United States Department of Agriculture | **Natural Resources Conservation Service** | **5 Radnor Corporate Center, Suite 200 Radnor, PA 19087-4585**

Subject: Archaeology -- Geophysical Assistance -- **Date:** 14 October 1998

To: Joseph D. Bartlett
Tippecanoe County Historical Association
Wetherill Resource Center and Administration
1001 South Street
Lafayette, IN 47901

PURPOSE:
To assist the Tippecanoe County Historical Association assess the site of Fort Quiatenon.

PARTICIPANTS:
Karen Bergman, Archaeologist, Indiana Division of Historic Preservation, Indianapolis, IN
Jim Doolittle, Research Soil Scientist, USDA-NRCS, Radnor, PA
Byron Jenkinson, Research Assistant, Purdue U., Lafayette, IN
Mark Nearing, USDA-ARS, National Erosion Research Laboratory, West Lafayette, IN

ACTIVITIES:
All field activities were completed on 6 October 1998.

EQUIPMENT:
The requested geophysical tool, ground-penetrating radar, became inoperable during field operations the preceding day. This was an unfortunate development as the soils were electrically resistive and presumably well suited to GPR. A survey was performed using electromagnetic induction (EMI). However, the meter was difficult to calibrated, measurements tended to drift during operation, and the liquid crystal display often froze. The meter has subsequently been returned to the manufacturer for repairs.

The electromagnetic induction meter was the EM38 manufactured by Geonics Limited.[1] This meter is portable and requires only one person to operate. McNeill (1986) has described principles of operation. No ground contact is required with this meter. This meter provides limited vertical resolution and depth information. Lateral resolution is approximately equal to the intercoil spacing. The EM38 meter operates at a frequency of 14,600 Hz. It has theoretical observation depths of about 0.75 and 1.5 meters in the horizontal and vertical dipole orientations, respectively (McNeill, 1986). Values of apparent conductivity are expressed in milliSiemens per meter (mS/m).

The position of all observation points was obtained with a Rockwell Precision Lightweight GPS Receiver (PLGR)[1]. The receiver was operated in the continuous mode using an external power source (portable 9-volt battery). The Universal Transverse Mercator (UTM) coordinate system was used.

To help summarize the results of this study, the SURFER for Windows software program developed by Golden Software Inc. was used to construct two-dimensional simulations.[1] Grids were created using kriging methods. In the enclosed plots, shading and filled contour lines have been used. These options were selected to help emphasize spatial patterns. Other than showing trends and patterns in values of apparent conductivity (i.e., zones of higher or lower electrical conductivity), no significance should be attached to the shades themselves.

BACKGROUND:
Fort Quiatenon was a French fort and settlement located along the Wabash River near West Lafayette, Indiana.

[1] Trade names have been used to provide specific information. Their use does not constitute endorsement.

The site represents a significant eighteenth century historical site. Indiana University and Michigan State University have conducted archaeological fieldwork at this site. However, in spite of these efforts, a large portion of the site remained unexplored. This study was conducted in conjunction with a wet-soil monitoring project being conducted at Purdue University.

FIELD PROCEDURES:

An inexact 225 by 275-foot, rectangular grid was laid out across the site. The grid interval was about 25 feet. Survey flags were inserted in the ground at each grid intersection and served as observation points. This procedure resulted in 120 observation points. At each observation point, measurements were taken with an EM38 meter placed on the ground surface in both the horizontal and vertical dipole orientations.

ELECTROMAGNETIC INDUCTION (EMI):

Background:

Electromagnetic induction techniques use 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 theoretical observation depth. Variations in apparent conductivity are produced by changes in the electrical conductivity of earthen materials. The electrical conductivity is influenced by the volumetric water content, type and concentration of ions in solution, temperature and phase of the soil water, and amount and type of clays in the soil matrix, (McNeill, 1980). The apparent conductivity of soils increases with increases in the amount of soluble salts, water, and/or clays.

Electromagnetic induction (EMI) has been used to locate and define archaeological features (Bevan, 1983; Frohlich and Lancaster, 1986; and Dalan, 1991). Studies have demonstrated the utility of EMI for locating, identifying, and determine the boundaries of various types of cultural features such as buried structures, tombs, filled fortification ditches, and earthen mounds. Advantages of EMI methods include speed of operation and moderate resolution of subsurface features. Results of EMI surveys are interpretable in the field. This technique can provide in a relatively short time the large number of observations needed for site characterization and assessments. Maps prepared from correctly interpreted apparent conductivity data provide a basis for assessing site conditions and for planning further investigations.

Values of apparent conductivity are seldom diagnostic in themselves, but variations in these measurements have used to infer the locations of buried cultural features. Interpretations of EMI data are based on the identification of spatial patterns within data sets. The location, orientation, size, and shape of patterns revealed on two-dimensional plots often provide clues as to the cultural features producing them.

The detection of buried cultural features is affected by the electromagnetic gradient existing between the buried cultural feature and the soil. The greater or more abrupt the difference in electrical properties between the buried cultural feature and the surrounding soil matrix, the more likely the artifact will be detected. Buried cultural features with electrical properties similar to the surrounding soil matrix are often difficult to discern.

Results:

Basic statistics for the EMI data collected within the study site are displayed in Table 1. These statistics characterize the site as being underlain by comparatively resistive materials with low electrical conductivity. In general, values of apparent conductivity were low and decreased slightly with increasing observation depths. One-half of the observations had values of apparent conductivity between 4.4 and 8.6 mS/m in the shallower-sensing (0 to 30 inches), horizontal dipole orientation. In the deeper-sensing (0 to 60 inches), vertical dipole orientation, one-half of the observations had values of apparent conductivity between 3.2 and 8.4 mS/m. The vertical trend was attributed to slightly higher clay, organic matter, and moisture contents in the upper part of the soil profile.

Figure 1 contains two-dimensional plots of data collected with the EM38 meter in the horizontal (left-hand plot) and vertical (right-hand plot) dipole orientations. In Figure 1, the left-hand plot represents the spatial distribution of apparent conductivity within the upper 30 inches of the soil profile. The right-hand plot represents the spatial distribution of apparent conductivity within the upper 60 inches of the soil profile. In each plot, the isoline interval is 3 mS/m.

Values of apparent conductivity were low within the site. Apparent conductivity averaged 7.34 mS/m and 6.23 mS/m in the horizontal and vertical dipole orientations, respectively. In general, apparent conductivity is comparatively high along the north and south border while it is low in the central portion of the site. This spatial pattern conforms to the topography and reflects changes in soil types and properties. The central portion of the site, is a slightly higher-lying, convex surface that is underlain at shallower depths by electrically resistive coarse-textured materials. Along the north and south margins of the site, soils are lower lying, more poorly drained, and contain more clay.

Table 1
Basic Statistics
EMI Survey
Brady Study Site
(All values are in mS/m)

Meter	Orientation	Minimum	Maximum	Quartiles 1st	Quartiles 3rd	Average	Standard Deviation
EM38	Horizontal	0.0	25.9	4.4	8.6	7.34	4.82
EM38	Vertical	1.5	23.2	3.2	8.4	6.23	4.45

In the plots shown in Figure 1, spatial patterns principally reflect gradual changes in soil types and properties. Surprisingly, no anomalously high or low (negative value) measurements were recorded. Such anomalous values could indicate the presence of a buried metallic, cultural feature. Considering the relative coarse grid interval used, it is probable that, if present, many of these cultural features would be overlooked. However, with 120 observation, it seems strange that, if present, no buried metallic artifact was detected.

Figure 2 contains two-dimensional image maps of data collected with the EM38 meter in the horizontal (left-hand plot) and vertical (right-hand plot) dipole orientations. In Figure 2, the left-hand plot represents the spatial distribution of apparent conductivity within the upper 30 inches of the soil profile. The right-hand plot represents the spatial distribution of apparent conductivity within the upper 60 inches of the soil profile. In each plot, colors are associated with percentage values that have been aggregated to produce a smooth color gradation across each map. The percentage values are in relation to the minimum and maximum values shown in Table 1.

In the central portion of the left-hand plot, spatial patterns appear to be rectangular (therefore artificial) and could represent the outline of Fort Quiatenon. Three inter-connected structure can be visualized or fantasized. These patterns could represent debris from an occupational event scattered in the surface layers. In the central portion of the right-hand plot, a rectangular (therefore artificial) pattern of very low (less than 3 mS/m) could represent a more deeply buried cultural feature.

Conclusions:

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

2. Although the EM38 meter was acting fitfully, recorded spatial patterns (see Figure 2) appear to reflect cultural features.

3. With the concurrence of the State Conservationist, I would like to complete a GPR survey of the site on my next scheduled visit to the wet-soil monitoring project in Jasper County, Indiana.

With kind regards,

James A. Doolittle
Research Soil Scientist

cc:

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References

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The following is a list of data recorded at the site on 6 October 1998.

Waypoint	Easting	Northing	EM38H	EM38V	INPHASE	ELEVATION
WP001	501640	4472768	7.6	8.4	21.8	519.0
WP002	501632	4472768	10.6	8.4	28.7	519.8
WP003	501624	4472768	10.4	9.0	25.3	518.8
WP004	501616	4472768	11.8	8.6	25.6	519.0
WP005	501609	4472768	12.5	8.9	26.5	519.3
WP006	501601	4472769	10.1	10.6	25.8	519.3
WP007	501593	4472769	10.8	10.5	2.7	520.0
WP008	501586	4472770	13.0	9.0	32.8	519.6
WP009	501578	4472770	10.5	10.2	26.3	518.1
WP010	501570	4472770	11.0	9.9	25.2	518.7
WP011	501571	4472762	12.2	10.1	26.0	520.4
WP012	501579	4472762	10.3	9.0	28.2	520.8
WP013	501587	4472762	11.2	7.1	33.5	519.5
WP014	501594	4472762	10.5	3.8	35.5	521.0
WP015	501602	4472762	10.5	8.9	30.9	520.2
WP016	501610	4472762	9.9	9.4	27.9	520.0
WP017	501617	4472761	8.6	9.4	22.8	520.4
WP018	501625	4472761	9.1	8.2	24.2	520.2
WP019	501633	4472761	8.2	9.3	26.3	519.5
WP020	501640	4472761	7.8	9.4	22.8	519.9
WP021	501639	4472753	7.9	9.9	20.4	521.3
WP022	501631	4472753	9.1	8.1	25.8	521.5
WP023	501624	4472753	5.9	9.5	24.2	519.3
WP024	501616	4472753	7.3	8.3	26.8	519.5
WP025	501609	4472754	7.5	7.9	26.2	519.0
WP026	501601	4472754	7.5	7.8	29.1	519.8
WP027	501593	4472754	6.2	7.1	28.7	521.1
WP028	501583	4472755	5.4	4.0	30.4	514.0
WP029	501576	4472755	5.0	5.6	27.8	512.9
WP030	501568	4472755	6.8	6.8	25.9	515.0
WP031	501569	4472747	5.8	6.3	25.4	514.9
WP032	501577	4472747	5.6	4.6	28.6	514.7
WP033	501585	4472747	6.2	2.2	35.3	514.4
WP034	501592	4472747	6.8	3.5	32.9	514.1
WP035	501600	4472746	3.8	5.7	31.1	514.1
WP036	501608	4472746	0.8	4.8	26.8	513.9
WP037	501615	4472746	1.2	3.0	28.5	514.3
WP038	501623	4472746	2.8	5.1	24.4	517.1
WP039	501630	4472746	2.8	5.8	20.6	514.5
WP040	501638	4472745	2.4	6.0	20.3	515.5
WP041	501637	4472738	4.2	5.1	22.6	518.0
WP042	501629	4472738	1.8	4.2	24.4	516.9
WP043	501621	4472738	3.6	5.0	23.8	514.2
WP044	501613	4472738	5.1	3.2	27.7	516.7
WP045	501606	4472739	4.4	4.0	31.9	516.7
WP046	501598	4472739	5.2	4.6	28.9	516.5
WP047	501591	4472739	3.9	4.3	28.4	516.7
WP048	501583	4472739	5.4	5.0	25.4	515.7

Waypoint	Easting	Northing	EM38H	EM38V	INPHASE	ELEVATION
WP049	501576	4472739	4.0	4.6	25.6	516.0
WP050	501568	4472740	3.7	5.3	24.3	513.8
WP051	501569	4472731	7.8	2.1	24.9	517.9
WP052	501577	4472731	3.9	3.8	25.5	516.4
WP053	501584	4472731	4.4	3.7	29.8	517.9
WP054	501592	4472731	4.2	2.9	29.3	517.2
WP055	501600	4472731	9.9	3.7	29.9	517.7
WP056	501607	4472731	7.3	2.5	34.7	517.4
WP057	501615	4472731	6.9	1.9	32.6	516.7
WP058	501623	4472731	6.2	2.8	25.6	516.4
WP059	501630	4472730	6.6	3.3	28.2	516.4
WP060	501638	4472730	6.6	2.7	23.2	516.8
WP061	501637	4472722	6.0	3.6	23.9	516.4
WP062	501629	4472723	4.2	3.6	25.2	515.1
WP063	501621	4472723	4.4	2.9	26.4	515.9
WP064	501614	4472723	3.8	1.6	30.1	516.7
WP065	501606	4472723	4.9	3.2	27.4	518.8
WP066	501598	4472723	6.6	1.8	31.0	519.0
WP067	501591	4472723	5.2	2.3	27.0	518.5
WP068	501583	4472723	4.2	2.3	30.1	517.5
WP069	501576	4472724	0.0	2.2	27.7	516.5
WP070	501568	4472724	3.4	3.7	23.7	517.8
WP071	501569	4472716	3.4	2.3	24.4	518.9
WP072	501576	4472716	2.5	2.2	26.8	519.7
WP073	501584	4472716	1.9	3.3	28.2	519.5
WP074	501592	4472716	4.4	2.1	28.8	520.0
WP075	501599	4472716	3.3	1.5	28.6	519.2
WP076	501607	4472715	4.9	2.0	32.8	519.7
WP077	501615	4472715	4.8	1.5	28.1	518.9
WP078	501622	4472715	4.6	1.8	25.4	518.2
WP079	501630	4472715	3.9	2.2	26.7	518.6
WP080	501637	4472714	4.2	3.1	23.8	519.6
WP081	501636	4472707	4.6	3.7	21.9	518.5
WP082	501628	4472707	4.6	3.6	26.6	517.5
WP083	501620	4472708	4.4	3.3	25.0	516.4
WP084	501613	4472708	4.9	2.0	26.7	516.7
WP085	501605	4472708	4.9	2.0	27.2	517.5
WP086	501598	4472708	4.5	3.1	26.2	517.0
WP087	501590	4472708	5.2	1.8	27.2	517.2
WP088	501583	4472709	5.0	3.0	24.6	516.8
WP089	501575	4472709	4.8	3.5	24.8	517.5
WP090	501567	4472709	5.6	3.2	23.3	516.5
WP091	501568	4472701	5.9	4.4	24.5	517.1
WP092	501576	4472701	6.4	5.8	23.6	515.6
WP093	501583	4472701	4.4	4.2	23.9	517.2
WP094	501591	4472701	5.7	3.4	29.8	518.2
WP095	501599	4472701	5.3	4.6	26.6	518.5
WP096	501606	4472701	5.1	3.2	24.9	514.8
WP097	501614	4472701	5.2	3.2	27.1	516.4

Waypoint	Easting	Northing	EM38H	EM38V	INPHASE	ELEVATION
WP098	501621	4472700	4.6	4.0	25.6	513.2
WP099	501628	4472700	5.4	4.0	26.6	511.9
WP100	501636	4472700	4.9	4.8	24.1	512.9
WP101	501635	4472692	9.4	9.5	18.2	514.2
WP102	501627	4472692	9.4	10.1	18.5	511.5
WP103	501619	4472693	8.2	8.7	22.8	511.0
WP104	501612	4472693	8.2	7.8	23.2	512.3
WP105	501604	4472693	7.9	7.4	24.9	511.3
WP106	501600	4472692	7.2	7.5	25.0	520.4
WP107	501590	4472693	6.6	6.1	26.9	516.5
WP108	501582	4472694	7.5	5.9	20.2	515.4
WP109	501573	4472694	6.5	6.6	18.8	509.1
WP110	501566	4472694	5.2	6.1	22.7	511.0
WP111	501567	4472686	13.6	11.6	18.7	512.8
WP112	501576	4472686	17.3	14.2	16.4	513.9
WP113	501584	4472686	16.2	15.5	13.6	515.2
WP114	501589	4472686	17.8	14.1	15.9	505.6
WP115	501601	4472686	19.6	14.9	16.7	521.6
WP116	501606	4472686	22.2	17.8	18.6	512.8
WP117	501613	4472686	22.1	22.8	14.1	509.1
WP118	501620	4472685	24.8	21.2	12.7	510.1
WP119	501628	4472685	25.9	21.6	11.6	510.6
WP120	501635	4472685	24.2	23.2	8.3	509.8