Informing the Planning Phase of Energy Development with Probabilistic Modeling of Cultural Resources: A Southern Wyoming Example

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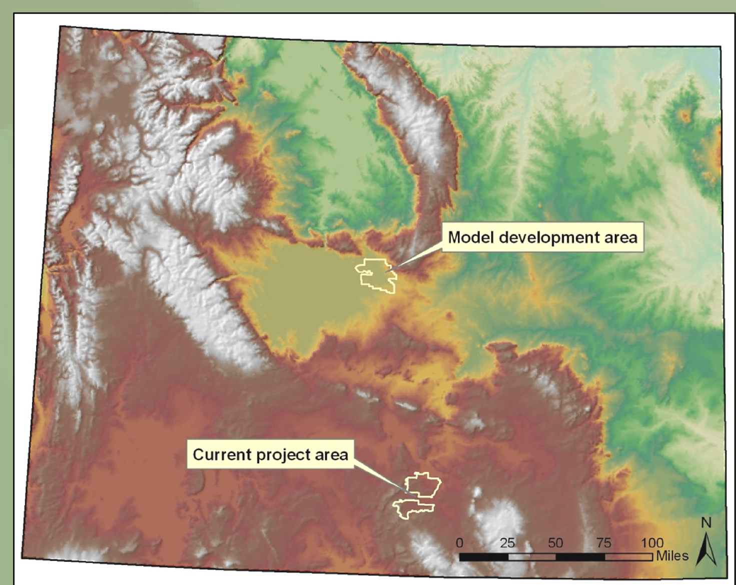
Introduction

For an environmental impact statement involving a proposed wind energy project, SWCA has produced a probability model designed to assist in the identification of sites with potential Native American significance. In this part of Wyoming, these often include rock piles, cairns, stone circles, and alignments.

Because the project extent covers over 164,100 acres, a probability model is being used to guide a sample (Class II) survey of nearly 8,000 acres. The purpose of this model is to forecast the location of potentially sensitive sites in previously unsurveyed areas.

This sample survey is being done before the project footprint is finalized. The goal is to sample cultural sites to be discussed during the consultation phase between the Bureau of Land Management and the tribes during project planning.

A full (Class III) survey of the project footprint will be conducted independently from the current sample inventory. This poster provides an overview of model development and implementation.



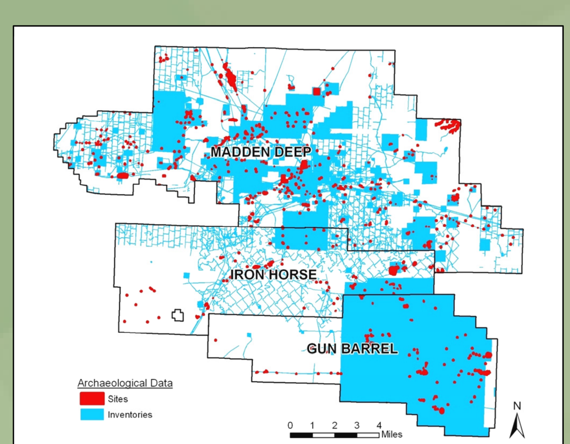
Project locations in Wyoming.

Model Development

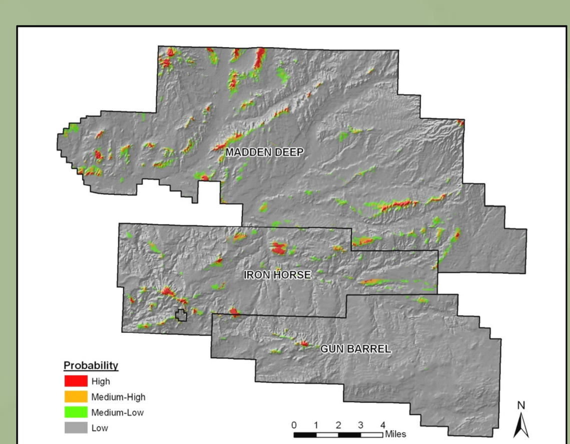
The intent of the current project is to sample the landscape for sites of potential Native American significance. In the current project area, previous consultation indicates that these are most often stone cairns, piles, alignments, and circles.

In 2008, we developed a probability model for cairns, among other site types, for a project in central Wyoming. This model was applied to the current project.

The cairns site sample was randomly split into two samples, and a model was made for each. This allows the models to be compared for estimates of accuracy and consistency.



2008 Site and inventory data

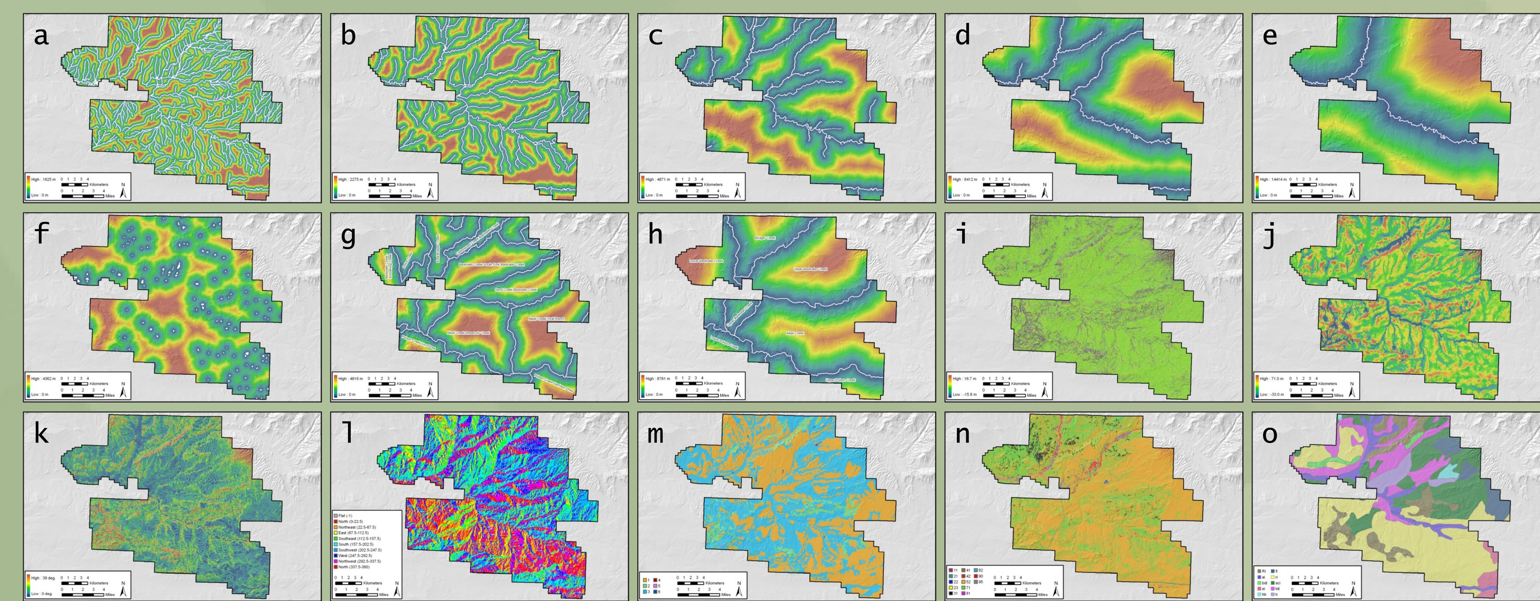


2008 cairns model

This modeling approach uses the correlation of environmental variables and archaeological site locations to identify high probability areas. Environmental variables that are found to significantly correlate with site locations are uniquely weighted to describe the magnitude of their effect on site placement.

The environmental and archaeological data must first be combined into a spatial dataset, which is done using GIS. Due to the limits of the National Elevation Dataset (a main data input), the project area was gridded into 30 m cells. This fishnet provides the basic spatial framework for analysis. Every 30 m cell is then assigned site/nonsite data and the host of other data.

Environmental Variables



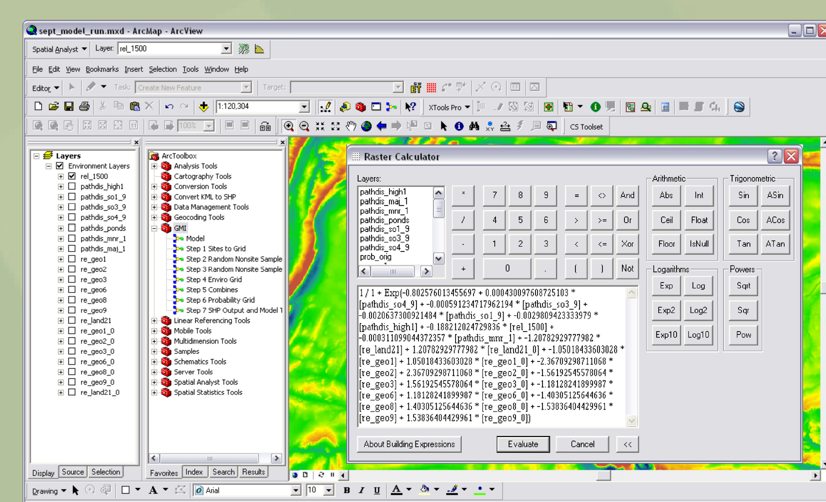
a-e. Distance to each stream order
f. Distance to natural ponds
g. Distance to minor watershed boundary
h. Distance to major watershed boundary
i. Relative elevation within 90 m
j. Relative elevation within 1500 m
k. Slope
l. Aspect
m. Soil type
n. Land cover type
o. Surface Geology

Stepwise Logistic Regression

Stepwise logistic regression, performed using data analysis software, produces a probability equation describing the relationship of site placement and environment:

Probability(site) = 1/(1+exp[linear combination])

The linear combination equation includes a y-intercept and the multipliers of the selected environmental variables.



Probability equation in the Raster Calculator

The probability equation is mapped in GIS using the Raster Calculator, which produces a probability grid ranging from 0 to 1 (low to high).

The probability grid can be divided categories, such as high, medium-high, medium-low, and low probabilities. Alternatively, a single p-level can be chosen to represent high probability areas.

Model Testing and Selection

Cell by cell tests for correct/false predictions show that over 75% of combined site and nonsite the cells were correctly predicted.

Model gain describes the percent of sites captured by a model in relation to the proportion of acreage covered by the high probability areas. This test shows that the models are performing efficiently.

$$\text{Gain} = 1 - \frac{\text{\% of area predicted to contain sites}}{\text{\% sites within predicted site area}}$$

Model tests and efficiency estimates (gain).

Site Type	30 m Cell Data: % Correct Site Cells	% Correct Nonsite Cells	Total % Correct	Gain Data: % Predicted Sites Acreage	% Sites Predicted	Gain
All Sites (568)	6.7	97.5	**79.3**	4.8	18.0	**0.73**
Prehistoric Sites (502)	6.7	97.6	**79.3**	5.1	16.7	**0.70**
Historic Sites (117)	15.6	96.8	**80.5**	3.2	23.9	**0.86**
Ground Stone (45)	42.0	96.4	**91.6**	4.9	40.0	**0.88**
Hearth/FAR (243)	12.8	96.8	**79.9**	3.7	24.3	**0.85**
Stone Circles (65)	10.3	99.1	**92.9**	2.4	40.0	**0.94**
Lithic Procurement (54)	31.1	97.5	**84.1**	3.0	44.4	**0.93**
Cairn Sites (49)	23.8	98.7	**95.7**	2.1	32.7	**0.93**

Applying the Model

The central Wyoming cairns model was applied to the project area in southern Wyoming. With the exception of soil data, all environmental variables were replicated.

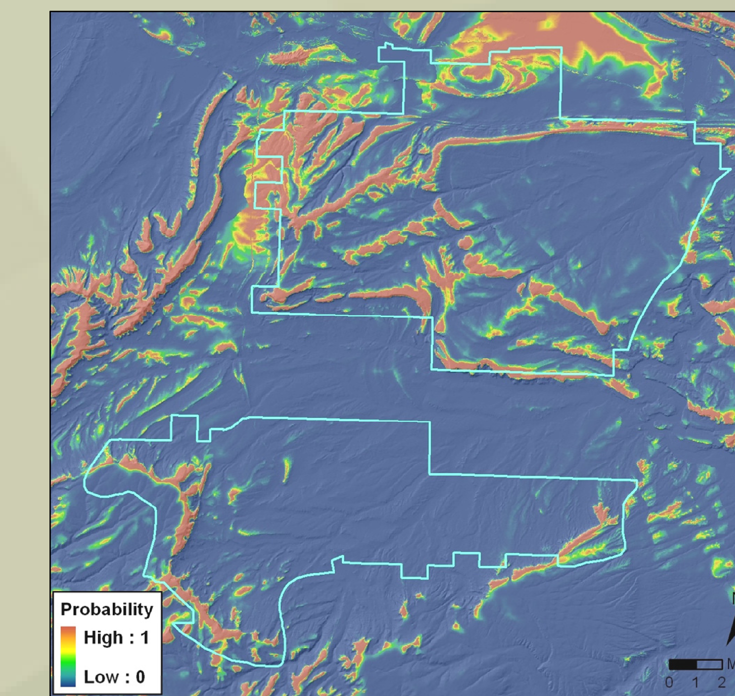
57 previously recorded sites of potential Native American concern were used to evaluate the model efficiency (gain) within the new project area.

Gain was found to increase with the probability value, indicating that the model developed for central Wyoming.

Acres and gain per probability level.

Minimum Probability	Acreage Percent	Number of Sensitive Sites	Percent of Sensitive Sites	Gain
0	100.0	57	100.0	0.000
0.1	21.4	39	68.4	0.687
0.2	17.3	33	57.9	0.702
0.3	14.9	30	52.6	0.716
0.4	13.1	30	52.6	0.750
0.5	11.6	28	49.1	0.764
0.6	10.2	25	43.9	0.768
0.7	**8.9**	**24**	**42.1**	**0.790**
0.8	7.5	20	35.1	0.787
0.9	5.7	17	29.8	0.810
0.95	4.3	15	26.3	0.836

A probability level of 0.7 was selected for the high probability areas in the project area. This value was chosen because increasing the probability to 0.8 did not result in an increased gain.

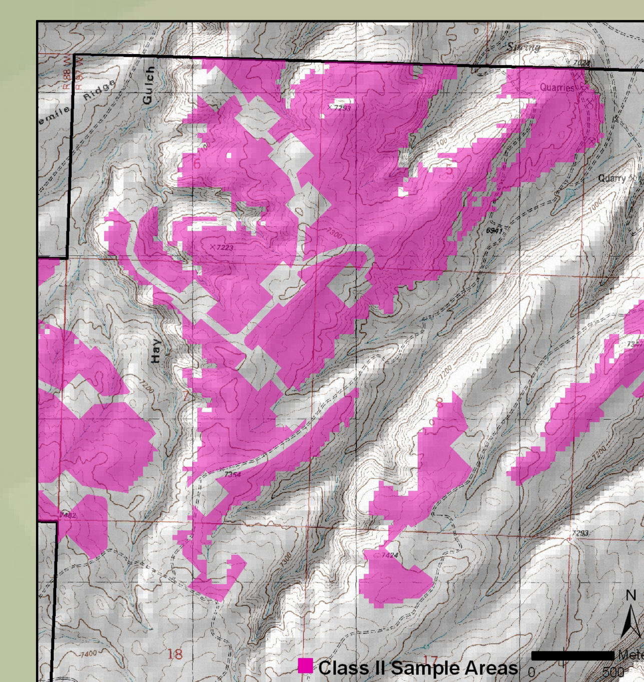


Sensitive sites model applied to southern Wyoming.


Sensitive sites model (yellow) and known sites (green).

Refining the Sample Area

Of the 164,110 project acres, 15,411 acres have a high probability of containing sensitive features (9.4 %).



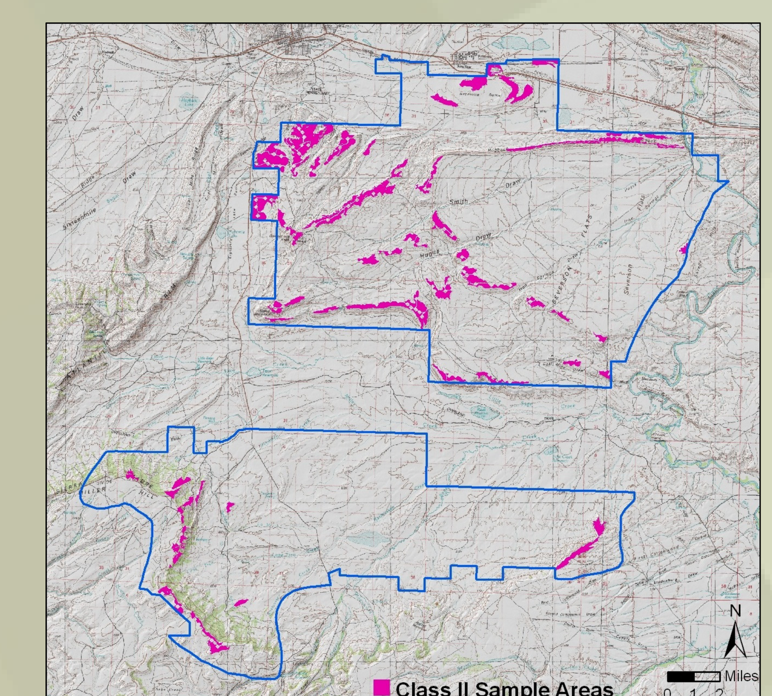
Class II sample areas example.

2,967 acres of high probability were previously inventoried for the project and removed from the current sample area.

1,614 acres of steep slopes exceeding 30 percent grade were also removed.

Finally, high probability areas less than 40 acres in size were removed due to the effort required to travel to and sample 865 individual plots.

The final sample survey areas include 76 polygons totaling 7,964 acres (4.9 %).



All Class II sample areas

Conclusions

To reduce the influence of edge-effect and arbitrary model areas, we need to move away from modeling project boundaries and toward modeling environmental and/or archaeological regions.

Given the model design and previously recorded site density, we anticipate encountering another 43.3 potentially sensitive sites in our sample areas (0.005441 sites per acre). While fieldwork is underway, below are examples of features encountered thus far. The results of this fieldwork will support the Native American consultation in the planning phase of this project.





Examples of cairns documented during the ongoing fieldwork.

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