GIS AND THE PREHISTORIC LANDSCAPE:
AN EXAMINATION OF APPLICABILITY

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Chapter I

Introduction

Can a geographic information system (GIS), which relies on known geographic data as the input for analysis, be used to examine prehistoric landscapes where the geographic data are unknown? The use of GIS in historical studies has become more prevalent in the past decade. Researchers from different disciplines, such as historical geographers and archaeologists, are utilizing the technology to investigate such topics as agricultural patterns, demographic changes, landscape visibility, and human movement through a landscape (Conolly & Lake 2006; Gregory & Ell, 2007; Knowles 2000; McCoy & Ladefoged 2009). Data such as archival maps, census records, and terrain information are used as the input for the GIS. There are difficulties, however, when studying prehistoric landscapes using a GIS. Issues such as the availability and accuracy of the data, landscape changes since the time period under study, and even general concurrence on the geographic location of the site in question must be considered.

The application of GIS to study prehistoric landscapes is dependent upon the type of landscapes studied. The large floodplain across the Mississippi River from modern-day St. Louis was the setting for the largest prehistoric urban area on the North
American continent north of Mexico (Fowler 1974; Hall 1991; Pauketat & Emerson 1997). The residents of what we refer to as Cahokia were able to utilize a wealth of natural resources, favorable agricultural conditions, and a location near the confluence of three major rivers to create a civilization whose influence at its peak (AD 1050-1275) stretched across the whole of the midcontinent. Artifacts characteristic of Cahokia (or imitations of those styles) have been found from Oklahoma to Minnesota to Tennessee. This exchange network served as a case study for the applicability of using GIS on a prehistoric landscape.

This study consists of six sections. First is review of the relevant literature on movement and mobility, cultural geography, historical GIS, and the use of GIS in archaeology. Secondly, the model used for this case study is discussed. A least cost path analysis was conducted in an effort to visualize travel routes between Cahokia and other sites. It should be noted that this model is simply one way of examining the applicability of GIS to prehistoric landscapes and is not meant to preclude other approaches to assessing applicability.

The third element of this thesis provides a background of Cahokia, the artifacts and features which are significant to the identification of a Middle Mississippian site, and the archaeological sites utilized in the model. Next is a discussion of the results generated by the model for each least cost path. Fifth is a discussion of the overall findings of the research. Finally, conclusions are drawn concerning GIS and prehistoric landscapes.
This case study of Middle Mississippian exchange illustrated some of the issues and limitations involved when a GIS is utilized to examine a prehistoric landscape. An understanding of these limitations is the key to GIS’s applicability. The scope of any individual project will dictate whether GIS is applicable for that project.
Chapter II

Literature Review

Mobility is not just a synonym for movement. Within the discipline of geography, it is the combination of movement and the situation, meaning, and context in which that movement takes place (Adey 2010; Cresswell 2001). Through context and meaning, geographers point to factors such as the landscape through which the movement takes place, its purpose, the significance placed on that movement by society, and how other cultures interpret it. It is the context, the answer to the “why” question, that makes understanding and interpreting mobility possible.

Discussions of mobility are often couched in terms of sedentism and nomadism (Adey 2010). People and cultures which tend toward sedentism focus on the meaning of place to the exclusion of the space in between those places. Nomadism reflects people and cultures which value the space and movement between the places. This is not simply a discussion of nomadic and sedentary cultures in terms of their subsistence practices such as hunter/gatherers or agriculturists. Rather, it is a function of the worldview of that person or culture and placing more value on either place or space. These two world views also provide substance for critical theoretical approaches as well as social and political movements (Deleuze and Guattari, 1987).
Within an emerging cultural landscape tradition, Sauer (1944) examined the movement and spread of the first migrants into what are now the Americas. This tradition viewed movement as a part of the creation of the cultural landscape. Movement through the physical landscape is an expression of the cultural perceptions and attitudes about that physical landscape - the context on which mobility is formed. Sauer’s suggestions for routes of migration into both continents were based on such variables as regional climates, vegetation types and coverage, topography and hydrology, estimates of the skill sets of the people, and glacial extent. For example, the timing of migration into what is now South America would have depended upon the extent of the rain forest. He noted that, if the migration was later in time when the climate was similar to that of modern times, the dense forest and swamps would have created an impenetrable barrier to humans without the skills to work their way through. However, if the migration was at an earlier time when the climate was less favorable to the development of the rain forest, passage south would have been much easier.

Current studies in socio-cultural geography suggest a more iterative relationship between the natural environment and the cultural environment (Mitchell 2000). For example, Wylie (2006) discusses how the personal and cultural subjectivities of an individual will impact that individual’s perception of a landscape. In the context of British rail travel, Bissell (2008) examines the relationship between the visual practices of the passengers and the landscape. McCormack (2008) uses dance to study cultural geography by looking at not only the varying ways in which bodies move, but also the spaces in which that movement takes place. Alternatively, Whatmore (2006) discusses...
the rematerialization of cultural geography through the physicality of movement and its impact on cultural geography.

A geographic information system can help the researcher visualize movement in an effort to understand mobility. Kwan (2002) has used GIS in the context of feminist geography to examine space-time mobilities of African-American women in Portland, Oregon. This study indicated that this group was more restricted in their movements than any other ethnic group. Kwan’s geovisualizations use 3D space with the 4th dimension of time to create time-space diagrams that have propelled more recent explorations of everyday mobility and of developments in qualitative GIS (Cope and Elwood 2009). This development, as well as that of critical GIS, has its roots in the ‘GIS wars’ of the 1990s which debated the merits of the technology and is even today based upon the tension in the relationship between the researcher and the technology (Schuurman 1999; Wilson 2009).

**Historical GIS**

Since the mid-1990s, the use of GIS by historical geographers has increased dramatically (Gregory & Ell 2007). An historical GIS incorporates information from historical sources such as archival maps and census records. The combination of spatial, attribute, and temporal information provides a method of research to visualize spatial patterns as well as see how those patterns change over time (Gregory & Ell 2007; Knowles 2000). An historical GIS can be developed utilizing geographical references contained in archival documents. For example, Dobbs (2009) used survey
measurements in eighteenth century land grant records to examine the pattern of European settlement in one area of North Carolina. The spatial and temporal aspects of the data revealed stages in the development of the settlement and the influence that a Native American trail had on that development.

When the data from archival maps are combined with that from historical documents, an even more robust GIS can be created. Wilson (2005) analyzed the changes in the environment through time and the human involvement in those changes by studying the extent of the forest in the Shenandoah Valley over time. Three sets of archival maps (the earliest dating to the Civil War) along with aerial photography and satellite imagery were combined with agricultural census data. This combination of resources was utilized to determine the timeframe and location of the maximum forest clearance and how that could possibly relate to soil conditions and the establishment of a national forest. An agricultural map from the early twentieth century of the Gila River Indian Reservation in Arizona plus information gathered through personal interviews at the time the map was surveyed have been used to analyze variations in the type of crops grown and field dimensions as they were impacted by the availability of water resources (Bigler 2005). Diminished water availability through time due to increasing upstream diversion is evident in the smaller size of newly established fields and the selection of less water-intensive grains over vegetables.

Data on social statistics are also enhanced through the use of an historical GIS which utilizes census records in combination with archival maps. The movement/mobility of populations over time can be examined through the use of
systems such as the Great Britain Historical GIS Project (Gregory & Southall 2002). Census data and maps for England and Wales dating back to the late nineteenth century were used as the base data for the project. The inclusion of information on parish boundaries provides for comparisons back to the Middle Ages. One issue with the data, however, was the changing of administrative boundaries over time. By utilizing target districts (in this case 1911 boundaries), researchers are now able to make equivalent comparisons. The system allows for calculations of net migration, even to the level of detail of age and gender.

GIS and Archaeology

Archaeologists have also used GIS to examine the places of the past (Conolly & Lake 2006; McCoy & Ladefoged 2009). As in other disciplines, a GIS used in archaeology can combine various types of data including aerial photography, historical maps, locations and information concerning artifacts, and ground survey information. These systems can be used in such applications as predictive modeling, intervisibility or viewshed analysis, and cost surfaces.

Predictive modeling uses the environmental and cultural variables associated with known archaeological site locations to predict where other sites might be located (Conolly & Lake 2006; McCoy & Ladefoged 2009). One example of this method is the development of a GIS to assist with archaeological research in the glacial environments of Wrangell-St. Elias National Park and Preserve (Dixon, et al 2005). The system – Modeling Archaeological Potential of Ice and Snow (MAPIS) – included such information
as the locations of known sites, physical characteristics of the glaciers, mammal ranges and trails, subsistence hunting practices, and lithic source locations. This system allowed archaeologists to focus their surveys in areas of highest probability for prehistoric artifacts, that includes certain types of glaciers and patches of permanent snow near caribou habitat and trails.

Many researchers have utilized GIS for intervisibility or viewshed analysis to study the visual context of a site – what can be viewed from that location, if it can be viewed from other locations in that area, and how it and other sites are visually connected (McCoy & Ladefoged 2009). One such study examined the intervisibility of rock platforms on hills surrounding the Paquimé site in northern Chihuahua, Mexico, to determine if they could have been used as signaling towers in a communication network (Swanson 2003). Data included the height of each platform, topography, and potential obstructions in the line of sight. The results indicated that the platforms could have been used for a signaling system which had a built-in redundancy such that no one point would have been isolated should a signaling station be unavailable. The addition of the examination of movement through a prehistoric cultural landscape has also been attempted through the use of GIS. Boaz and Uleberg (2000) utilized a viewshed analysis to determine potential reasons behind movements from one hunter-gatherer occupation site to another in a dynamic coastal environment.

Movement through the landscape can be modeled using cost surfaces and a least cost analysis. These methods apply a cost or energy expenditure to the movement from one cell to another in a raster grid. The costs are then accumulated to estimate a
potential pathway between two points on that grid. Such analyses can be used at various scales to study migration, trade, transportation, or rituals (Conolly & Lake 2006; McCoy & Ladefoged 2009). In a study similar to Sauer’s noted above, Anderson and Gillam (2000) used a GIS to suggest four possible sets of migration routes for the initial colonization of the western hemisphere. Utilizing data on the terrain, glacial extent, and the locations of Paleoindian archaeological sites, the researchers mapped an initial route through to the farthest end of each continent as well as secondary branches diverging to other regions.

Another cost surface analysis of the movement/mobility of prehistoric humans in what is now Michigan involved potential routes between various village sites and a set of earthworks believed to be a ritual center (Howey 2007). The elements factored into the cost surfaces were vegetation, water courses, and terrain. The accumulated cost of each path was then compared to the distance along that path to develop an index of the difficulty in travel from that specific village to the earthworks. This index provided a tentative link between the earthworks under study and another set of earthworks that had not previously been examined – that the location of the two sites was intentional based upon the ease of travel between them.

Geographic information systems have been used in a variety of ways to try to understand the many different aspects of a society, whether that society is a modern one or historical. The use of maps, documents, and other resource materials is essential in the development of the GIS in order to understand the context – the answer to the
‘why’ question. But what if the time period under study is prior to a written language or other documentation? Is a GIS applicable for an examination of a prehistoric landscape?

As noted above, an understanding of mobility requires a consideration of both the movement and the context in which that movement takes place. This research will attempt to determine the potential issues and pitfalls involved in the use of GIS to examine mobility through prehistoric landscapes. The anticipated outcomes will include a set of precautions for others to use when conducting their own studies in the use of GIS in situations where resource materials are scarce or non-existent.
Chapter III

Case Study: Middle Mississippian Exchange – Background

The site of Cahokia lies in the Mississippi River floodplain across from present day St. Louis. The site totaled over five square miles and included approximately 120 earthen mounds (Fowler 1974). These mounds were of various shapes and sizes and were used for a range of functions such as ceremonies and habitation. In the center of the site stands Monks Mound, the largest prehistoric structure in this hemisphere north of Mexico.

People of the culture we now know as Cahokia or Middle Mississippi inhabited the site from approximately 900 CE to 1400 CE with the height of its influence and power at approximately 1000 CE to 1200 CE during the Lohmann, Stirling and Moorehead phases (Fowler and Hall 1975, Hall 1991, Kelly 1991, Pauketat & Emerson 1997). The Middle Mississippian settlement system can be characterized as a hierarchical system consisting of three or four tiers of communities (Gregg, 1975, Pauketat 2004). The first tier was Cahokia itself. The second tier included other multi-mound settlements. The third tier was made of single-mound sites and the fourth consisted of villages and farmsteads. This system focused upon Cahokia as the sole
front-line community and the center of the political, religious, and economic activity.

Cahokia’s power and influence was certainly derived in part from its location near the confluence of three major river systems (Fowler 1974, Kelly 1991, Peregrine 1991). Evidence of the extent of this influence can be found at archaeological sites across the mid-continent from the Gulf of Mexico to South Dakota, from Tennessee to Oklahoma. It takes a variety of forms including goods manufactured in Cahokia (or locally-crafted goods created in a Cahokian style) being found at distant sites as well as earthen platform mounds and other building elements similar to those at Cahokia being utilized by other peoples. For example, pottery made of local material in a Cahokian style and platform mounds have been found in the Red Wing locality in southern Minnesota (Gibbon 1991; Gibbon & Dodd 1991; Rodell 1991). Evidence of exchange in the other direction can be found by the fact that materials from distant locations have been found at Cahokia. A more in-depth discussion of some of these items can be found below.

Whether the purpose of this exchange of goods and ideas was purely economic trade or was more political or ritualistic in nature is up for debate and could well depend on the particular item and location under discussion (Hall 1991, Pauketat & Emerson 1997). Exchange goods have been found in both elite burials and everyday habitation or workshop areas. Exotic artifacts have not been found at Cahokia in numbers which would indicate pure economic trade. This imbalance has led some to speculate that goods coming back toward Cahokia were more perishable in nature, such as bison meat or bow wood (Lafferty 1994, Tiffany 1991). Others have argued, however, that the
distances involved to the farthest sites would not lend themselves to an economically feasible trade agreement, but that the interaction would more likely have been either to enhance the power of both the Cahokian elite and the leaders of the local group or to perform some ritualistic function (Hall 1991, Pauketat & Emerson 1997).

The Cahokia variant of Middle Mississippian culture can be identified by several key elements including certain styles of pottery and figurines, tools made of certain types of stone, and platform mounds and wall-trench construction. A description follows of some of these elements as well as the archaeological sites used in this study where these elements have been found. My focus on artifacts for this study is not to imply that trait lists are my only interest in the culture. There is no written record indicating where and why a trader or emissary was sent to distant locales. The context required in defining the mobility is missing. As a result, the existence of artifacts is the sole indicator of some type of contact between the two groups.
Classic Cahokia/Middle Mississippian Elements

Platform or Conical Mounds

Perhaps the most iconic of Mississippian elements is the platform or conical earthen mound (Figure 3-1). There were over 120 of these mounds at Cahokia itself in various shapes and sizes (Fowler 1974). These mounds were used for a variety of functions including platforms for habitation structures, rituals, and burials. Similar mounds are found at most of the archaeological sites used in this research. While many cultures, such as the Hopewell, built earthen mounds, only the Mississippian culture built mounds of these shapes and sizes (Milner 2004).

Figure 3-1. Platform Mound – portion of Townsend Mural at Cahokia Visitor Center (Source: National Park Service)
Ramey Incised and Powell Plain Pottery

The Middle Mississippian culture had a very distinctive style of pottery, Ramey Incised and Powell Plain pottery (Stoltman 1991) (Figures 3-2 and 3-3). Both the style and the shell tempering of the pots allow the pottery to be used as an indicator of contact between Cahokia and another locality. Either Ramey Incised/Powell Plain pottery from Cahokia or pottery of those styles made from local materials have been found at each of the archaeological sites used in this research (Birmingham & Eisenberg 2000; Black 1967; Gibbon 1991; Goldstein 1991; Harn 1991; Henning 2007; Hilgeman 2000; Rodell 1991; Tiffany 1991).

Figure 3-2. Ramey Incised Pot
(Source: Illinois State Museum)

Figure 3-3. Powell Plain Pot
(Image captured by the author at Cahokia Visitor Center)
Flint Clay Figurines and Pipes

Another type of item produced in Cahokia and used in trading or gifting is the figurine or pipe made from flint clay (Emerson & Hughes 2000; Emerson et al 2003) (Figure 3-4). The particular style of these figurines and effigy pipes is what is so distinctive and what makes them appropriate as evidence of contact between Cahokia and the locality in which the figurine is found. While only found at one of the archaeological sites examined in this study, they have been found in many sites from Oklahoma to Georgia (Emerson & Hughes 2000; Emerson et al 2002).

Figure 3-4. Birger Figurine made of flint clay (Source: Illinois State Museum)
Mill Creek Chert Hoes

Stone hoes made of Mill Creek chert were one of the most widely distributed items in the Middle Mississippian world (Cobb 2000). The chert hoe is shown in Figure 3-5 and appears in hafted form in the Birger Figurine in Figure 3-4. The hoes were completely formed at workshops near the quarries and exchanged as a finished product. These were utilitarian objects found typically in habitation contexts rather than status symbols or ritualistic objects. Mill Creek chert hoes have been found at most of the archaeological sites used in this study (Black 1967; Goldstein 1991; Harn 1991).

Archaeological Sites Used in this Research

Each of the sites discussed below were occupied both prior to and after the Middle Mississippian peak period at Cahokia of 1000 to 1200 CE. In addition, artifacts recovered from these sites indicate a mix of both Mississippian and Late Woodland influence. While not “pure” Middle Mississippian sites, there is certainly evidence of contact with Cahokia and movement of goods from the American Bottom to each of

_Eveland /Dickson Mounds_

The Eveland site and its associated cemetery, Dickson Mounds, are located on the Illinois River just above its confluence with the Spoon River in west-central Illinois (Figure 3-6) (Harn 1991). The burials in Dickson Mounds date to approximately 1000 CE to 1250 CE. These are relatively small sites when compared to the others. Features and artifacts discovered at Eveland and Dickson Mounds which are of Middle Mississippian origin or influence include one pyramidal mound, locally made pottery in the Ramey Incised and Powell Plain styles, and Mill Creek chert hoes.

![Figure 3-6. Location of Eveland/Dickson Mounds Site](image-url)
Angel

Angel is located in southwestern Indiana along the Ohio River (Black 1967; Hilgeman 2000; Monaghan & Peebles 2010). This site was occupied from approximately 1050 CE to 1450 CE and is shown in Figure 3-7. Middle Mississippian features and artifacts found at this site include multiple mounds, locally made pottery in the Ramey Incised and Powell Plain styles, and Mill Creek chert hoes.

Figure 3-7. Location of Angel Mounds Site
Aztalan

The Aztalan site (Figure 3-8) is located in southern Wisconsin along the Crawfish River north of its confluence with the Rock River and was occupied from approximately 900 CE to 1100 CE (Goldstein 1991; Goldstein & Richards 1991; Birmingham & Eisenberg 2000). Features and artifacts of Mississippian influence and origin discovered at Aztalan include multiple platform mounds (as well as mounds in other shapes), locally made pottery in Cahokian styles, and Mill Creek chert hoes. Aztalan is considered the most “Mississippian” of the settlements along the northern periphery of Cahokian influence, but there was still influence from other cultures.

Figure 3-8. Location of Aztalan Site
Red Wing Locality

The Red Wing locality (Figure 3-9) is a group of sites along the Cannon and Mississippi Rivers in southeastern Minnesota which were occupied from approximately 1000 CE to 1300 CE (Gibbon 1991; Gibbon & Dobbs 1991; Rodell 1991). There is a great deal of influence from cultures other than Middle Mississippian at these sites. Artifacts and features of Mississippian origin and influence found in this area include multiple platform mounds and locally-made pottery in Cahokian styles. This is one of the locations in this research where Mill Creek chert hoes have not been found.

Figure 3-9. Location of Red Wing Locality
**Mill Creek Locality (Iowa)**

The Mill Creek locality (Figure 3-10) in northwestern Iowa is a collection of small sites along the Big Sioux River north of its confluence with the Missouri River which were occupied from approximately 900 CE to 1300 CE (Tiffany 1991; Henning 2007). Like the Red Wing locality, multiple other cultures had a great influence at this site. Locally made pottery in Cahokian styles has been found at this site. This is one of the locations used in this research where Mill Creek chert hoes have not been found.

![Figure 3-10. Location of Mill Creek Locality](image-url)
Raw Material Source Points

*Mill Creek Chert Source (Illinois)*

Mill Creek chert was a highly prized material for hoes, knives, and other tools in Mississippian culture (Cobb 2000). The quarries for Mill Creek chert are located in the southern tip of Illinois (Figure 3-11). The location used in this study was determined by comparing the map on page 99 of the Cobb text to the elevation raster dataset being used. The general area of the quarries is indicated by the black rectangle with the specific location used indicated by the point.

Figure 3-11. Location of Mill Creek Chert Source
Flint Clay Source

The source of the flint clay used for the figurines and pipes discussed above was located in east-central Missouri (Emerson & Hughes 2000; Emerson et al 2003). The stone was quarried and transported to Cahokia for carving. The location used for the quarries in this study (Figure 3-12) was determined by comparing information from the Emerson articles including the map on page 83 of the Emerson and Hughes (2000) article with geologic datasets of Missouri. The general area of the source material is indicated by the black circle with the specific location used in this research indicated by the dot.

Figure 3-12. Location of Flint Clay Source
**Copper Source**

While the discovery of copper at Cahokia has been rare, the specific locations where it has been found indicate the importance of this material. One prime example of this is the rolled sheet copper included with other grave goods in the fantastic burial in Mound 72 (Fowler 1974). The actual source of this copper has never been determined, but there are many potential sources during this time period including the Upper Peninsula of Michigan, the Appalachian Mountains, and even “float” copper deposited on the surface by glaciers across the upper Midwest (Rapp 2000). For this study, the copper source location (Figure 3-13) was selected from one of the Michigan mines with the coordinates determined by comparing the maps on pages 11 and 12 of the Rapp text with a geologic dataset of Michigan. The overall potential copper source area from northern Michigan/Wisconsin is represented by the black outline.

![Figure 3-13. Location of Copper Source](image-url)
Conclusion

The extent of Cahokian contact and influence spreads across the North American mid-continent. Five of the sites chosen to reflect this sphere of influence are locations where items have been found that were manufactured in Cahokia or were locally-made items in a Cahokian style. The other three sites are locations of source materials for items found at Cahokia. It should be noted that there are many other sites which could have been included in this study, but for which data (such as land cover data for that particular state) could not be found.
Chapter IV

Case Study: Middle Mississippian Exchange - Model

Every culture is represented by certain objects, structures, or belief systems which are characteristic of that particular group, to invoke a Sauerian notion of culture (Mitchell 2000). For Cahokia, some of these characteristics are certain pottery and figurine styles and platform mounds. Various Cahokia characteristics or locally-made imitations in the same style from the same time period have been found throughout the North American midcontinent (Figure 4-1). These locations were used as the end points of a least-cost analysis of the Cahokia exchange network.
One must consider the methods of transport which were available to humans prior to the introduction of the horse by European explorers. It requires a greater expenditure of energy to carry a load overland than it does to transport that same load by watercraft. Overland travel also takes longer than transport by water to go the same distance. Alternatively, water travel may be a prohibitively indirect route. These factors must be calculated into the weighting structure of the cost surfaces. Drennan (1984a, 1984b) estimated costs for various transport modes in pre-Hispanic Mesoamerica.
According to his calculations, overland travel requires approximately 3.5 times more labor than does transporting the same load while paddling upstream. And paddling upstream requires twice the labor than does paddling downstream (Drennan 1984a). Howey (2007) utilized similar estimates of the relative exertion required for different modes of travel. For example, major river travel was weighted at five while travel through forested areas were weighted as 40. These estimates were used in calculating weights for the land cover and hydrography cost surfaces for this analysis.

Two types of geographic representation in a GIS are vector (features) and raster (surfaces) (ESRI 2009). Vector data are points, lines, or polygons which represent some feature on the surface of the earth (e.g., buildings, streets, land cover type). Raster data are grids of cells which contain a numeric value related to conditions at the center of that cell (e.g., temperature, elevation, land cover classification). Figures 4-2 and 4-3 represent the same area of land cover in both vector and raster format.

Figure 4-2. Vector Representation of Land Cover Data

Figure 4-3. Raster Representation of Land Cover Data (90 m)
A least-cost analysis begins with the development of raster grids or cost surfaces which approximate the “cost” or expenditure of energy required to move through each cell of the grid. For example, in a slope raster, there is a higher cost involved with walking uphill than with walking downhill. The route through the cost surface with the least amount of accumulated costs can then be determined; this route is the least-cost path. It is similar to the path of least resistance in water flows. If multiple elements are involved in the analysis, multiple cost surfaces are developed and combined into one cumulative cost surface to be used in the analysis (Collischonn & Pilar 2000; Conolly & Lake 2006). For this examination of the Cahokia exchange network, three separate cost surfaces were developed: slope, land cover, and hydrography (Table 4-1). All analyses were conducted using ESRI’s ArcGIS 9.3.1 software.
Table 4-1. Listing of Cost Surface Data

<table>
<thead>
<tr>
<th>Cost Surface</th>
<th>Dataset/Source</th>
</tr>
</thead>
<tbody>
<tr>
<td>Slope</td>
<td>DEM, ESRI</td>
</tr>
<tr>
<td>Landcover</td>
<td>Illinois, Illinois Natural History Survey, University of Illinois</td>
</tr>
<tr>
<td>Indiana</td>
<td>Myaamia Project, University of Miami (Ohio)</td>
</tr>
<tr>
<td>Iowa</td>
<td>Iowa Department of Natural Resources, Iowa Geologic and Water Survey</td>
</tr>
<tr>
<td>Michigan</td>
<td>Michigan Center for Geographic Information</td>
</tr>
<tr>
<td>Minnesota</td>
<td>Minnesota DNR</td>
</tr>
<tr>
<td>Missouri</td>
<td>Geographic Resources Center, Department of Geography, University of Missouri</td>
</tr>
<tr>
<td>Nebraska</td>
<td>University of Nebraska-Lincoln, School of Natural Resources</td>
</tr>
<tr>
<td>North Dakota, South Dakota</td>
<td>Environmental Protection Agency, Region 8</td>
</tr>
<tr>
<td>Ohio</td>
<td>Myaamia Project, University of Miami (Ohio)</td>
</tr>
<tr>
<td>Wisconsin</td>
<td>Wisconsin DNR</td>
</tr>
<tr>
<td>Hydrography</td>
<td>Missouri River, Missouri River Recovery Program, US Army Corps of Engineers</td>
</tr>
<tr>
<td>Upper Mississippi River</td>
<td>Upper Midwest Environmental Sciences Center, USGS</td>
</tr>
<tr>
<td>Illinois River</td>
<td>Illinois land cover dataset</td>
</tr>
<tr>
<td>Rock/Crawfish Rivers</td>
<td></td>
</tr>
<tr>
<td>Ohio River</td>
<td>ESRI</td>
</tr>
<tr>
<td>Chippewa/Flambeau Rivers</td>
<td></td>
</tr>
<tr>
<td>Rock/Crawfish Rivers</td>
<td></td>
</tr>
<tr>
<td>St Louis/Cloquet Rivers</td>
<td></td>
</tr>
<tr>
<td>Wabash River</td>
<td></td>
</tr>
<tr>
<td>Wisconsin River</td>
<td></td>
</tr>
</tbody>
</table>
Creation of Cost Surfaces

Slope

Slope is a significant factor in how humans move through the landscape; it is much easier to walk through flat terrain than through a mountainous area. A digital elevation model (DEM) was obtained from ESRI. In this instance, modern-era data should be acceptable because the topography has not changed significantly since the time period under study. The conversion of the DEM to a slope raster to serve as one cost surface consisted of several steps.

The digital elevation model from ESRI (based on USGS data) covered the entire North American continent. In order to reduce the extent of the data, a rectangular vector file was developed which encompassed the study area. An empty vector file was created in ArcCatalog (right-click on the target location → New → Shapefile). This empty vector file was added as a layer in ArcMap along with the DEM. The Rectangle Tool in the Editor toolbar was used to draw a simple rectangle which covered the entire study area. This vector file was then used as the mask to extract the desired portion of the raster DEM (Spatial Analyst → Extraction → Extract by Mask). The result was a DEM which encompassed only the study area.

Future processes required that the DEM have a projection assigned to it as well as having the resulting linear units of meters rather than decimal degrees. The acquired DEM did not have a projection, so it was necessary to utilize the Project Raster Tool (Data Management → Projections and Transformations → Raster → Project Raster).
Universal Transverse Mercator (UTM) Zone 15N was selected as the projection as most of the land cover datasets were projected in UTM Zone 15N or 16N.

The Slope Tool (Spatial Analyst → Surface → Slope) was used to convert the elevation information into slope. Degree of slope (0-90) was selected as the output measurement rather than percent rise due to its ease of manipulation in other processes. Other studies (Bell & Lock 2000; Howey 2007) have used the tangent of the slope as the cost variable rather than the slope itself. There were no apparent differences generated when the two cost surfaces were tested, so the slope itself was used.

One requirement of least cost paths is that all of the cost surfaces need to have the same range of values. The range used for this project was 0-100. As a result, the cell values in the slope raster needed to be reclassed and stretched from its original 0-58.87 to 0-100 to create the slope cost surface. The equation below reflects the arithmetic used for the conversion.

\[
\frac{\text{Slope degree} \times 100}{\text{Highest slope degree in the study area}}
\]

The actual conversion was performed using the Reclass by Table function. The original reclass table was obtained through the Reclassify Tool (Spatial Analyst → Reclass → Reclassify). When the input raster information is entered into the tool parameters, a reclassification table is generated and appears in the dialogue box. The
Save option button allows the table to be saved as a separate file. This table was then converted into Excel and the necessary calculations performed. To return the new cell values to the raster, the Reclass by Table tool (Spatial Analyst → Reclass → Reclass by Table) was used. Using this process saved time, effort, and potential error when compared to manually entering the new values in the table in the Reclass tool.

Land Cover

A second cost surface was generated from a layer consisting of an approximation of pre-European settlement land cover. Beginning in the early nineteenth century, surveyors from the federal General Land Office (GLO - a predecessor of the Bureau of Land Management) surveyed all federal land in the country to provide documentation for the transfer of specific parcels to private or state ownership. Those surveys, along with associated field notes concerning features such as vegetation, water, and human-made objects, have been digitized by many states and made available to the public (Bureau of Land Management; Oregon State University). Researchers and state officials in several states have utilized these surveys and field notes to create GIS data which approximate the vegetation or land cover as it was when the surveys were conducted. While not actually a representation of pre-European settlement land cover, these files are the closest approximation available.

Because each dataset was developed by different organizations for different purposes, each one had a different classification scheme. In order to combine these disparate files into one, the classification schemes had to be modified to match the one
with the fewest number of classes (three). Two new fields were added to the attribute
table to hold the revised classification: Type, which noted a description of the new class
(prairie, forest, water); and Type Code, which displayed a numerical value for each type
(1-prairie, 2-forest, 3-water). The original classes were then combined into the new
classes by selecting those classes which were similar. For example, Wisconsin had a
total of 18 land cover classes distinguishing different types of forests, wetlands, and
other land cover types. Using the Select by Attribute tool, the various forest classes
were selected. The attribute table was opened, the Editor mode turned on, and the
Selected button at the bottom of the attribute table was clicked so that only the
selected polygons were showing. The new Type and Type Code fields were filled using
the Field Calculator (right click on the field heading → Field Calculator). This method
was chosen as it was more efficient and had less likelihood for error than manually
entering the information for each individual polygon.

The land cover datasets for some states required additional processing.
Corrections were required in some to delete nineteenth century towns and cities and
replace them with land cover categories estimated from surrounding areas. The land
cover information for one state had to be completely recreated as the acquired dataset
had gaps between the polygons and other technical issues. This recreation was
accomplished by overlaying a single polygon of the entire state over the original dataset
and using the Cut Polygon Features tool in the Editor task list to trace the outlines of the
original polygons.
For some states, there was no dataset available for the entire state. In most cases, that state and any archaeological sites within it were simply left out of the analysis. For example, a pre-contact land cover dataset for Oklahoma does not exist, so the Spiro site could not be included. In other instances, however, the land cover information was vital for processing reasons. One example is that of Kansas. Some land cover information was necessary along the Missouri River so that the river itself would remain whole during analysis. The dataset for the Missouri River included land cover information encompassing an approximate five-kilometer ribbon of data. The land cover information was pulled out using the Erase tool (Analysis → Overlay → Erase). The vector files for Missouri, Nebraska, and Iowa were used as the erase features which left only that portion of the original vector file which corresponded to Kansas. The classifications were then modified using the steps outlined above. Kentucky was another state for which data had to be constructed. In this instance, however, there was no land cover information in the Ohio River dataset. A one mile buffer was created around the river polygon using the Buffer tool (Analysis → Proximity → Buffer). This buffer was then trimmed so that only the south side remained and was manually matched to the borders of Illinois, Indiana, and Ohio. There was no information on land cover classes, so the entire polygon was classified as forest because that was the predominant classification along the north side of the river.

While not technically land cover, a similar situation occurred with the Great Lakes. In order to maintain the integrity of the hydrography feature used for the Great Lakes (discussed below), a 5 km buffer was created around that feature and trimmed to
the area needed using the methods noted above. That area was classified as water in an effort to prohibit movement out of the Great Lakes feature.

The datasets for some of the states included information on river systems within that state. If information from another source for that river was being used for the analysis, the polygons in the land cover vector file had to be changed to avoid duplicated river information. This was accomplished by clicking on the polygons while in Editor mode to select them and then changing the class through the Field Calculator as described above. The new assigned class was based upon the classes of the surrounding polygons.

Another type of special case involved situations where the original land cover dataset was much larger than necessary. The information for North and South Dakota was a part of a larger vector file which included a total of six states of the Rocky Mountain region of the west. Only the eastern portion of those two states was necessary. In the Editor mode, the Cut Polygon Features task was used to trim off that area needed.

Once necessary changes were made to the land cover vector files, they were converted to raster files based upon the Type Code field (Conversion → To Raster → Polygon to Raster). This conversion maintained the three classes of prairie, forest, and water. The cell size was designated as 90 meters to coordinate with the elevation/slope surface. The creation of the land cover cost surface required reclassifying the raster files to incorporate the assigned weight for each land cover class (Table 4-2, based on Howey, 2007). These weights took into account the difficulty in traversing the different
types of land cover and ranged from 0 to 100. The relatively high weight assigned to water was designed to prevent the least cost path from crossing major rivers or lakes which would not, in reality, have been passable without a boat. Water travel was addressed in the Hydrography cost surface.

<table>
<thead>
<tr>
<th>Land Cover Type</th>
<th>Cost Surface Weight</th>
</tr>
</thead>
<tbody>
<tr>
<td>Prairie</td>
<td>35</td>
</tr>
<tr>
<td>Forest</td>
<td>45</td>
</tr>
<tr>
<td>Water</td>
<td>80</td>
</tr>
</tbody>
</table>

The final step in developing the land cover cost surface was mosaicking the individual states into one raster file for each analysis scenario. This was done using the Mosaic to New Raster tool (Data Management → Raster → Raster Dataset → Mosaic to New Raster). A different raster file was created for each scenario (as opposed to one land cover raster file incorporating the entire study area) to keep processing time to a minimum.

**Hydrography**

The final cost surface is one reflecting an approximation of the hydrography during the time prior to first contact. For a few states, the GLO survey-generated land cover data incorporates the water features in that state (e.g., Illinois). In other situations, river commissions from prior centuries surveyed the river under their care.
and those surveys were used to generate GIS files in a manner similar to the use of the GLO surveys (e.g., the Mississippi River Commission of the late 1800s). For those rivers where GIS data approximating pre-European settlement conditions could not be located, it was necessary to acquire modern-era hydrography data from ESRI.

As in the land cover data, each river dataset was unique in its information and classification and each required specialized pre-analysis processing. The vector file of the Missouri River consisted of 25 land cover types and included a band approximately five kilometers wide. The river itself was isolated using the Select by Attribute function and selecting for “river.” A layer was created from the selection and that data converted into a separate vector file. Some obviously human-made features such as dikes were still present and were manually removed by deleting vertices using the Reshape Feature task of the Editor toolbar.

A pre-contact approximation of the upper Mississippi River was only available as 28 individual segments rather than the entire river in one file. These also included land cover information on each side of the river itself. As with the Missouri River, the river was isolated using Select by Attribute for each segment and selecting for “main channel” and “secondary channel.” Again, unwanted human-made features were removed by deleting vertices. The individual segment vector files were combined using the Union tool (Analysis → Overlay → Union). This resulted in two separate polygons of the river in one vector file. These two portions were combined using the Merge function of the Editor mode. Any remaining gaps were eliminated by deleting vertices.
The Illinois River vector file was created by isolating the river from the land cover dataset of Illinois. Because the attribute table did not include identifying information on individual rivers, the Illinois River had to be selected manually. In the Editor mode, the individual river segments were selected by simply clicking on them while holding the Shift key. When all of the segments had been selected, a map layer was created and the data from that layer was converted into a single vector file. The individual segments were then combined using the Merge function of the Editor toolbar.

A similar procedure was used to create vector files for the other rivers used in the analysis. ESRI’s dtl_wat feature class (based on USGS data) was used as the base file. The vector file used to extract the elevation data for the study area was used in the Clip tool (Analysis → Extract → Clip) to reduce the feature class to a more manageable file size. The manual selection process described above for the Illinois River was used to create the vector files for every other river needed for the analysis.

Prehistoric humans in the mid-continent also used the Great Lakes as a travel route. To create a dataset, a buffer of two kilometers was created around the combination of the state outline vector files for Michigan, Wisconsin, Minnesota, Illinois, Indiana, and Ohio. The state vector files were used with the Clip tool to create a “doughnut” around them. This doughnut was then trimmed to the area of the actual lakes. This method was chosen rather than using a dataset of the Great Lakes and creating an internal buffer due to ease of matching to the state land cover datasets. The Great Lakes vector file did not have the detail that the land cover datasets did and, as a result, there were many gaps between the resulting internal buffer and the land cover
vector files. It was a much more efficient use of time to use the state vector files rather than the Great Lakes dataset.

Another issue resulting from the fact that the hydrography datasets were acquired from different sources is that the rivers and lakes didn’t match at their convergence points. To correct this, the layers were overlapped and the vector files edited manually by either deleting vertices or using the Cut Polygon Features task of the Editor toolbar.

Once the vector files were complete, they were converted to raster files. One concern at this juncture was maintenance of connectivity for some of the rivers. The larger rivers, where there was little concern that connectivity would be lost, were converted based upon the value at the cell center and at a cell size of 50 meters. They were then resampled (Data Management → Raster → Raster Processing → Resample) to 90 meters to match the other cost surfaces using the Nearest Neighbor algorithm. There were greater connectivity concerns for the smaller rivers. They were converted to 50m rasters based on the Maximum Combined Area method which combines features with common attributes when determining the value for the cell. The 50m rasters were then resampled to 90m using the Majority algorithm to increase the likelihood of maintaining connectivity.

For most scenarios, the rivers were then mosaicked into the combinations necessary using the Mosaic to New Raster tool described above. Again, the hydrography datasets for the different scenarios were created individually rather than
one large dataset in an effort to reduce processing time. There were a few exceptions to this procedure which will be discussed below.

The rasters were then reclassified to create the hydrography cost surface for each scenario. Following Drennan (1984a, 1984b) and Howey (2007), the weights for the rivers were set at five for downstream travel, 10 for upstream and Great Lakes travel which is more difficult than downstream travel, and 100 for areas of no data. A weight for the no data areas is required because, when the cost surfaces are stacked and combined, areas of no data in any one surface become areas of no data in the total cost surface raster. Not assigning a weight to the no data areas would result in the land cover information being lost. A value of 100 is used to provide a barrier to non-water travel in this surface (similar to the relatively high weight given to water in the land cover cost surface). Another option for cost values would have been an index based upon the flow rates of the rivers used in the analysis. However, channelization in the modern era would impact the accuracy of that index for this study.

One exception to the mosaic-then-reclassify procedure noted above was the Cahokia to Angel scenario. This scenario involved both upstream and downstream travel. As a result, the river rasters were reclassified with their respective weights (five for the Mississippi and 10 for the Ohio) prior to mosaicking.

Other exceptions were the Copper Source to Cahokia and Cahokia to Aztalan scenarios in which the Great Lakes were reclassified to 10 and the various rivers to either five or 10 (depending upon whether the travel would be downstream or upstream) before mosaicking. In addition, these two separate cost surfaces overlapped.
with areas of No Data (with a cost of 100) overlapping areas of the rivers or lakes with costs of five or 10. To maintain the cost values, the mosaic method was set to Minimum which selected the minimum value of overlapping cells for the output cell value.

**Combining Cost Surfaces**

Once the individual cost surfaces had been developed, they were combined to create a total cost surface which reflects the total cost of moving through any one cell. This was accomplished using the Plus tool (Spatial Analyst → Math → Plus). As the input parameters for this tool only allows two rasters to be added at a time, the procedure was executed twice. The first time added the land cover and slope cost surfaces and the second added the hydrography cost surface. Map Algebra provides another possibility for combining the cost surfaces.

As noted above, if there is an area of no data in any one surface, the total cost surface will have no data for that area. During procedure tests, the portion of the Missouri River which runs between Missouri and Kansas was lost because there was an area of no data in the land cover cost surface. This loss greatly impacted the results of the test. When the Kansas land cover estimation was added, the river remained complete and the test was successful. Similarly, the Kentucky land cover vector file was created to protect the Ohio River.
End Points

Finally, in a least-cost analysis, there must be a source point and a destination point to serve as end points of the least-cost path. In this study, one of those end points was the location of Cahokia itself. The geographic locations which served as the other end points were either archaeological sites in other areas where artifacts or platform mounds dating to the time period in question have been discovered (Table 4-3) or locations which were sources of non-local objects and materials found at Cahokia (Table 4-4). The sites selected were those with multiple types of Cahokian or Cahokian-influenced artifacts and structures. The source of this information was reports of excavations and analyses found in the archaeology literature.

To develop the points, literature resources were examined for descriptions or maps of the location in question. This was relatively easy for Cahokia and the archaeological sites where Cahokia-related materials have been found. In many instances, state parks or museums related to the site have been developed and the location of those parks was used for the endpoint. The latitude and longitude of each site was determined using Google Earth.
<table>
<thead>
<tr>
<th>Archaeological Site</th>
<th>Location</th>
<th>Artifacts</th>
<th>Features</th>
<th>Information Source</th>
</tr>
</thead>
<tbody>
<tr>
<td>Angel</td>
<td>Indiana</td>
<td>Locally made pottery in the Ramey Incised style; stone hoes; marine shell beads; chunkey stones</td>
<td>Platform mounds; plaza; wall-trench construction; palisade</td>
<td>Black, 1967; Hilgeman, 2000; Monaghan &amp; Peebles, 2010</td>
</tr>
<tr>
<td>Aztalan</td>
<td>Wisconsin</td>
<td>Locally made pottery in Cahokia styles; triangular notched and unnotched points; chert hoes; chunkey stones; earspools; shell pendants; copper long-nosed god masks</td>
<td>Palisade; plaza; pyramidal mounds</td>
<td>Goldstein, 1991; Goldstein &amp; Richards, 1991; Birmingham &amp; Eisenberg, 2000</td>
</tr>
<tr>
<td>Eveland/Dicksen</td>
<td>Illinois</td>
<td>Various ceramics, including locally made pottery in the Ramey Incised &amp; Powell Plain styles; triangular/nontriangular notched points; Mill Creek chert hoes; marine shell beads, pendants, gorgets, and long-nosed god mask; copper-covered wood/stone earspools; Mill Creek and Kaolin chert Ramey knives; chunkey stones; elbow pipes</td>
<td>Pyramidal mound; wall-trench structures; fortifications</td>
<td>Harn, 1991</td>
</tr>
<tr>
<td>Mill Creek</td>
<td>Iowa</td>
<td>Locally made pottery in Cahokia styles; notched and unnotched triangular points; chunkey stones; stone hoes; marine shell pendants, columella and disc beads; long-nosed god masks</td>
<td>Fortifications</td>
<td>Henning, 2007; Tiffany, 1991</td>
</tr>
<tr>
<td>Red Wing</td>
<td>Minnesota</td>
<td>Locally made pottery in Cahokia styles; tri-notched triangular projectile points; ears pool; figurines; chunkey stones; marine shell long-nosed god mask; small copper maces; thunderbird motifs</td>
<td>Wall-trench architecture; platform mounds</td>
<td>Emerson, 1991; Gibbon, 1991; Gibbon &amp; Dobbs, 1991; Rodell, 1991</td>
</tr>
</tbody>
</table>
The source locations of exotic materials found at Cahokia were more difficult to establish. The particular types of flint clay and chert involved cover large areas of Missouri and Illinois respectively. The source of the copper found at Cahokia has never been positively determined. The most likely source area is in the Great Lakes region, but again, there is not one specific point. To generate the source point for the analysis, maps in the literature were compared to geologic datasets of each state (in the case of flint clay and copper) and elevation data (in the case of chert). Points were selected and latitude/longitude determined using Google Earth.

An Excel spreadsheet was created with this information for each point and converted to a .csv file. In ArcMap, the coordinates were added as a layer using the Add X,Y Data tool (from the menus, Tools → Add X,Y Data). When the .csv table was identified, the tool automatically inserted longitude as the X field and latitude as the Y field. The coordinate system was established as WGS 1984 to match the other data being used. A point vector file of the location was created by right-clicking on the .csv file in ArcCatalog→ Create Feature Class→ From XY Table.
Least Cost Analysis

The least cost analysis consists of three parts: cost distance, cost direction, and the cost path itself. Both the cost distance and cost direction surfaces were created using the Cost Distance tool (Spatial Analyst → Distance → Cost Distance). The source point vector file and the total cost surface are the inputs. Although designation of an Output Backlink Raster is listed as optional, this is actually the cost direction surface and is required for creation of the cost path in later steps. The output will be two surfaces which have little meaning on their own (Figures 4-2 and 4-3). These are essentially throughputs for the generation of the cost path.

Figure 4-4. Cost Distance Surface – Cahokia to Eveland/Dickson Mounds Scenario

Figure 4-5. Cost Direction Surface – Cahokia to Eveland/Dickson Mounds Scenario
The least cost path is created using the Cost Path tool (Spatial Analyst → Distance → Cost Path). The cost distance and cost direction rasters are used as inputs along with the destination point vector file. The output is a raster file representing the least costly way to move through the cells from the source to the destination. Because this is a raster file depiction of movement from one cell to another, it is very thin and must be converted to a line vector file to be visible at the scales used in the analysis. The Raster to Polyline tool (Conversion → From Raster → Raster to Polyline) was used for this procedure. Converting the raster to a line provides the ability to vary the width of the line depending on the backdrop chosen for the final product. The least cost path for the Cahokia to Eveland/Dickson Mounds scenario is represented in Figure 4-4 with the elevation as a background.

![Least Cost Path](image)

*Figure 4-6. Least Cost Path – Cahokia to Eveland/Dickson Mounds Scenario*
Chapter V

Case Study: Middle Mississippian Exchange – Results

The purpose of this research is to examine the applicability of using GIS to study prehistoric landscapes. With this in mind, the discussion which follows will mainly focus on a description of the results at various scales of the least cost path analyses conducted and any problems or issues which occurred with the particular paths. Generally speaking, the least cost paths generated were as expected given the input variables and seemed appropriate when viewed at small scales. At larger scales, however, issues appeared which stemmed from such things as differences between the vector file and the raster file as well as idiosyncrasies of the model itself. These problems could impact the results of any research being conducted at larger scales.

The map in Figure 5-1 reflects all of the paths combined onto one map. It is very obvious from this image that the model trends toward water routes rather than overland routes. This result makes sense in that the input variables applied a lower cost to water travel than to overland travel given the weight of any goods being carried and the fact that water travel is easier than overland travel (Drennan 1984a, 1984b; Howey 2007).
Figure 5-1. Least Cost Paths Centering on Cahokia
Paths from Cahokia to Other Locales

Eveland/Dickson Mounds

Figure 5-2 shows the small-scale result of the generated least cost path from Cahokia to Eveland/Dickson Mounds. Given that the input variables placed a higher cost on overland travel, one might expect that the least cost path would follow the water routes and that is what was calculated by the software. This result makes sense in that heavy objects from Cahokia such as pottery and chert were found at Eveland/Dickson Mounds and this was a time without horses for carrying heavy loads. Water transport would have been more efficient.
Figure 5-3 shows a portion of the path at a much larger scale along a section of the Mississippi River. The zig-zagging pattern of the path is representative of the path along the entire route. This result is understandable in areas where there are islands to navigate around, but this pattern also is exhibited in open sections of the rivers. Given that the total costs associated with this particular section of the river are the same throughout, the issue is most likely due to the fact that it was generated as a raster file. Movement in a raster is from cell to cell either up, down, sideways, or corner to corner. As a result, even when the raster is converted into a polyline, the zig-zagging remains. When conducting an analysis at larger scales, a researcher would have to account for this pattern and keep this tendency in mind when interpreting results.
Angel

The least cost path generated for the route from Cahokia to Angel is shown in Figure 5-4. As with Eveland/Dickson, the small scale path which was generated is a reasonable output given the input variables. A water route would have been easier given the distance and modes of transportation available.

Figure 5-4. Least Cost Path from Cahokia to Angel – Small Scale

However, there are issues with the route at larger scales. Figure 5-5 shows a location along the Ohio River where the path, in addition to the zig-zagging pattern
discussed previously, crosses islands and moves on land for a bit. When the 90-meter cell raster of the river is added to the map as in Figure 5-6, however, part of the reason for this result becomes clear. There are obvious differences between the vector file of the river (blue – the original dataset and also used for mapping the final path) and the raster file of the river (yellow - used for the actual analysis). As can be seen, the island in the middle of the image is much smaller in the raster version than in the vector version. This difference is rooted in the conversion from the vector to the raster and would certainly impact any analysis conducted at larger scales.

Figure 5-5. Least Cost Path from Cahokia to Angel – Large Scale

Figure 5-6. Least Cost Path from Cahokia to Angel Including Raster File in Yellow
As with the previous examples, the small scale least cost path from Cahokia to Aztalan seems to be a reasonable outcome (Figure 5-7). The path follows along the Rock/Crawfish and Mississippi river systems, as one would expect given the input variables.

However, the large scale version again has some problems which need to be considered (Figure 5-8). The least cost path strays away from the river even more so than in the previous examples. The total costs at those points are indeed lower than at
points in the river. A comparison of the vector (blue) to the raster (yellow) as seen in Figure 5-9 does not answer the question as the path falls outside the raster version of the river. Once the hydrography cost surface (orange) is included in Figure 5-10, however, the reason is clear. The riverbanks were shifted by one cell to the right and down. An examination of the dataset created in each step of the process reveals that the shift probably occurred when the individual river raster files were mosaicked into one raster dataset. The shift occurred because each river had a different datum (NAD 27 and NAD83). This type of error can be avoided by matching the two datums (Data Management → Projections and Transformations → Raster → Project Raster). As can be seen in Figure 5-11, after the datums are matched, the raster river file and the river representation in the cost surface align much more closely. In addition, the revised cost path now runs within the raster version of the river.
Figure 5-9. Least Cost Path from Cahokia to Aztalan Including Raster File in Yellow

Figure 5-10. Least Cost Path from Cahokia to Aztalan Including Raster File in Yellow and Hydrography Cost Surface in Orange

Figure 5-11. Revised Least Cost Path from Cahokia to Aztalan Including Raster File in Yellow and Hydrography Cost Surface in Orange
Red Wing

As in the other examples, the small scale version of the least cost path between Cahokia and the Red Wing Locality (Figure 5-12) is what would be expected. Since both locations are on or near what we now know as the Mississippi River, it seems logical to use water transportation to go from one to the other.

Figure 5-12. Least Cost Path from Cahokia to Red Wing Locality – Small Scale

There were issues again with the least cost path at large scales, however. Figure 5-13 shows a location along the Mississippi River where the least cost path was not generated as expected. The path follows a side channel of the river rather than the main channel. Differences between the vector and raster files should not be
responsible for this problem as the main channel would be the widest regardless of the format.

When the total cost surface is examined (Figure 5-14), the reason for the route of the least cost path becomes clear. What appears to be a green band through the center of the image is actually an area of “No Data” showing through from a lower layer. The least cost path will avoid such areas because there is no cost associated with those pixels; they do not exist. This particular area of no data is the result of gaps between the land cover datasets for two states which were not corrected when they were combined. These types of “user error” can greatly affect the outcome of a model.
**Mill Creek Locality**

The small scale least cost path from Cahokia to Mill Creek, the farthest outbound locality examined in this study, is what was expected (Figure 5-15). For such long distances, water transport would have been the most efficient method of travel.

![Least Cost Path from Cahokia to Mill Creek Locality - Small Scale](image)

*Figure 5-15. Least Cost Path from Cahokia to Mill Creek Locality – Small Scale*

The main issue at a large scale with this scenario can be found in all of the scenarios. Figure 5-16 shows an area along the Missouri River where the least cost path cuts across several meanders in the river rather than actually following the river. Based upon the input variables, the model calculated that the cost to cut across the land was less than the accumulated costs of the increased distance involved in traveling along the
loop. The model calculated the path exactly as it should have. However, from a logic standpoint, a person is not going to come ashore, unload the boat, portage the boat and cargo across to the other side, reload the boat, and continue along his or her way. These additional costs cannot be factored into the model other than by over-manipulating the input variables which would have had adverse impacts on the rest of the model. For example, the land cover or slope costs could have been increased to a point where land travel would have been essentially prohibited, but that would have eliminated any potential for a land route between locales.

Figure 5-16. Least Cost Path from Cahokia to Mill Creek Locality – Large Scale
Paths from Material Source Locations to Cahokia

*Flint Clay*

Figure 5-17 shows the small scale results of the least cost path model from the source of flint clay to Cahokia. At this scale, the path appeared to be as expected. One thing to note is that the route of the least cost path is dependent upon the location established as the source of the flint clay. As noted above, the coordinates used were determined by comparing comments in the literature with geologic maps of Missouri. There is no one spot for this type of clay; it is found within a wide region of southeastern Missouri. In addition, the path might have been different if all of the hydrographic features were included in the analysis; that is, if the streams or rivers of the drainage systems surrounding the flint clay source location had been included. Perhaps it would not have changed, however, since the tendency shown by the model in other scenarios has been to cut across land rather than increase distance along a water route.
At a larger scale, the least cost path was perhaps not exactly as expected (Figure 5-18). The base map for all of these images is elevation – the darker oranges indicate a higher elevation while the lighter yellow and green tones indicate lower elevations. The path seemed to cut across higher and lower elevations rather than, for example, staying at a higher elevation once that had been achieved. This holds true even when the slope (which was used for the model rather than elevation) is used for the base image (Figure 5-19). In the slope image, darker blues indicate lower, more easily traversed slopes and lighter blues and white indicate higher, more difficult slopes. The path did cut across
more difficult terrain rather than add distance by taking a route with what appeared to be easier terrain.

Figure 5-18. Least Cost Path from a Source of Flint Clay to Cahokia – Large Scale

Elevation
- High: 2027
- Low: -55

Figure 5-19. Least Cost Path from a Source of Flint Clay to Cahokia with Slope Background

Slope
- High: 20.0911
- Low: 0
Mill Creek Chert

The result of the least cost path from the source of Mill Creek chert to Cahokia could have been either a water or overland route because a historical Native American trail runs through this area (Tanner, 1989, map p. 8). From a logic standpoint, however, given that the cargo would have been completed heavy stone hoes (Cobb, 2000), it makes sense that a river route would have been used. In fact, the model generated a path which travels on the Mississippi River (as shown in the small scale map in Figure 5-20).

At a larger scale, the least cost path from the source of Mill Creek chert to Cahokia has some of the same issues discussed in connection with other paths. Figure 5-21 shows the path cutting across a meander as well as zig-zagging along a relatively open portion of the river.

Figure 5-20. Least Cost Path from the Source of Mill Creek Chert to Cahokia – Small Scale

Figure 5-21. Least Cost Path from the Source of Mill Creek Chert to Cahokia – Large Scale
**Copper**

Figure 5-22 shows the model’s result at small scale for a least cost path from a potential source of copper to Cahokia. The fact that the path climbs to a relatively high elevation rather than follow the lake shore farther to cross at a lower elevation reflects the model’s tendency to reduce distance by crossing land rather than route a longer water-borne path. Obviously, the accumulated costs of the longer water route are higher than the route across the higher elevations. The same analysis holds true when looking at the path on the slope background (Figure 5-23).
As noted previously and again in Figure 5-24, the possible source location for copper was not a single point, but a large area covering sections of present-day Michigan, Wisconsin, and Minnesota. The scenario was run multiple times with different source points and additional river datasets to determine if the least cost path would be changed. For example, one such run moved the source point to the southwest near a known historical Native American copper mine and travel route down the Wisconsin River. The generated path, however, remained the same as the original run - across land and down the Chippewa River (Figure 5-25).

Figure 5-24. Location of Copper Source

Figure 5-25. Least Cost Path from Second Copper Source Location to Cahokia
At a larger scale, the least cost path between the original copper source and Cahokia exhibits the same problems that other paths have shown. Figure 5-26 shows the path crossing a point of land rather than continuing in the water and around that point. When the raster file (in black) for the lakes is added to the map (Figure 5-27), it is apparent that the path remains in the raster “lake” which was used in the analysis. This is at least partially a result of how the dataset used for the analysis was created - - a 2 km buffer around the land cover vector file was used rather than an interior buffer of the lake vector file. Therefore, the two do not overlap as well. Another recurring issue that is apparent is the zig-zagging of the path through the lake.

Figure 5-26. Least Cost Path from a Source of Copper to Cahokia – Large Scale

Figure 5-27. Least Cost Path from a Source of Copper to Cahokia with Lake Raster File in Black
A similar issue occurs along the Flambeau River (Figure 5-28). The least cost path roams in and out of the river. When the raster file used in the analysis is added to the map in yellow (Figure 5-29), the differences between the vector and the raster files are obvious.

Figure 5-28. Least Cost Path from a Source of Copper to Cahokia – Flambeau River

Figure 5-29. Least Cost Path from a Source of Copper to Cahokia with River Raster File in Yellow
Conclusion

The model developed for this study is one method of using geographic information systems to explore possible pathways of movement through a prehistoric landscape. The applicability of GIS for this type of situation can be determined through examining the generated results. Issues with this particular model included the impact of input variables and differences between vector and raster files. These problems, as well as issues with data availability and accuracy, will be discussed in detail in the next chapter.
Chapter VI
Discussion

The question of whether GIS is applicable for the study of prehistoric landscapes cannot be answered without an examination of data or processing issues which might arise during the research. Such issues may lie with the quality of the data being used or with the model being constructed. An awareness and understanding of the data and geoprocessing issues is vital in that such problems may compromise the outcome of any research.

The locations of many historic places are unknown. Thus, it is very difficult to utilize a GIS for a study of those places (Knowles 2000). For example, there is no consensus as to the location of the town of Alesia, site of the decisive battle between Julius Caesar and the Gauls (Henige 2007). Even if a location is known, good quality data are not guaranteed. Historical data sources, if available, may not be complete or accurate (Gregory & Ell 2007). For example, Wilson (2005) encountered nineteenth century maps with no legend and had to research Confederate map-making practices in order to determine the meaning behind the land cover symbols used. If there is such uncertainty with historical places and events, then there will no doubt be even more uncertainty over locations from pre-history and early historical times. Additionally, the
construction of a model is another issue in the use of GIS with prehistoric landscapes. Geoprocessing functions may exacerbate errors within the data (Gregory & Ell 2007).

The use of GIS to study Middle Mississippian exchange was found to be useful, but not without significant considerations in terms of data, processing, and model flexibility. I will first examine problems with the availability and accuracy of the data. Some desired datasets were not available which changed the scope of the study. Other datasets were only an estimation of prehistoric conditions rather than an actual representation. Secondly, I will review problems encountered developing the model and using geoprocessing functions. Model/processing concerns included the selection of input variables and the appropriateness of using certain geoprocessing functions. Finally, I will discuss the ease of exchanging datasets within the model which makes GIS ideal for changing scenarios to see if those changes influence the output. The applicability of GIS to prehistoric landscapes hinges on an understanding of the limitations and pitfalls reflected by these issues.

Data Issues

With any GIS research, the availability and accuracy of data are of primary importance to the validity of that research. Any dataset of a prehistoric landscape, if available at all, will be only an estimation of that landscape and will, no doubt, contain some error. The research being conducted will dictate what level of error is acceptable. Because this research focused on small-scale paths (such as 1:3,136,930 for the Mill
Creek locality and 1:961,521 for the Eveland/Dickson Mounds site), the error in the datasets used was acceptable.

Data Availability

The availability of data greatly impacted this research on Middle Mississippian exchange. Marine shell was one of the primary items of exchange during this time period (Trubitt 2005). Shell was harvested in the Gulf of Mexico, formed into beads and other items in Cahokia, and transported throughout the mid-continent. I was unable to model this pathway, however, because land cover data for the southern tier of states was unavailable. As a result, this important aspect of Middle Mississippian exchange could not be included.

The fact that these exchange routes spread across what are now multiple states presents another difficulty in the acquisition of data. The individual states are organized differently in terms of agencies responsible for geographic or archaeological data and also have differing protocols for access to available data. For example, geographic datasets could be housed in either information technology or natural resources departments (among others). Public access to those datasets varies from a simple website download to a data request submittal. As it relates to archaeological data, specific location information about some sites is understandably restricted due to looting concerns. Some states provided geographic locations in an email, some required an application for access to a database, and others denied access completely.
Data Accuracy

The fact that data is available does not mean that it is accurate. For example, the land cover data which was available represented conditions during the 1800s, not those conditions present during Cahokia’s peak of 1000 CE to 1200 CE. Human impact on the land cover such as agriculture and construction, while certainly present during the Middle Mississippian time period, would have been much greater after European colonization and expansion into the interior of the continent. This error was acceptable for this research, but might not be for other studies such as those examining land cover change over time.

The hydrography cost surface also had accuracy issues. Early representations of rivers (mid- to late-1800s) were only available for the Upper Mississippi River and the Missouri River. Datasets for current conditions were the only available option for all of the other rivers. As a result, some of the rivers did not match at their confluences and editing was required to enlarge or reduce the tributary river. These edits consisted of either deleting vertices or using the Cut Polygon Features task of the Editor toolbar. Figure 6-1 shows the gap between the Upper Mississippi River dataset (yellow) and the dataset which included the Wisconsin River (blue).
The selection of end points for the least cost paths is another possible source of error. The locations of the sources of materials such as flint clay and copper are generally known (southeast Missouri and the Upper Peninsula of Michigan respectively), but the exact geographic coordinates are not. In fact, the copper found at Cahokia could have come from boulders dropped by glaciers in central Illinois (Rapp et al 2000). Points were selected based upon a comparison between literature sources and geologic datasets. Again, this approximation was acceptable given the scope of this study at smaller scales, but it may not be for others. For example, research examining the environmental and geographic conditions of particular sites or conducting a least cost path analysis at a larger scale would need the exact locations of the sites.
**Processing Issues**

The decisions made with regard to the variables and processing functions utilized could also impact the results of the analysis (Harris 2000). Each step in the process of model development brings with it potential sources of error such as the application of inappropriate costs to a cost surface or the selection of function algorithms which produce unforeseen results. These potential errors must be considered when making choices as to data conversion and manipulation.

**Vector vs. Raster Data**

The conversion of vector data to raster in order to perform the least cost path analysis proved in itself to be a source of error in the results. For example, some segments of the path from Cahokia to Angel ran outside the ‘banks’ of the vector dataset for the Ohio River, but those segments are within the boundaries of the raster version (Figure 6-2). The decision of whether to use vector or raster data should be based upon the needs inherent in the research question (Couclelis 1992). Should a higher priority be placed on the accuracy ensured by using vector data or should it be placed on the processing ease of using raster data? For this research, the possibility of overland travel, and therefore the inclusion of terrain and land cover information, required the use of raster data.
River Connectivity

In an effort to maintain river connectivity when resampling to a cell size of 90 meters, smaller rivers were resampled using the Majority algorithm rather than the Nearest Neighbor algorithm which was used for the larger rivers. This difference created a thicker river dataset which included more cells that it might otherwise have. In some cases, this meant that the raster version of the river was significantly larger.

Figure 6-2. Difference between Vector and Raster Versions of Ohio River
than the vector version. For example, in the Copper scenario, the raster version of the Flambeau River is larger than the vector data version (Figure 6-3). In this instance, there was a trade-off between the accuracy of the river boundaries in the vector dataset and maintaining connectivity in the raster dataset. For this research, whether the rivers remained connected or not might not have had an impact on the outcome and placement of the least cost path. Small jumps from river to land and back to river occurred throughout the results even with connectivity. Perhaps using the same algorithm throughout regardless of the size of the river would have produced the same least cost path and would have avoided the issue of the raster version being larger than the vector version.

![Figure 6-3. Flambeau River - Evidence of Vector to Raster Conversion Variables Enlarging River](image)
Cost Assignment

The assignment of costs to each surface, and even the selection of which cost surfaces to create, is a subjective undertaking. The costs assigned in this research were based upon similar studies and theories as reflected in the literature (Drennan 1984a and 1984b, Howey 2007). But the outcome of the least cost path definitely hinged on the value of those costs in relation to each other. For example, during testing, different costs were assigned in an effort to find those costs which seemed to produce the most reasonable least cost path. The meander issue discussed with the Mill Creek Locality scenario (Figure 5-16) could have been eliminated by increasing land cover costs to a point where the path would not leave the water. Doing so, however, would have also eliminated any possibility of a land route between points. Manipulation of the input variables in a GIS will impact the output in ways which may or may not be intended.

Model Flexibility

One primary advantage of using a GIS was the ease with which spatial data could be incorporated, manipulated, or rejected during the development and testing of the model. The testing of different cost values noted above was very easy to accomplish by reclassifying the cost surface and re-running the model. Pieces were added and removed even once the model was finalized. For example, the Copper scenario was run several times with rivers being added and removed to see if the least cost path would be altered (it wasn’t). This ability to mix and match parts makes GIS a valuable asset in studying any landscape, regardless of the time period.
Conclusion

The applicability of GIS for the study of prehistoric landscapes can only be determined through an understanding of the issues and problems associated with each individual research project. The difficulties encountered in my case study of Middle Mississippi exchange related to the data and geoprocessing functions. My first finding is that the availability of data can impact the scope of the research. Secondly, the accuracy of the data may require additional pre-processing time if edits or adjustments are needed. My third finding is that the decision on using vector data or raster data requires a trade-off between accuracy and processing speed. Finally, the subjective nature of the selection of input variables may overly influence the results of the research. These findings are consistent with the literature as noted at the beginning of this chapter (Harris 2000; Knowles 2000; Gregory & Ell 2007). However, the specific problems outlined in the discussion of the results in Chapter V (e.g., differences between the vector and raster files and gaps in the data causing areas of “No Data”) should provide researchers with information to help them avoid potential pitfalls.
Chapter VII

Conclusion

As noted previously, mobility is the combination of movement and the situation, meaning, and context in which that movement takes place (Adey 2010; Cresswell 2001). When that movement takes place during a time period in which there is little or no documentation of the human decisions involved, there is no context for us to understand or employ in our models. We cannot truly know which view was important or which routes were taken (Fitzjohn 2007). We can find the most efficient path, but we cannot find the actual path.

One example of the differences between the most efficient route and the actual route during historical times is that of the French in Montreal travelling a circuitous route to reach the Mississippi River to avoid the Iroquois of New York (Thwaites 1896-1901, as cited in Little 1987). The context greatly impacted the movement. Even when the context is known, it is very difficult to build that decision-making process into a GIS model (Harris 2000). When the context is not known, it is virtually impossible.

While the scope of this research was more methodological in nature, a discussion is warranted of the social and political aspects of Cahokian exchange and how
those aspects impact the research. Alliances and hostilities would have altered the route travelled. If the relationships are known, they could easily be modeled by adding an additional cost surface with a high, prohibitive cost for areas with hostile groups and low costs for areas with allies. However, the results would simply be a snapshot of one particular moment as relationships between groups change and evolve over time.

Another aspect of Cahokian exchange not considered in this research is the impact of its settlement structure. As noted previously, the Middle Mississippian settlement system was a hierarchical system consisting of three or four tiers of communities (Gregg, 1975, Pauketat 2004). The first tier was Cahokia itself, followed by other multi-mound settlements, single-mound sites, and finally villages and farmsteads. In such a system, it is entirely possible and even probable that exchange occurred between Cahokia and its secondary centers rather than between Cahokia and the remote source location of raw materials. For example, the people of Cahokia might not have acquired copper directly from its source location. Some have argued that Aztalan was located specifically for the purpose of acquiring copper for Cahokia (Goldstein 1991). It is possible to model these variables, if known, by producing separate least cost paths of Aztalan to the Copper Source and Cahokia to Aztalan. But, again, they would represent only that particular moment in time as, for instance, the importance of certain materials for a culture shift over time.

The issues which were discussed earlier (and outlined in Table 7.1) are issues encountered in developing and implementing the model used for this research. However, these issues pertain in some fashion to any model being used. If data is
unavailable or inaccurate, it doesn’t matter which geoprocessing tools and functions are being used. The decision of whether to use vector or raster will still need to be made. And the values selected for the input variables will impact the output regardless of the model being developed.

<table>
<thead>
<tr>
<th>Issue</th>
<th>Implication</th>
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<tbody>
<tr>
<td>Data Availability</td>
<td>May change the scope of the research</td>
</tr>
<tr>
<td>Data Accuracy</td>
<td>May require editing or other adjustments (lengthening pre-processing time) or may corrupt results</td>
</tr>
<tr>
<td>Data Type (Vector/Raster)</td>
<td>Trade-off between accuracy of vector data and processing ease of raster data</td>
</tr>
<tr>
<td>Input Variables</td>
<td>Subjective nature may overly influence results</td>
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Therefore, the argument of this thesis is that geographic information systems are applicable for use with prehistoric landscapes when the shortfalls of the data are understood and the appropriate geoprocessing functions and input variables are utilized. In support of this argument, I first reviewed relevant literature on mobility in general, historical GIS studies, and projects where GIS was used in archaeological contexts. Secondly, I described the model used in my case study to test the applicability of GIS. I then provided background information on Cahokia and the archaeological sites used in the study. The fourth substantive section discussed the least cost paths generated by the model and their associated issues at various scales such as the paths
flowing outside the vector files. Lastly, I discussed these issues more broadly in terms of data availability and accuracy, the vector vs. raster decision, and the selection of input variables for geoprocessing functions.

The case study designed for this research was not intended to encompass every possible factor of the discussion of GIS applicability to prehistoric landscapes. This research involved only one aspect of one culture at one point in time. Other studies, such as the spatial distribution of Hopewell mounds or the relationship between Chacoan roads and ruins, might reveal a vastly different set of issues and potentials. Other areas of further research include conducting the analysis on known travel routes from historic time periods to test the results or examining the implications for Cahokian exchange or the location of Cahokia.

An understanding of the limitations involved with using a GIS to examine a prehistoric landscape is the key to its applicability. The scope of any individual project will dictate whether GIS is applicable for that project. The availability and accuracy of the data used, as well as the inclusion of the appropriate functions and geoprocessing tools, will determine the outcome of the research or even if the research question should be adjusted. There are potential pitfalls, but if the researcher understands the data issues and if the data and methodology are appropriate for the scale of the research, then GIS is indeed an appropriate means for examining prehistoric landscapes.
Work Flow - Preprocessing

**Slope**
- DEM
  - Extraction
    - Study Area DEM
      - Project Raster
        - Projected DEM
          - Conversion To Slope (degree)
            - Slope Raster
              - Reclass to 0 - 100
                - Slope Cost Surface

**Land Cover**
- Original file
  - Removal of human impact
    - Pre-contact dataset
      - Reclassify to three land classes
        - Simplified classification
          - Editing: removal of rivers, addition of new areas, etc
            - Final land cover shapefile
              - Conversion to 90m raster
                - Land cover raster
                  - Reclass to 35, 45, 80
                    - Land Cover Cost Surface

**Hydrography**
- Original file
  - Adjustments:
    - combining segments
    - selecting channels
    - extracting desired rivers
    - creating buffer for Great Lakes
      - River dataset
        - Editing to align different datasets
          - Aligned dataset
            - Conversion to 50m raster
              - Stage 1 raster
                - Resample to 90m
                  - River raster
                    - Mosaic
                      - River combination
                        - Reclass to 5, 10, 100
                          - Hydrography Cost Surface

**End Points**
- Lat, long location (.csv)
  - Add X,Y Data & coordinate system
    - X,Y Data Layer
      - Convert to shapefile
        - Location Shapefile
Work Flow - Processing

- Slope Cost Surface
- Land Cover Cost Surface
- Hydrography Cost Surface
- Location Shapefile

1. Combine cost surfaces
2. Create cost distance and cost direction surfaces
3. Create cost path
4. Convert to polyline
5. Cost Path (vector)
References


Drennan, R.D.


References – Archaeological Sites


Monaghan, G.W. and Peebles, C.S. (2010). The construction, use, and abandonment of Angel site Mound A: Tracing the history of a Middle Mississippian town through its


