ARCHAEOLOGICAL LANDSCAPES OF THE LOWER MAINLAND, BRITISH COLUMBIA
A Settlement Study using a Geographic Information System

by

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B.A., The University of British Columbia, 1990

A THESIS SUBMITTED IN PARTIAL FULFILLMENT OF

THE REQUIREMENTS FOR THE DEGREE OF

MASTER OF ARTS

in

THE FACULTY OF GRADUATE STUDIES

(Department of Anthropology and Sociology)

We accept this thesis as conforming
to the required standard

THE UNIVERSITY OF BRITISH COLUMBIA

December 1995

DE-6 (2/88)

ABSTRACT

A selection of archaeological sites located in the Lower Mainland area of coastal British Columbia is used to test the use of the landscape in evaluating certain statements about prehistoric human settlement for the region. In total, 62 sites were chosen which show at least some evidence of occupation or limited activity use during the Marpole period (2400-1400 BP).

The main problem in describing settlement strategies for this area is the inability to infer site use from subsistence or lithic assemblages recovered through either excavation or surface collection. This lack of information for the majority of the sites makes it impossible to use such traditional approaches to settlement analysis as determining sociopolitical relationships between locations or describing a seasonal round or movement from one type of site to another.

An alternative approach to circumventing this dilemma is to use the landscape in the immediate vicinity of each site as a source of new data that can be used to determine some of the criteria involved in making the settlement choice. A Geographic Information System was used to gather information about the terrain, both generally for the region and near the sites and then comparing this local profile with the other sites across the region.

This information is presented in a series of tabular and statistical displays that allow evaluations, not only about settlement choices inherent in the collection of sites but also about the efficacy of the landscape approach in archaeological research. The non-randomness of site location decisions is demonstrated along with evidence that certain landscape features were favoured over others. It is also apparent that a preliminary site typology can be affirmed as a result of certain types of sites selecting for specific terrain elements.

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ACKNOWLEDGEMENT

R.G. Matson inspired this research many years ago when he commented that archaeological sites in this part of the world often seemed to be near the base of steeply rising headlands. This sparked my interest in looking at the landscape as a lasting set of clues to ancient human occupation. To him and to Prof. David Pokotylo as my other thesis committee member I owe a great debt, not only for their guidance but also for their patience during this overlong process.

I wish to also thank Kathryn Bernick for pointing me towards the area surrounding the mouth of the Fraser River as an area of study. Her knowledge of the region and her subsequent help with new data on sites were a great benefit. I am greatful as well to Morley Edridge of Millenia Research for providing me with up-to-the-minute material from his recent survey work on the Fraser.

I relied extensively on the Department of Geography and a group of people there who helped me with computer access and the navigation of the confusing byways of Geographic Information Systems. Prof. Brian Klinkenberg was most helpful in arranging my use of the comuter lab facilities and obtaining data for the research. Graduate Student Catherine Griffiths was most gracious with her time in answering my many banal questions. Vincent Kujala was always available to help me with system problems.

My colleagues in the Department of Anthropology and Sociology were very supportive over the years. I want to mention particularly fellow classmates Andrew Mason and Vicki Feddema. Doug Brown and Warren Hill were a great help at a particularly bleak time at the end of the project. Like most archaeology students here at UBC, I too have many fond memories of the help and the kindness of Joyce Johnson.

In the course of this research I have felt the loss of both my parents, Robert Graham and Katherine Grace Beattie. My thoughts were often of them as I tried to bring this work to completion.

And finally I thank my dearest friend and companion, Lalya Wickremasinghe. Her presence in my life through all these years has been my inspiration and my source of strength.

Introduction

This study uses a Geographic Information System to extract information from the physical landscape surrounding archaeological sites. The assertion here is that by making a series of measurements of the way the local landscape is connected to archaeological locations, statements can be made about how people came to choose these particular spots for living and working. A region surrounding the mouth of the Fraser River in southwestern British Columbia (see Figure 1) provides a test case for this proposition. Within this area, a set of sixty-two archaeological sites has been selected which show evidence of human activity during the Marpole period (2400 to 1400 BP).

Since the main research focus is on landscape and not specifically on Marpole, the settlement questions addressed here have been prompted by the overall study of subsistence and settlement and, therefore, remain general and preliminary. Three basic hypotheses guide the research. First, landscape data should show that the sites are not randomly distributed over the terrain. Secondly, specific landforms will be located close to sites because they are desirable features to be near; and thirdly, distinctions will be possible between types of sites based on greater or lesser diversity of the local landscape.

The Geographic Information System, (GIS) has been used here to generate the large amount of data necessary for a meaningful analysis. A major problem in an approach such as this is the difficulty in acquiring the information using traditional methods. Individual site reports, produced by almost as many authors as there are sites, cannot provide a consistent or comprehensive collection of data. Many measurements used in this present research were never a part of the original field documentation. Trying to extract this material manually from paper maps would be far too time-consuming, inaccurate, and in many cases impossible.

A short background examination of approaches to settlement patterns in archaeology begins this discussion. Next, it is shown how landscape and a GIS can generate new information. This is followed by a description of the study area and the methods used to examine it. The data that came out of the study are then examined and finally the results are summarized.

Settlement and Landscape

Settlement pattern studies can be generally lumped into two broad approaches. The first takes a *socio-political* view and looks at individual buildings and settlements and then attempts to link these localised phenomena across a broader territory or region (Trigger 1968). These approaches often attempt to look at the nature and use of

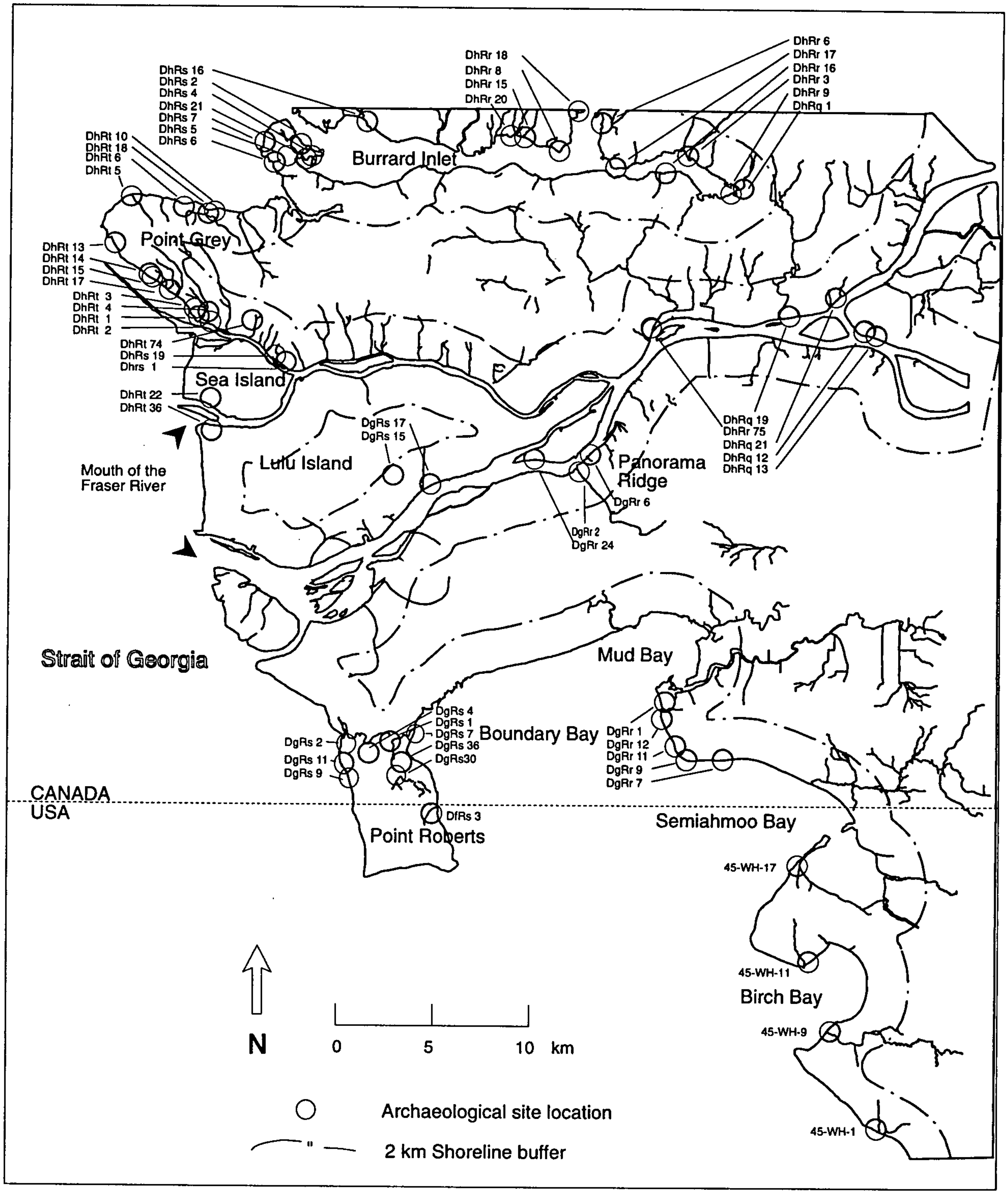


Figure 1: Map of the Study Area with site locations

buildings, religious activities, relationships to agriculture, as well as broader city-town-village-hamlet-farm connections. Classic efforts of this type in the Americas include Gordon Willey's Viru Valley study (1953), his work in the Maya Lowlands (1989), and the large scale projects in the Oaxaca Valley (Blanton *et al.* 1981) and the Valley of Mexico (Sanders *et al.* 1979).

The second approach, embedded in the *cultural ecology* paradigm, looks at relationships between human actors and various environmental elements to which they have adapted. A cycle of economic activity, often in the form of a seasonal round, is deemed to be the main determining factor behind why particular locations are chosen over others (Dewar & McBride 1992:228). Subsistence analysis and the remains of various technologies used to exploit the resources provide the data used to describe these patterns. Optimal foraging (Winterhalder & Smith 1981), catchment area (Vita-Finzi & Higgs 1970; Flannery 1976), and mobility strategy studies (Binford 1980, 1982; Chatters 1986) would all fit this category. Several projects in the American Southwest would come under this approach (Plog 1971, 1978; Plog & Hill 1971; Euler & Chandler 1978; Matson *et al.* 1988). Most forays into settlement description for the Northwest Coast and interior British Columbia follow these methods as well (Pokotylo 1978; Thompson 1978; Matson *et al.* 1979; Pomeroy 1980; Hobler 1983; Lepofsky 1985).

Both approaches rely heavily on knowledge of the *contents* of sites which they attempt to place into the settlement system, mainly as a means of determining site type and the related activities performed there. "Archaeologists must begin their analyses on materials remaining at archaeological sites" (Binford 1982:5). This reliance is fine in an ideal world of unlimited time and money but in reality it often means using a very small number of sites to explain very complex living systems. One way around this dilemma has been to suggest a greater reliance on surface remains (Schlanger 1992; Ebert 1992; Camilli & Ebert 1992). However, this requires a particular setting with open, sparsely populated, arid areas which is not possible in most situations in the Pacific Northwest where the very extent of known sites is often impossible to determine because of extensive plant cover or partial destruction from modern development. These schemes have, in fact, been accused of following a simple functionalist perspective that selects for areas of open and obvious prehistoric evidence (Wheatley 1993:137).

Even when sites are excavated, the researcher's particular agenda may not involve a search for information that would place the particular site into a settlement scheme. Trigger (1968) may place dwelling structures at the top of his list of insights into settlement but this does not help in a region such as the one being looked at here. After almost 50 years of archaeological research in the Lower Mainland and with records on over 200 sites, we have a grand total of *one* probable house structure having been excavated and that single find was made purely by chance during a project with a completely different research focus (Matson & Coupland 1995:161; Matson *et al.* 1991).

To these problems we can add the factors of a region presently covered by the third largest urban concentration in Canada. What sites we do know of are almost entirely the results of serendipitous discovery and any future survey would be hampered by the presence of hundreds of kilometers of concrete, asphalt, landfills, sea and river dykes, and modern housing.

If traditional ways of studying prehistoric land use place impossible demands on the archaeological record in most areas and have limited application in a coastal rainforest environment, it may seem folly to even attempt such a study. This is a depressing notion given that the Fraser is recognized as "one of the greatest producers of salmon in the world" (Kew 1992:178) and at the very heart of the so-called Developed Northwest Coast ethnographic pattern (Matson & Coupland 1995). One potential way around some of these problems is to approach the subject from a new perspective, that of *landscape*. Despite the busy efforts of over 150 years of Euro-Canadian occupation, post-contact activity has still not managed to entirely change every shoreline, obliterate every freshwater stream or flatten every hillside and headland. These elements still remain as sources of information on the sorts of terrain and environment that prehistoric users of the area adapted to.

The use of landscape here as a means of focusing research and grouping various types of data requires definition. In much of the literature on settlement landscape has acted as little more than a synonym for similar terms. In one of the pioneering attempts at using the terrain surrounding sites as a source of information it is referred to as the "natural environment" (Plog 1971:47). Other terms include "settlement space" (Wood 1978), an area of "economic zonation" (Binford 1982), a site's micro-, meso-, and macro- environments (Butzer 1982:39), "off-site archaeology" (Foley 1981) and so on. Recently an entire volume devoted to its use as a concept in archaeological research (Rossignol 1992; Rossignol & Wandsnider 1992) simply employs the term without actually defining it, but using it as a source of "ecological and geological system variables" (p.4). In a somewhat puzzling discussion, one writer sees it as a term "surprisingly difficult to define" (Roberts 1987:78) and then vaguely refers to it as "the assemblages of real-world features - natural, semi-natural, and wholly artificial" (*ibid.* 79). Finally, from a post-processualist perspective, landscape is a *story*: "the world as it is known to those who dwell therein, who inhabit its places and journey along the paths connecting them" (Ingold 1993:156).

In this study landscape is defined on a slightly more practical basis:

> a heterogeneous land area containing a number of important visible elements that influenced humans in choosing to interrupt their movement over the earth's surface and to persist in that place long enough to leave a material record.

This definition utilizes ideas taken from geography as well as landscape ecology. Landscape is first of all something we can see with our eyes, beginning as a *source* of information and then as a familiar *set* of information for the human viewer. A standard distinction that is made is between natural and cultural landscapes (Haggett 1965:11; Naveh & Lieberman 1994:11; McGarigal & Marks 1993) with the cultural landscape further partitioned as managed (eg. a pasture), cultivated (agriculture), suburban (town and country mixed), and urban (cities) (Forman and Godron 1986:286). Under this distinction modern-day Vancouver comprises almost entirely a cultural landscape with only the larger landforms and subsurface geology still unchanged.

For the work described here the landscape is regarded for the most part as a natural one, with the archaeological site representing only a small remnant of the cultural landscape that it once would have formed. In other words, the attempt here is try and view the landscape as the first settlers might have, albeit in a very simplified form. By extracting a small number of elements from this complex aggregate it is hoped that some fundamental statements about the prehistoric use of the landscape can be made. What is largely omitted here are the usual components of a settlement system analysis - the resources, the technologies, and the costs of operating within the system (time and distance involved in acquiring resources). This exclusion is generally because of the non-existence of these sorts of information for the majority of Lower Mainland sites.

Landscape Analysis and Geographic Information Systems

As noted above, the use of the surrounding landscape as a source of quantifiable information first achieved a highpoint in the early 1970's with the work of the Southwest Archaeological Group (SARG). Starting with the question "Why did the prehistoric inhabitants of the Southwest locate sites where they did?" (Plog 1971:45), their goal was to explain the distribution of archaeological sites using variables taken from both the natural and social landscapes. These would include water and soil resources, plant and animal communities, and various measured social distances between sites (Plog 1971:47-48). While these pioneering efforts made great strides in developing fieldwork methodologies (Plog & Hill 1971) and survey techniques (Mueller 1975), the ambitiousness and complexities of the problems they set for themselves may have proved too overwhelming for subsequent workers.

Their results often tend to close on a note of "more work is needed" (Plog 1978; Euler & Chandler 1978) and something of a hiatus followed.

Since then there have been a few small-scale attempts at integrating landscape variables into research (Schermer & Tiffany 1985; Kellogg 1987; Snyder 1991; Ellis & Waters 1991) plus one large study in a European setting that looked at complex Iron Age spatial patterning (Marquardt & Crumley 1987). Most recently, however, there has been a strong renewal of interest, largely as a result of new computer technology known as Geographic Information Systems.

These systems can be roughly characterised as putting printed map data into a computer where it can be subsequently viewed and manipulated. What they in fact entail, however, is something far more complex than the simple scanned-in images of a drawing or desktop publishing program. A GIS retains information on how various map parameters, (lines, points, text, and shapes), are defined in space (coordinates) and how they relate to each other. This information is in turn linked to attribute information stored in a separate database or data bases. Because the system operates as a relational database, all of this information can be brought together as standard map images either on a computer monitor's screen or as plotted paper output or it can be selected or manipulated in various different or new forms. Querying capabilities allow for a wide range of statistical and summary outputs. Figure 2 illustrates how a simple square would be stored in a GIS.

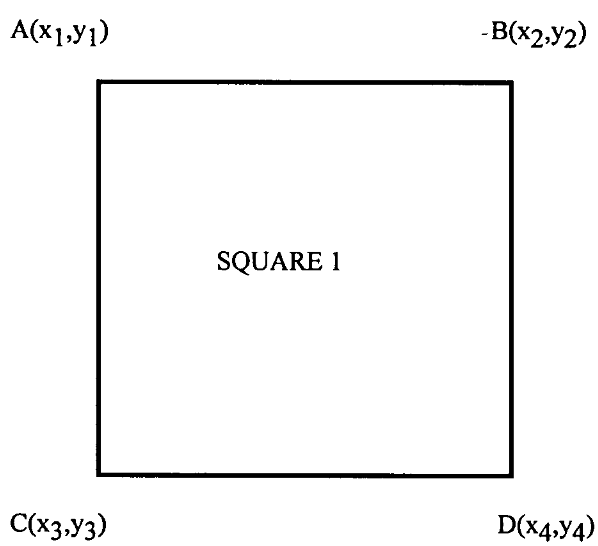


Figure 2: Storage of spatial information in a GIS.

Each of the four points A,B,C,D can be located in real-world terms (eg. as UTM coordinates); they form four distances (AB, AC, BD, CD) which in turn form an areal shape ("SQUARE 1") with its own label. Because each line is stored in terms of its relation both to the outside as well as the inside of the figure, a query could provide details on the figure's neighbours as well as its area and perimeter. From an attribute database special information can be stored. If this were a building lot in a municipal setting, for example, its assessed value and address might be external variables. As mentioned, the figure could be displayed on a screen or sent out to a printing device (Aronoff 1989).

The real power of a GIS is in the way it can store multiple sets of data in layers, all of which can be related to each other thereby creating new forms of data. Figure 3 is a simplified illustration of how water, elevation and cultural intrusions are represented by separate layers. A more sophisticated query, using all three layers could provide the elevation for the building plus its distance to the nearest stream, for example.

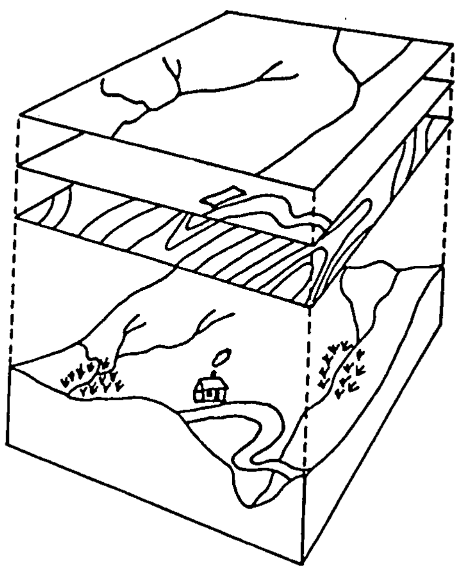


Figure 3: Storing data by layers in a GIS (from Gaffney & Stancic 1991:25).

A final aspect of how a GIS works is the way it actually encodes the data. This can take two forms, *vector* and *raster*. In a vector-based situation, the data are stored much as they are shown in Figure 3, as a series of points, lines, and text identifiers, all linked within a coordinate system. In a raster system the entire area of the map is defined in terms of individual pixels which vary in size according to the fineness of grain required. Figure 4 shows a comparison of the two methods. (In this example three landscape features, water, plants and buildings, are shown as being in the same layer). Some systems are based entirely on one or the other of these two storage methods. Others, such as the system used in this study, TerraSoft, employ both. Although raster-style storage is very useful for areal based analysis, it can require tremendous amounts of storage to maintain all of its information.

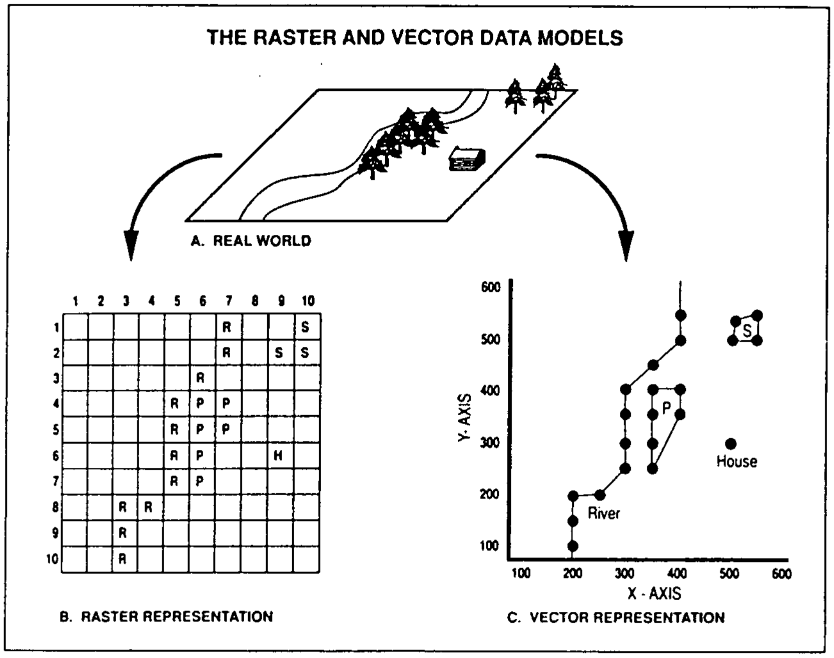


Figure 4: Raster vs Vector in a GIS (from Aronoff 1989:164).

GIS has found many uses in municipal settings and among resource applications, especially forestry. Whether or not it merits such kudos as "the biggest step forward in the handling of geographic information since the invention of the map" (Gaffney & Stancic 1991:13) remains to be seen. Much of GIS use so far by archaeologists has been partly driven by the novelty of it. Some projects have not involved much more than developing a familiarity with the systems and their capabilities (Green 1990; van Leusen 1993; Ruggles *et al.* 1993). Others have attempted to apply GIS to some of the earlier forms of settlement research such as catchment area analysis (Hunt 1992) and predictive modeling (Maschner & Stine 1995). Attempts have been made to carry out the sorts of analyses that were suggested by the people involved in the SARG projects. These involve trying to describe optimal locations on the basis of comparisons with soil quality (Gaffney & Stancic 1991) as well as aspects, distances to water, and separation between sites over the territory (Brandt *et al.* 1992; Kvamme & Jochim 1990; Kvamme 1992; Savage 1990). A collection of essays and reports from 1990, *Interpreting Space: GIS and archaeology* (Allen *et al.*), acts as an early signpost to these developments.

The Study Area

This area (see Figure 1) has been and continues to be dominated by the Fraser River, one of the great rivers of the world. At present, with a length of 1370 km, it drains over one-quarter of the province of British Columbia (Clague *et al.* 1983:1314). For the last 9000 years, following the opening of its basin after the last glaciation (11,000 years ago), the Fraser River has been building its delta (presently about 1000 square kilometers in area) out into the Strait of Georgia, currently at a rate of between 12 and 30 million tons of sediment per year (Williams & Roberts 1989:1658). Sea levels have been stable, fluctuating no more than 2 m in the last 5000 years (Clague *et al.* 1983:1325). In the last 2300 years the delta has extended itself about 5.4 km (2.4 m per year) (Williams & Roberts 1989:1665), about half the length of Lulu Island and all of Sea Island (see Figure 1). Boundary Bay would not have been affected by this recent growth since there is no indication of the Fraser entering it in the last 5000 years (Clague *et al.* 1983:1325). One consequence of this delta growth may have been the abandonment within the last one thousand years of two of the major archaeological sites in the area, the Marpole site (DhRs 1) and the Glenrose Cannery site (DgRr 6) (Burley 1979:557, 1980:58).

The Fraser River historically had and continues to have the status as "the greatest producer of salmonine fishes of any single large river in the world" with an annual production of about 14 million salmon (Northcote & Larkin 1989:172).

Cultural Background

We have evidence of human use of the mouth of the Fraser dating back 8500 years BP at the Glenrose Cannery site, DgRr 6 (Matson 1976) but the principal focus here is on the occupation from 2400 to about 1400 years ago, the so-called Marpole period. There is some overlap with the subsequent Late or Strait of Georgia period which dates from about 1400 BP to 200 BP. The culture associated with Marpole was first described by Charles Borden based on materials recovered from a large midden site within the Vancouver city limits - DhRs 1 (Borden 1950, 1970). This work was further refined by Mitchell (1971) and Burley (1979, 1980). It has been described as displaying

> the Developed Northwest Coast Pattern of winter villages with large plank houses, dependence on stored fish, usually salmon, abundant sophisticated art, and ascribed status, as well as seasonal moves to specialized resource procurement locations (Matson & Coupland 1995:224).

Archaeological research on Marpole sites in this area began with excavation at the Marpole midden at the turn of the century (Hill-Tout 1895; Smith 1903) but modern approaches and techniques only appear after the Second World War, work that for the period 1946 to 1970 is embodied in the efforts of one man, Charles Borden. Most of the sites used in this study were initially visited and reported on by Borden and many of them were in fact excavated by him. Following his efforts, archaeology in the Lower Mainland has been conducted in three main areas. Academic research, sometimes inspired by impending site destruction, has been carried out at the Marpole site (DhRs 1) (Burley 1979), Glenrose Cannery (DgRr 6) (Matson 1976, 1981), St. Mungo Cannery (DgRr 2) (Calvert 1970), Beach Grove (DgRs 1) (Matson *et al.* 1980), Point Grey (DhRt 5) (Coupland 1991), and Crescent Beach (DgRr 1) (Ham 1982; Matson *et al.* 1991).

Salvage activity has been conducted throughout the area, often producing very important and, in some cases, the only documentation (Archer 1972; Bernick 1989; Ham et al. 1986; Grabert & Spear 1976; Arcas Consulting 1991). As well there have been a number of surveys of the area. None of these has been of the probabilistic variety and most have been conducted for various heritage conservation and monitoring purposes (Kenyon 1953; Kidd 1964; Cranny & Bunyan 1975; Bussey 1985; Ham 1987, 1988; Ham et al. 1978; Bernick 1991; Eldridge & Mackie 1993b). In essence then, the archaeological record for the mouth of the Fraser is by and large the product of serendipitous discovery and it has rarely been on any particular investigator's agenda to relate particular sites to the specific settlement of the Fraser Delta region. The usual result is to assign a type of activity to the site which in turn is linked to the broader pattern of the seasonal round. As Matson and Coupland point out "Northwest Coast archaeology has traditionally been 'single site oriented'" (1995:313) and Thompson's 1978 work on the Skagit River delta of Northwestern Washington stands as the only attempt at describing settlement patterns in the Gulf of Georgia area.

The last source of information reviewed here is the ethnographic research conducted in this area. The Mouth of the Fraser is the traditional territory of the Central Coast Salish people, particularly the Downriver Halkomelem speakers of the Lower Mainland (Suttles 1990). They include the Musqueam in the Vancouver city area, the Tsawwassen to the south at Point Roberts, the Kwantlen and Katzie further inland on the Fraser, and the Nikomekl in the area of the South Fraser extending down into the United States. In addition to the Halkomelem, Squamish speakers to the immediate north have had regular influence over Burrard Inlet. The region has seen a number of ethnographic investigations carried out, including major ones by Suttles (1951, 1955, 1987), Barnett (1955), and Duff (1952).

The focus on settlement and its relationship to the surrounding terrain, however, remains sketchy. Barnett makes a few general points:

> Villages were located near the mouths of rivers on sheltered bays or inlets out of reach of storms and marauding strangers
> .... interest centered upon beach sites conveniently located with respect to gathering and hunting grounds
> .... the village groups occupying simultaneously or in turn several traditionally assigned spots for their hunting, gathering and wintering activities. The winter villages are always to be regarded as the foci of these pursuits. (1955:18-19).

Suttles is more direct when he describes the shore as a critical element in the Salish landscape, "the midline in the life of man" (1951:46).

A few other small hints can be culled from these works. In the summer the local soil was not a very important consideration for dwelling structures but in winter solid supportive soils were needed for the big plank houses (Suttles 1951:46). A prairie was important to have close to a winter village for camas and other bulbs (Suttles 1951:59). Other "nice to have" features included mudflats, eel grass beds, and protection from northeast and southwest winds. Fishing locations and root and clam beds were, in many instances owned by certain family groups (Suttles 1951:56). Cedar was critical for both its wood and its bark for use in building, basketry, netting, and a variety of other household items while Douglas fir was employed apparently only as a fuel (especially its bark) (Suttles 1951:48). Both Barnett and Suttles pretty much avoid the topics of sewage and garbage disposal and the subsequent possibility for local pollution. Suttles makes one minute mention of a location translated as "feces net", stating that "the name comes from the fact that the beach was used as a latrine" (1951:207). He does not expand on this further so we can only speculate that this might have been the standard sewage disposal method. Barnett makes one mention of ritual disposal of animal and salmon bones (1939). Leonard Ham, citing an American ethnographic example from Oregon, says the shell refuse was always placed in specific locations around permanent settlements and, using the Beach Grove site (DgRs 1), speculates that these may have been between and behind the houses (1982:160-162). In his view the beach/shoreline represents a critical interface for daily activities. In another archaeological setting further to the south on San Juan island, the habitation area was on the highest, best drained part of the site and the refuse was dumped into the intertidal zone adjacent to it (Whittaker & Stein 1992).

The last issue to be discussed here is the apparent regular movement from location to location. "Nature is exploited by the intensive use of specific places at specific times in the year ... the yearly round is fairly rigidly determined" (Suttles 1951:50); or as an archaeologist has put it "We all know the people moved around a lot and that they did so as a means of acquiring various resources from various places during the year" (Mitchell 1983:97). It is important to emphasize that Suttles was describing the lifeway of a particular group of Salish who were located in more of an island setting (the Haro and Rosario Straits south of the area being looked at in this study). In the case of the Lower Mainland, researchers are not so sure. There is a hint of a less mobile pattern in the above quote from Barnett of *simultaneous* occupation, ie. not seasonal abandonment; plus Mitchell states that "Most of the Musqueam people remained in residence at their principle villages ... from fall to spring. Some villagers seem also to have stayed there through the summer." (1983:101). Finally, the travel distances involved here do not necessitate the wholesale movement of people from one resource area to another. Ethnographic records of canoe travel suggest that no location in the study area would be more than a single day's journey (Croes & Hackenberger 1988:35; Sproat 1868[1987]).

The sense from this is that many sites may not have had to accommodate most or all of a village on a particular visit. Short term usage by smaller numbers may have been a more typical pattern. What this says in terms of site structure is that the larger village sites would have had extensive year-round use while more limited activity locations would have seen more of camp or work station type visits. This problem of mobility and the image it presents of land use has recently led to renewed warnings on the way the ethnographies are used. Ford cautions that, even with good data from the site, we cannot easily determine a seasonal use or abandonment (1989). Bernick and Wigen present a similar case where a focus on one resource (Chum salmon) may have skewed the entire sense of how a particular site was used (1990). One study where the author had good data on site locations as well as prime salmon harvesting areas could not conclusively link the two (Hobler 1983).

Finally, some of the mobility that was described by Suttles and Mitchell may have been the result of the movement of European colonisers into the region. A recent investigation of Kwakwaka'akw post-contact settlement shows what a radical impact it had on a stable sedentary lifeway (Galois 1994). A study on the Dena'ina of Alaska also relates how disease, white settlement, and the introduction of the trading post as a new economic focus greatly disrupted the old settlement structure (Ingold 1992:792).

One implication from all of this is that the presence of a big and important resource (salmon) may have determined the overall general location of people in the mouth of the Fraser region, but this initial motivation is superceded at some point by the choice of specific locations based on optimal landscape elements.

Methods

Model

The model employed here states that site location is the outcome of a choice made by actors operating within the settlement system (*i.e.*, it is not a random point on the landscape). We gain information about that choice by attempting to describe the settlement space (Wood 1978). This can be done by first determining the values for a select set of environmental and topographic variables related to those site locations and then comparing these values to see what patterns (if any) exist among them. A comparable set of random points is used as a check on such patterns.

The objective here is to relate fundamental landscape information to settlement choice and from that information develop basic descriptions of Marpole period land use for the mouth of the Fraser region. This is somewhat in contrast to much of the current activity in settlement pattern studies which involve site prediction, a harkening back to the enthusiasm for predictive modeling in the 1970's and early 80's (Williams *et al.* 1973; Carr 1985; Parker 1985). Some of this renewed interest is directly related to the powerful data capturing abilities of GIS computer software plus demands being placed on cultural resource managers by governments and, in turn, major resource companies (Warren 1990; Carmichael 1990; Altschul 1990; Eldridge & Mackie 1993a). For this reason, this study does not provide a detailed profile of the entire landscape itself. It is used instead as a source of new variables and new attributes that can add to our knowledge of archaeological sites. (For an example of trying to describe the broader landscape in terms of chunks of empty, non-site spaces to be compared with chunks containing sites, see Maschner & Stine 1995).

Hypotheses

A number of interesting problems specific to Marpole settlement have been raised. Ham (1982:359) states that "all of the major archaeological sites in this area are either multicomponent, or consist of a complex of sites from different time periods in close proximity to each other". In contrast, Croes and Hackenberger (1988) felt that a shift had taken place during this period away from marine shores to more riverine and estuarine areas. Thompson (1978) saw the adaptation as still fairly diffuse during Marpole with, as yet, no particular focus on any resource or geographic region. As already mentioned in the Introduction, however, it was felt that in this study, with the landscape being primary, questions should be of a more "generic" nature. Three hypotheses have been formulated to guide the research process. The first looks at the issue of randomness.

> A comparison of the landscape variables will demonstrate that archaeological sites in this study are not randomly arrayed across the region.

This basically involves comparing variable values at both actual and random locations. In some cases, the overall background is looked at, particularly for the two sets of environmental variables, vegetation and soils.

The second hypothesis looks at local topography for clues as to differences and similarities among the sites.

> Since similar solutions were used to overcome similar topographic restrictions, some variables will show that sites are found on or near certain landforms throughout the study area, specifically on or near the lower levels of a rising headland.

This primarily involves looking at variations in elevation within the immediate site area. As well, since a freshwater stream and distance to a major shoreline are considered critical, these distances are measured as well. Again comparisons are made with the set of random points.

A most basic attempt at a site typology is made using these data, trying to distinguish extended use habitation sites and more limited use sites.

> Habitation sites, deemed to be at "the center of exploitative activities in general" (Plog & Hill 1971:13), will display *greater diversity* of environmental and topographic variables.

This again involves a comparison between actual site locations and random coordinates. The presence or character of certain variable values should show habitation sites sharing specific attributes in a combination not found at other site locations.

Data Sources

Sites: Within the study area, information on over 180 prehistoric sites was reviewed for possible inclusion in an inventory of Marpole occupation and use locations. (See Appendix A for a sample of the form used in this selection). The sites were chosen from this period because they are the the best represented in the archaeological record for the Lower Mainland. A small sample, for example using the preceeding St. Mungo or Locarno Beach period sites, would not have provided a sufficient test case for the landscape analysis. This review involved checking Archaeological Site Inventory Forms completed by investigators in the region over the past fifty years. These forms are part of the initial site designation process required by the Provincial Government (Apland & Kenny 1989). Wherever possible other sources of information were also used. These included university undergraduate reports and graduate theses, consultant reports, survey reports, field notes, journal articles, and books.

From this material, 62 sites were chosen as being either definitely in use during the Marpole period or highly likely to have been so. This number is in rather marked contrast to the usual interpretation for this region. Out of the 40 sites that Matson and Coupland are willing to designate as having a Marpole component (1995:Table 7-1, p.202) only 17 are in the area reviewed here. Some sites included here would fit better in the subsequent Late period but owing to the problems of dating the end of Marpole, it was thought that their inclusion here was justified (Matson & Coupland 1995:218). Other sites which we know very little about are included because of the presence of diagnostic artifacts, the site being of large size, or close physical association with known Marpole sites. Appendix B lists these sites along with the justification for their inclusion.

Random Locations: Using a random number generator (SYSTAT Data 1992) and the UTM coordinate range for the area under study, 300 point locations were produced. These in turn were automatically plotted on the map by the GIS software. At this point it was decided to restrict the map area to a buffer zone 2 km inland from all marine and riverine shorelines as none of the selected sites were outside this strip (see Figure 1). All random points that fell outside of it were removed from the map. As a result, 80 random points were retained.

Maps: The base maps for the Canadian locations at a scale of 1:20,000 were Terrain Resource Information Management (T.R.I.M.) maps produced by the British Columbia Ministry of Lands and Parks in both digital and hardcopy form. American map information was derived from US Department of the Interior Geological Survey maps. Soils information was taken from surficial geology maps (Vancouver, New Westminster) produced by the Geological Survey of Canada (1978). Vegetation cover came from *Vegetation of the Southwestern Fraser Lowland, 1858-1860* (North *et al.* 1979). Since many of the old streams are now confined to sewer pipes if they exist at all, information on them was taken from the vegetation map, *Waterways of Burnaby* (City of Burnaby 1993), and *Vancouver's Old Streams* (Harris 1989). Because the T.R.I.M. maps use the new North American Datum (NAD 83), all the other maps which used NAD 27 had to be adjusted to match it. This was necessary because when a map is digitized for use in a GIS it must be *registered* in real space, in this case to coordinates in the Universal Trans Mercator (UTM) projection system. With the NAD 83 correction there was a slight shift in these coordinates of about 95 metres on the Easting and 200 metres on the Northing; therefore, no map drawn according to NAD 27 quite matched the T.R.I.M. maps. All such non-T.R.I.M. registration points had to be fed into a "geographic calculator" for correction (The Geographic Calculator Version 2.0 (1993)).

Initially climate, in the form of wind, precipitation, and temperature data (Oke & Hay 1994), was to be used in this study. The lack of differentiation in these values across the region, however, led to their deletion.

Data Summary and Analysis

The Geographic Information System used here was TerraSoft, a software product developed in Nanaimo, British Columbia and used extensively in forestry applications. Once all digitizing was completed two further elements were added to aid in collecting information about the local area surrounding each actual site location and random point. This was done by drawing a 50 and a 500 meter buffer around each point. The 500m buffer was used to look at local vegetation, soil types, and slope and elevation values (see Figure 8). The 50 m buffer was used to determine an aspect value for each site (the general direction it faces, sometimes referred to as exposure).

As already discussed, although the map used here was created as a vector file the TerraSoft system has the capability to convert vector data to raster. In order to determine elevation, slope, aspect and viewshed information a raster file was necessary. A fifty meter pixel size was used and, because of the number of processing tasks involved and the time required to perform them, the overall map was broken down into smaller raster maps. For example, a map of this size (2500 km^2) would involve approximately 550,000 pixels if converted to raster in its entirety, and, since some of the routines involve checking *every pixel* in the map (viewshed for example), the processing becomes onerous.

The goal at this point was twofold - to summarize the spatial data and to attempt some analysis of this material. In their present state of development, GISs are most noted for their summarization abilities. Spatial information can be manipulated to produce new variables or forms of data. Visual displays, either on computer monitors or hardcopy graphic images, can answer many basic inquiries. Since most of the raw data is stored in a series of relational databases, this can be retrieved in tabular form with some basic summary statistics. The analytical power of these systems is, however, quite limited. The investigation of patterns, seeking relationships between patterns, and the modeling of such relationships remains outside of the GIS itself (Bailey 1994). In the case of this exercise this further manipulation of the data has been done using the statistical software package SYSTAT for Windows (1992).

The first set of information was taken directly from the map displayed on the monitor using the distance measuring facility. These were distances from both actual and random site coordinates to the closest shore, stream, and nearest site (See Appendix C). Again using the vector map files, all vegetation and soil polygons within the 500m buffer of each active site and random point along with their intersected areas was determined (Appendices D and E). Figure 8 illustrates how this measurement was done. For many sites, close proximity to either a marine or riverine shoreline often reduced the total land area for the buffer, therefore this "aquatic" area was also determined.

Using separate rasterized segments of the larger map, minimum, maximum, and mean elevation as well as slope values were calculated for the 500m buffered area around each actual site and random point location. This was done by recording elevation and slope of each pixel in the buffered area, passing this information into a database (dBASE III+) and then into SYSTAT where these values were weighted by their total areas within the buffer. (See Appendix C). For example, if from the GIS we learn that 40 of the pixels within the buffer show an elevation of 17 m, 20 show 14 m, 10 show 11m, and 30 show 9 m, each pixel type is weighted by the total as follows:

$$\frac{(40 \text{ X } 17) + (20 \text{ X } 14) + (10 \text{ X } 11) + (30 \text{ X } 9)}{100} = \text{an average of } 13.4 \text{ m for the buffer.}$$

Since aspect was determined in a similar way, it was felt that the variations present in a 500m buffered area would be too great and ultimately meaningless, therefore, a 50m buffer was used instead. This resulted in the manual averaging of at most 4 pixel values (degrees from north) to determine a typical "most viewable" direction for each site (Appendix C).

The final set of information drawn from the GIS came from the viewshed analysis. This type of measurement is seen as being a truly original capability of a GIS (B. Klinkenberg, personal communication). Only a computer can perform the millions of calculations required to examine the elevation value of each pixel in every direction from a point on a map to determine if or at what point the view is obstructed. This viewshed capability, however, is not used here to measure what an individual might be able to see from a vantage point located at a site.

This has proven fruitful in some situations where sufficient elevation can be achieved or where there is little or no tree cover (eg. Kvamme 1992:77). The presence of extensive forests in the Lower Mainland area, however, would prevent much lateral or landward viewing. At the same time, with most sites being on or very near a shoreline, good views out over the water would be present in most cases.

Instead, the viewshed analysis was used here as a measure of "openness" around a site, of how much relatively unobstructed movement would be possible inland from the shore, as well as laterally to either the left or the right, while remaining in view of the site. Hills, cliffs, bluffs, and headlands would act as natural boundaries (although not insurmountable ones) to easy movement in the immediate area of the site. The assumption here is that habitation sites would have broader and deeper viewshed areas compared to limited activity sites. (The exception being sites located in totally open environments such as the Fraser Delta). This information was added to the other distance measures (see Appendix C).

The Variables

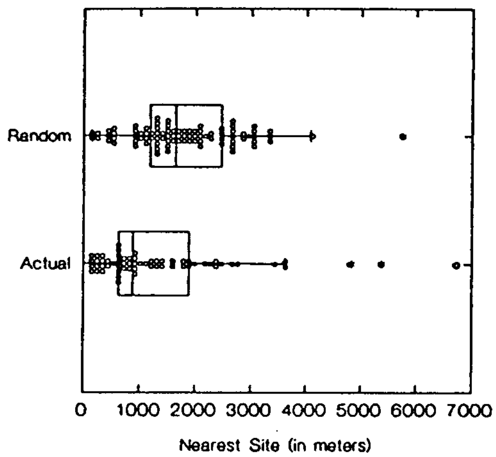
Distance Measurements

The three distance measurements, to the nearest site, marine or riverine shore, and freshwater stream, were examined using box-and-dot plots and stem-and-leaf diagrams (see Figures 5, 6, and 7). This was done for both actual sites and for the random points. Despite the appearance of obvious dissimilarities between the actual and random values, a further comparison was done using a Mann-Whitney test (SYSTAT Statistics 1992:480). Both sets were melded into one file with each record identified as either "a" for actual or "r" for random and then the resulting data was tested to see if it could form a single population. As can be seen from Table 1, none of the three variables show any similarity between the actual and random samples.

Table 1: Comparative Statistics - Actual Sites and Random Points
(Distance Values in Meters).

	NEAREST SITE	STREAM	SHORE
Mean ---- Actual	1386	441	219
Random	1796	943	794
Median -- Actual	881	248	95
Random	1648	699	741
Mann-Whitney	1805	1704	1231.5
Probability	0.00	0.00	0.00

From the box plots, stem-and-leaf diagrams, and the statistical results a number of observations can be made. Looking first at the NEAREST SITE variable, we see that with the randomly generated points there is a near normal distribution of intersite distances (based on a visual examination of Figure 5a and 5c as well as the closeness of the mean and median values in Table 1).



a)

```
MINIMUM IS:           133.
LOWER HINGE IS:           627.
MEDIAN IS:            881.
UPPER HINGE IS:          1887.
MAXIMUM IS:          6731.

0  11112222333344
0M 56666666666777788888
1  01222244
1H 667888
2  02333
2  567
3  4
3  66
   ***OUTSIDE VALUES***
4  8
5  3
6  7
```

b) Actual

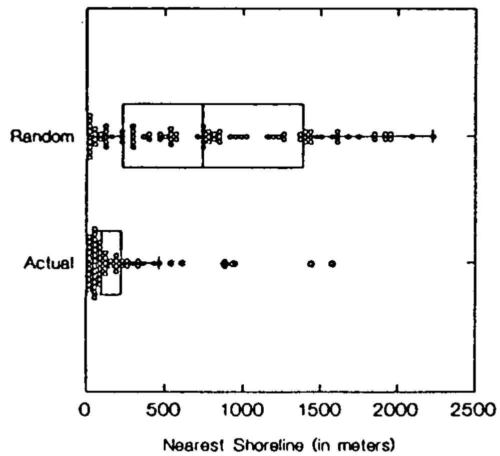
```
MINIMUM IS:             138.
LOWER HINGE IS:            1192.
MEDIAN IS:             1648.
UPPER HINGE IS:            2471.
MAXIMUM IS:            5740.

0  1122444
0  555588999
1H 0011112222233333344444
1M 555566668888899
2H 0000000122444
2  56666666889
3  00000333
3
4  0
   ***OUTSIDE VALUES***
5  7
```

c) Random

Figure 5: NEAREST SITE.

From this, then, we can assume that they provide a reasonable representation of the background environment. The actual site locations, in contrast, however, show something different. The median value is opted for here, rather than the mean, because of skewness in both Figures 5a and 5b. This value, 881 m, is almost half of the one determined for the random points, 1648 m, and indicates that, where sites are found, we can expect at least one other site within the space of a kilometer or less. Also we can state that, whereas random points are arrayed in a more even fashion across the landscape, actual sites tend to be found in groups. A probable explanation for the outliers among the actual sites (see Figure 5b) is that they are in areas where survey work is spotty or where most sites are deemed to have been obliterated by modern development.

The situation for the other two distance variables is, if anything, even more striking, especially with the SHORE values (Figure 6). Here, while the random points fall close to the midpoint of the 2 km buffer, (a median 741 m in from the shoreline), the actual sites are located almost entirely within 200 m of it (a median value of 95 m). With the STREAM values (Figure 7), despite the presence of a greater number of outliers (Figure 7b), we can still see that the majority of actual sites are within 500 m of fresh water versus 1200 m for the general landscape (Figure 7c).



a)

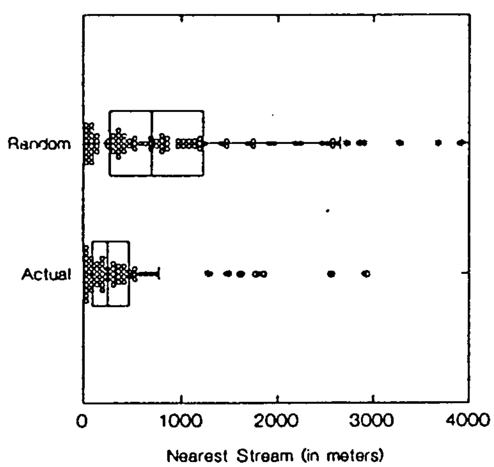
```
MINIMUM IS:            6.
LOWER HINGE IS:          45.
MEDIAN IS:            95.
UPPER HINGE IS:         220.
MAXIMUM IS:         1576.

OH 01222222233344444444
OM 55666778899999
1  0011244
1  899
2H 012
2  778
3  12
3  7
4  2
4  6
   ***OUTSIDE VALUES***
5  4
6  1
8  78
9  3
14 4
15 7
```

b) Actual

```
MINIMUM IS:               0.
LOWER HINGE IS:            229.
MEDIAN IS:               741.
UPPER HINGE IS:           1386.
MAXIMUM IS:              2225.

0     00000000334558
1     0111124
2H    23378999
3     689
4     779
5     234467
7M    123556789
8     12335
9     258
10    0
11    59
12    456
13H   579
14    0112569
15    5
16    0116
17    6
18    36
19    0256
20    0
22    2
```

c) Random

Figure 6: SHORE.



a)

```
MINIMUM IS:            0.
LOWER HINGE IS:          93.
MEDIAN IS:           248.
UPPER HINGE IS:         467.
MAXIMUM IS:         2931.

0  000001244
OH 55666999
1  0122
1  5599
2M 000123
2  67889
3  12
3  56889
4  233
4H 67
5  001
5  6
6  2
6  8
7
7  7
   ***OUTSIDE VALUES***
12 7
14 9
16 1
17 7
18 5
25 5
29 3
```

b) Actual

```
MINIMUM IS:               0.
LOWER HINGE IS:            268.
MEDIAN IS:               699.
UPPER HINGE IS:           1228.
MAXIMUM IS:              3922.

.0    0000011157788999
1     1136
2H    34899
3     3344666899
4     245
5     344
6M    049
7     002688
8     12577
9     59
10    2357
11    16679
12H   6
13    8
14    56
17    127
19    25
21    8
22    6
24    5
25    179
26    5
28    5
29    0
32    7
36    7
39    2
```

c) Random

Figure 7: STREAM.

Even with actual site values showing discrepancies via outliers we can still conclude that interesting patterns are displayed here. There is definite selection for nearness to shorelines and streams and also a tendency for the sites to not stand isolated on the landscape but rather to form clusters or groups.

Vegetation and Soils

These variables describe the local environments of the sites. However, they present some limitations. The vegetation map produced by North et al. (1979) does not cover the entire area looked at in this study, extending north only up to latitude 49° 15' and south to the US border. Thus, only 34 of the actual sites and 50 of the random locations could be looked at. The soil maps were more extensive but soil types that matched the Canadian system were lacking for the four US sites and they were excluded. The other note of caution is that the vegetation data are for the mid-19th century and can at best be an estimate of the plant communities of two thousand years ago.

As already mentioned, a circular 500m buffer was drawn around each site location (see Figure 8). This was not meant to indicate anything like an original site area but rather to capture a space in which the local site environment could be explored. In the GIS this buffer was made to intersect information from other parts of the database. This is the so-called layering capability of a GIS where a site buffer "layer" is placed over a vegetation or soil "layer" and, like a cookie cutter, removes the local information. For each layer two sorts of information result, first, the number and identity of vegetation or soil areas within the buffer, and, second, their areas.

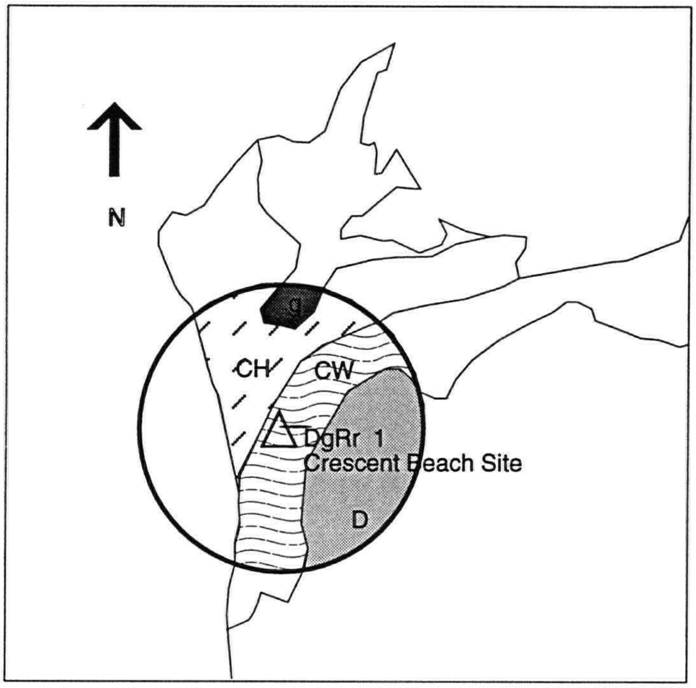


Figure 8: Vegetation polygons intersected at DgRr 1 - Crescent Beach.

In analysing the results for these variables three assumptions were made:

1. the actual sites would not parrot the background environment
2. the sites would align with certain soil and vegetation types more than others and not in proportions identical to the general landscape
3. particularly in the case of vegetation, they would show greater numbers of types in the immediate vicinity of a site than the random locations.

Figure 9 compares both sets of locations to the general background environment. (The background here is limited to the 2km strip around all shorelines from within which actual sites and random locations were taken). Both sets of site locations bear a reasonable resemblance to the overall vegetation landscape. The discrepancies are discussed for each variable.

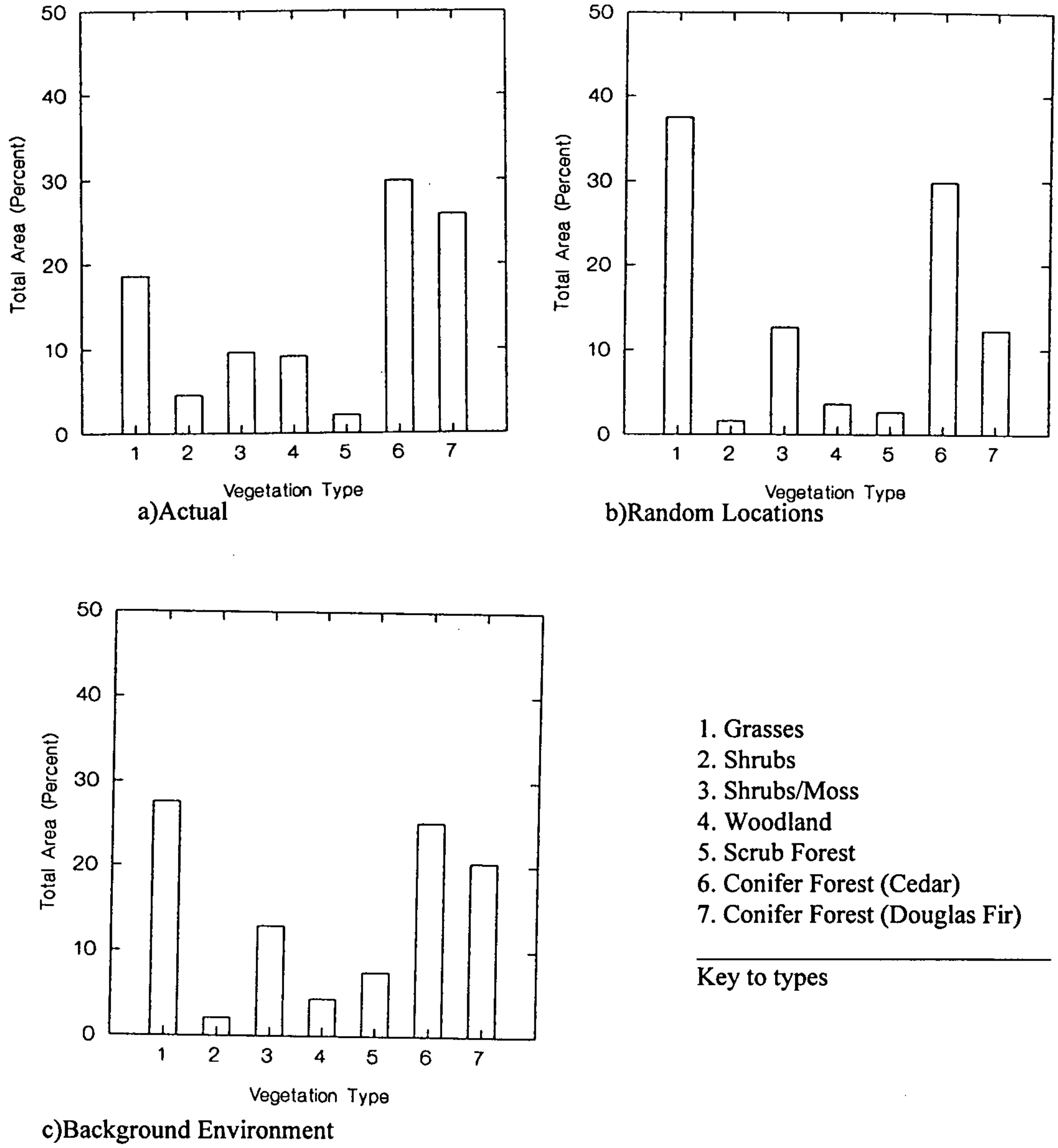
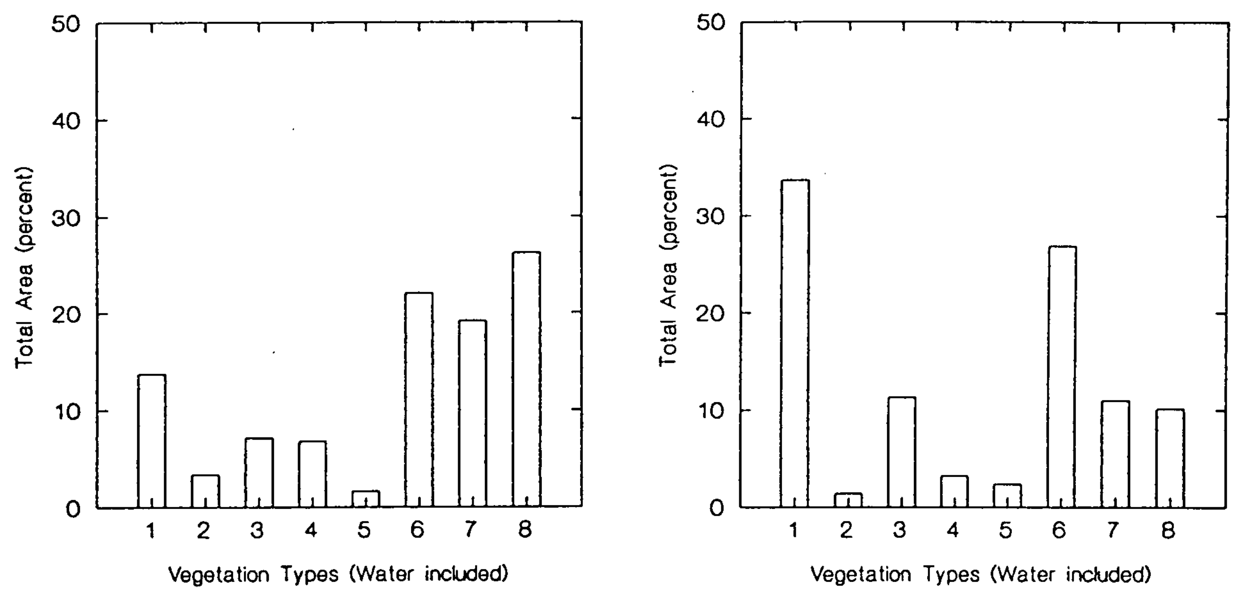


Figure 9: Vegetation Area Comparisons.

Vegetation: In addition to the seven general plant groups used by North *et al.* (1979), (see Appendix F for the complete list within the groupings), the area of any marine or riverine water intersected by the site buffers is also shown in Figure 10 (as "Type 8"). As expected from the previous analysis of distance to nearest shoreline, the actual sites show three times the water area of the random locations. This fits well with what we know of the importance of the resources from the marine foreshore in the lifeway.

The first noticeable discrepancy between the actual sites and the background environment (Figures 9a and 9c) is that the actual sites are half as likely to encompass the grass communities, vegetation type 1. With the two communities of smaller tree types, vegetation categories 4 and 5, actual locations are almost the opposite of the background environment. The "woodland" community is almost double what might be expected, and "scrub forest" less than half the proportion in the general landscape. The woodland group is typically made up of maple, alder, cottonwoods, and some willow. Alder particularly is the first tree to grow in recently vacated areas (for example, following a fire) (Slaymaker et al. 1992:34). This may indicate local clearing practices around sites either for wood products or the maintenance of a prairie environment.



a)Actual b)Random

Figure 10: Vegetation profile including intersected water

One of the problems with presenting data in the manner of Figures 9 and 10 is that it does not tell us very much about how locally complex the vegetation really is. Is it a matter of the entire buffer being dominated by a particular plant community or are many represented at each location? In the case of the actual sites 76% (26 out of 34) had 3 or more communities within their 500m radius. Figures 11a and b try to illustrate this. They show the actual numbers and sizes of the communities intersected in the two situations. As a result, we see that in an actual site setting there is a finer grained selection of plant groups; the polygon areas are smaller but also more numerous. A random location tends to be dominated by a single plant type. The 50 random point buffers intersected a total of

127 plant polygons, an average of 2.5 per site; the 34 actual sites intersected 131 polygons for an average of 3.9 per site. Somewhat puzzling here are the slight discrepancies between the random locations and the background environment, especially in the case of vegetation types 5 and 7. The assumption here is that this is a product of sampling error.

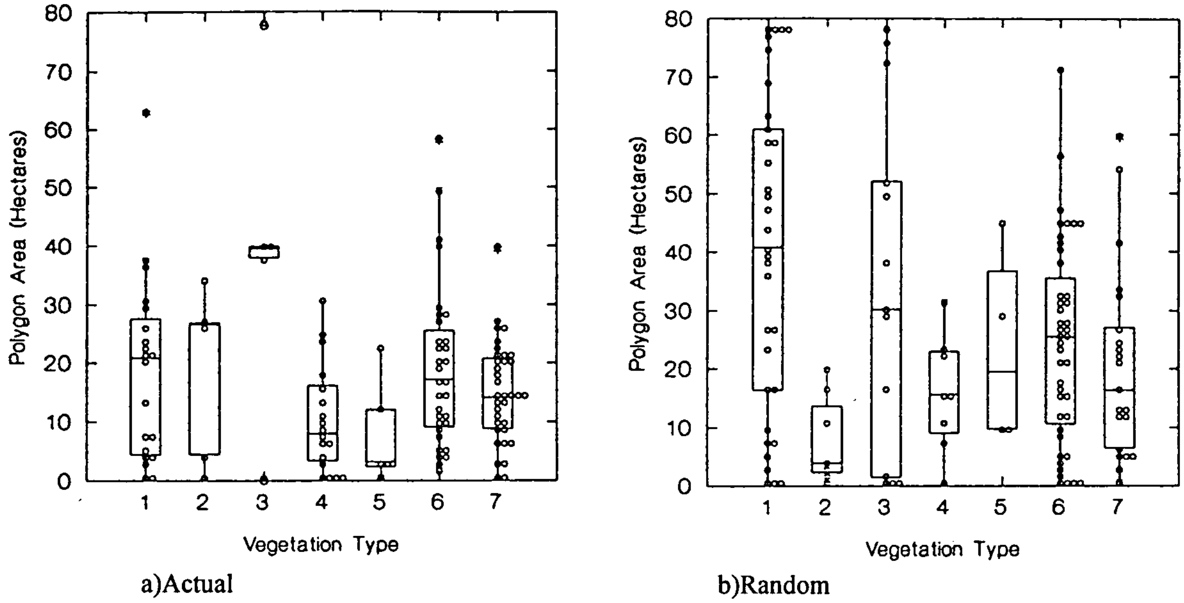
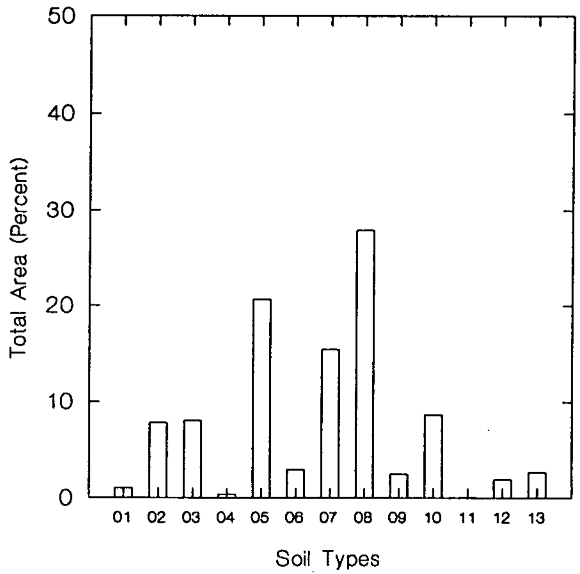


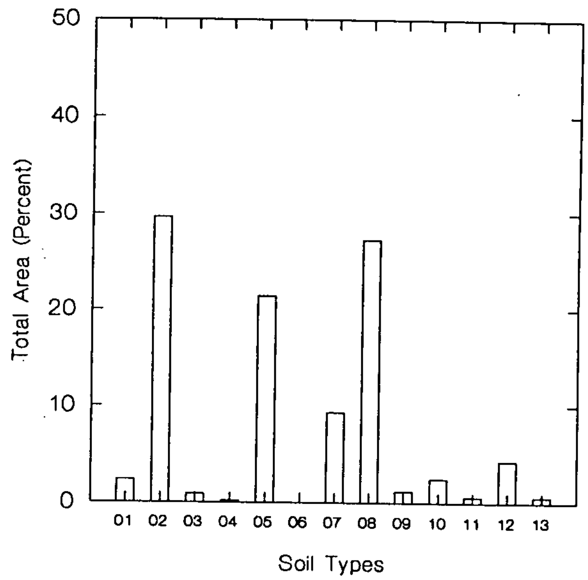
Figure 11: Site size by Vegetation Type.

At this point two general statements are possible about vegetation. There is indication that with the actual sites there is a selection for more arboreal surroundings, particularly the large conifer communities (vegetation types 6 and 7). There is also evidence for a more diverse vegetation mosaic within the immediate area of actual sites as was seen in Figure 11. A closer examination of this diversity will be presented below.

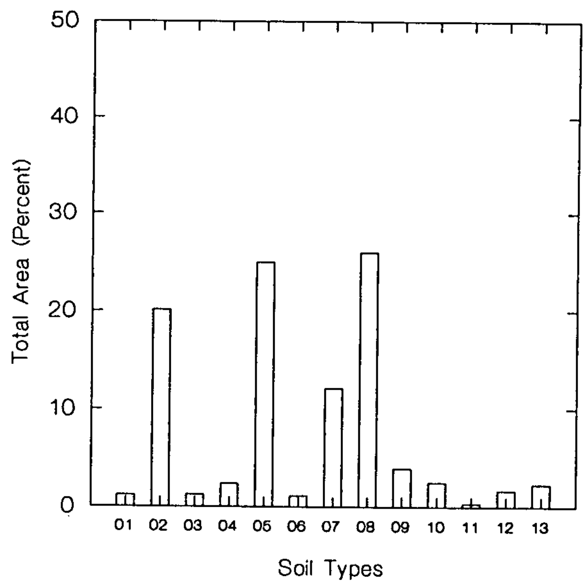
Soils: Although we can assume that soil type is a less critical variable for a non-agricultural people, it can play a factor in the placement and the type of housing. The analysis here was carried out in the same fashion as with vegetation, again using the 500m buffers. (See Appendix G for a detailed list of the soil types). The results show that the actual site locations follow fairly closely the distribution of soils in the general landscape (Figures 12 a-c). A major discrepancy occurs with soil group 02, bog, swamp and shallow lake deposits, which is fairly self-explanatory. There is a slight tendency to select more for marine shore deposits (soil group 03) which is again to be expected with the close association between actual sites and shorelines as already discussed.The high correlation with the general landscape on the Fraser River sediments (soil group 05) was a bit surprising but these soils do intrude well into the Point Roberts and Marpole areas, both with a fair number of sites. A higher than expected presence of Pre-Vashon deposits (soil group 10) is also interesting since these are quite rare as surface soils but where they do occur, on the outer edge of both Point Grey and Panorama Ridge, we do have a number of sites.



a)Actual Locations



b)Random Locations



c)Background Environment

01 Landfill
02 Bog, swamp, shallow lake deposits
03 Marine shore sediments
04 Lowland and mountain stream deltaic, channel fill
05 Fraser River sediments
06 Marine shore & fluvial sand
07 Capilano sediments - raised marine, deltaic & fluvial deposits
08 Vashon Drift & Capilano sediments
09 Vashon Drift
10 Pre-Vashon deposits
11 Undivided Pre-Vashon deposits
12 Tertiary
13 Pre-tertiary

Key to Types

Figure 12: Soil Area Comparisons.

Looking at the second part of the display of this data (Figures 13a and b), it is harder to discern distinct patterning. Almost in opposition to what was observed with vegetation, the actual sites tend to intersect *larger* soil polygon areas than the random locations do. One example is the Fraser River sediments (soil type 5). For random locations the polygons appear to be almost half the size of those for the actual sites. Part of this is due to the overall larger size of the soil polygons; in this case there are more sites (n=55) intersecting fewer polygons (n=118) for an average of 2.0 per site. There is also, however, no reason to suspect that the original settlers would have looked for diversity in the local soils if their primary consideration was for solid and stable foundation for dwellings.

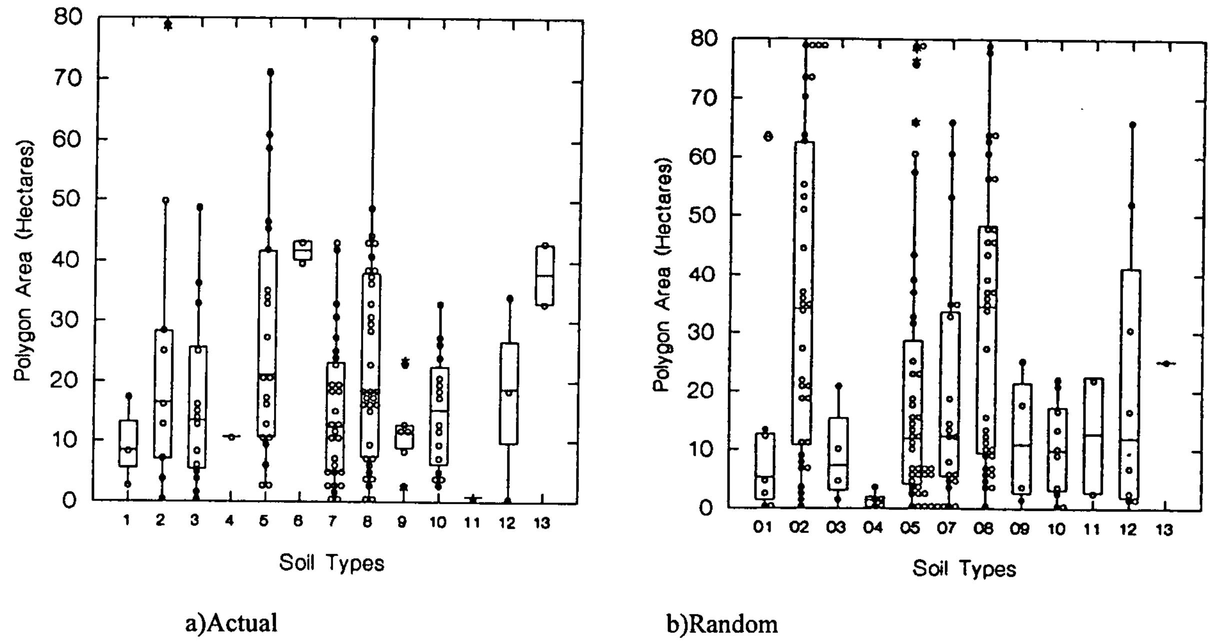
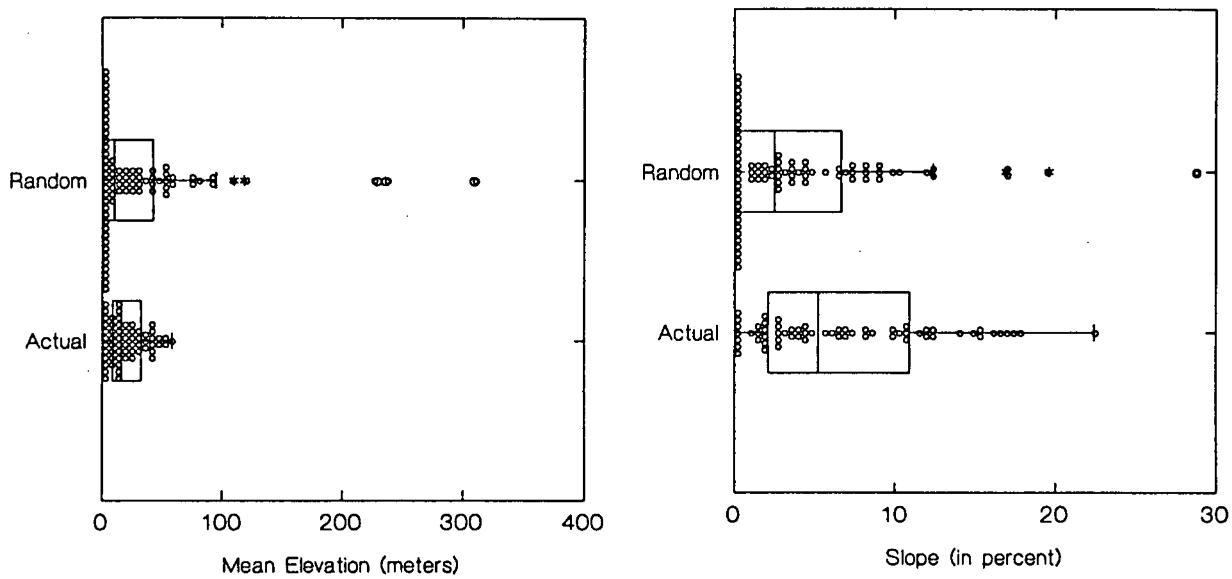


Figure 13: Site size by Soil Type.

<u>Topographic Variables</u>

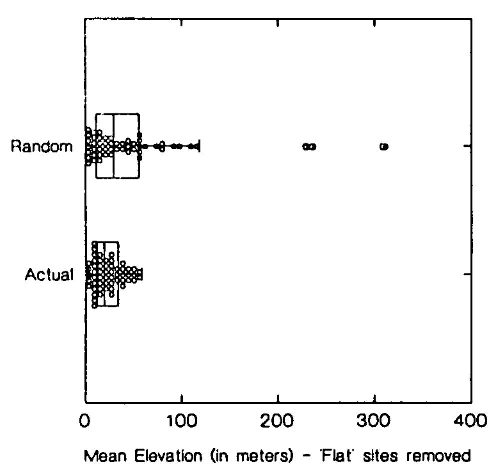
This section again uses the method of looking at the contents of a circular buffer around each site to gather certain generalised information. Without knowing the center or extent of the sites it is unreasonable to expect that an elevation, slope, or aspect value taken at just one single point truly represents the situation at that setting. Once an average value for these variables was obtained for each actual site and random location, the procedure was much the same as for the three distance measures already discussed. Figure 14 provides a basic graphic comparison of the actual and random elevation and slope values. One problem with these particular measurements, however, is the high number of random point locations located in *flat* regions, particularly in the Fraser Delta Lowlands. 27 of the 80 random locations fall into this category whereas only 7 of the 62 actual sites do so. While this immediately tells us something about the actual site choices that were being made, it also may unduly bias further understanding about the overall elevation, slope, and aspect. For this reason all "flat" locations were removed from both datasets. Figures 15 and 17 show the results including stem-and-leaf diagrams.



a) b)

Figure 14: ELEVATION and SLOPE - all sites and random points included.

Looking at the ELEVATION variable first (Figure 15), we can see that for the random locations (or the general non-flat background landscape), the situation is quite skewed because of the inclusion of a few high elevation locations. The actual distribution, however, approaches an almost normal shape.




```
MINIMUM IS:           3.
LOWER HINGE IS:         12.
MEDIAN IS:           19.
UPPER HINGE IS:         34.
MAXIMUM IS:          58.

      0  2334
      0  5677899
     1H  001111223344
     1M  56889
      2  01144
      2  556789
     3H  234
      3  6899
      4  0334
      4  78
      5  3
      5  58
```

```
MINIMUM IS:           0.
LOWER HINGE IS:         11.
MEDIAN IS:           29.
UPPER HINGE IS:         56.
MAXIMUM IS:         309.

      0  0011245788999
     1H  23356788
     2M  336799
      3  2269
      4  2349
     5H  2345679
      6
      7  47
      8  0
      9  45
     10  9
     11  8
         ***OUTSIDE VALUES***
     22  9
     23  6
     30  9
```

a) b) Actual c) Random

Figure 15: ELEVATION values with "flat" locations removed.

In fact, when these actual elevation values were further analysed using a *normal probability plot* (SYSTAT Graphics 1992:232) in which the actual elevations are compared with a computer generated mathematically normal distribution, the values do approach a fairly straight line (Figure 16). The other important thing to note is the much narrower range of values as compared to the random locations (especially evident on the stem-and-leaf diagrams in Figures 15b and 15c).

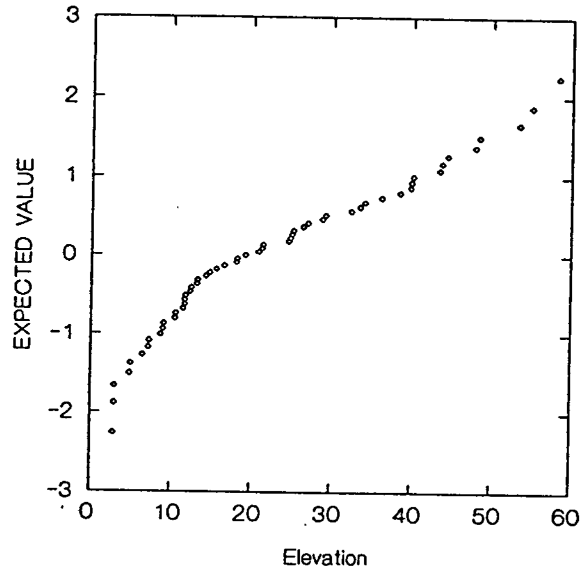
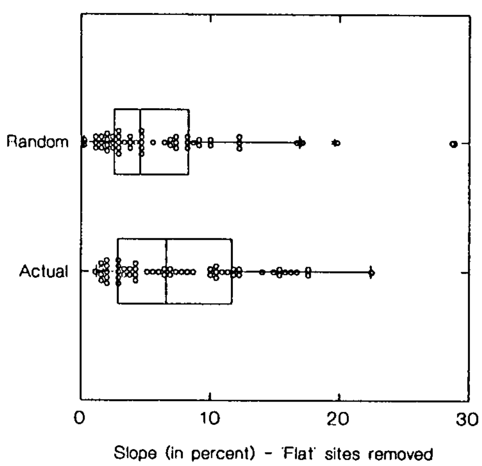


Figure 16: Normal Probability Plot for Actual ELEVATION values.

The comparison for the SLOPE variable (Figure 17) shows a greater similarity between the two sets of locations, although the actual sites do show slightly higher values.




```
MINIMUM IS:            1.
LOWER HINGE IS:              3.
MEDIAN IS:             7.
UPPER HINGE IS:             12.
MAXIMUM IS:           22.

0  1111111
OH 222222223333
0  4444455
OM 66677
0  88899
1H 0000111
1  22
1  4555
1  66677
1
2
2  2
```

```
MINIMUM IS:            0.
LOWER HINGE IS:              3.
MEDIAN IS:             5.
UPPER HINGE IS:              8.
MAXIMUM IS:           29.

0  0001111111
OH 22222222233333
OM 4444445
0  666777
OH 888899
1  00
1  222
1
1  6
   ***OUTSIDE VALUES***
1  79
2  8
```

a) b) Actual c) Random

Figure 17: SLOPE values with "flat" sites removed.

Both ELEVATION and SLOPE were put through the same routine used in the distance analysis above where random and actual locations were combined into a single dataset and then compared to see if they could be interpreted as being part of the same population. This time the probability is somewhat higher (see Table 2) with the slope values statistically similar enough to suggest that, for actual sites, they conform to the background environment. The fact that they are about 2 percent (4.6 vs. 6.6) higher, however, is important to note. In an area that receives a modern average annual precipitation of 1167 mm (Oke and Hay 1994:29) good drainage would be an important factor for any location with longterm use.

Table 2: Comparative Statistics - Actual Sites and Random Points
(Elevation Values in Meters; Slope Values are Percents).

	Elevation	**Slope**
Mean ---- Actual	23.0	7.8
Random	47.9	6.1
Median -- Actual	19.2	6.6
Random	29.2	4.6
Mann-Whitney	1108.5	1711.0
Probability	0.045	0.08

The third topographic variable to be examined is ASPECT and again the so-called "flat" locations were eliminated. It should be noted that two of the random points with very low average elevations showed an aspect value of zero and were dropped from the dataset. Figure 18 shows the results. It can be seen that the actual sites

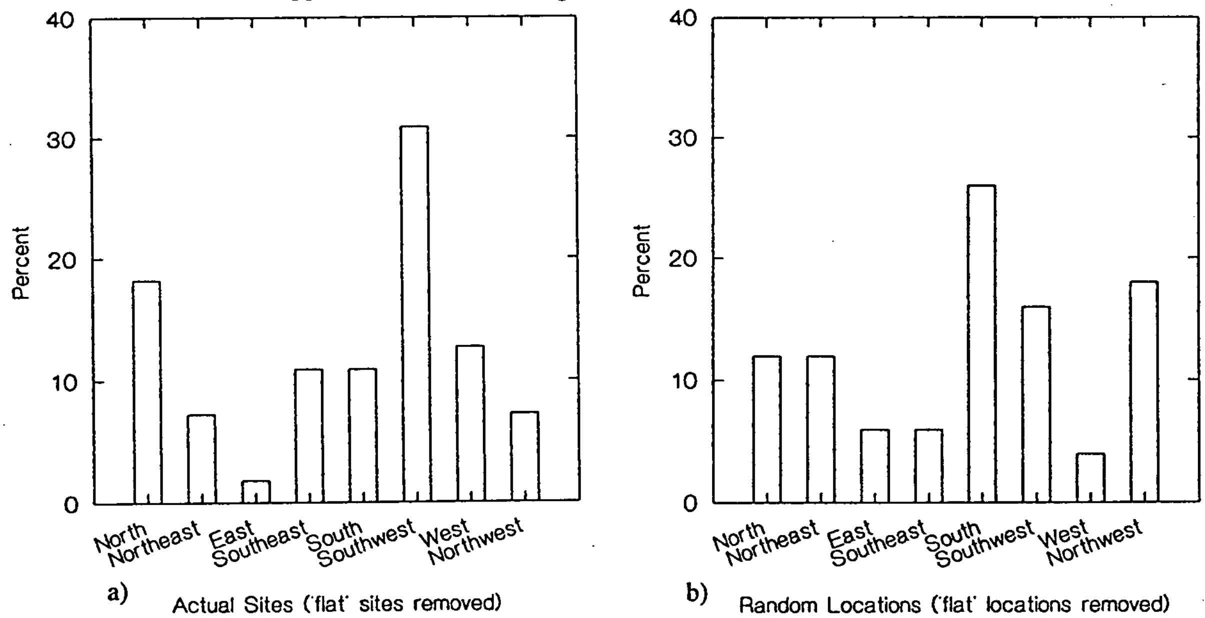


Figure 18: Comparison of ASPECT values.

show a marked tendency for a southwestern aspect in comparison to the random locations. In other settings, the American Southwest for example, exposure to the sun was deemed to be an important factor in choosing a location, for both long-term and short-term occupation. In a study conducted in Utah, Haase was able to demonstrate a strong preference for a southern exposure (Haase 1985:71-75). A chi-square test was performed on the information shown in Figure 18 to see if something similar might exist within this study area (see Figure 19). If we accept a critical value of 0.05 the result shown here falls within the accepted limits and does not represent a significant deviation from a normal population (3.209 falling within the range of 0 to 3.841). However, if the critical value is extended to 0.10 we do have a significant deviation (3.209 being outside the range of 0 to 2.706). Although 0.05 is often used in archaeology as a benchmark it is by no means an outside limit (Shennan 1988:69). The result here, therefore, remains in somewhat of a grey area; further analysis using additional site settings would be helpful.

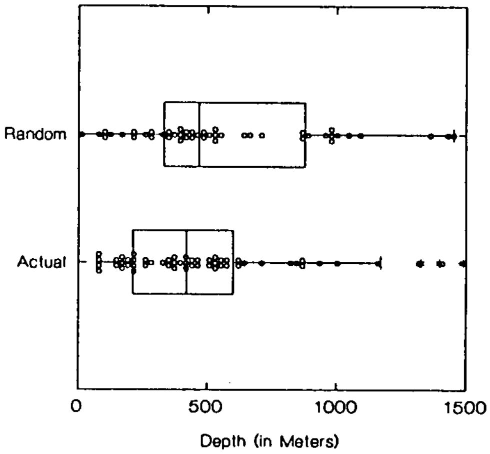
	Actual	Random	Total
Southwest	17	8	25
Other	38	42	80
Total	55	50	105

Pearson Chi-square 3.209 DF 1 Prob 0.073

Figure19: Chi-square statistic for ASPECT

Viewshed and "Openness"

As already discussed, the capability of the GIS to generate information about viewable area around a particular point on a landscape was considered of questionable value in a heavily treed setting like the one being looked at here. Nevertheless, two variables were defined for this analysis. The first was DEPTH - the distance inland from the site to the point where the viewshed stopped. The second is BREADTH - the lateral distance to the left and right of the site location showing again the extent of the viewshed analysis in these directions. Any outward spread of the viewshed, usually over open water, was considered meaningless here since it often meant extending to the edge of the map itself. Both variables were viewed with box plots and stem-and-leaf diagrams (Figures 20 and 21) and, although the actual sites showed that both variables were skewed towards high values, a probability plot check showed that the distribution was reasonably normal (Figure 22). The stem-and-leaf diagrams for the actual sites (Figures 20b and 21b), relay some interesting information on the general shape of the landscape. We can see from DEPTH (Figure 20b) that space, in terms of distance back from the shoreline, was limited to approximately 1/2 km for most sites in this region. At the same time lateral space (BREADTH) was not usually a problem with from 1 to 2 km usually available on either side of a site (Figure 21).



a)

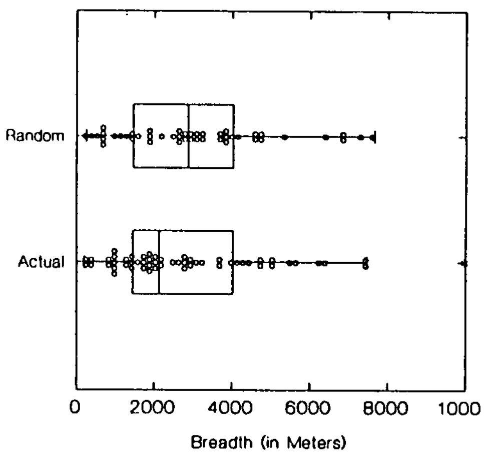
```
MINIMUM IS:           71.
LOWER HINGE IS:          211.
MEDIAN IS:           418.
UPPER HINGE IS:          599.
MAXIMUM IS:         1489.

 0  7778
 1  4556788
2H  0001568
 3  244777
4M  001133679
5H  02334567
 6  114
 7  1
 8  1366
 9  3
10  1
11  7
    ***OUTSIDE VALUES***
13  29
14  8
```

b) Actual

```
MINIMUM IS:             0.
LOWER HINGE IS:          331.
MEDIAN IS:           467.
UPPER HINGE IS:          878.
MAXIMUM IS:         1452.

 0  079
 1  036
 2  12778
3H  35569
4M  002244577
 5  11234
 6  46
 7  1
8H  679
 9  56889
10  5
11  0
12
13  5
14  25
```

c) Random

Figure 20: DEPTH in back of actual sites and random locations (meters).



a)

```
MINIMUM IS:          195.
LOWER HINGE IS:         1443.
MEDIAN IS:          2128.
UPPER HINGE IS:         4018.
MAXIMUM IS:         9970.

 0  1234
 0  88999
1H  0022444
 1  66778888
2M  00012
 2  557789
 3  012
 3  679
4H  023
 4  77
 5  004
 5  6
 6  23
 6
 7  34
    ***OUTSIDE VALUES***
 9  9
```

b) Actual

```
MINIMUM IS:          248.
LOWER HINGE IS:         1459.
MEDIAN IS:          2859.
UPPER HINGE IS:         4015.
MAXIMUM IS:         7650.

 0  234
 0  6677
1H  01244
 1  5899
 2  14
2M  5667899
 3  0012
 3  66788
4H  00
 4  5578
 5  4
 5
 6  3
 6  88
 7  2
 7  6
```

c) Random

Figure 21: BREADTH in front of actual sites and random locations (meters).

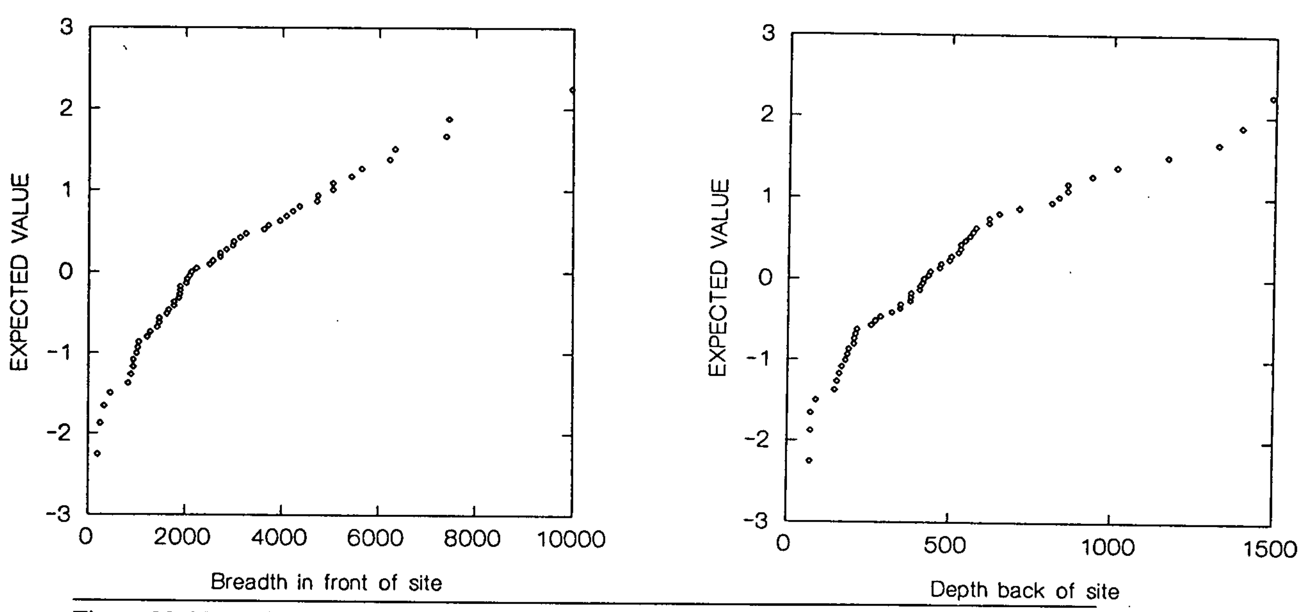


Figure 22: Normal Probability Plots for BREADTH and DEPTH.

When compared to the set of random locations, however, there is no discernible difference between the two. Again a Mann-Whitney exercise was performed and for both the BREADTH and DEPTH variables the probability is good that both active and random situations comprise the same population (DEPTH probability is 0.246; BREADTH is 0.468).

Clustering and Multidimensional Scaling

Background

Up to this point the analysis has used the site database in its entirety to show that it does not represent a random distribution of points across a landscape and that it can be seen as displaying broad patterns related to an adaptation to the physical and biotic features of the surrounding terrain. The next question is whether or not *within* this collection of sites further patterning can be detected, specifically whether we can discern any groupings or *clusters* of sites that might aid us in classifying the sites on the basis of the landscape elements already described (Hypothesis 3).

Cluster analysis is most effective as a research tool when three different processes take place (Everitt 1993). First there should be some prior indication that there is the possibility that groups or clusters exist within the data. The box-and-whisker plots, stem-and-leaf diagrams, and bar charts have already shown diverse ranges in the values of the various variables, suggesting further patterns between the various sites. Secondly, a clustering technique must be chosen which best suits the data being analysed. This in turn involves a number of decisions as to how the data are to be viewed, compared and manipulated. The third step is to somehow confirm that the results of the clustering are showing valid groups and not simply arcane products of the algorithms employed, "artifacts" as one writer describes them (Everitt 1993:142). This may primarily involve the analyst's own intuition regarding the material but certain other data display techniques such as multidimensional scaling can also be employed.

If the clustering is successful in splitting the actual sites into two or more groups, some means of testing whether or not it validates Hypothesis 3 is still required. As has already been discussed, one of the great frustrations with the Lower Mainland sites is the vagueness surrounding their original function. In some cases, however, the original investigators have gone out on an intuitive limb and actually assigned a site type. Therefore, those sites that have shown some reasonably good evidence for prolonged habitation are being used as a test of the clustering exercise. These include the major Point Roberts sites, Beach Grove (DgRs 1), Brandrith Park (DgRs 4), Whalen

Farm (DfRs 3) and Tsawwassen (DgRs 2), the Musqueam sites (DhRt 1,2,3,4), the two major Fraser River sites, Glenrose (DgRr 6) and St. Mungo (DgRr 2), the Marpole site (DhRs 1), the Locarno Beach site (DhRt 6), one of the Stanley Park sites (Lumberman's Arch, DhRs 2), one of the Burrard Inlet sites (Belcarra Park, DhRr 6) and the two American sites on Birch Bay (45-WH-9, 45-WH-11). Crescent Beach (DgRr 1), although usually designated a limited activity site, is also included here because of its extensive use over millennia.

The clustering was performed three times (see Figures 23, 25, and 27). The first run used all 62 sites and their associated topographic variables: NEAREST SITE, STREAM, SHORE, ELEVATION, SLOPE, ASPECT, DEPTH, and BREADTH. (ASPECT in this case is the numeric value assigned by the GIS, in the range of 0 to 8). In the initial attempts the NEAREST SITE and ASPECT variables created particular problems. NEAREST SITE tended to pull all isolated sites out as a group. Since this is felt to be more a product of a gap in the record than a reflection of past reality, it was decided to not use it. The ASPECT variable has already been looked at above and may be reflecting more the general orientation of the landscape rather than a particular choice (see pp. 29-30 and Figure 19). In the clustering and scaling analyses it tended to sequence the data in a way that proved confusing and finally inappropriate for the analysis (grouping sites first according to orientation rather than according to more meaningful variables). It was subsequently dropped from the variable set.

The second clustering routine used only the 34 sites with vegetation data. This first required a choice as to how these variables were structured. As shown in Appendix D, the vegetation content of the 500m site buffers was displayed in two separate matrices. The first, Table 1, showed the actual plant communities encountered around each site plus the area of that plant community. The maximum number of plant communities, seven at DgRs 4, determined the width of the matrix. The second display (Table 2) records the information differently; here the individual plant communities are assigned to one of seven broader types plus intersected water - type 8 (see Appendix F). The assumption here is that a site could potentially have all seven types within its environs, although in reality this does not occur with the sample used here.

Both matrices were fed into the cluster routine with the results from using the Table 1 matrix proving unsatisfactory. Clustering the data in this form simply grouped sites according to numbers of plant types without saying very much about the vegetation itself. The second matrix, which included the area of intersected water as an eighth type, was more productive and the results are retained here.

Finally, a third cluster exercise was done combining the eight vegetation variables with the six topographic variables used in the first clustering operation. All three routines used *standardised* values for the variables in order to allow each to contribute equally to the calculations (Matson & True 1974:55; Pokotylo 1978). (The mean for the particular variable is subtracted from each observation and the result is then divided by the standard deviation for that variable [SYSTAT Data 1992:111]). As part of the clustering process SYSTAT requires a "distance metric" to compute similarity between cases. Two coefficients are provided for continuous scales, Euclidean distance and Pearson product moment correlation, (SYSTAT Statistics 1992:25), and for the analysis performed here Euclidean distance was chosen. The Pearson coefficient tends to average out all the variable values for each case (Everitt 1993:43) and because of the diversity of measurements in this study, this was not considered desirable; if a particular variable was responsible for making a case a member of a cluster this was deemed to be important information. Although SYSTAT provides a number of clustering or "linkage" methods, (single [nearest neighbour], complete [furthest neighbour], centroid, average, median, and Ward's [SYSTAT Statistics 1992:27]), it was decided to use Ward's. This was partly due to its preferential use in archaeological applications (Matson & True 1974; Pokotylo 1978; Shennan 1988) as well as its recommendation for providing the most *homogenous* clusters (Shennan 1988:217; Everitt 1993:65).

As part of the confirmation step mentioned above, two techniques were employed. First multidimensional scaling was done to try and replicate the groupings of cases produced by the clustering. If there were major discrepancies, these would be investigated further. SYSTAT provides only non-metric multidimensional scaling (SYSTAT Statistics 1992:109) and, although up to five dimensions can be chosen, the default of two dimensions was used here. The second confirmation technique simply involved re-ordering the various data matrices in the same sequence as the clustering and multidimensional scaling diagrams and examining the results (Pokotylo 1982). This proved to be most beneficial in explaining what was behind the various groupings as well as confirming that both statistical procedures had divulged meaningful patterns in the data.

Results

A cluster diagram and a multidimensional scaling plot were produced for each of the three groups of variables (Figures 23 through 28). In each case the "habitation" sites are identified with a triangle. Although a

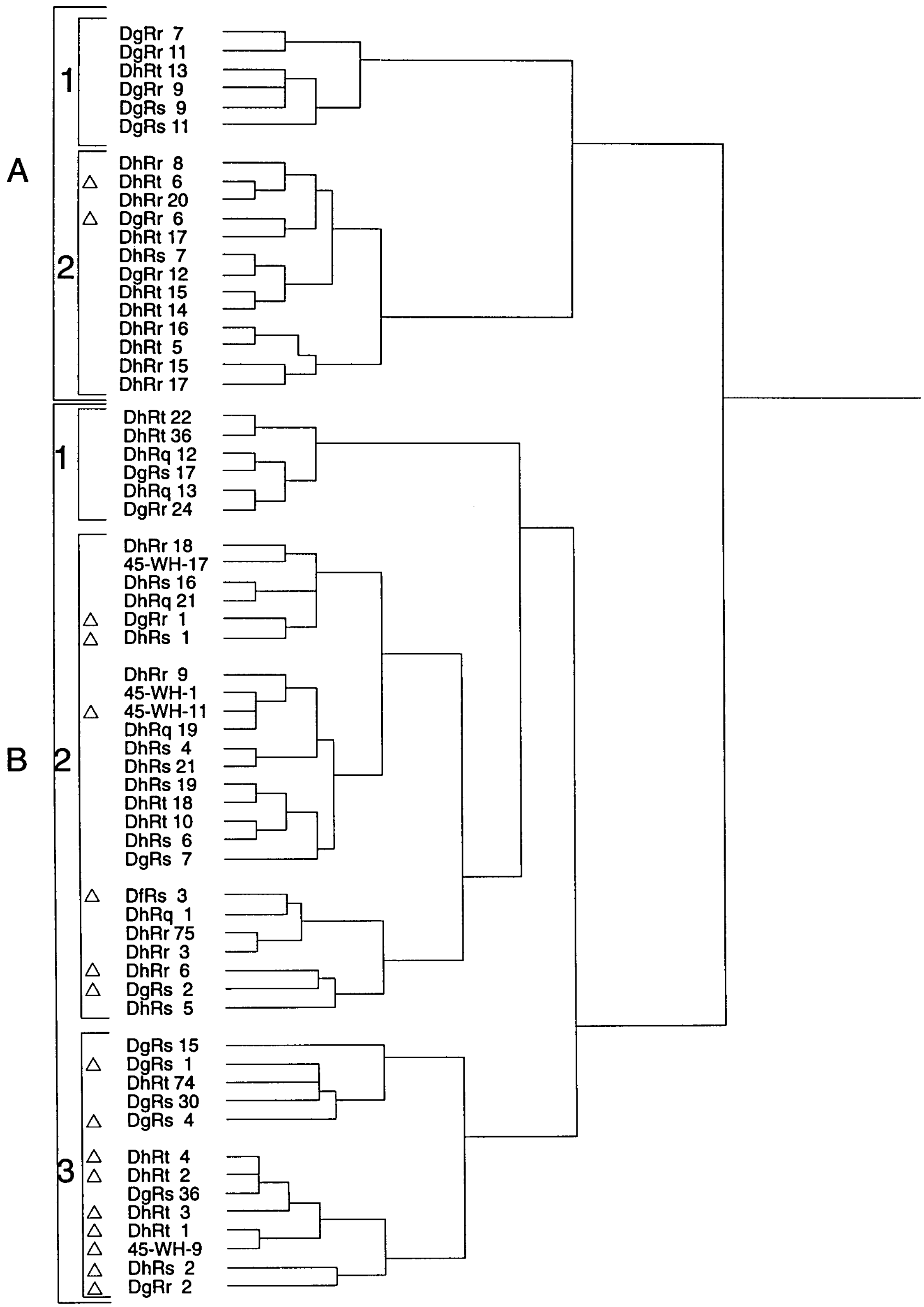


Figure 23: Cluster Diagram of the topographic variables

number of tables of the re-ordered data were generated, only one is included here and will be discussed further on (see Table 3). Looking first at the topographic variables (Figure 23), we can see two large clusters, A and B, with the majority of the habitation sites in cluster B (15 out of 17). The main variables determining this split are ELEVATION and SLOPE which gives an initial indication of a preference for moderate elevations and reasonably flat areas. Cluster A has an average elevation of 39.8 m above sea level with a slope value of 13.5 degrees whereas the remaining 15 habitation sites show average elevation to be only 14.9 m with an average slope of 4.8 degrees. (These calculations were made from a table of the variables resequenced in the order of the cluster diagram). The other cluster with distinct elevation and slope values is the one containing the so-called "flat" sites (cluster A1).

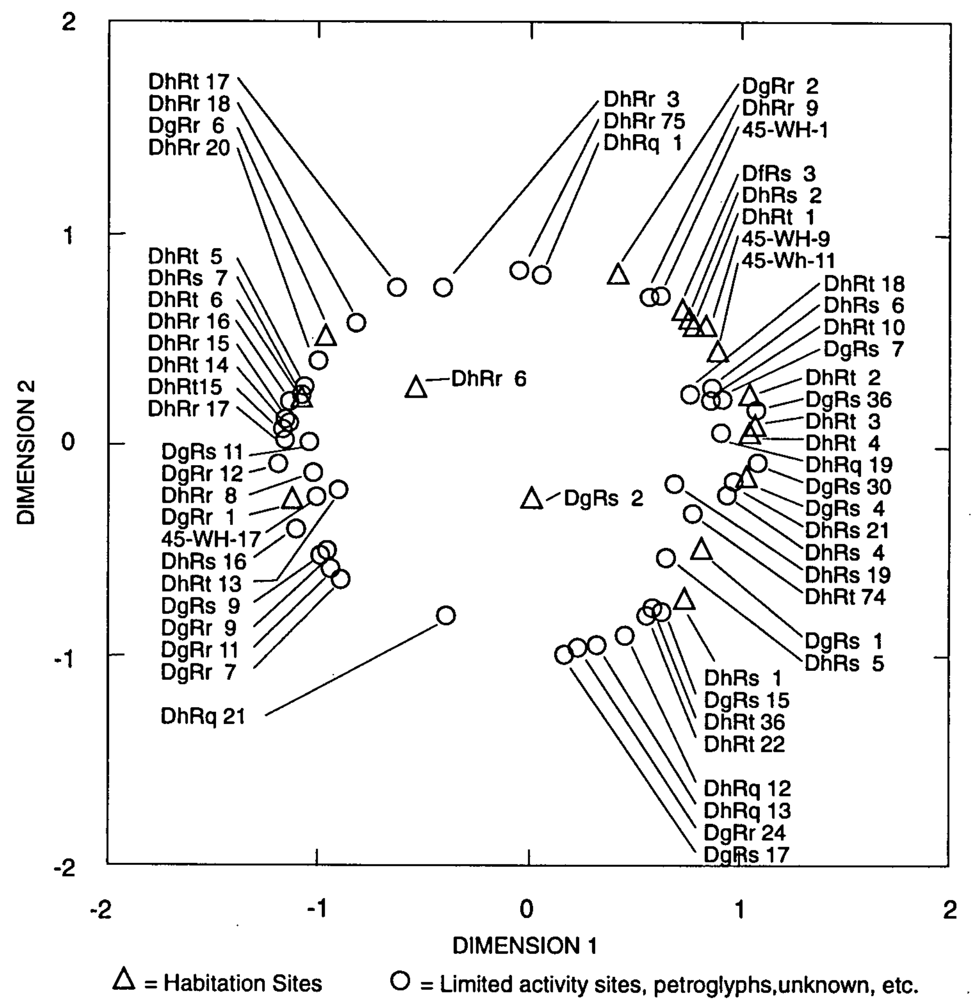


Figure 24: Multidimensional scaling plot of topographic variables

Not as recognizable in the cluster diagram but something which was very apparent in the multidimensional scaling plot (Figure 24), was the importance of a broad open area in front of the habitation sites, represented here by the variable BREADTH. This realization was partly the result of the scaling being prone to produce a seriation using at least one of the variables. As already mentioned, this tendency to re-order the cases from low to high and then back down to low on the strength of the values of a particular variable initially led to the discarding of the ASPECT variable. For the remaining topographic variables, however, the seriation effect actually had the benefit of revealing a pattern that was not clear in the cluster diagram or, for that matter, in the initial analysis of the viewshed variables, BREADTH and DEPTH (pp. 30-32). While the average value for BREADTH for the entire set of 62 sites is 2488 m, this average goes up to 5263 m for the 12 habitation sites in the arc on the upper right side of the plot (Figure 25).

Already, then, we have seen three distinct characteristics that seem to have been taken into account when choosing habitation locations: a moderate elevation, generally flat surroundings, and above average openness in front of the site. It must be pointed out, however, that these elements do not indicate rare locations in the landscape generally. A quick check with the random locations revealed that an almost identical proportion of the terrain held the same range of elevation and slope values (21.3% of random locations versus 22.6% of the actual site locations). Upon reflection, these may all seem to be commonsense attributes to select for when choosing an appropriate location for longterm use but they are still very hard to pick out without the aid of the clustering and scaling exercises.

Turning to the vegetation variables, the clustering diagram (Figure 25) does not provide any quick insights into the distribution of the sites. Again two large clusters were produced (A and B) but with approximately equal numbers of habitation sites in each (4 and 6). When looked at individually, the smaller sub-clusters form mostly around particular plant communities. What is interesting in these sub-clusters is the tendency of the habitation sites to have a good volume of cedar in their immediate vicinity. Both the sub-clusters A2 and B2 which contain seven out of the ten habitation sites have a reasonably high concentration of this plant type (between 15 and 52 hectares out of a possible 78.6 hectares within the 500m buffer). This trend is repeated on the multidimensional scaling plot (Figure 26) with the sites forming an arc in the upper half of the figure (from DhRs1 on the right through to DgRs 9 on the left) all showing this preference for cedar within the buffered area.

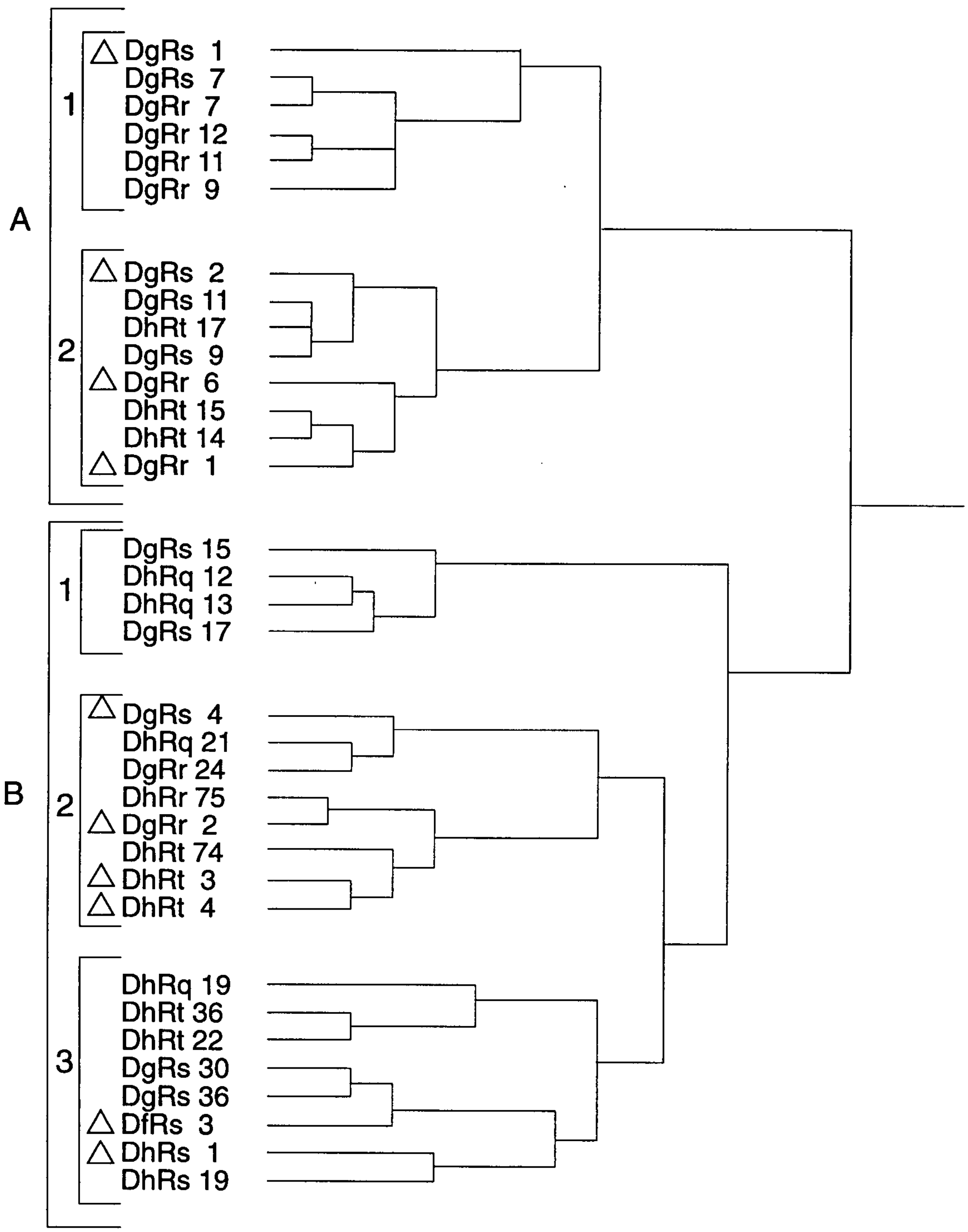


Figure 25: Cluster Diagram of the vegetation variables.

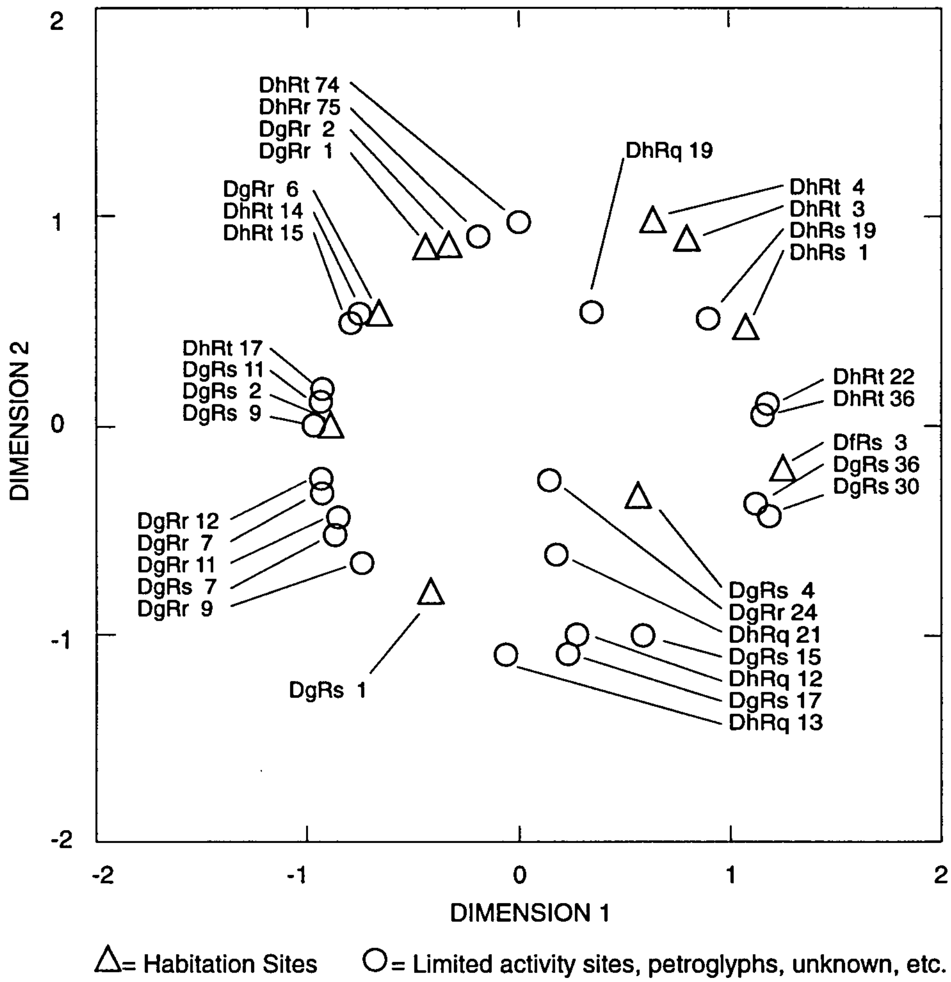


Figure 26: Multidimensional scaling plot of vegetation variables.

The final clustering and scaling routine, using the combined set of 14 variables, produced the most satisfying results in terms of identifying those landscape elements most closely linked to habitation locations. Here the cluster diagram (Figure 27) shows three clusters with the third one, cluster C, containing nine of the ten habitation sites. This group again contains those sites with moderate elevation and slope plus a wide open area in front (see also the boxed area of the third section of Table 3). Heavily treed environments tend to prevail (both the cedar and Douglas fir communities) but, interestingly, often in combination with a large segment of grassland which is reminiscent of the ethnographic contention for the importance of a prairie setting nearby (see page 11). Cluster A, with only the one habitation site, represents the least desirable elements for long term use - high, sloping terrain with the plant community dominated by Douglas fir (see shaded areas in top section of Table 3). It is in this group that we find the largest values for intersected water and the shortest distances to the shoreline (boxed areas of top section of Table 3), both indicative of the site being hemmed in by the rising headland in back and the water in front.

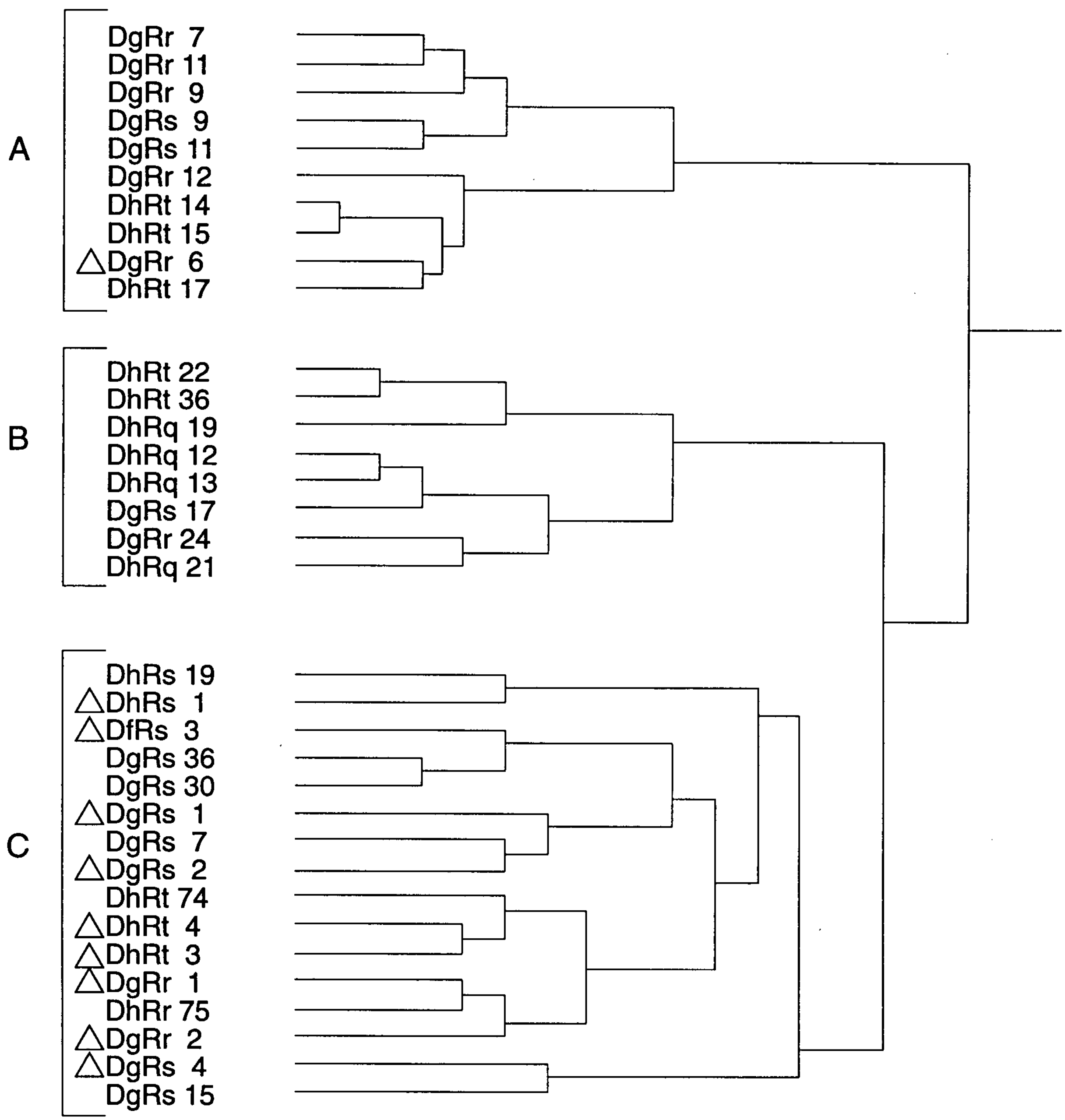


Figure 27: Cluster diagram of the combined topographic and vegetatiion variables.

Table 3: Topographic and Vegetation data resequenced to follow the order of Figure 27.

	Site ID	Stream	Shore	Eleva-tion	Slope	Brea-dth	Depth	V1	V2	V3	V4	V5	V6	V7	V8
	DgRr 7	2931	21	55.0	16.4	1020	205	0.0	0.0	0.0	0.0	0.0	0.0	40.6	38.0
	DgRr 11	2558	22	48.4	17.8	329	189	0.0	0.0	0.0	6.6	0.0	0.0	26.3	45.7
	DgRr 9	1854	20	43.4	14.2	1212	340	0.0	0.0	0.0	13.7	0.0	0.0	28.0	36.9
	DgRs 9	1611	43	38.5	12.2	2506	195	0.0	0.0	0.0	0.0	0.0	14.4	29.5	34.7
	DgRs 11	1274	113	44.4	15.1	4083	370	0.0	0.0	0.0	0.0	0.0	19.3	28.1	31.2
	DgRr 12	500	6	36.2	11.9	450	194	0.0	0.0	0.0	0.0	0.0	3.2	29.9	45.5
	DhRt 14	10	41	43.7	10.9	1464	113	0.0	0.0	0.0	0.0	0.0	28.0	21.0	27.2
	DhRt 15	291	25	39.9	9.9	1464	97	0.0	0.0	0.0	0.0	0.0	28.1	22.6	27.9
Δ	DgRr 6	212	45	34.1	10.3	3000	116	0.0	0.0	0.0	0.0	0.0	28.4	13.2	37.0
	DhRt 17	66	93	25.0	6.6	3132	181	0.0	0.0	0.0	0.0	0.0	18.0	27.9	32.7
	DhRt 22	0	328	0.0	0.0	0	328	38.0	33.7	0.0	0.0	0.0	0.0	0.0	6.9
	DhRt 36	0	276	0.0	0.0	0	276	36.4	26.9	0.0	0.0	0.0	0.0	0.0	15.3
	DhRq 19	436	108	7.2	3.5	2845	546	0.0	26.6	0.0	0.0	0.0	22.7	0.0	29.3
	DhRq 12	220	220	0.0	0.0	0	220	0.0	0.0	39.5	0.0	0.0	11.1	8.3	19.7
	DhRq 13	96	96	0.0	0.0	0	96	0.0	0.0	38.0	0.0	0.0	0.0	15.0	25.6
	DgRs 17	352	90	0.0	0.0	0	90	0.0	0.0	39.9	9.6	0.0	0.0	0.0	29.1
	DgRr 24	0	34	0.0	0.0	0	34	0.0	0.0	0.0	25.0	0.0	20.1	0.0	33.5
	DhRq 21	271	119	14.3	5.5	1282	534	3.8	0.0	0.0	30.4	0.0	9.5	8.2	26.7
	DhRs 19	69	273	14.8	4.3	1893	922	22.7	0.0	0.0	5.8	22.2	12.4	0.0	15.5
Δ	DhRs 1	386	219	11.5	3.7	1658	565	23.8	4.5	0.0	9.0	12.0	12.0	0.0	17.3
Δ	DfRs 3	129	286	18.1	5.9	4719	864	63.0	0.0	0.0	4.6	0.0	2.2	0.0	8.8
	DgRs 36	399	541	7.3	1.4	6225	1038	50.1	0.0	0.0	11.2	0.0	0.0	16.5	0.0
	DgRs 30	516	887	10.6	1.2	6330	1411	51.4	0.0	0.0	3.7	0.0	0.0	23.5	0.0
Δ	DgRs 1	92	937	10.5	2.1	2128	1314	4.9	0.0	0.0	16.7	0.0	0.0	56.9	0.0
	DgRs 7	565	35	2.9	1.5	3953	1048	0.0	0.0	0.0	7.0	0.0	0.0	39.4	32.2
Δ	DgRs 2	772	192	24.8	9.9	2023	1518	4.0	0.0	0.0	0.4	0.0	15.0	35.6	23.6
	DhRt 74	204	879	27.0	4.4	4219	1092	0.0	0.0	0.0	0.0	0.9	51.3	26.1	0.0
Δ	DhRt 4	118	611	11.7	1.8	5053	1142	25.6	0.0	0.0	0.0	3.2	49.8	0.0	0.0
Δ	DhRt 3	421	420	11.8	2.8	4741	705	29.1	0.0	0.0	0.0	2.4	32.5	9.4	5.2
Δ	DgRr 1	383	190	20.9	6.8	2035	569	2.6	0.0	0.0	0.0	0.0	36.9	20.5	18.6
	DhRr 75	23	96	24.6	8.8	3625	908	0.0	0.1	0.0	0.0	0.0	53.0	0.0	29.2
Δ	DgRr 2	200	140	19.2	7.0	9970	607	0.5	0.0	0.0	0.0	0.0	47.2	7.5	30.9
Δ	DgRs 4	431	1440	21.3	1.7	7450	2376	0.1	0.0	0.0	42.3	0.0	27.0	9.2	0.0
	DgRs 15	1494	1576	0.0	0.0	0	1576	0.5	0.0	78.0	0.0	0.0	0.0	0.0	0.0

Note: The final site in the table, DgRs 15, is erroneously included in the third group because of an extreme DEPTH value. It belongs to the central group.

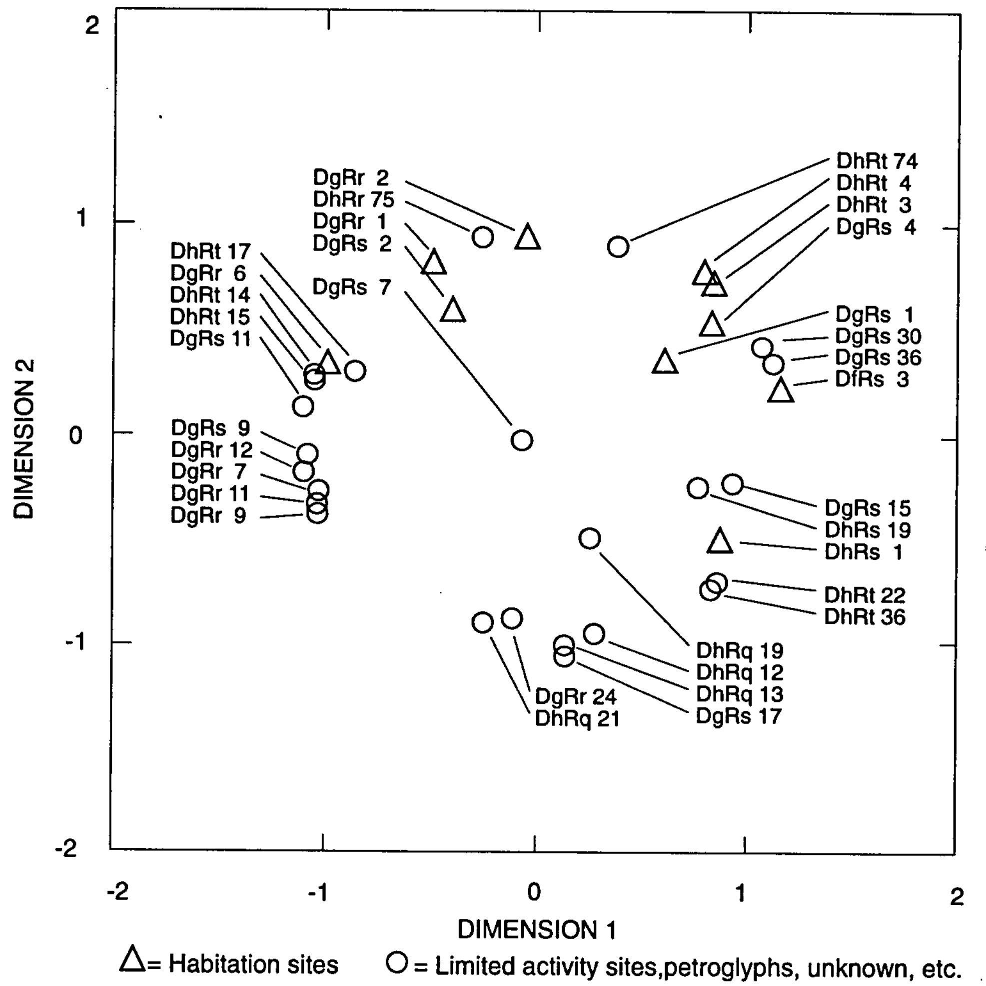


Figure 28: Multidimensional scaling plot of topographic and vegetation variables combined.

The multidimensional scaling plot (Figure 28) this time follows the cluster diagram much more closely. One interesting addition to the insights already provided by the first and second cluster exercises is the appearance of the DEPTH variable as an important factor in habitation choice. All of the sites in the upper group on the plot, which contains eight of the ten habitation sites, show much higher than average values for DEPTH (1122 m versus 342 m - see also boxed segments on lower section of Table 3). Again we have the somewhat unexpected demonstration of the importance of *openness* for long term site use. One other notable pattern in this plot is the strong grouping of low elevation sites in the lower left corner. All eleven of these sites share high concentrations of the first four vegetation types (stepwise shaded area of middle section of Table3), partly attributable to their common landscapes but nevertheless showing the value of vegetation in forming the groups we have seen here.

Summary

The goal of this study was to employ a series of measurements taken from the landscape surrounding a group of archaeological sites and from those measurements make some statements about why those particular locations were chosen for occupation or other related activities. The first hypothesis simply stated that these locations were not randomly distributed in space. This was easily demonstrated by the distribution of most of the variables. NEAREST SITE, STREAM and SHORE for the actual sites all showed distinctive differences from the randomly plotted points. Of particular note was the importance of a close by shoreline (a median value of 95 m for actual locations versus 741 m for the random ones), thereby confirming the point Suttles (1951:46) had made in his ethnographic research. Nearby vegetation showed a definite pattern for a more diverse plant population within the immediate area of a site. Among the topographic variables (ELEVATION, SLOPE, and ASPECT), we again saw distinct patterns among the actual locations. In the case of ELEVATION, the sites were in a much tighter range; SLOPE showed a slight preference for higher values. The weakest differences were with SOILS, ASPECT, and, initially, the two viewshed variables, BREADTH and DEPTH, although interesting information was still produced.

Hypothesis two is closely related to the first one and can be regarded as being accepted. Settlement to Marpole people meant not having great distances between neighbouring activity and occupation areas. A freshwater stream was always important, preferably within a walking radius of 250 meters. The shore truly was a "midline", always present, always a basic component of everyday life. This did not, however, directly translate into living on the beach. On average, living and working in this region meant staying about 20 m above sea level. A slightly higher than average slope was also a practical consideration. The direction a location faced was apparently, however, pretty much determined by the terrain.

Vegetation was definitely selected for, partly for a varied range of plants within the immediate vicinity and also for stands of the large conifers, cedar and Douglas fir. The tendency for modern industrial-agricultural societies to destroy plant diversity in settlement areas tends to bias our thinking towards other cultures. It would make eminent sense for any group of people contemplating a settlement location to choose diversity even if the result of their lifeway might often result in its destruction. For the early Salish settlers it may have been more possible to preserve that local diversity than it would have been for more agricultural land users.

The results for the soil analysis were not as clear-cut, but commonsense choices for solid ground and away from swampy boggy areas were demonstrated. The viewshed analysis was equivocal when it was initially looked at as support for Hypothesis 2 since there appeared to be little difference between the general landscape and the local landscapes of the sites. It did, however, help to disprove a personal notion that rising headlands were somehow preferred in close proximity to the actual sites. Instead they appear as problems that simply had to be dealt with by the original settlers.

The third hypothesis was by far the most contentious in this study with all of its implications of "predicting the past". Yet the use of landscape did provide some valuable insights into the problem. From the clustering and scaling routines it was apparent that when a major occupation was planned, a number of elements were looked for. The site was definitely not to be placed directly on the beach but rather, on average, about 20 m above sea level. A moderate slope to the land was required and an overall sense of open space was important, with a broad expanse in front and a greater than average depth behind the site. Although it may be stating the obvious in a region such as this, it can also be said that there was a preference for large tree types, especially cedar.

In the case of the sites presumed to have had limited use, two general groups emerged, each aligned with two broad features of the terrain in the study area. This is most easily seen in Table 3 with one set of sites situated on narrow strips of land between the shore and the backing headlands; the other is found in flat open settings close to, or on, the river delta. The near absence of habitation sites within these two groups again demonstrates the key role of landscape in not only the choice of site location but also for the type of activity that took place there.

Conclusion

One of the chronic problems in the study of Northwest Coast archaeology is that "little settlement pattern work has been carried out" (Matson & Coupland 1995:313). An underlying objective of this study has been to investigate the applicability of using a theoretical construct, landscape, and, on a more technical level, a set of computer-based tools in a Geographic Information System to make statements about settlement using a collection of Marpole period sites as a test case. From the landscape a range of variables were used for analysis. When elements as different as local vegetation, elevation, soils, and distances to various features in the surrounding area help to show distinct patterns, it demonstrates how useful the landscape can be as a supplement to our often paltry archaeological data base. As has been already stated, up to this point, very little has been said either by ethnographers or archaeologists about why particular locations were chosen over others.

In the Summary section those landscape features that were important in the selection of sites were identified. Using these measurements from a large number of sites allows us increased confidence in making statements about site location in the area surrounding the mouth of the Fraser. How rigorously we apply these statements specifically to the Marpole period remains a problem, however. They can certainly be used in a general descriptive sense and thus provide us with insight into the way this land was used two thousand years ago. We cannot, however, extend this to say that this represents a Marpole *pattern* somehow distinct from a Locarno Beach pattern or a St. Mungo pattern. The landscape approach is certainly capable of contributing to such conclusions, but only after a comparative analysis beyond the scope of the test case approach employed here.

The use of the GIS has, in many ways, made this analysis possible. The volume and the variety of information employed here present horrendous data management problems and many of the variable values would be impossible to obtain otherwise. For example, elevation and slope averages and areas from the 500 m site buffers would be most difficult to obtain manually and the viewshed data would simply not be available. When a high number of sites is factored in, anything beyond a dozen or so locations would involve an impractical amount of time and effort to obtain even a part of the information presented here. Once the critical components of the landscape are stored in the computer, any number of repeated queries and analyses are possible without a great deal of cost to the analyst.

A major caveat must be made, however. Geographic Information Systems are not "user friendly" computer packages. With a project such as the one described here, the user requires a good working knowledge of all aspects of the system. This entails setting up the working environment, digitizing maps, correcting errors in the resulting spatial data, developing useable databases from that data, generating new forms of data from the various point, line, and text features that were taken from the maps, performing various analytic functions, and finally producing the sorts of outputs required to answer the research questions that initiated the process in the first place. Much time, effort, and money can be spent in trying to acquire pre-digitized maps. The maps that formed the base of the work done here, although provided free in this instance, could cost over seven thousand Canadian dollars. The basic knowledge required to use such a system, therefore may place prohibitive demands on the time, patience, and pocketbook of the researcher. Nevertheless, it can be a powerful and sophisticated tool in the study of human settlement space.

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Appendix A

SITE DATABASE RECORD FORM

IDENTIFICATION

Site # ____________ Name ____ Rating ______

LOCATION

Latitude: begin ______° ____' _____" end ______° _____' ______"

Longitude: begin ______° ____' _____" end ______° _____' ______"

SIZE

	<500 M^2	500 - 10000 M^2	10000 - 20000 M^2	20000 M^2 +
Current	_____	_______	_______	______
Estimate	_____	_______	_______	______

TYPE

__________________________________ (Shell Midden _____)

AGE

Radiocarbon _____________ Judgemental _________

CULTURE

	Date	Artifacts	Judgement
Late	_____	______	_______
Marpole	_____	______	_______
Locarno	_____	______	_______
St Mungo	_____	______	_______
Old Cord	_____	______	_______

COMMENTS / REFERENCES

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Appendix B: Sites used in the landscape study.

Site ID	Site Name (Location)	Site Type	Culture	Basis For Inclusion	Reference
45-WH-1	Cherry Point	Midd	Marpole	radiocarbon	Grabert & Larsen 1975
45-WH-9	Birch Bay State Park	HAB	Marpole	radiocarbon	Grabert & Spear 1976
45-WH-11	Birch Bay	HAB	Marpole	artifacts	Grabert & Larsen 1975
45-WH-17	Semiahmoo Spit	LAS	Marpole	radiocarbon	Grabert & Larsen 1975
DfRs 3	Whalen Farm	HAB	Marpole	radiocarbon	Thom 1992; Matson & Coupland 1995
DgRr 1	Crescent Beach	LAS	Marpole	radiocarbon	Ham 1982; Matson 1992
DgRr 2	St Mungo Cannery	HAB	Marpole	radiocarbon	Calvert 1970; Ham *et al* 1986
DgRr 6	Glenrose Cannery	HAB	Marpole	radiocarbon	Matson 1976, 1981
DgRr 7	(White Rock)	Petr		association	Hill & Hill 1974
DgRr 9	Ocean Park Beach Petroglyph	Petr		association	Hill & Hill 1974
DgRr 11	Thousand Steps Petroglyph	Petr		association	Ham 1982
DgRr 12	Sunburst Petroglyph	Petr		association	Ham 1982
DgRr 24	Annacis Island	Midd	Marpole	site size	Eldridge & Mackie 1993b
DgRs 1	Beach Grove	HAB	Marpole	radiocarbon	Abbott 1962; Matson *et al.* 1980
DgRs 2	Tsawwassen	Midd	Marpole	radiocarbon	Arcas 1991
DgRs 4	Brandrith Farm Park	HAB	Marpole	artifacts	Borden 1958
DgRs 7	(Point Roberts)	LAS		site size	site inventory form
DgRs 9	Tsawwassen Beach	LAS	Late	artifacts	Sutherland 1975
DgRs 11	English Bluff	Midd	Marpole	artifacts	Sutherland 1975
DgRs 15	Blundell Rd. Basketry	Isol	Marpole	radiocarbon	Bernick 1991
DgRs 17	Tlekines	HAB	Late	site size	Eldridge & Mackie 1993b
DgRs 30	Water Hazard	Unkn	Marpole	radiocarbon	Bernick 1989
DgRs 36	(Point Roberts)	Unkn	Marpole	radiocarbon	site inventory form
DhRq 1	Noon's Creek	LAS	Marpole	artifacts	Post & Van Male 1963; Charlton 1972
DhRq 12	(Pitt Meadows)	HAB	Marpole	artifacts	site inventory form
DhRq 13	(Pitt Meadows)	LAS	Marpole	artifacts	site inventory form
DhRq 19	Mary Hill Site	Unkn	Late	radiocarbon	Eldridge & Mackie 1993b
DhRq 21	Pitt River	Midd	Marpole	radiocarbon	Broderick *et al.* 1979; Patenaude 1985
DhRr 3	(Burrard Inlet)	Midd		site size	site inventory form
DhRr 6	Belcarra Park	HAB	Marpole	artifacts	Charlton1972, 1980
DhRr 8	Cates Park	Midd	Marpole	artifacts	Charlton 1974
DhRr 9	Pigeon Cove	LAS	Marpole	artifacts, burial	McMillan 1971
DhRr 15	Trading Beach	LAS	Marpole	burial mounds	site inventory form
DhRr 16	Barnet Site	LAS	Marpole	artifacts	Apland & Beattie 1972
DhRr 17	Caraholly Midden	LAS	Marpole	artifacts	Struthers 1971
DhRr 18	Cove Cliff	LAS	Marpole	artifacts	site inventory form
DhRr 20	Berry Creek	Unkn		burial mounds	site inventory form
DhRr 75	skwekwtexwqen	Isol	Marpole	artifact	Eldridge & Mackie 1993b
DhRs 1	Marpole	HAB	Marpole	radiocarbon	Burley 1979
DhRs 2	Lumberman's Arch	HAB	Late	artifacts	site inventory form
DhRs 4	(Stanley Park)	Midd		association	site inventory form
DhRs 5	Lost Lagoon	Midd		site size	site inventory form
DhRs 6	Second Beach	Midd		association	site inventory form
DhRs 7	Third Beach	Midd		site size	site inventory form
DhRs 16	(North Vancouver)	LAS		site size	site inventory form

DhRs 19	Liquid Air	Midd	Marpole	artifacts	Percy 1977
DhRs 21	(Stanley Park)	Midd	Marpole	artifact	site inventory form
DhRt 1	Male Village (Musqueam W)	HAB	Late	artifacts	Ham & Beattie 1976
DhRt 2	Stselax (Musqueam E)	HAB	Late	radiocarbon	Borden 1970
DhRt 3	Musqueam N. ("Old")	Midd	Marpole	radiocarbon	Monks 1976
DhRt 4	Musqueam NE	Midd	Marpole	radiocarbon	Borden 1976; Archer 1972
DhRt 5	Point Grey	LAS	Marpole	radiocarbon	Coupland 1991
DhRt 6	Locarno Beach	Midd	Marpole	radiocarbon	Borden 1970; Arcas 1993
DhRt 10	Wallace St.	Unkn		artifacts	site inventory form; UBC Book A24
DhRt 13	Canoe Run	LAS		association	site inventory form; UBC Book N16
DhRt 14	(Point Grey)	Midd	Marpole	artifacts	UBC Book N16
DhRt 15	(Point Grey)	Midd	Marpole	artifacts	UBC Book N16; Eldridge & Mackie 1993b
DhRt 17	Booming Grounds	Midd		association	Eldridge & Mackie 1993b
DhRt 18	(Point Grey)	Midd		association	site inventory form
DhRt 22	Mah Farm	Midd	Marpole	site size	Ham 1987
DhRt 36	Tait Farm	LAS	Late	radiocarbon	Ham 1987
DhRt 74	Mc Cleary Golf Crse.	LAS	Marpole	burial mound	site inventory form

Appendix C: Variable measurements.

Site ID	Site Name (Location)	Near Site	Stream	Shore	Elevation	Aspect	Slope	Breadth	Depth
45-WH- 1	Cherry Point	5379	152	71	12.4	SW	4.4	2979	542
45-WH- 9	Birch Bay 2	3627	122	120	4.9	NW	1.6	5646	665
45-WH-11	Birch Bay	3627	196	48	6.5	SE	2.8	2571	455
45-WH-17	Semiahmoo Spit	4835	109	104	16.6	N	8.0	250	282
DfRs 3	Whalen Farm	2759	129	286	18.1	N	5.9	4719	864
DgRr 1	Crescent Beach	880	383	190	20.9	NW	6.8	2035	569
DgRr 2	St Mungo Cannery	789	200	140	19.2	NW	7.0	9970	607
DgRr 6	Glenrose Cannery	789	212	45	34.1	NW	10.3	3000	116
DgRr 7	(White Rock)	1772	2931	21	55.0	S	16.4	1020	205
DgRr 9	Ocean Park Beach Pet	882	1854	20	43.4	W	14.2	1212	340
DgRr 11	Thousand Steps Petr	882	2558	22	48.4	SW	17.8	329	189
DgRr 12	Sunburst Petroglyph	880	500	6	36.2	W	11.9	450	194
DgRr 24	Annacis Island	2330	0	34	0.0	0	0.0	0	0
DgRs 1	Beach Grove	884	92	937	10.5	N	2.1	2128	1314
DgRs 2	Tsawwassen	531	772	192	24.8	N	9.9	2023	1518
DgRs 4	Brandrith Farm Park	1216	431	1440	21.3	N	1.7	7450	2376
DgRs 7	(Point Roberts)	784	565	35	2.9	E	1.5	3953	1048
DgRs 9	Tsawwassen Beach	400	1611	43	38.5	SW	12.2	2506	195
DgRs 11	English Bluff	400	1274	113	44.4	SW	15.1	4083	370
DgRs 15	Blundell Rd. Basketr	1887	1494	1576	0.0	0	0.0	0	0
DgRs 17	Tlekines	1887	352	90	0.0	0	0.0	0	0
DgRs 30	Water Hazard	370	516	887	10.6	NE	1.2	6330	1411
DgRs 36	(Point Roberts)	370	399	541	7.3	NE	1.4	6225	1038
DhRq 1	Noon's Creek	640	51	312	28.8	SW	8.3	3715	881
DhRq 12	(Pitt Meadows)	627	220	220	0.0	0	0.0	0	0
DhRq 13	(Pitt Meadows)	627	96	96	0.0	0	0.0	0	0
DhRq 19	Mary Hill Site	2500	436	108	7.2	SW	3.5	2845	546
DhRq 21	Pitt River	2211	271	119	14.3	SE	5.5	1282	534
DhRr 3	(Burrard Inlet)	1421	48	61	26.4	SW	11.9	3250	895
DhRr 6	Belcarra Park	1296	471	15	32.4	W	17.5	1616	1504
DhRr 8	Cates Park	1804	623	63	21.4	S	11.4	1898	481
DhRr 9	Pigeon Cove	640	368	25	9.0	N	4.9	4356	584
DhRr 15	Trading Beach	670	93	27	47.9	S	15.5	882	172
DhRr 16	Barnet Site	1421	281	64	40.1	N	16.9	1422	469
DhRr 17	Caraholly Midden	2354	467	48	53.4	S	22.4	195	253
DhRr 18	Cove Cliff	1296	42	46	15.6	SE	6.6	1885	255
DhRr 20	Berry Creek	670	200	34	25.2	S	12.2	2087	412
DhRr 75	skwekwtexwqen	6731	23	96	24.6	SE	8.8	3625	908
DhRs 1	Marpole	663	386	219	11.5	S	3.7	1658	565
DhRs 2	Lumberman's Arch	741	508	52	13.3	E	3.9	7394	1449
DhRs 4	(Stanley Park)	161	318	23	3.0	SE	2.1	1769	642
DhRs 5	Lost Lagoon	697	683	375	13.2	SW	2.9	996	1545
DhRs 6	Second Beach	697	7	98	8.7	SW	2.8	2229	810
DhRs 7	Third Beach	1129	0	44	33.5	W	10.6	821	248
DhRs 16	(North Vancouver)	3430	282	50	18.2	SW	7.2	1045	553
DhRs 19	Liquid Air	663	69	273	14.8	SW	4.3	1893	922
DhRs 21	(Stanley Park)	161	236	48	3.0	SE	2.1	1769	667
DhRt 1	Male Vill. (Musqm W)	347	158	201	5.0	SW	2.7	5436	470
DhRt 2	Stselax (Musqueam E)	133	193	461	11.7	W	1.8	5053	992
DhRt 3	Musqueam N. ("Old")	347	421	420	11.8	W	2.8	4741	705

DhRt 4	Musqueam NE	133	118	611	11.7	W	1.8	5053	1142
DhRt 5	Point Grey	2652	65	77	39.8	N	15.3	932	424
DhRt 6	Locarno Beach	1242	324	143	29.2	NE	10.6	1866	575
DhRt 10	Wallace St.	248	260	86	9.1	N	3.3	2720	947
DhRt 13	Canoe Run	2300	1773	83	58.3	SW	16.0	931	242
DhRt 14	(Point Grey)	281	10	41	43.7	SW	10.9	1464	113
DhRt 15	(Point Grey)	281	291	25	39.9	SW	9.9	1464	97
DhRt 17	Booming Grounds	1003	66	93	25.0	SW	6.6	3132	181
DhRt 18	(Point Grey)	248	53	183	12.5	N	4.1	2720	1044
DhRt 22	Mah Farm	1646	0	328	0.0	0	0.0	0	0
DhRt 36	Tait Farm	1646	0	276	0.0	0	0.0	0	0
DhRt 74	Mc Cleary Golf Crse.	2027	204	879	27.0	SW	4.4	4219	1092

Appendix D: Vegetation Measurements

Table 1: Vegetation Polygons with plant community and area (all values in hectares).
See Appendix F for corresponding plant community names.

Site ID	Polygon 1	Area	Polygon 2	Area	Polygon 3	Area	Polygon 4	Area	Polygon 5	Area	Polygon 6	Area	Polygon 7	Area	Water Area
DfRs 3	g	63.0	A	4.6	C M	2.2		0.0		0.0		0.0		0.0	8.8
DgRr 1	D	20.5	C M	19.7	C H	17.2	g	2.6		0.0		0.0		0.0	18.6
DgRr 2	C M	39.7	C H	7.5	D	0.5		0.0		0.0		0.0		0.0	30.9
DgRr 6	C M	28.4	D	13.2		0.0		0.0		0.0		0.0		0.0	37.0
DgRr 7	D F C	20.5	D	20.1		0.0		0.0		0.0		0.0		0.0	38.0
DgRr 9	D	14.0	D F C	14.0	A B Ch	13.7		0.0		0.0		0.0		0.0	36.9
DgRr 11	D F C	14.1	D	12.2	A B Ch	6.6		0.0		0.0		0.0		0.0	45.7
DgRr 12	D	27.3	C M	3.2	D F C	2.6		0.0		0.0		0.0		0.0	45.5
DgRr 24	Cw	25.0	C H	20.1		0.0		0.0		0.0		0.0		0.0	33.5
DgRs 1	D	26.5	D F C	18.9	Cw	16.1	D	11.5	g	4.9	A B Ch	0.6		0.0	0.0
DgRs 2	D	21.4	C M	15.0	D F C	14.2	g	4.0	Cw	0.4		0.0		0.0	23.6
DgRs 4	A B Ch	23.9	Cw	18.4	C H	17.1	C M	9.9	D	6.7	D F C	2.5	g	0.1	0.0
DgRs 7	D	39.4	Cw	7.0		0.0		0.0		0.0		0.0		0.0	32.2
DgRs 9	D	16.4	C M	14.4	D F C	13.1		0.0		0.0		0.0		0.0	34.7
DgRs 11	D	21.9	C M	19.3	D F C	6.2		0.0		0.0		0.0		0.0	31.2
DgRs 15	m P	77.8	g	0.5	cb P	0.2		0.0		0.0		0.0		0.0	0.0
DgRs 17	m P	39.9	Cw	9.6		0.0		0.0		0.0		0.0		0.0	29.1
DgRs 30	g	37.9	D F C	23.5	sg sw s	13.5	A B Ch	3.4	Cw	0.2	A	0.1		0.0	0.0
DgRs 36	g	29.6	sg sw s	21.5	Cw	11.2	D F C	10.4	D	5.9		0.0		0.0	0.0
DhRq 12	lt cb P	39.5	C H	11.1	D F C	8.3		0.0		0.0		0.0		0.0	19.7
DhRq 13	lt cb P	38.0	D F C	15.0		0.0		0.0		0.0		0.0		0.0	25.6
DhRq 19	W ca hh r	26.6	C H	22.7		0.0		0.0		0.0		0.0		0.0	29.3
DhRq 21	A B Ch	30.4	C H	9.5	D F C	8.2	g W hh ca	3.8		0.0		0.0		0.0	26.7
DhRr 75	C M	29.2	C H	23.8	W ca hh r	0.1		0.0		0.0		0.0		0.0	25.5
DhRs 1	g	23.8	C M	12.0	P	12.0	A	9.0	W ca hh r	4.5		0.0		0.0	17.3
DhRs 19	g	22.7	P	22.2	C H	8.7	A	5.8	C M	3.7		0.0		0.0	15.5
DhRt 3	C H	26.9	g	21.6	D F C	9.4	br s ct	7.5	C M	5.6	H C P	2.4		0.0	5.2
DhRt 4	C H	49.8	g	25.6	H C P	3.2		0.0		0.0		0.0		0.0	0.0
DhRt 14	C M	24.2	D F C	21.0	C H	3.8		0.0		0.0		0.0		0.0	27.2
DhRt 15	C M	22.7	D F C	22.6	C H	5.4		0.0		0.0		0.0		0.0	27.9
DhRt 17	D F C	27.9	C M	18.0		0.0		0.0		0.0		0.0		0.0	32.7
DhRt 22	W ca hh r	33.7	g	31.0	br s ct	7.0		0.0		0.0		0.0		0.0	6.9
DhRt 36	g	36.4	ca	26.9		0.0		0.0		0.0		0.0		0.0	15.3
DhRt 74	C H	40.7	D F C	26.1	C M	10.6	P	0.9		0.0		0.0		0.0	0.0

Table 2: Vegetation Types and associated areas (all values in hectares).
See Appendix F for corresponding plant community names.

Site ID	Type 1	Type 2	Type 3	Type 4	Type 5	Type 6	Type 7	Type 8
DfRs 3	63.0	0.0	0.0	4.6	0.0	2.2	0.0	8.8
DgRr 1	2.6	0.0	0.0	0.0	0.0	36.9	20.5	18.6
DgRr 2	0.5	0.0	0.0	0.0	0.0	47.2	7.5	30.9
DgRr 6	0.0	0.0	0.0	0.0	0.0	28.4	13.2	37.0
DgRr 7	0.0	0.0	0.0	0.0	0.0	0.0	40.6	38.0
DgRr 9	0.0	0.0	0.0	13.7	0.0	0.0	28.0	36.9
DgRr 11	0.0	0.0	0.0	6.6	0.0	0.0	26.3	45.7
DgRr 12	0.0	0.0	0.0	0.0	0.0	3.2	29.9	45.5
DgRr 24	0.0	0.0	0.0	25.0	0.0	20.1	0.0	33.5
DgRs 1	4.9	0.0	0.0	16.7	0.0	0.0	56.9	0.0
DgRs 2	4.0	0.0	0.0	0.4	0.0	15.0	35.6	23.6
DgRs 4	0.1	0.0	0.0	42.3	0.0	27.0	9.2	0.0
DgRs 7	0.0	0.0	0.0	7.0	0.0	0.0	39.4	32.2
DgRs 9	0.0	0.0	0.0	0.0	0.0	14.4	29.5	34.7
DgRs 11	0.0	0.0	0.0	0.0	0.0	19.3	28.1	31.2
DgRs 15	0.5	0.0	78.0	0.0	0.0	0.0	0.0	0.0
DgRs 17	0.0	0.0	39.9	9.6	0.0	0.0	0.0	29.1
DgRs 30	51.4	0.0	0.0	3.7	0.0	0.0	23.5	0.0
Dgrs 36	50.1	0.0	0.0	11.2	0.0	0.0	16.5	0.0
DhRq 12	0.0	0.0	39.5	0.0	0.0	11.1	8.3	19.7
DhRq 13	0.0	0.0	38.0	0.0	0.0	0.0	15.0	25.6
DhRq 19	0.0	26.6	0.0	0.0	0.0	22.7	0.0	29.3
DhRq 21	3.8	0.0	0.0	30.4	0.0	9.5	8.2	26.7
DhRr 75	0.0	0.1	0.0	0.0	0.0	53.0	0.0	29.2
DhRs 1	23.8	4.5	0.0	9.0	12.0	12.0	0.0	17.3
DhRs 19	22.7	0.0	0.0	5.8	22.2	12.4	0.0	15.5
DhRt 3	29.1	0.0	0.0	0.0	2.4	32.5	9.4	5.2
DhRt 4	25.6	0.0	0.0	0.0	3.2	49.8	0.0	0.0
DhRt 14	0.0	0.0	0.0	0.0	0.0	28.0	21.0	27.2
DhRt 15	0.0	0.0	0.0	0.0	0.0	28.1	22.6	27.9
DhRt 17	0.0	0.0	0.0	0.0	0.0	18.0	27.9	32.7
DhRt 22	38.0	33.7	0.0	0.0	0.0	0.0	0.0	6.9
DhRt 36	36.4	26.9	0.0	0.0	0.0	0.0	0.0	15.3
DhRt 74	0.0	0.0	0.0	0.0	0.9	51.3	26.1	0.0

Appendix E: Soil polygons with soil type and area (all values in hectares).

See Appendix G for soil type details.

Site ID	Polygon 1	Area	Polygon 2	Area	Polygon 3	Area	Polygon 4	Area	Polygon 5	Area	Polygon 6	Area
DfRs 3	SAf	33.4		0.0		0.0		0.0		0.0		0.0
DgRr 1	Va	23.5	Cd	13.4	SAg	13.3	PVa,f	12.0		0.0		0.0
DgRr 6	PVa,c,f	26.2	Fc	21.1	Cd	11.2		0.0		0.0		0.0
DgRr 7	PVa,f	24.5	Cd	18.5	Va	11.5	Cb	3.0		0.0		0.0
DgRr 9	Cd	23.2	PVa,f	20.1	Va	12.7		0.0		0.0		0.0
DgRr 11	PVa,f	27.9	Cd	19.0	Va	8.9		0.0		0.0		0.0
DgRr 12	Cd	15.6	Va	11.4	PVa,f	4.2		0.0		0.0		0.0
DgRr 24	Fb	13.3	Fc	2.5		0.0		0.0		0.0		0.0
DgRs 1	Cb	19.8	SAd	16.5	SAf	15.8	SAf	15.5	VCb	6.8	VCb	3.4
DgRs 4	Cb	42.6	Fb	17.3	Cd	11.6	SAf	3.9	Fb	2.8	SAd	0.3
DgRs 11	VCb	30.0	PVa,f	10.0	SAf	5.5	Cb	1.4		0.0		0.0
DgRs 15	SAb	78.5		0.0		0.0		0.0		0.0		0.0
DgRs 17	SAb	49.5		0.0		0.0		0.0		0.0		0.0
DgRs 36	SAf	25.7	SAd	25.2	Fb	16.8	Cb	3.2	Cd	3.0		0.0
DhRq 1	SA-C	40.3	VC	32.7		0.0		0.0		0.0		0.0
DhRq 12	Fc	59.0		0.0		0.0		0.0		0.0		0.0
DhRq 13	Fc	45.9	SAb	7.1		0.0		0.0		0.0		0.0
DhRq 19	Fc	46.7		0.0		0.0		0.0		0.0		0.0
DhRq 21	VC	44.4	Fc	6.2		0.0		0.0		0.0		0.0
DhRr 3	Ca	23.6	VC	17.3		0.0		0.0		0.0		0.0
DhRr 16	VC	18.5	PVa,d	5.3		0.0		0.0		0.0		0.0
DhRr 18	Ca	12.4	Va	2.4	VC	0.3		0.0		0.0		0.0
DhRr 75	VCb	38.0	SAa	8.5	UPV	0.9		0.0		0.0		0.0
DhRs 1	VCb	40.4	Fc	9.1	SAa	2.8		0.0		0.0		0.0
DhRs 2	VCb	49.3		0.0		0.0		0.0		0.0		0.0
DhRs 6	VCb	30.6	T	18.8	VCa	15.9		0.0		0.0		0.0
DhRs 7	T	34.6	VCa	18.4	VCb	16.2		0.0		0.0		0.0
DhRs 16	VCb	36.9	SAi	10.7		0.0		0.0		0.0		0.0
DhRt 1	Fc	27.4	Cb	7.0		0.0		0.0		0.0		0.0
DhRt 4	Fc	61.4	SAe	13.1	VCb	4.0	Cb	5.1		0.0		0.0
DhRt 5	PVa	18.3	VCb	9.8	SAG	2.1		0.0		0.0		0.0

Site ID	Polygon 1	Area	Polygon 2	Area	Polygon 3	Area	Polygon 4	Area	Polygon 5	Ares	Polygon 6	Area
DhRt 6	VCb	22.9	PVA	17.8	SAg	6.3		0.0		0.0		0.0
DhRt 13	PVa	20.6	VCb	18.2	Cb	5.1		0.0		0.0		0.0
DhRt 14	VCb	38.2	PVa	12.6		0.0		0.0		0.0		0.0
DhRt 17	Cb	26.9	VCb	15.1	PVa	3.9		0.0		0.0		0.0
DhRt 18	Cd	33.0	SAg	8.4	VCb	2.6		0.0		0.0		0.0
DhRt 22	Fa	71.6		0.0		0.0		0.0		0.0		0.0
DhRt 36	Fc	33.4	Fb	21.2		0.0		0.0		0.0		0.0
DhRt 74	Cb	42.1	Fc	35.3	VCb	1.1		0.0		0.0		0.0

Appendix F - Vegetation Codes
(from North et al. 1979)

PLANT CODE	PLANT TYPES
1. GRASSES	
sg sw s	Salt Marsh: saltgrass, saltwort, sedge
br s ct	Tidal Marsh: bulrush, sedge, cattails
ct	Freshwater Marsh: cattails
g	Prairie: grass
g W hh ca	Prairie grass with shrubs: grass, willow, hardhack, crabapple
2. SHRUBS	
ca	crabapple
W	willow
W ca hh r	Mixed shrubs: Willow, crabapple, hardhack, rose
3. SHRUBS/MOSS	
lt cb P	Labrador tea: labrador tea, cranberry, salal, Pine
cb P	Cranberry marsh: cranberry, Pine
m P	Moss with scrub pine: sphagnum, scattered Pine, Hemlock
4. WOODLAND	
M	Maple bottom: Broadleaf maple, vine maple, ferns, some Cedar
A	Alder bottom: Alder, Willow, ferns, some Cedar,Hemlock, Spruce
Cw	Mixed woodland: Cottonwood, Alder, Willow, crabapple
A B Ch	Mixed deciduous regeneration forest: Alder, Birch, Cherry, Willow
5. SCRUB FOREST	
W sk	Willow scrub: Willow, Alder, skunk cabbage
W A pv rc	Scrub with herbs: Willow, Alder, Hazel, ferns, pea vine, red clover

PLANT CODE	PLANT TYPES
P	Pine scrub: Pine species
H C P	Mixed scrub: Hemlock, Cedar, Pine, some Douglas fir, Alder, Cherry
6. CONIFEROUS FOREST (CEDAR)	
C P H	Mixed coniferous forest on organics: Cedar, Pine, Hemlock, Spruce
C A sk	Cedar swamp: Cedar, Alder, Willow, hardhack, skunk cabbage
C H	Mixed wet: Cedar, Hemlock, Spruce, Alder, Willow, Yew, some Cottonwood
S W	Spruce: Spruce, Willow, Alder, crabapple
S C	Spruce: Spruce, Cedar, some Hemlock, Broadleaf Maple
C H D	Mixed Coniferous: Cedar, Hemlock, Douglas fir, Alder, Willow
C M	Slope: Cedar, Broadleaf maple, Hemlock, some Douglas fir, Alder
7. CONIFEROUS FOREST (DOUGLAS FIR)	
D F C	Mixed coniferous: Douglas fir, Grand fir, Cedar, some Hemlock, Pine
D	Douglas fir: Douglas fir, salal, oregon grape, some Cedar, hawthorn

Appendix G - Soil codes
(from Geological Survey of Canada 1978)

SOIL CODE	SOIL TYPE
01 LANDFILL	
SAa	sand, gravel, till, crushed stone, refuse
02 BOG, SWAMP, SHALLOW LAKE DEPOSITS	
SAb	lowland peat overlaying Fb,c;
SAc	lowland peat underlyingFb
SAd	organic rich sandy loam to clay loam
SAe	upland peat
03 MARINE SHORE SEDIMENTS	
SAf	sand to sandy loam
SAg	sand to gravel
04 LOWLAND AND MOUNTAIN STREAM DELTAIC, CHANNEL FILL	
SAh	lowland stream channel fill
SAi	mountain stream marine deltaic medium to coarse gravel
SAj	mountain stream channel fill sand to gravel
05 FRASER RIVER SEDIMENTS	
Fa	channel deposits, fine to medium sand
Fb	overbank sandy to silt loam
Fc	overbank silty to silt clay loam
Fd	deltaic and distributary channel fill
Fe	estuarine, fossiliferous interbedded fine sand
06 MARINE SHORE & FLUVIAL SAND	
SA-C	postglacial and pleistocene marine shore & fluvial sand

SOIL CODE		SOIL TYPE
07 CAPILANO SEDIMENTS		
Ca		raised marine beach, poorly sorted sand to gravel
Cb		raised beach, medium to coarse sand
Cc		raised deltaic and channel fill
Cd		marine and glaciomarine stony to stoneless silt
08 VASHON DRIFT & CAPILANO SEDIMENTS		
VCa		bedrock within 10m or less of the surface
VCb		bedrock more than 10m below the surface
09 VASHON DRIFT		
Va		lodgement tilland minor flow till
Vb		glaciofluvial sandy gravel
10 PRE-VASHON DEPOSITS (usually intebedded)		
PV	a	Quadra fluvial channel fill
	b	Quadra deltaic deposits
	c	Quadra marine interbedded fine sand
	d	Coquitlam till
	e	Cowichan Head organic sediments
	f	Semiahmoo glaciomarine, glaciofluvial sediments
11 UNDIVIDED PRE-VASHON DEPOSITS		
UPV		till, glaciofluvial, glaciolacustrine, fluvial, marine, & organic deposits
12 TERTIARY		
T		Tertiary bedrock - sandstone, siltstone, shale, conglomerate
13 PRE-TERTIARY		
PT		Mesozoic bedrock including granitic & associated rock types