chaco Research Archive, various researchers were busy refining and expanding from that same original Chaco World Database. In July 2015, the senior author hosted four scholars for a Chaco GIS Summit to help aggregate existing geospatial datasets, discuss how to resolve existing discrepancies, and
decide if/how to share these data with scholars and the public. The project team included

- University of Nebraska–Lincoln (UNL) / Chaco Research Archive dataset (C. Heitman, project lead)
- Southwest Social Networks dataset (P. Reed, M. Peeples)
- Binghamton University dataset (R. Van Dyke and K. Bocinsky)
- Independent Scholar (R. Friedman)
- UNL’s Center for Advanced Land Management Technologies (M. Vaitkus)

Through collaboration with UNL’s Center for Advanced Landscape Management Information Technologies, we were able to quantify discrepancies in great house site locations, reconcile those discrepancies into an authoritative dataset, and create the necessary GIS metadata. The final stages of this process are outlined in table 14.1. Together we identified and reconciled disparate UTM locations for 49 sites and were able to aggregate reconciled data on 262 total great house community locations. The resulting GIS (Heitman et al. 2016) was shared with the BLM Farmington Field Office as well as the NPS. The Chacoan Great House Community dataset is not intended to be comprehensive, but it is currently the most complete and accurate information available for Chacoan great house locations within the greater Chaco Canyon cultural landscape. This dataset provides feature geometry representations (point only) and is intended to be supplemented with descriptive attributes maintained by other external database systems.

COLLABORATION BEGETS COLLABORATION: NASA DEVELOPMENT PARTNERSHIP

In the midst of these activities in the spring of 2016, Tom Lincoln was approached by NASA’s DEVELOP program to see if he had any NPS projects in mind that might benefit from NASA data and expertise. Richard Friedman and others (Friedman et al. 2017, chapter 13 in this volume) have been able to show how LiDAR data can dramatically enhance our ability to locate prehispanic roads. With Friedman’s prior success in mind, we wrote a NASA DEVELOP proposal focused on developing LiDAR workflows and data-processing methods to identify previously unrecorded Chacoan landscape features. The NASA program did not have the capacity to obtain
Table 14.1. Outline of the process of reconciling the two most complete great house community databases.

<table>
<thead>
<tr>
<th></th>
<th>Van Dyke et al.</th>
<th>SWSN</th>
<th>Reconciled</th>
</tr>
</thead>
<tbody>
<tr>
<td>Number of sites in original dataset</td>
<td>366</td>
<td>464</td>
<td></td>
</tr>
<tr>
<td>Matched by location and UNIQUE_ID</td>
<td>208</td>
<td>214</td>
<td>213</td>
</tr>
<tr>
<td>Sites unique to dataset</td>
<td>111</td>
<td>203</td>
<td></td>
</tr>
<tr>
<td>Sites matched by UNIQUE_ID only</td>
<td>47</td>
<td>47</td>
<td></td>
</tr>
<tr>
<td>Total Number of sites analyzed for location differences</td>
<td>47</td>
<td>49</td>
<td></td>
</tr>
<tr>
<td>Total number of sites in final dataset</td>
<td></td>
<td>262</td>
<td></td>
</tr>
</tbody>
</table>

Source: Van Dyke et al. and the Southwest Social Networks.
Note: Shrines and other non-great-house site locations were removed from both datasets prior to reconciliation.

additional LiDAR data for the San Juan Basin, so we worked together to develop an alternative proposal.

Over a series of conference calls and shared documents, we came up with a project proposal that would utilize existing NASA data in hopes of identifying a more cost-effective method and workflow for identifying cultural landscape features in the San Juan Basin. Our main objective was “to identify Chacoan community signature profiles, such as roads, villages, middens, and structures, throughout the San Juan Basin to help with preservation and protection strategies by using NASA Earth observations.” The project was thus named “Chaco Canyon Cross-Cutting.” Our objectives for this project included using remotely sensed data to identify areas with the potential to contain unknown Chacoan features as well as identifying known Chacoan sites and roads that are in areas that could be threatened by encroaching infrastructure. Additionally, we sought to further delineate known Chacoan sites and roads using remotely sensed data. The NASA team focused on a smaller study area within the greater Chaco Landscape (figure 14.2).

Two data sources created and supplied by UNL were fundamental to this project’s success. The team relied on the reconciled GIS of Chacoan Great House locations (put together by Heitman et al.) as well as the GIS of prehistoric Chacoan roads created by Sean Field for his MA thesis research (discussed below).

The NASA project created a Chacoan Sites Risk Map to identify areas where Chacoan sites would be at risk from developing infrastructure. Risk was defined in the model as any area in close proximity to one of the following: (1) areas with an expected population increase from 2015 to 2020, (2) existing roads, (3) existing or planned oil and gas drills, and (4) perennial hydrological
features. They used the “Fuzzy Membership” tool in ArcMap 10.3 to assign a fuzzy membership between 0 and 1 to each variable. Spread, midpoint, and membership type were decided based on a review of the literature describing the size and extent of these variables.

The NASA risk map (figure 14.3) suggests that a large area of the San Juan Basin is being impacted by developing infrastructure. Forty-five of the 123

Figure 14.2. NASA DEVELOP Chaco Canyon Cross-Cutting study area.

Figure 14.3. NASA DEVELOP Chacoan Sites Risk Map.
(37%) known Chacoan great houses in the study area are at a high risk for disturbance from developing infrastructure. Fortunately, thirteen of these sites are already protected by National Park Boundaries and at least three others are protected by the Bureau of Land Management as “Areas of Critical Environmental Concern.”

This project revealed both the potential and challenges of using remote sensing to identify and describe ancient Chacoan sites in the San Juan Basin. The NASA project analysts concluded that higher-resolution satellite imagery is needed to delineate known ancient Chaco sites and roads and to identify new sites and roads. Their risk map showed that many Chaco sites and roads are at risk from developing infrastructure, and they highlighted particular areas within the San Juan Basin that we recommend be given priority in protection strategies. Future NASA ECOSTRESS and HysPIRI missions will provide thermal data that can be used to identify archaeological features in Chaco Canyon and throughout the world.

Looking ahead, we have a number of leads we’d like to explore. In addition to doing more work with the HyTES data, we’d like to compare the relative cost of flying HyTES imagery relative to LiDAR to see how we might best leverage this technology. We’d also like to look for intersections where known prehistoric roads have now been impacted by active oil and gas wells or access roads. We also plan to look at other “high value” areas to see if these same data sources might reveal additional archaeological features. Our ultimate goal is to leverage these technologies to better document and protect these fragile cultural resources and to help guide future research.

AGGREGATING ROAD DATA

The challenges of identifying prehispanic roadways has resulted in significant variability in the estimates, interpretations, and representations of the Chacoan road network. Consequently, there is no consistent researcher-based documentation on the Chacoan road system, resulting in a “general uncertainty as to the empirical basis for evaluating Chaco roads—thus hindering our ability to better understand what they are” (Snead 2017:2). This uncertainty is easily demonstrated in the numerous maps delineating the Chacoan road network (see Betancourt et al. 1986; Friedman et al. 2017; Kantner 1997; Kincaid et al. 1983; Snygg and Windes 1998). Although similarities exist, the cartographic variation demonstrated in these maps directly impacts (1) researcher interpretations of Ancestral Puebloan relationships at a landscape scale and (2) land management efforts. For instance, how can we understand the
cultural affiliation between sites if we have not accurately documented the physical features (i.e., roads) that connect those sites? Furthermore, how can we protect and manage features or cultural landscapes that are inconsistently documented? Therefore, addressing the confusion on Chacoan roads (and thus changing the negative consequences that follow) is a vital objective in continuing the preservation and archaeological analysis of the Chacoan cultural landscape. Overcoming this challenge requires reconciling many existing inconsistencies in Chaco road data. This reconciliation has proven difficult due to several key factors:

1. Shortcomings in the geospatial documentation of Chacoan roads
2. Difficulties in reconciling diverse data types
3. Feature degradation

Recognizing and accurately documenting prehispanic roads is complex, fuzzy work, which makes empirical validation of entire road surfaces difficult. Chacoan roads are archaeologically ambiguous; they are difficult to identify on the surface, do not share wholly consistent characteristics, and are not ground-truthed in many places. Further, long-distance roads have most often been interpreted phenomenologically, where short linear depressions that appear to align are translated as continuous features. These challenges have not stopped researchers from delineating large regional roads throughout the San Juan Basin. Take, for instance, the empirical basis for the South Road—considered by many as one of the most prominent regional roads that extends from Chaco Canyon. The Chaco Roads Project (Kincaid et al. 1983; Nials et al. 1987) documented most of the South Road via aerial photography, but only a small portion of the corridor was ground surveyed, and only ~6 km of the road was mapped with high locational accuracy in the project’s final report. Small sections of the road, in the area surrounding the Kin Yá’a outlier, are also mapped in John Kantner (1997), but these too only represent a fraction of the entire road surface. Therefore, even though researcher consensus validates the South Road as a long prehispanic feature, our geospatial documentation of it is poor.

Diverse data types, housed in variable formats, by multiple agencies, and in different databases, also provide significant challenges for reconciling Chaco road data. Foremost, accessible road data (especially geospatial data) is relatively sparse. The best exceptions are analog datasets created from aerial photography, gathered by the Chaco Roads Project (Kincaid et al. 1983; Nials et al. 1987) who published both specific and generalized location maps. However, few source images were published by the Chaco Roads Project or other reports,
and currently, most aerial data exists in analog form and can be accessed either through BLM offices or R.GIS.UNM, requiring various monetary, technological, and time allocations. Similarly, digital data on Chacoan roads exists in fragmentary datasets belonging to independent researchers, institutions, or universities. Integrating digital data, especially geospatial data, carries its own complications, which are reviewed earlier in this chapter. Due to these access issues, full aggregation of high-resolution data for the regional road system has yet to be successfully achieved.

Feature degradation is perhaps the most pressing threat to reconciling Chacoan road data. There is no doubt that roadway features are becoming more and more difficult to identify in the landscape, and in many cases they cannot be observed on the surface without additional sensing methodologies. As the NASA DEVELOP partnership demonstrated with the Holmes Group, HyTES data have allowed for the identification of roadway features when traditional aerial/satellite imagery has proven ineffective. Further, recent work by Friedman et al. (2017, chapter 13 in this volume) has demonstrated highly effective use of LiDAR for documenting the North Road. Although expanding sensing parameters is an exciting option for the future, it is imperative that we review, coalesce, and digitize legacy data to realize the rate of feature erasure in the region and efficiently direct additional remote sensing technologies. To better contextualize how legacy data can increase our understanding of the Chaco road network, we refer to a case study of the Pueblo Pintado to Chaco Canyon Road.

The Pueblo Pintado to Chaco Canyon Road is hypothesized to connect Pueblo Pintado with the eastern mouth of Chaco Canyon. Today the origin of this road is protected within the Pueblo Pintado protected boundary, and the assumed termination of the road (which is open for interpretation) would also be protected within the Chaco Culture National Historical Park, both of which are managed by the NPS. The identification and extent of this roadway are supported through ethnohistoric evidence (Kincaid et al. 1983) and aerial imagery taken by the Soil Conservation Service (SCS) in the mid-1930s. Over the years skepticism has grown, questioning whether the road is actually a fully continuous segment. This skepticism is evident in published maps (from research directly analyzing the Chacoan road system) that do not delineate the feature (see Betancourt et al. 1986, and Kantner 1997), which is likely a result of degradation and decreased visibility of the feature over time. To contextualize the variation in the Pueblo Pintado Roads signature profile across time, we review a host of survey data (figure 14.4) on the road gathered in the last half-century.
In the SCS aerial imagery, the road is marked by four aligning depressions, which emanate several kilometers northwest from rooms 18 and 22 of Pueblo Pintado. These aligned segments are highlighted here (figure 14.5) to demonstrate the continuity of characteristics in width, coloration, and context shared among each of these linearities. Aerial imagery and ground survey conducted on behalf of the Chaco Roads Project in the 1970s and 1980s revealed a long, semicontinuous segment of the road (see Kincaid et al. 1983:fig. 5-3), noting considerable vegetation differences between the general landscape and the roadway surface. At the time of the ground survey, this vegetation difference was readily visible for much of the distance between Pueblo Pintado and the head of Chaco Canyon. Unfortunately, aerial imagery covering the full distance from Pueblo Pintado to the canyon was not published with the report. Reviewing aerial imagery taken by Jacob Smith III in 1991 (figure 14.6), and donated to the University of Nebraska–Lincoln (UNL), it is clear that most of the Pueblo Pintado Road had become largely undetectable through aerial surveillance by this time.

While the short segment within the protected boundary is observable, no other segments outside of the protected boundary can be confidently
identified. Interestingly, modern remotely sensed data demonstrate conflicting reports for the presence and quality of this road. Modern (2017) Google Earth LANDSAT data do not support the presence of a continuous feature; again, only the short segment within the protected boundary is visible. However, LiDAR data conducted, processed, and shared by the BLM Farmington office in 2017 tells a different story. Most of the segments seen in the 1935 SCS imagery are also present in the modern LiDAR data (figure 14.7).

In examining this chronology, we observe a decreased ability for aerial photography to detect the Pueblo Pintado to Chaco Canyon road. Specifically, we cite a difference between the 1935–1983 and the 1991–2017 timeframes, wherein the former displayed greater feature visibility. Although this trend has been previously recognized (Kincaid et al. 1983:4-4), we direct attention to the speed of recent feature degradation through certain methodology. From this comparison we find that the Pueblo Pintado to Chaco Canyon Road, a once highly visible feature, became invisible through aerial photographic methodology between the years 1983 and 1991. Additionally, this degradation appears to be prominently impacted by land management decisions. In the 1991–2017 imagery, the only viable segments are within the protected boundary, while
all segments outside of that boundary are either completely absent from the landscape or are decontextualized by modern infrastructure (two-track roads, dirt-pack roads, and fencing).

Advances in remote sensing technology provide a possible response (but not a solution) to feature degradation. As demonstrated here and in Friedman et al. (2017, chapter 13 in this volume), LiDAR has proven useful in detecting prehispanic roads when traditional imaging methodologies were not successful. Further, the efficacy of the BLM acquired LiDAR as shown here should signal for increased collaboration between researchers and federal agencies to pursue joint efforts of advanced remote sensing survey of prehispanic roadway features.

Even though LiDAR supersedes aerial imagery as a detection tool, we argue that if similar sensing technologies reveal different feature signatures over time, there must be degrading landscape shifts of some form. Advances in sensing technologies should not be seen as solutions to the forces that impact feature degradation. Through the use of aerial imagery, coupled with a reassessment of ethnohistoric and archaeological legacy data, we have
demonstrated that unprotected Chacoan roadway features are vanishing in some capacity from the landscape. Extant roadways outside of protected boundaries are demonstrated to be at a greater risk. If the landscape shifts exhibited here are applied to the region as a whole, it is plausible that we are left without indication or awareness of the extent of the Chacoan road network, leaving researchers empirically blind to the extent of the Chacoan cultural landscape.

We have thus outlined the primary factors that challenge the reconciliation of Chacoan road data, an obstacle that has certainly exacerbated the cartographic miscommunications seen in Chacoan road representations and the varied interpretations of where prehispanic roads are, where they lead to, and what they look like. While data reconciliation challenges cannot be immediately overcome, we contend that some of the confusion regarding Chacoan roads can be addressed through different cartographic methods. In most maps outlining the Chacoan network, all roads are given one or two symbolic representations, leading to unilateral interpretations of their actual presence within.
the landscape and significant misconceptions that may unintentionally misdirect preservation efforts or misinform our understanding of the past. To counteract these challenges, we propose demonstrating Chacoan roads through more diverse symbologies. Under this system, roads would be given a confidence ratio that is determined through two confidence variables described as the following.

Presence confidence—degree of confidence that road is prehispanic in origin and exists in the landscape, connecting specific places

Geospatial confidence—degree of sensing/survey confidence that describes specific location and extent of verified road surface

We have constructed a generalized confidence map of the major Chacoan roads (figure 14.8), populated from maps published by the Chaco Roads Project (Kincaid et al. 1983; Nials et al. 1987) and a popular NPS map (2000), to illuminate the diversity in research‐based consensus on Chacoan roads.

We demonstrate a confidence map with three road qualifications. Roads qualified as “road alignments” have both high presence and geospatial confidences; “projected road alignments” have moderate presence and/or geospatial confidences; “suggested road alignments” have low presence and/or geospatial confidences.

We do not intend for this map to be disseminated on the basis of geospatial accuracy, but rather to be employed as a heuristic guide; this map demonstrates a far different interpretation of the Chacoan road network from what has been communicated in the past, and it highlights the challenges faced in aggregating Chaco road data. Confidence ratios seen here are nonuniform and complex, largely due to the factors we have spent time reviewing—shortcomings in the geospatial documentation, diversity of data types, and feature degradation.

CONCLUSIONS

In conclusion, we would like to make a number of recommendations. Collectively, we need to (1) acknowledge the cumulative and lasting negative impacts data segregation has had on our ability to document, preserve, and manage the Greater Chaco Landscape; (2) foster awareness of the weaknesses and potential improvements for the digital data ecosystems on which we rely; (3) incorporate legacy data sources into land management decisions; (4) recognize that some of our digital data ecosystems have the capacity to infringe on the sovereignty of Native lands and take appropriate actions to
Figure 14.8. Chacoan Road Confidence Map. Graphic by Sean Field.
prevent this; and (5) promote and support responsible data sharing and the timely dissemination of research findings. While there is no perfect digital data ecosystem, we have an opportunity and an obligation to do the most with the information in hand.

NOTES
3. Paul Reed (Preservation Archaeologist and Chaco Scholar, Archaeology Southwest) provided comparable information about the Salmon Pueblo great house. R. G. Matson and Bill Lipe, Mark Varien, Scott Ortman, and Susan Ryan also provided updated information on various sites.

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