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GEOPHYSICAL INVESTIGATIONS AND ARCHEOLOGICAL MONITORING OF THE UNDERGROUND ELECTRIC LINE INSTALLATION PROJECT AREA AT THE FORT LARNED NATIONAL HISTORIC SITE, 14PA305, PAWNEE COUNTY, KANSAS

BY
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AND
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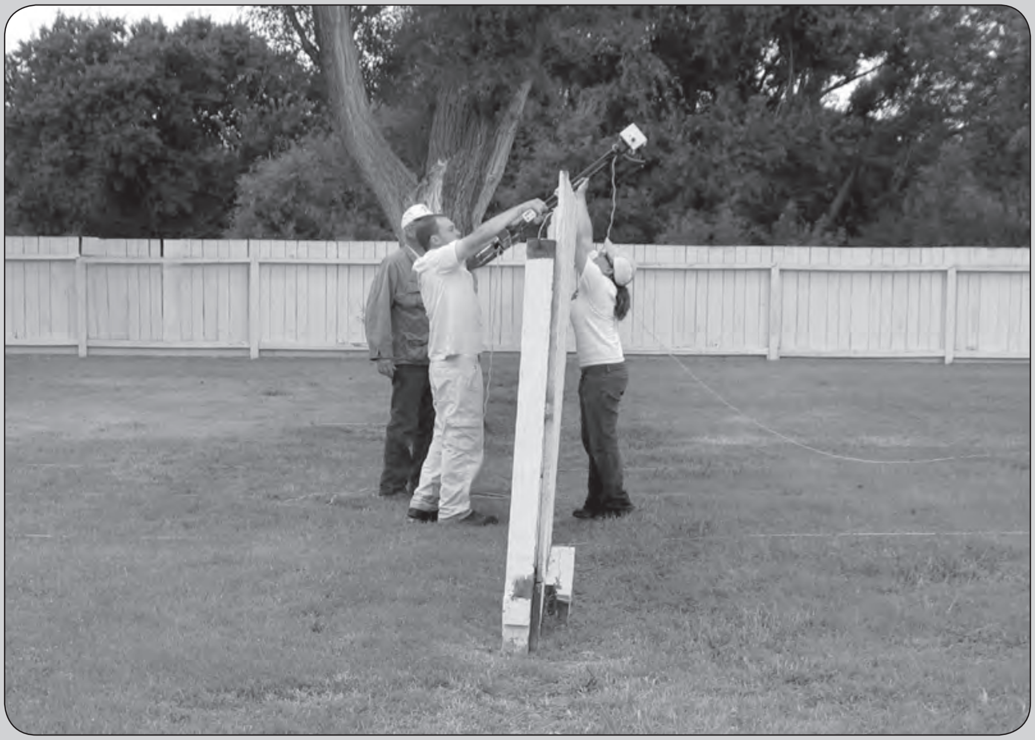

Technical Report 136

NATIONAL PARK SERVICE
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Lincoln, Nebraska
2014

This report has been reviewed against the criteria contained in 43CFR Part 7, Subpart A, Section 7.18 (a) (1) and, upon recommendation of the Midwest Regional Office and the Midwest Archeological Center, has been classified as

AVAILABLE

Making the report available meets the criteria of 43CFR Part 7, Subpart A, Section 7.18 (a) (1).

ABSTRACT

The National Park Service's Midwest Archeological Center staff with Volunteer-In-Parks participants conducted geophysical investigations of the underground electric line installation construction project at Fort Larned National Historic Site (14PA305) in Pawnee County, Kansas. The geophysical investigations were conducted between July 13 and July 18, 2009. The investigations were requested by the resource manager at Fort Larned National Historic Site. The project was located along the western side of the fort next to the row of Officers' Quarters. The geophysical survey included a magnetic survey with dual fluxgate gradiometer and a resistance survey with a resistance meter and twin-probe array. The geophysical survey was conducted in an attempt to identify any buried archeological remains associated with the fort in the vicinity of the construction project for the installation of the park's underground electric line. The archeological monitoring of the underground electric line installation occurred between November 17 and 19, 2009. The monitoring activities included the documentation of the installation line and new transformer locations with a global positioning system unit and the monitoring of excavations for the directional boring access pits. The geophysical survey identified numerous buried archeological remains associated with the remnants of the military activities at the site, as well as more recent 19th- and 20th-century farming and park activities at the site. The total area investigated by the geophysical survey in the FOLS geophysical project area was 16,161 m2 or 3.99 acres.

ACKNOWLEDGEMENTS

This project was completed with the support and assistance from the Fort Larned National Historic Site staff. Sincere appreciation is extended to the FOLS Superintendent Kevin McMurry, the FOLS Chief of Resource Management George Elmore, and the FOLS Facility Manager Bill Chapman who participated in the planning and implementation of the geophysical survey and archeological monitoring project. All of the FOLS park staff went out of their way to make the MWAC crew and volunteers feel welcome and provided assistance in getting the work done efficiently, safely, and as comfortably as possible during the archeological investigations.

The authors would also like to thank the Volunteers-In-Parks participants Laura McClatchey and David Wolf for their time and effort spent on the project. Their enthusiasm made the project much more enjoyable than it would have been without their participation. A total of 88 VIP hours were donated to the project.

At the Midwest Archeological Center, we would like to thank Dr. Mark Lynott (MWAC Manager) and Dr. Ralph Hartley (MWAC Archeological Assistance and Partnership Program Manager), both now retired, for their direction, leadership, and support during the project. We also appreciate the geophysical survey efforts of Drew LaBounty. We are also grateful for the support provided by Administrative Officer Jill Lewis, and the rest of the MWAC staff for all of their help without which this project would not have been completed as smoothly or efficiently as it was. Darin Schlake and Bryttie Duren provided logistical, computer, transportation, and personnel support during the project while Allan Weber and Jeff Larson provided editing and report preparation in the publishing of this document. We are grateful for their review comments of the draft manuscript.

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INTRODUCTION

The geophysical survey and archeological monitoring activities at Fort Larned National Historic Site (Site 14PA305), in Pawnee County, Kansas, were conducted as part of the National Park Service's (NPS) Midwest Archeological Center (MWAC) archeological assistance to the park's construction and compliance activities related to the installation of an underground electric line from overhead power lines on the west side of the park along 180th Avenue, a gravel county road. The investigations were requested by the park's resource specialist, George Elmore, to evaluate the archeological resources in the underground utility construction zone in compliance with Section 106 of the National Historic Preservation Act of 1966, as amended through 2006 (NPS 2006a:35-99).

Fort Larned National Historic Site (FOLS) was authorized by legislation enacted by the Congress of the United States in 1964 under Public Law 88-541 (FOLS 1995:6). The national historic site was established to commemorate the significant role of the fort in the opening of the West. The law provided for the acquisition of 750 ac of land including the fort site and nearby remains of the Santa Fe Trail along with scenic easements. Fort Larned served as a base of military operations against the hostile Plains Indians and for protection of commerce along the eastern part of the Santa Fe Trail during the 1860s and 1870s. The military post also served as the Indian Bureau Agency for the administration of the terms of the Fort Wise Treaty of 1861 with the Central Plains Indian tribes.

The geophysical investigations were conducted from July 13 to July 18, 2009, along the western side of the fort next to the row of Officers' Quarters (Figure 1). The geophysical survey included a magnetic survey with dual fluxgate gradiometer and a resistance survey with a resistance meter and twin-probe array. These techniques offered inexpensive, rapid, and relatively non-destructive and non-invasive methods of identifying buried archeological resources and site patterns that were detectable; they also provided a means for sampling relatively large areas in an efficient manner (Roosevelt 2007:444-445; and Von Der Osten-Woldenburg 2005:621-626). The geophysical survey was conducted in an attempt to identify buried archeological remains associated with the fort in the vicinity of the construction project corridor for the installation of the park's underground electric line. The geophysical survey was conducted by MWAC archeologist Steven L. De Vore and archeological technician Andrew "Drew" LaBounty. Volunteers-In-Parks (VIP) program participants during the geophysical investigations included Laura McClatchey and David Wolf.

The archeological monitoring of the underground electric line installation occurred between November 17 and 19, 2009. The monitoring activities were conducted by MWAC archeologist Melissa A. Baier. The monitoring activities included the documentation of the installation line and new transformer locations with a global positioning system (GPS) unit and the monitoring of the excavations of directional boring access pits.

ENVIRONMENTAL SETTING

Fort Larned National Historic Site is located within the Plains Border section of the Great Plains province of the Interior Plains division of the North American continent (Fenneman 1931:25-30). The site also lies within the Rolling Plains and Breaks land resource region of the Central Great Plains Winter Wheat and Range Region major land resource area (USDA 2006:195-196,200-202). The region consists of submature to mature dissected plains. The dissected plains are broad with undulating and rolling uplands that generally contain narrow valleys with steep hilly side slopes. Local relief in the region is measured in meters to tens of meters. However, broad flood plains and terraces occur along the larger rivers. Fort Larned is located on the right or south bank of the Pawnee Fork, a tributary of the Arkansas River. The area surrounding Fort Larned is relatively flat with featureless terraces and bottom lands of the Great Bend lowland region of the Arkansas River lowlands (Schoewe 1949:291-296). The area is transected by numerous abandoned channels of the Pawnee Fork. Sedimentary rock outcrops in the county range from the Cretaceous to Quaternary periods (McLaughlin 1949; Schoewe 1949:261-273). Terrace deposits along the Pawnee Fork consist of Pleistocene and Holocene Epoch alluvium from the Quaternary Period; however, some of the alluvial deposits may date to the Tertiary Period.

The area also lies on the western edge of the Illinoian biotic province (Dice 1943:21-23). The native vegetation is dominated by mixed grass prairie vegetation, which consists of tall and mid-height grasses. Little bluestem, big bluestem, switchgrass, sideoats grama, and western wheatgrass represent the major grass species (Brown 1985:46-53; Dodge and Roth 1978:65; Küchler 1974; Shelford 1963:334-344; USDA 2006:202). Stands of cottonwoods occur on the flood plains along the major rivers. Numerous species of forbs are also present including sunflowers, goldenrods, and ragweed. Wildlife in the region includes white-tailed deer, coyote, raccoon, black-tailed jackrabbit, pheasant, bobwhite quail, meadowlark, and mourning dove along with a variety of songbirds, rodents and smaller mammals, reptiles, amphibians, insects, and aquatic fauna, including bass, catfish, bluegill, and bullhead (Brown 1985:46-53; Shelford 1963:334-344; USDA 2006:202). Bison, pronghorn antelope, elk, and wolves were present in the region during the prehistoric and early historic periods.

Mollisols dominate the soil groups in the region (Foth and Schafer 1980:111-142; USDA 2006:202). Entisols are also present but to a lesser extent (Foth and Schafer 1980:37-62; USDA 2006:202). The loamy to clayey soils range from shallow to very deep and moderately well drained to somewhat excessively drained. The soil temperature is a mesic regime. The soils also have an ustic soil moisture regime (USDA 2006:202). Within the immediate project area, the soils belong to the New Cambria-Bridgeport-Hord soil association identified by "deep, nearly level, well drained and moderately well drained soils that have a silt loam to silty clay subsoil (Dodge and Roth 1978:4). The soil within the project area is identified as a Bridgeport silt loam" (soil mapping unit Br) with 0 to 2 percent slopes (Dodge and Roth 1978:8,37). The nearly level Bridgeport soil is a deep, well-drained soil found on low terraces, which are occasionally flooded. The silt loam soil is formed in silty alluvial sediments on long, convex areas adjacent to major streams. It is moderately permeable with a high available water capacity. Fertility is high while the runoff rate is slow. The soil has a low shrink-swell potential. The surface layer is very friable. It has a moderately alkaline pH reaction (Dodge and Roth 1978:8,37).

The climate is a temperate continental climate with warm summers and cold winters (Bark 1978:2-3; Trewartha and Horn 1980:299-302; USDA 2006:201). Annual precipitation averages 60 cm. Most of the precipitation occurs in the form of rain between April and September. Snowfalls can be heavy with an annual average of 55 cm. The average annual temperature is 13.4° C with a January daily average of -0.39° C and a July daily average of 26.7° C (Bark 1978:60-61). The region averages a freeze-free period of approximately 180 days ranging from 145 to 210 days (USDA 2006:201). The prevailing winds are from the south. Severe windstorms can occur along with occasional tornadoes in well-developed thunderstorms (Bark 1978:2-3).

CULTURAL HISTORY OF THE FORT LARNED NATIONAL HISTORIC SITE

Little physical evidence is available from archeological investigations of the Fort Larned National Historic Site for the prehistoric occupation of the area (Boszhardt and Bednarchuk 2008). The numerous archeological investigations at the park have focused on the historic military occupation of Fort Larned (MWAC 1998). Information concerning the prehistoric use of the region is summarized in the publications of Robert J Hoard and William E. Banks (2006), Patricia J. O'Brien (1984), John D. Reynolds and William B. Lees (2004), and Waldo R. Wedel (1959). The project area lies within the Arkansas River Lowlands archeological study unit (Brown 1987:XVI-1—XVI-16).

The prehistoric period has been divided into several traditions denoting changes in technology, subsistence, and settlement patterns. The project area lies within the Central Plains Subarea of the Plains archeological cultural area of North America (Willey 1966:311-329). The prehistoric period is generally divided into the Paleoindian (11,000-7,000 B.C), Archaic 7,000 B.C. to A.D. 1), Ceramic (A.D. 1-1500), and Protohistoric (A.D. 1500-1800) periods, although the durations and manifestations of any individual tradition are specific to the local region. The historic period begins in 1541 with the arrival of Coronado's band of Spanish explorers. The historic period (Holt 1990; HPD 1984,1987; Lees 1989; Reynolds and Lees 2004:44-55) has been divided into five separate study contexts including the European and American exploration and contact with Native Americans (1541-1820), American exploration and settlement (1820-1865), rural and agricultural dominance (1865-1900), time of contrasts (1900-1939), and the recent past (1939-present).

Prehistoric Periods

The prehistoric periods have been described in several publications. The prehistoric contexts have been summarized by Patricia J. O'Brien (1984) and in the State's prehistoric archeological preservation plan by Kenneth L. Brown (1987:XVI-1—XVI-16) and Kenneth L. Brown and Marie E. Brown (1987:IX-1—IX-26). These include the Paleoindian Period (11,000 to 7,000 B.C.), the Archaic Period (7,000 B.C.to A. D. 1), the Ceramic Period (A.D. 1-1500), and the Protohistoric Period (A.D. 1500-1541).

The Paleoindian Period in the Arkansas River lowlands is poorly represented in the archeological record (Blackmar and Hofman 2006:46-75; Brown and Brown 1987:IX-16—IX-24; O'Brien 1984:27-37; Reynolds and Lees 2004:11-14; Wedel 1959:536-538). The Paleoindians are represented by small bands of nomadic hunter-gatherers who subsisted off large game animals such as mammoths and bison, as well as other Pleistocene fauna and supplemented their diets with seeds, roots, berries, nuts, and small animals. The Paleoindian Period is divided into three stages based on projectile point forms: 1) Llano or Clovis Complex (11,000-9,000 B.C.), 2) Folsom Complex (9,000-8,000 B.C.), and 3) Plano Complexes (8,000-7,000 B.C.). In the Arkansas River lowlands, the Paleoindian period is represented by isolated finds of Clovis and later Paleoindian projectile points (Brown and Brown 1987:IX-1—IX-26).

The Archaic Period represents a shift in the reliance on large game to an increasing diversity of technologies associated with hunting, fishing, trapping, foraging, plant processing, and woodworking. The Archaic is further divided into the Early (6,000-5,000 B.C.), Middle (5,000-2,000 B.C.), and Late Archaic (2,000 B.C-A. D. 1) stages with increases in highly regionalized adaptation to local environmental niches and increasing populations (Blackmar and Hofman 2006:46-75; O'Brien 1984:39-44; Reynolds and Lees 2004:14-22; Wedel 1959:538-542). Stemmed and notched projectile points dominate the tool kit. Ground-stone tools are being incorporated into the Archaic tool kit for grinding seeds into meal. Subsistence consists of a seasonal round of exploitation of a diversity of faunal and floral resources. Habitation sites are becoming more permanent with increasing populations. The Archaic period within the Arkansas River lowlands is not very well represented.

The Ceramic Period spans the Early Ceramic or Plains Woodland period (A.D. 1-1000), the Middle Ceramic period (A.D. 900-1500), and the Late Ceramic or Protohistoric period (A.D. 1500-1825). The Early Ceramic period is marked by the introduction of pottery, as well as changes in social organization, subsistence strategies, and technology (Bozell 2006:93-104; Logan 2006:76-92; O'Brien 1984:45-55; Reynolds and Lees 2004:22-32; Wedel 1959:542-557). Bow-and-arrow technology is introduced during the Early Ceramic period. Subsistence is largely based on hunting and intensive plant gathering; however, by the end of the Early Ceramic period, incipient plant domestication is occurring along with the introduction of tropical cultigens such as maize. Mound construction associated with mortuary activities occur across the eastern United States including the eastern and northern parts of Kansas. Hopewellian influences from Ohio are documented in the eastern part of the state. The Early Ceramic period within the Arkansas River lowlands is not very well represented. The Middle Ceramic period in the eastern United States is associated with the Mississippian cultures with their development of urban centers and temple mounds. The Middle Ceramic cultures have adapted a dual economy with maize, squash, and bean agriculture supplemented by hunting and wild food gathering. The bow and arrow becomes widespread during the period. Introduction of the rectangular earthlodge occurs in the northern part of the state associated with the Central Plains Tradition village farmers of the Upper Republican, Nebraska, and Smoky Hill complexes (O'Brien 1984:59-62; Reynolds and Lees 2004:32-41; Roper 2006:105-132; Wedel 1959:557). The Middle Ceramic period in central Kansas, including Pawnee County, is defined by the poorly documented Pratt Culture (Brown 1987:XVI-2—XVI-5; Wedel 1959:503-512). The Pratt complex exhibits aspects of the Central Plains tradition and the Southern Plains cultures. The economy consists of hunting, gathering, and agriculture. Structures consist of flattened sides with rounded and braced corners with four center support posts and a central hearth and interior cache pits. Artifacts consist of small, notched and unnotched triangular projectile points, alternately beveled diamond-shaped knives, bone tools, and sand tempered and shell tempered ceramics. The Late Ceramic period, including the protohistoric and early historic tribal periods, consist of the Great Bend aspect, the historic Wichita, and the Dismal River aspect/Plains Apache (Blakeslee and Hawley 2006:165-179; Brown 1987:XVI-6—XVI-16; Lees 1989:69-71,83-84; Marshall 2006:219-232; O'Brien 1984:67-78; Reynolds and Lees 2004:41-44; Scheiber 2006:133-150; Vehik 2006:206-218; Wedel 1959:47-82,571-615). The Late Ceramic period represents a period of change in the Great Plains region of Kansas with the arrival of the European explorers in Kansas, including the Spanish under Coronado in 1541 and the French under de Bourgmont in 1724. During this period, specific historic tribes, such as the Kansas, Pawnee, Wichita, and Plains Apache are identifiable in the archeological record. The period ends with the removal of Native American tribes from the Eastern United States into Kansas in the early 1800s. The period presents the development of historic Native American tribes and the initial contact of the tribes with European explorers. The Great Bend aspect in central and southern Kansas is associated with the development of the historic Wichita while the Dismal River aspect is associated with the historic Apache and the Oneota aspect may be associated with the Kansa. The Wichita, Pawnee, and Kansa represent agricultural villagers while the Plains Apache remain nomadic.

Historic Periods

Compared to the prehistoric period in the region, the historic periods are extremely well documented. The initial exploration of the region by Europeans and contact with Native American tribes in Kansas had a profound effect on the native populations during the historic period between 1541 and 1825. The 16th-century explorations by the Spanish with Coronado in 1541, Onate in 1601, and Ulibarri in 1706, and the 17th-century explorations by the French explorers de Bourgmont in 1724 and Trudeau in 1794 provide written accounts of their observations of the landscape and interactions with Native American tribes (Lees 1989:71; Reynolds and Lees 2004:44-48). The American Lewis and Clark 1804-1086 expedition traveled along the northeastern part of Kansas while Pike in 1806 traveled across Kansas to Colorado and New Mexico. Thomas Say of the Stephen Long expedition provided additional insight into the Kansas territory in 1819 (Lees 1989:69-71).

Between 1820 and 1865, Kansas saw the resettlement of many eastern Native American tribes, as well the establishment of American settlement within the state (HPD 1987; Lees 1989:71-73; Reynolds and Lees 2004:48-51). While the Pawnee, Wichita, and Plains Apache were no longer permanent residents in the state, the Kansa and the Osage remained important state residents. During the late 1820s and the 1830s, several eastern woodland tribes including the Sac and Fox, the Ioway, the Illinois, the Otoe, Delaware, Cherokee, Chippewa, and others were resettled in eastern Kansas (O'Brien 1984:79-82). In addition to the Native American tribes, American missionaries and traders moved into the state to work with the tribes. The Santa Fe Trail and the Oregon and California trails carried American emigrants and commerce across Kansas during this period. Kansas Territory was established in 1854 under the Kansas-Nebraska Act. In 1861, Kansas was admitted to the Union. American settlement occurred rapidly along the eastern third of the state. Settlement during this portion of the period was characterized by the establishment of forts, farms, roads, schools, towns, and the completion of the government land office surveys of the state (O'Brien 1984:83-86). In the years leading up to the Civil War and during the Civil War, eastern Kansas was the focus of much violence over the issue of slavery. Fort Larned was established along the Santa Fe Trail in 1860. The Indian War of 1864 resulted in hostilities between the Plains Indians and the American settlers in the state.

Following the Civil War, Kansas developed from a frontier to a state with a diversified economy during the period of rural and agricultural dominance between

1865 and 1900 (HPD 1984; Lees 1989:73-74; Reynolds and Lees 2004:51-53). Most of these tribes were moved elsewhere by the 1870s, although the Iowa Tribe of Kansas and Nebraska, the Kickapoo Tribe of Indians in Kansas, the Prairie Band Potawatomi Nation, and the Sac and Fox Nation retained reservations within the state to the present day. This opened more land in the state to American settlement. Railroad construction in Kansas began in the late 1860s. The railroads played a significant role in the further development of the state's agricultural dominance throughout the period. The location of the railroads played an important role in the deciding factor in the location of new towns across the state. During this period, the state's agricultural economy focused on wheat cultivation and on livestock production and processing. During the early part of the period, Kansas railheads provided shipping points for the Texas cattle drives to the eastern market places. Additional hostilities with the Plains Indians resulted in conflicts during 1867 and 1868. By 1870, American settlement in the eastern half of the state was complete. In 1877, a large group of Cheyenne left their Oklahoma reservation and crossed Kansas. By 1890, the entire state was settled; however, this was not without severe hardships for the American emigrants. The economic collapse in the 1890s resulted in the decrease in the farming population in the western part of the state; however, this economic downturn was to provide development of the state's mineral extraction industries, including drilling for oil and natural gas and mining for coal and salt. The Fort Larned military reservation was transferred from the Department of War to the Department of the Interior's General Land Office in 1883. In 1884, the buildings and lands of the military reservation were sold at public auction and adapted for use as a private ranch (Quinn Evans/Architects 1996:1-1—1-3).

During the time of contrast from 1900 to 1939, the agricultural industry in the state rebounded with increasing mechanization and diversity (Holt 1990; Lees 1989:74-75; Reynolds and Lees 2004:53-54). The mineral extraction industries continued to expand throughout the period. The automobile was becoming an important means of transportation for people and goods during this period. World War I and the Great Depression also had significant impacts on the state's economy and population. The 1930s drought had a major impact on the state, especially in the agricultural region in western Kansas.

The recent past from1939 to the present resulted in many major changes in the nation, which were also represented in the state (Lees 1989:75; Reynolds and Lees 2004:54-55). World War II had a major impact on the state's population with increases in military training at the army and army air corps bases and the deployment of the fighting men overseas. Women filled the industrial and manufacturing roles that the men had occupied prior to the start of the war. Prisoner-of-War camps were established throughout the state. Following the war, the period continued to see a decline in the rural population with smaller farms and communities suffering from the movement away from the rural areas to larger urban areas. Following the war large-scale land leveling and agricultural terracing made it possible for fewer farmers to grow the crops and livestock needed to produce the grain, dairy, and meat for public consumption. Federal highway and reservoir construction also altered the landscape. In 1957, the Fort Larned Historical Society was founded and opened the old fort to the public. The Fort Larned site was designated a National Historic Landmark in 1960. In 1964, Congress authorized the establishment of the Fort Larned National Historic Site as a national park unit. The fort property was acquired by the National Park Service in 1966. The National Park Service continued to restore the fort's buildings to represent the 1868 military use since becoming a National Historic Site (Quinn Evans/Architects 1996:2-28—2-30).

PREVIOUS CULTURAL RESOURCE INVESTIGATIONS

The cultural resource investigations at the Fort Larned National Historic Site have produced numerous archeological reports, which are summarized in the cultural sites inventory for the park (MWAC 1998, 2007). The first archeological investigations at the site in the late 1960s, the 1970s, the 1980s, and the 1990s occurred as preliminary steps in the reconstruction of the military post (Albright and Scott 1974; Dial 1991; Hunt 1983; Griffin 1991; Monger 1981; Perttula and Shaw 1980; Richner 1979; Scott 1974, 1975, 1998a, 1998b; Spears 1978; Sudderth 1981, 1983a, 1983b; Thiessen 1983; Zalucha and Olinger 1976a, 1976b). Other archeological projects in the 1970s included the archeological survey of a detached landholding containing trail ruts associated with the Santa Fe Trail southwest of the park (Nickel 1975), the archeological survey of a proposed sandstone quarry exhibit (Nickel 1987), salvage archeology associated with the construction of the museum and visitors center (Monger 1976), construction of the maintenance facility (Lees 1984), archeological monitoring of utility line installations and reconstruction activities (Elmore 1983a, 1983b, 1984, 1986, 1988a, 1988b, 1989; Griffin 1987; Hunt 1990; Monger 1980; Thiessen 1987), and other archeological compliance-related projects (Scott 2005). In addition to the archeological investigations, geophysical investigations at the fort included the magnetic survey of HS-3 and suspected privy location (Weymouth 1978), the metal-detector survey of the proposed new visitors center location (Scott 1995), and the geophysical investigations of the potential location for the Cavalry Stables (Kern and De Vore 1999).

A number of histories have been written about Fort Larned and its association with the Santa Fe Trail (Brown 1964; Oliva 1985, 1990, 1997; Reaves 1995; Unrau 1956; Utley and Watkins 1993). In addition to the histories, several historic furnishing studies and structure reports, management documents, and other cultural resource studies related to Fort Larned National Historic Site were compiled for the park since its establishment in 1966 (Albright and Scott 1974; Clemensen 1978, 1980; Cockrell et al. 1991; FOLS 1988, 1995; MWRO 1978; Quinn Evans/ Architects 1996, 1999; Rickey and Crellin 1967; Sheire 1968, 1969; Stinson 1966).

PRESENT GEOPHYSICAL AND ARCHEOLOGICAL INVESTIGATIONS

The archeological/geophysical project area is located around the northwest, west, and southwest perimeter of the buildings surrounding the quadrangular parade ground (Figures 2, 3, and 4). The investigations are concentrated along the back side of the Officers' Row buildings on the west side of the parade ground along the route of the proposed utility line that had been flagged by the Midwest Energy, Inc., personnel. The proposed route is slightly different from the originally proposed route and the existing buried electrical utility line. The majority of the route will be bored underground with access points for connections placed in vaults.

The 2009 archeological investigations of the underground electric line installation project corridor consists of two phases with the geophysical survey representing the first phase and archeological monitoring of the utility line installation representing the second phase of the field project. The geophysical phase includes the survey of the project area with a dual fluxgate gradiometer system and a resistance meter and twin-probe array. The monitoring phase includes the visual inspection of the excavation of the access pits for the directional boring of the underground utility lines and the connection of the new line with the existing utility lines connecting the fort buildings.

Geophysical Survey Methods

The geophysical survey project at the Fort Larned National Historic Site (Site 14PA305) included the area behind the row of Officers' housing on the southwest, west, and northwest sides of the fort's parade ground. The geophysical project area was located to the west of the park's two-track access road extending south of the gravel access road on the south side of Officers' Row and north of the farm era irrigation ditch, in the backyards of HS-7 and HS-8 and west of the backyard fences of the Officers' Quarters between the wood fences and the bank of Pawnee Fork, and on the north side of Officers' Row to the park entrance road and the bank of Pawnee Fork. The project area was planted in domestic grasses. Thirty-four complete and 16 partial 20-m-by-20-m grid units, which were used to control the placement of the instruments during data acquisition, were established in the FOLS geophysical project area (De Vore 2009). The total area investigated by the geophysical survey in the FOLS geophysical project area was 16,161 m^2 or 3.99 ac.

Initially, the mapping station for the surveying compass (Ushikata 2005) and first geophysical grid point with the arbitrary mapping coordinates of N60/E100 was established 1 m west of the southwest corner of the Company Officers' Quarters (HS-7) backyard fence and approximately 5 cm south of the southern fence wall (Figure 5). A reference point was placed to the north of the mapping station at one meter from the west wooden fence line to serve as a backsight to establish the geophysical grid's north-south baseline. The baseline orientation was 27.5° west of magnetic north. The southern portion of the north-south base line established with the surveying compass and a 100-m tape. The grid baseline was established with wooden hub stakes placed at 20-m intervals out to 100 m south of the initial mapping station. The east-west baseline extended 40 m to the east and 60 m to the west. The rest of the north-south baseline to the north of the initial mapping station extended an additional 189 m at 20-m intervals until the final grid stake was placed near the edge of the levee above the Pawnee Fork. Additional grid unit stakes were placed on the east and west sides of the north-south baseline stakes with the grid extending 40 m to the east and 60 m to the west of the baseline.

Twenty-meter ropes were placed along the east-west grid lines connecting the grid unit corners. These ropes formed the north and south boundaries of each grid unit during the data collection phase of the survey. Additional ropes were placed at 1-m intervals across the grid unit in a north-south orientation (Figure 6). The survey ropes served as guides during the data acquisition. The ropes were marked with different color tape at half-meter and meter increments designed to help guide the survey effort. Once the geophysical survey of each grid unit was completed the survey ropes were flipped to the next adjacent grid unit. As the survey activities progressed across the geophysical project area, a sketch map was completed indentifying both cultural and natural surface features in the project area (Figure 7). The geophysical data were acquired across the grid units beginning in the lower left hand corner of each grid unit (Geoscan Research 1987:43-54,2003:5/2-5/11).

Site Mapping Methods

The geophysical survey grid corner stakes at the project area within the FOLS geophysical project area were mapped with a Trimble GeoXH global positioning system (GPS) handheld receiver and external antenna (Trimble 2007a) along with surface features including access roads, the irrigation ditch, trees, the Pawnee Fork bank and levee, etc. The GPS readings at stationary points (i.e., grid unit corners and individual surface features) were collected with 30 readings from five or more satellites while line segment data were collected at one second intervals along the path of the line. The field GPS data were collected in the universal transverse mercator (UTM) projection for the Zone 14 North coordinates of the North American Datum of 1983 (NAD83) horizontal datum. The data were transferred to a laptop computer via the Trimble TerraSync software (Trimble 2007b,2007c). The data were then differentially corrected using the Trimble Pathfinder Office software (Trimble 2007d) using the continuously operating reference station (CORS) HAVILAND (HVLK) site located 60 km away at Haviland, Kansas (Table 1). Four files were processed with 2,777 (93.8%) of 2,959 selected positions were code corrected by post-processed. One thousand four hundred sixty-six (49.5%) of 2,959 selected positions were carrier corrected by post-processing with one (0.1%) of the code positions chosen over carrier since it was higher quality. The estimated range for the 2,959 corrected positions yielded 2.8% within an accuracy range of 0-15 cm, 14.2% within and accuracy range of 15-30 cm, 219.8% within an accuracy range of 30-50 cm, 9.7% within an accuracy range of 0.5-1.0 m, 1.0% within an accuracy range of 1.0-2.0 m, 43.9% within an accuracy range of 2.0-5.0 m, and 8.6% at an accuracy range greater than 5.0 m. The high DOP values resulted from a variety of sources including multi-pathing of the satellite signal through the overhead tree canopy, poor satellite geometry, and the number of satellites present during the collection phase. After the raw survey data in the standard storage format (SSF) was post processed, the corrected data were exported to Excel data files and imported into Surfer 9 (Golden Software 2009) for final display (Figure 8).

Geophysical Prospection Techniques

Geophysical prospection techniques available for archeological investigations consist of a number of techniques that record the various physical properties of earth, typically in the upper couple of meters; however, deeper prospection can be utilized if necessary. Geophysical techniques are divided between passive techniques and active techniques. Passive techniques are primarily ones that measure inherently or naturally occurring local or planetary fields created by earth-related processes under study (Heimmer and DeVore 1995:7,2000:55; Kvamme 2001:356,2005:424). The primary passive method utilized in archeology is magnetic surveying. Other passive methods with limited archeological applications include self-potential methods, gravity survey techniques, and differential thermal analysis. Active techniques transmit an electrical, electromagnetic, or acoustic signal into the ground (Heimmer and DeVore 1995:9,2000:58-59; Kvamme 2001:355-356). The interaction of these signals and buried materials produces altered return signals that are measured by the appropriate geophysical instruments. Changes in the transmitted signal of amplitude, frequency, wavelength, and time-delay properties may be observable. Active methods applicable to archeological investigations include electrical resistance/resistivity, electromagnetic conductivity (including ground-conductivity and metal detectors), magnetic susceptibility, and ground-penetrating radar. Acoustic active techniques, including seismic, sonar, and acoustic sounding, have very limited or specific archeological applications. Additional information on the basic geophysical techniques used during the present survey may be found in publications by Arnold Aspinall, Chris Gaffney, and Armin Schmidt (2008), Bruce Bevan (1991,1998), Anthony Clark (2000), Lawrence B. Conyers (2004), Lawrence B. Conyers and Dean Goodman (1997), Andrew David (1995, 2001), Rinita Dalan (2008), Andrew David, Neil Linford, and Paul Linford (2008), Chris Gaffney and John Gater (2003), Chris Gaffney, John Gater, and Sue Ovenden (1991, 2002), Don H. Heimmer and Steven L. De Vore (1995, 2000), Kenneth Kvamme (2001, 2003, 2005), I. Scollar, A. Tabbagh, A. Hesse, and I. Herzog (1990), and John Weymouth (1986).

Magnetic Survey

A magnetic survey is a passive geophysical survey (see Aspinall et al. 2008; Bevan 1991, 1998:29-43; Breiner 1973;1992:313-381; Burger 1992:389-452; Clark 2000:92-98, 174-175; Davenport 2001: 50-71; David 1995:17-20; David et al. 2008:20-24; Dobrin and Savit 1988:633-749; Gaffney and Gater 2003:36-42, 61-72; Gaffney et al. 1991:6, 2002:7-9; Hanson et al. 2005:151-175; Heimmer and DeVore 1995:13, 2000:55-56; Kvamme 2001:357-358, 2003:441, 2005:434-436, 2006a:205-233, 2006b:235-250; Lowrie 1997:229-306; Milsom 2003:51-70; Mussett and Khan 2000:139-180; Nishimura 2001:546-547; Oswin 2009:43-54, 126-135; Robinson and Çoruh 1988:333-444; Scollar et al. 1990:375-519; Telford et al. 1990:62-135; Weymouth 1986:343; and Witten 2006:73-116 for more details on magnetic surveying). A dual system fluxgate gradiometer was used during the geophysical investigations at the FOLS geophysical project area.

A magnetic survey is a passive geophysical prospection technique used to measure the earth's total magnetic field at a point location. Its application to archeology results from the local effects of magnetic materials on the earth's magnetic field. These anomalous conditions result from magnetic materials and minerals buried in the soil matrix. Iron artifacts have very strong effects on the local earth's magnetic field. Other cultural features that affect the local earth's magnetic field include fire hearths and soil disturbances (e.g., pits, mounds, wells, pithouses, and dugouts), as well as geological strata. Magnetic field strength is measured in nanoteslas (nT; Sheriff 1973:148). In North America, the earth's magnetic field strength ranges from 40,000 to 60,000 nT with an inclination of approximately 60° to 70° (Milsom 2003:43; Weymouth 1986:341). The project area has a magnetic field strength of approximately 59,280 nT (Peddie 1992; Sharma 1997:72-73) with an inclination of approximately 71° 36' (Peddie and Zunde 1988; Sharma 1997:72-73). Magnetic anomalies of archeological interest are often in the ±5 nT range, especially on prehistoric sites. Target depth in magnetic surveys depends on the magnetic susceptibility of the soil and the buried features and objects. For most archeological surveys, target depth is generally confined to the upper 1-2 m below the ground surface with 3 m representing the maximum limit (Clark 2000:78-80; Kvamme 2001:358). Magnetic surveying applications to archeological investigations have included the detection of architectural features, soil disturbances, and magnetic objects/artifacts (Bevan 1991; Clark 2000;92-98; Gaffney et al 1991:6; Heimmer and DeVore 1995,2000; Weymouth 1986:343).

Two modes of operation for magnetic surveys exist: the total field survey and the gradient survey. The instrument used to measure the magnetic field strength is the magnetometer (Bevan 1998:20). The total field survey uses a single magnetic sensor. Three different types of magnetic sensors have been used in the magnetometer: 1) proton-free precession sensors, 2) alkali vapor (cesium or rubidium) sensors, and 3) fluxgate sensors (for a detailed description of the types of magnetometers constructed from these sensors see Clark 2000:66-71; Milsom 2003:45-47; Scollar et al. 1990:450-469; Weymouth 1986:343-344).

The total field magnetometer is designed to measure the absolute intensity of the local magnetic field. This type of magnetometer utilizes a single sensor. Due to diurnal variation of the earth's magnetic field, the data collected with a single sensor magnetometer must be corrected to reflect these diurnal changes. One method is to return to a known point and take a reading that can be used to correct the diurnal variation. A second method is to use two magnetometers with one operated at a fixed base station collecting the diurnal variation in the magnetic field. The second magnetometer is used to collect the field data in the area of archeological interest. Common magnetometers of this types used in archaeological investigations include the proton-precession magnetometer, the Overhauser effect magnetometer (a variation of the proton-precession magnetometer), and the cesium magnetometer.

The magnetic gradient survey is conducted with a gradiometer or a magnetometer with two magnetic sensors at a fixed vertical distance apart. The instrument measures the magnetic field at two separate heights. The top sensor reading is subtracted from the bottom sensor reading. The resulting difference is recorded. This provides the vertical gradient or change in the magnetic field. Diurnal variations are automatically canceled.

This setup also minimizes long-range trends. The gradiometer provides greater feature resolution and potentially provides better classification of the magnetic anomalies. Two commonly used gradiometers in archeological investigations are the cesium gradiometer and the fluxgate gradiometer. They are capable of yielding 5 to 10 measurements per second at a resolution of 0.1 nT (Kvamme 2001:358). Cesium gradiometers record the absolute total field values like the single-sensor total field magnetometers. It also records the gradient change between the bottom and top sensors. The fluxgate sensors are highly directional, measuring only the component of the field parallel to the sensor's axis (Clark 2000:69). They also require calibration (Milsom 2003:46-47). Both cesium and fluxgate gradiometers are capable of high-density sampling over substantial areas at a relatively rapid rate of acquisition (Clark 2000:69-71; Milsom 2003:46-47).

The dual fluxgate gradiometer system, the Bartington Grad 601-2 single axis magnetic gradiometer (Figure 9), is a vector magnetometer, which measures the strength of the magnetic field in a particular direction (Bartington Instruments 2007). The dual fluxgate gradiometer sensor configuration of the instrument uses two fluxgate gradiometer sensor tubes separated by a distance of 1 m. The dual gradiometer records two lines of data during each traverse reducing the distance walked and the survey time by half compared to the time and distance covered with a single gradiometer system. The sensors must be accurately balanced and aligned along the direction of the field component to be measured. The first reference point for balancing and aligning the dual gradiometer is located at N0/E60; however, it was moved to N0/E40 during the course of the magnetic survey. The instrument is aligned on magnetic north. The fluxgate gradiometer sensor tubes in the dual gradiometer are spaced 1 m apart with the two tubes also spaced at 1 m apart. The instrument is carried so the two sensors in each tube are vertical to one another with the bottom sensors approximately 30 cm above the ground. Each sensor reads the magnetic field strength at its height above the ground. The gradient or change of the magnetic field strength between the two vertical sensors is recorded in the instrument's memory for both sensor tubes. These gradients are not in absolute field values but rather voltage changes, which are calibrated in terms of the magnetic field strength. The dual fluxgate gradiometer also provides a continuous record of the magnetic field strength across each line for each traverse across the grid unit.

The magnetic survey for the dual fluxgate gradiometer was designed to collect eight samples per meter along 1.0-m traverses or eight data values per square meter at the FOLS geophysical project area (Table 2). The data were collected in a zigzag fashion with the surveyor alternating the direction of travel along each traverse across the grid. Thirty-two hundred data values were collected for each complete 20-m-by-20-m grid unit surveyed during the project. The magnetic data were recorded in the memory of the dual fluxgate gradiometer and downloaded to a field laptop computer when the instrument's memory became full, at the end of the day, and at the completion of the survey in the FOLS geophysical project area. The magnetic data from the dual fluxgate gradiometer were downloaded into the Bartington GRAD 601 software (Bartington 2007). The data were then imported into ARCHAEOSURVEYOR for processing (DW Consulting 2008). Shade-relief and trace-line plots were generated in the field before the instrument's memory was cleared.

Resistance Survey

The resistance survey is an active geophysical technique, which injects a current into the ground (see Bevan 1991, 1998:7-18; Burger 1992:241-318; Carr 1982; Clark 2000:27-63, 171-174; Davenport 2001:29-30; David 1995:27-28; David et al. 2008:24-28; Dobrin and Savit 1988:750-773; Gaffney and Gater 2003:26-36, 56-61; Gaffney et al. 1991:2; 2002:7; Hallof 1992: 39-176; Heimmer and DeVore 1995:29-35, 2000:59-60; Kvamme 2001:358-362, 2003:441-442, 2005:434-436; Lowrie 1997:206-219; Milsom 2003:83-116; Mussett and Khan 2000:181-201; Nishimura 2001:544-546; Oswin 2009: 32-43, 118-126; Robinson and Çoruh 1988:445-478; Scollar et al. 1990:307-374; Sharma 1997:207-264; Somers 2006:109-129; Telford et al. 1990:522-577; Van Nostrand and Cook 1966; Weymouth 1986:318-341; Witten 2006:299-317; and Zonge et al. 2005:265-300 for more details on resistivity surveys). The voltage is measured and by Ohm's Law, one may compute the resistance at any given point (**R=V/I** where **R** is resistance, **V** is voltage, and **I** is current). Due to the problem of contact resistance between two electrodes in the ground, a typical resistance survey makes use of four electrodes or probes. The current passes through two electrodes and the voltage is measured between the other two probes. The configuration of the electrodes also varies (see Milsom 2003:99 and Weymouth 1986:324 for common configurations).

Resistance or resistivity changes result from electrical properties of the soil matrix. Changes are caused by materials buried in the soil, differences in soil formation processes, or disturbances from natural or cultural modifications to the soil. In archeology, the instrument is used to identify areas of compaction and excavation, as well as buried objects such as brick or stone foundations. It has the potential to identify cultural features that are affected by the water saturation in the soil, which is directly related to soil porosity, permeability, and chemical nature of entrapped moisture (Clark 2000; Heimmer and De Vore 1995:30). Its application to archeology results from the ability of the instrument to detect lateral changes on a rapid data acquisition, high-resolution basis, where observable contrasts exist. Lateral changes in anthropogenic features result from compaction, structural material changes, buried objects, excavation, habitation sites, and other features affecting water saturation (Heimmer and De Vore 1995:37). The resistivity survey may sometimes detect the disturbed soil matrix within a grave shaft.

The Geoscan Research RM15-D resistance meter uses the PA20 multiple-probe array (Geoscan Research 2007). Arranged as a twin-probe array, a current and voltage probes are located on a mobile frame, which is moved around the site (Figure 10). Two additional probes are located away from the survey area, which also consists of a current probe and voltage probe. The mobile probes are set 0.5 m apart on the multiprobe array frame. The remote probes are set a distance 30 times the mobile probe separation. The probes on the frame are located at a fixed distance apart. A general rule of thumb for the depth investigation of resistance survey is that the depth is equal to the distance of probe separation. This value is not a unique number but an average for the volume of soil 0.5 m depth and a surface diameter of 0.5 m under the center point of the instrument frame. The probes are connected to the resistance meter, which is also on the frame. Wings may be added to the frame to expand the separation distance of the probes; however, this requires the resurvey of the grid for each change in the probe separation distance.

The measurement is taken when the mobile probes make contact with the ground and completes the electrical circuit. The resulting resistance value is the average of 16 readings. The average value is stored in the resistance meter's memory until downloaded to a field laptop computer.

The resistance survey was designed to collect two samples per meter along 1.0-m traverses or two data values per square meter at the FOLS geophysical project area (Table 3). The data were collected in a zigzag fashion with the surveyor maintaining the alternating the direction of travel for each traverse across the grid. Eight hundred data values were collected for a complete 20-m-by-20-m grid unit. The resistance data were recorded in the memory of the resistance meter and downloaded to a laptop computer at the completion of each day's survey effort. The resistance data were imported into Geoscan Research's GEOPLOT software (Geoscan Research 2003) for processing. Both shade-relief and trace-line plots were generated before the instrument's memory was cleared.

Geophysical Data Processing

Processing of geophysical data requires care and understanding of the various strategies and alternatives (Kvamme 2001:365; Music 1995; Neubauer et al. 1996). Roger Walker and Lewis Somers (Geoscan Research 2003) provide strategies, alternatives, and case studies on the use of several processing routines commonly used to process magnetic, resistance, and conductivity data in the GEOPLOT software. David et al. (2008:42-45) presents a basic description of steps involved in the processing of magnetic, resistance, and ground-penetrating radar data. Kenneth Kvamme (2001:365) also provides a series of common steps used in computer processing of geophysical data:

> *Concatenation* of the data from individual survey grids into a single composite matrix;
>
> *Clipping and despikin*g of extreme values (that may result, for example, from introduced pieces of iron in magnetic data);
>
> *Edge matching* of data values in adjacent grids through balancing of brightness and contrast (i.e., means and standard deviations);
>
> *Filtering* to emphasize high-frequency changes and smooth statistical noise in the data;
>
> *Contrast enhancement* through saturation of high and low values or histogram modification; and
>
> *Interpolation* to improve image continuity and interpretation.

It is also important to understand the reasons for data processing and display (David et al. 2008:45-49; Gaffney et al. 1991:11). They enhance the analyst's ability to interpret the relatively huge data sets collected during the geophysical survey. The type of display can help the geophysical investigator present his interpretation of the data to the archeologist who will ultimately use the information to plan excavations or determine the archeological significance of the site from the geophysical data.

Processing Dual Fluxgate Gradiometer Magnetic Data

The magnetic data were recorded in the memory of the gradiometer and downloaded to a field laptop computer when the instrument's memory was full or at the completion of day's survey effort. Upon completion of the magnetic survey with the dual fluxgate gradiometer system at the FOLS geophysical project area, the data were processed in the ARCHAEOSURVEYOR computer program. The grid data file was assembled into a composite file (DW Consulting 2008:31-32). The data were destriped to remove any traverse discontinuities that may have occurred from operator handling or heading errors (DW Consulting 2008:9,60). The magnetic data from the geophysical survey area ranged from -127.2 nT to 134.3 nT with a median of -0.03 nT, a mean of -1.37 nT, and a standard deviation of 26.893 nT after the application of the destriping operation. Upon completion of the destriping function, the data were interpolated by expanding the number of data points in the traverse direction and by reducing the number of data points in the sampling direction to provide a smoother appearance in the data set and to enhance the operation of the low-pass filter (DW Consulting 2008:9,61). This changed the original 8-x-1 data point matrix into a 4-x-4 data point matrix. The low-pass filter was then applied over the entire data set to remove any high-frequency, small-scale spatial detail (DW Consulting 2008:9,71). This transformation may result in the improved visibility of larger, weak archeological features. The data were then exported as an ASCII dat file (DW Consulting 2008:39) and placed in the SURFER 9 contouring and 3D surface mapping program (Golden Software 2009). Image and contour maps of the dual fluxgate gradiometer data were generated for the survey grid area at the FOLS geophysical project area (Figure 11).

Processing Resistance Data

At the end of the day, or upon completion of the resistance survey, the data were downloaded into a field laptop computer for further processing in GEOPLOT (Oswin 2009:79-80). The grid files were combined to form a composite file and further processed in GEOPLOT (Oswin 2009:80-86). The edge-match routine was applied to remove discontinuities between grid edges (Geoscan Research 2001:6/45-6/47). Discontinuities may result from the improper placement of the remote probes as they are moved across the survey area, as well as changes in soil moisture content resulting from loss of moisture due to evaporation or increase in moisture from rain showers. The resistance data composite file from the FOLS survey grid area was despiked to remove any random, spurious measurements caused by contact with buried cobbles during the averaging of the multiple readings taken at each survey point (Geoscan Research 2001:6/35-6/39). Despiking may be accomplished with the processing routine in GEOPLOT or manually by editing each individual grid file. The resistance data from the resistance survey at the FOLS survey grid area, after the application of the edge-matching and despiking routines, ranged from 0.0 ohms to 146.5 ohms with a mean of 105.09 ohms and a standard deviation of 3.153 ohms. The interpolation routine was then applied to the data set to arrange the data from a 2-x-1 square matrix to an equally spaced 4-x-4 square matrix (Geoscan Research 2001:6/53-6/56). A high-pass filter was then applied over the composite data set. The high-pass filter was used to remove low-frequency, large-scale spatial detail such as a slow changing geological "background" trend (Geoscan Research 2001:6/49-6/52). The data were then exported as an ASCII dat file and placed in the SURFER 9 mapping program (Golden Software 2009; Oswin 2009:86-95). Image and contour maps of the resistance data were generated for the FOLS survey grid area (Figure 12).

Geophysical Data Interpretations

Andrew David (1995:30) defines interpretation as a "holistic process and its outcome should represent the combined influence of several factors, being arrived at through consultation with others where necessary." Interpretation may be divided into two different types consisting of the geophysical interpretation of the data and the archaeological interpretation of the data. At a simplistic level, geophysical interpretation involves the identification of the factors causing changes in the geophysical data. Archeological interpretation takes the geophysical results and tries to apply cultural attributes or causes. In both cases, interpretation requires both experience with the operation of geophysical equipment, data processing, and archeological methods; and knowledge of the geophysical techniques and properties, as well as known and expected archeology. Although there is variation between sites, several factors should be considered in the interpretation of the geophysical data. These may be divided between natural factors, such as geology, soil type, geomorphology, climate, surface conditions, topography, soil magnetic susceptibility, seasonality, and cultural factors including known and inferred archeology, landscape history, survey methods, data treatment, modern interference, etc. (David 1995:30; David et al. 49). It should also be pointed out that refinements in the geophysical interpretations are dependent on the feedback from subsequent archeological investigations. The use of multiple instrument surveys provides the archeologist with very different sources of data that may provide complementary information for comparison of the nature and cause (i.e., natural or cultural) of a geophysical anomaly (Clay 2001). Each instrument responds primarily to a single physical property: magnetometry to soil magnetism, electromagnetic induction to soil conductivity, resistivity to soil resistance, and ground-penetrating radar to dielectric properties of the soil to (Weymouth 1986:371).

Interpreting the Magnetic Data

Interpretation of the magnetic data (Bevan 1998:24) from the project requires a description of the buried archeological feature or object (e.g., its material, shape, depth, size, and orientation). The magnetic anomaly represents a local disturbance in the earth's magnetic field caused by a local change in the magnetic contract between buried archeological features, objects, and the surrounding soil matrix. Local increases or decreases over a very broad uniform magnetic surface would exhibit locally positive or negative anomalies (Breiner 1973:17). Magnetic anomalies tend to be highly variable in shape and amplitude. They are generally asymmetrical in nature due to the combined effects from several sources. To complicate matters further, a given anomaly may be produced from an infinite number of possible sources. Depth between the magnetometer and the magnetic source material also affect the shape of the apparent anomaly (Breiner

1973:18). As the distance between the magnetic sensor on the magnetometer and the source material increases, the expression of the anomaly becomes broader. Anomaly shape and amplitude are also affected by the relative amounts of permanent and induced magnetization, the direction of the magnetic field, and the amount of magnetic minerals (e.g., magnetite) present in the source compared to the adjacent soil matrix. The shape (e.g., narrow or broad) and orientation of the source material also affects the anomaly signature. Anomalies are often identified in terms of various arrays of dipoles or monopoles (Breiner 1973:18-19). A magnetic object is made of magnetic poles (North or positive and South or negative). A simple dipole anomaly contains the pair of opposite poles that are relatively close together. A monopole anomaly is simply one end of a dipole anomaly and may be either positive or negative depending on the orientation of the object. The other end is too far away to have an effect on the magnetic field.

Magnetic anomalies of archeological objects tend to be approximately circular in contour outline. The circular contours are caused by small size of the objects. The shape of the object is seldom revealed in the contoured data. The depth of the archaeological object can be estimated by half-width rule procedure (Bevan 1998:23-24; Breiner 1973:31; Milsom 2003:67-70). The approximations are based on a model of a steel sphere with a mass of 1 kg buried at a depth of 1.0 m below the surface with the magnetic measurements made at an elevation of 0.3 m above the ground. The depth of a magnetic object is determined by the location of the contour value at half the distance between the peak positive value of the anomaly and the background value. With the fluxgate gradiometer, the contour value is half the peak value since the background value is approximately zero. The diameter of this contour (Bevan 1998:Fig. B26) is measured and used in the depth formula where **depth = diameter – 0.3 m** (Note: The constant of 0.3 m is the height of the bottom fluxgate sensor above the ground in the Geoscan Research FM36 where I carry the instrument during data acquisition. This value needs to be adjusted for each individual that carries the instrument.). The mass in kilograms of the object (Bevan 1998:24, Fig. B26) is estimated by the following formula: **mass = (peak value - background value) * (diameter)^3/60**. It is likely that the depth and mass estimates are too large, rather than too small, since they are based on a compact spherical object made of iron. Archeological features are seldom compact but spread out in a line or lens. Both mass and depth estimates will be too large. The archaeological material may be composed of something other than iron such as fired earth or volcanic rock. Such materials are not usually distinguishable from the magnetic data collected during the survey (Bevan 1998:24). The depth and mass of features composed of fired earth, like that found in kilns, fireplaces, or furnaces could be off by 100 times the mass of iron. If the archeological feature were composed of bricks (e.g., brick wall, foundation, or chimney), estimates could be off by more than a 1,000 times that of iron. The location of the center of the object can also be determined by drawing a line connecting the peak positive and peak negative values. The rule of thumb is that the center of the object is located approximately one-third to one-half of the way along the line from the peak positive value for the anomaly. One should also be cautious of geophysical anomalies that extend in the direction of the traverses since these may represent operator-induced errors. The magnetic gradient anomalies may be classified as three different types: linear, dipole, and monopole.

The first step in interpreting the magnetic anomalies from the project area is to identify areas of high magnetic contrast and, especially, the positive magnetic anomalies or the North pole of the dipole. The dual fluxgate gradiometer tends to emphasize weaker changes, enhancing the contrasts between the high and low values of the magnetic anomalies. The dual fluxgate gradiometer data from the FOLS project area contains numerous magnetic anomalies (Figure 13). These anomalies appear to be associated with metal artifacts and buried archeological features, as well as modern intrusions. The gravel access roads on the west and south sides of the row of Officers' Quarters appear as slight linear magnetic disturbances. Buried utility (electric, storm water, sewage, water, etc.) lines are also indicated by stronger linear magnetic anomalies consisting of the typical high/low value beaded pattern. There is also a series of weak linear anomalies in the northern part of the project area that may relate to the leach field or may represent historic features associated with the military or farming activities at the post. In the backyards of the Officers' Quarters, there are dense concentrations of magnetic anomalies. Although some magnetic anomalies in the northern portion of the survey area of the backyards are associated with modern intrusions including a sheet-metal shed and park vehicles along with the modern wooden fence lines, reconstructed outhouses, and park restoration activities, other magnetic anomalies are associated with the historic military activities and later farming activities on the property. There is an area outside of the backyard fences that contains slightly fewer magnetic anomalies than found on the inside of the backyard fences. These magnetic anomalies also appear to be associated with military and farming activities. Ground-truthing would help identify the nature of these anomalies and their association to historic activities or more recent ground-disturbing activities. The areas containing the manhole covers and buried utility vaults are clearly identified by extremely strong magnetic anomalies. In addition to these large clusters of magnetic anomalies, there are smaller clusters located outside of these large ones. The smaller clusters may be locations of discarded material, as well as building locations associated with the military occupation or more recent farming activities. These anomalies all bear further ground-truthing examination with traditional archeological excavation techniques.

Interpreting the Resistance Data

Interpretation of the resistivity data results in the identification of lateral changes in the soil. Since the array parameters are kept constant throughout the survey, the resulting resistance values varies with changes in the subsurface sediments/soil matrix and buried archeological resources. For each probe separation, the depth penetration is approximately the same as the distance between the current and potential probe on the mobile array frame, which was 0.5 m. The resistance measurement for each point represents the average value for the hemispheric volume of soil with the same radius. If the soil below the survey area were uniform, the resistivity would be constant throughout the area. Changes in soil characteristics (e.g., texture, structure, moisture, compactness, etc.) and the composition of archeological features result in differences in the resistances across the surveyed grid. Large general trends reflect changes in the site's geology whereas small changes may reflect archeological features. An advantage to the resistance survey and its interpretation is its usefulness in areas that have high concentrations of metal objects such as the three project areas in this study.

The resistance data from the FOLS geophysical survey area illustrates a number of resistance anomalies previously identified in the dual fluxgate gradiometer magnetic data set from the project area (Figure 14). The resistance anomalies include the gravel access road and the location of the wooden backyard fences. In addition to these linear resistance anomalies, there are several linear anomalies across the project area. Some may represent locations of old trails, fence lines, and other cultural features. Concentrations of resistance anomalies in the backyards appear to represent the locations of privies or small sheds, as well as possible garden plots. As with the magnetic anomalies, ground-truthing with traditional archeological excavation techniques are warranted to determine the nature of these anomalies and their relationship to the military occupation at Fort Larned.

Combined Geophysical Data Set Interpretations

A different way of looking at the geophysical data collected during the investigations of the survey area at parking lot area is to combine the complementary data sets into one display. Several different geophysical anomalies overlap suggesting a strong correlation between the geophysical data and the buried archeological features (Ambrose 2005). These areas of overlap would be considered areas of high probability for ground-truthing and the investigations of buried archeological resources. While these correlations are important, individual isolated occurrences also need ground-truthing in order to determine their unique nature as well. Complementary data from the geophysical survey efforts at the FOLS geophysical project area indicate the locations of historic military artifact or sheet midden concentrations and more recent 19th- and 20th-century farming building locations and related activity areas, as well as modern National Park Service modifications to the military landscape (Figure 15).

Archeological Monitoring Methods

The archeological monitoring activities at FOLS included the documentation of the proposed installation line and new transformer locations with a global positioning system (Figure 16) unit and the monitoring of the directional boring access pits (Baier 2009). Using the geophysical data as a guide for the selection of relatively clear areas devoid of artifact or feature concentrations, locations for the directional boring access pits were identified in relatively cultural sterile areas. The access pits were excavated by the JK Electric personnel with a backhoe prior to the directional boring of the underground electric lines (Figure 17). The main electrical vault was also uncovered (Figure 18). The vault had been installed several years ago and re-excavated numerous times for additional maintenance. The top of the vault was located approximately 47 cm below the ground surface. The sediments above and surrounding the vault were homogeneous brown silty clay. No artifacts were observed during the excavation.

During the excavation of the pit for the west transformer, an old telephone line was uncovered at a depth of approximately 65 cm below the surface. The transformer pit (Pit 1) was moved further south of the initial location (Figure 19a). The pit measured 3.5

m north-south, including the 1.5 m portion of the pit where a phone line was uncovered, by 1.1 m east-west. The pit was excavated to a depth of approximately 1.4 m. The upper 86 cm of sediment was very loose and fine textured, but below 86 cm the sediments became more compact. The soil stratigraphy was very clearly defined in all four walls of the pit (Figure 19b). The upper stratigraphic layer was brown silty clay that extended to 52-58 cm below the ground surface. A thin lens of dark gray silt measuring approximately 2 cm was located below the upper silty clay layer. The third stratigraphic layer was very pale brown clayey silt that extended to 110-120 cm below the surface. The bottom layer of sediment was dark brown silty clay. No artifacts were observed during the excavation of the transformer pit or in the pit walls.

Pit 2 was placed along the projected route of the buried electric line next to the existing electric line where the line turned north (Figure 20a). Excavation of Pit 2 with the backhoe revealed very clear stratigraphic layers in the pit wall profiles (Figure 20b). The uppermost layer was damp, dark brown silty clay that extended 30-40 cm below surface. These sediments overlaid pale brown clayey silt similar to that seen in Pit 1. This second layer extended to a depth of 60 cm throughout most of the pit but gradually dipped to 80 cm to the west. The next layer was dark brown silty clay found 100 cm below surface on the east and 115 cm in the west. The bottommost layer was also dark brown silty clay, but it was lighter in color (10YR4/3 as opposed to 10YR3/3). The pit originally measured 2.35 m east-west by 1.5 m north-south, with additional steps for easier access during the profiling. The steps measured 1.5 m east-west and 0.75 m north-south making the maximum length of the pit 3.85 m east-west. The maximum depth of the pit was approximately 1.45 m. No artifacts were observed during the excavation, and no features were observed in any of the profile walls.

The final pit (Pit 3) was located in the yard northwest of HS-9 (Figure 21a). The soil stratigraphy in this area was also very well defined (Figure 21b). The uppermost sediment was loose, brown silty clay. From about 55-65 cm to 75 cm was compact, dark brown silty clay. Below this layer was very pale brown clayey silty from 75-105 cm. At the bottom of the pit beginning around 105 cm below surface was brown silty clay. The pit measured 2.02 m north-south by 1.52 m east-west and was excavated to a maximum depth of approximately 1.6 m. No artifacts or features were observed during the excavation or in the walls of the pit.

Two hand-dug holes were also excavated in order to identify the presence of electrical conduit along the eastern route of the electric line. Midwest Energy identified where the conduit was supposed to be located, but the JK Electric contractors wanted to confirm the location. The first hole was excavated near the levee north of HS-12. The conduit was found approximately 50 cm below surface. Sediments were brown silty clay. The second hole was excavated approximately 3 m south of the southeast corner of HS-6. The conduit was found 90 cm below surface. Sediments were brown silty clay. Additional trenching occurred from the county road by the maintenance facility to the irrigation ditch. The trench was confined to the existing electric line trench, which was previously disturbed by its initial construction. The access pits were profiled and photographed.

CONCLUSIONS AND RECOMMENDATIONS

During the period from July 13 to July 18, 2009, geophysical investigations were conducted at Fort Larned National Historic Site (14PA305) along the western side of the fort next to the row of Officers' Quarters. The geophysical survey included a magnetic survey with dual fluxgate gradiometer and a resistance survey with a resistance meter and twin-probe array. The geophysical survey was conducted in an attempt to identify buried archeological remains associated with the fort in the vicinity of the construction project for the installation of the park's underground electric line. The archeological monitoring of the underground electric line installation occurred between November 17 and 19, 2009. The monitoring activities included the documentation of the proposed installation line and new transformer locations with a global positioning system unit and the monitoring of excavations for the directional boring access pits. The geophysical survey identified numerous buried archeological remains associated with the remnants of the military activities at the site, as well as more recent 19th- and 20th-century farming and park activities at the site. The total area investigated by the geophysical survey in the FOLS geophysical project area was 16,161 m^2 or 3.99 ac.

The surveys resulted in the identification of numerous subsurface anomalies. The magnetic and resistance data collected at the site provided information on the physical properties (magnetic and soil resistance properties) of the subsurface materials. Standard methods for conducting geophysical investigations were used with standard 20-m-by-20-m grid sizes where feasible. The results of the geophysical survey indicated the presence of buried features and artifact concentrations related to the military period, historic farming era, and modern park activities associated with the occupation of the Fort Larned National Historic Site in the late 19th and 20th centuries.

Finally, refinement of the archeological and geophysical interpretation of the survey data is dependent on the feedback of the archeological investigations following geophysical survey (David 1995:30). Should additional archeological investigations occur at the site investigated during this project, the project archeologist is encouraged to share additional survey and excavation data with the geophysical investigator for incorporation into the investigator's accumulated experiences with archeological problems. Throughout the entire geophysical and archeological investigations, communication between the geophysicist and the archeologist is essential for successful completion of the archeological investigations. It is also important for the investigators to disseminate the results of the geophysical survey and archeological investigations to the general public. It is through their support in funds and labor that we continue to make contributions to the application of geophysical techniques to the field of archeology.

This report has provided a review and analysis of the geophysical and archeological monitoring data collected during the investigations of the proposed underground electric line installation at Fort Larned National Historic Site. The geophysical techniques applied to the investigations at Site 14PA305 have proven successful in the identification of buried archeological resources in the present archeological/geophysical project area. The geophysical techniques combined with traditional archeological monitoring methods have the potential to identify the subsurface features associated with the historic and possibly the prehistoric use across the park. This information will be used by the Midwest Archeological Center and the Fort Larned National Historic Site staffs to guide further archeological inquiry into the nature of the archeological resources at the military post (Site 14PA305) and help direct future National Park Service geophysical surveys and archeological excavations at other locations within the boundary of the Fort Larned National Historic Site.

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TABLES

Table 1. Global positioning system corrected grid coordinates for the FOLS geophysical project area (Site 14PA305).

ID	Longitude	Latitude	HAE	Easting	Northing	MSL
1	-99.218	38.182	592.945	480877	4226027	619.629
1	-99.218	38.182	593.106	480878	4226026	619.79
1	-99.218	38.1819	593.109	480879	4226022	619.793
1	-99.218	38.1819	593.187	480881	4226018	619.871
1	-99.218	38.1818	593.194	480882	4226014	619.879
1	-99.218	38.1818	593.014	480884	4226009	619.698
1	-99.218	38.1818	593.06	480886	4226004	619.745
1	-99.218	38.1817	593.134	480887	4225999	619.818
1	-99.218	38.1817	593.284	480889	4225994	619.968
1	-99.218	38.1816	593.277	480891	4225990	619.962
1	-99.218	38.1816	593.276	480893	4225985	619.96
1	-99.218	38.1815	593.143	480895	4225980	619.828
1	-99.218	38.1815	593.176	480897	4225975	619.861
1	-99.218	38.1815	593.154	480899	4225970	619.839
1	-99.218	38.1814	593.311	480901	4225965	619.995
1	-99.218	38.1814	593.33	480903	4225960	620.015
1	-99.218	38.1813	593.274	480906	4225955	619.958
1	-99.218	38.1813	593.455	480908	4225950	620.139
1	-99.218	38.1812	593.59	480910	4225945	620.275
1	-99.218	38.1812	593.776	480912	4225940	620.461
1	-99.218	38.1811	593.717	480914	4225935	620.402
1	-99.218	38.1811	593.553	480916	4225930	620.238
1	-99.218	38.181	593.037	480918	4225925	619.722
1	-99.218	38.181	592.999	480920	4225920	619.684
1	-99.218	38.181	593.097	480922	4225915	619.782
1	-99.218	38.1809	592.984	480925	4225910	619.669
1	-99.218	38.1809	592.755	480927	4225904	619.44
1	-99.218	38.1808	592.856	480929	4225899	619.541
1	-99.218	38.1808	592.968	480931	4225894	619.653
1	-99.218	38.1807	592.862	480932	4225889	619.547
1	-99.218	38.1807	592.819	480935	4225884	619.504
1	-99.218	38.1806	592.716	480937	4225878	619.401
1	-99.218	38.1806	592.916	480939	4225873	619.601
1	-99.218	38.1805	592.817	480942	4225868	619.502
1	-99.218	38.1805	592.778	480944	4225863	619.463
1	-99.218	38.1804	592.737	480946	4225858	619.422
2	-99.218	38.1809	592.71	480925	4225911	619.396
2	-99.218	38.1809	592.853	480925	4225913	619.538
2	-99.218	38.181	592.882	480923	4225917	619.567

Table 1. Continued.

ID	Longitude	Latitude	HAE	Easting	Northing	MSL
2	-99.218	38.181	592.804	480921	4225921	619.489
2	-99.218	38.181	592.953	480919	4225925	619.638
2	-99.218	38.1811	593.058	480918	4225930	619.743
2	-99.218	38.1811	593.229	480916	4225934	619.914
2	-99.218	38.1812	593.446	480914	4225939	620.131
2	-99.218	38.1812	593.35	480912	4225942	620.035
2	-99.218	38.1812	593.425	480911	4225941	620.109
2	-99.218	38.1812	593.418	480912	4225939	620.102
2	-99.218	38.1811	593.22	480913	4225934	619.905
2	-99.218	38.1811	592.986	480915	4225929	619.671
2	-99.218	38.181	592.966	480917	4225924	619.651
2	-99.218	38.181	592.811	480919	4225919	619.496
2	-99.218	38.1809	592.807	480921	4225914	619.492
2	-99.218	38.1809	592.669	480923	4225910	619.354
2	-99.218	38.1809	592.725	480924	4225911	619.41
2	-99.218	38.1809	592.723	480925	4225911	619.408
2	-99.218	38.1809	592.71	480925	4225911	619.396
3	-99.218	38.1811	593.194	480915	4225933	619.879
4	-99.22	38.1816	593.531	480746	4225982	620.214
4	-99.22	38.1816	593.549	480747	4225982	620.233
4	-99.22	38.1816	593.543	480750	4225983	620.227
4	-99.22	38.1816	593.535	480754	4225984	620.219
4	-99.22	38.1816	593.532	480758	4225986	620.216
4	-99.22	38.1816	593.606	480763	4225988	620.29
4	-99.22	38.1816	593.522	480768	4225990	620.206
4	-99.22	38.1816	593.32	480773	4225992	620.004
4	-99.219	38.1817	593.4	480778	4225994	620.083
4	-99.219	38.1817	593.472	480783	4225996	620.156
4	-99.219	38.1817	593.315	480788	4225998	619.999
4	-99.219	38.1817	593.274	480794	4226000	619.958
4	-99.219	38.1817	593.293	480799	4226002	619.977
4	-99.219	38.1818	593.276	480805	4226004	619.96
4	-99.219	38.1818	593.395	480810	4226006	620.079
4	-99.219	38.1818	593.272	480815	4226008	619.956
4	-99.219	38.1818	593.292	480820	4226010	619.976
4	-99.219	38.1818	593.141	480825	4226012	619.825
4	-99.219	38.1819	593.193	480830	4226015	619.877
4	-99.219	38.1819	593.262	480836	4226017	619.946
4	-99.219	38.1819	593.224	480841	4226019	619.908
4	-99.219	38.1819	593.163	480847	4226021	619.847
4	-99.219	38.1819	593.143	480852	4226023	619.828
4	-99.219	38.1819	593.115	480858	4226025	619.799
4	-99.219	38.182	593.245	480863	4226026	619.929

Table 1. Continued.

ID	Longitude	Latitude	HAE	Easting	Northing	MSL
4	-99.218	38.182	593.226	480869	4226027	619.91
4	-99.218	38.182	593.143	480875	4226029	619.828
4	-99.218	38.182	593.091	480881	4226030	619.776
4	-99.218	38.182	593.145	480887	4226030	619.829
4	-99.218	38.182	593.098	480892	4226031	619.782
4	-99.218	38.182	593.041	480898	4226032	619.726
5	-99.219	38.1819	593.024	480844	4226020	619.708
5	-99.219	38.1819	593.085	480843	4226020	619.769
5	-99.219	38.1819	593.206	480838	4226020	619.89
5	-99.219	38.1819	593.205	480832	4226020	619.889
5	-99.219	38.1819	593.144	480827	4226021	619.828
5	-99.219	38.1819	593.336	480822	4226024	620.02
5	-99.219	38.182	593.349	480818	4226027	620.032
5	-99.219	38.182	593.485	480814	4226031	620.169
5	-99.219	38.182	593.506	480810	4226036	620.189
5	-99.219	38.1821	593.451	480807	4226042	620.135
5	-99.219	38.1821	593.531	480805	4226047	620.215
5	-99.219	38.1822	593.569	480803	4226053	620.253
5	-99.219	38.1822	593.684	480800	4226059	620.367
5	-99.219	38.1823	593.65	480798	4226064	620.334
5	-99.219	38.1823	593.6	480796	4226070	620.283
5	-99.219	38.1824	593.916	480794	4226075	620.599
5	-99.219	38.1824	593.677	480792	4226081	620.361
5	-99.219	38.1825	594.521	480792	4226082	621.204
5	-99.219	38.1825	593.916	480792	4226083	620.6
5	-99.219	38.1825	593.951	480790	4226085	620.634
5	-99.219	38.1825	593.903	480790	4226087	620.587
5	-99.219	38.1825	593.973	480790	4226087	620.656
6	-99.22	38.1815	593.924	480722	4225972	620.608
6	-99.22	38.1815	594.014	480723	4225973	620.697
6	-99.22	38.1815	593.856	480728	4225974	620.54
6	-99.22	38.1815	593.843	480733	4225976	620.526
6	-99.22	38.1815	593.935	480737	4225978	620.619
6	-99.22	38.1815	593.823	480742	4225980	620.507
6	-99.22	38.1816	593.902	480747	4225982	620.586
6	-99.22	38.1816	593.828	480751	4225985	620.511
6	-99.22	38.1816	593.925	480756	4225988	620.609
6	-99.22	38.1816	593.919	480760	4225992	620.603
6	-99.22	38.1817	593.867	480764	4225997	620.551
6	-99.22	38.1817	593.682	480768	4226001	620.366
6	-99.22	38.1818	593.781	480772	4226006	620.464
6	-99.22	38.1818	593.77	480775	4226011	620.453
6	-99.219	38.1819	593.754	480778	4226016	620.438

Table 1. Continued.

ID	Longitude	Latitude	HAE	Easting	Northing	MSL
6	-99.219	38.1819	594.04	480780	4226022	620.723
6	-99.219	38.182	594.088	480782	4226027	620.771
6	-99.219	38.182	594.063	480784	4226033	620.747
6	-99.219	38.1821	593.998	480785	4226039	620.682
6	-99.219	38.1821	594.106	480786	4226045	620.79
6	-99.219	38.1822	594.016	480787	4226051	620.7
6	-99.219	38.1822	594.114	480788	4226057	620.797
6	-99.219	38.1823	594.272	480789	4226063	620.955
6	-99.219	38.1824	593.964	480789	4226072	620.648
6	-99.219	38.1824	593.942	480789	4226072	620.626
6	-99.219	38.1824	594.043	480789	4226074	620.727
6	-99.219	38.1824	594.094	480790	4226075	620.777
6	-99.219	38.1824	594.148	480790	4226078	620.831
6	-99.219	38.1824	594.136	480790	4226081	620.819
6	-99.219	38.1825	594.175	480789	4226085	620.858
6	-99.219	38.1825	594.096	480789	4226086	620.78
6	-99.219	38.1825	594.086	480789	4226090	620.769
6	-99.219	38.1826	594.129	480788	4226094	620.813
6	-99.219	38.1826	594.071	480786	4226098	620.754
6	-99.219	38.1826	593.752	480784	4226103	620.435
6	-99.219	38.1827	594.05	480784	4226104	620.733
6	-99.219	38.1827	594.076	480784	4226104	620.76
6	-99.219	38.1827	593.86	480784	4226104	620.543
6	-99.219	38.1827	594.425	480783	4226106	621.108
6	-99.219	38.1827	592.168	480780	4226111	618.851
6	-99.219	38.1827	594.295	480781	4226110	620.978
6	-99.219	38.1827	594.353	480781	4226110	621.037
6	-99.219	38.1827	594.505	480780	4226112	621.188
6	-99.219	38.1828	594.226	480778	4226116	620.909
6	-99.22	38.1828	593.739	480775	4226121	620.422
6	-99.22	38.1829	595.149	480771	4226132	621.832
6	-99.22	38.183	594.127	480769	4226137	620.81
6	-99.22	38.183	594.157	480767	4226142	620.84
6	-99.22	38.183	594.196	480765	4226146	620.879
6	-99.22	38.1831	594.233	480763	4226150	620.916
6	-99.22	38.1831	594.392	480762	4226155	621.075
6	-99.22	38.1832	594.177	480760	4226159	620.859
6	-99.22	38.1832	594.229	480759	4226164	620.911
6	-99.22	38.1832	594.057	480759	4226168	620.74
6	-99.22	38.1833	594.014	480761	4226173	620.697
6	-99.22	38.1833	593.867	480763	4226177	620.55
6	-99.22	38.1834	593.954	480767	4226181	620.636
6	-99.22	38.1834	593.871	480770	4226185	620.553

Table 1. Continued.

ID	Longitude	Latitude	HAE	Easting	Northing	MSL
6	-99.22	38.1834	593.927	480775	4226188	620.61
6	-99.219	38.1834	593.894	480779	4226191	620.577
6	-99.219	38.1835	593.727	480783	4226195	620.409
6	-99.219	38.1835	593.69	480787	4226198	620.373
6	-99.219	38.1835	593.672	480790	4226203	620.354
6	-99.219	38.1836	593.659	480792	4226208	620.341
6	-99.219	38.1836	593.71	480794	4226214	620.392
6	-99.219	38.1837	593.856	480794	4226219	620.539
6	-99.219	38.1837	593.979	480793	4226225	620.662
6	-99.219	38.1838	594.172	480792	4226231	620.855
6	-99.219	38.1838	594.208	480792	4226233	620.89
7	-99.219	38.1838	594.222	480792	4226233	620.905
7	-99.219	38.1838	594.23	480792	4226233	620.913
7	-99.219	38.1838	594.294	480791	4226237	620.976
7	-99.219	38.1839	591.5	480790	4226237	618.182
7	-99.219	38.184	593.413	480789	4226249	620.096
7	-99.219	38.184	596.372	480790	4226252	623.054
7	-99.219	38.184	591.541	480788	4226256	618.224
7	-99.219	38.1841	601.001	480795	4226261	627.683
7	-99.219	38.1841	597.833	480791	4226262	624.515
7	-99.219	38.1841	594.933	480789	4226266	621.615
7	-99.219	38.1841	593.399	480790	4226267	620.081
8	-99.219	38.1841	592.448	480790	4226268	619.13
9	-99.22	38.184	594.351	480768	4226254	621.033
10	-99.22	38.1839	594.394	480750	4226246	621.076
11	-99.22	38.1838	593.95	480744	4226235	620.632
12	-99.22	38.1837	593.518	480738	4226221	620.201
13	-99.22	38.1836	593.981	480736	4226210	620.663
14	-99.22	38.1836	593.271	480742	4226212	619.954
15	-99.22	38.1837	593.795	480761	4226220	620.477
16	-99.22	38.1839	593.573	480753	4226239	620.256
17	-99.22	38.1839	594.528	480772	4226245	621.21
18	-99.219	38.1838	590.491	480779	4226228	617.174
19	-99.219	38.1836	592.661	480787	4226210	619.344
20	-99.219	38.1834	592.451	480794	4226191	619.134
21	-99.22	38.1834	589.025	480775	4226184	615.708
22	-99.22	38.1836	587.395	480767	4226204	614.078
23	-99.22	38.1835	589.574	480748	4226196	616.257
24	-99.22	38.1834	594.63	480742	4226190	621.312
25	-99.22	38.1833	595.541	480751	4226171	622.224
26	-99.22	38.1833	591.565	480748	4226178	618.247
27	-99.22	38.1833	593.752	480757	4226176	620.435
28	-99.22	38.1831	593.401	480765	4226158	620.084

Table 1. Continued.

ID	Longitude	Latitude	HAE	Easting	Northing	MSL
29	-99.22	38.1831	595.226	480759	4226153	621.909
30	-99.22	38.1829	592.946	480765	4226136	619.629
31	-99.22	38.183	594.725	480772	4226139	621.408
32	-99.219	38.1828	596.978	480781	4226120	623.662
33	-99.22	38.1828	598.583	480768	4226115	625.266
34	-99.22	38.1826	594.198	480769	4226096	620.881
35	-99.22	38.1826	594.597	480770	4226094	621.28
36	-99.22	38.1825	594.929	480769	4226090	621.612
37	-99.219	38.1826	595.629	480788	4226101	622.312
38	-99.219	38.1829	596.448	480799	4226129	623.131
39	-99.219	38.1827	594.028	480806	4226109	620.711
40	-99.219	38.1825	589.989	480815	4226090	616.673
41	-99.219	38.1825	595.499	480795	4226084	622.182
42	-99.219	38.1824	596.497	480777	4226078	623.18
43	-99.22	38.1824	593.617	480775	4226075	620.3
44	-99.22	38.1822	591.96	480773	4226052	618.644
45	-99.219	38.1822	592.533	480785	4226056	619.216
46	-99.219	38.1823	594.374	480804	4226063	621.058
47	-99.219	38.1824	593.883	480822	4226073	620.566
48	-99.219	38.1823	593.268	480848	4226061	619.952
49	-99.219	38.1822	593.547	480829	4226054	620.231
50	-99.219	38.1821	592.803	480811	4226047	619.486
51	-99.219	38.1821	593.136	480793	4226039	619.819
52	-99.22	38.182	593.189	480774	4226032	619.872
53	-99.22	38.182	593.68	480764	4226027	620.364
54	-99.22	38.1819	592.716	480758	4226017	619.4
55	-99.22	38.1818	593.037	480752	4226006	619.721
56	-99.22	38.1818	593.986	480763	4226005	620.67
57	-99.219	38.1818	595.342	480782	4226012	622.026
58	-99.219	38.1819	593.425	480800	4226020	620.109
59	-99.219	38.182	594.249	480819	4226027	620.933
60	-99.219	38.182	592.631	480837	4226035	619.315
61	-99.219	38.1821	594.266	480856	4226043	620.95
62	-99.219	38.1819	594.478	480863	4226023	621.162
63	-99.218	38.1819	593.79	480866	4226022	620.474
64	-99.219	38.1819	593.445	480844	4226016	620.13
65	-99.219	38.1818	592.635	480826	4226009	619.319
66	-99.219	38.1817	592.913	480807	4226001	619.597
67	-99.219	38.1817	592.307	480789	4225993	618.991
68	-99.22	38.1816	592.13	480770	4225985	618.814
69	-99.219	38.1814	592.087	480778	4225968	618.771
70	-99.219	38.1815	593.062	480797	4225975	619.746
71	-99.219	38.1816	592.815	480815	4225984	619.5

Table 1. Continued.

ID	Longitude	Latitude	HAE	Easting	Northing	MSL
72	-99.219	38.1816	591.135	480833	4225991	617.819
73	-99.219	38.1817	593.048	480852	4225999	619.733
74	-99.218	38.1818	593.19	480871	4226006	619.874
75	-99.218	38.1816	594.166	480877	4225985	620.85
76	-99.219	38.1815	591.77	480861	4225977	618.454
77	-99.219	38.1815	592.865	480842	4225974	619.549
78	-99.219	38.1814	592.492	480823	4225966	619.176
79	-99.219	38.1813	592.904	480804	4225957	619.588
80	-99.219	38.1812	594.099	480810	4225944	620.783
81	-99.219	38.1812	593.677	480825	4225942	620.361
82	-99.219	38.1812	595.847	480830	4225945	622.532
83	-99.219	38.1813	593.578	480849	4225952	620.262
84	-99.218	38.1814	592.618	480868	4225960	619.303
85	-99.218	38.1814	592.646	480886	4225968	619.331
86	-99.218	38.1813	592.008	480935	4225950	618.692
86	-99.218	38.1813	591.78	480934	4225949	618.465
86	-99.218	38.1812	594.094	480931	4225946	620.779
86	-99.218	38.1812	595.742	480928	4225945	622.427
86	-99.218	38.1812	596.241	480926	4225943	622.926
86	-99.218	38.1812	595.695	480923	4225942	622.38
86	-99.218	38.1812	592.462	480921	4225940	619.147
86	-99.218	38.1812	591.787	480918	4225939	618.472
86	-99.218	38.1812	594.101	480914	4225939	620.786
86	-99.218	38.1812	595.603	480909	4225940	622.288
86	-99.218	38.1812	595.768	480905	4225941	622.453
86	-99.218	38.1812	594.936	480901	4225941	621.621
86	-99.218	38.1812	591.892	480897	4225941	618.577
86	-99.218	38.1812	592.12	480893	4225941	618.805
86	-99.218	38.1812	592.745	480888	4225940	619.429
86	-99.218	38.1812	595.477	480884	4225940	622.162
86	-99.218	38.1812	593.851	480875	4225940	620.535
86	-99.218	38.1812	591.768	480871	4225940	618.453
86	-99.218	38.1812	592.311	480867	4225941	618.996
86	-99.219	38.1812	593.096	480862	4225941	619.78
86	-99.219	38.1812	595.448	480857	4225941	622.132
86	-99.219	38.1812	595.8	480853	4225940	622.484
86	-99.219	38.1812	594.662	480848	4225941	621.346
86	-99.219	38.1812	591.166	480843	4225940	617.851
86	-99.219	38.1812	590.912	480838	4225940	617.596
86	-99.219	38.1812	591.8	480834	4225940	618.484
86	-99.219	38.1812	595.54	480828	4225940	622.225
86	-99.219	38.1812	596.269	480823	4225940	622.953
86	-99.219	38.1812	593.847	480818	4225940	620.532

Table 1. Continued.

ID	Longitude	Latitude	HAE	Easting	Northing	MSL
86	-99.219	38.1812	591.668	480814	4225940	618.352
86	-99.219	38.1812	591.964	480809	4225940	618.648
86	-99.219	38.1812	592.539	480805	4225940	619.223
86	-99.219	38.1812	595.383	480799	4225940	622.068
86	-99.219	38.1812	596.143	480794	4225940	622.827
86	-99.219	38.1812	593.416	480790	4225940	620.1
86	-99.219	38.1812	591.004	480785	4225940	617.689
86	-99.219	38.1812	591.236	480780	4225940	617.92
86	-99.22	38.1812	593.397	480775	4225940	620.081
86	-99.22	38.1812	595.622	480770	4225940	622.306
86	-99.22	38.1812	595.928	480766	4225940	622.612
87	-99.22	38.1812	594.729	480726	4225940	621.413
88	-99.22	38.1812	595.264	480733	4225940	621.948
88	-99.22	38.1812	593.881	480732	4225939	620.565
88	-99.22	38.1812	593.546	480735	4225941	620.23
88	-99.22	38.1812	591.453	480740	4225943	618.137
88	-99.22	38.1812	593.362	480744	4225945	620.046
88	-99.22	38.1812	594.085	480748	4225948	620.769
88	-99.22	38.1813	594.928	480753	4225950	621.612
88	-99.22	38.1813	593.107	480758	4225953	619.791
88	-99.22	38.1813	589.12	480764	4225954	615.804
88	-99.22	38.1813	584.809	480770	4225957	611.493
88	-99.22	38.1814	581.046	480775	4225959	607.73
88	-99.219	38.1814	601.514	480778	4225962	628.198
88	-99.219	38.1814	597.389	480783	4225965	624.074
88	-99.219	38.1814	593.239	480789	4225967	619.923
88	-99.219	38.1814	614.347	480791	4225969	641.031
88	-99.219	38.1815	610.298	480797	4225972	636.982
88	-99.219	38.1815	607.153	480802	4225974	633.837
88	-99.219	38.1815	597.906	480814	4225979	624.591
88	-99.219	38.1816	593.781	480820	4225982	620.465
88	-99.219	38.1816	591.587	480826	4225984	618.271
88	-99.219	38.1816	592.083	480831	4225986	618.767
88	-99.219	38.1816	592.827	480836	4225989	619.511
88	-99.219	38.1816	595.678	480841	4225991	622.363
88	-99.219	38.1817	596.51	480846	4225993	623.194
88	-99.219	38.1817	593.702	480851	4225996	620.386
88	-99.219	38.1817	590.214	480853	4225998	616.899
88	-99.219	38.1817	591.217	480852	4226003	617.902
88	-99.219	38.1818	591.708	480851	4226008	618.392
88	-99.219	38.1818	594.704	480848	4226012	621.388
88	-99.219	38.1819	595.388	480846	4226017	622.072
88	-99.219	38.1819	593.331	480845	4226022	620.015

Table 1. Continued.

ID	Longitude	Latitude	HAE	Easting	Northing	MSL
88	-99.219	38.1819	592.493	480844	4226025	619.177
89	-99.219	38.1819	592.512	480844	4226025	619.196
89	-99.219	38.182	592.533	480845	4226026	619.217
89	-99.219	38.182	592.624	480845	4226027	619.308
89	-99.219	38.182	592.636	480844	4226028	619.32
89	-99.219	38.182	592.638	480844	4226028	619.322
89	-99.219	38.182	592.595	480843	4226027	619.279
89	-99.219	38.1819	592.548	480844	4226026	619.232
89	-99.219	38.1819	592.512	480844	4226025	619.196
90	-99.219	38.182	592.491	480843	4226027	619.175
90	-99.219	38.182	592.631	480842	4226027	619.315
90	-99.219	38.182	592.653	480840	4226029	619.337
90	-99.219	38.182	592.606	480838	4226032	619.29
90	-99.219	38.182	592.665	480835	4226035	619.349
90	-99.219	38.1821	592.576	480833	4226039	619.26
90	-99.219	38.1821	592.784	480830	4226042	619.468
90	-99.219	38.1821	592.766	480827	4226046	619.449
90	-99.219	38.1822	592.914	480824	4226049	619.597
90	-99.219	38.1822	592.727	480823	4226051	619.411
90	-99.219	38.1822	592.821	480823	4226052	619.505
90	-99.219	38.1822	592.959	480823	4226052	619.643
90	-99.219	38.1822	593.08	480822	4226053	619.764
90	-99.219	38.1822	593.002	480819	4226057	619.686
90	-99.219	38.1823	593.003	480816	4226061	619.687
90	-99.219	38.1823	593.1	480813	4226065	619.784
90	-99.219	38.1823	593.271	480811	4226068	619.955
90	-99.219	38.1824	591.26	480810	4226070	617.944
91	-99.219	38.1824	592.106	480808	4226073	618.789
91	-99.219	38.1824	592.421	480809	4226073	619.105
91	-99.219	38.1824	592.31	480810	4226074	618.993
91	-99.219	38.1824	592.588	480814	4226074	619.271
91	-99.219	38.1824	592.671	480815	4226078	619.355
91	-99.219	38.1824	592.355	480819	4226079	619.039
91	-99.219	38.1824	593.02	480821	4226079	619.703
91	-99.219	38.1824	592.816	480823	4226081	619.499
92	-99.219	38.1821	592.681	480836	4226041	619.365
93	-99.219	38.182	592.672	480844	4226028	619.356
93	-99.219	38.182	592.675	480844	4226028	619.359
93	-99.219	38.182	592.846	480846	4226030	619.53
93	-99.219	38.182	592.734	480849	4226032	619.418
93	-99.219	38.182	592.779	480853	4226034	619.463
93	-99.219	38.182	592.78	480857	4226036	619.464
93	-99.219	38.1821	592.761	480861	4226039	619.445

Table 1. Concluded.

ID	Longitude	Latitude	HAE	Easting	Northing	MSL
93	-99.218	38.1821	592.774	480866	4226041	619.458
93	-99.218	38.1821	592.749	480870	4226044	619.433
93	-99.218	38.1821	592.703	480875	4226046	619.387
93	-99.218	38.1822	592.578	480879	4226048	619.262
94	-99.219	38.182	592.633	480844	4226027	619.317
94	-99.219	38.182	592.662	480844	4226027	619.346
94	-99.219	38.182	592.691	480847	4226028	619.375
94	-99.219	38.182	592.641	480851	4226029	619.325
94	-99.219	38.182	592.593	480855	4226030	619.277
94	-99.219	38.182	592.687	480860	4226031	619.371
94	-99.218	38.182	592.651	480865	4226032	619.336
94	-99.218	38.182	592.751	480870	4226033	619.436
94	-99.218	38.182	592.698	480875	4226035	619.382
94	-99.218	38.182	592.57	480876	4226035	619.254
94	-99.218	38.182	592.713	480877	4226034	619.397
94	-99.218	38.182	592.411	480877	4226033	619.095
94	-99.218	38.182	592.654	480878	4226030	619.339
94	-99.218	38.182	592.815	480880	4226026	619.499
94	-99.218	38.1819	592.804	480882	4226021	619.488
94	-99.218	38.1819	592.576	480883	4226019	619.26
95	-99.219	38.1822	593.366	480841	4226059	620.05
96	-99.219	38.1821	593.006	480811	4226046	619.689
97	-99.22	38.1832	593.79	480763	4226165	620.473
98	-99.219	38.1833	593.873	480792	4226178	620.556
99	-99.219	38.1834	593.314	480790	4226186	619.997

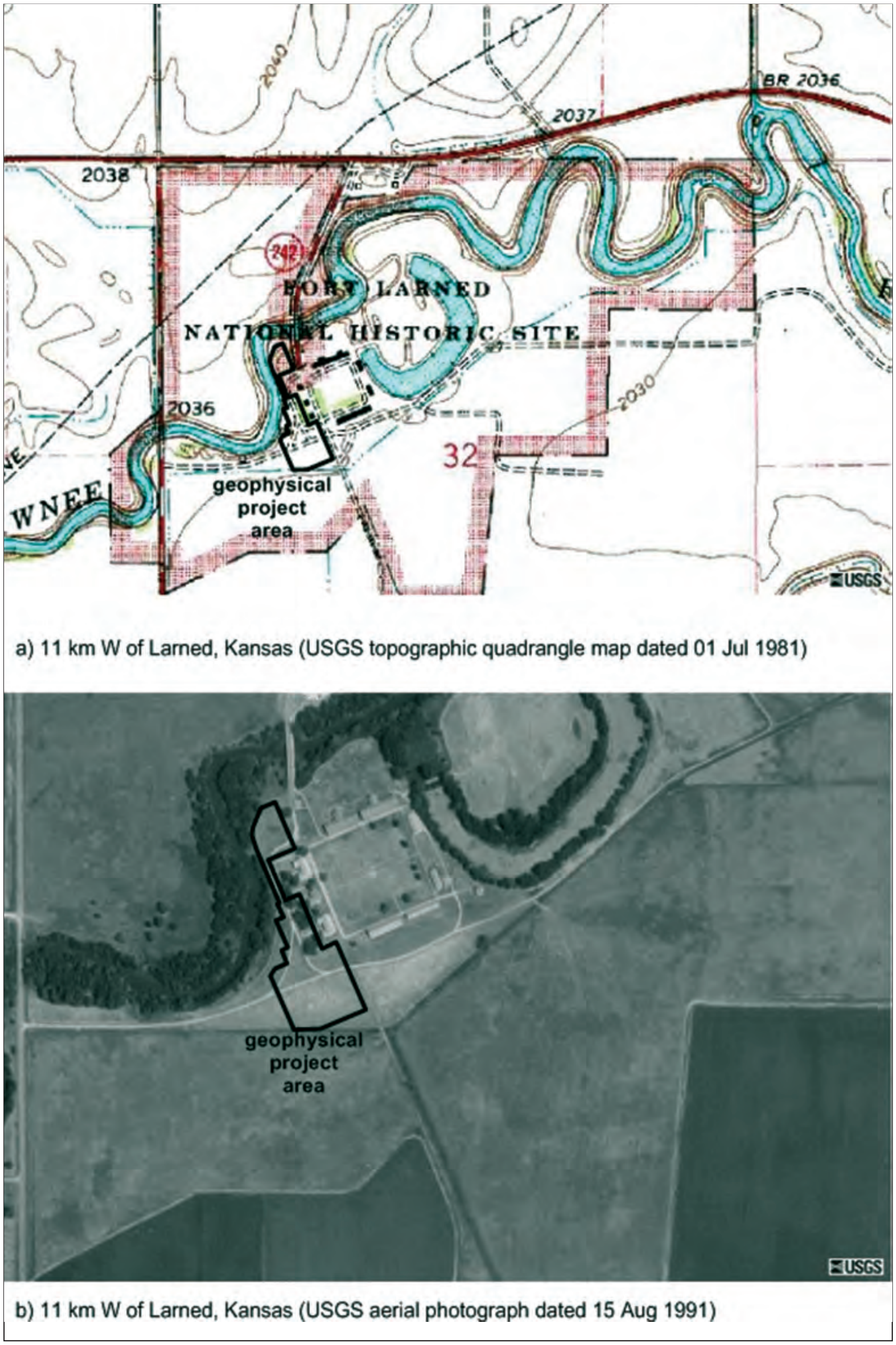
Table 2. Acquisition and instrumentation information for the dual fluxgate gradiometer survey used in the grid input template at the FOLS geophysical project area (Site 14PA305).

GENERAL			
Acquisition	**Value**	**Instrumentation**	**Value**
Sitename	FOLS2009	Survey Type	Dual Gradiometer
Map Reference	Fort Larned, KS 7.5 minute quadrangle	Instrument	Bartington Grad601-2
Dir. 1st Traverse	Grid N	Units	nT
Grid Length (x)	20 m	Range	AUTO
Sample Interval (x)	0.125 m	Log Zero Drift	Off
Grid Width (y)	20 m	Baud Rate	19200
Traverse Interval (y)	1.0 m	Number of Sensors (tubes)	2
Traverse Mode	ZigZag	Download Software	Bartington GRAD601
FILE NOMINCLATURE	**Raw Data**	**Processed Data**	**Corrected Data**
Processing Software	Archeosurveyor		
Grid	g01-g50		
Composite	gc	gcz, gczi, gczil, gczilr	

Table 3. Acquisition and instrumentation information for the resistance survey used in the grid input template at the FOLS geophysical project area (Site 14PA305).

GENERAL			
Acquisition	**Value**	**Instrumentation**	**value**
Sitename	FOLS2009	Survey Type	Resistance
Map Reference	Fort Larned, KS 7.5 minute quadrangle	Instrument	RM15
Dir. 1st Traverse	Grid N	Units	Ohm
Grid Length (x)	20 m	Current Range	AUTO
Sample Interval (x)	0.5 m	Gain Range	AUTO
Grid Width (y)	20 m	Baud Rate	9600
Traverse Interval (y)	1.0 m	Frequency	137 Hz
Traverse Mode	Zigzag	High Pass Filter	13 Hz
ACCESSORIES			
	Accessories	**Value**	
	Array Hardware	PA5	
	Interface	AD1	
	Log Mode	Single	
	Configuration	Twin	
	Probe Spacing	0.5	
FILE NOMINCLATURE	**Raw Data**	**Processed Data**	**Corrected Data**
Processing Software	GEOPLOT		
Grid	r21-r50		r33a
Mesh	rm, rma, rmt		
Composite	rc, rca, rce	rcae, raced, rcaedi, rcaedih, rcaedihr, rcta	

FIGURES



a) 11 km W of Larned, Kansas (USGS topographic quadrangle map dated 01 Jul 1981)

b) 11 km W of Larned, Kansas (USGS aerial photograph dated 15 Aug 1991)

Figure 1. Location of the geophysical project area at the Fort Larned National Historic Site (14PA305), Pawnee County, Kansas.

Figure 2. General view of the southern portion of the geophysical project (view to the east northeast).

Figure 3. General view of the western portion of the geophysical project behind Officers Row (view to the north northwest).

Figure 4. General view of the northern portion of the geophysical project (view to the southwest).

Figure 5. Laying out the geophysical survey grid corner stakes with the surveying compass and 100-meter tape (view to the west southwest).

Figure 6. Placing the surveying ropes on the geophysical grid (view to the south southeast).

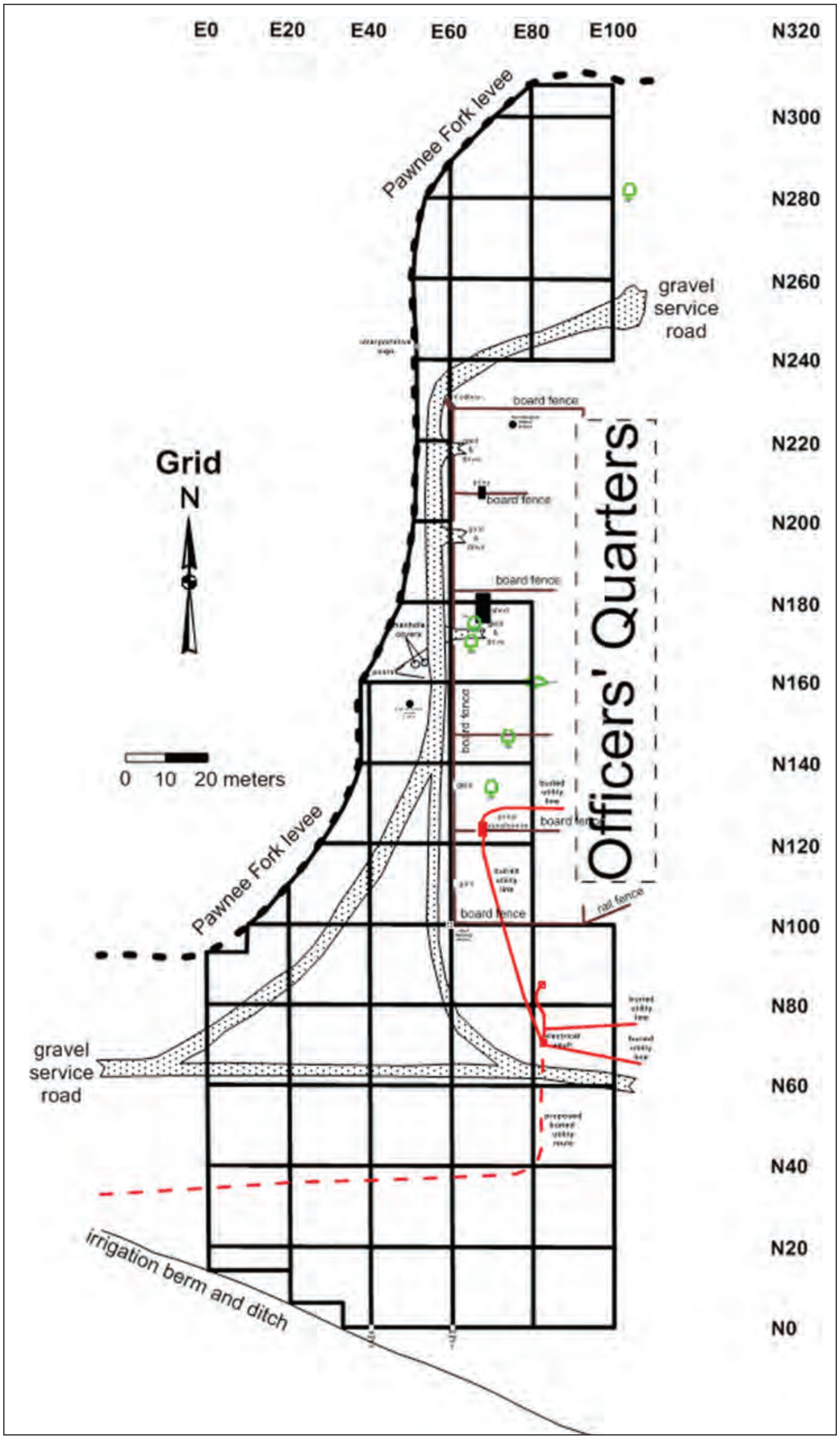


Figure 7. Sketch map of the geophysical investigations at the Fort Larned National Historic Site.

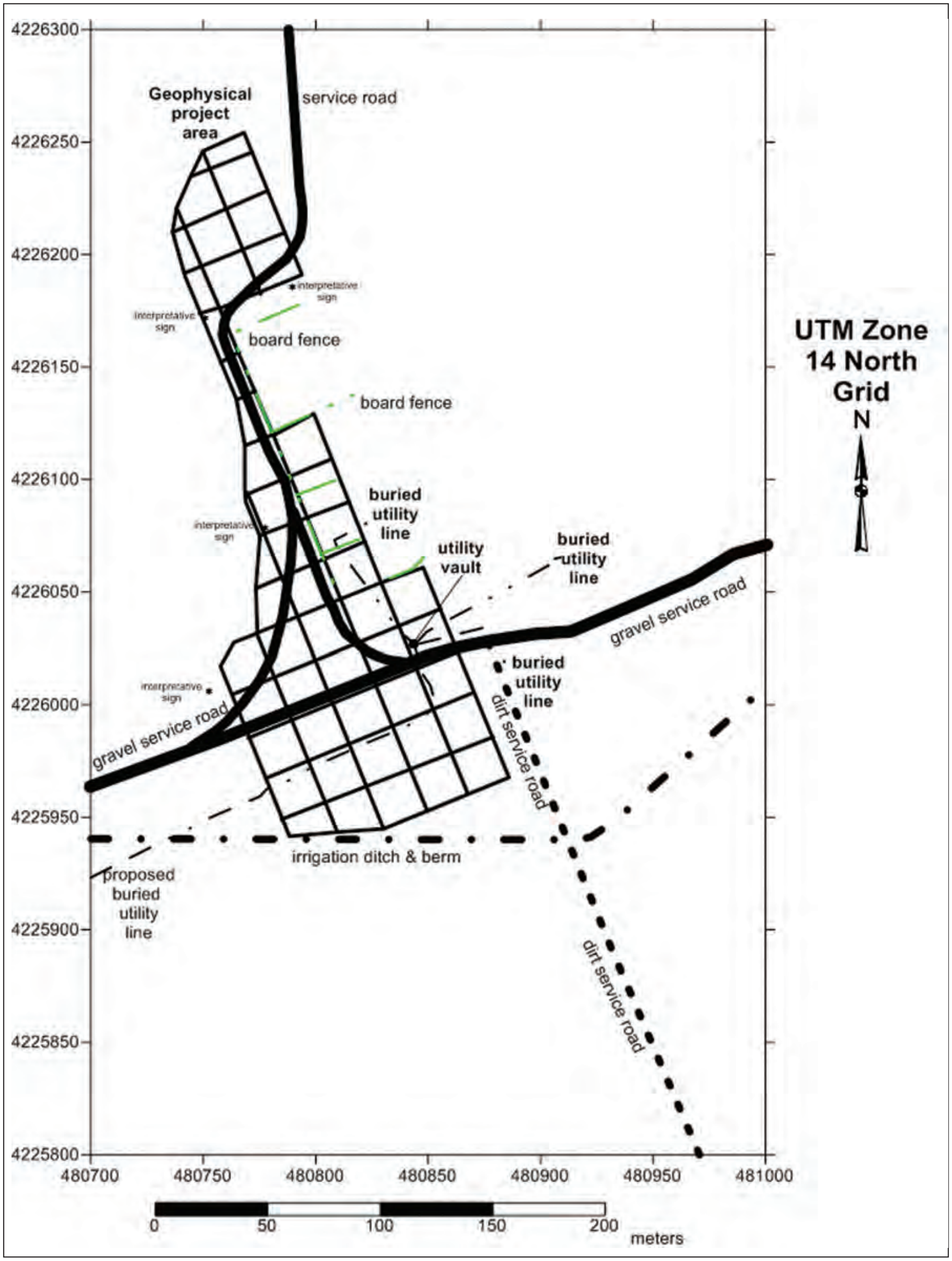


Figure 8. UTM grid of the geophysical project area at the Fort Larned National Historic Site.

Figure 9. Conducting the magnetic survey with the dual fluxgate gradiometer (view to the southeast).

Figure 10. Conducting the resistance survey with the resistance meter and twin probe array (view to the south southeast).

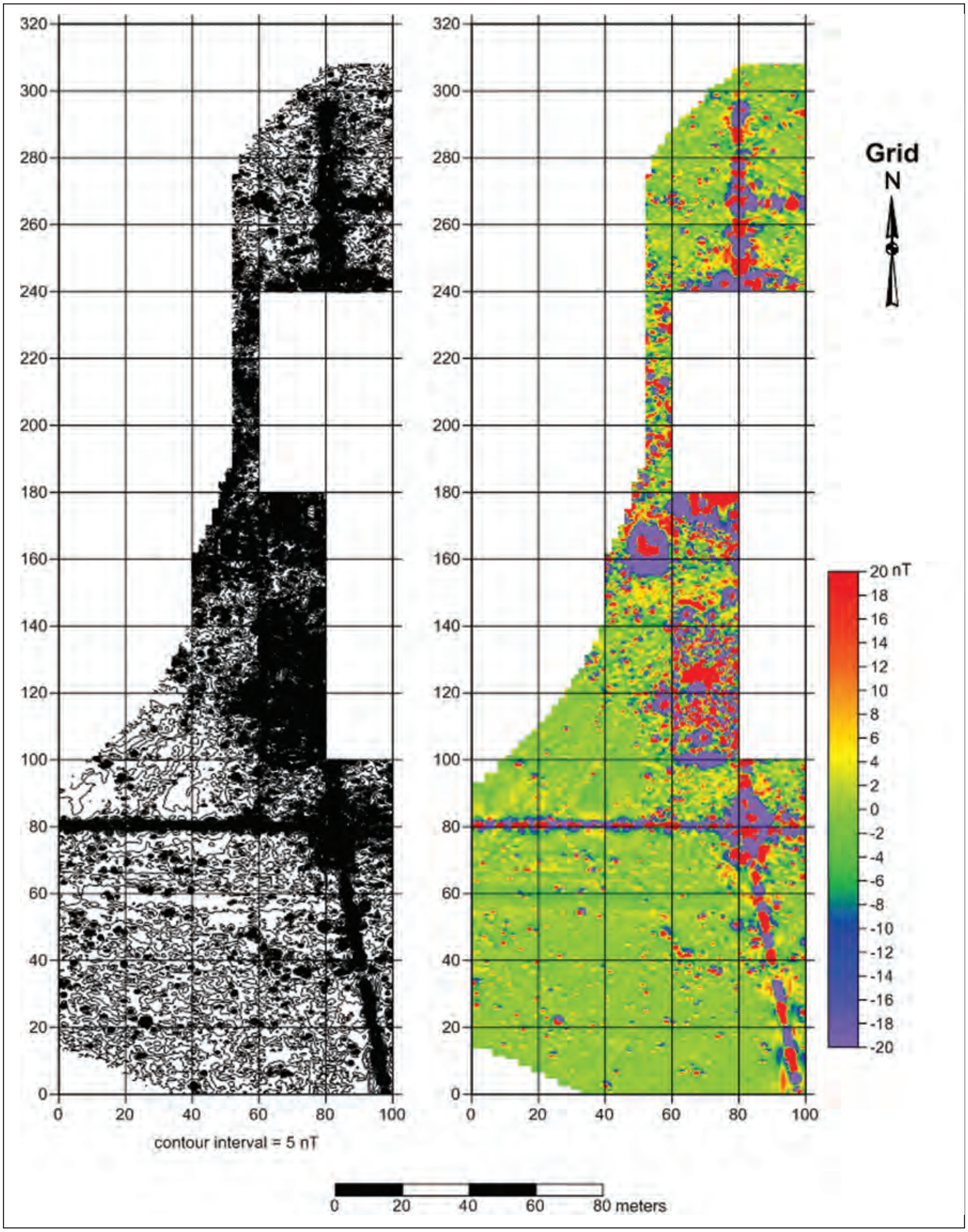


Figure 11. Image and contour plots of the dual fluxgate gradiometer magnetic data from FOLS.

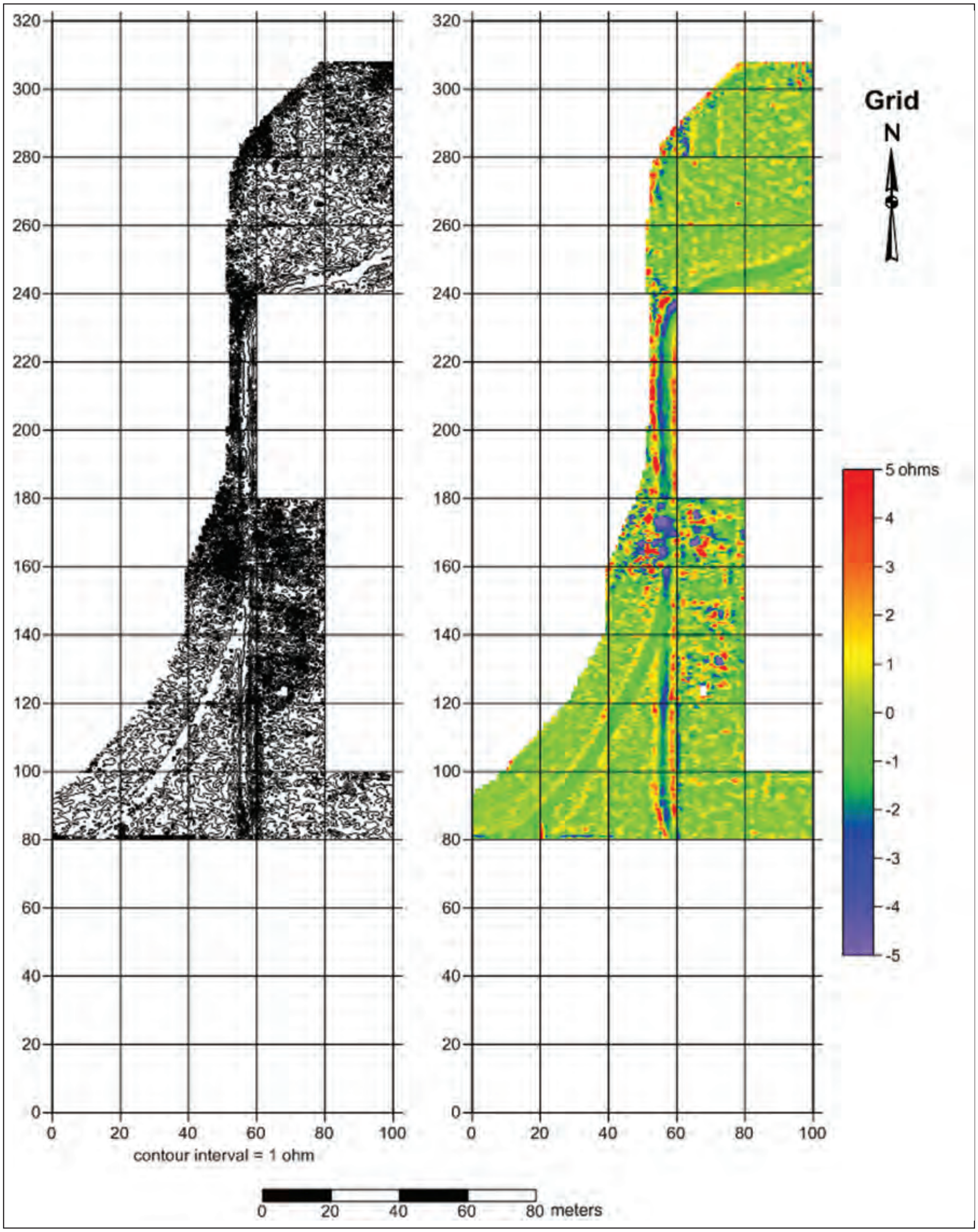


Figure 12. Image and contour plots of the resistance data from FOLS.

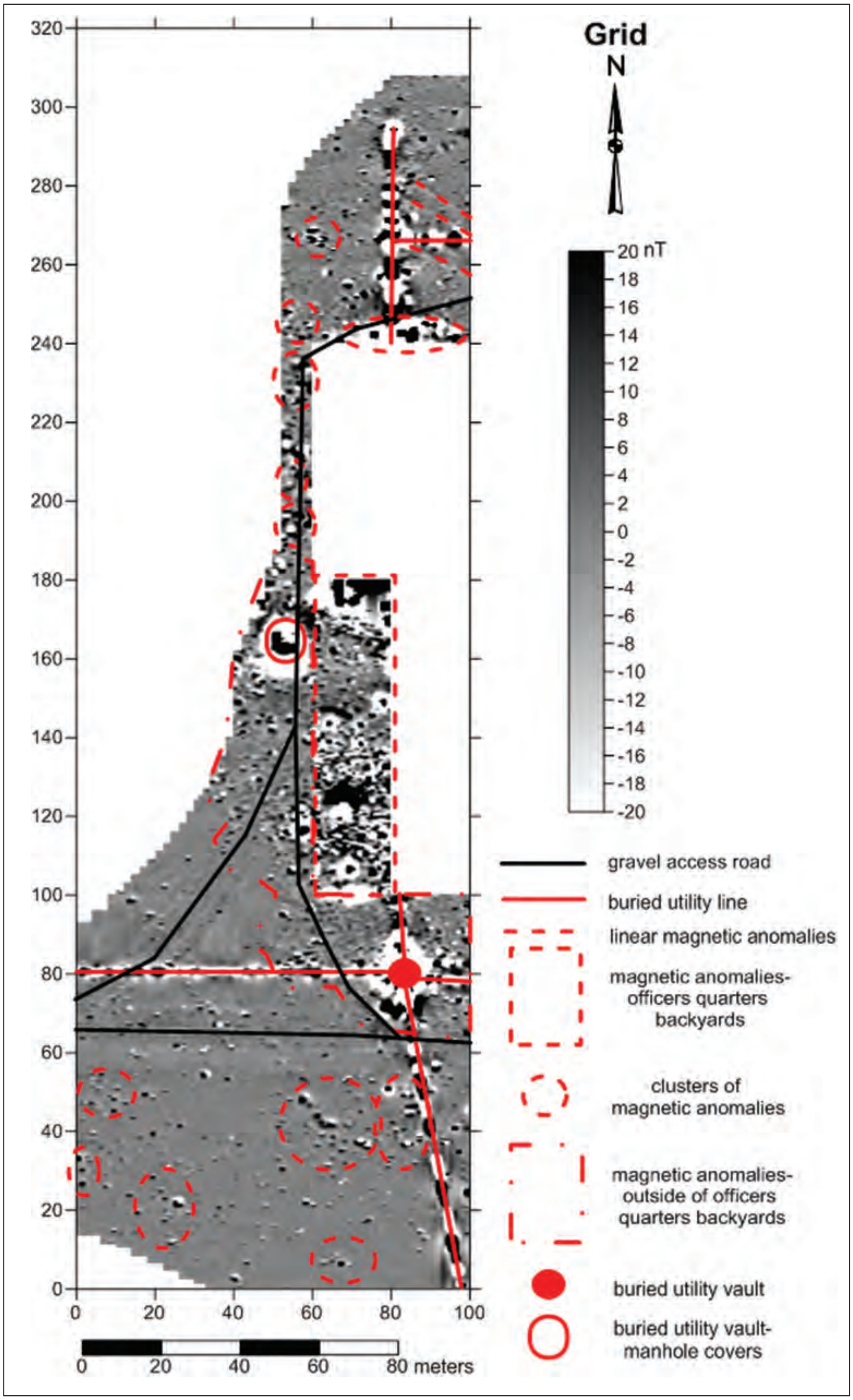


Figure 13. Interpretation of the magnetic data from the dual fluxgate gradiometer in the FOLS geophysical project area.

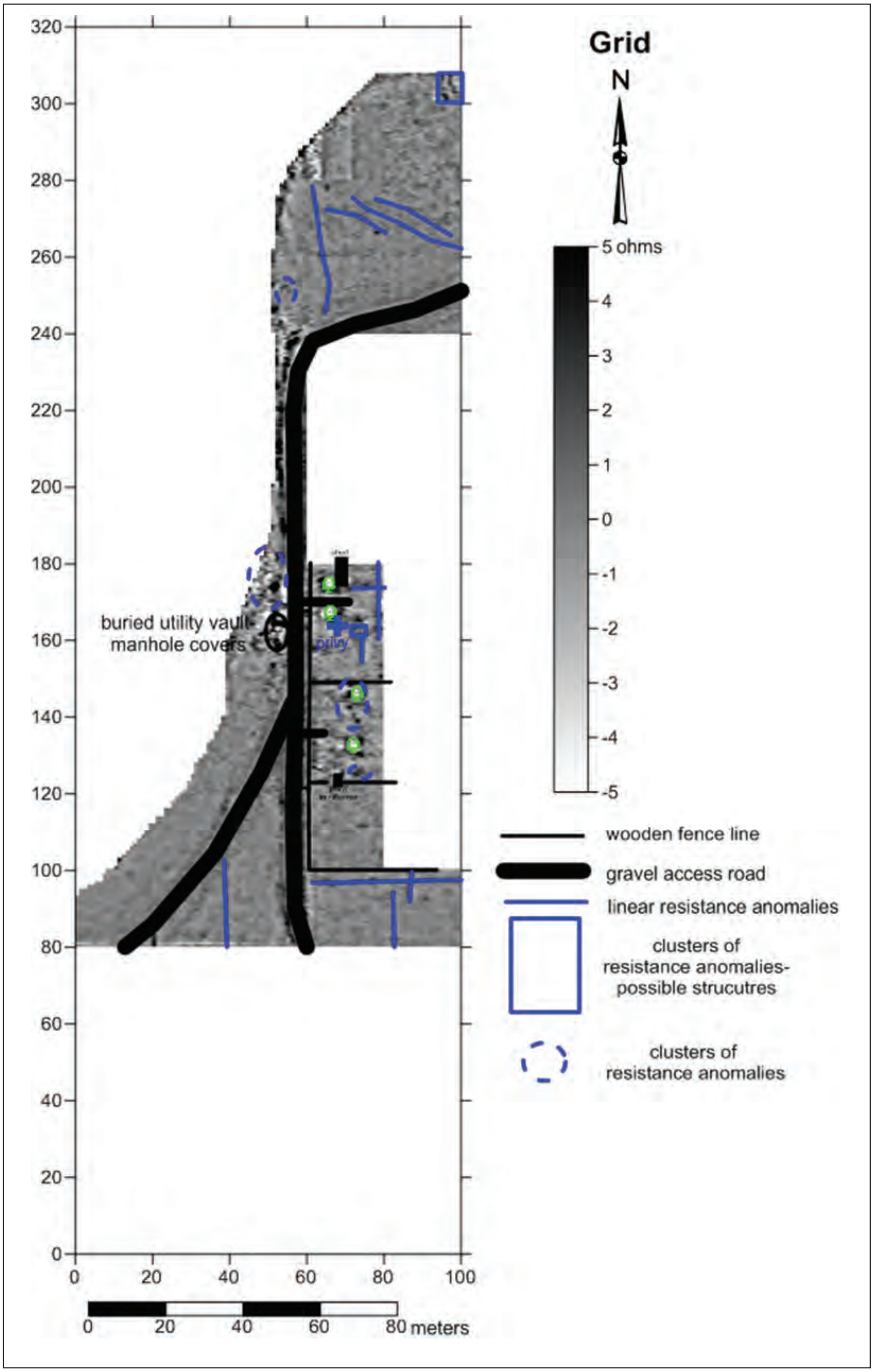


Figure 14. Interpretation of the resistance data from the FOLS geophysical project area.

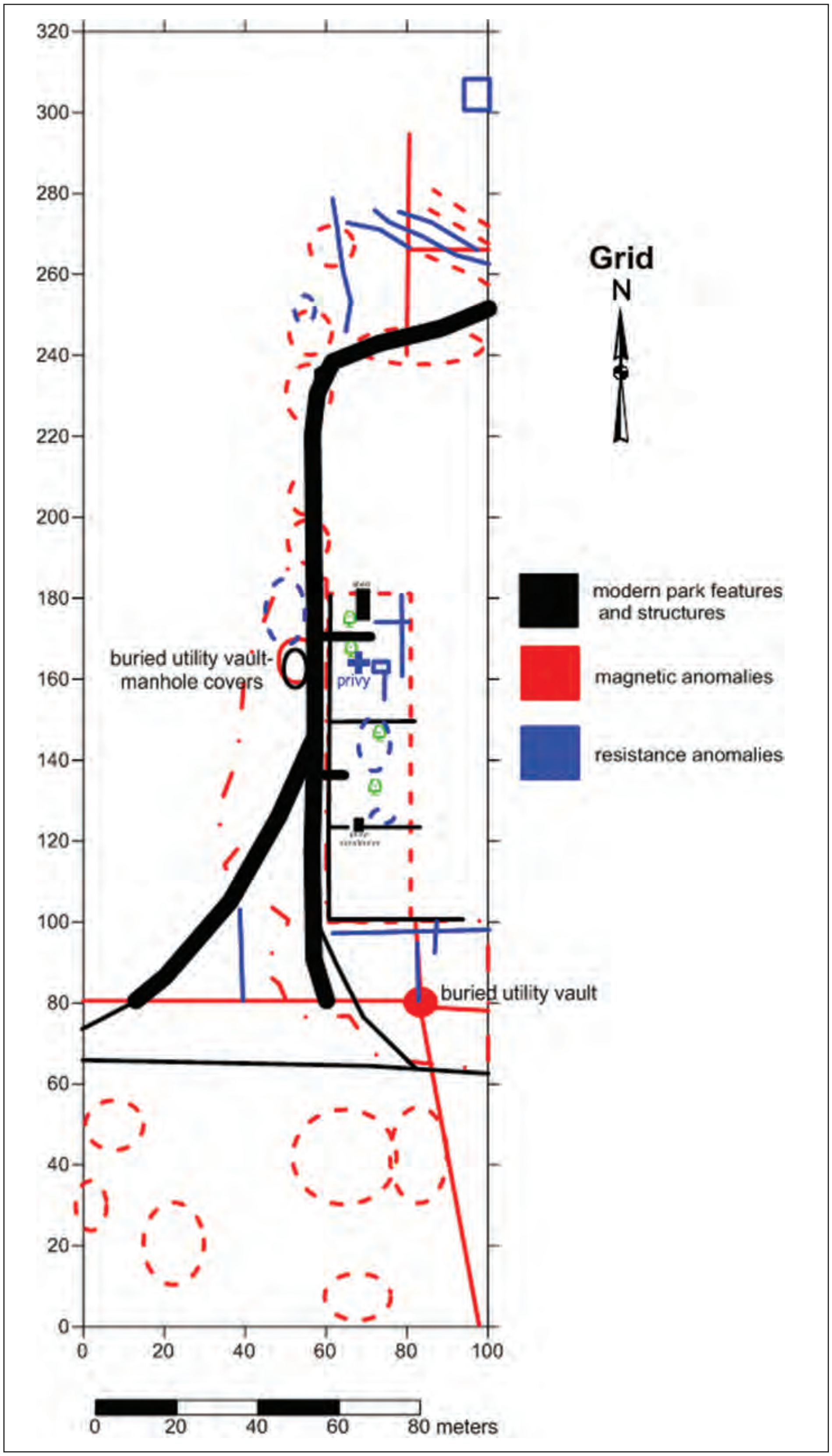


Figure 15. Combined geophysical anomalies from the FOLS geophysical project area.

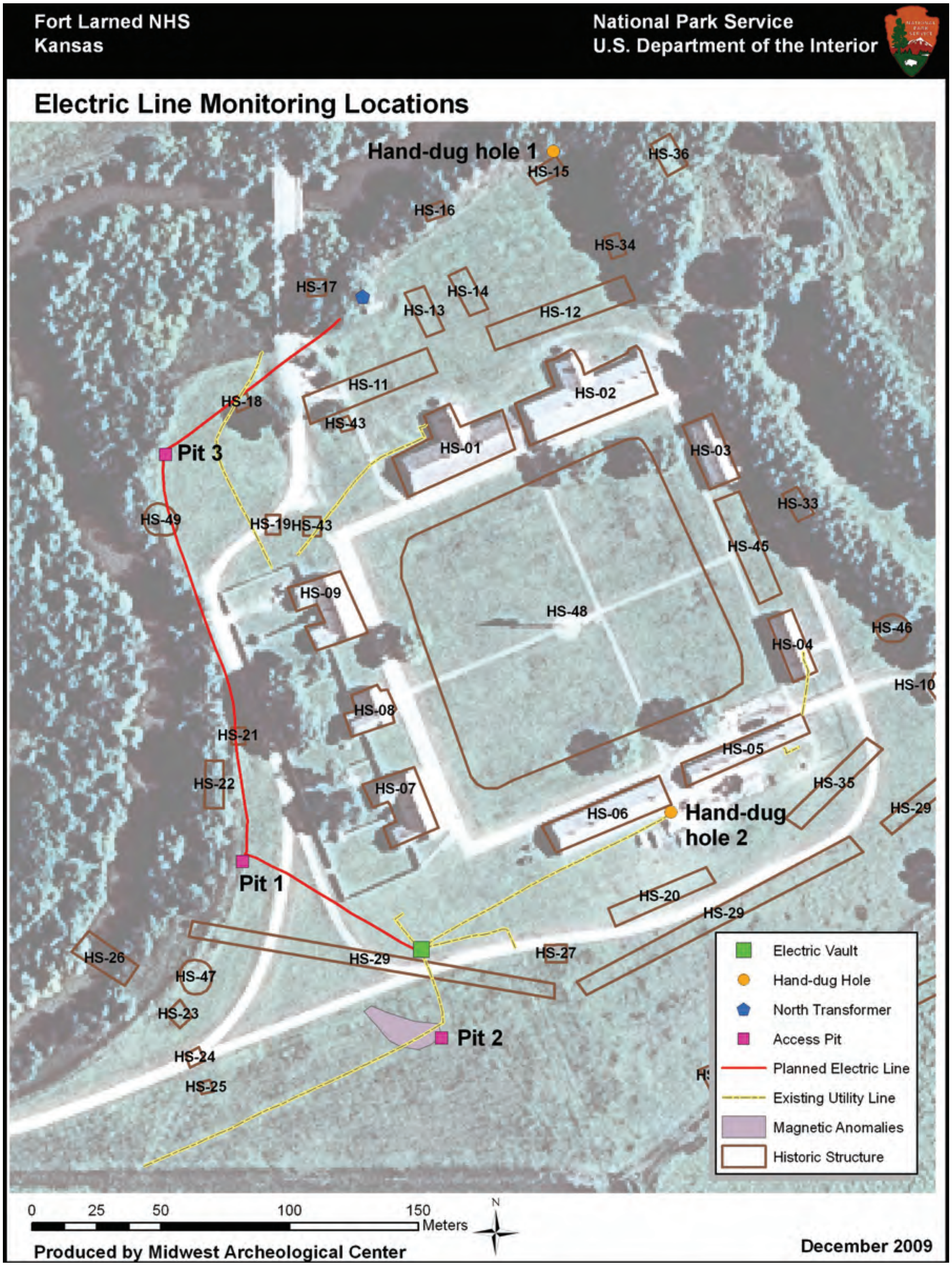
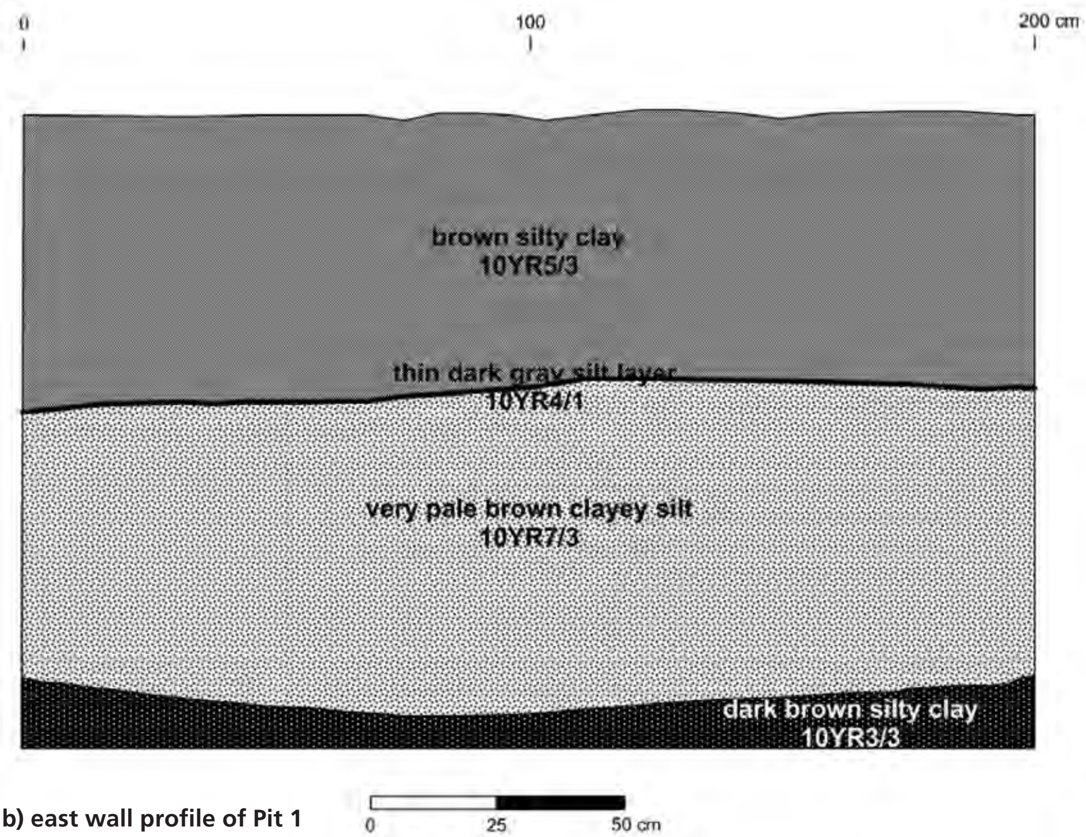


Figure 16. Archeological monitoring of the buried electric line installation at FOLS.

Figure 17. Excavation of access pit 1 with a backhoe (view to the southwest).

Figure 18. View of the open electric vault (view to the north northwest).

a) View of south wall profile of Pit 1 (view to the south)



b) east wall profile of Pit 1

Figure 19. Wall profiles of Pit 1.

a) view of west wall profile of Pit 2 (view to the west)

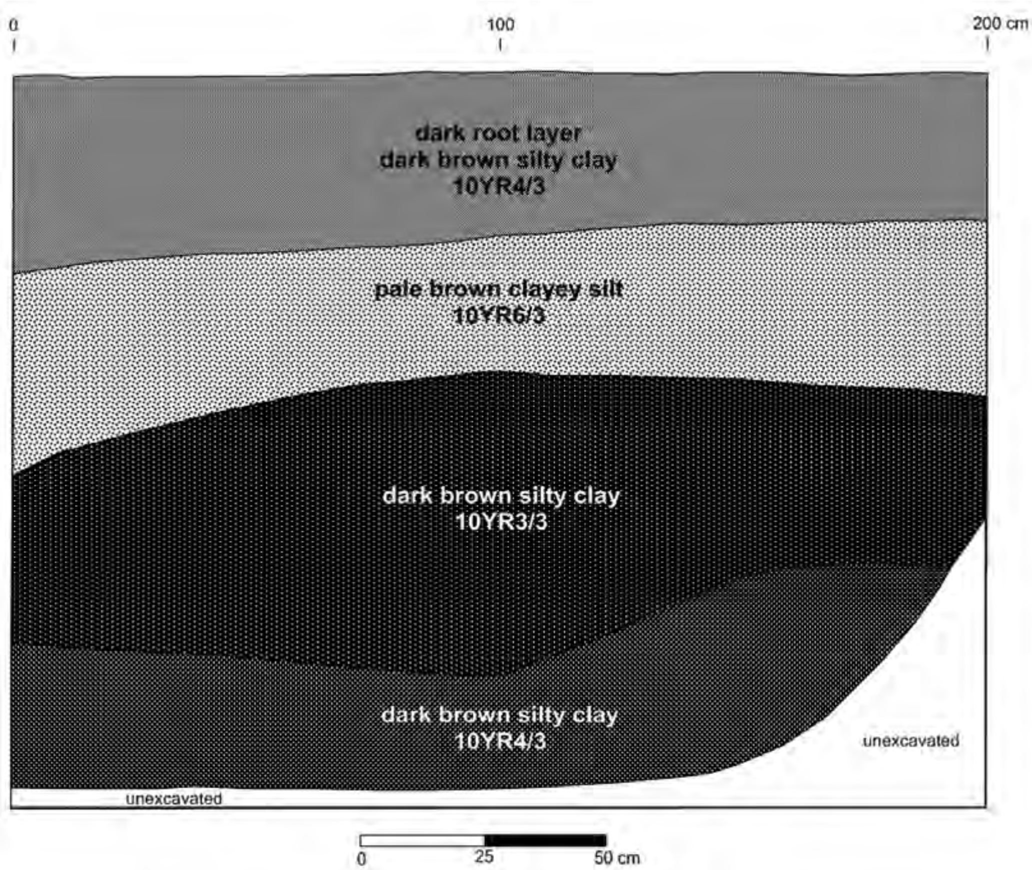


Figure 20. Wall profiles of Pit 2.

a) south wall profile of Pit 3 (view to the south)

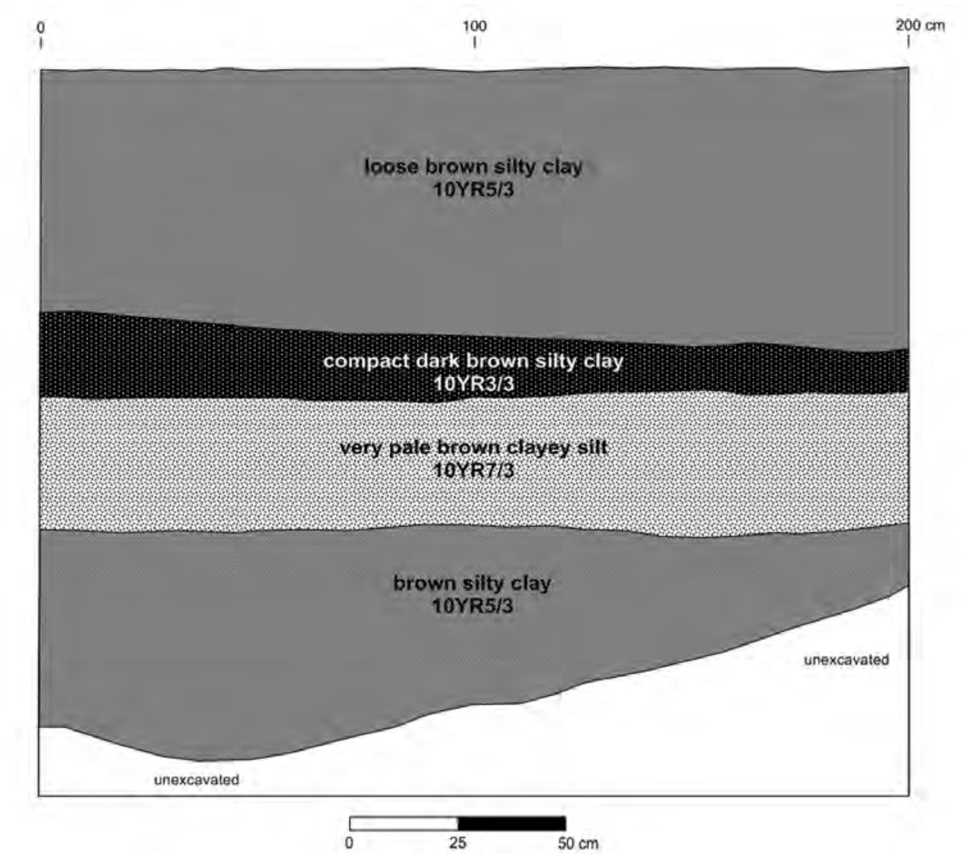


Figure 21. Wall profiles of Pit 3.