Using Wetland Mapping to Guide Restoration Decisions and Determine Wetland Trends: Final Report

FY2015, §104(b)(3), CD-01F10501 Project 2

Submitted by:

Oklahoma Conservation Commission

Water Quality Division

2800 N Lincoln Blvd, Suite 200

Oklahoma City, Oklahoma 73105

Phone: (405) 522-6908

January 2018

INTRODUCTION

The Oklahoma Conservation Commission (OCC) has partnered with Oklahoma State University to (1) update National Wetland Inventory (NWI) maps within 2 priority watersheds, (2) estimate wetland losses/gains, and (3) identify potential wetland restoration sites within these watersheds. This final report summarizes our efforts to meet all objectives of the US Environmental Protection Agency (USEPA) Wetland Program Development Grant: FY15 §104(b)(3) CD-01F10501, Project 2.

It has been estimated that approximately 67% of wetlands in Oklahoma have been lost since European colonization and that wetlands currently only comprise 2.1% of the area in the state (Dahl 1990). Because wetlands provide essential hydrologic, biogeochemical and habitat functions (Brinson 1993), it is critical that we understand where wetlands have historically existed and where they currently remain. Documenting the causes and locations of wetland loss can aid planning efforts to reduce future loss. Furthermore, wetland managers can implement wetland loss data to inform management decisions. For example, rates of wetland loss can be integrated into a ranking system for prioritizing watersheds in non-point source pollution prevention programs. Additionally, rapid assessment methods of wetland condition have integrated metrics that include an assessment of wetland loss on the landscape (Johnson et al. 2013). In this report, we assess the historic wetland loss in two priority watersheds (Tishomingo and Little Deep Fork), and the feasibility of including a historic loss metric into the Oklahoma Rapid Assessment Method (OKRAM) used for evaluating wetland condition. We then applied the Restorable Wetlands Identification Protocol (RWIP), a recently developed tool by OCC (2016), to identify potential restoration areas in these watersheds. The RWIP consists of three components (1) identification of potential historic wetland areas, (2) organization of sites based on the likelihood of restoration success, and (3) prioritization of restoration sites for the improvement of downstream receiving water quality. This effort will provide targeting for protection and restoration of wetlands and an avenue through the Nonpoint Source Management Strategy (NPS) Program to improve water quality in Oklahoma. In addition, wetland areas targeted for restoration or rehabilitation could be utilized for future mitigation needs.

METHODS

NWI Mapping

NWI Maps were updated for two priority watersheds selected for this study, Tishomingo HUC 10 (1113030402) and Little Deep Fork HUC 10 (1110030308) watersheds (Figure 1). Complete updated NWI maps for the study watersheds were created using on-screen or “heads-up” mapping in ARCGIS 10.1 and following the guidelines of Dahl et al. (2009). National Agriculture Imagery Program (NAIP) images from 2015 served as the primary base layer. However, additional aerial images from 2003, 2006, 2008, 2010 and 2013 were relied upon to assess dynamic wetland boundaries. We also relied on collateral datasets that included digital elevation models (DEMs) generated by U.S. Geological Survey (USGS) and soil survey geographic database (SSURGO) layers generated by the Natural Resource Conservation Service (NRCS). All wetlands were attributed according to the Cowardin Classification System (Cowardin

et al. 1979) and Federal Geographic Data Committee (FGDC) compliant metadata were included (FGDC 2009). Personnel conducting wetland mapping completed the USFWS training about NWI provided at:
http://www.fws.gov/habitatconservation/nwi/wetlands_mapping_training/index.html.

Once draft wetland maps were completed, project employees completed quality assurance protocols. Quality control included a complete screen-by-screen review of all wetland polygons displayed on base imagery and utilization of collateral datasets. Quality control was conducted by staff not involved in the initial mapping effort, but trained in NWI mapping procedures. Additionally, the USFWS NWI Wetlands Data Verification Toolset was applied to identify any potential mistakes in wetland maps (Bergeson 2011).

Wetland Loss/Gains

Wetland loss/gain metrics were calculated by comparing newly updated National Wetlands Inventory (NWI) maps with historic aerial imagery. Once current maps were completed, they were overlaid on historic aerial imagery to assess changes in wetland area. In the Tishomingo Watershed, aerial imagery from 1963 was used (Figure 2) and in the Little Deep Fork Watershed, aerial imagery from 1969 was used (Figure 3). Originally, we had planned to use earlier aerial imagery, but the limited coverage of aerial imagery in the study watersheds precluded use of imagery earlier than the 1960s. The small portions of the study watersheds for which aerial imagery was not available were excluded from status and trends calculations.

Historical images were georeferenced using ESRI ArcMap 10.4. Current NAIP imagery from 2015 acquired from the USDA was used as the reference layer. NAIP collects aerial images during the growing season at 1-meter ground sampling distance and provides orthorectified and georeferenced products that utilize the Universal Transverse Mercator (UTM) projection and NAD83 coordinate system. In ArcMap, the NAIP imagery served as the reference layer and the un-referenced historical imagery was the “georeferencing layer”. After orienting both sets of images, we identified landmarks present on both layers (historical and current images) to serve as Ground Control Points (GCP). We selected appropriate GCPs that were not likely to change between the two image timeframes (e.g., road and building features). We also selected a minimum of 5 GCPs from across the entire layer to reduce image warping that often results from clustered GCPs. For each GCP located on both images, the historical image shifted so that both layers were more closely aligned. Increasing the amount of GCPs used increased certainty in the georeferencing. Finally, we calculated the root mean square (RMS) error to evaluate the accuracy of the georeferencing process. We used GCPs that produced RMS error values below 30 m for each image. Average RMS error for Tishomingo and Deep Fork images was 7.7 m and 4.5 m, respectively. After georeferencing, the historical imagery was contained in the same projection and coordinate system as the reference layer (UTM, NAD83).

In order to calculate wetland losses and gains in each watershed, we followed a protocol based on Dahl and Bergeson (2009). The current wetland layer was overlaid on the georectified historic aerial imagery and attributed with historic wetland status determined through visual inspection of historic imagery. Wetlands observed on the historic imagery, but unmapped in the current wetland map layer, were mapped following NWI protocols (Dahl et al. 2009, FGDC 2009) for boundary delineation and classification. Disagreement between the historic and current wetland map was only recorded as a change if there were visible signs of alteration that removed or created a wetland (e.g., ditching, excavation, topographic leveling, and impoundment). Furthermore, boundary differences of a wetland polygon between images were not considered to be true change without evidence of alteration. Each wetland polygon in the wetland loss/gain layer was then attributed with (1) historic wetland class, (2) current wetland class, (3) evidence of alteration, (4) historic land-use, and (5) current land-use (Table 1).

We then calculated the total area of wetlands lost as well as those gained. We also calculated statistics for Cowardin wetland classes and upland land-use attributes to determine the wetlands most susceptible to loss, the land-use that most commonly replaced lost wetlands, and the types of wetlands created. For wetlands present in historic imagery but subsequently lost, the land-use that replaced the wetland was determined through visual inspection of current NAIP imagery and 2011 National Land Cover Data (NLCD). For wetlands constructed after collection of historic imagery, historic land-use was determined solely through visual inspection of the historic imagery. Using these data, we determined the area of wetlands in each Cowardin class lost to specific upland land-uses, as well as the area of wetlands in each Cowardin class created from specific land-uses.

Initially, we planned to evaluate the feasibility of an OKRAM metric that calculates historic wetland loss. OKRAM is a stressor- based condition assessment that aggregates hydrologic, water quality and biotic metrics into an overall score of wetland quality (OWRB 2015). We planned to calculate wetland loss at several scales surrounding a number of wetlands to determine the range in scores. However, it was clear after completing the loss/gain calculations that this is not feasible at this time. More details on OKRAM metric feasibility are provided in the discussion.

RWIP

The protocol developed to identify potential wetland restoration sites in Oklahoma was based on methods developed in Wyoming (Robertson 2012), Wisconsin (Hatch and Bernthal 2008) and Minnesota (Donnelly 2001). The RWIP was conducted in geographic information systems (GIS) and followed the steps outlined in Appendix A. The initial step is to identify where wetlands have likely been lost by comparing the historic extent of wetlands to the current extent. The potential historic extent is approximated by poorly drained soils from SSURGO and the current extent is represented by NWI. Potential restorable wetlands exist where poorly drained soils occur and no NWI polygons are mapped. These areas were further filtered based on hydrology, topography, and surrounding land-use to determine the likelihood of restoration success. Digital elevation models (10 meter resolution) were used to identify basins and potentially restorable areas not in basins were excluded. Additionally, poorly drained soils that now occur in high intensity or mid intensity urban areas, water, or barren land-cover were deemed non-restorable. Land-use/land-cover data were obtained from the 2011 NLCD. Furthermore, because wetland restoration sites require a water source, we filtered the list of potential restoration locations to ensure that sufficient flow was available to restore wetland hydrology. This was accomplished by creating a flow accumulation layer from DEMs. The degree of flow required was manually determined for each watershed based on best professional judgment of regional climate and drainage patterns.

Finally, the completed potential restorable wetlands layer was prioritized based on the potential for a site to improve the water quality of downstream receiving waters. Each potentially restorable polygon was attributed with (1) wetland size, (2) watershed to wetland ratio, and (3) percent crop and urban land-use within the restorable wetland watershed. These attributes provide information on the degree to which a restored wetland can improve water quality to downstream receiving waterbodies. Larger sites can capture and treat more runoff than smaller sites. Furthermore, sites that are relatively large compared to their watersheds have a greater probability of receiving and treating runoff prior to outflow. Sites surrounded by human-altered land-uses are more likely to receive runoff in need of treatment (e.g., high quantities of nutrients and sediment). Each attribute (e.g., wetland size) is scored 1 to 4. Scores for all three attributes are summed to provide a total possible score ranging from 3 (least likely to improve water quality) to 12 (most likely to improve water quality). For each attribute, the scores (i.e., 1 through 4) are determined based on the quartiles for all the potentially restorable sites within the study watershed. For example, the largest 25% of sites within a specific watershed are given a score of 4 for the wetland size attribute, while the smallest 25% receive a score of 1. For each potentially restorable wetland, all attributes are also scored on a statewide scale with pre-determined thresholds set for the entirety of Oklahoma. Calculating the attribute on watershed and statewide scales allows for the comparison of sites to determine optimal restoration locations both within a watershed and for all of Oklahoma. More information on the development of the RWIP can be found in OCC (2016).

RESULTS and DISCUSSION

NWI Mapping

The Little Deep Fork watershed covers 67,793 ha, in which a total of 3,851 wetlands (2,530 ha) were mapped using 2015 NAIP imagery. There were approximately 160 ha of freshwater emergent wetlands, 1,221 ha of freshwater forested/shrub wetlands, 880 ha of freshwater ponds, 171 ha of lacustrine wetlands, and 98 ha of riverine wetlands mapped. The Tishomingo watershed encompasses 55,785 ha and a total of 2,524 wetlands (5,450 ha) were mapped using 2015 NAIP imagery. There were 238 ha of freshwater emergent wetlands, 2,168 ha of freshwater forested/shrub wetlands, 684 ha freshwater ponds, 2,116 ha of lacustrine wetlands, and 244 ha of riverine wetlands mapped. For more information, completed maps can be found at the Oklahoma Wetlands Program Website (https://www.ok.gov/wetlands).

Wetlands Losses/Gains

Overall, the amount of wetland area in both of the watersheds increased from the historic maps (1960s) to the updated current NWI maps (2015) (Table 2). In the Tishomingo Watershed, wetland area increased by 378 ha or an approximate 8% increase in wetland area. An increase in the number of farm ponds in the watershed accounted for most of this increase; there was a 330 ha increase of unconsolidated bottom (PUB) wetlands, which was attributed to farm ponds. We did document the loss of a few farm ponds due to filling or sedimentation, but the number of ponds constructed was approximately 50 times greater than that of ponds lost. We also found an increase in the amount of forested (PFO) and scrub shrub (PSS) wetlands. The increase in PFO wetlands was primarily from reforestation of emergent wetlands as well as sedimentation around deepwater reservoirs and subsequent vegetation to forested habitat. There was a decrease in the amount of emergent (PEM) wetlands in the watershed, but the majority of PEM area lost during this period was due to conversion to PFO (Table 3). Another source of wetland change in the watershed was the result of water level fluctuations in the upper reaches of Lake Texoma that converted deepwater habitat into vegetated wetlands through sedimentation. In fact, more than 95% of the wetland area "created" in this watershed was attributed to wetland creation in these upper reaches. However, the amount of wetland area created by sedimentation was offset by the loss of similar amounts of vegetated wetland surrounding the lake being converted to deep-water habitat during the same time period (Table 4).

In the Little Deep Fork Watershed wetland area increased by over 1,000 ha or an approximate 69% increase in wetland area (Table 2). We also documented an increase in wetland area for all wetland classes during the time period. Similar to the Tishomingo Watershed, the increase in farm ponds and associated flooded vegetation accounted for most of the increase in wetland area. Within the watershed, more than 750 ha of farm ponds and small reservoirs were created from forested uplands and grasslands since 1969 (Table 3). The remainder of the increase in wetland area was due to flooding of forests and grasslands surrounding the impoundments (i.e., fringe habitat; Table 4). Overall, wetland loss in the Little Deep Fork Watershed was minimal and any losses were mitigated by creation of new wetlands during the time period.

Overall, we found the amount of wetland area increased in both watersheds from 1969 to 2015. In both watersheds, the construction of farm ponds was the primary explanation for the increase in wetland area. These results follow the nationwide trend for the period, during which much of the increase in wetland area was due to pond construction (Dahl et al. 1991). Ponds function as deep water aquatic habitat in most cases. While ponds do provide some wetland functions, including habitat and water storage, they often lack the wet-dry cycles typcial of wetlands and necessary for a number of other wetland functions (i.e., biogeochemical). However, pond construction can lead to increases in wetland area. In the Little Deep Fork in particular, the construction of farm ponds has led to the creation of forested and emergent wetland habitat in areas adjacent to the pond. Larger ponds are often associated with emergent wetland fringes and forested wetlands in the upstream portion where stream inputs are backed-up. Additionally, as ponds "age" and fill-in with sediment, they may acquire a wet-dry cycle more typical of depressional wetlands. While ponds can provide some wetland functions, these areas function more as deepwater habitat and do not replace the functions lost to natural wetland conversion.

We also found very little evidence of wetland loss. There are several explanations for this. Firstly, it possible that most of the wetland conversion in these watersheds to agricultural and urban land-use happened prior to the 1960s. We had initially planned to utilize earlier aerial imagery, but the availability of images from previous decades was limited. Secondly, it is possible that wetlands were missed in the historic aerial imagery due to the reduced quality of the images. The historic imagery is black and white photography with average pixel size ranging from 1.7 to 5.1

meters, while current NAIP imagery is collected in color-infrared with 1 meter pixel size. The additional spectral bands and improved resolution of NAIP imagery is almost certain to make identification of small wetlands easier. It is also possible that pond construction locations were selected because of the tendency of those sites to store water. However, due to the relatively small size of these ponds, it is quite difficult to discern the hydrology in the 1960s imagery. In other words, it is possible that ponds were constructed in small natural wetlands, but it is not possible to determine this from historic imagery. Figure 4 shows an area before and after pond construction. It appears that the location may be wet in the early image but it is very difficult to delineate a wetland with any certainty. An alternative to comparing current and historic aerial imagery moving forward may be to use current high resolution aerial imagery (e.g., WorldView-3, DigitalGlobe) to map the presence of hydrologic alterations such as ditches to infer wetland loss.

Originally, we had planned to determine the feasibility of developing a landscape metric for OKRAM that assesses the historic loss of wetlands surrounding a study site. However, due to the negligable wetland loss identified in both watersheds, we determined that this metric is not feasible at this point. Because of the potential influence that surrounding wetlands have on ecosystem function, other states have integrated historic wetland loss metrics into rapid assessment methods (e.g., Colorado, FacWET; Johnson et al. 2013), The loss of surrounding wetlands can influence the functionality of a wetland ecosystem, particularly for organisms that require closely connected networks of wetlands for population or community dynamic maintenance (Liebowitz 2003). However, at this time we do not have accurate spatially-referenced data on wetland loss. If we are able to develop measurements of wetland loss using older aerial imagery or by mapping hydrologic alterations (ditching), we will reconsider the addition of a historic wetland loss metric to OKRAM.

RWIP

RWIP results are presented in Figure 5 and summarized by HUC-10 watershed in Table 5. The RWIP identified 224 potential wetland restoration sites in the Little Deep Fork Watershed. Sites ranged from 0.2 to 33 ha, with a median of 0.5 ha. Of those sites, 28 received scores of 10 or above for potential to improve water quality within the watershed. Initially, following the established methods, the RWIP did not identify any potential wetland restoration sites in the Tishomingo Watershed. We determined that in the Tishomingo Watershed there were few poorly drained soils and few areas of zero slope. We adjusted the protocol criteria to include moderately well-drained soils and basin slopes less than or equal to 0.5%. With the updated criteria, the RWIP identified 225 potential wetland restoration sites. Sites ranged from 0.2 to 57 ha with a median of 0.4 ha. Of the 225 potential sites, 46 sites received scores of 10 or above. Examples of potential restoration sites with high priority are presented in Figure 6.

After identification of potential restoration sites in each watershed, we entered 10 of the highest ranked sites (score of 10-12) into the Wetland Registry (OCC 2014). Among the highest ranked sites, the 10 selected in each watershed were chosen after visual observation of aerial photography. Signs of restoration potential included proximity to water source, marginal hydrology (i.e., wet field or pasture), and obvious hydrologic alteration (e.g., ditching). The

Wetland Registry (OCC 2014) is a database that can be queried to identify suitable restoration opportunities that meet the size and location requirements of a party in need of restoration. Fillable forms on the Wetland Program Website (www.wetlands.ok.gov) can be used to request a search of the database.

Initially, we planned to field verify a subset of sites in each watershed and assess landowner interest in pursuing restoration. However, after the initial application of RWIP in the North Canadian Watershed in 2016, we found that while several landowners granted us permission to access the property and conduct an assessment of the wetland, they were generally disinterested in continued communication (OCC 2016). We believe that in general the hypothetical concept of future restoration on private property is too vague to interest most landowners. As a result, given the amount of time required to gain landowner permission, we believe it is more efficient (in most cases) for those in need of restoration to determine the suitability of restoration sites listed in the Wetland Registry. The primary advantage of this being that landowners are made aware of a more concrete opportunity to generate income through restoration. We plan to continue to add potential restoration sites identified through RWIP in these watersheds to the Wetland Registry as time allows. In 2017, we received 8 requests for Wetland Registry searches. Continued promotion of the Wetland Registry will also be a priority moving foward. Combining statewide RWIP application with the Wetland Registry will help streamline wetland restoration in Oklahoma by identifying potential restoration locations, prioritizing those locations based on the level of functions restored (e.g., water quality improvement) and providing those locations to the public in an easily searchable format.

CONCLUSION

Maintaining updated NWI maps is critical for wetland monitoring and management. Wetland maps are used for preliminary determinations of permitting requirements under Section 404 of the Clean Water Act. Additionally, wetland maps can be integrated into other analyses for calculating trends in wetland loss/gain, assessing condition, and identifying potential restoration sites. We have updated wetland maps in the Tishomingo and Little Deep Fork watersheds in Oklahoma, where previously created maps are now over 35 years old. These new maps will provide more reliable desktop approximations of the location and extent of wetlands. Additionally, we have utilized those new maps to track changes in wetland area since the 1960s and locate potential restoration sites. Based on a comparison of these updated maps with historic aerial imagery, we found that wetland area has increased in both watersheds. However, the increase in wetland area is primarily due to the construction of farm ponds. These ponds do not provide all of the typical ecosystem functions of wetlands that maintain seasonal wet/dry cycles. Furthermore, it is possible that historic wetland losses were underestimated in this study due to the relatively lower resolution of historic imagery and the age of the historic maps. Future studies of historic wetland loss in Oklahoma may need to focus on using more recent high resolution imagery to detect indicators of wetland loss such as ditching and tile drainage or focus in areas where there is good coverage of older aerial imagery (i.e., 1940s).

Because wetlands continue to undergo degradation from anthropogenic impacts (e.g., point and non-point source runoff, road construction, and conversion to farm ponds), it is important that we continue to update NWI maps and identify areas where wetlands have been lost. Protocols such as RWIP provide an invaluable tool for identifying the location of potential wetland restoration areas that can be restored to offset development impacts requiring mitigation under §404 of the Clean Water Act. RWIP prioritizes restoration areas based on their potential to provide wetland functions such as improving water quality downstream. In the study watersheds, we have identified approximately 450 potential restoration opportunities. Integrating RWIP with the Wetland Registry, hosted on the Wetlands Program Website, will help expedite restoration projects that improve water quality in these watersheds and throughout Oklahoma.

REFERENCES

Bergeson M.T. (2011) Wetlands Data Verification Toolset: Installation Instructions and User Information. U.S. Fish and Wildlife Service, Washington, D.C. 6pp.

Brinson, M.M. (1993) A Hydrogeomorphic Classification for Wetlands. Technical report WRP-DE-4. U.S. Army Corps of Engineers, Waterways Experiment Station, Washington, D.C. 79 pp.

Cowardin, L.M., V. Carter, F.C. Golet, and E.T. LaRoe (1979) Classification of Wetlands and Deepwater Habitats of the United States. USDI Fish and Wildlife Service, Washington, D.C. 142pp.

Dahl, T.E., J. Dick, J. Swords and B.O. Wilen (2009). Data Collection Requirements and Procedures for Mapping Wetland, Deepwater and Related Habitats of the United States. Division of Habitat and Resource Conservation, National Standards and Support Team, Madison, WI. 85 pp.

Dahl, T.E. and M.T. Bergeson (2009) Technical Procedure for Conducting Status and Trends of the Nation's Wetlands. U.S. Fish and Wildlife Service Division of Habitat and Resource Conservation, Washington, D.C. 74 pp.

Dahl, T.E., C.E. Johnson, and W.E. Frayer (1991) Wetlands Status and Trends in the Conterminous United States mid 1970s - mid 1980s. U.S. Department of the Interior, Fish and Wildlife Service, Washington, D.C. 28 pp

Dahl, T.E. (1990) Wetlands Losses in the United States 1780's to 1980's. U.S. Department of the Interior, Fish and Wildlife Service, Washington, D.C. 13pp.

Donnelly, C. (2001) Evaluating the Potential of Using a GIS for a Drained Wetlands Inventory: 7- County Metropolitan Area, Minnesota. Minnesota Board of Water and Soil Resources, MN. 17pp.

FGDC (2009) Wetlands Mapping Standard. USGS, Reston, Virginia. 39pp.

Hatch, B., and T. Bernthal. (2008) Mapping Potentially Restorable Wetlands in the Rock River Basin. Final Report. Wisconsin Department of Natural Resources, Madison, WI. 56pp

Johnson B, M. Beardsley, and J. Doran (2013) Functional Assessment of Colorado Wetlands (FACWet) Method- Version 3.0. Colorado Department of Transportation, Denver, CO. 126pp.

Liebowitz, S. G. (2003) Isolated wetlands and their functions: An ecological perspective. Wetlands 23:517-531

OWRB (2015) Oxbow System Assessment and Protocol Development Phase III: Final Report. Oklahoma City, OK. 125pp. FY2012 §104(b)(3) Wetland Program Development Project CD-00F42801, Project 2

Robertson, A. (2012) Mapping Potentially Restorable Wetlands in Wyoming. Presentation at the Association of State Wetland Managers State/Tribal/Federal Coordination Meeting.

OCC (2016) Method Development to Incorporate Wetland Resources into Watershed Planning efforts in Oklahoma: Final Report. Oklahoma City, OK. 22pp. FY2013 §104(b)(3) Wetland Program Development Project CD-00F56801, Project 1

OCC (2014) Wetland Registry: Final Report. Oklahoma City, OK. 14pp. FY2014 §104(b)(3) Wetland Program Development Project CD-00F74001, Project 2.

TABLES AND FIGURES

Figure 1. Study area for historic wetland mapping and wetland status and trends calculations

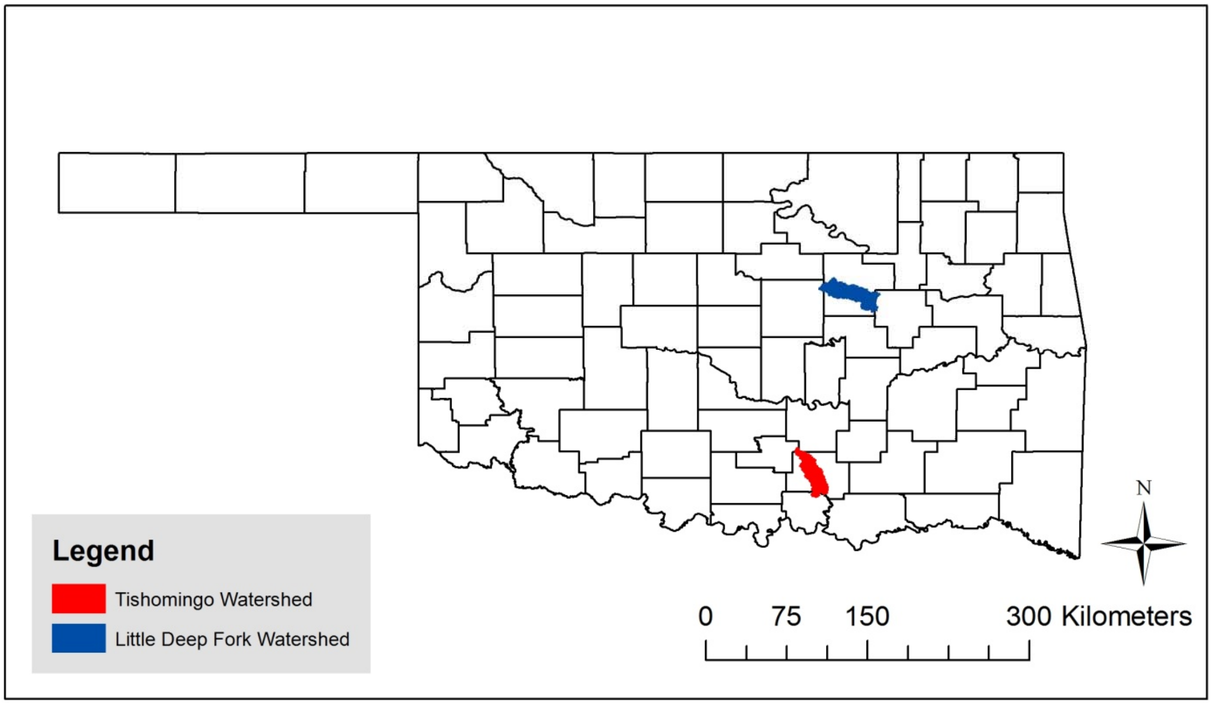


Figure 2. Historic aerial imagery available in the Tishomingo Watershed. Blue areas represent missing imagery

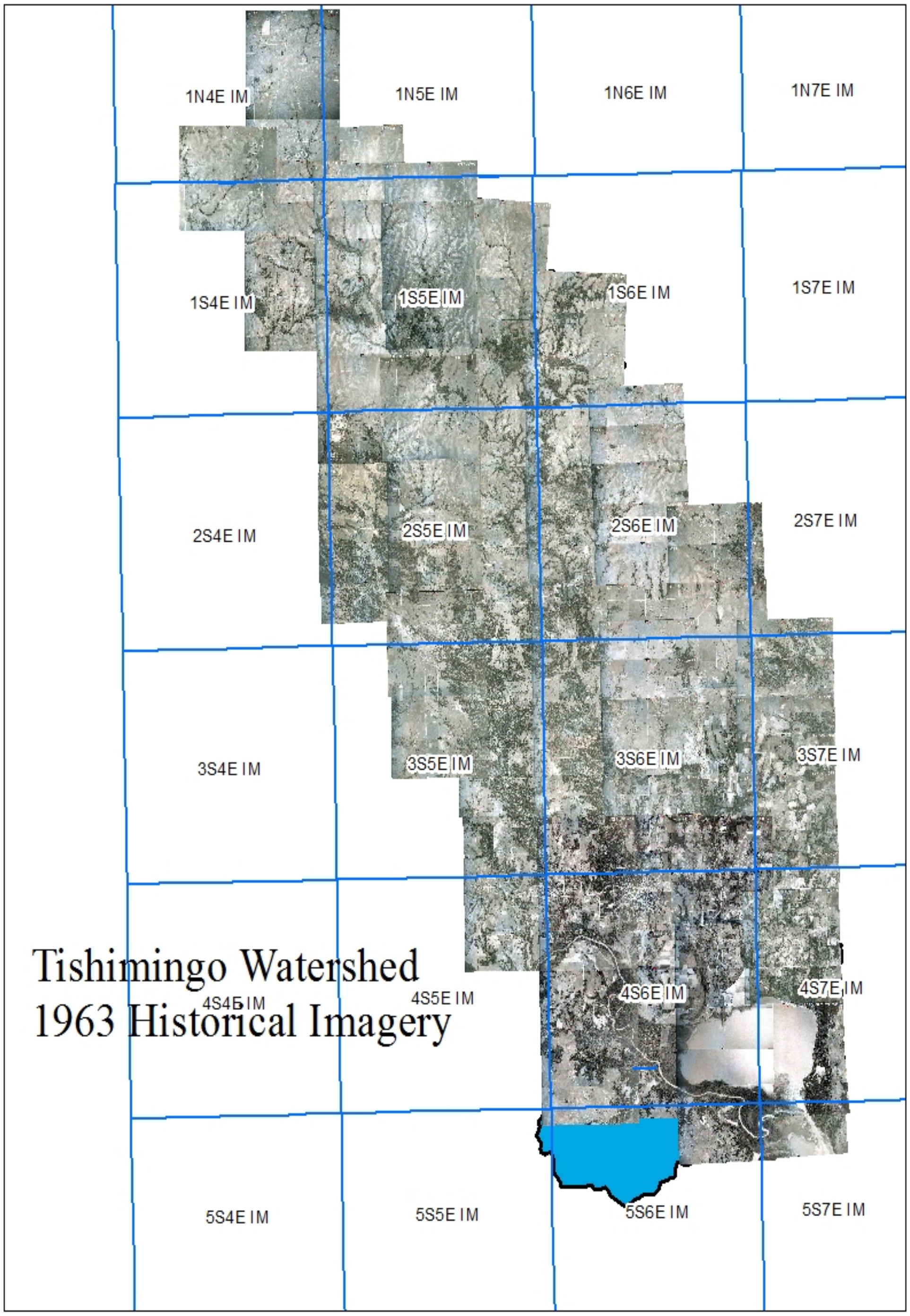


Figure 3. Historic aerial imagery available in the Little Deep Fork Watershed. Blue represents missing imagery

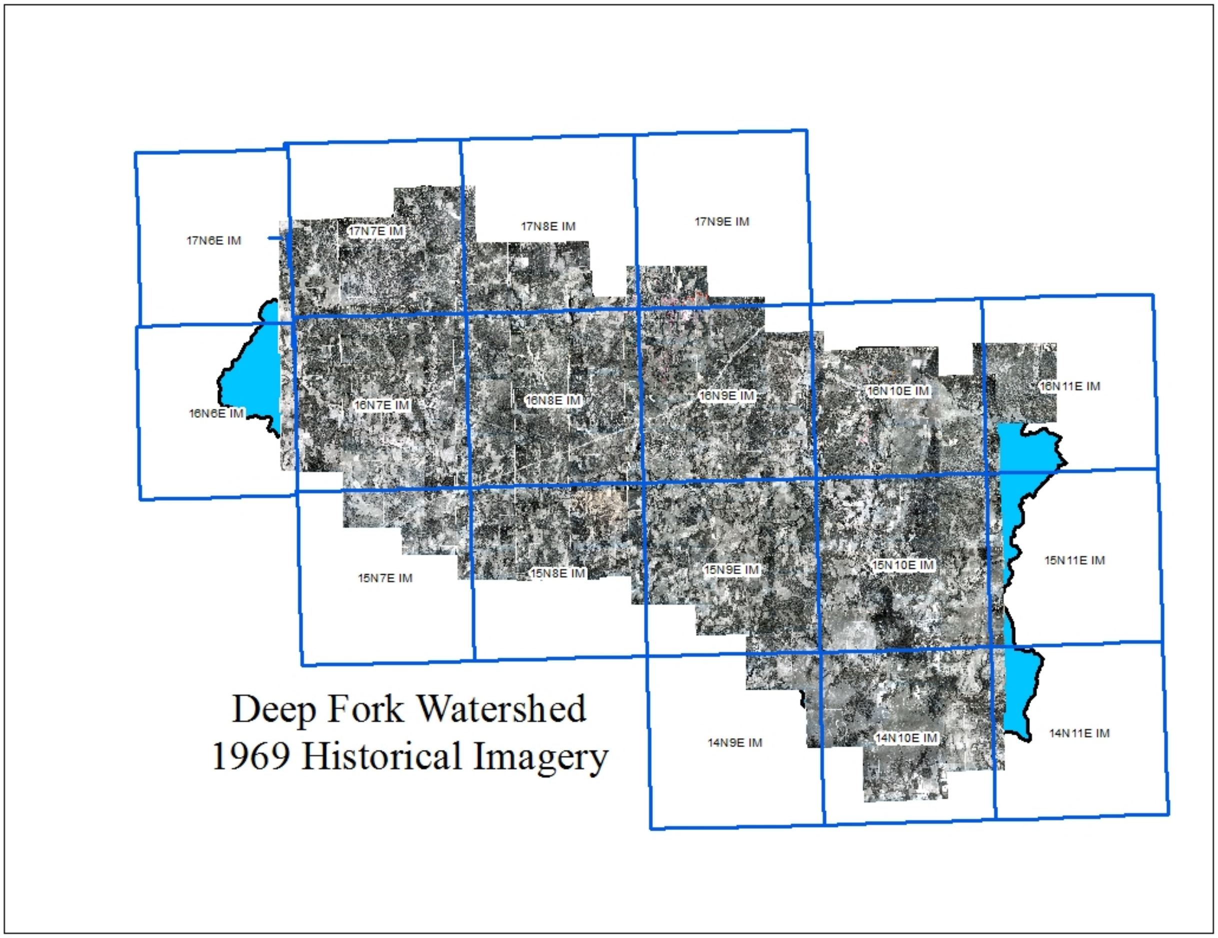
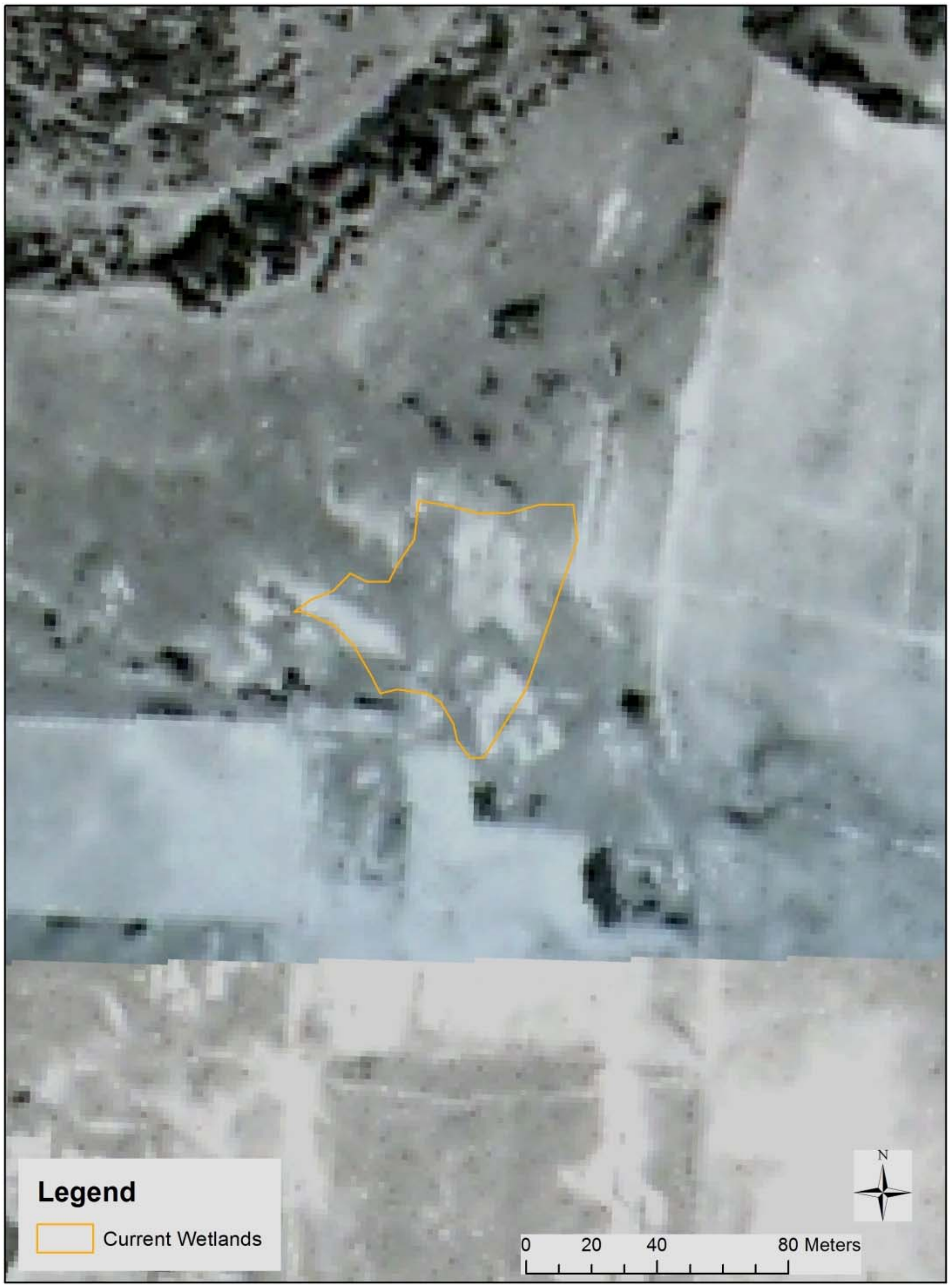


Figure 4. Pond construction in the Little Deep Fork watershed. (a) 1969 imagery before pond construction (b) 2015 imagery after pond construction

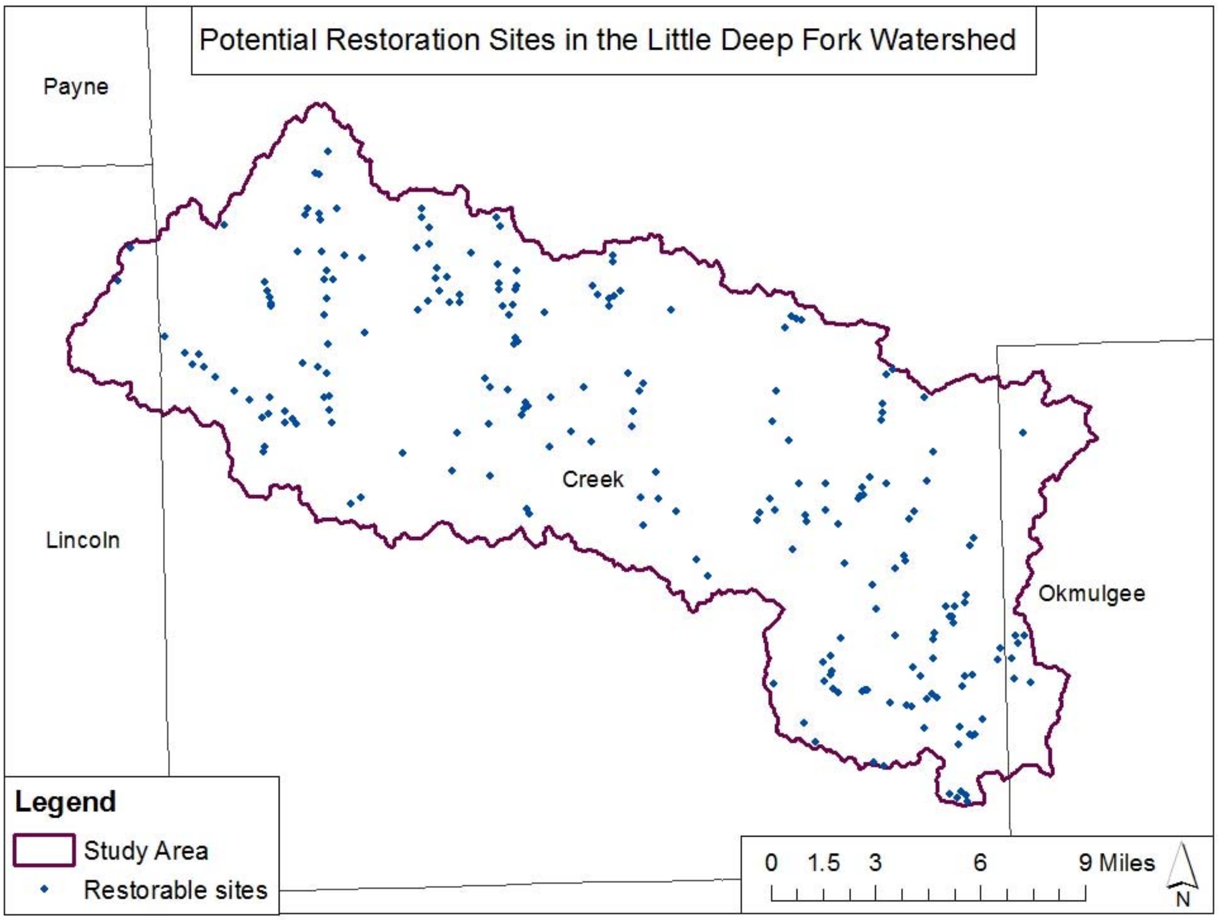
(a) 1969 Imagery



(b) 2015 Imagery

Figure 5: Locations of potential restoration sites identified through the Restorable Wetland Identification Protocol in the (a) Little Deep Fork Watershed and (b) Tishomingo Watershed

(a) Little Deep Fork Watershed



(b) Tishomingo Watershed

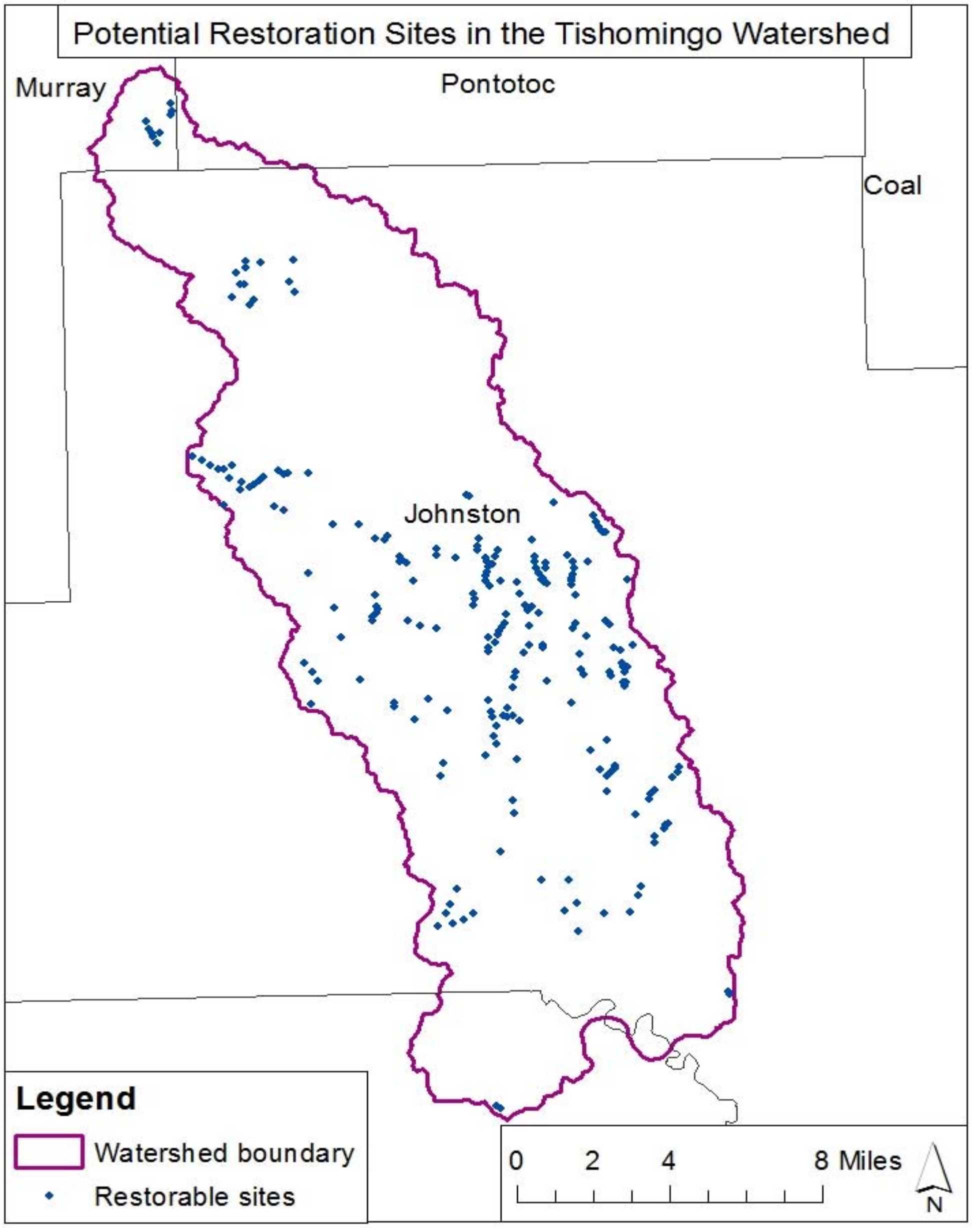
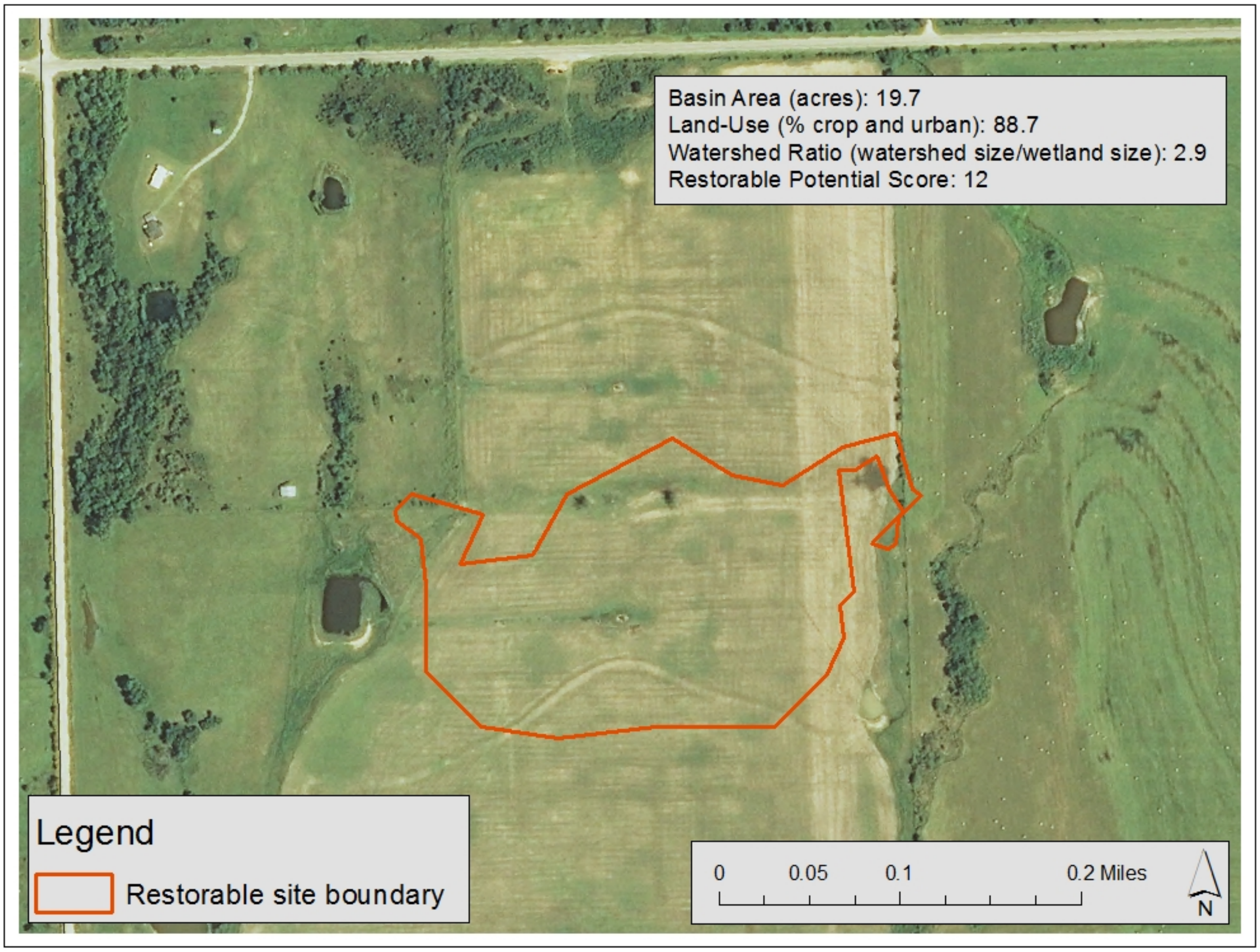


Figure 6: Examples of potential restoration sites in the (a) Little Deep Fork Watershed and (b) Tishomingo Watershed

(a) Little Deep Fork Watershed



(b) Tishomingo Watershed

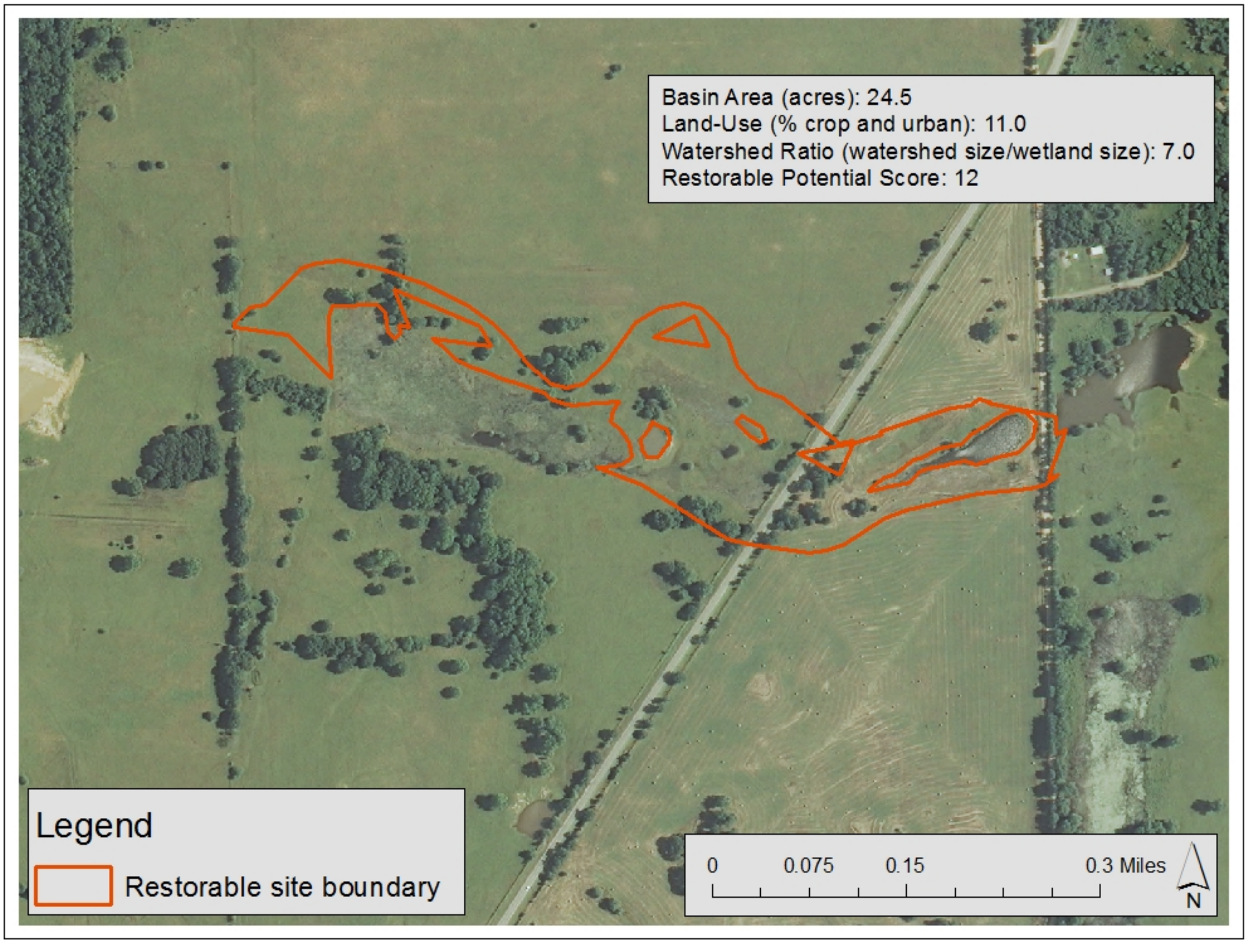


Table 1. Summary of codes used during historic mapping of wetlands. (a) Wetland and Upland Attribute Codes, (b) Wetland Alteration Codes, and (c) Change Indicators

(a)Wetland and Upland Attribute Codes

Wetland Code	**Attribute**	**Description**
RIV	Riverine	River systems
LAC	Lacustrine	Lakes and reservoirs
PEM	Palustrine Emergent	Inland marshes and wet meadows
PSS	Palustrine Scrub-Shrub	Shrub Wetlands
PFO	Palustrine forested	Swamps
PUBi	Palustrine unconsolidated bottom (industrial)	Flooded mines, treatment lagoons, holding ponds
PUBn	Palustrine unconsolidated bottom (natural)	Small natural lakes, beaver ponds, vernal pools
PUBf	Palustrine unconsolidated bottom (agricultural use)	Ponds in proximity to farming or cattle operations
PUBu	Palustrine unconsolidated bottom (urban)	Recreational ponds, golf course ponds, residential lakes
PUS	Palustrine unconsolidated shore	Natural shallow ponds
UF	Upland Forested	Natural and silvicultural forests
UG	Upland Grassland	Natural grasslands, rangelands, pasture and croplands
USS	Upland Scrub Shrub	Shrub uplands
UD	Upland Urban	Developed or paved areas
Modifiers	**Attribute**	**Description**
x	Excavated	Any area that has been excavated for water storage or flooding wetlands
h	Impounded	Impoundments used for water storage or flooding wetlands

(b)Wetland Alteration Codes

Alteration Code	**Description**
D	Draining
L	Leveling
P	Pond Creation
W	Wetland Creation

(c)Change Indicators

Change Indicator Code	Description
DK	Dike/Dam
DT	Ditching
S	Sedimentation
DR	Dredging, Water Level Increase
E	Excavation
F	Filling
DaRe	Dam Removal
DE	Dam Expansion

Table 2. Change in amount of wetland area for National Wetlands Inventory (NWI) classes in the (a) Tishomingo and (b) Little Deep Fork Watersheds.

(a)Tishomingo

Wetland Class	Historic Area (ha)	Current Area (ha)	Area Change (ha)	Percent Change
Lacustrine	2,057.4	2,115.9	58.6	2.85%
Palustrine Emergent	339.5	237.9	-101.6	-29.93%
Palustrine Forested	2,082.1	2,139.2	57.2	2.75%
Palustrine Scrub-Shrub	2.6	21.5	18.9	726.92%
Palustrine Unconsolidated Bottom	308.8	639.0	330.2	106.93%
Palustrine Unconsolidated Shore	0.1	0.5	0.4	400.00%
Riverine	229.5	243.9	14.4	6.27%
TOTAL	***5,019.9***	***5,397.9***	***378.0***	***7.53%***

(b)Little Deep Fork

Wetland Class	Historic Area (ha)	Current Area (ha)	Area Change (ha)	Percent Change
Lacustrine	16.5	171.0	154.5	936.36 %
Palustrine Emergent	115.0	160.2	45.2	39.30%
Palustrine Forested	885.1	1,081.4	196.4	22.19%
Palustrine Scrub-Shrub	134.1	137.0	2.9	2.16%
Palustrine Unconsolidated Bottom	211.0	817.3	606.3	287.35 %
Palustrine Unconsolidated Shore	0.9	2.0	1.0	111.11 %
Riverine	98.3	98.3	0.0	0.00%
TOTAL	***1,460.9***	***2,467.3***	***1,006.3***	***68.88%***

Table 3. Summary of the wetland/land-cover changes from the historic imagery to current imagery for the (a) Tishomingo and (b) Little Deep Fork Watersheds. Land cover codes can be found in Table 1

(a) Tishomingo

Historic Land Cover	Current Land Cover	Area Change (ha)
LAC	PEMh	10.09
	PFOh	247.59
	PUBn	0.73
	RIV	11.58
PEM	LAC	10.87
	PFO	91.23
	PFOh	15.66
	PFOx	0.76
	PSS	5.16
	PUBf	2.14
	PUBn	0.89
PFO	LAC	291.78
	PEM	5.95
	PEMh	6.02
	PSS	10.83
	PSSh	2.96
	PUBf	7.45
	PUBn	0.89
	RIV	2.81
PUBf	UD	0.19
	UF	1.48
	UG	2.19
PUBn	PFO	11.08
	PFOh	9.14
UF	LAC	13.41
	PEM	0.24
	PFO	0.23
	PFOh	7.28
	PUBf	180.50
	PUBi	1.41
	PUBn	0.20
	PUBu	0.40
UG	LAC	12.48
	PEM	0.11
	PEMh	1.15
	PEMx	1.52
	PFOx	2.91
	PUBf	115.43
	PUBi	44.14
	PUSx	0.38
USS	PUBf	0.06

(b) Little Deep Fork

Historic Land Cover	Current Land Cover	Area Change (Ha)
PEM	PFO	19.01
	PUBf	0.35
PFO	PEM	22.35
	PEMh	0.39
	PEMx	0.04
	PUBf	2.46
	PUBn	1.52
	PUS	0.76
	UG	0.84
PUBf	PEMh	7.51
	PFOh	0.07
	UD	0.08
	UF	1.84
	UG	4.61
PUBi	UF	0.43
	UG	1.02
UF	LAC	44.58
	PEM	1.37
	PEMh	2.82
	PFO	9.36
	PFOh	112.67
	PSSh	0.56
	PUBf	320.62
	PUBi	0.35
	PUBn	1.69
	PUS	0.05
	PUSf	0.17
UG	LAC	109.93
	PEMh	30.12
	PFO	9.91
	PFOh	73.37
	PFOx	0.31
	PSSh	2.35
	PUBf	293.30
	PUBi	0.57
	PUBu	0.49
	PUS	0.03
USS	PUBf	0.56

Table 4. Summary of the area of wetland alteration classes as well as the indicator of change from aerial imagery for the (a) Tishomingo and (b) Little Deep Fork Watersheds.

(a)Tishomingo

Change	Type of Conversion	Amount (ha)
Pond Removal	Dam Removal	3.45
	Filled	0.40
	Pond Removal Subtotal	*3.85*
Pond Creation	Dam Expansion	1.70
	Dam Construction	323.84
	Dredging/Water Level Increase	302.65
	Excavation	54.84
	Pond Creation Subtotal	*683.03*
Wetland Creation	Dam Construction	8.80
	Excavation	2.10
	Sedimentation	278.63
	Wetland Creation Subtotal	*289.53*

(b)Little Deep Fork

Change	Type of Conversion	Amount (ha)
Drainage	Ditching	0.07
Pond Removal	Dam Removal	2.74
	Filling	5.08
	Sedimentation	0.84
	Pond Removal Subtotal	*8.65*
Pond Creation	Dam Expansion	1.00
	Dam Creation	762.01
	Excavation	10.70
	Pond Creation Subtotal	*773.71*
Wetland Creation	Dam Creation	242.53
	Excavation	0.31
	Wetland Creation Subtotal	*242.83*

Table 5: Potentially restorable wetlands by watershed

		Potential to Improve Water Quality Score		
Watershed	**Restorable Sites**	**12 through 10**	**9 through 7**	**6 through 3**
Little Deep Fork	224	28	122	74
Tishomingo	225	46	93	86

Appendix A: GIS processing steps for Restorable Wetlands Identification Protocol (RWIP)

<u>Identify Restorable Wetlands</u>

1. Create a poorly drained soils layer representing the potential historic extent of wetlands in the study area
    a. **Query** dominant drainage class (extremely poorly drained, poorly drained, somewhat poorly drained)
    b. **Export** to a new shapefile
    c. **Clip** to study area
2. Create National Wetlands Inventory layer representing the current extent of wetlands in the study area
    a. **Clip** to study area
3. Create basins layer
    a. **Fill sinks** on DEM
    b. **Convert** filled DEMs to slope.
    c. **Reclassify** the slope maps to separate 0 values from all other slope values
    d. **Vectorize** reclassed slope maps
    e. **Delete** non-zero slope polygons
        i. Uncheck create multipart features
    f. **Clip** to watershed
    g. **Dissolve** adjacent polygons
4. Create urban land-use layer
    a. **Reclassify** NLCD
        i. 1: Barren, water, developed medium intensity, developed high intensity
        ii. 2: All other cover
    b. Vectorize
    c. **Clip** to area
    d. **Delete** all polygons with a reclassified land-use class of "2"
5. **Union** NWI (layer 2) and poorly drained soils (layer 1)
    a. **Remove** polygons where NWI wetlands currently exist
6. **Union** poorly drained soils with no NWI wetlands (layer 5) with basins (layer 3)
    a. **Remove** basins not on poorly drained soils
    b. **Remove** poorly drained soils not in basins
7. **Union** poorly drained basins (layer 6) with developed land-use (layer 4)
    a. **Remove** developed land
8. Clean up poorly drained basins not developed (layer 7)
    a. **Dissolve** adjacent polygons
    b. **Multipart to singlepart** polygons
    c. Calculate area
    d. **Remove** polygons <0.5 acres
9. Limit polygons by flow
    a. **Fill Sinks** on DEM

   b. **Create flow direction** raster from filled DEM
   c. **Create flow accumulation** raster from flow direction (layer 9b)
   d. Manually determine flow threshold based on climate and drainage patterns (for North Canadian 500 pixel flow or >12.7 acres drainage area was used)
   e. Using **map algebra** on flow accumulation raster (layer 9c) [con(layer>=threshold,1) create a raster of only pixels above determined threshold
   f. Use **stream to feature** with processed flow accumulation raster (layer 9e) and flow direction raster (layer 9b)
   g. **Use select by location** on poorly drained basins (layer 8d) that intersect stream feature (layer 9f)
   h. **Export** selected features to new shapefile called restorable wetlands
      i. Use **trace** to merge polygons with near adjacency (e.g., < 10 meters)

<u>Prioritize Restorable wetlands</u>

10. **Create** Watershed layer
    a. **Create** new point shapefile called pourpoints
    b. **Create** pourpoints at downstream intersection of restorable wetlands layer (layer 9h) and the flow accumulation raster (layer 9c)
       i. Note: Wetland boundaries can contain multiple pourpoints
    c. **Split** pourpoint layer by attributes to create a new shapefile for pourpoints at each restorable basin
    d. **Snap pour point** layers (layers 10c) to flow accumulation raster (layer 9c)
    e. Use **watershed tool** on snapped pour points (layer 10d) and flow direction layer (layer 9b)
    f. **Vectorize** watershed rasters (layer 10e)
    g. **Merge** watershed vectors (layer 10f)
    h. **Dissolve** merged layer by ID
    i. **Calculate area** for each watershed
11. **Create** crop and urban land-use layer
    a. **Reclassify** NLCD into two classes
       i. 1: All crops and urban land covers
       ii. 2: All others
    b. In Geospatial modeling run **isectpolyrst** and determine percent urban/crop in each watershed
    c. **Join** watershed to restorable wetland basins (layer 9h) by attribute ID
    d. **Export** layer to new shapefile called prioritized restorable wetlands
12. **Calculate** attributes for prioritized restorable wetlands
    a. **Calculate** watershed ratio by creating new field called "wat_rat" and using field calculator (watershed area/restorable basin area)
    b. **Calculate** scores using standard statewide scoring applied for all watersheds in Oklahoma
       i. **Create** four new fields for restorable basin size score (bas_sc), watershed ratio score (rat_sc), land-use score (lu_score) and site score (site_sc)
       ii. Restorable basin score is calculated as follows:
          1. 1: <2.5 acres

        2. 2: 2.5-4.99 acres
        3. 3: 5.0-9.99 acres
        4. 4: >=10.0 acres
    iii. Watershed Ratio score is calculated using "wat_rat" as follows:
        1. 1: >50
        2. 2: 50-20.01
        3. 3: 20-10.01
        4. 4: <=10
    iv. Land-use score is calculated as follows
        1. 1: <25% urban and crop
        2. 2: 25%-49.99% urban and crop
        3. 3: 50-74.99% urban and crop
        4. 4: >=75% urban and crop
    v. **Sum** restorable basin (bas_sc), watershed ratio (rat_sc) and land-use scores (lu_sc) in the site score (site_sc) field
c. **Calculate** scores specific for each watershed
    i. **Create** four new fields for watershed specific restorable basin size score (ws_bas_sc), watershed specific watershed ratio score (ws_rat_sc), watershed specific land-use score (ws_lu_sc) and watershed specific site score (ws_site_sc)
    ii. "Ws_bas_sc", "ws_rat_sc" and "ws_lu_sc" are calculated using quartiles.
        1. First quartile =1
        2. Second quartile=2
        3. Third quartile=3
        4. Fourth quartile=4
    iii. **Sum** "ws_bas_sc", "ws_rat_sc" and "ws_lu_sc" in the watershed specific site score (ws_site_sc) field.

Note: Many of the steps outlined above can be accomplished in batch processor and/or model builder to expedite data processing.