United States Department of Agriculture

Natural Resources Conservation Service

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Subject: SOI -- Electromagnetic Induction (EMI) Assistance **Date:** 30 November 2001

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Purpose:
The purpose of this investigation was to assess the use of EMI to delineate and characterize changes in soil and hydrologic properties within depressional wetlands on flatwoods.

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Activities:
All field activities were completed during the period of 5 to 8 November 2001.

Equipment:
The GEM300 sensor is manufactured by Geophysical Survey systems, Inc.[1] This sensor is configured to simultaneously measure up to 16 frequencies between 330 and 20,000 Hz with a fixed coil separation (1.3 m). Won and others (1996) have described the use and operation of this sensor. With the GEM300 sensor, penetration depth is considered "skin depth limited" rather than "geometry limited." The skin-depth represents the maximum depth of penetration and is frequency and soil dependent: low frequency signals travel farther through conductive mediums than high frequency signals. Theoretical penetration depths of the GEM300 sensor are dependent upon the bulk conductivity of the profiled earthen material(s) and the operating frequency (ies). Multifrequency sounding with the GEM300 has been marketed as allowing multiple depths to be profiled with one pass of the sensor.

[1] Trade names have been used for specific information. Their mention does not constitute endorsement.

To enhance data interpretations and results of this study, the SURFER for Windows (version 7.0) program, developed by Golden Software, Inc.,[1] was used to construct two- and three-dimensional simulations. These simulations improve the comprehensibility of the data. Grids were created using kriging methods with an octant search.

Conclusions:

1. In a prior EMI studies, apparent conductivity was used in semiarid environments to distinguish recharge, discharge, and flowthrough depressional wetlands (Doolittle, 2000) and to characterize soil and hydrologic properties within slope wetlands (Doolittle. 2001). This study focused on depressional wetlands that formed in sandy soils in humid areas and have low concentrations of soluble salts. Apparent conductivity measured with the GEM300 sensor was low and often negative in the three depressional wetlands that were surveyed. Low values were anticipated as soils were sandy, acidic and had low cation exchange capacities. Even with low values and ranges of apparent conductivity, plausible spatial patterns were evident on constructed plots of the three depressional wetlands. Though, results are unconfirmed, EMI appears to be a suitable tool for the rapid assessment and mapping of depressional wetlands formed in acidic, coarse-textured materials in humid areas.

2. The response of the GEM300 sensor was severely degraded by unexpected and exceptionally high levels of interference from cultural sources and sferics in the Kissimmee area of Florida. This interference degraded the accuracy of some measurements, and reduced the number of wetlands that could be investigated. This level of degradation is considered unique and is not universal in occurrence. However, the broad bandwidth and low strength of the GEM300's transmitted field makes this instrument vulnerable to external noise.

3. The ease of operation and the mobility of the GEM300 sensor were assets in wetlands that have dense undergrowth of palmettos and numerous fallen tree limbs, stumps, and debris. The GEM300 sensor is designed to be operated at hip-height and not on the ground surface. This is an advantage for surveying wetlands with ponded or flooded conditions.

4. Though results of this study are unconfirmed, EMI appears to be suited to characterizing spatial patterns within depressional wetlands. This method can provide in a relatively short time the large number of observations that are needed to comprehensively cover sites. Maps prepared from correctly interpreted EMI data provide the basis for assessing site conditions and for planning further investigations.

5. Geophysical interpretations are considered preliminary estimates of site conditions. The results of geophysical site investigations do not substitute for direct observations, but rather reduce their number, direct their placement, and supplement their interpretations. Interpretations contained in this report should be verified by ground-truth observations.

It was my pleasure to work with you and the Corps of Engineers on this project.

With kind regards,

James A. Doolittle
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Background:
The hydrogeomorphic (HGM) approach to wetland classification recognizes several classes of wetlands: riverine, depressional, tidal fringe, lacustrine fringe, slope, depressional, and mineral or organic soil flats (Smith et al., 1995). In this study, three mineral depressional wetlands on the flatwoods of south central Florida were surveyed. The depressions have low, concave relief and lack outlets. In general, soils that form in depressions on the flatwoods are very poorly drained, acidic, and have low cation exchange capacity (Watts et al. 2001). In addition, these soils are typically saturated or inundated with surface waters, and have low to medium water holding capacity (Watts et al., 2001). The water table is seasonally within depths of 15 to 45 cm, and after heavy rains may be ponded on the surface (Watts et al., 2001). During wet periods, water is slowly transmitted from flatwoods into depressions by subsurface and overland flow (Watts et al., 2001). During dry periods, flow is reversed and water is transmitted from the depressions to the flatwoods. The hydrodynamics of depressional wetlands is best characterized by the dominance of vertical fluctuations in water table. The principal sources of water in depressional wetlands are precipitation, groundwater discharge, and interflow from adjoining areas (Smith et al., 1995). Water is lost through evapotranspiration, saturation overland flow, and seepage to the groundwater. (Smith et al., 1995).

Three depressional wetlands located in south central Florida were selected for this study. These wetlands are referred to as the *Grass Wetland*, *Cypress Dome*, and *Created Wetland*. The objective of this study was to ascertain whether EMI could be used to identify and map changes in soil and/or hydrologic properties within depressional wetlands on the flatwoods of the Florida section of the Atlantic Coastal Plain.

EMI:
<u>Background:</u>
Electromagnetic induction is a noninvasive geophysical tool that is used for high intensity surveys and detailed site assessments. Advantages of EMI are its portability, speed of operation, flexible observation depths, and moderate resolution of subsurface features. Results of EMI surveys are interpretable in the field. This geophysical method can provide in a relatively short time the large number of observations that are needed to comprehensively cover sites. Maps prepared from correctly interpreted EMI data provide the basis for characterizing site conditions, planning further investigations, and locating sampling or monitoring sites.

Electromagnetic induction uses electromagnetic energy to measure the apparent conductivity of earthen materials. Apparent conductivity is a weighted, average conductivity measurement for a column of earthen materials to a specific observation depth (Greenhouse and Slaine, 1983). Electromagnetic induction measures vertical and lateral variations in apparent conductivity. Values of apparent conductivity are seldom diagnostic in themselves, but lateral and vertical variations in these measurements can be used to infer changes in soils and soil properties. Interpretations are based on the identification of spatial patterns within data sets. To assist interpretations, the spatial distributions of apparent conductivity are normally simulated in two- and three-dimensional plots.

Variations in apparent conductivity are caused by changes in the electrical conductivity of earthen materials. Electrical conductivity is influenced by the volumetric water content, phase of the soil water, temperature, type and concentration of ions in solution, and amount and type of clays in the soil matrix (McNeill, 1980). Apparent conductivity is principally a measure of the combined interaction of the soil's soluble salt content, clay content and mineralogy, and water content. The apparent conductivity of soils increases with increased soluble salts, clay, and water contents (Kachanoski et al., 1988; Rhoades et al., 1976). In any soil-landscape, variations in one or more of these factors may dominate the EMI response.

Apparent conductivity is affected by changes in the electrolyte concentration of the soil water and the soil water content (Johnston et al., 1997). For soils with low concentrations of dissolved electrolytes, such as the surveyed depressional wetlands of this study, changes in apparent conductivity have been associated with changes in water content (Kachanoski et al., 1988, 1990; Sheets and Hendrickx, 1995). At low soil moisture contents, EMI is relatively insensitive to changes in soil-water content. However, at high soil moisture contents, and in the absence of significant changes in soluble salt or clay contents, EMI is more sensitive to changes in soil moisture (Hanson, 1997).

The presence of exchangeable cations on clay surfaces contributes to the total electrical conductivity of soils. Depending on the type and amount of clays present, the number of exchangeable cations available to conduction when an electrical field is applied will vary. If the soil water conductivity is low, the high conductivity near some clay surfaces can dominate the overall conductance (Greenhouse et al., 1998). Clays also contribute to the water-holding capacity of soils and, therefore, influences the soil water content. Soils surveyed in this investigation are sandy with low cation exchange capacities.

The soils of the three depressional wetlands surveyed in this investigation have low concentrations of soluble salts. In a study conducted at the Brandy Ranch Research Site in Montana (Doolittle, 2000), the sensitivity of EMI to variations in the amount of soluble salts in soil profiles were used to distinguish recharge, flowthrough, and discharge depressional wetlands. Recharge, flowthrough, and discharge wetlands had low, intermediate and high apparent conductivity, respectively. In areas of saline or salt-affected soils, 65 to 70 percent of the variance in apparent conductivity can be explained by changes in the concentration of soluble salts alone (Williams and Baker, 1982). Moderate to high correlations have been found between apparent conductivity and soil salinity (de Jong et al., 1979; Williams and Baker, 1982; and Wollenhaupt et al., 1986

Noise:
The broad bandwidth and low strength of the transmitted field makes the GEM300 sensor vulnerable to external noise. Where the signal from the earth can be isolated from the transmitted field (as the quadrature component is isolated by phase) the noise level is inversely proportional to the strength of the transmitted field. The GEM300 sensor has a broadband transmitter that operates over a range of frequencies. As a consequence, the GEM300 sensor is typically about 10-times less efficient than meters that have a transmitter tuned to a specific frequency.

Non-static electric fields of EMI instruments are linked to the broadband magnetic noise in the atmosphere (sferics) that originates from sun spot activities, thunderstorms, etc. The GEM300 sensor is susceptible to “burps” when a sferic contains an unusually large amount of energy that is centered on one of the operating frequency.

High levels of external noise from cultural sources were observed during this study. Abnormal problems were noted communicating over short distances with both cell phones and CB units. Many instruments incorporate internal shielding to nullify these electric field, although the sophistication and effectiveness of the shielding seems to vary significantly among instruments. The GEM300 sensor is highly susceptible to this noise. Frequently, measurements would fluctuate by as much as 100 mS/m over a single point in a matter of seconds. This was unacceptable and the number of surveys completed was reduced because of unreliable data.

Depths of Penetration and Observation:
The theoretical penetration depth of the GEM300 sensor is dependent upon the bulk conductivity of the profiled earthen material(s) and the operating frequency of the sensor. Penetration depths are governed by the “skin-depth” effect (Won, 1980 and 1983). Skin-depth is the maximum depth of penetration for an EMI sensor operating at a particular frequency and sounding a medium with a known conductivity. Penetration depth or “skin-depth” is inversely proportional to frequency (Won et al., 1996). Low frequency signals can travel farther through mediums than high frequency signal. In some soils, decreasing the frequency will extend the observation depth. At a given frequency, the depth of penetration is greater in low conductivity than in high conductivity soils.

The “skin depth” is estimated using the following formula (McNeill, 1996):

$$D = 500/(s*f)^{-2} \quad [1]$$

Where D is the skin depth, s is the ground conductivity (mS/m), and f is the frequency (kHz).

Within a defined skin depth, earthen materials from all depths contribute, in varying degrees, to the measured response. With increasing depth, the relative contribution from various depth layers passes through a maximum and then decreases with increasing depth. While the induced magnetic fields may achieve these estimated skin depths, the response strengths diminish with increasing depth and, at lower soil depths, are too weak to be sensed with the GEM300 sensor. The *depth of observation* may be defined as the depth that contributes the most to the total EMI response. Although contributions to the measured response come from all depths, the contribution from the *depth of observation* is the largest (Roy and Apparao, 1971). As noted by Roy and Apparao (1971), for any system, the depth of observation is a good deal shallower than is generally assumed or reported.

In this study, the high correlation among apparent conductivity measurements obtained with the GEM300 sensor at different frequencies suggests that the response is from similar observation depths. Multifrequency soundings with the GEM300 sensor in either one of the two dipole orientations produced similar spatial patterns. However, spatial patterns resulting from measurements obtained in the two dipole orientations were more dissimilar. As patterns from multifrequency sounding in the same dipole orientation are similar, it is assumed that the depth of observation is also comparable. In this study, interpretations were neither changed nor improved with multifrequency soundings. For most soil investigations with the GEM300 sensor, the use of one frequency with measurements in both dipole orientations will provide as much information as multifrequency soundings.

Survey Area:
All fieldwork was conducted within the Nature Conservancy's Disney Wilderness Preserve in southern Osceola and northern Polk counties. The preserve was established in 1992 through the cooperative actions of The Walt Disney Company, Greater Orlando Aviation Authority, The Nature Conservancy and several public agencies.

Three sites were surveyed with EMI within the Preserve. The *Grass Wetland* site is located in the northern half of Section 9, Township 28 South and Range 29 East. This shallow depression is covered with grasses. The depression is in an area that has been mapped as Smyrna and Myakka fine sands (Ford et al., 1990). The very deep, poorly drained Smyrna and Myakka soils formed in sandy marine sediments on flatwoods. Smyrna and Myakka soils are members of the sandy, siliceous, hyperthermic Aeric Haplaquods family. A 100 by 100 m grid was set up across this depression. The grid interval was 10 m. Survey flags were inserted in the ground at each grid intersection and served as observation points. This procedure provided 121 observation points.

The *Cypress Dome* site is also located in the northern half of Section 9, Township 28 South and Range 29 East. This depression is dominated by baldcrpress (Taxodium distichum) and is inundated with surface water. This depression has been mapped as Basinger mucky fine sand, depressional (Ford et al., 1990). The very deep, very poorly drained Basinger soil formed in sandy marine sediments on flatwoods. Basinger soil is a member of the siliceous, hyperthermic Spodic Psammaquent family. A 180 by 180 m grid was set up across this depression. The grid interval was 20 m. Survey flags were inserted in the ground at each grid intersection and served as observation points. This procedure provided 100 observation points.

The *Created Wetland* site is located in the northeast quarter of Section 19, Township 27 South and Range 29 East. This depression is covered with grasses, sedges, and rushes. The central core of this depression is inundated with surface water. This created wetland is in an area that has been mapped as Smyrna fine sands (Ford et al., 1990). A 100 by 160 m grid was set up across this depression. The grid interval was 20 m. Survey flags were inserted in the ground at each grid intersection and served as observation points. This procedure provided 54 observation points.

Field Procedures:
Measurements were taken at each observation point with the GEM300 sensor held at hip-height in both the horizontal and vertical dipole orientations. In-phase, quadrature phase, and conductivity data were recorded with the GEM300 sensor at three different frequencies (6030, 9450, and 14790 Hz) at each observation point. While in-phase and quadrature data were recorded and stored on disc, these values are neither shown nor discussed in this report.

At all sites, a large number of negative measurements were recorded with the GEM300 sensor. Negative values reflect, in part, the resistive nature of the soils and the calibration of the GEM300 sensor. In many EMI studies, negative conductivity values are removed by electronic nulling of the data set. The negative offset was not taken out of the EMI data. As a consequence, negative values appear in the data set and simulated plots. As spatial patterns and relative values of apparent conductivity are important to interpretations, these negative values are not a cause for any concerns.

Results:
Grass Wetland:
Table 1 summarizes the results of this EMI survey. Apparent conductivity was very low and essentially invariable across this wetland. In general, apparent conductivity was slightly lower in the deeper-sensing vertical dipole orientation than in the shallower-sensing horizontal dipole orientation. In addition, apparent conductivity increased with increasing frequency and presumably decreasing penetration depth. One half of the observations are between the first and third quartiles. As shown in Table 1, the inter-quartile range reflects the extremely low conductivity of the soil. The standard deviation and the inter-quartile range are within the commonly accepted measurement error (1 to 2 mS/m) of this device.

Table 2 summarizes the correlations among measurements obtained at different frequencies and dipole orientations within the *Grass Wetland*. All correlations were moderately high and significant at the 0.001 level. However, correlations were lower within this depression than within the other two investigated depressions. The lower correlation within the *Grass Wetland* site is attributed to the composition, depth and arrangement of soil horizons, the response of the GEM300 sensor to these horizons, and variations in the observation depths with different frequencies.

Table 1
Grass Wetland
Basic Statistics
Apparent Conductivity
(All values are in mS/m)

	6030V	**6030H**	**9450V**	**9450H**	**14790V**	**14790H**
Average	-2.1	1.3	-2.3	-1.1	-0.7	-0.7
Minimum	-5.0	-0.7	-4.6	-2.9	-4.5	-2.9
Maximum	0.1	3.0	-0.1	1.3	1.4	1.1
First	-2.8	0.7	-3.1	-1.7	-1.4	-1.2
Third	-1.5	2.0	-1.6	-0.6	0.1	-0.2
SD	1.0	0.8	1.0	0.8	1.0	0.9

Table 2.
Grass Wetland
Pearson Product-Moment Correlation Coefficients

	6030V	6030H	9450V	9450H	14790V	14790H
6030V	1.000	0.656	0.822	0.707	0.783	0.635
6030H		1.000	0.675	0.740	0.716	0.677
9450V			1.000	0.751	0.842	0.738
9450H				1.000	0.769	0.741
14790V					1.000	0.769
14790H						1.000

Figure 1 contains two-dimensional plots showing the spatial distribution of apparent conductivity collected with the GEM300 sensor. In each plot, the isoline interval is 2 mS/m. The approximate location of the wetland boundary is delineated with a red segmented line in each plot. The locations of the 121 observation points are shown in the upper left-hand plot.

In Figure 1, the upper row of plots represent data collected in the horizontal dipole orientation. The lower row of plots represent data collected in the vertical dipole orientation. Plots are arranged in columns by frequency. The plot of data collected in the horizontal dipole orientation and at a frequency of 14790 Hz (see upper left-hand plot) represents the shallowest depth of penetration. The plot of data collected in the vertical dipole orientation and at a frequency of 6030 Hz (see lower right-hand plot) represents the deepest depth of penetration. In general, depths of penetration increase from left to right, and from the top to bottom row. Spatial patterns are remarkable similar in these plots. This wetland is characterized by low and invariable apparent conductivity. In each plot the northern and central portions of the depressional wetland have slightly higher apparent conductivity. This weak zone of low, but slightly higher apparent conductivity appears to extend from the center of the depressional wetland into the northwest corner of the grid site, which is located on the flatwoods.

Cypress Dome:
Table 3 summarizes the results of this EMI survey. Apparent conductivity increased variable with increasing penetration depth. Apparent conductivity was slightly higher and more variable in the deeper-sensing vertical dipole orientation than in the shallower-sensing horizontal dipole orientation. However, apparent conductivity increased with increasing frequency and presumably decreasing penetration depth. This seemingly contradictory trend may reflect increasing field strength or amplitude with increasing frequency. One half of the observations are between the first and third quartiles. As shown in Table 3, the inter-quartile range reflects the extremely low conductivity of the soil. Compared with the *Grass Wetland*, apparent conductivity within the *Cypress Dome* was more variable, suggesting more contrasting soil materials.

Table 4 summarizes the correlations among measurements obtained at different frequencies and dipole orientations within the *Cypress Dome* Wetland. All correlations were very high and significant at the 0.001 level. The high correlations suggest that similar observation depths were achieved using different dipole orientations and operating frequencies. The close association of these measures may reflect the presence of a more conductive layer at shallow to moderately deep soil depths. Some cypress domes have argillic horizons that occur at shallower depths than in adjoining flatwoods soils.

Table 3
Cypress Dome
Basic Statistics
Apparent Conductivity
(All values are in mS/m)

	6030V	6030H	9810V	9810H	14790V	14790H
Average	-1.1	-2.6	-0.5	-3.7	4.1	0.4
Minimum	-8.5	-6.7	-7.4	-7.9	-2.6	-4.0
Maximum	14.1	9.1	15.2	7.7	19.2	11.6
First	-3.8	-4.3	-3.6	-5.6	1	-1.4
Third	0.9	-1.5	1.3	-2.4	6.1	1.4
SD	4.5	2.7	4.5	2.7	4.7	2.8

Table 4
Cypress Dome
Pearson Product-Moment Correlation Coefficients

	6030V	6030H	9450V	9450H	14790V	14790H
6030V	1.000	0.938	0.981	0.920	0.977	0.833
6030H		1.000	0.909	0.970	0.889	0.940
9450V			1.000	0.896	0.987	0.857
9450H				1.000	0.877	0.934
14790V					1.000	0.839
14790H						1.000

Figure 2 contains two-dimensional plots showing the spatial distribution of apparent conductivity collected with the GEM300 sensor. In each plot, the isoline interval is 2 mS/m. The approximate location of the wetland boundary is delineated with a red segmented line in each plot. The locations of the 100 observation points are shown in the upper left-hand plot.

In Figure 2, the left-hand column of plots represent data collected in the horizontal dipole orientation. The right-hand column of plots represents data collected in the vertical dipole orientation. Plots are arranged in rows by frequency, decreasing in frequency from top to bottom. The plot of data collected in the horizontal dipole orientation and at a frequency of 14790 Hz (see upper left-hand plot) represents the shallowest depth of penetration. The plot of data collected in the vertical dipole orientation and at a frequency of 6030 Hz (see lower right-hand plot) represents the deepest depth of penetration. In general, depths of penetration increase from top to bottom and from the left to right row.

The spatial patterns are remarkable similar in these plots. The wetland boundary closely approximates an area of higher conductivity. Within the wetland, comparatively large variations in apparent conductivity suggest variable soils or soil properties. The apparent conductivity of the surrounding flatwoods soils is lower than within the depression.

In Figure 2, values of apparent conductivity are higher within the wetland boundary. As conductivity increases with moisture content, ponded conditions could produce the higher EMI responses within the wetland. The depth of water was measured at six observation points within the wetland and compared with EMI response. Depths of water ranged from 3 to 12 inches. A negative correlation (r =- 0.72; 0.09 level) was obtained between depth of water and EMI response. Within the wetland, areas having greater depths to water generally have lower EMI responses. The higher values of apparent conductivity within the *Cypress Dome* can not be attributed to moisture contents. Though unconfirmed, it was assumed that the dome might be underlain at comparatively shallower depths by strata of finer textured materials.

Created Wetland:

Table 5 summarizes the results of this EMI survey. In general, apparent conductivity was higher and more variable in the deeper sensing vertical dipole orientation than in the horizontal dipole orientation. However, in both dipole orientations, apparent conductivity varied with frequency and presumably penetration depths. One half of the observations are between the first and third quartiles. As shown in Table 3, the inter-quartile range reflects the negative to low conductivity of the disturbed soil. Compared with the *Grass Wetland* and the *Cypress Dome*, apparent conductivity was higher and more variable within the *Created Wetland*.

Table 5
Created Wetland
Basic Statistics
Apparent Conductivity
(All values are in mS/m)

	6030V	6030H	9810V	9810H	14790V	14790H
Average	3.0	-0.6	2.6	-2.5	6.8	1.2
Minimum	-11.8	-18.9	-14.3	-19.7	-13.7	-21.8
Maximum	19.6	8.8	19.9	7.5	24.8	12.6
First	-3.7	-3.5	-4.1	-4.9	0.2	-1.9
Third	10.1	3.1	9.9	1.2	14.5	6.6
SD	8.5	5.4	8.9	6.2	9.5	7.2

Table 6 summarizes the correlations among measurements obtained at different frequencies and dipole orientations within the *Created Wetland*. All correlations were high and significant at the 0.001 level. The similarity is assumed to reflect similar depth responses for the different frequencies and similar observation depths.

Table 6
Created Wetland
Pearson Product-Moment Correlation Coefficients

	6030V	6030H	9450V	9450H	14790V	14790H
6030V	1	0.789	0.995	0.817	0.986	0.83
6030H		1	0.805	0.969	0.806	0.937
9450V			1	0.842	0.996	0.859
9450H				1	0.854	0.981
14790V					1	0.879
14790H						1

Figure 3 contains two-dimensional plots showing the spatial distribution of apparent conductivity collected with the GEM300 sensor. In each plot, the isoline interval is 2 mS/m. The approximate location of the wetland boundary is delineated with a red segmented line in each plot. The locations of the 54 observation points are shown in the upper left-hand plot.

In Figure 3, the left-hand column of plots represent data collected in the horizontal dipole orientation. The right-hand column of plots represents data collected in the vertical dipole orientation. The plot of data collected in the horizontal dipole orientation and at a frequency of 14790 Hz (see upper left-hand plot) represents the shallowest depth of penetration. The plot of data collected in the vertical dipole orientation and at a frequency of 6030 Hz (see lower right-hand plot) represents the deepest depth of penetration. In general, depths of penetration increase from left to right, and from the top to bottom row. Once again, the plots are remarkable similar suggesting that the GEM300 sensor is measuring similar columns of earthen materials at different operating frequencies and coil orientations.

The plots of the *Created Wetland* are distinctly different from those of the *Grass Wetland* and *Cypress Dome*. In plots of the *Grass Wetland* and *Cypress Dome*, apparent conductivity increased towards the central core of these wetland. In the *Created Wetland*, a zone of lower apparent conductivity traverses the eastern portion from north to south. This could reflect the presence of drains or other cultural features related to the construction of this wetland. Values of apparent conductivity increase towards the southwestern corner of the wetland and into the surrounding flatwoods. Base on apparent conductivity measurements obtained on flatwoods soil that adjoin the *Grass Wetland* and *Cypress Dome*, values obtained on the flatwoods soils that surround the western side of the *Created Wetland* are conspicuously high. This is noteworthy as the mapped soils are similar.

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