GIS Predictive Model of Potential Undiscovered Native American Archeology Sites for the Red Wing Locality, Red Wing, Minnesota

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Abstract

The Red Wing Locality represents the largest known concentration of ancient Native American cultural sites in Minnesota, including mounds and villages from the Oneota, Woodland, Silvernale, and Pre-Contact archeological eras. This research focuses on the use of Geographic Information Systems (GIS) to create a predictive model to identify parcels with potential previously undocumented village and mound archeology sites for the City of Red Wing. Project methodologies are organized into the following major themes: (a) value of research (b) required data and availability: known sites, DEM (Digital Elevation Model) raster, LiDAR (Light Detection and Ranging), historic vegetation, geomorphology, surface hydrology, and (c) predictive modeling methodology and deliverables. The research hypothesis posits known cultural resources are not random, and sites strongly correlate with environmental variables to create probabilistic models to predict undiscovered site locations. Utilizing a weighted model index in GIS to select land parcels that may contain undiscovered cultural resources would assist in identifying areas of cultural sensitivity to support Phase 1 archeological resource assessments in advance of potential land development.

Introduction

The Red Wing, Minnesota area has long been known as one of the richest archaeological regions in Minnesota (Gibbon, 2008). The area at the junction of the Cannon and Mississippi Rivers was host to at least nine large villages - perhaps more (Fleming, 2014). Silvernale is one of the earliest and largest of at least nine large village sites inhabited between ca. A.D. 950 and 1400 at the junction of the Cannon and Mississippi rivers (Johnson, Schirmer, and Dobbs, 2003) (Figure 1). Within the 58 square miles of the Locality, more than 2,000 mounds and dozens or smaller sites have been documented (Dobbs, 1990).

Between ca. A.D. 1050 – 1250, inhabitants of the Red Wing Locality participated in intensive interaction among several regional cultural traditions (Johnson *et al*., 2003). This phenomenon resulted in a localized cultural development that is unique to the sites in the Locality and that has been an ongoing source of anthropological research for the last 55 years (Johnson *et al.*).

Key identifying characteristics of Silvernale phase components include the presence of large, fortified villages usually surrounded by numerous conical earthen burial mounds (Gibbon, 2008).

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Figure 1. Red Wing Locality area of interest (www.fromsitetostory.org 2014).

Red Wing Locality Archeological Site Investigations

During the mid-1880s, T. H. Lewis recorded and mapped more than 2,000 mounds clustered in this locality (Winchell, 1911). At the turn of the century, J. V. Brower and W. M. Sweeney also recorded mounds in the region, particularly on Prairie Island and documented the presence of several village sites (Gibbon, 2008).

Modern archaeological investigations began in the late 1940s with Moreau Maxwell's excavations for Beloit College at the Mero site across the river in Wisconsin and Lloyd Wilford's excavations at the Bryan and Silvernale sites (Gibbon, 2008).

Lewis mapped most of the mounds at the site and noted the presence of a village site as well (Johnson *et al.*, 2003). However, no further work took place at the site for another 62 years until Lloyd Wilford (University of Minnesota) excavated there in 1947 and 1950. This work in the village area revealed a number of subsurface features that Wilford interpreted as storage pits and fire hearths (Johnson *et al.*). Bryan (21GD4, 21GD45) is a large Silvernale phase village and earthen burial mound complex on a high terrace overlooking the Cannon River not far from its juncture with the Mississippi River (Gibbon, 2008).

Purpose of This Study

Undocumented Red Wing Locality sites are at risk for destruction if their land use is marked for development. Almost all of the mounds and a substantial part of the village site have been destroyed by the construction of the Red Wing Industrial Park and housing developments on the uplands overlooking the industrial park (Johnson *et al*., 2003) (Figure 2).

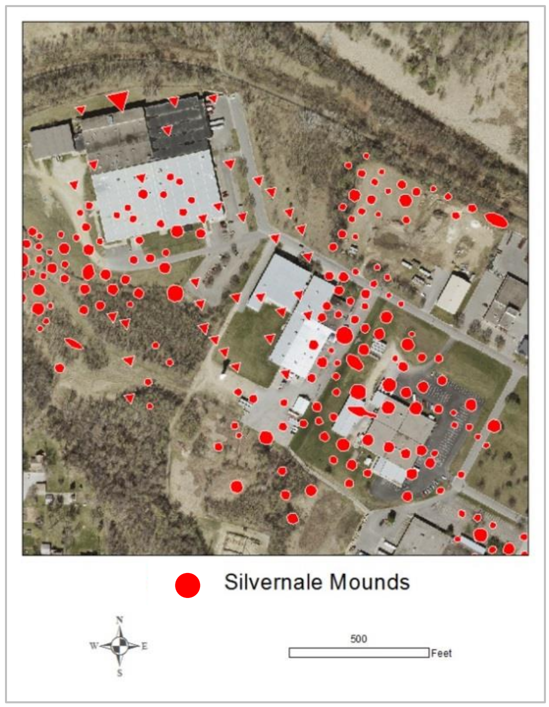

Figure 2. Mound distribution in the Red Wing Business Park, many of which have been destroyed by development.

Land development in Red Wing faces many challenges due to the unique topography of bluffs, river valleys, and wetland areas. Availability of developable land is limited to bluff tops and flat land areas, often adjacent to the Mississippi River, Cannon River, Spring Creek stream, and Hay Creek stream. These areas have been well-established as known locales for archeological mounds and villages and it is reasonable to assume that some of these same areas are now prime locations for future land development.

Creation of a predictive model would assist in identifying areas of cultural sensitivity to support Phase 1 archeological resource assessments for local government land use administrators. By using GIS, digital outputs and traditional maps can delineate areas of high, medium, and low archeological site potential based on weighted index totals of site characteristics.

Geographic Context

Red Wing covers a land area of 42 miles square miles and is located in Goodhue County in southeastern Minnesota (Figure 3).

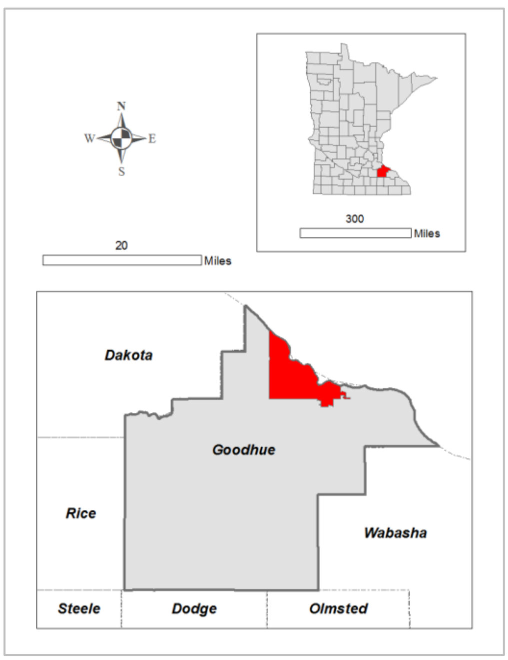

Figure 3. Goodhue County and Red Wing, Minnesota.

Figure 4 shows the majority of known Red Wing Locality archeological sites are within the City of Red Wing municipal boundary.

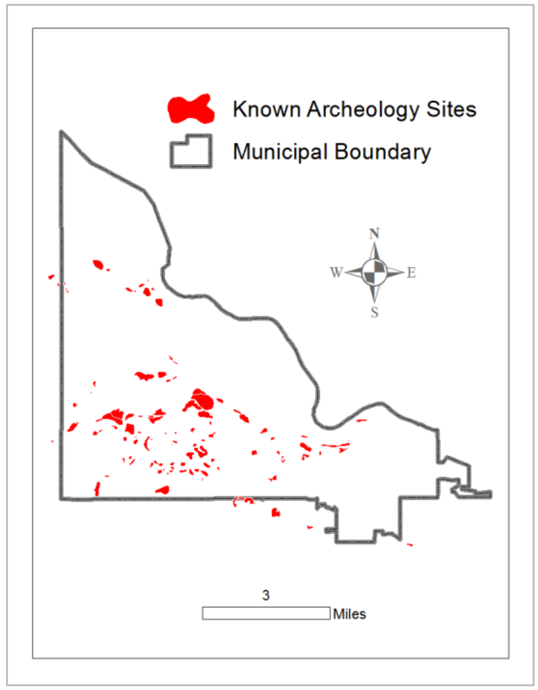

Figure 4. Known archeology sites in Red Wing.

An important delimitation for this study included a project focus area within the City of Red Wing municipal boundary due to the completeness of data sources as compared to those available for adjacent areas.

Physical Setting

Red Wing's topography is marked by bluffs, valleys, and river bottoms. The highest elevation point is 1,278 ft. and lowest elevation point is 622 ft. Although the Red Wing area was occasionally glaciated during the Pleistocene period, it was not covered with glacial ice during the later stages of the Wisconsin glacial periods. As a result, the landscape of the region is mature and deeply dissected (Dobbs, 1990) (Figure 5).

Red Wing's surface hydrology water features include the Mississippi

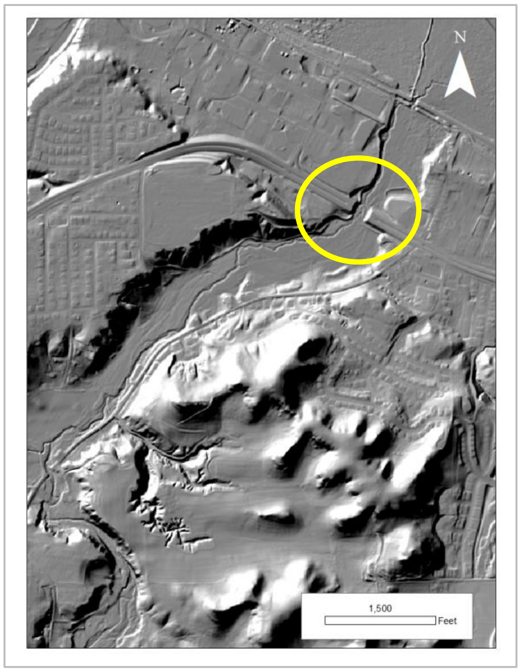

Figure 5. Shaded DEM showing Spring Creek valley near the intersection of Hwy 61 (yellow circle).

River, 50 miles of streams, and approximately 16 square miles of wetlands (Figure 6).

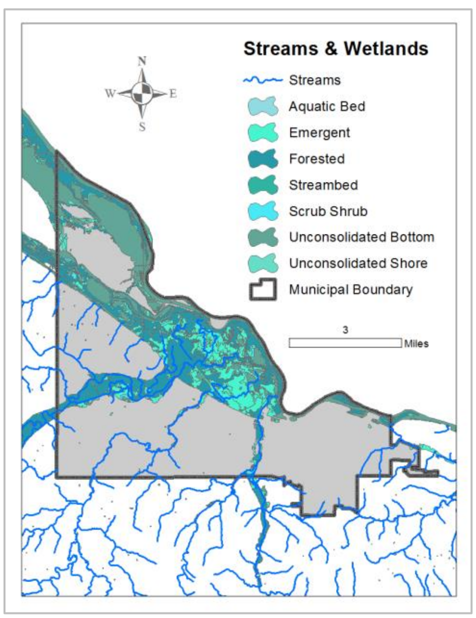

Figure 6. Streams and wetlands water surface features.

Figure 7 shows predominant landform types within the Red Wing boundary including Outwash, Terrace, Bedrock dominated, Alluvium, and Till Plain. Terraces are composed of glacial sands and gravels with sometimes extensive zones of silts and clays. The sediments in valley areas are alluvial in origin and consist of finely textured silts and sands (Dobbs, 1985).

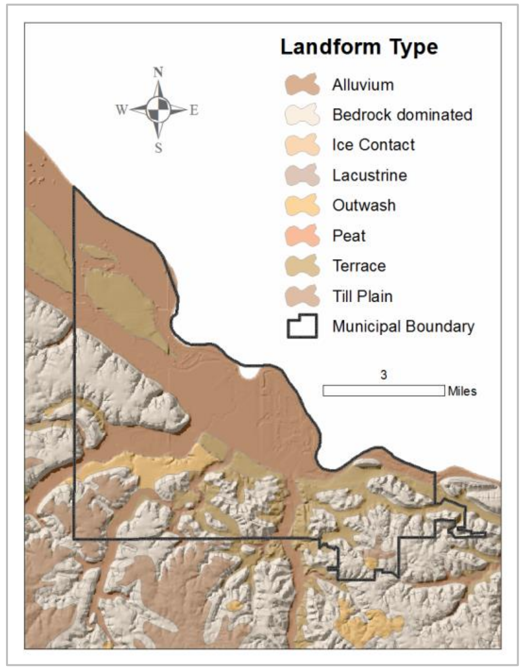

Figure 7. Landform types in the Red Wing area.

Methods

Analysis for this predictive model was conducted in three phases – Phase 1 included a clustering analysis for significance of known archeology sites; Phase 2 examined environmental characteristics of the known site areas; Phase 3 utilized a weighted model index for Red Wing parcels to indicate high, medium, or low site potential. All data sources were clipped to the Red Wing municipal boundary extent for geoprocessing.

It should be noted that predicative model outputs would not provide a suitable basis for legal or statutory land use requirements due to generalized varying scales of input datasets.

Data Required for Study

Known Sites

A variety of field methods were used to create the Red Wing Locality archeological database. Dobbs (1985) placed these field methods in the following categories: 1) Pedestrian Survey, 2) Controlled Surface Collection, 3) Shovel Testing, 4) Bucket Auger Testing, and 5) Soil Probe.

Known site areas were plotted in the 1990's using Esri ArcPlot technology. Known site data included these ArcPlot sites, sites georeferenced from historic maps and surveys, and graphical areas drawn on a USGS (U.S. Geological Survey) 1:24,000 scale digital orthoquad map by Dr. Ronald Schirmer (2007). Attribute data for the GIS data layer originated from Clark Dobb's 'An Archeological Survey of the City of Red Wing, MN' (1985).

The four major eras of archeological cultural context include Woodland, Silvernale, Oneota, and Pre-Contact. Figure 8 shows percentages of each context for known sites.

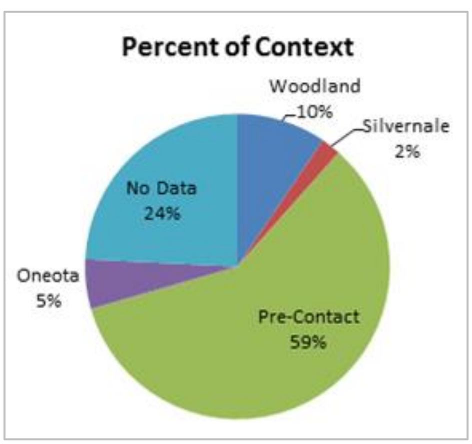

Figure 8. Percent of cultural contexts within the clipped boundary area from a total of 95 site areas.

Common cultural characteristics of these sites include earthen mounds and evidence of both habitation sites and villages. Less common cultural characteristics include cairns, lithic scatter, and petroglyphs (Figure 9).

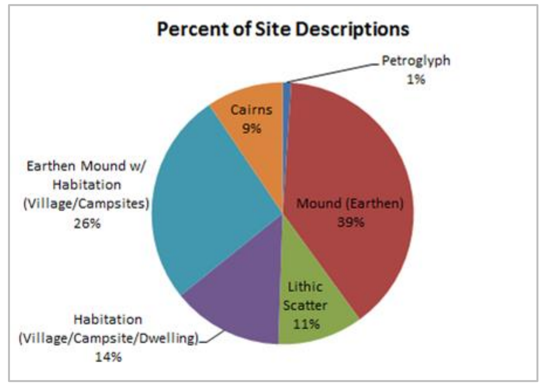

Figure 9. Percent of cultural site descriptions within the clipped boundary area.

Elevation

Variables derived from elevation included height above surroundings, prevailing orientation, relative elevation, and slope (Hudek, Hobbs, Brooks, Sersland, and Phillips, 2001).

Elevation data used in this study originated with the Minnesota Department of Natural Resources in 2012. DEM (Digital Elevation Model) data sources were processed from bare earth LiDAR (Light Detection and Ranging) points. The dataset also includes 2', 10', and 50' contours, LiDAR-derived hillshade, hydro breaklines, and buildings.

Geomorphology

Gouma, van Wijngaarden, and Soetens (2011) state the assessment of their survey results is based on detailed geomorphological mapping of the study area. The results of the models are comparatively applied on the archaeological artifact distribution maps in order to test the hypothesis that the numbers of artifacts in the survey tracts are related to topographic factors and geomorphic processes (Gouma *et al.*).

The statewide bedrock, landform, geomorphology, and quaternary geology layers from MGC100 had a source resolution of 40 acres (Hudek *et al*., 2001). They were suitable for regionalization and interpretation, for stratifying models, and for providing some general information on landscape features where higher resolution data were not available (Hudek *et al*.).

Geomorphology data used in this study originated with the Minnesota Geological Survey and the Minnesota DNR at a 1:100,000 scale. Geomorphology data describe a wide variety of conditions related to surficial geology within a hierarchical classification scheme that was devised for use within Minnesota (DNR Data Deli, 2014).

Historic Vegetation

Vegetation was an integral part of the hunter-gatherer's landscape. Trees and shrubs provided food, fuel, building materials, and protection from the elements. Oaks were of particular importance because of the acorns they provided for food (Hudek *et al*., 2001). Prairies were significant for hunting large game, while waterfowl concentrated in and around wetlands. Some vegetation resources were available only seasonally, others year-round. High local diversity of vegetation types would have made a wider range of resources easily accessible (Hudek).

Historic vegetation data used in this study originated with the Minnesota DNR and was based on Marschner's original analysis of Public Land Survey notes and landscape patterns. Francis Marschner, a U.S. Forest Service employee, compiled a map in the 1930s of the vegetation of Minnesota from PLSS records. Marschner's map was drawn at a scale of 1:500,000, so it is a generalization of the surveyors' records (Hudek *et al*., 2001). Marschner compiled his results in map format, which was subsequently captured in digital format (DNR Data Deli, 2014) (Figure 10).

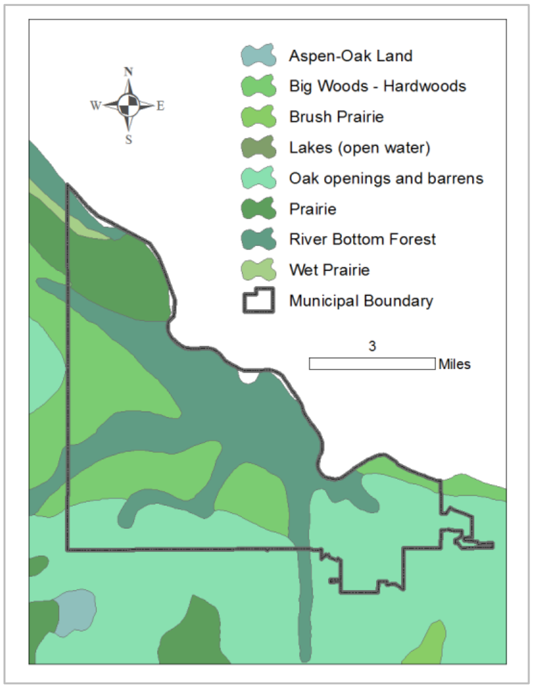

Figure 10. Historic vegetation in the Red Wing area.

Surface Hydrology

Proximity to water is a vital consideration for settlement location. Distances to water were measured in meters (Hudek *et al*., 2001). Sites, particularly villages and campsites, are expected to be close to shorelines (Hudek *et al.*). Lake edges were important for fishing and wild rice harvesting. Distances can be used to model sites at higher elevations than the modern lakeshore, or into the lake, to model sites that are now under water (Hudek *et al.*).

The single most important variable used by Scott Anfinson of the Minnesota

SHPO (State Historic Preservation Office) in his intuitive model of Pre-contact site locations is distance to present and past water sources (Hudek *et al*., 2001). The actual distance he uses in his review and compliance responsibilities has undergone some changes over the years. An early horizontal distance from water measure of 1,000 feet (305 meters) has recently been replaced by a figure of 500 feet (Hudek *et al.*).

Surface hydrology data used in this study originated with the Minnesota DNR and included streams, wetlands, and lakes. 1:24,000 scale streams were captured from USGS seven and one-half minute quadrangle maps, with perennial vs. intermittent classification, and connectivity through lakes, rivers, and small wetland basins. Wetlands data contains standard USGS DLG 100K hydrography polygon features representing wetlands, swamps, marshes, bogs and intermittent hydrography features. Medium scale lake polygons were derived from the National Wetlands Inventory (NWI) polygons and MnDOT Basemap lake delineations. NWI attributes have been transformed into habitat types based on depth and associations with deep water habitats and rivers (DNR Data Deli, 2014).

Parcels

The focus on environmental or biophysical characteristics of land parcels, such as slope, soil type, elevation, plant community type, and distance to water, is also a practical one as these variables are relatively easy to identify today through measurements or observations made on maps, aerial photographs, remotely sensed data sets, and even computer-generated spatial information sources, such as GIS (Hudek *et al*., 2001). Environmentally-based predictive locational models work by correlating the location of a sample of sites with the environmental characteristics of the land parcels where they occur and predicting that other, unknown sites will be present in parcels with similar sets of characteristics. The goal is to define those characteristics of parcels that have some bearing on the distribution of archaeological resources in a study area (Hudek *et al.*).

Parcel data utilized in this study originated with Goodhue County Survey/GIS and were created through a combination of converted AutoCAD plats, scanned and digitized non-platted areas, and legal land descriptions.

Predictive Model Methodology

Site probability models predict potential for finding Pre-contact archeological sites and were the first to be developed. Models classify landscapes as high, medium, or low potential for sites (Hudek *et al*., 2001). In these models, dependent variables are archeological events (i.e. sites), and the independent variables are the biophysical characteristics of locations, such as slope, geomorphology, elevation, visual markers, and distance to water (Hudek *et al.*).

The following GIS datasets have been identified to create the predictive model: 1) Elevation, 2) Geomorphology, 3) Historic vegetation, 4) Generalized known sites, 5) Hydrological resources, and 6) Parcels.

GIS Design

Analysis was performed utilizing Esri (Environmental Systems Research Institue) ArcGIS Desktop software, including the Spatial Analysis extension. A weighted model index was created in the parcel data attribute table. Parcels with potential archeological resources received a rating of high, medium, or low for site probability. Ratings were based on the weighted index totals derived from analysis of input dataset site characteristics. Data inputs and outputs were represented with the NAD 1983 HARN Adj MN Goodhue coordinate system. Metadata was developed utilizing Esri ArcCatalog.

Statistical Analysis

The first step of the predictive modeling process was to establish whether known sites patterns were random/dispersed (Ho) or clustered (Ha). An Average Nearest Neighbor analysis was performed on the Known Sites data (Figure 11).

The Nearest Neighbor Index (NNI) calculates the distance between each feature and its closest neighboring features (Mitchell, 2005). The calculated average minimum distance between all features is compared to an approximation of the expected average distance of a random distribution of points (Johnston, 2010). The Nearest Neighbor Index is the observed distribution over the generalized distribution. The ratio provides a generalized distribution pattern with a given study area (Johnston).

For a nearest neighbor analysis, a z-score value is calculated by dividing the difference between the observed and expected values with the standard error (Mitchell, 2005). Positive z-scores are reflective of dispersed distributions and negative values correspond to the clustering (Mitchell).

The Spatial Statistics tool calculates a nearest neighbor index based on the average distance from each feature to its nearest neighbor. Z-score and p-score values are measures of statistical significance. Given the z-score here of -5.64, there is less than 1% likelihood that this clustered pattern could be the result of random chance. This rejects the null (Ho) hypothesis that states features are randomly distributed.

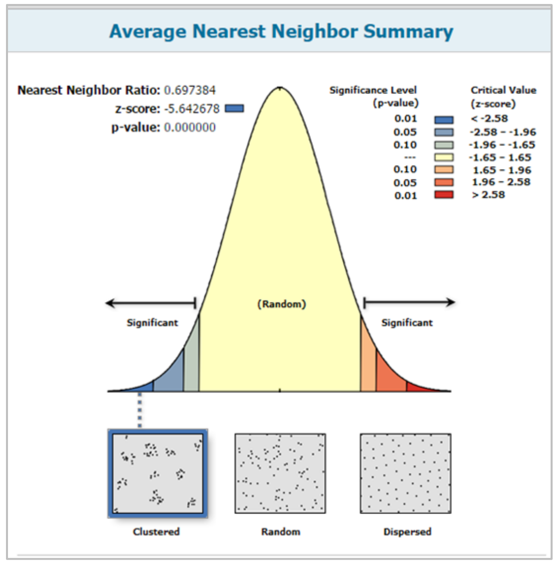

Figure 11. Cluster analysis summary for Known Sites.

Environmental Characteristics of Known Sites

Data from each of the predictive model datasets was clipped by the Known Sites polygon feature dataset and environmental characteristics analyzed. Acreage of geomorphology landform types was calculated, aggregated, and assigned weighted values (Table 1).

Table 1. Weighted model index characteristics of geomorphology.

Geomorphology Type	Acreage	% of Total	Weight
Alluvium	126	13	2
Bedrock Dominated	178	18	2
Outwash	258	27	3
Terrace	397	41	3
Till Plain	8	1	1
Total	967	100	

The weighted score is an indication of the likelihood of that associated characteristic being present within the known site polygons. The same process was performed on historic vegetation with weighted results shown in Table 2. Note there were fewer categories than in Table 1 with no aggregation.

Table 2. Weighted model index characteristics of historic vegetation.

Historic Vegetation Type	Acreage	% of Total	Weight
Big Woods	476	49	3
Oak Openings & Barrens	166	17	1
River Bottom Forest	323	34	2
Total	967	100	

Slope values were derived from DEM raster data with the mean slope resulting in 4.92 percent (Figure 12).

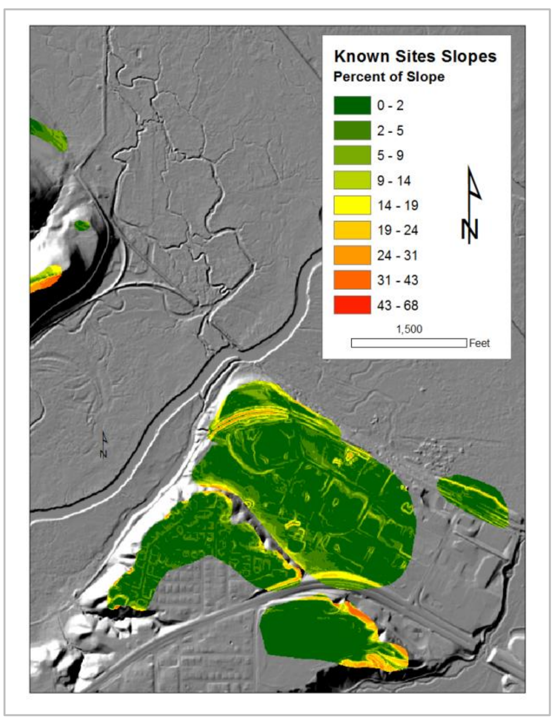

Figure 12. Slope values of Known Sites by percent of slope.

Raster surface values were recalculated using the Map Algebra Raster Calculator tool. Figure 13 shows slopes greater than 5 percent were assigned a value of 0, while slopes that were less than or equal to 5 percent were assigned a value of 1. Raster values of 1 were converted into shapefile vector format.

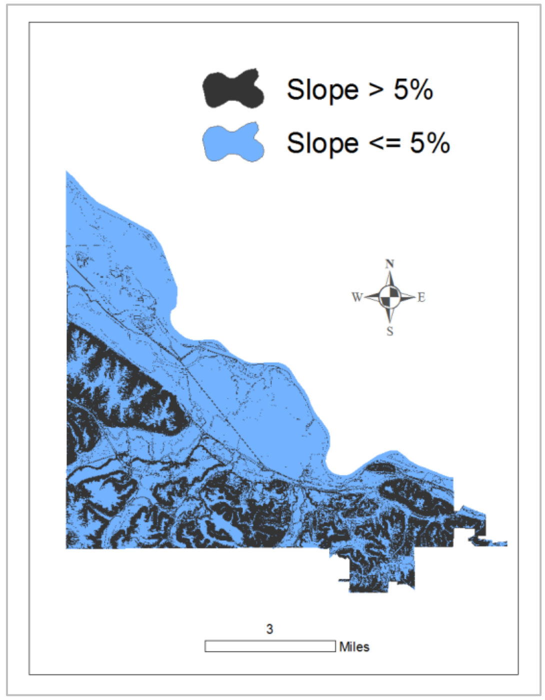

Figure 13. Slope raster recalculated into values of 0 or 1.

Proximity to surface hydrology was calculated utilizing the Spatial Analyst Cost Distance tool using an input value of 500 ft. Cost distance rasters were calculated using both the surface hydrology datasets (streams, wetland, and lakes) and DEM raster dataset. Results varied for each dataset, and so a decision was made to analyze which percentage of each water feature datasets were within a 500 ft buffer of Known Sites (Figure 14).

Wetlands were selected for the Cost Distance Analysis. Values were reclassified using ArcGIS. Lower values on the scale indicate higher proximity to wetland features (Figure 15).

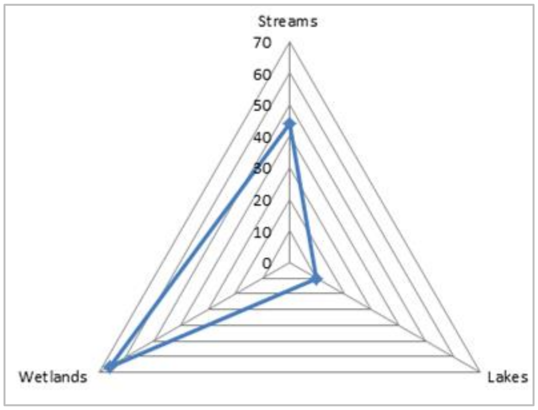

Figure 14. Percent of each water feature dataset within 500 ft buffer of Known Sites.

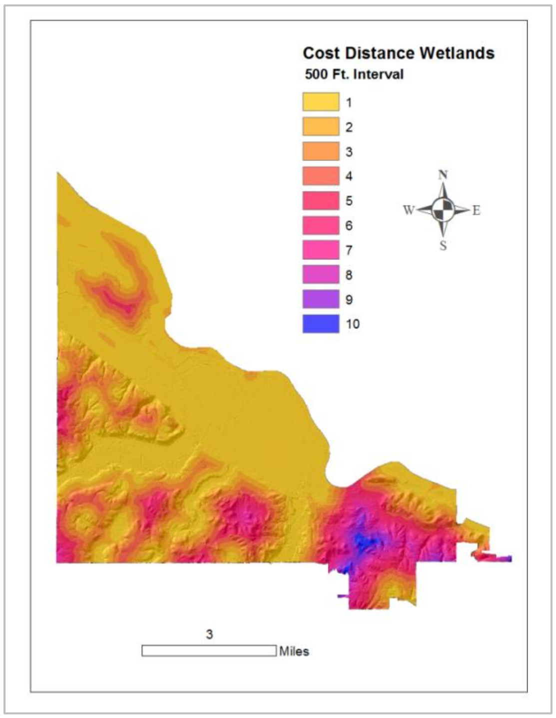

Figure 15. Cost distance analysis of wetlands and surface DEM. Higher values indicate greater distance from wetland resources.

Raster values were converted into shapefiles, aggregated, and then weighted. Higher weighted index values indicate greater proximity to wetland resources.

- Values 1-3 = 3
- Values 4-6 = 2
- Values 7-10 = 1

Parcel Weighted Index Model

Fields were added to the parcel dataset attribute table. These fields included: Geomorph Score, Hist Veg Score, Cost Dist Score, Slope Score, and Known Sites Score. Parcels containing Known Sites were assigned a score of 1 while parcels not containing Known Sites were assigned a value of 0.

Parcels were selected using Select by Location from each of the weighted output datasets and assigned weighted model scores (Table 3).

Table 3. Sample values from Parcels attribute table showing weighted model scores.

Geomorph Score	Hist Veg Score	Cost Dist Score	Slope Score	Known Sites Score	Final Score
2	2	3	0	0	7
2	2	3	0	1	7
2	0	1	0	0	3
3	0	1	1	0	5
2	1	2	0	0	5
1	1	2	0	1	5
2	3	3	1	2	11
2	1	2	1	0	6
1	0	2	0	1	4

Weighted model scores were added for a final score output. ‘Final Score’ attribute values ranged from 3 to 11and were aggregated into 3 categories. Higher weighted index scores indicated a higher probability of archeology sites within the parcel. Choosing 3 categories simplified visualization and reflected the generalized nature of the input datasets.

- Values 3-5 = 1
- Values 6-8 = 2
- Values 9-11 = 3

A final score value of 3 indicated high potential for archeology sites, a value of 2 indicated medium potential, and a value of 1 indicated low potential (Figure 16).

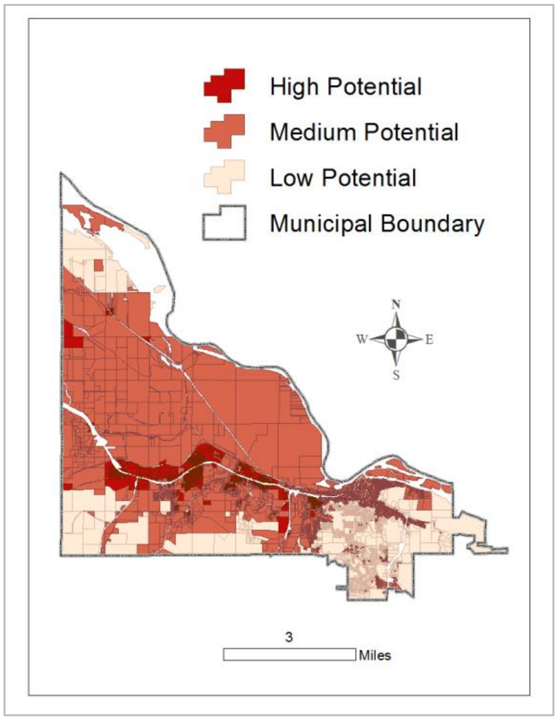

Figure 16. Predictive values by parcel of having potential archeological sites.

Results

A predictive value was assigned to each of the approximately 8,000 parcels in the Red Wing parcel dataset. The analysis pattern indicated strong potential along areas with a relatively flat slope with adjacency to surface water features, terrace or outwash geomorphology, historic vegetation types that included Big Woods (including Oak, Maple, Basswood, and Hickory trees), and proximate to Known Sites.

Percent by predictive value was analyzed (Figure 17). This shows the largest percent of parcels indicate a medium potential for archeology sites.

Total parcels per rating are shown in Figure 18. 1,182 parcels indicated high potential, 4,219 parcels indicated medium potential, and 2,557 parcels indicated low potential.

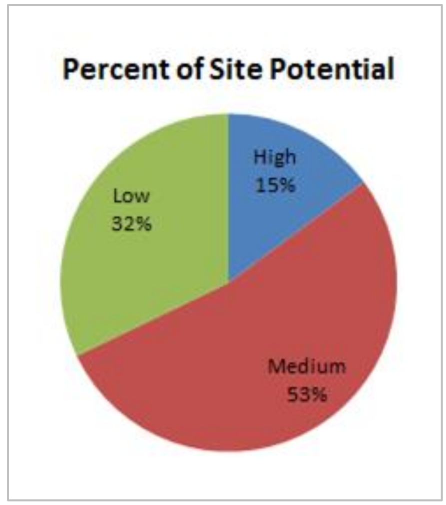

Figure 17. Percent of parcels by site potential type.

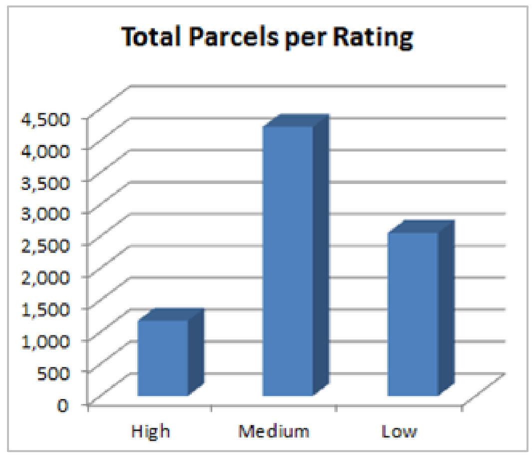

Figure 18. Total parcels per rating as broken down by predictive potential of having archeological sites.

Conclusions

Summary project outcomes from the GIS design and methodology achieved a desired weighted rating system that can lay the groundwork for further investigation by City of Red Wing staff when reviewing zoning applications. GIS databases, geoprocessing, and visualization tools were all key factors in reaching desired project outcomes. An ArcGIS Online application built using the Esri WebApp Builder will be made available as an internal staff resource for site potential evaluation. Future model refinements could include analysis of average distance to bluff edges, slope aspect, distance to water features edges, and average elevation.

Visual methods utilizing hillshade DEM raster data may support the validity of site potential identification. Even mounds and mound groups that have been degraded by erosion and/or modern agricultural practices can be identified by shape and pattern distribution (Figure 19).

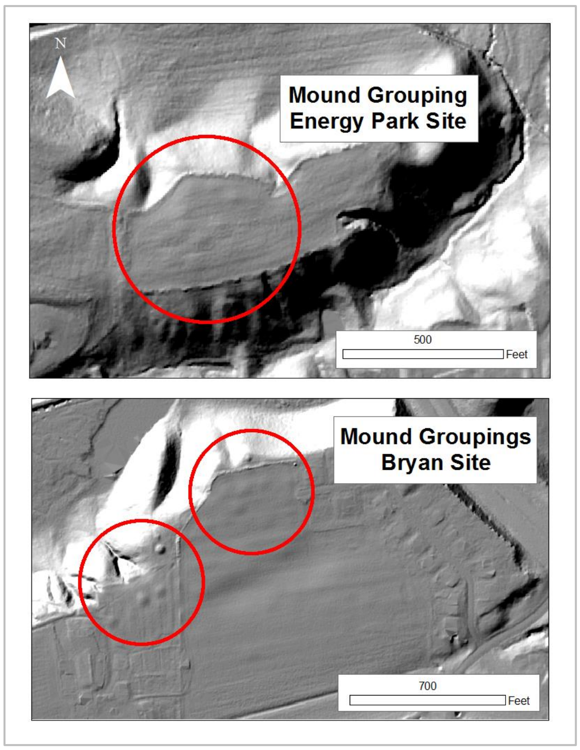

Figure 19. Hillshade DEM visual identification of known mounds and mound groups.

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