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Evaluating Wetland Expansion In A Tallgrass Prairie-Wetland Restoration

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EVALUATING WETLAND EXPANSION
IN A TALLGRASS PRAIRIE-WETLAND RESTORATION

by

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This thesis, submitted by Katie Engelmann in partial fulfillment of the requirements for the Degree of Master of Science in Geography from the University of North Dakota, has been read by the Faculty Advisory Committee under whom the work has been done and is hereby approved.

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Katie Mae Engelmann

May 1, 2017

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ABSTRACT

Remote sensing is an effective tool to inventory and monitor wetlands at large spatial scales. This study examined the effect of wetland restoration practices at Glacial Ridge National Wildlife Refuge (GRNWR) in northwest Minnesota on the distribution, location, size and temporal changes of wetlands. A Geographic Object-Based Image Analysis (GEOBIA) land cover classification method was applied that integrated spectral data, LiDAR elevation, and LiDAR derived ancillary data of slope, aspect, and TWI. Accuracy of remote wetland mapping was compared with onsite wetland delineation.

The GEOBIA method produced land cover classifications with high overall accuracy (88 – 91 percent). Wetland area from a June 12, 2007 classified image was 20.09 km^2 out of a total area of 147.3 km^2. Classification of a July 22, 2014 image, showed wetlands covering an area of 37.96 km^2. The results illustrate how wetland areas have changed spatially and temporally within the study landscape. These changes in hydrologic conditions encourage additional wetland development and expansion as plant communities colonize rewetted areas, and soil conditions develop characteristics typical of hydric soils.

CHAPTER I

INTRODUCTION

In the Prairie Pothole Region (PPR) of the northern Great Plains, agriculture is the dominant economic and social driver of land use and land use change. Since European settlement of the region began, wetlands have been drained, often with the encouragement and aid of local, state, and federal government agencies (van der Valk 1989). It is estimated that more than half of the original 8 million hectares of wetlands in the PPR have been lost, with rates exceeding 90 percent in the eastern portion of the region (Dahl 1990, 2006; Tiner 2003).

Change to U.S. federal environmental policy under President G. H. W. Bush in the late 1980's led to a national goal of "no net loss" of wetland area. Under this policy, unavoidable wetland losses must be offset by restoration or creation, thus, the science and practice of wetland restoration gained momentum (Mitsch and Gosselink 2007). Wetland creation and restoration are significant conservation practices in hydrologically altered and ecologically degraded landscapes. Although only a fragment of drained basins have been restored, wetland restoration in the PPR is an important component of the endangered tallgrass prairie ecosystem.

In the eastern portion of the PPR more than 99 percent of tallgrass prairie has been converted to other land uses, mostly row crop agriculture (Samson, Knopf, and Ostlie

1998). Temperate grasslands are among the most altered and least protected of the world's terrestrial biomes, making their protection a global conservation priority (Hoekstra et al. 2005). Recent reports continue to detect grassland and wetland conversion, and increasing habitat fragmentation as a result of changing trends in agriculture (Wright and Wimberly 2013; Roch and Jaeger 2014).

Loss of biodiversity, reduced ecological function and declining ecosystem services necessitate continued conservation planning and strategic management of existing habitat. Scientists and land managers are responding to these needs by directing focus on entire ecosystem preservation, targeted restoration, and adaptive management (Rowe 2010; Zedler, Dohery, and Miller 2012). These approaches are rooted in the biodiversity and ecosystem functioning hypothesis, that a large proportion of species diversity is necessary to maximize ecosystem productivity, stability, invasibility, and nutrient dynamics (Tilman, Isbell, and Cowles 2014), and that ecosystems should be preserved at the scale at which collective evolutionary processes that drive ecological diversity are sustained (Grumbine 1994;Hoekstra et al. 2005).

The driving force of wetland ecosystem restoration is an understanding of hydrologic processes, the goal being to return a wetland to its original or previous condition (Mitsch and Gosselink 2007). Attributes of restored ecosystems develop at different temporal scales. While hydrology is returned quickly, vegetation may take several years to establish, and soils require decades (Zedler 2000). The success of restoration is often measured by the degree to which wetland function has been replaced (Mitsch and Gosselink 2007). Three broad requirements have been proposed for achieving successful restoration: understanding wetland function, designing structures that are ecologically sustainable in the long-term, and giving the system time (Mitsch and Wilson 1996). Mitsch and Wilson (1996) also suggest ecosystem-level research after the system has had time to reach a steady-state or equilibrium as a more appropriate measure of success and guide for future restoration science than what is currently required to achieve regulatory satisfaction. Restorative programs typically require once or twice per year monitoring shortly after restoration completion.

Following restoration, land managers have the task of land use planning and ecosystem management. Ecosystem monitoring is a long-term obligation in which land managers commit to a process of assessment and response. It is important to note that restoration sites are novel ecosystems that often contain decreased species richness and invasive or exotic species (Zedler, Dohery, and Miller 2012). To document ecological character or functional condition, a combination of attributes or indicators are established and monitored to characterize landscapes at any given point of time or detect changes over longer periods of time. Furthermore, to achieve optimum conservation management, ecological character and functional condition should be spatially projected at multiple scales across mixed land ownership (Jensen et al. 2000).

The physical characteristics and spatial scale of wetlands can make quantitative analysis difficult. Remote sensing is an effective tool to inventory and monitor wetlands at large spatial scales (Mitsch and Gosselink 2007). Conservationists have traditionally used remote sensing to characterize and map habitat, however trends in remote sensing capabilities have expanded to incorporate ecosystem functioning variables such as energy balance, primary productivity, and hydrological characteristics (Cabello et al. 2012).

Study Objective

Glacial Ridge National Wildlife Refuge (GRNWR) is located in the eastern portion of the PPR within the Northern Tallgrass Prairie/Aspen Parklands physiographic area (USFWS 2016). The refuge contains important fragments of remnant prairie and savanna, along with restored grassland and wetland ecosystems. Unique prairie-wetland complexes at GRNWR are habitat to resident wildlife, migratory wildlife, and other wetland and grassland obligate species including populations of greater prairie chicken (*Tympanuchus cupido*) and western prairie fringed orchid (*Platanthera praeclara*). The orchid is declared federally threatened with extinction and regulated under the Endangered Species Act (USFWS 2016). The site is presently the largest temperate-tallgrass prairie-wetland restoration in the nation (Gerla et al. 2012). Initial goals to restore hydrology and vegetation to the site have been reached, however localized effects of restoration measures and baseline habitat conditions remain in question (USFWS 2016).

The U.S. Fish and Wildlife Service (USFWS) Comprehensive Conservation Plan (CCP) for the newly restored and established GRNWR identifies the collection of baseline biotic and abiotic information necessary to aid long-term refuge planning and management. The CCP also strives to complete a hydro-geomorphic analysis to evaluate wetland ecosystems in all refuge management units (USFWS 2016). By closing drainage ditches and applying wetland design principles, groundwater and surface water levels at GRNWR have changed, resulting in more water retained on the land (Cowdery, Lorenz, and Arntson 2008). These changes in hydrologic conditions affect the physical, chemical, and biological processes of the area. Anaerobic conditions encourage additional wetland development and expansion as plant communities colonize rewetted areas, and soil conditions develop characteristics typical of hydric soils.

This study aimed to analyze the relationship of hydrologic processes of restored prairie-wetlands on the adjacent land surface using remote sensing and Geographic Information Systems (GIS). The project examined the reconstruction of wetlands within GRNWR at two distinct periods of development. A better understanding of the spatial distribution of restored wetlands and wetland expansion will be valuable for adaptive management and future ecological research. The specific objectives of this research were to:

1. Evaluate the effect of engineered wetlands and waterways on the distribution, location, size and temporal changes of wetlands within the Glacial Ridge National Wildlife Refuge using high-resolution, multispectral imagery, and ancillary data;
2. Determine the accuracy of remote wetland mapping with onsite wetland delineation;
3. Document baseline characteristics of vegetation, soils and hydrology of selected wetlands as a way to assess the biotic and abiotic conditions of these wetlands.

Study Area

The research area (147.3 km^2) comprised land within the acquisition boundary of the GRNWR, located in Polk County, MN (Figure 1). Some of the land within the boundary is owned and managed by private individuals or conservation partners, including the Minnesota Department of Natural Resources (MN DNR) and TNC. The land cover of the study area consists of mostly level to gently rolling remnant and restored tallgrass prairie interspersed with wetlands.

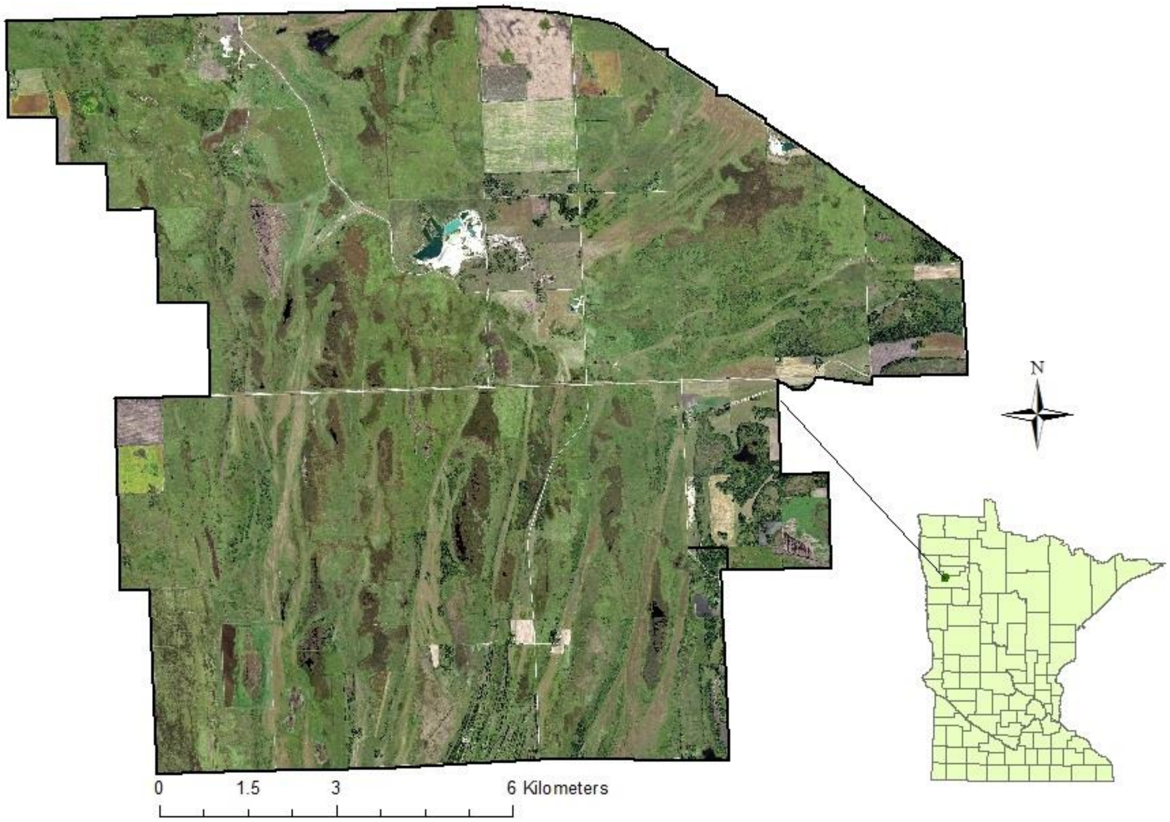


Figure 1. Study area (147.3 km^2), GRNWR located in Polk County in northeastern Minnesota. Image source: 2015 National Agriculture Imagery Program (NAIP).

The climate of the study area is sub-humid continental and characterized by extreme variations in temperature and precipitation. Long-term climate trends reveal multi-year droughts often followed by wet periods. Air masses typically flow from west to east. Climate data from 2000 through 2014 indicate the extreme annual precipitation totals during the years 2000-2014 were 66.04 cm (26.00 in.) in 2010 and 33.86 cm (13.33 in.) in 2011. The average January temperature is -15.5 degrees C (4.1 degrees F) and the average July temperature is 21.39 degrees C (70.5 degrees F). The majority of precipitation falls during the growing season months of May through September (High Plains Regional Climate Center 2017).

Monthly precipitation data for 2007 and 2014, the image years analyzed in the study, are shown in Figure 2. Data were obtained from a gridded database whose values were calculated using data interpolated from Minnesota's precipitation database (Minnesota Climatology Working Group 2017). A two-sample difference of means (t-test) compared monthly precipitation data for significant difference. Among monthly precipitation data from the study area (N=12), there was no statistically significant difference between 2007 (M=5.09, SD=4.05) and 2014 (M=4.36, SD=4.67), t (11)= 1.11, $p = 0.29 \geq 0.05$, CI_{95}.

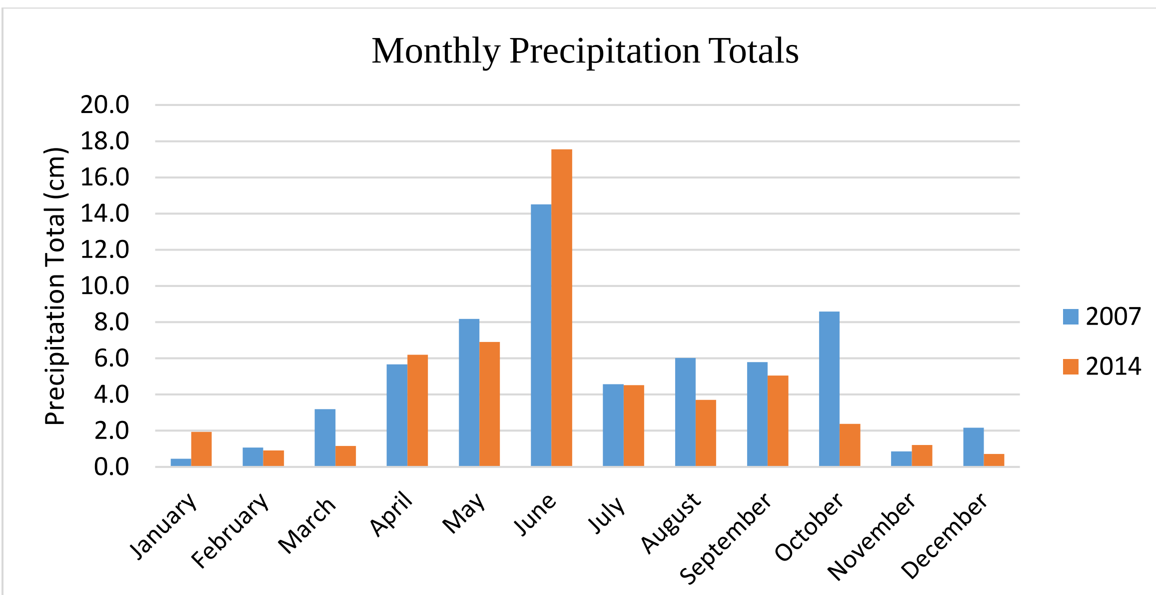
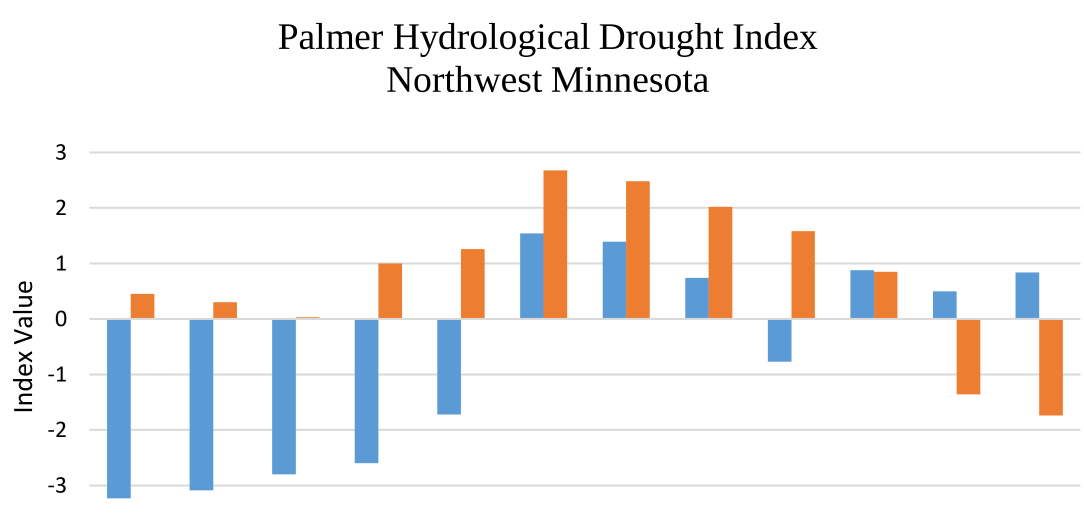


Figure 2. Comparison of monthly precipitation totals from 2007 and 2014. Precipitation data set obtained from gridded database at 47.70297 degrees latitude, 96.28060 degrees longitude.

The Palmer Hydrological Drought Index (PHDI) for northwest Minnesota shows long-term hydrological drought and wet conditions that affect groundwater conditions and surface water levels (Figure 3). The PHDI values typically range from -6 to +6, low values denote dry conditions while the higher values indicate wet conditions (NOAA National Centers for Environmental Information, Climate at a Glance: U.S. Time Series, Palmer Hydrological Drought Index (PHDI) 2017). In both 2007 and 2014, drought index values denote dryer conditions leading into the growing season, and wetter conditions throughout the growing season.



	Jan	Feb	March	April	May	June	July	Aug	Sept	Oct	Nov	Dec
2007	-3.23	-3.09	-2.8	-2.6	-1.72	1.54	1.39	0.74	-0.77	0.88	0.5	0.84
2014	0.45	0.3	0.03	1	1.26	2.68	2.48	2.02	1.58	0.85	-1.36	-1.74

Figure 3. Palmer Hydrological Drought Index values (2007 and 2014) for northwest MN.

CHAPTER II

LITERATURE REVIEW

Ecosystem Management

Management of landscapes requires a systemic understanding of action and response through an experiment-based approach known as adaptive management. The USFWS adaptive management strategy uses data from inventories of plant communities to design and implement optimal management actions (Grant et al. 2009). The belt transect method is used by the agency to assess the general composition of tallgrass prairie vegetation managed by the USFWS (Grant et al. 2004; Grant et al. 2009). The method reliably conveys the status and trends of certain plant species and groups of management interest, can be applied quickly and effectively, and provides basic information to support development and application of models that describe wildlife habitat relationships (Grant et al. 2004).

Landscape indicators of ecosystem condition are measures of the current state relative to reference conditions or predetermined limits of acceptable change. A combination of attributes or indicators are established and monitored to document ecological character at any given point of time or to detect changes over longer periods of time (Horwitz and Finlayson 2011). Ecological classifications of vegetation patterns are important to ecosystem assessments because they provide a summary of resource information when combined with associated plot-level attribute information. Field data collected at the plot level through random sampling protocols can be spatially projected at larger mapping scales (Jensen et al. 2000).

Wetland Identification

Wetlands are spatially diverse and temporally dynamic, thus, there are no universally applicable methods for their identification and classification. Selection of data sources and methodology are often determined based on available information, type of wetland, and desired level of detail. There are several methods to classify and delineate wetlands. Onsite wetland delineation is the most precise method, in which a trained wetland delineator identifies the boundary between upland and wetland based on indicators of hydrophytic vegetation, hydric soil, and hydrology (USACE 1987). This method produces accurate results but is often the most expensive, being both time and labor intensive. Onsite wetland delineation is often required for impacts to wetlands regulated under federal, state or local environmental policies. For unregulated activities, such as wetland ecosystem management or monitoring, onsite wetland delineation methods are not the most cost-effective or efficient.

Remote sensing of wetlands has the advantage of repeat coverage at large spatial scales and integrates easily with other geospatial technology (Ozesmi and Bauer 2002). There are several methods to delineate and monitor wetlands using aerial photography or satellite data. Traditional image classification methods are based on spectral reflectance values of surfaces captured as individual pixels, therefore referred to as pixel-based methods (Ozesmi and Bauer 2002). The unsupervised classification or clustering method groups together similar pixels within multispectral data and requires the analyst to discern the informational classes that result (Campbell and Wynne 2011). Unsupervised classification has historically been the most commonly applied remote wetland classification method; however, the technique often requires a large number of clusters and subsequent separation of mixed clusters to achieve success (Ozesmi and Bauer 2002).

Supervised classification is another method where samples of known pixel identity are used to classify pixels of unknown identity based on user defined training data (Cambell and Wynne 2011). Supervised classification methods commonly used to map wetlands are minimum distance to means, parallelpiped, and maximum likelihood classification (Ozesmi and Bauer 2002). These methods are limited by the spatial resolution of sensors used to collect the data. Coarse spatial data can omit small wetlands or result in mixed pixels that can reduce classification accuracy (Mui, He, and Weng 2015).

High Spatial Resolution Remote Sensing Data

High-resolution data are becoming increasingly available and have greater potential to accurately map wetlands, including identifying small wetlands (Moffett and Gorelick 2013). The increase in resolution results in greater detail, but also greater intra-class spectral variability making separation of land cover classes more difficult as single pixels are no longer representative of classification targets (Blaschke et al. 2000; Yu et al. 2006; Mui, He, and Weng 2015). Classification of high spatial resolution imagery using traditional pixel-based methods often result in a salt-and-pepper effect where the outcome of classified pixels differ from adjacent pixels (Blaschke et al. 2000; Yu et al. 2006). For these reasons, traditional unsupervised and supervised classification methods are less suitable for processing high-resolution data (Blaschke et al 2000).

Geographical Object-based Image Analysis (GEOBIA*)*

Object-based image analysis (OBIA) is an alternative to pixel-based analysis, where images are segmented into spectrally homogenous objects that are the building blocks for analysis (Blaschke et al. 2000). The term geographical object-based image analysis (GEOBIA) is used to distinguish earth science applications from other disciplines (Hay and Castilla 2008). This method simultaneously integrates spectral and non-spectral data such as pixel spectrum, spatial location, spectral homogeneity and shape of adjacent clusters of similar pixels (Moffett and Gorelick 2013). The resulting objects contain features such as measures of central tendency of the individual bands, spectral variability, and spatial dimensions that are geographically valuable and that can be related to landscape features (Blaschke et al. 2000; Maxwell et al. 2015). The most widely used commercial software for object-based image analysis is eCognition Developer (Trimble Inc., Sunnyvale, CA).

GEOBIA involves two primary steps: segmentation or grouping of spatially adjacent pixels into spectrally homogenous objects, and classification with objects as the minimum processing unit (Yu et al. 2006). The variation and inconsistency among user inputs are noted as current barriers to broad application of GEOBIA methods to map wetlands (Moffett and Gorelick 2013). Wetland mapping using GEOBIA can be improved with the inclusion of information from ancillary data (Yu et al. 2006; Kim, Madden, and Xu 2010). Additional environmental information such as elevation, slope, aspect and landscape indicators represented by indices have been added to improve classification on the premise that plant diversity patterns are influenced by environmental conditions that create microhabitat conditions (Yu et al. 2006; Moeslund et al. 2013).

Also, wetlands and water bodies are positioned topographically low in the landscape in close association with groundwater and surface runoff (Mitsch and Gosselink 2007; Mui, He, and Weng 2015).

Segmentation

A variety of segmentation algorithms are available using eCognition Developer 9.1 software, multiresolution segmentation being the most commonly applied in wetlands research (Moffett and Gorelick 2013; Mui, He, and Weng 2015). Multiresolution segmentation is a bottom up merging algorithm that begins with individual pixels as seeds that are clustered together into groups based on spectral and spatial heterogeneity criteria (Trimble Inc. 2015). In this process, user defined threshold parameters constrain the size of objects (Yu et al. 2006).

Three user defined inputs are required to apply the multiresolution segmentation algorithm: (1) color and shape parameters that are weights between zero and one that determine the contribution of spectral heterogeneity (color); (2) smoothness and compactness parameters that are weights between zero and one and determine how the object shape is calculated; and (3) scale parameter, a unitless number or threshold which limits overall object color and shape complexity (Platt and Rapoza 2008; Moffett and Gorelick 2013). Spectral heterogeneity is defined as the sum of standard deviations of each image band (Platt and Rapoza 2008). Small scale parameters produce small objects while larger scale parameters produce larger objects. Pixels with similar spectral, textural and shape characteristics are merged together. Any type of spatially distributed data such as elevation can added as an input segmentation parameter to produce image objects (Jensen 2005). Presently there are no unified recommendations for segmentation parameters, selection is best determined through a trial-and-error based approach (Platt and Rapoza 2008; Ke, Quackenbush, and Im 2010; Duro, Franklin, and Dubé 2012; Mui, He, and Weng 2015).

Classification

Once scenes are segmented into homogenous objects, the next step is classification, or assignment of classes to objects based on feature characteristics. Spatially distributed environmental data within objects, such as elevation, slope, aspect and vegetation or wetness indices can also be used for classification (Ke, Quackenbush, Im 2010). One method commonly used for GEOBIA classification is a supervised approach known as nearest neighbor classification (Yu et al. 2006; Platt and Rapoza 2008; Mui, He, and Weng 2015). This method is popular because variables derived for image objects do not typically obey normal parametric statistical distributions; thus, is suitable for integration of spatial data into the classification process, and the training sample size for each class may vary due to the uneven distribution of vegetation (Foody 2002; Trimble Inc. 2015; Pham, Brabyn, and Ashraf 2016). The supervised nearest neighbor algorithm classifies unknown samples by comparing their location in the feature space to those of known training samples based on suitable similarity or distance metric (Yu et al. 2006).

Ancillary Data

Image data and ancillary data of various origins can be analyzed simultaneously in GEOBIA (Trimble Inc. 2015). In addition to image band derivatives, ancillary data sources can provide useful information to improve classification results. Ancillary data can be incorporated into the GEOBIA process during either the segmentation or the classification phase. The utility of including ancillary data sources has been evaluated in wetland and non-wetland landscapes (Yu et al. 2006; Mui, He, and Weng 2015; Pham, Brabyn, and Ashraf 2016). Data of differing resolution can be synchronized using software. To combine image layers with different resolutions, images with lower resolution are resampled to the size of the smallest pixel size (Trimble Inc. 2015).

A detailed vegetation classification by Yu et al. (2006) used high spatial resolution aerial imagery to test the efficiency of a supervised nearest neighbor object-based approach incorporating image band derivatives and ancillary layers. The study sought to determine the most important features for classification. Spectral features of objects in the analysis included mean, standard deviation, band ratio, intensity, hue and saturation. Topographic parameters used in the study were elevation, slope, aspect and distance to watercourses. Findings concluded that the addition of topographic information as ancillary information was a very important feature to improve vegetation classification accuracy whereas textural and geometric features were less significant. This study also concluded that supervised nearest neighbor object-based method outperformed traditional pixel-based methods.

Mui, He, and Weng (2015) delineated wetlands across natural and human-altered landscapes using a supervised nearest neighbor classification approach in eCognition. The study detected wetlands across natural, agricultural, and urban landscapes and achieved overall accuracy results greater than eighty percent across all study sites. Multiple input layers were incorporated into image segmentation including the four multispectral bands of blue, green, red and near-infrared, a digital elevation model (DEM) layer, normalized difference vegetation index (NDVI) layer, and a standard deviation texture layer. Results determined that input of these layers improved overall results, most notably that elevation data improved segmentation of wetland boundaries of palustrine (inland) wetlands.

Pham, Brabyn, and Ashraf (2016) combined GIS and image analysis techniques to improve classification accuracy by including mean and standard deviation values of elevation, slope, aspect and topographic wetness index (TWI) as image object features. Results showed that the green and near-infrared bands were the most valuable for separating classes, and that topographic features, especially mean slope and mean elevation were more valuable than textural data. Studies of forest land cover have confirmed the benefit of combining spectral and LiDAR-derived metrics during both segmentation and classification concluding that inclusion of this data leads to higher classification accuracy (Ke, Quackenbush, and Im 2010; Pham, Brabyn, and Ashraf 2016).

Restoration History of Glacial Ridge National Wildlife Refuge

Restoration measures at GRNWL have been completed; land managers now have the task of long-term planning, implementation, and monitoring. Although the goal of restoration is the return of an ecosystem to a historic, less-degraded condition, this goal is not always achievable due to the severity of impact or irreversible changes to biotic or abiotic factors (Zedler, Dohery, and Miller 2012). Community composition and structure of restored landscapes change over time as ecological succession occurs. Restoration measures at GRNWL began in 2000 and completed in 2012. The project was initiated by The Nature Conservancy (TNC) and was a coordinated partnership among more than thirty organizations. In total, 14 small tallgrass prairie remnants were reconnected to create 15,200 ha of contiguous habitat. It is estimated that approximately 177 km of drainage ditches were filled, 1,242 ha of wetlands were restored, and 8,100 ha of native vegetation were reestablished (Gerla et al. 2012). Ownership was transferred to USFWS beginning in 2004, with a second transfer in 2012 (Benjamin Walker, Wildlife Biologist, USFWS 2016, personnel communication).

According to Cowdery, Lorenz, and Arntson (2008), the site is located on the former eastern shoreline of glacial Lake Agassiz, which was present on the landscape approximately 11,600 to 9,500 years ago. After the lake drained, the area remained a complex of north-south beach ridges, dry prairie, mesic prairie and diverse shallow wetlands. The distinct linear beach ridge formations that persist are three to five meters high, and greater than thirty-five meters wide, with continuous length that varies upon location. Soils range from gravel, till, coarse sand, fine sand, silt and clay. The primary influences on local hydrology are precipitation, local groundwater flow and evapotranspiration.

Beach ridges are surficial aquifer features. Historically, the ridges acted as dams, creating back-beach basin wetland formations. On the western side of slopes, where groundwater seeps down gradient, discharge fens and wet meadows often develop. This unique geomorphology results in wetlands that are closely interwoven between dry gravel prairies. Prior to agricultural drainage, surface water flow was parallel to and behind beach ridges. Surface flow was often inhibited until depressions or low areas allowed the flow to cut across a ridge to join an adjacent inter-beach swale. Hydrologic flow trends from southeast to northwest, intersecting several beach ridge recharge and discharge zones on its path towards the Red and Red Lake Rivers (Cowdery, Lorenz, and Arntson 2008; Gerla et al. 2012).

Beginning in the 1920s, an extensive network of private and public drainage ditches were constructed to remove excess water and drain wetlands to make farming conditions favorable. Most small private drainage ditches were constructed in the 1980's as wheat and soybean production in the area increased (Cowdery, Lorenz, and Arntson 2008). Ditches ranged in size from small scrapes on private land to large drainage channels administered by local governments (Gerla et al. 2012). Major ditches were constructed parallel to the beach ridge orientation, and in places cut directly through a ridge.

Design and financial support for wetland restoration was largely provided through Wetland Reserve Program (WRP) contracts administered by the Natural Resources Conservation Service (NRCS). According to Gerla et al. (2012), a combination of approaches were employed to restore hydrology including installing ditch plugs, filling, compacting, and re-grading previously excavated soil. Some ditches that could not be decommissioned due to potential effects on neighboring property were reconstructed to a more natural configuration while still maintaining runoff.

Project managers set high standards for the vegetative quality of the restoration. Native seed was mechanically harvested from nearby native prairies according to landscape position, and was tested by private laboratories to assure seed germination success. In addition to this, spring flowering species were collected by hand and supplemented to the mixture. Seeding techniques varied between drilling and dormant season broadcasting. Long-term vegetation goals identified early in the planning process stated all restorations would contain at least 25 percent of possible native plant species characteristic of the target community, and at least 75 percent cover in all restorations would be native vegetation (Gerla et al. 2012).

Regional Hydrological Assessments

Prairie wetlands are spatially, temporally, and chemically diverse (van der Valk 1989). Because the restoration of GRNWR was such a vast undertaking, several studies address hydrological properties unique to the site. Melesse et al. (2006) document the spatial and temporal evapotranspiration response of restoration activities from 2000 to 2003. Five sub-basins were delineated to represent different stages of restoration and response. Remotely sensed data were used to estimate components of the surface energy budget related to evapotranspiration. The study detected a 50 percent increase in evapotranspiration over the study period as a result of increased hydrology because of wetland restoration. Gerla (2007) investigated the flood mitigation potential of large restoration projects, specifically, the effect of cropland to grassland conversion on peak storm run-off in five and 25 year, 24 hour rainfall events. The methodology combined curve numbers, GIS and stochastic analysis to predict changes in run-off. The study concluded that cropland to grassland conversion would lead to an average 40-55 percent reduction in peak run-off.

The most comprehensive characterization of local hydrology near GRNWL is a report produced by Cowdery, Lorenz, and Arntson (2008). This investigation sought to address concerns identified during early planning stages of the restoration related to blocking, modifying, or removing ditches, reconstruction of wetland basins, and reintroducing and managing native plant communities. The study was a cooperation between the U.S. Geological Survey (USGS), TNC, and Red Lake Watershed District, and provided detailed, pre-restoration hydrologic information on the study area to assist restoration managers and decision makers. Groundwater, surface water, and water quality were evaluated though a network of 72 groundwater wells, seven ditch gauges, 11 wetland gauges, and one lake gauge.

The report predicted groundwater levels would rise in response to increased water in surrounding wetlands and result in overall increased ground-water storage. Authors address uncertainty of the effect an increase in groundwater storage would have on wetlands, particularly in areas where ditches that cut through beach ridges have been filled in. Two scenarios were presented regarding hydrological effects of restoration activities: 1) the water table was expected to rise in these areas, which could increase wet meadow or fen development in positions down gradient from restored wetlands; 2) existing fens that receive water from a surficial aquifer down gradient from newly constructed wetlands could experience changes to groundwater discharge that are either diffuse or concentrated. If discharge is diffuse, the size of fen could increase as plant communities recolonize wet areas. If discharge to the fen is concentrated in a few areas, conditions could become wetter to the point that fen communities are no longer tolerant to the rising water levels.

As GRNWR enters a new phase of long-term monitoring and adaptive habitat management, this study will be a valuable exploratory evaluation of remote sensing and GIS capabilities coupled with field-based data collection efforts of targeted communities within the prairie-wetland landscape. GRNWR land managers will begin to employ the belt transect method of data collection in 2017 in an effort to implement, monitor, and evaluate conservation plan objectives (Benjamin Walker, Wildlife Biologist, USFWS 2016, personnel communication). The combination of remote sensing with field study can be used to quantify specific variables of ecosystem function that are broadened regionally to support conservation efforts such as setting baseline conditions to assess environmental change, monitoring ecological restorations, and supporting ecosystem services evaluation.

CHAPTER III

METHODS

Analytical Processes

In this study, combination of remote sensing and GIS analytical approaches were used to evaluate and classify patterns of land cover change over time. A multilevel procedure was implemented including: data acquisition and preprocessing, segmentation, creation of training objects, object classification, accuracy assessment, GIS hydrological analysis, and field validation. An overview workflow is shown in Figure 4.

First multispectral image scenes and LiDAR DEM data were acquired. Second, ancillary data sets of slope, aspect and TWI were produced from the LiDAR DEM. Next, objects were created based on multispectral image data and LiDAR DEM using the multiresolution segmentation algorithm. Training samples were generated based on review of aerial imagery and site knowledge. Classification was performed separately on images incorporating spectral and spatial features using the nearest neighbor algorithm. Classification accuracy assessment was conducted for each image through the creation of an error matrix based on a random sampling method of point generation. Next, a GIS-based hydrological analysis was conducted that incorporated vector files from wetland restoration practices and classification results. A final classification field validation was completed on selected wetlands based on methods derived from the belt transect method and standard wetland delineation procedures.

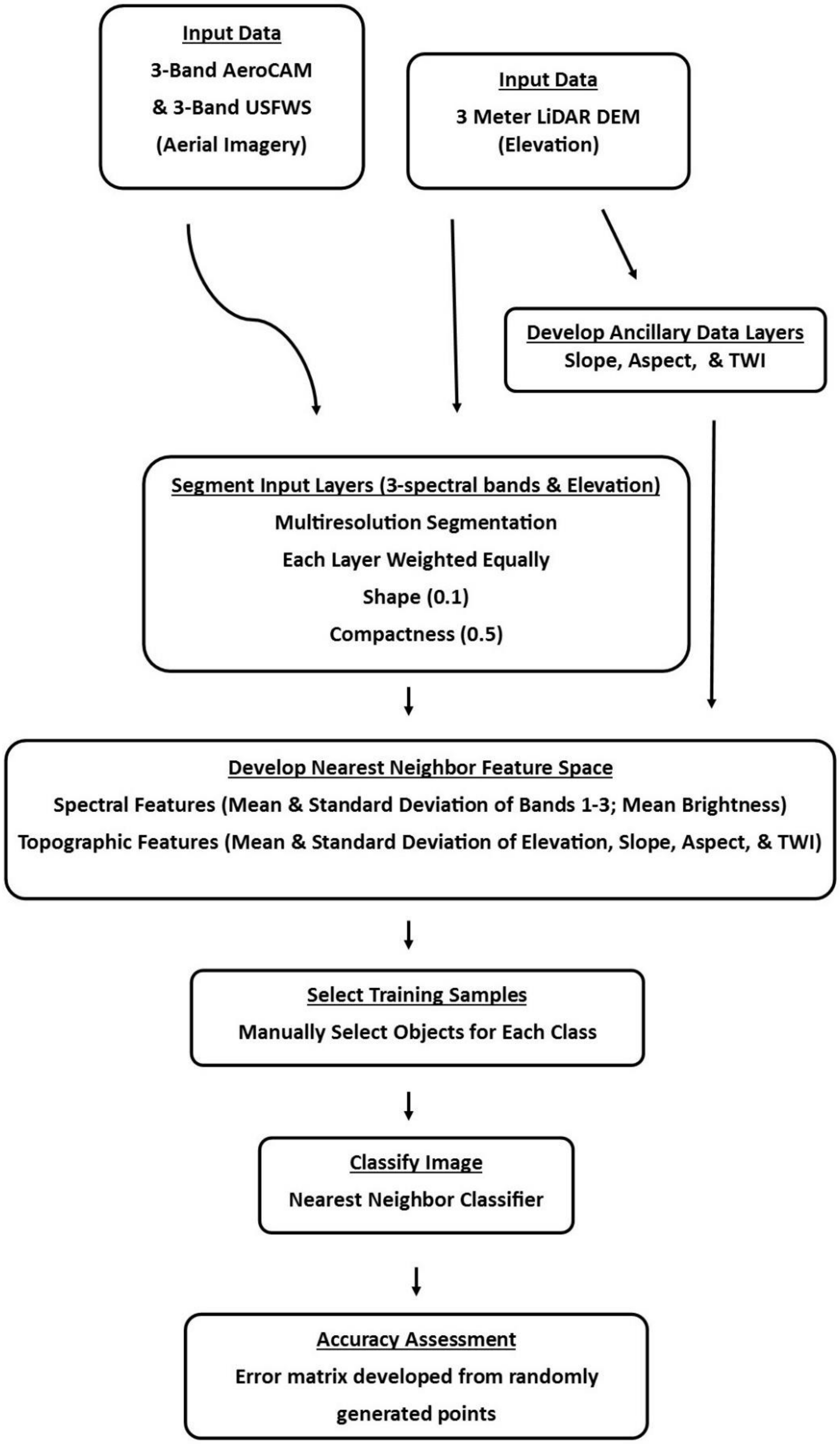


Figure 4. Process workflow for GEOBIA classification of GRNWR.

Data Acquisition and Preprocessing

Data included in the analysis (Table 1) represent variables of two main categories: 1) spectral data derived from aerial sensors and 2) spatial or ancillary data derived from a LiDAR DEM that represents terrain attributes of the physical environment. The study area boundary ArcGIS file was obtained from the USFWS. All spectral and ancillary data were coregistered and clipped to the study area boundary using ArcGIS™ 10.4 (ESRI, Redlands, California). Image object creation and classification was performed using eCognition Developer 9.1 (Trimble Inc., Sunnyvale, CA) object-based image analysis software. Wetland restoration vector data were obtained from TNC restoration project records and imported directly into ArcGIS™ 10.4 (ESRI, Redlands, California) for hydrological analysis.

Table 1. Summary of data collection

Data	Type	Origin	Spatial/Temporal	Reference
AEROCAM	Aerial Color Infrared Imagery	Remote Sensing	2.44 m/ June 12, 2007	UND Department of Earth System Science & Policy, Grand Forks, ND
USFWS IMAGE	Aerial Color Infrared Imagery	Remote Sensing	0.2 m/ July 22, 2014	USFWS Region 3, St. Paul, MN
LiDAR DEM	Digital Elevation Model	Derived from LiDAR	3 m/ April 18-19, 2008	Minnesota Geospatial Commons https://gisdata.mn.gov/
Restored Ditches	Line Vector	Geo-referenced Digital Data	2002-2010	Dr. Phil Gerla UND Department of Geology & Geological Engineering
Restored Wetlands	Polygon	Geo-referenced Digital Data	2002-2010	Dr. Phil Gerla UND Department of Geology & Geological Engineering
Study Area	Polygon	Geo-referenced Digital Data	147.3 km^2 2016	USFWS GRNWR Erskine, MN

Multispectral Image Data

Two high-resolution, multispectral images were selected for their potential to differentiate variable ground conditions. The spectral range of visible and near-infrared bands allowed for detailed information extraction. Because of the specific target dates of the change detection analysis, images from two sources were acquired. The first image represents conditions during the middle phase of the grassland and wetland restoration period. The later image represents post-restoration conditions.

An Airborne Environmental Research Observational Camera (AEROCam) multispectral image was captured on June 12, 2007 as a result of the Upper Midwest Aerospace Consortium (UMAC) project at the University of North Dakota (UND). This image had a 2.44 m spatial resolution and three multispectral bands, green, red, and near-infrared (NIR). A second image captured on July 22, 2014 was obtained from the USFWS, and had a spatial resolution of 0.2 m. This image also contained three multispectral bands: green, red and NIR. Both multispectral images were radiometrically corrected and georeferenced prior to acquisition.

LiDAR Data

A 3-m spatial resolution LiDAR DEM was obtained from Minnesota Geospatial Commons (https://gisdata.mn.gov/). LiDAR data covering the study area were acquired on April 18 and 19, 2008, as a part of the Red River Basin Mapping Initiative 2008-2010, coordinated by the International Water Institute (IWI). The original data have a horizontal positional accuracy of one meter and vertical positional accuracy of 15 cm. This study uses the LiDAR DEM to develop the ancillary data sets of slope, aspect and topographic wetness index (TWI) used in the nearest neighbor classification.

Ancillary Data

The Spatial Analyst toolset in ArcGIS™ 10.4 (ESRI, Redlands, California) was used to create several raster datasets from the LiDAR DEM. The slope tool was applied to produce a slope grid, in degrees. Slope is related to overland and subsurface flow, and quantifies the maximum rate of change in value from each cell to its neighbors. An aspect surface raster was created using the Aspect tool. Aspect represents downslope direction of the maximum rate of change between neighboring cells.

A flow accumulation grid and slope comprise TWI. For development of TWI, a value of 0.001 was added to each cell of the slope grid using Raster Calculator tool. This marginal addition increased the angle to avoid division by zero in subsequent TWI calculations. The final slope grid was multiplied by 0.0175 to convert to radians. Elevation irregularities or sinks were removed from the LiDAR DEM using the Fill tool. A flow direction grid was produced using the Flow Direction tool. The flow direction grid represents flow from each cell to its steepest downslope neighbor. Next, the flow direction grid was applied to the Flow Accumulation tool to produce a flow accumulation grid, a grid of accumulated flow into each cell. Flow accumulation is also referred to as catchment area as it represents overland flow paths within the watershed or drainage area.

TWI is commonly used to derive information about the spatial distribution of wetness. It is a function of both slope angle and upslope contributing cells (Moeslund et al. 2013). TWI was produced using the Raster Calculator tool using the following formula:

$$TWI = \ln \left(\frac{A_s}{\tan \beta i} \right)$$

where TWI is the natural log (ln) of the ratio of the specific catchment area (A_s) expressed as m^2 per unit, divided by the tangent of the slope angle βi expressed in radians (Grabs et al. 2009). A low-pass 3 x 3 filter was run over the TWI output to remove minor variability produced using the Neighborhood tool. The slope, aspect and TWI were based on 12-Digit HUC, USGS watershed boundary, later clipped to the study area boundary.

Segmentation

The image segmentation operation in eCognition Developer 9.1 subdivides images into new image objects. Image objects contain both spectral and spatial elements referred to as, features. The multiresolution segmentation setting was selected due to its predominant use in previous studies. Input layers for image segmentation were the three spectral bands and elevation. For each image layer, the segmentation weight was equal. Scale parameters were designated for each image through a trial-and-error approach.

Two different scale parameters were selected due to the differing spatial resolution of the images. A scale parameter of 50 was selected for the June 12, 2007 image. A scale parameter of 70 was selected for the July 22, 2014 image. For both images, the color and shape parameter was set at 0.1; and the smoothness and compactness parameter was set at 0.5. A subset example of segmentation results are shown in Figure 5.

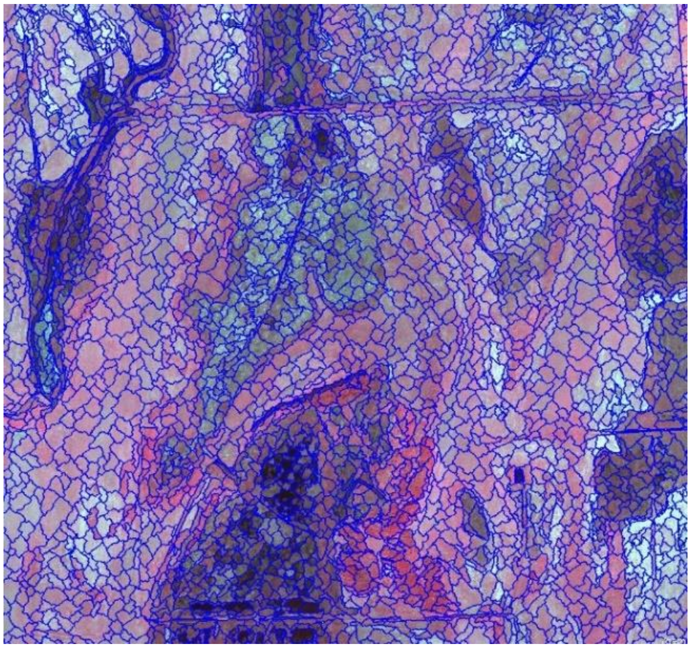


Figure 5. Subset of image segmentation results.

Training Samples

Nearest neighbor classification uses training samples of different classes to assign membership values (Trimble Inc. 2015). Training samples, typical representations of each class were manually selected based on aerial imagery and prior site knowledge. A minimum of 100 training sample objects were selected for each class. The following classes were defined: Grassland, Wetland, Open Water, Forest, and Developed (Table 2). A Cropland class was analyzed for the 2007 image classification due to the significant occurrence of the land cover. It was standard practice during the restoration period to complete the restoration seeding following a crop rotation of soybeans. In the 2014 image analysis, remaining Cropland is included with the Grassland class. A subset portion of manually selected training samples are shown in Figure 6.

Table 2. Land cover class descriptions.

Class	Description
Grassland	Land where vegetation is dominated by grass and forbs
Wetland	Fen, wet meadow, marsh, shrub wetland and similar wetland types
Open Water	Areas persistently covered with water (e.g. lakes, open water wetlands, gravel pit pond
Forest	Closed canopy forests
Developed	Areas with man-made structures (e.g. roads, gravel pit, buildings)
Cropland	Land used for agricultural production

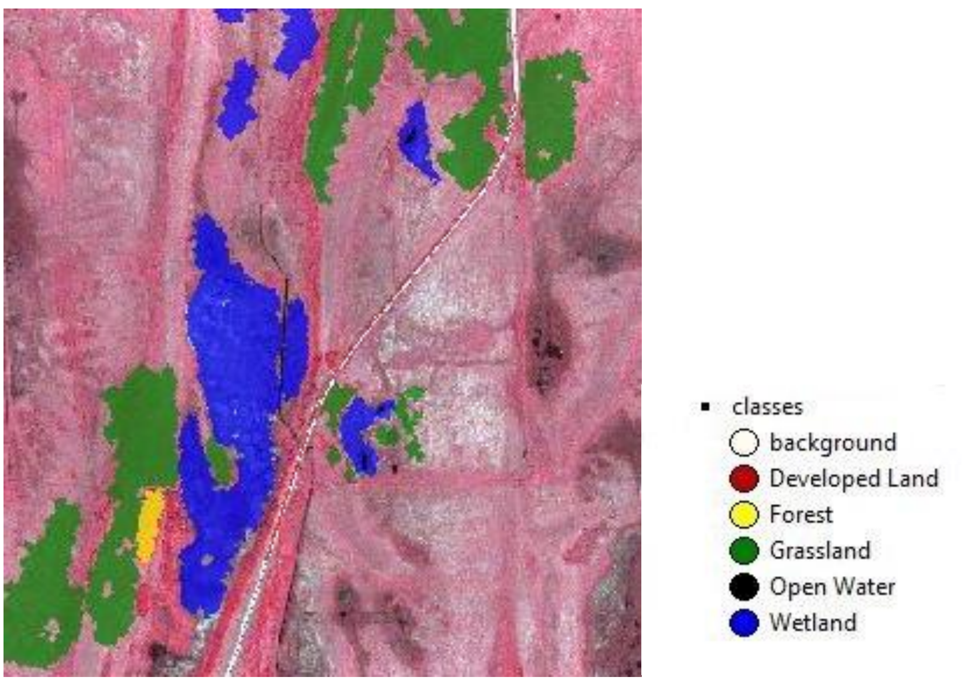


Figure 6. Manually selected training sample objects.

Classification

Classification was performed with the supervised nearest neighbor classifier method, in which image objects are distributed to classes based on their nearest sample neighbors. The nearest neighbor calculation in eCognition Developer 9.1 computes distance using the formula:

$$d = \sqrt{\sum_{f}\left(\frac{vf(s) - vf(o)}{\sigma f}\right)^2}$$

where *d* is the distance between sample object *s* and image object *o*; *vf* (s) is the feature value of sample object for feature *f*; *vf* (o) is the feature value of the image object for feature *f*, and *σf* is the standard deviation of the feature value for feature *f*. Distance of the feature space between a sample object and the classified image object is standardized by the standard deviation of all feature values (Trimble Inc. 2015). The nearest neighbor feature space was constructed using mean and standard deviation feature values of pixels within objects calculated from input layers of all three multispectral image bands, elevation, slope, aspect and TWI. These features were selected based on their identified importance in previous studies.

The two classified images were stacked and reclassified based on the mode value of the class name to distinguish areas of potential wetland change. Objects classified as *Open Water* and *Wetland* were combined into a new category representing wetness (*Wet).* All remaining classes were grouped as *Dry*. The stacked images were separated into four image classes: 1) Dry (Both 2007 & 2014); 2) Wet (Both 2007 & 2014); 3) Wet 2007; 4) Wet 2014. The results of this final image processing step were used for the GIS hydrological analysis. Both of the classified images and the stacked image product were exported as shapefiles to be further analyzed in ArcGIS.

Assessment of Classification Accuracy

The multinomial distribution method was used to determine sample point size according to the formula:

$$N = \frac{B\,\Pi_i\,(1-\Pi_i)}{b_i^2} = B = 1\text{-}(\alpha/k)\ \text{x}100$$

where Π is the proportion of a population in the *i*th class out of *k* classes that is closest to 50 percent; *b* is the desired precision (5 percent); and *B* is the upper (α/k) x 100 percentile of the chi squared distribution with 1 degree of freedom; *k* is the number of classes (Manly 2009). The probability of error was established at 95 percent.

An error matrix was constructed for each of the classified images to evaluate the overall accuracy, user's accuracy (measure of omission error) and producer's accuracy (measure of commission error). Post classified image objects were converted from polygon features to raster data using the Polygon to Raster tool in ArcGIS™ 10.4 (ESRI, Redlands, California). Two separate point generation methods were adjoined using the Create Accuracy Assessment Points tool. First fifty points were randomly generated for each class. Random points were supplemented by a stratified random sample. This method of point generation creates randomly distributed points within each class where each class has a number of points proportional to its relative area (Campbell and Wynne 2011). The two methods were combined to assure that each class had a minimum of 50 sample points. For each point, the land cover class assigned was visually compared with the corresponding area in the aerial imagery. The totals from both methods of point generation were combined in a single error matrix. Overall accuracy was derived by counting how many of the image points were correctly classified.

Classification results were compared to the original aerial images used in the classification procedure. This was done because no other high-resolution images were available for the location and dates of the study. The option of using a former or later year image from another source was considered and rejected due to the rapidly changing hydrological conditions on the restoration site. Also, the images used for classification were easily distinguishable, having very high spatial resolution. Results of the confusion matrix indicate how many points were assigned to their correct class or misclassified into another class.

GIS Hydrological Analysis

Two vector shapefiles were obtained from the restoration and design plans of GRNWR: a *ditch* file showing locations of filled ditches; and a *wetland restoration* file showing locations of restored wetlands. The *ditch* file was a line-based shapefile feature class representing ditches filled during the restoration period between 2002-2010. The *wetland restoration* polygon shapefile was a digitized representation of restored wetland basins constructed between 2002-2010. A 121.92 meter (400 ft.) buffer was created around the *ditch* file using the Buffer tool in ArcGIS™ 10.4 (ESRI, Redlands, California). This distance was selected to represent maximum lateral distance of influence of a ditch restoration on hydrology as determined from local soil type and ditch depth, also called, lateral effect. Lateral effect is defined as the width of land adjacent to a ditch that has had its hydrology modified such that it no longer satisfies wetland hydrologic criteria (Skaggs,Chescheir, and Phillips 2005).

Using the results of the stacked classified images, objects representing wetness (*Wet)* were analyzed according to their proximity within the ditch buffer or outside of it. To quantify classified wetlands influenced by ditch systems in 2007, the Wet 2007 and Wet (Both 2007 & 2014) objects were summed within the ditch buffer and outside the ditch buffer. To quantify wetlands influenced by filled ditch systems in 2014, the Wet

2014 and Wet (Both 2007 & 2014) objects were summed within the ditch buffer and outside the ditch buffer.

Determining Field Sampling Sites

A new *Wet_2014* vector polygon shapefile was extracted from the results of the image analysis. This file represented "newly wet" hydrologically restored areas that were classified as *wetland* or *open water*, in the July 22, 2014 image, and classified *Dry* based on the June 12, 2007 image results. The *Wet_2014* polygons were clipped using the buffered *ditch* file as clip feature. This resulted in a new output of wetland areas locally affected by the filled ditches. This new feature class was overlaid with the *wetland restoration* shapefile containing known restored wetland basins. The Erase tool was used to eliminate the known restored wetland basins, leaving only those wetland polygon areas within the lateral effect of the ditch buffer, but not contained in the *wetland restoration* shapefile. This process was done to target areas of potential wetland expansion to be further investigated through the field validation process. Furthermore, these potential wetlands were highlighted as they are directly attributed to restoration practices.

Field Validation

The field validation effort was completed to gain further insight as to how automated land cover mapping from remote sensing data relates to different land cover types on the ground. Belt transects were used to assess general composition characteristics of select wetland sites. The onsite wetland delineation provides precise boundary data that can be related to the remote land cover mapping from the image classification. It is important to note that data collection occurred during the growing season of 2016, two years after the image analyzed so conditions are not directly relatable.

Belt Transect Method

The belt transect method was applied on five randomly selected sites within the study area according to procedures described in the Grassland Monitoring Team Standardized Monitoring Protocol (Vacek et al. 2015). This vegetation assessment method was undertaken to be consistent with ongoing USFWS data collection efforts. The method is an efficient, yet reliable, way to measure and monitor the ecological condition of large expanses of grassland habitat (Grant et al. 2004).

Random points were located in the field using a Trimble Geo XT handheld GPS unit. Because the sample points were anticipated to be in wetland habitats, the direction of the transect was determined perpendicular to the wetland edge. A measuring tape was stretched across the vegetation to a transect length of twenty-five meters and staked to prevent shifting. Visual obstruction reading (VOR) measurements were taken at the center-point of the transect (12.5 m), from the four cardinal directions (north, east, south, west) using a VOR pole. VOR readings were observed at a height of one meter and a distance of four meters from the pole. Litter depth measurements were recorded at five meter intervals along the transect.

Dominant plant groups (Appendix B) were identified at each 0.1-meter by 0.5-meter segment along the tape and plant group codes recorded. According to the protocol, plant group codes represent a range that spans from native-dominated to invasive-dominated vegetation. The prevalence of invasive species along the transect were recorded according to whether they were present or dominant (greater than 50 percent of the quadrant). Finally, the presence of quality indicator species were documented. Field data collection was completed in late summer when both cool and warm-season plants were recognizable.

Onsite Wetland Delineation

At each of the selected transect sites an attempt was made to delineate a portion of the wetland boundary as additional validation for classification results. Standardized wetland delineation procedures from the United States Army Corps of Engineers (USACE) Wetlands Delineation Manual and Great Plains Regional Supplement were used to identify boundaries based on evaluation of three criteria: soils, vegetation and hydrology (USACE 1987; 2010). Test points were identified in obvious upland positions, and contrasted with points in obvious wetland positions. A portion of the wetland boundary was recorded via GPS points between the two reference test points.

Hydric soil indicators were evaluated in the field by digging a borehole approximately forty-five centimeters deep. The soil color was evaluated using hue, value, and chroma characteristics from the Munsell Color Chart for soils and recorded on field data sheets (Munsell Color 2015). Wetland hydrology indicators were inspected within the test hole to observe whether water seepage was encountered within thirty centimeters of the surface, as the presence of water within this depth is a strong indicator of a seasonal high water table (Lyon and Lyon 2011). Hydrological conditions were recorded on field data sheets.

Wetland vegetation was assessed by identifying dominant plant species and comparing their occurrence to the National Wetland Plant List of plant species that occur in wetlands, published by the USFWS and maintained by the USACE (USACE 2016).

The probability of a plants occurrence in wetlands was rated in one of five categories: upland, facultative upland, facultative, facultative wetland, and obligate wetland. Table 3 provides the estimated probability of occurrence in a wetland for each of the five categories. Estimates of areal cover were used to define dominant plant species. The plot sample sizes varied according to type of vegetation ranging from 1.5-m radius for herbaceous vegetation and 4.5 m for sapling/shrub vegetation. Locations were determined to have wetland vegetation when the total dominance of FAC, FACW, and OBL plants exceeded 50 percent of the total dominant plants found on the site (USACE 1989; 2010).

Table 3. Vegetation categories for assessing wetland vegetation including abbreviation and probability percentage of occurring within a wetland.

Plant Category	Abbreviation	Probability of Wetland Occurrence
Upland	UPL	< 1%
Facultative Upland	FACU	< 33 %
Facultative	FAC	34% - 66%
Facultative Wetland	FACW	67% - 99%
Obligate	OBL	> 99%

CHAPTER IV

RESULTS

Nearest neighbor object-based land cover classification was performed on both images. The June 12, 2007 image was extracted into six classes: open water, wetland, grassland, forest, developed, and cropland. The July 22, 2014 image was extracted into five classes: open water, wetland, grassland, forest and developed. Multispectral aerial imagery, DEM and LiDAR derived ancillary data were integrated into the classification dataset. Results of the GIS-based hydrological analysis provide detail on areas of potential wetland expansion resulting from adjacent constructed wetlands. Results of the field validation provide supplemental information to remote sensing classification.

Ancillary Data

Non-spectral ancillary data were derived from LiDAR DEM and integrated into the classification process. The slope gradient for the study area was calculated in degrees, and ranged from 0-55.75 (Figure 7). The mean slope value was 0.98, consistent with the general subdued topography of the landscape. Beach ridge features and roads have moderate slope. High slope values were concentrated in locations of gravel pits, roads, and steep berms of large impoundments.

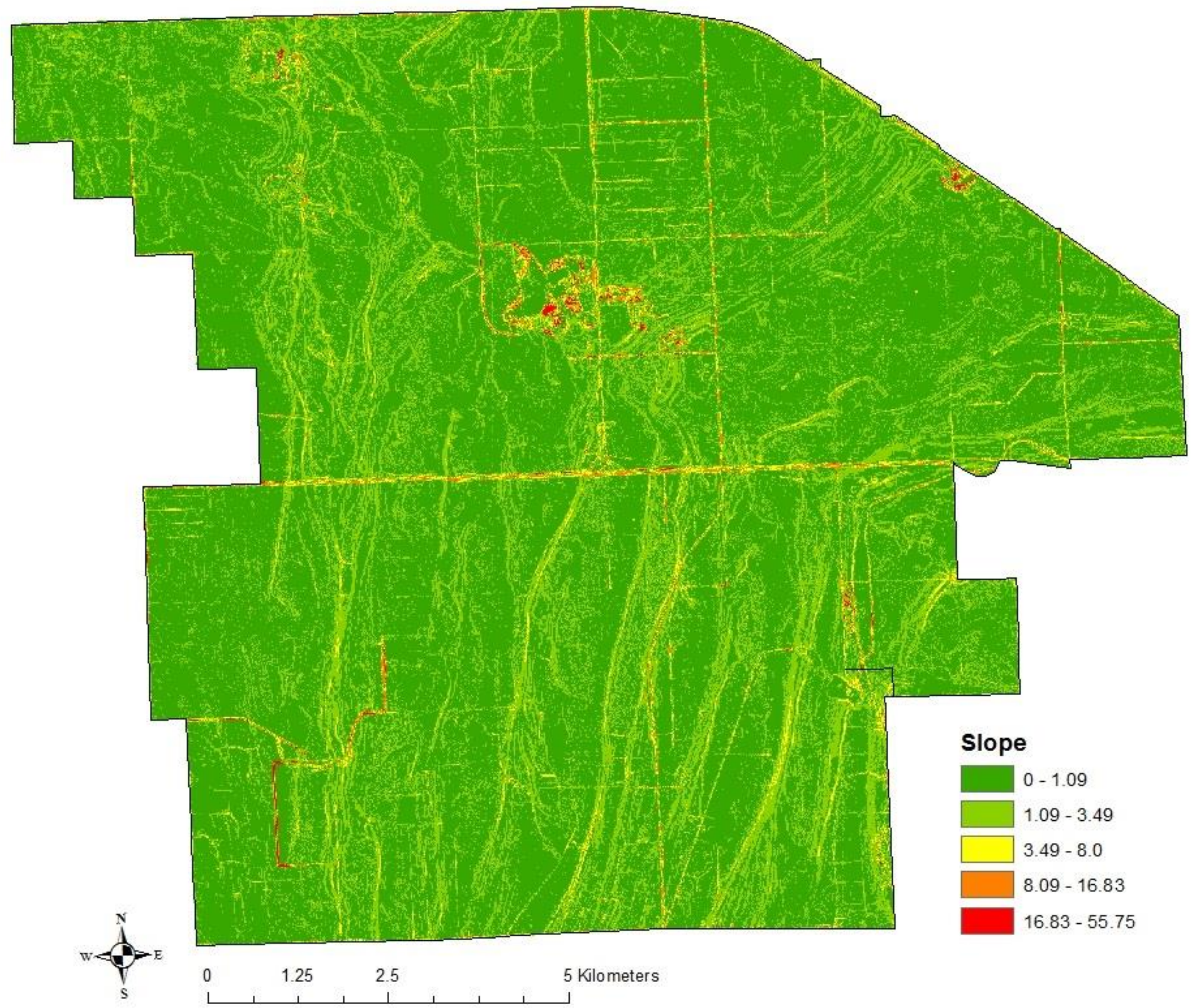


Figure 7. Slope values within study area reported in degrees.

Results of the aspect raster are shown in Figure 8. Aspect is the cardinal direction of slope, measured clockwise in degrees from 0 to 360, where 0-22.5 is north-facing, 67.5-112.5 is east-facing, 157.5-202.5 is south-facing, and 247.5-292.5 is west-facing. The aspect of a slope has significant influence on microclimate and on the distribution of vegetation (Domac and Suzen 2006).

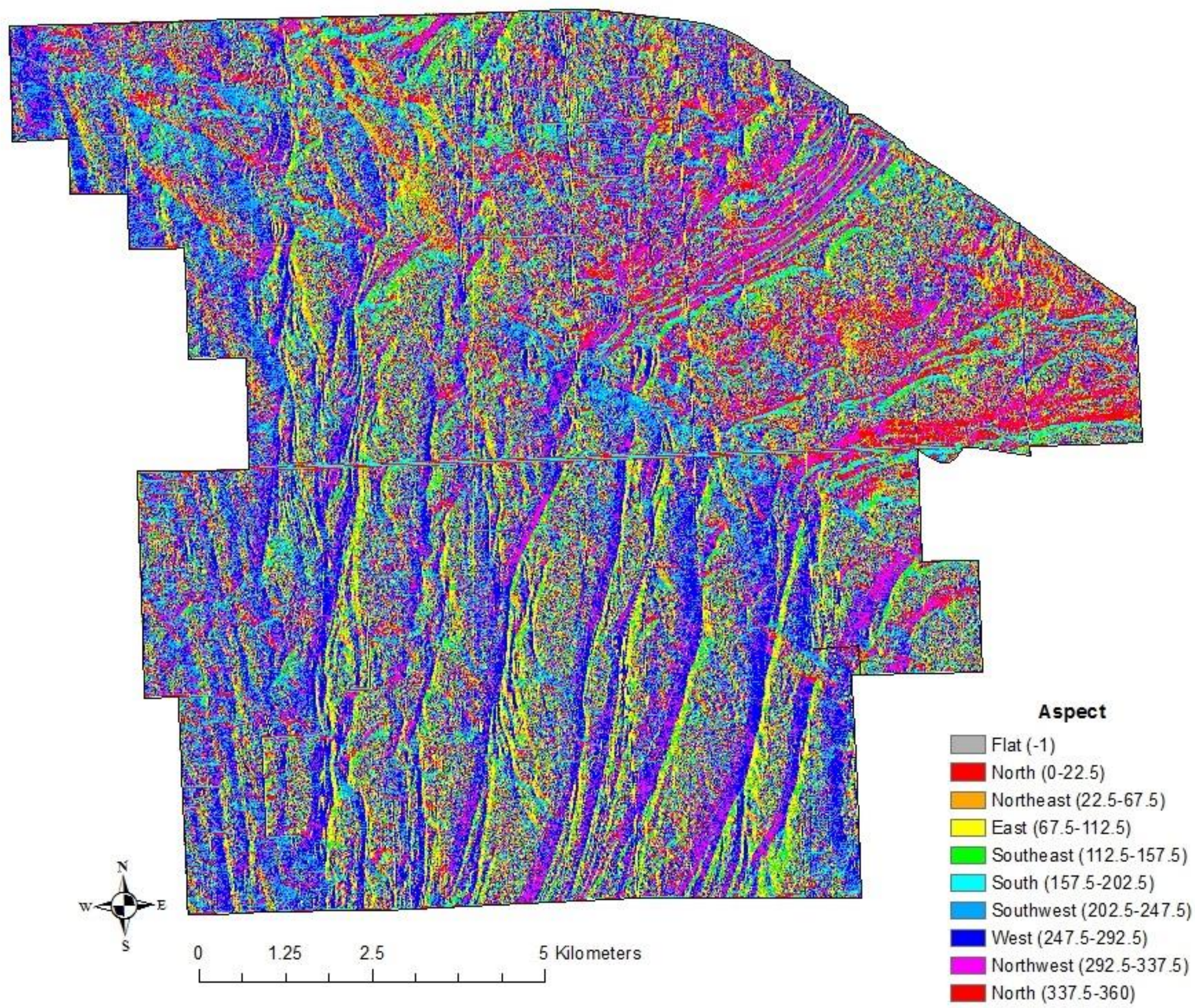


Figure 8. Aspect values within study area shown in compass degrees.

Results of the TWI show where water collects or ponds on the landscape (Figure 9). Low TWI values are attributed to land that is almost never saturated and high values indicate land that is always saturated (Moeslund et al. 2013). Flow paths and areas of flow accumulation occur based on topography and slope, therefore TWI is a predictor of potential wetlands on landscape. In addition, water is a key driver of vegetation distribution (Pham, Brabyn, and Ashraf 2016). The mean TWI value across the study area was 6.67.

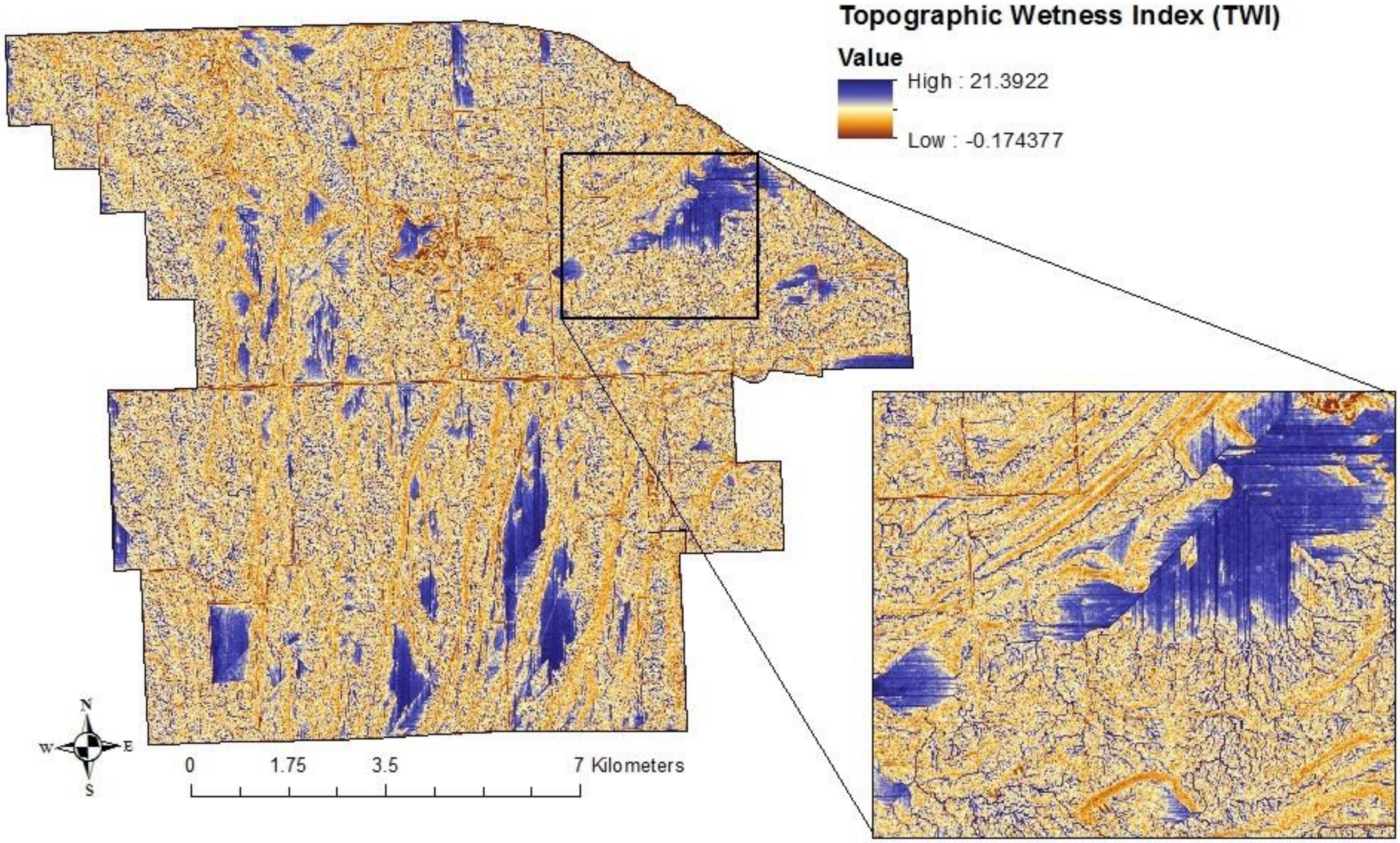


Figure 9. Study area with values of topographic wetness index. Areas that are predicted to be wet are dark, while red areas are predicted to be relatively dry.

Image Classification Results

The nearest neighbor image classification model integrated spatial and spectral properties. The classification maps (Figures 10 and 11) illustrate how wetland areas have changed spatially and temporally within the study landscape. For the June 12, 2007 image, the area associated with wetlands was 20.09 km^2 (± 3.82) out of a total area of 147.3 km^2 (Table 4). In the July 22, 2014 image, the classification resulted in wetlands covering 37.96 km^2 (± 8.35) of a total area of 147.3 km^2 (Table 4).

Table 4. Land cover classification results including percentages.

	6/12/2007			7/22/2014		
Class	km^2	Acres	Percent	km^2	Acres	Percent
Cropland*	34.35 (± 5.50)	8,489.2 (±1,358.27)	23%	*Included in Grassland Class	*	*
Developed	2.51 (± 0.05)	619.7 (±12.39)	2%	1.94 (± 0.14)	478.81 (±33.52)	1%
Forest	8.63 (± 0.60)	2,133 (±149.31)	6%	7.96 (± 0.48)	1,966.93 (±118.02)	5%
Open Water	0.97 (± 0.03)	239.65 (±7.19)	1%	1.00 (± 0.05)	247.63 (±12.38)	1%
Grassland*	80.73 (± 8.88)	19,948.2 (±2194.30)	55%	98.43 (±1.97)	24,323.91 (±486.48)	67%
Wetland	20.09 (± 3.82)	4,965.3 (±943.41)	14%	37.96 (± 8.35)	9,380.22 (±2,063.65)	26%

*Cropland estimates only produced in 2007 data. For 2014 data, cropland was combined into grassland class.

Results of the error matrix compare classified data to reference data. The diagonal of the matrix shows the number of points where the classified data are the same as the reference data, the values outside the diagonal show the number of points where the classified data is different from the reference data. The columns of the error matrix represent the reference data, while rows represent the classification data (Campbell and Wynne 2011). For each image year, overall accuracy, Producer's Accuracy (omission error) and User's Accuracy (commission error) were generated.

The Producer's Accuracy is a measure of the correctness of classified data, and is calculated by dividing the number of correctly classified points by the column total. It represents points that belong to a certain class but fail to be classified into that class (omitted). User's Accuracy is a measurement of the probability that a point on a map accurately represents that category on the ground, and is calculated by dividing the number of correctly classified points by the row total. It represents points that belong to another class but are classified as belonging to the class (committed). Overall accuracy is the sum of all points classified correctly, divided by the total points assessed. It is a metric of overall correctness of the entire classified image without regard to specific classes (Campbell and Wynne 2011).

The error matrix for the June 12, 2007 classified image produced an overall accuracy of 88 percent (Table 5). Open water was most accurately classified with a producer's accuracy of 95 percent (omission error 5 percent).The user's accuracy for the open water class was 97 percent (commission error of 3 percent). The classes that were least accurately classified were cropland and wetland. Cropland resulted in 83 percent producers accuracy (17 percent omission error); user's accuracy of 84 percent (commission error of 16 percent). The wetland class resulted in 86 percent producer's accuracy (14 percent omission error), and 81 percent user's accuracy (19 percent commission error).

With regard to the July 22, 2014 classified image, the overall accuracy achieved was 91 percent (Table 6). Open water was most accurately classified with a producer's accuracy of 93 percent (7 percent omission error) and a user's accuracy of 98 percent (2 percent commission error. The wetland class also had a producer's accuracy of 93 percent

(7 percent omission error), but a lower user's accuracy of 78 percent (22 percent commission error).

The final image processing step produced a stacked image that distinguished areas of potential wetland change. The spatial distribution of wetland areas that have undergone change are illustrated in Figure 12. Objects which were classified as *Open Water* and *Wetland* are shown as a combined new category representing both (*Wet).* All remaining classes are grouped as *Dry*. Areas identified as *Wet* in both images are assumed to be pre-existing wetlands or wetlands restored prior to 2007. Areas that were classified as *Wet* (in) 2014, but dry in 2007 indicate areas of expanded wetland change.

Results of GIS Hydrological Analysis

Restoration efforts at GRNWR resulted in the closure of drainage ditches constructed adjacent to, or through, wetlands. These drainage systems changed the hydrology of adjacent wetlands. The GIS Hydrological analysis used an estimation of lateral effect of a drainage ditch on the hydrology of wetlands to approximate wetland change that can be attributed to restoration practices. Table 7 provides an estimate of classified wetlands whose hydrology are affected by restored drainage ditches in their proximity. In 2007, restoration measures were ongoing; by 2014, the restoration structures were well established.

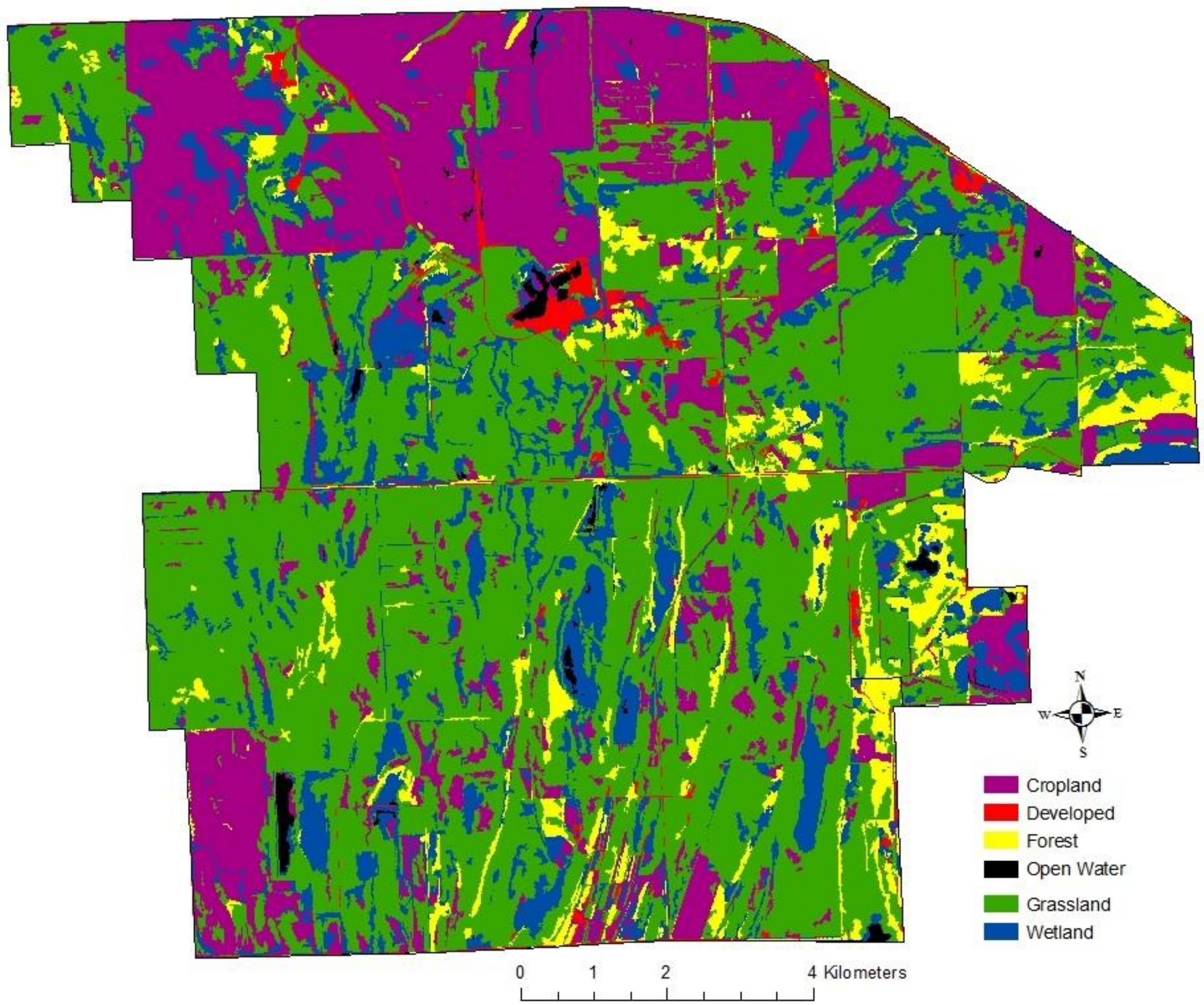


Figure 10. Output classification from June 12, 2007 image of GRNWR.

Table 5. Classification error matrix for June 12, 2007 image.

	Cropland	Developed	Forest	Open Water	Grassland	Wetland	Total
Cropland*	**176**	3	1	2	19	8	209
Developed	1	**56**	0	0	0	0	57
Forest	2	0	**77**	0	3	1	83
Open Water	1	1	0	**56**	0	0	58
Grassland	28	2	11	0	**403**	9	453
Wetland	4	1	0	1	20	**111**	137
Total	212	63	89	59	445	129	997

Overall Accuracy
879/997= 88%

Producer's Accuracy (measure of omission error)			
Cropland*	83%	17%	omission error
Developed	89%	11%	omission error
Forest	87%	13%	omission error
Open Water	95%	5%	omission error
Grassland	91%	9%	omission error
Wetland	86%	14%	omission error

User's Accuracy (measure of commission error)			
Cropland	84%	16%	commission error
Developed	98%	2%	commission error
Forest	93%	7%	commission error
Open Water	97%	3%	commission error
Grassland	89%	11%	commission error
Wetland	81%	19%	commission error

*Cropland was combined with grassland in the 2014 image analysis.

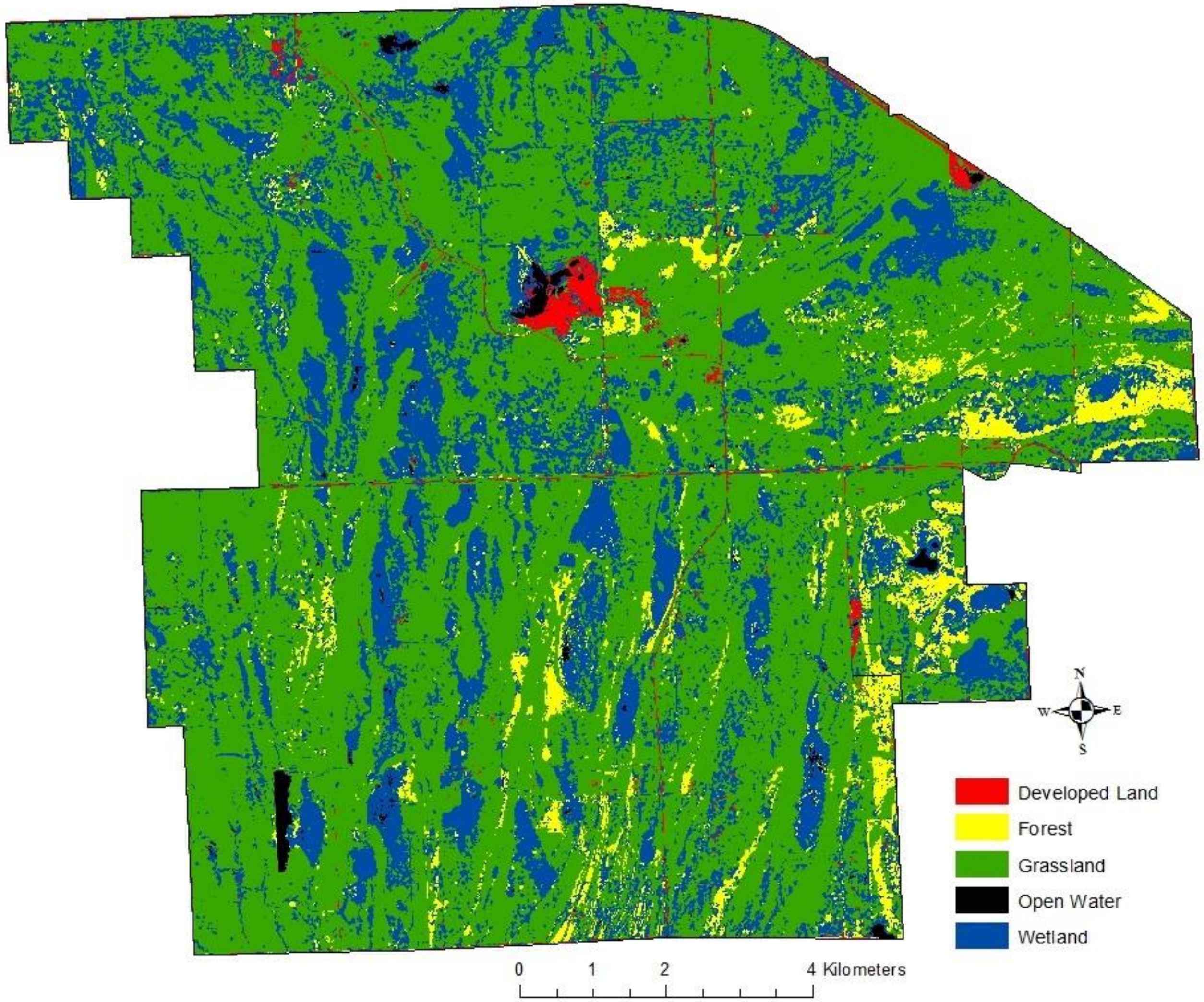


Figure 11. Output classification from July 22, 2014 image of GRNWR.

Table 6. Classification error matrix. July 22, 2014 image.

	Developed	Forest	Grassland	Open Water	Wetland	Total
Developed	**52**	0	2	1	1	56
Forest	0	**72**	0	2	3	77
Grassland*	2	13	**433**	0	9	457
Open Water	1	0	0	**56**	0	57
Wetland	5	4	36	1	**161**	207
Total	60	89	471	60	174	854

Overall Accuracy
774/854= 91%

Producer's Accuracy (measure of omission error)			
Developed	87%	13%	omission error
Forest	81%	19%	omission error
Grassland*	92%	8%	omission error
Open Water	93%	7%	omission error
Wetland	93%	7%	omission error

User's Accuracy (measure of commission error)			
Developed	93%	7%	commission error
Forest	94%	6%	commission error
Grassland	95%	5%	commission error
Open Water	98%	2%	commission error
Wetland	78%	22%	commission error

*Remaining cropland was combined with grassland class in the 2014 image analysis.

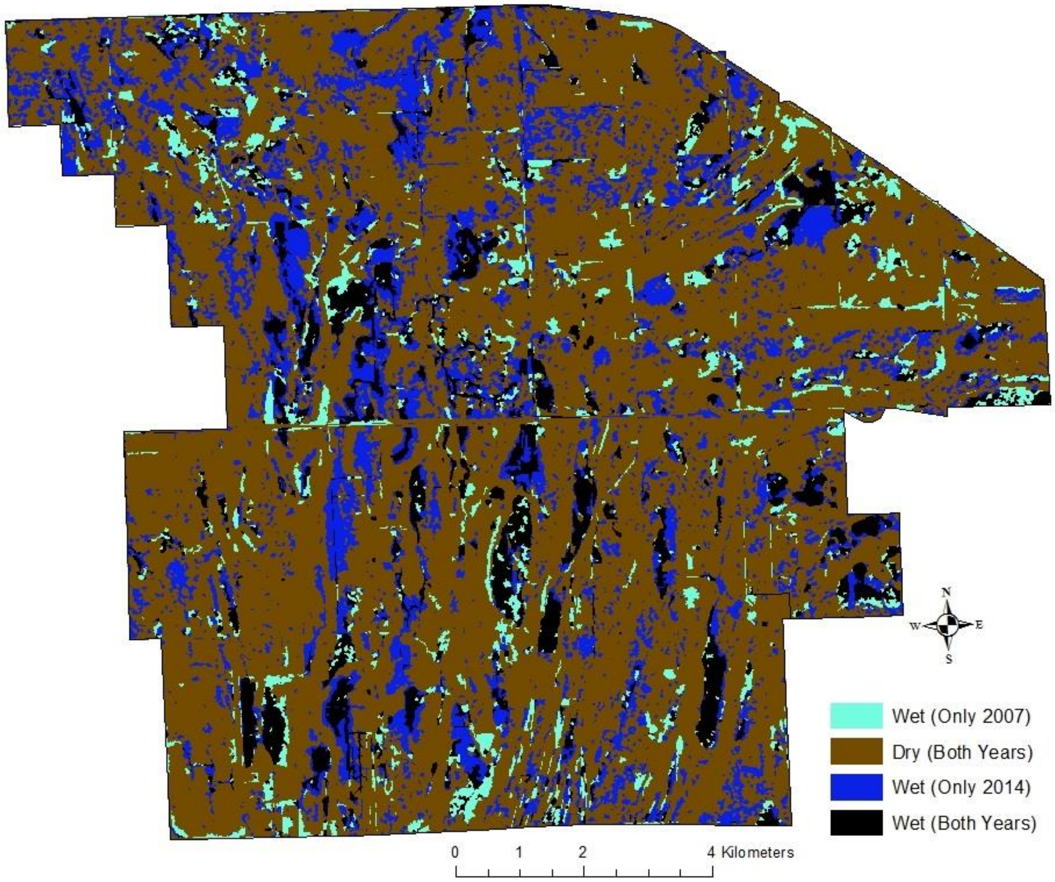


Figure 12. Spatial distribution of wetland areas that have undergone change. Wet (Both Years) objects indicate preexisting wetlands or wetlands restored prior to 2007. Wet (Only 2014) objects are assumed areas of wetland expansion occurring after 2007.

Table 7. Total classified wetland and open water objects within and outside the lateral effect zone of restored ditches according to classification year.

	2007		2014	
	(km^2)	(acres)	(km^2)	(ha)
Within Ditch Buffer	7.07	1747.04	16.48	4072.3
Outside Ditch Buffer	13.86	3424.88	20.67	5107.67
Total	20.93	5171.92	37.15	9179.96

Results of Field Validation

To validate the results, five potential wetland areas were randomly selected to visit during the summer of 2016 (Figure 13). The selected field sites were classified as wetland based on the July 22, 2014 output, but non-wetland in the June 12, 2007 output. The sites were located within a 121.92 m (400 ft.) buffer of a filled ditch and outside of a constructed wetland basin. Plant composition and structure were assessed by applying the belt transect method. Site specific data from the collection protocol are provided on Vegetation Field Monitoring Datasheets in Appendix C. The resulting field validation maps in Figures 14-18 show locations of belt transect sites, which correspond to data sheets. The field-delineated wetland boundary was based on data collected from an upland sample point and a wetland sample point; the boundary was determined between these two points (USACE 1987). Wetland Determination Data Forms corresponding to upland and wetland sample points (SP) are provided in Appendix D.

Figures 14-18 contain field data including locations of belt transect sites, wetland delineation boundaries and respective upland and wetland sample point locations. The data are overlaid on 2015 NAIP imagery and the July 22, 2014 image classification output in order to contrast automated land cover mapping and ground conditions. Locations of ditch closures and restored wetland basins are also shown in proximity to validation sites. Of the five potential wetland points selected for validation, four were confirmed to be within wetlands. Site three, shown in Figure 15, was classified as wetland but was determined to be non-wetland in the field.

According to the grassland monitoring protocol, data collected in the field is meant to detect broad trends within the landscape. Variables related to prairie structure and composition will be shared with USFWS staff. Variables are analyzed through an Access database hosted by the USFWS for biological monitoring. Data analysis serves the purpose of adaptive management modeling (Vacek et al. 2015).

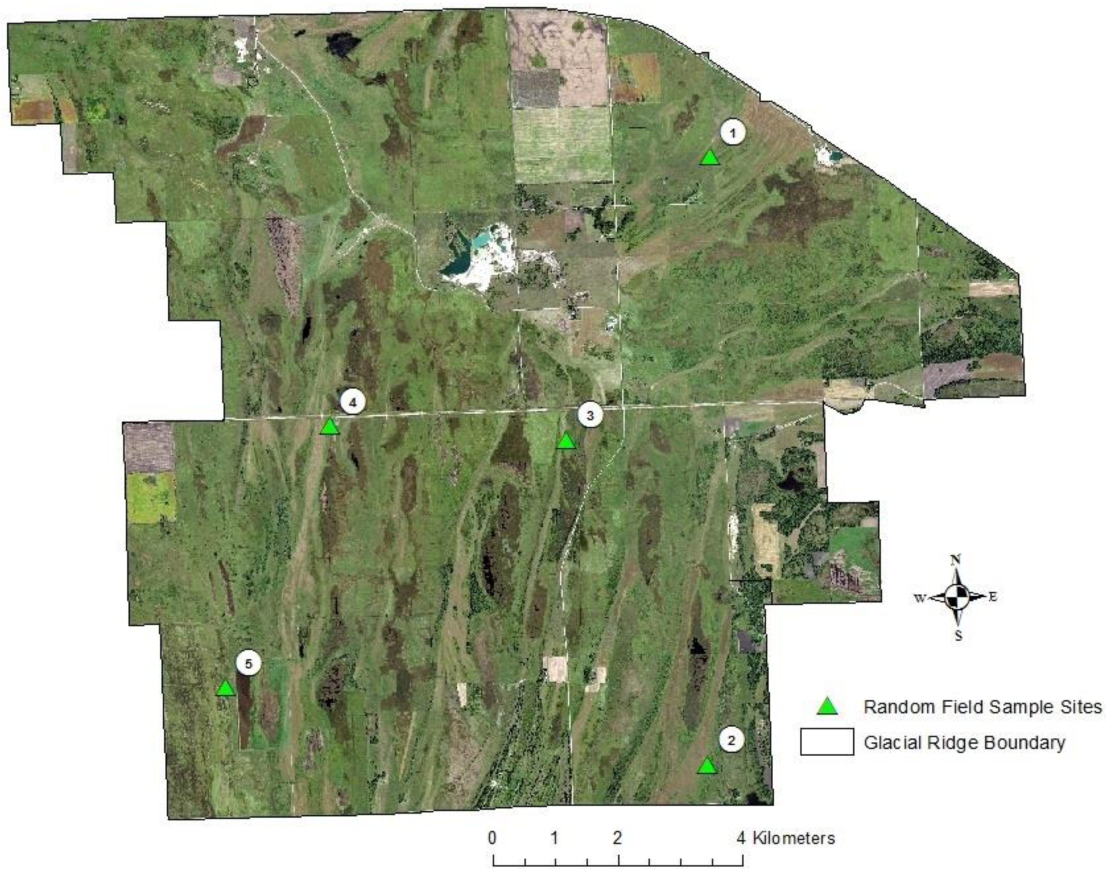


Figure 13. Randomly selected field validation sites visited to collect belt transect data and perform onsite wetland delineation. Image source: 2015 NAIP.

Vegetation composition at site one (Figure 14) was mostly invasive (50-75 percent), herbaceous grass. No quality indicators were present at site one. Invasives noted were *Phalaris arundinacea* (Reed Canary Grass), *Agrostis gigantea* (Redtop), *Poa pratensis* (Kentucky Bluegrass), and *Cirsium arvense* (Canada Thistle). Litter depth on the site ranged from 4-7 cm.

At site two (Figure 15), the vegetation composition was mostly native (50-75 percent), herbaceous grass-forbs. Native quality indicators observed were *Solidago speciosa* (Showy Goldenrod), *Solidago ptarmicoides* (White Aster-like Goldenrod), *Veronicastrum virginicum* (Culver's Root) and Zizia aptera (Heart-leaved Alexanders). Invasive species present were *Poa pratensis* (Kentucky Bluegrass), *Bromus inermis* (Smooth Brome), *Agrostis gigantea* (Redtop), *Phalaris arundinacea* (Reed Canary Grass), *Cirsium arvense* (Canada Thistle), and *Melilotus alba* (Sweet Clover). Litter depth ranged from 5-8 cm.

Vegetation composition at site three (Figure 16) consisted of mostly native (50-75 percent), herbaceous grass-forbs. Native quality indicator species included *Solidago speciosa* (Showy Goldenrod), *Sorghastrum nutans* (Indian Grass), and *Solidago ptarmicoides* (White Aster-like Goldenrod). Invasive species present were *Poa pratensis* (Kentucky Bluegrass) and *Bromus inermis* (Smooth Brome). Litter depth ranged from 4-9 cm.

At site four (Figure 16), the vegetation composition consisted of mostly native (50-75 percent), herbaceous, grass-forbs. Native quality indicator species included *Zizia aurea* (Golden Alexander), *Thalictrum dasycarpum* (Tall Meadow Rue), and *Solidago ptarmicoides* (White Aster-like Goldenrod). The most common invasive present was *Phalaris arundinacea* (Reed Canary Grass), interspersed along the transect. Litter depth ranged from 4-6 cm.

The vegetation composition at site 5 (Figure 18) comprised a mixture of mostly native (50-75 percent) herbaceous grass and grass forbs, and mostly invasive (50-75 percent grass and forbs. Native quality indicator species included *Sorghastrum nutans*

(Indian Grass), *Solidago ptarmicoides* (White Aster-like Goldenrod), and *Solidago speciosa* (Showy Goldenrod). Invasive species present in the transect include *Poa pratensis* (Kentucky Bluegrass), *Bromus inermis* (Smooth Brome), *Agrostis gigantea* (Redtop), *Phalaris arundinacea* (Reed Canary Grass), *Cirsium arvense* (Canada Thistle), and *Melilotus alba* (Sweet Clover). Litter depth ranged from 1-5 cm.

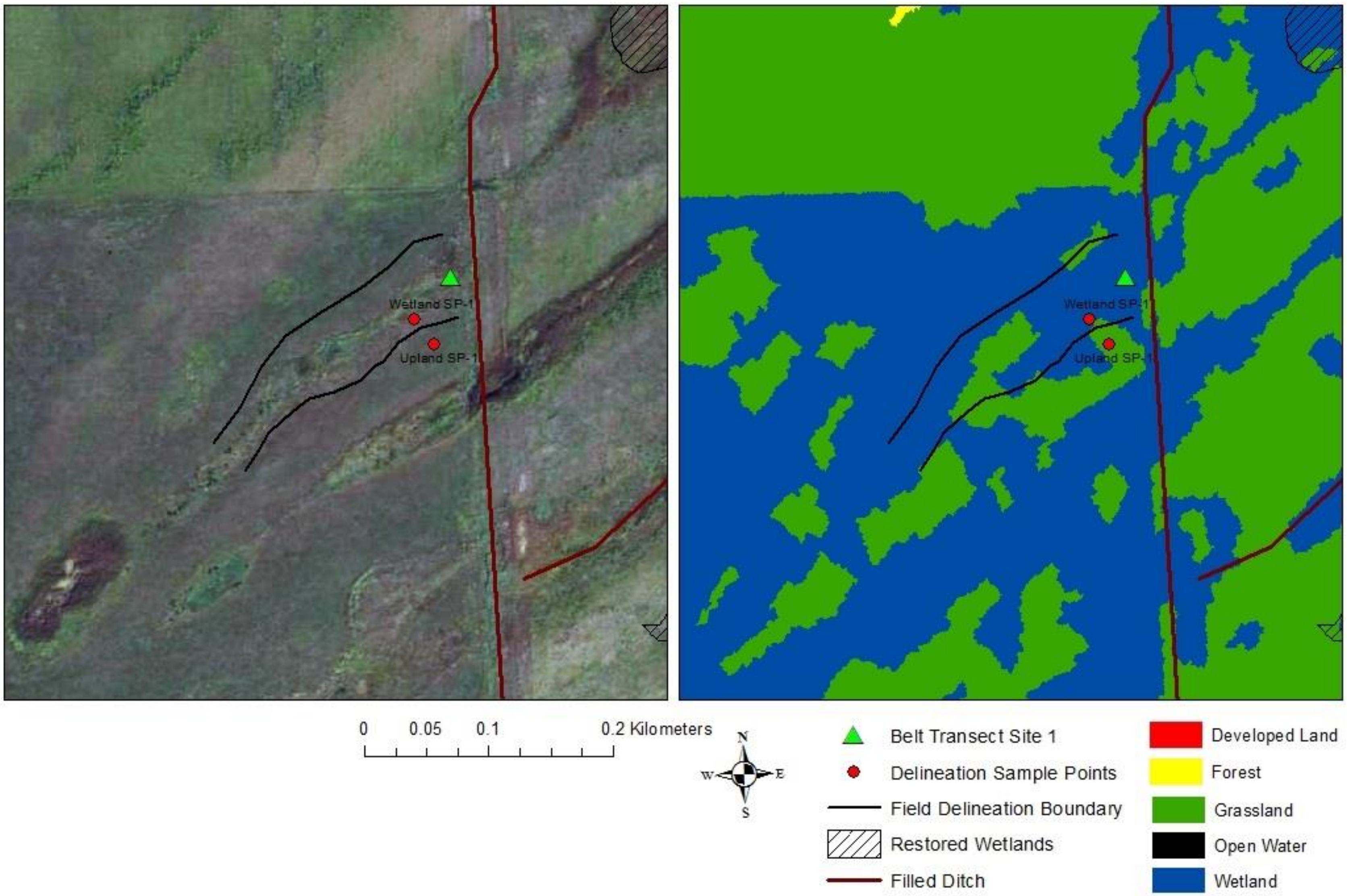


Figure 14. Field validation site one. Contrasting 2015 NAIP imagery (left) and results from the July 22, 2014 output (right).

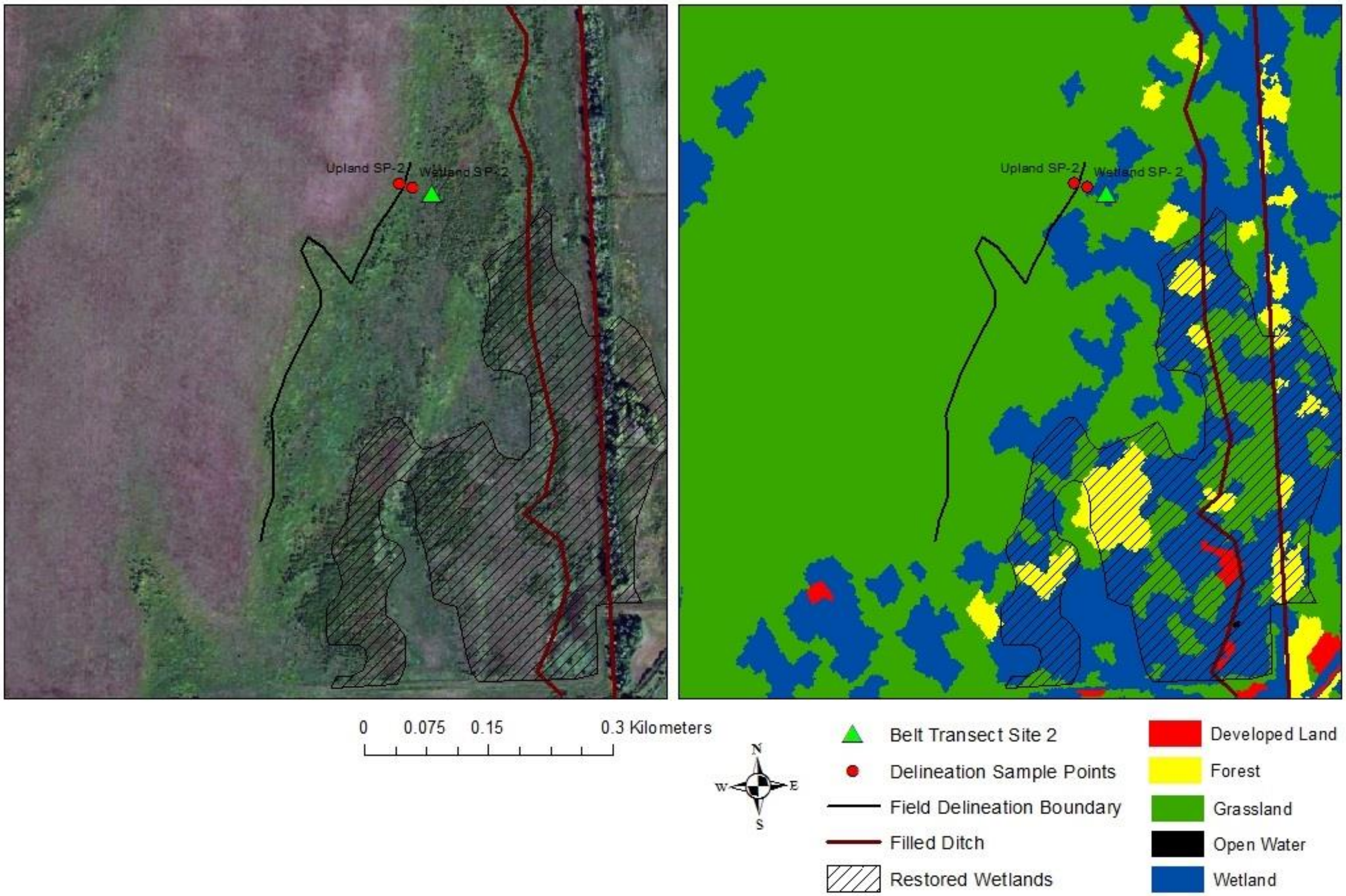


Figure 15. Field validation site two. Contrasting 2015 NAIP imagery (left) and results from the July 22, 2014 output (right).

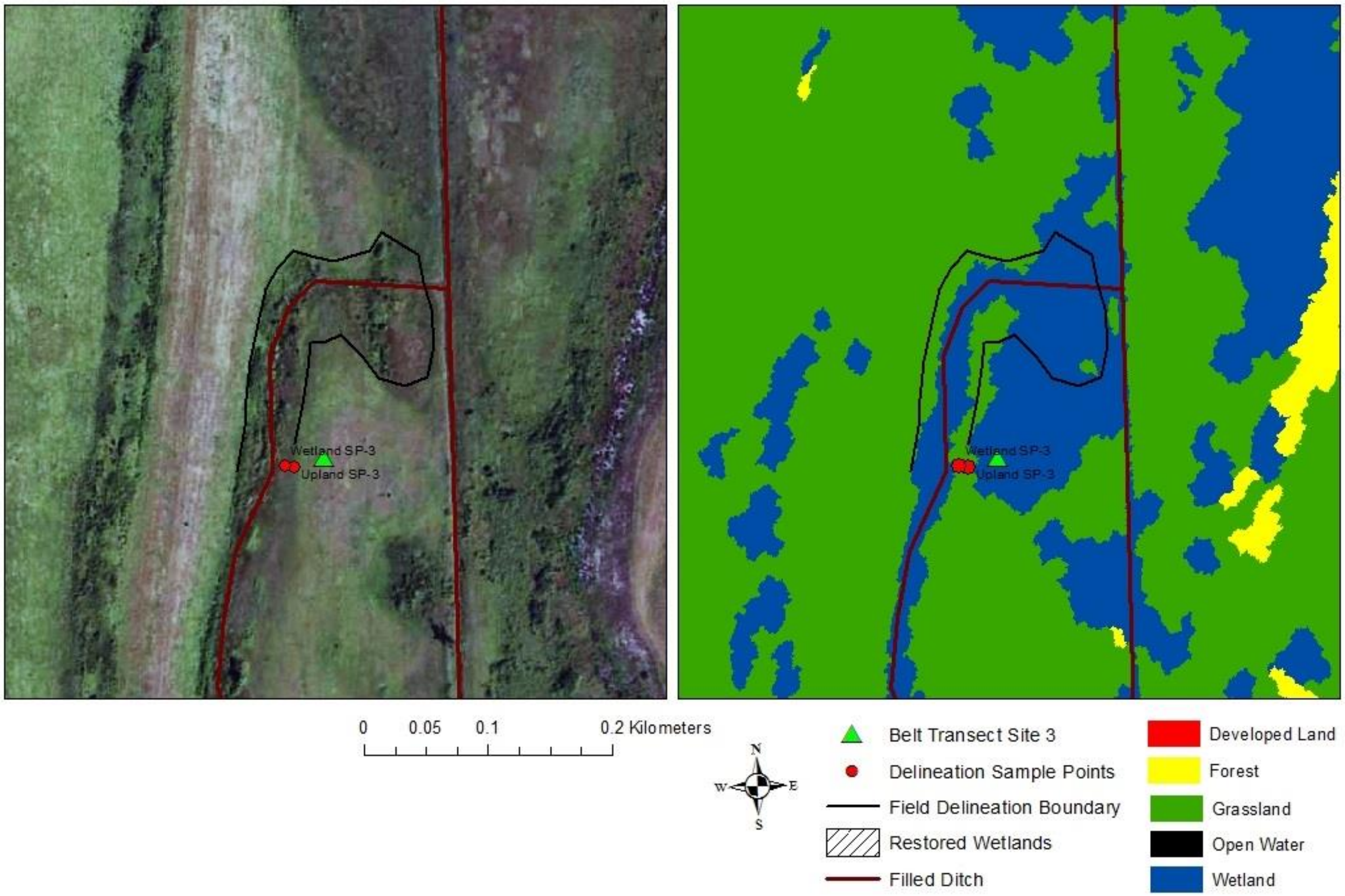


Figure 16. Field validation site three. Contrasting 2015 NAIP imagery (left) and results from the July 22, 2014 output (right).

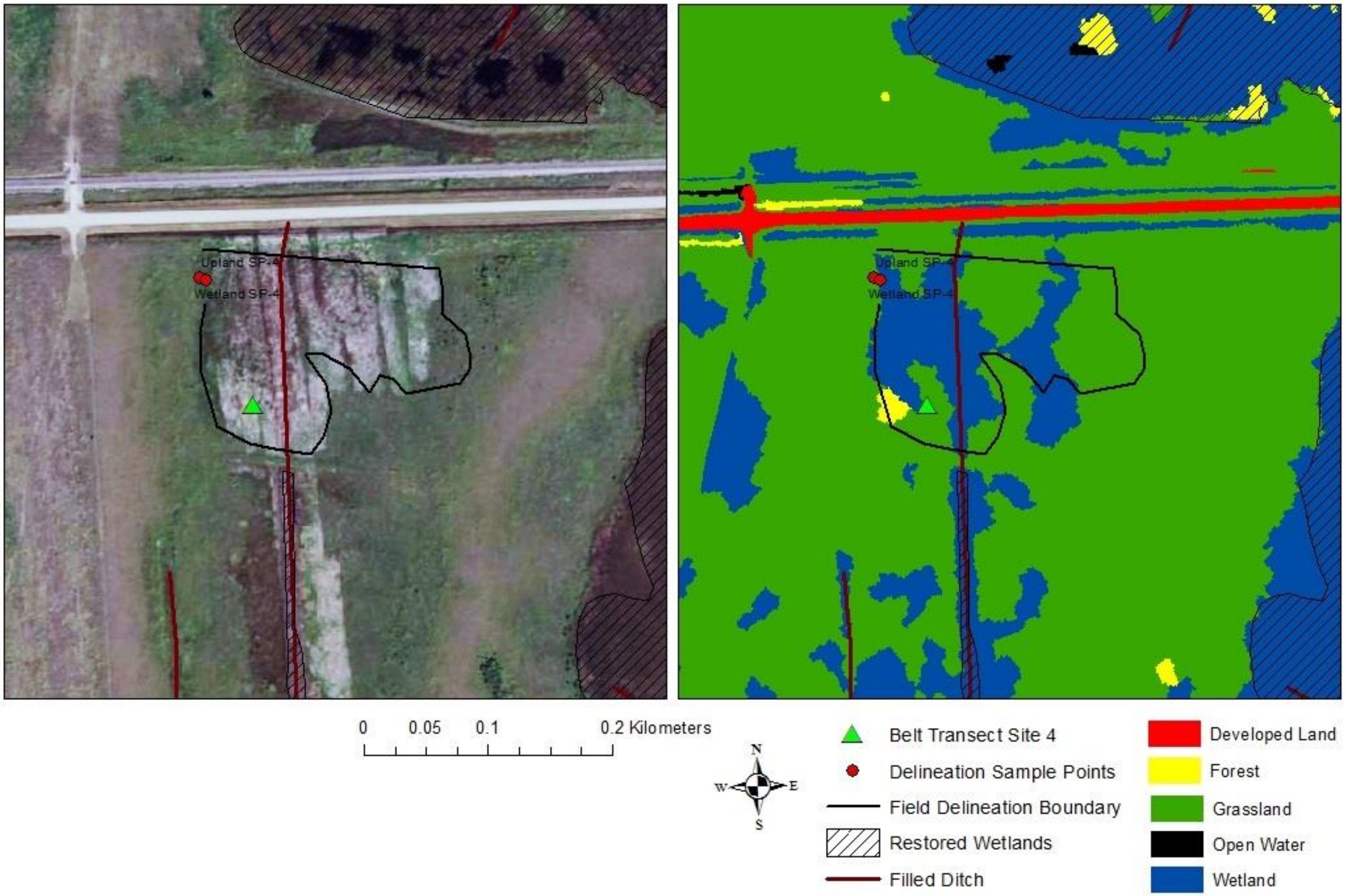


Figure 17. Field validation site four. Contrasting 2015 NAIP imagery (left) and results from the July 22, 2014 output (right).

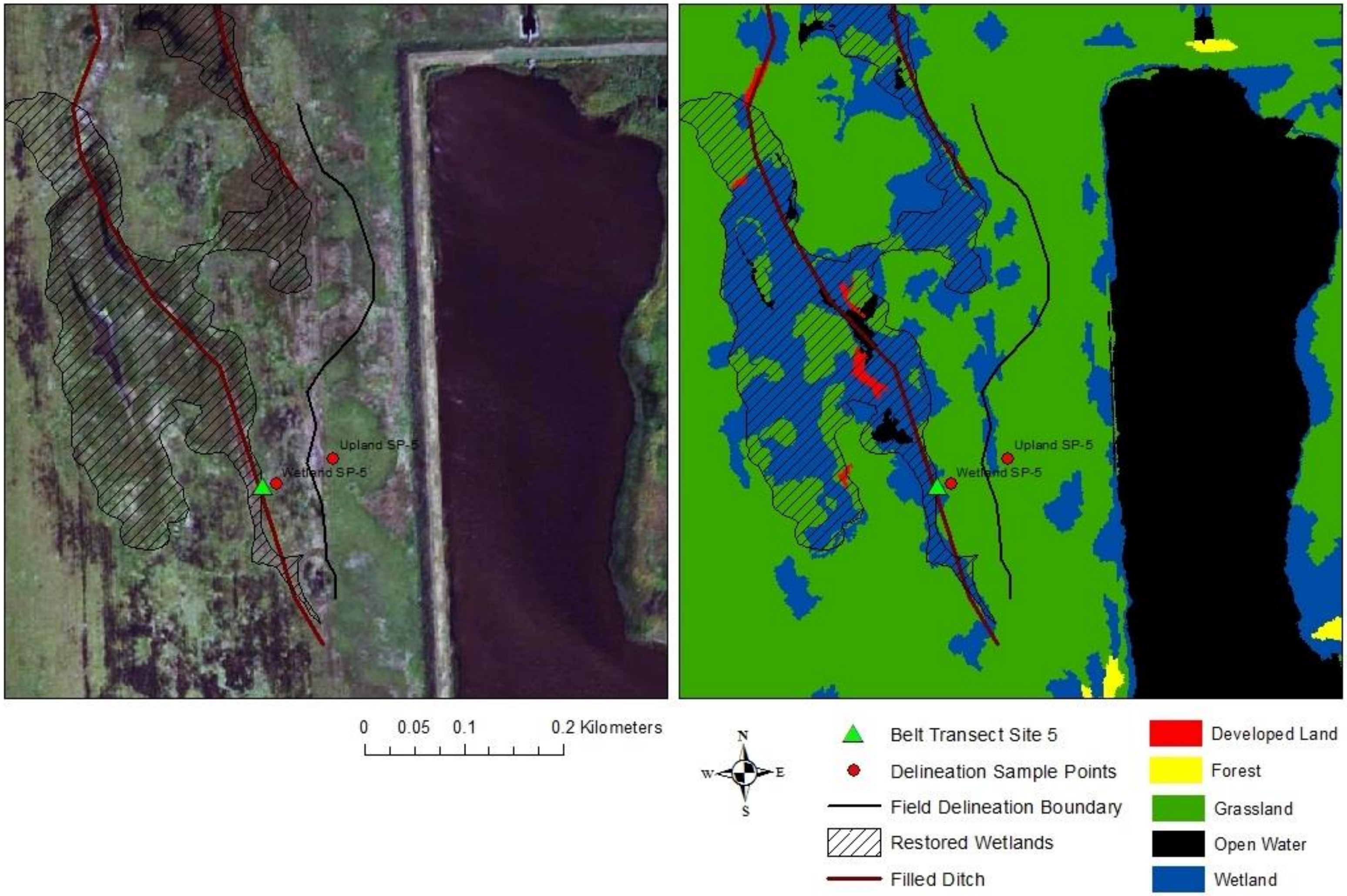


Figure 18. Field validation site five. Contrasting 2015 NAIP imagery (left) and results from the July 22, 2014 output (right).

CHAPTER V

DISCUSSION

Image Classification

This study addressed GEOBIA results of two image classifications of GRNWR that tested its potential to evaluate wetland changes with high-resolution, multispectral imagery, and non-spectral ancillary data. The image classification model that integrated spectral data, LiDAR elevation, and LiDAR derived ancillary data of slope, aspect, and TWI resulted in classifications with high overall accuracy. The incorporation of ancillary topographic data was considered to be an important addition, as vegetation distribution is highly influenced by topographic features (Kim, Madden, and Xu 2010, Moeslund et al. 2013). In this study, the segmentation with spectral bands and elevation data produced results with high overall accuracy comparable to those achieved in similar studies.

The overall accuracy for the June 12, 2007 image is 88 percent (Table 5). Results show that the accuracy of the classification varies from one land cover type to another. For example, open water achieved the lowest omission error, five percent, omitting portions of cropland and wetland. Grassland had the second lowest omission error (9 percent), omitting wetland and cropland areas. The wetland class (14 percent omission error) omitted areas of cropland and grassland. Results of user’s accuracy show developed land was correctly classified 98 percent of the time. Similarly, open water was correctly classified 97 percent of the time with a few commission errors from developed land and cropland. The classification model confused grassland areas with cropland, forest and wetland areas 11 percent of the time. The wetland class had the highest error of commission (19 percent) due to inclusions predominantly from grassland.

The July 22, 2014 classified image achieved an overall accuracy of 91 percent (Table 6). The open water class (7 percent omission error) omitted areas of forest, wetlands and developed lands. The wetland class (7 percent omission error) omitted areas of grassland, forest and developed land. The grassland class (8 percent omission error) omitted mostly wetland areas. The developed land class (13 percent omission error) omitted areas of wetland, grassland and open water. The forest class had the highest error of omission (19 percent), resulting from grassland and wetland omissions. Regarding errors of commission, open water produced the lowest result at two percent. Developed, grassland and forest classes resulted in similar commission errors at 7 percent, 6 percent and 5 percent, respectively. The wetland class had the highest commission error at 22 percent due to misclassification errors mainly of grassland.

Open water resulted in the highest classification accuracy in both images. This is consistent with surface water extraction studies, which conclude that the NIR band has a high ability to discriminate water, in which is strongly absorbed, while NIR is strongly reflected by terrestrial vegetation (Campbell and Wynne 2011). In both images, the classification accuracy assessment showed the wetland class resulted in the greatest percentage of commission (user's accuracy) error. This means that a portion of wetlands were classified by the model, yet confirmed to be grassland when compared to aerial images representing actual ground conditions. These results suggest the model slightly overestimated wetland areas, as compared with other classes.

The overestimation of wetland areas may be an effect of several conditions. In this model, wetland areas may be prone to misclassification due to data redundancy in the input variables. The topographic variables used in this study are influenced by the quality and resolution of the DEM from which they were derived. Errors within the original DEM are propagated into the subsequent data sets. Addition of the TWI may overestimate wetness conditions, as TWI is static and relies on the assumption that local slope is a proxy for the downslope hydraulic gradient which is not always the case in low relief terrain such as found in the study area. In flat terrain, the local slope tends to overestimate the downslope hydraulic gradient. In these landscapes, groundwater gradients can be significantly different from ground surface slopes (Grabs et al. 2009). The classes, as they were established, may be difficult to distinguish spectrally. Errors in classification may also result from the high spectral heterogeneity within classes due to the high spatial resolution of the imagery used and the diversity of wetland types grouped together (Laliberte et al. 2004, Platt and Rapoza 2008).

GIS Hydrological Analysis

An analysis of the landscape distribution of wetland change as a function of proximity to filled ditches offers additional insights into the class area changes. The purpose of the GIS hydrological analysis was to evaluate the impact of engineered wetlands and waterways on the distribution, location, size and temporal changes of wetlands within the GRNWR. Between 2007 and 2014 the spatial distribution of wetland area has changed. While many wetland basins had been restored and were present on the landscape in 2007, results from this analysis show wetland area increased in 2014. The increase in wetlands is evident, in many cases, spatially adjacent to existing wetlands and filled ditches.

Area occupied by wetland has increased in 2014 by 11 percent, compared to area occupied by the same class in 2007. Results of the analysis show the changes in wetland relative to proximity within and outside the ditch buffer of filled ditches. The area occupied by wetlands within the ditch buffer more than doubled from 2007 to 2014, comprising 7.07 km^2 and 16.48 km^2 respectively. Wetland area outside the ditch buffer increased significantly from 13.86 km^2 to 20.67 km^2. Recalling that the accuracy assessment revealed a slight overestimation of wetlands, results from this process are likely an overestimation of what exists on the landscape.

Analysis of monthly precipitation totals that compared 2007 with 2014 revealed there was no statistically significant difference between the years. The Palmer Hydrological Drought Index values show how monthly moisture conditions depart from normal. The index considers long-term impacts of drought on hydrological systems. In 2007, conditions leading into the growing season were below normal as compared to 2014. In both 2007 and 2014, values during the growing season return to normal levels. Evaluation of weather and climate data suggest that changes to wetland areas are likely the result of construction and restoration practices and not due to changes in climate.

Field Validation

The field validation process sought to relate image objects to real landscape features. The accuracy of the remote wetland mapping was compared with onsite wetland delineation at five random sites. The remote land cover classification showed that the model was able to predict the general distribution of wetlands although there were clear differences with precise boundaries that were delineated during the field validation process.

Four out of five sample points classified as wetland were affirmed in the field. One sample point classified as wetland was determined to be upland. None of the wetlands visited had boundaries that corresponded precisely to the remote wetland mapping results. Time and logistical constraints limited the amount of data collected consequently, partial wetland boundaries were recorded. The large size, diversity of type, and interconnectivity of wetlands observed in the field confirmed the challenges of field based wetland delineation at this scale. The field validation reveals a tradeoff between precision and practicality.

Onsite wetland delineation and belt transect methods were employed to document baseline characteristics of vegetation, soils and hydrology of selected wetlands as a way to assess the biotic and abiotic conditions of these wetlands. Plant diversity was recorded on a spectrum, which ranged from native-dominated to invasive-dominated (Vacek et al. 2015). Vegetation observed onsite was highly variable, containing mixtures of native and introduced grasses and forb species. Plant diversity was reflective of seed mixture planted and age of the restoration.

Future Research

Ancillary data layers of elevation, slope, aspect and TWI were all weighted equally in the analysis, without further exploration; it is not possible to know the contribution of each data layer in isolation. A statistical analysis of object feature properties resulting from various input layers could be conducted to better understand each source’s utility to classification; doing so would further corroborate the use of ancillary data layers.

The classification scheme was designated at a broad level. This was due to an absence of plot-level data or similar resources from which to establish a more comprehensive classification. To reduce spectral heterogeneity within classes, more refined training sample data would be beneficial. This training data would ideally be based on plot data. Collection of plot data that includes plant community types such as the Ecological Classification Systems (ECS) developed by the MN DNR and U.S. Forest Service (e.g. Northern Wet Prairie, Upland Prairie, Prairie Wet Meadow/Carr), could produce more specificity among classes, and reduce heterogeneity within classes. As the refuge moves forward with the establishment of a comprehensive system of observation points, collection of community type data would be beneficial for incorporating into future remote sensing evaluations.

CHAPTER VI

CONCLUSION

Land cover mapping of GRNWR presents challenges due to its unique geomorphology positioned on the eastern beach ridges of former glacial Lake Agassiz, land use history and restoration, expansive terrain, and high diversity of interspersed wetlands. The USFWS, managers of the complex, are concerned with understanding spatial distribution of habitats seen as critical for assessing conservation status of populations, and predicting species distributions and their response to environmental change. The USFWS seeks baseline biotic and abiotic information as a foundation to base long-term refuge planning and management and to evaluate the effectiveness of land management strategies (USFWS 2016).

This study aimed to analyze the hydrologic processes of restored prairie-wetlands on the adjacent land surface using remote sensing and Geographic Information Systems (GIS). The specific objectives of this research were to:

1. Evaluate the effect of engineered wetlands and waterways on the distribution, location, size and temporal changes of wetlands within the Glacial Ridge National Wildlife Refuge using high-resolution, multispectral imagery, and ancillary data;

2. Determine the accuracy of remote wetland mapping with onsite wetland delineation;
3. Document baseline characteristics of vegetation, soils and hydrology of selected wetlands as a way to assess the biotic and abiotic conditions of these wetlands.

The overall classification results illustrate how wetland areas have changed spatially and temporally within the study landscape. For the June 12, 2007 image, wetland area was 20.09 km^2 out of a total area of 147.3 km^2. In the July 22, 2014 image, the classification resulted in wetlands covering an area of 37.96 km^2. The accuracy assessment for the June 12, 2007 classified image resulted in an overall accuracy of 88 percent. The July 22, 2014 classified image resulted in an overall accuracy of 91 percent.

The study also attempted a GIS-based analysis to evaluate the impact of engineered wetlands and waterways on the overall changes of wetlands within the GRNWR using lateral effect as the determinant. Results of the analysis document the changes in wetland relative to proximity within and outside the buffer of filled ditches. The area occupied by wetlands within the ditch buffer more than doubled from 2007 to 2014, comprising 7.07 km^2 and 16.48 km^2 respectively. Wetland area outside the ditch buffer increased significantly from 13.86 km^2 to 20.67 km^2 during this same time period.

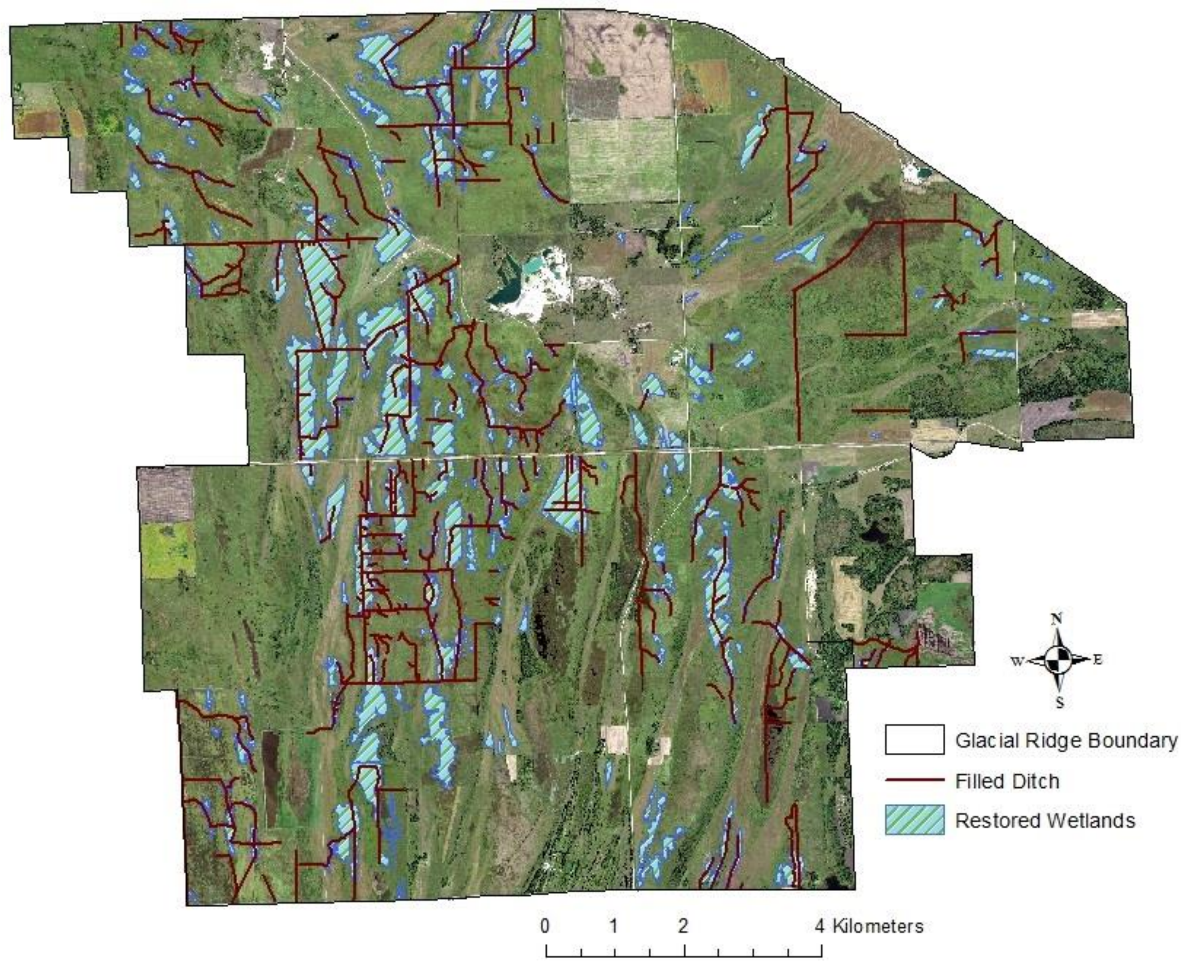
The field validation process was completed to determine the accuracy of remote wetland mapping compared with onsite wetland delineation. Four out of five transect locations classified as wetland were affirmed in the field. Plant composition and structure were assessed by applying the belt transect method. The remote land cover classification was able to predict the general distribution of wetlands although there were clear differences with precise boundaries that were delineated during the field validation process.

The GEOBIA approach to classify land cover at GRNWR and evaluate wetland change is promising. Use of GEOBIA software eCognition object-based remote mapping method, which integrated spectral and spatial properties, resulted in high overall land cover classification accuracy. A framework of integrating field-collected, plot data with remote sensing and a more refined hydro-geomorphic analysis is critical for predicting specific habitat conditions and hydrological process. This would aid a better evaluation of tallgrass prairie-wetland ecosystem dynamics.

APPENDICES

Appendix A

Map of Vector GIS Data from TNC Records



Study area, GRNWR with restoration practices including filled ditches and restored wetland basins.

Appendix B
Excerpt from Grassland Monitoring Team Standardized Monitoring Protocol Version 8

Invasive species lists.
This list was developed by Robert Dana (MCBS, 2008). Note that some species on this list are native to parts of Minnesota, but all are considered invasive threats to the integrity of a remnant tallgrass prairie plant community.

Tier 1 Invasives

Code	Common Name	Scientific Name	Old Code
ACENEG	Boxelder	*Acer negundo*	
AGRCRI	Crested Wheatgrass	*Agropyron cristatum*	
AGRGIG	Redtop	*Agrostis gigantea/stolonifera*	
ARTABS	Absinthe Sagewort	*Artemisia absinthium*	
BROANN	Annual Bromes	*B. japonicus, tectorum, secalinus*	
BROINE	Smooth Brome	*Bromus inermis*	
CARACA	Plumeless Thistle	*Carduus acanthoides*	
CARNUT	Musk Thistle	*Carduus nutans*	
CENSTO	Spotted Knapweed	*Centaurea stoebe subsp. micranthos*	CENMAC
CIRARV	Canada Thistle	*Cirsium arvense*	CIRCAN
CIRVUL	Bull Thistle	*Cirsium vulgare*	
CORVAR	Crown-vetch	*Coronilla varia*	
DAUCAR	Queen Anne's Lace	*Daucus carota*	
ELAANG	Russian Olive	*Elaeagnus angustifolia*	
ELYREP	Quack-grass	*Elytrigia repens*	
EUPESU	Leafy Spurge	*Euphorbia esula*	
FRAALN	Glossy Buckthorn	*Frangula alnus*	RHAFRA
FRAPEN	Green Ash	*Fraxinus pennsylvanica*	
JUNVIR	Eastern red cedar	*Juniperus virginiana var. virginiana*	
LEUVUL	Ox-eye Daisy	*Leucanthemum vulgare*	CHRLEU
LINVUL	Butter-and-eggs	*Linaria vulgaris*	
LONTAT	Tartarian Honeysuckle	*Lonicera tatarica*	
LOTCOR	Birdsfoot Trefoil	*Lotus corniculatus*	
MEDSAT	Alfalfa	*Medicago sativa*	
MELISP	Sweet Clovers	*Melilotus alba & officinalis*	
PASSAT	Parsnip	*Pastinaca sativa*	
PHAARU	Reed Canary-grass	*Phalaris arundinacea*	
PHLPRA	Timothy	*Phleum pratense*	
POACPX	Canada and Kentucky Bluegrass	*Poa compressa, pratensis*	
POPDEL	Cottonwood	*Populus deltoides*	
RHACAT	Common Buckthorn	*Rhamnus cathartica*	
ROBPSE	Black Locust	*Robinia pseudoacacia*	
SONARV	Sow-thistle	*Sonchus arvensis*	
TRIPRA	Red & Alsike clovers	*Trifolium pratense, hybridum*	
TRIREP	White Clover	*Trifolium repens*	

ULMAME	American Elm	*Ulmus americana*	
ULMPUM	Siberian Elm	*Ulmus pumila*	

Tier 2 Invasives

Code	Common Name	Scientific Name	Old Code
AMABLI	Prostrate Pigweed	*Amaranthus blitoides*	
ARCMIN	Burdock	*Arctium minus*	
BERINC	Hoary Alyssum	*Berteroa incana*	
CALSEP	Hedge Bindweed	*Calystegia sepium*	
CARARB	Siberian Pea-tree	*Caragana arborescens*	
CHERUB	Alkali Blite	*Chenopodium rubrum*	
CONARV	Field Bindweed	*Convolvulus arvensis*	
CRETEC	Hawk's Beard	*Crepis tectorum*	
DACGLO	Orchard Grass	*Dactylis glomerata*	
ERUGAL	Dog-mustard	*Erucastrum gallicum*	
FESELA	Meadow and Tall Fescues	*Festuca pratensis & elatior*	
GRISQU	Curly-top Gum Weed	*Grindelia squarrosa*	
KOCSCO	Summer-cypress	*Kochia scoparia*	
LAPPSP	Stickseeds	*Lappula redowski & squarrosa*	
MEDLUP	Black Medick	*Medicago lupulina*	
MORALB	White Mulberry	*Morus alba*	
NEPCAT	Catnip	*Nepeta cataria*	
PERMAC	Lady's Thumb	*Persicaria maculosa*	POLPER
PINSYL	Scotch Pine	*Pinus sylvestris*	
PLANSP	Common & American Plantains	*Plantago major & rugellii*	
POTARN	Silvery Cinquefoil	*Potentilla argentea*	
POTREC	Sulphur-flowered Cinquefoil	*Potentilla recta*	
PUCDIS	European Alkali-grass	*Puccinellia distans*	
RUMACE	Sheep Sorrel	*Rumex acetosella*	
RUMSPP	Dock	*Rumex patientia, crispus, stenophyllus*	
SALALB	White Willow	*Salix alba*	
SALTRA	Russian Thistle	*Salsola tragus*	
SAPOFF	Bouncing Bet	*Saponaria officinalis*	
SETASP	Foxtails	*Setaria glauca, viridis, faberi*	
SILCSE	Smooth Catchfly	*Silene csereii*	
SILVUL	Bladder-campion	*Silene vulgaris*	
SINARV	Charlock	*Sinapis arvensis*	
SISALT	Tumble Mustard	*Sisymbrium altissimum*	
TAROFF	Dandelion	*Taraxacum officinale*	
VERTHA	Common Mullein	*Verbascum thapsus*	
XANSTR	Cocklebur	*Xanthium strumarium*	

Native indicator species lists.
The list was developed by Robert Dana and Fred Harris (MN DNR) and includes conservative species that are sensitive to grazing and easily identified.

Tier 1 Natives

Code	Common Name(s)	Scientific Name	Old Code
AMOCAN	Leadplant	*Amorpha canescens*	
ANEPAT	Pasque Flower	*Anemone patens*	
ASTCRA	Ground Plum, Buffalo-bean	*Astragalus crassicarpus*	
CALSER	Toothed Evening Primrose	*Calylophus serrulatus*	
CORPAL	Bird's Foot Coreopsis	*Coreopsis palmata*	
DALCAN	White Prairie Clover	*Dalea candida*	
DALPUR	Purple Prairie Clover	*Dalea purpurea*	
ECHANG	Narrow-leaved Purple Coneflower	*Echinacea angustifolia*	ECHPAL
HELAUT	Sneezeweed	*Helenium autumnale*	
HEURIC	Alum Root	*Heuchera richardsonii*	
LIAASP	Rough Blazing Star	*Liatris aspera*	
LIALIG	Northern Plains Blazing Star	*Liatris ligulistylis*	
LIAPUN	Dotted Blazing Star	*Liatris punctata*	
LIAPYC	Great Blazing Star	*Liatris pycnostachya*	
LILPHI	Wood Lily	*Lilium philadelphicum*	
LYSQUA	Prairie Loosestrife	*Lysimachia quadriflora*	
PEDESC	Prairie Turnip	*Pediomelum esculentum*	
PHLPIL	Prairie Phlox	*Phlox pilosa*	
POTARGU	Tall Cinquefoil	*Potentilla arguta*	
PRERAC	Smooth Rattlesnakeroot	*Prenanthes racemosa*	
SYMSER	Silky Aster	*Symphyotrichum sericeum*	ASTSER
TRABRA	Bracted Spiderwort	*Tradescantia bracteata*	
ZIGELE	White Camas	*Zigadenus elegans*	
ZIZAPT	Heart-leaved Alexanders	*Zizia aptera*	
ZIZAUR	Golden Alexanders	*Zizia aurea*	

Tier 2 Natives

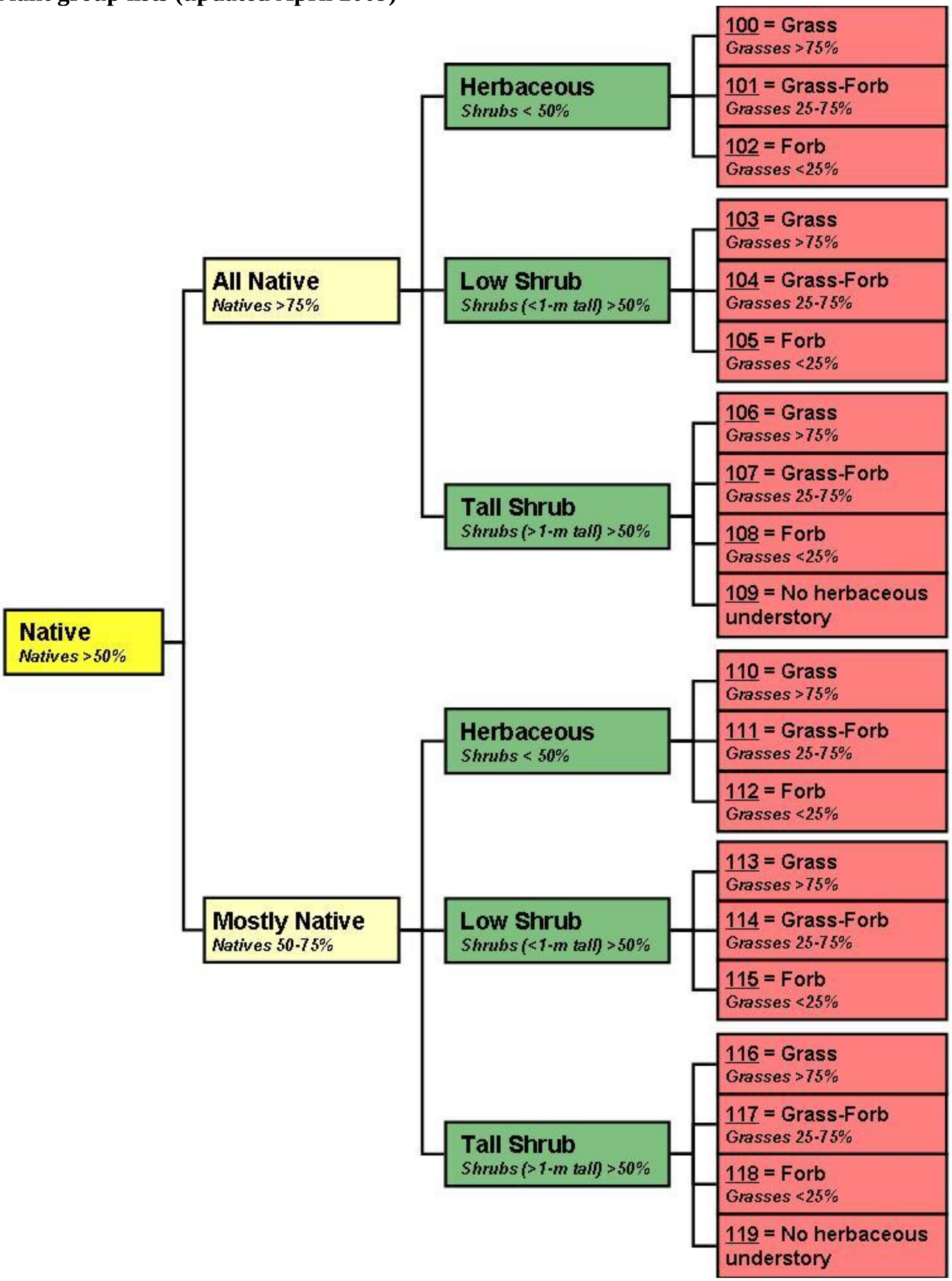
Code	Common Name(s)	Scientific Name	Old Code
AGOGLA	Glaucus False Dandelion	*Agoseris glauca*	
AMONAN	Fragrant False Indigo	*Amorpha nana*	
ASCOVA	Oval-leaved Milkweed	*Asclepias ovalifolia*	
ASCSPE	Showy Milkweed	*Asclepias speciosa*	
ASCTUB	Butterfly Weed	*Asclepias tuberosa*	
ASTADS	Prairie Milk Vetch	*Astragalus adsurgens*	
CARFIL	Thread-leaved Sedge	*Carex filifolia*	
CASSES	Downy Paintbrush	*Castilleja sessiliflora*	
DELCAR	Prairie Larkspur	*Delphinium carolinianum subsp. virescens*	DELVIR
DICLEI	Leiberg's Panic Grass	*Dichanthelium leibergii*	PANLEI
DOEUMB	Flat-topped Aster	*Doellingeria umbellata*	ASTUMB

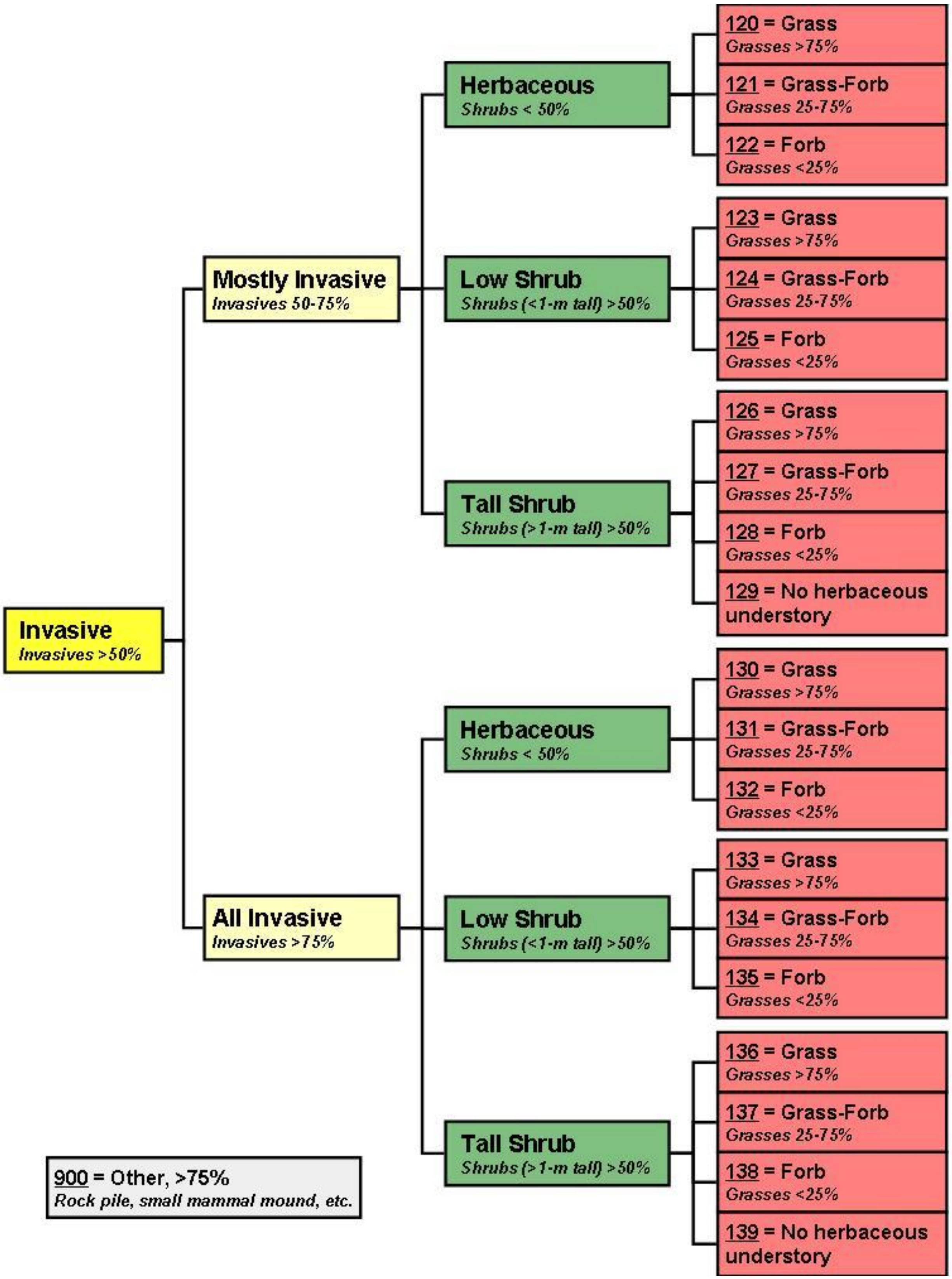
GAIARI	Blanket Flower	*Gaillardia aristata*	
GENPUB	Downy Gentian	*Gentiana puberulenta*	
LATVEN	Veiny Pea	*Lathyrus venosus*	
LIACYL	Few-headed Blazing Star	*Liatris cylindracea*	
LYTALA	Winged Loosestrife	*Lythrum alatum*	
MUHCUS	Plains Muhly	*Muhlenbergia cuspidata*	
PEDLAN	Swamp Lousewort	*Pedicularis lanceolata*	
SILLAC	Compass Plant	*Silphium laciniatum*	
SOLPTA	White Aster-like Goldenrod	*Solidago ptarmicoides*	
SOLRID	Riddell's Goldenrod	*Solidago riddellii*	
SOLSPE	Showy Goldenrod	*Solidago speciosa*	
SORNUT	Indian Grass	*Sorghastrum nutans*	
SPOHET	Prairie Dropseed	*Sporobolus heterolepis*	
SYMLAE	Smooth Blue Aster	*Symphyotrichum laeve var. laeve*	ASTLAE
SYMOBL	Aromatic Aster	*Symphyotrichum oblongifolium*	ASTOBL
SYMOOL	Sky-blue Aster	*Symphyotrichum oolentangiense*	ASTOOL
SYNNOV	New England Aster	*Symphyotrichum novae-angliae*	ASTNOV
THADAS	Tall Meadow-rue	*Thalictrum dasycarpum*	
VERVIR	Culver's Root	*Veronicastrum virginicum*	

Distubrance increaser indicator species list.

Code	**Common name**	**Scientific Name**	**Old Code**
ACHMIL	Yarrow	*Achillea millefolium*	
AMBART	Ragweed	*Ambrosia artemisiifolia*	
AMBTRI	Giant Ragweed	*Ambrosia trifida*	
BECSYZ	American Sloughgrass	*Beckmannia syzigachne*	
CONCAN	Horseweed	*Conyza canadensis*	
CYCXAN	Marsh-elder	*Cyclachaena xanthifolia*	IVAXAN
HORJUB	Foxtail Barley	*Hordeum jubatum*	
JUNARC	Baltic Rush	*Juncus arcticus (balticus)*	
LEPDEN	Prairie Pepperweed	*Lepidium densiflorum*	
PANCAP	Witchgrass	*Panicum capillare*	
PLAPAT	Wooly Plantain	*Plantago patagonica*	
RANCYM	Seaside Crowfoot	*Ranunculus cymbalaria*	
SCIPAL	Pale Bulrush	*Scirpus pallidus*	

Plant group lists (updated April 2009)




Invasive
Invasives >50%
Mostly Invasive
Invasives 50-75%
All Invasive
Invasives >75%
Herbaceous
Shrubs < 50%
Low Shrub
Shrubs (<1-m tall) >50%
Tall Shrub
Shrubs (>1-m tall) >50%
Herbaceous
Shrubs < 50%
Low Shrub
Shrubs (<1-m tall) >50%
Tall Shrub
Shrubs (>1-m tall) >50%
120 = Grass
Grasses >75%
121 = Grass-Forb
Grasses 25-75%
122 = Forb
Grasses <25%
123 = Grass
Grasses >75%
124 = Grass-Forb
Grasses 25-75%
125 = Forb
Grasses <25%
126 = Grass
Grasses >75%
127 = Grass-Forb
Grasses 25-75%
128 = Forb
Grasses <25%
129 = No herbaceous understory
130 = Grass
Grasses >75%
131 = Grass-Forb
Grasses 25-75%
132 = Forb
Grasses <25%
133 = Grass
Grasses >75%
134 = Grass-Forb
Grasses 25-75%
135 = Forb
Grasses <25%
136 = Grass
Grasses >75%
137 = Grass-Forb
Grasses 25-75%
138 = Forb
Grasses <25%
139 = No herbaceous understory
900 = Other, >75%
Rock pile, small mammal mound, etc.

: VEGETATION FIELD MONIOTORING DATASHEET

N-S Transect

Plot	1	Plot		Plot		Plot	
Point	1	Point		Point		Point	
Date	9-11-16	Date		Date		Date	
Observer	Engelmann	Observer		Observer		Observer	
Aspect		Aspect		Aspect		Aspect	
Slope		Slope		Slope		Slope	
Bering		Bering		Bering		Bering	

	Plant Group Score		Tier 1 Invasives			Quality Indicators		Litter depth
0.5	130	0.5	PHAARU	D	0.5		0.5	
1	130	1	PHAARU	D	1		1	
1.5	130	1.5	PHAARU	D	1.5		1.5	
2	120	2	PHAARU	D	2		2	
2.5	120	2.5		D	2.5		2.5	
3	120	3		D	3		3	
3.5	120	3.5		D	3.5		3.5	
4	120	4		D	4		4	
4.5	120	4.5		D	4.5		4.5	
5	120	5		D	5		5	Standing water
5.5	120	5.5		D	5.5		5.5	
6	120	6		D	6		6	
6.5	120	6.5		D	6.5		6.5	
7	120	7		D	7		7	
7.5	120	7.5		D	7.5		7.5	
8	120	8		D	8		8	
8.5	120	8.5	" "	D	8.5		8.5	
9	120	POACPX 9	AGRGIG	D	9		9	
9.5	120	POACPX 9.5	PHAARU, AGRGIG	D	9.5		9.5	
10	120	10	" "	D	10		10	7cm
10.5	120	10.5	" "	D	10.5		10.5	
11	120	11	AGRGIG, POACPX	D	11		11	
11.5	120	11.5	" "	D	11.5		11.5	
12	120	12	" "	D	12		12	
12.5	120	12.5	POACPX	D	12.5		12.5	
13	120	13		D	13		13	
13.5	120	13.5		D	13.5		13.5	
14	120	14		D	14		14	
14.5	110	14.5	" "	P	14.5		14.5	
15	110	15		P	15		15	5cm
15.5	110	15.5		P	15.5		15.5	
16	110	16		P	16		16	
16.5	110	16.5		P	16.5		16.5	
17	110	17		P	17		17	
17.5	110	17.5		P	17.5		17.5	
18	110	18	" "	P	18		18	
18.5	110	18.5	POACPX, CIRARV	P	18.5		18.5	
19	110	19	POACPX	P	19		19	
19.5	110	19.5	CIRARV-P, POACPX-P		19.5		19.5	
20	110	20	" "		20		20	6cm
20.5	110	20.5	POACPX-P		20.5		20.5	
21	110	21	" " - P		21		21	
21.5	111	21.5	POACPX P		21.5		21.5	
22	111	22	PHAARU D, CIRARV		22		22	
22.5	120	22.5	PHAARU	P	22.5		22.5	
23	110	23		P	23		23	
23.5	120	23.5		D	23.5		23.5	
24	120	24		D	24		24	
24.5	120	24.5		D	24.5		24.5	
25	120	25	" "	D	25		25	4cm

Photo 1 - S
2 - N

VOR
E - 32.5cm
N - 40cm
W - 65cm
S - 32.5cm

Transect 2 N-S

Photo 1 - N
2 - S

VEGETATION FIELD MONIOTORING DATASHEET

Plot	2	Plot		Plot		Plot	
Point	2	Point		Point		Point	
Date	9-11-16	Date		Date		Date	
Observer	KME	Observer		Observer		Observer	
Aspect	—	Aspect		Aspect		Aspect	
Slope	—	Slope		Slope		Slope	
Bering	—	Bering		Bering		Bering	

VOR
W = 95cm
S = 50cm
E = 42.5cm
N = 45cm

	PGS		Invasive		Native		Litter
0.5	111	0.5	4 P	0.5	SOLPTA	0.5	
1	111	1	3/4 P	1	SOLSPE	1	
1.5	111	1.5	3/4 P	1.5	VERVIR	1.5	
2	111	2	3/4 P	2	ZIZAPT	2	
2.5	111	2.5	3/4 P	2.5		2.5	
3	111	3	3/4 P	3		3	
3.5	111	3.5	3/4 P	3.5		3.5	
4	111	4	3/4 P	4		4	
4.5	111	4.5	3/4 P	4.5		4.5	
5	111	5	3/4 P	5		5	5cm
5.5	111	5.5	3/4 P	5.5		5.5	
6	111	6	3/4 P	6		6	
6.5	111	6.5	3/4 P	6.5		6.5	
7	111	7	3/4 P	7		7	
7.5	111	7.5	3/4 P	7.5		7.5	
8	111	8	3/4 P	8		8	
8.5	111	8.5	3/4 P	8.5		8.5	
9	111	9	3/4 P	9		9	
9.5	111	9.5	3/4 P	9.5		9.5	
10	111	10	3/4 P	10		10	6cm
10.5	111	10.5	3/4 P	10.5		10.5	
11	111	11	3/4 P	11		11	
11.5	111	11.5	3/4 P	11.5		11.5	
12	111	12	3/4 P	12		12	
12.5	111	12.5	3/4 P	12.5		12.5	
13	111	13	3/4 P	13		13	
13.5	111	13.5	3/4 P	13.5		13.5	
14	111	14	3/4 P	14		14	
14.5	111	14.5	3/4 P	14.5		14.5	
15	111	15	3/4 P	15		15	8cm
15.5	111	15.5	3/4 P	15.5		15.5	
16	120	16	3/4 P	16		16	
16.5	120	16.5	34 D	16.5		16.5	
17	120	17	30 4P	17		17	
17.5	120	17.5	3 4 P	17.5		17.5	
18	111	18	3/4 P	18		18	
18.5	111	18.5	3 4 D	18.5		18.5	
19	121	19	3,4 D	19		19	
19.5	121	19.5	3,4 D	19.5		19.5	
20	111	20	3/4 P	20		20	5cm
20.5	111	20.5	3/4 P	20.5		20.5	
21	111	21	3/4 P	21		21	
21.5	111	21.5	3/4 P	21.5		21.5	
22	111	22	3/4 P	22		22	
22.5	111	22.5	3/4 P	22.5		22.5	
23	111	23	3/4 P	23		23	
23.5	111	23.5	3/4 P	23.5		23.5	
24	111	24	3/4 P	24		24	
24.5	111	24.5	3/4 P	24.5		24.5	
25	111	25	3/4 P	25		25	5cm

POACPX = 1
BROINE = 2
AGRGIG = 3
PHAARU = 4
CIRCAN = 5
~~[illegible]~~
MELISP = 6

*UPLAND

Transect 3 EW

VOR Reading

VEGETATION FIELD MONIOTORING DATASHEET

Photo 1 = W
2 = E

S=57.5cm
E=42.5cm
N=25cm
W=65cm

Plot	3
Point	3
Date	9/11/16
Observer	Engelmann
Aspect	—
Slope	—
Bering	—

Plot	
Point	
Date	
Observer	
Aspect	
Slope	
Bering	

Plot	
Point	
Date	
Observer	
Aspect	
Slope	
Bering	

Plot	
Point	
Date	
Observer	
Aspect	
Slope	
Bering	

	Plant Cover Score		Invasives		Quality Indicators		Litter Depth
0.5	111	0.5	1P	0.5	SOLSPE	0.5	
1	111	1	1P	1	SORNUT	1	
1.5	111	1.5	1P	1.5	SOLPTA	1.5	
2	111	2	1P	2		2	
2.5	112	2.5	1P	2.5		2.5	
3	111	3	1P	3		3	
3.5	111	3.5	1P	3.5		3.5	
4	111	4	1D	4		4	
4.5	120	4.5	1D	4.5		4.5	
5	120	5	1D	5		5	4cm
5.5	111	5.5	1P	5.5		5.5	
6	111	6	1P	6		6	
6.5	111	6.5	1P	6.5		6.5	
7	111	7	1P	7		7	
7.5	111	7.5	1P	7.5		7.5	
8	121	8	1D	8		8	
8.5	121	8.5	1D	8.5		8.5	
9	121	9	1D	9		9	
9.5	111	9.5	1P	9.5		9.5	
10	111	10	1P	10		10	4cm
10.5	121	10.5	2D	10.5		10.5	
11	120	11	2D	11		11	
11.5	111	11.5	1,2 P	11.5		11.5	
12	111	12	1,2 P	12		12	
12.5	111	12.5	1,2 P	12.5		12.5	
13	111	13	1,2 P	13		13	
13.5	111	13.5	1,2 P	13.5		13.5	
14	111	14	1P	14		14	
14.5	111	14.5	1P	14.5		14.5	
15	112	15	1P	15		15	5cm
15.5	111	15.5	1P	15.5		15.5	
16	111	16	1P	16		16	
16.5	111	16.5	1P	16.5		16.5	
17	111	17	1P	17		17	
17.5	111	17.5	1P	17.5		17.5	
18	111	18	1P	18		18	
18.5	111	18.5	1P	18.5		18.5	
19	111	19	1P	19		19	
19.5	111	19.5	1P	19.5		19.5	
20	101	20		20		20	9cm
20.5	101	20.5		20.5		20.5	
21	101	21		21		21	
21.5	111	21.5	1P	21.5		21.5	
22	111	22	1P	22		22	
22.5	111	22.5	1P	22.5		22.5	
23	111	23	1P	23		23	
23.5	111	23.5	1P	23.5		23.5	
24	111	24	1P	24		24	
24.5	111	24.5	1P	24.5		24.5	
25	111	25	1P	25		25	9cm

POACPY=1
BROINE=2

VEGETATION FIELD MONIOTORING DATASHEET Transect 4 (East-West)

Plot	4	1		
Point	41	1		
Date	9-11-2016			
Observer	Engelmann			
Aspect				
Slope				
Bering				

Point	Plant Group Score	Tier 1 Invasives		Quality Indicators	Litter Depth / VOR Reading
0.5	110	PHAARU	P		
1	120	PHAARU	D		
1.5	110	PHAARU	P		
2	120	PHAARU	D		
2.5	111	PHA ARU	D		
3	120	PHAARU	P		
3.5	110	PHAARU	P		
4	110	PHA ARU	P		
4.5	110				
5	100				4cm
5.5	100				
6	100				
6.5	101				
7	111	PHA ARU	P		
7.5	110	PHA ARU	P		
8	120	PHAARU	P		
8.5	120	PHAARU	D		
9	120	PHAARU	D		
9.5	120	PHA ARU	D		
10	120	PHAARU	D		6cm
10.5	110	PHAARU	P		
11	120	PHA ARU	D		
11.5	100				
12	101				
12.5	101			ZIZAUR	
13	101			ZIZAUR	
13.5	111	PHAARU	P		
14	101				
14.5	101			ZIZAUR	
15	101			ZIZAUR	4cm
15.5	101				
16	101			ZIZAUR	
16.5	101				
17	102				
17.5	121	PHAARU	D		
18	111	PHAARU	P	THADAS	
18.5	101				
19	111	PHA ARU	P		
19.5	111	PHAARU	P		
20	111	PHA ARU	P		4cm
20.5	111			ZIZAUR	
21	120	AGRGIG	D		
21.5	121	PHAARU	D		
22	111			ZIZAUR, SOLPTA	
22.5	121	PHAARU	D		
23	111	PHA ARU	P		
23.5	102				
24	101				
24.5	101				
25	101				4cm

VOR
East - 30cm
North - 80cm
West - 55cm
South - 52.5cm

VEGETATION FIELD MONIOTORING DATASHEET

Transect E-W

Plot	5
Point	5
Date	9-11-16
Observer	Engelman
Aspect	—
Slope	—
Bering	—

Photo 1-E
2-W

VOR-#
N=35
W=37.5cm
S=37.5
E=40cm

Point	Plant Group Score	Tier 1 Invasives	Quality	Litter depth
0.5	120	4D	SORNUT	
1	120	4D	SOLPTA	
1.5	120	4D	SOLSPE	
2	120	4D		
2.5	120	4D		
3	120	4D		
3.5	120	4D		
4	120	3/4D		
4.5	110	3/4 P		
5	110	3/4 P		5cm
5.5	120	1/3 P		
6	110	1,3 P		
6.5	110	1,3 P		
7	110	1,3 P		
7.5	110	1,3 P		
8	110	1P		
8.5	110	1P		
9	110	1P		
9.5	111	1P		
10	111	1P		4cm
10.5	111	1P		
11	111	1P		
11.5	111	1P		
12	111	1P		
12.5	111	1P		
13	111	1P		
13.5	111	1P		
14	120	1,3P		
14.5	120	1,3 P		
15	111	3P		1cm
15.5	111	1P		
16	111	1P		
16.5	111	1P		
17	111	1P		
17.5	111	1P		
18	111	1P		
18.5	111	1P		
19	122	6P, 4D		
19.5	122	6D, 4P		
20	122	6D 4P		1cm
20.5	122	5/6 D		
21	122	6D		
21.5	122	6D		
22	122	6D		
22.5	120	4/5D P		
23	120	4D		
23.5	110	4D		
24	110	4P		
24.5	110	4P		
25	110	4P		4cm

POACPV=1
BROINE=2
AGRGIG=3
PHAARU=4
CIRCAN=5
MELISP=6

Appendix D
Field Data Sheets: Wetland Determination Data Form

WETLAND DETERMINATION DATA FORM – Great Plains Region

Project/Site: Transect 1 City/County: Polk Sampling Date: 9/17/16

Applicant/Owner: USFWS State: MN Sampling Point: Upland SP-1

Investigator(s): K. Engelmann Section, Township, Range: ______

Landform (hillslope, terrace, etc.): T. S. Local relief (concave, convex, none): concave Slope (%): 0-2%

Subregion (LRR): ______ Lat: ______ Long: ______ Datum: ______

Soil Map Unit Name: Karlsruhe Sandy Loam NWI classification: None

Are climatic / hydrologic conditions on the site typical for this time of year? Yes ____ No ✓ (If no, explain in Remarks.)

Are Vegetation ____, Soil ____, or Hydrology ____ significantly disturbed? Are "Normal Circumstances" present? Yes ✓ No ____

Are Vegetation ____, Soil ____, or Hydrology ____ naturally problematic? (If needed, explain any answers in Remarks.)

SUMMARY OF FINDINGS – Attach site map showing sampling point locations, transects, important features, etc.

Hydrophytic Vegetation Present? Yes ✓ No ____ Hydric Soil Present? Yes ____ No ✓ Wetland Hydrology Present? Yes ✓ No ____	Is the Sampled Area within a Wetland? Yes ✓ No ____

Remarks: Wetter than average conditions

VEGETATION – Use scientific names of plants.

Tree Stratum (Plot size: ______)	Absolute % Cover	Dominant Species?	Indicator Status
1.			
2.			
3.			
4.			
= Total Cover			
Sapling/Shrub Stratum (Plot size: ______)			
1.			
2.			
3.			
4.			
5.			
= Total Cover			
Herb Stratum (Plot size: 5')			
1. Panicum virgatum	25	Y	FAC
2. Agrostis gigantea	20	Y	FACW
3. Poa pratensis	20	Y	FAC
4. Symphyotrichum ericoides	5	N	FACU
5. Phalaris arundinacea	5	N	FACW
6. Rudbeckia hirta	5	N	FACU
7. Symphyotrichum lanceolatum	5	N	FAC
8. Solidago canadensis	5	N	FACU
9. Solidago gigantea	5	N	FACW
10. Helianthus maximiliani	2	N	FACU
= Total Cover	97		
Woody Vine Stratum (Plot size: ______)			
1.			
2.			
= Total Cover			
% Bare Ground in Herb Stratum ______			

50% = 48.5

20% = 19.4

Dominance Test worksheet:

Number of Dominant Species That Are OBL, FACW, or FAC (excluding FAC−): 3 (A)

Total Number of Dominant Species Across All Strata: 3 (B)

Percent of Dominant Species That Are OBL, FACW, or FAC: 100 (A/B)

Prevalence Index worksheet:

Total % Cover of:		Multiply by:
OBL species	______	x 1 = ______
FACW species	______	x 2 = ______
FAC species	______	x 3 = ______
FACU species	______	x 4 = ______
UPL species	______	x 5 = ______
Column Totals:	______ (A)	______ (B)

Prevalence Index = B/A = ______

Hydrophytic Vegetation Indicators:

- ___ 1 - Rapid Test for Hydrophytic Vegetation
- ✓ 2 - Dominance Test is >50%
- ___ 3 - Prevalence Index is ≤3.0[1]
- ___ 4 - Morphological Adaptations[1] (Provide supporting data in Remarks or on a separate sheet)
- ___ Problematic Hydrophytic Vegetation[1] (Explain)

[1]Indicators of hydric soil and wetland hydrology must be present, unless disturbed or problematic.

Hydrophytic Vegetation Present? Yes ✓ No ____

Remarks:

US Army Corps of Engineers Great Plains – Version 2.0

SOIL

Sampling Point: UP-1

Profile Description: (Describe to the depth needed to document the indicator or confirm the absence of indicators.)

Depth (inches)	Matrix Color (moist)	%	Redox Features Color (moist)	%	Type[1]	Loc[2]	Texture	Remarks
0-5	10 YR 2/1						Sandy loam	
5-11	10 YR 3/1						Sandy loam	
11-15	10YR 3/1						Loamy sand	
15-20	10YR 3/2		10 YR 2/3	5%				redox concentrations

[1]Type: C=Concentration, D=Depletion, RM=Reduced Matrix, CS=Covered or Coated Sand Grains. [2]Location: PL=Pore Lining, M=Matrix.

Hydric Soil Indicators: (Applicable to all LRRs, unless otherwise noted.)

- ___ Histosol (A1)
- ___ Histic Epipedon (A2)
- ___ Black Histic (A3)
- ___ Hydrogen Sulfide (A4)
- ___ Stratified Layers (A5) (LRR F)
- ___ 1 cm Muck (A9) (LRR F, G, H)
- ___ Depleted Below Dark Surface (A11)
- ___ Thick Dark Surface (A12)
- ___ Sandy Mucky Mineral (S1)
- ___ 2.5 cm Mucky Peat or Peat (S2) (LRR G, H)
- ___ 5 cm Mucky Peat or Peat (S3) (LRR F)
- ___ Sandy Gleyed Matrix (S4)
- ___ Sandy Redox (S5)
- ___ Stripped Matrix (S6)
- ___ Loamy Mucky Mineral (F1)
- ___ Loamy Gleyed Matrix (F2)
- ___ Depleted Matrix (F3)
- ___ Redox Dark Surface (F6)
- ___ Depleted Dark Surface (F7)
- ___ Redox Depressions (F8)
- ___ High Plains Depressions (F16) (MLRA 72 & 73 of LRR H)

Indicators for Problematic Hydric Soils[3]:

- ___ 1 cm Muck (A9) (LRR I, J)
- ___ Coast Prairie Redox (A16) (LRR F, G, H)
- ___ Dark Surface (S7) (LRR G)
- ___ High Plains Depressions (F16) (LRR H outside of MLRA 72 & 73)
- ___ Reduced Vertic (F18)
- ___ Red Parent Material (TF2)
- ___ Very Shallow Dark Surface (TF12)
- ___ Other (Explain in Remarks)

[3]Indicators of hydrophytic vegetation and wetland hydrology must be present, unless disturbed or problematic.

Restrictive Layer (if present):

Type: ___

Depth (inches): ___

Hydric Soil Present? Yes ___ No ✓

Remarks:

HYDROLOGY

Wetland Hydrology Indicators:

Primary Indicators (minimum of one required; check all that apply)

- ___ Surface Water (A1)
- ___ High Water Table (A2)
- ✓ Saturation (A3)
- ___ Water Marks (B1)
- ___ Sediment Deposits (B2)
- ___ Drift Deposits (B3)
- ___ Algal Mat or Crust (B4)
- ___ Iron Deposits (B5)
- ___ Inundation Visible on Aerial Imagery (B7)
- ___ Water-Stained Leaves (B9)
- ___ Salt Crust (B11)
- ___ Aquatic Invertebrates (B13)
- ___ Hydrogen Sulfide Odor (C1)
- ___ Dry-Season Water Table (C2)
- ___ Oxidized Rhizospheres on Living Roots (C3) (where not tilled)
- ___ Presence of Reduced Iron (C4)
- ___ Thin Muck Surface (C7)
- ___ Other (Explain in Remarks)

Secondary Indicators (minimum of two required)

- ___ Surface Soil Cracks (B6)
- ___ Sparsely Vegetated Concave Surface (B8)
- ___ Drainage Patterns (B10)
- ___ Oxidized Rhizospheres on Living Roots (C3) (where tilled)
- ___ Crayfish Burrows (C8)
- ___ Saturation Visible on Aerial Imagery (C9)
- ___ Geomorphic Position (D2)
- ___ FAC-Neutral Test (D5)
- ___ Frost-Heave Hummocks (D7) (LRR F)

Field Observations:

Surface Water Present? Yes ___ No ___ Depth (inches): ___

Water Table Present? Yes ✓ No ___ Depth (inches): 14"

Saturation Present? (includes capillary fringe) Yes ✓ No ___ Depth (inches): 6"

Wetland Hydrology Present? Yes ✓ No ___

Describe Recorded Data (stream gauge, monitoring well, aerial photos, previous inspections), if available:

Remarks:

WETLAND DETERMINATION DATA FORM – Great Plains Region

Project/Site: Transect 1 City/County: Polk Sampling Date: 9-17-16
Applicant/Owner: USFWS State: MN Sampling Point: Wetland SP-1
Investigator(s): K. Engelmann Section, Township, Range: ______
Landform (hillslope, terrace, etc.): flat Local relief (concave, convex, none): Concave Slope (%): 0%
Subregion (LRR): ______ Lat: ______ Long: ______ Datum: ______
Soil Map Unit Name: Karlsruhe Sandy loam NWI classification: none
Are climatic / hydrologic conditions on the site typical for this time of year? Yes ______ No ✓ (If no, explain in Remarks.)
Are Vegetation ______, Soil ______, or Hydrology ______ significantly disturbed? Are "Normal Circumstances" present? Yes ✓ No ______
Are Vegetation ______, Soil ______, or Hydrology ______ naturally problematic? (If needed, explain any answers in Remarks.)

SUMMARY OF FINDINGS – Attach site map showing sampling point locations, transects, important features, etc.

Hydrophytic Vegetation Present? Yes ✓ No ______	Is the Sampled Area within a Wetland? Yes ✓ No ______	
Hydric Soil Present? Yes ✓ No ______		
Wetland Hydrology Present? Yes ✓ No ______		

Remarks: Wetter than average field conditions

VEGETATION – Use scientific names of plants.

Tree Stratum (Plot size: ______)	Absolute % Cover	Dominant Species?	Indicator Status
1.			
2.			
3.			
4.			
	______ = Total Cover		
Sapling/Shrub Stratum (Plot size: ______)			
1.			
2.			
3.			
4.			
5.			
	______ = Total Cover		
Herb Stratum (Plot size: 5')			
1. Carex sp.	30%	y	?
2. Phalaris arundinacea	30%	y	FACW
3. Agrostis gigantea	20%	y	FACW
4. Typha angustifolia	5%	N	OBL
5. Schoenoplectus tabernaemontani	5%	|	OBL
6. Stachys palustris	2%	|	OBL
7. Symphyotrichum lanceolatum	2%	|	FAC
8.			
9.			
10.			
	94% = Total Cover		
Woody Vine Stratum (Plot size: ______)			
1.			
2.			
	______ = Total Cover		
% Bare Ground in Herb Stratum ______			

50% 47
20% - 18.8

Dominance Test worksheet:

Number of Dominant Species That Are OBL, FACW, or FAC (excluding FAC–): 3 (A)

Total Number of Dominant Species Across All Strata: 3 (B)

Percent of Dominant Species That Are OBL, FACW, or FAC: 100 (A/B)

Prevalence Index worksheet:

Total % Cover of:		Multiply by:
OBL species	______	x 1 = ______
FACW species	______	x 2 = ______
FAC species	______	x 3 = ______
FACU species	______	x 4 = ______
UPL species	______	x 5 = ______
Column Totals:	______ (A)	______ (B)

Prevalence Index = B/A = ______

Hydrophytic Vegetation Indicators:
✓ 1 - Rapid Test for Hydrophytic Vegetation
✓ 2 - Dominance Test is >50%
__ 3 - Prevalence Index is ≤3.0[1]
__ 4 - Morphological Adaptations[1] (Provide supporting data in Remarks or on a separate sheet)
__ Problematic Hydrophytic Vegetation[1] (Explain)

[1]Indicators of hydric soil and wetland hydrology must be present, unless disturbed or problematic.

Hydrophytic Vegetation Present? Yes ✓ No ______

Remarks:

US Army Corps of Engineers Great Plains – Version 2.0

SOIL

Sampling Point: WP-1

Profile Description: (Describe to the depth needed to document the indicator or confirm the absence of indicators.)

Depth (inches)	Matrix Color (moist)	Matrix %	Redox Features Color (moist)	Redox Features %	Type[1]	Loc[2]	Texture	Remarks
0-8"	10YR 2/1						Sandy loam	
8-24"	5GY 7/1						Sandy Loam	

[1]Type: C=Concentration, D=Depletion, RM=Reduced Matrix, CS=Covered or Coated Sand Grains. [2]Location: PL=Pore Lining, M=Matrix.

Hydric Soil Indicators: (Applicable to all LRRs, unless otherwise noted.)

- __ Histosol (A1)
- __ Histic Epipedon (A2)
- __ Black Histic (A3)
- __ Hydrogen Sulfide (A4)
- __ Stratified Layers (A5) (LRR F)
- __ 1 cm Muck (A9) (LRR F, G, H)
- ✓ Depleted Below Dark Surface (A11)
- __ Thick Dark Surface (A12)
- __ Sandy Mucky Mineral (S1)
- __ 2.5 cm Mucky Peat or Peat (S2) (LRR G, H)
- __ 5 cm Mucky Peat or Peat (S3) (LRR F)
- __ Sandy Gleyed Matrix (S4)
- __ Sandy Redox (S5)
- __ Stripped Matrix (S6)
- __ Loamy Mucky Mineral (F1)
- __ Loamy Gleyed Matrix (F2)
- __ Depleted Matrix (F3)
- __ Redox Dark Surface (F6)
- __ Depleted Dark Surface (F7)
- __ Redox Depressions (F8)
- __ High Plains Depressions (F16) (MLRA 72 & 73 of LRR H)

Indicators for Problematic Hydric Soils[3]:

- __ 1 cm Muck (A9) (LRR I, J)
- __ Coast Prairie Redox (A16) (LRR F, G, H)
- __ Dark Surface (S7) (LRR G)
- __ High Plains Depressions (F16) (LRR H outside of MLRA 72 & 73)
- __ Reduced Vertic (F18)
- __ Red Parent Material (TF2)
- __ Very Shallow Dark Surface (TF12)
- __ Other (Explain in Remarks)

[3]Indicators of hydrophytic vegetation and wetland hydrology must be present, unless disturbed or problematic.

Restrictive Layer (if present):
Type: ______
Depth (inches): ______

Hydric Soil Present? Yes ✓ No ____

Remarks:

HYDROLOGY

Wetland Hydrology Indicators:

Primary Indicators (minimum of one required; check all that apply)

- ✓ Surface Water (A1)
- __ High Water Table (A2)
- __ Saturation (A3)
- __ Water Marks (B1)
- __ Sediment Deposits (B2)
- __ Drift Deposits (B3)
- __ Algal Mat or Crust (B4)
- __ Iron Deposits (B5)
- __ Inundation Visible on Aerial Imagery (B7)
- __ Water-Stained Leaves (B9)
- __ Salt Crust (B11)
- __ Aquatic Invertebrates (B13)
- __ Hydrogen Sulfide Odor (C1)
- __ Dry-Season Water Table (C2)
- __ Oxidized Rhizospheres on Living Roots (C3) (where not tilled)
- __ Presence of Reduced Iron (C4)
- __ Thin Muck Surface (C7)
- __ Other (Explain in Remarks)

Secondary Indicators (minimum of two required)

- __ Surface Soil Cracks (B6)
- __ Sparsely Vegetated Concave Surface (B8)
- __ Drainage Patterns (B10)
- __ Oxidized Rhizospheres on Living Roots (C3) (where tilled)
- __ Crayfish Burrows (C8)
- __ Saturation Visible on Aerial Imagery (C9)
- __ Geomorphic Position (D2)
- __ FAC-Neutral Test (D5)
- __ Frost-Heave Hummocks (D7) (LRR F)

Field Observations:

Surface Water Present? Yes ✓ No ____ Depth (inches): 1"
Water Table Present? Yes ____ No ____ Depth (inches): ______
Saturation Present? (includes capillary fringe) Yes ____ No ____ Depth (inches): ______

Wetland Hydrology Present? Yes ✓ No ____

Describe Recorded Data (stream gauge, monitoring well, aerial photos, previous inspections), if available:

Remarks:

WETLAND DETERMINATION DATA FORM – Great Plains Region

Project/Site: Transect 2 City/County: Polk Sampling Date: 9-11-16
Applicant/Owner: ARNWR State: MN Sampling Point: UPland SP-2
Investigator(s): K. Engelmann Section, Township, Range: ______
Landform (hillslope, terrace, etc.): Flat Local relief (concave, convex, none): ______ Slope (%): ______
Subregion (LRR): ______ Lat: ______ Long: ______ Datum: ______
Soil Map Unit Name: Hamar NWI classification: None
Are climatic / hydrologic conditions on the site typical for this time of year? Yes ______ No X (If no, explain in Remarks.)
Are Vegetation ______, Soil ______, or Hydrology ______ significantly disturbed? Are "Normal Circumstances" present? Yes X No ______
Are Vegetation ______, Soil ______, or Hydrology ______ naturally problematic? (If needed, explain any answers in Remarks.)

SUMMARY OF FINDINGS – Attach site map showing sampling point locations, transects, important features, etc.

Hydrophytic Vegetation Present?	Yes ______	No ✓
Hydric Soil Present?	Yes ______	No ✓
Wetland Hydrology Present?	Yes ______	No ✓

Is the Sampled Area within a Wetland? Yes ______ No ✓

Remarks:
Climate wetter then normal

VEGETATION – Use scientific names of plants.

Tree Stratum (Plot size: ______)	Absolute % Cover	Dominant Species?	Indicator Status
1.			
2.			
3.			
4.			
= Total Cover			
Sapling/Shrub Stratum (Plot size: ______)			
1.			
2.			
3.			
4.			
5.			
= Total Cover			
Herb Stratum (Plot size: 5')			
1. Andropogon gerardii	20	y	FACU
2. Sorghastrum nutans	30	y	FACU
3. Poa pratensis	20	y	FACU
4. Solidago canadensis	5	N	FACU
5. Solidago gigantea	4	|	FAC
6. Pascopyrum smithii	3	|	FACU
7.			
8.			
9.			
10.			
= Total Cover	92		
Woody Vine Stratum (Plot size: ______)			
1.			
2.			
= Total Cover			

50% = 46
20% = 18.4

% Bare Ground in Herb Stratum ______

Dominance Test worksheet:

Number of Dominant Species That Are OBL, FACW, or FAC (excluding FAC–): Ø (A)

Total Number of Dominant Species Across All Strata: ______ (B)

Percent of Dominant Species That Are OBL, FACW, or FAC: ______ (A/B)

Prevalence Index worksheet:

Total % Cover of:		Multiply by:
OBL species	______	x 1 = ______
FACW species	______	x 2 = ______
FAC species	______	x 3 = ______
FACU species	______	x 4 = ______
UPL species	______	x 5 = ______
Column Totals:	______ (A)	______ (B)

Prevalence Index = B/A = ______

Hydrophytic Vegetation Indicators:

- ___ 1 - Rapid Test for Hydrophytic Vegetation
- ___ 2 - Dominance Test is >50%
- ___ 3 - Prevalence Index is ≤3.0[1]
- ___ 4 - Morphological Adaptations[1] (Provide supporting data in Remarks or on a separate sheet)
- ___ Problematic Hydrophytic Vegetation[1] (Explain)

[1]Indicators of hydric soil and wetland hydrology must be present, unless disturbed or problematic.

Hydrophytic Vegetation Present? Yes ______ No ✓

Remarks:
Upland Vegetation

SOIL

Sampling Point: UP SP-2

Profile Description: (Describe to the depth needed to document the indicator or confirm the absence of indicators.)

Depth (inches)	Matrix Color (moist)	%	Redox Features Color (moist)	%	Type[1]	Loc[2]	Texture	Remarks
0-24	10YR 2/1						loamy Sand	
24+	10YR 2/2		7.5YR 4/6	4	C	PL	loamy sand	Few fine redox concentrations

[1]Type: C=Concentration, D=Depletion, RM=Reduced Matrix, CS=Covered or Coated Sand Grains. [2]Location: PL=Pore Lining, M=Matrix.

Hydric Soil Indicators: (Applicable to all LRRs, unless otherwise noted.)

- ___ Histosol (A1)
- ___ Histic Epipedon (A2)
- ___ Black Histic (A3)
- ___ Hydrogen Sulfide (A4)
- ___ Stratified Layers (A5) (LRR F)
- ___ 1 cm Muck (A9) (LRR F, G, H)
- ___ Depleted Below Dark Surface (A11)
- ___ Thick Dark Surface (A12)
- ___ Sandy Mucky Mineral (S1)
- ___ 2.5 cm Mucky Peat or Peat (S2) (LRR G, H)
- ___ 5 cm Mucky Peat or Peat (S3) (LRR F)
- ___ Sandy Gleyed Matrix (S4)
- ___ Sandy Redox (S5)
- ___ Stripped Matrix (S6)
- ___ Loamy Mucky Mineral (F1)
- ___ Loamy Gleyed Matrix (F2)
- ___ Depleted Matrix (F3)
- ___ Redox Dark Surface (F6)
- ___ Depleted Dark Surface (F7)
- ___ Redox Depressions (F8)
- ___ High Plains Depressions (F16) (MLRA 72 & 73 of LRR H)

Indicators for Problematic Hydric Soils[3]:

- ___ 1 cm Muck (A9) (LRR I, J)
- ___ Coast Prairie Redox (A16) (LRR F, G, H)
- ___ Dark Surface (S7) (LRR G)
- ___ High Plains Depressions (F16) (LRR H outside of MLRA 72 & 73)
- ___ Reduced Vertic (F18)
- ___ Red Parent Material (TF2)
- ___ Very Shallow Dark Surface (TF12)
- ___ Other (Explain in Remarks)

[3]Indicators of hydrophytic vegetation and wetland hydrology must be present, unless disturbed or problematic.

Restrictive Layer (if present):
Type: ______
Depth (inches): ______

Hydric Soil Present? Yes ___ No X

Remarks:

HYDROLOGY

Wetland Hydrology Indicators:

Primary Indicators (minimum of one required; check all that apply)

- ___ Surface Water (A1)
- ___ High Water Table (A2)
- ___ Saturation (A3)
- ___ Water Marks (B1)
- ___ Sediment Deposits (B2)
- ___ Drift Deposits (B3)
- ___ Algal Mat or Crust (B4)
- ___ Iron Deposits (B5)
- ___ Inundation Visible on Aerial Imagery (B7)
- ___ Water-Stained Leaves (B9)
- ___ Salt Crust (B11)
- ___ Aquatic Invertebrates (B13)
- ___ Hydrogen Sulfide Odor (C1)
- ___ Dry-Season Water Table (C2)
- ___ Oxidized Rhizospheres on Living Roots (C3) (where not tilled)
- ___ Presence of Reduced Iron (C4)
- ___ Thin Muck Surface (C7)
- ___ Other (Explain in Remarks)

Secondary Indicators (minimum of two required)

- ___ Surface Soil Cracks (B6)
- ___ Sparsely Vegetated Concave Surface (B8)
- ___ Drainage Patterns (B10)
- ___ Oxidized Rhizospheres on Living Roots (C3) (where tilled)
- ___ Crayfish Burrows (C8)
- ___ Saturation Visible on Aerial Imagery (C9)
- ___ Geomorphic Position (D2)
- ___ FAC-Neutral Test (D5)
- ___ Frost-Heave Hummocks (D7) (LRR F)

Field Observations:

Surface Water Present? Yes ___ No ___ Depth (inches): ______
Water Table Present? Yes X No ___ Depth (inches): 15"
Saturation Present? (includes capillary fringe) Yes X No ___ Depth (inches): 13"

Wetland Hydrology Present? Yes ___ No X

Describe Recorded Data (stream gauge, monitoring well, aerial photos, previous inspections), if available:

Remarks:

WETLAND DETERMINATION DATA FORM – Great Plains Region

Project/Site: Transect 2 City/County: Polk Sampling Date: 9/11/16

Applicant/Owner: USFWS State: MN Sampling Point: Wetland SP-2

Investigator(s): K. Engelmann Section, Township, Range: ______

Landform (hillslope, terrace, etc.): Flat Local relief (concave, convex, none): None Slope (%): 0

Subregion (LRR): Great Plains Lat: ______ Long: ______ Datum: ______

Soil Map Unit Name: Hamar NWI classification: PSS1C

Are climatic / hydrologic conditions on the site typical for this time of year? Yes ____ No X (If no, explain in Remarks.)

Are Vegetation ____, Soil ____, or Hydrology ____ significantly disturbed? Are "Normal Circumstances" present? Yes ✓ No ____

Are Vegetation ____, Soil ____, or Hydrology ____ naturally problematic? (If needed, explain any answers in Remarks.)

SUMMARY OF FINDINGS – Attach site map showing sampling point locations, transects, important features, etc.

Hydrophytic Vegetation Present?	Yes ✓	No ____
Hydric Soil Present?	Yes ✓	No ____
Wetland Hydrology Present?	Yes ✓	No ____
Is the Sampled Area within a Wetland?	Yes X	No ____

Remarks:
*Wetter than average climate conditions

VEGETATION – Use scientific names of plants.

	Absolute % Cover	Dominant Species?	Indicator Status
Tree Stratum (Plot size: ______)			
1.			
2.			
3.			
4.			
= Total Cover			
Sapling/Shrub Stratum (Plot size: ______)			
1.			
2.			
3.			
4.			
5.			
= Total Cover			
Herb Stratum (Plot size: ______)			
1. Muhlenbergia richardsonis	30	Y	FAC
2. Agrostis gigantea	30	Y	FACW
3. Poa palustris	20	Y	FACW
4. Phalaris arundinacea	10	N	FACW
5. Helianthus pauciflorus	3		—
6. Solidago gigantea	3		FACW
7. Veronicastrum virginicum	2		FAC
8.			
9.			
10.			
= Total Cover	98		
Woody Vine Stratum (Plot size: ______)			
1.			
2.			
= Total Cover			

50% = 49
20% = 19.6

% Bare Ground in Herb Stratum ______

Remarks:

Dominance Test worksheet:

Number of Dominant Species That Are OBL, FACW, or FAC (excluding FAC–): 3 (A)

Total Number of Dominant Species Across All Strata: 3 (B)

Percent of Dominant Species That Are OBL, FACW, or FAC: 100% (A/B)

Prevalence Index worksheet:

Total % Cover of:		Multiply by:
OBL species	______	x 1 = ______
FACW species	______	x 2 = ______
FAC species	______	x 3 = ______
FACU species	______	x 4 = ______
UPL species	______	x 5 = ______
Column Totals:	______ (A)	______ (B)

Prevalence Index = B/A = ______

Hydrophytic Vegetation Indicators:

- ___ 1 - Rapid Test for Hydrophytic Vegetation
- ✓ 2 - Dominance Test is >50%
- ___ 3 - Prevalence Index is ≤3.0[1]
- ___ 4 - Morphological Adaptations[1] (Provide supporting data in Remarks or on a separate sheet)
- ___ Problematic Hydrophytic Vegetation[1] (Explain)

[1]Indicators of hydric soil and wetland hydrology must be present, unless disturbed or problematic.

Hydrophytic Vegetation Present? Yes ✓ No ____

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SOIL

Sampling Point: Wet SP-2

Profile Description: (Describe to the depth needed to document the indicator or confirm the absence of indicators.)

Depth (inches)	Matrix Color (moist)	%	Redox Features Color (moist)	%	Type[1]	Loc[2]	Texture	Remarks
0-7"	10YR 2/1						loamy sand	
7-12	10YR 2/1		7.5YR 4/4	5%	C	PL	loamy sand	common fine redox concentrations
12-20	10YR 3/1		10YR 4/4	10%	C	PL	loamy sand	

[1]Type: C=Concentration, D=Depletion, RM=Reduced Matrix, CS=Covered or Coated Sand Grains. [2]Location: PL=Pore Lining, M=Matrix.

Hydric Soil Indicators: (Applicable to all LRRs, unless otherwise noted.)

- ___ Histosol (A1)
- ___ Histic Epipedon (A2)
- ___ Black Histic (A3)
- ___ Hydrogen Sulfide (A4)
- ___ Stratified Layers (A5) (LRR F)
- ___ 1 cm Muck (A9) (LRR F, G, H)
- X Depleted Below Dark Surface (A11)
- ___ Thick Dark Surface (A12)
- ___ Sandy Mucky Mineral (S1)
- ___ 2.5 cm Mucky Peat or Peat (S2) (LRR G, H)
- ___ 5 cm Mucky Peat or Peat (S3) (LRR F)
- ___ Sandy Gleyed Matrix (S4)
- X Sandy Redox (S5)
- ___ Stripped Matrix (S6)
- ___ Loamy Mucky Mineral (F1)
- ___ Loamy Gleyed Matrix (F2)
- ___ Depleted Matrix (F3)
- ___ Redox Dark Surface (F6)
- ___ Depleted Dark Surface (F7)
- ___ Redox Depressions (F8)
- ___ High Plains Depressions (F16) (MLRA 72 & 73 of LRR H)

Indicators for Problematic Hydric Soils[3]:

- ___ 1 cm Muck (A9) (LRR I, J)
- ___ Coast Prairie Redox (A16) (LRR F, G, H)
- ___ Dark Surface (S7) (LRR G)
- ___ High Plains Depressions (F16) (LRR H outside of MLRA 72 & 73)
- ___ Reduced Vertic (F18)
- ___ Red Parent Material (TF2)
- ___ Very Shallow Dark Surface (TF12)
- ___ Other (Explain in Remarks)

[3]Indicators of hydrophytic vegetation and wetland hydrology must be present, unless disturbed or problematic.

Restrictive Layer (if present):
Type: ______
Depth (inches): ______

Hydric Soil Present? Yes X No ___

Remarks:

HYDROLOGY

Wetland Hydrology Indicators:

Primary Indicators (minimum of one required; check all that apply)

- X Surface Water (A1)
- ___ High Water Table (A2)
- ___ Saturation (A3)
- ___ Water Marks (B1)
- ___ Sediment Deposits (B2)
- ___ Drift Deposits (B3)
- ___ Algal Mat or Crust (B4)
- ___ Iron Deposits (B5)
- ___ Inundation Visible on Aerial Imagery (B7)
- ___ Water-Stained Leaves (B9)
- ___ Salt Crust (B11)
- ___ Aquatic Invertebrates (B13)
- ___ Hydrogen Sulfide Odor (C1)
- ___ Dry-Season Water Table (C2)
- ___ Oxidized Rhizospheres on Living Roots (C3) (where not tilled)
- ___ Presence of Reduced Iron (C4)
- ___ Thin Muck Surface (C7)
- ___ Other (Explain in Remarks)

Secondary Indicators (minimum of two required)

- ___ Surface Soil Cracks (B6)
- ___ Sparsely Vegetated Concave Surface (B8)
- ___ Drainage Patterns (B10)
- ___ Oxidized Rhizospheres on Living Roots (C3) (where tilled)
- ___ Crayfish Burrows (C8)
- ___ Saturation Visible on Aerial Imagery (C9)
- ___ Geomorphic Position (D2)
- ___ FAC-Neutral Test (D5)
- ___ Frost-Heave Hummocks (D7) (LRR F)

Field Observations:

Surface Water Present? Yes ___ No ___ Depth (inches): ___
Water Table Present? Yes X No ___ Depth (inches): 8 inches
Saturation Present? (includes capillary fringe) Yes ___ No ___ Depth (inches): ___

Wetland Hydrology Present? Yes X No ___

Describe Recorded Data (stream gauge, monitoring well, aerial photos, previous inspections), if available:

Remarks:

WETLAND DETERMINATION DATA FORM – Great Plains Region

Project/Site: Transect 3 City/County: Polk Sampling Date: 9/11/16
Applicant/Owner: USFWS State: ______ Sampling Point: Upland SP-3
Investigator(s): K. Engelmann Section, Township, Range: ______
Landform (hillslope, terrace, etc.): Flat Local relief (concave, convex, none): none Slope (%): 0
Subregion (LRR): ______ Lat: ______ Long: ______ Datum: ______
Soil Map Unit Name: Grimstad Fine Sandy Loam NWI classification: PEM1Bdg
Are climatic / hydrologic conditions on the site typical for this time of year? Yes ___ No ✓ (If no, explain in Remarks.)
Are Vegetation ___, Soil ___, or Hydrology ___ significantly disturbed? Are "Normal Circumstances" present? Yes X No ___
Are Vegetation ___, Soil ___, or Hydrology ___ naturally problematic? (If needed, explain any answers in Remarks.)

SUMMARY OF FINDINGS – Attach site map showing sampling point locations, transects, important features, etc.

Hydrophytic Vegetation Present?	Yes ___	No X
Hydric Soil Present?	Yes ___	No X
Wetland Hydrology Present?	Yes ___	No X
Is the Sampled Area within a Wetland?	Yes ___	No X

Remarks:
Wetter than average conditions

VEGETATION – Use scientific names of plants.

	Absolute % Cover	Dominant Species?	Indicator Status
Tree Stratum (Plot size: ______)			
1.			
2.			
3.			
4.			
= Total Cover			
Sapling/Shrub Stratum (Plot size: 15')			
1. Salix interior	3%	N	FACW
2. Salix bebbiana	3%	N	FACW
3.			
4.			
5.			
= Total Cover	6%		
Herb Stratum (Plot size: ______)			
1. Andropogon gerardii	60%	Y	FACU
2. Poa pratensis	20%	Y	FAC
3. Solidago ptarmicoides	5%	N	NA
4. Solidago speciosa	2%	N	—
5. Symphyotrichum ericoides	2%	N	FACU
6.			
7.			
8.			
9.			
10.			
= Total Cover	89		
Woody Vine Stratum (Plot size: ______)			
1.			
2.			
= Total Cover			

% Bare Ground in Herb Stratum ______

Remarks:
50% = 47.5
20% = 19

Dominance Test worksheet:

Number of Dominant Species That Are OBL, FACW, or FAC (excluding FAC–): 1 (A)

Total Number of Dominant Species Across All Strata: 2 (B)

Percent of Dominant Species That Are OBL, FACW, or FAC: 50% (A/B)

Prevalence Index worksheet:

Total % Cover of:		Multiply by:
OBL species	______	x 1 = ______
FACW species	______	x 2 = ______
FAC species	______	x 3 = ______
FACU species	______	x 4 = ______
UPL species	______	x 5 = ______
Column Totals:	______ (A)	______ (B)

Prevalence Index = B/A = ______

Hydrophytic Vegetation Indicators:

___ 1 - Rapid Test for Hydrophytic Vegetation
___ 2 - Dominance Test is >50%
___ 3 - Prevalence Index is ≤3.0[1]
___ 4 - Morphological Adaptations[1] (Provide supporting data in Remarks or on a separate sheet)
___ Problematic Hydrophytic Vegetation[1] (Explain)

[1]Indicators of hydric soil and wetland hydrology must be present, unless disturbed or problematic.

Hydrophytic Vegetation Present? Yes ___ No X

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SOIL

Sampling Point: UpSP-3

Profile Description: (Describe to the depth needed to document the indicator or confirm the absence of indicators.)

Depth (inches)	Matrix Color (moist)	Matrix %	Redox Features Color (moist)	Redox Features %	Type[1]	Loc[2]	Texture	Remarks
0-9"	10YR 2/1						Sandy loam	
9-16"	10YR 4/1						loamy sand	
16-24+	2.5Y 5/2						loamy sand	

[1]Type: C=Concentration, D=Depletion, RM=Reduced Matrix, CS=Covered or Coated Sand Grains. [2]Location: PL=Pore Lining, M=Matrix.

Hydric Soil Indicators: (Applicable to all LRRs, unless otherwise noted.)

___ Histosol (A1)
___ Histic Epipedon (A2)
___ Black Histic (A3)
___ Hydrogen Sulfide (A4)
___ Stratified Layers (A5) (LRR F)
___ 1 cm Muck (A9) (LRR F, G, H)
___ Depleted Below Dark Surface (A11)
___ Thick Dark Surface (A12)
___ Sandy Mucky Mineral (S1)
___ 2.5 cm Mucky Peat or Peat (S2) (LRR G, H)
___ 5 cm Mucky Peat or Peat (S3) (LRR F)
___ Sandy Gleyed Matrix (S4)
___ Sandy Redox (S5)
___ Stripped Matrix (S6)
___ Loamy Mucky Mineral (F1)
___ Loamy Gleyed Matrix (F2)
___ Depleted Matrix (F3)
___ Redox Dark Surface (F6)
___ Depleted Dark Surface (F7)
___ Redox Depressions (F8)
___ High Plains Depressions (F16) (MLRA 72 & 73 of LRR H)

Indicators for Problematic Hydric Soils[3]:

___ 1 cm Muck (A9) (LRR I, J)
___ Coast Prairie Redox (A16) (LRR F, G, H)
___ Dark Surface (S7) (LRR G)
___ High Plains Depressions (F16) (LRR H outside of MLRA 72 & 73)
___ Reduced Vertic (F18)
___ Red Parent Material (TF2)
___ Very Shallow Dark Surface (TF12)
___ Other (Explain in Remarks)

[3]Indicators of hydrophytic vegetation and wetland hydrology must be present, unless disturbed or problematic.

Restrictive Layer (if present):
Type: ______
Depth (inches): ______

Hydric Soil Present? Yes ______ No X

Remarks:

HYDROLOGY

Wetland Hydrology Indicators:

Primary Indicators (minimum of one required; check all that apply)

___ Surface Water (A1)
___ High Water Table (A2)
___ Saturation (A3)
___ Water Marks (B1)
___ Sediment Deposits (B2)
___ Drift Deposits (B3)
___ Algal Mat or Crust (B4)
___ Iron Deposits (B5)
___ Inundation Visible on Aerial Imagery (B7)
___ Water-Stained Leaves (B9)
___ Salt Crust (B11)
___ Aquatic Invertebrates (B13)
___ Hydrogen Sulfide Odor (C1)
___ Dry-Season Water Table (C2)
___ Oxidized Rhizospheres on Living Roots (C3) (where not tilled)
___ Presence of Reduced Iron (C4)
___ Thin Muck Surface (C7)
___ Other (Explain in Remarks)

Secondary Indicators (minimum of two required)

___ Surface Soil Cracks (B6)
___ Sparsely Vegetated Concave Surface (B8)
___ Drainage Patterns (B10)
___ Oxidized Rhizospheres on Living Roots (C3) (where tilled)
___ Crayfish Burrows (C8)
___ Saturation Visible on Aerial Imagery (C9)
___ Geomorphic Position (D2)
___ FAC-Neutral Test (D5)
___ Frost-Heave Hummocks (D7) (LRR F)

Field Observations:

Surface Water Present? Yes ______ No ______ Depth (inches): ______
Water Table Present? Yes X No ______ Depth (inches): 18"
Saturation Present? (includes capillary fringe) Yes X No ______ Depth (inches): 16"

Wetland Hydrology Present? Yes ______ No X

Describe Recorded Data (stream gauge, monitoring well, aerial photos, previous inspections), if available:

Remarks:

WETLAND DETERMINATION DATA FORM – Great Plains Region

Project/Site: Transect 3 City/County: Polk Sampling Date: 9-11-16
Applicant/Owner: USFWS State: MN Sampling Point: Wetland SP-3
Investigator(s): K. Engelmann Section, Township, Range: ____
Landform (hillslope, terrace, etc.): flat Local relief (concave, convex, none): none Slope (%): 0
Subregion (LRR): ____ Lat: ____ Long: ____ Datum: ____
Soil Map Unit Name: Grimstad fine Sandy Loam NWI classification: PEM1Bdg
Are climatic / hydrologic conditions on the site typical for this time of year? Yes ____ No X (If no, explain in Remarks.)
Are Vegetation ____, Soil ____, or Hydrology ____ significantly disturbed? Are "Normal Circumstances" present? Yes X No ____
Are Vegetation ____, Soil ____, or Hydrology ____ naturally problematic? (If needed, explain any answers in Remarks.)

SUMMARY OF FINDINGS – Attach site map showing sampling point locations, transects, important features, etc.

Hydrophytic Vegetation Present?	Yes X No ____	Is the Sampled Area within a Wetland? Yes ____ No ____
Hydric Soil Present?	Yes X No ____	
Wetland Hydrology Present?	Yes X No ____	

Remarks:
Wetter than average climate conditions

VEGETATION – Use scientific names of plants.

Tree Stratum (Plot size: ____)	Absolute % Cover	Dominant Species?	Indicator Status
1.			
2.			
3.			
4.			
	= Total Cover		
Sapling/Shrub Stratum (Plot size: 15')			
1. Salix interior	2°		
2.			
3.			
4.			
5.			
	= Total Cover		
Herb Stratum (Plot size: ____)			
1. Poa palustris	50%	Y	FACW
2. Typha angustifolia	20%	Y	OBL
3. Agrostis gigantea	10%	N	FACW
4. Solidago gigantea	3%		FACW
5. Phalaris arundinacea	3%		FACW
6. Stachys palustris	2%		OBL
7. Solidago riddellii	2%		OBL
8. Carex sp.	2%		
9. Juncus sp.	2%		
10. Apocynum cannabinum	1%		FAC
	95% = Total Cover		
Woody Vine Stratum (Plot size: ____)			
1.			
2.			
	= Total Cover		

% Bare Ground in Herb Stratum ____

Dominance Test worksheet:

Number of Dominant Species That Are OBL, FACW, or FAC (excluding FAC−): 2 (A)
Total Number of Dominant Species Across All Strata: 2 (B)
Percent of Dominant Species That Are OBL, FACW, or FAC: 100% (A/B)

Prevalence Index worksheet:

Total % Cover of:	Multiply by:
OBL species ____	x 1 = ____
FACW species ____	x 2 = ____
FAC species ____	x 3 = ____
FACU species ____	x 4 = ____
UPL species ____	x 5 = ____
Column Totals: ____ (A)	____ (B)

Prevalence Index = B/A = ____

Hydrophytic Vegetation Indicators:

- ___ 1 - Rapid Test for Hydrophytic Vegetation
- X 2 - Dominance Test is >50%
- ___ 3 - Prevalence Index is ≤3.0[1]
- ___ 4 - Morphological Adaptations[1] (Provide supporting data in Remarks or on a separate sheet)
- ___ Problematic Hydrophytic Vegetation[1] (Explain)

[1]Indicators of hydric soil and wetland hydrology must be present, unless disturbed or problematic.

Hydrophytic Vegetation Present? Yes X No ____

Remarks:
50% = 47.5
20% = 19

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SOIL

Sampling Point: Wetland SP-3

Profile Description: (Describe to the depth needed to document the indicator or confirm the absence of indicators.)

Depth (inches)	Matrix Color (moist)	Matrix %	Redox Features Color (moist)	Redox Features %	Type[1]	Loc[2]	Texture	Remarks
0-10"	10YR 2/1						Muck	
10-18	10YR 2/1		10YR 4/1		C	PL	loam	

[1]Type: C=Concentration, D=Depletion, RM=Reduced Matrix, CS=Covered or Coated Sand Grains. [2]Location: PL=Pore Lining, M=Matrix.

Hydric Soil Indicators: (Applicable to all LRRs, unless otherwise noted.)

- X Histosol (A1)
- __ Histic Epipedon (A2)
- X Black Histic (A3)
- __ Hydrogen Sulfide (A4)
- __ Stratified Layers (A5) (LRR F)
- __ 1 cm Muck (A9) (LRR F, G, H)
- __ Depleted Below Dark Surface (A11)
- __ Thick Dark Surface (A12)
- __ Sandy Mucky Mineral (S1)
- __ 2.5 cm Mucky Peat or Peat (S2) (LRR G, H)
- __ 5 cm Mucky Peat or Peat (S3) (LRR F)
- __ Sandy Gleyed Matrix (S4)
- __ Sandy Redox (S5)
- __ Stripped Matrix (S6)
- __ Loamy Mucky Mineral (F1)
- __ Loamy Gleyed Matrix (F2)
- __ Depleted Matrix (F3)
- __ Redox Dark Surface (F6)
- __ Depleted Dark Surface (F7)
- __ Redox Depressions (F8)
- __ High Plains Depressions (F16) (MLRA 72 & 73 of LRR H)

Indicators for Problematic Hydric Soils[3]:

- __ 1 cm Muck (A9) (LRR I, J)
- __ Coast Prairie Redox (A16) (LRR F, G, H)
- __ Dark Surface (S7) (LRR G)
- __ High Plains Depressions (F16) (LRR H outside of MLRA 72 & 73)
- __ Reduced Vertic (F18)
- __ Red Parent Material (TF2)
- __ Very Shallow Dark Surface (TF12)
- __ Other (Explain in Remarks)

[3]Indicators of hydrophytic vegetation and wetland hydrology must be present, unless disturbed or problematic.

Restrictive Layer (if present):

Type: ______

Depth (inches): ______

Hydric Soil Present? Yes X No ___

Remarks:

HYDROLOGY

Wetland Hydrology Indicators:

Primary Indicators (minimum of one required; check all that apply)

- __ Surface Water (A1)
- X High Water Table (A2)
- __ Saturation (A3)
- __ Water Marks (B1)
- __ Sediment Deposits (B2)
- __ Drift Deposits (B3)
- __ Algal Mat or Crust (B4)
- __ Iron Deposits (B5)
- __ Inundation Visible on Aerial Imagery (B7)
- __ Water-Stained Leaves (B9)
- __ Salt Crust (B11)
- __ Aquatic Invertebrates (B13)
- __ Hydrogen Sulfide Odor (C1)
- __ Dry-Season Water Table (C2)
- __ Oxidized Rhizospheres on Living Roots (C3) (where not tilled)
- __ Presence of Reduced Iron (C4)
- __ Thin Muck Surface (C7)
- __ Other (Explain in Remarks)

Secondary Indicators (minimum of two required)

- __ Surface Soil Cracks (B6)
- __ Sparsely Vegetated Concave Surface (B8)
- __ Drainage Patterns (B10)
- __ Oxidized Rhizospheres on Living Roots (C3) (where tilled)
- __ Crayfish Burrows (C8)
- __ Saturation Visible on Aerial Imagery (C9)
- X Geomorphic Position (D2)
- X FAC-Neutral Test (D5)
- __ Frost-Heave Hummocks (D7) (LRR F)

Field Observations:

Surface Water Present? Yes ___ No ___ Depth (inches): ______

Water Table Present? Yes X No ___ Depth (inches): 15"

Saturation Present? (includes capillary fringe) Yes X No ___ Depth (inches): 11"

Wetland Hydrology Present? Yes X No ___

Describe Recorded Data (stream gauge, monitoring well, aerial photos, previous inspections), if available:

Remarks:

WETLAND DETERMINATION DATA FORM – Great Plains Region

Project/Site: Transect 4 City/County: Polk Sampling Date: 9-16-16

Applicant/Owner: USFWS State: MN Sampling Point: upland SP-4

Investigator(s): K. Engelmann Section, Township, Range: ______

Landform (hillslope, terrace, etc.): ______ Local relief (concave, convex, none): concave Slope (%): 0

Subregion (LRR): ______ Lat: ______ Long: ______ Datum: ______

Soil Map Unit Name: Strathcona fine Sandy loam NWI classification: none

Are climatic / hydrologic conditions on the site typical for this time of year? Yes ______ No ✓ (If no, explain in Remarks.)

Are Vegetation ______, Soil ______, or Hydrology ______ significantly disturbed? Are "Normal Circumstances" present? Yes ✓ No ______

Are Vegetation ______, Soil ______, or Hydrology ______ naturally problematic? (If needed, explain any answers in Remarks.)

SUMMARY OF FINDINGS – Attach site map showing sampling point locations, transects, important features, etc.

Hydrophytic Vegetation Present?	Yes ______ No ✓	Is the Sampled Area within a Wetland? Yes ______ No ✓
Hydric Soil Present?	Yes ✓ No ______	
Wetland Hydrology Present?	Yes ✓ No ______	

Remarks: Wetter than average year

VEGETATION – Use scientific names of plants.

Tree Stratum (Plot size: NA)	Absolute % Cover	Dominant Species?	Indicator Status
1.			
2.			
3.			
4.			
	______ = Total Cover		
Sapling/Shrub Stratum (Plot size: ______)			
1. NA			
2.			
3.			
4.			
5.			
	______ = Total Cover		
Herb Stratum (Plot size: 5')			
1. Sorghastrum nutans	30 %	Y	FACU
2. Andropogon gerardii	30%	Y	FACU
3. Agrostis gigantea	10%	N	FACW
4. Panicum virgatum	10%	N	FAC
5. Solidago gigantea	5%	N	FACW
6. Solidago ptarmicoides	1%	N	NA
7. Thalictrum pubescens	1%	N	NA
8. Symphyotrichum ericoides	1%	N	FACU
9. Asclepias incarnata	1%	N	FACW
10. Solidago riddellii	1%	N	OBL
Helianthus maximiliani	1%	N	FACU
	91% = Total Cover		
Woody Vine Stratum (Plot size: ______)			
1.			
2.			
	______ = Total Cover		
% Bare Ground in Herb Stratum ______			

50% = 45.5

20% = 18.2

Dominance Test worksheet:

Number of Dominant Species That Are OBL, FACW, or FAC (excluding FAC−): Ø (A)

Total Number of Dominant Species Across All Strata: 2 (B)

Percent of Dominant Species That Are OBL, FACW, or FAC: 0% (A/B)

Prevalence Index worksheet:

Total % Cover of:	Multiply by:
OBL species 1	x 1 = 1
FACW species 16	x 2 = 32
FAC species 10	x 3 = 30
FACU species 62	x 4 = 248
UPL species ______	x 5 = ______
Column Totals: 89 (A)	311 (B)

Prevalence Index = B/A = 3.494

Hydrophytic Vegetation Indicators:

___ 1 - Rapid Test for Hydrophytic Vegetation
___ 2 - Dominance Test is >50%
___ 3 - Prevalence Index is ≤3.0[1]
___ 4 - Morphological Adaptations[1] (Provide supporting data in Remarks or on a separate sheet)
___ Problematic Hydrophytic Vegetation[1] (Explain)

[1]Indicators of hydric soil and wetland hydrology must be present, unless disturbed or problematic.

Hydrophytic Vegetation Present? Yes ______ No ✓

Remarks:

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SOIL

Sampling Point: UP SP-4

Profile Description: (Describe to the depth needed to document the indicator or confirm the absence of indicators.)

Depth (inches)	Matrix Color (moist)	Matrix %	Redox Features Color (moist)	Redox %	Type[1]	Loc[2]	Texture	Remarks
0-16	N 2.5/0	95%					loam	
16+	5GY 8/1	95%					Loam	

[1]Type: C=Concentration, D=Depletion, RM=Reduced Matrix, CS=Covered or Coated Sand Grains. [2]Location: PL=Pore Lining, M=Matrix.

Hydric Soil Indicators: (Applicable to all LRRs, unless otherwise noted.)

- ___ Histosol (A1)
- ___ Histic Epipedon (A2)
- ___ Black Histic (A3)
- ___ Hydrogen Sulfide (A4)
- ___ Stratified Layers (A5) (LRR F)
- ___ 1 cm Muck (A9) (LRR F, G, H)
- ___ Depleted Below Dark Surface (A11)
- ✓ Thick Dark Surface (A12)
- ___ Sandy Mucky Mineral (S1)
- ___ 2.5 cm Mucky Peat or Peat (S2) (LRR G, H)
- ___ 5 cm Mucky Peat or Peat (S3) (LRR F)
- ___ Sandy Gleyed Matrix (S4)
- ___ Sandy Redox (S5)
- ___ Stripped Matrix (S6)
- ___ Loamy Mucky Mineral (F1)
- ___ Loamy Gleyed Matrix (F2)
- ___ Depleted Matrix (F3)
- ___ Redox Dark Surface (F6)
- ___ Depleted Dark Surface (F7)
- ___ Redox Depressions (F8)
- ___ High Plains Depressions (F16) (MLRA 72 & 73 of LRR H)

Indicators for Problematic Hydric Soils[3]:

- ___ 1 cm Muck (A9) (LRR I, J)
- ___ Coast Prairie Redox (A16) (LRR F, G, H)
- ___ Dark Surface (S7) (LRR G)
- ___ High Plains Depressions (F16) (LRR H outside of MLRA 72 & 73)
- ___ Reduced Vertic (F18)
- ___ Red Parent Material (TF2)
- ___ Very Shallow Dark Surface (TF12)
- ___ Other (Explain in Remarks)

[3]Indicators of hydrophytic vegetation and wetland hydrology must be present, unless disturbed or problematic.

Restrictive Layer (if present):
Type: ______
Depth (inches): ______

Hydric Soil Present? Yes ✓ No ___

Remarks:

HYDROLOGY

Wetland Hydrology Indicators:

Primary Indicators (minimum of one required; check all that apply)

- ___ Surface Water (A1)
- ✓ High Water Table (A2)
- ___ Saturation (A3)
- ___ Water Marks (B1)
- ___ Sediment Deposits (B2)
- ___ Drift Deposits (B3)
- ___ Algal Mat or Crust (B4)
- ___ Iron Deposits (B5)
- ___ Inundation Visible on Aerial Imagery (B7)
- ___ Water-Stained Leaves (B9)
- ___ Salt Crust (B11)
- ___ Aquatic Invertebrates (B13)
- ___ Hydrogen Sulfide Odor (C1)
- ___ Dry-Season Water Table (C2)
- ___ Oxidized Rhizospheres on Living Roots (C3) (where not tilled)
- ___ Presence of Reduced Iron (C4)
- ___ Thin Muck Surface (C7)
- ___ Other (Explain in Remarks)

Secondary Indicators (minimum of two required)

- ___ Surface Soil Cracks (B6)
- ___ Sparsely Vegetated Concave Surface (B8)
- ___ Drainage Patterns (B10)
- ___ Oxidized Rhizospheres on Living Roots (C3) (where tilled)
- ___ Crayfish Burrows (C8)
- ___ Saturation Visible on Aerial Imagery (C9)
- ___ Geomorphic Position (D2)
- ___ FAC-Neutral Test (D5)
- ___ Frost-Heave Hummocks (D7) (LRR F)

Field Observations:

Surface Water Present? Yes ___ No ___ Depth (inches): ______
Water Table Present? Yes ✓ No ___ Depth (inches): 12"
Saturation Present? (includes capillary fringe) Yes ___ No ___ Depth (inches): ______

Wetland Hydrology Present? Yes ✓ No ___

Describe Recorded Data (stream gauge, monitoring well, aerial photos, previous inspections), if available:

Remarks:

WETLAND DETERMINATION DATA FORM – Great Plains Region

Project/Site: Transect 4 City/County: Polk Sampling Date: 9/1/16
Applicant/Owner: USFWS State: MN Sampling Point: Wetland SP-4
Investigator(s): K. Engelmann Section, Township, Range: ______
Landform (hillslope, terrace, etc.): TS Local relief (concave, convex, none): concave Slope (%): 0
Subregion (LRR): ______ Lat: ______ Long: ______ Datum: ______
Soil Map Unit Name: Strathcona fine sandy loam NWI classification: PEM1Cd
Are climatic / hydrologic conditions on the site typical for this time of year? Yes ______ No ✓ (If no, explain in Remarks.)
Are Vegetation ______, Soil ______, or Hydrology ______ significantly disturbed? Are "Normal Circumstances" present? Yes ✓ No ______
Are Vegetation ______, Soil ______, or Hydrology ______ naturally problematic? (If needed, explain any answers in Remarks.)

SUMMARY OF FINDINGS – Attach site map showing sampling point locations, transects, important features, etc.

Hydrophytic Vegetation Present?	Yes ✓ No ______	Is the Sampled Area within a Wetland? Yes ✓ No ______
Hydric Soil Present?	Yes ✓ No ______	
Wetland Hydrology Present?	Yes ✓ No ______	

Remarks: Wetter than average year

VEGETATION – Use scientific names of plants.

	Absolute % Cover	Dominant Species?	Indicator Status
Tree Stratum (Plot size: NA)			
1.			
2.			
3.			
4.			
		= Total Cover	
Sapling/Shrub Stratum (Plot size: NA)			
1.			
2.			
3.			
4.			
5.			
		= Total Cover	
Herb Stratum (Plot size: 5')			
1. Phalaris arundinacea	60%	Y	FACW
2. Agrostis gigantea	20%	N	FACW
3. Juncus arcticus	20%	N	FACW
4. Rumex crispus	1%	N	FAC
5.			
6.			
7.			
8.			
9.			
10.			
	101%	= Total Cover	
Woody Vine Stratum (Plot size: NA)			
1.			
2.			
		= Total Cover	
% Bare Ground in Herb Stratum ______			

Dominance Test worksheet:

Number of Dominant Species That Are OBL, FACW, or FAC (excluding FAC−): ______ (A)

Total Number of Dominant Species Across All Strata: ______ (B)

Percent of Dominant Species That Are OBL, FACW, or FAC: ______ (A/B)

Prevalence Index worksheet:

Total % Cover of:		Multiply by:
OBL species	______	x 1 = ______
FACW species	______	x 2 = ______
FAC species	______	x 3 = ______
FACU species	______	x 4 = ______
UPL species	______	x 5 = ______
Column Totals:	______ (A)	______ (B)

Prevalence Index = B/A = ______

Hydrophytic Vegetation Indicators:
- ✓ 1 - Rapid Test for Hydrophytic Vegetation
- ___ 2 - Dominance Test is >50%
- ___ 3 - Prevalence Index is ≤3.0[1]
- ___ 4 - Morphological Adaptations[1] (Provide supporting data in Remarks or on a separate sheet)
- ___ Problematic Hydrophytic Vegetation[1] (Explain)

[1]Indicators of hydric soil and wetland hydrology must be present, unless disturbed or problematic.

Hydrophytic Vegetation Present? Yes ✓ No ______

Remarks:

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SOIL

Sampling Point: Wet SP-4

Profile Description: (Describe to the depth needed to document the indicator or confirm the absence of indicators.)

Depth (inches)	Matrix Color (moist)	Matrix %	Redox Features Color (moist)	Redox Features %	Type[1]	Loc[2]	Texture	Remarks

[1]Type: C=Concentration, D=Depletion, RM=Reduced Matrix, CS=Covered or Coated Sand Grains. [2]Location: PL=Pore Lining, M=Matrix.

Hydric Soil Indicators: (Applicable to all LRRs, unless otherwise noted.)

- __ Histosol (A1)
- __ Histic Epipedon (A2)
- __ Black Histic (A3)
- __ Hydrogen Sulfide (A4)
- __ Stratified Layers (A5) (LRR F)
- __ 1 cm Muck (A9) (LRR F, G, H)
- __ Depleted Below Dark Surface (A11)
- ✓ Thick Dark Surface (A12)
- __ Sandy Mucky Mineral (S1)
- __ 2.5 cm Mucky Peat or Peat (S2) (LRR G, H)
- __ 5 cm Mucky Peat or Peat (S3) (LRR F)
- __ Sandy Gleyed Matrix (S4)
- __ Sandy Redox (S5)
- __ Stripped Matrix (S6)
- __ Loamy Mucky Mineral (F1)
- __ Loamy Gleyed Matrix (F2)
- __ Depleted Matrix (F3)
- __ Redox Dark Surface (F6)
- __ Depleted Dark Surface (F7)
- __ Redox Depressions (F8)
- __ High Plains Depressions (F16) (MLRA 72 & 73 of LRR H)

Indicators for Problematic Hydric Soils[3]:

- __ 1 cm Muck (A9) (LRR I, J)
- __ Coast Prairie Redox (A16) (LRR F, G, H)
- __ Dark Surface (S7) (LRR G)
- __ High Plains Depressions (F16) (LRR H outside of MLRA 72 & 73)
- __ Reduced Vertic (F18)
- __ Red Parent Material (TF2)
- __ Very Shallow Dark Surface (TF12)
- __ Other (Explain in Remarks)

[3]Indicators of hydrophytic vegetation and wetland hydrology must be present, unless disturbed or problematic.

Restrictive Layer (if present):
Type: ______
Depth (inches): ______

Hydric Soil Present? Yes ✓ No ______

Remarks:

HYDROLOGY

Wetland Hydrology Indicators:

Primary Indicators (minimum of one required; check all that apply)

- ✓ Surface Water (A1)
- __ High Water Table (A2)
- __ Saturation (A3)
- __ Water Marks (B1)
- __ Sediment Deposits (B2)
- __ Drift Deposits (B3)
- __ Algal Mat or Crust (B4)
- __ Iron Deposits (B5)
- __ Inundation Visible on Aerial Imagery (B7)
- __ Water-Stained Leaves (B9)
- __ Salt Crust (B11)
- __ Aquatic Invertebrates (B13)
- __ Hydrogen Sulfide Odor (C1)
- __ Dry-Season Water Table (C2)
- __ Oxidized Rhizospheres on Living Roots (C3) (where not tilled)
- __ Presence of Reduced Iron (C4)
- __ Thin Muck Surface (C7)
- __ Other (Explain in Remarks)

Secondary Indicators (minimum of two required)

- __ Surface Soil Cracks (B6)
- __ Sparsely Vegetated Concave Surface (B8)
- __ Drainage Patterns (B10)
- __ Oxidized Rhizospheres on Living Roots (C3) (where tilled)
- __ Crayfish Burrows (C8)
- __ Saturation Visible on Aerial Imagery (C9)
- __ Geomorphic Position (D2)
- __ FAC-Neutral Test (D5)
- __ Frost-Heave Hummocks (D7) (LRR F)

Field Observations:

Surface Water Present? Yes ✓ No ____ Depth (inches): 1.2"
Water Table Present? Yes ____ No ____ Depth (inches): ______
Saturation Present? (includes capillary fringe) Yes ____ No ____ Depth (inches): ______

Wetland Hydrology Present? Yes ✓ No ______

Describe Recorded Data (stream gauge, monitoring well, aerial photos, previous inspections), if available:

Remarks:

WETLAND DETERMINATION DATA FORM – Great Plains Region

Project/Site: Transect 5 City/County: Polk Sampling Date: 9-11-16

Applicant/Owner: USFWS State: ______ Sampling Point: Upland SP-5

Investigator(s): K. Engelmann Section, Township, Range: ______

Landform (hillslope, terrace, etc.): flat Local relief (concave, convex, none): concave Slope (%): 0-2%

Subregion (LRR): ______ Lat: ______ Long: ______ Datum: ______

Soil Map Unit Name: Hedman Fram complex NWI classification: non

Are climatic / hydrologic conditions on the site typical for this time of year? Yes ______ No ✓ (If no, explain in Remarks.)

Are Vegetation ____, Soil ____, or Hydrology ____ significantly disturbed? Are "Normal Circumstances" present? Yes ✓ No ____

Are Vegetation ____, Soil ____, or Hydrology ____ naturally problematic? (If needed, explain any answers in Remarks.)

SUMMARY OF FINDINGS – Attach site map showing sampling point locations, transects, important features, etc.

Hydrophytic Vegetation Present?	Yes ____	No ✓
Hydric Soil Present?	Yes ____	No ✓
Wetland Hydrology Present?	Yes ____	No ✓

Is the Sampled Area within a Wetland? Yes ____ No ✓

Remarks: Wetter than average year

VEGETATION – Use scientific names of plants.

Tree Stratum (Plot size: NA)	Absolute % Cover	Dominant Species?	Indicator Status
1.			
2.			
3.			
4.			
= Total Cover			
Sapling/Shrub Stratum (Plot size: NA)			
1.			
2.			
3.			
4.			
5.			
= Total Cover			
Herb Stratum (Plot size: 5')			
1. Sorghastrum nutans	40%	yes	FACU
2. Andropogon gerardii	40%	yes	FACU
3. Solidago canadensis	5	N	FACU
4. Apocynum cannabinum	5	N	FAC
5. Panicum virgatum	5	N	FAC
6. Symphyotricum ericoides	2	N	FACU
7.			
8.			
9.			
10.			
= Total Cover	97	50% = 48.5 20% = 19.4	
Woody Vine Stratum (Plot size: NA)			
1.			
2.			
= Total Cover			

% Bare Ground in Herb Stratum ______

Dominance Test worksheet:

Number of Dominant Species That Are OBL, FACW, or FAC (excluding FAC−): Ø (A)

Total Number of Dominant Species Across All Strata: ______ (B)

Percent of Dominant Species That Are OBL, FACW, or FAC: Ø (A/B)

Prevalence Index worksheet:

Total % Cover of:	Multiply by:
OBL species ______	x 1 = ______
FACW species ______	x 2 = ______
FAC species ______	x 3 = ______
FACU species ______	x 4 = ______
UPL species ______	x 5 = ______
Column Totals: ______ (A)	______ (B)

Prevalence Index = B/A = ______

Hydrophytic Vegetation Indicators:

- __ 1 - Rapid Test for Hydrophytic Vegetation
- __ 2 - Dominance Test is >50%
- __ 3 - Prevalence Index is ≤3.0[1]
- __ 4 - Morphological Adaptations[1] (Provide supporting data in Remarks or on a separate sheet)
- __ Problematic Hydrophytic Vegetation[1] (Explain)

[1]Indicators of hydric soil and wetland hydrology must be present, unless disturbed or problematic.

Hydrophytic Vegetation Present? Yes ____ No ✓

Remarks:

SOIL

Sampling Point: UP-5

Profile Description: (Describe to the depth needed to document the indicator or confirm the absence of indicators.)

Depth (inches)	Matrix Color (moist)	Matrix %	Redox Features Color (moist)	Redox %	Type[1]	Loc[2]	Texture	Remarks
0-7	10YR 4/2						Sandy loam	
7-24+	10YR 8/3						Sandy loam	

[1]Type: C=Concentration, D=Depletion, RM=Reduced Matrix, CS=Covered or Coated Sand Grains. [2]Location: PL=Pore Lining, M=Matrix.

Hydric Soil Indicators: (Applicable to all LRRs, unless otherwise noted.)

- ___ Histosol (A1)
- ___ Histic Epipedon (A2)
- ___ Black Histic (A3)
- ___ Hydrogen Sulfide (A4)
- ___ Stratified Layers (A5) (LRR F)
- ___ 1 cm Muck (A9) (LRR F, G, H)
- ___ Depleted Below Dark Surface (A11)
- ___ Thick Dark Surface (A12)
- ___ Sandy Mucky Mineral (S1)
- ___ 2.5 cm Mucky Peat or Peat (S2) (LRR G, H)
- ___ 5 cm Mucky Peat or Peat (S3) (LRR F)
- ___ Sandy Gleyed Matrix (S4)
- ___ Sandy Redox (S5)
- ___ Stripped Matrix (S6)
- ___ Loamy Mucky Mineral (F1)
- ___ Loamy Gleyed Matrix (F2)
- ___ Depleted Matrix (F3)
- ___ Redox Dark Surface (F6)
- ___ Depleted Dark Surface (F7)
- ___ Redox Depressions (F8)
- ___ High Plains Depressions (F16) (MLRA 72 & 73 of LRR H)

Indicators for Problematic Hydric Soils[3]:

- ___ 1 cm Muck (A9) (LRR I, J)
- ___ Coast Prairie Redox (A16) (LRR F, G, H)
- ___ Dark Surface (S7) (LRR G)
- ___ High Plains Depressions (F16) (LRR H outside of MLRA 72 & 73)
- ___ Reduced Vertic (F18)
- ___ Red Parent Material (TF2)
- ___ Very Shallow Dark Surface (TF12)
- ___ Other (Explain in Remarks)

[3]Indicators of hydrophytic vegetation and wetland hydrology must be present, unless disturbed or problematic.

Restrictive Layer (if present):
Type: ___
Depth (inches): ___

Hydric Soil Present? Yes ___ No ✓

Remarks:

HYDROLOGY

Wetland Hydrology Indicators:

Primary Indicators (minimum of one required; check all that apply)

- ___ Surface Water (A1)
- ___ High Water Table (A2)
- ___ Saturation (A3)
- ___ Water Marks (B1)
- ___ Sediment Deposits (B2)
- ___ Drift Deposits (B3)
- ___ Algal Mat or Crust (B4)
- ___ Iron Deposits (B5)
- ___ Inundation Visible on Aerial Imagery (B7)
- ___ Water-Stained Leaves (B9)
- ___ Salt Crust (B11)
- ___ Aquatic Invertebrates (B13)
- ___ Hydrogen Sulfide Odor (C1)
- ___ Dry-Season Water Table (C2)
- ___ Oxidized Rhizospheres on Living Roots (C3) (where not tilled)
- ___ Presence of Reduced Iron (C4)
- ___ Thin Muck Surface (C7)
- ___ Other (Explain in Remarks)

Secondary Indicators (minimum of two required)

- ___ Surface Soil Cracks (B6)
- ___ Sparsely Vegetated Concave Surface (B8)
- ___ Drainage Patterns (B10)
- ___ Oxidized Rhizospheres on Living Roots (C3) (where tilled)
- ___ Crayfish Burrows (C8)
- ___ Saturation Visible on Aerial Imagery (C9)
- ___ Geomorphic Position (D2)
- ___ FAC-Neutral Test (D5)
- ___ Frost-Heave Hummocks (D7) (LRR F)

Field Observations:

Surface Water Present? Yes ___ No ✓ Depth (inches): ___
Water Table Present? Yes ✓ No ___ Depth (inches): 18"
Saturation Present? (includes capillary fringe) Yes ✓ No ___ Depth (inches): 14"

Wetland Hydrology Present? Yes ___ No ✓

Describe Recorded Data (stream gauge, monitoring well, aerial photos, previous inspections), if available:

Remarks:

WETLAND DETERMINATION DATA FORM – Great Plains Region

Project/Site: Transect 5 City/County: Polk Sampling Date: 9-11-16
Applicant/Owner: USFWS State: MN Sampling Point: Wetland SP5
Investigator(s): K. Engelmann Section, Township, Range: ______
Landform (hillslope, terrace, etc.): flat Local relief (concave, convex, none): Concave Slope (%): 0
Subregion (LRR): ______ Lat: ______ Long: ______ Datum: ______
Soil Map Unit Name: Hedman-Fram Complex NWI classification: None
Are climatic / hydrologic conditions on the site typical for this time of year? Yes ______ No ✓ (If no, explain in Remarks.)
Are Vegetation ______, Soil ______, or Hydrology ______ significantly disturbed? Are "Normal Circumstances" present? Yes ✓ No ______
Are Vegetation ______, Soil ______, or Hydrology ______ naturally problematic? (If needed, explain any answers in Remarks.)

SUMMARY OF FINDINGS – Attach site map showing sampling point locations, transects, important features, etc.

Hydrophytic Vegetation Present?	Yes ✓ No ______	Is the Sampled Area within a Wetland? Yes ✓ No ______
Hydric Soil Present?	Yes ✓ No ______	
Wetland Hydrology Present?	Yes ✓ No ______	

Remarks: Wetter than average conditions

VEGETATION – Use scientific names of plants.

Tree Stratum (Plot size: N/A)	Absolute % Cover	Dominant Species?	Indicator Status
1.			
2.			
3.			
4.			
= Total Cover			
Sapling/Shrub Stratum (Plot size: N/A)			
1.			
2.			
3.			
4.			
5.			
= Total Cover			
Herb Stratum (Plot size: 5')			
1. Phalaris arundinacea	80%	yes	FACW
2. Typha angustifolia	10%	No	OBL
3. Apocynum cannabinum	3%	No	FAC
4. Asclepias incarnata	2%	No	FW
5.			
6.			
7.			
8.			
9.			
10.			
= Total Cover	95	50% = 47.5 20% = 19	
Woody Vine Stratum (Plot size: N/A)			
1.			
2.			
= Total Cover			

% Bare Ground in Herb Stratum ______

Dominance Test worksheet:
Number of Dominant Species That Are OBL, FACW, or FAC (excluding FAC−): ______ (A)
Total Number of Dominant Species Across All Strata: ______ (B)
Percent of Dominant Species That Are OBL, FACW, or FAC: ______ (A/B)

Prevalence Index worksheet:

Total % Cover of:	Multiply by:
OBL species ______	x 1 = ______
FACW species ______	x 2 = ______
FAC species ______	x 3 = ______
FACU species ______	x 4 = ______
UPL species ______	x 5 = ______
Column Totals: ______ (A)	______ (B)

Prevalence Index = B/A = ______

Hydrophytic Vegetation Indicators:
✓ 1 - Rapid Test for Hydrophytic Vegetation
__ 2 - Dominance Test is >50%
__ 3 - Prevalence Index is ≤3.0[1]
__ 4 - Morphological Adaptations[1] (Provide supporting data in Remarks or on a separate sheet)
__ Problematic Hydrophytic Vegetation[1] (Explain)

[1]Indicators of hydric soil and wetland hydrology must be present, unless disturbed or problematic.

Hydrophytic Vegetation Present? Yes ✓ No ______

Remarks:

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WETLAND DETERMINATION DATA FORM – Great Plains Region

Project/Site: Transect 5 City/County: Polk Sampling Date: 9-11-16

Applicant/Owner: USFWS State: MN Sampling Point: Wetland SP-5

Investigator(s): K. Engelmann Section, Township, Range: ____

Landform (hillslope, terrace, etc.): flat Local relief (concave, convex, none): Concave Slope (%): 0

Subregion (LRR): ____ Lat: ____ Long: ____ Datum: ____

Soil Map Unit Name: Hedman-Fram Complex NWI classification: None

Are climatic / hydrologic conditions on the site typical for this time of year? Yes ____ No ✓ (If no, explain in Remarks.)

Are Vegetation ____, Soil ____, or Hydrology ____ significantly disturbed? Are "Normal Circumstances" present? Yes ✓ No ____

Are Vegetation ____, Soil ____, or Hydrology ____ naturally problematic? (If needed, explain any answers in Remarks.)

SUMMARY OF FINDINGS – Attach site map showing sampling point locations, transects, important features, etc.

Hydrophytic Vegetation Present? Yes ✓ No ____	Is the Sampled Area within a Wetland? Yes ✓ No ____	
Hydric Soil Present? Yes ✓ No ____		
Wetland Hydrology Present? Yes ✓ No ____		

Remarks: Wetter than average conditions

VEGETATION – Use scientific names of plants.

Tree Stratum (Plot size: N/A)	Absolute % Cover	Dominant Species?	Indicator Status
1.			
2.			
3.			
4.			
	= Total Cover		
Sapling/Shrub Stratum (Plot size: N/A)			
1.			
2.			
3.			
4.			
5.			
	= Total Cover		
Herb Stratum (Plot size: 5')			
1. Phalaris arundinacea	80%	Yes	FACW
2. Typha angustifolia	10%	No	OBL
3. Apocynum cannabinum	3%	No	FAC
4. Asclepias incarnata	2%	No	FW
5.			
6.			
7.			
8.			
9.			
10.			
	95 = Total Cover 50% = 47.5 20% = 19		
Woody Vine Stratum (Plot size: NA)			
1.			
2.			
	= Total Cover		
% Bare Ground in Herb Stratum ____			

Dominance Test worksheet:

Number of Dominant Species That Are OBL, FACW, or FAC (excluding FAC–): ____ (A)

Total Number of Dominant Species Across All Strata: ____ (B)

Percent of Dominant Species That Are OBL, FACW, or FAC: ____ (A/B)

Prevalence Index worksheet:

Total % Cover of:		Multiply by:
OBL species	____	x 1 = ____
FACW species	____	x 2 = ____
FAC species	____	x 3 = ____
FACU species	____	x 4 = ____
UPL species	____	x 5 = ____
Column Totals:	____ (A)	____ (B)

Prevalence Index = B/A = ____

Hydrophytic Vegetation Indicators:

- ✓ 1 - Rapid Test for Hydrophytic Vegetation
- __ 2 - Dominance Test is >50%
- __ 3 - Prevalence Index is ≤3.0[1]
- __ 4 - Morphological Adaptations[1] (Provide supporting data in Remarks or on a separate sheet)
- __ Problematic Hydrophytic Vegetation[1] (Explain)

[1]Indicators of hydric soil and wetland hydrology must be present, unless disturbed or problematic.

Hydrophytic Vegetation Present? Yes ✓ No ____

Remarks:

US Army Corps of Engineers Great Plains – Version 2.0

SOIL

Sampling Point: Wetland SP-5

Profile Description: (Describe to the depth needed to document the indicator or confirm the absence of indicators.)

Depth (inches)	Matrix Color (moist)	Matrix %	Redox Features Color (moist)	Redox %	Type[1]	Loc[2]	Texture	Remarks
0-11"	2.5Y 2.5/1						loam	
11-20"	2.5Y 6/2		7.5YR 5/6	5%	Fe+		sandy-loam	
21+	2.5Y 5/2		10YR 5/6	5%	Fe+		loam	

[1]Type: C=Concentration, D=Depletion, RM=Reduced Matrix, CS=Covered or Coated Sand Grains. [2]Location: PL=Pore Lining, M=Matrix.

Hydric Soil Indicators: (Applicable to all LRRs, unless otherwise noted.)

- ___ Histosol (A1)
- ___ Histic Epipedon (A2)
- ___ Black Histic (A3)
- ___ Hydrogen Sulfide (A4)
- ___ Stratified Layers (A5) (LRR F)
- ___ 1 cm Muck (A9) (LRR F, G, H)
- ✓ Depleted Below Dark Surface (A11)
- ___ Thick Dark Surface (A12)
- ___ Sandy Mucky Mineral (S1)
- ___ 2.5 cm Mucky Peat or Peat (S2) (LRR G, H)
- ___ 5 cm Mucky Peat or Peat (S3) (LRR F)
- ___ Sandy Gleyed Matrix (S4)
- ___ Sandy Redox (S5)
- ___ Stripped Matrix (S6)
- ___ Loamy Mucky Mineral (F1)
- ___ Loamy Gleyed Matrix (F2)
- ___ Depleted Matrix (F3)
- ___ Redox Dark Surface (F6)
- ___ Depleted Dark Surface (F7)
- ___ Redox Depressions (F8)
- ___ High Plains Depressions (F16) (MLRA 72 & 73 of LRR H)

Indicators for Problematic Hydric Soils[3]:

- ___ 1 cm Muck (A9) (LRR I, J)
- ___ Coast Prairie Redox (A16) (LRR F, G, H)
- ___ Dark Surface (S7) (LRR G)
- ___ High Plains Depressions (F16) (LRR H outside of MLRA 72 & 73)
- ___ Reduced Vertic (F18)
- ___ Red Parent Material (TF2)
- ___ Very Shallow Dark Surface (TF12)
- ___ Other (Explain in Remarks)

[3]Indicators of hydrophytic vegetation and wetland hydrology must be present, unless disturbed or problematic.

Restrictive Layer (if present):
Type: ___
Depth (inches): ___

Hydric Soil Present? Yes ✓ No ___

Remarks:

HYDROLOGY

Wetland Hydrology Indicators:

Primary Indicators (minimum of one required; check all that apply)

- X Surface Water (A1)
- ___ High Water Table (A2)
- ___ Saturation (A3)
- ___ Water Marks (B1)
- ___ Sediment Deposits (B2)
- ___ Drift Deposits (B3)
- ___ Algal Mat or Crust (B4)
- ___ Iron Deposits (B5)
- ___ Inundation Visible on Aerial Imagery (B7)
- ___ Water-Stained Leaves (B9)
- ___ Salt Crust (B11)
- ___ Aquatic Invertebrates (B13)
- ___ Hydrogen Sulfide Odor (C1)
- ___ Dry-Season Water Table (C2)
- ___ Oxidized Rhizospheres on Living Roots (C3) (where not tilled)
- ___ Presence of Reduced Iron (C4)
- ___ Thin Muck Surface (C7)
- ___ Other (Explain in Remarks)

Secondary Indicators (minimum of two required)

- ___ Surface Soil Cracks (B6)
- ___ Sparsely Vegetated Concave Surface (B8)
- ___ Drainage Patterns (B10)
- ___ Oxidized Rhizospheres on Living Roots (C3) (where tilled)
- ___ Crayfish Burrows (C8)
- ___ Saturation Visible on Aerial Imagery (C9)
- ___ Geomorphic Position (D2)
- ___ FAC-Neutral Test (D5)
- ___ Frost-Heave Hummocks (D7) (LRR F)

Field Observations:

Surface Water Present? Yes ✓ No ___ Depth (inches): 1"
Water Table Present? Yes ___ No ___ Depth (inches): ___
Saturation Present? (includes capillary fringe) Yes ___ No ___ Depth (inches): ___

Wetland Hydrology Present? Yes ✓ No ___

Describe Recorded Data (stream gauge, monitoring well, aerial photos, previous inspections), if available:

Remarks:

Appendix E
Field Photographs

Belt transect site 2. Photo oriented towards the transect center from south looking north.

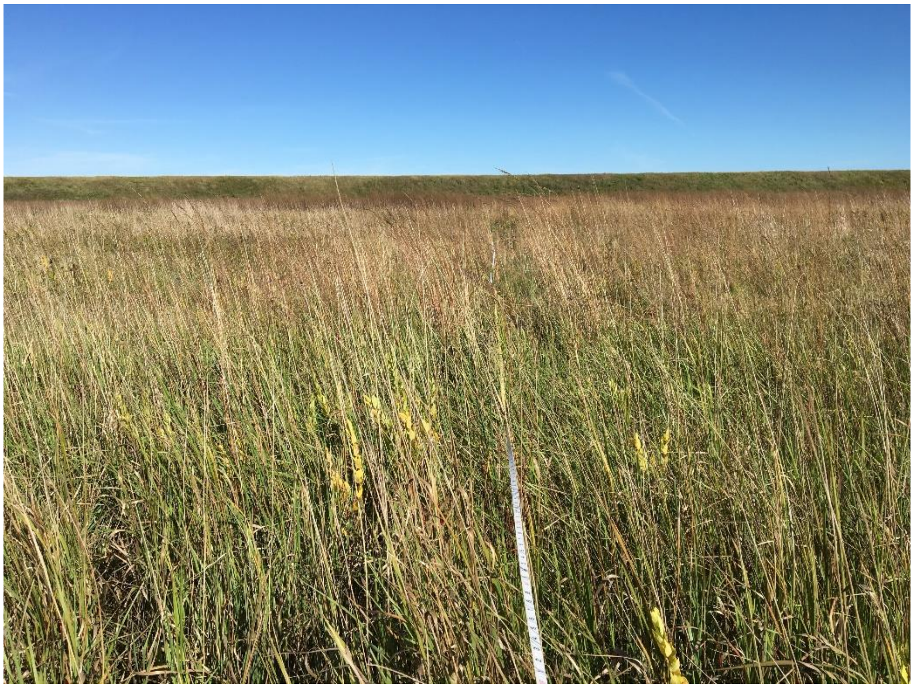
Belt transect site 2. Photo oriented towards the transect center from north looking south.

Belt transect site 3. Photo oriented towards the transect center from east looking west.

Belt transect site 3. Photo oriented towards the transect center from west looking east.

Belt transect site 4. Photo oriented towards the transect center west looking east.

Belt transect site 4. Photo oriented towards the transect center east looking west.



Belt transect site 5. Photo oriented towards the transect center west looking east.

Belt transect site 5. Photo oriented towards the transect center east looking west.

REFERENCES

Blaschke, T., S. Lang, E. Lorup, S. Strobl, and P. Zeil. 2000. Object-oriented image processing in an Integrated GIS/remote sensing environment and perspectives for environmental application. *Environmental Information for Planning* 2: 555-559.

Cabello, J., N. Fernández, D. Alcara-Segura, C. Oyonarte, G. Piñeiro, A. Altesor, M. Delibes and J. Paruelo. The ecosystem functioning dimension in conservation: Insights from remote sensing. *Biodiversity Conservation* 21: 3287-3305.

Campbell J., and R. Wynne. 2011. *Introduction to remote sensing.* New York, NY: The Guilford Press.

Cowdery, T., D. Lorenz, and A. Arntson. 2008. Hydrology prior to wetland and prairie restoration in and around the Glacial Ridge National Wildlife Refuge, northwestern Minnesota, 2002-5: U.S. Geological Survey Scientific Investigations Report 2007-5200.

Dahl, T. 1990. Wetlands losses in the United States, 1780s to 1980s. U.S. Department of Interior, Fish and Wildlife Service, Washington, D.C.

Dahl, T. 2006. Status and trends of wetlands in the conterminous United States 1998 to 2004. U.S. Department of Interior, Fish and Wildlife Service, Washington, D.C.

Domac, A, and M. Suzen. 2006. Integration of environmental variables with satellite images in regional scale vegetation classification. *International Journal of Remote Sensing* 27(7): 1329-1350.

Duro, D., S. Franklin, and M. Dubé. 2012. A comparison of pixel-based and object-based image analysis with selected machine learning algorithms for the classification of agricultural landscapes using SPOT-5 HRG imagery. *Remote Sensing of Environment* 118: 259-272.

Foody, G. 2002. Status of land-cover classification accuracy assessment. *Remote Sensing of Environment* 80(1): 185-201.Gerla, P. 2007. Estimating the effect of cropland to prairie conservation on peak storm run-off. *Restoration Ecology* 15(4): 720-730.

Gerla, P., M. Cornett, J. Eckstein and M. Ahlering. 2012. Talking big: Lessons learned from a 9,000 hectare restoration in the northern tallgrass prairie. *Sustainability* 4: 3066-3087.

Grabs, T., J. Seibert, K. Bishop, and H. Laudon. 2009. Modeling spatial patterns of saturated areas: A comparison of the topographic wetness index and a dynamic distributed model. *Journal of Hydrology* 373: 15-23.

Grant, T. A., E. M. Madden, R. K. Murphy, K. A. Smith and M. P. Nenneman. 2004. Monitoring native prairie vegetation: The belt transect method. *Ecological Restoration* 22(2): 106-112.

Grant, T., B. Flanders-Wanner, T. Shaffer, R. Murphy, and G. Knutsen. 2009. An emerging crisis across northern prairie refuges: Prevalence of invasive plants and a plan for adaptive management. *Ecological Restoration* 27(1): 58-65.

Grumbine, R. 1994. What is ecosystem management? *Conservation Biology* 8(1): 27-38.

Hay, G., and G. Castilla. 2008. *Spatial concepts for knowledge-driven remote sensing applications* Berlin:Springer-Verlag.

High Plains Regional Climate Center. 2017. http://www.hprcc.unl.edu/ (last accessed 4 May 2017).

Jensen M., R. Redmond, J. Dibenedetto, P. Bourgeron, and I. Goodman. 2000. Application of ecological classification and predictive vegetation modeling to broad-level assessments of ecosystem health. *Environmental Monitoring and Assessment* 64: 197-212.

Jensen, J.R. 2005. *Introductory Digital Image Processing: A Remote Sensing Perspective,* ed. K. C. Clarke. New Jersey: Pearson Prentice Hall.

Ke, Y., L. Quackenbush, and J. Im. 2010. Synergistic use of QuickBird multispectral imagery and LiDAR data for object-based forest species classification. *Remote Sensing of Environment* 114: 1141-1154.

Kim, M., M. Madden, and B. Xu. 2010. GEOBIA vegetation mapping in Great Smoky Mountains National Park with spectral and non-spectral ancillary information. *Photogrammetric Engineering & Remote Sensing* 76(2): 137-149.

Laliberte, A., A. Rango, K. Havstad, J. Paris, R. Beck, R. McNeedly, and A. Gonzalez. 2004. Object-oriented image analysis for mapping shrub encroachment from 1937 to 2003 in southern New Mexico. *Remote Sensing of Environment* 93: 198-210.

Lyon, J., and L. Lyon. 2011. *Practical handbook for wetland identification and delineation.* 2nd ed. Boca Raton, FL: Taylor & Francis Group.

Maxwell, A., T. Warner, M. Strager, J. Conley, and A. Sharp. Assessing machine-learning algorithms and image- and lidar-derived variables for GEOBIA classification of mining and mine reclamation. *International Journal of Remote Sensing* 36 (4): 954-978.

Manly, B. 2009. *Statistics for environmental science and management*. Boca Raton, FL: Chapman & Hall/CRC Press.

Melesse, A., J. Oberg, V. Nangia, O. Beeri, and D. Baumgartner. 2006. Spatiotemporal dynamics of evapotranspiration at the Glacial Ridge prairie restoration in northwestern Minnesota. *Hydrological Processes* 20: 1451-1464.

Minnesota Climatology Working Group. 2017. Precipitation data retrieval from a gridded database.http://climate.umn.edu/gridded_data/precip/monthly/monthly_gridded_precip.asp (last accessed 1 May 1 2017).

Mitsch, W. and R. Wilson. 1996. Improving the success of wetland creation and restoration with know-how, time, and self-design. *Ecological Applications* 6: 77-83.

Mitsch, W., and J. Gosselink. 2007. *Wetlands.* 4th ed. Hoboken, New Jersey: John Wiley & Sons, Inc.

Moeslund, J., L. Arge, P. Bocher, T. Dalgaard, R. Ejrnaes, M. Odgaard, and J. Svenning. 2013. Topographically controlled soil moisture drives plant diversity patterns within grasslands. *Biodiversity Conservation* 22: 2151-2166.

Moffett, K. and S. Gorelick. 2013. Distinguishing wetland vegetation and channel features with object-based image segmentation. *International Journal of Remote Sensing* 34(4): 1332-1354.

Mui, A. Y. He, and Q. Weng. 2015. An object-based approach to delineate wetlands across landscapes of varied disturbance with high spatial resolution satellite imagery. *International Society for Photogrammetry and Remote Sensing Inc.* 109: 30-46.

Munsell Color. 2015. *Munsell Soil Color Book.* Grand Rapids, MI: Munsell Color X-rite.

NOAA National Centers for Environmental Information, Climate at a Glance: U.S. Time Series, Palmer Hydrological Drought Index (PHDI) 2017. http://www.ncdc.noaa.gov/cag/ (last accessed 27 April 2017).

Ozesmi, S., and M. Bauer. 2002. Satellite remote sensing of wetlands. *Wetlands Ecology and Management* 10(5): 381-402.

Pham, L., L. Brabyn, and S. Ashraf. 2016. Combining QuickBird, LiDAR, and GIS topography indices to identify a single native tree species in a complex landscape using an object-based classification approach. *International Journal of Applied Earth Observation and Geoinformation* 50: 187-197.

Platt, R. and L. Rapoza. 2008. An evaluation of an object-oriented paradigm for land use/land cover classification. *The Professional Geographer* 60(1): 87-100.

Roch, L. and J. Jaeger. 2014. Monitoring an ecosystem at risk: What is the degree of grassland fragmentation in the Canadian Prairies? *Environmental Monitoring and Assessment* 186(4): 2505-2534.

Rowe, H. 2010. Tricks of the trade: Techniques and opinions from 38 experts in tallgrass prairie restoration. *Restoration Ecology* 18(2): 253-262.

Samson, F, F. Knopf, and W. Ostlie. 1998. Status and trends of the Nation's biological resources. *Grasslands* 2: 437-472.

Skaggs, R., G. Chescheir, and B. Phillips. 2005. Methods to determine lateral effect of a drainage ditch on wetland hydrology. *American Society of Agricultural Engineers* 48(2): 577-584.

Tilman, D., F. Isbell, and J. Cowles. 2014. Biodiversity and ecosystem function. *Annual Review of Ecology, Evolution and Systematics* 45: 471-493.

Tiner, R. W. 2003. Geographically isolated wetlands of the United States. *Wetlands* 23: 494-516.

Trimble Inc. 2015. eCognition Developer 9.1 User Guide. Munich, Germany.

United States Army Corps of Engineers. 1987. Corps of Engineers wetlands delineation manual. http://www.bwsr.state.mn.us/wetlands/publications/corpsmanual.pdf (last accessed at 1 February 2017).

United States Army Corps of Engineers. 2010. Regional supplement to the Corps of Engineers wetland delineation manual: Great Plains Region. http://www.bwsr.state.mn.us/wetlands/delineation/Great_Plains_Supplement.pdf (last accessed at 1 February 2017).

United States Army Corps of Engineers. 2016. National wetland plant list. http://rsgisias.crrel.usace.army.mil/NWPL/ (last accessed at 1 February 2017).

United States Fish and Wildlife Service. 2016. Glacial Ridge National Wildlife Refuge environmental assessment and comprehensive conservation plan. https://www.fws.gov/Midwest/Planning/GlacialRidge/EA-CCP%20Complete/GR%20EA-CCP%20Final%2009-13-2016.pdf (last accessed at 1 February 2017).

Vacek, S., M. Cornett, D. Carlson, M. Ahlering. 2015. Grassland monitoring team standardized monitoring protocol. https://www.conservationgateway.org/ConservationByGeography/NorthAmerica/UnitedStates/minnesota/Documents/GMT_Protocol_v7.pdf (last accessed at 4 May 2017).

Van der Valk, A. 1989. *Northern Prairie Wetlands.* Ames, Iowa: Iowa State University Press.

Wright, C., and M. Wimberly. 2013. Recent land use change in the western corn belt threatens grasslands and wetlands. *Proceedings of the National Academy of Sciences* 110(10): 4134-4139.

Yu, Q., P. Gong, N. Clinton, G. Biging, M. Kelly, and D. Schirokauer. 2006. Object-based detailed vegetation classification with airborne high spatial resolution remote sensing imagery. *Photogrammetric Engineering & Remote Sensing* 72(7): 799-811.

Zedler, J. 2000. Progress in wetland restoration ecology. *Trends in Ecology and Evolution* 15: 402-407.

Zedler, J., J. Doherty, and N. Miller. 2012. Shifting restoration policy to address landscape change, novel ecosystems, and monitoring. *Ecology and Society.* 17(4): 36.