CHAPTER 3

LITERATURE REVIEW

Classic Studies GIS in Archaeology

Two important literature reviews allowed me to form a reading list that related the use of GIS to the study of archaeology. Two authors, Kenneth Kvamme (1999) and David Ebert (2004), deserve credit for informing my initial search for a project. Classic themes in GIS and archaeology were identified in Kvamme's 1999 publication, and volumes of work and individual manuscripts were chosen from his massive references cited as being of most importance to the foundation of my study (Aldenderfer and Maschner 1996; Allen et al. 1990; Lock and Stančič 1995; Maschner 1996). Each of these works is described below with the intent of showing how emphases changed over time and how each makes a contribution to my project.

A landmark volume describing use of GIS in relation to archaeology was found in Kathleen Allen, Stanton Green, and Ezra Zubrow (1990). The chapters from this volume have been cited repeatedly in many subsequent studies. Some of them have stood the test of time. For example, Kathleen Allen (1990), modeled historic trade networks using GIS, while Jeffrey Altschul (1990), argued for the importance of outliers in predictive modeling rather than use of the model for predicting site location. Landscape theory and GIS formed the foundation of the chapter by Carole Crumley and William Marquart (1990). Robert Warren (1990) wrote a chapter on predictive modeling that became standard method for many projects. Finally, Ezra Zubrow (1990), considered the way archaeological theory was redefined through the use of GIS in archaeological research. Some chapters are dated because hardware and software have changed so rapidly over the last 17 years as can be seen in Scott Madry's (1990) chapter on computer hardware requirements.

Counting the number of themes represented in this volume, by titles, the predictive model is by far the most prevalent, with six titles having some reference to predictive modeling, or site location modeling. Modeling (in other contexts), regional archaeology, and landscape archaeology followed in number and importance behind predictive modeling and were mentioned in three titles each. A comparison of themes from *Interpreting Space* to those of the next classic volume by Gary Lock and Zoran Stančič (1995) is presented below and is interesting how the two volumes differ in focus. However, one should note that the 1996 viewpoint was on European use of GIS whereas the 1990 volume was written from an American perspective.

In *Archaeology and Geographical Information Systems: A European Perspective* (Lock and Stančič 1995), the focus of the presentations moved to landscape archaeology with four titles referring to the word landscape in some capacity. The second most important areas were resource management, settlement, and archaeological theory, with reference to two titles each. Predictive modeling was mentioned in only one title, and was called prehistoric location preference. This volume had its focus on European archaeology, and the reader is made aware of differences between American and European focus and also funding. Two books came out the following year (Aldenderfer and Maschner 1996; Maschner 1996) that provide a better view of the trends in the mid-1990s.

Mark Aldenderfer and Herbert Maschner's (1996) *Anthropology, Space and Geographic Information Systems* edited volume is focused on case studies in anthropology using GIS, six of which were archaeological. Of these six case studies, the titles belied a breakdown of more focus on cognition or cognitive theory in archaeology and settlement, and secondarily on landscape theory. Maschner (1996) in *New Methods, Old Problems* showed a trend towards expanding themes in archaeology. This book is better described using its section titles, as the themes were spread thin with only location modeling, regional archaeology, and landscape archaeology mentioned more than once each. *New Methods* is divided into four sections: 1) Exploratory Data Analysis and Visualization, 2) Cost Surfaces; Viewsheds, or Line-of-Site Analyses; and Site Catchments, 3) Site Location and Environmental Modeling, and 4) New Directions for GIS in Archaeology (Maschner 1996:v-vi).

The review of literature by Ebert (2004) verifies Kvamme's classic themes, with one additional "new" work (Wescott and Brandon 2000). This volume differed from the others as it contains "Predictive Modeling Toolkit" as part of its title. Of the nine chapters (one being the Introduction), five titles contain the phrase predictive modeling, one contains the term settlement pattern, and one contains the term archaeological theory. Table 1 shows how the themes are distributed through these five volumes. It is interesting to note that predictive modeling, so at the core of research studies in 1990, loses ground to landscape between 1990 and 2000, only to become a main focus of attention again in 2000. European archaeology shows much more interest in landscape archaeology, and the European volume is the only volume to use the theme of resource management in its titles.

Table 1. Distribution of Classic Themes in GIS and Archaeology

	Predictive Modeling	Modeling	Regional	Landscape	Settlement	Resource Management	Theory	Cognition
1	xxxxxx	xxx	xxx	xxx	xx			
2	x	x		xxxx	xx	xx	xx	
3				x	x			xx
4	xx		xx	xx	x		x	
5	xxxxx				x		x	

1) Allen et al. 1990; 2) Lock and Stančič 1995; 3) Aldenderfer and Maschner 1996; 4) Maschner 1996; 5) Wescott and Brandon 2000.

RECENT GIS STUDIES IN ARCHAEOLOGY

Beyond the five classics discussed above, there are some recent volumes describing, using, and analyzing archaeological data incorporating GIS methodology. These include David Wheatley and Mark Gillings (2002), a foundational text for GIS in archaeology; Gary Lock (2003), on computing and archaeology; James Conolly and Mark Lake (2006), a generalized text on GIS and archaeology; and Thomas Evans and Patrick Daly (2006), an edited volume covering a range of topics and research studies important to GIS and archaeology. All of these volumes are European in origin. I will move through each of the volumes chronologically.

A very important book by Wheatley and Gillings (2002), *Spatial Technology and Archaeology*, defines all facets of GIS as it relates to work in archaeology. Wheatley and Gillings wrote this book as a reference source to archaeologists who wish to incorporate GIS into their studies. Archaeologists need more training to get more out of the vast potential of GIS, since the discipline is concerned with spatial information. Early theory in archaeology was based on culture history. Artifacts and features found in a certain space could be plotted on a map, and inspection of the map by a cultural historian would reveal what well-defined group of people created the patterns. Space was thought of as a neutral backdrop to culture. Culture History, or the Classificatory Historical approach, is summarized in this statement:

> …processes of diffusion created discrete 'culture zones' which corresponded to culturally homogeneous complexes which were clearly and unambiguously bounded in space…identified through the establishment of cross-classified trait lists based upon aspects of material culture, then visualized through the careful plotting of the distribution of these traits upon maps (Wheatley and Gillings 2002:5).

In other words, Culture Historians collected and documented artifacts, which were classified, then compared to other classified lists of artifacts to find out which ethnic group left them behind. There has been a change in thinking about space today as being culturally defined and constantly negotiated, no longer thought of as a neutral backdrop for human activity, but one that it is "socially rendered" (Wheatley and Gillings 2002).

Wheatley and Gillings also discuss the theoretical change in archaeology from a focus on diffusionism, to that of the environment in relation to settlement in the U.S. Julian Steward led this change in approach, identified as cultural ecology, in the 1920s and 1930s (Trigger 1989:279), which was later taken up by Gordon Willey as settlement archaeology (Viru Valley late 1940s) (Trigger 1989:282). Mapping on a regional scale, in the form of distribution maps, was employed in these studies to visualize change in adaptations "of social and settlement patterns within an environmental context" (Wheatley and Gillings 2002:5). The concern was for "recording and analyzing the spatial dimensions of archaeological material…one of the main instruments of archaeological research and exposition" (Wheatley and Gillings 2002:6).

In the 1960s there was a decided move away from description through mapping to identify unambiguous culture groups, to the identification of patterning in the archaeological record leading to explanation. The New Archaeology demanded scientific proof of noted observed patterns, in measurements and statistics, and explanation of those patterns. Change was caused by external factors and these could be seen as traces in the archaeological record that could be measured (Wheatley and Gillings 2002). Even though the whole book is important for understanding and using GIS in archaeology, three chapters stand out that were of particular interest to my research. These were the chapters titled "Digital Elevation

Models," "Location Models and Prediction," and "Sites, Territories, and Distance" (Wheatley and Gillings 2002)

The chapter, "Sites, Territories, and Distance," explores the spatial property of distance or proximity, and the relationship of distance between objects. "Proximity and distance are…at the core of many important archaeological questions" (Wheatley and Gillings 2002:147). Why is an archaeological object in one place, and not in another? We are looking for explanation. GIS has prompted renewed interest in spatial archaeology and quantitative techniques.

Spatial archaeology uses buffer zones, usually of distance from a point, line, or area. The authors note that cultural factors could be integrated into a buffer analysis (also called a proximity analysis). Vector GIS produce distance buffers and corridors. "The generation of distance buffers or corridors can be regarded as a form of spatial allocation" (Wheatley and Gillings 2002:149).

Voronoi Tessellation is another method of spatial allocation. Tessellation divides up the space surrounding sites into territories. Voronoi Tessellation is also called Thiessen Polygons. A graph is created from a set of points; in this case, the points represent archaeological sites. Another tessellation method is Delaunay Triangulation, which is "the creation of a graph in which the points are used to form the corners of a set of triangles" (Wheatley and Gillings 2002:150).

Distance is a geometric property that can be used in simple analogies and comparisons. More complex analyses require the addition of real factors, such as obstacles to travel, differential cost of movement over varying surfaces, or perception of landscape by the traveler. Instead of distance, the time it takes to travel a certain route can be estimated by the use of cost surfaces. Cost surfaces "can be regarded as modifications to the continuous proximity product that take account not only of proximity but also of the character of the terrain over which that proximity is measured…like distance, these are still simply mathematical models whose archaeological meaning is not fixed: it is up to us to use these as building blocks to create methodologies that have some archaeological meaning" (Wheatley and Gillings 2002:151). The authors provided many avenues of thought about my own least-cost path analysis of travel routes through Lost Valley. The year after the Wheatley and

Gillings book became available for purchase, Gary Lock published a book on computer use in archaeology that included the use of GIS as part of the methodology covered.

Using Computers in Archaeology: Towards Virtual Pasts (Lock 2003) was written to be used as a textbook and so explanations of, for instance, the difference between GIS and Computer Aided Design (CAD), are concise and complete. Lock covers such topics as prospection (looking for sites through use of remote sensing equipment), use of computers during excavation, landscape theory, preservation of digital files in Cultural Resource Management (CRM), presentation of work (as in museums, interactive media, online or electronic publication, and in the classroom), and future possibilities that include virtual worlds. Another book that is written in much same vein is that by Conolly and Lake (2006).

Geographic Information Systems in Archaeology (Conolly and Lake 2006) is presented as a handbook for those involved in academia or CRM as students or professionals in archaeology. Similar in outline to Wheatley and Gilling's book (2002), Conolly and Lake write in a much simpler style. And there are additional sections and chapters that show the expanding network of ideas pertaining to the science of GIS in archaeology that include a section on geodatabases, a section on landscape archaeology, a chapter on theory that applies to GIS and archaeology, a chapter on exploratory data analysis, and most relevant to this study, a chapter on routes, networks, cost paths, and hydrology. The same year (2006) another book became available that brought together different authors into an edited volume.

Evans and Daly (2006) are included here because of the fine chapter by Ezra Zubrow on the historical development of digital archaeology (Zubrow 2006). Zubrow provides the context for his chapter through archaeological theory rather than case studies, comparing the development of archaeological theory to the development in technologies affecting archaeological thought. His sequence of historical development of archaeological theory moves from observation (coupled with “calculating machines”), to cultural history (coupled with early mainframe computers), to processual archaeology (coupled with the first, smaller sized computers, but using punch cards), to post-processual archaeology (coupled with the advancement of smaller yet more powerful PCs and the move away from punch card technology), to cognitive archaeology (coupled with more modern PCs and supercomputing workstations) (Zubrow 2006:17, Table 1.1).

SITE PREDICTION, PROCEDURE, AND LANDSCAPE THEORY

According to Ebert (2004), there are three main ways that GIS are used in archaeology: 1) site location prediction, 2) "procedure-related studies," and 3) landscape theory (Ebert 2004:320). My own review of the literature found this organization to be true and so wish to use it in organizing a review of research papers focused on these topics. I have limited the review to those papers concerning site prediction and landscape theory. Studies that are based on procedure are common and centered on how to do some of the tasks related to GIS use in archaeological studies.

Site Location Prediction

By far the most prevalent research using GIS in archaeology, especially in the U.S., are site prediction location studies. Examples abound in the literature. There are many ways to produce a predictive model. Many of the studies report on the methods of producing their predictive model (e.g., Brandt, Groenewouldt, and Kvamme 1992; Dalla Bona 2000; Duncan and Beckman 2000; Hasenstab and Resnick 1990; Kuna and Adelsbergerová 1995;), while others report on case studies using predictive modeling in a specific area (Carmichael 1990; Dalla Bona and Larcombe 1996; Warren 1990b; Warren and Asch 2000; Wescott and Kulper 2000). Other aspects reported on for predictive modeling are the history and evolution of the methods that have been developed (e.g., Kvamme 1995; van Leusen 1996).

One San Diego State University graduate student in anthropology used predictive modeling as the core of his thesis (Tsunoda 2006). Koji Tsunoda's thesis is a good example of using GIS with previously recorded archaeological site data. As part of the project Tsunoda interned for California State Parks and worked with the records necessary for his thesis. He was able to show environmental connections between site locations that were previously recorded and archived. Tsunoda anticipated that the information could be used to predict where sites may be located in areas that had not been previously surveyed, or to resurvey areas that may have missed site locations in earlier surveys if the environmental variables were met in the location analysis. This is the beauty of the predictive model. The information on the environment comes from previously recorded sites. There is no doubt that environmental factors play a part in the decision making process that humans use in deciding where to locate for a day, a week, or a year. Slope, aspect, distance to water source, and elevation were the environmental factors that were considered relevant to Tsunoda's study.

In 1995, Edward J. Pasahow, also an SDSU graduate student in anthropology with a focus in archaeology, employed early GIS to do an analysis of the prehistoric settlement systems for all of San Diego County. Pasahow had access to SCIC (South Coastal Information Center) that had in its database over 14,000 records of prehistoric sites. Pasahow used the site locations to plot sites by site attribute (such as site type, presences of features, rock art presence, quarry, ceramics present, and etc.) and to show the relationship of the distributions of sites in San Diego County.

Pasahow's work led me to think about conducting a regional analysis in the much smaller area of Lost Valley. The valley itself proved too small for an analysis of the size needed for this type of study, and so I needed to expand it to a contiguous series of DEMs that are easily accessible for the project. My project took an alternate route to a least-cost path analysis. Pasahow's thesis informs a predictive model for site location.

Similarly the following authors created predictive models for use in archaeological survey. In 1997, William Hayden used GIS and site locations in the San Joaquin Hills to look at spatial patterning of Late Prehistoric Period sites. He also performed statistical tests in order to show predictive values through artifact counts found in CRM reports. He was able to illustrate the relationship between territorial boundaries and modeled Theissen polygons.

A study of prehistoric site distribution in the Lower Cuyahoga River Valley, Ohio, by Andrew Bauer, Kathleen Nicoll, Lisa Park, and Timothy Matney (2004), used data available from archives to plot 79 archaeological sites into a GIS application. They then added available soil shapefiles as layers for their study area map. The original 79 archaeological sites had been recorded and placed into categories according to time of occupation and archived in the State of Ohio Historical Preservation Office, an agency whose work it is to document and store all materials related to Ohio history and prehistory. The Bauer team (2004) found that the later periods of occupation (Historic, Woodland period, and Late Prehistoric sites) clustered at certain geological locations over a broad range of location types, while early sites (Paleoindian, and Archaic) clustered around fewer geological location types, mainly Pleistocene terraces and areas between ancient, river-borne sediments.

A master's thesis by Nicole Pletka (2005) contains a predictive model that also uses least-cost path. The area of focus was the Newport Coast in Orange County, California. Pletka used available archival data as the basis for regional spatial analysis of sites that have been recorded either as surface sites or as excavated sites. Site location data and corresponding dates were obtained from either the South Central Coastal Information Center (SCCIC) or CRM reports. The study focused on Late Period Gabrielino settlement pattern.

Pletka's analysis does not include any information about the artifacts recorded from any of the sites. Her method of analysis was to generate hypotheses from archaeological theory and then test her hypotheses with information derived from GIS analysis of the data. Pletka describes the different subsistence strategies used during the Early Holocene, Middle Holocene, and Late Holocene time periods, and the two theoretical paradigms she has framed her research questions around. The first is evolutionary ecology with an optimal foraging model as the main benchmark. The second is cultural ecology with Binford's (1980) forager-collector continuum as the basis of the argument. She is able to show clustering of the paths, created using Nearest Neighbor analysis, as belonging to different settlement types.

Finally, Robert Legg and David Taylor describe a research project centered on predictive modeling of a particular archaeological feature, the placement of Irish Early Medieval Ringforts (2006). The ringfort is found throughout Ireland. The height of construction occurred during a window in time from about A.D. 600 to A.D. 900. Ringforts have some superstition involved with them, as well as being practical for herd animals to be kept. Thus, the presences of ringforts on the landscape of Ireland have, it is assumed, been largely left as is. They are thought to be agricultural farmsteads that needed protection from thieves and animals at the time. The authors of the study wanted to create a predictive model on where ringforts might be located on lands where there has been no survey, or where the ringforts may have been destroyed and have left no visible evidence. GIS were used to map areas by level of probability using a standard logistic regression equation for the multiple independent variables. However, the model that was produced had limited value in predicting the location of forts in areas outside the study area.

Landscape Theory

A relatively new theoretical position in archaeology is that of landscape theory. One of the early and well-cited volumes on landscape archaeology was edited by Wendy Ashmore and A. Bernard Knapp (1999). In the introductory chapter, "Archaeological Landscapes: Constructed, Conceptualized, and Idealized," Knapp and Ashmore (1999) concentrate on explanation and some of the terms used in landscape archaeology. Their position in writing this paper is as an introduction to a volume of papers collected on the topic of landscape archaeology. They state that the terms and concepts are not theirs, nor were individual authors given any guidelines on the use of terms in the constructions of the papers. Four themes connecting the submissions are landscape as memory, landscape as identity, landscape as social order, and landscape as transformation.

Landscape as memory – Knapp and Ashmore begin with a simple explanation of landscape in this quote: "Landscape is often regarded as the materialization of memory, fixing social and individual histories in space" (1999:13). They go on to say that the "…most frequently cited embodiment of memory in land is the intricately conceptualized landscape array of Aboriginal Australians" (1999:13). National and ethnic identity is embedded in the memory of the landscape. Many old sites contain memories of the way things were at such physical locations as cathedrals, and cemeteries.

Landscape as identity – Landscape as memory and landscape as identity are linked. People use and reuse certain places in the landscape. They identify with these places just as I return to the same seat in a class. I associate this place in the classroom with the security of a position within the class, and with the ability to return again and again to a specific location. Knapp and Ashmore use the landscape as identity to mean a place to which people return again and again for ritual, ceremonial, or social uses. Activities bind people together and as such become part of their social identity. At these special places the people will leave their mark, such as rock markings, offerings, shrines, monuments, or temples. Identifying with a location in the concept of landscape of identity is well explained in this statement: "At any particular moment in time, certain places become vested with identity be it supernatural, social, or self-identity" (Knapp and Ashmore 1999:15).

Landscape as social order – Landscape "offers a key to interpreting society…the land itself, as socially constituted, plays a fundamental role in the ordering of cultural relations"

(Knapp and Ashmore 1999:16). Similarly, "Social roles, relations and identities, too, are mapped on the land…" (Knapp and Ashmore 1999:16), referring to the placement of houses and whether you live on Park Place or Mediterranean Avenue. Your living space will dictate which schools your children will attend, and what stores you will frequent. Your living space announces individual economic status. In other words the landscape plays a role in social ordering.

Landscape as transformation – Landscapes change over time and according to the uses and alterations to which they have been put, are thus transformed. "The transformations of landscapes is most often linked interpretively with cyclical time…" (Knapp and Ashmore 1999:18), such as the cycles of crops sown and harvested, or the movement of hunter-gatherers in the quest for available food sources, or the site of an annual pilgrimage to a certain monument of natural or man-made origin and the decay and reconstruction that evolves around that memorial site.

The three aspects of cultural landscape defined by Knapp and Ashmore (1999:21) are cultural landscapes, conceptualized landscapes, and ideational landscapes. These labels are used in the identification process of different landscapes in order to preserve important or unique landscapes of either natural formation or those culturally derived.

Constructed landscapes occur when something is altered or added to the landscape as the result of human interaction with it. Human non-sedentary groups (mobile hunter-gatherers or nomadic peoples) leave trails, views, campsites, and other clues about their activities. Sedentary groups (horticulturalists or agrarians) alter the landscape more obtrusively through the development of permanent gardens, houses, villages (often near natural landmarks), burial mounds, temples, dumps, and slag heaps.

Conceptualized landscapes are given meaning by how the people use specific areas of land for social or ritual practices. These may be artistic uses as in cave or rock art, religious uses, as in use of particular areas for vision quests, or awe inspiring uses, as in power spots with great meaning. An example of sacredness associated with place is Mount Shasta, a mountain that dominates the landscape of Northern California (you can see it for miles - even hundreds of miles in some places). Another example of a conceptualized landscape is the Buddhist cave temples (Knapp and Ashmore 1999:11).

Ideational landscapes can also have sacred or symbolic meaning. An ideational landscape is a mental construct, a perceived or conceptualized landscape that is "embedded within ways of living and being" (Knapp and Ashmore 1999:13). This straightforward and highly organized introduction by Knapp and Ashmore is a good starting point for comprehending the meaning and uses of landscape archaeology. Again and again they return to the idea of the uniquely human and "social nature of landscape" (Knapp and Ashmore 1999:7).

Tim Ingold puts forth a different point of view on landscape archaeology in his presentation, "The Temporality of the Landscape" (Ingold 1993). In this article, Ingold defines and clarifies four principle sections in presenting his argument. They are the following: landscape, temporality, temporality of landscape, and the analysis of an actual 1565 landscape painting by Pieter Brugel, "The Harvester" (Ingold 1993:165).

According to Ingold: "…the landscape is the world as it is known to those who dwell therein, who inhabit its places and journey along the paths connecting them" (Ingold 1993:156). Landscape is what you see when you go outside and look around. As you walk from one place to the next, landscape changes as you move through it.

Temporality has to do with time as it relates to a sequence of time or a point in time. Ingold says temporality is not chronology and not history. Temporality is intrinsic in the patterns of activity associated with the construction and maintenance of a living space (dwelling), which Ingold (1993:153) has named the taskscape. Taskscape has to do with what people are doing, what work they engage in. Ingold refers to the qualitativeness and heterogeneousness (what and how rather than how many, and of diffuse blends) of taskscape as opposed to being quantitative and homogenous (countable numbers of similar undertakings).

Ingold discusses the temporality of landscape, and the taskscape and its relationship to landscape saying the distinction between them is blurred. The landscape is a living process, a work in progress. "…[T]he activities that comprise the taskscape are unending, the landscape is never complete…" (Ingold 1993:162). The taskscape is the sounds of activity; the landscape is what you see. The landscape retains the palimpsests of past occupation and habitation just as a landscape painting might.

Using the painting by Bruegel to illustrate his approach to the analysis of landscape, Ingold (1999) explains how the still antiquated landscape painting captures the essence of lives lived at this point in time. The moment captured was one instance in the nature/culture cycle of land use and dwelling, so this same scene no doubt repeated year after year in a similar way. There is another way to depict landscape, one that possibly more clearly captures the nuances of landscape over a large area and from a different point of view. This is by viewing the landscape from above.

The use of GIS and mapping techniques, and geophysical surveying allows a landscape perspective from a plan view. In an *American Antiquity* article, Kenneth L. Kvamme (2003) explains how GIS and archeo-geophysics can be used to coordinate a view of landscape via digital methods. Using the archeo-geophysical methods of non-invasive ground penetrating radar, resistivity and conductivity, and magnetometry, one can obtain a picture of an ancient landscape with many of its features of use and non-use that lie below the surface.

The technologies of archaeo-geophysics tend to be used over large areas to glimpse a totality of hidden landscape features. These geophysical methods are used to better determine where archaeological digs should be placed so that standard units of excavation may be more fruitful. Use of these archaeo-geophysical tools would preclude the need for shovel test pits (STPs) that are expensive and time consuming for the results that they provide. According to Kvamme's article, only one percent of STPs yield some sort of artifactual content. STPs are used to determine the best area for layout of project units, where the yield may be the most beneficial to the area under study.

Archaeo-geophysical methods are used extensively in European archaeology, but have not caught on in the United States. Old methods die hard. The equipment necessary to use archeo-geophysical methods for pre-excavation research come at a dear price, in the range of 10 to 20 thousand dollars or much more for one piece of equipment, depending on which avenue is taken. The cost of equipment and the cost and time needed for necessary training in new hardware and new software programs may be the reason why these methods are being adopted more slowly the U.S. Using a technological approach to landscape archaeology would boost both qualitative and quantitative analysis.

As is evidenced by the three examples of the application and approach of landscape archaeology just discussed, there are very different ways of applying and interpreting landscape archaeology. Knapp and Ashmore (1999) presented an organized and thorough overview of landscape archaeology with some new terms. Ingold (1993) philosophized over music and paintings and how resonance, cycles, and rhythms of daily, weekly, yearly activity relate to landscape and taskscape temporally. Kvamme (2003) approached landscape analysis through quantification using new technological developments in GIS and remote sensing. Landscape archaeology contains a diverse set of ideas and approaches, all of which are relevant to study, survey, and analyze in archaeology.

One of the goals of this investigation was to include the use of GIS as a foundation of the project. A second goal was to use previously collected archaeological data and incorporate these into a GIS analysis. One of the problems in the discipline of archaeology is that analyses and reports on excavations lag behind collection and curation of artifacts, even though it is considered unethical to fail to publish a record or report once an excavation is complete (see the Society for American Archaeology website for the eight principles of Archaeological Ethics: http://www.saa.org/aboutSAA/committees/ethics/principles.html). One way of approaching the problem of compliance to ethical principles in archaeology is to provide avenues of analysis that use new technologies for the vast stores of data collected over the years. Even for those data collections that have been published, new questions can be asked, and old assumptions challenged through the use of new methods such as GIS. Linking disciplinary tools is another avenue worthy of exploration.

GIS Least-cost Path Analyses in Archaeology

One of the earliest studies involving least-cost path and network analysis using GIS in archaeology is that of Kathleen Allen (1990). In her study of trade networks in the northeastern United States, Allen showed how GIS could be used to model trade networks following the watersheds or waterways. Waterways, used as transportation networks, played a part in the distribution of goods between tribes in the Great Lakes area of New York State.

Allen used the NETWORK module of Arc/Info to create a model of trade networks using the New York State hydrology layer as the path of least resistance for connections between known prehistoric sites and known historic trading post locations. In the state of

New York, the prehistoric inhabitants were those of the Five Nations Iroquois. In this early design of GIS used in archaeology, Allen marked out the steps taken to create her model of change in the major trade routes between incoming Euro-American traders and the aboriginal inhabitants, using present New York State as the area boundary. With a background in the prehistory and history of the area, Allen was able to assign time periods for different configurations in trade relations. The models show that the Iroquois first had more control over trade through the region, but gradually, as Euro-American colonists advanced into Iroquois territory, Euro-Americans gained control over trade. Hydrology models follow least-cost paths directionally down slope, as this is the path that water would follow naturally.

Ten years later, Marcos Llobera (2000) takes ideas from some very obtuse philosophers (i.e., Foucault and Bordieu) and makes them understandable. Using a creative approach to the blending of archaeology and GIS, Llobera is a master at the mathematics of cost paths, which is the focus of his writing. Digital Elevation Models (DEMs) form the foundational data layers in this study of foot trails in rural areas. Llobera's study compares modeled paths to those that are present to this day in an area where monumental architectural features are present. He wishes to formulate ideas of how these features function to alter paths that would follow the direction of least resistance. He goes in to some depth about the impact of features on those who use a route near the feature. Well-worn trails are created in a predictable manner, one that can be predicted through the use of mathematical formulae.

Llobera's model of movement has to do with the study of ancient landscapes. He adds to previous models that take into account specific landscape features and the creation of pathways that guide the traveler through the landscape in a way predicted to inspire awe. Llobera's focus is on movement through the landscape. Enhanced by the addition of GIS, Llobera creates what he calls a "new GIS routine" (Llobera 2000:65).

The new routine can be described with the goal of exploring "dynamics of movement" in natural landscapes (Llobera 2000:66). Starting with the topography or shape of the landscape, he finds the energy cost of moving through that landscape, taking into consideration the effects of landscape features (a quite extensive step in the routine) (Llobera 2000: 71-74). Then, Llobera combines previous ideas with DEM information, models the movement process, states his assumptions, and presents his results. Presently, ArcView 9.2 will perform a lot of these functions automatically with the correct input.

In the next example of GIS and least-cost path in archaeology, author Trevor Harris (2002) suggests that the most advanced use of GIS in archaeology is simulation of sites in three and four-dimensions. The earliest use in archaeology was to map data and to keep it organized. The next advancement was "spatial analysis and modeling" (Harris 2002:131). Harris covers a range of topics, which include archaeological mapping, 2.5-D display, viewshed analysis, cost surface analysis, 3-D multidimensional modeling, archaeological site prediction, virtual GIS, and virtual worlds. But the main discussion of interest to my study is that of a GIS project that he and Gary Lock completed on Iron Age hillforts. They used cost surface or friction surface to calculate time and effort needed to reach Iron Age hillforts from surrounding habitations, the methods of which have much in common with the modeling of Cupeño travel networks.

One of the most influential papers to my research was posted online in 2003, by the research team of Whitley and Hicks (2003), who showed how an archaeological research project could adapt the use of GIS to predict the location of ancient travel routes between archaeological site locations. The goal of the project was to forge new avenues for thinking about the archaeological record, and to expand discussion of research areas previously limited by available technology. GIS are one such technology that provides a potential avenue for expansion in this area. Digital elevation models (DEMs) were "fused" together, and then the slope, hillshade, and runoff models were derived from the DEMs. A friction surface was created, as well as the point files for the beginning and ending of paths across the friction surface. Of note, their study area was a large rectangular area that crossed three counties and converged a total of 16 USGS Quad maps that represent the basis for the DEMs.

This study is of interest because first, it is exploratory, second, they use DEM derivatives and available data from a project done for archaeological site prediction (so they have a layer of sites with attributes that include the estimated time of occupation), and third (even though it does not say exactly how they do it), they are experimenting with least-cost path from edge to edge of their study area over multiple iterations that move the start and end points at intervals. These cost paths are combined and cleaned up, especially at the edge, where "edge effect" causes the line of least-cost to travel along the study boundary (when it really should continue outside the boundary).

My final example of the use of least cost paths in archaeological study is based on a thesis by Nicole Pletka (2005) (described previously), that uses least-cost path analysis to show clustering of archaeological sites in the Newport Coast area of southern Orange County, California. Pletka used distance to the coast as one of the main attributes for her research that described the movements of prehistoric and protohistoric peoples across the landscape, and how the known sites clustered into three regionally distinct settlement patterns (Pletka 2005).

Pletka used available data as the basis for regional spatial analysis of sites that have been recorded either as surface sites or as excavated sites. All of the sites associated with the study have an associated date from radiocarbon testing that was done under contract, as all of the area is now under development for homes. Her analysis does not include any information about the artifacts recorded from any of the sites. The method of analysis was to generate hypotheses from archaeological theory and then test the hypotheses with information derived from GIS analysis of the data.

Data on site location, dates of occupation, and survey boundaries were entered into a GIS. These data were from site reports filed at South Central Coast Information Center (SCCIC) at California State University, Fullerton and include the following: a report by Macko (1998); a report by Mason and Peterson (1994); and a report on Crystal Cove State Park (Barter 1991). Archaeological sites were digitized using a digital USGS topo quad as the base map. Modifications of boundaries were made where necessary. Pletka posed a series of six hypotheses. One of Pletka's hypotheses is Hypothesis 1, which states that the sites are randomly placed or clustered. Using nearest neighbor analyses, Pletka found the single closest neighbor to each of the sites, and then ran the statistics for the nearest neighbor. A line was formed on the GIS map between nearest neighbors. The results of this analysis included a map with lines between the sites, which were closest together. This test showed that the sites were clustered in three distinct zones. Hypothesis testing was also conducted for distance from the coast; random or clustered site distribution; placement of intermediate zone sites on least-cost paths; and the distribution of sites with regards to soil type, which Pletka used as a proxy for vegetation type. Pletka's thesis was inspiring and informative in possible methods that could be used in testing the results of GIS routines.

LEAST-COST PATH IN OTHER DISCIPLINES

The use of GIS have important implications for other disciplines as well. I will summarize those that are pertinent to this thesis. Important work is being conducted in the area of wildlife habitat. The work of Gallo et al. (n.d.) is a good example of inroads into construction of mountain lion breeding corridors to ensure the presence of mates and therefore future populations of mountain lions in California. This particular work was conducted in the Santa Barbara area. Another example of use of least cost path is in a study by Helbing et al. (1997). Working in urban areas, this team found that people walking across wide expanses of undeveloped land would soon create regular trails across the area that could be predicted in advance. In the work of Ganskopp et al. (2000), the probable paths of livestock were modeled in GIS to show that cattle do follow the path of least resistance. The paths that they would form over a range could be predicted.

In Brumm et al. (2002), GIS are utilized for transportation planning in the construction of a road. Finally, Stahl (2005) used GIS to find the best route to send out autonomous ground vehicles. In order for the robotic vehicles to arrive at their destinations without mishap, the path they would follow is figured ahead of their travel. These five examples of least-cost path outside of archaeology show the utility of the program and the multiple ways it can be used in analyzing least-cost paths.

THEORETICAL FOUNDATION

The foundation of this thesis is based on the theoretical framework used by authors of works using GIS for least cost path or for other avenues of inquiry in archaeology. There were as many different theoretical models as there were papers. This section describes the cogent theoretical bases used and argues for the appropriateness of the theoretical framework chosen for this study.

Landscape Archaeology

I looked for explanations of landscape archaeology that were conducted after Knapp and Ashmore (1999) and Ingold (1984) published their work. I was especially interested in how landscape theory is incorporated into newer studies utilizing GIS functionality in archaeological research. In the following section I briefly describe several studies that contained three primary ingredients: landscape theory, GIS, and archaeology.

According to Crumley and Marquardt (1990:73): "Landscape is the spatial manifestation of the relations between humans and their environment." Landscape can include unoccupied space that is used for religious purposes, resources extraction, rivers, mountains, and so on. Furthermore, two structures determine landscape, sociohistorical structures and physical structures (Crumley and Marquardt 1990:74). Sociohistorical structures include those structures, which are political, legal, and economic, while physical structures include those outside of human control such as climate, soil type, and topography. Within these structures the landscape is produced through human interpretation as in how the world appears to the beholder in the way of aesthetics, sacredness, significance, provider, and protector.

Crumley and Marquardt's original research focus was on changes to administrative boundaries. In their research they wanted to locate the changes in regional boundaries over time. In defining a region, they choose a comprehensible, identifiable unit that could be selected and compared to other units of a comparable size. Scale is an important comparable between regions. "To find an appropriate scale of analysis, one must search for (1) a measure of the connectivity (at different scales) of the area under consideration with contiguous areas and (2) areas that seem to exhibit a high degree of overlap of a variety of boundaries. Viewed this way, a region never has the same meaning, nor does it occupy the same boundaries throughout its history" (Crumley and Marquardt 1990:75-76). Crumley and Marquardt (1990:78) believe that successful modeling of archaeological regions will depend on the addition of cognitive and historical features. They chose GIS as the tool to help them achieve the goals of the research in combining landscape as a concept in the understanding of regional development (Crumley and Marquardt 1990).

Ten years later, an important book on bridging theory in archaeology helps to define the use and connection of the landscape perspective in archaeology. Schiffer's 2002 *Social Theory in Archaeology* presents ideas related to the necessity of bridging seemingly opposed theoretical paradigms. As the first chapter of an edited volume, Schiffer starts by describing the practice of redlining in archaeological theory, as there is at present too much literature to master. In a comparison of theoretical camps, Schiffer says that Binfordians can easily redline postprocessual or behavioral theoretical literature, thus paring down their reading load. In the same way Dunnell, from the evolutionary archaeological perspective, can redline behavioral and processual literature. Since Schiffer is a behavioral, processual archaeologist, he suggests that postprocessual theory should be ignored (Schiffer 2000:4).

The other way to exclude through redlining is on the basis of complexity of the society under study usually divided into three levels: mobile hunter-gatherers (bands), intermediate tribes and chiefdoms, and complex societies (Schiffer 2000:4). Studies of complex societies easily set aside those theoretical works pertaining to intermediate level, and band level societies and so on. Schiffer says redlining on the basis of theoretical school, or level of complexity "is no different than traditional redlining in archaeology based on areal specializations" (Schiffer 2002:4). However, he says that this type of redlining is justified by reading Kuhn's *Structure of Scientific Revolutions*, which puts forth that competitive theories are too incompatible (in their assumptions) to be combined. Researchers with opposing paradigms cannot comprehend each other's ideas, so no discourse can take place.

However, Schiffer believes that it is time to stop the separation, and begin integration of these theoretical camps. He thinks that division by camp impedes theory building in archaeology and says there is another way (Schiffer 2000:5). Bridge building is defined as "the construction of any conceptual integument that can connect previously disparate theoretical formulations or relate, theoretically, formerly discrete phenomena" (Schiffer 2000:5-6). Rather than redlining, a better practice would be to become educated in the main literature from all sides and use a blend of theories that best supports the data that you are interested in exploring.

One of the chapters in the Schiffer (2000) volume is by María Nieves Zedeño (2000), who manages public lands for cultural resources. Part of her research has been focused on land tenure policies that affect aboriginal populations. Ideas of land ownership and administrative policy are explored.

Zedeño, looking to explore human-nature relations, does so within a framework of landscape theory. She bridges the management of cultural resources on public lands with a landscape approach (Zedeño 2000:97). She says that in the development of programs dealing with the need for safe havens for immigrants to the United States, policies were made and altered to contend with whatever was required for a repopulation by colonizing Euro-Americans to take place, decidedly not in the best interest of the aboriginal inhabitants. "I am concerned with understanding how people build social environments through interactions with nature" (Zedeño 2000:97).

Built environments have been frequently studied as far as architecture and monumental building are concerned. The lifeways of hunter-gatherers do not usually leave such remains, so a different approach is necessary to deal with their idiosyncrasies. In contrast to the study of monumental architectural remains, hunter-gatherers "built their social environment around the extraction and appropriation of localized natural resources—plants, animals, minerals, and landforms" (Zedeño 2000:98).

In order to accomplish her landscape study, Zedeño examined the history of land tenure and land tenure policies and the language definitions required for such understanding. Cultural differences in the concepts of bounded space, property ownership, land tenure, and differences between hunter-gatherer and agrarian needs are explored. American political history led to the "notion of space bound tenures" (Zedeño 2000:99). Current legislation, Zedeño reminds us, is the reason we have our archaeological jobs in some cases. The legislation halts some of the procedures of traditional archaeology, but creates new avenues for approaches, which now include a landscape approach. Zedeño sees the link of current research studies between "eclectic approaches and postmodern approaches to human-nature relations" (Zedeño 2000:102), and also between the landscape approach and Native American land tenure systems. The landscape approach, says Zedeño, "provides a frame of reference for understanding human-nature relations at various scales" (Zedeño 2000:102).

One of the ideas that Zedeño wishes to explore is that of landscape theory in archaeology and the way in which single landmarks (localized places or resources that are transformed through use into a places of importance to the culture—I think of site here) are linked "into an integrated network or *landscape*" (Zedeño 2000: 98, emphasis in original), which is a perfect parallel to what my study is seeking to accomplish. My network would be the trails linking the landmarks or sites that have been recorded. My network model may show areas where sites should be found but have not been recorded yet, in kind of a predictive model of nodes along a network.

From the foundations of these theoretical pieces on landscape archaeology, some with a connection to GIS in archaeology, I lay the framework for my study of the network of trails through Lost Valley, and the possible connections that may be seen in the modeling of such networks.

GIS: Tool or Science?

Geographic Information Systems have a brief history going back to its original use in the 1960s as a tool for plotting Canada's land usage by the Canadian government (Longley et al. 2005:16). In the several decades since, GIS have expanded their capabilities to include census data encoding in 1967 (USA). In 1969, map overlay processes were added to GIS arsenals. The development of microcomputers in 1981 allowed the expansion GIS capabilities. Then, the addition of Global Positioning Systems in 1985 furthered the development of GIS using GPS coordinates from the field. Internet based GIS (including MapQuest in 1996) allowed further growth of the GIS industry, which now claims a huge global market. Huge volumes of data available for access in the early to mid 2000s by government and private business entities have furthered the ability for people to learn to use the software without the huge expense of data collection (Longley et al. 2005:19-21).

A debate about whether GIS are science or tool was inadvertently begun through a listserve discussion (GIS-L) in 1993. A tangential discussion about peer reviewed literature led to a point of "GIS as a science" which led to counter point of "GIS as tool", and the debate was begun. The authors of *GIS: Tool or Science?* (Wright et al. 1997) collected the transcripts of the discussion through listserve to try to answer the question. They coded the transcripts and divided answers into groupings. It seems that there was a split between those who viewed GIS as a tool, and those that related it with science. This broke down into discussions about the definition of science. According to Wright and colleagues (1997:352-354) the research on the listserve discussion revealed three divisions of use that GIS are put to. These positions are fuzzy and represent a continuum from GIS as tool, to GIS as toolmaking, to the "science of GIS." From an archaeological perspective, GIS are a suite of tools that can be used to enhance scientific understanding depending on how it is used. The use, and therefore what it is, depends on the user.

Chapter Summary

Some say that the history of GIS in archaeology is long; some say it has been utilized only a short period of time. In the review of literature I have included those works that are relevant to my area of study, which is modeling a network of least-cost path trails that will locate Lost Valley in relation to surrounding known sites. One possible result could be the prediction of the location of undiscovered sites. The literature review begins in 1990 with a major publication (Allen et al. 1990) and progresses from there to include those foundational works that are cited again and again in research papers contributing to the growing volume of literature containing methods of GIS in archaeology. I then researched literature containing least-cost path studies, continuing to literature explaining and using the theoretical foundation of landscape archaeology (or theory) that has gained notoriety in the past ten or more years. This body of literature is the foundation on which my thinking has evolved over the two plus years that I have been cogitating on Lost Valley and the modeling of a possible network of trails that could show relationships with areas within and outside of Cupeño territory. In the next chapter, I review the methodology used in this research project.