Final Report to the
U.S. Environmental Protection Agency, Region 7

Headwater Wetlands in Agricultural Areas in Missouri
(CD 98753301)

Funds for this project were provided by

U.S. Environmental Protection Agency

and

Missouri Department of Natural Resources

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Water Resources Center
June 30, 2008

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1. Abstract

The goal of this project was to develop a GIS-based model to identify areas at a landscape scale with the greatest potential for the restoration or creation of sustainable wetlands. The first step of the model combines data from ten raster layers into a weighted overlay which calculates results at a 30 meter resolution. Data layers used include slope, flow accumulation, hydric soils, flooding frequency and duration, land use/land cover, distance from first and second order streams, and distance from existing wetlands. Values assigned to each layer enable the model to be adapted to suit the specific region, terrain type, and ecology to which it is to be applied. All data layers are commonly available to users and no new data was collected during this study. The second step of the model includes a neighborhood analysis, which considers the majority land use and average slope within a given radius of each point, and a process that calculates the size of each restorable area. During the summer and fall of 2007, the model was applied to a portion of the watershed of the Little Chariton River and the watershed of Paddy Creek in Missouri to create maps of wetland potential. Three versions of the model have been developed to meet the specific goals of improving water quality, providing habitat for wetland species, and evaluating land for enrollment in the Wetland Reserve Program.

2. Introduction

Between 1998 and 2004 there was an average annual net gain of 32,000 acres in wetland area in the conterminous United States (Figure 1). This trend is only just now beginning to replace the wetland area lost since the middle of the twentieth century. Wetland losses from the 1950s to the 1970s were dramatic, with average annual net losses of approximately 458,000 acres. The net gain in wetland acreage from 1998 to 2004 is the result of restored and created wetland acres exceeding wetland losses of 228,500 acres (Dahl 2006).

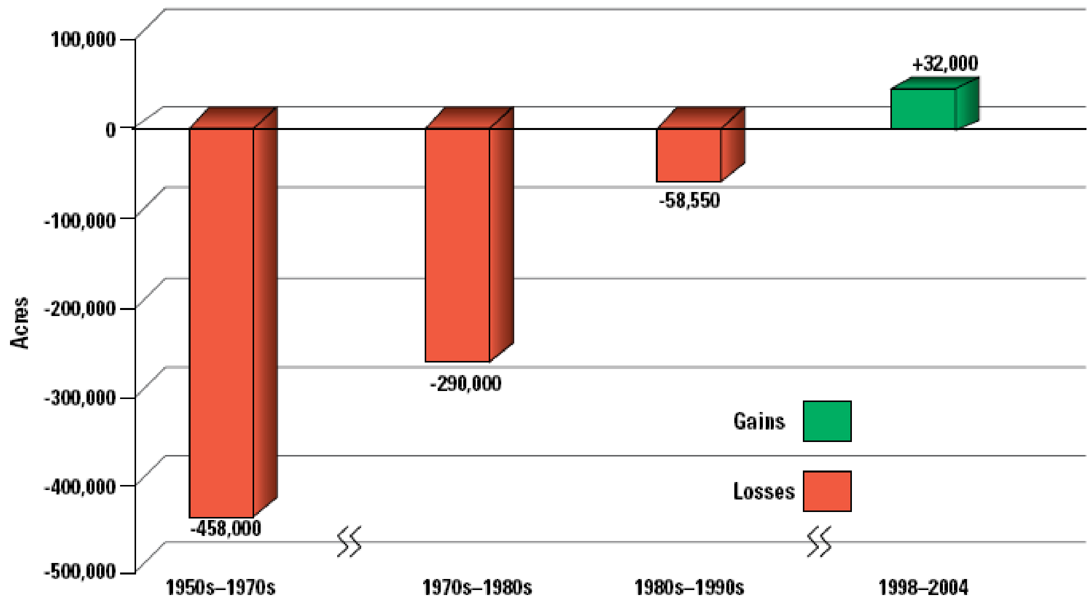

Figure 1. Average annual net loss and gain estimates for the conterminous United States, 1954 to 2004. *From Dahl 2006*

When considering the narrow margin between wetland losses and wetland gains, the importance of restored and created wetlands becomes apparent. Since these wetlands are responsible for the net gain in wetland area, it becomes especially important to ensure that restored and created wetlands perform as expected when sited and designed. In many cases this can prove difficult. Breaux and Serefiddin (1999) studied the criteria used to measure success at 116 created or restored wetland sites. They discuss some of the problems encountered in measuring and assessing sites qualitatively as well as quantitatively. Hoeltje and Cole (2006) conclude that in the created wetlands they studied, function was related to their location in a watershed, and that the functions these wetlands provided were not always equivalent to functions provided by natural wetlands.

The goal in developing the Wetland Potential Screening Tool (WPST) was to provide planners, developers, and engineers with a geographical information system (GIS) based method to identify areas on a landscape scale with the highest potential of accommodating a healthy, sustainable wetland. To make the WPST as accessible to as many users as possible, commonly available input data were employed. The structure of the WPST allows it to be adapted to the specific region, terrain type, and ecology to which it is to be applied.

It is important to distinguish that the goal of this effort is not to locate existing wetlands, nor is it to assess the quality, function or value of existing wetlands. The main purpose of the WPST is to identify land that is suitable for the restoration or creation of wetlands.

There are two major uses for the WPST. First, the WPST can be used to identify areas of high potential for restoration or creation of wetlands. If wetland mitigation is to occur in a specific region, the WPST can be used to identify the area of highest potential for creating wetlands. This will improve the probability of identifying an effective and functional wetland location. Similarly, the WPST can be used to avoid disturbing areas of high wetland potential. For example, if land disturbance is necessary during a project, disturbance can be planned in such a way as to minimize impact to areas of high wetland potential.

There is some evidence that a wetland's function is related to its location in a watershed (Greiner and Hershner 1998; Hoeltje and Cole 2006). For this reason the WPST was designed to calculate wetland potential at a landscape or watershed scale, as opposed to a site specific scale. Due to the importance of function in wetland restoration and creation, three independent variations of the WPST were developed to identify potential wetlands for different intended functions or goals: water quality improvement, wetland habitat creation, and enrollment in the Wetland Reserve Program (WRP). These three goals are intended as examples, but the end user may adapt the WPST to meet new goals and objectives.

3. Background

Mitsch and Gosselink (1986) state that wetland definitions frequently include the following three components: "1. Wetlands are distinguished by the presence of water. 2. Wetlands often have unique soils that differ from adjacent uplands. 3. Wetlands support vegetation adapted to the wet conditions (*hydrophytes*), and conversely are characterized by an absence of flooding intolerant vegetation." The influence of these requirements can be seen in tools whose goal is to assess wetland potential.

Previous attempts have been made by Palmeri and Trepel (2002), Van Lonkhuyzen et al. (2004), and White and Fennessy (2005) to develop methods for assessing wetland potential. Due to the nature of the task, all three studies have similar aspects. It is apparent that there are components, considerations, and problems common to models of this type.

To satisfy a wetland's condition for water, each method employs data related to topography and hydrology. Palmeri and Trepel (2002) use elevation, slope, depression, and river network data. Van Lonkhuyzen et al. use floodplain data, and an inventory of local topographic depressions. White and Fennessy (2005) use topographical, stream order, and flow accumulation data. All three studies include soils data. All three studies include land use data, and Van Lonkhuyzen et al. (2004) include vegetative cover, and adjacent vegetation. Palmeri and Trepel (2002) and Van Lonkhuyzen et al. (2004) also use historic wetland data.

The differences in these three methods are found in assigning weights and scale values to the data and in the method used to calculate results. White and Fennessy (2005) used values that were ranked relative to each other by experts, and combined using a simply weighted summation. Van Lonkhuyzen et al. (2004) used values that were assigned values based on professional judgment, and combined using a geometric mean. Palmeri and Trepel (2002) used values that were chosen arbitrarily by the user and combined using a simple weighted mean. Each of the three studies acknowledged the subjectivity inherent in their methods, the importance of judgment in choosing values, and placed the responsibility for choosing values on the user.

An additional difference is found in the application of the models. White and Fennessy (2005) and Palmeri and Trepel (2002) applied their models on a watershed scale, while Van Lonkhuyzen et al. (2004) applied their model to a specific site in northern Illinois.

4. Methods

The WPST was developed with the ModelBuilder application of the ArcGIS software distributed by the Environmental Systems Research Institute (ESRI). ModelBuilder allows the user to aggregate numerous GIS processes and operations into a single model that can be executed as a whole. In this paper the WPST is referred to as such when discussing its practical application, and as a model when discussing its structure and processes.

The model uses data from ten cell-based (raster) data layers. The datasets used were selected for this model not only for their recognized importance to wetland development and function, but also because each data type is commonly available. Two of the data layers are products of elevation data, six of the data layers are extracted from data published by government agencies, and two of the layers are derived from commonly available land use data.

Nine of the ten input layers employed in the model were generated at a resolution of 10 meters, making for a cell size of about 0.025 acres. The LU/LC layer, however, was only available at a resolution of 30 meters, or a cell size of 0.222 acres. The final results can only be calculated at the coarsest resolution of the input data. Therefore, the resolution of the final results is 30 meters. The following data layers were used in the model.

4.1 *Slope*

A slope layer was used as input data (Figure 2). Slopes were classified into six categories: 0-1 %, 1-2 %, 2-5 %, 5-10 %, 10-40 %, and greater than 40%. These data represent the maximum percent change in elevation for each cell. The slope layer can be derived from a Digital Elevation Model (DEM). Results produced for the study areas in this project were calculated using slope data derived from a DEM and published by the Center for Applied Research and Environmental Systems (CARES) at the University of Missouri-Columbia.

4.2 *Flow Accumulation*

A flow accumulation layer was used as input data (Figure 3). Flow accumulation data were classified into four categories: 0-5 contributing cells, 5-10 cells, 10-100 cells, and greater than 100 cells. Flow accumulation is a measure of how many other cells contribute flow to a cell. The flow accumulation layer is derived from slope data which are, in turn, derived from a DEM. The flow accumulation data used in this project were published by CARES. The availability of inflows of water is a crucial factor in supporting the structure and function of a wetland (Mitsch and Gosselink 1986). Therefore, rivers and streams have the highest flow accumulation and upland areas near watershed boundaries have the lowest flow accumulation.

4.3 *Hydric Soils*

A map of hydric soils was used as input data (Figure 4). The hydric soil layer is taken from the State Soil Geographic Database, or SSURGO, published by the United States Department of Agriculture, Natural Resource Conservation Service (NRCS). A cell is classified as either hydric or non-hydric soils, or as no data. The NRCS uses the Federal Register (1994) definition of hydric soils: "Soils that formed under conditions of saturation, flooding, or ponding long enough during the growing season to develop anaerobic conditions in the upper part" (USDA 2006). Because of the conditions in which they form, hydric soils are considered a major component of a wetland (Mitsch and Gosselink 1986).

4.4 *Flooding Frequency and Duration*

The flooding frequency layer and the flooding duration layer (Figures 5 and 6) used in the model are also derived from SSURGO data. Flooding conditions are described qualitatively. For example, an area might be categorized as flooding rarely, frequently, never flooding, or having no data. Flooding conditions have a definite effect on wetlands, and riverine wetlands are dependent on periodic flooding to improve water quality (Whigham et al. 1988).

4.5 *Special Flood Hazard Areas*

An additional measure of terrain employed in the model is the Special Flood Hazard Area (SFHA) (Figure 7). A cell is classified as located either inside or outside a SFHA. This layer is a product of the Q3 Flood Studies conducted by the Federal Emergency Management Agency. SFHAs are areas that will be flooded by a 100-year flood. The model uses SFHAs as a generalized indicator of low slopes, frequent flooding, and proximity to streams.

4.6 *National Wetland Inventory*

A portion of the National Wetlands Inventory (NWI) map (Figure 8) was employed in the model. In the study areas of this project, NWI maps identify four types of wetlands: riverine, lacustrine, palustrine, and upland. The map was created by the U.S. Fish and Wildlife Service using aerial imagery as the primary data source, and indicates the type and location of most wetland areas using the definition of Cowardin et al. (1979) (Mitsch and Gosselink 1986). The type of an existing wetland influences its function. Palustrine wetlands are important for removing phosphorus and sediment from surface water where the water is passed through vegetation. Riverine areas are efficient sites for nutrient processing, especially during flooding events. Lacustrine wetlands are less effective at improving water quality because less water comes into contact with vegetation (Whigham et al. 1988).

4.7 *Land Use/Land Cover*

A Land Use/Land Cover (LU/LC) layer was employed in the model (Figure 9). This layer was developed by the Missouri Resource Assessment Partnership (MORAP). The data is based on satellite imagery from 2000-2004, and classifies land as one of fifteen types: impervious, high intensity urban, low intensity urban, barren or sparsely vegetated, cropland, grassland, deciduous forest, evergreen forest, mixed forest, deciduous woody/herbaceous woodland, evergreen woody/herbaceous woodland, mixed woody/herbaceous woodland, woody-dominated wetland, herbaceous-dominated wetland, and open water. Existing and surrounding land use and vegetative cover have an effect on potential and existing wetlands (Mitsch and Gosselink 1986; Gove et al. 2001; Van Lonkhuyzen et al. 2004; White and Fennessy 2005).

4.8 *Wetland Buffer*

To encourage wetland connectivity, the model includes a wetland buffer layer (Figure 10) that indicates proximity to an existing wetland. A multiple ring buffer was created around existing wetlands on the LU/LC layer. Distances from wetlands were classified into five categories: 0-50 m, 50-150 m, 150-300 m, 300-600 m, and 600-4200 m.

4.9 *First and Second Order Stream Buffer*

The First and Second Order Stream Buffer (Figure 11) indicates proximity to streams with a Strahler (1952) stream order of one and two. A multiple ring buffer was applied to first and second order streams selected from National Hydrography Dataset 1:100,000-scale data. Distance from the streams was classified into five categories: 0-100 m, 100-200 m, 200-300 m, 300-600 m, and 600-4000 m. There is evidence that wetlands and riparian buffers can improve water quality (Mitsch and Gosselink 1986; Greiner and Hershner 1998; Baker et al. 2001). However, there is also evidence that maximum contact between water and wetlands occurs where those wetlands are associated with smaller streams and that "as water moves into higher order streams (rivers) the percentage of total flow that passes through wetland ecosystems decreases" (Whigham et al. 1988).

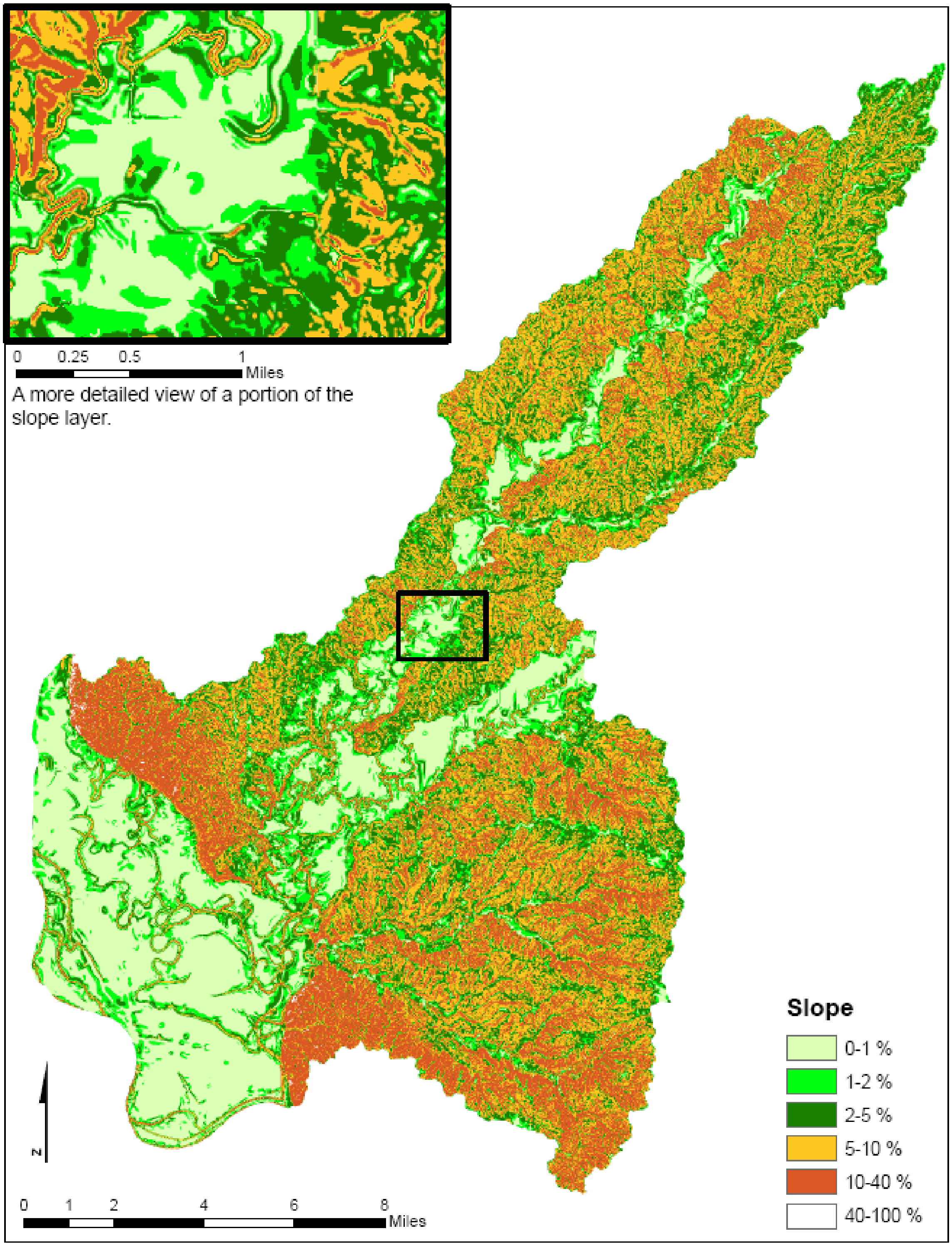

Figure 2. Slope displayed for the Little Chariton study area.

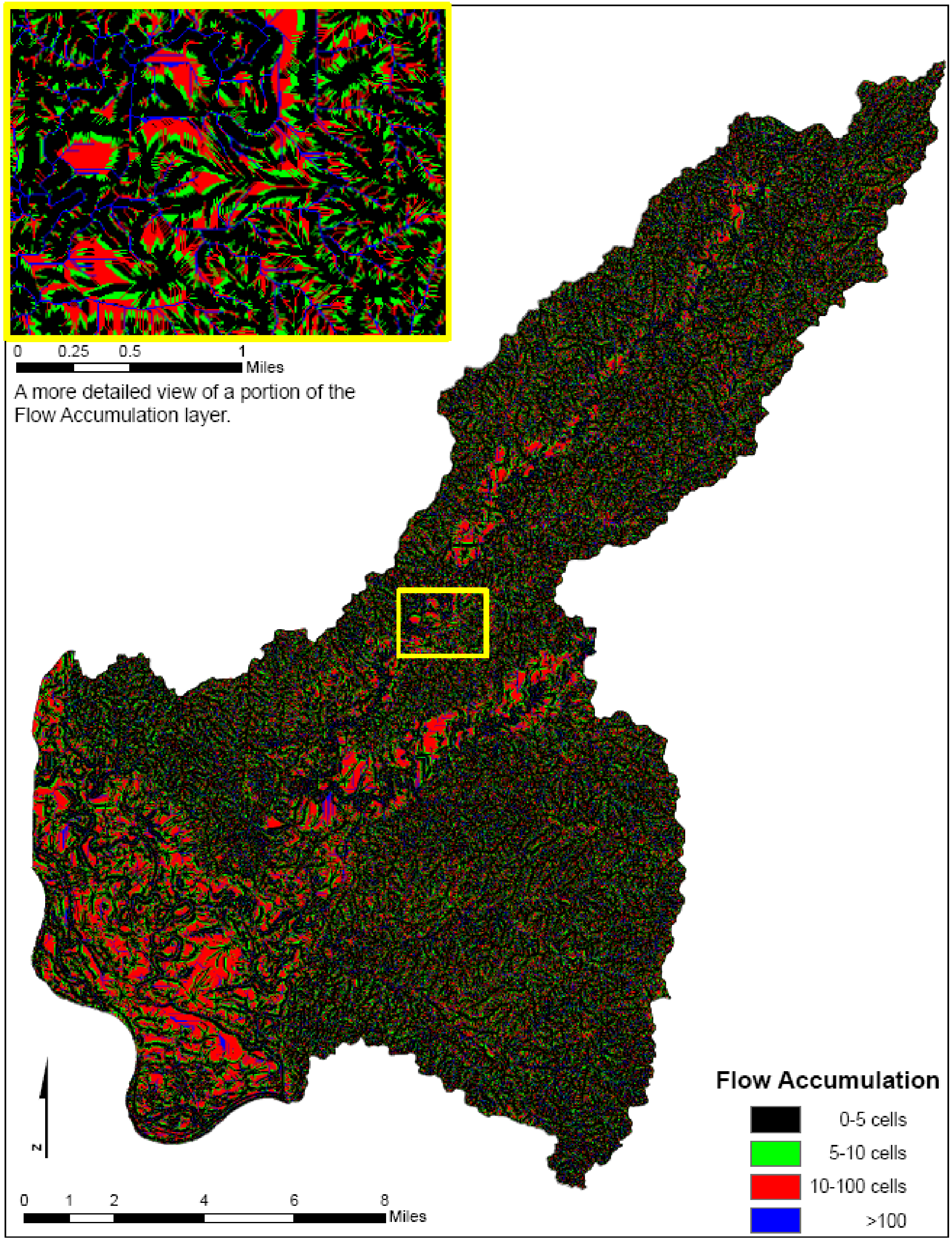

Figure 3. Flow accumulation displayed for the Little Chariton study area.

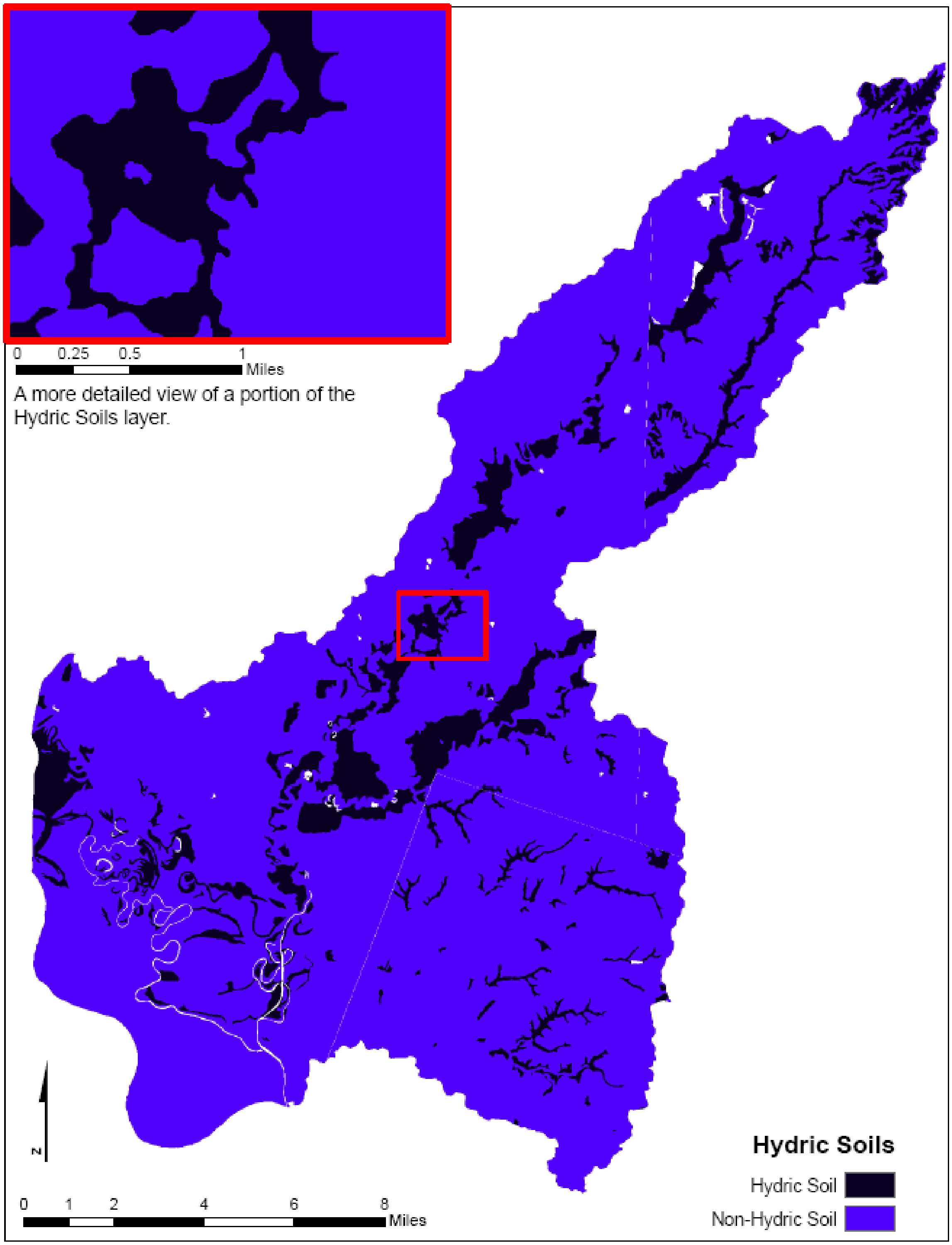

Figure 4. Hydric soils displayed for the Little Chariton study area.

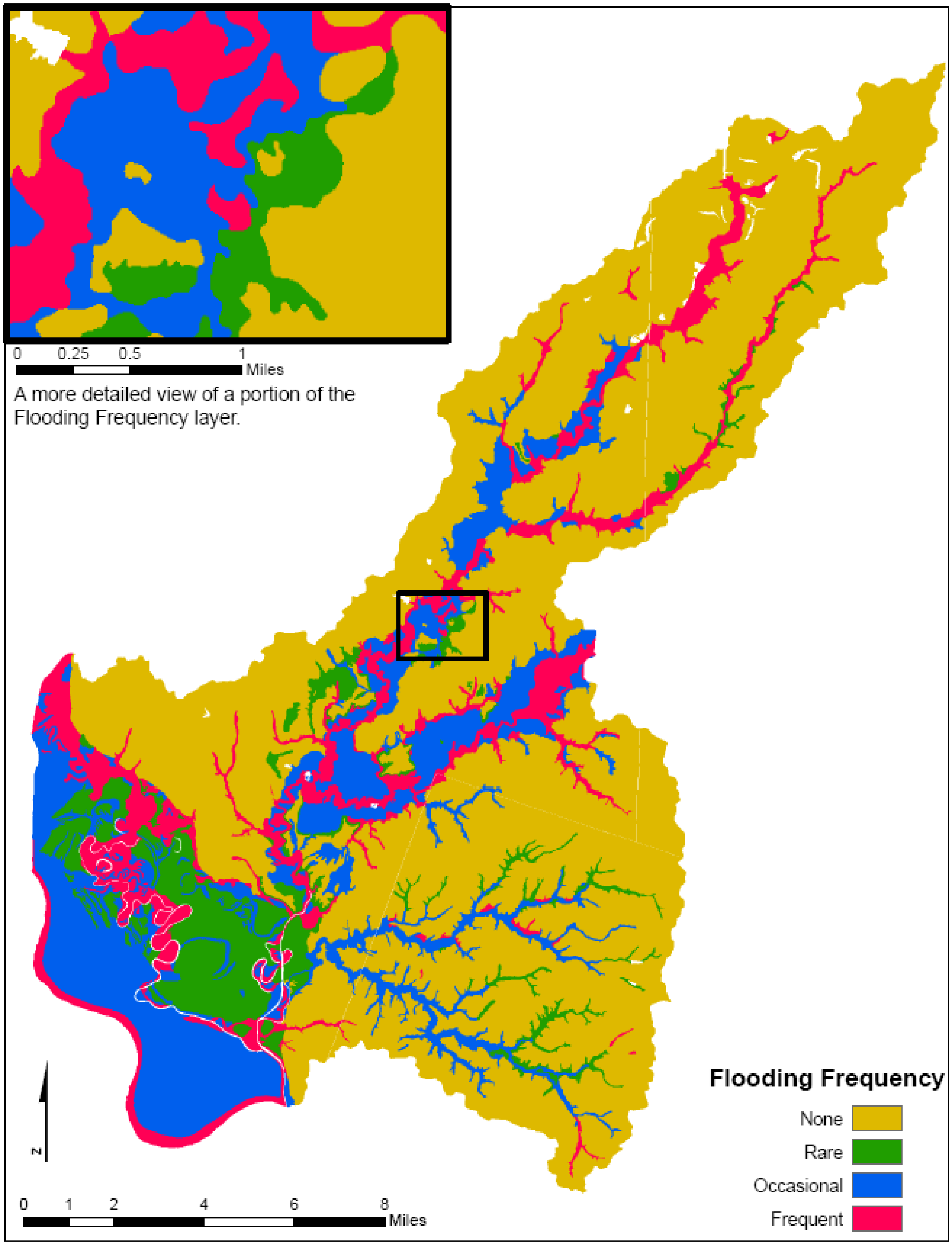

Figure 5. Flooding frequency displayed for the Little Chariton study area.

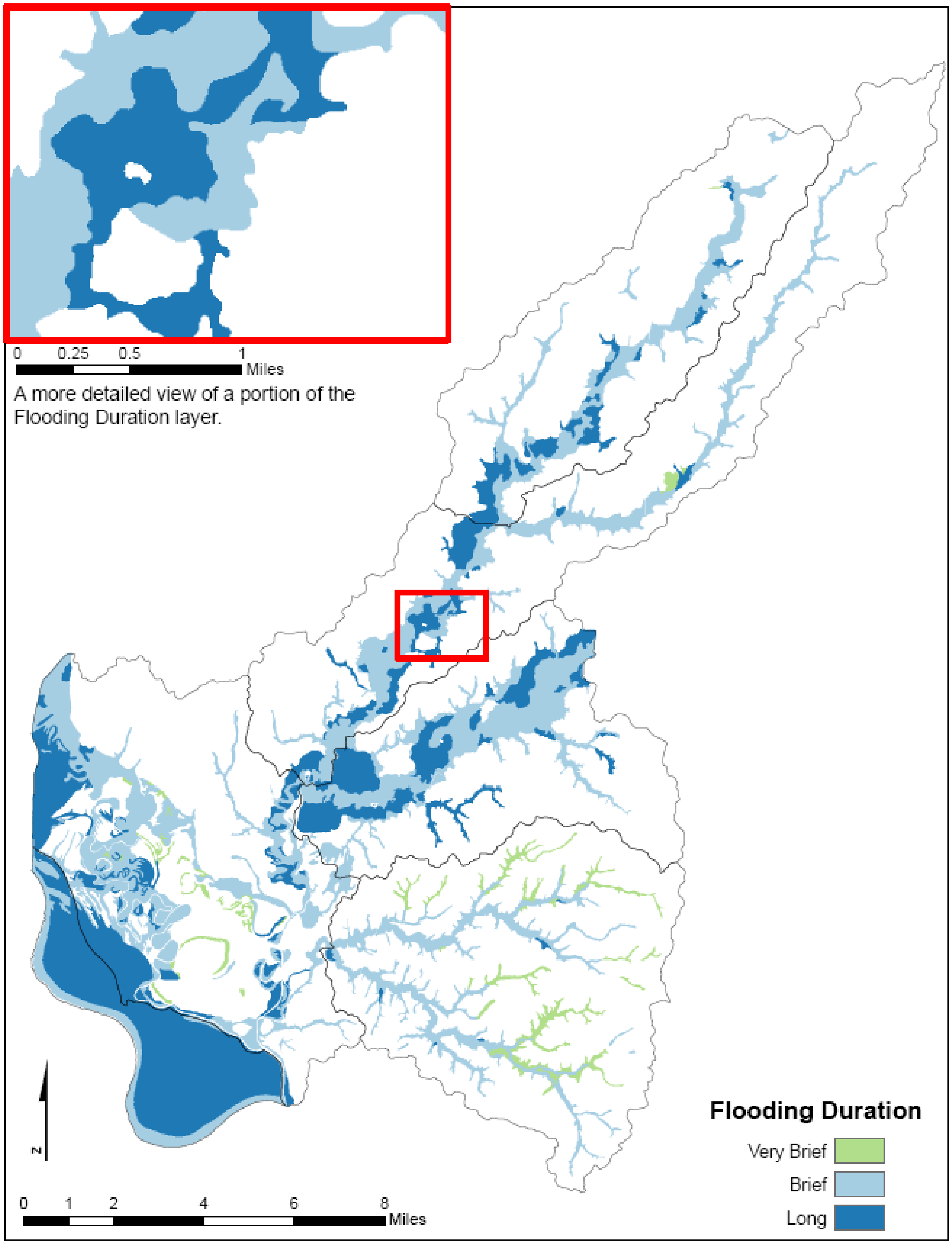

Figure 6. Flooding duration displayed for the Little Chariton study area.

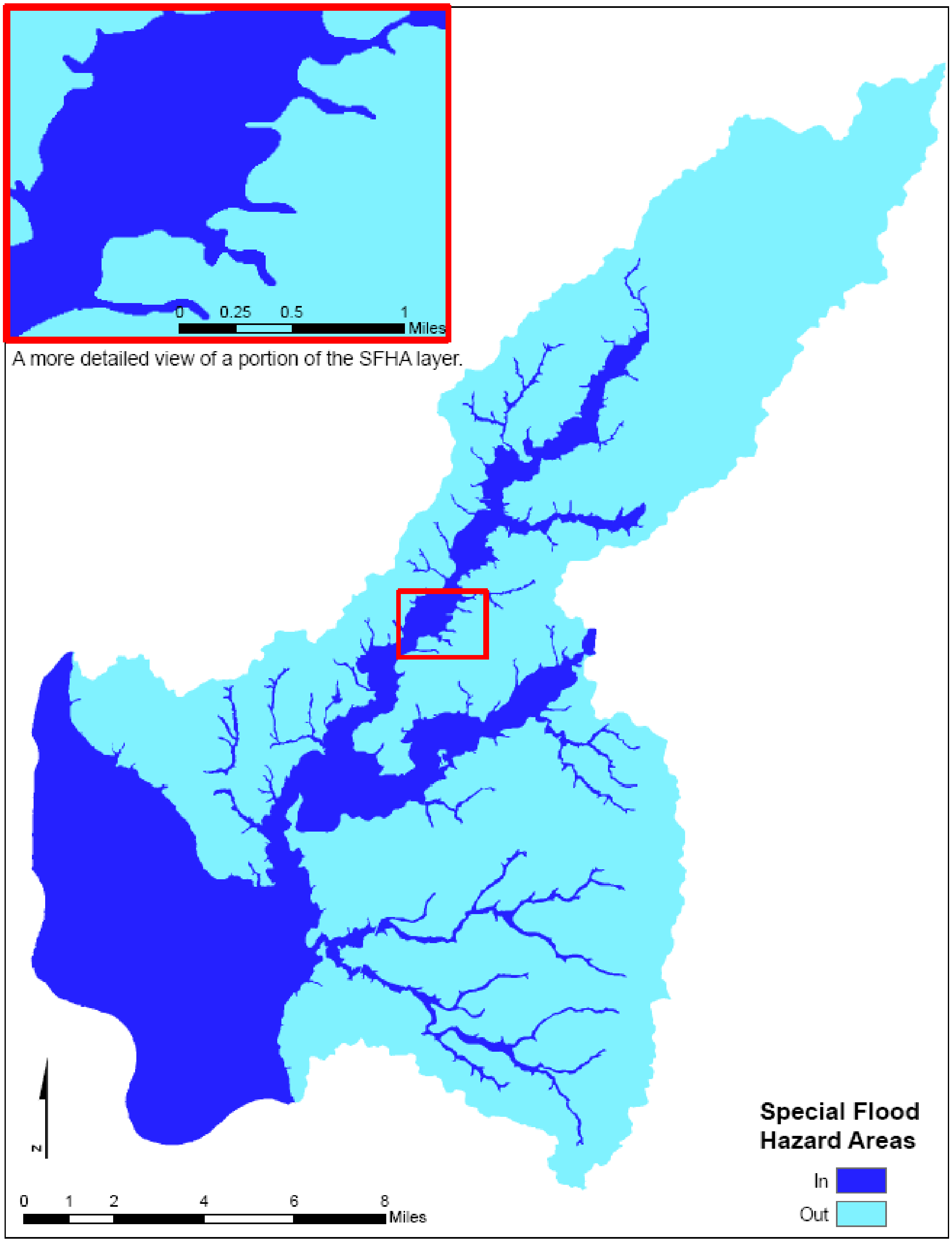

Figure 7. Special Flood Hazard Areas displayed for the Little Chariton study area.

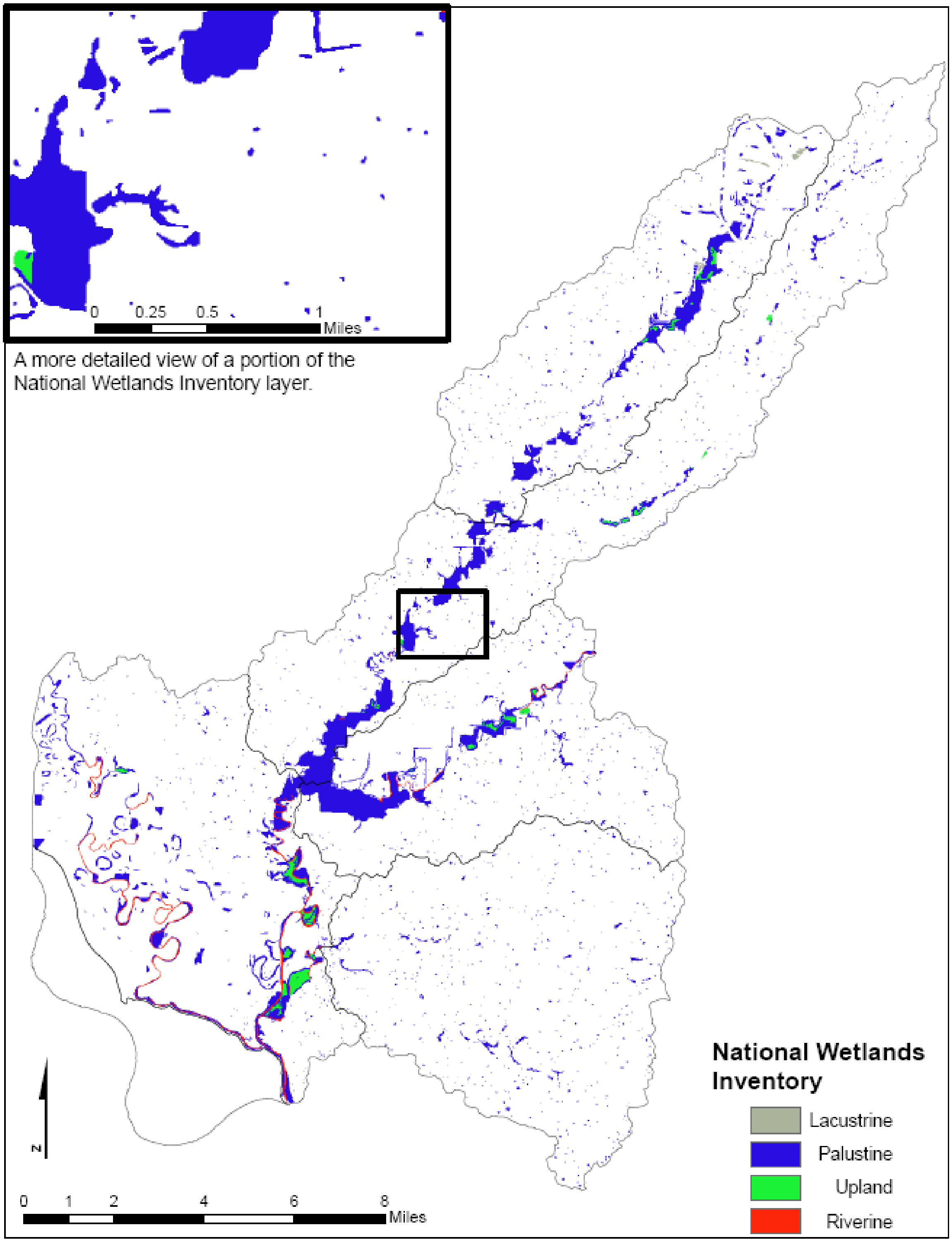

Figure 8. National Wetlands Inventory map for the Little Chariton study area.

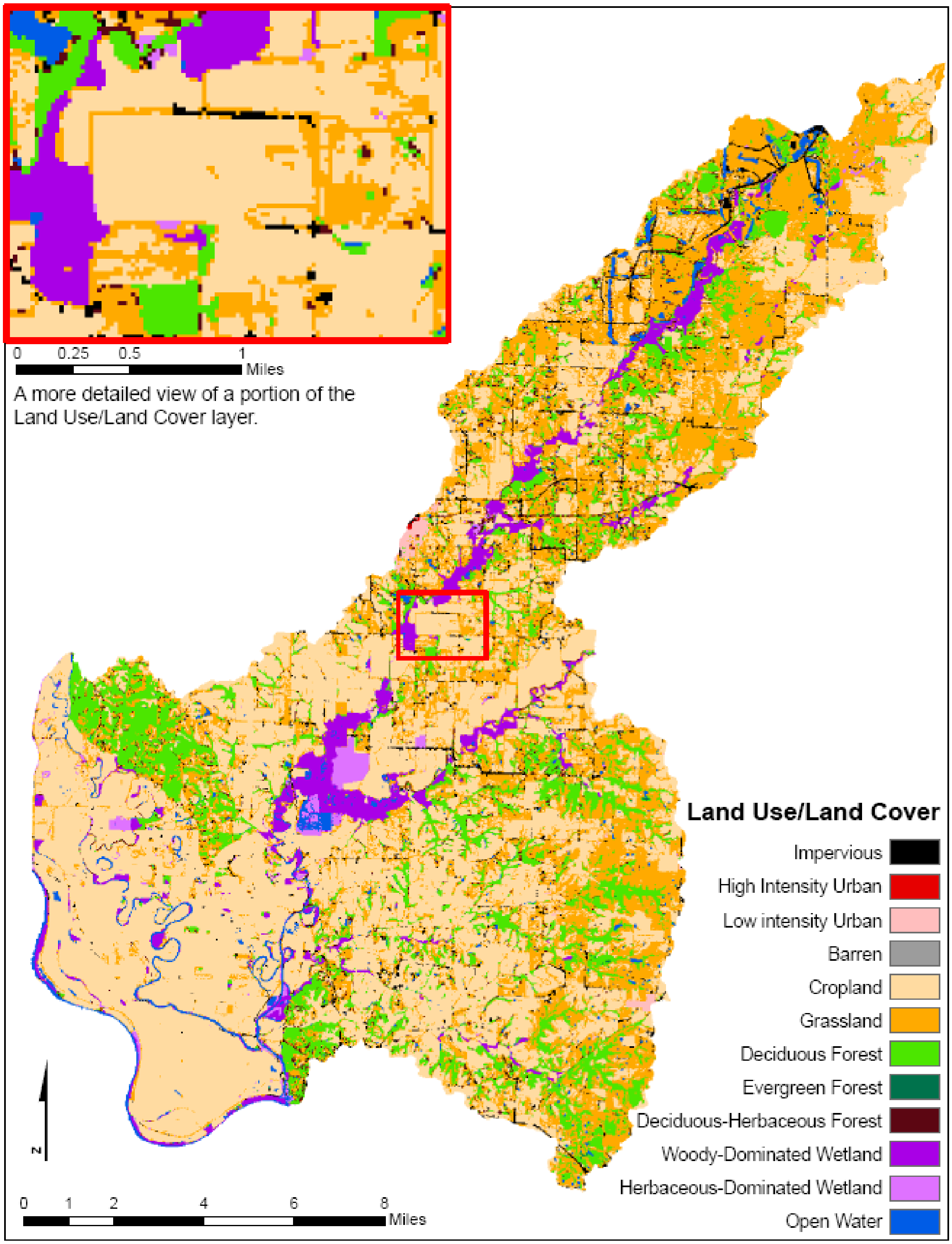

Figure 9. Land Use/Land Cover displayed for the Little Chariton study area.

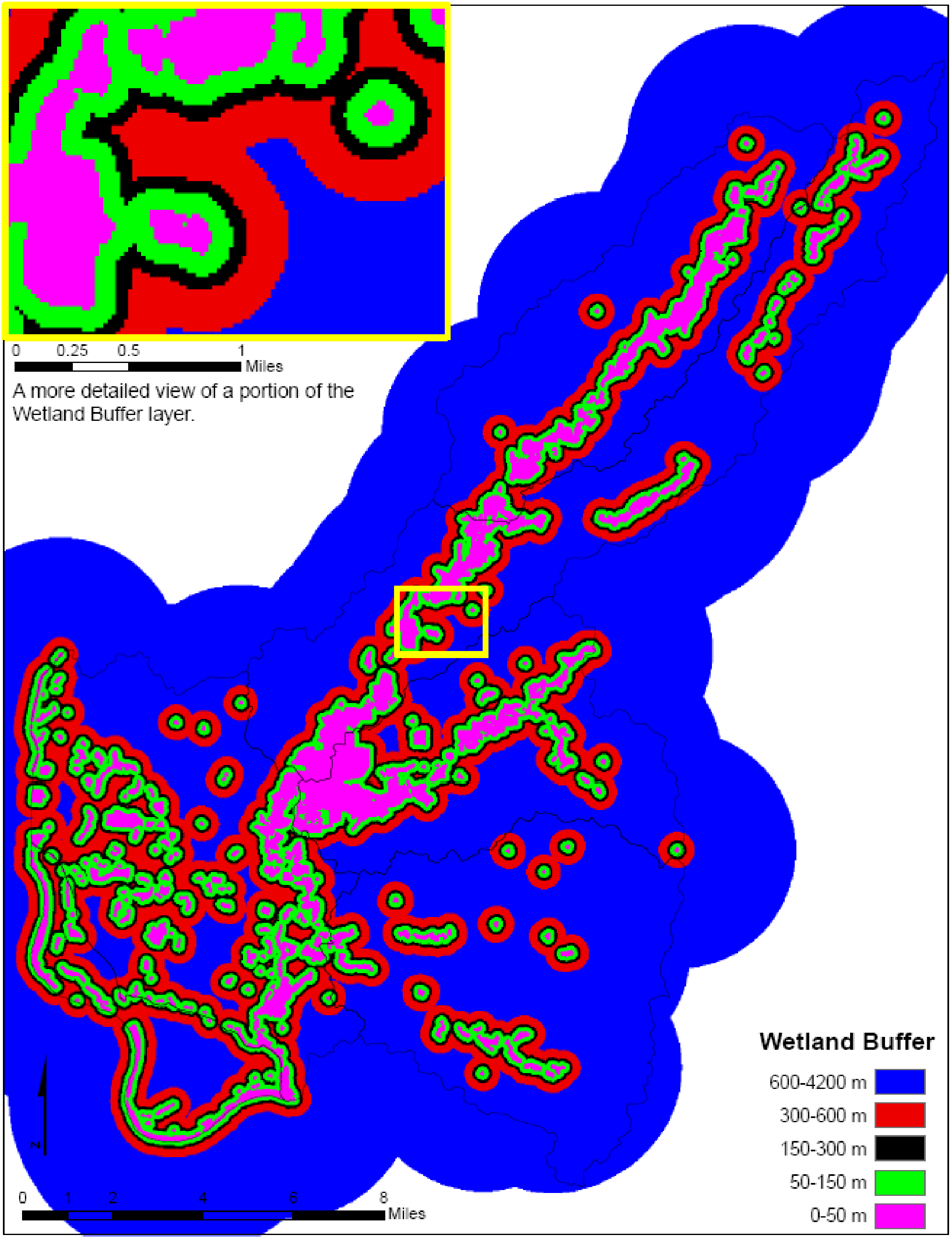

Figure 10. Wetland buffer displayed for the Little Chariton study area.

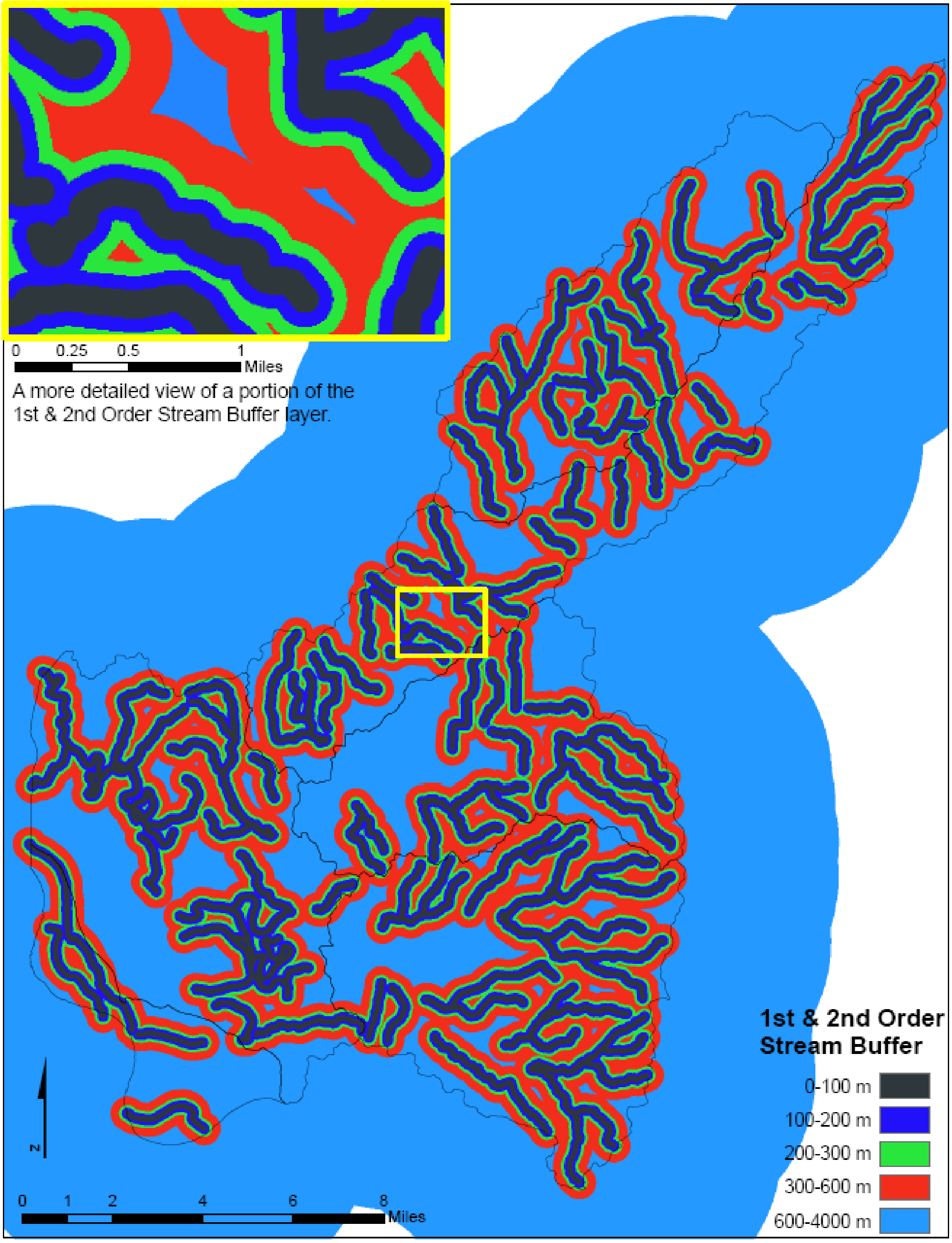

Figure 11. First and second order stream buffer displayed for the Little Chariton study area.

4.10 *Model Processes*

The central features of the model are two Weighted Overlay processes. A Weighted Overlay process collects data from the input data layers and calculates a resulting data layer. The results of each Weighted Overlay are calculated using the values entered in its Weighted Overlay Table (Figure 12). Each possible parameter in each input data layer is assigned a scale value indicating its favorability toward wetlands. Because not all input data layers have an equal importance in determining wetland potential, each layer is assigned a "percent influence," or weight. For each cell, the Weighted Overlay collects the corresponding scale value from each of the input layers and multiplies it by the percent influence of that layer. The values are then summed to obtain the result for that pixel (Figure 13). This result is a weighted mean of the input data values representing wetland potential on a scale of 1 to 10 with a result of 10 indicating highest wetland potential. It is intended that each user will develop a set of Weighted Overlay Table values specially suited to the conditions in which the WPST will be applied. The generic tables used to generate the results discussed in this paper were developed by applying professional judgment and with input from a wetland steering committee assigned to assist with this grant. The Weighted Overlay Tables applied to the study areas are located in their entirety in Appendix A.

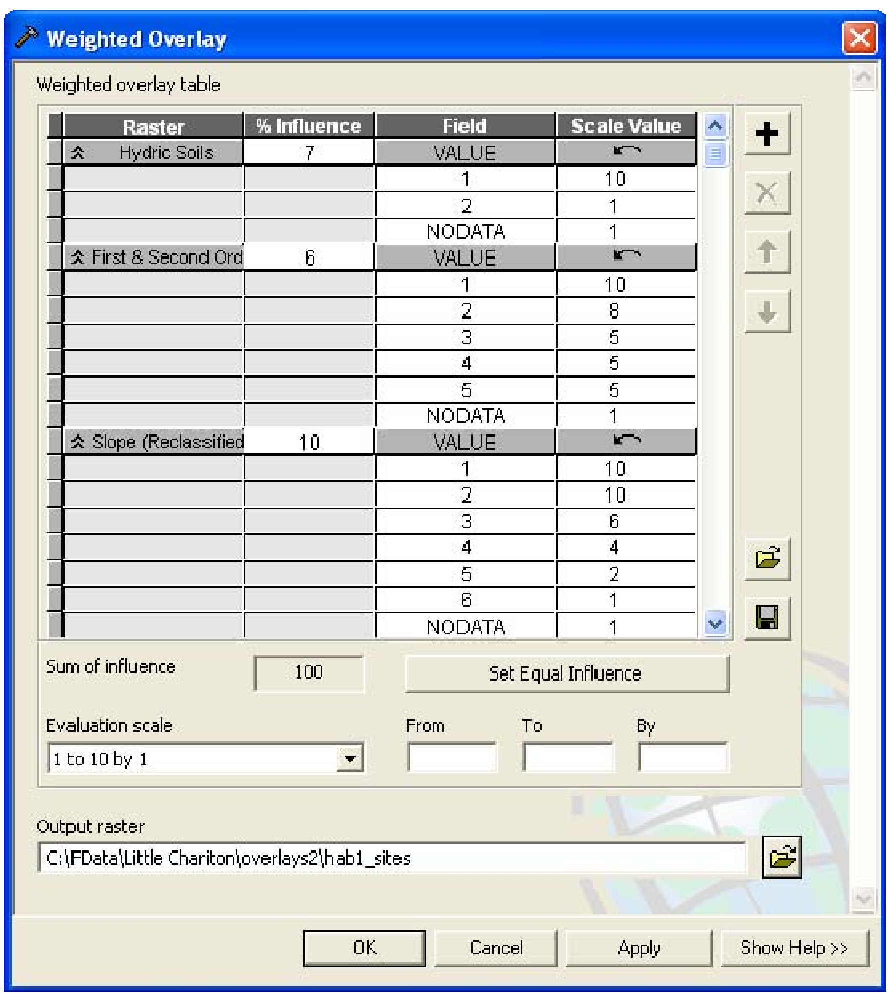

Figure 12. A portion of the weighted overlay table from the Step 1 Weighted Overlay.

Layer		Percent Influence (PI)	Scale Value (SV)	PI x SV
Slope	0-1%	0.1	10	0.1 x 10 = 1.0
Flow Accumulation	10-100 cells	0.09	10	0.09 x 10 = 0.9
Hydric Soils	Yes	0.07	10	0.07 x 10 = 0.7
Flooding Frequency	Occasional	0.13	9	0.13 x 9 = 1.17
Flooding Duration	Long	0.1	10	0.1 x 10 = 1.0
SFHA	Yes	0.07	10	0.07 x 10 = 0.7
NWI	NoData	0.13	0	0.13 x 0 = 0
Land Use/Land Cover	Cropland	0.12	5	0.12 x 5 = 0.6
Wetland Buffer	50 meters	0.13	10	0.13 x 10 = 1.3
1st & 2nd Order Stream Buffer	>600 meters	0.06	5	0.06 x 5 = 0.3
		Σ= 1		Σ= 7.67

Figure 13. The results of the calculations for one example cell. The wetland potential score is rounded to 8.

Data in layers such as the slope, flow accumulation, wetland buffer, and first and second order stream buffer are continuous in nature. Because a scale value must be assigned to every possible value or state within each layer, the Weighted Overlay cannot calculate continuous data without some simplification. Therefore, continuous data layers require reclassification before they can be used in weighted overlay calculations. The data are grouped into discrete ranges so a scale value can be assigned to each range. Selection of data ranges is an additional source of subjectivity in the model. As with the determination of scale values and percent influences, local knowledge and judgment should be used to choose reasonable reclassification ranges. The ranges can be used to emphasize portions of the data. For example, low slopes are more likely to have high wetland potential than steep slopes. Therefore, in choosing ranges for the six classes of slopes, more detail was allowed in the lower slopes than the steeper slopes by making the classes smaller for low slopes. Three classes represent slopes from 0-5%, while only one class represents slopes of 40% and greater. The ranges used in the study areas were defined based on input from the grant steering committee and professional judgment.

The processes of the model are divided into two steps each utilizing a Weighted Overlay. During the Step 1 Initial Evaluation (Figure 14), the Weighted Overlay calculates the result for a cell based on the data in the corresponding cells in all ten input data layers. Step 1 considers each cell individually, and does not consider conditions in adjacent or nearby cells.

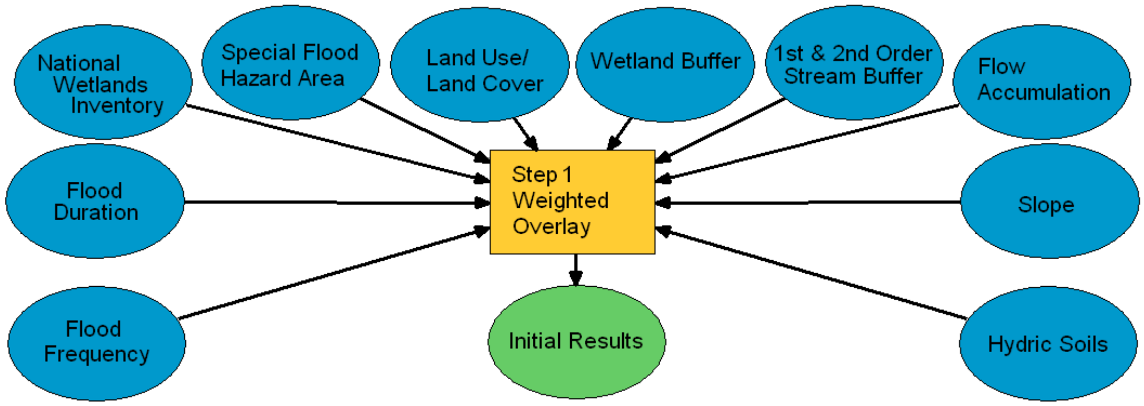

Figure 14. A simplified schematic of the WPST illustrating Step 1: Initial Evaluation.

Step 2, the Neighborhood Analysis (NA), considers the landscape in a specified radius around each cell. Four layers contribute data to the Step 2 Weighted Overlay (Figure 15): average slope, majority land use/land cover, the Initial Evaluation Results, and their size. Using unclassified slope data, a GIS process (Focal Statistics) calculates the average slope of all cell centers within 100 meters of each cell. The average slopes are then classified into the same categories as the slope layer in Step 1. Using the same land use/land cover data from Step 1, a second Focal Statistics process calculates the majority land use/land cover in a 300 meter radius around each cell. The slope and land use/land cover calculations use different radii because they have different resolutions: 10 and 30 meters respectively. In order to maintain the same level of precision for both layers, the same number of cells must be used in the calculations for each, which results in different radii.

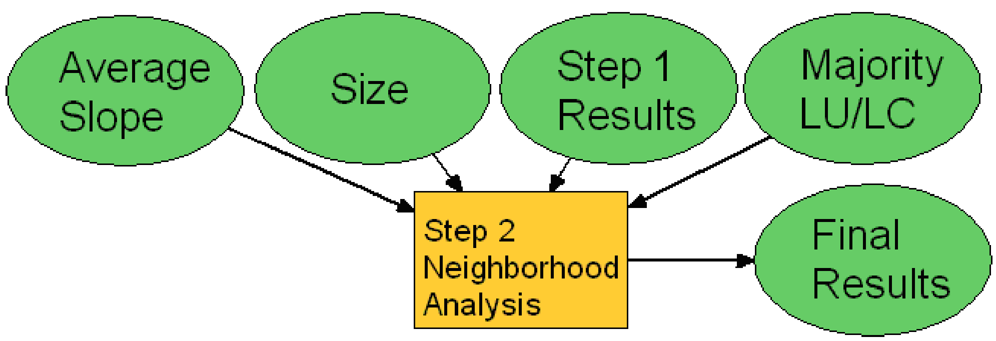

Figure 15. A simplified schematic of the WPST illustrating Step 2: Neighborhood Analysis.

The third set of input data in Step 2 is the size of the results from Step 1. The purpose of this layer is to give higher potential scores to larger areas of high potential land. The area of each block of cells with a common potential score is calculated by a series of processes. Each block is then reclassified by area independent of potential score. Figure 16 illustrates the results of the size calculation performed on a sample set of Step 1 Results. The block of three purple cells in the upper left corner of the Step 1 Results is determined by the Size Calculation process to have an area of three cells. That block of cells is colored yellow in the Size Calculation results, indicating that its area is three cells. The blue block immediately to the right of the purple block is also colored yellow in the Size Calculation because it has an area of three cells as well.

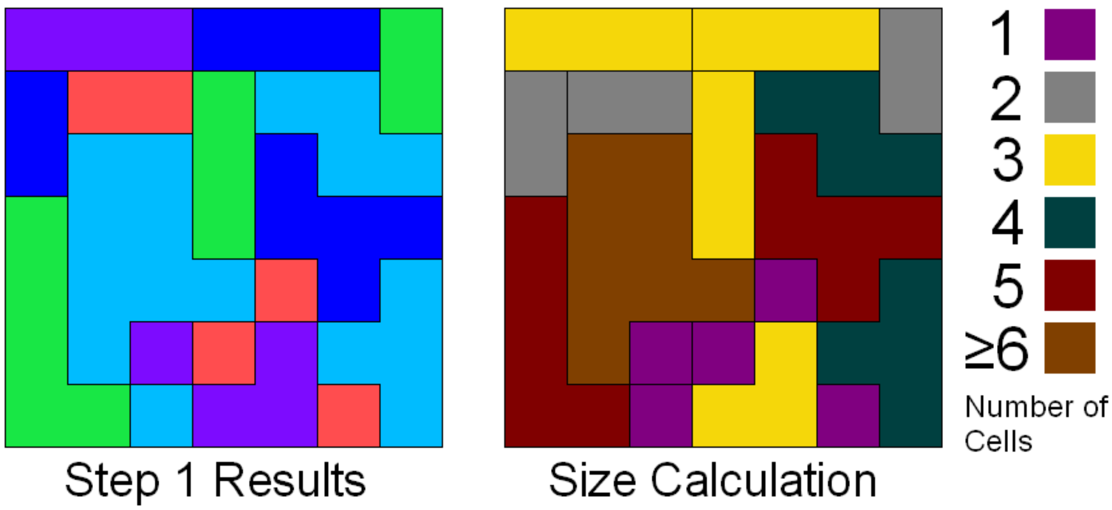

Figure 16. An example of the size calculation (right) performed on sample results (left). Colors in the Step 1 Results indicates an arbitrary Wetland Potential Score. Colors in the Size Calculation indicate the number of cells in each block.

Areas with a potential score of less than 5 are excluded from the calculations. This is done because, being more common, the areas of very low potential tend to be quite large. This caused large tracts of land that had very low potential to be rated higher simply because they were large.

The results from Step 1 are included as input data for the Neighborhood Analysis Weighted Overlay. Step 2 is an iteration of Step 1 in that the results of the Initial Evaluation are altered slightly to take into account the surrounding landscape. Step 1 results were assigned an influence of 70% in all variations of the tool developed during this project.

All scale values and percent influences in both the Step 1 and Step 2 Weighted Overlay tables can be altered by the user. This allows the user to tailor the WPST for use in a variety of physiographic regions, ecosystems, and terrain types. The user can adapt the weighted overlay tables to screen for potential wetlands of a specific type, or to meet specific goals such as improving water quality, building wetland habitat, or enrolling land in the WRP. Before using the WPST, a stakeholder group with local expertise and knowledge of the behavior of wetlands in the region should be gathered to develop and agree upon the values used in the Weighted Overlay Table. Drawing on local knowledge, judgment, and expertise is crucial to the accuracy and usefulness of the WPST.

5. Study Areas

The study areas for this project were chosen for their suitability to develop and demonstrate the WPST, rather than to fulfill a need for results from a specific area. The first area chosen was a portion of the watershed of the Little Chariton River, just north of the Missouri River in central Missouri (Figure 17), defined by six 14-digit Hydrologic Unit Codes (HUC). The Little Chariton study area is approximately 200 square miles in area, and located in Chariton, Randolph, and Howard Counties. The Missouri River forms part of the southern and western border of the region, the Chariton River forms part of the western border, and the Middle and East Forks of the Chariton River join to make the Little Chariton, which then flows into the Missouri. Also in the study area is the Old Channel of the Chariton River and its many oxbow lakes. In total there are over 340 miles of rivers and streams that meander through 6,600 acres of wetlands and 63,000 acres of cropland. Additionally, there are two developed areas partially located in the study area: Armstrong (population 282) and Salisbury (population 1614) (U.S. Census Bureau 2007).

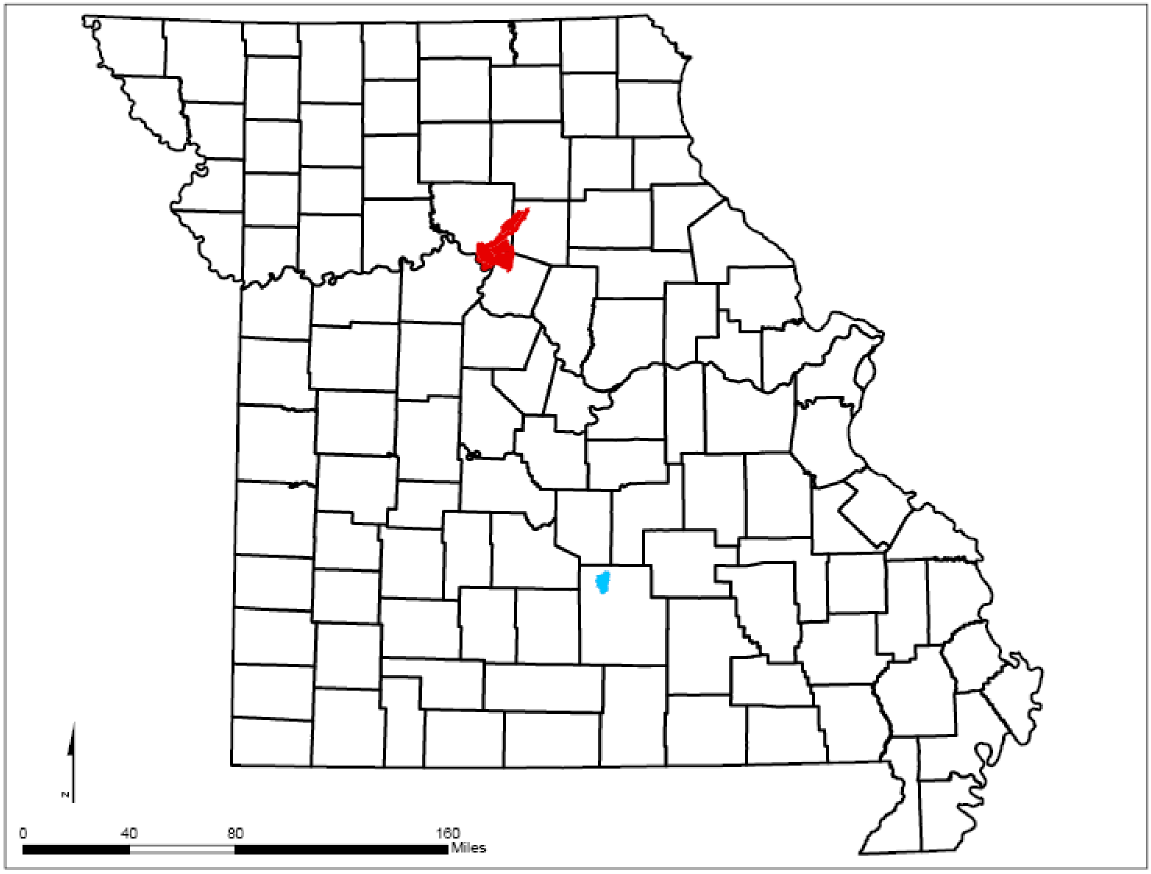

Figure 17. Location of the Little Chariton (red) and Paddy Creek (blue) study areas in Missouri.

The study area includes Missouri River floodplain in the southwest, as well as floodplain along the East Fork, Middle Fork, and Little Chariton Rivers. In the westernmost portion of the study area there is a 5,000-acre area of loess hills. Loess can be cut into a nearly vertical face, which accounts for some of the steeply sloping terrain found in the area. The area was favorable for developing the WPST due to the combination of hills, extensive floodplain, large areas of existing wetland, and numerous rivers and streams. When the WPST was applied to the study area, it identified many large areas with high wetland potential (Figure 18).

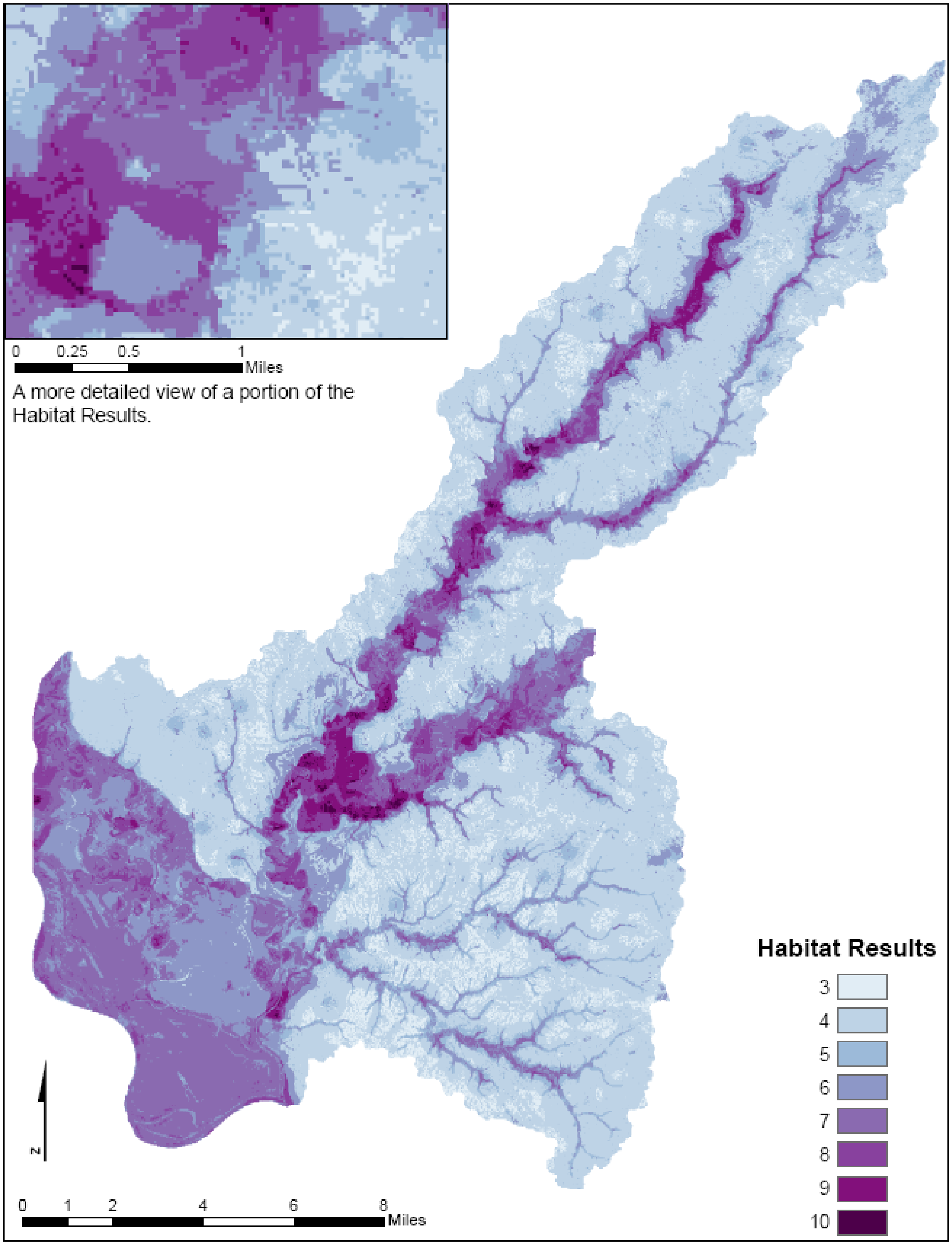

Figure 18. The results of the Habitat variation of the tool when applied to the Little Chariton study area.

The Little Chariton area was also chosen because of the likelihood that it would contain many areas of high wetland potential. As a comparison, the WPST was also applied to an area that was predicted to have lower potential for wetland restoration or creation. The 31 square mile watershed of Paddy Creek was chosen for this comparison. Located in Texas

County, Missouri (Figure 17), most of the Paddy Creek study area is located in the Mark Twain National Forest and the Paddy Creek Wilderness Area. Due to its location in the Ozarks, this study area has high slopes and is over 80% forested. The region has very few areas with hydric soils and very few existing wetlands identified on the NWI map. When the WPST was applied to this study area it found very few sites with a high wetland potential (Figure 19). This was the expected result.

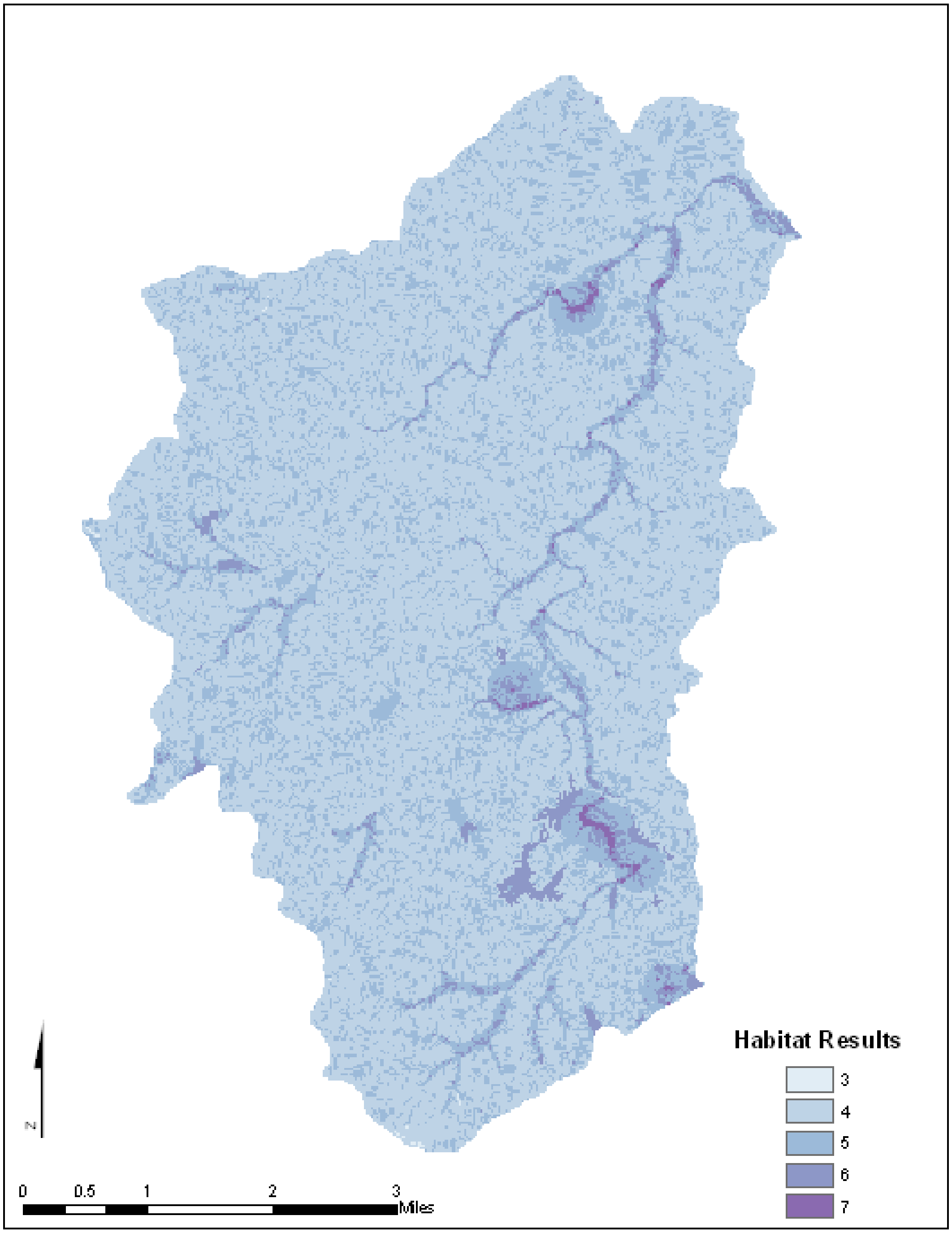

Figure 19. The results of the Habitat variation of the tool when applied to the Paddy Creek study area.

6. Results

The final product of the model is a map of wetland potential at a watershed scale with a resolution of 30 meters. Scores range from 1 to 10, with a score of 10 indicating the highest potential. The results can be overlain by aerial photography or roadmaps using ArcGIS to provide reference to aid the user in locating specific sites.

The results produced by the model reflect the scale values and percent influences entered in the Weighted Overlay Tables. For example, the areas of highest wetland potential for the habitat results in the Little Chariton study area lie in areas of 1-2% slope, in frequently flooded areas, and within 150 meters of existing wetlands. The high wetland potential scores in these areas correspond to the large percent influences and high scale values assigned to such areas. This is an indication that the model is operating as intended based on the assigned values.

6.1 *Distribution of Results*

The results of the habitat variation of the WPST when applied to the two study areas are illustrated in Figure 20. As expected, the Little Chariton study area has more cells with high wetland potential scores than Paddy Creek. As a percentage of total land area, 37% of the Little Chariton study area had scores of 6 or higher, while only 3% of Paddy Creek had scores of 6 or higher. The majority of this highest scoring 3% of the Paddy Creek study area corresponds to the few areas of existing wetlands and frequent or occasional flooding found there. The remaining 97% of the study area had scores of 4 or 5, due to the steep, heavily forested terrain, lack of hydric soils, and absence of existing wetlands. The majority of the 55% of the Little Chariton study area that scores 3 or 4 corresponds to areas with slopes steeper than 5% and areas that are farther than 300 meters away from existing wetlands.

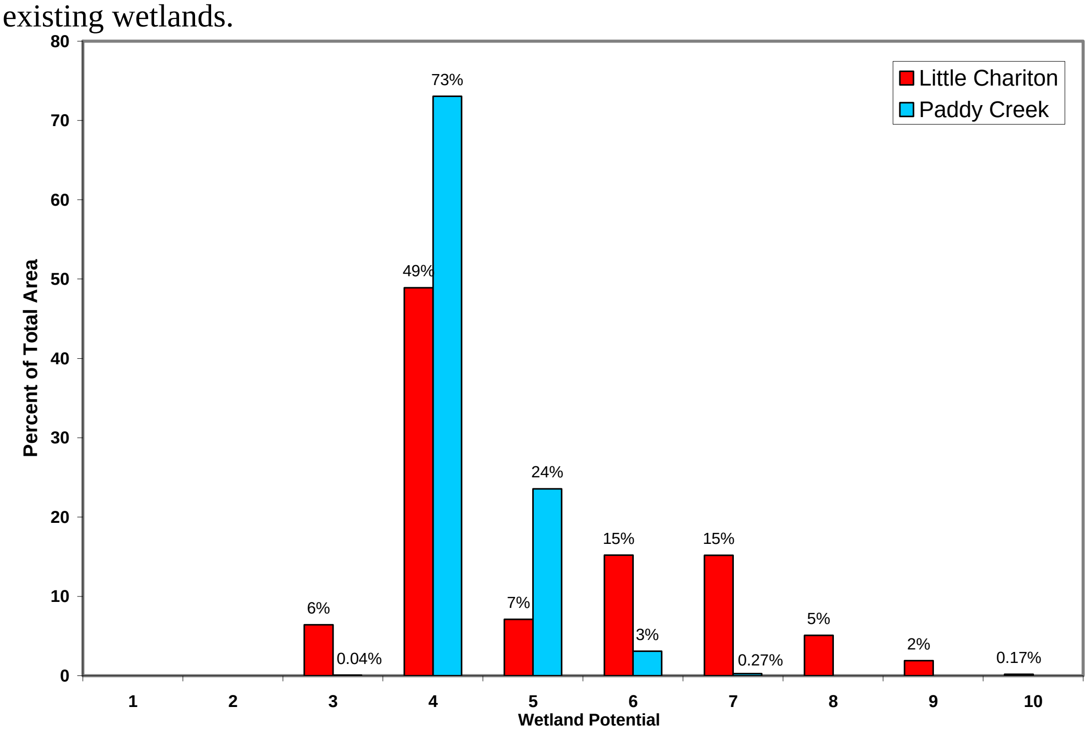

Figure 20. Distribution of Wetland Potential scores for habitat as a percentage of total area in the two study areas.

The results of the Water Quality, Habitat, and WRP variations of the WPST when applied to the Little Chariton study area are illustrated in Figure 21. The distribution of these results is similar to the distribution of the habitat results for the Little Chariton and Paddy Creek study areas, as few cells have wetland potential scores of 8, 9 or 10. The results indicate that 9.8% of cells fall into this category for the WRP variation, 8.9% of cells for the Habitat variation, and 3.5% of cells for the Water Quality variation. The results indicate that 6.4% of cells in the Habitat Results, and 6.0% of cells in the WRP results have wetland potential scores of 2 or 3. However, in the Water Quality variation 43.3% of cells have scores of 2 or 3. This difference is caused by decisions made when assigning percent influences and scale values to the slope, flooding frequency, flooding duration, and flow accumulation layers in the Weighted Overlay Tables. The scale values assigned to the parameters in these layers that are less favorable to wetlands are lower in the Water Quality variation than in the other variations. The effect of these decisions is to make the Water Quality variation more selective, resulting in more cells with lower wetland potential scores.

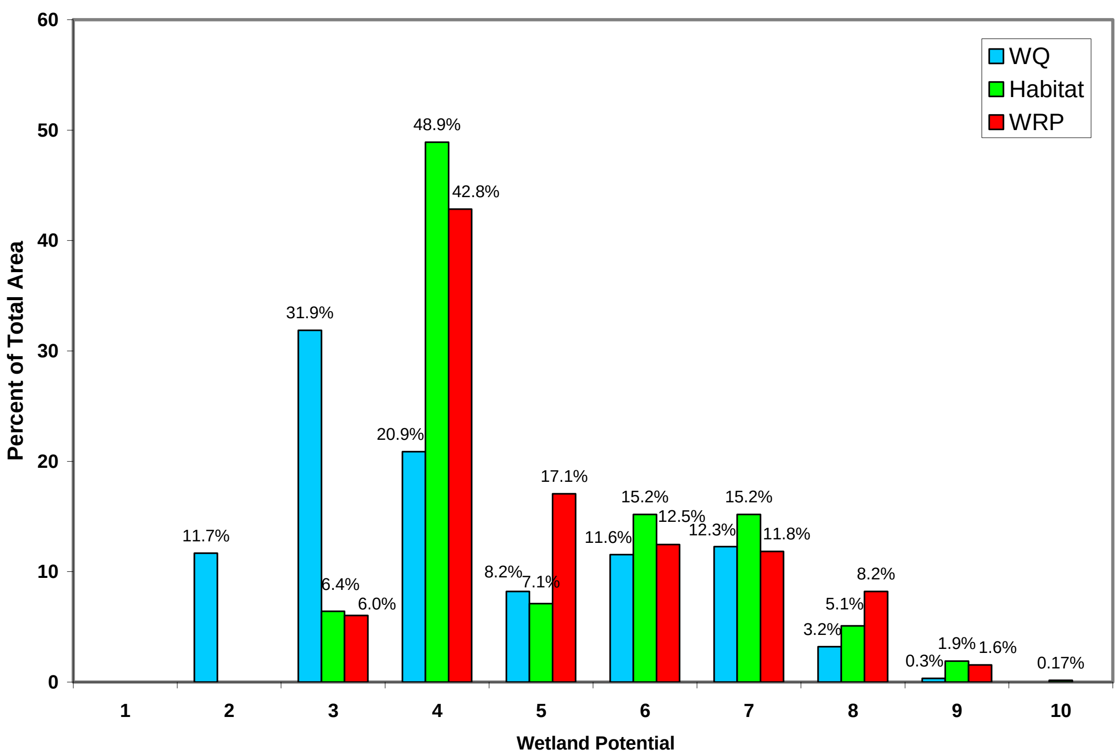

Figure 21. Distribution of Wetland Potential scores as a percentage of total area for Water Quality, Habitat, and WRP results for the Little Chariton study area.

The results for each of the three variations in both study areas have a common feature. The majority of cells have wetland potential scores between 4 and 7, while few cells have scores of 8 or higher, or scores of 3 or lower. There is no controlling variable that causes a cell to have a score of 9 or 10. Rather cells with wetland potential scores of 8 or higher are those cells that are associated with all or nearly all of the conditions with the highest scale values for each layer. Conversely, the cells with wetland potential scores of 3 or lower are associated with all or nearly all of the conditions with the lowest scale values for each layer. It is less likely that a cell will be associated with all the best or worst conditions for each layer than that it will be associated with some favorable and some unfavorable conditions. Therefore there are fewer cells with high or low wetland potential scores than with moderate scores.

Figure 22 illustrates some the differences in a portion of the results for the three variations of the WPST when they are applied to the Little Chariton study area. The differences in the results for the three models are all caused by differences in the percent influences and scale values in the Weighted Overlay Tables. For example, in the region of the Little Chariton study area shown in Figure 22, the Habitat results indicate more areas of higher wetland potential along the East Fork of the Little Chariton River. This is a result of higher scale values assigned to cells with occasional, rare, and very brief flooding in the Habitat variation than in the Water Quality variation. The white areas of NoData in the WRP results represent areas of open water and impervious surfaces that were assigned the value of Restricted in the WRP Weighted Overlay Table.

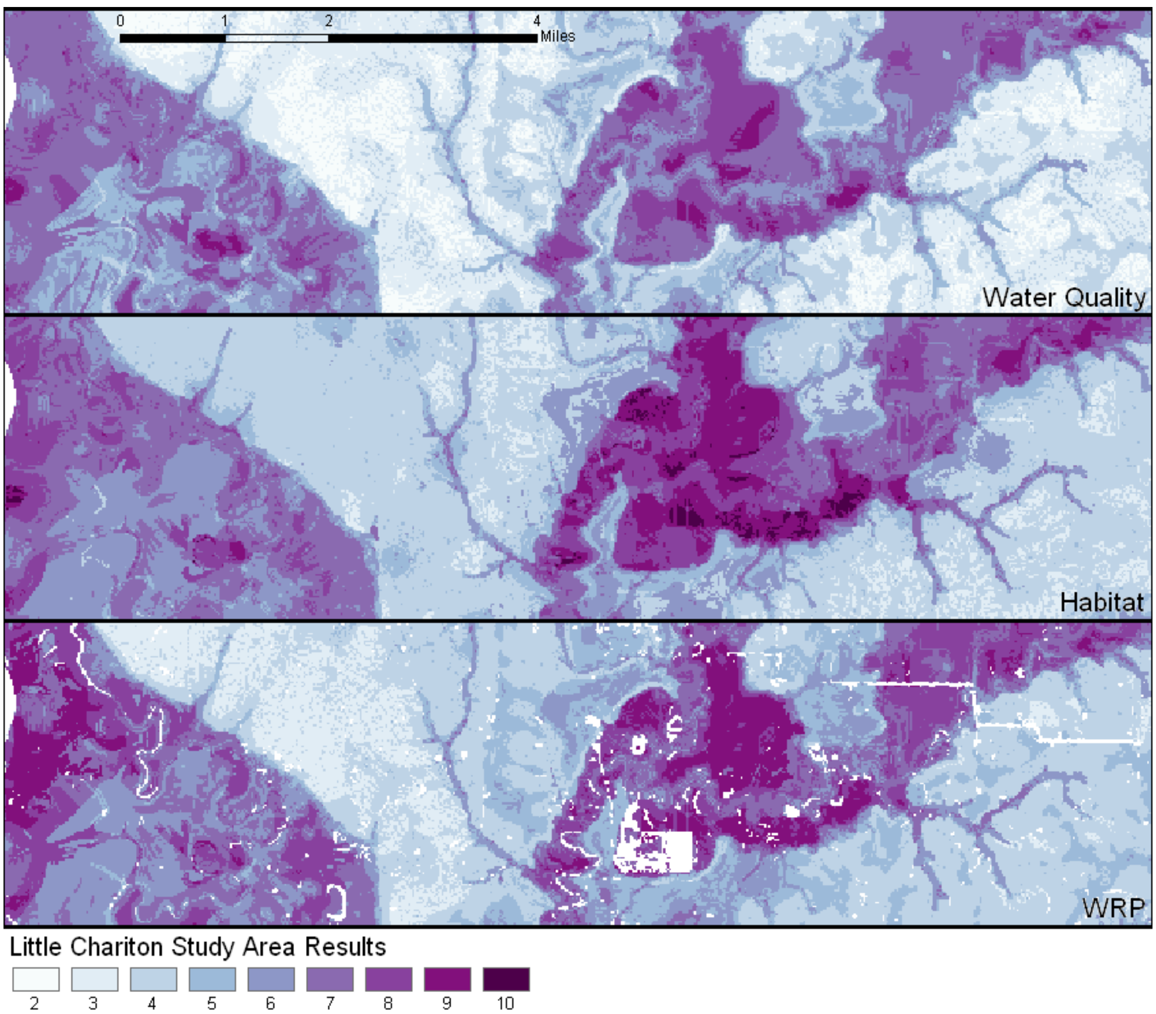

Figure 22. A portion of the wetland potential results from the Little Chariton Study Area for Water Quality, Habitat, and WRP.

6.2 *Considerations for Existing Wetlands*

When locating areas of high potential for wetland creation and restoration, existing wetlands pose a problem: wetlands cannot be created where wetlands already exist. To solve this problem, a process was added to the model to remove existing wetlands from the LU/LC and NWI input layers, and to create a second set of results at the same time as the first. This second set of results does, however, still retain the influence of wetlands, such as the wetland buffer layer. This allows the user to view the results as if there were no existing wetlands (Figure 23). Existing wetlands are assigned high scale values in the Weighted Overlay Tables, so the removal of that data will lower the score of any cell that contained a wetland. It is important to note, however, that the areas of existing wetlands still have high potential scores even when wetlands are not considered in the Weighted Overlay calculations.

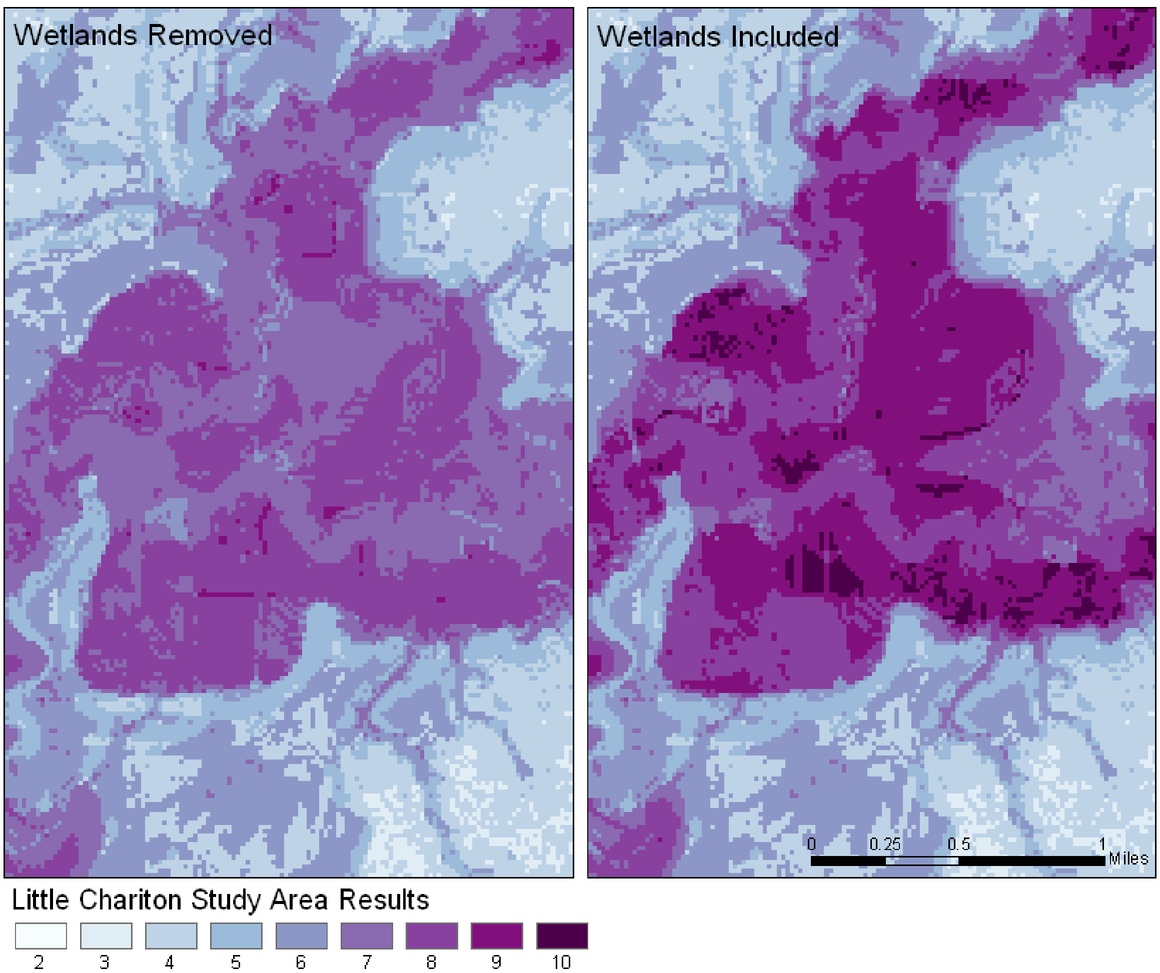

Figure 23. A portion of the results with existing wetlands removed from input data.

7. Discussion

Nine of the ten input layers employed in the model were generated at a resolution of 10 meters. However, the tenth layer, land use/land cover, was only available at a resolution of 30 meters. Thus the final results can only be calculated at a resolution of 30 meters: the coarsest resolution of the input data. This raises the question of the practical limits of resolution in the results. Even if the results could be increased to a resolution of 10 meters, or 1 meter, a map of wetland potential may not be useful at such a scale. As the results increase in resolution, the accuracy and precision of the input data becomes more crucial. A small error in the horizontal accuracy of a soil layer will affect the results. Furthermore, it would be impractical to restore or create wetlands by the square meter.

The results of any model dependent on scale values and weights or influences are sensitive to variations of these values. Some studies (White and Fennessy 2005) go to great lengths to analyze this sensitivity, while others (Van Lonkhuyzen et al. 2004; Palmeri and Trepel 2002) merely acknowledge it. The sensitivity to weights and values is the most important feature of the model, giving it adaptability to study diverse regions and flexibility to achieve diverse goals. However, it is critical to utilize local and expert knowledge to choose weights and scale values because of their inescapable subjectivity. Additionally, it should be remembered that this is a screening tool. Before choosing any particular site for a restoration or mitigation project it is important to conduct a more careful and detailed study of that site.

Special Flood Hazard Area maps are produced from Federal Emergency Management Agency Q3 Flood Studies, and published by county. However, not all counties have been the subject of Q3 Flood Studies. For some study areas this will result in the model lacking one of the ten input data layers. In this case, any raster layer with constant or uniform values can be substituted to indicate that all cells are outside of an SFHA. This method maintains the proportions of percent influence among the remaining data layers.

The foremost consideration in developing the WPST was to maximize its utility and applicability as a screening tool. The WPST is not intended to achieve the pinnacle of accuracy and sophistication in wetland potential models. Some accuracy and complexity have been sacrificed in the structure of the model and selection of data layers for the sake of ease of use for anyone with GIS software, access to basic geographic data, and a need to assess wetland potential.

8. Conclusions

Considering the importance of created and restored wetlands in maintaining the nation’s net gain in wetlands, it is desirable that newly identified sites are capable of sustaining an intended function. The Wetland Potential Screening Tool provides planners, developers, and engineers with a starting point to identify sites with the highest potential to become a restored or created wetland. Any tool, such as the WPST, that is dependent upon user assigned values is subject to an inherent subjectivity. Furthermore, because the analysis is dependent upon the assigned values, the results will be sensitive to changes in those values. Concerns about the subjectivity and sensitivity of a tool are amplified when measuring an abstract concept such as wetland potential on a large scale. The variety of wetlands and the diversity of conditions in which they occur, compounds the problem of subjectivity. Any analysis relying on landscape data of this scale and resolution must always consider that a model is only as good as its data. The accuracy and consistency of input data must always be considered when taking action based on the results of a GIS process. For these reasons the WPST is heavily reliant on the expertise and local knowledge of the user to make subjective judgments to select scale values. The inherent subjectivity of models such as the WPST should be incentive to conduct further research to determine the relative influence and importance of various conditions to wetlands.

With current knowledge of wetlands, the subjectivity of the analysis may be unavoidable, but may be considered the WPST's greatest strength. Subjectivity can be turned to flexibility and adaptability, not only for a diversity of conditions, but also for a diversity of goals. Despite the concerns and limitations mentioned above, the Wetland Potential Screening Tool can be a powerful and useful tool for creating, restoring, and protecting a valuable and vital natural resource.

9. Acknowledgements

I would like to thank the U.S. Environmental Protection Agency for funding this project. Their support for wetlands research and their recognition of the utility of efforts such as this can only lead to a greater understanding of wetlands and our ability to protect them.

I would like to recognize Xiafen (Sherry) Chen (formerly of the Missouri Department of Natural Resources) for her early work on this project, including the original design of the model processes. This project would not have been possible without her efforts.

I would also like to thank Steve McIntosh and the Wetland Steering Committee for developing the concept of the Weighted Overlay Tables for the three variations of the model.

The endless ideas, comments, and feedback I received from John Drew, Charles DuCharme, Karen Rouse and Rod Ellis were invaluable to the success of this project. I am very thankful for their generosity with both their time and effort. I would also like to thank Ryan Mueller and Steve McIntosh for their guidance and support throughout the course of this project.

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