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Using GIS To Evaluate The Kentucky Wetland Rapid Assessment Method

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USING GIS TO EVALUATE THE KENTUCKY WETLAND RAPID ASSESSMENT METHOD

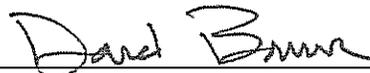
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USING GIS TO EVALUATE THE KENTUCKY WETLAND RAPID ASSESSMENT METHOD

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DEDICATION

This thesis is dedicated to my son, Teddy Mott, who may still be convinced his dad is just “playing on the computer.”

ACKNOWLEDGEMENTS

I give many thanks to my co-advisors, Dr. Stephen Richter and Dr. David Brown, and committee member, Dr. Chuck Elliott, for the guidance they have given me and for the opportunity to work on this challenging and fascinating project. This research was funded by a U.S. Environmental Protection Agency Wetland Program Development grant via a contract through the Kentucky Division of Water to Drs. David Brown and Stephen Richter. Thanks go to Michelle Guidugli for her instrumental help in understanding the KY-WRAM, how it is being developed, and how it is used. I also thank Dr. Tyler Huffman for his invaluable perspectives on GIS, its limitations, its value, and how it impacts society. I owe a great deal to the late Dr. Robert Weih, who formally introduced me to GIS and did an excellent job of challenging his students to push themselves past what they thought they could do. I thank my family, Caye-Stubbings Mott, Dr. Hilda Stubbings, Stan Mott, Peggy Mott, and Seth Mott, for all the support and encouragement they have given me throughout this process.

ABSTRACT

Wetlands are a vital part of our environment and serve important functions, including water quality improvement, nutrient management, pollution control, storm buffering, flood control, sediment stabilization, groundwater replenishment, fish and wildlife habitat, aesthetics, and recreation opportunities (Costanza et al., 2008; Mitsch & Gosselink, 2000; USEPA, 2006; Woodward & Yong-Suhk, 2001). A number of laws have been enacted to help to protect existing wetlands, promote rehabilitation of degraded wetlands, and encourage the creation of new wetlands. Also, since 1988 all United States presidents have stated a “No Net Loss” policy for wetlands in the United States. There is a need to better assess and monitor the amount and condition of existing wetlands to assess the No Net Loss policy, to determine the effectiveness of preservation and mitigation efforts, and to provide a better description of wetland assets.

In an effort to identify, describe, and assess wetlands, a 3-level framework has been broadly adopted by federal and state government agencies. The levels vary in methodology and intensity from the broadest spatial scale and lowest detail (Level I) to the narrowest spatial scale and highest intensity (Level III) (Fennessy et al., 2004, 2007). Rapid Assessment Methods (RAMs) are Level II assessments and considered instrumental in many state-level wetland monitoring and regulatory programs (Fennessy et al., 2007; Stein et al., 2009). A RAM for use with Kentucky wetlands (KY-WRAM) is in development based on recommendations by Fennessy et al. (2007) (KYDOW, 2013a, 2013b).

The KY-WRAM has six metrics, each with submetrics (KYDOW, 2013a, 2013b). Several submetrics in the KY-WRAM are well suited for scoring with GIS analysis techniques. The purpose of this study was to develop GIS methods to calculate scores for the three submetrics described below, and compare those resulting

scores to scores for the same Wetland Assessment Area (WAA) sites that had already been manually rated by human analysts. It was expected that in utilizing GIS techniques that there would be benefits in improved consistency, speed, accuracy, and transparency. Python scripting language was used with ArcGIS 10.1 to programmatically apply GIS methods to score Wetland Assessment Areas (WAA) for KY-WRAM submetrics 1b, 2a, and 2b. Scores determined using a GIS were statistically compared to scores determined from manual methods for the same submetrics and WAA. For all three submetrics, there were no statistical differences between GIS-method scores and scores from manual methods. In addition to statistical analyses, I qualitatively illustrate some of the advantages and drawbacks of using a programmatic GIS solution.

Consistent with the literature it was found that developing a GIS solution has greater up-front costs than solutions using manual methods. Manual methods could be changed with less cost in effort and time compared to making changes to a GIS solution. In this study scripted GIS methods out-performed manual methods in terms of repeatability of results, consistency in reporting, and transparency of steps taken to score submetrics for each WAA. GIS scoring of wetlands was at least as fast as manual methods but was more efficient because it did not require a user to attend during processing. Although it could not be demonstrated quantitatively within the scope of this study, it follows logic that the GIS solution's precise results for calculated areas would be more accurate than those results from visual estimation based on manual methods using the same spatial data. The GIS solution relies on spatial data and therefore is limited by those data in terms of availability and quality. When used in conjunction with ground-truthing during the on-site visit to a WAA a GIS solution can be a useful tool to aid in the assessment of wetlands.

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I. INTRODUCTION

Wetlands serve a vital role in our environment. Important functions of wetlands include water quality improvement, nutrient management, pollution control, storm buffering, flood control, sediment stabilization, groundwater replenishment, fish and wildlife habitat, aesthetics, and recreation opportunities (Costanza et al., 2008; Mitsch & Gosselink, 2000; USEPA, 2006; Woodward & Yong-Suhk, 2001). The importance of wetlands has not always been understood. Historically wetlands were often perceived and treated as undesirable lands that were not productive and that contributed to disease prevalence. In the United States, many wetlands were converted to terrestrial land types, often for use as farm land (Dahl, 1990; Mitsch & Gosselink, 2007). In what is now the United States of America, the amount of wetlands in the contiguous states prior to colonization was estimated at 221 million acres (Dahl, 1990). By the 1980s, wetlands in the same area comprised only 104 million acres, which is only 47% of the estimated pre-colonial level (Dahl, 1990).

Attitudes about wetlands have changed as the benefits and services they provide have been better recognized (Dahl, 1990; Mitsch & Gosselink, 2007). Changes in attitudes led to policy and legislation. Beginning with President George H. W. Bush in 1988, all U.S. presidents since have stated a “No Net Loss” policy for wetlands of the United States (Turner, Redmond, & Zedler, 2001). Beginning in the latter part of the 20th century, a number of laws were enacted that help to protect existing wetlands, promote rehabilitation of degraded wetlands, and encourage the creation of new wetlands. At the federal level, these include regulatory measures, such as those found in sections 404 and 401 of the 1972 Clean Water Act. Non-regulatory and incentive provisions also helped protect wetlands, including the 1970 Water Bank Act, sections 101, 303, 319, and 402 of the 1972 Clean Water Act, and the Swampbuster provisions in the Farm Bills of 1985 (*Food Security Act of 1985*, 1985)

and 1990 (*Food, Agriculture, Conservation, and Trade Act of 1990*, 1990) (Dahl, 2011; Fretwell et al., 1996; USFWS, 1996).

Although there is a goal of wetland retention, restoration, mitigation, and creation, it is not clear how effective efforts have been in achieving the “No Net Loss” policy. National status and trend reports for wetlands describe the existing acreage and changes over time (Dahl, 2011), but there is little information on the quality of those wetlands with regard to functions performed. Wetlands can be categorized in a number of ways, but within categories there is considerable variation in quality and function (Cowardin et al., 1979; Fretwell et al., 1996; Mitsch & Gosselink, 2000, 2007).

Until recently, wetland acreage was reported to still be decreasing at the national level, but recent reports indicated that wetland acres lost are nearly offset by acres gained in new wetlands (Dahl, 2011; Turner et al., 2001) However, describing wetlands only by area may be misleading. Many of the new freshwater wetlands appear to be ponds constructed where a wetland did not historically exist (Dahl, 2011). Because these were not historically wetland sites it follows that the types of wetlands lost or degraded are different from those being created, and the evidence is clear that constructed and restored wetlands have reduced functions compared to natural wetlands (Moreno-Mateos et al., 2012). Thus, even though progress has been made in preventing a net loss of wetland acreage, it cannot be said that no net loss of wetland functionality has been achieved (Dahl, 2011). There is a need to better assess and monitor the amount and condition of existing wetlands so that the condition of those areas can be used to more accurately assess the No Net Loss policy. This is critical for determining the effectiveness of preservation and mitigation efforts, as well as providing a better description of wetland assets than by acres alone.

Describing what makes an area a wetland is difficult, and there is no universally agreed upon single definition to describe all wetlands (Mitsch & Gosselink, 2007). Even within wetland types there may be difficulty arriving at consensus because by their nature wetlands occur as a transition region between aquatic and terrestrial environments; therefore, they are found among, and defined by, features that exist as gradients (Dahl, 2011; Mitsch & Gosselink, 2007). It may be very subjective to decide along a gradient or several features' gradients where to place the exact boundary line (Mitsch & Gosselink, 2007). One broadly accepted system for wetland classification is the Cowardin method (Cowardin et al., 1979).

Hydrology is the most important feature defining a wetland, and wetlands must have periods of inundation or saturation (Cowardin et al., 1979; Dahl, 2011). Water depth is typically variable, and the hydroperiod can be permanent or temporary, occur periodically or irregularly, and include surface or subsurface flooding. The soils are typically indicative of flooding and associated anaerobic conditions, and to some degree the soil types control the presence of plant species, which must be adapted to wet conditions and to the associated soil types (Cowardin et al., 1979).

In an effort to identify, describe, and assess wetlands, a 3-level framework has been broadly adopted by federal and state government agencies. The three levels vary in methodology and intensity from the broadest spatial scale and lowest detail (Level I) to the narrowest spatial scale and highest intensity (Level III) (Fennessy et al., 2004, 2007). Level I assessments typically use preexisting data and are largely based on geographic information systems (GIS). These analyses offer the quickest, least cost, and coarsest wetland assessments (Fennessy et al., 2004; Fennessy et al., 2007). Level II assessments are typically more time intensive than Level I methods, but are more rapid than Level III methods (Fennessy et al., 2004; Fennessy et al., 2007). Rapid Assessment Methods (RAMs) are Level II assessments and considered instrumental in many state-level wetland monitoring and regulatory programs

(Fennessy et al., 2007; Stein et al., 2009). RAMs have become popular because they take relatively little time and require less specialized expertise to perform compared to Level III methods (Fennessy et al., 2007). Level III assessments are the most intensive methods, require the most knowledge, time and effort, and are the most expensive to perform. Examples of Level III assessment methods are Indices of Biological Integrity (IBI) and Hydrogeomorphic (HGM) methods (Fennessy et al., 2007). The three assessment levels complement each other and are used as a suite of tools to assess wetlands.

Due to the utility of RAMs, many different methods have been developed by state agencies for use within their jurisdictional areas. Fennessy et al. (2007) evaluated a number of existing RAMs and made recommendations for the future development of RAMs, including the need to verify them using independent, more intensive measures of wetland condition (e.g., Level III assessments). According to Fennessy et al. (2004) a RAM should include an onsite visit, should take two people no more than half a day to perform the onsite visit, and should only take two people half a day to perform the preparation and analysis, and provide as a final result a single score that allows a site to be compared to other sites.

A RAM for use with Kentucky wetlands (KY-WRAM) is being developed based on recommendations by Fennessy et al. (2007) (KYDOW, 2013a, 2013b). The KY-WRAM has six metrics, each with submetrics (KYDOW, 2013a, 2013b). Several submetrics in the KY-WRAM are well suited for scoring with GIS analysis techniques. Currently, the score for one submetric is calculated using information from a GIS application. The remaining four submetrics suitable for analysis within a GIS are scored using manual techniques. The values for these manually scored submetrics are potentially affected by subjectivity of the operator both in terms of measurement error and error incurred in cases where the operator must make decisions based on best personal judgment. Those types of errors can be difficult to identify, prevent, or correct, and

could reduce reproducibility and accuracy of the method. Also the work involved in manually scoring these submetrics is time consuming. Of those four submetrics, three were selected for use with this research project based on scope and complexity.

The objectives of this study were to develop GIS methods to calculate scores for the three submetrics described below, and compare the resulting scores to scores for the same Wetland Assessment Area (WAA) sites that had already been manually rated by human analysts. It was expected that in utilizing GIS techniques that there would be benefits in improved consistency, speed, accuracy, and transparency.

Submetric 1b “Wetland Scarcity”

Submetric 1b is a measure of how much wetland area exists within a 2-mile radius of the investigated wetland’s center. This includes surface area of the investigated wetland and other wetlands. Excluded are excavated ponds and open water area from lakes, rivers, and streams. The calculation result is reported as percent wetland area within a 2-mile radius circle. Metric scoring is determined by calculating the percent wetland area within the 2-mile radius circle and awarding points based on which of three categories that percent wetland area is within. If more than 80% of the 2-mile radius area is wetland then 1 point is awarded. If more than 20% but up to 80% of the 2-mile radius area is wetland then 2 points are awarded. If 20% or less is wetland then 3 points are awarded (KYDOW, 2013a, 2013b). It was expected that this submetric would be the simplest to develop a software solution to score it. It was also expected that for this submetric the improved accuracy would be achieved because the available data used for decision-making by both analysts and a GIS would be the same and because the manual method used by analysts relied solely on visual estimation.

Submetric 2a “Average Buffer Width around the Wetland’s Perimeter”

As described in KYDOW (2013b) submetric 2a is a measure of surrounding “landscape features that protect the biological, chemical, and physical integrity of the wetland from the effects of human activity.” The metric considers a 150-foot buffer area around the wetland. It is estimated by noting the distance to land-use features from the wetland’s perimeter along four cardinal lines (lines running north – south and lines running east – west) and four ordinal lines (lines running northwest – southeast and lines running northeast – southwest). Specifically, the average distance from the wetland edge along those lines to the nearest non-buffer land-use type is calculated. The average distance to non-buffer land-use is assigned to one of four categories: “Very Narrow Buffer Width” (0-25 feet) worth 0 points, “Narrow Buffer Width” (less than 75 feet but 25 feet or more) worth 2 points, “Medium Buffer Width” (less than 150 feet but at least 75 feet) worth 3 points, and “Wide Buffer Width” (at least 150 feet) worth 4 points (KYDOW, 2013a, 2013b). It was expected that this submetric would be the most challenging of the three to develop a software solution because it involved more complicated spatial data than that used with submetric 1b and relatively more complex logic than submetric 1b and submetric 2b.

Submetric 2b “Intensity of Surrounding Land-Use Within 1000 feet of the Wetland”

Submetric 2b is a measure of the intensity of surrounding land-use based on the dominant land-use types within a 1,000-foot buffer area around the wetland. A land-use intensity category is considered dominant if its associated land-use types comprise more than 25% of the area within the 1,000-foot buffer. There are four categories that earn points from 0 to 4. The land use categories are: “High Intensity” (commercial, industrial, high-density residential, heavily grazed pasture, row crop field, multi-lane paved roadway, construction activity, parking lot, and hazardous/toxic areas) worth 0 points, “Moderately High Intensity (residential and lawns, manicured parkland, golf course, grazed pasture, utility right-of-way,

conservation tillage, recent logging and clear-cut, two-lane road, railroad, man-made lake) worth 1 point, “Low Intensity” (shrubland/young forest, hay field, lightly managed parkland, old field, single track and two track dirt roads, one-lane paved roads) worth 2 points, and “Very Low Intensity” (mature growth forest, other wetland, lake, stream, and river) worth 4 points. Each dominant land-use intensity category within the buffer area contributes to the point value. All points from those represented categories are averaged. The average point value is rounded to the nearest 0.5 for scoring. The possible final points score for this submetric ranges from 0 to 4 in increments of 0.5 (KYDOW, 2013a, 2013b). It was expected that GIS quantification of this submetric would be moderately challenging (between submetric 1b and submetric 2a) because it involved spatial data with complexity comparable to submetric 2a but simpler logic.

II. METHODS

Submetric values for each Wetland Assessment Area (WAA) (N = 38) were calculated using *ArcGIS* (2012) with scripts developed using *Python* (2010). In all cases, the spatial data were in the Geographic Coordinate System of 1983's North American Datum (NAD83). Each WAA had a GIS spatial feature delineating the perimeter of the assessment area for a wetland. In addition to the WAA features, associated spatial datasets (baselayers) were used to perform the KY-WRAM submetric score determinations. Baselayers included landcover, roads, and wetlands spatial data.

For the landcover baselayer, I used the National Landcover Database 2001 (NLCD01) for Kentucky updated to 2005 produced by the Kentucky Landscape Census Project and published in 2007 by the Kentucky Division of Geographic Information. That raster dataset was downloaded from ftp://ftp.kymartian.ky.gov/kls/KY_LC2005.zip on 9 November 2013. Anderson level II landcover types (Anderson et al., 1976) were assigned to each raster cell. Each landcover type also had an associated numeric "GRIDCODE" value (Table 1; Table 2). A polygon feature was created from the raster dataset. The dataset was in Albers Conical Equal Area and projected to Kentucky State Plane Single Zone (FIPS 1600). ArcGIS 10.1 was used to transform the shapefile feature to Lambert's Conformal Conic, while retaining the Kentucky State Plane Single Zone (FIPS 1600) projection. The resulting polygon feature was used in this project for the landcover dataset and will be referred to as "KY_Landcover." The original raster resolution was 30 meters, and the polygon feature dataset had a resolution of 98.425 US Survey Feet.

For the roads baselayer, I used the Kentucky State Maintained Roads published by the Kentucky Transportation Cabinet in 2002. That polyline dataset was downloaded from <ftp://ftp.kymartian.ky.gov/trans/statewide/shape/AllRds.zip> on 9 November 2013. The dataset was created from 1:24000 maps created by the United States

Geological Survey. The dataset is currently being updated based on GPS ground-truthing, but no specifics were available regarding what parts of the dataset had been updated; so the lower precision of that provided by digitization from 1:24000 maps was assumed throughout. This dataset will be referred to as “KY_Roads.”

Table 1. Anderson landcover classes and assigned KY-WRAM submetric 2a categories

| GRIDCODE | Anderson Landcover Class | KY-WRAM Submetric 2a Category |
|-----------------|---------------------------------|--------------------------------------|
| 11 | Open Water | Buffer |
| 21 | Developed, Open Space | NonBuffer |
| 22 | Developed, Low Intensity | NonBuffer |
| 23 | Developed, Medium Intensity | NonBuffer |
| 24 | Developed, High Intensity | NonBuffer |
| 31 | Barren Land | NonBuffer |
| 41 | Deciduous Forest | Buffer |
| 42 | Evergreen Forest | Buffer |
| 43 | Mixed Forest | Buffer |
| 52 | Scrub/Shrub | Buffer |
| 71 | Grassland/Herbaceous | Buffer |
| 81 | Pasture/Hay | Buffer |
| 82 | Cultivated Crops | NonBuffer |
| 90 | Woody Wetlands | Buffer |
| 95 | Emergent Herbaceous Wetlands | Buffer |

For the wetlands baselayer, I used the National Wetlands Inventory published in 2002 and downloaded from ftp://data.gis.eppc.ky.gov/shapefiles/nwi_polygons.zip on 4 November 2013. The dataset was digitized from 1:24000 National Wetland Inventory maps created by the United States Fish and Wildlife Service. This dataset includes only wetlands in Kentucky and will be referred to as “KY_Wetlands.”

WAA boundaries were supplied as a shapefile by Michelle Guidugli, the technician at Eastern Kentucky University overseeing statewide validation of KY-WRAM. Individual WAA sites were copied as individual shapefile features with one shapefile per WAA.

The WAA sites used in this project were a subset of Kentucky wetland assessments chosen from those with manually completed KY-WRAM worksheets. Sites were selected based on a high level of confidence in the WAA boundary delineation. When possible, sites were used that had KY-WRAM rating completed by multiple analysts, and the average scores were used to minimize observer bias. The number of analyst scores for each site ranged from one to nine with most sites having three or four analyst scores. The small and variable number of analyst scores per site made it impractical to perform statistical analysis of scoring variability among analysts by WAA site. The names used for the WAA sites used in this study included a prefix based on the assessment method (KYW = KY-WRAM) and the last two digits of the year. For example, WAA names with the prefix “KYW11” were assessed in 2011, and WAA names with the prefix “KYW13” were assessed in 2013.

Table 2. Anderson landcover classes and assigned KY-WRAM submetric 2b categories

| GRIDCODE | Anderson Landcover Class | KY-WRAM Submetric 2b Category |
|-----------------|---------------------------------|--------------------------------------|
| 11 | Open Water | VeryLow |
| 21 | Developed, Open Space | ModeratelyHigh |
| 22 | Developed, Low Intensity | ModeratelyHigh |
| 23 | Developed, Medium Intensity | High |
| 24 | Developed, High Intensity | High |
| 31 | Barren Land | Low |
| 41 | Deciduous Forest | VeryLow |
| 42 | Evergreen Forest | VeryLow |
| 43 | Mixed Forest | VeryLow |
| 52 | Scrub/Shrub | Low |
| 71 | Grassland/Herbaceous | Low |
| 81 | Pasture/Hay | Low |
| 82 | Cultivated Crops | High |
| 90 | Woody Wetlands | VeryLow |
| 95 | Emergent Herbaceous Wetlands | VeryLow |

Output from processing WAAs with the GIS consisted of a descriptively named text file for each WAA and submetric. These text files contained sufficient information to not only complete the KY-WRAM worksheet but also to provide supporting evidence for the points awarded, record the date and time of processing, record the full paths and names of all source datasets, and give users a starting point for troubleshooting if any issues were encountered. Text files were saved with standard comma-delimited formatting (*.csv) and values quotation-enclosed, for simple import into a spreadsheet. A file of this type will be referred to as “results text file” within this document.

SUBMETRIC 1b “Wetland Scarcity”

The KY-WRAM Submetric 1b awarded points to a WAA based on the percentage of wetland area within 2 miles of the WAA center. GIS processing for this submetric used individual WAA shapefiles as well as the KY_Landcover and KY_Roads datasets. Submetric 1b was calculated as the total acres contained within all wetland polygons within a two-mile radius of the WAA center divided by the total acres within a two-mile radius circle (8042.14 acres) and then multiplied by 100 to convert the value to a percentage.

The workflow for processing the submetric within ArcGIS began by calculating the true centroid of the WAA polygon and creating a point feature at that location. A two-mile buffer was created on this centroid point. The KY_Wetlands dataset was clipped with the two-mile buffer feature, which dramatically reduced the size of the dataset for future processing and thus improved processing efficiency. The WAA feature was assumed to be wetland landcover and was combined with the clipped KY_Wetlands feature using the ArcGIS Spatial Analyst Union tool. That created a WAA-specific WetlandsWithin2Miles feature. A column named “WtIndAcres” was added to that feature’s table. That column was populated with the acreage of each polygon record. All the values under that column were summed to calculate the

total wetland acres within two miles of the WAA center. That total was divided by the number of acres with the entire two miles around the WAA center. The value was then converted to a percentage and reported in the results text file. The points scored for the submetric were calculated using the same criteria found in the KY-WRAM and points were reported in the results text file. Spatial datasets created during processing and retained for future review included: the point feature at the true centroid location and the WetlandsWithin2Miles feature with the updated table containing acreage values. Please see Appendix A for figures of example submetric 1b output from the GIS method¹.

SUBMETRIC 2a “Average Buffer Width around the Wetland’s Perimeter”

The KY-WRAM Submetric 2a awarded points to a WAA based on the average distance, up to 150 feet, that could be traveled in a straight line from the WAA edge while remaining within a buffering landcover type. The KY-WRAM approximates this using eight lines radiating in the four cardinal and four ordinal directions from a central (centroid or near-centroid) point within the WAA. GIS processing for this submetric used individual WAA shapefiles as well as the KY_Landcover and KY_Roads datasets.

The workflow for processing the submetric within ArcGIS began by creating a 150-foot buffer feature around the WAA polygon. This WAA polygon feature within the buffer was then erased to produce a new feature, called “WAA_Buff150Erased” that includes only the region within 150 feet of the WAA but not including the WAA itself.

The central location for origin of cardinal and ordinal lines creation was determined within the WAA. If the true centroid for the WAA polygon fell within the WAA boundary then it was used as the central location. If the true centroid did not fall

¹ All figures may be found in the Appendix.

within the WAA boundary, then the ArcGIS applications algorithm for selecting a label point was used to provide a near-centroid location for the central point. Cardinal (North, South, East, and West) and ordinal (Northeast, Southeast, Southwest, and Northwest) lines were created with each having one end at the central point location and the other a distance away equal to the greatest extent of the WAA_Buff150Erased feature. For the purposes of this project these lines will be referred to as “CardOrd” lines.

Each CardOrd line was clipped with the WAA_Buff150Erased feature to create new CardOrdSegments features. In cases where the WAA boundary was complex, it was possible for a CardOrdSegments feature for a specific direction to contain more than one segment. Because only the outermost segment of each CardOrd line (i.e., the one farthest from the central point) was of interest, the outermost line segment was determined and saved as a new shapefile feature. To do this, the two end points for each line segment were generated and the farthest two points from the central point were used to recreate only the valid line segment. The resulting outermost segments of each of the eight cardinal and ordinal lines were termed CardOrdValidSegment features. To ensure each segment was a maximum of 150 feet in length, a 150-foot buffer was created on each CardOrdValidSegment feature’s point that intersected the WAA boundary. Each CardOrdValidSegment was clipped to its associated 150-foot buffer, thus producing eight CardOrdValidSegment150Foot features. These eight features were then combined into a single new shapefile “AllCardOrdValidSegments150Foot” and a layer created with that shapefile so selection by location could be performed using this data.

The KY_Landcover dataset was clipped using the WAA_Buff150Erased feature to produce a feature containing landcover data only within the region of interest (“WAA_LandcoverClipped”). The KY_Roads dataset was also clipped using the WAA_Buff150Erased feature to produce a feature containing road data only within

the region of interest. KY_Roads is a line feature dataset, so all roads within the region of interest were buffered by five feet to produce a polygon feature with roads represented as ten feet wide. This new buffered road feature was combined with the WAA_LandcoverClipped feature by first erasing it from WAA_LandcoverClipped and then merging the result with the WAA_LandcoverClipped feature to produce a feature with both landcover and roads data (“WAA_LandcoverAndRoads”).

To create a feature containing only areas defined as “Buffer” types, WAA_LandcoverAndRoads table records were selected by specified values under the “GRIDCODE” column (see Table 1). These selected records were saved as a new shapefile “WAA_BufferTypes.” All remaining records were saved as a new shapefile “WAA_NonbufferTypes.” So that selection by location could be performed, layers were created from the shapefiles for both WAA_BufferTypes and WAA_NonBufferTypes.

Selection by location was done on WAA_BufferTypes with AllCardOrdValidSegments150Foot to select all land-use buffer polygons that intersected with the buffer line segments. This step captured the buffer types within 150 feet of the WAA along the CardOrd line directions. Selection by location was done on WAA_NonbufferTypes with AllCardOrdValidSegments150Foot to select all WAA_NonbufferType polygons that were intersected with the CardOrd line segments. This step captured the non-buffer types within 150 feet of the WAA along the CardOrd line directions. The encountered buffer and non-buffer types were reported to the results text file.

To determine the approximated average buffer width around the WAA perimeter, the AllCardOrdValidSegments150Foot feature was erased by the WAA_NonbufferType feature. What remained were only the parts of AllCardOrdValidSegments150Foot feature within the areas of buffer types. Because

line segments could exist that were not in contact with the WAA perimeter, segments that intersected the WAA polygon were selected and saved as “WAA_CardOrdFinal.” The length values for the WAA_CardOrdFinal line segments were summed and divided by eight to calculate the average buffer width, and the result was reported to the results text file. The points scored for the submetric were calculated using the same criteria found in the KY-WRAM and the points were reported in the results text file. Spatial datasets created during processing and retained for future review included: the point feature at the central location, WAA_BufferTypes, WAA_NonBufferTypes, and WAA_CardOrdFinal.

In five cases the WAA boundary was complex and shaped in such a way that the Python scripting code used for this project was not sophisticated enough to correctly identify only the outermost cardinal and ordinal segments. For those WAA sites (“KYW11_020”, “KYW13_030”, “KYW13_232”, and “KYW13_BGAD1”), the GIS-determined submetric 2a scores were incorrect, and excluded from the analysis and results for submetric 2a (see Discussion for additional detail about this technical issue and how it may be addressed in the future).

SUBMETRIC 2b “Intensity of Surrounding Land Use within 1,000 feet of the Wetland”

The KY-WRAM Submetric 2b awarded points to a WAA based on the percent areas of intensity levels described with specified land use types. GIS processing for this submetric used the KY_Landcover and KY_Roads datasets in conjunction with the individual WAA shapefiles.

The workflow for processing this submetric within ArcGIS began by creating a 1000-foot buffer feature around the WAA polygon. This buffer feature was then erased by the WAA polygon feature to produce a new feature called “WAA_Buff1000Erased”, which contained only the region within 1000 feet of the WAA but not the WAA itself.

The KY_Landcover dataset was clipped using the WAA_Buff1000Erased feature to produce a feature containing landcover data only within the region of interest (“WAA_LandcoverClipped”). The KY_Roads dataset was also clipped using the WAA_Buff1000Erased feature to produce a feature containing roads data only within the region of interest. KY_Roads, which is a line feature, was then buffered by five feet to produce a polygon feature with roads represented as being ten feet wide. This new buffered road feature was combined with the WAA_LandcoverClipped feature by first erasing it from WAA_LandcoverClipped and then merging the result with the WAA_LandcoverClipped feature to produce a feature with both landcover and roads data (“WAA_LandcoverAndRoads”). The WAA_LandcoverAndRoads shapefile was updated to include a populated column in the table for polygon area in acres and another column for the land-use intensity level for each polygon. The values for acreage were calculated and written to the feature attribute table using ArcGIS functionality. This was done by calling within Python code the `arcpy.CalculateField_management` method with the passed expression “!shape.area@acres!”. Updating the feature’s table made each calculated acreage value available for review post-processing. The values for the intensity level were determined as specified previously and contained in a configuration file (Table 2). The total acres for each intensity category were obtained by summing by the intensity category the calculated acres for each polygon. The total acreage for the submetric’s area of interest around the WAA was obtained by summing the total acres for all the intensity categories. For each intensity category, its total acres was divided by the area of interest’s total acres and multiplied by 100 to convert to a percent area value. The points scored for the submetric were calculated using the same criteria found in the KY-WRAM and the points were reported in the results text file. The WAA_LandcoverAndRoads spatial dataset created during processing and the updated table containing acre and intensity values were retained for future review.

In addition to processing with actual wetlands baselayer, landcover baselayer, roads baselayer, and WAA polygons, testing was also performed using simplified versions of each of those features. The computed results were compared to manual calculations. The manual calculations were quick and intuitive to perform due to the test spatial data being much simpler than real-world cases. This testing was used to support the case that the software instructions written in Python for the GIS would produce the expected and correct results.

Shapefiles created during WAA scoring with the GIS were reviewed for any indications that there had been issues with the spatial data or processing of the spatial data features. Original source baselayers and WAA shapefiles, as well as aerial imagery, were used as-needed to assess the shapefiles created by the GIS during WAA scoring. All results text files were reviewed for indications of errors.

To test the null hypothesis that there was no difference between analyst-determined scores and GIS-determined scores, a two-tailed paired t-test was performed using Microsoft Excel 2007. This was done for each set of paired submetric results. Along with each t-test, a p-value was calculated to quantify the likelihood of the observed t-test calculated values occurring by chance.

III. RESULTS

Submetric 1b “Wetland Scarcity”:

The mean analyst-determined score (2.72) was not statistically different from the mean GIS-determined score (2.84) ($t_{37} = -1.857$, $p = 0.071$; Table 3). For both methods the mode was 3, the median 3, the minimum 1, and the maximum 3.

Submetric 2a “Average Buffer Width around the Wetland’s Perimeter”:

The mean analyst-determined score (2.99) was not statistically different from the mean GIS-determined score (2.71) ($t_{33}=1.45$, $p=0.156$; Table 4). For both methods the mode was 3, the median 3, the minimum 0, and the maximum 4.

Submetric 2b “Intensity of Surrounding Land Use Within 1,000 feet of the Wetland”:

The mean analyst-determined score (2.83) was not statistically different from the mean GIS-determined score (3.07) ($t_{37}=-1.623$, $p=0.113$; Table 5). For both methods the mode was 4 and the maximum score was 4. The minimum analyst-determined score was 0.5 and for the GIS-determined scores it was 0. The median of analyst-determined scores was 3.08 and for GIS-determined scores it was 4.

Table 3. Analyst and GIS scoring results by WAA for submetric 1b

| WAA Id | Average Analyst Score | GIS Score |
|-------------|-----------------------|-----------|
| KYW11_001 | 3.0 | 3.0 |
| KYW11_002 | 3.0 | 3.0 |
| KYW11_003 | 3.0 | 3.0 |
| KYW11_004 | 3.0 | 3.0 |
| KYW11_005 | 3.0 | 3.0 |
| KYW11_006 | 3.0 | 3.0 |
| KYW11_007 | 3.0 | 3.0 |
| KYW11_008 | 3.0 | 3.0 |
| KYW11_009 | 3.0 | 3.0 |
| KYW11_010 | 3.0 | 3.0 |
| KYW11_011 | 3.0 | 3.0 |
| KYW11_012 | 3.0 | 3.0 |
| KYW11_013 | 3.0 | 3.0 |
| KYW11_014 | 3.0 | 3.0 |
| KYW11_015 | 3.0 | 3.0 |
| KYW11_016 | 3.0 | 3.0 |
| KYW11_017 | 3.0 | 2.0 |
| KYW11_018 | 3.0 | 3.0 |
| KYW11_019 | 3.0 | 3.0 |
| KYW11_020 | 2.5 | 3.0 |
| KYW11_021 | 3.0 | 3.0 |
| KYW11_022 | 2.0 | 3.0 |
| KYW11_024 | 1.0 | 2.0 |
| KYW11_025 | 1.0 | 2.0 |
| KYW11_026 | 2.0 | 2.0 |
| KYW11_027 | 2.0 | 2.0 |
| KYW11_029 | 1.0 | 2.0 |
| KYW13_013 | 3.0 | 3.0 |
| KYW13_228 | 2.0 | 3.0 |
| KYW13_232 | 3.0 | 3.0 |
| KYW13_288 | 3.0 | 3.0 |
| KYW13_BGAD1 | 3.0 | 3.0 |
| KYW13_BRW | 3.0 | 3.0 |
| KYW13_CLA | 3.0 | 3.0 |
| KYW13_CPD | 3.0 | 3.0 |
| KYW13_I75_2 | 3.0 | 3.0 |
| KYW13_OHM | 3.0 | 3.0 |
| KYW13_SCR2 | 3.0 | 3.0 |

Table 4. Analyst and GIS scoring results by WAA for submetric 2a

| WAA Id | Average Analyst Score | GIS Score |
|-------------|-----------------------|-----------|
| KYW11_001 | 4.00 | 4.00 |
| KYW11_002 | 3.00 | 0.00 |
| KYW11_003 | 4.00 | 3.00 |
| KYW11_004 | 3.00 | 0.00 |
| KYW11_005 | 2.50 | 2.00 |
| KYW11_006 | 4.00 | 4.00 |
| KYW11_007 | 2.00 | 3.00 |
| KYW11_008 | 2.67 | 0.00 |
| KYW11_009 | 4.00 | 3.00 |
| KYW11_010 | 3.33 | 4.00 |
| KYW11_011 | 3.00 | 2.00 |
| KYW11_012 | 4.00 | 4.00 |
| KYW11_013 | 4.00 | 4.00 |
| KYW11_014 | 3.00 | 3.00 |
| KYW11_015 | 3.00 | 3.00 |
| KYW11_016 | 3.00 | 3.00 |
| KYW11_017 | 3.00 | 3.00 |
| KYW11_018 | 3.67 | 4.00 |
| KYW11_019 | 2.50 | 3.00 |
| KYW11_021 | 2.75 | 3.00 |
| KYW11_022 | 4.00 | 4.00 |
| KYW11_024 | 3.75 | 3.00 |
| KYW11_025 | 4.00 | 4.00 |
| KYW11_026 | 2.25 | 3.00 |
| KYW11_027 | 0.00 | 2.00 |
| KYW11_029 | 3.00 | 3.00 |
| KYW13_228 | 2.50 | 3.00 |
| KYW13_288 | 3.00 | 3.00 |
| KYW13_CLA | 3.00 | 3.00 |
| KYW13_CPD | 3.00 | 0.00 |
| KYW13_I75_2 | 2.00 | 2.00 |
| KYW13_OHM | 3.00 | 3.00 |
| KYW13_SCR2 | 0.00 | 4.00 |

Table 5. Analyst and GIS scoring results by WAA for submetric 2b

| WAA Id | Average Analyst Score | GIS Score |
|-------------|-----------------------|-----------|
| KYW11_001 | 3.75 | 4.00 |
| KYW11_002 | 3.25 | 4.00 |
| KYW11_003 | 3.50 | 4.00 |
| KYW11_004 | 1.63 | 4.00 |
| KYW11_005 | 3.00 | 4.00 |
| KYW11_006 | 2.75 | 4.00 |
| KYW11_007 | 3.25 | 4.00 |
| KYW11_008 | 4.00 | 4.00 |
| KYW11_009 | 4.00 | 4.00 |
| KYW11_010 | 2.83 | 4.00 |
| KYW11_011 | 3.67 | 4.00 |
| KYW11_012 | 3.67 | 4.00 |
| KYW11_013 | 2.67 | 2.00 |
| KYW11_014 | 3.50 | 4.00 |
| KYW11_015 | 3.17 | 4.00 |
| KYW11_016 | 4.00 | 4.00 |
| KYW11_017 | 3.33 | 2.00 |
| KYW11_018 | 3.33 | 4.00 |
| KYW11_019 | 2.25 | 2.00 |
| KYW11_020 | 2.75 | 4.00 |
| KYW11_021 | 2.63 | 4.00 |
| KYW11_022 | 3.25 | 4.00 |
| KYW11_024 | 3.00 | 4.00 |
| KYW11_025 | 3.63 | 4.00 |
| KYW11_026 | 2.25 | 2.50 |
| KYW11_027 | 1.00 | 2.00 |
| KYW11_029 | 2.00 | 2.00 |
| KYW13_013 | 1.78 | 2.00 |
| KYW13_228 | 1.25 | 2.00 |
| KYW13_232 | 2.50 | 2.00 |
| KYW13_288 | 3.50 | 4.00 |
| KYW13_BGAD1 | 2.00 | 0.00 |
| KYW13_BRW | 0.50 | 0.00 |
| KYW13_CLA | 4.00 | 4.00 |
| KYW13_CPD | 1.50 | 0.00 |
| KYW13_I75_2 | 0.50 | 0.00 |
| KYW13_OHM | 4.00 | 2.00 |
| KYW13_SCR2 | 0.00 | 2.00 |

IV. DISCUSSION

Although GIS methods are often used in the literature there are relatively few studies that evaluate the applicability of GIS techniques by directly comparing results from software-driven GIS methods to results from human-driven manual methods. Many studies, including Brown & Vivas (2005), Herman (2005), and Newlon (2012) apply the technical use of a GIS solution but do not address how results from the GIS might compare to those from non-GIS methods. In a comparable study, Angel et al. (2004) explored how GIS methods performed compared to manual methods for determining sinkhole densities. The motivation for that study was to assess if GIS methods were a viable alternative to existing manual methods that were effective but time-consuming. They found that GIS methods had a higher initial cost in time and effort required while the methods were being developed. Once that development phase was complete, however, the GIS methods were much faster than manual methods and the GIS results were comparable to the results from manual methods. Harris et al. (1997) examined not only the quality of results from a GIS to those from manual methods, but also considered other factors such as personnel and monetary costs. It was noted that there were higher costs in training staff and in having equipment for a GIS, but that benefits were realized when working with large geographic areas or repeated tasks (Harris et al., 1997). Also, it was concluded that both manual methods and GIS methods could produce results of satisfactory quality, but Harris et al. (1997) reminded the reader that GIS results should not be used without some type of data validation.

The objective of this project was to explore the feasibility of using software to easily, rapidly, and reliably perform several submetric calculations for the KY-WRAM using readily available spatial data. Feasibility was assessed using three criteria. First, are GIS-determined scores comparable to analyst-determined scores? Second, can GIS-methodology provide as-good or better performance in terms of accuracy,

repeatability, transparency, and efficiency? Third, is the process of preparing for and performing the GIS solution easy enough that it not a barrier to its usability? I address each of these below.

Scoring Comparability

For all three of the submetrics, the results suggest very similar score values for manual and GIS methods. For submetric 1b 82% of results were identical and all result pairs were within 1 point of each other. For submetric 2a 91% of score pairs were within 1 point of each other. For submetric 2b 74% of score pairs were within 1 point of each other. Anecdotally, in many cases where analyst scores varied for the same WAA, at least some individual analyst scores were in agreement with the GIS-determined scores. There was not sufficient sample size however to quantitatively analyze the variation of analyst scores within WAA, so no conclusions can be drawn about if the GIS-determined scores fall within the range of observed variation for analyst-determined scores.

Manual methods for submetric 1b and submetric 2b both involve visual estimation of percent area composed of a specific category. For submetric 1b there were two categories for wetlands ('wetland' and 'non-wetland') and for submetric 2b there were four categories for land-use intensity ('very low', 'low', 'moderately high', and 'high') that each required estimation of a percent area. Much like visually estimating percent cover for vegetation types, this technique can be somewhat subjective and imprecise, especially in cases of limited inter-observer training, but it must be used when no other practical technique is readily available. The GIS methods for submetrics 1b and 2b involve the actual mathematical calculation of area for categories and then computing the percent area each category comprised of the total area. For submetric 1b both the manual visual estimation and GIS calculation for percent area were determined from the NWI spatial dataset; hence it is expected the GIS technique has higher consistency and greater accuracy.

Given the advantages of GIS over manual methods in working with calculations involving area, it is logical to expect GIS-determined scores for submetric 1b and submetric 2b to be more accurate, but this study did not conduct the simulations that would be necessary to directly test this assumption. Although this study suggests the scores from the two methods are similar, and it was not possible to evidentially support that GIS-determined scores were more accurate, it is still possible to recognize several performance benefits for GIS score determinations.

GIS Solution Performance

Efficiency

Like similar studies (Angel et al., 2004; Harris et al., 1997), this study involved a high initial effort for development of the GIS Solution compared to manual methods, but once development was complete there were advantages to the GIS methods for large landscape datasets and repeated tasks. The time required to determine the three submetric scores for a WAA was approximately three minutes per WAA site. No exact times were available for how long it took an analyst to complete the same submetrics, but anecdotal notes suggest similar times. Yet, a quantitative description of the relative speed of the two techniques currently is not possible. Although for this study we cannot directly compare the speeds of scoring with GIS methods versus manual methods we can consider the efficiency of the two methods in other ways. The GIS solution for this study was designed so that scores for all three submetrics for multiple WAA sites could be processed as a batch. The GIS solution required no interaction with the user until processing was finished and the results ready for review, which left the user free to perform other tasks until submetric rating was complete. Alternatively, text files containing results could be opened, and the information therein used as soon as the file was written because subsequent WAA results would be written to different files, so it was possible for the user to begin reviewing completed submetric score determinations before results were available for all of the WAA sites in the batch. The efficiency and flexibility

afforded by the unattended processing of the GIS solution could not be matched by manual methodology because it inherently requires the analyst to remain involved in the mechanics of WAA scoring for each submetric. Related to the efficiency of the GIS solution is that it makes it much less costly to re-score WAA sites using different baselayers. Re-scoring may be desirable if more up-to-date spatial data or other alternative spatial data become available or if different boundaries for a WAA were used in exploratory “what-if” scenarios.

Repeatability

The GIS solution consists of a set of instructions for GIS methods to be applied consistently for each WAA. Because the GIS solution has the analysis techniques applied the same way for every given set of baselayers and WAA, it may be concluded that the results of those techniques will be the same regardless of who is starting the GIS software.

Transparency

The Python source code used for this project is readable to any user of the tools used in this project, and the code is available upon request. Because the software instructions for the GIS methods are accessible it is possible to know exactly how scores were determined. This transparency is useful for defending calculated scores and increasing confidence in the methodology. Systematic and consistent retention of spatial data generated during scoring determinations also provides a visual way to demonstrate how a score was determined for a WAA. A map of these spatial data can be created within ArcGIS and attached to the KY-WRAM worksheet as documentation, and the spatial data readily allow for double-checking or troubleshooting GIS results if there are questions regarding a score.

GIS Solution Usability

As discussed by Harris et al. (1997) a GIS requires a person to have specialized training before he/she can use the system effectively. This may serve as a barrier to GIS usage. With that in mind, the GIS solution for this study was designed to require the end-user only have minimal amount of GIS or other technology experience. Increasingly, wetland permitting requires applicants to include GIS-derived maps, so use of this method should not add considerably to the skill set already required for those tasks. To make changes to the software instructions and GIS methods themselves does require specialized software development skills not required for actual use of the GIS solution. To use the GIS solution, the user only has to specify in a plain text file the computer folder and file path locations of the baselayers and each of the WAA polygon features and then run the software. Basic familiarity with ArcGIS is needed to review spatial data created during WAA score determinations, which should be retained for quality assurance and documentation of completed assessments.

Although GIS experience is not required to have this study's GIS solution process WAA features and only entry-level ArcGIS skills are needed to review resulting spatial data, it is expected that the WAA analyst have expert knowledge of wetland assessment in order to apply the information in the result text files to the KY-WRAM worksheet. Also, it is expected that the onsite visit to the WAA to complete other submetrics of the KY-WRAM will also serve as an opportunity for ground-truthing the GIS spatial data and results. The analyst of the WAA is responsible for recognizing if a submetric score "makes sense" regardless of if the score was determined manually or using a GIS.

Technical Issues

The current procedure for analyst scoring of submetric 2a makes it difficult to duplicate exactly using a programmatic GIS approach. This submetric, unlike

submetric 1b, is not performed exactly the same way by the GIS methodology as it is by analysts. When placing cardinal and ordinal lines analysts can place line origins (where a cardinal or ordinal intersects the WAA boundary) using best judgment to capture information that may otherwise be missed with the rigid application of the only eight transect lines. The software instructions for the GIS have no such flexibility because a calculated central point based on the WAA polygon center-of-gravity was used. This issue was amplified with large-perimeter WAAs because as the WAA extent increases so does the distance between transects lines and therefore the possibility increases of important land-use information being missed. A possible way to improve the GIS scoring to more closely match analyst scoring may be to increase the number of transects for assessment areas with greater perimeter extents. It might also be beneficial to use additional spatial datasets. In the same way that KY_Roads was used with KY Landcover in this study, vector datasets for railroads and streams that are publicly available could be included in submetric processing and would provide a better level of detail than the 30-m raster landcover datasets that were available at the time of this research.

For this project, a landcover dataset from 2005 was used. More up-to-date data might more-closely resemble the current land-use around WAA sites and therefore help improve scoring comparability. One issue that cannot be corrected with more-current data is that the land-use buffer types listed in the KY-WRAM do not correspond exactly with the landcover classes in the spatial dataset. For submetric 2a, it is necessary to assign the available landcover classes into the “buffer” or “non-buffer” categories based on best judgment. For submetric 2b it is necessary to assign the available landcover classes into the four categories for land use intensity. Expert knowledge of wetland assessment is important for appropriate category assignments. As with other GIS analyses ground-truthing should be a part of the process to validate the spatial data and give additional credibility to KY-WRAM ratings scored based on the spatial data.

Conclusions

Given the overall advantages GIS solutions offer in efficiency, accuracy, reporting, and repeatability, I believe further development is warranted. I believe the results from this study's GIS techniques produced submetric scores at least as accurate as the manual techniques, and arguably better than manual techniques involving visual estimation of area. These results could be expected to improve when using more-recent datasets. Combined with additional software development to help reduce the barrier of use for typical users, and there is great potential for such GIS solutions to be employed to improve the quality of the KY-WRAM and reduce effort.

Alternatively, the saved effort in the field and in training could be reallocated to the other submetrics in the assessment and improve the overall quality of the KY-WRAM results.

This study considered the application of GIS techniques to improve the consistency, speed, accuracy, and transparency for three of the submetrics in the KY-WRAM for wetland assessment in Kentucky. It was possible to illustrate some of the advantages and limitations of using a programmatic GIS solution. We will continue to have a need for wetland assessment and monitoring, and so we expect rapid assessment methods like the KY-WRAM to be increasingly used by regulators, consultants, and scientists. GIS can be a useful tool, along with other tools and an onsite visit, in completing a RAM efficiently and accurately. With better tools and methods hopefully we can gather the information needed in order to make informed land use decisions about our wetlands and determine where we stand with regard to the "No Net Loss" policy.

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APPENDIX

Sample Output from GIS Methods

Submetric 1b: Wetland Scarcity

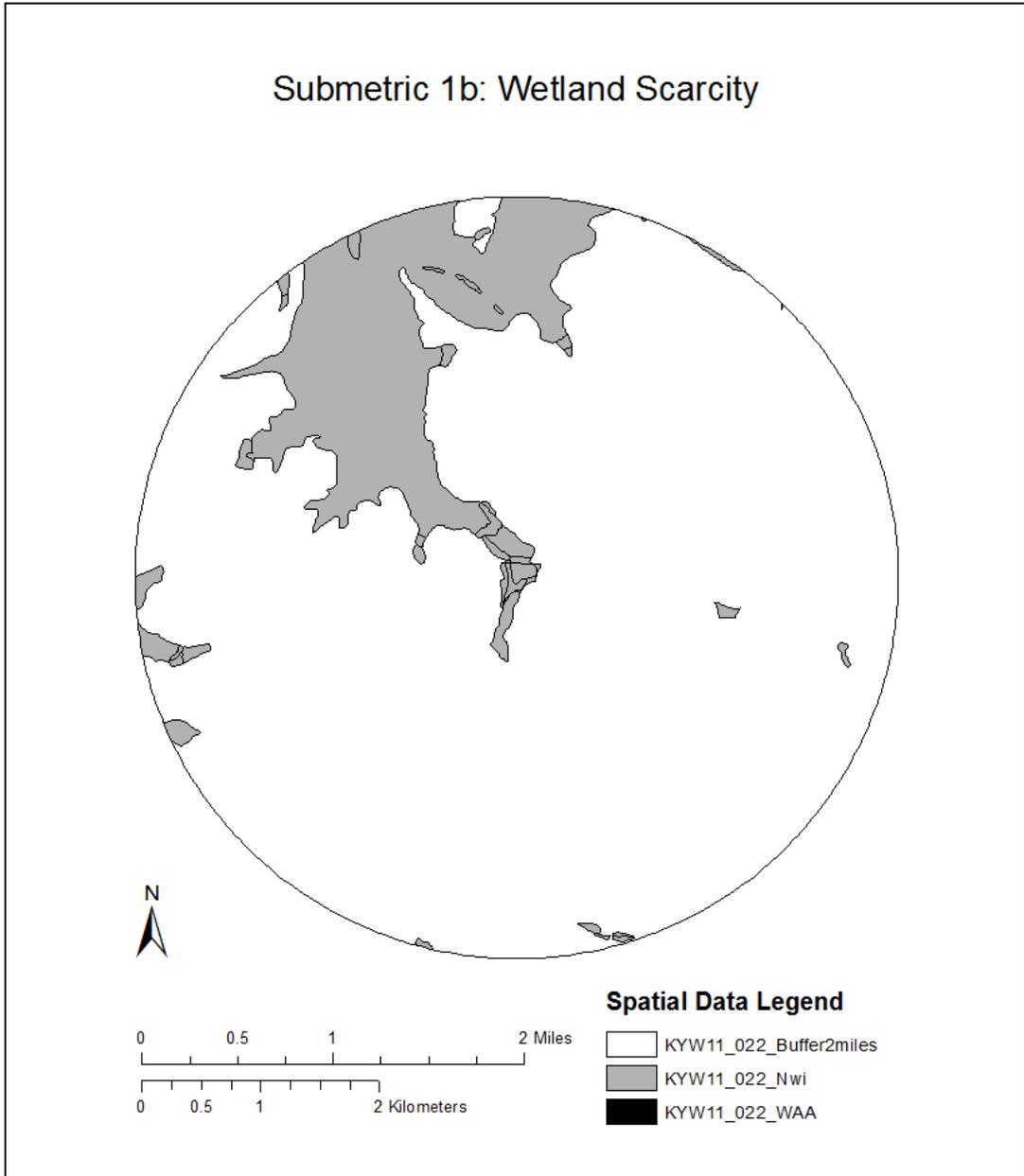


Figure 1: Map for WAA KYW11_022 submetric 1b

```
"Wetland Source File:","C:\KYWRAM_Project\SpatialData\ReadyWAA\KYW11_022.shp"  
"Point Score:","3"  
"Acres Within 2 Miles of True Centroid that are Wetland (to nearest 10th acre):","1119.7"  
"Acres Within 2 Miles of True Centroid that are Wetland (not rounded):","1119.70263511"  
"Acres Within Circle With 2-Mile Radius (hard-coded value):","8042.144804"  
"Percent Area Within 2 Miles of True Centroid that is Wetland:","13"  
"This report written t:","2014-03-30 17:16:04.289000"
```

Figure 2: Results text file for WAA KYW11_022 submetric 1b

Submetric 1b: Wetland Scarcity

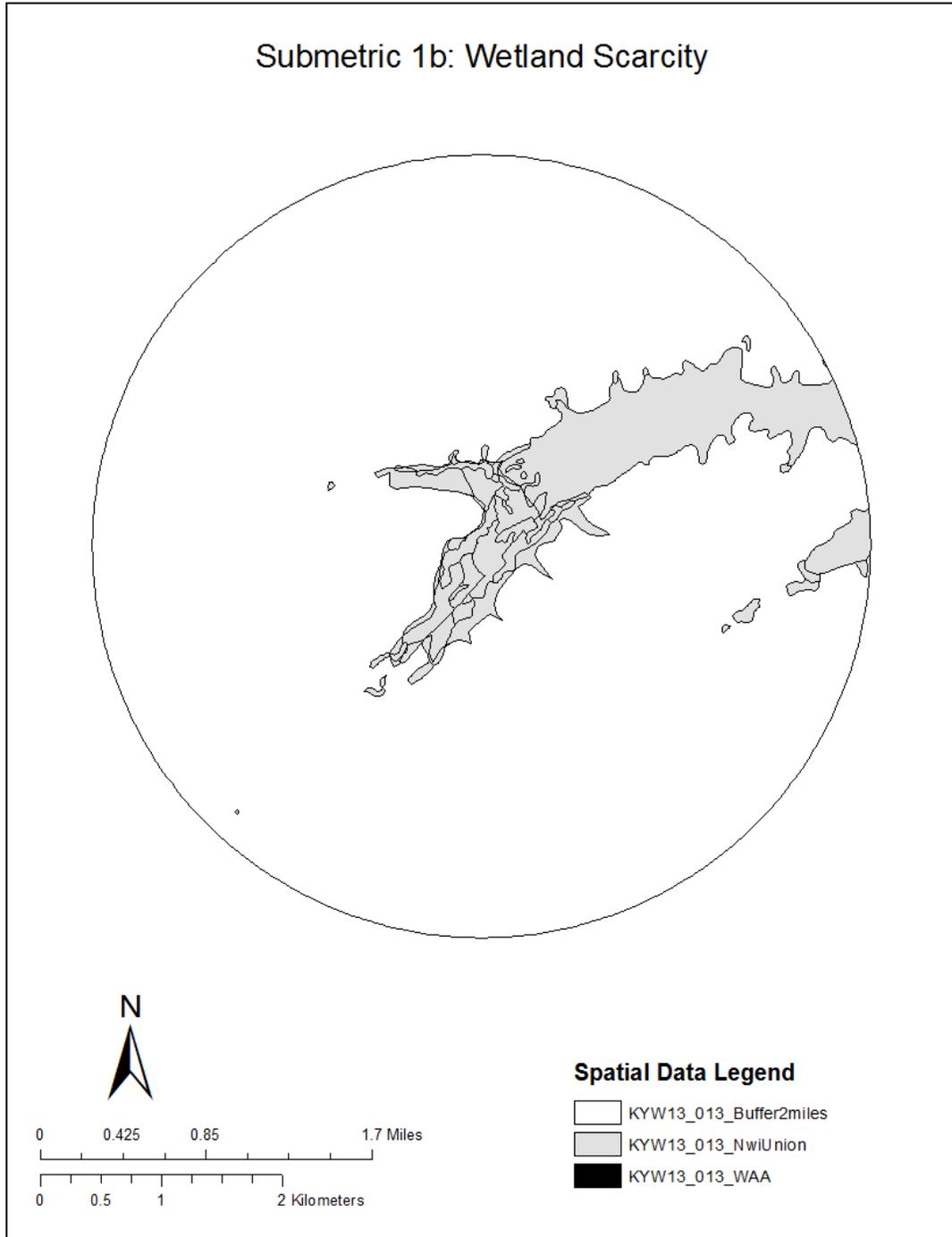


Figure 1: Map for WAA KYW13_013 submetric 1b

```
"Wetland Source File:","C:\KYWRAM_Project\SpatialData\ReadyWAA\KYW13_013.shp"  
"Point Score:","3"  
"Acres Within 2 Miles of True Centroid that are Wetland (to nearest 10th acre):","750.0"  
"Acres Within 2 Miles of True Centroid that are Wetland (not rounded):","750.021829121"  
"Acres Within Circle With 2-Mile Radius (hard-coded value):","8042.144804"  
"Percent Area Within 2 Miles of True Centroid that is Wetland:","9"  
"This report written at:","2014-03-30 17:17:22.445000"
```

Figure 2: Results text file for WAA KYW13_013 submetric 1b

Submetric 1b: Wetland Scarcity

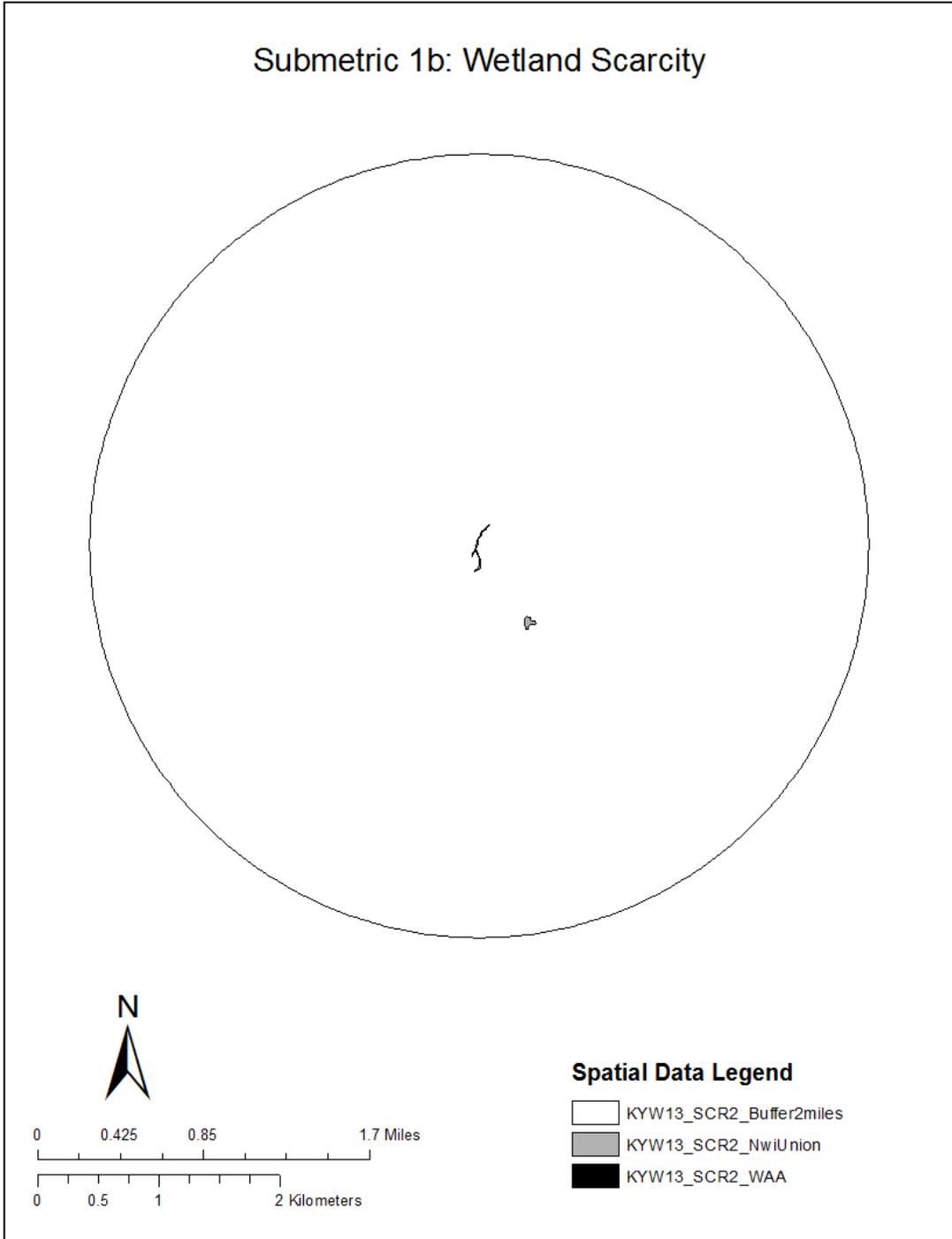


Figure 3: Map for WAA KYW13_SCR2 submetric 1b

```
"Wetland Source File:","C:\KYWRAM_Project\SpatialData\ReadyWAA\KYW13_SCR2.shp"  
"Point Score:","3"  
"Acres Within 2 Miles of True Centroid that are Wetland (to nearest 10th acre):","2.2"  
"Acres Within 2 Miles of True Centroid that are Wetland (not rounded):","2.1503076608"  
"Acres Within Circle With 2-Mile Radius (hard-coded value):","8042.144804"  
"Percent Area Within 2 Miles of True Centroid that is Wetland:","<0.1"  
"This report written at:","2014-03-30 17:19:27.713000"
```

Figure 4: Results text file for WAA KYW13_SCR2 submetric 1b

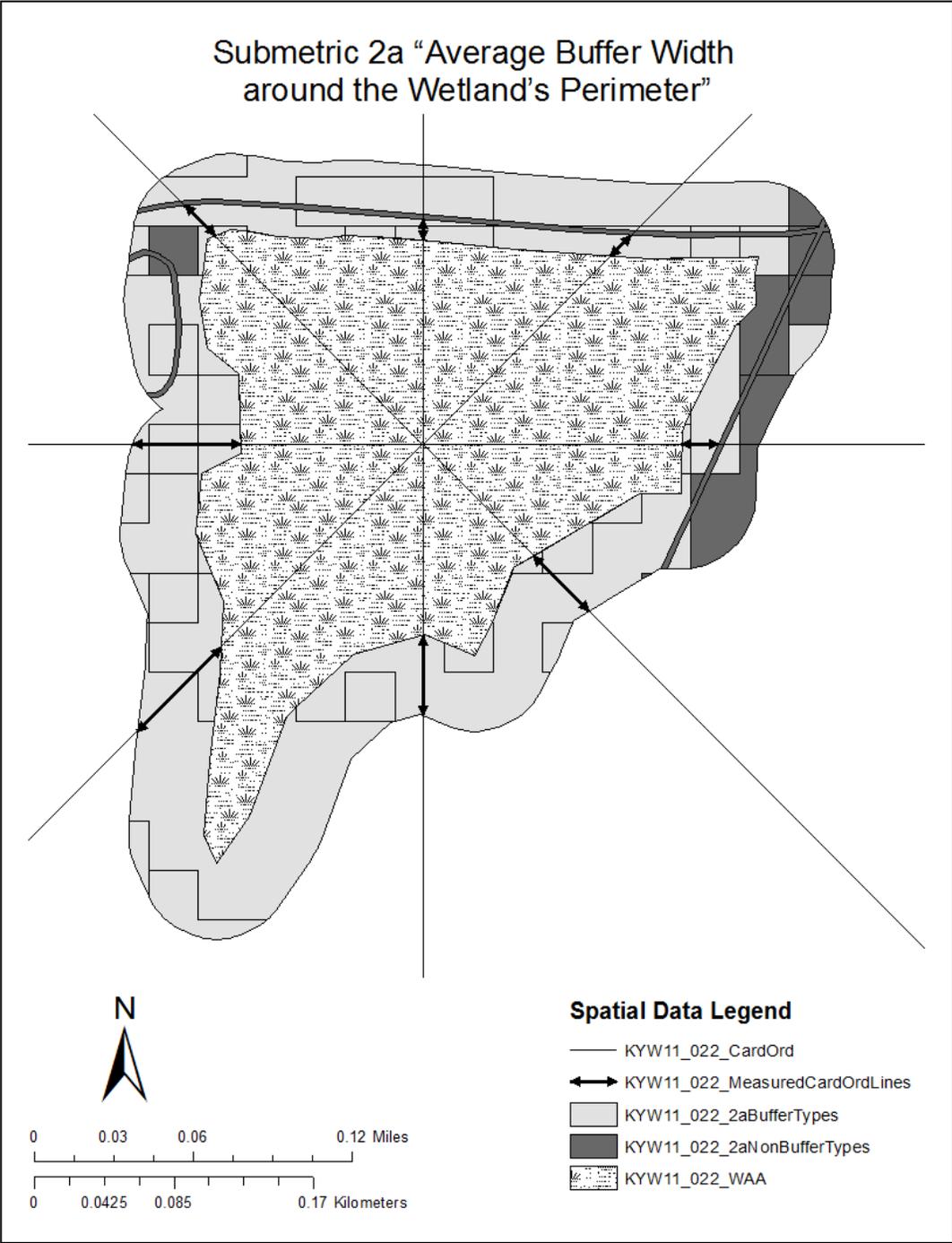


Figure 5: Map for WAA KYW_11_022 submetric 2a

```
"Wetland Source File:","C:\KYWRAM_Project\SpatialData\ReadyWAA\KYW11_022.shp"  
"Point Score:","3"  
"avg. buffer length (feet):","107.2"  
"Landcover Source File:","C:\KYWRAM_Project\SpatialData\BaseSpatialData\ky_lc2005.shp"  
"This report written at:","2014-03-30 18:05:55.527000"
```

Figure 6: Results text file for WAA KYW11_022 submetric 2a

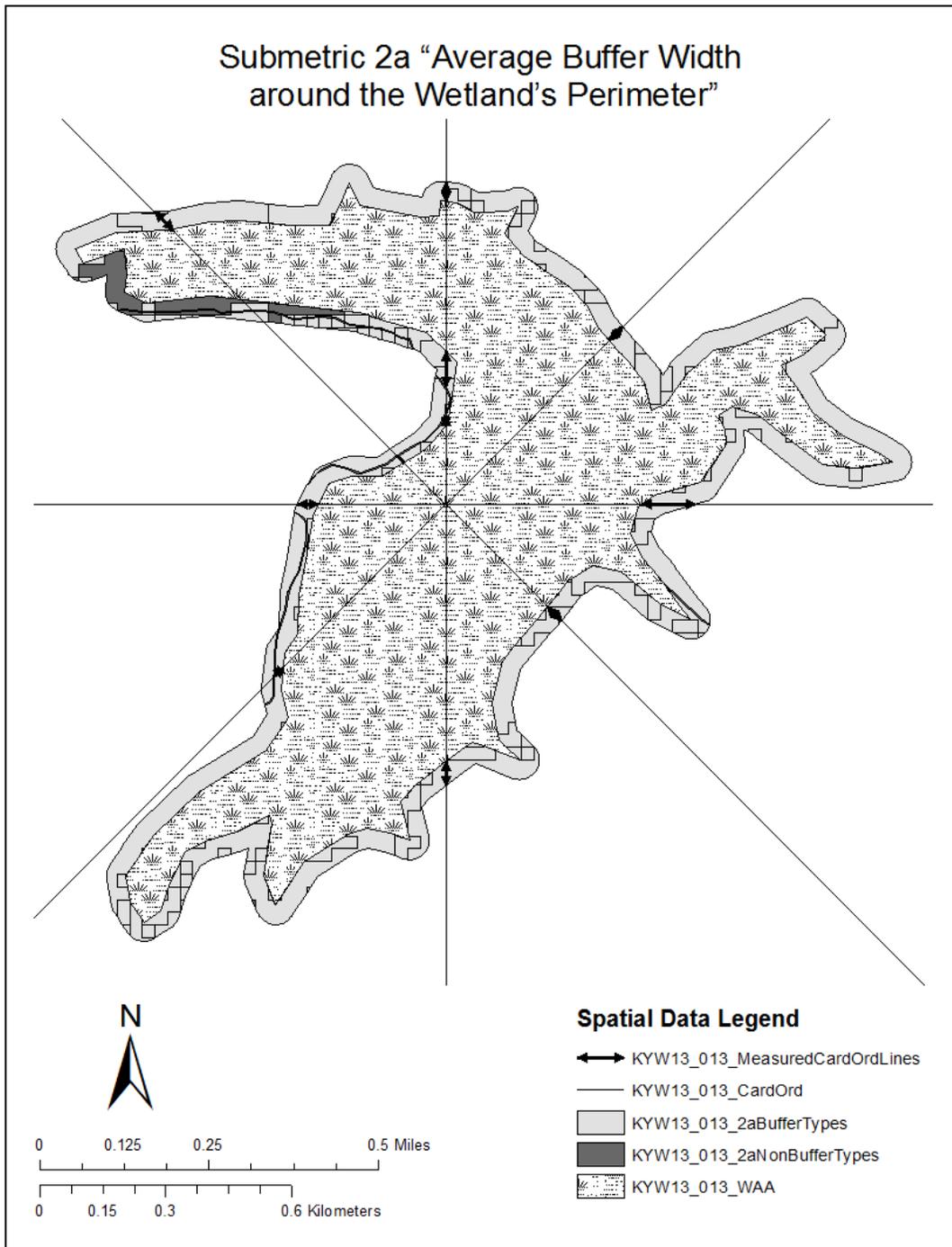


Figure 7: Map for WAA KYW13_013 submetric 2a

```
"Wetland Source File:","C:\KYWRAM_Project\SpatialData\ReadyWAA\KYW13_013.shp"  
"Point Score:","4"  
"avg. buffer length (feet):","180.5"  
"Landcover Source File:","C:\KYWRAM_Project\SpatialData\BaseSpatialData\ky_lc2005.shp"  
"This report written at:","2014-03-30 18:16:52.985000"
```

Figure 8: Results text file for WAA KYW13_013 submetric 2a

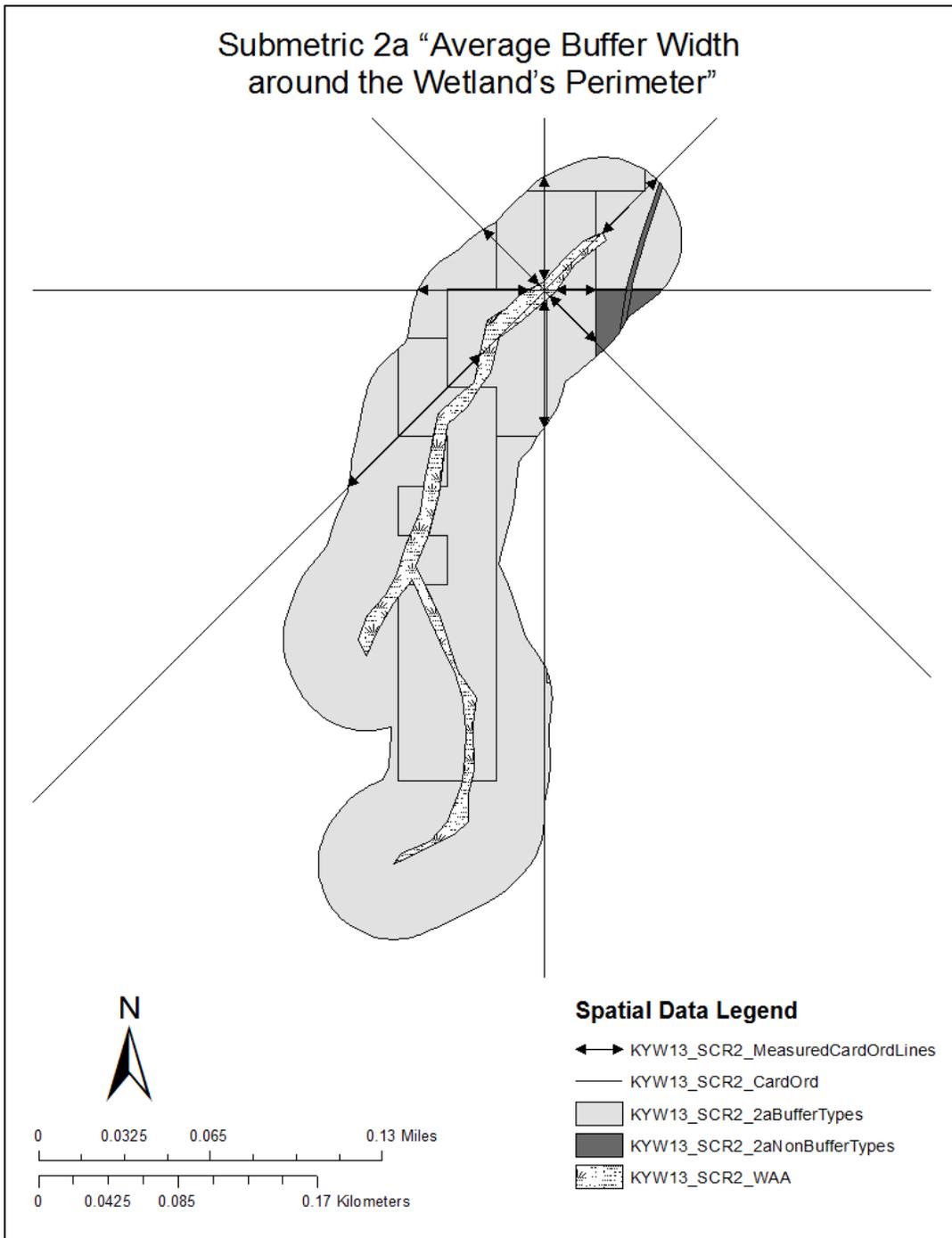
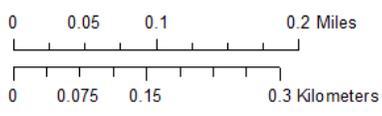
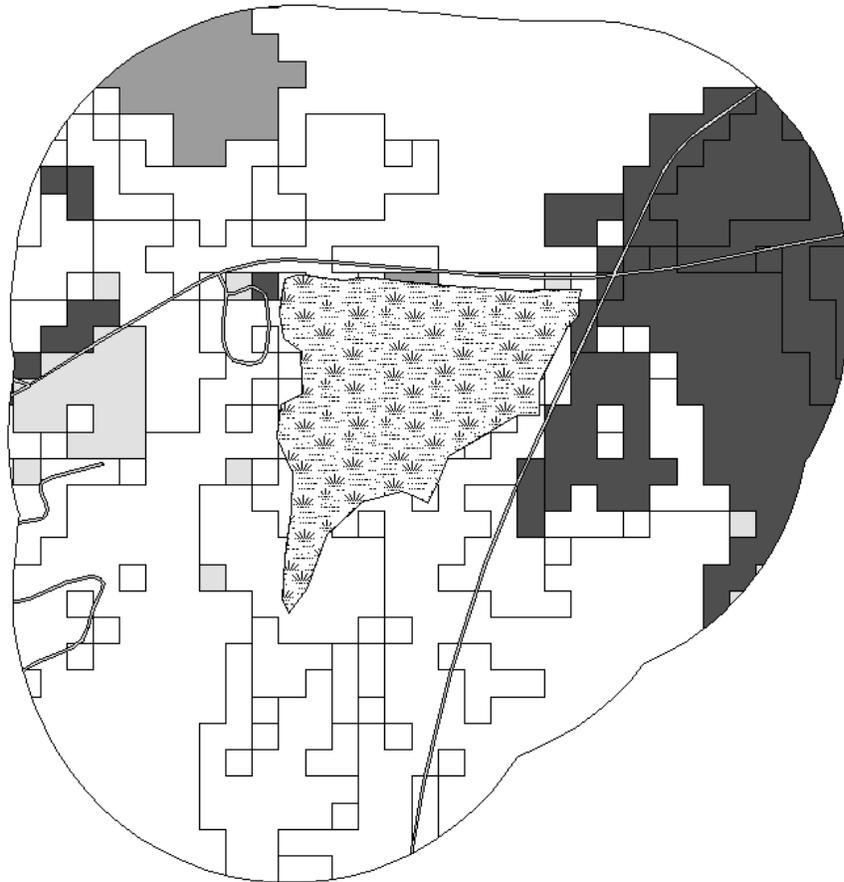


Figure 9: Map for WAA KYW13_SCR2 submetric 2a

```
"Wetland Source File:","C:\KYWRAM_Project\SpatialData\ReadyWAA\KYW13_SCR2.shp"  
"Point Score:","3"  
"avg. buffer length (feet):","138.2"  
"Landcover Source File:","C:\KYWRAM_Project\SpatialData\BaseSpatialData\ky_lc2005.shp"  
"This report written at:","2014-03-30 18:34:07.776000"
```

Figure 10: Results text file for WAA KYW13_SCR2 submetric 2a

Submetric 2b "Intensity of Surrounding Land-Use Within 1000 feet of the Wetland"



Spatial Data Legend

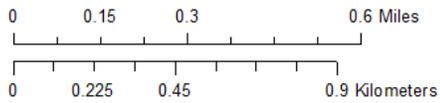
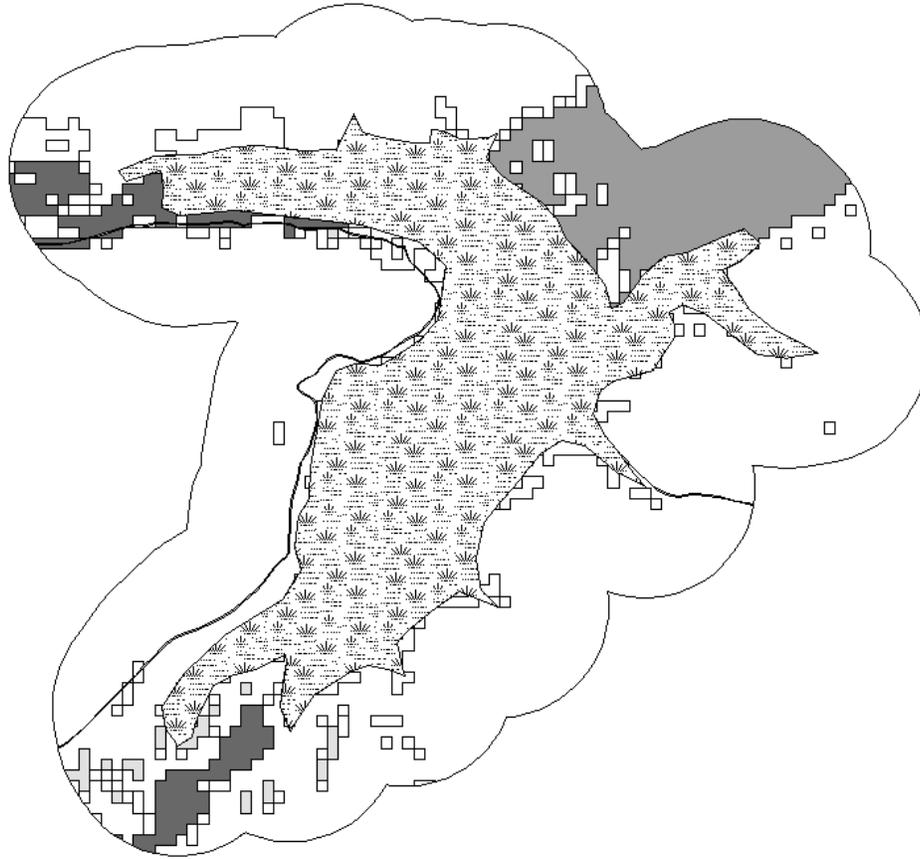
- INTENSITY**
-  High
 -  Low
 -  Moderate
 -  VeryLow
 -  KYW11_022_WAA

Figure 11: Map for WAA KYW11_022 submetric 2b

```
"Wetland Source File:","C:\KYWRAM_Project\SpatialData\ReadyWAA\KYW11_022.shp"  
"Point Score:","4.0"  
"Dominant Intensity Types: ","VeryLow"  
"Percent Area (High Intensity):","19.1"  
"Percent Area (Moderate Intensity):","3.5"  
"Percent Area (Low Intensity):","4.4"  
"Percent Area (Very low Intensity):","73.0"  
"Number of Acres (High Intensity):","31.9"  
"Number of Acres (Moderate Intensity):","5.9"  
"Number of Acres (Low Intensity):","7.3"  
"Number of Acres (Very Low Intensity):","122.1"  
"Number of Acres: Wetland 1000-foot Buffer:","167.2"  
"All Landcover Types Within 1000 feet of Wetland:  
","0.0","11.0","21.0","22.0","23.0","31.0","41.0","42.0","52.0","71.0","81.0","82.0","90.0","95.0  
"  
"This report written at:","2014-03-30 19:57:21.634000"
```

Figure 12: Results text file for WAA KYW11_022 submetric 2b

Submetric 2b "Intensity of Surrounding Land-Use
Within 1000 feet of the Wetland"



Spatial Data Legend

INTENSITY

-  High
-  Low
-  Moderate
-  VeryLow
-  KYW13_013_WAA

Figure 13: Map for WAA KYW13_013 submetric 2b

```
"Wetland Source File:","C:\KYWRAM_Project\SpatialData\ReadyWAA\KYW13_013.shp"  
"Point Score:","4.0"  
"Dominant Intensity Types: ","VeryLow"  
"Percent Area (High Intensity):","4.1"  
"Percent Area (Moderate Intensity):","9.8"  
"Percent Area (Low Intensity):","1.3"  
"Percent Area (Very low Intensity):","84.9"  
"Number of Acres (High Intensity):","27.6"  
"Number of Acres (Moderate Intensity):","66.4"  
"Number of Acres (Low Intensity):","8.8"  
"Number of Acres (Very Low Intensity):","576.7"  
"Number of Acres: Wetland 1000-foot Buffer:","679.6"  
"All Landcover Types Within 1000 feet of Wetland:  
","0.0","11.0","21.0","41.0","42.0","52.0","82.0","90.0","95.0"  
"This report written at:","2014-03-30 19:58:23.768000"
```

Figure 14: Results text file for WAA KYW13_013 submetric 2b

Submetric 2b "Intensity of Surrounding Land-Use Within 1000 feet of the Wetland"

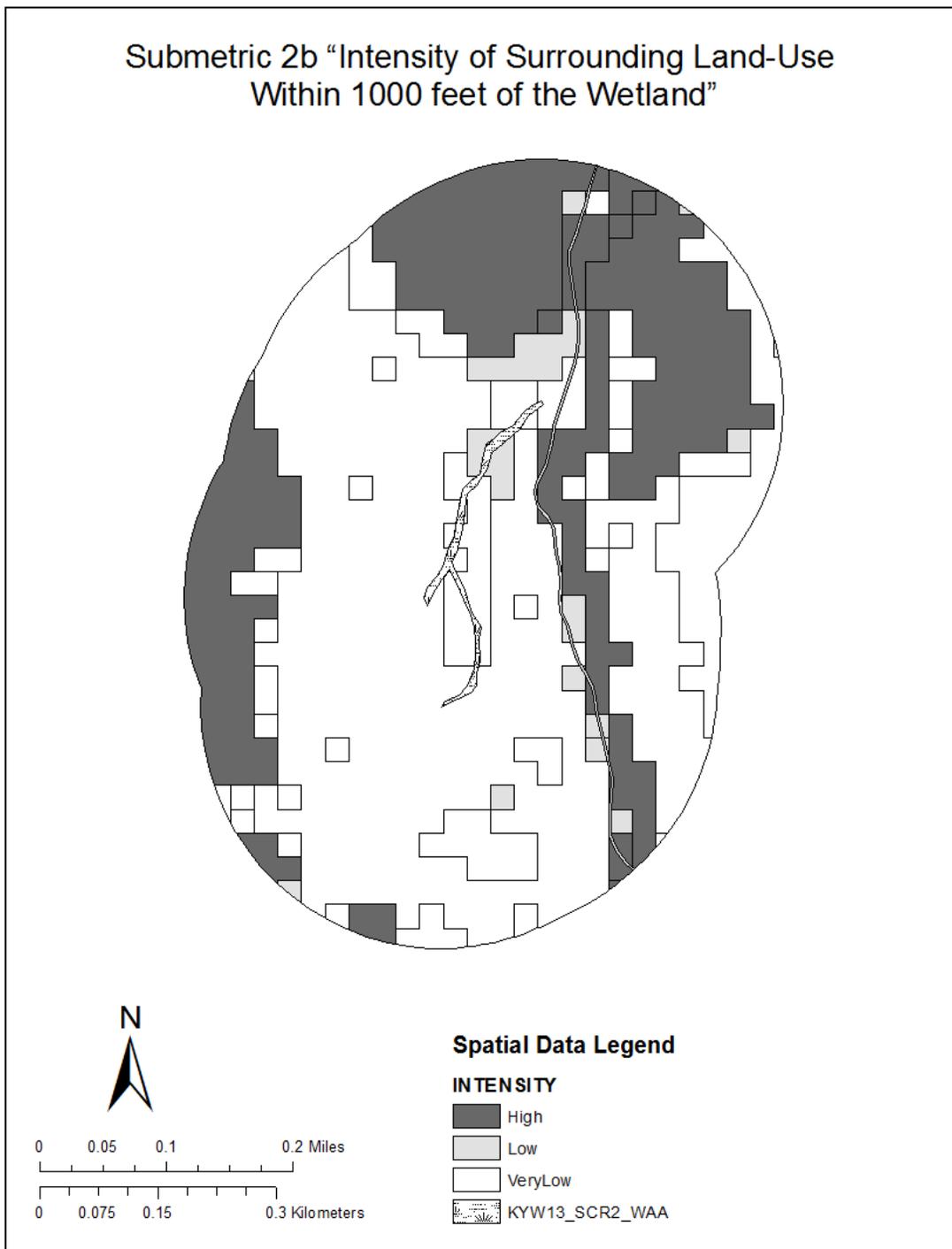


Figure 15: Map for WAA KYW13_SCR2 submetric 2b

```
"Wetland Source
File:","C:\KYWRAM_Project\SpatialData\ReadyWAA\KYW13_SCR2.shp"
"Point Score:","2.0"
"Dominant Intensity Types: ","High","VeryLow"
"Percent Area (High Intensity):","31.2"
"Percent Area (Moderate Intensity):","0.0"
"Percent Area (Low Intensity):","3.8"
"Percent Area (Very low Intensity):","65.0"
"Number of Acres (High Intensity):","43.9"
"Number of Acres (Moderate Intensity):","0.0"
"Number of Acres (Low Intensity):","5.4"
"Number of Acres (Very Low Intensity):","91.6"
"Number of Acres: Wetland 1000-foot Buffer:","140.9"
"All Landcover Types Within 1000 feet of Wetland:
","0.0","21.0","22.0","31.0","41.0","42.0","43.0","52.0","71.0","81.0"
"This report written at:","2014-03-30 20:00:28.007000"
```

Figure 16: Results text file for WAA KYW13_SCR2 submetric 2b