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Final Report

What Lies Beneath: Combining Archaeology and Geoscience to Model the Submerged Landscape of Lake Erie

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Introduction and Objectives

The purpose of this of this project was to create a preliminary model of submerged prehistoric site potential within the Pennsylvania portion of Lake Erie using available data. The current model is based on available archaeological and environmental data, and projects the environmental settings of sub-aerially exposed sites onto the submerged lands of Lake Erie to predict likely locations of submerged prehistoric sites.

Several factors recommend Lake Erie for such a study. Circa 12,000 BP the Lake Erie basin contained a narrow lake feeding a larger lake via a short stream – all of these features lie partially within the Pennsylvania portion of the lake (Figure 1). There is also evidence of former wetlands within the basin. With lakes, wetlands, and streams supporting a variety of plants and animals, the post-glacial Lake Erie Basin would likely have attracted early settlers. As the glaciers continued to recede and flow into the Lake Erie Basin increased, the water level rose (Table 1). At times this rise was dramatic, rising 5 m in 100 years between 5400 and 5300 BP, and an additional 12 m over the next 600 years. These floods may have quickly inundated sites allowing for their preservation. Additionally, large portions of the Lake Erie bottom are blanketed in a thick layer of sediment that may have protected sites depending on when the sediment was deposited.

In recent years there has been increasing discussion of installing windfarms along the eastern shores of Lake Erie, as well as laying pipelines across its bottom. In response to this potential, Pennsylvania Department of Environmental Protection has begun to inventory known shipwrecks, but little attention has been paid to the potential for submerged prehistoric sites.

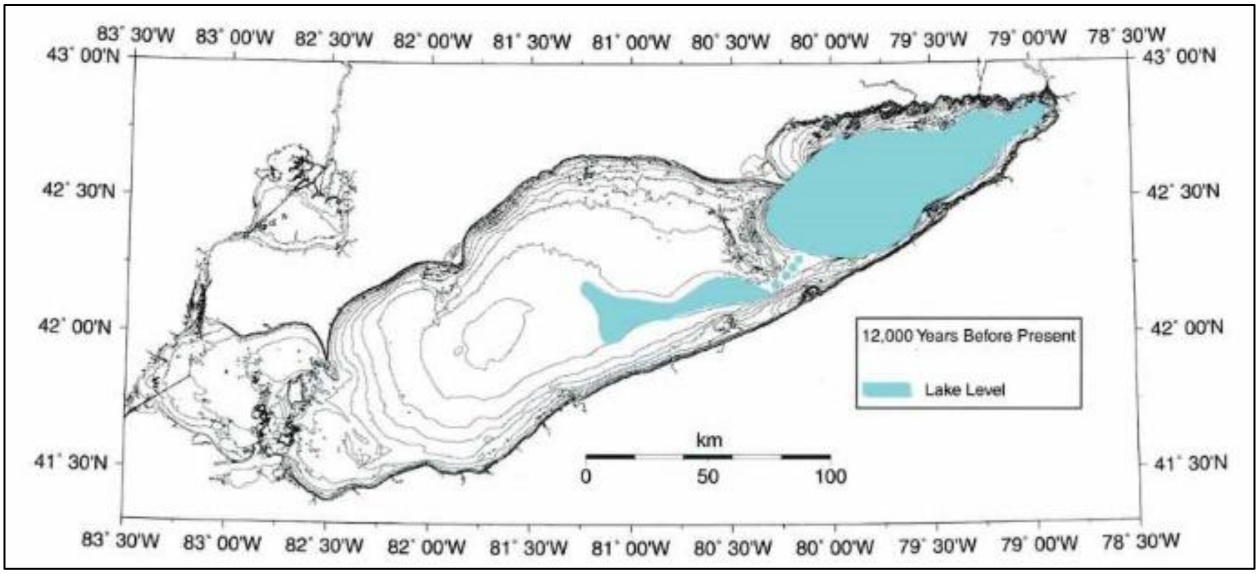

Figure 1. Lake Erie basin ca. 12,000 years ago showing current lake and lake level 12,000 years before present (Herdendorf 2013: 29).

Lake Stage	Radiocarbon Years (bp)	Relative Depth of Lake Level (m)
Early Lake Erie	~ 12,000	-54
Lake Algonquin Discharge	~ 10,400	-34
Early Lake Erie	~ 10,300	-44
Middle Lake Erie	~ 7,500	-29
Middle Lake Erie	~ 5,400	-14
Lake Nipissing Discharge	~ 5,300	-9
Lake Erie	~ 4,700	+3
Modern Lake Erie	~ 3,500	--

Table 1. Lake Erie Stages (Herdendorf 2013; Holcombe et al. 2003).

For these reasons we felt it is worthwhile exploring the potential of submerged prehistoric sites within Lake Erie. The Pennsylvania portion of the lake, which stretches along approximately 51 miles of shoreline forms a convenient sample area.

Methods

Terrestrial Model Construction and Validation

Our submerged prehistoric site location model utilizes terrestrial prehistoric sites surrounding Lake Erie, based on the assumption that these sites are the closest correlate for sites that are now submerged. Archaeological site data were gathered for the counties contiguous to the lake in the states of Ohio, Pennsylvania, and New York. Historic period sites were excluded; however, the states did not all list site period or site type, so all prehistoric sites of all periods and types were included. The total sample included 3047 sites. A sub-sample of 297 sites was removed for later model validation, so that the model was based on 2750 identified sites.

The predictive characteristics included slope, aspect, and proximity to water. This list of attributes is shorter than is generally applied in archaeological predictive modelling. However, we limited the attributes to those that we could reproduce offshore. The limited amount of comparable data for the submerged environment influenced our choice of predictive characteristics.

Slope and aspect values were generated from a 5m digital elevation model (DEM). The number of sites situated on each slope, aspect, and distance to water value were graphed and the graphs analyzed to determine the weights to assign each characteristic (Figure 2). Slope percentages 0-1 were weighted 44, 1-2 22, 2-3 11, 3-4 6, and more than 4 were weighted 0. Lands within 125 m of water were weighted 44, those between 125 and 250 were weighted 17, 240 to 350 10, and more than 350 m were weighted 0. Aspect appeared to be a less strong predictor of site location with sites spread across all 360 degrees. However, some patterns were evident so that 270 to 330 degrees was weighted 12, 330 to 350 was weighted 3, 350 to 25 0, 25 to 130 6, 130 to 185 9, and 185 to 270 6. The predominance of northwest facing sites likely has more to do with the dominant topography sloping towards Lake Erie and less to do with a preference for that aspect. This weighting scheme was designed so that a site situated on the most common predictive characteristics (e.g. slope less than 1, within 15 m of water, and facing between 270 and 330 degrees) scored 100 (44 + 44 + 12).

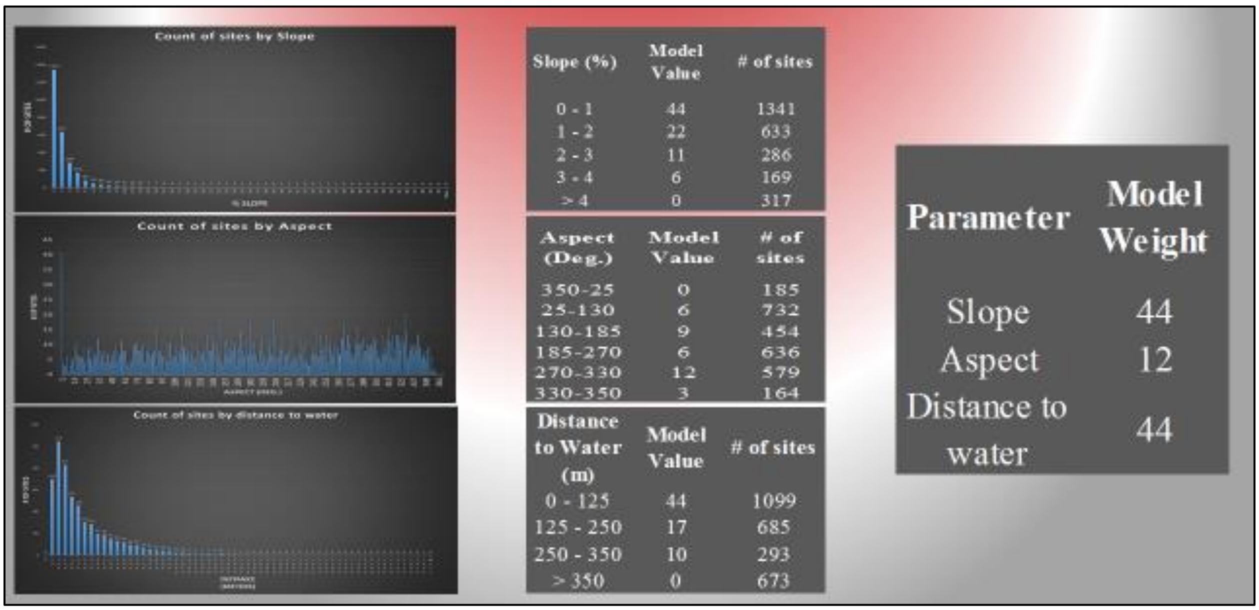

Figure 2. Summary of predictive attributes.

The weighted predictor factors were then applied to the study area of lands contiguous to Lake Erie in Ohio, Pennsylvania, and New York to create a predictive surface. The predictive surface was divided into five categories: very unlikely to contain sites (1), unlikely to contain sites (2), neutral (3), likely to contain sites (4), and very likely to contain sites (5) (Figure 3).

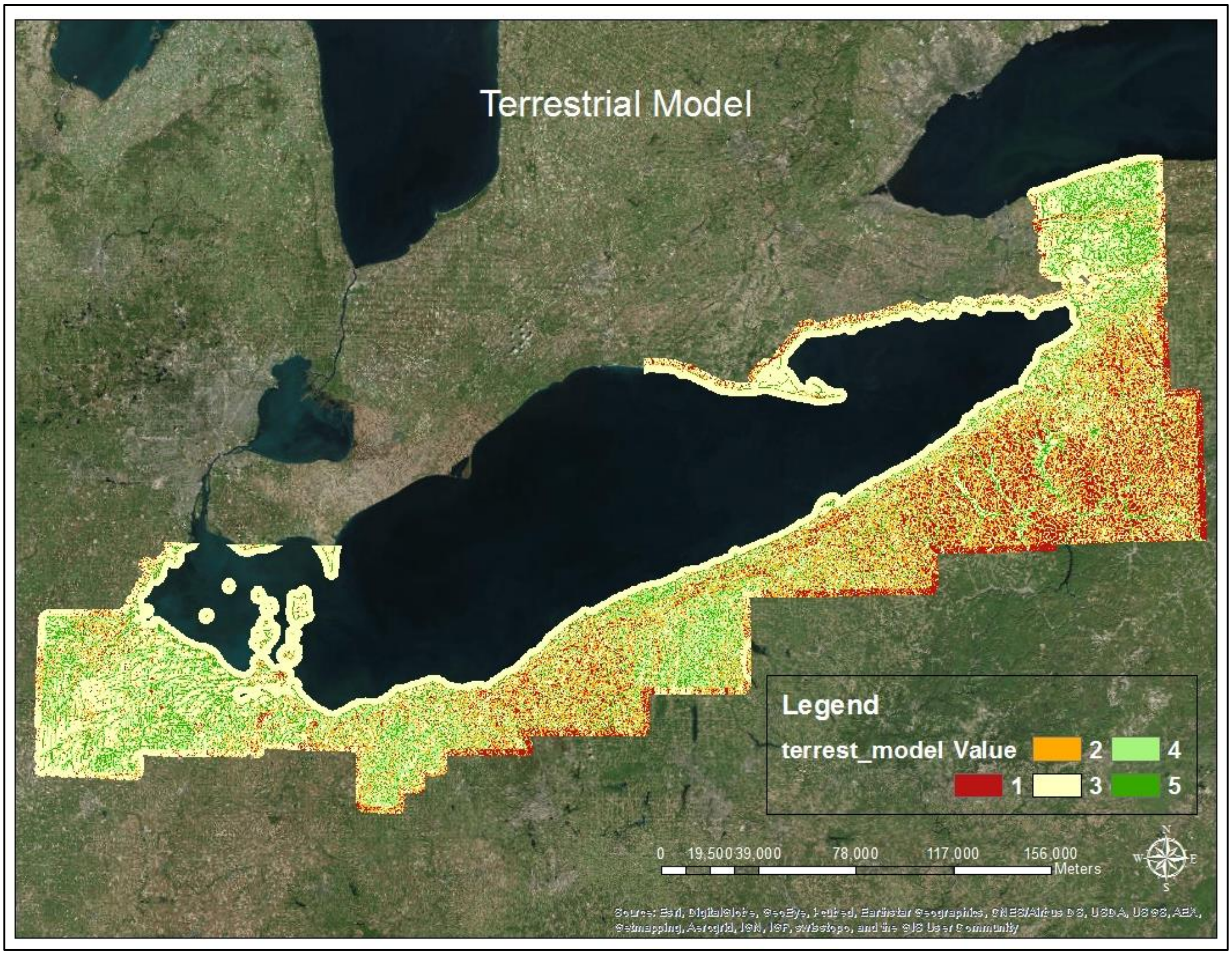

Figure 3. Archaeological predictive surface.

The validity of this surface was then checked using the 10% validation sample and the 'gain' statistic. 79% of the validation sample was situated on lands ranked as neutral to very likely to contain sites, 42% were situated on likely and very likely to contain sites land. This result closely mirrored the sample as a whole – 78% and 45%. The 'statistic' normalizes predictive power against area predicted:

$$G = 1 - (\% \text{ of area} / \% \text{ of sites})$$

A high ‘gain’, with a score near 1 denotes a model with high predictive power. For the test sample very likely to contain sites had a gain of 0.3077, likely and very likely to contain sites had a gain of 0.4048, and neutral through very likely to contain sites had a gain of 0.1139. When the entire sample was considered, very likely to contain sites had a gain of 0.4706, likely and very likely to contain sites had a gain of 0.4444, and neutral through very likely to contain sites had a gain of 0.1026. Thus, while extending the model to the neutral areas increased the number of sites it predicted, limiting it to only the areas ranked as likely and very likely to contain sites increased the ability of the model to predict sites while limiting the area searched.

This is admittedly not a very powerful predictive model, in large part because factors that are normally considered in archaeological predictive models, such as soil type and permeability, were not included here. These factors were excluded because there is no way to reproduce them from available offshore data.

Offshore Model

The predictive values determined for the terrestrial model was then applied to the portions of Pennsylvania submerged beneath Lake Erie (Figure 4). The initial intent was to utilize bathymetry data generated by the National Oceanic and Atmospheric Administration (NOAA) to create slope, aspect, and stream channel data. The slope and aspect layers were to be generated just like they would using a terrestrial DEM. The channels were to be generated using the hydrological modeling capabilities of ArcMap, where flow direction and accumulation are determined by comparing adjacent raster cells to extract the most likely location of streams. However, the bathymetry data did not lend itself to this analysis. Several confounding factors are likely at play here: the lake floor has been smoothed by erosion and infilling, so that many of the channels may not be apparent at the surface. There is also the possibility that the original data had been smoothed and the near-shore component of the data may have been interpolated from coarser-grained soundings. As a result of these factors, it was not possible to confidently produce a streams layer for the offshore portion of the project area – leaving us with only slope and aspect as predictive factors.

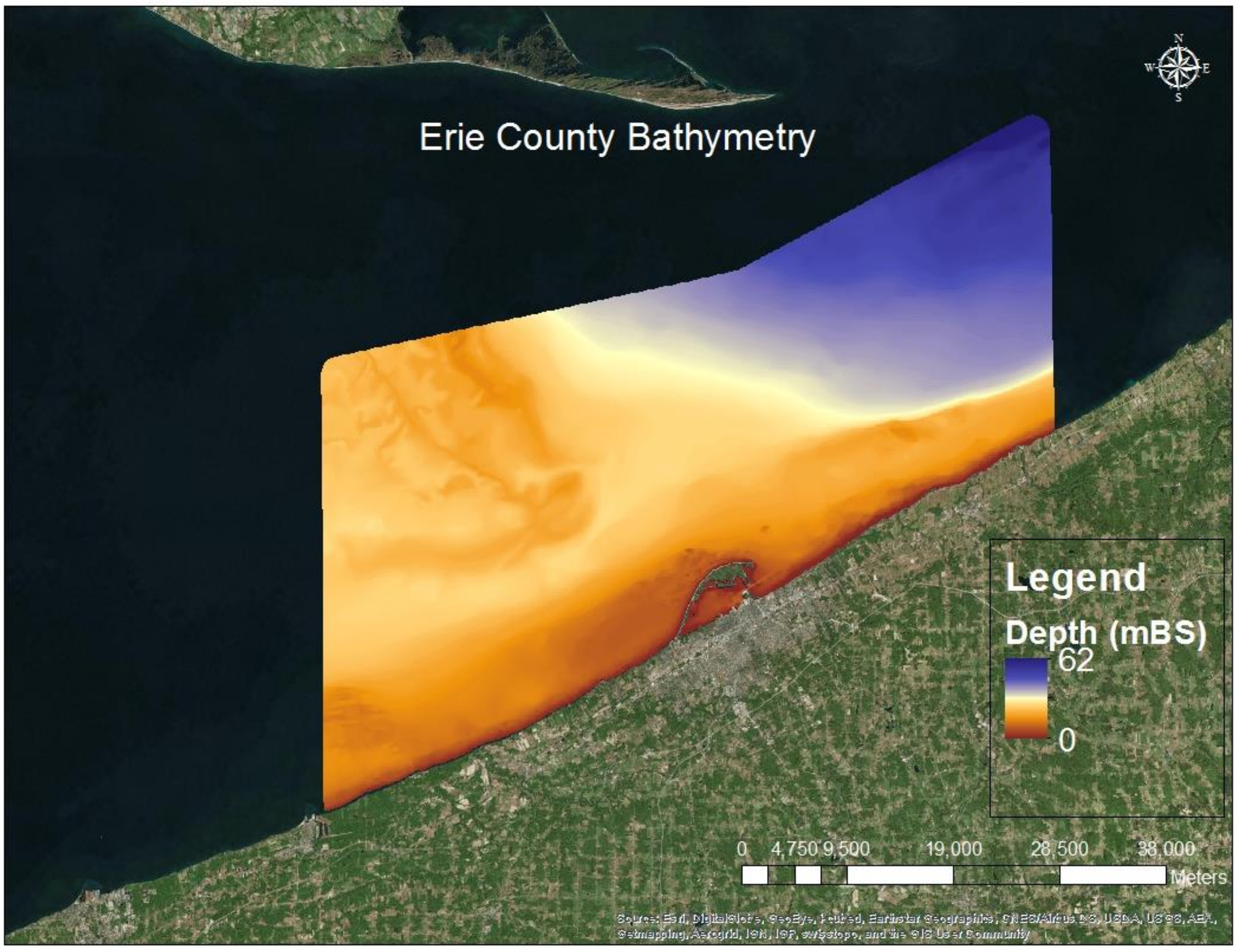

Figure 4. Lake Erie Bathymetry

<u>Results</u>

The predictive layer created from those factors is presented Figure 5, but we do not pretend that this is a valid predictive model for submerged prehistoric sites within Lake Erie – it simply does not contain enough predictive characters to effectively narrow the search areas. However, to follow the process to completion, we took the final step of applying what is known about modern bottom conditions to the predictive model. Data for this test were originally collected by Scudder Mackey and made available through the Tom Ridge Environmental Center at Presque Isle. These data, derived from side-scan sonar and drop-camera surveys, were

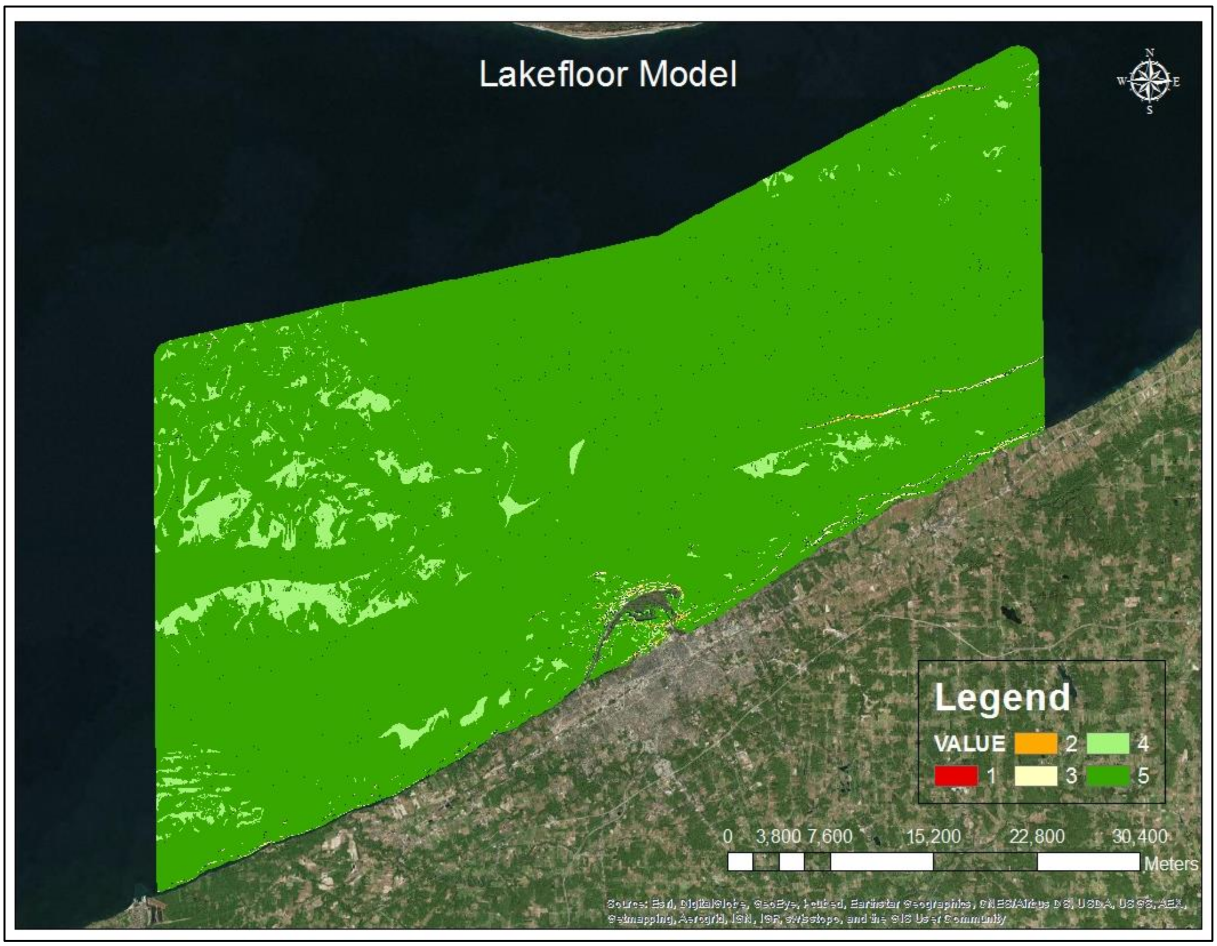

Figure 5. Lakefloor archaeological predictive model.

originally intended to identify fish habitat, but included useful information about bottom type (Figure 6). Areas of exposed bedrock, boulders, and cobbles – evidence of erosion – were excluded, leaving only those where sites may have survived. Thus the model "predicted" areas where sites may have been located and the bottom-type data indicated areas where those sites may have survived. Unfortunately, the bottom-type data was limited to a small portion of the Pennsylvania shore near the New York border. The limited amount of potentially intact sediments in this area is likely due to its proximity to shore where shallow water allows for the maximum of wave and ice erosion.

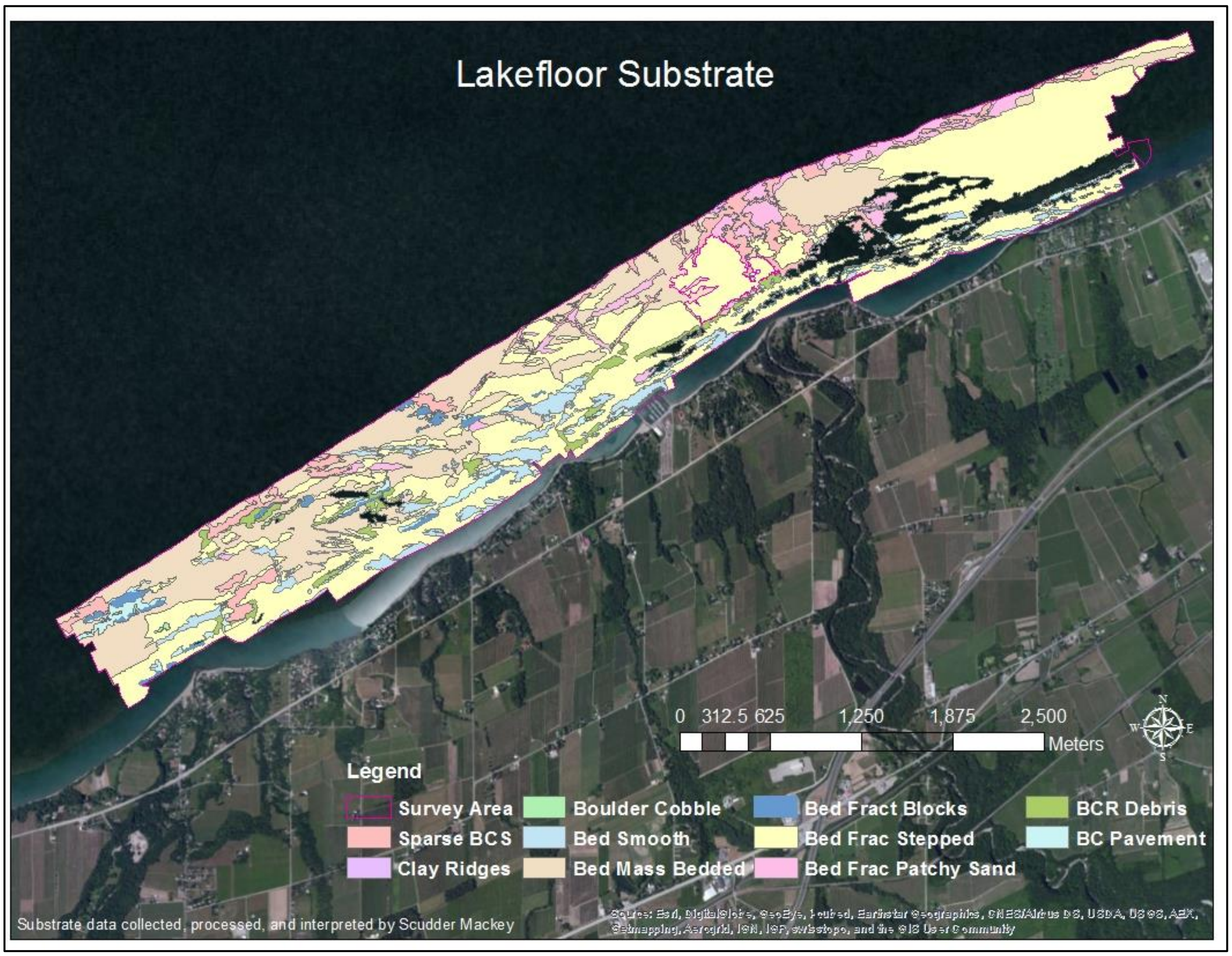

Figure 6. Lakefloor substrate (courtesy of Scudder Mackey).

The final model for the area with available substrate data is presented in Figure 7. As discussed, there are shortcoming in the current data that make this model unsuitable for predicting actual site locations, but the limited search areas and overall approach is what we were hoping to achieve.

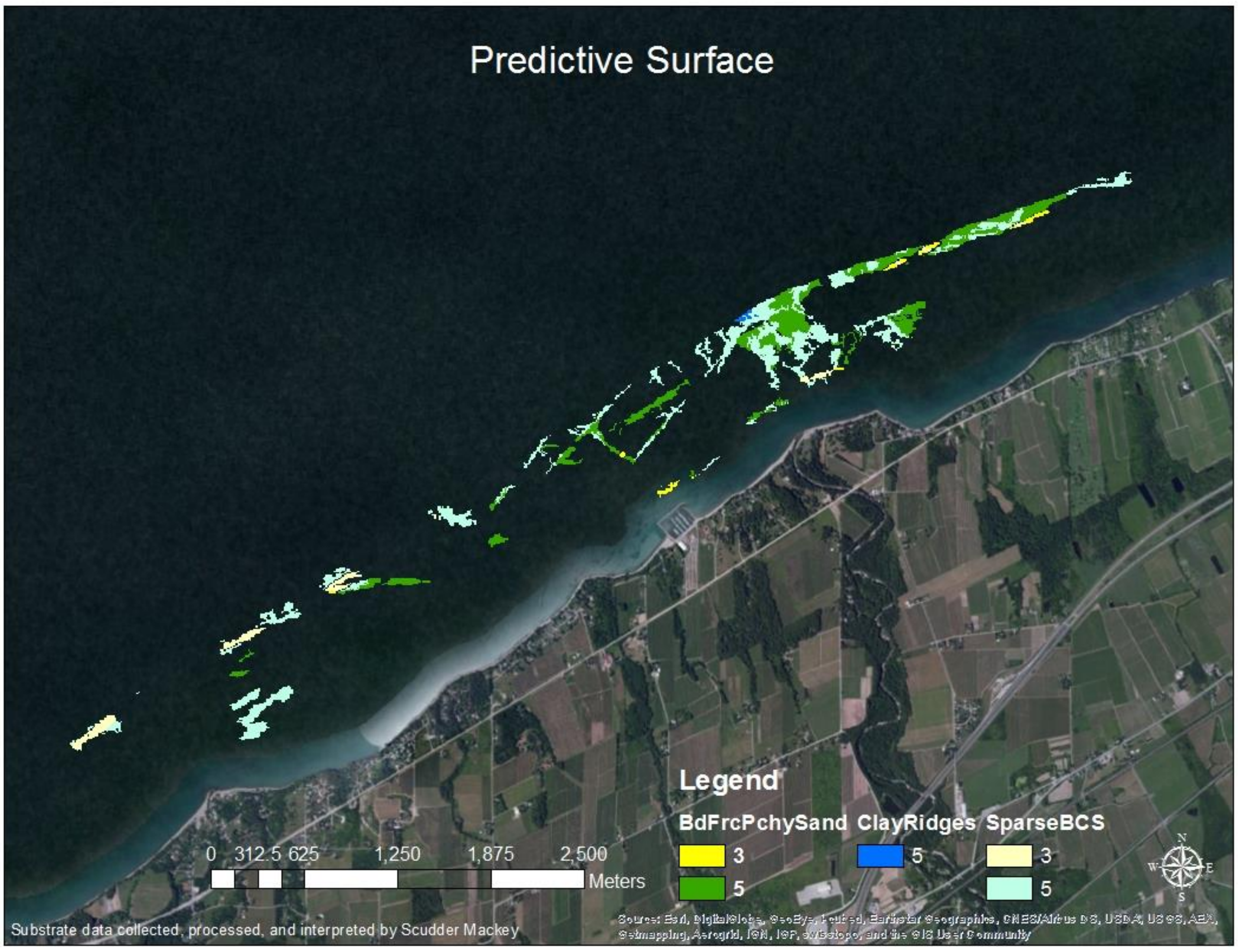

Figure 7. Predictive surface for areas with potential for intact formerly sub-aerially exposed surfaces. The archaeological potential (numeric, 3 = neutral and 5 = very likely to contain sites) is listed by bottom type.

Discussion

Clearly this model failed to perform as we had hoped. The lack of offshore data limited the initial terrestrial model and the nature of the offshore data further limited the submerged model that was the purpose of the entire undertaking. The type of desk-top modeling employed here has been used with some success for terrestrial sites, but the lack of comparable data for submerged lands made the methods useless. If nothing else, this drives home how little we know about the lands just on the other side of the waterline.

The necessary data does not appear to be available from existing sources so in the future we will need to collect new data, likely for a much smaller area. Our intent is to focus on an area along an identifiable shoreline of one of Lake Erie's lowstands. By collecting side-scan sonar and sub-bottom profiler data for this area, combined with sediment cores and visual inspections, we hope to be able to build-out the offshore model for this limited area and identify locations that are likely to have supported habitation sites and have intact deposits. Ultimately, we'd like to identify locations to archaeologically investigate to find evidence of early lakefront living in Pennsylvania.

This objective is clearly a long-term goal and there are numerous hurdles to overcome but we hope that this research has the potential to answer larger anthropological questions. For instance, how did Archaic Period peoples adapt to changes in the lake? For approximately 5000 years, from ca. 10,300 to 5,300 BP, Lake Erie was cut off from the other Great Lakes as the upper lakes drained directly to the St. Lawrence River. The reduction in flow, combined with decreased precipitation during this period, likely caused stagnant and possibly eutrophic conditions within Lake Erie. One possible future research question might be whether this condition made the basin less attractive to prehistoric peoples. The only way that we can answer this question, which has significant implications for our understanding of settlement history across a swath of the Midwest, is by finding sites beneath Lake Erie.

References Cited

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Acknowledgements

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