Field Evaluation of Restored Wetlands in North Carolina Using Floristic Indices, Rapid Assessments, and Environmental Parameters

FINAL REPORT

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Mark B. Fernandez, M.S. Graduate Student (*Primary author*)

Michael R. Burchell, Ph.D. - Associate Professor & Extension Specialist (*Project contact*)

Gregory D. Jennings, Ph.D. – Professor Emeritus

Executive summary

The restoration of previously-drained wetlands is an important mechanism in mitigating anthropogenic impacts to these existing ecosystems. Various floristic-based, rapid, and GIS-based assessments have been developed to evaluate wetlands. While most if not all were originally developed for natural (i.e. not created or restored) wetlands, some have not been used extensively to evaluate restored sites. We assessed 30 restored wetlands across North Carolina using the USEPA National Wetland Condition Assessment protocols. Wetland assessments include the Vegetation Index of Biotic Integrity (VIBI), the Adjusted Floristic Quality Assessment Index (AFQI), the Floristic Assessment Quotient for Wetlands (FAQWet), the Ohio Rapid Assessment Method (ORAM), the North Carolina Wetland Assessment Method (NCWAM), and the Landscape Development Index (LDI). NCWAM is a new, rapid ecological assessment that uses conditional computer programming (e.g. IF-THEN statements) to produce an overall site rating as well as a hydrology, water quality, and habitat function ratings. Floristic indices and rapid assessment scores were not significantly different among mitigation providers. Overall, the correlations among the wetland assessments was low and not significant, with the exception being between the FAQWet level 3 assessment and level 2 ORAM and NCWAM rapid assessments. A shared emphasis on site hydrology likely explains the relationship among these three assessments. While the correlation among assessment scores was generally not significant, a majority of the restorations were rated as medium or higher quality by the VIBI, ORAM, and NCWAM assessments, and only two sites were rated as low quality with those three assessments. Based on these similar rating distributions, one may

conclude that assigning success or failure to a restored wetland can be performed adequately using a level 2 assessment, with the more resource-intensive level 3 assessment reserved for questionable sites.

Introduction

Wetland ecosystem services such as supplying food and water, regulating climate and flooding, fostering recreational and educational activities, and supporting nutrient cycling and plant production (Millennium, 2005) have been conservatively estimated at $3.4 billion worldwide based on data from 630,000 km^2 of wetlands (Schuyt and Brander, 2004). When extrapolated to the global estimate of 12.8 million km^2 of wetlands (Finlayson, 1999), the estimated value of wetland services was $70 billion worldwide. Flood control, recreational fishing, general recreation, water filtering, and biodiversity were identified globally as the most economically valuable functions.

These ecosystem benefits, however, have been jeopardized through the removal and degradation of the ecosystems that provide them. By the mid-1970, wetland in the conterminous United States had dropped from a pre-settlement estimated 870,000 km^2 (Roe and Ayres, 1954) to 400,600 km^2 (Tiner, 1984), a decrease of 54%. North Carolina has lost approximately 49% of its wetlands, from an estimated 44,900 km^2 pre-settlement (Dahl, 1990) to 23,000 km^2 in mid-1980s (Hefner and Brown, 1985). Based on available data from 2003, 85 km^2 of wetlands in the United States that are removed or impacted annually are replaced with 176 km^2 of mitigation wetlands, at a cost of $3.45 billion ($195,700 per ha), (ELI, 2007).

In response to continued ecological impacts, the Clean Water Act of 1972 (33 USC § 1251) charged the United States to “restore and maintain the chemical, physical, and biological integrity of the nation’s waters.” Though the degradation of wetlands has been reduced in response to the Clean Water Act, impacts to existing wetlands continue to occur.

Compensatory mitigation—the remedy of unavoidable impacts—may be satisfied through one of three different mechanisms: 1) permitee-responsible (when a developer that impacts an ecosystem restores another ecosystem), 2) mitigation bank (when a developer purchases mitigation credits from a private company), or 3) in-lieu fee (when a developer pays a fee to a state agency) (USEPA, 2012). Compensatory wetland mitigation has become a large industry across the U.S. and especially within the southeast. Based on USACE data, wetlands impacted under Section 404 of the Clean Water Act were mitigated in the U.S. on average with 2.03 mitigation ha for each impacted hectare of wetland (Martin et al., 2006). The USACE South Atlantic division (North Carolina, South Carolina, Georgia, Alabama, Florida, and half of Mississippi) accounted for 23.7% of the permits, more than any other division.

Not every mitigation site is successful, however. In North Carolina, mitigation success rates in the mid-1990's based on two independent studies were a low 20% (one out of five sites successful) and 42% (10 out of 24 sites successful) (see Hill et al., 2013; Pfeifer and Kaiser, 1995; respectively). More recently, a comprehensive review of wetland mitigation projects across North Carolina reported marked improvements in mitigation success rates. Hill et al. (2013) assessed 83 wetland mitigation projects (8,000 ha) and reported a success rate of 70% by sites and 64% by area. Significant differences in success rates were observed across North Carolina ecoregions, as Mountain site success rates were significantly lower than Piedmont and Coastal Plain region rates, by area. Also, permitee-responsible sites had a significantly higher success rate than North Carolina Department of Transportation (NCDOT) sites, by area. However, significant differences in success rates were not observed across mitigation providers based on project counts.

The aforementioned Hill et al. (2013) paper provided an update on the current trends in North Carolina wetland mitigation. On a national scale, the U.S. Environmental Protection Agency (USEPA) currently completing the National Aquatic Resource Surveys (NARS), a suite of ecological surveys focusing on natural (i.e. not created or restored) ecosystems including rivers (2006), lakes (2007), coastal waters (2010), and wetlands (2011) (USEPA, 2011a). Field work for the National Wetland Condition Assessment (NWCA)—the wetland portion of NARS—was conducted in 2011 and involved surveying 1,179 *natural* wetlands across the conterminous US and Alaska (USEPA, 2011a). A final report of the NWCA findings is scheduled for publication in 2014.

The NWCA protocols rely heavily on floristic data collected at each wetland. Biotic assessments that involve measurements of the flora or fauna community present at a site have long been used to rate the quality of an ecosystem. Floristic metrics and indices—multiple metric scores combined to produce an index score that is typically rescaled to be within predefined range, e.g. 1 to 10—are commonly in part because vegetation is readily assessed and does not require the installation and long-term monitoring of wells. Also, because wetland vegetation is a product of the soil and hydrologic conditions, floristic assessments are thought by some to capture all three jurisdictional criteria of a wetland. Traditional floristic metrics include richness, diversity, and evenness. More recently developed floristic indices such as the Vegetative Index of Biological Integrity (VIBI; Mack, 2004), the Floristic Quality Assessment Index (FQAI; Andreas et al., 2004), the Adjusted Floristic Quality Assessment Index (AFQI; Miller and Wardrop, 2006) and the Floristic Assessment Quotient for Wetlands (FAQWet; Ervin et al., 2006) have increasingly been used to evaluate natural wetlands. Though some of these assessments have been applied to created or restored wetlands, few large sample (> 20) peer-reviewed studies of restoration projects exist.

Floristic indices (also known as level 3 assessments, see Brooks et al., 2004) require trained ecologists to identify species in the field. Recently there has been a trend toward Rapid Assessment Methods (RAM). Also known as level 2 assessments, RAMs are broader in scope than level 3 assessments in that biotic and abiotic ecosystem components are evaluated. RAMs are mostly qualitative, making them more efficient than quantitative biotic assessments. Rapid assessment methods include the USA Rapid Assessment Method (USA-RAM; USEPA, 2011b), the hydrogeomorphic classification method (HGM; Brinson, 1993), and the Ohio Rapid Assessment Method (ORAM; Mack, 2001). Recently North Carolina has introduced the North Carolina Wetland Assessment Method (NCWAM; NCWFAT, 2010). Developed by the US Army Corps of Engineers, The North Carolina Division of Water Quality, and the North Carolina Department of Transportation, NCWAM is a rapid functional assessment that use conditional computer programming (e.g. IF-THEN statements calculated via a macro-enabled spreadsheet) to produce an overall site rating as well as a hydrology, water quality, and habitat function ratings. While NCWAM was extensively calibrated across a range of natural ecosystems, a study on how NCWAM evaluate restored ecosystems across the state has not been published (see Burton, 2008, for an evaluation of Coastal Plain mitigation sites using NCWAM; see Steele, 2013, for an evaluation of natural headwater wetlands using NCWAM).

Specific objectives for this study include 1) qualitatively describe the current state of wetland restoration in North Carolina across mitigation providers, 2) compare the results among floristic indices, ORAM, and NCWAM using correlation and constrained correspondence analysis (CCA) ordination, and 3) determine the relationships between various environmental parameters and a GIS-based land disturbance index with the floristic indices, ORAM, and NCWAM scores. This was the first time that these various ecological assessments have been simultaneously applied to wetlands—natural or restored—across the state of North Carolina. Also, as all of sampled sites are restored wetlands, results of this study will provide specific insight into the application of these assessments on restoration projects.

Methods

Site Selection

The target population of restored wetlands was collected from an internal North Carolina Division of Water Quality (NCDWQ)[1] maintained database of mitigation sites. Site criteria for this study included being a restored mitigation wetland permitted between 2002 and 2006, older than four years old post-construction, with an area of at least 0.1 ha, and a width of greater than 20 m (for linear wetlands). Selected restoration projects were restricted to those completed after 2001 to coincide with new compensatory mitigation guideline recommendations published by the National Research Council (NRC, 2001). This criterion helped ensure that current restoration science and construction techniques were evaluated in this study. The target population was initially limited to riverine or riparian restored wetlands

[1] Note: that the NCDWQ merged with the North Carolina Division of Water Resources (NCDWR) on August 1, 2013, after field work for this project was completed.

that had been planted with trees and shrubs, to minimize site-to-site variability. After screening the NCDWQ maintained database with the aforementioned site criteria, the target population contained 42 in-lieu fee, 11 mitigation bank, and 11 permittee-responsible restored wetlands.

Documented vegetation and hydrology success was also a target population site criterion. Sites were considered successful if they had either been closed out after 5 years (the typical post-construction monitoring period in North Carolina) or deemed successful in the most recent monitoring year if a site has not been closed out. Success was defined in the original monitoring plan for both vegetation (typically 642 stems per ha by year five for forested sites) and hydrology (typically the water table must be within 30 cm of the surface for at least 5% of the growing season days (USACE, 1987), consecutively).

Adequate if not equal sampling among mitigation providers (in-lieu fee, mitigation bank, or permittee-responsible) was desired. In this study, in-lieu fee (ILF) referred to mitigation sites under the North Carolina Ecosystem Enhancement Program (NCEEP), mitigation bank referred to sites restored by an ecosystem mitigation company, and permittee-responsible referred to sites restored by private companies, local municipalities, county governments, or the North Carolina Department of Transportation (NCDOT). A sample size of 30 restored wetlands was desired. Due to their relatively larger target population, samples for the in-lieu fee sites were selected via a generalized random-tessellation stratified (GRTS) design (Stevens and Olsen, 2004), which spatially balances selected sites where simple random sampling may not. The mitigation bank and permittee-responsible sites were randomly ordered and the first ten were to be used for the study. Mitigation bank or permittee-responsible sites were replaced with in-lieu fee sites if a mitigation bank or permittee-responsible site was not deemed usable.

Ultimately 30 restored wetlands were surveyed (Figure 1). Twenty-seven of the 30 restored wetlands were located within rural watersheds (< 10% impervious cover). Of the remaining three, two were located adjacent to a large retail store's parking lot, while the third was a riparian wetland situated within a residential neighborhood (<0.1 ha lot size). At least 26 of the rural sites were previously in row crop or hay production before restoration, based on historic aerial imagery. Field sampling occurred during the growing season between July 1st and September 30th, 2012.

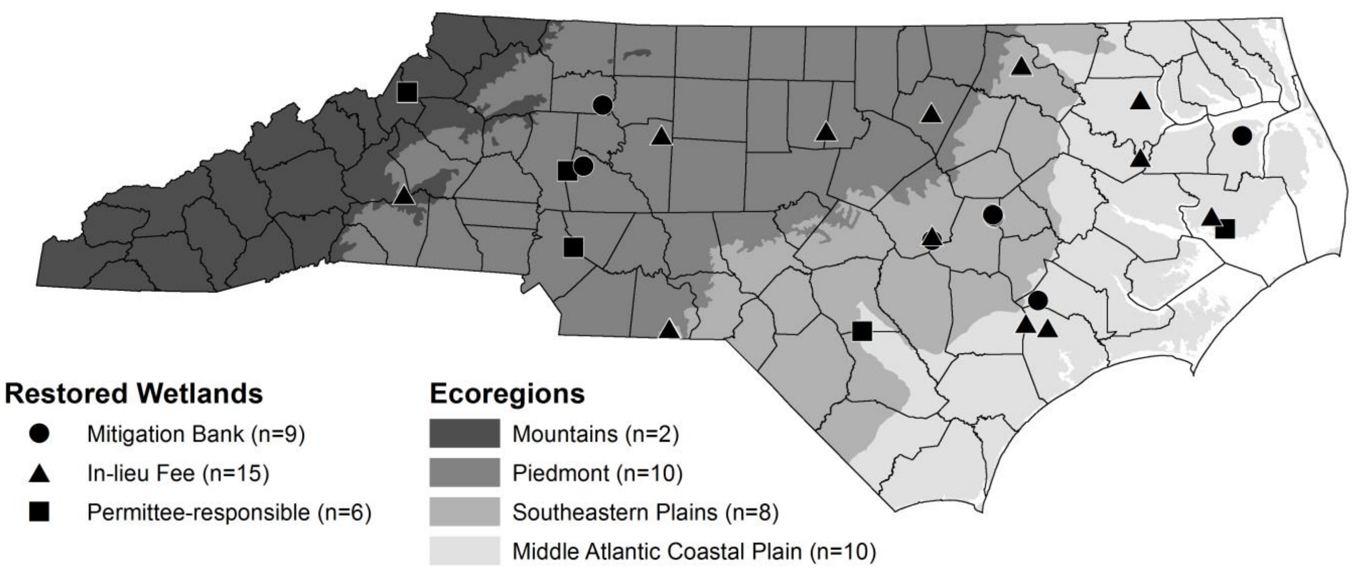

Figure 2. Sampled restored wetlands (n=30) by USEPA ecoregions. Mitigation provider of each site denoted by symbols.

Assessment Methods

Floristic Indices

Vegetation at each site was sampled following the National Wetland Condition Assessment (NWCA) protocols (USEPA, 2011b). The wetland assessment area was defined as the area enclosed by a 40 m radius circle (0.5 ha) of a randomly generated sampling point. Five 10 x 10 m vegetation plots, typically arranged in a "+" pattern aligned to the cardinal directions, were laid out within the wetland assessment area (Figure 1). Within the southwest and northeast corner of each 100 m^2 plot was a pair of 1 m^2 and 10 m^2 nested quadrants. Linear wetlands, wetlands with sampling obstructions such as deep water, or wetlands smaller than 0.5 ha were specified an alternative wetland assessment area and vegetation plot layout, per NWCA protocols. However, five 10 x 10 m vegetation plots were always sampled regardless of the layout configuration. The sampling point at the center of the assessment area was randomly selected from within the wetland component boundary before the field visit. Note that a single wetland mitigation project may contain land that has been restored, enhanced, or is part of a stream restoration. Therefore, a wetland restoration component for each site was delineated based on mitigation documents before the sampling points were randomly generated, ensuring that only areas of wetland restoration were surveyed. Per NWCA protocols, the center of the assessment area was moved as much as 60 m in any direction if a vegetation plot was unable to be sampled due to deep water or upland areas, for instance. In restoration sites where trees were planted, the center of the assessment area was also moved as much as 60 m in order to better assess the intended dominant vegetation.

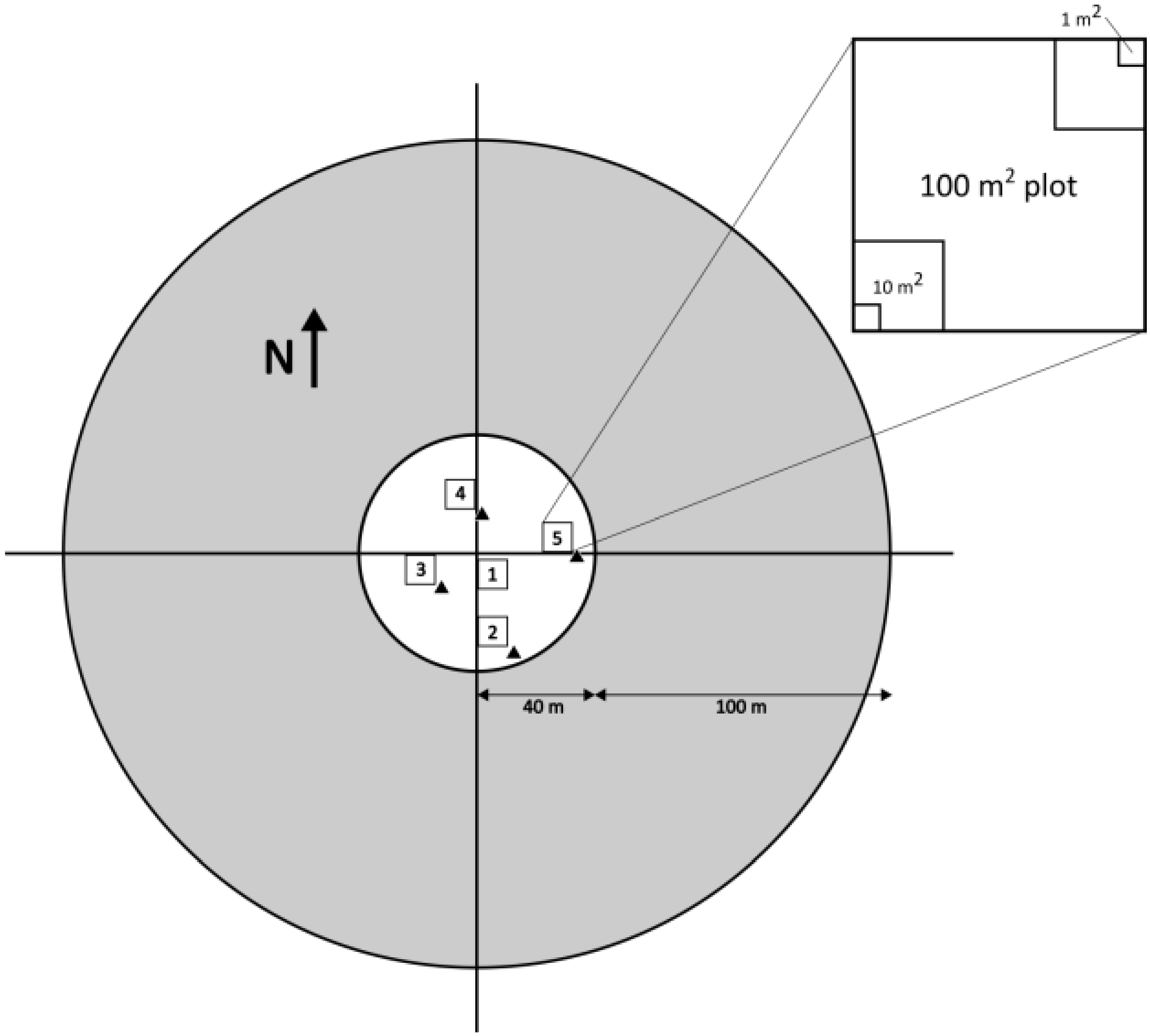

Figure 1. Typical site layout for vegetation, soil, and landscape development index (LDI) assessments, approximately to scale. Layout of vegetation plots and soil pits per NWCA protocols (USEPA, 2011b). The wetland assessment area is denoted by the inner white circle (40 m radius; 0.5 ha), which contains five 10 x 10 m vegetation plots arranged along the cardinal directions. Triangles denote location of four soil pits adjacent to the southeast corner of a vegetation plot. The LDI assessment area is denoted by the gray buffer area (100 m radius). Map inset of a vegetation plot highlights the nested plots that are present in all five plots.

Vegetation taxa were identified to the lowest taxonomic level possible in the field. Unknown species were collected for later identification by NCDWQ or the University of North Carolina herbarium staff. Coverage of each species rooted in or overhanging the plots was estimated from 1% to 100% for each plot, with species occupying less than 1% (1 m^2) of a plot assigned 0.1% coverage per NWCA protocols. Wetland indicator status (http://plants.usda.gov/wetland.html) and non-native status (http://plants.usda.gov/java/) were determined for each identified species. Additional vegetation metrics such as tree diameter at breast height (DBH) and percent bare ground cover were also collected. Three floristic indices (level 3 assessments) that include VIBI, AFQI, and FAQWet were calculated from the vegetation coverage data and applied to all sites.

VIBI

The Ohio Vegetation Index of Biotic Integrity version 1.3 (VIBI; Mack, 2004) has been applied extensively to both natural, restored, and created wetlands (Mack 2004; Mack 2006; Micacchion et al., 2010; PG Environmental, 2012; Stapanian et al., 2013). VIBI scores are a summation of 10 equally weighted floristic metrics. The specific metrics used are determined by the dominant vegetation type (emergent, shrub, or forested; Cowardin et al., 1979). Only the floristic quality assessment index (FQAI), percent tolerant, and percent sensitive metrics are common to all three wetland vegetation type VIBI scores (Table 1).

Table 2. Metrics for calculating VIBI scores (adapted from Mack, 2004)

VIBI-emergent	VIBI-shrub	VIBI-forested
Carex	Carex	-
Dicot, native	Dicot, native	-
Shrub, native, wetland	Shrub, native, wetland	-
Hydrophyte, native	Hydrophyte, native	-
Annual:Perennial ratio	-	-
FQAI	FQAI	FQAI
% Tolerant	% Tolerant	% Tolerant
% Sensitive	% Sensitive	% Sensitive
% Invasive graminoids	-	-
% Unvegetated	-	-
-	-	Shade†
-	Seedless vascular plants	Seedless vascular plants
-	-	% Hydrophyte
-	% Bryophyte	% Bryophyte
-	-	Pole timber density
-	Subcanopy IV†	Subcanopy IV†
-	-	Canopy IV

† Metric not used in VIBI calculations due to a lack of regional data and/or NWCA methodology limitations.
VIBI score is the summation of each metric from the appropriate column
VIBI scores calculated with less than 10 metrics were scaled to a maximum potential value of 100
FQAI = Floristic Quality Assessment Index (Andreas et al., 2004)

VIBI formulas used were originally developed for Ohio. Due to incompleteness in regional data for shade tolerance ratings for certain North Carolina species and limitations of the NWCA method related to the measurement of shrub species DBH, one metric for VIBI-shrub and two metrics for VIBI-forest were dropped. In addition, the biomass metric for VIBI-emergent was replaced with the percent unvegetated metric as per VIBI methodology on emergent mitigation wetland sites. To allow for comparisons among VIBI-emergent and other published studies, the potential maximum value of shrub and forest VIBI scores were scaled up to 100.

VIBI scores range from 0 to 100. VIBI scores can be converted into an ordinal rating scale known as the Wetland Tiered Aquatic Life Uses (WTALU; Mack, 2004). Sites that received a VIBI score between 0 to 29 were classified as Low Quality Wetland Habitat, scores between 30 to 59 were classified as Restorable Wetland Habitat, scores between 60 to 75 were classified as Wetland Habitat, and scores between 76 to 100 were classified as Superior Wetland Habitat. These rating thresholds are for riverine wetlands. Field evaluation classified 23 (77%) of the sites in our study as HGM type riverine (Brinson, 1993) when using the appropriate NWCA form. The rest of the sites with the exception of one were HGM classified as flats. Mack's study (2004) did not provide WTALU rating thresholds for flats. Therefore the riverine threshold values for determining WTALU were applied to all of the sampled sites for this study.

AFQI

The adjusted floristic quality assessment index (AFQI; Miller and Wardrop, 2006), a modification of the floristic quality assessment index (FAQI; Andreas et al., 2004), was calculated for each site. The AFQI score for a site is

$$AFQI = \frac{FQAI}{10\sqrt{N_{total}}} * 100 = \frac{\bar{C}\sqrt{N_{native}}}{10\sqrt{N_{total}}} * 100 \qquad \text{(Equation 1)}$$

where $\bar{C}$ is the average of the coefficient of conservatism (C) values, N_{native} is the native species richness, and N_{total} is the total species richness. Since it is dependent upon species richness, AFQI has no theoretical upper bound. The C value is an index that describes a species' fidelity toward a specific habitat type. The minimum C value of zero describes a plant that tolerates a wide range of habitats; the maximum C value of 10 indicates a plant has a high degree of fidelity for a narrow range of habitats. Ruderal species (species that are the first to colonize disturbed lands) receive lower C values than more habitat-sensitive species (Taft et al., 1997). See Taft et al. (2007) for more detailed criteria of C values. C values have yet to be published for all North Carolina species. Therefore, C values for North Carolina wetland species (partial list) developed for other NCDWQ wetland studies (Baker et al., 2008; Savage et al., 2010; Baker et. al, 2013) and Virginia wetland species list (DeBerry et al., 2006) were used in this study. Only 15 out of 434 observed species (3%) did not have a regionally published C value. Another 55 taxa were not identified to species level due to a lack of identifiable characteristics (e.g. Carex species without seed heads) and therefore were excluded from AFQI calculations.

As previously mentioned, the AFQI is a modification of the FQAI. FQAI has been used extensively to assess wetlands nationwide (Lopez and Fennessy, 2002; Mack, 2004; Cohen et al, 2004; Bourdaghs et al, 2006; Johnston et al., 2009). However, various studies found FQAI scores to be positively correlated with site size and site richness (see Ervin et al., 2006). Bias toward site richness could be a problem if vegetation plot size or wetland type varies across sampled sites. For example, a pocosin wetland will typically have lower richness than a riverine swamp, even if both wetlands are of high quality. In contrast to FQAI results, AFQI scores have been shown to not suffer from collinearity with native richness (Miller and Wardrop, 2006). The same study reported that both FQAI and AFQI scores correlated well with a land disturbance index, but AFQI did a better job of discriminating between low and moderately disturbed sites. Given these findings and the fact that FQAI scores are already incorporated into the reported VIBI scores, AFQI scores were analyzed in this study.

FAQWet

AFQI scores each require a database of C values that are region dependent and not currently available nationwide. In contrast, the Floristic Assessment Quotient for Wetlands (FAQWet; formula version 3 in Ervin et al., 2006) uses wetness coefficients based on the readily available national wetland indicator status categories (http://plants.usda.gov/wetland.html, see Table 1). The FAQWet score for a site is

$$FAQWet = \frac{\overline{WC} * N_{native}}{\sqrt{N_{total}}} \quad \text{(Equation 2)}$$

where $\overline{WC}$ is the average of the wetness coefficient values, N_{native} is the native species richness, and N_{total} is the total species richness.

Table 1. Wetland indicator status and corresponding wetness coefficient (adapted from Ervin et al, 2006)

Indicator Status†	Probability of occurrence in wetlands	Wetness Coefficient
Obligate (OBL)	>99%	+5
Facultative Wetland (FACW)	67-99%	+3
Facultative (FAC)	34-66%	0
Facultative Upland (FACU)	1-33%	-3
Upland (UPL)	<1%	-5

† The most recently available (2012) wetland plant list does not include plus (+) or minus (-) designations

Rapid Assessment Methods (RAM)

ORAM

The Ohio Rapid Assessment Method (ORAM; Mack, 2001) was applied to all sites. ORAM version 5.0 has been rigorously tested on natural, restored, and created wetlands across Ohio (Mack, 2006). ORAM scores (range of 0 to 100) are a summation of six metrics that include wetland size (6 pts), wetland buffers (14 pts), hydrology (30 pts), habitat (20 pts), and vegetation (20 pts) (maximum points per metric in parentheses). The sixth metric, special wetlands (10 pts), is appropriate for specific Ohio wetland types and therefore was not answered in this study. Subsequently, ORAM scores were rescaled to reflect a potential maximum score of 100 to allow for comparisons with other studies.

ORAM-ordinal is an ordinal version of the ORAM score. Low quality sites that received an ORAM score from 0 to 29.9 are classified as Category 1, scores from 30 to 34.9 are classified as Category 1 or 2, scores from 35 to 59.9 are classified as Category 2, scores from 60 to 64.9 are classified as Category 2 or 3, and scores greater than or equal to 65 are classified as the highest quality Category 3 (Mack, 2006).

NCWAM

The North Carolina Wetland Assessment Method version 4.1 (NCWFAT, 2010) was also applied to all sites. NCWAM was developed for natural wetlands, but has been applied to North Carolina Coastal Plain mitigation sites (Burton, 2008). Answers to the NCWAM field form were entered into a macro-enabled spreadsheet that uses conditional computer programming (e.g. IF-THEN statements with Boolean operators) to produce an overall site rating as well as hydrology, water quality, and habitat function ratings (Figure 2). Due to the use of conditional computer programming, there is not necessarily a one-to-one relationship between a specific field form question and a given output. Wetland functions and the overall site score are rated as low, medium, or high with NCWAM.

The NCWAM wetland type (Table 2) determines the specific rating algorithm used by the macro-enabled spreadsheet. The assessor discriminates between 16 different wetlands types using a combination of landscape position and dominant vegetation criteria via the NCWAM dichotomous key. The target population was initially limited to riverine or riparian restored wetlands that had been planted with trees and shrubs, to minimize site-to-site variability. However, during field assessment it became apparent that some sites were misclassified in the database.

NCWAM protocols assess microtopography, soil texture, hydric soil indicators, non-soil hydric indicators, visible stressors, riparian buffer width, wetland size, connectivity with non-wetland natural area, wetland buffer width to non-forested land, vegetation structure, invasive vegetation species, large woody debris, open water distribution, and floodplain connectivity. Certain questions are applicable only to specific NCWAM wetland types. In addition to assessing the wetland's function, NCWAM can determine whether the wetland has the opportunity to improve water quality within the watershed. Opportunity ratings are calculated using land use categories measured 1) within the watershed, 2) within the watershed and a five mile radius of the assessed area, and 3) within the watershed and a two mile radius of the assessed area. Geographic information system (GIS) raster land cover data from the National Land Cover

Database (http://www.mrlc.gov/) or aerial imagery may be used to answer these questions. NCWAM water quality opportunity questions are optional, do not influence wetland functional ratings, and were not analyzed in this study.

NC WAM Wetland Rating Sheet
Accompanies User Manual Version 4.1
Rating Calculator Version 4.1

Wetland Site Name	Sample Site	Date	Date
Wetland Type	Bottomland Hardwood Forest	Assessor Name/Organization	Agency

Notes on Field Assessment Form (Y/N)	NO
Presence of regulatory considerations (Y/N)	NO
Wetland is intensively managed (Y/N)	NO
Assessment area is located within 50 feet of a natural tributary or other open water (Y/N)	YES
Assessment area is substantially altered by beaver (Y/N)	NO
Assessment area experiences overbank flooding during normal rainfall conditions (Y/N)	YES
Assessment area is on a coastal island (Y/N)	NO

Sub-function Rating Summary

Function	Sub-function	Metrics	Rating
Hydrology	Surface Storage and Retention	Condition	**MEDIUM**
	Sub-Surface Storage and Retention	Condition	**MEDIUM**
Water Quality	Pathogen Change	Condition	**HIGH**
		Condition/Opportunity	**HIGH**
		Opportunity Presence? (Y/N)	**YES**
	Particulate Change	Condition	**MEDIUM**
		Condition/Opportunity	**HIGH**
		Opportunity Presence? (Y/N)	**YES**
	Soluble Change	Condition	**MEDIUM**
		Condition/Opportunity	**HIGH**
		Opportunity Presence? (Y/N)	**YES**
	Physical Change	Condition	**HIGH**
		Condition/Opportunity	**HIGH**
		Opportunity Presence? (Y/N)	**YES**
	Pollution Change	Condition	NA
		Condition/Opportunity	NA
		Opportunity Presence? (Y/N)	NA
Habitat	Physical Structure	Condition	**LOW**
	Landscape Patch Structure	Condition	**LOW**
	Vegetation Composition	Condition	**MEDIUM**

Function Rating Summary

Function	Metrics/Notes	Rating
Hydrology	Condition	**MEDIUM**
Water Quality	Condition	**HIGH**
	Condition/Opportunity	**HIGH**
	Opportunity Presence? (Y/N)	**YES**
Habitat	Conditon	**LOW**

Overall Wetland Rating **MEDIUM**

Figure 2. NCWAM output for a sampled site. All wetlands receive overall and main function ratings. However, certain wetland types are not rated for all sub-functions and therefore receive “NA”.

Table 2. Distribution of sampled wetland types by NCWAM (n=30).

NCWAM Wetland Type	Sampled
Salt/Brackish Marsh	-
Estuarine Woody Wetland	1
Tidal Freshwater Marsh	-
Riverine Swamp Forest	8
Seep	-
Hardwood Flat	-
Non-Riverine Swamp Forest	2
Pocosin	-
Pine Savanna	-
Pine Flat	3
Basin Wetland	-
Bog	-
Non-Tidal Freshwater Marsh	4
Floodplain Pool	-
Headwater Forest	5
Bottomland Hardwood Forest	7

Landscape Development Index (LDI)

The landscape development index (LDI; Brown and Vivas, 2005), a level 1 GIS-based assessment (Brooks et al, 2004), was calculated for each site. LDI scores are a weighted summation of the land use percentages,

$$LDI = \sum (\%LU_i * C_i) \qquad \text{(Equation 3)}$$

where $\%LU_i$ is the discretized land use area fraction (0 to 1.0) and C_i is the corresponding land development intensity coefficient. Land uses within a 100 m buffer around the wetland assessment area were discretized in ArcMap version 10.0 (ESRI, 2010) manually using recent aerial imagery (Figure 1). LDI coefficients range from 1 (natural areas or open water) to 10 (heavily urbanized areas) and represent the amount of supplemental emergy needed to maintain the given land use, log transformed. Emergy (from the "memory of energy") is the summation of all the energy used to produce an item, including all the energy used to produce the individual components of said item (Brown and Vivas, 2005). The emergy-based land use coefficients in Brown and Vivas (2005) were derived for Florida but have been applied to land uses in other states (Mack, 2006; Micacchion et al., 2010).

Soil and Water Analysis Protocols

The soil methodology used in this study was a modification of the NWCA soil protocols (USEPA, 2011b) and were similar to the protocols outlined by PG Environmental (2012). Four soil pits were dug within 1 m of the southeast corners of the outer vegetation plots at each site (Figure 1). Texture, matrix color, depth to water or saturation level, and redoximorphic field indicators (NRCS, 2010) were noted at 12, 20, and 30 cm depths for each soil pit. A composite soil sample from the surface to 30 cm deep was collected from the most representative pit and sent to an independent laboratory (Midwest Laboratories, Omaha, Nebraska) where a suite of macronutrients, micronutrients, physical, and chemical properties were measured. A separate bulk density sample was collected laterally within the soil pit at a depth of 15 cm and sent for lab analysis.

Water quality measurements were collected within the wetland assessment area at sites with standing or flowing water greater than 15 cm deep (15 out of 30 surveyed sites), per NWCA protocols. Dissolved oxygen, specific conductivity, and pH values were measured in the field using an YSI 2030 water quality meter. Grab water quality samples taken per NWCA protocols were analyzed for Total Kjeldahl nitrogen (TKN), nitrate and nitrite (NO_3/NO_2 - N), ammonia (NH_4^+ - H), and phosphorus content at the NCDWQ laboratory.

Statistical Analyses

The R statistical software package version 2.15 was used to analyze the data (R Core Team, 2013). Throughout our study, Pearson correlations were used to compare interval measurements while Spearman correlations were reserved for ordinal measurements such as NCWAM ratings (Stevens, 1946). Correlation values between floristic indices (level 3) and rapid assessments (level 2) scores were calculated. Correlations between soil and water parameters (log transformed) and wetland assessment scores were calculated. Parameters such as nutrients that can be described as a resource for vegetation were log transformed prior to analyses (Palmer, 1993). Age of a restored wetland was also log transformed, as the vegetation structure of a nascent wetland was assumed to change non-linearly with time. Variables already expressed in a log scale (pH and LDI—see Brown and Vivas (2005) for the formulation of the land development intensity coefficients) were not transformed. Significant relationships between VIBI, AFQI, FAQWet, and ORAM scores and categorical variables were tested using ANOVA F-tests; significant relationships between NCWAM ratings and categorical variables were tested using Fisher exact tests.

Constrained correspondence analysis (CCA; Ter Braak, 1986) ordination plots were created using the coverage data on the 434 identified vegetation species. The R package “vegan” was used to generate the plots (Oksanen et al., 2013). CCA has been shown to be superior in certain respects to correspondence analysis (CA), detrended correspondence analysis (DCA), and nonmetric dimensional scaling (NMDS) ordination methods (Palmer, 1993). Ordination is a multivariate dimensional reduction technique where the most important dimensions (typically two or three) are identified and plotted. CCA is a direct gradient ordination method where the ordination axes are constrained to be linear combinations of separately measured factors. In our study, CCA was constrained by the three floristic index scores, as indicated with arrows emanating from the plot's origin. In general, a site's score increases as its plotted location moves in the direction of the arrow. Longer arrow length denotes a stronger correlation between the floristic index and the ordination results computed from the vegetation coverage data. Weighted average site scores were plotted on the first two CCA axes, per Oksanen et al. (2013). Rapid assessment scores were overlaid on the CCA plots to allow visual comparisons between the level 3 and level 2 assessment results. Overlaid ORAM contours were computed using thin-plate splines from a general additive model (GAM). Overlaid NCWAM polygons represent the extent of each NCWAM rating in ordination space.

Results and Discussion

Overview of Restoration Sites

The majority of the 30 restored wetlands appeared to be stable, functional wetlands based on initial field inspections, immaturity of the vegetation structure of the forested sites notwithstanding. At a few sites, the planted trees displayed poor vigor, most likely due to site conditions being too dry for the planted taxa. For example, planted cypress (*Taxodium spp.)* were performing poorly at one site, while volunteers like sweet gum (*Liquidambar stryraciflua*), loblolly pine (*Pinus taeda*), and red maple (*Acer rubrum*) were volunteering. This may imply that this restoration was dryer than intended, or that the planting list was not appropriate for the designed soil saturation levels. Six sites had highly disturbed soils from either the construction process or previous land use. Two of these sites did not have apparent soil horizons. Both sites were adjacent to a large retail store and involved moderate to large amounts of excavation, the later most likely responsible for the lack of soil horizons.

Sixteen out of the 30 mitigation projects included a stream channel that was located within 15 m of the assessment area boundary. Fifteen of these streams were restored in conjunction with the wetland. All of the restored streams were in stable condition, though three out of the 15 streams had noticeably low water levels, with one streambed covered in herbaceous wetland vegetation. The bankfull depth of these three restored streams appeared appropriate (i.e. not incised). Therefore it did not appear that these three restored streams were adversely affecting the wetland's hydrology by acting as a drainage ditch. Maps from the North Carolina Drought Management Advisory Council (http://www.ncdrought.org/archive/index.php) indicated no drought conditions at the time these three sites were surveyed. However, aerial imagery dating back to 1994 indicated no stream was previously located where the three restored streams were constructed. Also, each of the three streams flowed roughly parallel as opposed to obliquely toward the receiving river. The alignment of these stream restorations did not appear to coincide with the prevailing contours of the landscape, which likely accounted for the low stream water levels observed at these three sites.

Three out of the 30 restored wetlands were located near large, incised rivers. Two of these sites were located approximately 100 m away from an incised river. No hydric soil field indicators were observed at one of these sites, while only the bottom of the 30 cm soil pits showed signs of saturation at the other site. The third site, located approximately 25 m away from the incised river, was the only restored wetland out of 30 to receive a low NCWAM rating. All three of these sites received VIBI scores less than 50, which corresponded to a Restorable Wetland Habitat WTALU rating. It is likely that the incised river produced a lateral drainage effect (Skaggs et al., 2005) on the sub-surface hydrology on the site 25 m away from the incised river, though no groundwater modeling of these three sites was performed due to insufficient field measurements. The probability that the incised rivers located 100 m away were having a lateral effect on the other two sites is much lower; however, wetland setback distances of up to 120 m have been published for other regions of the U.S. (MN NRCS, 2012).

Categorical Factors

Categorical factors and whether they significantly affected assessment scores are listed in Table 3. Assessment scores did not significantly differ among mitigation providers. A recent study of 60 restored and created wetlands in Ohio also found no significant difference between VIBI scores from bank and permittee-responsible sites (PG Environmental, 2012). Ohio does not have in-lieu fee wetlands, so comparison with his type of restoration was not possible.

Table 3: ANOVA F-values (unless noted) between categorical factors and wetland assessments.

	Floristic Assessments			Rapid Assessments	
Factors	VIBI	AFQI	FAQWet	ORAM	NCWAM†
Dominant Vegetation	5.84*	3.57	4.45*	0.90	0.792
HGM Classification	0.31	2.39	0.11	0.18	0.100
Ecoregion	0.69	1.80	0.27	0.61	0.927
Mitigation Provider	1.31	0.13	0.37	0.20	0.834
Sandy Soil	2.44	1.06	1.78	1.99	1.000

Significance denoted as *p < 0.05; ***p* < 0.01; ****p* < 0.001; *****p* < 0.0001

† Fisher exact test pvalue reported

Dominant Vegetation = emergent (17) vs woody (13); HGM Classification = riverine (23), flat (6), or tidal fringe (1); Ecoregion = Mountains (2), Piedmont (10), Southeast Coastal Plains (8), or Coastal Plains (10); Mitigation Provider = in-lieu fee (15), mitigation bank (9), or permittee-responsible (6); Sandy Soil = < 50% sand (13) vs ≥ 50% sand (17). Numbers in parentheses are sampled sizes.

Herbaceous sites received significantly higher VIBI and FAQWet scores than woody sites (ANOVA F-test, $p<0.05$). Mean scores for VIBI were 69.9 and 56.1, while mean scores for FAQWet were 12.2 and 8.6 for herbaceous and woody sites, respectively. Age may partially explain differences at these sites, as no sampled restoration site was older than 11 years (median 8 yrs.). Therefore, the woody vegetation was less structurally mature compared to the herbaceous vegetation. No other tested categorical factors had a significant effect on assessment scores.

Floristic Indices and Rapid Assessments

The distributions of Wetland Tiered Aquatic Life Uses (WTALU; derived from VIBI scores), ORAM-category, and NCWAM ratings are shown in Figure 3. No conversion criteria from raw scores to ordinal rankings exist for AFQI or FAQWet; therefore these indices were not plotted. WTALU, ORAM, and NCWAM scores agreed that few (0 or 1) restored wetlands surveyed were of low quality, but disagreed in their distribution of medium to high quality sites. The WTALU distribution from low-medium to high ratings was relatively uniform. WTALU results from this study indicated higher quality restored wetlands than in other studies of created and restored wetlands (Micacchion et al., 2010; PG Environmental, 2012) and natural urban wetlands (Mack and Micacchion, 2007). The rapid assessment distributions, however, were unimodal and generally rated sites more highly than WTALU. ORAM rated 24 sites (80%) as medium quality (category 2), while NCWAM rated 24 sites (80%) as high quality wetlands. Another study reported a similar NCWAM distribution where a majority (65%) of the sampled restored North Carolina wetlands received a high rating (Burton, 2008).

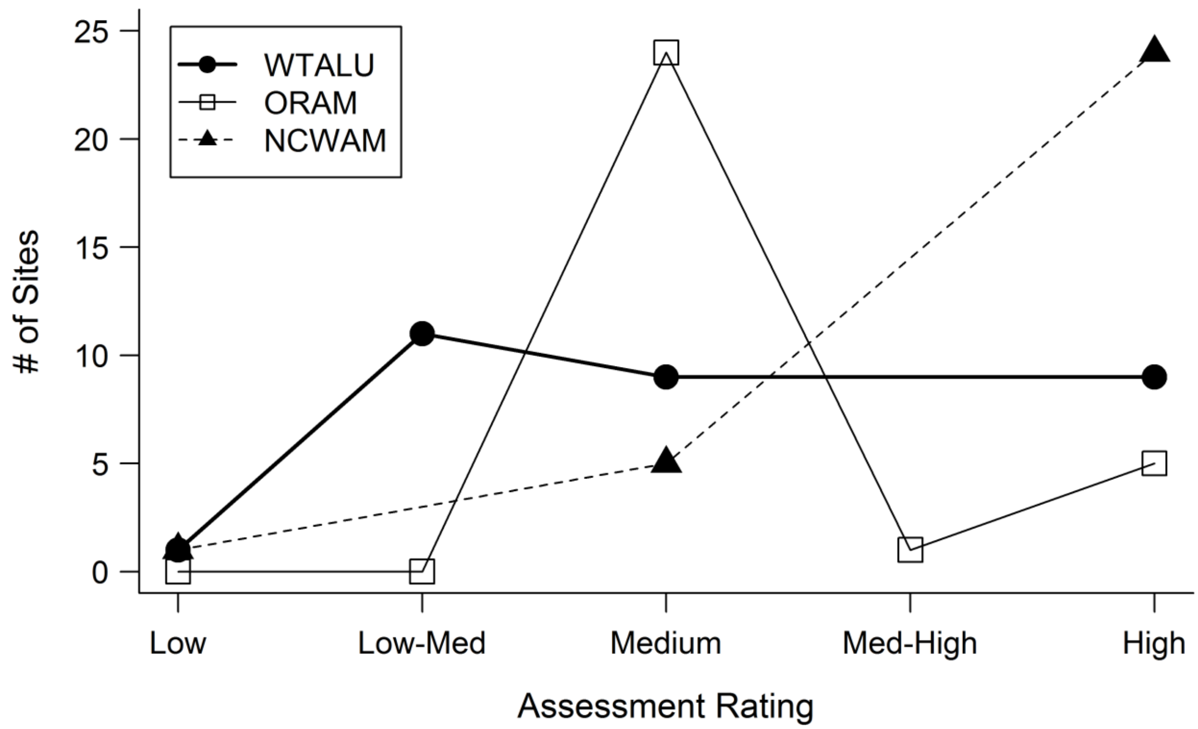

Figure 3: Frequency of sites versus categorical assessment rating, by wetland assessment. For this plot, Ohio Rapid Assessment Method (ORAM) Category 1, Category 1 or 2, Category 2, Category 2 or 3, and Category 3 categories correspond to Low, Low-Med, Medium, Med-High, and High, respectively (Mack, 2006). Similarly, Wetland Tiered Aquatic Life Uses (WTALU) "Limited quality wetland habitat", "Restorable wetland habitat", "Wetland habitat", and "Superior wetland habitat" correspond to Low, Low-Med, Medium, and High, respectively (riverine hydrogeomorphic (HGM) class; Mack, 2004). Potential NCWAM ratings are low, medium, or high.

Overall, the scarcity of sites that received a low quality rating is encouraging with respect to restoration quality across these sites. The fact that WTALU classified 11 sites (37%) as "restorable" could be due in part to the immaturity of the sampled restorations (project age ranged from 5 to 11 years). ORAM and NCWAM ratings were less harsh, with almost all (n=29) of the restored wetlands were classified as medium or high quality. WTALU did rate more sites as superior quality (n=9) than did ORAM (n=5).

Correlations among floristic index scores are listed in Table 4. Only VIBI and FAQWet were significantly correlated (r=0.39, p=0.037; Figure 4), and only after the removal of one site with a

Cook's distance greater than 4/n, where n is the sample size (Cook, 1979). The site in question was rather wet with a preponderance of *Typha spp.* (cattails), but would not have been considered an outlier based on visual inspection.

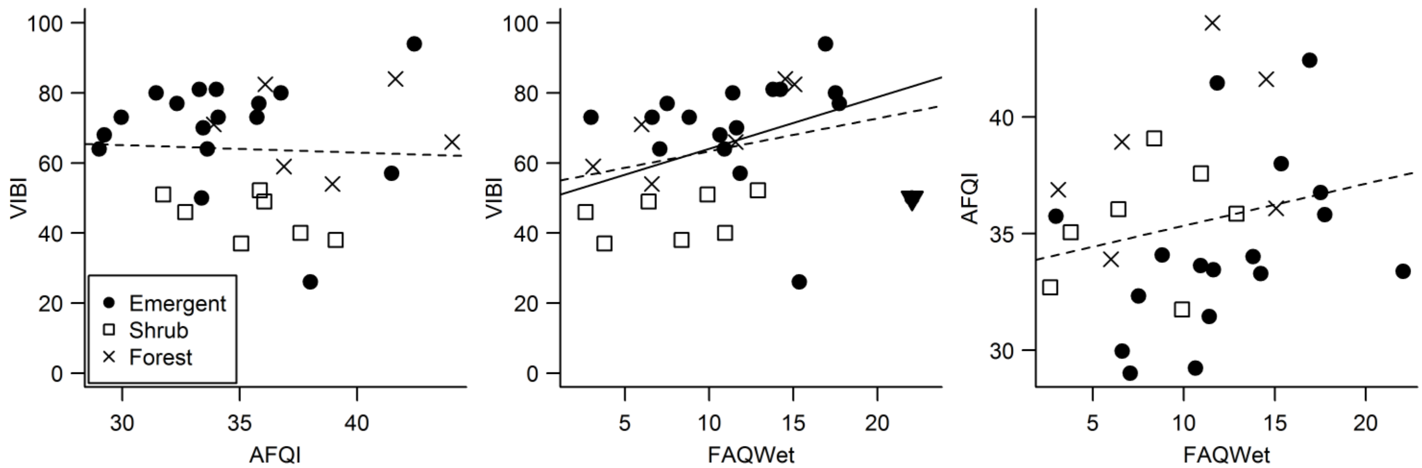

Figure 4. Scatterplots of floristic indices. LEFT: VIBI vs AFQI; r=-0.05; p=0.802. MIDDLE: VIBI vs FAQWet; r=0.28; p=0.141. RIGHT: AFQI vs FAQWet; r=0.23; p=0.220. Lines are least squared fit. Solid lines denote significant correlation (p<0.05). VIBI vs FAQWet was significant only after one emergent site, denoted by a upside down triangle (▼), with a relatively high Cook's distance value was removed. See Table 5 for additional statistics.

Table 4. Pearson correlation values (unless otherwise noted) between among wetland assessments.

		Floristic Indices		
Parameters	Mean (SD)	VIBI	AFQI	FAQWet
Floristic Indices				
VIBI	63.9 (16.7)	-	-	-
AFQI	35.5 (3.8)	-0.05	-	-
FAQWet	10.6 (4.9)	0.28††	0.23	-
ORAM Assessment				
ORAM	51.6 (9.3)	0.15	-0.04	0.44*
ORAM-Ordinal†	-	0.12	0.11	0.28
ORAM-Size	4.2 (1.2)	-0.09	0.25	0.01
ORAM-Buffer	8.4 (3.1)	0.01	0.05	-0.05
ORAM-Hydrology	15.8 (5.0)	0.13	-0.15	0.39*
ORAM-Habitat	9.4 (1.9)	0.12	0.16	0.44*
ORAM-Vegetation	8.6 (2.3)	0.19	-0.14	0.44*
NCWAM Assessment†				
NCWAM†	-	0.05	-0.07	0.25
NCWAM-Hydrology†	-	-0.04	-0.03	0.33
NCWAM-Water Quality†	-	0.06	-0.14	0.07
NCWAM-Habitat†	-	-0.08	-0.17	-0.13

Significance denoted as *p < 0.05; ***p* < 0.01; ****p* < 0.001; *****p* < 0.0001
† Spearman correlation values reported
†† Significant after one site was removed; r=0.39, p=0.037

The lack of correlation among floristic indices implies that each index evaluated a different aspect of the wetland's condition, even though all three index scores were calculated from the same vegetation coverage data. FAQWet scores can be viewed as a richness metric weighted by the taxa's affinity for saturated conditions, while AFQI scores can be viewed as a richness metric weighted by the taxa's fidelity for habitat conditions. Therefore a site may receive both a high FAQWet score and a low AFQI score if it is a wet site colonized with exotic invasive and ruderal species. VIBI is theoretically a more robust assessment in that the score is a summation of 10 metrics that evaluate functional groups (e.g. dicot richness) and community structure (e.g. pole timber density) in addition to hydrophytic affinity and floristic quality (recall Table 1).

Of the three floristic indices, FAQWet scores correlated most strongly with the rapid assessment scores (Table 4; Figure 5). FAQWet was significantly correlated with ORAM ($r=0.44$, $p=0.015$) and marginally correlated with NCWAM-hydrology (Spearman $\rho=0.33$, $p=0.080$). Many rapid assessment methods emphasize site hydrology metrics above other parameters. For example, hydrology accounts for a larger portion (30%) than any other ORAM metric. Also, the NCWAM-hydrology parameter had a higher correlation (Spearman $\rho=0.90$, $p<0.0001$) with the overall NCWAM score than NCWAM-water quality or NCWAM-habitat scores in this study. This emphasis on hydrology likely explains why the rapid assessments correlated more strongly with FAQWet—an index calculated using wetness coefficients— than with the VIBI or AFQI indices in our study.

VIBI and ORAM scores were not significantly correlated in this study of restored wetlands. VIBI and ORAM have shown high levels of correlation (R-squared values from 0.60 to 0.79) for natural wetlands (Mack, 2006; Micacchion et al., 2010). While a few restoration projects were sampled in the aforementioned studies (7% and 13%, respectively), a separate correlation analysis containing only restoration projects was not reported. A search of the existing literature also found no comparison of VIBI and ORAM results of restoration projects only. One study suggests that the physical disturbances associated with wetland construction may bias rapid assessments that penalize habitat disturbances (PG Environmental, 2012). The fact that 23 out of 30 sites in our study were rated higher by VIBI than ORAM could be interpreted as corroborating this theory. However, only six sites had evidence of highly disturbed substrate based on field evaluations of multiple soil pits per site.

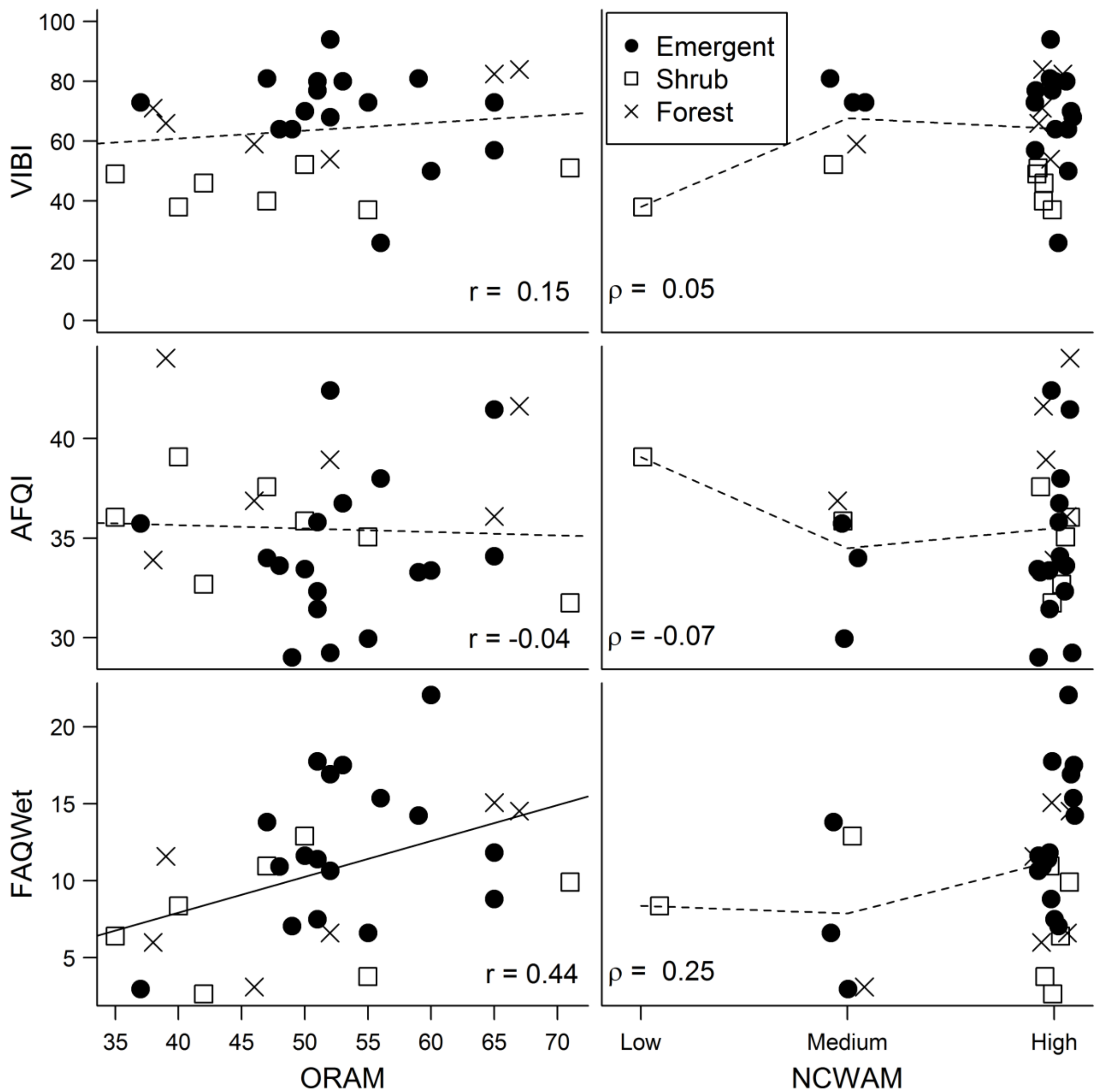

Figure 5. Scatterplots of floristic index scores versus ORAM (LEFT) and NCWAM (RIGHT, jittered horizontally to clearly display points) rapid assessment scores. Lines for ORAM plots are least squared fit. Lines for NCWAM plots connect mean scores for low, medium and high NCWAM sites. Solid lines denote significant correlation ($p<0.05$). Pearson r and Spearman ρ correlation values provided. See Table 4 for additional statistics.

<u>Constrained Correspondence Analysis (CCA) Ordination</u>

Constrained correspondence analysis (CCA) ordination plots visually corroborated the relationships between the floristic indices and the rapid assessments. The vectors representing the floristic indices pointed in different directions, indicating that each assessment evaluated a different facet of the wetland vegetation structure (Figure 6). This agreed with the previously mentioned low correlation among floristic indices (recall Table 4 and Figure 4). Coincident or opposing vectors would have indicated perfect collinearity among assessments; orthogonal vectors would have implied no overlap of information.

The overlaid ORAM contours were perpendicular to the FAQWet vector, indicating correlation between the two assessments. This agreed with the previously mentioned correlation results between ORAM and FAQWet (recall Table 4 and Figure 5). Categorical and ordinal ratings such as NCWAM's low, medium, and high ratings were represented using convex polygons that denote the extent in ordination space of a given rating. Non-overlapping polygons would have implied the assessment discriminated based on the ordination results. Little discriminating power between NCWAM ratings and the CCA ordination results was interpreted based on the overlapping NCWAM rating polygons. NCWAM-hydrology convex polygons (not shown), which had slightly higher correlation with the floristic indices, also fully overlapped each other. These CCA plots agreed with the previously mentioned non-significant ($p<0.05$) correlation between both NCWAM and the floristic indices.

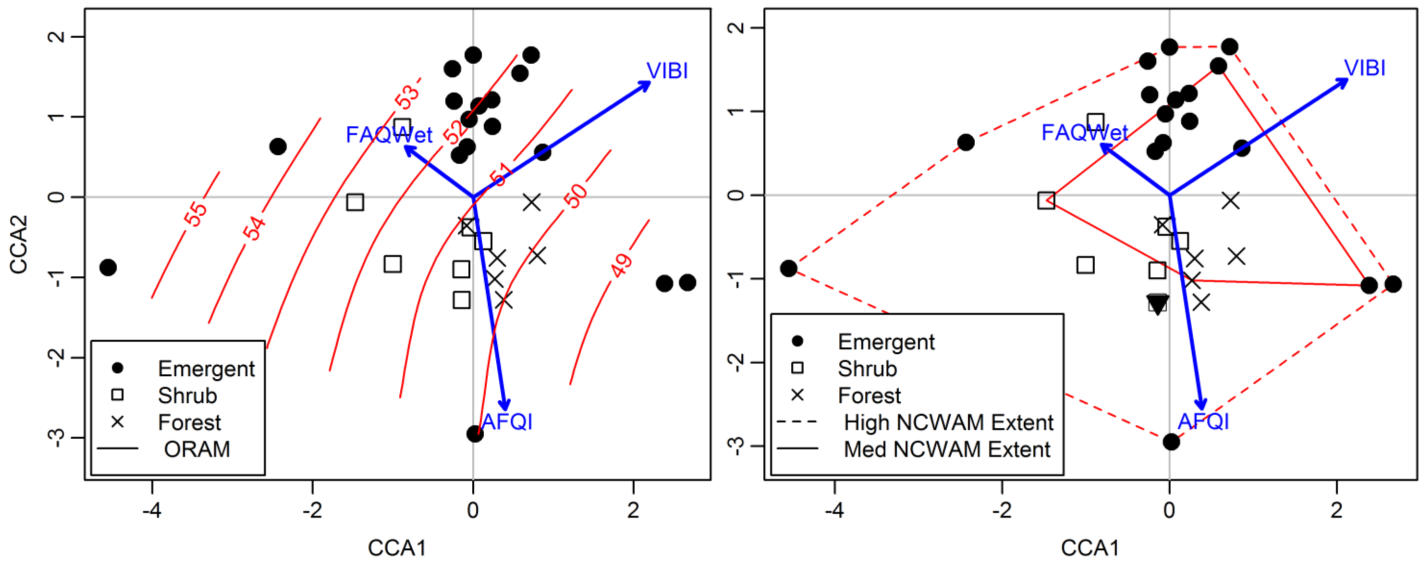

Figure 6: Constrained Correspondence Analysis (CCA) plots. Sites symbols denote wetland type. Vectors indicate positive direction of floristic index score gradient. LEFT: Overlaid ORAM rating contours from thin plate splines via a general additive model. RIGHT: Extent of NCWAM ratings indicated by convex polygon hulls. Singular site that received an NCWAM low rating denoted by ▼.

Soils

Field analysis of 30 cm soil pits indicated that six sites had highly disturbed soils from either the construction process or previous land use, with two of these sites lacking any apparent soil horizons. All mitigation providers were represented across these six sites. Two of these six sites were located adjacent to a large retail store parking lot in an urban setting, while the other four were previously used for row crop or hay production before restoration.

Laboratory analysis of composite soil samples indicated that 8 out of 22 soil parameters (log transformed) were significantly correlated with at least one of the floristic indices (Table 5); however, no soil parameter was significant with all three floristic indices. Both sand and clay soil percentages were significantly correlated (negatively and positively, respectively) with VIBI

($p<0.05$) and marginally correlated with FAQWet ($p<0.1$), while percent silt was not significant with any assessment.

Table 5: Median (range) values and Pearson correlation values (unless noted) between soil parameters (log transformed) and assessments, n=30 unless noted.

			Floristic Indices			Rapid Assessments	
Soil Parameter	Units	Median (Range)	VIBI	AFQI	FAQWet	ORAM	NCWAM[4]
Soil Organic Matter[1]	%	2.5 (0.5-43.3)	0.01	0.33	0.14	0.16	0.04
Bulk Density	g/cm^3	1.1 (0.5-1.4)	-0.07	-0.44*	-0.21	-0.23	-0.03
Sand	%	54.0 (30.0-80.0)	-0.38*	-0.17	-0.34	0.18	-0.27
Clay	%	10.0 (3.0-33.0)	0.41*	0.17	0.34	-0.01	0.26
pH-soil[3]	-	5.0 (4.0-6.1)	-0.32	-0.47**	-0.16	0.07	0.19
Buffer Index	-	6.6 (6.1-6.9)	-0.31	-0.38*	-0.36	0.08	-0.05
Cation Exchange Capacity	meq/100g	8.2 (2.4-20.0)	0.19	0.13	0.42*	-0.05	0.18
Carbon:Nitrogen ratio[1]	-	12.8 (4.1-19.8)	-0.21	0.31	0.12	0.13	-0.13
Carbon[1]	%	1.5 (0.2-9.5)	-0.18	0.40*	0.21	0.07	0.03
Nitrogen	%	0.1 (0.0-0.9)	-0.14	0.46*	0.23	0.13	0.14
NO_3	ppm	17.0 (1.0-74.0)	0.26	0.16	0.28	-0.08	0.10
Phosphorus-1 (weak Bray)	ppm	11.0 (2.0-103.0)	-0.31	0.11	-0.15	0.03	-0.26
Phosphorus-2 (strong Bray)	ppm	20.0 (6.0-132.0)	-0.28	0.06	-0.10	0.01	-0.10
Potassium	ppm	52.5 (20.0-116.0)	-0.07	0.13	0.04	0.08	-0.14
Magnesium	ppm	156.5 (39.0-378.0)	-0.02	-0.15	0.27	-0.10	0.13
Calcium	ppm	639.5 (202.0-1865.0)	-0.03	-0.36	0.17	-0.07	0.38*
Sulfur[2]	ppm	22.0 (10.0-47.0)	0.20	-0.04	0.22	-0.15	-0.05
Zinc[2]	ppm	0.8 (0.3-4.3)	0 .00	0.07	0.28	0.01	0.09
Manganese[2]	ppm	4.0 (1.0-113.0)	0.36	-0.30	0.15	-0.03	0.34
Iron[2]	ppm	83.0 (18.0-285.0)	-0.20	0.18	0.12	0.24	0.20
Copper[2]	ppm	0.4 (0.2-2.2)	0.15	-0.13	0.34	0.01	0.21
Boron[2]	ppm	0.3 (0.2-0.5)	-0.33	0.23	0.25	0.37*	0.31

Significance denoted as *$p < 0.05$; **$p < 0.01$; ***$p < 0.001$; ****$p < 0.0001$

[1] n=29. Correlations do not include one permanently inundated site with high soil organic matter (43.3%), C:N ratio (33.7), and carbon (29.7%)

[2] n=29 due to incomplete lab data

[3] No parameter transformation, i.e. linear correlation

[4] Spearman correlation values reported for NCWAM

Phosphorus-1 is phosphorus that is readily available for plants. Phosphorus-2 is less soluble phosphorus acting as a reserve in the soil.

Table 6: Median (range) values and Pearson correlation values (unless noted) between water quality parameters and other variables (log transformed) and assessments.

			Floristic Indices			Rapid Assessments	
Parameters	Units	Median (Range)	VIBI	AFQI	FAQWet	ORAM	NCWAM[2]
		Water Quality Parameters (n=15):					
Dissolved oxygen	mg/L	5.3 (0.2-8.1)	-0.36	0.06	-0.42	-0.21	-0.50
pH-water	-	5.6 (3.8-6.4)	-0.11	-0.52*	-0.28	0.00	0.14
Specific conductivity	µS/cm	114.0 (22.7-2064.0)	-0.50	-0.23	0.09	-0.02	-0.05
Total Kjeldahl nitrogen	mg/L - N	1.0 (0.2-3.8)	-0.10	0.61*	0.46	-0.20	0.46
$NO_2 + NO_3$	mg/L - N	0.02 (0.02-1.60)	-0.05	-0.23	-0.49	0.22	-0.08
NH_4	mg/L - N	0.02 (0.02-1.00)	-0.27	0.47	-0.24	-0.13	0.23
Organic nitrogen	mg/L - N	0.8 (0.2-3.7)	-0.08	0.57*	0.51	-0.17	0.46
Phosphorus	mg/L - P	0.1 (0.0-1.2)	0.09	0.07	0.20	-0.25	0.59*
		Other Parameters (n=30):					
Site Age	yr	8.0 (5.0-11.0)	-0.16	0.16	0.03	-0.01	-0.11
Site Size	ha	7.8 (0.2-164.1)	-0.11	0.34	0.10	0.17	0.08
Coefficient of Conservation[1]	-	3.6 (3.1-4.5)	-0.05	0.97****	0.30	0.05	-0.05
Wetness Coefficient[1]	-	1.7 (0.4-4.4)	0.00	0.40*	0.82****	0.46**	0.21
Landscape Development Index[1]	-	1.3 (1.0-4.3)	0.11	-0.34	-0.16	-0.23	-0.29

Significance denoted as *$p < 0.05$; **$p < 0.01$; ***$p < 0.001$; ****$p < 0.0001$

[1] No parameter transformation, i.e. linear correlation

[2] Spearman correlation values reported for NCWAM

More soil parameters were significantly correlated (p<0.05) with AFQI scores (5 parameters) compared to VIBI (2 parameters) or FAQWet scores (1 parameter). The fact that AFQI is a measurement of habitat quality may partially explain why more soil parameters were significantly correlated with the index. Scatterplots between AFQI and select soil parameters are shown in Figure 7. It was not surprising that bulk density was highly collinear (negatively) with soil organic matter (r=-0.73, p<0.0001) and percent carbon (r=-0.75, p<0.0001); therefore plots of each of these parameters would also have indicated a strong relationship with AFQI. Also, nitrogen was positively correlated with AFQI scores while phosphorus was not.

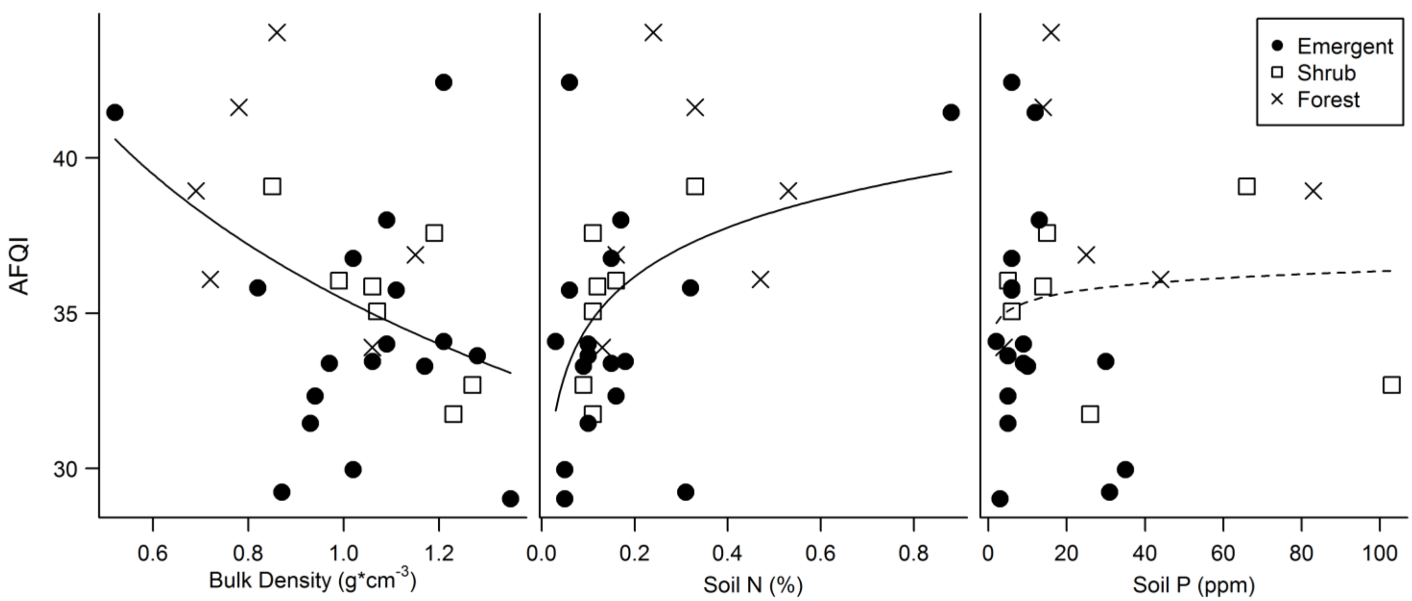

Figure 7: Scatterplots of AFQI scores versus select soil parameters. LEFT: AFQI vs bulk density. r = -0.44, p=0.015. MIDDLE: AFQI vs nitrogen. r = 0.46, p=0.012. RIGHT: AFQI vs phosphorus. r =0.11; p=0.554. Fitted lines are from a *y = log(x)* model. Solid lines denote significant correlation (p<0.05).

ORAM and NCWAM scores indicated no significant correlation with physical soil parameters. For many rapid assessments, direct questions regarding soil texture or redoximorphic features are minimally developed or non-existent (Fennessy et al., 2007). NCWAM and ORAM each have limited soil-specific metrics: NCWAM requires the assessor to evaluate the soil texture, the presence of any redoximorphic features, and whether the soil is a peat or muck, while ORAM only requires the assessor to rate the level of substrate disturbance.

Soil organic matter (SOM) content is commonly measured in wetland studies, as the accumulation of SOM due to anaerobic substrate conditions is a defining feature in organic soil wetlands. SOM values across 29 sites ranged from 0.5% to 12.2%, with a mean of 3.5%. The remaining sampled site had a SOM value 43.3%. This restoration was the only site that appeared to be inundated year-round, and was covered by approximately 50 cm of water during the field assessment in July, when water levels are generally low. The mean SOM value of 3.5% was similar to reported mean values of Virginia restoration projects (4.2% to 6.4%; Dee and Ahn, 2012) but was less than SOM mean values reported in another North Carolina study of restored and created wetlands (11.8 ± 3.9%; Bruland and Richardson, 2006). The SOM levels of restoration projects reported by Bruland and Richardson were significantly lower than levels observed in that study's paired natural sites (29.0 ± 8.0%).

SOM was not significantly correlated with project age in our study, though the relatively low sampled values (project age ranged from 5 to 11 years) were likely not conducive to detecting a potential effect. A sample with a wider project age range, or a sample that captured the more rapid structural changes that occur in the first years post-construction would likely indicate a larger effect. SOM was, however, significantly higher in woody sites (mean 4.9 ± 3.8%, n=13) than in herbaceous sites (mean 2.4 ± 1.9%, n=16) (ANOVA F-test, n=29, p=0.028). This is likely due to woody restorations producing detritus (e.g. leaves) at a higher rate than herbaceous sites, or else having a larger amount of legacy SOM. Shade from trees is another potential explanation for the higher SOM content in woody sites. Increased shade can reduce soil temperatures and minimize evaporation, sustaining saturated conditions near the surface for longer periods of time.

Water Quality and Other Parameters

Correlations between water quality samples (log transformed) and assessment scores are listed in Table 5. Overall, fewer water quality parameters were significant with assessments compared to soil parameters. This may be due to the smaller sample size, as only 15 sites had surface water with a depth greater than 15 cm (per NWCA protocols) for sampling. Also, eight out of the 15 water quality samples were from flowing water from a stream, as opposed to standing surface water. It is possible that analytes measured within a sufficiently large stream characterize the upstream watershed condition but do not necessarily reflect the condition of the adjacent wetland assessment area.

Mean coefficient of conservation (C) values were positively correlated with AFQI scores ($r=0.97$, $p<0.0001$). The range of observed mean C values was notably narrow (3.1 to 4.5) compared to the potential range of 0 to 10. Based on VIBI metric criteria for tolerant (C value ≤ 2) or sensitive species (C value ≥ 6) (Mack, 2004), all of the sites were dominated by vegetation with mean C-value ratings between tolerant and sensitive. It is unknown whether we can expect mean C values to increase over time at these restoration sites. However, obligate and facultative wet species richness values have been reported to significantly increase over time in restored wetlands (Nedland et al., 2007).

Mean wetness coefficient (WC) values were positively correlated with AFQI ($r=0.40$, $p=0.030$), FAQWet ($r=0.82$, $p<0.0001$), and ORAM assessment scores ($r=0.46$, $p=0.0099$). Mean WC values ranged from 0.4 to 4.4, indicating that no restored wetland was dominated by facultative upland or upland species in this study.

Project age had no significant effect on wetland assessment scores, likely because the sampled range (5 to 11 years) was either too narrow or did not capture the more rapid structural changes that occur in the first years post-construction. Micacchian et al. (2010) also reported no significant difference in VIBI scores on restored or created wetlands in response to age.

Wetland size had no significant effect on wetland assessment scores. Both NCWAM and ORAM metrics require the approximate size of the wetland to be entered, though only ORAM explicitly awards more points to larger wetlands. There is debate on whether larger wetlands sites are better than smaller wetlands. Trochlell and Bernthal (1998) provided a synthesis of literature on small wetlands (<0.8 ha) across the nation, noting that hydroperiod, soil composition, and landscape position are typically more important than size in determining the level of ecosystem functions provided. Steinhoff (2008) argued that consolidation of wetlands—the replacement of small, isolated, spatially distributed wetlands with fewer, larger wetland restoration projects—threatens biodiversity of amphibians and waterfowl. Smaller wetlands typically have an increased shoreline to open water ratio, which provides more nesting and feeding habitat for certain mammal and bird taxa (Knight, 1992) and increases evapotranspiration (Miller, 1971). In North Carolina, wetland impacts smaller than 0.40 ha do not require mitigation, though wetland impacts larger than 0.12 ha on the eastern third (east of interstate I-95) of the state (0.04 ha on the western two-thirds of the state, west of I-95) require a combined NCDWQ and Army Corps of Engineers Pre-Construction Notification (North Carolina Administrative Code, 15A NCAC 02H .0506). In addition, North Carolina does not require isolated wetlands that are impacted to be mitigated by another in-kind isolated wetland. The Society of Wetland Scientists stated that larger wetlands are generally preferred over smaller wetlands because they provide habitat for species that do not survive in isolated wetlands (which are often small in size), but make exceptions for wetlands with vernal pools (found in NC) and the mid-west prairie pothole wetlands (SWS, 2007). Large (>100 ha) restored or created wetlands have been shown to approach equilibrium with reference sites more rapidly than smaller projects (Moreno-Mateos et al., 2012).

LDI

Land development index (LDI; Brown and Viva, 2005) scores were not significantly correlated with any assessment at the $p<0.05$ level, but were marginally significant at the $p<0.10$ level with AFQI scores ($r=-0.34$, $p=0.062$; Table 5; Figure 8). The low correlation between LDI and other assessments was attributed to an insufficient sampling of restored wetlands adjacent to developed areas.

As characterized by this study's sample population, a majority of North Carolina wetland restorations were previously used for row crop or hay production. LDI scores have a potential range of 1 to 10, with agricultural land use receiving a score of 3.7 to 4.5 (Miccachion et al., 2010). LDI values observed in this study ranged from 1 to 4.3. Only three wetlands—all permittee-responsible sites—received an LDI score above 3.0, which has been associated with severe degradation of the vegetative community (Micacchion et al., 2010). LDI scores of permittee-responsible sites in this study were significantly higher than in-lieu fee and mitigation bank sites (Tukey post-hoc test, adjusted $p<0.05$). If permittee-responsible sites are located in more developed areas, perhaps to minimize the mobilization distance of large earth-moving equipment from the project site (where a natural wetland was disturbed) to the mitigation site, or to ensure that the mitigation site is close to the disturbed wetland, then this result would be expected. Restoring wetlands in developed areas has additional challenges such as increased land costs, limited connections to natural areas that can serve as wildlife corridors, and potentially higher levels of incoming pollutants. Therefore, impacted urban wetlands are commonly replaced with rural mitigation sites in some areas of the U.S. (Ruhl and Salzman, 2006).

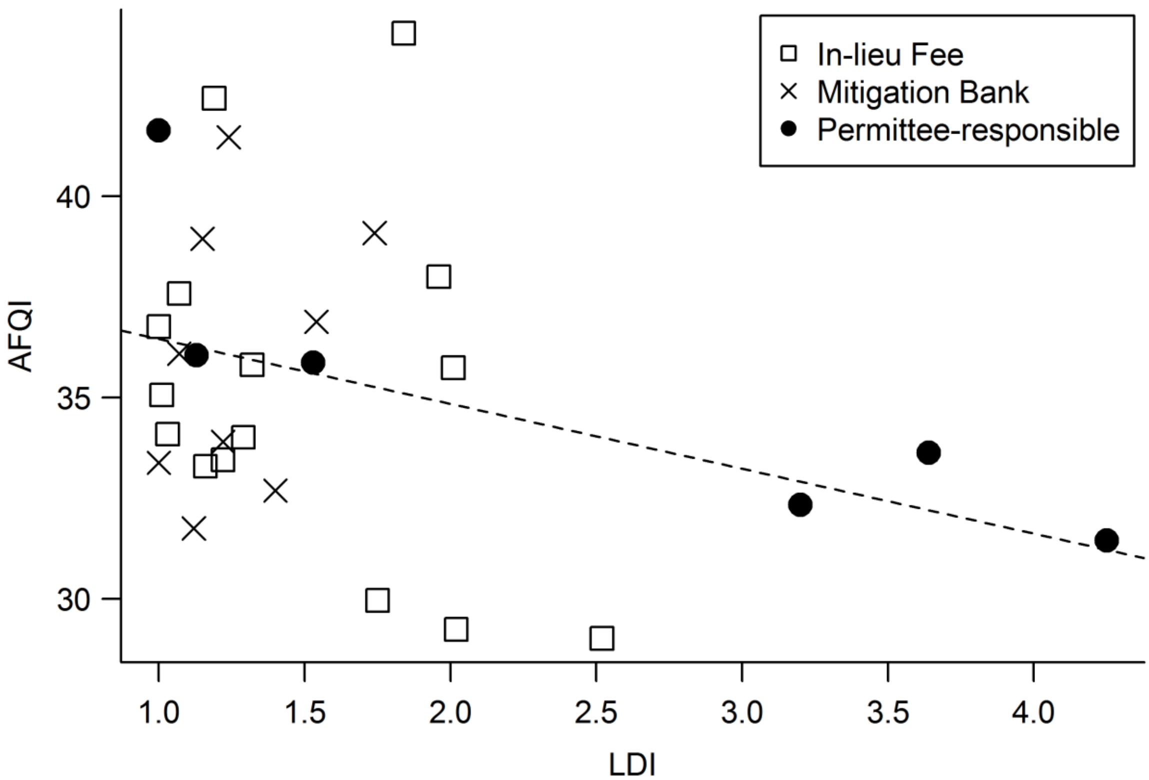

Figure 8: Scatterplot of AFQI vs LDI. Pearson r=-0.34; p=0.062. Fitted line from ordinary least squares.

Conclusions

Both level 2 and level 3 assessment scores were not significantly predicted by mitigation providers. That is, floristic indices—VIBI, AFQI, and FAQWet—as well as ORAM and NCWAM scores did not vary significantly among mitigation providers. However, permittee-responsible sites received significantly higher LDI scores than in-lieu fee and mitigation bank sites. Also, sites dominated by herbaceous vegetation received significantly higher VIBI and FAQWet scores than sites dominated by woody vegetation. This was attributed to a lack in vegetation structural maturity due to the young age of the sampled population.

Overall, the correlations among the wetland assessments was low and not significant, with the exception being between the FAQWet level 3 assessment and level 2 ORAM and NCWAM rapid assessments. While the correlation among assessment scores was generally not significant, a majority of the restorations were rated as medium or higher quality by the WTALU/VIBI, ORAM, and NCWAM assessments, and only two sites were rated as low quality with those three assessments. Based on these similar rating distributions, one may conclude that assigning success or failure to a restored wetland can be performed adequately using a level 2 assessment, with the more resource-intensive level 3 assessment reserved for questionable sites.

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Appendix A: North Carolina Wetland Assessment Method (NCWAM)

Dichotomous Key to General North Carolina Wetland Types

Accompanies NC WAM User Manual, Version 4.1

Before using this key, the assessor should read and become familiar with descriptions of the general wetland types. The assessor should use best professional judgment to verify that the wetland type determined with the use of this key matches the written description (see User Manual page number following wetland type name).

The following rule should be used to assist in the selection of the most appropriate general wetland type. Narrative descriptions are also available to assist in this choice (see User Manual Section 3.1).

> Wetlands with alterations (man-made or natural) should generally be classified as the original, naturally occurring type if this determination can be made. However, if the full range of stable, existing, wetland parameters (vegetation, hydrology, and soils) better resembles another wetland type because of long-established, permanent alterations, the wetland should be classified as this current, more appropriate type.

If there is evidence suggesting the wetland is a type other than the keyed type, the wetland may be classified as the evidenced type. Also, if the wetland does not appear to conform to any of the following general types, the site should be evaluated based on what the assessor believes is the closest wetland type. If the wetland is "intensively managed" or "intensively disturbed," the assessor should note this fact on the field assessment form and then select the most appropriate general wetland type based on the guidance provided above.

- I. Wetland affected by lunar or wind tide, may include woody areas contiguous with tidal marsh
  - A. Wetland affected, at least occasionally, by brackish or salt water
    - i. Dominated by herbaceous vegetation – **Salt/Brackish Marsh** (p. 12)
    - ii. Dominated by woody vegetation – **Estuarine Woody Wetland** (p. 15)
  - B. Wetland primarily affected by freshwater
    - i. Dominated by herbaceous vegetation – **Tidal Freshwater Marsh** (p. 17)
    - ii. Dominated by woody vegetation – **Riverine Swamp Forest** (p. 19)
- II. Wetland not affected by tides
  - A. Not in a geomorphic floodplain or a natural topographic crenulation <u>and</u> not contiguous with an open water 20 acres or larger
    - i. On a side slope – **Seep** (p. 24)
    - ii. On interstream divides <u>or</u> on a coastal island
      - 1. Flats on interstream divides in Coastal Plain ecoregions
        - a. Dominated by deciduous trees
          - i. Seasonally saturated to seasonally inundated (typically dominated by sweetgum and oaks) – **Hardwood Flat** (p. 26)
          - ii. Seasonally to semi-permanently inundated (typically dominated by cypress and black gum) – **Non-Riverine Swamp Forest** (p. 28)
        - b. Dominated by evergreens
          - i. Dominated by dense, waxy shrub species (typically include gallberries, fetterbushes, honeycup, greenbriar); canopy may include pond pine, Atlantic white cedar, and bays – **Pocosin** (p. 30)
          - ii. Not dominated by dense, waxy shrub species
            - 1. Dominated by long-leaf or pond pine and wire grass – **Pine Savanna** (p. 32)
            - 2. Dominated by loblolly or slash pines – **Pine Flat** (p. 33)
      - 2. In depressions surrounded by uplands anywhere in the state (mafic depressions, lime sinks, Carolina bays) or contiguous with an open water

NC Wetland Assessment Method (NC WAM) v4.1 vii Dichotomous Key to General Wetland Types

Figure A.1: NCWAM wetland type dichotomous key, page 1

Dichotomous Key to General NC Wetland Types, Continued

2. In depressions surrounded by uplands anywhere in the state (mafic depressions, lime sinks, Carolina bays) or contiguous with an open water (repeated from the previous page)
    a. Dominated by dense, waxy shrub species (typically include gallberries, fetterbushes, honeycup, greenbriar); canopy may include pond pine, Atlantic white cedar, and bays and not characterized by clay-based soils– **Pocosin** (p. 30)
    b. Not dominated by dense, waxy shrub species and not characterized by a peat-filled bay – **Basin Wetland** (p. 35)

B. In a geomorphic floodplain or a natural topographic crenulation or contiguous with an open water 20 acres or larger
  i. Northern Inner Piedmont or Blue Ridge Mountains ecoregions and dense herbaceous or mixed shrub/herbaceous vegetation with characteristic bog species (see wetland type description), with or without tree canopy; at least semi-permanent saturation; typically on organic or mucky soils; sphagnum moss commonly present – **Bog** (p. 37)
  ii. Anywhere in the state and not Bog
    1. Dominated by herbaceous vegetation. At least semi-permanently inundated or saturated. Includes lacustrine and riparian fringe and beaver ponds with dense herbaceous vegetation; sphagnum moss scarce or absent – **Non-Tidal Freshwater Marsh** (p. 40)
    2. Dominated by woody vegetation. Trees may be present on edges or hummocks.
        a. Localized depression and semi-permanently inundated – **Floodplain Pool** (p. 43)
        b. Not "a"
            i. Less than second-order stream or in a topographic crenulation without a stream. Diffuse surface flow and groundwater more important than overbank flooding.
                1. Seasonally to semi-permanently saturated and/or only intermittently inundated – **Headwater Forest** (p. 45)
                2. Seasonally to semi-permanently inundated – **Riverine Swamp Forest** (p. 19)
            ii. Second-order or greater stream or contiguous with an open water 20 acres or larger
                1. Intermittently to seasonally inundated (may be dominated by sweetgum, ash, sycamore, and oaks) – **Bottomland Hardwood Forest** (p. 49)
                2. Seasonally to semi-permanently inundated (may be dominated by cypress and blackgums in Coastal Plain and ash, overcup oak, and elms in Piedmont and Mountains) – **Riverine Swamp Forest** (p. 19)

[1]See stream order schematic diagrams in User Manual Appendix C.

NC Wetland Assessment Method (NC WAM) v4.1 viii Dichotomous Key to General Wetland Types

Figure A.2: NCWAM wetland type dichotomous key, page 2

NC WAM FIELD ASSESSMENT FORM
Accompanies User Manual Version 4.1

Wetland Site Name		**Date**	
Wetland Type		**Assessor Name/Organization**	
Level III Ecoregion		**Nearest Named Water Body**	
River Basin		**USGS 8-Digit Catalogue Unit**	
☐ **Yes** ☐ **No**	**Precipitation within 48 hrs?**	**Latitude/Longitude (deci-degrees)**	

Evidence of stressors affecting the assessment area (may not be within the assessment area)

Please circle and/or make note on the last page if evidence of stressors is apparent. Consider departure from reference, if appropriate, in recent past (for instance, within 10 years). Noteworthy stressors include, but are not limited to the following.

- Hydrological modifications (examples: ditches, dams, beaver dams, dikes, berms, ponds, etc.)
- Surface and sub-surface discharges into the wetland (examples: discharges containing obvious pollutants, presence of nearby septic tanks, underground storage tanks (USTs), hog lagoons, etc.)
- Signs of vegetation stress (examples: vegetation mortality, insect damage, disease, storm damage, salt intrusion, etc.)
- Habitat/plant community alteration (examples: mowing, clear-cutting, exotics, etc.)

Is the assessment area intensively managed? ☐ **Yes** ☐ **No**

Regulatory Considerations (select all that apply to the assessment area)

☐ Anadromous fish
☐ Federally protected species or State endangered or threatened species
☐ NCDWQ riparian buffer rule in effect
☐ Abuts a Primary Nursery Area (PNA)
☐ Publicly owned property
☐ N.C. Division of Coastal Management Area of Environmental Concern (AEC) (including buffer)
☐ Abuts a stream with a NCDWQ classification of SA or supplemental classifications of HQW, ORW, or Trout
☐ Designated NCNHP reference community
☐ Abuts a 303(d)-listed stream or a tributary to a 303(d)-listed stream

What type of natural stream is associated with the wetland, if any? (check all that apply)

☐ Blackwater
☐ Brownwater
☐ Tidal (if tidal, check one of the following boxes) ☐ Lunar ☐ Wind ☐ Both

Is the assessment area on a coastal island? ☐ Yes ☐ No

Is the assessment area's surface water storage capacity or duration substantially altered by beaver? ☐ Yes ☐ No

Does the assessment area experience overbank flooding during normal rainfall conditions? ☐ Yes ☐ No

1. Ground Surface Condition/Vegetation Condition – assessment area condition metric

Check a box in each column. Consider alteration to the ground surface (GS) in the assessment area and vegetation structure (VS) in the assessment area. Compare to reference wetland if applicable (see User Manual). If a reference is not applicable, then rate the assessment area based on evidence of an effect.

GS	VS	
☐A	☐A	Not severely altered
☐B	☐B	Severely altered over a majority of the assessment area (ground surface alteration examples: vehicle tracks, excessive sedimentation, fire-plow lanes, skidder tracks, bedding, fill, soil compaction, obvious pollutants) (vegetation structure alteration examples: mechanical disturbance, herbicides, salt intrusion [where appropriate], exotic species, grazing, reduced diversity [if appropriate], hydrologic alteration)

2. Surface and Sub-Surface Storage Capacity and Duration – assessment area condition metric

Check a box in each column. Consider surface storage capacity and duration (Surf) and sub-surface storage capacity and duration (Sub). Consider both increase and decrease in hydrology. Refer to the current NRCS lateral effect of ditching guidance for North Carolina hydric soils (see USACE Wilmington District website) for the zone of influence of ditches in hydric soils. A ditch ≤ 1 foot deep is considered to affect surface water only, while a ditch > 1 foot deep is expected to affect both surface and sub-surface water. Consider tidal flooding regime, if applicable.

Surf	Sub	
☐A	☐A	Water storage capacity and duration are not altered.
☐B	☐B	Water storage capacity or duration are altered, but not substantially (typically, not sufficient to change vegetation).
☐C	☐C	Water storage capacity or duration is substantially altered (typically, alteration sufficient to result in vegetation change) (examples: draining, flooding, soil compaction, filling, excessive sedimentation, underground utility lines).

3. Water Storage/Surface Relief – assessment area/wetland type condition metric (evaluate for non-marsh wetlands only)

Check a box in each column for each group below. Select for the assessment area (AA) and the wetland type (WT).

	AA	WT	
3a.	☐A	☐A	Majority of wetland with depressions able to pond water > 1 foot deep
	☐B	☐B	Majority of wetland with depressions able to pond water 6 inches to 1 foot deep
	☐C	☐C	Majority of wetland with depressions able to pond water 3 to 6 inches deep
	☐D	☐D	Depressions able to pond water < 3 inches deep
3b.	☐A		Evidence that maximum depth of inundation is greater than 2 feet
	☐B		Evidence that maximum depth of inundation is between 1 and 2 feet
	☐C		Evidence that maximum depth of inundation is less than 1 foot

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Figure A.3: NCWAM field form, page 1

4. **Soil Texture/Structure – assessment area condition metric**

Check a box from each of the three soil property groups below. Dig soil profile in the dominant assessment area landscape feature. Make soil observations within the top 12 inches. Use most recent guidance for National Technical Committee for Hydric Soils regional indicators.

4a. ☐A Sandy soil
☐B Loamy or clayey soils exhibiting redoximorphic features (concentrations, depletions, or rhizospheres)
☐C Loamy or clayey soils not exhibiting redoximorphic features
☐D Loamy or clayey gleyed soil
☐E Histosol or histic epipedon

4b. ☐A Soil ribbon < 1 inch
☐B Soil ribbon ≥ 1 inch

4c. ☐A No peat or muck presence
☐B A peat or muck presence

5. **Discharge into Wetland – assessment area opportunity metric**

Check a box in each column. Consider surface pollutants or discharges (Surf) and sub-surface pollutants or discharges (Sub). Examples of sub-surface discharges include presence of nearby septic tank, underground storage tank (UST), etc.

Surf	Sub	
☐A	☐A	Little or no evidence of pollutants or discharges entering the assessment area
☐B	☐B	Noticeable evidence of pollutants or discharges entering the wetland and stressing, but not overwhelming the treatment capacity of the assessment area
☐C	☐C	Noticeable evidence of pollutants or discharges (pathogen, particulate, or soluble) entering the assessment area and potentially overwhelming the treatment capacity of the wetland (water discoloration, dead vegetation, excessive sedimentation, odor)

6. **Land Use – opportunity metric**

Check all that apply (at least one box in each column). Evaluation involves a GIS effort with field adjustment. Consider sources draining to assessment area within entire upstream watershed (WS), within 5 miles <u>and</u> within the watershed draining to the assessment area (5M), <u>and</u> within 2 miles and within the watershed draining to the assessment area (2M).

WS	5M	2M	
☐A	☐A	☐A	≥ 10% impervious surfaces
☐B	☐B	☐B	< 10% impervious surfaces
☐C	☐C	☐C	Confined animal operations (or other local, concentrated source of pollutants)
☐D	☐D	☐D	≥ 20% coverage of pasture
☐E	☐E	☐E	≥ 20% coverage of agricultural land (regularly plowed land)
☐F	☐F	☐F	≥ 20% coverage of maintained grass/herb
☐G	☐G	☐G	≥ 20% coverage of clear-cut land
☐H	☐H	☐H	Little or no opportunity to improve water quality. Lack of opportunity may result from hydrologic alterations that prevent drainage or overbank flow from affecting the assessment area.

7. **Wetland Acting as Vegetated Buffer – assessment area/wetland complex condition metric**

7a. Is assessment area within 50 feet of a tributary or other open water?
☐Yes ☐No If Yes, continue to 7b. If No, skip to Metric 8.
Wetland buffer need only be present on one side of the open water. Make buffer judgment based on the average width of wetland. Record a note if a portion of the buffer has been removed or disturbed.

7b. How much of the first 50 feet from the bank is wetland?
☐A ≥ 50 feet
☐B From 30 to < 50 feet
☐C From 15 to < 30 feet
☐D From 5 to < 15 feet
☐E < 5 feet <u>or</u> buffer bypassed by ditches

7c. Tributary width. If the tributary is anastomosed, combine widths of channels/braids for a total width.
☐≤ 15-feet wide ☐> 15-feet wide ☐ Other open water (no tributary present)

7d. Do roots of assessment area vegetation extend into the bank of the tributary/open water?
☐Yes ☐No

7e. Is the tributary or other open water sheltered or exposed?
☐Sheltered – open water width < 2500 feet and no regular boat traffic.
☐Exposed – open water width ≥ 2500 feet or regular boat traffic.

8. **Wetland Width at the Assessment Area – wetland type/wetland complex condition metric (evaluate for riparian wetlands only)**

Check a box in each column. Select the average width for the wetland type at the assessment area (WT) and the wetland complex at the assessment area (WC). See User Manual for WT and WC boundaries.

WT	WC	
☐A	☐A	≥ 100 feet
☐B	☐B	From 80 to < 100 feet
☐C	☐C	From 50 to < 80 feet
☐D	☐D	From 40 to < 50 feet
☐E	☐E	From 30 to < 40 feet
☐F	☐F	From 15 to < 30 feet
☐G	☐G	From 5 to < 15 feet
☐H	☐H	< 5 feet

x

Figure A.4: NCWAM field form, page 2

9. Inundation Duration – assessment area condition metric

Answer for assessment area dominant landform.
☐A Evidence of short-duration inundation (< 7 consecutive days)
☐B Evidence of saturation, without evidence of inundation
☐C Evidence of long-duration inundation or very long-duration inundation (7 to 30 consecutive days or more)

10. Indicators of Deposition – assessment area condition metric

Consider recent deposition only (no plant growth since deposition).
☐A Sediment deposition is not excessive, but at approximately natural levels.
☐B Sediment deposition is excessive, but not overwhelming the wetland.
☐C Sediment deposition is excessive and is overwhelming the wetland.

11. Wetland Size – wetland type/wetland complex condition metric

Check a box in each column. Involves a GIS effort with field adjustment. This metric evaluates three aspects of the wetland area: the size of the wetland type (WT), the size of the wetland complex (WC), and the size of the forested wetland (FW) (if applicable, see User Manual). See the User Manual for boundaries of these evaluation areas. If assessment area is clear-cut, select "K" for the FW column.

WT	WC	FW (if applicable)	
☐A	☐A	☐A	≥ 500 acres
☐B	☐B	☐B	From 100 to < 500 acres
☐C	☐C	☐C	From 50 to < 100 acres
☐D	☐D	☐D	From 25 to < 50 acres
☐E	☐E	☐E	From 10 to < 25 acres
☐F	☐F	☐F	From 5 to < 10 acres
☐G	☐G	☐G	From 1 to < 5 acres
☐H	☐H	☐H	From 0.5 to < 1 acre
☐I	☐I	☐I	From 0.1 to < 0.5 acre
☐J	☐J	☐J	From 0.01 to < 0.1 acre
☐K	☐K	☐K	< 0.01 acre <u>or</u> assessment area is clear-cut

12. Wetland Intactness – wetland type condition metric (evaluate for Pocosins only)

☐A Pocosin is the full extent (≥ 90%) of its natural landscape size.
☐B Pocosin is < 90% of the full extent of its natural landscape size.

13. Connectivity to Other Natural Areas – landscape condition metric

13a. **Check appropriate box(es) (a box may be checked in each column).** Involves a GIS effort with field adjustment. This metric evaluates whether the wetland is well connected (Well) and/or loosely connected (Loosely) to the landscape patch, the contiguous naturally vegetated area and open water (if appropriate). Boundaries are formed by four-lane roads, regularly maintained utility line corridors the width of a four-lane road or wider, urban landscapes, maintained fields (pasture and agriculture), or open water > 300 feet wide.

Well	Loosely	
☐A	☐A	≥ 500 acres
☐B	☐B	From 100 to < 500 acres
☐C	☐C	From 50 to < 100 acres
☐D	☐D	From 10 to < 50 acres
☐E	☐E	< 10 acres
☐F	☐F	Wetland type has a poor or no connection to other natural habitats

13b. **Evaluate for marshes only.**
☐Yes ☐No Wetland type has a surface hydrology connection to open waters/tributary or tidal wetlands.

14. Edge Effect – wetland type condition metric (skip for all marshes)

May involve a GIS effort with field adjustment. Estimate distance from wetland type boundary to artificial edges. Artificial edges include non-forested areas ≥ 40 feet wide such as fields, development, roads, regularly maintained utility line corridors, and clear-cuts. Consider the eight main points of the compass.
☐A No artificial edge within 150 feet in all directions
☐B No artificial edge within 150 feet in four (4) to seven (7) directions
☐C An artificial edge occurs within 150 feet in more than four (4) directions <u>or</u> assessment area is clear-cut

15. Vegetative Composition – assessment area condition metric (skip for all marshes and Pine Flat)

☐A Vegetation is close to reference condition in species present and their proportions. Lower strata composed of appropriate species, with exotic plants absent or sparse within the assessment area.
☐B Vegetation is different from reference condition in species diversity or proportions, but still largely composed of native species characteristic of the wetland type. This may include communities of weedy native species that develop after clearcutting or clearing. It also includes communities with exotics present, but not dominant, over a large portion of the expected strata.
☐C Vegetation severely altered from reference in composition. Expected species are unnaturally absent (planted stands of non-characteristic species or at least one stratum inappropriately composed of a single species). Exotic species are dominant in at least one stratum.

16. Vegetative Diversity – assessment area condition metric (evaluate for Non-tidal Freshwater Marsh only)

☐A Vegetation diversity is high and is composed primarily of native species (< 10% cover of exotics).
☐B Vegetation diversity is low or has > 10% to 50% cover of exotics.
☐C Vegetation is dominated by exotic species (> 50% cover of exotics).

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Figure A.5: NCWAM field form, page 3

17. **Vegetative Structure – assessment area/wetland type condition metric**

17a. Is vegetation present?

☐Yes ☐No If Yes, continue to 17b. If No, skip to Metric 18.

17b. Evaluate percent coverage of assessment area vegetation **for all marshes only**. Skip to17c for non-marsh wetlands.

☐A ≥ 25% coverage of vegetation

☐B < 25% coverage of vegetation

17c. **Check a box in each column for each stratum.** Evaluate this portion of the metric **for non-marsh wetlands**. Consider structure in airspace above the assessment area (AA) and the wetland type (WT) separately.

	AA	WT	
Canopy	☐A	☐A	Canopy closed, or nearly closed, with natural gaps associated with natural processes
	☐B	☐B	Canopy present, but opened more than natural gaps
	☐C	☐C	Canopy sparse or absent
Mid-Story	☐A	☐A	Dense mid-story/sapling layer
	☐B	☐B	Moderate density mid-story/sapling layer
	☐C	☐C	Mid-story/sapling layer sparse or absent
Shrub	☐A	☐A	Dense shrub layer
	☐B	☐B	Moderate density shrub layer
	☐C	☐C	Shrub layer sparse or absent
Herb	☐A	☐A	Dense herb layer
	☐B	☐B	Moderate density herb layer
	☐C	☐C	Herb layer sparse or absent

18. **Snags – wetland type condition metric**

☐A Large snags (more than one) are visible (> 12 inches DBH, or large relative to species present and landscape stability).

☐B Not A

19. **Diameter Class Distribution – wetland type condition metric**

☐A Majority of canopy trees have stems > 6 inches in diameter at breast height (DBH); many large trees (> 12 inches DBH) are present.

☐B Majority of canopy trees have stems between 6 and 12 inches DBH, few are > 12 inch DBH.

☐C Majority of canopy trees are < 6 inches DBH or no trees.

20. **Large Woody Debris – wetland type condition metric**

Include both natural debris and man-placed natural debris.

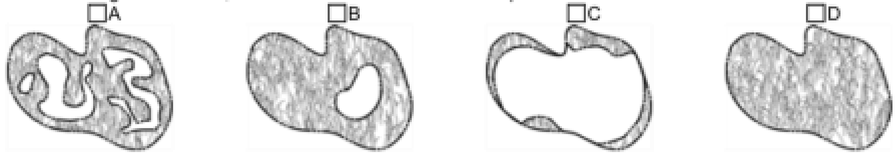
☐A Large logs (more than one) are visible (> 12 inches in diameter, or large relative to species present and landscape stability).

☐B Not A

21. **Vegetation/Open Water Dispersion – wetland type/open water condition metric (evaluate for Non-Tidal Freshwater Marsh only)**

Select the figure that best describes the amount of interspersion between vegetation and open water in the growing season. Patterned areas indicate vegetated areas, while solid white areas indicate open water.

☐A ☐B ☐C ☐D



22. **Hydrologic Connectivity – assessment area condition metric (evaluate for riparian wetlands only)**

Examples of activities that may severely alter hydrologic connectivity include intensive ditching, fill, sedimentation, channelization, diversion, man-made berms, beaver dams, and stream incision.

☐A Overbank <u>and</u> overland flow are not severely altered in the assessment area.

☐B Overbank flow is severely altered in the assessment area.

☐C Overland flow is severely altered in the assessment area.

☐D Both overbank <u>and</u> overland flow are severely altered in the assessment area.

Notes

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Figure A.6: NCWAM field form, page 4

Table 1. Relationship of metrics, sub-functions, and functions for generation of wetland functional ratings for a Bottomland Hardwood Forest assessment area.

Figure A.7: NCWAM input-output flowchart for a bottomland hardwood wetland type

NC WAM Wetland Rating Sheet
Accompanies User Manual Version 4.1
Rating Calculator Version 4.1

Wetland Site Name	Sample Site	Date	Date
Wetland Type	Bottomland Hardwood Forest	Assessor Name/Organization	Agency

Notes on Field Assessment Form (Y/N)	NO
Presence of regulatory considerations (Y/N)	NO
Wetland is intensively managed (Y/N)	NO
Assessment area is located within 50 feet of a natural tributary or other open water (Y/N)	YES
Assessment area is substantially altered by beaver (Y/N)	NO
Assessment area experiences overbank flooding during normal rainfall conditions (Y/N)	YES
Assessment area is on a coastal island (Y/N)	NO

Sub-function Rating Summary

Function	Sub-function	Metrics	Rating
Hydrology	Surface Storage and Retention	Condition	**MEDIUM**
	Sub-Surface Storage and Retention	Condition	**MEDIUM**
Water Quality	Pathogen Change	Condition	**HIGH**
		Condition/Opportunity	**HIGH**
		Opportunity Presence? (Y/N)	**YES**
	Particulate Change	Condition	**MEDIUM**
		Condition/Opportunity	**HIGH**
		Opportunity Presence? (Y/N)	**YES**
	Soluble Change	Condition	**MEDIUM**
		Condition/Opportunity	**HIGH**
		Opportunity Presence? (Y/N)	**YES**
	Physical Change	Condition	**HIGH**
		Condition/Opportunity	**HIGH**
		Opportunity Presence? (Y/N)	**YES**
	Pollution Change	Condition	NA
		Condition/Opportunity	NA
		Opportunity Presence? (Y/N)	NA
Habitat	Physical Structure	Condition	**LOW**
	Landscape Patch Structure	Condition	**LOW**
	Vegetation Composition	Condition	**MEDIUM**

Function Rating Summary

Function	Metrics/Notes	Rating
Hydrology	Condition	**MEDIUM**
Water Quality	Condition	**HIGH**
	Condition/Opportunity	**HIGH**
	Opportunity Presence? (Y/N)	**YES**
Habitat	Conditon	**LOW**

Overall Wetland Rating **MEDIUM**

Figure A.8: NCWAM sample output

Appendix B: Additional Wetland Analyses

Table B.1: Assessment results for all sites.

Site	Age (yr)	Dominant Vegetation	Mitigation Provider	Floristic Indices				Rapid Assessments		GIS Asses.
				VIBI	WTALU	AFQI	FAQWet	ORAM	NCWAM	LDI
NC12-01	10	Emergent	MB	50.0	RWH	33.38	22.07	60	High	1.00
NC12-02	10	Forest	MB	59.0	RWH	36.88	3.10	46	Medium	1.54
NC12-03	8	Shrub	MB	38.0	RWH	39.08	8.37	40	Low	1.74
NC12-05	8	Forest	MB	54.0	RWH	38.94	6.60	52	High	1.15
NC12-06	8	Forest	MB	82.5	SWH	36.09	15.07	65	High	1.07
NC12-07	9	Shrub	MB	51.0	RWH	31.75	9.91	71	High	1.12
NC12-09	8	Emergent	MB	57.0	RWH	41.46	11.84	65	High	1.24
NC12-10	8	Shrub	MB	46.0	RWH	32.69	2.65	42	High	1.40
NC12-12	9	Shrub	PR	52.2	RWH	35.86	12.90	50	Medium	1.53
NC12-17	8	Emergent	PR	64.0	WH	33.63	10.92	48	High	3.64
NC12-18	8	Forest	PR	84.0	SWH	41.63	14.53	67	High	1.00
NC12-20	7	Emergent	PR	80.0	SWH	31.45	11.40	51	High	4.25
NC12-21	9	Shrub	PR	49.0	RWH	36.05	6.40	35	High	1.13
NC12-22	7	Emergent	PR	77.0	SWH	32.33	7.51	51	High	3.20
NC12-25	5	Emergent	ILF	70.0	WH	33.45	11.63	50	High	1.22
NC12-26	9	Emergent	ILF	81.0	SWH	33.29	14.24	59	High	1.16
NC12-27	8	Emergent	ILF	73.0	WH	34.09	8.82	65	High	1.03
NC12-28	8	Shrub	ILF	40.0	RWH	37.58	10.95	47	High	1.07
NC12-30	7	Emergent	ILF	80.0	SWH	36.76	17.52	53	High	1.00
NC12-33	7	Emergent	ILF	73.0	WH	29.96	6.61	55	Medium	1.75
NC12-34	8	Emergent	ILF	77.0	SWH	35.81	17.75	51	High	1.32
NC12-36	6	Emergent	ILF	73.0	WH	35.74	2.97	37	Medium	2.01
NC12-37	9	Forest	MB	71.0	WH	33.90	5.99	38	High	1.22
NC12-38	9	Emergent	ILF	81.0	SWH	34.01	13.81	47	Medium	1.29
NC12-39	6	Emergent	ILF	64.0	WH	29.02	7.06	49	High	2.52
NC12-41	8	Shrub	ILF	37.0	RWH	35.06	3.78	55	High	1.01
NC12-42	6	Emergent	ILF	26.0	LQWH	38.00	15.36	56	High	1.96
NC12-43	11	Forest	ILF	66.0	WH	44.04	11.58	39	High	1.84
NC12-44	8	Emergent	ILF	68.0	WH	29.24	10.64	52	High	2.02
NC12-46	6	Emergent	ILF	94.0	SWH	42.43	16.92	52	High	1.19

ILF = In-lieu fee; MB = Mitigation bank; PR = Permittee-responsible
LQWH = Low quality wetland habitat; RWH = Restorable wetland habitat; WH = Wetland habitat; SWH = Superior wetland habitat

Table B.2: Mean (SD) values by mitigation provider. Kruskal-Wallis Chi-square values (unless noted) by mitigation providers. Significant differences among mitigation providers noted.

Parameters	Units	n	Kruskal-Wallis Chi-Square	Mean (SD) In-lieu Fee	Mitigation Bank	Permitee Responsible
Floristic Assessments						
VIBI	-	30	2.89	66.9 (18.6)	56.5 (13.3)	67.7 (14.9)
AFQI	-	30	1.74	26.4 (3.1)	24 (4.2)	25.5 (1.7)
FAQWet3	-	30	1.38	11.3 (4.8)	9.5 (6.2)	10.6 (3.1)
ORAM						
ORAM	-	30	0.35	51.1 (7.1)	53.2 (12.4)	50.3 (10.2)
ORAM-category†	-	30	0.14	-	-	-
ORAM-size	-	30	3.71	4.3 (0.9)	4.7 (1)	3.2 (1.8)
ORAM-buffer	-	30	7.19*	8.3 (3.4) [A/B]	10.1 (2.6) [A]	6.2 (1.3) [B]
ORAM-hydrology	-	30	1.06	15.2 (4.8)	15.4 (5.9)	17.7 (4.3)
ORAM-habitat	-	30	1.48	9 (1.8)	9.4 (1.7)	10.3 (2.3)
ORAM-vegetation	-	30	1.92	9.1 (2)	8.3 (2.8)	7.8 (2.1)
NCWAM						
NCWAM†	-	30	0.834	-	-	-
NCWAM-hydrology†	-	30	0.668	-	-	-
NCWAM-water quality†	-	30	0.513	-	-	-
NCWAM-habitat†	-	30	0.606	-	-	-
Soil Parameters						
Organic Matter	%	30	5.58	2.4 (2)	9.7 (13.3)	3.7 (2.5)
Bulk Density	g/cm^3	30	2.30	1.1 (0.1)	0.9 (0.3)	1 (0.2)
Sand	%	30	5.77	53.6 (12.8)	65.7 (14)	47.3 (12.6)
Clay	%	30	7.27*	15.5 (7.3) [A]	7.3 (4.1) [B]	15.7 (12.4) [A/B]
pH	-	30	1.53	4.9 (0.6)	4.9 (0.6)	5.2 (0.8)
Buffer Index	-	30	1.10	6.5 (0.3)	6.6 (0.2)	6.6 (0.2)
Cation Exchange Capacity	meq/100g	30	2.78	10.5 (5.6)	7.3 (1.8)	9 (3.2)
Carbon:Nitrogen ratio	-	30	3.27	11.2 (5.7)	16.4 (7.8)	14 (7)
Carbon	%	30	4.09	1.7 (1.5)	6.9 (9.2)	2.7 (2.8)
Nitrogen	%	30	4.55	0.1 (0.1)	0.3 (0.3)	0.2 (0.1)
NO3	ppm	30	0.80	21.3 (21.8)	20 (16.2)	12.8 (9.3)
Phosphorus-1 (weak Bray)	ppm	30	6.69*	12.9 (10.7) [A/B]	41.3 (35.3) [A]	8 (4.6) [B]
Phosphorus-2 (strong Bray)	ppm	30	5.01	20.8 (15.19)	62.78 (49.56)	21 (8.99)
Potassium	ppm	30	1.32	52.2 (22.6)	64 (27.5)	56 (14.2)
Magnesium	ppm	30	3.06	157.7 (82.5)	118.2 (53.5)	200 (104.6)
Calcium	ppm	30	0.57	749.1 (504.9)	544.4 (287.3)	674.3 (410.3)
Sulfur	ppm	29	1.14	24.2 (9)	20.1 (5.3)	23.4 (13.3)
Zinc	ppm	29	2.12	1.2 (1.2)	1.1 (0.5)	1.7 (1.3)
Manganese	ppm	29	4.26	7.7 (6.8)	3.6 (3.5)	35.8 (47)
Iron	ppm	29	3.22	74.7 (41.5)	112.2 (79.6)	121.4 (54)
Copper	ppm	29	5.38	0.8 (0.7)	0.4 (0.3)	1.1 (0.5)
Boron	ppm	29	3.50	0.3 (0.1)	0.3 (0.1)	0.3 (0.1)

Table D.2. (CONTINUED) Mean (SD) values by mitigation provider. Kruskal-Wallis Chi-square values (unless noted) by mitigation providers. Significant differences among mitigation providers noted.

Parameters	Units	n	Kruskal-Wallis Chi-Square	Mean (SD) In-lieu Fee	Mean (SD) Mitigation Bank	Mean (SD) Permitee Responsible
Water Quality Parameters						
Dissolved oxygen	mg/L as N	15	2.04	4.6 (2.6)	2.7 (2.7)	3.2 (4.2)
pH (water)	-	15	3.05	5.7 (0.6)	5.2 (1)	4.8 (0.9)
Specific conductivity	µS/cm	15	0.96	139.5 (131.5)	138.6 (52.1)	1395.3 (1872.0)
Total Kjeldahl nitrogen	mg/L as N	15	0.03	1.4 (1)	1.5 (1.5)	1 (0.6)
NO2+NO3	mg/L as N	15	4.68	0.1 (0.1)	0.7 (0.7)	0 (0)
Organic nitrogen	mg/L as N	15	0.04	1.27 (0.92)	1.38 (1.53)	0.98 (0.56)
NH3	mg/L as N	15	4.88	0.1 (0.3)	0.1 (0.1)	0 (0)
P	mg/L as P	15	0.21	0.3 (0.4)	0.1 (0.1)	0.2 (0.2)
Other Parameters						
Site Age	yr	30	4.98	7.5 (1.6)	8.7 (0.9)	8 (0.9)
Site Size	ha	30	2.63	9.09 (5.96)	13.44 (11.62)	30.55 (65.78)
Coefficient of Conservation	-	30	0.23	3.66 (0.4)	3.75 (0.36)	3.68 (0.31)
Wetness Coefficient	-	30	0.43	1.74 (0.83)	1.76 (1.34)	1.72 (0.6)
Landscape Development Index	-	30	2.18	1.5 (0.5)	1.3 (0.2)	2.5 (1.4)

Significance denoted as $*p < 0.05$; $**p < 0.01$; $***p < 0.001$; $****p < 0.0001$

Post-hoc significant difference among mitigation providers denoted by [A/B/C] adjusted for multiple comparisons (α=0.05).

† Fisher Exact Test pvalues reported for categorical and ordinal parameters.

Appendix C: Restored Wetland Sites

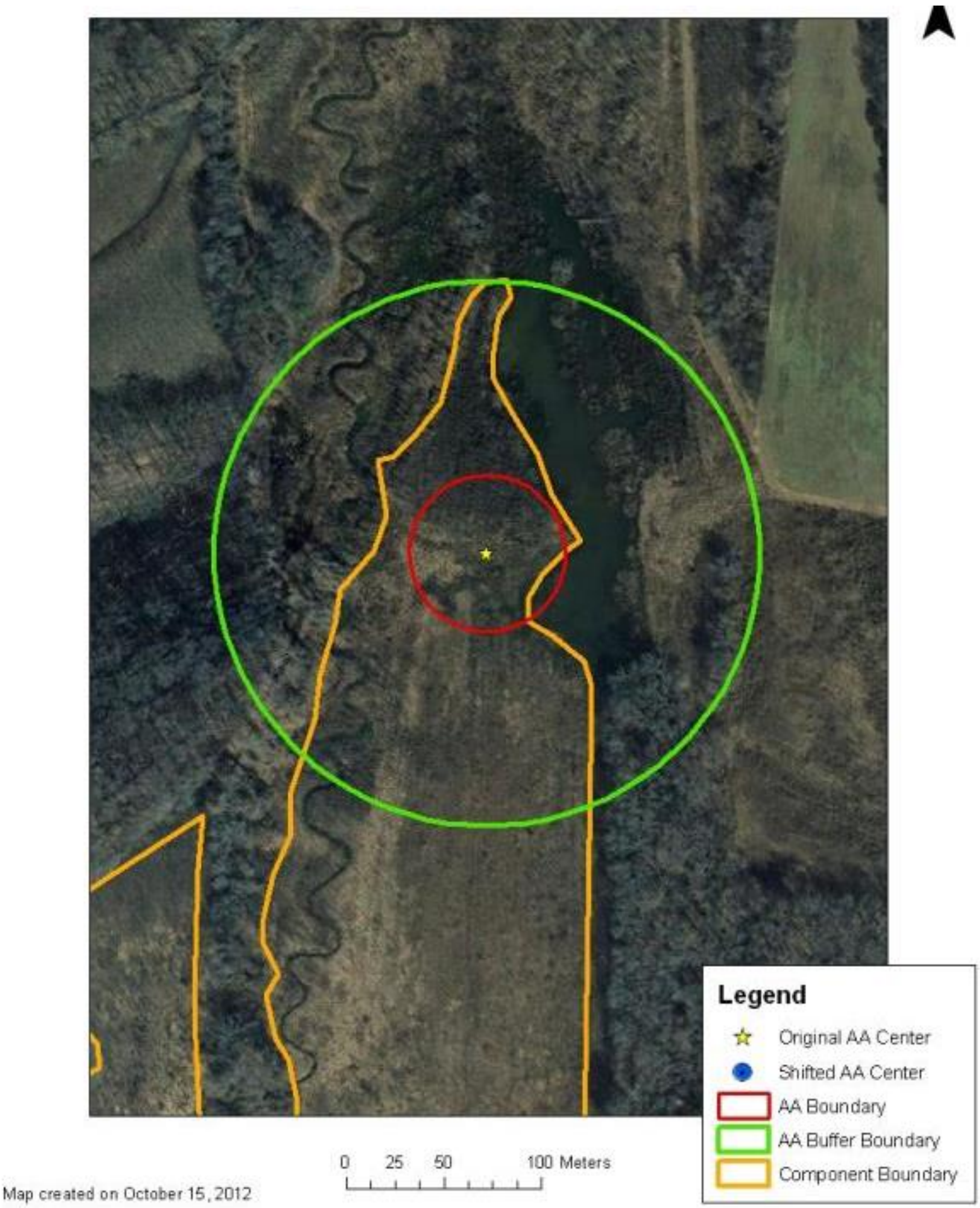

Figure C.1: NC12-01 site map

NC12-01

7.2 ha 10 yr old

Emergent Mitigation Bank

Figure C.2: NC12-01 site images

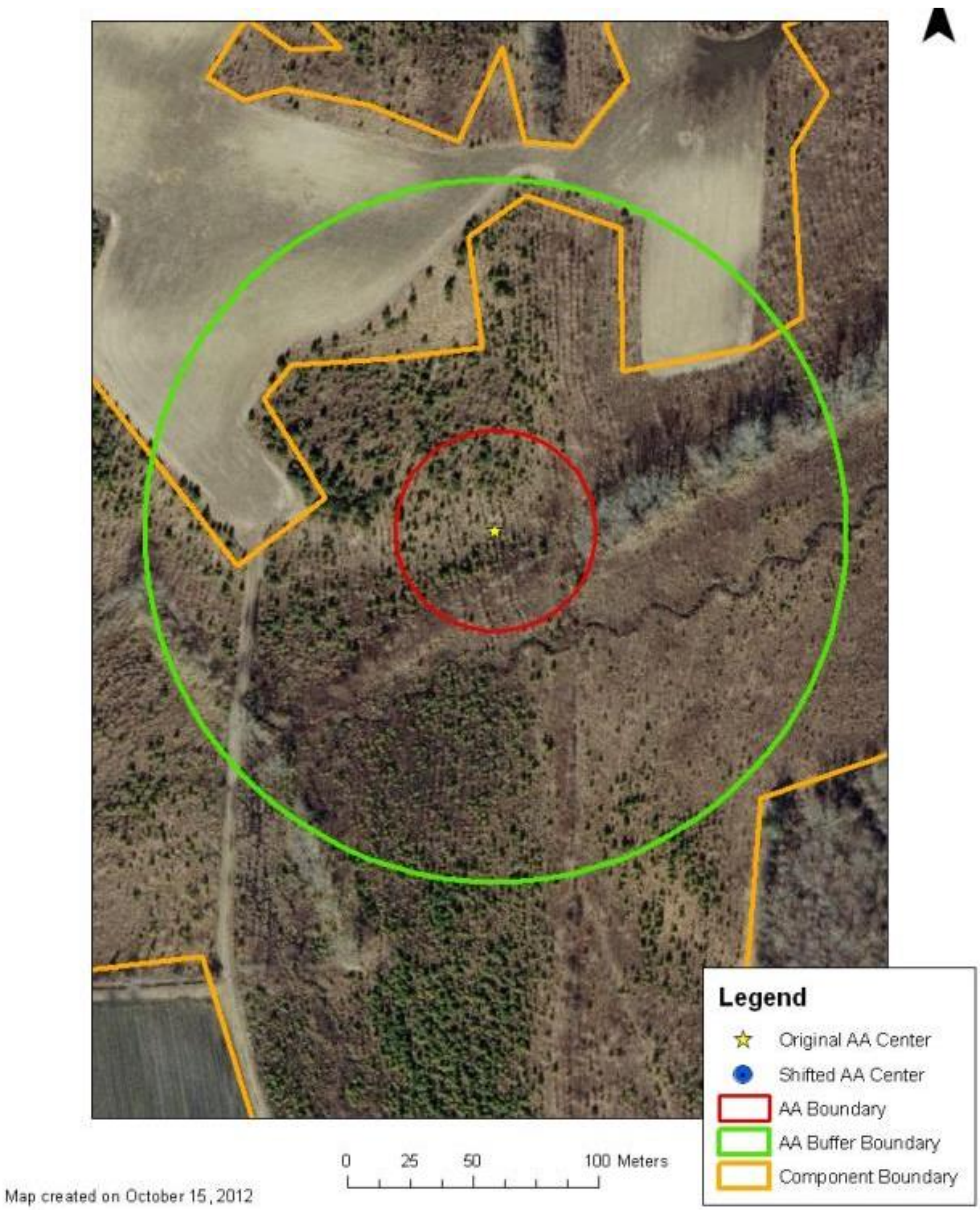

Figure C.3: NC12-02 site map

NC12-02

20.3 ha	10 yr old
Forest	Mitigation Bank

Figure C.4: NC12-02 site images

Figure C.5: NC12-03 site map

NC12-03

10.2 ha	8 yr old
Shrub	Mitigation Bank

Figure C.6: NC12-03 site images

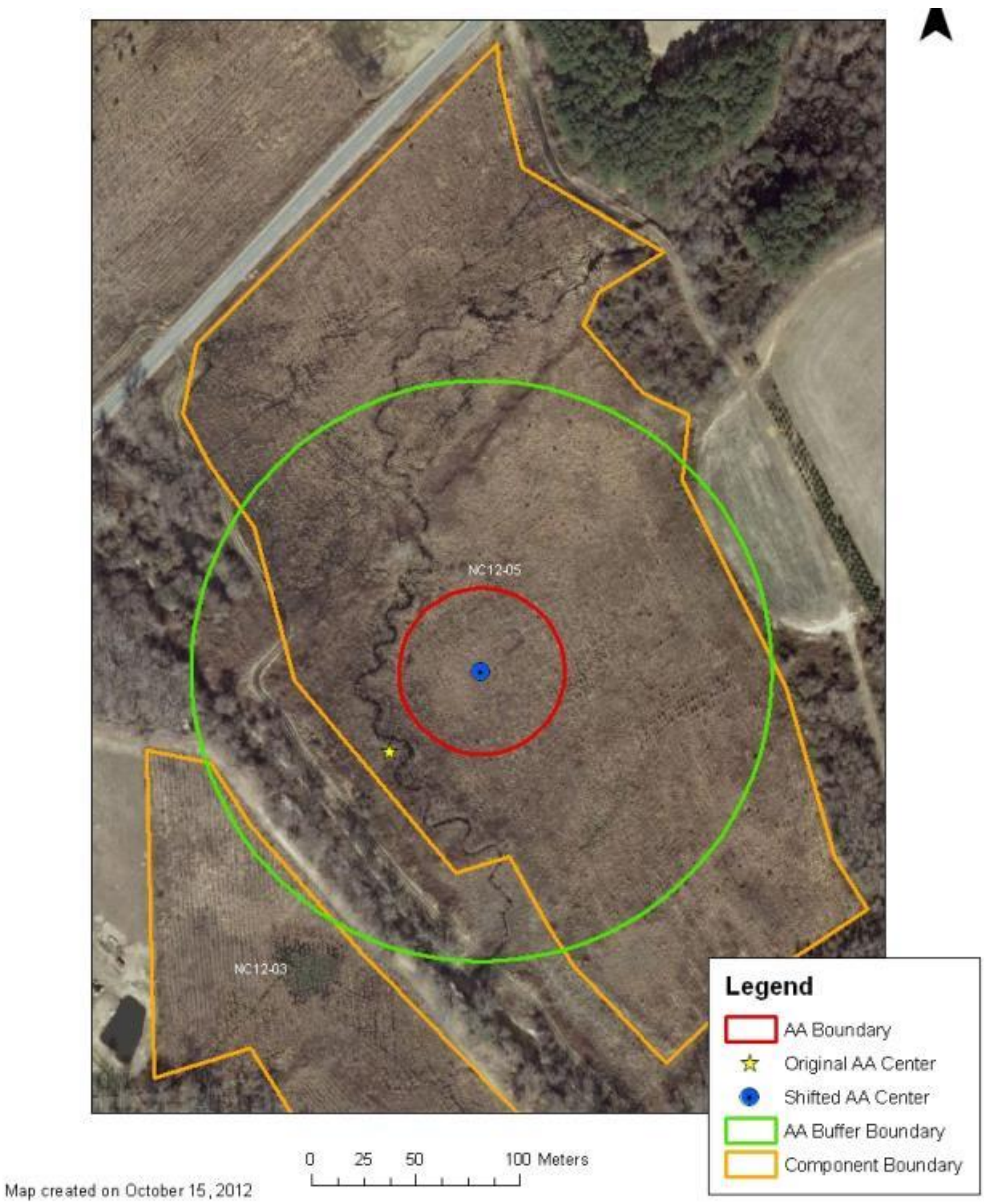

Figure C.7: NC12-05 site map

<u>NC12-05</u>

7.9 ha 8 yr old

Forest Mitigation Bank

Figure C.8: NC12-05 site images

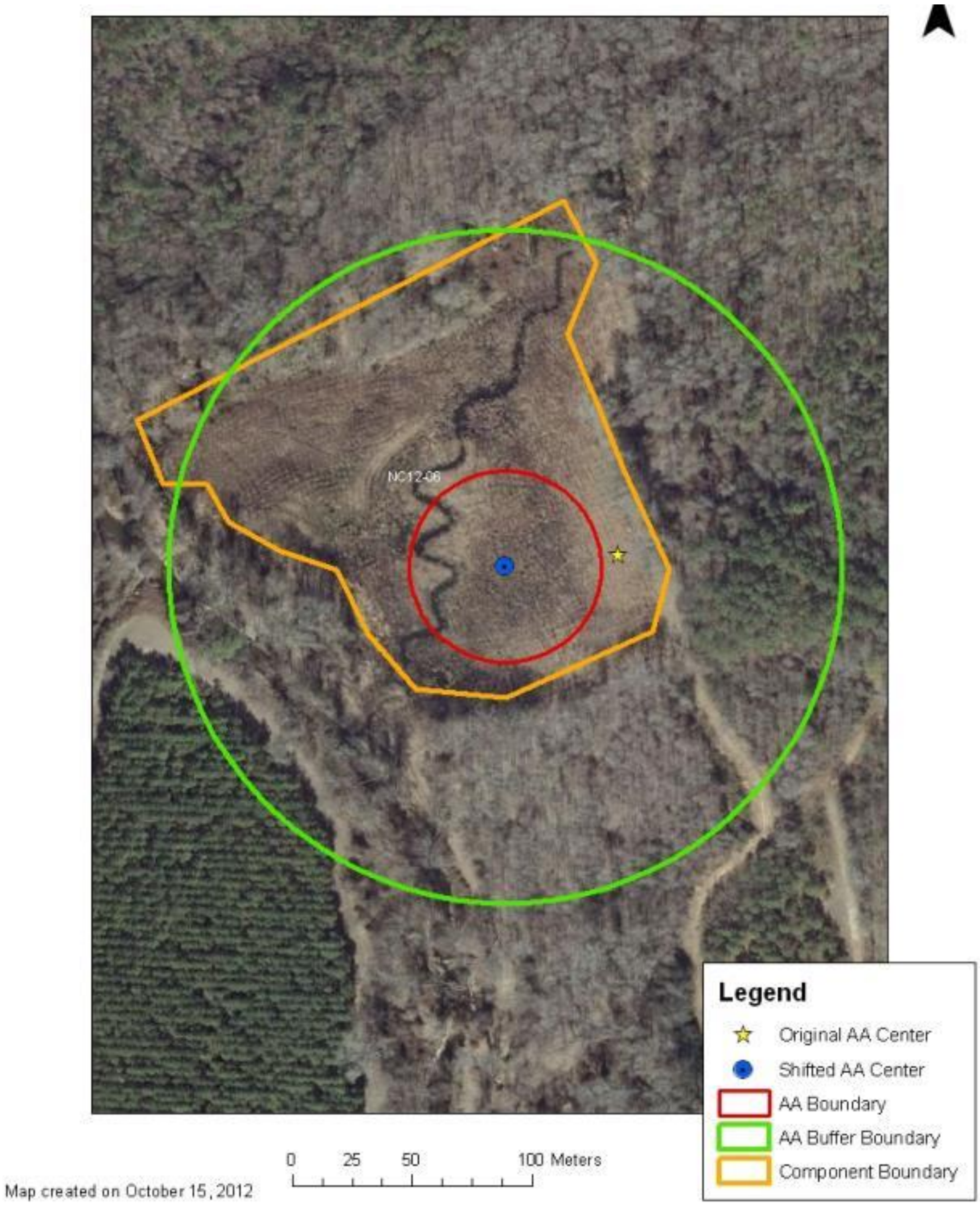

Figure C.9: NC12-06 site map

NC12-06

2.5 ha	8 yr old
Forest	Mitigation Bank

Figure C.10: NC12-06 site images

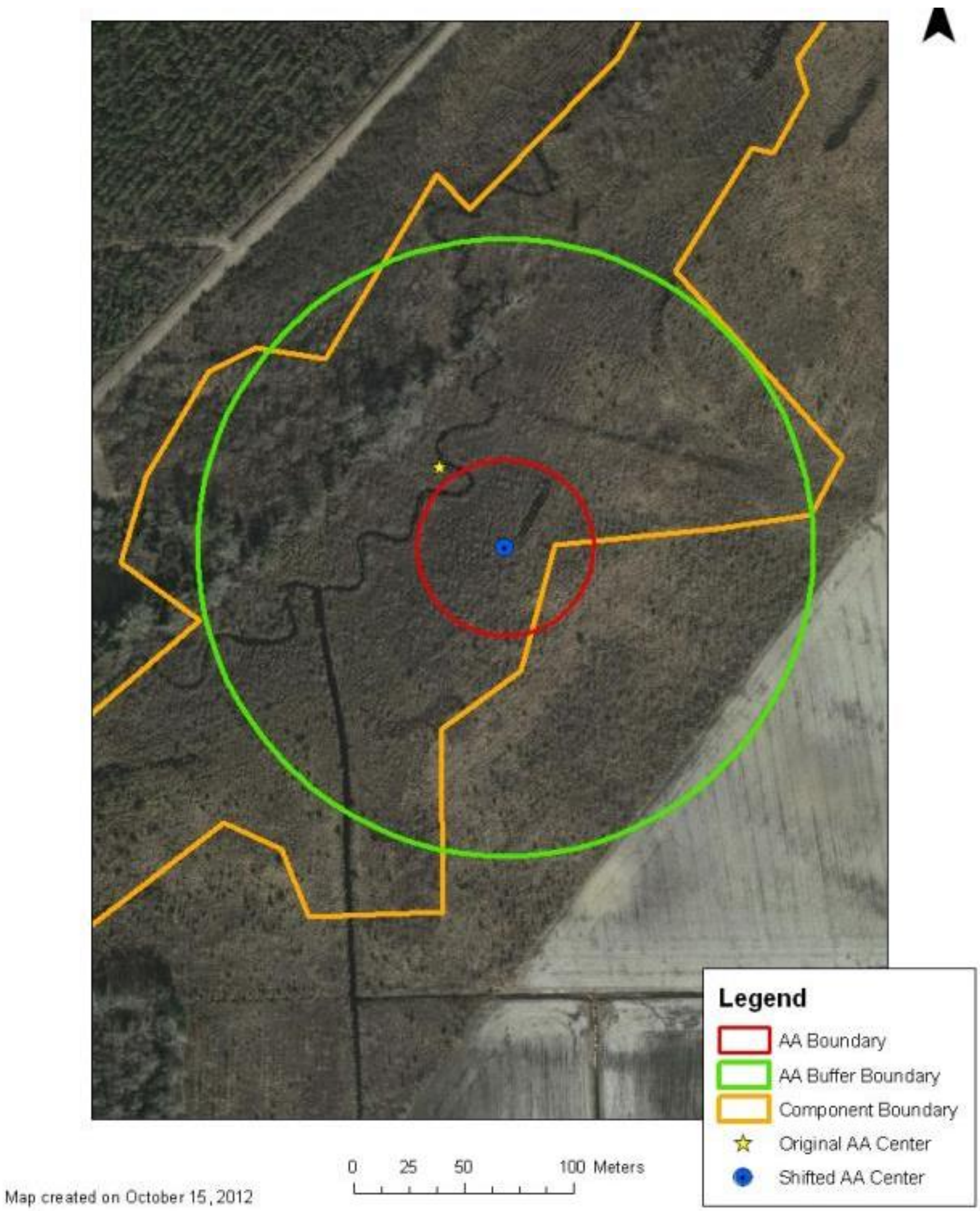

Figure C.11: NC12-07 site map

NC12-07

14.7 ha	9 yr old
Shrub	Mitigation Bank

Figure C.12: NC12-07 site images

Figure C.13: NC12-09 site map

NC12-09

41.1 ha 8 yr old

Emergent Mitigation Bank

Figure C.14: NC12-09 site images

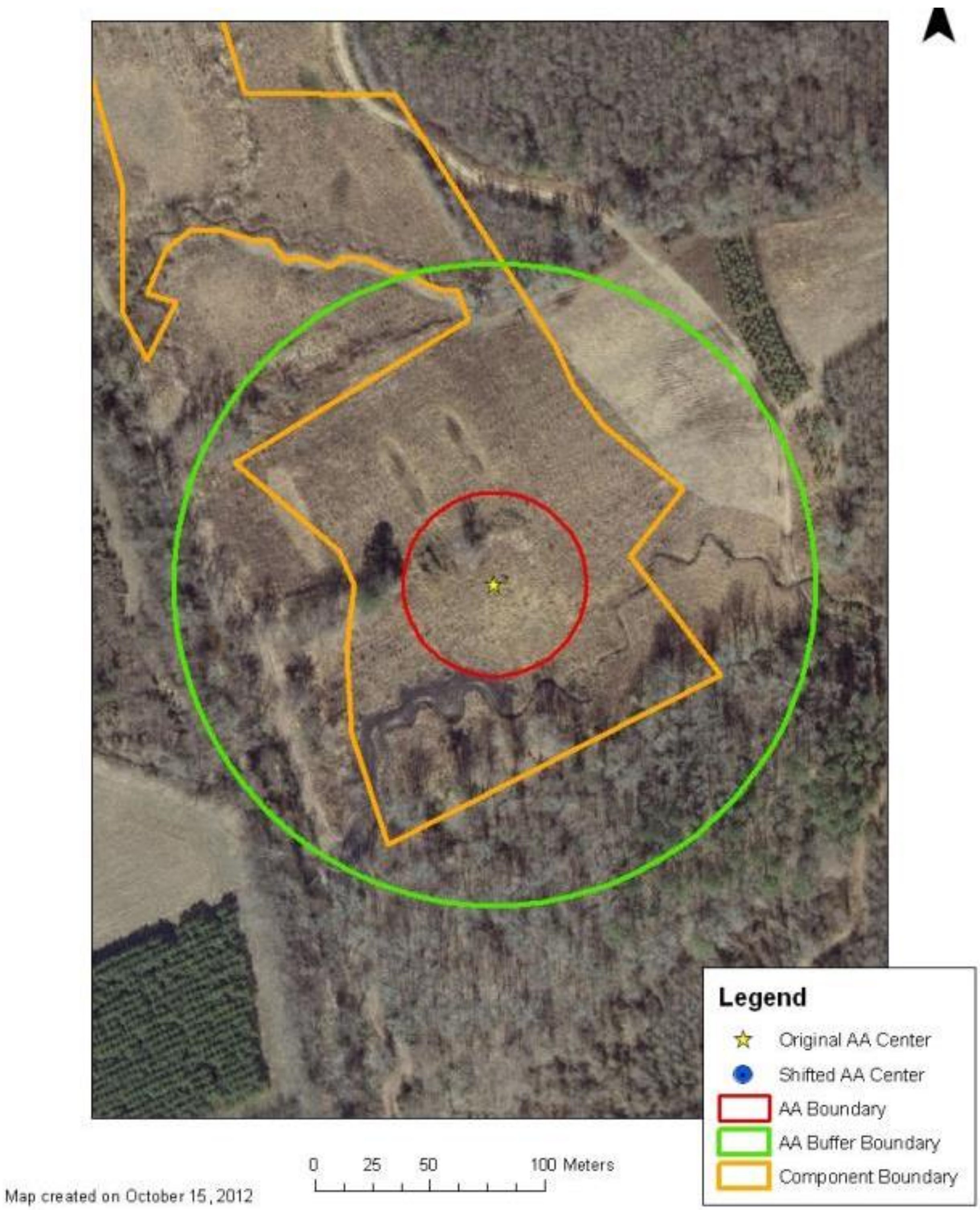

Figure C.15: NC12-10 site map

<u>NC12-10</u>

5.5 ha 8 yr old

Shrub Mitigation Bank

Figure C.16: NC12-10 site images

Figure C.17: NC12-12 site map

NC12-12

1.2 ha 9 yr old

Shrub Permittee-responsible

Figure C.18: NC12-12 site images

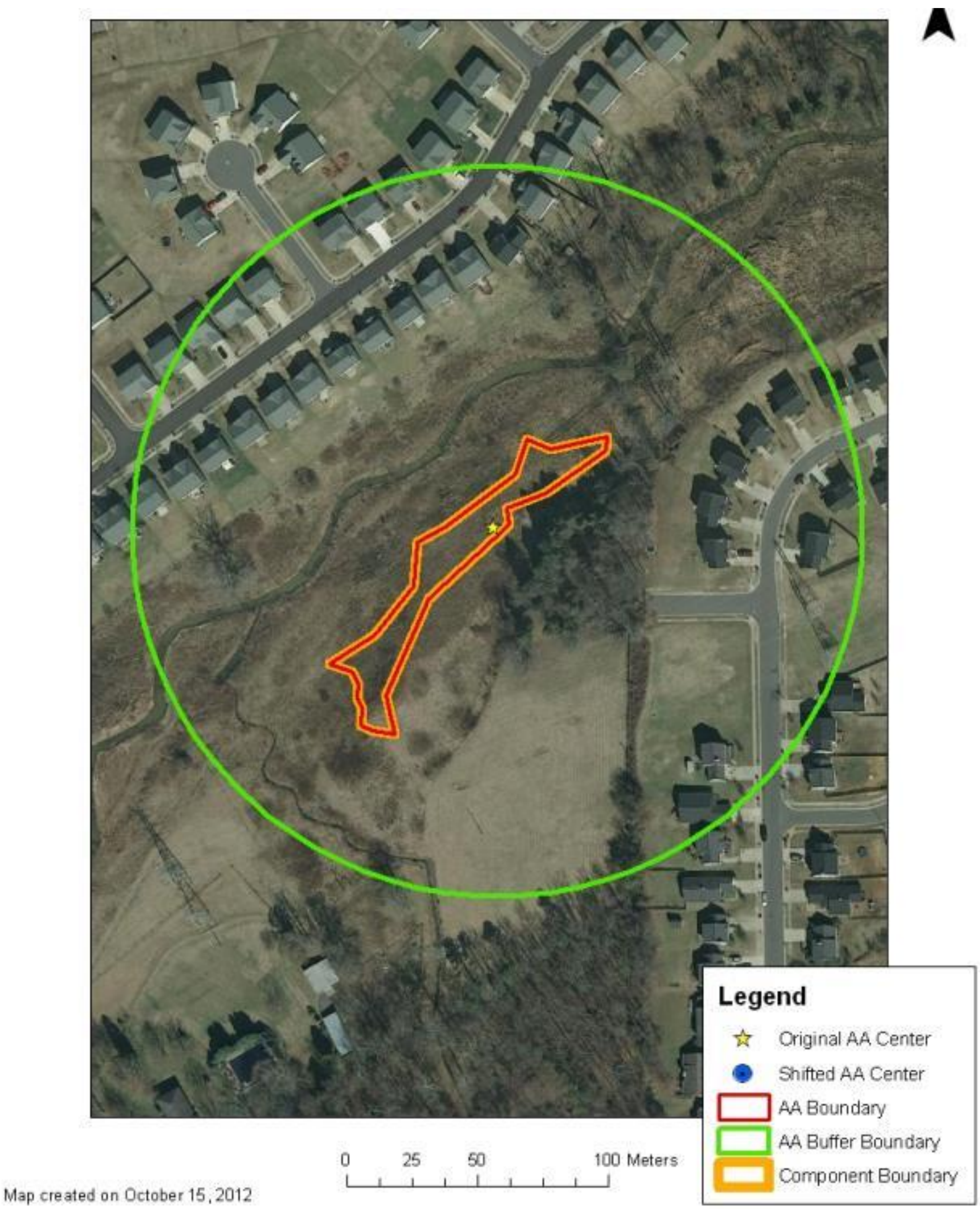

Figure C.19: NC12-17 site map

NC12-17

0.2 ha 8 yr old

Emergent Permittee-responsible

Figure C.20: NC12-17 site images

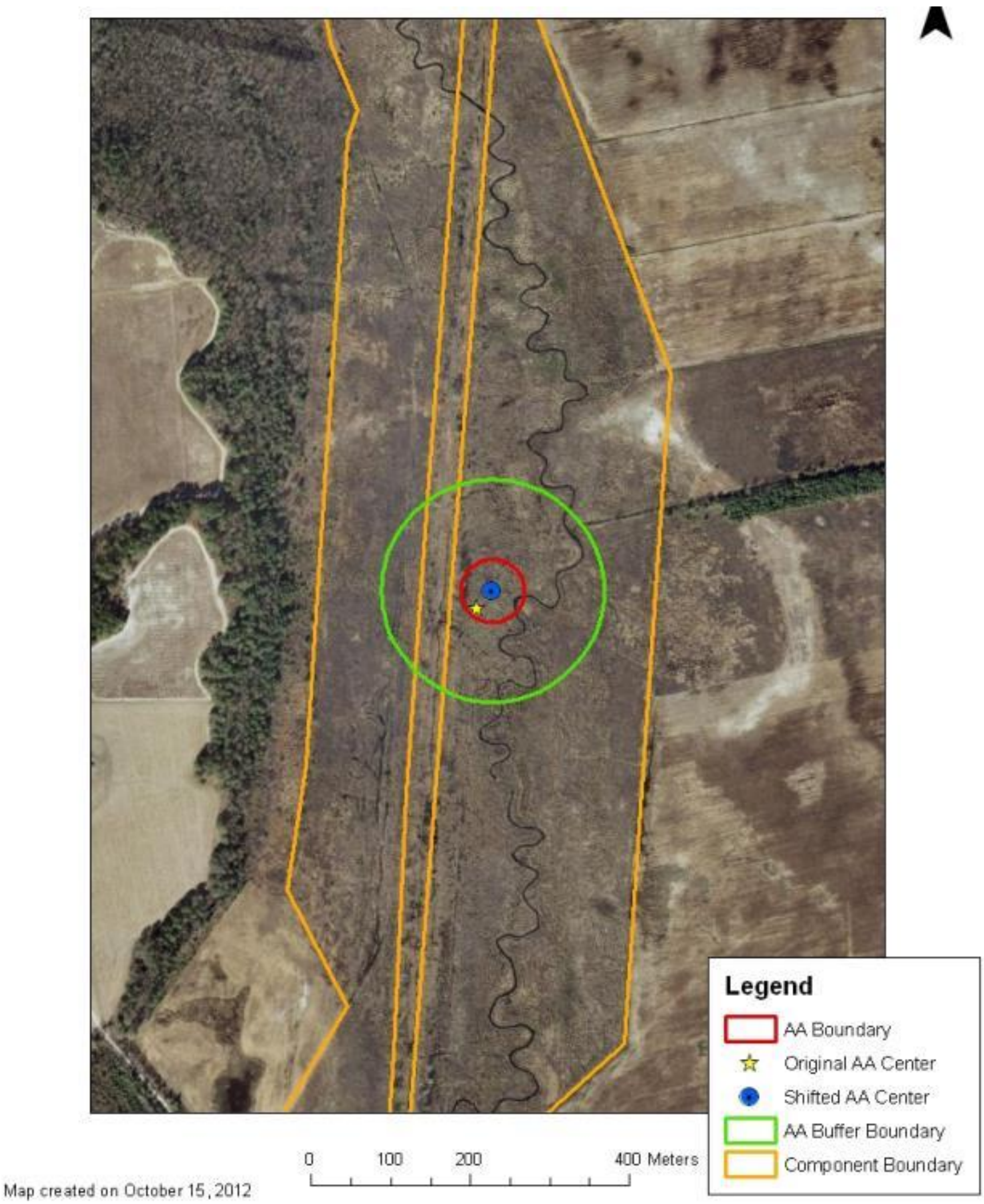

Figure C.21: NC12-18 site map

NC12-18

164.1 ha 8 yr old

Forest Permittee-responsible

Figure C.22: NC12-18 site images

Figure C.23: NC12-20 site map

NC12-20

0.2 ha	7 yr old
Emergent	Permittee-responsible

Figure C.24: NC12-20 site images

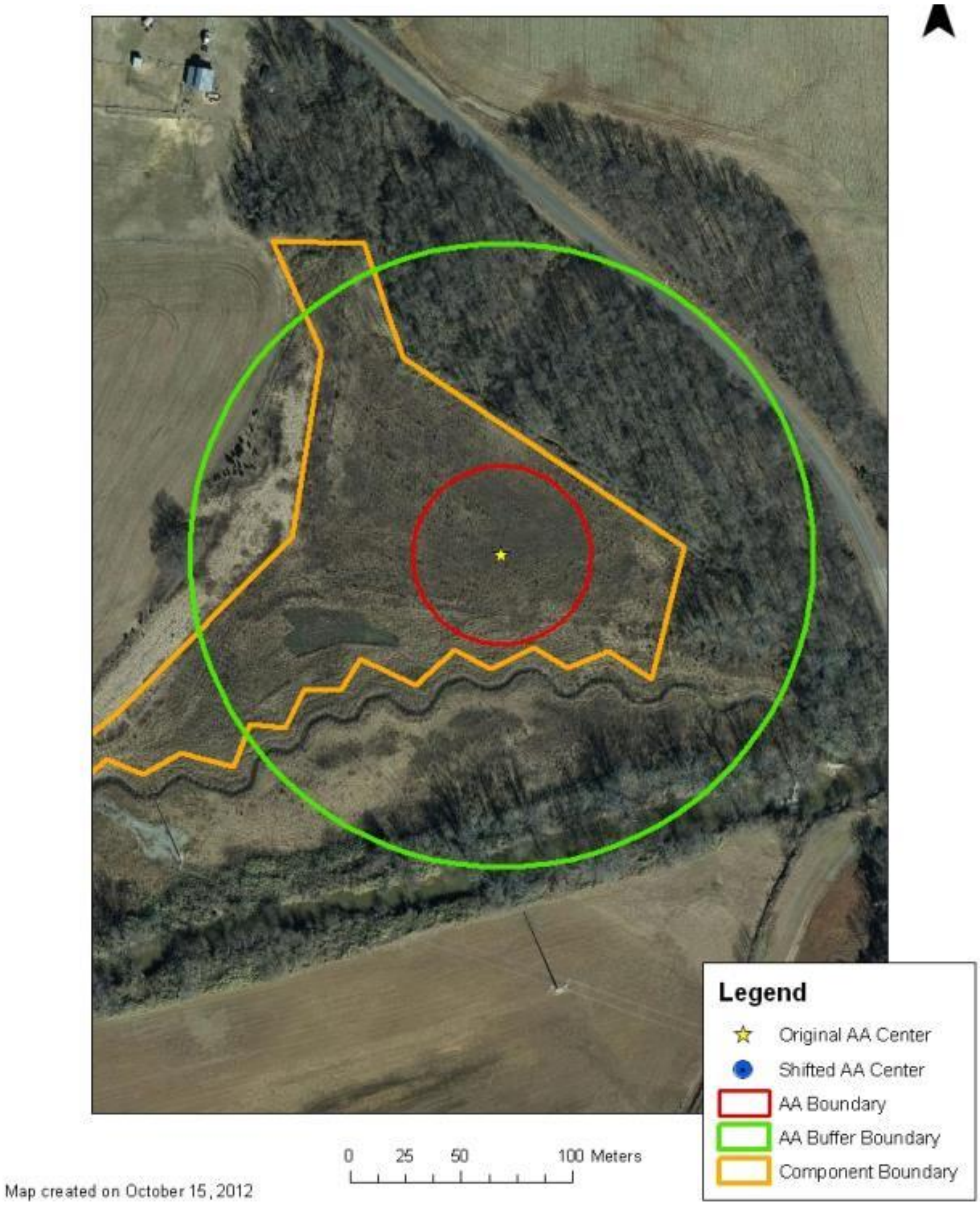

Figure C.25: NC12-21 site map

NC12-21

17.4 ha 9 yr old

Shrub Permittee-responsible

Figure C.26: NC12-21 site images

Figure C.27: NC12-22 site map

NC12-22

0.2 ha 7 yr old
Emergent Permittee-responsible

Figure C.28: NC12-22 site images

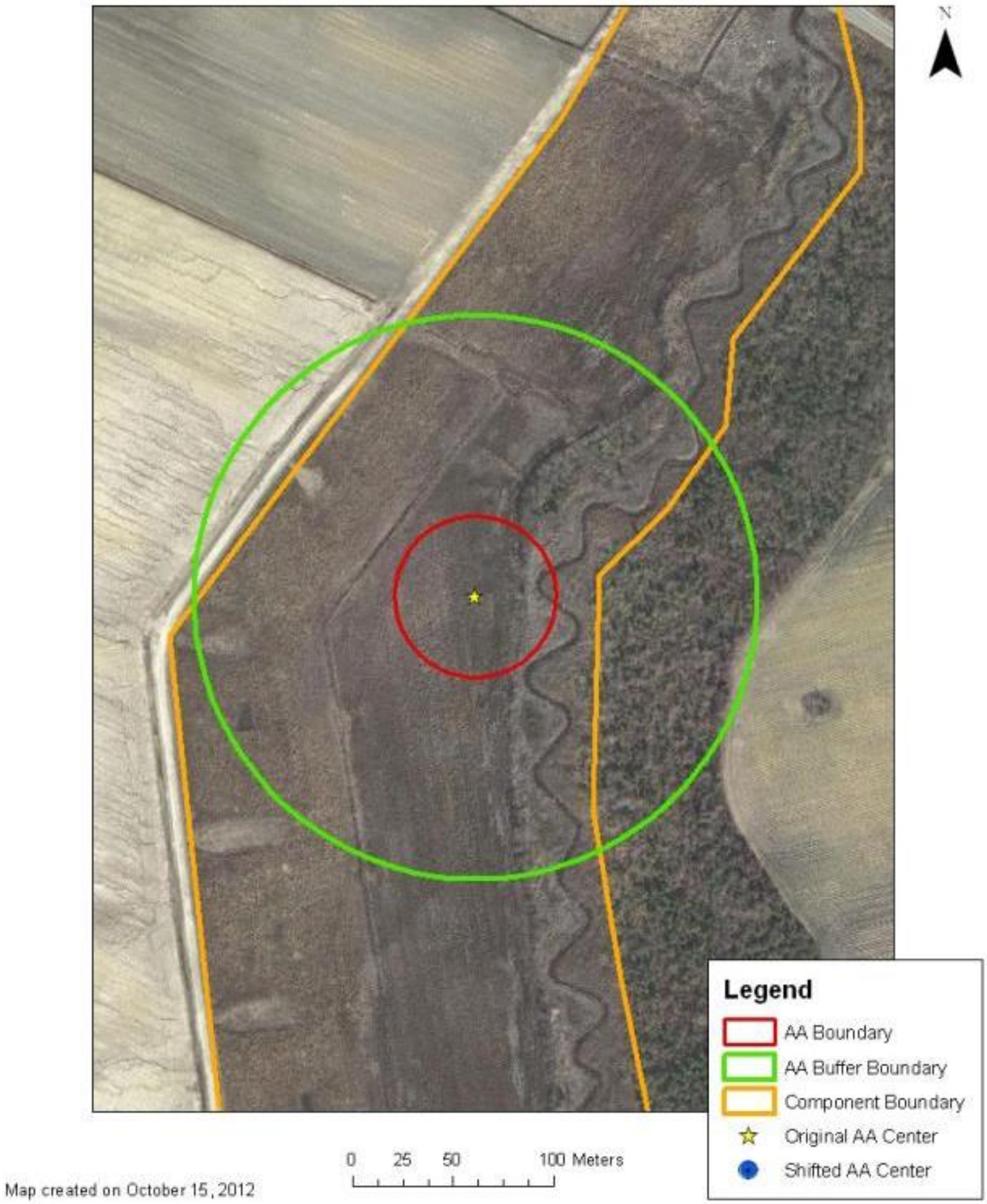

Figure C.29: NC12-25 site map

<u>NC12-25</u>

19.3 ha	5 yr old
Emergent	In-lieu Fee

Figure C.30: NC12-25 site images

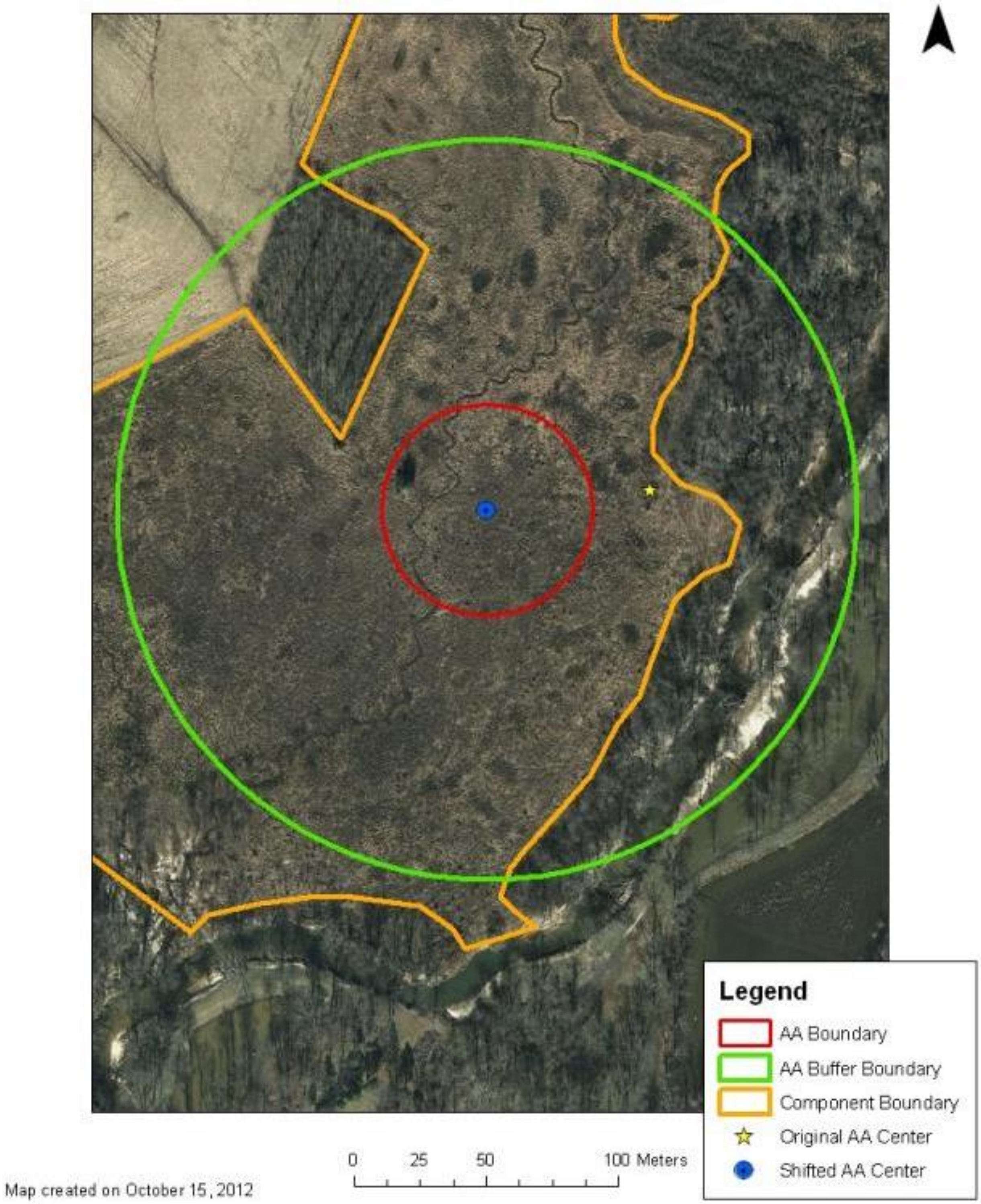

Figure C.31: NC12-26 site map

NC12-26

7.4 ha	9 yr old
Emergent	In-lieu Fee

Figure C.32: NC12-26 site images

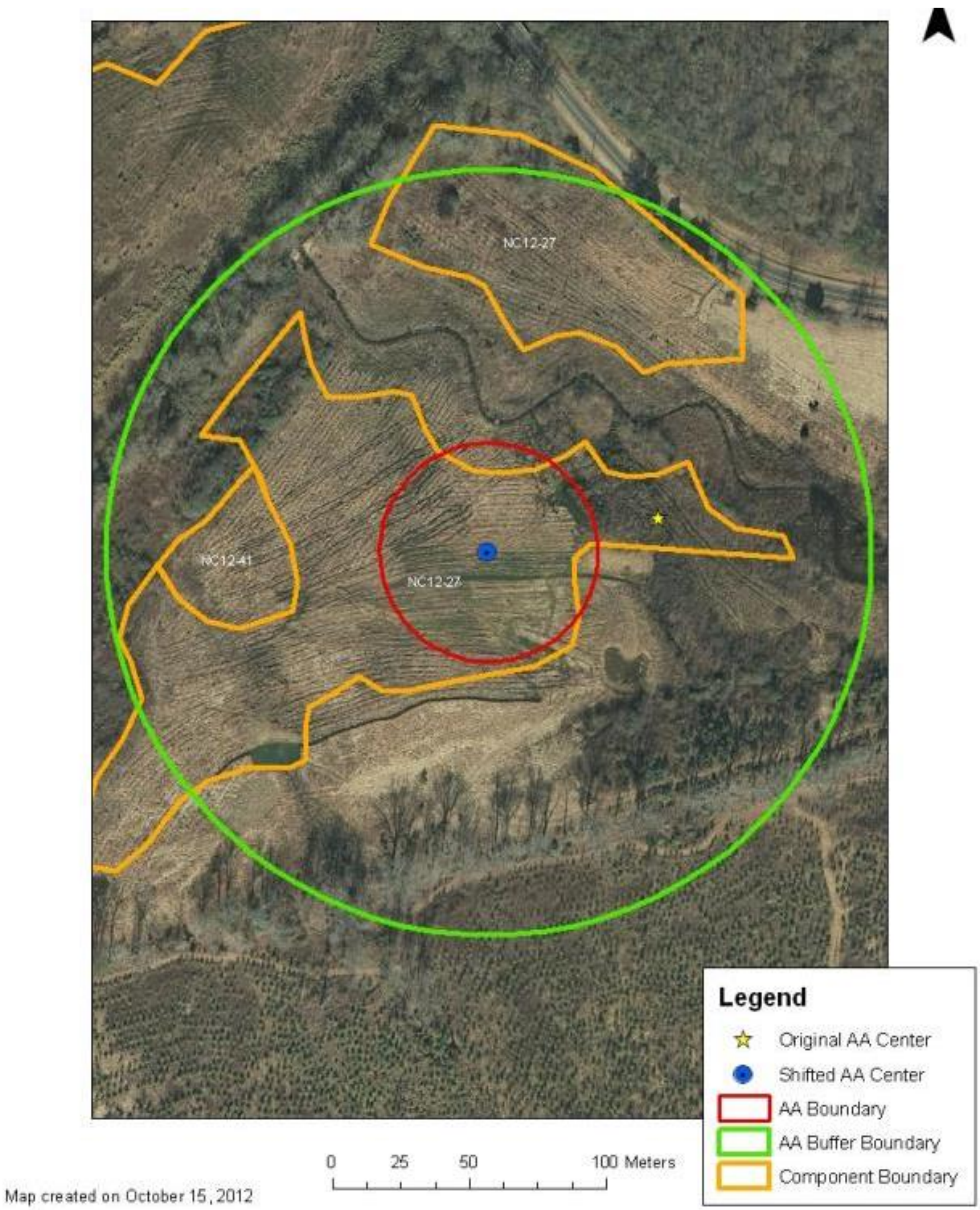

Figure C.33: NC12-27 site map

NC12-27

3.4 ha	8 yr old
Emergent	In-lieu Fee

Figure C.34: NC12-27 site images

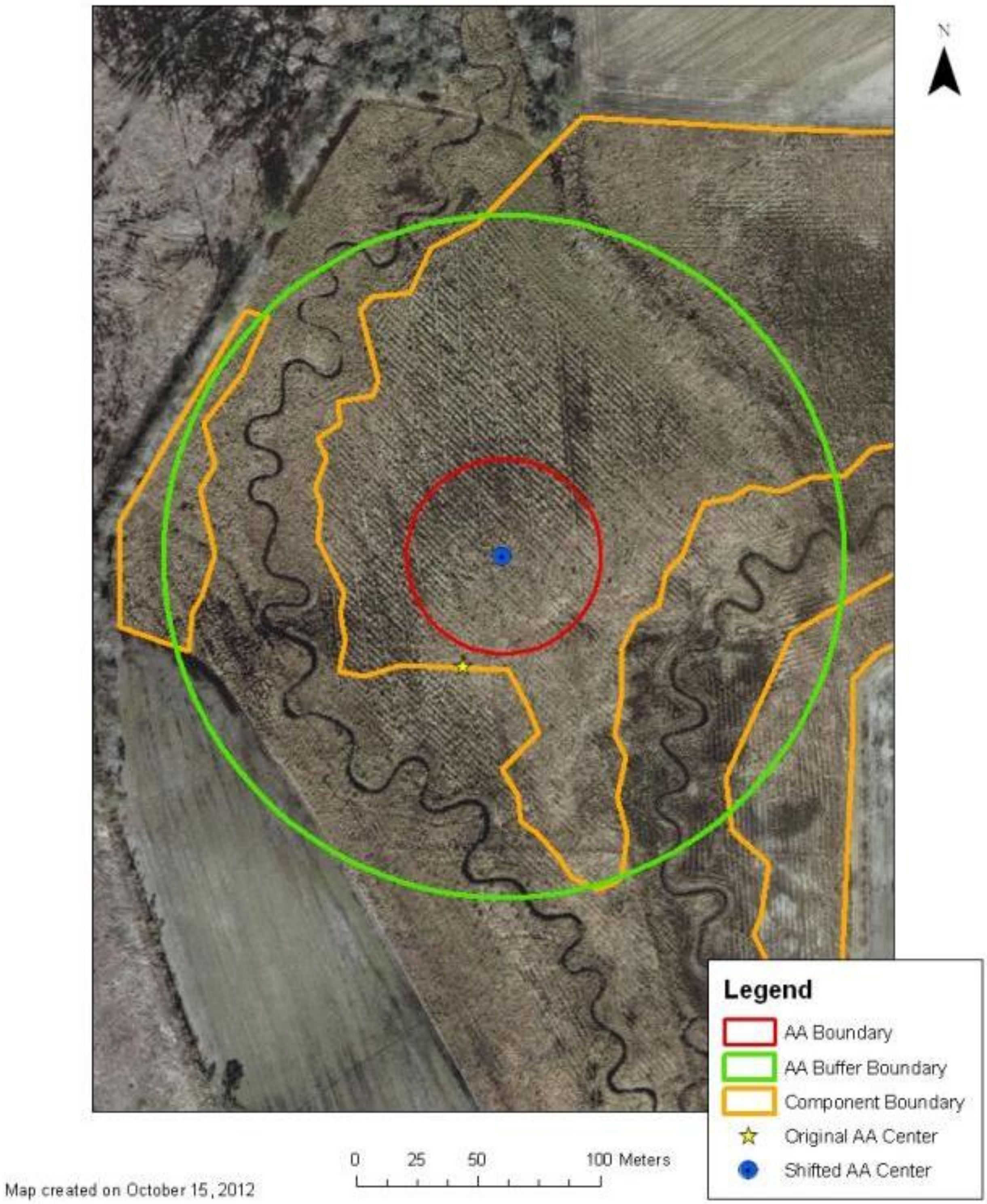

Figure C.35: NC12-28 site map

NC12-28

14.2 ha	8 yr old
Shrub	In-lieu Fee

Figure C.36: NC12-28 site images

Figure C.37: NC12-30 site map

NC12-30

7.7 ha	7 yr old
Emergent	In-lieu Fee

Figure C.38: NC12-30 site images

Figure C.39: NC12-33 site map

NC12-33

1.5 ha 7 yr old

Emergent In-lieu Fee

Figure C.40: NC12-33 site images

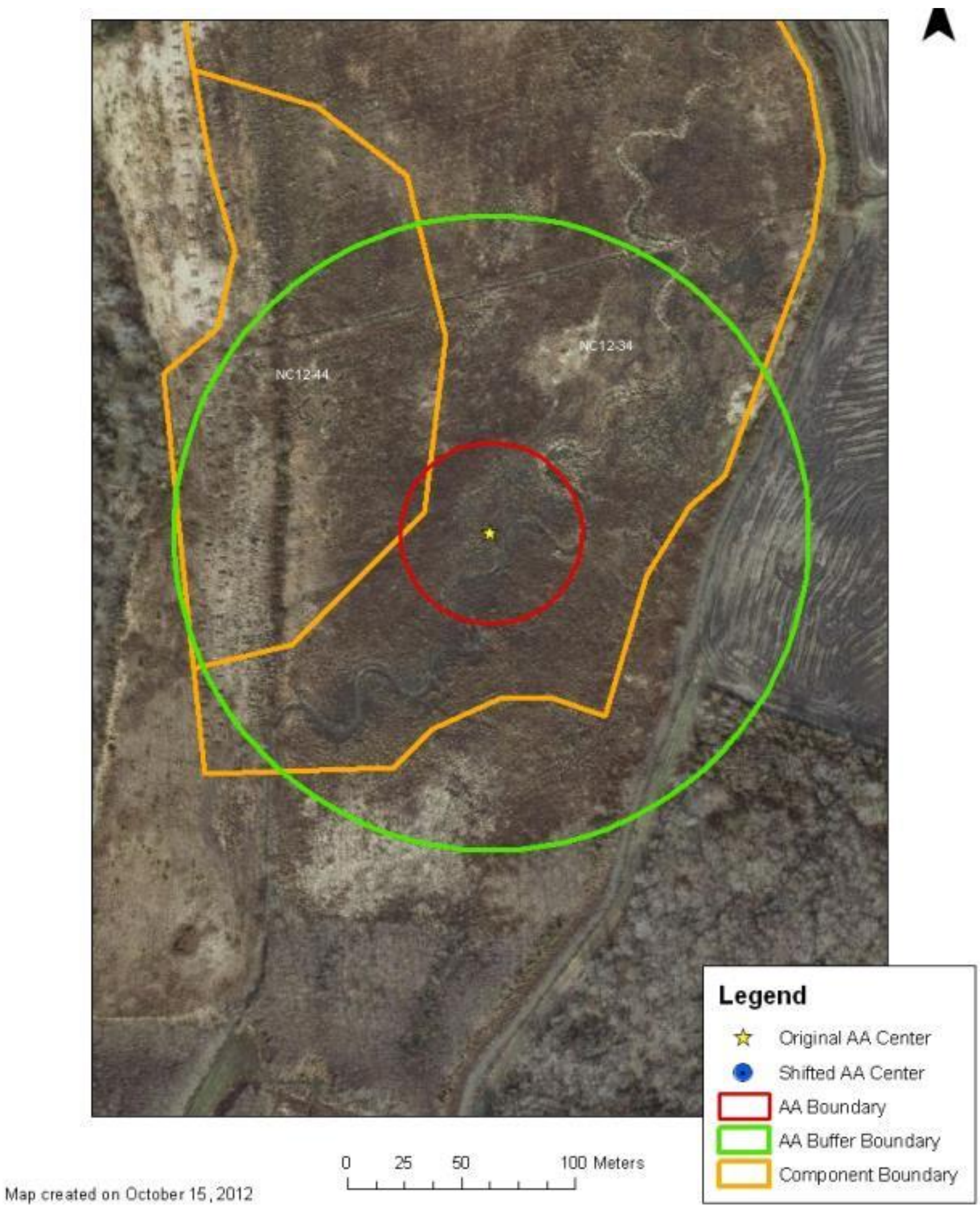

Figure C.41: NC12-34 site map

NC12-34

12.8 ha	8 yr old
Emergent	In-lieu Fee

Figure C.42: NC12-34 site images

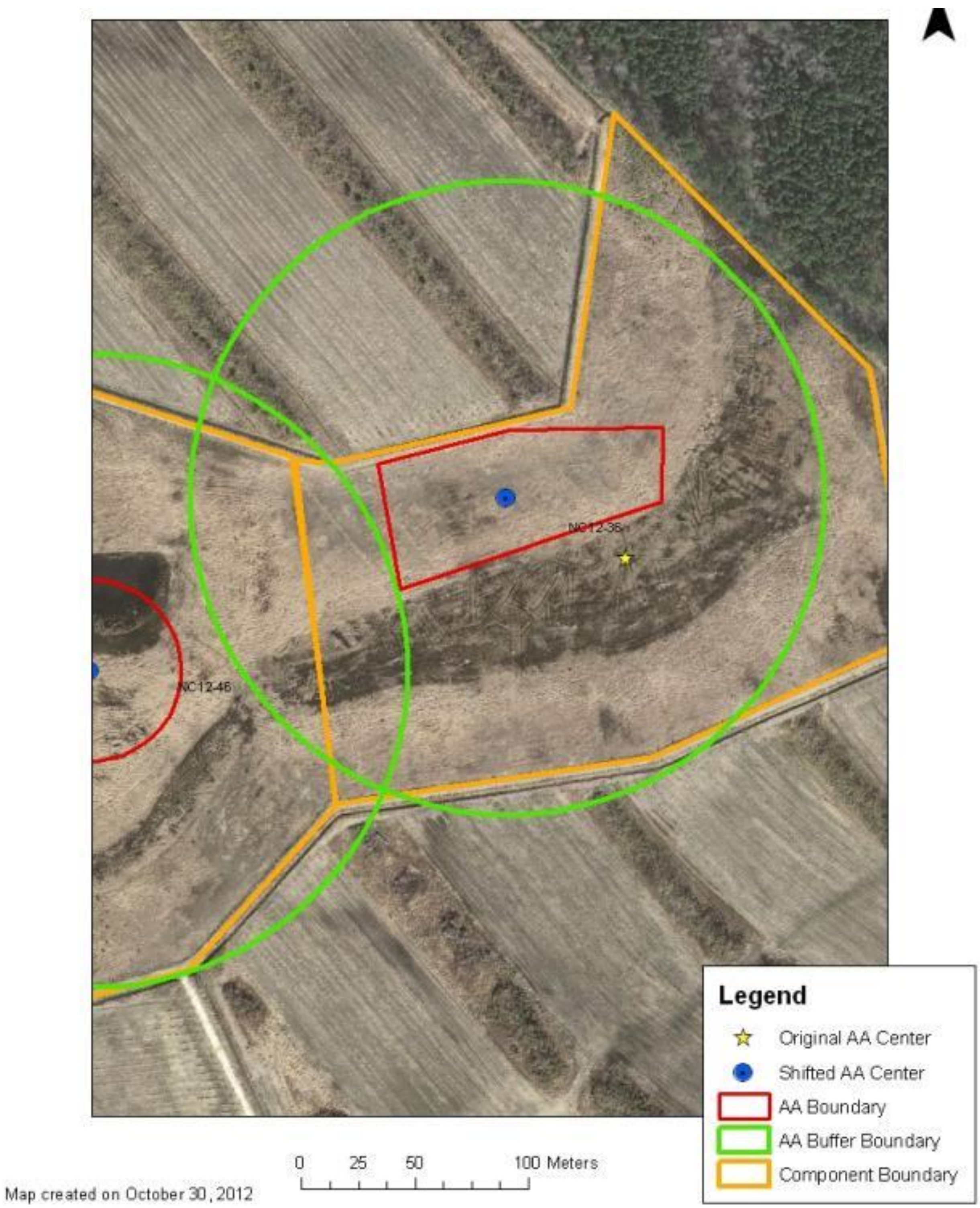

Figure C.43: NC12-36 site map

NC12-36

4.7 ha 6 yr old

Emergent In-lieu Fee

Figure C.44: NC12-36 site images

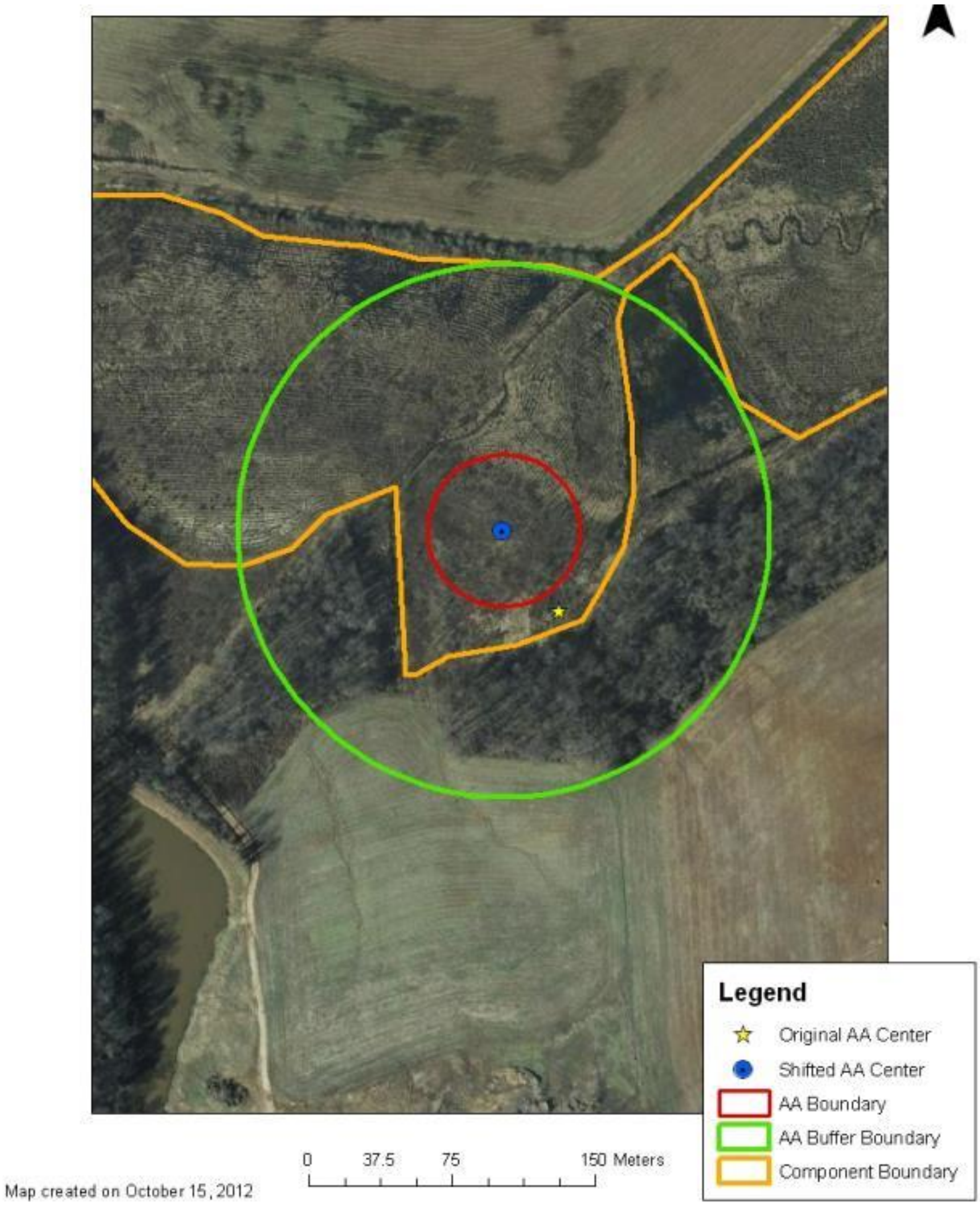

Figure C.45: NC12-37 site map

NC12-37

11.6 ha 9 yr old

Forest Mitigation Bank

Figure C.46: NC12-37 site images

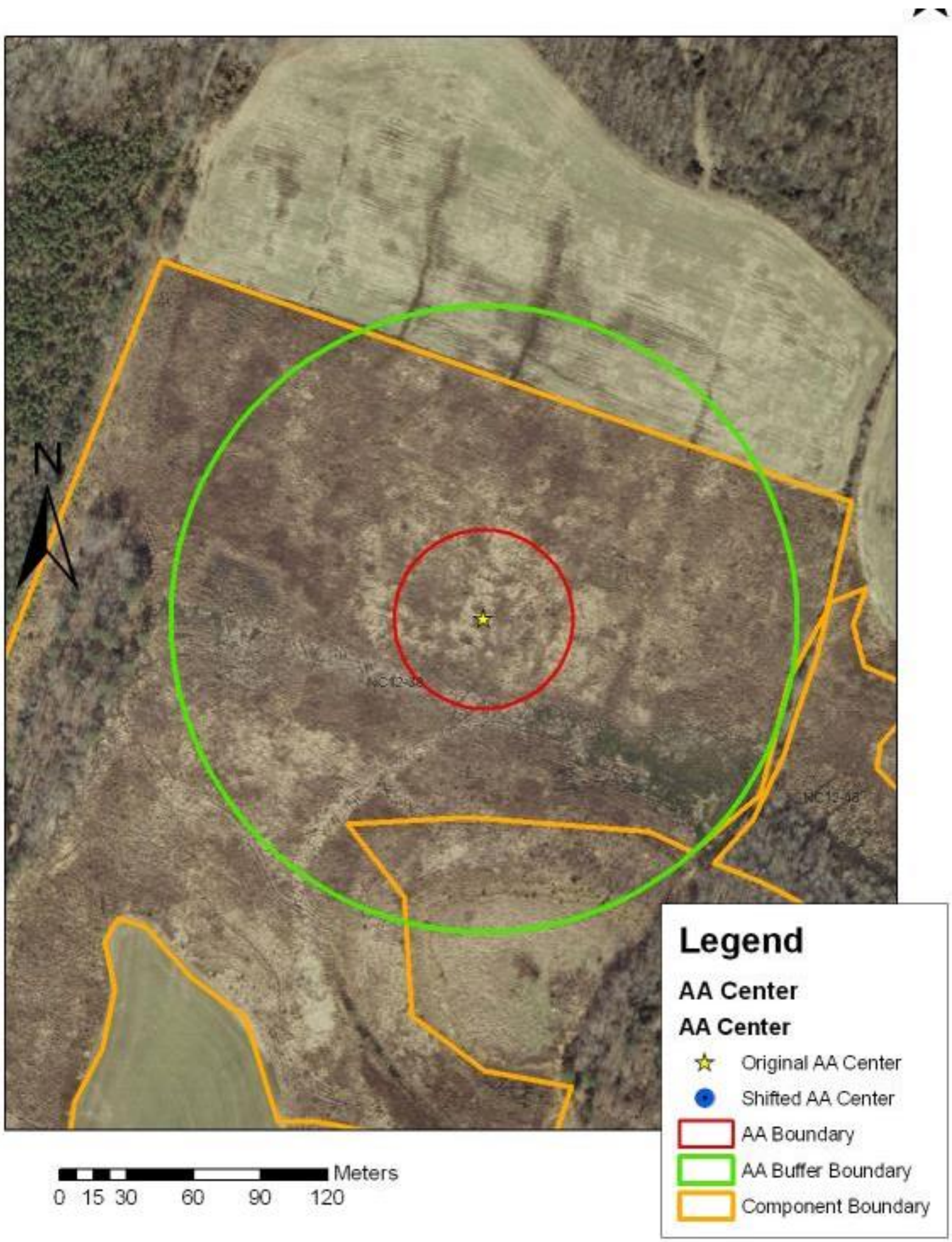

Figure C.47: NC12-38 site map

NC12-38

11.7 ha	9 yr old
Emergent	In-lieu Fee

Figure C.48: NC12-38 site images

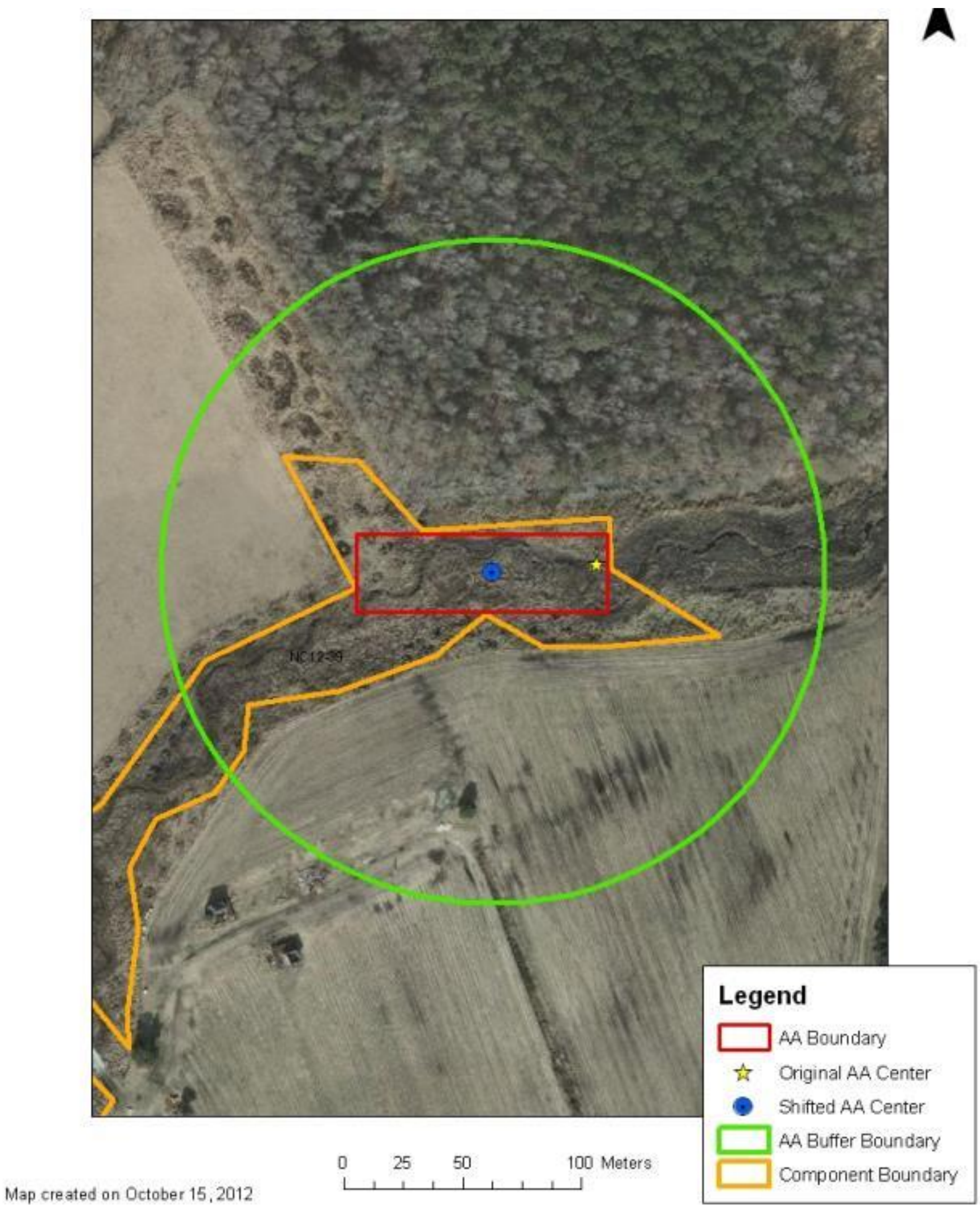

Figure C.49: NC12-39 site map

NC12-39

4.5 ha 6 yr old

Emergent In-lieu Fee

Figure C.50: NC12-39 site images

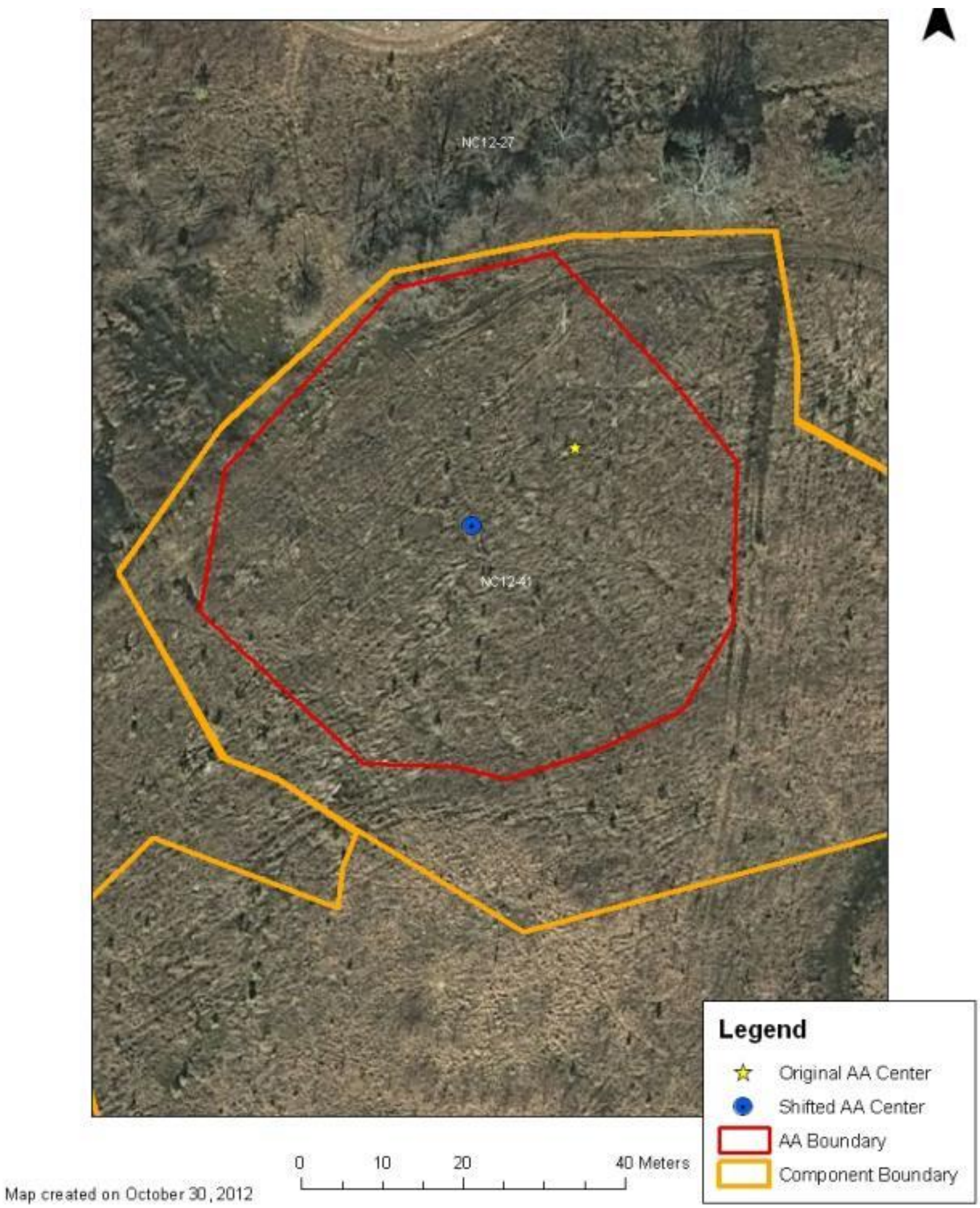

Figure C.51: NC12-41 site map

NC12-41

7.8 ha	8 yr old
Shrub	In-lieu Fee

Figure C.52: NC12-41 site images

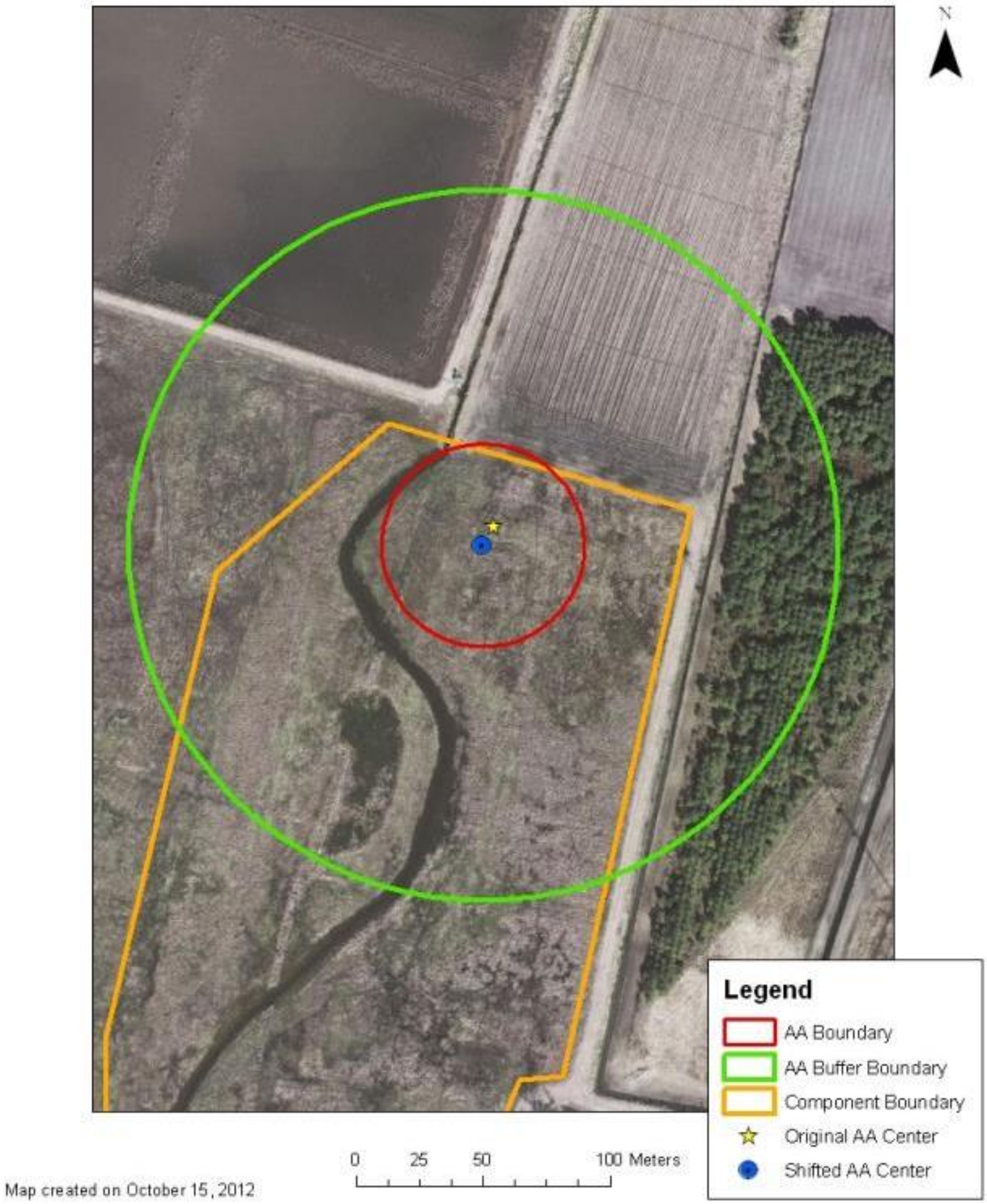

Figure C.53: NC12-42 site map

NC12-42

6.5 ha 6 yr old

Emergent In-lieu Fee

Figure C.54: NC12-42 site images

Figure C.55: NC12-43 site map

NC12-43

1.6 ha 11 yr old

Forest In-lieu Fee

Figure C.56: NC12-43 site images

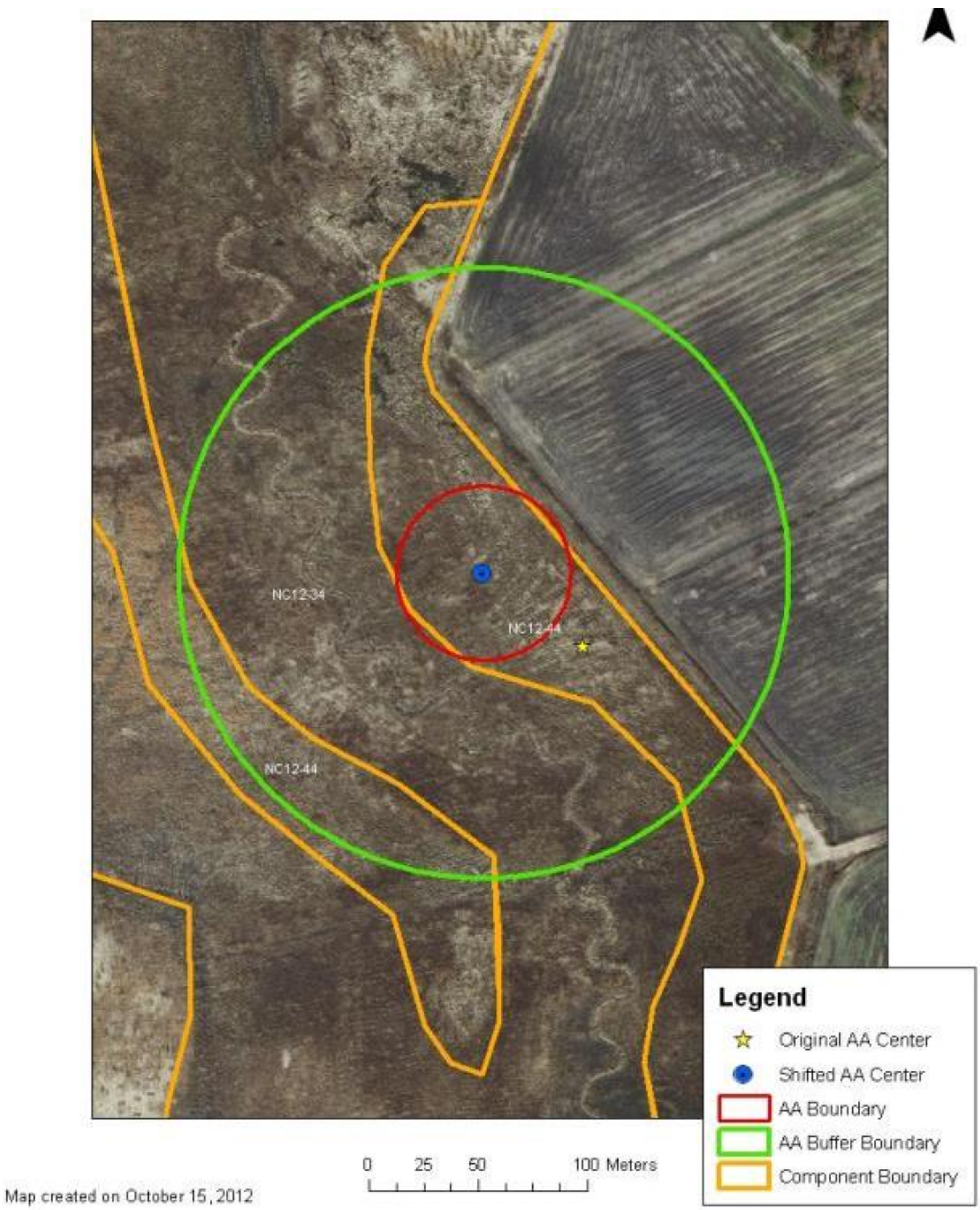

Figure C.57: NC12-44 site map

<u>NC12-44</u>

20.7 ha	8 yr old
Emergent	In-lieu Fee

Figure C.58: NC12-44 site images

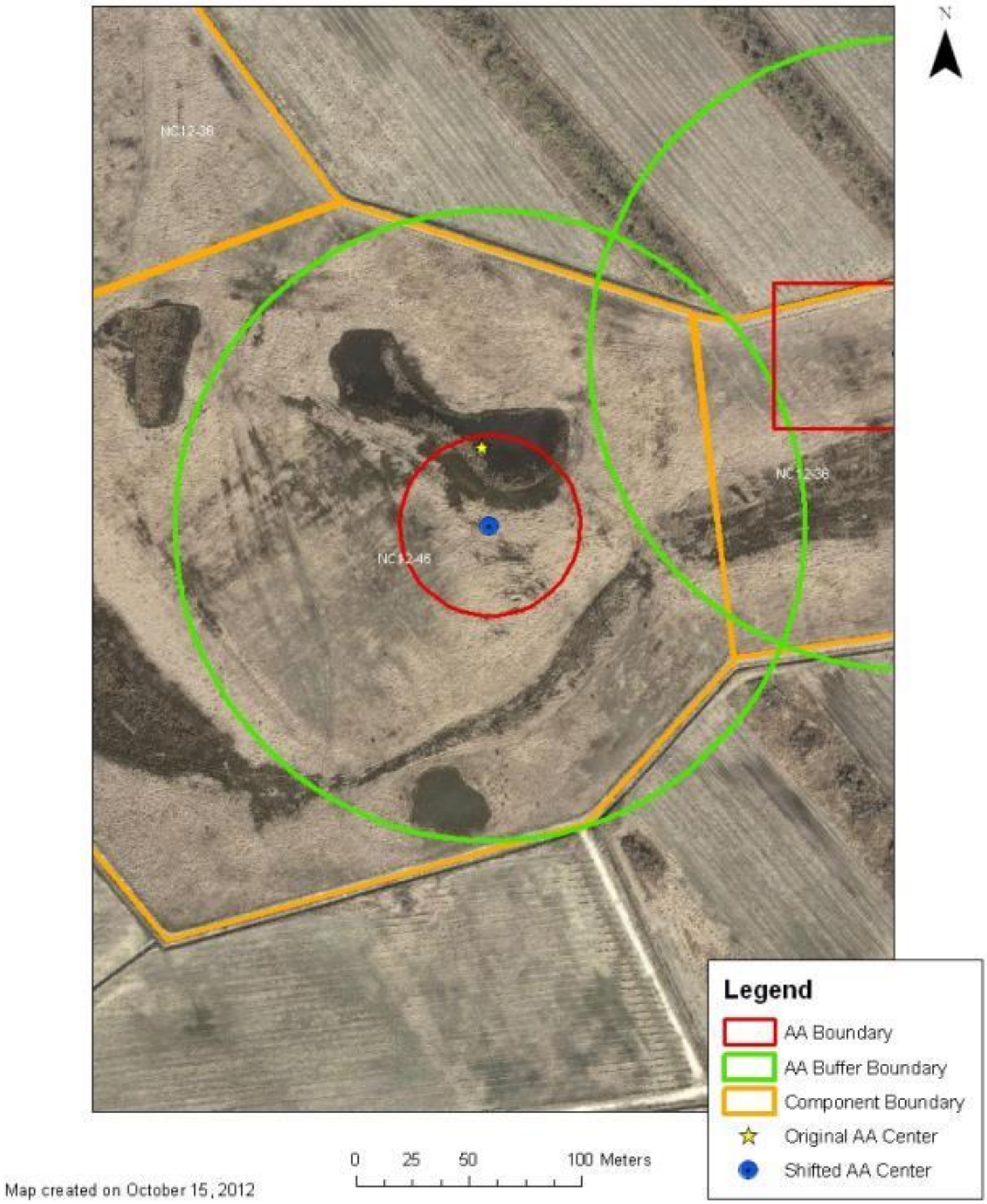

Figure C.59: NC12-46 site map

NC12-46

12.5 ha	6 yr old
Emergent	In-lieu Fee

Figure C.60: NC12-46 site images