AN ABSTRACT OF THE THESIS OF

Elizabeth Rae Wilson – Agin for the Master of Science degree

in Earth Science presented on December 10, 2003.

Title:

The Use of Geophysical and Remote Sensing Technology to Locate and Delineate Unmarked Graves in Clay-Rich Soils of Kansas.

Abstract approved: ______________________
(Dr. Richard Sleezer, Thesis Advisor)

Maplewood Memorial Lawn Cemetery in Emporia, Kansas, contains a tract of land documented as containing approximately 705 unmarked graves. In 1870, this area was set aside as "Potter's Field" and used for burials of the underprivileged and minorities. Thesis research was carried out to determine the feasibility of locating unmarked graves in Potter's Field using geophysical and remote sensing technology. Positive identification of burials with an electromagnetic ground conductivity meter and kite aerial photography has provided evidence that both techniques can be successful in locating and delineating unmarked graves in clay-rich soils of Kansas. Research with the electromagnetic ground conductivity meter determined that extremely dry conditions and too wet soil moisture conditions were not favorable for the identification of anomalous values of geophysical data. It appeared that the electromagnetic ground conductivity meter required moderate soil moisture conditions for successful results for the location and delineation of unmarked graves. Geophysical field work was complemented with the use of a penetrometer which reinforced the conclusion that moderate soil moisture conditions were best for the location and delineation of unmarked graves. Different

sessions of kite aerial photography revealed that late spring was better than early spring for the identification of patterned vegetative differences associated with possible graves. Furthermore, kite aerial photography detected vegetative differences outside of the study area contributing to a possible explanation for the location of numerous unmarked graves. Future research is necessary to determine how specific soil moisture conditions affect electromagnetic conductivity, however successful results may currently allow preservation and protection of unmarked graves.

THE USE OF GEOPHYSICAL AND REMOTE SENSING TECHNOLOGY TO LOCATE AND DELINEATE UNMARKED GRAVES IN CLAY-RICH SOILS OF KANSAS.

A Thesis

Presented to

The Department of Physical Sciences

EMPORIA STATE UNIVERSITY

In Partial Fulfillment

Of the Requirements for the Degree

Master of Science

By

Elizabeth Rae Wilson-Agin

December 2003

DeWayne Backhus

Approval by the Department Chair
Dr. DeWayne Backhus

Richard Sleezer

Thesis Advisor
Dr. Richard Sleezer

James Aber

Committee Member
Dr. James Aber

Nathaniel Eugene Terrell

Committee Member
Dr. Nathaniel Terrell

Robert Grover

Dean of Graduate Studies and Research
Dr. Robert Grover

ACKNOWLEDGEMENTS

I wish to extend a sincere and gracious appreciation to my thesis advisor, Dr. Richard Sleezer for committing his extended amounts of time, wisdom, and guidance in this research project. My gratitude is also extended to committee member, Dr. James Aber, who has contributed his time and expertise in kite aerial photography sessions significant to the goals of this research and to the enhancement of this thesis. I would also like to acknowledge committee member, Dr. Nathaniel Terrell for his enthusiastic encouragement and contributions to making this thesis a finer piece of work.

Other significant acknowledgements include the Kansas State Historical Society for encouraging me to pursue unmarked grave research, Maplewood Memorial Lawn Cemetery for their wonderful cooperation, enthusiasm, and support, and the Physical Sciences Department for their support in my research objectives and academic goals. Finally, I wish to extend my appreciation to Mrs. Betty Boylan and the Graduate Studies and Research Department for playing a large role in funding my research.

These individuals must be acknowledged for their contribution to my life, my academic career, and my dreams. The most important are my parents, Larry and Betty Wilson for instilling in me the value of life, never-ending encouragement to follow my dreams, and unconditional love. My genuine love is extended to my husband Clay, my sister Jaclyn, and my brother Stephen whose admiration, love, and support inspire me everyday. My sincere appreciation and love is also extended to the rest of my terrific family, my true friends, and to all of my fellow earth science students who have given their friendship and support.

In closing, I present this thesis in memory of my loving grandmother; Aletha Belle Frost (Nana).

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

CHAPTER 1

INTRODUCTION

Importance of Unmarked Grave Location and Delineation

Unmarked cemeteries and graves may pose a serious problem for land development. All over the world, unmarked cemeteries are discovered in construction crew efforts to begin excavations for buildings, roads, highways, and bridges. For example, in Lisbon, Spain, archaeologists recently recovered a 4,000-year-old tomb, revealed by excavators who were opening a new road (News 24, 2003). In northeast England, graves dating between the 7th and 9th Centuries were discovered beneath a school playground when the site was inspected to build an extension for the school (BBC News, 2003). In Phoenix, Arizona, archaeologists repatriated human remains to the descendants of the ancient Hohokam culture from what was to be a major subdivision of 760 houses (AZ Central, 2003). In Emporia, Kansas, an unmarked cemetery holds back plans for future land development (K. Cope, pers. comm., 2003).

The dilemma of unmarked cemeteries and graves is not limited to urban development, but includes the request for plot space in known, but old cemeteries. Individuals and families requesting plots in old cemeteries encounter the same problem as urban development: unmarked graves. According to Maplewood Memorial Lawn Cemetery (K. Cope, pers. comm., 2002) in Emporia, Kansas, the ground can be probed to delineate the location of an unmarked grave. However, an old enough grave may have already deteriorated to the point of non-detection. Furthermore, it is often a time consuming procedure if no plot map is available for reference. Thus, an individual or family's request for plot space may be refused.

These unfortunate circumstances underline the need for rapid and accurate methods to locate and delineate the unmarked gravesites. If a construction crew accidentally stumbles upon an unmarked grave or encounters unmarked graves and disturbs them unknowingly, the situation may have been completely avoided had they been located using non-invasive techniques prior to excavation. Within cemeteries, an unmarked grave may be detected with non-invasive, time efficient methods, even when the graves have reached a point of near complete deterioration.

Applications of Different Methodology

There are a number of geophysical methods that have been applied with varying success to non-invasive exploration (Conyers and Goodman, 1997). Two of the most common geophysical methods are electromagnetic induction and ground penetrating radar. Determining which of these methods is most likely to yield successful results in locating and delineating unmarked cemeteries and graves depends on a number of different factors. For example, ground-penetrating radar may be successful at locating subsurface features in sandy soils, but unsuccessful in clay-rich soils which attenuate radar energy (Conyers and Goodman, 1997). However, the identification of subsurface features in clay-rich soils may be successful with electromagnetic conductivity if soils are not too wet or too salty.

Electromagnetic induction and ground-penetrating radar have been employed in a number of different circumstances within forensic science and archaeology to determine these geophysical instruments' feasibility in locating buried features in various settings and soil conditions. Recent studies in forensic science may be especially noteworthy in the research of locating and delineating unmarked graves. Research into the geophysical response of known buried features under known soil parameters may assist in the comparison to research where the conditions of buried features are unknown.

For example, on a geophysical research site located on the Highlands Ranch Law Enforcement Training Facility in Douglas County, Colorado, pig carcasses are buried to simulate human remains in different soil conditions at different stages of decay. In a geophysical study, it was determined that electromagnetic conductivity surveys were more useful than magnetometry, a survey sensitive to iron bearing materials for locating such burials (France et al., 1992). On the research site surveys, ground conductivity decreased over graves, due to the increased porosity of the backfill materials. This geophysical method ignores the presence of the actual burial as a location indicator and focuses on soil bulk density, increasing the feasibility of detecting the grave shaft rather than the actual remains.

Another potential method for locating and delineating unmarked graves is ground-penetrating radar (GPR). GPR uses radar pulses, which reflect off buried features to provide three-dimensional images of buried features. On the Japanese Island of Kyushu, GPR revealed intact burials dating to A.D. 300-700. Although surface soils in this area of Japan are well developed, their clay contents are relatively low and the underlying parent material is comprised of prehistoric largely unweathered ash (Conyers and Goodman, 1997). According to Bevan (1983), GPR is limited to a shallow profiling depth in some soils, in particular those with high clay content. GPR was, therefore, highly successful locating burials at the Kyushu site because of the clay-poor matrix.

It is essential to understand the limitations of each geophysical instrument that may be used for any given setting. Although geophysical methods have proved to be successful for identifying buried features in the above circumstances, geophysical surveying is not 100 percent successful, for almost any landscape has a unique set of physical characteristics that may adversely affect the successful use of a given technique.

Methods for locating and delineating unmarked cemeteries and graves are not limited to geophysical technology. Another possibility is remote sensing using a variety of different sensors. While satellite imagery and various forms of aerial photography provide moderate resolution of the Earth's surface they may not be successful at locating unmarked cemeteries and graves because they do not have sufficient resolution to detect the adult size graves of approximately 2.1 x .9 meters (7 x 3 feet). Kite aerial photography is a low-cost and time-efficient method for acquiring high resolution photographs to accomplish these goals (Aber et al. 2002). Where the target for investigation is small surface features, such as vegetative patterns from unmarked graves, kite aerial photographs have a pixel resolution of 5 – 10 cm, which provides a more detailed observation of these small surface objects.

CHAPTER 2

SITE SELECTION

This study focused on soils in Lyon County. Lyon County soils are characteristic of most other soils in Kansas with silt loam, silty clay loam, silty clay, and clay loam textures being dominant (Neill, 1981). With the exception of Kansas' sand dune regions, the thick and clayey soils common in Kansas impede radar transmission limiting the success of ground penetrating radar GPR (Conyers and Goodman, 1997). On the other hand, if GPR were used to delineate unmarked graves in sand dune regions in Kansas the given technique may be highly successful. Thus, to successfully locate and delineate unmarked graves in Lyon County's clayey soils, the use of another geophysical tool must be considered. Research was conducted to determine the feasibility of locating and delineating unmarked graves with geophysical and remote sensing methods in clay-rich soils. The question to be answered was: which methods would be most successful in delineating unmarked burials and what factors would influence the feasibility of detecting these features?

I selected Maplewood Memorial Lawn Cemetery in Emporia, Kansas, to conduct research on locating and delineating unmarked graves with non-invasive geophysical and remote sensing technology. The study area is located within the city limits of Emporia in the southwest corner of section 4, Township 19 South, Range 11 East (Fig. 1), in Lyon County in east-central Kansas. The site occupies an area of approximately 2,000 square meters on the northeast side of Maplewood Memorial Lawn Cemetery. Maplewood Memorial Lawn Cemetery was an ideal research site for three primary reasons. First, the cemetery includes a tract of land with approximately 705 unmarked graves. From 1871 to 1928, poor and minority individuals were interred in a segregated part of Maplewood Cemetery referred to as Potter's Field. Secondly, Potter's Field includes a small number of marked graves, contemporaneous with the unmarked graves that can be used to field check results. Anomalous features associated with known graves served as test cases for the more numerous unmarked graves. Finally, the location of the study site relative to Emporia State University's resources and cooperation of cemetery officials made research quite convenient.

Lyon County. Emporia, Kansas

Potter's Field, Maplewood Memorial Lawn Cemetery
SW 1/4 of Section 4, in T 19 S, Range 11 E

Figure 1. Research Site. Potter's Field of Maplewood Memorial Lawn Cemetery. Lyon County, Emporia, Kansas.

CHAPTER 3

METHODS

3.1 Historical Methods

Potter's Field burials were marked with numbered wooden stakes from 1871-1928 and few had headstones (M. Rodenbeck, pers. comm., 2002). Although historical documentation has yet to be found, it is believed that a prairie fire swept through Potter's Field in the 1920s. The fire would have burnt the wooden stakes, leaving the graves without headstones unmarked. Maplewood Cemetery was sold to the Memorial Lawn Association in 1928, which is the year Potter's Field burials ceased. Given the absence of wooden stakes marking numerous burials, it is likely that new ownership decided against additional burials in this region. For more than 80 years now, this vicinity has remained vacant, allowing time for vegetative growth, soil development, surface erosion, and grave deterioration. Although a plot map did exist (Fig. 2), Potter's Field burial records did not indicate burials according to the plot numbers of the map, thus locating and delineating graves in this area is challenging.

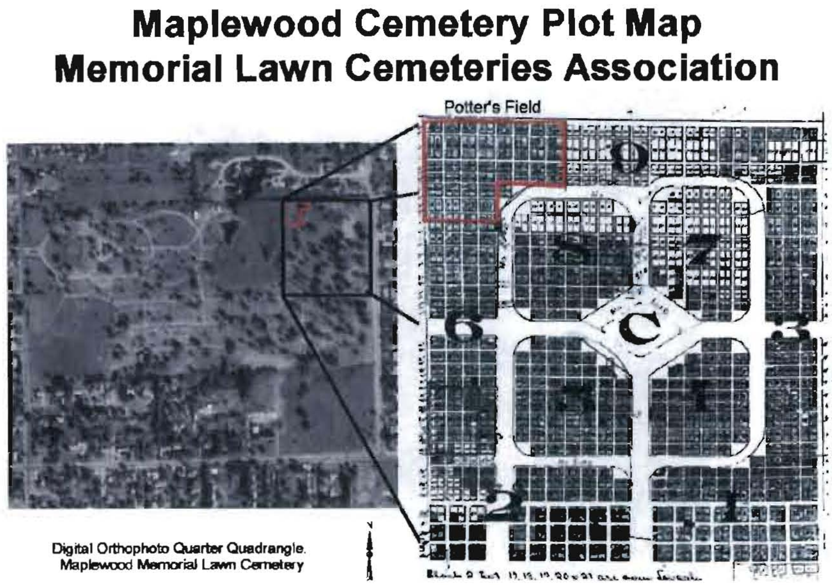

Figure 2. Potter's Field Plot Map. Memorial Lawn Cemeteries Association (Maplewood Memorial Lawn Cemetery, 2002).

However, one can infer from customary Christian burial practices that interments would have been placed in rowed, east/west orientation (Matthew, 1978; Smoot, 2002). The predictability of Euro-American burial tradition lends itself to this kind of conclusion and can simplify this type of investigation. North/south burials associated with criminals may also exist amongst the traditional Christian burials. Given this was an area designated for burials which were probably paid by the town, it is likely criminals were also buried in Potter's Field.

Original burial records of Potter's Field also contributed to the geophysical and remote sensing investigation. Archived at the Lyon County Historical Society in Emporia, Kansas, burial records include the deceased name, interment number, date interred into Potter's Field, and stake number (Fig. 3).

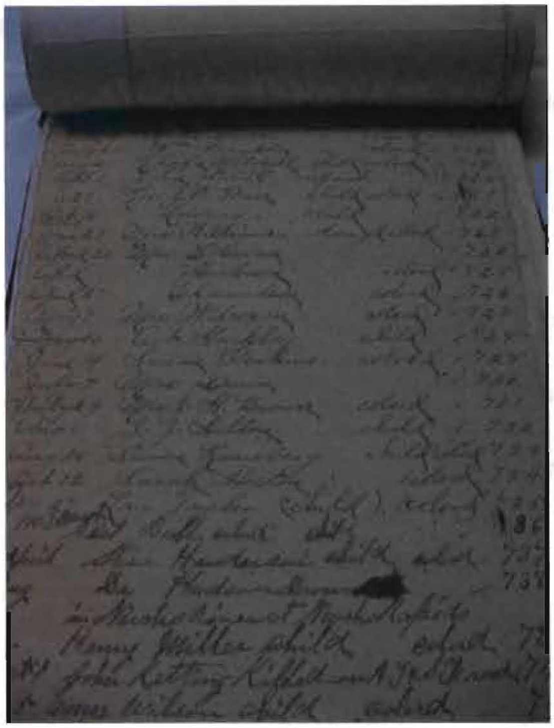

Figure 3. Original Potter's Field Burial Records (Lyon County Historical Society).

Some records provide miscellaneous information such as disinterment date, child versus adult burials, and ethnicity. Burial records along with obituaries have been a valuable resource in understanding Potter's Field history. In the analyses of geophysical and remote sensing data for locating and delineating unmarked graves, burial records and obituaries have also provided some useful information. For example:

> Laurent Blanc, a shoemaker, being short of work at his trade, went to work on the M.K. and T. railroad on Tuesday, and yesterday, just after dinner, complained of feeling unwell, sat down and soon after laid down on the track. Near five o'clock, his fellow workmen saw a train approaching and called to him to move. As he did not get up, one of them

> went up to him and found him insensible. They put him on a car and brought him to town, but he died before he reached home. He resided on south Commercial Street, just below the Commercial Hotel. He was a Frenchman, came to this country about eighteen months ago. We understand that he has something near two thousand dollars, but he lived very penuriously, and his wife wanted his body nailed up in a rough box and taken to the cemetery with just as little expense as possible. He had not been accustomed to out-door work and his death was caused, no doubt, by the intense heat (Emporia Ledger, 1878).

Laurent Blanc is an example of a marked burial in Potter's Field and his headstone is only one of the 26 found in Potter's Field. Based on the information provided in the obituary, it is likely his wife was able to afford a marker, but for whatever reason, did not want to purchase a plot or elaborate coffin. The reason why most individuals of Potter's Field did not have a headstone and other burials did have headstones is likely the availability of funds to purchase one. Obituaries provide resourceful facts, which aid in reconstructing the history associated with burials of Potter's Field. For example, documentation that Mr. Blanc was "nailed up in a rough box" may indicate the burial method of other graves in Potter's Field. For our discussion, the burial in a simple box and a date provides some context for age and method of burial to be compared with geophysical and remote sensing results. Burial method was considered while analyzing geophysical data in questioning the likelihood of a non-deteriorated, still intact grave. While original documentation of Potter's Field burials indicated some burials in wooden boxes, other records suggested that in some cases no box was used at all. Forensic studies, such as those conducted on the Highlands Ranch Law Enforcement Training Facility, may help to determine if decreased apparent conductivity values are indicative of an intact, non-deteriorated grave or if depressions on the surface point toward a collapsed grave. These studies may also assist in the identification and dating of a grave where no wooden box was used.

As some obituaries and burial records reveal potential burial methods and historical information, other records reveal information on disinterments. Disinterments are essential to note while evaluating geophysical and remote sensing data because, like remaining graves, they do cause soil disturbances. However, without proper and careful identification, a disinterment could be mistaken for an unmarked grave.

> Died of typhoid fever Sunday afternoon, October 12th and 3 o'clock, W.E. Riggs at the residence of J.W. Thatcher. Mr. Riggs was a young man who has been in the employ of Thatcher and Payne for only a few weeks. He has no relatives here. His mother, who lives in New York State, had been sent for, but did not arrive before her son's death (Emporia Weekly News, 1879).

Mr. Riggs was disinterred from Potter's Field shortly after he was buried in 1879 and placed in another section of Maplewood Cemetery. Records exist for nine other individuals like Mr. Riggs, disinterred from Potter's Field, two of which were babies. These individual's names, original stake number, interment and disinterment date are included on the list of Potter's Field burials in addition to the 705 unmarked graves.

> Maggie, an eight year old daughter of J.B. Gordon died of Scarlet fever last Monday and was buried that evening at 5 o'clock from the family residence. This is the second child whom Mr. Gordon has lost within a week from the disease (Emporia Weekly News, 1882).

Potter's Field burial records and obituaries are definite signs of the time. Diseases, such as typhoid fever, Bright's disease, scarlet fever, and smallpox afflicted these individuals. Without vaccinations and medical technology, chances of survival were reduced for the young and old. This is evidenced throughout burial records, which indicate 309 children: nearly half of the Potter's Field graves. Noting the numerous child graves becomes important in analyzing geophysical data. First, children's graves are likely to be smaller than adult size graves. Therefore, looking for small, discrete anomalous features becomes a significant factor in the attempt to locate and delineate unmarked graves. Second, some burial records reference a child's burial at the foot of an adult. Other records document that some children shared stake numbers, possibly signifying their burial on top of the other or sharing an adult size plot. Such documentations led to considering the possibility of anomalous features appearing shallower than adult graves or two small anomalies in the same plot space. Finally, if a child's grave is near complete deterioration, it may be more difficult to identify than an adult size grave because the grave shaft disturbance will be smaller in size. I speculated that adult size graves may, therefore, be more discernable than the significant number of child graves.

It was clear that obituaries and burial records gave indications of burial material, disinterment, and size of grave, directly influencing anomalous readings. Although no burial was referenced to the plot map, headstones were cross-referenced with 16 stake numbers to attempt to decipher any possible burial pattern with time. If a burial pattern could be identified, it may be possible to determine the number of graves between headstones as a field check for geophysical and remote sensing results.

3.2 FIELD METHODS

Soil properties of Lyon County and Kansas climatic conditions were considered in the decision to use an electromagnetic conductivity meter, a penetrometer, and kite aerial photography to locate and delineate unmarked burials in Emporia, Kansas. Based on similar research of the delineation of unmarked graves (France et al., 1992; Bevan, 1983; Trinkley, 1999) and evaluation of equipment limitations (McNeill, 1980; Cook and Walker, 1992; Ellwood, 1990) it was determined that these methods were most likely be successful for identifying unmarked graves.

Potter's Field Soil Morphology

Clay and chert content were important soil factors for determining which geophysical method would most likely be successful for locating and delineating the unmarked graves in Potter's Field. For instance, typical graves are excavated to a depth of at approximately 1.5 meters (150 cm) below the surface (M. Rodenbeck, pers. comm., 2002). One imperative parameter for choosing a technique was the soil properties at the site. Different geophysical techniques will be more effective in soils with different clay and chert gravel content to this depth.

The soils in Potter's Field are mapped as the Olpe-Kenoma Complex (Neill, 1981). The Olpe-Kenoma Complex is 50 – 70 percent Olpe soil, which is a clayeyskeletal, smectitic, thermic Typic Paluedoll. It is also 30 – 50 percent Kenoma soil, which is a fine, smectitic, thermic Vertic Arguidoll. Areas of the two soils are so intricately mixed that it would not be possible to delineate each for Potter's Field at the scale that the Lyon County Soil Survey was originally mapped.

Topsoil in Olpe soils are typically described as gravelly silt loam (Neill, 1981). The upper part of the subsoil is described as firm gravelly silty clay loam, and it extends approximately 70 cm to the lower part of the subsoil which is mottled and extremely firm gravelly silty clay. Permeability is slow, runoff is rapid, and available water capacity is high in Olpe soils.

Topsoil in Kenoma soils is typically described as silt loam (Neill, 1981). The upper subsoil is described as mottled, very firm silty clay, and extends to the lower part of the subsoil which is also mottled, very firm silty clay. Permeability is very slow in Kenoma soils as well with a high available water capacity.

To gain a more detailed understanding of the soils present in Potter's Field, Table 1a contains the soil morphology for Olpe Soils and Table 1b contains the soil morphology for Kenoma Soils. It was evident that both Olpe and Kenoma soils were clay rich with significant amounts of chert gravel in the Olpe Series.

Horizon	Depth (cm)	%Clay (Texture)	% Chert Gravel	Color (Moist)
A1	0 – 20.32	0 – 20 (Silt Loam)	Few pebbles	Very dark grayish brown
A2	20.32 – 33.02	30 – 40 (Silty Clay Loam)	10	Dark brown
BA	33.02 – 48.26	30 – 40 (Silty Clay Loam)	50	Dark brown
Bt1	48.26 – 63.50	40 – 60 (Silty Clay)	80	Dark brown
Bt2	63.50 – 91.44	40 – 60 (Silty Clay)	80	Reddish brown
Bt3	91.44 – 137.16	40 – 60 (Silty Clay)	45	Reddish brown
2Bt	137.16 – 152.40	40 – 60 (Silty Clay)	-	Yellowish brown

Table 1a. Soil Morphology of Olpe Soil Series (Neill, 1981).

Horizon	Depth (cm)	%Clay (Texture)	Color (Moist)
A	0 – 17.78	0 – 20 (Silt Loam)	Very dark grayish brown
Bt1	17.78 – 27.94	40 – 60 (Silty Clay)	Very dark grayish brown
Bt2	27.94 – 43.18	40 – 60 (Silty Clay)	Dark brown
Bt3	43.18 – 66.04	40 – 60 (Silty Clay)	Brown
BC	66.04 – 96.52	40 – 60 (Silty Clay)	Dark yellowish brown
C1	96.52 – 142.24	40 – 60 (Silty Clay)	Brown
C2	142.24 – 152.40	30 – 40 (Silty Clay Loam)	Mottled reddish brown

Table 1b. Soil Morphology of Kenoma Soil Series (Neill, 1981).

As stated previously, GPR is limited to a shallow profiling depth in some soils; in particular, those with high clay content (Bevan, 1983). In Tables 1a and 1b, the highlighted rows indicate the general depth of a burial, which corresponds with soil horizons containing high clay content that would be incompatible with GPR. In contrast, Bevan (1983) concluded that clay-rich soils present no difficultly for electromagnetic surveys. Thus, in the effort to delineate unmarked graves in Potter's Field which has clayey soils (Neill, 1981), GPR would not be the optimal choice of instrumentation. Magnetometry is sensitive to iron bearing materials and it may have been successful in identifying remnants of metal from caskets, nails, or clothes. However, burials of this time period were often in wooden caskets, if a casket was used at all. The unknown quantity and depth of nails may also be difficult to resolve. Furthermore, it is likely that any nails are nothing more than a trace of rust due to clay soil moisture of the over many years. Thus, it was likely that magnetometry would also be unsuccessful in locating and delineating unmarked graves of Potter's Field. Additionally, France et al., (1992), determined that electromagnetic surveys were more successful than magnetometry in locating graves as conductivity decreased over graves due to the increased porosity of backfill materials.

While it seems likely that an electromagnetic ground conductivity meter was the optimal choice of instrumentation, it was important to understand electromagnetic response to the significant amount of chert gravel present in Olpe soils. According to the Geonics Technical Note of the Electrical Conductivity of Soils and Rocks (1980), rock material allows increased circulation of groundwater. Essentially, the presence of chert gravel and the resulting large pores that drain quickly, *unsaturated* soil conditions should generate lower electromagnetic response than might be expected if the chert gravel was not present. In a *saturated* soil that contains a large amount of chert gravel, the electromagnetic conductivity should increase dramatically as soil water is generally conductive.

On the other hand, heavy rainfall should *saturate* both the disturbed and non-disturbed soils such that conductivity differences are diminished, perhaps masking the identifying features which may have been a lower conductive response under *unsaturated* soil conditions. Also, Olpe and Kenoma soil characteristics affecting conductivity will vary with depth. Such characteristics include the number, size, and shape of pores; the extent to which the pores are filled with water, the soil's compaction, clay content and chert gravel content.

Geonics Limited EM-38 Electromagnetic Ground Conductivity Meter

I chose to utilize an electromagnetic ground conductivity meter (EM-38) designed by Geonics Limited, Mississauga, Canada and borrowed from the Natural Resources Conservation Service (NRCS) to conduct a geophysical survey at Potter's Field (Fig. 4). The EM-38 weighs 2.5 kg (5.5 lbs) and operates using a 9-volt battery power source to measures a depth-weighted average of the earth's electrical conductivity (Clay 2003; McNeill, 1980). The EM-38 contains a coil at both ends of the 1-meter-long instrument. The transmitter coil, at one end of the EM-38, generates an electric current, which creates a primary electromagnetic field. The electromagnetic field causes electrical current to flow through underlying soil, inducing a secondary electromagnetic field sensed by the receiver coil at the other end of the EM-38 (Bevan, 1983). The strength of the electromagnetic field measured at the receiver indicates the depth weighted average of conductivity of the soil in the upper 0.75 to 1.5 meters of the soil (Cook and Walker, 1992). Referred to as the apparent conductivity, it is measured in units of milliSiemens per meter (mS/m). A Siemen is a measurement of a material's conductance. Expressing the value in milliSiemens per meter (mS/meter) removes the volume from the equation—just as a material's density is independent of its volume.

The meter's depth response is a function of its fixed intercoil spacing of 1 meter and its dipole orientation. In a vertical dipole configuration, as shown in Figure 4, electrical current transmission is dominantly through the upper 1.5 meters of the soil.

Figure 4. Geonics Limited Electromagnetic Ground Conductivity Meter (EM-38)

In this position, the instrument is most sensitive to soil conductivity at depth 0.25 – 1.25 meters (Fig. 5). When the instrument is laid on its side in a horizontal dipole position, the meter is more sensitive to near surface features down to a depth of approximately 75 cm below the surface (McNeill, 1980).

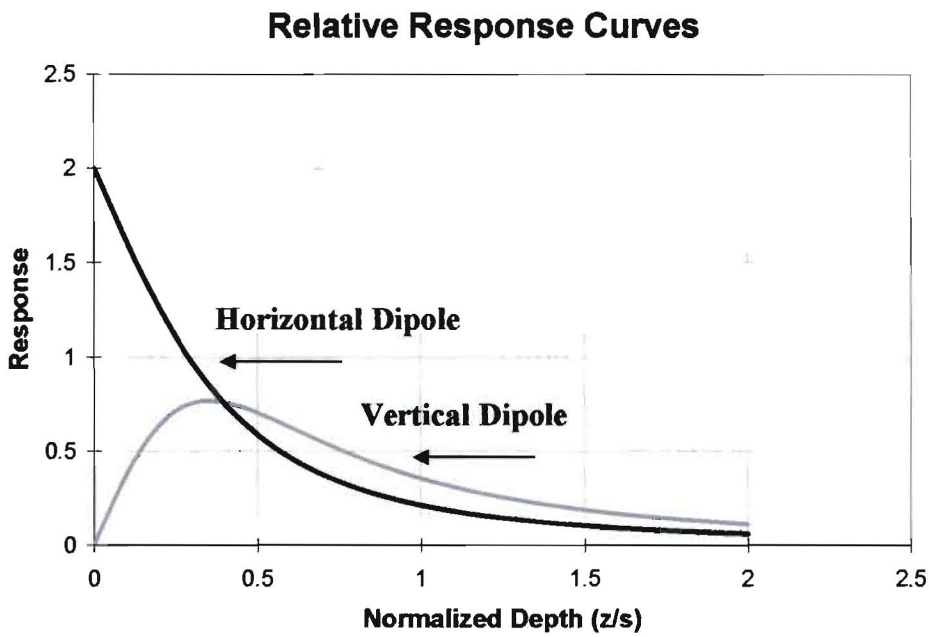

Figure 5. Depth response curves of the EM-38 in the horizontal and vertical dipole positions (Geonics, 2002).

Because different soils and buried features have varying capacities to conduct electrical current, changes in the conductivity across the surface can indicate the presence of a buried feature (Conyers and Goodman, 1997). Ground conductivity is affected by soil parameters, as well as buried objects and external features. Ground conductivity is primarily a function of the soil's moisture content, clay content, porosity, and salinity (Ellwood, 1990). Smith-Rose (1934) concluded that clays have the highest conductivities, whereas sandy or gritty soils are appreciably less. If clay content were the exclusive factor affecting conductivity, Olpe Soils would exhibit higher conductivities than Kenoma soils due to their higher clay content with increasing with depth (Neill, 1981). However, the presence of chert gravel in Olpe soils lower its overall conductivity. Also, the influences of spatial variability of soil properties such as moisture content, clay content, porosity, and salinity, *all* affect electromagnetic conductivity, and must be taken into consideration for accurate interpretations of conductivity results.

Conductivity measurements are not solely a function of soil properties. Objects buried within soil, such as metal, may also affect conductivity values. Potter's Field contains approximately 705 unmarked graves, at least 10 of which have been disinterred. Although wooden boxes were historically used for burials, steel vaults were used as early as 1917 (M. Rodenbeck, pers. comm., 2003). Figure 6 demonstrates relative conductivity of different earth materials. Metal is shown as having highest conductivity. Therefore, if steel vaults were present in Potter's Field, the metal would generate conductivity anomalies significantly different compared to the surrounding clay-rich soil matrices. On the other hand, an air void, representative of an intact grave, is a poor conductor of electric current. If a non-deteriorated, intact unmarked grave remained in Potter's Field, one would expect indications of low conductivity in comparison to the surrounding non-disturbed Olpe-Kenoma soil. Understanding how different materials affect conductivity can help interpret EM-38 data.

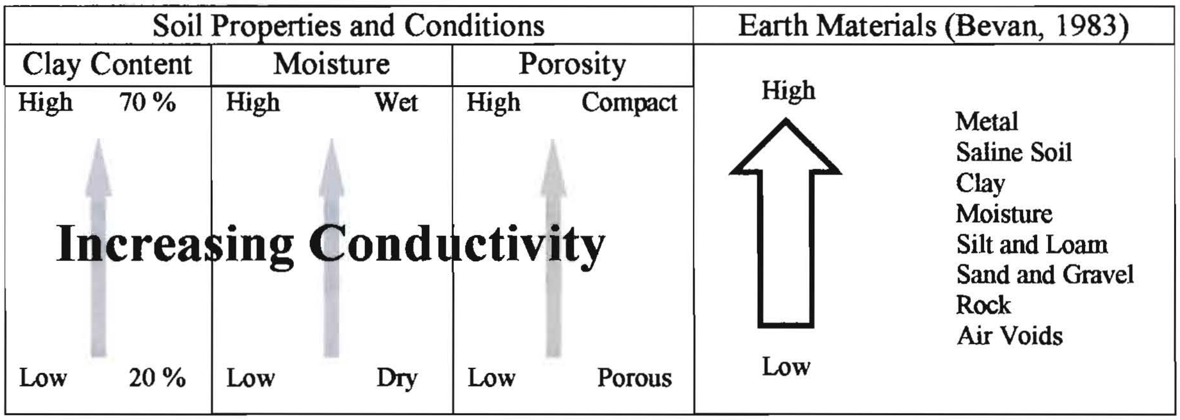

Figure 6. Approximate relative conductivity of soil conditions, soil properties, and different earth materials.

Finally, external features such as fences, tree roots, metal poles, and power lines can influence conductivity and distract from the location and delineation of unmarked graves. A disturbance map of Potter's Field (Fig. 7) has been created to point out potential interruptions of conductivity not related to unmarked graves. Figure 7 indicates each feature identified as a potential disturbance and its expected conductivity influence within the study area.

Electromagnetic Ground Conductivity: Session I

As stated previously, based on the information derived from obituaries and burial records, I expected small and discrete disturbances because of numerous children burials and subsequent grave deterioration. I knew that varying soil conditions, such as clay content, moisture, and porosity of the soil would affect apparent conductivity measurements depending on surveying schedule. Furthermore, I knew that adjacent features, such as power lines and metal poles would introduce "noise" into the electromagnetic data. Therefore, to acknowledge each of these factors, I began with a 20 x 20 meter grid. The grid was situated in the center of Potter's Field, away from power lines, metal poles, and trees to eliminate unnecessary noise from conductivity results. To ensure small disturbances were not missed, the perimeter of the grid was marked with steel wire post surveying flags at 0.5-meter intervals. The sampling grid included eight marked graves, of which the marked anomalies would serve as a comparison for those that were unmarked. Information on the headstones indicated known graves of three children and three adults. One headstone was illegible and the other has sunken too far beneath the surface to read.

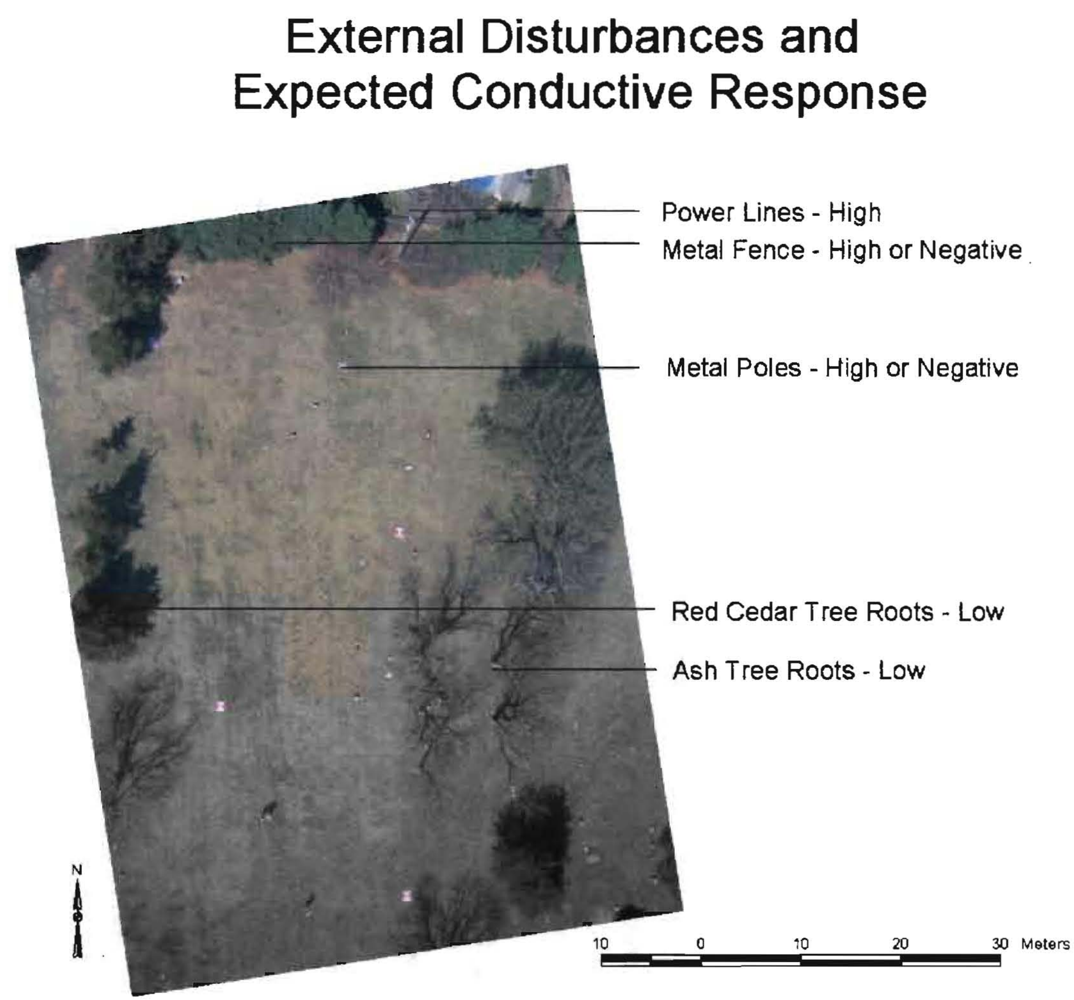

Figure 7. Identified disturbances and the conductive response near study site.

I began an electromagnetic study on April 13, 2002, surveying in 20 meter long transects at 0.5-meter intervals. Prior to the survey, the instrument was calibrated and nulled to zero at the center of the sampling grid. This procedure is done to cancel the large primary electromagnetic field from the transmitter, such that it does not overload the electronic circuitry, particularly on the most sensitive range scale (Geonics Ltd., 2002). Due to the high sensitivity of the EM-38, metal objects such as watches, rings, keys, necklaces, etc., were removed when making the adjustments and conducting the EM survey.

In the April survey, apparent conductivity values were acquired in vertical and horizontal dipole configurations at east/west and north/south orientations. Readings were taken from a sitting position and placing the instrument on the surface in the select orientation. In the vertical dipole mode, measurements were acquired for the upper 1.5 meters of the soil, increasing the potential for locating and delineating an unmarked grave at its typical depth of approximately 1.8 meters (6 feet) (M. Rodenbeck, pers. comm., 2002). In the horizontal dipole, at its 0-75 cm depth response, near surface features such as shallow graves may be identified. At an east/west orientation, the EM-38 is positioned to acquire readings along the length of a grave. If an east/west soil disturbance is less than 0.5-meters, the east/west orientation of the EM-38 may be unsuccessful in identifying the anomaly if measurements are made at evenly spaced grid points. In contrast, across their long axis a north/south orientation for the EM-38 would intersect unmarked graves across their long axis. An east/west soil disturbance would more likely be detected in this orientation. To cancel unnecessary noise in the electromagnetic field, the instrument was nulled to zero between each change in east/west and north/south orientations and between each 0.5-meter interval.

This intensive survey was conducted April 13 – April 28, 2002. During this period of time precipitation fell and was evaporated. Temperature fluctuated, and vegetative cover increased. Changes in soil moisture are particularly significant to note because each day a different soil moisture condition existed and a different geophysical result was measured. Successful and unsuccessful geophysical results during this time frame would ultimately correspond to the fluctuations in soil moisture conditions between EM surveys.

Vegetative differences noted during the EM survey are important for the interpretation for of EM survey results. Vegetative cover and lushness may be correlated to apparent conductivity results for the location and delineation of unmarked graves in Potter's Field. Kite aerial photography sessions, which will be discussed later, would determine whether or not these noted vegetative differences were a function of unmarked graves.

Electromagnetic Ground Conductivity: Session II

As before, the Geonics Ltd. EM-38 was borrowed from NRCS to conduct the next EM survey on September 22, 2002, under different soil moisture conditions. It was apparent from results of the survey conducted in April that delineation of unmarked graves would require a measurement interval of no more than 0.5 meter. It was also evident that apparent conductivity varied daily due to climate fluctuations such as precipitation. Thus for climatic consistency, a 5 x 10 meter sampling grid was established so that all conductivity measurements could be acquired in a single day.

To avoid unnecessary misinterpretations and interferences possibly incurred by metal surveying flags, the perimeter of the September sampling grid was designated with rope marked every 0.5 meter. Within the grid areas there was one marked adult grave, as well as, indication of several unmarked graves based on tonal differences visible from aerial photographs (Fig. 8).

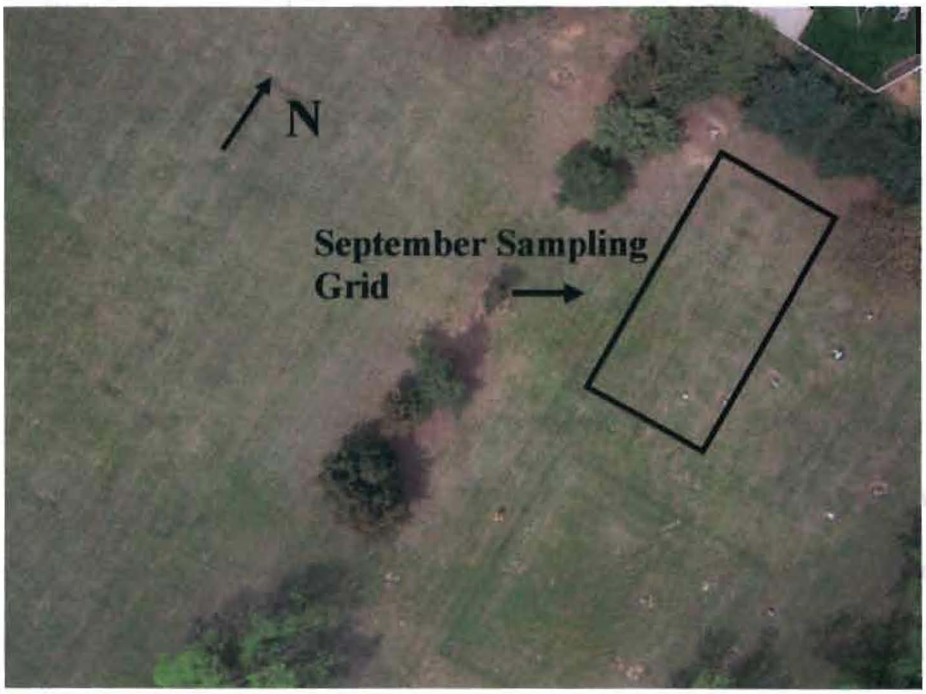

Figure 8. September EM sampling location chosen based on vegetative tonal differences indicative of potential grave locations.

September 22 was the closing of a drier than normal summer. Table 2 indicates a precipitation summary of Emporia, Kansas, for June – September 2002. The table compares average precipitation with the precipitation received in 2002. Less than normal amounts of precipitation were received in Emporia during this time interval particularly in July and September.

Month	2002 Precipitation (in)	Normal Average Precipitation (in)
June	4.13	6.56
July	2.99	4.01
August	4.10	4.00
September	1.30	4.34

Table 2. Precipitation Summary for Emporia, Kansas. (KSU Research and Extension, 2002).

As found with the EM survey conducted in April, climatic fluctuations, such as precipitation events can influence conductivity measurements by changing soil moisture content. I theorized that the dry conditions would yield lower apparent conductivity values than the previous field session in April where soil conditions were moister.

To determine conductivity response and its effect on locating and delineating the unmarked graves, the EM-38 was calibrated as previously done. The EM survey was conducted exactly as in April. Four apparent conductivity readings were acquired at each 0.5 meter interval; vertical and horizontal dipole at an east/west orientation and vertical and horizontal dipole at a north/south orientation.

Relatively few anomalous readings, in the vertical and horizontal dipole mode, were apparent in the September survey. In fact, all apparent conductivity values were lower and less variable suggesting an overall reduction in apparent conductivity in comparison to April readings when more soil moisture was present. Furthermore, *all* horizontal dipole values appeared to be lower than values obtained in the vertical dipole, indicating that surface soil materials were consistently less conductive than subsoil material. If the vegetative tonal differences apparent in kite aerial photographs *did* represent actual unmarked graves, backfill material should result in lower apparent conductivity readings indicating a more porous and thus less conductive soil. However, values in the vertical and the horizontal dipole indicated slight anomalies. Given the lower than average precipitation levels and the overall low apparent conductivity values, it was determined that the soil was too dry for the EM-38 to be successful at delineating the unmarked graves. The decision was made to conduct another EM session in the same location, under moist soil conditions, to see if locating the unmarked graves could be more successful under those conditions.

Electromagnetic Ground Conductivity: Session III

In March 2003, six EM surveys, including the areas previously surveyed, were conducted in Potter's Field to further investigate the effects of variations in soil moisture. For this survey, moderate soil moisture conditions were present, as the ground was wet yet not saturated. Again, the main objective of this EM survey was to determine if unmarked graves were more easily identifiable under moderate soil moisture conditions, in the same area surveyed in September. I questioned whether or not the same anomalous features, identified in April 2002, would emerge using the different surveying method discussed below. For this survey, a Geonics Ltd. EM-38B with a Juniper Systems Pro4000 data-logger (Fig. 9) was rented from Geonics Ltd.

Figure 9. Geonics Limited Electromagnetic Ground Conductivity Meter Dual Output (EM-38B) with Juniper Systems Pro-4000 Data Logger.

The EM-38B is a similar version of the Geonics EM-38; 1 meter in length and 2.5 kg. In contrast with the EM-38, the EM-38B has dual output capabilities: conductivity and inphase, for measuring soil magnetic susceptibility (Geonics Ltd., 2002). The Juniper Systems Pro4000 data-logger uses a data logging program called EM38pro, which connects to the Geonics EM-38B instrument for recording conductivity or inphase data automatically in the field.

Survey parameters can be set up in EM38pro, such as readings per second, component (conductivity, inphase, or both), dipole (vertical or horizontal), line increment (distance between survey lines), sequence (alternating or one-way when surveying each transect), direction (heading of survey line), and start station (number at which to start survey ex. 0) (Geonics Ltd., 2001). A field option is available on the log data screen to insert a comment at any point during the survey, which helps to avoid misinterpretations of anomalous readings. For instance, a metal pole protrudes out of the ground near a headstone in Potter's Field. The conductivity response to the metal pole is similar to a buried feature elsewhere in a different sampling grid. Therefore, I inserted a comment referencing the metal pole to the EM data to eliminate the potential for misinterpretation.

I chose to survey only in the vertical east/west dipole mode as previous EM surveys yielded anomalies in the horizontal dipole orientation not associated with unmarked graves. Unlike previous EM surveys where I acquired discrete measurements at specific grid points, I acquired continuous data in this survey. Apparent conductivity readings were logged at a rate of approximately 5 readings per second. As opposed to previous surveys, readings were taken from a standing position using a carrying handle to drag the instrument across the surface. In April 2002, discrete points took approximately two weeks to acquire. The data-logger allowed continuous surveying of the same 20 x 20 meter grid in 0.5-meter intervals in approximately an hour and a half.

The Pro4000 data-logger was set to acquire five vertical dipole readings per second along each 20 meter transect. Each transect was parallel but offset 0.5 meters from the previous transect. An attempt was made to maintain a consistent pace of 0.5 meters/sec along each transect. Although spatial coverage of 20 meters remained consistent for each transect, the walking pace of 0.5 meters/sec was not consistent. My walking pace was not timed, which resulted in transects with varying amounts of EM readings. Six other EM sampling grids were also established to survey other areas within Potter's Field. Three 20 x 20 meter grids, one of which was the same as the 20 x 20 meter grid established in April 2002 were surveyed. Three 7.5 x 20 meters grids were also established adjacent and surveyed adjacent to the larger grids, including the region surveyed in September 2002.

Soil Cores

Soil cores were extracted and analyzed from Potter's Field for two primary reasons. First, cores were acquired to demonstrate the soil morphology of disturbed versus non-disturbed soil. Second, the soil cores served as a small field check for the geophysical and remote sensing results. Figure 10a illustrates an A horizon sample of non-disturbed soil from the east edge Potter's Field. Figure 10b illustrates a sample of disturbed soil from the center Potter's Field. Both the Olpe and Kenoma soils in an undisturbed state become reddish or yellowish brown with increasing depth (Neill, 1981). However, in the upper horizon of Figure 10b, this reddish or yellowish brown color is evident suggesting soil disturbance due to excavation of a grave shaft and backfill at an unmarked grave. If this were the backfill of an unmarked grave, it would be an indication of increased porosity (less compact). Therefore, one would expect to see decreased apparent conductivity in backfill areas. This hypothesis would be consistent with the results of studies by France et al. (1992) in an electromagnetic survey at the Highlands Ranch Law Enforcement Training Facility in Colorado. In Potter's Field, clearly the gravelly silty clay found at the surface probably originated from the B-horizons of Olpe Soil that had been removed from their original position and then replaced in a sequence different from its original layering. Figure 11 illustrates the significant amount of rounded chert gravel left on the surface after grave shafts have been filled.

Figure 10a. Non-disturbed Kenoma Soil

Figure 10b. Disturbed Kenoma Soil

Figure 11. Rounded chert gravel deposits from backfill of graves in Potter's Field.

Penetrometer

A penetrometer is a device used for measuring soil compaction or density as a function of resistance to penetration. A penetrometer was used in Potter's Field to distinguish between disturbed and non-disturbed soils. The EM-38 response had suggested that grave shafts exhibited decreased apparent conductivity. This phenomenon has been attributed to the backfill material of an unmarked grave being less compact than the surrounding non-disturbed soil (France et al., 1992). Furthermore, acquired soil cores indicated disturbed soils in selected regions which also may be attributed to backfill material of unmarked graves.

A Dickey-John penetrometer was selected for this part of the investigation. The penetrometer consists of a 3-foot stainless steel rod connected to a T-handle (Fig. 12a). As the rod is pressed into the soil, a needle on a dial indicates compaction levels in units of pounds per square inch (psi) (Fig. 12b). Two tips, 1.27 cm (0.5 inch) and 1.91 cm (0.75 inch) diameters are provided for use in different soil types. The smaller tip is used for firm soils while the larger tip is used for softer soils (Fig. 12c). The 1.27 cm (0.5 inch) tip was used in this study since the clay-rich soil in this study was more firm.

Potter's Field was too large to conduct an intensive penetrometer survey of the entire area; therefore, two small surveys (systematic and random) were performed to determine the penetrometer's success. On July 9, 2003, the systematic survey was conducted along a 6-meter transect oriented north/south, perpendicular to the unmarked graves. The transect line included marked graves and unmarked graves, as indicated by EM data. Both were included to examine the compaction of marked graves and compare the compaction levels to the unmarked graves. To maintain surveying consistency, compaction measurements were made every 0.5 meter. Due to the amount of chert gravel present in these soils, five measurements were made around each survey point and an arithmetic mean of the five values was recorded.

To gain more spatial coverage of Potter's Field, a random penetrometer survey was also performed on July 9, 2003. This survey consisted of selecting random sampling points by blindly tossing a Frisbee within the study area. At each sample point compaction measurements were acquired in the same sampling method for each of these locations. All sampling points were flagged and numbered for re-sampling under different soil moisture conditions. I chose to resample under varying soil moisture conditions due to results found during Trinkley's (1999) research with a penetrometer and locating unmarked graves, which determined that penetrometer readings are strongly affected by soil moisture.

Figure 12a. Left Dickey-John Penetrometer

Figure 12b. Compaction Dial.

Figure 12c. 1.27 cm (0.5 in) and 1.91 cm (0.75 in) tips

On August 1, Emporia received significant rains to moisten, but not saturate, the ground. The next day the same penetrometer survey was performed in the same locations. Compaction levels demonstrated different results, which showed an association with the less compact backfill material of the graves of Potter's Field. On August 29, 2003, following a significant rainfall event, a final penetrometer survey was performed along the 6 meter transect and at the same random sampling locations with the same sampling method.

Kite Aerial Photography: Session I

As stated previously, vegetative cover and lushness increased during the April 2002 two-week field session in Potter's Field. To determine if vegetative tonal differences would be apparent, possibly representing unmarked graves, kite aerial photographs were acquired of the study site. On May 3, 2002, Dr. James and Susan Aber of Emporia State University assisted with the first session of kite aerial photography. Aerial photographs were acquired at approximately 1:00 p.m., to reduce the appearance of shadows from trees, or other standing features, which may be mistaken for an unmarked grave. A digital camera (although other imaging devices can be used) was placed in a single camera rig attached to the kite line. A large kite was utilized as the lifting device to place the camera rig 50 – 150 meters above the surface (Aber et al., 2002). To avoid turbulence and sudden movement caused by the kite, the camera rig was attached approximately 15 – 30 meters below the kite. Sixty-six digital photographs were acquired of Potter's Field and various other parts of the cemetery using binoculars to view the lens direction and a radio control to capture the photographs.

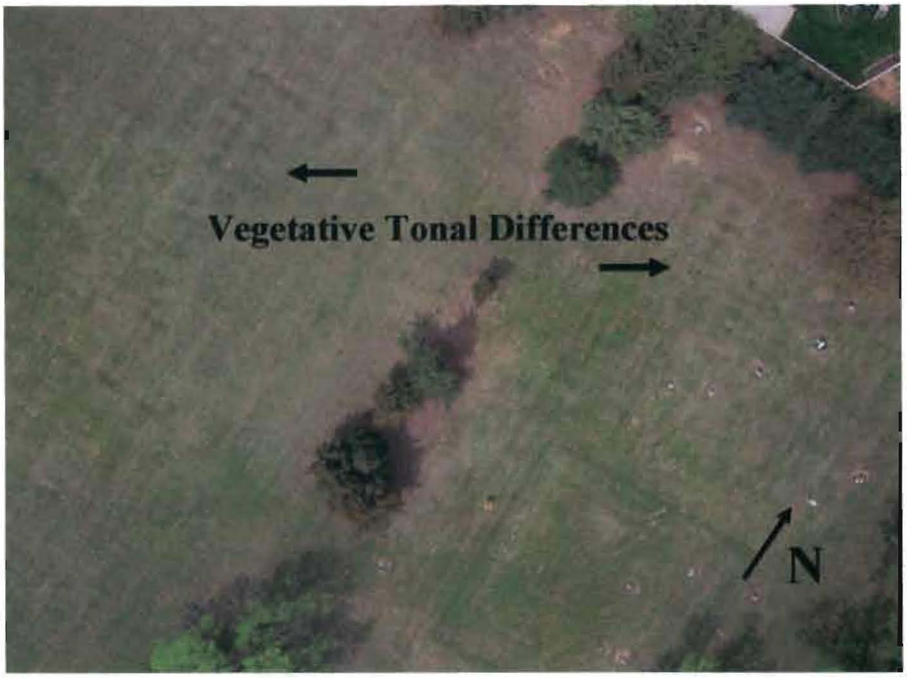

Figure 13. Vegetative tonal differences for unmarked grave delineation. May 3, 2002

Figure 13 illustrates a digital photograph taken of Potter's Field on May 3, 2002. The kite aerial photographs obtained using the methods described above typically have pixel resolution of 5 – 10 cm and include an area of about 0.5 to 1 hectare of ground in a single image (Aber et al., 2002). Kite aerial photography was successful in representing vegetative tonal differences indicated in Figure 13. The successful results of kite aerial photography underlined the need to conduct the second, September EM survey over the areas with vegetative tonal differences that appeared to be in an east/west rowed pattern.

Kite Aerial Photography: Session II

Another session of kite aerial photography was conducted on March 31, 2003, following the final EM survey. To view potential patterns, flags marking anomalous features were left in the ground to be photographed (Fig. 14).

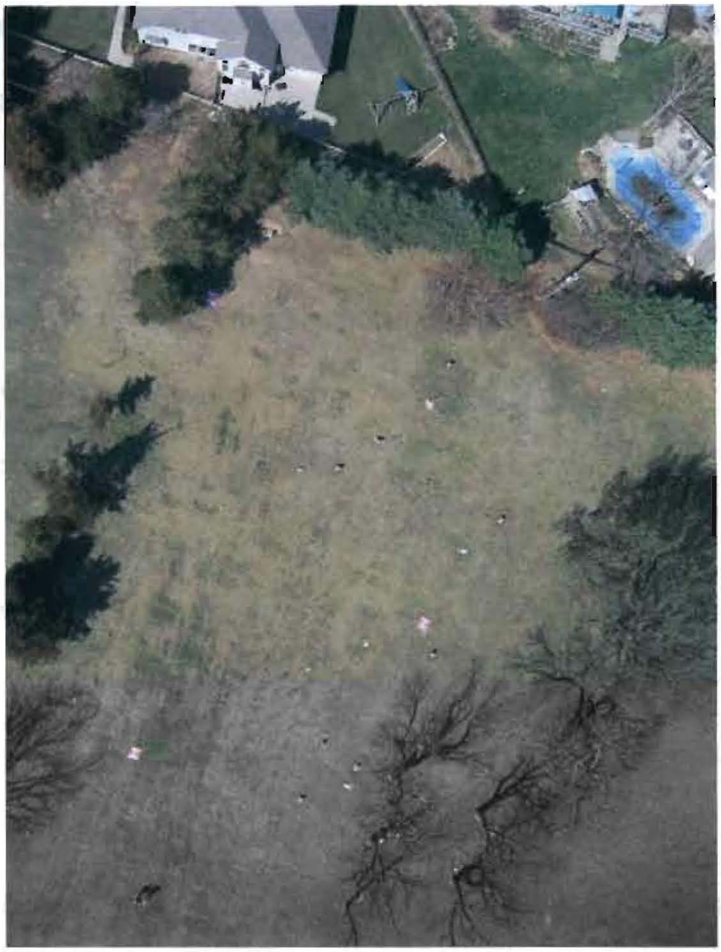

Figure 14. Kite aerial photograph slightly showing flagged anomalous EM readings. March 31, 2003. North toward top.

In this session, vegetative tonal differences apparent in the previous session were not as evident. The lack of vegetative differences may be attributed to it still being early in the growing season.

Disinterment

The opportunity arose to test the results and observations of the EM-38 at disinterment of a 1946 burial in another section of Maplewood Memorial Lawn Cemetery. The grave was marked and recorded to have been buried in a pine box. Given the age of the burial, the remaining condition of the pine box was in question. Cemetery administrators questioned whether the wooden box was still intact or had deteriorated?

While Potter's Field soils are part of the Olpe-Kenoma complex, the 1946 disinterment took place in Kenoma silt loam map unit (Neill, 1981). These soils are similar to the Olpe portion of the Olpe-Kenoma complex. The major difference with Potter's Field would be smaller amounts of chert gravel. I expected Kenoma silt loam to be overall more conductive due to generally higher clay content and lower chert gravel content.

Prior to making measurements at the disinterment site the EM-38 was nulled to zero over what should have been non-disturbed soil approximately 5 meters away from the disinterred grave. A transect was surveyed across three graves including the one to be disinterred. The first grave was dated 1946, the second was the 1946 burial to be disinterred, and the third grave was dated 1971. As anticipated, apparent conductivity values were higher than those measured at Potter's Field. They ranged from approximately 50 – 60 mS/m higher than those of Potter's Field in non-disturbed soil. The first grave that was contemporaneous with the one to be disinterred exhibited vertical and horizontal dipole conductivity values approximately 30 mS/m lower than adjacent non-disturbed soil. These values appeared to demonstrate the decrease of apparent conductivity probably due to backfill material having a lower bulk density and subsequent increased porosity. No extremely low apparent conductivity values were observed that would be indicative of a large void to suggest the presence of a still intact grave. The second grave, the one to be disinterred, exhibited higher conductivity values in the vertical dipole orientation and significantly lower conductivity values in the horizontal dipole. Unlike the previous grave, the higher conductivity values suggested the presence of a good conductor at greater depth, possibly metal. The significantly lower conductivity values in the horizontal dipole orientation appeared to indicate a non-conductive material near the surface. The next grave dated to 1971, contained a cement vault. Apparent conductivity values were similar to that of the future disinterment in both the vertical and horizontal dipole orientation. Given my relative certainty that the 1971 grave was intact and contained an air void, I felt assured the disinterment was also still intact as a result of the similar apparent conductivity readings. After completing the survey, the 1946 grave was carefully outlined with surveying flags according to anomalous readings.

CHAPTER 4

RESULTS

Geophysical and remote sensing investigations emphasized the application of geographic information systems (GIS) for locating and delineating the unmarked graves of Potter's Field. Spatial analysis of EM data and aerial photographs was carried out using ArcView and ArcGIS software (ESRI). ArcView and ArcMap were utilized to create interpolated grids of EM data, registered and rectified aerial photographs, and to conduct overlay operations of the different datasets. Statistical analysis was also performed to determine the statistical significance differences in apparent conductivity related to differences in soil moisture conditions between the different EM sessions.

Geonics Limited EM-38 Electromagnetic Ground Conductivity Meter

Apparent conductivity values were entered into ArcView for interpolation of grids, contouring, and spatial analysis. Values were derived from apparent conductivity data stored in an x, y, and z database file. Grids of apparent conductivity were interpolated using an inverse distance weighting algorithm in the spatial analyst extension in ArcView 3.3. The resulting grids were then used to create apparent conductivity contours. Knowing that variations in conductivity values were small, contour intervals of 1 mS/m were used.

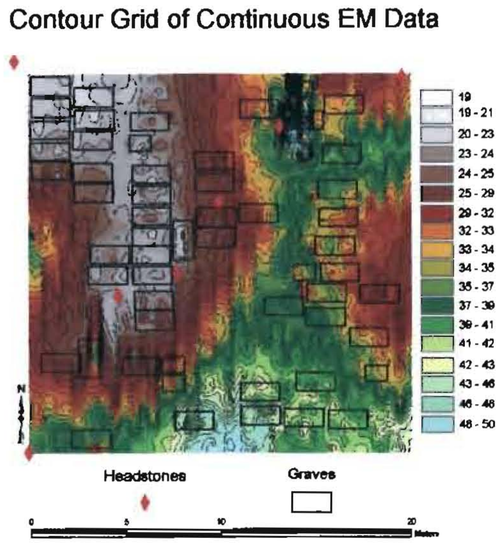

Figure 15. Contour grid of continuous apparent conductivity readings.

Figure 15 is an interpretation of a March 2003 contour map of continuous apparent conductivity within a 20 x 20 meter grid in Potter's Field. Squares and rectangles indicate anomalies that are interpreted as graves. Graves were delineated based on a series of interpolations beginning with a contour interval of 1mS/m. The contour interval was decreased until most apparent conductivity values were assigned a shade and contour line. Based on contouring pattern and interpolation colors in each series, graves were selected. Rectangles were selected to delineate possible adult graves and squares are used to delineate possible child graves. This grid contained four marked graves, at which the associated anomalies were used as ground truth to identify nearby unmarked graves. One of the marked graves had metal poles surrounding the marker, which appeared to overload the instrument making the delineation of the associated grave difficult to discern.

The two small anomalies that appear on the north and south side of the large metallic feature are a result of the instrument taking a running average of measurements over approximately the last 0.5 second (Clay, 2003) in the 1-meter vicinity while I surveyed in a north/south direction. I do not feel contour maps are the best way to display the apparent conductivity data of Potter's Field because apparent conductivity measurements demonstrated quite large and quite small variations. Selecting a small contour interval for a large range of apparent conductivity measurements in one grid created a cluttered graphical display, which made interpretation difficult. If a larger contour interval was selected to eliminate clutter, small variations were potentially overlooked. In a grid where the ranges of apparent conductivity measurements were small, a small contour interval was chosen, and appeared to be more effective at identifying anomalous features even when the magnitude of the anomalies were small.

Figure 16 illustrates an interpolation of apparent conductivity values at the same sampling grid of Potter's Field. The raster image eliminates clutter associated with the contour lines and tends to be easier to interpret for the delineation of unmarked graves. As before, anomalous features associated with the metal "noise" appeared on both the north and south side of the marked grave with metal poles. The gradual changes in color indicated local soil variations. Once again, anomalies associated with the marked graves were used as a comparison for the identification of unmarked graves that were indicated as rectangles and square boxes.

Comparing contours and interpolated grids of apparent conductivity assisted in the location and delineation of unmarked graves. Respectively, contour and interpolated grids took into consideration small and large differences in EM conductivity data and spatial variability. Comparing the delineation of unmarked graves within each grid allowed for the differentiation of what could have been mistaken for spatial patterns due to soil variability causing slight changes in apparent conductivity values. The amount of anomalous features interpreted as graves was 56. If burials in this region were referenced to the plot map, there should only be approximately 40.

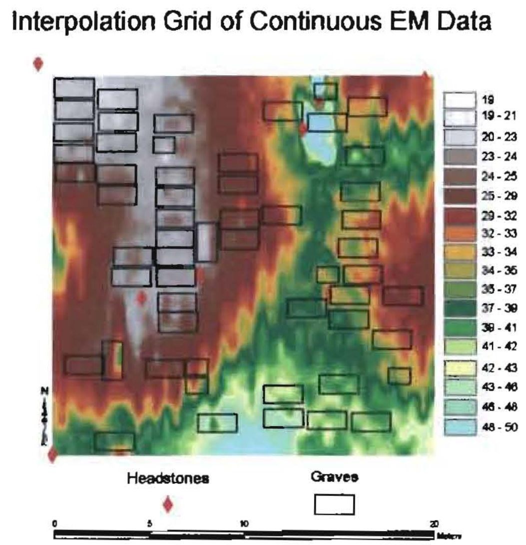

Figure 16. Interpolated grid of continuous apparent conductivity readings.

The images shown in Figure 17 demonstrate the difference between the processing of discrete data of the April 2002 survey vs. continuous data of the March 2003 survey. It is clear that anomalous features evident in the April 2002 image are not evident in the March 2003 image. Given that a larger amount of data was collected during the continuous survey, further data processing would be required to reveal the small anomalous features identified in the April 2002 image. Recall that continuous surveying acquires a "running average" of collected data. If my walking pace allowed the instrument to stabilize between readings during the continuous survey, precise locations of anomalous features might be possible. However, as a result of the running average factor and variations in my walking pace, locations of any anomalous feature evident in the March 2003 survey would only be approximate. Other geophysical software packages may have applications to correct this "lag time" error, however time did not allow for me to investigate this possibility in ArcView.

Apparent conductivity data acquired in April 2002, March 2003, and the 1946 disinterment appeared to demonstrate that over disturbed soils where backfill material was present, apparent conductivity decreased. When porous and non-disturbed soils are saturated, all empty spaces between pores are filled with water. Given that soil water is generally a good conductor of electric current, saturated soil yielded generally higher conductivity measurements. As demonstrated in the April 2002 and March 2003 surveys, increased moisture produced increased apparent conductivity. During one morning of surveying in the April 2002 field session, after a precipitation event demonstrated relatively few anomalous features compared to the afternoon after soil moisture had been reduced by evaporation and anomalous conductivity readings became more apparent.

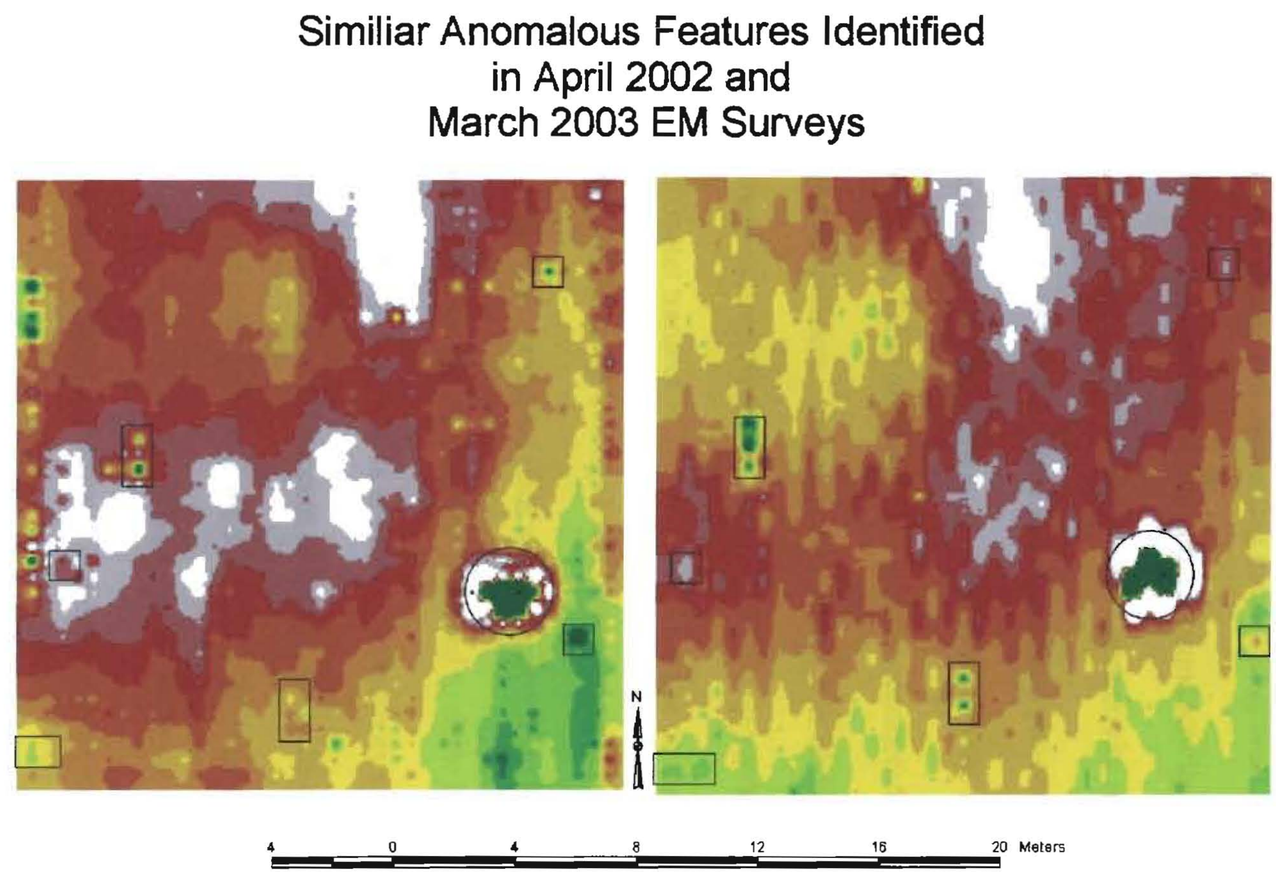

Figure 17. April 2002 discrete EM survey (left). March 2002 continuous EM survey (right). Note the small anomalous features evident in the discrete EM survey which are not in the continuous EM survey.

These EM survey results implied that significantly moist soils produce higher conductivity readings, but mask anomalous features, thus increasing the difficulty for locating and delineating unmarked graves. It seems that moderate soil moisture conditions are best for locating and delineating unmarked graves.

The three EM surveys indicated that apparent conductivity is strongly affected by soil moisture content. To demonstrate the apparent conductivity response to moisture, average conductivity response is compared to precipitation patterns in Table 3a – 3b. Table 3a illustrates average apparent conductivity readings in the vertical dipole mode compared to precipitation; Table 3b compares apparent conductivity obtained in the horizontal dipole to precipitation. Average conductivity was obtained by eliminating significant anomalous readings (negative and very high) and averaging the conductivity response of each 20 meter transect. Each transect's average conductivity was then calculated for a daily conductivity average to be compared with total precipitation levels of the previous five days. Precipitation data were acquired from Kansas State University Weather Data Library (2002). This procedure was used to show how precipitation levels affects soil moisture which in turn affects apparent conductivity and to demonstrate how dipole orientation may determine the success or failure of locating and delineating unmarked graves under certain soil moisture conditions. It is evident from Tables 3a and 3b that apparent conductivity is more sensitive to precipitation in the horizontal dipole. Recall that in this dipole orientation the meter is more sensitive to near surface features including precipitation, down to a depth of approximately 75 cm below the surface (McNeill, 1980). Note that when precipitation is received prior to measurements that

Vertical Conductivity vs. Precipitation

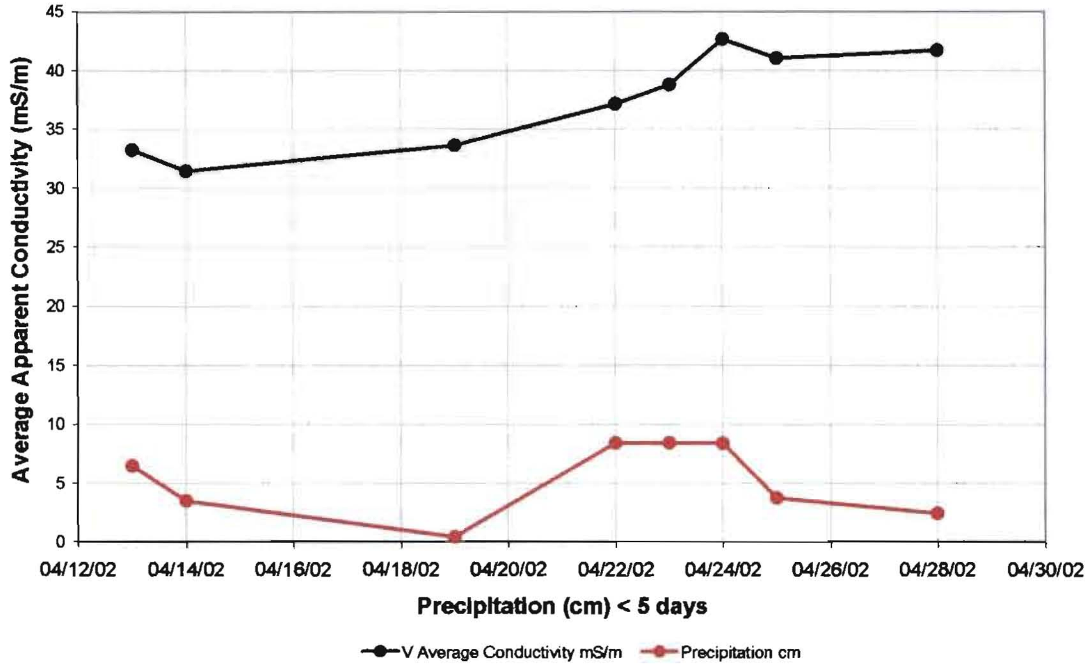

Table 3a. Vertical dipole apparent conductivity vs. precipitation. April 13 – 28, 2002.

Horizontal Conductivity vs. Precipitation

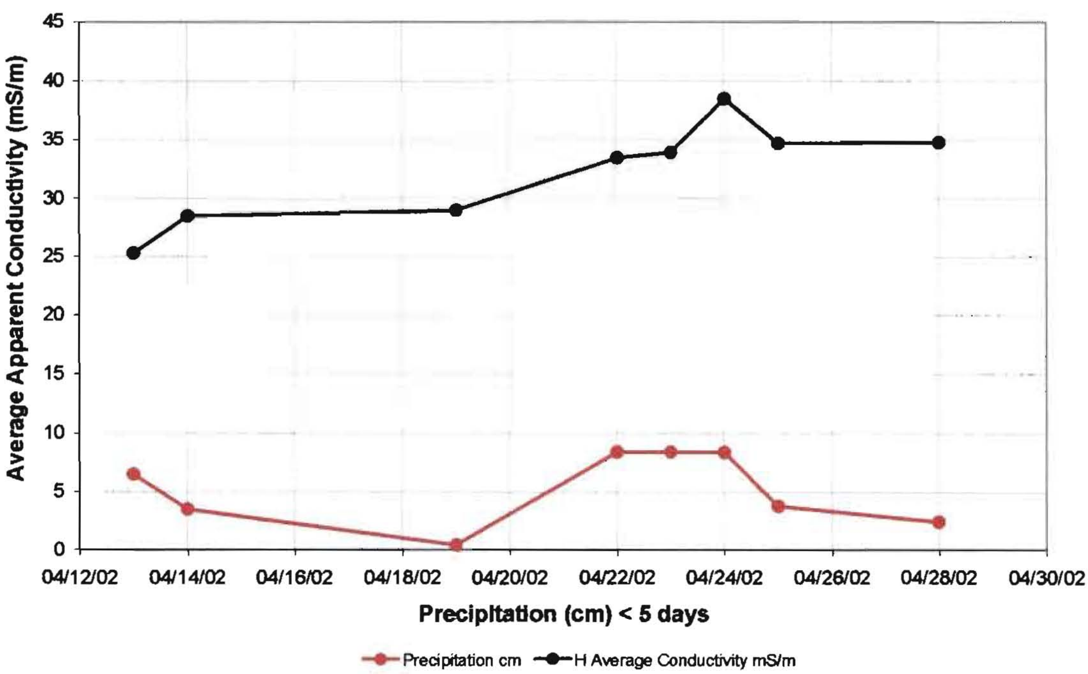

Table 3b. Horizontal dipole apparent conductivity vs. precipitation. April 13 – 28, 2002.

apparent conductivity values are higher, reinforcing the hypothesis that conductivity is a function of soil moisture content.

The second EM session was conducted under extremely dry conditions and reinforced the hypothesis that increased soil moisture, as in the April survey, produced higher conductivity values, which demonstrated moist soil's ability to conduct electric current. In contrast, the significantly drier conditions that prevailed during the second EM session produced low conductivity values, which illustrated the soils reduced ability to conduct electric current. It was hypothesized that if another EM survey was conducted, under more moist conditions, then apparent conductivity anomalies would be more apparent. Table 4 demonstrates the comparison of apparent conductivity values between the April 2002 and September 2002 when soil moisture conditions were respectively moist and dry. Extreme highs and negative apparent conductivity values were removed to eliminate biased results. It is evident that there is a reduction in apparent conductivity in September in comparison to April, in addition to a significant reduction in apparent conductivity range.

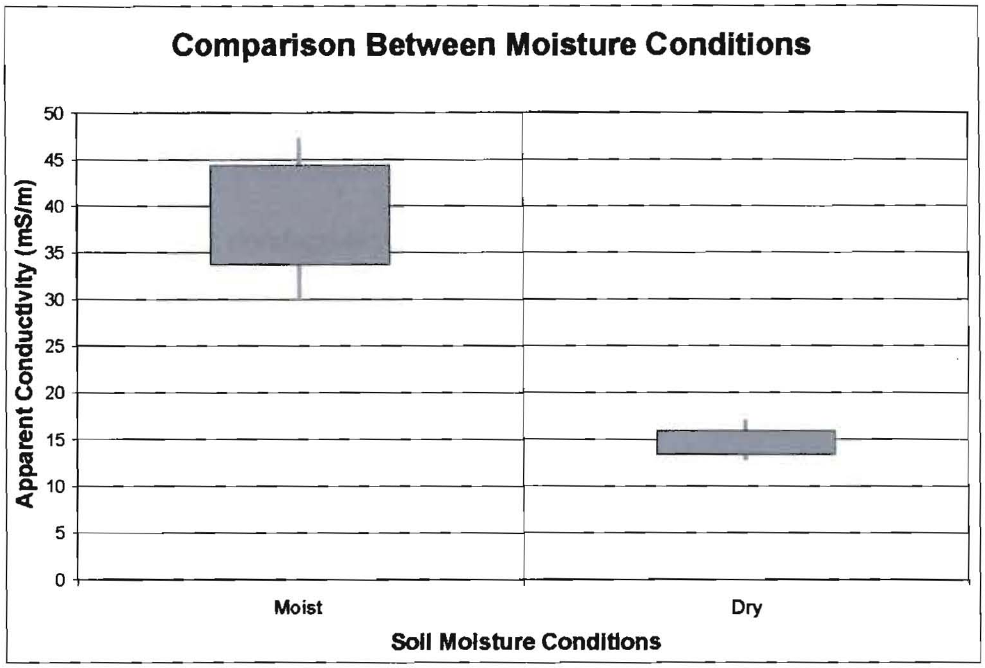

Table 4. Apparent conductivity comparison to soil moisture conditions of April (moist) and September (dry) 2002.

Dry soil conditions reduce apparent conductivity overall minimizing the feasibility of detecting anomalous EM readings. Moderate soil moisture conditions, as in April, increase conductivity as well as strengthening the likelihood of identifying anomalous EM readings and delineating unmarked graves.

A two sample T-test was performed to determine the statistical significance of the differences in apparent conductivity as measured in Table 4 April 2002 and September 2002. Differences in apparent conductivity were statistically significant ($\alpha = 0.01$). In other words, the probabilities that differences in apparent conductivity were a result of random variability were < 0.01%. The same statistical analysis was performed to determine the statistical significance of differences between both dipole orientations in April and September. Results were similar with differences significant at an $\alpha = 0.01$, therefore the hypothesis that differences in apparent conductivity measured in April and September were significantly different can be accepted.

It is valuable for this research to note the range difference between April vertical and horizontal apparent conductivity readings and September vertical and horizontal apparent conductivity readings. April apparent conductivity readings demonstrate a smaller range between dipole orientations (Table 5), which is probably a function of differences in soil moisture content near the surface and increasing clay content with depth resulting in increasing conductive response in both dipole positions. The box plots shown in Table 5 provide a visual summary of the distribution of April apparent conductivity values. The lower hinge of the box, defined as the 25th percentile, stretches to the upper hinge of the box, defined as the 75th percentile and therefore contains the middle half of the values in the distribution. The median is shown as the line across the box. Therefore, ¼ of the apparent conductivity values are above the line to the upper hinge and ¼ of the apparent conductivity values are below the line to the lower hinge. The red circle defines the mean of April's apparent conductivity values. In this box plot, asterisks indicate anomalous values, two steps beyond the box plot. The t-test still revealed significance between the horizontal and vertical dipole orientation.

It appears that a moderate range of apparent conductivity values enables slight soil disturbances to be more identifiable in this soil condition. The September vertical and horizontal apparent conductivity readings demonstrate a much larger range between dipole positions (Table 6); a function of the extremely dry soil conditions. Note the absence of asterisks on this box plot indicating lack of anomalous values beyond the range. As a result, slight and anomalous features are likely to go unnoticed. On the other

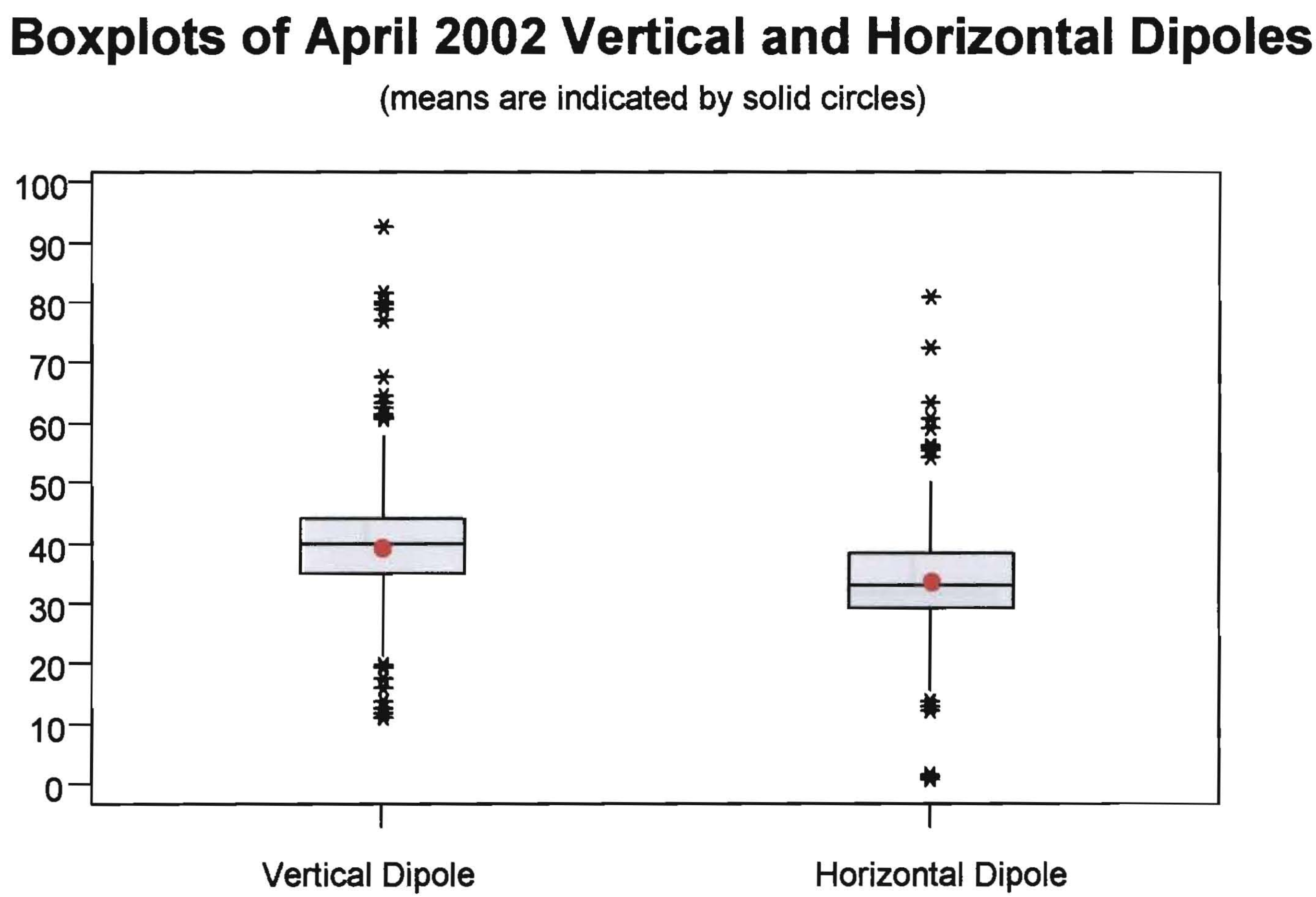

Table 5. Box plot of April 2002 vertical and horizontal dipole EM readings.

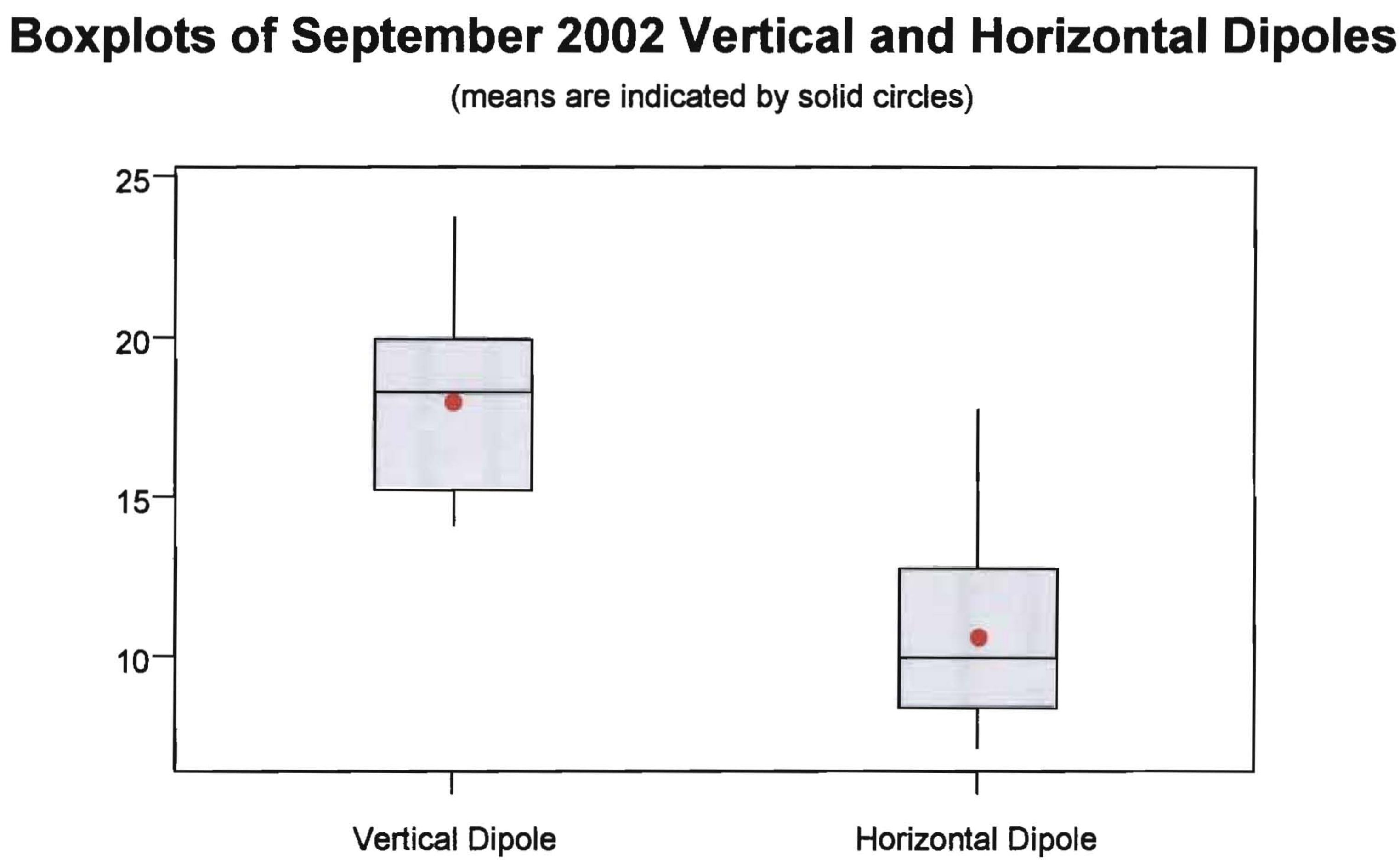

Table 6. Box plot of September 2002 vertical and horizontal dipole EM readings.

hand, April vertical and horizontal apparent conductivity readings under moderate soil moisture conditions exhibited a smaller range and maps showed evident anomalies. As described earlier, significant soil moisture content may overall increase the conductivity decreasing the range in apparent conductivity readings. As a result, slight and anomalous features are likely to go unnoticed.

In the third EM session, given continuous apparent conductivity measurements were acquired throughout Potter's Field rather than discrete measurements, the precise location of each anomalous value could not be determined. However, anomalous features identified in the April 2002 EM survey, were also identified in the March 2003 EM survey. Figure 18 illustrates similar anomalous features identified within both. April 2002 and March 2003, EM sampling grids. The March 2003 sampling grid was established in approximately the same location as the April 2002 grid, therefore anomalous features are generally in a matching location, even though they might not line up perfectly.

The EM-38 can be useful in locating and delineating unmarked graves; however, research revealed that apparent conductivity values are not always representative of the soil conductivity alone. For example, anomalously high apparent conductivity values are not always an indicator of a highly conductive soil. Buried metal objects are very conductive and can result in readings that are excessively high or negative (Bevan, 1983). According to Bevan (1983) and Clay (pers. com., 2003), metal is the only buried feature which will result in a negative EM response delineating the buried feature with such an EM response.

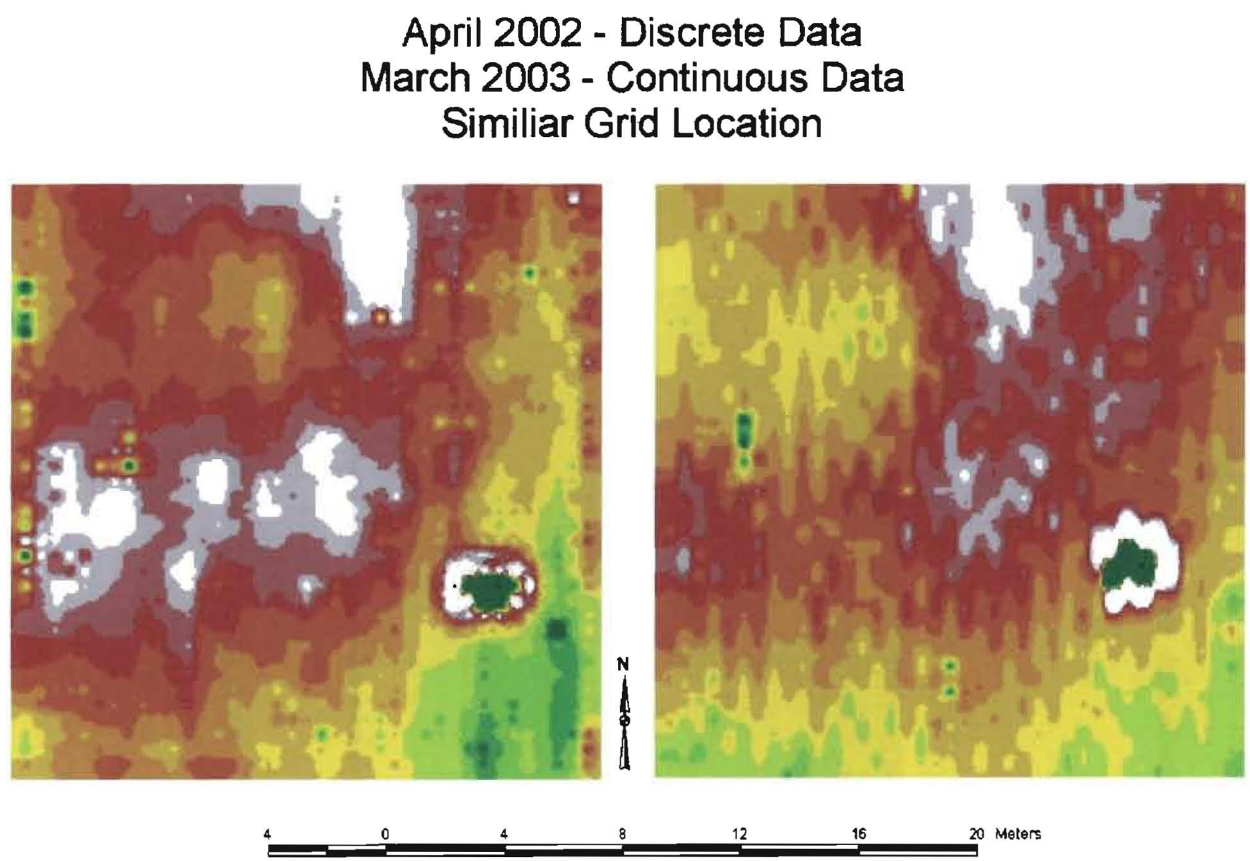

Figure 18. April 2002 discrete EM survey (left). March 2002 continuous EM survey (right). Anomalous features evident in both surveys appear in generally the same location despite different surveying technique.

The large anomalous feature in the southeast corner of Figure 19 probably indicates the presence of buried metal material, which corresponds to a marked grave. In a continuous survey, recall the instrument acquires a running average of approximately the last 0.5 second (Clay, 2003), therefore a buried feature may appear larger graphically than it actually is. However, figure 19 is a result of discrete data which allows for a more detailed location and delineation of the associated grave.

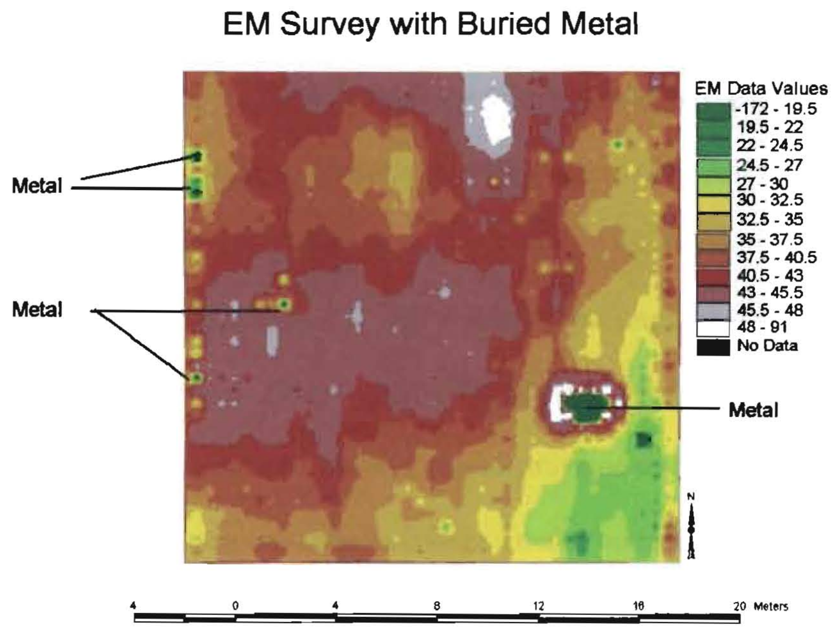

Figure 19. EM survey with possible graves containing metal.

Unfortunately, the headstone for this grave was illegible. Therefore, no date or name could be acquired to find more information on whether or not the large metal anomaly was a result of a steel vault or contents of the grave. As stated previously, steel vaults were used as early as 1917 in Maplewood Memorial Lawn Cemetery (M. Rodenbeck, pers. comm., 2003). A steel vault may have been used for the burial, however for most burials in Potter's Field and for that time, it is unlikely.

To interpret a geophysical survey with an electromagnetic ground conductivity meter, it is essential to know how different materials conduct electrical current. For example, research revealed that a void resulting from an intact grave may result in very low apparent conductivity values. Under moderate soil moisture conditions disturbed soil revealed decreased apparent conductivity in comparison to non-disturbed soil due to backfill material. Research at Potter's Field yielded a few unmarked graves that may contain metal. Others had not deteriorated to the point of collapse, and others may only exhibit slight apparent conductivity anomalies indicative of soil disturbances. Thus, understanding the electromagnetic conductivity of metal material and void spaces assisted in the interpretation of EM data for the ultimate location and delineation of unmarked graves.

Figure 20 illustrates an interpolated grid of horizontal east/west apparent conductivity readings acquired in April 2002. While flagging anomalous features, surface artifacts such as a coin, sunken headstones, and dead tree roots were encountered. Shallow unmarked graves may be delineated using the horizontal dipole orientation but these surface features, in addition to others that were not encountered with the surveying flag, may be interpreted as an anomalous feature that may or may not be related to the unmarked graves. Without the ability to ground truth each anomalous feature, the methodology does not appear to be as precise as surveying in the vertical dipole where less surface artifacts are present. Furthermore, upon interpretation of maps, I would be unable to say for certain which anomalous feature is or is not related to an unmarked grave without excavation. As stated before, understanding the electromagnetic conductivity of various buried materials assist in the interpretation of EM data for the ultimate location and delineation of unmarked graves.

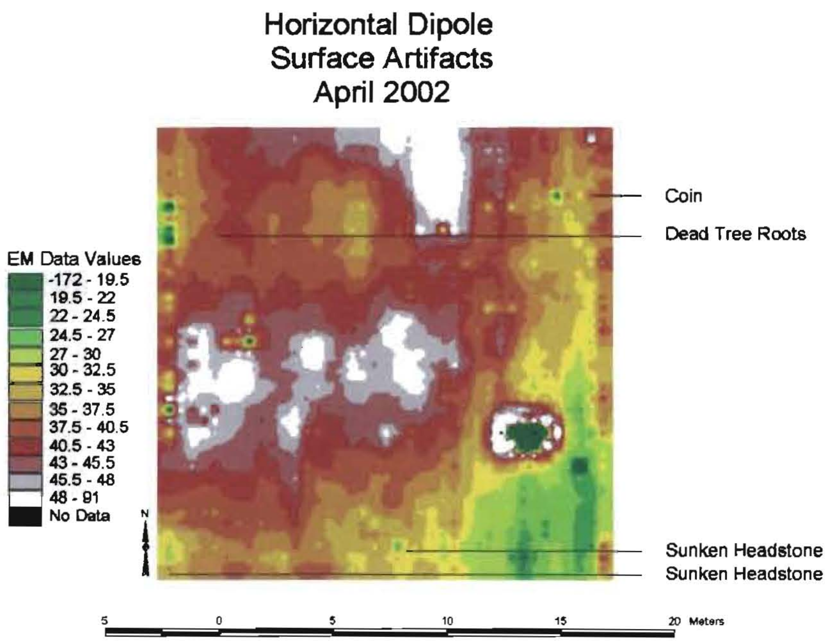

Figure 20. April 2002 EM survey in the horizontal dipole orientation showing surface artifacts both related and unrelated to unmarked graves.

To successfully interpret geophysical data, it is not enough to understand the conductive response of different external and buried materials and note anomalous features that may or may not be related to the targeted feature. Geophysical data which involves options of instrumentation and spatial variability associated with soil moisture conditions and soil variability, also involves variations in data processing and interpretation. Anomalous features may easily go unidentified with only one process of data interpretation, therefore a comparison of different map interpretations may yield more successful results.

Figures 21 – 24 illustrates four different map interpretations of the April 2002 EM survey. The first two map interpretations illustrate an interpolation of the vertical dipole at 0.5 mS/m and 1 mS/m contour intervals. While some anomalous features remain constant, other features are evident in one and not the other.

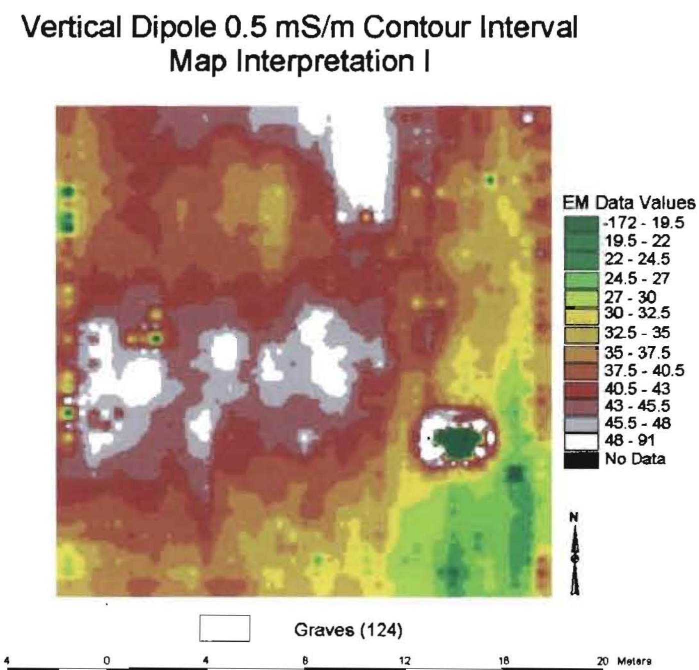

Figure 21. Interpolated grid of vertical dipole. 0.5 mS/m contour interval. April 2002.

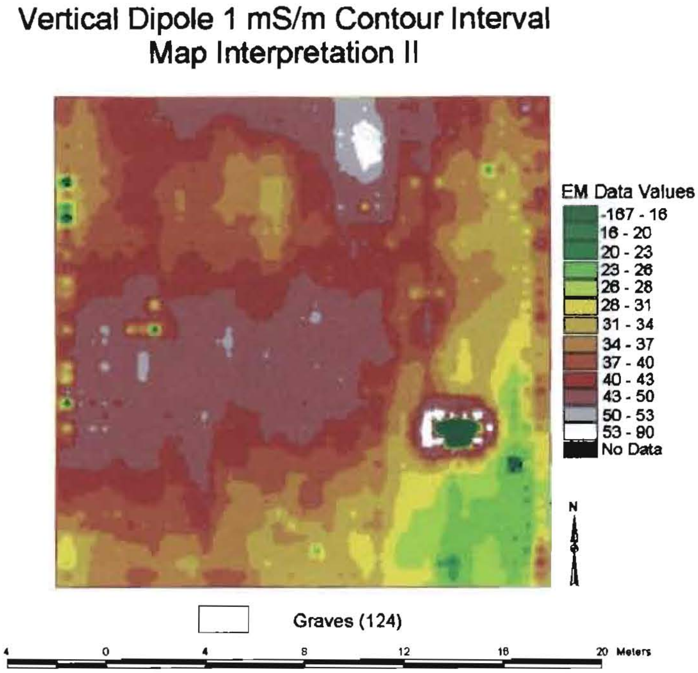

Figure 22. Interpolated grid of vertical dipole. 1 mS/m contour interval. April 2002.

It is interesting to compare the second set of map interpretations of the horizontal dipole at 0.5 mS/m and 1 mS/m contour interval to the first set of maps in the vertical dipole. Notice that the line of anomalous features along the west edge of the grid is no longer apparent. An anomalous feature in the south-center part of the grid is now evident in the horizontal dipole however was not in the vertical. This may be indicative of a shallow grave.

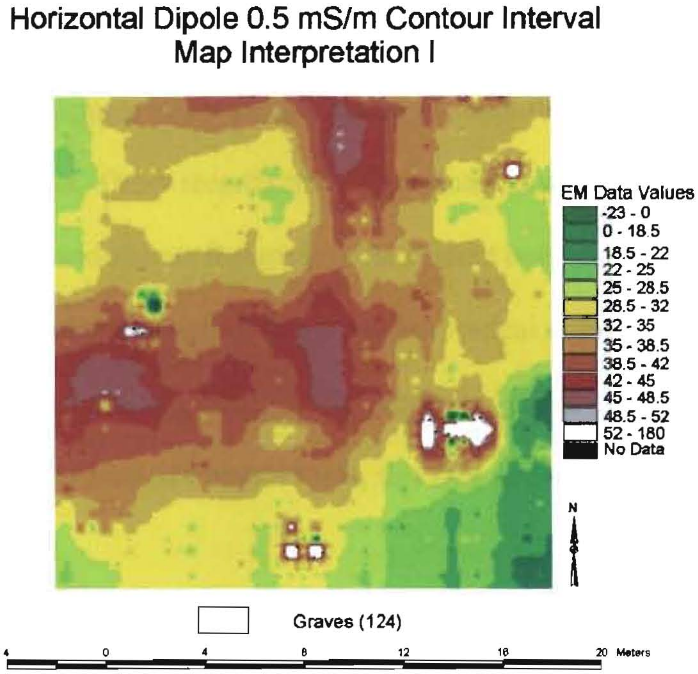

Figure 23. Interpolated grid of horizontal dipole. 0.5 mS/m contour interval. April 2002.

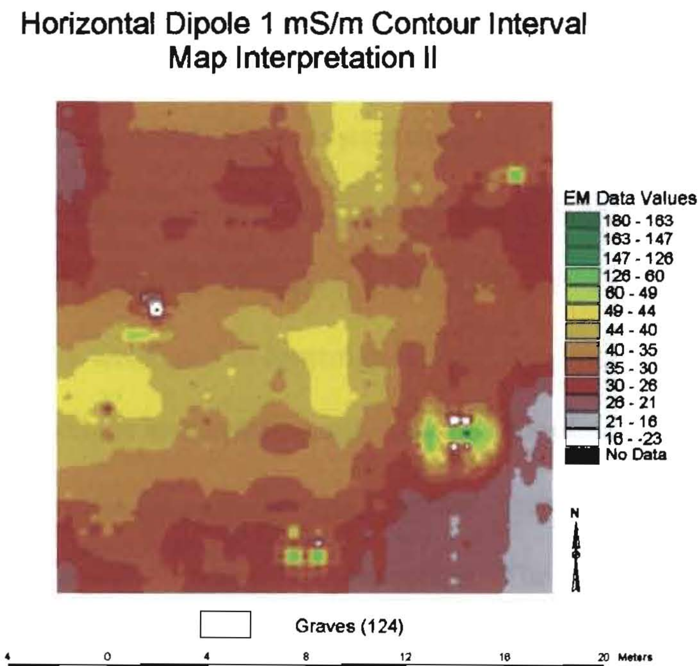

Figure 24. Interpolated grid of horizontal dipole. 1 mS/m contour interval. April 2002.

Original records of Potter's Field documented that some individuals shared stake numbers, possibly indicating one burial stacked on top of another. In this instance, anomalous features may appear in the same location for both the vertical and horizontal dipole map interpretations. Other records revealed an individual buried at the foot of another. In this case, an anomalous feature may be evident only in the horizontal dipole or unusually close to another anomalous feature in the vertical dipole. The number of anomalous features interpreted as graves for this particular grid is 124. Had these burials been referenced to the plot map of Potter's Field, this area should only contain approximately 65 burials.

Kite Aerial Photography

To facilitate the objective of locating and delineating the unmarked graves of Potter's Field, air photos of the site were referenced to a real world coordinate system. Utilizing a Sokkia GPS unit with ±10 cm accuracy coordinates for headstones within Potter's Field were obtained. The kite aerial photographs of Potter's Field were then referenced to the UTM, Zone 14 coordinate system using the "known" locations obtained using the GPS unit. The ArcGIS geo-referencing tools used to convert kite aerial photographs with non-real-world coordinates to a real-world coordinate system. GPS coordinates for headstones were used as control points to build a polynomial transformation that warped the aerial photograph from one coordinate space to another (ArcGIS, 2001). To complete the georeferencing process, each control point was referenced to its known location on the aerial photograph. The relationship between the control points and the aerial photograph was then determined, producing a photograph referenced to the UTM coordinate system for accurate identification of select features and overlay with other data.

Headstones not associated with stake numbers were either not legible or were never assigned a stake number. After registering and rectifying the kite aerial photograph with the headstones associated with stake numbers (Fig. 25), it appeared that the lower stake numbers were located on the east side of Potter's Field and the higher stake numbers were located on the west side. However, there did not seem to be any specific pattern to the stake sequence. Thus a burial pattern was unable to be determined.

Figure 26 illustrates the kite aerial photograph after the georeferencing process. Given the aerial photograph was referenced to the UTM, Zone 14 coordinate system, vegetative tonal differences could now be accurately identified in Potter's Field. The visible rowed pattern of possible unmarked graves in the northeast section of Potter's field corresponds to east/west burial traditions. Additional unmarked graves may also exist outside the east boundary of Potter's Field, which may have gone unidentified without aerial photography.

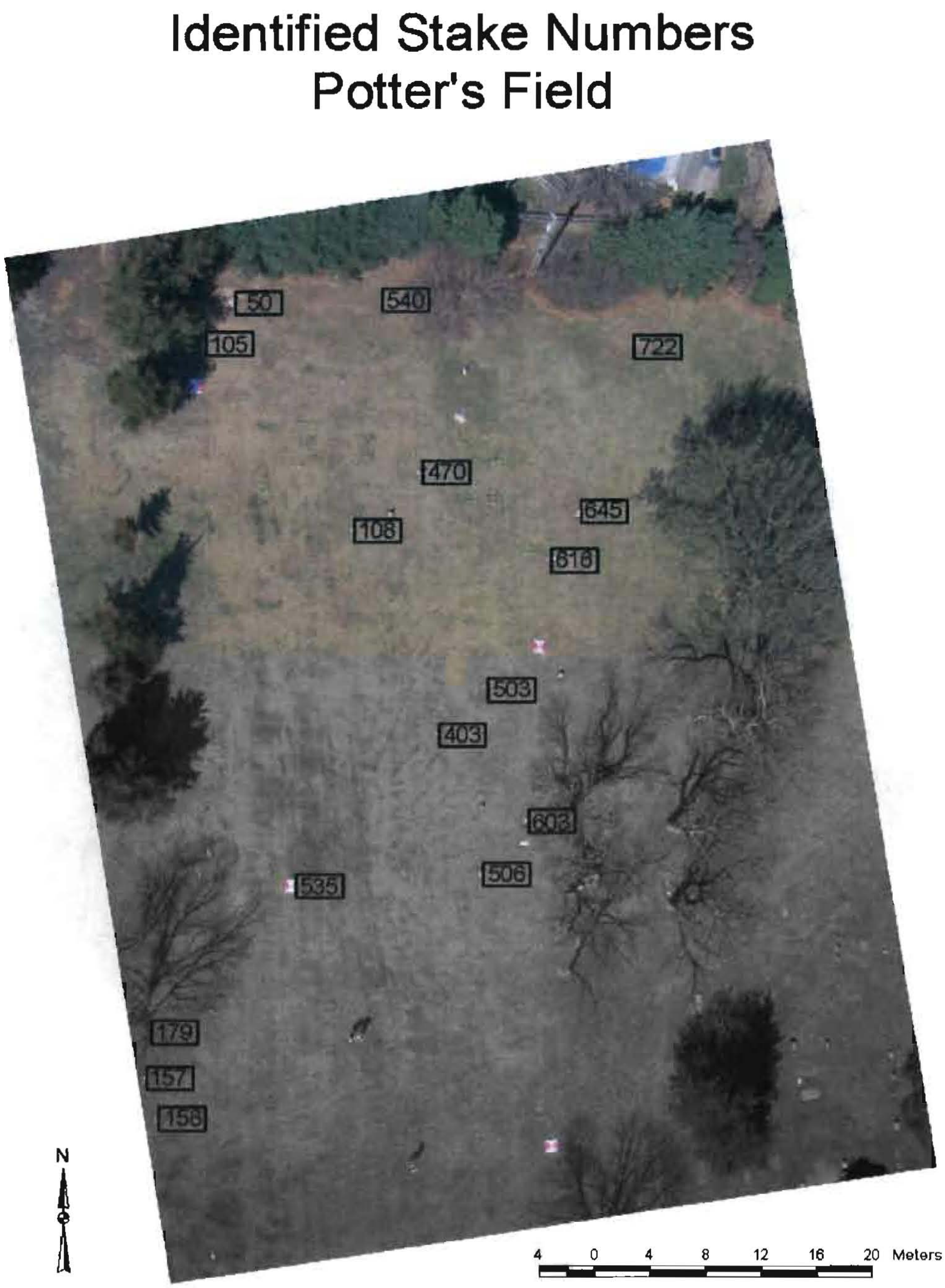

Figure 25. Identified stake numbers with the associated Potter's Field headstones.

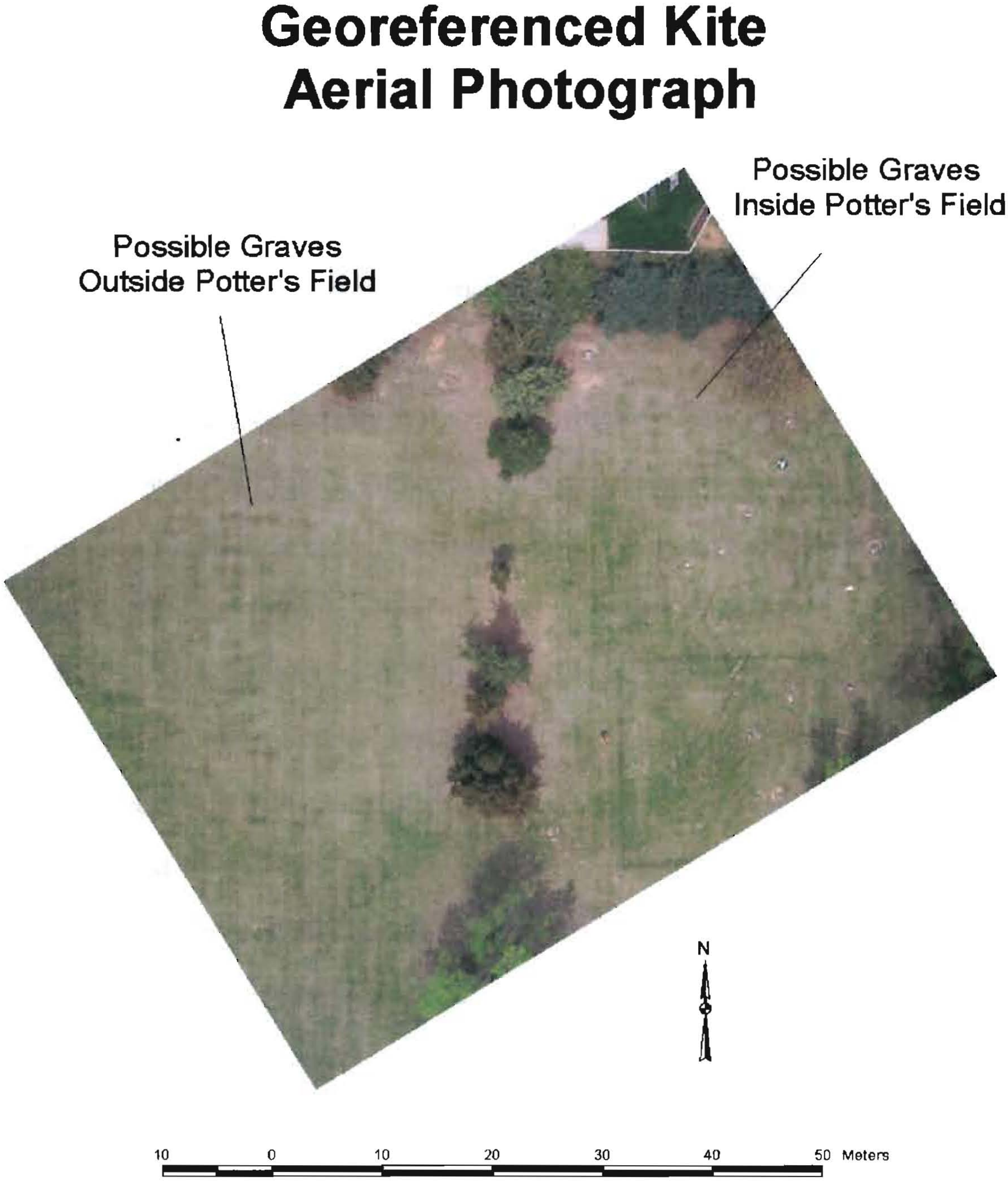

Figure 26. Georeferenced kite aerial photograph representing potential grave patterns.

CHAPTER 5

5.1 DATA INTERPRETATION

Geonics Limited EM-38 Electromagnetic Ground Conductivity Meter

The primary objective of the EM survey was to locate and delineate unmarked graves in Potter's Field. The most successful way of accomplishing this was by identifying anomalous features in the apparent conductivity data. Data from each EM sampling grid were used to interpolate grids and create contours of apparent conductivity for spatial analysis.

The apparent conductivity data acquired using the EM-38 was a series of many individual conductivity values. Although within these values there are a few obvious anomalies, the majority of conductivity values demonstrate slight spatial variability. Recalling that burials in Potter's Field occurred approximately 75 – 130 years ago, this slight variability in apparent conductivity values was expected. Often, a change may be no more than a difference of one-tenth mS/m between adjacent measurements. Soil conditions also have spatial variability which was a factor to take into consideration when evaluating EM survey results demonstrating gradual changes in apparent conductivity. Understanding site conditions such as age of burials and soil variability is essential in interpreting apparent conductivity values of EM data and for the accurate location and delineation of unmarked graves.

Eastern Kansas' clay-rich soils have slow infiltration capacity and low internal permeability, therefore a few days may be required for sufficient internal drainage to remove or redistribute excess water. Due to increasing porosity from backfill material of an unmarked grave, water is likely to infiltrate more quickly through these disturbed soils as compared to adjacent non-disturbed soil. The remaining moisture in disturbed soils can cause differences in EM response that are distinguishable from very moist, non-disturbed soil. These changes in EM response may make it possible to locate unmarked graves. When the moisture evaporated, the backfill materials were less conductive than the non-disturbed soil. In September 2002, when the soil was extremely dry, little moisture was present to conduct electric current. At any given site, unsaturated subsurface material has a lower conductivity than saturated material (McNeill, 1980). Low conductivity values were a direct result of the significantly dry soil conditions, which masked differences in soil properties influencing EM response thus making it difficult to locate any unmarked graves that were present. Furthermore, it verified that extreme dry conditions, like the September 2002 EM survey, were not optimal for identifying anomalous features. Figure 27 illustrates a map comparison of apparent conductivity for the moist soil conditions of the April EM survey and the dry soil conditions of the September EM survey.

Kite Aerial Photography

Kite aerial photography was successful at distinguishing vegetative tonal differences in the rowed, east/west pattern in and adjacent to Potter's Field. Late spring was determined to be better than early spring for aerial photography for detecting the vegetative differences associated with unmarked graves. Decreased electromagnetic apparent conductivity values may indicate that the backfill material of the unmarked graves was more porous. A porous material may allow ease for infiltration of spring-time moisture to facilitate new vegetative growth, which in air photos appears as a grave

April (moist) vs. September (dry) 2002 EM Surveys

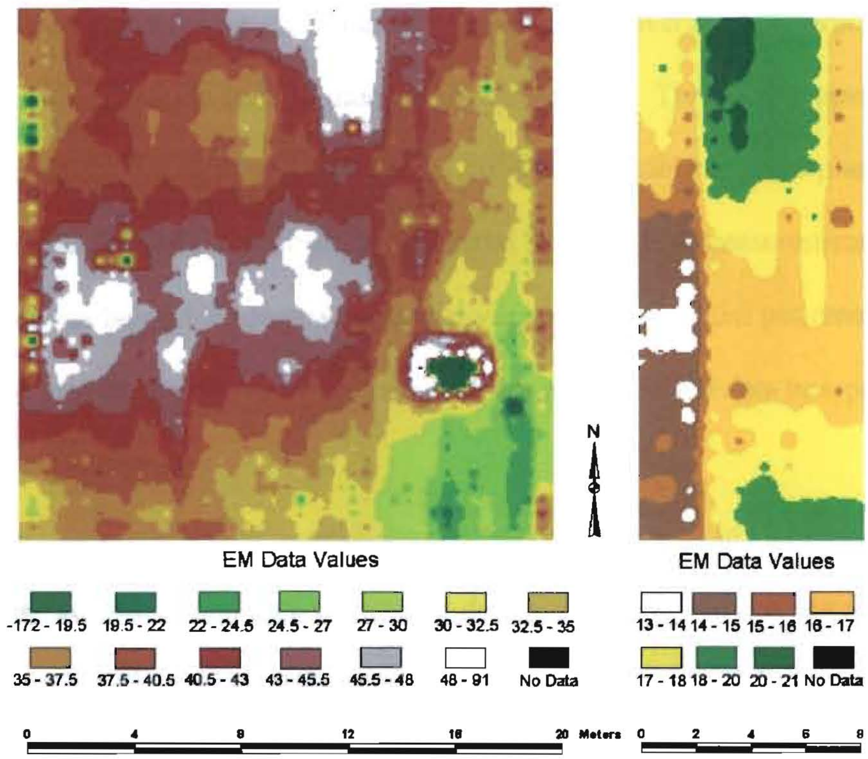

Figure 27. April 2002 moist EM survey compared to September 2002 dry EM survey. Moist soil conditions are necessary for the identification for the anomalous features.

pattern. New growth may also be facilitated by the evident depressions on the surface which fill with water. New vegetative growth is apparent in late spring kite aerial photographs, to assist in the identification of disturbed soil however was not evident in early spring photographs. Figures 28a and 28b reveal the vegetative differences between early and late spring.

ArcView and ArcMap proved to be a useful tool in overlaying interpolated grids of EM data onto registered and rectified aerial photographs. The overlay operation was able to successfully correlate vegetative tonal differences visible in aerial photographs with some of the subsurface anomalies interpreted from the EM measurements. Interpolation was helpful in identifying spatial variability and spatial patterns not related to unmarked graves, such as soil changes which are evident in the data interpretation of any geophysical survey.

Anomalies represented as vegetative differences apparent in kite aerial photographs, were identified with the EM-38 during the March survey. As shown in Figure 29, unmarked graves located in the resurveyed September EM sampling grid were correlated to vegetative tonal differences in kite aerial photographs. March 2003 results indicated that moisture is an essential factor influencing the location and delineation of unmarked graves in eastern Kansas' clay-rich soils. To reiterate, for the EM-38 to be successful, moderate soil moisture conditions must be present.

Figure 28a. May 2002 Kite aerial photograph of Potter's Field. Vegetative growth apparent.

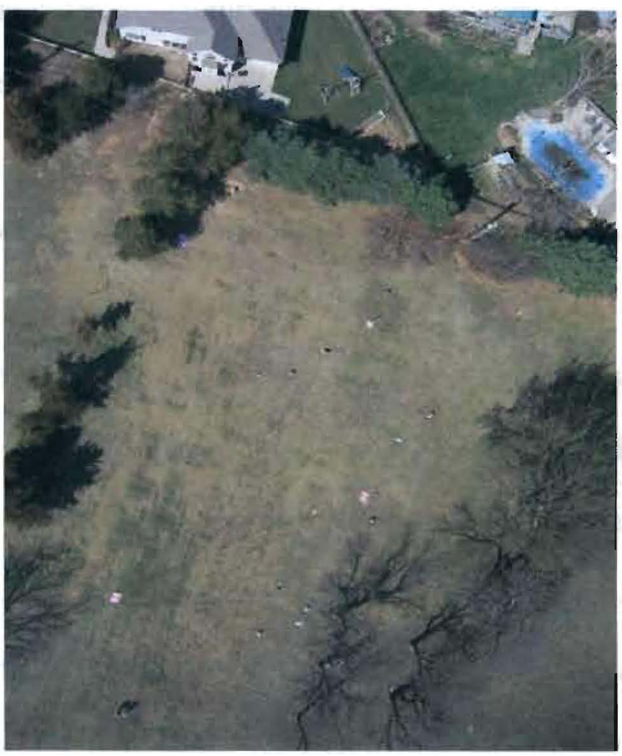

Figure 28b. April 2003 Kite aerial photograph. Vegetative growth not as apparent.

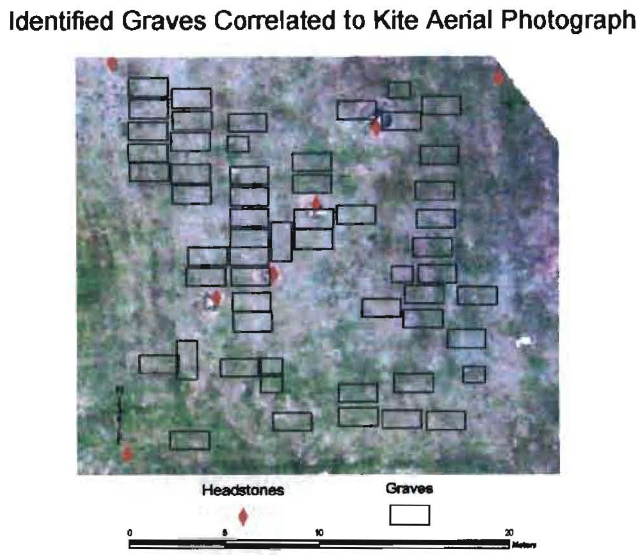

Figure 29. Graves identified from resurveyed September region have been correlated to vegetative tonal differences evident in kite aerial photographs.

Penetrometer

It was evident that the disturbed soils in a grave shaft have different soil characteristics. One possible explanation is a change in porosity as compared with the surrounding non-disturbed soil. The first penetrometer systematic survey revealed compaction levels consistently above 300 psi between both known disturbed and non-disturbed soil, likely because of the dryness of the soil. The prevailing difference between known soil disturbances and undisturbed soil was that after approximately 23 centimeters in disturbed soil, chert gravel was not as prevalent. Results from the second penetrometer survey were acquired the day after a moderate rainfall event. The disturbed soil over known, marked and unmarked graves revealed compaction levels between 100 –

225 psi. Between burials, compaction levels were above 300 psi. The random survey showed compaction of disturbed soil between 100 – 225 psi, and above 300 psi for non-disturbed soil. The final penetrometer survey acquired after a heavy rainfall event revealed soupy soil conditions with compaction levels between 100-225 psi. Much like the EM survey, it appears that moderate soil moisture conditions must be present for the success of a penetrometer survey.

Disinterment

The disinterment yielded positive results as the EM-38 successfully outlined the 1946 grave. The first grave again produced vertical and horizontal apparent conductivity values approximately 30 mS/m lower than non-disturbed soil. I presume the low values are a result of the increased porosity of backfill material. Because the values are similar in both the vertical and horizontal dipole orientation, I would presume that this grave has collapsed. The disinterred grave was intact and lined with a thin sheet of metal, which probably caused the higher apparent conductivity values in the vertical dipole orientation. I presume the low anomalous reading appeared in the horizontal dipole of the disinterment and 1971 grave because either different soil was used for backfill rather than what was left over, backfill material was replaced in a different order, or the simply because the soils were less compact. I would hypothesize that if the disinterred grave had collapsed, the metal lining would not have been evident in EM results for two reasons. First, the quantity was so minimal and second, in a collapsed state it would have been past the depth of EM response.

The pine wood had nearly completely deteriorated, however the metal lining probably restrained its collapse. Assuming this burial was similar to those of Potter's

Field, which are 20 – 75 years older than the disinterred grave; I presumed deterioration of Potter's Field burials to be in the same condition or worse. Thus, apparent conductivity readings in Potter's Field were likely to be similar to those just described. However, I was careful not to expect as many significant readings as metal containing graves may be minimal and different soil may not have been used. Overall, I was assured the instrument was successful in identifying soil disturbances and in this case: locating and delineating a grave.

CHAPTER 6

CONCLUSIONS

The 2002 – 2003 geophysical and remote sensing investigation of Emporia's Potter's Field demonstrated that technology, such as electromagnetic conductivity and kite aerial photography has the capacity to locate unmarked graves in clay-rich, eastern Kansas cemeteries. The electromagnetic conductivity technology can produce a time efficient, thorough investigation with good spatial coverage or can be done very precisely and accurately in a small area over an extended amount of time. I found for a detailed, precise location and delineation of unmarked graves, discrete measurements should be acquired. On the other hand, continuous data may be sufficient to delineate broader areas of disturbance vs. areas of non-disturbance. Regardless of data collection method, this research revealed that in order for the EM-38 to be successful, moderate soil moisture conditions must be present for apparent conductivity values to yield anomalous features.

Kite aerial photography was successful at distinguishing vegetative tonal differences in the rowed, east/west pattern associated with Christian burial practices. The method is cost-effective, time-efficient, and provides high-resolution photographs practical for delineating small features. This non-invasive method for identifying soil disturbances revealed unmarked graves outside of the plot map, which may have gone unrevealed with the use of geophysical technology alone. On the other hand, research revealed that site location and seasonality may affect the success rate of kite aerial photography.

Great differences in soil properties can occur even within short distances (Neill, 1981). Spatial variability is a factor that must be taken into consideration prior to every

EM or any geophysical survey. More research needs to be conducted in different soil conditions and properties throughout Kansas to determine which EM technique would be most effective and if other geophysical technologies would be more successful than the EM-38 in locating and delineating unmarked graves.

The EM-38 provided a thorough investigation of soil discontinuities and unmarked graves. As stated previously, horizontal dipole apparent conductivity readings may not always be a reliable method for locating and delineating the unmarked graves of Potter's Field. First, the horizontal dipole mode was too sensitive to variability in soil moisture. If an EM survey in this dipole orientation can be completed under consistent soil moisture conditions, this obstacle may be overcome. Second, a few surface artifacts caused false anomalies in the EM data preventing an accurate interpretation for the location and delineation of unmarked graves. Problems with shallow artifacts are probably inevitable for any survey and must be factored into data interpretation causing a certain percentage of error. My results indicated that for locating unmarked graves at standard depth, the EM-38 would be used most successfully in the vertical dipole orientation and complimented with the EM-38 used in the horizontal dipole orientation for gravelly clay-rich soil. With the exception of extremely saturated soil conditions, vertical dipole apparent conductivity readings do not appear to be as susceptible to changes in surface soil moisture as horizontal dipole readings. Furthermore, the depth response for the EM-38 in the vertical dipole is such that it is less sensitive to surface artifacts.

FUTURE RESEARCH

Future research is necessary to accurately test the effects of soil moisture variability on conductivity. Methods should include a sampling grid in non-disturbed soil to determine the effects of spatial variability of soil moisture content prior to surveying. Next, the non-disturbed soil should be fully saturated at which point another EM survey should be conducted in the exact method as the previous survey. Finally, the sampling grid should be allowed to significantly dry for a third EM survey to be conducted in the consistent manner. This test would accurately demonstrate the effects of soil moisture variability on apparent conductivity. To further examine moisture effects of disturbed soils, experiments should be conducted utilizing the same tests on known graves of different ages. Unfortunately, time and availability of equipment did not permit this in depth research to be conducted for this research project.

Research should also be conducted to test if metal-surveying flags actually interfered with apparent conductivity readings. EM surveys should be conducted twice over the same area: Once with the metal survey flags in place and once without. EM readings would have to be acquired on the same day, same exact location, and using same method to ensure consistency for both EM surveys. Unfortunately, time did not allow this EM test to be conducted so the effects of metal flags are not known.

For future kite aerial photography sessions at other sites, evaluating circumstances where soil disturbance has occurred after burials must be considered while determining the success of kite aerial photography. Such circumstances may include plowed fields, which may disrupt the pattern of buried features masking the presence of buried features. In the case of Potter's Field, kite aerial photography revealed unmarked graves, which may have gone unidentified with surface reconnaissance methods alone. Given this, it was determined that without knowing the location of potential buried features, kite aerial photography may be the most successful method for surveying a large spatial area in a time efficient manner. GIS georeferencing tools used for registering and rectifying imagery, proved to be a valuable tool for aerial photographs for accurate and precise location and delineation of revealed features for comparison with other results.

As in most field investigations, additional research is often necessary for a thorough understanding of successful methods and procedures. The knowledge of how to best utilize geophysical instruments in a given setting enable more precise and time-efficient site investigation. The instruments' capabilities to create imagery beneath and above the ground surface open up many opportunities for delineation, mapping, and straightforward analysis. These instruments provide stepping-stones on the path to future discoveries, protection, and preservation. With the advent of geophysical surveying and remote sensing technology, there now is a way to determine the existence of an unmarked grave.

LITERATURE CITED

Aber, J.S., S.W. Aber, and F. Pavri. 2002. Unmanned Small-Format Aerial Photography From Kites for Acquiring Large-Scale, High-Resolution, Multview-Angle Imagery. *Proceedings of the International Society for Photogrammetry and Remote Sensing.* 34:1-6.

Arc GIS. 2001. Environmental Science Research Institute. Computer Software. Redlands, California.

AZ Central. 2003. Phoenix Uncovers More on Hohokam. Online article @ http://www.azcentral.com (accessed 05/03).

BBC News. 2003. Skeletons Found in School Yard. Online article @ http://www.newvote.bbc.co.uk (accessed 03/03).

Bevan, B. W. 1983. Electromagnetics for Mapping Buried Earth Features. *Journal of Field Archaeology.* 10:1:47-54.

Clay, B.R. 2003. Conductivity (EM) Survey: A Survival Manual. *Cultural Resource Analysts, Inc.*

Conyers, L.B. and D. Goodman. 1997. *Ground Penetrating Radar.* AltaMira Press, Walnut Creek.

Cook, P.G. and G.R. Walker. 1992. Depth Profiles of Electrical Conductivity from Linear Combination of Electromagnetic Induction Measurement. *Soil Science Society of America Journal.* 5:1015-1022.

Ellwood, B.B. 1990. Electrical Resistivity Surveys in Two Historical Cemeteries in Northeast Texas: A Method for Delineating Unidentified Burial Shafts. *Society for Historical Archaeology*. 24:3:91-98.

Emporia Ledger. 1878. Lorent Blanc. *Emporia Ledger*. August 22, 1878. p. 3.

Emporia Weekly News. 1879. W.E. Riggs. *Emporia Weekly News.* October 17, 1879 p.3.

Emporia Weekly News. 1882. Maggie Gordon. *Emporia Weekly News.* June 22, 1882. p. 3.

France, D.L., T.J. Griffin, J.G. Swanburg, J.W. Lindemann, G.C. Davenport, V. Trammell, C.T. Armbrust, B. Kondratieff, A. Nelson, K. Castellano, and D. Hopkins. 1992. A Multidisciplinary Approach to the Detection of Clandestine Graves. *Journal of Forensic Science.* 37:6:1445-1458.

Geonics Limited. 2001. *Operating Instructions: EM38pro Data Logging System for Field Computer Pro4000.* Geonics Limited. Ontario, Canada.

Geonics Limited. 2002. *EM38B Ground Conductivity Meter: Dual Output Version Operating Manuel.* Geonics Limited. Ontario, Canada.

Kansas State University Research and Extension. 2002. Precipitation Summary of Kansas. Lyon County, Emporia. Online Reference @ http://www.oznet.ksu.edu/wdl/ (accessed on 6/03).

Matthew. 1978. *The Holy Bible: New International Version.* Matthew 24:27, p 1324. Zondervan Bible Publishers, Grand Rapids.

McNeill, J.D. 1980. *Electrical conductivity of soils and rocks.* Geonics Limited. Ontario, Canada.

Neill, J.T. 1981. *Soil Survey of Lyon County, Kansas.* U.S. Department of Agriculture, Soil Conservation Service and the Kansas Agricultural Experiment Station. Washington, D.C.: U.S. Government Printing Office. 96 p.

News 24. 2003. Ancient Remains of Teen Found. Online article @ http://www.news24.com (accessed on 05/03).

Smith-Rose, R.L. 1934. Electrical Measurements on Soil with Alternating Currents. *Proceedings of the Institute of Electrical Engineers.* 75:221-237.

Smoot, F. 2002. Facing East, the Traditional Burial Position. *USGenNet.* Online article @ http://www.tngenweb.org/darkside/facing-east.html (accessed on 02/03).

Trinkley, M. 1999. Penetrometer Survey of Settler's Cemetery, Charlotte, Mechlenburg County, North Carolina. *Chicora Research Contribution.* 273:1-14.

I, Elizabeth Rae Wilson-Agin, hereby submit this thesis/report to Emporia State University as partial fulfillment of the requirements for an advanced degree. I agree that the Library of the University may make it available to use in accordance with its regulations governing materials of this type. I further agree that quoting, photocopying, or other reproduction of this document is allowed for private study, scholarship (including teaching) and research purposes of a nonprofit nature. No copying which involves potential financial gain will be allowed without written permission of the author.

Elizabeth R. Wilson-Agin

Elizabeth R. Wilson-Agin (Author)

01-15-04

Date

The Use of Geophysical and Remote Sensing Technology to Locate and Delineate Unmarked Graves in Clay-Rich Soils of Kansas

(Thesis Title)

Darcy Cooper

Signature of Graduate Office Staff

1-16-04

Date Received

original