# Site Suitability Analysis of Stone Circle Sites in McKenzie County, North Dakota, at Site 32MZSWC

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## Abstract

Site suitability modeling in Archaeology is useful for determining the environmental parameters for site placement, thereby exceeding chance or random factors. If one is able to predict which factors dictate a site's placement, then the salient question is "Why did Prehistoric people choose a certain location? Which terrestrial qualities were considered most useful for placing a circle of stones necessary for holding a tipi in place?" After surveying the 32MZSWC site, located in McKenzie County, North Dakota, certain patterns began to emerge. Many stone circle sites were placed on valley floors close to water, gently sloping open terraces, and bluff tops. Mapping the distribution of environmental factors is a key to understanding the distribution of human activity patterns in the Prehistoric time period. These terrestrial variables can be quantified in a model that helps support a more robust determination of a site's possible location thereby maximizing efficiency of resources in the surveying process.

## Introduction

McKenzie County, North Dakota, was established in 1883, named after Alexander McKenzie. He was a prominent citizen who helped establish the University of North Dakota and North Dakota State University. The county's first nickname was the "Island Empire." It is aptly named because the Missouri River borders the North, the Little Missouri on the East, and the Musselshell on the West. The county is part of the Missouri Plateau, located within the Great Plains Province. The terrain is part of the area known as the North Dakota Badlands. According to the National Resource Conservation Service (NRCS), the Badlands are characterized by steep, short slopes, intricate drainage patterns, little or no vegetative cover, with soils consisting of unconsolidated or poorly cemented clays, silts, shale, and sandstone.

The bedrock is weakly paralithic, meaning it is partially weathered and sometimes weakly consolidated. The soils range from silty, clayey, sandy, and loamy. The Farnuf and Williams's loams are highly represented in the flats and terraces of the study area. They have the highest agricultural value and contain a low percentage of calcium carbonate. Thus, these soils are very fertile and are ideal for farming and ranching. Historically, Norwegian immigrants settled the area, with a smaller population of Swedish, Dutch, German, and Russians (Well, 2005). Prehistorically, the Native American

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tribes that populated the area were the Mandan, Hidatsa, and Arikara (Old Sanish). These tribes still live in the region today on or near the Fort Berthold Reservation. They are commonly referred to as “The Three Affiliated Tribes.”

The purpose of this survey was to locate Historic and Prehistoric archaeological events for the United States Army Corps of Engineers (USACE). They own and monitor the complete extent of the survey area. Inside the USACE boundary, there is a wide range of topography, including slopes that reach 70 % in many places. The study area contains the full gamut of land-use practices. It supports ranching, farming, cattle grazing, pipelines, oil well pads, and coal production. Lignite coal production in the county ranks second, statewide. In parts of the study area, lignite outcrops are 10-40-ft. thick. The lowland areas adjacent to the primary waterways have been heavily plowed for agriculture and grazed by livestock for well over a century. The terrain has been highly affected by USACE damming, water letdowns and even droughts. In short, the terrain has been subject to many forms of topographical disturbances. The USACE area has been heavily impacted by the introduction of invasive plant species of Russian olive, Canada thistle, and salt cedar. These species were highly visible during the survey. There are heavy erosional and colluvial processes in the study area, along with many types of human derived disturbances. Thus, these tipi sites range from high-to-low quality of preservation.

The project area is flanked on the north by Lake Sakakawea (Figure 1). It, however, is a modern structure in the environment. It was created in 1956 when the Garrison Dam was built on the Missouri River in adjacent McLean County. The Three Affiliated Tribes that lived on the Missouri River floodplain were re-located to the newly created city of Newtown and the Fort Berthold Reservation. They had continuously occupied that area for millennia. Many Prehistoric archaeological events were inundated by the newly formed Lake Sakakawea. Given the long-standing history of occupation in the Missouri River floodplain and abutting terraces and bluffs, it is obvious the locale was a beneficial place to thrive.

In this study, 58.8% of the stone circle sites were located on ridges, 29.4% on terraces, and 11.8% were located on the floodplain of Lake Sakakawea, and its adjacent flats. It was obvious upon first sight that plant productivity was greater on the terraces and uplands. There were wide ranges of floral and faunal diversity. Bison, bear, elk, beaver, otter, and pheasant populated the area. The grasses, trees, and forbs, were those listed in tabular STATSGO data. Grasses included: side oats grama, western wheat, needle-and-thread, big blue stem, prairie june grass, barley, buffalo grass, and alfalfa. A short list of plants with high food value included: wild turnip, elderberry, chokecherry, juneberry, prickly pear, winterfat, and buffalo berry. The trees were those usually found along riverine systems and included: American elm, green ash, rocky mountain juniper, willow, scrub oak, and cottonwood. It is highly probable that the carrying capacity of the bluff and terraces was better than the valley floor in Prehistoric time.

Foraging strategies on the uplands played a role, but to what extent and degree? Currently, there is no dating or chronology associated with these stone circle sites. This would require subsurface testing and excavation.

Consequently, no inferences regarding cultural affiliation or temporal/ chronological use and resource allocation can be made at this juncture in time. A major unknown is how many people resided in the stone circles, how long they stayed in-situ, or even if the sites were re-used. It is clear that bluffs and ridges were more attractive than other topographical settings, because they offer a better line-of-sight and defensive protection. If one could predict where a stone circle site had the highest likelihood of being located, sites could then be located and preserved.

"If powerful resource location models can be developed then cultural resource managers could use them as planning tools to guide development and land disturbing activities around a predicted archaeologically sensitive region. This planning potential of predictive models can itself represent significant cost savings for government agencies" (Kvamme, 1998).

There are many circular stone configurations, including cairns, which have religious and social significance. In this research, the focus was on tipi-related stone circle sites. For reasons of ethnographic site protection, no georeferenced coordinates were associated with stone circle sites in this report.

## Methodology

The USACE survey area can be seen in Figure 1. It is bordered entirely on the North by Lake Sakakawea, and spans between the towns of Williston and New Town. It is a distance of 78 miles. Data points were collected on a Garmin Map 60 CS and a Trimble MS860. A team of four people investigated one survey block per day. Each block was three square miles. The team found Historic (post-European contact) North Dakota homesteads as well as Prehistoric Native American settlements.

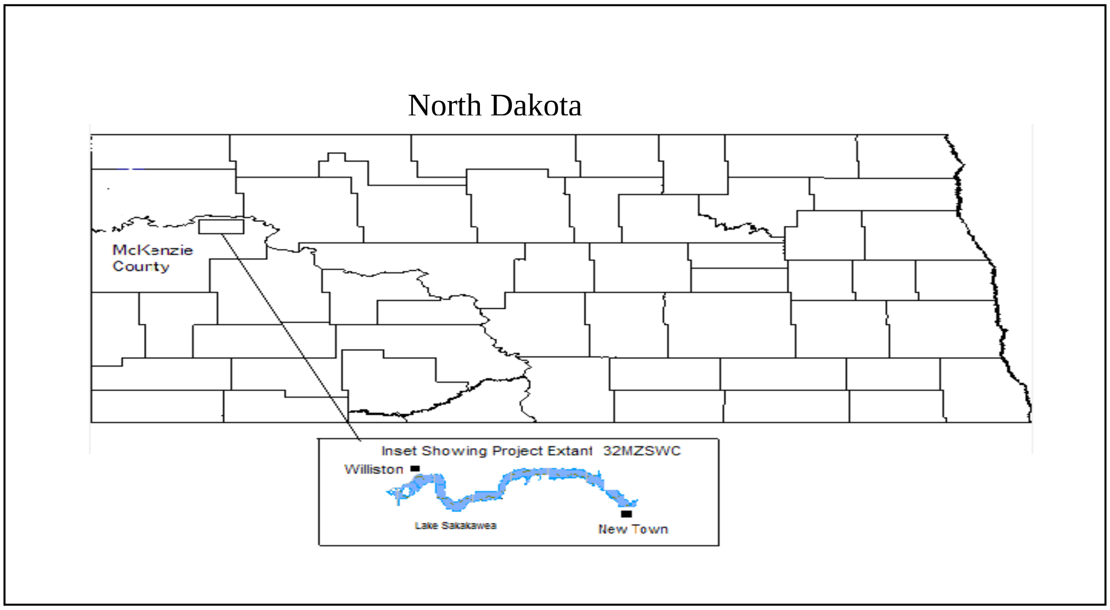

Figure 1. Inset map showing project area.

Seventeen Prehistoric stone circle sites were located. The majority were on bluffs and upland knolls. The stones themselves were comprised of granite and quartzite, and ranged in measurement between 12 and 110 cm in diameter. Many stones were deeply embedded in a layer of sod, and covered with lichen. Only two stone sites had associated cultural material. The objects consisted of Knife River flint fire cracked rock, a grey quartzite secondary modified flake, and two Knife River flint secondary flakes. No dating has been conducted on the flakes at this point. As a result, the small lithic scatter provides no diagnostic cultural information. Five sites consisted of a single stone circle ring. The remaining sites included hearths, assorted depressions, and were comprised of multiple stone circle features; they were multi-component and multi-use.

The survey area spanned 19,693-acres/79,698,790 m². A 5 meter cell size was necessary because several of the sites measured less than 30 meters. The stone circle sites comprised 0.28% of the total survey area.

Preprocessing data was necessary to achieve a common raster size of 5 meters. All shapefiles were converted from polygon to raster, and were displayed in Universal Transverse Mercator (UTM) NAD83 Zone 13. A mask was set in Spatial Analyst using the UTM coordinates of the project boundary. Next, the grids were clipped to the extent of the mask via the Spatial Analyst Clipping tool. Any cells that were outside the project boundary were trimmed, via the Nibble function. Stone Circle sites were termed Sites. The background, Non-Sites, was created by the “Create Random Points” tool in the ArcMap Spatial Analyst Toolbox. The points were converted to shapefile, and then to raster. Summary statistics were tabulated to ensure that the number of Non-Sites grid cells were within range of the Sites grid cell count. The Sites grid cells totaled 9,043, while the Non-Sites contained 9,308.

The data used in this study were nominal, ordinal, and interval. The variables initially applied were: slope, distance to permanent water, land cover, aspect, soil, topographical setting, stream ranking and drainage, and elevation.

The digital elevation models, landcover, soils, and hydrology datasets were obtained from the NRCS (http://datagateway.nrcs.usda.gov/). The slope and elevation data were derived from a National Elevation dataset. The National Landcover dataset was reclassified twice. Initially each and every site was comprised of at least four different types of land cover. The 15 land cover classes were reclassed into seven classes: wetland, mixed grasses, cropland, forest, developed, barren, and open water. All sites were then categorized as grassland. It is likely that grass was the majority land cover. The land cover dataset was removed from the analysis. State soil survey maps, (STATSGO) spatial and tabular data were initially explored, then omitted. The soils map unit contained a mix of soil types such as Farnuf/Zahl/Williams, or Cabba/Zahl/Williams. Each individual site was comprised of varying percentages of soil types, and was not a useful predictor. Most of the sites contained varying degrees of aspect, ranging from 0-365 degrees. Also, using a 5 meter cell size increased the number of aspect readings across larger sites, so it was also omitted. The hydrologic units and drainage were omitted; the creation of the dam skewed their usefulness. The final set of independent variables was “slope”, “distance to water”, and “elevation.” They were assigned weights and re-evaluated. The “slope” variable was given a weight of 0.5 (50%). It was given the highest weight because no archaeological events were found on slopes exceeding 19 %. “Distance to water” was given a medium weight of 0.3 (30%), because it had some bearing on site distribution. No sites were found in excess of 800 meters from Lake Sakakawea. “Elevation” was given a weight of 0.2 (20%), because elevation played a small factor in site distribution. There were 17 Sites and 17 Non-Sites, with the three (weighted) independent variables for each site, for a total of 51 observations. The distribution of the independent variables’ values is shown below (Figure 2). The x-axis is the number of observations and the y-axis, their values.

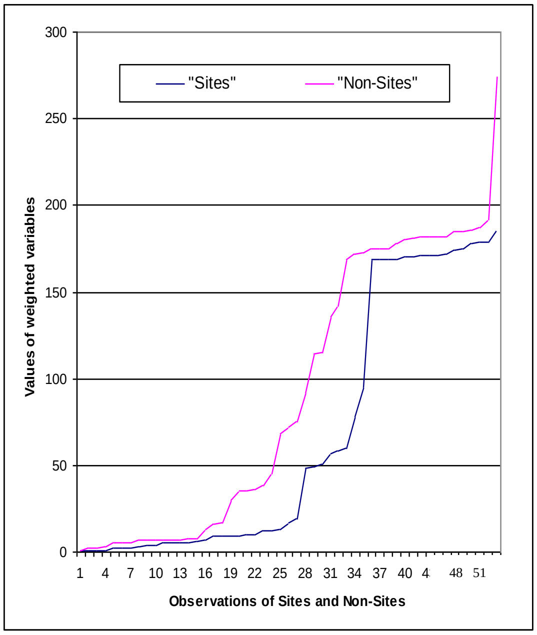

Figure 2. Observations and their values.

The independent variables were described in Excel. Mean and variance descriptive statistics were generated. The non-parametric probability model, Mann-Whitney U (MWU) was implemented at the .05 level. For the parametric tests, a two-sample, one-tail, ANOVA statistic to test equality of variances; and a two-sample, two-tail, Student’s t-test to examine means were generated, both at the .05 significance level (Table 1). These statistical tests were used by Allen (1990) and Kvamme (1998) to assess whether or not the Sites and Non-Sites were normally distributed and came from the same distribution. The probability values generated by the ANOVA test showed no significant difference between the variances of “slope” and “elevation”. The “distance to water” independent variable did exhibit a difference in variance between the Sites and Non-Sites. The Student’s t-test found no significant difference between the means of the slope variables for Sites and Non-Sites. “Distance to water” and “elevation” had a significant difference in their means. In order to see whether or not the independent variables derived from the same distribution, a Mann-Whitney U test was used. “Elevation” and “distance to water” showed significant differences in their probability distributions. Statistically, the “distance to water” variable was the single strongest predictor of site location, with “elevation” ranking second. Slope values between Sites and Non-Sites exhibited no significant difference in the MWU test, although the value was only 0.10 of a percent greater than the 0.05< p level. The range of slope values was small, and spanned from 1-19 %. In addition, there were only 17 stone circle sites. Thus, a small sampling number would account for the

Table 1. Statistical tests.

| Variable | Grouping | Mean | Variance | f-test | t-test | Mann-Whitney |
|---|---|---|---|---|---|---|
| Slope | Sites | 5.47 | 11.38 | | | |
| | Non-Sites | 6.53 | 15.51 | | | |
| | Both | | | P = 0.2717 | P = 0.4062 | P = 0.0629 |
| Elevation | Sites | 173.06 | 23.43 | | | |
| | Non-Sites | 180.53 | 33.76 | | | |
| | Both | | | P = 0.2366 | P = 0.0003 | P = 0.0006 |
| Dist. To Water | Sites | 35.5 | 91.25 | | | |
| | Non-Sites | 890.4 | 4522.46 | | | |
| | Both | | | P = 0.0015 | P = 0.0054 | P = 0.0059 |

lack of deterministic quality of the “slope” variable. Slopes in the Badlands often reached 70 % in the project boundary, so it was confounding to see the variable “slope” as not diagnostically significant. From an ethnographic perspective, it is possible that the people who made camp took an overland route, rather than climbing up the slopes from the river bottoms.

In the next phase, a two-sample Kolmogorov-Smirnov (K-S) goodness of fit test was implemented, to corroborate the t-test results. In this case, each sample contained all of the independent variables for the Sites and Non-Sites. According to Kirkman (2006), the K-S test is useful because it makes no assumptions about the normality and distribution of these data; it is non-parametric and distribution free. The test generates a critical “D” value that is the threshold for determining differences between the Sites and Non-Sites. The K-S test is used to ascertain whether the probability distribution of the two populations differed. The null and alternative hypotheses are as stated:

Ho: There is no difference between the cumulative frequency distribution of the variables of Sites and Non-Sites.

Ha: There is a difference in the cumulative frequency distributions.

For the model, the computation of the critical value, “D” is defined as: 1.95*√ (17+17)/(17*17) = .229 (Westcott, 2000), where 17 is the number of sites. According to the K-S test, the computed D value for all independent variables was .215; thereby falling short of the critical value. This test determined that the distributions are similar. The null hypothesis cannot be rejected.

It was necessary to develop a location model to predict the probability of a site occurring. “Predictive models are tools for projecting known patterns or relationships into unknown times or places” (Wheatly and Gillings, 1995). The classic approach in archaeology for determining site probability is the log regression approach. It allows for a mixed level of variables; ordinal and interval. It was chosen because it supports many different levels of data and the result is easily identifiable in terms of predicting an archaeological event (Wheatly and Gillings, 1995). Regression coefficients for each variable were generated in Excel. These coefficients were applied to the following equation: L= a + bx, where: "a" is the intercept, "b" is the regression coefficient and "x" is the value of each independent variable. The value of L was used to predict site locations, via the following equation: For "P" such that P = 1/1+ e(1 – L). "L" is the cumulative logistically derived discriminant function, and "e" is the natural log (Allen, 1990). The test was not a good fit for these data. According to Kvamme (1998), "One assumes equal probabilities for Sites and Non-Sites. Values greater than 0.50 are interpreted as predicted site locations." Thus, 0.50 is the cut-point for which a site may occur. It infers that at least half of the sites must reach this level for predicted site locations. For this study, no values exceeded 0.50, and only three observations attained 0.50. Only one stone circle site attained the cut-point. However, the Non-Sites variable outperformed the Sites variable and attained the cut-point in two locations. This is the bare minimum for any model's performance, given that it only asks for 50 % success. This model performed poorly and was not appropriate for the small dataset. In addition, "Logistic regression assumes a linear relationship between dependent and independent variables, an assumption that is rarely tested...the nature of the interactions between the independent variables can take the form of correlation, confounding, or interaction" (Wheatly and Gillings, 1995). According to the literature, one may correct for biases by "Selecting a random sample of the negative responses, so there are an equal number of positive and negative responses, although, this involves discarding data" (Wheatly and Gillings, 1995). This could be achieved if a larger sample size was available. In addition, one could use the results to adjust the y-intercept to better fit the sample size (Wheatly and Gillings, 1995). With an adequate sample size, the distributions could be compared in ESRI's (Environment Systems Research Institute) Geostatistical Analyst extension.

In pursuit of a model that better fits the constraints of a small sample of 17; the Aberdeen Proving Ground (APG) frequency combination predictive model was applied (Tables 2 and 3). It allows for nominal components, thereby expanding the dataset (Wescott, 2000). The model was a good fit for these data. Combined classes were created for the topographic setting, similar to the APG test model. No sites were found more than 800 meters from water. The top 25 % was the cut-point for the extreme "distance to water" variable (i.e. greater than 600 meters). For the "slope" variable, values greater than 17 % slope were considered extreme. This threshold was determined by taking the top 10 % of the highest slope value of 19 %, for the stone circle sites. Since "distance to water" had the largest range of values, 25 % was considered appropriate as the borderline for the extreme level. The model proved to be a good indicator of site suitability (Table 4). The Sites attained a 70 % level in the high potential class, which was an ideal modeling situation. In comparison, the Non-Sites were less diagnostic and only 53 % of the data fell into the high potential class. Kvamme's gain statistic was used to show the increase in class percentages. The gain statistic is: 1 - [% site / % area]

Table 2. APG model for Sites.

Frequencies for Sites

| Distance to Water (m) | Elevation (m) | Topographical Setting | Slope | Frequency | % | Cumulative Frequency | Cumulative Percentage |
|---|---|---|---|---|---|---|---|
| 0-200 | <600 | Bluff/Knoll/Terr. | <17 | 8 | 47.1 | 8 | 47.1 |
| 0-200 | <600 | Floodplain/Flat | <17 | 1 | 5.9 | 9 | 53 |
| 200-800 | <600 | Bluff/Knoll/Terr. | >17 | 4 | 23.5 | 13 | 76.5 |
| 200-800 | <600 | Floodplain/Flat | <17 | 1 | 5.9 | 14 | 82.4 |
| 200-800 | <600 | Bluff/Knoll/Terr. | <17 | 2 | 11.7 | 16 | 94.1 |
| 200-800 | >600 | Bluff/Knoll/Terr. | <17 | 1 | 5.9 | 17 | 100 |

Table 3. APG model for Non-Sites.

Frequencies for Non-Sites

| Distance to Water (m) | Elevation (m) | Topographical Setting | Slope | Frequency | % | Cumulative Frequency | Cumulative Percentage |
|---|---|---|---|---|---|---|---|
| 0-200 | <600 | Bluff/Knoll/Terr. | <17 | 2 | 11.8 | 2 | 11.8 |
| 0-200 | >600 | Bluff/Knoll/Terr. | >17 | 1 | 5.9 | 3 | 17.7 |
| 0-200 | <600 | Floodplain/Flat | <17 | 1 | 5.9 | 4 | 23.6 |
| 0-200 | >600 | Bluff/Knoll/Terr. | <17 | 2 | 11.8 | 6 | 35.4 |
| 200-1200 | <600 | Bluff/Knoll/Terr. | <17 | 3 | 17.6 | 9 | 53 |
| 200-1200 | >600 | Bluff/Knoll/Terr. | >17 | 1 | 5.9 | 10 | 58.9 |
| 200-1200 | >600 | Bluff/Knoll/Terr. | <17 | 7 | 41.1 | 17 | 100 |

Table 4. Kvamme's gain statistic for the APG model.

Sites

| Potential | Percentages | Kvamme's Gain Statistic |
|---|---|---|
| High 20% | 70.60% | 0.10 |
| Medium 6.25-19% | 17.60% | 0.99 |
| Low 0-6% | 11.80% | 0.90 |

Non-Sites

| Potential | Percentages | Kvamme's Gain Statistic |
|---|---|---|
| High 20% | 53% | no gain |
| Medium 6.25-19% | 29.40% | no gain |
| Low 0-6% | 17.60% | 0.93 |

(Kvamme, 1998). Overall, the stone circle sites gained in all three classes of potential. The Non-Sites gained only in the low potential class, which means the model could be applied to hypothetical data, and refined. The APG model was very useful because the results could be used in the field to optimize survey design and to remove locales from the study that were topographically extreme.

Zones of potential suitability were then created for the stone circle sites only. With the Spatial Analyst extension, the weighted variables were classified into three equal intervals, via the Slice command (Mehrer, 2006). Weights were applied in the Raster Calculator and then grouped into low, medium, and high groups, via the Weighted Overlay Tool (Figure 3). The resulting raster had the expected value and count fields. Low potential cell values ranged from 1-1.8, Medium potential cells ranged from 1.9- 2.7, and high potential cells ranged from 2.8 - 4.6. The high and medium potential areas were found on the upland knolls and bluffs. The islands of medium potential found within the low potential zones correspond to wide grassy bluffs that have excellent line of sight and provide heavy vegetation. The low potential zones were found in the floodplain and flats. The lowland areas contained a smaller percentage of sites. This might be attributed to the fact that the lowland areas have been flooded, ranched, and farmed; therefore, are heavily disturbed. Also, they may have been less desirable defensively and in terms of resource distribution.

In the final approach, ArcMap was used to determine the cell statistics of the individual raster cells based on the

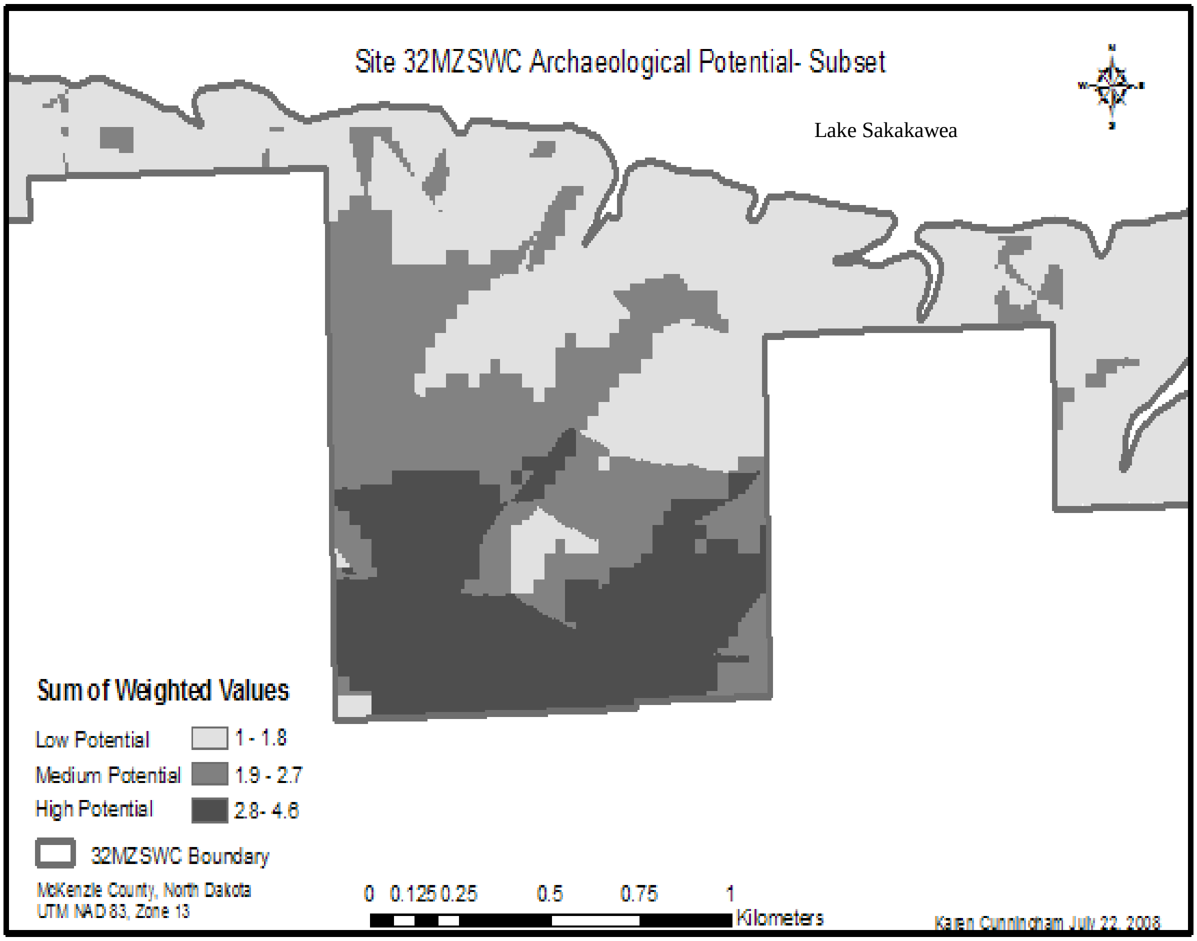

Figure 3. Zones of site potential for Sites.

value and cell counts generated by the Weighted Overlay (Table 5). One site was located in a no-data area of the project boundary. It was located in the topographically disturbed floodplain. This caused the number of sites to be reduced to 16. The Sites category did out-perform the Non-Sites by having a higher order of class majority. 81.6 % of the stone circle sites were categorized as medium potential. For the Non-Sites, the largest class was the low potential category, at 40 %. Both the Sites and the Non-Sites sites had only one site in the high potential class. The distribution of raster cells was more evenly distributed for the Non-Sites then the Sites; this is due to the fact that many of the stone circle sites varied in size, while the Non-Sites were manually created, and of similar size. This approach was useful for analyzing how the software categorized the raster cells into a supervised classification.

Table 5. Cell Statistics.

| | Sites | | |
|---|---|---|---|
| Potential | # of Sites | # of Cells | % Cell Total |
| Low | 10 | 1656 | 0.183 |
| Medium | 5 | 7383 | 0.816 |
| High | 1 | 4 | 0.004 |
| Total | 16 | 9043 | 100 |

| | Non-Sites | | |
|---|---|---|---|
| Potential | # of Sites | # of Cells | % Cell Total |
| Low | 7 | 3732 | 0.40 |
| Medium | 8 | 2980 | 0.32 |
| High | 1 | 2596 | 0.28 |
| Total | 16 | 9308 | 100 |

## Conclusion

The weighted variable method is a standard approach for site suitability models, but its highly subjective nature can reduce the diagnostic power of statistical evaluation models. The "slope" variable was given the highest weight, based on a visual assessment of extreme slopes in the field survey. Statistically, for the "slope" variable, no significant difference between the Sites and Non-Sites was documented. This finding may be a result of the small range of slope values in the two populations, and the applied weight. The weighted method was limiting because, the "slope" variable had a narrow range of values. Applying the weight of 0.50 reduced the range of values by 50 %. Both "elevation" and "slope" failed the ANOVA test. "Elevation" did poorly in the above test also because of the small range of values. This may be due to the small percentage of lowland stone circle sites. There was, however, a significant difference in the Student's t-test and probability distribution of Sites and Non-Sites for "elevation." "Distance to water" proved to be the strongest variable for determining site location. This is consistent with the findings of Westcott. "Distance to water is the single greatest predictor of site location" (Westcott, 2000). The assumptions necessary to assign weights can be nebulous. Their use requires an in-depth knowledge of the terrain, a large data set, and a cell size greater than 5 meters.

The log regression method did not fit the constraints of the small dataset. It required a larger sample size and more robust dataset. This approach has an inherent bias. The estimate of "L" will be biased towards prediction of the larger class. In this case, the Non-Sites are slightly larger, and that may explain why the Non-Sites reached the cut-point and the Sites fell short (Wheatly and Gillings, 1995).

Generating zones of potential was useful because one could see larger trends in the terrain, and have the georeferenced coordinates to use in tandem with topographical maps in the field. In terms of determining cell statistics, the small area of several sites necessitated a 5 meter cell size. The Sites contained a matrix of 100,807,992 raster cells, while the Non-Sites were comprised of 109,807,992 cells. Thus, the portion of cells that could be placed into individual classes was often an exceedingly small percentage of the total project area. Both methods categorized the majority of terrain as containing low potential for site placement.

The Aberdeen Proving Ground approach was the best model that fit the dataset. Moreover, it allows for human-derived clustering of these data, which create meaningful classes that delineate the limits of the independent variables in the topography. It also allowed for the combination of similar classes. Thus, by looking at the groupings of data, one could ascertain where topographic factors barred placement of stone circle sites. The gain statistics helped to further refine the model and highlight the class parameters within which a site could occur. The model also proved useful for the hypothetically derived Non-Site data. In the final assessment, the Aberdeen Proving Ground model had the highest rate of utility for this study. It was able to delineate local patterns in the environment and trends in the dataset.

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