National Wetland Condition Assessment Intensification and Method Development Study

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INTRODUCTION

In Oklahoma development and implementation of a comprehensive wetland monitoring program is a high priority. One of the key goals of Oklahoma's Wetland Program Plan is to develop the capacity to assess the condition of wetland habitats in the state (OCC 2013). Development of a statewide rapid wetland assessment method began in 2012 as a partnership between Oklahoma State University (OSU), Oklahoma Conservation Commission (OCC) and Oklahoma Water Resources Board (OWRB) (OWRB 2015). The Oklahoma Rapid Assessment Method (OKRAM) is a stressor based condition assessment created for management applications including identifying degraded wetlands in need of restoration and locating pristine wetlands in need of protection. An additional application of critical importance to the state is a wetland assessment tool that can be used to plan and track mitigation in the context of §404 of the Clean Water Act (CWA).

OKRAM was initially calibrated for depressional wetlands of the Central Great Plains. Initial results indicated that OKRAM condition scores correlated well with measures of vegetation community diversity and sediment chemistry. In order for OKRAM to be effective as an assessment tool, the method needs to be calibrated and validated at the numerous wetland types, and variable wetland conditions found across Oklahoma. To that end, it is critical that OKRAM continue to be trialed at additional wetland classes such as riverine and slope wetlands. For calibration and validation to be completed successfully, independent measures of ecosystem condition must be collected concurrently with RAM data (Fennessey et al. 2004). In this way, the assumptions of a rapid assessment can be tested against more intensive measures of ecosystem condition such as biotic community data.

Collecting intensive biotic data can be time-consuming and expensive when compared with the relatively low cost and time required for rapid assessments. As a result, it has proven challenging for many states to complete RAM validation (Stein et al. 2009). The National Wetland Condition Assessment (NWCA) provides a unique opportunity to collect intensive biotic, water quality and soil data (USEPA 2016a, USEPA 2016b) concurrently with OKRAM data across the variable wetland conditions in Oklahoma. Oklahoma was assigned 17 sites for the 2016 application of the NWCA. However, 17 sites are insufficient to complete calibration and validation of OKRAM, especially given the diverse wetland types and broad geographic range of the assessment. As a result, Oklahoma requested and was granted an NWCA intensification to complete an abridged NWCA protocol and OKRAM at additional wetland sites in central Oklahoma. This intensification created the opportunity to further refine OKRAM metrics and tailor the assessment to the unique wetland types (e.g. riverine) that have not yet been assessed during method development.

The overall goal of this project will be to advance the State's ability to monitor and assess wetland condition throughout Oklahoma. It is of primary importance to Oklahoma to have a condition assessment that can be deployed for impact assessment as well as mitigation planning and tracking for §404 of the CWA projects. A rapid, accurate and repeatable assessment tool will help Oklahoma to maintain the quantity and quality of wetlands across the state. Furthermore, completing an intensive application of NWCA protocols provides the additional benefit of using nationally validated methods to estimate the overall health of the population of wetlands in the central portion of Oklahoma.

The objectives for this project are to:

1. Validate OKRAM's effectiveness at tracking wetland condition through comparison with NWCA intensive biotic and abiotic data.

2. Refine OKRAM metrics for application at all wetland types in Oklahoma.

3. Use the NWCA intensification data to provide a regional assessment of the current condition of wetlands in central Oklahoma.

METHODS

Study area

The spatial limit of the project was six, 8-digit Hydrologic Unit Code (HUC) watersheds in central Oklahoma including the:

- Lower Cimarron River (11050003),
- Lower North Canadian: Deep Fork Sub-basin (11100303),
- Lower North Canadian River (11100302),
- Lower Canadian River, Little River Sub-basin (11090203),
- Lower Canadian, Walnut Creek Sub-basin (11090202), and
- Middle Washita River (11130303) (Figure 1).

This study area was selected because it is projected to have the highest mitigation need for the Oklahoma Department of Transportation (ODOT) for the next 8 years. Therefore, it is critical that we understand the health of wetlands in this region and develop OKRAM to ensure that it is a suitable assessment tool to be used in conjunction with §404 of the CWA in central Oklahoma.

Site Selection

The USEPA-ORD National Health and Environmental Effects Research Laboratory in Corvallis, Oregon produced the draw for the intensification study after assisting OCC with the study design. Sites were selected following a generalized random tessellation stratified (GRTS) approach, and the selection protocol was designed to get an even distribution of study sites among three wetland categories:

open water (OW), freshwater wooded (FW) and freshwater herbaceous (FH). Using the output generated by USEPA-ORD, sites were evaluated sequentially to determine landowner permission, accessibility, and site suitability for NWCA. We sampled 30 sites in the study area. Sampleable sites were defined as target wetlands, not currently in crop production, with rooted vegetation, and when present, shallow open water less than 1 meter in depth (USEPA 2016a). Sites were removed from the project if access permission was denied, the site was not safely accessible or if the site was a non-target wetland.

Field Protocols

Sites were sampled during the growing season of 2017, between June, 1 and September, 30. Data were collected within an Assessment Area (AA), ranging from 0.1 to 0.5 ha in size, and an associated 100-m surrounding buffer. Within each AA, we followed NWCA protocols to conduct vegetation surveys, collect water samples (standard chemistry only, no chlorophyll, dissolved organic carbon or microsystin) when sampleable water was present, and complete soil profiles. Additionally, hydrologic and buffer assessments were completed according to NWCA protocols (USEPA 2016b). For more detailed description of the field protocols followed, see USEPA (2016b).

In addition, to NWCA protocols, we completed a separate assessment of wetland condition using the Oklahoma Rapid Assessment Method (OKRAM) within each wetland AA. OKRAM aggregates 9 metrics that assess the hydrology, biogeochemistry and biotic condition into a single condition score. OKRAM was created in 2011 and has since been calibrated and validated at depressional sites across Oklahoma (Gallaway et al., 2016, OWRB 2015). OKRAM application followed standard protocols developed through USEPA 104(b)(3) wetland program development grants (Gallaway et al. 2016, OWRB 2015). The OKRAM field datasheets used for this study can be found in Appendix A.

Laboratory Protocols

Water samples were analyzed at the Oklahoma Department of Agriculture Food and Forestry (ODAFF) water quality lab. The ODAFF water quality lab follows USEPA approved protocols and was approved to complete water quality analysis for the initial draw of NWCA wetlands. Quality control procedures for NWCA data are further outlined in the NWCA QAPP (USEPA 2016b).

Plants were identified to the lowest taxonomic level possible while in the field. Unknown specimens were collected and identified in the laboratory. Quality Assurance (QA) specimens were collected according to NWCA protocols (USEPA 2016b), and identified by an independent botanist.

Analysis

Inference Population Calculation and Site Weights

The target population of our assessment was the entirety of wetlands within the study area. However, the extent to which we were able to infer the condition of wetlands in the study area depended upon the portion of the accessible wetlands evaluated. Therefore, the first step in assessing condition metrics for wetlands within the study area is to determine the inference population. The inference population was calculated according to the National Wetland Condition Assessment 2011 Technical Report (USEPA 2016a). The inference population represents the portion of the regional wetlands that are represented by these analyses.

To calculate the inference population, each study site must be assigned a weight. Initially, during the GRTS selection process all sites in the sample draw are assigned a weight, which designates the portion of the target population represented. However, removing sites from the study reduces the size of the inference population relative to the target population. After all site assessments were completed, site weights were reassigned based on the number of sites visited among the sample draw. We calculated site weights according to USEPA (2016a) using the function "adjwgt" in the package "spsurvey" (Kincaid et al. 2018) in program R (R core team 2013).

Site Condition Scores and Extent

Site condition scores were calculated by applying a Vegetation Multimetric Index (VMMI) following protocols outlined in the NWCA 2011 Technical Report (USEPA 2016a). The VMMI includes four metrics:

1. Relative cover of native monocots,
2. Number of plant species tolerant to disturbance,
3. Relative importance of native plants, and
4. Floristic Quality Assessment Index.

Each metric is scored on a continuous scale from 0 to 10. Scores for each metric are aggregated and standardized on a continuous scale from 0 to 100, with higher values representing less disturbed condition. For more details on the calculation of VMMI metrics see USEPA (2016a).

Each site was then placed in a condition category of good, fair or poor based on the VMMI score. Condition score thresholds were established for the Interior Plains Ecoregion (following the 2011 NWCA data collection efforts), where our study area falls, for both herbaceous and wooded wetlands (USEPA 2016a). VMMI scores greater than or equal to the 25th percentile of least disturbed sites represented good condition, scores less than the 5th percentile of least disturbed sites represented poor condition, and scores between the 5th and 25th percentile represented fair condition. The percentage of the inference population in good, fair and poor condition can then be calculated by summing the site weights in each category. We calculated condition extent calculations and confidence intervals using the function "category.est" in the package "spsurvey" (Kincaid et al. 2018) in Program R (R Core team 2013).

Stressor Calculations

At each site, we calculated seven indicators of stress, based on field data collected at NWCA intensification site locations. The indicators utilized were those established in the 2011 NWCA Technical Guidance and include six measures of physical stress: vegetation removal, vegetation replacement, damming, hardening, ditching and filling/erosion. Sites were then placed in three categories including low, moderate and high stress for each indicator based on thresholds established in USEPA (2016a). Additionally, a biological measure of stress, the Non-native Plant Stressor Indicator (NPSI) was calculated, which aggregates relative cover, richness and frequency of non-native species. An additional stressor level of very high was included for NPSI. We calculated stressor extent estimates and confidence intervals using the function "category.est" in the package "spsurvey" (Kincaid et al. 2018) in Program R (R Core team 2013).

Risk Assessment

We calculated relative and attributable risk for the six physical stressor indicators. Relative risk is the probability of a site being in poor condition when the stressor-level is high relative to when the stressor-level is low (USEPA 2016a). Relative risk was estimated with contingency tables using two condition classes and two stressor categories. Condition classes included “poor” and “not poor”, the latter of which combined good and fair condition sites. Stressor categories included “high stress” and “not high stress”, the latter of which combined low and moderate stress level sites. Attributable risk is a measure of the proportion of the study population that would be improved if the effects of a particular stressor were restored to an unimpacted state. Relative and attributable risk calculations followed those established in USEPA (2016a), using the functions "relrisk.analysis" and "attrisk.analysis" in the package "spsurvey" (Kincaid et al. 2018) in Program R (R core team 2013).

OKRAM/NWCA Correlations.

We performed spearman rank correlations to determine how well the NWCA VMMI condition metric correlated with OKRAM site scores. We compared the overall OKRAM score with both the NWCA VMMI and FQAI. In previous studies, we have found that OKRAM scores at depressional wetlands were well correlated with FQAI (Gallaway et al., 2016). Additionally, because VMMI and FQAI are measures of the biotic community, we compared the biotic attribute component score of OKRAM with both VMMI and FQAI. We also summed the stressor score for all six physical stressors and quantified the correlation with OKRAM and VMMI.

Additionally, we utilized condition classes established for OKRAM from previous studies (Gallaway et al., 2016; OWRB 2015) to compare the agreement of the condition class designations of both methods (OKRAM and VMMI).

RESULTS

Vegetation Surveys

We identified a total of 264 unique plant species (Appendix B). An additional 43 plants were identified to genus or family, while 24 plant specimens were unidentifiable both in the field and the lab. The field botanist agreed with the laboratory botanist on the identification of 94% of the quality assurance specimens. On the 6% where field and lab botanists disagreed, specimens were identified to the same genus and the laboratory botanist's ID was used for analyses.

Inference Population Calculation and Site Weights

To estimate the extent of wetland acreage used in our analysis, we calculated the inference population (i.e., area of wetlands represented by our samples), from our target population (i.e., total target-wetland area in the study area). To reach our sample of 30 sites, we evaluated 325 sites from the draw. Of these, permission was denied for 75% of the sites, eight sites were inaccessible, and 43 sites were considered non-target (Figure 2). The final acreage represented by our sampled sites was 32,460 acres, approximately 9.6% of the target population (339,827.1 acres).

Site Condition Scores and Extent

VMMI scores for the nine herbaceous sites ranged from 30.2 to 74.6 (5 fair condition sites and 4 good condition sites). For the 21 wooded sites, VMMI scores ranged from 14.1 to 65.1 (9 poor condition sites, 6 fair condition sites, and 6 good condition sites; Table 1). Overall, approximately 29.6% (9,617 acres) of the inference population wetlands are in poor condition, 38.7% (12,570 acres) are in fair condition and 31.6% 10,272 acres) are in good condition (Figure 3). All of the sites in poor condition were wooded.

Stressor Calculations

The majority of the inference population exhibited low to moderate vegetation stress according to the NPSI (~72%). While approximately 28% of the inference population was under high to very high vegetation stress (Figure 4). Hardening was the most prevalent physical stress. Approximately, 22% of the inference population exhibited high levels of stress from hardening. Few sites in the inference population exhibited stress from filling (6.6%), damming (2.7%), vegetation replacement (6.6%) and vegetation removal (3.9%). No sites were impacted by ditching (Figure 5). Twenty-one of the 30 study sites had zero stress calculated for all physical stress categories (Table 1).

Risk Assessment

Filling was the only stressor associated with a positive relative risk (1.4). However the confidence interval crossed 0, indicating that there is no evidence of increased risk of a site being in poor condition due to filling. All stressors had attributable risk with confidence intervals that intersected zero (Figure 6). Therefore, it is difficult to predict any ecological improvement from eliminating any of the measured stressors.

OKRAM Scores

OKRAM scores at the thirty study sites ranged from 1 to 0.67 (Table 2). Previous studies calibrating OKRAM have placed the threshold for good condition sites at 0.84, and poor condition sites at 0.48 (Gallaway et al., 2016). According to these previously established thresholds, 25 sites were in good condition and five sites were in fair condition. Four of the five fair condition sites were close to the good threshold (0.81 through 0.83). In general there was poor agreement between the OKRAM condition designations and the VMMI, with only 10 sites placed in the good category using both methods. Eleven of the good condition OKRAM sites were assessed as fair using the VMMI. Four good OKRAM sites and all five fair OKRAM sites were assessed as poor using the VMMI (Table 3). Comparing the OKRAM to previously established FQAI thresholds for Oklahoma yielded greater agreement. Sixteen sites were in good condition using both methods. Though OKRAM tended to estimate condition higher than the FQAI for the remaining sites (Table 3)

OKRAM/NWCA Correlations

VMMI scores were moderately to strongly correlated with OKRAM overall (ρ=0.48; p=0.008) and biotic scores (ρ=0.62; p=0.0003). The correlation between FQAI score and OKRAM overall score was similar to the VMMI (ρ=0.45; p=0.01). FQAI score was not significantly correlated with the OKRAM biotic attribute score (ρ=0.31; p=0.09). The overall stressor score and OKRAM score had no significant correlation (ρ=-0.12; p=0.5). There was also no significant correlation between VMMI score and overall stressor score (ρ=-0.01; p=0.9).

DISCUSSION

Using the NWCA-derived VMMI we found that wetlands in central Oklahoma were in slightly worse condition than the inference population of wetlands in the entirety of the Interior Plains Ecoregion calculated from the 2011 NWCA (USEPA 2016a). We found a higher percentage of sites in poor condition (~30% vs. ~20%), and lower percentage of good condition sites (~30% vs. ~40%). Though our condition extent estimates had a large amount of uncertainty due to the relatively small sample size. Our condition extents might be slightly skewed as well due to the inclusion of more wooded than herbaceous wetlands. Of the sites sampled 21 out of 30 were wooded, and all of the sites classified as poor were wooded.

Interestingly, while we found a relatively high percentage of sites in poor condition, we found it difficult to attribute the low VMMI score to any of the stressor metrics assessed for NWCA. The primary reason for the poor relationship between stress and condition is likely that the sites included in this study, had relatively low levels of anthropogenic stress. Not surprisingly then, OKRAM, a stressor based measure of condition, consistently scored wetlands into higher condition categories. Though the correlation between OKRAM scores and VMMI scores were moderate, we found little agreement between VMMI and OKRAM condition category designations.

One possibility for the incompatibility of OKRAM and VMMI class designations is that the VMMI is underestimating the condition of some wetlands in Oklahoma. In a previous study we found that the established threshold FQAI score of 20 for statewide reference wetlands (Bried et al. 2014) was too high for wetlands in the western half of the state (Gallaway et al. 2016). Precipitation is a strong driver of the distribution of plant species, and more tolerant species are found at semi-arid western Oklahoma wetlands (Gallaway et al. 2016). These wetlands are exposed to more extreme fluctuations in water levels, and at times can be dominated by more upland adapted taxa that have lower coefficients of conservatism (Gallaway et al. 2016). While, least disturbed depressional wetlands in Eastern Oklahoma (east of I-35) had an average FQAI score of 19.9, those in the western half of the state (west of I-35) had an average FQAI score of 13. The ceiling for the FQAI metric used in the VMMI was scaled such that a 38.59 would receive a perfect score (USEPA 2016a). Meaning, that what Gallaway et al. (2016) found to be an average least disturbed wetland would receive an FQAI metric score of 4.1 and 1.9 in the eastern and western parts of the state respectively. In fact, three of the four western sites (west of I-35) were classified as poor using VMMI, despite having almost no recorded indicators of stress.

Furthermore, we found anecdotal evidence that the VMMI metrics can be strongly influenced by natural stressors. Riverine wetlands exhibit high degrees of natural stress from flooding that can dramatically alter some of the metrics included in the VMMI. We observed that wooded floodplain wetlands, generally had lower "relative cover of native monocots" than herbaceous wetlands, a trend that was intensified as these wooded wetlands responded to recent flooding events. We assessed several wooded floodplain wetlands soon after flood waters receded, which left an impoverished understory community. Not only did wooded floodplain wetlands appear to score lower for one of the four metrics (relative cover of native monocots) due to natural hydrologic impacts, but the threshold for good condition wooded wetlands was higher than herbaceous wetlands (herbaceous:36.2 and wooded 49.4; USEPA 2016a). All of the sites classified as poor in this study were wooded wetlands.

Additionally, it is likely that OKRAM, in its current format, is overestimating the quality of some wetlands. OKRAM was initially calibrated for depressional wetlands and we have found good agreement between OKRAM condition and more intensive vegetation assessments of depressional wetlands (Gallaway et al. 2016). However, many of the wetlands included in this study were riverine. We observed that several of the metrics don't adequately account for the types of anthropogenic stress that occurs at riverine wetlands. Based on the results of this study and anecdotal observations, we have considered alternative methods of calculating 3 of the metrics. We are currently involved in a two year study to determine the feasibility and accuracy of these new methods. Firstly, the "Water Source" metric deals with the quantity of water reaching a study wetland. Previously, the metric did not account for alterations to lotic systems, which would be the primary water source for riverine wetlands. The alternative "Water Source" metric attempts to quantify stress from river impoundments, as well as landscape level changes that alter the movement of surface water (Figure 7). Secondly, the "Hydrologic Connectivity" metric in depressional systems dealt primarily with the movement of water between uplands and the wetland ecosystem. However, we needed a method to quantify the ability of the wetlands to receive water from the river system that supplies floodwater. Anthropogenic induced entrenchment is a major problem for Oklahoma streams and can dramatically alter the frequency and intensity of flood events that are critical to functioning floodplain wetlands. We have developed two new alternative methods of assessing "Hydrologic Connectivity". The first is based on the "Hydrologic Connectivity" metric developed for California (California Wetlands Monitoring Group 2013) and is an estimate of the source river entrenchment (Figure 8). The second is a more qualitative assessment of indicators of altered flood regime to be utilized if it is not feasible to access the lotic system that floods or if the river is too large to safely enter (Figure 9). Finally, the "Buffer Filter" metric, a component of the water quality attribute, considers the contribution of degraded water quality to a wetland from the surrounding landscape. Previously, this metric did not consider the topography of the surrounding landscape. However, the alternative metric only looks at the surrounding land, up-slope from the study wetland (Figure 10).

We also noticed that the manner in which OKRAM metrics are aggregated is potentially nullifying the influence of measured stressors on the site condition score. For example, in the current format, all water quality metrics (nutrients, sediment and chemical contaminants) are averaged together to give a component water quality attribute score. While, several of our sites exhibited relatively high stress from nutrients and sedimentation, no site had any indicators of chemical contaminants. As a result low nutrient and sedimentation scores (e.g. 0.25-0.5) were averaged together with a contaminant score of 1, causing a narrow range in the water quality attribute of 0.73-1. Capturing the degree of chemical contamination is conceptually critical in evaluating the degree of anthropogenic stress at wetlands. However, identifying oil spills or point source discharges is quite rare. Therefore, we are currently working on a better method to aggregate metrics such that the influence of severe stress is not down-weighted by the absence of other rare stressors.

This project provided some critical insight into where OKRAM needs to be improved to assess the condition of riverine wetlands in Oklahoma. As a result, we have created new metrics and are considering new methods of metric aggregation to develop a method that accurately classifies the condition of wetlands. During the summer of 2018, we completed 30 assessments at riverine wetlands in central Oklahoma, using these new methods. We targeted the highest and lowest quality wetlands, such that OKRAM can continue to be calibrated with concurrently completed vegetation surveys following NWCA protocols. In 2019, we plan to complete a statewide survey of riverine wetlands to quantify and account for any geographic influence on OKRAM metrics. Next steps also include developing clear and concise guidebooks for assessing wetlands using OKRAM, as well as offering trainings on method application in the field.

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TABLES AND FIGURES

Table 1. Vegetation condition and stress levels for thirty wetlands assessed for the NWCA intensification project in six central Oklahoma HUC 8 watersheds. FQAI is floristic quality assessment index and VMMI is vegetation multi-metric index. Both metrics were calculated following NWCA guidelines. Condition levels include good, fair and poor. Stress levels include very high, high, moderate (mod) and low. The total stress was calculated by aggregating the stress scores for Vegetation Removal (Veg Rem.), Vegetation Replacement (Veg. Rep), Damming (Dams), Ditching (Ditches) Hardening (Hard) and Filling.

Sites		Vegetation Condition				Stress Levels							
#	Wetland Type	FQAI	FQAI Condition	VMMI	VMMI Condition	NPSI	Veg. Rem.	Veg. Rep.	Dams	Ditches	Hard	Filling	Total Stress
1006	Woody	25.79	Good	56.38	Good	mod	low	low	low	low	low	low	0
1012	Herbaceous	6.88	Poor	32.28	Fair	high	low	high	high	low	high	low	2.26
1017	Woody	19.35	Good	45.16	Fair	mod	low	low	low	low	low	low	0
1018	Herbaceous	14.14	Fair	71.88	Good	mod	low	low	low	low	low	low	0
1019	Woody	21.22	Good	33.90	Poor	mod	mod	low	mod	low	high	high	2.36
1024	Woody	11.49	Good	14.07	Poor	very high	low	low	low	low	low	low	0
1027	Woody	22.23	Good	34.50	Poor	high	low	low	low	low	low	low	0
1040	Woody	14.15	Fair	23.77	Poor	high	low	low	low	low	low	low	0
1045	Woody	20.62	Good	51.94	Good	mod	low	low	low	low	low	low	0
1052	Herbaceous	16.24	Good	30.21	Fair	high	low	low	low	low	low	low	0
1057	Woody	20.27	Good	50.81	Good	low	low	low	low	low	low	low	0
1059	Herbaceous	22.66	Good	74.57	Good	low	low	low	low	low	low	low	0
1087	Herbaceous	18.88	Good	33.34	Fair	high	high	high	low	low	high	low	1.87
1091	Woody	19.27	Good	49.28	Fair	mod	low	low	low	low	high	high	1.26
1092	Herbaceous	9.19	Poor	31.83	Fair	high	low	low	low	low	low	low	0
1094	Woody	19.19	Good	65.07	Good	low	low	low	low	low	low	low	0
1100	Woody	12.05	Good	31.86	Poor	mod	mod	low	low	low	low	low	0.06
1121	Woody	21.26	Good	38.75	Poor	mod	low	low	low	low	low	low	0
1124	Herbaceous	12.96	Fair	40.20	Good	mod	low	low	low	low	low	low	0
1146	Woody	14.62	Fair	38.22	Poor	mod	low	low	low	low	high	low	1.07
1147	Woody	17.8	Fair	29.45	Poor	mod	low	low	low	low	low	low	0

Sites		Vegetation Condition				Stress Levels							
#	Wetland Type	FQAI	FQAI Condition	VMMI	VMMI Condition	NPSI	Veg. Rem.	Veg. Rep.	Dams	Ditches	Hard	Filling	Total Stress
1174	Herbaceous	19.33	Good	50.18	Good	mod	mod	low	low	low	low	low	0.05
1185	Woody	20.57	Good	56.16	Good	low	low	low	low	low	high	low	1.26
1209	Woody	14.6	Fair	45.71	Fair	low	low	low	low	low	low	low	0
1215	Woody	22.32	Good	41.35	Fair	mod	low	low	low	low	low	low	0
1236	Herbaceous	9.17	Poor	35.10	Fair	mod	low	low	low	low	low	low	0
1244	Woody	13.77	Good	25.36	Poor	high	low	low	low	low	low	low	0
1260	Woody	17.49	Fair	40.31	Fair	mod	low	low	low	low	low	low	0
1282	Woody	12.3	Fair	42.21	Fair	mod	low	low	low	low	low	low	0
1325	Woody	19.31	Good	52.90	Good	low	low	low	low	low	high	low	1.49

Table 2. Oklahoma Rapid Assessment Method (OKRAM) metric, attribute (Hydrology, Water Quality and Biotic) and overall scores for thirty wetlands assessed for the NWCA intensification project in six central Oklahoma HUC 8 watersheds. Hydrology metrics include hydroperiod, water source and hydrologic connectivity (Hydro. Con.). Water Quality metrics include nutrients, sedimentation (Sediment), contaminants and buffer. Biotic metrics include vegetation and habitat connectivity (Habitat Con.)

Sites		Hydrology Attribute				Water Quality Attribute					Biotic Attribute			Overall
#	Wetland Type	Hydro-period	Water Source	Hydro. Con.	Hydrology Score	Nutrients	Sediment	Contaminants	Buffer	WQ Score	Vegetation	Habitat Con.	Biotic Score	Condition
1006	Woody	1	0.94	1	0.98	1	1	1	1	1	0.96	0.76	0.86	0.95
1012	Herbaceous	0.75	0.99	0.5	0.75	0.78	1	1	1	0.94	0.6	1	0.8	0.83
1017	Woody	1	0.9	1	0.97	1	1	1	1	1	1	1	1	0.99
1018	Herbaceous	0.75	0.99	0.75	0.83	1	1	1	1	1	1	1	1	0.94
1019	Woody	1	0.94	1	0.98	1	1	1	1	1	0.55	0.41	0.48	0.82
1024	Woody	1	0.93	1	0.98	1	0.25	1	1	0.81	0.42	0.03	0.22	0.67
1027	Woody	1	1	1	1	1	1	1	1	1	0.93	1	0.96	0.99
1040	Woody	1	0.74	1	0.91	1	1	1	1	1	0.92	0.67	0.79	0.9
1045	Woody	1	0.85	1	0.95	0.94	1	1	1	0.98	1	0.86	0.93	0.95
1052	Herbaceous	1	0.55	1	0.85	1	1	1	1	1	0.96	0.37	0.67	0.84
1057	Woody	1	0.99	1	1	1	1	1	1	1	1	0.87	0.94	0.98
1059	Herbaceous	1	0.99	1	1	0.44	1	1	1	0.86	0.85	1	0.93	0.93
1087	Herbaceous	1	0.99	1	1	0.75	1	1	1	0.94	0.55	1	0.78	0.9
1091	Woody	1	0.98	1	0.99	1	1	1	1	1	0.99	0.82	0.91	0.97
1092	Herbaceous	1	0.98	1	0.99	1	1	1	1	1	0.7	0.86	0.78	0.92
1094	Woody	1	0.98	1	0.99	0.25	1	1	1	0.81	1	1	1	0.94
1100	Woody	1	0.69	1	0.9	1	1	1	1	1	0.94	0.51	0.73	0.87
1121	Woody	1	0.97	1	0.99	1	1	1	1	1	0.93	1	0.97	0.99
1124	Herbaceous	1	0.99	1	1	1	1	1	1	1	0.9	0.9	0.9	0.97
1146	Woody	1	0.99	1	1	1	1	1	1	1	1	1	1	1
1147	Woody	1	0.9	1	0.97	1	1	1	1	1	0.89	0.61	0.75	0.91
1174	Herbaceous	1	0.97	1	0.99	0.44	0.5	1	1	0.73	0.76	1	0.88	0.87
1185	Woody	1	1	1	1	0.8	1	1	1	0.95	0.86	1	0.93	0.96
1209	Woody	1	0.94	1	0.98	0.75	1	1	1	0.94	0.99	0.87	0.93	0.95
1215	Woody	1	0.99	1	1	1	1	1	1	1	0.93	0.99	0.96	0.99

Sites		Hydrology Attribute				Water Quality Attribute					Biotic Attribute			Overall
#	Wetland Type	Hydro-period	Water Source	Hydro. Con.	Hydrology Score	Nutrients	Sediment	Contaminants	Buffer	WQ Score	Vegetation	Habitat Con.	Biotic Score	Condition
1236	Herbaceous	1	0.98	1	0.99	1	1	0.5	1	0.88	0.99	1	0.99	0.95
1244	Woody	1	0.44	1	0.81	1	1	1	1	1	0.83	0.4	0.61	0.81
1260	Woody	1	0.98	0.5	0.83	1	1	1	1	1	0.99	0.31	0.65	0.83
1282	Woody	1	0.99	1	1	0.88	0.88	1	1	0.94	0.82	0.82	0.82	0.92
1325	Woody	1	0.95	1	0.98	1	1	1	1	1	0.89	0.99	0.94	0.97

Table 3. Agreement of condition class categories using the Oklahoma Rapid Assessment Method (OKRAM, Vegetation Multimetric Index (VMMI) and Floristic Quality Assessment Index (FQAI) for thirty wetlands in six central Oklahoma HUC 8 watersheds. Areas shaded in gray were placed in the same condition class using both methods.

		OKRAM			% Agreement
		Good	Fair	Poor	
VMMI	Good	10	0	0	
	Fair	9	2	0	
	Poor	6	3	0	40%
FQAI	Good	16	3	0	
	Fair	7	1	0	
	Poor	2	1	0	57%

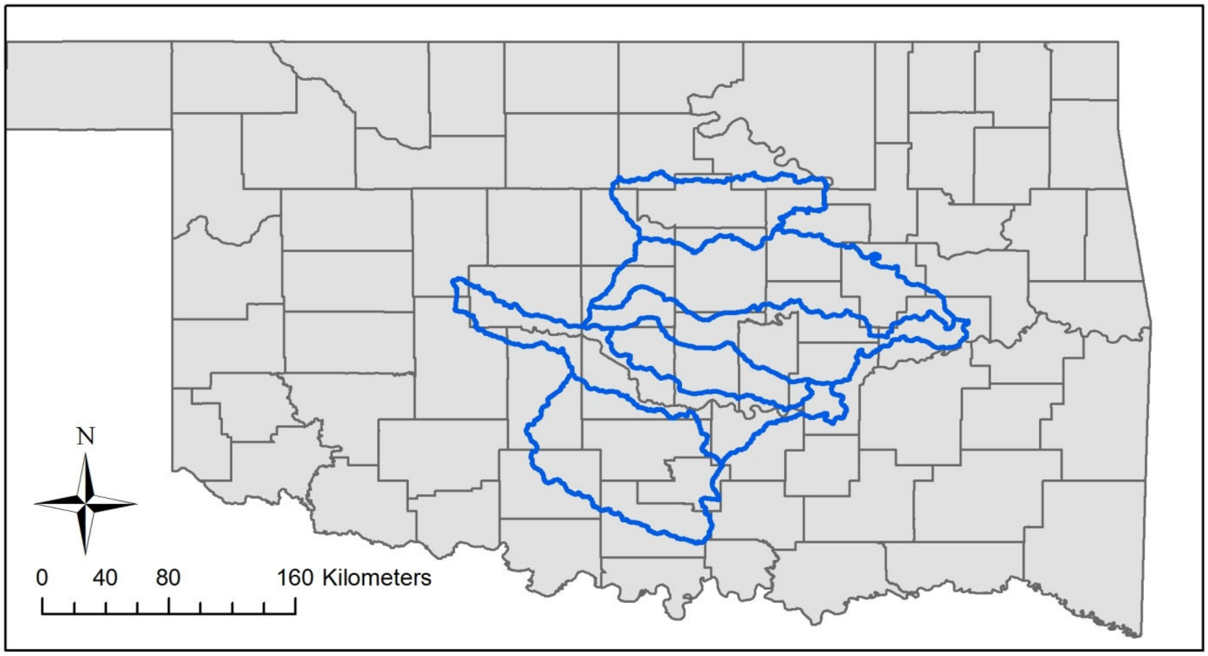


Fig 1. Study area for the application of the National Wetland Condition Assessment Intensification in Oklahoma. The study included 6, 8-digit Hydrologic Unit Code watersheds in central Oklahoma including the Lower Cimarron River (11050003), Lower North Canadian: Deep Fork Sub-basin (11100303), Lower North Canadian River (11100302), Lower Canadian River, Little River Sub-basin (11090203), Lower Canadian, Walnut Creek Sub-basin (11090202), and Middle Washita River (11130303).

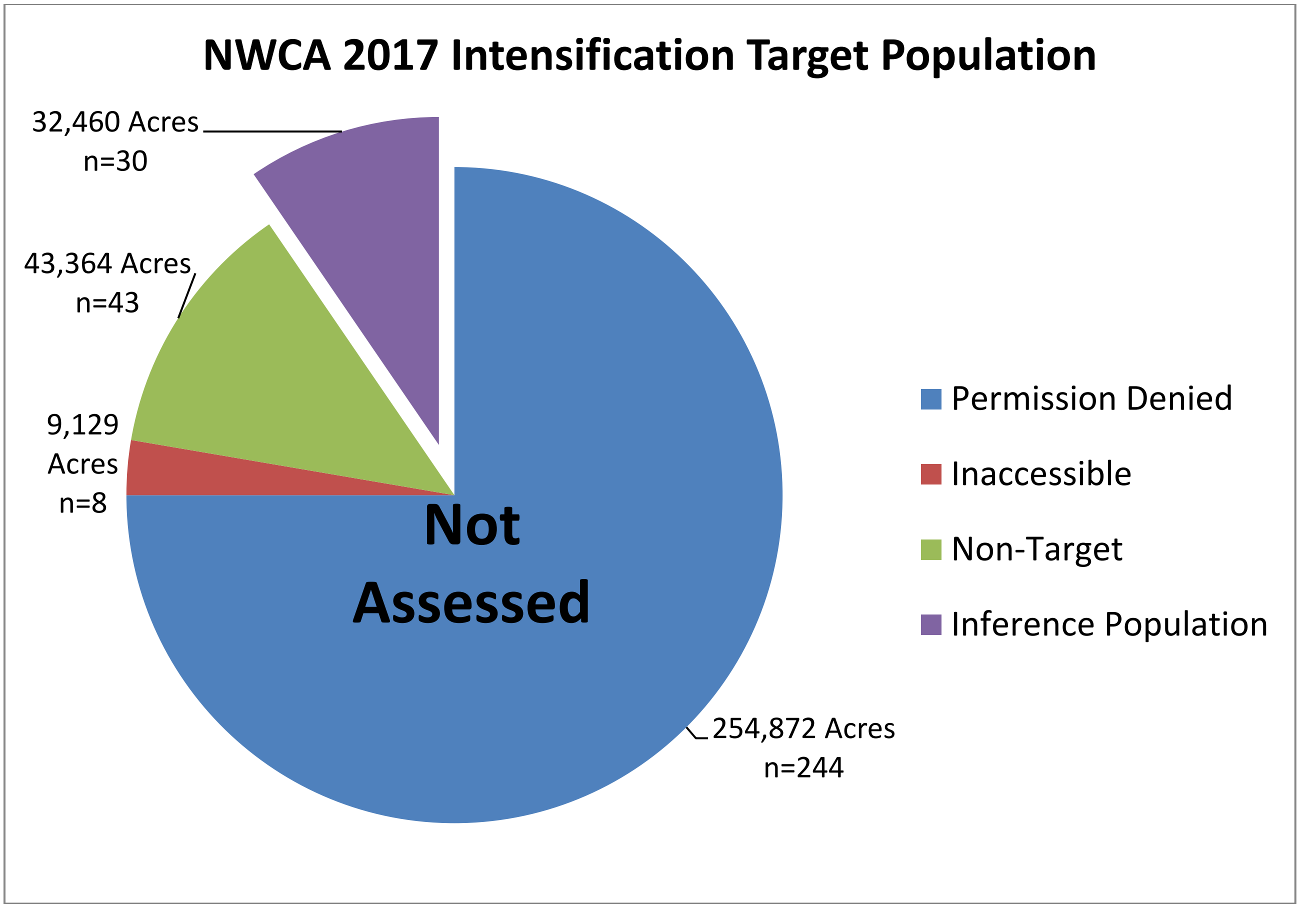
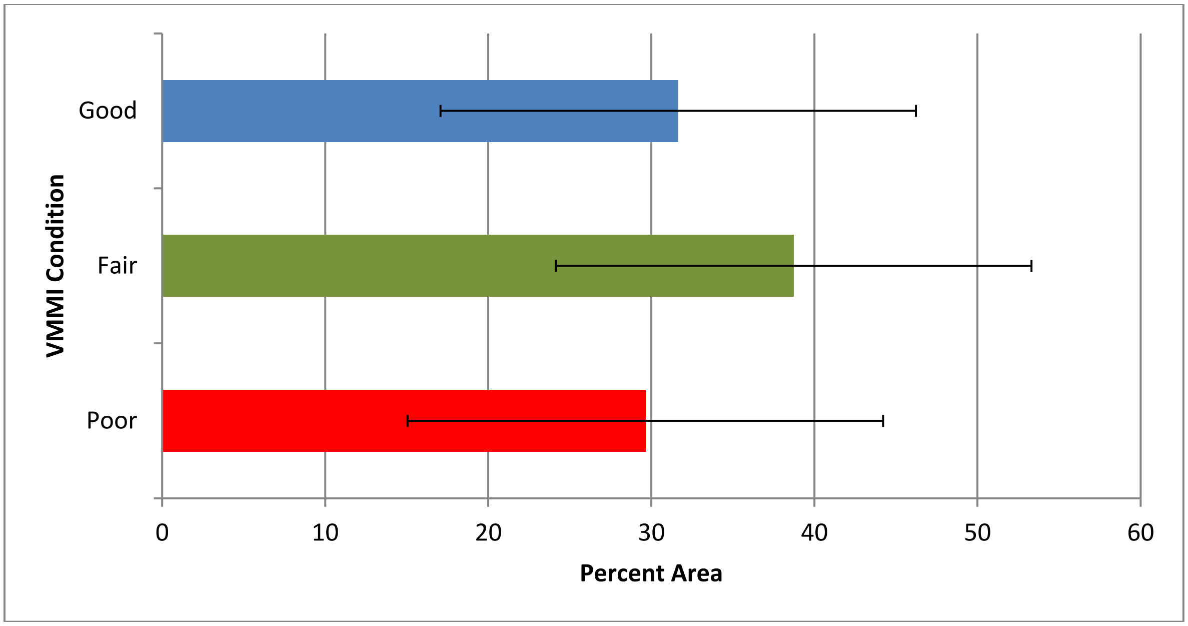
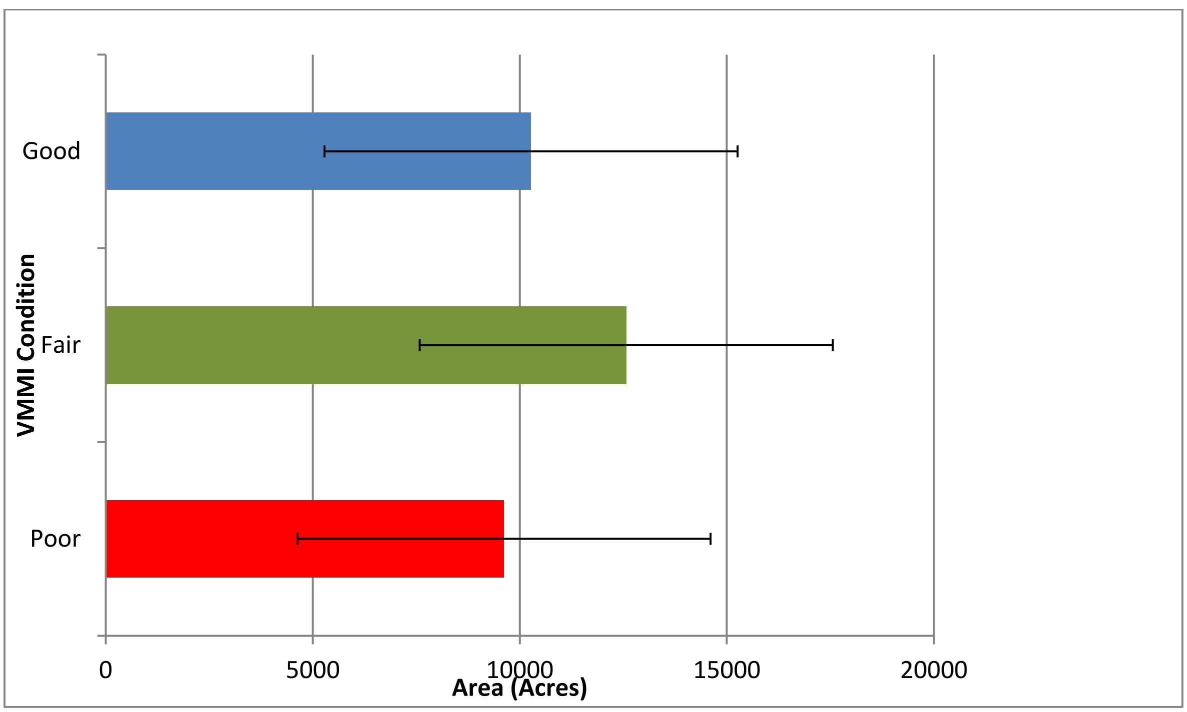


Fig 2. The 2017 NWCA intensification "Target Population" for Oklahoma. The target population is divided into the "Inference Population", for which condition extent is estimated, as well as the proportion of sites that were inaccessible, where permission was denied and non-target sites.

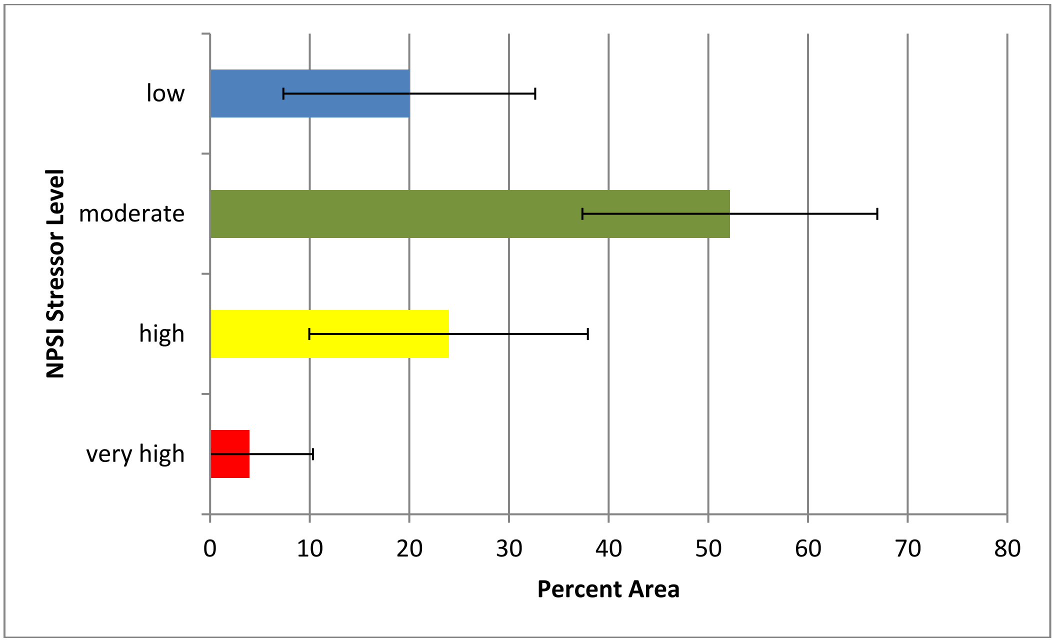


(a)

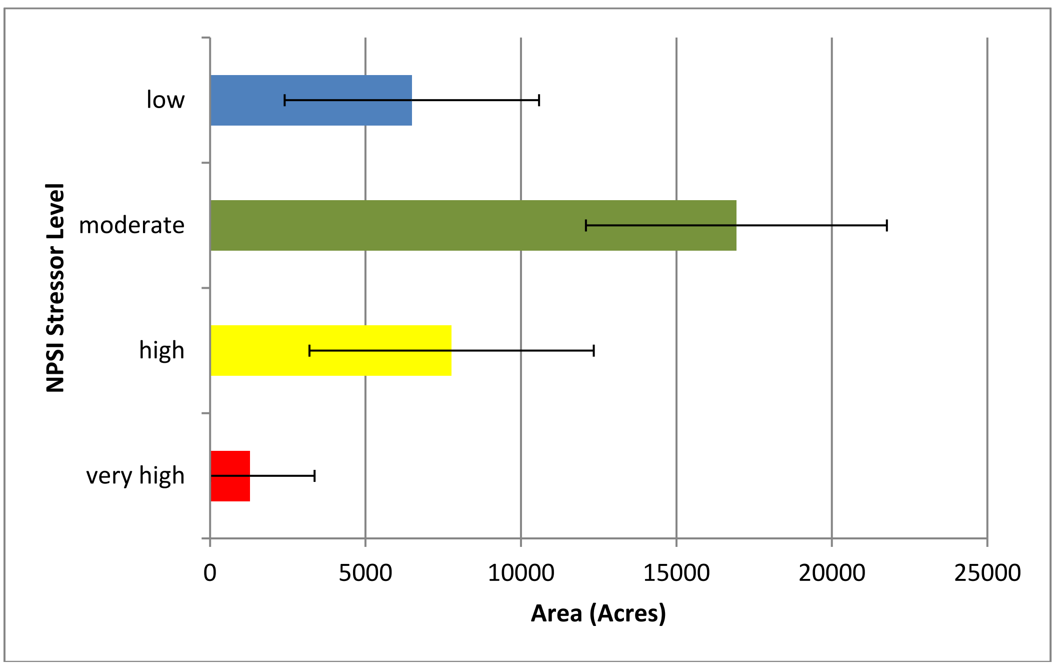


(b)

Fig. 3. Percentage (a) and area (b) of wetland sites in good, fair and poor condition based on the National Wetlands Condition Assessment (NWCA) Vegetation Multimetric Index (VMMI) in six HUC 8 watersheds of central Oklahoma.



(a)



(b)

Fig 4. Percentage (a) and area (b) of wetland sites exhibiting stress in six HUC 8 watersheds of central Oklahoma. Stress was determined by assessing the presence of non-native plant communities, based on the National Wetlands Condition Assessment (NWCA) Non-native Plant Stressor Indicator (NPSI).

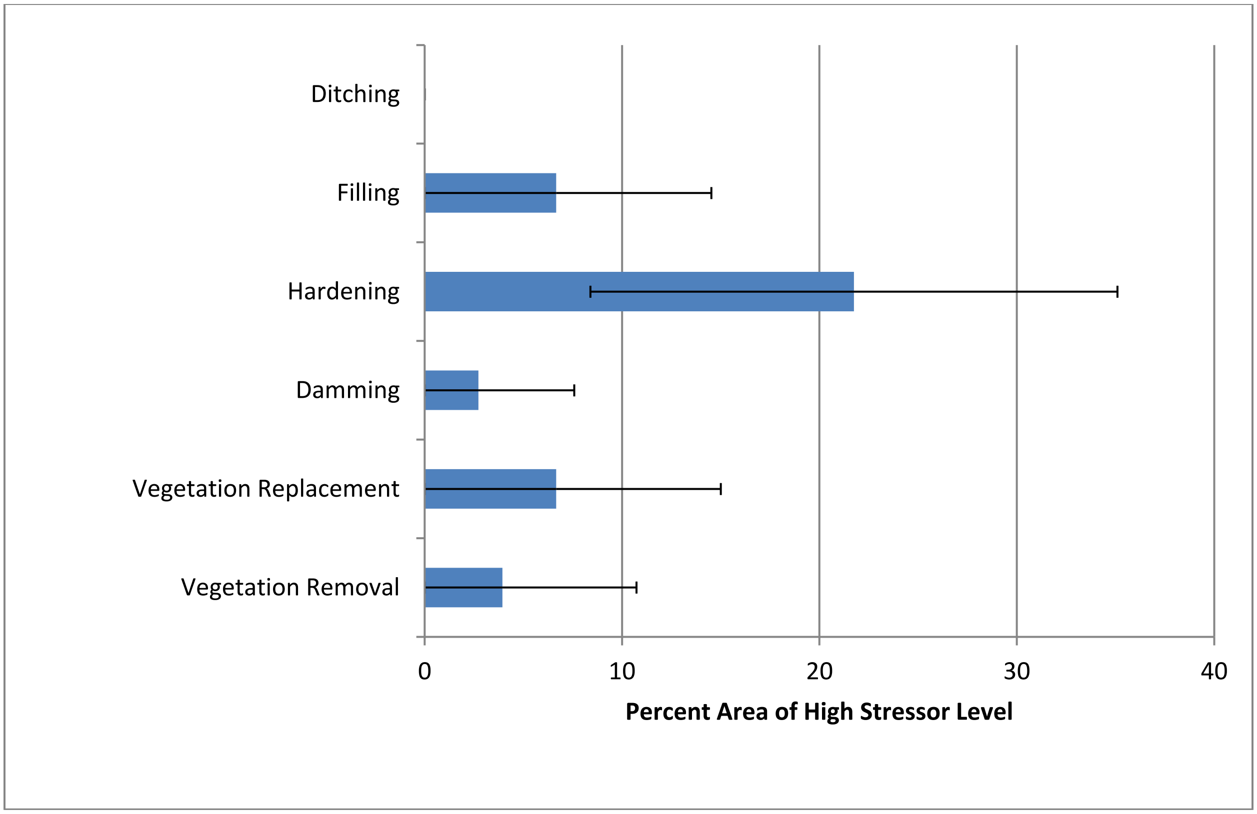
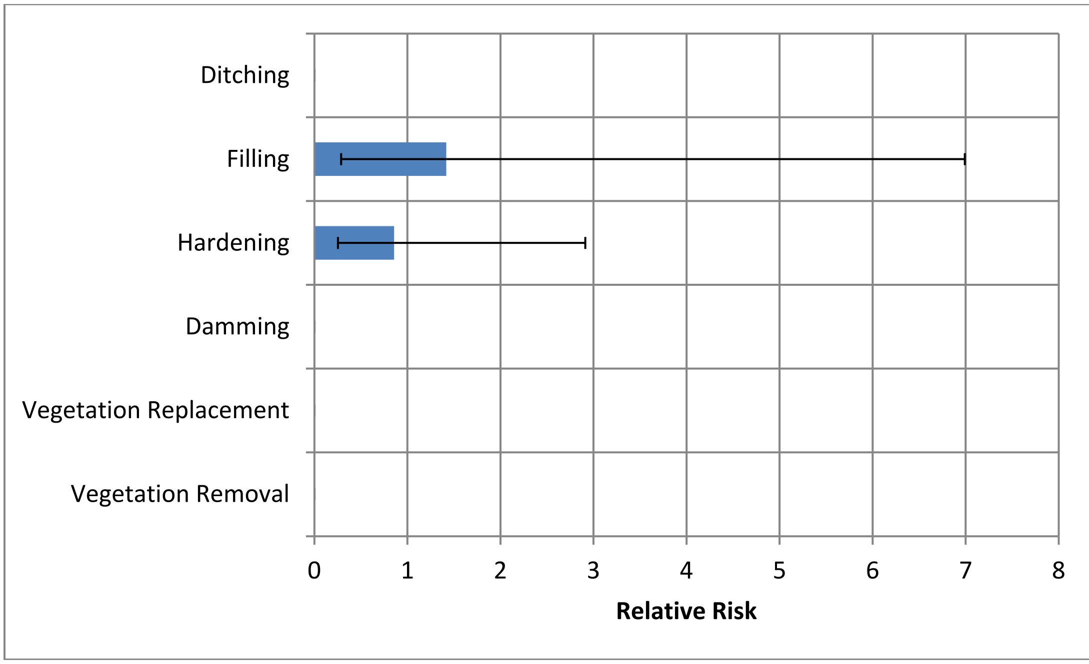
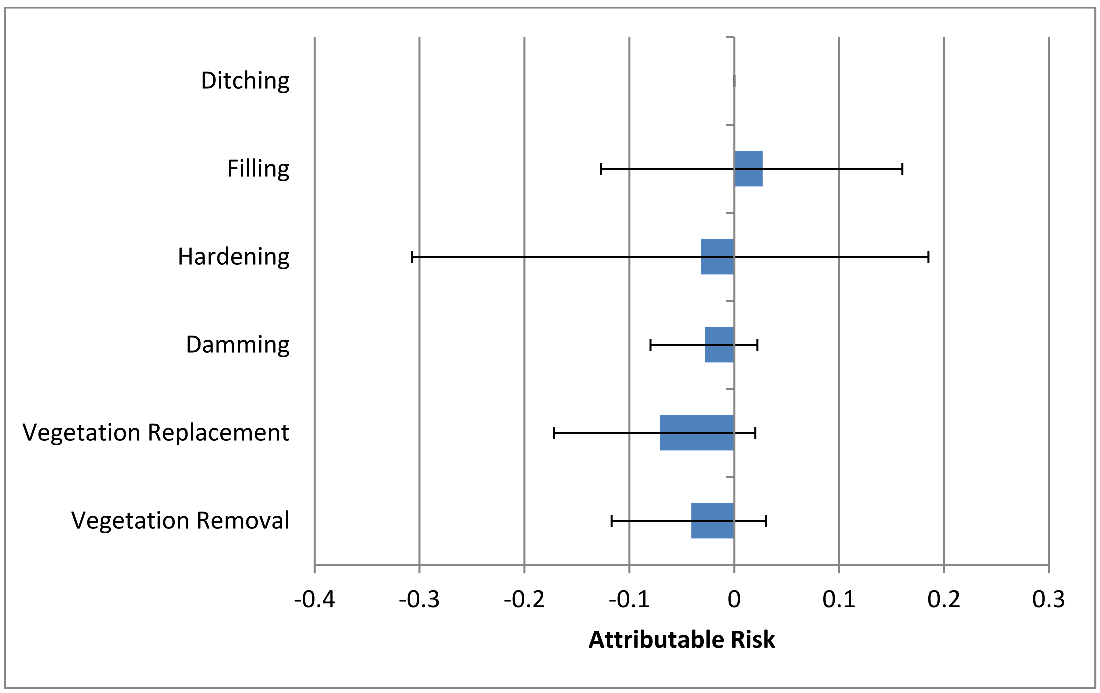


Fig 5. Percentage of wetland sites exhibiting stress in six HUC 8 watersheds of central Oklahoma. Stress was determined by assessing wetlands according to the National Wetlands Condition Assessment (NWCA) protocols for six measures of physical alteration.



(a)



(b)

Fig 6. Relative (a) and attributable (b) risk for six physical stressors at wetlands in six central Oklahoma HUC 8 watersheds. Risk was determined by assessing wetlands according to the National Wetlands Condition Assessment (NWCA) protocols.

1. Hydrologic condition			
b. Water Source			
Instructions:			
1. Follow the stream from the wetland location to the stream headwaters or the HUC 8 watershed boundary. Identify the distance to the nearest impoundment on the stream that supplies water to the wetland. Impoundments within 500m will receive a score reduction of 0.3, within 5km will receive a score reduction of 0.2 and within the HUC 8 boundary will receive a score reduction of 0.1. Score reductions reduce the total possible score for this metric. For example a wetland with an upstream impoundment at 300m from the wetland will have a maximum possible score of 0.7 or 1.0-0.3.			
2. Repeat step 1 but follow the river downstream to it's confluence or until the HUC 8 boundary is reached. Measure the distance to any portion of the river or stream that shows a clear indicator of influence from a downstream impoundment (e.g. widening or lack of flow). Use the same distance thresholds for applying score reductions.			
3. Delineate an area in which to calculate the cover of indicators of altered water source. Follow the river or stream, upstream for 2 km. Use the 2 km river segment to create a 2km buffer. Use a topographic map to remove the portion of the buffer downstream of the study site as well as the area upstream of the upstream edge of the 2km channel segment. Exclude any area within the 2km buffer that falls outside of the HUC 12 that contains the study site, or the HUC 12 immediately upstream of the study site. Fill in the % Cover of each of the indicators of altered water source within the created buffer. Each area is then multiplied by the severity multiplier listed for that indicator of altered water source.			
4. The percentage of altered land within the HUC 12 watershed is scaled to the maximum possible score determined by impoundment score reductions and subtracted from the best possible score for that wetland based on the impoundment score reductions. ((100*(1-(HUC 8 score reductions)))-(Total Altered cover*(HUC 8 score reductions)))/100. Because some severity multipliers are greater than 1, it is possible to have a score less than 0. Scores less then 0 are changed to 0.			
HUC 8 Upstream Indicators of altered water source	**Distance**		**Score Reduction**
Upstream Impoundment			
Downstream Impoundment			
HUC 12 Indicators of altered water source	**% Cover**	**Severity Multiplier**	**Description**
Impervious surface (paved roads, parking lots, structures and compacted gravel and dirt roads)		1.5	
Irrigated agricultural land (center pivot, ditch, flood etc.)		1.5	
Dryland agricultural land that is tilled		0.5	
Woody encroachment (e.g. eastern red cedar (*Juniperus virginiana*) and salt cedar (*Tamarix* sp.))		0.5	
Impounded water		2	
Topographic alteration (leveling, excavation, mining)		1	
Total Altered Cover			
METRIC SCORE 1b			

Fig 7. Updated OKRAM "Water Source" metric created for riverine wetlands.

1. Hydrologic condition

c. Hydrologic Connectivity- Riverine

Instructions:

1. If stream access is possible (landowner permission and less than 500 meters from the wetland), begin at the stream location closest to the wetland. If river access is not possible then begin at the closest bridge that crosses the source stream, and is representative of stream condition.
2. Identify bankfull indicators on both banks. Estimate bankfull width by measuring the distance between the right and left bankfull indicators.
3. Estimate maximum bankfull depth as the height of the channel from the deepest part of the channel to an imaginary line at bankfull width.
4. Estimate flood prone depth by doubling the estimate of bankfull depth.
5. Imagine a level line at a height equal to the flood prone depth. This line begins and ends where it intersects the channel banks. Measure the distance of this line
6. Calculate entrenchment ratio by dividing the flood prone width by the bankfull width
7. If stream access was possible Repeat steps 2 through 6 for three cross sections and calculate the average entrenchment ratio. If assessing connectivity from a bridge crossing, repeat steps 2 through 6 for two cross sections, one upstream and one downstream of the bridge.
8. Determine if wetland elevation is >3 times bankfull depth and is permanently disconnected from flood waters or only receives flood water in the most extreme flood events.
9. Score the metric using the scoring guidelines below based on entrenchment ratio.

	Cross Section		
Measurement	**1**	**2**	**3**
Bankfull width			
Maximum bankfull depth			
Flood prone depth			
Flood prone width			
Entrenchment ratio			
Average entrenchment ratio			
Wetland elevation is >3 times bankfull depth.		yes/no	
METRIC SCORE 1c			

Guidelines for wetlands associated with non-confined rivers

Score	Scoring Guidelines
1	Entrenchment ratio is >2.2
0.75	Entrenchment ratio is 1.9 to 2.2
0.5	Entrenchment ratio is 1.5 to 1.8
0.25	Entrenchment ratio is < 1.5
0	Wetland elevation is > 3 times bankfull depth and only receives flood waters in the most extreme events.

Guidelines for wetlands associated with confined rivers

Score	Scoring Guidelines
1	Entrenchment ratio is >1.8
0.75	Entrenchment ratio is 1.6 to 2.8
0.5	Entrenchment ratio is 1.2 to 1.5
0.25	Entrenchment ratio is <1.2
0	Wetland elevation is > 3 times bankfull depth and only receives flood waters in the most extreme events.

Fig 8. Updated OKRAM "Hydrologic Connectivity" metric created for riverine wetlands.

1. Hydrologic condition		
c. Hydrologic Connectivity		
Instructions:		
1. If river access is possible find the closest point in the river to the wetland. This metric will be assessed 100 m upstream and 100 m downstream of that point, for both banks of the channel. If this metric is scored from a bridge crossing, use a range finder to determine the maximum distance visible upstream and downstream. The stream will be assessed for the maximum visible distance, on both banks of the channel. In the field estimate the length of stream assessed and impacted by the indicators of channel degradation or aggradation listed below. For each meter of stream, only count one indicator.		
2. The metric is scored simply as the percentage of unaltered stream length assessed. For example a channel length of 100m (200 m total using both banks of the channel) that has 40 meters of undercut banks and 20 meters of leaning riparian vegetation would score 1-((40+20)/200)=0.7		
Channel Length	1	
Indicators of Reduced Connectivity	**Channel Length Impacted**	**Indicator Description**
Vertical/Sheer banks		
Undercut banks		
Bank slumps or slides		
Lower banks uniformly scoured and un-vegetated		
Riparian vegetation leaning or declining		
Channel bed scoured to bedrock/dense clay		
Braided stream coallesced into one channel		
Channel has knickpoints indicating headward erosion		
Channel straightening		
Indicators of Aggradation	**Channel Length Impacted**	**Indicator Description**
Active floodplain with fresh splays of coarse sediment deposited in the current or previous year		
Partially buried living tree trunks or shrubs along banks		
Bed is planar (flat or uniform gradient) overall; lacks well defined pools or poolsare evenly spaced		
Partially buried or sediment choked culverts		
Perennial terrestrial or riparian vegetation is encroaching into the channel or onto channel bars below the bankfull contour		
Avulsion channels on the floodplain or adjacent valley floor		
TOTAL IMPACTED AREA	**0**	
METRIC SCORE 1A	**1**	

Fig 9. Updated alternate OKRAM "Hydrologic Connectivity" metric created for riverine wetlands.

2. Water Quality Condition

d. Buffer filter

Instructions:

1. On a topographic map or in GIS, observe the topography of the area surrounding the wetland. Approximate the area that drains to the wetland using the available contour maps. Draw eight evenly spaced 250 m lines emanating from the portion of the AA boundary downslope of the surrounding area. For example, if 100 meters of the AA boundary is at a higher elevation than the surrounding area it is excluded from this metric. The eight buffer lines would then be spaced evenly in the remaining area. If the AA is directly adjacent to permanent open water exclude that portion of the boundary from buffer calculations.

2. Calculate the distance to human impacted land-use (see table below). First observe the distance to high impact land-use. For high impact land-use the buffer must be 250 m in length to be fully functioning. If no high impact land-use is encountered, observe the distance to moderate impact land-use. The buffer must be 100 m to moderate impact land-use be fully functioning. If no high or moderate land-use is encountered, observe the distance to low impact land-use. The buffer must be 30 m to low impact land-use to be considered fully functioning.

3. For each buffer line calculate the percentage of intact buffer distance. For example if the buffer is intact for 80 meters before intersecting a golf course the buffer is 80% of fully functioning (80/100). On the other hand, if the buffer is intact for 80 meters before intersecting a feedlot the buffer is only 32% functioning (80/250). If no altered land-use is encountered on a buffer line both the required distance and intact distance are recorded as 250.

4. For the overall buffer filter score, take the average of all eight buffer lines.

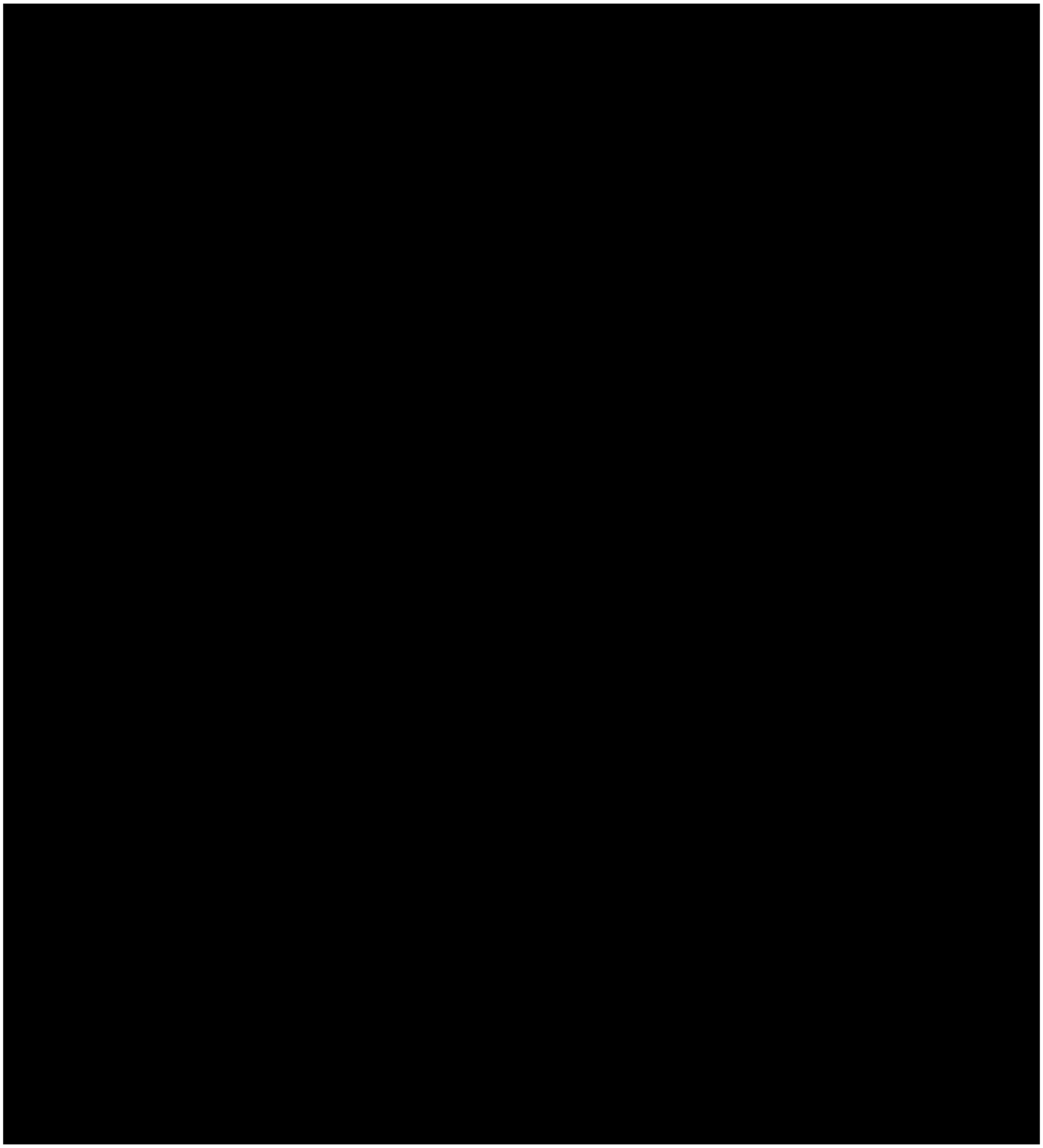
Land-uses that can be included in a functioning buffer: natural uplands, water bodies not directly adjacent to AA, wildland parks, bike trails, foot trails, horse trails, gravel/dirt roads, railroads

Land use category	Types of Land-use Beyond Buffer	Buffer width
High Impact	Intensive livestock (feedlot, dairy farm, pig farm) or urban area	250m
Moderate Impact	Conventional tilled agriculture, landscaped park, golf course, suburban area, active construction sites, areas of vegetation removal, earth moving operations	100m
Low Impact	No till agriculture, hay meadow, active paved road, minimal use recreation area, improved pasture	30m

Buffer	Required Distance (based on first encountered land-use)	Intact Distance
1	0	0
2	0	0
3	0	0
4	0	0
5	0	0
6	0	0
7	0	0
8	0	0
METRIC SCORE 2d	**1**	

Fig 10. Updated OKRAM "Buffer Filter" metric created for riverine wetlands.

APPENDIX A: OKRAM Datasheets



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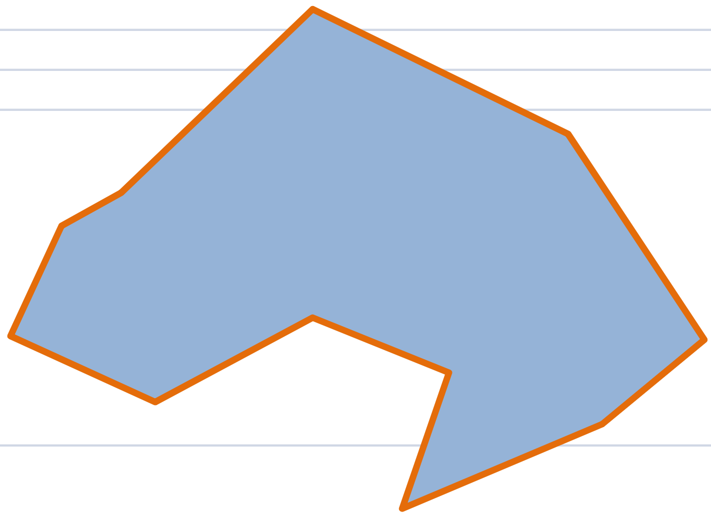
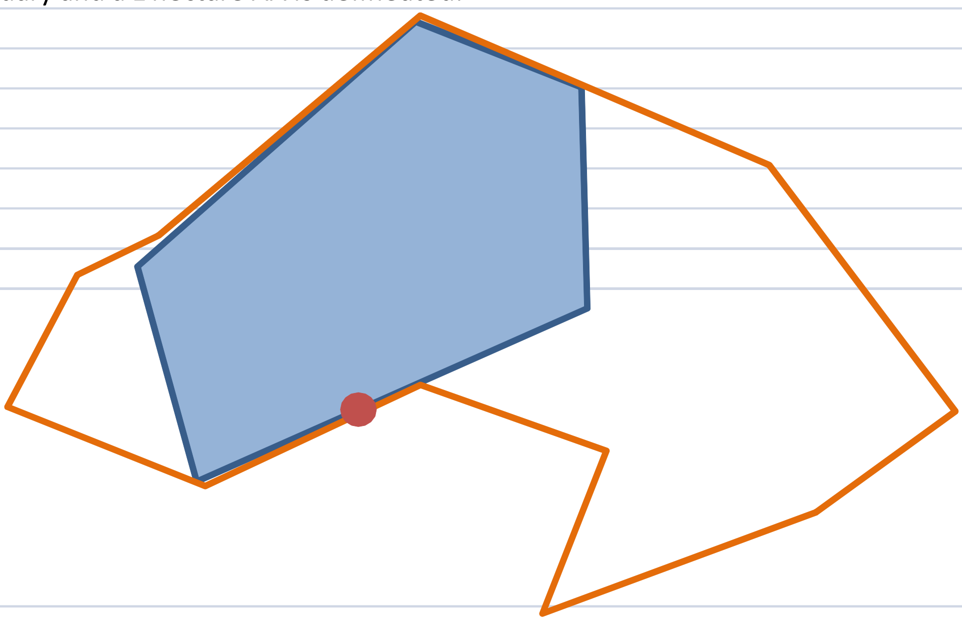
Assessment Area Diagrams

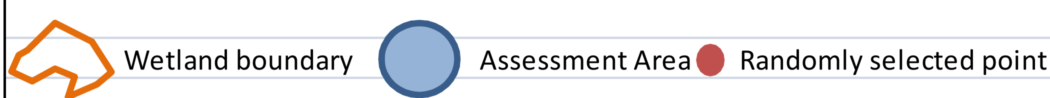
When a wetland is smaller than 1 hectare the entire wetland is the Assessment Area



When a wetland is greater than 1 hectare, a point is randomly assigned along the wetland boundary and a 1 hectare AA is delineated.



Legend



Site Description

Site Name					
Date of Assessment					
Assessor Name(s)					
Assessor Affiliation(s)					
Site Latitude					
Site Longitude					
Coordinate System					
Ecoregion					
Directions					
Size of Wetland					
Assessment Area size					
Reason for Assessment					
Dominant Water Source	Surface flow	Precipitation		Groundwater	Overbank flooding
Hydrodynamics	Unidirectional	Bidirectional		Vertical	
Geomorphic Setting	Depression	Flat		Fringe	Slope
HGM Class	**Depression**	**Flat**	**Slope**	**Lacustrine**	**Riverine**
Regional Subclass	*Closed Impounded*	*Hardwood*	*Headwater*	*Disconnected Oxbow*	*Connected Oxbow*
	Open Impounded		*Low-gradient*	*Reservoir Fringe*	*Beaver Complex*
	Groundwater			*Pond Fringe*	*In-Channel*
	Open Surface Water				*Floodplain*
	Closed Surface Water				*Floodplain Depression*
					Riparian
Cowardin Class (four most dominant and area as a % of AA)	Class			% AA	
	Class			% AA	
	Class			% AA	
	Class			% AA	
Notes					

[redacted]

[redacted]

[redacted]

[redacted]

[redacted]

[redacted]

[redacted]

[redacted]

[redacted]

[redacted]

[redacted]

[redacted]

[redacted]

3. Biotic Condition	
b. Habitat connectivity	
Instructions:	
1. On an aerial photograph or in GIS delineate the connected habitat surrounding the AA within a 1000 m buffer. Connected habitat does not include any of the dispersal barriers below.	
2. Calculate the metric by dividing the total connected area by the total area in the 1000 m buffer.	
Included in connected habitat	
open water	
other wetlands	
natural uplands	
nature or wildland parks	
bike trails	
railroads	
roads not hazardous to wildlife	
swales and ditches	
vegetated levees	
open range land	
Dispersal Barriers not included in connected habitat	
Commercial Developments	
Fences that interfere with animal movements	
intensive agriculture (e.g. row crops, orchards, vineyards)	
dryland farming	
paved roads	
lawns	
parking lots	
intensive livestock production (e.g. horse paddocks, feedlots, chicken ranches etc.)	
residential areas	
sound walls	
sports fields	
traditional golf courses	
urbanized parks with active recreation	
pedestrian/bike trails with near constant traffic	
Area of Connected Habitat	0
Area within 1000 m buffer	0
METRIC SCORE 4c	1

[redacted]

APPENDIX B: Plant Species

Species	Number of Sites Present
ACALYPHA RHOMBOIDEA	1
ACALYPHA VIRGINICA	3
ACER NEGUNDO	16
ACER SACCHARINUM	3
ALISMA SPP.	2
AMARANTHUS PALMERI	7
AMARANTHUS SPP.	2
AMARANTHUS TUBERCULATUS	7
AMBROSIA ARTEMISIIFOLIA	1
AMBROSIA PSILOSTACHYA	2
AMBROSIA TRIFIDA	14
AMMANNIA AURICULATA	3
AMMANNIA COCCINEA	7
AMORPHA FRUTICOSA	6
AMPELOPSIS ARBOREA	7
AMPELOPSIS CORDATA	8
AMPHICARPAEA BRACTEATA	3
AMPHICARPAEA BRACTEATA	1
ANDROPOGON VIRGINICUS	3
APIACEAE SPP.	2
APIOS AMERICANA	2
APOCYNACEAE SPP.	1
APOCYNUM CANNABINUM	3
ARISAEMA DRACONTIUM	2
ARTEMISIA LUDOVICIANA	1
ARUNDO DONAX	1
AZOLLA FILICULOIDES	3
BETULA NIGRA	3
BIDENS BIPINNATA	1
BIDENS DISCOIDEA	1
BIDENS FRONDOSA	5
BOEHMERIA CYLINDRICA	12
BOTHRIOCHLOA LAGUROIDES	1
BOTRYCHIUM DISSECTUM	1
BOTRYCHIUM VIRGINIANUM	1
BROMUS JAPONICUS	1
BROMUS SECALINUS	1
CAMPSIS RADICANS	16

Species	Number of Sites Present
CARDIOSPERMUM HALICACABUM	5
CAREX CHEROKEENSIS	3
CAREX CRUS-CORVI	4
CAREX FRANKII	1
CAREX HYALINOLEPIS	7
CAREX HYSTERICINA	1
CAREX LUPULINA	3
CAREX SPP.	10
CAREX TETRASTACHYA	1
CAREX TRIBULOIDES	1
CAREX VULPINOIDEA	1
CARYA CORDIFORMIS	4
CARYA ILLINOINENSIS	14
CATALPA BIGNONIOIDES	1
CELTIS LAEVIGATA	16
CELTIS TENUIFOLIA	1
CENCHRUS SPP.	2
CEPHALANTHUS OCCIDENTALIS	12
CERATOPHYLLUM DEMERSUM	3
CERCIS CANADENSIS	3
CHAMAECRISTA FASCICULATA	2
CHAMAESYCE MACULATA	3
CHAMAESYCE PROSTRATA	3
CHASMANTHIUM LATIFOLIUM	10
CHENOPODIUM ALBUM	3
CHENOPODIUM SPP.	1
CINNA ARUNDINACEA	1
CIRSIUM ALTISSIMUM	1
CLEMATIS SPP.	2
CLITORIA MARIANA	1
COCCULUS CAROLINUS	1
COLEATAENIA ANCEPS	1
COMMELINA ERECTA	1
COMMELINACEAE SPP.	1
CONOCLINIUM COELESTINUM	2
CONVOLVULACEAE SPP.	4
CONYZA CANADENSIS	13
COREOPSIS TINCTORIA	2
CORNUS DRUMMONDII	6
CRATAEGUS VIRIDIS	2

Species	Number of Sites Present
CRYPTOTAENIA CANADENSIS	2
CUSCUTA POLYGONORUM	2
CYNODON DACTYLON	8
CYPERACEAE SPP.	6
CYPERUS ACUMINATUS	2
CYPERUS ERYTHRORHIZOS	1
CYPERUS ODORATUS	12
CYPERUS REFLEXUS	1
CYPERUS SQUARROSUS	5
CYPERUS STRIGOSUS	3
DESMODIUM SPP.	2
DICHANTHELIUM ACICULARE	1
DICHANTHELIUM ACUMINATUM	2
DICHANTHELIUM COMMUTATUM	1
DICHANTHELIUM DICHOTOMUM	1
DICHANTHELIUM LAXIFLORUM	2
DICHANTHELIUM POLYANTHES	1
DICHANTHELIUM SCOPARIUM	1
DICHANTHELIUM SPHAEROCARPON	1
DICHANTHELIUM SPP.	2
DIGITARIA CILIARIS	3
DIODIA VIRGINIANA	3
DIOSPYROS VIRGINIANA	15
DRACOPIS AMPLEXICAULIS	2
ECHINOCHLOA CRUS-GALLI	10
ECHINODORUS BERTEROI	2
ECLIPTA PROSTRATA	14
ELEOCHARIS COMPRESSA	1
ELEOCHARIS PALUSTRIS	2
ELEOCHARIS PARVULA	2
ELEOCHARIS QUADRANGULATA	1
ELEOCHARIS SPP.	1
ELEPHANTOPUS CAROLINIANUS	7
ELYMUS VIRGINICUS	15
EQUISETUM LAEVIGATUM	1
EQUISETUM X FERRISSII	4
ERAGROSTIS HYPNOIDES	1
ERIGERON STRIGOSUS	4
EUPATORIUM PERFOLIATUM	7
EUPATORIUM SEROTINUM	8

Species	Number of Sites Present
EUPHORBIA DENTATA	1
EVOLVULUS NUTTALLIANUS	1
FABACEAE SPP.	2
FIMBRISTYLIS AUTUMNALIS	2
FIMBRISTYLIS VAHLII	3
FORESTIERA ACUMINATA	3
FRAXINUS PENNSYLVANICA	17
GALACTIA REGULARIS	1
GEUM CANADENSE	5
GLEDITSIA TRIACANTHOS	4
GONOLOBUS SUBEROSUS	4
GRINDELIA SQUARROSA	2
GYMNOCLADUS DIOICUS	2
HELENIUM AMARUM	1
HELIANTHUS PETIOLARIS	1
HELIANTHUS TUBEROSUS	1
HELIOTROPIUM CURASSAVICUM	3
HELIOTROPIUM INDICUM	3
HETEROTHECA SUBAXILLARIS	2
HIBISCUS MOSCHEUTOS	4
HIERACIUM SPP.	1
HYPERICUM MUTILUM	1
HYPERICUM SPP.	1
ILEX DECIDUA	10
IPOMOEA LACUNOSA	8
IRESINE RHIZOMATOSA	1
IVA ANNUA	1
JUGLANS NIGRA	1
JUNCUS ACUMINATUS	1
JUNCUS EFFUSUS	4
JUNCUS INTERIOR	1
JUNCUS SPP.	1
JUNCUS VALIDUS	3
JUNIPERUS VIRGINIANA	4
JUSTICIA AMERICANA	1
LACTUCA SERRIOLA	7
LATHYRUS HIRSUTUS	2
LEERSIA ORYZOIDES	6
LEERSIA VIRGINICA	4
LEMNA MINOR	1

Species	Number of Sites Present
LEMNA MINUTA	7
LEPIDIUM DENSIFLORUM	1
LEPTOCHLOA FUSCA	7
LEPTOCHLOA PANICEA	5
LESPEDEZA CUNEATA	6
LEUCOSPORA MULTIFIDA	5
LIGUSTRUM SINENSE	3
LINDERA BENZOIN	1
LINDERNIA DUBIA	2
LINUM MEDIUM	1
LINUM STRIATUM	2
LOBELIA CARDINALIS	1
LOLIUM PERENNE	1
LONICERA JAPONICA	6
LUDWIGIA ALTERNIFOLIA	1
LUDWIGIA DECURRENS	3
LUDWIGIA GRANDIFLORA	2
LUDWIGIA PALUSTRIS	1
LUDWIGIA PEPLOIDES	3
LUDWIGIA SPP.	2
LYCOPUS AMERICANUS	5
LYTHRUM ALATUM	3
MACLURA POMIFERA	4
MELOTHRIA PENDULA	4
MENISPERMUM CANADENSE	1
MIKANIA SCANDENS	1
MIMULUS ALATUS	1
MOLLUGO VERTICILLATA	3
MONARDA PUNCTATA	1
MORUS ALBA	7
MORUS RUBRA	4
NELUMBO LUTEA	2
OENOTHERA BIENNIS	1
OENOTHERA SPP.	4
OXALIS CORNICULATA	2
OXALIS DILLENII	4
OXALIS STRICTA	2
PANICUM CAPILLARE	2
PANICUM VIRGATUM	1
PARTHENOCISSUS QUINQUEFOLIA	12

Species	Number of Sites Present
PASPALUM PUBIFLORUM	3
PASPALUM SETACEUM	2
PASPALUM SPP.	1
PASSIFLORA INCARNATA	1
PENTHORUM SEDOIDES	1
PERILLA FRUTESCENS	1
PERSICARIA AMPHIBIA	5
PERSICARIA HYDROPIPER	2
PERSICARIA HYDROPIPEROIDES	6
PERSICARIA LAPATHIFOLIA	8
PERSICARIA PENSYLVANICA	1
PERSICARIA SPP.	3
PERSICARIA VIRGINIANA	2
PHYLA LANCEOLATA	6
PHYLA NODIFLORA	7
PHYSALIS ANGULATA	6
PHYSALIS PUBESCENS	3
PHYSALIS SPP.	1
PHYTOLACCA AMERICANA	3
PLATANUS OCCIDENTALIS	7
PLUCHEA ODORATA	10
POACEAE SPP.	4
POLYPREMUM PROCUMBENS	1
POPULUS DELTOIDES	13
PORTULACA OLERACEA	5
POTAMOGETON NODOSUS	2
PRUNUS SEROTINA	1
PYRRHOPAPPUS CAROLINIANUS	2
QUERCUS MACROCARPA	6
QUERCUS PALUSTRIS	3
QUERCUS SHUMARDII	9
QUERCUS SPP.	3
RANUNCULACEAE SPP.	1
RANUNCULUS SCELERATUS	1
RAYJACKSONIA ANNUA	1
RHUS COPALLINUM	1
RORIPPA PALUSTRIS	9
RORIPPA SESSILIFLORA	2
ROSA MULTIFLORA	2
ROSACEAE SPP.	1

Species	Number of Sites Present
RUBUS SPP.	13
RUBUS TRIVIALIS	3
RUDBECKIA HIRTA	2
RUMEX CRISPUS	9
RUMEX VERTICILLATUS	1
SABATIA CAMPESTRIS	1
SACCHARUM RAVENNAE	1
SAGITTARIA LATIFOLIA	2
SALIX INTERIOR	5
SALIX NIGRA	19
SAMBUCUS CANADENSIS	1
SAMOLUS VALERANDI	3
SAPINDUS DRUMMONDII	2
SAURURUS CERNUUS	1
SCUTELLARIA LATERIFLORA	2
SESBANIA HERBACEA	3
SIDA SPINOSA	3
SIDEROXYLON LANUGINOSUM	4
SMALLANTHUS UVEDALIUS	1
SMILAX BONA-NOX	14
SMILAX ROTUNDIFOLIA	4
SMILAX TAMNOIDES	6
SOLANACEAE SPP.	2
SOLANUM CAROLINENSE	3
SOLANUM PTYCANTHUM	2
SOLIDAGO GIGANTEA	6
SOLIDAGO SPP.	8
SORGHUM HALEPENSE	14
SPHENOPHOLIS OBTUSATA	1
SPOROBOLUS CRYPTANDRUS	1
SPOROBOLUS SPP.	1
STROPHOSTYLES HELVOLA	2
SYMPHORICARPOS ORBICULATUS	9
SYMPHYOTRICHUM DUMOSUM	1
SYMPHYOTRICHUM SPP.	2
TAMARIX RAMOSISSIMA	4
TEUCRIUM CANADENSE	12
TORILIS ARVENSIS	2
TOXICODENDRON RADICANS	16
TRAGOPOGON DUBIUS	4

Species	Number of Sites Present
TRIDENS FLAVUS	1
TRIFOLIUM REPENS	1
TYPHA DOMINGENSIS	2
TYPHA SPP.	1
ULMUS ALATA	1
ULMUS AMERICANA	13
ULMUS RUBRA	5
UTRICULARIA GIBBA	1
VALERIANELLA RADIATA	1
VERBENA URTICIFOLIA	6
VERBESINA ENCELIOIDES	1
VIBURNUM PRUNIFOLIUM	1
VIOLA SORORIA	2
VIOLA SPP.	8
VITIS AESTIVALIS	4
VITIS CINEREA	2
VITIS RIPARIA	5
VITIS SPP.	2
XANTHIUM STRUMARIUM	14
ZIZANIOPSIS MILIACEA	1