Evaluation of Indicator of Reduction in Soil (IRIS) Tubes to Verify Wetland Hydrology in Constructed Wetlands

by

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ABSTRACT

Wetlands are essential components of the environment that provide unique functions and values to the ecosystems in which they occur. As urban population and the economy continue to grow, impacts to wetlands are unavoidable as urban sprawl and development encroach on the surrounding natural ecosystems. Wetland restoration, enhancement, preservation, or creation projects used for compensatory mitigation for wetland impacts must go through a monitoring phase to verify the area is functioning as a wetland. Performance standards are set to verify the presence of wetland hydrology, hydric soil, and hydrophytic vegetation. Performance standards are typically monitored by methods approved for use in respective technical standards and applicable *Regional Supplements to the 1987 Wetland Delineation Manual*.

The *Hydric Soil Technical Standard* details three methods for verifying hydric soil conditions, two of which are based on the reduction of iron using alpha-alpha' dipyridyl dye or IRIS tubes. Although different methods, alpha-alpha' dipyridyl dye and IRIS tubes serve the same purpose, which is detecting soil conditions that result in the reduction of iron; therefore, both methods should have the same influencing factors. While alpha-alpha' dipyridyl dye is used to verify hydric soil, it can also be used to verify wetland hydrology, as it is listed as a primary indicator of wetland hydrology on the U.S. Army Corps of Engineers wetland determination data form.

The goal of this project was to expand upon the original intent of IRIS tubes to determine if they can be used as a robust field method for detecting wetland hydrology, similar to alpha-alpha' dipyridyl dye although it was not monitored as part of this study. The objectives are to find a relationship of depth and type of removal to depth of saturation or groundwater and type of hydrologic regime detected by groundwater monitoring wells. Temporal scales were investigated to determine the presence of wetland hydrology and the rate at which a positive reaction is detected on IRIS tubes. Soil parameters such as pH and organic carbon were collected to detect possible influences on IRIS tubes, and vegetation assessments were performed to assess hydrology and soil influences on vegetation establishment.

Results indicate that IRIS tubes appear to be variable in assessing wetland hydrology criteria for disturbed sites throughout the duration of the growing season; however, results have a higher correlation when used during the recommended time of the growing season. This study revealed a positive relationship exists between soil water levels and removal of iron oxide paint from IRIS tubes, and that the type of iron oxide paint removal is related to the type of hydrologic regime, although temporal scales may vary with influencing factors, which should be considered when interpreting IRIS tube data.

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1. Introduction

Wetlands are among the most productive ecosystems in the world, comparable to rain forests and coral reefs (US EPA, 2015). Wetlands are transition zones where the flow of water, the cycling of nutrients, and the energy of the sun meet to produce a unique ecosystem characterized by hydrology, soils, and vegetation, making them very important features of a watershed (U.S. EPA, 2004). Although wetlands provide many water quality benefits, they also provide unique habitats for many species of wildlife such as frogs, snakes, fish, waterfowl, and birds, as well as economic benefits to the surrounding areas.

As the human population and economies continue to grow, impacts to wetlands are unavoidable as urban sprawl and development encroach on the surrounding natural resources and ecosystems. Despite all the benefits provided by wetlands, it is estimated that the United States still loses approximately 24,280 hectares (60,000 acres) of wetlands each year (U.S. EPA, 2004). The United States Environmental Protection Agency (EPA), along with the United States Army Corps of Engineers (Corps of Engineers), establish environmental standards for reviewing permits for discharges that affect wetlands, such as residential development, roads, levees, and other construction activities (U.S. EPA, 2004). Under Section 404 of the Clean Water Act, the Corps of Engineers issues permits allowing adverse environmental impacts to wetlands, while still meeting environmental standards and requiring compensatory mitigation where applicable.

Compensatory mitigation for a permitted wetland impact can be obtained through permittee-responsible mitigation or the purchase of mitigation credits through a mitigation bank or in-lieu fee program, all of which involve the restoration, enhancement, preservation, or creation of wetlands. All wetlands used for compensatory mitigation must go through a monitoring phase to verify the area is successfully functioning as a wetland; thus, performance standards and success criteria are set to gauge the level of success for respective compensatory mitigation projects. Performance standards typically consist of verifying the presence of wetland hydrology, achieving a projected vegetation density and species diversity, and verifying the presence of hydric soil. Current monitoring methods for performance standards include using groundwater wells to monitor saturation or groundwater levels for wetland hydrology criteria, conducting vegetation surveys at random representative plots, and using hydric soil indicators or indicator of reduction in soil (IRIS) tubes to verify hydric soil conditions.

Recent permittee-responsible mitigation project experiences have resulted in hydrologic monitoring limitations due to shallow soils and underlying restrictive layers of bedrock. Although visual verification of wetland hydrology criteria, as listed on the Corps of Engineers wetland determination data form, has been accepted on case-by-case basis as a monitoring method for wetland hydrology, data-driven results are preferred for monitoring performance standards in an effort to eliminate biases and be in compliance with respective technical standards.

The *Hydric Soil Technical Standard* details three methods for verifying hydric soil conditions, two of which are based on the reduction of iron using alpha-alpha' dipyridyl dye or IRIS tubes. Although different methods, alpha-alpha' dipyridyl dye and IRIS tubes serve the same purpose, which is detecting soil conditions that result in the reduction of iron; therefore, both methods should have the same influencing factors. The difference in the two methods is that the alpha-alpha' dipyridyl dye represents soil conditions at the exact point in time the test is implemented, where IRIS tubes represent soil conditions throughout the period of installation which can be up to several weeks. While alpha-alpha' dipyridyl dye is used to verify hydric soil, it can also be used to verify wetland hydrology, as it is listed as a primary indicator of wetland hydrology on the Corps of Engineers wetland determination data form.

1.1 Research objectives

Sufficient efforts and research have been completed to determine influencing factors and reliability of IRIS tubes to support their intended use. The goal of this project is to expand upon the original intent of IRIS tubes to determine if they can be used as a robust field method for determining wetland hydrology, similar to alpha-alpha' dipyridyl dye. The objectives are to find a relationship of depth and type of removal to depth of saturation or groundwater and type of hydrologic regime detected by groundwater monitoring wells. Temporal scales will be investigated to determine the presence of wetland hydrology and the rate at which a positive reaction is detected on IRIS tubes. Soil parameters such as pH and organic carbon will be collected to detect possible influences on IRIS tube results. Monitoring well and IRIS tube data will be compared to vegetation data to assess hydrology and soil influences on vegetation establishment.

2. Literature Review

2.1 History of Wetlands

2.1.1 Historic Loss of Wetlands

At the time of European settlement in the early 1600's, the area that was to become the conterminous United States had approximately 89.5 million hectares (221 million acres) of wetlands (Dahl and Allord, 1996). During the 1700's, wetlands were regarded as swampy lands that bred diseases, restricted overland travel, impeded the production of food and fiber, and generally were not useful for frontier survival (Dahl and Allord, 1996). Settlers, commercial interests, and governments agreed that wetlands presented obstacles to development, and that wetlands should be eliminated and the land reclaimed for other purposes (Dahl and Allord, 1996). This led to mass draining and filling of wetlands across the United States. The Federal Government also directly subsidized or facilitated wetlands losses through its many public-works projects, technical practices, and cost-shared drainage programs administered by the United States Department of Agriculture (Dahl and Allord, 1996). By the mid 1980's, it is estimated that over half (54%) of all the wetlands in the United States had been drained or filled for agriculture or development (United States Department of Agriculture Natural Resources Conservation Service, 2014).

2.1.2 Wetland Functions and Values

Although once considered useless and a nuisance to society, wetlands are essential components of the environment that provide unique functions and values to the ecosystems in which they occur. Specific functions and values range widely as many different types of wetlands exist around the world. Generally, beneficial functions of wetlands include providing flood control and storage, improving water quality and hydrology, reducing eutrophication and nutrient overloading, providing carbon storage, and providing unique habitat to abundant wildlife and complex food webs, all of which have socioeconomic impacts on the surrounding communities (U.S. EPA, 2017). Since the 1970's there has been increasing awareness that wetlands are valuable areas that provide important environmental functions (Dahl and Allord, 1996). This increasing awareness sparked a chain of federal and state regulations providing protection to wetlands, which continue to be expanded upon and revised as the scientific knowledge of wetlands advances.

2.1.3 Clean Water Act

The Clean Water Act of 1972 significantly reorganized and expanded the 1948 Federal Water Pollution Control Act, establishing the basic structure for regulating discharge of pollutants into the waters of the United States, including wetlands, and regulating water quality standards for surface water (U.S. EPA, 2015). The Clean Water Act focused on wetlands that were not on agricultural land. The objective of the Clean Water Act was to maintain and restore the chemical, physical, and biological integrity of the waters of the United States (U.S. EPA, 2015). To accomplish this, Section 404 of the Clean Water Act essentially gave the Corps of Engineers the authority to issue permits for the discharge of dredge or fill material into waters of the United States, including wetlands (Vepraskas et al., 2016). In 1977, President Jimmy Carter signed Executive Order 11990 into law as an amendment to the National Environmental Protection Act of 1969, requiring government agencies to take steps to avoid to the extent possible the long and short term adverse impacts associated with the destruction or modification of wetlands and to avoid direct or indirect support of new construction in wetlands where there is a practicable alternative (U.S. EPA, 1990).

2.1.4 Food Security Act of 1985

The Clean Water Act focused on wetlands not on agricultural land while the Food Security Act focused on wetlands that were on agricultural land (Vepraskas et al., 2016). The Food Security Act contained the 1985 Farm Bill, also known as the “swampbuster” provision, which denied United States Department of Agriculture program benefits, such as price-support loans, purchases, payments, farm storage facility loans, federal crop insurance, and disaster payments, to producers that converted wetlands into cropland after December 23, 1985 (Vepraskas et al., 2016). Such activities include but are not limited to clearing, draining, dredging, or leveling for the purpose of or to make agricultural commodity production possible (U.S. EPA, 2015). This regulation significantly slowed the destruction of wetlands for agricultural purposes.

2.1.5 Waters of the United States

The definition of “waters of the United States” draws varying opinions from those effected by the jurisdiction of the Clean Water Act, such as developers, regulatory agencies, scientific and technical experts, and other professionals. The definition currently in effect is the definition promulgated in 1986/1988, implemented consistent with subsequent Supreme Court decisions and guidance documents (U.S. EPA, 2017). According to the 1986/1988 regulatory definition of “waters of the United States”, the term waters of the United States means:

1. “*All waters which are currently used, or were used in the past, or may be susceptible to use in interstate or foreign commerce, including all waters which are subject to the ebb and flow of the tide;*
2. *All interstate waters including interstate wetlands;*
3. *All other waters such as intrastate lakes, rivers, streams (including intermittent streams), mudflats, sandflats, wetlands, sloughs, prairie potholes, wet meadows, playa lakes, or natural ponds, the use, degradation or destruction of which could affect interstate or foreign commerce including any such waters:*
4. *Which are or could be used by interstate or foreign travelers for recreational or other purposes; or*
5. *From which fish or shellfish are or could be taken and sold in interstate or foreign commerce; or*
6. *Which are used or could be used for industrial purposes by industries in interstate commerce;*
7. *All impoundments of waters otherwise defined as waters of the United States under this definition;*
8. *Tributaries of waters identified in paragraphs (s)(1) through (4) of this section;*
9. *The territorial sea;*
10. *Wetlands adjacent to waters (other than waters that are themselves wetlands) identified in paragraphs (s)(1) through (6) of this section; waste treatment systems, including treatment ponds or lagoons designed to meet the requirements of CWA (other than cooling ponds as defined in 40 CFR 423.11(m) which also meet the criteria of this definition) are not waters of the*

United States (Corps of Engineers, Department of Army, Department of Defense, 2012)."

In 2008, the agencies developed guidance documents for implementing the above definition following the *Rapanos v. United States* and *Carabell v. United States* Supreme Court decision (U.S. EPA, 2017). The Rapanos case debated the jurisdictional status of a wetland that was not directly connected to a navigable water, but adjacent to a tributary to a navigable water. The final ruling recognized that a water or wetland constitutes "navigable waters" under the Clean Water Act if it possesses a "significant nexus" to waters that are navigable (Supreme Court of the United States, 2006). The rationale for the Act's wetlands regulation, as the Corps has recognized, is that wetlands can perform critical functions related to the integrity of other waters – such as pollutant trapping, flood control, and runoff storage (Supreme Court of the United States, 2006). Accordingly, wetlands possess the requisite nexus, and thus come within the statutory phrase "navigable waters" if the wetlands, alone or in combination with similarly situated lands in the region, significantly affect the chemical, physical, and biological integrity of other covered waters understood as navigable in the traditional sense (Supreme Court of the United States, 2006).

A 2015 revised regulatory definition of "waters of the United States" has been stayed by the United States Court of Appeals (U.S. EPA, 2017). The EPA, Department of Army, and the Corps of Engineers are currently in the process of reviewing the 2015 rule and considering a revised definition of "waters of the United States", as a result of an Executive Order issued by President Trump in February 2017 (U.S. EPA, 2017). As a result of the stay and revision process, the 1986/1988 regulatory definition and subsequent guidance remains as current law and regulation.

2.2 Jurisdictional Wetlands

2.2.1 1987 Wetland Delineation Manual and Regional Supplement

In enforcing Section 404 of the Clean Water Act, the Corps of Engineers developed a *Wetlands Protection Manual* that required for jurisdictional wetlands to be identified using a "three-parameter approach" (Vepraskas et al., 2016). The Corps of Engineers then published its *Wetland Delineation Manual* in 1987 to enable field personnel to enforce the mandates of the Clean Water Act by accurately identifying and delineating wetlands accordingly (Vepraskas et al., 2016). The *Manual* recognized the three-parameter approach as the interaction of hydrology, vegetation, and soil, which result in the development of characteristics unique to wetlands (Environmental Laboratory, 1987). This served as the national guidance for wetland delineations and "waters of the United States" determinations for wetlands until the mid-2000's. In 2007, the first "regional supplement" to the *1987 Manual* was published (Vepraskas et al., 2016). A total of ten regional supplements were developed to essentially update the *1987 Manual* by replacing sections that described how hydric soils, wetland hydrology, and hydrophytic vegetation were to be used to identify jurisdictional wetlands (Vepraskas et al., 2016). The regional supplements are more thorough in providing wetland delineation guidance by incorporating region-specific characteristics and addressing problematic soil and vegetation situations that may be encountered. Once a regional supplement was implemented, it superseded the *1987 Manual* in identifying and determining wetland characteristics, although the *1987 Manual* still serves as a technical guide for routine and comprehensive delineation methods and any other theories, issues, or topics not addressed in the regional supplement.

2.2.2 Wetland Characteristics

The term wetland has coined many definitions over the years. The variance in definitions is a natural result of the differences in emphasis in the definers' training and the different ways in which individual disciplines deal with wetlands (Mitsch and Gosselink, 2007). The *1987 Manual* defines wetlands as: Those areas that are inundated or saturated by surface and groundwater at a frequency and duration sufficient to support, and that under normal circumstances do support, a prevalence of vegetation typically adapted for life in saturated soil conditions (Environmental Laboratory, 1987). Since the establishment of the *1987 Manual*, the subsequent term jurisdictional wetland is commonly used for legally defined wetlands in the United States to delineate those areas that are under the jurisdiction of the Clean Water Act or the swampbuster provision of the Food Security Act (Mitsch and Gosselink, 2007). Consistent with the three-parameter approach outlined in the *1987 Manual* and subsequent *Regional Supplements*, an area must contain evidence of hydrophytic vegetation, hydric soil, and wetland hydrology to be determined a jurisdictional wetland, with the exception of special circumstances or problematic areas outlined in the *Regional Supplements*. Wetland characteristics and assessment methods addressed herein reflect the *Eastern Mountains and Piedmont Regional Supplement*.

2.2.2.1 Hydrophytic Vegetation

Vegetation across all strata and some species have a wide range of tolerance for the type of environment in which they can survive. The *1987 Manual* defines hydrophytic vegetation as the community of macrophytes that occurs in areas where inundation or soil saturation is either permanent or of sufficient frequency and duration to influence plant occurrence (U.S. Army Corps of Engineers, *ERDC/EL TR-12-9, 2012*). Many factors besides site wetness affect the composition of the plant community in an area, including regional climate, local weather patterns, topography, soils, natural and human-caused disturbances, and current and historic plant distributional patterns at various spatial scales (U.S. Army Corps of Engineers, *ERDC/EL TR-12-9, 2012*). These site-specific factors must be considered when assessing vegetative communities, especially in sparsely vegetated, highly disturbed, or problematic areas.

The *1987 Manual* uses a plant-community approach to evaluate vegetation (U.S. Army Corps of Engineers, *ERDC/EL TR-12-9, 2012*). The definition of a wetland includes the phrase "prevalence of vegetation", where prevalent vegetation is characterized by the dominant species comprising the plant community or communities (Environmental Laboratory, 1987). The two most commonly used estimates of dominance are basal area and percent areal cover (Environmental Laboratory, 1987). The Eastern Mountains and Piedmont Regional Supplement outlines a 4-tier evaluation process to determine the presence or absence of hydrophytic vegetation, which considers the dominance of species and their respective wetland indicator status across 5 strata, including trees, saplings, shrubs, herbs, and woody vines, within a designated plot usually approximately 0.04 hectares (1/10th acre) in size. This 4-tier procedure begins with the rapid test for hydrophytic vegetation, then proceeds to the dominance test, prevalence index, and morphological adaptations, respectively, and is outlined in Chapter 2 page 24 of the *Regional Supplement*. Hydrophytic vegetation is considered present when the plant community is dominated by species that require or can tolerate prolonged inundation or soil saturation during the growing season (U.S. Army Corps of Engineers, *ERDC/EL TR-12-9, 2012*).

2.2.2.2 Hydric Soil

The National Technical Committee for Hydric Soils (NTCHS) defines a hydric soil as a soil that formed under conditions of saturation, flooding, or ponding long enough during the growing season to develop anaerobic conditions in the upper part (U.S. Army Corps of Engineers, *ERDC/EL TR-12-9, 2012*). Soil saturation or inundation, when combined with microbial activity, causes the depletion of oxygen, which promotes biogeochemical processes such as the accumulation of organic matter and the reduction, translocation, or accumulation of iron and other reducible elements, resulting in distinctive morphological characteristics (U.S. Army Corps of Engineers, *ERDC/EL TR-12-9, 2012*). The most obvious feature of a soil profile is its color, which is strongly influenced by the presence of iron as it is the primary coloring agent in the subsoil (Vepraskas et al., 2016). Well-drained, non-hydric soils often have brighter soil colors, such as brown, orange, or red, which indicate a strong presence of oxidized iron content. Soils with a fluctuating water table usually have a mottled or spotted pattern of gray, and/or orange colors (Vepraskas et al., 2016). Soils with a high water table for a significant portion of the year have very gray matrix colors, or even gley colors, which result from water logging and iron reduction (Vepraskas, et al., 2016). Respective soil colors and profile descriptions are denoted with *Munsell® Soil Color Charts*. These distinctive morphological characteristics have been complied into a list of hydric soil indicators in the *Regional Supplement* that detail characteristics of hydric soils commonly found within the area of coverage. Procedures for sampling soils are outlined in Chapter 3 page 39 of the *Regional Supplement*.

In the case of problematic soils that do not meet a current hydric soil indicator, or in the case of having to prove the presence of hydric soil, the NTCHS developed the *Hydric Soil Technical Standard* to provide a method of determining if a soil currently meets the definition of a hydric soil. Given the definition of a hydric soil, the *Technical Standard* requires proof of anaerobic conditions and soil saturation for at least 14 consecutive days for most soils during normal rainfall periods when soil microbes are active (NTCHS, 2015). The *Technical Standard* outlines in detail three methods for determining hydric soils: Indicator of Reduction in Soil (IRIS) tubes, oxidation-reduction potential (Eh) measurements using platinum electrodes, and alpha-alpha dipyridyl dye.

2.2.2.3 Wetland Hydrology

Wetland hydrology is the driving force behind other wetland characteristics. For example, the hydrologic regime of an area strongly influences the respective vegetative community and soil morphological characteristics. Areas with evident characteristics of wetland hydrology are those in which the presence of water has an overriding influence of vegetation and soils caused by anaerobic and reducing conditions (Mitsch and Gosselink, 2007). The *Regional Supplement* outlines wetland hydrology indicators based on four categories of wetland hydrology characteristics. Indicators in Group A are based on direct observation of surface water or groundwater , Group B is based on evidence of flooding or ponding, Group C is based on evidence that the soil is or was saturated for an extended period, and Group D is based on landscape, vegetation, and soil features that indicate contemporary rather than historical wet conditions (U.S. Army Corps of Engineers, *ERDC/EL TR-12-9, 2012*). Each of these groups are further divided into two groups – primary and secondary – based on their estimated reliability in the region (U.S. Army Corps of Engineers, *ERDC/EL TR-12-9, 2012*). Observation of, at minimum, one primary indicator and/or two secondary indicators is satisfactory for meeting wetland hydrology criteria when delineating or determining the status of a jurisdictional wetland.

Highly disturbed or problematic sites may not display typical wetland characteristics; therefore, direct hydrologic monitoring may be undertaken to determine whether wetland hydrology is present (U.S. Army Corps of Engineers, *ERDC/EL TR-12-9*). The Corps of Engineers has a technical standard for such monitoring, which outlines appropriate equipment such as groundwater wells and piezometers, installation methods, data interpretation and analysis, and results reporting. According to the *Technical Standard*, wetland hydrology is considered to be present on an atypical or problematic site if the site is inundated or the water table is $\leq$ 30 cm (12 inches) below the soil surface for $\geq$14 days during the growing season at a minimum frequency of 5 out of 10 years (U.S. Army Corps of Engineers, *WRAP Technical Notes Collection (ERDC TN-WRAP-05-02)*). The *Technical Standard for Wetland Hydrology* is based on the depth of the water table because, in most cases, water table depth can be monitored readily and consistently through the use of shallow wells with either manual or automated data collection (U.S. Army Corps of Engineers, *WRAP Technical Notes Collection (ERDC TN-WRAP-05-02)*).

2.3 Mitigation

2.3.1 Mitigation Sequence and Permitting

A 1990 Memorandum of Agreement between the United States Department of the Army and the United States Environmental Protection Agency was formed to implement the objective of the Clean Water Act to restore and maintain the physical, chemical, and biological integrity of the Nation's waters, including wetlands (U.S. EPA, 1990). The Memorandum of Agreement is specifically limited to the Section 404 Regulatory Program and is written to provide guidance for the type and level of appropriate and practicable mitigation which demonstrates compliance with requirements in the Guidelines (U.S. EPA, 1990). Under the Regulatory Program and Guidelines, the Corps of Engineers strives to avoid impacts and offset unavoidable adverse impacts to existing aquatic resources, and for wetlands, strives to achieve a goal of no overall net loss of functions and values (U.S. EPA, 1990). The Memorandum of Agreement details a three-step mitigation sequence, consisting of avoidance, minimization, and compensatory mitigation, that must be addressed in Section 404 permit applications for discharge of dredge or fill material into waters of the United States. A permittee proposing a discharge must first prove they have avoided aquatic resources to the extent practicable, minimized adverse impacts through alternative designs, and lastly, once an impact is deemed unavoidable, they must provide compensatory mitigation.

2.3.2 Compensatory Mitigation

Compensatory mitigation means the restoration, establishment, enhancement, or in certain circumstances preservation of aquatic resources for the purposes of offsetting unavoidable adverse impacts to waters of the United States authorized by Department of Army permits which remain after all appropriate and practicable avoidance and minimization has been achieved (U.S. EPA, 2016). On March 31, 2008, EPA and the Corps of Engineers issued revised regulations governing compensatory mitigation for authorized impacts to wetlands, streams, and other waters of the U.S. under Section 404 of the Clean Water Act (U.S. EPA, 2015). The purpose of this was to establish standards and criteria for the use of all types of compensatory mitigation, including on-site and off-site permittee-responsible mitigation, mitigation banks, and in-lieu fee mitigation (Department of Defense, Department of the Army Corps of Engineers, U.S. EPA. 2008). The 2008 Compensatory Mitigation Rule established the requirement that all types of compensatory mitigation must follow a 12-step mitigation plan outlined as: Objectives, Site Selection, Site Protection Instrument, Baseline Information, Determination of Credits, Mitigation Work Plan, Maintenance Plan, Performance Standards, Monitoring Requirements, Long-term Management Plan, Adaptive Management Plan, and Financial Assurances (Department of Defense, Department of the Army Corps of Engineers, U.S EPA, 2008). Although the same overall 12-step plan is required for all types of compensatory mitigation, details within the 12-step outline vary with the type and level of compensatory mitigation being performed.

2.4 Compensatory Mitigation Wetland Evaluations

2.4.1 Performance Standards

Compensatory mitigation projects have goals and objectives that are used to guide the operation and maintenance of the site to ensure it adequately offsets the impacts it compensates for in order to achieve no net loss of functions and values. Performance standards are ecologically-based standards used to determine whether the compensatory mitigation project is achieving its goals and objectives (Department of Defense, Department of the Army Corps of Engineers, U.S. EPA, 2008). Performance standards are typically set for vegetation, hydrology, and hydric soil, and have a timeline associated with them in order to gauge development trends and determine if any adaptive management may be needed. Typical performance standards for vegetation consist of an average survival rate of at least 220 stems per 0.4 hectare (1 acre) of planted trees, and a dominance of hydrophytic herbaceous vegetation composed of multiple species. Since most compensatory mitigation sites are considered highly disturbed areas, performance standards for hydrology are consistent with the *Technical Standard for Wetland Hydrology*, requiring the presence of saturation or groundwater in the upper 30 cm (12 inches) of the soil profile for 14 or more consecutive days during the growing season in most years. Lastly, hydric soil performance standards require one or more hydric soil indicator to be met at respective soil test pit locations throughout the site. Little data-driven results have been required for hydric soils until recent emphasis for using Indicator of Reduction in Soil (IRIS) tubes to verify success of proposed wetland restoration or creation efforts.

2.4.2 Monitoring Requirements

Monitoring the compensatory mitigation project site is necessary to determine if the project is meeting its performance standards, and to determine if measures are necessary to ensure the compensatory mitigation project is accomplishing its objectives (Department of Defense, Department of the Army Corps of Engineers, U.S. EPA, 2008). Monitoring is conducted at least once annually, and consists of verifying that a site displays a prevalence of hydrophytic vegetation, wetland hydrology, and wetland soil characteristics that meet proposed performance standards. Common methods for monitoring vegetation include randomly establishing permanent plots or transects to be assessed annually for vegetative density and species diversity, and are considered representative of the site as a whole. Hydrology is currently monitored with shallow groundwater wells to verify saturation or groundwater levels within the soil profile. Hydric soil has most commonly been monitored with soil profile descriptions meeting hydric soil indicators at randomly established test pit locations throughout the site; however, recent mitigation projects have indicated a change in performance standards and monitoring methods for hydric soils, requiring them to be verified with IRIS tubes in conjunction with soil profile descriptions meeting hydric soil indicators.

2.5 Indicator of Reduction in Soil (IRIS) Tubes

2.5.1 Description and Theory

IRIS tubes are a field test method used to detect the presence or absence of reducing soil conditions, and aid in the identification of hydric soil properties (Berkowitz, 2009). IRIS tubes are sections of 1.27 cm (0.5 inch) schedule 40 polyvinyl chloride (PVC) tubing that have been coated with an iron (Fe) oxide paint (Rabenhorst, 2008). IRIS tubes are installed in the ground in "nests" comprised of 5 tubes, usually during the wet part of the growing season when soils are most likely to be saturated. Under saturated conditions, heterotrophic soil microbes deplete dissolved oxygen as they oxidize soil organic matter (Rabenhorst, 2008). Once the oxygen has been depleted, soil microbes use an alternate electron acceptor, such as oxidized Fe, to continue to oxidize soil organic matter (Rabenhorst, 2008). As soils become progressively reduced and soil microbes continue to use oxidized Fe as an alternate electron acceptor, the Fe oxides in their solid form (Fe^{3+}) will be reduced to their soluble form (Fe^{2+}), which causes the Fe oxide paint on the IRIS tubes to become dissolved and removed from the tube (Rabenhorst, 2008). Although the *Protocol for Using and Interpreting IRIS Tubes* requires $\geq$25% removal within a 10 cm (4-inch) zone, the *Hydric Soil Technical Standard* requires $\geq$30% removal within a 15 am (6-inch) zone on at least 3 of 5 tubes in a single nest, which is the standard held when using IRIS tubes for jurisdictional and mitigation purposes. IRIS tubes are a convenient mechanism to accurately examine current soil conditions, can be used to provide preliminary data, and provide monitoring and quality control in restored or created wetlands where typical indicators of hydric soils may have not had adequate time to develop (Berkowitz, 2009).

2.5.2 Influencing Factors of Soil Reduction

According to Vepraskas, et.al. (2016), four conditions are needed for a soil to become anaerobic and support the reducing reactions leading to reduction in soils: (1) the soil must be saturated or inundated to exclude atmospheric O_2; (2) the soil must contain accessible organic tissues (organic matter) that can be oxidized or decomposed; (3) a microbial population must be respiring and oxidizing the organic tissues; and (4) the water should be stagnant or moving very slowly. These four factors are dependent upon one another in the soil reduction process; therefore, if one or more of these factors are removed from a given soil environment, reduction should not occur. Although similar, Jenkinson and Franzmeier (2005) give slightly different requirements for reduction, indicating that the four soil conditions needed to reduce Fe in soils are: (1) saturation with stagnant water; (2) presence of microorganisms; (3) a supply of organic carbon (OC), which serves as an energy source for these organisms; and (4) suitable soil temperatures, although exactly which temperatures are suitable is open to debate. Additionally, given the relationship of pH and oxidation-reduction potential (Eh), soil pH values could potentially influence the rate of reduction in a soil environment, particularly in environments strongly influenced by parent materials such as limestone and karst.

2.5.3 Past Research

In the developmental stages, Jenkinson and Franzmeier (2006) installed IRIS tubes in saturated and unsaturated soils in Indiana, North Dakota, and Minnesota, and found a significant correlation between depth to water table and removal of Fe(III) from the IRIS tubes (Castenson and Rabenhorst, 2006). The Fe(III) was removed from the tubes where the soil was saturated by the seasonally high water table, and the Fe(III) coating was left undisturbed in locations where the soil was unsaturated (Castenson and Rabenhorst, 2006). Jenkinson and Franzmeier (2006) noted a fairly definitive line on some of the IRIS tubes, below which evidence of reduction increased significantly, and called it the Upper Depletion Depth (UDD). However, occasional depleted zones above the UDD were observed and attributed to short periods of saturation, microsites of reduction in an otherwise aerobic horizon, or chelation (Jenkinson and Franzmeier, 2006). A positive relationship was also found between soil temperature, organic carbon (OC) content, and Fe(III) coating removal. During late winter and early spring, reduction rates increased with increasing soil temperature and presumed availability of OC and other nutrients, and soils with medium and high OC contents had faster reduction rates than those with low OC content (Jenkinson and Franzmeier, 2006).

One study (Stolt, 2005) inadvertently discovered that when IRIS tubes were placed into a wetland system that contained soluble sulfide (S^{2-}), black Fe sulfide coatings formed on the tubes that later faded when exposed to the air (Rabenhorst et al., 2010). In anaerobic systems, sulfate (SO_4^{2-}) is reduced to S^{2-}, which rapidly react with Fe to form black, insoluble iron sulfides (FeS), which are then precipitated onto an IRIS tube (Vaughan et al., 2016). Because SO_4^{2-} is a less favorable terminal electron acceptor than Fe^{3+}, the deposition of FeS on IRIS tubes suggest that reducing conditions are more sever in a soil displaying S reduction compared with only Fe^{3+} reduction (Vaughan et al., 2016). An expanded study on the observance of FeS on IRIS tubes (Vaughan et al., 2016) aimed to determine the minimum percentage of black staining (FeS) on IRIS tubes or panels indicative of strongly reducing conditions as corroborated by measured redox potential and Fe removal from IRIS tubes. Results of the study noted that in all cases when FeS staining was >9%, Fe^{3+} reduction exceeded the existing technical standard of 30% removal, which demonstrated that observation of SO_4^{2-} reduction on IRIS surfaces is a viable method for determining hydric soil status (Vaughan et al., 2016). Additionally, evidence of SO_4^{2-} reduction on IRIS surfaces proves highly reducing conditions and could be used in lieu of the requirements for Fe removal from IRIS surfaces (Vaughan et al., 2016).

An additional study using IRIS tubes to detect S presence concluded that IRIS tubes could be used to effectively and rapidly determine levels of S^{2-}, and provide a fine-resolution spatial information on the concentrations of S^{2-} that is unavailable by other methods currently used (Rabenhorst et al., 2010). Although some research has been conducted expanding upon ways IRIS tubes can verify hydric soil, little research has been conducted investigating alternative uses of IRIS tubes from their original intent, which is detecting reducing soil conditions.

3. Materials and Methods

3.1 Site Description

The project site consists of preserved and constructed wetlands (Figure 1) that were created and preserved for mitigation purposes to offset unavoidable impacts to jurisdictional wetlands permitted under section δ404 of the Clean Water Act.

Prior to construction, multiple wetlands were delineated and deemed jurisdictional by the Corps of Engineers and Tennessee Department of Environment and Conservation (TDEC). One of the larger and more mature forested wetlands was preserved as part of the mitigation requirements for impacting the other lower quality wetlands that were deemed unavoidable. The preservation wetland is a forested wetland dominated by sugarberry, American elm, and green ash trees and is comprised of Lindell silt loam soil. A typical profile of Lindell silt loam consists of Ap horizon 0-18 cm (0-7 inches) comprised of silt loam, Bw horizon 18-38 cm (7-15 inches) comprised of silt loam, Bg 38-132 cm (15-52 inches) comprised of silt loam, and Cg 132-200 cm (52-80 inches) comprised of silty clay loam (United States Depratment of Agriculture Natural Resources Conservation Service, 2016). Lindell silt loam is moderately well drained with a depth to water table about 30-41 cm (12-16 inches) and depth to a restrictive layer of more than 200 cm (80 inches) (United States Depratment of Agriculture Natural Resources Conservation Service, 2016). The upper 30 cm (12 inches) of topsoil was harvested from the wetlands proposed for impact in an effort to preserve the natural seed bank and soil characteristics. Impacted wetlands were primarily composed of Egam silty clay loam, which is classified as a well-drained soil with a typical profile consisting of silty clay loam from 0-36 cm (0-14 inches) and silty clay from 36-158 cm (14-62 inches) (United States Depratment of Agriculture Natural Resources Conservation Service, 2016).

Constructed wetlands (Figure 1, Area B and Area C) are located in areas originally comprised of mostly Lindell silt loam and some minor areas of Nesbitt silt loam and Bradyville silt loam (United States Depratment of Agriculture Natural Resources Conservation Service, 2016). A typical profile of Nesbitt silt loam consists of silt loam from 0-18 cm (0-7 inches), silty clay loam from 18-102 cm (7-40 inches), and clay from 102-152 cm (40-60 inches) (United States Depratment of Agriculture Natural Resources Conservation Service, 2016). Its natural drainage class is moderately well-drained with a depth to restrictive layer at more than 200 cm (80 inches) and depth to water table at 61-122 cm (24-48 inches) (United States Depratment of Agriculture Natural Resources Conservation Service, 2016). A typical profile of Bradyville silt loam is composed of Ap 0-15 cm (0-6 inches) comprised of silt loam, Bt1 15-48 cm (6-19 inches) comprised of silty clay loam, Bt2 48-122 cm (19-48 inches) comprised of clay, and R 122-147cm (48-58 inches) comprised of bedrock (United States Depratment of Agriculture Natural Resources Conservation Service, 2016). Its natural drainage class is well-drained and has a depth to water table more than 200 cm (80 inches) (United States Depratment of Agriculture Natural Resources Conservation Service, 2016).

Figure 1. Map of constructed wetland and preservation areas.

Constructed wetlands were built by excavating 30-122 cm (12-48 inches) throughout Areas B and C to achieve various design elevations as close as possible. During excavation, bedrock was encountered in some isolated areas, resulting in undulating areas of higher elevation than originally designed and shallow soils approximately 15 cm (6 inches) in depth. Following excavations, approximately 15 cm (6 inches) of topsoil harvested from the permitted wetlands was spread throughout the excavated areas.

Precipitation was anticipated to be the primary hydrologic source for Area B and Area C, as well as some overbank flooding from adjacent streams. Three approximately 60 cm (24 inch) earthen berms were constructed across Area C in an effort to reduce sheet flow and increase water retention. The site was not planted after construction, as natural regeneration from the harvested wetland topsoil was expected. At the time of this study, the constructed areas were dominated by herbaceous vegetation with some saplings interspersed throughout the site.

3.2 Determination of Growing Season

The beginning of the growing season was determined by an approved method outlined in the *Regional Supplement* (U.S. Army Corps of Engineers, *ERDC/EL TR-12-9, 2012*) as follows:

The growing season has begun on a site in a given year when two or more non-evergreen vascular plant species in the wetland or surrounding areas exhibit one or more of the following indicators of biological activity:

a. Emergence of herbaceous plants from the ground

b. Appearance of new growth from vegetative crowns

c. Coloeptile/cotyledon emergence from seed

d. Bud burst on woody plants

e. Emergence or elongation of leaves of woody plants

f. Emergence or opening of flowers

3.3 Normal Weather Conditions

Rainfall normality was determined by a 30-year average, as outlined in the *Guidance for Making Hydrologic Determinations Version 1.4* (Tennessee Department of Environment and Conservation, 2011), which is consistent with acceptable methods outlined in the *Wetland Hydrology Technical Standard*.

3.4 Atmospheric Temperature

Average atmospheric temperatures and respective standard errors were calculated for each installation period using temperature recordings by nearby weather stations from the National Oceanic and Atmospheric Administration National Centers for Environmental Information Online Climate Dataset (NOAA, 2018).

3.5 Hydrologic Monitoring

Hydrology was monitored with electrical Ecotone™ Water Level Loggers (Remote Data Systems, Inc., Raleigh, NC). Water level loggers were installed in accordance with the *Technical Standard for Water-Table Monitoring for Potential Wetland Sites* (U.S. Army Corps of Engineers, *ERDC TN-WRAP-05-2*). Data was downloaded in the field bi-annually with an Ecotone™ Family PalmOS Handheld Connected Organizer® (Remote Data Systems, Inc., Raleigh, NC). Data was transferred to Windows 7® on a Dell® desktop computer with Meazura RDA & Ecotone™ Handheld Software Version 1.11 for Windows 7® in accordance with *The Quick Start Guide for the Meazura RDA & Ecotone Handheld Software Version 1.11 for Windows Vista and Windows 7*. Once downloaded to the computer, the .txt file was converted to a .csv file using Microsoft Excel® and organized within the spreadsheet. When water level data was analyzed and compared to IRIS tube data, water level data was limited to a range of 0 cm to -30 cm to remain within the range of detection of IRIS tubes.

3.6 Vegetation Assessment

Vegetation was assessed in 0.4 hectare (1 acre) circular plots established every 40m (130 feet) along transects through each wetland (Figure 2). One transect was established across each wetland from boundary to boundary across the widest section of each wetland. The transect and assessment plots were created in ArcGIS® and loaded onto a handheld Trimble® XT 6000 Series GPS unit capable of achieving sub-meter accuracy for guidance in the field. Each assessment plot was flagged in the field for high visibility and consistency throughout the duration of the project.

Figure 2. Vegetation assessment plots established across each wetland area.

The vegetation assessments consisted of completing a Corps of Engineers Wetland Determination Form (Appendix A) at each plot and evaluating the vegetation dominance using both the 50/20 Rule and the Prevalence Index in accordance with the Regional Supplement to the *Corps of Engineers Wetland Delineation Manual: Eastern Mountains and Piedmont Region Version 2.0*.

3.7 Soil Sampling and Analysis

Soil samples were collected to analyze site conditions at each nest location. Three random samples were taken at each nest using a 2.2 cm (7/8 inch) diameter push probe. Each sample was divided into depth increments of 0-5 cm (0-2 inches), 5-15 cm (2-6 inches), 15-30 cm (6-12 inches), and 30-50 cm (12-20 inches), and stored in plastic Ziploc® bags to comprise 4 composite samples of respective depth increments for each nest. Composite samples from each nest were analyzed for soil particle size and texture, pH, and soil organic carbon. Soil particle size and texture analyses were performed using the pipette method as outlined in Soil Science Society of America Methods of Soil Analysis: Physical Methods (Soil Science Society of America, 2002). Soil pH was analyzed using the 1:1 water pH method as outlined in the Kellog Soil Survey Laboratory Methods Manual, Version 5.0 (Soil Survey Staff, 2014). Percent organic carbon was determined by Waters Agricultural Laboratories, Inc. using the wet-dry combustion method.

3.8 IRIS Tubes

An IRIS Tube study was conducted to monitor the presence of reducing soil conditions during each growing season. The Fe oxide paint was prepared in accordance with the *Quick (7 day) IRIS Tube Paint Recipe and Construction Procedure* developed by Matrin C. Rabenhorst. To produce the tubes, 3-meter (10 feet) sections of 1.27 cm (0.5 inch) polyvinyl chloride (PVC) tubes were cut into 38-46 cm (15-18 inch) sections. The tubes were then individually cleaned with acetone to remove the ink on the pipe as best as possible, as well as any lingering residue. After cleaning the tubes, each section was sanded with 100 grade sandpaper to form a texture that would allow the Fe oxide paint to stick to the tubes better. Each tube was then placed on a rubber stopper attached on the end of a drill and balanced by a metal rod on the other end so the tube is level. The drill was used to spin the tube while using a 5 cm (2 inch) foam brush to apply the Fe oxide paint as evenly as possible to the first 30 cm (12 inches) of the tube. Once the tube was painted, the tubes were placed on a drying rack under a closed hood vent to dry. Once the paint dried, the finished IRIS tubes were individually wrapped with saran-wrap to protect them from scratches and prevent moisture from effecting the paint, and finally sotred in a plastic bin.

One nest of IRIS tubes was installed within 3 meters (10 feet) of each electric water monitoring well on the site, and one control nest was installed in an adjacent known upland area. IRIS tube nests were installed in accordance with *The Protocol for Using and Interpreting IRIS Tubes* (Rabenhorst, 2008), as well as *Using IRIS Tubes to Monitor Reduced Conditions in Soils – Project Design* (Berkowitz, 2009). Each wetland nest was interchanged with new IRIS tubes every 4 weeks, with the exception of Nest-6 in the Preservation Area (Figure 3), which was left in place throughout the duration of the growing season. The upland control Nest-7 was also left throughout the duration of the growing season. When the IRIS tubes were removed, the soil surface was marked on the tubes and the depth of installation was recorded in a field book.

Figure 3. Overview of IRIS tube nest and groundwater well locations.

To analyze the tubes, a SharkBite® 1.27 cm x 1.27 cm (0.5 inch x 0.5 inch) female adapter was attached to the upper end of each tube, which has three prongs on the outter edge, spaced evenly around the circumference at every 120 degrees. The tubes were then placed on a Cannon® 5560 printer scanner with a ruler next to it to determine depth measurements. Each tube was scanned three times, turning the tube 120 degrees each scan to result in a full 360-degree coverage. Windows Media® was used to crop each scan to 10 cm (4 inch) and 15 cm (6 inch) sections of greatest removal, as well as depth of installation. The cropped images were then combined using Microsoft Powerpoint® to represent each tube as one flat surface (Appendix B).

R® is a statistical computing and graphics software for data manipulation, calculation, and graphical display (The R Foundation, 2018). R® was used to digitally analyze the percent removal of iron oxide paint on each tube by importing the combined images and running the custom script in Appendix C. The custom script performs a digital analysis by detecting red, green, and blue (RGB) values of each image and converting them to hue, saturation, and brightness (HSB) values. Color thresholds for determining reduced areas (iron oxide paint removed or significantly faded) from non-reduced areas (iron oxide paint remianing) were set for hue at 26-255, saturation at 0-255, and brightness at 110-255. Areas of iron oxide paint removal are converted to white, areas of non-removal are converted to black, and area of coverage is calculated for each to determine percent removal. A visual analysis was also performed to compare with digital analysis results in order to assess the accuracy and variability of each analysis method. This was done separately for the 10 cm (4 inch), 15 cm (6 inch), and depth of installation images. The 10 cm (4 inch) and 15 cm (6 inch) sections of greatest removal were performed to compare the respective protocol requirements and evaluate how representative they are of the entire soil profile being evaluated (depth of installation).

The digital images for the depth of installation analysis were then used to generate a profile of percent removal of iron oxide paint in an effort to accurately determine an upper depletion depth (UDD). In some cases, water was perched in the upper portion of the soil and not saturated throughout, so a perched depletion depth (PDD) was determined. Both UDD and PDD were determined by running the custom R® script in Appendix C. In summary, UDD was determined by detecting where ≥60% removal of iron oxide paint was continuous below a reported depth and ≤40% removal of iron oxide paint above, and PDD was determined by detecting where ≥60% removal of iron oxide paint was continuous above a reported depth and ≤40% removal of iron oxide paint below.

The effect of installation time, nest, and consecutive or total time of saturation on reducing conditions present (according to the *Hydric Soil Technical Standard*) was evaluated with an ANCOVA and binary response variables, as well as binomial errors using the glm function in R (R Core Team, 2018). The continuous variable was consecutive days of saturation or total days of saturation. The categorical variables were installation and nest. Non-significant variables were removed from the model. Different levels of the categorical variables were contrasted against each other and evaluated based on $\alpha=0.05$. Levels of categorial variables which were found to be not different were collapsed in one group. Finally, the consecutive and total time of saturation were predicted for a likelihood of $p=0.95$, and $p=0.99$, for each group, respectively.

4. Results

4.1 Normal Weather Conditions

Weather conditions were determined by comparing actual rainfall to the 30 year average rainfall and respective standard deviations to determine if abnormal conditions occurred during the course of the study. Results for rainfall normality are displayed in Figure 4 and listed in Table 1 and Table 2.

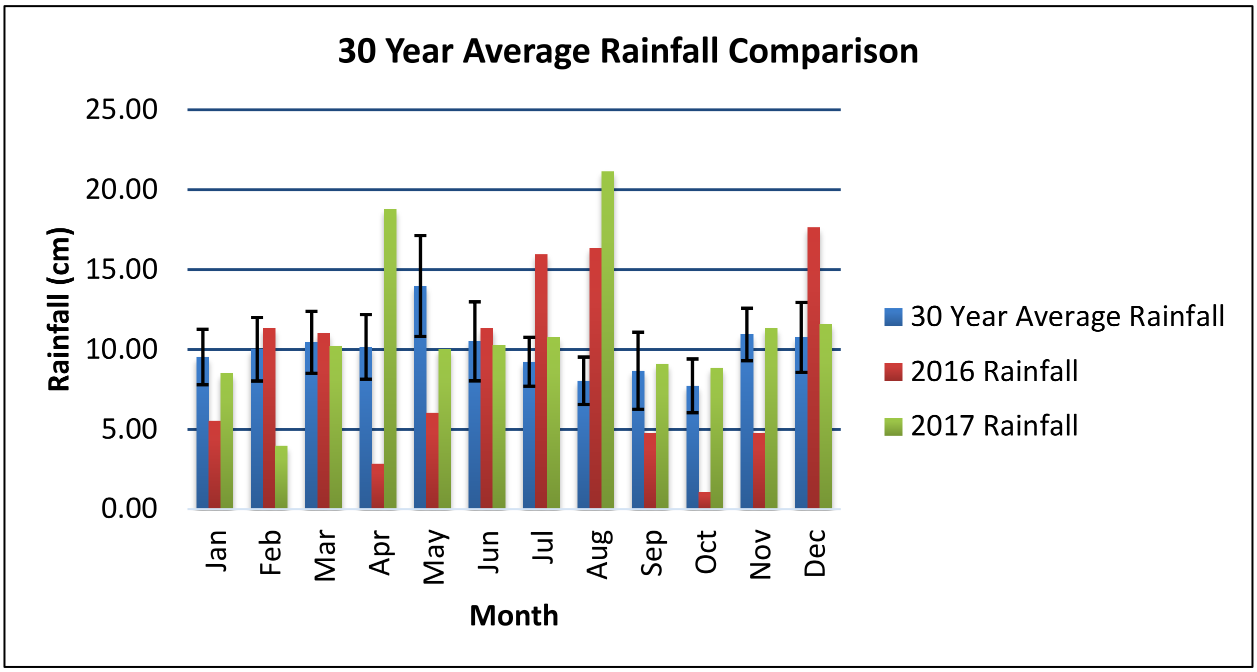

Figure 4. Normal weather conditions determined for 2016 and 2017.

Table 1. Normal weather conditions determined for 2016 installations periods.

2016	
Installation	**Rainfall Normality**
1	Normal
2	Normal
3	Wet
4	Wet

Table 2. Normal weather conditions determined for 2017 installations periods.

2017	
Installation	**Rainfall Normality**
1	Normal
2	Normal
3	Normal
4	Normal
5	Normal
6	Normal
7	Normal

Normal weather conditions were present during installations 1 and 2 during 2016, with wetter than normal conditions occurring during installations 3 and 4. Normal weather conditions were present throughout all installations during 2017.

4.2 Hydrology

Saturation and groundwater levels were monitored at the site for a total of 5 years (2012-2017). Monitoring began with one electronic well in each constructed wetland cell. After the first two years, minimum wetland hydrology criteria were met or exceeded in Area-B and the Preservation Area, but were not met either year in Area-C; therefore, two additional electronic wells were installed in Area-C, referred to as Area-C (north) and Area-C (south). The subsequent three monitoring years (years 3-5) resulted in Area-B, Area-C (north), and Area-C (south) meeting or exceeding minimum wetland hydrology criteria all three years. Area-C (original) met minimum wetland hydrology criteria during year 3, and the Preservation Area met minimum wetland hydrology criteria during years 3 and 5. Technical issues with the electronic wells were encountered sporadically throughout the 5 year monitoring period. Table 3 shows the longest duration of saturation recorded annually at each well location. Figures 5 - 9 display annual monitoring well data recorded at each well location.

Table 3. Longest annual duration of saturation recorded at each well location.

Well Location	2013	2014	2015	2016	2017
Area-B	99	17	24	19	50
Area-C (original)	4	4	18	N/A	4
Area-C (north)	N/A	N/A	19	21	38
Area-C (south)	N/A	N/A	25	31	25
Preservation Area	48	24	15	8	51

*Red indicates failure to meet minimum wetland hydrology criteria.
N/A indicates monitoring well malfunction.

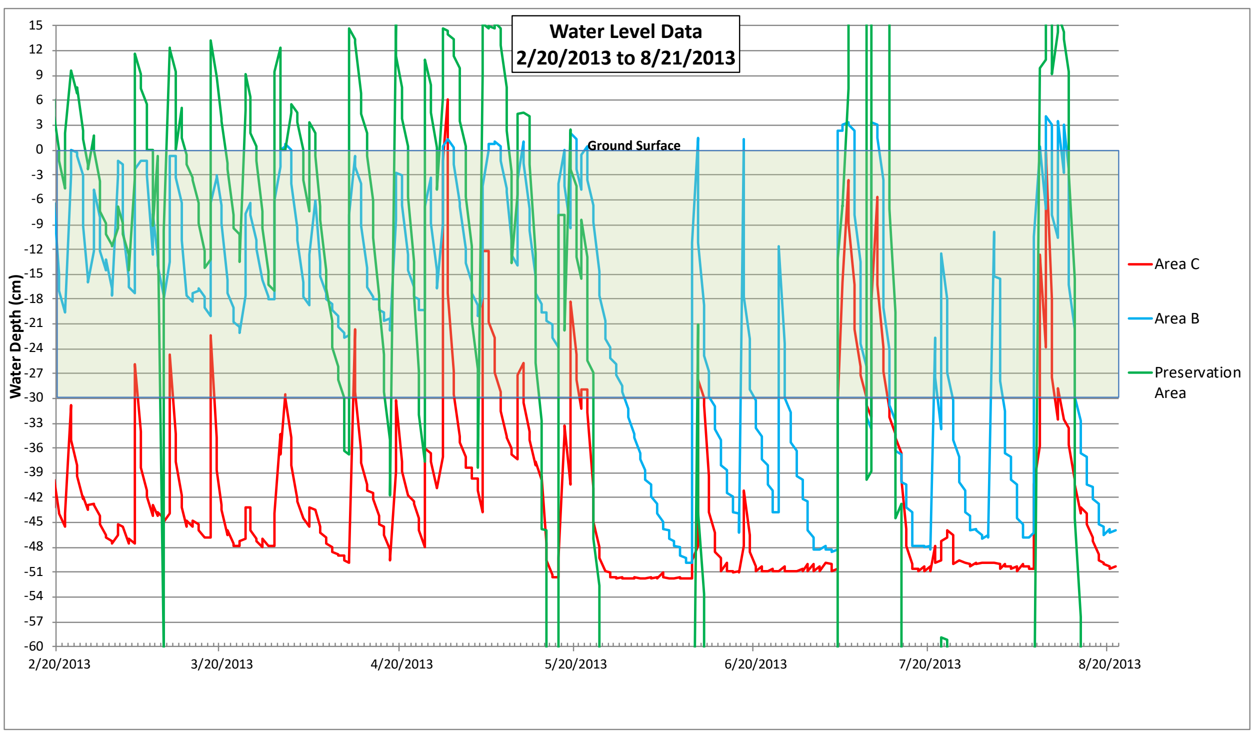

Figure 5. Water level data recorded at electronic well locations during 2013 growing season.

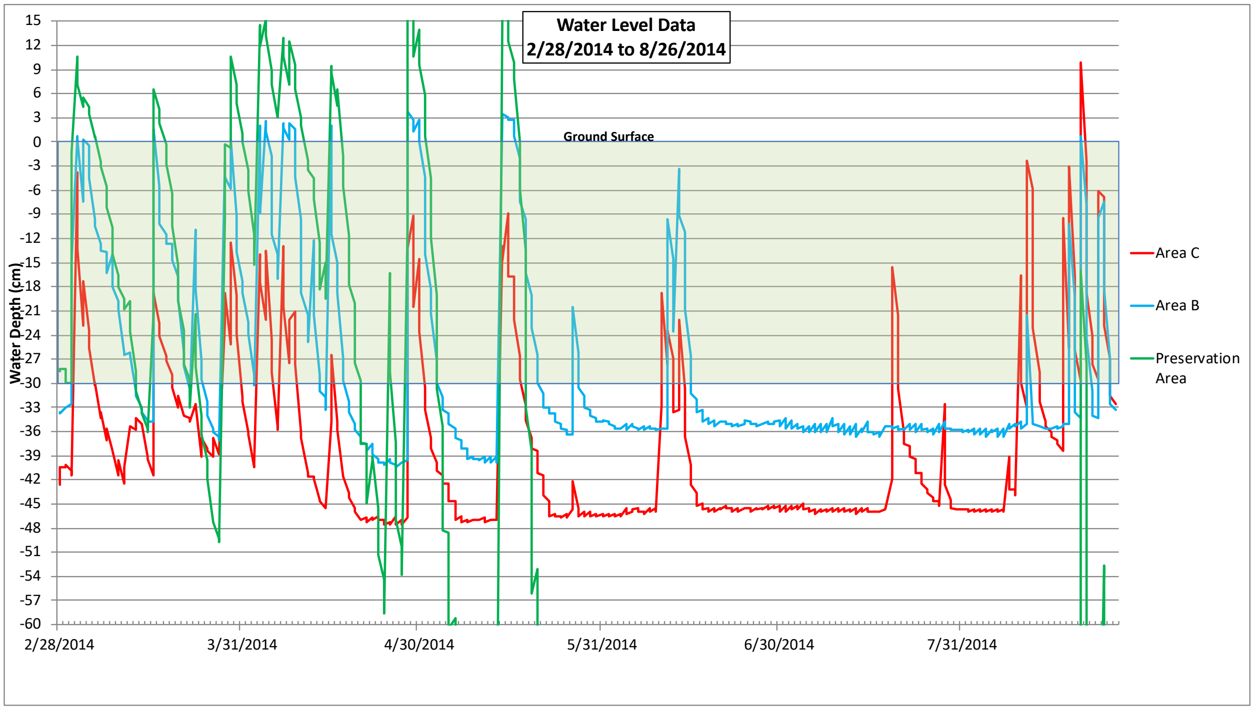

Figure 6. Water level data recorded at electronic well locations during 2014 growing season.

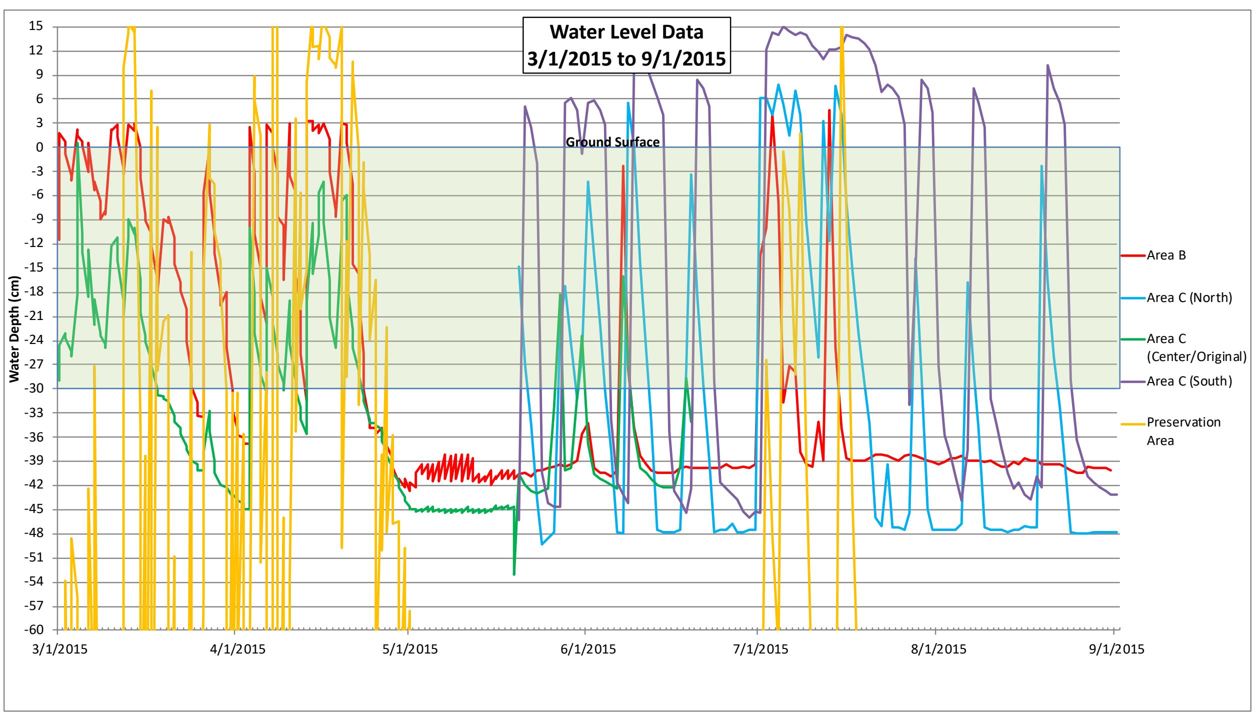

Figure 7. Water level data recorded at electronic well locations during 2015 growing season.

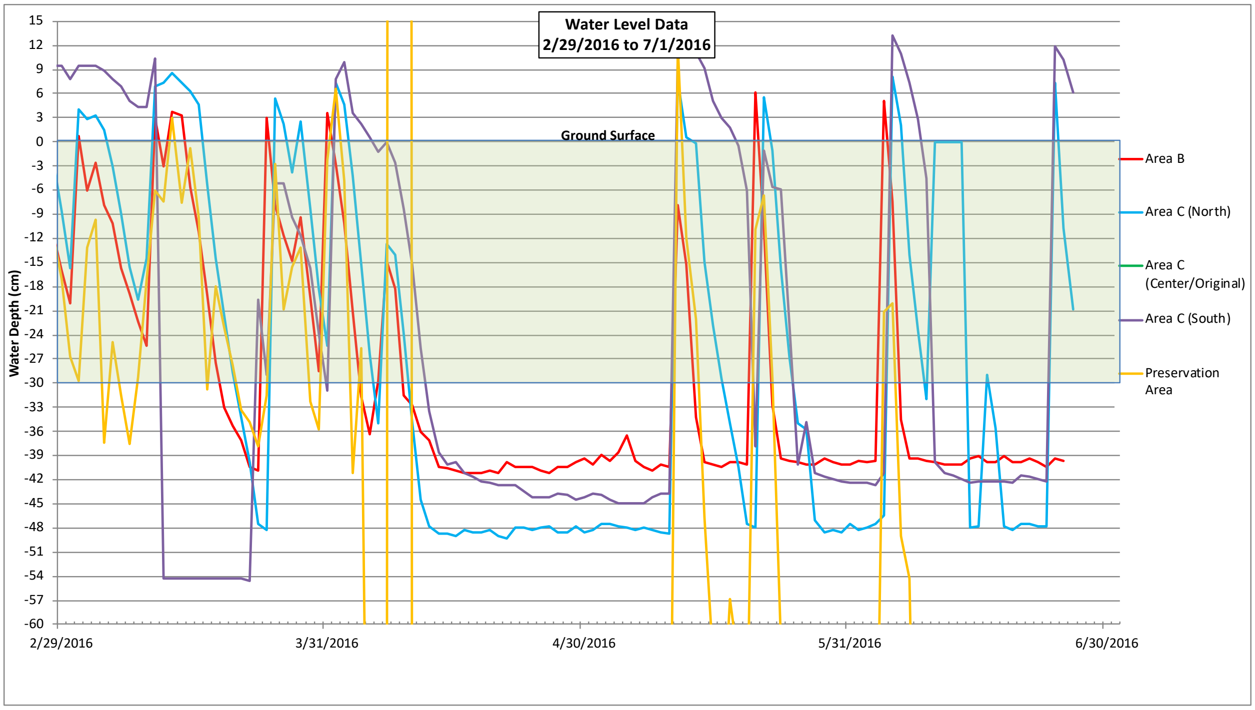

Figure 8. Water level data recorded at electronic well locations during 2016 growing season.

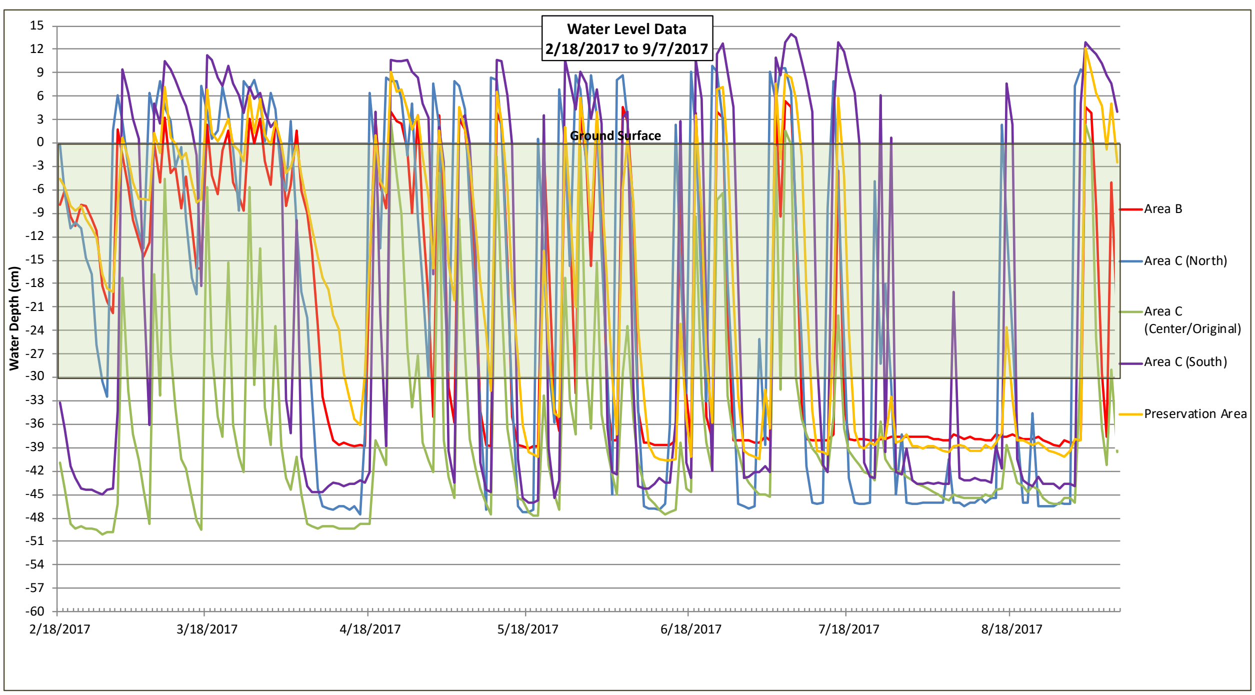

Figure 9. Water level data recorded at electronic well locations during 2017 growing season.

As shown in Figures 5 - 9, these wetlands have fluctuating water levels that result in intermittent periods of saturation and inundation throughout the growing season, mostly occurring during the beginning weeks of the growing season. The sharp rise and falls in water levels indicate a perched water table rather than fluctuating groundwater, but some are also caused by technical issues with the electronic wells. Some readings indicate water levels below 60 cm (24 inches), which is the depth of the monitoring well, when in reality it was inundated and could not process an accurate reading.

4.3 Vegetation

Vegetation assessment plots were monitored annually for a period of 5 years and are depicted on Figure 10. Vegetation assessments during the monitoring period consisted of keeping a running list of vegetative species and achieving a dominance ($\geq$50%) of facultative (FAC), facultative wetland (FACW), or obligate (OBL) species. Due to the large size of this data, the combined list of species and respective dominance at various assessment plots is located in Appendix D.

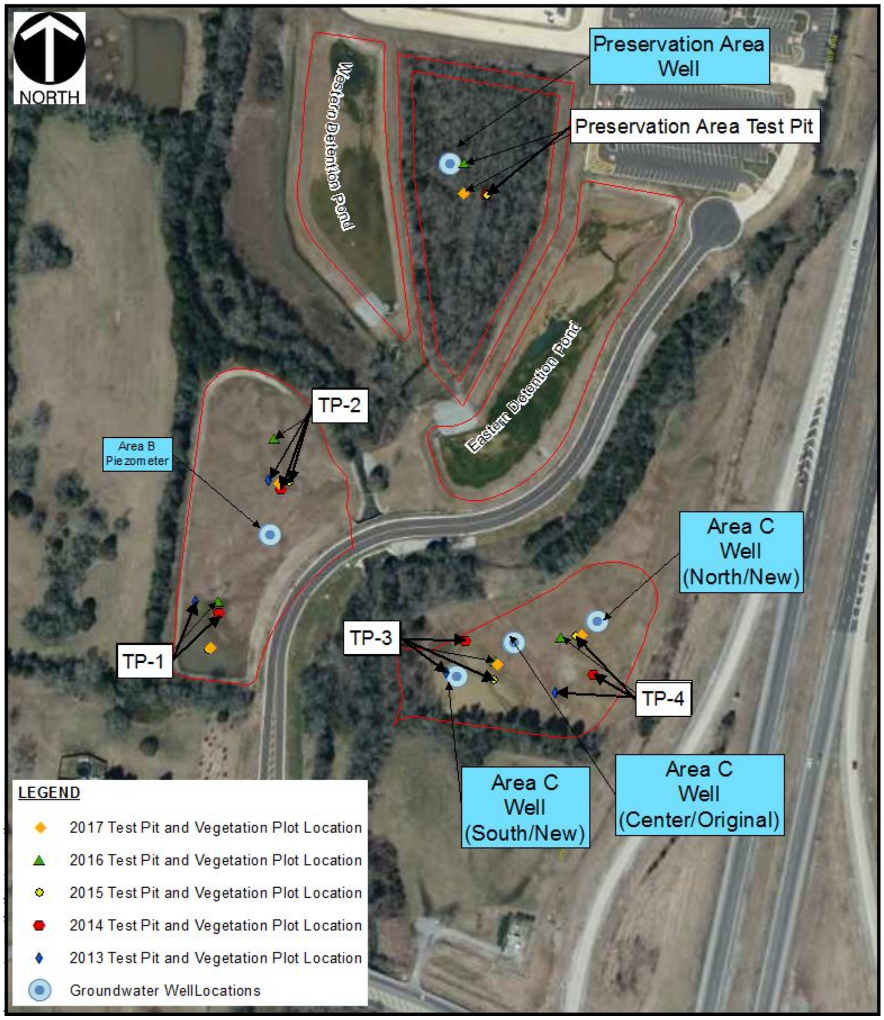

Figure 10. Overview of soil test pits and vegetation assessment plot locations during annual monitoring events.

Vegetation data collected at assessment plots during the course of this study included both the dominance test and the prevalence index, and is summarized in Table 4. Figure 11 displays the dominance test and prevalence index values at each plot.

Table 4. Summary of vegetation assessment results.

	2016		2017	
	Dominance Test	**Prevalence Index**	**Dominance Test**	**Prevalence Index**
Plot-1 (Area-B)	Pass	Pass	Pass	Pass
Plot-2 (Area-B)	Fail	Pass	Fail	Pass
Plot-3 (Area-B)	Pass	Pass	Fail	Fail
Plot-4 (Area-C)	Pass	Pass	Pass	Pass
Plot-5 (Area-C)	Pass	Pass	Pass	Pass
Plot-6 (Preservation Area)	Pass	Pass	Pass	Pass
Plot-7 (Preservation Area)	Pass	Pass	Pass	Pass
Plot-8 (Preservation Area)	Pass	Pass	Pass	Pass

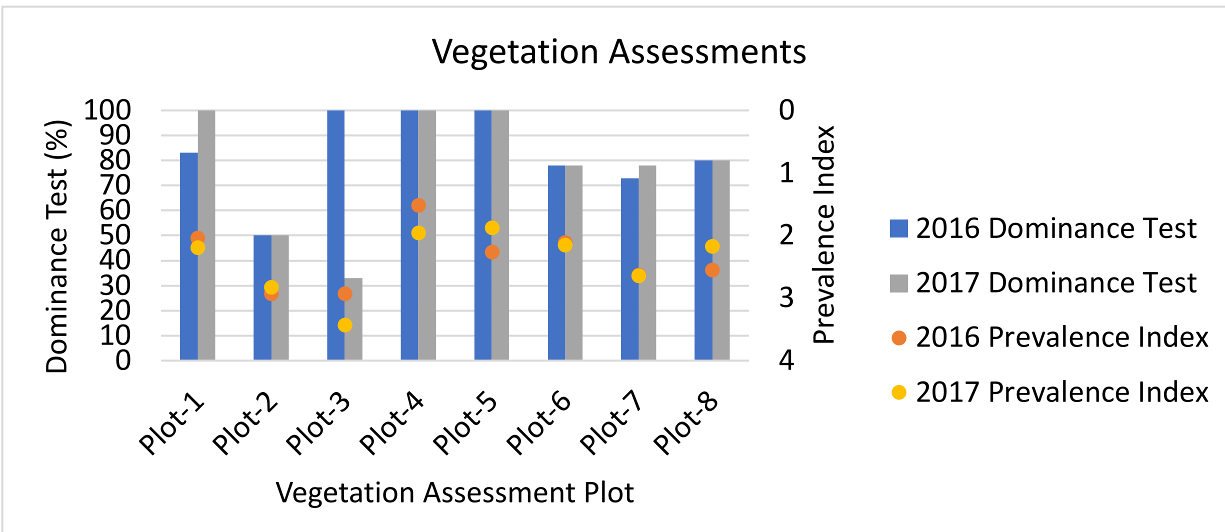

Figure 11. Comparison of dominance test and prevalence index values at vegetation assessment plots.

4.4 Soil Analysis

4.4.1 Particle Size Data

Soil texture determined by the particle size data analysis was fairly uniform throughout the constructed wetlands. All wetland nest locations are composed of at least 15 cm of silt loam underlain by a clay loam subsoil with the exception of Nest-4, which only has 5 cm of silt loam underlain by a clay loam. The slight variations of soil texture at respective depths is likely due to mixing of harvested wetland topsoil and the excavated soil within the constructed wetland areas. Soil texture and particle size data are show in Table 5.

Table 5. Soil texture analysis performed at nest locations.

Site	Soil Depth (cm)	Sand (%)	Silt (%)	Clay (%)	Texture
Nest-1	0-5	20.0	54.6	25.4	Silt Loam
Nest-1	5-15	19.2	54.6	25.4	Silt Loam
Nest-1	15-30	23.0	45.7	31.3	Clay Loam
Nest-1	30-50	7.7	34.0	58.2	Clay
Nest-2	0-5	14.1	64.1	21.8	Silt Loam
Nest-2	5-15	14.6	64.7	20.7	Silt Loam
Nest-2	15-30	18.3	58.7	22.9	Silt Loam
Nest-2	30-50	37.8	36.6	25.5	Clay Loam
Nest-3	0-5	9.7	65.2	25.1	Silt Loam
Nest-3	5-15	21.5	57.9	20.6	Silt Loam
Nest-3	15-30	21.9	56.7	21.4	Silt Loam
Nest-3	30-50	27.8	44.0	28.2	Clay Loam
Nest-4	0-5	13.5	59.7	26.8	Silt Loam
Nest-4	5-15	20.5	39.5	40.1	Clay Loam
Nest-4	15-30	27.5	34.5	38.0	Clay Loam
Nest-4	30-50	28.1	30.2	41.7	Clay Loam
Nest-5 & 6	0-5	18.5	61.9	19.6	Silt Loam
Nest-5 & 6	5-15	24.0	59.4	16.6	Silt Loam
Nest-5 & 6	15-30	24.8	58.3	16.9	Silt Loam
Nest-5 & 6	30-50	35.5	45.8	18.7	Loam
Nest-7	0-5	17.6	54.4	28.0	Silty Clay Loam
Nest-7	5-15	14.0	63.3	22.8	Silt Loam
Nest-7	15-30	14.9	60.8	24.3	Silt Loam
Nest-7	30-50	22.1	56.2	21.6	Silt Loam

4.4.2 Hydric Soil Indicators

Munsell soil colors documented annually throughout the 5-year monitoring period revealed that the preservation area met hydric soil indicator F3 depleted matrix every year, with the exception of the first annual monitoring event in 2013, as it was not sampled. Soil test pits assessed during annual monitoring events in the same general area every year are shown in Figure 10 and outlined in Table 6. Figure 12 shows an example of soil development over time at one of the assessment plots.

<table>
<tr><th colspan="2">2013</th><th colspan="2">2014</th><th colspan="2">2015</th><th colspan="2">2016</th><th colspan="2">2017</th></tr>
<tr><th>Depth (cm)</th><th>Color</th><th>Depth (cm)</th><th>Color</th><th>Depth (cm)</th><th>Color</th><th>Depth (cm)</th><th>Color</th><th>Depth (cm)</th><th>Color</th></tr>
<tr><td>0</td><td rowspan="15">2.5Y 3/3</td><td>0</td><td rowspan="16">10YR 4/3</td><td>0</td><td rowspan="16">10YR 3/4</td><td>0</td><td rowspan="21">10 YR 3/2</td><td>0</td><td rowspan="19">10 YR 4/2</td></tr>
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<tr><td>14</td><td>14</td><td>14</td><td>14</td><td>14</td></tr>
<tr><td>15</td><td rowspan="11">10YR 5/6</td><td>15</td><td>15</td><td>15</td><td>15</td></tr>
<tr><td>16</td><td>16</td><td rowspan="15">Resistance</td><td>16</td><td rowspan="15">Resistance</td><td>16</td><td>16</td></tr>
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<tr><td>19</td><td>19</td><td>19</td><td>19</td><td>19</td><td rowspan="12">10YR 5/4</td></tr>
<tr><td>20</td><td>20</td><td>20</td><td>20</td><td>20</td></tr>
<tr><td>21</td><td>21</td><td>21</td><td>21</td><td rowspan="10">Resistance</td><td>21</td></tr>
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</table>

Figure 12. Example of soil development over time at assessment plot 2.

Table 6. Hydric Soil indicators observed at annual monitoring test pit locations.

Test Pit	2013	2014	2015	2016	2017
Preservation Area	Not Sampled	F3: Depleted Matrix	F3: Depleted Matrix	F3: Depleted Matrix	F3: Depleted Matrix
1B	F6: Redox Dark Surface	F6: Redox Dark Surface	No Indicator Met	F6: Redox Dark Surface	F3: Depleted Matrix
2B	No Indicator Met	No Indicator Met	No Indicator Met	F6: Redox Dark Surface	F3: Depleted Matrix
3C	No Indicator Met	No Indicator Met	F7: Depleted Dark Surface	F3: Depleted Matrix	No Indicator Met
4C	No Indicator Met	F3: Depleted Matrix	No Indicator Met	F6: Redox Dark Surface	F6: Redox Dark Surface

Soil colors and characteristics documented at respective vegetation assessment plots during the course of this study were evaluated each year to determine if hydric soil indictors were met, and are outlined in Table 7.

Table 7. Hydric soil indicators noted in respective vegetation assessment plots.

Plot	2016	2017
1	F6: Redox Dark Surface	F3: Depleted Matrix F6: Redox Dark Surface
2	F6: Redox Dark Surface	No Indicator Met
3	F6: Redox Dark Surface	F3: Depleted Matrix
4	F3: Depleted Matrix	F3: Depleted Matrix
5	F6: Redox Dark Surface	F3: Depleted Matrix
6	F3: Depleted Matrix	F3: Depleted Matrix
7	F3: Depleted Matrix	F3: Depleted Matrix
8	F3: Depleted Matrix	F3: Depleted Matrix

Soil colors and characteristics observed during the initial monitoring years were largely attributable to the harvested wetland topsoil being mixed with natural soils within the constructed wetland areas. The somewhat slow and spotty development of hydric soil within the constructed wetland areas could also be attributed to the hydrologic regime at the site. Having a hydrologic regime consisting of a perched water table saturating the soil for a few weeks during the beginning of the growing season will likely produce a slower rate of soil development than one consisting of high groundwater levels throughout the majority of the growing season. Although soil indicators became more consistent as monitoring continued, soil descriptions and indicators suggest that soils are still developing.

4.4.3 Soil Parameters

Soil sample parameters were analyzed for total percent carbon and pH at respective depths, and are shown in Table 8. All of the parameters appear to generally decrease with sample depth. Nests 5 and 6 are located in the Preservation Area and should be used as reference soil conditions, as it is an undisturbed natural wetland.

Table 8. Soil parameters analyzed at respective depth increments to detect possible influences on percent removal of IRIS tube paint.

Nest	Soil Depth (cm)	Total %Carbon	Average Total %Carbon	pH	Average pH
1	0-5	2.8	1.8	7.1	7.0
1	5-15	1.8		7.5	
1	15-30	1.2		6.0	
1	30-50	1.3		7.6	
2	0-5	2.5	1.6	5.7	6.3
2	5-15	1.6		6.1	
2	15-30	1.3		6.5	
2	30-50	1.0		7.1	
3	0-5	2.2	1.7	6.8	7.0
3	5-15	1.5		7.3	
3	15-30	1.6		7.0	
3	30-50	1.5		7.2	
4	0-5	2.0	1.4	7.0	6.2
4	5-15	1.3		5.5	
4	15-30	1.1		5.7	
4	30-50	1.1		6.6	
5&6	0-5	3.5	1.9	6.4	6.9
5&6	5-15	1.6		6.8	
5&6	15-30	1.4		7.0	
5&6	30-50	1.3		7.2	
7	0-5	2.7	2.3	7.5	7.5
7	5-15	2.3		7.5	
7	15-30	2.2		7.5	
7	30-50	1.9		7.6	

While the same general trend of soil parameters appear at all nest locations, total carbon values at Nests 5 and 6 are considerably higher than the other nests. This is likely due to the undisturbed nature of the area, and the fact that it receives annual organic deposits of leaf litter from the forest canopy. As the constructed wetland soils continue to develop and stabilize, total carbon values are expected to increase as root decay and other organic deposits accumulate.

4.5 IRIS Tubes

Digital and visual analyses were performed on IRIS tubes for each installation. Analyses were carried out consistent with respective protocols to compare the accuracy of each protocol, as well as differences in digital and visual analyses results. The same analyses were performed for depth of installation in an effort to assess the entire soil profile in contact with the IRIS tubes. Figure 13 shows an example of a digital analysis of an IRIS tube and Table 9 shows an example of how the results were reported for each protocol. Results are listed in Appendix E.

Figure 13. Example of digital analysis for depth of installation of IRIS tube 4-3 from Installation-4 during 2017.

Table 9. Example of IRIS tube results comparing calculated digital analysis results with visual analysis results.

	Installation-4 - IRIS Tube Results May 13 - June 11, 2017				
	IRIS Tube	**Calculated Percent Removal**	**Reducing Conditions Present**	**Visual Percent Removal**	**Reducing Conditions Present**
Nest-1	1-1	86%	**Yes**	85%	**Yes**
	1-2	84%		85%	
	1-3	64%		60%	
	1-4	32%		15%	
	1-5	90%		88%	
Nest-2	2-1	81%	**Yes**	50%	**Yes**
	2-2	99%		95%	
	2-3	97%		85%	
	2-4	98%		90%	
	2-5	99%		98%	
Nest-3	3-1	9%	**No**	10%	**No**
	3-2	19%		12%	
	3-3	20%		15%	
	3-4	9%		10%	
	3-5	8%		8%	
Nest-4	4-1	89%	**Yes**	90%	**Yes**
	4-2	91%		90%	
	4-3	86%		80%	
	4-4	72%		50%	
	4-5	18%		10%	
Nest-5	5-1	27%	**Yes**	20%	**Yes**
	5-2	78%		75%	
	5-3	79%		80%	
	5-4	50%		30%	
	5-5	60%		50%	

Comparisons of results from respective protocols in relation to depth of installation (soil depth) are shown in Figure 14, and comparison of digital (calculated) and visual analyses are shown in Figure 15.

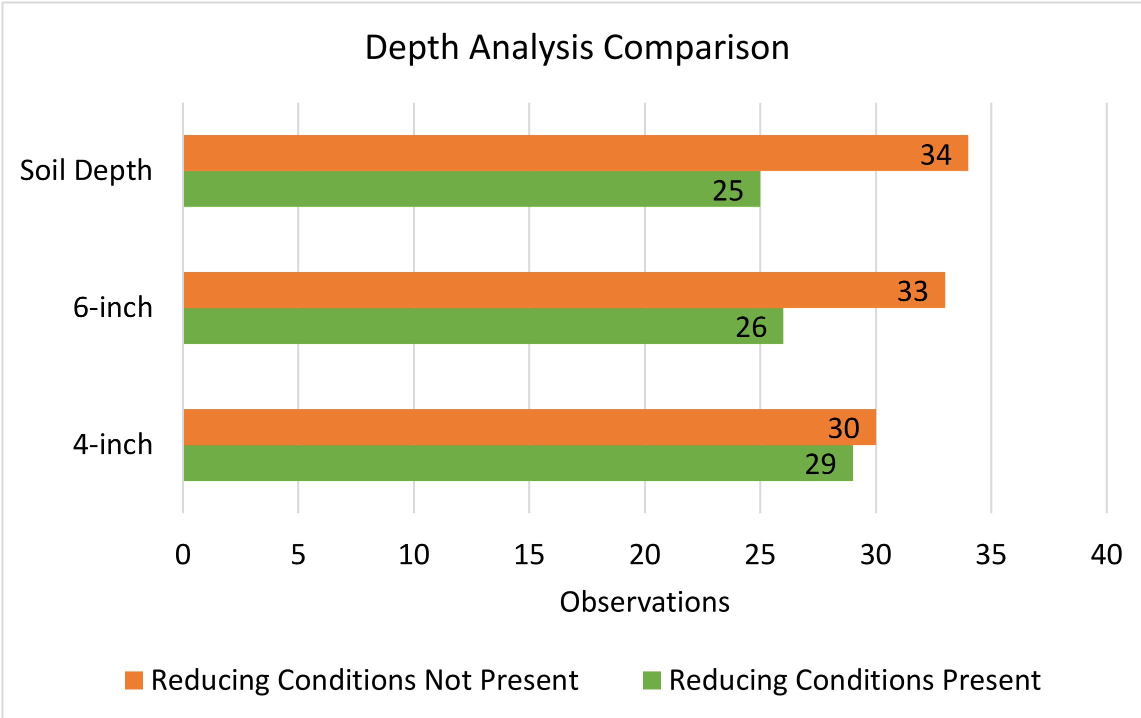

Figure 14. Protocol comparisons to depth of installation.

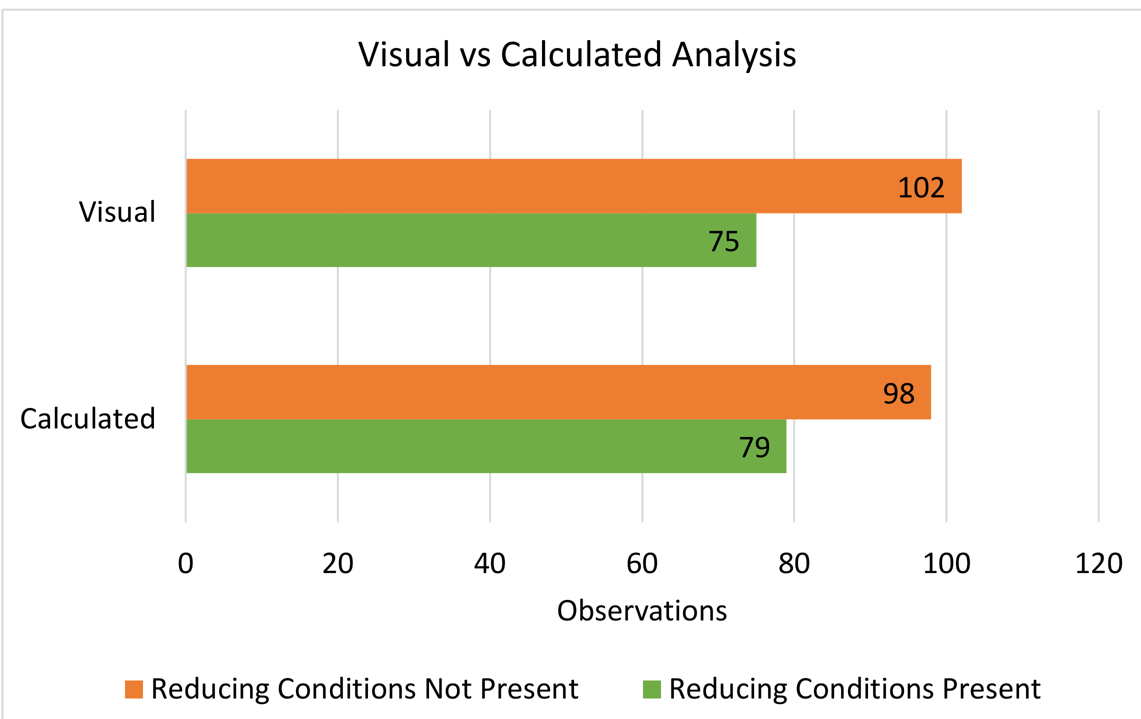

Figure 15. Comparison of digital and visual analysis results.

As shown in Figure 16 and Figure 17, digital images for depth of installation analysis were used to generate a profile of percent removal of iron oxide paint and determine an upper depletion depth (UDD) and perched depletion depth (PDD), respectively. Percent removal profiles with reported UDD and PDD are located in Appendix B.

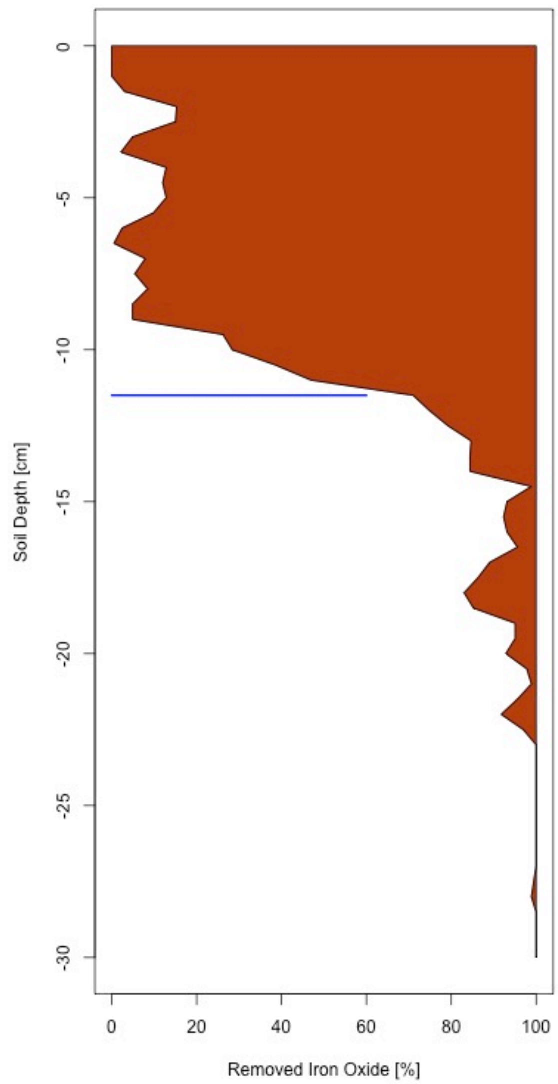

Figure 16. Example of percent removal profiles and detection of UDD (solid blue line) at 11.5 cm.

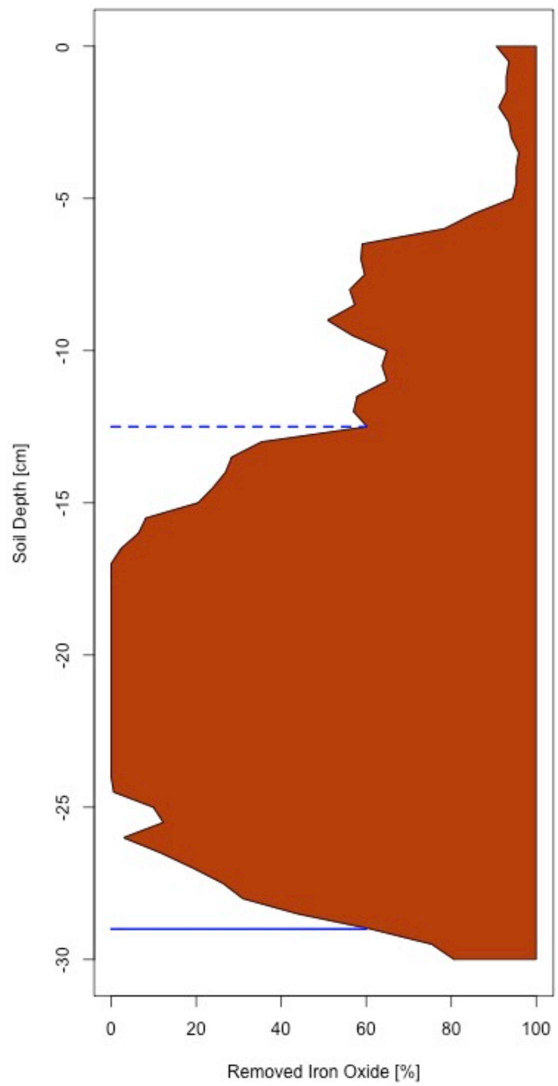

Figure 17. Example of percent removal profiles and detection of PDD (dashed blue line) at 12.5 cm and UDD (solid blue line) at 29 cm.

5. Discussion

5.1 Vegetation Composition

When comparing the vegetation data during the initial years of monitoring, it appears TP-2 and TP-4 did not meet the dominance test for hydrophytic vegetation, but the assessment plots conducted for this study in the vicinity of those test plots did meet the dominance test at least once during the course of this study and the final years of monitoring. The initial years of monitoring were conducted during August each year, which is late in the growing season and one of the hottest and driest months of the year. This study and the final years of monitoring were conducted during May and June, which is in the earlier and usually wetter part of the growing season. As shown in Figures 5 - 9, the hydrologic regimes of these wetlands vary drastically throughout the duration of the growing season. As such, vegetational composition observed throughout the study also varied, with more water-tolerant species dominating the early and wetter part of the growing season and less water-tolerant species dominating the later and drier part of the growing season. Some of the upland vegetation encountered during annual monitoring was also due to topographical differences created by the undulating bedrock.

Vegetation assessment data show that hydrophytic vegetation was present at all assessment plots during the course of this study, with the exception of Plot-3 during the 2017 assessment, although it did contain hydric soil. Vegetation at this location was mostly dominated by white thoroughwort (*Eupatorium album*), which has no wetland indicator status, and narrowleaf lespedeza (*Lespedeza angustifolia*), which is a FAC species, when it passed during the 2016 assessment. Contrarily, hydric soil was not observed in Plot-2 during the 2017 assessment, although hydrophytic vegetation was present. Similar to Plot-3, species composition at this location was dominated by a variety of mostly FAC species. These inconsistent characteristics could indicate that the wetlands are still developing, that these particular areas do not receive enough hydrologic input to sustain wetland characteristics and are slowly drying out, or it is possible that these are isolated areas that are slightly higher in elevation due to the undulating bedrock and therefore have varying characteristics.

Figure 11 compares dominance test values with prevalence index values. The results show what was expected, that the dominance test values aren't necessarily representative of the entire vegetative community. Dominance test values can be easily skewed since it considers FAC, FACW, and OBL species to have the same value. Similarly, a dominance of one or two species can have a misrepresentation of the entire assessment area. Although the dominance test is a quick and easy field test for assessing the presence of hydrophytic vegetation, the prevalence index is a much more representative method.

5.2 Protocols and Digital vs. Visual Analysis Comparison

When comparing protocols, it appears that the NTCHS protocol requiring ≥ 30% removal within a 15 cm (6 inch) zone beginning within the upper 15 cm (6 inches) of the soil profile is most closely related to the entire depth of installation results, having only 1 out of 59 outcomes that was different, resulting in a 98% agreeance. Although the *Protocol for Using and Interpreting IRIS Tubes,* which requires > 25% removal within a 10 cm (4 inch) zone, only had 4 out of 59 outcomes that were different (93% agreeance), the NTCHS is more representative of the entire soil profile in contact with the IRIS tube.

Both visual analysis and digital analysis are acceptable methods in both protocols for assessing percent removal of iron oxide paint. Although percent removals varied with these methods, the results were generally within a 10-15% range. When combining 10 cm (4 inch), 15 cm (6 inch), and 30 cm (12 inch) results, a total of 177 assessments were performed, of which 4 results were different. The 98% agreeance of results confirms that both methods should be acceptable, when conducted in a non-bias manor.

It is good practice to record soil descriptions at each nest location to compare to IRIS tube results. In some instances, IRIS tube results may not indicate the presence of reducing (hydric) soil conditions, but soil descriptions may disagree. The likelihood of encountering this is more common in areas containing a depleted matrix, which allows for a depleted zone to begin at 25 cm (10 inches), where IRIS tubes require a zone of sufficient paint removal to begin within the upper 15 cm (6 inches).

5.3 Influencing Factors

The differences in the four conditions required for reduction to occur, as listed by Michael J. Vepraskas, et. al. (2016) and Jenkinson and Franzmeier (2006), are important in determining if and when IRIS tubes should be used, as well as how to interpret the results. According to Jenkinson and Franzmeier (2006), a study by Evans and Franzmeier (1988) showed that soil reduction features were much better correlated with the time the soil was saturated when soil temperatures were >5°C (41°F) than with the time the soil was saturated when soil temperatures were ≤5°C (41°F). For this study, it is notable that during the first installation of the 2017 growing season 4 of the 5 nests were saturated for 20 or more consecutive days, yet only 1 of them resulted in a positive reaction to IRIS tubes showing the presence of reducing conditions; however, some of the nests did show evidence of reduction, but not enough to meet the minimum requirements for IRIS tubes. Although soil temperature data was not collected, it is anticipated that the lack of reaction to IRIS tubes was due to cooler temperatures, although it is unclear if the same 5°C (41°F) correlation applies. Table 10 shows the dates associated with installation periods.

Table 10. Dates of installation periods.

Year	Installation	Date
2016	Installation-1	May 28 - June 25
	Installation-2	June 25 - July 23
	Installation-3	July 23 - August 20
	Installation-4	August 20 - September 17
2017	Installation-1	February 19 - March 19
	Installation-2	March 19 - April 15
	Installation-3	April 15 - May 13
	Installation-4	May 13 - June 11
	Installation-5	June 11 - July 9
	Installation-6	July 9 - August 5
	Installation-7	August 5 - September 2

Additionally, as temperatures increased as the growing season progressed, the duration of saturation required for sufficient removal of paint decreased. For example, during Installation-1 in 2017 (February 19 – March 19), Nest-1 was saturated for 29 consecutive days, Nest-2 was saturated for 29 consecutive days, Nest-4 was saturated for 20 consecutive days, and Nest-5 was saturated for 29 consecutive days, but only Nest-5 documented reducing conditions with IRIS tubes. However, during Installation-5 in 2017 (June 11 – July 9), Nest-1 was saturated for 5 consecutive days, Nest-2 was saturated for 12 consecutive days, Nest-4 was saturated for 7 consecutive days, and Nest-5 was saturated for 6 consecutive days, and all nests documented reducing conditions with IRIS tubes. These results indicate that temperature could possibly affect the duration of saturation required for reducing conditions to develop.

When comparing various results among nests, Nest-2 and Nest-4 are located within the same constructed wetland area; therefore, it was anticipated that hydrologic regimes and IRIS tube results would be similar as well. However, the duration of saturation is very inconsistent, with Nest-2 being saturated for several days longer than Nest-4 during some installations and Nest-4 being saturated for several days longer than Nest-2 during other installations. For example, during Installation-1 in 2017, Nest-2 was saturated for 29 consecutive days and Nest-4 was saturated for 20 consecutive days, while Nest-2 was saturated for 13 consecutive days and Nest-4 was saturated for 21 consecutive days during Installation-3 in 2017. These inconsistencies could be due to the disturbed nature of the soils and may be attributed to the mixing of harvested wetland topsoil with the excavated soil or varying areas of soil compaction from construction activities. Regardless of the varying durations of saturation, Nest-4, as a whole, consistently resulted in lower percent removal of iron oxide paint. When comparing soil parameters from each nest location, Nest-4 has the lowest percent total carbon (1.4%) and pH (6.2) results, which might explain the lower percent removals. It should also be noted that the vegetation at Nest-2 is dominated by mostly narrow leaf cattails (*Typha angustifolia*) and broad leaf cattails (*Typha latifolia*), which provide an annual contribution of organic deposits. The vegetation documented at Nest-4 is dominated by mostly Frank's sedge (*Carex frankii*), fox sedge (*Carex vulpinoidea*), and giant goldenrod (*Solidago gigantea*), which provide less organic deposits annually and are mostly observed in the same clumps every year. Although these results indicate that soil carbon content and pH could possibly influence IRIS tube results, reducing conditions were still documented at Nest-4 during multiple installations; therefore, no threshold for what is considered to be a sufficient amount of soil organic carbon or pH required to produce a positive reaction to IRIS tubes can be concluded, and it is unclear how the availability of soil organic carbon effects the rate or amount of removal of iron oxide paint.

As noted by Stolt (2005) black splotches were noted on some of the IRIS tubes during removal, indicating the presence of iron sulfide (FeS). Vaughan et al. (2016) indicate that the presence of FeS suggests more severe reducing conditions are present; however, the observations in this study were present in small quantities (approximately 1%-3%) on microsites on the tube. Additionally, observations of FeS on microsites occurred during installations that resulted in both reducing and nonreducing conditions. Percent coverage of FeS was not documented in the field to compare to the 9% standard for documenting reducing conditions developed by Vaughan et al., 2016.

5.4 Depletion Depths and Water Level Data

The iterative nature of this study captured many different soil saturation conditions, thus several different patterns of iron oxide paint removal from IRIS tubes were encountered. As shown in Figure 18, six categories were developed to represent the different types of removal encountered while developing the method for determining depletion depths and categories. Jenkinson and Franzmeier (2006) created the term “upper depletion depth” (UDD) and defined it as the point at which there is a significant difference in removal of iron oxide paint below a certain depth on the IRIS tube; however, no numerical values were associated with this determination. This study reports a UDD where there is continuous removal of ≥ 60% below a reported depth, where ≤40% removal of iron oxide paint exists at some point above that depth. Conversely, if there is continuous removal of ≥ 60% above a reported depth to the ground surface, where ≤40% removal of iron oxide paint exists at some point below that depth, a perched depletion depth (PDD) was reported.

Category A represents a situation where a UDD is reported at a certain depth. Category B represents a condition where a PDD is reported at a certain depth. Category C represents a situation where the entire tube has >60% removal of iron oxide paint, so a UDD is reported at the ground surface (0 cm). Category D represents a condition where the percent removal of iron oxide paint fluctuates above and below 60% removal, but it never reaches below 40% removal, so no UDD or PDD can be reported. Category E represents a condition where both minimum requirements for UDD and PDD exist on the same IRIS tube, so both are reported at respective depths. Category F represents a condition where the percent removal of iron oxide paint is no more than 60%, so no UDD or PDD is reported.

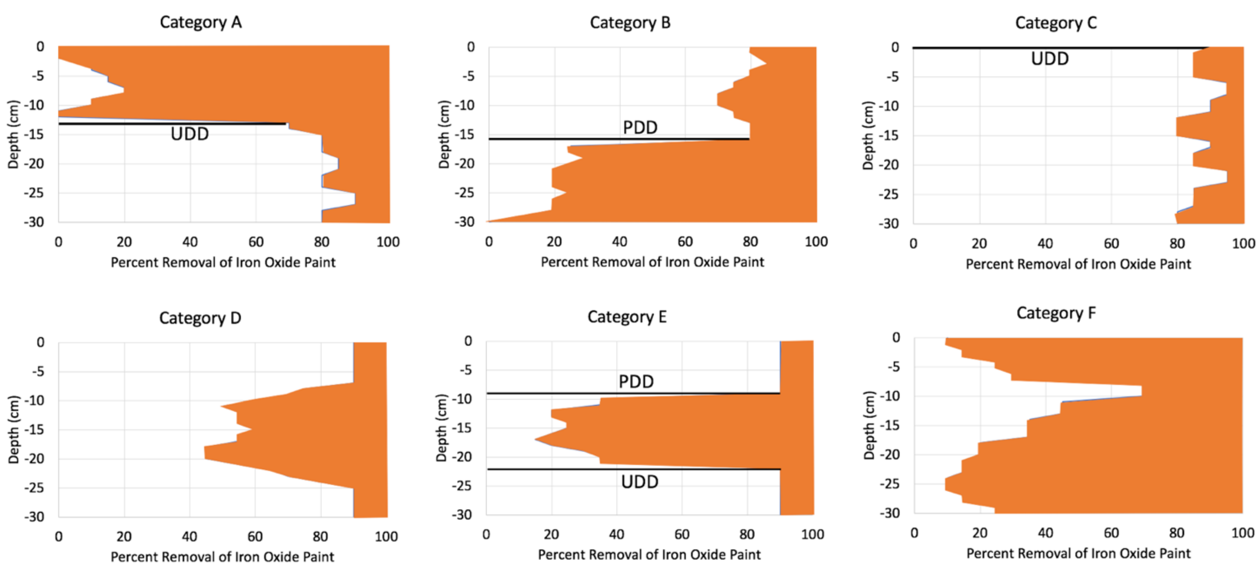

Figure 18. Removal categories observed on IRIS tubes.

Average water levels recorded during installation periods at each nest were plotted against the average upper depletion depths observed at respective nests during respective installations and are shown in Figure 19 and Figure 20.

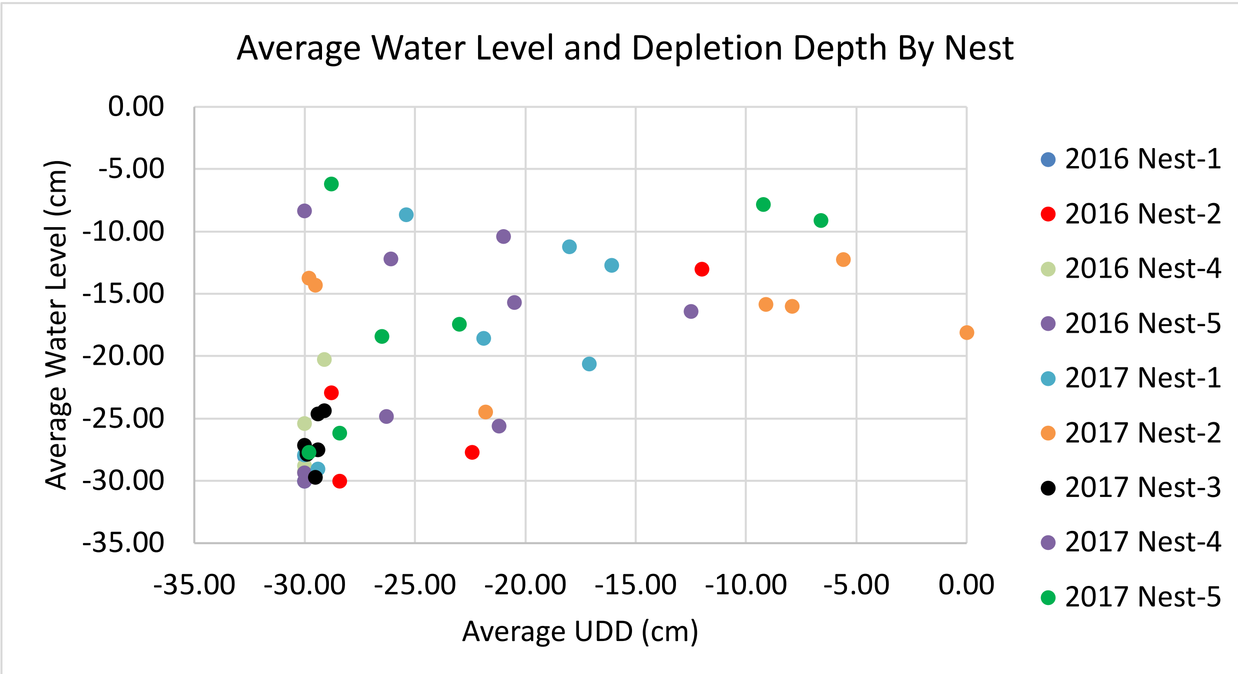

Figure 19. Average water level and upper depletion depth (UDD) by nest.

The points displayed in Figure 18 show a range of relationships observed at each nest. The outlier points grouped in the top left of the graph showing high average water levels associated with low average depletion depths were from installations early during the growing season. Points showing higher average upper depletion depths associated with lower average water levels were recorded during installations later in the growing season. These results could possibly be explained by the influence of temperature on microbial activity.

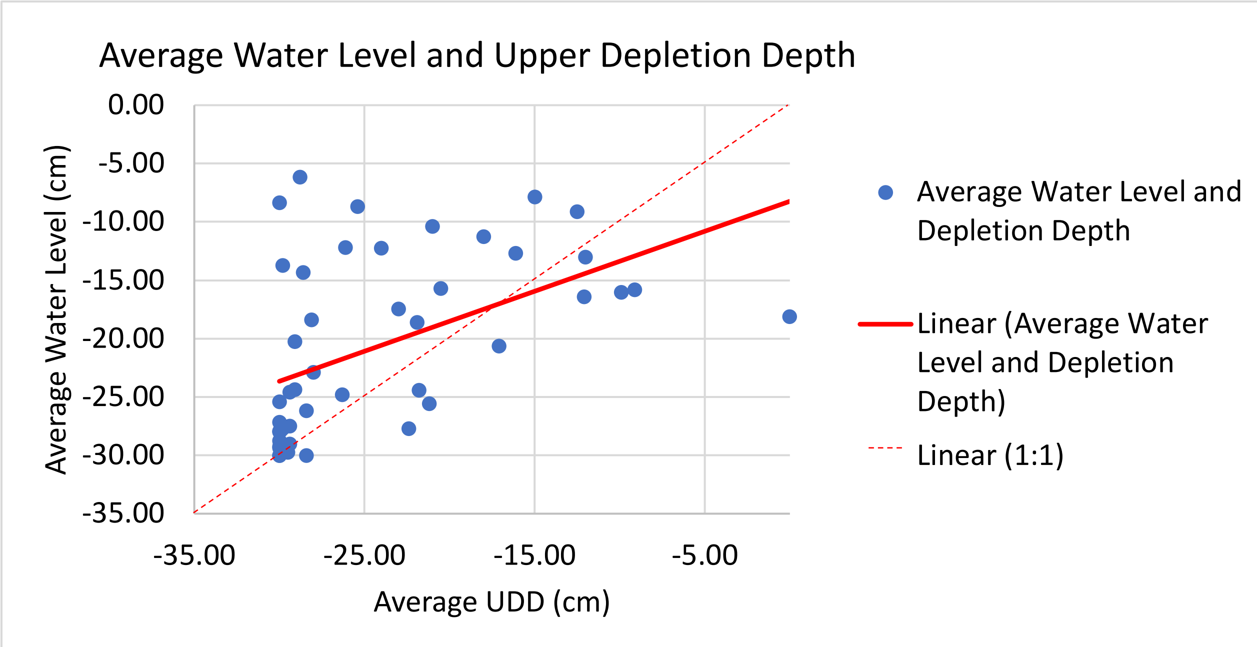

Figure 20. Average water level and upper depletion depths (UDD) recorded during installations.

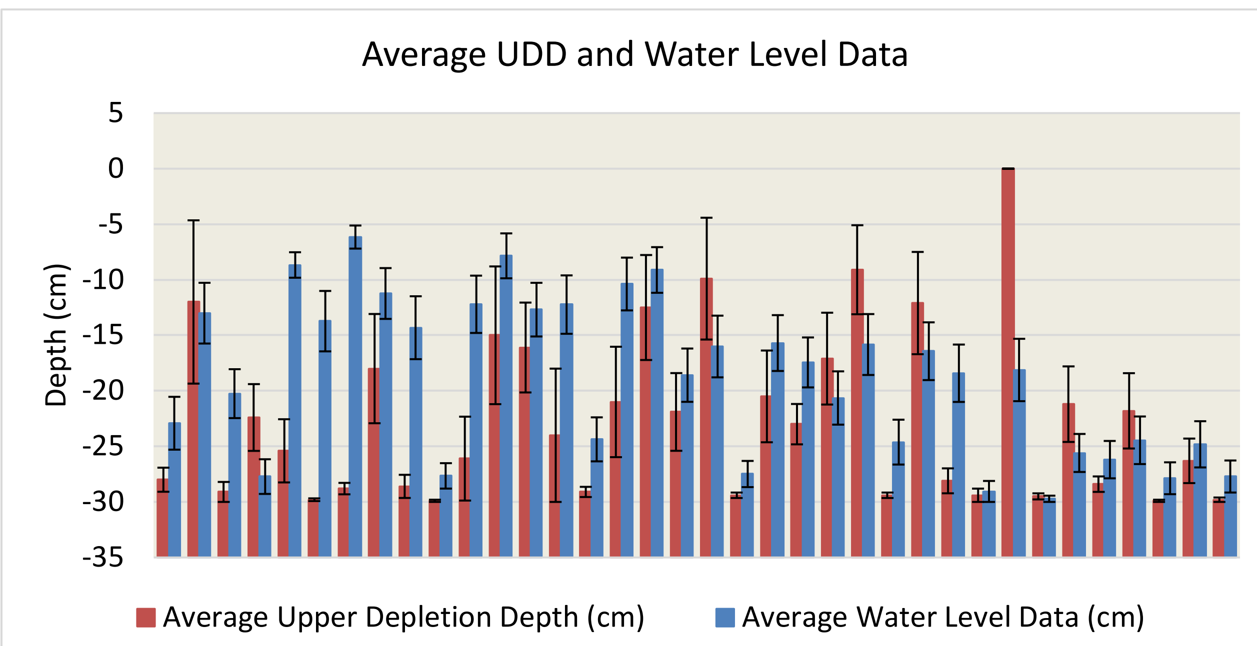

Figure 21. Average water level data compared to average upper depletion depth. Error bars indicate standard error for one standard deviation where n = 28 or 29, number of days during installation for water levels and n = 5, number of IRIS tubes per nest for Upper Depletion Depths.

As shown in Figure 20, there is a positive relationship between average water levels and average upper depletion depths. Figure 21 displays the same data as Figure 20, but also includes standard error bars for each data set. Some of the variability is likely due to the inconsistency of the hydrologic regimes, having a large presence of fluctuating water levels and perched water tables. It should also be noted that electric groundwater monitoring wells have potential to produce misleading results for water levels in the soil. For example, if a perched water table is present from 0-15 cm (0-6 inches), electric groundwater wells will produce a water level of 0 cm (0 inches), indicating that the entire soil profile is saturated when in reality it is not. Additionally, depletion depths are likely influenced by hydrologic conditions overlapping during installation periods. For example, if a nest area had been saturated to the surface for 5 days prior to an installation, the reduction process had already begun at a time frame outside the detection range of the IRIS tubes for that installation and may not be reflected appropriately in the results. However, results do indicate that the type of removal of iron oxide paint could reveal the type of hydrologic regime occurring in an area. Given the positive relationship of average upper depletion depths and average water levels, if an upper depletion depth is detected, it is likely that that area was saturated for an extended period of time, although the duration is unclear and appears to vary throughout the growing season. In areas where a spotty removal of iron oxide paint is observed, it is likely that that area experienced fluctuating water levels and intermittent periods of saturation that developed anaerobic pockets in the soil.

Figure 22 and Figure 23 below show the same comparisons for perched depletion depths. As noted by the many data points at the -30 cm (12 inch) average depletion depth, a PDD was a much less common occurrence among nest locations than UDD, but was distinct enough to acknowledge. However, as noted in Figure 23, a positive relationship does exist where a PDD is observed. One explanation for less observations could be the aeration of the zone of saturation in a perched water table from recent rainfall and near-surface gas exchanges in the soil. Another explanation is that a Category C condition exists where a UDD exists at the surface; therefore, a PDD is not detected.

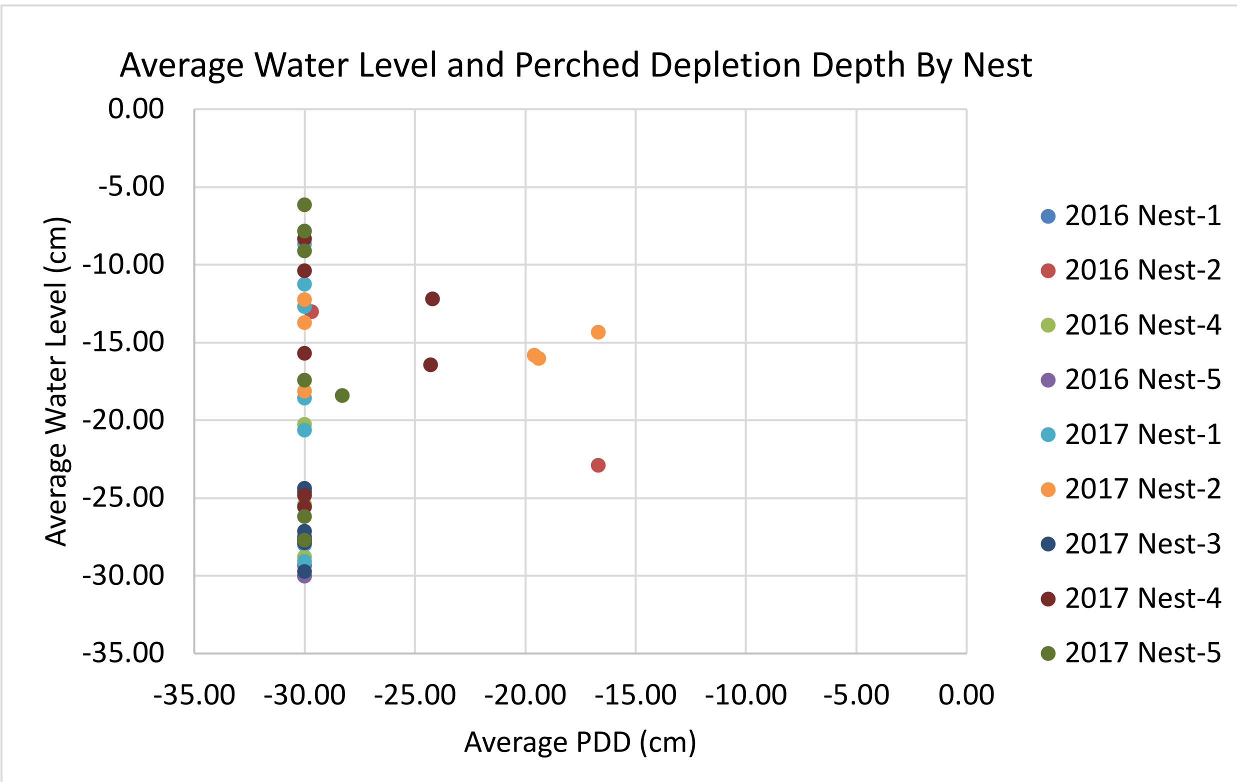

Figure 22. Average water level and perched depletion depth (PDD) by nest.

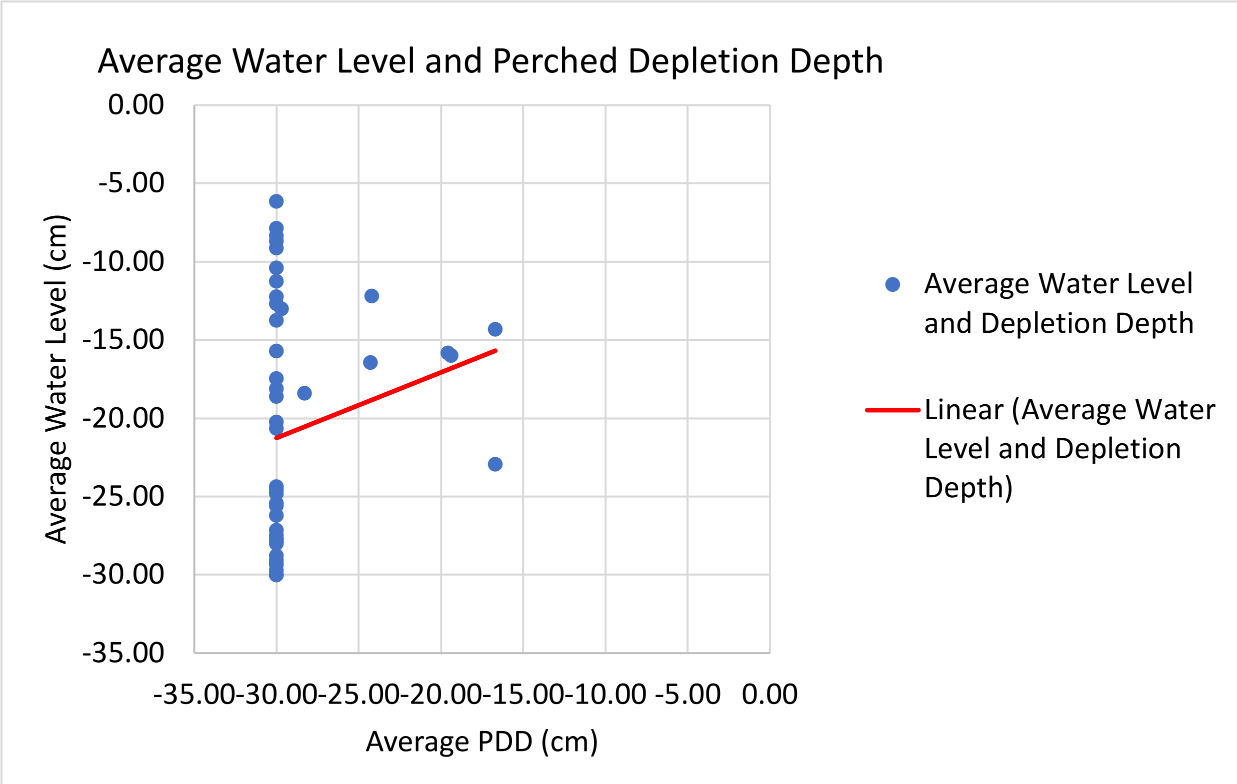

Figure 23. Average water level and perched depletion depths (PDD) recorded during installations.

5.5 Pros and Cons of Using IRIS Tubes to Assess Wetland Hydrology

When assessing wetland hydrology criteria for disturbed sites, which requires 14 or more consecutive days of saturation or inundation in the upper 30 cm (12 inches) of the soil profile, IRIS tube data appear to be variable. Figure 24 shows the comparison of wetland hydrology criteria with the 15 cm (6 inch) IRIS tube analysis requirements, which is the current method approved for use in the *Hydric Soil Technical Standard*.

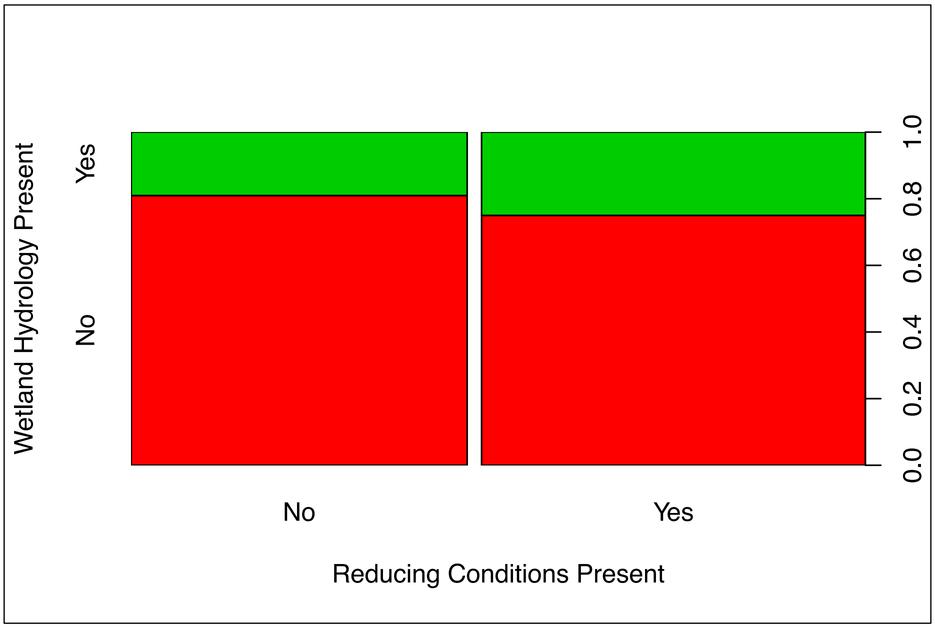

Figure 24. Comparison of wetland hydrology and IRIS tube data during respective installations.

Figure 24 shows the inconsistency of using IRIS tubes to determine wetland hydrology throughout the duration of the growing season. Similar to the influences of determining depletion depths, an iterative study of this nature overlaps hydrologic regimes with various installations, which effect the correlation of wetland hydrology to reducing soil conditions. Additionally, several factors have the potential to influence IRIS tube results outside the presence of soil saturation and groundwater levels. However, it should be noted that when used during the early part of the growing season, as recommended by the protocols, their reliability is higher, as shown in Table 11. Installation summary tables are located in Appendix F.

Table 11. Example of soil water and IRIS tube data collected at each nest.

	Parameter							Summary	
2017 Installation-2 (March 19 - April 15)	IRIS Tubes with >30% Removal	Consecutive Days of Saturation	Total Days of Saturation	Average Upper Depletion Depth (cm)	Upper Depletion Depth Standard Error	Average Water Level Data (cm)	Water Level Standard Error	Reducing Conditions Present	Wetland Hydrology Present
Nest-1	5	21	21	-18.00	4.92	-11.24	2.29	Yes	Yes
Nest-2	5	14	14	-28.60	1.04	-14.32	2.83	Yes	Yes
Nest-3	0	2	5	-29.90	0.10	-27.65	1.14	No	No
Nest-4	2	19	19	-26.10	3.78	-12.21	2.58	No	Yes
Nest-5	5	26	26	-15	6.20	-7.85	2.02	Yes	Yes

The effect of installation time, nest, and consecutive or total time of saturation on reducing conditions present (according to the *Hydric Soil Technical Standard*) was evaluated with an ANCOVA and binary response variables, as well as binomial errors. The continuous variable was consecutive days of saturation or total days of saturation. The categorical variables were installation and nest. Nest was found to be non-significant and were removed from the model. Once the levels of categorial variables for installation periods which were found to be not different were collapsed into one group, the consecutive and total time of saturation were predicted for a likelihood of $p=0.95$, and $p=0.99$ for each group, respectively, and are listed in Table 12. No prediction was possible for 2016, as there were only 5 complete data sets due to monitoring well malfunctions.

Table 12. Results of predictive model for total days of saturation and consecutive days of saturation required to produce reducing conditions.

Total Days of Saturation			Consecutive Days of Saturation		
Groups	t95	t99	Groups	t95	t99
Installation-1 (February 19 – March 19)	NA	NA	Installation-1 (February 19 – March 19)	NA	NA
Installation-2&3 (March 19 – May 13)	19.7	21.8	Installation-2 (March 19 – April 15)	20.2	22.3
Iinstallation-4&5 (May 13 – July 9)	13.2	15.3	Installation-3 (April 15 – May 13)	11.6	13.7
Installation-6&7 (July 9 – September 2)	8.2	10.3	Installation-4,5,6&7 (May 13 – September 2)	6.8	9

According to the predictive model results listed in Table 12, it takes 20.2 (approximately 20) consecutive days of saturation during Installation 2 to have a 95% chance of reducing conditions according to the IRIS tube protocol as listed in the *Hydric Soil Technical Standard*, but only 6.8 (approximately 7) consecutive days of saturation during Installations 4-7. These results indicate that IRIS tubes could be used to detect the presence of wetland hydrology for disturbed sites (≥14 consecutive days of saturation in the upper 30 cm of the soil profile) during certain times of the year. For example, while one can assume more than 14 consecutive days of saturation are present if installed during Installation 2 (March 19 – April 15), one can only assume 6.8 (approximately 7) consecutive days of saturation during Installations 4-7 (May 13 – September 2). Figure 27 shows the predictive model for consecutive days of saturation and Figure 28 shows the predictive model for total days of saturation.

Figure 25 and Figure 26 show the average atmospheric temperatures and respective standard errors recorded during installation periods by nearby weather stations. Both Figure 25 and Figure 26 show an overall increase in atmospheric temperature as the growing season progresses, with temperatures reaching a peak during the installations within July and August, and begin to decrease during the last installations near the end of the growing season (late August – September).

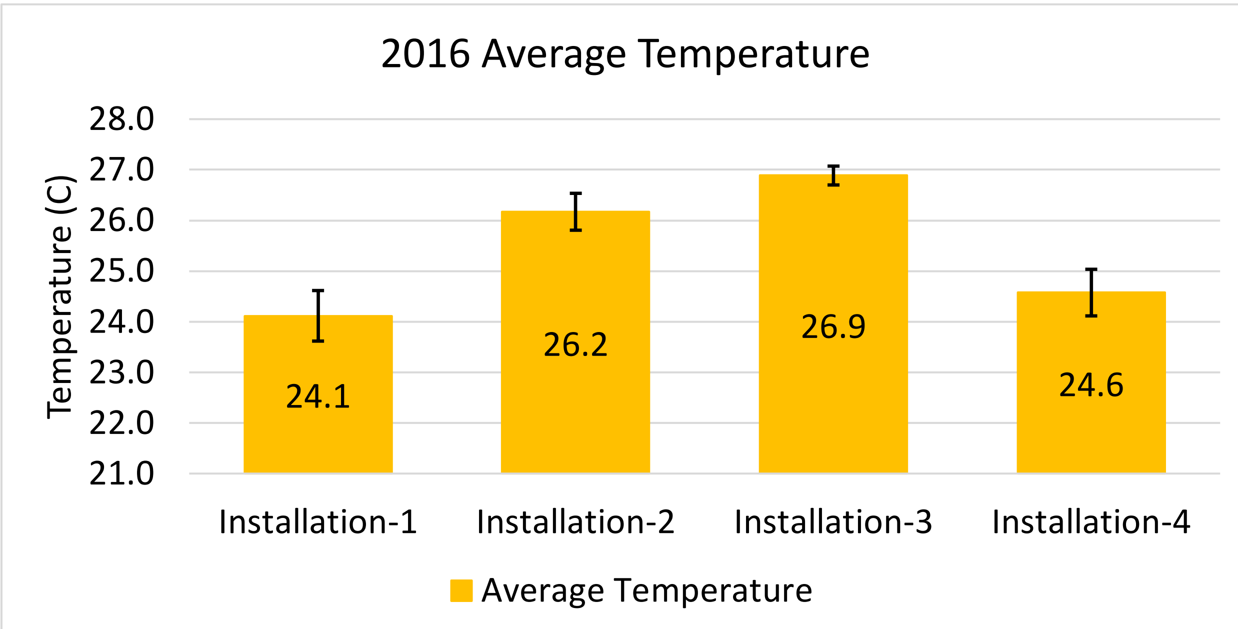

Figure 25. Average atmospheric temperature recorded during installation periods. Error bars indicate standard error for one standard deviation where n = 28 or 29, number of days during installation.

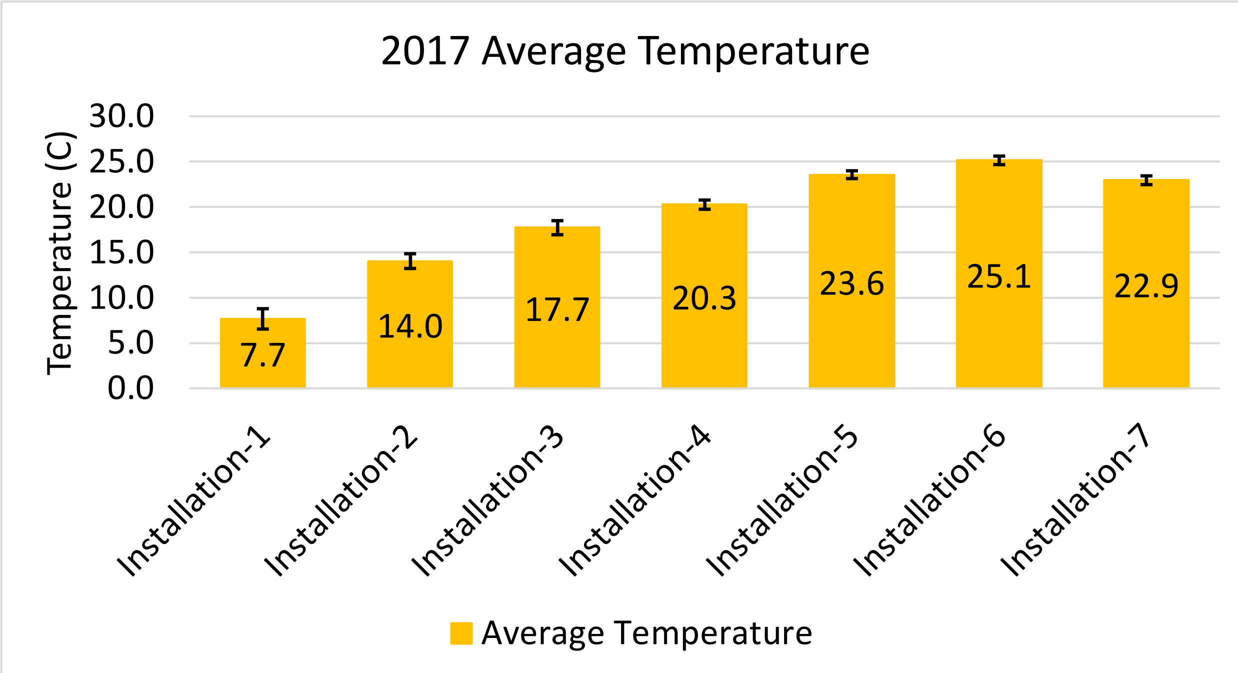

Figure 26. Average atmospheric temperature recorded during installation periods. Error bars indicate standard error for one standard deviation where n = 28 or 29, number of days during installation.

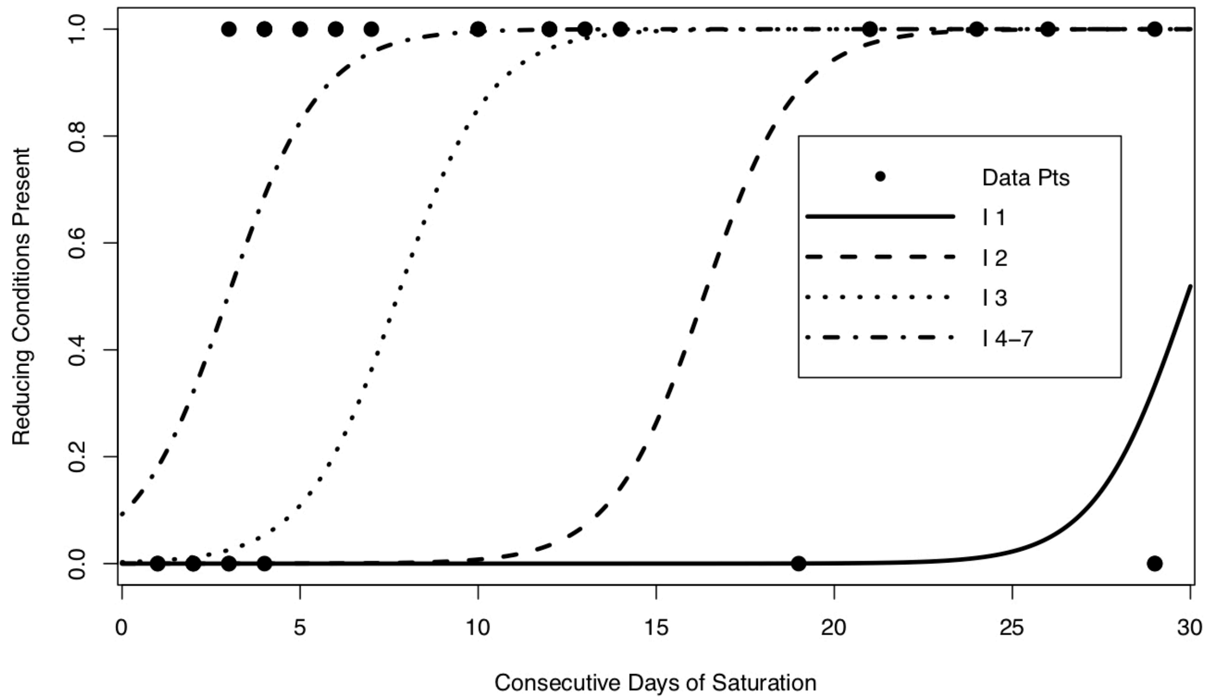

Figure 27. Comparison of reducing conditions detected by IRIS tubes to consecutive days of saturation detected by monitoring wells.

Figure 27 supports the concept that the duration of saturation required for reducing conditions to be present decreases as the growing season progresses. One possible explanation for this is that microbial communities are more active at higher temperatures, which hasten the reduction process. Another possible explanation is that microbial community populations increase throughout the growing season, which can also increase the rate of the reduction process. Lastly, another possible explanation is that organic carbon becomes more available as the growing season progresses.

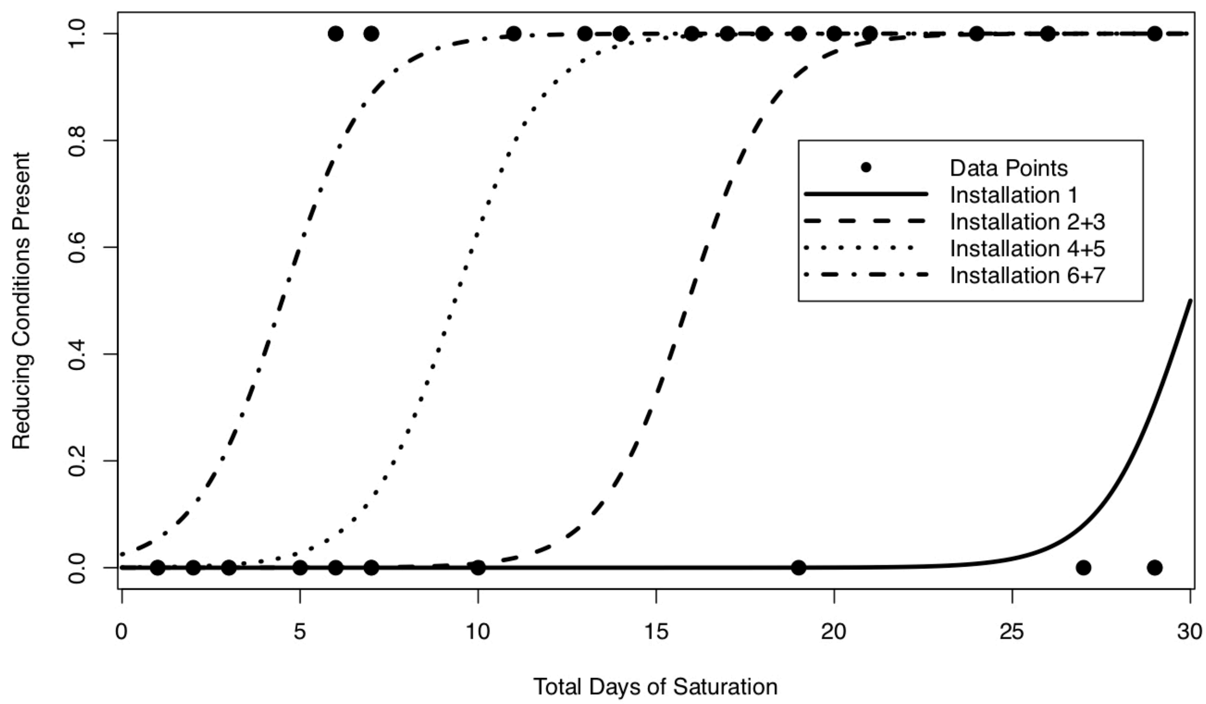

Figure 28. Comparison of reducing conditions detected by IRIS tubes to total days of saturation detected by monitoring wells.

When comparing Figure 27 and Figure 28, the results are very similar, as the days of saturation required for reducing conditions to be present decrease as the growing season progresses. Given the results of Figure 27 and Figure 28, a hypothesis is drawn that a relationship exists between temperature and days of saturation that result in a rate of reduction, and that a higher rate of reduction is associated with higher temperatures and less days of saturation, and a lower rate of reduction is associated with more days of saturation and lower temperatures.

6. Conclusions

While IRIS tubes are a great tool for detecting reducing and anaerobic soil conditions, they appear to be variable in assessing wetland hydrology criteria for disturbed sites throughout the duration of the growing season; however, results have a better correlation when used during the time of the growing season as recommended by respective protocols. Additionally, the results of this study draw a hypothesis that a relationship exists between temperature and days of saturation that result in a rate of reduction, and that a higher rate of reduction is associated with higher temperatures and less days of saturation, and a lower rate of reduction is associated with more days of saturation and lower temperatures. If attempting to use IRIS tubes to detect wetland hydrology, it may be imperative that they are only used at certain times of the year to achieve accurate results.

The nature of IRIS tube usage is very similar to that of a,a' dipyridyl dye. The $\geq$60% removal of iron oxide paint to determine depletion depths was established in an effort to remain consistent with the *Hydric Soil Technical Standard* requirements for a,a' dipyridyl dye, which is also accepted as a primary indicator of wetland hydrology. Given the fact that many of the same influencing factors affect the results of IRIS tubes as a,a' dipyridyl dye, the results of this study could indicate that a positive reaction to a,a' dipyridyl dye may not require saturated soil conditions for 14 or more consecutive days, although reactions to a,a' dipyridyl dye were not monitored as part of this study.

While the results of this study do not conclusively determine that IRIS tubes can be used to accurately determine the presence of wetland hydrology for disturbed sites, it does conclude that a positive relationship exists between soil water levels and removal of iron oxide paint from IRIS tubes, and that the type of iron oxide paint removal is related to the type of hydrologic regime. As such, IRIS tubes detect saturated conditions sufficient for iron reduction, and should be considered as providing supplemental or secondary wetland hydrology data, particularly for disturbed or mitigation sites that may not meet the 14 consecutive days of saturation criteria but support hydrophytic vegetation and contain hydric soils.

7. Future Research

The reduction of iron occurs in soils that have been saturated long enough to become anaerobic and chemically reduced (U.S. Army Corps of Engineers, *ERDC/EL TR-12-9, 2009*). IRIS tubes detect saturated conditions sufficient for iron reduction; therefore, an attempt should be made to establish a protocol for using IRIS tubes as wetland hydrology indicators. Particularly, efforts should be made in a less extreme environment than the constructed wetlands in this study, although a developed protocol should remain applicable to all wetlands, whether natural or constructed. Research in known reference wetlands that have been stable for many years may produce more reliable data than what was gathered in this study. Alternatively, further research could be performed in a lab setting to control variables and influencing factors such as hydrologic regime, organic carbon content, and temperature. Consideration should be given to using the more recently developed oxide-coated plastic films, as they are a more sustainable and green technology in comparison with traditional IRIS tubes (Rabenhorst, 2018). The use of manganese-coated IRIS tubes could also be simultaneously evaluated and compared with iron-coated IRIS tubes, although a protocol for assessing manganese-coated IRIS technology has not been established to date. Under all future research options, all potential influencing factors should be monitored, and other approved methods such as a,a’ dipyridyl dye and redox potential should be assessed for comparison.

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APPENDIX A

WETLAND DETERMINATION DATA FORMS

WETLAND DETERMINATION DATA FORM – Eastern Mountains and Piedmont Region

Project/Site: Thesis Research City/County: ______ Sampling Date: 05-28-2016

Applicant/Owner: ______ State: TN Sampling Point: Plot-1

Investigator(s): C. Liggett Section, Township, Range: ______

Landform (hillslope, terrace, etc.): Depression Local relief (concave, convex, none): Concave Slope (%): <2%

Subregion (LRR or MLRA): LRR N Lat: ______ Long: ______ Datum: ______

Soil Map Unit Name: Lindell Silt Loam NWI classification: ______

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

Are Vegetation ___, Soil ___, or Hydrology ___ significantly disturbed? Are "Normal Circumstances" present? Yes X No ___

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

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

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

Remarks:

HYDROLOGY

Wetland Hydrology Indicators:

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

- ☐ Surface Water (A1)
- ☐ High Water Table (A2)
- ☐ Saturation (A3)
- ☐ Water Marks (B1)
- ☐ Sediment Deposits (B2)
- ☐ Drift Deposits (B3)
- ☑ Algal Mat or Crust (B4)
- ☐ Iron Deposits (B5)
- ☐ Inundation Visible on Aerial Imagery (B7)
- ☑ Water-Stained Leaves (B9)
- ☐ Aquatic Fauna (B13)
- ☐ True Aquatic Plants (B14)
- ☐ Hydrogen Sulfide Odor (C1)
- ☐ Oxidized Rhizospheres on Living Roots (C3)
- ☐ Presence of Reduced Iron (C4)
- ☐ Recent Iron Reduction in Tilled Soils (C6)
- ☐ Thin Muck Surface (C7)
- ☐ Other (Explain in Remarks)

Secondary Indicators (minimum of two required)

- ☐ Surface Soil Cracks (B6)
- ☐ Sparsely Vegetated Concave Surface (B8)
- ☐ Drainage Patterns (B10)
- ☐ Moss Trim Lines (B16)
- ☐ Dry-Season Water Table (C2)
- ☐ Crayfish Burrows (C8)
- ☐ Saturation Visible on Aerial Imagery (C9)
- ☐ Stunted or Stressed Plants (D1)
- ☐ Geomorphic Position (D2)
- ☐ Shallow Aquitard (D3)
- ☐ Microtopographic Relief (D4)
- ☑ FAC-Neutral Test (D5)

Field Observations:

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

Wetland Hydrology Present? **Yes** X **No** ___

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

Remarks:

VEGETATION (Five Strata) – Use scientific names of plants.

Sampling Point: Plot-1

Tree Stratum (Plot size: ______)	Absolute % Cover	Dominant Species?	Indicator Status
1. Salix nigra	10	Yes	OBL
2.			
3.			
4.			
5.			
6.			
	5 = Total Cover		
50% of total cover: 5	20% of total cover: 2		

Sapling Stratum (Plot size: ______)	Absolute % Cover	Dominant Species?	Indicator Status
1. Cercis canadensis	5	Yes	FACU
2. Fraxinus pennsylvanica	5	Yes	FAC
3.			
4.			
5.			
6.			
	10 = Total Cover		
50% of total cover: 5	20% of total cover: 2		

Shrub Stratum (Plot size: ______)	Absolute % Cover	Dominant Species?	Indicator Status
1.			
2.			
3.			
4.			
5.			
6.			
	____ = Total Cover		
50% of total cover: ____	20% of total cover: ____		

Herb Stratum (Plot size: ______)	Absolute % Cover	Dominant Species?	Indicator Status
1. Lespedeza angustifolia	20	Yes	FAC
2. Scirpus cyperinus	15	Yes	FACW
3. Carex frankii	15	Yes	OBL
4. Carex vulpinoidea	10	No	OBL
5. Bidens aristosa	10	No	FACW
6. Polygonum hydropiperoides	10	No	OBL
7. Juncus tenuis	10	No	FAC
8. Ranunculus acris	5	No	FAC
9. Ptilimnium costatum	5	No	FACW
10.			
11.			
	100 = Total Cover		
50% of total cover: 50	20% of total cover: 20		

Woody Vine Stratum (Plot size: ______)	Absolute % Cover	Dominant Species?	Indicator Status
1.			
2.			
3.			
4.			
5.			
	____ = Total Cover		
50% of total cover: ____	20% of total cover: ____		

Dominance Test worksheet:

Number of Dominant Species That Are OBL, FACW, or FAC: 5 (A)

Total Number of Dominant Species Across All Strata: 6 (B)

Percent of Dominant Species That Are OBL, FACW, or FAC: 83% (A/B)

Prevalence Index worksheet:

Total % Cover of:		Multiply by:	
OBL species	45	x 1 =	45
FACW species	30	x 2 =	60
FAC species	40	x 3 =	120
FACU species	5	x 4 =	20
UPL species	0	x 5 =	0
Column Totals:	120 (A)		240 (B)

Prevalence Index = B/A = 2.04

Hydrophytic Vegetation Indicators:

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

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

Definitions of Five Vegetation Strata:

Tree – Woody plants, excluding woody vines, approximately 20 ft (6 m) or more in height and 3 in. (7.6 cm) or larger in diameter at breast height (DBH).

Sapling – Woody plants, excluding woody vines, approximately 20 ft (6 m) or more in height and less than 3 in. (7.6 cm) DBH.

Shrub – Woody plants, excluding woody vines, approximately 3 to 20 ft (1 to 6 m) in height.

Herb – All herbaceous (non-woody) plants, including herbaceous vines, regardless of size, and woody plants, except woody vines, less than approximately 3 ft (1 m) in height.

Woody vine – All woody vines, regardless of height.

Hydrophytic Vegetation Present? **Yes** X **No** ____

Remarks: (Include photo numbers here or on a separate sheet.)

SOIL

Sampling Point: Plot-1

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

Depth (inches)	Matrix Color (moist)	Matrix %	Redox Features Color (moist)	Redox %	Type[1]	Loc[2]	Texture	Remarks
0-12"	10YR 3/2	95%	7.5YR 5/8	5%	C	M	Silt loam	

[1]Type: C=Concentration, D=Depletion, RM=Reduced Matrix, MS=Masked Sand Grains. [2]Location: PL=Pore Lining, M=Matrix.

Hydric Soil Indicators:

- ___ Histosol (A1)
- ___ Histic Epipedon (A2)
- ___ Black Histic (A3)
- ___ Hydrogen Sulfide (A4)
- ___ Stratified Layers (A5)
- ___ 2 cm Muck (A10) **(LRR N)**
- ___ Depleted Below Dark Surface (A11)
- ___ Thick Dark Surface (A12)
- ___ Sandy Mucky Mineral (S1) **(LRR N, MLRA 147, 148)**
- ___ Sandy Gleyed Matrix (S4)
- ___ Sandy Redox (S5)
- ___ Stripped Matrix (S6)
- ___ Dark Surface (S7)
- ___ Polyvalue Below Surface (S8) **(MLRA 147, 148)**
- ___ Thin Dark Surface (S9) **(MLRA 147, 148)**
- ___ Loamy Gleyed Matrix (F2)
- ___ Depleted Matrix (F3)
- ✓ Redox Dark Surface (F6)
- ___ Depleted Dark Surface (F7)
- ___ Redox Depressions (F8)
- ___ Iron-Manganese Masses (F12) **(LRR N, MLRA 136)**
- ___ Umbric Surface (F13) **(MLRA 136, 122)**
- ___ Piedmont Floodplain Soils (F19) **(MLRA 148)**
- ___ Red Parent Material (F21) **(MLRA 127, 147)**

Indicators for Problematic Hydric Soils[3]:

- ___ 2 cm Muck (A10) **(MLRA 147)**
- ___ Coast Prairie Redox (A16) **(MLRA 147, 148)**
- ___ Piedmont Floodplain Soils (F19) **(MLRA 136, 147)**
- ___ Very Shallow Dark Surface (TF12)
- ___ Other (Explain in Remarks)

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

Restrictive Layer (if observed):

Type: ______________

Depth (inches): ______________

Hydric Soil Present? Yes X **No** ______

Remarks:

WETLAND DETERMINATION DATA FORM – Eastern Mountains and Piedmont Region

Project/Site: Thesis Research City/County: ______ Sampling Date: 05-28-2016

Applicant/Owner: ______ State: TN Sampling Point: Plot-2

Investigator(s): C. Liggett Section, Township, Range: ______

Landform (hillslope, terrace, etc.): Depression Local relief (concave, convex, none): Concave Slope (%): <2%

Subregion (LRR or MLRA): LRR N Lat: ______ Long: ______ Datum: ______

Soil Map Unit Name: Lindell Silt Loam NWI classification: ______

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

Are Vegetation ___, Soil ___, or Hydrology ___ significantly disturbed? Are "Normal Circumstances" present? Yes X No ___

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

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

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

Remarks:

HYDROLOGY

Wetland Hydrology Indicators:

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

- ☐ Surface Water (A1)
- ☐ High Water Table (A2)
- ☐ Saturation (A3)
- ☐ Water Marks (B1)
- ☐ Sediment Deposits (B2)
- ☐ Drift Deposits (B3)
- ☐ Algal Mat or Crust (B4)
- ☐ Iron Deposits (B5)
- ☐ Inundation Visible on Aerial Imagery (B7)
- ☐ Water-Stained Leaves (B9)
- ☐ Aquatic Fauna (B13)
- ☐ True Aquatic Plants (B14)
- ☐ Hydrogen Sulfide Odor (C1)
- ☐ Oxidized Rhizospheres on Living Roots (C3)
- ☐ Presence of Reduced Iron (C4)
- ☐ Recent Iron Reduction in Tilled Soils (C6)
- ☐ Thin Muck Surface (C7)
- ☐ Other (Explain in Remarks)

Secondary Indicators (minimum of two required)

- ☐ Surface Soil Cracks (B6)
- ☐ Sparsely Vegetated Concave Surface (B8)
- ☐ Drainage Patterns (B10)
- ☐ Moss Trim Lines (B16)
- ☐ Dry-Season Water Table (C2)
- ☐ Crayfish Burrows (C8)
- ☐ Saturation Visible on Aerial Imagery (C9)
- ☐ Stunted or Stressed Plants (D1)
- ☑ Geomorphic Position (D2)
- ☑ Shallow Aquitard (D3)
- ☐ Microtopographic Relief (D4)
- ☑ FAC-Neutral Test (D5)

Field Observations:

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

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

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

Wetland Hydrology Present? Yes x **No** ___

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

Remarks:

VEGETATION (Five Strata) – Use scientific names of plants.

Sampling Point: Plot-2

Tree Stratum (Plot size:)	Absolute % Cover	Dominant Species?	Indicator Status
1.			
2.			
3.			
4.			
5.			
6.			
	= Total Cover		
50% of total cover:		20% of total cover:	

Sapling Stratum (Plot size:)	Absolute % Cover	Dominant Species?	Indicator Status
1.			
2.			
3.			
4.			
5.			
6.			
	= Total Cover		
50% of total cover:		20% of total cover:	

Shrub Stratum (Plot size:)	Absolute % Cover	Dominant Species?	Indicator Status
1.			
2.			
3.			
4.			
5.			
6.			
	= Total Cover		
50% of total cover:		20% of total cover:	

Herb Stratum (Plot size:)	Absolute % Cover	Dominant Species?	Indicator Status
1. Lespedeza angustifolia	50	Yes	FAC
2. Eupatorium album	30	Yes	NI
3. Echinochloa crus-galis	15	No	FAC
4. Ptilimnium costatum	5	No	FACW
5.			
6.			
7.			
8.			
9.			
10.			
11.			
	95 = Total Cover		
50% of total cover: 48		20% of total cover: 19	

Woody Vine Stratum (Plot size:)	Absolute % Cover	Dominant Species?	Indicator Status
1.			
2.			
3.			
4.			
5.			
	= Total Cover		
50% of total cover:		20% of total cover:	

Dominance Test worksheet:

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

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

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

Prevalence Index worksheet:

Total % Cover of:		Multiply by:
OBL species		x 1 =
FACW species	5	x 2 = 10
FAC species	65	x 3 = 195
FACU species		x 4 =
UPL species		x 5 =
Column Totals:	70 (A)	205 (B)

Prevalence Index = B/A = 2.93

Hydrophytic Vegetation Indicators:

1 - Rapid Test for Hydrophytic Vegetation

☐ 2 - Dominance Test is >50%

☑ 3 - Prevalence Index is ≤3.0[1]

___ 4 - Morphological Adaptations[1] (Provide supporting data in Remarks or on a separate sheet)

___ Problematic Hydrophytic Vegetation[1] (Explain)

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

Definitions of Five Vegetation Strata:

Tree – Woody plants, excluding woody vines, approximately 20 ft (6 m) or more in height and 3 in. (7.6 cm) or larger in diameter at breast height (DBH).

Sapling – Woody plants, excluding woody vines, approximately 20 ft (6 m) or more in height and less than 3 in. (7.6 cm) DBH.

Shrub – Woody plants, excluding woody vines, approximately 3 to 20 ft (1 to 6 m) in height.

Herb – All herbaceous (non-woody) plants, including herbaceous vines, regardless of size, and woody plants, except woody vines, less than approximately 3 ft (1 m) in height.

Woody vine – All woody vines, regardless of height.

Hydrophytic Vegetation Present? **Yes** X **No** ___

Remarks: (Include photo numbers here or on a separate sheet.)

SOIL Sampling Point: Plot-2

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

Depth	Matrix		Redox Features					
(inches)	Color (moist)	%	Color (moist)	%	Type[1]	Loc[2]	Texture	Remarks
0-10"	10YR 3/2	95%	7.5YR 5/8	5%	C	M	Silt loam	

[1]Type: C=Concentration, D=Depletion, RM=Reduced Matrix, MS=Masked Sand Grains. [2]Location: PL=Pore Lining, M=Matrix.

Hydric Soil Indicators:

- ___ Histosol (A1)
- ___ Histic Epipedon (A2)
- ___ Black Histic (A3)
- ___ Hydrogen Sulfide (A4)
- ___ Stratified Layers (A5)
- ___ 2 cm Muck (A10) **(LRR N)**
- ___ Depleted Below Dark Surface (A11)
- ___ Thick Dark Surface (A12)
- ___ Sandy Mucky Mineral (S1) **(LRR N, MLRA 147, 148)**
- ___ Sandy Gleyed Matrix (S4)
- ___ Sandy Redox (S5)
- ___ Stripped Matrix (S6)
- ___ Dark Surface (S7)
- ___ Polyvalue Below Surface (S8) **(MLRA 147, 148)**
- ___ Thin Dark Surface (S9) **(MLRA 147, 148)**
- ___ Loamy Gleyed Matrix (F2)
- ___ Depleted Matrix (F3)
- ✓ Redox Dark Surface (F6)
- ___ Depleted Dark Surface (F7)
- ___ Redox Depressions (F8)
- ___ Iron-Manganese Masses (F12) **(LRR N, MLRA 136)**
- ___ Umbric Surface (F13) **(MLRA 136, 122)**
- ___ Piedmont Floodplain Soils (F19) **(MLRA 148)**
- ___ Red Parent Material (F21) **(MLRA 127, 147)**

Indicators for Problematic Hydric Soils[3]:

- ___ 2 cm Muck (A10) **(MLRA 147)**
- ___ Coast Prairie Redox (A16) **(MLRA 147, 148)**
- ___ Piedmont Floodplain Soils (F19) **(MLRA 136, 147)**
- ___ Very Shallow Dark Surface (TF12)
- ___ Other (Explain in Remarks)

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

Restrictive Layer (if observed):

Type: ______

Depth (inches): ______

Hydric Soil Present? **Yes** X **No** ______

Remarks:

WETLAND DETERMINATION DATA FORM – Eastern Mountains and Piedmont Region

Project/Site: Thesis Research City/County: ______ Sampling Date: 05-28-2016

Applicant/Owner: ______ State: TN Sampling Point: Plot-3

Investigator(s): C. Liggett Section, Township, Range: ______

Landform (hillslope, terrace, etc.): Depression Local relief (concave, convex, none): Concave Slope (%): <2%

Subregion (LRR or MLRA): LRR N Lat: ______ Long: ______ Datum: ______

Soil Map Unit Name: Lindell Silt Loam NWI classification: ______

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

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

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

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

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

Remarks:

HYDROLOGY

Wetland Hydrology Indicators:

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

- [ ] Surface Water (A1)
- [ ] High Water Table (A2)
- [ ] Saturation (A3)
- [ ] Water Marks (B1)
- [ ] Sediment Deposits (B2)
- [ ] Drift Deposits (B3)
- [ ] Algal Mat or Crust (B4)
- [ ] Iron Deposits (B5)
- [ ] Inundation Visible on Aerial Imagery (B7)
- [ ] Water-Stained Leaves (B9)
- [ ] Aquatic Fauna (B13)
- [ ] True Aquatic Plants (B14)
- [ ] Hydrogen Sulfide Odor (C1)
- [x] Oxidized Rhizospheres on Living Roots (C3)
- [ ] Presence of Reduced Iron (C4)
- [ ] Recent Iron Reduction in Tilled Soils (C6)
- [ ] Thin Muck Surface (C7)
- [ ] Other (Explain in Remarks)

Secondary Indicators (minimum of two required)

- [ ] Surface Soil Cracks (B6)
- [ ] Sparsely Vegetated Concave Surface (B8)
- [ ] Drainage Patterns (B10)
- [ ] Moss Trim Lines (B16)
- [ ] Dry-Season Water Table (C2)
- [ ] Crayfish Burrows (C8)
- [ ] Saturation Visible on Aerial Imagery (C9)
- [ ] Stunted or Stressed Plants (D1)
- [ ] Geomorphic Position (D2)
- [ ] Shallow Aquitard (D3)
- [ ] Microtopographic Relief (D4)
- [ ] FAC-Neutral Test (D5)

Field Observations:

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

Water Table Present? Yes ______ No X Depth (inches): ______

Saturation Present? (includes capillary fringe) Yes ______ No X Depth (inches): ______

Wetland Hydrology Present? Yes X **No** ______

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

Remarks:

VEGETATION (Five Strata) – Use scientific names of plants.

Sampling Point: Plot-3

Tree Stratum (Plot size: ______)	Absolute % Cover	Dominant Species?	Indicator Status
1.			
2.			
3.			
4.			
5.			
6.			
	= Total Cover		
50% of total cover: ______	20% of total cover: ______		

Sapling Stratum (Plot size: ______)			
1.			
2.			
3.			
4.			
5.			
6.			
	= Total Cover		
50% of total cover: ______	20% of total cover: ______		

Shrub Stratum (Plot size: ______)			
1.			
2.			
3.			
4.			
5.			
6.			
	= Total Cover		
50% of total cover: ______	20% of total cover: ______		

Herb Stratum (Plot size: ______)			
1. Lespedeza angustifolia	55	Yes	FAC
2. Eupatorium album	15	No	NI
3. Juncus tenuis	10	No	FAC
4. Carex frankii	5	No	OBL
5. Dichanthelium clandestinum	5	No	FAC
6. Solidago canadensis	5	No	FACU
7.			
8.			
9.			
10.			
11.			
	95 = Total Cover		
50% of total cover: 48	20% of total cover: 19		

Woody Vine Stratum (Plot size: ______)			
1.			
2.			
3.			
4.			
5.			
	= Total Cover		
50% of total cover: ______	20% of total cover: ______		

Dominance Test worksheet:

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

Total Number of Dominant Species Across All Strata: 1 (B)

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

Prevalence Index worksheet:

Total % Cover of:		Multiply by:
OBL species	5	x 1 = 5
FACW species	0	x 2 = 0
FAC species	10	x 3 = 210
FACU species	5	x 4 = 20
UPL species	0	x 5 = 0
Column Totals:	80 (A)	235 (B)

Prevalence Index = B/A = 2.93

Hydrophytic Vegetation Indicators:

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

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

Definitions of Five Vegetation Strata:

Tree – Woody plants, excluding woody vines, approximately 20 ft (6 m) or more in height and 3 in. (7.6 cm) or larger in diameter at breast height (DBH).

Sapling – Woody plants, excluding woody vines, approximately 20 ft (6 m) or more in height and less than 3 in. (7.6 cm) DBH.

Shrub – Woody plants, excluding woody vines, approximately 3 to 20 ft (1 to 6 m) in height.

Herb – All herbaceous (non-woody) plants, including herbaceous vines, regardless of size, and woody plants, except woody vines, less than approximately 3 ft (1 m) in height.

Woody vine – All woody vines, regardless of height.

Hydrophytic Vegetation Present? **Yes** X **No** ______

Remarks: (Include photo numbers here or on a separate sheet.)

SOIL

Sampling Point: Plot-3

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

Depth (inches)	Matrix Color (moist)	Matrix %	Redox Features Color (moist)	Redox %	Type[1]	Loc[2]	Texture	Remarks
0-10"	10YR 3/2	95%	7.5YR 5/8	5%	C	PL/M	Silt loam	

[1]Type: C=Concentration, D=Depletion, RM=Reduced Matrix, MS=Masked Sand Grains. [2]Location: PL=Pore Lining, M=Matrix.

Hydric Soil Indicators:

- ___ Histosol (A1)
- ___ Histic Epipedon (A2)
- ___ Black Histic (A3)
- ___ Hydrogen Sulfide (A4)
- ___ Stratified Layers (A5)
- ___ 2 cm Muck (A10) **(LRR N)**
- ___ Depleted Below Dark Surface (A11)
- ___ Thick Dark Surface (A12)
- ___ Sandy Mucky Mineral (S1) **(LRR N, MLRA 147, 148)**
- ___ Sandy Gleyed Matrix (S4)
- ___ Sandy Redox (S5)
- ___ Stripped Matrix (S6)
- ___ Dark Surface (S7)
- ___ Polyvalue Below Surface (S8) **(MLRA 147, 148)**
- ___ Thin Dark Surface (S9) **(MLRA 147, 148)**
- ___ Loamy Gleyed Matrix (F2)
- ___ Depleted Matrix (F3)
- ☑ Redox Dark Surface (F6)
- ___ Depleted Dark Surface (F7)
- ___ Redox Depressions (F8)
- ___ Iron-Manganese Masses (F12) **(LRR N, MLRA 136)**
- ___ Umbric Surface (F13) **(MLRA 136, 122)**
- ___ Piedmont Floodplain Soils (F19) **(MLRA 148)**
- ___ Red Parent Material (F21) **(MLRA 127, 147)**

Indicators for Problematic Hydric Soils[3]:

- ___ 2 cm Muck (A10) **(MLRA 147)**
- ___ Coast Prairie Redox (A16) **(MLRA 147, 148)**
- ___ Piedmont Floodplain Soils (F19) **(MLRA 136, 147)**
- ___ Very Shallow Dark Surface (TF12)
- ___ Other (Explain in Remarks)

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

Restrictive Layer (if observed):

Type: ______

Depth (inches): ______

Hydric Soil Present? **Yes** X **No** ______

Remarks:

WETLAND DETERMINATION DATA FORM – Eastern Mountains and Piedmont Region

Project/Site: Thesis Research City/County: ______ Sampling Date: 05-28-2016

Applicant/Owner: ______ State: TN Sampling Point: Plot-4

Investigator(s): C. Liggett Section, Township, Range: ______

Landform (hillslope, terrace, etc.): Depression Local relief (concave, convex, none): Concave Slope (%): <2%

Subregion (LRR or MLRA): LRR N Lat: ______ Long: ______ Datum: ______

Soil Map Unit Name: Lindell Silt Loam NWI classification: ______

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

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

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

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

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

Is the Sampled Area within a Wetland? **Yes** X **No** ______

Remarks:

HYDROLOGY

Wetland Hydrology Indicators:

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

- ☐ Surface Water (A1)
- ☐ High Water Table (A2)
- ☐ Saturation (A3)
- ☐ Water Marks (B1)
- ☐ Sediment Deposits (B2)
- ☐ Drift Deposits (B3)
- ☐ Algal Mat or Crust (B4)
- ☐ Iron Deposits (B5)
- ☐ Inundation Visible on Aerial Imagery (B7)
- ☑ Water-Stained Leaves (B9)
- ☐ Aquatic Fauna (B13)
- ☐ True Aquatic Plants (B14)
- ☐ Hydrogen Sulfide Odor (C1)
- ☐ Oxidized Rhizospheres on Living Roots (C3)
- ☐ Presence of Reduced Iron (C4)
- ☐ Recent Iron Reduction in Tilled Soils (C6)
- ☐ Thin Muck Surface (C7)
- ☐ Other (Explain in Remarks)

Secondary Indicators (minimum of two required)

- ☐ Surface Soil Cracks (B6)
- ☐ Sparsely Vegetated Concave Surface (B8)
- ☐ Drainage Patterns (B10)
- ☐ Moss Trim Lines (B16)
- ☐ Dry-Season Water Table (C2)
- ☐ Crayfish Burrows (C8)
- ☐ Saturation Visible on Aerial Imagery (C9)
- ☐ Stunted or Stressed Plants (D1)
- ☐ Geomorphic Position (D2)
- ☐ Shallow Aquitard (D3)
- ☐ Microtopographic Relief (D4)
- ☑ FAC-Neutral Test (D5)

Field Observations:

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

Wetland Hydrology Present? **Yes** X **No** ______

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

Remarks:

VEGETATION (Five Strata) – Use scientific names of plants.

Sampling Point: Plot-4

Tree Stratum (Plot size:)	Absolute % Cover	Dominant Species?	Indicator Status
1.			
2.			
3.			
4.			
5.			
6.			
= Total Cover			
50% of total cover:		20% of total cover:	

Sapling Stratum (Plot size:)	Absolute % Cover	Dominant Species?	Indicator Status
1. Salix nigra	10	Yes	OBL
2. Fraxinus pennsylvanica	5	Yes	FACW
3.			
4.			
5.			
6.			
= Total Cover	15		
50% of total cover: 8		20% of total cover: 3	

Shrub Stratum (Plot size:)	Absolute % Cover	Dominant Species?	Indicator Status
1.			
2.			
3.			
4.			
5.			
6.			
= Total Cover			
50% of total cover:		20% of total cover:	

Herb Stratum (Plot size:)	Absolute % Cover	Dominant Species?	Indicator Status
1. Typha angustifolia	20	Yes	OBL
2. Carex frankii	20	Yes	OBL
3. Carex vulipnoidea	15	Yes	OBL
4. Eleocharis palustris	10	No	OBL
5. Polygonum hydropiperoides	10	No	OBL
6. Juncus tenuis	10	No	FAC
7. Lespedeza angustifolia	5	No	FAC
8. Panicum virgatum	5	No	FAC
9. Solidago canadensis	5	No	FACU
10.			
11.			
= Total Cover	100		
50% of total cover: 50		20% of total cover: 20	

Woody Vine Stratum (Plot size:)	Absolute % Cover	Dominant Species?	Indicator Status
1.			
2.			
3.			
4.			
5.			
= Total Cover			
50% of total cover:		20% of total cover:	

Dominance Test worksheet:

Number of Dominant Species That Are OBL, FACW, or FAC: 5 (A)

Total Number of Dominant Species Across All Strata: 5 (B)

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

Prevalence Index worksheet:

Total % Cover of:		Multiply by:
OBL species	85	x 1 = 85
FACW species	5	x 2 = 10
FAC species	20	x 3 = 60
FACU species	5	x 4 = 20
UPL species	0	x 5 = 0
Column Totals:	115 (A)	175 (B)

Prevalence Index = B/A = 1.52

Hydrophytic Vegetation Indicators:

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

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

Definitions of Five Vegetation Strata:

Tree – Woody plants, excluding woody vines, approximately 20 ft (6 m) or more in height and 3 in. (7.6 cm) or larger in diameter at breast height (DBH).

Sapling – Woody plants, excluding woody vines, approximately 20 ft (6 m) or more in height and less than 3 in. (7.6 cm) DBH.

Shrub – Woody plants, excluding woody vines, approximately 3 to 20 ft (1 to 6 m) in height.

Herb – All herbaceous (non-woody) plants, including herbaceous vines, regardless of size, and woody plants, except woody vines, less than approximately 3 ft (1 m) in height.

Woody vine – All woody vines, regardless of height.

Hydrophytic Vegetation Present? Yes X No ___

Remarks: (Include photo numbers here or on a separate sheet.)

SOIL

Sampling Point: Plot-4

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

Depth	Matrix		Redox Features					
(inches)	Color (moist)	%	Color (moist)	%	Type[1]	Loc[2]	Texture	Remarks
0-12"	10YR 4/2	95%	7.5YR 5/8	5%	C	M	Silt loam	

[1]Type: C=Concentration, D=Depletion, RM=Reduced Matrix, MS=Masked Sand Grains. [2]Location: PL=Pore Lining, M=Matrix.

Hydric Soil Indicators:

- ___ Histosol (A1)
- ___ Histic Epipedon (A2)
- ___ Black Histic (A3)
- ___ Hydrogen Sulfide (A4)
- ___ Stratified Layers (A5)
- ___ 2 cm Muck (A10) **(LRR N)**
- ___ Depleted Below Dark Surface (A11)
- ___ Thick Dark Surface (A12)
- ___ Sandy Mucky Mineral (S1) **(LRR N, MLRA 147, 148)**
- ___ Sandy Gleyed Matrix (S4)
- ___ Sandy Redox (S5)
- ___ Stripped Matrix (S6)
- ___ Dark Surface (S7)
- ___ Polyvalue Below Surface (S8) **(MLRA 147, 148)**
- ___ Thin Dark Surface (S9) **(MLRA 147, 148)**
- ___ Loamy Gleyed Matrix (F2)
- ✓ Depleted Matrix (F3)
- ___ Redox Dark Surface (F6)
- ___ Depleted Dark Surface (F7)
- ___ Redox Depressions (F8)
- ___ Iron-Manganese Masses (F12) **(LRR N, MLRA 136)**
- ___ Umbric Surface (F13) **(MLRA 136, 122)**
- ___ Piedmont Floodplain Soils (F19) **(MLRA 148)**
- ___ Red Parent Material (F21) **(MLRA 127, 147)**

Indicators for Problematic Hydric Soils[3]:

- ___ 2 cm Muck (A10) **(MLRA 147)**
- ___ Coast Prairie Redox (A16) **(MLRA 147, 148)**
- ___ Piedmont Floodplain Soils (F19) **(MLRA 136, 147)**
- ___ Very Shallow Dark Surface (TF12)
- ___ Other (Explain in Remarks)

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

Restrictive Layer (if observed):

Type: ______

Depth (inches): ______

Hydric Soil Present? Yes X **No** ______

Remarks:

WETLAND DETERMINATION DATA FORM – Eastern Mountains and Piedmont Region

Project/Site: Thesis Research   City/County: ______   Sampling Date: 05-28-2016

Applicant/Owner: ______   State: TN   Sampling Point: Plot-5

Investigator(s): C. Liggett   Section, Township, Range: ______

Landform (hillslope, terrace, etc.): Depression   Local relief (concave, convex, none): Concave   Slope (%): <2%

Subregion (LRR or MLRA): LRR N   Lat: ______   Long: ______   Datum: ______

Soil Map Unit Name: Lindell Silt Loam   NWI classification: ______

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

Are Vegetation ___, Soil ___, or Hydrology ___ significantly disturbed?   Are "Normal Circumstances" present? Yes X No ___

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

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

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

Remarks:

HYDROLOGY

Wetland Hydrology Indicators:

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

- [ ] Surface Water (A1)
- [ ] High Water Table (A2)
- [ ] Saturation (A3)
- [ ] Water Marks (B1)
- [ ] Sediment Deposits (B2)
- [ ] Drift Deposits (B3)
- [ ] Algal Mat or Crust (B4)
- [ ] Iron Deposits (B5)
- [ ] Inundation Visible on Aerial Imagery (B7)
- [x] Water-Stained Leaves (B9)
- [ ] Aquatic Fauna (B13)
- [ ] True Aquatic Plants (B14)
- [ ] Hydrogen Sulfide Odor (C1)
- [ ] Oxidized Rhizospheres on Living Roots (C3)
- [ ] Presence of Reduced Iron (C4)
- [ ] Recent Iron Reduction in Tilled Soils (C6)
- [ ] Thin Muck Surface (C7)
- [ ] Other (Explain in Remarks)

Secondary Indicators (minimum of two required)

- [ ] Surface Soil Cracks (B6)
- [ ] Sparsely Vegetated Concave Surface (B8)
- [ ] Drainage Patterns (B10)
- [ ] Moss Trim Lines (B16)
- [ ] Dry-Season Water Table (C2)
- [ ] Crayfish Burrows (C8)
- [ ] Saturation Visible on Aerial Imagery (C9)
- [ ] Stunted or Stressed Plants (D1)
- [ ] Geomorphic Position (D2)
- [ ] Shallow Aquitard (D3)
- [ ] Microtopographic Relief (D4)
- [x] FAC-Neutral Test (D5)

Field Observations:

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

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

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

Wetland Hydrology Present? Yes X **No** ___

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

Remarks:

VEGETATION (Five Strata) – Use scientific names of plants.

Sampling Point: Plot-5

Tree Stratum (Plot size: ___)	Absolute % Cover	Dominant Species?	Indicator Status
1.			
2.			
3.			
4.			
5.			
6.			
= Total Cover			
50% of total cover: ___ 20% of total cover: ___			

Sapling Stratum (Plot size: ___)	Absolute % Cover	Dominant Species?	Indicator Status
1. Fraxinus pennsylvanica	5	Yes	FACW
2. Acer rubrum	5	Yes	FAC
3. Gleditsia triacanthos	2	No	FAC
4.			
5.			
6.			
= Total Cover	12		
50% of total cover: 6 20% of total cover: 3			

Shrub Stratum (Plot size: ___)	Absolute % Cover	Dominant Species?	Indicator Status
1.			
2.			
3.			
4.			
5.			
6.			
= Total Cover			
50% of total cover: ___ 20% of total cover: ___			

Herb Stratum (Plot size: ___)	Absolute % Cover	Dominant Species?	Indicator Status
1. Lespedeza angustifolia	20	Yes	FAC
2. Carex frankii	20	Yes	OBL
3. Solidago gigantea	20	Yes	FACW
4. Juncus tenuis	15	No	FAC
5. Panicum virgatum	10	No	FAC
6. Carex vulipnoidea	10	No	OBL
7.			
8.			
9.			
10.			
11.			
= Total Cover	95		
50% of total cover: 48 20% of total cover: 19			

Woody Vine Stratum (Plot size: ___)	Absolute % Cover	Dominant Species?	Indicator Status
1.			
2.			
3.			
4.			
5.			
= Total Cover			
50% of total cover: ___ 20% of total cover: ___			

Dominance Test worksheet:

Number of Dominant Species That Are OBL, FACW, or FAC: 5 (A)

Total Number of Dominant Species Across All Strata: 5 (B)

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

Prevalence Index worksheet:

Total % Cover of:		Multiply by:
OBL species	30	x 1 = 30
FACW species	25	x 2 = 50
FAC species	62	x 3 = 186
FACU species	0	x 4 = 0
UPL species	0	x 5 = 0
Column Totals:	117 (A)	266 (B)

Prevalence Index = B/A = 2.27

Hydrophytic Vegetation Indicators:

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

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

Definitions of Five Vegetation Strata:

Tree – Woody plants, excluding woody vines, approximately 20 ft (6 m) or more in height and 3 in. (7.6 cm) or larger in diameter at breast height (DBH).

Sapling – Woody plants, excluding woody vines, approximately 20 ft (6 m) or more in height and less than 3 in. (7.6 cm) DBH.

Shrub – Woody plants, excluding woody vines, approximately 3 to 20 ft (1 to 6 m) in height.

Herb – All herbaceous (non-woody) plants, including herbaceous vines, regardless of size, and woody plants, except woody vines, less than approximately 3 ft (1 m) in height.

Woody vine – All woody vines, regardless of height.

Hydrophytic Vegetation Present? Yes X No ___

Remarks: (Include photo numbers here or on a separate sheet.)

SOIL

Sampling Point: Plot-5

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

Depth (inches)	Matrix Color (moist)	Matrix %	Redox Features Color (moist)	Redox %	Type[1]	Loc[2]	Texture	Remarks
0-10"	10YR 3/2	90%	7.5YR 5/8	10%	C	M	Si.CL	

[1]Type: C=Concentration, D=Depletion, RM=Reduced Matrix, MS=Masked Sand Grains. [2]Location: PL=Pore Lining, M=Matrix.

Hydric Soil Indicators:

- ___ Histosol (A1)
- ___ Histic Epipedon (A2)
- ___ Black Histic (A3)
- ___ Hydrogen Sulfide (A4)
- ___ Stratified Layers (A5)
- ___ 2 cm Muck (A10) **(LRR N)**
- ___ Depleted Below Dark Surface (A11)
- ___ Thick Dark Surface (A12)
- ___ Sandy Mucky Mineral (S1) **(LRR N, MLRA 147, 148)**
- ___ Sandy Gleyed Matrix (S4)
- ___ Sandy Redox (S5)
- ___ Stripped Matrix (S6)
- ___ Dark Surface (S7)
- ___ Polyvalue Below Surface (S8) **(MLRA 147, 148)**
- ___ Thin Dark Surface (S9) **(MLRA 147, 148)**
- ___ Loamy Gleyed Matrix (F2)
- ___ Depleted Matrix (F3)
- ✓ Redox Dark Surface (F6)
- ___ Depleted Dark Surface (F7)
- ___ Redox Depressions (F8)
- ___ Iron-Manganese Masses (F12) **(LRR N, MLRA 136)**
- ___ Umbric Surface (F13) **(MLRA 136, 122)**
- ___ Piedmont Floodplain Soils (F19) **(MLRA 148)**
- ___ Red Parent Material (F21) **(MLRA 127, 147)**

Indicators for Problematic Hydric Soils[3]:

- ___ 2 cm Muck (A10) **(MLRA 147)**
- ___ Coast Prairie Redox (A16) **(MLRA 147, 148)**
- ___ Piedmont Floodplain Soils (F19) **(MLRA 136, 147)**
- ___ Very Shallow Dark Surface (TF12)
- ___ Other (Explain in Remarks)

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

Restrictive Layer (if observed):

Type: ______

Depth (inches): ______

Hydric Soil Present? **Yes** X **No** ______

Remarks:

WETLAND DETERMINATION DATA FORM – Eastern Mountains and Piedmont Region

Project/Site: Thesis Research City/County: ________ Sampling Date: 05-28-2016

Applicant/Owner: ________ State: TN Sampling Point: Plot-6

Investigator(s): C. Liggett Section, Township, Range: ________

Landform (hillslope, terrace, etc.): Depression Local relief (concave, convex, none): Concave Slope (%): <2%

Subregion (LRR or MLRA): LRR N Lat: ________ Long: ________ Datum: ________

Soil Map Unit Name: Lindell Silt Loam NWI classification: ________

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

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

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

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

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

Is the Sampled Area within a Wetland? **Yes** X **No** ____

Remarks:

HYDROLOGY

Wetland Hydrology Indicators:

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

- [ ] Surface Water (A1)
- [ ] High Water Table (A2)
- [ ] Saturation (A3)
- [ ] Water Marks (B1)
- [ ] Sediment Deposits (B2)
- [ ] Drift Deposits (B3)
- [ ] Algal Mat or Crust (B4)
- [ ] Iron Deposits (B5)
- [ ] Inundation Visible on Aerial Imagery (B7)
- [x] Water-Stained Leaves (B9)
- [ ] Aquatic Fauna (B13)
- [ ] True Aquatic Plants (B14)
- [x] Hydrogen Sulfide Odor (C1)
- [x] Oxidized Rhizospheres on Living Roots (C3)
- [ ] Presence of Reduced Iron (C4)
- [ ] Recent Iron Reduction in Tilled Soils (C6)
- [ ] Thin Muck Surface (C7)
- [ ] Other (Explain in Remarks)

Secondary Indicators (minimum of two required)

- [ ] Surface Soil Cracks (B6)
- [ ] Sparsely Vegetated Concave Surface (B8)
- [x] Drainage Patterns (B10)
- [ ] Moss Trim Lines (B16)
- [ ] Dry-Season Water Table (C2)
- [x] Crayfish Burrows (C8)
- [ ] Saturation Visible on Aerial Imagery (C9)
- [ ] Stunted or Stressed Plants (D1)
- [ ] Geomorphic Position (D2)
- [ ] Shallow Aquitard (D3)
- [x] Microtopographic Relief (D4)
- [x] FAC-Neutral Test (D5)

Field Observations:

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

Wetland Hydrology Present? Yes X **No** ____

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

Remarks:

VEGETATION (Five Strata) – Use scientific names of plants.

Sampling Point: Plot-6

Tree Stratum (Plot size:)	Absolute % Cover	Dominant Species?	Indicator Status
1. Ulmus Americana	25	Yes	FACW
2. Celtis Laevigata	20	Yes	FACW
3. Fraxinus pennsylvanica	20	Yes	FACW
4.			
5.			
6.			
	65 = Total Cover		
50% of total cover: 33	20% of total cover: 13		

Sapling Stratum (Plot size:)	Absolute % Cover	Dominant Species?	Indicator Status
1. Cornus amomum	15	Yes	FACW
2. Ligustrum sinense	10	Yes	FACU
3. Juniperus virginiana	5	No	FACU
4.			
5.			
6.			
	30 = Total Cover		
50% of total cover: 15	20% of total cover: 6		

Shrub Stratum (Plot size:)	Absolute % Cover	Dominant Species?	Indicator Status
1.			
2.			
3.			
4.			
5.			
6.			
	= Total Cover		
50% of total cover:	20% of total cover:		

Herb Stratum (Plot size:)	Absolute % Cover	Dominant Species?	Indicator Status
1. Panicum rigidulum	35	Yes	FACW
2. Dicanthelium clandestinum	15	Yes	FAC
3. Carex vulpinoidea	15	No	OBL
4. Scirpus atrovirens	15	No	OBL
5. Carex frankii	10	No	OBL
6.			
7.			
8.			
9.			
10.			
11.			
	90 = Total Cover		
50% of total cover: 45	20% of total cover: 18		

Woody Vine Stratum (Plot size:)	Absolute % Cover	Dominant Species?	Indicator Status
1. Toxicodendron radicans	5	Yes	FAC
2. Parthenocissus quinquefolia	5	Yes	FACU
3. Campsis radicans	2	No	FAC
4.			
5.			
	12 = Total Cover		
50% of total cover: 6	20% of total cover: 3		

Dominance Test worksheet:

Number of Dominant Species That Are OBL, FACW, or FAC: 7 (A)

Total Number of Dominant Species Across All Strata: 9 (B)

Percent of Dominant Species That Are OBL, FACW, or FAC: 78% (A/B)

Prevalence Index worksheet:

Total % Cover of:		Multiply by:
OBL species	40	x 1 = 40
FACW species	115	x 2 = 230
FAC species	22	x 3 = 66
FACU species	20	x 4 = 80
UPL species	0	x 5 = 0
Column Totals:	197 (A)	416 (B)

Prevalence Index = B/A = 2.11

Hydrophytic Vegetation Indicators:

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

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

Definitions of Five Vegetation Strata:

Tree – Woody plants, excluding woody vines, approximately 20 ft (6 m) or more in height and 3 in. (7.6 cm) or larger in diameter at breast height (DBH).

Sapling – Woody plants, excluding woody vines, approximately 20 ft (6 m) or more in height and less than 3 in. (7.6 cm) DBH.

Shrub – Woody plants, excluding woody vines, approximately 3 to 20 ft (1 to 6 m) in height.

Herb – All herbaceous (non-woody) plants, including herbaceous vines, regardless of size, and woody plants, except woody vines, less than approximately 3 ft (1 m) in height.

Woody vine – All woody vines, regardless of height.

Hydrophytic Vegetation Present? **Yes** X **No** ___

Remarks: (Include photo numbers here or on a separate sheet.)

SOIL Sampling Point: Plot-6

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

Depth (inches)	Matrix Color (moist)	Matrix %	Redox Features Color (moist)	Redox %	Type[1]	Loc[2]	Texture	Remarks
0-12"	10YR 5/2	60%	7.5YR 4/6	40%	C	PL/M	Silt loam	

[1]Type: C=Concentration, D=Depletion, RM=Reduced Matrix, MS=Masked Sand Grains. [2]Location: PL=Pore Lining, M=Matrix.

Hydric Soil Indicators:

- ___ Histosol (A1)
- ___ Histic Epipedon (A2)
- ___ Black Histic (A3)
- ✓ Hydrogen Sulfide (A4)
- ___ Stratified Layers (A5)
- ___ 2 cm Muck (A10) **(LRR N)**
- ___ Depleted Below Dark Surface (A11)
- ___ Thick Dark Surface (A12)
- ___ Sandy Mucky Mineral (S1) **(LRR N, MLRA 147, 148)**
- ___ Sandy Gleyed Matrix (S4)
- ___ Sandy Redox (S5)
- ___ Stripped Matrix (S6)
- ___ Dark Surface (S7)
- ___ Polyvalue Below Surface (S8) **(MLRA 147, 148)**
- ___ Thin Dark Surface (S9) **(MLRA 147, 148)**
- ___ Loamy Gleyed Matrix (F2)
- ✓ Depleted Matrix (F3)
- ___ Redox Dark Surface (F6)
- ___ Depleted Dark Surface (F7)
- ___ Redox Depressions (F8)
- ☐ Iron-Manganese Masses (F12) **(LRR N, MLRA 136)**
- ___ Umbric Surface (F13) **(MLRA 136, 122)**
- ___ Piedmont Floodplain Soils (F19) **(MLRA 148)**
- ___ Red Parent Material (F21) **(MLRA 127, 147)**

Indicators for Problematic Hydric Soils[3]:

- ___ 2 cm Muck (A10) **(MLRA 147)**
- ___ Coast Prairie Redox (A16) **(MLRA 147, 148)**
- ___ Piedmont Floodplain Soils (F19) **(MLRA 136, 147)**
- ___ Very Shallow Dark Surface (TF12)
- ___ Other (Explain in Remarks)

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

Restrictive Layer (if observed):

Type: ____________

Depth (inches): ____________

Hydric Soil Present? **Yes** X **No** ______

Remarks:

WETLAND DETERMINATION DATA FORM – Eastern Mountains and Piedmont Region

Project/Site: Thesis Research City/County: ______ Sampling Date: 05-28-2016

Applicant/Owner: ______ State: TN Sampling Point: Plot-7

Investigator(s): C. Liggett Section, Township, Range: ______

Landform (hillslope, terrace, etc.): Depression Local relief (concave, convex, none): Concave Slope (%): <2%

Subregion (LRR or MLRA): LRR N Lat: ______ Long: ______ Datum: ______

Soil Map Unit Name: Lindell Silt Loam NWI classification: ______

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

Are Vegetation ___, Soil ___, or Hydrology ___ significantly disturbed? Are "Normal Circumstances" present? Yes X No ___

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

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

Hydrophytic Vegetation Present?	Yes X	No ___
Hydric Soil Present?	Yes X	No ___
Wetland Hydrology Present?	Yes X	No ___

Is the Sampled Area within a Wetland? **Yes** X **No** ___

Remarks:

HYDROLOGY

Wetland Hydrology Indicators:

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

- ☐ Surface Water (A1)
- ☐ High Water Table (A2)
- ☐ Saturation (A3)
- ☐ Water Marks (B1)
- ☐ Sediment Deposits (B2)
- ☐ Drift Deposits (B3)
- ☐ Algal Mat or Crust (B4)
- ☐ Iron Deposits (B5)
- ☐ Inundation Visible on Aerial Imagery (B7)
- ☑ Water-Stained Leaves (B9)
- ☐ Aquatic Fauna (B13)
- ☐ True Aquatic Plants (B14)
- ☐ Hydrogen Sulfide Odor (C1)
- ☑ Oxidized Rhizospheres on Living Roots (C3)
- ☐ Presence of Reduced Iron (C4)
- ☐ Recent Iron Reduction in Tilled Soils (C6)
- ☐ Thin Muck Surface (C7)
- ☐ Other (Explain in Remarks)

Secondary Indicators (minimum of two required)

- ☐ Surface Soil Cracks (B6)
- ☐ Sparsely Vegetated Concave Surface (B8)
- ☑ Drainage Patterns (B10)
- ☐ Moss Trim Lines (B16)
- ☐ Dry-Season Water Table (C2)
- ☐ Crayfish Burrows (C8)
- ☐ Saturation Visible on Aerial Imagery (C9)
- ☐ Stunted or Stressed Plants (D1)
- ☐ Geomorphic Position (D2)
- ☐ Shallow Aquitard (D3)
- ☑ Microtopographic Relief (D4)
- ☑ FAC-Neutral Test (D5)

Field Observations:

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

Wetland Hydrology Present? Yes X **No** ___

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

Remarks:

VEGETATION (Five Strata) – Use scientific names of plants.

Sampling Point: Plot-7

Tree Stratum (Plot size: ______)	Absolute % Cover	Dominant Species?	Indicator Status
1. Ulmus Americana	30	Yes	FACW
2. Celtis Laevigata	25	Yes	FACW
3. Fraxinus pennsylvanica	25	Yes	FACW
4.			
5.			
6.			
	80 = Total Cover		
50% of total cover: 40	20% of total cover: 16		
Sapling Stratum (Plot size: ______)			
1. Cornus amomum	15	Yes	FACW
2. Ligustrum sinense	10	Yes	FACU
3. Juniperus virginiana	5	No	FACU
4.			
5.			
6.			
	30 = Total Cover		
50% of total cover: 15	20% of total cover: 6		
Shrub Stratum (Plot size: ______)			
1.			
2.			
3.			
4.			
5.			
6.			
	= Total Cover		
50% of total cover:	20% of total cover:		
Herb Stratum (Plot size: ______)			
1. Panicum capillare	30	Yes	FAC
2. Dicanthelium clandestinum	20	Yes	FAC
3. Eupatorium album	15	Yes	NI
4. Juncus tenuis	5	No	FAC
5.			
6.			
7.			
8.			
9.			
10.			
11.			
	70 = Total Cover		
50% of total cover: 35	20% of total cover: 14		
Woody Vine Stratum (Plot size: ______)			
1. Toxicodendron radicans	10	Yes	FAC
2. Parthenocissus quinquefolia	10	Yes	FACU
3. Campsis radicans	5	Yes	FAC
4.			
5.			
	25 = Total Cover		
50% of total cover: 13	20% of total cover: 5		

Dominance Test worksheet:

Number of Dominant Species That Are OBL, FACW, or FAC: 8 (A)

Total Number of Dominant Species Across All Strata: 11 (B)

Percent of Dominant Species That Are OBL, FACW, or FAC: 73% (A/B)

Prevalence Index worksheet:

Total % Cover of:		Multiply by:
OBL species	0	x 1 = 0
FACW species	95	x 2 = 190
FAC species	70	x 3 = 210
FACU species	25	x 4 = 100
UPL species	0	x 5 = 0
Column Totals:	190 (A)	500 (B)

Prevalence Index = B/A = 2.63

Hydrophytic Vegetation Indicators:

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

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

Definitions of Five Vegetation Strata:

Tree – Woody plants, excluding woody vines, approximately 20 ft (6 m) or more in height and 3 in. (7.6 cm) or larger in diameter at breast height (DBH).

Sapling – Woody plants, excluding woody vines, approximately 20 ft (6 m) or more in height and less than 3 in. (7.6 cm) DBH.

Shrub – Woody plants, excluding woody vines, approximately 3 to 20 ft (1 to 6 m) in height.

Herb – All herbaceous (non-woody) plants, including herbaceous vines, regardless of size, and woody plants, except woody vines, less than approximately 3 ft (1 m) in height.

Woody vine – All woody vines, regardless of height.

Hydrophytic Vegetation Present? **Yes** X **No** ______

Remarks: (Include photo numbers here or on a separate sheet.)

SOIL

Sampling Point: Plot-7

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

Depth	Matrix		Redox Features					
(inches)	Color (moist)	%	Color (moist)	%	Type[1]	Loc[2]	Texture	Remarks
0-12"	10YR 5/2	85%	7.5YR 5/8	15%	C	PL/M	Silt loam	

[1]Type: C=Concentration, D=Depletion, RM=Reduced Matrix, MS=Masked Sand Grains. [2]Location: PL=Pore Lining, M=Matrix.

Hydric Soil Indicators:

- ___ Histosol (A1)
- ___ Histic Epipedon (A2)
- ___ Black Histic (A3)
- ___ Hydrogen Sulfide (A4)
- ___ Stratified Layers (A5)
- ___ 2 cm Muck (A10) **(LRR N)**
- ___ Depleted Below Dark Surface (A11)
- ___ Thick Dark Surface (A12)
- ___ Sandy Mucky Mineral (S1) **(LRR N, MLRA 147, 148)**
- ___ Sandy Gleyed Matrix (S4)
- ___ Sandy Redox (S5)
- ___ Stripped Matrix (S6)
- ___ Dark Surface (S7)
- ___ Polyvalue Below Surface (S8) **(MLRA 147, 148)**
- ___ Thin Dark Surface (S9) **(MLRA 147, 148)**
- ___ Loamy Gleyed Matrix (F2)
- ☑ Depleted Matrix (F3)
- ___ Redox Dark Surface (F6)
- ___ Depleted Dark Surface (F7)
- ___ Redox Depressions (F8)
- ☐ Iron-Manganese Masses (F12) **(LRR N, MLRA 136)**
- ___ Umbric Surface (F13) **(MLRA 136, 122)**
- ___ Piedmont Floodplain Soils (F19) **(MLRA 148)**
- ___ Red Parent Material (F21) **(MLRA 127, 147)**

Indicators for Problematic Hydric Soils[3]:

- ___ 2 cm Muck (A10) **(MLRA 147)**
- ___ Coast Prairie Redox (A16) **(MLRA 147, 148)**
- ___ Piedmont Floodplain Soils (F19) **(MLRA 136, 147)**
- ___ Very Shallow Dark Surface (TF12)
- ___ Other (Explain in Remarks)

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

Restrictive Layer (if observed):

Type: ______

Depth (inches): ______

Hydric Soil Present? **Yes** X **No** ______

Remarks:

WETLAND DETERMINATION DATA FORM – Eastern Mountains and Piedmont Region

Project/Site: Thesis Research City/County: ______ Sampling Date: 05-28-2016
Applicant/Owner: ______ State: TN Sampling Point: Preservation Area
Investigator(s): C. Liggett Section, Township, Range: ______
Landform (hillslope, terrace, etc.): Depression Local relief (concave, convex, none): Concave Slope (%): <2%
Subregion (LRR or MLRA): LRR N Lat: ______ Long: ______ Datum: ______
Soil Map Unit Name: Lindell Silt Loam NWI classification: ______
Are climatic / hydrologic conditions on the site typical for this time of year? Yes X No ___ (If no, explain in Remarks.)
Are Vegetation ___, Soil ___, or Hydrology ___ significantly disturbed? Are "Normal Circumstances" present? Yes X No ___
Are Vegetation ___, Soil ___, or Hydrology ___ naturally problematic? (If needed, explain any answers in Remarks.)

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

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

Remarks:

HYDROLOGY

Wetland Hydrology Indicators:

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

- [ ] Surface Water (A1)
- [ ] High Water Table (A2)
- [ ] Saturation (A3)
- [ ] Water Marks (B1)
- [ ] Sediment Deposits (B2)
- [ ] Drift Deposits (B3)
- [ ] Algal Mat or Crust (B4)
- [ ] Iron Deposits (B5)
- [ ] Inundation Visible on Aerial Imagery (B7)
- [x] Water-Stained Leaves (B9)
- [ ] Aquatic Fauna (B13)
- [ ] True Aquatic Plants (B14)
- [ ] Hydrogen Sulfide Odor (C1)
- [x] Oxidized Rhizospheres on Living Roots (C3)
- [ ] Presence of Reduced Iron (C4)
- [ ] Recent Iron Reduction in Tilled Soils (C6)
- [ ] Thin Muck Surface (C7)
- [ ] Other (Explain in Remarks)

Secondary Indicators (minimum of two required)

- [ ] Surface Soil Cracks (B6)
- [ ] Sparsely Vegetated Concave Surface (B8)
- [x] Drainage Patterns (B10)
- [ ] Moss Trim Lines (B16)
- [ ] Dry-Season Water Table (C2)
- [ ] Crayfish Burrows (C8)
- [ ] Saturation Visible on Aerial Imagery (C9)
- [ ] Stunted or Stressed Plants (D1)
- [ ] Geomorphic Position (D2)
- [ ] Shallow Aquitard (D3)
- [ ] Microtopographic Relief (D4)
- [x] FAC-Neutral Test (D5)

Field Observations:

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

Wetland Hydrology Present? Yes X **No** ___

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

Remarks:

VEGETATION (Five Strata) – Use scientific names of plants.

Sampling Point: Preservation Area

Tree Stratum (Plot size: ________)

	Absolute % Cover	Dominant Species?	Indicator Status
1. Ulmus Americana	30	Yes	FACW
2. Celtis Laevigata	25	Yes	FACW
3. Fraxinus pennsylvanica	25	Yes	FACW
4. Quercus palustris	10	No	FACW
5.			
6.			
	90 = Total Cover		

50% of total cover: 45 20% of total cover: 18

Sapling Stratum (Plot size: ________)

	Absolute % Cover	Dominant Species?	Indicator Status
1. Cornus amomum	15	Yes	FACW
2. Ligustrum sinense	10	Yes	FACU
3. Juniperus virginiana	5	No	FACU
4.			
5.			
6.			
	30 = Total Cover		

50% of total cover: 15 20% of total cover: 6

Shrub Stratum (Plot size: ________)

	Absolute % Cover	Dominant Species?	Indicator Status
1.			
2.			
3.			
4.			
5.			
6.			
	____ = Total Cover		

50% of total cover: ____ 20% of total cover: ____

Herb Stratum (Plot size: ________)

	Absolute % Cover	Dominant Species?	Indicator Status
1. Juncus tenuis	20	Yes	FAC
2. Carex sp.	15	Yes	FAC
3. Echinochloa crus-galis	10	No	FAC
4. Panicum rigidulum	10	No	FACW
5.			
6.			
7.			
8.			
9.			
10.			
11.			
	55 = Total Cover		

50% of total cover: 28 20% of total cover: 11

Woody Vine Stratum (Plot size: ________)

	Absolute % Cover	Dominant Species?	Indicator Status
1. Toxicodendron radicans	10	Yes	FAC
2. Parthenocissus quinquefolia	10	Yes	FACU
3. Campsis radicans	5	Yes	FAC
4.			
5.			
	25 = Total Cover		

50% of total cover: 13 20% of total cover: 5

Dominance Test worksheet:

Number of Dominant Species That Are OBL, FACW, or FAC: 8 (A)

Total Number of Dominant Species Across All Strata: 10 (B)

Percent of Dominant Species That Are OBL, FACW, or FAC: 80% (A/B)

Prevalence Index worksheet:

Total % Cover of:		Multiply by:
OBL species	0	x 1 = 0
FACW species	115	x 2 = 230
FAC species	60	x 3 = 180
FACU species	25	x 4 = 100
UPL species	0	x 5 = 0
Column Totals:	200 (A)	510 (B)

Prevalence Index = B/A = 2.55

Hydrophytic Vegetation Indicators:

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

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

Definitions of Five Vegetation Strata:

Tree – Woody plants, excluding woody vines, approximately 20 ft (6 m) or more in height and 3 in. (7.6 cm) or larger in diameter at breast height (DBH).

Sapling – Woody plants, excluding woody vines, approximately 20 ft (6 m) or more in height and less than 3 in. (7.6 cm) DBH.

Shrub – Woody plants, excluding woody vines, approximately 3 to 20 ft (1 to 6 m) in height.

Herb – All herbaceous (non-woody) plants, including herbaceous vines, regardless of size, and woody plants, except woody vines, less than approximately 3 ft (1 m) in height.

Woody vine – All woody vines, regardless of height.

Hydrophytic Vegetation Present? Yes X No ____

Remarks: (Include photo numbers here or on a separate sheet.)

SOIL

Sampling Point: Preservation Area

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

Depth (inches)	Matrix Color (moist)	Matrix %	Redox Features Color (moist)	Redox %	Type[1]	Loc[2]	Texture	Remarks
0-12"	10YR 5/2	90%	7.5YR 4/6	10%	C	PL/M	Silt loam	

[1]Type: C=Concentration, D=Depletion, RM=Reduced Matrix, MS=Masked Sand Grains. [2]Location: PL=Pore Lining, M=Matrix.

Hydric Soil Indicators:

- ___ Histosol (A1)
- ___ Histic Epipedon (A2)
- ___ Black Histic (A3)
- ___ Hydrogen Sulfide (A4)
- ___ Stratified Layers (A5)
- ___ 2 cm Muck (A10) **(LRR N)**
- ___ Depleted Below Dark Surface (A11)
- ___ Thick Dark Surface (A12)
- ___ Sandy Mucky Mineral (S1) **(LRR N, MLRA 147, 148)**
- ___ Sandy Gleyed Matrix (S4)
- ___ Sandy Redox (S5)
- ___ Stripped Matrix (S6)
- ___ Dark Surface (S7)
- ___ Polyvalue Below Surface (S8) **(MLRA 147, 148)**
- ___ Thin Dark Surface (S9) **(MLRA 147, 148)**
- ___ Loamy Gleyed Matrix (F2)
- ✓ Depleted Matrix (F3)
- ___ Redox Dark Surface (F6)
- ___ Depleted Dark Surface (F7)
- ___ Redox Depressions (F8)
- ___ Iron-Manganese Masses (F12) **(LRR N, MLRA 136)**
- ___ Umbric Surface (F13) **(MLRA 136, 122)**
- ___ Piedmont Floodplain Soils (F19) **(MLRA 148)**
- ___ Red Parent Material (F21) **(MLRA 127, 147)**

Indicators for Problematic Hydric Soils[3]:

- ___ 2 cm Muck (A10) **(MLRA 147)**
- ___ Coast Prairie Redox (A16) **(MLRA 147, 148)**
- ___ Piedmont Floodplain Soils (F19) **(MLRA 136, 147)**
- ___ Very Shallow Dark Surface (TF12)
- ___ Other (Explain in Remarks)

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

Restrictive Layer (if observed):

Type: ______

Depth (inches): ______

Hydric Soil Present? **Yes** X **No** ______

Remarks:

WETLAND DETERMINATION DATA FORM – Eastern Mountains and Piedmont Region

Project/Site: Thesis Research City/County: ______ Sampling Date: 6-11-2017

Applicant/Owner: ______ State: TN Sampling Point: Plot-1

Investigator(s): C. Liggett Section, Township, Range: ______

Landform (hillslope, terrace, etc.): Depression Local relief (concave, convex, none): Concave Slope (%): <2%

Subregion (LRR or MLRA): LRR N Lat: ______ Long: ______ Datum: ______

Soil Map Unit Name: Lindell Silt Loam NWI classification: ______

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

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

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

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

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

Remarks:

HYDROLOGY

Wetland Hydrology Indicators:

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

- ☐ Surface Water (A1)
- ☐ High Water Table (A2)
- ☐ Saturation (A3)
- ☐ Water Marks (B1)
- ☐ Sediment Deposits (B2)
- ☐ Drift Deposits (B3)
- ☑ Algal Mat or Crust (B4)
- ☐ Iron Deposits (B5)
- ☐ Inundation Visible on Aerial Imagery (B7)
- ☑ Water-Stained Leaves (B9)
- ☐ Aquatic Fauna (B13)
- ☐ True Aquatic Plants (B14)
- ☐ Hydrogen Sulfide Odor (C1)
- ☑ Oxidized Rhizospheres on Living Roots (C3)
- ☐ Presence of Reduced Iron (C4)
- ☐ Recent Iron Reduction in Tilled Soils (C6)
- ☐ Thin Muck Surface (C7)
- ☐ Other (Explain in Remarks)

Secondary Indicators (minimum of two required)

- ☐ Surface Soil Cracks (B6)
- ☐ Sparsely Vegetated Concave Surface (B8)
- ☐ Drainage Patterns (B10)
- ☐ Moss Trim Lines (B16)
- ☐ Dry-Season Water Table (C2)
- ☐ Crayfish Burrows (C8)
- ☐ Saturation Visible on Aerial Imagery (C9)
- ☐ Stunted or Stressed Plants (D1)
- ☐ Geomorphic Position (D2)
- ☐ Shallow Aquitard (D3)
- ☐ Microtopographic Relief (D4)
- ☐ FAC-Neutral Test (D5)

Field Observations:

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

Water Table Present? Yes ______ No X Depth (inches): ______

Saturation Present? (includes capillary fringe) Yes ______ No X Depth (inches): ______

Wetland Hydrology Present? Yes X **No** ______

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

Remarks:

VEGETATION (Five Strata) – Use scientific names of plants.

Sampling Point: Plot-1

Tree Stratum (Plot size:)	Absolute % Cover	Dominant Species?	Indicator Status
1. Salix nigra	10	Yes	OBL
2.			
3.			
4.			
5.			
6.			
	5 = Total Cover		
50% of total cover: 5	20% of total cover: 2		

Sapling Stratum (Plot size:)	Absolute % Cover	Dominant Species?	Indicator Status
1. Fraxinus pennsylvanica	10	Yes	FACW
2. Cornus amomum	5	Yes	FACW
3. Acer negundo	5	No	FACW
4. Salix nigra	2	No	OBL
5. Populus deltoides	2	No	FAC
6. Celtis laevigata	2	No	FACW
	26 = Total Cover		
50% of total cover: 13	20% of total cover: 5.2		

Shrub Stratum (Plot size:)	Absolute % Cover	Dominant Species?	Indicator Status
1.			
2.			
3.			
4.			
5.			
6.			
	= Total Cover		
50% of total cover:	20% of total cover:		

Herb Stratum (Plot size:)	Absolute % Cover	Dominant Species?	Indicator Status
1. Ptilimnium costatum	40	Yes	FACW
2. Lespedeza angustifolia	10	Yes	FAC
3. Eupatorium album	10	No	NI
4. Solidago gigantea	10	No	FACW
5. Ranunculus	5	No	FACW
6. Sibara virginica	5	No	UPL
7. Cynodon dactylon	5	No	FACU
8. Dicanthelium clandestinum	2	No	FACW
9. Leersia oryzoides	2	No	OBL
10.			
11.			
	88 = Total Cover		
50% of total cover: 44	20% of total cover: 17.6		

Woody Vine Stratum (Plot size:)	Absolute % Cover	Dominant Species?	Indicator Status
1.			
2.			
3.			
4.			
5.			
	= Total Cover		
50% of total cover:	20% of total cover:		

Dominance Test worksheet:

Number of Dominant Species That Are OBL, FACW, or FAC: 5 (A)

Total Number of Dominant Species Across All Strata: 5 (B)

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

Prevalence Index worksheet:

Total % Cover of:		Multiply by:
OBL species	14	x 1 = 14
FACW species	81	x 2 = 162
FAC species	12	x 3 = 36
FACU species	5	x 4 = 20
UPL species	5	x 5 = 25
Column Totals:	117 (A)	257 (B)

Prevalence Index = B/A = 2.20

Hydrophytic Vegetation Indicators:

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

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

Definitions of Five Vegetation Strata:

Tree – Woody plants, excluding woody vines, approximately 20 ft (6 m) or more in height and 3 in. (7.6 cm) or larger in diameter at breast height (DBH).

Sapling – Woody plants, excluding woody vines, approximately 20 ft (6 m) or more in height and less than 3 in. (7.6 cm) DBH.

Shrub – Woody plants, excluding woody vines, approximately 3 to 20 ft (1 to 6 m) in height.

Herb – All herbaceous (non-woody) plants, including herbaceous vines, regardless of size, and woody plants, except woody vines, less than approximately 3 ft (1 m) in height.

Woody vine – All woody vines, regardless of height.

Hydrophytic Vegetation Present? Yes X No ___

Remarks: (Include photo numbers here or on a separate sheet.)

SOIL

Sampling Point: Plot-1

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

Depth	Matrix		Redox Features					
(inches)	Color (moist)	%	Color (moist)	%	Type[1]	Loc[2]	Texture	Remarks
0-5"	10YR 4/2	70	7.5YR 4/6	30	C	PL/M	Silt loam	
5-9"	10YR 3/2	85	7.5YR 4/6	15	C	PL/M	Silt loam	
9-11"	10YR 5/4	85	10YR 5/2	15	D	M	Silty clay	

[1]Type: C=Concentration, D=Depletion, RM=Reduced Matrix, MS=Masked Sand Grains. [2]Location: PL=Pore Lining, M=Matrix.

Hydric Soil Indicators:

- ___ Histosol (A1)
- ___ Histic Epipedon (A2)
- ___ Black Histic (A3)
- ___ Hydrogen Sulfide (A4)
- ___ Stratified Layers (A5)
- ___ 2 cm Muck (A10) **(LRR N)**
- ___ Depleted Below Dark Surface (A11)
- ___ Thick Dark Surface (A12)
- ___ Sandy Mucky Mineral (S1) **(LRR N, MLRA 147, 148)**
- ___ Sandy Gleyed Matrix (S4)
- ___ Sandy Redox (S5)
- ___ Stripped Matrix (S6)
- ___ Dark Surface (S7)
- ___ Polyvalue Below Surface (S8) **(MLRA 147, 148)**
- ___ Thin Dark Surface (S9) **(MLRA 147, 148)**
- ___ Loamy Gleyed Matrix (F2)
- ✓ Depleted Matrix (F3)
- ✓ Redox Dark Surface (F6)
- ___ Depleted Dark Surface (F7)
- ___ Redox Depressions (F8)
- ___ Iron-Manganese Masses (F12) **(LRR N, MLRA 136)**
- ___ Umbric Surface (F13) **(MLRA 136, 122)**
- ___ Piedmont Floodplain Soils (F19) **(MLRA 148)**
- ___ Red Parent Material (F21) **(MLRA 127, 147)**

Indicators for Problematic Hydric Soils[3]:

- ___ 2 cm Muck (A10) **(MLRA 147)**
- ___ Coast Prairie Redox (A16) **(MLRA 147, 148)**
- ___ Piedmont Floodplain Soils (F19) **(MLRA 136, 147)**
- ___ Very Shallow Dark Surface (TF12)
- ___ Other (Explain in Remarks)

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

Restrictive Layer (if observed):

Type: ______

Depth (inches): ______

Hydric Soil Present? Yes X **No** ______

Remarks:

WETLAND DETERMINATION DATA FORM – Eastern Mountains and Piedmont Region

Project/Site: Thesis Research City/County: ______ Sampling Date: 06-11-2017

Applicant/Owner: ______ State: TN Sampling Point: Plot-2

Investigator(s): C. Liggett Section, Township, Range: ______

Landform (hillslope, terrace, etc.): Depression Local relief (concave, convex, none): Concave Slope (%): <2%

Subregion (LRR or MLRA): LRR N Lat: ______ Long: ______ Datum: ______

Soil Map Unit Name: Lindell Silt Loam NWI classification: ______

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

Are Vegetation ___, Soil ___, or Hydrology ___ significantly disturbed? Are "Normal Circumstances" present? Yes X No ___

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

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

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

Remarks:

HYDROLOGY

Wetland Hydrology Indicators:

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

- ☐ Surface Water (A1)
- ☐ High Water Table (A2)
- ☐ Saturation (A3)
- ☐ Water Marks (B1)
- ☐ Sediment Deposits (B2)
- ☐ Drift Deposits (B3)
- ☐ Algal Mat or Crust (B4)
- ☐ Iron Deposits (B5)
- ☐ Inundation Visible on Aerial Imagery (B7)
- ☐ Water-Stained Leaves (B9)
- ☐ Aquatic Fauna (B13)
- ☐ True Aquatic Plants (B14)
- ☐ Hydrogen Sulfide Odor (C1)
- ☐ Oxidized Rhizospheres on Living Roots (C3)
- ☐ Presence of Reduced Iron (C4)
- ☐ Recent Iron Reduction in Tilled Soils (C6)
- ☐ Thin Muck Surface (C7)
- ☐ Other (Explain in Remarks)

Secondary Indicators (minimum of two required)

- ☐ Surface Soil Cracks (B6)
- ☐ Sparsely Vegetated Concave Surface (B8)
- ☐ Drainage Patterns (B10)
- ☐ Moss Trim Lines (B16)
- ☐ Dry-Season Water Table (C2)
- ☐ Crayfish Burrows (C8)
- ☐ Saturation Visible on Aerial Imagery (C9)
- ☐ Stunted or Stressed Plants (D1)
- ☑ Geomorphic Position (D2)
- ☐ Shallow Aquitard (D3)
- ☐ Microtopographic Relief (D4)
- ☑ FAC-Neutral Test (D5)

Field Observations:

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

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

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

Wetland Hydrology Present? Yes X **No** ___

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

Remarks:

VEGETATION (Five Strata) – Use scientific names of plants.

Sampling Point: Plot-2

Tree Stratum (Plot size: ______)	Absolute % Cover	Dominant Species?	Indicator Status
1.			
2.			
3.			
4.			
5.			
6.			
		= Total Cover	
50% of total cover: ______	20% of total cover: ______		

Sapling Stratum (Plot size: ______)	Absolute % Cover	Dominant Species?	Indicator Status
1.			
2.			
3.			
4.			
5.			
6.			
		= Total Cover	
50% of total cover: ______	20% of total cover: ______		

Shrub Stratum (Plot size: ______)	Absolute % Cover	Dominant Species?	Indicator Status
1.			
2.			
3.			
4.			
5.			
6.			
		= Total Cover	
50% of total cover: ______	20% of total cover: ______		

Herb Stratum (Plot size: ______)	Absolute % Cover	Dominant Species?	Indicator Status
1. Eupatorium album	40	Yes	NI
2. Ranunculus	10	Yes	FACW
3. Lespedeza angustifolia	10	No	FAC
4. Ptilimnium costatum	10	No	FACW
5. Juncus tenuis	10	No	FAC
6. Erigeron annuus	5	No	FACU
7. Sibara virginica	5	No	UPL
8. Leersia oryzoides	2	No	OBL
9.			
10.			
11.			
	92	= Total Cover	
50% of total cover: 46	20% of total cover: 18.4		

Woody Vine Stratum (Plot size: ______)	Absolute % Cover	Dominant Species?	Indicator Status
1.			
2.			
3.			
4.			
5.			
		= Total Cover	
50% of total cover: ______	20% of total cover: ______		

Dominance Test worksheet:

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

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

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

Prevalence Index worksheet:

Total % Cover of:		Multiply by:	
OBL species	2	x 1 =	2
FACW species	20	x 2 =	40
FAC species	20	x 3 =	60
FACU species	5	x 4 =	20
UPL species	5	x 5 =	25
Column Totals:	52 (A)		147 (B)

Prevalence Index = B/A = 2.83

Hydrophytic Vegetation Indicators:

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

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

Definitions of Five Vegetation Strata:

Tree – Woody plants, excluding woody vines, approximately 20 ft (6 m) or more in height and 3 in. (7.6 cm) or larger in diameter at breast height (DBH).

Sapling – Woody plants, excluding woody vines, approximately 20 ft (6 m) or more in height and less than 3 in. (7.6 cm) DBH.

Shrub – Woody plants, excluding woody vines, approximately 3 to 20 ft (1 to 6 m) in height.

Herb – All herbaceous (non-woody) plants, including herbaceous vines, regardless of size, and woody plants, except woody vines, less than approximately 3 ft (1 m) in height.

Woody vine – All woody vines, regardless of height.

Hydrophytic Vegetation Present? **Yes** X **No** ______

Remarks: (Include photo numbers here or on a separate sheet.)

SOIL

Sampling Point: Plot-2

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

Depth	Matrix		Redox Features					
(inches)	Color (moist)	%	Color (moist)	%	Type[1]	Loc[2]	Texture	Remarks
0-7"	10YR 4/2	80	10YR 3/1	20		M	Silt loam	
7-12"	10YR 5/4	100						

[1]Type: C=Concentration, D=Depletion, RM=Reduced Matrix, MS=Masked Sand Grains. [2]Location: PL=Pore Lining, M=Matrix.

Hydric Soil Indicators:

- ___ Histosol (A1)
- ___ Histic Epipedon (A2)
- ___ Black Histic (A3)
- ___ Hydrogen Sulfide (A4)
- ___ Stratified Layers (A5)
- ___ 2 cm Muck (A10) **(LRR N)**
- ___ Depleted Below Dark Surface (A11)
- ___ Thick Dark Surface (A12)
- ___ Sandy Mucky Mineral (S1) **(LRR N, MLRA 147, 148)**
- ___ Sandy Gleyed Matrix (S4)
- ___ Sandy Redox (S5)
- ___ Stripped Matrix (S6)
- ___ Dark Surface (S7)
- ___ Polyvalue Below Surface (S8) **(MLRA 147, 148)**
- ___ Thin Dark Surface (S9) **(MLRA 147, 148)**
- ___ Loamy Gleyed Matrix (F2)
- ☐ Depleted Matrix (F3)
- ___ Redox Dark Surface (F6)
- ___ Depleted Dark Surface (F7)
- ___ Redox Depressions (F8)
- ___ Iron-Manganese Masses (F12) **(LRR N, MLRA 136)**
- ___ Umbric Surface (F13) **(MLRA 136, 122)**
- ___ Piedmont Floodplain Soils (F19) **(MLRA 148)**
- ___ Red Parent Material (F21) **(MLRA 127, 147)**

Indicators for Problematic Hydric Soils[3]:

- ___ 2 cm Muck (A10) **(MLRA 147)**
- ___ Coast Prairie Redox (A16) **(MLRA 147, 148)**
- ___ Piedmont Floodplain Soils (F19) **(MLRA 136, 147)**
- ___ Very Shallow Dark Surface (TF12)
- ___ Other (Explain in Remarks)

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

Restrictive Layer (if observed):

Type: ______

Depth (inches): ______

Hydric Soil Present? Yes ______ No x

Remarks:

WETLAND DETERMINATION DATA FORM – Eastern Mountains and Piedmont Region

Project/Site: Thesis Research City/County: ______ Sampling Date: 06-11-2017

Applicant/Owner: ______ State: TN Sampling Point: Plot-3

Investigator(s): C. Liggett Section, Township, Range: ______

Landform (hillslope, terrace, etc.): Depression Local relief (concave, convex, none): Concave Slope (%): <2%

Subregion (LRR or MLRA): LRR N Lat: ______ Long: ______ Datum: ______

Soil Map Unit Name: Lindell Silt Loam NWI classification: ______

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

Are Vegetation ___, Soil ___, or Hydrology ___ significantly disturbed? Are "Normal Circumstances" present? Yes X No ___

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

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

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

Remarks:

HYDROLOGY

Wetland Hydrology Indicators:

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

- [ ] Surface Water (A1)
- [ ] High Water Table (A2)
- [ ] Saturation (A3)
- [ ] Water Marks (B1)
- [ ] Sediment Deposits (B2)
- [ ] Drift Deposits (B3)
- [ ] Algal Mat or Crust (B4)
- [ ] Iron Deposits (B5)
- [ ] Inundation Visible on Aerial Imagery (B7)
- [ ] Water-Stained Leaves (B9)
- [ ] Aquatic Fauna (B13)
- [ ] True Aquatic Plants (B14)
- [ ] Hydrogen Sulfide Odor (C1)
- [x] Oxidized Rhizospheres on Living Roots (C3)
- [ ] Presence of Reduced Iron (C4)
- [ ] Recent Iron Reduction in Tilled Soils (C6)
- [ ] Thin Muck Surface (C7)
- [ ] Other (Explain in Remarks)

Secondary Indicators (minimum of two required)

- [ ] Surface Soil Cracks (B6)
- [ ] Sparsely Vegetated Concave Surface (B8)
- [ ] Drainage Patterns (B10)
- [ ] Moss Trim Lines (B16)
- [ ] Dry-Season Water Table (C2)
- [ ] Crayfish Burrows (C8)
- [ ] Saturation Visible on Aerial Imagery (C9)
- [ ] Stunted or Stressed Plants (D1)
- [x] Geomorphic Position (D2)
- [ ] Shallow Aquitard (D3)
- [ ] Microtopographic Relief (D4)
- [ ] FAC-Neutral Test (D5)

Field Observations:

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

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

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

Wetland Hydrology Present? Yes x **No** ___

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

Remarks:

VEGETATION (Five Strata) – Use scientific names of plants.

Sampling Point: Plot-3

Tree Stratum (Plot size:)	Absolute % Cover	Dominant Species?	Indicator Status
1.			
2.			
3.			
4.			
5.			
6.			
	= Total Cover		
50% of total cover:	20% of total cover:		

Sapling Stratum (Plot size:)	Absolute % Cover	Dominant Species?	Indicator Status
1.			
2.			
3.			
4.			
5.			
6.			
	= Total Cover		
50% of total cover:	20% of total cover:		

Shrub Stratum (Plot size:)	Absolute % Cover	Dominant Species?	Indicator Status
1.			
2.			
3.			
4.			
5.			
6.			
	= Total Cover		
50% of total cover:	20% of total cover:		

Herb Stratum (Plot size:)	Absolute % Cover	Dominant Species?	Indicator Status
1. Eupatorium album	30	Yes	NI
2. Lespedeza angustifolia	25	Yes	FAC
3. Sibara virginica	20	Yes	UPL
4. Ptilimnium costatum	10	No	FACW
5. Ranunculuus	5	No	FACW
6. Rumex crispus	5	No	FAC
7. Chasmathium latifolium	5	No	FACU
8.			
9.			
10.			
11.			
	100 = Total Cover		
50% of total cover: 50	20% of total cover: 20		

Woody Vine Stratum (Plot size:)	Absolute % Cover	Dominant Species?	Indicator Status
1.			
2.			
3.			
4.			
5.			
	= Total Cover		
50% of total cover:	20% of total cover:		

Dominance Test worksheet:

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

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

Percent of Dominant Species That Are OBL, FACW, or FAC: 33% (A/B)

Prevalence Index worksheet:

Total % Cover of:		Multiply by:
OBL species	0	x 1 = 0
FACW species	15	x 2 = 30
FAC species	30	x 3 = 90
FACU species	5	x 4 = 20
UPL species	20	x 5 = 100
Column Totals:	70 (A)	240 (B)

Prevalence Index = B/A = 3.43

Hydrophytic Vegetation Indicators:

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

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

Definitions of Five Vegetation Strata:

Tree – Woody plants, excluding woody vines, approximately 20 ft (6 m) or more in height and 3 in. (7.6 cm) or larger in diameter at breast height (DBH).

Sapling – Woody plants, excluding woody vines, approximately 20 ft (6 m) or more in height and less than 3 in. (7.6 cm) DBH.

Shrub – Woody plants, excluding woody vines, approximately 3 to 20 ft (1 to 6 m) in height.

Herb – All herbaceous (non-woody) plants, including herbaceous vines, regardless of size, and woody plants, except woody vines, less than approximately 3 ft (1 m) in height.

Woody vine – All woody vines, regardless of height.

Hydrophytic Vegetation Present? **Yes** ______ **No** X

Remarks: (Include photo numbers here or on a separate sheet.)

SOIL

Sampling Point: Plot-3

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

Depth	Matrix		Redox Features					
(inches)	Color (moist)	%	Color (moist)	%	Type[1]	Loc[2]	Texture	Remarks
0-7"	10YR 4/2	85	7.5YR 4/6	15	C	PL/M	Silt loam	
7-12"	10YR 6/4	100					Clay loam	

[1]Type: C=Concentration, D=Depletion, RM=Reduced Matrix, MS=Masked Sand Grains. [2]Location: PL=Pore Lining, M=Matrix.

Hydric Soil Indicators:

- ___ Histosol (A1)
- ___ Histic Epipedon (A2)
- ___ Black Histic (A3)
- ___ Hydrogen Sulfide (A4)
- ___ Stratified Layers (A5)
- ___ 2 cm Muck (A10) **(LRR N)**
- ___ Depleted Below Dark Surface (A11)
- ___ Thick Dark Surface (A12)
- ___ Sandy Mucky Mineral (S1) **(LRR N, MLRA 147, 148)**
- ___ Sandy Gleyed Matrix (S4)
- ___ Sandy Redox (S5)
- ___ Stripped Matrix (S6)
- ___ Dark Surface (S7)
- ___ Polyvalue Below Surface (S8) **(MLRA 147, 148)**
- ___ Thin Dark Surface (S9) **(MLRA 147, 148)**
- ___ Loamy Gleyed Matrix (F2)
- ✓ Depleted Matrix (F3)
- ___ Redox Dark Surface (F6)
- ___ Depleted Dark Surface (F7)
- ___ Redox Depressions (F8)
- ___ Iron-Manganese Masses (F12) **(LRR N, MLRA 136)**
- ___ Umbric Surface (F13) **(MLRA 136, 122)**
- ___ Piedmont Floodplain Soils (F19) **(MLRA 148)**
- ___ Red Parent Material (F21) **(MLRA 127, 147)**

Indicators for Problematic Hydric Soils[3]:

- ___ 2 cm Muck (A10) **(MLRA 147)**
- ___ Coast Prairie Redox (A16) **(MLRA 147, 148)**
- ___ Piedmont Floodplain Soils (F19) **(MLRA 136, 147)**
- ___ Very Shallow Dark Surface (TF12)
- ___ Other (Explain in Remarks)

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

Restrictive Layer (if observed):

Type: ______

Depth (inches): ______

Hydric Soil Present? **Yes** X **No** ______

Remarks:

WETLAND DETERMINATION DATA FORM – Eastern Mountains and Piedmont Region

Project/Site: Thesis Research City/County: ______ Sampling Date: 06-11-2017

Applicant/Owner: ______ State: TN Sampling Point: Plot-4

Investigator(s): C. Liggett Section, Township, Range: ______

Landform (hillslope, terrace, etc.): Depression Local relief (concave, convex, none): Concave Slope (%): <2%

Subregion (LRR or MLRA): LRR N Lat: ______ Long: ______ Datum: ______

Soil Map Unit Name: Lindell Silt Loam NWI classification: ______

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

Are Vegetation ___, Soil ___, or Hydrology ___ significantly disturbed? Are "Normal Circumstances" present? Yes X No ___

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

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

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

Remarks:

HYDROLOGY

Wetland Hydrology Indicators:

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

- [ ] Surface Water (A1)
- [ ] High Water Table (A2)
- [ ] Saturation (A3)
- [ ] Water Marks (B1)
- [ ] Sediment Deposits (B2)
- [ ] Drift Deposits (B3)
- [x] Algal Mat or Crust (B4)
- [ ] Iron Deposits (B5)
- [ ] Inundation Visible on Aerial Imagery (B7)
- [x] Water-Stained Leaves (B9)
- [ ] Aquatic Fauna (B13)
- [ ] True Aquatic Plants (B14)
- [ ] Hydrogen Sulfide Odor (C1)
- [ ] Oxidized Rhizospheres on Living Roots (C3)
- [ ] Presence of Reduced Iron (C4)
- [ ] Recent Iron Reduction in Tilled Soils (C6)
- [ ] Thin Muck Surface (C7)
- [ ] Other (Explain in Remarks)

Secondary Indicators (minimum of two required)

- [x] Surface Soil Cracks (B6)
- [ ] Sparsely Vegetated Concave Surface (B8)
- [ ] Drainage Patterns (B10)
- [ ] Moss Trim Lines (B16)
- [ ] Dry-Season Water Table (C2)
- [ ] Crayfish Burrows (C8)
- [ ] Saturation Visible on Aerial Imagery (C9)
- [ ] Stunted or Stressed Plants (D1)
- [ ] Geomorphic Position (D2)
- [ ] Shallow Aquitard (D3)
- [ ] Microtopographic Relief (D4)
- [x] FAC-Neutral Test (D5)

Field Observations:

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

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

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

Wetland Hydrology Present? Yes X **No** ___

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

Remarks:

VEGETATION (Five Strata) – Use scientific names of plants.

Sampling Point: Plot-4

Tree Stratum (Plot size:)	Absolute % Cover	Dominant Species?	Indicator Status
1.			
2.			
3.			
4.			
5.			
6.			
	= Total Cover		
50% of total cover:	20% of total cover:		

Sapling Stratum (Plot size:)	Absolute % Cover	Dominant Species?	Indicator Status
1. Fraxinus pennsylvanica	20	Yes	FACW
2. Salix nigra	5	No	OBL
3. Ulmus americana	5	No	FACW
4.			
5.			
6.			
	30 = Total Cover		
50% of total cover: 15	20% of total cover: 6		

Shrub Stratum (Plot size:)	Absolute % Cover	Dominant Species?	Indicator Status
1.			
2.			
3.			
4.			
5.			
6.			
	= Total Cover		
50% of total cover:	20% of total cover:		

Herb Stratum (Plot size:)	Absolute % Cover	Dominant Species?	Indicator Status
1. Carex vulipnoidea	20	Yes	OBL
2. Lespedeza angustifolia	20	Yes	FAC
3. Typha angustifolia	10	Yes	OBL
4. Typha latifolia	10	No	OBL
5. Carex frankii	10	No	FACW
6. Dicanthelium clandestinum	10	No	FAC
7. Juncus effusus	5	No	FACW
8. Solidago canadensis	5	No	FACU
9. Leersia oryzoides	5	No	OBL
10. Juncus tenuis	5	No	FAC
11.			
	100 = Total Cover		
50% of total cover: 50	20% of total cover: 20		

Woody Vine Stratum (Plot size:)	Absolute % Cover	Dominant Species?	Indicator Status
1.			
2.			
3.			
4.			
5.			
	= Total Cover		
50% of total cover:	20% of total cover:		

Dominance Test worksheet:

Number of Dominant Species That Are OBL, FACW, or FAC: 4 (A)

Total Number of Dominant Species Across All Strata: 4 (B)

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

Prevalence Index worksheet:

Total % Cover of:		Multiply by:
OBL species	50	x 1 = 50
FACW species	40	x 2 = 80
FAC species	35	x 3 = 105
FACU species	5	x 4 = 20
UPL species	0	x 5 = 0
Column Totals:	130 (A)	255 (B)

Prevalence Index = B/A = 1.96

Hydrophytic Vegetation Indicators:

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

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

Definitions of Five Vegetation Strata:

Tree – Woody plants, excluding woody vines, approximately 20 ft (6 m) or more in height and 3 in. (7.6 cm) or larger in diameter at breast height (DBH).

Sapling – Woody plants, excluding woody vines, approximately 20 ft (6 m) or more in height and less than 3 in. (7.6 cm) DBH.

Shrub – Woody plants, excluding woody vines, approximately 3 to 20 ft (1 to 6 m) in height.

Herb – All herbaceous (non-woody) plants, including herbaceous vines, regardless of size, and woody plants, except woody vines, less than approximately 3 ft (1 m) in height.

Woody vine – All woody vines, regardless of height.

Hydrophytic Vegetation Present? **Yes** X **No** ___

Remarks: (Include photo numbers here or on a separate sheet.)

SOIL

Sampling Point: Plot-4

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

Depth	Matrix		Redox Features					
(inches)	Color (moist)	%	Color (moist)	%	Type[1]	Loc[2]	Texture	Remarks
0-8"	10YR 4/2	85	7.5YR 4/6	15	C	M	Silt loam	
8-12"	10YR 3/2	100						

[1]Type: C=Concentration, D=Depletion, RM=Reduced Matrix, MS=Masked Sand Grains. [2]Location: PL=Pore Lining, M=Matrix.

Hydric Soil Indicators:

- ___ Histosol (A1)
- ___ Histic Epipedon (A2)
- ___ Black Histic (A3)
- ___ Hydrogen Sulfide (A4)
- ___ Stratified Layers (A5)
- ___ 2 cm Muck (A10) **(LRR N)**
- ___ Depleted Below Dark Surface (A11)
- ___ Thick Dark Surface (A12)
- ___ Sandy Mucky Mineral (S1) **(LRR N, MLRA 147, 148)**
- ___ Sandy Gleyed Matrix (S4)
- ___ Sandy Redox (S5)
- ___ Stripped Matrix (S6)
- ___ Dark Surface (S7)
- ___ Polyvalue Below Surface (S8) **(MLRA 147, 148)**
- ___ Thin Dark Surface (S9) **(MLRA 147, 148)**
- ___ Loamy Gleyed Matrix (F2)
- ✓ Depleted Matrix (F3)
- ___ Redox Dark Surface (F6)
- ___ Depleted Dark Surface (F7)
- ___ Redox Depressions (F8)
- ___ Iron-Manganese Masses (F12) **(LRR N, MLRA 136)**
- ___ Umbric Surface (F13) **(MLRA 136, 122)**
- ___ Piedmont Floodplain Soils (F19) **(MLRA 148)**
- ___ Red Parent Material (F21) **(MLRA 127, 147)**

Indicators for Problematic Hydric Soils[3]:

- ___ 2 cm Muck (A10) **(MLRA 147)**
- ___ Coast Prairie Redox (A16) **(MLRA 147, 148)**
- ___ Piedmont Floodplain Soils (F19) **(MLRA 136, 147)**
- ___ Very Shallow Dark Surface (TF12)
- ___ Other (Explain in Remarks)

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

Restrictive Layer (if observed):

Type: ______

Depth (inches): ______

Hydric Soil Present? Yes X **No** ______

Remarks:

WETLAND DETERMINATION DATA FORM – Eastern Mountains and Piedmont Region

Project/Site: Thesis Research City/County: ______ Sampling Date: 06-11-2017

Applicant/Owner: ______ State: TN Sampling Point: Plot-5

Investigator(s): C. Liggett Section, Township, Range: ______

Landform (hillslope, terrace, etc.): Depression Local relief (concave, convex, none): Concave Slope (%): <2%

Subregion (LRR or MLRA): LRR N Lat: ______ Long: ______ Datum: ______

Soil Map Unit Name: Lindell Silt Loam NWI classification: ______

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

Are Vegetation ___, Soil ___, or Hydrology ___ significantly disturbed? Are "Normal Circumstances" present? Yes X No ___

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

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

Hydrophytic Vegetation Present?	Yes X	No ___
Hydric Soil Present?	Yes X	No ___
Wetland Hydrology Present?	Yes X	No ___

Is the Sampled Area within a Wetland? **Yes** X **No** ___

Remarks:

HYDROLOGY

Wetland Hydrology Indicators:

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

- ☐ Surface Water (A1)
- ☐ High Water Table (A2)
- ☐ Saturation (A3)
- ☐ Water Marks (B1)
- ☐ Sediment Deposits (B2)
- ☐ Drift Deposits (B3)
- ☐ Algal Mat or Crust (B4)
- ☐ Iron Deposits (B5)
- ☐ Inundation Visible on Aerial Imagery (B7)
- ☑ Water-Stained Leaves (B9)
- ☐ Aquatic Fauna (B13)
- ☐ True Aquatic Plants (B14)
- ☐ Hydrogen Sulfide Odor (C1)
- ☐ Oxidized Rhizospheres on Living Roots (C3)
- ☐ Presence of Reduced Iron (C4)
- ☐ Recent Iron Reduction in Tilled Soils (C6)
- ☐ Thin Muck Surface (C7)
- ☐ Other (Explain in Remarks)

Secondary Indicators (minimum of two required)

- ☐ Surface Soil Cracks (B6)
- ☐ Sparsely Vegetated Concave Surface (B8)
- ☐ Drainage Patterns (B10)
- ☐ Moss Trim Lines (B16)
- ☐ Dry-Season Water Table (C2)
- ☐ Crayfish Burrows (C8)
- ☐ Saturation Visible on Aerial Imagery (C9)
- ☐ Stunted or Stressed Plants (D1)
- ☐ Geomorphic Position (D2)
- ☐ Shallow Aquitard (D3)
- ☐ Microtopographic Relief (D4)
- ☑ FAC-Neutral Test (D5)

Field Observations:

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

Wetland Hydrology Present? **Yes** X **No** ___

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

Remarks:

VEGETATION (Five Strata) – Use scientific names of plants.

Sampling Point: Plot-5

Tree Stratum (Plot size:)	Absolute % Cover	Dominant Species?	Indicator Status
1.			
2.			
3.			
4.			
5.			
6.			
		= Total Cover	
50% of total cover:		20% of total cover:	

Sapling Stratum (Plot size:)	Absolute % Cover	Dominant Species?	Indicator Status
1. Fraxinus pennsylvanica	10	Yes	FACW
2. Acer rubrum	5	Yes	FAC
3. Populus deltoides	5	Yes	FAC
4.			
5.			
6.			
	20	= Total Cover	
50% of total cover: 10		20% of total cover: 4	

Shrub Stratum (Plot size:)	Absolute % Cover	Dominant Species?	Indicator Status
1.			
2.			
3.			
4.			
5.			
6.			
		= Total Cover	
50% of total cover:		20% of total cover:	

Herb Stratum (Plot size:)	Absolute % Cover	Dominant Species?	Indicator Status
1. Carex vulipnoidea	20	Yes	OBL
2. Carex frankii	15	Yes	OBL
3. Dicanthelium clandestinum	15	Yes	FAC
4. Juncus effusus	15	No	FACW
5. Leersia oryzoides	15	No	OBL
6. Solidago gigantea	10	No	FACW
7. Lespedeza angustifolia	10	No	FAC
8.			
9.			
10.			
11.			
	100	= Total Cover	
50% of total cover: 50		20% of total cover: 20	

Woody Vine Stratum (Plot size:)	Absolute % Cover	Dominant Species?	Indicator Status
1.			
2.			
3.			
4.			
5.			
		= Total Cover	
50% of total cover:		20% of total cover:	

Dominance Test worksheet:

Number of Dominant Species That Are OBL, FACW, or FAC: 6 (A)

Total Number of Dominant Species Across All Strata: 6 (B)

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

Prevalence Index worksheet:

Total % Cover of:		Multiply by:	
OBL species	50	x 1 =	50
FACW species	35	x 2 =	70
FAC species	35	x 3 =	105
FACU species	0	x 4 =	0
UPL species	0	x 5 =	0
Column Totals:	120 (A)		225 (B)

Prevalence Index = B/A = 1.88

Hydrophytic Vegetation Indicators:

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

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

Definitions of Five Vegetation Strata:

Tree – Woody plants, excluding woody vines, approximately 20 ft (6 m) or more in height and 3 in. (7.6 cm) or larger in diameter at breast height (DBH).

Sapling – Woody plants, excluding woody vines, approximately 20 ft (6 m) or more in height and less than 3 in. (7.6 cm) DBH.

Shrub – Woody plants, excluding woody vines, approximately 3 to 20 ft (1 to 6 m) in height.

Herb – All herbaceous (non-woody) plants, including herbaceous vines, regardless of size, and woody plants, except woody vines, less than approximately 3 ft (1 m) in height.

Woody vine – All woody vines, regardless of height.

Hydrophytic Vegetation Present? **Yes** X **No** ___

Remarks: (Include photo numbers here or on a separate sheet.)

SOIL Sampling Point: Plot-5

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

Depth (inches)	Matrix Color (moist)	Matrix %	Redox Features Color (moist)	Redox %	Type[1]	Loc[2]	Texture	Remarks
0-5"	10YR 4/2	90	7.5YR 5/8	10	C	M	Silt loam	
5-9"	10YR 5/3	60	7.5YR 5/8	40	C	M	Clay loam	
9-12"+	10YR 5/4	60	7.5YR 4/6	40	C	M	Clay loam	

[1]Type: C=Concentration, D=Depletion, RM=Reduced Matrix, MS=Masked Sand Grains. [2]Location: PL=Pore Lining, M=Matrix.

Hydric Soil Indicators:

- ___ Histosol (A1)
- ___ Histic Epipedon (A2)
- ___ Black Histic (A3)
- ___ Hydrogen Sulfide (A4)
- ___ Stratified Layers (A5)
- ___ 2 cm Muck (A10) **(LRR N)**
- ___ Depleted Below Dark Surface (A11)
- ___ Thick Dark Surface (A12)
- ___ Sandy Mucky Mineral (S1) **(LRR N, MLRA 147, 148)**
- ___ Sandy Gleyed Matrix (S4)
- ___ Sandy Redox (S5)
- ___ Stripped Matrix (S6)
- ___ Dark Surface (S7)
- ___ Polyvalue Below Surface (S8) **(MLRA 147, 148)**
- ___ Thin Dark Surface (S9) **(MLRA 147, 148)**
- ___ Loamy Gleyed Matrix (F2)
- ✓ Depleted Matrix (F3)
- ___ Redox Dark Surface (F6)
- ___ Depleted Dark Surface (F7)
- ___ Redox Depressions (F8)
- ___ Iron-Manganese Masses (F12) **(LRR N, MLRA 136)**
- ___ Umbric Surface (F13) **(MLRA 136, 122)**
- ___ Piedmont Floodplain Soils (F19) **(MLRA 148)**
- ___ Red Parent Material (F21) **(MLRA 127, 147)**

Indicators for Problematic Hydric Soils[3]:

- ___ 2 cm Muck (A10) **(MLRA 147)**
- ___ Coast Prairie Redox (A16) **(MLRA 147, 148)**
- ___ Piedmont Floodplain Soils (F19) **(MLRA 136, 147)**
- ___ Very Shallow Dark Surface (TF12)
- ___ Other (Explain in Remarks)

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

Restrictive Layer (if observed):

Type: ______

Depth (inches): ______

Hydric Soil Present? Yes X **No** ______

Remarks:

WETLAND DETERMINATION DATA FORM – Eastern Mountains and Piedmont Region

Project/Site: Thesis Research City/County: ______ Sampling Date: 06-11-2017

Applicant/Owner: ______ State: TN Sampling Point: Plot-6

Investigator(s): C. Liggett Section, Township, Range: ______

Landform (hillslope, terrace, etc.): Depression Local relief (concave, convex, none): Concave Slope (%): <2%

Subregion (LRR or MLRA): LRR N Lat: ______ Long: ______ Datum: ______

Soil Map Unit Name: Lindell Silt Loam NWI classification: ______

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

Are Vegetation ___, Soil ___, or Hydrology ___ significantly disturbed? Are "Normal Circumstances" present? Yes X No ___

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

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

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

Remarks:

HYDROLOGY

Wetland Hydrology Indicators:

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

- [ ] Surface Water (A1)
- [ ] High Water Table (A2)
- [ ] Saturation (A3)
- [x] Water Marks (B1)
- [ ] Sediment Deposits (B2)
- [ ] Drift Deposits (B3)
- [ ] Algal Mat or Crust (B4)
- [ ] Iron Deposits (B5)
- [ ] Inundation Visible on Aerial Imagery (B7)
- [x] Water-Stained Leaves (B9)
- [ ] Aquatic Fauna (B13)
- [ ] True Aquatic Plants (B14)
- [ ] Hydrogen Sulfide Odor (C1)
- [x] Oxidized Rhizospheres on Living Roots (C3)
- [ ] Presence of Reduced Iron (C4)
- [ ] Recent Iron Reduction in Tilled Soils (C6)
- [ ] Thin Muck Surface (C7)
- [ ] Other (Explain in Remarks)

Secondary Indicators (minimum of two required)

- [ ] Surface Soil Cracks (B6)
- [ ] Sparsely Vegetated Concave Surface (B8)
- [x] Drainage Patterns (B10)
- [x] Moss Trim Lines (B16)
- [ ] Dry-Season Water Table (C2)
- [x] Crayfish Burrows (C8)
- [ ] Saturation Visible on Aerial Imagery (C9)
- [x] Stunted or Stressed Plants (D1)
- [ ] Geomorphic Position (D2)
- [ ] Shallow Aquitard (D3)
- [x] Microtopographic Relief (D4)
- [x] FAC-Neutral Test (D5)

Field Observations:

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

Wetland Hydrology Present? Yes X **No** ___

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

Remarks:

VEGETATION (Five Strata) – Use scientific names of plants.

Sampling Point: Plot-6

Tree Stratum (Plot size: ______)

	Absolute % Cover	Dominant Species?	Indicator Status
1. Ulmus Americana	25	Yes	FACW
2. Celtis Laevigata	20	Yes	FACW
3. Fraxinus pennsylvanica	20	Yes	FACW
4.			
5.			
6.			
	65 = Total Cover		

50% of total cover: 33 20% of total cover: 13

Sapling Stratum (Plot size: ______)

	Absolute % Cover	Dominant Species?	Indicator Status
1. Fraxinus pennsylvanica	35	Yes	FACW
2. Cornus amomum	10	Yes	FACW
3. Ligustrum sinense	10	Yes	FACU
4. Juniperus virginiana	5	No	FACU
5.			
6.			
	60 = Total Cover		

50% of total cover: 30 20% of total cover: 12

Shrub Stratum (Plot size: ______)

	Absolute % Cover	Dominant Species?	Indicator Status
1.			
2.			
3.			
4.			
5.			
6.			
	____ = Total Cover		

50% of total cover: ____ 20% of total cover: ____

Herb Stratum (Plot size: ______)

	Absolute % Cover	Dominant Species?	Indicator Status
1. Panicum rigidulum	35	Yes	FACW
2. Dicanthelium clandestinum	25	Yes	FAC
3. Carex vulpinoidea	15	No	OBL
4. Carex frankii	15	No	OBL
5. Scirpus atrovirens	10	No	OBL
6.			
7.			
8.			
9.			
10.			
11.			
	100 = Total Cover		

50% of total cover: 50 20% of total cover: 20

Woody Vine Stratum (Plot size: ______)

	Absolute % Cover	Dominant Species?	Indicator Status
1. Toxicodendron radicans	5	Yes	FAC
2. Parthenocissus quinquefolia	5	Yes	FACU
3. Campsis radicans	5	No	FAC
4.			
5.			
	15 = Total Cover		

50% of total cover: 7.5 20% of total cover: 3

Dominance Test worksheet:

Number of Dominant Species That Are OBL, FACW, or FAC: 7 (A)

Total Number of Dominant Species Across All Strata: 9 (B)

Percent of Dominant Species That Are OBL, FACW, or FAC: 78% (A/B)

Prevalence Index worksheet:

Total % Cover of:		Multiply by:
OBL species	40	x 1 = 40
FACW species	145	x 2 = 290
FAC species	35	x 3 = 105
FACU species	20	x 4 = 80
UPL species	0	x 5 = 0
Column Totals:	240 (A)	505 (B)

Prevalence Index = B/A = 2.15

Hydrophytic Vegetation Indicators:

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

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

Definitions of Five Vegetation Strata:

Tree – Woody plants, excluding woody vines, approximately 20 ft (6 m) or more in height and 3 in. (7.6 cm) or larger in diameter at breast height (DBH).

Sapling – Woody plants, excluding woody vines, approximately 20 ft (6 m) or more in height and less than 3 in. (7.6 cm) DBH.

Shrub – Woody plants, excluding woody vines, approximately 3 to 20 ft (1 to 6 m) in height.

Herb – All herbaceous (non-woody) plants, including herbaceous vines, regardless of size, and woody plants, except woody vines, less than approximately 3 ft (1 m) in height.

Woody vine – All woody vines, regardless of height.

Hydrophytic Vegetation Present? **Yes** X **No** ____

Remarks: (Include photo numbers here or on a separate sheet.)

SOIL

Sampling Point: Plot-6

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

Depth	Matrix		Redox Features					
(inches)	Color (moist)	%	Color (moist)	%	Type[1]	Loc[2]	Texture	Remarks
0-12"	10YR 4/2	80	7.5YR 4/6	20	C	PL/M	Silt loam	

[1]Type: C=Concentration, D=Depletion, RM=Reduced Matrix, MS=Masked Sand Grains. [2]Location: PL=Pore Lining, M=Matrix.

Hydric Soil Indicators:

- ___ Histosol (A1)
- ___ Histic Epipedon (A2)
- ___ Black Histic (A3)
- ☐ Hydrogen Sulfide (A4)
- ___ Stratified Layers (A5)
- ___ 2 cm Muck (A10) **(LRR N)**
- ___ Depleted Below Dark Surface (A11)
- ___ Thick Dark Surface (A12)
- ___ Sandy Mucky Mineral (S1) **(LRR N, MLRA 147, 148)**
- ___ Sandy Gleyed Matrix (S4)
- ___ Sandy Redox (S5)
- ___ Stripped Matrix (S6)
- ___ Dark Surface (S7)
- ___ Polyvalue Below Surface (S8) **(MLRA 147, 148)**
- ___ Thin Dark Surface (S9) **(MLRA 147, 148)**
- ___ Loamy Gleyed Matrix (F2)
- ☑ Depleted Matrix (F3)
- ___ Redox Dark Surface (F6)
- ___ Depleted Dark Surface (F7)
- ___ Redox Depressions (F8)
- ☐ Iron-Manganese Masses (F12) **(LRR N, MLRA 136)**
- ___ Umbric Surface (F13) **(MLRA 136, 122)**
- ___ Piedmont Floodplain Soils (F19) **(MLRA 148)**
- ___ Red Parent Material (F21) **(MLRA 127, 147)**

Indicators for Problematic Hydric Soils[3]:

- ___ 2 cm Muck (A10) **(MLRA 147)**
- ___ Coast Prairie Redox (A16) **(MLRA 147, 148)**
- ___ Piedmont Floodplain Soils (F19) **(MLRA 136, 147)**
- ___ Very Shallow Dark Surface (TF12)
- ___ Other (Explain in Remarks)

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

Restrictive Layer (if observed):

Type: ______

Depth (inches): ______

Hydric Soil Present? Yes X **No** ______

Remarks:

WETLAND DETERMINATION DATA FORM – Eastern Mountains and Piedmont Region

Project/Site: Thesis Research City/County: ______ Sampling Date: 06-11-2017

Applicant/Owner: ______ State: TN Sampling Point: Plot-7

Investigator(s): C. Liggett Section, Township, Range: ______

Landform (hillslope, terrace, etc.): Depression Local relief (concave, convex, none): Concave Slope (%): <2%

Subregion (LRR or MLRA): LRR N Lat: ______ Long: ______ Datum: ______

Soil Map Unit Name: Lindell Silt Loam NWI classification: ______

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

Are Vegetation ___, Soil ___, or Hydrology ___ significantly disturbed? Are "Normal Circumstances" present? Yes X No ___

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

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

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

Remarks:

HYDROLOGY

Wetland Hydrology Indicators:

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

- [ ] Surface Water (A1)
- [ ] High Water Table (A2)
- [ ] Saturation (A3)
- [ ] Water Marks (B1)
- [ ] Sediment Deposits (B2)
- [ ] Drift Deposits (B3)
- [ ] Algal Mat or Crust (B4)
- [ ] Iron Deposits (B5)
- [ ] Inundation Visible on Aerial Imagery (B7)
- [x] Water-Stained Leaves (B9)
- [ ] Aquatic Fauna (B13)
- [ ] True Aquatic Plants (B14)
- [ ] Hydrogen Sulfide Odor (C1)
- [x] Oxidized Rhizospheres on Living Roots (C3)
- [ ] Presence of Reduced Iron (C4)
- [ ] Recent Iron Reduction in Tilled Soils (C6)
- [ ] Thin Muck Surface (C7)
- [ ] Other (Explain in Remarks)

Secondary Indicators (minimum of two required)

- [ ] Surface Soil Cracks (B6)
- [ ] Sparsely Vegetated Concave Surface (B8)
- [x] Drainage Patterns (B10)
- [ ] Moss Trim Lines (B16)
- [ ] Dry-Season Water Table (C2)
- [ ] Crayfish Burrows (C8)
- [ ] Saturation Visible on Aerial Imagery (C9)
- [x] Stunted or Stressed Plants (D1)
- [ ] Geomorphic Position (D2)
- [ ] Shallow Aquitard (D3)
- [x] Microtopographic Relief (D4)
- [ ] FAC-Neutral Test (D5)

Field Observations:

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

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

Remarks:

VEGETATION (Five Strata) – Use scientific names of plants.

Sampling Point: Plot-7

Tree Stratum (Plot size:)	Absolute % Cover	Dominant Species?	Indicator Status
1. Ulmus Americana	30	Yes	FACW
2. Celtis laevigata	25	Yes	FACW
3. Fraxinus pennsylvanica	25	Yes	FACW
4.			
5.			
6.			
	80 = Total Cover		
50% of total cover: 40	20% of total cover: 16		

Sapling Stratum (Plot size:)	Absolute % Cover	Dominant Species?	Indicator Status
1. Cornus amomum	15	Yes	FACW
2. Ligustrum sinense	10	Yes	FACU
3. Fraxinus pennsylvanica	5	No	FACW
4. Juniperus virginiana	5	No	FACU
5.			
6.			
	35 = Total Cover		
50% of total cover: 17.5	20% of total cover: 7		

Shrub Stratum (Plot size:)	Absolute % Cover	Dominant Species?	Indicator Status
1.			
2.			
3.			
4.			
5.			
6.			
	= Total Cover		
50% of total cover:	20% of total cover:		

Herb Stratum (Plot size:)	Absolute % Cover	Dominant Species?	Indicator Status
1. Panicum capillare	35	Yes	FAC
2. Dicanthelium clandestinum	25	Yes	FAC
3. Eupatorium album	10	No	NI
4. Juncus tenuis	10	No	FAC
5.			
6.			
7.			
8.			
9.			
10.			
11.			
	80 = Total Cover		
50% of total cover: 40	20% of total cover: 16		

Woody Vine Stratum (Plot size:)	Absolute % Cover	Dominant Species?	Indicator Status
1. Toxicodendron radicans	15	Yes	FAC
2. Parthenocissus quinquefolia	10	Yes	FACU
3. Campsis radicans	5	No	FAC
4.			
5.			
	30 = Total Cover		
50% of total cover: 15	20% of total cover: 6		

Dominance Test worksheet:

Number of Dominant Species That Are OBL, FACW, or FAC: 7 (A)

Total Number of Dominant Species Across All Strata: 9 (B)

Percent of Dominant Species That Are OBL, FACW, or FAC: 78% (A/B)

Prevalence Index worksheet:

Total % Cover of:		Multiply by:
OBL species	0	x 1 = 0
FACW species	100	x 2 = 200
FAC species	90	x 3 = 270
FACU species	25	x 4 = 100
UPL species	0	x 5 = 0
Column Totals:	190 (A)	570 (B)

Prevalence Index = B/A = 2.65

Hydrophytic Vegetation Indicators:

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

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

Definitions of Five Vegetation Strata:

Tree – Woody plants, excluding woody vines, approximately 20 ft (6 m) or more in height and 3 in. (7.6 cm) or larger in diameter at breast height (DBH).

Sapling – Woody plants, excluding woody vines, approximately 20 ft (6 m) or more in height and less than 3 in. (7.6 cm) DBH.

Shrub – Woody plants, excluding woody vines, approximately 3 to 20 ft (1 to 6 m) in height.

Herb – All herbaceous (non-woody) plants, including herbaceous vines, regardless of size, and woody plants, except woody vines, less than approximately 3 ft (1 m) in height.

Woody vine – All woody vines, regardless of height.

Hydrophytic Vegetation Present? **Yes** X **No** ___

Remarks: (Include photo numbers here or on a separate sheet.)

SOIL

Sampling Point: Plot-7

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

Depth	Matrix		Redox Features				Texture	Remarks
(inches)	Color (moist)	%	Color (moist)	%	Type[1]	Loc[2]		
0-1"	10YR 3/2	100					organics	
1-3"	10YR 4/2	100					silt loam	
3-12"	10YR 5/2	90	7.5YR 4/6	10	C	PL/M	silt loam	

[1]Type: C=Concentration, D=Depletion, RM=Reduced Matrix, MS=Masked Sand Grains. [2]Location: PL=Pore Lining, M=Matrix.

Hydric Soil Indicators:

- ___ Histosol (A1)
- ___ Histic Epipedon (A2)
- ___ Black Histic (A3)
- ___ Hydrogen Sulfide (A4)
- ___ Stratified Layers (A5)
- ___ 2 cm Muck (A10) **(LRR N)**
- ___ Depleted Below Dark Surface (A11)
- ___ Thick Dark Surface (A12)
- ___ Sandy Mucky Mineral (S1) **(LRR N, MLRA 147, 148)**
- ___ Sandy Gleyed Matrix (S4)
- ___ Sandy Redox (S5)
- ___ Stripped Matrix (S6)
- ___ Dark Surface (S7)
- ___ Polyvalue Below Surface (S8) **(MLRA 147, 148)**
- ___ Thin Dark Surface (S9) **(MLRA 147, 148)**
- ___ Loamy Gleyed Matrix (F2)
- ✓ Depleted Matrix (F3)
- ___ Redox Dark Surface (F6)
- ___ Depleted Dark Surface (F7)
- ___ Redox Depressions (F8)
- ☐ Iron-Manganese Masses (F12) **(LRR N, MLRA 136)**
- ___ Umbric Surface (F13) **(MLRA 136, 122)**
- ___ Piedmont Floodplain Soils (F19) **(MLRA 148)**
- ___ Red Parent Material (F21) **(MLRA 127, 147)**

Indicators for Problematic Hydric Soils[3]:

- ___ 2 cm Muck (A10) **(MLRA 147)**
- ___ Coast Prairie Redox (A16) **(MLRA 147, 148)**
- ___ Piedmont Floodplain Soils (F19) **(MLRA 136, 147)**
- ___ Very Shallow Dark Surface (TF12)
- ___ Other (Explain in Remarks)

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

Restrictive Layer (if observed):

Type: ______

Depth (inches): ______

Hydric Soil Present? Yes X **No** ______

Remarks:

WETLAND DETERMINATION DATA FORM – Eastern Mountains and Piedmont Region

Project/Site: Thesis Research City/County: ______ Sampling Date: 06-11-2017

Applicant/Owner: ______ State: TN Sampling Point: Preservation Area

Investigator(s): C. Liggett Section, Township, Range: ______

Landform (hillslope, terrace, etc.): Depression Local relief (concave, convex, none): Concave Slope (%): <2%

Subregion (LRR or MLRA): LRR N Lat: ______ Long: ______ Datum: ______

Soil Map Unit Name: Lindell Silt Loam NWI classification: ______

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

Are Vegetation ___, Soil ___, or Hydrology ___ significantly disturbed? Are "Normal Circumstances" present? Yes X No ___

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

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

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

Remarks:

HYDROLOGY

Wetland Hydrology Indicators:

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

- [ ] Surface Water (A1)
- [ ] High Water Table (A2)
- [ ] Saturation (A3)
- [ ] Water Marks (B1)
- [ ] Sediment Deposits (B2)
- [ ] Drift Deposits (B3)
- [ ] Algal Mat or Crust (B4)
- [ ] Iron Deposits (B5)
- [ ] Inundation Visible on Aerial Imagery (B7)
- [x] Water-Stained Leaves (B9)
- [ ] Aquatic Fauna (B13)
- [ ] True Aquatic Plants (B14)
- [ ] Hydrogen Sulfide Odor (C1)
- [x] Oxidized Rhizospheres on Living Roots (C3)
- [ ] Presence of Reduced Iron (C4)
- [ ] Recent Iron Reduction in Tilled Soils (C6)
- [ ] Thin Muck Surface (C7)
- [ ] Other (Explain in Remarks)

Secondary Indicators (minimum of two required)

- [ ] Surface Soil Cracks (B6)
- [ ] Sparsely Vegetated Concave Surface (B8)
- [x] Drainage Patterns (B10)
- [ ] Moss Trim Lines (B16)
- [ ] Dry-Season Water Table (C2)
- [ ] Crayfish Burrows (C8)
- [ ] Saturation Visible on Aerial Imagery (C9)
- [x] Stunted or Stressed Plants (D1)
- [ ] Geomorphic Position (D2)
- [ ] Shallow Aquitard (D3)
- [ ] Microtopographic Relief (D4)
- [ ] FAC-Neutral Test (D5)

Field Observations:

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

Wetland Hydrology Present? Yes X No ___

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

Remarks:

VEGETATION (Five Strata) – Use scientific names of plants.

Sampling Point: Preservation Area

Tree Stratum (Plot size: ______)	Absolute % Cover	Dominant Species?	Indicator Status
1. Ulmus Americana	30	Yes	FACW
2. Celtis Laevigata	25	Yes	FACW
3. Fraxinus pennsylvanica	25	Yes	FACW
4. Quercus palustris	10	No	FACW
5.			
6.			
	90 = Total Cover		
50% of total cover: 45	20% of total cover: 18		

Sapling Stratum (Plot size: ______)	Absolute % Cover	Dominant Species?	Indicator Status
1. Cornus amomum	15	Yes	FACW
2. Ligustrum sinense	10	Yes	FACU
3. Juniperus virginiana	5	No	FACU
4.			
5.			
6.			
	30 = Total Cover		
50% of total cover: 15	20% of total cover: 6		

Shrub Stratum (Plot size: ______)	Absolute % Cover	Dominant Species?	Indicator Status
1.			
2.			
3.			
4.			
5.			
6.			
	___ = Total Cover		
50% of total cover: ___	20% of total cover: ___		

Herb Stratum (Plot size: ______)	Absolute % Cover	Dominant Species?	Indicator Status
1. Juncus tenuis	30	Yes	FAC
2. Carex sp.	15	Yes	FAC
3. Echinochloa crus-galis	10	No	FAC
4. Panicum rigidulum	10	No	FACW
5. Solidago canadensis	10	No	FACU
6.			
7.			
8.			
9.			
10.			
11.			
	75 = Total Cover		
50% of total cover: 37.5	20% of total cover: 15		

Woody Vine Stratum (Plot size: ______)	Absolute % Cover	Dominant Species?	Indicator Status
1. Toxicodendron radicans	20	Yes	FAC
2. Parthenocissus quinquefolia	10	Yes	FACU
3. Campsis radicans	10	Yes	FAC
4.			
5.			
	40 = Total Cover		
50% of total cover: 20	20% of total cover: 8		

Dominance Test worksheet:

Number of Dominant Species That Are OBL, FACW, or FAC: 8 (A)

Total Number of Dominant Species Across All Strata: 10 (B)

Percent of Dominant Species That Are OBL, FACW, or FAC: 80% (A/B)

Prevalence Index worksheet:

Total % Cover of:		Multiply by:
OBL species	0	x 1 = 0
FACW species	115	x 2 = 230
FAC species	80	x 3 = 210
FACU species	35	x 4 = 60
UPL species	0	x 5 = 0
Column Totals:	230 (A)	500 (B)

Prevalence Index = B/A = 2.17

Hydrophytic Vegetation Indicators:

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

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

Definitions of Five Vegetation Strata:

Tree – Woody plants, excluding woody vines, approximately 20 ft (6 m) or more in height and 3 in. (7.6 cm) or larger in diameter at breast height (DBH).

Sapling – Woody plants, excluding woody vines, approximately 20 ft (6 m) or more in height and less than 3 in. (7.6 cm) DBH.

Shrub – Woody plants, excluding woody vines, approximately 3 to 20 ft (1 to 6 m) in height.

Herb – All herbaceous (non-woody) plants, including herbaceous vines, regardless of size, and woody plants, except woody vines, less than approximately 3 ft (1 m) in height.

Woody vine – All woody vines, regardless of height.

Hydrophytic Vegetation Present? **Yes** X **No** ___

Remarks: (Include photo numbers here or on a separate sheet.)

SOIL

Sampling Point: Preservation Area

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

Depth	Matrix		Redox Features					
(inches)	Color (moist)	%	Color (moist)	%	Type[1]	Loc[2]	Texture	Remarks
0-1"	10YR 3/2	100					organics	
1-3"	10YR 4/2	90	7.5YR 4/6	10	C	PL/M	silt loam	
3-12"	10YR 5/2	85	7.5YR 4/6	15	C	PL/M	silt loam	

[1]Type: C=Concentration, D=Depletion, RM=Reduced Matrix, MS=Masked Sand Grains. [2]Location: PL=Pore Lining, M=Matrix.

Hydric Soil Indicators:

- ___ Histosol (A1)
- ___ Histic Epipedon (A2)
- ___ Black Histic (A3)
- ___ Hydrogen Sulfide (A4)
- ___ Stratified Layers (A5)
- ___ 2 cm Muck (A10) **(LRR N)**
- ___ Depleted Below Dark Surface (A11)
- ___ Thick Dark Surface (A12)
- ___ Sandy Mucky Mineral (S1) **(LRR N, MLRA 147, 148)**
- ___ Sandy Gleyed Matrix (S4)
- ___ Sandy Redox (S5)
- ___ Stripped Matrix (S6)
- ___ Dark Surface (S7)
- ___ Polyvalue Below Surface (S8) **(MLRA 147, 148)**
- ___ Thin Dark Surface (S9) **(MLRA 147, 148)**
- ___ Loamy Gleyed Matrix (F2)
- ✓ Depleted Matrix (F3)
- ___ Redox Dark Surface (F6)
- ___ Depleted Dark Surface (F7)
- ___ Redox Depressions (F8)
- ___ Iron-Manganese Masses (F12) **(LRR N, MLRA 136)**
- ___ Umbric Surface (F13) **(MLRA 136, 122)**
- ___ Piedmont Floodplain Soils (F19) **(MLRA 148)**
- ___ Red Parent Material (F21) **(MLRA 127, 147)**

Indicators for Problematic Hydric Soils[3]:

- ___ 2 cm Muck (A10) **(MLRA 147)**
- ___ Coast Prairie Redox (A16) **(MLRA 147, 148)**
- ___ Piedmont Floodplain Soils (F19) **(MLRA 136, 147)**
- ___ Very Shallow Dark Surface (TF12)
- ___ Other (Explain in Remarks)

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

Restrictive Layer (if observed):

Type: ____________

Depth (inches): ____________

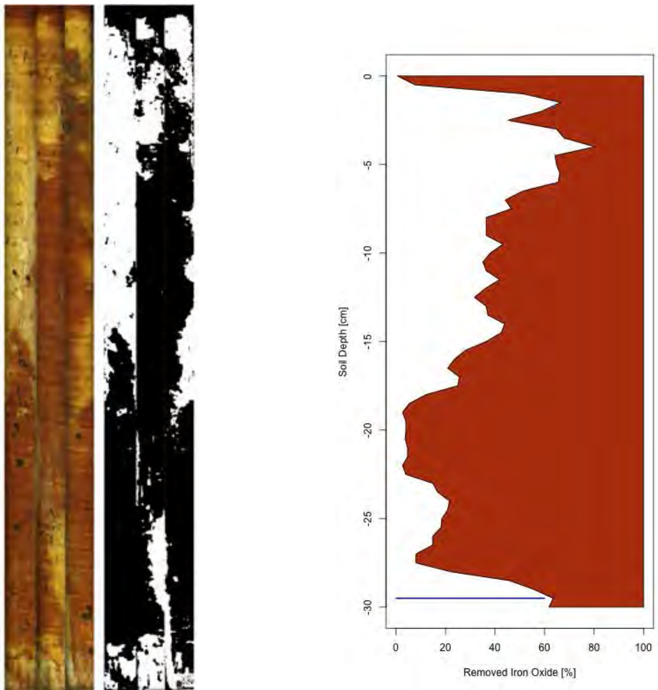
Hydric Soil Present? **Yes** X **No** ______

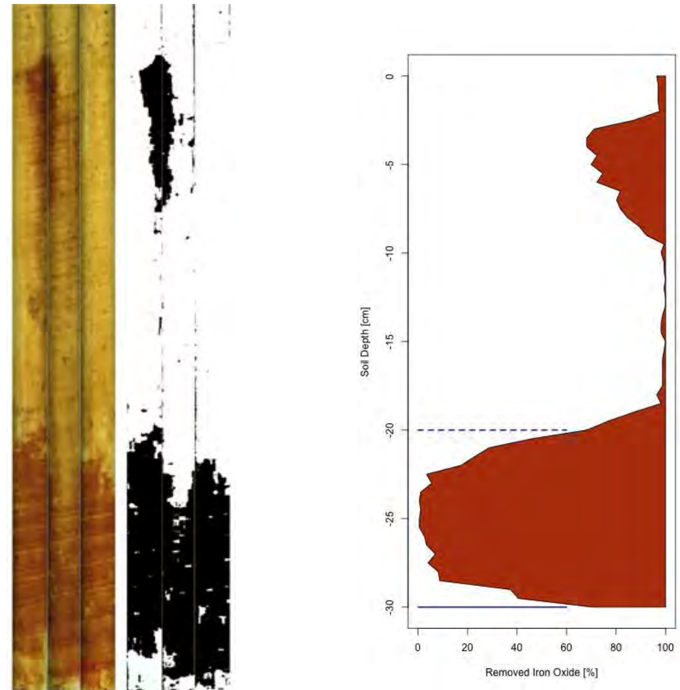
Remarks:

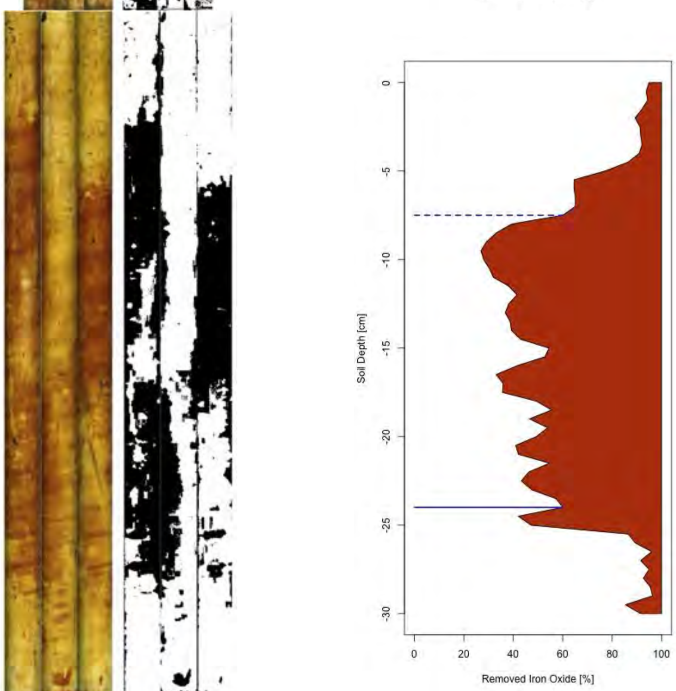
APPENDIX B

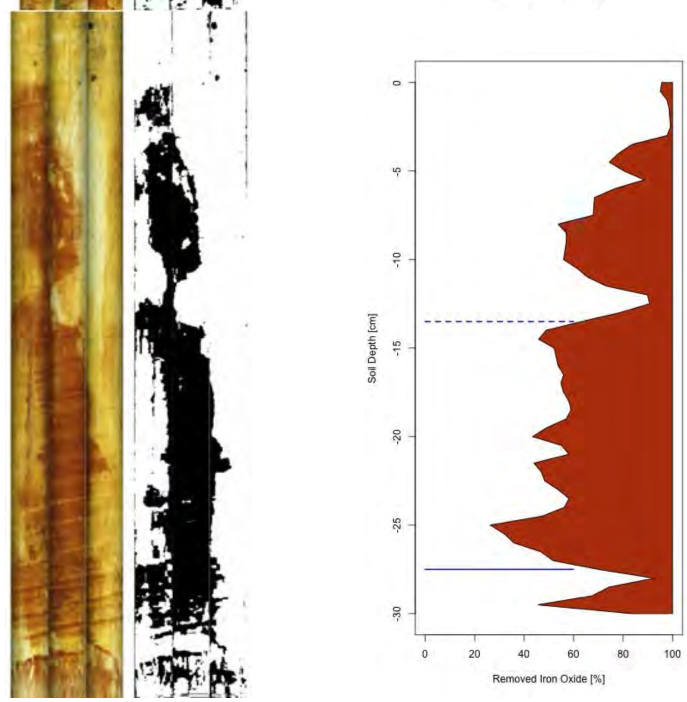
IRIS TUBE IMAGES AND PROFILES

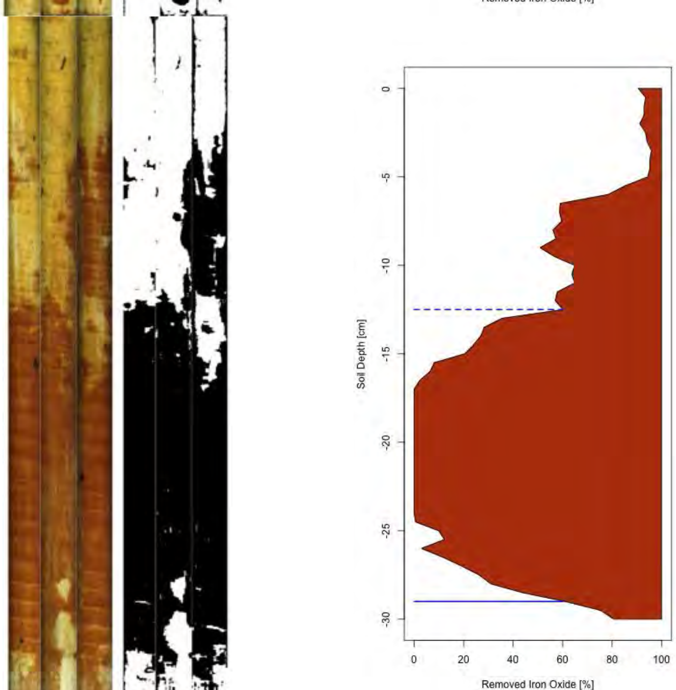
2016 – Nest 2 – Installation 1



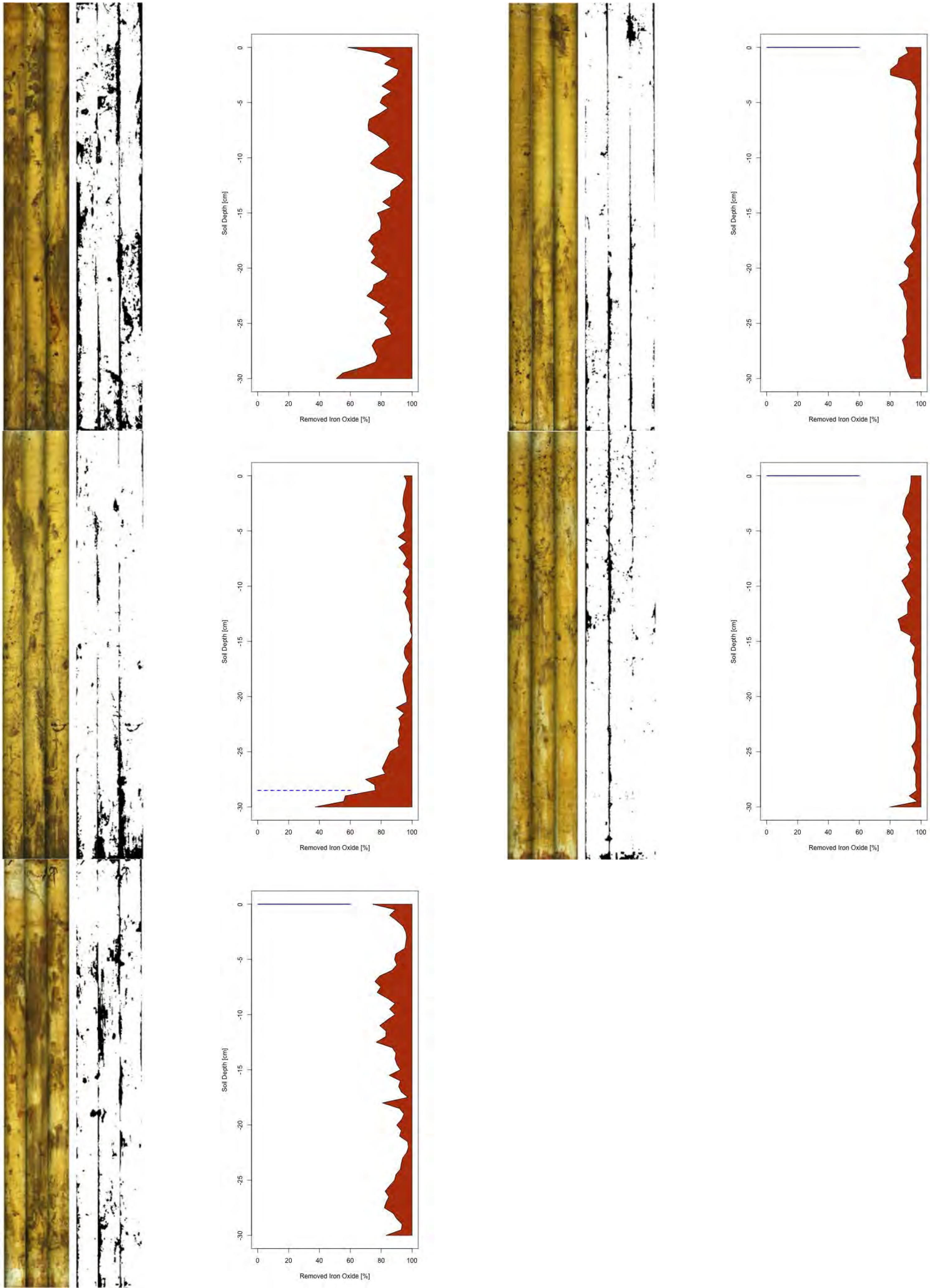




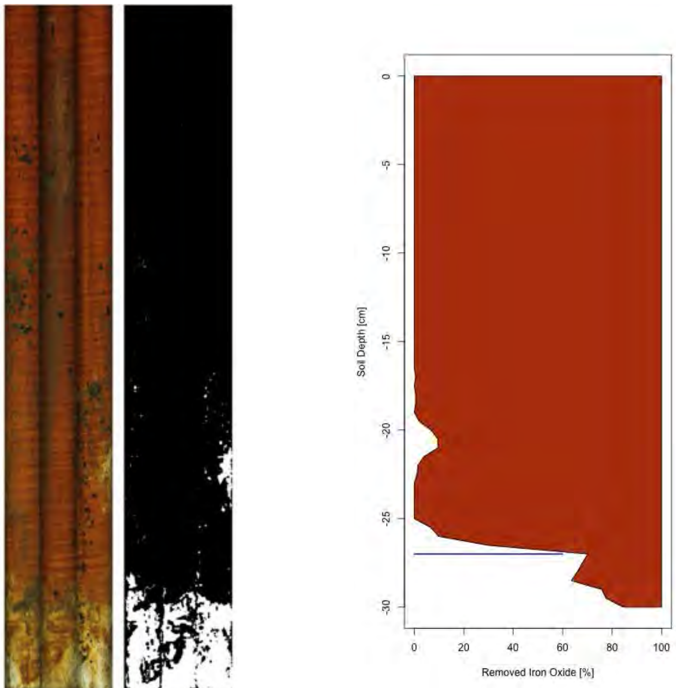


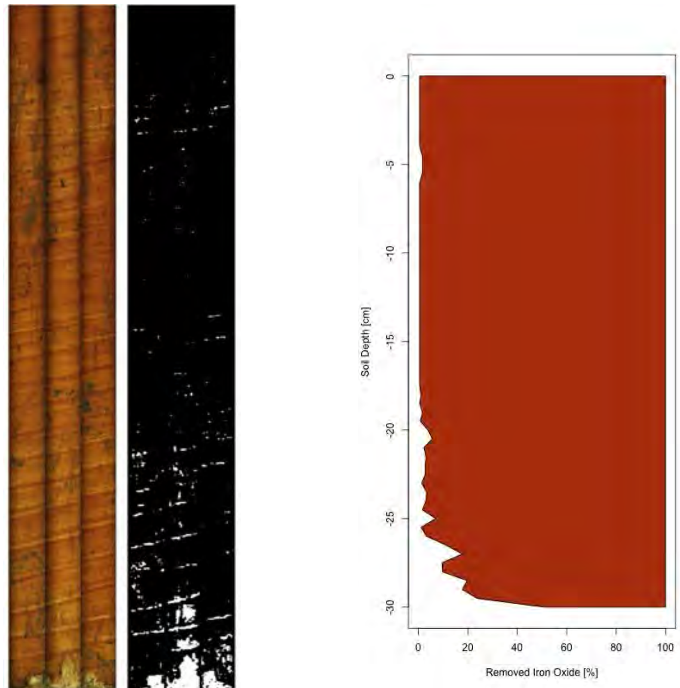


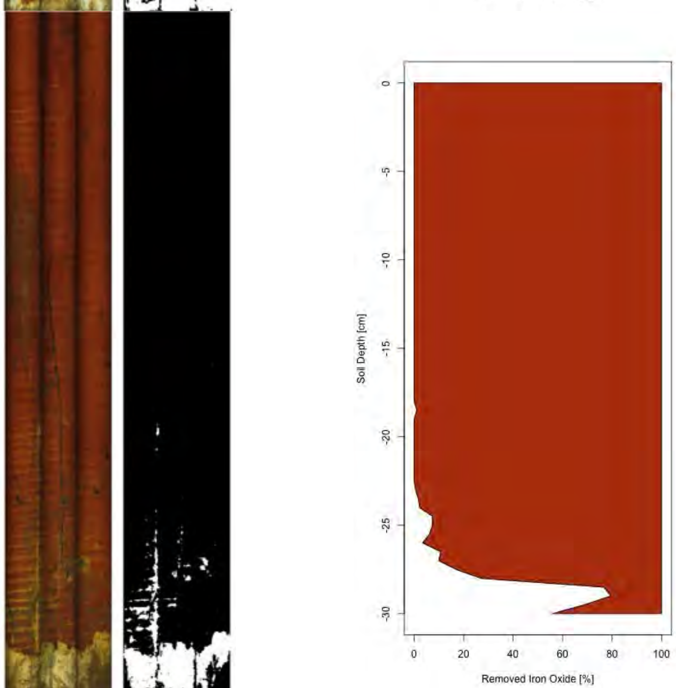
2016 – Nest 2 – Installation 2

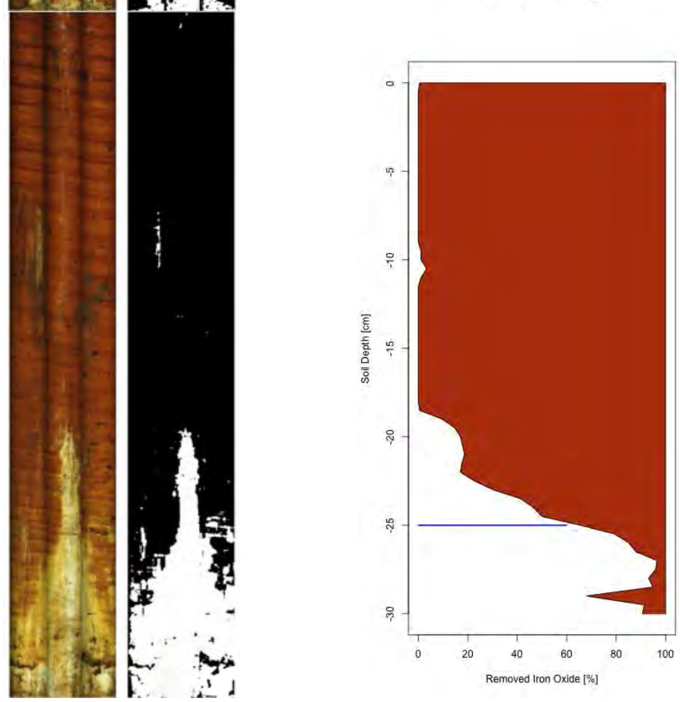


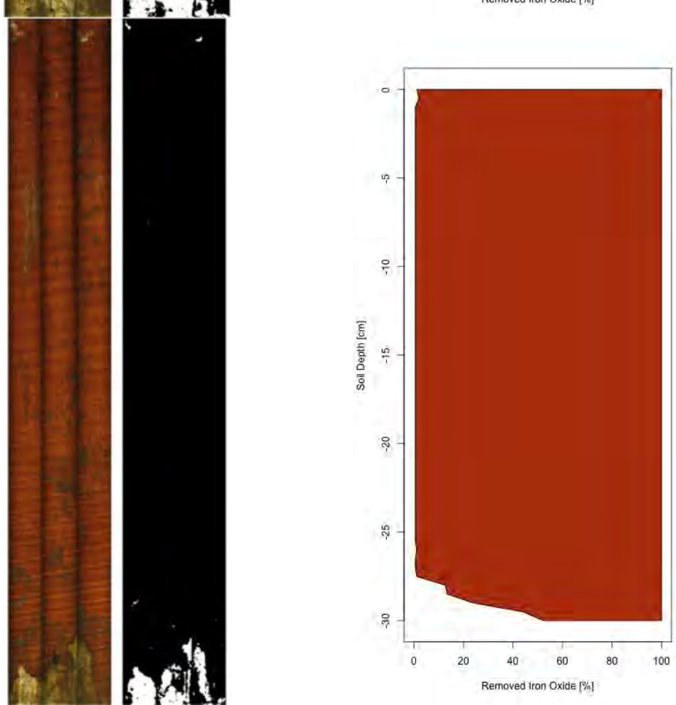
2016 – Nest 2 – Installation 3



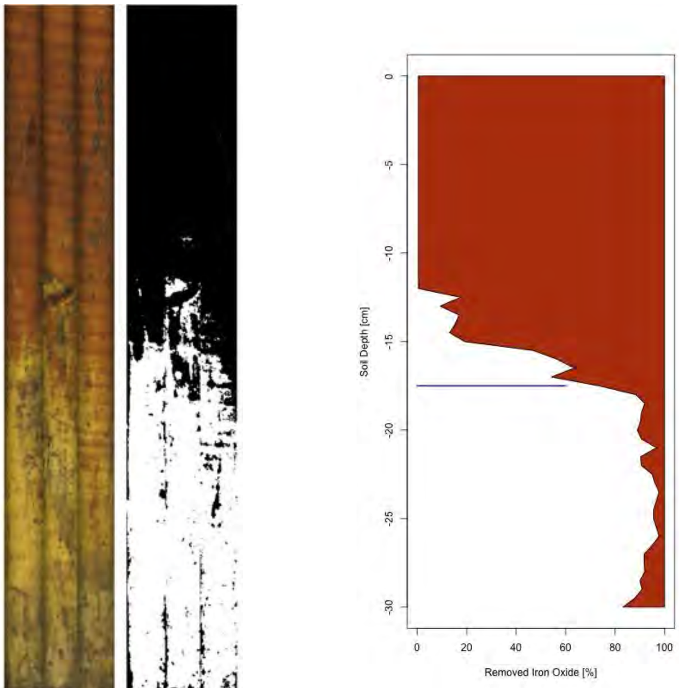


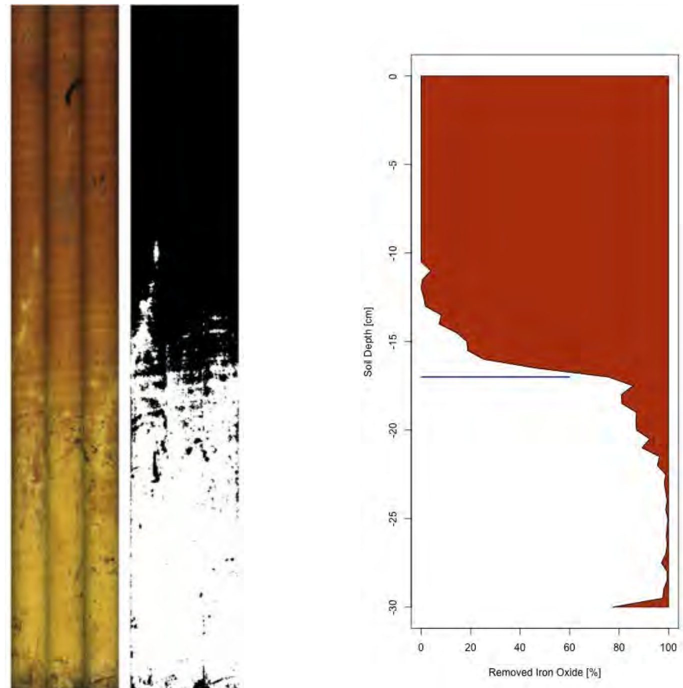


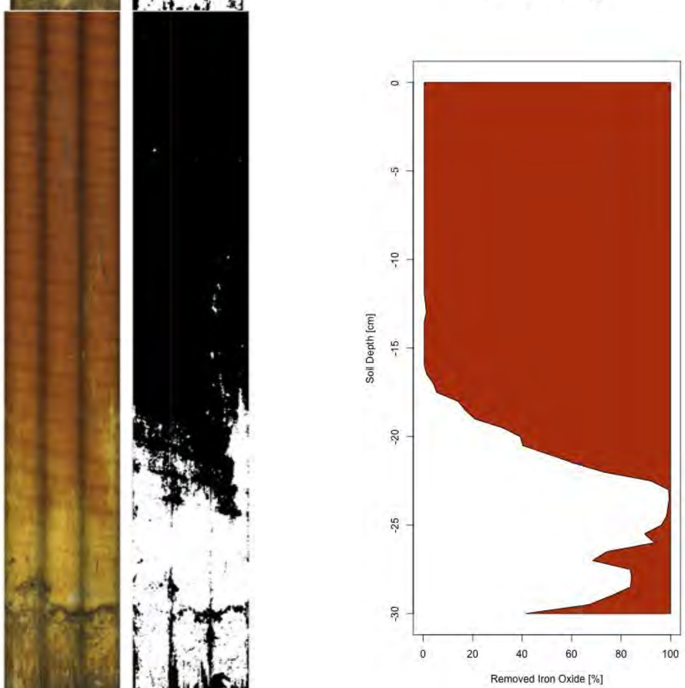


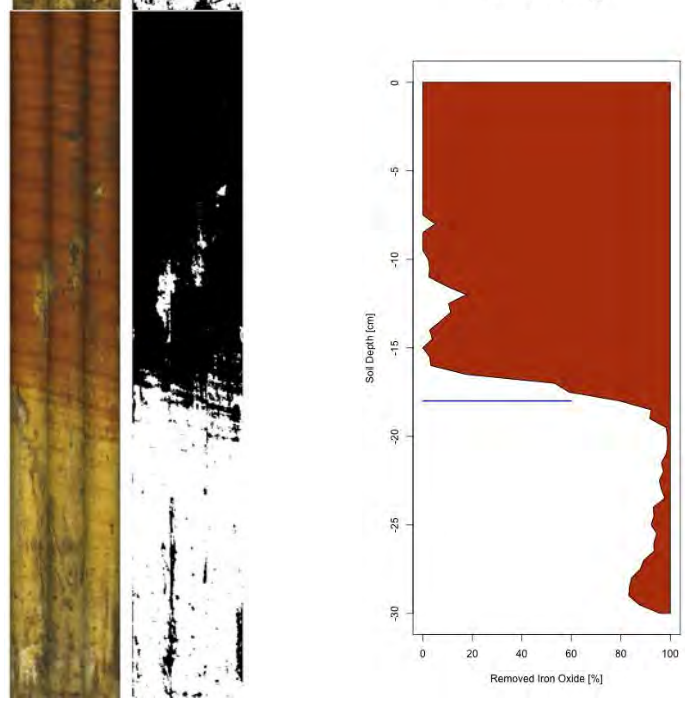


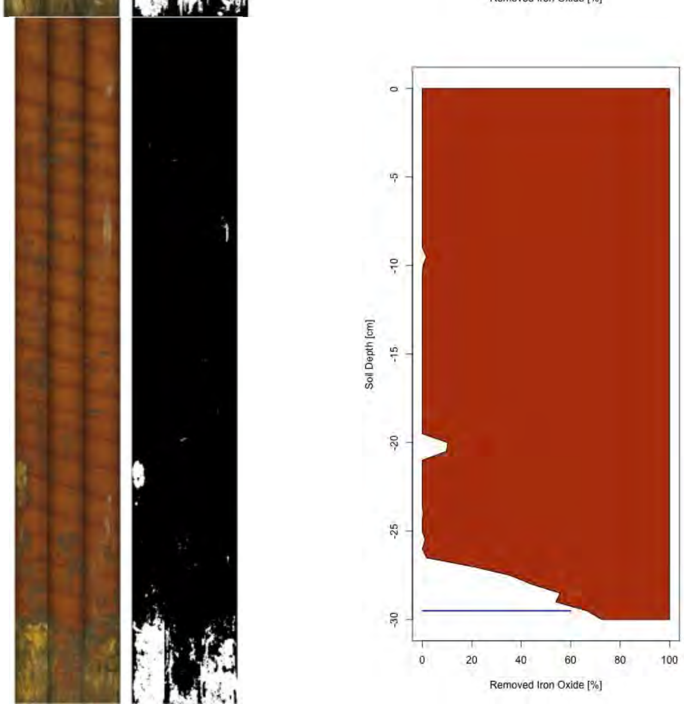
2016 – Nest 2 – Installation 4



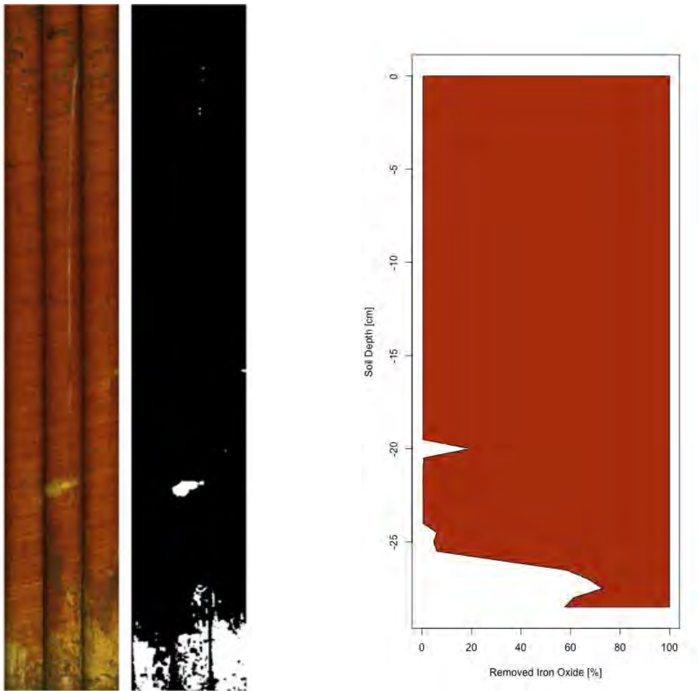


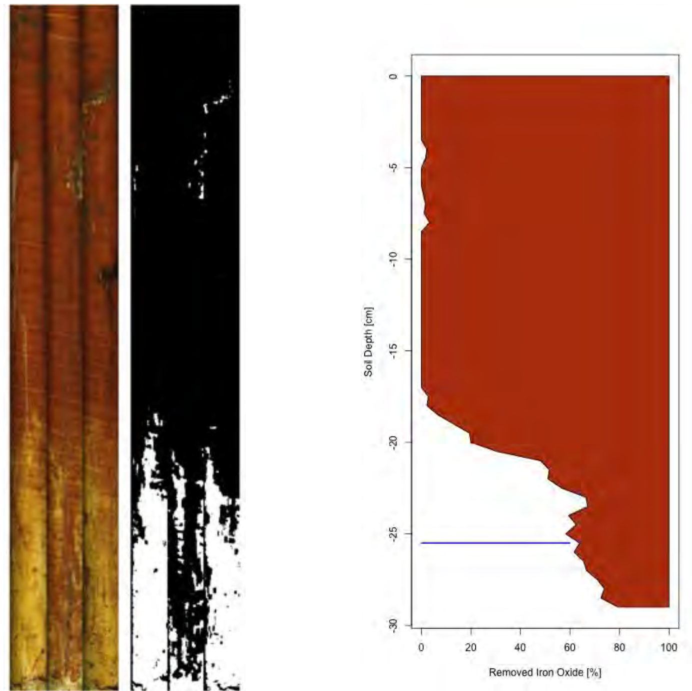


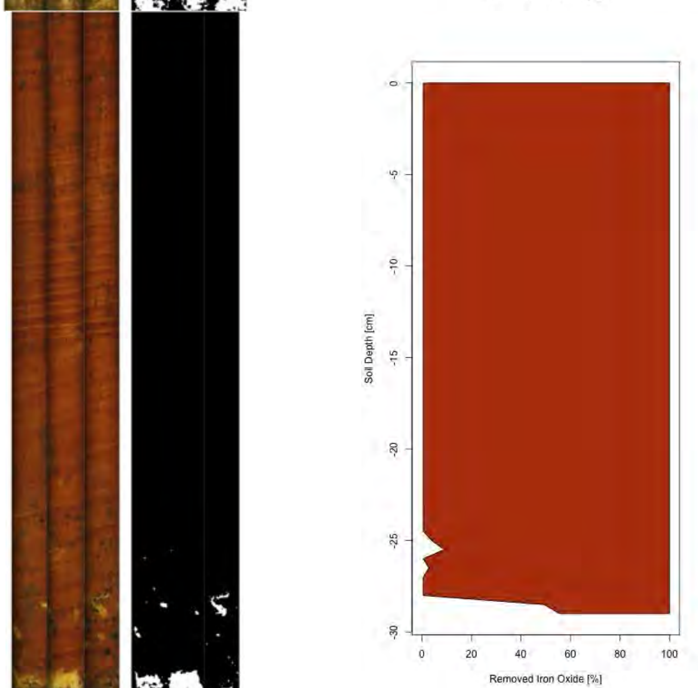


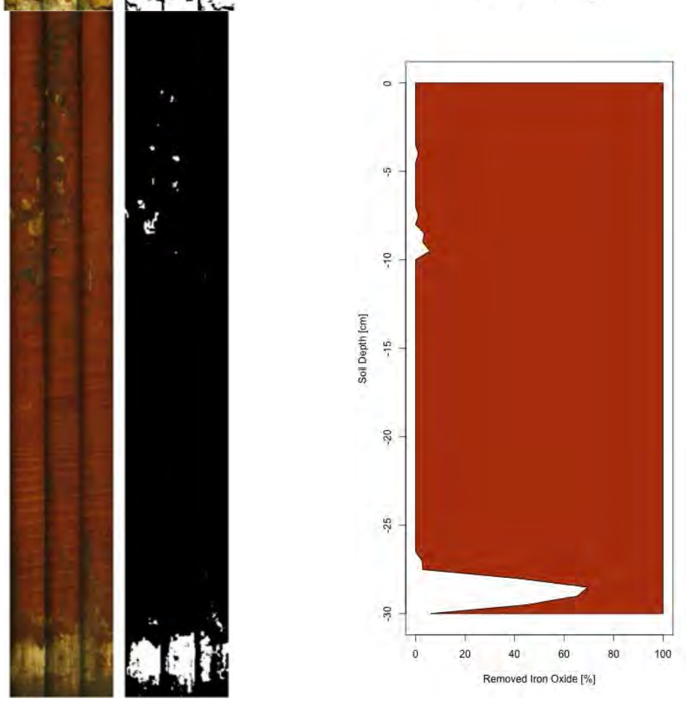


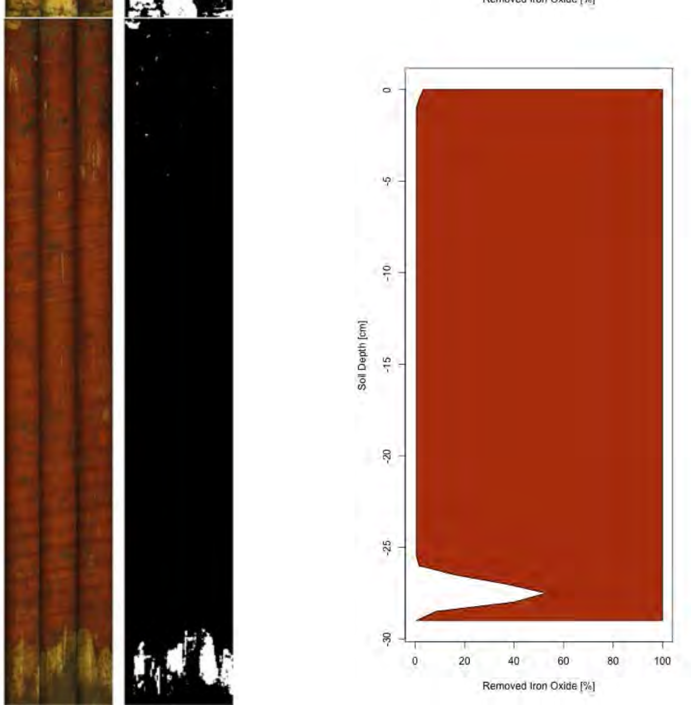
2016 – Nest 3 – Installation 2



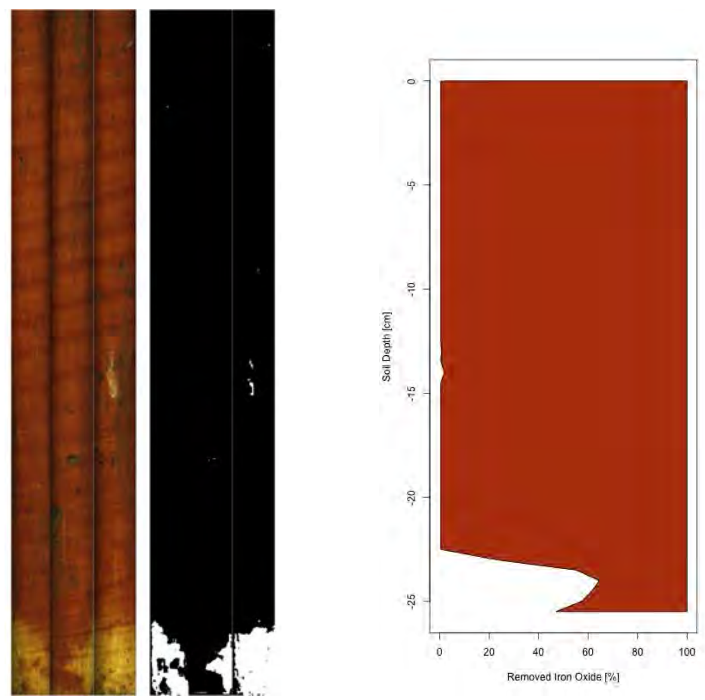




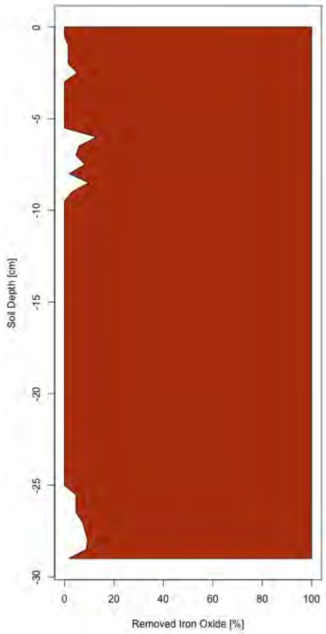


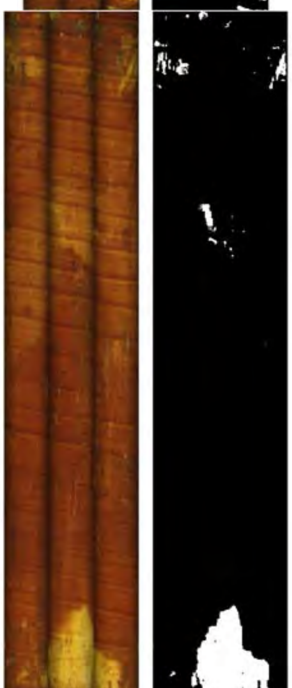


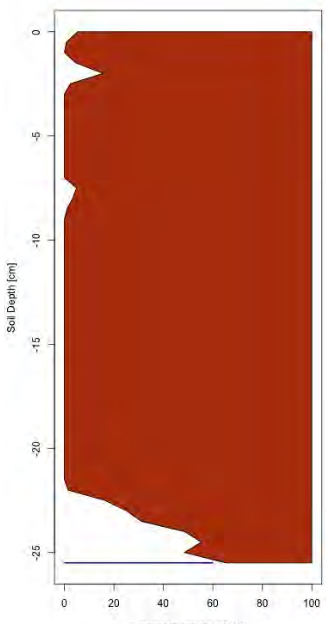
2016 – Nest 4 – Installation 1

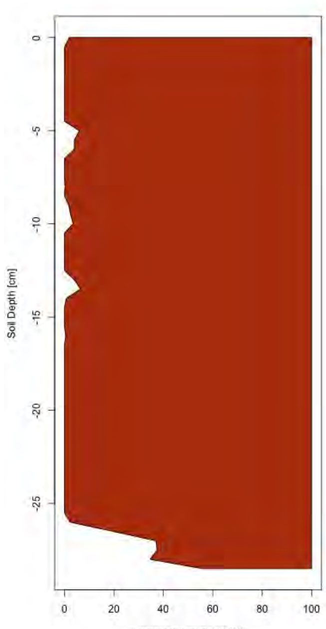


2016 – Nest 4 – Installation 2

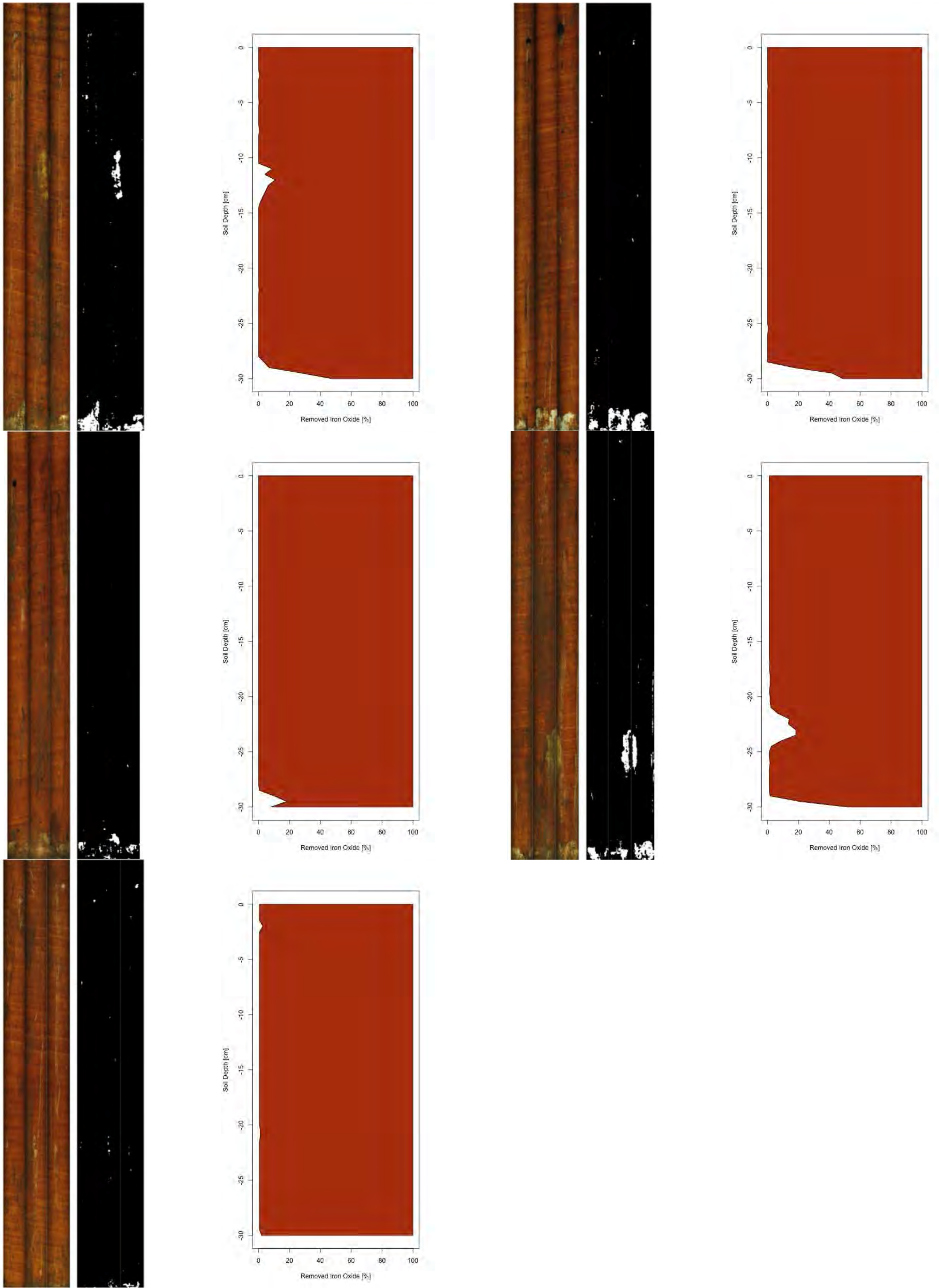




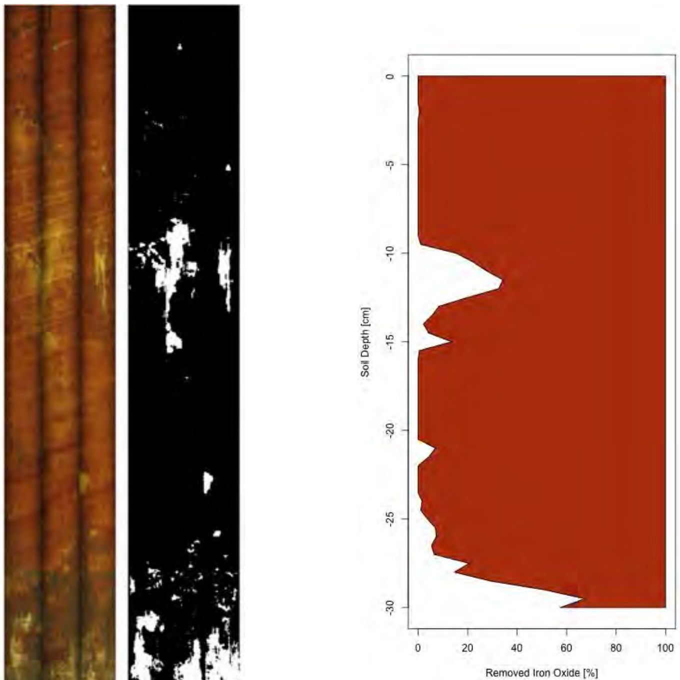


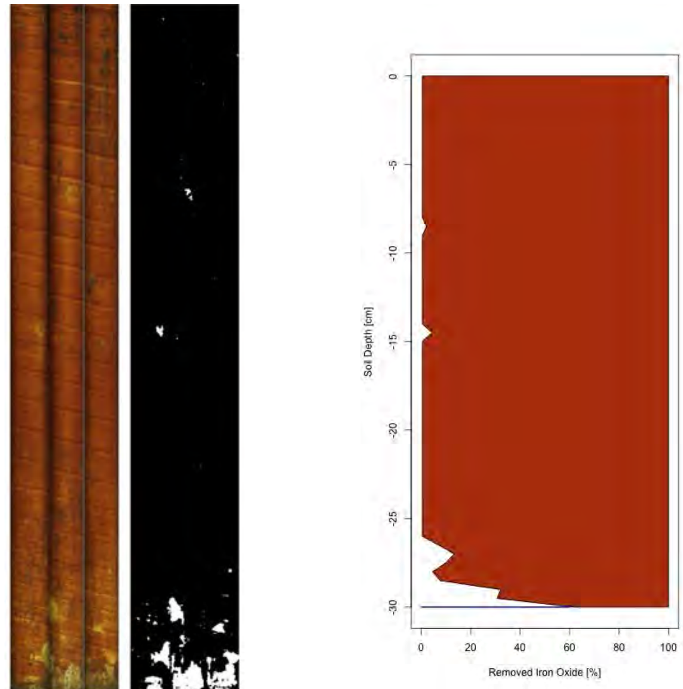


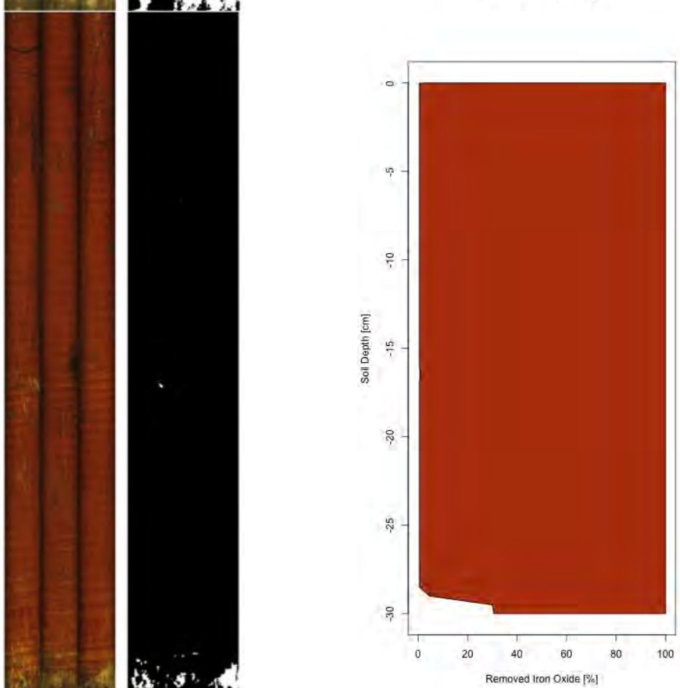
2016 – Nest 5 – Installation 1

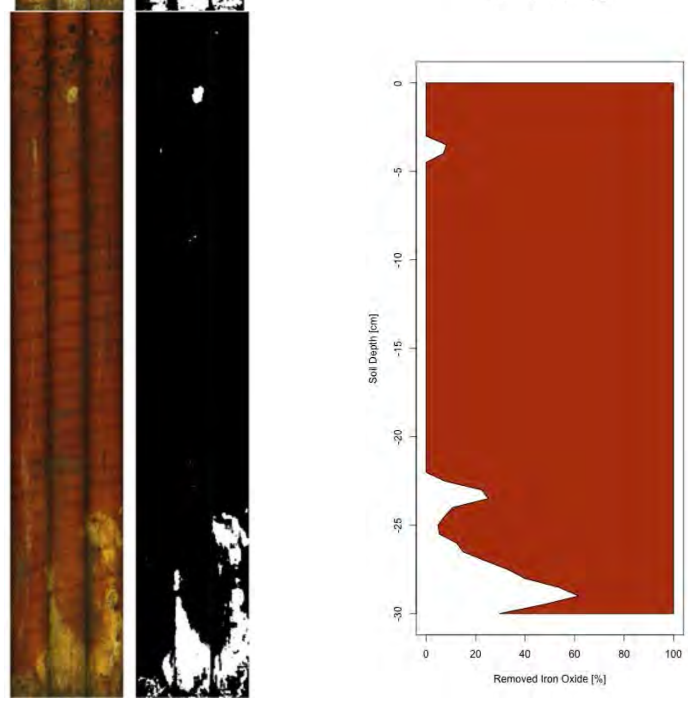


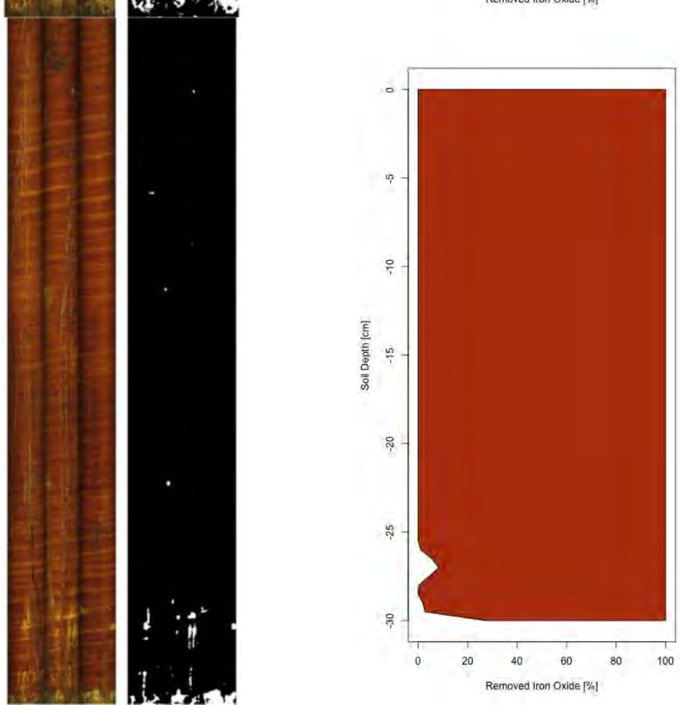
2016 – Nest 5 – Installation 2



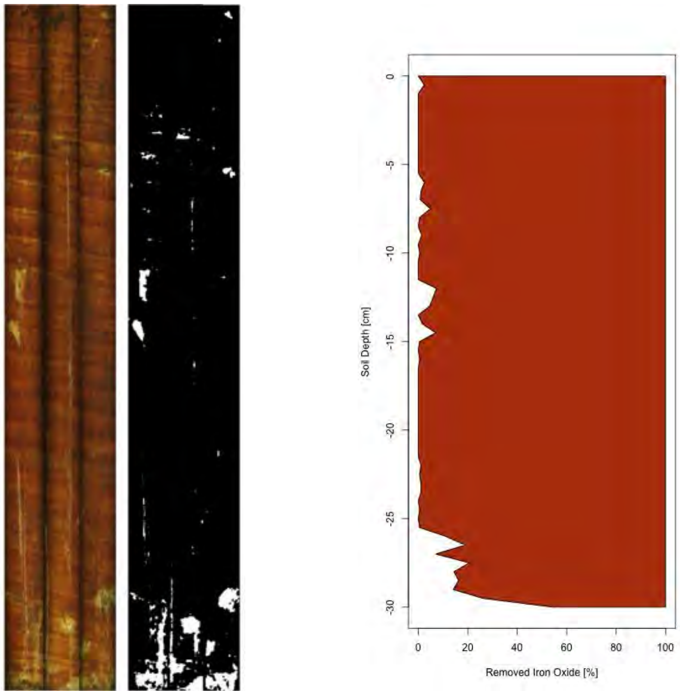


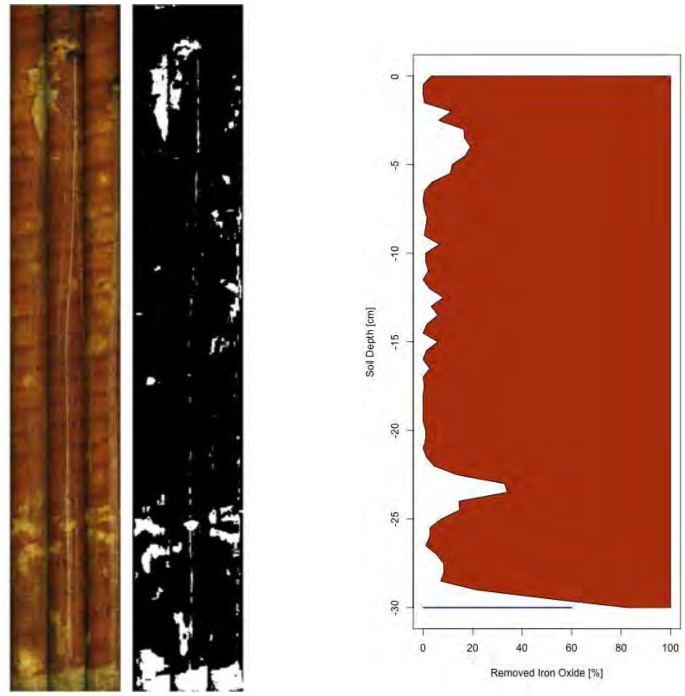


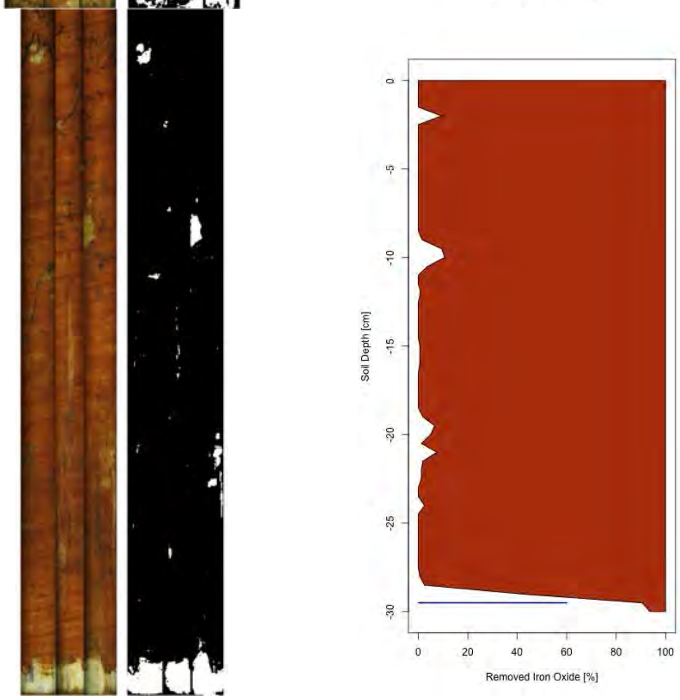




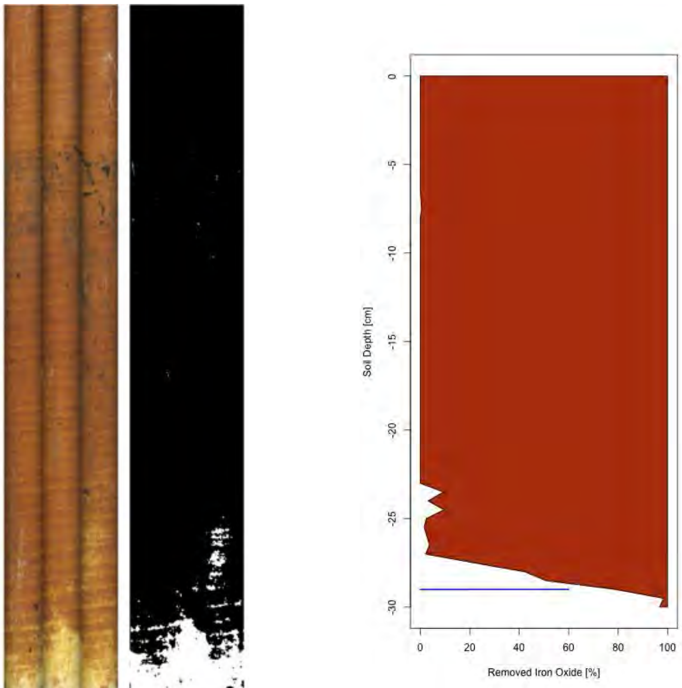
2016 – Nest 6 – Installation 1

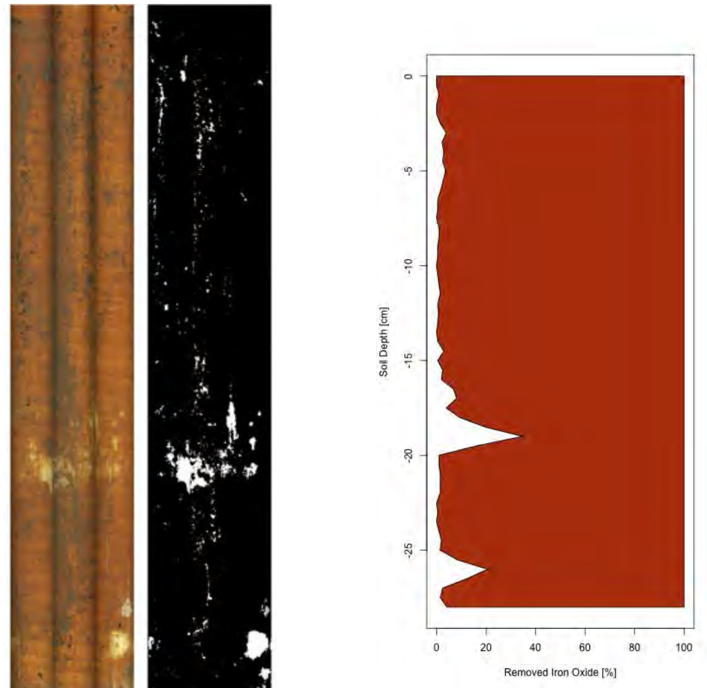


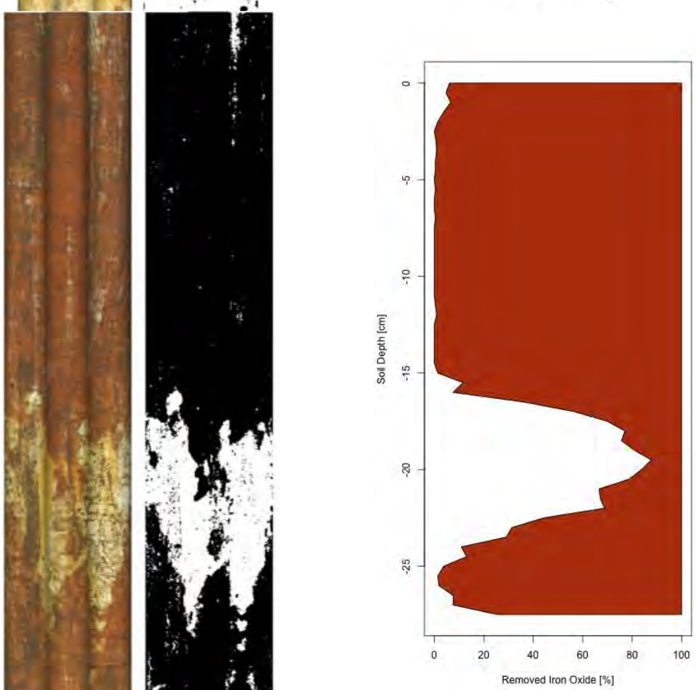


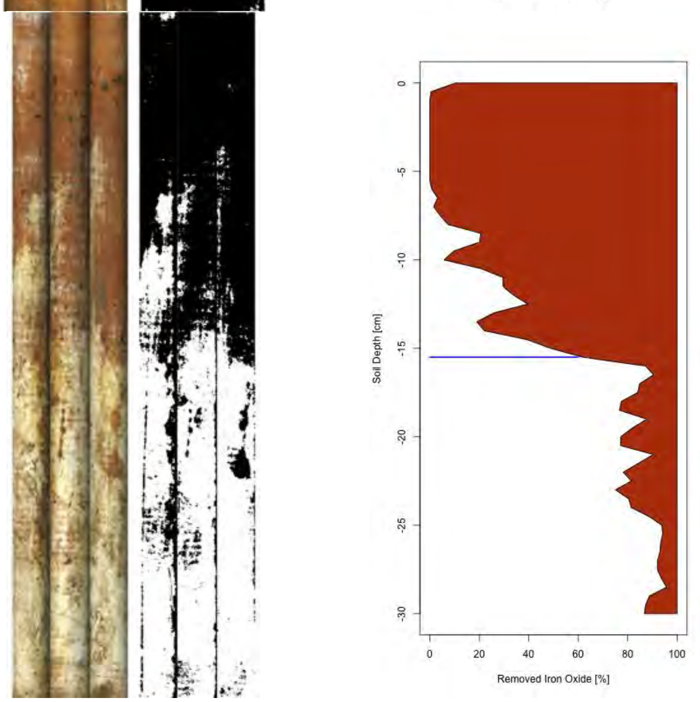


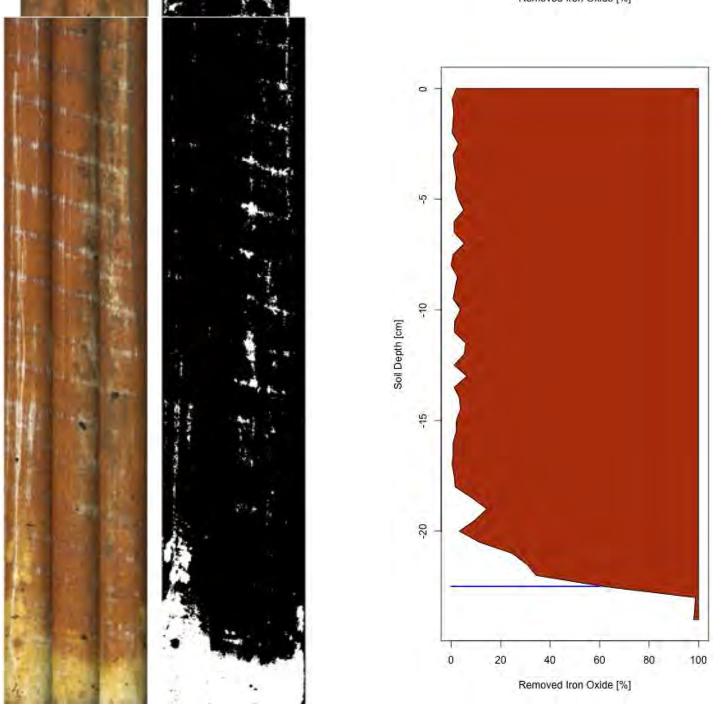
2017 – Nest 1 – Installation 1



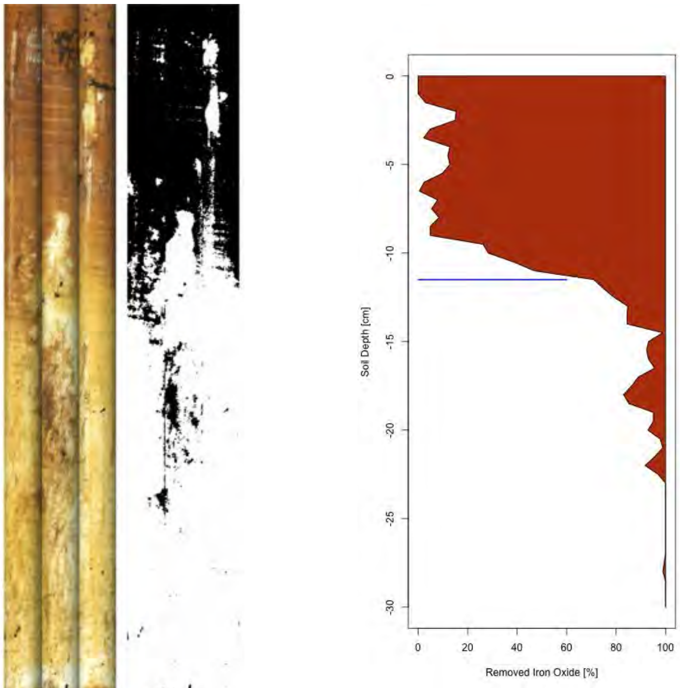


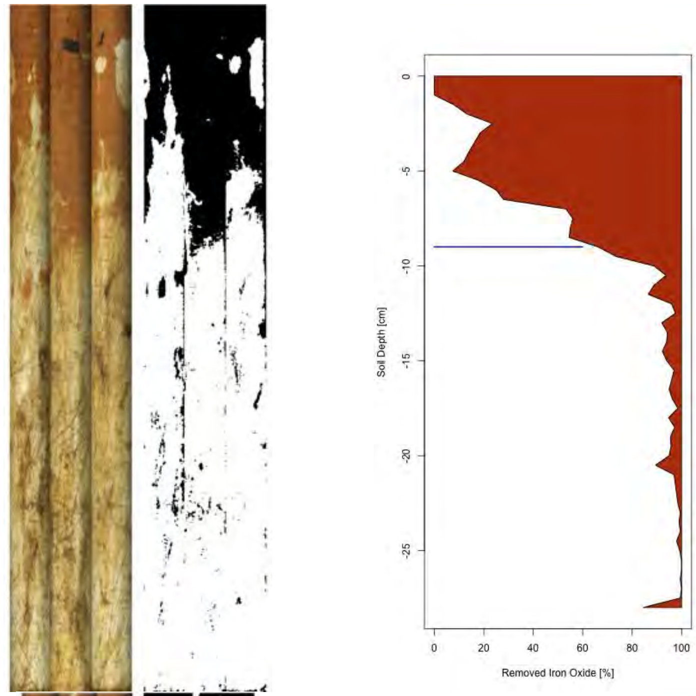


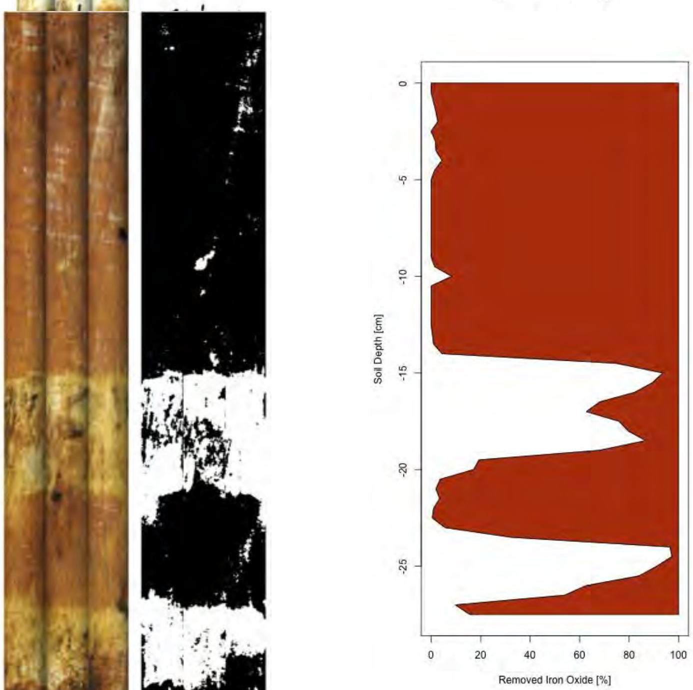


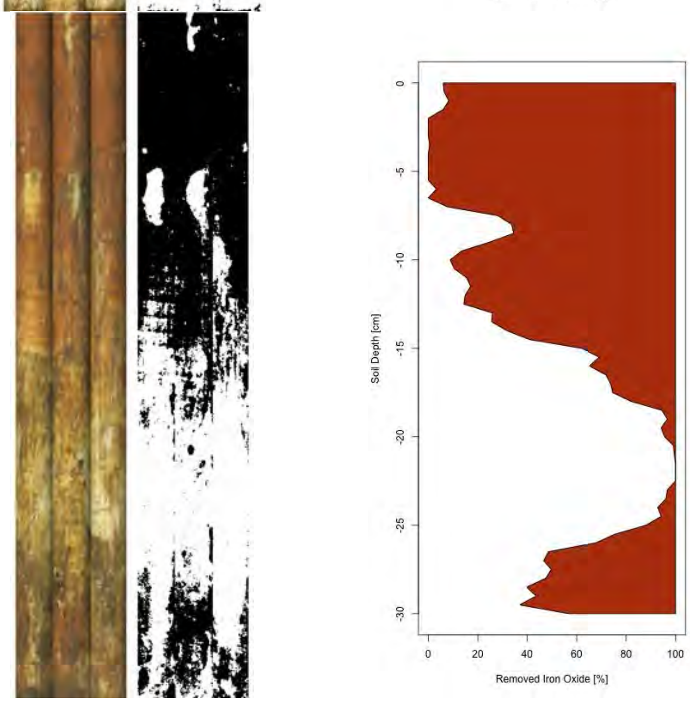


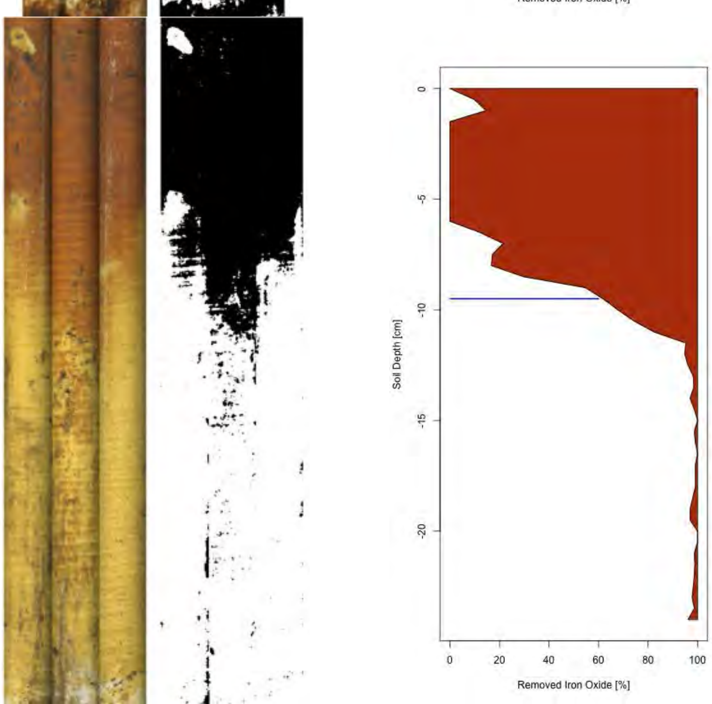
2017 – Nest 1 – Installation 2



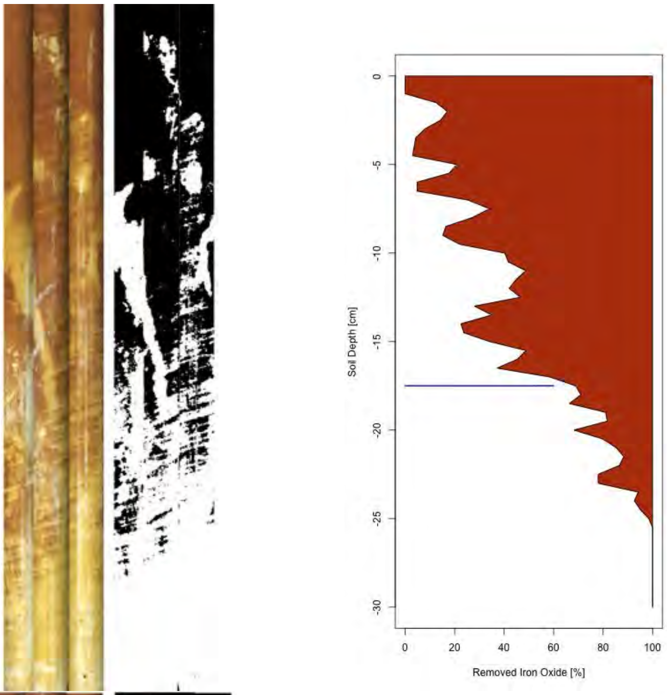


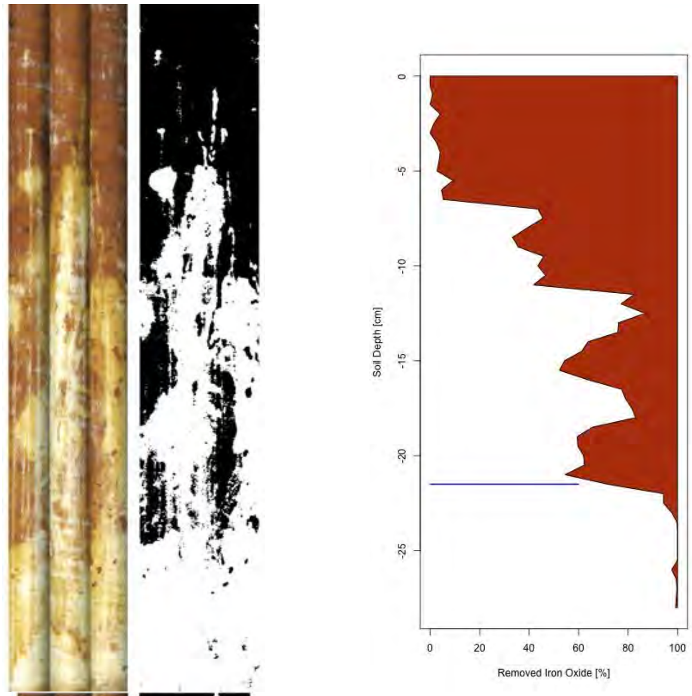


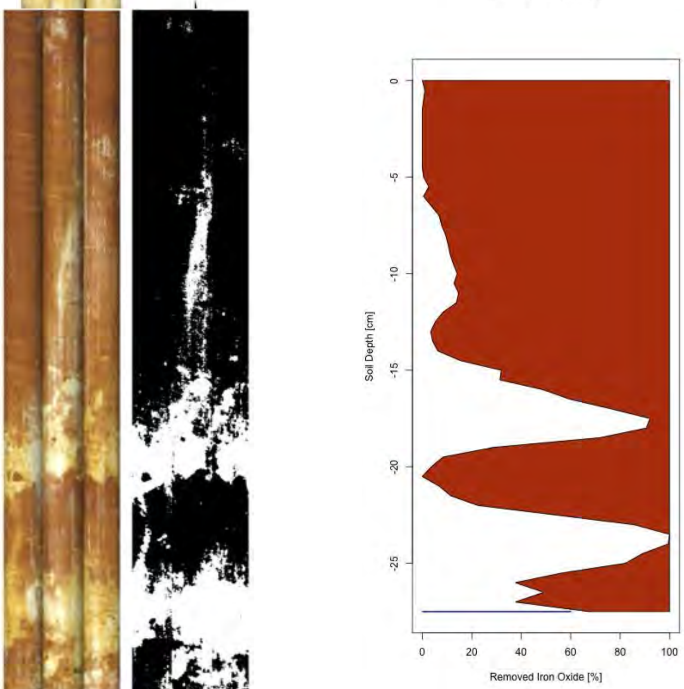


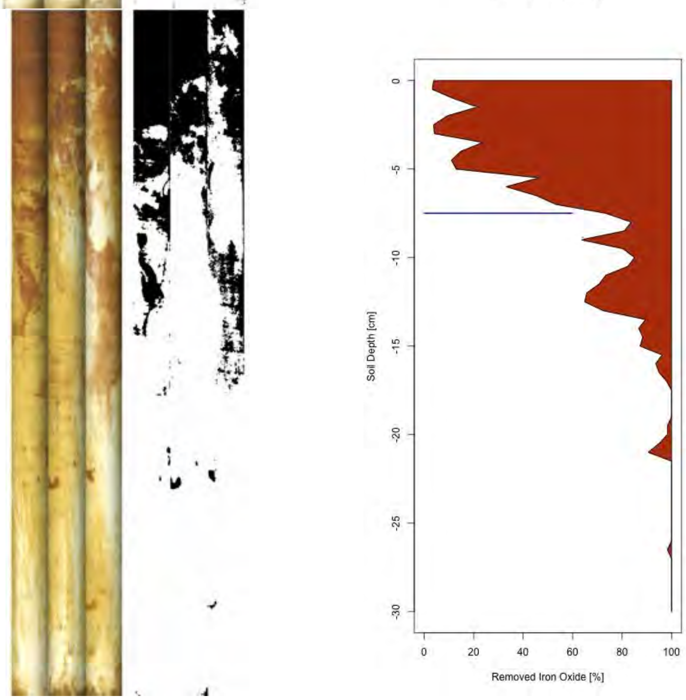


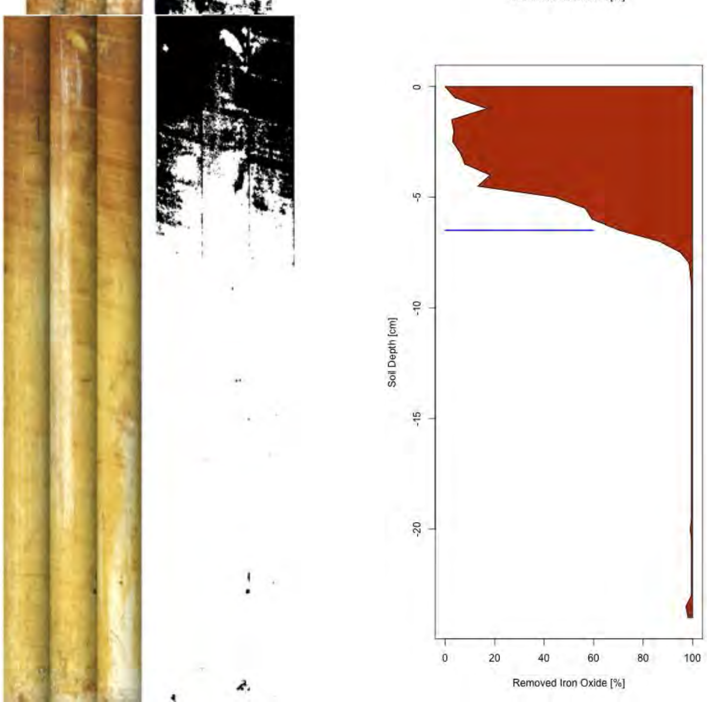
2017 – Nest 1 – Installation 3



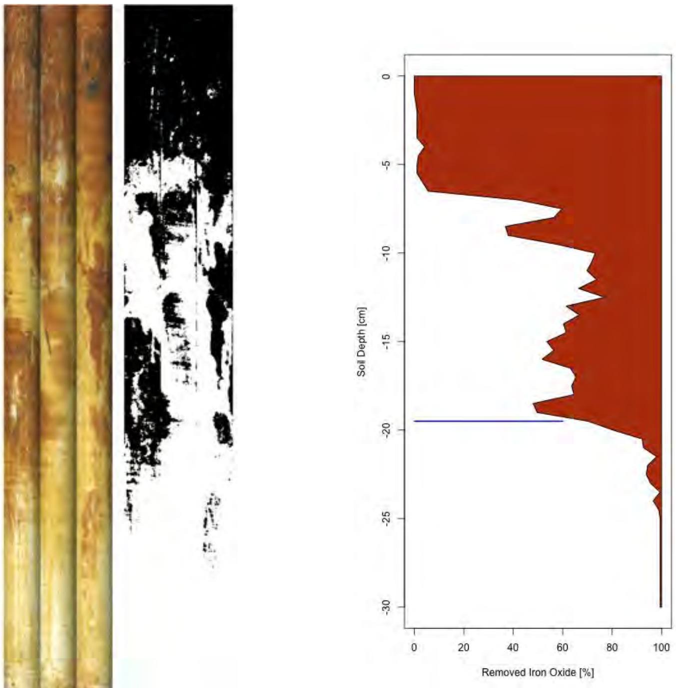


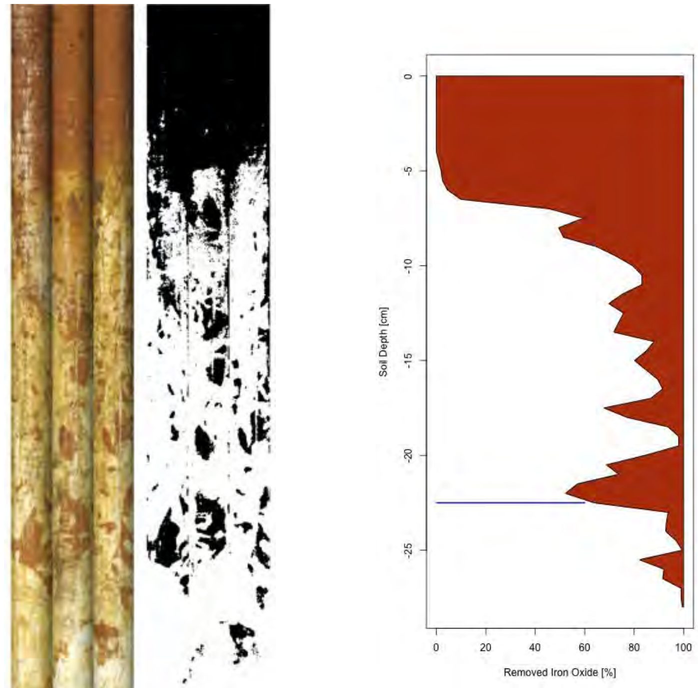


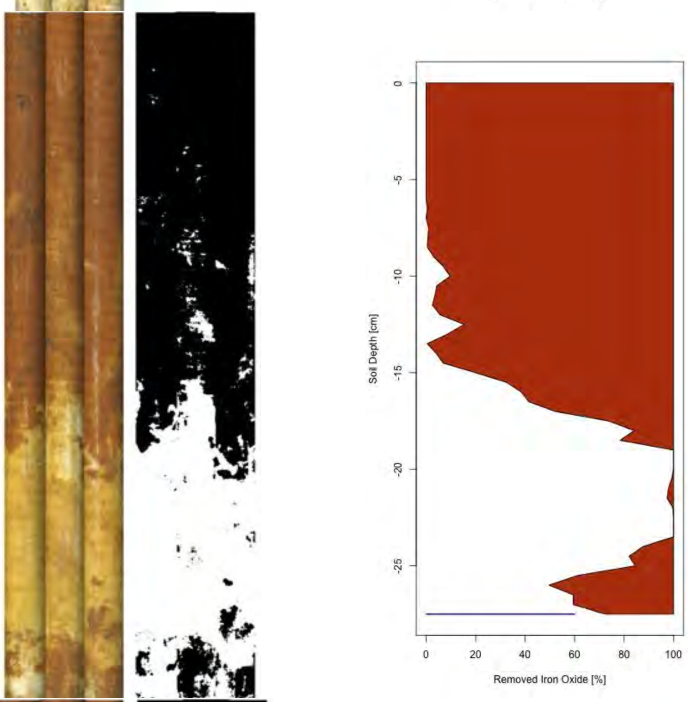


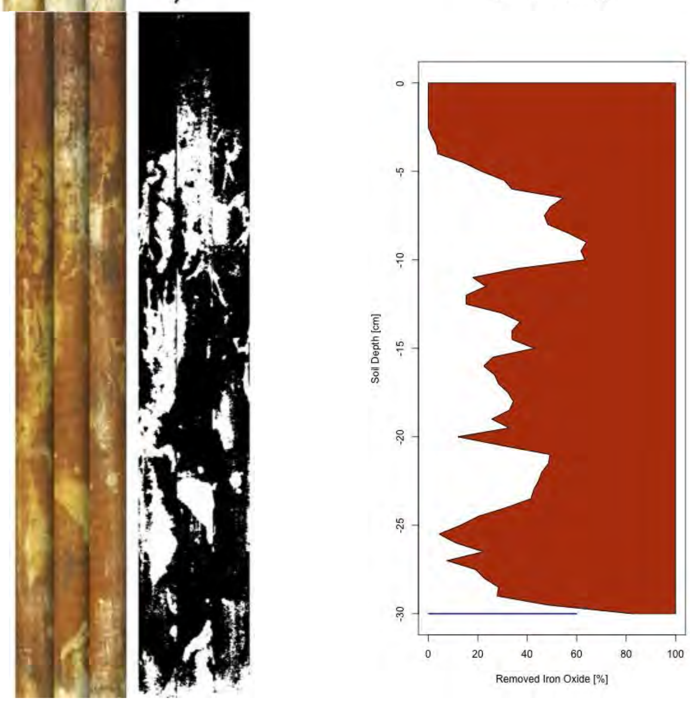


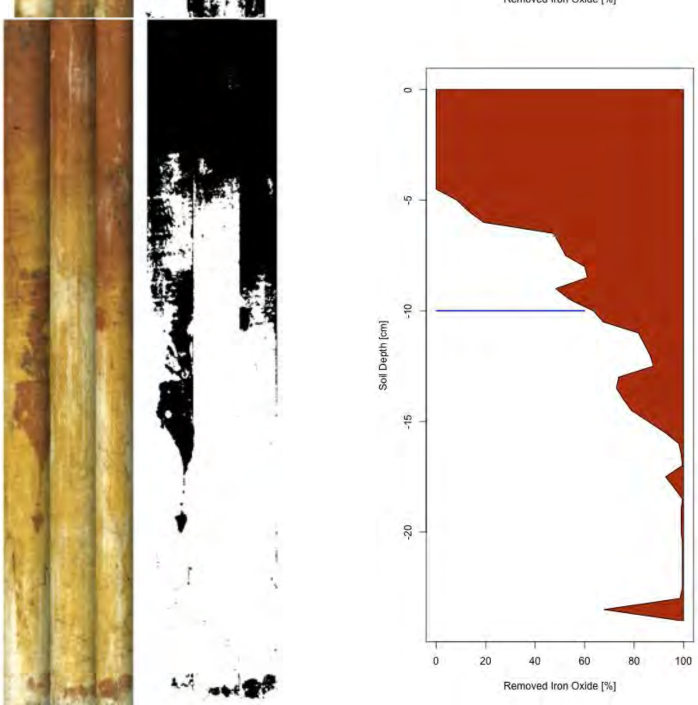
2017 – Nest 1 – Installation 4



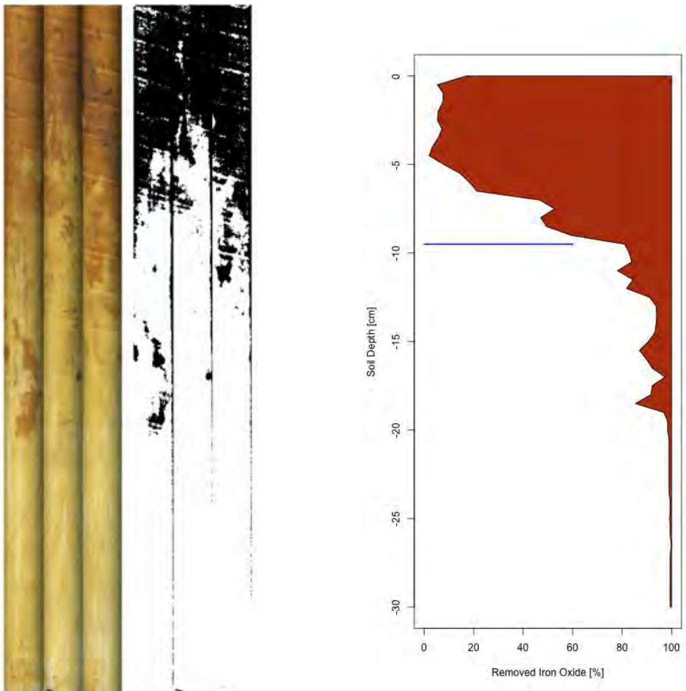


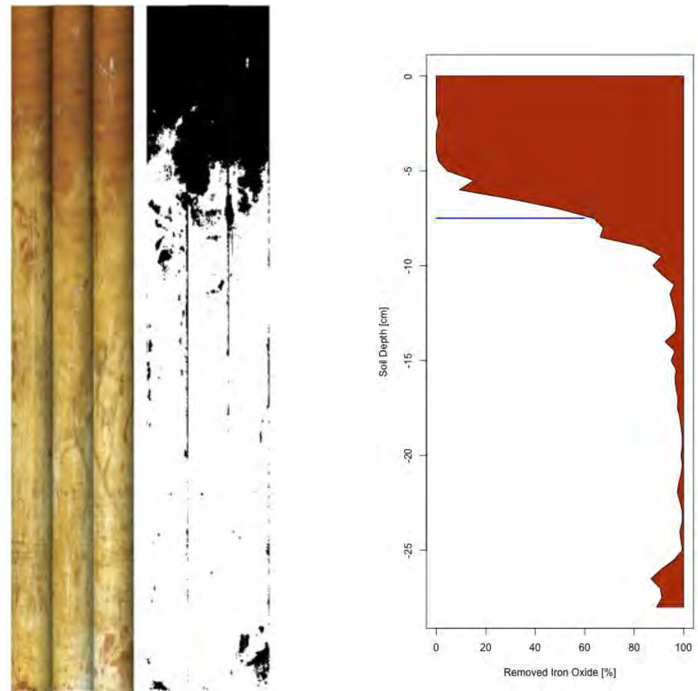


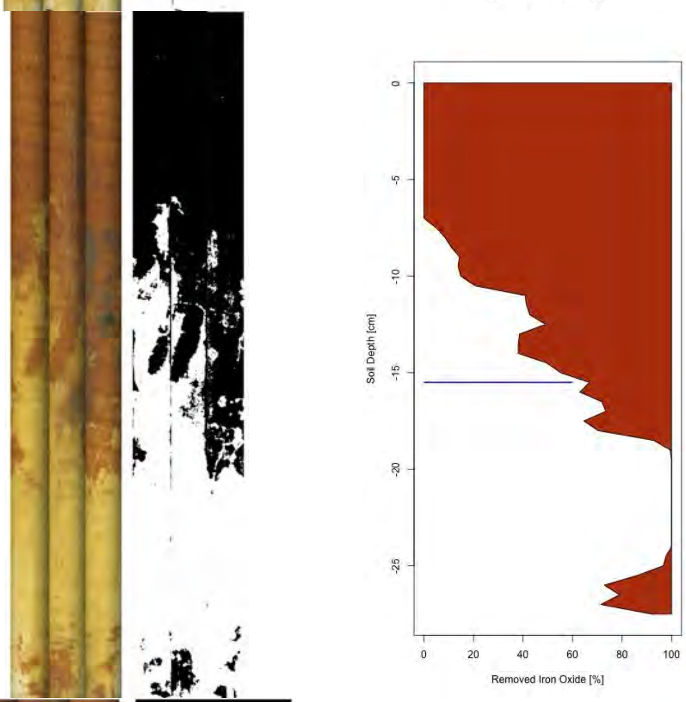


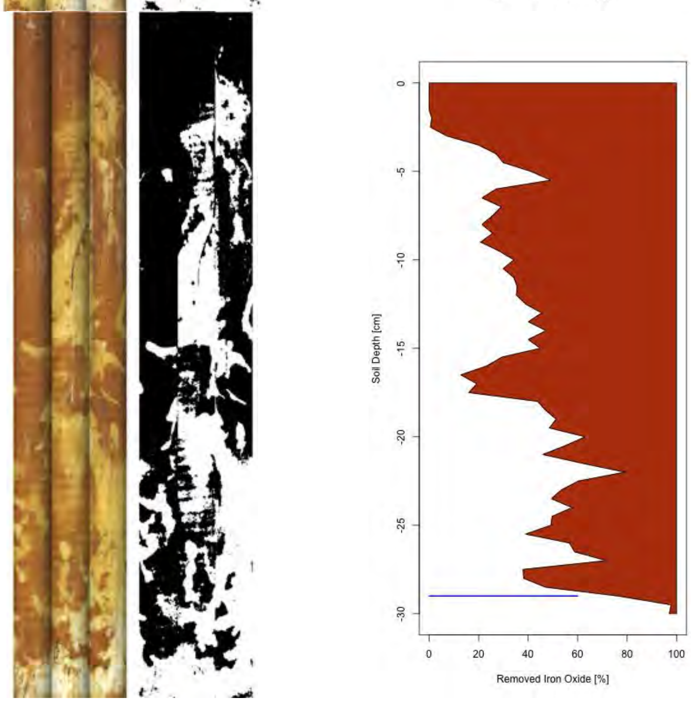


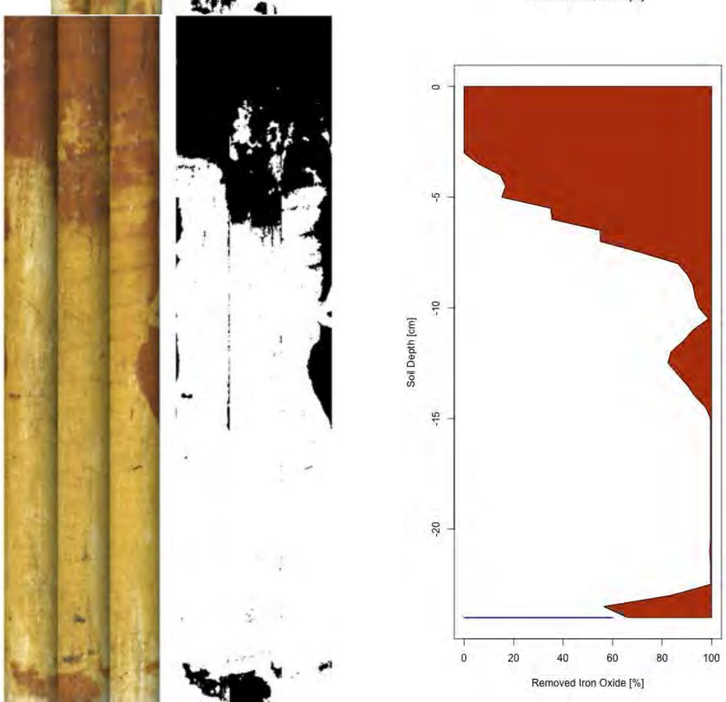
2017 – Nest 1 – Installation 5



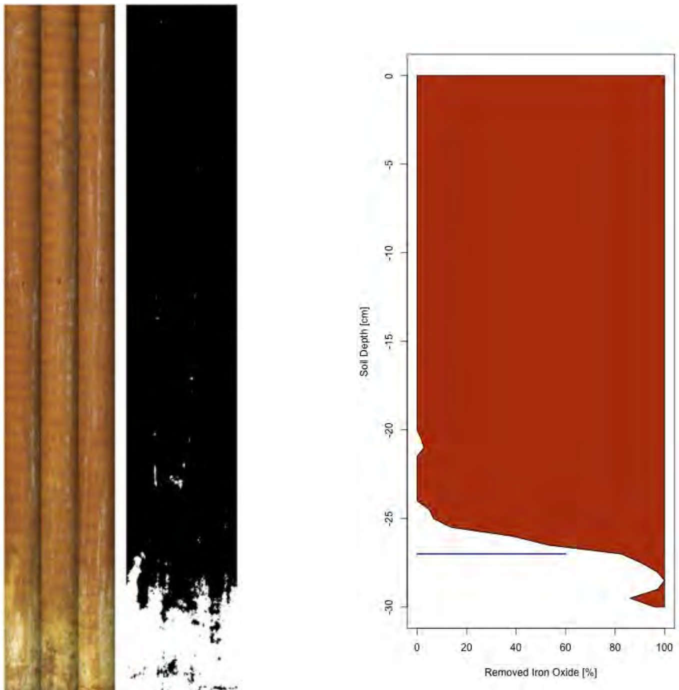


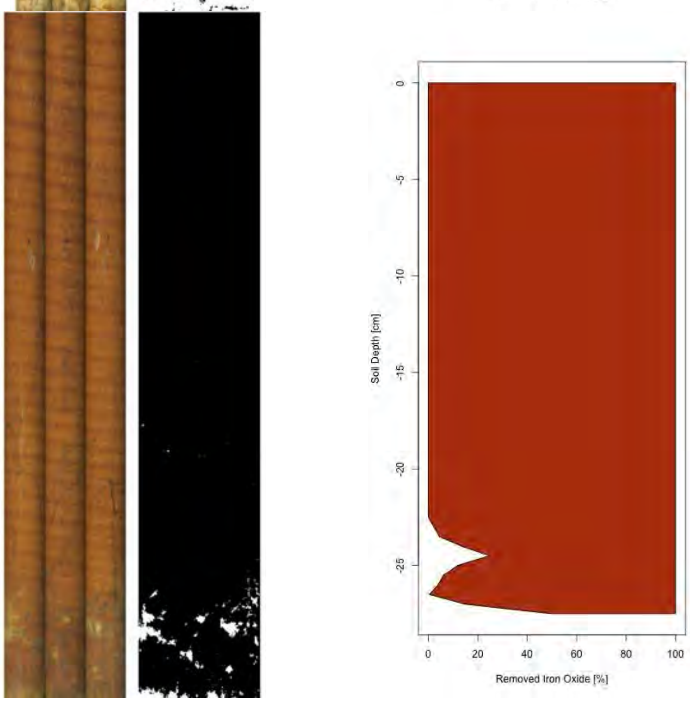


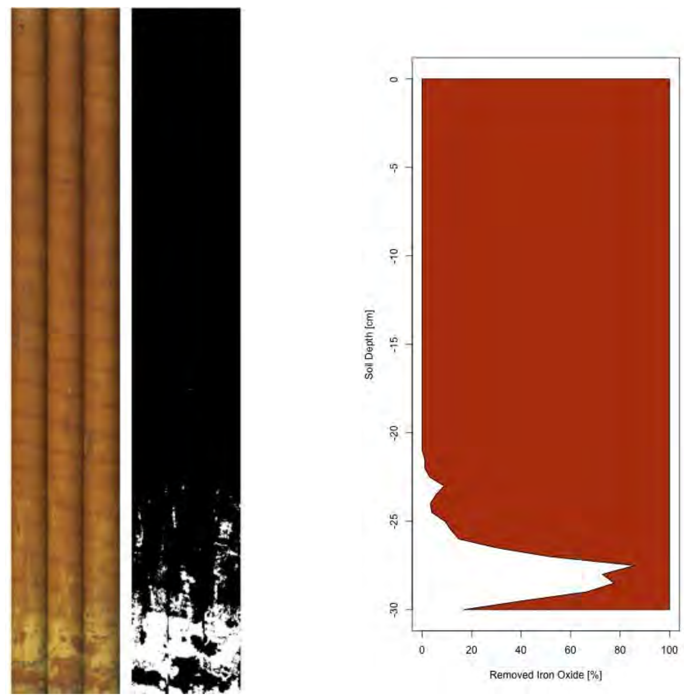




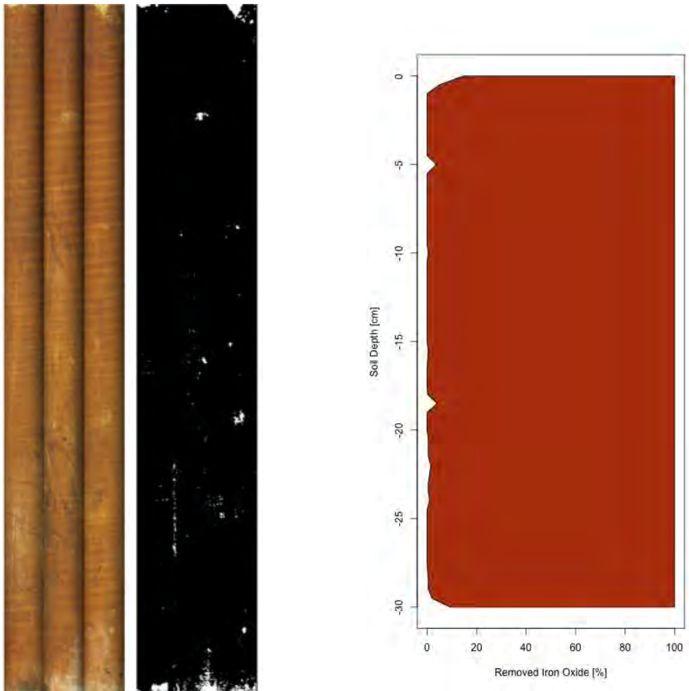
2017 – Nest 1 – Installation 6

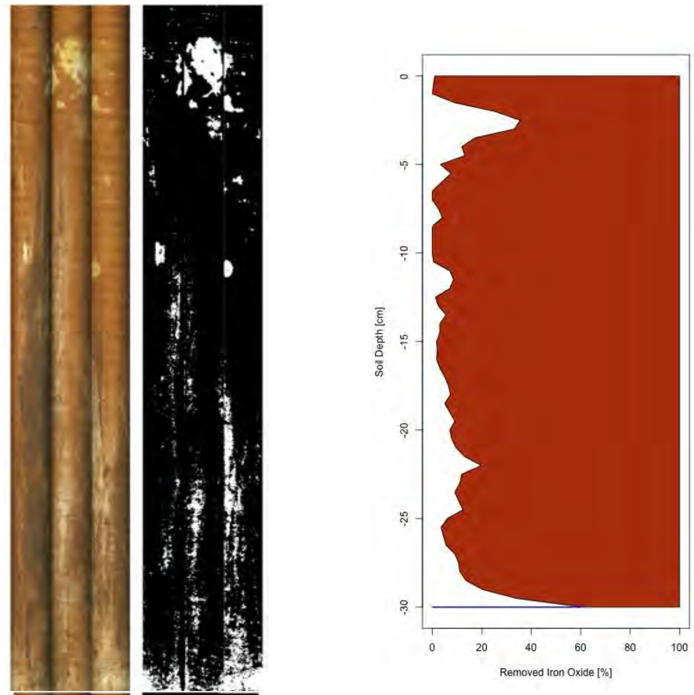


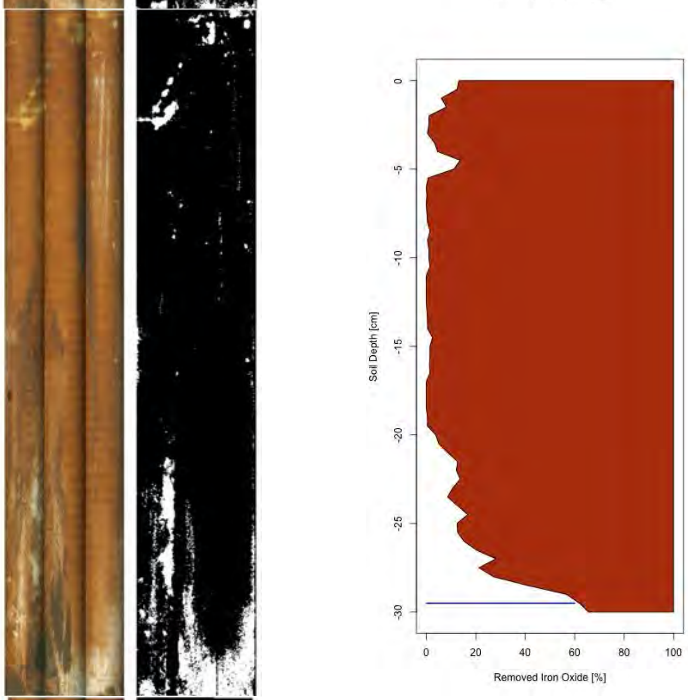


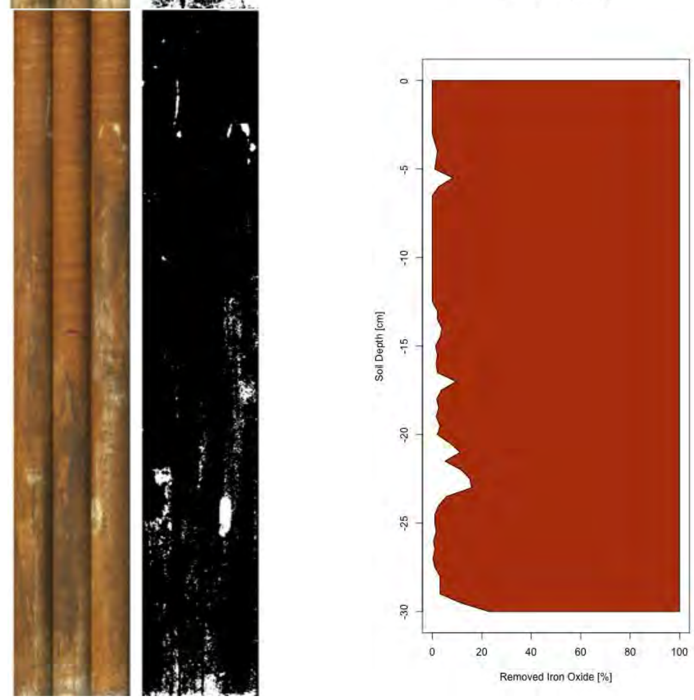


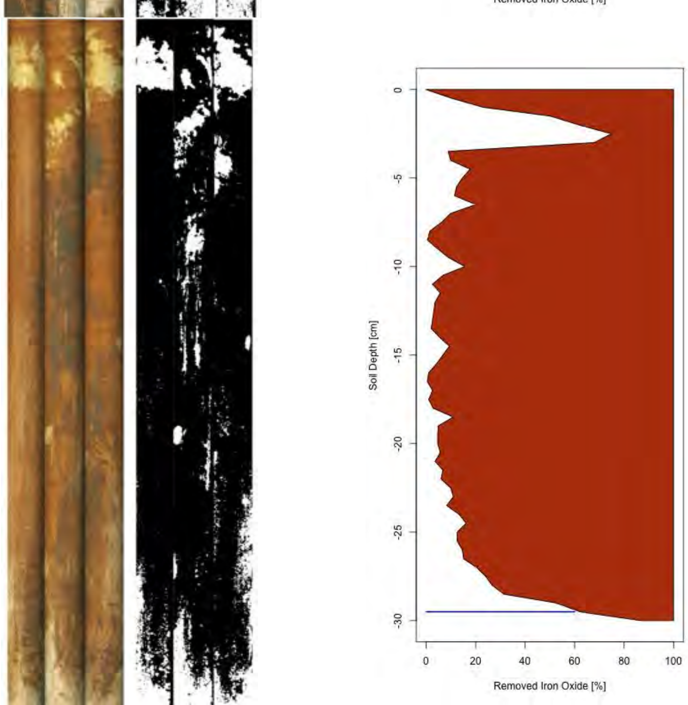
2017 – Nest 2 – Installation 1



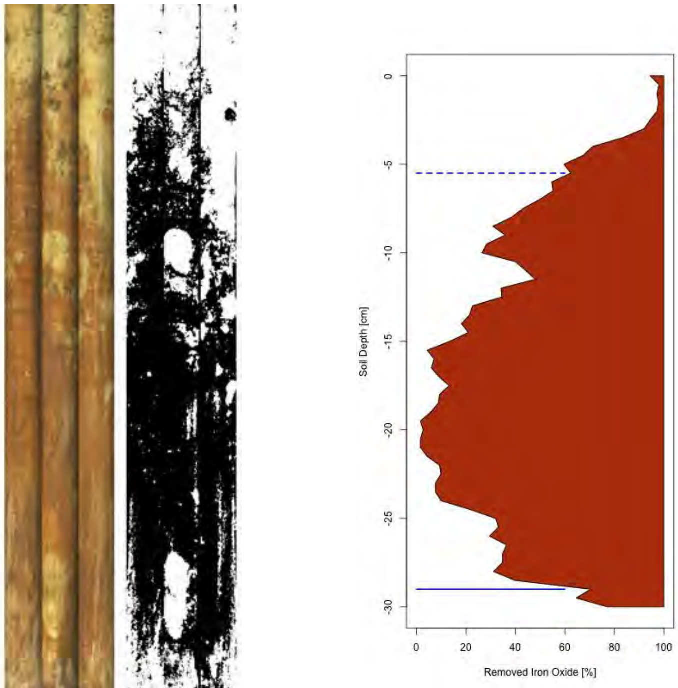


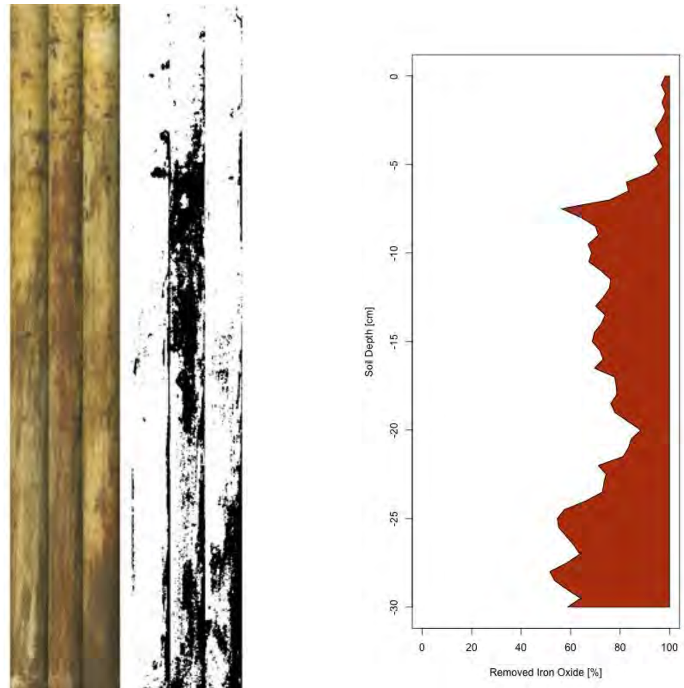


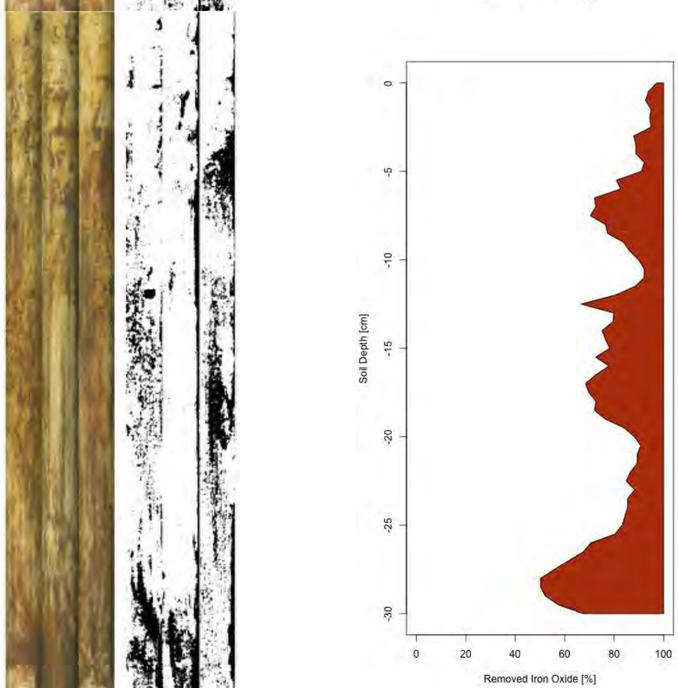


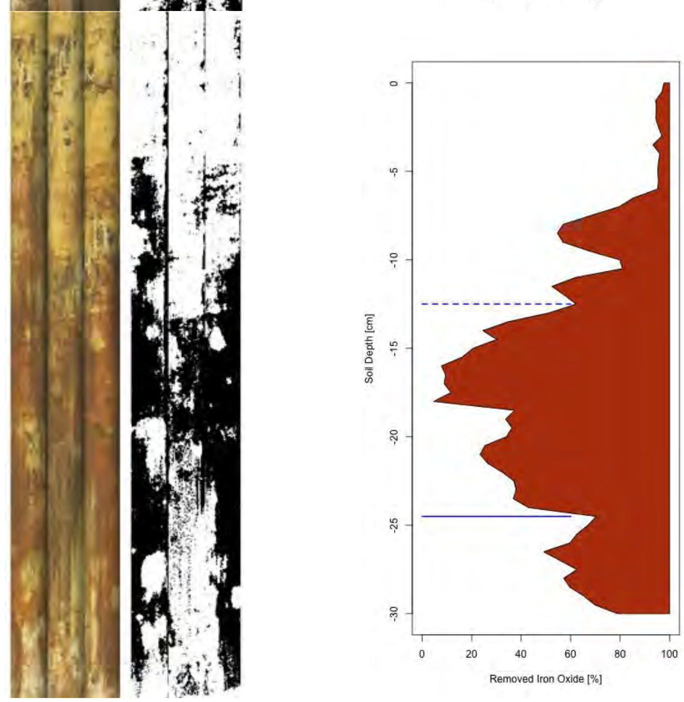


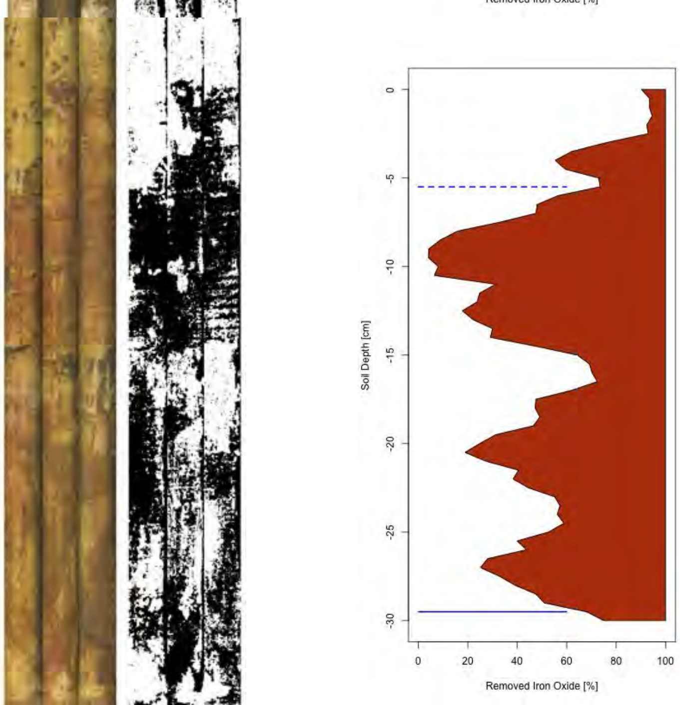
2017 – Nest 2 – Installation 2



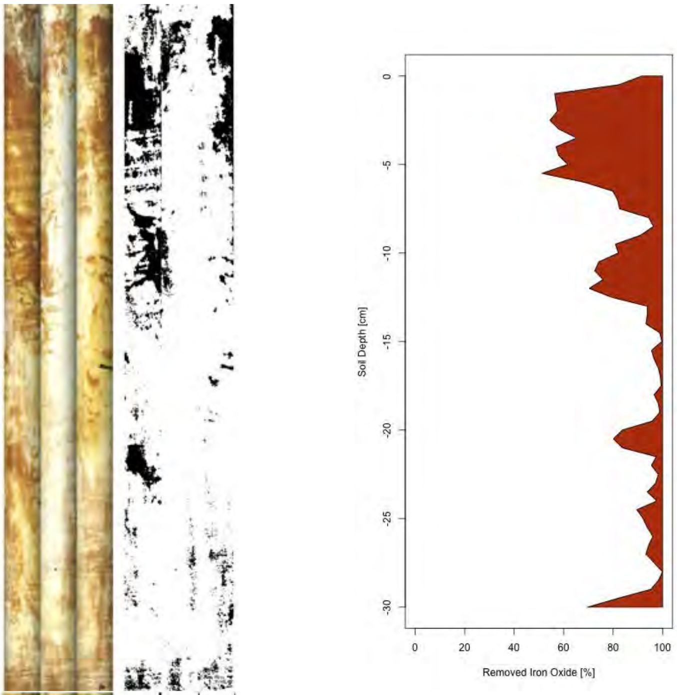


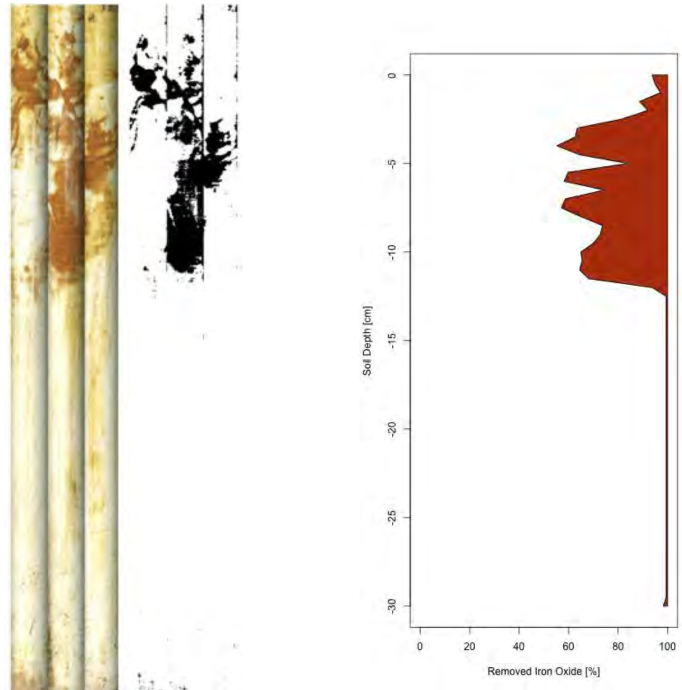


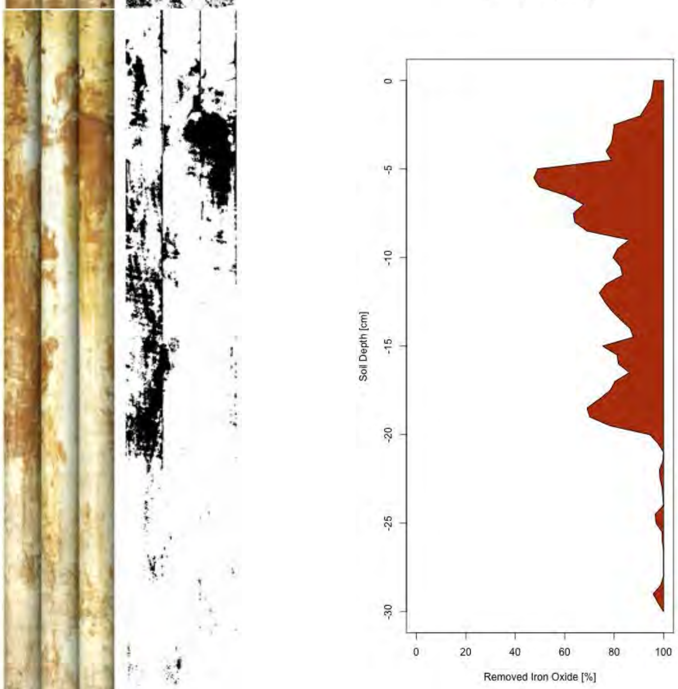


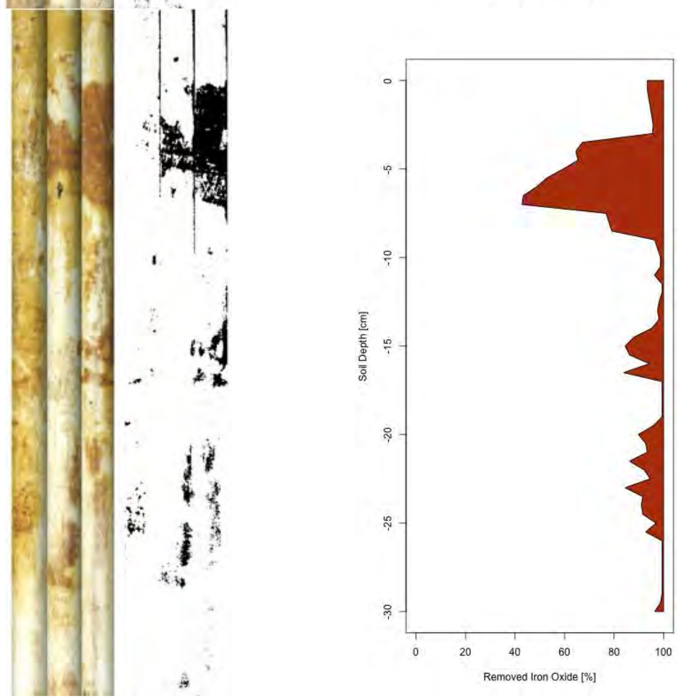


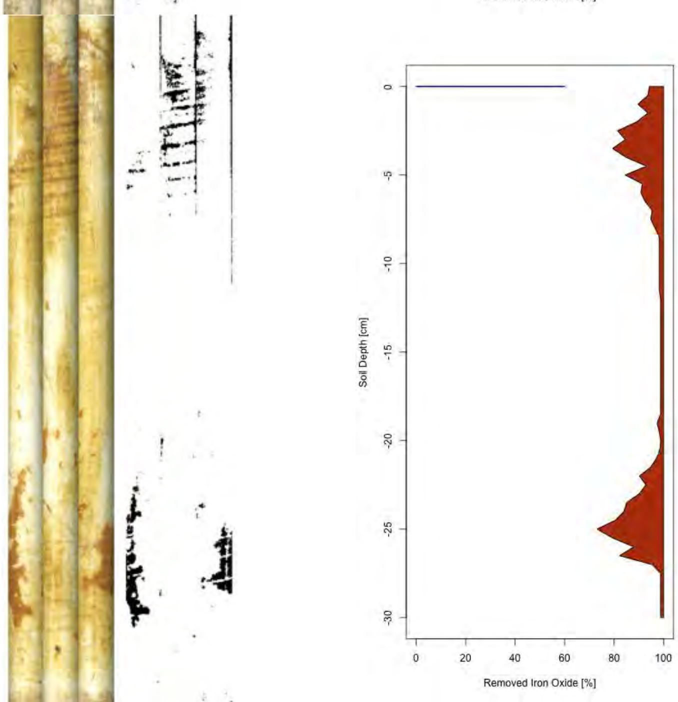
2017 – Nest 2 – Installation 3



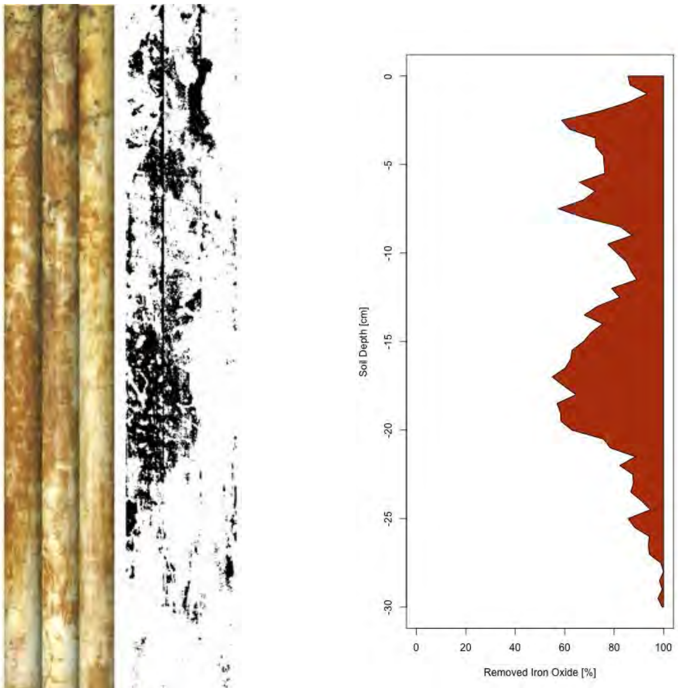


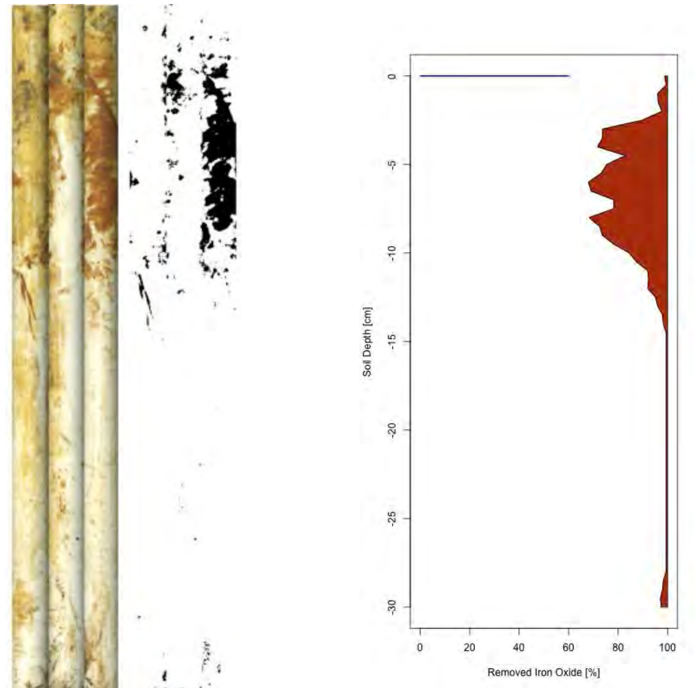


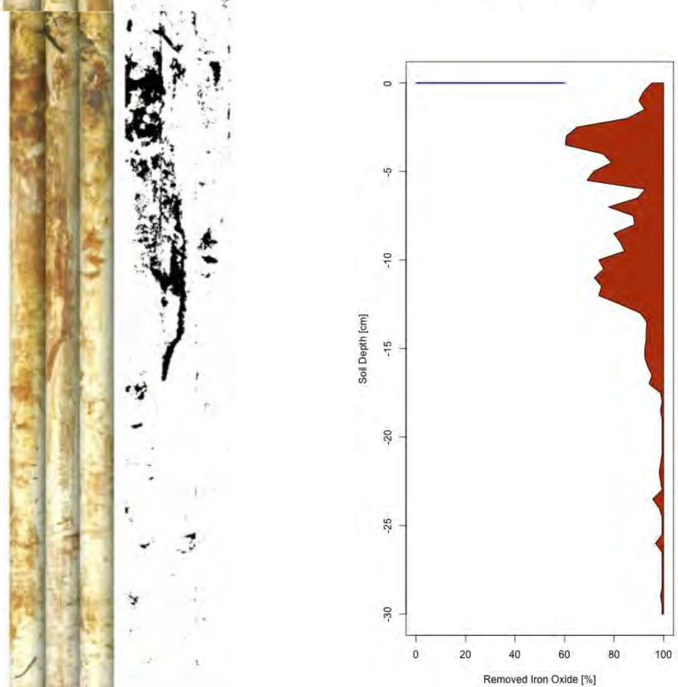


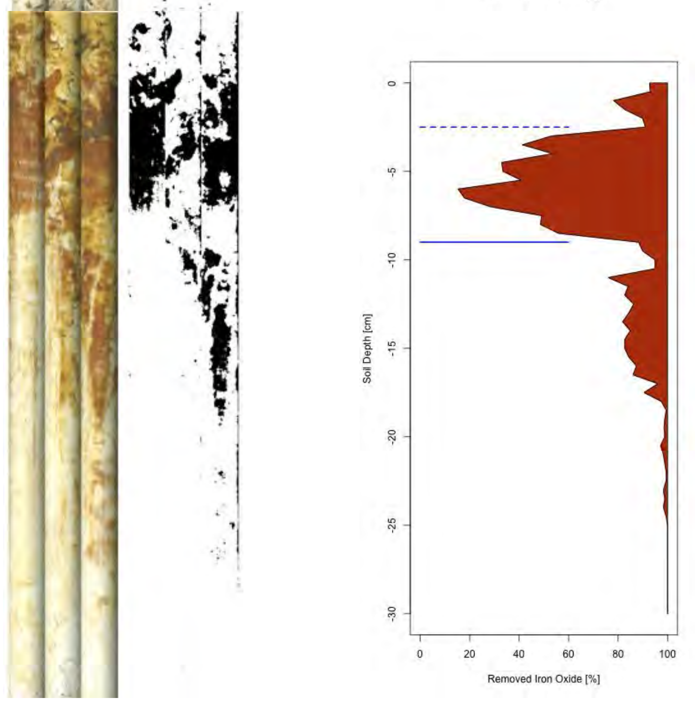


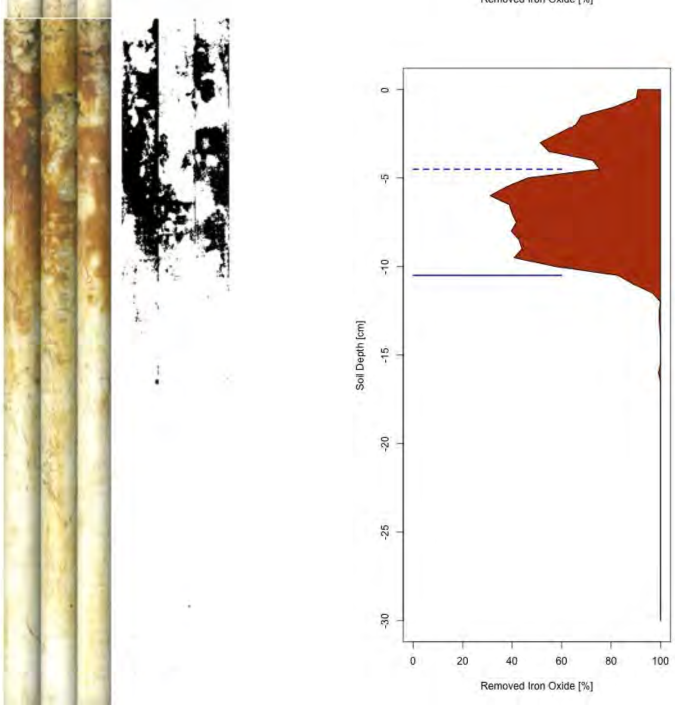
2017 – Nest 2 – Installation 4



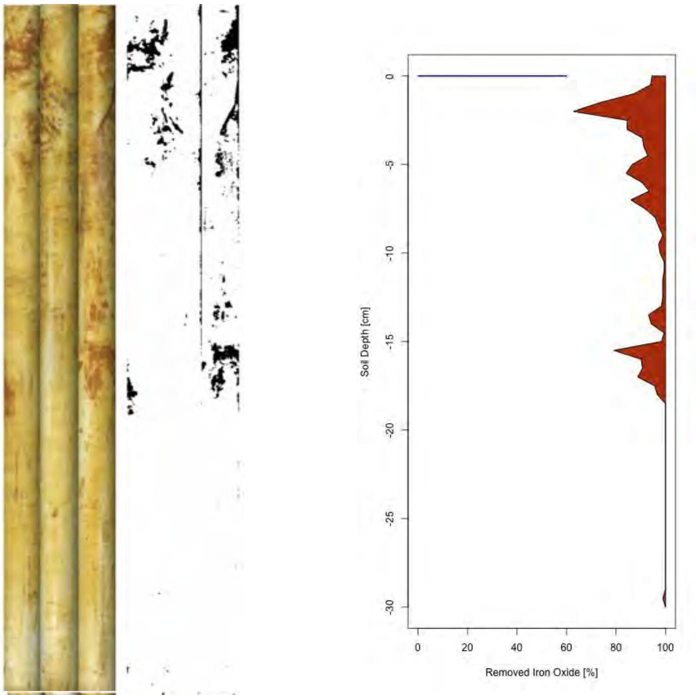


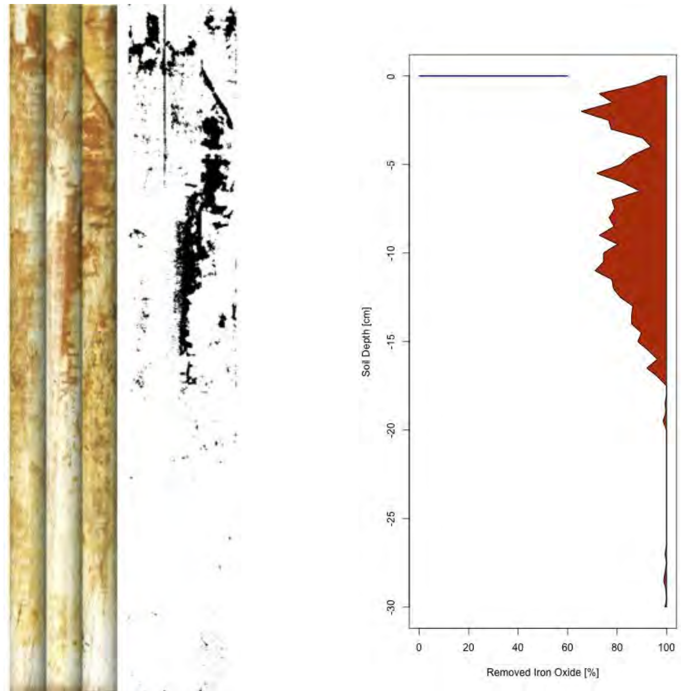


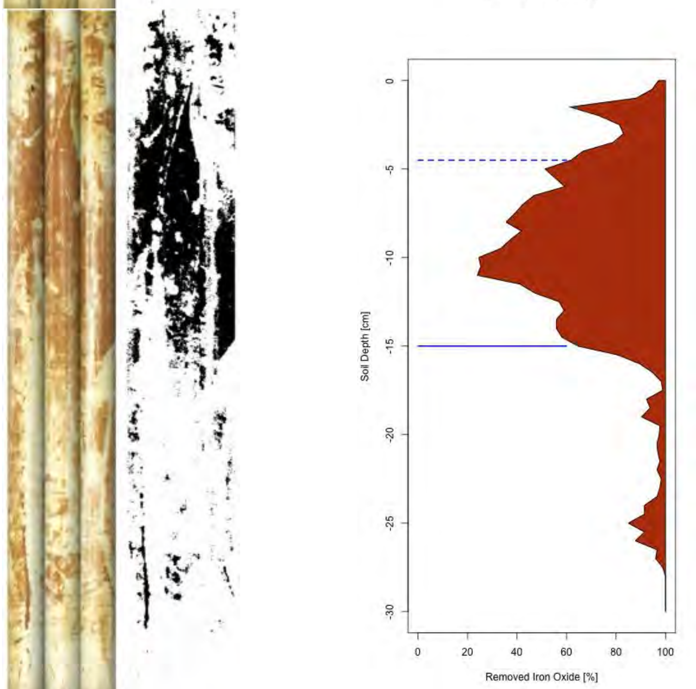


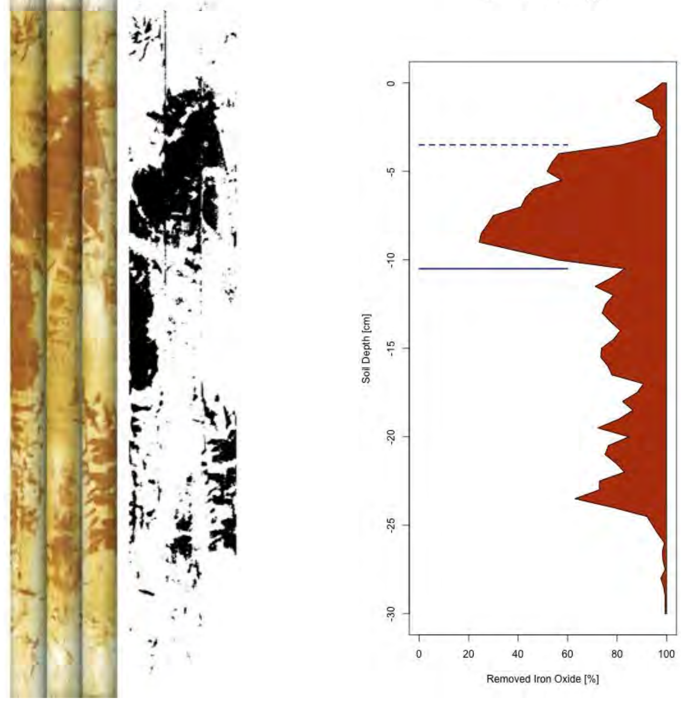


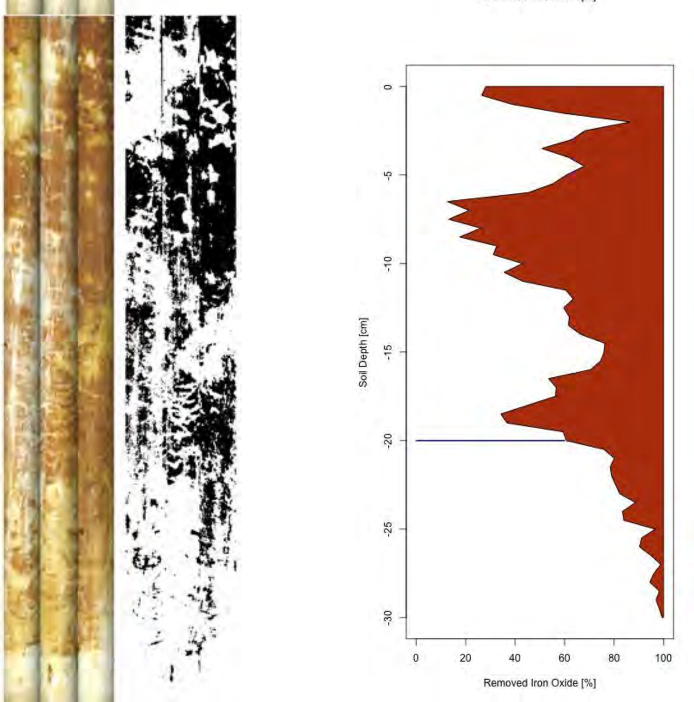
2017 – Nest 2 – Installation 5



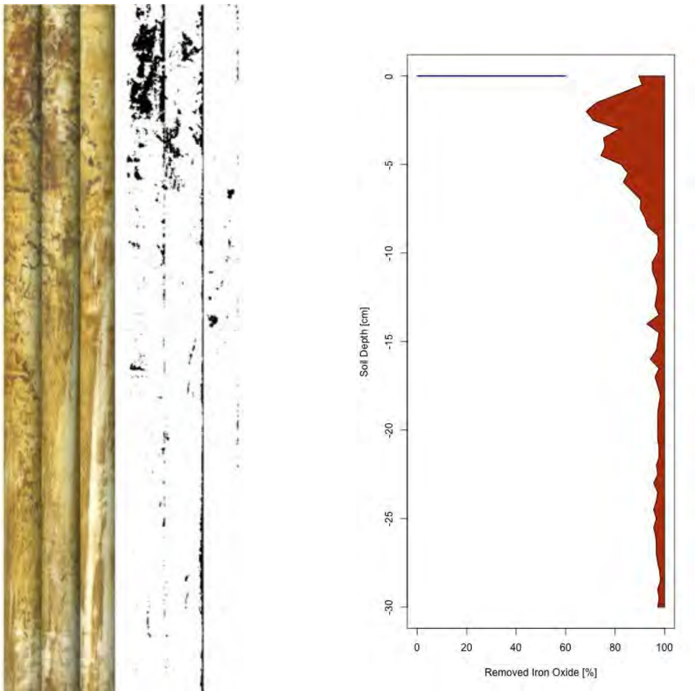


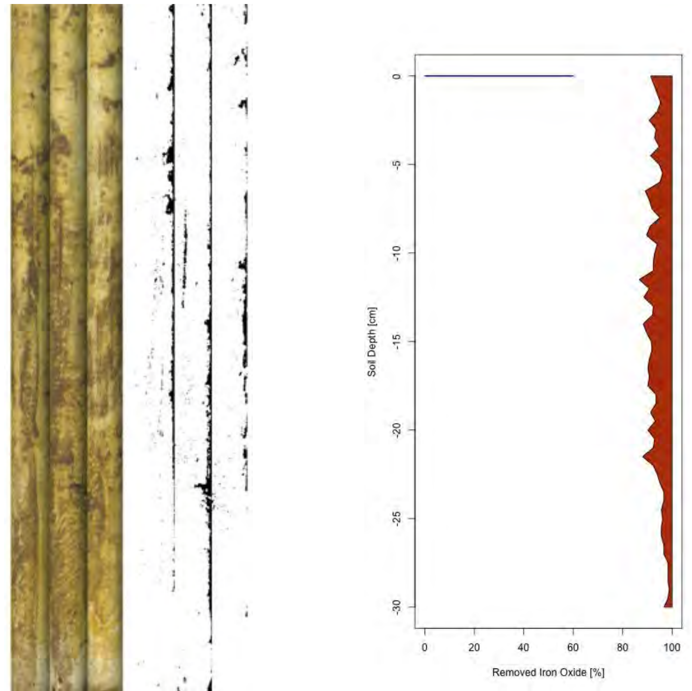


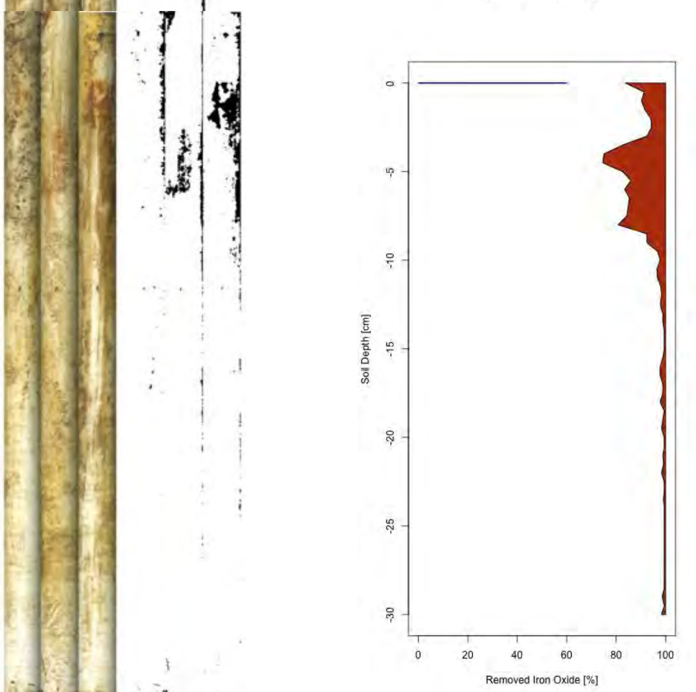


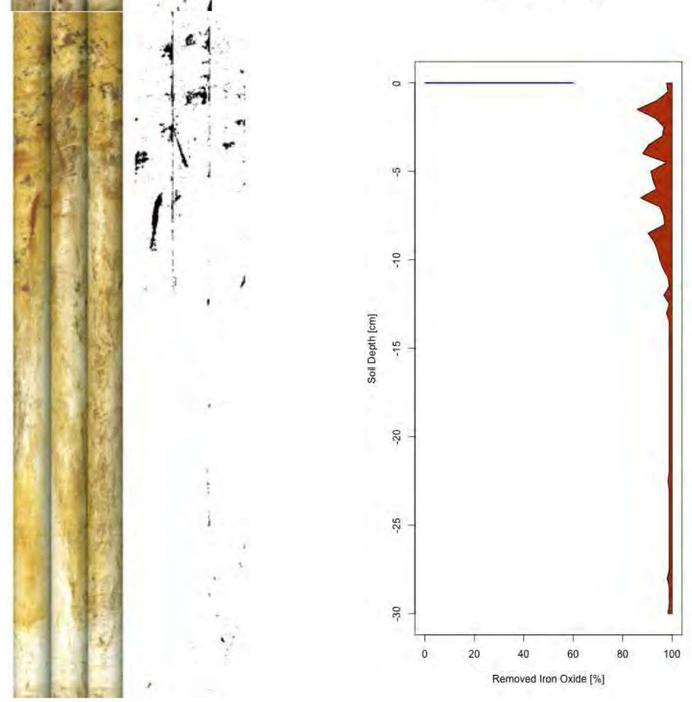


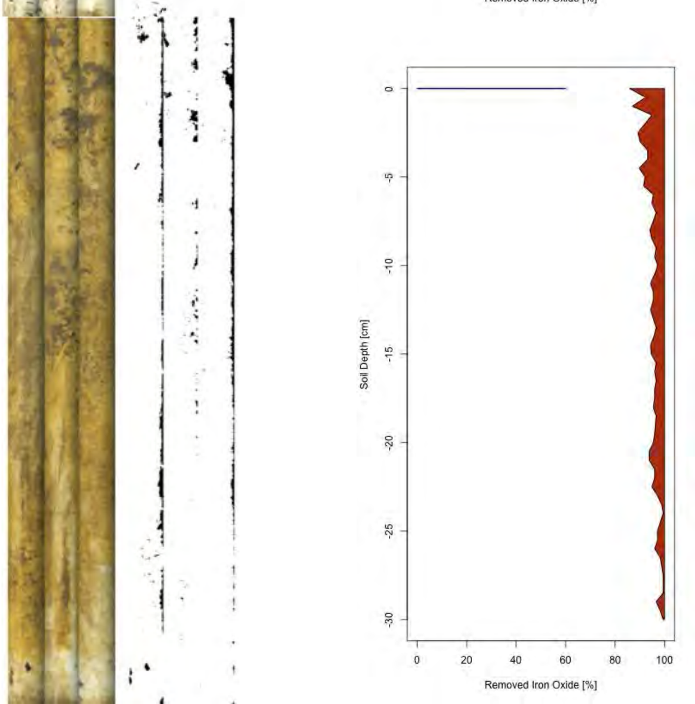
2017 – Nest 2 – Installation 6



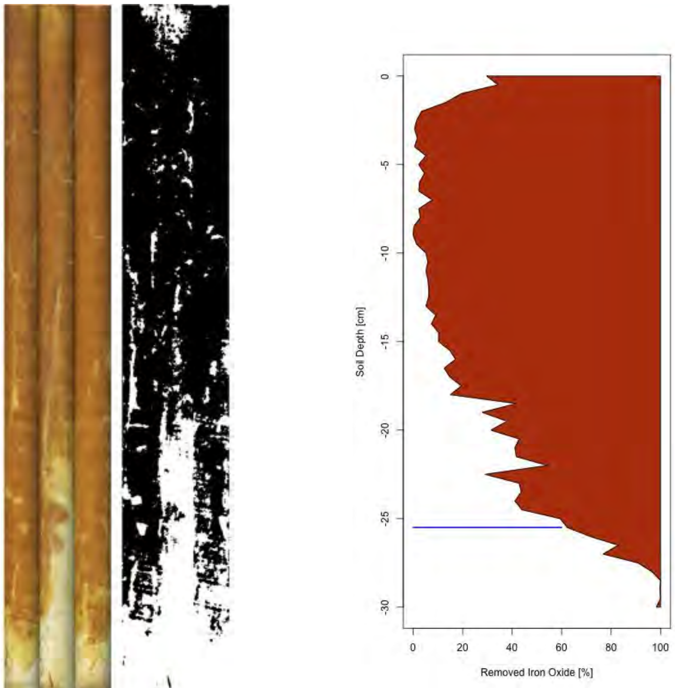


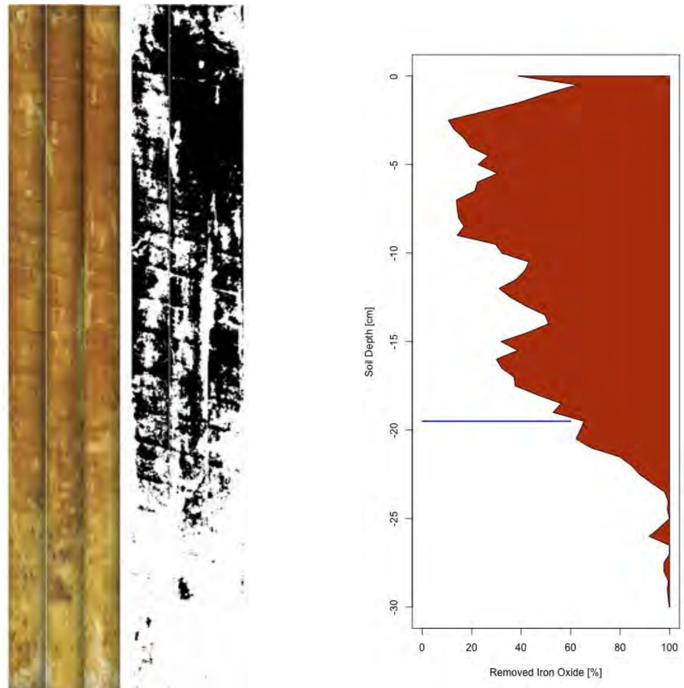


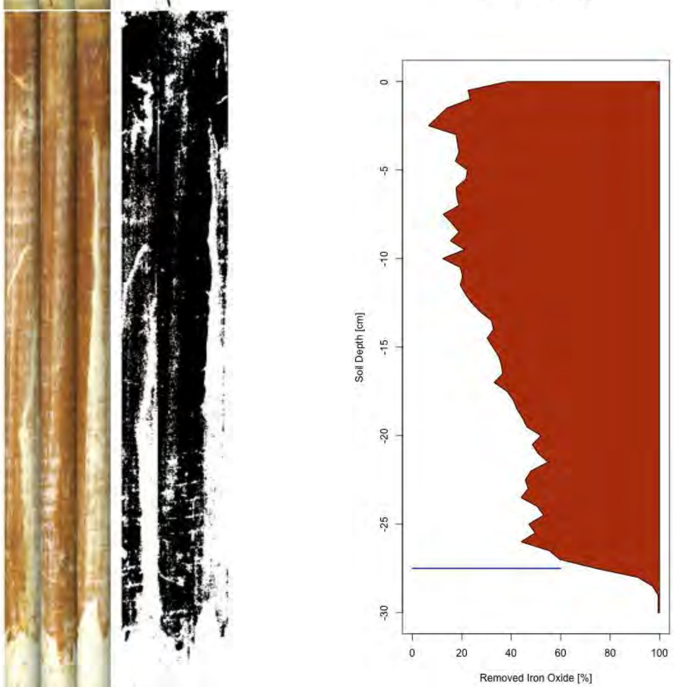


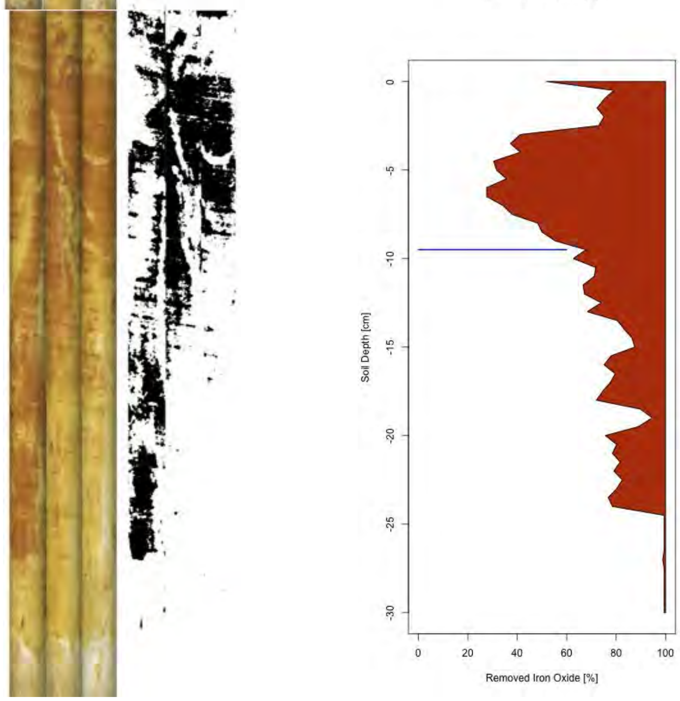


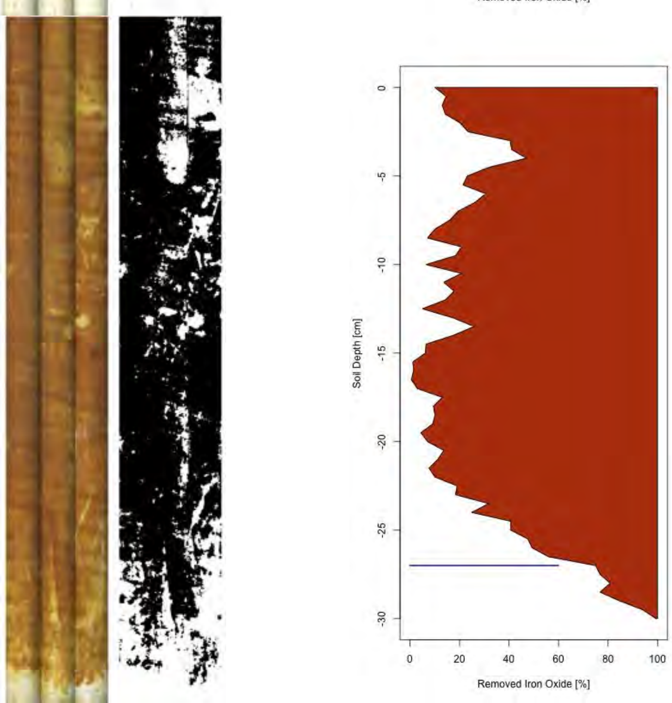
2017 – Nest 2 – Installation 7



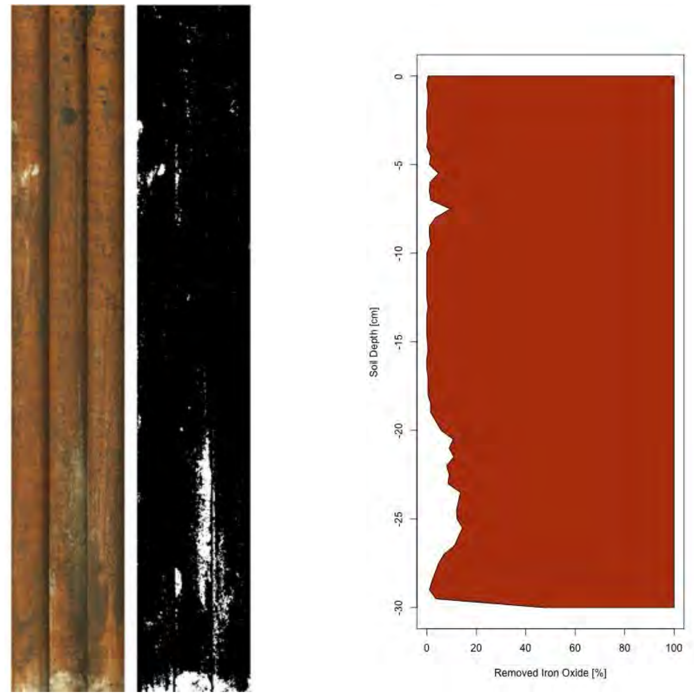


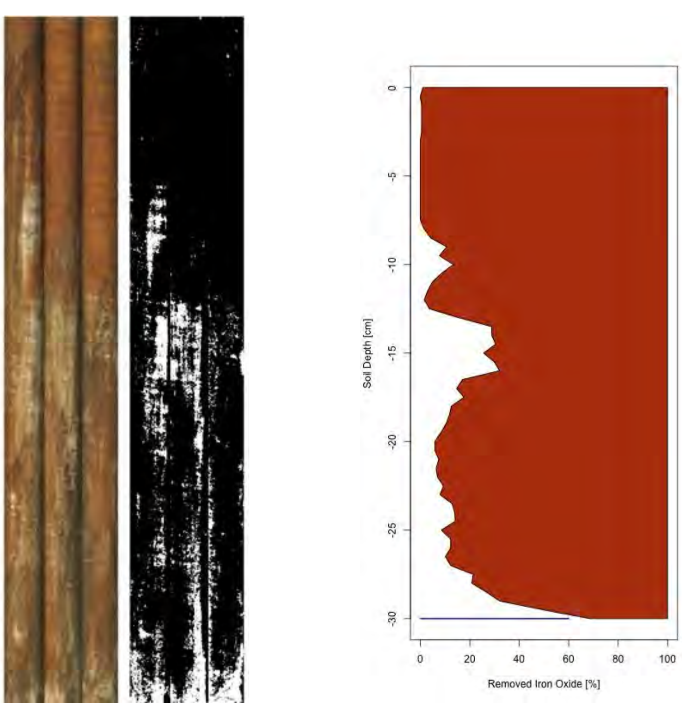




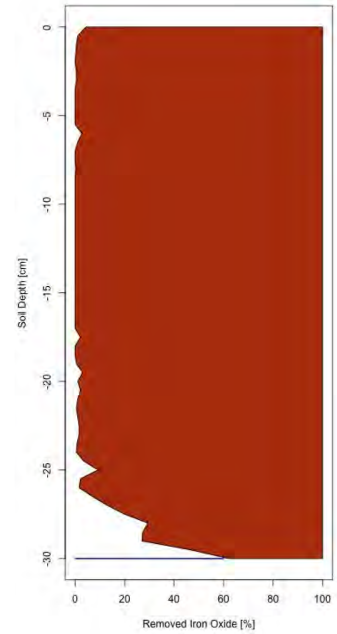


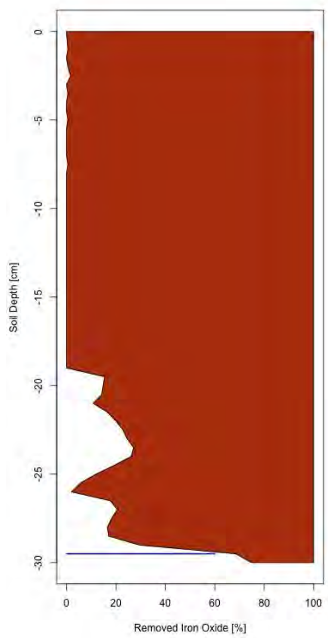
2017 – Nest 3 – Installation 1

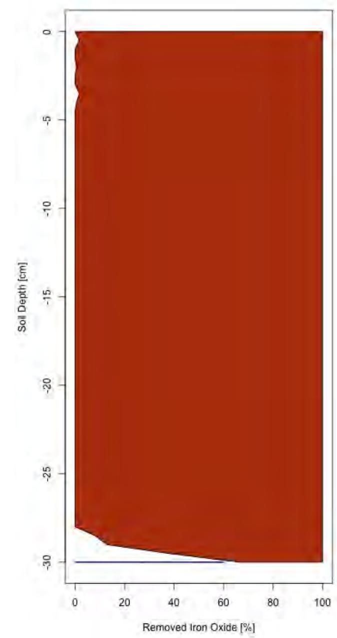


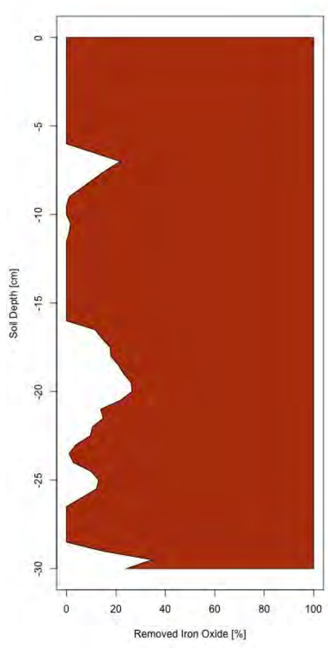


2017 – Nest 3 – Installation 2

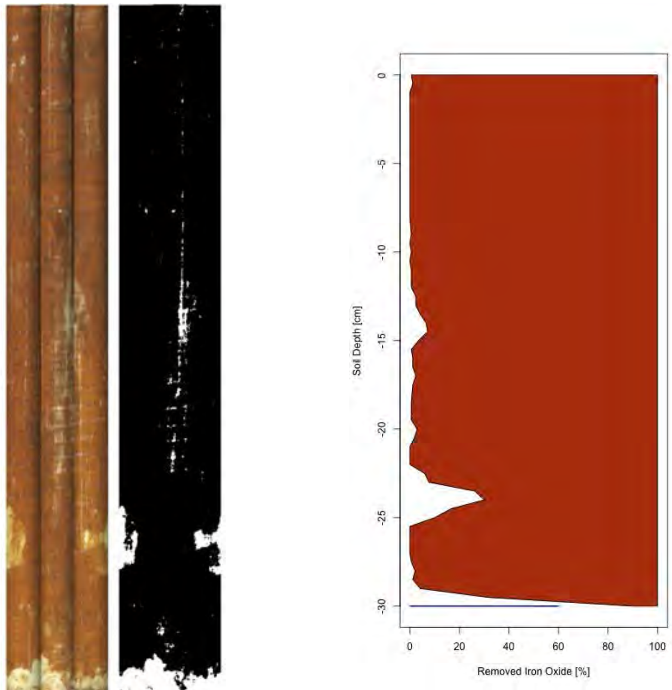


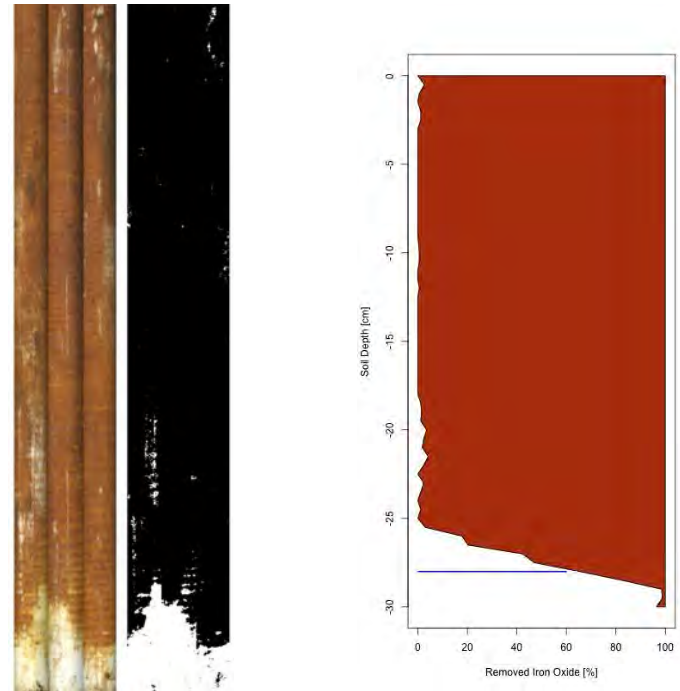


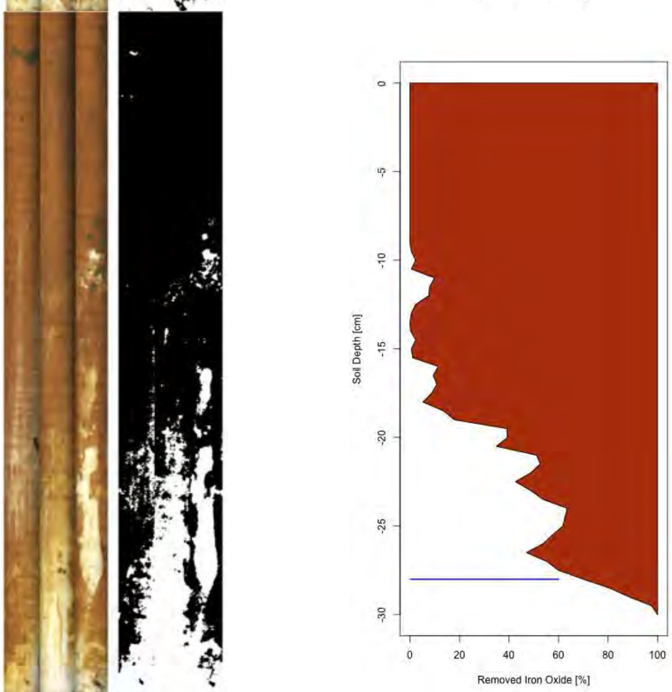


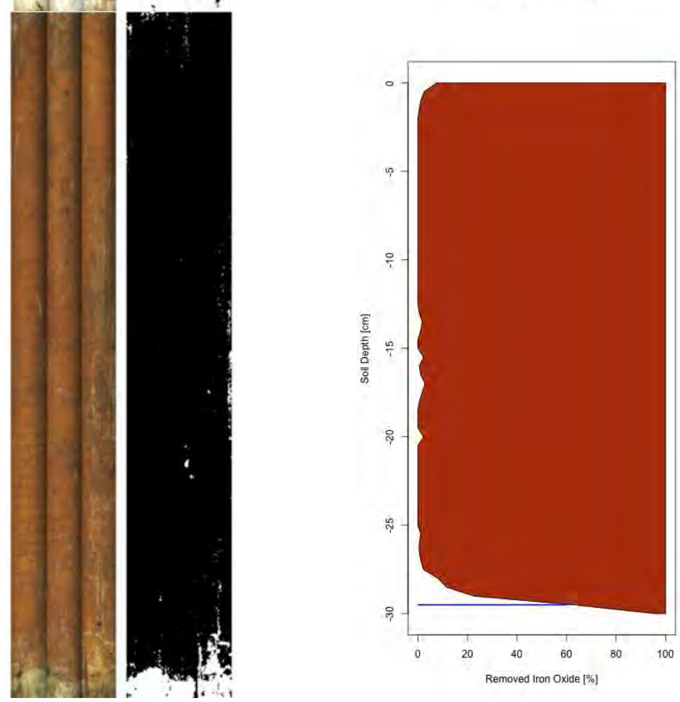


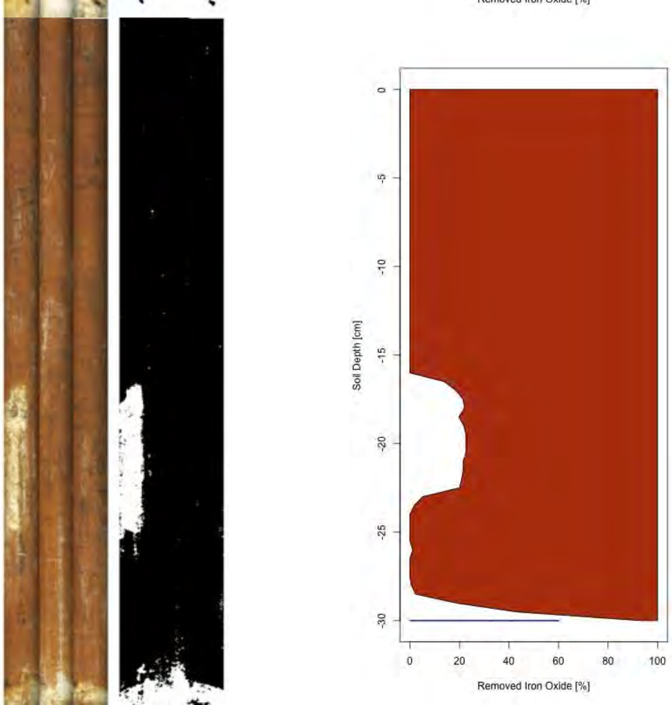
2017 – Nest 3 – Installation 3



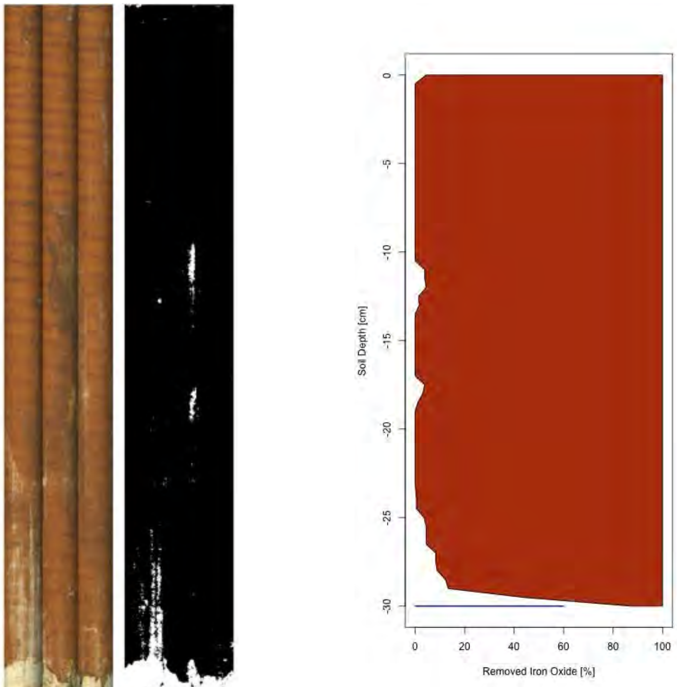


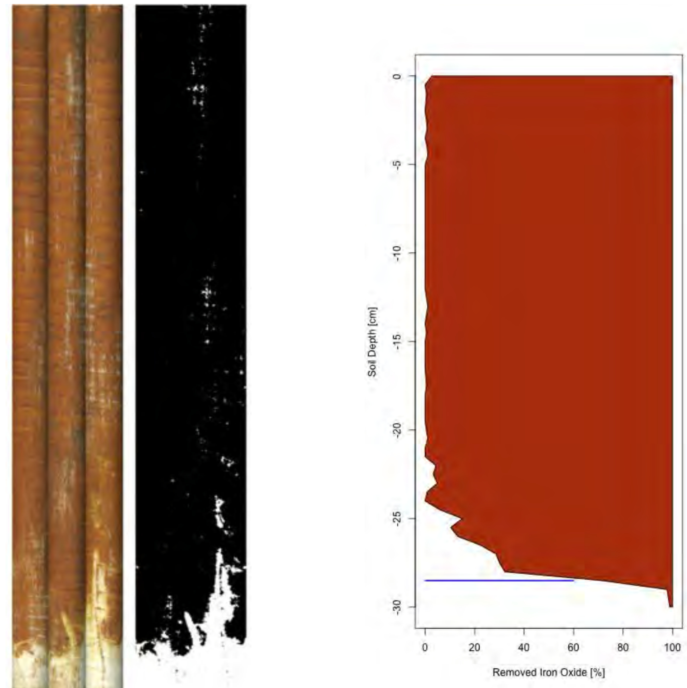


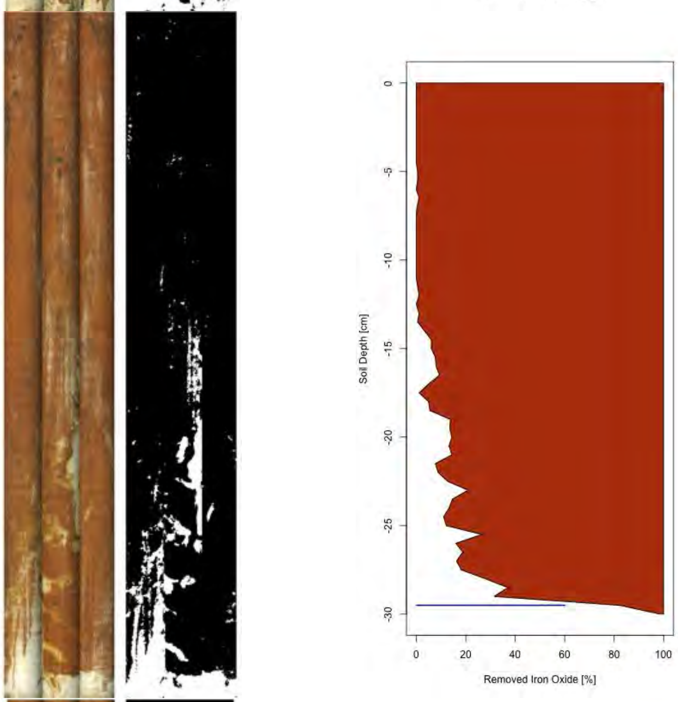


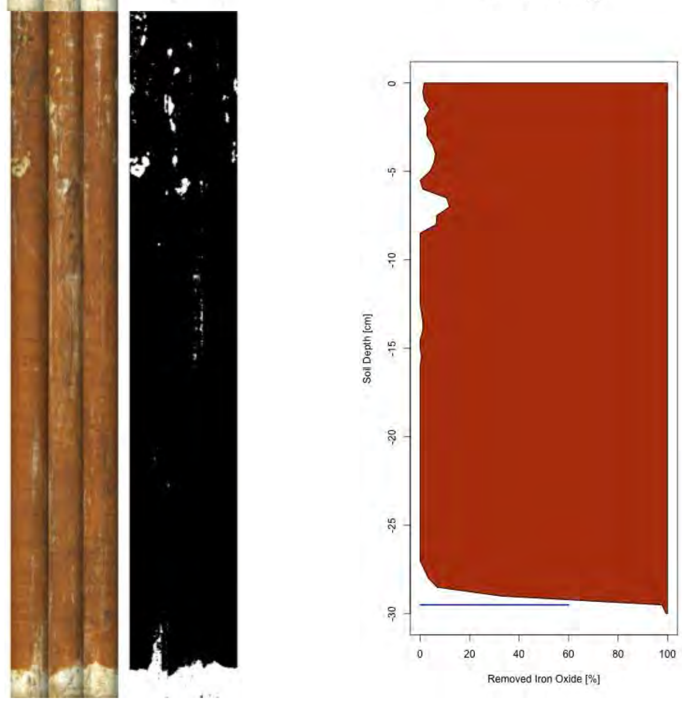


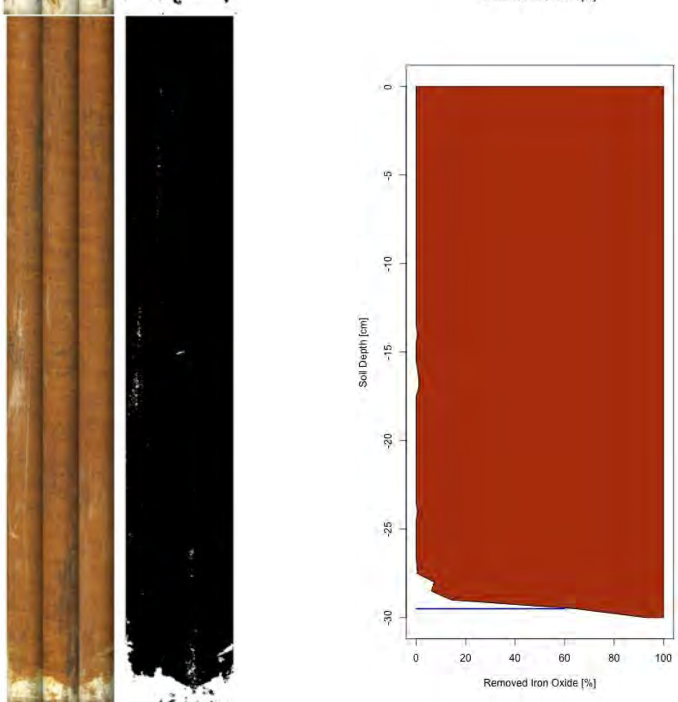
2017 – Nest 3 – Installation 4



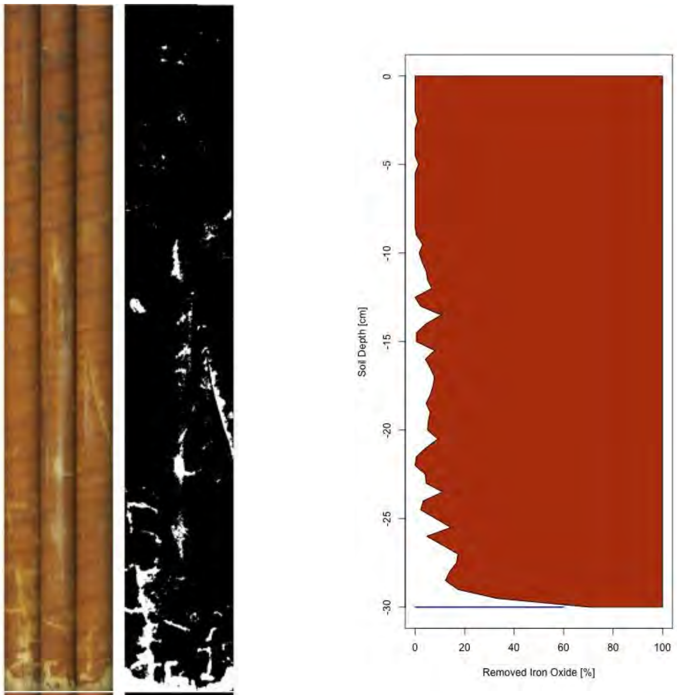


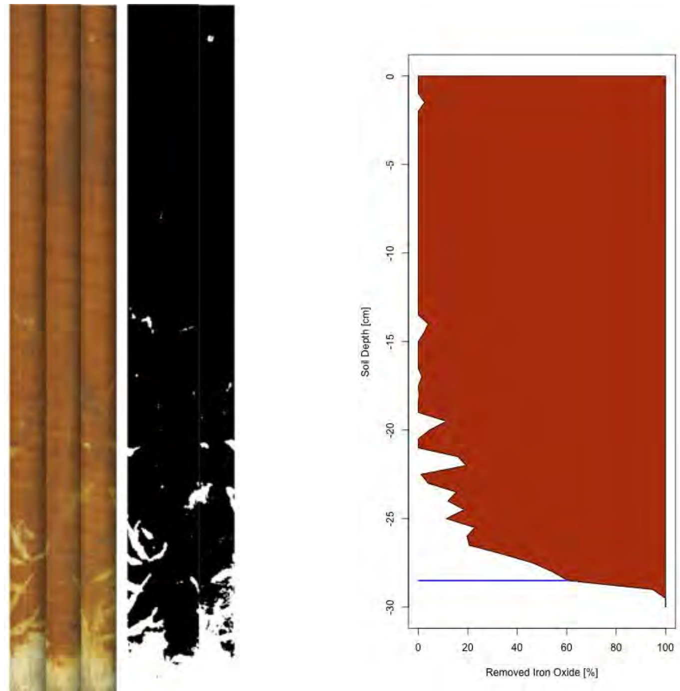


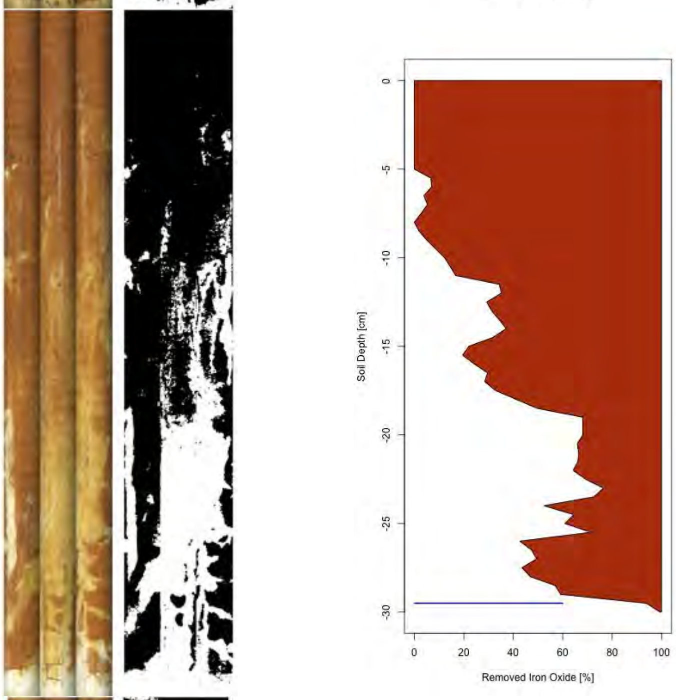


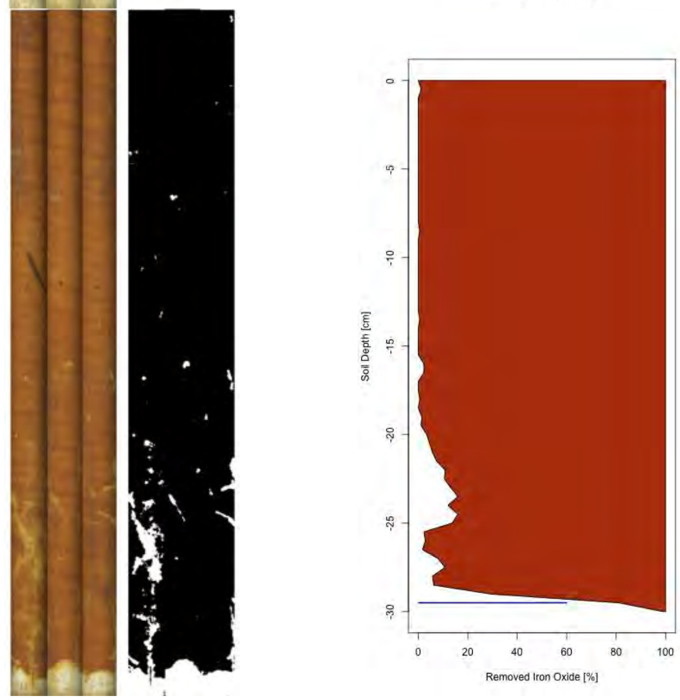


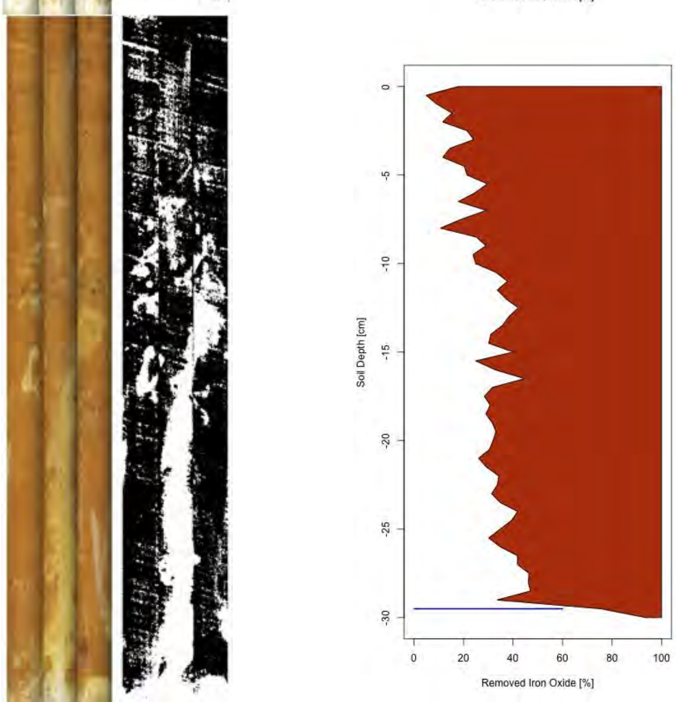
2017 – Nest 3 – Installation 5



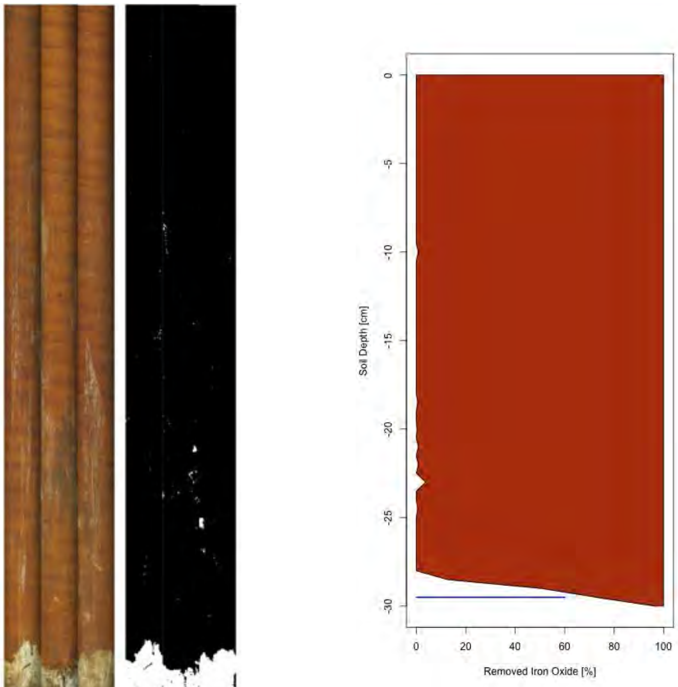


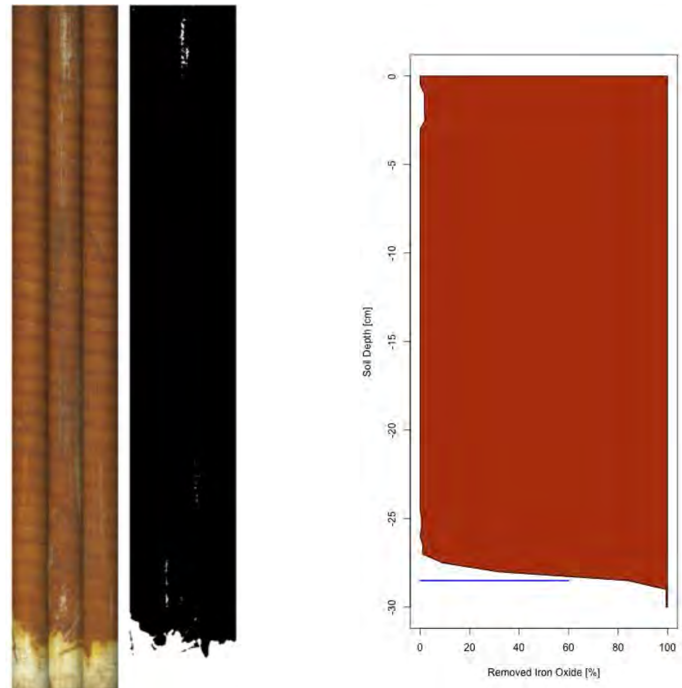


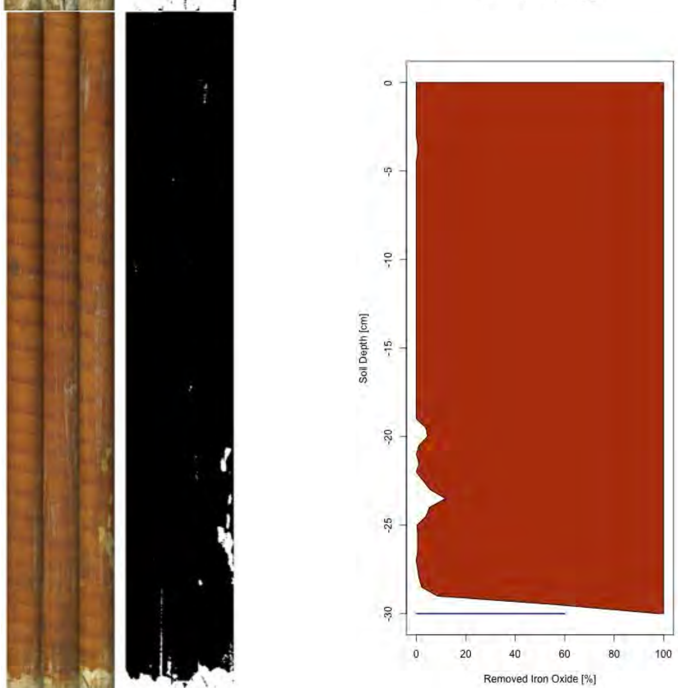


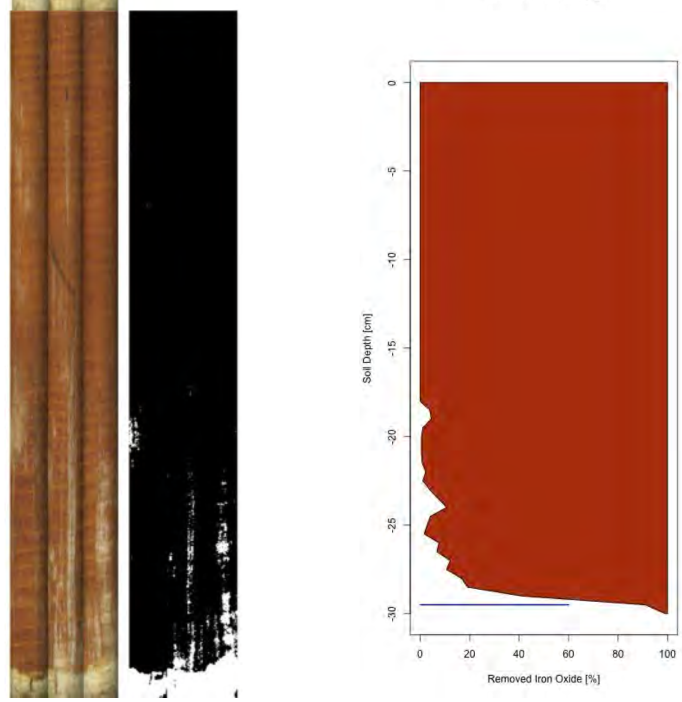


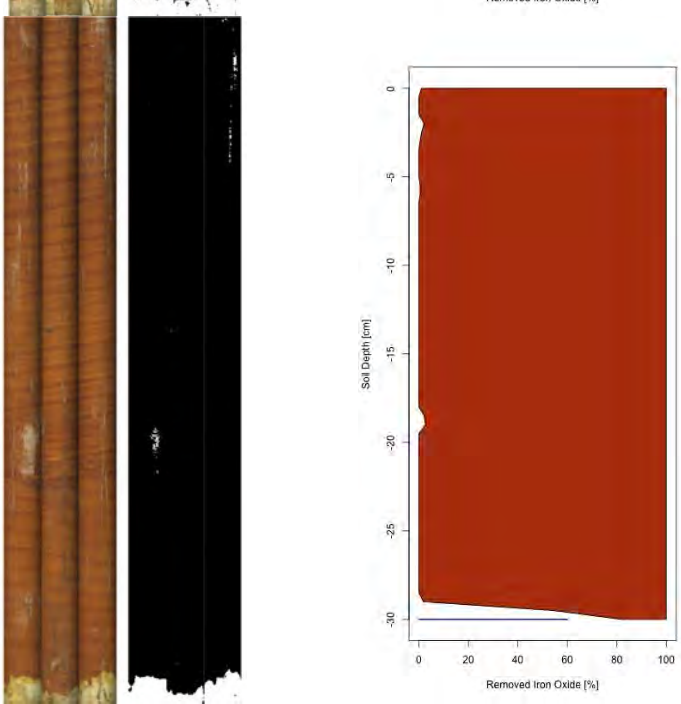
2017 – Nest 3 – Installation 6



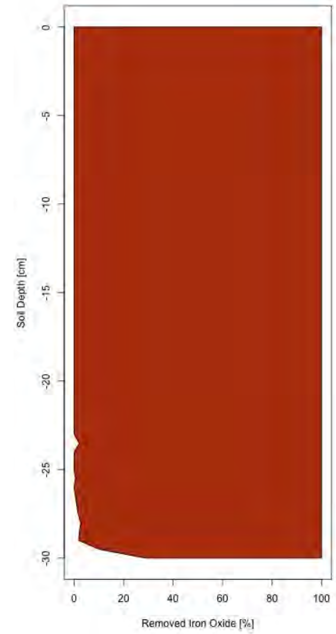


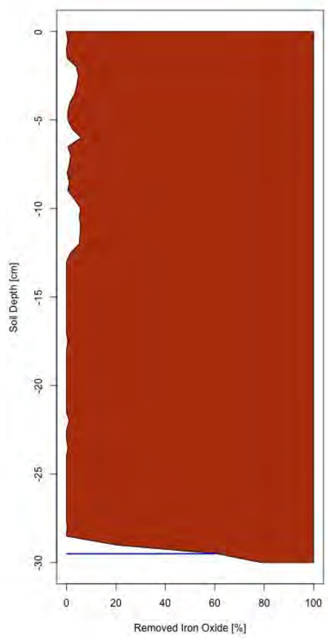


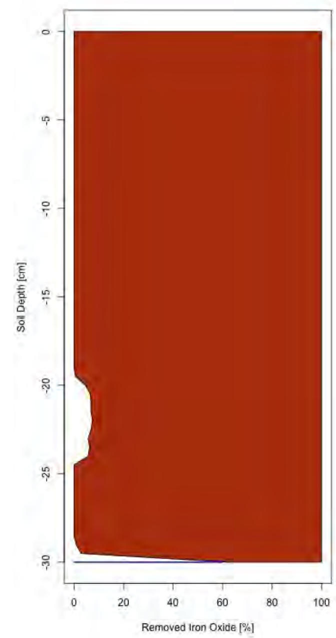




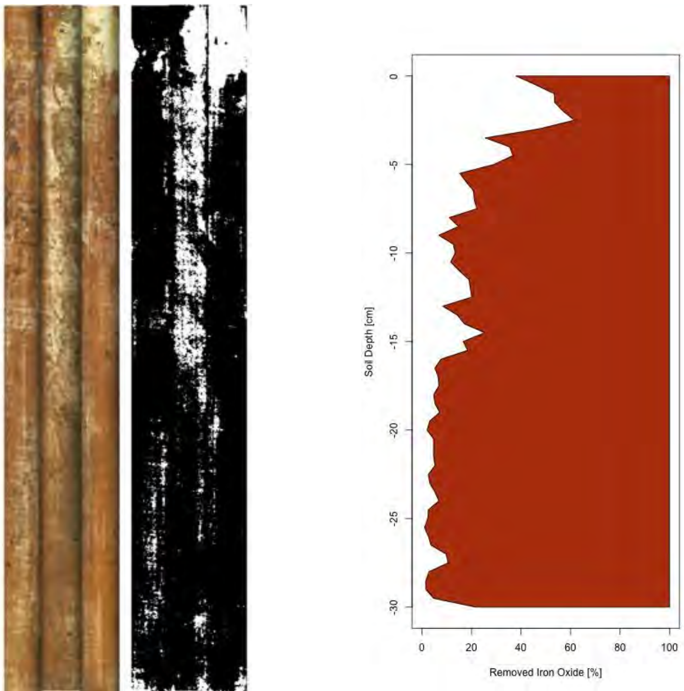
2017 – Nest 3 – Installation 7

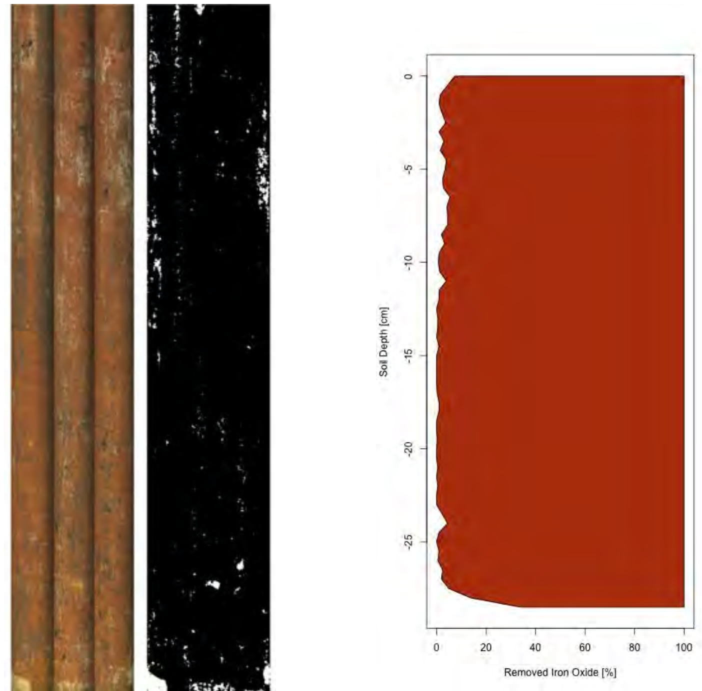


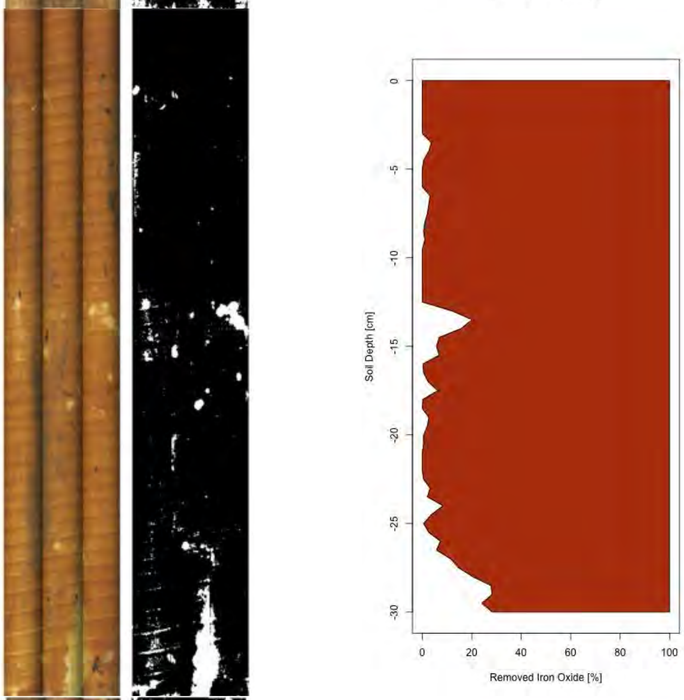


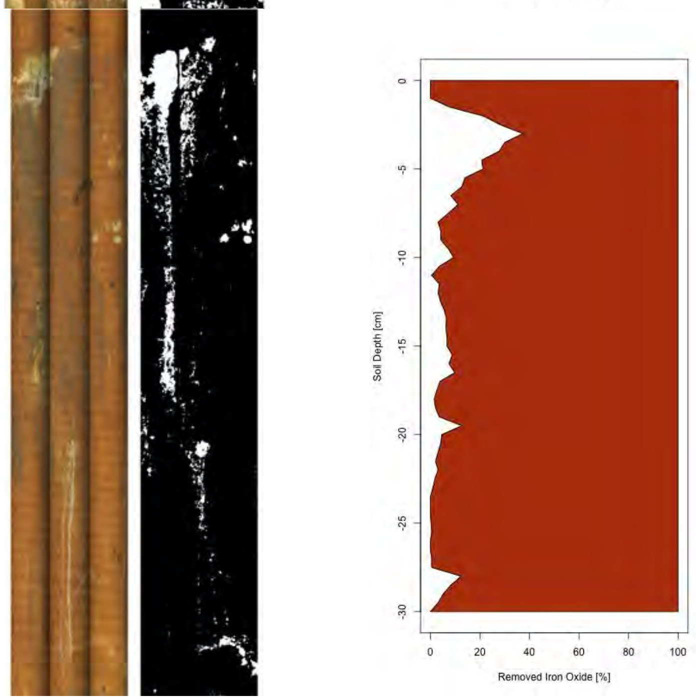


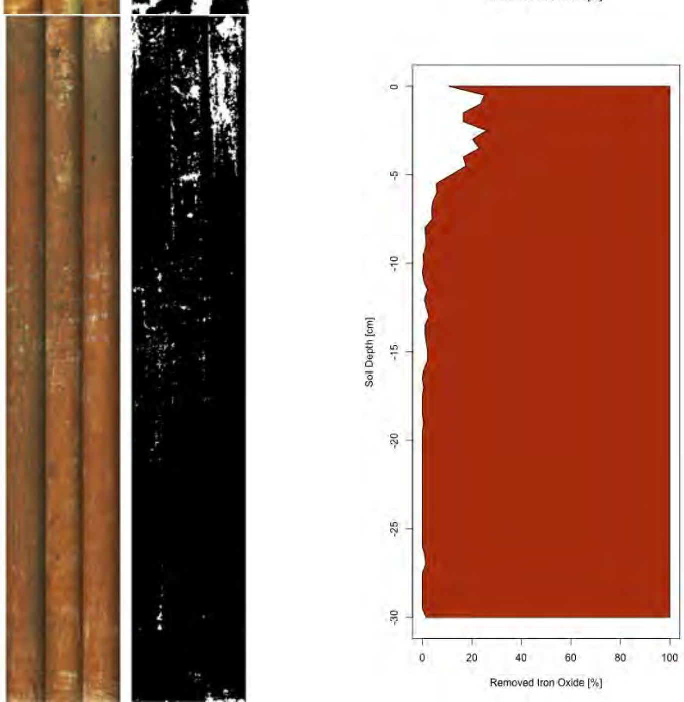
2017 – Nest 4 – Installation 1



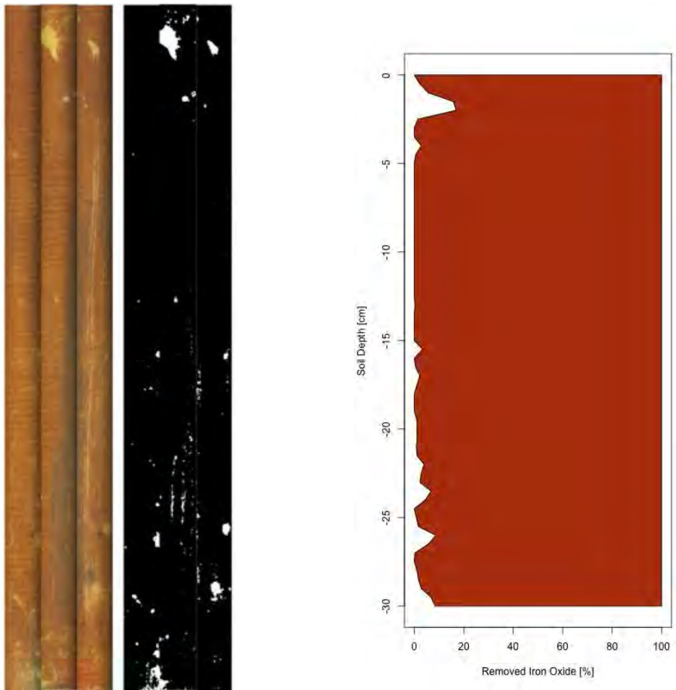


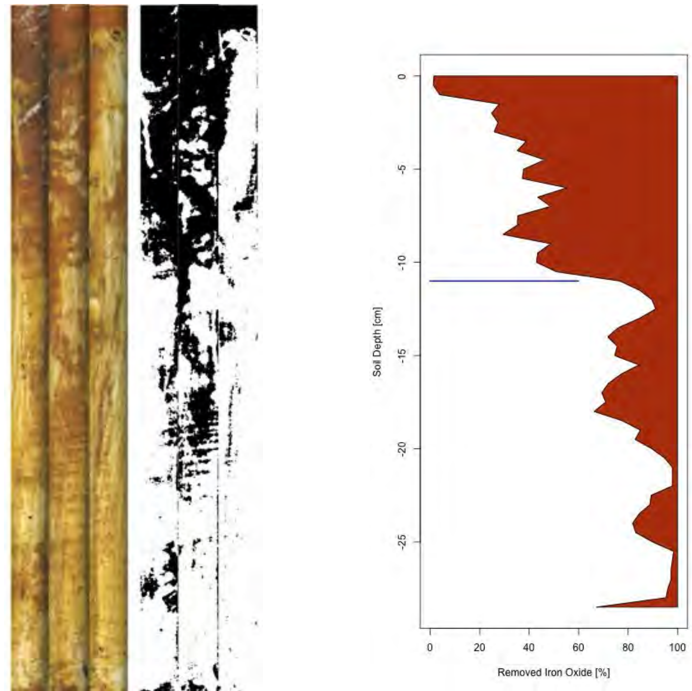


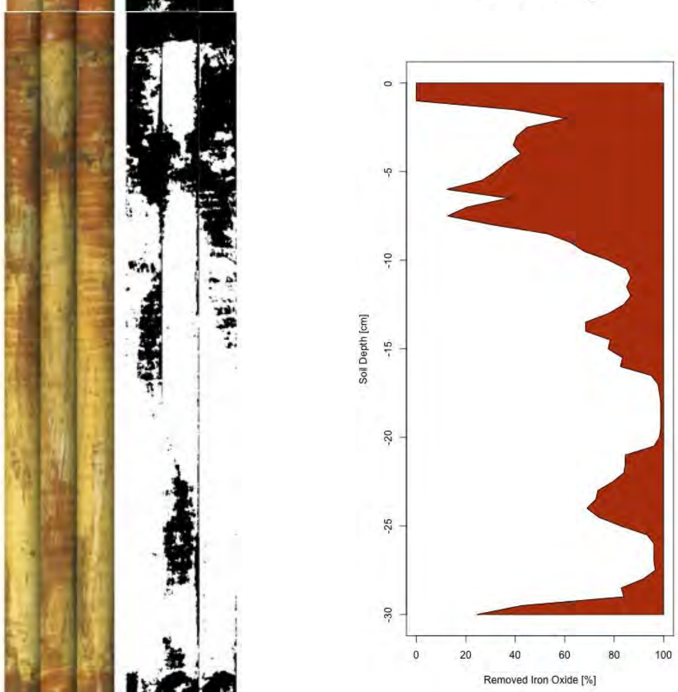


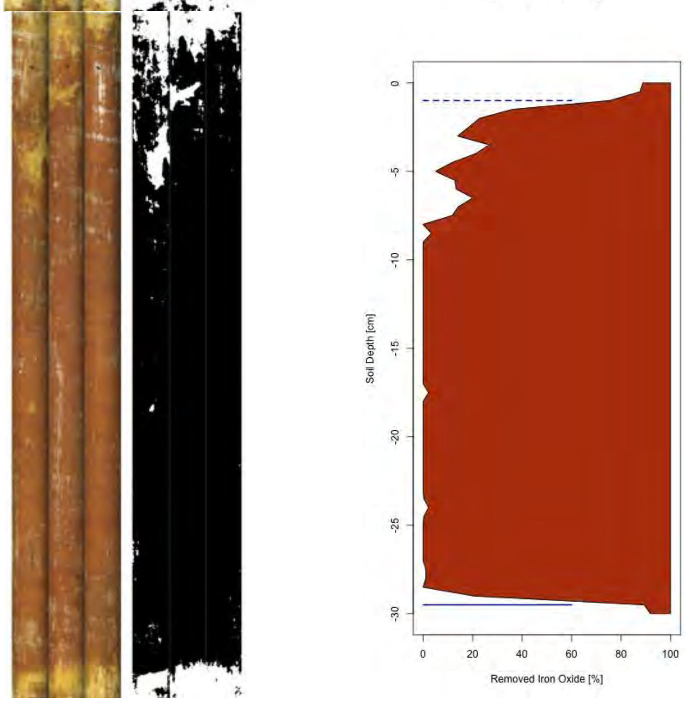


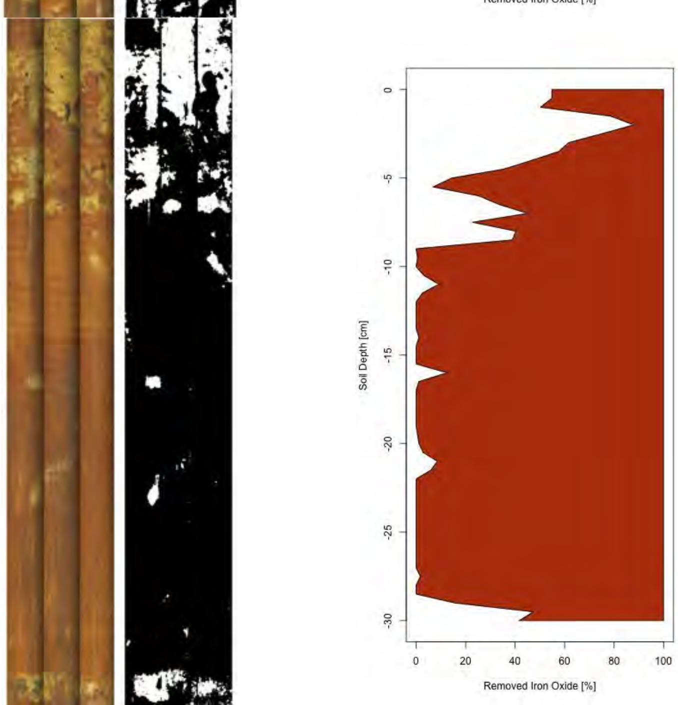
2017 – Nest 4 – Installation 2



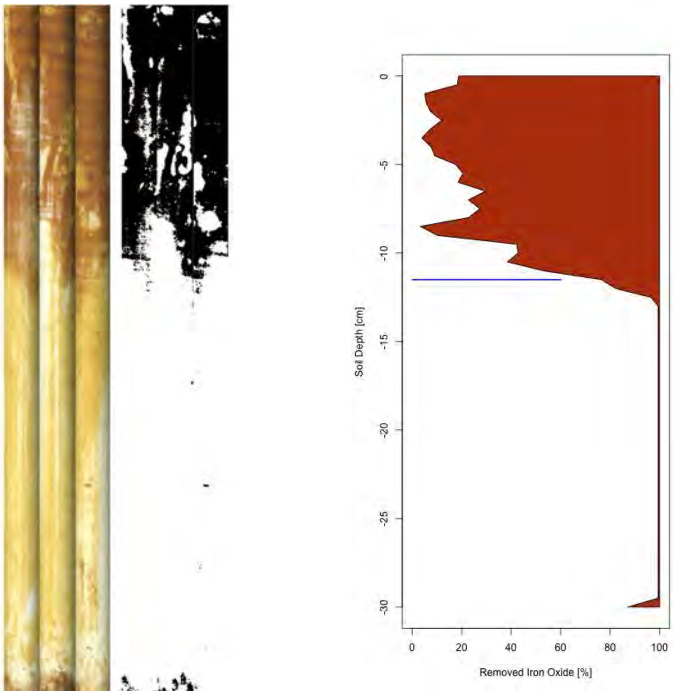


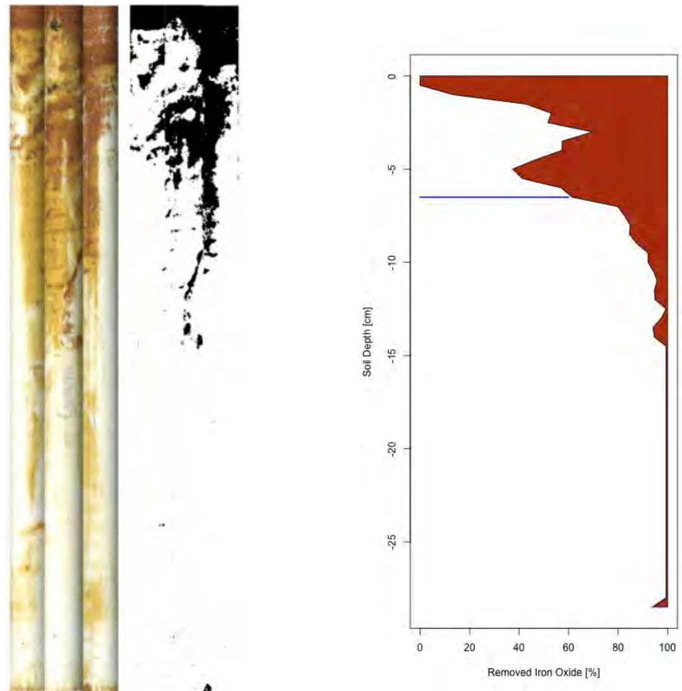


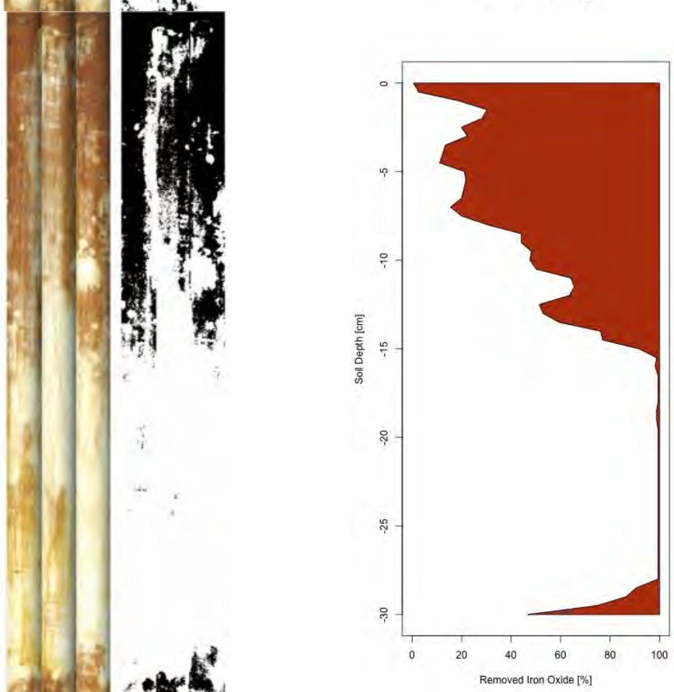


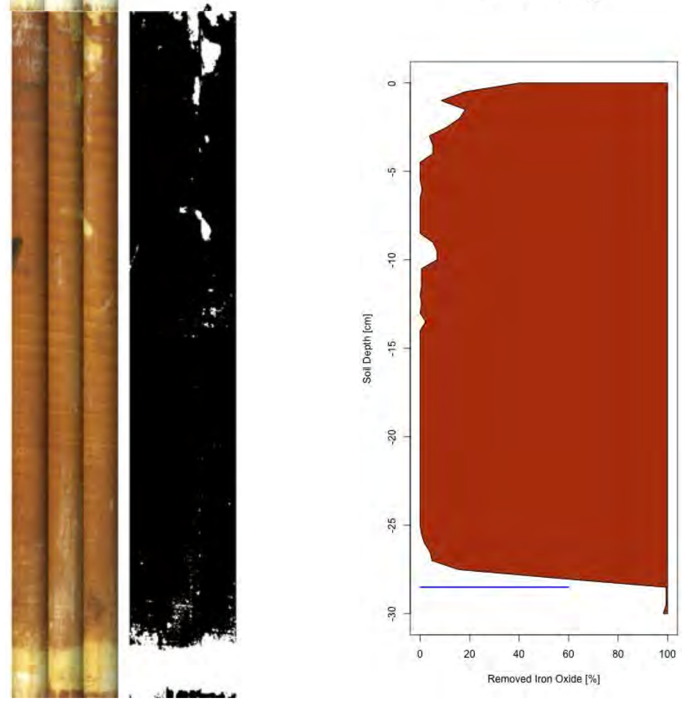


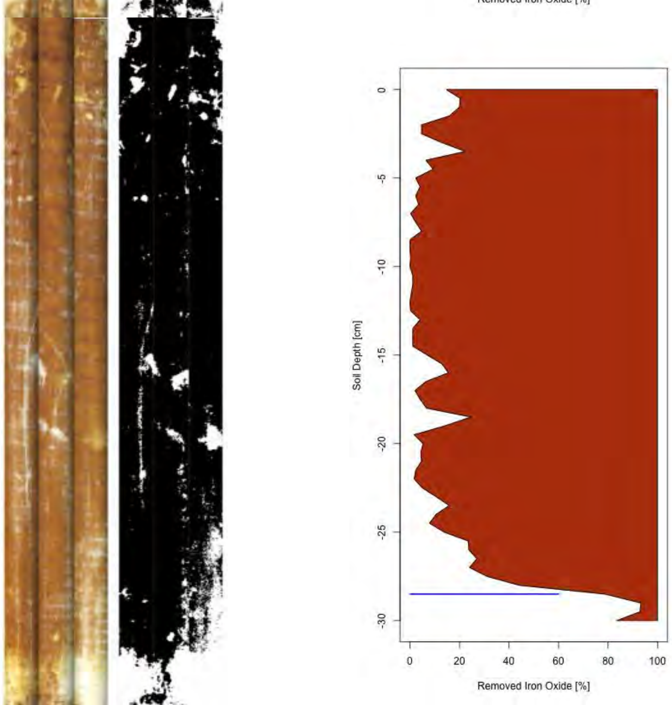
2017 – Nest 4 – Installation 3



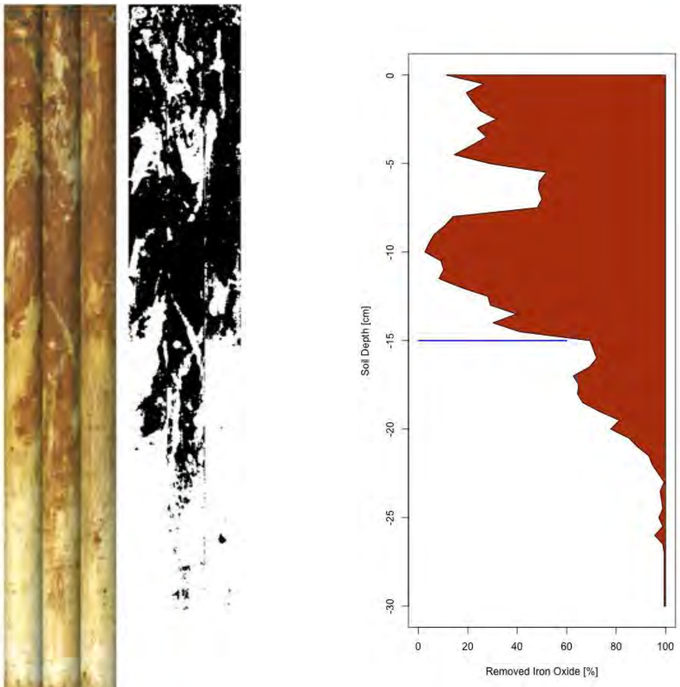


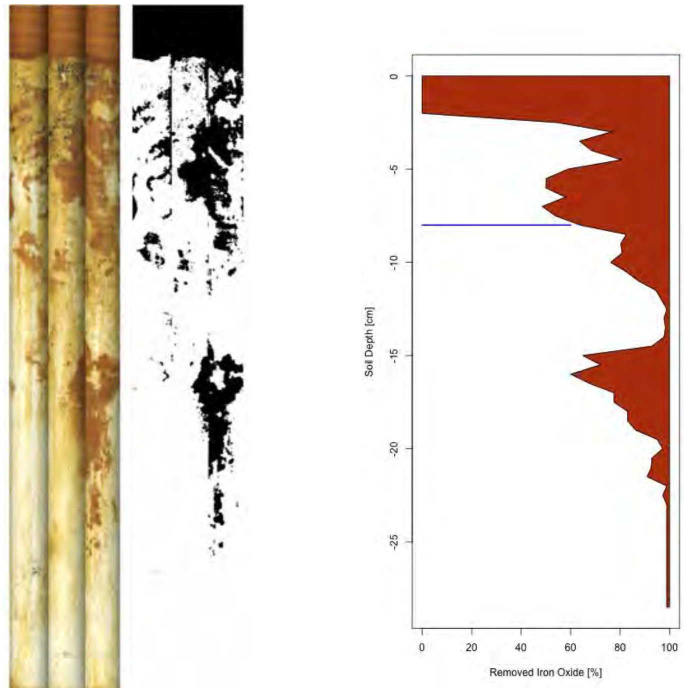


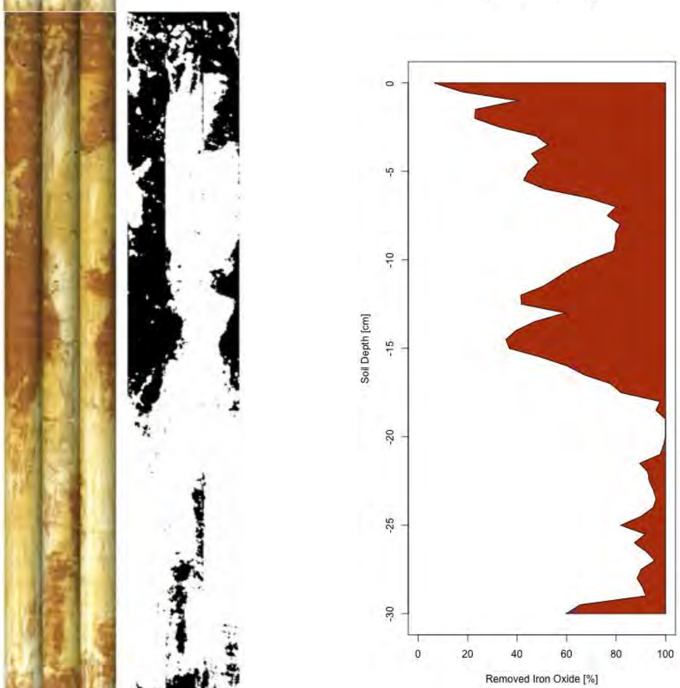


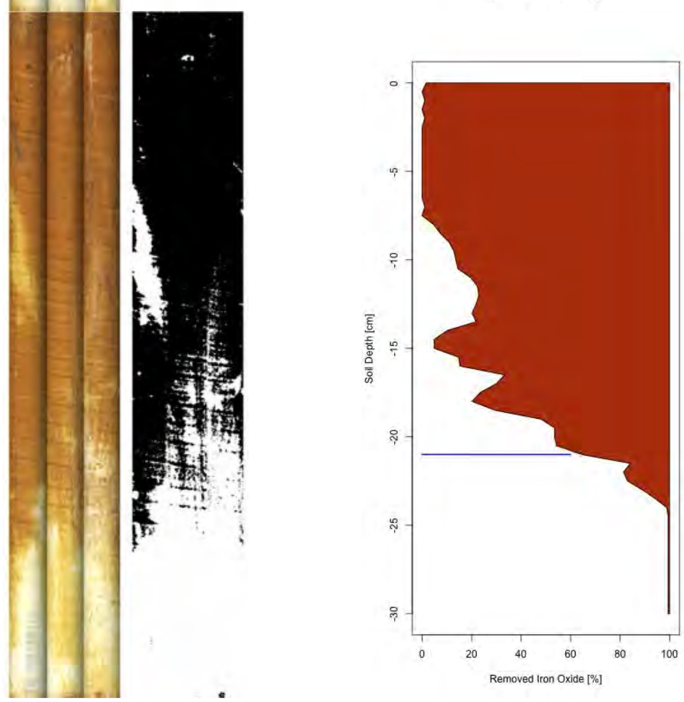


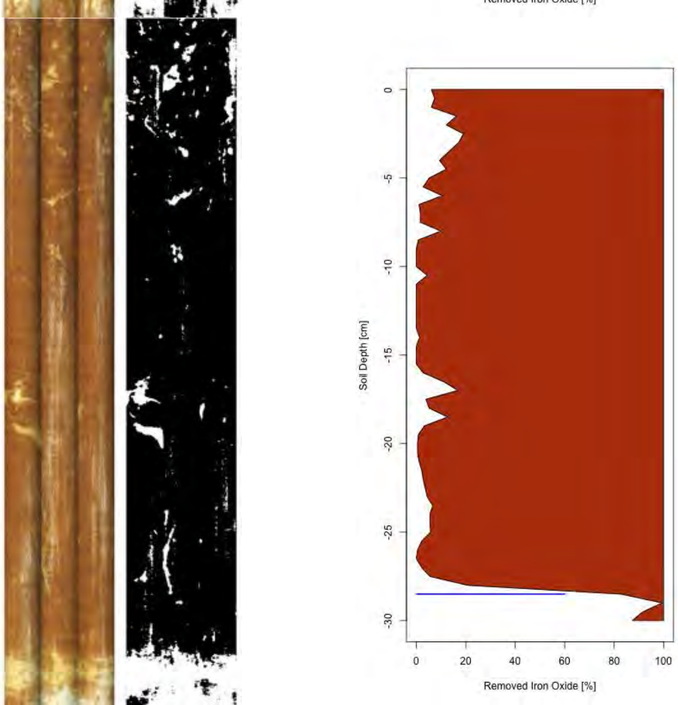
2017 – Nest 4 – Installation 4



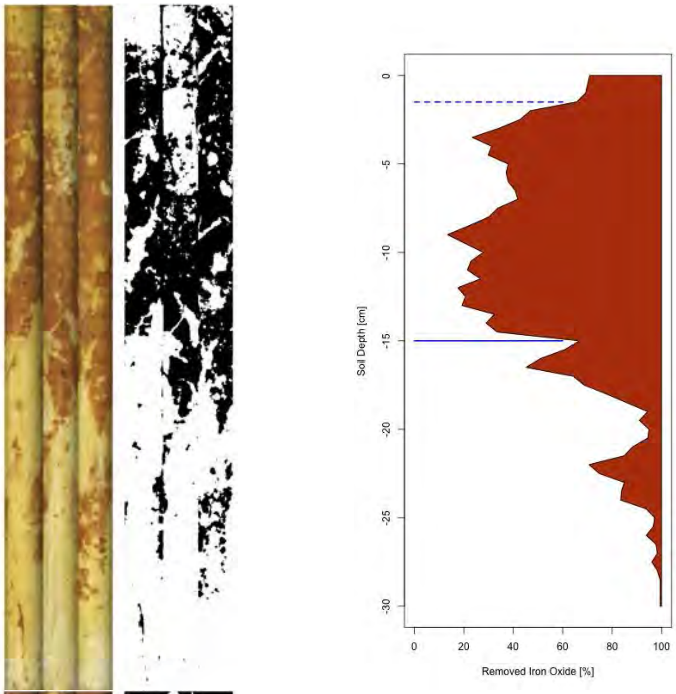


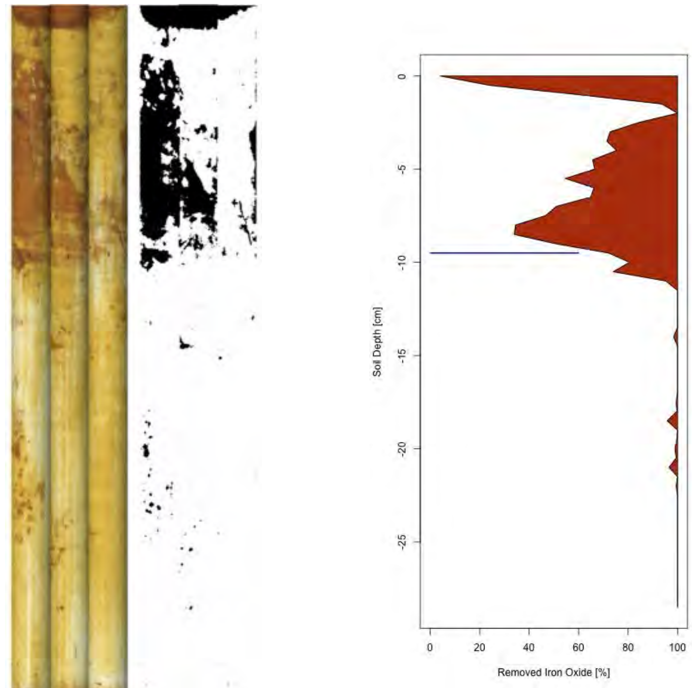


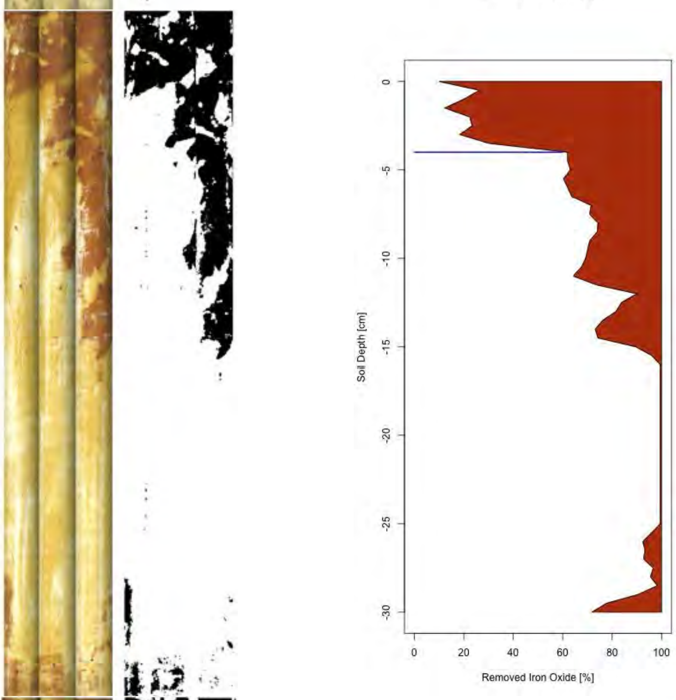


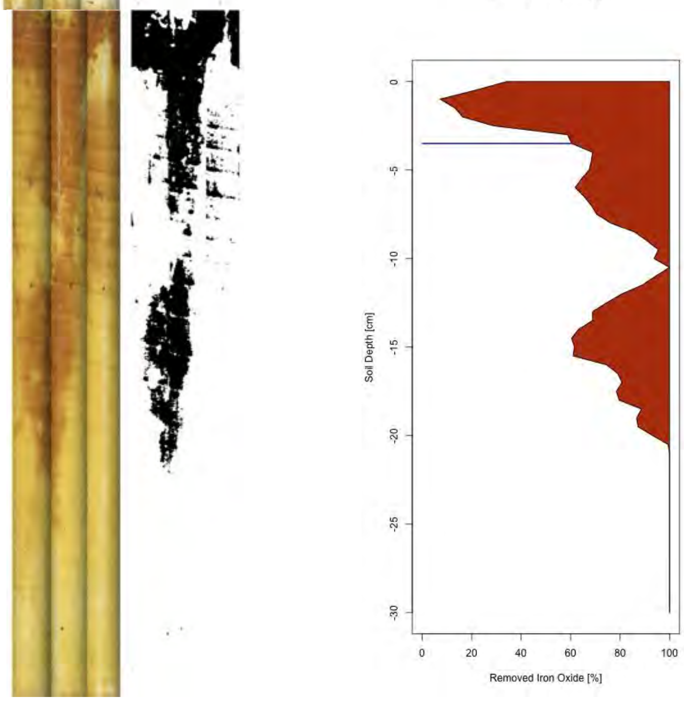


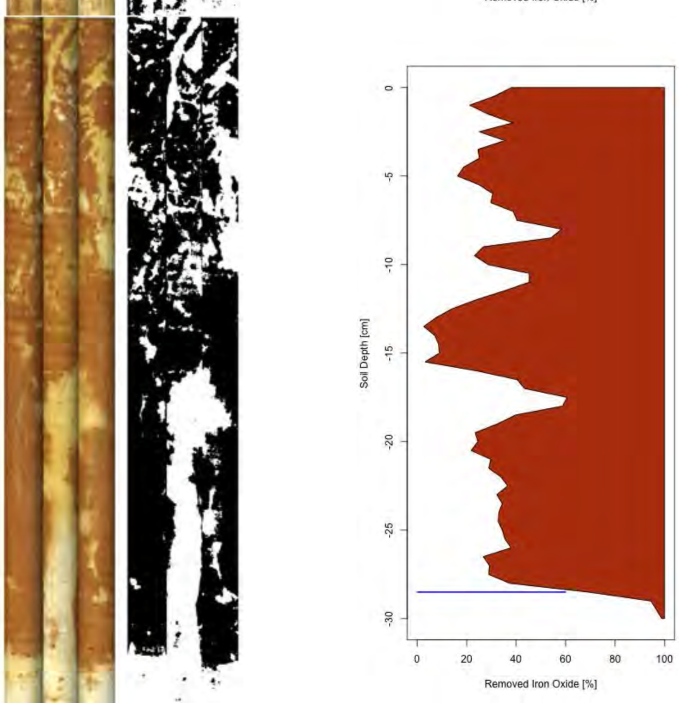
2017 – Nest 4 – Installation 5



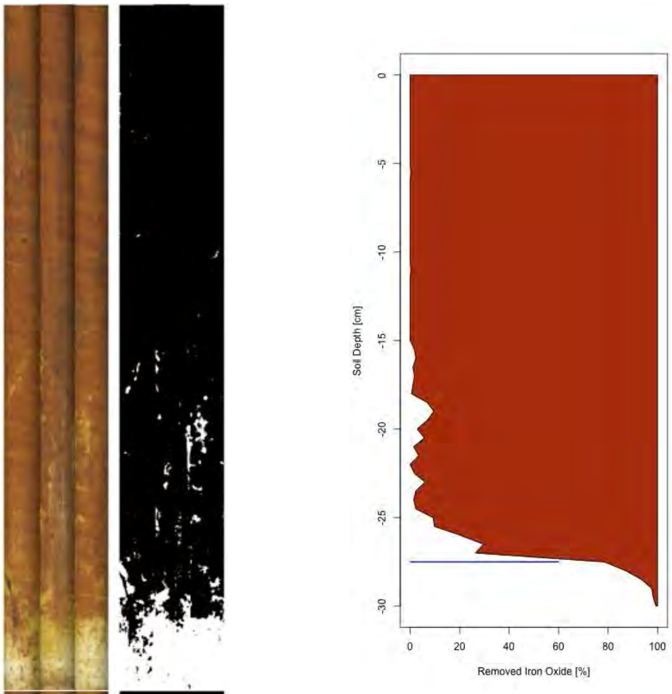


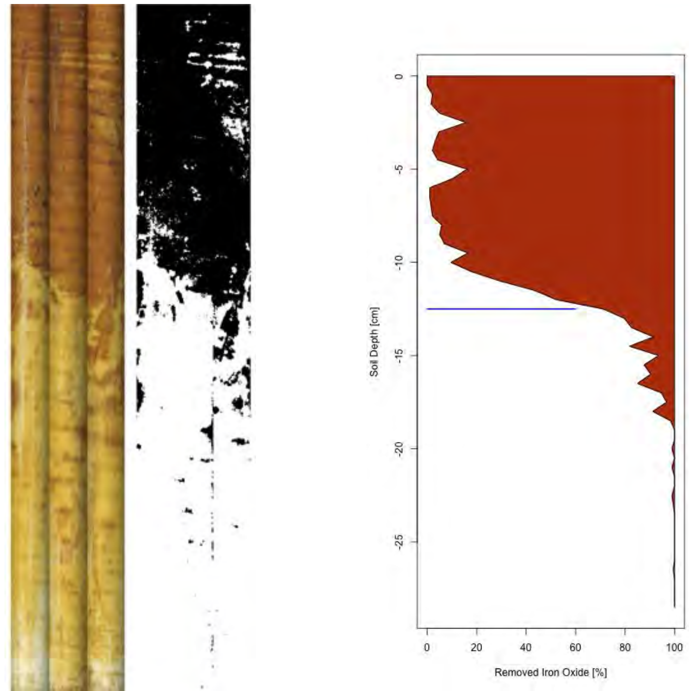


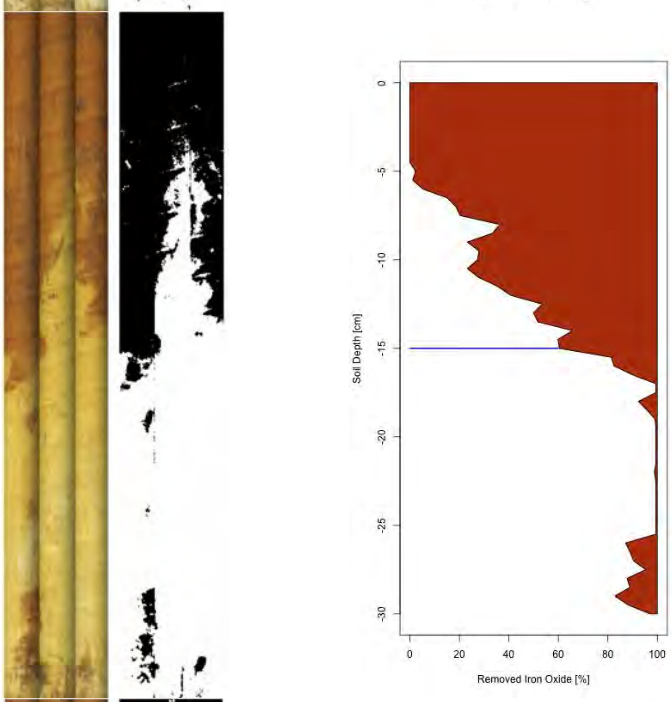


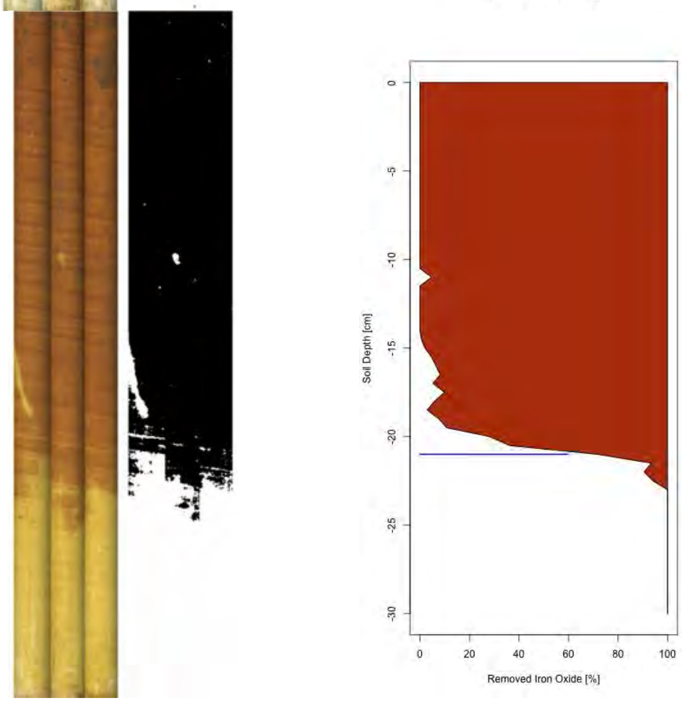


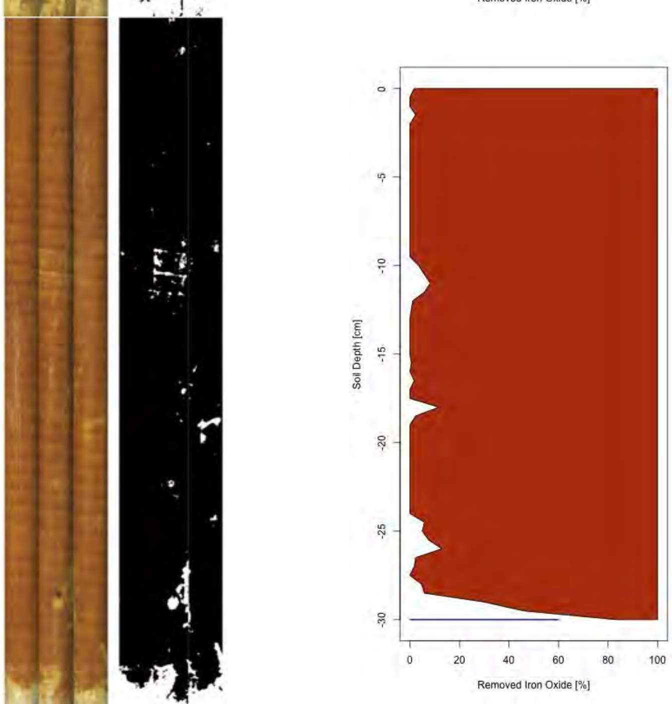
2017 – Nest 4 – Installation 6



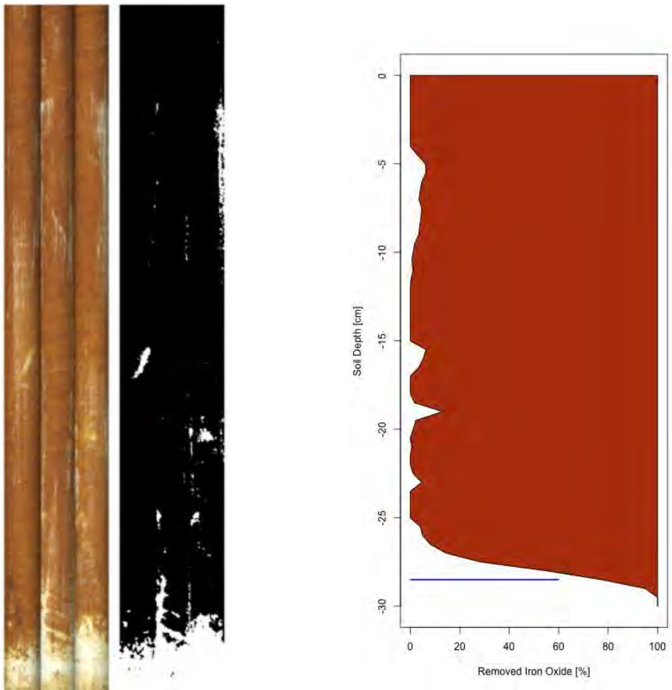


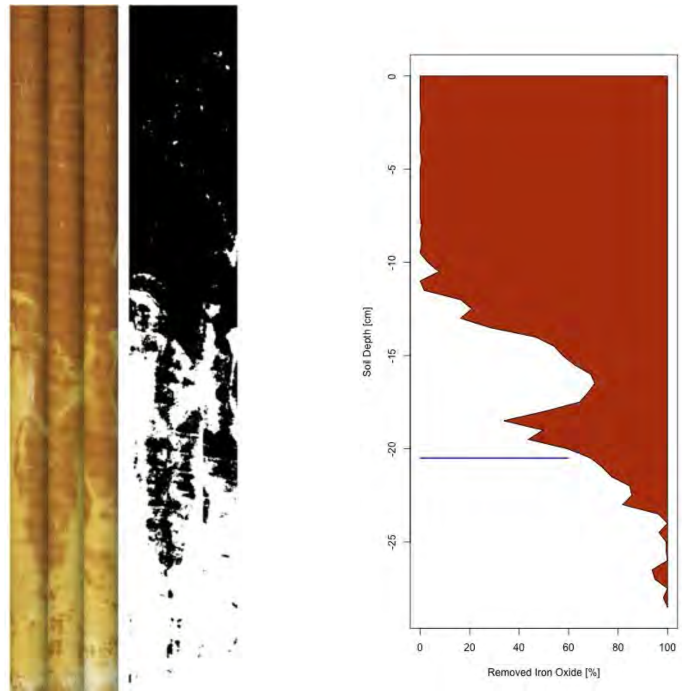


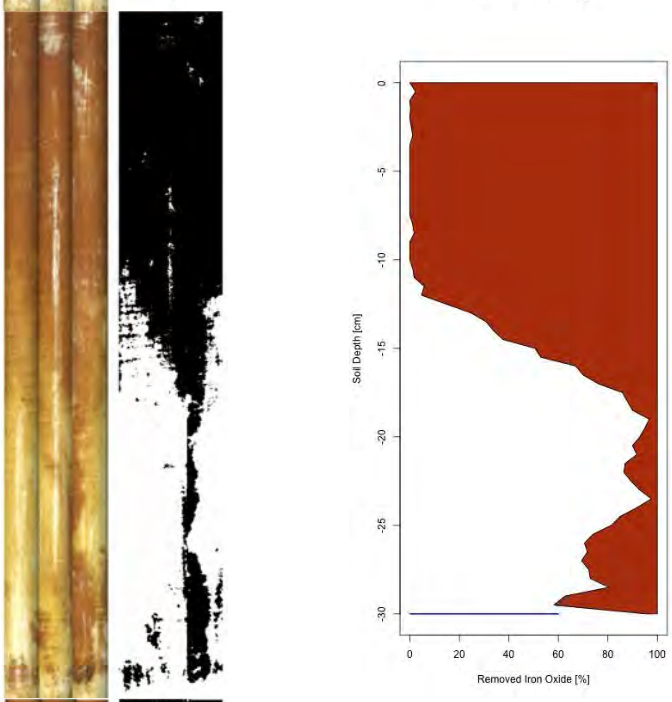


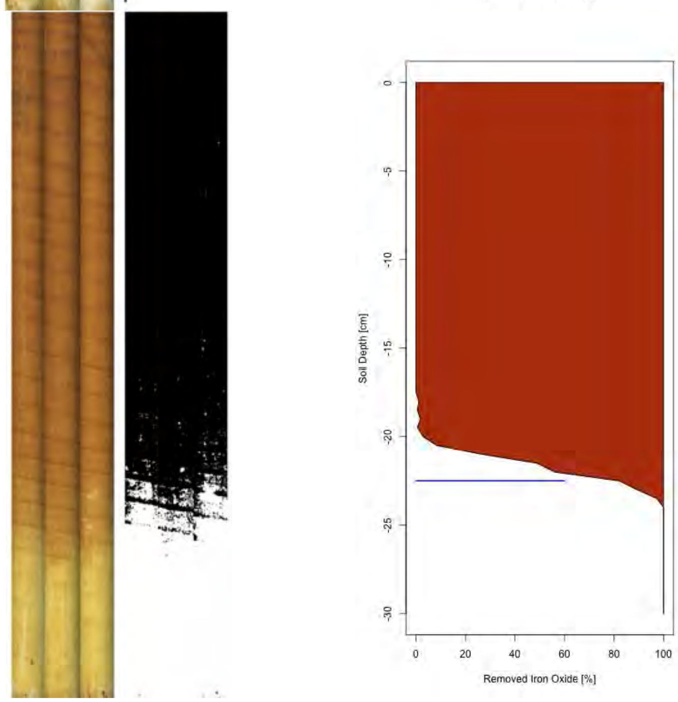


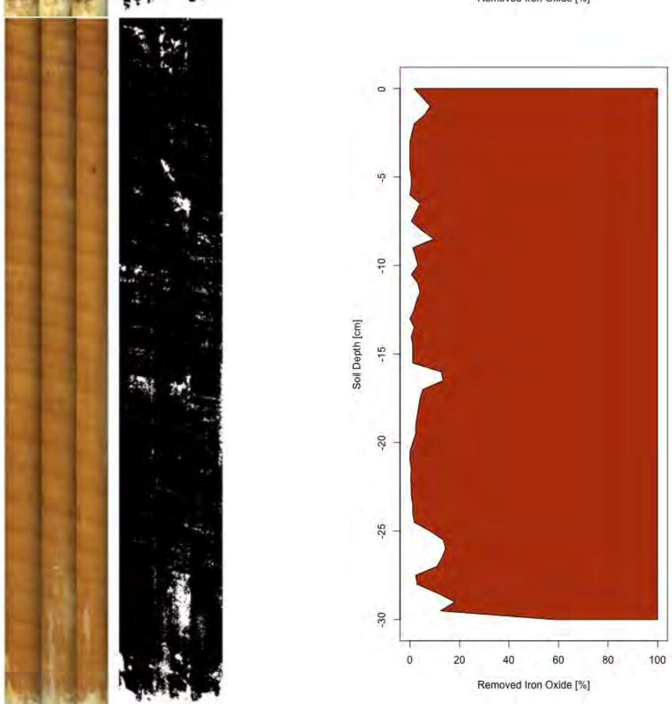
2017 – Nest 4 – Installation 7



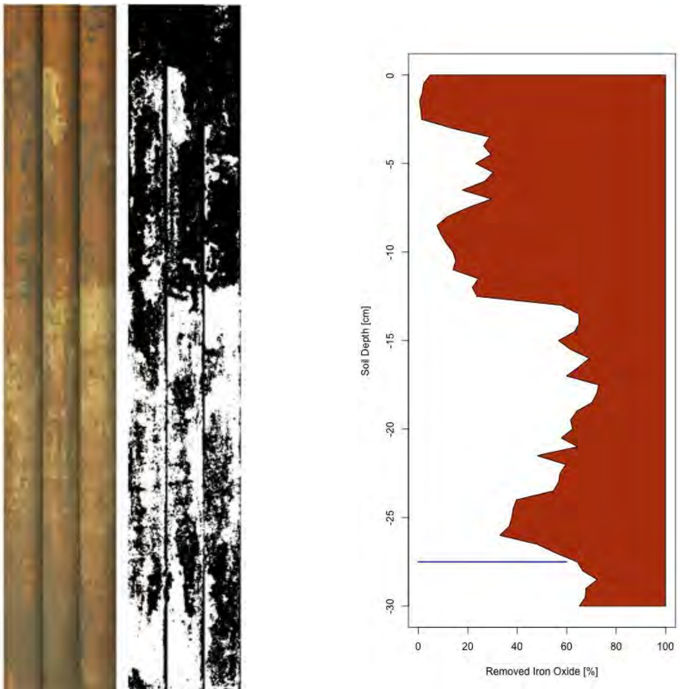


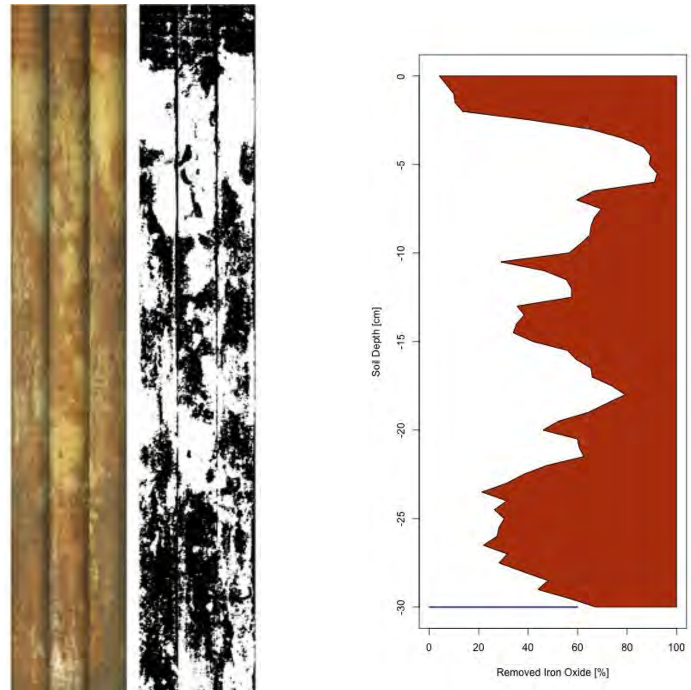


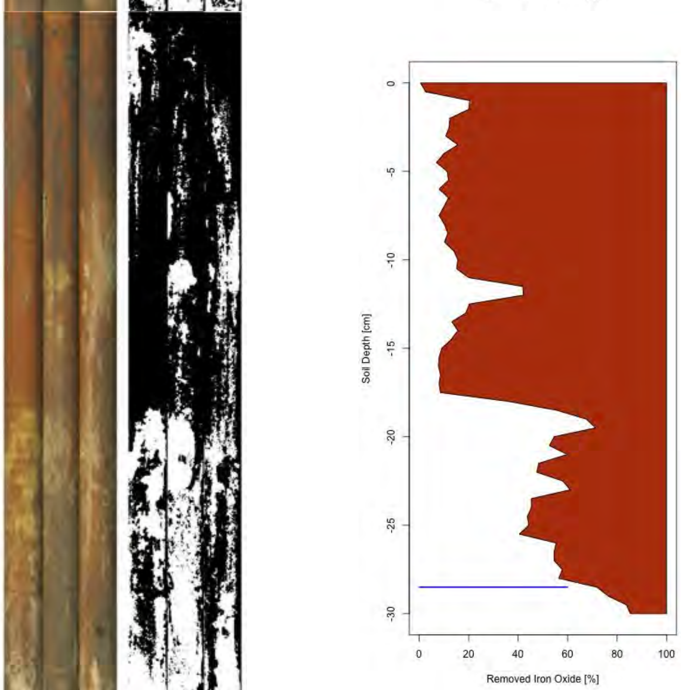


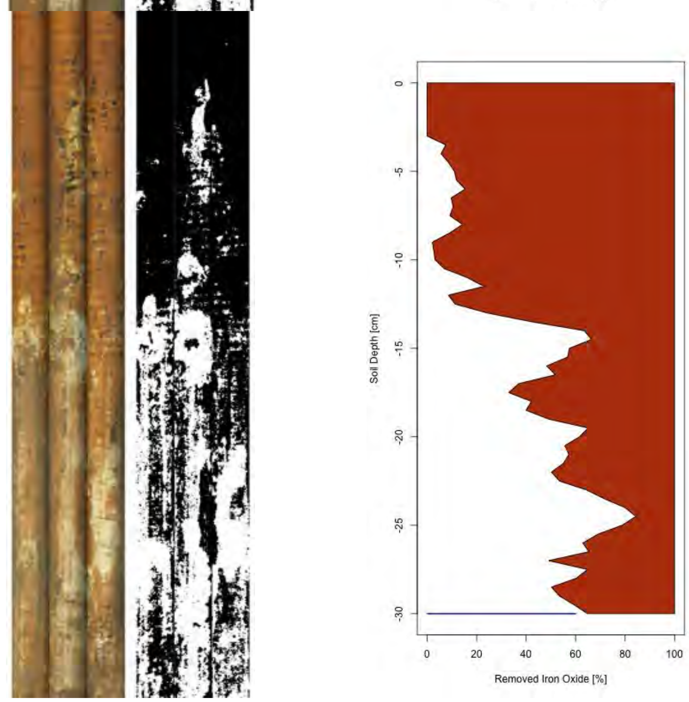


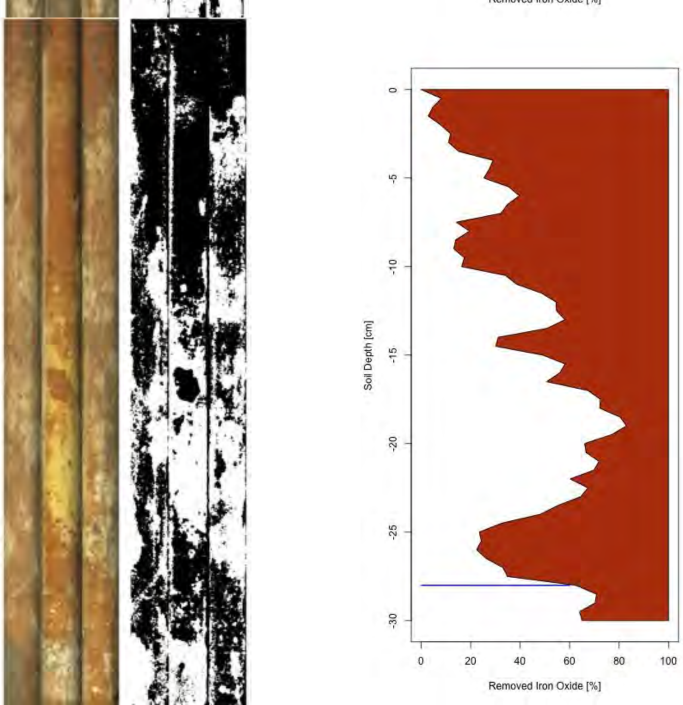
2017 – Nest 5 – Installation 1



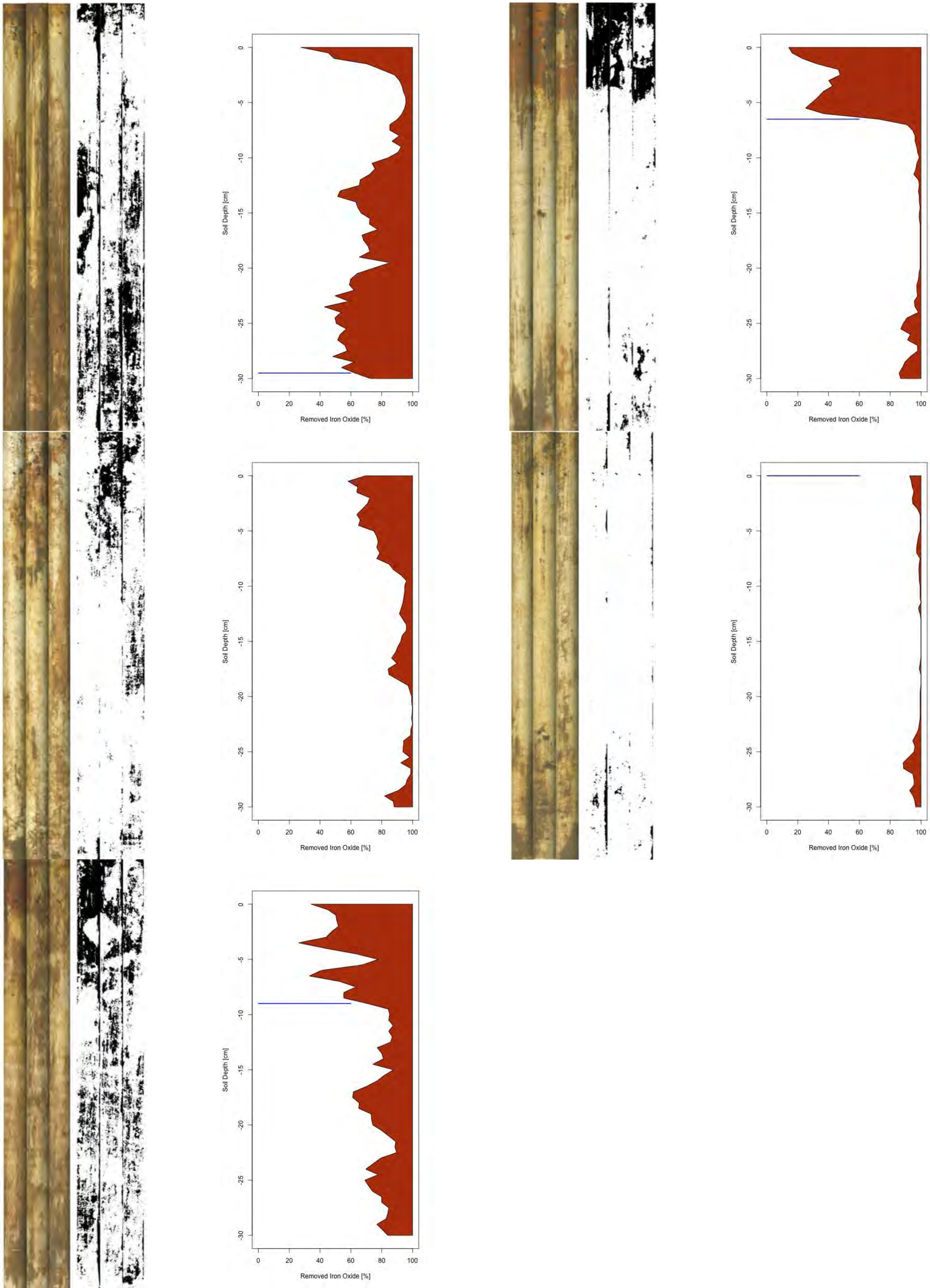




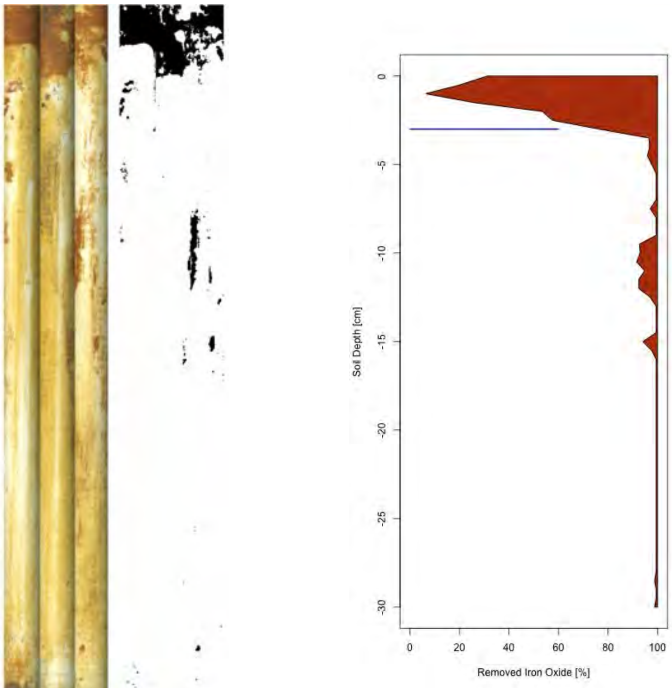


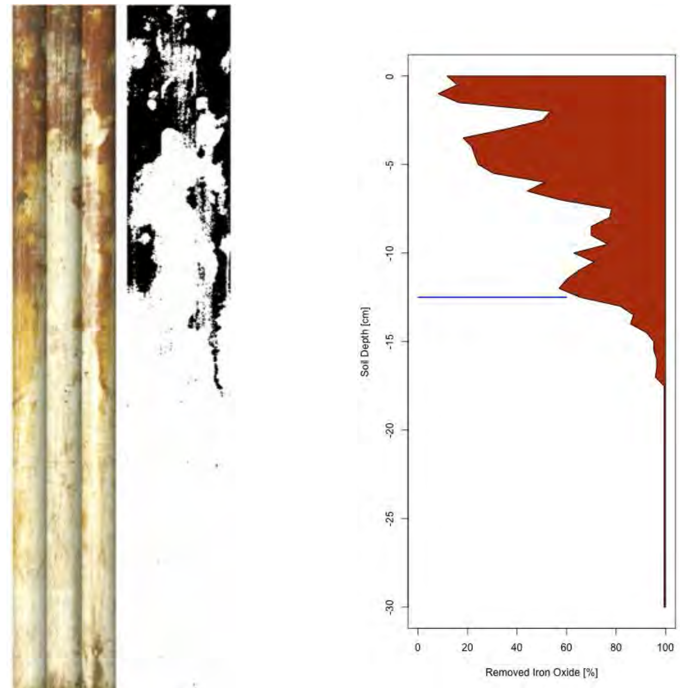


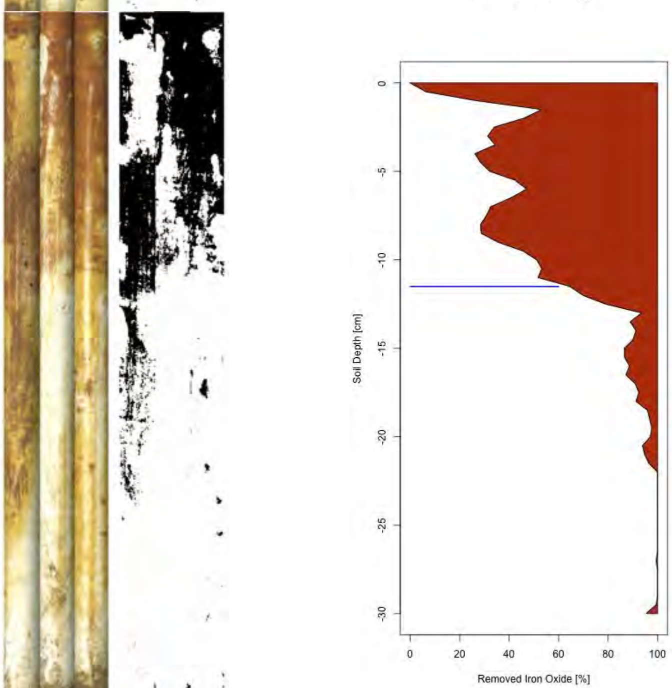
2017 – Nest 5 – Installation 2

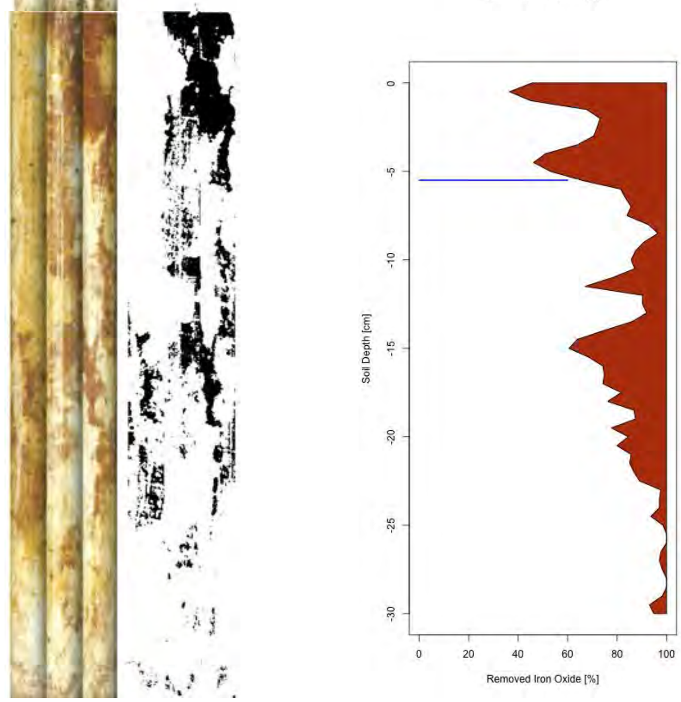


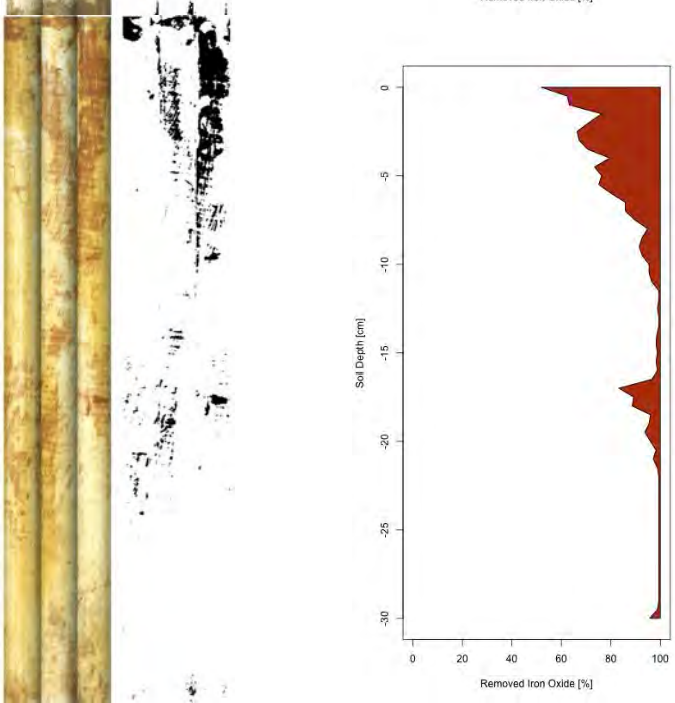
2017 – Nest 5 – Installation 3



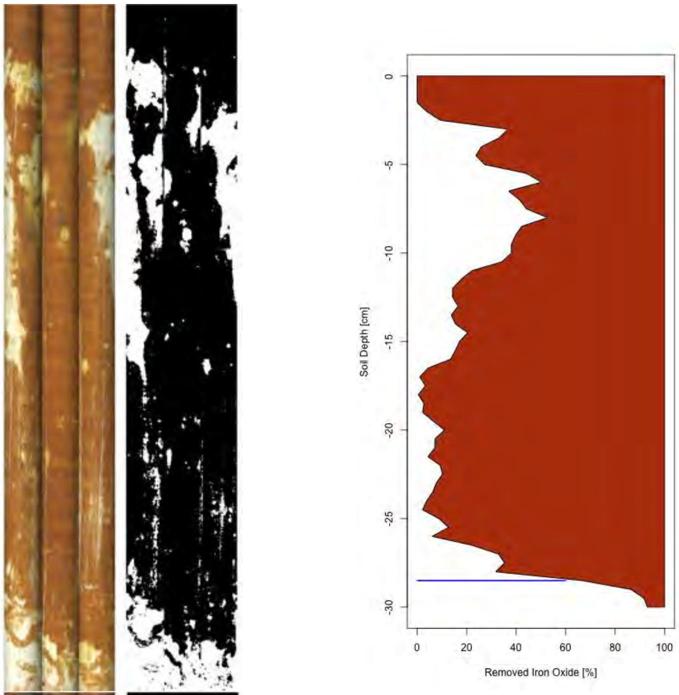


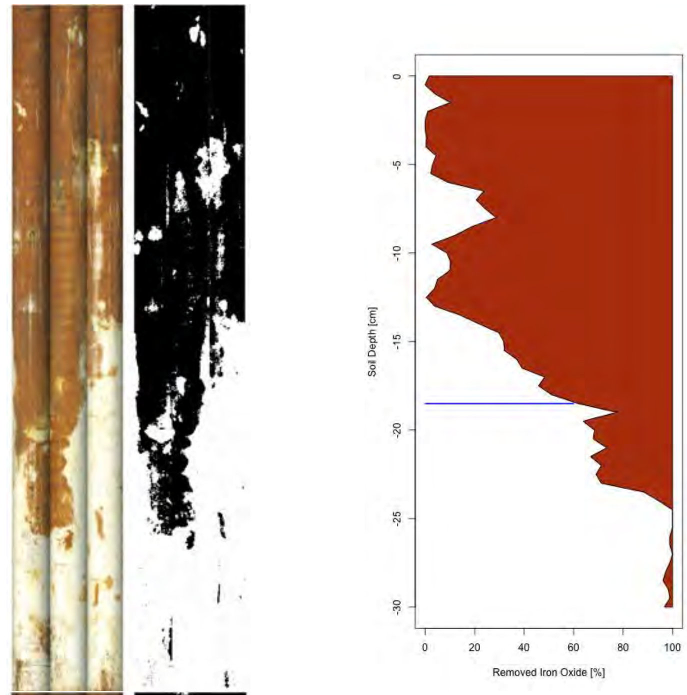


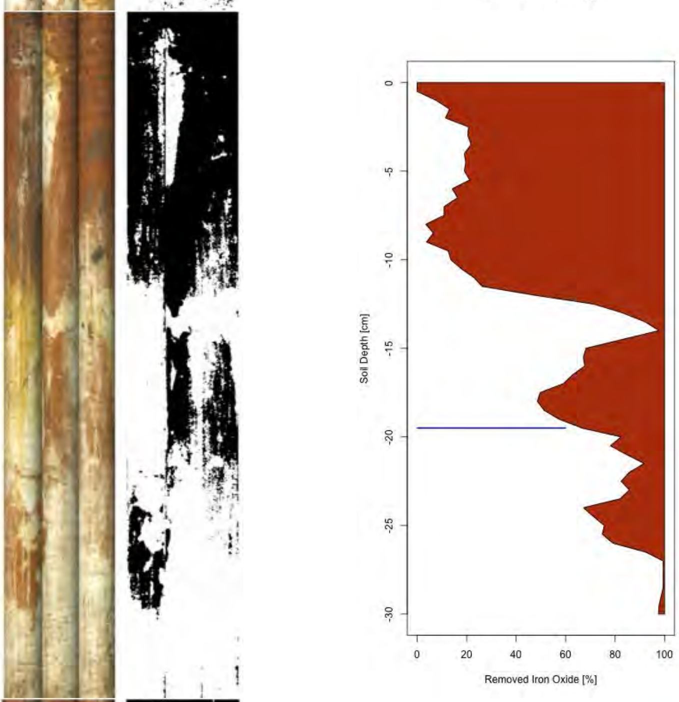


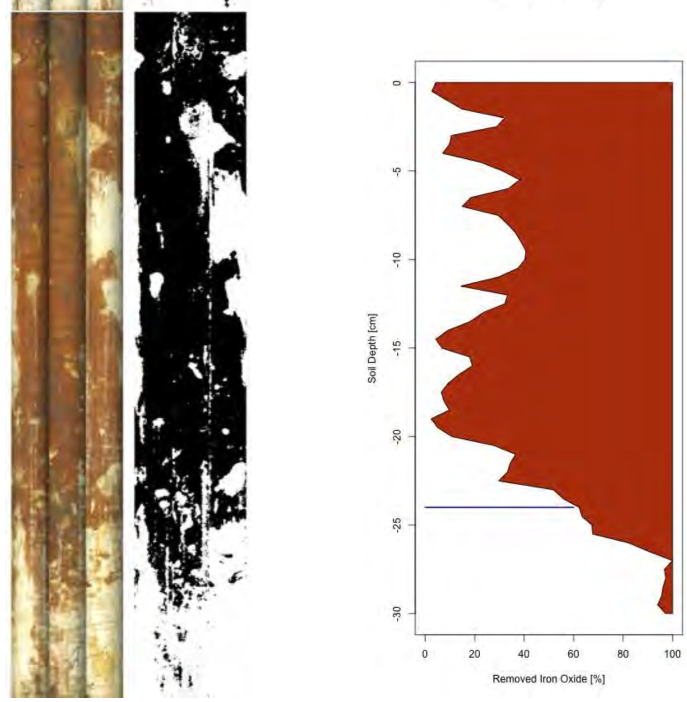


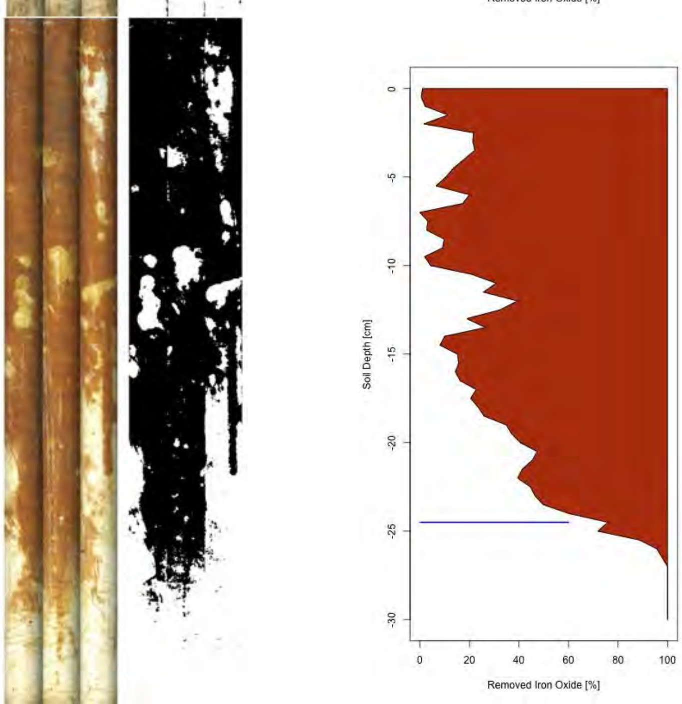
2017 – Nest 5 – Installation 4



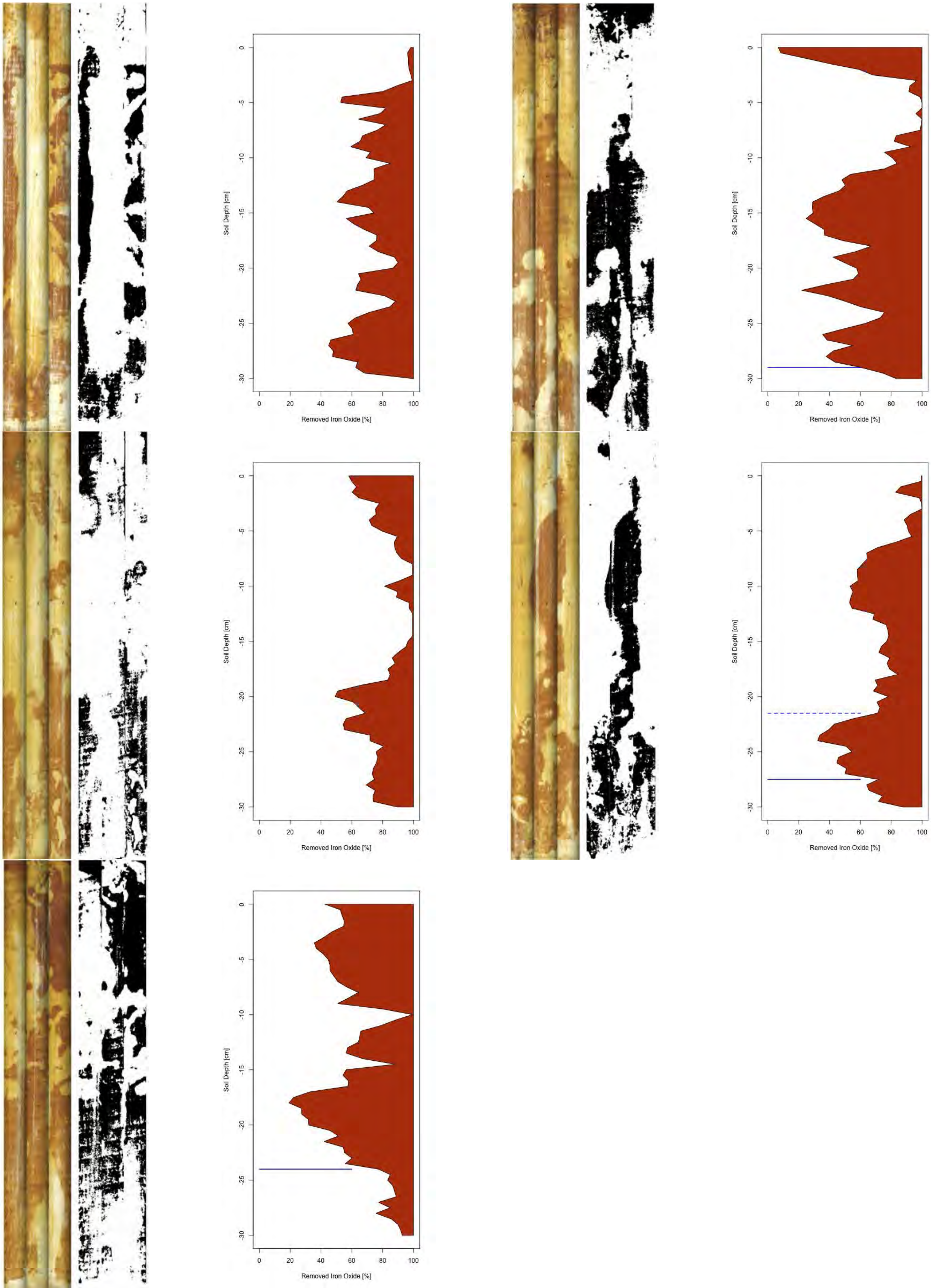




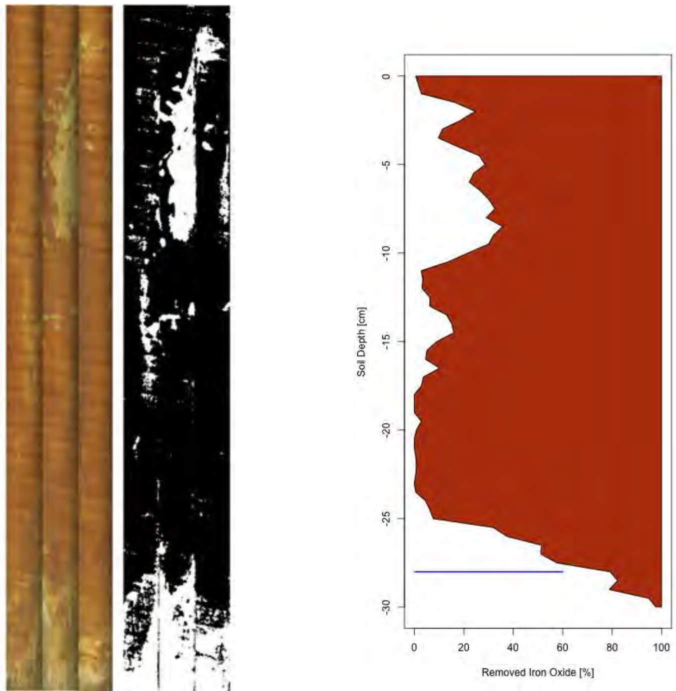


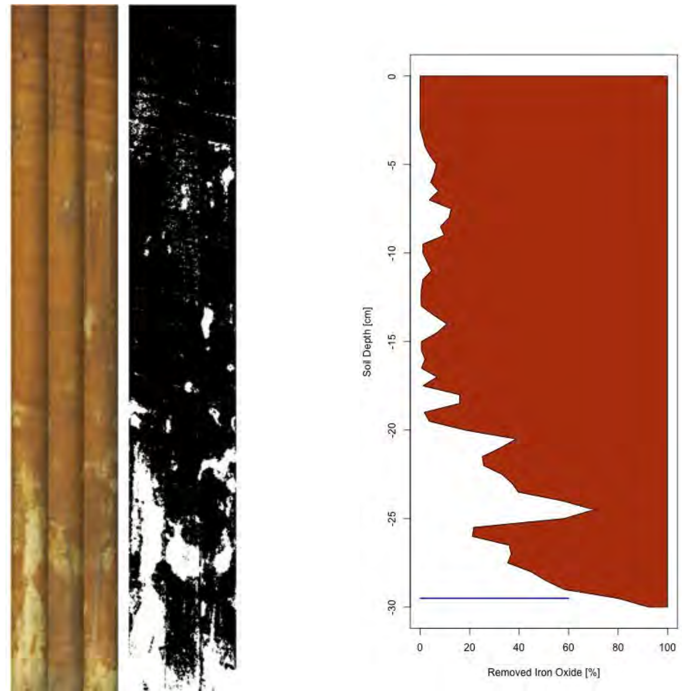


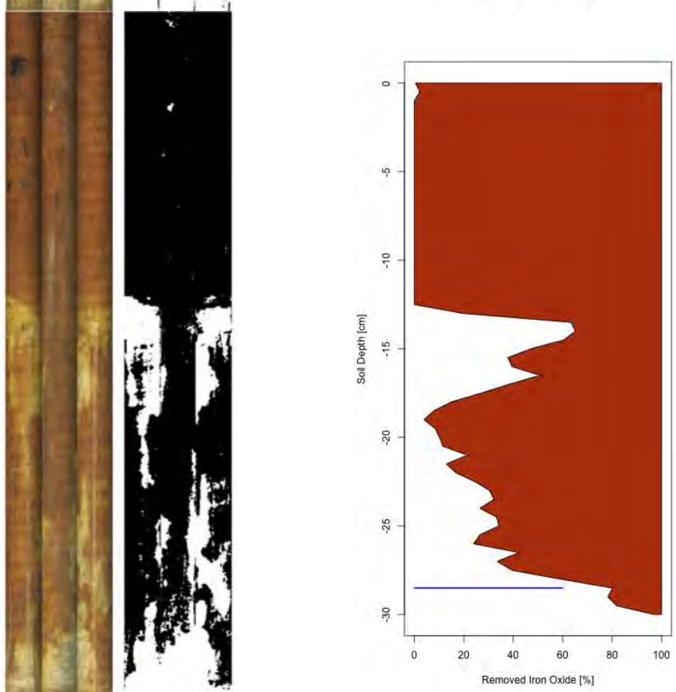
2017 – Nest 5 – Installation 5

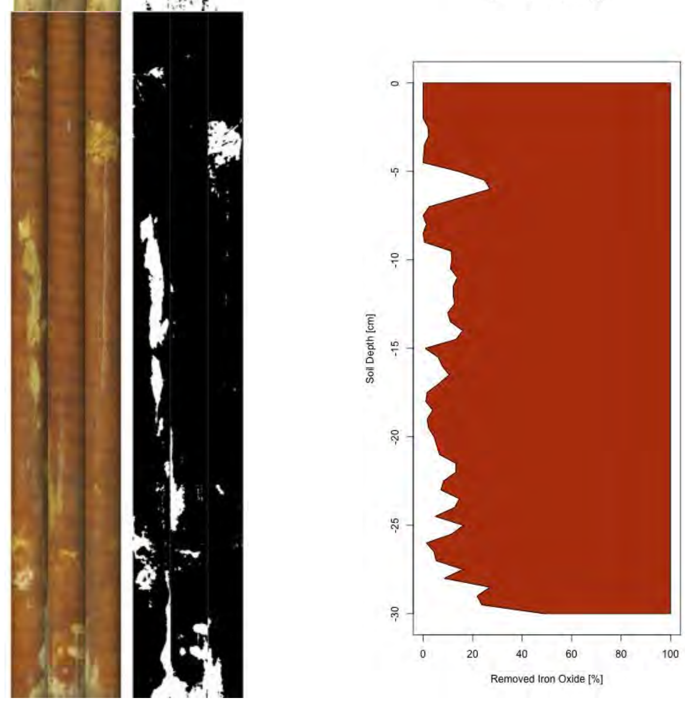


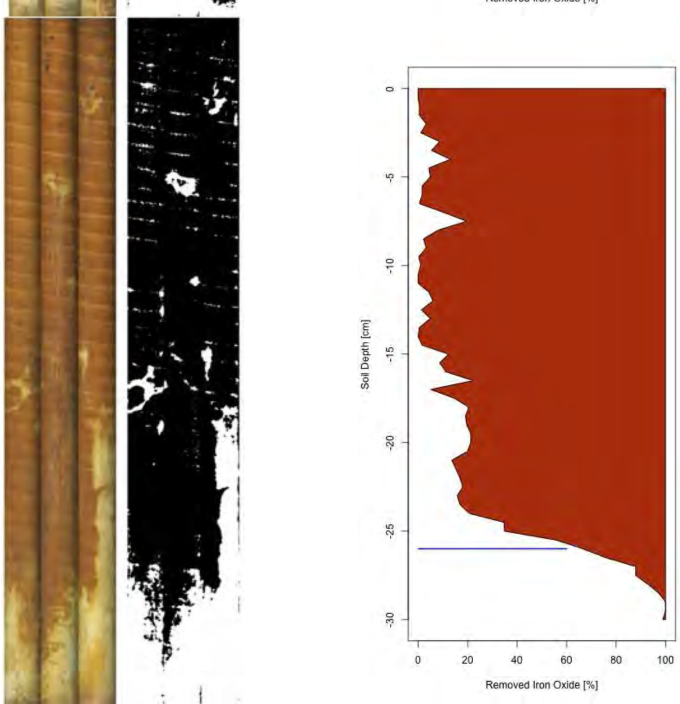
2017 – Nest 5 – Installation 6



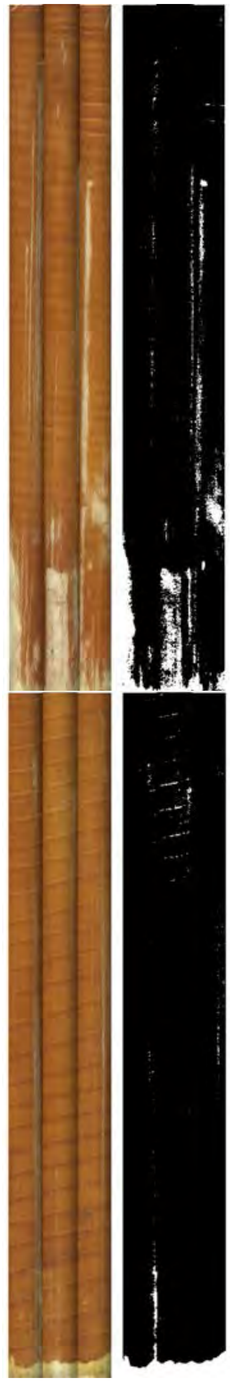


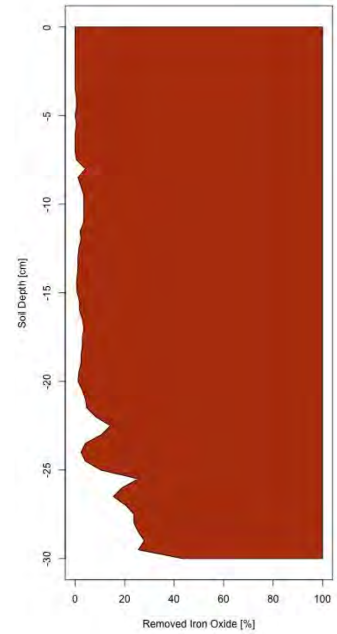


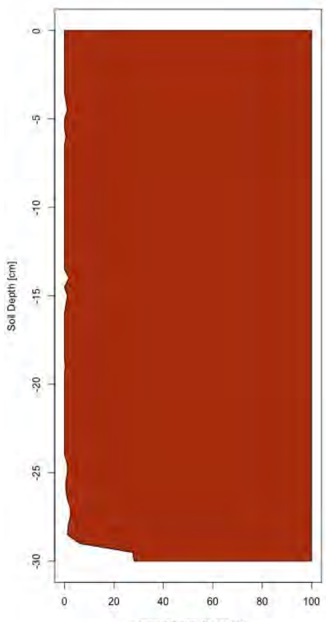


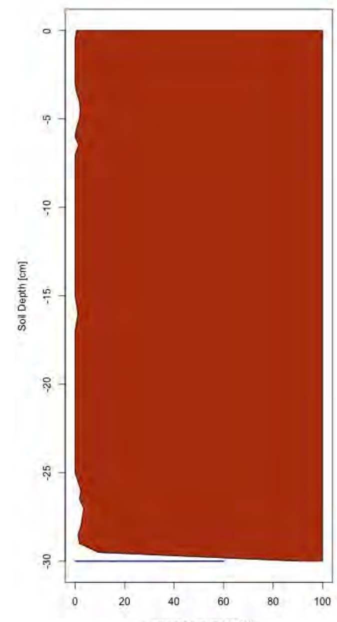


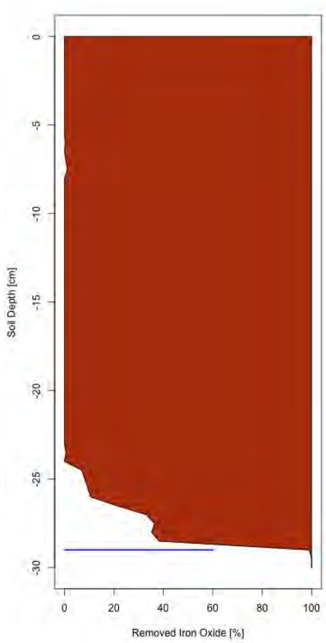
2017 – Nest 5 – Installation 7











APPENDIX C

CUSTOM R® SCRIPT

```
# source("http://bioconductor.org/biocLite.R")
# biocLite("EBImage")
library(Matrix)
library(EBImage)

CatProfile <- function(depth, removal) {
  cg <- "NA"
  udd <- NA
  ldd <- NA
  if (min(removal) > 60) {
    cg <- "C"
    udd <- 0
  }
  if (max(removal) < 60) {
    cg <- "F"
  }
  if (min(removal) > 40 & max(removal) > 60) {
    cg <- "D"
  }
  if (min(removal) < 40 & max(removal) > 60) {
    # test for >60% -> <60%
    u.id <- which(diff(removal > 60) < 0)
    udd.p <- length(which(diff(removal > 60) < 0))
    # delete udd if bottom layer >60% removal
    if (removal[1] < 60) {
      udd.p = 0
    }
    # test for <60% -> >60%
    l.id <- which(diff(removal > 60) > 0)
    ldd.p <- length(which(diff(removal > 60) > 0))
    # delete ldd if top layer >60% removal
    if (removal[length(removal)] < 60) {
      ldd.p = 0
    }
    if (udd.p > 0 & ldd.p == 0) {
      cg = "A"
      udd <- depth[u.id[1]]
    }
    # if both are zero cat as F
    if (ldd.p == 0 & udd.p == 0) {
      cg = "F"
    }
    if (ldd.p > 0 & udd.p == 0) {
      cg = "B"

      ldd <- depth[l.id[ldd.p] + 1]
    }
    if (ldd.p > 0 & udd.p > 0) {
      if (min(removal[u.id[1]:l.id[ldd.p]]) < 40) {
        cg = "E"
        # determine where the curve crosses 40%
        u.id2 <- which(diff(removal > 40) < 0)
        l.id2 <- which(diff(removal > 40) > 0)
        # then select the udd below and the ldd above that zone
        u.id3 <- which(u.id <= u.id2[1])
        l.id3 <- which(l.id > l.id2[length(l.id2)] - 1)
        udd <- depth[u.id[u.id3[length(u.id3)]]]
        ldd <- depth[l.id[l.id3[1]] + 1]
      } else{
        cg = "D"
      }
    }
  }
  return(list(cg, udd, ldd))
}


GetImageAnalyzed <- function(filename, depth) {
  # initialize the return variables
  df2 <- "NA"
  cg <- "NA"
  pr5 <- -999
  udd <- -999
```

```
  ldd <- -999
  x = readImage(filename)
  red <- x@.Data[, , 1]
  red <- matrix(red, nrow = 1)
  dim(red)
  blue <- x@.Data[, , 2]
  blue <- matrix(blue, nrow = 1)
  green <- x@.Data[, , 3]
  green <- matrix(green, nrow = 1)
  cm <- rbind(red, green, blue)
  ch <- rgb2hsv(cm, maxColorValue = 1)
  # set hue threshold
  h.t <- (255 - 26) / 255
  # select hue values
  h.s <- ch[1, ] < h.t
  # select saturation values
  s.s <- ch[2, ] >= 0
  # select brightness values
  b.t <- 110 / 255
  b.s <- ch[3, ] > b.t
  # identify values where all 3 are true
  all.s <- h.s & s.s & b.s
  # dimensions of the original data
  dim(x@.Data[, , 1])[1]
  all.s.s <- matrix(all.s, nrow = dim(x@.Data[, , 1])[1])
  dim(all.s.s)
  n <- matrix(as.numeric(all.s), nrow = dim(x@.Data[, , 1])[1])
  dim(n)

  # copy image
  z <- x
  z@.Data[, , 1] <- as.numeric(all.s.s)
  z@.Data[, , 2] <- as.numeric(all.s.s)
  z@.Data[, , 3] <- as.numeric(all.s.s)

  pr5 <- sum(n) / (dim(n)[1] * dim(n)[2])
  # plot everything
  fn2 <- paste(strsplit(filename, ".png"), "_HSB_all.jpg", sep = "")
  jpeg(
    filename = fn2,
    height = dim(z@.Data)[2],
    width = dim(z@.Data)[1] * 2.2
  )
  par(mfrow = c(1, 2))
  plot(x)
  plot(z)
  dev.off()
  # plot only the final image
  fn3 <- paste(strsplit(filename, ".png"), "_HSB.jpg", sep = "")
  jpeg(
    filename = fn3,
    height = dim(z@.Data)[2],
    width = dim(z@.Data)[1]
  )
  par(mfrow = c(1, 1))
  plot(z)
  dev.off()
  # calculate profile
  if (depth > 0) {
    cat("depth")
    m <- apply(n, 2, sum) / dim(x)[1] * 100
    profile <- -seq(1, dim(x)[2]) * (depth / dim(x)[2])
    stopifnot(length(m) == length(profile))
    # combine to data frame
    df <- data.frame(depth = profile, removal = m)
    # cut depth intro increments of 0.5cm
    df$inc <- cut(profile, breaks = seq(-30.25, 0.25, 0.5))
    # change to numeric values
    levels(df$inc) <- seq(-30.0, 0.0, 0.5)
    # compute the median for each depth increment
    df2 <-
      aggregate(list(removal = df$removal), list(depth = df$inc), median)
    # make numeric
```

```
    df2$depth <- as.numeric(as.character(df2$depth))
    fn4 <-
      paste(strsplit(filename, ".png"), "_profile.jpg", sep = "")
    jpeg(
      filename = fn4,
      width = 400,
      height = 800,
      units = "px"
    )
    plot(
      df2$removal,
      df2$depth,
      type = "l",
      ylab = "Soil Depth [cm]",
      xlab = "Removed Iron Oxide [%]",
      xlim = c(0, 100)
    )
    # calculate max soil depth for plot
    pmin <- min(df2$depth)
    polygon(
      c(100, df2$removal, 100),
      c(pmin, df2$depth, 0),
      col = rgb(183, 65, 14, maxColorValue = 255)
    )
    # determine udd and ldd
    r.list <- CatProfile(df2$depth, df2$removal)
    # extract results
    cg <- unlist(r.list[1])
    udd <- unlist(r.list[2])
    ldd <- unlist(r.list[3])
    if (is.numeric(udd)) {
      lines(c(0, 60), c(udd, udd), col = "blue", lwd = 2)
    }
    if (is.numeric(ldd)) {
      lines(
        c(0, 60),
        c(ldd, ldd),
        col = "blue",
        lwd = 2,
        lty = 2
      )
    }

    dev.off()
    fn5 <-
      paste(strsplit(filename, ".png"), "_profile.csv", sep = "")
    write.csv(df2, file = fn5, row.names = F)
  }
  return(list(pr5, udd, ldd, cg, df2))
}

setwd("~/Google Drive/IrisTubes/Analysis/combined")
# load soil data
soil.depth <- read.csv("soil.depth.csv")
# compute soil depth in cm
soil.depth$depth <- soil.depth$depth * 2.54
# obtain a file list
fl <- list.files(recursive = TRUE)
# determine if "/Cropped_Images/" is in the file list
fl.p <- grepl("/Stitched_Images/", fl)
# eliminate elements without "/Stitched_Images/" from fl
fl <- fl[fl.p]
# determine if "/Icon" is in the file list
fl.p <- grepl("/Icon", fl)
# eliminate elements with Icon
fl <- fl[!fl.p]
# determine if "_analyzed.jpg" is in the file list
fl.p <- grepl("_analyzed.jpg", fl)
# eliminate elements with analyzed
fl <- fl[!fl.p]
# determine if "_analyzed_all.jpg" is in the file list
fl.p <- grepl("_analyzed_all.jpg", fl)
# eliminate elements with analyzed
```

```
fl <- fl[!fl.p]
# determine of .pp3 files are in the list
fl.p <- grepl(".pp3", fl)
# eliminate elements with .pp3
fl <- fl[!fl.p]
# select only pngs and jpgs
fl.1 <- grepl(".png", fl)
fl.2 <- grepl(".jpg", fl)
fl.p <- fl.1 | fl.2
fl <- fl[fl.p]

# determine if .csv files are in the list
fl.p <- grepl(".csv", fl)
# eliminate elements with csv
fl <- fl[!fl.p]

# determine if "_analyzed.jpg" is in the file list
fl.p <- grepl("_HSB.jpg", fl)
# eliminate elements with analyzed
fl <- fl[!fl.p]
# determine if "_analyzed_all.jpg" is in the file list
fl.p <- grepl("_HSB_all.jpg", fl)
# eliminate elements with analyzed
fl <- fl[!fl.p]
# determine if "_analyzed_all.jpg" is in the file list
fl.p <- grepl("_profile.jpg", fl)
# eliminate elements with analyzed
fl <- fl[!fl.p]


fl.m <- t(matrix(unlist(strsplit(fl, "/")), nrow = 6))
# convert to data frame
fl.d <- data.frame(fl.m)
# make meaningful column names
colnames(fl.d) <-
  c("year",
    "installation",
    "nest",
    "dummy",
    "depth.inc",
    "filename")
# delete dummy column
fl.d$dummy <- NULL
# add full file path
fl.d$file.path <- fl
# combine with soil depth and save
fl.d <- merge(fl.d, soil.depth)

# add percent reduction to table
fl.d$percent <- -999
# add upper and lower depletion limit
fl.d$udd <- -999
fl.d$ldd <- -999
fl.d$category <- "NA"

if (exists("profile.all")) {
  rm("profile.all")
}
for (i in 1:nrow(fl.d)) {
  if (fl.d$depth.inc[i] == "Soil Depth") {
    temp <- GetImageAnalyzed(fl.d$file.path[i], fl.d$depth[i])
    # derive profile
    profile.1 <- as.data.frame(temp[5])
    # add year, nest, etc
    profile.1$year = fl.d$year[i]
    profile.1$installation = fl.d$installation[i]
    profile.1$nest = fl.d$nest[i]
    profile.1$tube = fl.d$tube[i]
    profile.1$tube.id = fl.d$tube.id[i]
    if (exists("profile.all")) {
      profile.all <- rbind(profile.all, profile.1)
    } else{
      profile.all <- profile.1
```

```
    }

  } else{
    temp <- GetImageAnalyzed(fl.d$file.path[i], 0)
  }

  fl.d$percent[i] <- unlist(temp[1])
  fl.d$udd[i] <- unlist(temp[2])
  fl.d$ldd[i] <- unlist(temp[3])
  fl.d$category[i] <- unlist(temp[4])
  cat(paste(i, ";"))
}

fl.d$percent <- fl.d$percent * 100
fl.d$udd <- ifelse(fl.d$udd < -100, NA, fl.d$udd)
fl.d$ldd <- ifelse(fl.d$ldd < -100, NA, fl.d$ldd)
fl.d$category <- ifelse(fl.d$category == "NA", NA, fl.d$category)
write.csv(fl.d, file = "resultsHSB.csv", row.names = F)
write.csv(profile.all, file = "profiles.csv", row.names = F)
```

APPENDIX D

DOMINANT SPECIES LIST DURING MONITORING PERIOD

Common Name	Scientific Name	Wetland Indicator Status	Dominant Species																			
			Area B										Area C									
			2013		2014		2015		2016		2017		2013		2014		2015		2016		2017	
			TP1	TP2	TP1	TP2	TP1	TP2	TP1	TP2	TP1	TP2	TP3	TP4	TP3	TP4	TP3	TP4	TP3	TP4	TP3	TP4
White snakeroot	*Agerantina altissima*	FACU				**X**										**X**						
Bluestem	*Andropogon L.*	FACU														**X**						
Tickseed Sunflower	*Bidens aristosa*	FACW		**X**			**X**		**X**													
Frank's sedge	*Carex frankii*	OBL	**X**	**X**	**X**				**X**	**X**					**X**		**X**	**X**	**X**	**X**		
Bottlebrush/ Porcupine sedge	*Carex hystericina*	OBL	**X**		**X**																	
Fox sedge	*Carex vulpinoidea*	OBL							**X**									**X**	**X**	**X**	**X**	
Globe sedge	*Cyperus echinatus*	FACU	**X**																			
Straw-color flat sedge	*Cyperus strigosus*	FACW	**X**		**X**		**X**							**X**			**X**					
Deertongue	*Dichanthelium clandestinum*	FAC								**X**							**X**					
Barnyard grass	*Echinochloa crus-galli*	FAC	**X**		**X**										**X**							
Rough barnyard grass	*Echinochloa muricata*	FACW															**X**					
Spike rush	*Eleocharis palustris*	OBL	**X**		**X**		**X**						**X**	**X**			**X**		**X**			
Daisy fleabane	*Erigeron annuus*	FACU		**X**																		
White thoroughwort	*Eupatorium album*	NI					**X**	**X**		**X**							**X**	**X**				
Soft/Lamp rush	*Juncus effusus*	FACW												**X**								

Common Name	Scientific Name	Wetland Indicator Status	Dominant Species																			
			Area B										Area C									
			2013		2014		2015		2016		2017		2013		2014		2015		2016		2017	
			TP1	TP2	TP1	TP2	TP1	TP2	TP1	TP2	TP1	TP2	TP3	TP4	TP3	TP4	TP3	TP4	TP3	TP4	TP3	TP4
Path rush	*Juncus tenuis*	FAC			X		X		X	X						X		X	X	X		
Canada lettuce	*Lactuca canadensis*	FAC					X		X													
Common Duckweed	*Lemna minor*	OBL			X																	
Narrowleaf lespedeza	*Lespedeza angustifolia*	FAC					X	X	X	X	X	X					X	X	X	X		
Sericea lespedeza	*Lespedeza cuneata*	FACU		X		X																
Panic grass	*Panicum capillare*	FAC	X									X	X	X	X							
Switchgrass	*Panicum virgatum*	FAC					X												X	X	X	X
Redtop panicgrass	*Panicum rigidulum*	FACW															X	X				
Swamp smartweed	*Polygonum hydropiperoides*	OBL					X		X								X	X	X			
Tall buttercup	*Ranunculus acris*	FAC		X					X													
Black-eyed Susan	*Rudbeckia hirta*	FACU				X																
Curly dock	*Rumex crispus*	FAC	X	X		X									X							
Woolgrass / Cottongrass bulrush	*Scirpus cyperinus*	FACW	X		X				X					X	X							
Giant goldenrod	*Solidago gigantea*	FACW															X	X		X	X	X
Goldenrod	*Solidago L.*	FACU				X		X		X					X	X			X			
Narrow-leaf cattail	*Typha angustifolia*	OBL															X		X			

Common Name	Scientific Name	Wetland Indicator Status	Dominant Species																			
			Area B										Area C									
			2013		2014		2015		2016		2017		2013		2014		2015		2016		2017	
			TP1	TP2	TP1	TP2	TP1	TP2	TP1	TP2	TP1	TP2	TP3	TP4	TP3	TP4	TP3	TP4	TP3	TP4	TP3	TP4
Broad-leaf cattail	*Typha latifolia*	OBL	**X**		**X**		**X**						**X**	**X**	**X**							
Ragweed	*Ambrosia artemisiifolia*	FACU									**X**	**X**										
Cocklebur	*Xanthium strumarium*	FAC									**X**	**X**										
Percent OBL, FACW, FAC			90	67	100	**20**	80	**33**	83	100	100	100	100	100	86	**25**	82	86	100	100	100	100

Note: Red averages fail dominance test for hydric vegetation.

APPENDIX E

IRIS TUBE PERCENT REMOVAL TABLES

4-INCH ANALYSIS

	Installation-1 - IRIS Tube Results May 28 - June 25, 2016				
	IRIS Tube	Calculated Percent Removal	Reducing Conditions Present	Visual Percent Removal	Reducing Conditions Present
Nest-1	1-1	0%	No	0%	No
	1-2	0%		0%	
	1-3	0%		0%	
	1-4	0%		0%	
	1-5	0%		0%	
Nest-2	2-1	44%	Yes	40%	Yes
	2-2	95%		95%	
	2-3	71%		65%	
	2-4	78%		70%	
	2-5	78%		80%	
Nest-3	3-1	0%	No	0%	No
	3-2	0%		0%	
	3-3	0%		0%	
	3-4	0%		0%	
	3-5	0%		0%	
Nest-4	4-1	0%	No	0%	No
	4-2	0%		0%	
	4-3	0%		0%	
	4-4	15%		15%	
	4-5	0%		0%	
Nest-5	5-1	6%	No	0%	No
	5-2	8%		8%	
	5-3	2%		0%	
	5-4	9%		0%	
	5-5	2%		0%	

	Installation-1 - IRIS Tube Results May 28 - September 17, 2016				
	IRIS Tube	Calculated Percent Removal	Reducing Conditions Present	Visual Percent Removal	Reducing Conditions Present
Nest-6	6-1	10%	No	8%	No
	6-2	17%		15%	
	6-3	14%		10%	
Nest-7 (Upland Control)	7-1	0%	No	0%	No
	7-2	0%		0%	
	7-3	0%		0%	
	7-4	0%		0%	
	7-5	0%		0%	

	Installation-2 - IRIS Tube Results June 25 - July 23, 2016				
	IRIS Tube	Calculated Percent Removal	Reducing Conditions Present	Visual Percent Removal	Reducing Conditions Present
Nest-1	1-1	0%	**No**	0%	**No**
	1-2	0%		0%	
	1-3	0%		0%	
	1-4	0%		0%	
	1-5	0%		0%	
Nest-2	2-1	74%	**Yes**	98%	**Yes**
	2-2	91%		99%	
	2-3	96%		100%	
	2-4	93%		98%	
	2-5	90%		98%	
Nest-3	3-1	18%	**No**	22%	**Yes**
	3-2	57%		50%	
	3-3	6%		10%	
	3-4	12%		25%	
	3-5	8%		25%	
Nest-4	4-1	3%	**No**	3%	**No**
	4-2	0%		0%	
	4-3	13%		10%	
	4-4	0%		0%	
	4-5	9%		5%	
Nest-5	5-1	14%	**No**	10%	**No**
	5-2	9%		3%	
	5-3	3%		8%	
	5-4	20%		33%	
	5-5	4%		5%	

	Installation-3 - IRIS Tube Results July 23 - August 20, 2016				
	IRIS Tube	Calculated Percent Removal	Reducing Conditions Present	Visual Percent Removal	Reducing Conditions Present
Nest-1	1-1	0%	**No**	0%	**No**
	1-2	0%		0%	
	1-3	0%		0%	
	1-4	0%		0%	
	1-5	0%		0%	
Nest-2	2-1	29%	**No**	25%	**Yes**
	2-2	10%		5%	
	2-3	18%		25%	
	2-4	58%		70%	
	2-5	8%		12%	
Nest-3	3-1	0%	**No**	0%	**No**
	3-2	0%		0%	
	3-3	0%		0%	
	3-4	0%		0%	
	3-5	0%		0%	
Nest-4	4-1	0%	**No**	0%	**No**
	4-2	0%		0%	
	4-3	0%		0%	
	4-4	0%		0%	
	4-5	0%		0%	
Nest-5	5-1	0%	**No**	0%	**No**
	5-2	0%		0%	
	5-3	0%		0%	
	5-4	0%		0%	
	5-5	0%		0%	

Installation-4 - IRIS Tube Results Auguts 20 - September 17, 2016					
	IRIS Tube	Calculated Percent Removal	Reducing Conditions Present	Visual Percent Removal	Reducing Conditions Present
Nest-1	1-1	0%	No	0%	No
	1-2	0%		0%	
	1-3	0%		0%	
	1-4	0%		0%	
	1-5	0%		0%	
Nest-2	2-1	89%	Yes	98%	Yes
	2-2	95%		95%	
	2-3	76%		90%	
	2-4	90%		100%	
	2-5	20%		20%	
Nest-3	3-1	0%	No	0%	No
	3-2	0%		0%	
	3-3	0%		0%	
	3-4	0%		0%	
	3-5	0%		0%	
Nest-4	4-1	0%	No	0%	No
	4-2	0%		0%	
	4-3	0%		0%	
	4-4	0%		0%	
	4-5	0%		0%	
Nest-5	5-1	0%	No	0%	No
	5-2	0%		0%	
	5-3	0%		0%	
	5-4	0%		0%	
	5-5	0%		0%	

	Installation-1 - IRIS Tube Results February 19 - March 19, 2017				
	IRIS Tube	Calculated Percent Removal	Reducing Conditions Present	Visual Percent Removal	Reducing Conditions Present
Nest-1	1-1	23%	Yes	10%	No
	1-2	7%		2%	
	1-3	48%		35%	
	1-4	85%		98%	
	1-5	24%		15%	
Nest-2	2-1	3%	No	1%	No
	2-2	9%		5%	
	2-3	4%		2%	
	2-4	8%		2%	
	2-5	21%		10%	
Nest-3	3-1	0%	No	0%	No
	3-2	12%		3%	
	3-3	0%		0%	
	3-4	0%		0%	
	3-5	21%		10%	
Nest-4	4-1	30%	No	20%	No
	4-2	4%		1%	
	4-3	20%		3%	
	4-4	14%		5%	
	4-5	12%		8%	
Nest-5	5-1	62%	Yes	20%	No
	5-2	67%		40%	
	5-3	32%		18%	
	5-4	55%		15%	
	5-5	62%		35%	

	Installation-1 - IRIS Tube Results February 19 - September 02, 2017				
	IRIS Tube	Calculated Percent Removal	Reducing Conditions Present	Visual Percent Removal	Reducing Conditions Present
Nest-6	6-1	96%	Yes	95%	Yes
	6-2	99%		99%	
	6-3	97%		99%	
Nest-7 (Upland Control)	7-1	62%	Yes	55%	Yes
	7-2	56%		30%	
	7-3	93%		98%	
	7-4	74%		25%	
	7-5	97%		95%	

	Installation-2 - IRIS Tube Results March 19 - April 15, 2017				
	IRIS Tube	Calculated Percent Removal	Reducing Conditions Present	Visual Percent Removal	Reducing Conditions Present
Nest-1	1-1	98%	**Yes**	98%	**Yes**
	1-2	94%		95%	
	1-3	43%		20%	
	1-4	69%		30%	
	1-5	96%		98%	
Nest-2	2-1	65%	**Yes**	25%	**Yes**
	2-2	83%		90%	
	2-3	87%		92%	
	2-4	85%		95%	
	2-5	55%		60%	
Nest-3	3-1	0%	**No**	0%	**No**
	3-2	14%		5%	
	3-3	23%		20%	
	3-4	8%		5%	
	3-5	11%		8%	
Nest-4	4-1	4%	**Yes**	1%	**Yes**
	4-2	88%		92%	
	4-3	79%		80%	
	4-4	2%		10%	
	4-5	38%		30%	
Nest-5	5-1	85%	**Yes**	90%	**Yes**
	5-2	99%		99%	
	5-3	93%		85%	
	5-4	99%		100%	
	5-5	77%		90%	

	Installation-3 - IRIS Tube Results April 15 - May 13, 2017				
	IRIS Tube	**Calculated Percent Removal**	**Reducing Conditions Present**	**Visual Percent Removal**	**Reducing Conditions Present**
Nest-1	1-1	93%	**Yes**	85%	**Yes**
	1-2	85%		90%	
	1-3	52%		30%	
	1-4	99%		99%	
	1-5	100%		99%	
Nest-2	2-1	93%	**Yes**	85%	**Yes**
	2-2	100%		99%	
	2-3	98%		92%	
	2-4	96%		90%	
	2-5	98%		95%	
Nest-3	3-1	14%	**No**	12%	**No**
	3-2	31%		30%	
	3-3	61%		40%	
	3-4	13%		8%	
	3-5	15%		10%	
Nest-4	4-1	98%	**Yes**	98%	**Yes**
	4-2	99%		99%	
	4-3	93%		90%	
	4-4	25%		20%	
	4-5	32%		20%	
Nest-5	5-1	99%	**Yes**	99%	**Yes**
	5-2	99%		99%	
	5-3	98%		98%	
	5-4	92%		90%	
	5-5	99%		97%	

	Installation-4 - IRIS Tube Results May 13 - June 11, 2017				
	IRIS Tube	Calculated Percent Removal	Reducing Conditions Present	Visual Percent Removal	Reducing Conditions Present
Nest-1	1-1	98%	**Yes**	92%	**Yes**
	1-2	85%		85%	
	1-3	85%		85%	
	1-4	34%		12%	
	1-5	94%		90%	
Nest-2	2-1	90%	**Yes**	60%	**Yes**
	2-2	99%		98%	
	2-3	98%		90%	
	2-4	99%		95%	
	2-5	100%		99%	
Nest-3	3-1	12%	**No**	10%	**No**
	3-2	29%		15%	
	3-3	26%		15%	
	3-4	14%		10%	
	3-5	12%		10%	
Nest-4	4-1	97%	**Yes**	95%	**Yes**
	4-2	98%		98%	
	4-3	88%		82%	
	4-4	93%		85%	
	4-5	23%		10%	
Nest-5	5-1	31%	**Yes**	20%	**Yes**
	5-2	90%		90%	
	5-3	87%		90%	
	5-4	70%		60%	
	5-5	76%		75%	

	Installation-5 - IRIS Tube Results June 11 - July 09, 2017				
	IRIS Tube	Calculated Percent Removal	Reducing Conditions Present	Visual Percent Removal	Reducing Conditions Present
Nest-1	1-1	99%	**Yes**	100%	**Yes**
	1-2	97%		95%	
	1-3	93%		92%	
	1-4	61%		35%	
	1-5	94%		95%	
Nest-2	2-1	100%	**Yes**	100%	**Yes**
	2-2	99%		100%	
	2-3	95%		95%	
	2-4	88%		85%	
	2-5	90%		80%	
Nest-3	3-1	16%	**Yes**	5%	**No**
	3-2	34%		15%	
	3-3	65%		40%	
	3-4	20%		12%	
	3-5	42%		25%	
Nest-4	4-1	92%	**Yes**	95%	**Yes**
	4-2	99%		99%	
	4-3	94%		92%	
	4-4	99%		98%	
	4-5	46%		40%	
Nest-5	5-1	78%	**Yes**	80%	**Yes**
	5-2	84%		85%	
	5-3	94%		85%	
	5-4	80%		75%	
	5-5	60%		55%	

	Installation-6 - IRIS Tube Results July 09 - August 05, 2017				
	IRIS Tube	**Calculated Percent Removal**	**Reducing Conditions Present**	**Visual Percent Removal**	**Reducing Conditions Present**
Nest-1	1-1	39%	**No**	22%	**No**
	1-2	0%		0%	
	1-3	5%		1%	
	1-4	28%		15%	
	1-5	0%		0%	
Nest-2	2-1	98%	**Yes**	100%	**Yes**
	2-2	97%		100%	
	2-3	99%		100%	
	2-4	99%		100%	
	2-5	96%		95%	
Nest-3	3-1	14%	**No**	18%	**No**
	3-2	23%		20%	
	3-3	12%		12%	
	3-4	19%		15%	
	3-5	10%		10%	
Nest-4	4-1	36%	**Yes**	30%	**Yes**
	4-2	99%		98%	
	4-3	95%		95%	
	4-4	95%		95%	
	4-5	13%		5%	
Nest-5	5-1	36%	**Yes**	15%	**Yes**
	5-2	46%		35%	
	5-3	42%		30%	
	5-4	15%		5%	
	5-5	56%		60%	

	Installation-7 - IRIS Tube Results August 05 - September 02, 2017				
	IRIS Tube	Calculated Percent Removal	Reducing Conditions Present	Visual Percent Removal	Reducing Conditions Present
Nest-1	1-1	0%	**No**	0%	**No**
	1-2	0%		0%	
	1-3	0%		0%	
	1-4	0%		0%	
	1-5	0%		0%	
Nest-2	2-1	66%	**Yes**	45%	**Yes**
	2-2	92%		85%	
	2-3	64%		35%	
	2-4	92%		85%	
	2-5	50%		15%	
Nest-3	3-1	0%	**No**	0%	**No**
	3-2	4%		2%	
	3-3	10%		8%	
	3-4	8%		2%	
	3-5	0%		0%	
Nest-4	4-1	20%	**Yes**	10%	**Yes**
	4-2	83%		80%	
	4-3	80%		80%	
	4-4	86%		70%	
	4-5	11%		2%	
Nest-5	5-1	0%	**No**	0%	**No**
	5-2	18%		20%	
	5-3	5%		3%	
	5-4	7%		5%	
	5-5	27%		30%	

6-INCH ANALYSIS

	Installation-1 - IRIS Tube Results May 28 - June 25, 2016				
	IRIS Tube	Calculated Percent Removal	Reducing Conditions Present	Visual Percent Removal	Reducing Conditions Present
Nest-1	1-1	0%	No	0%	No
	1-2	0%		0%	
	1-3	0%		0%	
	1-4	0%		0%	
	1-5	0%		0%	
Nest-2	2-1	34%	Yes	35%	Yes
	2-2	87%		95%	
	2-3	64%		70%	
	2-4	55%		40%	
	2-5	68%		75%	
Nest-3	3-1	0%	No	0%	No
	3-2	0%		0%	
	3-3	0%		0%	
	3-4	0%		0%	
	3-5	0%		0%	
Nest-4	4-1	0%	No	0%	No
	4-2	0%		0%	
	4-3	0%		0%	
	4-4	10%		10%	
	4-5	0%		0%	
Nest-5	5-1	4%	No	0%	No
	5-2	6%		8%	
	5-3	2%		0%	
	5-4	7%		0%	
	5-5	2%		0%	

	Installation-1 - IRIS Tube Results May 28 - September 17, 2016				
	IRIS Tube	Calculated Percent Removal	Reducing Conditions Present	Visual Percent Removal	Reducing Conditions Present
Nest-6	6-1	8%	No	5%	No
	6-2	11%		12%	
	6-3	10%		8%	
Nest-7 (Upland Control)	7-1	0%	No	0%	No
	7-2	0%		0%	
	7-3	0%		0%	
	7-4	0%		0%	
	7-5	0%		0%	

	Installation-2 - IRIS Tube Results June 25 - July 23, 2016				
	IRIS Tube	Calculated Percent Removal	Reducing Conditions Present	Visual Percent Removal	Reducing Conditions Present
Nest-1	1-1	0%	**No**	0%	**No**
	1-2	0%		0%	
	1-3	0%		0%	
	1-4	0%		0%	
	1-5	0%		0%	
Nest-2	2-1	75%	**Yes**	98%	**Yes**
	2-2	92%		99%	
	2-3	93%		100%	
	2-4	94%		97%	
	2-5	91%		97%	
Nest-3	3-1	12%	**No**	15%	**No**
	3-2	37%		40%	
	3-3	5%		5%	
	3-4	8%		15%	
	3-5	6%		15%	
Nest-4	4-1	2%	**No**	2%	**No**
	4-2	0%		0%	
	4-3	8%		10%	
	4-4	0%		0%	
	4-5	6%		8%	
Nest-5	5-1	11%	**No**	10%	**No**
	5-2	6%		5%	
	5-3	2%		5%	
	5-4	13%		20%	
	5-5	3%		2%	

	Installation-3 - IRIS Tube Results July 23 - August 20, 2016				
	IRIS Tube	Calculated Percent Removal	Reducing Conditions Present	Visual Percent Removal	Reducing Conditions Present
Nest-1	1-1	0%	No	0%	No
	1-2	0%		0%	
	1-3	0%		0%	
	1-4	0%		0%	
	1-5	0%		0%	
Nest-2	2-1	19%	No	20%	No
	2-2	7%		5%	
	2-3	13%		15%	
	2-4	40%		45%	
	2-5	6%		10%	
Nest-3	3-1	0%	No	0%	No
	3-2	0%		0%	
	3-3	0%		0%	
	3-4	0%		0%	
	3-5	0%		0%	
Nest-4	4-1	0%	No	0%	No
	4-2	0%		0%	
	4-3	0%		0%	
	4-4	0%		0%	
	4-5	0%		0%	
Nest-5	5-1	0%	No	0%	No
	5-2	0%		0%	
	5-3	0%		0%	
	5-4	0%		0%	
	5-5	0%		0%	

	Installation-4 - IRIS Tube Results Auguts 20 - September 17, 2016				
	IRIS Tube	Calculated Percent Removal	Reducing Conditions Present	Visual Percent Removal	Reducing Conditions Present
Nest-1	1-1	0%	**No**	0%	**No**
	1-2	0%		0%	
	1-3	0%		0%	
	1-4	0%		0%	
	1-5	0%		0%	
Nest-2	2-1	85%	**Yes**	90%	**Yes**
	2-2	85%		80%	
	2-3	56%		70%	
	2-4	79%		90%	
	2-5	13%		15%	
Nest-3	3-1	0%	**No**	0%	**No**
	3-2	0%		0%	
	3-3	0%		0%	
	3-4	0%		0%	
	3-5	0%		0%	
Nest-4	4-1	0%	**No**	0%	**No**
	4-2	0%		0%	
	4-3	0%		0%	
	4-4	0%		0%	
	4-5	0%		0%	
Nest-5	5-1	0%	**No**	0%	**No**
	5-2	0%		0%	
	5-3	0%		0%	
	5-4	0%		0%	
	5-5	0%		0%	

	Installation-1 - IRIS Tube Results February 19 - March 19, 2017				
	IRIS Tube	Calculated Percent Removal	Reducing Conditions Present	Visual Percent Removal	Reducing Conditions Present
Nest-1	1-1	16%	No	8%	No
	1-2	6%		2%	
	1-3	34%		25%	
	1-4	84%		98%	
	1-5	17%		10%	
Nest-2	2-1	1%	No	1%	No
	2-2	7%		3%	
	2-3	3%		1%	
	2-4	1%		1%	
	2-5	16%		5%	
Nest-3	3-1	0%	No	0%	No
	3-2	9%		2%	
	3-3	0%		0%	
	3-4	0%		0%	
	3-5	19%		15%	
Nest-4	4-1	26%	No	30%	No
	4-2	3%		1%	
	4-3	8%		5%	
	4-4	11%		3%	
	4-5	9%		1%	
Nest-5	5-1	51%	Yes	15%	No
	5-2	64%		30%	
	5-3	33%		15%	
	5-4	58%		18%	
	5-5	57%		30%	

	Installation-1 - IRIS Tube Results February 19 - September 02, 2017				
	IRIS Tube	Calculated Percent Removal	Reducing Conditions Present	Visual Percent Removal	Reducing Conditions Present
Nest-6	6-1	94%	Yes	90%	Yes
	6-2	99%		95%	
	6-3	94%		92%	
Nest-7 (Upland Control)	7-1	63%	Yes	45%	Yes
	7-2	47%		15%	
	7-3	86%		80%	
	7-4	71%		25%	
	7-5	94%		90%	

	Installation-2 - IRIS Tube Results Marcb 19 - April 15, 2017				
	IRIS Tube	Calculated Percent Removal	Reducing Conditions Present	Visual Percent Removal	Reducing Conditions Present
Nest-1	1-1	95%	**Yes**	97%	**Yes**
	1-2	95%		99%	
	1-3	44%		28%	
	1-4	75%		85%	
	1-5	93%		95%	
Nest-2	2-1	53%	**Yes**	22%	**Yes**
	2-2	78%		75%	
	2-3	84%		92%	
	2-4	73%		80%	
	2-5	47%		20%	
Nest-3	3-1	0%	**No**	0%	**No**
	3-2	10%		3%	
	3-3	17%		15%	
	3-4	5%		3%	
	3-5	12%		12%	
Nest-4	4-1	3%	**No**	1%	**No**
	4-2	84%		88%	
	4-3	84%		80%	
	4-4	15%		12%	
	4-5	26%		20%	
Nest-5	5-1	80%	**Yes**	80%	**Yes**
	5-2	98%		99%	
	5-3	93%		85%	
	5-4	99%		100%	
	5-5	77%		90%	

	Installation-3 - IRIS Tube Results April 15 - May 13, 2017				
	IRIS Tube	Calculated Percent Removal	Reducing Conditions Present	Visual Percent Removal	Reducing Conditions Present
Nest-1	1-1	83%	**Yes**	60%	**Yes**
	1-2	78%		75%	
	1-3	44%		20%	
	1-4	97%		95%	
	1-5	99%		99%	
Nest-2	2-1	92%	**Yes**	80%	**Yes**
	2-2	100%		95%	
	2-3	92%		85%	
	2-4	95%		90%	
	2-5	95%		90%	
Nest-3	3-1	10%	**No**	8%	**No**
	3-2	21%		15%	
	3-3	46%		25%	
	3-4	9%		5%	
	3-5	16%		15%	
Nest-4	4-1	99%	**Yes**	98%	**Yes**
	4-2	99%		98%	
	4-3	96%		90%	
	4-4	17%		15%	
	4-5	25%		15%	
Nest-5	5-1	99%	**Yes**	99%	**Yes**
	5-2	99%		98%	
	5-3	96%		95%	
	5-4	88%		80%	
	5-5	98%		85%	

	Installation-4 - IRIS Tube Results May 13 - June 11, 2017				
	IRIS Tube	Calculated Percent Removal	Reducing Conditions Present	Visual Percent Removal	Reducing Conditions Present
Nest-1	1-1	86%	**Yes**	85%	**Yes**
	1-2	84%		85%	
	1-3	64%		60%	
	1-4	32%		15%	
	1-5	90%		88%	
Nest-2	2-1	81%	**Yes**	50%	**Yes**
	2-2	99%		95%	
	2-3	97%		85%	
	2-4	98%		90%	
	2-5	99%		98%	
Nest-3	3-1	9%	**No**	10%	**No**
	3-2	19%		12%	
	3-3	20%		15%	
	3-4	9%		10%	
	3-5	8%		8%	
Nest-4	4-1	89%	**Yes**	90%	**Yes**
	4-2	91%		90%	
	4-3	86%		80%	
	4-4	72%		50%	
	4-5	18%		10%	
Nest-5	5-1	27%	**Yes**	20%	**Yes**
	5-2	78%		75%	
	5-3	79%		80%	
	5-4	50%		30%	
	5-5	60%		50%	

	Installation-5 - IRIS Tube Results June 11 - July 09, 2017				
	IRIS Tube	Calculated Percent Removal	Reducing Conditions Present	Visual Percent Removal	Reducing Conditions Present
Nest-1	1-1	98%	**Yes**	97%	**Yes**
	1-2	97%		98%	
	1-3	83%		85%	
	1-4	52%		25%	
	1-5	90%		95%	
Nest-2	2-1	97%	**Yes**	97%	**Yes**
	2-2	98%		99%	
	2-3	94%		75%	
	2-4	86%		80%	
	2-5	78%		20%	
Nest-3	3-1	13%	**No**	5%	**No**
	3-2	23%		12%	
	3-3	58%		35%	
	3-4	14%		10%	
	3-5	40%		30%	
Nest-4	4-1	86%	**Yes**	90%	**Yes**
	4-2	99%		98%	
	4-3	96%		95%	
	4-4	94%		95%	
	4-5	43%		40%	
Nest-5	5-1	74%	**Yes**	55%	**Yes**
	5-2	69%		50%	
	5-3	89%		85%	
	5-4	77%		75%	
	5-5	59%		50%	

	Installation-6 - IRIS Tube Results July 09 - August 05, 2017				
	IRIS Tube	Calculated Percent Removal	Reducing Conditions Present	Visual Percent Removal	Reducing Conditions Present
Nest-1	1-1	27%	**No**	20%	**No**
	1-2	0%		0%	
	1-3	3%		1%	
	1-4	19%		10%	
	1-5	0%		0%	
Nest-2	2-1	98%	**Yes**	99%	**Yes**
	2-2	96%		100%	
	2-3	100%		99%	
	2-4	99%		100%	
	2-5	96%		99%	
Nest-3	3-1	10%	**No**	10%	**No**
	3-2	16%		15%	
	3-3	9%		5%	
	3-4	13%		10%	
	3-5	6%		8%	
Nest-4	4-1	25%	**Yes**	20%	**Yes**
	4-2	96%		95%	
	4-3	95%		95%	
	4-4	66%		70%	
	4-5	9%		5%	
Nest-5	5-1	25%	**Yes**	15%	**No**
	5-2	34%		25%	
	5-3	36%		20%	
	5-4	11%		10%	
	5-5	42%		40%	

	Installation-7 - IRIS Tube Results August 05 - September 02, 2017				
	IRIS Tube	Calculated Percent Removal	Reducing Conditions Present	Visual Percent Removal	Reducing Conditions Present
Nest-1	1-1	0%	**No**	0%	**No**
	1-2	0%		0%	
	1-3	0%		0%	
	1-4	0%		0%	
	1-5	0%		0%	
Nest-2	2-1	52%	**Yes**	35%	**Yes**
	2-2	77%		55%	
	2-3	57%		40%	
	2-4	88%		80%	
	2-5	35%		12%	
Nest-3	3-1	0%	**No**	0%	**No**
	3-2	2%		1%	
	3-3	7%		5%	
	3-4	5%		2%	
	3-5	0%		0%	
Nest-4	4-1	19%	**Yes**	12%	**Yes**
	4-2	75%		50%	
	4-3	81%		70%	
	4-4	58%		50%	
	4-5	8%		2%	
Nest-5	5-1	0%	**No**	0%	**No**
	5-2	13%		10%	
	5-3	3%		2%	
	5-4	5%		3%	
	5-5	18%		15%	

DEPTH OF INSTALLATION ANALYSIS

	Installation-1 - IRIS Tube Results May 28 - June 25, 2016				
	IRIS Tube	Calculated Percent Removal	Reducing Conditions Present	Visual Percent Removal	Reducing Conditions Present
Nest-1	1-1	0%	**No**	0%	**No**
	1-2	0%		0%	
	1-3	0%		0%	
	1-4	0%		0%	
	1-5	0%		0%	
Nest-2	2-1	33%	**Yes**	35%	**Yes**
	2-2	66%		65%	
	2-3	61%		60%	
	2-4	64%		60%	
	2-5	41%		35%	
Nest-3	3-1	0%	**No**	0%	**No**
	3-2	0%		0%	
	3-3	0%		0%	
	3-4	0%		0%	
	3-5	0%		0%	
Nest-4	4-1	0%	**No**	0%	**No**
	4-2	0%		0%	
	4-3	0%		0%	
	4-4	6%		8%	
	4-5	0%		0%	
Nest-5	5-1	3%	**No**	0%	**No**
	5-2	2%		3%	
	5-3	1%		0%	
	5-4	4%		0%	
	5-5	1%		0%	

	Installation-1 - IRIS Tube Results May 28 - September 17, 2016				
	IRIS Tube	Calculated Percent Removal	Reducing Conditions Present	Visual Percent Removal	Reducing Conditions Present
Nest-6	6-1	4%	**No**	5%	**No**
	6-2	9%		12%	
	6-3	5%		8%	
Nest-7 (Upland Control)	7-1	0%	**No**	0%	**No**
	7-2	0%		0%	
	7-3	0%		0%	
	7-4	0%		0%	
	7-5	0%		0%	

Installation-2 - IRIS Tube Results June 25 - July 23, 2016					
	IRIS Tube	Calculated Percent Removal	Reducing Conditions Present	Visual Percent Removal	Reducing Conditions Present
Nest-1	1-1	0%	**No**	0%	**No**
	1-2	0%		0%	
	1-3	0%		0%	
	1-4	0%		0%	
	1-5	0%		0%	
Nest-2	2-1	79%	**Yes**	95%	**Yes**
	2-2	93%		99%	
	2-3	90%		100%	
	2-4	93%		100%	
	2-5	88%		97%	
Nest-3	3-1	7%	**No**	12%	**No**
	3-2	20%		25%	
	3-3	3%		4%	
	3-4	4%		12%	
	3-5	3%		10%	
Nest-4	4-1	2%	**No**	5%	**No**
	4-2	0%		0%	
	4-3	6%		10%	
	4-4	0%		0%	
	4-5	4%		5%	
Nest-5	5-1	8%	**No**	12%	**No**
	5-2	4%		5%	
	5-3	2%		4%	
	5-4	7%		10%	
	5-5	1%		2%	

Installation-3 - IRIS Tube Results July 23 - August 20, 2016					
	IRIS Tube	Calculated Percent Removal	Reducing Conditions Present	Visual Percent Removal	Reducing Conditions Present
Nest-1	1-1	0%	**No**	0%	**No**
	1-2	0%		0%	
	1-3	0%		0%	
	1-4	0%		0%	
	1-5	0%		0%	
Nest-2	2-1	10%	**No**	10%	**No**
	2-2	5%		2%	
	2-3	7%		10%	
	2-4	22%		30%	
	2-5	4%		8%	
Nest-3	3-1	0%	**No**	0%	**No**
	3-2	0%		0%	
	3-3	0%		0%	
	3-4	0%		0%	
	3-5	0%		0%	
Nest-4	4-1	0%	**No**	0%	**No**
	4-2	0%		0%	
	4-3	0%		0%	
	4-4	0%		0%	
	4-5	0%		0%	
Nest-5	5-1	0%	**No**	0%	**No**
	5-2	0%		0%	
	5-3	0%		0%	
	5-4	0%		0%	
	5-5	0%		0%	

	Installation-4 - IRIS Tube Results Auguts 20 - September 17, 2016				
	IRIS Tube	Calculated Percent Removal	Reducing Conditions Present	Visual Percent Removal	Reducing Conditions Present
Nest-1	1-1	0%	**No**	0%	**No**
	1-2	0%		0%	
	1-3	0%		0%	
	1-4	0%		0%	
	1-5	0%		0%	
Nest-2	2-1	45%	**Yes**	45%	**Yes**
	2-2	44%		45%	
	2-3	29%		30%	
	2-4	42%		40%	
	2-5	7%		10%	
Nest-3	3-1	0%	**No**	0%	**No**
	3-2	0%		0%	
	3-3	0%		0%	
	3-4	0%		0%	
	3-5	0%		0%	
Nest-4	4-1	0%	**No**	0%	**No**
	4-2	0%		0%	
	4-3	0%		0%	
	4-4	0%		0%	
	4-5	0%		0%	
Nest-5	5-1	0%	**No**	0%	**No**
	5-2	0%		0%	
	5-3	0%		0%	
	5-4	0%		0%	
	5-5	0%		0%	

	Installation-1 - IRIS Tube Results February 19 - March 19, 2017				
	IRIS Tube	Calculated Percent Removal	Reducing Conditions Present	Visual Percent Removal	Reducing Conditions Present
Nest-1	1-1	8%	No	5%	No
	1-2	4%		1%	
	1-3	19%		8%	
	1-4	49%		65%	
	1-5	12%		5%	
Nest-2	2-1	1%	No	1%	No
	2-2	10%		2%	
	2-3	10%		5%	
	2-4	4%		2%	
	2-5	16%		10%	
Nest-3	3-1	0%	No	0%	No
	3-2	5%		2%	
	3-3	0%		0%	
	3-4	0%		0%	
	3-5	13%		20%	
Nest-4	4-1	16%	No	18%	No
	4-2	2%		1%	
	4-3	5%		2%	
	4-4	7%		2%	
	4-5	5%		1%	
Nest-5	5-1	41%	Yes	10%	No
	5-2	50%		20%	
	5-3	32%		12%	
	5-4	36%		20%	
	5-5	42%		15%	

	Installation-1 - IRIS Tube Results February 19 - September 02, 2017				
	IRIS Tube	Calculated Percent Removal	Reducing Conditions Present	Visual Percent Removal	Reducing Conditions Present
Nest-6	6-1	89%	Yes	85%	Yes
	6-2	97%		92%	
	6-3	82%		75%	
Nest-7 (Upland Control)	7-1	61%	Yes	35%	Yes
	7-2	48%		18%	
	7-3	63%		40%	
	7-4	42%		20%	
	7-5	80%		80%	

Installation-2 - IRIS Tube Results March 19 - April 15, 2017					
	IRIS Tube	Calculated Percent Removal	Reducing Conditions Present	Visual Percent Removal	Reducing Conditions Present
Nest-1	1-1	64%	**Yes**	60%	**Yes**
	1-2	72%		75%	
	1-3	26%		15%	
	1-4	45%		25%	
	1-5	62%		70%	
Nest-2	2-1	38%	**Yes**	15%	**Yes**
	2-2	75%		65%	
	2-3	79%		80%	
	2-4	57%		50%	
	2-5	47%		28%	
Nest-3	3-1	0%	**No**	0%	**No**
	3-2	5%		3%	
	3-3	9%		10%	
	3-4	3%		2%	
	3-5	7%		5%	
Nest-4	4-1	2%	**No**	1%	**No**
	4-2	66%		75%	
	4-3	67%		75%	
	4-4	11%		10%	
	4-5	16%		12%	
Nest-5	5-1	70%	**Yes**	30%	**Yes**
	5-2	83%		85%	
	5-3	88%		85%	
	5-4	97%		98%	
	5-5	71%		80%	

	Installation-3 - IRIS Tube Results April 15 - May 13, 2017				
	IRIS Tube	Calculated Percent Removal	Reducing Conditions Present	Visual Percent Removal	Reducing Conditions Present
Nest-1	1-1	53%	**Yes**	40%	**Yes**
	1-2	55%		70%	
	1-3	27%		15%	
	1-4	75%		80%	
	1-5	78%		80%	
Nest-2	2-1	84%	**Yes**	70%	**Yes**
	2-2	89%		85%	
	2-3	84%		70%	
	2-4	89%		90%	
	2-5	94%		90%	
Nest-3	3-1	5%	**No**	5%	**No**
	3-2	11%		10%	
	3-3	24%		15%	
	3-4	5%		2%	
	3-5	8%		5%	
Nest-4	4-1	69%	**Yes**	70%	**Yes**
	4-2	84%		85%	
	4-3	66%		65%	
	4-4	10%		10%	
	4-5	15%		8%	
Nest-5	5-1	92%	**Yes**	90%	**Yes**
	5-2	77%		85%	
	5-3	73%		80%	
	5-4	81%		80%	
	5-5	91%		85%	

Installation-4 - IRIS Tube Results May 13 - June 11, 2017					
	IRIS Tube	Calculated Percent Removal	Reducing Conditions Present	Visual Percent Removal	Reducing Conditions Present
Nest-1	1-1	60%	**Yes**	65%	**Yes**
	1-2	61%		75%	
	1-3	37%		20%	
	1-4	30%		10%	
	1-5	62%		70%	
Nest-2	2-1	78%	**Yes**	25%	**Yes**
	2-2	92%		85%	
	2-3	90%		75%	
	2-4	82%		75%	
	2-5	84%		70%	
Nest-3	3-1	5%	**No**	5%	**No**
	3-2	10%		8%	
	3-3	11%		10%	
	3-4	6%		5%	
	3-5	4%		5%	
Nest-4	4-1	57%	**Yes**	45%	**Yes**
	4-2	77%		80%	
	4-3	69%		65%	
	4-4	40%		25%	
	4-5	11%		10%	
Nest-5	5-1	23%	**Yes**	12%	**Yes**
	5-2	44%		40%	
	5-3	54%		35%	
	5-4	37%		25%	
	5-5	37%		30%	

	Installation-5 - IRIS Tube Results June 11 - July 09, 2017				
	IRIS Tube	**Calculated Percent Removal**	**Reducing Conditions Present**	**Visual Percent Removal**	**Reducing Conditions Present**
Nest-1	1-1	72%	**Yes**	80%	**Yes**
	1-2	71%		80%	
	1-3	48%		60%	
	1-4	39%		25%	
	1-5	70%		80%	
Nest-2	2-1	95%	**Yes**	95%	**Yes**
	2-2	90%		90%	
	2-3	75%		65%	
	2-4	76%		70%	
	2-5	63%		35%	
Nest-3	3-1	7%	**No**	2%	**No**
	3-2	12%		5%	
	3-3	34%		25%	
	3-4	7%		3%	
	3-5	32%		15%	
Nest-4	4-1	61%	**Yes**	60%	**Yes**
	4-2	86%		85%	
	4-3	78%		75%	
	4-4	79%		60%	
	4-5	35%		30%	
Nest-5	5-1	72%	**Yes**	60%	**Yes**
	5-2	60%		45%	
	5-3	79%		65%	
	5-4	70%		65%	
	5-5	60%		40%	

Installation-6 - IRIS Tube Results July 09 - August 05, 2017					
	IRIS Tube	Calculated Percent Removal	Reducing Conditions Present	Visual Percent Removal	Reducing Conditions Present
Nest-1	1-1	13%	**No**	10%	**No**
	1-2	0%		0%	
	1-3	2%		1%	
	1-4	9%		8%	
	1-5	0%		0%	
Nest-2	2-1	93%	**Yes**	92%	**Yes**
	2-2	93%		100%	
	2-3	95%		98%	
	2-4	97%		98%	
	2-5	95%		98%	
Nest-3	3-1	5%	**No**	4%	**No**
	3-2	8%		8%	
	3-3	4%		3%	
	3-4	6%		5%	
	3-5	3%		3%	
Nest-4	4-1	13%	**Yes**	10%	**Yes**
	4-2	59%		60%	
	4-3	59%		55%	
	4-4	34%		30%	
	4-5	5%		3%	
Nest-5	5-1	22%	**No**	15%	**No**
	5-2	19%		10%	
	5-3	22%		15%	
	5-4	10%		8%	
	5-5	23%		20%	

	Installation-7 - IRIS Tube Results August 05 - September 02, 2017				
	IRIS Tube	Calculated Percent Removal	Reducing Conditions Present	Visual Percent Removal	Reducing Conditions Present
Nest-1	1-1	0%	**No**	0%	**No**
	1-2	0%		0%	
	1-3	0%		0%	
	1-4	0%		0%	
	1-5	0%		0%	
Nest-2	2-1	29%	**Yes**	15%	**Yes**
	2-2	54%		30%	
	2-3	38%		40%	
	2-4	73%		50%	
	2-5	27%		10%	
Nest-3	3-1	0%	**No**	0%	**No**
	3-2	1%		1%	
	3-3	5%		5%	
	3-4	3%		1%	
	3-5	0%		0%	
Nest-4	4-1	10%	**No**	8%	**No**
	4-2	41%		35%	
	4-3	44%		40%	
	4-4	29%		25%	
	4-5	6%		1%	
Nest-5	5-1	0%	**No**	0%	**No**
	5-2	7%		8%	
	5-3	2%		2%	
	5-4	3%		3%	
	5-5	9%		12%	

APPENDIX F

IRIS TUBE INSTALLATION SUMMARY TABLES

	Parameter							Summary	
2016 Installation-1 (May 28 - June 25)	IRIS Tubes with > 30% Removal	Consecutive Days of Saturation	Total Days of Saturation	Average Upper Depletion Depth (cm)	Upper Depletion Depth Standard Error	Average Water Level Data (cm)	Water Level Standard Error	Reducing Conditions Present	Wetland Hydrology Present
Nest-1	0	2	2	N/A	N/A	-28.01	1.42	No	No
Nest-2	5	5	7	-28.00	1.08	-22.92	2.38	Yes	No
Nest-3	0	N/A	N/A	N/A	N/A	N/A	N/A	No	N/A
Nest-4	0	4	7	N/A	N/A	-25.41	1.85	No	No
Nest-5	0	2	2	N/A	N/A	-29.35	0.45	No	No

	Parameter							Summary	
2016 Installation-2 (June 25 - July 23)	IRIS Tubes with > 30% Removal	Consecutive Days of Saturation	Total Days of Saturation	Average Upper Depletion Depth (cm)	Upper Depletion Depth Standard Error	Average Water Level Data (cm)	Water Level Standard Error	Reducing Conditions Present	Wetland Hydrology Present
Nest-1	0	N/A	N/A	N/A	N/A	< -30	N/A	No	N/A
Nest-2	5	13	18	-12.00	7.35	-13.01	2.73	Yes	No
Nest-3	1	N/A	N/A	-29.10	0.90	N/A	N/A	No	N/A
Nest-4	0	13	16	-29.10	0.90	-20.25	2.20	No	No
Nest-5	0	N/A	N/A	N/A	N/A	< -30	N/A	No	N/A

	Parameter							Summary	
2016 Installation-3 (July 23 - August 20)	IRIS Tubes with > 30% Removal	Consecutive Days of Saturation	Total Days of Saturation	Average Upper Depletion Depth (cm)	Upper Depletion Depth Standard Error	Average Water Level Data (cm)	Water Level Standard Error	Reducing Conditions Present	Wetland Hydrology Present
Nest-1	0	N/A	N/A	N/A	N/A	N/A	N/A	No	N/A
Nest-2	1	0	0	-28.40	1.03	< -30	0.00	No	No
Nest-3	0	N/A	N/A	N/A	N/A	N/A	N/A	No	N/A
Nest-4	0	2	2	N/A	N/A	-29.27	0.00	No	No
Nest-5	0	N/A	N/A	N/A	N/A	N/A	N/A	No	N/A

	Parameter							Summary	
2016 Installation-4 (August 20 - September 17)	IRIS Tubes with > 30% Removal	Consecutive Days of Saturation	Total Days of Saturation	Average Upper Depletion Depth (cm)	Upper Depletion Depth Standard Error	Average Water Level Data (cm)	Water Level Standard Error	Reducing Conditions Present	Wetland Hydrology Present
Nest-1	0	N/A	N/A	N/A	N/A	N/A	N/A	No	N/A
Nest-2	4	2	3	-22.40	3.01	-27.72	1.56	Yes	No
Nest-3	0	N/A	N/A	N/A	N/A	N/A	N/A	No	N/A
Nest-4	0	3	7	N/A	N/A	-28.77	0.56	No	No
Nest-5	0	N/A	N/A	N/A	N/A	N/A	N/A	No	N/A

	Parameter							Summary	
2017 Installation-1 (February 19 - March 19)	IRIS Tubes with > 30% Removal	Consecutive Days of Saturation	Total Days of Saturation	Average Upper Depletion Depth (cm)	Upper Depletion Depth Standard Error	Average Water Level Data (cm)	Water Level Standard Error	Reducing Conditions Present	Wetland Hydrology Present
Nest-1	2	29	29	-25.40	2.84	-8.67	1.15	No	Yes
Nest-2	0	29	29	-29.80	0.12	-13.73	2.72	No	Yes
Nest-3	0	2	6	N/A	N/A	-27.16	1.30	No	No
Nest-4	0	20	27	N/A	N/A	-8.33	1.75	No	Yes
Nest-5	5	29	29	-28.8	0.51	-6.16	1.04	Yes	Yes

	Parameter							Summary	
2017 Installation-2 (March 19 - April 15)	IRIS Tubes with > 30% Removal	Consecutive Days of Saturation	Total Days of Saturation	Average Upper Depletion Depth (cm)	Upper Depletion Depth Standard Error	Average Water Level Data (cm)	Water Level Standard Error	Reducing Conditions Present	Wetland Hydrology Present
Nest-1	5	21	21	-18.00	4.92	-11.24	2.29	Yes	Yes
Nest-2	5	14	14	-28.60	1.04	-14.32	2.83	Yes	Yes
Nest-3	0	2	5	-29.90	0.10	-27.65	1.14	No	No
Nest-4	2	19	19	-26.10	3.78	-12.21	2.58	No	Yes
Nest-5	5	26	26	-15	6.20	-7.85	2.02	Yes	Yes

	Parameter							Summary	
2017 Installation-3 (April 15 - May 13)	IRIS Tubes with > 30% Removal	Consecutive Days of Saturation	Total Days of Saturation	Average Upper Depletion Depth (cm)	Upper Depletion Depth Standard Error	Average Water Level Data (cm)	Water Level Standard Error	Reducing Conditions Present	Wetland Hydrology Present
Nest-1	5	12	21	-16.10	4.04	-12.69	2.41	Yes	No
Nest-2	5	13	19	-24.00	6.00	-12.24	2.63	Yes	No
Nest-3	1	4	10	-29.10	0.46	-24.37	1.98	No	No
Nest-4	3	21	24	-21.00	4.97	-10.38	2.38	Yes	Yes
Nest-5	5	24	26	-12.5	4.72	-9.12	2.06	Yes	Yes

	Parameter							Summary	
2017 Installation-4 (May 13 - June 11)	IRIS Tubes with > 30% Removal	Consecutive Days of Saturation	Total Days of Saturation	Average Upper Depletion Depth (cm)	Upper Depletion Depth Standard Error	Average Water Level Data (cm)	Water Level Standard Error	Reducing Conditions Present	Wetland Hydrology Present
Nest-1	5	5	14	-21.90	3.50	-18.59	2.40	Yes	No
Nest-2	5	12	17	-9.90	5.48	-16.01	2.78	Yes	No
Nest-3	0	2	7	-29.40	0.24	-27.49	1.18	No	No
Nest-4	4	10	20	-20.50	4.13	-15.70	2.51	Yes	No
Nest-5	4	10	20	-23	1.82	-17.44	2.25	Yes	No

	Parameter							Summary	
2017 Installation-5 (June 11 - July 9)	IRIS Tubes with > 30% Removal	Consecutive Days of Saturation	Total Days of Saturation	Average Upper Depletion Depth (cm)	Upper Depletion Depth Standard Error	Average Water Level Data (cm)	Water Level Standard Error	Reducing Conditions Present	Wetland Hydrology Present
Nest-1	5	5	11	-17.10	4.13	-20.64	2.40	Yes	No
Nest-2	5	12	18	-9.10	4.01	-15.83	2.74	Yes	No
Nest-3	1	3	7	-29.40	0.24	-24.62	2.02	No	No
Nest-4	5	7	16	-12.10	4.60	-16.43	2.60	Yes	No
Nest-5	5	6	14	-28.1	1.12	-18.42	2.58	Yes	No

	Parameter							Summary	
2017 Installation-6 (July 9 - August 5)	IRIS Tubes with > 30% Removal	Consecutive Days of Saturation	Total Days of Saturation	Average Upper Depletion Depth (cm)	Upper Depletion Depth Standard Error	Average Water Level Data (cm)	Water Level Standard Error	Reducing Conditions Present	Wetland Hydrology Present
Nest-1	0	1	1	-29.40	0.60	-29.06	0.94	No	No
Nest-2	5	6	13	0.00	0.00	-18.12	2.81	Yes	No
Nest-3	0	1	1	-29.50	0.27	-29.72	0.28	No	No
Nest-4	3	4	7	-21.20	3.40	-25.59	1.71	Yes	No
Nest-5	3	4	6	-28.4	0.70	-26.19	1.68	Yes	No

	Parameter							Summary	
2017 Installation-7 (August 5 - September 2)	IRIS Tubes with > 30% Removal	Consecutive Days of Saturation	Total Days of Saturation	Average Upper Depletion Depth (cm)	Upper Depletion Depth Standard Error	Average Water Level Data (cm)	Water Level Standard Error	Reducing Conditions Present	Wetland Hydrology Present
Nest-1	0	2	2	N/A	N/A	-27.93	1.44	No	No
Nest-2	5	3	6	-21.80	3.39	-24.45	2.14	Yes	No
Nest-3	0	3	3	-29.90	0.10	-27.87	1.43	No	No
Nest-4	3	4	7	-26.30	2.00	-24.81	2.08	Yes	No
Nest-5	0	2	3	-29.8	0.20	-27.71	1.44	No	No