Classifying Access on Whitewater Wildlife Management Area Callahan Unit using GIS

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Keywords: Geographic Information System (GIS), Outdoor Recreation System, Wildlife Management Areas, Access, Path Distance, Percent Slope, Zonal Statistics.

Abstract

The Minnesota Department of Natural Resources (MN DNR) would like to be proactive in the development of Wildlife Management Area (WMA) Access Plans to assist with any potential disagreement that may result in different views of access to WMAs as well as to plan future access needs. A WMA access classification system was developed to help describe access on WMAs. A GIS model was developed to provide a means to develop a WMA access classification system through a path distance function. Path distance analysis is a very effective way to model distances a user could travel from parking areas on a WMA to any portion of a WMA that is not restricted by barriers. Several statistics were calculated across walking distance zones to describe the percent slope. Many recreation managers describe the degree of difficulty for traversing a path or area with classifications of percent slope. As with many types of GIS analyses, the accuracy of the data used is very important to the quality of the resulting analysis. Future data collection and acquisition for the use of maps and the WMA access classification system should be considered for providing a clear picture of access on WMAs.

Introduction

Minnesota is blessed with having one of the best assemblages of public and private outdoor recreation lands in the United States for both quantity and quality. Minnesota has made it a priority over the past century to set aside recreational lands from every corner of the state. Recreational land ownership encompasses a wide distribution of private organizations along with local, state and federal agencies. Recreation lands for all jurisdictions range across the outdoor recreation spectrum from modernized recreation on parks, trails and golf courses to more pristine recreation found on nature preserves, wildlife areas and forestlands. However, even with the abundance, distribution and variety in recreational opportunities, conflicts and other concerns have become more apparent due to the demands to provide enough supply and in many cases separation of incompatible outdoor recreational uses.

Scharenbroich, Chris. 2006. Classifying Access on Whitewater Wildlife Management Area Callahan Unit using GIS. Volume 8, Papers in Resource Analysis. 11 pp. Saint Mary's University of Minnesota Central Services Press. Winona, MN. Retrieved (date) from http://www.gis.smumn.edu/Pages/GraduateProjects.htm

State Wildlife Management Areas (WMAs) are part of the Minnesota State Recreation System. Their main purpose in the system is to protect natural resources that have a high potential for wildlife production and to develop and manage these lands and waters for the production of wildlife, public hunting, fishing, and trapping, and for other compatible outdoor recreational uses (Office of Revisor of Statutes, State of Minnesota, 2002). Motorized and many types of non-motorized trail use are generally restricted on WMAs due to their potential for harming natural resources or potential conflicts with other recreation. Pressures to provide other types of trail access on WMAs are also occurring in other parts of the state.

The first step for the State to help resolve disputes over access is to inventory and describe what the State's perspective is on access rights through each WMA. State Area Wildlife Managers have been inventorying WMA features in a Geographic Information System (GIS) for the past 6 years, but the inventory is not complete and was initially intended to provide basic information to the public on WMA access.

The DNR Wildlife Management Section plans to initiate a process to develop WMA Access Plans. WMA Access Plans will demand the need to identify all access features leading to and within WMA boundaries. Furthermore, part of the plan will develop a standardized way to classify the accessibility of a WMA from a user's perspective. Classifying WMA access for the purpose of providing hunting, fishing, trapping and other compatible outdoor recreational uses will focus on distance of foot travel throughout a WMA.

The US Forest Service and other government agencies have recognized the public's desire to have various levels of access to public lands that allow for a variety of recreation opportunities (Clark and Stankey, 1979). Providing information that classifies access in a way that is easy to understand will allow users to make easier decisions on WMAs to visit. Furthermore, the information provided on classifying WMA access statewide will help wildlife managers identify areas to increase and maintain WMA access to provide a balanced approach to recreation opportunities.

GIS will provide a thorough and accurate means for mapping existing WMA access features to allow wildlife managers to quickly verify and update existing inventoried access features. GIS modeling and subsequent analysis will provide the needed access classification system that will allow wildlife managers to compare access on WMAs at local, regional or statewide scales.

Study Area

The area chosen to illustrate features identified for the WMA access inventory and WMA access classification was the Callahan Subunit within Whitewater WMA (Figure 1). The unit was selected because of the landscape's steeper slopes and numerous drainages, which may pose as barriers to foot travel. The Callahan Subunit also has variations in topography resulting in an increase of distance that needs to be traveled over the slopes versus lesser distances traveled over more level surfaces. The attributes of the unit's location mentioned above provide a good example for inventorying and classifying WMA access for WMAs across the state.

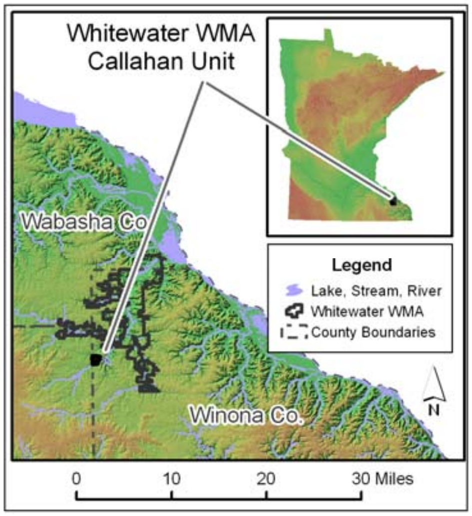

Figure 1. Study Area Whitewater WMA Callahan Subunit.

Software

Software used in this project focused on Environmental Research Systems Institute (ESRI) ArcGIS 9.1 software including ArcMap, Model Builder and associated Spatial Analyst and Maplex extensions. In addition, Microsoft Excel was used to modify tabular figures included in this paper.

Data Collection

The data collected to identify access features for this project began with a series of DNR WMA inventoried features including WMA boundaries and WMA access facilities including all forms of roads, trails, parkable areas, bridges, culverts, gates, water access sites, camping areas and wheelchair accessible blinds. Since most of the WMA inventoried features have been collected within WMA boundaries, other access-related features were collected exterior to the WMA boundary in order to determine access to get to WMAs. MN Department of Transportation (MN DOT) basemap roads were used as well as forest roads inventoried by the MN DNR, Division of Forestry.

Other than access features, the inventory and subsequent analysis to determine a WMA access classification system required information that identified barriers to walking within WMAs. WMA sanctuary boundaries were identified from the WMA polygon facilities layer. WMA sanctuaries are areas in which the public is completely restricted from access during certain periods of fall hunting seasons or throughout the year. WMA cover type data included wetland cover types that could be identified by water regime mirrored from National Wetland Inventory data. Water regimes that are classified as semipermanently flooded, intermittently exposed and permanently flooded were identified as well as open water systems including lakes and rivers. In addition to the WMA cover types, the MN DNR 24K streams and ditch layer provided information that was used to identify narrow, deep water channels that are not identified in the WMA cover type classification and have a high potential to restrict foot travel. Considering the landscapes in SE MN, elevation data from the USGS 30 meter Digital Elevation Models (DEM) were used to identify areas with a high degree of slope.

The majority of the data described in this section was acquired from the MN DNR Data Resource Site enterprise data holdings. WMA management facilities (sanctuaries, gates, and culverts) were obtained from the DNR Wildlife Management Section GIS data holdings. All feature layers were in ESRI shapefile format and the DEM in the ARC GRID Raster Format.

Data Review

A map was created with the use of ArcMap 9.1 to identify access features on the Whitewater WMA Callahan Unit. Data sources related to access and barrier features listed in the data collection section were added to the map. The Maplex labeling engine was used to dynamically label all MN DOT inventoried roads. The map was then exported in ArcMap to Portable Document Format (pdf) and e-mailed to Jon Cole, the Whitewater WMA Area Wildlife Manager. Jon accepted the current facilities and potential barriers on the map so there was no need for edits before performing analysis for the WMA access classification.

Methods

The Spatial Analyst extension provided several distance functions that were ideal to use for classifying access on WMAs. Two potential cost distance functions were identified that would effectively calculate distance from parking lots to any portion of a WMA that was not inhibited by some kind of physical barrier limiting foot travel. Cost distance analysis determines the least accumulative cost from each valued cell in a study area to the nearest source (ESRI, 2002). In many real world applications, this type of distance analysis better suits the needs of a model when there are barriers to straight-line travel. A form of cost distance, called path distance, uses the process of determining the distance of travel to the closest sources and around barriers, while calculating the actual surface distance contributed from variations in elevation (ESRI, 2005). Due to the potential for elevation to significantly affect surface distance traveled on WMAs in SE MN, data was prepared in a model to use the path distance function.

Model Builder was used in order to efficiently visualize, track and store a procedure for modeling the WMA access classification calculated through path distance. Since the data was not specifically designed to provide data parameters for path distance, many geoprocessing procedures were performed in order to effectively model the distances from any part of a WMA to its closest available parking area. The procedure to synthesize the GIS data in a format for the path distance function is outlined in a conceptual model (Appendix A).

Identify Parkable Areas for WMA Access

Several GIS datasets were identified earlier as features that would provide parking access to WMAs. MN DOT inventoried road features were selected as the main source of WMA parking access adjacent and some times within WMA boundaries. Most public roads inventoried by MN DOT have at least the potential to have a wide enough shoulder or Right-of-Way (ROW) to park a vehicle. The exception made to parkable roads in the DOT layers were the Federal Interstates where a vehicle can only be parked on the shoulder or ROW in an emergency. Other roads identified that would have a good chance of allowing parking along their shoulders or ROW included the WMA roads open to Highway Licensed Vehicles (HLVs) and state forest roads.

Once selections were made from the appropriate GIS layers, the roads were merged and buffered by 60 feet to identify potential distances of ROWs and any spatial inaccuracies in the road and/or WMA boundaries that would not identify roads that are actually adjacent or go through WMA lands.

In addition to roads, several WMA facilities were selected as being parkable locations within a WMA. Parkable locations in the WMA facility points layer included parking areas, water access sites, and camping areas. WMA parkable points were then buffered by 60 feet to adjust for any inaccuracies in their spatial relationship with their associated WMA boundaries. The buffered parkable roads and WMA facilities point features were unioned, dissolved and further extracted to an extent within the Callahan Unit to derive all parkable locations along and within the WMA boundary.

Identify the Extent of WMAs Accessible to Foot Travel

Several datasets were identified earlier as barriers that would inhibit foot travel on WMAs including WMA sanctuaries (areas closed to public access), steep slopes, and open water features. WMA sanctuaries were selected from the WMA polygon facilities layer. The spatial accuracy of the sanctuaries was assumed to be within the actual WMA boundary that it protected, so further adjustment to its spatial position was not performed.

Features represented as permanent wetlands and open water systems were selected from the WMA cover types layer. Again, due to the assumption that the water features represented in the cover types were spatially accurate with the WMA boundaries, no further spatial adjustments were performed. DNR 24 K streams and ditches were then used to identify small linear corridors of deep-water areas that were not represented in the WMA cover types layer as water features. Any surface stream or ditch feature identified as being perennial in the attribute table, was selected and intersected with WMA boundaries in order to subset stream and ditch features to be buffered. Stream and ditch features were buffered by a distance of 15 feet because it was assumed that any stream or river 30 feet wide would have been inventoried in the WMA cover type layer. The WMA cover type water features were selected and unioned with the buffered stream and ditch features to generate all water barrier features.

DEM data was processed to develop a percent slope raster with the slope function from Spatial Analyst. The WMA boundary layer was buffered by 30 meters to provide a mask in order to extract slope data within WMA boundaries. Slope data were then reclassified to identify only those areas with slopes > 84 % within the buffered distance of WMA boundaries. The raster representing slopes > 84 % was then converted to polygon features and further unioned with the rest of the WMA barrier features. After the barrier features were combined in a union, the features were used to erase out portions of the Callahan Unit that would impede foot travel.

Analysis

Path Distance Analysis

In order to give the public and Wildlife managers resulting analysis that would not need to be interpreted, the decision was made to provide a cost surface free of barriers that would have a weight of '1'. A cost surface with all areas equal to '1' gave the shortest unaltered surface distance from any accessible portion of a WMA to its closest parking area. The WMA boundary layer without barrier features had a cost field added and calculated to '1' to provide the cost portion of the path distance function.

Parking area features were also weighted the same in providing equal access to the WMA and was given a new field to populate as 2. A union was performed with the parking area features and the WMA boundary to set the analysis extent of the parking areas to the extent of the rest of the WMA to provide a source feature in the path distance function. Both the features that would be represented as the source and cost distance were converted to a raster layer with a cell size of 3 meters. The raster representing the parking features was then reclassified in order to identify the portion of the raster for parking as 2 and the rest of the extent of the raster as NoData. Once all parameters were in raster format, they were entered into the path distance function described below:

Cell Distance = Cost Surface * Surface Distance

Whereas the cost surface represents the raster with all valued cells identifying areas accessible to foot travel on the WMA and the surface distance is the distance calculated through the Pythagorean Theorem from elevation data (ESRI, 2005).

Even though the DEM data was represented as 30 meter cells, the raster analysis cell size was set to 3 meters in order to determine distances through thin areas representing the source and cost layers.

Classification of the Path Distance Raster

The resulting path distance raster was now ready to provide a classification system to define access on the Callahan Unit. The raster was first divided by a factor of 1609.344 in order to convert distances from meters to miles. The path distance raster was then reclassified to 5 classes with 4 classes in increments of ¼ mile, and 1 increment greater than 1 mile. The resulting classified raster was converted to a polygon shapefile. It was then used with several iterations of the identity function to add back all portions of WMA lands that were not included in the path distance raster because they either represented barriers or were areas of the WMA limited to foot travel from barriers. The resulting polygon features had fields added and calculated in the attribute table to determine acres and percent area outside of barriers. The attribute table was then summarized to define the WMA Access Classification for the Whitewater WMA Callahan unit illustrated below in Table 1.

Table 1. WMA Access Classification for Whitewater WMA Callahan Unit.

Access Classification / Distance from Parking	Acres	% Area Non-Barrier
Parking Area	0.22	0.11
< 1/4 Mile	53.15	25.47
1/4 - 1/2 Mile	56.84	27.24
1/2 - 3/4 Mile	25.38	12.16
3/4 - 1 Mile	10.97	5.26
> 1 Mile	6.72	3.22
Limited Walking Access	55.37	26.54
Water Barrier	6.06	NA
Slope Barrier (> 40°)	90.40	NA

Zonal Statistics for Percent Slope across the Walking Distance Zones

Walking distance traveled over the Callahan Unit was not the only variable that described walking access. Some kind of percent slope classification was needed in order for users to anticipate the degree of difficulty to traverse the unit. The walking distance classification mentioned in the section above was used as zones for describing the percent slope over the WMA. The zonal statistics function from Spatial Analyst was used to calculate several statistics including minimum, maximum, range, mean, standard deviation, and sum of percent slope over each walking distance zone. The range, max and mean slope percent statistics for each walking distance zone were then plotted in a bar graph within ArcMap to illustrate the degree of difficulty a user would expect to travel across each walking distance zone.

Discussion and Results

The landscape of the Callahan Unit illustrated the sinuous barriers of steep slope and deep water from its location within the driftless zone where river channels have cut into the exposed limestone bedrock. This unit provided a good test to the model in that it provided areas where narrow corridors between barrier features allowed for a visual comparison between a cost distance function and the euclidian distance.

Path Distance Advantages

As illustrated in the middle portion of the map in Figure 2, steep slopes stopped the progression of the ¼ - ½ mile distance interval until that interval wrapped back up and around the slope barrier to the north. Through a straight line distance from the parking area and moving east ½ mile, the actual walking distance a user would have to travel that same ½ mile is nearly 1 mile.

Another way the path distance function differed from both the cost distance and euclidian distance functions is that it calculated the surface distance

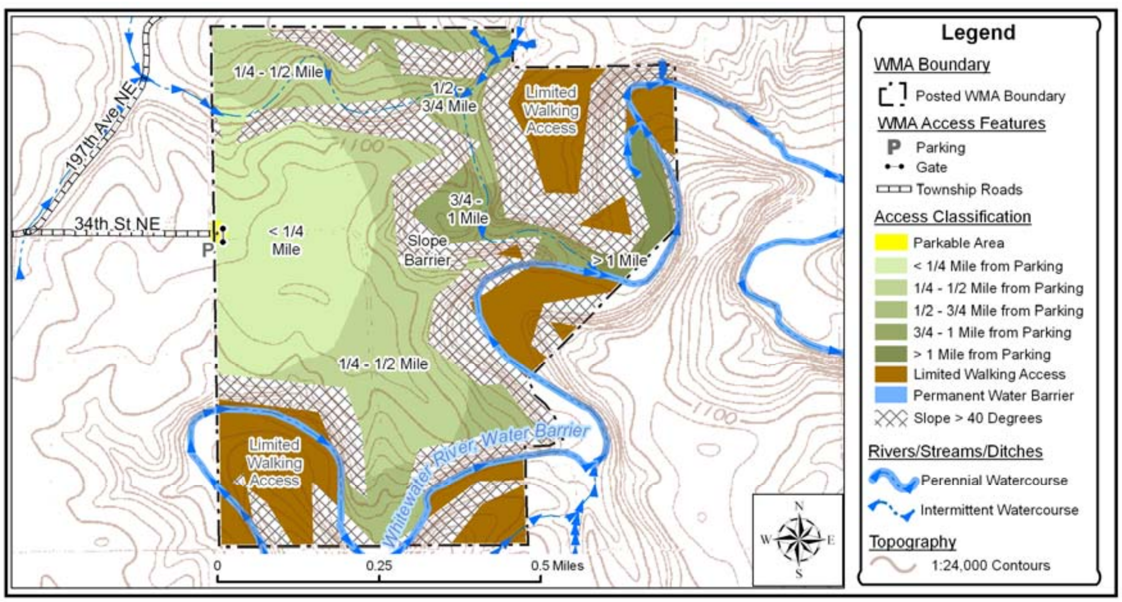

Figure 2. WMA Access Classification for the Callahan Unit of Whitewater WMA

as opposed to the map distance. In Figure 2, one can observe how the surface distance calculation affects the radius of each successive distance classification ring. Perhaps an area on the map that is most noticeable to the affects of surface distance is the steep saddle down to the intermittent stream that cuts through the north part of the unit. In this case, the actual map distance, as measured with the scale bar, was only 1/5 of a mile to the outer ring of the actual surface distance traversed down slope to ¼ of a mile.

Analyzing Percent Slope

The MN DNR, Division of Trails and Waterways has developed draft guidelines and ratings for access on recreational lands. Walker/hunter trails are described in the guidelines as areas where trails have been established from old logging access roads or trails (Brauer & Associates, Ltd. and MN DNR, 2006). These trails closely represent paths that hunters and hikers would choose to traverse over WMAs. A difficultly rating for hiking trails was described in terms of grade ranges in Table 2.

Table 2. Hiking trail grade rating.

Grade Rating	Average Grade	Maximum Grade
Easy	5 % or less	15 % short distances
More Difficult	10% or less	15 % long distances
Very Difficult	15 % or less	15% or more

The zonal statistics calculated for each walking distance zone represented in Figure 3 was compared to the hiking trail grade rating to establish a relative degree of difficulty to traverse through each walking distance zone. As described earlier, the landscape in which the Callahan Unit lies has a very wide range of topographic relief. This wide range of topographic relief makes access throughout the Callahan Unit very difficult according to the hiking trail grade rating. Each walking distance zone on the Callahan Unit has a mean percent slope greater than 15% with maximum slopes near or at the ceiling established for accessible slopes identified in the model as 84%. Overall, the mean percent slope across areas accessible to foot travel on the Callahan Unit is nearly 36%.

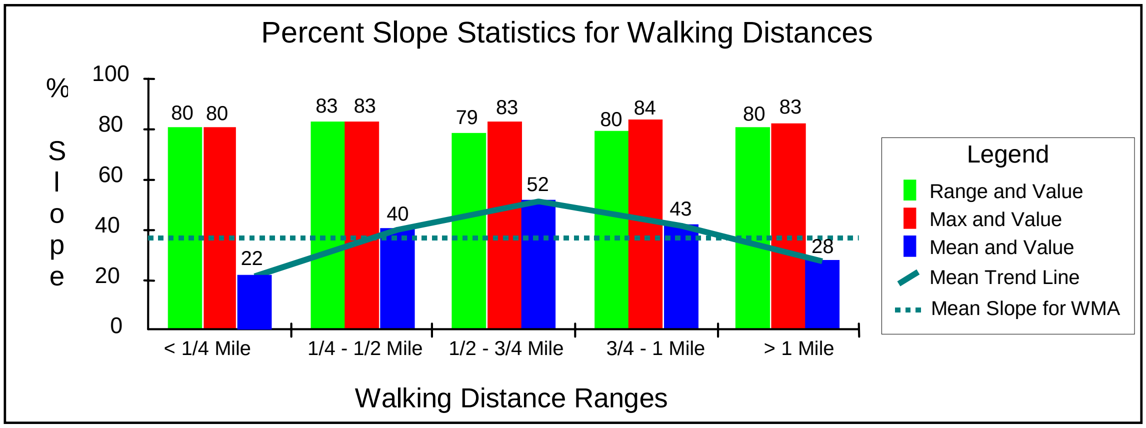

Figure 3. Callahan Unit percent slope statistics across each walking distance zone. Range, max and mean % slope of each walking distance zone with mean trend line and overall mean % slope of the Callahan Unit within the walking zones.

Data Accuracy Considerations

Although the advantages of the model seem to be worth their effort, without knowing the true accuracy of all data used to derive the path distance, the accuracy of the model itself is difficult to assess. Care was taken to consider both the accuracy of the spatial and attribute data as well as the accuracy of parameters in the functions to derive data.

Road classifications and other road attributes were carefully examined to determine which values would have the best opportunities for identifying parkable shoulders and ROWs. Once identified, only those roads that met the classification of roads that may have parkable shoulders or ROWs were selected for buffering to intersect adjacent WMA boundaries. The distance used to buffer the parkable roads was determined by comparing distances of known road ROWs adjacent to WMA boundaries and other ROWs that were known to be separated from WMA boundaries by private property. Based on the exploration of the relationships among roads, ROWs and WMA boundaries, a 60-foot buffer was sufficient for predicting the ROW for roads as well as providing some room for error when comparing the road adjacency to WMA boundaries.

Selecting the 15-foot buffer width for the DNR 24 K Stream and Ditch layer required some investigation into the DNR 24 K Stream and Ditch layer spatial accuracy as well as the level of detail for the spatial representations of WMA water cover types. In most cases, the minimum mapping width of the WMA water cover types was no less than 30 feet. A metadata search for the DNR 24 K Streams and Ditch layer identified that the spatial accuracy of the data varied greatly and was known to be off as much as 100 feet. In order to affectively model stream and ditch barriers, especially in the SE portion of the state where the streams were close to steep banks, a 15-foot buffer was used to allow thin corridors capable of foot travel to not be blocked by hypothetical barriers.

Traversing the Callahan Unit by foot seems to be affected the most by the steep slope barriers. The justification behind using 83% (40°) slope as the maximum slope traversable by most WMA users was based on a study of "Walk-on-able" slopes and wildlife manager recommendations (Kinsella-Shaw, Shaw, and Turvey, 1992). In the "Walk-on-able" slope study, the maximum slope traversed by one of the participants was 33° (65 % slope). Wildlife manager recommendations increased the walkable slope for WMA users to 40° (84% slope). Although some users may not be willing to travel 40° slopes, it was felt that most users would travel that slope for turkey hunting, which is one of the primary uses of WMAs in SE MN.

Conclusion

The process of making maps of access features to WMAs and exploring the data accuracy and resulting relationships among the data greatly enhanced knowledge of developing a model to classify WMA access. As the WMA Access facilities are reviewed and updated by Area Wildlife Managers, consideration should be made to improve the modeling capabilities of the data by designing a set of data that will specifically answer the questions in the path distance model such as if a road is parkable or if a stream is actually wide enough and deep enough to restrict most users from crossing. In addition, acquisition of more accurate elevation data is being created or is already available for some parts of the state from Light Detection and Ranging (LIDAR) sources. More accurate elevation data would allow the model to more effectively identify areas of inaccessible slope, provide more accurate surface distance calculations and calculate more accurate statistics for percent slope across accessible areas on the WMA.

Overall, the WMA access classification will provide a product that wildlife managers will be able to use now and into the future as they tackle access related issues on WMAs. The resulting mapping and initial model development is the first step that is needed to discuss how the Section of Wildlife Management will go about putting together information in a WMA Access Plan. Further, it is a step in the right direction to hopefully get ahead of issues relating to access on a WMA before they get to the point that they cause permanent resentment among various levels of government, private agencies and the users of the outdoor recreation systems of Minnesota.

Acknowledgements

I would like to thank all of the instructors at Saint Mary's University of Minnesota, Department of Resource Analysis for encouraging their students to explore GIS through the format of these graduate projects.

I would also like to thank all of my colleagues at the MN DNR who have greatly enhanced my knowledge of the great outdoors and how to have fun with GIS.

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Appendix A. Conceptual Model for Classifying Walking Distances on a WMA from Access Points.