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

Subject: Electromagnetic Induction (EMI) Field Assistance; Awbury Arboretum, Philadelphia

Date: 23 November 1998

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Purpose:
The purpose of this study was to conduct an EMI survey of the Victorian Garden adjacent to the Cope House, Awbury Arboretum, Germantown, Pennsylvania. Natural Resource Conservation Service is providing assistance to the Arboretum as part of the Philadelphia Urban Resource Partnership program.

Participating Agencies:
Awbury Arboretum Association
Natural Resource Conservation Service

Participants:
John Chibirka, Soil Scientist, USDA-NRCS, Leesport, PA
Jim Doolittle, Research Soil Scientist, USDA-NRCS, Radnor, PA
Elbert Wells, Project Leader, USDA-NRCS, West Chester, PA

Activities:
All field activities were on 12 November 1998.

Equipment:
The electromagnetic induction meter used in this study 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).

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 each of the enclosed plots, shading has been used 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.

Field Procedures:
An irregular shaped, 85 by 55-foot, rectangular grid was laid out across a portion of the Victorian garden site. The grid interval was 5 feet. Survey flags were inserted in the ground at each grid intersection and served as

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

observation point. This procedure resulted in 206 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):

Electromagnetic induction (EMI) is a noninvasive geophysical tool that 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.

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 of soils 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.

In this study, EMI was used to measure lateral variations in apparent electrical conductivity. Values of apparent conductivity are seldom diagnostic in themselves, but variations in these measurements can be used to infer the locations of buried cultural features. Interpretations of the 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 provide clues as to the features causing 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.

The size, orientation, and depth to a buried cultural feature affect interpretations. Large objects are easier to detect than small objects. Small cultural features may be detectable at shallow depths. However, these features are generally undetectable where deeply buried. The presence of scattering bodies in the soil complicates interpretations. Strongly stratified soil horizons, stones and cobbles, roots, animal burrows, modern cultural features or recently disturbed soils produce unwanted noise that can mask the presence of some buried cultural features.

Results:

Figures 1 and 2 represent the spatial distribution of apparent conductivity within the upper 0.75 and 1.5 meters, respectively. The isoline interval is 1 mS/m. In each plot, the locations of the gravel walkway, enclosed oval-shaped, grassed area and monument have been shown.

In Figures 1, two lines of relatively high (> 12 mS/m) apparent conductivity linear intersect near the lower left-hand boundary of the surveyed site. These linear features are believed to represent buried utility or pipelines. In Figure 1 and 2, several areas of negative conductivity have been labeled "A." For earthen materials, negative conductivity is physically unattainable. Negative values often result from non-linear electromagnetic coupling in the profiled materials. Negative values represent the normalized conductivity relative to the background conductivity. Though pragmatically unattainable, the imaging of these values is useful as it provides information as to the location of anomalous features. The features labeled "A" represent shallowly buried anomalous objects.

The utility or buried pipe lines, manifested as distinct linear features in the imaged horizontal dipole data, are obscure in the vertical dipole orientation data (see Figure 2). In Figures 2, these lines appear as a series of points (labeled "A") spaced at intervals of about 10 feet. Many of the imaged points have negative conductivity. Within the "grassed area" clustered arrangements of point anomalies define three rectangular areas (enclosed in segmented lines).

The complexity and arrangement of spatial patterns within the "grassed area" suggest disturbance. With more insight into the design of the former garden, these patterns may provide clues identifying specific features.

Summary:

The electromagnetic induction survey of the former Victorian garden site disclosed the location of buried utility lines and several point anomalies. Spatial patterns evident in the enclosed plots indicate disturbance and the probable occurrence other features. Some of these features may relate to the former garden. It is hoped that these enclosed plots will provide archaeologist and planners with insight into the location of features within the former Victorian garden.

It was my pleasure to work with and to be of assistance to members of your fine staff.

With kind regards,

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Research Soil Scientist

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