Development of New Remote Sensing Techniques for Wetland Mapping

Final Report

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MU Contact: Clayton Blodgett

Remote Sensing Coordinator

Missouri Resource Assessment Partnership

University of Missouri

4200 New Haven Rd

Columbia, MO 65201

blodgettc@missouri.edu

Introduction

Past wetland protection projects have been hampered by the lack of accurate, up to date, wetland maps. Restoration efforts have likewise been limited due to a lack of relevant site locations where restoration efforts can provide maximal impact. The results of this project will aid protection and restoration efforts along the Missouri River due to the creation of up to date digital data outlining the location and type of wetland within the study area. The goals of the project were:

- 1. **Increase the accuracy to which wetland areas can be identified** using remotely sensed information together with fine-resolution site type modeling.
- 2. **Determine recent wetland trends** by comparing data from Objective 1 above to earlier National Wetlands Inventory (NWI) data sets. .
- 3. **Identify areas of potential wetland restoration** by mapping abiotic site types and flooding potential using multiple environmental data layers (e.g. soil variables, elevation relative to river level, landform) within a geographic information system.
- 4. **Quantify and set priorities for both conservation and restoration** based on analyses of data created in 1 – 3, including proximity to public lands and roads

Study Area

The area of interest for the updated wetland mapping and potential wetland restoration modeling is located within the Missouri River bottom from river mile 427 (North of Atchison, KS) to 378 (approximately Kansas City, MO), 8-digit Hydrologic Unit Code 10240011 (Nishnabotna Drainage), within the Missouri counties of Andrew, Buchanan, Holt and Platte and the Kansas counties of Atchison, Doniphan, Leavenworth, and Wyandotte. Additional modeling for potential wetlands restoration was completed for the study area as well as areas extending downstream from the study area at river mile 378 to river mile 278, which includes the Missouri Counties of

Carroll, Clay, Jackson, Lafayette, Ray, and Saline. The current wetland mapping study area was extended 1,000 meters beyond the flood plain to include areas on the bluffs. However, the extent used for potential restoration modeling includes only the floodplain, which is the extent of the digital elevation model used in the modeling process, and begins at river mile 477 in Holt county Missouri, North of St. Joseph, MO (Figure 1).

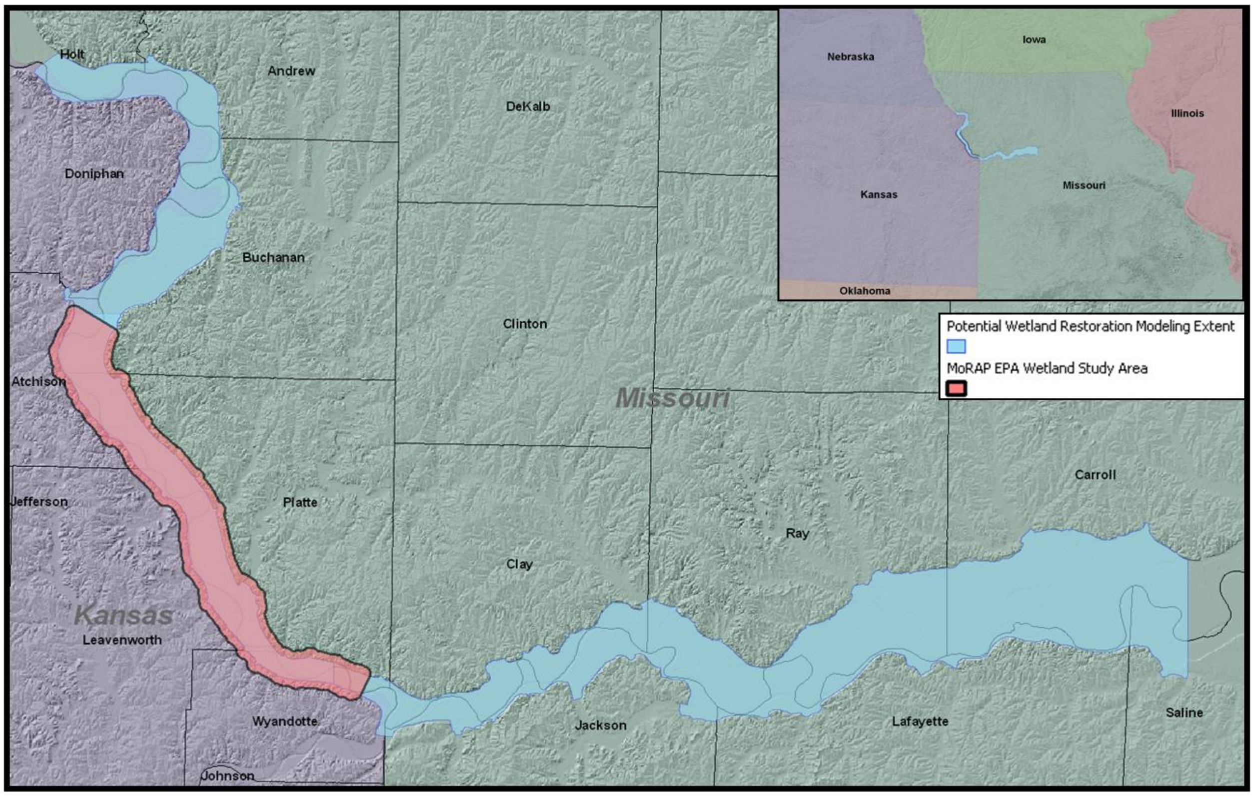


Figure 1. Updated Current Wetlands and Potential Wetlands Restoration Study Area.

<u>Data Acquisition and Methods</u>

Wetland Mapping Methods

Remotely Sensed Data

Multiple imagery types, platforms, and resolutions were used to identify different components of the wetland system (Table 1). We were able to utilize the strength of each remotely sensed dataset, capture unique information, and synthesize it together in a way that is not possible using only one image dataset. Acquired imagery includes SPOT 5, Landsat ETM+, and Radarsat. Minimal pre-processing was performed on the acquired image datasets. Each image was geo-corrected to a master reference 10 meter Landsat Panchromatic image to minimize registration error.

SPOT 5 data was acquired to aid in the detection of vegetation cover. In order to capture vegetation cover imagery from multiple seasons was required. The SPOT image consists of 4 bands: band 1 (green, 0.50-0.59 μm), band 2 (red, 0.61-0.68 μm), band 3 (near-ir, 0.78-0.89 μm), band 4 (middle-ir, 1.58-1.75 μm). Bands 1-3 have a spatial resolution of 10 meters and band 4 has a spatial resolution of 20 meters. A level 2A product was used, which means that radiometric and geometric preprocessing was applied to the image by the vendor, Spot Image. This level of preprocessing is recommended if the data is to be used for analysis with GIS and other images. A spring image date of April 16, 2007 was acquired to capture a leaf-off scene (Figure 2). To capture a full canopy, summer imagery date of August 13, 2007 was acquired (Figure 3). The differences in spectral values highlight areas of vegetation around and within wetlands.

To aid in the delineation of permanent wetlands, Landsat ETM+ imagery was acquired. Landsat ETM+ has a 30 meter spatial resolution and 6 spectral bands ranging from blue to middle-ir. The presence of the near-ir band and its ability to effectively detect water and water boundaries, as well as the sheer volume of archived images available are the primary reasons

Table 1. Acquired remote sensing data used in analysis.

Dataset	Description
Spot 5	**Native Spatial Resolution:** 10 meters **Resampled Spatial Resolution:** 10 meters **Image Acquisition Date:** April 16, 2007 – leaf –off August 13, 2007 – leaf-on **Purpose:** Primary dataset used to aid in the delineation of vegetation cover
Landsat ETM+	**Spatial Resolution:** 30 meters **Resampled Spatial Resolution:** 10 meters **Image Acquisition Date:** December 31, 2002 **Purpose:** Primary dataset used to aid in the delineation of permanent wetlands based on image coincidence with low river levels
Radarsat	**Spatial Resolution:** 8 meters **Resampled Spatial Resolution:** 10 meters **Image Acquisition Date:** August 28, 2007 **Purpose:** Primary dataset used to aid in the delineation of vegetation structure and to be coincident with the Spot data used to map vegetation cover

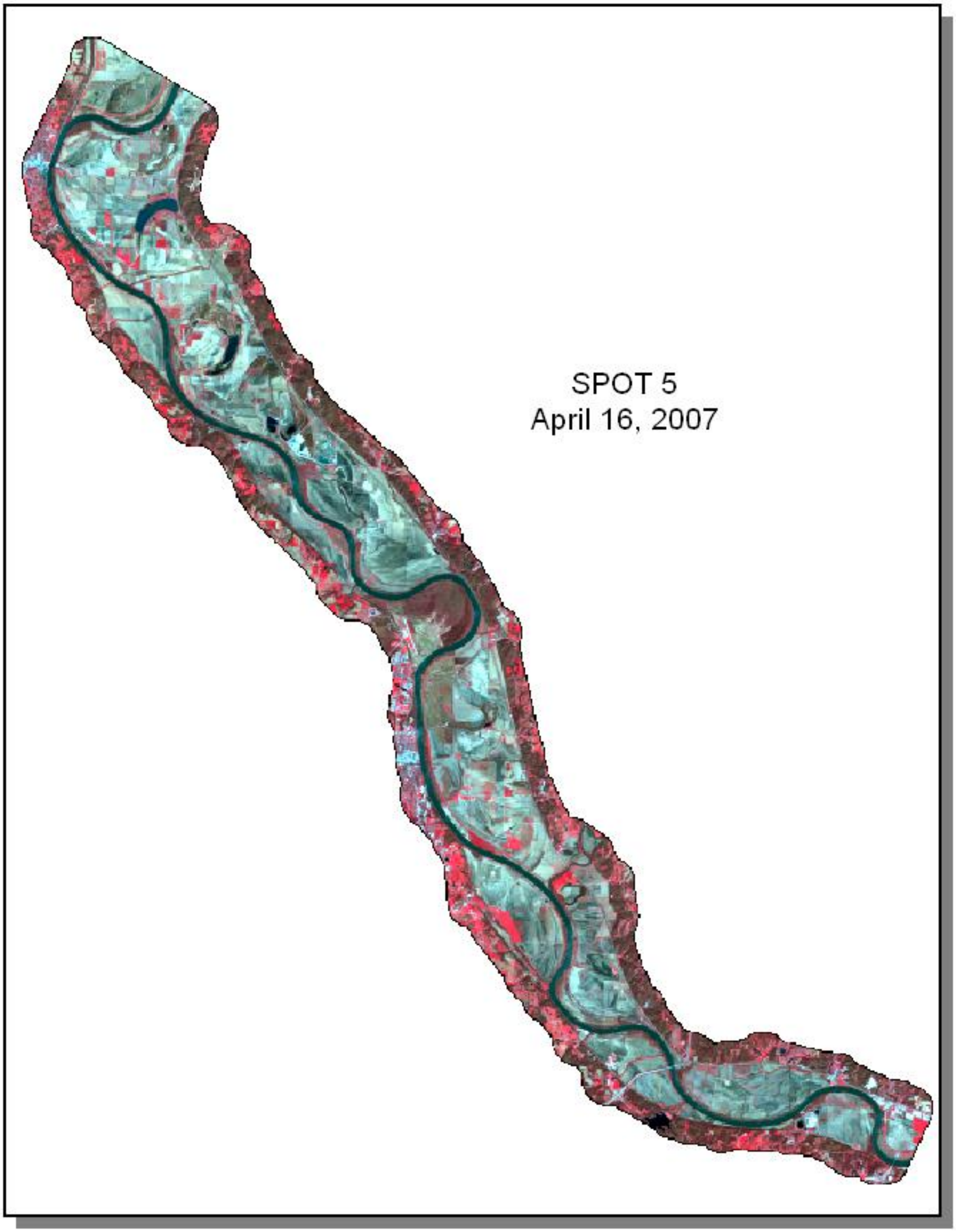


Figure 2. SPOT 5 satellite image acquired April 16, 2007.

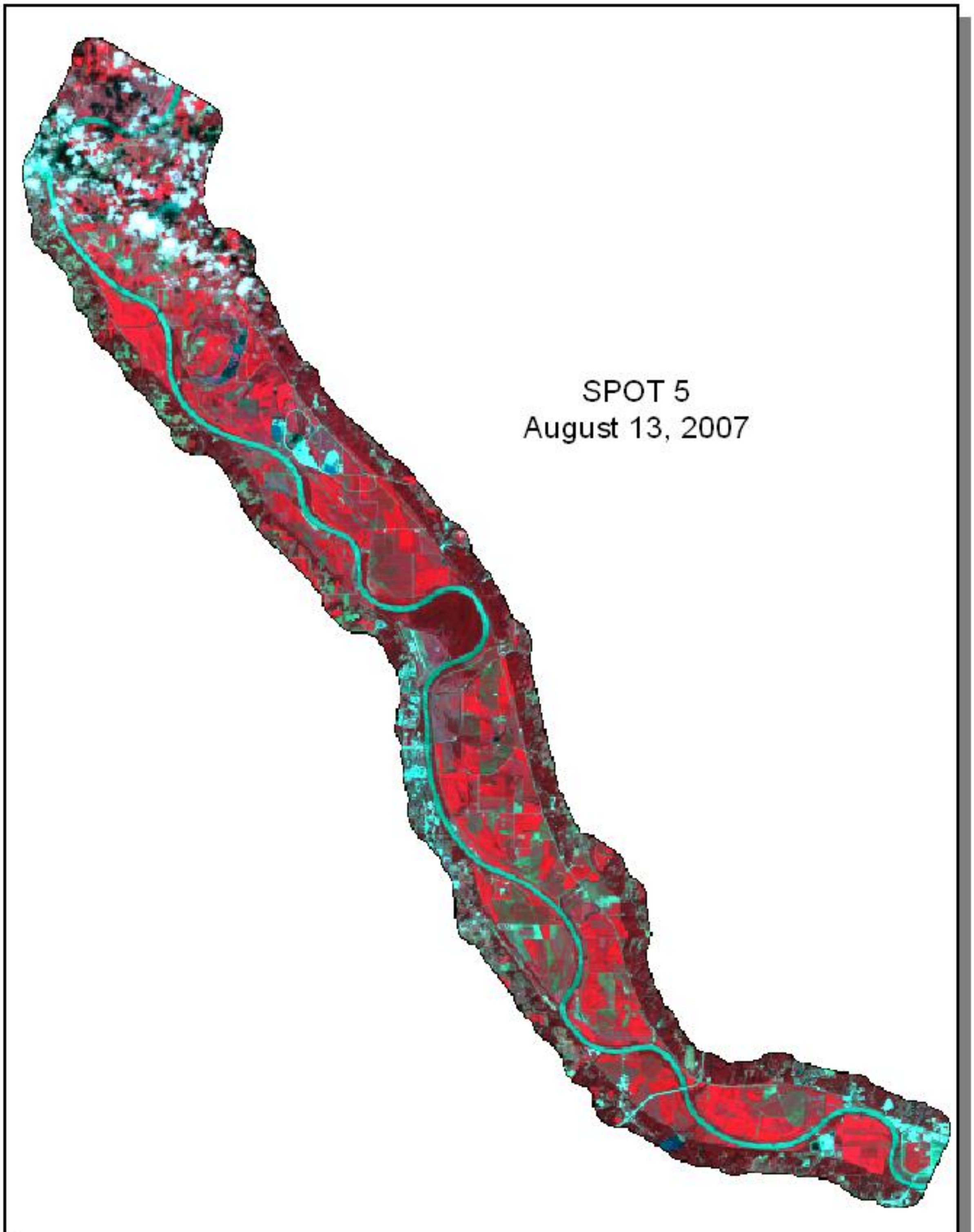


Figure 3. SPOT 5 satellite image acquired August 13, 2007.

why the Landsat imagery was selected (Figure 4). To insure that permanent wetlands would be detected, the image date of December 31, 2002 coincides with low water data from the USGS stream gage at St. Joseph, MO (Figure 5)). The rationale being that any wetlands detectable at the lowest water stage indicate the presence of a permanent wetland.

Radarsat 1 Synthetic Aperture Radar (SAR) fine beam data with a spatial resolution of 8 meters was acquired to map vegetation structure (Figure 6). Radar data has the ability to provide vegetation structure information in the form of plant geometry, canopy roughness, and vegetation moisture. Collecting imagery at the appropriate time can significantly improve classification, thus the Radarsat image acquisition date of August 28, 2007 coincides with the leaf-on SPOT image as to capitalize on the opportunity to map vegetation cover and structure with images from the same time period. Mapping of vegetation cover and vegetation structure should be enhanced by collecting imagery within a couple of weeks of one another, insuring that the exact same vegetation is being mapped at the cover and structure levels. A Gamma filter was used to reduce speckle noise prior to processing.

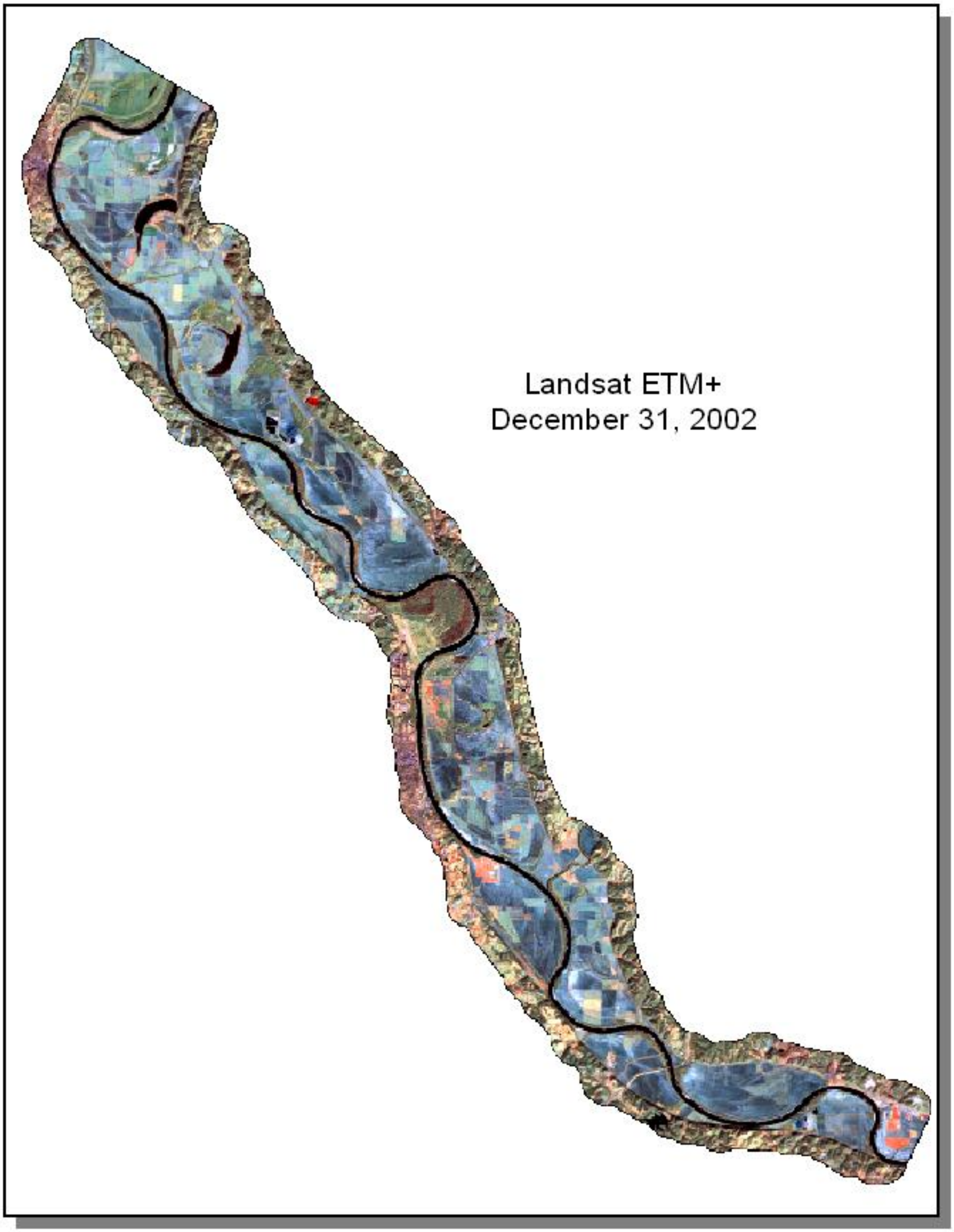


Figure 4. Landsat ETM+ satellite image acquired December 31, 2002.

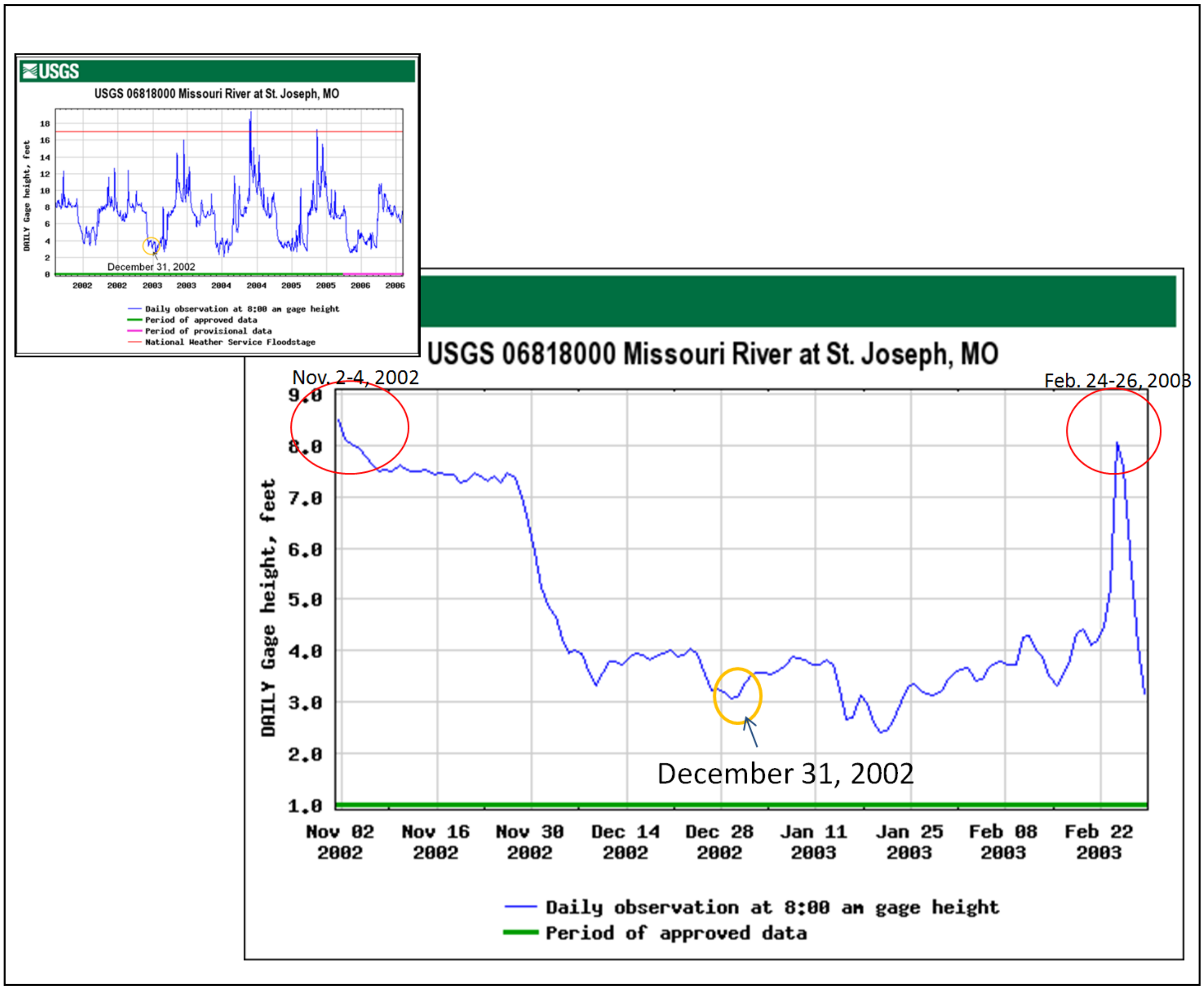


Figure 5. USGS Missouri River gage readings at St. Joseph Missouri used to identify low water periods.

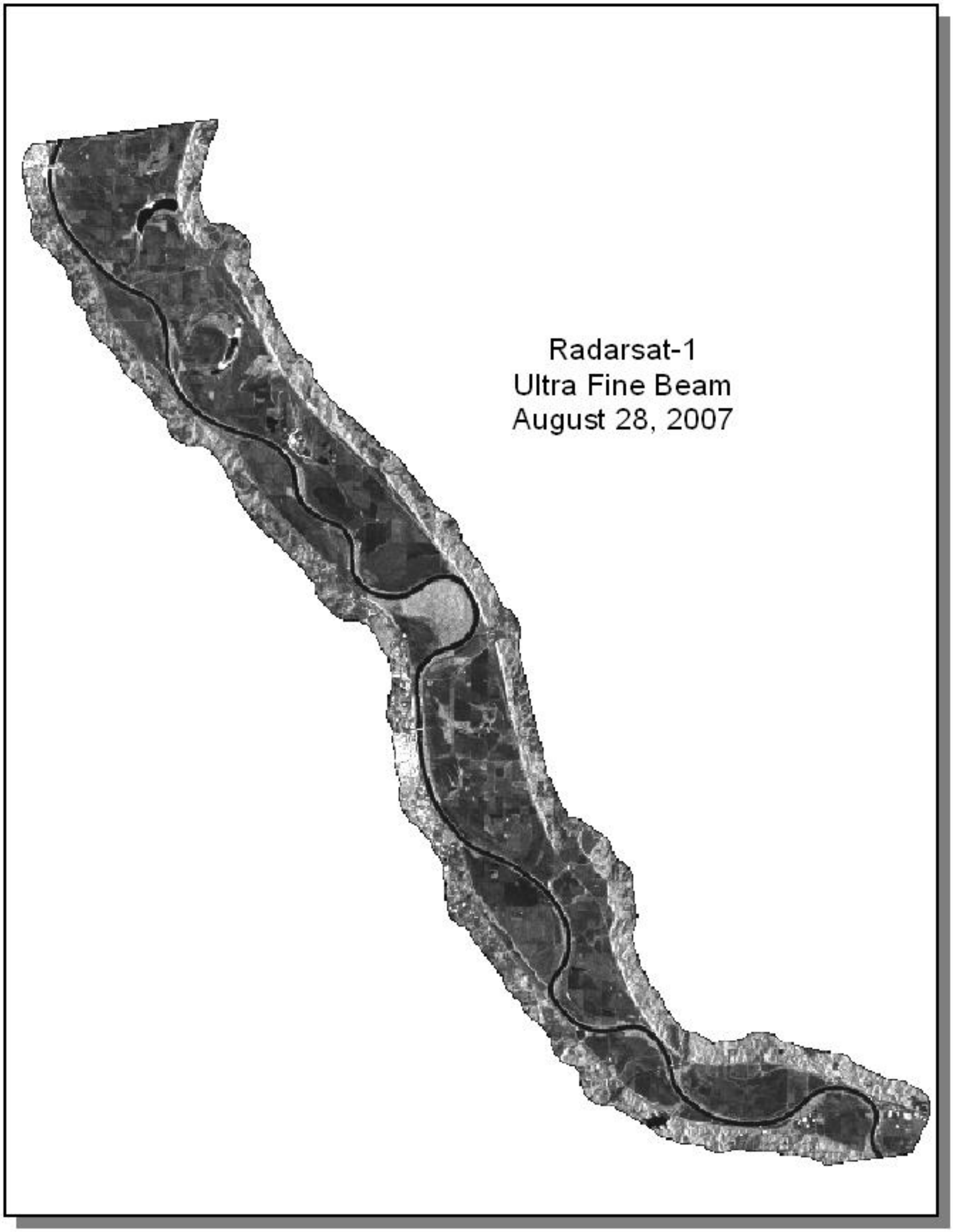


Figure 6. Radarsat-1 ultra fine beam Synthetic Aperture Radar satellite image acquired August 28, 2007.

Modeled Data

A high resolution digital elevation model (DEM) was created using data obtained from the United States Army Corps of Engineers (USACE), Kansas City District and was collected for them by Horizons, Inc of Rapid City, SD in 1998(for more details on data creation see below). The DEM was resampled to 5 meters from 25 foot postings. The fine-scale resolution of the elevation dataset allows for a precise analysis of the topography of the study area and to identify local areas of low elevation (Figure 7).

A sinks dataset was created using the 5 meter DEM to identify depressions and relatively low-lying areas throughout the study area. The fill command was used to fill DEM depressions. During the process flow direction is created, when the flow is stopped due to a depression or sink, the depression is filled until the flow can continue. At this point the surface is relatively flat and can be subtracted from the raw DEM to create a localized depressions surface that represent locations to which water naturally flows and often indicates the presence of intermittent wetlands (ESRI ArcGIS Desktop 9.1 Help; O'Hara, 2002).

The Radarsat, SPOT, Landsat ETM+ and elevation datasets were stacked to create a 14 band dataset to perform the analysis on. Stacking the data allows for a comprehensive view of a particular location in one analysis, reducing the risk for error. Prior to stacking the datasets, the Radarsat, SPOT, and Landsat ETM+ data were resampled to 10 meters. All wetland mapping and analysis was performed on this data stack

Classification Methods

Object-oriented classification was employed in lieu of the traditional pixel classification method. The object-oriented approach uses pixel spectral values, as well as information based

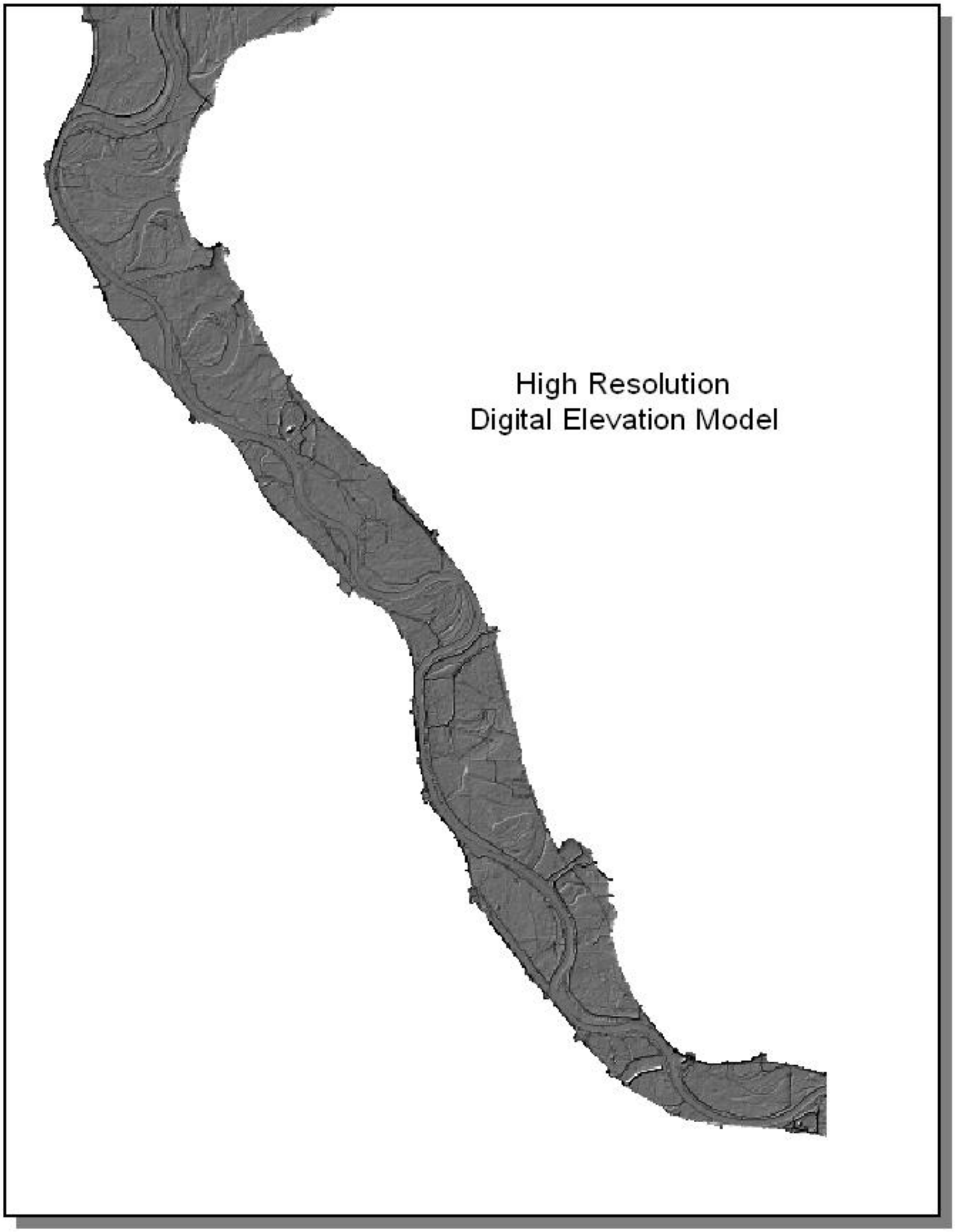


Figure 7. High resolution Digital Elevation Model constructed from Army Corp of Engineers mass points and break lines.

on pattern, shape, and texture to create objects that are then classified. To take advantage of the robust nature of the eCognition software and the object-oriented approach, multiple datasets were used to map various features and characteristics of wetlands. Data used included SPOT, Landsat ETM+, Radarsat, and digital elevation models (DEM).

Wetland habitat classification was approached in a hierarchical manner. The classification levels begin at the broad system level and become more detailed at the class level and even more detailed at the water regime level. The 3 levels of classification are then combined to produce a single wetland habitat classification that represents multiple levels. The object oriented approach is designed for such a classification scheme, where large objects can be further segregated in smaller and smaller objects with new and related classifications at each object level.

Classification of Wetland System

Wetland System classes consist of Lacustrine, Palustrine, Riverine and Other. The initial step in creating the system classification was creating the objects to be classified. Objects were generated on the14 band data stack to create relatively large and homogenous objects. A supervised classification approach was applied to the objects. Randomly generated points from the current National Wetlands Inventory (NWI) were used as training sites to represent each system class. Each point was checked against multiple dates of the National Agriculture Imagery Program (NAIP) aerial photography to ensure that the points in question still contained wetland areas. The imagery was then classified based on the attributes determined to be significant by the eCognition software using the Feature Class Optimization tool.

Classification of wetland Class

Wetland Class describes the general land cover that is present at a given location. Five classes were classified: Forested, Scrub/Shrub, Herbaceous, Uncosolidated Bottom, and Other. eCognition was used to generate smaller objects that were nested within the objects generated for the system classification. The same supervised training method used for the system classification was used at the class level. The same randomly generated points were used to train the classifier. The classification was again performed using shape and spectral values identified as being significant by the eCognition software Feature Class Optimization tool.

Classification of Wetland Water Regime

Wetland Water Regime indicates the frequency and duration of flooding that occurs for a give parcel of land. The development of the water regime layer was accomplished in two phases. The first involved classification of the Landsat ETM+ imagery to define areas where water was present at the surface. These areas were deemed to be permanently flooded. The next phase involved using the sinks layer developed from the fine scale DEM's and a layer describing soil drainage properties. The sinks layer was used to seperate areas where the potential existed for water to pond from those areas where the potential to pond was less. These areas where then further defined by the drainage class assigned to them by the SSURGO soils of the area. The combination of these two aspects allowed for the inclusion of greater detail within the water regime classification (Table 2).

Table 2. Crosswalk Table Used for Water Regime Classification.

Water Regime	Mapped from Imagery	Potential to Pond	Drainage Class
A – Temporarily Flooded	No	High	Well drained, Moderately well drained
A – Temporarily Flooded	No	Low	Very poorly drained
F – Semipermanently Flooded	No	High	Somewhat poorly drained
G – Intermittently Exposed	No	High	Poorly drained, Very poorly drained
H – Permanently Flooded	Yes	NA	NA
J – Intermittently Flooded	No	High	Excessively drained, Somewhat excessively drained
J – Intermittently Flooded	No	Low	Poorly drained

Wetland Habitat Classification

System, class, and water regime classifications were concatenated to create a hierarchical wetland classification. This allows multiple attributes and scales of the wetland to be interpreted from a single classification value. A wetland that was classified as a permanently flooded, palustrine, forested wetland would receive the code PFOH.

Field visitation

Prior to data processing multiple wetland areas within the study area were visited to get a feel for the types of wetland classes present. After the initial classification was completed, another visit to the field was conducted to identify obvious problem areas contained with the classification of the study area. Multiple wetland areas and other areas of interest were visited including Little Bean Marsh Conservation Area, Lewis and Clark Lake, and Weston Bend. Windshield surveys were conducted in which the NAIP imagery and classification were consulted to evaluate classification and collect additional sample points.

Wetland Modeling

Wetland modeling incorporated various datasets including soils, fine-scale dem, local depressions, and landcover to model potential wetlands and rank potential restoration areas based on proximity to public lands, urban areas, and existing natural vegetation. This analysis was performed for the study area from Missouri River mile marker 428 to 378 and further downstream from mile marker 378 to 278. The complete study area covers 136,320 ha (526 square miles) and includes part of the Missouri counties of Andrew, Buchanan, Carroll, Clay, Holt, Jackson, Lafayette, Platte, Ray, and Saline and the Kansas counties of Atchison, Doniphan, Leavenworth, and Wyandotte (Figure 8).

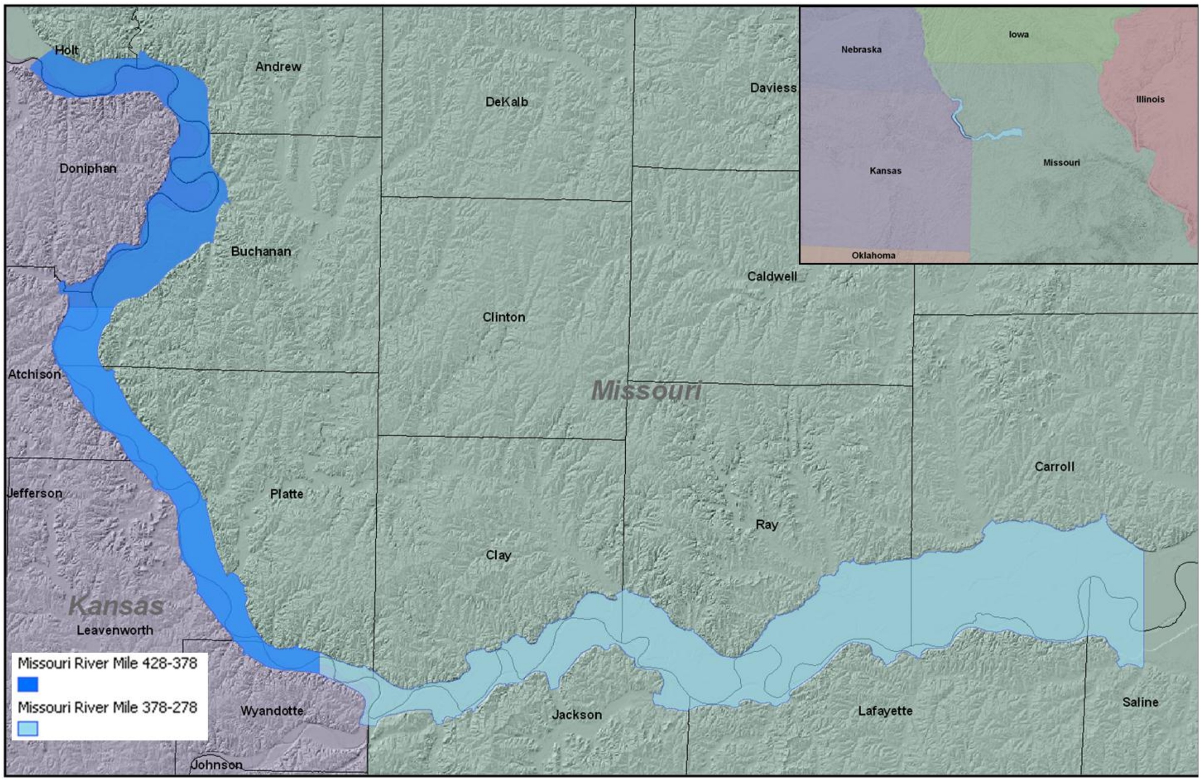


Figure 8. Potential Wetland Modeling study area from Missouri River mile 428 to 278.

Potential Wetland Restoration Model Data and Methods

The potential wetland restoration areas model uses local/relative elevation information along with soil information to determine wetland restoration potential. The purpose of this data is to indicate where water naturally flows and the soil infiltration rates at those locations. It can be used in conjunction with the landscape context model to gain a bigger picture of wetland restoration to rank based on feasibility.

Digital Elevation Model (DEM)

Digital elevation data was obtained from the United States Army Corps of Engineers (USACE), Kansas City District and was collected for them by Horizons, Inc of Rapid City, SD in 1998. Horizons, Inc created the elevation information from 25 foot postings of mass points "interpolated" from the breakline, TIN spot, and random spot elevation mapping. USACE delivered the data to MoRAP as text files that required processing in order to create the raster elevation data (Figure 9). Digital elevation data was used to create the local depressions (sinks) dataset to aid in the identification of areas of natural water ponding, which are a component of the potential wetland restoration areas model.

Figure 9. Raw elevation points (left) provided by U.S. Army Corps of Engineers to create fine scale DEM's (right) for Missouri River bottomland from river mile marker 428 to 278.

The procedure to create the elevation data set required the mass point and break line files to create a raster data set. There were 18 map sheets of elevation data for the immediate study area and 76 additional map sheets downstream. In order for the mass point and break line files to be readable by ESRI ArcGIS the suffix of the break line and mass point files were changed from .brk and .pts to .txt. The .txt text files were then opened using Word Pad and the header information was deleted, so that the text file could be converted to a data base file (.dbf). The text file was then imported into Microsoft Access to assign each elevation point a unique identifier, convert the x, y, and z values from feet to meters, and save the text file as a .dbf. Each point must have a unique id in order to be readable in ArcGIS and converted to a raster. The mass point and break line .dbf files for all map sheets were opened in ArcGIS and vector point files were created by using the x and y values that had been converted to meters. Using ArcGIS 3D Analyst tools, the elevation values within the break line and mass point vector point files were used to generate a Triangulated Irregular Network (TIN) elevation surface. In a TIN model, the world is represented as a network of linked triangles drawn between irregularly spaced points with x, y, and z values (ESRI ArcGIS Desktop 9.1 Help). To create a smoother elevation surface, the TIN elevation dataset was converted to a 32 bit floating point raster dataset with a 5 meter cell size using the natural neighbors sampling method, which can efficiently handle large numbers of input points. Over 1.3 million points were used to create the elevation surface for the study area alone.

Hydrologic Depressions (Sink) Dataset

Hydrologic depressions, or sinks, were created to determine local low areas where water would naturally drain and become trapped, indicating a potential for water ponding. The fill command was used to fill DEM depressions. During the process flow direction was created, when the flow was stopped due to a depression or sink, the depression was filled until the flow could continue. At this point the surface is relatively flat and can be subtracted from the raw

DEM to create a localized depressions surface (ESRI ArcGIS Desktop 9.1 Help; O'Hara, 2002) (Figure 10). The greater the resulting value, the deeper the sink. The sinks dataset was combined with soil information to model potential wetlands.

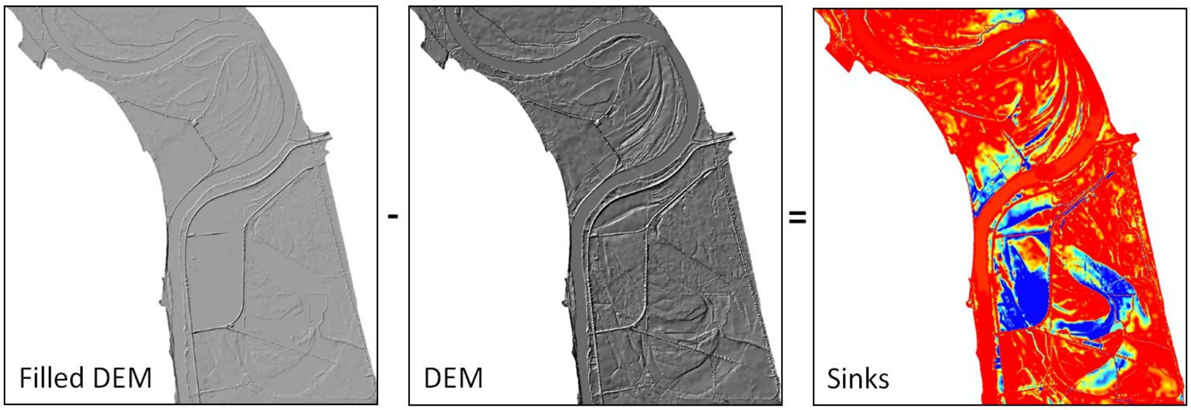


Figure 10. The sinks or local depressions data set was created by subtracting the filled fine resolution DEM from the DEM with the result indicating areas of localized low spots where water can be expected to naturally pool.

USDA NRCS Soil Survey Geographic (SSURGO) Database

SSURGO soil data was obtained from the Soil Data Mart (http://soildatamart.nrcs.usda.gov/) for the counties within the study area. SSURGO data depicts information about soils on the landscape. The SSURGO database was created by soil scientists as part of a National Cooperative Survey. The digital data used for this project was published in 2005 (USDA NRCS 2005), but the on-the-ground soil surveys used to create the dataset are of various ages. The database contains numerous relational tables with a vast array of soil information. The Soil Data Viewer 5.0 (http://soildataviewer.nrcs.usda.gov/) was used to ensure that tables were properly related to one another and the appropriate information was extracted.

The soil characteristic that best highlighted water holding properties was soil hydrologic group. This dataset was used in conjunction with the sinks dataset to identify relatively low spots with slow infiltration rates , which are ideal candidates for wetland restoration.

Soil Hydrologic Group

Hydrologic soil groups are based on estimates of runoff potential. Soils are assigned to 1 of 4 groups according to the rate of water infiltration when the soils are not protected by vegetation, are thoroughly wet, and receive precipitation from long-duration storms. The soils in the United States are placed into four groups, A, B, C, and D, and three dual classes, A/D, B/D, and C/D (see Figure 3 and Appendix 6). Definitions of the classes are as follows:

Group A. Soils having a high infiltration rate (low runoff potential) when thoroughly wet. These consist mainly of deep, well drained to excessively drained sands or gravelly sands. These soils have a high rate of water transmission.

Group B. Soils having a moderate infiltration rate when thoroughly wet. These consist chiefly of moderately deep or deep, moderately well drained or well drained soils that have moderately fine texture to moderately coarse texture. These soils have a moderate rate of water transmission.

Group C. Soils having a slow infiltration rate when thoroughly wet. These consist chiefly of soils having a layer that impedes the downward movement of water or soils of moderately fine texture or fine texture. These soils have a slow rate of water transmission.

Group D. Soils having a very slow infiltration rate (high runoff potential) when thoroughly wet. These consist chiefly of clays that have a high shrink-swell potential, soils that have a high water table, soils that have a claypan or clay layer at or near the surface, and soils that are shallow over nearly impervious material. These soils have a very slow rate of water transmission.

If a soil is assigned to a dual hydrologic group (A/D, B/D, or C/D), the first letter is for artificially drained areas and the second is for undrained areas. Only soils that are rated D in their natural condition are assigned to dual classes, thus we included these soils in group D.

Potential Wetland Restoration Area Model

Potential herbaceous wetland and bottomland forest restorations areas were identified by intersecting the sinks and soil hydrologic group datasets. Holbrook et al. (2006) suggested that ideal locations for wetland restoration within the Missouri River floodplain occur at locations that have relatively low topographic elevation and have slow rates of infiltration. Thus, ideal locations for herbaceous wetland restoration are those that have low relative elevation as well as slow infiltration. Those areas that have relatively high elevation and high infiltration rates were considered ideal bottomland forest restoration areas.

The potential restoration areas were created by adding the sinks and hydrologic group layers. The sinks data was recoded into 4 classes using quantile division and the hydrologic group letters were recoded to numbers 1 through 4 (Table 3).

Table 3. Reclass of sinks and soil hydrologic groups used to model potential wetland restoration areas.

Sinks	Soil Hydrologic Groups
1 – Low Elevation	**1 – D – Very Slow Infiltration, B/D – Moderate Infiltration, C/D – Slow Infiltration**
2 – Medium Low Elevation	**2 – C – Slow Infiltration**
3 – Medium High Elevation	**3 –B – Moderate Infiltration**
4 – High Elevation	**4 – A – High Infiltration**

The results of adding the two datasets yields a range of values from 2 to 8, with a value of 2 identifying locations with low relative or local elevation (1) and very slow infiltration (D), moderate infiltration (B/D), or slow infiltration (C/D), which indicates that this location is most suitable for herbaceous wetland restoration (Figure 11). As values increase, the areas have a higher relative elevation and soils with higher infiltration rates, until the maximum value of 8 is reached. A value of 8 identifies locations with high relative elevation and soils with high infiltration rates.

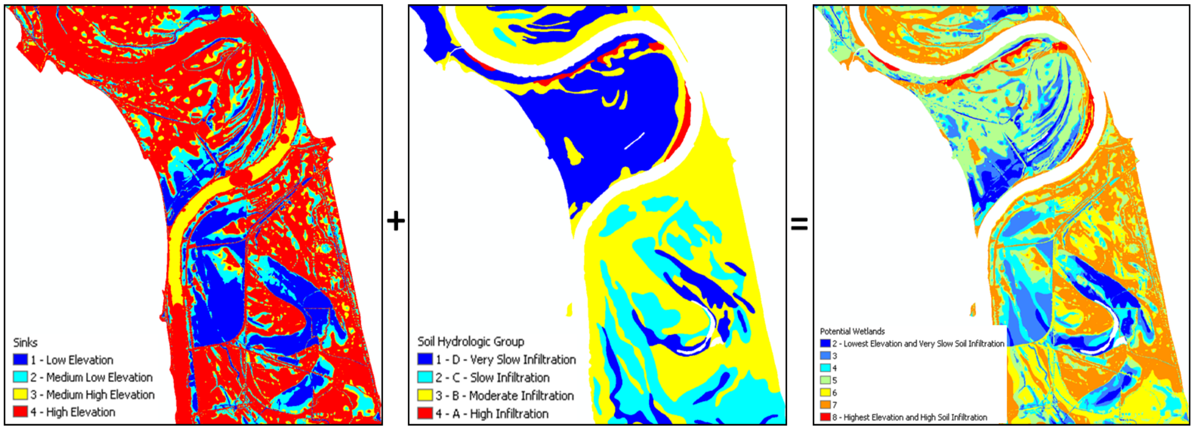


Figure 11. Potential wetland model was created by adding sinks (1-4) and soil hydrologic group (1-4) to produce a potential wetland layer (1-8) to identify low lying areas with poor soil infiltration (1) to high areas with high soil infiltration rates (8).

Landscape Context Modeling

The landscape context model was created to determine potential restoration areas based on distance from various land cover types and distance to public lands. This data set is to be used in conjunction with the potential wetlands restoration areas model to determine relative elevation, soil infiltration, and landscape context to gain a more complete picture of potential restoration feasibility. These data layers are to be used as general indicators of where wetland restoration efforts should be focused; additional, more detailed hydrologic studies and surveys should be conducted prior to restoration efforts.

Public Lands

The public lands data was used to help provide contextual information regarding the proximity of public lands to that of a potential restoration area. The Public Lands data consists of Missouri public lands updated in 2003 by MoRAP from the 1997 version as well as the Public

Areas Database (PAD) for Kansas. The dataset consists of polygons of all publicly owned lands within the state.

2005 MoRAP Land Use/Land Cover (LULC)

The land use/land cover (LULC) data for the state of Missouri was used to create distance grids from natural vegetation and urban areas for use in the landscape context model. The LULC dataset can also be used to view current land cover throughout the study area and beyond. Land cover classification for Missouri was created by MoRAP based on circa 2000-2004 30 meter satellite imagery, and published in 2005 (Table 4 and Figure 12). There are 14 classes of LULC that were mapped:

Table 4. Morap 2005 LULC Classes

LULC Class	LULC Class
Impervious	**Evergreen Forest**
High Density Urban	**Mixed Forest**
Low Density Urban	**Deciduous Woody/Herbaceous**
Barren or Sparsely Vegetated	**Evergreen Woody/Herbaceous**
Cropland	**Woody-Dominated Wetland**
Grassland	**Herbaceous-Dominated Wetland**
Deciduous Forest	**Open Water**

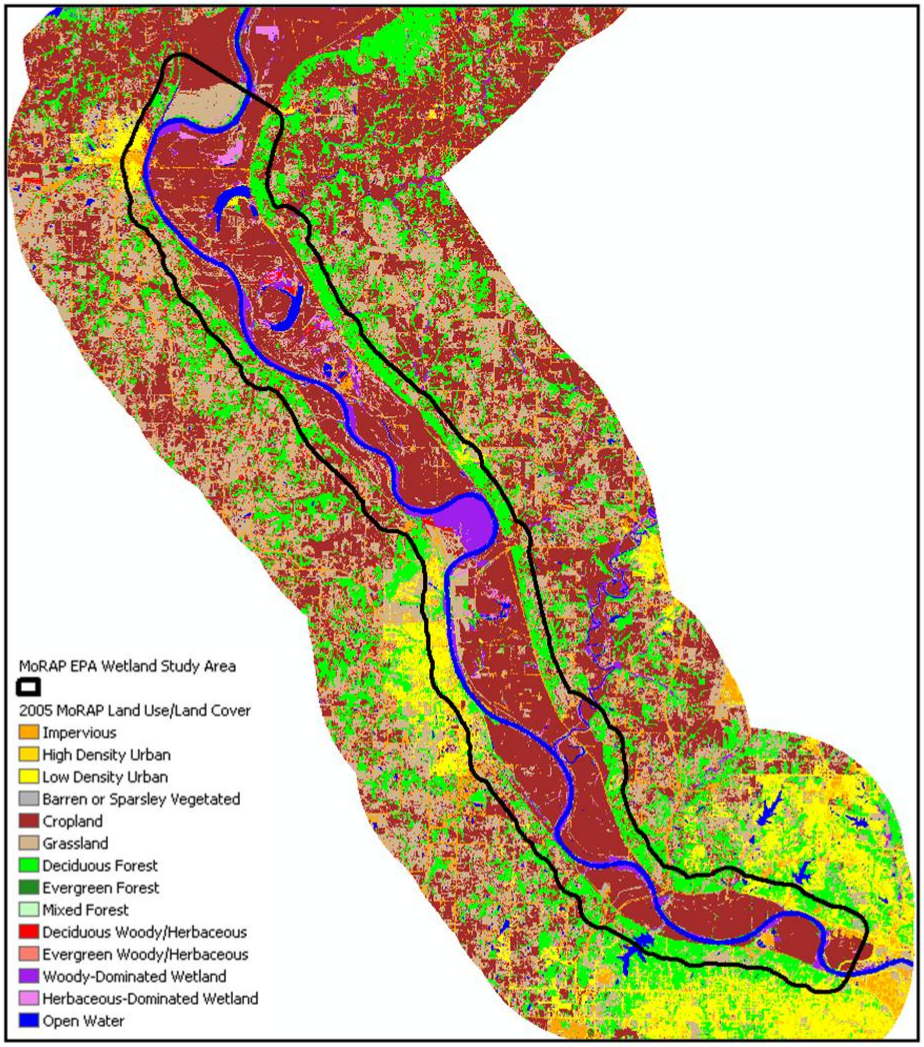


Figure 12. 2005 MoRAP LULC.

Distance from Natural Vegetation

All natural and semi-natural land cover classes from the 2005 MoRAP LULC (grassland as well as all forest, herbaceous, and wetland types) were selected and a distance grid was created illustrating the distance from patches of natural vegetation. The distances were then grouped into 5 classes (Table 5):

Table 5. Distance from Natural Vegetation Class Rankings

Distance Class Rankings	Distance
1	0-50 meters
2	50-100 meters
3	100-250 meters
4	250-500 meters
5	500 + meters

The closer to natural vegetation the higher the rank, based on the rationale that it is generally more effective to build on existing natural vegetation to create larger blocks, rather than to create new restoration areas distant from other natural or semi-natural vegetation (Figure 13A).

Distance from Public Lands

Public lands within the study area were used to create a distance from public lands grid. The distances were then grouped into 5 classes (Table 6):

Table 6. Distance from Public Lands Class Rankings

Distance Class Rankings	Distance
1	0-50 meters
2	50-100 meters
3	100-250 meters
4	250-500 meters
5	500 + meters

The closer to public lands the better the ranking based on the rationale that areas adjacent to current public lands would be ideal locations for restoration areas because larger contiguous blocks and vegetation can be created, and because public lands are generally actively managed for wildlife habitat (Figure 13B).

Distance from Urban Areas and Impervious Surfaces

All urban and impervious classes from the 2005 MoRAP LULC were selected and a distance grid was created. The distances were then grouped into 5 classes (Table 7):

Table 10. Distance from Public Lands Class Rankings

Distance Class Rankings	Distance
1	500 + meters
2	500-250 meters
3	250-100 meters
4	100-50 meters
5	0-50 meters

The further from urban areas and impervious surfaces the better the ranking, based on the rationale that areas within or adjacent to urban areas suffer more from deleterious urban impacts and edge effects, and are more likely to be converted to urban land over time (Figure 13C).

Landscape Context

In order to gain some contextual information, all three distance grids were added together to identify those areas that are most ideal for restoration based on proximity to urban areas, natural vegetation, and public lands. This dataset represents a composite of the distance grids in which pixels with the lower values are “most ideal” for restoration based on landscape context (Figure 13D). A value of three indicates the most ideal area for restoration, as it is furthest from

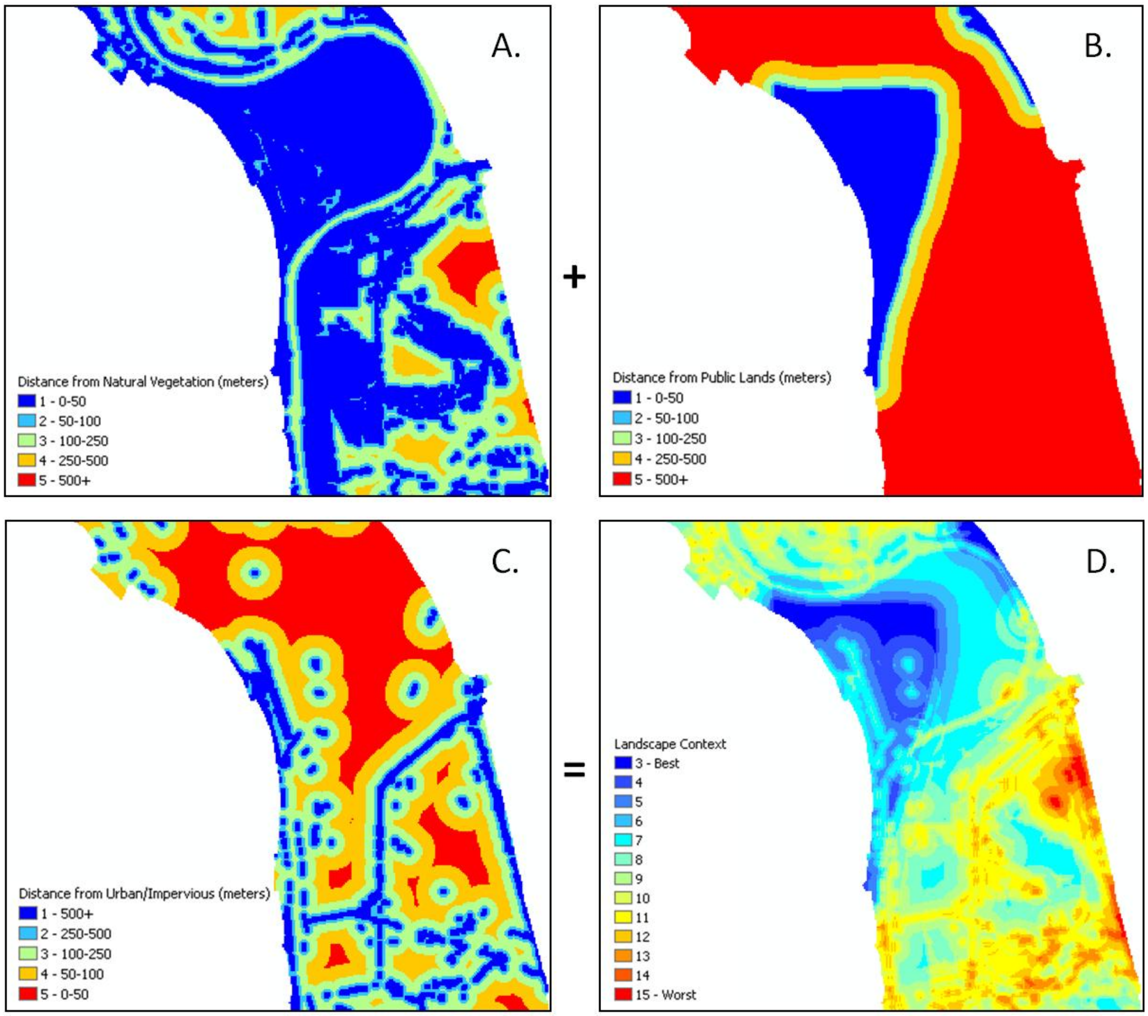


Figure 13. Landscape context model was created to identify wetland restoration areas based on proximity to current land cover and public lands. The model was created by recoding (1-5) and adding the distance from natural vegetation (A), distance from public lands (B), and distance from urban/impervious (C) to create and landscape context model (D) with values from 3 to 15. The most ideal restoration would have a value of 3, which indicates that the location is close to natural vegetation and public lands and furthest from urban/impervious areas.

urban and closest to natural vegetation and public lands. As the value increases, the less ideal the location becomes for restoration, until the maximum value of 15 is reached. A value of 15 indicates that the area is within or directly adjacent to urban areas and impervious surfaces and the furthest distance from natural vegetation and public areas. It must be noted that this index is strongly influenced by the distance to public lands, since so few exist within the floodplain.

Results and Discussion

A classification of wetland type within the study area was developed using the procedures outlined above (Figure 14). Information gathered from field visitation indicated that primary issues were associated with forested wetlands that were not being captured. During subsequent classification attempts, measures were taken to improve the classification of forested wetlands by further incorporating the sinks layer into the object generation process by using them as a thematic mask, insuring that all major localize depressions would be delineated by the objects.

The resulting final classification of wetlands within the study area differs from what is depicted in the NWI (Table 8). Areas classified as Lacutrine, Forested, Unconsolidated Bottom, and Riverine all showed a decrease in the area of wetland type mapped with the new technique. Emergent and Scrub/Shrub wetland types showed an increase in area mapped. Overall, the amount of wetland mapped increased by more than 1300ha, this is not an expected or accurate result.

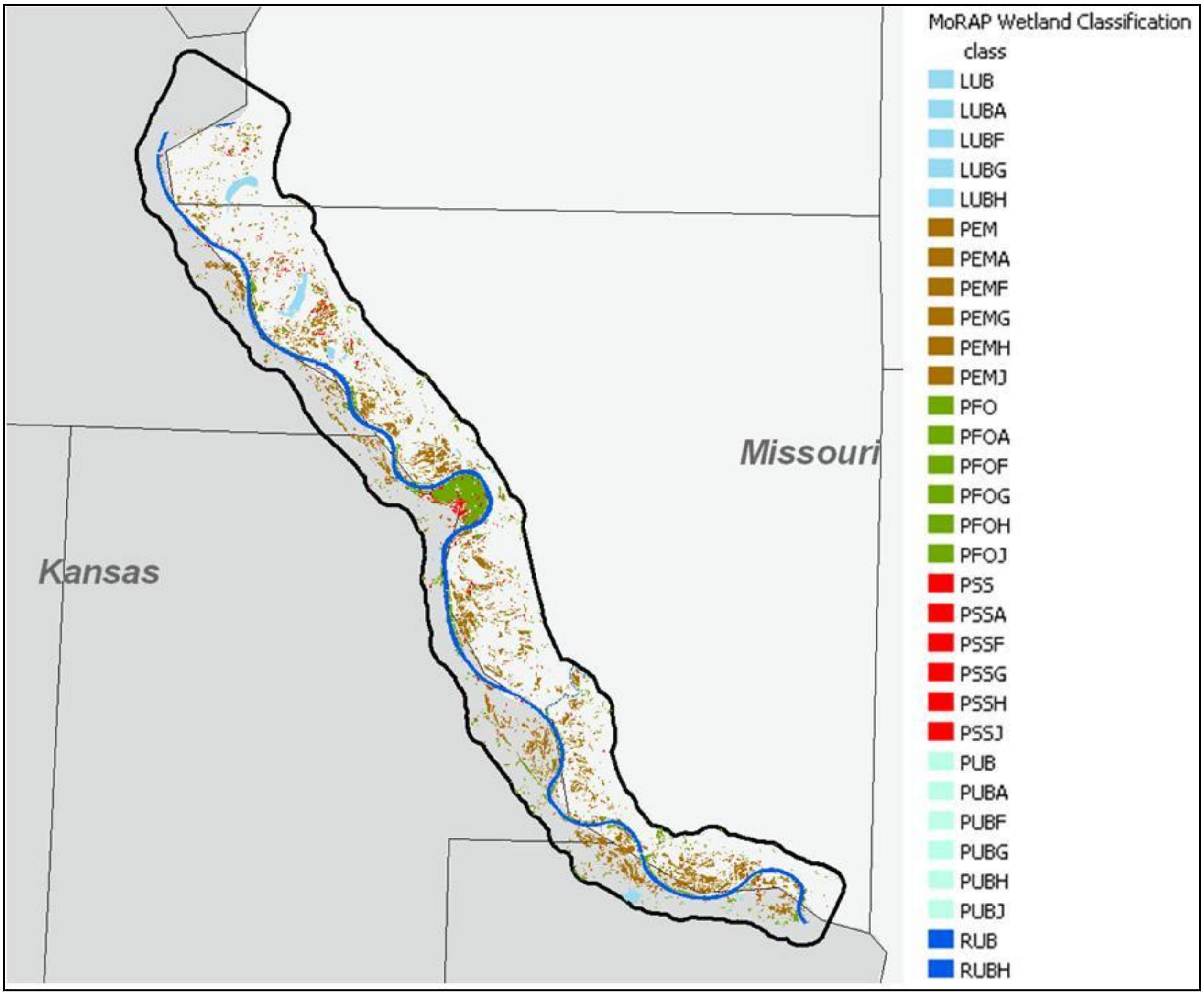


Figure 14. Wetland classification using the object oriented approach.

Table 8. Comparison of area(ha) mapped by wetland type.

Wetland Type	NWI (ha)	MoRAP (ha)
Lacustrine	531.36	369.56
Emergent	1,245.05	3,227.72
Forested	1,820.80	1,633.31
Scrub/Shrub	293.26	434.50
Unconsolidated Bottom	152.72	46.49
Riverine	2,167.51	1,888.11
Total	6,210.70	7,599.69

The largest discrepancy in the amount of wetland area mapped exists for the Emergent type. The new technique exhibits an increase of over 250% over what is depicted by the NWI. This is due to the over classification of emergent wetlands in areas where agricultural activities are presently active (Figure 15). These areas are incorrectly mapped, but they are also areas that meet the depression/drainage requirements for being deemed wetlands. They may be of use in the future for outlining areas where conservation reserve program land could be located or where wetland reserve program restoration projects may be initiated.

The decrease in the amount of Forested wetland area mapped may be partially due to a simple reduction in the amount of Forested wetland present. The reduction is also due in part to an increase in the amount of Scrub/Shrub area mapped (Figure 16). Inclusion of the Radarsat 1 data, which was included to increase the classifiers sensitivity to vegetation structure, did a very good job of aiding in the differentiation between those areas that were forested and those that contained shrub vegetation. Without the addition of the Radarsat-1 data, the discrimination between these two vegetation types would have been severely impacted.

Differences in the amount of Riverine wetland mapped are due two distinct factors. First, the new mapping technique was able to identify the interface between the river and the surrounding vegetation, but was not able to classify it correctly. Therefore, the shoreline was included in the “other” class and did not receive a wetland code. This was due to the bright nature of the exposed shoreline and its confusion with urban and impervious surfaces within the area. Secondly, some of the small tributaries to the main stem of the Missouri River were mapped as Palustrine as opposed to Riverine due to their similarity to swallow water wetlands.

Overall, the location and type of wetland mapped using the new approach makes sense. The different types of wetland encountered within the study area are located where one would think they should be, based on the imagery used for the project. Direct comparison to the NWI though reveals another story (Figures 17, 18, and 19). The two datasets are vastly different, and though the general patterns are similar, the local mapping can be very dissimilar. This is due primarily to the difference in imagery used (satellite based imagery vs. aerial photography) and the mapping protocol employed (machine derived classification vs. heads up digitizing).

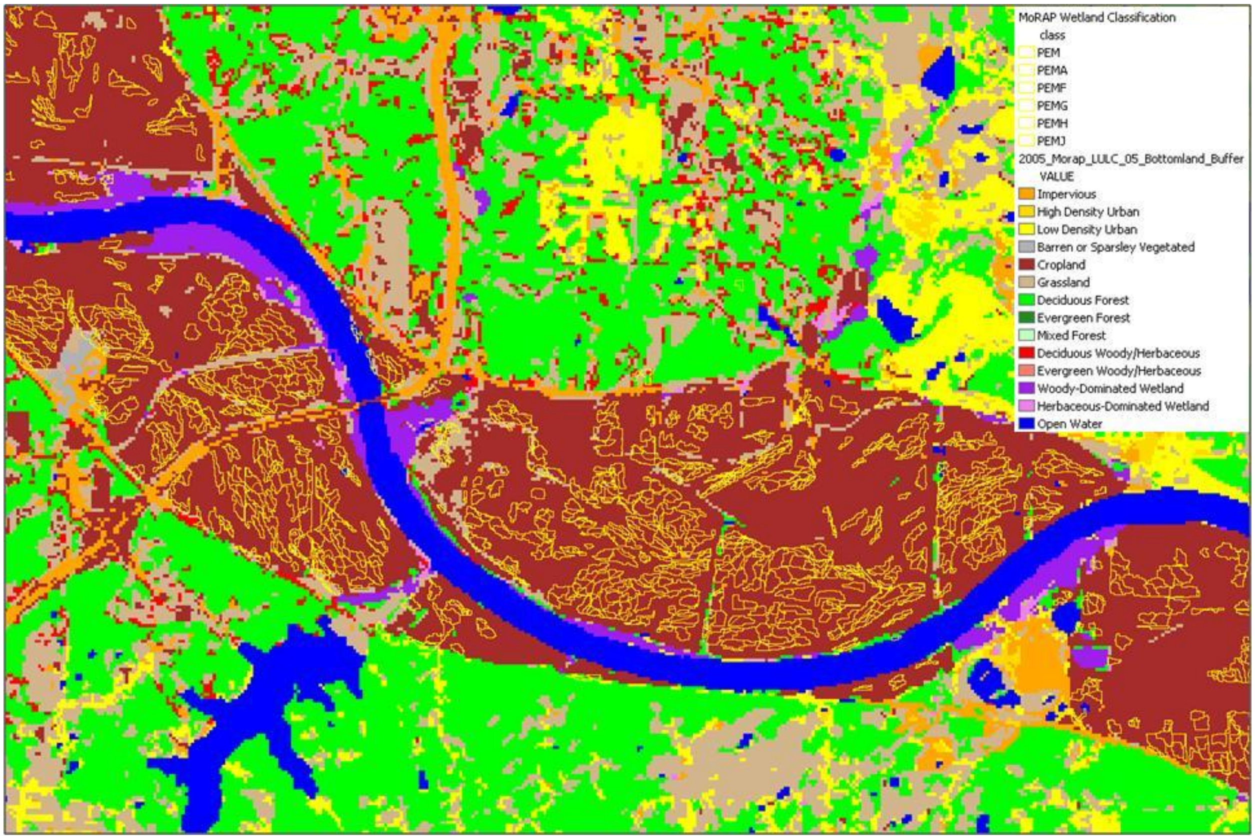


Figure 15. Example of Emergent Wetland being mapped in areas where active agricultural practices are being employed.

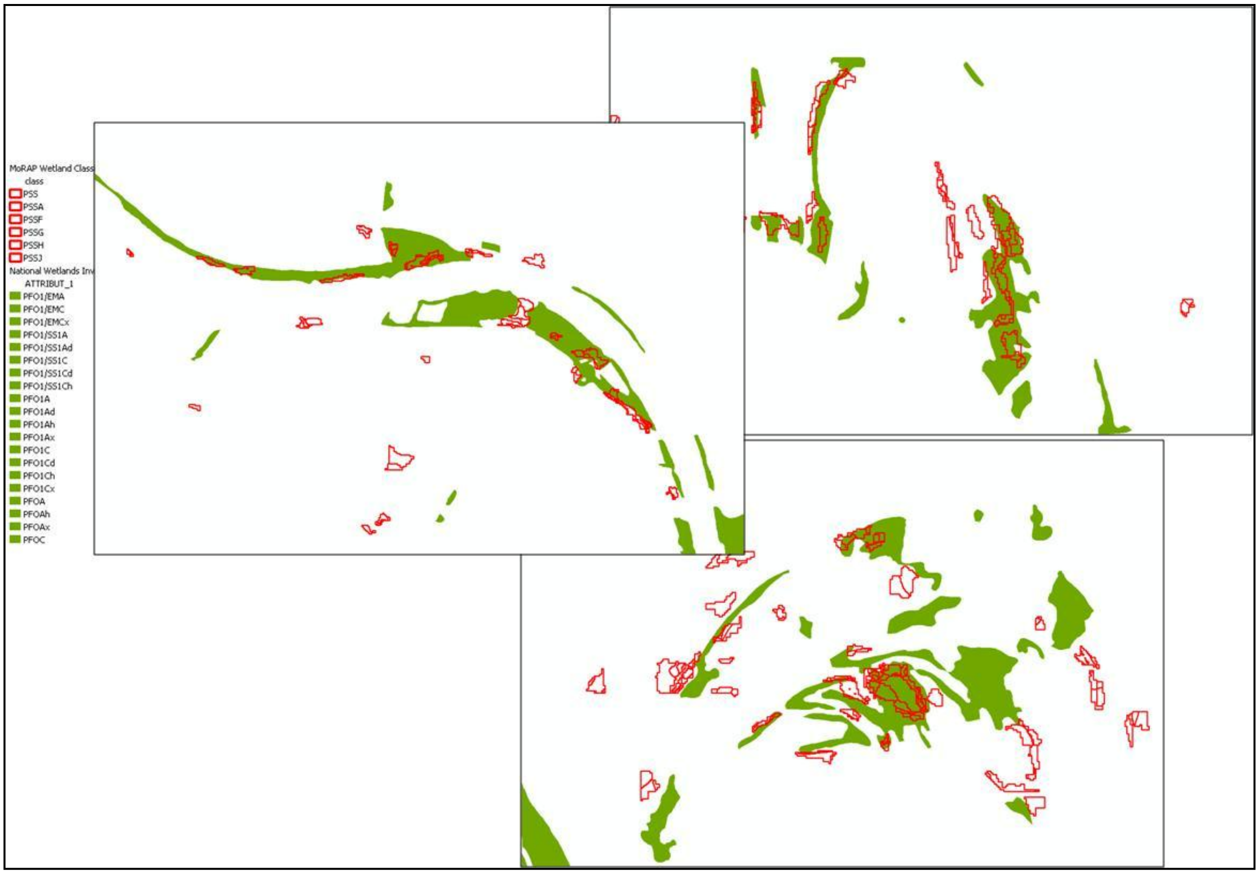


Figure 16. Comparison of areas where NWI mapped Forested Wetlands, but the new classification mapped Scrub/Shrub Wetlands.

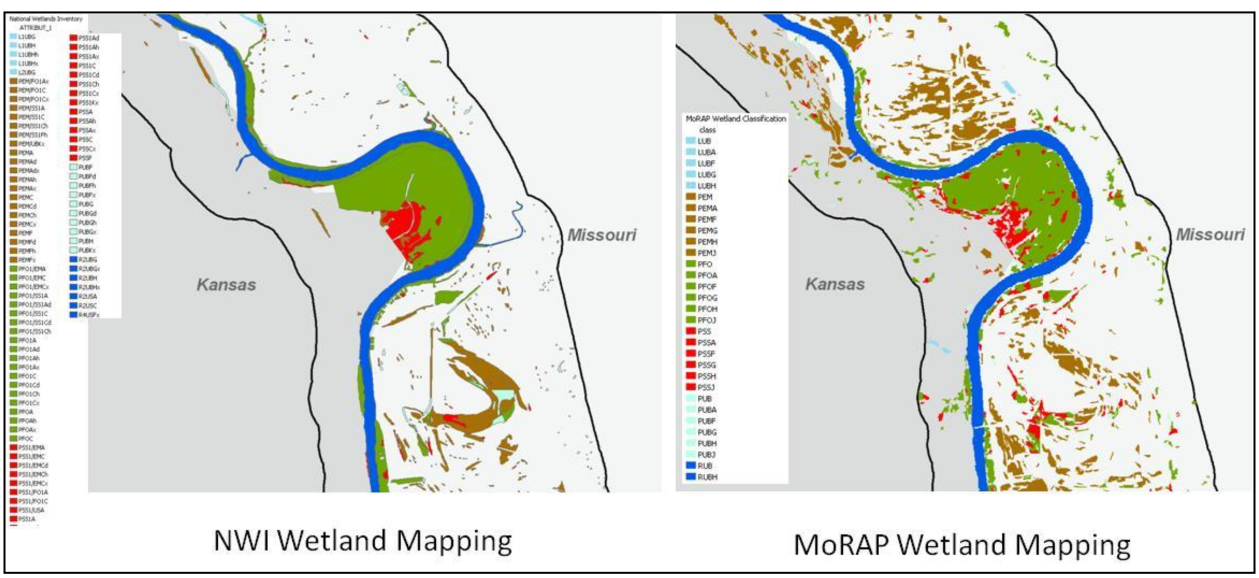
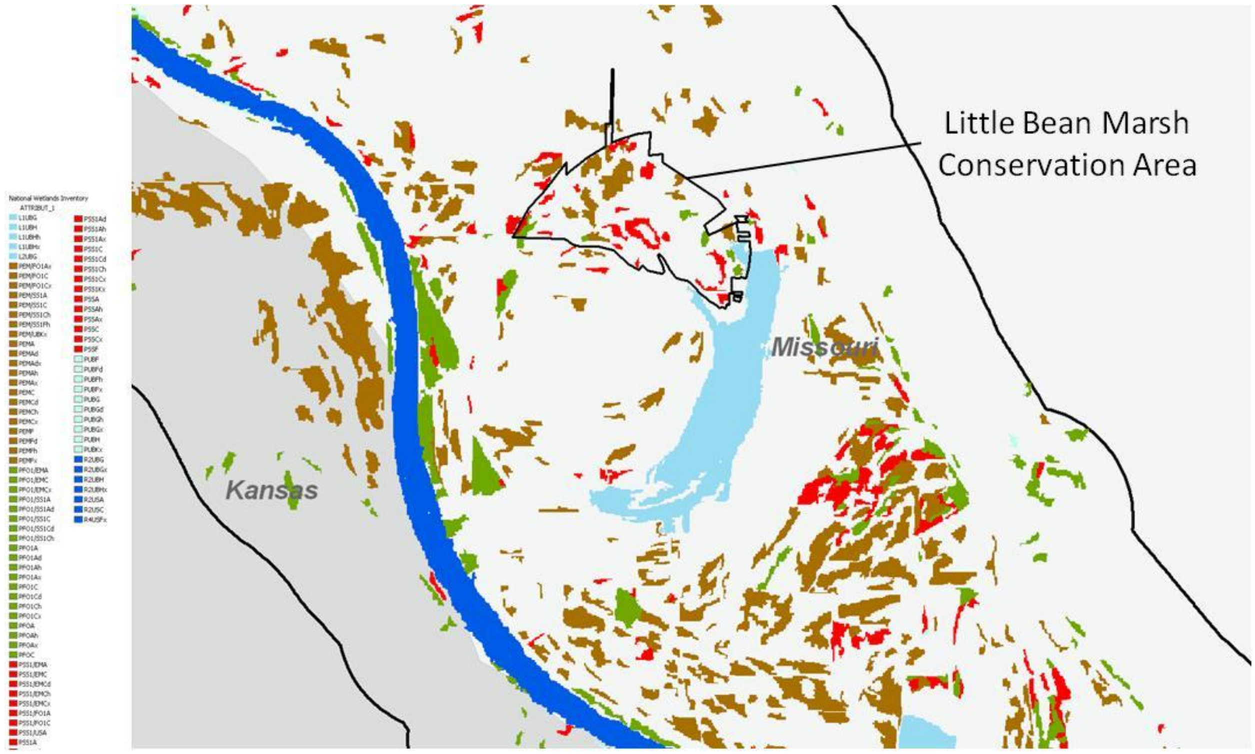
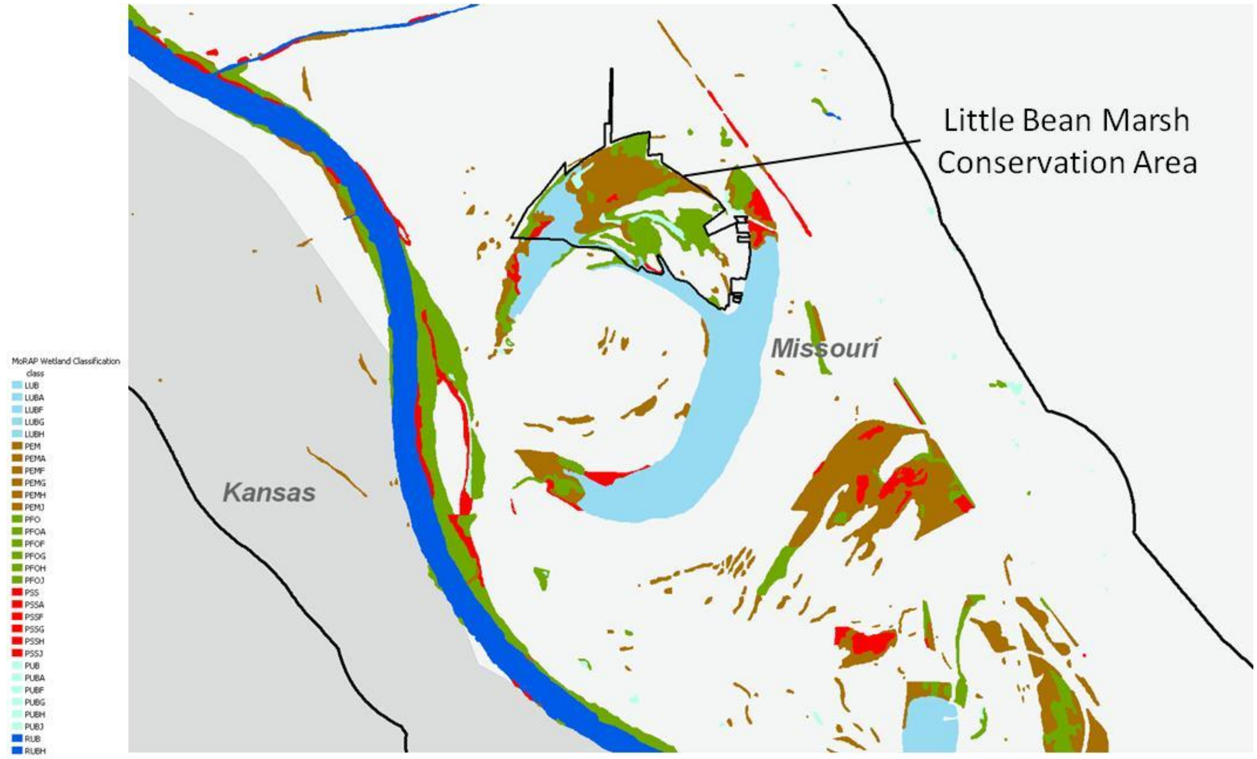


Figure 17. Comparison of wetland maps over the Weston Bend area of the Missouri River.



MoRAP Wetland Mapping

Figure 18. Little Bean Marsh conservation area mapped with the object oriented approach.



NWI Wetland Mapping

Figure 19. Little Bean Marsh conservation area as mapped by the National Wetlands Inventory.

Results from the potential wetland restoration areas model indicate that within the EPA study area boundary, just over 7% of the total area is considered to be ideal for herbaceous wetland in low lying areas with poor soil infiltration (Figure 20.). These are locations where water will naturally flow and the soil infiltration rate is slow so that water will pond and remain for an extended period of time. The presence of water in these locations is dependent upon rainfall. The majority of the study area falls into the intermediate category somewhere between low areas with poor soil infiltration and high areas with good soil infiltration. Approximately 14% of the area is considered to be ideal for bottomland forest restoration, indentifying areas within the floodplain that are higher than surrounding areas and have soils with good infiltration rates (Figure 20). These areas are dryer than surrounding lands, but still in a relatively wet environment, which is suitable for bottomland forests.

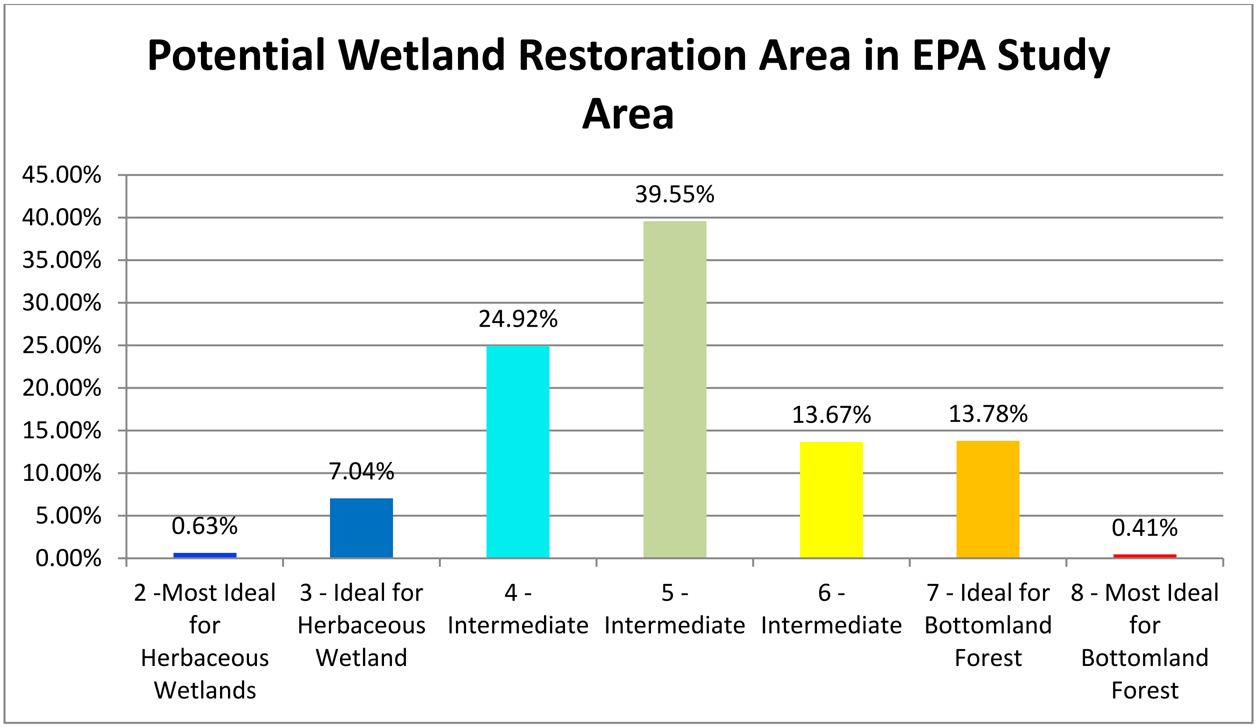


Figure 20. Percent of EPA Wetland Study area suitable for potential wetland restoration.

Conclusion

The object oriented mapping approach was successfully applied to the mapping of wetlands along the Missouri River. But the accuracy of that mapping is in question. The wetlands portrayed in the new classification appear reasonable when compared to the imagery used for the project, but when compared to the current standard, the National Wetlands Inventory, they come up lacking. The difference in the imagery used and the mapping techniques employed are a part of the reason why the two classifications do not compare more favorably. An intensive, on the ground, field sampling effort would determine the true accuracy of the wetland product.

The single brightest point from the mapping point of view was the inclusion of the Radarsat-1 imagery into the classification process. This data allowed for the accurate differentiation between treed and non-treed areas that would have been otherwise confused using only the optical (Landsat and SPOT) imagery. With a 3 meter spatial resolution product now available, the inclusion of radar data into mapping projects where vegetation structure is important is a must.

The potential wetland restoration model provides precise locations where wetland restoration may be suitable, from herbaceous wetlands to forested bottomlands. The results of the model can be a powerful aide in targeting locations to be considered for restoration projects. However, this model does not take into consideration where wetlands currently exist or urban and impervious areas, where wetlands can not be created without considerable effort. Use of the dataset with the current wetland map can provide information regarding the existence of current wetlands. The use of the landscape context layer can help with the latter by identifying candidate areas by proximity to public lands, natural vegetation, and urban areas. All in all, this model provides a simple, yet robust method to identify ideal locations for potential wetland restoration.

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