ABSTRACT

Title of Thesis: **IMPACT OF RESTORATION ACTIVITY ON WETLAND SOIL PROPERTIES AND FUNCTIONS**

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Due to the essential nature of wetlands and their historic losses, wetland restoration has been a recent focus of conservation activity. The objective of this study was to compare selected physical soil properties and those properties and processes associated with carbon sequestration in restored and natural freshwater depressional wetlands on the Delmarva Peninsula. Three distinct hydrological zones within nine restored and five natural wetlands were sampled and monitored over the course of a year. As a result of earthmoving activities, restored wetlands demonstrated significant compaction, potentially limiting root and hydrological infiltration. Restored wetlands also demonstrated shorter periods of saturation, which led to increased carbon decomposition rates. As a result of soil disturbance, restored wetlands had significantly lower carbon stocks than natural wetlands. Restored wetlands also demonstrated no difference in carbon content across the three hydrological zones, the time since restoration being too short for carbon stocks to appreciably accumulate.

IMPACT OF RESTORATION ACTIVITY ON WETLAND SOIL PROPERTIES AND FUNCTIONS

by

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Chapter 1: Introduction

Wetlands are unique and critical ecosystems, that, until recent decades have largely gone unappreciated. The environmental services and functions provide by wetlands are numerous. Wetlands play a critical role in stormflow buffering, nutrient cycling, and wildlife habitat. Additionally, wetlands are host to some of the highest areas of primary productivity found in nature. Additionally, wetlands act as valuable carbon sinks, storing carbon in the form of soil organic matter.

Historically, many of these important roles and functions of wetlands were unknown or unappreciated, and therefore wetlands haven't traditionally been afforded the respect they deserve. A large proportion of wetlands (nationally and regionally) have been drained for numerous reasons, but primarily to utilize their organic-rich soils for agriculture. They have been also drained in an attempt at mosquito and pest control, as well as for urban development. It is estimated that over half of the nation's pre-colonial wetlands had been destroyed by the mid-twentieth century.

It was only relatively recently that the importance of wetlands was recognized and they were afforded legal protection. These protections were afforded under such laws as the Rivers and Harbors Act, Clean Water Act, and Swampbuster provisions of the Food Security Act. While important to preventing further wetland loss, these protections, did nothing to address the extensive prior historical loss of wetlands.

New focus was placed upon restoration of wetlands and expanding wetland acreage. Numerous federal programs such as the Wetlands Reserve Program, Conservation Reserve Program, and Conservation Reserve Enhancement Program were created in order to restore and/or establish wetland conditions on privately owned land. Ultimately, a combination of legal protections and restoration of disturbed wetlands have taken us from annual net losses of wetland acreage to net gains.

Wetland restoration is undertaken by attempting to establish saturated soil conditions at the soil surface long enough for anaerobic soils conditions to establish themselves during the growing season. Efforts to establish wetland plant communities often follow. In the Delmarva region of Delaware and Maryland the most common way to implement the hydrological component of wetland restoration is through scraping – the intentional alteration and removal of soil material in order to raise the water table relative to the soil surface (by lowering the soil surface). Given the high water tables of the region, this is generally an easy approach, but could lead to several possible negative effects. The use of heavy machinery in the scraping process could lead to alterations in soil properties and to other serious disturbances to the soil itself. One focus of this study was to observe and quantify these disturbances.

Another major focus of this study was to monitor and quantify a number of wetland properties related to the sequestration of carbon. Hydrology, considered the "master variable" of wetland conditions, was measured and modeled to document the hydroperiod and the duration of saturated soil conditions. Various components of carbon dynamics were documented in the form of the measuring decomposition rates, which when joined with carbon input data was related to soil carbon stocks. Using this approach, comparisons were made between restored and natural wetlands.

Thus the overall goal of this study was to compare wetlands restored using common techniques (scraping) over a 7 to 28 year period with natural wetland counterparts with regard to selected physical soil properties and also those properties and processes that contribute to the sequestration of organic carbon.

Chapter 2: Background

Wetland Functions

Wetlands are critical and unique environments that provide a bevy of environmental services. Wetlands represent the ecotone between terrestrial and aquatic ecosystems that fosters a number of highly productive and varied vegetative communities adapted to wet conditions (Mitsch & Gosselink, 2007). Additionally, wetlands provide habitat for numerous animal species. Fully eighty percent of waterfowl species, fifty percent of protected migratory bird species, and ninety five percent of commercially harvested fish and shellfish species are wetland-dependent (Wharton *et al.*, 1982; Feierabend & Zelazny, 1987). Wetlands modify local hydrology by mitigating stormflow. One study of the Chesapeake Bay drainage basin found that although wetlands only comprised 4% of the total basin area, they resulted in a floodflow reduction of 50% compared to basins without wetlands (Novitzki, 1985).

Wetlands play a major role in a number of biologically mediated, redox-driven, biogeochemical nutrient cycles. Soils are central to the nitrogen cycle, and due to their wet nature, wetlands provide an environment facilitating denitrification (Brady & Weil, 2008). Aerobic soils, (whether on account of proximity to the soil surface or seasonal dryness) allow for nitrification to occur and ammonia to be oxidized to nitrate and leached. In contrast, wetland soil under anaerobic conditions due to prolonged wetness, allow for denitrification to occur and nitrate to be reduced to nitrogen gas and lost to the atmosphere. Some wetland soils also play an important role in the sulfur cycle. Salt marshes, in particular, are the location where tidally-borne soluble sulfates are reduced to sulfides under strongly anaerobic conditions. Under these aerobic conditions, sulfides can either be immobilized and retained in the soil by being adsorbed to soil colloids or bonded to metal cations, or they can be volatized and released into the atmosphere in the form of hydrogen sulfide. Salt marshes are so central to the sulfur cycle that they account for twenty five percent of all yearly biogenic atmospheric sulfur input (Gosselink & Maltby, 1993).

Of particular importance is the role wetlands play in the global carbon cycle. Rising atmospheric carbon dioxide levels are the principle driver behind climate change, and it is anticipated that their rate of atmospheric accumulation over the next few decades will only increase (Raupach *et al.*, 2007). Wetland ecosystems are a natural carbon sink, as anaerobic conditions caused by prolonged saturation inhibit organic matter decomposition, that allows for carbon to accumulate in the soil (Collins & Kuehl, 2001). Globally, wetlands are responsible for storing a total of 513 Pg, of carbon, which is 23% of all soil carbon storage (Bridgham *et al.*, 2006). Thus, restoration of wetland environments to increase soil carbon storage capacity is seen as one possible strategy to mitigate accelerating atmospheric carbon dioxide levels (Lal, 2004).

Wetland Losses

Prior to European colonization, North America was home to an abundance of wetlands. It is estimated that the lower 48 states alone contained 87 million hectares of wetlands pre-settlement (Mitsch & Gosselink, 2007). Many of those wetlands have subsequently been lost. Nationally, it is estimated that 53% of presettlement wetlands have been lost. Wetland loss in Maryland and Delaware, the two states of interest of this study, has exceeded the national average. These states have lost 73% and 54% of their precolonial wetlands, respectively (Mitsch & Gosselink, 2007).

Wetland loss has been attributed to various factors, but the primary cause has been the intentional draining, dredging, or filling of wetlands by human activity (Mitsch & Gosselink, 2007). Wetland soils are often rich in organic matter and have been drained in order to be put into agriculture. During the 19th and 20th centuries, half a million hectares of land were drained yearly for agricultural use, of which, 65% was previously wetland (Gosselink and Maltby, 1993). To meet the demand for additional farmland, bottomland forests, traditionally harvested for timber, were clearcut for agriculture. Flood control measures to expand agriculture and human settlement along the Mississippi alluvial plain resulted in further wetland disturbance; levees resulted in changes to wetland hydrology and sedimentation patterns. Except for a decrease during World War II, the rate of wetland loss by conversion to agriculture has been remarkably steady during the past two centuries (Gosselink and Maltby, 1993).

Urban development is another major cause of wetland loss, particularly on the East and West coasts of the United States. Two thirds of the world's population lives near the coast, and population expansion often comes at the cost of wetland alteration and disruption. Coastal wetlands, as could be expected, are disproportionately impacted by drainage and clearance for urban or industrial uses. Nevertheless, wetland loss due to urban development accounts for a much smaller percentage of total wetland loss than that due to agriculture, but the rate of loss has accelerated greatly since the end of World War II, and is closely tied to locations of high population density (Mitsch & Gosselink, 2007).

A third major cause for wetland loss has been the ditching of salt marshes in an attempt to control mosquito populations. Salt marshes serve as the habitat for the larval stage of several species of disease-vector mosquitoes. Shallow pools in the salt marshes allow for mosquito larvae to develop while sheltering them from predatory fish (Leisnham & Sandoval-Mohapatra, 2011). Parallel ditches were cut into marshes to drain these pools and allow mosquito predators access to the larvae. From the 1930's to 1950's, it is estimated that the Civilian Conservation Corps dug a total of 562,000 miles of parallel ditches into salt marshes from Maine to Virginia (Gedan *et al.*, 2009). Approximately 90% of salt marshes of this region were impacted. Although mosquitoes were the target of this control measure, evidence shows that grid ditching has had widespread negative impacts on the ecology of salt marshes (Bourn & Cottam, 1951).

Soil Changes Upon Conversion to Agriculture

Human disturbance of wetlands can result in major changes in soil composition and properties. Conversion of wetland soil to an agricultural system results in several particular changes. Changes in hydrology are often the most noticeable alterations. Prior to modification, wetland soils have a water table at or near the surface for a portion of the year, show slow drainage after precipitation events, and surface flow is often intermittent. Upon conversion to agriculture, the water table is greatly lowered by the installation of tile drains or drainage ditches.

Drainage after precipitation events is rapid, and surface flow is redirected towards ditches and drains, and is continuous (Bruland *et al.*, 2003).

Changes in the hydrology of wetland soils facilitate additional changes in soil composition. Wetland hydrology allows the accumulation of soil organic matter, as aerobic decomposition is inhibited. The lowering of the water table allows the introduction of oxygen and facilitates aerobic decomposition. This greatly increases the rate at which soil organic matter is decomposed (Schlesinger, 1999). Liming, a common agricultural practice used to raise the pH of the soil, has been shown to further increase the rate of organic matter decomposition (Compton & Boone, 2000). In particularly organic-rich soils, this increased rate of decomposition can result in soil subsidence and loss (Lilly, 1981).

Increases in soil compaction have also been shown to accompany the conversion of wetland soils to agricultural use. Tillage, in particular, is responsible for much of the compaction increase (Brady & Weil, 2008). Tillage often results in the creation of a compacted plowpan directly beneath the plow depth, and also an increase in subsoil compaction. Surface soil compaction is the result of the use of heavy machinery for tillage and planting, as well as the homogenization of existing soil horizons during tillage. Tillage also further aerates the soil, contributing to soil organic matter loss. Compaction as a result of agricultural activity has been shown to deteriorate soil structure, inhibit soil strength, lower hydraulic conductivity, and limit root penetration (Lipiec & Hatano, 2003).

Wetland Protection/Restoration

Modern federal protection of wetlands was established under the 1972 Clean Water Act. Regulatory authority over wetlands was established by defining them as (or associated with) navigable water bodies. Section 404 of the Clean Water Act established a permitting system for controlling wetland disturbance under the auspices of regulating discharge of dredge or fill materials into the waters of the US. Permitting authority was split between the EPA and the US Army Corps of Engineers, the latter of which had previous experience running a permitting program under the 1899 Rivers and Harbors Act (Hough & Robertson, 2009). Questions of jurisdictional rights between the EPA and the Corps of Engineers led to some confusion over permitting rights and requirements. In 1980, the EPA established a set of guidelines for wetland regulation called the Section 404(b)(1) Guidelines (EPA, 1980). Both agencies agreed to adopt the 1980 guidelines in a 1990 joint memorandum of understanding (Corps & EPA, 1990).

Wetland protection legislation on the state and local level varies greatly by locale. In the mid-Atlantic region, the economic and environmental importance of the Chesapeake Bay has led to several efforts in Maryland and other states in the Chesapeake Bay watershed to protect nontidal wetlands as a means to limit nutrient runoff to the Bay. The first multistate, formalized agreement to this end was the 1987 Chesapeake Bay Agreement. Under this agreement, Maryland, Pennsylvania, Virginia, Washington DC, and the federal government committed to cooperation in preserving the region's nontidal wetlands in order to preserve the health of the Bay. Under this initiative, the Maryland Department of Natural Resources, Water

Resources Administration was put in charge of a subcommittee to devise a wetlands policy for the Chesapeake Bay watershed. Their stated goal was a “net resource gain” in wetland acreage and function for the region (McNeer, 1992).

The state of Maryland put the policy suggestions of the Chesapeake Bay Wetlands Policy group into effect with the 1989 passage of the Maryland Nontidal Wetlands Protection Act. This law gave the Maryland Department of Natural Resource, Water Resources Administration (and later, the Maryland Department of the Environment, Water Management Administration) regulatory authority over “conservation, enhancement, regulation, creation, and monitoring” of nontidal wetlands. A permitting program was put in place in 1991 that required approval for all non-exempt activities within 25 feet of a nontidal wetland. Agricultural and forestry activities are exempted from this requirement, but still require local Soil Conservation District approval of the implementation of best management practices for soil conservation, sediment control, and water quality protection. These activities also require mitigation for any impacts on nontidal wetlands (McNeer, 1992).

The 1980 EPA guidelines codified the protection requirements of the CWA into what has come to be known as the “mitigation sequence”(Hough & Robertson, 2009). This is a tiered series of emphases that should be addressed during the regulatory process. This approach emphasizes that impact avoidance is the prime concern of wetland protection, such that if an activity would negatively impact wetlands, that activity should not be allowed. When complete avoidance is not feasible, the subsequent concern should be to minimize any negative impact from the activity on wetlands. However, when substantial negative impact cannot be avoided, then the third tier of this approach is to provide compensation for the impact, such as repairing, restoring, or rehabilitating impacted wetlands. Wetland creation and restoration falls under this category. As stipulated in the CWA, all damages to wetlands were required to be compensated with on-site and in-kind restorations.

A variety of governmental programs were established to facilitate and encourage wetland protection and restoration. In 2003, a series of conservation programs were established by and funded through the US Department of Agriculture. These programs were aimed at providing private landowners with financial and technical support and incentives to engage in conservation activities. Each individual program is aimed towards protecting a particular environment of interest, and the majority of wetland restorations were done under the auspices of the Conservation Reserve (Enhancement) Program (CRP/CREP) and the Wetland Reserve Program (WRP) (De Steven & Lowrance, 2011). The WRP alone accounts for 2.3 million acres of private land being enrolled in wetland protection.

Comprehensive review of conservation policy was undertaken by the National Research Council in 2001 (NRC, 2001). Among their findings were that the requirements under the CWA, that compensation for wetland impacts must occur as in-kind and on-site actions, proved to be problematic. They observed that In-kind restorations often resulted in undesirable wetlands being replaced with additional undesirable wetlands. The on-site requirement hampered efforts to properly locate wetland restorations, as poorly suited upland sites would have to be utilized if there were no better on-site locations available. Oftentimes these poorly suited restorations would fail or be less desirable than wetlands that were appropriately located or situated, but further away. The NRC recommended moving away from the emphasis of in-kind and on-site restorations found in the CWA. By expanding the view of wetland restoration to the landscape or watershed level, they argued, emphasis could be placed on properly siting wetland restorations in the landscape to maximize both the chances for restoration success, but also improved wetland function across the watershed.

Further review of federal wetland conservation efforts came in the form of the establishment of the Conservation Effects Assessment Program (CEAP) in 2003. Formed within the USDA, CEAP was intended to assess, review, and quantify the benefits of conservation practices implemented under federal Farm Bill programs (Goldman & Needelman, 2015). Since its inception, CEAP has been engaged in several regional and watershed-scale studies (Brinson & Eckles, 2011). Of particular interest to this research has been the CEAP Wetlands Mid-Atlantic Region (MIAR) Study, ongoing since 2008. The goal of this (MIAR-CEAP) study has been the collection of data on natural wetlands, restored wetlands, and prior-converted croplands in MD, DE, and VA. This study has encountered difficulties as privacy provisions of the Food Security Act preclude restoration monitoring, and information on the implementation of conservation practices is often lacking, thus sometimes limiting their ability to document effectiveness of the conservation efforts (De Steven & Lowrance, 2011).

Critical Elements of Restoration

Wetlands, as ecosystems, rely on a very specific set of soil, water, and plant properties to ensure their proper function and composition. Any restoration or creation of a wetland must properly replicate these properties to ensure that the restoration behaves like a comparable natural wetland. These properties can be broadly divided into three categories: those related to wetland hydrology, those relating to wetland vegetation, and those related to wetland soil.

Wetland hydrology is often considered the "master variable" of wetland properties (Bridgham & Richardson, 1993). It has been shown that proper hydrologic conditions are required for wetland biogeochemical function (Richardson, 2001). It follows that properly emulating natural wetland hydrology is a critical goal of successful wetland restoration. Unfortunately, hydrology is highly variable across multiple scales, from local to the watershed level, and affected by a multitude of factors, from topography, plant communities, climate, land use, etc. Furthermore, it has been shown that natural hydroperiods are critical to wetland function (Zedler & Kercher, 2005), so timing of saturated soil conditions must be taken into account, not merely their frequency or duration. Wetland plant community composition also heavily relies on hydrology; changes in hydrology often benefit invasive species (Bunn & Arthington, 2002). Changes in plant community structure can feedback and further impact other wetland properties, and, ultimately, wetland function, itself. The essential, complex, and interconnected nature of wetland hydrology requires long-term monitoring to document and ensure that natural hydrology is both restored, and that it is sustainable (Hunt, 1996).

The presence of wetland vegetation, or hydrophytes, is one of the three defining characteristics of a wetland environment. These plants are well-adapted to surviving in the saturated and anaerobic conditions found within wetland ecosystems and tend to out-compete dryland species in these environments. Plant communities contribute to the function a number of wetland services, including animal habitat, stormflow mitigation, and high rates of primary productivity. Plant communities also tend to be the most noticeable property of wetlands on account of them being primarily located above ground. Perhaps because of this ease of observation, wetland plant ecosystems are the most well studied and documented property of wetlands. For this reason, plant communities will not be a major focus of this study.

Soils have been described as the physical foundation of wetland ecosystems (Stolt *et al.*, 2000). A successful restoration should aim to minimize soil disturbance, as deviations in soil properties can have cascading effects on multiple wetland properties. One instance of this phenomenon occurring was in a section of San Diego Bay being restored for the purpose of providing endangered species habitat. The soil imported to provide wetland substrate proved to be too sandy to retain sufficient nitrogen to support the desired plant density, and the diminished plant cover failed to attract the target species. Soil texture proved to be a limiting factor to wetland restoration success (Zedler, 1998).

The importance of soil properties is further amplified by their slowness to respond to restoration activity when compared to wetland hydrology and ecology. Though understudied, there are several long-term studies of soil development in restored wetlands. A 25-year study of created and natural North Carolina coastal tidal marshes found that, even after 25 years, created marshes still had less organic C than reference sites, despite similar accumulation rates (Craft *et al.*, 1999). A longer-term study was undertaken by Ballantine and Schneider. They observed restored wetlands in New York across a 55-year timespan. They noted a slower, establishment phase of wetland development dominated by allocthonous inputs, followed by a successional phase of development dominated by autocthonous inputs. Depressional wetlands, due to a lack of sedimentary or tidal inputs, respond to restoration even slower. Changes in soil properties were observed to be slow at first, but gradually accelerated with time. In the top 5 cm of soil, soil organic matter, bulk density, and cation exchange capacity were all less than 50% of reference levels after 55 years (Ballantine & Schneider, 2009). This sets the time frame for recovery of soil parameters in the range of decades to centuries.

The capacity for soil recovery and development can be constrained by any number of factors, including restoration method, management decisions, and initial soil conditions (Zedler & Callaway, 1999). This stresses the importance factoring soil properties into restoration planning and maintenance, as well as monitoring of the restoration to ensure recovery is occurring along the expected trajectory. Site-specific strategies should be employed to address specific changes in soil properties (Zedler, 2000).

Methods of Restoration

Methods of freshwater wetland restoration in the Mid-Atlantic region can be broadly classified into two categories: scraping and plugging. Scraping is the excavation, modification, or removal of soil material to form a depressional landform. Wetland hydrology is established by lowering the soil surface to be closer to the existent water table. Scraping is highly disruptive to the soil and plant communities, but does not require preexisting wetland hydrology, and thus can be implemented in areas regardless of site history. As such, scraping can be considered akin to wetland creation. Plugging, in contrast, is the reestablishment of wetland hydrology by removal of drains or damming of ditches. Upon removal of the artificial drainage, the water table is elevated closer to the soil surface, and hydric conditions result. This has a lesser environmental impact than scraping, but is limited to locations that were previously wetlands until being hydrologically modified. As such, plugging is more akin to true wetland restoration than wetland creation.

Impacts of Scraping Method of Restoration

The scraping method of restoration is much more common in the Mid-Atlantic region than any other means of restoration (Fenstermacher, 2012). As a result, the impacts on the soil inherent in its implementation have been widespread. Soil compaction as a result of wetland restoration can either be intentional or unintentional. Unintentional compaction can be an artifact of the use of heavy machinery during the restoration process. Often, however, soil compaction is an intended part of the restoration design. Regardless of local hydrology, once soil in the restoration area is excavated, water-limiting, clay-rich layers are laid down and compacted before being overlain with the excavated soil. Compaction of soil has the effect of increasing soil bulk density as well as skewing pore size distribution in favor of smaller micropores by collapsing larger macropores (Brady & Weil, 2008). This lowers the hydraulic conductivity of the soil and can alter the hydrology of the wetland system. Such low conductivity, clay rich soil horizons have been shown to cause water table perching following rain events, as well as promoting rapid, lateral water movement (Vadas *et al.*, 2007). In addition to impacting hydrology, these confining layers may impact nutrient cycling, as they may limit interaction between anoxic sediments and groundwater nitrate (Denver *et al.*, 2014).

Beyond compaction, scraping has additional soil impacts through the disturbance, homogenization, and removal of topsoil. Soil excavation negatively impacts soil structure, aerates previously anoxic soil material, encourages rapid decomposition of organic material, and can expose underlying soil material (Brady & Weil, 2008). This has been shown to have negative effects on the amount of available soil carbon, and the degree of surface-groundwater interactions (Goldman & Needelman, 2015).

Evaluating Restoration Success

In order to evaluate the success of a wetland restoration, it is necessary to establish measurable and realistically obtainable criteria to monitor the progress of the restoration towards achieving its design goals. These criteria are known as wetland performance standards, and must be approved by the US Army Corps of Engineers as part of the permitting process for all CWA Section 404 mitigation projects (NRC, 2001). In order to be useful, performance standards must be tailored to the specific goals of the proposed restoration and the properties of the location where the restoration activity will be undertaken. As such, wetland performance indicators as a group are extremely variable. The Wetland Reserve Program provides guidance to establishing wetland performance criteria in a 1999 technical note. Through an analysis of 300 permit applications, seven distinct approaches to the establishment of performance indicator criteria were described. These approaches are requirements for survival of planted species, requirements for plant density or plant cover, requirements staged over time, requirements based on wetland delineation methods, requirements employing wetland indices, comparison to reference wetlands, and requirements limiting exotic or nuisance species (Streever, 1999).

Vegetation is the major focus of most wetland performance standards. There are several reasons for this. Wetland restoration goals are overwhelmingly focused on plant communities (Matthews & Endress, 2008), so it is logical that standards to measure a restoration's success towards meeting these goals also focus on plant community properties. There is also a practical element to this focus. Plant communities tend to respond much more rapidly to the environmental disturbance brought about by restoration activities than other aspects of the wetland ecosystem. As such, monitoring timeframes can be much shorter than those measuring slower-changing criteria. In addition, observation of plant community changes can be performed relatively easily as compared to observation of other wetland properties. Annual sampling of wetland vegetation during the late summer has been shown to be sufficient to maximize the number of identifiable species obtained, though this may underestimate early-flowering species (Matthews, 2003).

Performance indicators relating to vegetation, though highly variable in form and scope, tend to rely on a few common plant community metrics. One commonly employed metric is monitoring survival of planted species. A certain percentage of species is required to survive over a designated number of growing seasons. This can be implemented as generalized planted species, or as different classes such as woody species, herbaceous species, or approved natural species. Often times these standards are specified to be measured by growing season, necessitating replanting if the targeted survival percentage is not met. Another metric to measure vegetative wetland performance is by determining percent vegetative cover. Several methods for measuring vegetative cover are available (Floyd & Anderson, 1987), but areal cover percentage and canopy cover percentage seem to be relatively common. Plant cover percentage standards can be established for specific target species, for specific plant types, or just generalized for all species. These values can be utilized by themselves, used to determine species dominance, or used to calculate a vegetation quality index.

Vegetative indices are metrics utilized to quantify numerous plant properties, both quantitative and qualitative (i.e. frequency, desirability, resilience) as a single variable. Determination of the dominance of species in a system is one such method (Delineation., 1989). Species dominance is based solely on plant prevalence, and does not incorporate any qualitative metrics. All species present in an area are identified and their extent determined. An importance value for each species is calculated based on both the species frequency and percent cover in sampled areas. The importance values for the most prevalent species in the area are summed until a certain threshold is met. These species, as well as any species with 20% total cover, are considered dominant. This method can be employed to set standards by species, plant type, invasiveness, or desirability.

Two commonly used indices attempting to incorporate qualitative data are the coefficient of conservatism (C) and the floristic quality index (FQI). The indices were developed for use in the Chicago region (Swink & Wilhelm, 1994), but were later adapted for use in other regions of the world as well. The coefficient of conservatism is a subjective value established for each native species in a region. Values are based upon how tolerant a species is towards environmental degradation. The mean C value for each native species in an area is used, in concert with the number of species, to calculate the FQI for the area. FQI was developed to rapidly assess and quantify environment disturbance and biodiversity. Higher FQI values are associated with a less disturbed environment and greater species diversity. Standards can be set by a target FQI value to be met over a given timeframe.

Beyond vegetation, hydrology is the second most common factor to base wetland performance standards upon. One cause for this that hydrology is generally more difficult to monitor than vegetation. Monitoring hydrological activity requires monitoring equipment (such as recording wells), and, unlike vegetation, which can be sufficiently gauged with annual measurement, requires much more frequent observation. Multiple seasons of data are often required, as precipitation anomalies can greatly affect seasonal data. Hydrology, however, is often considered the master variable in a wetland environment, so, even when not monitored directly, it can be viewed as being indirectly monitored through its impacts on the soil and vegetative community. When hydrology is directly monitored, several metrics can be employed, though some are rather vague. One metric to assess wetland hydrological performance is by measurement of areal hydrology (Matthews & Endress, 2008). Other performance indicators employed involve assessing the presence or degree of saturated soil conditions, or setting standards for water quality or salinity (Streever, 1999). The most common standard by which hydrologic performance is assessed is by inclusion as a factor in a delineation-based assessment of whether the restoration meets the 31 growing season days of saturation requirement to meet the jurisdictional definition of wetland hydrology (Laboratory, 1987).

Beyond being the generally least studied of the three criteria of jurisdictional wetland properties, hydric soil conditions also tend to be the least monitored as a criteria for restoration success. The reasons for this are manifold. Soil monitoring is both labor and skill intensive, requiring a multitude of field descriptions performed by technicians knowledgeable in both soil morphology and use of wetland indicators. Soil properties tend to be highly variable spatially, particularly in areas disturbed by restoration activity. This necessitates additional field descriptions to ensure the entirety of the wetland is covered by a monitoring protocol. Changes in soil properties also occur over a much longer timescale, requiring monitoring periods much longer than those for observation of vegetation or hydrology. On the other hand, the general stability of soil properties ensures that properties are not seasonally variable, and there is no need for continuous monitoring equipment.

Metrics for monitoring of soil properties for evaluation of restoration success are rather rare. I was only able to locate one example of a monitoring plan that dictated the direct observation of a soil property. A 1999 technical note providing for guidance for developing wetland performance standards cited a 1998 creation of a forested/herbaceous mixed wetland calling for the formation of subsurface muck layers to be a criteria for restoration success (Streever, 1999). Six inches of muck was required to be present in designated areas for the restoration to be considered a success. The protocol allotted an extended monitoring period of 25 years for the restoration to meet this goal.

A much more common approach employed to monitor the formation of wetland soil properties is to monitor soils as a part of a delineation-based approach. A review of MD, VA, and NJ monitoring protocols shows that all call for the entirety of the wetland restoration to meet the 1987 USACOE jurisdictional definition of a wetland. Duration of monitoring varies by state, but all three states require regular monitoring over a period of 3-10 years.

Regardless of the specific criteria monitored, the timeframe over which the monitoring is mandated plays an important role in the gauging of restoration success. Different wetland properties change at different rates, and observation timeframes for individual wetland properties should reflect this. Even the trajectory of change of individual properties is shown to be time sensitive. A 25-year study of constructed wetlands showed that soil organic matter was lost rapidly upon wetland restoration and only slowly re-accumulated. While vegetative and hydrological properties recovered quickly, the timeframe for restoration of soil properties was estimated to be in the range of decades to centuries (Craft et al., 1999). The typical duration of restoration monitoring is in the range of 3-5 years and focused primarily on development of plant communities (Matthews & Endress, 2008).

Given these discrepancies in timeframe, it would be useful to examine the rate at which redoximorphic features and hydric indicators form. Redoximorphic features have been shown to develop quickly under ideal conditions. One study demonstrated development of redoximorphic depletions after seven days of ponding (Vepraskas *et al.*, 2006). Though resulting from saturated soil conditions, these depletions were, on their own, insufficient to meet a hydric soil indicator. The same study, however, found that hydric indicators did form in all plots after 3 years of periodic flooding. This study relied on ideal conditions for formation of redoximorphic features: homogenous, high-organic-matter-content (4.2%) A horizon material ponded for a duration longer than minimally required to be jurisdictionally classified as hydric. Other studies where soil conditions were less than ideal, show formation of hydric soil indicators in a period of five years (Vepraskas *et al.*, 1999).

This presents a dilemma for using hydric soil indicators as criteria for wetland success. The rate at which hydric soil indicators form is highly variable and dependent on a multitude of factors. Soil organic matter content, ponding duration, ponding frequency, and temperature all play a role at the rate redoximorphic features form and accumulate. A proper monitoring timeframe for measuring restoration success is, therefore, difficult to establish, and may well exceed the 3-5 year timeframe common for observation of other wetland features. Additionally, hydric indicator analysis doesn't take into account the soil disturbance which occurs during restoration activity. Hydric indicators do not differentiate between relict and active redoximorphic features. Disturbance of soil material during restoration may result in existent features being translocated upwards in the solum where they would not form naturally, or for soil material being moved far from the hydrologic conditions where it formed. Soil disturbance may also cause hydric indicator formation to occur in a spatially variable manner. Additionally, homogenization of multiple soil horizons is common during restoration, resulting in soil material which would artificially meet a hydric indicator.

Alternative measurements of hydric soil condition should be entertained to address the shortfalls of relying exclusively on hydric soil indicators for assessment of wetland restoration success. One suggestion would be to use methods which do not rely on direct observation of indicator formation, but rather the measurement of the conditions required for the formation of reducing conditions. One proven method would be use of IRIS tubes (Rabenhorst, 2008). Through measurement of iron oxide paint removal from the surface of tubes placed in the soil during the growing season, the presence of reducing conditions in the soil can be rapidly assessed (Castenson & Rabenhorst, 2006; Rabenhorst & Burch, 2006). Use of IRIS tubes for identification of hydric soil conditions is a well-established methodology, and standards have already been established for their use (Soils, 2007). Another potential method of assessment would be use of α-α-dipyridyl dye to test for the presence of ferrous iron in the soil. Reduction of ferric iron to ferrous iron is an important intermediary step in the formation of redoximorphic soil features, and has been shown to occur as rapidly as within 3 days of soil inundation (Meek *et al.*, 1968). This method can rapidly assess the presence of reducing conditions, and, in conjunction with hydrologic data, can assess the trajectory of wetland change towards hydric conditions. A third potential alternate to current assessment methods of hydric soil formation could be observation of the development of redoximorphic features over time as compared to baseline observations taken immediately after restoration. This would have the benefit of compensating for relict redoximorphic features and pseudofeatures created by the soil disturbance inherent in restoration activity.

Geographic Setting of this Study

This study is focused on the Delmarva Peninsula, a portion of the states of Maryland, Delaware, and Virginia bordered on the west by the Chesapeake Bay and the east by the Atlantic Ocean. The peninsula is 14,130 km^2 in area and comprises the largest portion of the Chesapeake Bay watershed. It is located entirely within the Atlantic Coastal Plain and is primarily comprised of fluvial and deltaic coastal plain sediments. The land is notable for its flat topography, highly permeable soils, and generally high water tables. The predominant land use on the peninsula is for agriculture, except for areas too wet for agriculture, which typically remain forested. There is a widespread history of cultivation and artificial drainage in the region (Goldman & Needelman, 2015). Hydrologically, subsurface flow is the favored method of groundwater transport, and groundwater is well oxygenated due to the high permeability of the soil (Hamilton *et al.*, 1993).

The Delmarva lends itself well towards restoration activities for a variety of reasons. In its natural state, the peninsula is home to a great deal of depressional wetlands known as Delmarva Bays, and, despite agricultural drainage, these wetlands remain common throughout its upper and middle portions (Fenstermacher *et al.*, 2014). The naturally high water table allows for the easy reestablishment of wetland hydrologic conditions, and does not necessitate the construction of a confining soil layer to maintain them. In addition, the prevalence and general mutability of agricultural land use allows for a great deal of flexibility in restoration siting.

Chapter 3: Physical Effects of Wetland Restoration

Introduction

The importance of wetlands is widely understood today, but as recently as 30 years ago, this was not the case. Wetlands have often been viewed as obstacles to development at best, and breeding grounds for disease vectors at worst. From colonial times, wetlands were traditionally drained for use as farmland (Gosselink & Maltby, 1993). Their organic-rich soil material was highly fertile, but, once drained, was subject to rapid organic matter decomposition and soil subsidence (Brady & Weil, 2008). During the Great Depression of the 1930s, wetlands became the target of mosquito control measures brought on by public works projects. Targeting the habitat of malaria-bearing mosquitoes, vast swathes of wetlands were ditched and drained. More recently, other causes for land clearing and drainage, such as clearing for urban land or future development have emerged as major contributors to wetland loss, but agriculture remains the leading cause (Dahl *et al.*, 1991). So extensive were these various efforts at land clearing and drainage that it is estimated that 53% of wetlands have been lost nationwide (Dahl, 1990)..

Fortunately, there has been a recent change in attitude towards wetlands, and society now generally acknowledges their positive benefits to both the environment in general, and our species in particular. As such, wetlands have been protected from development and drainage under a variety of federal laws, from the Clean Water Act to "Swampbuster" provisions under the Food Security Act of 1985 (Hough & Robertson, 2009). While protection of existing wetlands is necessary, the loss of so much of their original extent has necessitated efforts to achieve restoration of degraded land to its original wetland condition.

Various government programs have begun to address this need for wetland restoration. One of the primary efforts designed to restore wetland acreage was the Wetland Reserve Program (WRP) run through the US Department of Agriculture Natural Resources Conservation Service (USDA, 2016). Under this program, the federal government leased private land under conservation easements. The Natural Resource Conservation Service (NRCS) was charged with implementing efforts to restore the leased land to a wetland state. Landowners maintain all rights to the land short of development, and may reclaim complete ownership at the end of the easement period. After 2014, the WRP program was subsumed under the Agricultural Conservation Easement Program (ACEP) with relatively few changes to the program, but with some loss in funding. The NRCS has been placed in charge of overseeing and assessing the success of these restoration efforts through the Conservation Effects Assessment Program (CEAP).

Two major methods are implemented in restoring wetlands in the region of the Delmarva Peninsula; “plugging” and “scraping” (Fenstermacher, 2012; Goldman & Needelman, 2015). Plugging is the damming, filling in, or otherwise obstruction of ditches, drains, or other artificial construct that has modified the hydrology of the land to be restored. When these drainage structures are effectively removed, the land is returned to its native wetland hydrologic character. This allows for the re-establishment of hydrophytic species of vegetation and wetland hydrology; hydric soils are commonly already present. Scraping differs from plugging in that heavy machinery is used to lower the soil surface to the water table. It can result in heavy disturbance to the soil profile as surface soil horizons are moved about and homogenized, and can also cause compaction of subsurface layers. Soil surface compaction is a well-studied phenomena as it pertains to agriculture and is noted as a result of machinery traffic during both tilling and planting (Raper, 2005; Brady & Weil, 2008). Compaction has been shown to deteriorate soil structure, modifies soil strength, lower hydraulic conductivity, and limit root penetration (Lipiec & Hatano, 2003). Soil compaction has been anecdotally observed at several restored sites within the Delmarva region and is hypothesized to be an artifact of restoration (Fenstermacher, 2012; Goldman & Needelman, 2015). Additionally, it appears that restoration by scraping is far more common in this region than other methods.

The primary goal of this study is the documentation of the physical impacts of wetland restoration efforts on soil physical properties. In order to accomplish such, selected physical properties of wetlands restored through the most common restoration process of scraping were evaluated and compared with those of natural counterparts. The way in which these physical properties vary across a hydrological and topographical gradient and affect wetland soil function were further documented.

Methods

Site Selection

This study was conducted in the Delmarva region of Maryland and Delaware on the Atlantic Coast of the United States. The Delmarva is primarily an agricultural region, notable for poultry and feed corn production. The land is relatively flat and near sea level (elevation <30 m). Soils in the region were formed from fluvial and deltaic coastal plain sediments, are well developed, and tend to have textures ranging from loamy to sandy. The average annual rainfall in the region is 116 cm and occurs evenly throughout the year. Seasonal water tables in the region are often found high in the soil profile and fluctuate as a result of evapotranspiration.

Nine restored and five natural sites were selected for study. The restored sites were among a group of Conservation Reserve Program, Conservation Reserve Enhancement Program, or Wetland Reserve Program sites located across the Delmarva Peninsula. As documenting the properties of restored wetlands was a major component of this research, a greater proportion of restored sites were included in this study. Additionally, because restored sites tend to exhibit a greater variability of hydrological and pedological properties, a larger number of restored sites were required.

Both restored and natural sites were freshwater and depressional in nature, but seasonally and spatially variable in hydrology. Both display topographic gradients that lead to gradual transitions between ponded wetland, saturated wetland, and upland zones. Natural sites, however, tend to be dominated by woody vegetation, while restored sites tend to mainly contain herbaceous plants. They both, however, provide habitat for a variety of emergent vegetative species in their wetter portions. An effort was made to try to avoid restorations that featured more abrupt changes in topography that resulted in a pond-like wetland.

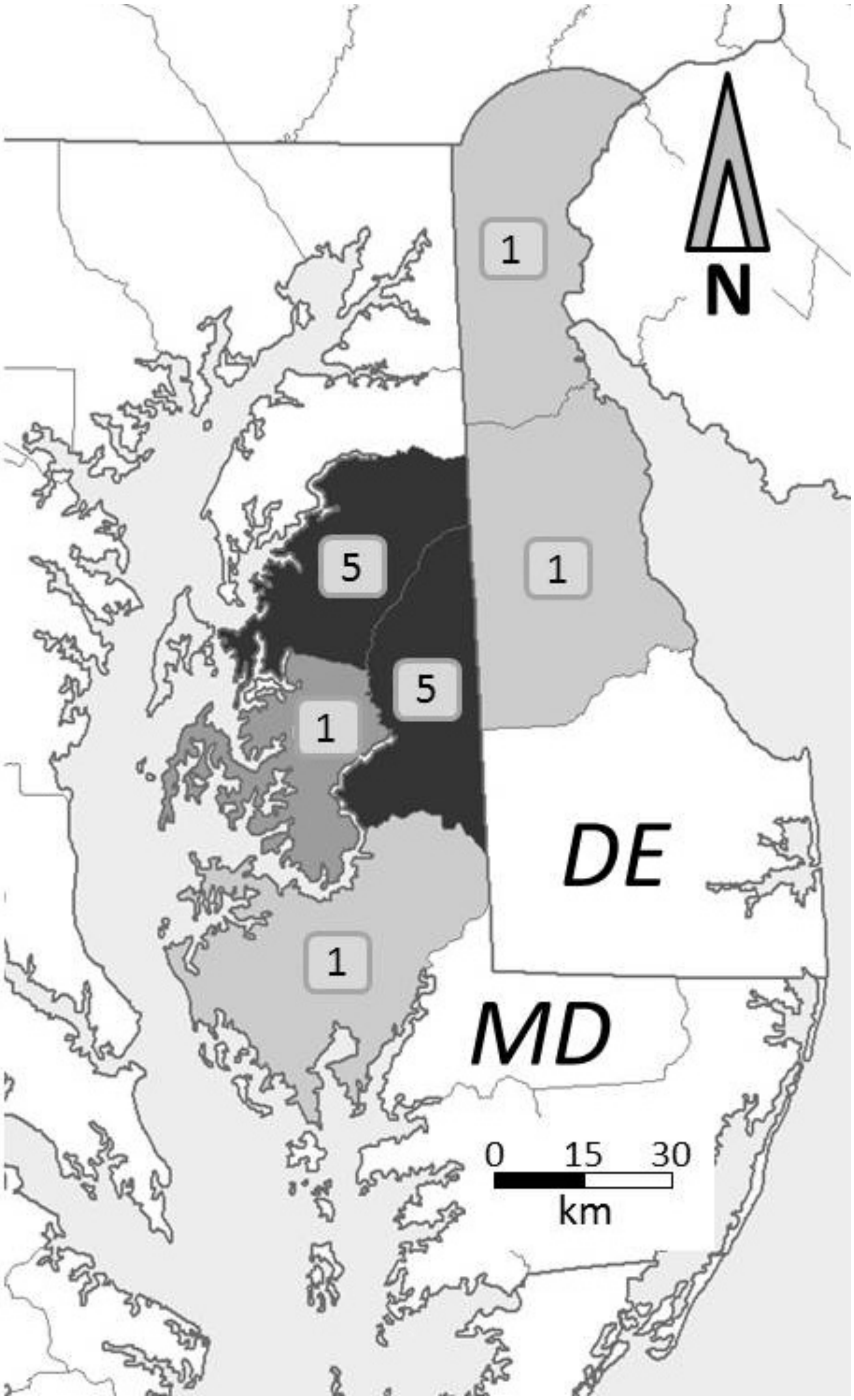


Figure 3-1. Number of wetland sites in this study located within counties of Maryland and Delaware on the Delmarva Peninsula.

Research sites were distributed among 6 counties in MD and DE across the Delmarva Peninsula. As shown in Figure 3-1, twelve sites were located within the state of Maryland, with the remaining two in Delaware. The largest concentration of sites was located within Caroline and Queen Anne's Counties, MD, but sites ranged as far northeast as New Castle Co, DE and as far south as Dorchester Co, MD. Sites were largely hydrologically isolated, with no major features providing surficial inflow or outflow.

Site Zonation

Since research sites were selected based on similarities in hydrology and topography, it was possible to define hydrologic zones that represented areas of broadly similar hydrologic character common throughout the research sites. During field visits, wetland sites were examined and three or four hydrological zones were identified at each study sites (0, 1, 2, and 3 - in order of decreasing wetness).

Zone 0 was a deeply (and in some cases perennially) ponded (> 35 cm) wetland with little or no emergent vegetation present. Zone 0 was not observed at all sites, but when present, it was located centrally within the wetland, and often represented a small portion (10-20%) of the wetland. Because it was not present in all sites, and due to potential difficulty in sampling and the lack of vegetation, zone 0 was not included for observation in this study.

Zone 1 was a seasonally ponded wetland with emergent vegetation present. The water table would often draw down during the warmer months, sometimes dropping below the soil surface, but typically remained ponded throughout the colder months. Depth of ponding was generally less than 35 cm. This zone was present in all study sites, and represented the wettest zone studied.

Zone 2 was a seasonally saturated wetland with a variety of vegetative wetland species present. This zone was rarely ponded (with a few cm of water) but commonly saturated. The water table dropped below the surface as the growing season progressed, but remained at or near the surface during the winter and spring. Zone 2 was present at all sites and was included in this study.

Zone 3 consisted of upland areas adjacent to, but not included in, the wetland. This zone lacked hydric soils (and ranged from somewhat poorly drained to well drained), and was dominated by growth of non-wetland vegetation. Zone 3 was present at all sites, and marked the driest areas of observation in this study.

Transects

Three replicate transects of three plots each were established at each site. Each site was considered as if roughly circular in shape, and transects were established radially outward from the center. Each transect spanned the hydrologic gradient from zone 1 to 2 to 3.

A system of stratified randomization was utilized in plot selection. Three compass bearings were randomly determined to be 36, 144 and 252 degrees (1, 4 and 7 tenths). Then, three transects (of three plots each) were established from the center of each wetland along these bearings.

Rather than being located randomly along transects, plots were placed centrally within each hydrologic zone of interest (1, 2 and 3) using field observation and LiDAR DEMs (Digital Elevation Models). Specifically, evidence of seasonal water table height, presence/absence of hydric soils, and vegetation type were used to help situate plots.

Penetration Resistance

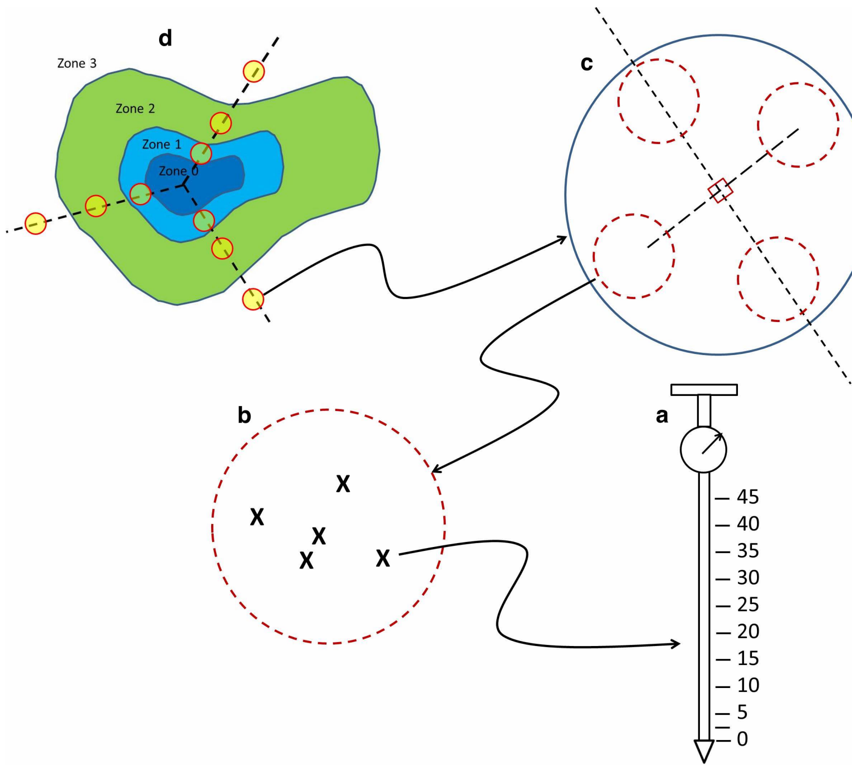


Figure 3-2. Schematic illustrating the stratified/nested design for measuring penetration resistance. Five sets (b) of ten vertical measurements (a) were made in four areas (c) within each plot (d).

Penetration resistance was used as an indicator of soil compaction. It is measured by the amount of force required to push a cone of known surface area a given distance through the soil, and thus it is a function of the force of resistance exerted on the cone and cone size. This reading of pressure is known as the cone index, and was recorded using an Eijkelkamp analog handheld penetrometer (Hummel *et al.*, 2004). The penetrometer consists of a handheld dynamometer attached to a rod with a cone of standard size and shape affixed to the end. The meter records the force exerted as the cone is pushed vertically through the soil. The maximum force exerted was recorded for each depth increment of 0-2.5 cm, 2.5-5 cm, then at 5 cm intervals thereafter to a total depth of 45 cm (Figure 3-2a). Thus, one set of penetrometer readings consisted of 10 measurements, at the depths prescribed above, as the cone was pushed progressively through the soil.

In each plot, sets (of 10 measurements with depth) were taken in 4 groups of 5, with each grouping (of 5) being clustered within a 0.5 m^2 area, and being located approximately 1-2 m from the plot center (Figure 3-2b). The four groups (of 5 sets) were equally spaced in relation to plot center, with one group towards the center of the wetland, one group away from center, and one group each radially left and right (Figure 3-2c). Therefore, at each site there were three plots being located along each of the three radial (replicate) transects so that a total of 60 sets of penetrometer readings were collected for each zone at each wetland site (Figure 3-2d).

Penetrometer measurements are highly sensitive to moisture content of the soil (Hummel et al., 2004; Kumar *et al.*, 2012). To control for moisture content, penetrometer readings in zones 1 and 2 were only taken at times when the water table was at or near the surface. Zone 3, being the driest area to be measured, was measured in the winter, when soils were moist and at or near field capacity. Zone 1, being the wettest, was taken in the summer when the water table drew down near the surface. Zone 2 was measured in the spring or fall when the water table was at or near the soil surface.

Soil Morphology

Soil morphological characteristics were assessed by means of soil profile descriptions generated from observations of samples retrieved using a bucket auger or

Macaulay auger at each study plot, for a total of 9 descriptions per research site. The soil was described to a depth of 1-2 m. Soil texture by feel, color, coarse fragment content, and redox features were described in the field using standard protocols (Schoeneberger *et al.*, 2012a). From these data, soil horizon boundaries were established and horizons were described (Staff, 1999).

Bulk density measurements for the upper 50 cm of the soil were acquired using a single 5 cm diameter aluminum core driven 50 cm into, and extracted from, each plot. The core was inserted vertically through the soil profile to a depth of 50 cm. The core was then carefully exhumed to avoid disturbance of the soil profile contained within. Once back at the lab, the core was frozen to aid in soil extrusion. The soil was extruded, horizonated, and the thickness of each horizon recorded. Bulk density of each horizon was determined from the dry weight of the horizon divided by its volume (as determined by core cross sectional area multiplied by recorded horizon depth).

Results and Discussion

Site Information

Location, time since restoration and other site details are presented in Table 3-1. The mean time since restoration for the 9 sites included in this study was 15 years, with a range of 21 years difference between the minimum and maximum. The site ages, however, were not normally distributed across this range. Six sites were restored relatively recently (from 2000 to 2007), while sites R-4, R-5, and R-9 were much older, having been restored between 1986 and 1993.

Table 3-1. Site information for natural and restored wetland study sites.

Site	Wetland Type	County	State	Restoration Method	Year Restored	Maintenance	Additional Notes
N-1	Natural	New Castle	DE	-	-	-	
N-2	Natural	Caroline	MD	-	-	-	
N-3	Natural	Caroline	MD	-	-	-	
N-4	Natural	Caroline	MD	-	-	-	
N-5	Natural	Caroline	MD	-	-	-	
R-1	Restored	Kent	DE	Scraped	2007		
R-2	Restored	Caroline	MD	Scraped	2004		
R-3	Restored	Dorchester	MD	Scraped	2000		
R-4	Restored	Queen Anne's	MD	Scraped	1986		Pond-like restoration
R-5	Restored	Queen Anne's	MD	Scraped	1992		Pond-like restoration
R-6	Restored	Queen Anne's	MD	Scraped	2002	Mowed 2-3 times yearly	
R-7	Restored	Queen Anne's	MD	Scraped	2004		
R-8	Restored	Queen Anne's	MD	Scraped	2004		
R-9	Restored	Talbot	MD	Scraped	1993		Pond-like restoration

As outlined in Table 3-1, all restored sites were restored by scraping, or the removal of soil through use of heavy equipment. In addition to loss of soil material, this method had the secondary effect of amalgamating existing soil horizons. These horizons primarily consisted of surface organic-rich O and A material with associated subsurface E and B horizons. The depth to which this homogenization occurred varied between sites and location within the wetland, but evidence of this disturbance was often found at depths in excess of 50 cm. The regular mowing at site R-6 to control the growth of pioneering woody species such as *Acer rubrum* and *Liquidambar styraciflua* was an additional source of site disturbance.

Cone Index

Penetration resistance was reported as cone index values, or the pressure exerted on a cone as it is pushed or driven through a given distance of soil. The cone index has a history of use in the literature as a measure of soil strength, but its use has primarily been limited to agricultural settings. In this study, penetration resistance was used as an indicator of soil compaction.

Figure 3-3 shows penetration resistance data for all sites by hydrologic zone. Both restored and natural sites demonstrate a trend of increased penetration resistance with depth, but the restored sites show a greater magnitude of increase, as well as greater variability between sites. Differences between natural and restored sites appear greatest in the zone 1 plots, although it is evident in all 3 zones.

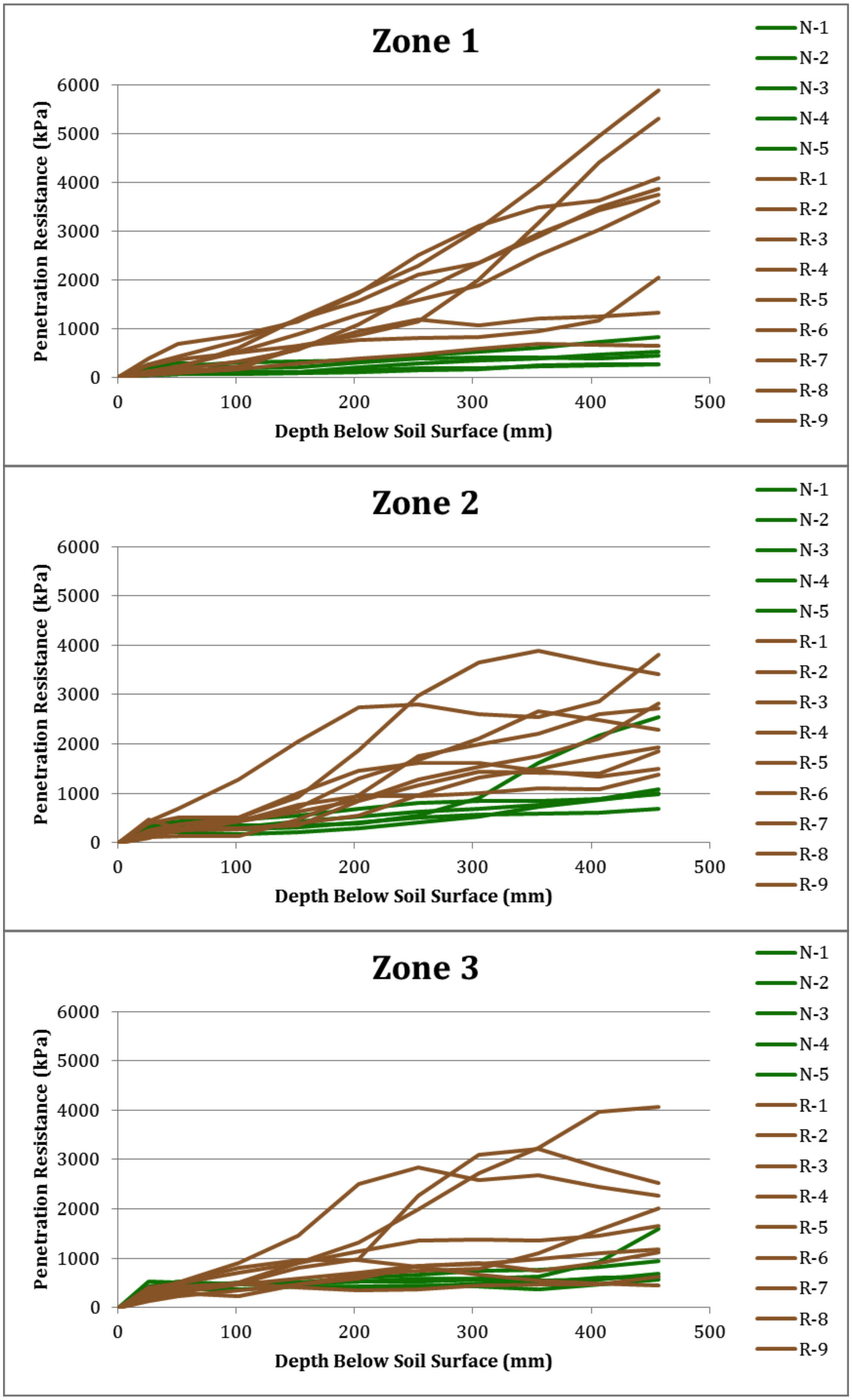


Figure 3-3. Penetration resistance data for all sites by hydrologic zone. Each line represents the average of penetration resistance measured at three transect plots.

Figure 3-4 demonstrates the magnitude of penetration resistance observed at sites to the maximum observed depth (45 cm), grouped by restoration status and hydrologic zone. Although there was tremendous variation between restored sites, penetration resistance was significantly greater than in natural sites ($p<0.0001$). Among restored sites, the cone index was greatest in hydrologic zone 1 and decreased in hydrologic zones 2 and3 (stats) while no similar trend occurred in the natural sites (stats). This is believed to be the result of wetland restoration practices that utilized heavy equipment, either intentionally to create a confining layer in the soil profile, or unintentionally as a part of other activities.

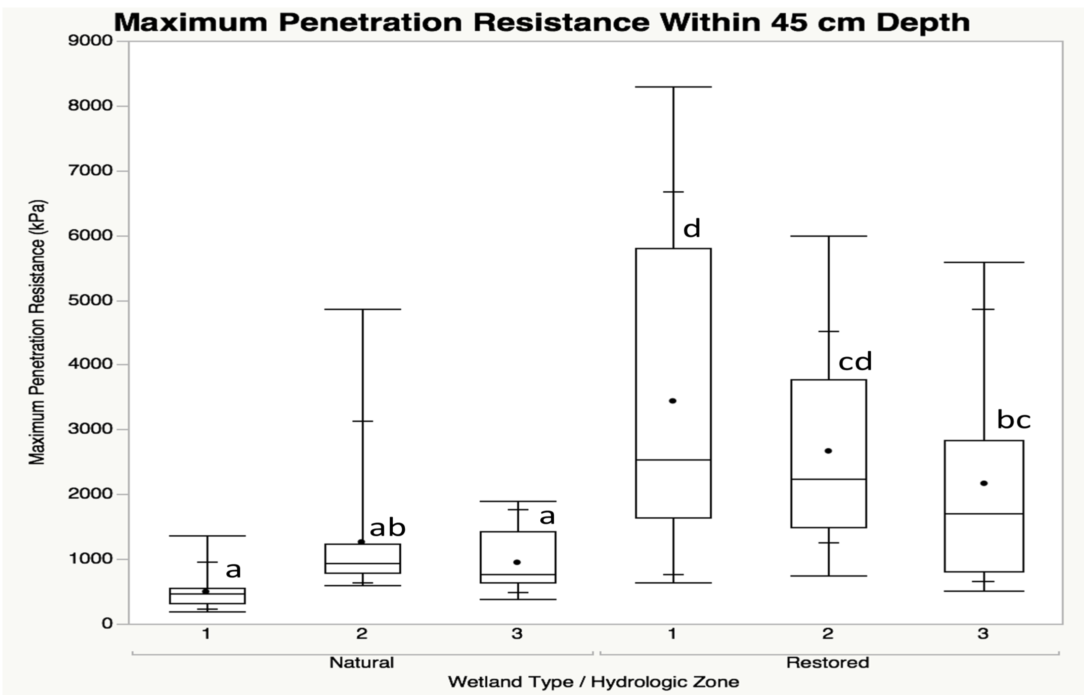


Figure 3-4. Box and whisker diagram (median, quartiles and range) illustrating the maximum cone index measured within 45 cm of the soil surface. The mean is shown by the dot; the central horizontal line is the median; the box represents the 25th and 75th percentiles; the short lines are the 10th and 90th percentiles; the whiskers represent the range of the data Plots with the same letter are not significantly different at the 0.05 level.

Figure 3-5, demonstrates that the maximum cone index within 25 cm was also much greater for the restored sites, although the magnitude of penetration resistance was approximately half that measured within 45 cm. We know that penetration resistance normally increases with depth (Raper, 2005). Nevertheless, the comparably high cone index values in the rooting zone (0-25 cm) of the restored sites compared to their natural counterparts has important implications both for plant growth and also for other soil functions. Excessive compaction generally reduces porosity and therefore lowers the rate of groundwater percolation and the soil's overall water retention capacity. These effects delay the delivery of downstream waters until the volume storage capacity of the depression is exceeded. In addition, compaction limits groundwater discharge into the wetland from the water table. This also limits the ability of the soil to properly cycle nutrients, as these processes require hydrological connectivity between groundwater and the wetland.

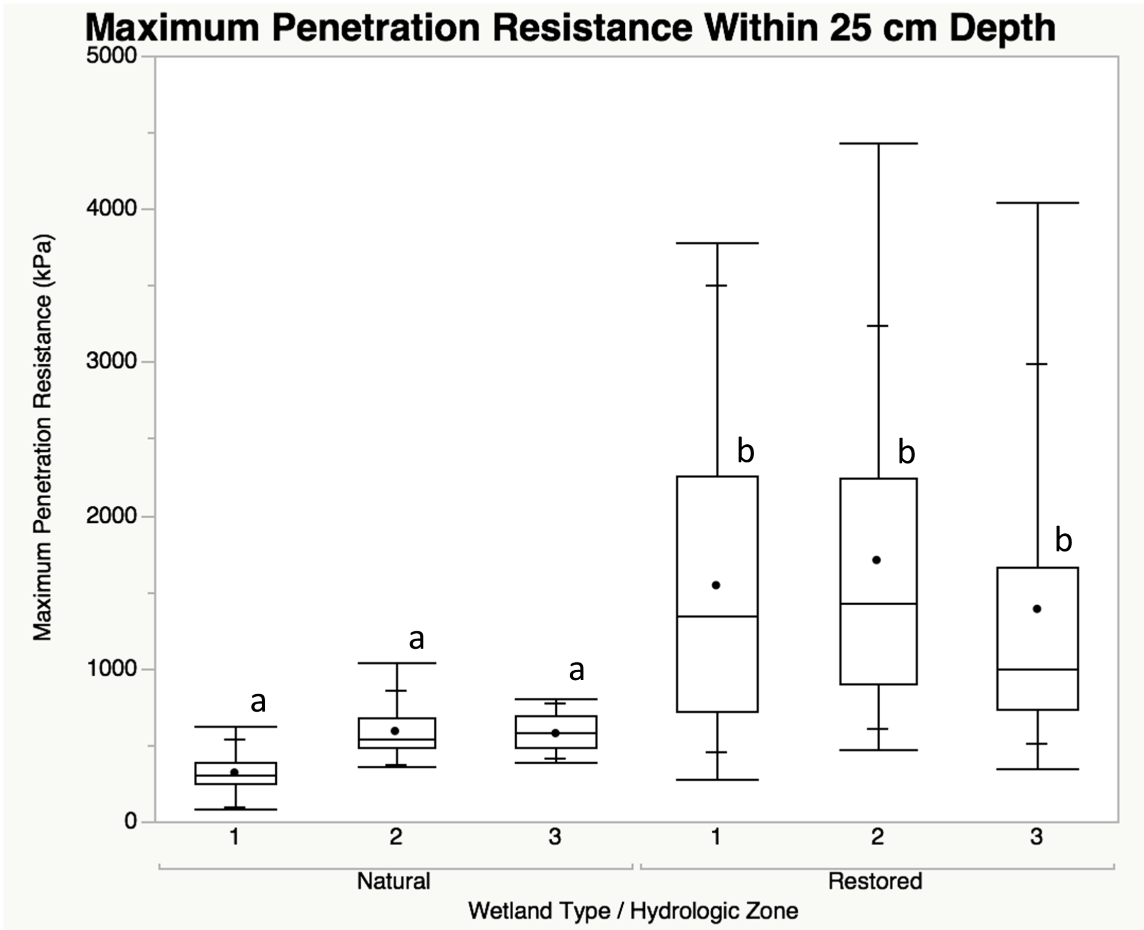


Figure 3-5. Box and whisker diagram illustrating the maximum cone index measured within 25 cm of the soil surface. The mean is shown by the dot; the central horizontal line is the median; the box represents the 25th and 75th percentiles; the short lines are the 10th and 90th percentiles; the whiskers represent the range of the data Plots with the same letter are not significantly different at the 0.05 level.

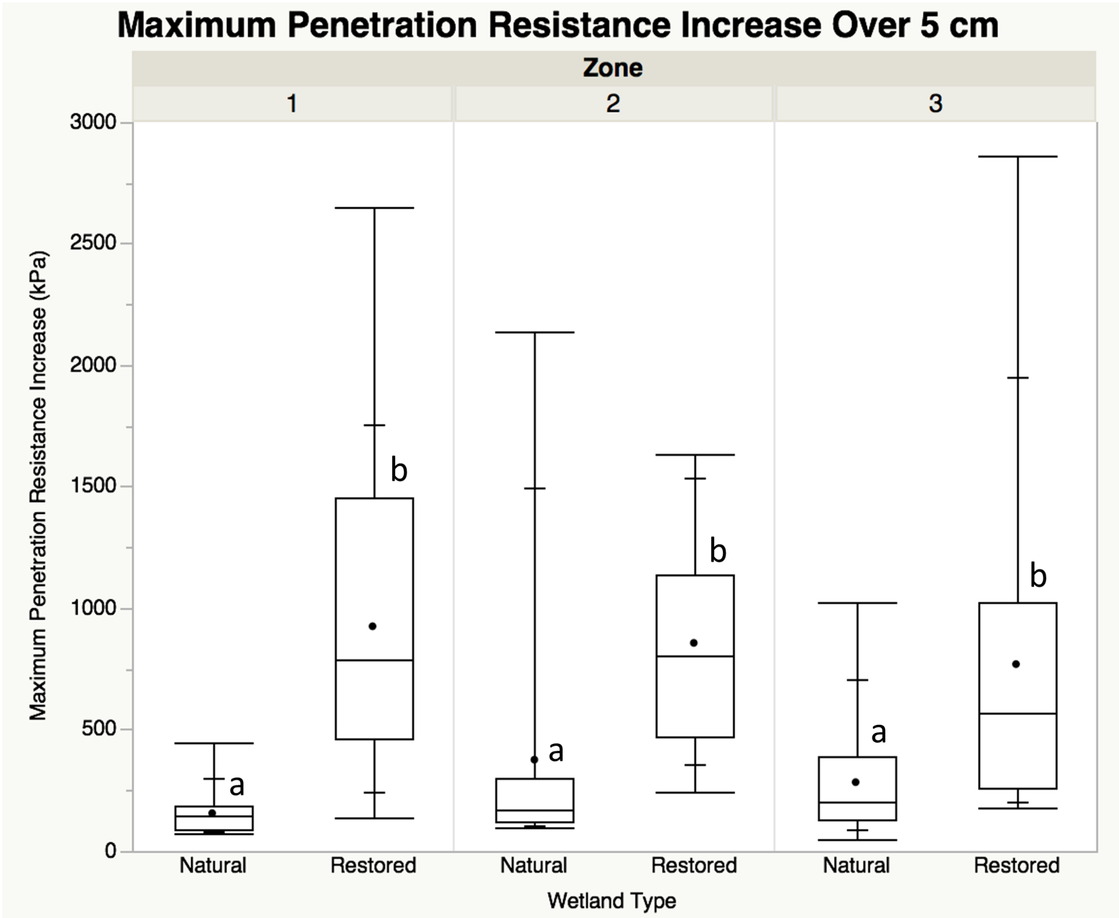


Figure 3-6. Maximum increase in cone index over a 5 cm vertical distance. The mean is shown by the dot; the central horizontal line is the median; the box represents the 25th and 75th percentiles; the short lines are the 10th and 90th percentiles; the whiskers represent the range of the data Plots with the same letter are not significantly different at the 0.05 level.

Figure 3-6 illustrates the maximum increase in penetration resistance between two successive depths recorded at each plot. This metric demonstrates the abruptness with which these changes in cone index occur. Similar to the overall penetration resistance, restored sites demonstrated a much more abrupt change in penetration resistance as compared to their natural counterparts, and the differences were greatest in zone 1. The abruptness of the increase in soil penetration resistance may be the result of an abrupt change in soil texture, soil compaction, or a combination of the both. We expect that this represents either a pan that was unintentionally formed by heavy machinery when the wetland was ‘scraped’ or the presence of an intentionally compacted clay layer laid down as part of the restoration effort.

High penetration resistance was also found to be much more common in restored than in their natural counterparts. Figure 3-7 demonstrates the proportion of plots with a cone index of greater than 1000 kPa at each of two depths. The lower depth, 45 cm, was the maximum depth of observation, while the 25 cm was chosen to be representative of that portion of the soil profile most important for microbial activity and plant rooting. A cone index value of 1000 kPa has been reported to negatively affect plant root growth (Raper, 2005; Kumar et al., 2012). Across all hydrologic zones, high penetration values were much more frequently observed in restored than natural sites. A total of 86% of restored plots were found to have cone index values in excess of 1000 kPa compared to only 24% of natural plots. A similar trend was observed when limiting observation to the upper 25 cm of the soil profile, where 58% of restored plots (52 plots) exceeded this value, while only a single natural plot did (2%). This further confirms that in restored sites, soil compaction is much more prevalent and occurs much shallower in the soil profile.

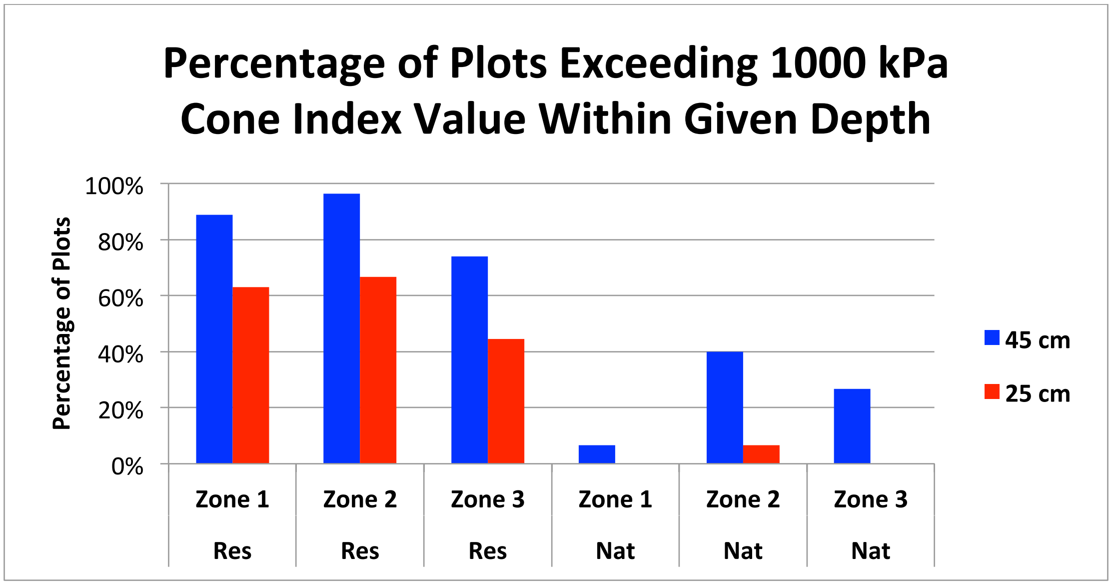


Figure 3-7. Frequency of plots with cone index above 1000 kPa at depths of 45 cm and 25 cm.

Bulk Density

In addition to penetration resistance, bulk density is another parameter that could reflect soil compaction. Figure 3-8 provides information on the bulk density of soil horizons with lower boundaries between 30 and 50 cm (excludes upper horizons). The subsoil bulk densities of restored sites were greater than those in natural sites in all hydrological zones, although there were no significant differences between hydrological zones among the restored sites. Like the greater observed penetration resistance, the higher bulk densities also may be related to the heavy equipment traffic on these sites during the restoration process.

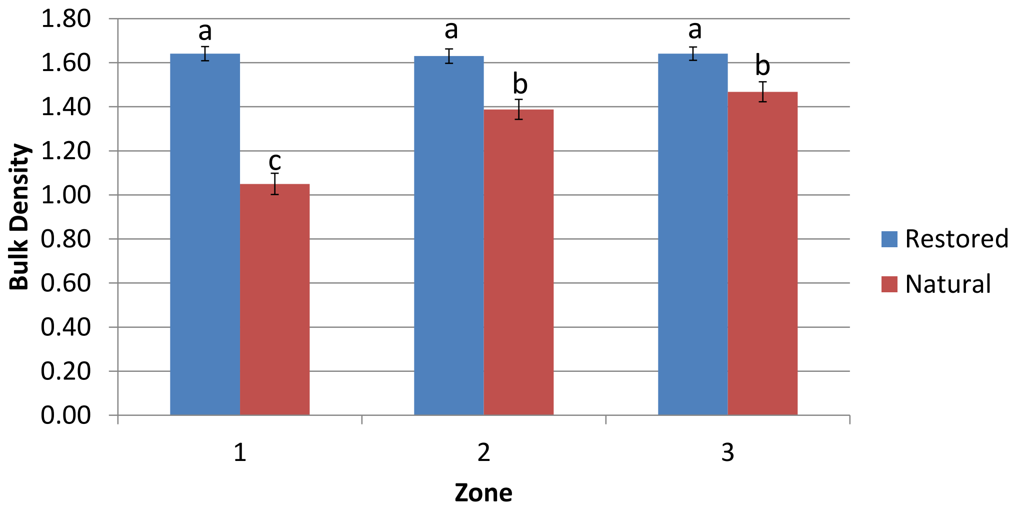


Figure 3-8. Mean (+/- SEM) bulk density (g/cm^3) of horizons with lower boundaries between 30 cm and 50 cm. Columns with the same letter are not significantly different at p=0.05).

Conclusions

A majority of wetland restoration activity on the Delmarva Peninsula has involved substantial earthmoving by heavy equipment (Fenstermacher *et al.*, 2016). It appears that traffic from the machinery during wetland restoration/construction has resulted in pronounced soil compaction at these sites. This can be seen in higher overall penetration resistance, more abrupt increases in penetration resistance, and higher penetration resistance near the soil surface of restored sites, when compared to their natural counterparts. Additionally, restored sites demonstrated a higher subsurface soil bulk density.

Soil compaction this severe is likely to result in numerous effects on wetland plant communities. Soil penetration resistance values observed are high enough to have deleterious effects on root penetration and growth of wetland plants. This can result in slower growth rates, reduced vegetation spread, and changes in speciation.

Additionally, compaction of this degree is likely to slow or reduce the transmission of water into and out of the restored wetland.

Additionally, wetland soil functions themselves are likely to be impacted by soil compaction. Compaction of the degree observed might result in reduction in soil hydraulic conductivity, which can limit connectivity between the wetland and the surrounding watershed. Besides altering the wetland's hydrology, this can have the effect of hydrologically isolating the wetland and preventing nutrient flux, impeding important nutrient cycling functions. This can also affect changes in wetland hydroperiod, which can impact amphibians and other wetland dependent species.

When groundwater is deemed insufficient to maintain wetland conditions, and location within the catchment is suitable, compaction may be done intentionally in order to create a perched water table that could facilitate the development of wetland conditions. Apart from these specific conditions, greater effort should be made to utilize alternate strategies for wetland restoration. Less impactful practices (such as ditch plugging) can limit soil disturbance during the process of restoration. This will reduce the deleterious effects on wetland soil currently observed by the "scraping" method of restoration. Ultimately, new restoration strategies and practices should be devised and implemented with the goal of facilitating, rather than compromising, high levels of wetland function.

Chapter 4: Carbon Dynamics in Restored and Natural Wetlands

Introduction

The modern view of wetlands as a unique and valued ecosystem did not come into being until the mid-20th century. Wetlands were traditionally viewed as obstacles to development and/or breeding grounds for disease vectors. Post-colonization, American wetlands were often drained for cropland. This land was nutrient- and organic matter-rich, but, once drained, was susceptible to rapid carbon loss and soil subsidence from aerobic decomposition (Holden *et al.*, 2004). These losses necessitated further clearing and draining of wetlands to compensate for decreased soil productivity. Further wetland losses occurred as mosquito control efforts resulted in systematic draining of wetlands as part of Depression-era stimulus measures. More recently, wetland loss due to urbanization has become an area of increasing concern. In total, it is estimated that, nationwide, 53% of traditional extent of wetlands have been lost (Bridgham et al., 2006).

In the last few decades, a shift in attitudes towards wetlands has begun that places value on the positive environmental services they offer, as well as their intrinsic value as an ecosystem. Wetlands first achieved federal protection by their hydrological connection with navigable waters under the Clean Water Act (Hough & Robertson, 2009). Additional protection was afforded to them under the "Swampbuster" provisions of the Food Security Act of 1985 as well as further regulations established on the state and local level (NRCS, 2008).

While protection of existing wetlands was necessary, the degree to which wetlands have been disturbed necessitated a strategy to restore previously-degraded wetlands to their original state. The Wetland Reserve Program (WRP) was one such program, administered through the US Department of Agriculture (USDA), and aimed at restoring degraded wetlands on private property through conservation easements. The Natural Resources Conservation Service (NRCS) was in charge of implementing these restorations, and the Wetlands Conservation Effects Assessment Program (CEAP-Wetlands) was initiated to provide feedback and guidance as to the success of WRP and similar efforts (USDA, 2016). Following it's expiration in 2014, the WRP program was subsumed under the Agricultural Conservation Easement Program (ACEP).

Wetland restoration can be viewed as an effort to unify the water table (either apparent or perched) and the soil surface (for at least some portion of the year); one can either raise the water table to the soil surface, or lower the soil surface to the water table. On the Delmarva Peninsula, these goals have mostly been accomplished by either of two methods - 'plugging' or 'scraping.' Plugging is the restoration of wetland hydrology by eliminating (plugging or filling) ditches, drains, or other artificial structures which altered (removed) the original wetland hydrology. Once successfully restored, wetland hydrology often allows for the reestablishment of hydrophytic vegetation, and, since hydric soils are typically already present, wetland restoration is complete. Scraping, on the other hand, lowers the current soil surface to the water table by removal of soil material by heavy machinery. This restores (or establishes) saturated hydrologic conditions, which allows for the establishment of hydrophytic vegetation. It also, however, results in extensive soil disturbance as soil horizons are moved about, homogenized or relocated. Additionally, it is thought that the use of heavy machinery during the process can result in soil compaction, much like has been extensively described in agricultural settings (Lipiec & Hatano, 2003; Raper, 2005). Soil compaction has been anecdotally observed at several restored wetlands in the Mid-Atlantic region (Fenstermacher, 2012). Restoration by scraping is far more common in this region than other methods (Fenstermacher, 2012; Goldman & Needelman, 2015).

WRP-restored wetlands on the Delmarva Peninsula, which are generally depressional, have many commonalities with natural depressional wetlands. Both wetland types are freshwater wetlands with no tidal influence. They are also hydrologically variable, both spatially and seasonally. Both groups of wetlands feature small scale topographic changes that result in a gradual transition between wetter and drier portions. At a glance, their chief difference may be vegetative; natural sites are dominated by woody vegetation, while restored sites tend to be dominated by herbaceous vegetation (McFarland *et al.*, 2015).

The goal of restoration is generally to reinstate various functions and services, which are often facilitated by the presence/accumulation of soil organic matter. However, the accumulation of soil organic matter in restored wetlands is often a slow process. While accumulation of OC is an important process in wetland restoration, and one that drives other wetland functions, one should not expect soil OC stocks to increase quickly following restoration.

There have been numerous studies comparing carbon in restored and natural wetlands. One such study of Virginia wetlands found that cutting and scraping activity during restoration resulted in drastically lower C content compared to reference sites that remained little changed after 10 years (Stolt et al., 2000). These observations confirmed earlier studies that found no relation between restored wetland age and C content (Bishel-Machung *et al.*, 1996). More recent studies, however, found that longer-term observation was required to document changes in SOM content in restored wetlands. One such study of New York wetlands demonstrated a increase in SOM content of restored wetlands, after 35-55 years (at a depth of 0-15 cm), but even then, SOM levels failed to approach natural levels within 55 years (Ballantine & Schneider, 2009).

The objectives of this study were to compare natural and restored wetlands with regard to: 1) hydrology and cumulative saturation; 2) decomposition of organic matter; 3) and soil carbon stocks. Comparing restored wetlands to their natural counterparts will allow us to better judge the success of these efforts, which will, in turn, allow us to provide better guidance for future restoration efforts. This study will also advance our knowledge of the soil properties and processes involved in restored wetlands, an understudied portion of Earth's critical zone (Lin, 2010).

Methods

Study Location

This study was conducted across the Delmarva Peninsula of Maryland, Delaware, and Virginia in the Mid-Atlantic region of the Atlantic coast of the United States. The region is notable for it's relatively flat topography and elevation near sea level (elevation <30 m). Average rainfall is 116 cm and occurs evenly throughout the year. Soils of the region are predominantly formed in fluvial and deltaic coastal plain sediments, pedogenically mature, and having seasonally high water tables that in some cases extend high in the soil profile. The predominant land use in the region is agriculture.

Site Selection

Ten restored and five natural wetland sites were initially selected for study on the Delmarva Peninsula. One of the restored sites was abandoned mid-study due to land owner practices that resulted in loss of data from that site. Restored sites had been included in the Conservation Reserve Program, Conservation Reserve Enhancement Program, or Wetland Reserve Program and varied in age from 7 to 28 years. Both restored and natural sites were freshwater, depressional wetlands, and were both spatially and temporally variable in hydrology. Additionally, all sites were hydrologically isolated from major surface water flows. Sites demonstrated a gradual topographic and hydrologic transition from the upland into the ponded wetland, with ponding in the deepest portions being generally less than 1 m depth during the winter (hydrologically wet) months.

Zonation

Research sites were subdivided into three or four hydrologic zones that represented a gradient from the wettest (zone 0) to the driest (zone 3). Sites were roughly circular, with the wettest zone occurring in the center, with sequentially drier zones occurring outward in concentric rings.

Zone 0 was permanently and deeply (> 35 cm) ponded wetland, and represented the wettest portion of each site included in the study. No emergent vegetation was present, and the water table never drew down below the surface. Zone 0 did not occur at all sites and thus was excluded from the study (Fig. 4-1).

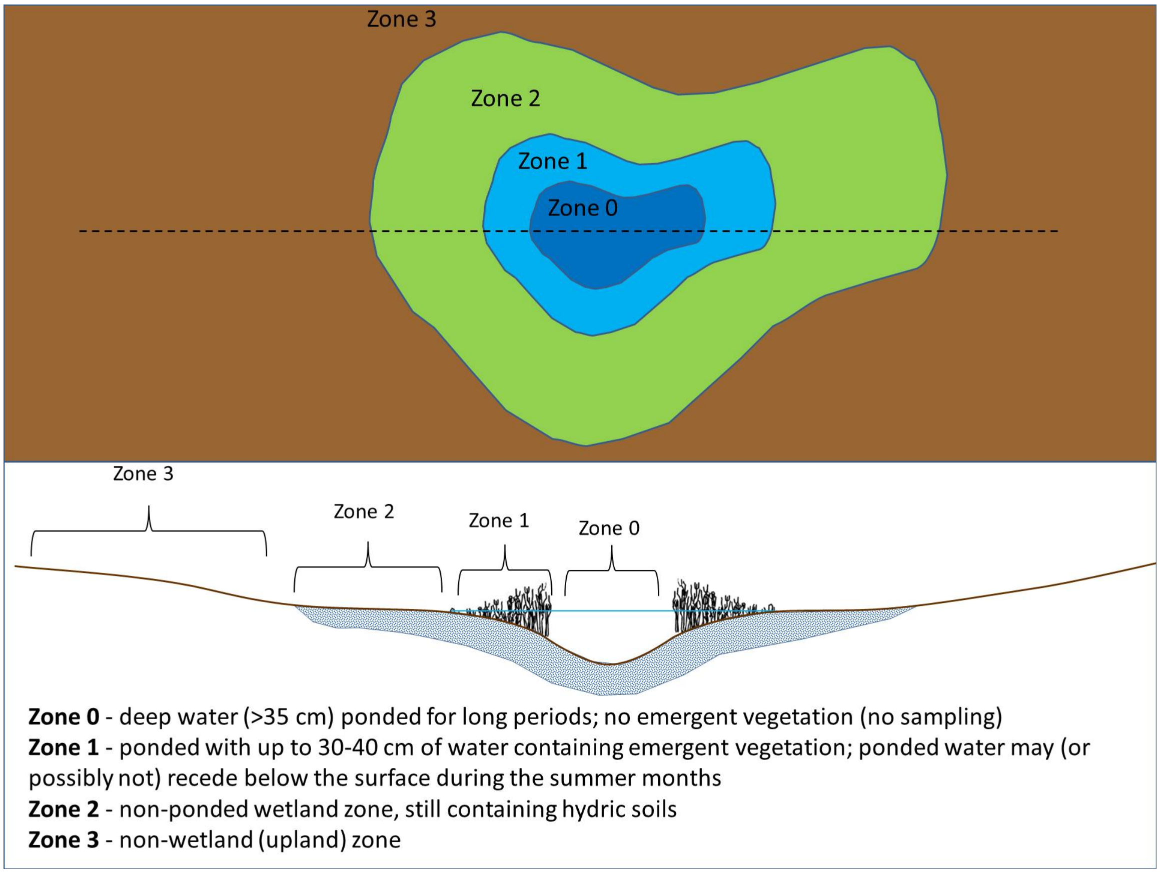


Figure 4-1. Cross section through a schematic representation of the wetland sites showing 4 distinct hydrological zones. Plots were established in zones 1, 2 and 3 but not in zone 0 (which was absent from some sites).

Zone 1 was seasonally ponded wetland that contained emergent vegetation. The water table was above the soil surface during the colder months (generally <35 cm water depth), but drew down throughout the growing season, sometimes retreating below the ground surface.

Zone 2 was seasonally saturated wetland containing hydrophytic vegetation and hydric soils. This zone was typically saturated during the winter and early spring months, but was rarely ponded. Water tables typically dropped during the growing season.

Zone 3 was upland located beyond the extent of the wetland proper, contained no hydric soils, and was dominated by non-hydrophytic vegetation. This was the driest zone addressed in the study.

Siting Research Plots

Three replicate transects were situated within each wetland. Each transect consisted of three research plots, with one located in each hydrologic zone previously described. Transects extended radially from the center of the wetland site, from zone 1 to zone 3 (Fig 4-2A).

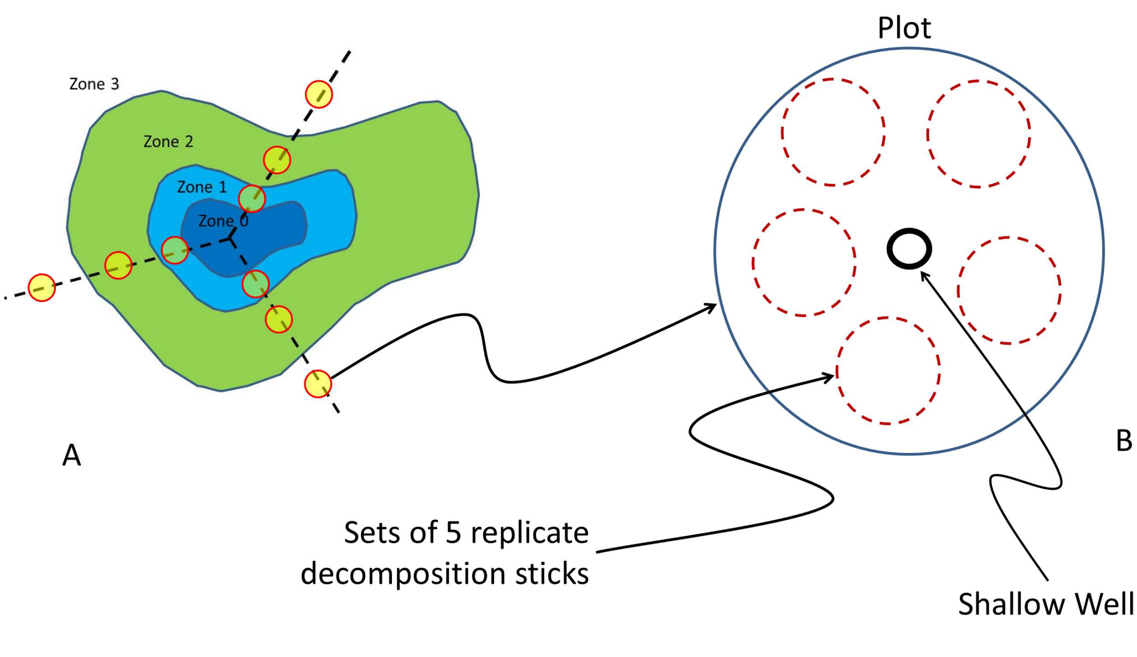


Figure 4-2. Three radially oriented transects were situated at each site, and plots were located within zones 1, 2 and 3 (A). Within each plot, 5 sets of replicate birch decomposition sticks were distributed around a shallow (50 cm) well (B).

The radial direction of transects was determined randomly, but the location of each plot along each transect was located centrally within each hydrologic zone of interest (stratified randomization). Transects were situated along compass bearings randomly selected at 36, 144 and 252 degrees, from a hypothetical center of the wetland. Plots were then located along the transect in the center of each of the three hydrologic zones of interest (1-3). Field observations of soil conditions, vegetation, water tables, topography and remotely sensed (color IR) imagery were utilized during placement of research plots (Fig 4-2B).

Field Methods

Hydrology - Two methods were utilized to record shallow water table levels. A well was inserted into the soil at the center of each research plot to a depth of 50 cm, from which the water table height for each plot was measured manually, approximately monthly. In addition, a single, continuous water table logger was situated within the wettest portion of each wetland site (zone 0 or 1). The water table level at this location was recorded at 30-minute intervals.

IRIS Tubes - IRIS (Indication of Reduction In Soils) Tubes were used to measure the extent of reducing conditions in the soil. IRIS Tubes are PVC tubes coated in an iron oxide paint that is solubilized and removed in strongly reducing soil conditions. One nest of 3 replicate IRIS Tubes was installed within each plot in zones 1 and 2 in mid-March 2013. Tubes were retrieved in mid-May for analysis (Rabenhorst, 2008).

Soil Sampling - Soils were sampled by horizon at each plot using a single, 5-cm-diameter, aluminum core that was inserted vertically into the soil to a depth of 50 cm. Depth from soil surface to the top of the tube was measured both inside and outside the tube in order to calculate the degree of soil compaction as a result of the coring process. To ensure that the core was not disturbed by retrieval, soil was removed around the core and the bottom of the core was capped before removal. Soil cores were packed and capped for transit, and upon return to the lab, stored in a freezer until processing.

Sampling for Soil Inorganic N - Soil samples for nitrate analysis were acquired during a previous study (McFarland et al., 2015). In August 2013, two 5 cm cores, 10 cm in length were composited into a single soil sample from each plot. The sample obtained was dried and ground before analysis.

Decomposition Stick Installation/Removal - Decomposition was estimated by measuring mass loss of wooden sticks inserted into the soil and exhumed periodically. Thirty cm long northern white birch (*Betula papyrifera*) garden stakes were dried for 72+ hours at 60°C before being cooled in a desiccator and weighed. Sticks were strung in sets of five with baling twine to aid with recovery, and identification (Fig 4-3).

Figure 4-3. One set of 5 replicate decomposition sticks connected with bailing twine and labeled with an aluminum tag. Five sets (of 5) sticks were installed at each research plot.

Sticks were installed in January of 2013. Five sets of five sticks each were inserted vertically into the soil at each plot, roughly equidistant around the plot center (Fig. 4-4). A sharpened steel bar slightly thicker than the decomposition sticks was used to create pilot holes to aid with installation. Baling twine was used to connect each set of sticks to the plot center stake to aid with retrieval.

Figure 4-4. Five sets of decomposition sticks installed in a zone 2 of a research plot around a flagged stake for identification. Also shown is the white top of the shallow 50 cm PVC well used for measuring water table levels.

One set of five replicate sticks was exhumed and retrieved from each plot quarterly. Retrieval method varied by hydrologic zone, duration of exposure, and stick condition. Sticks in wetter hydrologic zones and sticks removed at the end of the 1st and 2nd quarters could mostly be removed by hand, or with the assistance of pliers. In some situations (where sticks were more deteriorated), a steel core was required to be driven into the soil around the stick, then the entirety of the core (soil and stick) removed. Sticks were briefly rinsed in the field before returning to the lab.

Lab Methods

IRIS Processing - IRIS tubes were gently washed to remove adhering soil or other debris. Washed tubes were then photographed and then rotated 180° to collect images of both sides of the tube. Pairs of photographs of each tube were composited into a single image. Paint removal was then estimated visually (Rabenhorst, 2010) for the upper 30 cm of each tube, utilizing percent area standards (Schoeneberger *et al.*, 2012b) for comparison.

Soil Core Processing - Frozen cores were partially thawed, and electric sheet metal shears were used to cut a slot along each aluminum core lengthwise. The partially frozen sample was then gently extruded from the end of the core, taking care to keep the core intact and to minimize disturbance. The extruded soil core was divided into sections by soil horizons using standard morphological observations (Schoeneberger et al., 2012b). The thickness of each horizon was recorded, and the entire mass of each horizon was sampled separately, taking care to avoid cross-contamination. Soil horizons were dried in a 80°C oven for 72+ hours before weighing. Horizons were then ground in preparation for analysis.

Total C and N Analysis - Soil samples from each horizon were crushed in a flail grinder and homogenized. Organic horizons were ground, using a modified coffee grinder. Approximately 2 grams of each horizon were transferred to glass scintillation vials and several small steel rods added to each. Vials were rotated on a spinner table for 24 hours to allow for the tumbling of the rods to grind the samples finely. Ground samples were then placed in a 100°C oven for 24 hours before weighing for analysis. Total C and N were run in duplicate using a LECO CN

Analyzer (Nelson & Sommers, 1996). If sufficient agreement between the duplicates was not obtained (both CV > 12% and SD > 0.2), additional subsamples were analyzed until sufficient analytical replication was achieved to bring these parameters below these thresholds.

Inorganic N Analysis - Soil samples for N analysis were composites of two (5cm X 10cm) cores from each plot that were homogenized, ground and dried. Duplicate 2.5 g samples of were extracted using 25 mL of 2 M KCl. Samples were agitated on a shaker table for 1 hour and filtered through #4 filter paper. The resultant filtrate was then centrifuged at 1200 RPM for 10 minutes in order to eliminate any residual particulate matter. Ammonium and nitrate were determined on the extract using a Lachat 8500 flow injection analyzer (Maynard *et al.*, 2007).

Processing of Decomposition Sticks - Decomposition sticks collected from the field were hand washed to gently remove any remaining soil or organic material that adhered to the sticks following extraction. Sticks were then dried at 60°C for 72+ hours before being weighed (0.01 g), following the same protocol used initially.

Hydrological Data Processing - Hydrographs were generated (modeled) by combining periodic water table measurements at each plot with continuous water table data collected using one central logger at each site. The long-term continuous data were adjusted (calibrated and optimized) using the manual measurements at each plot. Based on this modeling effort, a continuous water table hydrograph (for two years) was created for each individual plot. Using these data, a cumulative frequency curve for soil saturation vs depth was also developed for each plot.

Weather Data - Monthly rainfall data for the period of the study were obtained from the Royal Oak 2 SSW Station (187806, Coop; USC00187806, GHCN - Global Historical Climatology Network; Lat: 38.7153, Long: -76.1908), located near Easton, MD. These data were compared to long term rainfall data obtained at the the same station.

Results and Discussion

Weather and Hydrology

As demonstrated in Figure 4-5, 9 of 12 months in 2013 had precipitation levels that fell between the 30th and 70th percentiles. The months of June and December had precipitation in excess of the 70th percentile and September was slightly below the 30th percentile. The total precipitation for 2013 was 1152 mm which was within 1% of the long term average of 1165 mm. For the period leading up to, and during the deployment of IRIS tubes, the monthly rainfall and the 3 month running average of the rainfall, all fell within the 30th and 70th percentiles. Therefore, we concluded that the precipitation of 2013 should be considered a normal year.

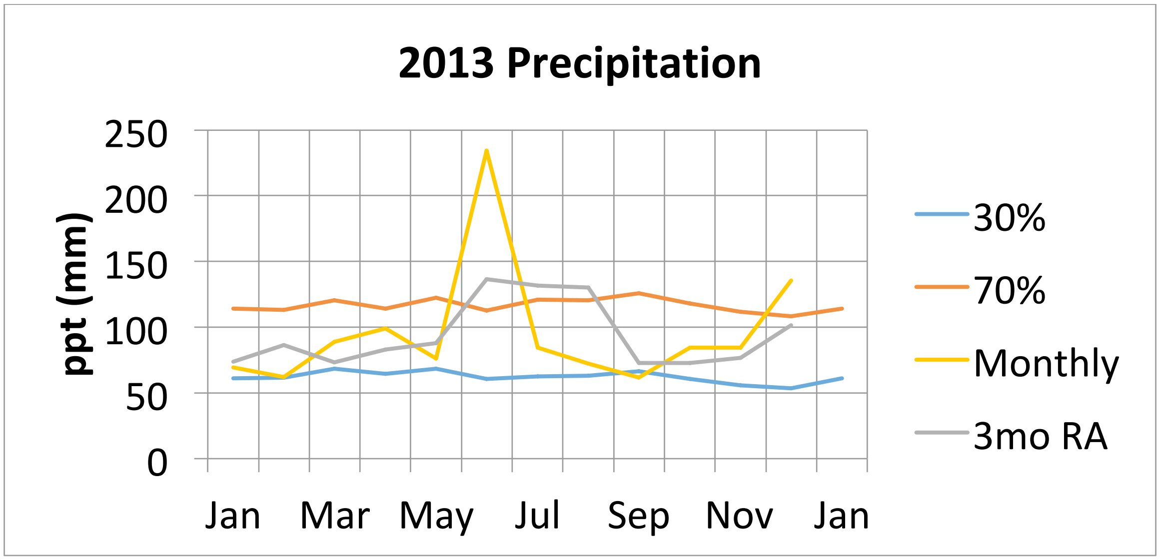


Figure 4-5. Precipitation data for Royal Oaks, MD compared to 30% and 70% monthly averages. All data obtained from the WETS (NRCS Climate Analysis for Wetlands Tables) database.

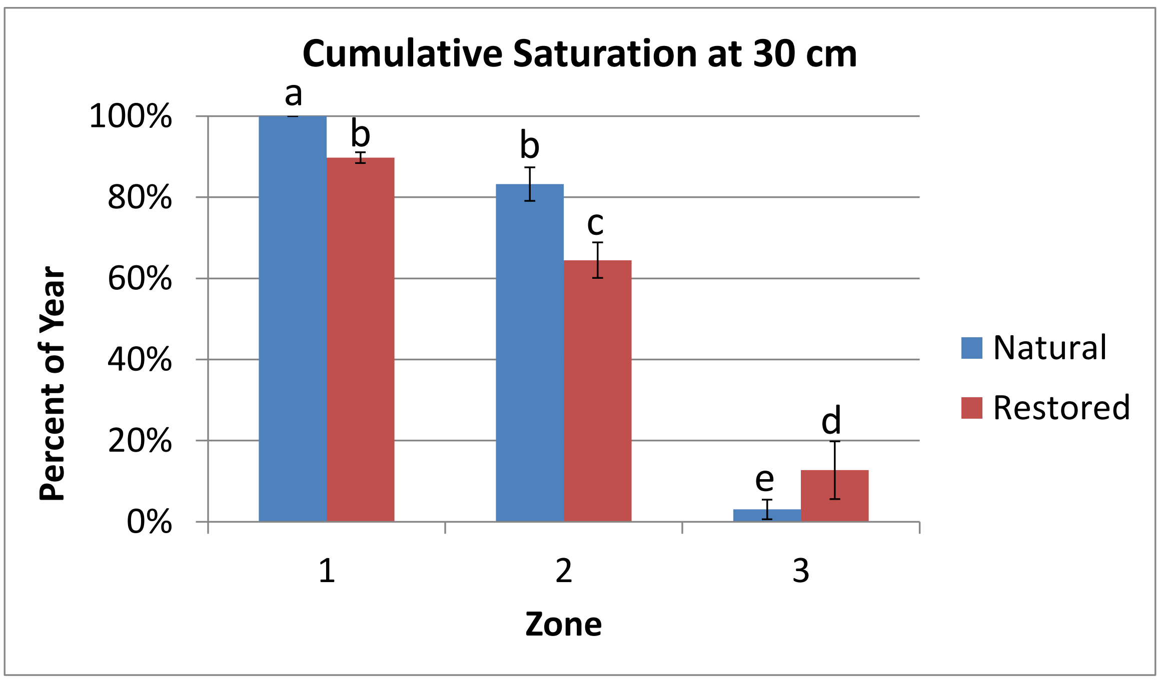


Figure 4-6. Percentage of the year research plots remained saturated at 30 cm depth. Columns sharing the same letter are not significantly different.

The cumulative percent of the year that the soil was saturated (water table at or above) at 30 cm is presented in Figure 4-6. The statistical analysis demonstrates that the percent of time the soil is saturated at or above 30 cm is significantly related to the hydrological zone (zone 1, 2 or 3) ($p<0.0001$) and also by the wetland type (natural vs restored) ($p=0.0220$). There was also a zone by wetland type interaction ($p<0.0001$). Seasonally ponded (zone 1) restored plots maintained saturation for fewer days than their natural counterparts, and were not statistically different than natural plots in zone 2. Interestingly, restored upland sites (zone 3) demonstrated a greater duration of saturation than their natural counterparts. This could be attributed to compaction caused from construction, causing a degree of water table perching, or it may simply be an artifact of plot selection. Regardless, the percent of time that the upland plots were saturated within 30 cm of the surface was minimal (<10%).

IRIS Paint Removal

The percentage of IRIS tube paint removed from the upper 30 cm of tubes placed in wetland zones 1 and 2 is shown in Fig. 4-7. ANOVA results indicate a significant effect on paint removal both by wetland type ($p<0.0001$) and wetland zone ($p=0.0246$). Interaction of the two effects was insignificant. All plots, however, demonstrated paint removal well in excess of the 30% removal required by technical standard of the NTCHS (2008) to demonstrate the presence of reducing conditions. These data corroborate the previous hydrologic analysis and indicate that zone 1 and 2 plots underwent extended periods of reducing conditions as well as (during) periods of saturation.

Greater paint removal was observed in restored sites compared to their natural counterparts. Three environmental variables can viewed as controlling the degree to which paint removal occurs. These variables are saturation, carbon availability, and temperature. Since all sites are situated within the same geographic area, temperature should vary little between the sites. Likewise, saturation should remain constant between the sites because IRIS tubes were deployed during a period in which both natural and restored sites were fully saturated. Carbon availability, however, differs between natural and restored sites. Natural sites are woody and the majority of soil carbon is added to the soil surface in the form of leaf litter. Restored sites tend to be dominated by herbaceous vegetation, which provides the soil with more labile carbon within the soil added as fine roots. Restored sites might therefore have more available carbon, supporting higher levels of microbial activity, which would result in greater iron reduction.

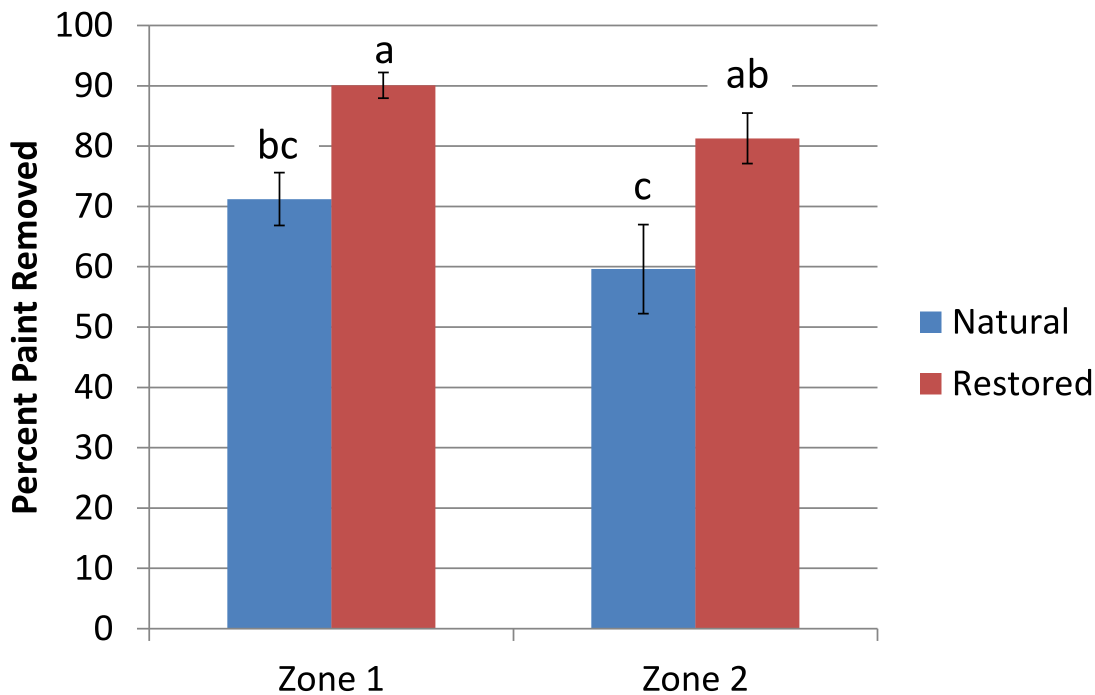


Figure 4-7. Summary of paint removal from the upper 30 cm of IRIS tubes in natural and restored wetland zones 1 and 2. Columns with the same letter are not significantly different.

Nitrogen Content of the Soils

Nitrogen data are presented in Figure 4-8 and in Table 4-1. Nitrate levels were generally very low, ranging from 5 to 7 mg/kg and did not differ significantly across zones and wetland types (Fig. 4-8). Most of the inorganic N was present as ammonium. Ammonium was significantly correlated ($p<0.001$) with total N ($r2= 0.70$), and total N was significantly correlated ($p<0.001$) with organic C ($r2= 0.95$).

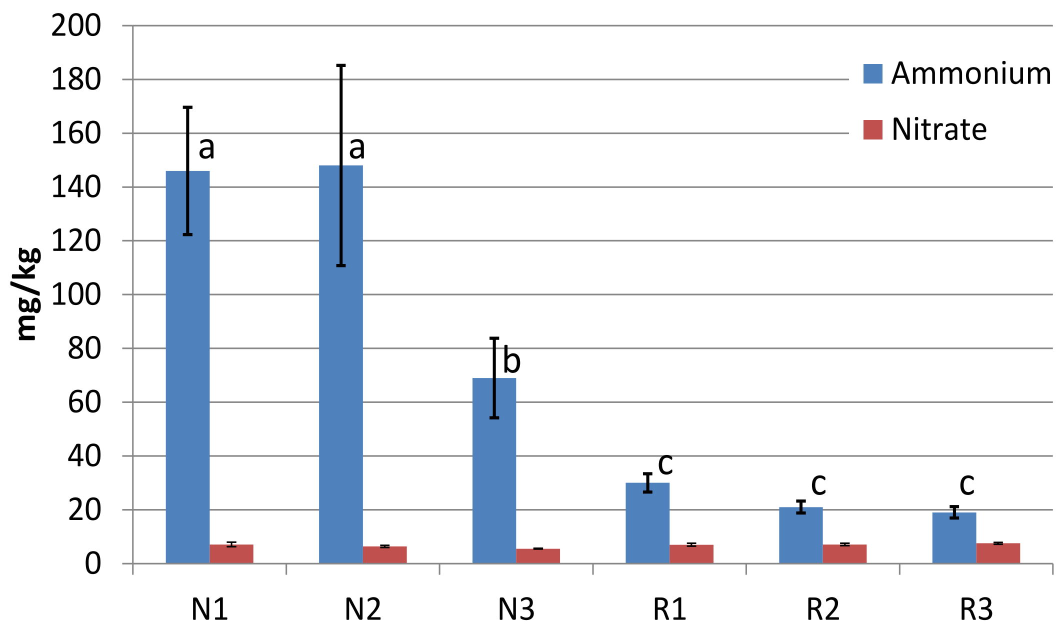


Figure 4-8. Means of inorganic N measured on 10 cm cores collected from plots in zones 1, 2 and 3 in both natural (N) and restored (R) sites. Bars with different letters were significantly different at the 0.05 level. There were no significant differences in nitrate levels across zones or wetland types.

Table 4-1. Nitrogen data (means) for surface (0-10cm) soil samples in three hydrological zones from natural and restored sites. There were no significant differences in nitrate content among treatment or zones. For ammonium and total N, means followed by the same letter were not significantly different at the 0.05 level.

	Natural			Restored		
	N1	N2	N3	R1	R1	R3
Nitrate mg/kg (NS)	7.1	6.4	5.5	7	7.1	7.5
Ammonium mg/kg	146a	148a	69b	30c	21c	19c
Total N g/kg	14.6a	9.3b	4.6c	1.4d	1.8d	1.4d

Decomposition of Sticks

Data for the decomposition sticks are shown in Fig. 4-9, which were examined on the basis of wetland type and hydrologic zone. ANOVA demonstrates that both wetland type ($p=0.0254$) and hydrologic zone ($p<0.0001$) had significant effects on the organic matter decomposition, but that these effects showed no significant interaction. Decomposition was lowest in zone 1 where the soil was saturated longest. Decomposition was also significantly lower in natural wetlands than in restored wetlands.

Because the wooden sticks had such a large C:N ratio (approximately 400:1), it was postulated that nitrogen levels in the soil might affect decomposition. Nitrate

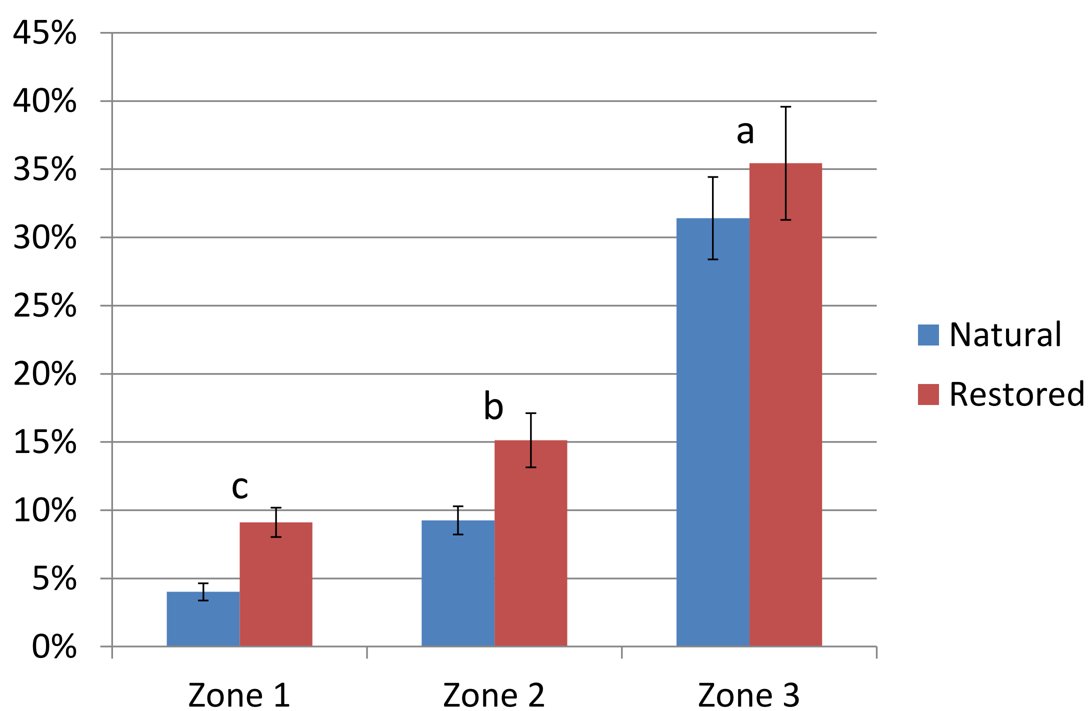


Figure 4-9. Percent of organic matter decomposition as mass loss over a 1-year period. Data connected with the same letter are not significantly different at the p = 0.05 level.

levels were uniformly low across all zones and treatments and therefore would not be expected to have an effect. Ammonium levels, however, were significantly higher in natural sites, and decomposition of the sticks was also significantly ($p=0.0254$) greater in the natural sites. Thus, it is possible that ammonium could be enhancing decomposition of the sticks. On the other hand, ammonium levels also increased from the drier to the wetter zones (Fig. 4.8) where decomposition rates were dramatically and significantly lower ($p<0.001$). Therefore, if ammonium levels in the wetter zones contribute positively to the decomposition of the sticks, those effects appear to be negated or overwhelmed by the strong impact of wetter hydrological conditions.

Prior analysis (Fig 4-6) clearly demonstrated that for a given hydrological zone, the natural sites remained saturated for a significantly longer period than the same zones in restored wetlands. Therefore, further analysis was undertaken to more carefully examine the effects of soil saturation on decomposition.

Using the modeled hydrographs for each site and plot, decomposition was analyzed as a function of the percentage of the year the soil was saturated at or above a depth of 30 cm (Fig 4-10). Across all hydrologic zones and wetland types, there was a strong, statistically significant ($p<0.001$) exponential correlation ($R^2=0.6575$) between stick decomposition and the percentage of the year the plot was saturated within 30 cm. Hydrological differences appear to be the major driver of the observed differences is organic matter decomposition and can explain about 2/3 of the observed variability in decomposition. Separate analysis of natural and restored sites showed that there was no difference in stick decomposition as a function of saturation.

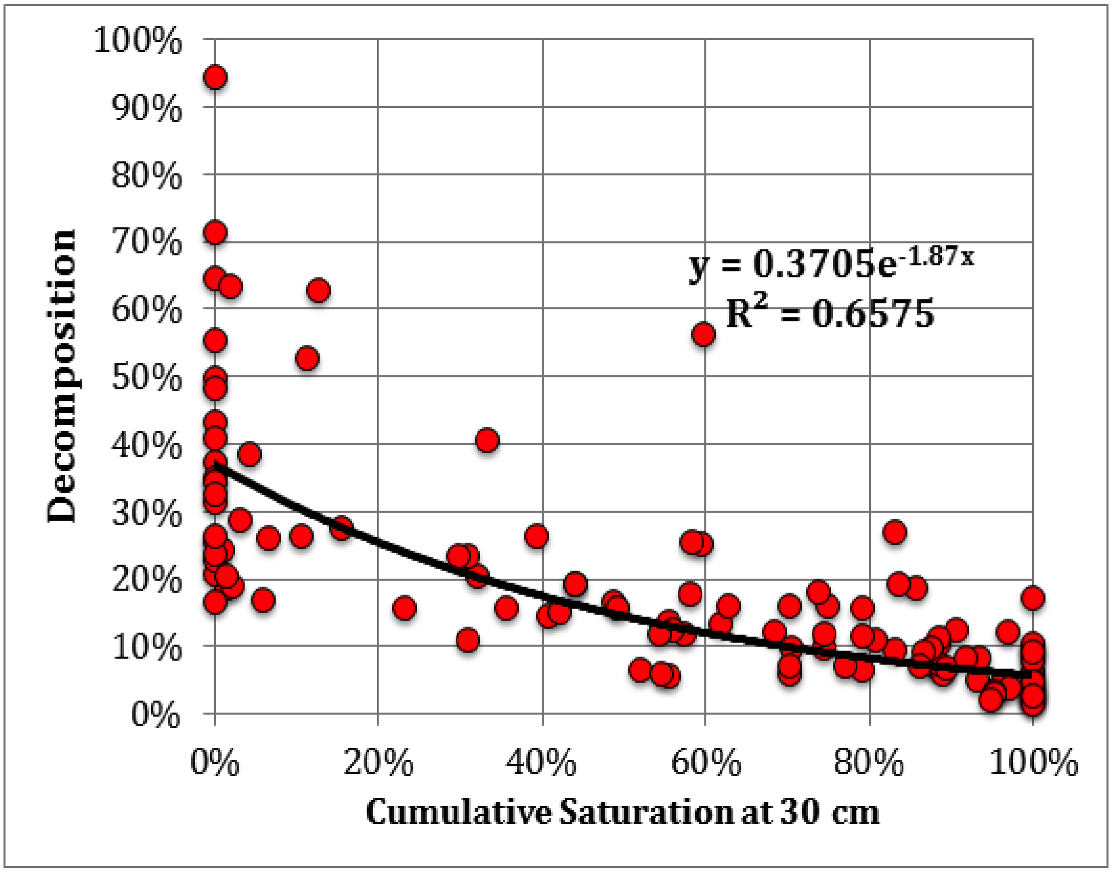


Figure 4-10. Percent decomposition of sticks after 12 months plotted as a function of the percent of the year that the water table occurred within 30 cm of the soil surface.

Carbon Stocks

Figure 4-11 illustrates the quantity of C stored in the upper 50 cm of soils in each of the three hydrological zones and in the two wetland types. Wetland type ($p<0.0001$) and hydrologic zone ($p=0.0003$) both have highly significant affects on soil carbon stocks. A significant interaction was also observed ($p<0.0001$). In the natural sites, C stocks in the two wetland zones (1 and 2), which were not different from each other, were both significantly greater than in the upland zone (3).

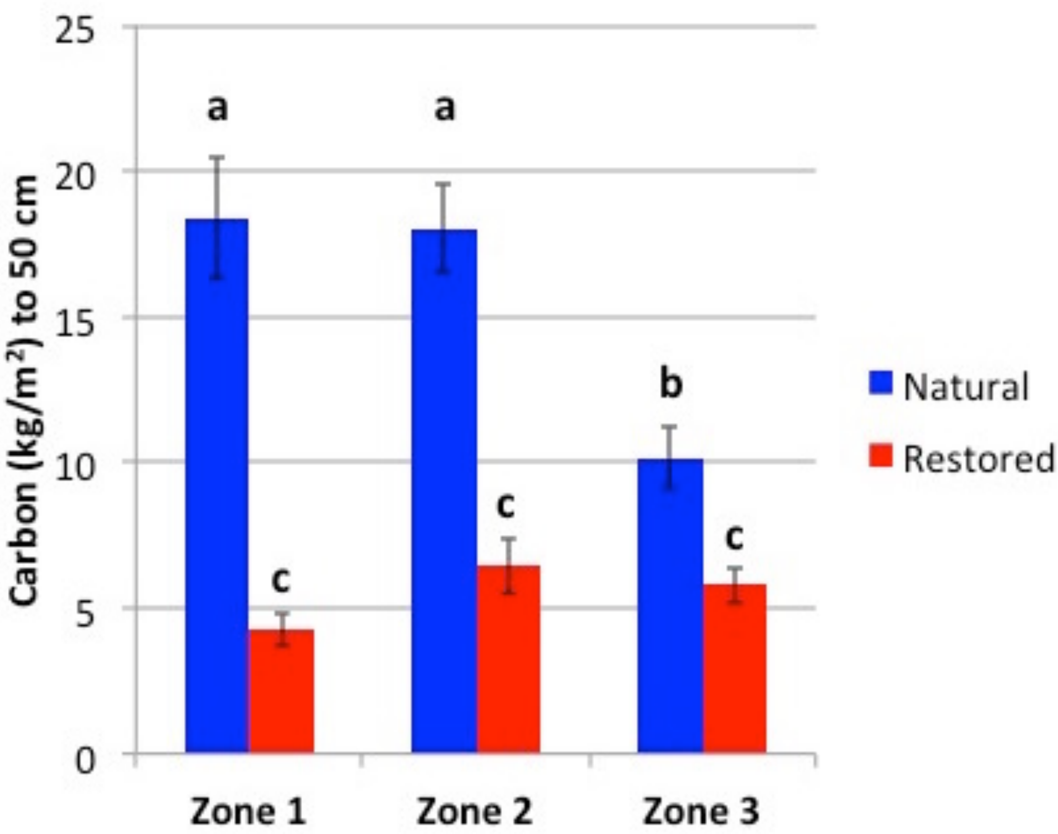


Figure 4-11. Carbon stocks in the upper 50 cm of the soil in natural and restored wetland sites.

In the restored sites, however, there were no significant differences in C stocks among the hydrological zones. This is most likely due to homogenization, mixing and removal of soil horizons during the restoration process, and a lack of sufficient time for carbon to accumulate post-restoration (Stolt et al., 2000; Ballantine & Schneider, 2009). Also of note is that natural upland sites have more carbon than restored uplands. This, again, can be attributed to soil and land disturbance associated both with normal cultivation and restoration activity, even outside the extent of the wetland itself.

Synthesis

A companion study detailing the vegetation communities of these wetlands was conducted earlier (McFarland et al., 2015). Using the same research plots as this study, annual carbon inputs were estimated as the sum of annual herbaceous growth and annual leaf litter fall. Although restored wetlands were dominated by herbaceous inputs, and natural wetlands by leaf litter, total plant carbon inputs to restored and natural sites were not significantly different.

We know that the soils in wetland zones 1 and 2 are ponded or saturated substantially longer than the soils in the non-wetland zone 3. This leads to establishment of anaerobic conditions for extended periods during the wet season as evidenced by the IRIS tube data. These saturated and anaerobic soil conditions force microbial decomposition to proceed through anaerobic pathways, which generally impedes the rates of organic matter decomposition. This is demonstrated by the much higher rates of decomposition recorded to sticks in the non-wetland zone 3 sites. Since McFarland's (2015) data indicate that C inputs have been generally uniform across the sites, the lower rates of decomposition in the wetland zones 1 and 2 would lead us to expect that C stocks in these wetland zones would be greater than in the non-wetland sites. However, while we observe this in the natural sites, there is no difference in carbon in the restored sites.

During the period since restoration (7 to 28 years depending on the particular site), the quantity of C stored in the restored wetland soils has not become detectably greater than in the non-wetland zones. There are likely two reasons for this. First, other researchers (Ballantine & Schneider, 2009; Fenstermacher et al., 2016) have demonstrated that the expected timeframe to see significant increases in soil organic carbon in restored wetlands can be 30 to 55 years or even more. Secondly, restoration activity from earth-moving equipment can introduce variability through mixing of soil materials, which can make detection of small changes more difficult. Nevertheless, the data from this study indicate that organic carbon should be accumulating within the soils of the zones 1 and 2 restored wetlands. Eventually this should lead to the development and formation of A and O horizons and the accumulation of soil carbon stocks in the restored wetlands that are greater than in the surrounding non-wetland areas.

In order to further evaluate whether organic carbon was measurably accumulating in the restored wetlands, the carbon stocks in the zone 1 plots were regressed against the time since restoration. This regression was not significant ($p = 0.32$). In addition, the ratio of organic C stocks in zone 1 to those in zone 3 (wetland:upland) were regressed against the age of the restored wetlands. Although this ratio would be expected to increase with restored wetland age, this regression also was not significant ($p = 0.42$). This further confirms that there has been insufficient time for organic carbon to appreciably accumulate in these restored wetlands.

Chapter 5: Conclusions

The overall goal of this study was to compare selected physical soil properties, and also those properties and processes that contribute to the sequestration of organic carbon, between natural wetlands and those restored using common techniques (scraping). Fourteen freshwater depressional wetlands, including 5 natural sites and 9 sites restored over a 7 to 28 year period, were examined across the Delmarva Peninsula, and a total of 126 plots were established according to 3 distinct hydrological zones (ponded hydric soils; non-ponded hydric soils; and non-hydric soils). Each plot was sampled and instrumented in order to measure a number of physical and chemical soil properties over the course of a year. The observations made can be broadly divided into three categories: those pertaining to the physical effects of restoration activities, those pertaining to water tables, and those pertaining to soil carbon.

The physical impact of restoration activity was primarily evidenced by increased soil compaction. This was manifest in both higher bulk density and higher penetration resistance in restored sites relative to the natural sites. Penetration resistance (as cone index) was higher overall in restored sites. It also increased more abruptly and at shallower depths in the soil profile in restored sites than in natural sites. This compaction and penetration resistance was most likely the result of vehicular traffic on the restored sites where heavy equipment was utilized during excavation, scraping, and shaping the land surface. It is also possible that there was intentional compacting of the soil during restoration with the goal of creating a perching soil layer to maintain wetland hydrological conditions. The degree of soil compaction observed in restored sites was sufficient to be both root restricting and hydrologically limiting, which could impact the restored wetland in a number of ways. Resistance to root penetration can stunt plant growth, and can also cause changes in the plant community (that is better adapted to compacted soil conditions). These sorts of changes in wetland plant communities can lead to soil changes in the magnitude and form of soil carbon inputs.

Two years of water table data were modeled for each plot from monthly manual water table readings and automatic water table data obtained from data loggers. These data confirmed initial assessments that the 3 zones identified by field methods were in fact hydrologically distinct in both restored and natural wetlands. Additionally, within each hydrologic zone, natural wetlands maintained longer periods of saturated soil conditions throughout the year than restored wetlands. This was further reflected in the decomposition rates obtained as mass loss of buried wooden sticks. Decomposition rates were correlated with duration of soil saturation, and hydric soils had demonstrably lower rates of decomposition than non-hydric soils. Other factors, such as quantity of soil nitrogen, did not appear to affect decomposition rates, or the effect was masked by the much larger effect of hydrology. Despite the observed difference in duration of saturation over the course of a year, IRIS tube analysis demonstrated that all the soils (in zones 1 and 2) in all sites were sufficiently saturated during the spring to allow the development of anaerobic conditions and to facilitate the reduction of iron in the soil.

Soil carbon data were obtained by horizon for each plot to a depth of 50 cm. Natural sites demonstrated greater overall carbon stocks than their restored counterparts. Additionally, natural sites had more carbon stored within hydric soil zones (1 and 2) than in the surrounding non-hydric zones. This was expected, given the greater duration of saturation and slower rates of decomposition in the wetter zones of natural sites. As a group, the restored sites stored less organic carbon than the natural sites. This is likely best attributed to the physical mixing and removal of organic-rich surface soil material during restoration, and the drier conditions (and resulting higher decomposition rates) post-restoration. Interestingly, restored sites showed no significant differences in carbon stocks between the three hydrologic zones, despite differences in the duration of inundation. This could be the result of homogenization of soil material during restoration activity, but it could also be as the result of the relatively short period of time since restoration that these soils have had had to accumulate carbon.

Analysis of the plant communities and vegetative growth at these same sites (undertaken by McFarland in 2015) demonstrated that total carbon inputs to wetlands were similar between restored and natural wetlands, and were also similar among the three hydrologic zones. The proportion of inputs from herbaceous vegetation and leaf litter varied, but the overall carbon input did not. The restored wetlands in this study do not appear to have not accumulated appreciable amounts of carbon since restoration. This may be due in part to the greater overall decomposition rates demonstrated in the restored wetlands. Other studies, however, have demonstrated that carbon sequestration in restored wetlands my be a very slow process, and that it may sometimes require in excess of 50 years (perhaps far more), in order for soil carbon stocks in restored wetlands to approach levels comparable to their natural state.

This study suggests several implications for future restoration activity. If the goal of restoration is to foster development of natural-like systems, restoration methodology should seek to, above all, minimize soil disturbance and compaction. Approaches utilizing excavation and intentional compaction will likely result in wetlands with soil properties that are strongly contrasting with their natural counterparts. Therefore, when this is the primary goal, future restoration efforts should seek to target sites that do not require extensive earth moving effort to accomplish the restoration. One way to accomplish this would be to focusing restoration activity on prior-converted cropland (areas that formerly were wetlands). In addition to changes in restoration strategies, here should also be changes to restoration monitoring. This study is in agreement with numerous other studies that have found that some wetland soil properties are slow to change (such as increased accumulation of carbon stocks), often taking many decades to return to levels comparable to natural wetlands. Therefore, it should be expected that longer periods of monitoring and observation will be required in order to properly demonstrate that the soils of restored wetlands are on trajectory to return to a natural state. Nevertheless, some short term monitoring strategies (such as IRIS technology) may be useful in demonstrating that anaerobic wetland soil functions may be operating long before changes in carbon storage could be documented.

Appendix A. Bulk density, percent C and carbon stocks to 50 cm.

Site	Plot	Segment	Bottom Depth (cm)	Width (cm)	Horizon	Bulk Density (g/cm^3)	Mean %C	Total C (kg/m^2)	C Stocks (kg/m^2)
DEK-R-Jr	1-1	1	3.0	3.0	A	1.15	3.44	1.19	3.61
		2	18.6	15.6	Ap	1.89	0.59	1.74	
		3	26.0	7.4	A/Bt	1.88	0.23	0.31	
		4	38.1	12.1	Btg/A	1.71	0.13	0.27	
		5	42.2	4.1	Btg	1.74	0.13	0.09	
	1-2	1	11.5	11.5	A	1.49	1.18	2.02	4.24
		2	24.3	12.8	Ap/Btg	1.80	0.73	1.68	
		3	34.6	10.3	Btg	1.84	0.22	0.42	
		4	40.4	5.8	BCg	1.74	0.12	0.12	
	1-3	1	7.0	7.0	A	0.69	3.26	1.59	8.87
		2	37.9	30.9	A/Btg	1.51	1.13	5.28	
		3	47.0	9.1	A'	1.57	1.41	2.01	
	4-1	1	6.3	6.3	A	1.24	2.59	2.02	4.66
		2	14.1	7.8	Ap	1.56	1.42	1.72	
		3	21.0	6.9	A/Bt	1.83	0.31	0.39	
		4	39.1	18.1	Btg/A	1.87	0.13	0.45	
		5	42.7	3.6	Btg	2.06	0.12	0.09	
	4-2	1	10.0	10.0	A	0.99	2.69	2.66	6.03
		2	21.5	11.5	Ap	1.31	1.80	2.72	
		3	36.7	15.2	Btg/A1	1.67	0.18	0.45	
		4	48.5	11.8	Btg/A2	1.89	0.09	0.21	
	4-3	1	5.6	5.6	A	1.11	2.80	1.74	10.87
		2	20.0	14.4	A/Btg 1	1.52	1.39	3.05	
		3	46.4	26.4	A/Btg 2	1.55	1.49	6.08	
	7-1	1	2.7	2.7	A	1.12	2.99	0.90	2.95
		2	10.3	7.6	Ap	1.66	1.01	1.27	
		3	17.1	6.8	A/Btg	2.03	0.21	0.30	
		4	38.3	21.2	Btg/A1	1.71	0.11	0.40	
		5	43.7	5.4	Btg/A2	1.58	0.10	0.09	
	7-2	1	12.2	12.2	Ap	1.40	1.56	2.65	3.90
		2	25.5	13.3	Btg1	1.75	0.33	0.78	
		3	36.3	10.8	Btg2	1.71	0.20	0.36	
		4	40.5	4.2	BCg	1.94	0.13	0.11	
	7-3	1	6.0	6.0	A1	1.07	1.72	1.10	6.32
		2	16.1	10.1	A2	1.26	1.23	1.56	

		3	29.3	13.2	A3	1.24	1.02	1.68	
		4	50.0	20.7	A/Btg	1.56	0.61	1.98	
DENC-N-BB	1-1	1	3.1	3.1	Oe	0.16	35.07	1.78	17.86
		2	11.9	8.8	Oa	0.51	11.02	4.95	
		3	29.0	17.1	A	0.93	5.93	9.38	
		4	35.2	6.2	AB	1.19	2.39	1.76	
	1-2	1	12.2	12.2	Oe	0.28	25.88	8.86	12.39
		2	22.9	10.7	A	0.96	2.97	3.04	
		3	39.7	16.8	Btg	1.67	0.18	0.50	
	1-3	1	5.6	5.6	Oe	0.33	14.79	2.71	6.64
		2	13.5	7.9	A	0.82	3.42	2.21	
		3	27.2	13.7	E	1.44	0.61	1.21	
		4	42.2	15.0	Bt	1.42	0.24	0.51	
	4-1	1	4.9	4.9	Oe	0.20	25.33	2.42	13.69
		2	13.8	8.9	Oa	0.65	6.66	3.87	
		3	29.8	16.0	A	0.81	5.42	6.98	
		4	34.3	4.5	C	1.36	0.69	0.42	
	4-2	1	2.0	2.0	Oe	0.43	11.82	1.02	17.43
		2	7.1	5.1	A1	0.76	5.12	1.97	
		3	15.7	8.6	A2	1.24	3.35	3.58	
		4	45.7	30.0	A3	1.26	2.86	10.85	
	4-3	1	3.7	3.7	Oe	0.35	12.80	1.68	6.32
		2	10.9	7.2	A	0.86	3.17	1.97	
		3	17.5	6.6	E	1.15	1.05	0.80	
		4	31.8	14.3	Bt	1.47	0.61	1.29	
		5	40.8	9.0	AE	1.44	0.45	0.58	
	7-1	1	2.8	2.8	Oe	0.12	30.20	1.04	13.49
		2	12.5	9.7	Oa	0.48	13.28	6.20	
		3	28.1	15.6	A	0.91	4.40	6.25	
	7-2	1	3.2	3.2	Oe	0.22	26.81	1.92	18.55
		2	9.0	5.8	A1	0.47	7.92	2.16	
		3	30.4	21.4	A2	1.10	3.81	8.97	
		4	43.8	13.4	AE	1.16	3.53	5.50	
	7-3	1	4.0	4.0	Oe	0.17	32.52	2.24	10.86
		2	13.2	9.2	A	0.90	5.03	4.15	
		3	29.3	16.1	Bt	1.33	1.22	2.60	
		4	36.5	7.2	Ab	1.31	1.32	1.24	
		5	46.8	10.3	BC	1.54	0.40	0.63	
MDC-N-AB	1-1	1	4.6	4.6	Oe	0.16	41.77	3.12	22.09
		2	12.1	7.5	A1	0.50	17.98	6.77	
		3	24.3	12.2	A2	0.69	8.18	6.92	

		4	30.0	5.7	BEg	0.92	4.55	2.40	
		5	39.4	9.4	Btg	0.92	3.33	2.87	
	1-2	1	4.2	4.2	Oe	0.32	21.29	2.84	17.10
		2	20.5	16.3	A	0.86	7.76	10.90	
		3	28.9	8.4	AB	1.40	1.48	1.75	
		4	37.4	8.5	Btg1	1.56	0.70	0.93	
		5	46.7	9.3	Btg2	1.39	0.52	0.68	
	1-3	1	2.9	2.9	Oe	0.36	16.25	1.68	19.29
		2	18.7	15.8	A	0.79	6.90	8.62	
		3	27.4	8.7	E	0.90	3.26	2.55	
		4	36.9	9.5	Bs	1.12	3.00	3.19	
		5	42.9	6.0	Bhs	0.87	6.27	3.26	
	4-1	1	6.2	6.2	Oe	0.20	36.10	4.44	24.12
		2	19.2	13.0	A1	0.59	11.09	8.46	
		3	29.6	10.4	A2	0.66	9.94	6.78	
		4	38.7	9.1	AB	0.74	5.04	3.42	
		5	43.9	5.2	Bt	0.66	2.96	1.02	
	4-2	1	2.8	2.8	Oe	0.37	27.56	2.82	21.32
		2	11.8	9.0	Oa	0.86	9.53	7.40	
		3	26.3	14.5	A	1.11	5.13	8.22	
		4	43.4	17.1	Btg	1.38	1.22	2.88	
	4-3	1	4.2	4.2	Oi	0.14	38.57	2.24	10.26
		2	10.4	6.2	Oe	0.59	9.35	3.41	
		3	16.6	6.2	AB	1.02	3.17	1.99	
		4	37.8	21.2	Bt	1.34	0.85	2.42	
		5	43.1	5.3	BC	1.62	0.23	0.20	
	7-1	1	3.7	3.7	Oe	0.14	40.95	2.16	26.49
		2	12.0	8.3	A1	0.44	18.24	6.69	
		3	22.4	10.4	A2	0.65	12.50	8.47	
		4	31.7	9.3	AB1	0.78	6.84	4.98	
		5	41.0	9.3	AB2	0.91	4.94	4.19	
	7-2	1	3.1	3.1	Oe	0.36	30.34	3.41	21.03
		2	17.6	14.5	Oa	0.59	14.16	12.02	
		3	27.2	9.6	A	1.17	3.12	3.50	
		4	49.6	22.4	Btg	1.57	0.60	2.10	
	7-3	1	5.9	5.9	Oe	0.40	19.98	4.72	9.97
		2	15.0	9.1	A	1.08	3.04	2.98	
		3	25.9	10.9	AB	1.28	1.01	1.41	
		4	40.0	14.1	Bt1	1.20	0.37	0.62	
		5	46.4	6.4	Bt2	1.57	0.24	0.24	
MDC-N-BC	1-1	1	4.5	4.5	Oe	0.09	45.94	1.87	35.33

	2	46.0	41.5	Oa	0.44	18.38	33.47	
1-2	1	5.7	5.7	Oe	0.25	34.16	4.84	24.26
	2	24.1	18.4	A1	0.81	8.04	11.93	
	3	35.5	11.4	A2	1.16	3.79	5.03	
	4	41.5	6.0	AB	1.20	3.41	2.47	
1-3	1	5.5	5.5	Oe	0.23	32.48	4.09	11.03
	2	9.4	3.9	A1	0.79	6.38	1.96	
	3	15.6	6.2	A2	1.10	2.73	1.86	
	4	27.9	12.3	AB	1.31	1.48	2.38	
	5	50.0	22.1	Bw	1.58	0.21	0.74	
4-1	1	8.0	8.0	Oe	0.16	36.76	4.67	27.47
	2	36.0	28.0	Oa	0.30	27.12	22.80	
4-2	1	9.2	9.2	Oe	0.15	47.00	6.47	30.64
	2	26.9	17.7	A1	0.62	13.34	14.75	
	3	43.0	16.1	A2	1.10	5.30	9.42	
4-3	1	4.3	4.3	Oe	0.44	15.22	2.88	6.35
	2	9.1	4.8	A1	0.79	2.20	0.83	
	3	13.5	4.4	A2	1.42	1.33	0.83	
	4	21.5	8.0	AB	1.37	0.82	0.89	
	5	46.8	25.3	BE	1.58	0.23	0.92	
7-1	1	5.5	5.5	Oe	0.13	45.53	3.34	26.15
	2	43.2	37.7	Oa	0.43	14.05	22.81	
7-2	1	8.0	8.0	Oe	0.15	38.98	4.72	21.53
	2	18.7	10.7	A1	0.79	7.47	6.33	
	3	37.5	18.8	A2	1.27	3.46	8.26	
	4	42.7	5.2	AB	1.27	1.38	0.91	
	5	47.3	4.6	Ab	1.72	1.67	1.32	
7-3	1	4.8	4.8	Oe	0.21	30.31	3.12	10.52
	2	10.8	6.0	A1	1.10	3.88	2.57	
	3	21.2	10.4	A2	0.92	3.16	3.02	
	4	35.8	14.6	BE	1.16	0.81	1.38	
	5	45.9	10.1	Bw	1.46	0.29	0.43	
MDC-N-BeW 1-1	1	8.2	8.2	Oe	0.16	30.53	4.02	11.48
	2	18.5	10.3	A1	0.89	3.41	3.11	
	3	30.5	12.0	A2	0.96	1.86	2.15	
	4	42.5	12.0	AB	1.09	1.69	2.20	
1-2	1	2.6	2.6	Oe	0.51	13.12	1.74	8.30
	2	11.6	9.0	A	1.03	3.30	3.07	
	3	21.7	10.1	AB	1.47	1.02	1.52	
	4	32.3	10.6	Bt	1.37	1.37	1.98	
1-3	1	4.0	4.0	Oe	0.34	20.95	2.82	7.11

		2	14.1	10.1	A	1.09	2.22	2.44	
		3	25.2	11.1	AE	1.37	0.68	1.03	
		4	42.0	16.8	E	1.46	0.22	0.55	
		5	47.3	5.3	Bt	1.83	0.28	0.27	
	4-1	1	7.2	7.2	Oe	0.42	15.40	4.69	15.12
		2	25.0	17.8	A1	1.13	3.56	7.18	
		3	35.5	10.5	A2	1.30	1.09	1.49	
		4	48.0	12.5	AB	1.28	1.10	1.76	
	4-2	1	5.1	5.1	Oe	0.50	12.60	3.19	10.58
		2	12.3	7.2	A	0.86	5.61	3.48	
		3	19.9	7.6	Btg1	1.39	1.94	2.04	
		4	28.3	8.4	Btg2	1.26	0.91	0.97	
		5	38.9	10.6	Btg3	1.78	0.48	0.90	
	4-3	1	4.5	4.5	Oe	0.35	19.40	3.03	8.57
		2	9.2	4.7	A	1.04	2.92	1.43	
		3	17.6	8.4	Bt/A	1.17	1.92	1.89	
		4	34.3	16.7	Bt	1.49	0.72	1.80	
		5	46.5	12.2	BC	1.67	0.21	0.43	
	7-1	1	6.6	6.6	Oe	0.40	14.96	3.95	9.62
		2	22.0	15.4	A	1.10	2.35	3.98	
		3	39.3	17.3	BEg	1.70	0.44	1.28	
		4	45.7	6.4	Btg	1.56	0.40	0.40	
	7-2	1	4.1	4.1	Oe	0.30	18.76	2.31	9.44
		2	11.2	7.1	A1	1.10	3.98	3.11	
		3	19.6	8.4	A2	1.37	2.16	2.48	
		4	32.4	12.8	Btg1	1.73	0.55	1.22	
		5	44.5	12.1	Btg2	2.13	0.13	0.33	
	7-3	1	5.3	5.3	Oe	0.54	9.50	2.74	8.79
		2	10.6	5.3	A1	1.10	3.23	1.89	
		3	18.1	7.5	A2	1.15	1.59	1.37	
		4	28.0	9.9	AB	1.42	1.05	1.47	
		5	45.6	17.6	Btg	1.59	0.47	1.32	
MDC-N-JL	1-1	1	10.0	10.0	Oa	0.34	7.62	2.60	9.06
		2	20.3	10.3	A	1.54	2.99	4.73	
		3	29.1	8.8	ABg	1.42	0.96	1.20	
		4	38.5	9.4	Btg	1.64	0.34	0.52	
	1-2	1	5.7	5.7	Oe	0.44	12.38	3.13	19.07
		2	27.4	21.7	A1	1.07	4.13	9.61	
		3	40.2	12.8	A2	1.18	3.63	5.46	
		4	46.4	6.2	A/Bt	1.22	1.17	0.88	
	1-3	1	6.6	6.6	Oe	0.46	15.70	4.74	10.93

		2	11.0	4.4	A	0.79	4.25	1.47	
		3	21.5	10.5	AB	1.45	2.33	3.55	
		4	43.4	21.9	Bt	1.68	0.32	1.17	
	4-1	1	5.5	5.5	Oe	0.31	19.49	3.30	11.88
		2	15.5	10.0	A	0.99	4.32	4.29	
		3	32.1	16.6	Ag	1.41	1.26	2.95	
		4	37.5	5.4	Ab	1.16	2.13	1.33	
	4-2	1	6.5	6.5	Oa	0.74	9.96	4.77	17.90
		2	22.9	16.4	A1	1.38	2.59	5.86	
		3	34.5	11.6	A2	1.35	2.70	4.23	
		4	43.2	8.7	Bt	1.39	2.52	3.04	
	4-3	1	8.5	8.5	Oe	0.32	26.78	7.38	18.80
		2	14.4	5.9	A/A1	1.16	5.04	3.45	
		3	20.5	6.1	AE/A2	1.04	3.89	2.47	
		4	27.8	7.3	Bhs/A3	0.90	4.29	2.82	
		5	42.7	14.9	Bt/AB	1.39	1.30	2.69	
	7-1	1	5.9	5.9	Oe	0.10	49.90	2.97	11.77
		2	19.2	13.3	A1	0.88	6.09	7.16	
		3	29.0	9.8	A2	1.39	0.44	0.60	
		4	33.8	4.8	A3	1.30	1.67	1.04	
	7-2	1	3.7	3.7	Oe	0.27	30.63	3.04	21.04
		2	31.4	27.7	A	0.97	5.56	15.00	
		3	42.6	11.2	AB	1.38	1.94	3.00	
	7-3	1	5.0	5.0	A1	0.47	15.18	3.54	6.88
		2	18.0	13.0	A2	1.25	1.54	2.51	
		3	30.4	12.4	BE	1.66	0.26	0.52	
		4	44.7	14.3	Bt	1.78	0.12	0.30	
MDC-R-JL	1-1	1	3.2	3.2	Oe	0.48	6.38	0.98	11.03
		2	19.2	16.0	A	1.49	2.98	7.10	
		3	35.5	16.3	A/Btg	1.34	1.35	2.95	
	1-2	1	15.4	15.4	A	1.08	5.25	8.74	20.06
		2	27.7	12.3	Ap	1.17	5.54	7.97	
		3	40.3	12.6	A/Btg	1.39	1.58	2.78	
		4	48.4	8.1	Btg	1.42	0.49	0.57	
	1-3	1	6.5	6.5	A	0.93	5.08	3.06	5.57
		2	11.8	5.3	Ap	1.40	1.15	0.85	
		3	28.9	17.1	^E/A	1.75	0.20	0.61	
		4	33.9	5.0	^Btg/A	1.93	0.18	0.17	
		5	47.7	13.8	^E/A'	1.67	0.38	0.87	
	4-1	1	2.2	2.2	Oe	0.49	9.82	1.06	10.79
		2	24.5	22.3	A	1.60	2.21	7.88	

	3	33.5	9.0	AB	1.33	1.54	1.84	
4-2	1	1.3	1.3	Oe	0.77	8.11	0.81	16.18
	2	13.5	12.2	A	1.37	2.18	3.66	
	3	33.1	19.6	Ap/Btg	1.64	2.03	6.52	
	4	42.4	9.3	2Ap/Btg2	0.73	7.70	5.19	
4-3	1	4.6	4.6	A	1.37	2.25	1.42	4.18
	2	15.5	10.9	Ap1	1.35	0.92	1.35	
	3	25.0	9.5	Ap2	1.71	0.60	0.97	
	4	40.2	15.2	EB	1.89	0.10	0.28	
	5	49.0	8.8	Bt	1.88	0.10	0.17	
7-1	1	22.0	22.0	A	1.23	3.61	9.77	12.17
	2	37.0	15.0	A/Btg	1.41	1.14	2.40	
7-2	1	13.8	13.8	A	0.99	5.24	7.12	22.32
	2	29.9	16.1	Ap	1.23	4.24	8.39	
	3	45.5	15.6	A/Btg	1.36	3.20	6.82	
7-3	1	4.1	4.1	A	1.06	2.24	0.97	5.21
	2	25.1	21.0	Ap	1.49	1.22	3.82	
	3	39.0	13.9	BE	1.73	0.10	0.25	
	4	50.2	11.2	Bt	1.60	0.09	0.17	
MDD-R-Ck 1-1	1	1.0	1.0	A	1.40	0.59	0.08	1.09
	2	6.2	5.2	Bw	1.84	0.17	0.17	
	3	24.0	17.8	BC	1.64	0.13	0.39	
	4	44.1	20.1	Cg	1.75	0.13	0.45	
1-2	1	2.3	2.3	A	0.67	5.94	0.91	8.22
	2	6.6	4.3	Ap	1.50	2.43	1.56	
	3	19.1	12.5	2A1	1.30	1.69	2.73	
	4	29.2	10.1	2A2	1.45	1.40	2.05	
	5	42.8	13.6	A/Btg	1.76	0.40	0.96	
1-3	1	8.5	8.5	Ap	1.45	2.47	3.04	13.30
	2	30.0	21.5	Ap/E1	1.43	1.43	4.39	
	3	47.0	17.0	Ap/E2	1.72	2.01	5.87	
4-1	1	6.4	6.4	Ap	1.30	2.77	2.29	4.67
	2	13.5	7.1	A/Cg	1.80	0.83	1.07	
	3	21.7	8.2	Cg/A	1.82	0.38	0.56	
	4	34.2	12.5	Cg/Btg	1.76	0.19	0.43	
	5	44.3	10.1	Btg	1.69	0.19	0.32	
4-2	1	2.2	2.2	A	1.12	3.49	0.86	3.78
	2	10.2	8.0	Ap/Bt	1.69	1.24	1.68	
	3	20.0	9.8	BA	1.84	0.40	0.71	
	4	34.1	14.1	Btg	1.86	0.12	0.30	
	5	44.3	10.2	BCg	1.80	0.12	0.22	

	4-3	1	12.9	12.9	Ap1	1.40	2.97	5.37	8.86
		2	30.0	17.1	Ap2	1.67	1.12	3.19	
		3	34.7	4.7	Btg	1.81	0.15	0.13	
		4	47.0	12.3	BCg	1.96	0.07	0.16	
	7-1	1	4.9	4.9	Ap	1.08	1.47	0.78	2.17
		2	12.7	7.8	A/Btg	1.79	0.33	0.46	
		3	26.4	13.7	Btg	1.94	0.18	0.47	
		4	43.8	17.4	Btg/A	1.79	0.15	0.46	
	7-2	1	7.5	7.5	Ap	1.30	2.86	2.80	6.22
		2	16.7	9.2	Ap/Bt	1.50	1.85	2.55	
		3	27.3	10.6	Bt	1.79	0.24	0.45	
		4	48.7	21.4	Btg	1.70	0.12	0.42	
	7-3	1	10.6	10.6	Ap	1.06	2.15	2.42	10.58
		2	30.6	20.0	Ap/E	1.54	1.04	3.20	
		3	42.0	11.4	Ap'	1.49	2.93	4.97	
MDQA-R-BsO	1-1	1	12.1	12.1	Ap1	0.91	1.82	2.01	3.14
		2	23.3	11.2	Ap2	1.71	0.31	0.59	
		3	32.3	9.0	BE	1.75	0.24	0.38	
		4	41.0	8.7	Bt	1.52	0.12	0.16	
	1-2	1	3.1	3.1	A1	1.01	5.77	1.80	6.52
		2	9.5	6.4	A2	0.96	3.08	1.90	
		3	29.5	20.0	BE	1.36	0.72	1.95	
		4	49.8	20.3	Bt	1.60	0.27	0.87	
	1-3	1	6.2	6.2	A	0.51	13.61	4.31	11.27
		2	16.6	10.4	Ap	0.90	3.58	3.34	
		3	31.1	14.5	BE	1.21	1.11	1.95	
		4	49.0	17.9	Bt	1.47	0.64	1.67	
	7-1	1	2.1	2.1	Oe	1.06	1.49	0.33	1.93
		2	10.0	7.9	A	1.32	0.69	0.72	
		3	18.4	8.4	Ap	1.65	0.35	0.49	
		4	31.7	13.3	BA	1.72	0.10	0.23	
		5	47.2	15.5	BE	1.63	0.07	0.17	
	7-2	1	3.3	3.3	A1	0.74	4.24	1.04	2.84
		2	7.0	3.7	A2	1.05	1.98	0.77	
		3	18.4	11.4	BA	1.53	0.43	0.74	
		4	29.8	11.4	Btg	1.80	0.07	0.14	
		5	48.3	18.5	BCg	1.53	0.05	0.14	
	7-3	1	4.0	4.0	A	1.25	2.20	1.10	3.26
		2	15.9	11.9	AB	1.44	0.75	1.29	
		3	38.0	22.1	Btg	1.73	0.19	0.74	
		4	47.5	9.5	BC	1.56	0.08	0.12	

	9-1	1	2.5	2.5	Oe	0.84	2.65	0.55	1.79
		2	12.7	10.2	A	1.47	0.37	0.55	
		3	21.0	8.3	Ap	1.59	0.15	0.20	
		4	38.5	17.5	Btg	1.51	0.13	0.36	
		5	41.4	2.9	Ab	1.44	0.30	0.13	
	9-2	1	4.8	4.8	A	0.32	19.68	3.00	4.16
		2	16.5	11.7	BAg	1.32	0.49	0.75	
		3	29.5	13.0	Btg1	1.87	0.07	0.18	
		4	49.2	19.7	Btg2	1.77	0.06	0.22	
	9-3	1	3.0	3.0	A1	1.13	1.95	0.66	2.06
		2	7.9	4.9	A2	1.43	0.58	0.40	
		3	23.8	15.9	Btg	1.68	0.26	0.70	
		4	48.1	24.3	BCg	1.64	0.07	0.30	
MDQA-R-BsY	0-1	1	4.5	4.5	Oe	0.61	8.34	2.31	5.02
		2	11.2	6.7	Ag	1.36	0.72	0.66	
		3	20.2	9.0	ABtg	1.59	0.61	0.87	
		4	28.5	8.3	Btg1	1.70	0.45	0.63	
		5	46.5	18.0	Btg2	1.80	0.17	0.56	
	0-2	1	4.5	4.5	Oe	0.79	4.64	1.65	4.97
		2	18.1	13.6	Ap1	1.58	0.68	1.46	
		3	36.1	18.0	2Ap2	1.70	0.48	1.45	
		4	49.8	13.7	3Btg	1.79	0.17	0.41	
	0-3	1	9.1	9.1	A	1.13	1.41	1.46	3.79
		2	37.0	27.9	BE	1.59	0.43	1.92	
		3	46.2	9.2	Bt	1.74	0.26	0.42	
	6-1	1	3.5	3.5	Oe	0.73	6.92	1.77	2.76
		2	6.9	3.4	Ag	1.66	0.31	0.17	
		3	18.5	11.6	Btg/Ag	1.84	0.13	0.28	
		4	36.1	17.6	Btg1	1.72	0.13	0.40	
		5	42.8	6.7	Btg2	1.83	0.11	0.13	
	6-2	1	6.9	6.9	A	1.24	2.39	2.04	5.18
		2	21.3	14.4	A/Btg1	1.54	0.57	1.26	
		3	33.8	12.5	A/Btg2	1.59	0.51	1.02	
		4	45.0	11.2	A/Btg3	1.63	0.47	0.86	
	6-3	1	8.4	8.4	A	1.06	2.47	2.19	5.22
		2	20.1	11.7	AB	1.50	0.72	1.26	
		3	31.8	11.7	BEg	1.60	0.39	0.73	
		4	47.2	15.4	Btg	1.57	0.43	1.03	
	8-1	1	5.3	5.3	Ag	0.75	4.00	1.59	3.51
		2	10.2	4.9	Btg	1.77	0.46	0.40	
		3	20.0	9.8	Bt1	1.72	0.37	0.62	

	4	28.2	8.2	Bt2	1.79	0.26	0.39	
	5	43.0	14.8	BC	1.61	0.21	0.51	
8-2	1	5.4	5.4	A1	1.17	1.19	0.75	3.11
	2	11.6	6.2	A2	1.63	0.45	0.46	
	3	28.8	17.2	A/Btg	1.73	0.43	1.27	
	4	46.4	17.6	Btg	1.81	0.20	0.63	
8-3	1	6.6	6.6	A	1.19	2.39	1.88	4.04
	2	23.5	16.9	BA	1.58	0.56	1.49	
	3	46.0	22.5	2Bt	1.75	0.17	0.67	
MDQA-R-En 1-1	1	3.2	3.2	A	1.22	1.43	0.56	3.81
	2	17.5	14.3	Ap1	1.47	0.93	1.95	
	3	26.1	8.6	Ap2	1.53	0.44	0.58	
	4	42.7	16.6	Btg	1.48	0.29	0.72	
1-2	1	8.5	8.5	A	1.42	1.16	1.41	3.63
	2	17.5	9.0	Ap	1.65	0.85	1.27	
	3	24.5	7.0	Btg1	1.83	0.30	0.39	
	4	42.5	18.0	Btg2	1.82	0.17	0.57	
1-3	1	6.3	6.3	A	1.09	4.30	2.96	6.06
	2	12.9	6.6	AB	1.17	1.95	1.50	
	3	21.1	8.2	BA	1.31	0.82	0.88	
	4	42.6	21.5	BE	1.35	0.25	0.72	
4-1	1	3.8	3.8	A	1.28	1.74	0.84	3.72
	2	10.9	7.1	Ap1	1.52	1.10	1.18	
	3	20.2	9.3	Ap2	1.76	0.60	0.98	
	4	42.8	22.6	Btg	1.59	0.20	0.72	
4-2	1	5.0	5.0	A	1.34	1.99	1.34	3.22
	2	12.5	7.5	Ap	1.82	0.86	1.17	
	3	23.8	11.3	Btg	2.10	0.14	0.32	
	4	35.6	11.8	C1	1.86	0.11	0.25	
	5	43.5	7.9	C2	1.66	0.11	0.14	
4-3								0.00
7-1	1	3.4	3.4	A	0.48	6.91	1.13	3.35
	2	10.0	6.6	Ap	1.74	0.73	0.84	
	3	15.1	5.1	AB	1.54	0.56	0.44	
	4	30.2	15.1	Btg	1.56	0.26	0.60	
	5	43.7	13.5	CBg	1.84	0.14	0.34	
7-2	1	3.8	3.8	A	0.93	3.41	1.21	5.74
	2	19.3	15.5	Ap1	1.56	0.90	2.18	

		3	30.9	11.6	Ap2	1.58	0.85	1.55	
		4	49.0	18.1	Btg	1.45	0.31	0.80	
	7-3	1	3.0	3.0	Oe	0.80	7.87	1.88	4.77
		2	8.5	5.5	A	1.42	1.22	0.95	
		3	16.5	8.0	E	1.65	0.44	0.58	
		4	32.0	15.5	Bt1	1.46	0.37	0.84	
		5	42.0	10.0	Bt2	1.69	0.31	0.53	
MDQA-R-Ss	1-1	1	3.6	3.6	Oe	0.30	10.96	1.20	3.24
		2	10.0	6.4	Ag	1.00	1.49	0.95	
		3	28.7	18.7	Btg1	1.52	0.22	0.63	
		4	41.0	12.3	Btg2	1.47	0.21	0.38	
		5	45.0	4.0	Btg3	1.36	0.14	0.08	
	1-2	1	2.6	2.6	A	0.54	6.17	0.86	5.46
		2	11.8	9.2	AB1	1.35	1.23	1.53	
		3	30.6	18.8	AB2	1.52	0.76	2.17	
		4	48.0	17.4	Btg	1.55	0.34	0.91	
	1-3	1	3.1	3.1	A	1.08	2.67	0.89	3.43
		2	11.4	8.3	Ap1	1.46	0.91	1.10	
		3	21.5	10.1	Ap2	1.63	0.36	0.60	
		4	38.0	16.5	Bt	1.67	0.24	0.65	
		5	45.9	7.9	BC	1.87	0.13	0.19	
	4-1	1	2.0	2.0		0.24	14.37	0.68	5.95
		2	10.0	8.0		0.98	2.24	1.75	
		3	24.0	14.0		1.52	0.89	1.89	
		4	29.0	5.0		1.38	1.10	0.76	
		5	46.0	17.0		1.56	0.33	0.86	
	4-2	1	4.2	4.2	A	0.71	3.63	1.08	6.00
		2	15.1	10.9	AB1	1.32	1.40	2.02	
		3	28.9	13.8	AB2	1.58	0.81	1.75	
		4	45.6	16.7	Btg	1.48	0.46	1.14	
	4-3	1	8.6	8.6	Ap	1.37	1.30	1.53	3.33
		2	17.2	8.6	Ap/Bt	1.44	0.63	0.78	
		3	34.1	16.9	Bt1	1.60	0.25	0.67	
		4	46.2	12.1	Bt2	1.55	0.19	0.35	
	7-1	1	4.0	4.0	Oe	0.27	10.77	1.18	3.47
		2	10.0	6.0	A	1.12	1.14	0.77	
		3	22.5	12.5	E	1.49	0.40	0.74	
		4	43.0	20.5	Btg1	1.42	0.24	0.68	
		5	46.0	3.0	Btg2	1.82	0.18	0.10	
	7-2	1	1.5	1.5	A	0.52	6.41	0.50	6.49
		2	10.5	9.0	AB1	1.26	1.30	1.47	

		3	27.5	17.0	AB2	1.48	0.86	2.17	
		4	35.6	8.1	Bt	1.27	0.90	0.93	
		5	45.5	9.9	Ab	1.26	1.13	1.42	
	7-3	1	4.2	4.2	A	0.99	1.79	0.74	3.12
		2	19.1	14.9	Ap	1.54	0.65	1.51	
		3	30.7	11.6	BE	1.74	0.21	0.42	
		4	46.4	15.7	Bt1	1.67	0.15	0.39	
		5	49.6	3.2	Bt2	1.74	0.12	0.07	
MDQA-R-Ws	1-1	1	2.6	2.6	Oe	0.28	15.52	1.12	4.42
		2	12.8	10.2	A	1.24	1.22	1.55	
		3	28.0	15.2	ABg	1.51	0.48	1.10	
		4	37.1	9.1	Btg1	1.72	0.21	0.33	
		5	47.0	9.9	Btg2	1.64	0.20	0.32	
	1-2	1	1.9	1.9	Oe	0.50	9.64	0.91	3.68
		2	18.4	16.5	Ap	1.48	0.80	1.96	
		3	31.3	12.9	Btg1	1.73	0.19	0.43	
		4	47.6	16.3	Btg2	1.82	0.13	0.38	
	1-3	1	6.4	6.4	A	1.05	1.76	1.19	4.35
		2	27.0	20.6	Ap	1.52	0.77	2.40	
		3	40.0	13.0	BE	1.72	0.22	0.49	
		4	50.3	10.3	Bt	1.62	0.17	0.28	
	4-1	1	2.0	2.0	Oe	0.56	9.07	1.02	3.35
		2	13.9	11.9	Ag	1.43	0.74	1.26	
		3	20.2	6.3	ABg	1.61	0.54	0.55	
		4	29.6	9.4	Btg1	1.75	0.17	0.28	
		5	41.0	11.4	Btg2	1.81	0.11	0.23	
	4-2	1	2.0	2.0	Oe	0.73	5.90	0.86	4.07
		2	11.3	9.3	A	1.69	0.88	1.39	
		3	23.0	11.7	AB	2.01	0.43	1.02	
		4	46.6	23.6	Btg	1.60	0.21	0.79	
	4-3	1	2.3	2.3	^A	0.89	4.00	0.82	4.24
		2	8.8	6.5	^C	1.61	0.41	0.43	
		3	34.0	25.2	Ab	1.55	0.61	2.39	
		4	48.6	14.6	Btg	1.64	0.25	0.60	
	7-1	1	5.1	5.1	Ag1	1.30	1.36	0.90	3.16
		2	21.2	16.1	Ag2	1.47	0.71	1.67	
		3	35.0	13.8	Btg1	1.67	0.16	0.38	
		4	44.4	9.4	Btg2	1.56	0.14	0.21	
	7-2	1	2.0	2.0	Oe	1.12	3.63	0.81	4.91
		2	15.0	13.0	A1	1.51	0.92	1.80	
		3	27.5	12.5	A2	1.64	0.64	1.32	

		4	42.5	15.0	Btg	1.58	0.41	0.97	
	7-3	1	18.4	18.4	A	1.34	1.19	2.93	4.35
		2	27.4	9.0	Ap	1.49	0.56	0.75	
		3	40.5	13.1	BE	1.66	0.23	0.49	
		4	46.5	6.0	Bt	1.70	0.17	0.18	
MDT-R-DF	1-1	1	6.1	6.1	A	1.12	1.88	1.28	2.39
		2	19.1	13.0	AB	1.79	0.22	0.52	
		3	33.1	14.0	Bt	1.85	0.13	0.33	
		4	43.6	10.5	BC1	1.73	0.10	0.19	
		5	49.0	5.4	BC2	1.51	0.09	0.08	
	1-2	1	2.6	2.6	^Ag	1.22	2.12	0.67	3.30
		2	12.6	10.0	^ABg	1.38	0.48	0.67	
		3	24.0	11.4	^Cg1	1.61	0.47	0.87	
		4	34.1	10.1	^Cg2	1.79	0.31	0.56	
		5	50.9	16.8	2Btg	1.75	0.18	0.53	
	1-3	1	6.6	6.6	A1	1.06	1.42	0.99	3.80
		2	15.4	8.8	A2	1.69	0.44	0.65	
		3	28.3	12.9	A3	1.68	0.37	0.80	
		4	47.7	19.4	Ag	1.68	0.42	1.35	
	3-1	1	4.1	4.1	A	1.10	1.99	0.90	2.76
		2	15.2	11.1	Ap	1.54	0.53	0.90	
		3	29.5	14.3	Btg1	1.67	0.21	0.49	
		4	46.6	17.1	Btg2	1.75	0.15	0.46	
	3-2	1	3.7	3.7	^A	0.83	3.88	1.19	3.63
		2	25.4	21.7	^Cg(Ag)	1.59	0.53	1.82	
		3	44.6	19.2	2Btg	1.70	0.19	0.63	
	3-3	1	6.5	6.5	A	1.17	1.61	1.22	2.71
		2	28.7	22.2	A/Btg	1.53	0.36	1.22	
		3	40.0	11.3	Btg	1.76	0.14	0.27	
	4-1	1	4.9	4.9	A	1.20	1.98	1.17	3.79
		2	13.6	8.7	AB	1.58	0.55	0.76	
		3	30.4	16.8	BA	1.62	0.48	1.30	
		4	45.4	15.0	Btg	1.53	0.25	0.56	
	4-2	1	2.0	2.0	^A	0.75	5.54	0.83	3.74
		2	6.2	4.2	^AB	1.30	1.55	0.85	
		3	24.0	17.8	^Bg	1.61	0.48	1.39	
		4	35.4	11.4	2Btg	1.59	0.21	0.38	
		5	46.0	10.6	2Btg2	1.89	0.15	0.29	
	4-3	1	3.3	3.3	A1	1.07	1.13	0.40	2.91
		2	25.4	22.1	A2	1.61	0.43	1.52	
		3	42.0	16.6	A/Btg	1.70	0.28	0.80	

		4	51.0	9.0	Btg	1.73	0.12	0.19	
MDT-R-Fr	1-1	1	11.0	11.0	Ap	0.74	3.08	2.50	3.04
		2	23.8	12.8	Cg1	1.76	0.10	0.22	
		3	34.0	10.2	Cg2	1.82	0.07	0.12	
		4	45.0	11.0	2Btg	1.68	0.11	0.20	
	1-2	1	4.0	4.0	Oe	0.46	10.00	1.84	3.47
		2	6.5	2.5	A	1.83	0.68	0.31	
		3	16.5	10.0	Ap	1.67	0.46	0.77	
		4	29.5	13.0	Cg1	1.58	0.13	0.26	
		5	43.0	13.5	Cg2	1.78	0.12	0.29	
	1-3	1	5.5	5.5	Ap1	1.33	1.48	1.08	3.88
		2	13.1	7.6	Ap2	1.44	0.74	0.81	
		3	21.5	8.4	EA	1.56	0.57	0.75	
		4	33.0	11.5	E	1.58	0.40	0.73	
		5	49.3	16.3	Btg	1.72	0.18	0.51	
	4-1	1	4.3	4.3	A	0.38	9.96	1.65	3.08
		2	9.0	4.7	Ap	1.05	1.51	0.75	
		3	19.8	10.8	Btg1	1.24	0.25	0.34	
		4	40.0	20.2	Btg2	1.47	0.12	0.35	
	4-2	1	7.0	7.0	Oa	0.47	6.83	2.23	5.36
		2	17.0	10.0	A	1.17	1.03	1.20	
		3	33.5	16.5	Btg1	1.43	0.62	1.47	
		4	44.0	10.5	Btg2	1.51	0.29	0.45	
	4-3	1	4.0	4.0	Oe	1.27	1.79	0.91	4.97
		2	20.0	16.0	A	1.44	0.92	2.12	
		3	33.0	13.0	AE	1.58	0.65	1.34	
		4	44.0	11.0	Bt	1.55	0.35	0.60	
	7-1	1	7.6	7.6	Ap	0.88	3.51	2.34	3.12
		2	16.6	9.0	Btg1	1.61	0.27	0.39	
		3	32.2	15.6	Btg2	1.61	0.12	0.29	
		4	43.0	10.8	CBg	1.43	0.06	0.10	
	7-2	1	3.5	3.5	Oe	0.61	7.00	1.50	4.27
		2	10.5	7.0	A	1.54	0.79	0.86	
		3	28.0	17.5	Ap	1.65	0.48	1.39	
		4	43.0	15.0	Btg	1.50	0.23	0.52	
	7-3	1	2.5	2.5	Oe	0.96	2.54	0.61	4.45
		2	22.0	19.5	A	1.40	0.95	2.60	
		3	37.0	15.0	Bt	1.52	0.37	0.83	
		4	47.0	10.0	Btg	1.55	0.26	0.40	

Appendix B. Percent of time saturated at 5 cm and 30 cm.

Based upon modeling of hydrographs at each plot over the two year period of July 2012 through June 2014.

Plot		Depth	1-1	4-1	7-1	Zone 1 Mean	Zone 1 SEM	1-2	4-2	7-2	Zone 2 Mean	Zone 2 SEM	1-3	4-3	7-3	Zone 3 Mean	Zone 3 SEM
BB	N1	5 cm	100.0%	100.0%	100.0%	100.0%	0.0%	0.0%	0.0%	7.4%	2.5%	2.5%	0.0%	0.0%	0.0%	0.0%	0.0%
		30 cm	100.0%	100.0%	100.0%	100.0%	0.0%	74.9%	48.7%	88.5%	70.7%	11.7%	0.0%	0.0%	0.0%	0.0%	0.0%
AB	N2	5 cm	91.7%	91.7%	91.5%	91.6%	0.1%	63.3%	66.7%	63.3%	64.4%	1.2%	0.0%	0.0%	0.0%	0.0%	0.0%
		30 cm	100.0%	100.0%	100.0%	100.0%	0.0%	88.6%	89.0%	88.6%	88.8%	0.1%	1.4%	0.0%	1.1%	0.8%	0.4%
BC	N3	5 cm	100.0%	98.2%	99.0%	99.1%	0.5%	71.6%	66.3%	27.0%	55.0%	14.1%	0.0%	0.0%	0.0%	0.0%	0.0%
		30 cm	100.0%	100.0%	100.0%	100.0%	0.0%	93.1%	90.5%	83.2%	89.0%	3.0%	0.0%	0.0%	0.0%	0.0%	0.0%
BeW	N4	5 cm	88.7%	88.0%	87.3%	88.0%	0.4%	39.4%	16.2%	0.0%	18.6%	11.4%	0.0%	0.0%	0.0%	0.0%	0.0%
		30 cm	100.0%	100.0%	100.0%	100.0%	0.0%	79.2%	74.6%	68.5%	74.1%	3.1%	0.0%	0.0%	0.0%	0.0%	0.0%
JLN	N5	5 cm	100.0%	97.4%	98.1%	98.5%	0.8%	63.4%	72.8%	74.4%	70.2%	3.4%	0.0%	0.0%	0.0%	0.0%	0.0%
		30 cm	100.0%	100.0%	100.0%	100.0%	0.0%	88.1%	96.1%	97.3%	93.8%	2.9%	0.6%	37.4%	4.8%	14.3%	11.6%
Jr	R1	5 cm	94.2%	94.1%	94.0%	94.1%	0.1%	39.9%	36.7%	36.7%	37.8%	1.1%	0.0%	0.0%	0.0%	0.0%	0.0%
		30 cm	95.3%	95.2%	94.9%	95.2%	0.1%	80.8%	79.1%	79.1%	79.7%	0.6%	0.0%	0.0%	0.0%	0.0%	0.0%
JLR	R2	5 cm	81.4%	78.0%	79.2%	79.5%	1.0%	49.2%	45.0%	46.6%	46.9%	1.2%	0.0%	0.0%	0.0%	0.0%	0.0%
		30 cm	93.5%	87.7%	89.6%	90.3%	1.7%	77.0%	73.7%	74.5%	75.1%	1.0%	0.0%	6.7%	15.6%	7.4%	4.5%
Ck	R3	5 cm	64.6%	63.5%	64.0%	64.1%	0.3%	29.3%	29.3%	23.3%	27.3%	2.0%	0.0%	1.1%	0.0%	0.4%	0.4%
		30 cm	70.4%	70.3%	70.3%	70.3%	0.1%	55.5%	55.5%	54.5%	55.2%	0.3%	1.9%	49.3%	3.2%	18.1%	15.6%
BsO	R4	5 cm	100.0%	100.0%	100.0%	100.0%	0.0%	12.5%	13.4%	38.1%	21.3%	8.4%	0.0%	0.0%	0.0%	0.0%	0.0%
		30 cm	100.0%	100.0%	100.0%	100.0%	0.0%	44.1%	56.1%	96.8%	65.7%	16.0%	0.0%	31.1%	29.9%	20.3%	10.2%
BsY	R5	5 cm	66.2%	100.0%	89.1%	85.1%	10.0%	27.4%	0.0%	27.8%	18.4%	9.2%	0.0%	0.0%	1.0%	0.3%	0.3%
		30 cm	85.6%	100.0%	100.0%	95.2%	4.8%	40.9%	39.0%	44.1%	41.3%	1.5%	11.4%	23.2%	33.3%	22.6%	6.3%
En	R6	5 cm	97.5%	98.2%	97.9%	97.9%	0.2%	34.9%	56.9%	38.9%	43.5%	6.8%	0.0%	0.0%	0.0%	0.0%	0.0%
		30 cm	100.0%	100.0%	100.0%	100.0%	0.0%	83.1%	91.8%	83.7%	86.2%	2.8%	0.0%	4.3%	0.0%	1.5%	1.5%
Ss	R7	5 cm	95.2%	91.2%	97.2%	94.5%	1.8%	30.7%	11.2%	26.6%	22.8%	5.9%	0.0%	0.0%	0.0%	0.0%	0.0%
		30 cm	100.0%	100.0%	100.0%	100.0%	0.0%	57.3%	35.7%	54.3%	49.1%	6.8%	1.6%	6.0%	0.0%	2.5%	1.8%
Ws	R8	5 cm	51.5%	55.5%	56.8%	54.6%	1.6%	22.1%	23.8%	35.4%	27.1%	4.2%	4.2%	0.0%	0.0%	1.4%	1.4%
		30 cm	59.5%	61.9%	62.9%	61.4%	1.0%	58.0%	58.3%	59.8%	58.7%	0.6%	42.2%	31.0%	0.0%	24.4%	12.6%
Fr	R9	5 cm	93.6%	84.0%	100.0%	92.5%	4.6%	36.8%	24.4%	21.9%	27.7%	4.6%	0.0%	0.0%	0.0%	0.0%	0.0%
		30 cm	100.0%	86.7%	100.0%	95.6%	4.4%	86.2%	51.9%	70.4%	69.5%	9.9%	12.6%	0.0%	39.4%	17.4%	11.6%

Appendix C. IRIS images and percent paint removed from IRIS tubes.

Plot	Site	Treatment	Zone	Transect	Tube 1a	Tube 1b	Tube 2a	Tube 2b	Tube 3a	Tube 3b	Tube 1 Mean	Tube 2 Mean	Tube 3 Mean	Plot Mean
AB 1-1	AB	N	1	1	68	59	61	80	59	52	64	71	56	63
AB 4-1	AB	N	1	4	42	50	56	51	62	76	46	54	69	56
AB 7-1	AB	N	1	7	75	60	46	53	72	64	68	50	68	62
AB 1-2	AB	N	2	1	95	92	94	94	83	97	94	94	90	93
AB 4-2	AB	N	2	4	94	83	98	90	78	97	89	94	88	90
AB 7-2	AB	N	2	7	69	81	68	83			75	76		75
BB 1-1	BB	N	1	1	85	95	72	75	79	77	90	74	78	81
BB 4-1	BB	N	1	4	87	86	92	100			87	96		91
BB 7-1	BB	N	1	7	96	92					94			94
BB 1-2	BB	N	2	1	40	40					40			40
BB 4-2	BB	N	2	4	14	11	3	0	5	6	13	2	6	7
BB 7-2	BB	N	2	7	43	52	16	32	100	93	48	24	97	56
BC 1-1	BC	N	1	1	97	90	92	89	99	100	94	91	100	95
BC 4-1	BC	N	1	4	69	76	74	81			73	78		75
BC 7-1	BC	N	1	7	100	99	72	73	98	96	100	73	97	90
BC 1-2	BC	N	2	1	71	73	63	70	57	72	72	67	65	68
BC 4-2	BC	N	2	4	74	98	77	97			86	87		87
BC 7-2	BC	N	2	7	78	77	76	79	68	72	78	78	70	75
BeW 1-1	BeW	N	1	1	41	46	39	61	76	59	44	50	68	54
BeW 4-1	BeW	N	1	4	79	76	72	71	75	78	78	72	77	75
BeW 7-1	BeW	N	1	7	73	74	68	56			74	62		68
BeW 1-2	BeW	N	2	1	11	21	52	53	17	17	16	53	17	29
BeW 4-2	BeW	N	2	4	7	13	4	5	16	42	10	5	29	15
BeW 7-2	BeW	N	2	7	69	71	16	26	41	31	70	21	36	42
BsO 1-1	BsO	R	1	1	42	71	97	100	62	96	57	99	79	78
BsO 7-1	BsO	R	1	7	100	100	100	100	100	100	100	100	100	100
BsO 9-1	BsO	R	1	9	100	98	100	99			99	100		99
BsO 1-2	BsO	R	2	1	99	83	64	73	96	76	91	69	86	82
BsO 7-2	BsO	R	2	7	52	74	53	54	49	51	63	54	50	56
BsO 9-2	BsO	R	2	9	98	98	100	97	100	100	98	99	100	99
BsY 0-1	BsY	R	1	0	100	100	90	80	100	100	100	85	100	95
BsY 6-1	BsY	R	1	6	100	100	100	100	99	100	100	100	100	100
BsY 8-1	BsY	R	1	8	100	100	100	100	97	100	100	100	99	100
BsY 0-2	BsY	R	2	0	99	100	100	100	90	99	100	100	95	98
BsY 6-2	BsY	R	2	6	88	71	93	89	94	94	80	91	94	88
BsY 8-2	BsY	R	2	8	100	99	100	98	100	100	100	99	100	100
Ck 1-1	Ck	R	1	1	92	92	90	91	89	100	92	91	95	92
Ck 4-1	Ck	R	1	4	77	92	99	99	100	74	85	99	87	90
Ck 7-1	Ck	R	1	7	94	90	99	100	60	86	92	100	73	88
Ck 1-2	Ck	R	2	1	7	18	66	52	44	80	13	59	62	45
Ck 4-2	Ck	R	2	4	81	54	94	95	93	98	68	95	96	86
Ck 7-2	Ck	R	2	7	90	95	90	43	44	61	93	67	53	71
DF 1-1	DF	R	1	1	100	100	100	100	100	100	100	100	100	100
DF 3-1	DF	R	1	3	100	100	99	94	98	97	100	97	98	98
DF 4-1	DF	R	1	4	77	75	100	100	78	83	76	100	81	86
DF 1-2	DF	R	2	1	20	18	56	88	13	17	19	72	15	35
DF 3-2	DF	R	2	3	96	96	13	31	6	20	96	22	13	44
DF 4-2	DF	R	2	4	37	89	29	58	41	67	63	44	54	54

Plot	Site	Treatment	Zone	Transect	Tube 1a	Tube 1b	Tube 2a	Tube 2b	Tube 3a	Tube 3b	Tube 1 Mean	Tube 2 Mean	Tube 3 Mean	Plot Mean
En 1-1	En	R	1	1	98	100	99	99	96	98	99	99	97	98
En 4-1	En	R	1	4	53	65	100	100	94	100	59	100	97	85
En 7-1	En	R	1	7	98	100	99	96	95	92	99	98	94	97
En 1-2	En	R	2	1	100	100	99	99	100	100	100	99	100	100
En 4-2	En	R	2	4	100	100	100	99	99	98	100	100	99	99
En 7-2	En	R	2	7	99	97	96	97	96	99	98	97	98	97
Fr 1-1	Fr	R	1	1	100	100	100	100	100	96	100	100	98	99
Fr 4-1	Fr	R	1	4	78	81	98	77	98	76	80	88	87	85
Fr 7-1	Fr	R	1	7	100	99	100	100	100	100	100	100	100	100
Fr 1-2	Fr	R	2	1	98	98	100	100	100	99	98	100	100	99
Fr 4-2	Fr	R	2	4	99	98	96	96	81	95	99	96	88	94
Fr 7-2	Fr	R	2	7	97	97	96	95	98	96	97	96	97	97
JLN 1-1	JLN	N	1	1	95	37	74	48	47	49	66	61	48	58
JLN 4-1	JLN	N	1	4	41	80	13	13	43	24	61	13	34	36
JLN 7-1	JLN	N	1	7	100	58	59	63	74	75	79	61	75	72
JLN 1-2	JLN	N	2	1	74	56	86	64	60	50	65	75	55	65
JLN 4-2	JLN	N	2	4	100	100	100	100	100	100	100	100	100	100
JLN 7-2	JLN	N	2	7	51	61	47	59			56	53		55
JLR 1-1	JLR	R	1	1	74	93	92	91	77	83	84	92	80	85
JLR 4-1	JLR	R	1	4	58	82	79	65	47	49	70	72	48	63
JLR 7-1	JLR	R	1	7	58	72	56	74	100	98	65	65	99	76
JLR 1-2	JLR	R	2	1	96	96	100	97	100	98	96	99	99	98
JLR 4-2	JLR	R	2	4	98	100	97	100	100	100	99	99	100	99
JLR 7-2	JLR	R	2	7	94	98	43	52	39	50	96	48	45	63
Jr 1-1	Jr	R	1	1	100	100	100	100	100	100	100	100	100	100
Jr 4-1	Jr	R	1	4	99	98	100	100	98	100	99	100	99	99
Jr 7-1	Jr	R	1	7	100	100	100	100	100	100	100	100	100	100
Jr 1-2	Jr	R	2	1	97	98	98	97	98	100	98	98	99	98
Jr 4-2	Jr	R	2	4	90	68	88	58	78	61	79	73	70	74
Jr 7-2	Jr	R	2	7	90	95	96	72	90	97	93	84	94	90
Ss 1-1	Ss	R	1	1	42	88	54	99	58	48	65	77	53	65
Ss 4-1	Ss	R	1	4	90	64	100	77	100	75	77	89	88	84
Ss 7-1	Ss	R	1	7	90	58	45	61	96	89	74	53	93	73
Ss 1-2	Ss	R	2	1	70	90	86	98			80	92		86
Ss 4-2	Ss	R	2	4	50	28	43	41	3	30	39	42	17	33
Ss 7-2	Ss	R	2	7	43	64	42	58	51	63	54	50	57	54
Ws 1-1	Ws	R	1	1	90	98	100	95	100	100	94	98	100	97
Ws 4-1	Ws	R	1	4	100	100	100	90	100	100	100	95	100	98
Ws 7-1	Ws	R	1	7	49	95	96	96			72	96		84
Ws 1-2	Ws	R	2	1	25	8	51	22	40	45	17	37	43	32
Ws 4-2	Ws	R	2	4	99	97	98	97	96	97	98	98	97	97
Ws 7-2	Ws	R	2	7	90	62	35	23	83	85	76	29	84	63

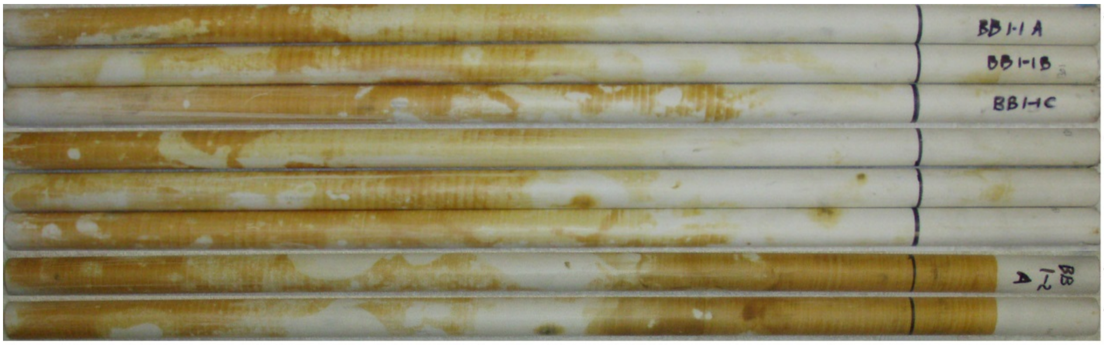
AB

1-1a
1-1b
1-2a
1-2b

4-1a
4-1b
4-2a
4-2b

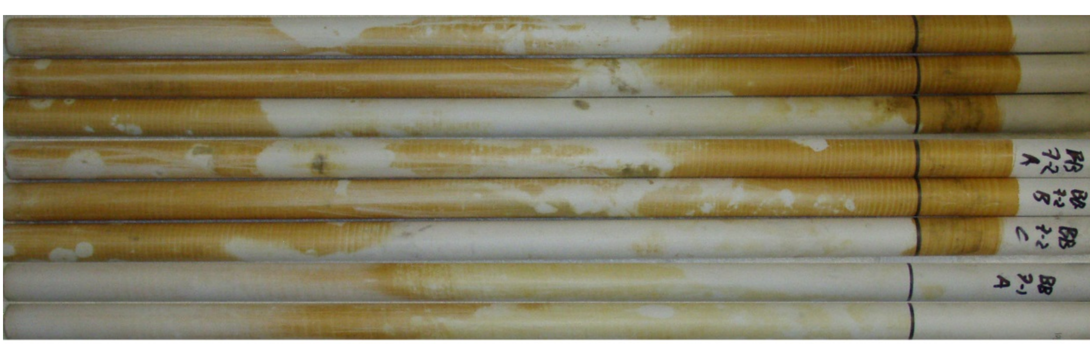
7-1a
7-1b
7-2b
7-2a

BB



1-1a
1-1b
1-2a
1-2b

4-1a
4-1b
4-2a
4-2b



7-2a
7-2b
7-1a
7-1b

BC

1-1a

1-1b

1-2a

1-2b

4-1a

4-1b

4-2a

4-2b

7-1a

7-1b

7-2a

7-2b

BeW

1-1a
1-1b
1-2a
1-2b

4-1a
4-1b
4-2a
4-2b

7-1a
7-1b
7-2a
7-2b

BsO

1-1a
1-1b
1-2a
1-2b

7-1a
7-1b
7-2a
7-2b

9-1a
9-1b
9-2a
9-2b

BsY

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0-1b
0-2a
0-2b

6-1a
6-1b
6-2a
6-2b

8-1a
8-1b
8-2a
8-2b

Ck

1-1a
1-1b
1-2a
1-2b

4-1a
4-1b
4-2a
4-2b

7-1a
7-1b
7-2a
7-2b

DF

1-1a

1-1b

1-2a

1-2b

3-1a

3-1b

3-2a

3-2b

4-1a

4-1b

4-2a

4-2b

En

Fr

1-1a
1-1b
1-2a
1-2b

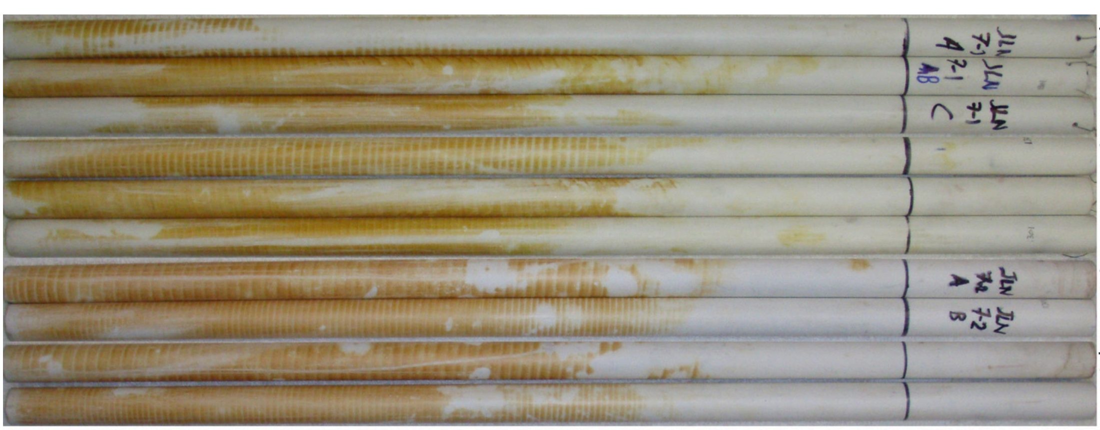
4-1a
4-1b
4-2a
4-2b

7-1a
7-1b
7-2a
7-2b

JLN

1-1a
1-1b
1-2a
1-2b

4-1a
4-1b
4-2a
4-2b



7-1a
7-1b
7-2a
7-2b

JLR

1-1a

1-1b

1-2a

1-2b

4-1a

4-1b

4-2a

4-2b

7-1a

7-1b

7-2a

7-2b

Jr

1-1a
1-1b
1-2a
1-2b

4-1a
4-1b
4-2a
4-2b

7-1a
7-1b
7-2a
7-2b

Ss

1-1a
1-1b
1-2a
1-2b

4-1a
4-1b
4-2a
4-2b

7-1a
7-1b
7-2a
7-2b

Ws

1-1a
1-1b
1-2a
1-2b

4-1a
4-1b
4-2a
4-2b

7-1a
7-1b
7-2a
7-2b

Appendix D. Penetration resistance (cone index kPa).

				Data for each plot represents Means of 20 points per plot					
Site	**Treatment**	**Transect**	**Zone**	**Max resistance within 45 cm**	**Max increase over 5 cm**	**1000 kPa within 45 cm?**	**Depth to 1000 kPa**	**2000 kPa within 45 cm?**	**Depth to 2000 kPa**
DENC-N-BB	Nat	1	1	332	84	0	>45	0	>45
DENC-N-BB	Nat	4	1	195	71	0	>45	0	>45
DENC-N-BB	Nat	7	1	390	190	0	>45	0	>45
DENC-N-BB	Nat	1	2	674	155	0	>45	0	>45
DENC-N-BB	Nat	4	2	1374	289	1	40	0	>45
DENC-N-BB	Nat	7	2	966	180	0	>45	0	>45
DENC-N-BB	Nat	1	3	577	206	0	>45	0	>45
DENC-N-BB	Nat	4	3	648	127	0	>45	0	>45
DENC-N-BB	Nat	7	3	730	213	0	>45	0	>45
MDC-N-AB	Nat	1	1	390	193	0	>45	0	>45
MDC-N-AB	Nat	4	1	479	198	0	>45	0	>45
MDC-N-AB	Nat	7	1	560	142	0	>45	0	>45
MDC-N-AB	Nat	1	2	1231	228	1	25	0	>45
MDC-N-AB	Nat	4	2	831	122	0	>45	0	>45
MDC-N-AB	Nat	7	2	856	157	0	>45	0	>45
MDC-N-AB	Nat	1	3	1687	495	1	40	0	>45
MDC-N-AB	Nat	4	3	1659	1028	1	45	0	>45
MDC-N-AB	Nat	7	3	1429	491	1	45	0	>45
MDC-N-BC	Nat	1	1	296	88	0	>45	0	>45
MDC-N-BC	Nat	4	1	272	106	0	>45	0	>45
MDC-N-BC	Nat	7	1	324	89	0	>45	0	>45
MDC-N-BC	Nat	1	2	603	117	0	>45	0	>45
MDC-N-BC	Nat	4	2	679	114	0	>45	0	>45
MDC-N-BC	Nat	7	2	798	99	0	>45	0	>45
MDC-N-BC	Nat	1	3	633	117	0	>45	0	>45
MDC-N-BC	Nat	4	3	385	48	0	>45	0	>45
MDC-N-BC	Nat	7	3	770	167	0	>45	0	>45
MDC-N-BeW	Nat	1	1	506	146	0	>45	0	>45
MDC-N-BeW	Nat	4	1	684	182	0	>45	0	>45
MDC-N-BeW	Nat	7	1	1365	446	1	40	0	>45
MDC-N-BeW	Nat	1	2	814	301	0	>45	0	>45
MDC-N-BeW	Nat	4	2	1996	1064	1	45	0	>45
MDC-N-BeW	Nat	7	2	4856	2137	1	30	1	35

MDC-N-BeW	Nat	1	3	780	156	0	>45	0	>45
MDC-N-BeW	Nat	4	3	800	241	0	>45	0	>45
MDC-N-BeW	Nat	7	3	572	111	0	>45	0	>45
MDC-N-JL	Nat	1	1	679	162	0	>45	0	>45
MDC-N-JL	Nat	4	1	464	94	0	>45	0	>45
MDC-N-JL	Nat	7	1	507	144	0	>45	0	>45
MDC-N-JL	Nat	1	2	1170	167	1	40	0	>45
MDC-N-JL	Nat	4	2	1132	367	1	45	0	>45
MDC-N-JL	Nat	7	2	947	139	0	>45	0	>45
MDC-N-JL	Nat	1	3	995	261	0	>45	0	>45
MDC-N-JL	Nat	4	3	1897	393	1	35	0	>45
MDC-N-JL	Nat	7	3	643	193	0	>45	0	>45
DEK-R-Jr	Res	1	1	5226	1006	1	15	1	25
DEK-R-Jr	Res	4	1	6608	1962	1	25	1	30
DEK-R-Jr	Res	7	1	5807	1041	1	15	1	20
DEK-R-Jr	Res	1	2	1882	686	1	40	0	>45
DEK-R-Jr	Res	4	2	2103	511	1	35	1	45
DEK-R-Jr	Res	7	2	2823	1136	1	25	1	35
DEK-R-Jr	Res	1	3	521	290	0	>45	0	>45
DEK-R-Jr	Res	4	3	781	205	0	>45	0	>45
DEK-R-Jr	Res	7	3	591	235	0	>45	0	>45
MDC-R-JL	Res	1	1	652	258	0	>45	0	>45
MDC-R-JL	Res	4	1	633	137	0	>45	0	>45
MDC-R-JL	Res	7	1	800	203	0	>45	0	>45
MDC-R-JL	Res	1	2	2247	654	1	30	1	45
MDC-R-JL	Res	4	2	1112	448	1	35	0	>45
MDC-R-JL	Res	7	2	1294	355	1	45	0	>45
MDC-R-JL	Res	1	3	3985	726	1	15	1	20
MDC-R-JL	Res	4	3	2638	931	1	25	1	30
MDC-R-JL	Res	7	3	5592	1442	1	20	1	30
MDD-R-Ck	Res	1	1	8295	1517	1	10	1	20
MDD-R-Ck	Res	4	1	1717	355	1	20	0	>45
MDD-R-Ck	Res	7	1	1707	506	1	25	0	>45
MDD-R-Ck	Res	1	2	3785	1116	1	10	1	25
MDD-R-Ck	Res	4	2	3459	946	1	10	1	15
MDD-R-Ck	Res	7	2	4435	1332	1	10	1	15
MDD-R-Ck	Res	1	3	4045	2548	1	20	1	30
MDD-R-Ck	Res	4	3	4731	1797	1	20	1	30
MDD-R-Ck	Res	7	3	2828	1392	1	20	1	35
MDQA-R-BsO	Res	1	1	2613	786	1	25	1	30
MDQA-R-BsO	Res	7	1	5220	1015	1	20	1	25
MDQA-R-BsO	Res	9	1	3760	996	1	20	1	35

MDQA-R-BsO	Res	1	2	2823	1136	1	25	1	35
MDQA-R-BsO	Res	7	2	4270	1051	1	15	1	20
MDQA-R-BsO	Res	9	2	4916	1637	1	15	1	20
MDQA-R-BsO	Res	1	3	2478	591	1	25	1	40
MDQA-R-BsO	Res	7	3	5341	2863	1	25	1	25
MDQA-R-BsO	Res	9	3	2233	606	1	15	1	35
MDQA-R-BsY	Res	0	1	1637	511	1	15	0	>45
MDQA-R-BsY	Res	6	1	4781	1282	1	15	1	25
MDQA-R-BsY	Res	8	1	6112	1532	1	15	1	20
MDQA-R-BsY	Res	0	2	2313	1071	1	20	1	20
MDQA-R-BsY	Res	6	2	4225	1612	1	25	1	30
MDQA-R-BsY	Res	8	2	1422	360	1	25	0	>45
MDQA-R-BsY	Res	0	3	1712	801	1	15	0	>45
MDQA-R-BsY	Res	6	3	2338	569	1	20	1	40
MDQA-R-BsY	Res	8	3	1717	1046	1	45	0	>45
MDQA-R-En	Res	1	1	2042	446	1	35	1	45
MDQA-R-En	Res	4	1	2178	606	1	15	1	45
MDQA-R-En	Res	7	1	6608	1537	1	20	1	25
MDQA-R-En	Res	1	2	1502	360	1	30	0	>45
MDQA-R-En	Res	4	2	6002	1517	1	20	1	25
MDQA-R-En	Res	7	2	1837	806	1	25	0	>45
MDQA-R-En	Res	1	3	671	182	0	>45	0	>45
MDQA-R-En	Res	4	3	816	225	0	>45	0	>45
MDQA-R-En	Res	7	3	1667	514	1	30	0	>45
MDQA-R-Ss	Res	1	1	1652	531	1	20	0	>45
MDQA-R-Ss	Res	4	1	1472	466	1	35	0	>45
MDQA-R-Ss	Res	7	1	1297	461	1	25	0	>45
MDQA-R-Ss	Res	1	2	1538	552	1	30	0	>45
MDQA-R-Ss	Res	4	2	1636	469	1	15	0	>45
MDQA-R-Ss	Res	7	2	1962	561	1	20	0	>45
MDQA-R-Ss	Res	1	3	1427	285	1	35	0	>45
MDQA-R-Ss	Res	4	3	1442	446	1	35	0	>45
MDQA-R-Ss	Res	7	3	3184	1021	1	35	1	40
MDQA-R-Ws	Res	1	1	1018	357	1	45	0	>45
MDQA-R-Ws	Res	4	1	2253	786	1	35	1	45
MDQA-R-Ws	Res	7	1	2852	1459	1	35	1	45
MDQA-R-Ws	Res	1	2	3484	911	1	20	1	25
MDQA-R-Ws	Res	4	2	1432	481	1	45	0	>45
MDQA-R-Ws	Res	7	2	3549	1282	1	25	1	40
MDQA-R-Ws	Res	1	3	2568	696	1	25	1	45
MDQA-R-Ws	Res	4	3	781	295	0	>45	0	>45
MDQA-R-Ws	Res	7	3	701	245	0	>45	0	>45

MDT-R-Fr	Res	1	1	6438	1707	1	15	1	25
MDT-R-Fr	Res	4	1	2528	856	1	35	1	45
MDT-R-Fr	Res	7	1	6943	2653	1	30	1	35
MDT-R-Fr	Res	1	2	3835	1427	1	20	1	30
MDT-R-Fr	Res	4	2	1382	461	1	25	0	>45
MDT-R-Fr	Res	7	2	736	245	0	>45	0	>45
MDT-R-Fr	Res	1	3	1367	260	1	35	0	>45
MDT-R-Fr	Res	4	3	1191	205	1	40	0	>45
MDT-R-Fr	Res	7	3	1156	345	1	45	0	>45

Appendix E. Stick decomposition data (mean values for each plot).

Site	Treatment	Transect	Zone	Decomp 3 mo	Decomp 6 mo	Decomp 9 mo	Decomp 12 mo
DENC-N-BB	Nat	1	1	0.02%	0.75%	2.35%	2.96%
DENC-N-BB	Nat	4	1	0.41%	1.42%	3.73%	3.67%
DENC-N-BB	Nat	7	1	0.42%	1.55%	2.38%	4.41%
DENC-N-BB	Nat	1	2	0.91%	4.28%	9.56%	16.09%
DENC-N-BB	Nat	4	2	1.27%	11.00%	19.07%	16.60%
DENC-N-BB	Nat	7	2	0.56%	3.88%	8.69%	11.28%
DENC-N-BB	Nat	1	3	-0.09%	12.42%	53.50%	55.23%
DENC-N-BB	Nat	4	3	0.62%	9.84%	16.15%	40.93%
DENC-N-BB	Nat	7	3	0.37%	10.68%		25.56%
MDC-N-AB	Nat	1	1	-0.66%	0.68%	3.19%	3.06%
MDC-N-AB	Nat	4	1	0.53%	1.78%	3.92%	4.49%
MDC-N-AB	Nat	7	1	0.40%	1.54%	2.90%	3.00%
MDC-N-AB	Nat	1	2	-0.60%	0.98%	7.47%	10.46%
MDC-N-AB	Nat	4	2	0.66%	1.08%	5.13%	6.00%
MDC-N-AB	Nat	7	2	0.49%	1.36%	7.68%	7.51%
MDC-N-AB	Nat	1	3	-0.48%	9.13%	16.94%	18.65%
MDC-N-AB	Nat	4	3	0.54%	6.89%	12.84%	20.82%
MDC-N-AB	Nat	7	3	0.67%	6.45%	23.27%	24.27%
MDC-N-BC	Nat	1	1	-0.32%	1.85%	2.06%	2.21%
MDC-N-BC	Nat	4	1	0.72%	1.78%	2.51%	3.02%
MDC-N-BC	Nat	7	1	0.50%	0.85%	2.69%	1.53%
MDC-N-BC	Nat	1	2	-0.45%	1.53%	2.06%	5.00%
MDC-N-BC	Nat	4	2	0.71%	2.13%	5.72%	12.40%
MDC-N-BC	Nat	7	2	0.58%	1.95%	6.36%	9.57%
MDC-N-BC	Nat	1	3	0.25%	5.38%	15.32%	19.11%
MDC-N-BC	Nat	4	3	0.23%	4.22%	17.77%	22.74%
MDC-N-BC	Nat	7	3	0.67%	9.76%	18.01%	31.32%
MDC-N-BeW	Nat	1	1	-0.46%	0.69%	6.95%	9.37%
MDC-N-BeW	Nat	4	1	-0.34%	1.34%	5.70%	4.41%
MDC-N-BeW	Nat	7	1	0.04%	0.74%	7.13%	9.93%
MDC-N-BeW	Nat	1	2	-0.37%	2.32%	5.39%	6.48%
MDC-N-BeW	Nat	4	2	-0.36%	3.60%	4.93%	9.74%
MDC-N-BeW	Nat	7	2	0.46%	2.60%	7.40%	12.34%
MDC-N-BeW	Nat	1	3	-0.60%	15.25%	34.82%	43.39%
MDC-N-BeW	Nat	4	3	-0.24%	7.34%	25.41%	37.48%
MDC-N-BeW	Nat	7	3	0.85%	15.64%	17.32%	34.92%
MDC-N-JL	Nat	1	1	-0.33%	0.86%	2.65%	2.03%

MDC-N-JL	Nat	4	1	0.35%	0.24%	2.43%	2.87%
MDC-N-JL	Nat	7	1	1.13%	1.72%	2.95%	3.31%
MDC-N-JL	Nat	1	2	0.04%	0.63%	6.62%	7.02%
MDC-N-JL	Nat	4	2	0.94%	1.26%	3.62%	4.22%
MDC-N-JL	Nat	7	2	1.10%	1.59%	3.72%	4.04%
MDC-N-JL	Nat	1	3	-0.01%	11.77%	41.86%	49.79%
MDC-N-JL	Nat	4	3	1.18%	8.08%	28.88%	20.44%
MDC-N-JL	Nat	7	3	0.72%	7.75%	16.10%	26.53%
DEK-R-Jr	Res	1	1	0.11%	0.81%	2.02%	3.44%
DEK-R-Jr	Res	4	1	-0.76%	1.00%	2.37%	3.00%
DEK-R-Jr	Res	7	1	0.11%	1.07%	2.06%	2.11%
DEK-R-Jr	Res	1	2	-0.70%	2.93%	10.77%	10.97%
DEK-R-Jr	Res	4	2	-1.26%	2.50%	14.24%	11.75%
DEK-R-Jr	Res	7	2	-1.12%	2.65%	13.79%	15.79%
DEK-R-Jr	Res	1	3	3.97%	24.02%	29.53%	64.58%
DEK-R-Jr	Res	4	3	-0.65%	11.13%	31.82%	71.49%
DEK-R-Jr	Res	7	3	0.51%	12.88%	38.18%	32.63%
MDC-R-JL	Res	1	1	-1.00%	1.51%	6.05%	8.40%
MDC-R-JL	Res	4	1	-0.29%	1.45%	7.65%	9.71%
MDC-R-JL	Res	7	1	0.27%	1.14%	5.05%	6.90%
MDC-R-JL	Res	1	2	-0.78%	1.11%	10.71%	7.24%
MDC-R-JL	Res	4	2	-0.44%	1.49%	11.43%	18.25%
MDC-R-JL	Res	7	2	0.29%	2.04%	7.65%	11.84%
MDC-R-JL	Res	1	3	0.51%	9.56%	20.58%	23.68%
MDC-R-JL	Res	4	3	0.36%	18.50%	13.15%	25.96%
MDC-R-JL	Res	7	3	1.54%	16.69%	29.19%	27.65%
MDD-R-Ck	Res	1	1	0.32%	1.01%	6.33%	9.83%
MDD-R-Ck	Res	4	1	0.62%	1.00%	3.30%	5.93%
MDD-R-Ck	Res	7	1	0.37%	1.21%	11.85%	15.97%
MDD-R-Ck	Res	1	2	-0.45%	1.15%	4.67%	5.70%
MDD-R-Ck	Res	4	2	0.49%	0.72%	17.77%	13.54%
MDD-R-Ck	Res	7	2	0.52%	0.71%	8.80%	5.97%
MDD-R-Ck	Res	1	3	1.09%	20.59%	26.85%	63.25%
MDD-R-Ck	Res	4	3	1.10%	2.87%	18.21%	15.82%
MDD-R-Ck	Res	7	3	1.18%	14.30%	15.10%	28.64%
MDQA-R-BsO	Res	1	1	-1.59%	2.33%	5.92%	5.89%
MDQA-R-BsO	Res	7	1	0.32%	2.68%	9.90%	10.16%
MDQA-R-BsO	Res	9	1	-0.11%	9.19%	14.84%	17.29%
MDQA-R-BsO	Res	1	2	-0.76%	4.66%	11.33%	19.19%

MDQA-R-BsO	Res	7	2	0.02%	1.33%	8.22%	12.40%
MDQA-R-BsO	Res	9	2	0.34%	2.16%	13.27%	12.32%
MDQA-R-BsO	Res	1	3	0.47%	16.50%	36.30%	
MDQA-R-BsO	Res	7	3	-0.24%	4.74%	7.16%	11.14%
MDQA-R-BsO	Res	9	3	0.56%	6.52%	17.04%	23.49%
MDQA-R-BsY	Res	0	1	-0.01%	3.01%	10.00%	18.84%
MDQA-R-BsY	Res	6	1	0.03%	2.40%	2.61%	3.72%
MDQA-R-BsY	Res	8	1	-0.13%	2.49%	7.17%	9.20%
MDQA-R-BsY	Res	0	2	0.26%	1.15%	23.66%	14.45%
MDQA-R-BsY	Res	6	2	-1.07%	12.09%	29.73%	
MDQA-R-BsY	Res	8	2	-0.58%	1.81%	9.51%	19.32%
MDQA-R-BsY	Res	0	3	1.48%	32.18%	33.20%	52.70%
MDQA-R-BsY	Res	6	3	-0.50%	16.85%	19.51%	15.73%
MDQA-R-BsY	Res	8	3	-1.05%	8.66%	35.80%	40.59%
MDQA-R-En	Res	1	1	-0.22%	2.89%	6.45%	6.34%
MDQA-R-En	Res	4	1	0.51%	2.97%	6.90%	5.15%
MDQA-R-En	Res	7	1	-0.12%	1.53%	4.01%	4.73%
MDQA-R-En	Res	1	2	-0.48%	4.47%	28.90%	26.93%
MDQA-R-En	Res	4	2	0.19%	0.68%	6.40%	8.42%
MDQA-R-En	Res	7	2	-0.03%	2.65%	12.17%	19.21%
MDQA-R-En	Res	1	3	1.28%	14.60%	27.48%	34.44%
MDQA-R-En	Res	4	3	1.35%	26.06%	27.19%	38.44%
MDQA-R-En	Res	7	3	0.57%	53.04%	43.46%	94.51%
MDQA-R-Ss	Res	1	1	-1.09%	1.59%	9.19%	5.98%
MDQA-R-Ss	Res	4	1	-0.56%	1.63%	6.91%	7.97%
MDQA-R-Ss	Res	7	1	-1.08%	1.29%	3.38%	2.74%
MDQA-R-Ss	Res	1	2	-1.51%	3.68%	6.53%	11.82%
MDQA-R-Ss	Res	4	2	-0.18%	4.18%	11.50%	15.67%
MDQA-R-Ss	Res	7	2	-1.71%	1.31%	6.08%	12.03%
MDQA-R-Ss	Res	1	3	-0.16%	9.27%	14.29%	20.54%
MDQA-R-Ss	Res	4	3	-0.14%	6.28%	15.92%	16.95%
MDQA-R-Ss	Res	7	3	-0.27%	7.85%	19.53%	16.66%
MDQA-R-Ws	Res	1	1	-0.17%	3.82%	21.57%	25.35%
MDQA-R-Ws	Res	4	1	-0.67%	4.02%	16.95%	13.36%
MDQA-R-Ws	Res	7	1	-0.70%	5.12%	36.59%	16.12%
MDQA-R-Ws	Res	1	2	-0.82%	3.70%	20.69%	17.75%
MDQA-R-Ws	Res	4	2	-1.48%	21.92%	23.76%	25.63%
MDQA-R-Ws	Res	7	2	-0.68%	4.15%	35.54%	56.21%

MDQA-R-Ws	Res	1	3	0.17%	8.23%	14.54%	15.05%
MDQA-R-Ws	Res	4	3	-0.48%	16.09%	32.23%	23.57%
MDQA-R-Ws	Res	7	3	1.28%	10.70%	35.11%	48.35%
MDT-R-Fr	Res	1	1	-0.19%	2.47%	6.38%	8.14%
MDT-R-Fr	Res	4	1	0.10%	3.33%	8.73%	9.16%
MDT-R-Fr	Res	7	1	0.09%	3.85%	8.30%	10.56%
MDT-R-Fr	Res	1	2	0.09%	0.95%	12.10%	7.28%
MDT-R-Fr	Res	4	2	-0.16%	0.45%	13.89%	6.55%
MDT-R-Fr	Res	7	2	-0.72%	1.47%	6.16%	7.08%
MDT-R-Fr	Res	1	3	-0.44%		55.07%	62.81%
MDT-R-Fr	Res	4	3	0.49%	17.74%	39.67%	26.25%
MDT-R-Fr	Res	7	3	0.05%	9.16%	49.69%	26.39%

Appendix F. Soil morphological descriptions

MDC-N-AB Zone 1

Site		MDC-N-AB	Date	9/25/2013
Plot Number		1-1	Describers	CAP,JV
Observation Method		small pit to 40 cm, augered to 142 cm		
HS FI				

Obs Method	Horizon	Field Horizon	Depth (cm)	Texture (% Clay)	Matrix Color Moist	RMF - Conc	RMF - Dep	Other
SP	Oe	Oe	8	Mky Pt	5YR 2.5/1			
SP	Oa	A1	24	Mk	10YR 2/1			
SP/BA	A1	A2	47	Mky SiL (12%)	2.5Y 3/1			Mucky modified
BA	A2	AB	71	SiL (15%)	2.5Y 3/1			
BA	Btg	Bt	96	L (20%)	2.5Y 6/1	15% D		
BA	BCg	BC	142+	SiL (13%)	5Y 5/1	5% P		

Site		MDC-N-AB	Date	9/25/2013
Plot Number		4-1	Describers	CAP,JV
Observation Method		small pit to 40 cm, augered to 191 cm		
HS FI				

Obs Method	Horizon	Field Horizon	Depth (cm)	Texture (% Clay)	Matrix Color Moist	RMF - Conc	RMF - Dep	Other
SP	Oa	Oe	11	Mky Pt	10YR 2/1			
SP	A1	A1	39	Mk	10YR 2/1			
BA	A2	A2	63	SiL (8%)	10YR 2/1			
BA	AB	AB	103	SiL (17%)	10YR 2/1			
BA	Abt		115	SiCL (28%)	10YR 3/1	6% D		
BA			157	L (11%)	10YR 4/1	3% D		
BA			191+	SiL (14%)	5Y 4/1			

Site		MDC-N-AB	Date	9/25/2013
Plot Number		7-1	Describers	CAP,JV
Observation Method		small pit to 40 cm, augered to 155 cm		
HS FI				

Obs Method	Horizon	Field Horizon	Depth (cm)	Texture (% Clay)	Matrix Color Moist	RMF - Conc	RMF - Dep	Other
SP	Oe	Oe	7	Mky Pt	5YR 2.5/1			
SP	Oa	A1	20	Mk	10YR 2/1			
SP/BA	A1	A2	49	Mk	10YR 2/1			
BA	A2	AB	69	SiL (20%)	10YR 3/1			
BA	Bg1	Bt	120	L (25%)	2.5Y 4/1	18% P		
BA	Bg2	BC	155+	SiL (15%)	2.5Y 5/1	10% P		

MDC-N-AB Zone 2

Site		MDC-N-AB	Date	11/20/2013
Plot Number	1-2		Describers	CAP,SE
Observation Method	small pit to 40 cm, augered to 193 cm			
HS FI				

Obs Method	Horizon	Field Horizon	Depth (cm)	Texture (% Clay)	Matrix Color Moist	RMF - Conc	RMF - Dep	Other
SP	Oe	Oe	9		10YR 2/1			
SP	A	A1	33	Mky L (12%)	10YR 2/1			
SP/BA	EA	A2	57	Mky L (15%)	10YR 3/1			
BA	EAg	AE	89	LS (5%)	2.5Y 5/2	15% F		3% gravel
BA	Eg	E	112	S (2%)	2.5Y 6/2			2% gravel
BA	Bg	Bt1	131	LS (6%)	2.5Y 7/2	25% P		1% gravel
BA	Bw	Bt2	147	LS (5%)	2.5Y 6/4	30% P		3% gravel
BA	B'g1	Bt3	162	LS (5%)	2.5Y 6/2	8% D		
BA	B'g2	Btg	178	SL (10%)	2.5Y 6/2			5% gravel
BA	CBg	CB	193+	S (2%)	2.5Y 7/2			

Site		MDC-N-AB	Date	11/20/2013
Plot Number	4-2		Describers	CAP,SE
Observation Method	small pit to 40 cm, augered to 194 cm			
HS FI				

Obs Method	Horizon	Field Horizon	Depth (cm)	Texture (% Clay)	Matrix Color Moist	RMF - Conc	RMF - Dep	Other
SP	Oa	Oa	8		7.5YR 2.5/1			
SP	A	A	33	Mky SL (8%)	10YR 2/1			
SP/BA	EAg	AE	56	SL (4%)	10YR 4/1			
BA	Eg	EB	79	SL (6%)	10YR 4/1			
BA	BEg	BE	100	SL (9%)	2.5Y 5/2	12% P		
BA	Btg1	Btg1	140	SL (19%)	2.5Y 6/1	10% D, 4% P		
BA	Btg2	Btg2	176	SCL (23%)	2.5Y 6/1	8% P		
BA	CBg	CBg	194+	S (2%)	2.5Y 6/2			

Site		MDC-N-AB	Date	11/20/2013
Plot Number	7-2		Describers	CAP,SE
Observation Method	small pit to 40 cm, augered to 168 cm			
HS FI				

Obs Method	Horizon	Field Horizon	Depth (cm)	Texture (% Clay)	Matrix Color Moist	RMF - Conc	RMF - Dep	Other
SP	Oe	Oe	5		10YR 2/1			
SP	Oa	A1	22		10YR 2/1			
SP	A	A2	35	Mky L (12%)	10YR 2/1			
BA	EAg	AB	54	L (8%)	10YR 4/1			
BA	Eg	EB	71	LS (4%)	2.5Y 5/2			
BA	Btg1	Bt	91	SL (18%)	10YR 4/1	35% P		
BA	Btg2	Btg	119	SCL (22%)	5Y 6/1	10% P, 20% D		
BA	Btg3	BC	147	SL (16%)	2.5Y 5/2	5% F		
BA	BCg	CBg	168+	SL (6%)	2.5Y 6/2			

MDC-N-AB Zone 3

Site		MDC-N-AB	Date	7/30/2014	
Plot Number		1-3	Describers	CAP,JR	
Observation Method		small pit to 40 cm, augered to 182 cm			
HS FI					

Obs Method	Horizon	Field Horizon	Depth (cm)	Texture (% Clay)	Matrix Color Moist	RMF - Conc	RMF - Dep	Other
SP	Oe	Oe	6		5YR 3/3			
SP	A	A	24	SL (11%)	10YR 2/1			
SP	AB	AB	39	SL (13%)	10YR 3/3	3% D		
BA	Bhsm	Bhsm	58	SL (15%)	2.5YR 2.5/2			Ortstein
BA	Bhs1	Bhs1	69	SL (17%)	2.5YR 2.5/1			
BA	Bhs2	Bhs2	99	LS (3%)	7.5YR 3/2			
BA	BC	BC	123	SL (12%)	2.5Y 6/2			
BA	CB	CB	146	SL (14%)	2.5Y 6/3	10% D	15% D	
BA	Cg	Cg	182+	SL (13%)	2.5Y 6/1	22% P		

Site		MDC-N-AB	Date	7/30/2014	
Plot Number		4-3	Describers	CAP,JR	
Observation Method		small pit to 40 cm, augered to 187 cm			
HS FI					

Obs Method	Horizon	Field Horizon	Depth (cm)	Texture (% Clay)	Matrix Color Moist	RMF - Conc	RMF - Dep	Other
SP	Oe	Oe	10		2.5YR 2.5/3			
SP	A	A	17	SL (12%)	10YR 2/2			
SP/BA	EA	AE	43	SL (10%)	2.5Y 5/4			
BA	E	E	74	SL (7%)	2.5Y 6/4			
BA	Bt	Bt	97	SL (10%)	2.5Y 6/4	10% P	9% D	
BA	Btg	Btg	128	SL (10%)	2.5Y 7/1	25% D, 7% P		
BA	B't	B't	172	SL (10%)	2.5Y 6/4	10% D	15% D	
BA	BCg	BCg	187+	Gr SL (10%)	2.5Y 7/2	10% D		20% gravel

Site		MDC-N-AB	Date	7/30/2014	
Plot Number		7-3	Describers	CAP,JR	
Observation Method		small pit to 40 cm, augered to 161 cm			
HS FI					

Obs Method	Horizon	Field Horizon	Depth (cm)	Texture (% Clay)	Matrix Color Moist	RMF - Conc	RMF - Dep	Other
SP	Oe	Oe	9		5YR 3/3			
SP	A	A	24	SL (11%)	10YR 3/2			
SP	EA	AE	39	SL (13%)	2.5Y 3/4			
BA	E1	E1	59	LS (5%)	2.5Y 6/4	25% P	2% D	
BA	E2	E2	83	LS (3%)	10YR 5/6	20% D		
BA	Bt1	Bt1	111	SL (6%)	2.5Y 6/3	50% P	10% D	
BA	Bt2	Bt2	139	Gr SL (9%)	10YR 5/6	5% F		20% gravel
BA	Bt3	Bt3	161+	SL (8%)	2.5Y 6/6	5% F		

Site		**DENC-N-BB**	Date	**9/16/2013**				
Plot Number		**1-1**	Describers	**CAP,JV**				
Observation Method		**small pit to 30 cm, augered to 165 cm**						
HS FI								

Obs Method	Horizon	Field Horizon	Depth (cm)	Texture (% Clay)	Matrix Color Moist	RMF - Conc	RMF - Dep	Other
SP	Oa	Oa1	9		10YR 2/2			
SP/BA	A1	Oa2	35		10YR 2/1			Possibly mucky A
BA	A2		65	SL (7%)	10YR 2/1			
BA	AB		83	SL (16%)	10YR 3/1			
BA	Bg1		107	SL (19%)	10YR 5/1	6% P 10YR 3/6		
BA	Bg2		130	SL (12%)	10YR 5/1	3% D 10YR 4/6		
BA	Bg3		152	L (14%)	2.5Y 4/1	5% P 10YR 4/6		
BA	BC		165+	L (14%)	10YR 3/2	1% D 10YR 4/6		

Site		**DENC-N-BB**	Date	**9/16/2013**				
Plot Number		**4-1**	Describers	**CAP,JV**				
Observation Method		**small pit to 40 cm, augered to 161 cm**						
HS FI								

Obs Method	Horizon	Field Horizon	Depth (cm)	Texture (% Clay)	Matrix Color Moist	RMF - Conc	RMF - Dep	Other
SP	Oa	Oa1	7	Mky Pt	10YR 2/1			
SP	A1	Oa2	28	Mk	10YR 3/1			Possibly mucky A
SP/BA	A2		48	Mk	10YR 2/1			
BA	A3		65	SL (8%)	10YR 3/1			
BA	AB		83	SCL (23%)	2.5Y 3/1			
BA	Btg1		103	SiCL (30%)	2.5Y 5/1			
BA	Btg2		132	SiCL (35%)	2.5Y 6/1			
BA	Btg3		161+	SiCL (28%)	5Y 6/1			

Site		**DENC-N-BB**	Date	**9/16/2013**				
Plot Number		**7-1**	Describers	**CAP,JV**				
Observation Method		**small pit to 40 cm, augered to 139 cm**						
HS FI								

Obs Method	Horizon	Field Horizon	Depth (cm)	Texture (% Clay)	Matrix Color Moist	RMF - Conc	RMF - Dep	Other
SP	Oa	Oa1	10	Mky Pt	10YR 2/1			
SP	A1	Oa2	37	Mk	10YR 2/1			Possibly mucky A
BA	A2		49	SL (8%)	10YR 3/1			
BA	ABt		73	SC (38%)	2.5Y 2.5/1			
BA	Btg1		105	SCL (30%)	2.5Y 4/1			
BA	Btg2		139+	SL (17%)	2.5Y 4/1			

Site		**DENC-N-BB**	Date	**3/17/2015**				
Plot Number		**1-2**	Describers	**CAP,MG,CS**				
Observation Method		**small pit to 40 cm, augered to 119 cm**						
HS FI								

Obs Method	Horizon	Field Horizon	Depth (cm)	Texture (% Clay)	Matrix Color Moist	RMF - Conc	RMF - Dep	Other
SP	Oa	Oa	7	PT	2.5YR 2.5/2			
SP	A	A	34	MKY SL (6%)	10YR 2/2			
SP/BA	Eg	Eg	57	LS (4%)	2.5Y 6/2			
BA		Btg1	83	SL (15%)	2.5Y 6/2	25% P 7.5YR 5/6	5% F 2.5Y 7/1	
BA		Btg2	104	SL (10%)	2.5Y 7/2	20% P 7.5YR 5/6	8% F 2.5Y 7/1	
BA		BCg	119+	LS (5%)	2.5Y 7/2	30% P 7.5YR 5/6		

Site		**DENC-N-BB**	Date	**8/27/2013**				
Plot Number		**4-2**	Describers	**CAP,JV**				
Observation Method		**small pit to 30 cm, augered to 153 cm**						
HS FI								

Obs Method	Horizon	Field Horizon	Depth (cm)	Texture (% Clay)	Matrix Color Moist	RMF - Conc	RMF - Dep	Other
SP	A1	Oe	10		5YR 3/3			
SP	A2	A1	21	SL (6%)	10YR 2/1			
SP/BA	A3	A2	50	SL (7%)	10YR 2/1			
BA	AB	AB	69	SL (8%)	10YR 2/2			
BA	EB	EB	91	LS (5%)	2.5Y 5/4			
BA	Bw	Bw	121	SL (6%)	2.5Y 5/3			
BA	BC	BC	153+	LS (3%)	2.5Y 6/3			

Site		**DENC-N-BB**	Date	**8/27/2013**				
Plot Number		**7-2**	Describers	**CAP,JV**				
Observation Method		**small pit to 30 cm, augered to 145 cm**						
HS FI								

Obs Method	Horizon	Field Horizon	Depth (cm)	Texture (% Clay)	Matrix Color Moist	RMF - Conc	RMF - Dep	Other
SP	Oe	Oe	8		5YR 3/3			
SP	A1		26	SL (8%)	10YR 2/1			
SP/BA	A2		63	SL (9%)	10YR 2/1			
BA	Bw		104	LS (3%)	2.5Y 5/4			Heavily intermixed
BA	BC		145+	LS (4%)	5Y 5/3			

Site		**DENC-N-BB**	Date	**3/17/2015**				
Plot Number		**1-3**	Describers	**CAP,MG,CS**				
Observation Method		**small pit to 40 cm, augered to 116 cm**						
HS FI								

Obs Method	Horizon	Field Horizon	Depth (cm)	Texture (% Clay)	Matrix Color Moist	RMF - Conc	RMF - Dep	Other
SP	Oe	Oe	4	MKY PT	2.5YR 2.5/2			
SP	A	A	17	SL (7%)	10YR 2/2			
SP/BA	Bw1		45	SL (5%)	2.5Y 5/4			
BA	Bw2		65	LS (4%)	2.5Y 5/4	5% F 10YR 5/6		
BA	Bw3		95	LS (3%)	2.5Y 6/3	20% D 7.5YR 5/6		
BA	Bw4		116+	S (2%)	2.5Y 7/3	15% D 10YR 5/6	25% D 2.5Y 7/2	

Site		**DENC-N-BB**	Date	**3/17/2015**				
Plot Number		**4-3**	Describers	**CAP,MG,CS**				
Observation Method		**small pit to 40 cm, augered to 107 cm**						
HS FI								

Obs Method	Horizon	Field Horizon	Depth (cm)	Texture (% Clay)	Matrix Color Moist	RMF - Conc	RMF - Dep	Other
SP	Oe	Oe	8	MKY PT	2.5Y 2.5/2			
SP	A	A	21	SL (6%)	10YR 2/1			
SP	Bw1		40	LS (5%)	10YR 5/6	3% D 5YR 5/6		
BA	Bw2		60	S (4%)	2.5Y 5/3			
BA	Bw3		81	S (2%)	2.5Y 6/3			
BA	Bw4		107+	S (2%)	2.5Y 6/3			

Site		**DENC-N-BB**	Date	**3/17/2015**				
Plot Number		**7-3**	Describers	**CAP,MG,CS**				
Observation Method		**small pit to 40 cm, augered to 110 cm**						
HS FI								

Obs Method	Horizon	Field Horizon	Depth (cm)	Texture (% Clay)	Matrix Color Moist	RMF - Conc	RMF - Dep	Other
SP	Oe	Oe	4	MKY PT	2.5YR 2.5/2			
SP	A	A	8	SL (6%)	10YR 2/2			
SP	BA	Bw1	25	LS (5%)	10YR 4/4			
SP	Bw1	Bw2	41	LS (5%)	2.5Y 6/4	3% F 10YR 6/6		
BA	Bw2	Bw3	59	S (4%)	2.5Y 5/3	3% F 10YR 6/6		
BA	Bw3	Bw4	80	S (4%)	2.5Y 6/3	15% P 10YR 5/6	5% 2.5Y 6/3	
BA	Bw4	BC1	101	S (3%)	2.5Y 6/3	30% P 7.5YR 5/6	10% F 2.5Y 6/2	
BA	BC	BC2	110+	S (2%)	2.5Y 6/3	40% D 7.5YR 5/6		3% subrounded gravel

MDC-N-BC Zone 1

Site	**MDC-N-BC**	Date	**9/24/13**
Transect Number	**1-1**	Describers	**CAP,JV**
Observation Method	**small pit to 40 cm, augered to 191 cm**		
HS FI			

Obs Method	Horizon	Field Horizon	Depth (cm)	Texture	Matrix Color Moist	RMF	Other
SP	Oe	Oe	8		7.5YR 3/3		
SP/BA	Oa	A	51		10YR 2/2		
BA	A	AB	89		10YR 2/1		
BA		Bt	107		10YR 4/3		Sand lens
BA		BCg	134		10YR 4/2		
BA		CBg	191+		2.5Y 4/1		

Site	**MDC-N-BC**	Date	**9/24/13**
Transect Number	**4-1**	Describers	**CAP,JV**
Observation Method	**small pit to 50 cm, augered to 203 cm**		
HS FI			

Obs Method	Horizon	Field Horizon	Depth (cm)	Texture	Matrix Color Moist	RMF	Other
SP	Oe	Oe	11		10YR 2/1		
SP	Oa	A1	45	Mky SiL (12%)	10YR 2/1		3 Gr structure
SP/BA	A	A2	73	SiL (16%)	10YR 2/1		2 Gr structure
BA		ABt1	101	SiL (22%)	10YR 2/1		1 SBk structure
BA		ABt2	130	SiL (25%)	10YR 2/1		
BA		BCg	203+	SiL (8%)	10YR 4/2		

Site	**MDC-N-BC**	Date	**9/11/15**
Transect Number	**7-1**	Describers	**CAP,JV**
Observation Method	**small pit to 40 cm, augered to 179 cm**		
HS FI			

Obs Method	Horizon	Field Horizon	Depth (cm)	Texture	Matrix Color Moist	RMF	Other
SP	Oe	Oe	5		7.5YR 3/3		
SP	Oa1	Oa	13		7.5YR 2.5/2		
SP	Oa2	A1	37	L (13%)	10YR 2/2		Mucky modified, 2-3 GR structure
SP/BA	A	A2	61	L (15%)	10YR 2/1		1-2 GR structure
BA		BE	85	FSL (10%)	10YR 3/1		
BA		Btg	99	L (20%)	10YR 4/2		
BA		BCg	144	FSL (12%)	10YR 4/2		
BA		CBg	163	SL (8%)	2.5Y 5/2		Raff prob mostly spoil
BA		Cg	179+	LS? (series of expletives %)	2.5Y 5/1		Raff prob mostly spoil

MDC-N-BC Zone 2

Site	**MDC-N-BC**	Date	**8/20/13**
Transect Number	**1-2**	Describers	**CAP,NG**
Observation Method	**small pit to 28 cm, augered to 157 cm**		
HS FI			

Obs Method	Horizon	Field Horizon	Depth (cm)	Texture	Matrix Color Moist	RMF	Other
SP	Oe	Oe	15		5YR 3/4		
SP	A1	A1	28	SL (6%)	10YR 2/1		
BA	A2	A2	44	SL (8%)	10YR 2.5/1		
BA	AB	AB	72	L (15%)	10YR 3/2		
BA	Bg1	Btg1	92	SL (16%)	2.5Y 6/2		
BA	Bg2	Btg2	117	SCL (21%)	2.5Y 6/2		
BA	CBg	BCg	157+	LCS (4%)	2.5Y 6/2		10% fluvial gravel

Site	**MDC-N-BC**	Date	**8/20/13**
Transect Number	**4-2**	Describers	**CAP,NG**
Observation Method	**small pit to 38 cm, augered to 192 cm**		
HS FI			

Obs Method	Horizon	Field Horizon	Depth (cm)	Texture	Matrix Color Moist	RMF	Other
SP	Oe	Oe	22		7.5YR 2.5/3		
SP	A	A	38	SL (6%)	10YR 2/1		
BA	AB	AB	46	SL (8%)	10YR 2/1		
BA	Bw	Bt	60	SL (17%)	10YR 3/2		
BA	CBg	BC	77	LCS (3%)	2.5Y 4.5/2		
BA	C	CB	192+	CS (2%)	10YR 4/3		

Site	**MDC-N-BC**	Date	**8/20/13**
Transect Number	**7-2**	Describers	**CAP,NG**
Observation Method	**small pit to 50 cm, augered to 81 cm**		
HS FI			

Obs Method	Horizon	Field Horizon	Depth (cm)	Texture	Matrix Color Moist	RMF	Other
SP	Oe	Oe	24		7.5YR 3/4		
SP	A1	A1	50	LS (5%)	10YR 2/1		
BA	A2	A2	62	LS (4%)	10YR 2/2		
BA	Bg	Bw	73	LS (3%)	10YR 4/2		
BA	C	BC	81+	S (2%)	2.5Y 5/4		

Site	**MDC-N-BC**	Date	**8/6/14**
Transect Number	**1-3**	Describers	**CAP,NG**
Observation Method	**small pit to 40 cm, augered to 187 cm**		
HSFI			

Obs Method	Horizon	Field Horizon	Depth (cm)	Texture	Matrix Color Moist	RMF conc	RMF dep	Other
SP	Oe	Oe	13		5YR 2.5/2			
SP	A	A	28	SL (11%)	10YR 2/2			
SP	EA	AE	42	SL (13%)	2.5Y 6/4			
SP/BA	E	E	53	SL (7%)	2.5Y 6/4	18% D 10YR 5/6		
BA	BE	BE	75	SL (8%)	2.5Y 6/4	25% D 10YR 5/6	10% D 2.5Y 7/2	
BA	Btg	Btg	98	SL (16%)	2.5Y 7/1	15% D 10YR 5/6		10% rounded gravel
BA	Bt	Bt	120	SL (13%)	2.5Y 6/4	22% D 10YR 5/6	7% 2.5Y 7/2	
BA	B'tg	B'tg	140	SL (16%)	2.5Y 7/2	15% P 7.5YR 5/8		
BA	BCg	BCg	181	SL (6%)	2.5Y 7/1			1% angular gravel
BA	Cg	Cg	187+	LS (3%)	2.5Y 7/1			

Site	**MDC-N-BC**	Date	**7/30/14**
Transect Number	**4-3**	Describers	**CAP,JR**
Observation Method	**small pit to 40 cm, augered to 202 cm**		
HSFI			

Obs Method	Horizon	Field Horizon	Depth (cm)	Texture	Matrix Color Moist	RMF conc	RMF dep	Other
SP	Oe	Oe	5		5YR 3/2			
SP	A	A	18	SL (12%)	10YR 2/1			
SP/BA	E1	AE	54	SL (8%)	2.5Y 5/4			
BA	E2	EA	85	SL (6%)	10YR 5/6	2% F		
BA	E3	E	102	LS (4%)	2.5Y 6/4	10% F	2% D	
BA		BE	140	SL (5%)	2.5Y 6/3	15% D	25% P	
BA		Btg	184	SL (19%)	5Y 7/1	15% D		
BA		Cg	202+	SiL (8%)	5Y 7/1	15% D		

Site	**MDC-N-BC**	Date	**7/30/14**
Transect Number	**7-3**	Describers	**CAP,JR**
Observation Method	**small pit to 40 cm, augered to 174 cm**		
HSFI			

Obs Method	Horizon	Field Horizon	Depth (cm)	Texture	Matrix Color Moist	RMF conc	RMF dep	Other
SP	Oe	Oe	6		5YR 3/2			
SP	A	A	15	SL (12%)	10YR 2/1			
SP/BA	AE	AE	55	SL (10%)	10YR 3/4			
BA		E	96	LS (3%)	2.5Y 6/4	15% F		
BA		EB	116	LS (4%)	2.5Y 6/6	30% P		
BA		BE	140	SL (6%)	2.5Y 6/6	10% P	5% D	
BA		Bt	160	SL (19%)	10YR 6/6	5% D	40% P	
BA		Cg	174+	S (2%)	2.5Y 6/2			10% gravel

Site	**MDC-N-BeW**	Date	**8/8/13**
Plot Number	**1-1**	Describers	**CAP,MG**
Observation Method	**small pit to 33 cm, augered to 151 cm**		
HS FI	**Meets A11 Depleted Below Dark Surface**		

Obs Method	Horizon	Field Horizon	Depth (cm)	Texture (% Clay)	Matrix Color Moist	RMF Conc	RMF Dep	Other
SP	Oa	A	18	L (12%)	2.5Y 3/2			
SP	Ag	BEg	33	L (14%)	10YR 4/1	C/D 10YR 4/6	C/F 10YR 5/1	
BA	ABg	Btg1	54	L (22%)	10YR 4/2	M/P 10YR 3/3	C/F 10YR 5/1	
BA	Bg	Btg2	81	CL (28%)	2.5Y 4/1	C/P 10YR 4/6	C/D 10YR 5/1	Some evidence of disturbance
BA	BC	^2C1	97	SCL (25%)	10YR 3/1	C/P 10YR 4/6		Increase in grain size of sand fraction. Evidence of disturbance
BA	CB	^2C2	114	SCL (30%)	7.5YR 3/1	C/P 10YR 4/6		Coarse sand grading into medium sand. Evidence of disturbance
BA	2CBg	3BCg	134	L (20%)	2.5Y 5/2	C/P 10YR 3/3		No evidence of disturbance
BA	2Cg	3CBg	151+	SiL (16%)	2.5Y 6/1	M/P 10YR 3/3 C/P 10YR 4/6		

Site	**MDC-N-BeW**	Date	**8/8/13**
Plot Number	**4-1**	Describers	**CAP,MG**
Observation Method	**small pit to 42 cm, augered to 137 cm**		
HS FI	**Meets A11 Depleted Below Dark Surface**		

Obs Method	Horizon	Field Horizon	Depth (cm)	Texture (% Clay)	Matrix Color Moist	RMF Conc	RMF Dep	Other
SP	Oa	A	19	SL (7%)	10YR 3/1			
SP	Ag	BEg	42	L (11%)	10YR 4/1	C/D 10YR 3/3 C/P 10YR 4/6		
BA	BAg	Bt1	59	L (18%)	10YR 3/1	M/P 10YR 5/6 F/D 10YR 3/3		Evidence of disturbance
BA	Bw	Bt2	114	SCL (22%)	2.5Y 3/1	M/P 10YR 4/6 C/P 10YR 5/6		Abrupt boundary at 114 cm, evidence of disturbance
BA	2BCg	2BCg	137+	SiCL (32%)	2.5Y 5/1	C/P 10YR 4/6 C/P 7.5YR 3/4		

Site	**MDC-N-BeW**	Date	**8/8/13**
Plot Number	**7-1**	Describers	**CAP,MG**
Observation Method	**small pit to 38 cm, augered to 148 cm**		
HS FI			

Obs Method	Horizon	Field Horizon	Depth (cm)	Texture (% Clay)	Matrix Color Moist	RMF Conc	RMF Dep	Other
SP	A	A	20	L (9%)	10YR 4/1			
SP	BEg	BEg	38	L (13%)	10YR 5/2	C/P 10YR 3/3 F/D 10YR 4/6		
BA	Bg1	Btg1	66	SCL (24%)	10YR 4/2	C/P 10YR 3/3 C/D 10YR 4/6		Evidence of disturbance
BA	Bg2	Btg2	101	SL (16%)	10YR 4/1	M/P 10YR 5/6 F/P 10YR 3/3		Coarse sand, evidence of disturbance
BA	2BC	2Bt	134	SiL (17%)	10YR 5/6		C/D 10YR 3/3	
BA	2BCg	2BC	148+	SiL (15%)	10YR 5/1	C/P 5YR 3/4 C/P 10YR 5/6		

Site	**MDC-N-BeW**	Date	**8/6/14**
Plot Number	**1-2**	Describers	**CAP,NG**
Observation Method	**small pit to 40 cm, augered to 200 cm**		
HS FI	**Meets A11 Depleted Below Dark Surface**		

Obs Method	Horizon	Field Horizon	Depth (cm)	Texture (% Clay)	Matrix Color Moist	RMF Conc	RMF Dep	Other
SP	Oe	Oe	13		7.5YR 2.5/2			
SP	A	A	23	L (10%)	10YR 3/1	5% F 7.5YR 3/4		
SP/BA	Ag	Ag	44	L (8%)	10YR 4/1	40% P 5YR 4/6		
BA		Btg	70	SCL (23%)	10YR 4/1	45% D 7.5YR 4/6		
BA		BCg	95	SL (12%)	10YR 6/1	5% D 10YR 5/6		
BA		CB	115	LS (4%)	2.5Y 5/3	3% D 10YR 5/6		
BA		CBg	142	LS (4%)	5Y 5/2	5% F 10YR 5/4		
BA		Cg1	172	S (3%)	5Y 5/1	2% F 2.5Y 5/4		
BA		Cg2	200+	S (2%)	5Y 5/1			

Site	**MDC-N-BeW**	Date	**8/6/14**
Plot Number	**4-2**	Describers	**CAP,NG**
Observation Method	**small pit to 40 cm, augered to 196 cm**		
HS FI			

Obs Method	Horizon	Field Horizon	Depth (cm)	Texture (% Clay)	Matrix Color Moist	RMF Conc	RMF Dep	Other
SP	Oe	Oe	5		5YR 2.5/2			
SP	A1	A1	22	L (12%)	10YR 2/1			
SP	AE	A2	37	L (10%)	10YR 3/1	5% D 7.5YR 3/4		
BA	Btg	Btg	53	SL (15%)	10YR 5/1	15% P 5YR 3/4		
BA	BC	BC	64	LS (5%)	10YR 5/4	10% D 10YR 5/6	5% D 2.5Y 7/1	
BA	CBg	CBg	87	LS (4%)	2.5Y 6/1	5% D 2.5Y 6/6		
BA	Cg	Cg	103	LS (3%)	2.5Y 6/2	10% F 2.5Y 6/4		
BA	C	C	124	LS (3%)	2.5Y 5/3	30% D 2.5Y 5/4		
BA	C'g1	C'g1	144	S (3%)	2.5Y 6/2	30% D 2.5Y 5/4		
BA	C'g2	C'g2	179	S (2%)	5Y 5/1	5% F 2.5Y 5/3		
BA	C'g3	C'g3	196+	CoS (2%)	5Y 5/1			

Site	**MDC-N-BeW**	Date	**8/27/14**
Plot Number	**7-2**	Describers	**CAP,NG**
Observation Method	**small pit to 40 cm, augered to 189 cm**		
HS FI			

Obs Method	Horizon	Field Horizon	Depth (cm)	Texture (% Clay)	Matrix Color Moist	RMF Conc	RMF Dep	Other
SP	Oe	Oe	8		5YR 2.5/2			
SP	A	A	29	SL (10%)	10YR 3/2			
SP/BA	BE	BE	55	S (3%)	2.5Y 6/3			
BA	Bw	Bw	94	LS (6%)	7.5YR 4/6		22% P 2.5Y 6/2	
BA	BC	BC	110	LS (4%)	10YR 4/3	15% D 7.5YR 4/6		
BA	CBg1	CBg1	143	Gr CS (2%)	2.5Y 5/2	5% D 10YR 4/6		20% gravel
BA	CBg2	CBg2	189+	SL (7%)	2.5Y 5/2			

Site **MDC-N-BeW** Date **8/27/14**
Plot Number **1-3** Descriptors **CAP,NG**
Observation Method **small pit to 40 cm, augered to 198 cm**
HS FI

Obs Method	Horizon	Field Horizon	Depth (cm)	Texture (% Clay)	Matrix Color Moist	RMF Conc	RMF Dep	Other
SP	Oe	Oe	4		5YR 2.5/2			
SP	A	A	23	SL (10%)	10YR 2/2			
SP/BA	Bw1	Bw1	59	SL (8%)	2.5Y 5/4			
BA	Bw2	Bw2	83	LS (5%)	2.5Y 5/4	15% P 10YR 3/6		
BA	CB1	CB1	116	S (2%)	2.5Y 6/3	10% D 10YR 5/6	5% F 2.5Y 6/2	
BA	CB2	CB2	171	S (3%)	2.5Y 6/3	20% D 10YR 6/6	7% F 2.5Y 6/2	
BA	CB3	CB3	198+	LS (4%)	2.5Y 6/3	10% P 10YR 4/6	5% F 2.5Y 6/2	

Site **MDC-N-BeW** Date **8/27/13**
Plot Number **4-3** Descriptors **CAP,NG**
Observation Method **small pit to 40 cm, augered to 201 cm**
HS FI

Obs Method	Horizon	Field Horizon	Depth (cm)	Texture (% Clay)	Matrix Color Moist	RMF Conc	RMF Dep	Other
SP	Oe	Oe	4		7.5YR 5/3			
SP	A	A	16	SL (14%)	10YR 2/1			
SP/BA	Bw	Bw	66	SL (10%)	2.5Y 5/4			
BA	BC	BC	100	S (3%)	2.5Y 5/3	8% F 2.5Y 4/4	4% F 5Y 6/2	
BA	CB1	CB1	134	S (3%)	2.5Y 6/3	6% F 2.5Y 4/4	6% F 5Y 6/2	
BA	CB2	CB2	164	S (4%)	2.5Y 6/3	15% P 7.5YR 5/6		
BA	CB3	CB3	201+	LS (4%)	2.5Y 6/3	40% P 7.5YR 5/6		

Site **MDC-N-BeW** Date **8/27/14**
Plot Number **7-3** Descriptors **CAP,NG**
Observation Method **small pit to 40 cm, augered to 203 cm**
HS FI

Obs Method	Horizon	Field Horizon	Depth (cm)	Texture (% Clay)	Matrix Color Moist	RMF Conc	RMF Dep	Other
SP	A1	Oe	4		5YR 3/3			
SP	A2	A1	21	SL (12%)	10YR 2/2			
SP	EB	A2	39	SL (10%)	10YR 3/4			
BA	Bw	Bw	79	SL (8%)	2.5Y 5/4	3% P 10YR 3/6		
BA	BC	BC	105	S (3%)	2.5Y 5/3	25% P 10YR 4/6	5% D 2.5Y 7/2	
BA	CB1	CB1	125	S (4%)	2.5Y 6/3	20% P 10YR 5/6	10% D 2.5Y 7/2	
BA	CB2	CB2	153	LS (5%)	2.5Y 6/3	10% D 2.5Y 6/6	30% D 2.5Y 6/2	
BA	CB3	CB3	179	LS (8%)	7.5YR 5/8	30% P 2.5Y 6/3	10% P 2.5Y 6/3	
BA	CB4	CB4	203+	LS (6%)	2.5Y 6/3	5% D 10YR 6/6	20% F 2.5Y 6/2	

Site	**MDQA-R-BsO**	Date	**3/18/15**
Transect Number	**1-2**	Describers	**CAP,CP,BW**
Observation Method	**small pit to 40 cm, augered to 109 cm**		
HS FI			

Obs Method	Horizon	Field Horizon	Depth (cm)	Texture	Matrix Color Moist	RMF Conc	RMF Dep	Other
SP	^A	A	9	FSL (6%)	10YR 3/2			
SP	^AC1	Ap1	19	FSL (7%)	10YR 5/3	10% D 5YR 4/6		
SP	^AC2	Ap2	33	FSL (10%)	10YR 5/3	15% D 10YR 5/6		
SP/BA	Btb	Bt	74	CL (30%)	10YR 5/6	25% D 5YR 5/6	20% P 10YR 6/1	Bone dry aquaclude?
BA	Btmgb1	Btg1	90	L (24%)	10YR 5/1	10% P 5YR 5/6		Cemented, bone dry aquaclude?
BA	Btmgb2	Btg2	109+	SCL (21%)	10YR 6/1	7% D 10YR 6/6		Cemented, bone dry aquaclude?

Site	**MDQA-R-BsO**	Date	**8/6/14**
Transect Number	**7-2**	Describers	**CAP,NG**
Observation Method	**small pit to 40 cm, augered to 157 cm**		
HS FI			

Obs Method	Horizon	Field Horizon	Depth (cm)	Texture	Matrix Color Moist	RMF Conc	RMF Dep	Other
SP	^A	A	7	FSL (14%)	7.5YR 3/2	3% F 5YR 3/4		
SP	^Cg	Btg	22	FSL (12%)	2.5Y 5/2	15% P 5YR 3/4		
SP	BCb	BC	41	LFS (5%)	2.5Y 5/3	22% D 10YR 5/6		
BA	C1b	C1	87	FS (3%)	2.5Y 6/3	3% F 10YR 5/6		
BA	C2b	C2	157+	FS (2%)	2.5Y 5/3			

Site	**MDQA-R-BsO**	Date	**8/6/14**
Transect Number	**9-2**	Describers	**CAP,NG**
Observation Method	**small pit to 40 cm, augered to 154 cm**		
HS FI			

Obs Method	Horizon	Field Horizon	Depth (cm)	Texture	Matrix Color Moist	RMF Conc	RMF Dep	Other
SP	Oe	Oe	6		7.5YR 3/2			
SP	ABg	ABg	17	FSL (12%)	2.5Y 5/2	1% D 10YR 5/6		
SP/BA	Btg1	BAg	65	FSL (15%)	2.5Y 6/2	40% D 2.5Y 6/4 5% D 10YR 5/6		
BA	Btg2	Btg	86	FSL (18%)	2.5Y 6/1	40% P 10YR 5/6		3% rounded gravel
BA	Cg	Cg	154+	LFS (4%)	2.5Y 6/1	25% D 10YR 5/6		

Site	**MDQA-R-BsO**	Date	**3/18/15**
Transect Number	**1-3**	Describers	**CAP,CP,BW**
Observation Method	**small pit to 40 cm, augered to 105 cm**		
HSFI			

Obs Method	Horizon	Field Horizon	Depth (cm)	Texture	Matrix Color Moist	RMF Conc	RMF Dep	Other
SP	Oe	Oe	7	MKY PT	10YR 3/3			
SP	A	A	19	FSL (12%)	10YR 3/4			
SP	AE	AE	29	FSL (10%)	10YR 4/4			Platy structure
SP/BA	Bt1	Bt1	60	FSL (26%)	10YR 5/6	10% F 7.5YR 5/6		
BA		Bt2	74	FSL (24%)	10YR 5/4	10% D 7.5YR 5/6	15% D 2.5Y 6/2	
BA		BC1	85	LFS (4%)	2.5Y 5/3	5% D 10YR 5/6	5% F 2.5Y 6/2	
BA		BC2	105+	FS (3%)	10YR 5/4	10% F 10YR 5/6	20% F 2.5Y 6/3	

Site	**MDQA-R-BsO**	Date	**3/18/15**
Transect Number	**7-3**	Describers	**CAP,CP,BW**
Observation Method	**small pit to 40 cm, augered to 109 cm**		
HSFI			

Obs Method	Horizon	Field Horizon	Depth (cm)	Texture	Matrix Color Moist	RMF Conc	RMF Dep	Other
SP	^A	A	8	FSL (7%)	10YR 4/3	4% D 7.5YR 4/6		
SP	^AC	Ap	31	FSL (16%)	10YR 6/3	20% D 7.5YR 4/6		
SP/BA	Bwb1	Bw1	53	LFS (5%)	10YR 6/6	25% D 7.5YR 5/6	18% D 10YR 6/2	
BA	Bwb2	Bw2	67	LFS (3%)	10YR 5/4			
BA	BCb	BC	105+	FS (2%)	10YR 5/3			

Site	**MDQA-R-BsO**	Date	**3/18/15**
Transect Number	**9-3**	Describers	**CAP,CP,BW**
Observation Method	**small pit to 40 cm, augered to 103 cm**		
HSFI			

Obs Method	Horizon	Field Horizon	Depth (cm)	Texture	Matrix Color Moist	RMF Conc	RMF Dep	Other
SP	^A	A	10	FSL (7%)	10YR 4/3			
SP	^AC	Ap	36	FSL (12%)	10YR 5/3	8% D 10YR 5/6		
SP/BA	Bwb1	Bw1	56	LFS (4%)	10YR 6/3	10% D 7.5YR 5/6		
BA	Bwb2	Bw2	75	FS (3%)	10YR 6/3			
BA	BCb	BC	103+	FS (2%)	10YR 5/3			

MDQA-R-BsY Zone 1

Site	**MDQA-R-BsY**	Date	**8/26/13**
Transect Number	**0-1**	Describers	**CAP,NG,JV**
Observation Method	**small pit to 35 cm, augered to 171 cm**		
HS FI			

Obs Method	Horizon	Field Horizon	Depth (cm)	Texture	Matrix Color Moist	RMF Conc	RMF Dep	Other
SP	^A	^Oe	5		10YR 2/2			
SP	^Ag1	^Ag1	20	L (18%)	10YR 4/2			
SP	^Ag2	^Ag2	35	L (20%)	10YR 4/1	10% F 10YR 3/4		
BA	Bg1	Bg1	53	FSL (13%)	10YR 6/1	15% F 2.5Y 6/4		
BA	Bg2	Bg2	70	FSL (10%)	10YR 6/1	22% D 10YR 6/6		
BA	Bg3	Bg3	83	FSL (12%)	10YR 6.5/1	22% D 10YR 6/6		
BA	BCg	BCg	116	FSL (4%)	2.5Y 6.5/1	15% D 10YR 6/6		
BA	CBg	CBg	135	LFS (3%)	2.5Y 6/2	25% D 10YR 5/6		
BA	Cg	Cg	171+	FS (2%)	10YR 6/2	30% D 10YR 4/6		

Site	**XXX**	Date	**X/XX/XXXX**
Transect Number	**XXX**	Describers	**XXX**
Observation Method	**small pit to XX cm, augered to XXX cm**		
HS FI			

Obs Method	Horizon	Field Horizon	Depth (cm)	Texture	Matrix Color Moist	RMF Conc	RMF Dep	Other

Site	**MDQA-R-BsY**	Date	**8/26/13**
Transect Number	**8-1**	Describers	**CAP,NG,JV**
Observation Method	**small pit to 35 cm, augered to 163 cm**		
HS FI			

Obs Method	Horizon	Field Horizon	Depth (cm)	Texture	Matrix Color Moist	RMF Conc	RMF Dep	Other
SP	^Ag1	^Ag1	13	SiL (6%)	10YR 4/2			
SP	^Ag2	^Ag2	20	L (18%)	7.5YR 4/1			
SP	^ABg	^ABg	35	SCL (23%)	2.5Y 4/4	40% F 10YR 4/6		
BA	BAg	BAg	49	SL (4%)	2.5Y 5/2	15% D 10YR 4/4		
BA		Bw1	78	SL (8%)	2.5Y 5/3	10% D 10YR 4/4	15% D 2.5Y 6/1	
BA		Bw2	91	SL (10%)	2.5Y 5/3	25% D 10YR 4/4	10% D 2.5Y 6/1	
BA		Bg	109	SL (15%)	10YR 6/1	25% P 10YR 5/6		
BA		BCg	134	SL (5%)	2.5Y 6/2	10% D 2.5Y 5/3		
BA		CBg	163+	SL (5%)	2.5Y 6/2			

Site		**MDQA-R-BsY**	Date	**7/27/2011**
Transect Number	**0-2**		Describers	**AMR, MCR**
Observation Method	**small pit to 32 cm, augered to 198 cm**			
HS FI	**almost meets A11 - Depleted Below Dark Surface**			
	Sandy material above the depleted matrix must have value of 3 or less and **chroma of 2 or less**, and, viewed through at 10x or 15x hand lens, **at least 70% of the visible soil particles must be masked with organic material**			

Obs Method	Horizon	Field Horizon	Depth (cm)	Texture	Matrix Color Moist	RMF	Other		Depth	%C
SP	Oe	Oe	13	MK PT	5YR 2.5/2				4.5	4.6415
SP	A	A	20	S	10YR 2.5/1.5				18.1	0.6781
SP	Cg1	Cg1	30	S	2.5Y 4.5/2		3-4% org. rich pockets, 2-10 mm diam., 7.5YR 2.5/3 and 10YR 3/1.5		36.1	0.4752
							H_2S smell		49.8	0.1682
SP/BA	Cg2	Cg2	56	S	2.5Y 4.5/1.5		H_2S smell			
BA	Cg3	Cg3	82	S	2.5Y 4.5/1		H_2S smell			
BA	2Ab	2Ab1	99	MK SIL	7.5YR 2.5/2					
BA	3Oa	2Oab	109	MUCK	7.5YR 2.5/1					
BA	3Cg1	3Cg1	157	S	10YR 4.5/1.5					
BA	3Cg2	3Cg2	177	S	2.5Y 3.5/1					
BA	4Cg3	3Cg3	198+	COS	2.5Y 3.5/1					

Site		**XXX**	Date	**7/27/2011**
Transect Number	**6-2**		Describers	**AMR, MCR**
Observation Method	**small pit to 32 cm, augered to 198 cm**			
HS FI	**almost meets A11 - Depleted Below Dark Surface**			
	Sandy material above the depleted matrix must have value of 3 or less and **chroma of 2 or less**, and, viewed through at 10x or 15x hand lens, **at least 70% of the visible soil particles must be masked with organic material**			

Obs Method	Horizon	Field Horizon	Depth (cm)	Texture	Matrix Color Moist	RMF	Other		Depth	%C
SP	Oe	Oe	13	MPT	5YR 2.5/2		surface: ~1 cm pine needles, leaf litter		6.9	2.387
SP	A	A	24	S	10YR 4.5/1.5		5-10% org. rich pockets around roots,		21.3	0.5675
SP	C1	C1	51	S	10YR 5.5/2		5% org. rich pockets around roots, 7.5YR		33.8	0.5147
SP	C2	C2	65	S	2.5Y 5.5/2		3% org. rich pockets around roots, 7.5YR		45	0.46855
BA	C3	C3	92	S	10YR 5/2					
BA	Cg	Cg	119	S	2.5Y 5/1		H_2S smell			
BA	2Ab1	2Ab1	131	MK SIL	10YR 2/2					
BA	3Ab2	2Ab2	136	MK L	10YR 2/1					
BA	4Ab3	3Ab	152	LS	10YR 3/1					
BA	4ACb	3AC	170	S	2.5Y 3.5/1.5					
BA	4Cg	3Cg	196+	S	2.5Y 4.5/1.5					

Site		**XXX**	Date	**7/27/2011**
Transect Number		**8-2**	Describers	**AMR, MCR**
Observation Method		**small pit to 32 cm, augered to 198 cm**		
HS FI	**almost meets A11 - Depleted Below Dark Surface**			
	Sandy material above the depleted matrix must have value of 3 or less and **chroma of 2 or less**, and, viewed through at 10x or 15x hand lens, **at least 70% of the visible soil particles must be masked with organic material**			

Obs Method	Horizon	Field Horizon	Depth (cm)	Texture	Matrix Color Moist	RMF	Other		Depth	%C
SP	Oe	Oe	13	MPT	5YR 2.5/2		surface: ~1 cm pine needles, leaf litter		5.4	1.1885
SP	A	A	24	S	10YR 4.5/1.5		5-10% org. rich pockets around roots,		11.6	0.4541
SP	C1	C1	51	S	10YR 5.5/2		5% org. rich pockets around roots, 7.5YR		28.8	0.42555
SP	C2	C2	65	S	2.5Y 5.5/2		3% org. rich pockets around roots, 7.5YR		46.4	0.1987
BA	C3	C3	92	S	10YR 5/2					
BA	Cg	Cg	119	S	2.5Y 5/1		H_2S smell			
BA	2Ab1	2Ab1	131	MK SIL	10YR 2/2					
BA	3Ab2	2Ab2	136	MK L	10YR 2/1					
BA	4Ab3	3Ab	152	LS	10YR 3/1					
BA	4ACb	3AC	170	S	2.5Y 3.5/1.5					
BA	4Cg	3Cg	196+	S	2.5Y 4.5/1.5					

Site		MDQA-R-BsY	Date	7/27/2011	
Transect Number	0-3		Describers	AMR, MCR	
Observation Method	small pit to 32 cm, augered to 198 cm				
HS FI	almost meets A11 - Depleted Below Dark Surface				
	Sandy material above the depleted matrix must have value of 3 or less and **chroma of 2 or less**, and, viewed through at 10x or 15x hand lens, **at least 70% of the visible soil particles must be masked with organic material**				

Obs Method	Horizon	Field Horizon	Depth (cm)	Texture	Matrix Color Moist	RMF	Other		Depth	%C
SP	Oe	Oe	13	MK PT	5YR 2.5/2				9.1	1.411
SP	A	A	20	S	10YR 2.5/1.5				37	0.4315
SP	Cg1	Cg1	30	S	2.5Y 4.5/2		3-4% org. rich pockets, 2-10 mm diam., 7.5YR 2.5/3 and 10YR 3/1.5		46.2	0.25975
							H_2S smell			
SP/BA	Cg2	Cg2	56	S	2.5Y 4.5/1.5		H_2S smell			
BA	Cg3	Cg3	82	S	2.5Y 4.5/1		H_2S smell			
BA	2Ab	2Ab1	99	MK SIL	7.5YR 2.5/2					
BA	3Oa	2Oab	109	MUCK	7.5YR 2.5/1					
BA	3Cg1	3Cg1	157	S	10YR 4.5/1.5					
BA	3Cg2	3Cg2	177	S	2.5Y 3.5/1					
BA	4Cg3	3Cg3	198+	COS	2.5Y 3.5/1					

Site		XXX	Date	7/27/2011	
Transect Number	6-3		Describers	AMR, MCR	
Observation Method	small pit to 32 cm, augered to 198 cm				
HS FI	almost meets A11 - Depleted Below Dark Surface				
	Sandy material above the depleted matrix must have value of 3 or less and **chroma of 2 or less**, and, viewed through at 10x or 15x hand lens, **at least 70% of the visible soil particles must be masked with organic material**				

Obs Method	Horizon	Field Horizon	Depth (cm)	Texture	Matrix Color Moist	RMF	Other		Depth	%C
SP	Oe	Oe	13	MPT	5YR 2.5/2		surface: ~1 cm pine needles, leaf litter		8.4	2.47
SP	A	A	24	S	10YR 4.5/1.5		5-10% org. rich pockets around roots, 10YR		20.1	0.7186
SP	C1	C1	51	S	10YR 5.5/2		5% org. rich pockets around roots, 7.5YR		31.8	0.39075
SP	C2	C2	65	S	2.5Y 5.5/2		3% org. rich pockets around roots, 7.5YR		47.2	0.42825
BA	C3	C3	92	S	10YR 5/2					
BA	Cg	Cg	119	S	2.5Y 5/1		H_2S smell			
BA	2Ab1	2Ab1	131	MK SIL	10YR 2/2					
BA	3Ab2	2Ab2	136	MK L	10YR 2/1					
BA	4Ab3	3Ab	152	LS	10YR 3/1					
BA	4ACb	3AC	170	S	2.5Y 3.5/1.5					
BA	4Cg	3Cg	196+	S	2.5Y 4.5/1.5					

Site		XXX	Date	7/27/2011	
Transect Number	8-3		Describers	AMR, MCR	
Observation Method	small pit to 32 cm, augered to 198 cm				
HS FI	almost meets A11 - Depleted Below Dark Surface				
	Sandy material above the depleted matrix must have value of 3 or less and **chroma of 2 or less**, and, viewed through at 10x or 15x hand lens, **at least 70% of the visible soil particles must be masked with organic material**				

Obs Method	Horizon	Field Horizon	Depth (cm)	Texture	Matrix Color Moist	RMF	Other		Depth	%C
SP	Oe	Oe	13	MPT	5YR 2.5/2		surface: ~1 cm pine needles, leaf litter		6.6	2.385
SP	A	A	24	S	10YR 4.5/1.5		5-10% org. rich pockets around roots, 10YR		23.5	0.5605
SP	C1	C1	51	S	10YR 5.5/2		5% org. rich pockets around roots, 7.5YR 4/4 and 10YR 4/3		46	0.16905
SP	C2	C2	65	S	2.5Y 5.5/2		3% org. rich pockets around roots, 7.5YR			
BA	C3	C3	92	S	10YR 5/2					
BA	Cg	Cg	119	S	2.5Y 5/1		H_2S smell			
BA	2Ab1	2Ab1	131	MK SIL	10YR 2/2					
BA	3Ab2	2Ab2	136	MK L	10YR 2/1					
BA	4Ab3	3Ab	152	LS	10YR 3/1					
BA	4ACb	3AC	170	S	2.5Y 3.5/1.5					
BA	4Cg	3Cg	196+	S	2.5Y 4.5/1.5					

Site	**MDD-R-Ck**	Date	**3/19/15**
Plot Number	**1-1**	Describers	**CAP,JF,SM**
Observation Method	**small pit to 40 cm, augered to 108 cm**		
HS FI			

Obs Method	Horizon	Field Horizon	Depth (cm)	Texture (% Clay)	Matrix Color Moist	RMF Conc	RMF Dep	Other
SP/BA	^C/A	^C/A	43	LS (6%)	2.5Y 5/3			
				LS (4%)	5YR 2.5/2			
BA	Bgb1	BAgb	65	LS (5%)	10YR 6/2	4% D 10YR 6/6		
BA	Bgb2	Bgb1	93	CoS (3%)	2.5Y 7/1	2% F 10YR 5/6		
BA	Bgb3	Bgb2	108+	LS (4%)	2.5Y 7/1			Significant dead root matter present

Site	**MDD-R-Ck**	Date	**3/19/15**
Plot Number	**4-1**	Describers	**CAP,JF,SM**
Observation Method	**small pit to 40 cm, augered to 103 cm**		
HS FI	**Meets A11 - Depleted Below Dark Surface**		

Obs Method	Horizon	Field Horizon	Depth (cm)	Texture (% Clay)	Matrix Color Moist	RMF Conc	RMF Dep	Other
SP	^A	^A	13	SL (6%)	10YR 2/1			
SP/BA	^Cg	^Cg	49	CL (30%)	10YR 5/1	20% P 7.5YR 4/6		
BA		Egb1	73	CoSL (10%)	2.5Y 5/1	5% F 10YR 5/6		Significant dead root matter present - potential A master horizon
BA		Egb2	91	CoS (2%)	10YR 5/1			10% gravel
BA		Btgb	103+	C (70%)	2.5Y 7/1	20% P 7.5YR 6/8		

Site	**MDD-R-Ck**	Date	**3/19/15**
Plot Number	**7-1**	Describers	**CAP,JF,SM**
Observation Method	**small pit to 40 cm, augered to 101 cm**		
HS FI	**Meets A11 - Depleted Below Dark Surface**		

Obs Method	Horizon	Field Horizon	Depth (cm)	Texture (% Clay)	Matrix Color Moist	RMF Conc	RMF Dep	Other
SP	^A	^A	6	MKY SL (6%)	10YR 3/2			
SP	^Cg1	^Ag	16	SL (9%)	2.5Y 6/1			
SP/BA	^Cg2	^Cg1	46	SCL (27%)	2.5Y 5/1	12% D 10YR 5/6		
BA	^Cg3	^Cg2	81	SCL (22%)	2.5Y 5/1	4% F 10YR 6/6		
BA	BCgb	BCgb	101+	CoS (2%)	2.5Y 5/1	1% D 10YR 6/6		

MDD-R-Ck Zone 2

Site	**MDD-R-Ck**	Date	**3/19/15**
Plot Number	**1-2**	Describers	**CAP,JF,SM**
Observation Method	**small pit to 40 cm, augered to 108 cm**		
HS FI			

Obs Method	Horizon	Field Horizon	Depth (cm)	Texture (% Clay)	Matrix Color Moist	RMF Conc	RMF Dep	Other
SP	^A1	^A1	6	MKY SL (11%)	10YR 3/2			
SP	^A2	^A2	27	L (10%)	10YR 3/2			
SP/BA	^C	^C	51	SL (15%)	2.5Y 5/3	20% P 10YR 6/8	5% F 2.5Y 6/2	
BA		^Cg	67	SCL (22%)	2.5Y 6/1	40% P 7.5YR 5/8		
BA		BCgb	87	S (4%)	2.5Y 7/1	20% P 7.5YR 5/8		
BA		CBb	108+	CoS (2%)	10YR 4/3			

Site	**MDD-R-Ck**	Date	**3/19/15**
Plot Number	**4-2**	Describers	**CAP,JF,SM**
Observation Method	**small pit to 40 cm, augered to 108 cm**		
HS FI			

Obs Method	Horizon	Field Horizon	Depth (cm)	Texture (% Clay)	Matrix Color Moist	RMF Conc	RMF Dep	Other
SP	^A1	^Oe	4	MKY PT	10YR 2/2			
SP	^A2	^A	21	L	10YR 2/2	2% D 10YR 5/6		
SP/BA	^C	^AC	48	S (4%)	10YR 5/3	15% P 5YR 4/6		
BA		^Cg1	64	S (3%)	2.5Y 7/1	30% D 10YR 6/6		
BA		^Cg2	78	SCL (24%)	2.5Y 6/1	10% D 10YR 6/6		
BA		Ebgb	87	LS (5%)	2.5Y 5/1	20% P 10YR 6/8		
BA		Btgb	99	SCL (21%)	2.5Y 6/1	1% D 10YR 6/6		
BA		BCgb	108+	S (2%)	2.5Y 6/2			

Site	**MDD-R-Ck**	Date	**3/19/15**
Plot Number	**7-2**	Describers	**CAP,JF,SM**
Observation Method	**small pit to 40 cm, augered to 114 cm**		
HS FI			

Obs Method	Horizon	Field Horizon	Depth (cm)	Texture (% Clay)	Matrix Color Moist	RMF Conc	RMF Dep	Other
SP	^A	^A	20	L (13%)	10YR 3/1			
SP/BA	^C	^C	43	SCL (21%)	10YR 5/4	20% P 10YR 5/6	30% D 10YR 6/2	
BA		Egb	65	S (3%)	2.5Y 5/1	10% D 2.5Y 6/6		
BA		Btgb	94	SC (36%)	5Y 6/1	15% D 2.5Y 6/6		
BA		BCgb	114+	CoS (2%)	2.5Y 6/2	30% F 2.5Y 6/6		

MDD-R-Ck Zone 3

Site	**MDD-R-Ck**	Date	**3/19/15**
Plot Number	**1-3**	Describers	**CAP,JF,SM**
Observation Method	**small pit to 40 cm, augered to 103 cm**		
HS FI			

Obs Method	Horizon	Field Horizon	Depth (cm)	Texture (% Clay)	Matrix Color Moist	RMF Conc	RMF Dep	Other
SP	^A1	^A1	14	SL (13%)	10YR 3/1			
SP	^A2	^A2	32	SL (11%)	10YR 3/2			
SP/BA	^A/Cg1	^A/Cg1	51	SL (8%)	10YR 2/1 10YR 6/2	5% P 10YR 6/6		RELICT REDOX
BA		^A/Cg2	67	SL (11%)	10YR 3/2 10YR 6/2			
BA		^A'	80	L (14%)	10YR 3/2			
BA		Ab	90	L (12%)	7.5YR 3/3			
BA		Bgb	103+	SL (14%)	10YR 5/2	10% P 7.5YR 5/6		

Site	**MDD-R-Ck**	Date	**3/19/15**
Plot Number	**4-3**	Describers	**CAP,JF,SM**
Observation Method	**small pit to 40 cm, augered to 106 cm**		
HS FI			

Obs Method	Horizon	Field Horizon	Depth (cm)	Texture (% Clay)	Matrix Color Moist	RMF Conc	RMF Dep	Other
SP	Oe	Oe	4	MKY PT	10YR 2/2			
SP	A	A	17	L (13%)	10YR 2/2			
SP	Ap	Ap	33	SL (11%)	10YR 2/2	3% D 7.5YR 4/6		
SP/BA	Eg	Eg	60	SL (9%)	2.5Y 6/1.5			
BA		Btg1	88	SCL (22%)	2.5Y 6/1	15% F 10YR 6/6		
BA		Btg2	106+	SL (12%)	2.5Y 6/1			

Site	**MDD-R-Ck**	Date	**3/19/15**
Plot Number	**7-3**	Describers	**CAP,JF,SM**
Observation Method	**small pit to 40 cm, augered to 108 cm**		
HS FI			

Obs Method	Horizon	Field Horizon	Depth (cm)	Texture (% Clay)	Matrix Color Moist	RMF Conc	RMF Dep	Other
SP	^A/C	^A/C	16	SL (10%)	10YR 2/1 10YR 5/4			
SP	^Cg/A	^Cg/A	36	SL (15%)	10YR 4/3 2.5Y 6/1	6% P 10YR 6/6		Platy structure
BA	Ab	Ab	74	L (12%)	10YR 2/1			
BA		Btgb	90	SL (17%)	2.5Y 5/1	10% P 10YR 4/6		
BA		BCgb	108+	S (2%)	2.5Y 6/1	3% P 10YR 6/8		

MDT-R-Fr Zone 1

Site	**MDT-R-Fr**	Date	**9/25/13**
Plot Number	**1-1**	Describers	**CAP,JV**
Observation Method	**small pit to 40 cm, augered to 121 cm**		
HSFI			

Obs Method	Horizon	Field Horizon	Depth (cm)	Texture (% Clay)	Matrix Color Moist	RMF Conc	RMF Dep	Other
SP	^Ag	Oa	11		2.5Y 4/2			
SP	^Cg1	A	18		2.5Y 5/1			
SP/BA	^Cg2		55	SiL (18%)	2.5Y 6/1	35% P		Conc decrease to 5% by 47 cm
BA			66	LS (4%)	5Y 6/1			
BA			80	SiL (25%)	5Y 6/1			
BA			98	SL (14%)	2.5Y 4/1			
BA			121	S (2%)	2.5Y 7/1			

Site	**MDT-R-Fr**	Date	**9/25/13**
Plot Number	**4-1**	Describers	**CAP,JV**
Observation Method	**small pit to 40 cm, augered to 168 cm**		
HSFI			

Obs Method	Horizon	Field Horizon	Depth (cm)	Texture (% Clay)	Matrix Color Moist	RMF Conc	RMF Dep	Other
SP	^A	^Oa	6		2.5Y 3/2			
SP	^Ag	^Ag	14		2.5Y 5/1	15% D		
SP	^Cg1	^Btg	38	SiCL (28%)	2.5Y 5/1			
SP/BA	^Cg2	^Bt	56	SCL (32%)	10YR 4/6		10% P	
BA		BE	85	LS (4%)	2.5Y 5/4			Intermixing
BA		Btg1	110	SL (11%)	5Y 6/1	25% D		
BA		Btg2	154	SL (13%)	5Y 6/1	10% D		
BA		CBg	168+	LS (3%)	5Y 6/1	15% P		

Site	**MDT-R-Fr**	Date	**9/25/13**
Plot Number	**7-1**	Describers	**CAP,JV**
Observation Method	**small pit to 40 cm, augered to 150 cm**		
HSFI			

Obs Method	Horizon	Field Horizon	Depth (cm)	Texture (% Clay)	Matrix Color Moist	RMF Conc	RMF Dep	Other
SP	^Ag	Oa	15		2.5Y 4/2			
SP	^Cg1	A	21		2.5Y 5/1	15% D		
SP/BA	^Cg2		49		5Y 6/1	30% P		
BA			62	SL (12%)	2.5Y 5/4			Intermixed
BA			82	LS (5%)	2.5Y 5/4			Intermixed
BA			92	SL (14%)	5Y 6/1			Intermixed
BA			150+	S (2%)	2.5Y 6/2	20% F		

Site **MDT-R-Fr** Date **3/19/15**
Plot Number **1-2** Describers **CAP,JF,SM**
Observation Method **small pit to 40 cm, augered to 105 cm**
HS FI

Obs Method	Horizon	Field Horizon	Depth (cm)	Texture (% Clay)	Matrix Color Moist	RMF Conc	RMF Dep	Other
SP	^Ag	^Oa	7	MK	10YR 4/2			
SP	^ACg	^Ag	19	SiL (12%)	10YR 5/2	25% P 7.5YR 5/8		
SP	^Cg1	^Cg1	33	C (45%)	2.5Y 6/1	30% P 7.5YR 5/8		
SP/BA	^Cg2	^Cg2	60	C (50%)	2.5Y 6/1	15% P 10YR 5/8		
BA	^Cg3	^Cg3	72	SiCL (32%)	N7	10%P 10YR 4/6	8% D 5GY 5/1	
BA	Cb	Cb	94	VGr LS (4%)	10YR 6/3	8% P 10YR 5/6		50% rounded gravel
BA	Cgb	Cgb	105+	S (2%)	10YR 6/2			

Site **MDT-R-Fr** Date **9/25/13**
Plot Number **4-2** Describers **CAP,JV**
Observation Method **small pit to 40 cm, augered to 168 cm**
HS FI

Obs Method	Horizon	Field Horizon	Depth (cm)	Texture (% Clay)	Matrix Color Moist	RMF Conc	RMF Dep	Other

Site **MDT-R-Fr** Date **3/19/15**
Plot Number **7-2** Describers **CAP,JF,SM**
Observation Method **small pit to 40 cm, augered to 107 cm**
HS FI

Obs Method	Horizon	Field Horizon	Depth (cm)	Texture (% Clay)	Matrix Color Moist	RMF Conc	RMF Dep	Other
SP	^A	^Oa	6	MK	10YR 5/3			
SP	^ACg	^Ag1	35	SiL (13%)	2.5Y 5/1	35% P 7.5YR 5/6		
SP/BA	^Cg	^Ag2	50	SiL (13%)	2.5Y 6/1	40% P 7.5YR 5/6		
BA	Btgb1	^Cg1	73	SiCL (31%)	2.5Y 6/1	20% P 7.5YR 5/8	15% F 2.5Y 7/1	
BA	Btgb2	^Cg2	91	SiCL (34%)	5Y 6/1	20% P 7.5YR 6/8		
BA	Btgb3	^Cg3	107+	SiCL (32%)	5Y 6/1	15% P 10YR 6/6		

Site	**MDT-R-Fr**	Date	**3/19/15**
Plot Number	**1-3**	Describers	**CAP,JF,SM**
Observation Method	**small pit to 40 cm, augered to 100 cm**		
HS FI			

Obs Method	Horizon	Field Horizon	Depth (cm)	Texture (% Clay)	Matrix Color Moist	RMF Conc	RMF Dep	Other
SP	A	A	15	SiL (16%)	10YR 4/3	2% F 10YR 5/6		
SP	BE	Ap	38	SiL (13%)	10YR 5/3	10% D 7.5YR 5/8	6% D 10YR 6/1	
BA	Bt	Bt	56	SiCL (32%)	2.5Y 5/4	30% P 10YR 6/8	15% D 10YR 6/1	
BA		Btg1	85	SiL (22%)	2.5Y 6/1	25% P 10YR 6/8		
BA		Btg2	100+	L (18%)	2.5Y 6/1	20% P 7.5YR 6/8		

Site	**MDT-R-Fr**	Date	**9/25/13**
Plot Number	**4-3**	Describers	**CAP,JV**
Observation Method	**small pit to 40 cm, augered to 168 cm**		
HS FI			

Obs Method	Horizon	Field Horizon	Depth (cm)	Texture (% Clay)	Matrix Color Moist	RMF Conc	RMF Dep	Other

Site	**MDT-R-Fr**	Date	**9/25/13**
Plot Number	**7-3**	Describers	**CAP,JV**
Observation Method	**small pit to 40 cm, augered to 150 cm**		
HS FI			

Obs Method	Horizon	Field Horizon	Depth (cm)	Texture (% Clay)	Matrix Color Moist	RMF Conc	RMF Dep	Other

Site	**MDC-N-JL**	Date	**10/9/13**
Plot Number	**1-1**	Describers	**CAP,SE**
Observation Method	**small pit to 40 cm, augered to 143 cm**		
HS FI	**Meets A11 Depleted Below Dark Surface**		

Obs Method	Horizon	Field Horizon	Depth (cm)	Texture (% Clay)	Matrix Color Moist	RMF Conc	RMF Dep	Other
SP	A1	Oe	11		10YR 2/1			
SP	A2		27	SiL (14%)	10YR 2/1			
SP/BA	Eg		48	L (12%)	2.5Y 5/1	8% D		
BA			66	SCL (32%)	2.5Y 4/1	15% P		
BA			86	SC (44%)	2.5Y 5/1	40% P		
BA			109	SCL (24%)	5Y 6/1	15% D		
BA			143+	SL (10%)	5Y 6/1	30% D		2% gravel, inc in sand size

Site	**MDC-N-JL**	Date	**10/9/13**
Plot Number	**4-1**	Describers	**CAP,SE**
Observation Method	**small pit to 40 cm, augered to 160 cm**		
HS FI			

Obs Method	Horizon	Field Horizon	Depth (cm)	Texture (% Clay)	Matrix Color Moist	RMF Conc	RMF Dep	Other
SP	Oe	Oe	16		5YR 2.5/2			
SP	A1		39	SL (12%)	10YR 2/1			
BA	A2		55	SL (13%)	10YR 3/1			
BA			83	SL (6%)	2.5Y 5/1	25% P		3% gravel
BA			105	S (2%)	2.5Y 6/2	10% P		
BA			126	LS (4%)	2.5Y 6/2	40% P		2% gravel
BA			144	S (2%)	2.5Y 6/3	30% F		5% gravel
BA			160+	Gr LCoS (3%)	2.5Y 6/2	15% F		15% gravel

Site	**MDC-N-JL**	Date	**10/9/13**
Plot Number	**7-1**	Describers	**CAP,SE**
Observation Method	**small pit to 40 cm, augered to 172 cm**		
HS FI			

Obs Method	Horizon	Field Horizon	Depth (cm)	Texture (% Clay)	Matrix Color Moist	RMF Conc	RMF Dep	Other
SP	Oe	Oe	20		10YR 2/1			
SP/BA	A		47	SL (10%)	10YR 3/1			
BA			67	SL (13%)	10YR 3/1			
BA			94	SL (16%)	2.5Y 4/1			
BA			113	SCL (25%)	10YR 4/1	25% P		
BA			138	SCL (22%)	2.5Y 6/1	30% P		
BA			172+	LS (6%)	2.5Y 6/1	10% D		

MDC-N-JL Zone 2

Site	**MDC-N-JL**	Date	**3/16/15**
Plot Number	**1-2**	Describers	**CAP,MG,CS**
Observation Method	**small pit to 40 cm, augered to 106 cm**		
HS FI			

Obs Method	Horizon	Field Horizon	Depth (cm)	Texture (% Clay)	Matrix Color Moist	RMF Conc	RMF Dep	Other
SP	A1	Oa	13	MK	10YR 2/2			
SP	A2	A1	24	MKY SL (5%)	10YR 2/1			
SP/BA	A3	A2	48	SL (5%)	10YR 3/1			
BA		Bg	87	SL (6%)	2.5Y 6/2			2% subrounded gravels
BA		BCg	106+	LCoS (4%)	2.5Y 5/2			8% subrounded gravels

Site	**MDC-N-JL**	Date	**3/16/15**
Plot Number	**4-2**	Describers	**CAP,MG,CS**
Observation Method	**small pit to 40 cm, augered to 96 cm**		
HS FI			

Obs Method	Horizon	Field Horizon	Depth (cm)	Texture (% Clay)	Matrix Color Moist	RMF Conc	RMF Dep	Other
SP	A1	Oa	14	MK	5YR 2.5/1			
SP/BA	A2	A	44	MKY LS (3%)	5YR 2.5/1			
BA		Bhsm	76	LS (3%)	5YR 2.5/2			Ortstein city!
BA		Bhs	96+	LS (3%)	5YR 2.5/2			

Site	**MDC-N-JL**	Date	**3/16/15**
Plot Number	**7-2**	Describers	**CAP,MG,CS**
Observation Method	**small pit to 40 cm, augered to 101 cm**		
HS FI			

Obs Method	Horizon	Field Horizon	Depth (cm)	Texture (% Clay)	Matrix Color Moist	RMF Conc	RMF Dep	Other
SP	Oe	Oe	11	MKY PT	5YR 2.5/2			
SP	A1	Oa	23	PT	10YR 2/1			
SP/BA	A2	A	56	MKY SL (4%)	10YR 2/1			
BA		Bg1	81	S (3%)	10YR 5/2			
BA		Bg2	101+	CoS (2%)	10YR 6/1			

Site **MDC-N-JL** Date **3/16/15**
Plot Number **1-3** Describers **CAP,MG,CS**
Observation Method **small pit to 40 cm, augered to 111 cm**
HS FI

Obs Method	Horizon	Field Horizon	Depth (cm)	Texture (% Clay)	Matrix Color Moist	RMF - Conc	RMF - Dep	Other
SP	Oe	Oe	4	MKY PT	5YR 2.5/2			
SP	A	A	15	SL (10%)	10YR 2/2			
SP	AB	AB	27	SL (7%)	10YR 3/3			
SP/BA	Bw	Bw	76	LS (5%)	2.5Y 5/4	3% F 10YR 5/6		
BA		BC1	96	S (4%)	2.5Y 6/3	20% P 10YR 4/6		
BA		BC2	111+	S (2%)	2.5Y 6/3	35% P 7.5YR 5/6	10% D 10YR 6/2	

Site **MDC-N-JL** Date **3/16/15**
Plot Number **4-3** Describers **CAP,MG,CS**
Observation Method **small pit to 40 cm, augered to 106 cm**
HS FI

Obs Method	Horizon	Field Horizon	Depth (cm)	Texture (% Clay)	Matrix Color Moist	RMF - Conc	RMF - Dep	Other
SP	Oe	Oe	5	MKY PT	5YR 2.5/2			
SP	A	A	38	SL (6%)	7.5YR 2.5/1			
BA	Bw1	Bw1	53	SL (5%)	10YR 4/4	10% P 5YR 3/3		
BA		Bw2	96	LS (3%)	10YR 4/4	15% P 5YR 3/4		
BA		BC	106+	S (2%)	5YR 3/4			

Site **MDC-N-JL** Date **3/16/15**
Plot Number **7-3** Describers **CAP,MG,CS**
Observation Method **small pit to 40 cm, augered to 108 cm**
HS FI

Obs Method	Horizon	Field Horizon	Depth (cm)	Texture (% Clay)	Matrix Color Moist	RMF - Conc	RMF - Dep	Other
SP	Oe	Oe	5	MKY PT	2.5YR 2.5/2			
SP	A	A	9	SL (6%)	5YR 2.5/1			
SP	BE	AB	31	SL (5%)	10YR 4/4			
SP/BA		Bt1	65	SL (10%)	2.5Y 5/4	2% D 7.5YR 5/6		
BA		Bt2	80	SL (12%)	2.5Y 5/4	30% P 7.5YR 5/6		
BA		Btg	108+	SL (9%)	2.5Y 6/1	20% P 7.5YR 5/6		

MDC-R-JL Zone 1

Site	**MDC-R-JL**	Date	**10/9/13**
Plot Number	**1-1**	Describers	**CAP,SE**
Observation Method	**small pit to 40 cm, bucket augur to 172 cm**		
HS FI	**Meets A11 Depleted Below Dark Surface**		

Obs Method	Horizon	Field Horizon	Depth (cm)	Texture (% Clay)	Matrix Color Moist	RMF Conc	RMF Dep	Other
SP	^A		7	SiL (15%)	2.5Y 3/1			
SP	^Ag		31	SiL (17%)	2.5Y 4/1			
SP/BA	^A'		52	SiL (12%)	2.5Y 3/1	5% D		
BA			68	SiCL (37%)	2.5Y 4/1	40% P		
BA			86	C (48%)	2.5Y 5/1	30% P		highly disturbed
BA			102	C (54%)	2.5Y 6/1		30% P	
BA			128	C (68%)	5Y 5/1	15% P		
BA			172+	SiCL (33%)	2.5Y 5/1	18% P		2% gravel

Site	**MDC-R-JL**	Date	**10/9/13**
Plot Number	**4-1**	Describers	**CAP,SE**
Observation Method	**small pit to 40 cm, bucket augur to 179 cm**		
HS FI			

Obs Method	Horizon	Field Horizon	Depth (cm)	Texture (% Clay)	Matrix Color Moist	RMF Conc	RMF Dep	Other
SP	^A1		21	SiL (17%)	2.5Y 2.5/1			
SP/BA	^A2		54	SiL (22%)	2.5Y 3/1			
BA	^A3		69	SiCL (28%)	2.5Y 3/1			64-78 cm intermixed
BA			96	SiCL (34%)	5Y 6/1	40% P		
BA			132	SiCL (35%)	5Y 6/1	35% P		
BA			179+	C (45%)	2.5Y 4/1			3% gravel

Site	**MDC-R-JL**	Date	**9/13/13**
Plot Number	**7-1**	Describers	**CAP,JV**
Observation Method	**small pit to 40 cm, bucket augur to 184 cm**		
HS FI			

Obs Method	Horizon	Field Horizon	Depth (cm)	Texture (% Clay)	Matrix Color Moist	RMF Conc	RMF Dep	Other
SP	^A1	Oe	5		10YR 2/2			
SP	^A2	A1	34	SiL (13%)	2.5Y 2.5/1			
SP/BA	^A3	A2	48	SiL (15%)	2.5Y 2.5/1			
BA	BAg	ABg	62	SiL (14%)	2.5Y 4/1			
BA	Btg1	Btg1	100	SiCL (28%)	5Y 5/1	45% P 10YR 5/6 2% P 10YR 3/6		
BA	Btg2	Btg2	127	SiL (24%)	5Y 6/1	5% P 7.5YR 4/6 10% D 10YR 6/6		
BA	BCg	BCg	184+	SiL (12%)	5Y 6/1	10% D 10YR 6/6		

Site	**MDC-R-JL**	Date	**8/15/13**
Plot Number	**1-2**	Describers	**CAP,MG**
Observation Method	**small pit to 40 cm, augered to 151 cm**		
HS FI			

Obs Method	Horizon	Field Horizon	Depth (cm)	Texture (% Clay)	Matrix Color Moist	RMF Conc	RMF Dep	Other
SP	Oi	Oi	8					
SP	Ap1	Ap1	20	SiL (12%)	10YR 2/1			
BA	Ap2	Ap2	40	SiL (14%)	10YR 3/1			
BA	BEg	BEg	52	SiL (17%)	10YR 4/2	F/P 10YR 4/6		
BA	Bg1	Btg1	75	SiL (24%)	10YR 6/1	C/P 10YR 5/6		
BA	Bg2	Btg2	98	SiL (23%)	2.5Y 6/1	C/P 10YR 5/6 M/P 10YR 6/6		
BA	Cg1	Cg1	118	LS (3%)	2.5Y 6.5/1	C/P 10YR 6/6		3% subangular gravel
BA	Cg2	Cg2	127	L (23%)	2.5Y 5/1	F/P 10YR 6/6		
BA	Cg3	Cg3	138	LS (5%)	2.5Y 6/1	F/P 10YR 6/6		
BA	Cg4	Cg4	151+	SCL (21%)	2.5Y 7/1			5% subangular gravel

Site	**MDC-R-JL**	Date	**3/16/15**
Plot Number	**4-2**	Describers	**CAP,MG,CS**
Observation Method	**small pit to 40 cm, augered to 106 cm**		
HS FI			

Obs Method	Horizon	Field Horizon	Depth (cm)	Texture (% Clay)	Matrix Color Moist	RMF Conc	RMF Dep	Other
SP	^A1	^A1	12	SL (11%)	2.5Y 2.5/1			
SP	^A2	^A2	41	SL (12%)	2.5Y 2.5/1			
BA	Agb	^Cg	67	L (20%)	10YR 4/1	1% D 7.5YR 4/6		
BA		Btgb1	88	SiL (26%)	10YR 4/1	10% P 5YR 4/6		
BA		Btgb2	106	CL (28%)	10YR 6/1	20% P 7.5YR 6/6		

Site	**MDC-R-JL**	Date	**8/15/13**
Plot Number	**7-2**	Describers	**CAP,MG**
Observation Method	**small pit to 44 cm, augered to 134 cm**		
HS FI			

Obs Method	Horizon	Field Horizon	Depth (cm)	Texture (% Clay)	Matrix Color Moist	RMF Conc	RMF Dep	Other
SP	^A1	Ap1	24	SiL (18%)	10YR 2/1			2 SBk, Fr
SP	^A2	Ap2	44	SiL (16%)	10YR 2/1	C/F 7.5YR 3/4		2 SBk, Fi, 2% subangular gravel
BA	Btgb1	Btg1	68	CL (30%)	7.5YR 4/1	F/D 10YR 5/6		2% angular gravel
BA	Btgb2	Btg2	94	CL (28%)	10YR 5/1	C/P 5YR 3/4 M/P 7.5YR 4/4 C/P 10YR 6/4	C/F 10YR 7/1	
BA	BCgb	BC	121	SCL (23%)	10YR 6/1	C/P 5YR 4/6 C/D 10YR6/4		
BA	CBgb	CB	134+	SCL (21%)	10YR 6/1	C/P 10YR 5/6		

Site	**MDC-R-JL**	Date	**3/16/15**
Plot Number	**1-3**	Describers	**CAP,MG,CS**
Observation Method	**small pit to 40 cm, augered to 100 cm**		
HS FI			

Obs Method	Horizon	Field Horizon	Depth (cm)	Texture (% Clay)	Matrix Color Moist	RMF Conc	RMF Dep	Other
SP	^A	^A1	4	LS (4%)	5YR 3/1			
SP	^Ag	^A2	17	LS (2%)	10YR 4/2			
SP	^C	^C	34	S (2%)	10YR 5/3	8% D 10YR 5/6	10% P 10YR 7/1	
SP/BA	^Cg/A	^Cg/A	56	S (3%)	10YR 5/2 2.5Y 4/1 7.5YR 2.5/1	9% P 5YR 4/6	10% D 10YR 6/1	
BA		Ab	73	SL (12%)	10YR 2/1			
BA		AEb	86	SL (9%)	10YR 3/1			
BA		Bwb	100+	S (3%)	2.5Y 5/1			

Site	**MDC-R-JL**	Date	**3/16/15**
Plot Number	**4-3**	Describers	**CAP,MG,CS**
Observation Method	**small pit to 40 cm, augered to 106 cm**		
HS FI			

Obs Method	Horizon	Field Horizon	Depth (cm)	Texture (% Clay)	Matrix Color Moist	RMF Conc	RMF Dep	Other
SP	A1	A1	10	SL (6%)	10YR 3/2			
SP	A2	A2	24	SL (6%)	10YR 3/2			
SP/BA	EB	EB	51	SL (6%)	2.5Y 6/4	18% F 10YR 5/6		
BA		Bw1	68	SL (7%)	2.5Y 5/4	40% P 2.5YR 4/6		
BA		Bw2	85	SL (5%)	2.5Y 6/4	21% P 7.5YR 5/6	13% D 2.5Y 6/2	
BA		BC	106+	LS (3%)	2.5Y 6/3		30% D 2.5Y 7/2	

Site	**MDC-R-JL**	Date	**3/16/15**
Plot Number	**7-3**	Describers	**CAP,MG,CS**
Observation Method	**small pit to 40 cm, augered to 104 cm**		
HS FI			

Obs Method	Horizon	Field Horizon	Depth (cm)	Texture (% Clay)	Matrix Color Moist	RMF Conc	RMF Dep	Other
SP	A1	A1	7	SL (12%)	7.5YR 3/1			
SP	A2	A2	20	SL (8%)	7.5YR 3/1			3% rounded gravel
SP	AE	AE	31	SL (9%)	10YR 3/2	8% D 10YR 5/6	20% F 10YR 5/3	
SP/BA		EB	48	LS (5%)	2.5Y 5/4	1% P 7.5YR 6/6		
BA		Bw1	63	SL (6%)	2.5Y 5/4	12% P 7.5YR 5/8		
BA		Bw2	89	LS (4%)	2.5Y 6/4	20% P 7.5YR 5/6	20% P 10YR 7/1	
BA		BC	104+	S (4%)	2.5Y 6/4	10% P 7.5YR 5/6	30% D 10YR 7/1	

DEK-R-Jr Zone 1

Site	**DEK-R-Jr**	Date	**9/24/13**
Plot Number	**1-1**	Describers	**CAP,JV**
Observation Method	**small pit to 40 cm, augered to 192 cm**		
HS FI	**Meets A11 Depleted Below Dark Surface**		

Obs Method	Horizon	Field Horizon	Depth (cm)	Texture (% Clay)	Matrix Color Moist	RMF Conc	RMF Dep	Other
SP	^A	^Oa	3		10YR 3/2			
SP	^Ap	^Ap	17		10YR 3/1			
SP	^Bg1	^Bg1	38	SL (19%)	2.5Y 6/1			
SP/BA	^Bg2	^Bg2	74	SL (6%)	2.5Y 7/2	20% D		
BA		^Bg3	92	SL (16%)	2.5Y 6/2			
BA		^Bg4	125	SL (15%)	2.5Y 6/2	30% P		
BA		^Bg5	153	SL (10%)	2.5Y 7/2			
BA		BC1	171	LS (3%)	2.5Y 6/3			
BA		BC2	192+	CoS (2%)	2.5Y 7/2			

Site	**DEK-R-Jr**	Date	**9/24/13**
Plot Number	**4-1**	Describers	**CAP,JV**
Observation Method	**small pit to 40 cm, augered to 196 cm**		
HS FI	**Meets A11 Depleted Below Dark Surface**		

Obs Method	Horizon	Field Horizon	Depth (cm)	Texture (% Clay)	Matrix Color Moist	RMF Conc	RMF Dep	Other
SP	^A	^Oa	5		10YR 3/2			
SP	^Ap	^A	19		10YR 3/1			
SP	^Bg1	^Bg1	33	SL (14%)	2.5Y 5/1			
SP/BA	^Bg2	^Bg2	45	SL (12%)	2.5Y 5/1	30% P		
BA		^Bg3	58	SL (18%)	2.5Y 5/1	20% D		
BA		^Bg4	83	SL (16%)	2.5Y 5/1	15% P		
BA		^Cg	100	C (45%)	5Y 6/1			25% sand
BA		Bg5	120	SCL (22%)	2.5Y 4/1	10% D		
BA		Bg6	148	SL (19%)	2.5Y 7/2	5% F		
BA		BC	172	LCoS (4%)	2.5Y 7/2	30% P		
BA		CB	196+	FSL (10%)	2.5Y 7/2	5% P		

Site	**DEK-R-Jr**	Date	**9/24/13**
Plot Number	**7-1**	Describers	**CAP,JV**
Observation Method	**small pit to 40 cm, augered to 189 cm**		
HS FI	**Meets A11 Depleted Below Dark Surface**		

Obs Method	Horizon	Field Horizon	Depth (cm)	Texture (% Clay)	Matrix Color Moist	RMF Conc	RMF Dep	Other
SP	^A	A	4		2.5Y 3/2			
SP	^Ag	Ap	25		2.5Y 4/1	15% D		
SP	^Bg1	^Bg1	37	LS (4%)	2.5Y 6/2	35% F		
SP/BA	^Bg2	^Bg2	49	SL (8%)	2.5Y 6/1	40% P		
BA		^Bg3	66	LS (3%)	2.5Y 6/1	20% P		
BA		^Bg4	77	SCL (22%)	2.5Y 5.5/1	5% F		
BA		^Bg5	91	SL (10%)	2.5Y 5.5/1.5			
BA		^Bg6	118	SL (14%)	2.5Y 6/1	20% P		
BA		^Bg7	130	SL (19%)	2.5Y 6.5/1			
BA		BC1	154	LCoS (5%)	2.5Y 6/2			
BA		BC2	176	LS (4%)	2.5Y 6/2	15% F		
BA		BC3	189+	LCoS (3%)	2.5Y 5/3			

DEK-R-Jr Zone 2

Site	**DEK-R-Jr**	Date	**3/18/15**
Plot Number	**1-2**	Describers	**CAP,CP,BW**
Observation Method	**small pit to 40 cm, augered to 104 cm**		
HS FI			

Obs Method	Horizon	Field Horizon	Depth (cm)	Texture (% Clay)	Matrix Color Moist	RMF - Conc	RMF - Dep	Other
SP	^Ag	Ag1	9	L (7%)	2.5Y 5/1			
SP	^ACg	Ag2	23	L (11%)	2.5Y 4/1	3% D 10YR 5/6		REDOX IS RELICT
SP/BA	^Cg	Ag3	44	L (12%)	2.5Y 5.5/1	15% D 10YR 5/6		
BA	Bgb1	Bg1	67	LS (6%)	2.5Y 6/1	20% P 10YR 4/6		
BA	Bgb2	Bg2	89	LS (4%)	2.5Y 7/1	25% P 10YR 5/6		
BA	Bgb3	Bg3	104+	LS (4%)	2.5Y 7/1	30% D 10YR 6/6		

Site	**DEK-R-Jr**	Date	**3/18/15**
Plot Number	**4-2**	Describers	**CAP,CP,BW**
Observation Method	**small pit to 40 cm, augered to 104 cm**		
HS FI	**Meets A11 - Depleted Below Dark Surface**		

Obs Method	Horizon	Field Horizon	Depth (cm)	Texture (% Clay)	Matrix Color Moist	RMF - Conc	RMF - Dep	Other
SP	^A1	^A1	4	MKY SL (7%)	10YR 3/1			
SP	^A2	^A2	30	L (14%)	10YR 3/2	2% D 10YR 5/6	3% D 10YR 6/2	RELICT REDOX
SP/BA	^Cg	^Cg	48	SiL (19%)	10YR 5/1	20% P 7.5YR 5/6		
BA	Egb	Egb	57	S (2%)	10YR 6/1			
BA	Btgb	Btgb1	78	SCL (22%)	10YR 5/1	15% P 10YR 5/6 20% F 2.5Y 6/3		
BA	Btmgb	Btgb2	94	SCL (25%)	2.5Y 7/2	5% D 10YR 5/6		Cemented!
BA	BCg	BCg	104+	LS (5%)	10YR 5/1			

Site	**DEK-R-Jr**	Date	**3/18/15**
Plot Number	**7-2**	Describers	**CAP,CP,BW**
Observation Method	**small pit to 40 cm, augered to 111 cm**		
HS FI			

Obs Method	Horizon	Field Horizon	Depth (cm)	Texture (% Clay)	Matrix Color Moist	RMF - Conc	RMF - Dep	Other
SP	^Ag	Ag1	14	L (8%)	2.5Y 5/1			
SP	^ACg	Ag2	28	L (12%)	2.5Y 4/1			
SP/BA	^Cg	Ag3	50	L (12%)	2.5Y 5/1	3% F 10YR 6/6		
BA	Bgb1	Bg1	70	LS (5%)	2.5Y 6/1	15% D 10YR 5/6		
BA	Bgb2	Bg2	86	LS (3%)	5Y 7/1	30% P 10YR 5/8		
BA	Bgb3	Bg3	111+	SL (6%)	5Y 7/1	5% D 10YR 6/6		

DEK-R-Jr Zone 3

Site **DEK-R-Jr** Date **3/18/15**
Plot Number **1-3** Describers **CAP,CP,BW**
Observation Method **small pit to 40 cm, augered to 104 cm**
HS FI

Obs Method	Horizon	Field Horizon	Depth (cm)	Texture (% Clay)	Matrix Color Moist	RMF Conc	RMF Dep	Other
SP	^Ag	^Ag1	11	L (10%)	10YR 4/1			
SP/BA	^A	^Ag2	59	L (15%)	10YR 3.5/1			
BA	^AC	^Ag3	73	L (12%)	10YR 3.5/1.5			
BA	^Cg1	^BCg	87	L (7%)	10YR 4/1			
BA	^Cg2	^CBg	93	SL (7%)	10YR 6/1			
BA	^Cg3	^Cg	104+	SCL (21%)	10YR 6/1	25% P 7.5YR 6/6		Limiting clay layer

Site **DEK-R-Jr** Date **3/18/15**
Plot Number **4-3** Describers **CAP,CP,BW**
Observation Method **small pit to 40 cm, augered to 113 cm**
HS FI

Obs Method	Horizon	Field Horizon	Depth (cm)	Texture (% Clay)	Matrix Color Moist	RMF Conc	RMF Dep	Other
SP	^A1	^A1	8	L (10%)	10YR 3/1			
SP/BA	^A2	^A2	85	L (14%)	10YR 3/1	5% D 10YR 5/6	10% D 10YR 5/6	REDOX IS RELICT, Layer is intermixed with darker A material, large ant colony seems to prefer this material, potential krotovina
BA	Ab	Ab	113+	MKY L (6%)	10YR 3/1			

Site **DEK-R-Jr** Date **3/18/15**
Plot Number **7-3** Describers **CAP,CP,BW**
Observation Method **small pit to 40 cm, augered to 121 cm**
HS FI

Obs Method	Horizon	Field Horizon	Depth (cm)	Texture (% Clay)	Matrix Color Moist	RMF Conc	RMF Dep	Other
SP	^Ag	^A1	11	L (9%)	10YR 4/2			
SP	^A	^A2	35	L (7%)	10YR 3/2			
SP/BA	^ACg	^Bw1	66	L (16%)	10YR 4/1	10% D 10YR 6/6	5% F 10YR 6/2	ALL REDOX IS RELICT
BA	^Cg2	^Bw2	100	L (18%)	10YR 4/1	2% D 10YR 6/6	3% F 10YR 6/2	ALL REDOX IS RELICT
BA	^Cg3	^Bg	112	L (24%)	2.5Y 5/2	20% P 7.5YR 5/6		ALL REDOX IS RELICT
BA	Ab	Ab	121+	MKY L (10%)	10YR 4/2			

MDQA-R-Ss Zone 1

Site **MDQA-R-Ss** Date **9/9/13**
Plot Number **1-1** Describers **CAP,JV**
Observation Method **small pit to 30 cm, augered to 197 cm**
HS FI

Obs Method	Horizon	Field Horizon	Depth (cm)	Texture (% Clay)	Matrix Color Moist	RMF Conc	RMF Dep	Other
SP	Oe	Oe	11		10YR 2/2			
SP	Ag	Ag	30	SiL (14%)	10YR 5/1	8% P 5YR 5/8		
BA	Btg1	Btg1	68	SiL (25%)	2.5Y 5/1	22% P 7.5YR 6/6		
BA		Btg2	103	SiL (26%)	5Y 6/1	40% P 10YR 5/6		
BA		Btg3	119	SiL (16%)	5Y 6/1	35% P 7.5YR 5/6		
BA		2Btg4	131	SCL (23%)	10YR 5/1	20% P 10YR 6/6		
BA		2Btg5	159	L (26%)	2.5Y 6/1	25% P 2.5Y 5/6		
BA		2BCg	197+	S (2%)	2.5Y 5/2			

Site **MDQA-R-Ss** Date **9/9/13**
Plot Number **4-1** Describers **CAP,JV**
Observation Method **small pit to 30 cm, augered to 190 cm**
HS FI

Obs Method	Horizon	Field Horizon	Depth (cm)	Texture (% Clay)	Matrix Color Moist	RMF Conc	RMF Dep	Other
SP	Oe	Oe	5		10YR 2/2			
SP	Ag1	Ag1	20	SiL (17%)	10YR 5/2	1% P 5YR 5/8		
SP/BA	Ag2	Ag2	38	SiL (20%)	10YR 5/1	1% D 10YR 5/6		
BA	BAg	BAg	56	SiL (25%)	10YR 4/1	30% P 7.5YR 6/6		
BA		Btg1	106	SiCL (32%)	2.5Y 6/1	40% P 10YR 5/6		
BA		Btg2	152	SiL (26%)	2.5Y 6/1	35% P 7.5YR 4/6		
BA		BCg	190+	SiL (13%)	2.5Y 6/2	20% P 7.5YR 6/6		

Site **MDQA-R-Ss** Date **9/9/13**
Plot Number **7-1** Describers **CAP,JV**
Observation Method **small pit to 30 cm, augered to 203 cm**
HS FI

Obs Method	Horizon	Field Horizon	Depth (cm)	Texture (% Clay)	Matrix Color Moist	RMF Conc	RMF Dep	Other
SP	Oe	Oe	4		2.5Y 3/2			
SP	Ag	Ag	15	SiL (12%)	2.5Y 5/1	1% P 7.5YR 6/6		
SP/BA	Bg1	Bg1	35	SiL (24%)	2.5Y 6/1	15% P 10YR 5/6		
BA	Bg2	Bg2	57	SiCL (30%)	2.5Y 5/1	25% P 7.5YR 6/6		
BA		Bg3	141	SiL (25%)	2.5Y 6/1	35% P 7.5YR 6/6		
BA		2BCg1	159	SL (10%)	10YR 6/1	40% P 10YR 5/6		
BA		2BCg2	176	LS (5%)	10YR 6/2			
BA		2CBg	191	LS (3%)	7.5YR 5/2			
BA		2C	203+	S (2%)	10YR 5/6		45% P 2.5Y 6/2	

MDQA-R-Ss Zone 2

Site	**MDQA-R-Ss**	Date	**3/17/15**
Plot Number	**1-2**	Describers	**CAP,MG,CS**
Observation Method	**small pit to 40 cm, augered to 110 cm**		
HSFI			

Obs Method	Horizon	Field Horizon	Depth (cm)	Texture (% Clay)	Matrix Color Moist	RMF Conc	RMF Dep	Other
SP	^Ag1	^Ag1	8	SiL (12%)	10YR 4/2	2% F 10YR 4/6		
SP	^Ag2	^Ag2	26	SiL 14%)	10YR 4/2	3% F 10YR 4/6		
SP	^ACg1	^Ag3	41	SiL (15%)	10YR 5/2	3% F 10YR 4/6		
BA	^Cg2	^Bg	62	SiL (10%)	10YR 4/1	3% D 10YR 4/6		
BA	Bgb1	Btgb1	90	SiL (24%)	10YR 5/1	20% P 7.5YR 5/6		
BA	Bgb2	Btgb2	110+	SiL (18%)	10YR 6/1	15% P 7.5YR 5/6		

Site	**MDQA-R-Ss**	Date	**3/17/15**
Plot Number	**4-2**	Describers	**CAP,MG,CS**
Observation Method	**small pit to 40 cm, augered to 106 cm**		
HSFI			

Obs Method	Horizon	Field Horizon	Depth (cm)	Texture (% Clay)	Matrix Color Moist	RMF Conc	RMF Dep	Other
SP	^Ag1	^Ag1	11	SiL (10%)	10YR 4/2			
SP	^Ag2	^Ag2	40	SiL (16%)	10YR 4/2			
BA	^ACg1	^Bg1	62	SiL (22%)	10YR 5/1	15% D 7.5YR 5/6		
BA	^ACg2	^Bg2	73	SiL (25%)	10YR 6/1	20% D 10YR 6/6		
BA	BCgb1	BCg1	94	SiL (14%)	2.5Y 6/1	10% D 10YR 6/6		Bone dry aquaclude?
BA	BCgb2	BCg2	106+	L (14%)	2.5Y 6/1	15% D 7.5YR 5/6		Bone dry aquaclude?

Site	**MDQA-R-Ss**	Date	**3/17/15**
Plot Number	**7-2**	Describers	**CAP,MG,CS**
Observation Method	**small pit to 40 cm, augered to 110 cm**		
HSFI			

Obs Method	Horizon	Field Horizon	Depth (cm)	Texture (% Clay)	Matrix Color Moist	RMF Conc	RMF Dep	Other
SP	^Ag1	^Ag1	12	SiL (6%)	10YR 4/2			
SP	^Ag2	^Ag2	28	SiL (18%)	10YR 4/2	8% D 7.5YR 5/6		
SP/BA	^ACg	^Bg1	45	SiL (16%)	10YR 5/2	10% D 7.5YR 5/6		
BA	Agb	^Bg2	70	SiL (12%)	2.5Y 5/1	20% P 7.5YR 5/6		
BA	Bgb	Btgb	97	SiCL (30%)	2.5Y 6/1	10% P 7.5Y 6/8		
BA	BCgb	BCgb	110+	SiL (16%)	2.5Y 6/1	30% P 7.5YR 5/6		

MDQA-R-Ss Zone 3

Site **MDQA-R-Ss** Date **3/17/15**
Plot Number **1-3** Describers **CAP,MG,CS**
Observation Method **small pit to 40 cm, augered to 106 cm**
HS FI

Obs Method	Horizon	Field Horizon	Depth (cm)	Texture (% Clay)	Matrix Color Moist	RMF Conc	RMF Dep	Other
SP	A1	A	4	L (15%)	10YR 4/3			
SP	BA	BA	18	L (23%)	10YR 5/3			
SP	Bt1	Bt1	33	L (26%)	10YR 5/3	10% F 10YR 5/6		
SP/BA	Bt2	Bt2	56	L (23%)	10YR 5/3	20% D 7.5YR 6/6	8% D 10YR 6/3	
BA		Bt3	91	SCL (21%)	10YR 5/3	30% D 7.5YR 5/6	15% D 10YR 7/2	
BA		CB	106+	S (4%)	7.5YR 5/6			

Site **MDQA-R-Ss** Date **3/17/15**
Plot Number **4-3** Describers **CAP,MG,CS**
Observation Method **small pit to 40 cm, augered to 102 cm**
HS FI

Obs Method	Horizon	Field Horizon	Depth (cm)	Texture (% Clay)	Matrix Color Moist	RMF Conc	RMF Dep	Other
SP	A1	A1	15	L (13%)	10YR 5/4			
SP	A2	A2	39	L (25%)	10YR 5/4	4% F 10YR 5/6		
BA	Bt1	Bt1	54	L (20%)	10YR 5/4	8% D 7.5YR 4/6		
BA		Bt2	77	L (16%)	10YR 5/4	15% F 7.5YR 6/6	10% D 10YR 6/2	
BA		BC1	94	L (10%)	2.5Y 6/3	20% D 7.5YR 4/6	5% F 2.5Y 6/2	
BA		BC2	102+	L (12%)	2.5Y 6/3	10% D 7.5YR 4/6	3% F 2.5Y 6/2	

Site **MDQA-R-Ss** Date **3/17/15**
Plot Number **7-3** Describers **CAP,MG,CS**
Observation Method **small pit to 40 cm, augered to 106 cm**
HS FI

Obs Method	Horizon	Field Horizon	Depth (cm)	Texture (% Clay)	Matrix Color Moist	RMF Conc	RMF Dep	Other
SP	A1	A1	7	SL (6%)	10YR 5/4			
SP	A2	A2	22	SL (10%)	10YR 4/4			
SP/BA	Bt1	Bt1	50	L (18%)	7.5YR 5/6	5% F 7.5YR 5/6		
BA		Bt2	70	SiL (20%)	10YR 5/4	10% D 7.5YR 5/6	10% P 10YR 6/2	
BA		Bt3	94	SiL (19%)	10YR 5/4	15% D 7.5YR 5/6	15% P 10YR 6/2	
BA		Btg	106+	SiL (17%)	10YR 6/2	20% P 7.5YR 6/6		

Site	**MDQA-R-Ws**	Date	**9/9/13**
Plot Number	**1-1**	Describers	**CAP,JV**
Observation Method	**small pit to 30 cm, augered to 193 cm**		
HSFI			

Obs Method	Horizon	Field Horizon	Depth (cm)	Texture (% Clay)	Matrix Color Moist	RMF Conc	RMF Dep	Other
SP	^Oe	^Oe	5		10YR 2/2			
SP/BA	^A	^A	38	L (15%)	10YR 4/3	3% D 7.5YR 5/6		
BA	^Bg1	^Bg1	71	L (25%)	10YR 5/1	25% P 7.5YR 4/6	10% D 2.5Y 6/1	
BA		^Bg2	90	L (22%)	2.5Y 6/1	30% P 10YR 5/6		4% gravel
BA		^BCg	127	LS (3%)	10YR 5.5/1	40% P 10YR 6/6		5% gravel
BA		Btg	138	SCL (24%)	2.5Y 4/1	25% P 7.5YR 4/6		
BA		Cg1	177	CoS (2%)	10YR 6/1			12% gravel
BA		Cg2	193+	CoS (3%)	2.5Y 6/2	8% D 10YR 5/6		

Site	**MDQA-R-Ws**	Date	**8/19/13**
Plot Number	**4-1**	Describers	**CAP,NG**
Observation Method	**small pit to 31 cm, augered to 191 cm**		
HSFI			

Obs Method	Horizon	Field Horizon	Depth (cm)	Texture (% Clay)	Matrix Color Moist	RMF Conc	RMF Dep	Other
SP	A	Oe	5	SiL (8%)	2.5Y 2.5/1	C/D N2		
SP	Ag1	Ag1	15	SiL (6%)	10YR 5/2			1 SBk
SP	Ag2	Ag2	31	SiL (9%)	10YR 5/2	C/D N2 M/P 7.5YR 3/4		2 SBk
BA	Btg1	Btg1	51	CL (36%)	10YR 6/1	C/P 10YR 4/6		
BA		Btg2	66	L (22%)	2.5Y 6/1	M/P 10YR 4/6		
BA		BCg	92	SL (14%)	10YR 6/1	M/P 10YR 4/6		
BA		BC	109	SL (10%)	7.5YR 4/6		M/P 10YR 6/2	
BA		Cg1	118	SiL (12%)	2.5Y 7/1	C/D 10YR 5/6		
BA		Cg2	126	SL (4%)	2.5Y 5/2	F/P 10YR 5/6		
BA		C	135	SL (14%)	7.5YR 4/6		M/P 2.5Y 6/2	
BA		C'g1	146	L (13%)	2.5YR 6/1	C/P 7.5YR 4/6		
BA		C'g2	173	SiL (18%)	2.5Y 6/1	F/D 10YR 4/6		
BA		2Cg	191+	LS (2%)	7.5YR 6/1			20% fluvial gravel

Site	**MDQA-R-Ws**	Date	**8/19/13**
Plot Number	**7-1**	Describers	**CAP,NG**
Observation Method	**small pit to 36 cm, augered to 154 cm**		
HSFI			

Obs Method	Horizon	Field Horizon	Depth (cm)	Texture (% Clay)	Matrix Color Moist	RMF Conc	RMF Dep	Other
SP	A	Oe	4		2.5Y 3/2			
SP	Ag	Ag1	18	SiL (12%)	2.5Y 5/2	C/D 7.5YR 3/4		10% fluvial gravel
SP	BAg	Ag2	36	SiL (13%)	2.5Y 5/2	M/P 10YR 6/6		
BA	Btg1	Btg1	56	CL (30%)	2.5Y 6/1	M/P 10YR 4/6		10% fluvial gravel
BA		Btg2	69	CL (32%)	2.5Y 5/1	M/P 10YR 4/6		
BA		BCg	88	SCL (30%)	2.5Y 5/1	M/P 10YR 4/6	C/F 2.5Y 7/1	
BA		CB	117	SiL (25%)	2.5Y 5/3	C/P 7.5YR 4/6	C/D 2.5Y 6/1	
BA		Cg1	130	SL (15%)	2.5Y 6/2	C/D 10YR 6/6 F/P 5YR 3/4		
BA		Cg2	142	SL (17%)	2.5Y 6/2	C/P 7.5YR 5/8		20% fluvial gravel
BA		Cg3	154	SCL (21%)	2.5Y 7/1	C/P 10YR 6/8		25% fluvial gravel

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