Using IRIS Tubes to Monitor Reduced Conditions in Soils — Project Design

by Jacob F. Berkowitz

PURPOSE: This document provides guidance for planning and implementing a monitoring project for the identification of reducing conditions in hydric soils for wetland regulatory purposes. It is intended to address situations commonly encountered in areas where the hydric soil Technical Standard (TS) established by the National Technical Committee for Hydric Soils (NTCHS) might be applied (NTCHS 2007), but is not intended to replace the TS. This document outlines procedures recommended to install indicator of reduction in soils (IRIS) tubes, and to evaluate and interpret data. It is not intended to be all-inclusive or supersede wetland delineations based on indicators of hydric soils, hydrophytic vegetation, and wetland hydrology. Wetland monitoring projects designed to combine additional information about hydric soils, hydrology, or water quality are beyond the scope of this document. Additional information concerning the gathering and interpretation of hydrology data for regulatory purposes is available in U.S. Army Corps of Engineers (2005) and Noble (2006). The procedure for IRIS tube production is described by Rabenhorst and Burch (2006) and will not be repeated here.

INTRODUCTION: This document provides guidance for planning and interpreting data collected during a hydric soil study involving the application of the NTCHS Technical Standard for hydric soils. The TS provides information concerning the number of IRIS tubes to install and the amount of iron removal required for a positive result. This document expands on the procedure for IRIS tube installation, evaluation, data interpretation, and other information required to confirm reducing conditions in hydric soils.

BACKGROUND AND OVERVIEW: IRIS tubes are used to determine the presence/absence of reducing conditions in soils, and aid in the identification of hydric soil properties for the purpose of wetland determination. IRIS tubes provide a convenient and affordable mechanism to accurately examine current soil conditions. IRIS tubes have a low failure rate (no moving parts, power source, etc.) and can be deployed with little risk both in remote areas with limited access and in urban areas susceptible to disturbance and vandalism. The tubes also can be used to provide preliminary data with limited effort and determine if a more robust study (including water-table monitoring, etc.) is warranted. IRIS tubes also show great potential to provide monitoring and quality control in restored or created wetlands, where typical indicators of hydric soils (redoximorphic features, carbon accumulation, etc.) have not had adequate time to develop.

The production of IRIS tubes involves painting a solution of iron oxides and oxyhydroxides onto sections of polyvinyl chloride (PVC) pipe to an installed depth of 12 in. The solution is allowed to dry and the tube can be installed in the ground using a soil push probe. Under anaerobic conditions, the oxidized iron will be reduced and removed from the surface of the tube. Iron reduction occurs on the IRIS tube surface when the soil is saturated, ponded, or flooded for sufficient periods of time during the growing season that allows anaerobic microbial activity to predominate. Sufficient organic material must also be present for reduction to occur. At the conclusion of the sampling period, IRIS tubes are removed from the soil and the amount of iron removal is measured. This can be done using visual estimates or image analysis software. If 30 percent or more of the iron is removed from the IRIS tube surface in a zone 6 in. long within the upper 12 in. of the soil, then the location is considered to meet the TS criteria for reduced conditions.

In many cases, the TS will be applied in a regulatory setting and may be part of a Clean Water Act section 404 permit action. Most of these cases involve Corps District personnel and an applicant. In more complex cases, consultants and others may also be involved. It is important for the principal parties to determine what questions will be answered by installing IRIS tubes to measure reduced soil conditions. Potential questions include: Will the soil in a particular location become anaerobic and reduced this year? Does it become reduced in most years? Where is the boundary on this site between soils that become reduced and those that do not?

NUMBER OF IRIS TUBES REQUIRED: The number of IRIS tubes necessary to provide adequate documentation of hydric soil status depends on several factors including: (a) objectives of the study, (b) study site size, (c) site complexity, (d) soil type(s), (e) vegetative communities, (f) wetland type, and (g) site disturbance or alteration. As the required number of IRIS tubes increases, the cost of materials and the time and cost of installation, removal, and data analysis also increase. Fortunately, IRIS tubes are inexpensive to produce and a large number of tubes may not be necessary if the tubes are properly installed and evaluated. In all cases, a “nest” of five IRIS tubes should be deployed at each area of interest (Figure 1). As described in the TS, three out of the five replicate IRIS tubes must display sufficient iron removal to conclude that reducing soil conditions are present.

Objectives. If the purpose of the investigation is to determine whether a small area contains hydric soils, then five IRIS tubes located in a tight group (Figure 1) may be adequate. However, if the project seeks to identify a hydric soil boundary, the study should include a minimum of three zones of investigation arrayed along a transect. Nests of five IRIS tubes should be installed, with each nest placed (1) above the estimated wetland boundary (i.e., in the upland zone), (2) at the estimated wetland boundary, and (3) below the estimated wetland boundary. Because a minimum of five tubes are required within each zone of interest, a minimum of 15 IRIS tubes is needed to determine a hydric soil boundary.

Study site size. If the area of interest is relatively small (e.g., less than 2 acres) and uniform in topography and soil type, only one or two IRIS tube nests may be needed to evaluate hydric soil status. If the area of interest is larger than a few acres in size, several nests may be needed on a homogeneous site. When determining a wetland boundary, several transects, each examining the three zones (upland, boundary, and wetland), may be required to define the hydric soil boundary. The number of transects must be determined on a site-specific basis.

Site complexity. The complexity of the site influences the number and placement of IRIS tubes because a number of different landscape positions may need to be monitored to characterize the site adequately. On flat to gently sloping terrain, one or two nests or transects may adequately describe a site. However, areas with complex topography, such as ridges, swales, hummocks, or dunes, will require additional sampling points (Figure 2).

Figure 1. IRIS tube nest with the minimum five IRIS tubes. Sites with uniform topography, soil type, and vegetative communities require fewer IRIS tube nests to characterize.

Soil type. In areas with a single soil type, few IRIS tube installations will be required. If several soil types are present, additional nests may be needed. Soil survey data and soil maps can provide guidance on IRIS tube placement and can aid interpretation of results. However, soil survey data vary in map scale and accuracy; care must be taken to verify the soil types and soil conditions on site. Soil maps are available on the Natural Resources Conservation Service (NRCS) Web Soil Survey (*http://websoilsurvey.nrcs.usda.gov/app/HomePage.htm*) and in published county soil surveys (NRCS 2008).

Vegetative communities. Changes in vegetative cover across a landscape can help to determine the wetland boundary and also provide guidance for IRIS tube placement. Some plants alter the hydrologic regime by retaining or transpiring large amounts of water and thus can affect the development of reducing conditions. Vegetation also provides a source of organic matter (one requirement for attaining reduced conditions) and IRIS tubes placed in areas with limited organic matter may not display reduction. If abrupt changes in vegetation occur within a site, nests of IRIS tubes should be distributed to capture this variability.

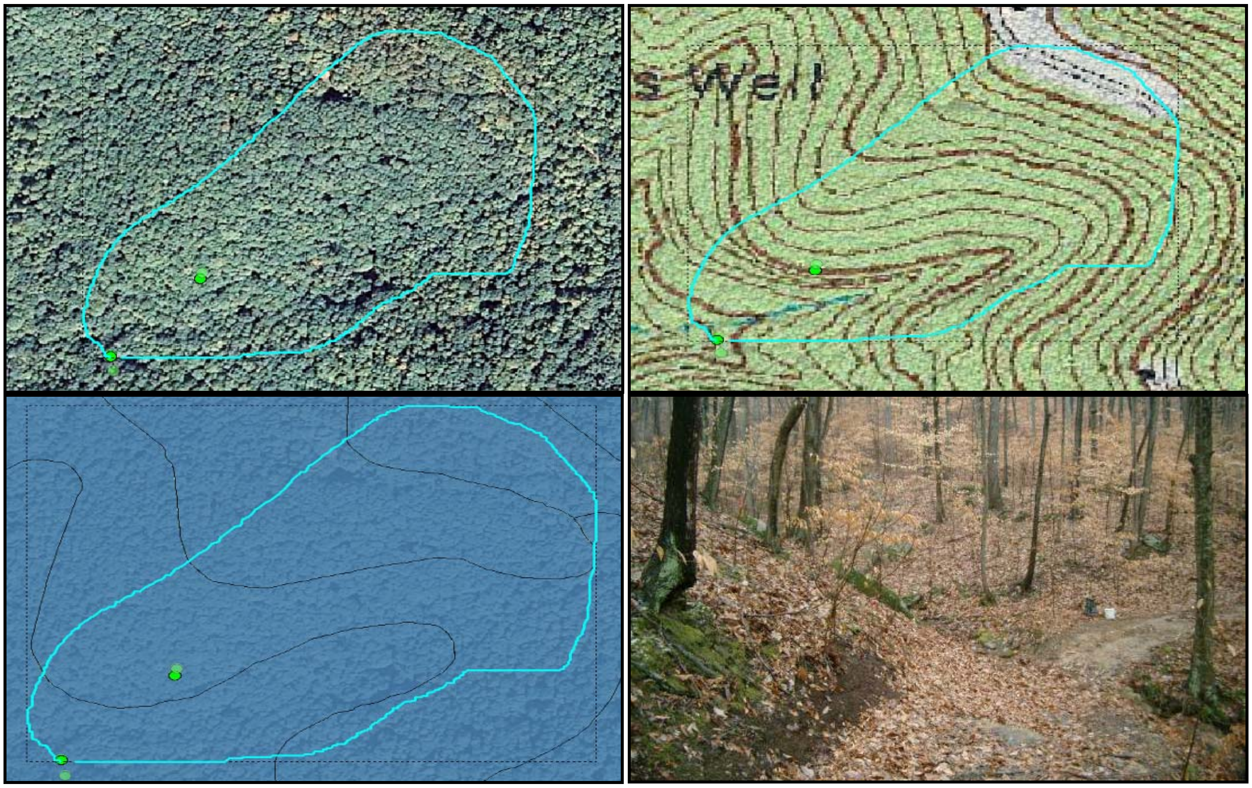

Figure 2. Sites with high complexity require additional IRIS tube nests. This example displays (clockwise from top left): vegetative communities and land use, complex topography, site photo, and overlapping soil types occurring on the site. Green dots represent potential sampling locations based on vegetation, slope, and soil type.

Wetland type. IRIS tubes can be used to investigate reduced soil conditions in any wetland type, including slope, fringe, depressional, riverine, and flat wetlands. When examining a wetland boundary, IRIS tubes should be placed along a transect from presumed upland to wetland areas, regardless of wetland type. For example, in a depressional landscape, IRIS tube nests should begin on the upland depressional edge and proceed down-gradient across the wetland boundary and into the known wetland area. In riparian landscapes, IRIS tubes should be placed along transects extending across the floodplain and should include areas that do not receive inputs from either floodwater or groundwater. In complex alluvial floodplains, depending upon the goals of the study, various geomorphic settings (e.g., natural levee, backswamp, abandoned channels) may need to be sampled.

Site disturbance and alteration. On a site with a history of significant disturbance or alteration, additional IRIS tube nests and transects may be needed to characterize the variability in natural and man-induced alteration (Figure 3). In areas where fill material may be present, insufficient organic matter may be present to induce reducing conditions. Soil compaction can impede the movement of water through or across a landscape and affect IRIS tube performance. Ditching and draining, removal of vegetation, and irrigation can also alter hydrologic regimes and lead to misinterpretation of IRIS tube data. However, IRIS tubes still provide a robust method for evaluating onsite conditions in most altered and disturbed sites. Background information concerning the area of interest and the history of disturbance or landscape modification can aid in determining the number of IRIS tube nests required to adequately characterize the site. IRIS tubes can provide information on the need for additional hydrology and soils information.

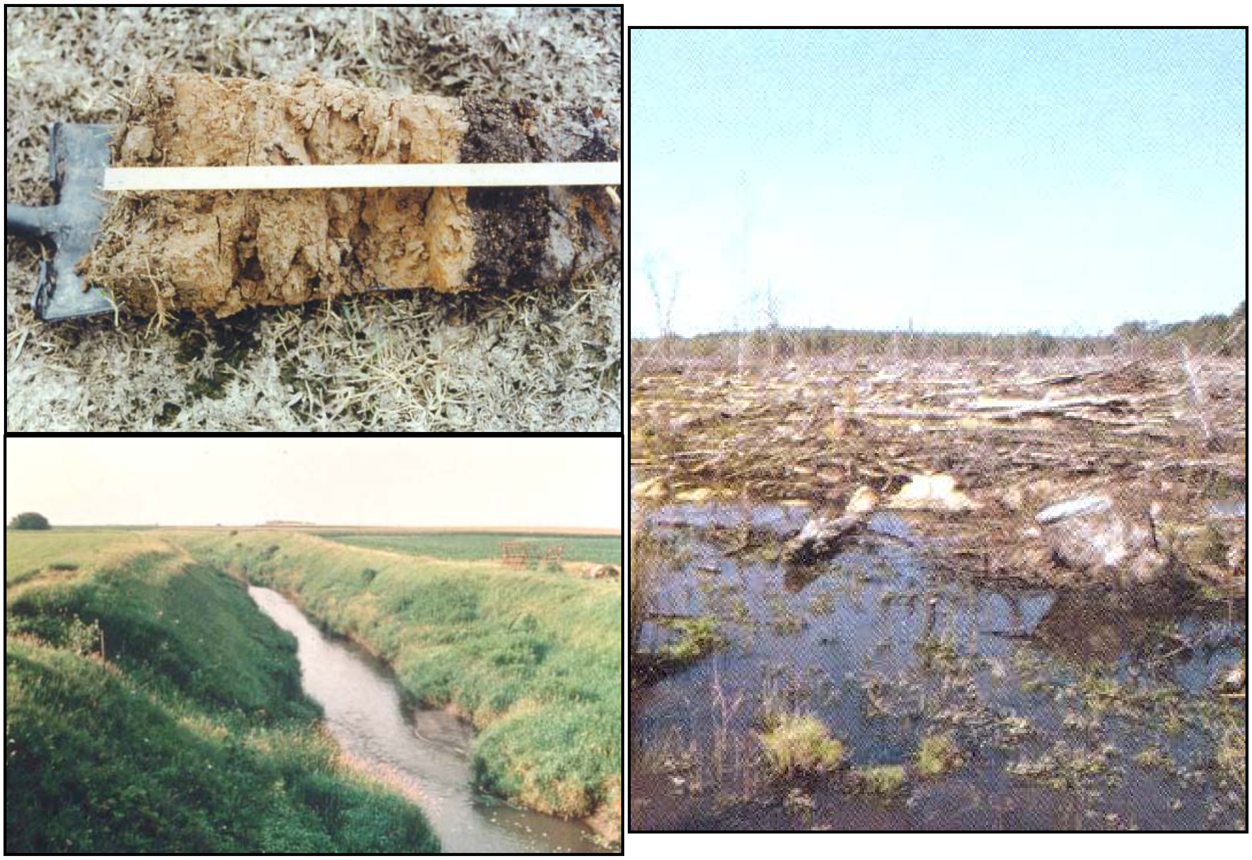

Figure 3. Sites with disturbance and alteration may require additional IRIS tube nests. This example displays (clockwise from top left): Soils with fill material, changes in vegetative communities, and large ditches that alter the movement of water across a landscape.

IRIS TUBE INSTALLATION AND REMOVAL: Prior to installation, data on site characteristics (e.g., soil description, landscape position, vegetation, land use and manipulation, etc.) should be recorded. Assign a unique identification number to each IRIS tube and write it on the top of the tube with an indelible marker. IRIS tubes should be wrapped in paper or other packing material to protect the tubes and prevent scratching of the iron paint during transport to the study area. Once at the site, unwrap the IRIS tubes and lay out each nest. IRIS tube nests should always include a minimum of five tubes and should be clustered together over an area less than 6 ft in diameter (Figures 1 and 4). Remove 12 in. of soil using a 1.25-in.-diam soil push probe. Install the IRIS tube directly into the hole, taking care to minimize scratching while ensuring complete contact with the surrounding soil. If the soil is dry, water can be used to aid in installation and help avoid scratching of the tube. In cases where restrictive soil layers are present, the tubes should be installed down to the restrictive layer and should not penetrate through the layer.

Figure 4. Plot layout and installation of IRIS tubes using a soil probe. Note the individual number given to each IRIS tube.

IRIS tubes should be installed at the beginning of the growing season and should remain in place during the normal wet part of the growing season that year. Growing season should be determined by vegetation green-up or soil temperature measurements. Due to regional variability in growing season and rainfall patterns, the installation and required residence time for IRIS tube studies also varies. Several useful resources for determining the timing and duration of the study can be found on the Internet. WETS tables developed by the USDA-NRCS National Water and Climate Center containing rainfall data can be found at *http://www.wcc.nrcs.usda.gov/climate/wetlands.html*. Also, Web WIMP is a resource that provides data concerning average water balances, air temperatures, and precipitation (*http://climate.geog.udel.edu/~wimp/*).

Additional information that should be recorded at the time of IRIS tube installation includes:

- Project name
- Source or manufacturer of the IRIS tubes and contact information
- Depth of installation
- Person(s) who installed the IRIS tubes and contact information
- Date of installation
- Detailed location, including GPS coordinates

IRIS tubes should be removed after seasonal high water tables have dropped or near the end of the growing season. When removing the IRIS tube, gently loosen the tube by moving it back and forth in the soil. Slowly pull the tube straight up, taking care not to scratch or abrade the PVC against the surrounding soil. In some cases, the IRIS tube may need to be dug out of the ground to avoid unintended removal of oxidized iron. In this case, a small soil pit (approximately 25 cm deep and 15 cm in diameter) is dug directly adjacent to the IRIS tube and the remaining soil is carefully removed, exposing the tube. The tube can then be easily removed. Once IRIS tubes have been removed from the soil, gently remove any soil adhering to the PVC surface. If soils are saturated and the tube is wet, gently dry the IRIS tube using a towel. IRIS tubes should then be wrapped in paper or other packing materials prior to transport; this will minimize scratching of the tube surfaces.

Figure 5. Removal of IRIS tubes (clockwise from top left) by gently pulling out of moist soil, digging out trench with shovel, gently rinsing off attached soil, and drying tubes prior to analysis.

Note: It is not recommended that tubes be placed back into the soil once they have been removed. To measure the "progress" of iron removal during the study period, install additional tubes that can be removed at intervals without disturbing the nest of five tubes. The nest of tubes that will be analyzed at the conclusion of the study should remain in the soil until the study period has ended.

ANALYSIS: Iron removal can be quantified using visual estimates or digital image analysis. For visual estimates, examine the surface of the IRIS tube, looking for regions where iron has been completely removed and the white PVC surface is clearly visible. Also, look for regions where the rusty red coloring of the iron oxide paint has significantly faded, revealing diffuse yellowish areas on the PVC surface (Figure 6). Estimate the percentage of the PVC surface where oxidized iron has been completely removed or significantly yellowed. The percentage guides found on pages 9 through 10 in the Munsell soil color book can be helpful in applying this technique (X-rite 2000). The use of a clear grid or dot paper may also aid in determining the amount of removal. Record the IRIS tube identification number and percentage removal.

More repeatable and defensible estimates of iron removal can be obtained using digital image analysis. IRIS tubes can be scanned three times, rotating the tube 120° between scans, and these images can be stitched together for further analysis. This method may result in distortion of the image and should be used with caution. Another option uses transparency paper to quantify iron removal. Wrap transparent film around the IRIS tube and using a permanent marker, outline and color in the areas where iron removal and/or significant yellowing have occurred. Remove the transparency, flatten and scan it. These images can be analyzed using a variety of software packages that are designed to quantify the areas that have been colored in (Figure 6). A number of software programs are available commercially and direct recommendations will not be given here. The percentage removal can then be calculated using the total area of PVC exposed to the soil. Record the IRIS tube identification number and percentage removal.

DATA INTERPRETATION: According to the NTCHS hydric soil TS, three out of the five IRIS tubes in a given nest must display 30 percent or more removal or significant yellowing in a zone 6 in. long to meet the criteria for anaerobic conditions. On the study site exhibiting normal rainfall during the study period, the highest landscape location where three of five IRIS tubes displayed 30 percent removal is considered to be the upper limit of reducing conditions.

FACTORS PREVENTING REDUCTION: Several soil conditions can prevent or retard the reduction process on IRIS tubes. These include high pH (>8), limited hydraulic conductivity, high salinity, cold temperatures, and limited organic matter content. Also, seasonal variability in precipitation, drought, landscape modification (filling, leveling, ditching, deep-ripping, etc.), and water table drawdown can occur, and care should be taken to ensure that study site conditions occur under normal climatic conditions.

CONCLUSIONS AND RECOMMENDATIONS: Any project designed to determine the anaerobic status of a soil requires planning, documentation, and careful analysis. Proper planning includes understanding the question that is being asked and designing the study accordingly. Important background information includes the landscape setting, wetland type (slope, fringe, etc.) being monitored, and other information discussed above. IRIS tubes should be labeled with a unique number and the location of placement should be recorded. The date of IRIS tube installation, removal, and on-site soil conditions should also be documented. Analysis should be completed using a systematic and repeatable process. It is also recommended that the IRIS tubes used in the study be saved for several years for documentation purposes and additional analysis as needed.

Figure 6. Typical iron removal patterns from IRIS tube study, and example of binary image analyzed for iron removal using digital analysis software (red color indicates areas of iron removal).

IRIS tubes represent a valuable tool for identification of anaerobic and reduced conditions in potential hydric soils. The proper use of IRIS tubes can aid in implementing the hydric soil TS on severely disturbed or problematic sites. They can aid in the identification of wetland boundaries and can help evaluate the success of wetland restoration or creation.

POINTS OF CONTACT: For additional information, contact Jacob Berkowitz, Environmental Laboratory, U.S. Army Engineer Research and Development Center, Vicksburg, MS (601-634-5218, *Jacob.F.Berkowitz@usace.army.mil*) or the Manager of the Wetlands Regulatory Assistance Program, Bob Lazor (601-634-2935, *Bob.L.Lazor@erdc.usace.army.mil*). This technical note should be cited as follows:

> Berkowitz, J. F. 2009. *Using IRIS tubes to monitor for reduced conditions in soils — project design.* WRAP Technical Notes Collection. ERDC TN-WRAP-09-1. U.S. Army Engineer Research and Development Center, Vicksburg, MS. *http://el.erdc.usace.army.mil/wrap/*

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