COMPARING SOIL AND HYDROLOGICAL CONDITIONS OF WETLANDS RESERVE PROGRAM RESTORATIONS AND NATURAL WETLANDS ALONG THE DEEP FORK RIVER, OKLAHOMA (USA)

By

MATTHEW W. HOUGH

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Oklahoma State University

Stillwater, Oklahoma

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COMPARING SOIL AND HYDROLOGICAL CONDITIONS OF WETLANDS RESERVE PROGRAM RESTORATIONS AND NATURAL WETLANDS ALONG THE DEEP FORK RIVER, OKLAHOMA (USA)

Thesis Approved:

Brian J. Carter

Thesis Adviser

Craig A. Davis

Joseph R. Bidwell

Karen R. Hickman

Mark E. Payton

Dean of the Graduate College

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CHAPTER I

Comparing Hydrological Conditions of Wetlands Reserve Program and Natural Wetlands in Central Oklahoma (USA)

INTRODUCTION

Wetland losses caused by destruction and conversion by humans have decreased the total area of wetlands in the United States. Historically, wetland drainage and destruction were an accepted practice for the establishment of agricultural fields and for commercial and residential development (Mitsch and Gosselink 2007). Approximately 47 million ha of the 89 million ha of wetlands that existed in what is now the United States at the beginning of European settlement have been lost (Dahl 2006). The loss of functions that wetlands provide is the primary reason of concern regarding wetland losses. Wetlands provide hydrological functions including surface and subsurface storage of water, floodwater dissipation, and groundwater recharge and discharge (Smith et al. 1995). Biogeochemical wetland functions include nutrient cycling, removing imported elements and compounds, retaining particulates, and exporting organic carbon (Smith et al. 1995). Biological wetland functions include providing vertebrate, invertebrate, and plant habitat (Smith et al. 1995). It is the loss of these functions which raises concerns regarding wetland losses and has created a need for research that focuses on wetland ecosystems.

Wetland conservation practices such as wetland restoration and creation have become more common as the importance of the functions and values of wetlands are better understood and appreciated by society and the preservation of functions have become a concern. In response to wetland losses, government programs such as the "Swampbuster" provisions in the 1985 Food Security Act and the Wetlands Reserve Program (WRP) have been enacted that assist in protecting wetlands. The Wetlands Reserve Program is a voluntary United States Department of Agriculture (USDA) Natural Resources Conservation Service (NRCS) program established in 1990 under amendments to the 1985 Farm Bill. The goal of WRP is to offer landowners "the opportunity to protect, restore, and enhance wetlands on their property at minimal cost to themselves" (NRCS 2008: 1). Landowner assistance is offered by WRP through cost-share agreements and other forms of financial and technical support to maximize wetland and wildlife habitat functions on landowner properties (NRCS 2008). Typical WRP projects involve the restoration of wetlands on lands impacted by agriculture.

Of the functions of wetlands, many scientists believe those linked with wetland hydrology are most important in the assessment of wetlands. Wetland hydrology, as it influences functioning and processes, is important as it relates to biogeochemical processes, wetland ecosystem structure, the accumulation of organic matter, and ecological functions (Cole and Brooks 2000, Maltby and Barker 2009). Hydrologic data are an important component used in the assessment of wetland restorations and creations, or projects designed to create or restore wetlands, which are often utilized to compensate for lost wetland area. Within wetland restoration and creation projects, creating appropriate wetland hydrology is a factor that can limit restoration success. Restoration of hydrology can be the most important aspect of a wetland restoration and can be difficult to implement (Tweedy and Evans 2001).

To determine if wetland restorations are successful based on resemblance to natural wetlands, a comparison of the hydrologic characteristics of natural and restored wetlands is often implemented (Galatowitsch and van der Valk 1994). Many studies have focused on the comparison of restored or created wetlands to natural sites. Natural sites are often used to represent normal wetland conditions in a region and to assess the success of a wetland restoration or creation. For example, Wisconsin sedge meadow wetlands research determined that greater fluctuations of water table levels within restored wetlands and a greater range of mean water table levels existed between all restored sites when compared to natural sites (Ashworth 1997). Cole and Brooks (2000) discovered that created mainstem-floodplain wetlands in Pennsylvania differed from natural wetlands by having deeper standing water, being wet for longer periods, and having larger open-water components. Stolt et al. (2000) compared water table fluctuations of constructed palustrine wetlands to paired natural sites in Virginia and determined water table fluctuations to occur similarly between wetland types. Research by Barton et al. (2008) established that hydroperiods were longer in restored wetlands than in natural sites in Carolina Bay wetlands. The results of these studies reflect the importance of hydrologic features in wetland creation and restoration assessment and also indicate the variability that can be encountered in the assessment of different wetland types in different regions. Similarities in hydrologic characteristics between created or restored wetlands to natural wetlands are interpreted as similarities in functionality, or level of function, and indicate success of a wetland restoration.

The primary objectives of this study were to compare the hydrologic characteristics of restored WRP wetlands to natural wetlands in central Oklahoma. No similar studies have been conducted in this region of Oklahoma. The measurement of hydrologic characteristics of wetlands was used to determine if the restoration and management practices of WRP wetlands in this study region have resulted in differences in hydrologic characteristics compared to natural wetlands. Comparisons between restored and natural wetlands were made using data gathered from the measurement of water table levels and soil moisture readings. Differences between wetland types were then related to potential differences in wetland functions and restoration success.

CHAPTER I

METHODS

Description of Study Area

The study was conducted along the Deep Fork River in Lincoln, Creek, Okfuskee, and Okmulgee counties in central Oklahoma (Figure 1). A total of 16 wetlands, 8 WRP wetlands and 8 natural wetlands, were examined between June 2009 and May 2010. All wetlands examined in the study were riverine wetlands, which were selected based on hydrogeomorphic (HGM) classification of wetlands (Brinson 1993). Riverine natural wetlands were utilized to attempt to standardize wetland classes used in this study as this wetland class was the dominant classification of the WRP wetlands in this region. The HGM classification of wetlands was used due to its link with the functional assessment of wetlands (Smith et al. 1995), which was a goal of this study. Wetlands were selected for inclusion in the study if they received occasional to very frequent flooding from the Deep Fork River based on soil survey flooding frequency classification data (websoilsurvey.nrcs.usda.gov). All wetlands in this project were characterized by emergent and submergent herbaceous vegetation.

The WRP wetland restorations were chosen for inclusion within the study based on a set of requirements that characterized typical WRP wetlands of this region. These requirements included a history of active management of water table levels by landowners using water control structures, installation of dikes at least on 2 sides during construction, and excavations established within them to provide soil for dike building. Characteristics of WRP wetlands, including restoration history, management history, and age (Table 1), were provided by NRCS personnel. Management strategies were similar for all WRP wetlands. Typically, landowners lower water table levels (drawdown) in the spring to manage for moist-soil vegetation, followed by the raising of water table levels in the late fall and winter months to increase waterfowl habitat during migration and duck hunting seasons. The time since restoration of WRP wetlands in this study ranged from 4 to 13 years in 2010.

Natural wetlands were identified using aerial photography, National Wetlands Inventory data, soil survey maps, and topographic maps. When potential natural wetlands were identified, site visits were conducted to verify that no evidence of disturbances related to anthropogenic modifications existed and hydrophytic vegetation was present. Further verification of site histories were provided by landowner accounts. Natural wetlands included in the study were required to possess hydrophytic vegetation communities predominately composed of emergent and submergent plants as WRP wetlands in the area were only inhabited by these types of plant communities. Forested natural wetlands were not included in the study.

Wetland sizes range between 1 and 40 ha (natural wetland mean area = 10.7 ha; WRP wetland mean area = 8.57 ha). Four sites were established and monitored per wetland in this study. Originally, 8 sites were selected for monitoring using a stratified random method based on the percent of vegetative cover type being either emergent or submergent. However, 4 sites were randomly selected from these 8 due to budgetary and time constraints. Sites were selected using ArcView version 3.3 (ESRI, Redlands, CA, USA).

Water table Level Monitoring

Water table monitoring wells were implemented to determine differences in hydrologic features between natural and WRP wetlands due to the importance of hydrologic features to wetland functioning and restoration success as discussed above. Well construction followed methods outlined by Wakeley (2005). A 1.5 m long, 5-cm-diameter PVC pipe served as the well casing. The bottom 85 cm segment of each casing was slotted at 1.3 cm intervals using a hacksaw. Screening was used to prevent particles from entering the well. An 8.5 cm diameter auger was used to create holes for well installation at the 4 sites established in each wetland. Each well was installed to a depth of 1.0 m below the soil surface. After the casing was inserted, coarse sand was used to fill around the well to the top of the slotted segment. A 2.5 cm thick layer of bentonite pellets covered the sand to prevent surface water from entering alongside of the well casing. Soil was used to create a mound around the well at the soil surface to prevent surface water from entering the hole. The top of each well was capped to prevent precipitation and debris from entering.

The monthly monitoring of shallow groundwater wells was implemented to assess water table levels and water table level fluctuations over time (Cole et al. 1997, Confer and Niering 1992, and Stolt et al. 2000). Wells were monitored between June 2009 and May 2010. Measurements of water table levels were collected relative to the soil surface using a measuring tape. Water table levels were recorded as either a (+) or (-) depth from the soil surface (0 cm). Water table levels were determined in the wells when the water table was at or below the soil surface. Water table levels were recorded beside the well when standing-water at or above the soil surface was present (inundation). These data were used to provide depth to water tables annually, seasonally, and monthly. These data were also used to determine the residence time of water above the soil surface and in the upper 30 cm of soil as this zone relates to the depth of saturation used in wetland delineations and is the typical rooting zone of wetland plants (Lewis 1995, Cole and Brooks 2000).

Air-filled Porosity

To determine differences in the potential of each wetland for subsurface storage of water, percent air-filled porosity (% AFP; defined as pore space not filled with water) was calculated using the soil water content and total porosity (S_t) of each wetland. The % AFP was used as it directly affects the gas diffusivity in a wetland, which affects the uptake and release of biologically important gases such as CO_2, N_2O, and CH_4 (Smith et al. 2003). Soil aeration and saturation also effects levels of reduction and redoximorphic processes in wetlands. Porosity and the air or water filling those pores is important as it relates to the movement of gases and nutrients in the soil, which control biological activity (Richardson et al. 2004). In wetlands, porosity is also important to subsurface water storage, water table fluctuations, plant available water, rain infiltration, and gas exchange (Gerla 1992, Lott and Hunt 2001).Subsurface storage of water was of interest in these systems due to its role in floodwater storage.

Once a month, soil water content samples were collected at depths of 5 cm and 20 cm at each well site (Magee et al. 1993, Stander and Ehrenfeld 2009) using an auger. When the water table level was at or above the soil surface, samples were considered at field capacity (100%) and were not gathered. Samples were returned to the laboratory, mixed within their storage bags to evenly distribute moisture, and subsamples were placed in preweighed sampling tins, weighed to determine total mass, dried to a constant weight at 105°C for 24 hours, and reweighed to determine dry soil mass and water mass lost (Faulkner et al. 1989). Gravimetric water content (θ_{dw}) was calculated as the mass of water divided by the mass of dry soil. Gravimetric soil water content was then converted to a volume-basis using the equation

$$\theta_{vb} = (\rho / \rho_w)\theta_{dw}$$

where θ_{vb} = volume-basis water content, ρ = soil bulk density, and ρ_w = the density of water (1 g/cm^3; Gardner 1986).

Total porosity, or the percent of the soil that is filled with water or air, was estimated using the equation

$$S_t = \left(1 - \rho / \rho_p\right)$$

where ρ_p = particle density (Danielson and Sutherland 1986). The standard particle density of 2.65 Mg/m^3 was used for the equation (Chong et al. 1996, Weir et al. 1996).

Field samples of soil bulk density were not sampled so an estimate based on direct measurement of soil texture and soil organic matter was calculated. A direct measurement of site soil bulk density would have been more accurate, but it became impractical within the timeline of this project to attempt to sample soil bulk density directly. Soil bulk density (g/cm^3) was estimated using Adams (1973) equation for soil bulk density

$$\rho = \frac{100}{\frac{X}{\rho_0} + \frac{100 - X}{\rho_m}}$$

where X = percent soil organic matter (SOM), ρ_0 = average bulk density of SOM (0.224 g/cm^3), and ρ_m= bulk density of mineral matter (g/cm^3; Rawls 1983). Percent soil organic matter (SOM) was converted from total organic carbon (TOC) samples collected at 5 and 20 cm below the soil surface at each site during the growing season (Hoeltje and Cole 2009, Xu et al. 2009) by multiplying TOC by 1.724 (Gosselink et al. 1984). Samples of TOC were analyzed using the dry combustion method outlined in Methods of Soil Analysis (Nelson and Sommers 1996) by the OSU Soil, Water, and Forage Analytical Laboratory. Mineral bulk density values were visually estimated from approximate midpoint values based on soil texture from the mineral bulk density contour map in Rawls (1983). Soil texture had been determined for each soil horizon using soil profile descriptions conducted at each sample site (4 sites) down to 30 cm using standard field-texture methods (Soil Survey Division Staff 1993, Schoeneberger et al. 2002).

The percent air-filled porosity (% AFP) was used to determine the amount of free air space in the total volume of pore space for each site for each month. This value was calculated as

$$\%APS = St - \theta_{vb}$$

The % AFP was used to determine differences between wetland site soil moisture and their potential to store subsurface water. The % AFP was determined for every month at all well sites in each wetland. The % AFP for WRP wetlands were compared to natural wetlands seasonally and annually.

Climate Characterization

Total monthly precipitation values were collected from the Oklahoma Mesonet website (http://climate.mesonet.org) from the 3 nearest weather stations (Chandler, Bristow, and Okmulgee stations). Each wetland was assigned climate data from the corresponding weather station in closest proximity. Precipitation values were used to determine if the amount of precipitation was typical for the sampling period (Cole et al. 1997) and if precipitation had similar effects on hydrologic properties of WRP and natural wetlands. Total monthly precipitation values were compared to USDA WETS tables (http://www.wcc.nrcs.usda.gov/water/w_clim.html) published by the National Weather Service and Climate Center, which publishes precipitation values from the nearest National Weather Service weather station for the past 30 years. The WETS tables provided ranges of normal monthly precipitation for each county. Methods outlined in Woodward (1997) were used to establish if each season had normal, high, or low precipitation based on antecedent precipitation. This information was used to establish if the study period was characterized by normal, high, or low precipitation. Monthly, seasonal, and annual precipitation data from each corresponding weather station were correlated to median water table levels for each wetland to determine if precipitation trends were correlated with fluctuations in water table levels and if these correlation results were similar between wetland types. The WETS tables also provided the average length of each county's growing season, and were utilized to determine differences between natural and WRP wetlands in water table fluctuations within the period most critical to plant growth.

Data Analyses

All statistics were calculated using MINITAB version 16 (MINITAB, Inc., State College, Pennsylvania, USA). All α values were set at 0.05. Comparisons were conducted using independent sample 2-sample t-tests to evaluate differences between wetland types when data were normally distributed, which was verified using an Anderson-Darling test. Variances were pooled when variance between treatments was equal, which was verified using an F-test, and were not pooled when variance was not equal. When data were not normally distributed and could not be transformed, were categorical, or when medians were used, a Kruskall-Wallis H test was used (Cole and Brooks 2000). Pearson's correlation coefficient was used to correlate parametric data. Spearman's rank correlation coefficient was utilized to establish if relationships existed between nonparametric data.

Monthly water table level measurements were analyzed to compare WRP and natural wetlands. Water-depth measurements were used to calculate the monthly median water table level rather than mean water table level, as some wells went dry during the study period and a direct measure of the actual water table level was not possible (Cole et al. 1997, Cole and Brooks 2000). This measurement provided a more conservative estimate of water table levels as actual levels may have been deeper than the values reported. Seasonal and annual median water depths for each wetland were compared between WRP and natural wetlands using a 2-sample-t-test and a Kruskall-Wallis test. Water table standard deviation, minimum values, maximum values, and range of all wells within each wetland were compared between WRP and natural wetlands as also performed by Ashworth (1997) by using observations in the differences in mean values, a 2-sample-t-test, and a Kruskall-Wallis test. The standard deviation of monthly water table levels of each well were used to assess the degree of fluctuation in water tables in each wetland. The percent time that the water table level was at or above 30 cm below the soil surface at each well was chosen to compare between wetland types due to the importance of this depth to wetland delineations and plant growth. The percent time the wetlands were inundated was also determined and compared between wetland types. Both depths were compared using a Kruskall-Wallis test.

Porosity and soil bulk density were compared between wetland types at both 5 cm and 20 cm using a two-sample-t-test and Kruskall-Wallis test. The mean of monthly % AFP values were calculated seasonally and annually at each wetland for both 5 cm and 20 cm samples. Mean 5 cm % AFP was compared to 20 cm % AFP samples using a Kruskall-Wallis test to determine which portion of the soil contained less moisture annually. Seasonal and annual precipitation means were correlated with seasonal and annual water table fluctuations and % AFP using Spearman’s correlation analysis to determine the effects of precipitation on water table levels and % AFP.

Precipitation data were also utilized in determining if the seasonal and annual precipitation was normal of the sampling period based on historic precipitation data collected by each weather station. Precipitation characterization was determined by applying a value for precipitation to each month (1 = dry, 2 = normal, and 3 = wet), determining the mean for each season and for the year, and rounding to the nearest value to determine which precipitation category the time-period best fit (dry, normal, or wet; Woodward 1997).

CHAPTER I

RESULTS

Water table Level Monitoring

General water table level characteristics consisting of water table medians of WRP and natural sites for the course of the study-period are presented in Table 2 and 3 and Figure 2. Comparisons of hydrologic data between WRP and natural wetlands (Table 4) determined that WRP wetlands had larger fluctuations (i.e., standard deviations) in water table levels when compared to natural wetlands. The percent time the water table level was located 30 cm below the soil surface or above (saturated) was significantly greater in natural sites versus WRP wetlands both annually and during the growing season. The percent time the wetlands were inundated was not different annually between WRP and natural sites higher in natural sites compared to WRP sites during the growing season. The WRP wetland wells had a greater range of water tables levels with lower minimum and greater maximum levels compared to natural wetlands.

Air-filled porosity

Comparisons between porosity data of natural and WRP wetlands (Table 5) determined several differences between wetland types. Samples at 5 cm and 20 cm in natural site soils were more porous than WRP site soils. The 5 cm and 20 cm soil bulk density samples were higher in WRP soils than in natural soils. The annual % AFP was higher in WRP than natural sites in 5 cm samples but not 20 cm samples. Seasonal 5 cm and 20 cm % AFP samples indicated WRP wetlands contained higher 5 cm % AFP in the summer and 5 cm and 20 cm % AFP in the fall. However, summer 5 cm and winter and spring 5 cm and 20 cm % AFP samples were not different between WRP and natural sites. The annual mean % AFP was lower at 5 cm than 20 cm in both wetland types. The % AFP at 5 cm and 20 cm were negatively correlated with median water table levels (ρ = -0.862, $P < 0.001$; ρ = -0.885, $P < 0.001$).

Climate Characterization

Mean annual and seasonal precipitation (Figure 3) for the study period was relatively normal for the study-region, except for the fall season, which had higher precipitation levels than normal. Precipitation was considered similar between wetland types and the mean of all county data was calculated as wetlands within the study-region were within relatively close proximity to one another (approximately 80 km between the most distant wetlands). No relationships existed between water table levels and precipitation within either wetland type on a seasonal or annual basis (Table 6). However, 5 cm % AFP was negatively correlated with precipitation levels annually and during the fall season, but not during winter and spring seasons. A positive correlation existed between summer precipitation and 5 cm % AFP.

CHAPTER I

DISCUSSION

Evidence suggests that WRP wetlands possess different hydrologic characteristics compared to natural wetlands. The restorations had a greater degree of water-depth fluctuation, decreased amount of time saturated in the rooting zone, decreased time inundated, and higher % AFP values as compared to natural sites. Ashworth (1997) produced similar findings for restored and natural wetlands in Wisconsin with restored wetlands possessing more variable water table level fluctuations than natural wetlands. Contrastingly, Confer and Niering (1992) determined natural wetlands in Connecticut to have greater fluctuations of water table levels than created wetlands. Also, within this study, water was found in the rooting zone or above the soil surface more often in natural wetlands than WRP wetlands, which is in contrast to the findings of Confer and Niering (1992), Ashworth (1997), Cole and Brooks (2000), and Hoeltje and Cole (2009). All of these studies determined constructed/restored wetlands to be wetter than natural wetlands. However, none of those authors discussed the use of water control structures or other water table level manipulations, which were present in this study.

Some of the physical features of the wetlands in this study were different between wetland types as well. The lower porosity and higher soil bulk densities in WRP sites compared to natural sites indicate differences in the physical properties of the soils, likely caused by compaction from agricultural practices or the restoration process, textural differences, and differences in SOM content. Similar findings were reported by Bishel-Machung et al. (1996) and Campbell et al. (2002), with natural wetlands containing lower mean bulk densities than created/restored wetlands. The lack of relationship between soil bulk density and age of WRPs suggests that the effects of compaction do not change over time, which was also determined by Campbell et al. (2002).

The similarity of median water table levels between wetland types could have been due to the high variability within wetland types. Within wetlands, study sites ranged between dry and wet and varied seasonally in median water table levels, which produced overlap of median water table levels between WRP and natural wetlands. These results suggest that WRP and natural wetlands both possess variable surface and subsurface characteristics such as macrotopgraphy and soil texture, which may have created the variability and overlap between wetland types. The dikes, excavations, and water control structures, characteristic of WRP wetland restorations, did not seem to create hydrological differences between WRP and natural wetlands regarding median water table levels.

Precipitation levels were normal to slightly high during the study-period (see appendix) so the hydrologic properties of both WRP and natural wetlands are representative of typical characteristics of these wetlands. The lack of a correlation between precipitation and water table levels may be explained by factors including a lag time following precipitation. This lag time can be influenced by runoff rates into wetlands depending on rainfall intensity and surface characteristics of the surrounding landscape, both of which potentially slowing the ability of water table levels to accurately reflect precipitation inputs. This lag time and the lack of relationships between precipitation and water table levels would have been influenced by several factors including open water control structures in WRP wetlands allowing water to be released, dikes surrounding WRP wetlands and other barriers to water runoff, the rate of runoff from uplands into wetlands, infiltration, evapotranspiration, the effects of flooding, and the effects of groundwater fluxes. It has been shown that, in the case of riverine wetlands, surface flow and groundwater are more important water sources than precipitation (Brinson 1993). Further explanation for the lack of correlations between precipitation and water table levels include inaccuracies of precipitation data due to the scattered, episodic nature of local precipitation events as found by Mallin et al. (1993), which may cause small precipitation events to not be accurately characterized for wetland sites by surrounding weather stations. Direct measurement of precipitation within study wetlands would improve the accuracy of precipitation data.

The decrease in annual and fall % AFP, which correlated with increasing precipitation levels in natural and WRP wetlands is likely due to water inputs from precipitation that filled soil pores and reduced the % AFP. This relationship did not exist during the winter and spring seasons. Wetlands had wetter conditions caused by high precipitation, stable water tables, and low evapotranspiration during these seasons so precipitation would have had less of an effect on % AFP as soil space was more often filled with water, regardless of precipitation events. Dry sites in the fall season provided more opportunities for precipitation to decrease % AFP since water tables were located below the surface more regularly and % AFP was higher. The positive correlation in the summer season is explained by very low precipitation that would have had little effect on % AFP. Regarding differences between wetland types, % AFP is higher in WRP wetlands so it is more likely to be reduced by precipitation events than natural wetlands. Further study may be required to verify the accuracy of these conclusions, however, due to the relatively weak correlations between precipitation and % AFP.

Human-induced water table manipulations by landowners are the largest contributing factor to greater hydrologic variability in WRP wetlands for this study region. Water control structures are installed in WRP restorations to aid landowners in water management and were utilized during the study period. Also, WRPs can receive water inputs through pumping from the Deep Fork River by landowners. The artificial manipulation of water table levels is the cause of the greater water table fluctuations and difference in % AFP in WRP sites compared to natural sites. The results of this study imply that the two wetland types are most similar hydrologically in winter, but have different hydrologic characteristics during the growing season due to human management of WRP wetland water table levels. The capture of water in the fall and winter of 2009 along with increased precipitation levels in the spring of 2010, may explain the similarities in % AFP between WRP and natural sites for the winter and spring seasons as both wetland types would have experienced similar precipitation and evaporation levels. The spring drawdown of 2010 did not affect % AFP. The higher % AFP in WRP wetlands in the summer and fall seasons compared to natural sites is caused by the spring drawdown and low precipitation in the summer of 2009. These results exhibit how WRP wetlands are different from natural wetlands hydrologically during much of the year due to water table manipulations in the spring.

The differences in hydrologic characteristics likely affect other features of these wetlands and the functionality of WRP and natural wetlands. Stable water-levels create different conditions in wetlands compared to fluctuating water tables, including differences in water supply for plant growth across the growing season and difference in oxygen availability (Cronk and Fennessy 2001). Many wetland plants do not have adaptations to manage the effects of water stress and shortages, and the development of anaerobic conditions in soils due to saturation promotes plants with adaptations for such environments (Cronk and Fennessy 2001). The difference between the distribution of water in WRP and natural wetlands during the growing season may cause plant stress in certain situations and differences in anaerobic and aerobic conditions, which may determine differences in the ability of the soils to provide similar plant habitats. For these reasons, the hydrologic characteristics of WRP wetlands in this region may not provide similar plant habitats to those provided by natural wetlands. The potential to store floodwater may also be different, as wetter sites are not able to store the same amount of floodwater as a drier site as a wet site does not contain as much free space for water storage. The greater % AFP in the soils of WRP wetlands would allow them to better perform the function of retaining floodwater through floodwater storage compared to natural sites that are consistently more saturated. However, the floodwater retention function may be rendered less effective in WRP wetlands if water control structures are open, allowing drainage into a larger water body (i.e., the Deep Fork River). These findings support that WRP and natural wetlands differ in hydrologic properties and may differ in functionality.

It is difficult to conclude the level of success of WRP wetland restorations in this region. Stolt et al. (2000) discovered the differences in water table levels to be similar between natural and constructed wetlands in Virginia and concluded that construction techniques to make the two wetland types similar hydrologically were successful. The results of this study do not indicate a similar success in reproducing natural hydrological conditions in WRP wetlands. A goal of the WRP is to restore wetlands to natural conditions to a practical extent (NRCS 2009). This suggests a high importance on the mimicry of natural hydrologic properties. However, it would require more research to determine that WRP wetlands are not successful from an ecological standpoint compared to natural wetlands. Perhaps WRP wetlands provide a greater diversity of wetland functions as they are more variable than natural wetlands. For example, promoting aerobic conditions in wetlands was determined to provide a more diverse plant community (Brooks et al. 1996).

Changes to WRP management and construction techniques solely based on the grounds of mimicking natural wetlands should be considered carefully. Altering WRP management strategies to mimic natural wetland hydrologic characteristics may not be desirable if the objectives of the NRCS and landowners are being met by the current management strategies that focus predominantly on maximizing waterfowl habitat. If WRP wetlands are providing a greater diversity of wetland functions than natural wetlands regarding landowner objectives, altering management of WRP wetlands to better mimic natural wetlands could serve as a deterrent to landowner participation in the WRP. The success of the WRP is dependent on landowner participation so their objectives should be of high priority. If the differences between wetland types are eventually deemed as unacceptable and changes to the program need to occur, convincing those participating and funding the WRP of the value of all wetland functions and services will be critical.

CHAPTER I

TABLES AND FIGURES

Table 1. Table of Wetlands Reserve Program (WRP) wetlands characteristics including age, location, area, previous land use, disturbance observed, management type and intensity, and if water control structures (WCS) were managed in 2009 or 2010.

WRP	Year Restored	County	Area (m^2)	Previous Land Use or Disturbances	Management	WCS Managed in 2009 or 2010?
1	1998	Lincoln	76,600		Low	No
2	2006	Lincoln	20,900	Dozer piles	High; moist soil	2009, 2010
3	2003	Lincoln	202,900	Plowed	High	2009, 2010
4	2006	Lincoln	13,750	Disked	Low	2009
5	1997	Lincoln	157,100	Mowed	High	2009, 2010
6	2005	Lincoln	13,950		High	2009
7	1999	Creek	115,250	Farmed; cropland; new excavations	High; moist soil	2009, 2010
8	2001	Okmulgee	85,350	Natural wetland; plowed	Low	2009

Table 2. Hydrologic characteristics of 16 natural (Nat) and Wetlands Reserve Program (WRP) wetlands containing 4 sites each in central Oklahoma recorded between June 2009 and May 2010. Data were recorded as either a (+) or (-) depth from the soil surface (0 cm).

Wetland	Median annual water table depth (cm)	Annual range in water table levels (cm)	Water table standard deviation	% time saturated ≥ -30 cm	% time inundated
Nat 1	37.3	-25.5 to 65.0	20.1	100	86.5
Nat 2	62.5	-13.5 to 82.0	31.1	100	90.6
Nat 3	18.5	-86.0 to 47.5	26.8	88.5	67.7
Nat 4	-0.80	-100 to 43.0	50.6	64.6	56.3
Nat 5	-54.3	-100 to 10.0	46.7	43.8	14.6
Nat 6	0.80	-100 to 54.0	42.0	75.0	54.2
Nat 7	28.0	-80.0 to 48.5	24.6	93.8	80.2
Nat 8	23.0	-100 to 49.0	40.8	89.6	82.3
WRP 1	-43.8	-100 to 69.5	31.5	45.8	43.8
WRP 2	22.3	-100 to 69.5	36.7	88.5	62.5
WRP 3	-0.90	-100 to 72.0	77.2	69.8	59.4
WRP 4	7.50	-100 to 118	62.9	65.6	40.6
WRP 5	11.3	-100 to 54.5	58.1	58.3	57.3
WRP 6	16.4	-100 to 91.0	58.1	65.6	46.9
WRP 7	63.8	-100 to 167	60.6	83.3	83.3
WRP 8	-10.5	-100 to 110	34.1	75.0	58.3

Table 3. Summarized hydrologic characteristics of all 8 natural (Nat) and 8 Wetlands Reserve Program (WRP) wetlands in central Oklahoma between June 2009 and May 2010. Data were recorded as either a (+) or (-) depth from the soil surface (0 cm).

Wetland	Median annual water table depth (cm)	Annual range in water table levels (cm)	Mean water table standard deviation	Mean % time saturated ≥ -30 cm	Mean % time inundated
Nat	5.30	-100 to 82.0	35.3	81.9	66.5
WRP	6.50	-100 to 166	52.4	69.0	56.3

Table 4. Means, standard errors (in parentheses), and P-values (Kruskall-Wallis) for comparisons between hydrologic characteristics of 4 sites in 8 natural and 8 Wetlands Reserve Program (WRP) wetlands including water table level standard deviation; the percent time wetlands were saturated and inundated annually and during the growing season; and the minimum and maximum water table level ranges of wetlands.

	Natural	WRP	P
Standard Deviation	34.7 (2.00)	50.3 (3.19(	< 0.001
% Time Saturated			
Annually	81.9 (3.34)	69.0 (4.17)	0.033
Growing Season	78.1 (3.85)	60.1 (5.60)	0.026
% Time Inundated			
Annually	66.5 (4.98)	56.5 (5.27)	0.140
Growing Season	60.2 (5.19)	44.9 (5.80)	0.046
Minimum Range (cm)	-65.3 (7.30)	-75.4 (8.85)	0.036
Maximum Range (cm)	37.5 (4.08)	61.6 (8.15)	0.011

Table 5. Means, standard errors (in parentheses), and P-values (Kruskall-Wallis) for data comparisons between 4 sites in 8 natural and 8 Wetlands Reserve Program (WRP) wetlands gathered at 5 cm and 20 cm below the surface including porosity (%), bulk density (g/cm^3), and the percent air-filled porosity (% AFP).

	Natural	WRP	P
Porosity (%)			
5 cm	57.5 (0.806)	53.7 (0.692)	0.001[a]
20 cm	53.2 (0.467)	50.6 (0.517)	<0.001[a]
Bulk density (g/cm^3)			
5 cm	1.13 (0.021)	1.23 (0.018)	0.002
20 cm	1.24 (0.012)	1.31 (0.014)	<0.001
% AFP			
Annual 5 cm	3.09 (0.850)	6.97 (1.25)	0.001
Annual 20 cm	4.33 (0.984)	6.73 (1.11)	0.064
Summer 5 cm	8.07 (2.01)	17.3 (4.35)	0.027
Summer 20 cm	9.67 (2.03)	12.7 (2.01)	0.546
Fall 5 cm	3.07 (1.14)	8.12 (1.18)	<0.001
Fall 20 cm	4.95 (1.31)	9.08 (1.52)	0.037
Winter 5 cm	0.885 (0.409)	1.38 (0.660)	0.259
Winter 20 cm	1.39 (0.685)	2.25 (0.881)	0.707
Spring 5 cm	0.269 (0.189)	1.58 (0.586)	0.081
Spring 20 cm	1.18 (0.708)	3.38 (1.08)	0.093

[a] P values based on arcsine transformation and analyzed using a t test.

Table 6: Correlations between hydrologic features and precipitation levels gathered from 16 wetlands in central Oklahoma.

Hydrologic Features	Precipitation (cm)	ρ	P
Median Water tables (cm)			
Annual	Annual	0.132	0.300
Summer	Summer	-0.192	0.129
Fall	Fall	0.191	0.131
Winter	Winter	0.045	0.723
Spring	Spring	0.104	0.413
Air-filled porosity (%)			
Annual 5 cm	Annual	-0.349	0.004
Annual 20 cm	Annual	-0.198	0.117
Summer 5 cm	Summer	0.299	0.016
Summer 20 cm	Summer	0.133	0.294
Fall 5 cm	Fall	-0.315	0.011
Fall 20 cm	Fall	-0.243	0.053
Winter 5 cm	Winter	0.108	0.428
Winter 20 cm	Winter	-0.030	0.813
Spring 5 cm	Spring	-0.069	0.587
Spring 20 cm	Spring	-0.058	0.648

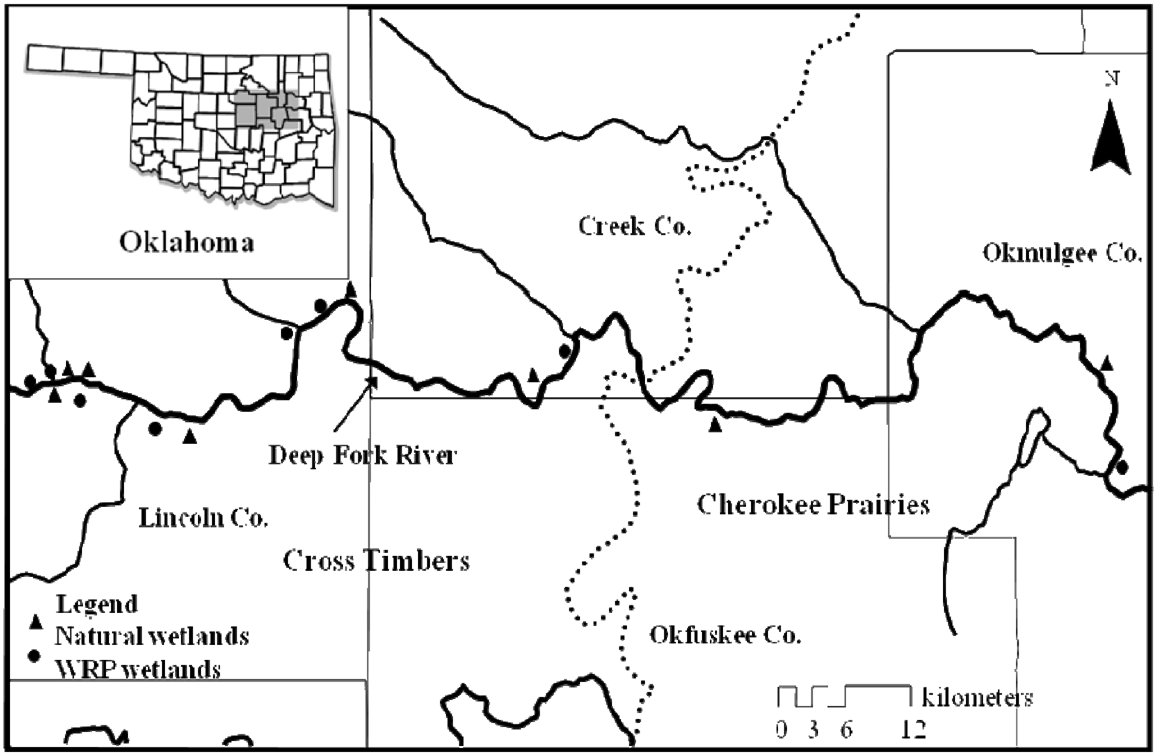

Figure 1. Map of study area in central Oklahoma including locations of natural and Wetlands Reserve Program (WRP) wetlands along the Deep Fork River, the tributaries of the river, and a dashed line representing the division between MLRA regions (Cross Timbers and Cherokee Prairies).

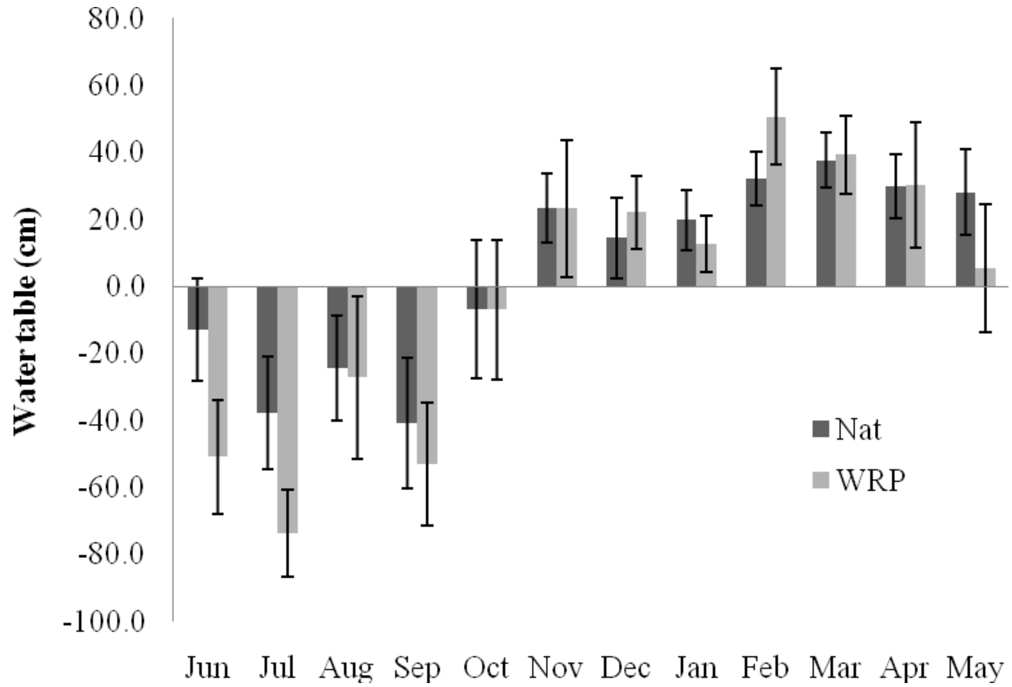

Figure 2. The monthly water table medians of 8 natural (Nat) and 8 Wetlands Reserve Program (WRP) wetlands gathered from June 2009 to May 2010. Data were recorded as either a (+) or (-) depth from the soil surface (0 cm).

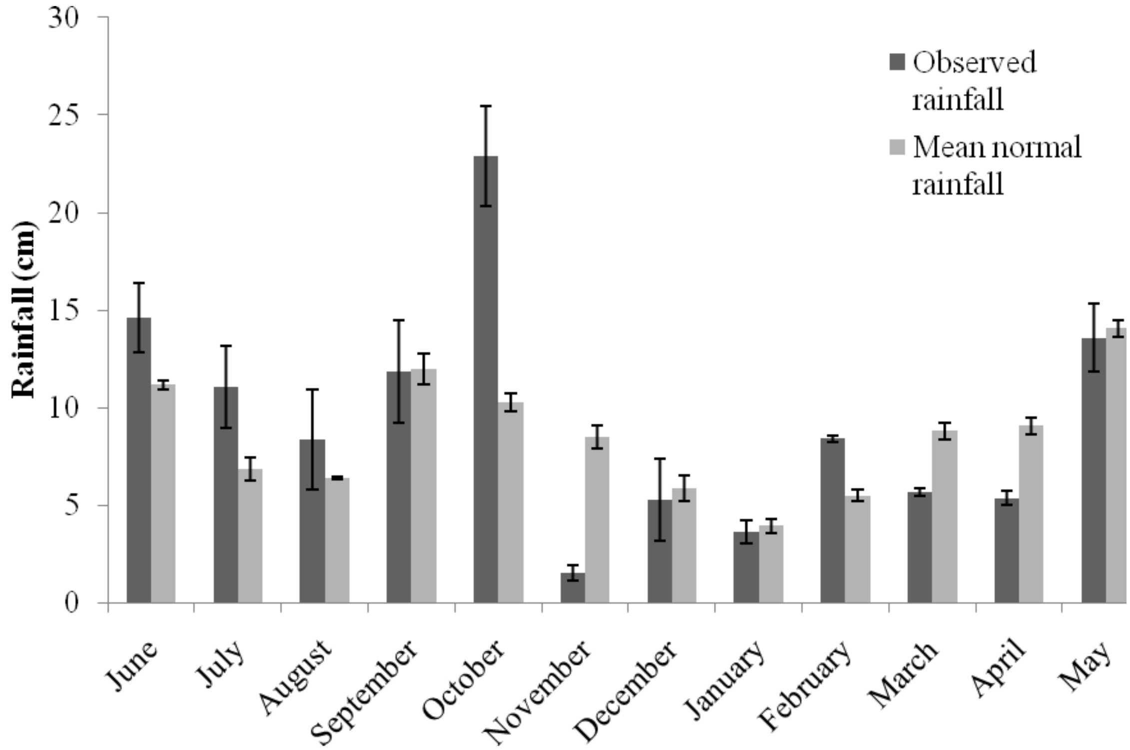

Figure 3. Observed mean monthly precipitation and normal precipitation based on calculations of normal rainfall from WETS table data for the study region (June 2009 – May 2010).

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REFERENCES

Adams, W. A. 1973. The effect of organic matter on the bulk and true densities of some uncultivated podzolic soils. Journal of Soil Science 24:10-17.

Ashworth, S. M. 1997. Comparison between restored and reference sedge meadow wetlands in south-central Wisconsin. Wetlands 17:518-527.

Barton, C. D., D. M. Andrews, and R. K. Kolka. 2008. Evaluating hydroperiod response in restored Carolina Bay wetlands using soil physiochemical properties. Restoration Ecology 16:668-677.

Bishel-Machung, L., R. P. Brooks, S. S. Yates, and K. L. Hoover. 1996. Soil properties of reference wetlands and wetland creation projects in Pennsylvania. Wetlands 16:532-541.

Brinson, M. M. 1993. A Hydrogeomorphic Classification for Wetlands. U.S. Army Corps of Engineers, Waterways Experiment Station, Washington, DC, USA. Wetlands Research Program Technical Report WRP-DE-4.

Brooks, R. P., C. A. Cole, D. H. Wardrop. L. Bishel-Machung, D. J. Prosser, D. A. Campbell, and M. T. Gaudette. 1996. Evaluating and implementing watershed approaches for protecting Pennsylvania's wetlands. Penn State Cooperative Wetlands Center Report Number 96-2. Environmental Resources Research Institute, Pensylvania State University, University Park, PA, USA.

Campbell, D. A., C. A. Cole, and R. P. Brooks. 2002. A comparison of created and natural wetlands in Pennsylvania, USA. Wetlands Ecology and Management 10:41-49.

Chong, S., S. Zhao, and B. P. Klubek. 1996. Field extraction of large intact soil cores for leaching studies in the laboratory. Weed Technology 10:210-216.

Cole, C. A. and R. P. Brooks. 2000. A comparison of the hydrologic characteristics of natural and created mainstem floodplain wetlands in Pennsylvania. Ecological Engineering 14:221-231.

Cole, C. A., R. P. Brooks, and D. H. Wardrop. 1997. Wetland hydrology as a function of hydrogeomorphic (HGM) subclass. Wetlands 17:456-467.

Confer, S. R. and W. A. Niering. 1992. Comparison of created and natural freshwater emergent wetlands in Connecticut (USA). Wetlands Ecology and Management 2:143-156.

Cronk, J. K. and M. S. Fennessy. 2001. Wetland Plants: Biology and Ecology. CRC Press, Boca Raton, FL, USA.

Dahl, T. E. 2006. Status and Trends of Wetlands in the Conterminous United States 1998 to 2004. U.S. Department of the Interior, Fish and Wildlife Service, Washington, DC, USA.

Danielson, R. E. and P. L. Sutherland. 1986. Porosity. p. 443-461. *In* A. Klute (ed.) Methods of Soil Analysis: Part 1. 2nd edition. Soil Science Society of America, Madison, WI, USA.

Faulkner, S. P., W. H. Patrick, Jr., and R. P. Gambrell. 1989. Field techniques for measuring wetland soil parameters. Soil Science Society of America Journal 53:883-890.

Galatowitsch, S. M. and A. E. van der Valk. 1994. Restoring Prairie Wetlands: An Ecological Approach. Iowa State University Press, Ames, IA, USA.

Gardner, W. H. 1986. Water content. p. 493–544. *In* A. Klute (ed.) Methods of Soil Analysis: Part 1. 2nd edition. Soil Science Society of America, Madison, WI, USA.

Gerla, P. J. 1992. The relationship of water-table changes to the capillary fringe, evapotranspiration, and precipitation in intermittent wetlands. Wetlands 12:91-98.

Gosselink, J. G., R. Hatton, and C. S. Hopkinson. 1984. Relationship of organic carbon and mineral content to bulk density in Louisiana marsh soils. Soil Science 137:177-180.

Hoeltje, S. and C. Cole. 2009. Comparison of function of created wetlands of two age classes in central Pennsylvania. Environmental Management 43:597-608.

Lewis, W. M. 1995. Executive summary: water. p. 5. *In* National Research Council (US) Committee on Characterization of Wetlands (ed.) Wetlands: Characteristics and Boundaries. National Academy Press. Washington, DC, USA.

Lott, R. B. and R. J. Hunt. 2001. Estimating evapotranspiration in natural and constructed wetlands. Wetlands 21:614-628.

Magee, T. K., S. E. Gwin, R. G. Gibson, C. C. Holland, J. E. Honea, P. W. Shaffer, J. C. Sifneos, and M. E. Kentula. 1993. Research Plan and Methods Manual for the Oregon Wetlands Study. EPA/600/R-93/072. U.S. Environmental Protection Agency, Environmental Research Laboratory, Corvallis, OR, USA.

Mallin M. A., H. W. Paerl, J. Rudek, and P. W. Bates. 1993. Regulation of estuarine primary production by watershed rainfall and river flow. Marine Ecology Progress Series 93:199-203.

Maltby, E. and T. Barker. 2009. The Wetlands Handbook. Wiley-Blackwell, Oxford, UK.

Mitsch, W. J. and J. G. Gosselink. 2007. Wetlands. 4th edition. John Wiley & Sons, Inc., Hoboken, NJ, USA.

Natural Resources Conservation Service. 2008. Ecological Monitoring Insights from the Wetlands Reserve Program in Missouri. U.S. Department of Agriculture, Washington, DC, USA. MO_WRP_021108.

Natural Resources Conservation Service. 2009. Wetland Reserve Program: Final Programmatic Environmental Assessment. U.S. Department of Agriculture, Washington, DC, USA. Final_WRP_EA_1-7-09.

Nelson, D. W. and L. E. Sommers. 1996. Total carbon, organic carbon, and organic matter. p. 961-1010. *In* D. L. Sparks, A. L. Page, P. A. Helmke, R. H. Loeppert, P. N. Soltanpour, M. A. Tabatabai, C. T. Johnson, and M. N. Summer (eds.) Methods of Soil Analysis, Part 3. 2nd edtion. Soil Science Society of America, Madison, WI, USA.

Rawls, W. J. 1983. Estimating soil bulk density from particle size analysis and organic matter content. Soil Science 135:123-125.

Richardson, T. L., A. H. M. Veeken, V. de Wilde, and H. V. M. Hamelers. 2004. Air-filled porosity and permeability relationships during soild-state fermentation. Biotechnology Progress 20:1372-1381.

Schoeneberger, P. J., D. A. Wysocki, E. C. Benham, and W. D. Broderson. 2002. Field Book for Describing and Sampling Soils. Version 2.0. U.S. Department of Agriculture, Natural Resources Conservation Service, National Soil Survey Center, Lincoln, NE, USA.

Smith, R. D., A. Ammann, C. Bartoldus, and M. M. Brinson. 1995. An Approach for Assessing Wetland Functions Using Hydrogeomorphic Classification, Reference Wetlands, and Functional Indices. U.S. Army Corps of Engineers, Waterways Experiment Station, Washington, DC, USA. Wetlands Research Program Technical Report WRP-DE-9.

Smith, K. A., T. Ball, F. Conen, K. E. Dobbie, J Massheder, and A. Rey. 2003. Exchage of greenhouse gases between soil and atmosphere: interactions of soil physical factors and biological processes. European Journal of Soil Science 54:779-791.

Soil Survey Division Staff. 1993. Soil Survey Manual. U.S. Government Printing Office, Washington, DC, USA. USDA-SCS Agricultural Handbook 430-V-SSM.

Stander, E. K. and J. G. Ehrenfeld. 2009. Rapid assessment of urban wetlands: functional assessment model development and evaluation. Wetlands 29:261-276.

Stolt, M. H., M. H. Genthner, W. L. Daniels, V. A. Groover, S. Nagle, and K. C. Haering. 2000. Comparison of soil and other environmental conditions in constructed and adjacent palustrine reference wetlands. Wetlands 20:671-683.

Tweedy, K. L. and R. O. Evans. 2001. Hydrologic characterization of two prior converted wetland restorations sites in eastern North Carolina. American Society of Agricultural Engineers 44: 1135-1142.

Wakeley, J. S. 2005. Technical standard for water-table monitoring of potential wetland sites. U.S. Army Corps of Engineers, Washington, DC, USA. ERDC TN-WRAP-05-2.

Weir, K. L., J. W. Doran, J. F. Power, and D. T. Walters. 1996. Denitrification and the dinitrogen/nitrous oxide ratio as affected by soil water, available carbon, and nitrate. Soil Science Society of America Journal 57:66-72.

Woodward, D. 1997. Hydrology tools for wetland determination. Engineering Field Handbook. Chapter 19. U.S. Department of Agriculture, Natural Resources Conservation Service, Washington, DC, USA. Part 650.

Xu, D., S. Meyer, J. Gaultier, A. Farenhorst, and D. Pennock. 2009. Land use and riparian effects on prairie wetland sediment properties and herbicide sorption coefficients. Journal of Environmental Quality 38:1757-1765.

CHAPTER II

Soil Properties of Wetlands Reserve Program and Natural Wetlands in Central Oklahoma (USA)

INTRODUCTION

In the United States, approximately half of wetland resources have been lost since the time of European settlement (Dahl 2006). The loss and degradation of wetlands drastically decreased wetland functions, including many of the biogeochemical services they provide, such as nutrient cycling, removing imported elements and compounds, retaining particulates, exporting organic carbon, as well as several hydrological and biological functions (Smith et al. 1995). Policies to protect wetlands and funding to create, restore, and protect wetlands have increased as public appreciation of wetlands has grown. One program that has resulted from wetland appreciation is the United States Department of Agriculture (USDA) Natural Resources Conservation Service's (NRCS) Wetlands Reserve Program (WRP). The WRP is a voluntary program established in the 1990 Farm Bill under amendments to the 1985 Farm Bill and is available to landowners to assist in the restoration of wetlands impacted by agriculture on their properties (Rewa 2005). The goal of WRP is to provide landowners "the opportunity to protect, restore, and enhance wetlands on their property at minimal cost to themselves" through the use of easements, cost-shares, and technical support (NRCS 2008: 1).

Wetland restorations, such as those conducted through the WRP, are a common technique used to compensate for the loss of wetlands and wetland functions by returning a degraded or altered wetland to a previous condition (Mitsch and Gosselink 2007). However, restoring a natural system can be challenging. Wetland restorations are particularly difficult since hydrologic restoration often fails (Tweedy and Evans 2001). To assess wetland restoration success, monitoring is conducted to determine how well these restorations mimic natural conditions. Monitoring projects often utilize comparisons between natural wetlands that are relatively undisturbed, naturally-occurring, and that occur in approximately the same area as the restoration (Kentula et al. 1992). Functional parameters are then used to compare natural wetlands to the created or restored wetlands (Bishel-Machung et al. 1996). Comparisons of functions between created or restored wetlands and natural wetlands are considered to be a definitive test of the success of restoration projects (Galatowitsch and Van der Valk 1996).

The assessment of characteristics related to wetland soils and other biogeochemical characteristics is often utilized when determining restoration success, as reliance on physical resemblance of restored wetlands to natural wetlands alone may not indicate functional replacement (Campbell et al. 2002). The reliance on the evaluation of soil characteristics relates to the importance of soil functions including water storage, water movement, improvement in water quality, nutrient cycling, and providing suitable habitat for plant and animal development (Zedler and Kercher 2005). Problems involving wetland soils may arise following a restoration which can be due to the restoration process, wetland management, or due to previous land use, which can arise from alterations to such components as soil texture; seed bank quality and quantity; nutrient availability; microbial population; soil development rates; salinity levels; erosion rates; and sedimentation rates (Zedler and Kercher 2005).

To assess wetland restoration successes, several aspects of wetland soils are commonly evaluated. For example, soil profile descriptions, which involve documenting soil texture, color, redoximorphic (redox) features, and may include several other components, are one method used for evaluating differences between wetlands. Differences in soil textures between wetland types are believed to indicate differences in the ability of wetlands to provide growth habitats for plants, variation in water-holding capacity, and are representative of different states of soil weathering (Bishel-Machung et al. 1996, Stolt et al. 2000, Zedler and Kercher 2005). Observations of soil color to identify gleying and redoximorphic features are also utilized in determining differences as these features can be related to evidence of reducing conditions and long-term saturation in soils (Richardson and Vepraskas 2001).

An additional soil feature commonly used when assessing created or restored wetlands is soil organic matter (SOM) content. Soil organic matter content is often limiting in wetland restorations and is considered an indicator of soil quality as it can be limiting to the success of colonizing plant and microbial communities. (Bruland and Richardson 2006). Soil organic matter content in wetlands also often correlates to soil nutrient levels and plant-available nitrogen (Stolt et al. 2000). Several studies determined natural wetlands had higher values of SOM compared to created or restored wetlands (Gwin and Kentula 1990, Stolt et al. 2000, Campbell et al. 2002, Bruland and Richardson

2005, Bruland and Richardson 2006, Bantilan-Smith et al. 2009). Bishel-Machung et al. (1996) determined that the higher SOM in natural wetlands caused differences in soil matrix chroma, pH, bulk density, and TN compared to wetlands with low SOM. They also determined SOM to be distributed differently in natural wetlands, being in lower concentrations in 20 cm compared to 5 cm zones, but distributed equally through the profile in created wetlands.

An additional method of assessing wetlands involves measuring nutrient levels as well as levels of various chemical properties of the soil. One study determined total nitrogen (TN) levels to be higher in natural wetlands than restored wetlands in Pennsylvania (Bishel-Machung et al. 1996). Stolt et al. (2000) reported that several of the natural wetlands that were compared to constructed wetlands had, along with differences in textures; higher TN levels, lower pH values, and a higher cation exchange capacity (CEC, i.e., the ability to hold essential nutrients). Other common soil nutrients and chemical properties used in making wetland comparisons are phosphorus (P), sulfur (S), sodium (Na), and electrical conductivity (EC) levels (Simmons et al. 2009).

Another assessment method is the measurement of sedimentation rates and amounts. Sedimentation rates determine a wetland’s ability to remove particulates from the water and to trap sediment from the surrounding landscape (Kleiss 1996). Johnston (1991) considers particulate removal to be the most important function of wetlands related to sedimentary processes due to its influence on water quality. Comparisons between sediment accumulation rates is another factor considered when comparing natural wetlands to created and restored wetlands. Mitsch (1992) found that sedimentation rates were greater for restored and created versus natural wetlands in the

Midwest. Understanding sedimentary processes can assist in the assessment of wetlands and their properties by determining how to improve wetland design, estimating the lifetimes of wetland systems, and assessing the ability of a wetland to provide organic and inorganic cycling as wetlands can function as a source, a sink, and a transformer for materials such as nutrients, organic matter, and chemicals (Harter and Mitsch 2003). Also, sedimentation has a major role in wetland degradation and decreased sustainability when sediment is deposited in excessive amounts (Wardrop and Brooks 1998, Braskerud et al. 2000, Braskerud 2001, White et al. 2002).

Objectives of this study included the comparison between WRP and natural wetland soil characteristics, which would be related to functionality to establish if WRP wetlands were similar to natural wetlands in the same area. The first objective of this study was to utilize selected soil field characteristics to compare and evaluate morphological differences in WRP versus natural wetlands. Comparisons were made using soil profile descriptions which included comparisons of the thickness of A horizons, the presence of buried A horizons, redox feature characteristics, soil texture, and matrix chroma. A second objective was to evaluate differences in SOM levels, nutrient levels, and salinity between wetland types. The final objective was the comparison of sediment accretion rates to evaluate differences in the ability of each wetland to retain particulates as well as to provide insight into wetland sustainability.

Data were then analyzed to determine if relationships existed between other known wetland features including age, location within the region, and wetland hydrologic data that might have suggested differences between wetland types. Correlations were conducted between SOM and age of WRP wetlands to determine if SOM was increasing over time. Nutrients that were different between sites were correlated with SOM to determine if SOM was a factor in nutrient holding capacity of soils. Soil properties, including the thickness of A horizons, the number of buried soils, redox feature presence, and if the profile met a hydric soil indicator, were correlated with wetland age to determine how aging affected soil properties and if WRP wetlands became more similar to natural sites over time. Correlations between wetland age and TN, P, K, and pH were conducted to determine if primary nutrients and pH were affected by wetland age as soils might begin reaching nutrient and chemical levels similar to the older, natural sites. Wetland locations based on MLRA region were correlated with pH, redox feature presence, chroma color, and if a hydric soil indicator was met to determine if wetland features developed differently in the two MLRA regions as the western region was known to have soils that do not easily exhibit wetland characteristics (Richardson and Vepraskas 2001). Correlations were conducted between annual median water table levels and soil properties including the thickness of A horizons, the number of buried soils, if a hydric indicator was met, chroma color, textures, redox presence, depth to redox, and sediment accumulation to determine what effects the hydrologic properties of the wetlands had on soil characteristics.

CHAPTER II

METHODS

Description of Study Area

Wetlands in this study included 8 WRP wetland restorations and 8 natural wetlands located along the Deep Fork River in central Oklahoma (Figure 1). A minimum five-year flooding frequency was common of all wetlands, which insured that all wetlands were classified under the riverine hydrogeomorphic (HGM) classification of wetlands (Brinson 1993). The HGM approach was utilized due to its link with functional assessment of wetlands (Smith et al. 1995), and relating wetland characteristics to function was a goal of this project. Also, riverine wetlands represented the typical class of WRP wetlands in the study area. Flooding frequency was verified through soil survey flooding frequency classification data (websoilsurvey.nrcs.usda.gov).

Wetlands Reserve Program restoration wetlands were actively managed by landowners through the use of water control structures to manipulate water table levels. The WRP wetlands also had dikes installed around them and had excavations within them that provided soil for dike building. Natural wetlands were required to have no history of active management or modifications by heavy equipment. Potential natural sites were identified using aerial photography, soil survey maps, topographic maps, and

National Wetlands Inventory data. When potential natural sites were identified, wetlands were visited to verify that no anthropogenic modifications had occurred on the site and that hydrophytic vegetation was present. Further verification of wetland histories were provided by landowner accounts. Natural wetlands were required to possess predominately emergent and submergent vegetation zones as this was the typical plant composition in WRP sites. The size of wetlands ranged between 1 and 40 ha (natural wetland mean area = 10.7 ha; WRP wetland mean area = 8.57 ha), and WRP wetland time since restoration ranged between 4 and 13 years in 2010 (for individual site descriptions see appendix). Four sample sites were established in each wetland. Originally, 8 stratified random sites were established per wetland based on vegetation zones. However, due to time and budgetary constraints, these sites were reduced to 4. Sites were selected using ArcView version 3.3 (ESRI, Redlands, CA, USA). These sites served as sampling and monitoring site locations between June 2009 and May 2010.

The wetlands included in this study occurred within two Major Land Resource Areas (MLRA; Soil Conservation Service 1979); the Cross Timbers (west section) and the Cherokee Prairies (east section; Figure 1). Wetlands in the Cross Timbers MLRA were considered western wetlands and wetlands in the Cherokee Prairies were considered eastern wetlands. Wetland location was utilized in determining trends in soil characteristics of wetlands based upon their position in the study area. Of the 16 wetlands, 7 WRP and 6 natural wetlands occurred in the western MLRA and 1 WRP and 2 natural wetlands occurred in the eastern MLRA.

Soil Morphologic Characteristics

Soil profile descriptions were conducted at each of the 4 well sites in each wetland. Soil profile descriptions were conducted to determine difference in the development of wetland soil characteristics. The soil was described to a depth of 30 cm (Simmons et al. 2009) using standard methods (Soil Survey Division Staff 1993, Schoeneberger et al. 2002). The soil profile description included horizon depths, texture, matrix color, percent redox features, and redox colors (Hoeltje and Cole 2009). Colors were determined using the Munsell color chart. One natural wetland was not sampled due to a damaged access road that was impassable late in the study period, and one WRP wetland site was not sampled due to a widened stream channel that incised our sample site. Profile descriptions were used to distinguish differences in the degree of soil formation based on differences in texture, soil color, and horizon depth, horizon type (A, B, C, or buried A), and number of horizons within 30 cm. Profile descriptions were also used to determine soil classification differences based on degree of redox feature formation, matrix chromas, and if the profile met hydric soil indicators. Hydric soil indicators were used to determine if the soils met criteria to be considered hydric (i.e., a wetland soil) based on federal protocols (Hurt et al. 2010).

Utilizing soil profile description data, comparisons between wetland types were conducted based on the number of soil horizons within the upper 30 cm; the thickness of A horizons; and the percent sand, silt, clay, and combined silt and clay determined from field textures, which were used to determine differences in soil development. Further comparisons between wetland types were conducted utilizing profile description data included the determination if redox features were present; the depth to redox features; if redox features existed in the upper horizon; redox feature abundance; if redox features were concentrations or depletions; the presence of buried A horizons; whether the description met a wetland indicator; and if the matrix was of a low chroma (2 or less; Hurt et al. 2010).

Soil Organic Matter Content

Soil samples for SOM determination were taken at each of the 4 sample sites using an 8.5 cm auger during the growing season (Xu et al. 2009), once in 2009 and once in 2010 at 5 and 20 cm below the soil surface (Magee et al. 1993, Bishel-Machung et al. 1996). These depths provided both a surface and subsurface sample to better analyze the variability of SOM distribution with depth. One natural wetland was not sampled in 2010 due to blocked road access. Once samples were collected, they were placed in plastic bags, returned to the laboratory, and each sample was mixed within the bag before being analyzed to ensure a homogenous sample for each depth. Samples were analyzed for total organic carbon (TOC) using the dry combustion method (Nelson and Sommers 1996) by the Oklahoma State University Soil, Water, and Forage Analytical Laboratory (SWAFL). Values for SOM were calculated utilizing the results of the TOC tests to compare differences in nutrient availability and distribution between and within wetlands. Soil organic matter was calculated by multiplying TOC by 1.724 (Gosselink et al. 1984). Mean wetland SOM was calculated by taking the mean of all converted TOC samples conducted at each site for each wetland.

Soil Nutrient Content

To assess differences in soil nutrient levels as well as soil chemical properties, samples were taken twice during the growing season at each of the four sites using an 8.5 cm auger (Xu et al. 2009). These tests provided macro-, micro-, and secondary nutrient levels and a measure of pH, which indicates plant habitat health and potential for nutrient cycling. Samples for TN were collected at 5 cm and 20 cm (Magee et al. 1993). All other nutrient samples were collected from 0 to 20 cm (Bruland and Richardson 2006). Collection of samples occurred once in 2009 and once in 2010, except for one natural wetland that was not sampled in 2010 due to blocked road access. Soil nutrient tests were conducted by SWAFL using methods outlined in Gavlak et al. (2003). The % TN was determined by the Kjeldahl Method (Bremner and Mulvaney 1982). Soil fertility tests provided available P, available K, Mg, and Ca using a Mehlich 3 extract; sulfate (SO_4-S) levels using calcium sulfate; iron (Fe), zinc (Zn), copper (Cu), and boron (B) using DTPA-sorbitol; and pH using a 1:1 soil-water extract and pH probe. Nutrient sample means were calculated for the two samples for each site in each wetland.

Soil Salinity and Sodic Conditions

Soil salinity tests were conducted to characterize soil chemical properties for wetlands in the region and to compare wetland types. Salinity tests were conducted on 0 to 20 cm soil samples collected at the 4 sample sites in each wetland in the late growing season of 2009, winter of 2009, and early growing season of 2010 (Bruland and Richardson 2006). Once samples were collected, they were placed in bags, returned to the laboratory, and mixed before being analyzed. Salinity tests were conducted by SWAFL using methods in Gavlak et al. (2003), which provided levels for Na, the sodium adsorption ratio (SAR), potassium adsorption ratio (PAR), total soluble salts (TSS), EC, exchangeable potassium percent (EPP), and the exchangeable sodium percentage (ESP). Salinity samples were collected 3 times over the course of the study and the mean of the results was calculated to compare differences between WRP and natural wetlands. Soil salinity testing was conducted to distinguish differences in soil chemical conditions between wetland types to relate to differences in plant habitat and soil quality.

Annual Sediment Deposition

Sediment plates were used to monitor mass accretion rates for each wetland over the one-year study period (Kleiss 1996, Braskerud et al. 2000). Differences in sedimentation between wetland types would provide insight into differences related to disturbance histories, potential differences in the lifetime of the wetlands, and their ability to retain particulates. Sediment plates consisted of 25 x 25 cm plexiglass squares, 0.3 cm thick. The upper side of each plate was sanded to provide a rough surface so sediment was not easily washed off. A 1.0 cm hole drilled in the center of each square, through which a 30 cm threaded steel rod, 0.6 cm in diameter, was placed, leaving approximately 5 cm of the rod above the soil surface. A wingnut was used to stabilize the plate to the soil surface. A total of 6 plates were installed in each wetland, one at each of the 4 sites used for other analyses and 2 at randomly selected sample sites. Sediment plates were collected at the end of the study. Sediment was removed from each plate, dried at 105°C for 24 hours, and the mass was recorded. Sediment was also tested for SOM by SWAFL using loss on ignition (Gavlak et al. 2003) to determine the differences between organic and inorganic sediment accumulation. Data were reported as grams of sediment that were deposited on a 625 cm^2 surface over one year.

Data Analyses

Statistical analyses were conducted using MINITAB version 16 (MINITAB, Inc., State College, Pennsylvania, USA). All soil parameters were compared between wetland types using a 2-sample t-test when data distribution was normal. Normality was tested with the Anderson-Darling normality test. When using the 2-sample-t-test, variances were pooled when variance between two treatments were equal and were not pooled when variance was unequal which was verified using an F-test. Data not normally distributed were compared between wetland types using a Kruskal-Wallis H test (Cole et al. 1997, Campbell et al. 2002). McNemar tests were used to compare binomial data (ex. presence or absence of redox features; Sokal and Rholf 1981). Differences were considered significant at $P \leq 0.05$.

Correlations between various data were also performed. Spearman's rho (ρ) correlation analysis was utilized to conduct all correlations as data sets were not normally distributed or were categorical (Zar 1984). Data gathered from WRP wetlands including thickness of A horizons, the number of buried soils, the number of individual soil horizons, percent sand, percent silt, percent clay, matrix chroma, redox feature characteristics, and nutrient levels were correlated with the number of years since restoration to determine if trends in soil development could be detected with maturity (Bishel-Machung et al. 1996). Location of wetlands (east or west) was then correlated to redox feature abundance, soil matrix chroma, pH, and if a hydric soil indicator was met to assess differences between MLRA regions as wetland soil characteristics were expected to be different between regions (Richardson and Vepraskas 2001). Soil profile description data were also correlated with hydrologic data which included median water table level data to assess the effects of hydrologic characteristics on soil features including soil texture (for a complete explanation of how water table levels were collected and calculated see Chapter 1).

CHAPTER II

RESULTS & DISCUSSION

Soil Morphologic Characteristics

Profile description comparisons (Table 1 and Table 2) indicated that WRP and natural sites did not differ in the number of horizons within 30 cm, the thickness of A horizons, matrix chroma colors, or the depth to redox features. Wetlands Reserve Program and natural wetland soils also had similar values for percent sand, silt, and clay as also found by Hoeltje and Cole (2007) when comparing natural to created floodplain wetlands in Pennsylvania. The lack of differences in field-described soil characteristics, specifically the thickness of A horizons and soil texture, indicate that WRP wetlands do not significantly differ morphologically from natural sites. Wetland creation projects are often characterized as containing larger soil particles near the soil surface compared to natural sites due to the removal of surface layers to create wetland hydrology (Buol 1990). Stolt et al. (2000) determined constructed wetlands possess larger soil particles than natural wetlands, which may lead to differences in functional capacities and ability to support similar vegetation. These differences are not apparent for WRP restorations in this region as particle size distribution was similar between WRP and natural sites.

Differences between wetland types included the number of buried soils. Natural wetlands contained fewer occurrences of buried A horizons and surface C horizons than WRP wetlands. Buried soils are indicative of sedimentation and disturbance (Carter et al. 2009). Disturbance occurs when conducting a wetland restoration due to heavy equipment use in earth-moving activities including the installation of dikes and nesting islands. A lack of disturbance explains the decreased occurrence of buried soils in natural wetlands compared to WRP wetlands. A higher occurrence of buried soils in WRP wetlands compared to natural wetlands may indicate increased sedimentation (Carter et al. 2009) and reduced sustainability if WRP wetlands are filling with sediment faster than natural wetlands, which could indicate reduced functional lifetimes of these wetlands (Richardson and Vepraskas 2001). However, these assumptions will require further study for verification as buried soils may also be due to recent disturbances from construction and agricultural practices and may diminish over time.

More WRP sites met all requirements to meet a hydric soil indicator and had greater numbers of horizons with matrix colors of 2 or less compared to natural sites. The presence or absence of redox features within the profile (down to 30 cm) was not different between wetland types. Wetland types also did not differ in the abundance of redox features (few, common, or many) or in the predominate type of redox features (concentrations or depletions). Similarly, Hoeltje and Cole (2007), using functional assessment models, did not find differences between redox features in created and natural floodplain wetlands in Pennsylvania. The WRP sites did have a greater proportion of redox features within the upper-most soil horizon compared to natural wetlands. Redox features near the surface are better indicators of prolonged flooding and hydric soil conditions than deep redox features as they more easily meet hydric soil indicators. Natural wetlands should have more hydric indicators, low chroma soils, and shallow redox features, compared to WRP sites because natural sites have been wet for a greater number of years and hydric features have had more time to form, though this was not true of natural wetlands in this study. Shallower redox features in WRP sites as compared to natural sites suggest that surface soils were displaced during construction of WRP restorations and relict features that are normally deeper in natural wetland soils are now closer to the soil surface in WRP sites. This hypothesis was supported by field observations, which indicated that redox features became more prominent with increasing depth in both wetland types. This displacement of surface soils may explain the greater abundance of redox features in surface horizons of WRP wetlands compared to natural wetlands.

Besides surface disturbances in WRP wetlands, another explanation for the fewer occurrences of wetland characteristics in natural wetlands may be explained by the location of 13 of the 16 wetlands in this study. The majority of wetlands occurred in the Cross Timbers MLRA which contains soils known to possess TF2 hydric soil indicators (Richardson and Vepraskas 2001). Wetland soils of the western portion of the study-region more often met hydric soil indicator requirements of the TF2 hydric soil indicator than soils of the eastern portion (11 wetlands of 59 total profile descriptions in the western portion met the TF2 indicator versus 4 in the eastern portion; 42 wetland sites met no indicator; see appendix). The TF2 soils are problematic to identify as hydric as they do not easily form redox features due to high chroma soils inherited from red parent material that are resistant to reduction (Hurt et al. 2010). Wetlands of this study-region are also characterized by relatively low SOM values (Table 2). Vepraskas et al. (1995) suggests that a minimum of 3 % SOM is required for redox features to form in created wetlands. Many SOM samples gathered within both natural and restored sites were below 3 % SOM including 8 of the 5 cm and 22 of the 20 cm SOM samples out of 32 sites in natural wetlands and 17 of the 5 cm and 26 of the 20 cm samples out of 32 sites in WRP wetlands. The degree of SOM accumulation may not be enough in soils of this region for the formation of redox features. These results indicate that hydric soil indicators are not commonly present for this region and emphasize the need for more extensive monitoring of water table levels and reducing conditions when conducting wetland delineations and assessments and when determining if a soil is hydric.

Soil Organic Matter Content

The 0 cm samples contained greater mean % SOM (Table 3) compared to 20 cm samples in both natural and WRP wetlands. Surface SOM samples were not correlated with 20 cm samples from the same sample site ($\rho = 0.120$, $P = 0.347$). The lack of relationship between 5 cm and 20 cm SOM levels is explained by the greater rate of surface accumulation of SOM through sedimentation and the buildup of SOM by vegetation. These processes are the predominant inputs of SOM in these systems, and occur near the soil surface. Higher SOM content in 5 cm samples versus 20 cm samples in both WRP and natural wetlands indicates that surface accumulation of SOM is occurring, likely from sedimentation and root decomposition, as also determined by Bishel-Machung et al. (1996).

Wetland types differed in the amount of SOM (Table 3). Natural sites contained greater SOM contents at both the 5 cm and 20 cm sampling depths compared to WRP sites. The lower SOM values determined for WRP sites versus natural sites are similar to other studies, which determined that both restored and created wetlands are characterized by lower SOM compared to natural wetlands (Bishel-Machung et al. 1996, Galatowitsch and Van der Valk 1996, Shaffer and Ernst 1999, Campbell et al. 2002, Bruland and Richardson 2005, Bruland and Richardson 2006, Bantilan-Smith 2009, Hoeltje and Cole 2009). These results likely reflect the impacts of disturbances from the construction and agricultural practices that occurred in the WRP wetland restorations. Differences in SOM are important regarding these systems due to its association with nutrient availability and processes such as denitrification and carbon sequestration, and since it is a major component of plant community establishment following wetland creation or restoration (Stauffer and Brooks 1997).

Low SOM content in WRP wetlands likely results from ecological immaturity (Reppert 1992) due to recent construction and agricultural activities. The WRP wetlands may increase in SOM over time. However, correlations between 5 cm SOM samples and WRP age ($\rho = 0.166$, $P = 0.363$) did not suggest that WRP wetlands are gaining SOM over time as there was not a significant relationship between SOM and increasing age. Campbell et al. (2002) discovered created wetlands have consistently lower SOM levels than natural wetlands and that created wetlands tended to stop accumulating significant amounts of SOM after the first 10 years following construction. When 5 cm % SOM contents of old WRP sites (greater than 10 years since construction) were compared to young sites (less than 10 years) and natural sites, no differences were found ($H = 1.19$, df

= 1, P =0.276; H = 3.31, df = 1, P =0.069) although mean SOM content did increase with age (young WRP wetlands = 3.22 % SOM, old WRP wetlands = 3.57 % SOM, natural wetlands = 5.18 % SOM). Natural wetlands had significantly higher SOM compared to young WRP wetlands (H = 8.07, df = 1, P =0.005). These results suggest that older WRP wetlands have similar amounts of SOM compared to both young WRP wetlands and natural wetlands, but aging WRP wetlands may approach natural wetland SOM levels.

The WRP wetlands of this study may eventually reach comparable SOM levels with natural wetlands. Bishel-Machung et al. (1996) also determined that no relationship existed between time since implementation and SOM accumulation in creation projects ranging from 1 to 8 years since constructed but concluded that sufficient time had not passed to verify that SOM would not accumulate over time. Only 3 WRP wetlands in this study had been restored for longer than 10 years, so evidence of low SOM accumulation and long-term differences in functions in WRP wetlands compared to natural wetlands of this region will require further study. However, study is warranted due to the link between low SOM levels and the decrease in the health of plant and microbe communities (Bruland and Richardson 2006), ability of wetlands to retain nutrients (Stolt et al. 2000), and wetland restoration success.

Soil Nutrient Content

Analyses of nutrient availabilities yielded varying results for WRP and natural sites (Table 3). Nutrient and chemical properties determined to differ between WRP and natural sites included extractable Fe, Zn, and Cu, which were greater in natural sites compared to WRP sites. Percent TN in 5 cm samples was also significantly higher in natural sites compared to WRP sites. Lower nutrient levels in WRP sites compared to natural sites are likely a product of soil age and SOM levels as SOM increases with increasing maturity, and SOM is closely linked with nutrient cycling and availability of nutrients (Richardson and Vepraskas 2001). Nutrient levels that were significantly higher in natural sites compared to WRP sites and that correlated with SOM content included Fe ($\rho = 0.596$, $P < 0.001$), Zn ($\rho = 0.369$, $P = 0.002$), and Cu ($\rho = 0.510$, $P < 0.001$), which are affected by oxidation-reduction and become more soluble and mobile in a reduced form. The higher % TN in natural sites versus WRP sites was also correlated with increasing SOM content ($\rho = 0.979$, $P \leq 0.001$) as also discovered by Stolt et al. (2000).

Available P, K, Mg, Ca, sulfate, B, and pH were similar between wetland types, and are less likely to be affected by disturbances such as previous agricultural practices or restoration techniques. Similar nutrient levels are accounted for by characteristics of these nutrients such as being immobile, not easily leached, or in very small amounts in the soil. Also, K^{+}, Mg^{++}, and Ca^{+} are cations that are not affected by oxidation-reduction so saturation and anaerobic conditions would not have an effect on their availability. Overall, nutrient levels are similar between natural and WRP wetlands, and the differences that occurred resulted from low SOM values in WRP wetlands compared to natural wetlands. Generally, the wetland types are similar except in soil maturity which affects SOM levels and leads to differences in nutrient levels.

Soil Salinity and Sodic Conditions

Most salinity test results were not different between natural and WRP wetlands (Table 3). Sodium levels and SAR were greater in natural sites compared to WRP sites.

Total soluble salts, EC, and ESP were similar between wetland types. Higher Na content and SAR levels in natural sites compared to WRP sites share a close relationship ($\rho = 0.591$, $P < 0.001$), and are explained by the increased soil age and the physical properties of natural sites versus WRP sites. Natural wetlands are closed basins which lose water from infiltration and evaporation compared to WRP wetland restorations which can be drained from the lowest area of the wetland (the water control structure). It is common for wetlands to accumulate salts when there is restricted drainage and a salt source in climates drier than central Oklahoma (Richardson and Vepraskas 2001) Perhaps even in a more humid environment such as this, Na accumulation can occur in significant amounts. This is because dissolved solids such as Na have had more time to accumulate in and are less easily flushed from natural wetlands compared to WRP wetlands containing water control structures. The lack of drainage accounts for the significantly higher levels of Na in natural wetlands compared to WRP wetlands. The long-term effects of increased Na in natural wetlands may decrease wetland quality as soils reach sodic levels (SAR > 12), which creates problems in soils such as dispersion and slaking and decreases suitable plant habitat (DeSutter 2008).

Annual Sediment Deposition

A total of 76 out of 94 sediment plates were recovered. Eighteen were damaged or lost. Sediment accumulation in natural and WRP sites did not differ in the accumulation of mineral sediment, the accumulation of organic sediment, or the accumulation of total sediment (Table 3). There was no difference in the ratio of mineral to organic sediment deposited on each plate between wetland types. The large standard error for sediment accumulation within each wetland type likely accounts for the inability to determine possible differences for sediment deposition amounts between WRP and natural wetlands. Sediment accumulation ranged greatly across the study area and within and among wetlands. High water tables or history of disturbance in WRP wetlands versus natural wetlands were expected to correlate with increased sediment accumulation, but no correlations were determined. Sediment accumulations may have been similar between natural and WRP wetlands since both wetland types shared floodwater from the same river system so they should have received similar sediment loads during flood events. Also, surrounding land use in uplands around both wetland types were predominately rangeland and forest. Surrounding land use did not include cultivated agricultural fields, which could have increased sediment loading into wetlands. Though not statistically different, mean annual sediment deposition and the mineral fraction of the sediment were considerably higher in WRP wetlands compared to natural wetlands. These results may be important regarding the sustainability of WRP wetlands as accelerated sedimentation into wetlands fill them, which has been linked changes in vegetative communities and loss of floodwater storage abilities in wetlands (Kleiss 1996). Also, these results may indicate differences in habitat quality as natural sites collected a higher ratio of organic to mineral sediment. Werner and Zedler (2002) consider sedimentation a factor in the alteration of the micro-environment of plants through changes to organic matter content and bulk density. By increasing the number of plates in future studies compared to this study, annual sediment deposition differences between wetland types may be determined.

Correlations

Age of WRP wetlands

The age of WRP wetlands correlated with the number of buried soils (Table 4). The number of buried soils in WRP wetlands was negatively correlated with increasing wetland age. Buried soils in WRP wetlands were commonly documented as a structureless C horizon overlying a darker A horizon found in low-lying portions of the wetlands and were likely a result of human disturbances. The effects of soil disturbance within WRP wetlands produced by initial construction activities and agricultural practices likely declined with increasing soil age as C and A horizons fused together forming thick A horizons. A decrease in pH of WRP wetlands correlated with increasing WRP wetland age. It is common for pH levels to decrease over time as bases are leached from the system, as also found by Stolt et al. (2000). Soil pH also decreases with increasing SOM content due to the acidifying effects of SOM decomposition. An increase in available P content may be due to an increase in pH. This is likely a result of the trend of decreasing pH levels from neutral and slightly alkaline to slightly acidic, which would have increased P availability. An increase in nutrients over time was expected in older WRP wetlands versus recently constructed WRP wetlands as natural wetlands are older than WRP wetlands, and as also determined by Bishel-Machung et al. (1996) and Stolt et al. (2000), natural wetlands are commonly characterized by higher nutrient and SOM levels.

Similarities between WRP wetlands of all ages likely result from the relatively young age of these restored wetlands. The few years that have passed since these restorations were conducted (4 to 13 years) were not long enough to induce significant changes to soil horizon thicknesses. Nutrient levels that did not change included TN and K. Total nitrogen is correlated with SOM and needs a significant time period to accumulate in soils. Available K is released to the soil from mineral weathering and would also take significant time to accumulate.

Location of WRP and natural wetlands

The location of wetlands (east or west; Table 5 and Table 6) influenced pH. The soil pH was lower in eastern wetlands than in western wetlands. Parent material differences are the probable cause for these differences. Western site soils formed from Permian era calcareous red shales, explaining the higher pH as compared to eastern site soils that are formed from Pennsylvanian era acidic gray shales (http://mrdata.usgs.gov/sgmc/ok.html; http://websoilsurvey.nrcs.usda.gov). The parent materials of these regions, upon weathering, have influenced soil pH.

Low chroma soils (2 or less), a good indicator of hydric soils (Hurt et al. 2010), were also more common in the eastern sites compared to the western sites. Hydric soil indicators were also met more frequently in eastern wetlands compared to western wetlands. These results can again be explained by parent material. The red shales in the west produce soils which do not easily meet hydric soil indicators due to very red soil matrices. It is unknown specifically why these soils do not exhibit redox features, but possible explanations involve mineralogical properties of these soils containing particles whose chroma color is too high to easily exhibit redox features or that have forms of Fe oxides coating the particles that are resistant to reduction (Rabenhorst and Parikh 2000).

Eastern wetlands formed in gray shales meet hydric indicators as they exhibit reduced and oxidized Fe oxide colors more readily than soils of western wetlands.

Water table levels versus soil profile description data

Increasing median annual water table levels (Table 7) correlated with an increased number of buried soils and a decreasing number of horizons in the upper 30 cm. Buried soil increases are correlated with water table level increases. This correlation is likely linked to wetlands receiving sediment loads from floodwater, and as water velocities slowed, sediment was deposited from the water column (Reddy and DeLaune 2008). Sediment levels, however, were not correlated with annual median water table levels (ρ = 0.234, P = 0.101) but did correlate with the number of buried soils, which supports sediment accumulation as a driving factor for the formation of buried soils. Sedimentation has been determined to be an important driver of buried soil formation in floodplain soils (Carter et al. 2009).

Increasing median water table levels also correlated with increased depth to observe redox features and decreased redox feature presence within the upper 30 cm. These trends are likely caused by the effect of increased anaerobic conditions in the soil, which increased reduction and decreased the oxidation of Mn in soils. Oxidized Mn is used in the identification of the TF2 hydric soil indicator (Hurt et al. 2010) as its dark color is easily seen against the red soil matrix. In a reduced form, Mn goes into solution (Richardson and Vepraskas 2001), and it would not be readily seen in TF2 soils so wet, anaerobic sites would not meet the indicator if oxidized Mn was not observed.

Median water table levels did not correlate with the thickness of A horizons or the chroma colors of the matrices. Increased water table levels were expected to increase sediment accumulation based on observations made in the field and to decrease SOM decomposition as decomposition decreases under anaerobic conditions (Bridgham and Lamberti 2009), which would both increase A horizon thicknesses, but this was not supported by the analyses. Correlations were also expected to support that increased saturation would decrease chroma colors through the reduction of Fe, but this was not the case, again, likely a result of the red soil matrices characteristic of this region. The percent sand was negatively correlated with increasing water table levels, and correspondingly, the clay percentage had a positive correlation with increasing median water table levels. This trend was expected as more fine textured particles compared to sand are deposited from the water column in sites with stable water table levels compared to areas of more fluctuating, swift-moving surface water that would deposit heavier particles such as sands as discussed by Reddy and DeLaune (2008). The possible effects of water table level increases on soil properties, such as increasing buried soils, increasing horizon thickness, increasing the depth to redox features, and its impacts on soil texture reflects the close link between soils and hydrologic properties. Further research is warranted to determine how WRP management might affect these processes if water table levels are managed differently from natural hydrologic processes in natural wetlands.

CHAPTER II

CONCLUSIONS

Wetlands Reserve Program restorations were similar to natural wetlands as represented by the many similarities in soil properties. Differences in soil properties that did exist can be explained by regional differences within the study-area, Na accumulation and its potentially negative impacts in natural wetlands associated with sodic soil conditions, and, most importantly, a lack of soil maturity in WRP wetlands created by disturbances from their initial construction and previous land uses. A key difference in soil features and wetland function between the WRP and natural wetlands created by the lack of soil maturity is the differences in SOM. Though SOM is known as a critical component of wetland systems, Bishel-Machung et al. (1996) indicated further study is needed to determine if low SOM values actually limit wetland creation success. Longer monitoring compared to the 4 to 13 years since restoration of wetlands in this study is warranted to determine if the WRP restorations are successful. Mitsch and Wilson (1996) suggest 15 to 20 years may be required before an accurate assessment can be determined regarding wetland restoration or creation success, which can be based on acceptable levels of functionality when compared to natural wetlands, similarity to wetlands that were lost or degraded, or when a biologically viable, sustainable system has been implemented. Overall, soil properties of WRP restorations in this region are becoming more similar to natural wetlands, which highlights the accomplishments of the program thus far as a goal of the WRP is to restore wetlands to natural conditions (NRCS 2009). However, the need exists for continued long-term monitoring to better assess the success of WRP restoration projects in this region.

CHAPTER II

TABLES AND FIGURES

Table 1. Means, standard errors (in parentheses), and P-values for soil profile description comparisons between 8 natural and 8 Wetlands Reserve Program (WRP) wetlands in central Oklahoma using a Kruskall-Wallis test.

	Natural	WRP	P
Soil horizons			
# horizons in profile	3.00 (0.145)	3.39 (0.211)	0.302
A horizon thickness (cm)	10.2 (1.23)	10.4 (1.18)	0.727
Texture			
Sand (%)	20.4 (2.15)	29.8 (3.89)	0.230
Silt (%)	43.9 (2.90)	38.1 (2.45)	0.156
Clay (%)	35.7 (3.19)	32.3 (2.76)	0.370
Redox			
Depth to redox (cm)	18.2 (2.48)	11.6 (2.12)	0.108

Table 2. Values (%), chi square (χ^2), and P-values for nominal data gathered from soil profile description comparisons between 4 sites in 8 natural (Nat) and 8 Wetlands Reserve Program (WRP) wetlands in central Oklahoma performed by a McNemar test.

	Nat	WRP	χ^2	P
Soil horizons				
Buried A horizon	11%	39%	4.57	<0.001
Hydric indicator met	11%	32%	13.5	<0.001
Chroma ≤ 2	4%	13%	24.1	<0.001
Redox				
Redox present	57%	77%	3.52	0.061
Redox in A	21%	23%	10.8	0.001
Redox abundance (common vs. few)	63%	54%	0.429	0.513
Redox concentration vs. depletion	44%	75%	0.077	0.782

Table 3. Means, standard errors (in parentheses), and P-values for soil data comparisons including soil organic matter (SOM) and total nitrogen (TN) gathered at 5 cm and 20 cm below the surface; phosphorus (P), potassium (K), Magnesium (Mg), calcium (Ca), sulfur (SO_4-S), iron (Fe), zinc (Zn), copper (Cu), boron (B), pH, sodium (Na), sodium adsorption ratio (SAR), potassium adsorption ratio (PAR), total soluble salts (TSS), electrical conductivity (EC), exchangeable potassium percent (EPP), and the exchangeable sodium percentage (ESP) gathered between 0 and 20 cm below the soil surface; and the amount of sediment gathered from sediment plates between 6 sites in 8 natural and 8 Wetlands Reserve Program (WRP) wetlands in central Oklahoma.

	Natural	WRP	P
SOM			
SOM (5 cm) (%)	5.18 (0.474)	3.40 (0.264)	0.003[b]
SOM (20 cm) (%)	2.62 (0.162)	2.20 (0.143)	0.040[b]
Soil Nutrient Content			
TN (5 cm) (%)	0.261 (0.020)	0.183 (0.012)	0.004[b]
TN (20 cm) (%)	0.152 (0.007)	0.138 (0.007)	0.145[a]
P (ppm)	19.0 (2.64)	17.4 (1.93)	0.968[b]
K (ppm)	202 (8.09)	193 (13.3)	0.573[a]
Mg (ppm)	761 (41.9)	786 (47.0)	0.405[b]
Ca (ppm)	2810 (148)	2580 (129)	0.260[a]
SO_4-S (ppm)	29.5 (3.80)	21.9 (2.76)	0.091[b]
Fe (ppm)	175 (23.8)	72.4 (8.86)	0.001[b]
Zn (ppm)	3.50 (0.435)	2.68 (0.578)	0.039[b]
Cu (ppm)	2.50 (0.151)	1.85 (0.136)	<0.001[a]
B (ppm)	0.986 (0.066)	1.14 (0.088)	0.425[a]
pH	6.77 (0.223)	7.28 (0.135)	0.104[b]
Salinity			
Na (ppm)	338 (124)	180 (51.0)	0.026[b]
SAR (%)	7.00 (1.58)	4.00 (0.776)	0.016[b]
PAR (%)	0.262 (0.015)	0.237 (0.015)	0.240[a]
TSS (ppm)	1880 (530)	1350 (284)	0.072[b]
EC (µmhos/cm)	2850 (804)	2040 (430)	0.072[b]
EPP (%)	5.96 (0.135)	5.53 (0.140)	0.242[a]
ESP (%)	7.23 (1.55)	4.75 (1.02)	0.083[b]
Annual Sedimentation			
Mineral (g/625cm^2)	238 (79.0)	274 (68.6)	0.560[b]
Organic (g/625cm^2)	27.5 (8.66)	45.7 (21.1)	0.573[b]
Total sediment (g/625cm^2)	265 (86.4)	320 (86.4)	0.698[b]

[a] Two-sample t-test
[b] Kruskal-Wallis

Table 4. Correlations between the age of 8 Wetlands Reserve Program (WRP) wetlands and soil properties of four sites within each wetland.

WRP age vs.	P	P
Thickness of A horizon	0.211	0.254
# of buried soils	0.398	0.027
Redox presence	0.293	0.110
Meets hydric soil indicator	0.333	0.0676
TN	0.247	0.172
P (phosphorus)	0.350	0.049
K	0.336	0.060
pH	-0.694	<0.001

Table 5. Mean values and the number of sites meeting certain criterion for soil features of 4 sites in 2 eastern and 13 western wetland sites*.

Soil feature	Eastern wetland sites	Western wetland sites
pH (mean)	5.58	7.36
Redox present in 30 cm	100%	86%
Chroma ≤ 2 (#/total)	63%	0%
Chroma (mean)	2.13	3.37
Hydric soil indicator met (#/total)	63%	16%

* One western site and 4 eastern sites were not included.

Table 6. Correlations between wetland locations (0 = west, 1 = east) and soil features (y = 1, n = 0) gathered from 16 wetlands in central Oklahoma.

Wetland location vs.	ρ	P
pH	-0.620	<0.001
Redox present (y/n)	0.272	0.036
Chroma ≤ 2 (y/n)	0.762	<0.001
Chroma (#)	-0.442	<0.001
Hydric soil indicator met (y/n)	0.387	0.002

Table 7. Correlations between median water table levels and soil profile description data of 16 wetlands in central Oklahoma.

Water table level vs.	ρ	P
Thickness of A horizon	-0.034	0.800
Buried A horizons	0.410	0.001
Meets hydric soil indicator	0.062	0.638
Chroma ≤ 2	0.080	0.545
% sand	-0.284	0.029
% silt	-0.136	0.305
% clay	0.512	<0.001
Redox presence	-0.339	0.009
Depth to redox	0.352	0.006

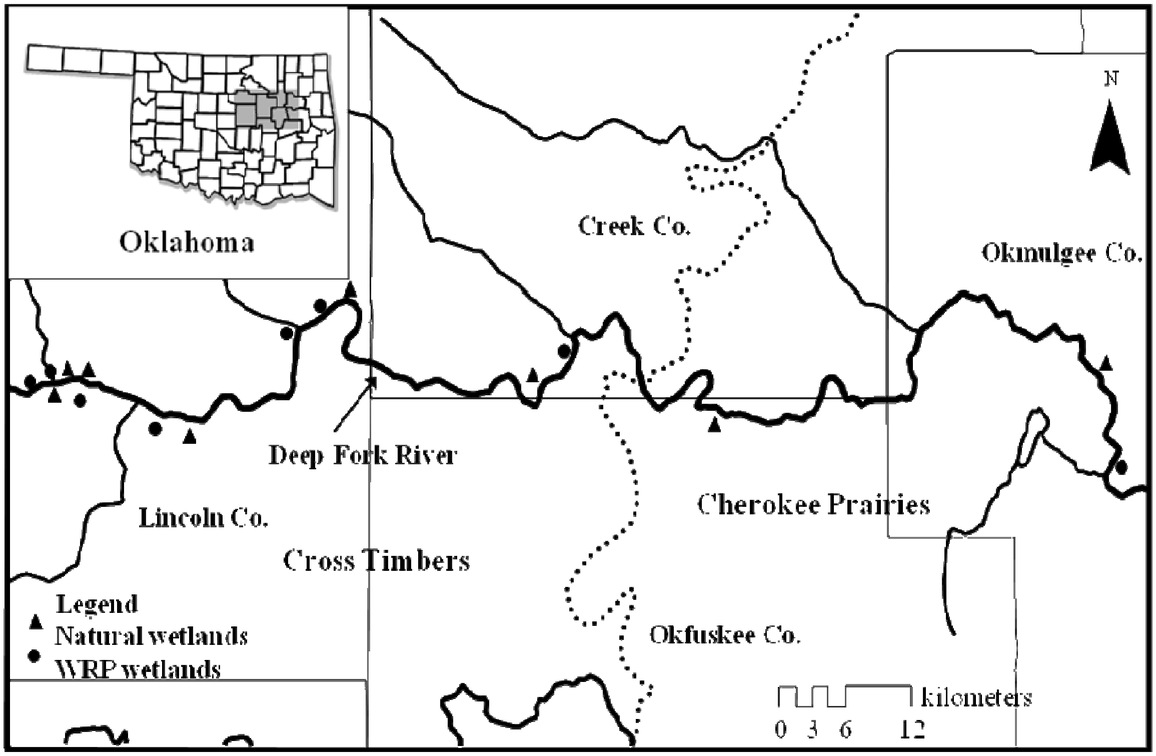

Figure 1. Map of study area in central Oklahoma including locations of natural and Wetlands Reserve Program (WRP) wetlands along the Deep Fork River, the tributaries of the river, and a dashed line representing the division between MLRA regions.

CHAPTER II

REFERENCES

Bantilan-Smith, M., G. L. Bruland, R. A. MacKenzie, A. R. Henry, and C. R. Ryder. 2009. A comparison of the vegetation and soils of natural, restored, and created coastal lowland wetland in Hawai'i. Wetlands 29:1023-1035.

Bishel-Machung, L., R. P. Brooks, S. S. Yates, and K. L. Hoover. 1996. Soil properties of reference wetlands and wetland creation projects in Pennsylvania. Wetlands 16:532-541.

Braskerud, B. C. 2001. The influence of vegetation on sedimentation and resuspension of soil particles in small constructed wetlands. Journal of Environmental Quality 30:1447-1457.

Braskerud, B. C., H. Lundekvam, and T. Krogstad. 2000. The impact of hydraulic load and aggregation on sedimentation of soil particles in small constructed wetlands. Journal of Environmental Quality 29:2013-2020.

Bremner, J. M. and C. S. Mulvaney. 1982. Nitrogen-total. p. 599-610. *In* A. L. Page, R. H. Miller, and D. R. Kenney (eds.) Methods of Soil Analysis. Part 2. Soil Science Society of America, Madison, WI, USA.

Bridgham, S. D. and G. A. Lamberti. 2009. Ecological dynamics III. p. 326-345. *In* E. Maltby and T. Barker (eds.) The Wetlands Handbook. Wiley-Blackwell, Oxford, UK.

Brinson, M. M. 1993. A Hydrogeomorphic Classification for Wetlands. U.S. Army Corps of Engineers, Waterways Experiment Station, Washington, DC, USA. Wetlands Research Program Technical Report WRP-DE-4.

Bruland, G. L. and C. J. Richardson. 2005. Spatial variability of soil properties in created, restored, and paired natural wetlands. Soil Science Society of America Journal 69:273-284.

Bruland, G. L. and C. J. Richardson. 2006. Comparison of soil organic matter in created, restored and paired natural wetlands in North Carolina. Wetlands Ecology and Management 14:245–251.

Buol, S. W. 1990. Soil Genesis and Classification. Iowa State University Press, Ames, IA, USA.

Campbell, D. A., C. A. Cole, and R. P. Brooks. 2002. A comparison of created and natural wetlands in Pennsylvania, USA. Wetlands Ecology and Management 10:41-49.

Carter, B. J., J. P. Kelley, J. B. Sudbury, and D. K. Splinter. 2009. Key aspects of A horizon formation for selected buried soils in late Holocene alluvium; southern prairies, USA. Soil Science 174:408.

Cole, C. A., R. P. Brooks, and D. H. Wardrop. 1997. Wetland hydrology as a function of hydrogeomorphic (HGM) subclass. Wetlands 17:456-467.

Dahl, T. E. 2006. Status and Trends of Wetlands in the Conterminous United States 1998 to 2004. U.S. Department of the Interior, Fish and Wildlife Service, Washington, DC, USA.

DeSutter, T. M. 2008 Problems in production fields – saline and sodic soils. p. 183 – 200. *In* S. Logsdon, D. Clay, D. Moore, and Teferi Tsegaye (eds.) Soil Science: Step-by-Step Field Analysis. Soil Science Society of America, Madison, WI, USA.

Galatowitsch, S. M. an d A. E. van der Valk. 1996. Vegetation and environmental conditions in recently restored wetlands in the prairie pothole region of the USA. Vegetatio 126:89-99.

Gavlak, R. G., D. A. Horneck, R. O. Miller, and J. Kotuby-Amacher. 2003. Soil organic matter. p. 110-111. *In* R. G. Gavlak, D. A. Horneck, and R. O. Miller (eds.) Soil, Plant and Water Reference Methods for the Western Region. 2nd edition. University of Alaska, Fairbanks, AK, USA.

Gosselink, J. G., R. Hatton, and C. S. Hopkinson. 1984. Relationship of organic carbon and mineral content to bulk density in Louisiana marsh soils. Soil Science 137:177-180.

Gwin, S. E. and M. E. Kentula. 1990. Evaluating design and verifying compliance of wetlands created under section 404 of the Clean Water Act in Oregon. U.S. Environmental Protection Agency, Environmental Research Laboratory, Corvallis, OR, USA. EPA/600/3-90/061.

Harter, S. and W. J. Mitsch. 2003. Patterns of short-term sedimentation in a freshwater created marsh. Journal of Environmental Quality 32:325-334.

Hoeltje, S. M. and C. A. Cole. 2007. Losing function through wetland mitigation in central Pennsylvania, USA. Environmental Management 39:385-482.

Hoeltje, S. M. and C. A. Cole. 2009. Comparison of function of created wetlands of two age classes in central Pennsylvania. Environmental Management 43:597-608.

Hurt, G. W., P. M. Whited, and R. F. Pringle. 2010. Field Indicators of Hydric Soils in the United States. Version 7.0. U.S. Department of Agriculture, Natural Resources Conservation Service in cooperation with the National Technical Committee for Hydric Soils, Fort Worth, TX, USA.

Johnston, C. A. 1991. Sediment and nutrient retention by freshwater wetlands: effects on surface water quality. Critical Reviews in Environmental Control. 21:491-565.

Kentula, M. E, R. P. Brooks, S. E. Gwin, C. C. Holland, A. D. Sherman, and J. C. Sinfneos. 1992. An Approach to Improved Decision Making in Wetland Restoration and Creation. U.S. Environmental Protection Agency, Environmental Research Laboratory, Corvallis, OR, USA.

Kleiss, B. A. 1996. Sedimentation retention in a bottomland hardwood wetland in eastern Arkansas. Wetlands 16:321-333.

Magee, T. K., S. E. Gwin, R. G. Gibson, C. C. Holland, J. E. Honea, P. W. Shaffer, J. C. Sifneos, and M. E. Kentula. 1993. Research Plan and Methods Manual for the

Oregon Wetlands Study. EPA/600/R-93/072. U.S. Environmental Protection Agency, Environmental Research Laboratory, Corvallis, OR, USA.

Mitsch, W. J. 1992. Landscape design and the role of created, restored, and natural riparian wetlands in controlling nonpoint source pollution. Ecological Engineering 1:27-47.

Mitsch, W. J. and J. G. Gosselink. 2007. Wetlands. 4th edition. John Wiley & Sons, Inc., New York, NY, USA.

Mitsch, W. J. and R. F. Wilson. 1996. Improving the success of wetland creations and restorations with know-how, time, and self-design. Ecological Applications 1:77-83.

Natural Resources Conservation Service. 2008. Ecological Monitoring Insights from the Wetlands Reserve Program in Missouri. U.S. Department of Agriculture, Washington, DC, USA. MO_WRP_021108.

Natural Resources Conservation Service. 2009. Wetland Reserve Program: Final Programmatic Environmental Assessment. U.S. Department of Agriculture, Washington, DC, USA. Final_WRP_EA_1-7-09.

Nelson, D. W. and L. E. Sommers. 1996. Total carbon, organic carbon, and organic matter. p. 963-977. *In* D. L. Sparks, A. L. Page, P. A. Helmke, R. H. Loeppert, P. N. Soltanpour, M. A. Tabatabai, C. T. Johnston, and M. E. Sumner (eds.) Methods of Soil Analysis. Part 3. Soil Science Society of America, Madison, WI, USA.

Rabenhorst, M. C. and S. Parikh. Propensity of soils to develop redoximorphic color changes. Soil Science Society of America Journal 64:1904-1910.

Reddy, K. R. and R. D. DeLaune. 2008. Biogeochemistry of Wetlands. Science and Applications. CRC Press, Boca Raton, FL, USA.

Reppert, R. R. 1992. Wetland Mitigation Banking Concepts. National Wetland Mitigation Banking Study. WR Report 92-WMB-1. US Army Corps of Engineers, Water Resources Board, Institute for Water Resources, Alexandria, VA, USA.

Rewa, C. A. 2005. Wildlife benefits of the Wetlands Reserve Program. p. 133-145. *In* J. B. Haufler (ed.) Fish and Wildlife Benefits of Farm Bill Programs: 2000-2005 Update. The Wildlife Society Technical Review 05-2, Bethesda, MD, USA.

Richardson, J. L. and M. J. Vepraskas. 2001. Wetland Soils: Genesis, Hydrology, Landscapes, and Classification. CRC Press, Boca Raton, FL, USA.

Schoeneberger, P. J., D. A. Wysocki, E. C. Benham, and W. D. Broderson. 2002. Field Book for Describing and Sampling Soils. Version 2.0. U.S. Department of Agriculture, Natural Resources Conservation Service, National Soil Survey Center,Lincoln, NE, USA.

Shaffer, P. W. and T. L. Ernst. 1999. Distribution of SOM in freshwater wetlands in the Portland, Oregon area. Wetlands 19:505-516.

Simmons, M. E. X. B. Wu, and S. G. Whisenant. 2009. Plant and soil responses to created microtopography and soil treatments in bottomland hardwood forest restorations. Restoration Ecology 17:1-11.

Smith, D., A. Ammann, C. Bartoldus, and M. Brinson. 1995. An Approach for Assessing Wetland Functions Using Hydrogeomorphic Classification, Reference Wetlands, and Functional Indices. U.S. Army Corps of Engineers, Waterways Experiment Station, Washington, DC, USA. WRP-DE-9.

Sokal, R. R., and F. J., Rohlf. 1981. Biometry. The principles and practice of statistics in biological research, 2nd ed. W. H. Freeman and Co., San Francisco, CA, USA.

Soil Conservation Service. 1979. Land resource areas Oklahoma. US Department of Agriculture, Fort Worth, TX, USA.

Soil Survey Division Staff. 1993. Soil Survey Manual. U.S. Government Printing Office, Washington, DC, USA. USDA-SCS Agricultural Handbook 430-V-SSM.

Stauffer, A. L. and R. P. Brooks. 1997. Plant and soil responses to salvaged marsh surface and organic matter amendments at a created wetland in central Pennsylvania. Wetlands 17:90-105.

Stolt, M. H., M. H. Genthner, W. L. Daniels, V. A. Groover, S. Nagle, and K. C. Haering. 2000. Comparison of soil and other environmental conditions in constructed and adjacent palustrine reference wetlands. Wetlands 20:671-683.

Tweedy, K. L. and R. O. Evans. 2001. Hydrologic characterization of two prior converted wetland restorations sites in eastern North Carolina. American Society of Agricultural Engineers 44:1135-1142.

Vepraskas, M. J., S. J. Teets, J. L. Richardson, and J. P. Tandarich. 1995. Development of Redoximorphic Features in Created Wetland Soils. Wetlands Research, Inc. Chicago, IL, USA.

Wardrop, D. H. and R. P. Brooks. 1998. The occurrence and impact of sedimentation in central Pennsylvania wetlands. Environmental Monitoring and Assessment 51:119-130.

Werner, K. J. and J. B. Zedler. 2002. How sedge meadow soils, microtopography, and vegetation respond to sedimentation. Wetlands 22:451-466.

White, W., R. Morton, and C. Holmes. 2002. A comparison of factors controlling sedimentation rates and wetland loss in fluvial-deltaic systems, Texas Gulf Coast. Geomorphology 44:47–66.

Xu D., S. Meyer, J. Gaultier, A. Farenhorst, and D. Pennock. 2009. Land use and riparian effects on prairie wetland sediment properties and herbicide sorption coefficients. Journal of Environmental Quality 38:1757-1765.

Zar, J. H. 1984. Biostatistical Analysis. Prentice-Hall, Englewood Cliffs, NJ, USA.

Zedler J. B. and S. Kercher. 2005. Wetland resources: satus, trends, ecosystem services, and restorability. Annual Review of Environmental Resources 30:39-74.

APPENDIX

Table of WRP wetlands characteristics including age, location, area, previous land use, disturbance observed, management type and intensity, and if water control structures (WCS) were managed in 2009 or 2010.

WRP	Year Restored	County	Area (m^2)	Previous Land Use or Disturbances	Manage-ment	WCS Managed in 2009 or 2010?
1	1998	Lincoln	76,600		Low	No
2	2006	Lincoln	20,900	Dozer Piles	High; Moist Soil	2009, 2010
3	2003	Lincoln	202,900	Plowed	High	2009, 2010
4	2006	Lincoln	13,750	Disked	Low	2009
5	1997	Lincoln	157,100	Mowed	High	2009, 2010
6	2005	Lincoln	13,950		High	2009
7	1999	Creek	115,250	Farmed; cropland; new excavations	High; Moist Soil	2009, 2010
8	2001	Okmulgee	85,350	Natural wetland; plowed	Low;	2009

Table of monthly water table level readings (cm) for each well site for each wetland (Treat 0 = natural sites; Treat 1 = Wetlands Reserve Program wetlands.

Treat	WL	1-Jun	1-Jul	Aug	Sep	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May
0	1	8.0	-23.0	33.5	-25.5	7.0	25.0	25.0	23.0	22.0	22.0	17.0	19.5
0	1	23.0	-4.0	-10.0	-7.0	25.0	30.0	30.0	36.5	36.0	40.0	33.0	35.5
0	1	35.5	13.0	-0.5	7.0	25.0	45.0	44.0	50.0	51.0	58.0	51.0	53.5
0	1	42.5	12.0	1.5	2.0	34.0	55.0	55.0	60.0	64.5	65.0	58.0	60.5
0	2	25.5	-8.0	21.0	14.0		63.0	61.0		67.5	66.5	72.0	68.0
0	2	26.0	-13.5	23.0	11.5		61.0	67.0		73.5	73.0	78.0	74.0
0	2	36.0	2.0	31.5	22.5		70.0	65.0		77.0	81.0	82.0	78.0
0	2	17.0	-8.5	18.5	10.0		54.0	54.0		66.0	70.0	68.0	64.0
0	3	-1.0	-60.0	-24.5	-13.5		7.0	2.0	12.0	17.0	16.0	12.0	28.0
0	3	16.0	-60.5	-5.0	-1.5		22.0	17.0	25.0	28.0	30.0	26.5	39.5
0	3	21.5	-36.0	1.5	2.0		28.5	22.5	31.0	37.0	40.0	33.5	47.5
0	3	7.0	-86.0	-17.0	-6.0		15.0	9.5	18.5	24.5	27.0	21.0	35.0
0	4	4.0	-63.0	-65.5	-79.0	-20.0		-8.0	0.5	24.5	27.5	17.5	
0	4	14.0	-30.0	-79.0	-78.0	-17.5		6.0	12.0	36.0	39.0	31.0	
0	4	17.5	-38.0	-79.5	-96.5	1.0		8.0	16.0	40.0	43.0	36.0	
0	4	17.5	-46.5	-105.0	-105.0	0.5		10.0	17.0	39.0	41.0	34.0	
0	5	-71.0	-103.5	-103.0	-101.5	-103.0	-30.5	-60.0	0.0	0.5		0.0	-47.0
0	5	-73.5	-105.0	-105.0	-105.0	-105.0	-13.0	-60.5	-10.5	-4.5		-11.0	-53.0
0	5	-64.5	-105.0	-105.0	-105.0	-105.0	-3.0	-48.5	0.0	0.0		0.0	-42.0
0	5	-56.5	-105.0	-105.0	-105.0	-105.0	4.0	-39.0	7.5	10.0		9.0	0.5
0	6	-61.0	-104.0	-3.5		0.0	-7.0	-10.5		0.5	0.0	0.0	-5.0
0	6	-79.5	-95.0	31.5		2.0	1.0	0.5		6.0	1.5	3.0	3.0
0	6	-73.0	-102.5	25.0		2.0	0.5	2.0		5.0	1.0	4.0	2.0
0	6	-105.0	-104.0	54.0		2.5	0.0	0.0		3.0	1.5	2.5	1.5
0	7	16.5	8.0	-6.0	-80.0	28.0	23.0	26.0		35.0	34.5		23.0

0	7	39.5	29.0	12.0	-2.0	44.5	43.5	40.0		45.5	45.0		44.0
0	7	24.5	2.0	1.0	-49.0	41.0	36.0	27.0		46.0	45.5		38.5
0	7	5.5	-26.0	-17.0	-65.0	17.0	15.0	14.0		10.0	9.5		13.0
0	8	32.5	17.0	7.0	-105.0	12.0		34.0		47.0	43.5	49.0	
0	8	32.0	17.0	9.0	-105.0	9.0		30.0		43.0	39.5	45.0	
0	8	16.5	1.0	-9.0	-69.0	1.0		16.0		25.0	23.0	22.0	
0	8	3.0	-20.0	-93.5	-79.0	-12.0		3.5		10.0	9.0	11.0	
1	1	-105.0	-106.5	-104.0	-105.5	-27.0	-43.0	-39.0	-18.0	1.0	-6.0		-52.0
1	1	67.5	0.5	-3.5	0.0	51.0	75.5	33.0	86.0	102.5	109.0		88.0
1	1	-66.5	-105.0	-105.5	-104.0	-80.0	-44.5	-46.5	-18.0	5.0	2.0		-41.0
1	1	-105.0	-105.0	-104.0	-104.0	-54.0	-47.0	-47.5	-9.0	5.0	3.0		-40.0
1	2	46.0	6.5	46.5	43.0	61.5		64.5	60.5	69.5	66.0	-9.5	-7.5
1	2	-6.5	-99.0	-6.0	-16.0	11.5		16.0	10.0	19.0	13.0	-100.0	-36.0
1	2	29.0	-38.5	12.0	19.5	39.0		41.0	39.5	45.0	38.5	-16.0	-12.0
1	2	29.0	-51.0	30.0	22.0	41.0		40.0	40.0	49.0	45.0	0.0	0.0
1	3	-68.5	-102.0	-42.0	-48.0	8.5	4.0	1.0	-5.0	-13.5	1.0	0.0	-61.5
1	3	-84.5	-105.5	-40.0	-53.5	-12.0	-14.0	-16.0	-27.0	-35.5	-28.0	-39.0	-94.5
1	3	-6.0	-105.0	15.0	10.5	36.0	31.5	26.0	23.0	9.0	13.0	1.0	-53.0
1	3	29.5	0.0	56.0	49.0	72.0	67.0	64.0	56.0	50.0	53.5	40.5	31.0
1	4	-105.0	-103.0	-99.0	-99.0	-98.5		-98.5	-8.0	64.0	59.0	56.0	55.0
1	4	11.0	-105.0	5.0	-105.0	13.5		14.0	21.5	111.5	106.5	103.5	102.5
1	4	-2.0	-102.5	-94.0	-100.5	0.0		1.0	5.0	95.0	90.0	87.0	86.0
1	4	17.0	-105.0	10.0	-105.0	19.0		20.5	27.5	117.5	112.5	109.5	108.5
1	5	-105.0		-105.0		-105.0	54.5	54.5		51.0	49.0		3.0
1	5	-105.0		-85.5		5.5	41.0	41.0		41.5	39.5		-42.0
1	5	-105.0		-76.5		4.0	30.5	30.5		35.0	33.0		-36.0
1	5	-105.0		-105.0		-105.0	44.0	44.0		47.0	45.0		2.0

1	6	39.0	-82.0	-38.0	-85.0	-104.0	35.0	4.0	29.0	60.0	44.5	44.0	30.0
1	6	-105.0	-101.0	-101.0	-105.0	-105.0	0.0	-47.0	-5.0	20.0	14.5	4.0	-16.0
1	6	12.0	16.0	9.0	-3.0	-105.0	65.0	40.0	60.0	91.0	86.5	74.0	60.0
1	6	-105.0	-93.5	-102.5	-102.5	-103.5	1.5	80.0	0.0	26.0	8.5	11.5	0.0
1	7	53.0	33.0	105.0	46.5	105.0	105.0	105.0		166.6	158.0		83.0
1	7	16.0	4.0	105.0	26.0	105.0	105.0	105.0		146.5	138.0		63.0
1	7	-105.0	-106.5	105.0	-105.5	25.0	18.0	-32.5		30.0	22.5		-53.0
1	7	-105.0	-102.5	105.0	-104.0	65.0	58.0	2.0		75.5	67.0		-17.0
1	8	-35.0	-86.0	-75.0	-105.0	-68.5		0.0		7.0	0.0	-5.0	
1	8	-105.0	-89.5	-96.5	-105.0	-105.0		0.0		10.0	-11.5	-23.0	
1	8	67.0	53.0	57.0	46.0	60.0		93.0		110.0	96.0	93.0	
1	8	14.0	43.0	44.0	32.0	40.0		80.0		97.0	83.0	80.0	

Table of median monthly water table level (Med; cm) for each wetland (N = natural wetlands, W = Wetlands Reserve Program wetlands).

Wetland	June Med	July Med	August Med	Sept Med	Oct Med	Nov Med	Dec Med	Jan Med	Feb Med	Mar Med	Apr Med	May Med
N1	21.3	4.0	0.5	-2.5	25.0	37.5	37.0	43.3	43.5	49.0	42.0	44.5
N2	12.8	-8.3	21.0	12.8		62.0	63.0		70.5	73.5	75.0	71.0
N3	-2.0	-60.3	-8.8	-3.8		18.5	13.3	21.8	26.3	28.5	23.8	37.3
N4	-13.5	-42.3	-82.3	-87.8	-8.5		7.0	14.0	37.5	40.0	32.5	
N5	-86.0	-105.0	-105.0	-105.0	-105.0	-8.0	-54.3	0.0	0.3		0.0	-16.5
N6	-73.8	-103.3	-17.3		2.0	0.3	0.3		4.0	1.3	2.8	1.8
N7	14.3	5.0	-2.5	-7.5	34.5	29.5	26.5		41.5	39.8		30.8
N8	24.3	7.5	-1.0	-92.0	10.5		23.0		34.0	31.3	34.0	
W1	-101.3	-105.0	-104.0	-104.0	-40.5	-43.8	-42.8	-13.5	5.0	2.5		-44.5
W2	12.0	-44.8	21.0	22.3	40.0		40.5	39.8	47.0	41.8	-12.8	-9.8
W3	-76.5	-103.5	-12.5	-18.8	22.3	17.8	13.5	9.0	-2.3	7.0	0.5	-57.3
W4	4.5	-104.0	-46.5	-102.8	6.8		7.5	13.3	103.3	98.3	95.3	94.3
W5	-105.0		-95.3		-50.5	42.5	42.5		44.3	20.0		2.5
W6	-88.3	-87.8	-69.5	-93.8	-104.5	18.3	22.0	14.5	43.0	29.5	27.8	30.0
W7	-42.5	-49.3	105.0	-39.0	85.0	81.5	53.5		111.0	74.0		23.0
W8	-10.5	-21.5	-15.5	-36.5	-14.3		40.0		53.5	41.5	40.0	

Table of annual and seasonal wetland site water table medians (Med; cm) for each wetland.

Treat	WL	Annual Med	Summer Med	Fall Med	Winter Med	Spring Med
Natural	1	19.5	1.5	7.0	23.0	19.5
Natural	1	30.0	0.0	25.0	36.0	35.5
Natural	1	44.0	19.3	25.0	50.0	53.5
Natural	1	55.0	15.8	34.0	60.0	60.5
Natural	2	61.0	21.0	38.5	64.3	70.0
Natural	2	61.0	21.0	36.3	70.3	76.0
Natural	2	65.0	28.5	46.3	71.0	81.5
Natural	2	54.0	17.0	32.0	60.0	69.0
Natural	3	2.0	-24.5	-3.3	12.0	16.0
Natural	3	17.0	-5.0	10.3	25.0	30.0
Natural	3	22.5	1.5	15.3	31.0	40.0
Natural	3	9.5	-17.0	4.5	18.5	27.0
Natural	4	-8.0	-65.5	-49.5	0.5	17.5
Natural	4	6.0	-31.0	-47.8	12.0	31.0
Natural	4	8.0	-39.0	-47.8	16.0	36.0
Natural	4	10.0	-65.0	-52.3	17.0	34.0
Natural	5	-60.0	-102.8	-101.5	0.0	-12.0
Natural	5	-60.5	-103.3	-105.0	-10.5	-21.0
Natural	5	-48.5	-101.8	-105.0	0.0	-3.0
Natural	5	-39.0	-103.3	-105.0	7.5	9.0
Natural	6	-7.0	-70.0	-3.5	-5.0	-2.5
Natural	6	1.5	-63.5	1.5	3.3	2.5
Natural	6	1.0	-72.5	1.3	3.5	1.5
Natural	6	1.5	-74.5	1.3	1.5	2.0
Natural	7	22.5	8.5	11.5	35.0	23.0
Natural	7	41.5	27.0	25.0	45.5	44.0
Natural	7	31.5	7.0	21.3	46.0	38.5
Natural	7	9.8	-10.5	1.0	12.0	12.0
Natural	8	33.0	20.0	12.0	40.5	47.0
Natural	8	30.0	15.0	9.0	36.5	43.0
Natural	8	16.5	1.5	1.0	20.5	22.5
Natural	8	3.0	-22.5	-12.0	6.8	10.5
WRP	1	-51.5	-104.5	-43.0	-18.0	-51.5
WRP	1	67.5	11.8	51.0	86.0	88.0
WRP	1	-48.0	-103.5	-80.0	-18.0	-41.0
WRP	1	-50.5	-104.5	-54.0	-9.0	-40.0
WRP	2	46.0	34.3	45.5	64.5	-7.5
WRP	2	-6.0	-45.0	0.0	16.0	-36.0
WRP	2	25.0	6.8	25.0	41.0	-12.0
WRP	2	29.0	15.3	22.5	40.0	0.0
WRP	3	-13.5	-85.3	4.0	-5.0	0.0
WRP	3	-39.0	-94.0	-14.0	-27.0	-39.0
WRP	3	10.5	-55.5	31.5	23.0	1.0
WRP	3	50.0	14.8	67.0	56.0	40.5
WRP	4	-98.5	-101.0	-98.8	-8.0	56.0

WRP	4	13.8	3.0	-45.8	21.5	103.5
WRP	4	0.5	-96.5	-50.3	5.0	87.0
WRP	4	19.8	9.5	-43.0	27.5	109.5
WRP	5	4.3	-105.0	-25.3	52.8	8.3
WRP	5	2.3	-95.3	23.3	41.3	2.3
WRP	5	-6.5	-90.8	17.3	32.8	-6.5
WRP	5	4.5	-105.0	-30.5	45.5	8.5
WRP	6	29.5	-60.0	-85.0	29.0	44.3
WRP	6	-31.5	-101.0	-105.0	-5.0	9.3
WRP	6	50.0	14.0	-3.0	60.0	80.3
WRP	6	0.0	-101.8	-102.5	26.0	10.0
WRP	7	105.0	48.5	105.0	135.8	129.5
WRP	7	105.0	17.5	105.0	125.8	109.5
WRP	7	-17.0	-105.0	18.0	-1.3	2.8
WRP	7	10.0	-101.8	58.0	38.8	38.5
WRP	8	-35.0	-70.0	-90.0	3.5	0.0
WRP	8	-67.0	-93.0	-105.0	5.0	-13.3
WRP	8	87.0	57.0	60.0	101.5	95.3
WRP	8	77.0	43.5	40.0	88.5	82.3

Table of water table annual standard deviation (STDEV), minimum depth (Min), maximum depth (Max), % time saturated at or above 30 cm annually and during the growing season, and the % time inundated annually and during the growing season for each site. Treat 0 = natural wetland, Treat 1 = Wetlands Reserve Program wetland.

Treat	WL	STDEV	Min	Max	Annual % time saturated at 30 or more	Growing season % time saturated at 30cm or more	Annual % time inundated	Growing season % time inundated
0	1	18.6	-25.5	33.5	100.0	100.0	79.2	75.0
0	1	18.3	-10.0	40.0	100.0	100.0	75.0	62.5
0	1	19.4	-0.5	58.0	100.0	100.0	91.7	87.5
0	1	24.1	1.5	65.0	100.0	100.0	100.0	100.0
0	2	30.3	-8.0	74.0	100.0	100.0	87.5	87.5
0	2	33.7	-13.5	80.0	100.0	100.0	87.5	87.5
0	2	30.2	2.0	82.0	100.0	100.0	87.5	87.5
0	2	30.1	-8.5	70.0	100.0	100.0	100.0	100.0
0	3	25.3	-60.0	28.0	83.3	77.8	58.3	37.5
0	3	25.9	-60.5	39.5	87.5	88. 9	62.5	50.0
0	3	23.1	-36.0	47.5	91. 7	88. 9	62.5	50.0
0	3	33.0	-86.0	35.0	91. 7	88. 9	87.5	87.5
0	4	46.2	-105.0	27.5	62.5	55. 6	45.8	50.0
0	4	46.0	-86.0	39.0	62.5	55. 6	62.5	50.0
0	4	51.0	-96.5	43.0	62.5	55. 6	62.5	50.0
0	4	59.2	-105.0	41.0	70.8	66.7	54.2	50.0
0	5	44.0	-103.5	0.5	41. 7	33.3	0.0	0.0
0	5	42.5	-105.0	-4.5	41. 7	33.3	8.3	0.0
0	5	47.1	-105.0	0.0	41. 7	33.3	0.0	0.0
0	5	53.1	-105.0	10.0	50.0	44.4	50.0	37.5
0	6	38.1	-104.0	0.5	75.0	66. 7	8.3	0.0
0	6	40.1	-95.0	31.5	75.0	66. 7	75.0	62.5
0	6	41.0	-102.5	25.0	75.0	66. 7	75.0	62.5
0	6	48.7	-105.0	54.0	75.0	66. 7	58.3	62.5
0	7	30.8	-80.0	37.5	91. 7	88. 9	62.5	50.0
0	7	16.9	-2.0	48.0	91. 7	88. 9	75.0	62.5
0	7	27.2	-49.0	48.5	91. 7	88. 9	91. 7	87.5
0	7	23.4	-65.0	17.0	100.0	100.0	91. 7	87.5
0	8	42.0	-105.0	49.0	91. 7	88. 9	83. 3	75.0
0	8	40.8	-105.0	45.0	83. 3	77. 8	62.5	50.0
0	8	26.0	-69.0	25.0	91. 7	88. 9	91. 7	87.5
0	8	35.5	-93.5	11.0	91. 7	88. 9	91. 7	87.5

1	1	41.2	-106.5	1.0	33.3	11.1	66. 7	50.0
1	1	40.3	-3.5	109.0	25.0	0.0	83.3	75.0
1	1	39.7	-105.5	5.0	25.0	0.0	8.3	0.0
1	1	42.0	-105.0	5.0	100.0	100.0	16. 7	0.0
1	2	27.8	-9.5	69.5	70.8	66. 7	16. 7	0.0
1	2	44.3	-100.0	19.0	91. 7	88. 9	75.0	50.0
1	2	26.3	-38.5	45.0	100.0	100.0	83.3	62.5
1	2	27.5	-51.0	49.0	91. 7	88. 9	75.0	50.0
1	3	40.4	-102.5	8.5	41. 7	33. 3	41. 7	0.0
1	3	34.7	-105.5	-12.0	58.3	44. 4	87.5	87.5
1	3	48.4	-105.0	36.0	79.2	77. 8	33.3	12.5
1	3	23.1	0.0	72.0	100.0	100.0	75.0	50.0
1	4	77.0	-105.0	64.0	41. 7	22.2	0.0	0.0
1	4	74.8	-105.0	111.5	62.5	55. 6	33. 3	37.5
1	4	80.5	-102.5	95.0	79.2	77. 8	50	37.5
1	4	76.6	-105.0	117.5	79.2	77. 8	79.2	75.0
1	5	71.6	-105.0	54.5	58.3	44.4	79.2	75.0
1	5	58.4	-105.0	41.5	58.3	44.4	41.7	12.5
1	5	53.0	-105.0	35.0	58.3	44.4	50.0	37.5
1	5	68.6	-105.0	47.0	58.3	44.4	58.3	37.5
1	6	61.2	-104.0	60.0	50	44. 4	58.3	37.5
1	6	54.2	-105.0	20.5	58.3	44. 4	25.0	12.5
1	6	51.9	-105.0	91.0	62.5	55. 6	41. 7	12.5
1	6	65.3	-105.0	80.0	91.7	88. 9	62.5	50.0
1	7	42.8	33.0	166.6	58.3	55. 6	83.3	75.0
1	7	49.5	4.0	146.5	75.0	66. 7	50.0	50.0
1	7	69.6	-106.5	105.0	100.0	100.0	100.0	100.0
1	7	80.7	-105.0	105.0	100.0	100.0	100.0	100.0
1	8	42.2	-105.0	7.0	50.0	22.2	16.7	25.0
1	8	46.6	-105.0	10.0	50.0	22.2	16. 7	25.0
1	8	21.5	46.0	110.0	100.0	100.0	100.0	100.0
1	8	26.1	14.0	97.0	100.0	100.0	100.0	100.0

Table of porosity (%) and bulk density (BD; g/cm^3) estimations at 5 and 20 cm depths of each site for each wetland.

Treatment	WL	Porosity (5 cm)	Porosity (20 cm)	BD (5 cm)	BD (20 cm)
Natural	1	60.8	54.2	1.04	1.21
Natural	1	66.5	51.0	0.89	1.30
Natural	1	64.0	54.1	0.95	1.22
Natural	1	63.9	51.5	0.96	1.29
Natural	2	55.9	50.5	1.17	1.31
Natural	2	55.2	51.5	1.19	1.29
Natural	2	53.7	52.8	1.23	1.25
Natural	2	54.9	56.1	1.20	1.16
Natural	3	53.7	51.3	1.23	1.29
Natural	3	52.4	49.2	1.26	1.35
Natural	3	54.1	46.7	1.22	1.41
Natural	3	53.4	52.1	1.24	1.27
Natural	4	59.3	52.1	1.08	1.27
Natural	4	60.8	54.6	1.04	1.20
Natural	4	59.1	52.5	1.08	1.26
Natural	4	57.5	54.3	1.13	1.21
Natural	5	57.9	56.2	1.12	1.16
Natural	5	55.1	54.5	1.19	1.20
Natural	5	55.5	52.5	1.18	1.26
Natural	5	59.3	56.2	1.08	1.16
Natural	6	60.5	52.0	1.05	1.27
Natural	6	50.8	56.4	1.30	1.16
Natural	6	54.4	54.7	1.21	1.20
Natural	6	53.5	57.4	1.23	1.13
Natural	7				
Natural	7				
Natural	7				
Natural	7				
Natural	8	58.5	53.5	1.10	1.23
Natural	8	66.9	57.2	0.88	1.14
Natural	8	58.0	52.7	1.11	1.25
Natural	8	53.1	52.6	1.24	1.26
WRP	1	48.9	48.7	1.35	1.36
WRP	1	52.2	55.4	1.27	1.18
WRP	1	48.9	44.5	1.36	1.47
WRP	1	48.8	52.1	1.36	1.27
WRP	2	56.0	50.0	1.17	1.33

WRP	2	49.5	51.0	1.34	1.30
WRP	2	48.4	45.1	1.37	1.46
WRP	2	52.8	45.7	1.25	1.44
WRP	3	52.4	46.2	1.26	1.43
WRP	3	50.5	47.2	1.31	1.40
WRP	3	49.7	49.9	1.33	1.33
WRP	3	52.2	51.4	1.27	1.29
WRP	4	51.6	52.0	1.28	1.27
WRP	4	57.4	51.5	1.13	1.29
WRP	4	60.2	50.8	1.05	1.30
WRP	4	62.3	52.0	1.00	1.27
WRP	5	57.9	50.6	1.12	1.31
WRP	5	59.4	52.4	1.08	1.26
WRP	5	57.4	53.4	1.13	1.24
WRP	5	53.7	50.6	1.23	1.31
WRP	6	47.7	48.7	1.38	1.36
WRP	6	53.2	50.6	1.24	1.31
WRP	6	54.3	54.7	1.21	1.20
WRP	6	56.0	55.4	1.16	1.18
WRP	7	53.9	52.9	1.22	1.25
WRP	7				
WRP	7	54.9	52.1	1.20	1.27
WRP	7	57.2	52.4	1.13	1.26
WRP	8	55.7	46.4	1.17	1.42
WRP	8	49.1	51.6	1.35	1.28
WRP	8	56.1	50.4	1.16	1.31
WRP	8	56.2	53.3	1.16	1.24

Table of the % air filled porosity annually (ANN) and seasonally (summer = SUM; fall = FALL; winter = WINT; and spring = SPR) for both 5 cm and 20 cm depths for each wetland site (natural = Nat; Wetlands Reserve Program = WRP) in each wetland.

			Air Filled Porosity (%) 5 cm					Air Filled Porosity (%) 20 cm				
TREAT	WL	SITE	5 cm ANN	5 cm SUM	5 cm FALL	5 cm WINT	5 cm SPR	20 cm ANN	20 cm SUM	20 cm FALL	20 cm WINT	20 cm SPR
Nat	1	1	0.00	0.00	0.00	0.00	0.00	2.57	4.82	4.61	0.00	0.00
Nat	1	3	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Nat	1	6	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Nat	1	7	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Nat	2	2	0.00	0.00	0.00	0.00	0.00	1.11	4.08	0.00	0.00	0.00
Nat	2	3	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Nat	2	4	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Nat	2	6	0.00	0.00	0.00	0.00	0.00	1.55	5.68	0.00	0.00	0.00
Nat	3	4	0.00	0.00	0.00	0.00	0.00	4.56	14.58	3.19	0.00	0.00
Nat	3	5	0.80	2.93	0.00	0.00	0.00	3.69	9.35	6.26	0.00	0.00
Nat	3	7	1.77	6.51	0.00	0.00	0.00	0.97	3.55	0.00	0.00	0.00
Nat	3	8	1.37	5.01	0.00	0.00	0.00	1.66	5.69	0.62	0.00	0.00
Nat	4	4	3.14	8.27	4.84	0.00	0.00	3.12	7.35	6.12	0.00	0.00
Nat	4	5	6.99	21.74	5.81	0.00	0.00	6.94	15.28	15.26	0.00	0.00
Nat	4	6	3.92	14.37	0.00	0.00	0.00	2.76	8.01	3.14	0.00	0.00
Nat	4	7	6.66	17.94	9.73	0.00	0.00	5.69	13.94	10.39	0.00	0.00
Nat	5	1	19.90	41.07	27.02	9.48	3.68	20.36	36.46	26.38	8.91	12.40
Nat	5	2	12.32	29.36	13.34	4.87	4.93	21.18	28.02	21.18	18.39	18.53
Nat	5	4	10.49	24.32	15.75	2.99	0.00	12.60	30.00	14.07	3.48	6.69
Nat	5	5	10.86	24.97	16.02	3.53	0.00	12.06	28.35	15.59	5.70	0.00
Nat	6	3	8.95	25.36	0.00	7.46	0.00	7.44	18.57	0.52	8.13	0.23
Nat	6	4	5.44	19.95	0.00	0.00	0.00	7.76	28.44	0.00	0.00	0.00

Nat	6	6	1.66	6.09	0.00	0.00	0.00	5.34	19.58	0.00	0.00	0.00
Nat	6	8	2.85	10.43	0.00	0.00	0.00	7.59	27.81	0.00	0.00	0.00
Nat	7	1	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Nat	7	2	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Nat	7	6	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Nat	7	7	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Nat	8	2	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Nat	8	3	0.00	0.00	0.00	0.00	0.00	1.90	0.00	6.97	0.00	0.00
Nat	8	5	0.95	0.00	3.18	0.00	0.00	1.46	0.00	4.87	0.00	0.00
Nat	8	7	0.82	0.00	2.45	0.00	0.00	6.37	0.00	19.11	0.00	0.00
WRP	1	2	11.46	19.15	18.79	8.02	2.43	18.06	27.96	19.78	10.60	17.19
WRP	1	4	1.00	0.00	3.67	0.00	0.00	2.64	0.00	9.68	0.00	0.00
WRP	1	5	9.26	26.55	11.20	1.51	3.54	7.04	13.07	5.92	7.56	3.62
WRP	1	8	11.70	24.07	19.35	4.93	2.59	21.97	35.65	28.44	16.29	12.05
WRP	2	1	0.00	0.00	0.00	0.00	0.00	0.18	0.00	0.99	0.00	0.00
WRP	2	4	4.49	8.73	0.00	0.00	9.16	9.67	15.66	8.85	0.00	15.89
WRP	2	7	0.11	0.40	0.00	0.00	0.00	0.20	-0.01	0.00	0.00	0.75
WRP	2	8	3.39	10.20	3.34	0.00	0.00	0.89	3.25	0.00	0.00	0.00
WRP	3	1	6.84	24.64	4.46	0.89	3.31	4.87	16.31	2.14	1.57	3.27
WRP	3	3	4.86	17.88	2.01	1.78	2.10	8.69	18.39	5.78	4.47	9.35
WRP	3	4	1.56	6.23	0.00	0.00	0.00	3.94	13.21	0.00	0.00	2.54
WRP	3	8	1.14	0.00	4.56	0.00	0.00	1.80	0.00	7.19	0.00	0.00
WRP	4	1	14.33	22.07	20.13	18.40	0.00	18.00	32.08	21.61	20.26	0.00
WRP	4	3	9.33	23.42	11.54	0.00	0.00	6.63	16.06	9.04	0.00	0.00
WRP	4	4	12.51	30.02	17.50	0.00	0.00	8.56	21.98	9.82	0.00	0.00
WRP	4	5	10.52	25.01	15.08	0.00	0.00	6.28	13.13	11.68	0.00	0.00
WRP	5	1	7.07	17.23	11.05	0.00	0.00	5.61	14.57	7.88	0.00	0.00
WRP	5	3	14.46	33.93	10.68	0.00	13.20	5.62	13.24	6.74	0.00	2.51

WRP	5	4	7.72	19.96	8.70	0.00	2.22	3.52	11.76	0.00	0.00	2.30
WRP	5	5	35.64	136.45	6.13	0.00	0.00	4.97	13.20	6.67	0.00	0.00
WRP	6	2	4.07	0.00	14.91	0.00	0.00	5.56	0.00	20.38	0.00	0.00
WRP	6	3	7.31	11.39	10.39	7.64	1.18	6.32	9.00	15.58	-0.02	1.60
WRP	6	6	1.81	0.00	7.24	0.00	0.00	5.50	0.00	21.99	0.00	0.00
WRP	6	7	9.24	28.55	13.84	1.02	0.00	11.77	31.68	16.47	5.57	0.00
WRP	7	2	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
WRP	7	3	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
WRP	7	6	12.53	24.16	11.05	0.00	10.74	11.72	20.15	9.63	5.78	9.34
WRP	7	8	11.21	29.18	11.94	0.00	0.00	8.07	18.85	7.48	0.00	3.25
WRP	8	2	7.65	12.73	17.02	0.00	0.00	3.87	9.64	6.46	0.00	0.00
WRP	8	3	1.88	1.26	5.42	0.00	0.00	23.44	35.90	29.78	0.00	24.42
WRP	8	6	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
WRP	8	8	0.00	0.00	0.00	0.00	0.00	0.13	0.00	0.48	0.00	0.00

Table of average (Aver) annual and seasonal rainfall totals for each wetland. 0 = Natural; 1 = WRP.

Treat	WL	Annual Ave	Sum Aver	Fall Aver	Wint Aver	Spring Aver
0	1	7.90	10.08	9.05	5.18	7.30
0	2	7.90	10.08	9.05	5.18	7.30
0	3	7.90	10.08	9.05	5.18	7.30
0	4	7.90	10.08	9.05	5.18	7.30
0	5	7.90	10.08	9.05	5.18	7.30
0	6	8.37	7.35	13.28	4.67	8.18
0	7	8.37	7.35	13.28	4.67	8.18
0	8	9.47	7.35	13.94	7.47	9.13
1	1	7.90	10.08	9.05	5.18	7.30
1	2	7.90	10.08	9.05	5.18	7.30
1	3	7.90	10.08	9.05	5.18	7.30
1	4	7.90	10.08	9.05	5.18	7.30
1	5	7.90	10.08	9.05	5.18	7.30
1	6	7.90	10.08	9.05	5.18	7.30
1	7	8.37	7.35	13.28	4.67	8.18
1	8	9.47	7.35	13.94	7.47	9.13

Table of rainfall characterization including actual monthly totals, average normal values, and ranking for each local climate station.

	Chandler			Bristow			Okmulgee		
Month	Monthly (cm)	Normal (cm)	Normal=1, dry=0, wet=2	Monthly (cm)	Normal (cm)	Normal=1, dry=0, wet=2	Monthly (cm)	Normal (cm)	Normal=1, dry=0, wet=2
June	2.92		0	6.60		0	6.55		0
July	14.50	6.45	2	11.48	6.15	2	7.21	8.00	1
August	12.83	6.53	2	3.96	6.38	1	8.28	6.30	2
September	7.11	10.69	1	16.21	11.76	2	12.17	13.49	1
October	19.30	9.73	2	21.59	9.96	2	27.84	11.18	2
November	0.74	7.44	0	2.03	8.69	0	1.80	9.37	0
December	3.58	4.57	1	2.74	6.38	0	9.45	6.63	2
January	3.23	3.61	1	2.90	3.53	1	4.80	4.67	1
February	8.74	5.08	2	8.38	5.38	2	8.15	6.02	2
March	5.46	8.03	1	6.05	8.94	0	5.46	9.45	0
April	5.94	8.38	1	4.78	8.97	0	5.41	9.83	0
May	10.49	13.36	0	13.72	14.86	1	16.51	14.02	1

Soil profile description data results of natural wetlands (y = yes, n = no).

Nat	Buried (y/n)	Hydric soil indicator (y/n)	# horizons in 30 cm	A horiz. thickness (cm)	% Sand	% Silt	% Clay	Matrix chroma	Redox in upper horizon	Depth to redox (cm)	Redox in 30 cm	Redox (few = 0, common=1)	Conc (c) or depl (d)
1	y	n	3	3	10	45	45	3	n	20	y	c	c
1	y	n	3	4	10	45	45	3	n	31	n		
1	y	n	3	4	10	45	45	3	n	12	y	f	c
1	y	n	3	10	10	55	35	4	n	31	n		
2	n	n	4	5	20	20	60	4	n	31	n		
2	y	n	3	4	20	20	60	3	n	31	n		
2	y	n	3	5	20	20	60	3	n	31	n		
2	y	n	2	8	20	20	60	4	n	31	n		
3	y	n	3	7	40	40	20	3	n	19	y	c	d
3	y	n	2	20	40	40	20	4	y	0	y	f	d
3	y	n	3	15	20	20	60	4	y	0	y	f	d
3	y	n	4	9	10	55	35	4	n	22	y	c	d
4	y	n	2	9	10	45	45	3	n	31	n		
4	y	n	2	21	20	20	60	4	n	21	y	f	c
4	y	n	3	5	10	45	45	3	n	31	n		
4	y	n	3	3	10	45	45	3	n	20	y	f	c
5	y	n	5	4	20	65	15	3	y	0	y	f	d
5	y	n	4	6	40	40	20	4	n	6	y	c	d
5	y	n	4	6	10	55	35	2	n	6	y	f	c
5	y	n	3	9	20	65	15	4	y	0	y	c	d
6	y	y	3	12	20	65	15	4	n	31	n		
6	y	n	2	20	40	40	20	4	n	31	n		
6	y	n	2	19	40	40	20	4	n	31	n		
6	y	n	2	14	40	40	20	4	n	31	n		
8	n	y	4	22	10	55	35	2	n	2	y	2	C
8	n	y	3	22	20	65	15	2	n	9	y	c	C
8	y	n	3	15	20	65	15	3	y	0	y	c	C
8	y	n	3	5	10	55	35	4	y	0	y	c	C

Soil profile description data results of WRP wetlands (y = yes, n = no).

WRP	Buried (y/n)	Hydric soil indicator (y/n)	# horizons in 30 cm	A horiz. thickness (cm)	% Sand	% Silt	% Clay	Matrix chroma	Redox in upper horizon	Depth to redox (cm)	Redox in 30 cm	Redox (few = f, common=c)	Conc (c) or depl (d)
1	y	n	3	8	65	25	10	3	y	0	y	c	d
1	y	y	2	19	30	35	35	3	y	0	y	c	c
1	y	y	5	7	65	25	10	2	n	7	y	c	d
1	y	y	5	6	65	25	10	1	n	6	y	c	d
2	y	n	4	7	10	55	35	3	n	31	n		
2	y	n	5	3	65	25	10	4	n	3	y	f	c
2	y	n	5	12	65	10	30	4	n	31	n		
2	n	n	3	0	10	55	35	4	n	5	y	f	d
3	y	n	4	13	10	45	45	3	y	2	y	c	d
3	y	n	7	16	40	40	20	4	y	0	y	f	d
3	y	y	3	20	10	45	45	3	y	0	y	f	d
3	n	n	3	18	30	35	35	3	n	4	y	f	d
4	n	n	3	13	40	40	20	4	n	4	y	f	d
4	n	n	2	21	20	65	15	4	n	10	y	c	d
4	n	y	3	11	10	45	45	3	n	2	y	c	d
4	n	n	3	6	10	45	45	4	n	31	n		
5	y	y	3	8	10	55	35	3	n	8	y	f	d
5	y	n	4	13	30	35	35	3	y	0	y	f	d
5	y	n	4	14	10	55	35	3	n	14	y	f	d
5	y	n	2	17	30	35	35	3	n	17	y	f	d
6	n	n	3	0	65	25	10	4	n	31	n		
6	y	n	3	5	10	55	35	3	n	6	y	f	d
6	n	n	2	0	10	45	45	4	n	31	n		
6	y	n	3	10	10	55	35	3	n	20	y	f	c
7	n	n	3	9	10	45	45	4	n	31	n		
7	y	n	3	14	20	20	60	3	n	31	n		
7	n	y	2	0	20	20	60	3	n	3	y	c	d
8	y	y	5	17	40	40	20	2	y	0	y	c	c
8	y	N	3	7	65	25	10	2	n	7	y	c	c
8	n	Y	2	23	20	20	60	1	n	8	y	c	d
8	n	Y	3	5	30	35	35	1	n	16	y	c	c

Table of wetland sites meeting hydric indicators, what indicator, and at what depths.

Profile	Hydric indicator met	Depths where met (cm)
Restored		
W1-4	TF2	IN ALL LAYERS
W1-5	TF2	
W1-8	TF2	17+
W3-4	TF2	20+
W4-4	TF2	2-13
W5-1	TF2	25-39
W7-8	TF2	3-40
W8-2	F3	4-9, 25-37
W8-6	TF2	8-35
W8-8	TF2	16-21
Natural		
N6-3	TF2	12-33
N8-2	F6	2-9
	F3	24-37
N8-3	F3	15-35
N8-6	F3?	15-35, this does not make it by the high chroma rule. Soil above an indicator with chroma of 3 or more must be in a layer <15 cm thick for the indicator to count. You are at 15 cm here. If the A were 0-14 cm this would make it.
N8-8	TF2	0-36

By M. Vepraskas, 29 October 2010

Profiles not listed did not meet an indicator.

Tables of all soil profile descriptions for each wetland site. Missing sites were not profiled (W = WRP, N = natural).

Table	Soil profile description			Well;(-)51.5						
Wetland	W1-2	Date	5/2/10							
	Horizon	Depth (cm)	Color	Structure	Texture	Consistence	Boundary	Effervescence	Special Features	RMF
1	A	0-8	5YR 4/3	2, F, SBK	SL	FR	A, S	NE	M, common roots	c, 1, F, 5YR 4/2, FED, MAT
2	Bw1	8-16	5YR 4/4	2, F, SBK	SCL	FR	C, S	NE	M, few roots	c, 1, F, 5YR 4/2, FED, MAT; f, 2, D, N 2/0, MNM, MAT
3	Bw2	16-36+	5YR 4/6	2, CO, ABK	LS	VFR		SL	M, few roots	c, 2, F, 5YR 4/2, FED, MAT; c, 2, D, N 2/0, MNM, MAT

Table	Soil profile description			Well 82.5 (+)						
Wetland	W1-4	Date	5/26/10							
	Horizon	Depth	Color	Structure	Texture	Consistence	Boundary	Effervescence	Special	RMF

		(cm)							Features	
1	A	0-19	5YR 4/3	1, M, SBK	CL	FR	C, S	NE	W, no roots	c, 3, F, 5YR 4/1, F3M, MAT; c, 1, D, N 2/0, MNM, MAT
2	Bw	19-42+	5YR 4/4	1, M, SBK	C	FI		NE	M, no roots	c, 3, F, 5YR 4/1, F3M, MAT; c, 1, D, N 2/0, MNM, MAT

Table	Soil profile description			Well: -48						
Wetland	W1-5	Date	5/26/10							
	Horizon	Depth (cm)	Color	Structure	Texture	Consistence	Boundary	Effervescence	Special Features	RMF
1	A	0-7	5YR 3/2	2, M, SBK	SL	FR	A, S	NE	M, many roots	None
2	1Bw	7-12	5YR 4/4	1, M, SBK	SL	FR	A, S	NE	M, few roots	c, 1, F, 5YR 4/3, FED, MAT; c, 1, D, N 2/0, MNM, MAT

3	2Bw	12-18	5YR 4/6	1, M, SBK	LS	VFR	A, S	NE	M, few roots	c, 1, F, 5YR 4/2, FED, MAT; c, 1, D, N 2/0, MNM, MAT
4	Ab1	18-26	5YR 4/3	1, CO, SBK	C	FI	A, S	NE	M, few roots	c, 1, F, 5YR 4/2, FED, MAT; c, 1, D, N 2/0, MNM, MAT
5	Ab2	26-38+	5YR 4/3	2, M, SBK	SL	FR		NE	M, few roots, decayed OM	c, 1, F, 5YR 4/2, FED, MAT

Table	Soil profile description			Well: (-)50.5						
Wetland	W1-8	Date	5/26/10							
	Horizon	Depth (cm)	Color	Structure	Texture	Consistence	Boundary	Effervescence	Special Features	RMF
1	A	0-6	5YR 3/1	1, M, SBK	SL	FR	A, S	NE	M, many roots, 20% 5YR 4/4 inclusion of Bw1 within A	None

2	Bw1	6-11	5YR 4/4	1, M, SBK	SL	FR	A, S	NE	M, few roots	c, 1, F, 5YR 4/2, FED, MAT; c, 1, D, 5YR 3/1, FED, MAT
3	Bw2	11-17	5YR 4/4	1, F, SBK	LS	VFR	A, S	NE	M, few roots	f, 1, F, 5YR 4/3, FED, MAT
4	Bw3	17-22	5YR 4/3	2, CO, SBK	C	FI	A, S	NE	M, few roots	c, 3, D, 5YR 3/1, FED, APF; few 1 D, N 2/0, MNM, MAT
5	Bw4	22-30	5YR 4/6	2, F, WEG	LS	FR	A, S	NE	M, few roots	f, 2, D, N 2/0, MNM, MAT; c, 2, F, 5YR 4/2, FED, MAT
6	Bw5	30-38+	5YR 4/3	2, M, ABK	C	FI		NE	M, few roots	m, 2, F, 5YR 4/2, FED, MAT; c, 2, D, N 2/0, MNM, MAT

Table	Soil profile description									
Wetland	W2-1	Date	5/20/10							
	Horizon	Depth	Color	Structure	Texture	Consistence	Boundary	Effervescence	Special	RMF

		(cm)							Features	
1	Ap	0-3	5YR 4/3	1, CO, SBK	SiCL	VFR	V, S	VS	W, few roots	None
2	A	3-7	5YR 4/3	3, VF, SBK	SiCL	FR	A, I	NE	W, few roots	None
3	Bw	7-26	5YR 4/4	2, VC, SBK	SiC	Fi	A, S	NE	W, no roots	None
4	C	26-38+	5YR 4/4	MA	LS			SL	W, no roots	None

Table	Soil profile description									
Wetland	W2-4	Date	5/20/10							
	Horizon	Depth (cm)	Color	Structure	Texture	Consistence	Boundary	Effervescence	Special Features	RMF
1	Ap	0-3	5YR 4/4	1, F, SBK	SL	VFR	V, S	NE	M, common roots	None
2	C	3-8	5YR 4/6	MA	LS		C, S	NE	M, few roots	f, 1, F, 5YR 5/8, F3M, MAT
3	Ab1	8-15	5YR 4/4	2, M, SBK	SL	FR	C, S	SC	M, few roots	None

4	Cb1	15-28	5YR 4/6	MA	CS		A, S	NE	M, no roots	f, 2 F, 5YR 5/8, F3M, MAT
5	Ab2	28-31	5YR 4/4	1, F, SBK	SC	FR	A, S	SL	M, no roots	f, 1, F, 5YR 5/8, F3M, MAT
6	Cb2	31-40+	5YR 5/6	MA	LS			VS	M, no roots	f, 1, F, 5YR 5/8, F3M, MAT

Table	Soil profile description									
Wetland	W2-7	Date	5/20/10							
	Horizon	Depth (cm)	Color	Structure	Texture	Consistence	Boundary	Effervescence	Special Features	RMF
1	A1	0-7	5YR 4/4	1, CO, SBK	SCL	FR	C, S	NE	M, common roots	None
2	A2	7-12	5YR 4/4	2, F, SBK	CL	FR	A, S	NE	M, few roots	None
3	Bw	12-23	5YR 4/3	1, CO, SBK	SCL	FR	C, S	VS	M, few roots	None
4	Ab	23-26	5YR 3/3	1, M, SBK	L	VFR	A, I	VS	M, few roots	None
5	Bssb	26-37+	5YR 4/4	2, M, ABK	C	FI		SL	M, no roots, slickensides	None

Table	Soil profile description									
Wetland	W2-8	Date	5/20/10							
	Horizon	Depth (cm)	Color	Structure	Texture	Consistence	Boundary	Effervescence	Special Features	RMF
1	C, ooze	0-5	5YR 4/4	MA	SiCL		A, S	VS	W, many roots	None
2	Bwb	5-24	5YR 4/3	1, M, SBK	SL	FR	A, I	SL	M, few roots	f, 2, F, 5YR 3/2, FED, APF; f 1 D, 10R 4/8, F3M, APF
3	Bssb	24-39+	5YR 4/3	2, M, ABK	C	FI		SL	M, no roots, slickensides	f, 1, D, 10R 4/8, F3M, APF

Table	Soil profile description									
Wetland	W3-1	Date	5/12/10							
	Horizon	Depth (cm)	Color	Structure	Texture	Consistence	Boundary	Effervescence	Special Features	RMF
1	Ap	0-2	5YR 3/3	1, F, PL	SiC	FI	V, S	NE	M, many roots	None
2	A	2-13	5YR 4/3	2, CO, SBK	SiC	FR	C, S	NE	M, few roots	c, 1, F, 5YR 4/2, FED,

										MAT
3	Bw1	13-20	5YR 4/4	2, CO, SBK	SL	VFR	A, S	NE	M, few roots	None
4	Bw2	20-30	5YR 4/3	1, M, PR	L	FR	A, S	NE	M, no roots	None
5	C	30-35+	5YR 4/4	MA	LS			NE	M, no roots	None

Table	Soil profile description									
Wetland	W3-3	Date	5/12/10							
	Horizon	Depth (cm)	Color	Structure	Texture	Consistence	Boundary	Effervescence	Special Features	RMF
1	Ap	0-5	5YR 4/4	1, F, SBK	L	FR	V, S	NE	M, many roots	f, 1, F 5YR 4/2, FED, MAT
2	A	5-16	5YR 4/4	2, M, SBK	SL	FR	C, S	NE	M, few roots	None
3	Bw1	16-20	5YR 4/6	1, F, SBK	LS	VFR	A, S	NE	M, Few roots	None
4	Bw2	20-23	5YR 4/4	1, F, SBK	SL	FR	A, W	NE	M, few roots	None

5	Bw3	23-25	5YR 4/6	1, F, SBK	LS	VFR	A, S	NE	M, few roots	None
6	Bw4	25-27	5YR 4/4	1, F, SBK	SL	FR	A, S	NE	M, few roots	None
7	Bw5	27-30	5YR 4/6	1, F, SBK	LS	VFR	A, S	NE	M, few roots	None
8	Ab	30-38+	5YR 4/4	2, M, SBK	L	FR		NE	M, no roots, high percent OM	None

Table	Soil profile description									
Wetland	W3-4	Date	5/12/10							
	Horizon	Depth (cm)	Color	Structure	Texture	Consistence	Boundary	Effervescence	Special Features	RMF
1	A1	0-15	5YR 4/3	2, CO, SBK	SiC	FR	C, S	NE	M, few roots	f, 1, F, 5YR 4/2, FED, MAT
2	A2	15-20	5YR 4/3	2, M, SBK	SiC	FR	A, S	NE	M, few roots	f, 1, F, 5YR 4/2,

										FED, MAT
3	Bss	20-40+	5YR 4/3	2, M, ABK	C	FI		NE	M, few roots	c, 3, P, N 2/0, MNM, MAT

Table	Soil profile description									
Wetland	W3-8	Date	5/18/10							
	Horizon	Depth (cm)	Color	Structure	Texture	Consistence	Boundary	Effervescence	Special Features	RMF
1	C, ooze	0-4	5YR 4/3	MA	CL		A, S	NE	W,no roots	None
2	Bw1b	4-22	5YR 4/3	2, M, SBK	CL	FI	A, S	NE	M, no roots	f, 1, F, 5YR 4/2, FED, MAT
3	Bw2b	22-36+	5YR 4/3	2, M, SBK	SCL	FI		NE	M, no roots	f, 1, D, N 2/0, MNM, MAT

Table	Soil profile									

	description									
Wetland	W4-1	Date	6/24/10							
	Horizon	Depth (cm)	Color	Structure	Texture	Consistence	Boundary	Effervescence	Special Features	RMF
1	C, ooze	0-4	5YR 4/4	MA	L		A, S	VS	W, no roots	None
2	Ab	4-17	5YR 4/3	1, F, SBK	CL	FR	C, S	VS	M, no roots	f, 1, F, 5YR 4/2, FED, MAT
3	Bwb	17-38+	5YR 4/3	2, M, SBK	C	FI		VS	M, no roots	f, 1, D, N 2/0, FMC, MAT; f, 1, F, 5YR 4/1, FED, MAT

Table	Soil profile description									
Wetland	W4-3	Date	6/24/20							
	Horizon	Depth	Color	Structure	Texture	Consistence	Boundary	Effervescence	Special Features	RMF
1	C, ooze	0-10	5YR 4/4	MA	SiL		A, S	SL	W, no roots	None
2	Ab	10-36+	5YR 4/4	2, M, SBK	C	FI		SL	M, no	c, 2, F, 5YR 4/2, FED; f,

									roots	1, D, N 2/0, FMC, MAT

Table	Soil profile description									
Wetland	W4-4	Date	6/24/10							
	Horizon	Depth (cm)	Color	Structure	Texture	Consistence	Boundary	Effervescence	Special Features	RMF
1	C, ooze	0-2	5YR 4/3	MA	SiC		A, S	VS	W, few roots	None
2	Ab	2-13	5YR 4/4	2, M, SBK	SiC	FR	A, S	VS	W, few roots	c, 2, D, 5YR 4/1, FED, MAT
3	Cb	13-39+	5YR 4/3	MA	C			VS	M, no roots	f, 1, D, N 2/0, FMC, MAT

Table	Soil profile description									
Wetland	W4-5	Date	6/24/10							
	Horizon	Depth (cm)	Color	Structure	Texture	Consistence	Boundary	Effervescence	Special Features	RMF

1	C, ooze	0-8	5YR 4/4	MA	SiC		A, S	SL	W, few roots	None
2	Ab	8-14	5YR 4/4	1, F, SBK	C	FR	A, S	SL	M, few roots	None
3	Abb	14-44+	5YR 3/3	1, CO, SBK	C	FI		VS	M, no roots	f, 1, D, N 2/0, FMC, MAT

Table	Soil profile description									
Wetland	W5-1	Date	5/31/10							
	Horizon	Depth (cm)	Color	Structure	Texture	Consistence	Boundary	Effervescence	Special Features	RMF
1	A	0-8	5YR 3/3	1, F, SBK	SiCL	FR	A, S	NE	W, many roots	None
2	Bw	8-25	5YR 4/4	2, M, SBK	SiC	FI	D, S	NE	W, few roots	f, 1, F, 5YR 4/2, FED, MAT
3	Bss	25-39+	5YR 4/4	2, M, ABK	C	FI		NE	M, no roots, slickensides	c, 1, D, N 2/0, MNM, MAT

Table	Soil profile									

	description									
Wetland	W5-3	Date	5/31/10							
	Horizon	Depth (cm)	Color	Structure	Texture	Consistence	Boundary	Effervescence	Special Features	RMF
1	A1	0-3	5YR 3/3	1, CO, SBK	SiCL	FI	A, S	NE	W, many roots	f, 1, F, 5YR 4/2, FED, MAT
2	A2	3-13	5YR 4/3	1, F, SBK	CL	FR	C, S	NE	M, few roots	f, 1, F, 5YR 4/1, FED, MAT
3	Bw	13-27	5YR 4/4	2, F, ABK	CL	FR	D, S	NE	W, few roots	f, 1, D, N 2/0, MNM, MAT; f, 1, F, 5YR 4/1, FED, MAT
4	Bss	27-39	5YR 4/4	2, F, ABK	SiCL	FR		NE	M, no roots, slickensides	f, 1, D, N 2/0, MNM, MAT

Table										
Wetland	W5-4	Date	5/31/10							
	Horizon	Depth (cm)	Color	Structure	Texture	Consistence	Boundary	Effervescence	Special Features	RMF

1	A1	0-6	5YR 4/3	2, M, GR	SiCL	VFR	A, S	NE	W, many roots	None
2	A2	6-14	5YR 4/3	2, F, SBK	SiCL	VFR	D, S	NE	M, common roots	None
3	Bw	14-22	5YR 4/4	2, CO, SBK	CL	FR	A, S	NE	W, few roots	f, 1, F, 5YR 4/1, FED, MAT
4	Bss	22-40+	5YR 4/4	2, F, ABK	C	FI		NE	M, few roots	f, 1, F, 5YR 4/2, FED, MAT

Table	Soil profile description									
Wetland	W5-5	Date	5/31/10							
	Horizon	Depth (cm)	Color	Structure	Texture	Consistence	Boundary	Effervescence	Special Features	RMF
1	A	0-17	5YR 4/3	1, M, SBK	CL	FR	C, S	NE	W, many roots	None
2	Bss	17-35+	5YR 4/4	1, F, ABK	C	FR		NE	M, few roots	f, 1, F, 5YR 4/1, FED, MAT

Table	Soil profile									

	description									
Wetland	W6-2	Date	5/24/10							
	Horizon	Depth (cm)	Color	Structure	Texture	Consistence	Boundary	Effervescence	Special Features	RMF
1	Cu	0-23	5YR 4/4	MA	FSL		A, S	NE	M, common roots	f, 1, F, N 2/0, MNM, MAT
2	Cb1	23-27	5YR 3/3	MA	SCL		A, S	NE	M, few roots	f, 1, F, N 2/0, MNM, MAT
3	Cb2	27-37+	5YR 4/4	MA	CL			NE	M, few roots	c, 2, F, 5YR 5/1, FED, MAT; f, 1, F, N 2/0, MNM, MAT

Table	Soil profile description									
Wetland	W6-3	Date	5/24/10							
	Horizon	Depth	Color	Structure	Texture	Consistence	Boundary	Effervescence	Special	RMF

		(cm)							Features	
1	A	0-6	5YR 4/3	1, VF, SBK	SiCL	VFR	A, S	NE	W, many roots	None
2	Bw	6-25	5YR 4/4	1, M, SBK	C	FR	A, S	NE	M, common roots	f, 1, F, 5YR 4/2, FED, MAT
3	Bss	25-40+	5YR 4/4	2, F, ABK	C	FI		NE	M, few roots	f, 2, D, 5B 5/1, FED, MAT; c, 2, F, 5YR 4/2, F3M, MAT

Table	Soil profile description									
Wetland	W6-6	Date	5/24/10							
	Horizon	Depth (cm)	Color	Structure	Texture	Consistence	Boundary	Effervescence	Special Features	RMF
1	C, ooze	0-7	5YR 3/4	MA	SiC		C, S	NE	W, no roots	c, 1, D, N 2/0, MNM, MAT
2	Bwb	7-40+	5YR 4/4	1, F, SBK	CL	FR		NE	M, no	None

									roots	

Table	Soil profile description									
Wetland	W6-7	Date	6/22/10							
	Horizon	Depth (cm)	Color	Structure	Texture	Consistence	Boundary	Effervescence	Special Features	RMF
1	A	0-10	5YR 4/3	1, F, SBK	SiCL	VFR	A, S	NE	W, few roots	None
2	Bw1	10-20	5YR 3/3	1, M, SBK	CL	FR	A, S	SL	M, few roots	None
3	Bw2	20-40+	5YR 4/4	2, M, SBK	SCL	FI		VS	M, no roots	f, 2, F, 5YR 4/6, F3M, MAT

Table	Soil profile description									
Wetland	W7-2	Date	7/19/10							
	Horizon	Depth (cm)	Color	Structure	Texture	Consistence	Boundary	Effervescence	Special Features	RMF
1	C, ooze	0-19	7.5YR	MA	SiC		A, S	NE	W, no	None

			4/4						roots	
2	Ab	19-28	7.5YR 4/3	2, F, ABK	SiC	FR	C, S	NE	M, no roots	None
3	Cb	28-40+	7.5YR 4/3	MA	C			NE	M, no roots	None

Table	Soil profile description									
Wetland	W7-6	Date	7/19/10							
	Horizon	Depth (cm)	Color	Structure	Texture	Consistence	Boundary	Effervescence	Special Features	RMF
1	Ap	0-4	5YR 4/3	1, F, SBK	C	FI	A, S	NE	M, common roots	None
2	A	4-14	5YR 4/3	2, M, SBK	C	FR	A, S	NE	Mist, common roots	None
3	Bw	14-43+	5YR 4/3	2, M, PR	C	FI		NE	M, few roots	None

Table	Soil profile description			This site is a recently created						

				island.						
Wetland	W7-8	Date	7/19/10							
	Horizon	Depth (cm)	Color	Structure	Texture	Consistence	Boundary	Effervescence	Special Features	RMF
1	C1	0-3	5YR 4/3	MA	C		A, S	NE	D, no roots, dried ooze layer	None
2	C2	3-40+	5YR 4/3	MA	C			NE	M, no roots	c, 2, D, 5YR 4/1, FED, MAT

Table	Soil profile description									
Wetland	W8-2	Date	6/10/10							
	Horizon	Depth (cm)	Color	Structure	Texture	Consistence	Boundary	Effervescence	Special Features	RMF
1	Oi	3-0	7.5YR 4/1				A, S	NE	W, com roots	None
2	Ag1	0-4	7.5YR 4/2	2, M, SBK	SiL	FR	A, S	NE	M, few roots	f, 1, D, 2.5YR 4/8, F3M, MAT.; c,

										1, f, 7.5YR 4/3, F3M, MAT
3	Ag2	4-9	7.5YR 4/2	2, M, ABK	L	FR	A, S	NE	M, few roots	c, 2, D, 2.5YR 4/6, F3M, MAT; c, 2, D, 2.5YR 4/8, F3M, MAT
4	Ag3	9-17	7.5YR 4/2	2, M, SBK	L	FR	A, S	NE	M, few roots	c, 2, P, 2.5 YR 3/4, F3M, MAT
5	Bw	17-25	7.5YR 5/3	2, F, SBK	SL	VFR	A, S	NE	W, few roots	c, 3, D, 7.5YR 5/1, FED, MAT; c, 2, P, 2.5YR 4/6, F3M, MAT; c, 1, D, 5YR 5/8, F3M, RPO
6	Bg	25-37+	7.5YR 4/1	2,M, GR	CL	FI		NE	M, few roots	c, 1, P, 2.5YR 3/4, F3M, MAT; f, 1, P, 2.5YR

										4/6, F3M, MAT

Table	Soil profile description									
Wetland	W8-3	Date	6/11/10							
	Horizon	Depth (cm)	Color	Structure	Texture	Consistence	Boundary	Effervescence	Special Features	RMF
1	A	0-7	10YR 4/2	1, M, SBK	SL	FI	C, S	NE	W, many roots	None
2	Bw1	7-20	10YR 4/4	1, M, SBK	LS	FR	G, S	NE	M, common roots	c, 2, F, 10YR 4/1, FED, MAT; c, 2, D, N 2/0, MNM, MAT; c, 2, D, 5YR 5/8, F3M, MAT; c, 2, D, 2.5 YR 3/4, F3M, HPF
3	Bw2	20-39+	10YR 5/4	1, M, SBK	S	FR		NE	M, few roots, medium and coarse	c, 2, F, 7.5YR 5/6, F3M, MAT; c, 2,

									gravels and cobbles	D, N 2/0, MNM, HPF

Table	Soil profile description									
Wetland	W8-6	Date	6/11/10							
	Horizon	Depth (cm)	Color	Structure	Texture	Consistence	Boundary	Effervescence	Special Features	RMF
1	Cg, ooze	0-8	7.5YR 4/1	MA			G, S	NE	W, no roots	None
2	Ab	8-35+	7.5YR 4/4	2, VC, SBK	C	FI		NE	M, no roots	m, 3, D, 7.5YR 4/2, FED, MAT; m, 3, P, G2 4/5B, FED, MAT

Table	Soil profile description									
Wetland	W8-8	Date	6/11/10							
	Horizon	Depth	Color	Structure	Texture	Consistence	Boundary	Effervescence	Special	RMF

		(cm)							Features	
1	Cg, ooze	0-16	7.5YR 4/1	MA			C, S	NE	W, no roots, HS smell	gley
2	Agb	16-21	G2 4/5B	1, F, SBK	CL	FR	G, S	NE	M, no roots	c, 2, P, 7.5 YR 4/6, F3M, MAT
3	Bwb	21-38+	7.5YR 4/4	2, VC, SBK	C	FI		NE	M, no roots	m, 3, D, 7.5YR 4/2, FED, MAT ; m, 3, P, G2 4/5B FED, MAT

Table	Soil profile description									
Wetland	N1-1	Date	7/7/10							
	Horizon	Depth (cm)	Color	Structure	Texture	Consistence	Boundary	Effervescence	Special Features	RMF
1	A	0-3	5YR 4/3	1, F, SBK	SiC	VF	A, S	NE	W, many roots	None
2	Bw1	3-20	5YR	2, M, SBK	SiCL	VF	C, S	VS	M, few	None

			4/3						roots	
3	Bw2	20-40+	5YR 4/4	2, CO, SBK	C	FI		SL	M, few roots	c, 2, F, 5YR 4/4, F3M, MAT

Table	Soil profile description		Well; +35.5							
Wetland	N1-3	Date	5/25/10							
	Horizon	Depth (cm)	Color	Structure	Texture	Consistence	Boundary	Effervescence	Special Features	RMF
1	A	0-4	5YR 3/3	1, F, SBK	SiC	VFR	A, S	NE	W, many roots, 20% fibric debris	None
2	1Bw	4-29	5YR 4/4	1, F, SBK	SiC	VFR	G, S	NE	W, common roots	None
3	2Bw	29-42+	5YR 3/3	2, CO, SBK	SL	FR		SL	W, no roots	f, 1, D, N 2/0, MNM, MAT

Table	Soil profile									

	description									
Wetland	N1-6	Date	7/7/10							
	Horizon	Depth (cm)	Color	Structure	Texture	Consistence	Boundary	Effervescence	Special Features	RMF
1	A	0-4	5YR 3/3	1, M, GR	SiC	VF	A, S	NE	W, common roots	None
2	Bw1	4-12	5YR 4/3	1, F, SBK	SiCL	FR	C, S	NE	W, few roots	None
3	Bw2	12-40+	5YR 4/4	1, CO, SBK	C	FI		NE	M, few roots	f, 1, F, 5YR 4/6, F3M, MAT; f, 1, F, 5YR 4/2, FED, MAT

Table	Soil profile description									
Wetland	N1-7	Date	7/7/10							
	Horizon	Depth (cm)	Color	Structure	Texture	Consistence	Boundary	Effervescence	Special Features	RMF
1	A	0-10	5YR 4/4	1, F, SBK	SiCL	FR	A, S	NE	W, common	None

									roots	
2	Bw1	10-20	5YR 4/4	2, M, SBK	SiC	FR	A, S	NE	M, few roots	None
3	Bg	20-40+	5YR 4/2	2, M, SBK	C	FI		NE	M, few roots	None

Table	Soil profile description									
Wetland	N2-2	Date	7/6/10							
	Horizon	Depth (cm)	Color	Structure	Texture	Consistence	Boundary	Effervescence	Special Features	RMF
1	C, ooze	0-5	5YR 4/4	MA	C		A, S	VS	W, common roots	None
2	Ab	5-10	5YR 4/4	1, F, GR	C	VF	A, S	VS	W, common roots	None
3	Bw1b	10-20	5YR 4/4	2, M, ABK	C	FR	A, S	SL	M, few roots	None
4	Bw2b	20-32	5YR 4/4	1, M, SBK	SC	FR	A, S	SL	M, few roots	None
5	Bw3b	32-40+	5YR 4/4	1, M, SBK	C	FR		SL	M, few roots	None

Table	Soil profile description									
Wetland	N2-3	Date	7/6/10							
	Horizon	Depth (cm)	Color	Structure	Texture	Consistence	Boundary	Effervescence	Special Features	RMF
1	A	0-4	5YR 4/3	2, F, GR	C	VF	A, S	SL	W, common roots	None
2	Bw1	4-8	5YR 4/4	2, M, SBK	C	FI	A, S	SL	W, common roots	None
3	Bw2	8-45+	5YR 4/4	1, CO, SBK	C	FR		SL	M, few roots	None

Table	Soil profile description									
Wetland	N2-4	Date	7/6/10							
	Horizon	Depth (cm)	Color	Structure	Texture	Consistence	Boundary	Effervescence	Special Features	RMF
1	A	0-5	5YR 4/3	1, M, SBK	C	FR	A, S	SL	W, common roots	None

2	Bw1	5-27	5YR 4/4	1, CO, SBK	C	FR	A, S	SL	W, few roots	None
3	Bw2	27-40+	5YR 4/4	2, CO, SBK	C	FI		SC	M, few roots	None

Table	Soil profile description									
Wetland	N2-6	Date	7/6/10							
	Horizon	Depth (cm)	Color	Structure	Texture	Consistence	Boundary	Effervescence	Special Features	RMF
1	A	0-8	5YR 4/4	1, M, SBK	C	FR	A, S	SL	W, common roots	None
2	Bw	8-42+	5YR 4/4	1, CO, SBK	C	FR		VS	M, few roots	None

Table	Soil profile description									
Wetland	N3-4	Date	5/18/10							
	Horizon	Depth (cm)	Color	Structure	Texture	Consistence	Boundary	Effervescence	Special Features	RMF
1	A	0-7	5Yr 4/3	1, F, SBK	L	VFR	A, S	NE	W, many	None

									roots	
2	Bw1	7-19	5YR 4/4	2, F, SBK	SiCL	FI	A, S	VS	W, common roots	None
3	Bw2	19-33	5YR 4/4	1, M, SBK	LS	FR	C, S	NE	W, few roots	c, 1, F, 5YR 4/2, FED, MAT
4	Bw3	33-38+	5YR 4/4	2, M, SBK	SiCL	FI		VS	W, few roots	c, 2, F, 5YR 4/2, FED, MAT; f, 1, D, N 2/0, MNM, MAT

Table	Soil profile description									
Wetland	N3-5	Date	5/18/10							
	Horizon	Depth (cm)	Color	Structure	Texture	Consistence	Boundary	Effervescence	Special Features	RMF
1	A	0-20	5YR 4/4	2, CO, SBK	L	FR	C, S	NE	W, many roots	f, 1, F, 5YR 4/2, FED, MAT

2	Bw1	20-30	5YR 4/4	2, M, SBK	LS	VFR	C, S	NE	W, no roots	f, 2, D, N 2/0, MNM, MAT
3	Bw2	30-35+	5YR 4/4	1, F, SBK	CL	VFR		NE	W, no roots	f, 2, D, 5YR 3/1, F3M, MAT; f, 1, F, 5YR 4/2, FED, MAT

Table	Soil profile description									
Wetland	N3-7	Date	5/18/10							
	Horizon	Depth (cm)	Color	Structure	Texture	Consistence	Boundary	Effervescence	Special Features	RMF
1	A	0-15	5YR 4/4	2, F, SBK	C	FI	A, S	NE	W, few roots	f, 1, F, 5YR 4/2, FED, MAT
2	Bw1	15-28	5YR 4/4	1, CO, SBK	SL	FR	A, S	NE	W, no roots	f, 1, F, 5YR 4/2, FED, MAT

3	Bw2	28-40+	5YR 4/4	2, M, SBK	SiCL	FI		NE	W, no roots	c, 1, D, 5YR 3/1, F3M, MAT

Table	Soil profile description									
Wetland	N3-8	Date	5/18/10							
	Horizon	Depth (cm)	Color	Structure	Texture	Consistence	Boundary	Effervescence	Special Features	RMF
1	A	0-9	5YR 4/4	1, F, SBK	SiCL	FR	A, S	SL	W, many roots	None
2	Bw1	9-22	5YR 4/4	2, CO, SBK	SiCL	FR	A, S	VS	W, common roots	None
3	Bw2	22-28	5YR 4/3	1, M, SBK	SL	VFR	A, S	NE	W, few roots	c, 1, F, 5YR 4/2, FED, MAT
4	Bw3	28-40+	5YR 4/4	1, F, SBK	LS	VFR		SL	W, no roots	f, 1, F, 5YR 4/2, FED, MAT

Table	Soil profile description									
Wetland	N4-4	Date	7/15/10							
	Horizon	Depth (cm)	Color	Structure	Texture	Consistence	Boundary	Effervescence	Special Features	RMF
1	A	0-9	5YR 4/3	1, F, SBK	SiC	VFR	A, S	NE	W, many roots	None
2	Bw	9-40+	5YR 4/4	2, M, SBK	C	FR		NE	M, common roots	None

Table	Soil profile description									
Wetland	N4-5	Date	7/15/10							
	Horizon	Depth (cm)	Color	Structure	Texture	Consistence	Boundary	Effervescence	Special Features	RMF
1	Oi	3-0	N 2/0				C, S	NE	W, many roots, fibric OM	None
2	A	0-21	5YR 4/4	2, M, SBK	C	FR	D, S	NE	M, few roots	None
3	Bw	21-40+	5YR 4/3	1, M, SBK	C	FI		NE	M, no roots	f, 2, F, 5YR 4/1, FED,

										MAT; f, 1, D, 2.5 YR 4/6, F3M, MAT

Table	Soil profile description									
Wetland	N4-6	Date	7/15/10							
	Horizon	Depth (cm)	Color	Structure	Texture	Consistence	Boundary	Effervescence	Special Features	RMF
1	A	0-5	5YR 4/3	2, F, SBK	SiC	VFR	A, S	NE	W, few roots	None
2	Bw1	5-27	5YR 4/4	2, M, SBK	C	FR	A, S	NE	W, few roots	None
3	Bw2	27-40+	5YR 4/2	2, M, SBK	C	FR		NE	W, few roots	None

Table	Soil profile description									
Wetland	N4-7	Date	7/15/10							
	Horizon	Depth (cm)	Color	Structure	Texture	Consistence	Boundary	Effervescence	Special Features	RMF

1	A	0-3	5YR 4/3	1, F, SBK	SiC	VF	A, S	NE	W, common roots	None
2	Bw1	3-20	5YR 4/4	1, M, SBK	C	FI	A, S	NE	M, few roots	None
3	Bw2	20-40	5YR 4/3	1, M, SBK	C	FI		NE	M, no roots	f, 1, F, 5YR 4/4, F3M, MAT; f, 2, F, 5YR 4/1, FED, MAT

Table	Soil profile description									
Wetland	N5-1	Date	8/4/09							
	Horizon	Depth (cm)	Color	Structure	Texture	Consistence	Boundary	Effervescence	Special Features	RMF
1	Oi	1-0					A, S	NE		None
2	A	0-4	5YR 3/3	2, F, GR	SiL		C, S	SL		f, 3, D, N 2/0, MNM, MAT
3	Bw1	4-10	7.5Yr 4/4	1, M, SBK	SiL		C, S	SL		f, 3, D, N 2/0, MNM,

										MAT
4	Bw2	10-14	5YR 4/4	1, M, SBK	SiC		C, S	NE		f, 3, D, N 2/0, MNM, MAT
5	BC	14-25	5YR 4/6	1, M, SBK	SiCL		A, S	NE		f, 3, D, N 2/0, MNM, MAT
6	C1	25-29	5YR 4/4	MA	SiCL		A, S	NE		f, 3, D, N 2/0, MNM, MAT
7	C2	29-30	2.5YR 4/4	MA	SiCL		A, S	NE		c, 3, D, N 4/0, MNM, MAT
8	C3	30-33	5YR 4/3	MA	SiCL		A, S	NE		c, 3, D, N4/0, MNM, MAT
9	2C4	33-36+	10YR 6/6	MA	FSL			NE		c, 3, D, 7.5YR 5/8 F3M, MAT; c, 3, D, N 4/0, MNM, MAT

Table	Soil profile description			Flooded recently; Silt lines on cedar 210cm above ground at N5-2						
Wetland	N5-2	Date	6/22/10							
	Horizon	Depth (cm)	Color	Structure	Texture	Consistence	Boundary	Effervescence	Special Features	RMF
1	A	0-6	5YR 4/4	2, F, SBK	L	VFR	C, S	NE	M, common roots	None
2	Bw1	6-16	7.5YR 4/4	2, M, PR	SL	FR	A, S	NE	M, few roots	c, 1, F, 5YR 4/2, FED, MAT
3	Bw2	16-25	5YR 4/3	2, CO, SBK	SiCL	FI	C, S	NE	M, few roots	None
4	Bw3	25-35+	5YR 4/4	1, M, SBK	C	FI		NE	M, few roots	f, 1, F, 5YR 4/2, FED, MAT

Table	Soil profile description									
Wetland	N5-4	Date	8/4/09							
	Horizon	Depth (cm)	Color	Structure	Texture	Consistence	Boundary	Effervescence	Special Features	RMF

Table	Soil profile description									
Wetland	N5-5	Date	6/22/10							
	Horizon	Depth (cm)	Color	Structure	Texture	Consistence	Boundary	Effervescence	Special Features	RMF
1	A	0-6	5YR 3/2	2, F, GR	SiCL		A, S	NE		None
2	Bw1	6-14	7.5YR 4/6	1, M, SBK	VFSL		A, S	SL		f, 1, D, 7.5YR 5/8, F3M, MAT; f, 1, D, N 2/0, MNM, MAT
3	Bw2	14-19	7.5YR 4/6	1, M, SBK	L		A, S	SL		f, 1, D, 7.5YR 5/8, F3M, MAT; f, 1, D, N 2/0, MNM, MAT
4	2Bw	19-38+	5YR 4/4	2, CO, PR	C			NE	Pressure faces	c, 2, D, N 2/0, MNM, MAT

1	A	0-9	5YR 4/4	1, F, SBK	SiL	FR	C, S	NE	W, common roots	c, 2, F, 7.5YR 4/1, FED, MAT
2	Bw	9-17	7.5YR 4/4	2, M, PR	L	FI	A, S	NE	W, few roots	c, 1, F, 7.5 YR 4/1, FED, MAT
3	Bss	17-42+	5YR 4/4	2, CO, ABK	C	VFI		NE	M, few roots, slickensides	None

Table	Soil profile description									
Wetland	N6-3	Date	9/9/09							
	Horizon	Depth (cm)	Color	Structure	Texture	Consistence	Boundary	Effervescence	Special Features	RMF
1	A1	0-5	5YR 4/4	1, F, SBK	L		A, S		M	None
2	A2	5-12	5YR 4/3	2, M, SBK	SiL		A, S		M	None
3	Bw1	12-33	5YR 4/4	2, CO, SBK	CL		A, S		M	c, 2, D, N 2/0, MNM, MAT

4	Bw2	33-36+	5YR 4/3	2, CO, SBK	SiCL				M	f, 1, F, N 2/0, MNM, MAT

Table	Soil profile description									
Wetland	N6-4	Date	5/11/10							
	Horizon	Depth (cm)	Color	Structure	Texture	Consistence	Boundary	Effervescence	Special Features	RMF
1	A	0-20	5YR 4/4	1, F, SBK	L	VFR	A, S		W, few roots	None
2	Bw	20-40+	5YR 4/3	2, CO, SBK	CL	FI			M, no roots	None

Table	Soil profile description									
Wetland	N6-6	Date	5/11/10							
	Horizon	Depth (cm)	Color	Structure	Texture	Consistence	Boundary	Effervescence	Special Features	RMF
1	A	0-19	5YR 4/4	1, M, SBK	L	VFR	A, S		W, many roots	None
2	Bw	19-40+	5Yr 4/3	2, CO,	CL	FI			M, few roots,	None

				SBK					black OM in root channels	

Table	Soil profile description									
Wetland	N6-8	Date	5/11/10							
	Horizon	Depth (cm)	Color	Structure	Texture	Consistence	Boundary	Effervescence	Special Features	RMF
1	A	0-14	5YR 4/4	1, F, SBK	L	VFR	A, S		W, many roots	None
2	Bw	14-35+	5YR 4/4	2, M, SBK	CL	FR			M, few roots	None

Table	Soil profile description									
Wetland	N8-2	Date	8/12/10							
	Horizon	Depth (cm)	Color	Structure	Texture	Consistence	Boundary	Effervescence	Special Features	RMF
1	C, ooze	0-2	5YR 3/2	MA	Si		C, S	NE	W	None
2	A1b	2-9	5YR 3/2	1, M, SBK	SiCL		G, S	NE	W	m, 3, D, 5YR 5/8, F3M,

										MAT
3	A2b	9-24	5YR 3/2	1, M, SBK	SiC		G, S	NE	M	m, 3, D, 5YR 5/8, F3M, MAT
4	Bgb	24-37+	5YR 4/1	1, M, SBK	SiC			NE	M	m, 3, P, 5YR 5/8, F3M, MAT

Table	Soil profile description									
Wetland	N8-3	Date	8/12/09							
	Horizon	Depth (cm)	Color	Structure	Texture	Consistence	Boundary	Effervescence	Special Features	RMF
1	Cg, ooze	0-9	7.5YR 4/2	MA	SiL		C, S	NE	W	None
2	Ag1b	9-16	7.5YR 4/2	2, F, SBK	SiL		C, S	NE	W	c, 3, F, 5YR 5/6, F3M, MAT
3	Ag2b	16-38+	7.5YR 4/2	1, F, SBK	SiCL		G, S	NE	M	m, 3, D, 5YR 5/6, F3M, MAT, c, 3,

										D, 7.5YR 5/1, FED, MAT

Table	Soil profile description									
Wetland	N8-6	Date	8/12/09							
	Horizon	Depth (cm)	Color	Structure	Texture	Consistence	Boundary	Effervescence	Special Features	RMF
1	A	0-15	7/5yr 4/3	MA	SiL		A, S	NE	W	c, 3, F, 7.5YR 5/6, F3M, MAT
2	Bg1	15-26	7.5yr 4/2	1, F, SBK	SiCL		A, S	NE	M	m, 3, P, 7.5YR 5/8, F3M, MAT
3	Bg2	26-35+	7/5yr 4/1	1, M, SBK	SiL			NE	M	c, 3, D, 7.5YR 5/6, F3M, MAT

Table	Soil profile description									

Wetland	N8-8	Date	8/12/09							
	Horizon	Depth (cm)	Color	Structure	Texture	Consistence	Boundary	Effervescence	Special Features	RMF
1	Oi	3-0					A, S	NE	D	None
2	A	0-5	5YR 4/4	1, F, SBK	SiCL		A, S	NE	M	c, 3, F, 7.5YR 5/6, F3M, MAT
3	Bw	5-36+	5YR 3/3	1, F, SBK	CL			NE	M	c, 3, D, 7.5YR 5/6, F3M, MAT

Key
NASIS;
Water State Class: D = dry, M = moist, and W = wet, satiated or saturated.
For roots, did not use NASIS, used Conv., which is few = 1, common = 2, and many = 3.
RMF quantity use Conv., which is few = f, common = c, and many = m.
RMF size is Fine = 1, Medium = 2, Coarse = 3
RMF contrast is Faint, = F, Distinct = D, and Prominent = P
RMF iron depletions = FED (NASIS)
RMF Fe+3 iron concentrations = F3M (NASIS)
RMF manganese concentrations = MNM (NASIS)
RMF iron-manganese concretions = FMC (NASIS)
RMF locations; in matrix = MAT (NASIS); on faces of peds = APF (NASIS); along root channels = RPO; on horizontal faces of peds = HPF

Table of total nitrogen levels (TN; %), total carbon levels (TC; %), and the TC converted to organic matter (OM; %) for 5 cm and 20 cm samples.

Treat	WL	TN (5 cm)	TN (20 cm)	TC (5 cm)	TC (20 cm)	TC (mean total)	%OM(5 cm)	%OM(20 cm)
Nat	1	0.33	0.17	4.19	1.69	2.94	7.22	2.91
Nat	1	0.50	0.13	6.71	1.24	3.98	11.58	2.14
Nat	1	0.47	0.17	5.51	1.68	3.60	9.50	2.90
Nat	1	0.44	0.13	5.13	1.36	3.25	8.85	2.34
Nat	2	0.20	0.08	2.20	0.74	1.47	3.79	1.27
Nat	2	0.18	0.13	1.97	0.99	1.74	3.39	1.70
Nat	2	0.17	0.17	1.57	1.31	1.44	2.71	2.25
Nat	2	0.17	0.20	1.89	2.26	1.84	3.27	3.89
Nat	3	0.16	0.11	1.93	0.94	1.44	3.33	1.62
Nat	3	0.15	0.09	1.59	0.81	1.20	2.74	1.40
Nat	3	0.17	0.09	1.68	0.96	1.32	2.90	1.65
Nat	3	0.13	0.12	1.47	1.13	1.30	2.54	1.94
Nat	4	0.31	0.13	3.64	1.13	2.39	6.28	1.95
Nat	4	0.33	0.17	3.83	1.82	2.83	6.61	3.14
Nat	4	0.31	0.12	3.57	1.25	2.41	6.15	2.16
Nat	4	0.28	0.15	3.05	1.74	2.39	5.26	2.99
Nat	5	0.15	0.19	1.52	2.26	1.89	2.63	3.90
Nat	5	0.21	0.17	2.32	1.79	2.06	4.01	3.09
Nat	5	0.19	0.18	2.08	1.62	1.85	3.58	2.80
Nat	5	0.19	0.22	2.03	2.29	2.16	3.50	3.94
Nat	6	0.22	0.13	2.46	1.12	1.79	4.24	1.93
Nat	6	0.14	0.19	1.18	2.33	1.76	2.04	4.02
Nat	6	0.20	0.17	2.11	1.84	1.97	3.63	3.17
Nat	6	0.19	0.24	1.88	2.66	2.27	3.24	4.58
Nat	7	0.39	0.14	5.43	1.20	3.31	9.35	2.07
Nat	7	0.33	0.13	3.65	0.86	2.26	6.29	1.49
Nat	7	0.46	0.16	5.30	1.26	3.28	9.14	2.18

Nat	7	0.44	0.15	4.85	1.44	3.15	8.37	2.49
Nat	8	0.27	0.18	3.02	1.86	2.44	5.20	3.21
Nat	8	0.41	0.21	5.39	2.58	3.98	9.29	4.44
Nat	8	0.16	0.14	1.56	1.28	1.42	2.68	2.21
Nat	8	0.14	0.13	1.41	1.26	1.33	2.43	2.17
WRP	1	0.14	0.18	1.43	1.67	1.55	2.46	2.88
WRP	1	0.13	0.21	1.16	2.04	1.60	2.00	3.53
WRP	1	0.15	0.10	1.41	0.83	1.12	2.43	1.43
WRP	1	0.15	0.13	1.39	1.14	1.26	2.39	1.96
WRP	2	0.18	0.12	2.20	1.00	1.60	3.80	1.72
WRP	2	0.15	0.19	1.54	2.20	1.87	2.66	3.79
WRP	2	0.16	0.11	1.61	0.94	1.27	2.77	1.61
WRP	2	0.14	0.08	1.32	0.75	1.04	2.28	1.30
WRP	3	0.17	0.09	1.57	0.86	1.22	2.71	1.48
WRP	3	0.13	0.15	1.12	1.36	1.24	1.92	2.34
WRP	3	0.09	0.12	0.93	0.98	0.96	1.60	1.69
WRP	3	0.10	0.11	1.16	0.96	1.06	2.00	1.66
WRP	4	0.12	0.13	1.39	1.11	1.25	2.39	1.92
WRP	4	0.12	0.12	1.37	0.98	1.17	2.35	1.68
WRP	4	0.32	0.10	3.97	0.82	2.40	6.85	1.42
WRP	4	0.38	0.14	4.80	1.12	2.96	8.27	1.93
WRP	5	0.27	0.13	2.82	1.15	1.98	4.86	1.98
WRP	5	0.29	0.14	3.31	1.21	2.26	5.71	2.08
WRP	5	0.25	0.16	2.65	1.47	2.06	4.58	2.53
WRP	5	0.16	0.11	1.56	0.77	1.17	2.69	1.32
WRP	6	0.13	0.15	1.17	1.37	1.27	2.02	2.36
WRP	6	0.13	0.09	1.43	0.77	1.10	2.46	1.32
WRP	6	0.18	0.18	2.09	1.83	1.96	3.60	3.16
WRP	6	0.21	0.21	2.23	2.04	2.14	3.85	3.52
WRP	7	0.21	0.18	1.97	1.70	1.84	3.40	2.93

WRP	7	0.20	0.21	2.49	2.05	2.27	4.29	3.53
WRP	7	0.16	0.13	1.89	1.13	1.51	3.26	1.94
WRP	7	0.23	0.13	2.58	1.21	1.90	4.45	2.09
WRP	8	0.21	0.10	2.49	0.90	1.69	4.29	1.55
WRP	8	0.16	0.22	1.46	2.33	1.89	2.51	4.02
WRP	8	0.24	0.08	2.23	0.72	1.48	3.85	1.24
WRP	8	0.23	0.13	2.29	1.44	1.86	3.94	2.48

Table of nutrient values for each site in each wetland.

Treat	WL	pH	Top N ppm	P ppm	K ppm	Top SO4 ppm	Ca ppm	Mg ppm	Fe ppm	Zn ppm	B ppm	Cu ppm
Nat	1	7.80	0.50	15.50	159.50	21.50	3127.50	976.00	59.09	4.33	1.47	2.17
Nat	1	6.30	0.50	8.00	210.00	13.50	2751.50	1144.00	318.19	2.28	1.25	2.14
Nat	1	5.80	0.50	13.50	271.00	75.50	3010.50	973.50	301.22	3.02	0.97	2.43
Nat	1	5.50	0.50	16.00	177.00	31.00	2668.00	909.00	369.79	4.65	1.28	2.66
Nat	2	7.90	1.00	17.50	207.00	17.50	4406.00	889.00	67.83	1.28	1.04	1.84
Nat	2	8.00	0.50	19.50	241.00	27.00	4520.50	872.50	54.98	1.39	0.87	1.82
Nat	2	8.20	6.00	17.50	205.00	28.50	4206.50	838.00	39.67	1.17	0.77	1.65
Nat	2	8.00	1.50	19.00	191.50	29.50	3021.00	736.50	67.12	1.76	1.01	2.05
Nat	3	6.90	0.50	17.00	138.00	10.00	1509.50	452.50	134.66	1.78	0.58	1.57
Nat	3	8.00	1.00	20.00	149.00	16.50	2555.00	575.50	78.42	1.25	0.85	1.49
Nat	3	8.10	0.50	20.50	194.00	28.50	3814.50	796.50	62.38	1.40	1.06	1.67
Nat	3	8.10	1.00	19.00	150.50	83.50	4398.50	736.50	54.71	1.43	1.07	1.52
Nat	4	6.50	31.00	35.00	229.50	27.00	2851.00	881.50	218.60	9.54	1.06	3.03
Nat	4	6.50	12.00	71.00	256.50	71.00	2653.00	964.50	143.14	5.49	1.43	2.41
Nat	4	6.40	11.50	56.00	270.00	37.50	2782.50	1065.00	140.09	8.19	1.14	2.58
Nat	4	6.60	16.00	81.50	291.00	28.50	2835.50	991.00	171.02	8.70	1.36	2.59
Nat	5	8.50	12.00	16.00	161.50	13.50	3746.50	547.50	47.15	1.66	1.58	1.74
Nat	5	8.20	22.00	13.50	123.00	11.50	1770.00	434.50	25.71	1.04	0.67	1.27
Nat	5	8.30	22.00	9.50	107.50	11.00	2182.00	425.00	24.08	0.87	0.79	1.48
Nat	5	8.00	15.50	11.50	169.50	11.50	2145.00	576.50	29.66	1.13	0.87	1.79
Nat	6	7.50	30.00	12.00	179.50	13.00	2608.00	743.50	64.69	2.21	1.71	2.49

Nat	6	7.80	24.50	28.00	187.50	16.00	3393.50	803.50	53.39	2.01	1.84	2.31
Nat	6	6.00	18.50	15.00	213.00	25.00	2608.00	767.00	169.68	3.30	1.11	3.50
Nat	6	6.90	21.00	19.50	220.50	21.50	2915.00	848.50	96.07	2.93	1.20	3.14
Nat	7	5.00	27.00	4.50	206.50	81.50	2350.00	550.00	386.91	4.98	0.74	3.75
Nat	7	5.00	1.00	4.50	244.00	71.00	1826.00	448.50	352.92	3.32	0.61	2.72
Nat	7	5.10	16.50	7.00	236.00	97.50	2577.00	655.50	382.80	3.53	0.65	3.41
Nat	7	5.70	1.00	12.50	190.00	45.50	2670.00	734.50	329.50	3.20	0.77	4.08
Nat	8	4.90	2.00	8.00	229.00	37.50	1975.00	464.00	360.50	6.51	0.51	3.58
Nat	8	5.00	9.50	12.00	185.00	27.00	1856.50	500.50	340.26	6.54	0.40	4.24
Nat	8	4.90	6.00	13.00	128.50	28.50	1517.00	344.50	380.79	7.14	0.45	3.99
Nat	8	5.30	13.50	11.00	145.50	21.00	1594.50	399.50	282.99	3.86	0.47	3.03
WRP	1	7.10	21.00	9.50	77.00	4.50	780.50	208.50	17.25	0.91	0.27	0.41
WRP	1	7.50	3.00	6.00	163.50	9.50	2503.50	980.00	24.47	0.23	1.38	1.25
WRP	1	7.60	31.00	34.00	120.50	8.00	1714.00	391.00	35.37	1.54	0.70	0.90
WRP	1	7.20	13.00	29.50	102.50	5.00	1252.00	350.00	35.03	1.21	0.45	0.79
WRP	2	7.90	1.50	24.00	245.50	31.50	3472.50	959.00	54.13	1.85	1.21	2.32
WRP	2	8.40	0.50	14.50	76.50	10.50	1889.00	319.00	43.96	0.70	0.64	0.75
WRP	2	7.70	0.50	31.50	150.50	18.50	2069.00	454.00	86.97	3.12	1.06	1.34
WRP	2	7.90	1.00	33.00	183.00	27.50	2940.00	614.50	72.90	2.40	1.00	1.66
WRP	3	8.00	28.00	17.50	191.00	21.50	3660.00	795.50	48.36	3.62	1.18	1.82
WRP	3	8.30	6.00	14.00	102.00	25.50	3492.00	584.00	37.60	1.22	0.73	0.91
WRP	3	7.90	12.50	19.50	213.50	39.50	3409.50	942.50	39.48	7.35	1.31	2.30
WRP	3	7.60	1.50	10.00	159.00	13.00	2391.50	749.50	35.04	2.43	1.07	1.74
WRP	4	7.90	15.50	6.50	187.00	6.50	2607.00	702.50	34.71	0.57	1.50	1.01
WRP	4	8.40	2.00	3.00	176.00	5.00	2833.50	1194.00	31.36	0.33	2.28	1.32
WRP	4	8.30	1.00	5.00	145.00	11.50	2434.00	864.00	34.13	0.41	2.11	1.33

WRP	4	8.10	0.50	6.50	163.50	5.00	2514.50	659.50	42.99	0.58	1.50	1.55
WRP	5	6.30	12.00	27.50	347.50	37.00	2934.50	969.00	189.87	3.49	1.37	2.92
WRP	5	6.60	25.00	24.50	339.50	12.50	3305.00	1045.00	97.72	3.92	0.98	2.94
WRP	5	6.50	24.50	20.00	302.50	12.50	3029.00	976.00	96.84	3.59	0.98	2.84
WRP	5	6.10	24.00	23.00	284.50	34.00	2862.50	945.00	194.95	3.28	1.17	3.35
WRP	6	7.50	6.00	4.50	95.50	24.00	1183.00	366.00	27.01	0.35	0.81	1.17
WRP	6	7.80	10.50	15.00	209.50	19.50	2734.00	801.00	45.04	1.25	2.30	1.94
WRP	6	7.80	2.00	5.50	132.50	38.50	1545.00	596.50	22.64	0.34	1.31	1.44
WRP	6	7.00	3.00	22.50	282.50	16.00	2475.00	877.00	71.41	1.76	1.92	2.00
WRP	7	6.50	0.50	19.00	285.00	70.50	2671.50	889.50	147.25	2.12	0.96	2.40
WRP	7	6.30	0.50	9.00	229.50	35.00	2382.00	834.00	150.96	1.28	0.97	2.56
WRP	7	6.20	17.00	18.00	248.50	15.50	2716.50	878.50	141.74	2.82	0.94	2.68
WRP	7	6.80	2.00	5.50	238.50	21.00	3321.00	1116.50	62.70	1.30	1.18	2.02
WRP	8	6.20	5.00	20.50	133.00	26.00	2560.50	752.00	107.88	16.99	1.12	2.59
WRP	8	6.60	7.50	9.50	49.50	16.50	1221.50	283.00	45.19	9.21	0.36	1.50
WRP	8	6.50	0.50	7.00	216.00	42.00	2886.00	1012.50	116.77	3.07	0.84	2.65
WRP	8	6.30	0.50	7.50	230.00	87.50	3072.50	1047.00	125.32	2.63	0.72	2.75

Table of salinity management test results.

Treat	WL	pH	EC	Na	K	Ca	Mg	B	TSS	PAR	SAR	EPP	ESP
Nat	1	7.20	1393.00	158.33	8.33	37.67	20.00	0.25	919.38	0.16	5.57	5.00	6.40
Nat	1	6.70	1338.00	125.67	10.33	42.67	23.67	0.45	883.08	0.19	3.83	5.27	4.13
Nat	1	5.70	1318.00	79.00	16.67	64.67	30.00	0.45	869.88	0.25	2.00	5.83	1.67
Nat	1	5.67	1128.00	64.00	13.33	45.67	21.00	0.65	744.48	0.24	1.93	5.77	1.57
Nat	2	7.77	1549.00	90.67	16.33	79.67	29.00	0.10	1022.34	0.23	2.23	5.70	1.97
Nat	2	7.87	1583.00	95.00	18.33	80.67	30.00	0.10	1044.78	0.26	2.33	5.93	2.07
Nat	2	7.93	1550.00	124.00	15.00	65.33	26.33	0.15	1023.00	0.23	3.30	5.70	3.43
Nat	2	7.77	2179.00	196.67	21.00	88.00	34.00	0.15	1438.14	0.28	4.53	6.17	5.07
Nat	3	7.17	1167.00	107.33	13.00	40.00	17.67	0.20	770.22	0.26	3.57	5.97	3.80
Nat	3	7.93	1645.00	127.67	16.33	72.33	25.33	0.15	1085.70	0.25	3.27	5.87	3.47
Nat	3	7.93	1727.00	135.67	15.33	75.00	28.33	0.10	1139.82	0.22	3.37	5.63	3.57
Nat	3	8.00	2974.00	247.33	18.00	134.67	49.00	0.15	1962.84	0.20	4.70	5.43	5.33
Nat	4	6.50	1508.00	125.33	13.33	56.33	26.33	0.30	995.28	0.22	3.67	5.53	4.00
Nat	4	6.63	1927.00	169.67	14.67	64.33	31.67	0.40	1271.82	0.22	4.50	5.60	5.00
Nat	4	6.47	1496.00	133.00	15.67	44.00	22.67	0.35	987.36	0.29	4.13	6.23	4.63
Nat	4	6.43	1158.00	105.67	17.00	43.67	21.00	0.40	764.28	0.32	3.33	6.50	3.50
Nat	5	8.23	2726.00	499.67	5.67	30.33	7.67	0.20	1799.16	0.14	21.20	4.83	22.90
Nat	5	8.03	2161.00	331.00	15.00	45.33	14.00	0.10	1426.26	0.29	10.80	6.23	12.63
Nat	5	8.10	2575.00	319.67	12.00	71.33	20.00	0.10	1699.50	0.20	8.17	5.37	9.57
Nat	5	7.77	1683.00	179.33	17.67	55.00	20.00	0.10	1110.78	0.31	5.23	6.40	5.97
Nat	6	7.30	7963.00	1203.67	13.33	109.67	47.67	0.20	5255.58	0.16	24.30	5.00	25.53
Nat	6	7.70	25920.00	3873.33	24.33	382.67	145.33	0.20	17107.20	0.16	42.87	4.97	38.03
Nat	6	6.13	5997.00	786.33	14.33	108.00	45.67	0.30	3958.02	0.17	15.93	5.13	18.07
Nat	6	6.73	7124.00	998.67	15.67	111.33	45.67	0.20	4701.84	0.19	20.73	5.33	22.50
Nat	7	5.25	1896.00	93.00	24.50	88.50	30.50	0.30	1251.36	0.35	2.20	6.70	1.95

Nat	7	5.15	1212.00	55.50	28.00	51.50	18.50	0.30	799.92	0.50	1.70	8.15	1.20
Nat	7	5.35	1797.00	105.00	23.50	77.00	28.50	0.30	1186.02	0.38	2.70	7.00	2.60
Nat	7	5.60	1551.00	103.50	19.50	63.50	25.50	0.30	1023.66	0.32	2.80	6.50	2.75
Nat	8	4.90	901.00	34.67	21.67	41.67	12.00	0.20	594.66	0.45	1.27	7.67	0.63
Nat	8	5.00	621.60	28.67	11.33	25.00	8.67	0.15	410.26	0.30	1.27	6.27	0.63
Nat	8	5.03	651.40	36.00	11.33	26.33	7.33	0.20	429.92	0.30	1.60	6.30	1.07
Nat	8	5.33	797.00	96.67	11.33	19.00	6.67	0.20	526.02	0.34	4.93	6.70	5.60
WRP	1	7.37	856.00	18.67	25.67	52.00	20.00	0.20	564.96	0.46	0.57	7.70	0.40
WRP	1	7.53	800.00	76.33	4.67	28.00	14.00	0.25	528.00	0.11	3.00	4.50	3.00
WRP	1	7.50	1065.00	15.67	23.00	73.00	22.67	0.15	702.90	0.36	0.40	6.90	#DIV/0!
WRP	1	7.30	601.30	12.33	18.67	32.67	13.33	0.10	396.86	0.41	0.47	7.33	#DIV/0!
WRP	2	7.73	1614.00	66.33	16.67	94.00	36.00	0.10	1065.24	0.22	1.47	5.60	0.90
WRP	2	8.23	937.00	59.33	14.67	46.00	14.33	0.10	618.42	0.29	1.93	6.13	1.57
WRP	2	7.57	1593.00	65.67	27.33	105.67	36.33	0.20	1051.38	0.35	1.40	6.80	0.80
WRP	2	7.80	1515.00	62.67	20.67	100.67	33.67	0.10	999.90	0.27	1.40	6.07	0.77
WRP	3	7.80	2539.00	168.67	15.67	125.33	47.67	0.15	1675.74	0.18	3.23	5.27	3.37
WRP	3	8.27	1574.00	125.00	17.33	67.67	31.00	0.10	1038.84	0.26	3.20	5.93	3.30
WRP	3	7.57	2306.00	176.00	15.33	111.33	44.33	0.15	1521.96	0.18	3.70	5.23	4.00
WRP	3	7.33	838.00	88.00	6.67	26.67	12.00	0.15	553.08	0.16	3.63	4.97	3.93
WRP	4	7.90	1048.00	25.67	13.67	66.33	29.33	0.20	691.68	0.21	0.67	5.47	#DIV/0!
WRP	4	8.10	1036.00	90.33	7.33	37.33	28.33	0.35	683.76	0.13	2.93	4.67	2.93
WRP	4	8.13	1093.00	97.00	8.00	42.67	26.00	0.45	721.38	0.14	2.87	4.80	2.90
WRP	4	8.00	925.00	26.33	10.67	61.00	25.67	0.20	610.50	0.17	0.73	5.10	#DIV/0!
WRP	5	6.43	1162.00	58.67	17.33	58.00	26.33	0.25	766.92	0.28	1.60	6.10	1.10
WRP	5	6.40	1207.00	45.67	19.00	64.67	28.00	0.15	796.62	0.30	1.27	6.33	0.60
WRP	5	6.43	1131.00	43.67	19.67	59.67	26.67	0.20	746.46	0.33	1.17	6.57	0.50
WRP	5	6.30	1210.00	71.33	16.00	55.33	24.67	0.25	798.60	0.27	2.03	6.07	1.67
WRP	6	7.47	1312.00	156.33	7.67	32.67	13.00	0.20	865.92	0.17	5.67	5.17	6.53
WRP	6	7.70	1622.00	276.33	5.67	23.00	8.00	0.40	1070.52	0.15	12.73	4.93	14.80
WRP	6	7.87	1742.00	127.33	16.67	74.00	35.33	0.30	1149.72	0.23	3.10	5.73	3.17

WRP	6	7.13	1091.00	71.00	15.67	49.00	23.00	0.40	720.06	0.27	2.10	6.10	1.77
WRP	7	6.43	1400.00	76.33	19.00	63.67	29.33	0.30	924.00	0.28	2.27	6.17	1.97
WRP	7	6.63	1296.00	126.33	13.67	38.33	18.33	0.30	855.36	0.26	4.40	5.90	4.93
WRP	7	6.23	932.00	46.67	12.33	44.33	19.33	0.20	615.12	0.23	1.47	5.67	0.87
WRP	7	6.67	1602.00	143.33	9.33	51.33	24.00	0.20	1057.32	0.17	3.93	5.10	4.30
WRP	8	6.17	9730.00	947.67	12.67	292.67	125.33	0.20	6421.80	0.09	11.73	4.37	13.70
WRP	8	6.27	11851.00	1376.33	22.67	341.00	97.67	0.10	7821.66	0.19	16.73	5.27	18.70
WRP	8	6.20	3616.00	500.33	12.67	54.33	25.00	0.10	2386.56	0.22	14.10	5.53	16.23
WRP	8	6.17	4094.00	519.33	18.00	82.33	37.00	0.10	2702.04	0.25	12.17	5.87	14.20

Table of all sediment plate points including extra 2 points per wetland (total of 6) and grams of mineral and organic sediment deposited on each plate. Missing data indicates a lost or broken sediment plate.

Treatment	WL	Site	Mineral Fraction (g)	Organic Fraction (g)
Natural	1	1	87.64	7.46
Natural	1	3	13.40	0.06
Natural	1	6	551.56	68.94
Natural	1	7	186.04	81.26
Natural	1			
Natural	1			
Natural	2	2	132.54	3.80
Natural	2	3		
Natural	2	4	553.58	25.42
Natural	2	6	20.97	8.82
Natural	2			
Natural	2			
Natural	3	4	490.15	34.35
Natural	3	5	198.34	30.16
Natural	3	7	90.00	3.88
Natural	3	8	82.65	3.63
Natural	3			
Natural	3			
Natural	4	4		
Natural	4	5	4.47	0.81
Natural	4	6	111.82	6.38
Natural	4	7		
Natural	4			
Natural	4			
Natural	5	1	3.01	0.33
Natural	5	2	507.85	21.55
Natural	5	4	4.26	0.11
Natural	5	5	47.25	1.40
Natural	5	8	9.56	3.19
Natural	5			
Natural	6	2	59.28	3.50
Natural	6	3	20.36	6.93
Natural	6	4	192.20	13.60
Natural	6	6	5.37	2.01
Natural	6	7	9.23	0.05
Natural	6	8	199.34	76.76
Natural	7	1		
Natural	7	2		
Natural	7	6		

Natural	7	7		
Natural	7			
Natural	7			
Natural	8	2		
Natural	8	3	1840.16	178.44
Natural	8	5		
Natural	8	6	56.19	1.39
Natural	8	7	56.11	1.83
Natural	8	8	309.92	82.38
WRP	1	2	2.87	0.39
WRP	1	4	23.75	4.64
WRP	1	5	5.42	0.44
WRP	1	6	8.20	1.16
WRP	1	7	3.79	2.80
WRP	1	8	8.21	1.54
WRP	2	1	338.72	14.08
WRP	2	4	78.17	3.67
WRP	2	7	58.29	10.87
WRP	2	8	46.82	9.82
WRP	2			
WRP	2			
WRP	3	1	353.43	25.87
WRP	3	2	18.82	1.98
WRP	3	3	624.48	129.72
WRP	3	4	215.06	34.14
WRP	3	5	142.33	4.33
WRP	3	8	1193.09	153.51
WRP	4	1	397.99	12.61
WRP	4	3		
WRP	4	4	198.51	25.79
WRP	4	5		
WRP	4			
WRP	4			
WRP	5	1	22.20	3.53
WRP	5	3	68.97	2.28
WRP	5	4	324.11	6.99
WRP	5	5	32.45	1.28
WRP	5			
WRP	5			
WRP	6	1	0.82	0.06
WRP	6	2	229.31	49.99
WRP	6	3	130.96	42.04
WRP	6	6	175.28	0.86
WRP	6	7		
WRP	6			

WRP	7	2		
WRP	7	3		
WRP	7	6	476.74	37.27
WRP	7	8	805.96	63.94
WRP	7			
WRP	7			
WRP	8	2	16.48	7.20
WRP	8	3	23.59	5.58
WRP	8	6		
WRP	8	8	1270.83	539.47
WRP	8			
WRP	8			

VITA

Matthew W. Hough

Candidate for the Degree of

Master of Science

Thesis: COMPARING SOIL AND HYDROLOGICAL CONDITIONS OF WETLANDS RESERVE PROGRAM RESTORATIONS AND NATURAL WETLANDS ALONG THE DEEP FORK RIVER, OKLAHOMA (USA)

Major Field: Plant and Soil Sciences

Biographical:

Education:

Completed the requirements for the Master of Science in Plant and Soil Sciences at Oklahoma State University, Stillwater, Oklahoma in May, 2011.

Completed the requirements for the Bachelor of Science in Plant and Soil Sciences at Oklahoma State University, Stillwater, Oklahoma in May, 2008.

Experience:

Student Temporary Employee Program, US Fish and Wildlife Service, Moline, Illinois in the summer of 2007.

Undergraduate Student Employee, Department of Plant and Soil Sciences, Oklahoma State University from January 2009 to May 2009.

Training:

Regulatory IV Wetlands Delineation: 2007, Prescribed Fire Safety and Implementation: 2008, Basic Processes in Hydric Soils: 2010, and Advanced Problems in Hydric Soils: 2010

Professional Memberships:

Soil Science Society of America: 2008. Society of Wetland Scientists: 2010. Ducks Unlimited: 2007. Delta Waterfowl: 2009.

Name: Matthew W. Hough

Date of Degree: May, 2011

Institution: Oklahoma State University

Location: Stillwater, Oklahoma

Title of Study: COMPARING SOIL AND HYDROLOGICAL CONDITIONS OF WETLANDS RESERVE PROGRAM RESTORATIONS AND NATURAL WETLANDS ALONG THE DEEP FORK RIVER, OKLAHOMA (USA)

Pages in Study: 158

Candidate for the Degree of Master of Science

Major Field: Plant and Soil Sciences

Scope and Method of Study: Wetlands Reserve Program (WRP) wetland restorations were compared to natural wetlands using hydrological and soil features to determine if WRP wetlands were similar to natural wetlands along the Deep Fork River in central Oklahoma. Hydrological comparisons between WRP and natural wetlands were conducted utilizing water-table levels and soil moisture values. Soil properties utilized in the comparison of WRP and natural wetlands included data gathered from soil profile descriptions to indicate differences in morphological features, soil nutrient and chemical properties, and levels of sediment accumulation. Data were correlated to determine trends that indicated further differences between WRP and natural wetlands.

Findings and Conclusions: Water-table levels in WRP wetlands were determined to fluctuate more than natural wetland water-table levels. Natural wetland soils were determined to be more frequently saturated and inundated than WRP wetland soils. Differences in hydrological features between WRP and natural wetlands were a result of water table management and agricultural and restoration practices in WRP wetlands. Soil profile descriptions indicated some morphological differences between wetland types, and soil organic matter and certain nutrients were lower in WRP wetlands than in natural wetlands. Sedimentation rates were similar between wetland types. Differences in soil characteristics between WRP and natural wetlands were likely a result of the decreased soil maturity and history of disturbance in WRP wetlands. Overall, soil characteristics of WRP wetlands indicated that these sites were becoming more similar to natural wetlands. The differences in WRP and natural wetlands that existed may indicate differences in functions. However, further study is warranted to establish how differences between wetland types may affect functioning and before changes to WRP wetland implementation should be applied.

ADVISER’S APPROVAL: Brian J. Carter