A PREDICTIVE MODEL OF PREHISTORIC ACTIVITY LOCATION FOR THE SOURIS RIVER, SASKATCHEWAN

A Thesis

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Department of Anthropology

by

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A Thesis submitted to the Faculty of Graduate Studies of the University of Manitoba in partial fulfillment of the requirements for the degree of

MASTER OF ARTS

ABSTRACT

This thesis presents a predictive model developed for the upper Souris River valley in southeastern Saskatchewan. It stems from a heritage resource impact assessment conducted as a result of the construction of the Rafferty Dam near Estevan, Saskatchewan, of which developing a predictive model was a small component. A review of the existing literature concerned with archaeological predictive modelling forms the base upon which this work is built. The methodology by which this model is developed allows for the experience of archaeologists to be quantified and incorporated into the modelling process. A number of variables were identified and weighted according to their perceived association with prehistoric activity locations. Using GIS software, these variables were combined to produce a computer map illustrating a scale of potential for prehistoric activity locations.

The predictive model was evaluated using three statistical tests. The first evaluated whether or not the model was successful in predicting the location of sites. The one-sample Kolmogorov test demonstrated that site locations were being predicted in a manner different than that expected by chance. The second was a Spearman's rank correlation test, the results of which indicate that knowing the rank of the weighted value assists in predicting the percentage frequency of site cells. A third set of tests evaluated if the two major site types in the area were associated with any specific variables. It was demonstrated that only one subcategory, proximity to permanent water, was statistically determined to be associated with stone circle sites. Overall, the tests demonstrated that the model was effective in identifying the combination of variables that

predicted the location of archaeological sites. In fact, using this model as a guide to surveying, 45% of sites (70% of site cells) would be identified by examining less than 13% of the survey area.

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I save my greatest gratitude for my wife Desire and my two children Anda and Nadia. You politely listened as I endlessly rambled on about the same subject for years and didn't complain when I disappeared to my desk to write another couple of pages. (Most times I listened to Beatles' albums but I managed to bang out a few paragraphs between songs.) It was with your help, advice and support that I was able to get this all down on paper.

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CHAPTER 1
AIMS

1.1 INTRODUCTION

This thesis presents a methodology for developing predictive models of prehistoric activity location. The research outlined here explores the role a predictive model can play in reliably indicating where people located their activities in the prehistoric past. In addition, this research will examine whether a model of prehistoric activity location can provide insight as to why people were choosing specific locations to conduct their activities as opposed to others. The predictive model proposed in this thesis will be applied to a portion of the Souris River Valley in southeastern Saskatchewan (Figure 1.1).

1.2 CONCEPTUAL AND SUBSTANTIVE IMPLICATIONS

> It is anticipated that further research...will lead to the refinement of these models. In addition, it is anticipated that this will lead to the generation of predictive models for hunter-gatherers in Northern Temperate Zones characterized by a marked diversity of subsistence resources (Nicholson 1988:364).

While predictive modelling has been developed and used primarily as a cultural resource management tool through the 1980s, its applicability as a research tool is becoming more apparent to archaeologists. On the prairies of Manitoba, Saskatchewan and Alberta, there are remarkably few regional archaeological studies. The majority of these regional studies focus on assimilating existing site information while very few attempt to understand the regional dynamics of the prehistoric past (*e.g.*, Byrne 1973; Reeves 1983; *c.f.* Syms 1977; Nicholson 1988). In this respect, settlement pattern studies and its

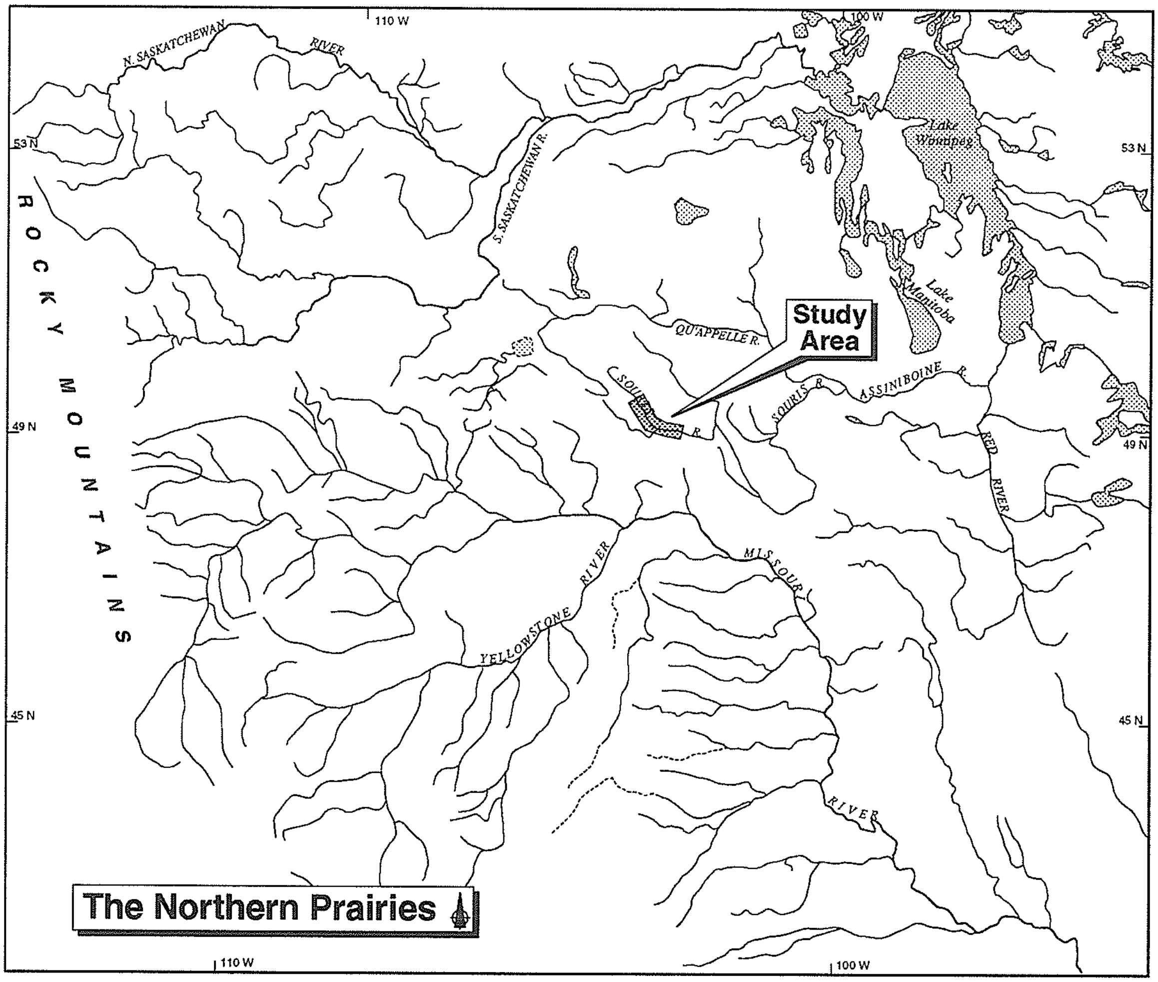

Figure 1.1. Location of the Study Area

subset, predictive modelling, can be used to make a substantial contribution to the pool of knowledge about Canadian Plains prehistory.

At a workshop entitled *Perspectives on Contract Archaeology* hosted in 1991 by the Saskatchewan Association of Professional Archaeologists, conference participants noted the contribution predictive modelling could make to Plains archaeology. "In order to ensure that the best possible data is being recovered now for future research, the academic community should be directing greater research attention to [archaeological resource management] issues. There is certainly no shortage of problem areas in this regard (*e.g.*, predictive site locational modelling)" (Germann 1991:8). This same view is echoed in the issues identified for discussion at this workshop. "Both industry representatives and archaeologists cautiously support the idea of developing regional predictive models to identify archaeologically sensitive areas" (Germann 1991:55). Predictive modelling is being recognized by many archaeologists as a methodology for better understanding site distribution patterns. In discussing a predictive modelling project for the high plains of Colorado, Kvamme (1992:19) states:

> The purpose of these models was to contribute to a description and understanding of prehistoric locational behavior, to guide subsequent survey efforts to those regions where sites were most probable in order that a significant portion of the limited amount of survey to be performed would be conducted in the most archaeologically sensitive areas, and to provide a planning mechanism that would aid in the future management of cultural resources by indicating where sites were likely to be located in unsurveyed areas.

The research in this thesis will be directed toward answering two questions. The first question asks: can a predictive model of prehistoric activity location reliably indicate where people were locating their activities? This question will be answered by: (a) placing predictive modelling within the theoretical context of settlement studies and; (b) applying existing theories of settlement pattern analysis and predictive modelling to the development of a new methodology for developing predictive models. This methodology will then be applied in the Souris River Valley in southeastern Saskatchewan. The success of the model developed herein will be evaluated by comparing the predicted locations of archaeological sites against the actual locations of archaeological sites identified during a survey of the study area.

The second question addressed in this thesis asks: can a predictive model of prehistoric activity location provide insight as to why people were choosing certain areas to conduct their activities as opposed to others? The predictive modelling methodology proposed here is structured in such a way that the locations predicted as having significant archaeological potential will also indicate the combinations of known factors resulting in those locations being significant. The methodology proposed here will indicate which known factors contribute to significant prehistoric activity locations and those factors may be associated with the choices made by prehistoric people when locating their activities.

1.3 ORGANIZATION OF CHAPTERS

This thesis will present the research according to the following organization. Chapter 1 reviews the development of predictive modelling and places it within the context of settlement studies.

Chapter 2 presents a discussion and evaluation of existing techniques of predictive modelling including the positive and negative aspects of this field of research. In addition, geographic information systems will be defined and explained. A discussion of predictive modelling methodology will bring the chapter to a close.

Chapter 3 introduces the study area by presenting a brief review of the archaeological culture history of southern Saskatchewan with specific reference to the Souris Valley region during the Late Prehistoric Period. The floral, faunal and geological history will be outlined. The project under which this research was carried out will be described as will the field survey conducted during the summer of 1990. This survey was carried out to establish the baseline data against which this predictive model is evaluated. Finally, a predictive model of prehistoric activity location for the Souris River Basin will be presented.

Chapter 4 presents an evaluation of the predictive model as a technique for identifying prehistoric activity locations by comparing predicted prehistoric activity locations with known prehistoric activity locations. The model will be evaluated in terms of its precision and accuracy with respect to its ability to identify unknown prehistoric activity locations. The predictive model will also be evaluated in terms of its ability to provide insight into explanations of the settlement system.

Chapter 5 summarizes the research in this thesis and will present conclusions drawn from the work. Avenues for further research will be offered.

1.4 THE DEVELOPMENT OF PREDICTIVE MODELLING

Predictive modelling is an avenue of research within archaeology that has gained prominence over the past two decades. Predictive modelling is defined as a "simplified set of testable hypotheses, based either on behavioral assumptions or on empirical correlations, which at a minimum attempts to predict the loci of past human activities resulting in the deposition of artifacts or alteration of the landscape" (Kohler 1988:33). Parker (1985) sees predictive modelling as a natural outgrowth of the theories and methodologies of spatial archaeology and predictive modelling has become the focus of a number of archaeological studies (*e.g.,* Allen *et. al.* 1990; Brown and Stone 1982; Judge and Sebastien 1988; Kvamme 1992).

Predictive modelling has its basis in the settlement studies first carried out in the 1950s and 1960s by Gordon Willey and other archaeologists. Willey (1953) intended to examine archaeological data on a regional level in an effort to understand the processes inherent in settlement systems in the Virú Valley in Peru. On the whole, Willey was successful at developing settlement pattern archaeology and his work provided the stimulus for other settlement studies to be conducted. Resulting publications by Willey (1956), Willey *et. al.* (1965), Chang (1968) and Adams and Nissen (1972) established studies of settlement patterns as a valued research methodology within archaeology. Settlement pattern studies were further refined and used by archaeologists to conduct catchment analyses (Vita-Finzi and Higgs 1970), interpret social and technological change in a region (Adams and Nissen 1972) while others focused on the environmental determinants of settlement location (Haury 1956; Heizer and Baumhoff 1956; Williams 1956).

Throughout much of the 1950s and 1960s, archaeologists operated within an inductive framework where research into settlement patterns was based upon little or no theory. Haggett *et. al.* (1965) provided a more solid grounding for locational theory to archaeologists by introducing many relevant concepts into the discipline from geography. He influenced a generation of archaeologists by outlining theories of settlement hierarchies, sampling procedures and hexagonal lattices (Haggett *et. al.* 1965). Trigger (1968) outlined more clearly the various aspects of settlement patterns and offered some determinants of settlement location. Concurrent research in other fields of archaeology was beginning to emphasize the importance of ecological variables in understanding settlement variability (*e.g.,* Flannery 1968).

In the decade that followed the 1960s, the manner in which archaeological data was handled changed considerably. Many archaeologists adopted more systematic approaches to collecting and analysing data. The use of computers allowed for the manipulation of greater amounts of data, the generation of more detailed analyses and more generally, for a greater variety of questions to be asked of the data by archaeologists at the time. Studies ranged from examinations of minute differences in artifact types, to macroscopic studies of ceramic variability, to studies of prehistoric culture change (*e.g.,* Flannery 1976). These studies contributed to further refining the level of detail in which settlement variability was presented by archaeologists.

As a result of settlement pattern studies, emphasis by archaeologists was shifting from the study of single sites to the study of regions and their archaeological contents. For example, following closely from the settlement studies of the 1950s and 1960s, the Southwestern Anthropological Research Group (SARG) set out to determine why "prehistoric populations locate sites where they did" (Plog and Hill 1971:8). Clearly stated in this research goal was the delineation of the "formal variability in sites, variability in temporal loci of sites, and variability in the spatial loci of sites" (Plog and Hill 1971:8). Indeed, settlement pattern research had turned, at least in print, from the simple description of archaeological remains to the recognition of site distibution patterning.

The SARG presented a detailed research design for the study of human settlement systems. They recognized that a regional approach to studying variation in human settlement patterns was absolutely necessary to understand settlement systems. Previous research in the American southwest concentrated primarily upon a few core areas and these interpretations were then generalized for the entire region. The need for more detailed and standardized investigations prompted the formation of the SARG. Foremost among the goals outlined by project leaders was the explanation of:

> variability in the distribution of prehistoric sites — settlement and limited activity sites...Why do we want to explain site location or settlement system patterning?...The most important reason for explaining settlement locations is that we hope to arrive at tested and useful laws that can be used by social scientists *to predict site locations anywhere at any time, including the present and the future* (Plog and Hill 1971: 10-11, original emphasis).

The majority of settlement studies carried out in the Americas contained more description of settlement locations than explanations for their specific existence. Plog and Hill (1971) recognized the need for explanation of the 'system behind the settlement pattern' but strived to arrive at explanation via other avenues. Realizing that the explanation of settlement systems derives from an understanding of their mechanics, SARG sought to predict unknown site locations from the principles of the known settlement system. Thus, SARG's goals anticipated those of many other archaeologists by several years. At the same time, much of the discipline was embroiled in a methodological debate concerning paradigms and polemics, but several research projects that complemented the directions and goals set out by SARG eventually emerged.

Plog and Hill (1971) were not the only archaeologists intent to predict site locations. Although not an explicitly stated research strategy, prediction as a subset of settlement pattern analysis was making its way into the archaeological literature. Perhaps the first settlement pattern study designed to identify sites using prediction was that carried out in the Reese River Valley in the Great Basin of the American southwest (Williams *et. al.* 1973). The authors carried out a settlement pattern study in central Nevada focusing on winter village placement. They stated that "given the proper set of environmental conditions, [they] could successfully predict presence/absence of archaeological sites" (Williams *et. al.* 1973:215). Wanting to confirm their intuition about 'where sites could be found,' they developed hypotheses based on those intuitions and measured their soundness. Variables, definitions and criteria used to develop their predictions were carefully outlined as follows (Williams *et. al.* 1973:227):

> 1) The locus should be on a ridge or saddle.
> 2) The ground should be relatively flat. (relatively flat <5% slope)
> 3) The locus should be in the low foothills. (low foothills <250 meters above the valley floor)
> 4) The locus should be within the modern piñon-juniper ecotone.
> 5) The locus should be near the modern piñon-juniper ecotone. (near <1000 meters)
> 6) The locus should be near a semipermanent water source. (near <1000 meters)
> 7) The locus should be some minimal distance from this source. (some minimal distance >100 meters)

These criteria were not revolutionary by any means. In fact, they appear to be criteria quite obviously related to site location. What was new about these criteria was their clear definition and implementation in the overall research strategy. If any five of the seven criteria were met, "the locus was recorded as an area of potential habitation, whether or not cultural material was found" (Williams *et. al.* 1973:231).

The results of the research were positive. The variables outlined above were shown to be present at 97% of the sites in the study area while 85% of the potential loci contained sites (Williams *et. al.* 1973:233). Although the authors acknowledged that refinements could be made to the prediction criteria, on the whole, they were successful. The authors showed that no one variable determined the location of a prehistoric habitation in this area. "In spite of the fact that a single locational criterion would not significantly restrict the spatial distributions of sites, combinations of two or more mildly restrictive criteria would quickly reduce the number of possible locations that will fit the specified criteria" (Williams *et. al.* 1973:234). On a more general level, the authors confirmed the suspicion held by many archaeologists concerned with location of sites; something acknowledged as a 'feel' or 'insight' gained from intimate familiarity with the data (Williams *et. al.* 1973:217). Indeed, insight was gained into the choices made by the prehistoric inhabitant of the Reese River Valley when they chose locations for their activities. In this example, prediction could provide insight into the explanation of the settlement system.

At approximately the same time, another settlement pattern study was being carried out in the British Honduras (now Belize) by Green (1973). Drawing her methodology primarily from Haggett *et. al.* (1965), Green mirrored the questions posed by SARG: "the analysis is aimed at answering the question: why did the ancient inhabitants settle where they did?" (Green 1973:279). Although the author's primary goal is to explain the variability in settlement locations:

> a corollary goal of the analysis is to predict the location of sites in portions of the region which have not yet been explored archaeologically. Prediction, in this case, is based on determining the correlation between sites and environmental features in the known region and projecting this knowledge to environmentally similar areas. The method can also suggest locations within the study area which should be rechecked for the presence of undiscovered sites (Green 1973:279).

Central to Green's analysis was the proposition that sites were located so as to minimize the effort expended in acquiring critical resources (1973:279). Green worked with a partial sample of the entire archaeological database. The results showed a strong association between site locations, soil types and vegetation (Green 1973:287). Also apparent from the study was the importance of proximity to navigable water. In fact, the author concludes that the location of every site in the sample can be explained by association with these three variables (Green 1973:289). Green's attempt to predict locations of undiscovered sites based upon the above criteria met with less success than did the Reese River Valley study discussed above. High measures of variability were generated from statistical tests. Areas that were predicted to have potential for site location were very large and impractical for efficient survey due to accessibility and the nature of the physical landscape.

Although Green had few or any precedents upon which to base her research, some inherent problems affect her results. First and foremost is the nature of the sample. Since Green was specifically attempting to correlate environmental variables from existing site locations, she could only use sites in which the location was known precisely. While this is a necessity, it resulted in a reduced sample of only 22 sites in an area of approximately 1000 km2 which is biased toward larger sites and taller structures (Green 1973:281). In this study, one must question the representativeness of Green's sample. Green may also have biased the sample by specifically selecting sites that were only located in areas that shared the environmental variables already selected. "Even if these particular unlocated sites (2 or 3) do exist, inspection of their alleged location on the map indicates that they would not share only one of the environmental variables used in the analysis; therefore, it is unlikely that their exclusion seriously biases the sample" (Green 1973:281). Secondly, one can raise the question of who determines what. Because Green is using environmental variables determined from existing site locations, she is virtually guaranteed of finding these sites all over again. Inclusion of sites from other environmental zones would introduce more restrictive criteria which "would quickly reduce the number of possible locations that will fit the specified criteria" (Williams *et. al.* 1973:234). Despite the questions raised by some of Green's conclusions and the pioneering nature of her study, the results of her attempts to use prediction to help explain the settlement pattern were promising.

Thus while some archaeologists were utilizing more sophisticated analytical techniques in performing regional archaeological analysis, many more archaeologists used analytical techniques scarcely more advanced than Willey's (1953) work. Peregrin's (1988:875) description of work conducted early in his career exemplifies this point:

> We began by laying out the Rosario phase 1:20,000 map. One inch colored beads were used to designate sites by level of population, mounded architecture, specialized activities, pottery characteristics, etc. *By standing up on stools we could get a visual impression of settlement patterns and other prominent aspects of the regional system* (emphasis added).

In summary, predictive modelling developed from studies of settlement patterns. Settlement studies often provided data on site location and their distribution and it was with this information that researchers attempted to predict other, unknown, site locations. The first predictive models attempted to turn an understanding of specific settlement systems into predictions of site location which would hopefully contribute to explaining the settlement pattern. The above examples of prediction within settlement studies are representative of the directions and results of research in this field of archaeology. By the 1980s, researchers built upon the base provided by settlement studies. Predictive modelling became the subject of much research, but its role in settlement pattern research diminished as it was applied more and more as a cultural resource management tool.

CHAPTER 2
SETTLEMENT STUDIES
AND PREDICTIVE MODELLING

2.1 INTRODUCTION

This chapter reviews predictive modelling as it has been presented in the literature. Existing theoretical frameworks and methodological techniques of this field of research are also discussed. There will be a discussion of geographic information systems and their applicability to archaeological research which will be followed by a presentation of a methodology for developing a predictive model.

2.2 PREDICTIVE MODELLING

The literature related to predictive modelling has become more extensive throughout the 1980s. For the most part, it has reflected the fact that developing a predictive model was not as elementary as that outlined by Williams *et. al.* (1973). Although much of the literature and examples of predictive models is buried in government files and consulting reports to business, some academic archaeologists doubt the efficacy and value of prediction in archaeology (Kohler and Parker 1986:396). It is seen as an expensive exercise to discover the obvious, regarded as suspect, unreliable or being limited in value (Kohler and Parker 1986:398). The concerns of cultural resource managers, contract archaeologists and academic archaeologists have resulted in a body of current literature that begins to address some of the issues relevant to developing a predictive model (Brown 1981; Carr 1985; Kohler and Parker 1986; Limp and Carr 1985; Ebert and Kohler 1988; Judge and Sebastien 1988; Kohler 1988; Kvamme 1988a, 1988b, 1989, 1990; Warren 1990). Kohler has contributed extensively to the literature of predictive modelling, both in published and unpublished (contract/ government) areas and sees predictive modelling developing in two directions: one he labels inductive modelling, and the other he labels deductive modelling (Kohler and Parker 1986:399; Kohler 1988:37) elsewhere called the behavioural approach (Hay *et. al.* 1982:14).

2.2.1 Inductive Models

The roots of inductive models can be traced to research conducted by Steward (1938) and Willey (1953). These archaeologists focused their analysis at the regional level rather than at the level of the site itself. These pioneering investigations, coupled with the increasing archaeological insistence upon representative sampling "has set the tone for two decades of work in CRM and in non-CRM work" (Kohler and Parker 1986:399).

An inductive model usually begins with data and then builds its conclusions based upon all the biases inherent in the original data set.

> They begin with survey data...and then they estimate the spatial distribution of the population of archaeological materials from which the sample was drawn...Any inferential locational model predicts only what would have been found had the population of space from which the sample was drawn been surveyed in the same manner as was the sample, using the same rules for attribute coding, site recognition and data analysis. Such inferential models predict neither the systemic interaction between a cultural system and a landscape nor the archaeological context resulting from it; rather they predict what we will find and how we will interpret it if we consistently follow a particular set of rules (Kohler 1988:37).

Inductive models form the basis for a large percentage of predictive models developed to date. Since for many areas of North America there already exist large site databases, their examination could provide tremendous amounts of site related information. In fact, these data are readily integrated into many predictive models. "[F]or this particular exercise the computerized data (AZITE computer database) faithfully represents our current knowledge of site location...[and] contains a variety of descriptive information pertaining to the environment, location, cultural affiliation, site function and temporal components..." (Altschul 1990:228). While existing databases contain a wealth of invaluable information, these data are not without error. For example, site locations may be incorrectly recorded, environmental information may be recorded in too little detail, data may be missing from some records, or information gathered by previous researchers may differ in quality compared to the standards of present-day archaeologist. That is not to say that this information should not be used; rather, it should be used carefully only after evaluation of its integrity as a complete database.

2.2.2 Deductive Models

Deductive models, are seen by Kohler to begin with a theory predicting human behaviour. "The challenge for deductive models is to build the bridge to the analytic context from the systemic context, which is where the outputs of the system can be observed. This bridge-building...is called explanation" (Kohler 1988:37). He (Kohler and Parker 1986:432) sees deductive models encompassing:

> 1. how humans make choices concerning location — requiring a consideration of
>   (a) a mechanism for decision making; and
>   (b) an end for decision making; what is the goal?
>
> 2. a means in which to specify the variables affecting location decisions for each significant chronological or functional subset of sites;
>
> 3. the capability to be operational; it must propose a means for measuring each of the relevant variables and must allow for a set of predictions that can be compared with the archaeological data.

A number of interesting points can be raised when considering deductive models. A first point involves a consideration of the environmental variables that archaeologists suggest conditioned the choice of activity location by prehistoric people. Most predictive models make the fundamental assumption that "settlement choices made by prehistoric peoples were strongly influenced by characteristics of the natural environment" (Warren 1990:202), an assumption that goes a long way toward determining which environmental characteristics or variables will be used in the modelling process. An examination of the literature reveals that there are a number of basic environmental variables used in predictive models: elevation, slope, aspect, and distance to water being the most common (Kvamme 1985; Parker 1985; Altschul 1990; Carmichael 1990; Warren 1990).

> From the standpoint of human adaptation, patterns of local vegetation are of crucial concern. Many plants serve as primary food and technological resources as well as secondary resources which attract economically important animals. The distribution of non-food resources, especially water and fuel, can be equally important to settlement decisions. Diversity is also beneficial when considering non-food resources. In addition to fuel, a variety of trees provide the raw materials for tools, utensils, shelter, and weapons, pitch for sealing seams, and fibres from the inner bark for cordage, bags, and nets. A variety of plants can be used to make dyes, reeds can be woven into mats, and clay from local stream banks can be made into pottery. Evaluations of topography, water, soils, vegetation, precipitation, temperature, and availability of rock outcrops or glacial till exposures all are important in decisions about the adequacy of shelter and the availability of economic resources (Schermer and Tiffany 1985:220).

Dean (1983:11) has pointed out that people may look for only a few clues in their surroundings when determining activity locations rather than process the entire range of environmental variables available. It may be only these basic variables that really have any association with archaeological sites. This raises interesting questions about our choice of the proper environmental variables for inclusion in the modelling process. "Perhaps in building predictive models we are too ready to make the assumption that only a complex multivariate model can adequately account for human locational behaviour, when in fact, a few (proxy?) variables, observed in the highly correlated data base that is our environment, may be sufficient for forming locational decisions" (Kohler and Parker 1986:433). Support for this position lies with the fact that archaeologists have presented successful predictive models using very few variables. For example, Altschul (1990) developed a predictive model for the 9000 acre Mount Trumbell area of Arizona. There were 228 known sites in the study area that had been sampled by various agencies throughout the past. Three environmental variables were identified to account for site location: elevation, slope and aspect. (Altschul 1990:229-230). Altschul concluded that in this area "over 70 per cent of all component locations can be predicted with just three variables" (1990:234).

Another point involves the consideration of choice of 'habit' in that choice for location may be drawn from cultural norms which in themselves are the product of trial and error over long periods of time (Kohler and Parker 1986:435). Factors related to actions having little archaeological visibility, such as spiritual influences, may have resulted activities being located in less 'typical' locations. Choice of activity location may also be the result of historical events that override environmental considerations. Other criteria have been recognized by archaeologists to be important in choosing activity location. Flannery (1976a) and Reynolds (1976) discuss social factors that condition site placement. Jochim (1976:12) details criteria of economic relevance and assumes that "the determination of resource use tends to precede and condition the site placements and demographic arrangements of a hunter-gatherer group." A predictive model may take into account distance to resources and activities carried out at a location. Wood (1978:161-162) offers the following criteria for different site types:

> 1) Limited activity sites will be located so that the distance between a site and the resource indicated by the activity will be minimal;
>
> 2) Multiple activity sites with dominant subsets of activities will be located so that the distances between a site and the matching resources indicated by the dominant subsets are minimal;
>
> 3) Multiple activity sites will be located so that the average distance to all of the critical resources is minimal.

Kohler and Parker (1986:438) point out that although Wood's propositions model in a more realistic manner the possible decisions made at those locations, applying them in a predictive sense could prove to be more difficult.

2.2.3 The Numerical Approach

In addition to the inductive and deductive theoretical frameworks, the methodological approaches employed in predictive modelling may be separated into two different groups. The first of these may be termed the numerical approach and the second may be termed the graphical approach. The numerical approach may be considered a direct outgrowth of the emphasis placed on the statistical analysis of archaeological data since the early 1970s. Predictive models using the numerical approach employ multivariate statistics as a discovery technique to identify associations among variables which ultimately lead to predictions of areas with archaeological resources.

This approach makes a number of primary assumptions that are crucial to the validity of the model. The first relates to the nature of the sample. Because statistical methodology discovers meaningful associations among variables from known site information, it is important that the known site information is representative of the actual sites that exist. "Probabilistic designs are of little use if the population sample is not the same as the population across which predictions are to be made (the target population)...As one practitioner remarks, '[We] cannot make inferences about the archaeology of verdant grasslands with good intermittent and permanent streams from a sample restricted to scoria ridge tops, badlands and breaks' (Peebles 1983:8)" (Parker 1985:406). Roper echoes this view in her comments on a predictive model developed for the Vermilion River/Embarass River region of Illinois:

> Methodologically, multiple regression should eventually be a valuable predictive tool but its use with the poor data available for east central Illinois is unwarranted. The discriminant function analysis at the end of the report is an interesting idea, but I wonder if it is really describing where sites are located or where people have intuitively felt they should be and have therefore looked for them (Roper 1981:149).

Thus, a predictive model in which assumptions are developed via the numerical approach must carefully evaluate the nature of the existing database. In addition to a very careful examination of the representativeness of these data, an assessment must be made as to whether known site locations reflect the actual distribution of archaeological sites or simply reflect where archaeologists have conducted their surveys (*i.e.,* Achesen and French 1992).

Secondly, it is important to recognize that the physical and cultural environment has changed over time and these changes may have affected the choice of activity location through time. Kohler and Parker (1986:408) state:

despite numerous studies in diverse areas indicating change in site location through time in response to changes in adaptation type, and despite evidence that within any adaptation type, functional subsets of sites may have differing environmental determinants, most empiric correlative models aggregate sites of all types and ages together for prediction.

Models developed under the numerical approach rarely take issue with temporal considerations. Some researchers opt to avoid the issue of 'time' and develop a generalized model, shown for example by the model generated by Lewis and Murphy (1981). Other researchers do not avoid 'time' as a variable, rather it is suggested that discernable patterns of human behaviour cross-cut considerations of time. This perspective is discussed by Kvamme (1992:23).

> By associating sites representing many different functional, chronological, and cultural types into a single open-air class, a great deal of locational variability is introduced to the modeling problem, thereby reducing the potential power of the result. Nevertheless, it is believed, and it has been elsewhere shown (*e.g.,*, Kvamme 1985, Kvamme and Jochim 1989), that there are common locational tendencies that may cross-cut functional categories, such as preferences for level ground or proximity to water.

Few researchers have developed models applicable to specific time periods (*e.g.,* Lewis and Murphy 1981). The reasons for this are not presented clearly in the literature. Perhaps controlling for many factors including changes in physical geography, climate, flora and fauna, cultural groups and technology prove too formidable a task for archaeologists working under tight budgets and/or strict mandates. Whatever the reason, the majority have developed predictive models that encompass all prehistoric time periods.

A third consideration relates to the choice of variables and the detail with which information will be selected and manipulated. The choice of variables is determined by the nature of the predictive modelling project, the type of data available, the nature of the study area, among others. Parker (1985) suggests two characteristics of variables used in predictive models. The first, site-focused data, all require measurement at the site level. Examples of site-focused data include, distance to water, vegetation, and slope. The second characteristic, and the one Parker suggests is more commonly employed, is quadrant data. These are data that are generalized from survey quadrants. In some cases, where a high resolution model is being developed, quadrant data may closely resemble and augment site-focused data. In other cases, where coarse resolution models are developed, the quadrant data may generalize the study area to the point where the data are less meaningful than is preferred (Kohler and Parker 1986:408).

An example of research using the numerical approach is Sandra Parker's Sparta Mine predictive model. In this study, Parker aims to

> ...develop an explanatory model relating site locations in an area to the biophysical characteristics of that area. To perform the desired functions, such a model must allow one to state the probability that a particular geographic unit in the area would have been selected for the location of a site. Such a model may be in the form of a prediction equation in which the dependent variable is site presence/absence and the independent or predictor variables are the biophysical variables (Parker 1985:176).

Parker's primary means of discovering associations between variables and site locations is multivariate statistics. Two basic data collection methods were employed. First, biophysical data were collected from USGS 7.5 minute topographic maps to provide the independent or predictor variables for the entire Sparta area. Secondly, a field survey was conducted to provide data about site presence/absence, the dependent variable (Parker 1985:182). The model was evaluated using a number of different tests: observed vs. predicted site frequencies, cross-validation tests, and field tests. Overall, Parker (1985:198) demonstrates by these tests her "confidence in the validity of the model".

The numerical approach is certainly a valuable method which can lead to the discovery of significant associations between site locations and variables. However, it is an approach which requires a high degree of statistical training and competence in order to develop the model, interpret the results and validate/ replicate the results. Invariably, with the results of the model presented in a numerical table outlining the associations between variables and sites, a high degree of interpretation is required to relate those results to on-the-ground locations. Roper, commenting on a specific predictive model, summarizes some deficiencies of the numerical approach:

> While the authors make a reasonably good start at such, they fail to produce a satisfactory end product because of naive use of statistics. They begin with cross tabulations of variables...cross tabulation of each variable with each other variable is not an efficient use of statistics, and does not discern those variables that do or do not have predictive power. Further, this report declines to summarize those statistics into a meaningful interpretation (*i.e.*, predictive model) of site location patterns; rather, it assumes that the tables will speak for themselves. The text reflects neither a good understanding of statistical analysis nor an ability to employ statistics in interpretation of archaeological data (Roper 1981:150-151).

Roper's negative criticism of the above model does not invalidate the use of statistics as a means for developing predictive models. In fact, the development of predictive modelling is coincident with the use of advanced statistical means. However, despite the sustained use of statistics in archaeology, there are still those, including some developers of predictive models, who are familiar with only basic statistical procedures and tests. The use of multivariate logistical regressions requires an advanced level of understanding of statistical theory and techniques. Accepting the validity of a model like Parker's requires a tacit acceptance of the calculations and results presented. Verification and/or duplication of the methodology might prove daunting to some archaeologists who may ultimately accept the results primarily on faith. This may contribute to the statistical approach not being the choice of some developers of predictive models. Thus, while the statistical approach is still used to generate valid predictive models, other models are developed using different approaches.

2.2.4 The Graphical Approach

The second methodological approach used in predictive modelling research may be considered a result of technological changes that have taken place since the early 1980s. This approach involves the development of predictive models again using environmental variables but where the development and testing of the predictive model involves the use of a graphical methodology like map overlay techniques. This technique is primarily achieved using computer software such as geographic informations systems (GIS). The different variables are represented as different computer map layers and these map layers are combined in such a way as to identify areas of association. Different combinations of variables give rise to various stages of the predictive model. Finally, apparent associations between variables and sites are evaluated using statistical techniques. In this approach, the statistics are not used as a means of *discovering* associations during model development, they are used as a means of *evaluating* associations between variables and sites after the model is applied.

An example using a graphical approach is the model developed for the Mt. Trumbell area of northern Arizona. Jeffrey Altschul conducted a study where he asked cultural resource managers if modelling was a useful tool for their specific needs. He discovered that what "...managers need to know is where the 'red flags' are...what is needed are not models predicting the unknown, but rather models that bring some order and direction to the huge databases that have been, and are continuing to be, amassed" (Altschul 1990:227).

Altschul has developed what he calls red flag models. "A model is judged to be successful if it correctly predicts where sites will and will not be located 80 to 90 per cent of the time" (Altschul 1990:227). In his red flag models, Altschul takes an entirely different approach. Clearly, the sites we can predict are those that cluster around general environmental variables: these are the 'average' site. Sophisticated models that are able to identify these sites are not discovering anything new. However, a predictive model that looks for sites not normally predicted is one that is looking for something new. A resource manager should be familiar enough with the existing database that sites, identified in areas presumed to be 'low potential', could be targeted for further study. By highlighting sites located in areas where cultural resources are generally assumed to absent, we can begin to explore portions of the archaeological record that are presently unclear. Sites in settings presumed to be anomalous by a resource manager by definition must be the result of behaviour that does not fit current explanations of why prehistoric inhabitants settled where they did. Under any definition, these sites must be significant, for they more than any others have the potential of telling us something about prehistory that not well understood or unknown (Altschul 1990:228). Additionally, as more anomalies are identified, patterns may emerge, become predictable and therefore are no longer anomalies. Those sites whose locations remain anomalous become the target of further study for it is these sites that will give us greater insight into the past (Altschul 1990:228).

Altschul developed a predictive model for the 9000 acre Mount Trumbell area of Arizona. There were 228 known sites in the study area that were sampled by various agencies throughout the past. Three environmental variables were created to account for site location: elevation, slope and aspect. Altschul outlines four steps in the development of his predictive models (1990:230-232):

> **Step 1: Data exploration.**
> Descriptive data are compiled on spatial location, temporal affiliation, and site function. The relationship of these variables with each environmental variable is confirmed through the use of simple associational statistics.
>
> **Step 2: Confidence and independence**
> The second step involves assessing the environmental variables on the questions of confidence and generalization. Altschul wants to determine whether survey coverage of each environmental zone is adequate in order to have any faith in the resulting distributions. He also wants to determine the degree of statistical independence between the three environmental zones.
>
> **Step 3: The favourability map**
> The third step is to create a map showing the relative probability of map unit to contain a site.
>
> **Step 4: The red flags**
> Once the favourability map is created, site locations are cross tabulated with favourability zones. Statistics are once again used to confirm associations of environmental variables and site locations.

Altschul's approach differs from that of other researchers in that he is focusing on predicting anomalies rather than predicting the already known. He is trying to identify why sites are located in unexpected places; in other words, why did we not expect them to be there? Rather than "viewing models as end products, we view them as analytical tools" (1990:237). Altschul's graphical approach is more useful to cultural resource managers because patterns or nonpatterns are much more readily apparent. While statistics are used for validation and confirmation, the results need not be translating from statistical tables to archaeologically-meaningful statements. Using the graphical approach "at a glance, managers can determine the likelihood of determining sites on a particular development project. For archaeologists, [a map such as this] represents a compilation of the relationship between environmental variables and site location" (Altschul 1990:233).

2.3 MODELLING PROCEDURES

There are two primary modelling procedures that can be extracted from the existing literature. These procedures refer to the manner in which different variables are manipulated to produce a predictive model. These may be called the intersection method and the weighted value method.

2.3.1 The Intersection Method

The intersection method is perhaps the most commonly used methodology for developing predictive models. The intersection method begins with the basic assumption that all variables used in the development of a predictive model contribute equally to the determination of site location potential. Calculating high, medium or low potential areas is simply a process of determining the number of variables that occur in a given location. Areas where the highest number of variables occur can be labelled high potential while areas where the lowest number of variables occur can be labelled low potential.

The assumption that all variables contribute equally to the determination of the predictive model is one that does not accurately reflect the complexity of decisions employed by people in choosing their activity locations. Indeed, if modelling the location of prehistoric fishing camps, some variables such as **close proximity to water** determine site location to a greater degree than a variable such as **vegetation zone**. Thus, while the intersection method is employed in a number of predictive models, it does not result in a model which represents the true range of prehistoric decisions employed in determining the location of activities.

2.3.2 The Weighted Value Method

The weighted value method is perhaps the least used methodology in the development of predictive models. The weighted value method begins with the basic assumption that each variable used in the development of a predictive model contributes differently to the final determination of predictive value. This is accomplished by developing an arbitrary weighting scale, for example 0 to 3 where 0 - poor, 1 - fair, 2 - good, 3 - excellent. Additionally, the variables to be modelled are divided into categories and subcategories. Categories encompass broadly defined divisions such as **Proximity to Water** or **Soil Drainage.** Subcategories encompass detailed subdivisions of categories. For example, if the category was **Proximity to Water**, the subcategories might be **Major Waterways**, **Minor Rivers**, **Minor Lakes.** Variables include even finer divisions of categories. Thus, for example, if the subcategory was **Major Waterways**, then the variables might be **0-100m from water**, **100-250m from water**, and **250-500m from water** (Table 2.1).

A value (V) is applied by the researcher to the category to reflect its importance and contribution in the modelling process. In addition, variables are assigned weights (W) to reflect differences within categories in their contribution to the modelling process. For example, the category **Proximity to Water** might be given a value of 3 to reflect its importance in determining site location. The variable **0-100 metres from water** might be given a weight of 3, **101-200 metres** a weight of 2, **201-**

SUBCATEGORY	VARIABLE	VALUE (V)	WEIGHTED VALUE (W x V)
CATEGORY: PROXIMITY TO WATER	*WEIGHT (W) = 3*		
Major Waterways	0-100m	3	9
	100-250m	2	6
	250-500m	1	3
Minor Rivers	0-200m	2	6
	200-400m	1	3
Minor Lakes	0-100m	2	6
	100-250m	1	3
CATEGORY: SLOPE	*WEIGHT (W) = 2*		
Slope	0-5°	3	6
	>5°	1	2
CATEGORY: ASPECT	*WEIGHT (W) = 2*		
Aspect	SE,S,SW Facing	3	6
	Horiz., W,E, Facing	2	4
	NE,N,NW Facing	1	2
CATEGORY: ASPECT	*WEIGHT (W) = 2*		
Soils	Dry	3	6
	Mixed Wet/Dry	2	4
	Wet	1	2

Table 2.1. An Example of Assigning Weights and Values to Variables and Subcategories

400 metres a weight of 1, and **401+ metres** a weight of 0. By multiplying the category value by the weight of the variable (W x V), a weighted value is defined for each variable used in the modelling process (Table 2.1). The determination of the numerical weight or value is researcher specific. There must be some basis upon which the researcher makes these numerical assignments. Reference may be made to previous archaeological work which has identified characteristics of the landscape presumed to be associated with archaeological sites. Ethnographic, ethnological, historic or ethnoarchaeological studies may also be sources upon which the basis for weighting of variables is based. The experience of the archaeologist and colleagues also working in the area may also contribute to determining a weighting scheme. Additionally, the nature of the project itself may have some bearing on the weighting applied to variables. For example, a researcher applying a predictive model within a given theoretical framework may give more importance to economically-related variables than some geographic variables. In another instance, a researcher may combine his or her own experience with data obtained from the ethnographic literature and derive weights and values accordingly. In conclusion, the manner in which weights and values are applied is subjective yet it is based upon data obtained and evaluated by the researcher from a variety of sources and applied within project specific frames of reference.

Because the weighted value method allows certain variables to have more 'predictive strength' than other variables, it results in a model that better reflects the decisions made by prehistoric people when choosing their activity locations. In addition, because it is imperative that the manner in which the categories and variables are weighted is clearly outlined, the contribution of each variable to the final model is also clearly established. This final point is the most important point of all. For any model to be valid, it must be reproducible and defendable. With the weighting factor of each variable clearly defined, discussions can occur concerning the weights of individual variables and, the effects of changing weights can be tested. The results of these tests can then be evaluated. In the end, one is left with a model for prehistoric activity location which is clearly defined, testable and reproducible.

2.4 METHODOLOGICAL ISSUES

There are a number of methodological issues concerning predictive modelling as it is represented in the literature. The first of these relates to the sources for all the data used to develop predictive models. Despite the theoretical framework or the methodological approach used in the development of predictive models, all make use of a limited number of primary variables. These are slope, aspect, elevation and distance to water, vegetation zones, and in some cases, a soil characteristic. These variables are ones that any archaeologist would find on a site record form. Additionally, these variables can be traced to three main sources: topographic maps (either paper or digital), existing archaeological data, or aerial photographs. For example, Parker's Sparta Mine predictive model lists fifteen variables used to predict site location. Seven of those fifteen relate to streams, one is soil moisture and another is depth to water table. Thus nine of the fifteen variables are expressions of a water variable. While the impression is given of a complex interplay of variables, it is simply that more emphasis is being given to water.

Also, while the choice of variables has been limited and the source for these variables even more so, there seems to be an absence of culturally relevant variables. Very few, if any, predictive models incorporate variables derived from native land use studies, ethnographic data or local informant interviews. While the utility of incorporating these kinds of data has yet to be demonstrated, there is invariably some value to incorporating them into predictive models of prehistoric activity locations (Dalla Bona and Larcombe 1992).

A second concern relates to the quality of some primary data sources. For example, Altschul states that the primary source for his three variables is a USGS digital terrain model. Kvamme (1990:114) has evaluated USGS digital terrain data and concludes:

> although there is a general correspondence, in the (purchased USGS data) (1) many small ridges and hills are absent, (2) minor drainages are missing, (3) large features are greatly smoothed, and (4) there is a major error in the form of a 120 ft. high cliff face which would surely make a spectacular waterfall on the Colorado River (which flows down the central valley) if it really existed!

In archaeology, it is the terraces, hills and small creeks that are extremely important for regional analysis. It is difficult to perform an analytical study using criteria such as terraces and small hills, when the map from which these criteria are drawn does not represent them accurately.

In addition to digital data of questionable quality is the issue of appropriate scale for modelling. For example, a predictive model is developed for a large region at an effective scale of 1:50,000. The majority of the data are derived from maps published at a scale of 1:125,000 and 1:250,000. The high level of data generalization on these maps relative to the 1:50,000 map seriously degrades the quality of the model when areas are identified on a 1:50,000 map. Also, data that are incorporated from 1:15,000 aerial photographs must have their level of detail reduced to match the scale of the 1:50,000 predictive model.

Thirdly, predictive models tend to present their results in terms of statements of high/medium/low potential areas, or areas of favourability/non-favourability but the means by which these terms were defined is never clearly expressed. The reader is rarely informed of the means by which determination of categories of potential is made. The cutoff point between high and medium, and medium and low potential is rarely if ever discussed. Clearly, this is an issue that is of importance to cultural resource managers and archaeological researchers alike.

2.5 ADVANTAGES OF PREDICTIVE MODELLING

Specifically with respect to the kind of research and applications being made by cultural resource managers, predictive modelling holds considerable promise as a planning tool. A predictive model can indicate likely/unlikely areas of cultural resources. This kind of information can greatly increase time in which cultural resource managers have to plan mitigation or survey - well ahead of development activities. This could result in the avoidance of conflicts between developers and the concerns of the cultural resource manager before any development takes place and also in time to make further recommendations to the developer or the proponent of the action. In addition, a predictive model can direct archaeologists to areas within a region that hold some significance. This can result in tremendous savings in time and money avoiding the expensive and relatively inefficient random sample surveys for large areas. Also, a good predictive model can be of use to both the cultural resource manager and the archaeologist interested in research applications. A predictive model may provide insight into the dynamics of the settlement system of a given region. By outlining the variables associated with specific types of sites, a predictive model may actually indicate some probable choices made by prehistoric people when choosing that location for an activity.

2.6 GEOGRAPHIC INFORMATION SYSTEMS AND ARCHAEOLOGY

2.6.1 Definition of a Geographic Information System (GIS)

A geographic information system (GIS) has been defined as "a powerful set of tools for collecting, storing, retrieving at will, transforming, and displaying spatial data from the real world for a particular set of purposes" (Burrough 1986:6). A GIS describes objects from the real world in terms of:

1) their position with respect to a known coordinate system
2) their attributes that are unrelated to position (such as pH, temporal order)
3) their spatial interrelations with each other (topological relations) (Burrough 1986:7).

A geographic information system consists primarily of computer software that functions in conjunction with computer hardware to transform and manipulate spatial data. A GIS should be considered as more than a simple data manipulation tool.

> Because these data can be accessed, transformed, and manipulated interactively in a geographical information system, they can serve as a test bed for studying environmental processes or for analysing the results of trends, or for anticipating the possible results of planning decisions. By using the GIS in a similar way that a trainee pilot uses a flight simulator, it is, in principle, *possible for planners and decision-makers to explore a range of possible scenarios and to obtain an idea of the consequences of a course of action before the mistakes have been irrevocably made in the landscape itself* (Burrough 1986:7, emphasis added).

Perhaps the best way to visualize how a GIS works is to visualize a standard topographic map. A topographic map contains a tremendous amount of information. One may view the various types of information as various categories. There are categories of roads, railways, water bodies, buildings, vegetation, legal boundaries and elevation among countless others. While each of these categories is indeed a separate class of information, they are all printed on one piece of paper and are therefore permanently combined.

A geographic information system uses all of the various categories of information but stores them as separate map layers (Figure 2.1). The map layer concerned with roads has only 'road' information on it. It may contain information pertaining to the location of various roads and/or the quality of various roads (*i.e.,* highways, secondary, dirt roads). The map layer concerned with water may

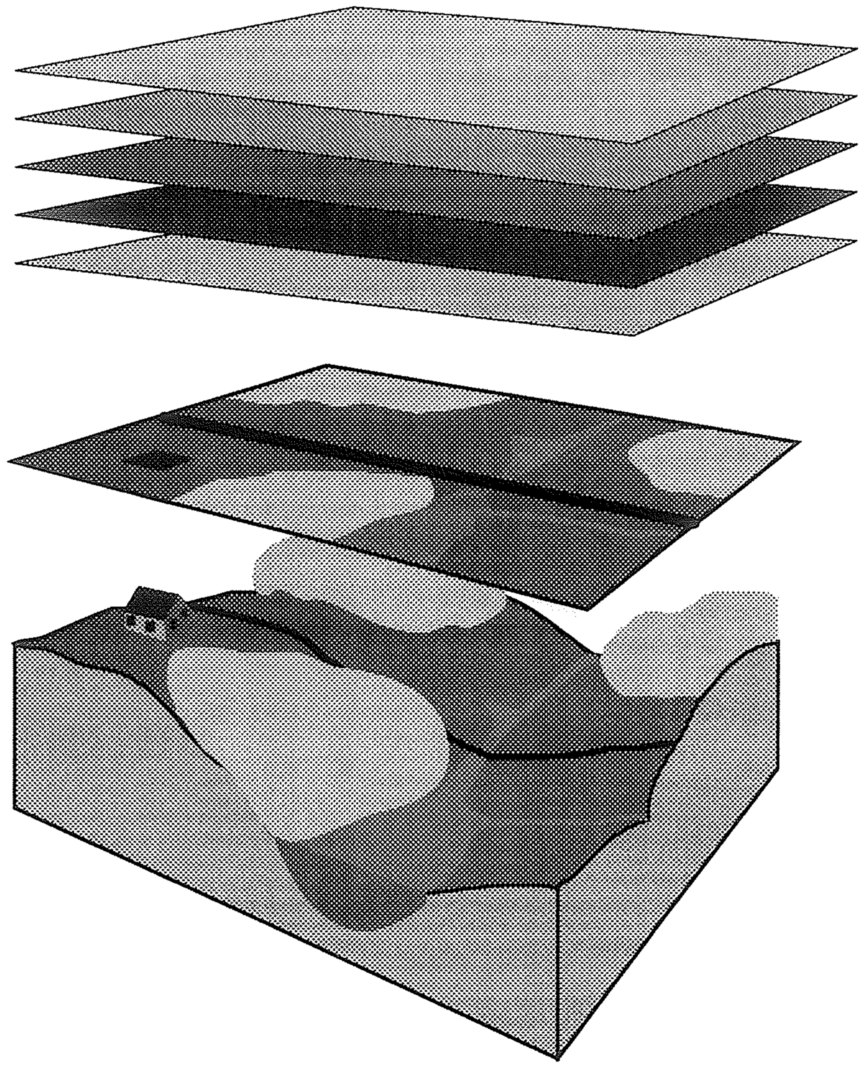

Figure 2.1 . Schematic Diagram Representing the Relationship of Real-World Data to GIS Data (after Tomlin 1990:Figure 1-4)

contain information about the type of water body (*i.e.,* river or lake), its name, volume or stream order. While each of these separate map layers contains only one category of data, they may be manipulated in such a way as to produce a desired result. For example, a map layer of 'roads' and a map layer of 'water' may be combined to determine where all intersections of roads and water exist in a given area. In these manipulations lies the power of a geographic information system. Data may be manipulated in countless ways to model any number of scenarios. For example, it may be necessary to identify all those areas within one kilometre of the junction of two streams. To search for and calculate these data manually using paper maps would take a considerable amount of time. Using a GIS, this information could be identified within minutes.

The geographic information system used in this research is MAP II (Pazner *et. al.* 1989). This software allows for the easy entry, storage, manipulation and analysis of spatial data using Macintosh personal computers as well as having powerful transformation capabilities. In addition, MAP II makes use of a map manipulation language called cartographic modelling (Tomlin 1990), a 'natural language' approach to GIS transformations where English-like commands are used to construct manipulation command lines. Cartographic modelling also necessitates the need to define the modelling issue to be addressed. The clear delineation of this goal greatly simplifies the task of identifying data needed for the modelling process. Flowcharts can be drawn outlining the various map manipulations to be conducted and numerous scenarios can be offered and compared: 'what if' analyses may be constructed and numerous options to potential difficulties can be identified and addressed. Thus even before the computer is turned on, the necessary data that need to be acquired are identified, the data manipulations that are expected to be performed are indicated, options and alternatives are outlined, and an expectation of the goal to be achieved can be calculated.

For more detailed discussion of the use of GIS in archaeological research, a number of studies have appeared in recent years outlining the advantages and disadvantages of this approach (Altschul 1990; Bailey *et. al.* 1985; Briur 1988; Brown and Rubin 1982; Calamia 1986; Carmichael 1990; Ferguson 1985; Forney *et. al.* 1985; Hasenstab 1983; Kvamme 1986, 1989, 1990; Kvamme and Kohler 1988; Limp 1987; Parker 1986; Zubrow 1987; Zulick 1986).

2.7 ON DEVELOPING A PREDICTIVE MODEL

As discussed in the sections above, there are many different approaches that are taken to develop a predictive model. These approaches make use of different theoretical and methodological frameworks. The methodology outlined in Chapter 3 of this thesis crosscuts all theoretical and methodological constraints. It can be applied to research applications or for cultural resource management purposes. It can be used from a deductive or inductive perspective or employ elements of both. It can be used to develop a numerical and/or graphical model and it can manipulate variables using the intersection and/or the weighted value approach. In summary, this methodology is relevant to many different archaeological applications with limits imposed only by the creativeness of individual researchers.

As stated in Kohler's definition (1988:33), a predictive model is comprised of a set of testable hypotheses. To arrive at testable hypotheses, a model must be explicit in the variables that are used and the manner in which those variables are manipulated. This includes clearly outlining the variables included in the model, the manner in which those variables are interacted, and any weights or emphasis placed on variables must be identified. Ideally, a flowchart-like diagram outlining the various processes involved in developing the model should be available. Such a diagram would graphically illustrate what variables are used and how those variables interact to produce the final result. One of the major stumbling blocks and criticisms of all predictive models is the subjective input of the researcher's own knowledge. All archaeologists will acknowledge that this information is important and should not be ignored. However, to be really useful, it should be made clear *what* knowledge is being applied to the development of the model as well as *how* it is being used. The methodology employed here makes that explicit - indeed the researcher is forced to be explicit.

There are a number of assumptions that one works under when developing a predictive model. The first involves the assumption that choices of activity locations made by prehistoric people were influenced by elements of the natural and physical environment. The researcher also assumes these elements of the environment have survived to be represented by data available at the present time. These data may be in the form of maps, monographs or may still be collected in the field. The third assumption implies that associations between archaeological site locations and the natural/physical environment made by modern day researchers may be some of the same associations made by prehistoric decision makers. These assumptions may be strengthened or confirmed by repeated testing or application of a model but the true nature of prehistoric people's actions will never be known.

As predictive models are attempting to codify aspects of human behaviour, one cannot expect a model to be simplistic in its makeup or to be developed in a single effort. The development period of a predictive model is not finite. Altschul calls this a "dynamic modelling approach. Once anomalies...are identified, they become the subject of additional research. As patterns are found, many anomalies become predictable. Those sites whose locations remain anomalous grow in importance" (1990:228). Modelling should be seen and conducted as a dynamic process where data collected from any source, at any time, can be incorporated into the modeling process to increase its integrity, accuracy and scope. As such, predictive modelling may be seen as involving three stages: (1) primary stage predictive modelling involving data collection and organization;

(2) secondary stage predictive modelling in which an initial model is developed and tested, and; (3) tertiary stage predictive modelling in which the model is subjected to an infinite number of applications and refinements.

2.7.1 Primary Stage Modelling: Organization and Data Collection

The development of the primary stage predictive model involves two activities: initial data collection and field reconnaissance. Initial data collection could be viewed as taking place within an inductive theoretical framework. Existing site databases can be accessed for information. Predictive models presented in the literature can be reviewed as to the data and variables used. In addition, information gathered from other sources such as ethnographic or land use studies can be evaluated and incorporated into the model. These data are important in developing a theoretical framework in which to interpret the results of the model. "To have confidence in any models which emerge, we need to know *why* the behavior we predict patterns as it does" (Tainter 1983:7). It is important to note that the researcher must start somewhere and existing data and successful examples of other predictive models offer an acceptable base, subject to a careful evaluation of their relevance and completeness.

The primary stage may be understood as the organizational stage of the modelling process. The researcher must make numerous decisions including:

a) the scale at which modelling will take place;
b) the boundaries within which the model is applicable;
c) the temporal scope of the model, and;
d) the functional scope of the model, *i.e.*, does it apply to all or selected activity types.

Many issues may already be decided for the researcher by an existing project proposal or terms of reference. It is during the primary stage that the researcher conducts a field program in an area previously not subjected to archaeological activity, to collect baseline data. While it may be that some archaeological information already exists in the form of a site database, this database is subject to a number of biases; some of which may not be controllable by the researcher. Thus the collection of new baseline archaeological data provides the researcher with a more complete database from which to build the model. The field program should include as complete a survey of an area as possible. The size of the survey area need not be exceedingly large but should representative of the study area as a whole. The intention of the survey is to understand the distribution, frequency, and component parts of all the sites in the survey area. With the completion of the initial data collection and archaeological reconnaissance, primary stage predictive modelling is complete.

2.7.2 Secondary Stage Modelling: Initial Model Development and Testing

A secondary stage predictive model can be said to begin when the requirements of primary stage modelling have been fulfilled. Once this has been achieved, the researcher enters into a deductive phase and can begin to incorporate this data into the second stage of the model. Associations between the sites discovered during the field survey and environmental variables can be made and verified. Existing variables derived from the literature can be evaluated as to their association with the known site database. Cultural variables such as plant gathering or species specific hunting activities can be incorporated into the variables to be modelled.

The researcher may now develop an initial predictive model and test it on the area surveyed in the primary stage. While it may appear that this step is a 'self-fulfilling prophecy", one must be reminded that a variety of data were used to develop the initial predictive model - not the data solely derived from the primary stage survey. Variables can be introduced or removed from the process by trial and error until the model is able to predict the highest percentage of sites possible. Necessarily, the researcher would also conduct a second field survey program in an area near the first to collect more baseline data and/or test the model. It is recognized however, that this may not always be feasible because of external limitations such as time and money. Once again, associations would be made with known site locations and identified relevant variables. This information would be incorporated into a new predictive model. This model would then be applied to both the primary and secondary stage survey areas. The variables would be modified in such a way as to produce a model predicting the highest percentages of known archaeological sites. Once this has been achieved, tertiary stage modelling may begin.

2.7.3 Tertiary Stage Modelling: Application and Refinement

A tertiary stage predictive model may begin when the secondary stage predictive model predicts the location of the highest number of sites possible in the two previous survey areas. It is at this point that the model may be considered applicable in a real sense. Testing procedures were carried out and demonstrated the validity and integrity of the model. The researcher must be vigilant at this point to ensure that the model is not applied blindly. Any continuing application of the model must undergo thorough testing, much like that conducted in the secondary stage to ensure the ongoing validity of the model. New data must be incorporated into the model year after year in an effort to produce the most robust model possible. In addition, as repeated applications of the model are effected, sites that were once 'anomalous' may now become patterned. Such observations must be anticipated and the results of using the model must be carefully interpreted to maintain and update its integrity.

Few, if any, models have achieved tertiary stage development because of the nature of the agencies employing them. Most cultural resource agencies manage the resources and conduct little research into them. They are interested in identifying the location of resources in order to facilitate development activities. As a result, predictive models developed for such agencies have often resembled a 'cook book' where if certain steps are followed, a result will follow. The three stage modelling process outlined here reduces the likelihood that such a 'cook book' approach will result. An additional point may be raised concerning a predictive model supplanting archaeological field work. There should never be a point where predictive models take the place of field work. As an academic modelling exercise, the negative implications of a poor model are relatively minor. However, in the cultural resource management arena, the implications of applying a poorly tested model could be substantially negative.

> I have no objection to the use of multivariate locational models for research and planning purposes, but they simply cannot provide sufficient evidence to warrant the granting of archaeological clearance without the benefit of field survey. Any such reliance on predictive models to 'write off' areas of low projected site density constitutes both an abuse of statistical methods and an abrogation of ... management responsibilities (Berry 1984:845-6).

Once again, the development of predictive models is a dynamic process where models are rigorously tested over many years and in many different areas. The results of one year's testing are also incorporated into the existing model.

Information gained in future years of application are also incorporated into the model development process. Ideally, this process should never stop.

2.8 SUMMARY

Predictive modelling is a research methodology used by archaeologists to identify prehistoric activity locations. It has its basis in settlement pattern analysis and the results of predictive models continue to further the aims of settlement pattern studies. Predictive models have been identified as operating within inductive and deductive theoretical frameworks. They are also developed using distinct methodological approaches. Since the mid 1970s, predictive models have become less associated with the settlement studies from which they were developed. For the most part, predictive models have been developed within the sphere of cultural resource management and their application has been primarily in a management context. However, their use by researchers is increasing as archaeologists are recognizing the potential of a predictive model as a research tool. Such a research application is made in this thesis. Chapter 3 discusses the study area for which a predictive model was developed. In addition, the field work that was conducted, the manner in which the model was developed and the resulting model is presented.

CHAPTER 3
PRIMARY AND SECONDARY STAGE MODELLING

3.1 INTRODUCTION

As Chapter 2 presented a review of other predictive models, this chapter continues the primary stage modelling process where background information concerning the study area is presented. The first section of this chapter reviews geological, floral and faunal information relevant to the upper Souris River Basin. Later sections of this chapter provide the archaeological history of southern Saskatchewan with specific reference to the southeastern corner of the province. Background information detailing the circumstances under which this research was carried out will be offered. This will bring to a close the primary stage modelling. The development of the secondary stage predictive model of prehistoric activity location will then be presented and the model itself will be offered for testing.

3.2 THE UPPER SOURIS VALLEY: NATURAL HISTORY BACKGROUND

This thesis considers an area of the Northern Plains of North America that focuses on the Souris River basin in southeastern Saskatchewan (Figure 3.1). The Souris River flows southward through southeastern Saskatchewan (Figures 3.2-3.4) into North Dakota where it turns sharply northward into Manitoba. It joins with the Assiniboine River downstream from the city of Brandon, Manitoba.

The Souris is a minor river on the Northern Plains. It is located near two major river systems: the Missouri River and the Saskatchewan River. The Missouri River is approximately 100 kilometres to the south of the Souris River at it's

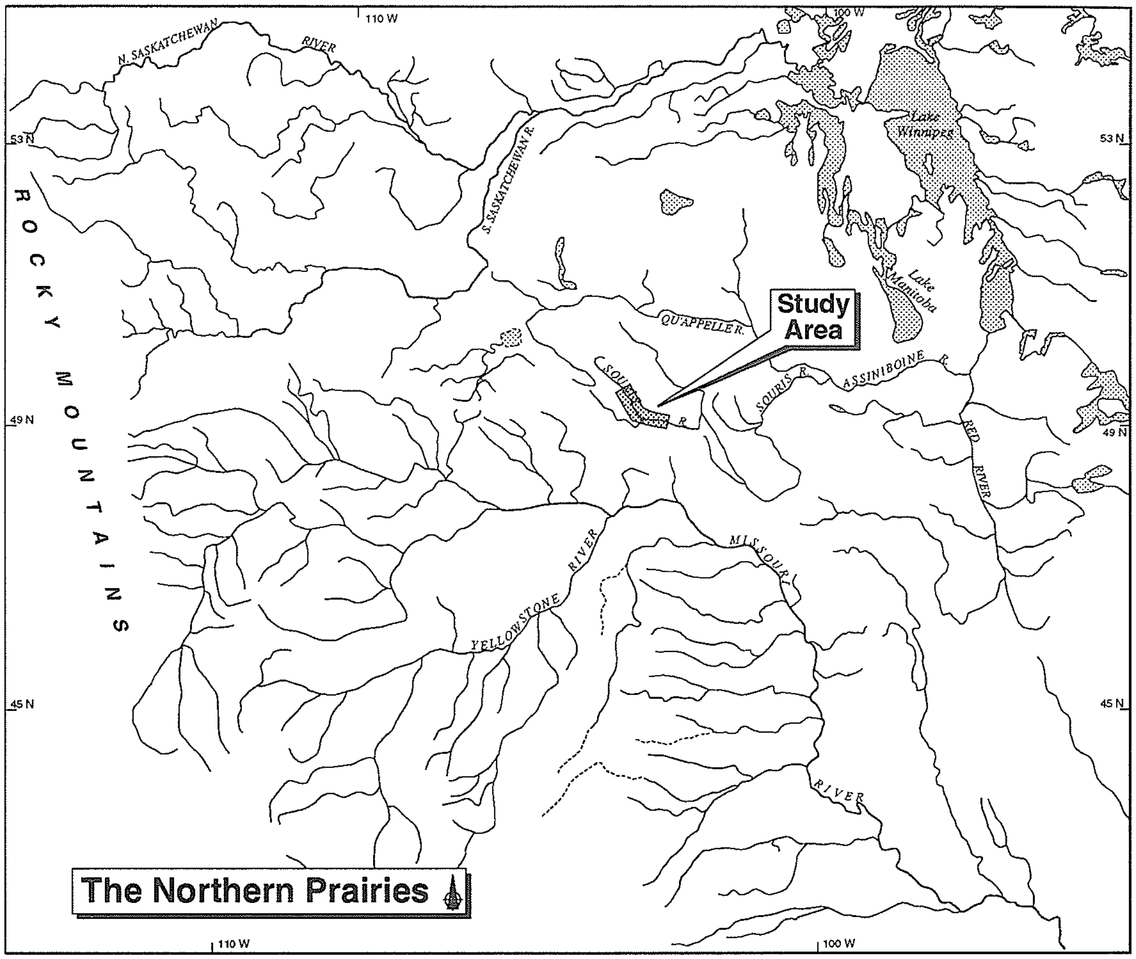

Figure 3.1. The Upper Souris River Valley Study Area


Figure 3.2. The Souris River, Southeastern Saskatchewan

Figure 3.3. Looking Downriver from the North Wall of the Valley at the Same Location as Figure 3.4

Figure 3.4. The Souris River Looking Upriver from the North Wall of the Valley at the Same Location as Figure 3.3

closest point, while access to the South Saskatchewan River can be gained via the Qu'Appelle River to the north, at its closest point. Equally important, the Souris River flows directly into the Assiniboine River which ultimately drains much of southern Manitoba.

The study area is physiographically designated as the Weyburn Plain (Christiansen 1956) and falls within the Saskatchewan Plain division of the Interior Plains physiographic region (Bostock 1970). Most of the region is nearly level to gently undulating with the greatest amount of relief occurring between the Souris valley wall and the first floodplain above the river (Figure 3.5). The Souris valley was created primarily as a result of glaciofluvial processes. During deglaciation at the end of the Wisconsinan glacial period, the Souris River valley and adjacent regions were a major spillway for Glacial Lake Regina. Meltwater poured through the Souris Basin area at an accelerated rate and eroded the

Figure 3.5. Characteristic Steep Walled Coulees Along the Souris River Valley

shallow tills and soft bedrock near the ground surface. A coarse boulder pavement resulting from this erosion, in addition to the severe relief of adjacent coulee systems, makes portions of the plains in the immediate vicinity of the Souris Valley predominantly unsuitable for crop agriculture (Figure 3.6). This latter fact results in large areas of unbroken prairie existing to the present day; a factor contributing to extremely high site visibility and integrity.

The study area encompasses the extensive Grasslands region of the Canadian prairies (Roe 1972). More specifically, the Souris River Basin is found in the Mixed Grass Prairie Ecodistrict, considered representative of the grasslands of southern Saskatchewan (SBDA 1987 Chapter 10:4), and by extension, northern North Dakota and extreme southwestern Manitoba (Figure 3.7). Studies of the region's flora identify seven vegetation communities that occur in proximity to the Souris River Basin (Table 3.1). Today, the area in the immediate vicinity of the Souris Basin is

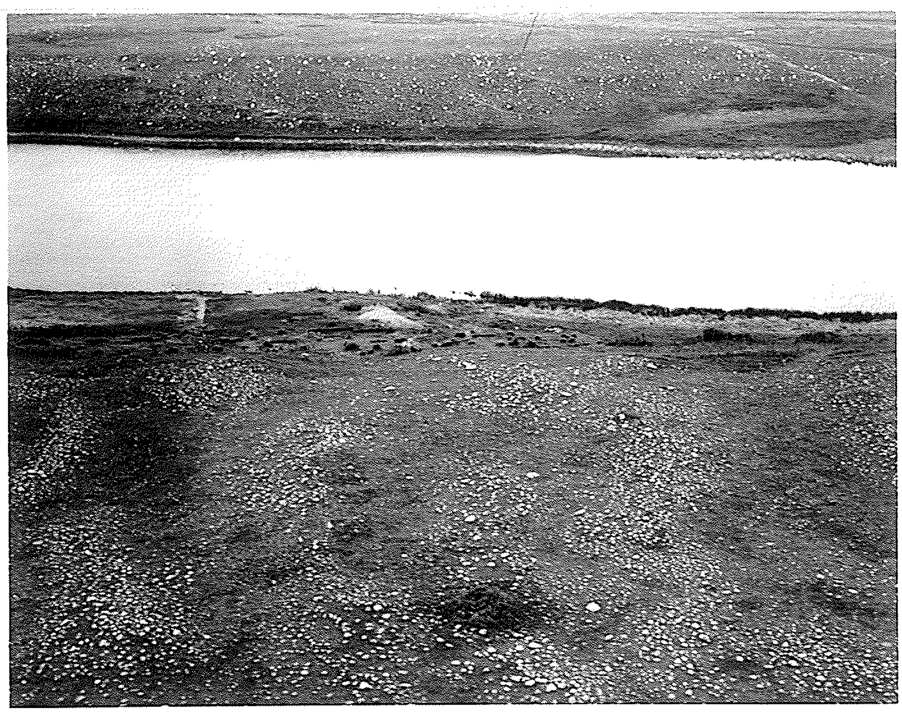

Figure 3.6. Boulder Strewn Landscape Along the Rim of the Souris River Valley

Figure 3.7. Typical Ground Cover Found Throughout the Study Area

Vegetation Communities	Vegetation Types
Upland Grassland	-dominated primarily by the Speargrass-Wheatgrass and the Speargrass-Wheatgrass-Blue grama-Wheatgrass communities
Upland Shrub	-dominated by western snowberry, blue grama, western porcupine grass, *Stipa spartea* var. *curtiseta*, needle and thread, western wheatgrass, pasture sage, and June grass
Valley Slope Grassland	-dominated by needle and thread and western porcupine grass
Valley Slope Shrubs	-dominated by western snowberry and wolf willow (NW facing slopes) and western wheatgrass
Lower Floodplain	-no obvious dominants, however three species occur regularly: three-square bulrush, cattail, and smartweeds
Intermediate Floodplain	-dominated by saskatoon berry and chokecherry. Manitoba maple may form a significant tree overstory and Green Ash forms a significant understory.
Upper FloodPlain	-highly variable due to cultivation. Natural vegetation includes Kentucky bluegrass, foxtail barley, western wheatgrass and sedges.

Table 3.1. Vegetation Communities Along the Upper Souris River Basin (SBDA 1987 Ch. 10:9-12)

> ...occupied by native vegetation. The Souris River...has steep, eroded slopes supporting a mosaic of grass and shrub types. The meandering of the river has also left oxbow channels with depths varying from slight depressions which have developed a meadow type of community, to near river-like channels occupied by marsh type vegetation communities. Where the moisture regime is adequate, a forest vegetation type is found on the [Souris] flood-plain (SBDA 1987 Chapter 10:7).

Prior to colonization of the area circa 1890, the wildlife were characterized by species adapted to an open prairie grasslands environment. These species included large herds of bison *(Bison bison)* (Roe 1972) since extirpated from the vast majority of the continent, and smaller herds of pronghorn antelope *(Antilocapra americana)*, white-tailed jack rabbit *(Lepus townsendii)*, coyote *(Canis latrans)*, red fox *(Vulpes fulva)*, badger *(Taxidea taxus)*, Richardson's ground squirrel *(Spermophilus richardsoni)*, grassland passerine birds and Sharp-tailed grouse. The numerous wetlands in the area are frequented by muskrats *(Ondatra zibethica)*, Sandhill Cranes *(Grus canadensis)*, Whooping Cranes *(Grus americana)* and a wide variety of other waterfowl. Predatory species include Ferruginous hawk, Swainson's Hawk *(Buteo swainsoni)*, Turkey Vulture *(Cathartes aura)* and the Golden Eagle *(Aquila chrysaetos)* (SBDA 1987 Chapter 15:7). Species such as deer *(Odocoilus sp.)*, elk *(Cervus sp.)* and moose *(Alces alces)* were restricted to the wooded uplands of Moose Mountain, north of the study area, until the early decades of the twentieth century when they moved down into the valley bottoms of rivers like the Souris.

Present day fish species inhabiting the Saskatchewan portion of the Souris River include northern pike *(Esox lucius)*, yellow perch *(Perca flavescens)*, walleye *(Stizostedion vitreum vitreum)*, white sucker *(Catostomus commersoni)*, black bullheads *(Ictalurus melas)*, trout-perch *(Percopsis omiscomaycus)*, fathead minnow *(Pimephales promelas)*, common shiner *(Notropis cornutus)*, brook stickleback *(Culaena inconstans)*, Iowa darter *(Etheostoma exile)*, occasionally rainbow trout *(salmo gairdneri)*, river shiners *(Notropis blennius)*, emerald shiners *(Notropis atherinoides)*, johnny darters *(Etheostoma nigrum)*, blackside darters *(Percina maculata)*, and longnose dace *(Rhinichthys cataractae)* (SBDA 1987 Chapter 14:1-5). Changes to the Souris River due to dams and flood control devices has altered the range of species inhabiting the river as well as their movements throughout the river system. The seasonal fluctuation of water levels as a result of dry/wet years and water control has a significant impact on fish movements throughout the Souris River, primarily in the upper reaches of the river.

3.3 CHRONOLOGICAL SURVEY OF SOUTHERN SASKATCHEWAN

The prehistory of southern Saskatchewan has recently been revised by Dyck (1983) and is considered here as representative of the prehistory of southeastern Saskatchewan. While revision and debate concerning the cultural sequences of the Northern Plains is ongoing (*e.g.*, Reeves 1983; Syms 1977), it is beyond the scope of this thesis to treat it in detail. This summary is drawn from Dyck (1983).

3.3.1 **Pleistocene Hunters Period** (17,000 B.P. to 10,500 B.P.)

Southern Saskatchewan has been unglaciated for approximately 17,000 years. While there is no direct evidence for human habitation before 11,300 B.P., finds from other parts of North and South America (*e.g.*, Hoffecker *et. al.*) suggest that the data may exist. The first evidence for people in Saskatchewan appears between 11,300 B.P. and 10,500 B.P. These people are represented by Clovis spear points and are assigned by Dyck to the Clovis Complex which dates between 11,300 B.P. and 10,500 B.P. (Dyck 1983:71). Clovis points have been found in all parts of North America south of the ice sheets and are represented in Saskatchewan at six sites. At one of these sites near Grenfell, Saskatchewan, buried remains were located (Wilmeth 1968), while all other Clovis sites have been surface finds. "The 6 Clovis surface finds mentioned here are only those for which information has been published. At least as many more are known but unpublished" (Dyck 1983:73).

3.3.2 **Early Plains Indian Period** (10,500 B.P. to 7800 B.P.)

Dyck defines the Early Plains Indian Period as initiated by the Lanceolate Fluted or Basally-Thinned Tradition (Folsom/Midland and Plainsview). Approximately 10,500 years ago, people using Folsom points first started leaving evidence for their presence in Saskatchewan. At least 26 Folsom points have been identified from surface finds in southern Saskatchewan (Dyck 1983:75). The Lanceolate Straight or Rounded Base Tradition (Agate Basin/Hell Gap) dates between 10,500 and 9400 B.P. There is an Agate Basin site, the Parkhill site near Moose Jaw (Nero 1959; Ebell 1980) excavated to date in Saskatchewan while all other evidence comes in the form of surface finds. The third tradition falling in the Early Plains Indian Period is called the Lanceolate Stemmed Tradition (Firstview/Alberta/Cody/Milnesand). This tradition is represented by numerous surface finds, primarily south of the North Saskatchewan River (Dyck 1983:79) all dated, by comparative means, between 10,150 and 8600 B.P. Recently, an intact component dating to this tradition was excavated in southwestern Saskatchewan near Prelate (Linnamae and Corbeil 1991).

3.3.3 **Middle Plains Indian Period** (7800 B.P. to 1850 B.P.)

The Middle Plains Indian period dates between 7800 B.P. and 1850 B.P. and is marked by environmental and technological changes. The Mummy Cave

Series (7700-4700 B.P.) is represented at only three Saskatchewan sites, two of which are located near the Souris River at the Oxbow Dam and Long Creek sites (Dyck 1983:92) and is defined by side-notched projectile points including "most of the tool kit common to all later bison-hunting complexes on the Northern Plains with the exception of clay pots and arrow-points" (Dyck 1983:92). The Oxbow Complex (4700-3050 B.P.) was first identified in Saskatchewan and is a period when people excelled in bison hunting. Oxbow sites are ubiquitous in southern Saskatchewan and the associated artifacts include "endscrapers, perforators, uniface and biface knives, bone awls, drilled shelled gorgets, drilled shell beads, bone beads, grooved mauls, occasional native copper objects such as beads and a crescent" (Dyck 1983:96). The McKean/Duncan/Hanna Complex (4150 - 3100 B.P.) overlaps the Oxbow complex but is identified on the basis of three distinct projectile point types. This complex is found throughout southern Saskatchewan extending up into the southern fringes of the boreal forest. The Pelican Lake Complex (3300-1850 B.P.) follows the McKean/Duncan/Hanna Complex but it is not clear if it is derived from it. Numerous Pelican Lake Complex sites exist in Saskatchewan including at least one in the Souris River basin (the Crane Site) and include "campsites, a bison pound and a cairn covered grave containing secondary burials" (Dyck 1983:105). The Un-named Complex (2500 B.P. - ?) is a poorly understood complex appearing at a few sites on the Northern Plains and is characterized by straight-based lanceolate side-notched projectile points. Dyck suggests that there is a similarity between projectile points found in the Un-named Complex and those of Early Woodland complexes to the east (1983:108) a proposition which is supported by Syms (1977:129). The Sandy Creek Complex (2450 - 1950 B.P.) is distinguished by projectile points very similar to Oxbow points except the two complexes are separated by some

600 years. Sandy Creek components are found at a number of sites in southern Saskatchewan.

3.3.4 Late Plains Indian Period (2000 B.P. to 170 B.P.)

The Late Plains Indian Period is distinguished by the introduction of two important technological innovations: pottery and the bow and arrow. Dyck suggests that the two innovations are not related. Rather, pottery appears to have come into Saskatchewan from the east while the bow and arrow appear to have come from the west (1983:110). The Besant Complex (2000 - 1150 B.P.) is the first to appear in the Late Plains Indian Period. From a number of sites across Saskatchewan, evidence suggests that people during this time period were extremely successful bison hunters leaving behind "more numerous and widespread remains than any other single complex in Saskatchewan" (Dyck 1983:113). The Besant tool kit may be indicative of a dart-using technology as opposed to bow and arrow. Habitation structures during this time period are clearly identified as post-in-ground dwellings (Wettlaufer 1955; Hoffman 1968) and hide covered conical tipis. Mortuary practises during this time period include burial mounds associated strongly with bison ceremonialism (Neuman 1975:89). Also ceramics are first encountered in the archaeological record at this time and are generally concoidal in shape. The Avonlea Complex (1750 - 1150 B.P.) is roughly contemporaneous with Besant on the Northern Plains. People associated with this complex are also regarded as excellent bison hunters but the Avonlea point is considered a true arrow point. The ceramics associated with the Avonlea Complex "are generally concoidal. Surface finish which may cover the whole exterior seems to be any of three distinctive types: (1) net impressed, (2) spiral channelled or (3) a smoothed version of the first two types" (Dyck 1983:123). Avonlea sites are found throughout southern Saskatchewan. The

Late Side-Notched Series—Prairie and Plains Side-Notched (1150 - 170 B.P.) is the last prehistoric time period of the Northern Plains but is poorly known for southern Saskatchewan (Dyck 1983:126). Evidence suggests that Prairie and Plains side-notched projectile points are from the Middle Missouri area. These points are found throughout southern Saskatchewan. The people of this time period are associated with burial mounds (found primarily in the southeastern portion of the province) and Blackduck and Selkirk ceramics.

3.4 THE UPPER SOURIS VALLEY: ARCHAEOLOGICAL BACKGROUND

Archaeological activity in southeastern Saskatchewan prior to 1984 identified less than fifty archaeological sites. In 1984, the Saskatchewan Power Corporation contracted the Saskatchewan Research Council (SRC) to perform a heritage resource impact assessment of the Rafferty Dam reservoir and associated impact zones. The Rafferty Dam reservoir will cover an area of approximately 4900 ha at full supply extending 57.3 km upstream from the dam (Environment Canada 1989: Table 3.1). As a result of the intensive surveys conducted by the Archaeology Section of the SRC (now Western Heritage Services), over 350 archaeological sites are recorded within the reservoir zone. This represents a tremendous increase in the archaeological database of southeastern Saskatchewan. Archaeological work prior to 1984 in the Souris River Basin area is summarized in Table 3.2.

3.4.1 1990 Field Work

Associated with this cultural resource management project, the Archaeological Section of the SRC funded two weeks of field work to allow data collection for the predictive model. During the first two weeks of June 1990, the author and one assistant surveyed a 25 square kilometre parcel of land (Figures 3.8, 3.9)

Date	Researcher	Research	Results	Reference
1951	Wettlaufer	Survey	Recorded sites	Wettlaufer 1951
1956	Metro and McCorquodale	Excavation	Oxbow Dam site	Nero and McCorquodale 1958
1957	Wettlaufer	Survey	Located 27 sites	Wettlaufer and Mayer-Oakes 1960
1957	Wettlaufer	Excavation	Long Creek Site	Wettlaufer and Mayer-Oakes 1960
1976	Lifeways Ltd.	Survey	Located 1 site	Lifeways Ltd. 1976
1976	Walker	Excavation	Prehistoric Burial	Walker 1984
1977	Radwanski and Blood	Overview Study		Radwanski and Blood 1977
1979	Aresco Ltd.	Survey	No sites recorded	Aresco Ltd. 1979
1980	Klimko	Survey, Assessment	Recorded 19 sites	Klimko 1981
1980	PSI	Survey, Assessment	Recorded 3 sites	Paleo-Sciences Integrated Ltd 1980

Table 3.2. Previous Archaeological Work in the Souris River Area. (from SBDA Ch. 14 1988:Table 2)

which falls entirely within the Prairie Farm Rehabilitation Administration (PFRA) Coalfields Community Pasture. This area was chosen because it was the first block of land, downstream from the Rafferty Dam, that had yet been impacted by any major development activities. A Right-of-Entry agreement allowed only for surface survey of the area due to ranching activities. Permission for sub-surface investigation was not granted.

The following survey methodology was employed. Both crew members were supplied with a 1:50,000 topographic map and the equipment necessary to perform identification, sketch mapping, recording and photography of sites. Township photo-mosaic maps were obtained toward the completion of the survey. While they were not employed directly in the field, site locations were later plotted directly onto the photo-mosaics.

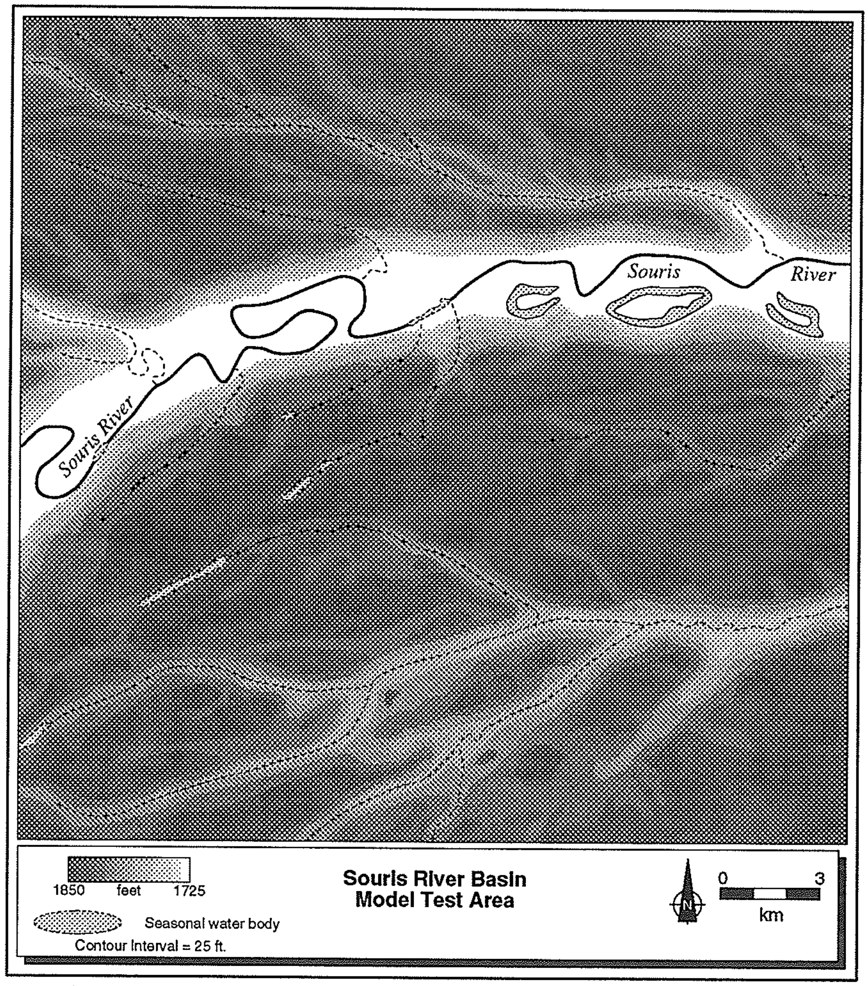

Figure 3.8. The Survey Area Located Along the Souris River (total area = 25 sq. km.)

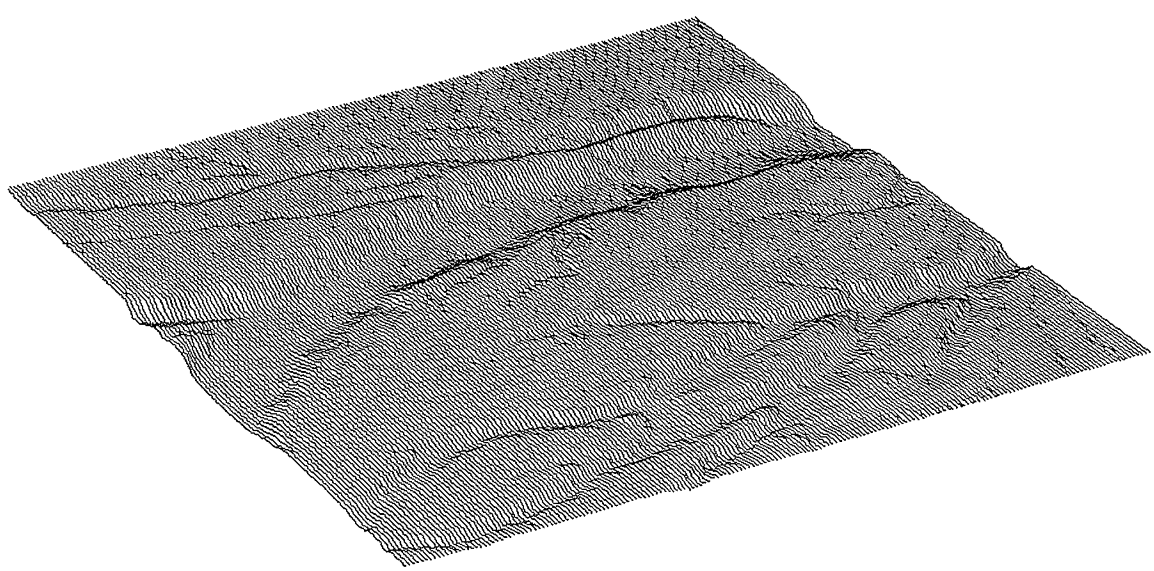

Figure 3.9. A 3-Dimensional View of the Survey Area Looking Northeast

The nature of the terrain allowed for easy correspondence between actual landforms and their representation on the topographic map. The survey was conducted by outlining reconnaissance areas that roughly corresponded to landscape features. Both members of the crew then surveyed separate blocks. Thus for example, a crew member would have surveyed from the crest of one coulee ridge to the crest of the opposite ridge, including the entire bottom and sides and all areas in between. As opposed to outlining linear transects, this method of survey proved very successful. At any given time, both crew members were easily able to locate themselves on the topographic map, an important consideration when on the open prairie. Delineation of areas already subjected to survey was facilitated due to the easy correspondence between the topographic map and landscape features. In addition, crew members were instructed to avoid the urge to walk directly to what they might presume as 'likely' areas, such as a flat terrace above the river. Rather, they were asked to perform the same level of examination for the entire area of their survey. It is important to note that the survey was conducted with no premeditation about variables, categories or subcategories. At this stage, there was no intention to look for sites, for example, in areas a given distance from water. Rather, the intention was to survey, as completely as possible, the entire study area, *with an equivalent level of examination in all locations.* In total >90% of areas outside the valley bottom were subjected to survey.

Due to financial restrictions and a two week period scheduled to complete the survey, it was not feasible to examine every square metre of the entire survey area. The reconnaissance was not conducted by walking a straight line in one direction for a specified distance and then returning in the same direction ten metres removed from the first transect. While this would have been most desirable, the restrictions discussed above made that approach unrealistic. The two crew members attempted to survey as much of their assigned blocks as possible. In almost all cases this resulted in 90%+ coverage of the survey block. The only area that was not subjected to systematic coverage was the Souris floodplain. At the time of the survey, the entire valley bottom was in crop. In all fields except one, the density of growth made surface survey unrealistic. In one field, located in the western portion of the valley bottom, the density of growth was low enough to permit a survey. It was not surprising to discover lithic artifacts scattered throughout the field. It would not be unreasonable to expect the other fields in the floodplain to contain archaeological material, especially when one considers the number of sites discovered in the floodplain elsewhere in the Souris Valley. However, an important point must be made. Any sites discovered in the floodplain would have been subjected to decades of crop agricultural activities. Ploughing undoubtedly brought artifacts to the surface and this fact introduces considerable bias into the database, especially when no subsurface examination took place elsewhere.

The survey resulted in the identification of 59 archaeological sites (Table 3.3; Figures 3.10, 3.11; Appendix A). Two of these sites date to the historic period (DgMp 5 and DgMp 57). Both are the remains of homesteads, most likely dating to the last decades of the nineteenth century or first decades of the twentieth century (Klimko 1990, pers. comm.). As this is a model of prehistoric activity location, historic sites are not considered part of the data set. Another site, DgMp 23, is an artifact scatter located in the Souris Valley floodplain. The floodplain was not subjected to the same level of investigation as other areas due to dense (Figures 3.15-3.18). "Cairns...occur singly, in groups, or in combination with other boulder monuments,. Size ranges from about 30 cm in diameter and 15 cm

Borden No.	Type	Size	Description
DgMp 4	Bison Drive	1000m x 250 m	30+ stone circles, 75+ stone cairns, rock alignments
DgMp 5	Homestead	200m x 500m	rock walls, homestead walls
DgMp 6	VQ-mounds?	25m x 25m	3 low mounds, 2 depressions, rock alignments
DgMp 7	Cairn	500m	9 cairns
DgMp 8	Cairn	2m x 1.5m	1 cairn
DgMp 9	Cairn	5m x 5m	1 stone cairn
DgMp 10	Cairn	35m x 3m	3 stone cairns
DgMp 11	Cairn	1.5m x 1m	1 stone cairn
DgMp 12	Cairn	2m x 2m	1 stone cairn
DgMp 13	Stone circles	100m x 100m	at least 18 stone circles
DgMp 14	Stone circles	25m x 15m	3 stone circles
DgMp 15	Cairn	250m x 10m	2 stone cairns
DgMp 16	Stone circles	25m x 20m	2 stone circles (possibly more buried circles)
DgMp 17	Cairn	6m x 4m	1 stone cairn
DgMp 18	Stone circles/cairns	170m x 75m	at least 24 stone circles and 2 cairns
DgMp 19	Stone circles	100m x 30m	at least 17 stone circles
DgMp 20	Stone circles	20m x 10m	4 stone circles
DgMp 21	Stone circles	10m x 5m	2 stone circles
DgMp 22	Stone circles	4m x 4m	1 stone circle
DgMp 23	Lithic Scatter	300m x 200m	artifact scatter in ploughed field
DgMp 24	Vision quest	2m x 2m	1 vision quest site (stone lined depression)
DgMp 25	Vision quest	2m x 2m	1 vision quest site (stone lined depression)
DgMp 26	Stone circles	20m x 10m	4 stone circles
DgMp 27	Stone circles/cairn	50m x 30m	5 stone circles, 1 cairn
DgMp 28	Cairn	80m x 10m	4 stone cairns
DgMp 29	Cairn	5m x 5m	1 stone cairn
DgMp 30	Cairn	75m x 10m	2 stone cairns
DgMp 31	Stone circles	200m x 200m	at least 12 stone circles
DgMp 32	Stone circles	25m x 15m	6 stone circles
DgMp 33	Cairn	3m x 2m	1 stone cairn
DgMp 34	Stone circles	20m x 15m	4 stone circles
DgMp 35	Stone circles	125m x 20m	at least 19 stone circles
DgMp 36	Stone circles	20m x 10m	3 stone circles
DgMp 37	Stone circles	20m x 20m	3 stone circles
DgMp 38	Stone circles	50m x 30m	at least 6 stone circles
DgMp 39	Stone circles	75m x 75m	at least 11 stone circles
DgMp 40	Stone circles	50m x 30m	at least 10 stone circles
DgMp 41	Stone circles	15m x 15m	4 stone circles
DgMp 42	Cairn	20m x 3m	2 stone cairns
DgMp 43	Stone circles	100m x 30m	5 stone circles
DgMp 44	Stone circles	20m x 5m	2 stone circles (possibly more buried)
DgMp 45	Cairn	4m x 2m	1 stone cairn
DgMp 46	Stone circles	75m x 25m	9 stone circles
DgMp 47	Stone circles	100m x 15m	6 stone circles
DgMp 48	Stone circles	50m x 25m	7 stone circles and 1 depression
DgMp 49	Cairn	1m x 1m	1 stone cairn
DgMp 50	Stone circles	1000m x 300m	at least 44 stone circles (more obscured by vegetation)
DgMp 51	Stone circles	40m x 15m	5 stone circles
DgMp 52	Stone circles	3m x 3m	1 stone circle
DgMp 53	Cairn	3m x 3m	1 stone cairn
DgMp 54	Stone circles	25m x 25m	2 stone circles
DgMp 55	Stone circles	30m x 10m	5 stone circles
DgMp 56	Cairn	5m x 3m	1 stone cairn
DgMp 57	Homestead	400m x 400m	homestead foundations, depressions, rock walls
DgMp 58	Stone circles	30m x 10m	5 stone circles
DgMp 59	Stone circles	10m x 10m	1 stone circle
DgMp 60	Cairn	5m x 5m	3 stone cairns
DgMp 61	Stone circles	15m x 15m	2 stone circles
DgMp 62	Vision quest	3m x 3m	1 vision quest site (stone lined depression)

Table 3.3. Sites Located During Survey of the Study Area

Figure 3.10. Sites Located in the Western Portion of the Study Area (all sites have the Borden prefix DgMp)

Figure 3.11. Sites Located in the Eastern Portion of the Study Area (all sites have the Borden prefix DgMp)

hay fields. In addition, ploughing has revealed subsurface archaeological materials while destroying all surface features. These factors bias the results of the floodplain survey as compared to that conducted on the prairie level. For these reasons, the floodplain is not included in the development of the predictive model. Thus, the remaining 56 prehistoric sites form the archaeological database used in this resarch.

Of the 56 prehistoric sites discovered during the survey, 33 may be characterized as stone circle sites (Figure 3.12-3.13). Stone circles are ubiquitous on the northern plains and are easily the most visible and numerous prehistoric features present in the study area. Finnigan (1982:4) has examined stone circles in detail and suggests the majority of stone circles found on the plains may be identified as tipi rings if:

1) the shape does not deviate significantly from a circle;
2) there are no interior stone features that would render the interior of the tipi ring uninhabitable unless they are clearly a post-use modification;
3) the inside diameter falls between 2.5m and 9m;
4) the slope of the ground is less than or equal to 5°;
5) the ground surface is dry and stable.

A total of 289 stone circles were counted in the areas surveyed. All observed stone circles conform to the criteria outlined above by Finnigan and thus they may be labelled as tipi rings. Given this association, all sites where stone circles are identified may be viewed as having a settlement component. The majority of these sites are found in immediate proximity to the north and south rim of the Souris River valley (Figure 3.14).

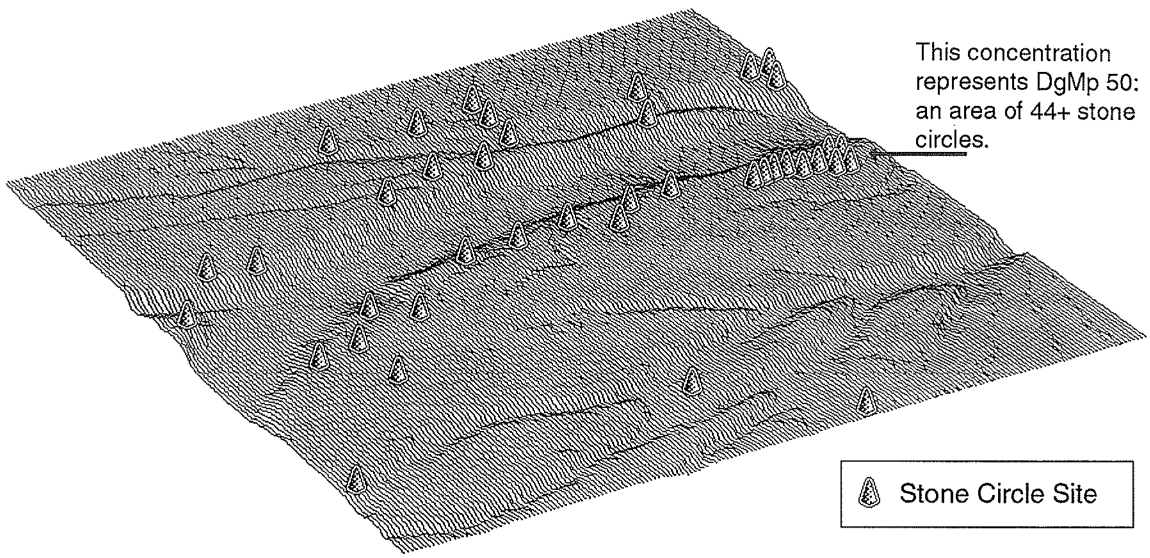

Figure 3.12. Spatial Distribution of Stone Circle Sites in the Study Area.

Figure 3.13. DgMp 31: Stone Circle With 8m Diameter (Looking Northeast)

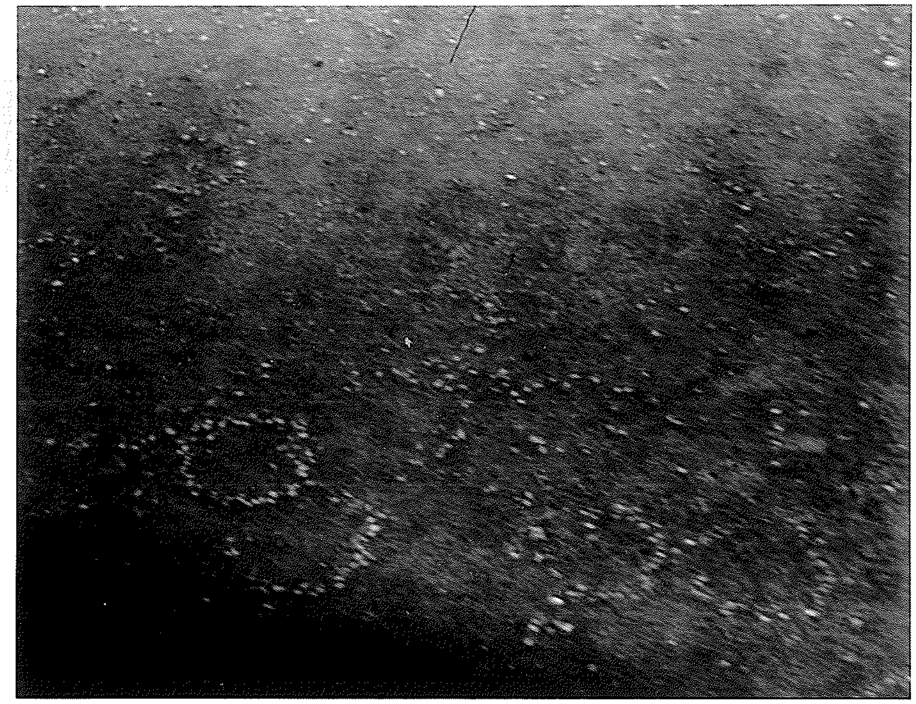

Figure 3.14. Stone Circles Located Along the South Wall of Souris River Valley with Liner Stone Alignment in Upper Left of Photo Located Approximately 300m Northwest of DgMp 6

in height to 8 or 10 m in diameter and up to one metre in height" (Dyck 1983b:17). In the hundreds or thousands of years since these cairns were constructed, the rocks often appear to have fallen or moved from their original placement thus determining the actual height of the cairn is difficult. Stone cairns appear to have served many functions. Cairns are associated with bison drive lanes (Verbicky-Todd 1984), for example the numerous cairns located during this survey at DgMp 4, as well as for geographical markers and grave markers (Dyck 1983b:17). Cairns also served as caches. A cairn excavated north of the Assiniboine River in Manitoba is suggested to have held buffalo robes and/or deboned meat (Nicholson 1985:179-180). Hind describes a structure that could be interpreted as a cairn while crossing the country south of Ft. Ellice in Saskatchewan:

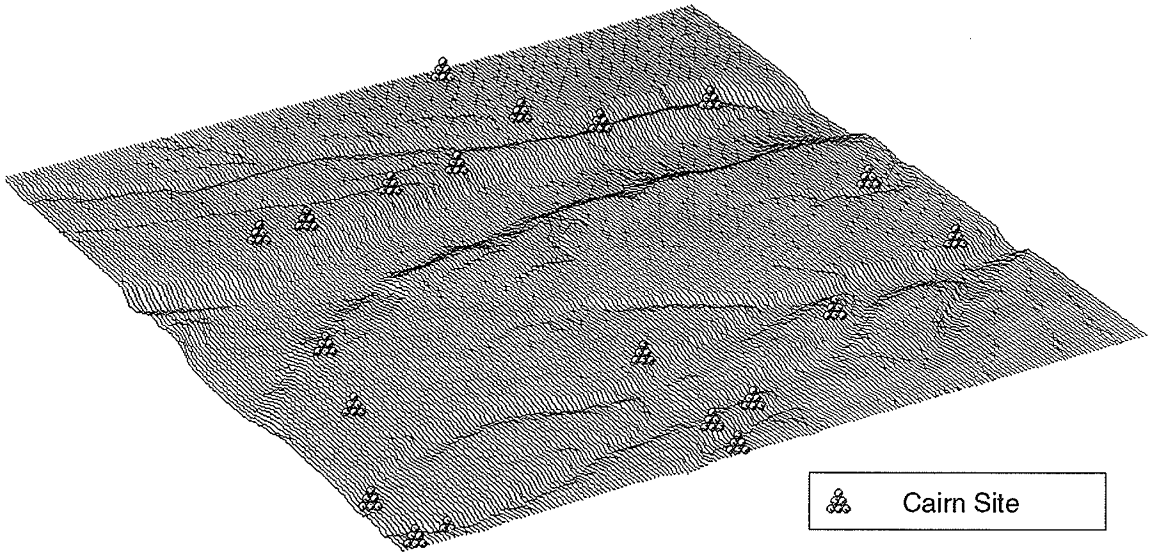

Figure 3.15. Spatial Distribution of Cairn Sites in the Study Area

Figure 3.16. DgMp 15: Looking Across a Single Stone Cairn Southwest into a Coulee

Figure 3.17. DgMp 30: Looking Upstream into the Souris Valley Across Two Stone Cairns Located on the Valley Rim

Figure 3.18. DgMp 30: Looking Downstream into the Souris Valley Across Two Stone Cairns Located on the Valley Rim

> On the hills in its [Pipestone Creek] neighbourhood boulders are uniformly distributed, but on the highest a considerable number have been collected together by the Assiniboine Indians, and a rude monument erected in commemoration of a battle fought at a remote period (Hind 1971:307).

A total of twenty-one sites are located in the survey area where cairns are present and 114 cairns were individually counted. North of the Souris River, cairns are located primarily along the rim of the valley. South of the river, cairns are noticeably absent from the valley rim but are numerous along the major coulee system.

A third category of sites discovered during the survey is characterized by cultural depressions, commonly known as vision quest pits. A vision quest site is characterized by a pit approximately 1 metre in diameter and one meter in depth, often lined with rock (Figure 3.19). Often there is evidence for a low rock construction, or 'wall', around the circumference of the pit. A large percentage of these pits are located on a small rise in the land surface. On this part of the prairies, a small rise of even 1 metre can dramatically increase the overall view of the landscape. The function of vision quest pits is unknown although it is suggested that they may have been used eagle trapping or for spiritual purposes (Syms 1990: pers. comm.). Four sites with vision quest pits were identified during the survey (Figure 3.20). Each pit is located on a small rise of land and no associated features were observed except at DgMp 6 which is discussed below.

Two sites were identified that merit separate discussion. The first was encountered the opening day of the survey. DgMp 4 is interpreted as a bison drive lane with at least 75 cairns defining the two arms of the drive, rock alignments and numerous stone circles. This extensive feature extends one

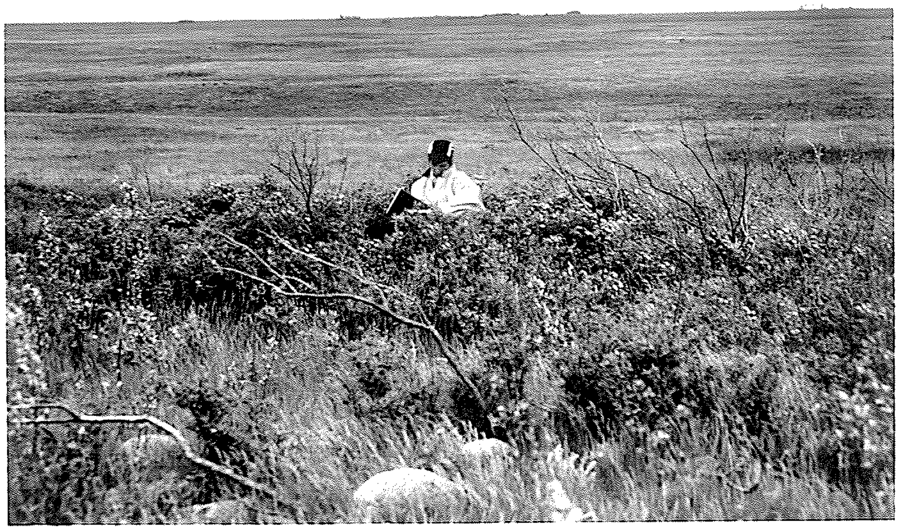

Figure 3.19. DgMp 6: Vision Quest Pit Located on a Ridge Between Two Coulee Systems (the dense growth around the pit hides the fact that the person is standing approximately 1 metre below the ground surface)

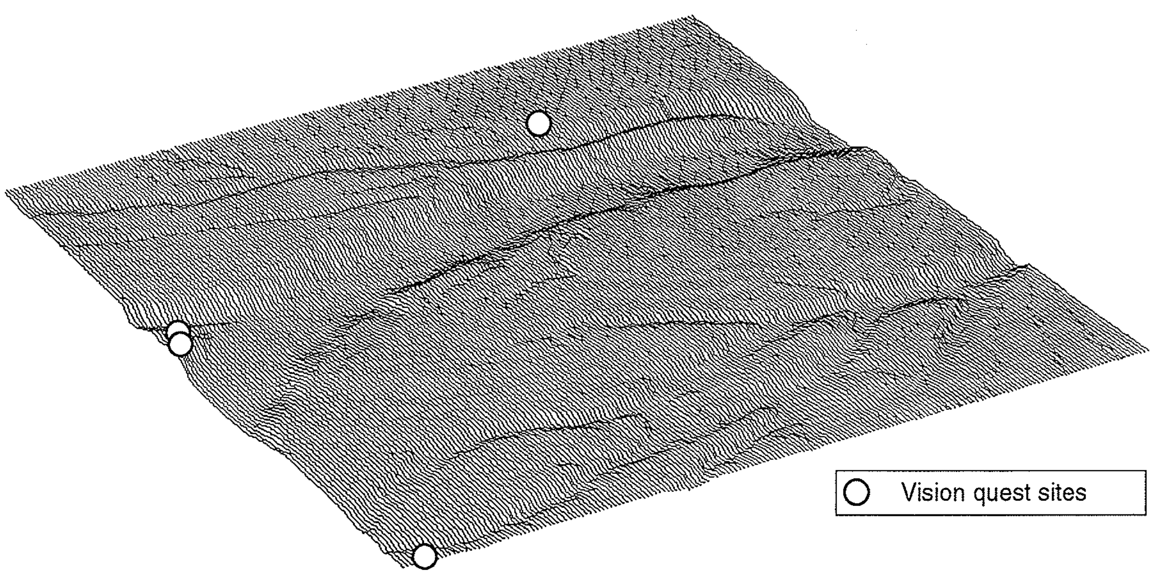

Figure 3.20. Spatial Distribution of Vision Quest Sites in the Study Area

kilometre from prairie level down into the coulee bottom and ends in a seasonal slough (Figures 3.21-3.23). At least 30 stone circles are located north of the 'opening' of the drive lane. Numerous other stone circles exist north of this area but time did not permit their reconnaissance. A large cairn approximately 1 metre in height and approximately 1.5 metres in diameter marks the southern extent of a rock alignment extending to the northwest (Figure 3.24). A second rock alignment extends west from the north wall of the coulee and is punctuated regularly by cairns (Figure 3.25). Numerous other cairns define the drive lane and appear to end deliberately at a seasonal slough located in the bottom of the coulee (Figure 3.26). It may be hypothesized that the bison were driven from the prairie level down into the arms of the drive lane and funnelled into the seasonal slough. The mud and water of the slough could have slowed the progress of the bison enough to simplify the task of dispatching them. A thorough surface inspection of the area was undertaken but no evidence for an associated kill area was found. No subsurface examinations took place because test pits were not allowed during this survey.

The second site, DgMp 6, is located on the crest of a coulee ridge in the southwest corner of the study area. It is characterized by 3 low mounds, 2 depressions, one of which is interpreted as a vision quest pit, and rock features (Figure 3.27). Some researchers associate low mounds with burials.

> "The few graves recorded by archaeologists [in Saskatchewan] indicate that a wide variety of burial practises was followed in prehistoric Saskatchewan varying from mass cemeteries containing multiple, individual, primary and secondary internments (sometimes all in one cemetery), to individual marked graves usually on the crest of a prominent hill, and even (rarely) burial mounds..." (Dyck 1983b:11).

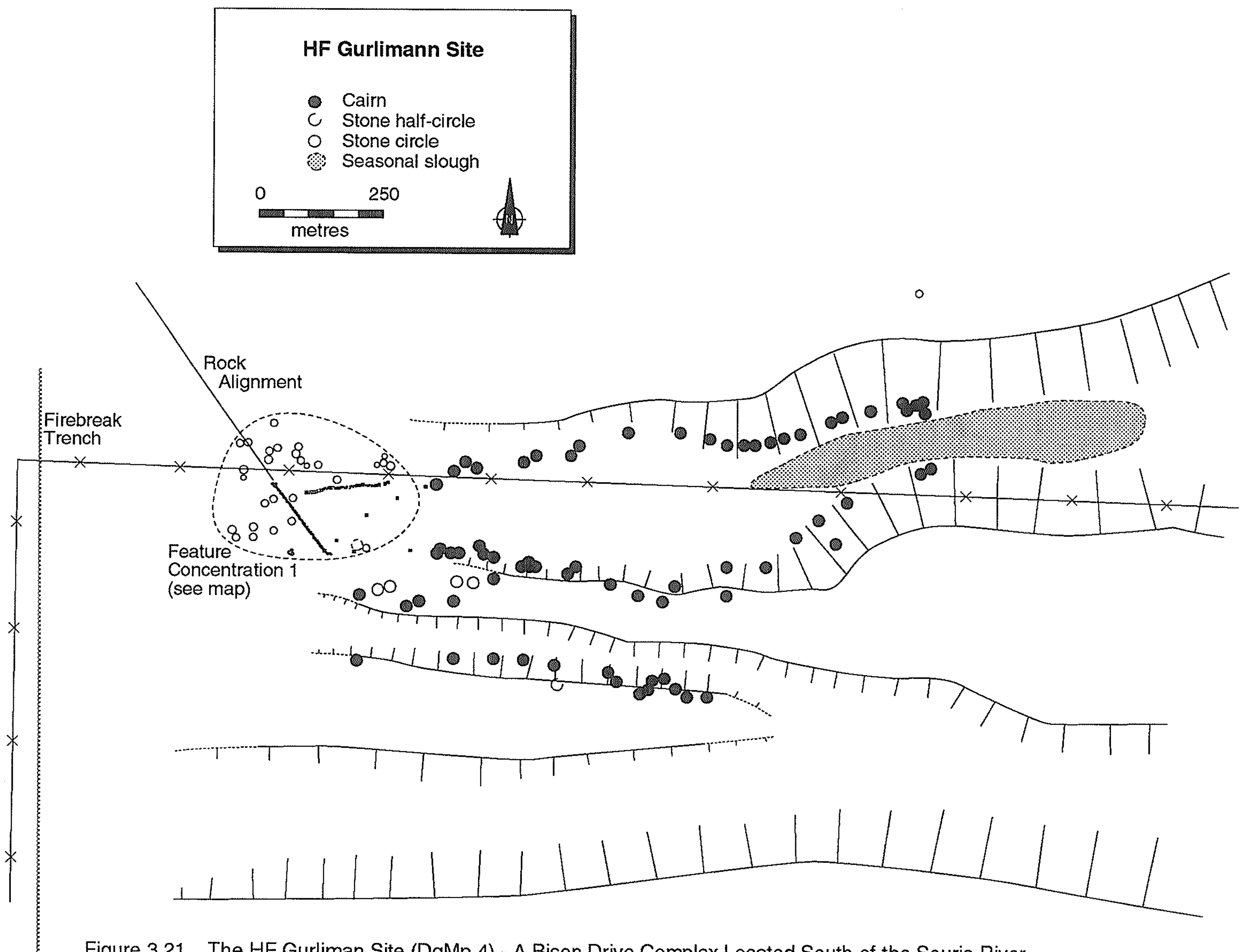

Figure 3.21. The HF Gurliman Site (DgMp 4) - A Bison Drive Complex Located South of the Souris River

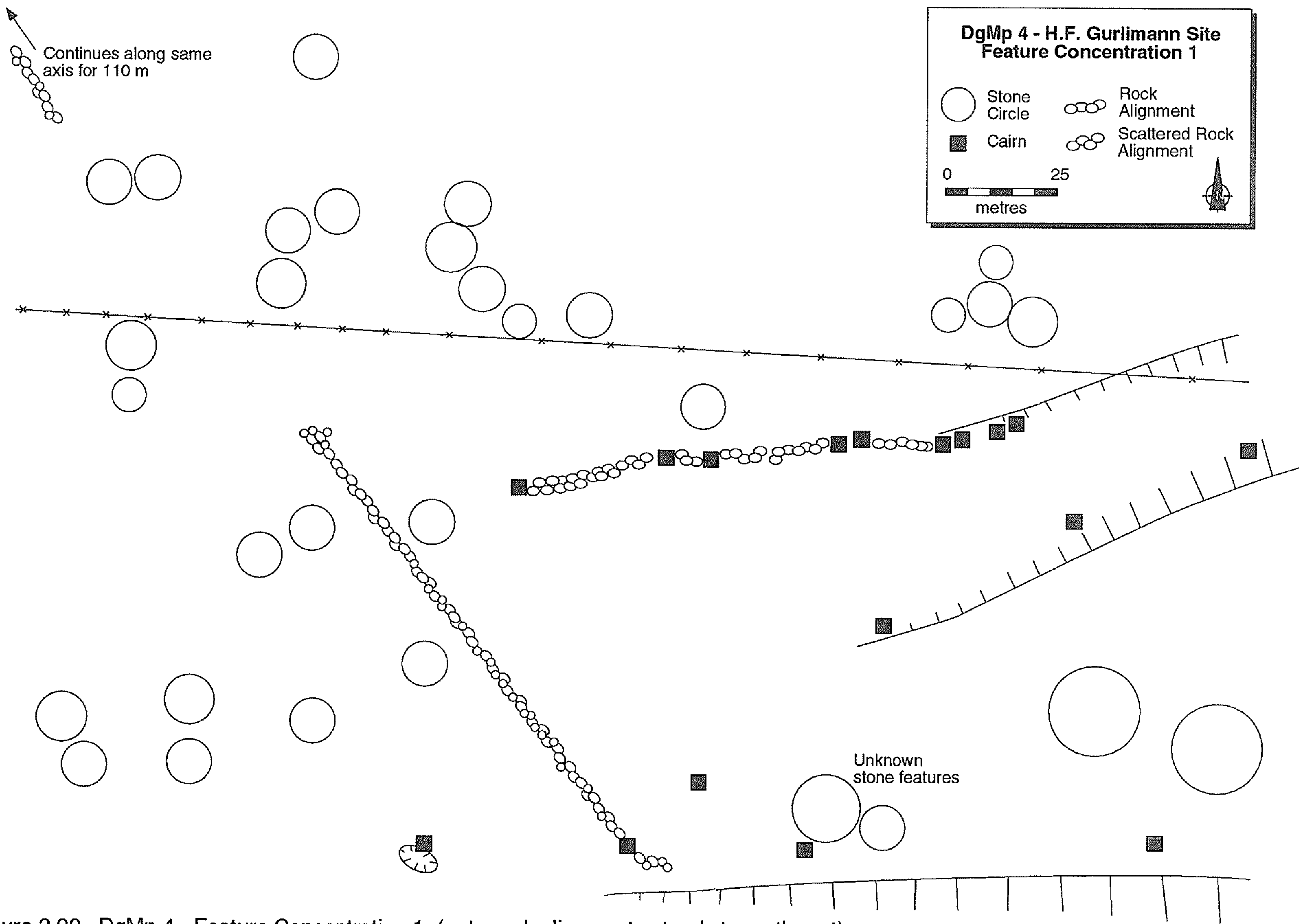

Figure 3.22. DgMp 4 - Feature Concentration 1 (note rock alignment extends to northwest)

Figure 3.23. DgMp 4: Looking ESE up the Coulee Toward the Rock Alignment (cairns follow the coulee walls to the bottom right of the photo)

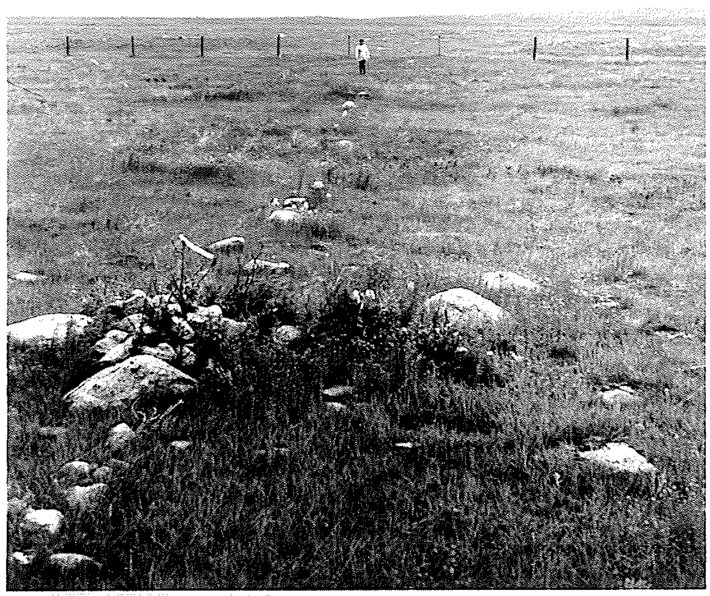

Figure 3.24. DgMp 4: Looking Northwest Along the Rock Alignment (The cairn in the near foreground is approximately 1 metre in height. The rock alignment continues over the crest of land in the background to a point where the Souris Valley is visible.)

Figure 3.25. DgMp 4: Looking to the North Wall of the Coulee with Three Cairns in Alignment Along the Base of the Coulee Wall (Distance between the cairns is approximately 20 metres. Cairn heights are approximately 1 metre.)

Figure 3.26. DgMp 4: Looking Northeast Along a Rock Alignment on the South Coulee Wall (The end of the bison run is located at the light-coloured area in the centre of the photo: a presently dry marsh.)

Dyck suggests that bison kill ceremonialism is important during the Besant Complex (2000 B.P. - 1150 B.P.):

> These burial mounds, the first on the Northern Plains, are part of the evidence that Besant either had origins in or else was strongly influenced by the Early and Middle Woodland complexes of the eastern United States. At the same time, the Besant complex is very clearly oriented to Plains bison hunting as indicated by their success at bison kill sites and also by bison ceremonialism as

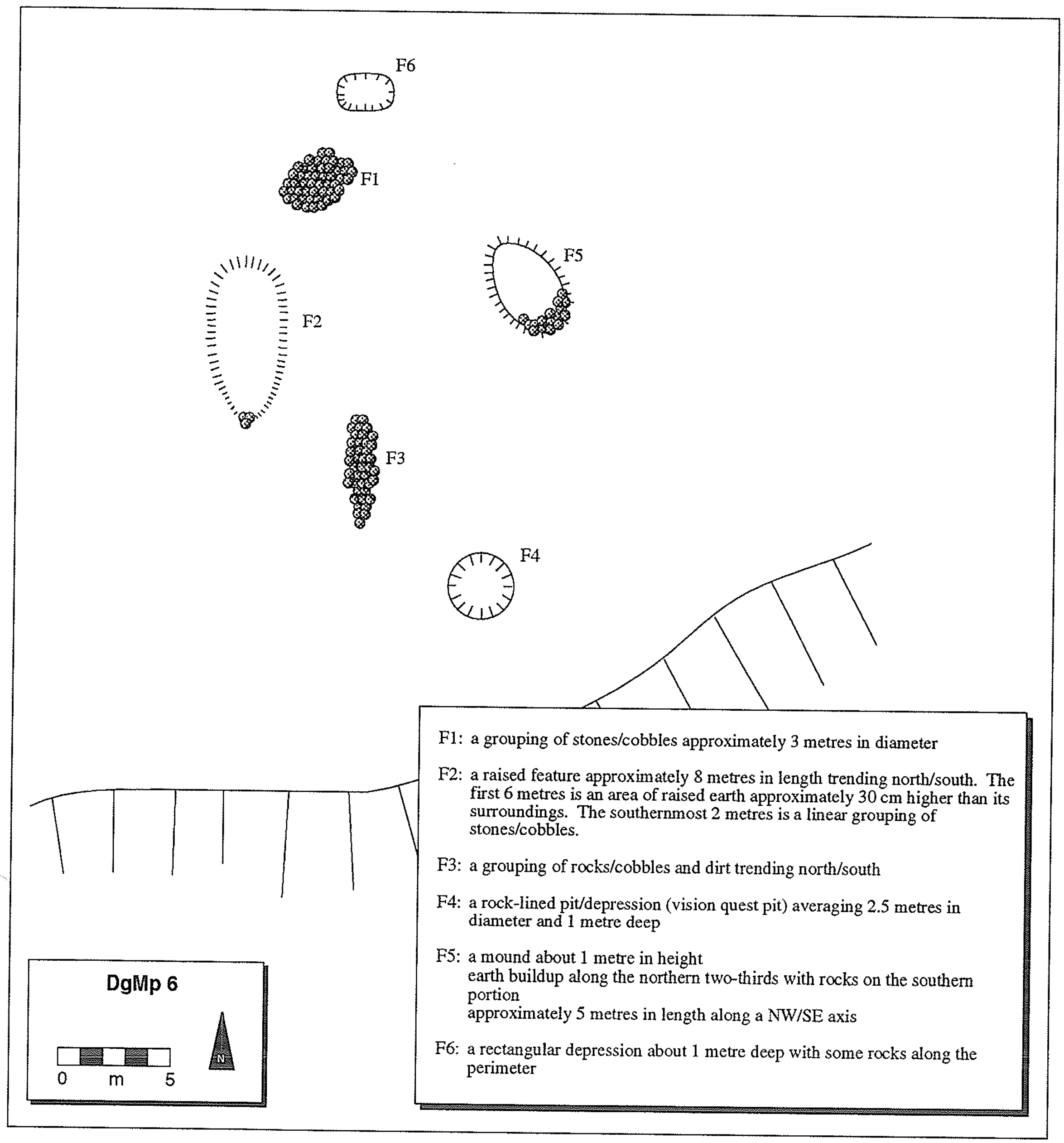

Figure 3.27. Map of Site DgMp 6 Located in the Southwest Corner of the Study Area

indicated by bison offerings placed in their burial mounds (Dyck 1983:115).

Dyck's interpretation may be important if this site is associated with the bison drive (DgMp 4) located less than 1 kilometre to the north west. However, site function will remain speculative until further testing is performed.

From the ubiquitous stone circle to the enigmatic vision quest pit, the 56 prehistoric sites discovered during the survey represent a cross-section of site types encountered on the Northern Plains. At least two factors must be considered. First, their identification results from a surface survey and therefore, the complete inventory of prehistoric resources can only be known by extensive subsurface examination. As this was not possible, this limitation in the data must be accepted. However, prehistoric material visible on the surface of the prairie is not limited to that from the most recent cultural time periods. Indeed, it is not unusual to find relatively old artifacts on the ground surface. Dyck (1983:71-80) identifies many of the Early Plains Indian Tradition artifacts as surface finds and these all date older than 8000 years. Thus it is possible that diachronic data can be obtained solely from surface survey, although it is acknowledged that subsurface examination is optimal. Secondly, dating any of the sites proves difficult due to the lack of diagnostic material resulting from this survey. Some researchers suggest that tipi ring size could be used as method of dating (Finnigan 1982:7). However, this method remains inconclusive. Short of full excavation at all stone circle sites, there is no way of establishing the contemporaneous use of one stone circle with another. Further, obvious features such as the bison drive lane are known to have been used at Head Smashed In Buffalo Jump up to 8000 years ago right through to historic times. Therefore, establishing temporal distinctions within sites and between sites is difficult. In summary, while an extensive site inventory was generated from the survey of the area, the database suffers from some of the problems resulting from doing archaeology on the northern plains. These include the need to conduct further subsurface investigations to complete the database and the general lack of dateable material, in turn clouding diachronic interpretations.

3.5 PRIMARY STAGE MODELLING: A SUMMARY

To this point, much of the organizational information necessary to continue developing the predictive model has been presented. Decisions may now be made concerning how the modelling will be conducted. The model will be developed for an area equivalent in size to the area in which the archaeological survey was conducted. Clearly, the scale of the model was predetermined and this information was used to assist in identifying the size and location of an area where an archaeological survey could take place. The data will be represented digitally at a scale where one cell of information on the digital map is equivalent to 25m x 25m on the ground. This scale presents a compromise between the cartographic issues of detail and generalization. Indeed, a large amount of detail is most desirable for any modelling exercise but extensive detail represents a relatively tremendous amount of digital data with correspondingly large amounts of storage space and computational effort. At the other end of the extreme, a large amount of generalization results in low storage and computational requirement but also presents an unacceptable representation of the landscape. The chosen scale allows for a reasonable amount of detail without compromising storage and computational requirements. This model is designed primarily to be applicable to the upper Souris River basin although it could undoubtedly be applied to other parts of the northern plains with further testing and refinement.

Determining the temporal scope of the model presents a small difficulty with which to contend. First one must consider how representative the contemporary environment is of the prehistoric environment. At least four major climatic episodes are known to have occurred relevant to the study area since 3500 B.P. (Reeves 1970:153-155). Changes in climate regimes ranged from conditions cooler/wetter than at present to conditions that were warmer/dryer than at present. Indeed, each of these climatic episodes resulted in changes to the natural environment of the area; changes which were reflected in expansions and contractions in the grassland communities and the borders of the Boreal Forest and parkland edges with coincident changes in the faunal populations inhabiting those ecozones (Reeves 1970:153-155). Clearly, a correspondence of contemporary natural environments with those of the past becomes less reliable the further into the past one goes. However, it would not be unreasonable to assume that the natural environment that exists today is similar to that which existed during the Late Plains Indian Period (2000 B.P. to 170 B.P.). A second issue of temporal scope arises from the lack of diagnostic material identified during the archaeological survey of the study area. There do not appear to be any methods of lifting the resulting constraints placed upon temporal control within and between sites. Indeed, only excavation at each site could result in the necessary information, however even excavation is not a solution as tipi ring sites are noted for excessive amounts of non-artifact material. With this in mind, what options can be exercised? Certainly, this research could be shelved due to the handicap presented by the 'temporal problem' but this is not acceptable as it is a situation common in archaeology, often alleviated by continued research. Rather, it is acceptable to continue the research bearing in mind the bias presented. Further research arising from the tertiary stage modelling process could produce the necessary temporal information to be introduced into the modelling process as it becomes available and refinements could be made to the model, as they become necessary.

The archaeological survey of the study area identified four site types with two types occurring in sufficient numbers to warrant investigation. With this information available, the model should be able to identify these two different site types and as a result contribute to an explanation why those sites are located where they are.

3.6 DEVELOPING THE SECONDARY STAGE PREDICTIVE MODEL

After years of doing research in an area, it is reasonable for an archaeologist to develop a 'sense' where certain sites may be found. The archaeological literature contains many statements that can be used to form the basis for variables used in a predictive model of prehistoric activity location:

> On the high banks of the valley the remains of ancient encampments in the form of rings of stones to hold down the skin tents are everywhere visible...The largest encampment we saw lies near a shallow lake in the prairie about a mile from the Qu'Appelle valley. It is surrounded by a few low sandy and gravelly hills, and is quite screened from observation (Hind 1971:340).

> The typical location is on the edge of a cliff, the highest points of the cuesta, or along the windswept edges of terrace fingers. Usually the locality is without shelter, wood or water and altogether a poor campsite (Mulloy 1960:2)

> It is reasonable to expect habitation sites to be located on dry, stable, ground with minimal slope. It is suggested here that minimal slope is less than or equal to 5°: this represents a drop of 50 cm across a six metre tipi (Finnigan 1982:3).

> Immediately on the banks of Qu'Appelle Valley near the 'Round Hill' opposite Moose Jaw Forks, are the remains of ancient encampments, where the [Indians]...had erected large skin tents, and strengthened them with rings of stones placed round the base. These circular remains were twenty-five feet in diameter, the stones or boulders being about one foot in circumference. They

> wore the aspect of great antiquity, being partially covered with soil and grass. When this camp ground was occupied...timber no doubt grew in the valley below, or on the prairie and ravines in detached groves, for their permanent camping grounds are always placed near a supply of fuel (Hind 1971:338).

As stated in Chapter 2, it is important to identify the subjective expectations of archaeologists, quantify them and present them for objective assessment. In the development of the predictive model, the statements presented above will serve as a point of departure. Several categories can be derived from those statements:

a) proximity to a dramatic change in slope or edge of a terrace;

b) well drained soils;

c) slope of 5° or less.

Other categories such as proximity to wood, water and shelter are discounted as explained below. With respect to the Souris Basin study area, some of these variables are not relevant. Vegetation is primarily limited to short grass prairie with almost no tree cover existing today. Small stands of trees can be found along the margins of permanent water bodies, such as the Souris River but they make up less an 1% of the total study area but the potential for substantial shrub and tree growth does exist along stream and river margins. This potential can be modelled using water as the dominant variable. Drainage is identified as fair-to-good throughout the entire study area (SBDA 1986: Chapter 5, Figure 3). Soil classes are homogeneous on the prairie level in this area. Elevation in the study area does not appear to be associated with specific site types. The reasons for this may lie in the fact that the only significant change in elevation occurs at valley and coulee walls. This change in elevation is abrupt and the resulting slopes are steeply graded. The remaining area is relatively flat. While sites such as vision quest pits are associated with small rises in elevation (approximately 1 metre), these changes are too minute to be represented on topographic maps and correspondingly, on digital elevation models. Short of re-mapping elevations in the study area at contour intervals less than 1 metre, there is no way to identify these micro-changes in topography. Other variables such as **aspect** are not relevant. Most areas are exposed to all compass directions and except in the early morning and early evening, all points on the land receive a relatively equivalent amount of sunlight throughout the day.

Therefore in summary, on an inductive level the following categories are relevant to the modelling process:

a) slope (land suitable/unsuitable for habitation);
b) areas near a water source (for both subsistence and wood);
c) areas near a major break in slope (terrace edges).

Each category was divided into subcategories. The two subcategories **Permanent Water** and **Seasonal Water** reflect the assumption that it is desirable to be closer to a water source than further from it. These categories represent many factors:

(a) proximity to drinking water and food (fish, animals drawn to water, plants);
(b) the potential for wood (fuel, raw materials for tools, building, shelter for animals);
(c) the potential for other items necessary for daily life such as clay for pottery, fibre for basketry, shells for tools and personal items.

A third subcategory, **Slope**, reflects statements made by some archaeologists that it is "reasonable to expect habitation sites to be located on…ground with minimal slope" (Finnigan 1982:3). Finnigan's suggestion that slope not exceed

5° forms the basis for areas of favourable slope. Areas with a slope exceeding 5° are considered to be unfavourable.

The fourth subcategory, **Prairie Edge** is drawn from statements presented above. It appears that it was desirable to locate sites near a terrace edge/major break in slope. In a sense, this category may be reflective of the necessity to locate near water. However, it may also be related to the winds that blow up terrace edges assisting in drying meat and keeping bugs away.

As outlined in Table 3.4, the four subcategories described above are divided into 11 variables, each of which is judgementally assigned a value to reflect its contribution to determining activity location. For example, variables defining areas closer to water are given a value higher than variables defining areas further from water. By multiplying the value of the category (V) by the weight of the variable (W), a weighted value for the subcategory is obtained. The categories, subcategories and variables outlined above are used in the secondary stage modelling.

As discussed in Chapter 2, a geographic information system (GIS) can be used to store information about each variable and then used to manipulate the variables in a desired manner. The main source for much of the digital data generated in this research is the 1:50,000 topographic map. These maps are readily available for virtually all parts of Canada. They are accepted as the *de facto* standard for recording the locations of archaeological resources. This is demonstrated by the fact that nearly all provincial and federal heritage resource management agencies plot the location of archaeological sites on 1:50,000 topographic maps. While it is acknowledged that these maps contain inaccura-

SUBCATEGORY	VARIABLE	VALUE (V)	WEIGHTED VALUE (W X V)
CATEGORY: PROXIMITY TO WATER		***WEIGHT (W) = 3***	
Permanent Water	0-200 metres*	3	9
	201-400 metres*	3	9
	401-800 metres	2	6
	800+ metres	1	3
Seasonal Water	0-100 metres§	3	9
	101-200 metres§	3	9
	201-400 metres	2	6
	400-800 metres	1	3
CATEGORY: SLOPE	***WEIGHT (W) = 2***		
Slope	0-5° Slope	3	6
	>5° Slope	0	0
CATEGORY: PROXIMITY TO TERRACE EDGE		***WEIGHT (W) = 2***	
Prairie Edge	<250 from Prairie Edge	3	6

* for reasons necessary to simplify the computing process, the variables *0-200 m* and *201-400m* were collapsed into one composite category *0-400m*. This change is reflected only at the level of the computer manipulations. It is also in evidence in Table 3.6 where the variable *0-400m from permanent water* is evident.

§for reasons necessary to simplify the computing process, the variables *0-100 m* and *101-200m* were collapsed into one composite category *0-200m*. This change is reflected only at the level of the computer manipulations. It is also in evidence in Table 3.6 where the variable *0-200m from seasonal water* is evident.

Table 3.4. Weighted Values Assigned to Variables Used in the Predictive Model

cies, they do form a baseline of accuracy for all of Canada. In the case of this survey, the information presented on the topographic maps was supplemented and corrected by field observations. For example, the topographic map indicated many of the minor streams in the study area were permanent water bodies. However, at the time of the survey, it was obvious that nothing had flowed in those water courses for several years. These 'permanent' water bodies were changed to seasonal water bodies in the digital database. Additional information such as specific topographic features not represented on the 1:50,000 map were also added to the digital database. The technical details for generating the digital data are outlined in Appendix B. Figure 3.28 illustrates the general progression of data transformation from the paper topographic map to the final product.

A digital map may be visualized as a piece of graph paper where every square, or cell, contains information relevant to the map layer. For example, each cell of the elevation map contains a numerical value expressing elevation in centimetres. The digital maps used here contain 39600 cells of information and an individual cell represents an area 25m x 25m (625 sq. m.). The eleven variables outlined above are stored as individual and combined map layers in the GIS program. A digital elevation model (DEM) was generated using contour data from the topographic map in order to calculate slope values (Figures 3.29-3.30). Slope values are expressed in degrees rather than gradients. Permanent and seasonal water courses were digitized from the 1:50,000 topographic map. Distance buffers from these water bodies were generated within the GIS program (Figures 3.31-3.32). A map illustrating proximity to terrace edges was also created by delimiting buffers 250 metres uphill from a sharp break in slope (Figure 3.33). The weighted values calculated for each variable were assigned accordingly (see Table 3.4).

To generate the secondary stage predictive model, a logical operation must take place; primarily the physical combination of all variables. This 'combine' operation takes the occupant of each cell from each map and merges them into a final result (Figure 3.34, Table 3.5). The eleven digitally-represented variables were combined to produce a secondary stage predictive model (Figure 3.35) with the total weighted value for each cell resulting in a range of archaeological potential. The bottom end of the range is represented by a value of 3 indicating

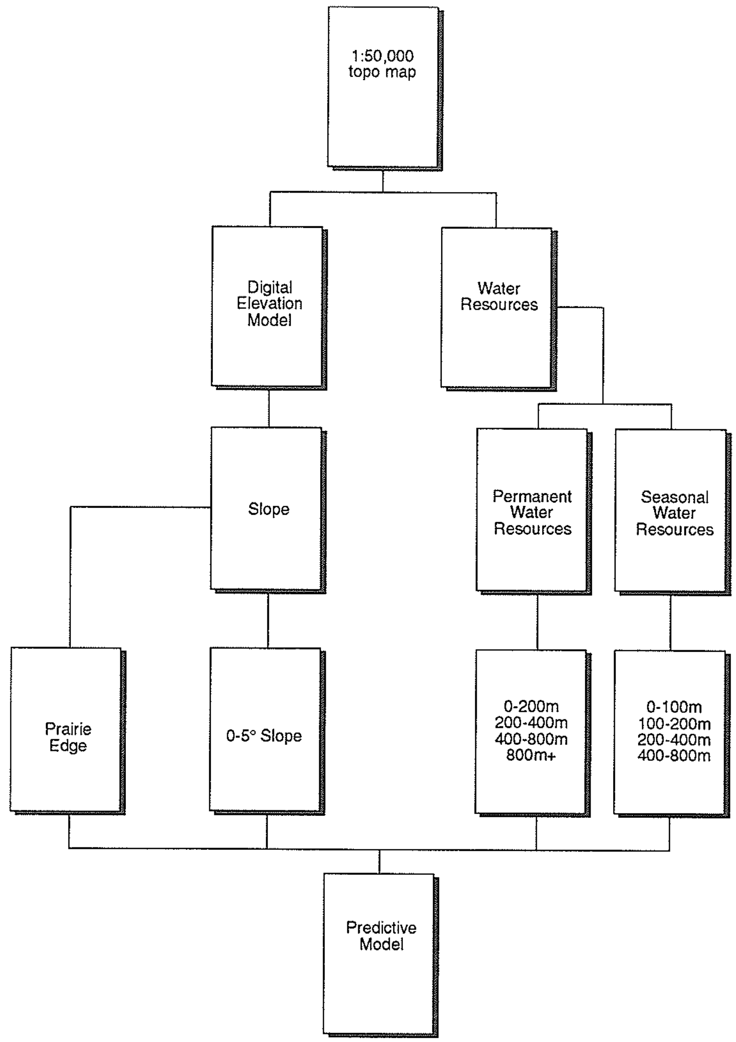

Figure 3.28. Flowchart Illustrating the Process of Generating Digital Data Used in this Study

the poorest potential for prehistoric activity. The highest weighted value is 30 indicating the best potential for prehistoric activity according to the variables used. It is important to note that potential for prehistoric activity translates into potential for the existence of archaeological resources according to the variables used. Therefore, areas with high weighted values are those areas where archaeological sites are predicted to exist.

This method for developing predictive models not only produces a range of potential but also a range of possible explanations for potential. Table 3.6

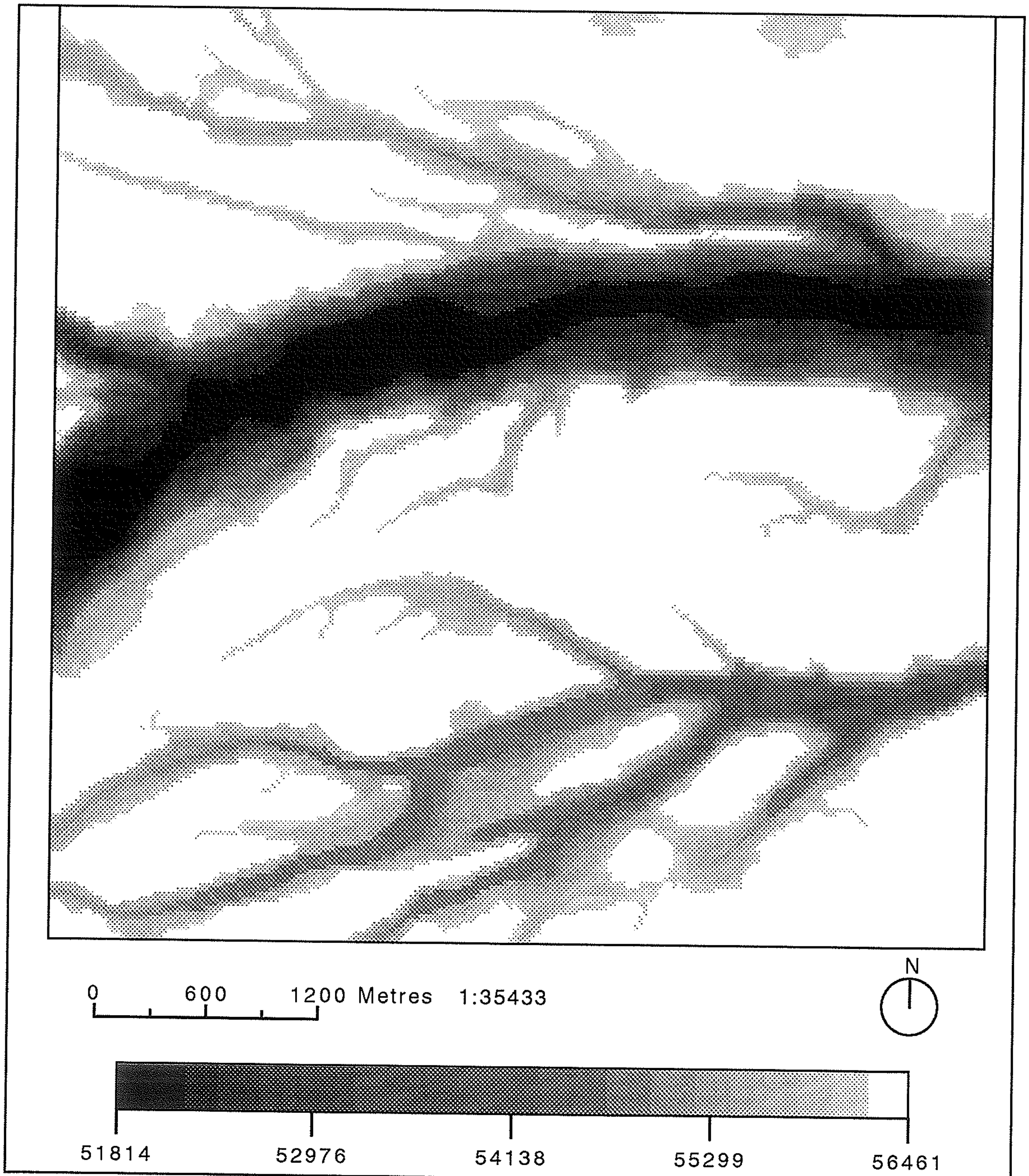

Figure 3.29. Digital Elevation Model of the Study Area (note elevations are in centimetres)

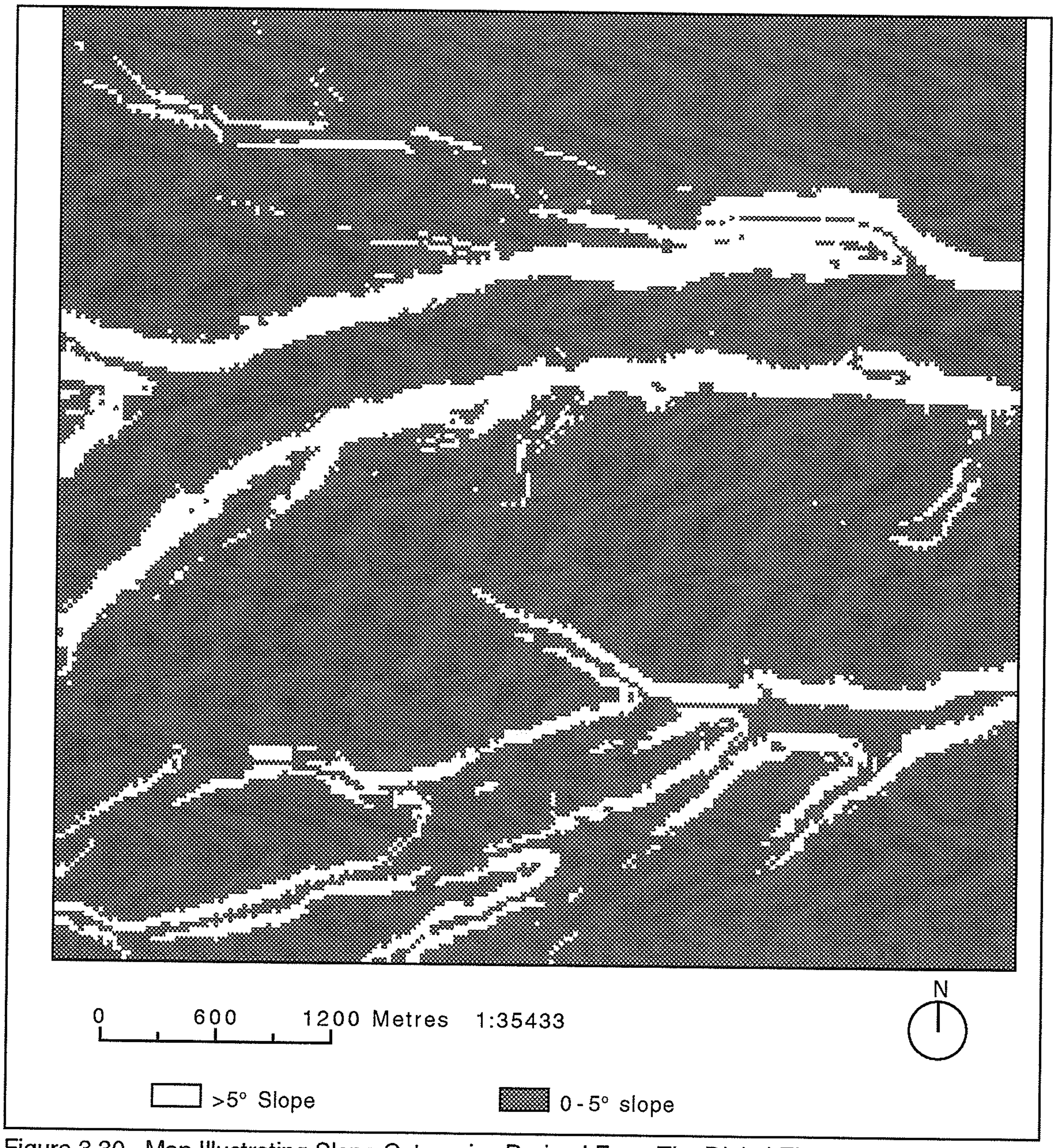

Figure 3.30. Map Illustrating Slope Categories Derived From The Digital Elevation Model

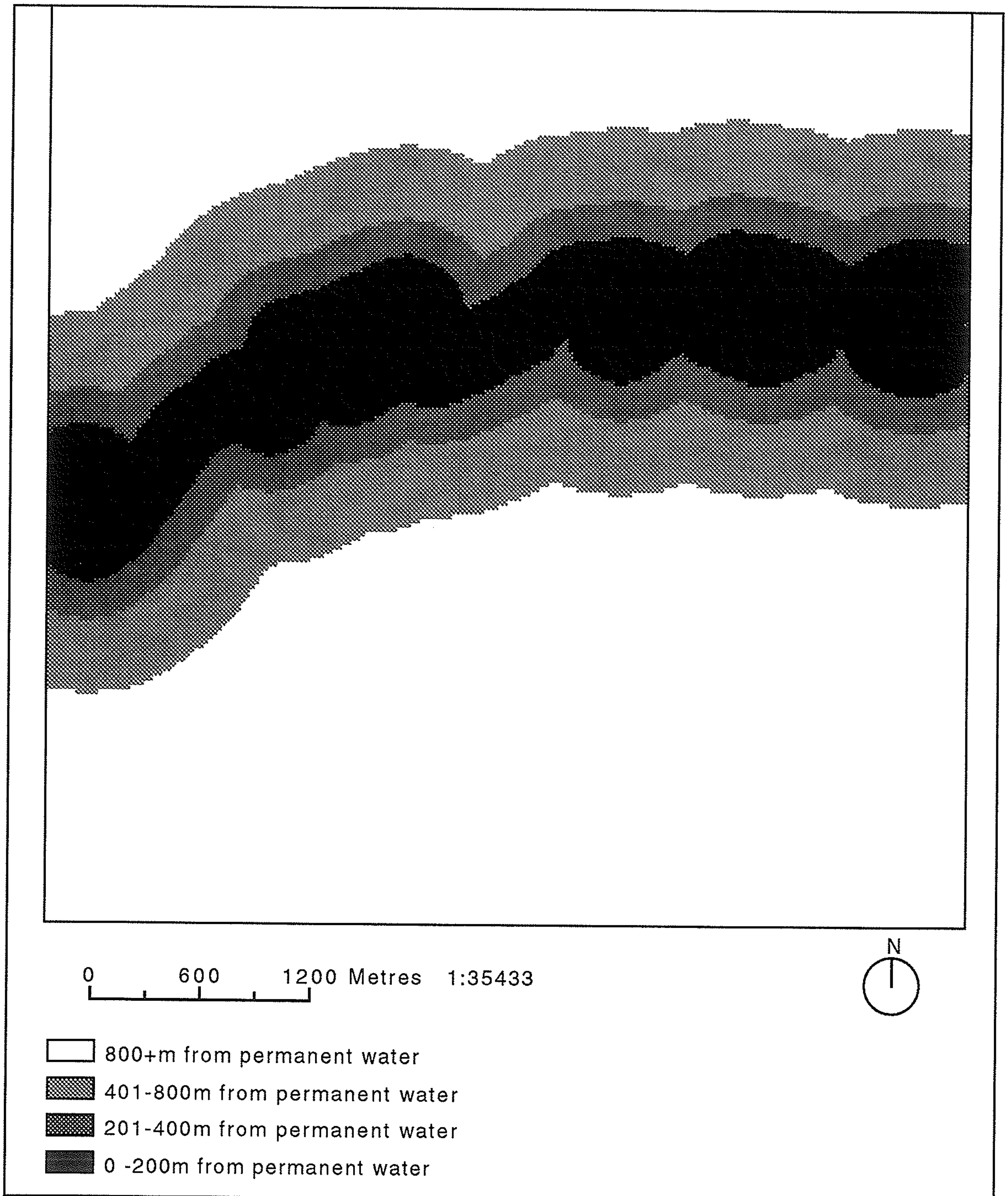

Figure 3.31. Map Illustrating Distances From Permanent Water Sources

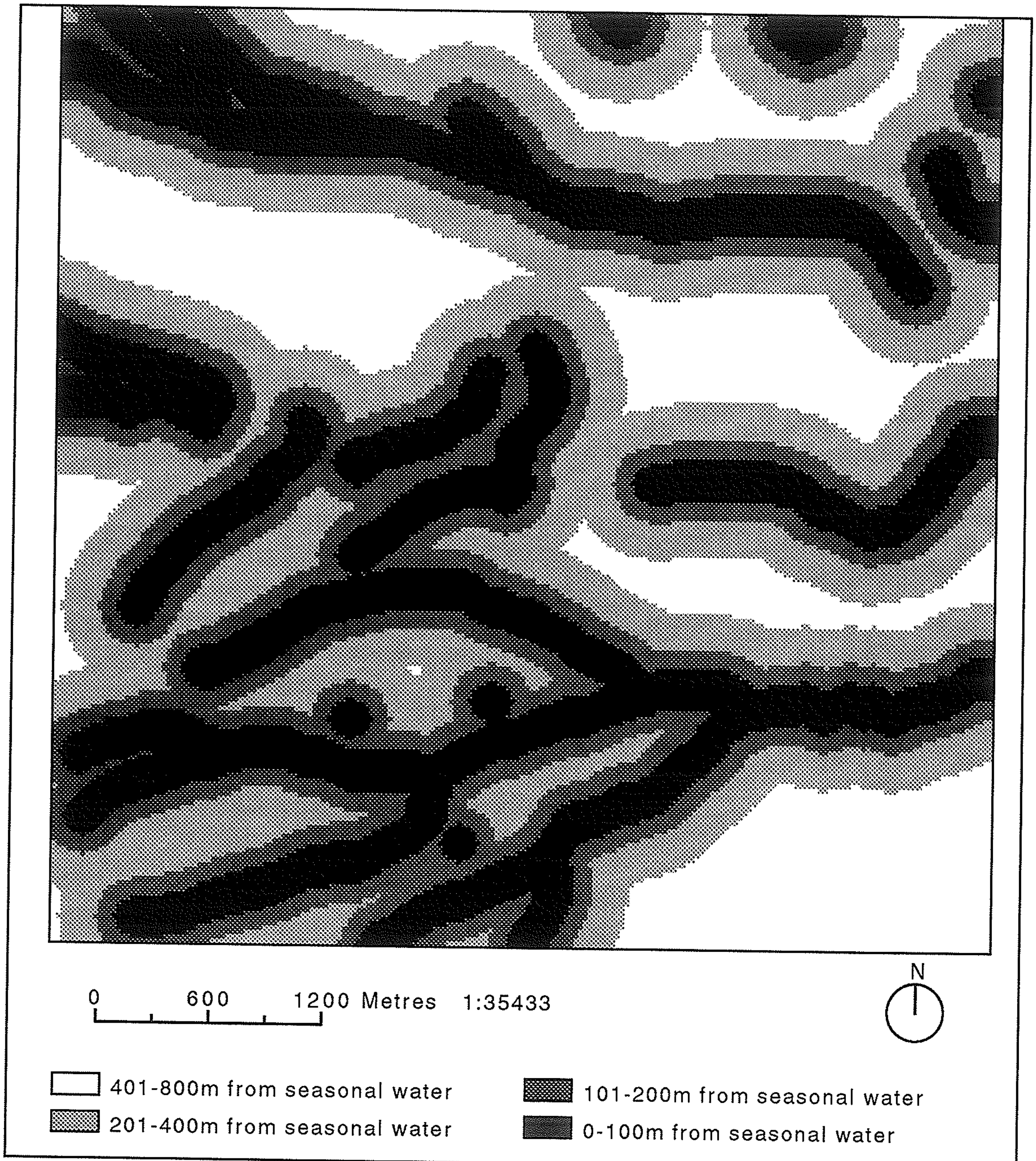

Figure 3.32. Map Illustrating Distances From Seasonal Water Sources

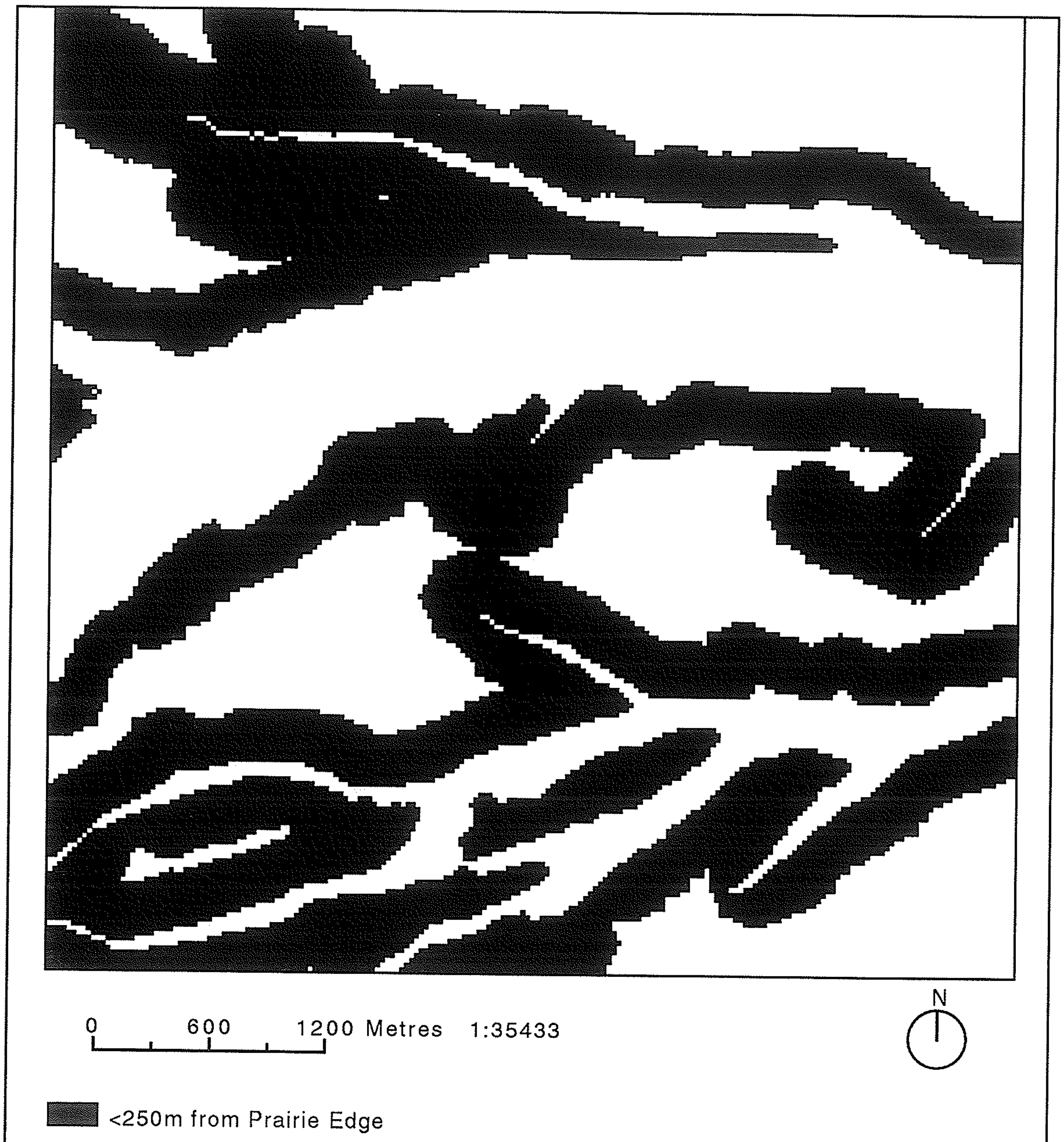

Figure 3.33. Map Illustrating Proximity to Terrace Edge

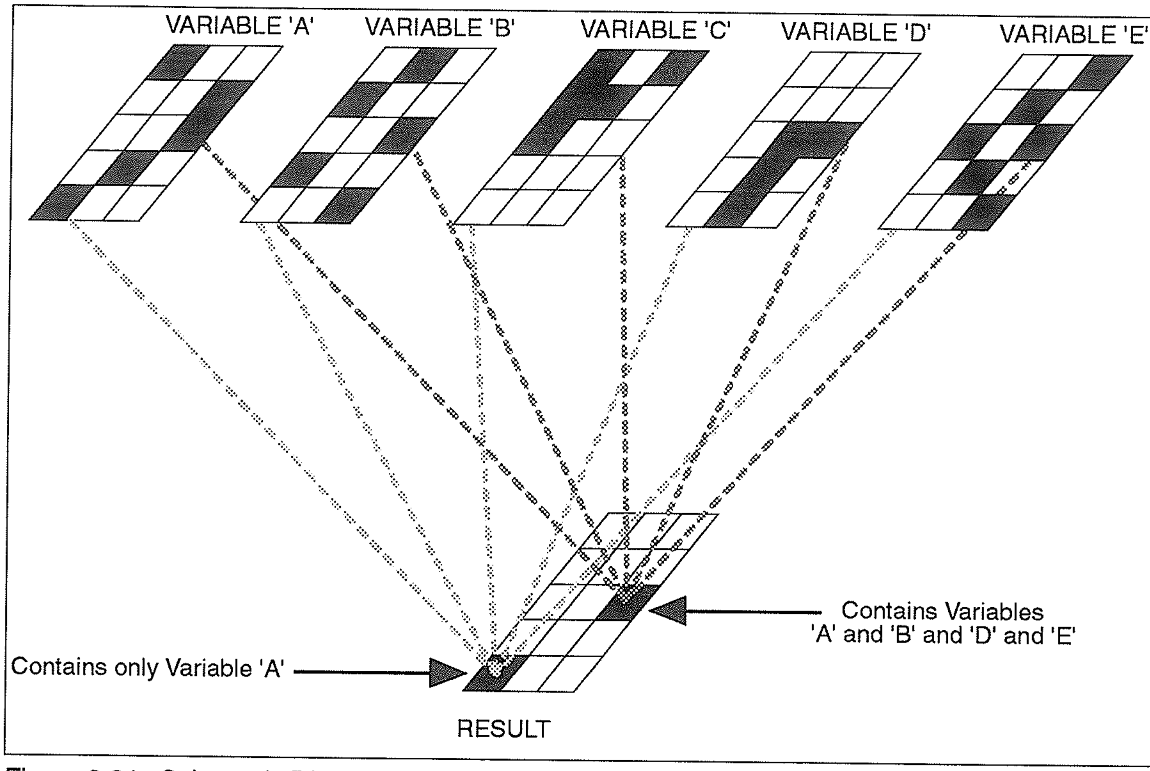

Figure 3.34. Schematic Diagram Outlining the Mechanics of 'Combining' All Digitally Represented Variables Together to Produce the Preliminary Predictive Model

VARIABLE	NO. OF CELLS	% OF TOTAL AREA
>5° Slope	6327	15.97
<5° Slope	33273	84.03
<250 m fromPrairie Edge	18536	46.81
>250m from Prairie Edge	21064	53.19
0-400m from Permanent Water	9305	23.50
401-800m from Permanent Water	7063	17.84
800m+ from Permanent Water	23232	58.66
0-200m from Seasonal Water	19087	48.20
201-400m from Seasonal Water	12218	30.85
401-800 from Seasonal Water	8295	20.95

Table 3.5. Occurrence of Subcategories Throughout the Study Area

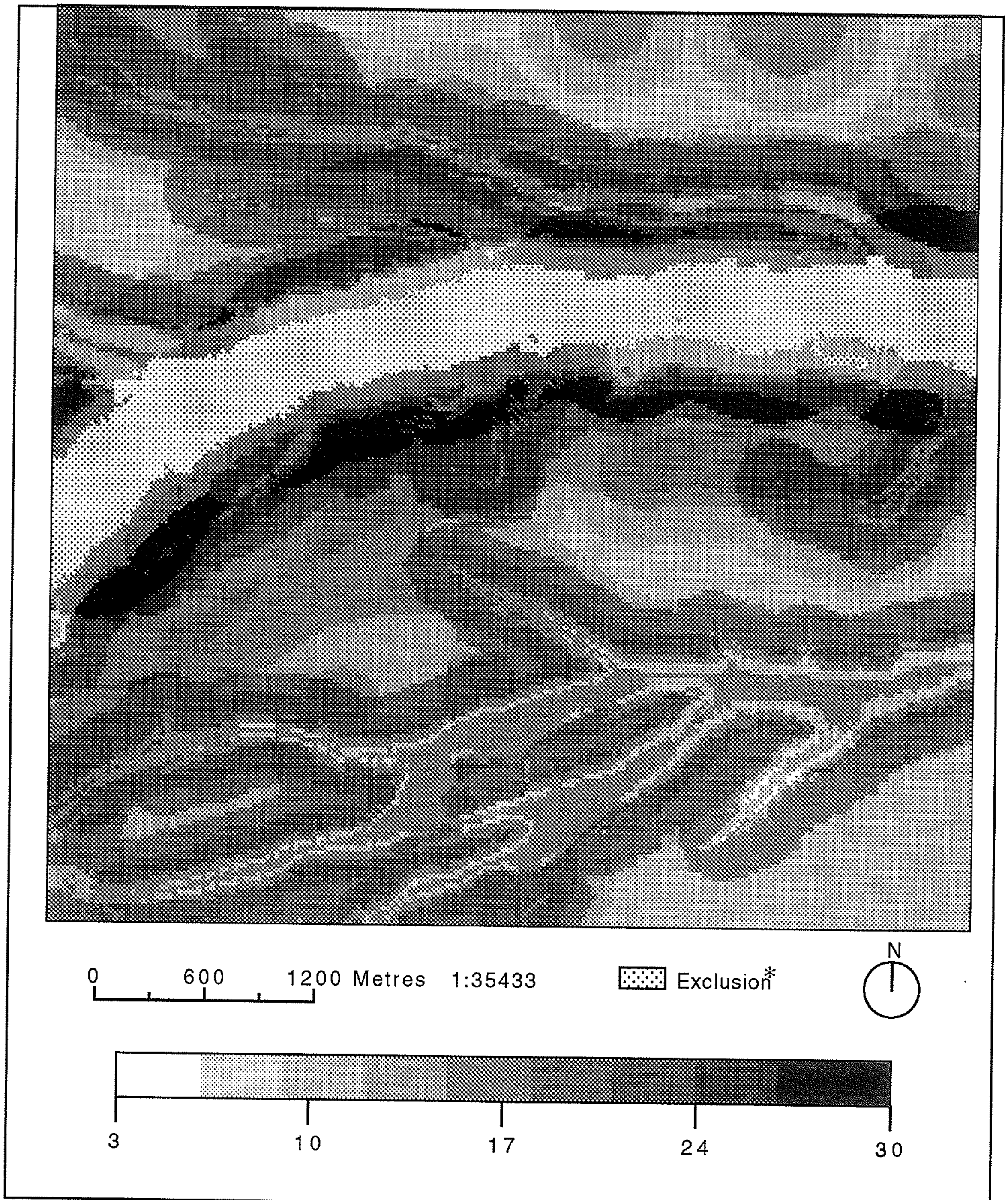

Figure 3.35. The Result of Secondary Stage Predictive Modelling Where Total Weighted Values Range From 3 (white) Through 30 (black) (darker shades represent a higher potential for prehistoric activity and thus higher potential for the presence of archaeological materials)

*the area identified in the exclusion zone is not included in any further manipulations because this area was not subjected to archaeological survey.

WEIGHTED VALUE	VARIABLES
03	>5° Slope & 800+m from permanent water & 401-800m from seasonal water
06	>5° Slope & 401-800m from permanent water & 401-800m from seasonal water
06	>5° Slope & 800+m from permanent water & 201-400m from seasonal water
09	0-5° slope & 800+m from permanent water & 401-800m from seasonal water
09	>5° Slope & 401-800m from permanent water & 201-400m from seasonal water
09	>5° Slope & 800+m from permanent water & 0-200m from seasonal water
09	>5° Slope & <250m from Prairie Edge & 800+m from permanent water & 401-800m from seasonal water
12	0-5° slope & 401-800m from permanent water & 401-800m from seasonal water
12	0-5° slope & 800+m from permanent water & 201-400m from seasonal water
12	>5° Slope & 0-400m from permanent water & 401-800m from seasonal water
12	>5° Slope & 401-800m from permanent water & 0-200m from seasonal water
12	>5° Slope & <250m from Prairie Edge & 401-800m from permanent water & 401-800m from seasonal water
12	>5° Slope & <250m from Prairie Edge & 800+m from permanent water & 201-400m from seasonal water
15	0-5° slope & 401-800m from permanent water & 201-400m from seasonal water
15	0-5° slope & 800+m from permanent water & 0-200m from seasonal water
15	0-5° slope & <250m from Prairie Edge & 800+m from permanent water & 401-800m from seasonal water
15	>5° Slope & 0-400m from permanent water & 201-400m from seasonal water
15	>5° Slope & <250m from Prairie Edge & 401-800m from permanent water & 201-400m from seasonal water
15	>5° Slope & <250m from Prairie Edge & 800+m from permanent water & 0-200m from seasonal water
18	0-5° slope & 0-400m from permanent water & 401-800m from seasonal water
18	0-5° slope & 401-800m from permanent water & 0-200m from seasonal water
18	0-5° slope & <250m from Prairie Edge & 401-800m from permanent water & 401-800m from seasonal water
18	0-5° slope & <250m from Prairie Edge & 800+m from permanent water & 201-400m from seasonal water
18	>5° Slope & 0-400m from permanent water & 0-200m from seasonal water
18	>5° Slope & <250m from Prairie Edge & 0-400m from permanent water & 401-800m from seasonal water
18	>5° Slope & <250m from Prairie Edge & 401-800m from permanent water & 0-200m from seasonal water
21	0-5° slope & 0 & 0-400m from permanent water & 201-400m from seasonal water
21	0-5° slope & <250m from Prairie Edge & 401-800m from permanent water & 201-400m from seasonal water
21	0-5° slope & <250m from Prairie Edge & 800+m from permanent water & 0-200m from seasonal water
21	>5° Slope & <250m from Prairie Edge & 0-400m from permanent water & 201-400m from seasonal water
24	0-5° slope & 0-400m from permanent water & 0-200m from seasonal water
24	0-5° slope & <250m from Prairie Edge & 0-400m from permanent water & 401-800m from seasonal water
24	0-5° slope & <250m from Prairie Edge & 401-800m from permanent water & 0-200m from seasonal water
24	>5° Slope & <250m from Prairie Edge & 0-400m from permanent water & 0-200m from seasonal water
27	0-5° slope & <250m from Prairie Edge & 0-400m from permanent water & 201-400m from seasonal water
30	0-5° slope & <250m from Prairie Edge & 0-400m from permanent water & 0-200m from seasonal water

Table 3.6. The Different Combinations of Variables Determining Weighted Values

outlines how different combinations of variables can result in identical weighted values. In addition, the reader will note that this method does not result in a 'hilighter effect': a circumstance where all the water bodies have equidistant buffers drawn around them. In fact, areas along water bodies in this predictive model have varying degrees of potential with some banks of rivers being preferred over others.

3.7 SUMMARY

This chapter reviewed the background information about the study area. The flora and fauna of the Souris River basin provided the basic requirements for the existence of human populations up to at least 8000 to 10,000 years ago. Because of the unique geological history of the area, portions of the valley remain undisturbed by modern agricultural practises resulting in a more complete picture of its archaeological resources. As a result of the construction of the Rafferty Dam, an archaeological reconnaissance of the Souris Basin was conducted, including the survey conducted in the study area for this research. Fifty-six prehistoric sites were located as a result of this study and form the base archaeological data for the development of the predictive model. Through examination of the literature, a number of variables were identified to be associated with prehistoric activity location. These variables were assigned weighted values reflecting their perceived importance in determining activity location. Using a geographic information system, the variables were transformed into digital representations of themselves and merged to produce a secondary stage predictive model. This model reflects varying degrees of potential for prehistoric activity locations, which in turn, reflects the potential for the existence of archaeological resources.

Chapter 4 takes the predictive model and presents the analyses conducted to evaluate its applicability. The predictive success of the model is evaluated for the study area. In addition, the model is analysed to determine its ability to predict the location of specific site types. It is anticipated that predicting specific site types will shed light on reasons why the activities associated with that site were carried out in that location.

CHAPTER 4
ANALYSIS OF THE PREDICTIVE MODEL

4.1 INTRODUCTION

Can a predictive model of prehistoric activity location reliably indicate where people located their activities? In previous chapters, this question was addressed by examining the history, methodologies and examples of predictive modelling. This chapter will evaluate the success of the model developed in this thesis by comparing the predicted locations of prehistoric activities against the actual locations of archaeological sites identified during the survey of the study area. This will take the model from the secondary stage to the tertiary stage. The predictive model will also be evaluated as a tool for contributing insights into an understanding why sites are where they are.

4.2 THE EVALUATION

> The comparison of model predictions to known site locations in surveyed areas provides a ready means for model testing and performance assessment. ...Most pattern recognition and classification algorithms are quite robust, even when there are only subtle differences between the feature classes of interest. In fact, archaeological location models produced by this methodology *must* work — they must yield predictions that perform at a better-than-chance level — when the following assumptions can be met: 1) the site locations in the region of study are nonrandomly distributed with respect to the environmental or other variables under consideration; and 2) the site samples used to develop the pattern classification model are representative of the site population under study (Kvamme 1992:21).

The 56 archaeological site locations identified during the study area survey are entered into a digital map layer (Figure 4.1) and are represented by 420 25x25m grid cell locations within which site locations fall. Some sites fall within

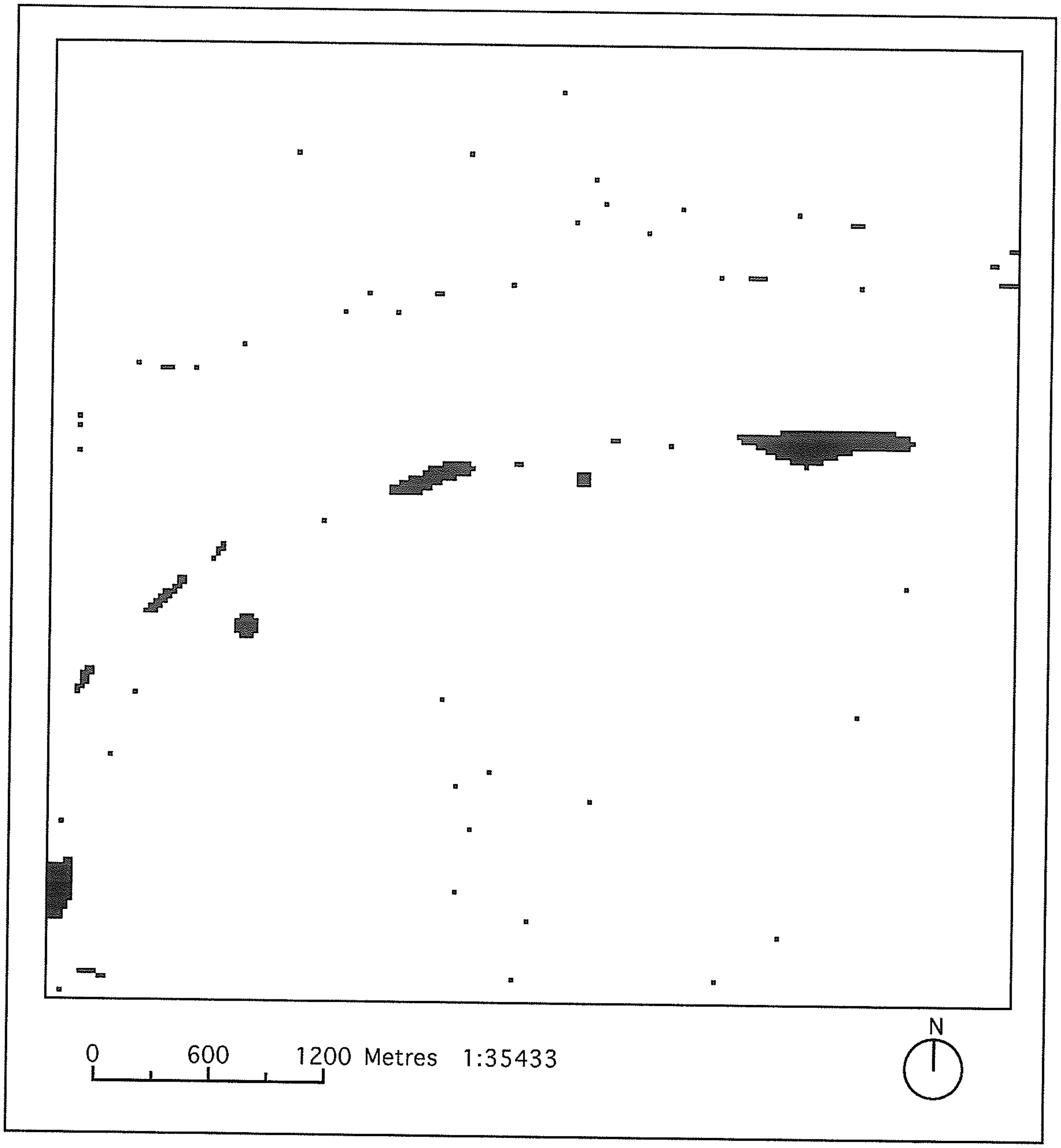

Figure 4.1. Spatial Distribution of Prehistoric Sites Identified During a Survey of the Study Area as Represented in a Digital Map Layer

many grid cells such as DgMp 50, which is represented by 167 cells, an area equivalent to 104,375 square metres. The smallest sites are represented by only 1 cell, equivalent to an area 625 m^2 in size. The combined area covered by all the prehistoric sites accounts for 420/35754 or 1.17% of the total study area.

To assess the 'strength' of the predictive model, we must determine if the weighted values identified at the cell locations of archaeological sites occur in patterns deviating from their distribution in background cells. For this application, the entire GIS database of 35754 cells, outside the Souris valley bottom, can serve as the background referent distribution (Figure 3.35). Since the valley bottom was not surveyed, digital data for that portion of the study are not included in further manipulations. The manner in which the weighted values in background cells are displaced in the study area as a whole can be compared to how weighted values are displaced at site location cells. For example, if background cells with weighted value 15 occurs over 22% of the entire study area, then cells with weighted value 15 should occur at 22% of the site locations. The effectiveness of using the background as a referent has been demonstrated in other studies (e.g., Kvamme 1990; Lafferty 1981) and the rationale for using this approach is discussed below:

> The background environment serves much like a control group approach used in experimental work. That is, interest lies in determining whether a particular class of interest (i.e., a site class) is unusual or deviates in some way from a background norm (the environment of a study region taken as a whole). Patterns that result, when null hypotheses of no difference between the distributions are rejected, generally are interpreted as reflecting locational preferences by prehistoric peoples for such features as proximity to water, good soils, level ground, and the like (Kvamme 1990:368).

As presented in the previous chapter, the predictive model offers a scale of potential. The low end of the scale is represented by weighted value 3 indicating the poorest potential for prehistoric activity while at the other end is weighted value 30 indicating the best potential for prehistoric activity based on the variables used. There are innumerable ways in which this scale of potential can be grouped. A cultural resource manager may decide that land with high potential for prehistoric activity includes those areas where 70% or more of the sites are predicted to exist. A research application of the predictive model may include a division of potential relative to certain theoretical propositions. A different application of the model may simply divide the range of potential into two groups: areas with potential and areas without potential based upon an analysis of sample data. This sample data would indicate at what point the greatest number of sites could be identified by examining the least amount of land. For this application, a priori assumptions about categories of potential will not be made. Rather, examination of the data will result in the development of high/medium/low categories.

4.2.1 The Probabilities of Prediction

The model is first evaluated by determining how well it predicts the presence of prehistoric activity areas. This is carried out by comparing the distribution of weighted values at all background cells against the distribution of weighted values at site cells. As the reference, the total database becomes the referent population (n=35754); that is, the distribution of cells with weighted values in the entire study area as shown in Figure 3.35. "In this perspective the sampling frame includes the totality of all cells in the database. Using this framework a statistical assessment can be made whether particular samples (i.e., cells with archaeological sites) are unusual or deviate from this population" (Kvamme 1990:371-372). An inventory of sites is known for the areas surveyed outside the valley bottom. The distribution of weighted values drawn from this sample of sites may be compared statistically against the background distribution of cells to determine if it differs significantly. The one-sample Kolmogorov test is ideal for comparing the difference between an archaeological sample and a referent distribution (Thomas 1986:336) and is applied in this manner in other studies (Hodder and Orton 1976: Lafferty 1981). The Kolmogorov test differs from the

Kolmogorov-Smirnov test in that the former compares the difference between a population and a sample drawn from it, while the latter compares the difference between two samples drawn from the same population.

Using MAP II, the site cells map layer (Figure 4.1) is combined with the result of primary stage predictive modelling (Figure 3.35). The result of this procedure is a map layer in which each grid cell corresponding to the location of a prehistoric site indicates its weighted value. Although many sites fall within only one grid cell in the digital database, other sites fall over many cells. In these cases, it is possible that more than one weighted value may be present at that site. For the purposes of this analysis, sites are categorized according the the highest weighted value present at the site location.

The principle behind the Kolmogorov test is straightforward (Blalock 1970:266-267):

> The test statistic used...is the maximum difference between the two cumulative distributions. If the maximum difference is larger than would be expected by chance under the null hypothesis, this means that the gap between the distributions has become so large that we decide to reject the hypothesis.

The methodology for performing the Kolmogorov test is drawn from Blalock (1979:266-269) and Kvamme (1990:373) where a sampled population is compared to the background population from which it was drawn. The background population (Table 4.1, Col. A) is, in effect, the entire study area and represents the number of cells in each weighted value category. The sample (Table 4.1, Col. B) is drawn from archaeological site locations in the study area and represents the number of sites in each weighted value category. The null hypothesis states that there is no difference between the cumulative distributions of the sample

	A	B	C	D	E	F	G	H	
WV	# Bgnd Cells	# Sites (n=56)	# Site Cells (n=200)	% Bgnd (A/35754)	% Sites (B/56)	% Site Cells (C/200)	Cum. Fr. Bgnd (of D)	Cum. Fr. Sites (of E)	Diff. (G - H)
3	24	0	0	0.07	0.00	0.00	0.0007	0.0000	0.0007
6	67	0	0	0.19	0.00	0.00	0.0025	0.0000	0.0025
9	5079	3	3	14.21	5.36	1.50	0.1446	0.0536	0.0910
12	4300	2	2	12.03	3.57	1.00	0.2649	0.0893	0.1756
15	7242	3	5	20.26	5.36	2.50	0.4674	0.1429	0.3246
18	**6979**	**6**	**7**	**19.52**	**10.71**	**3.50**	**0.6626**	**0.2500**	**0.4126**
21	7498	17	44	20.97	30.36	22.00	0.8723	0.5536	0.3188
24	3182	13	20	8.90	23.21	10.00	0.9613	0.7857	0.1756
27	409	3	47	1.14	5.36	23.50	0.9728	0.8393	0.1335
30	974	9	72	2.72	16.07	36.00	1.0000	1.0000	0.0000

*in this instance, n=200 and not 420 because of the choice to include only those site cells at which the highest weighted value was represented. This results in a site being represented by only one weighted value instead of a possible two or more

Table 4.1. Comparison of Weighted Values at Site Locations Against the Background Sample

and the background, thereby indicating that the occurrence of cells from weighted value categories at site locations is random. We may reject the null hypothesis if the maximum difference between the distributions exceeds a critical value. Accordingly, to reach significance at the .001 level, a value of D at least as large as:

$$\frac{1.95}{\sqrt{n}} \qquad (4.1),$$

is required. A minimum value of $D = 0.2605$ at the .001 level of significance results (Eq. 4.2).

$$\begin{aligned} D &= \frac{1.95}{\sqrt{n}} \\ &= \frac{1.95}{\sqrt{56}} \\ &= \frac{1.95}{7.4833} \\ &= 0.2605 \end{aligned} \qquad (4.2)$$

Cumulative relative frequencies for both the background and the sample were computed (Table 4.1: Cols. G, H). The largest difference between the two is 0.4126 (in bold in Table 4.1) which exceeds the minimum value for D calculated to be 0.2605 (Eq. 4.2). We can therefore reject the null hypothesis of no difference between the background and sample distributions and state with confidence that there is some difference between them.

Examination of the data provides illumination into patterns of association between site locations and the distribution of cells across weighted values (Table 4.1; Figures 4.2, 4.3). From Table 4.1 (Cols. D, E, F), it is evident that by examining only those areas where cells with weighted values 27 and 30 occur, 59.50% of the site cells (12/56 or 21.4% of sites) would have been identified. Those weighted value cells are represented at only 3.86% of the study area. If we expand the area of examination to include cells with a weighted value of 24, then 69.5% of the site cells (25/56 or 44.6% of sites) would be identified through a survey of only 12.76% of the study area. Correspondingly, very few sites are found on cells with lower weighted values. In fact, only 8.5% of the site cells (14/56 or 25% of sites) are found on cells with weighted values of 18 or lower representing 66.28% of the study area. This relationship is demonstrated graphically in Figure 4.3. As the percentage of background cells increases, the percentage of site cells remains very low until weighted value 18. By this point, almost 67% of background cells have been counted compared to only 25% of all sites.

With this information in hand, it is possible to determine categories of potential. From Table 4.1, three separate categories of potential become apparent. The zone of low potential is characterized by weighted values 3 through 18. Together they comprise 66.28% of the study area cells but encompass only 8.5% of the site cells or 25% of the sites. The zone of medium potential includes only weighted value 21. These cells comprise 20.97% of the study area and include 22% of the site cells or 30.36% of the sites. The zone of high potential includes cells with weighted values 24, 27, and 30. These cells represent 12.76% of the study area but include 69.50% of the site cells or 44.64% of the sites. These data are summarized in Table 4.2 (see also Figures 4.4, 4.5).

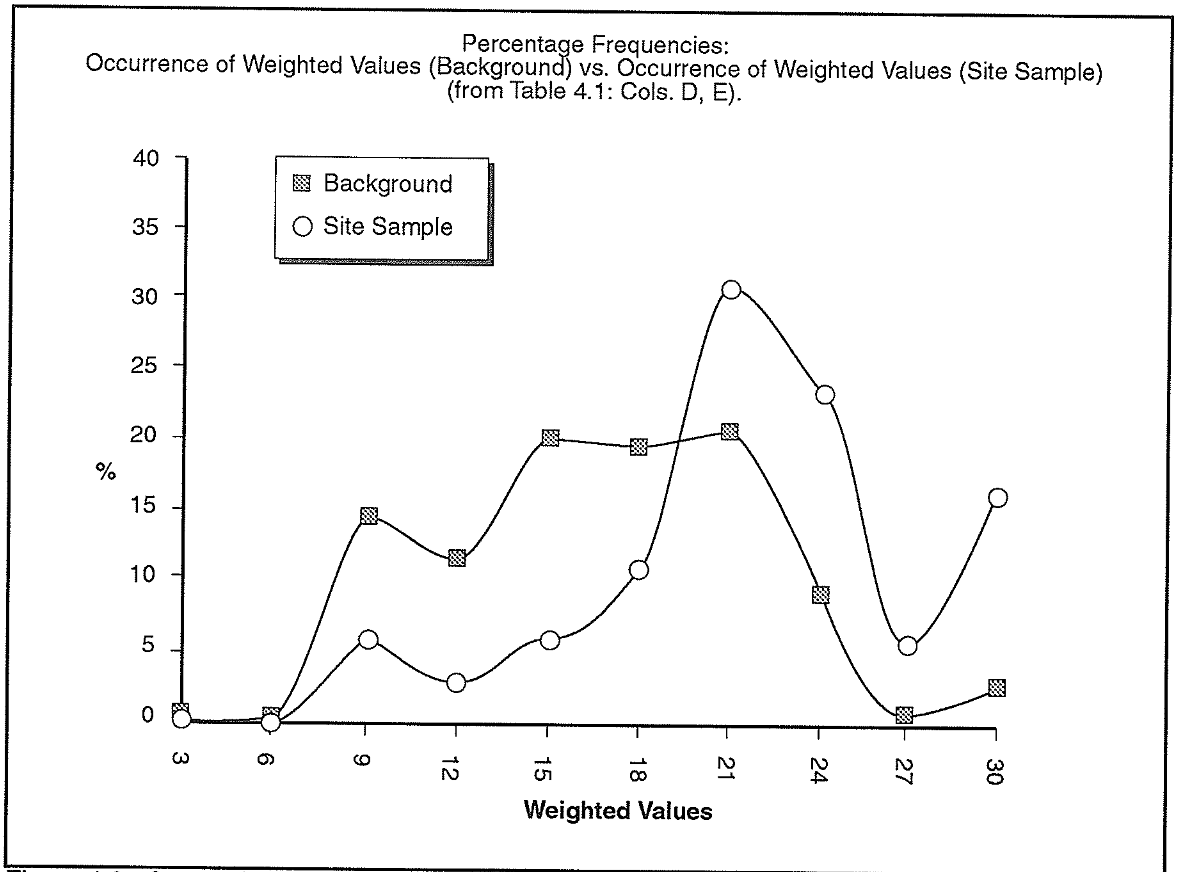

Figure 4.2. Comparison of Percentage Occurrence of Weighted Values at Background vs. Sites

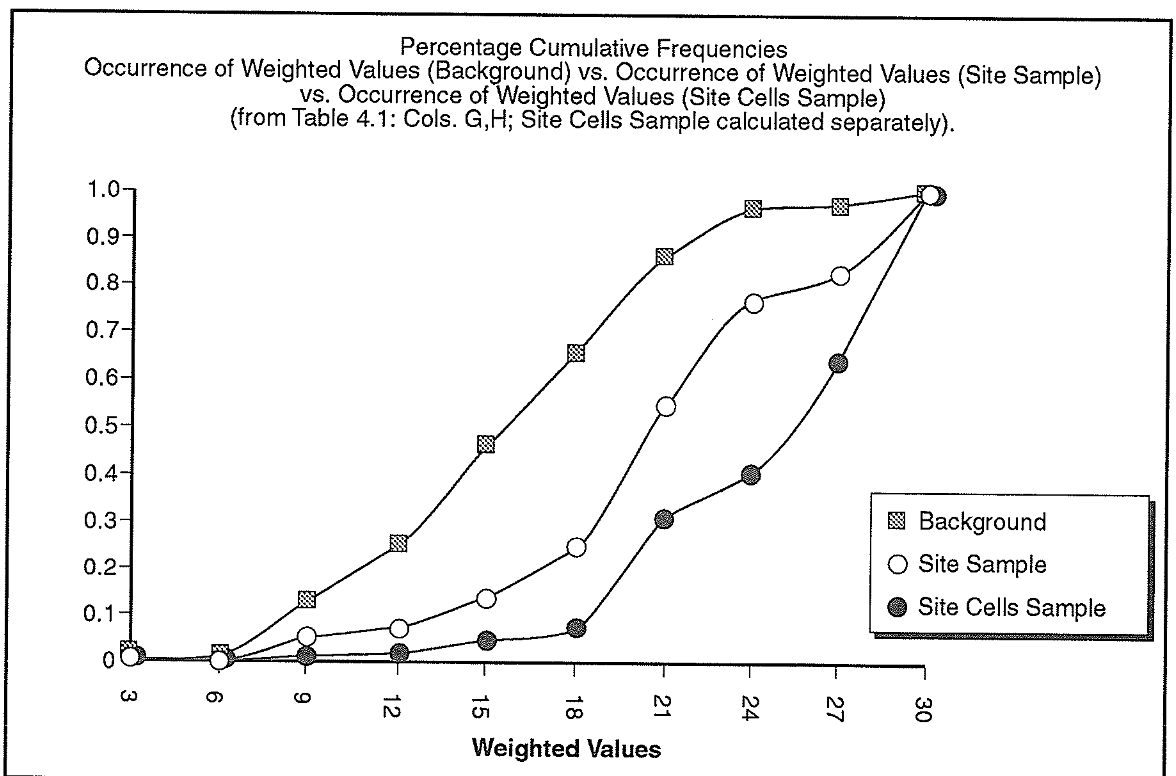

Figure 4.3. Comparison of Occurrence of Weighted Values at Background vs. Sites vs. Site Cells Based on Percentage Cumulative Frequencies

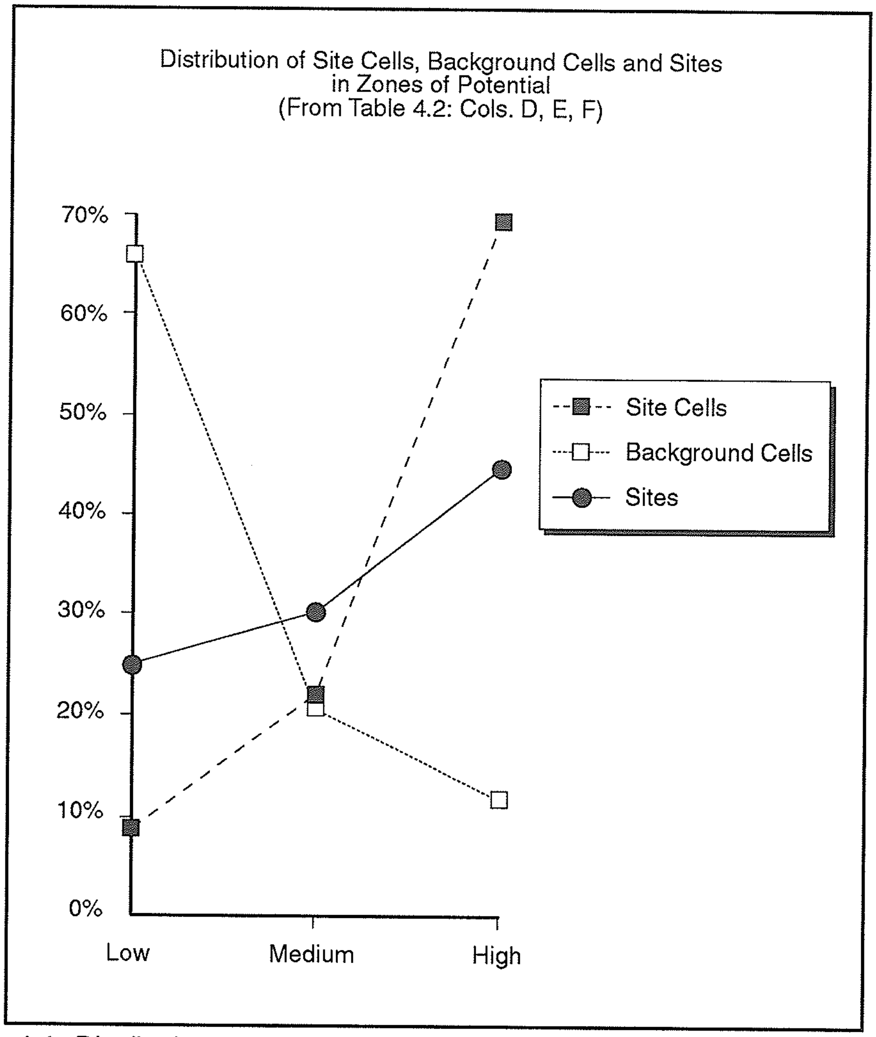

Figure 4.4. Distribution of Site Cells, Background Cells and Sites in Zones of Potential

		A	B	C	D	E	F
Zone of Potential	Weighted Values	# Bgnd Cells	# Sites (n=56)	# Site Cells (n=200)	% Bgnd Total	% Site Cells Total	% Sites Total
Low	3	24	0	0	66.28	8.50	25.00
	6	67	0	0			
	9	5079	3	3			
	12	4300	2	2			
	15	7242	3	5			
	18	6979	6	7			
Med	21	7498	17	44	20.97	22.00	30.36
High	24	3182	13	20	12.76	69.50	44.64
	27	409	3	47			
	30	974	9	72			

Table 4.2. Classification of Zones of Potential

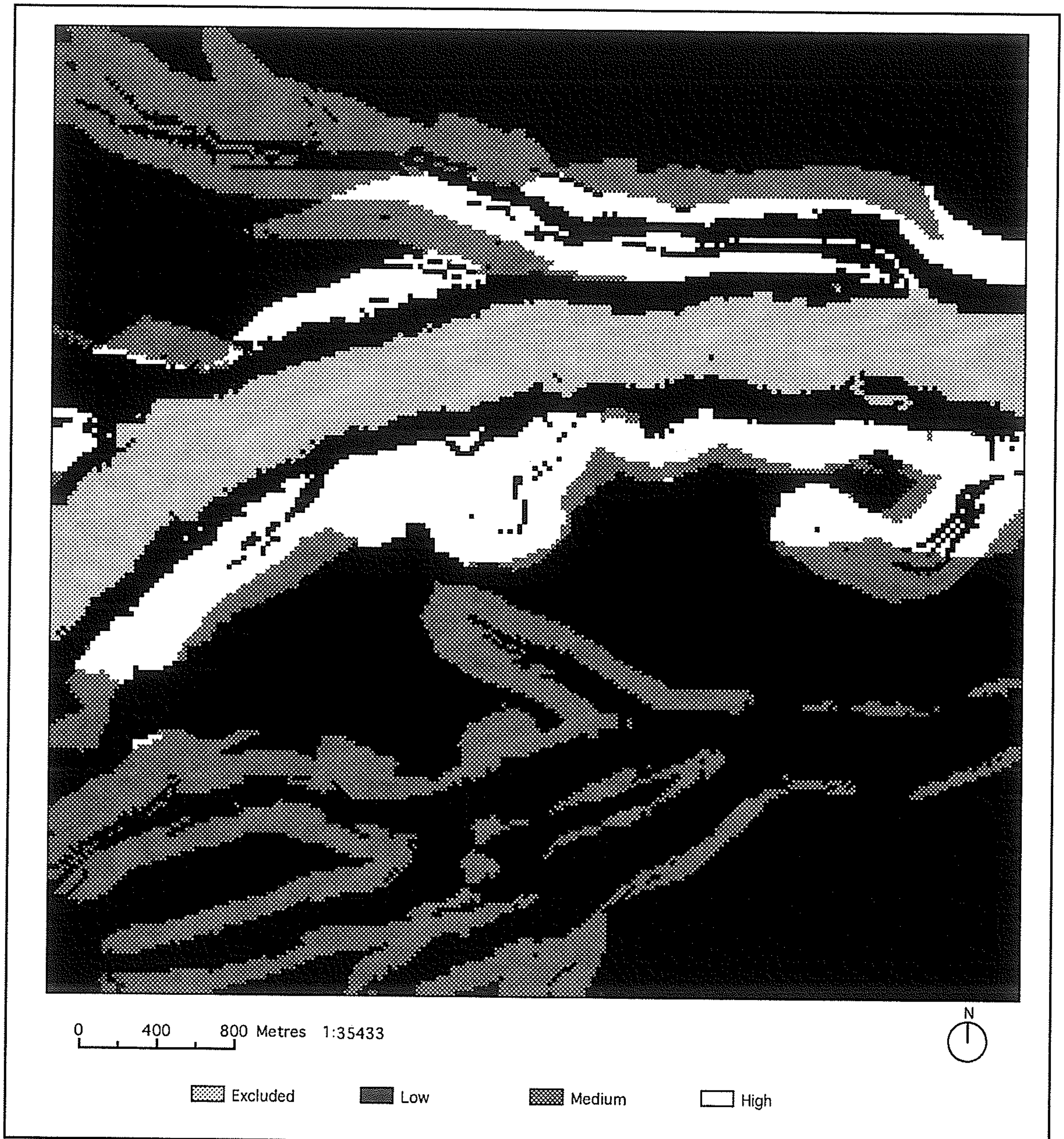

Figure 4.5 Zones of Potential Represented in the Study Area

A second test was applied to determine the effectiveness of the model. The Spearman's rank order correlation coefficient was used to demonstrate the degree of correlation between the rank of cell values and the percentage of the total cells for each value. The principle behind Spearman's test is taken from Blalock (1979:434):

> We compare the rankings on the two sets of scores by taking the differences of ranks, squaring these differences and then adding, and finally manipulating the measures so that its value will be +1.0 whenever the rankings are in perfect agreement, -1.0 if they are in perfect disagreement, and zero if there is no relationship whatsoever.

Two tests were conducted: one for background cells and one for site cells. These tests would demonstrate that the rank of the independent variable (cell value) can assist in predicting the rank of the dependent variable (% site cells) whereas this would only be possible in an inverse manner when considering the background (total) cell percentage frequencies. The coefficients calculated would indicate the strengths of the correlations and the probabilities would indicate the likelihood of those correlations occuring by chance alone.

The first test compares the rankings between cell weighted values and background cells. The null hypothesis for this test states that there is no relationship between cell weighted value and the percentage frequency of background cells. The data for the test is drawn from Table 4.3. The weighted value zones (Table 4.3: Col A) are ranked (Col. B) from 1 to 10. Correspondingly, the percentage of background cells occurring in the weighted values zones are also ranked (Col. D). The value for r is calculated to be 0.212 (Eq. 4.3).

A Weighted Values	B Rank 1	C # Bgnd Cells	D Rank 2	E Diff (B-D)	F Diff2 $(B-D)^2$
3	1	0.07	1	0	0
6	2	0.19	2	0	0
9	3	14.21	7	-4	16
12	4	12.03	6	-2	4
15	5	20.26	9	-4	16
18	6	19.52	8	-2	4
21	7	20.97	10	-3	9
24	8	8.90	5	3	9
27	9	1.14	3	6	36
30	10	2.72	4	6	36
				sum	130

Table 4.3. Table of Ranks of Weighted Values and Background Cells

$$\begin{aligned} r_s &= 1 - \frac{6\sum_{i=1}^{N} D_i^2}{N\left(N^2-1\right)} \\ &= 1 - \frac{6(130)}{10(99)} \\ &= 0.212 \end{aligned} \qquad (4.3)$$

The probability of each coefficient is calculated as follows (Eq. 4.4):

$$\begin{aligned} p &= \sqrt{\frac{n-2}{1-r}} \\ &= \sqrt{\frac{8}{.788}} \\ &= 3.19 \end{aligned} \qquad (4.4)$$

The value obtained for p is then compared with a Student's t distribution with n-2 degrees of freedom. The critical value for t at df=8 is 3.355 for a two-tailed test at the 0.01 level of significance (Blalock 1979: Table D). Thus we may not reject the null hypothesis of no relationship between the rank of weighted value and the rank of the percentage frequency of background cells.

The second test, similar to the first, compares the rankings between percentage site cells and background cells. The null hypothesis for this test states that there is no relationship between cell weighted value and the percentage frequency of site cells. The data for the test is drawn from Table 4.4. The weighted value zones (Table 4.4: Col A) are ranked (Col. B) from 1 to 10. Correspondingly, the percentage of site cells occurring in the weighted values zones are also ranked (Col. D). The value for r is calculated to be 0.973 (Eq. 4.5).

$$\begin{aligned} r_s &= 1 - \frac{6\sum_{i=1}^{N} D_i^2}{N(N^2-1)} \\ &= 1 - \frac{6(4.50)}{10(99)} \\ &= 0.973 \end{aligned} \tag{4.5}$$

The probability of each coefficient is calculated as follows (Eq. 4.6):

$$\begin{aligned} p &= \sqrt{\frac{n-2}{1-r}} \\ &= \sqrt{\frac{8}{0.027}} \\ &= 17.21 \end{aligned} \tag{4.6}$$

The value obtained for p is then compared with a Student's t distribution with n-2 degrees of freedom. The critical value for t at df=8 is 3.355 for a two-tailed test at the 0.01 level of significance. Since the value of p far exceeds the critical

A Weighted Values	B Rank 1	C # Site Cells	D Rank 2	E Diff (B-D)	F Diff2 $(B-D)^2$
3	1	0	1.5	-0.5	0.25
6	2	0	1.5	-0.5	0.25
9	3	1.5	4	-1	1
12	4	1.0	3	1	1
15	5	2.5	5	0	0
18	6	3.5	6	0	0
21	7	22.0	8	-1	1
24	8	10.0	7	1	1
27	9	23.5	9	0	0
30	10	36.0	10	0	0
				sum	4.50

Table 4.3. Table of Ranks of Weighted Values and Site Cells

value of t the null hypothesis is rejected and the hypothesis that there is some relationship between the two ranks is accepted. It can therefore be stated that knowing the rank of the weighted value helps to predict the rank of the percentage frequency of site cells and it does so quite accurately given the coefficient of 0.973. However, knowing the rank of weighted values does not help us predict the rank of percentage frequency of background cells.

The data may also be analysed with respect to the manner by which site types are distributed in the three zones of potential. Table 4.5 outlines the percentage occurrence of the four site types in zones of high, medium and low potential (see also Figure 4.6). While the vision quest and bison drive sites are included in the table, their respective small sample sizes do not merit their inclusion in the following discussion.

The one-sample chi-square goodness-of-fit test has been used extensively in archaeological research to examine archaeological distributions with respect to environmental categories (Kvamme 1990; Hodder and Orton 1976, Plog and Hill 1971). Kvamme (1990:376) states that "the chi-square goodness-of-fit test is appropriate for categorical data and should be used for evaluating archaeological distributions against such environmental variables as soil type, vegetation type, and geologic and landform classes." This test may also be used to evaluate the distribution of sites in categories of potential. The null hypothesis of no difference between the background and sample distributions applies to all tests below. The standard chi-square statistic presented by Kvamme (1990:376) is used here (Eq.4.7):

$$x^2 = \sum_{i=1}^{c} \frac{(O_i - E)^2}{E} = (1/E)\sum_{i=1}^{c} O_i^2 - n, \qquad (4.7)$$

	Weighted Values	Stone Circles	Cairns	Vision Quest	Bison Drive	Backg'nd Cells
Low	3-18	18.8%	33.33%	50.0%	0%	66.28%
Med	21	24.24%	38.89%	25.0%	100%	22.00%
High	24-30	57.58	27.78%	25.0%	0%	12.76%

Table 4.5. Percentage Occurrence of Site Types in Zones of Potential

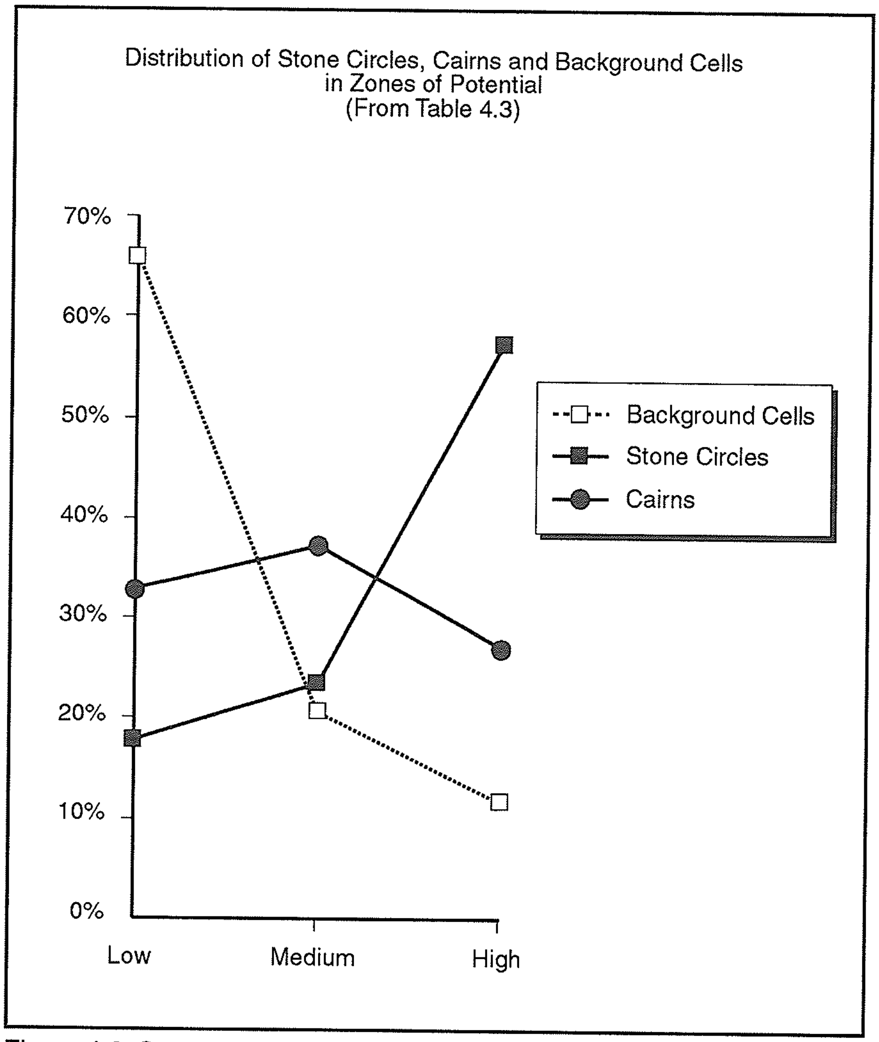

Figure 4.6 Occurrence of Cairns, Stone Circles, and Background Cells in Zones of Potential

where O_i is the observed empirical frequency in each cell, E is the constant expected value in each cell, and c is the number of class categories. Kvamme describes how the statistic is calculated.

> ...for each class the proportion of the entire background environment (i.e., data base) that falls in that class is computed and this proportion then is multiplied by the size of the site sample under consideration...to generate an expected frequency for each cell. The observed and expected frequencies may then be compared... (Kvamme 1990:376).

Table 4.6 presents the data used in the test for both stone circle and cairn sites.

		Low	Med	High
Stone Circles (n=33)	**Pr**	0.6628	0.22	0.1276
	E	21.8724	7.26	4.2108
	O	6	8	19
Cairns (n=18)	**Pr**	0.6628	0.22	0.1276
	E	11.9304	3.96	2.2968
	O	6	7	5

Table 4.6. Values Used to Evaluate Distribution of Site Types in Zones of Potential

When the values for stone circles are inserted into the chi-square equation (Eq. 4.7.), then:

$$\begin{aligned} x^2 &= \left(\frac{1}{21.8742}\right)(6)^2 + \left(\frac{1}{7.26}\right)(8)^2 + \left(\frac{1}{4.2108}\right)(19)^2 - 33 \\ &= (0.0457 \times 36) + (0.1377 \times 64) + (0.2375 \times 361) - 33 \\ &= 1.6452 + 8.8128 + 85.7375 - 33 \\ &= 96.1955 - 33 \\ &= 63.1955 \end{aligned} \qquad \text{(Eq. 4.8).}$$

Comparing this result against a chi-square distribution with c-1=2 degrees of freedom at 0.001 level of significance results in a critical value of x^2=13.815 (Blalock 1979: Table I). The null hypothesis is therefore rejected and as a result we may assume that there is a significant relationship between stone circles and their distribution within zones of potential.

When the values for cairns are inserted into the chi-square equation (Eq. 4.7.), then:

$$\begin{aligned} x^2 &= \left(\frac{1}{11.9304}\right)(6)^2 + \left(\frac{1}{3.96}\right)(7)^2 + \left(\frac{1}{2.2968}\right)(5)^2 - 18 \\ &= (0.0838 \times 36) + (0.2525 \times 49) + (0.4354 \times 25) - 18 \\ &= 3.0168 + 12.3725 + 10.885 - 18 \\ &= 26.2743 - 18 \\ &= 8.2743 \end{aligned} \qquad \text{(Eq. 4.9).}$$

Comparing this result against a chi-square distribution with c-1=2 degrees of freedom at 0.02 level of significance results in a critical value of x^2=7.824 (Blalock 1979: Table I). The null hypothesis is therefore rejected and as a result we may assume that there is a significant relationship between cairns and their distribution within zones of potential.

Therefore to summarize the above information, the data indicate the predictive model presented in Chapter 3 reliably predicts the location of archaeological sites. The weighting scheme applied to the variables used to predict archaeological sites enables one to identify almost 70% of site cells while examining less than 14% of the study area. Indeed, the data organize neatly into three categories of potential: high (weighted values 24 - 30); medium (weighted value 21) and; low (weighted values 3-18). There is a clear inverse relationship between the distribution of weighted value cells and archaeological sites/site cells. While there is a high percentage of the study area falling within the zone of low potential, relatively few sites/site cells are distributed as such. Conversely, while a small percentage of the study area is represented as high potential, a relatively high percentage of sites fall in that zone. Additionally, the model predicts the occurrence of the two major sites types at levels statistically determined to be significant. While the low potential category accounts for 66.28% of the background, 44.4% of cairn site cells or 36.36% of cairn sites are found there. The zone of medium potential accounts for 22% of the background but 36.36% of cairn site cells or 38.88% of cairn sites may be classed within medium potential. The high potential zone includes 12.76% of all background cells but 27.78% of cairn site cells (27.27% of cairn sites) are identified as high potential. Stone circle sites were also statistically determined to be associated with zones of potential. In low potential areas, 5.47% of stone circle site cells (6/33 or 18.8% of sites) occur; in areas of medium potential, 8.57% of stone circle site cells (8/33 or 24.24% of stone circle sites) are found and; in high potential zones, 85.94% of stone circle site cells (19/33 or 57.58% of stone circle sites) occur. Therefore, the predictive model reasonably predicts the locations of sites in general as well as stone circle and cairn sites specifically. With respect to these results, the model is successful.

4.3. EXAMINING RELATIONSHIPS AMONG VARIABLES AND SITES

The next step is to determine if specific variables are associated with specific site types. Kvamme suggests a number of one-sample tests for "examining whether characteristics of an archaeological sample depart significantly from the population. Thus, one-sample tests examine locational variation in an archaeological sample while the background environment is taken as a given" (Kvamme 1990:369). For this application, it is desirable to establish if variables are associated with the location of specific site types.

The chi-square test (Eq. 4.7) was used to evaluate the following subcategories: **Permanent Water, Seasonal Water, Slope and Prairie Edge**. The null hypothesis of no difference between the background and sample distributions applies to all tests

# Cells	WV*	Borden Site	Slope		Prairie Edge		Permanent Water			Seasonal Water		
			0-5°	>5°	<250m	>250m	0-400m	4-800m	800m+	0-200m	2-400m	4-800m
3	15	07		x	x				x	x		
1	15	08	x			x			x	x		
1	21	09	x		x				x	x		
1	9	10		x		x			x	x		
1	21	11	x		x				x	x		
1	21	12	x		x				x	x		
1	21	15	x		x				x	x		
1	21	17	x		x				x	x		
2	21	28	x		x			x			x	
1	24	29	x		x		x					x
2	24	30	x		x		x					x
1	24	33	x		x		x					x
1	30	42	x		x		x			x		
1	18	45		x		x	x			x		
1	21	49	x		x				x	x		
1	24	53	x		x			x		x		
1	12	56	x			x			x		x	
1	15	60	x			x			x			x

Table 4.7. Occurrence of Variables at Cairn Locations (* refers to weighted value)

presented below.

4.3.1 Cairn Sites and Permanent Water

There are 18 sites where only cairns are present. They occur at 22 cell locations within the study area. The combinations of variables that occur at each site cell location is presented in Table 4.7. The chi-square goodness-of-fit test is applied to each of the subcategories of data to evaluate their association with cairn sites. Cairn sites were first compared with the three variables associated with permanent water (Table 4.8).

	Permanent Water		
	0-400m	4-800m	800m+
Expected	2.75	3.55	11.70
Observed	5	2	11

Table 4.8 Values Used to Calculate the Chi-Square Statistic for Cairn Sites and Permanent Water

Inserting the data from Table 4.8 into Equation 4.7, the following results are obtained:

$$x^2 = \left(\frac{1}{2.75}\right)(5)^2 + \left(\frac{1}{3.55}\right)(2)^2 + \left(\frac{1}{11.70}\right)(11)^2 - 18$$
$$= (.3636 \times 25) + (0.2817 \times 4) + (0.0855 \times 121) - 18$$
$$= 9.09 + 1.1268 + 10.3455 - 18 \qquad (4.10)$$
$$= 20.5623 - 18$$
$$= 2.5623$$

Comparing this result against a chi-square distribution with c-1=2 degrees of freedom at the 0.05 level of significance results in a critical value of x^2=5.991 (Blalock 1979: Table I). The null hypothesis cannot be rejected and as a result we may assume that there is no significant relationship between the location of cairns and permanent water.

4.3.2 Cairn Sites and Seasonal Water

Cairn site locations were analysed with respect to their association with seasonal water resources. The observed and expected frequencies are presented in Table 4.9.

	Seasonal Water		
	0-200m	2-400m	4-800m
Expected	9.13	5.37	3.54
Observed	12	2	5

Table 4.9 Values Used to Calculate the Chi-Square Statistic for Cairn Sites and Seasonal Water

Inserting these data into Equation 4.7. results in the following:

$$x^2 = \left(\frac{1}{9.13}\right)(12)^2 + \left(\frac{1}{5.37}\right)(2)^2 + \left(\frac{1}{3.54}\right)(5)^2 - 18$$
$$= (0.1095 \times 144) + (0.1862 \times 4) + (0.2825 \times 25) - 18$$
$$= 15.768 + 0.7448 + 7.0625 - 18 \qquad (4.11)$$
$$= 23.5753 - 18$$
$$= 5.5753$$

Comparing this result against a chi-square distribution with c-1=2 degrees of freedom at 0.05 level of significance results in a critical value of x^2=5.991 (Blalock

1979: Table I). The null hypothesis cannot be rejected and as a result we may assume that there is no significant relationship between the location of cairns and seasonal water.

4.3.3 Cairn Sites and Slope

Cairn site locations were analysed with respect to their associations with the two slope variables developed for the study area. The observed and expected frequencies related to this analysis are presented in Table 4.10.

	Slope	
	0-5°	>5°
Expected	14.82	3.18
Observed	15	3

Table 4.10. Values Used to Calculate the Chi-Square Statistic for Cairn Sites and Slope

Inserting the data from Table 4.10 into Equation 4.7. results in the following:

$$\begin{aligned} x^2 &= \left(\frac{1}{14.82}\right)(15)^2 + \left(\frac{1}{3.18}\right)(3)^2 - 18 \\ &= (0.0675 \times 225) + (0.3145 \times 9) - 18 \\ &= 15.1875 + 2.8305 - 18 \\ &= 18.018 - 18 \\ &= 0.018 \end{aligned} \tag{4.12}$$

Comparing this result against a chi-square distribution with c-1=1 degrees of freedom at the 0.05 level of significance results in a critical value of x^2=3.841 (Blalock 1979: Table I). The null hypothesis cannot be rejected and as a result we may assume that there is no significant relationship between the location of cairns and slope.

4.3.4 Cairn Sites and Prairie Edge

Cairn site locations were analysed with respect to the Prairie Edge subcategories developed for the study area. The observed and expected frequencies related to this analysis are presented in Table 4.11.

	Prairie Edge	
	<250m	>250m
Expected	9.33	8.67
Observed	13	5

Table 4.11 Values Used to Calculate the Chi-Square Statistic for Cairn Sites and Prairie Edge

Inserting the data from Table 4.11 into Equation 4.7 presents the following results:

$$\begin{aligned} x^2 &= \left(\frac{1}{9.33}\right)(13)^2 + \left(\frac{1}{8.67}\right)(5)^2 - 18 \\ &= (0.1072 \times 169) + (0.1153 \times 25) - 18 \\ &= 18.1168 + 2.8825 - 18 \\ &= 20.9993 - 18 \\ &= 2.9993 \end{aligned} \tag{4.13}$$

Comparing this result against a chi-square distribution with c-1=1 degrees of freedom at the 0.05 level of significance results in a critical value of x^2=3.841 (Blalock 1979: Table I). Therefore, the null hypothesis cannot be rejected and as a result we may assume that there is no signficance to cairns being located within 250m of a major break in slope.

4.3.5 Stone Circle Sites and Permanent Water

There are 33 sites where stone circles only are present occurring at 312 cells within the study area. The variables that occur at each site cell location is presented in Table 4.12 (on the following page). The chi-square goodness-of-fit test was applied to each of the subcategories to evaluate their association with stone circle sites.

# Cells	WV*	Borden Site	Slope		Prairie Edge		Permanent Water			Seasonal Water		
			0-5°	>5°	<250m	>250m	0-400m	4-800m	800m+	0-200m	2-400m	4-800m
17	15	13	x			x		x			x	
4	21	13	x		x			x			x	
1	9	14		x		x			x	x		
1	12	16	x			x			x		x	
21	30	18	x		x		x			x		
4	21	19	x		x			x			x	
8	27	19	x		x		x				x	
1	18	20	x			x		x		x		
1	18	21	x			x		x		x		
1	30	22	x		x		x			x		
1	21	26	x		x			x			x	x
1	24	27	x		x		x					x
4	18	31		x		x	x			x		
18	24	31		x	x		x			x		
39	30	31	x		x		x			x		
1	21	32	x		x			x			x	
1	24	34	x		x		x					x
4	24	35	x			x	x			x		
1	30	35	x				x			x		
1	30	36	x				x			x		
1	21	37	x					x			x	
2	30	38	x		x		x			x		
7	21	39	x		x			x			x	
2	24	39	x		x			x		x		
2	27	40	x		x		x				x	
1	24	41	x		x		x					x
4	24	43		x	x		x			x		
1	24	44	x		x			x		x		
3	24	46	x		x			x		x		
4	30	47	x		x		x			x		
2	30	48	x		x		x			x		
37	27	50	x		x		x				x	
19	18	50		x	x		x					x
111	24	50	x		x		x					x
2	18	51	x			x		x		x		
1	24	52	x		x			x		x		
1	21	54	x		x			x			x	
1	21	55	x		x			x			x	
1	21	58	x		x				x	x		
1	21	59	x		x				x	x		
1	9	61	x			x			x			x

Table 4.12. Occurrence of Variables at Stone Circle Locations (* refers to weighted value)

Stone circle site locations were analysed with respect to permanent water resources. The observed and expected frequencies are presented in Table 4.13.

	Permanent Water		
	0-400m	4-800m	800m+
Expected	5.05	6.51	21.44
Observed	15	13	5

Table 4.13. Values Used to Calculate the Chi-Square Statistic for Stone Circle Sites and Permanent Water

Inserting these data into Equation 4.7. results in the following:

$$\begin{aligned} x^2 &= \left(\frac{1}{5.05}\right)(15)^2 + \left(\frac{1}{6.51}\right)(13)^2 + \left(\frac{1}{21.44}\right)(5)^2 - 33 \\ &= (0.1980 \times 225) + (0.1536 \times 169) + (0.0466 \times 25) - 33 \\ &= 44.55 + 25.9584 + 1.165 - 33 \\ &= 71.6734 - 33 \\ &= 38.6734 \end{aligned} \tag{4.14}$$

Comparing this result against a chi-square distribution with c-1=2 degrees of freedom at 0.001 level of significance results in a critical value of x^2=13.815 (Blalock 1979: Table I). The null hypothesis is therefore rejected and as a result we may assume that there is a significant relationship between the location of stone circles and proximity to permanent water resources.

4.3.6 Stone Circle Sites and Seasonal Water

Stone circle site locations were analysed with respect to seasonal water resources. The observed and expected frequencies are presented in Table 4.14.

	Seasonal Water		
	0-200m	2-400m	4-800m
Expected	16.74	9.84	6.49
Observed	19	10	4

Table 4.14. Values Used to Calculate the Chi-Square Statistic for Stone Circle Sites and Seasonal Water

Inserting these data into Equation 4.7. generates the following results:

$$\begin{aligned} x^2 &= \left(\frac{1}{16.74}\right)(19)^2 + \left(\frac{1}{9.84}\right)(10)^2 + \left(\frac{1}{6.49}\right)(4)^2 - 33 \\ &= (0.0597 \times 361) + (0.1016 \times 100) + (0.1541 \times 16) - 33 \\ &= 21.5517 + 10.16 + 2.4656 - 33 \\ &= 34.1773 - 33 \\ &= 1.1773 \end{aligned} \tag{4.15}$$

Comparing this result against a chi-square distribution with c-1=2 degrees of freedom at 0.05 level of significance results in a critical value of x^2=3.841 (Blalock 1979: Table I). The null hypothesis is therefore rejected and as a result we may assume that there is no significant relationship between the location of stone circles and proximity to seasonal water resources.

4.3.7 Stone Circle Sites and Slope

Stone circle site locations were analysed with respect to their occurrence on two slope variables: 0-5° slope and >5° slope. The observed and expected frequencies are presented in Table 4.15.

	Slope	
	0-5°	>5°
Expected	27.16	5.82
Observed	31	2

Table 4.15. Values Used to Calculate the Chi-Square Statistic for Stone Circle Sites and Slope

Inserting these data into Equation 4.7. generates the following results:

$$\begin{aligned} x^2 &= \left(\frac{1}{27.16}\right)(31)^2 + \left(\frac{1}{5.84}\right)(2)^2 - 33 \\ &= (0.0368 \times 961) + (0.1712 \times 4) - 33 \\ &= 35.3648 + 0.6848 - 33 \\ &= 36.0496 - 33 \\ &= 3.0496 \end{aligned} \tag{4.16}$$

Comparing this result against a chi-square distribution with c-1=1 degrees of freedom at 0.05 level of significance results in a critical value of x^2=3.841 (Blalock 1979: Table I). The null hypothesis is therefore accepted and as a result we may assume that there is no significant relationship between the location of stone circles and slope.

4.3.8 Stone Circle Sites and Prairie Edge

Stone circle site locations were analysed with respect to their occurrence on two prairie edge variables: <250m and >250m. The observed and expected frequencies are presented in Table 4.16.

	Prairie Edge	
	<250m	>250m
Expected	17.11	15.89
Observed	24	6

Table 4.16. Values Used to Calculate the Chi-Square Statistic for Stone Circle Sites and Prairie Edge

Inserting these data into Equation 4.7. generates the following results:

$$\begin{aligned} x^2 &= \left(\frac{1}{17.11}\right)(24)^2 + \left(\frac{1}{15.89}\right)(6)^2 - 33 \\ &= (0.0584 \times 576) + (0.0629 \times 36) - 33 \\ &= 33.6384 + 2.2644 - 33 \\ &= 35.9028 - 33 \\ &= 2.9028 \end{aligned} \tag{4.17}$$

Comparing this result against a chi-square distribution with c-1=1 degrees of freedom at 0.05 level of significance results in a critical value of x^2=3.841 (Blalock 1979: Table I). The null hypothesis is therefore rejected and as a result we may assume that there is no significant relationship between the location of stone circles and a distance of less than 250m from a major break in slope.

4.3.9 Discussion

Stone circles are ubiquitous across the northern prairies. The 289 stone circles identified during the 1990 archaeological survey are located throughout the study area but predominate along the north and south rim of the Souris valley (Figure 3.12). The chi-square goodness-of-fit tests conducted above demonstrate a significant association between stone circles and proximity to permanent water. This is shown by the variables **0-400m from permanent water** occurring +36.22%; **400-800m from permanent water** occurring +19.67 and the variable **800+m from permanent water** occurring -49.83% as compared to the background referent (Figure 4.7). This, in combination with no significant association of stone circle sites with seasonal water sources, suggests that locations within 400m of a permanent water source and being **<250m from a Prairie Edge** (occurring +22% compared to the background referent) were important factors when selecting areas to set up encampments.

Cairns are not an uncommon site on the northern prairies. In fact, with 18 cairn sites identified in the study area, they may be considered a major site type.

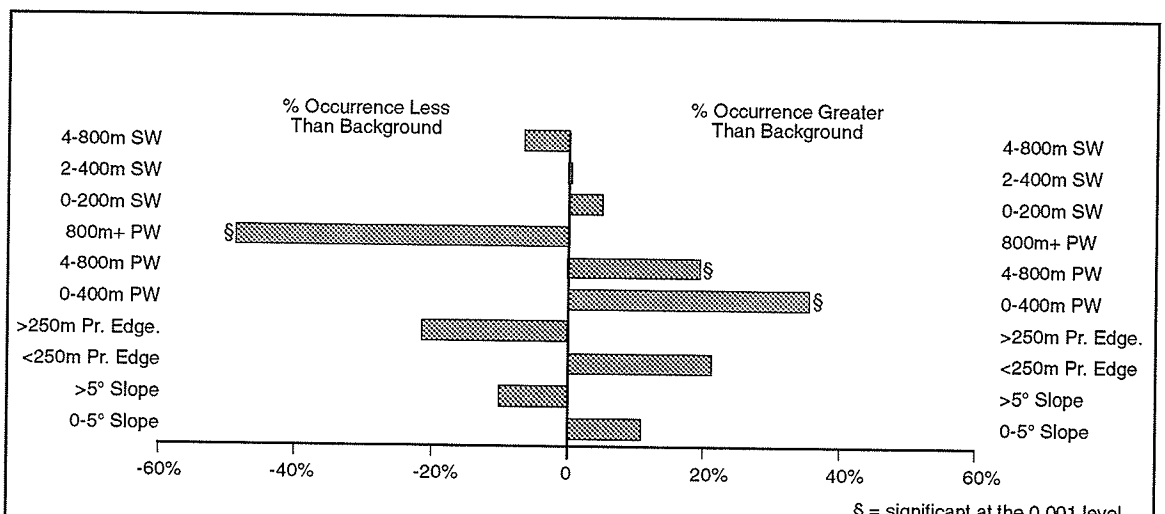

Figure 4.7. The Percentage Occurrence of Variables at Stone Circle Sites as Compared to the Occurrence of the Same Variables in the Background Referent

A visual examination of their distribution across the study area (Figure 3.15) indicates that north of the Souris River, cairns are located primarily along the rim of the valley while south of the river, they are predominant along the major coulee system. The tests of association presented above indicate that cairns are not associated with any one variable but an examination of Figure 4.8 suggests that a combination of the following variables may have been important when selecting locations to build cairns: **<250m to a Prairie Edge**, no more than **0-200m to Seasonal Water** and no more than **0-400m from Permanent Water**.

It is apparent that of the eight chi-square tests conducted, only one showed a positive result. This may be interpreted as indicating that no one variable is associated with site locations. If one or two variables were associated with all site locations then there would be no point to conducting a predictive modelling exercise. The negative results from the chi-square tests is an affirmation that

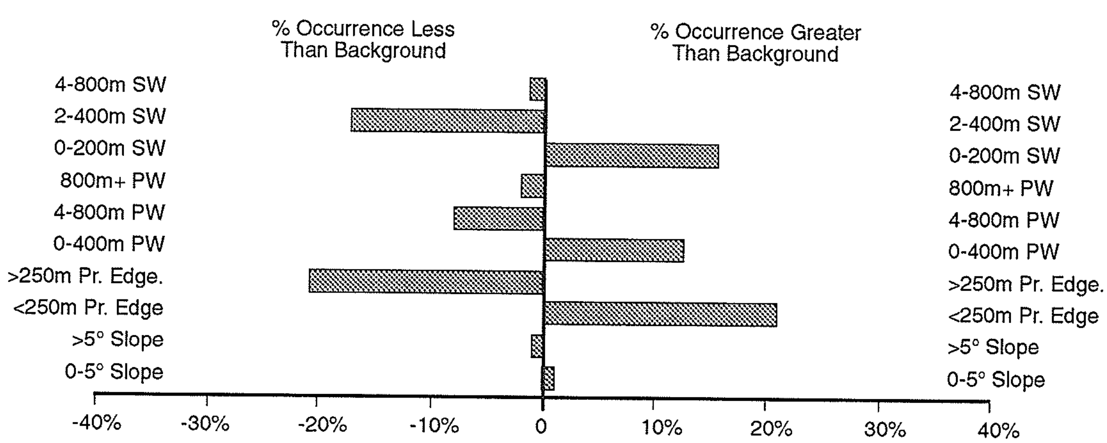

Figure 4.8. The Percentage Occurrence of Variables at Cairn Sites as Compared to the Occurrence of the Same Variables in the Background Referent

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[1] considering only those variables that occur more than once

Variable	Weighted Value	Zone									
		Low						Med	High		
		3[1]	6[2]	9[3]	12[4]	15[5]	18[6]	21[7]	24[8]	27[9]	30[10]
0-400m PW	9									x	x
0-200m SW	9					x		x			x
0-5° Slope	6			x	x	x	x	x	x	x	x
<250 PE	6						x	x	x	x	x
4-800m PW	6								x		
2-400m SW	6		x		x		x		x	x	
800m+ PW	3	x	x	x	x	x	x	x			
4-800m SW	3	x		x							
>5° Slope	0	x	x								
>250m PE	0	x	x	x	x	x					

This table was constructed by choosing the variables that occurred in the greatest proportion within the weighted value category. The numbers presented below indicate the frequency of cells in which the identified variables occur while the figure in brackets identifies at what percentage of the weighted value category that the variable occurs.
1 - 24(100%); 2 - 52(77%); 3 - 4151(87.7%); 4 - 3032(70.5%); 5 - 3615(49.9%); 6 - 3589(51.4%); 7 - 5706(76.1%); 8 - 1906(59.9%); 9 - 409(100%); 10 - 974(100%)

Table 4.17. Presence of Individual Variables in Weighted Value Categories

a combination of variables are associated with site locations, not any individual variable. This combination of variables is reflected by the weighted value method and the manner in which the relevant variables are identified by each weighted value category (Table 4.17). Examination of Table 4.17 reveals that in the category of high potential, a combination of the following variables identifies almost 45% of sites[1]: **0-400m from permanent water, 0-5° slope, <250m from Prairie Edge** and **0-200m from Seasonal Water**. Indeed, if a series of chi-square tests had been run prior to the development of the predictive model, perhaps as part of a numerical approach to modelling, it would have indicated that sites are not really associated with any of the variables chosen, except proximity to permanent water. Clearly, the weighted value method and its evaluation by statistical means has demonstrated the effectiveness of this approach to predictive modelling.

4.4 SUMMARY

This chapter presented an analysis of the predictive strength of the model presented in Chapter 3. The Kolmogorov test was employed to confirm observations made of the data. This test verified that the model predicted the location of a high percentage of sites. If the model was used as the basis for conducting a survey, almost 70% of the site cells or 44% of sites would have been identified by examining less than 14% of the study area. In addition, analysis of the data suggests that three categories of potential could be created for the study area. A low potential category would encompass all areas with weighted values between 0 and 18; medium potential would include areas designated by weighted value 21 and; high potential areas would include areas with weighted values ranging between 24 and 30. Additionally, the Spearman's rank order correlation test emonstrated that there is a relationship between cell weighted value and the perc tage frequency of site cells. This test demonstrated that knowing the rank of the weighted value can assist in predicting the percentage frequency of site cells while conversely, the same does not hold true in predicting the percentage frequency of background cells. The chi-square goodness-of-fit test was used to determine the strength of relationships between specific site types and specific variables. It was demonstrated that proximity to permanent water is statistically associated with stone circle sites. It was also shown that no single variable is statistically associated with all site types. In fact, only specific combinations of variables can result in the identification of prehistoric sites and the weighted value method presented in this thesis is effective in producing this result.

Chapter 5 will present the relevance of the findings outlined in Chapter 4 and discuss the scope and limitations of this predictive model In addition, the following chapter will summarize the research presented in this thesis and draw conclusions from it and finally, avenues for further research will be presented.

CHAPTER 5
SUMMARY AND CONCLUSIONS

5.1 INTRODUCTION

> An archaeological understanding of the past is never more than a provisional one that is doomed to be superseded, in whole or part, as new data and new interpretive techniques become available. ...If archaeologists are not to obscure the understanding of the past, they must learn to leave many questions unanswered and to offer alternative hypotheses to explain their data (Trigger 1985:52).

The preceding chapters in this thesis presented the background to the predictive model, the predictive model itself and a statistical evaluation of the model's strength. This chapter summarizes that information and offers answers for the two questions being addressed by this research. A section discussing directions this line of research might take in the future brings this chapter, and this thesis to a close.

5.2. THE SOURIS RIVER PREDICTIVE MODEL: A SUMMARY AND DISCUSSION

A heritage resource impact assessment was conducted as a result of the development of the Rafferty Dam on the upper Souris River near Estevan, Saskatchewan. A small component of that project involved developing a predictive model of prehistoric activity locations along the Souris River. The recognition that archaeological predictive models could benefit the study of the prehistory of Saskatchewan foreshadowed discussions held by the Saskatchewan Association of Professional Archaeologists almost 4 years later (Germann 1991). Furthermore, there were few studies specifically addressing prehistoric locational models on the northern plains. As a result, a predictive model of prehistoric activity location was timely and of potential benefit to understanding the archaeology of the northern plains.

In association with a review of the existing literature concerned with archaeological predictive modelling, a field program was initiated to collect baseline data specifically designed to develop, test and evaluate a predictive model for southeastern Saskatchewan. Concurrently, the increasing availability of computer technology and its application in archaeological research became a factor in this research. As a result, a predictive model for the upper Souris River valley was developed using GIS software.

The methodology by which this model was developed allowed for the experience of archaeologists to be quantified and incorporated into the modelling process. A number of variables were selected and weighted according to their perceived association with prehistoric activity locations. Using GIS software, these variables were combined together to produce a computer map illustrating a scale of potential for prehistoric activity locations.

The predictive modelling was evaluated using three statistical tests. The first evaluated whether or not the model was successful in predicting the locations of sites. The Kolmogorov test demonstrated that site locations were being predicted in a manner different than that expected by chance. The Spearman's rank order correlation test demonstrated that knowing the rank of the weighted value assisted in predicting the rank order of percentage frequency of site cells. The third set of statistical tests was conducted to evaluate if the two major site types represented in the study area were associated with any specific variables. It was demonstrated that only one subcategory, proximity to permanent water, was statistically determined to be associated with stone circle sites. No other variables were determined to associated with stone circles or cairns. Overall, the tests conducted demonstrated that the model was effective in identifying the combination of variables that predicted the location of archaeological sites.

5.2.1. Can a predictive model of prehistoric activity location reliably indicate where people located their activities?

This question was answered by examining the results of settlement pattern research. Predictive modelling as a subset of settlement pattern research addressed this question more directly. The research conducted by numerous archaeologists into predictive modelling, summarized and discussed in Chapter 1 and 2, suggests that one can reliably identify archaeological sites through the use of a predictive model. The question of just *how* reliably one can find these sites may still be open to further discussion. As outlined in Chapter 2, archaeologists working within the bounds of a research program may define a successful predictive model in a manner different to a cultural resource manager working within different constraints. However, the predictive modelling methodology presented here demonstrates that in addition to a successful model of prehistoric activity location being developed, the scale of potential generated by the model allows individual researchers to define their 'scale of reliability'. For example, a researcher may define a reliable or successful model as one that identifies specific site types or a specific percentage of sites. A cultural resource manager or contract archaeologist may define a reliable or successful model as one that identifies a high percentage of site locations within a specific geographic boundary. Additionally, within the above two examples, the archaeologist may again define the success of two separate applications of a model using two different standards each of which is applicable to a specific situation.

A predictive model is of considerably more use if it can be applied in many different situations by many different end users. The methodology presented and the predictive model developed here achieves that goal and in association with the models developed by other archaeologists answers the above question positively. A predictive model of prehistoric activity location can reliably indicate where people located their activities.

5.2.2. Can a predictive model of prehistoric activity location provide insight as to why people were choosing certain areas to conduct their activities as opposed to others?

> Efforts to build predictive models useful *only* for management are misplaced. Sites are not a worthwhile end in themselves, but the understanding of human behavior and development that can be extracted from them is. It is largely these "informational" values, derived from research contexts, that give cultural resources their value under existing historic preservation laws and regulations (Kohler and Parker 1986:442).

Chapter 4 demonstrates that we can predict the location of archaeological sites at probabilities much greater than chance. The modelling methodology presented here is one designed to contribute insight into why sites are located where they are, in addition to finding the sites themselves. This requires acceptance of the position that the variables associated with archaeological site locations, as defined in the predictive model, in some way embody or reflect some of the choices made by the prehistoric people who carried out activities at those locations.

It was determined through statistical analysis that there is no significant association between cairns and the other variables. Understanding why cairns are located where they are requires an understanding of their function. "Information on the function of small stone cairns is limited in both the historical and archaeological record. At present, these features have not captured the imagination of researchers in the same way that stone circles have" (Brumley and Dau 1988:134). While there is little known about cairns, perhaps some further speculation may be appropriate. In the study area, cairns were distinctly located north and south of the river. North of the river, cairns were found almost exclusively at the rim of the Souris valley. South of the river, cairns were found almost exclusively removed from the valley and found along the major coulee system to the south. While this may suggest different functional uses for cairns, all the cairns were found in similar topographical locations. It is suggested here that cairns are located so as to maximize their visibility from either the prairie level or from down in a coulee bottom. This hypothesis is based on the assumption that cairns, as deliberate constructions, were built to be seen. Whether they were built as caches, memorials, markers or burials, they were most likely built with the intention to at least see them again. As a result, it is suggested that they are positioned according to what has been called Poiker's First Law of Disappointment (Poiker 1987 pers. comm.). This law relates mostly to mountain climbing but is applicable here. It describes a specific point on a hillside. When climbing up the hill, that point gives every impression of being the apex of the climb. Upon reaching that point, one discovers that there is a great distance still to cover; hence the disappointment. Climbing downhill, this point again presents the same dilemma. Cairns are located at this 'point' on the prairie landscape. They are located close enough to the break-in-slope so that they may be seen from the coulee bottom, but not so far down the coulee wall that they cannot be seen from the surrounding prairie. This may account for why slope variables were not significantly associated with cairn locations. Cairns are located on the break-in-slope such that they fall on either a flat or steep parcel of land as defined in the digital database. Correspondingly, either (a) the digital slope data are not detailed enough to distinguish these characteristics accurately, (b) the cell resolution used in the study is too gross (25m) to represent these data, (c) the site locations were plotted with insufficient accuracy in the digitizing process, or (d) a combination of the above. Future applications of the model could test some of these assumptions and perhaps refine the model presented here. Indeed cairn location may be related to other variables not accounted for above including local drainage conditions or the other numerous cultural variables that would be associated with a burial cairn.

Stone circle sites are statistically determined to be associated with proximity to a permanent water source. This could be interpreted to indicate that campsites (the functional equivalent of stone circle sites) were being located so as to capitalize on all the benefits associated with a permanent water source. These include but are not limited to the availability of drinking water and food, the potential for wood and all its benefits, and the potential for other items necessary for daily life such as clay, basketry, shells among others. Additionally, proximity to a prairie edge suggests that observations like those of Mulloy (1960:2) who identified windswept terrace and cliff edges as ideal stone circle locations are also correct. These locations afford a number of advantages in addition to being close to the benefits of a permanent water source. In a manner similar to where cairns are located, stone circle sites take advantage of being able to monitor faunal resources moving through the valley bottoms and well as those moving over the prairie. Clearly, the killing of large numbers of bison was a common activity on the northern plains and the presence of a buffalo drive lane at DgMp 4 indicates these activities occurred at some point in time along the Souris River. Locating camps where both the prairie and the valleys could be seen would be of benefit to the local inhabitants.

"Almost any hill or knoll was used for the [vision quest]" (Fredlund 1969:14). With only 4 vision quest sites identified in the study area, a statistical analysis was not carried out on their association with variables. Unfortunately the detail of a 1:50,000 topographic map does not allow for representation of all the small hills and knolls and as a result the detail is not represented in the digital database. Therefore, the vision quest sites that were identified cannot confidently be correlated with the elevation information contained in the digital database. Perhaps further research could be conducted correlating vision quest sites with other features or site types, or advances could be made in aerial photograph interpretation or the detail at which topographic information is presented. Any of the above could increase our knowledge of vision quest sites.

The bison drive lane (DgMp 4) discovered in the southwest corner of the study area exemplifies the fourth site type discovered in the study area. This drive lane encompassed many individual features including stone circles, stone circles of extremely large diameter, cairns, rock alignments and depressions. While establishing contemporaneity among each of these features could possibly be accomplished through extensive excavations, this was not done. It is reasonable to suggest that the cairns forming the two arms of the drive lane are contemporaneous. When considering the distribution of stone circles in the study area, it is somewhat unusual to find such a large concentration of stone circles removed from the valley wall. Additionally, there are at least three stone circles measuring more than 15 metres in diameter (Figure 3.22). In their study of over 686 stone circles in the Forty Mile Coulee, southern Alberta, Brumley and Dau found that "mean inside diameters vary from 2.31 to 8.57m with an overall mean of 4.60m. At Forty Mile Coulee the range is from 2.40 to 7.50 metres with an overall mean of 4.45 metres" (Brumley and Dau 1988:119). This might suggest those stone circles at the H.F. Gurlimann site (DgMp 4) with unusually large diameters had functions other than as habitation structures. With all this in mind, in order to predict the location of bison drive lane sites, one cannot simply combine the predictive formulae for the different components of that site. Rather, one must identify the functional characteristics of a bison drive lane, and model their occurrence on the landscape. Therefore, in the case presented here, a bison drive might be found in areas that: (a) are at the head of coulee with coulee walls steep enough to discourage their overrunning by bison and; (b) have some natural trap in the bottom of the coulee to capture the bison such as a slough or constriction of the coulee walls. Other topographic features are associated with bison drive lanes. The most common of these is the 'jump': an almost vertical break-in-slope of a height sufficient enough to disable or kill the bison when they are driven over its edge.

In summary, the predictive model developed and presented in this thesis can provide insight as to why people were choosing certain locations over others. However, it must be recognized that at this initial stage in the predictive modelling process on the northern plains, this new insight must be considered elementary. Additionally, the repeated applications of the predictive model as part of the tertiary stage modelling process can only result in greater and more detailed information brought to light. As stated in Chapter 2, archaeologists who have worked on the plains for years may have already made some of these insights and personally apply them during the course of their research. The modelling process outlined and exemplified here, makes clear some of those elementary insights and the manner by which they were reached and holds promise to bring forth many more.

5.3 Future Research

Clearly the next step in this line of research is to apply the model in a different area of southeastern Saskatchewan. While the same methodology presented here could certainly be used in other areas, considerable background research should be effected to ensure that other relevant variables are evaluated for inclusion into the modelling process. If this model is applied in the future, researchers must be wary of not falling subject to what has been called the toy airplane model syndrome (Altschul 1989:273):

> The models can be quite sophisticated and the modeling process very involved. The final model, which is often in the form of a map, is usually perceived as *the* word on site location, the end product. There is usually no mechanism to update the model with new data. Instead, when an area of proposed development is evaluated, the model is reviewed and the likelihood of encountering a site is determined. Once developed, the model is treated as immutable. Much like a toy airplane model, after a predictive model is placed on the shelf, not to be altered or modified.

While this thesis obviously discusses a predictive model for the Souris River valley, it may not be so obvious that a methodology for conducting modelling exercises is also presented. This methodology is one that is adaptive in the sense that it can be used for management purposes but it also has 'scientific' relevance. Conversely, the model can be developed for purely academic purposes but still have relevance in the management sphere of archaeology. As Altschul explains (1989:274):

> The hallmark of a scientific model is that it is a dynamic analytic device. Models are based on the best guess as to their inner workings and the component parts of a particular phenomenon or class of phenomena. These 'guesses' are treated as hypotheses and continually tested. In time most hypotheses are refined or replaced with new ones and as the constituent hypotheses are altered the models are refined. A specific model is never treated as an end point, but rather as the best model of a phenomenon at a particular point in time. The emphasis in scientific modeling is clearly placed on the process and not the product.

There are several points raised by this research that deserve further treatment. A first relates to the suitability of using GIS software in archaeological research. Clearly, the construction of the model as presented here could not have been completed using a non-computerized approach. Indeed with the means available today, calculating continuous slope or elevation data for 39600 contiguous cells would be an exercise attempted only by the most ambitious researchers. In fact, as stated by Kvamme (1990:370)

> ...these [manual] methods for determining the nature of a region's background environmental distribution for a continuous variable are extremely labour intensive. Consequently they have not been employed often in regional studies. This difficulty provides an illustration of the relation between technology and analysis procedure. Because the ability to represent a continuous distribution over an entire region could only be arrived at with extreme difficulty, analysts generally have either (a) ignored continuous data types, (b) focused rather on categorizing continuous data to relatively few classes (e.g., level ground vs. steep ground) and employing chi-square goodness of fit tests, or (c) resorted to the taking of random samples from the background environment and their comparison to archaeological samples using ... two sample inference tactics. ... GIS easily and rapidly can provide accurate and systematic descriptions of background environmental distributions over entire regions, for continuous and categorical data, thereby facilitating the universal application of one-sample testing approaches regardless of data type.

Indeed, just as it is always preferable to survey an entire area than a percentage of it (Flannery 1976:134), it is preferable to conduct statistical tests using the entire background environment rather than a random sample drawn from it. Using GIS software not only allows for the entire background to be taken into consideration during statistical evaluation, but a much larger background can become the focus of study due to the ability of a GIS to handle tremendous amounts of data. Further research needs to be conducted on the use of GIS in archaeology for different parts of Canada. Issues such as the relationship of cell size to site size, elevation resolution and its applicability to archaeologically relevant data, the compatibility of contemporary mapped data to its prehistoric counterpart and, the applicability and transferability of models to different geographic, environmental, or physiographic zones all deserve further investigation.

Future applications of this, or similar models might incorporate revised or data different than that presented here. A valuable avenue for research could include a detailed ethnographic and ethnohistoric investigation of northern plains native land use. The inclusion of data derived from such a study would add immeasurably to an understanding of the different variables relevant to the modelling process. Indeed, such a study could also provide insight into some aspects of native spirituality and its relationship to archaeological sites and correspondingly their prediction. Such a study is underway in northern Ontario and has produced promising results (Dalla Bona and Larcombe 1993; Larcombe 1993)

The means by which some base data are developed needs to be investigated further. The northern plains present a unique situation to the digital modelling of the natural environment. The large expanses of the prairies with little or no physical relief, or relief 'falling between the contour lines' broken by concentrated localities of relatively extreme relief can be represented in digital form with acceptable accuracy. However, even more accurate topographic maps could alleviate some of the problems defining slope and perhaps even identify the tiny 'high spots' upon which vision quest sites can be found.

A second point of interest refers to the question of cairn function. Certainly, to understand why cairns are found in specific locations, there must be a recognition of their place and function in prehistory. Indeed, only when the different functions of cairns are better understood can the relationships between cairns and indicators of the physical environment be further researched. The third point, while similar to the second, relates to the sparse information available on vision quest sites. Once again, without a better understanding of their function and their place in native spirituality, being able to predict their occurrence on the plains may continue to prove difficult.

A further point raised by this research arises from the lack of temporal control over the database. Some will argue that this makes predicting site types difficult. Others might suggest that establishing temporal control among sites in a large survey area itself is difficult - especially without extensive subsurface investigation. Perhaps future research using this model could integrate sites with better temporal control into the process. This would allow revisions in the predictive statements made here, where necessary. At the very least, it would verify the model as presented while incorporating new and perhaps more detailed data.

A similar point relates to the 'incompleteness' of the sample. It may be argued that the inability to include the floodplain in the survey sample limits the overall effectiveness of the model for reconstructing or predicting settlement patterns in the Souris Basin. However, even a floodplain that was possible to survey presents an environment different than the higher prairie level. Had the floodplain never been plowed, surface features and artifacts would most certainly have been those limited to the most recent archaeological time periods due to the regular flooding and resulting soil deposition that has occurred in this valley. This is in contrast to the prairie level where very little soil development has occurred and where artifacts from the earliest occupations can be found on the surface in juxtaposition to artifacts from the most recent times. Despite this fact, the exclusion of the valley floodplain does limit the kinds of statements that can be made about some aspects of the subsistence round. Additionally, activities that were not related to or associated with petroforms will also be overlooked. As a first step in this type of research, these omissions may perhaps be acceptable with the caveat that future applications of this model begin to take these factors into account, thereby increasing the robustness and scope of the model.

There is one final point that arises from this thesis. A conscious effort has been made to avoid modelling 'site' locations; instead trying to model prehistoric activity locations. Sites are artificial categories archaeologists have developed to help understand phenomena generated in the past but existing today. Sullivan and Schiffer best describe this viewpoint (1978:169):

> ...prehistoric people most likely did not locate 'sites' anywhere. However, they did establish, occupy, and abandon behaviorally significant spaces, such as activity areas, camps and settlements. ...Sites are nothing but deposits of material remains in the environment that archaeologists recognize as being potentially informative about past cultural behaviour and organization. ...Owing to secondary deposition, multiple occupations, and other formation processes, sites usually are not equivalent on a one-to-one basis to camps, settlements, or population aggregates.

While some may see this as arguing over definitions, it is viewed here as an important point. By attempting to identify prehistoric activity areas, a researcher is reflecting the attempt to understand the many factors that could result in the existence of an archaeological site. Indeed, we might expect to find cultural remains in a predicted prehistoric activity location and as a result, a preliminary understanding of the place of those remains in the larger sphere of understanding will be facilitated. If archaeology is satisfied describing the phenomena it uncovers, then predictive modelling is nothing more than means of "wasting big bucks to come around to the obvious" (Kohler and Parker 1986:398). However, if it is our goal to describe the phenomena we uncover *and* propose explanations for their existence, then in conjunction with other tools at our disposal, predictive modelling will assist in opening our window on the past.

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APPENDIX A: SITES DISCOVERED DURING A FIELD SURVEY OF THE STUDY AREA

Borden	UTM	Legal Description	Dimensions	Description
DgMp 4	13U FE 720 395	NE/NW/32/1/5/W2	1000m x 250m	MULTIPLE FEATURE: 30+ stone rings, 75+ stone cairns, rock alignments, circle/grouping of stone/ boulders; linear feature;
DgMp 6	13U FE 772 391	SW/NE/32/1/5/W2	25m x 25m	ARTIFACT/FEATURE COMBO: rock alignment; pit/depression; mount; rectangular depression
DgMp 7	13U FE 723 391	SW/NE/32/1/5/W2	500m long	RECURRENT FEATURE: 9 stone cairns
DgMp 8	13U FE 741 396	NW/NE/33/1/5/W2	2m x 1.5m	SINGLE FEATURE: 1 stone cairn
DgMp 9	13U FE 744 391	SE/NE/33/1/5/W2	5m x 5m	SINGLE FEATURE: 1 stone cairn
DgMp 10	13U FE 745 395	NW/NW/34/1/5/W2	25m x 3m	RECURRENT FEATURE: 3 stone cairns
DgMp 11	13U FE 762 405	NW/SW/2/2/5/W2	1.5m x 1.0m	SINGLE FEATURE: 1 stone cairn
DgMp 12	13U FE 748 402	Centre/SW/3/2/5/W2	2m x 2m	SINGLE FEATURE: 1 stone cairn
DgMp 13	13U FE 730 410	NW/NW/4/2/5/W2	100m X 100m	RECURRENT FEATURE: 18+ stone rings
DgMp 14	13U FE 742 399	SE/SE/4/2/5/W2	25m x 15m	RECURRENT FEATURE: 2+ stone circles
DgMp 15	13U FE 741 402	NE/SE/4/2/5/W2	250m x 10m	RECURRENT FEATURE: 2 stone cairns
DgMp 16	13U FE 740 406	SW/NE/4/2/5/W2	25m x 20m	RECURRENT FEATURE: 2+ stone circles
DgMp 17	13U FE 721 399	SW/SE/5/2/5/W2	5m x 5m	SINGLE FEATURE: 1 stone cairn
DgMp 18	13U FE 727 412	NE/NE/5/2/5/W2	170m x 75m	ARTIFACT/FEATURE COMBO: 24+ stone circles and 2 cairns
DgMp 19	13U FE 722 407	SW/NE/5/2/5/W2	100m x 30m	RECURRENT FEATURE: 17+ stone circles
DgMp 20	13U FE 724 406	SE/NE/5/2/5/W2	20m x 10m	RECURRENT FEATURE: 4 stone circles
DgMp 21	13U FE 723 403	NW/SE/5/2/5/W2	10m x 5m	RECURRENT FEATURE: 2 stone circles

Borden	UTM	Legal Description	Dimensions	Description
DgMp 22	13U FE 721 418	NW/SE/8/2/5/W2	4m x 4m	SINGLE FEATURE: 1 stone circle
DgMp 23	13U FE 725 415	SE/SE/8/2/5/W2	300m x 200m	ARTIFACT SCATTER
DgMp 24	13U FE 720 420	NW/SE/8/2/5/W2	2m x 2m	SINGLE FEATURE: 1 vision quest site
DgMp 25	13U FE 720 421	NW/SE/8/2/5/W2	2m x 2m	SINGLE FEATURE: 1 vision quest site
DgMp 26	13U FE 725 423	SE/NE/8/2/5/W2	20m x 10m	RECURRENT FEATURE: 4 stone circles
DgMp 27	13U FE 735 426	NE/NW/9/2/5/W2	50m x 30m	MULTIPLE FEATURE: 5 stone rings, 1 cairn
DgMp 28	13U FE 727 423	SE/NE/8/2/5/W2	80m x 10m	RECURRENT FEATURE: 4 stone cairns
DgMp 29	13U FE 737 427	NW/NE/9/2/5/W2	5m x 5m	SINGLE FEATURE: 1 stone cairn
DgMp 30	13U FE 740 426	NE/NE/9/2/5/W2	75m x 10m	RECURRENT FEATURE: 2 stone cairns
DgMp 31	13U FE 740 418	NE/SE/9/2/5/W2	200m x 200m	RECURRENT FEATURE: 12+ stone circles
DgMp 32	13U FE 728 423	SW/NW/9/2/5/W2	25m x 15m	RECURRENT FEATURE: 6 stone circles
DgMp 33	13U FE 730 423	SW/NW/9/2/5/W2	3m x 2m	SINGLE FEATURE: 1 vision quest site
DgMp 34	13U FE 738 425	NW/NE/9/2/5/W2	20m x 15m	RECURRENT FEATURE: 4 stone circles
DgMp 35	13U FE 729 414	SW/SW/9/2/5/W2	125m x 20m	RECURRENT FEATURE: 19+ stone circles
DgMp 36	13U FE 734 416	SE/SW/9/2/5/W2	20m x 10m	RECURRENT FEATURE: 3 stone circles
DgMp 37	13U FE 744 427	NW/NW/10/2/5/W2	20m x 20m	RECURRENT FEATURE: 3 stone circles
DgMp 38	13U FE 745 419	NW/SW/10/2/5/W2	50m x 30m	RECURRENT FEATURE: 6+ stone circles
DgMp 39	13U FE 747 418	NW/SW/10/2/5/W2	75m x 75m	RECURRENT FEATURE: 11+ stone circles
DgMp 40	13U FE 750 420	NE/SW/10/2/5/W2	50m x 30m	RECURRENT FEATURE: 10+ stone circles
DgMp 41	13U FE 753 420	NW/SE/10/2/5/W2	15m x 15m	RECURRENT FEATURE: 4 stone circles

Borden	UTM	Legal Description	Dimensions	Description
DgMp 42	13U FE 755 428	NW/NE/10/2/5/W2	20m x 3m	RECURRENT FEATURE: 2 stone cairns
DgMp 43	13U FE 757 427	NE/NE/10/2/5/W2	100m x 30m	RECURRENT FEATURE: 5 stone circles
DgMp 44	13U FE 748 430	NE/NW/10/2/5/W2	20m x 5m	RECURRENT FEATURE: 2+ stone circles
DgMp 45	13U FE 762 427	NW/NW/11/2/5/W2	4m x 2m	SINGLE FEATURE: 1 stone cairn
DgMp 46	13U FE 761 429	NW/NW/11/2/5/W2	75m x 25m	RECURRENT FEATURE: 9 stone circles
DgMp 47	13U FE 770 427	NW/NE/11/2/5/W2	100m x 15m	RECURRENT FEATURE: 6 stone circles
DgMp 48	13U FE 769 428	NW/NE/11/2/5/W2	50m x 25m	MULTIPLE FEATURES: 7 stone circles, 1 depression
DgMp 49	13U FE 764 412	NE/NW/2/2/5//W2	1m x 1m	SINGLE FEATURE: 1 stone cairn
DgMp 50	13U FE 764 419	NW/SW/11/2/5/W2	1000m x 300m	RECURRENT FEATURE: 44+ stone circles
DgMp 51	13U FE 770 429	NW/NE/11/2/5/W2	40m x 15m	RECURRENT FEATURE: 5 stone circles
DgMp 52	13U FE 758 431	SE/SE/15/2/5//W2	3m x 3m	SINGLE FEATURE: 1 stone circle
DgMp 53	13U FE 751 430	SE/SW/15/2/5/W2	3m x 3m	SINGLE FEATURE: 1 stone cairn
DgMp 54	13U FE 749 432	SE/SW/15/2/5/W2	25m x 25m	RECURRENT FEATURE: 2 stone circles
DgMp 55	13U FE 748 433	SE/SW/15/2/5/W2	30m x 10m	RECURRENT FEATURE: 5 stone circles
DgMp 57	13U FE 746 434	NW/SW/15/2/5/W2	5m x 3m	SINGLE FEATURE: 1 stone cairn
DgMp 58	13U FE 733 434	NE/SW/16/2/5/W2	30m x 10m	RECURRENT FEATURE: 5 stone circles
DgMp 59	13U FE 742 434	SE/SE/16/2/5/W2	10m x 10m	SINGLE FEATURE: 1 stone circle
DgMp 60	13U FE 758 394	NE/NE/34/1/5/W2	5m x 5m	RECURRENT FEATURE: 3 stone cairns
DgMp 61	13U FE 754 392	SW/NE/34/1/5/W2	15m x 15m	RECURRENT FEATURE: 2 stone circles
DgMp 62	13U FE 753 430	SE/SW/15/2/5/W2	3m x 3m	SINGLE FEATURE: 1 vision quest site

APPENDIX B:
COMPUTER TRANSFORMATIONS USED TO CREATE VARIABLES USED IN THIS PREDICTIVE MODEL

The following map algebra formulae were followed using MAP II (v. 1.5) for the Apple Macintosh. The steps below assume that the data have already been digitized and saved as primary data layers. It is beyond the scope of this thesis to discuss how digitizing is performed and how data layers such as digital elevation models are created. The reader is referred to Burrough (1986) for a good general treatment of this subject.

<u>SLOPE MAPS</u>

MTA2 DEM ---> GRADE <<MTA2 DEM>> — creates a map of various slope values
—> RECODE ThatMap-1 Assigning 5 to 0 through 9 Assigning 6 to 10 through 35
—> RECODE ThatMap-2 Assigning 5 to 5 — isolates flat slopes (5° angle)
*****Saved as: MTA2 0-5° Slope*****
—> RECODE ThatMap-2 Assigning 6 to 6 — isolates steep slopes (>5° angle)
*****Saved as: MTA2 >5° Slope*****

<u>PRAIRIE EDGE MAP</u>

MTA2 >5° Slope
—> SPREAD <<MTA2 >5° Slope>> to 250 over <<MTA2 DEM>> — creates a 250m buffer from the steepest slopes which in the area just happen to be the coulees and valley wall

MTA2 DEM —> RECODE <<MTA2 DEM>> Assigning 0 to 0 through 55500 — creates a map that will mask out all of that land below 555m
—> COVER ThatMap-1 with ThatMap-2 — eliminating the coulee slopes
—> RECODE ThatMap-3 Assigning 250 to 1 through 25000 — results in a 250m buffer from edge of all coulees and valleys
*****Saved as: MTA2 <250m from Prairie Edge*****

DISTANCE ZONES FROM PERMANENT WATER

MTA2 Hydrology

—> RECODE <<MTA2 Hydrology>> Assigning 10000 to 10000 — isolates permanent water
—> SPREAD ThatMap-1 to 800 — creates an 800m buffer around permanent water
—> RECODE ThatMap-2 Assigning 1 to 0 through 100 Assigning 2 to 101 through 200 Assigning 4 to 201 through 400 Assigning 8 to 401 to 800 — isolates discrete distance buffers from permanent water
*****Saved as: MTA2 PWater*****

DISTANCE ZONES FROM SEASONAL WATER

MTA2 Hydrology

—> RECODE <<MTA2 Hydrology>> Assigning 10001 to 10001 — isolates permanent water
—> SPREAD ThatMap-1 to 800 — creates an 800m buffer around seasonal water
—> RECODE ThatMap-2 Assigning 1 to 0 through 100 Assigning 2 to 101 through 200 Assigning 4 to 201 through 400 Assigning 8 to 401 to 800 — isolates discrete distance buffers from seasonal water
*****Saved as: MTA2 SWater*****

GENERATING PROBABILITY MAP

—> COMPUTE <<MTA2 0-5° Slope>> + <<MTA2 <250m from Prairie Edge>> + <<MTA2 >5° Slope>> + <<MTA2 PWater>> + <<MTA2 SWater>> — this operation adds the various maps together and produces a final map that illustrates the total weighted value for each cell on the map.
*****Saved as: MTA2 Compute.1*****

CORRELATING PREDICTION WITH KNOWN SITE LOCATIONS

—> COMBINE <<Sites>> with <<MTA2 Compute.1>> — combines known sites with the weighted value for each cell indicating the weighted value for each cell of a site
*****Saved as: MTA2 ComputedSites*****