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A Prehistoric Archaeological Survey of the St. Jones and Murderkill Drainages, Kent County, Delaware

by

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A LANDSAT - Generated Predictive Model for Prehistoric Archaeological Sites in Delaware's Coastal Plain

by

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INTRODUCTION

Between January 1982 and June 1983, an archaeological survey project was carried out within the St. Jones and Murderkill drainage basins in Kent County, Delaware. This report describes the survey methods utilized, the findings of the survey, and the implications of the findings for regional settlement pattern models and interpretations of the region's prehistory. The main goal of this survey project to be discussed here was to test current models of regional settlement patterns for the central Delaware area. The specific study area focused on the St. Jones and Murderkill drainages of southern Kent County (Figure 1). The southern boundary of the study area was the northern limits of the Mispillion drainage while the northern boundary of the study area ran just north of Dover to the Little Creek drainage (Figure 1). The western boundary of the study area was the beginning of the poorly-drained mid-peninsular drainage divide which approximately parallels Route 13. From here, the study area extends east to the shore of the Delaware Bay.

This area was chosen for study for a number of reasons. First, it is one of the most completely studied areas of Delaware. Within the study area are several individual archaeological sites which are listed on the National Register of Historic Places, a National Register District that encompasses much of St. Jones Neck (Delaware Division of Historical and Cultural Affairs 1978), two intensively studied highway corridors (Cunningham et al. 1981; Griffith and Artusy n.d.), and the densest accumulation of known archaeological sites in Delaware. Nonetheless, most of the known sites are located along the major drainages and it was deemed desirable to study a sample of sites from interior areas to generate a more complete picture of local settlement patterns. Secondly, the study area is the focus of rather distinctive prehistoric cultures during Woodland I times (ca. 3000 B.C. - A. D. 1000). During this time period three cultural complexes (Barkers Landing, Delmarva Adena, and Webb) show indications of participation in long-distance trade and exchange networks and ranked social organizations (Custer 1983a). These societies are of special anthropological interest and theories about their development (Custer 1982) often discuss the changing regional settlement patterns. Therefore, analysis of a sample of varied site types and locations should help to clarify explanations random component. Also, because testing of site models was desired, it was necessary to ensure that a variety of potential site locations would be studied. It was also necessary to study locations of sites of different functions dating from different time periods. Previous studies in the area (Thomas et al. 1975; Griffith 1974) and the site models to be tested (Custer 1983a, 1983b) all emphasize the variation of site locations in relation to variable environmental settings. Therefore, a stratified sampling design which ensured coverage of varied environmental settings was utilized. In sum, a stratified random sample that considered all undeveloped and undisturbed areas was utilized. This type of sample design has been shown to provide the most accurate and precise estimates of archaeological site locations (Custer 1979) and has been successfully applied to other regional surveys (Wall 1981; Custer 1980).

Stratification of the study area was accomplished at two levels. First, the study area was divided into four large environmental zones (strata) that run roughly parallel to the Delaware Bay shore. These zones correspond to the variability in salinity of the esturaine drainages, the order of the drainage, and match with the edaphic zones described by Custer (1983a:Chapter 2) in a review of Delaware paleoenvironments. Past studies (Custer 1981, 1983a, 1983b) have demonstrated the variable site distributions among these strata and Figure 2 shows their location within the study area. Table 1 lists the major zones and provides a short description of each. It should be noted that these zones were defined taking into account paleoenvironmental changes and the effects of post-Pleistocene sea level rise. For example, Zone III (Mid-Drainage) was defined so that it includes all post-Pleistocene locations of the oligohaline as can be determined from the work of Kraft (Belknap and Kraft 1978; Kraft et al. 1976). Also, although the exact environments present in any given zone may have varied through the Holocene, at any given time environments within any given zone would have been more similar than when compared to environments between zones.

These large-scale environmental zones would have had varied site distributions; however, to monitor site variation over the landscape at a more local level, and to test the predictive models, it was necessary to divide the study area into smaller, more specifically defined sub-strata. The definitions of the major strata accounted for the variability in well-drained/poorly-drained soils and presence/absence of marsh settings. However, the presence/absence of surface water, its nature, and order are additional variables that account for up to 50% of the variability of the site locations in other areas of Delaware's Coastal Plain (Wells et al. 1981). Also, surface water setting was seen as an important variable in the models tested. Therefore, eight categories of surface water setting were recognized and used to define a series of sub-strata that comprised the actual strata sampled. Table 2 lists the various sample strata that were defined by combining the major strata and the observed surface water settings.

Table 1: Major Environmental Zones

Zone	Description
I	Bay Front Zone - includes the Delaware Bay shore and salt marsh areas at the mouths of the highest order drainages. Well-drained land is limited to isolated high spots within the marshes and headlands bordering the inland side of the salt marshes. Fresh water is limited.
II	Bay Front/Mid-Drainage Transition Zone - includes extensive marshy areas along major drainage channels and extensive well-drained headlands of the inland side of the bay front marshes. Freshwater low-order tributaries of the major drainages are limited in number and extent.
III	Mid-Drainage Zone - includes the area of saltwater/freshwater transition (oligonaline) along the major drainages. Freshwater tributaries of the major drainages are abundant as are tidal marshes of varying salinity. Fairly extensive poorly-drained woodlands characterize the interior areas away from the major drainages.
IV	Drainage Divide Transition Zone - includes the low-order tributaries and sources of the major drainages with extensive areas without associated surface water. Some poorly-drained bay/basin features with associated well-drained sand ridges are also present.

In order to apply this sampling design the entire study area was divided into 1826 400 m x 400 m quadrats (292 square km). Major environmental zones were delineated along quadrat boundaries and each quadrat was classified according to the type of surface water present. Rosters of all quadrats within each sample stratum listed in Table 2 were prepared and a 5% random sample was drawn from each stratum. Areas which were currently marsh and inaccessible, as well as developed areas, were not included in the sample. Once these sample quadrats were chosen they were subjected to field investigation. If a sample quadrat contained a known site, it was not field surveyed and the known site was included in the current study's sample results. Sample quadrats with no known sites were investigated by pedestrian survey and if the local topography indicated the possible presence of buried landscapes, or if ground surface visibility was limited, subsurface testing was carried out. In most cases, the areas surveyed were in locations with no possibility of undisturbed buried landscapes and wooded areas with poor surface visibility have been poorly drained since the end of the Pleistocene. Therefore, it can be assumed with some degree of confidence that all sites present in sample quadrats were discovered by these survey techniques.

As a final comment on the sampling design and research methods, it should be noted that the stratified sample drew us to consider many interior areas away from drainages that had rarely been surveyed previously. In most cases, quadrats with known sites were located along the drainages so that actual fieldwork was concentrated in areas that most predictive models would have classified as having a low probability of site locations. However, as will be seen from a consideration of the survey results, some sites were discovered in these areas.

SURVEY RESULTS

A total of 115 sample quadrats (18.4 square km) were surveyed and these contained 71 prehistoric archaeological sites (Table 3). Galasso (1983:Appendix D) provides a listing of all sample quadrats studied and the presence or absence of sites in them. Appendix I lists the sites in the survey sample and notes their associated surface water setting, time period of occupation, and inferred function. Functional site types, time periods, and archaeological complexes noted in Appendix I are derived from the conventions noted by Custer (1983a, 1983b) which recognize macro-band base camps (habitation sites occupied by multiple social units), micro-band base camps (habitation sites occupied by single or limited social units), and procurement sites (limited activity sites). Table 4 summarizes the distribution of sites and the association of varied archaeological complexes with the environmental zones and sample strata. Table 5 summarizes the functional site type counts and densities by the large environmental zones.

DISCUSSION

The results of the survey sample have numerous implications for testing of site distribution models and discussions of processes of regional cultural development. These implications are discussed below for each of the major time periods of Delaware prehistory.

<u>Paleo-Indian Period</u> (ca. 12,000 B.C. - 6500 B.C.) Only two sites dating from this time period were encountered in the survey. Both contained Kirk notched projectile points and consisted of small lithic scatters that indicate occasionally utilized procurement sites. One site was located at an interior setting in Zone IV and the other was located at the confluence of two minor streams in Zone III. The low number of sites from this time period and their location in inland areas adjacent to the mid-peninsular drainage divide generally corresponds to settlement models for this period that stress use of poorly drained game-attractive settings of the mid-peninsular drainage divide (Custer 1983a; Custer, Cavallo, and Stewart 1983). However, problems of site preservation and low frequency of site occurrence make this specific survey an inadequate test of Paleo-Indian site models.

Table 4: Archaeological Components and Environmental Strata

Environmental Zone	# of Sample Quadrats	Sites[a] Paleo-Indian	Archaic	Woodland I	Woodland II
Bay Front Zone (I)	9	0	2	4	3
I-Interior	1	0	0	1	1
I-Major Drainage	1	0	1	1	1
I-Minor Drainage	2	0	0	0	0
I-Bay Front Marsh	3	0	1	1	1
I-Minor/Minor Confluence	2	0	0	1	0
Bay Front/Mid-Drainage Transition Zone (II)	16	0	1	6	2
II-Interior	3	0	0	0	0
II-Interior Swamp	3	0	0	1	0
II-Major Drainage	2	0	0	0	1
II-Minor Drainage	5	0	1	4	1
II-2 Minor Confluence	2	0	0	1	0
II-Major/Minor Confluence	1	0	0	0	0
Mid-Dranage Zone (III)	32	1	1	9	5
III-Interior	9	0	0	2	1
III-Interior Swamp	1	0	0	0	0
III-Major Drainage	5	0	0	2	1
III-Minor Drainage	8	0	1	3	0
III-2 Minor Confluence	5	1	0	0	1
III-Major/Minor Confluence	3	0	0	1	1
III-2 Major Confluence	1	0	0	1	1
Drainage Divide Transition Zone (IV)	58	1	1	10	3
IV-Interior	24	1	0	2	1
IV-Interior Swamp	4	0	0	0	0
IV-Major Drainage	2	0	0	2	0
IV-Minor Drainage	16	0	1	4	2
IV-2 Minor Confluence	8	0	0	2	0
IV-Major/Minor Confluence	4	0	0	0	0

[a]Note: These counts represent components at sites, not the sites themselves. Table 3 lists the total numbers of sites per zone in the sample quadrats. See Appendix I for a listing of known complexes and site functions.

Archaic Period (6500 B.C. - 3000 B.C.) A total of 5 sites with Archaic components were discovered during the survey. Identification of components dating to the Archaic Period is difficult because there is an absence of excavated components from this time period. Therefore, the number of Archaic sites may be underestimated. Existing site models (Custer 1983a, 1983b) stress small sites in a variety of locations appearing with a frequency lower than later sites. A comparison of the site frequencies for the Archaic Period listed in Table 5 with Woodland I and II frequencies shows that this survey's results generally uphold the basic components of the models. However, there are some variances from the model's expectations.

Four of the Archaic sites in the survey were located along minor drainages in Zones II - IV and are difficult to place in standard functional categories. They are generally too large to be termed procurement sites and lack the range of varied tool types that characterize micro-band base camps (Galasso 1983:25). Similar patterns were noted by Wise (1983) in a survey in Delaware's High coastal Plain of southern New Castle County and a settlement system consisting of small seasonally mobile populations is suggested. Although this system would generally correspond to the Archaic settlement models proposed, there seem to be more sites in more varied environmental settings than originally proposed by Custer (1981). Consequently, intuitive probabilities of site potentials noted for Archaic sites in the Coastal Plain (Custer 1983b) should probably be revised upward. It should be noted that one Archaic macro-band base camp site was found along a major drainage in Zone II. Site locational models projected this kind of Archaic site in floodplain locations, but this is the first time that one was actually discovered in Delaware. Similar Archaic macro-band base camp site locations have been noted in other Middle Atlantic area surveys (e.g.- Custer 1980) and usually these sites are also the location of later macro-band base camps, as is the case for the site in this survey. These finds indicate that some kind of macro-band base camp focal point exists in the Archaic settlement systems which also include a variety of micro-band base camp/large procurement sites.

Woodland I Period (3000 B.C. - A. D. 1000) A total of 29 Woodland I sites were discovered in this survey and this is the largest number of sites from any time period. Examination of density figures in Table 5 shows a similar trend. Of these 29 sites, 23 (88% of the total Woodland I sites) were located in floodplain settings. Eleven sites (38%) were located along major drainages, or at stream confluences. These findings support existing site models that stress a shift of settlement pattern foci to major drainage floodplain settings as part of an adaptive response to the warm, dry climatic conditions of the mid-postglacial xerothermic (Custer 1982). All Woodland I sample sites in the floodplain settings were base camps, many with storage features and associated middens, thus supporting hypotheses of intensified settlement/ subsistence systems in floodplain settings during Woodland I times.

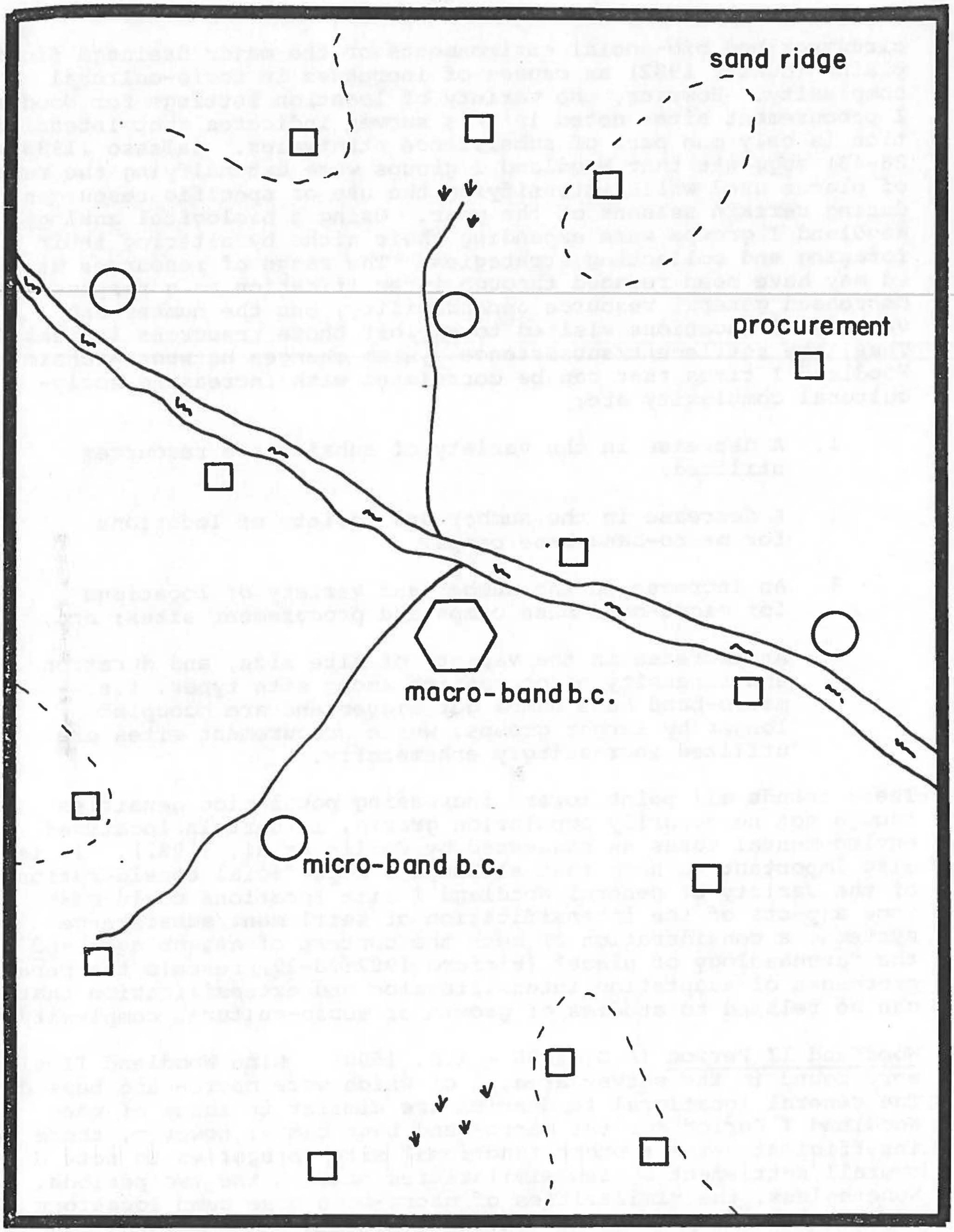

FIGURE 3: Woodland I Site Model

In conclusion, this survey of the St. Jones and Murderkill drainages provided significant information on site location tendencies for Delaware's Coastal Plain. Most importantly, the survey's systematic coverage of a variety of environmental zones, including the poorly-studied interior areas, provides a series of reliable estimates of densities of different functional site types from different time periods. Because these data can then be used to test and refine site distribution models, similar studies using controlled sample designs are recommended for other areas of Delaware.

Appenix I - Sites in Survey Sample (Cont'd.)

Frederica Quad (Cont'd.)

Sample Unit	Surface Water Setting	Time Period, Component, Function
IV.51	interior	Woodland I; procurement
IV.67	major/minor confluence	no diagnostics, procurement (?)

Harrington Quad

Sample Unit	Surface Water Setting	Time Period, Component, Function
IV.48	interior	(7-K-E96) Woodland I and II; Barkers Landing and Delmarva Adena Complexes; micro-band base camp/ large procurement
IV.35	minor	(7-K-E113) Woodland I; procurement
IV.65	major/minor confluence	(7-K-E48) Woodland I (Killens Pond Adena site); Delmarva Adena Complex; macro-band base camp and mortuary/exchange center
IV.67	interior	no diagnostics, procurement (?)
IV.73	major	no diagnostics, procurement (?)
IV.112	interior	no diagnostics, procurement (?)
IV.129	interior	no diagnostics, procurement (?)
IV.199	minor/minor confluence	(7-K-E115) Woodland I; Barkers Landing, Delmarva Adena/Wolfe Neck, Carey Complexes; micro-band base camp/ large procurement
IV.221	minor	no diagnostics, procurement (?)

Wyoming Quad

Sample Unit	Surface Water Setting	Time Period, Component, Function
III.12	interior	no diagnostics, procurement (?)
III.35	minor/minor confluence	(7-K-C89) Woodland I procurement
IV.109	interior	no diagnostics, procurement (?)
IV.21	interior	no diagnostics, procurement (?)
IV.67	minor	Archaic; micro-band base camp/large procurement
IV.79	minor/minor confluence	Woodland I; Wolfe Neck Complex; micro-band base camp
IV.105	minor/minor confluence	no diagnostics, procurement (?)
IV.77	minor	Woodland I; procurement
IV.38	minor	no diagnostics, procurement (?)
IV.291	minor/minor confluence	no diagnostics, procurement (?)

Milford Quad

Sample Unit	Surface Water Setting	Time Period, Component, Function
II.6	minor/minor confluence	Woodland I; micro-band base camp/ large procurement
III.24, 34	major/minor confluence	(7-K-F2) Woodland I and II; Barkers Landing, Wolfe Neck/Delmarva Adena, Carey, Webb, Slaughter Creek Complexes; macro-band base camp

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INTRODUCTION

The purpose of this paper is to describe the development of a quantified model that uses LANDSAT data to predict the locations of prehistoric archaeological sites in Delaware's Coastal Plain. The development of this model utilized a portion of the stratified random sample of archaeological sites gathered as part of the archaeological survey described in the previous article by Custer and Galasso. Figure 1 shows the portion of the St. Jones-Murderkill survey area utilized in this study. The size of the area utilized to develop the predictive model was dictated by the limitations of the Earth Resources Data Analysis Systems (ERDAS) computer used to analyze the LANDSAT satellite data. The selection of the section of the St. Jones-Murderkill survey area to be used in this analysis was made so as to provide almost complete coverage of a single drainage, the Murderkill, as well as to cross-cut all four major environmental zones.

The development of the predictive model was specifically oriented towards the use of environmental data generated by the LANDSAT satellite. The LANDSAT satellite passes over the Delmarva Peninsula every eighteen days at an altitude of 920 km (Klemas 1977:387) and records four wave lengths of light using a multi-spectral scanner and a return beam vidicon. The data is recorded and transmitted in digital form and analysis is carried out using digital data. LANDSAT data can be used to classify and map various types of environmental zones by first identifying special categories of land classes on-the-ground. These areas, called training sets, can then be identified on the LANDSAT image and the special spectral characteristics of that area can be determined using a variety of statistical techniques (Klemas 1977). Once the special spectral characteristics have been identified, other elements of the LANDSAT image, called pixels, can be compared to the original training set and classified accordingly. Mapping of environmental zones using LANDSAT is quite accurate and comparative studies of remote sensing methods and ground truth data indicate that LANDSAT data produces accurate classifications 87% of the time in coastal environmental settings (Klemas 1977:387). Also, the resolution of the mapping is approximately 80 meters which can discriminate among closely crop marks, shell scatters, or architectural features, to locate archaeological sites (Ebert and Lyons 1976). Because the resolution of the LANDSAT data is 80 m it is generally unsuitable for the specific remote sensing of archaeological sites, although it should be noted that Quann and Bevan (1977) were able to recognize the shadow of the pyramids at Giza. Nevertheless, given the non-spectacular nature of the archaeological remains in the Middle Atlantic region, specific sensing of archaeological sites using LANDSAT is unlikely to succeed in all but a very few cases.

The work of Ian Wells (1981; Wells et al. 1981) provides an alternative approach to the application of LANDSAT data to archaeological modeling. Wells' work did not use LANDSAT data directly to generate an archaeological predictive model; however, he did use a geographic data base that was similar to those that can be generated from LANDSAT. Rather than look for specific variables that could be correlated with archaeological site locations, Wells considered combinations of environmental variables that could be quantitatively correlated with known locations of archaeological sites such as distance to surface water of varying orders, distance to interfaces of well-drained and poorly-drained soils, and the presence of special topographic features such as sinkholes, bay/basin features, or river levees (Wells 1981:41-46). This kind of <u>synoptic</u> analysis is different from <u>specific</u> analysis in that it considers regional combinations of variables relevant to archaeological site locations rathern than indications of specific site locations. As such, it was able to take advantage of the best features of the LANDSAT data.

Wells used a statistical technique known as a logistical regression (Chung 1978) to analyze the relationship between locations of known archaeological sites, as well as locations known not to contain archaeological sites, and environmental variables. Although other statistical methods have been successfully used in similar analyses (e.g. - Kvamme 1981), the logistical regression model was used because it can be applied to gridded data bases, there are few restrictions on the distributions of independent variables, the dependent variable always lies between 0 and 1, and the algorithm is robust and can produce results even from noisy data (Wells 1981:23). The form of the logistic model, which estimates the probability that a certain cell contains at least one site is (Wells 1981:24):

$$PROB(Y(i)=1) = (E(Y(i) = \frac{e^{X(i)'b}}{1+e^{E(i)'b}}$$

where

$$X(i)' = (1, X_{i1}, X_{i2}, \ldots X_{ip})$$

is a vector of the p predictor variables at grid cell i and

The goal of the present study was to take the ODESSA model, with its use of the logistical regression analysis, and directly apply it to a new training set from the Kent County area that would include a grid cell data base of environmental variables developed directly from LANDSAT. The sample from the St. Jones/Murderkill survey was chosen as a training set because it was a controlled stratified random sample of a variety of environmental settings. Also, the Kent County area's general environmental structure was similar to the Appoquinnimink area studied by Wells. Finally, the time range of the majority of sites discovered in both the Appoquinnimink and St. Jones-Murderkill area was the same (ca. 3000 B.C. - A.D. 1000). Specifically, the goals of this study are:

1. Develope a grided environmental data base using strictly LANDSAT-generated data;

2. Apply the ODESSA model and logistical regression method to the LANDSAT-generated data base and develop predictive maps of potential site locations;

3. Test the predictions of the model using known site locations in the St. Jones-Murderkill area.

DEVELOPMENT OF THE DATA BASE

The problem of developing the data base was essentially one of proper classification of a LANDSAT scene. The LANDSAT scene chosen for analysis was taken during March 1979 because it was clear, cloudless, and had very little banding. A March scene was especially useful for classification, based on the variables seen to be useful in Wells' study, because the overall vegetation productivity was low and, consequently, the near IR channel (Band 7) was not oversaturated. This means that on the LANDSAT scene trees stand out a dark purple, wetlands appear as a mottled mixture of pink and blue-grey, and agricultural fields with varied cover (based on drainage characteristics of the soil) show up as reds and pinks of varying brightness. Drainage features appear as dendritic patterns varying from black to light blue depending on turbidity.

After the scene was chosen a series of analyses were carried out to generate a useful classification. Figure 2 shows a flow chart of the various steps involved in this process. The first step was to down-load a small subset of data from two LANDSAT Computer Compatible Tapes (CCT) using the SUBSET program of the ORSER computer program package which is available from the Office for Remote Sensing of Earth Resources, University of Pennsylvania. This provided a subset of the original scene that was statistically debanded after one iteration of the NMAP program of the ORSER package. At this point classification could be carried out using other ORSER sub-routines; however, further analysis of the Murderkill area was carried out using the Earth Resources Data Analysis Systems (ERDAS) system owned by the Center for Remote Sensing, College of Marine Studies University of Delaware. The ERDAS system was utilized because it was specially built to analyze multi-spectral data. The ERDAS system also has a high resolution color monitor, a specially adapted line printer with good graphic characters, and is easier to operate than the larger computers on which the ORSER system runs. The most useful feature of the ERDAS is its ability to interactively alter the display screen functions to enhance the effectiveness of classifications by accentuating faint brightness differences. Also, image enhancement programs can be used and they include high and low pass filters and a histogram equalisation filter.

Classification of the LANDSAT image was accomplished by applying a training program (FIELD). The operator interactively picks a series of LANDSAT sensing units (pixel) that seem to have similar spectral characteristics and which seem to match with culturally significant (Chenhall 1975) environmental characteristics. The FIELD program reports on the spectral characteristics and purity of the series by displaying histograms of pixel brightness and a series of statistical indicators. As accurate and useful classifications are obtained, they are saved in a signature catalogue file. This type of classification is termed a supervised classification (Klemas 1977:389) and 16 specified signatures were generated for the Murderkill area. These signatures and their spatial distribution were then compared to infrared aerial photographs, color aerial photographs, and USGS topographic maps to insure their utility. Table 1 lists the variables that were utilized in the final classified scene.

After the LANDSAT image had been classified into useful variables it was necessary to convert the image into a gridded data base. A series of programs were written to convert the classified LANDSAT data into a gridded data base and to add in the data on the presence or absence of archaeological sites generated from the archaeological survey. Figure 3 shows a flowchart of these programs. In general, these programs created a gridded data base similar to the AERIS data base from a classified LANDSAT image. It should be noted that the program package was written directly on the ERDAS computer and ideally can be run on any small computer with at least 64K of memory, a disk drive, some type of graphics output, and the ability to support Fortran. Machines of this calibre include the TRS-80, Apple II, and the IBM PC. However, the larger ERDAS and B7700 computers are still required to do the initial processing.

The data base generated contained a number of variables including percentages of ground truth grid cells that were classified into the variables listed in Table 1, and a series of minimum distance measures (converted to log distances) to a series of critical environmental variables (Table 1) similar to those shown to be important by Wells (1981:41-46). These variables formed the data base that was utilized in the ODESSA logistical regression model.

Table 1: Variables used in LANDSAT classification

Variable Label	Ground Description	Edaphic Factor
Deep Water	Bay and deeper parts of rivers	High order streams
Shallow, Turbid Water	Turbid sections of rivers	Moderate order streams
Shallow, Clear Water	Less turbid sections of rivers	Low order streams
Salt Marsh 1	Tidal wetland with low productivity	High salinity marshes
Salt Marsh 2	Tidal wetland with high productivity	Brackish and low salinity marshes
Trees	Wooded areas	Very poorly drained soils
Agricultural 1	High productivity farm land	Well-drained soils with some moisture retention
Agricultural 2	Low productivity farm land	Well-drained soils with little moisture retention
Bare Soil 1	Bare soils, dead grasses	Moderately drained soils
Bare Soil 2	Bare soils, dead grasses	Moderately drained soils

APPLICATION OF REGRESSION MODEL

In order to apply the regression model developed by Wells, the ODESSA programs were re-written to run on the ERDAS computer. Some changes in the original programs were made, but the re-written programs provided identical results when compared to Well's model run on the larger computer. The regression model was initially run using the variables listed in Table 1 and converged on a solution. The fact that the model converges on a solution implies that the variables selected do have some meaning for predicting locations. Unfortunately, there were an insufficient number of cases where no archaeological sites were located in the training set to carry out an analysis of variance for these runs of the regression models.

After the model had converged on a solution, the sections of the study area that had not been included as part of the 5% stratified random sample were run through the regression equation and the probabilities for each cell were noted. Figure 4 shows a contour map of the site probabilities. This map is the first map of archaeological site probabilities produced directly using LANDSAT data.

TESTING OF MODEL PREDICTIONS

In order to test the accuracy of the predictions of the logistical regression model, the predicted higher probability locations were compared to known archaeological site locations within the classified area. Although the best test would be to stratify the area by the probability values and then re-survey the area, this would be prohibitively expensive. Fortunately, there is a high density of surveyed and known site locations within the classified area and although these locations represent a biased sample, they do provide an initial test of the model's predictive accuracy.

In order to test the model's predictive accuracy, three probability classes ($p<.50$, $.50<p<.75$, and $p>.75$) were mapped using the original survey grid. The test utilized known sites and previously surveyed areas that were not included in the training set of the model and focused on the two higher probability zones. Specifically, the test of the model's accuracy considered each grid unit that was predicted to have a high or medium probability of having a site and checked to see if a site was truly present. This approach to model testing is consistent with the procedures for using hidden data as described by Snee (1977). Table 2 lists the data quality for each of the probability classes tested. In the high probability zone, 47 (54%) of the 87 grid units had test data available. Of these units 45 (95%) contained prehistoric sites. In the medium probability zone, 34 (29%) units had test data available and 29 (85%) of these units contained sites. In each case these results provide an initial indication that locations predicted by the model to be very likely to contain sites do indeed contain archaeological sites. However, it should be noted that the test data is biased and the results should only be viewed as a preliminary successful test. Further survey would be required to provide an unbiased test data base that could be compared statistically to the model's predictions. It should also be noted that the low incidence of previously surveyed areas within the test area makes it impossible, without further survey, to evaluate whether or not the model is accurate when it predicts an area to be unlikely to have archaeological sites present. Nonetheless, the results of the model's testing are promising and future studies will attempt to gather the additional field test data needed to more effectively test the model.

Table 2: Test Data in Varied Probability Classes

Probability Class	No Data	Developed	Marsh	No Site	Site Present	TOTAL
$p>.75$	30	3	7	2	45	87
$.50<p<.75$	69	2	12	5	29	117

Table 4: Distribution of Probability Classes by Major Environmental Classes

Probability Class	Environmental Zone I	II	III	IV	TOTAL
p>.75	17 (14%)	9 (7%)	23 (8%)	38 (7%)	87 (8%)
.50<p<.75	22 (18%)	17 (13%)	21 (8%)	57 (11%)	117 (11%)
p<.5	80 (68%)	105 (80%)	227 (84%)	421 (82%)	883 (81%)
TOTAL	119	131	271	516	1037

Table 6: Environmental Zones, Cultural Time Periods, and Functional Site Types by Probability Classes

Site Types	Environmental Zones I	II	III	IV	TOTAL
Probability Class: p>.75					
Woodland I					
micro-band	3	4	5	3	15
macro-band	1	0	2	1	4
procurement	0	0	1	1	2
Woodland II					
micro-band	2	0	0	0	2
macro-band	0	0	0	0	0
procurement	0	0	0	0	0
TOTAL	6	4	8	5	23
Probability Class: .50<p<.75					
Woodland I					
micro-band	3	4	5	3	15
macro-band	1	0	2	1	4
procurement	0	0	1	1	2
Woodland II					
micro-band	2	0	0	0	2
macro-band	0	0	0	0	0
procurement	0	0	0	0	0
TOTAL	6	4	8	5	23

The Island Field site is also located in the study area. However, it is not located in either the high or medium probability zones. This would suggest that factors other than the environmental variables used in the predictive model were responsible for the choices of the site's location. A similar pattern was noted in Wells' study (Wells et al. 1981) for a similarly dated exchange center, the Hell Island site. Both these sites belong to the same cultural complex and it has been suggested by Custer (1982, 1983) that these sites served as a focal point for supra-local social organizations that supported the rituals associated with the burials at the exchange/mortuary sites. The predictive model shows a series of potential support site locations in high and medium probability zones adjacent to the Island Field site and these locations are suggested as the habitation sites of the groups that supported the Island Field cemetery. The Island Field site location is centrally located to these support sites and this feature may be its most important locational characteristic, rather than ecological variables. It is also interesting to note that the earlier mortuary/exchange sites do not show a similar patterning. This may suggest that different social organizations produced the seemingly similar mortuary sites from different time periods within the Woodland I Period.

In sum, this paper has shown that quantified predictive models for prehistoric archaeological site locations can be developed using LANDSAT-generated environmental data. The logistical regression technique produces site location predictions that seem to be accurate based on preliminary tests using hidden data. Finally, the results of the predictive model not only have value for locating and managing unknown prehistoric archaeological resources; they can also lead to insights about the settlement-subsistence patterns of prehistoric peoples.

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