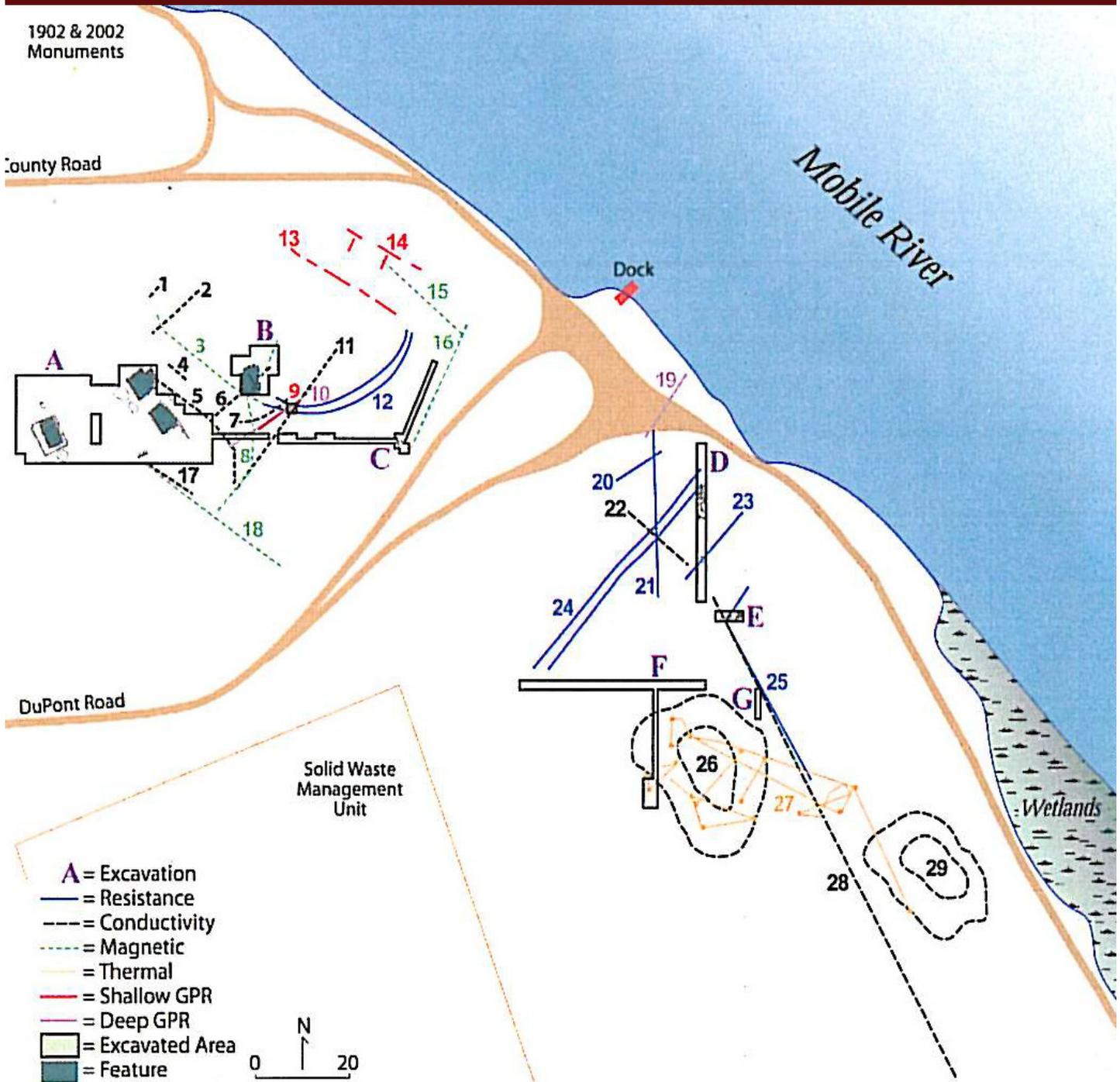




Application of Complementary Geophysical Survey Techniques in the Search for Fort Louis at Old Mobile: A Comparative Case Study | 2004-20

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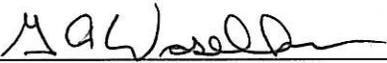
National Center for Preservation Technology and Training



**Narrative Final Report
NCPTT 2004 Grant #MT-2210-04-NC-01**

**Application of Complementary Geophysical Survey Techniques
in the Search for Fort Louis at Old Mobile: A Comparative Case Study**

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(signature)

with contributions by
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submitted by the
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Executive Summary

Application of five geophysical survey methods —earth conductivity, magnetometry, thermal imaging, electrical resistivity and ground penetrating radar—in the search for archaeological remains of Fort Louis, original capitol of the French colony of *Louisiane* (1702-1711), has yielded divergent yet complementary results. This project included test excavations to ground truth the geophysical results and to evaluate the relative effectiveness of these five geophysical survey technologies in conditions common to the Gulf coastal plain. Silty soils, a water table within a few meters of the ground surface, and shallow, ephemeral ground disturbances during prehistoric and historic occupations characterize many archaeological sites in the Gulf coastal plain. Geophysical survey techniques have so far been applied to only a handful of sites in this region, and their application in a systematic, comparative fashion, with follow-up ground truthing, is an even rarer phenomenon. At Old Mobile, none of the geophysical survey technologies discovered French colonial features (although one was found in the course of ground-truth test excavations). However, three technologies—conductivity, magnetometry, and resistance—did reveal modern, cultural, subsurface features. The results of this case study suggest several general lessons. (1) Geophysical surveys must deploy complementary technologies, since each has its own strengths, which should be anticipated and correlated to the kinds of subsurface archaeological features sought. (2) The kinds of archaeological features anticipated at any given site should not be permitted to overly influence pattern recognition and interpretation of geophysical results. Geophysical survey is especially susceptible to *ad hoc* interpretation, which makes intensive ground truthing by excavation so absolutely critical to its successful application. The goal should be an informed understanding of the range of features likely to be encountered. A successful geophysical survey must strike a fine balance between an inefficiently broad application of survey techniques and settings and too limited a range of anticipated results.

Introduction

In 1989 the University of South Alabama began a long-term investigation of Old Mobile, the first formal European colonial town on the US Gulf coast, established in 1702 as headquarters of the French colony of *Louisiane* and abandoned in 1711. Much of the 70-acre town site has since been investigated archaeologically, but the location of Fort Louis has not yet been determined with certainty. In December 2001 a geophysical survey of the Old Mobile archaeological site was conducted to search for remains of Fort Louis. Three methods were employed in the 2.3-hectare (5.7-acre) target area (Figure 1): earth conductivity, magnetometry, and thermal imaging (the first two by Berle Clay of Cultural Resource Analysts, with the assistance of Jay K. Johnson and Bryan S. Haley, University of Mississippi, supported by funding from the University of South Alabama and in-kind support from the University of Mississippi; and thermal imaging by Robert Melia of Real-Time Thermal Imaging, with funding from the National Park Service's Center for Preservation Technology and Training and the Friends of Old Mobile, Inc.). A grant from the National Center for Preservation Technology and Training (NCPTT) in 2004 enabled the application of two more geophysical survey methods, electrical resistance and ground penetrating radar (directed by Jay K. Johnson and Bryan S. Haley, University of Mississippi) with the goal of comparing in a controlled case study the applicability of all five remote sensing methods through ground truthing test excavations. An assessment of these various geophysical survey technologies should be useful for others engaged in historic preservation and investigation of other sites in similar settings.

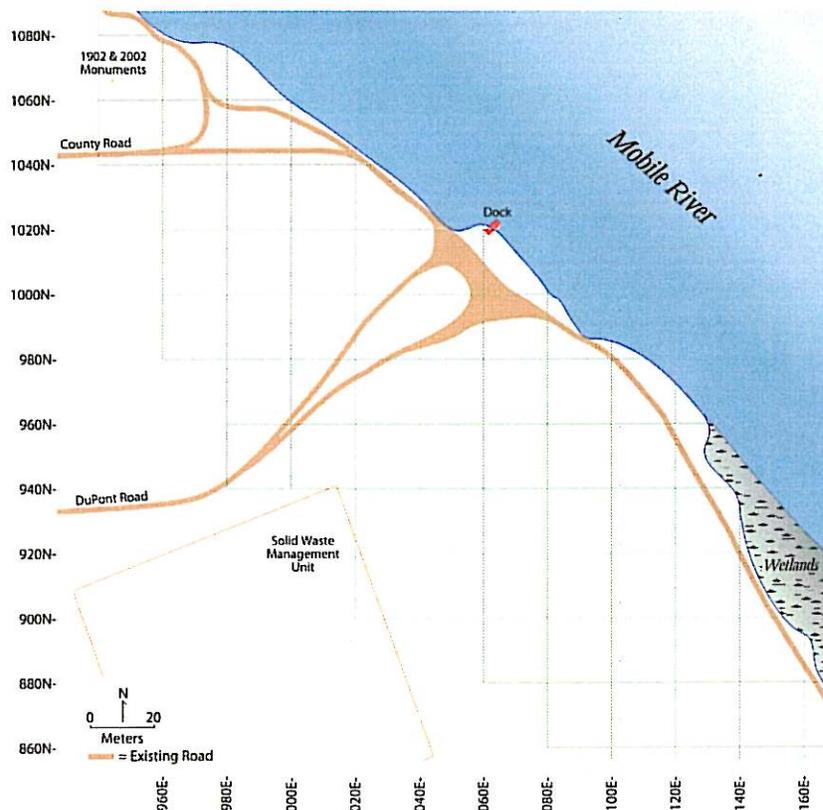


Figure 1. Map of project area, a 2.3 hectare (5.7-acre) tract of the Old Mobile site along the Mobile River, showing the 20-m geophysical survey grid.

In order to assess the effectiveness of these five search methods, this project involved ground truthing of the geophysical survey results, an essential step in understanding the appropriate utility of these five technologies. Ground truthing in this controlled setting, with all five technologies employed under similar soil and weather conditions, permits an evaluation of their usefulness in the common Gulf Coast silt and clayey silt soils represented by the Old Mobile site. Many years experience with French colonial features at Old Mobile suggests that small, dispersed test units do not provide definitive identifications of geophysical anomalies. Since this site was plowed from the mid-19th to mid-20th centuries, most of the remaining sub-plowzone features are trenches (from fences and structure walls) and daub pits used to obtain material for construction. After three centuries, the organic content of such features is depleted through leaching and they can be hard to detect visually, especially in small test units. Therefore, 2-meter square units were excavated by hand and arranged in contiguous trenches, for optimal visibility of subsurface features (see Hargrave et al. 2002:100-101, for the relative merits of trench excavations over other ground-truthing techniques). Placement of excavation units was determined by the geophysical results. Finally, soil samples were collected systematically across several anomalies for soil particle size analysis, which (it was hoped) might indicate the presence of “melted” buildings made of clay or silt.

Methods

Survey with different types of remote sensing equipment has several advantages when used in combination (Clay 2001). In fact, this series of surveys demonstrates that one cannot rely on a single method. The following descriptions of geophysical survey methods are based on reports provided by project consultants (Clay 2002; Melia and Yakubik 2002; Haley and Johnson 2005).

A magnetic survey was performed with an FM36 fluxgate gradiometer manufactured by Geoscan Research, a machine that can be triggered rapidly to gather very dense data sets of magnetic effects. At the latitude of Mobile, the earth’s magnetic field normally measures about 52,000 gammas or nanotesla (nT) (Breiner 1973:6), a product of the earth’s own magnetism, diurnal changes in magnetic forces caused by solar sun spot activity, magnetic storms, and local variation caused by many factors. In archaeology, only a very small range of the local variability—that due to human behavior—is normally of interest. In fact, archaeological features of interest are concentrated within a range of only 20 nT. The FM36 fluxgate gradiometer measures differences in local magnetic effects between two vertically aligned sensors (in this case set 1-m apart). Magnetometers respond to *remnant* magnetism in the ground and in archaeological features, particularly those from burned clays and clayey soils (Clark 1990:64). In the form of prepared burned hearths, structures destroyed by burning, and artifacts created by firing (for example, pottery and bricks), magnetic fields created at the time of burning retain their strength and register higher levels of nT when measured by a gradiometer. The magnetic pattern they create when surveyed varies with the extent to which the fired objects have been moved since they were fired (Bevan 2001). In addition, magnetometers record *induced* magnetism, caused by the presence of ferrous materials, but not other metals (Bevan 2001). In this survey of a portion of the Old Mobile site, 2.3 hectares were cleared of underbrush, then divided into 20-m grid squares (Figure 2). Survey transects 1 m apart crossed each square. Data were periodically downloaded into

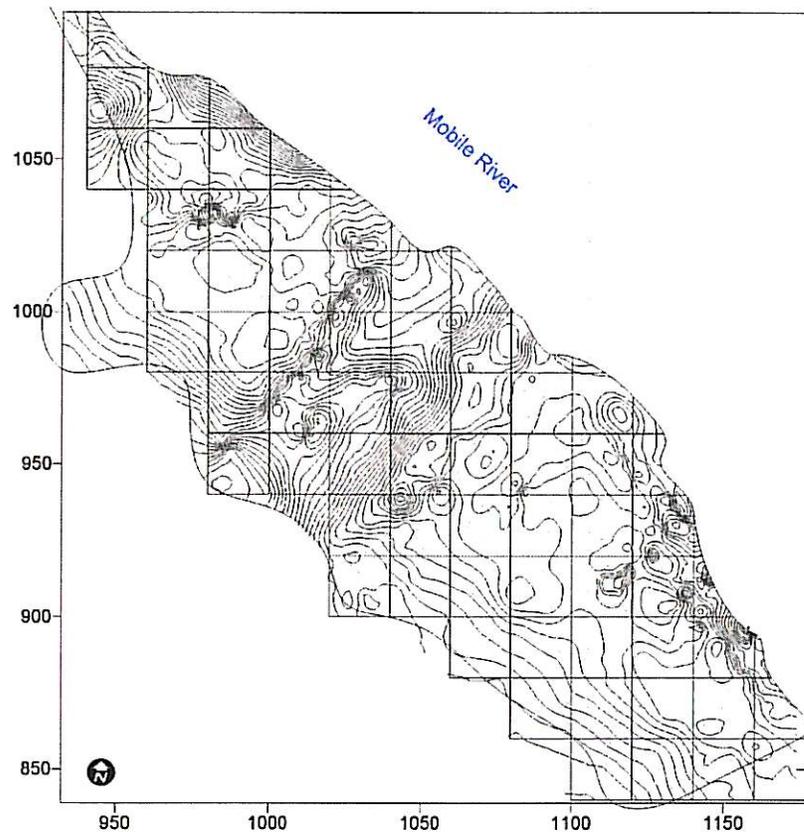


Figure 2. Topographic map of project area, a 2.3-hectare survey tract of the Old Mobile site along the Mobile River, showing the 20-m geophysical survey grid.

a field laptop computer and processed with Geoplot software to increase data resolution. Results are displayed graphically using Surfer 7 and Digger 3 software (Clay 2002:1-2).

An earth conductivity meter measures how well an induced electromagnetic force is conducted through the ground. Conductivity measures somewhat different characteristics of the ground than magnetometers. In prehistoric mound surveys, conductivity has determined the extent of mound fill and individual mound stages where degraded by agricultural plowing. An anomaly registering in magnetometer data but not in conductivity, could be a burned feature and not a metal signal. When both record an anomaly, it is probably a ferrous (iron) target. Where conductivity alone registers a discrete anomaly, the target may be non-ferrous metal. Consequently, a conductivity survey often complements magnetometer survey results. An EM38 earth conductivity meter manufactured by Geonics Ltd. was employed for the Old Mobile survey. This machine induces a 14.6 kHz electromagnetic field via a transmitter at an end of a 1-m instrument, and a receiver at the other end measures (in millisiemens per meter, mS/m) how well the electromagnetic force is conducted through the ground. This spacing between transmitter and receiver permits measurement of earth conductivity to depth of about 150 cm. Because the induced signal of a conductivity transmitter induces magnetism in the soil and in all types of metal beneath the instrument, the presence of large quantities of buried metal can swamp the much weaker signal from the soil. To offset this effect, the EM38 was carried approximately 30 cm above the ground. Importantly, the EM38 does not respond to remnant magnetism from burned structures,

thereby complementing magnetometer survey results. Finally, the EM38 is susceptible to thermal drift in its electronic components in warm temperatures. However, ambient temperatures during the Old Mobile survey remained low and stable, averaging about 55° F, plus or minus 10°, so the equipment was not insulated. The conductivity survey team employed the same grid and transects used for the magnetometer survey (Bevan 1998:42; Clay 2002:2-4).

Two thermal surveys were undertaken, on December 10-11, 2001 and January 29, 2002, using a hand-held Palm-IR 250 infrared camera with a 50-mm lens and an uncooled Ferro electric (320 x 240) focal plane array sensor with 0.05° C resolution. Real-time images were recorded on a Hi-8 Sony digital video camera, and individual images were processed with Spectrum Soft 2.0 software. The method depends on differential heating, during the course of the day, of features in the ground. Features of different consistency—soils with different density or particle size or moisture level—absorb and radiate heat at different rates. A thermal survey is best conducted over several hours, either in the morning as the sun warms the ground, or in the evening as the ground cools. The Old Mobile survey involved examination of the site both from the ground and from a helicopter (with “Chopper 5” and pilot time donated to the project by WKRG-TV). Anomalies seen on the ground were marked with spray paint and recorded using a Sokkia SET6E total station with an HP TDS-48GX data receiver. The most appropriate airframe for aerial thermal imaging is the helicopter, since versatility in hovering allows for superior imaging. Aerial thermographic survey was conducted at 500 feet and at 1,000 feet. Survey at the higher altitude proved most useful as it permitted views that included the anomalies in relation to the surrounding landscape. Advantages of thermal imaging include quick survey and post-survey data processing times, and the ability to immediately view and adjust image vantage point (Melia and Yakubik 2002).

This NCPTT grant project involved the application of two additional geophysical survey techniques—electrical resistivity and ground penetrating radar (GPR)—to enable a comparison of all five major remote survey methods in widespread use today in US archaeology. The resistivity and GPR surveys took place in December 2004, when site conditions were similar to those experienced during the 2001-2002 geophysical surveys—specifically, when daytime temperatures were around 55° F and soils at Old Mobile were moist but not saturated. A geophysical survey team from the University of Mississippi spent one week on site gathering field data.

Electrical resistance is the reciprocal of conductivity. Resistivity instruments measure (in Ohm-meters) how readily electrical current flows through the soil, which is sensitive to differences in moisture content of subsurface features (Weymouth 1986:319; Clark 1990:27). Since differences in relative moisture are due to differences in organic content, grain size, and porosity, humanly disturbed soils are often detectable from resistivity survey. Clay soils tend to retain moisture more readily than sands, so clays usually have lower resistance values than sands. High relative salinity also effects electrical current flow by lowering the resistance of soil. Measurements range from 5 Ohm-m in highly saline soils to 10,000 Ohm-m in some sandy soils (Bevan 1998:8). In geophysical survey, measurement of resistance over a volume of soil yields an estimate, termed apparent resistance, for any given point. This survey employed a Geoscan Research RM-15 instrument on a 2.0-m frame with MPX multiplexor, a data control unit that collected readings at 0.5 m intervals along both survey axes (Haley and Johnson 2005:3-5).

Both conductivity and resistivity measure conditions of the soil irrespective of its magnetic properties (Clay 2002:3). Bruce Bevan has provided the following values obtained from different soils using a resistivity meter and an earth conductivity meter:

Table 1. Resistivity and conductivity values for different soils (from (Bevan 1998:8; also Davis et al. 1997).

Soil Type	Resistivity (Ohm-m)	Conductivity (mS/m)
Sand, Gravel	1000-10000	0.1-1
Silty Sand	200-1000	1-5
Loam	80-200	5-12.5
Silt	40-80	12.5-25
Clay	5-10	100-200

Ground penetrating radar (GPR) operates by sending an electromagnetic wave pulse into the ground that reflects off materials with contrasting electrical properties. An interface is visible if the electrical properties of two substances or soils contrast enough to produce a reflection, and the strength of a reflection is determined by the relative dielectric permittivity (RDP) of adjacent materials. RDP values of soils range from the driest sands (3) to saturated clay (40) (Weymouth1986:371; Conyers and Goodman 1997:23). Wet clay soils and high salinity soils are not ideal conditions for GPR use. GPR surveys routinely measure (in nanoseconds, ns) the travel time of the transmitted and reflected wave pulse, which can be related to depth of the interface. Data processing for GPR is more complex and time-consuming than for any other of the geophysical survey methods employed at Old Mobile. Processing includes creating planimetric amplitude slice maps and three-dimensional data cubes. The University of Mississippi operated a Geophysical Survey Systems Inc. SIR2000 system with 400 MHz and 300 MHz antennae. the system operator wears a harness that carries a battery pack and a laptop computer that displays vertical profiles in real time (GSSI 1999:5). An integrated survey wheel attached to the radar sled (carrying the transmitter/receiver box) was used to determine distance along the 1.0-m transects. Data were collected at 30 scans per m, at 512 samples per scan, yielding an enormous data set that was sampled during processing (Haley and Johnson 2005:6-8). Optimal conditions for GPR survey include a clear ground surface devoid of trees, tree roots, vines and other impediments. A great deal of site preparation took place in October and November 2004, when volunteers spent many hours clearing away underbrush and small trees by hand prior to the arrival of the geophysical team. The same 20-m grid and transects used for magnetometry, conductivity, and resistivity were employed during the GPR survey.

The central 2.3-hectare portion of the Old Mobile site, and the focus of this geophysical survey, is owned by two landowners: Mobile County and DuPont Agricultural Chemicals. The DuPont portion is further protected by a preservation easement held by The Archaeological Conservancy (TAC). All parties granted permission for this project to occur on their properties. Hand excavation of 2.0 x 2.0-m units took place in April, May, and June 2005 to ground truth the anomalies revealed by geophysical survey. Excavations followed a protocol developed since 1989 for all such work at Old Mobile, including shoveling of plowzone soils, water screening of trench contents through $1/16$ -inch mesh, and systematic recording of unit plans and contents. Particle size analysis of selected samples of the site's silty and silty clay subsoils took place in July and August 2005.

Results: The Geophysical Anomalies

As expected, the five methods of geophysical survey at Old Mobile yielded very different results. Graphic displays of each method's data plots are presented first. Then the anticipated archaeological remains of Fort Louis's are briefly discussed. Finally, the results of ground truthing and the soils analysis are described and compared to the geophysical survey anomalies.

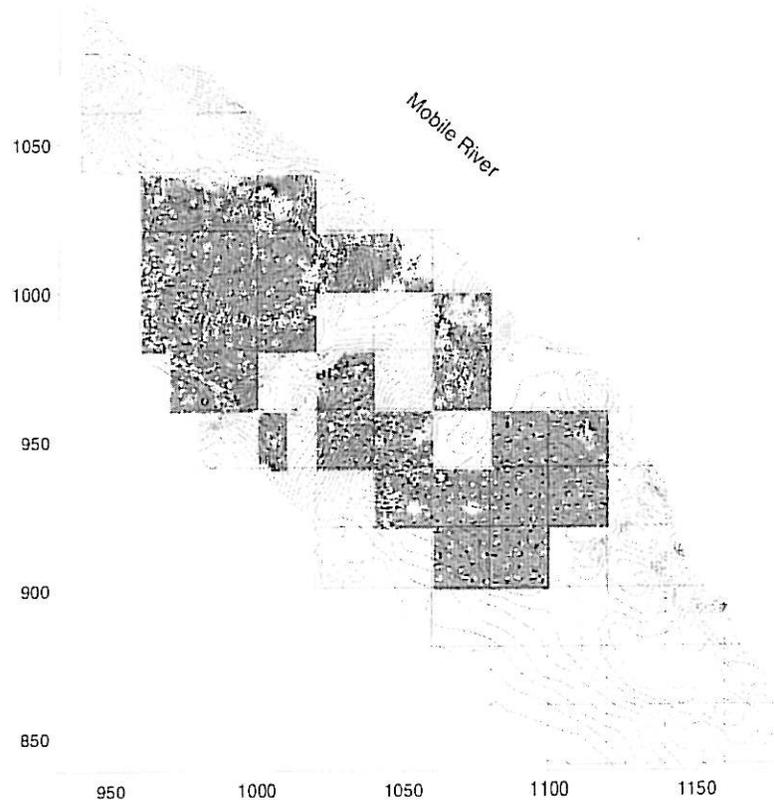


Figure 3. Graphic overview of fluxgate gradiometer (magnetometer) survey results. Dark shading represents higher nT readings, or greater magnetism; lighter shading, lower nT readings, or less magnetism (from Clay 2002: 10).

Magnetic survey suggested the plentiful presence of iron targets (Figure 3). Ferrous metal characteristically produces a dipole pattern in magnetometer plots—a combination of dark (high) and light (low) signals—produced as the gradiometer passes over a metal target. Many such anomalies are present in the survey tract. Several linear arrays of presumably ferrous targets diagonally cross the northern survey block (north of the DuPont road); these will be discussed further below. Other similar point targets occur in a highly systematic pattern across the southern survey block. These latter were immediately attributable to the steel wire pin flags used to mark the 4-meter interval shovel test grid dating to 1989. The flags had been mowed in the intervening years, leaving wire pins in place. Despite this abundance of modern iron, several alignments and clusters of small anomalies, particularly in the northwestern part of the survey area, are suggestive of early historic features. None, however, resembles the features expected to remain from Fort Louis. The extent and large

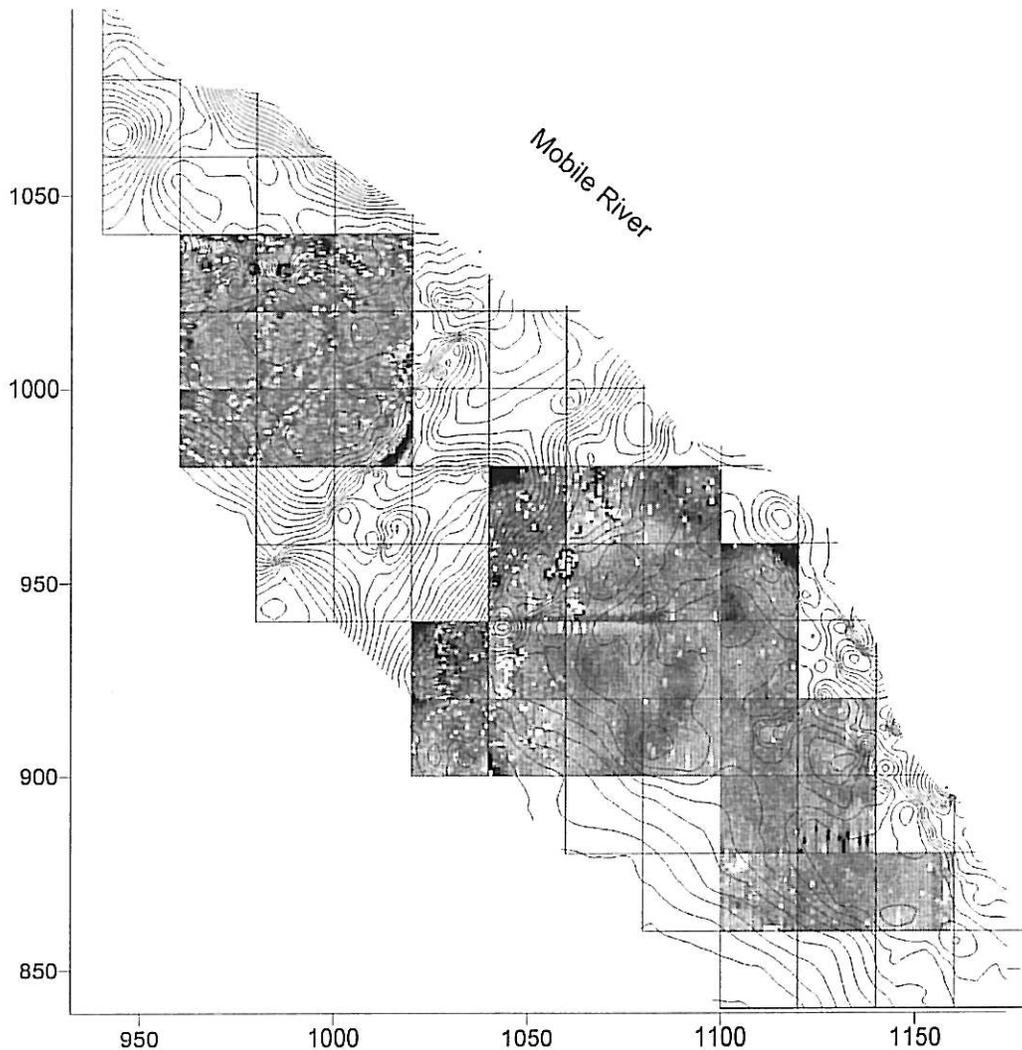


Figure 4. Graphic overview of conductivity survey results. Dark shading represents higher mS/m conductivity readings, and lighter shading represents lower mS/m conductivity readings (from Clay 2002:15).

number of apparently modern iron targets in large parts of the survey area effectively masks whatever more subtle early historic features may exist there.

The conductivity survey revealed several intriguing patterned anomalies that, in several instances, seem to complement results from the magnetometer survey. In the northern part of the survey area, several alignments are visible in Figure 4 that correspond to alignments in the magnetometry data, suggesting that metal targets are correlated with linear features. In the southern part of the survey area, conductivity indicates a very different kind of anomaly. The two examples are very similar, one near the river bluff and the other inland to the northwest. Each consists of a hollow conductivity “high” surrounding a “low” oval or rectangle. The difference between the high and the low is only about 2 mS/m. These two anomalies were suspected by the geophysicist as the possible locations of structures, where unburned clay walls decayed, producing a halo of higher conductivity around a floor, perhaps the remains of clay-walled Indian or French houses, or of clay-filled bastions from Fort Louis (Clay 2002).

Thermal imaging produced two distinct sorts of results. The ground-level survey detected linear anomalies that appeared to intersect at various sharp angles (Figure 5) (Melia and Yakubik 2002). The helicopter aerial platform provided a more complete view of anomalies that seemed to coalesce, at the altitude of 1,000 feet, into a rectangular pattern (Figure 6). All appeared in the southern portion of the survey area, immediately southeast of the DuPont road. Correlating the aerial image to the site survey grid is problematic, but the location corresponds roughly from the ground-level anomalies north to the river.

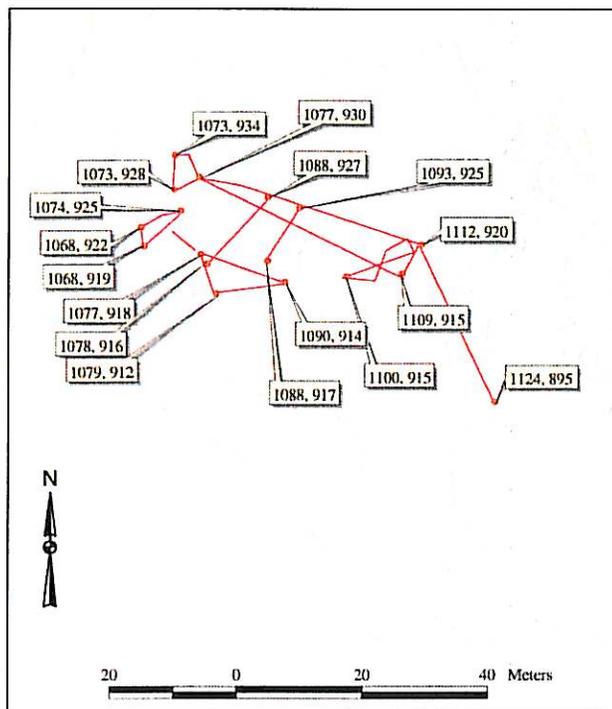


Figure 5. Graphic overview of ground-level thermal imaging results. Linear features were located with the infrared camera, spray painted on the ground, and mapped with a total station (from Melia and Yakubik 2002).



Figure 6. A frame from aerial thermographic survey video; thermal camera image taken at 1,000 feet, showing rectangular anomaly in right center. Mobile River is visible at upper right (from Melia 2002). Vertical shadow at far right corresponds to bluff overlooking bottomland swamp.

Electrical resistance results are characterized by highly variable background readings, making it difficult to detect variation in many areas. A high pass filter reduced that problem by enhancing local variation. Many significant resistance anomalies are evident in the resultant graphic (Figure 7). Several are long, linear, low resistance features, the sort of thing that rarely occurs in nature. Several are paired, including a curvilinear set of anomalies in the northern part of the survey area. A number of locations of high resistance resemble compacted clay house floors found during resistivity surveys at prehistoric sites. The area immediately east of the 1902 and 2002 commemorative monuments, at the extreme upper left of the graphic, shows no significant anomalies (Haley and Johnson 2005: 13-14).

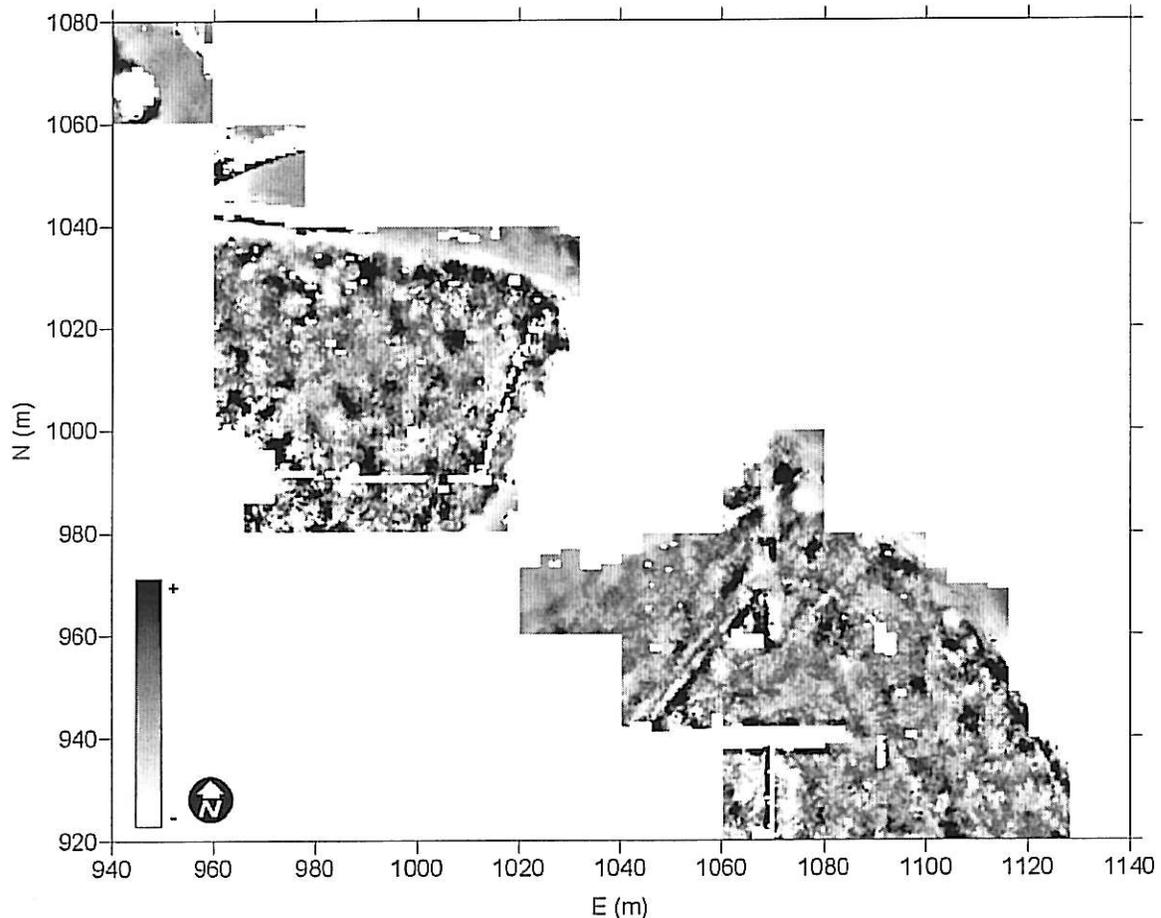


Figure 7. Graphic overview of high pass resistance data. Dark shading represents higher Ohm-m resistance readings, and lighter shading represents lower Ohm-m resistance readings (from Haley and Johnson 2005:13).

The ground penetrating radar data contains a large number of reflections from surface features, such as roads and ditches. After transform matching and vertical filtering, sufficient contrast was present for archaeological analysis. Twelve horizontal slices ranging from 0 to 22.2 ns in two-way travel time were processed. Based on the shape of reflections from areas of primary interest, a reasonable dielectric value of 14 was determined. A radar signal will travel at 8 cm per ns in soils with that dielectric value. On that basis, estimates of depth for each horizontal slice were calculated. Linear anomalies occur at two depths in the GPR imagery.

GPR time slice 3, corresponding approximately to a zone 13.2 to 29.2 cm from the surface, reveals a good deal of disturbance near the ground surface (Figure 8). There are, however, a few linear anomalies crossing the northern part of the survey area, north of the DuPont road (which is visible as a large black oval in the center of the graphic). GPR time slice 7 (Figure 9) reveals an anomaly that coincides with one in the previous graphic, in addition to a new one near the river. The area south of the DuPont road is dramatically free of anomalies in both images, except for a diagonal linear reflectance bordering the eastern edge that coincides with the river road (Haley and Johnson 2005: 15-20).

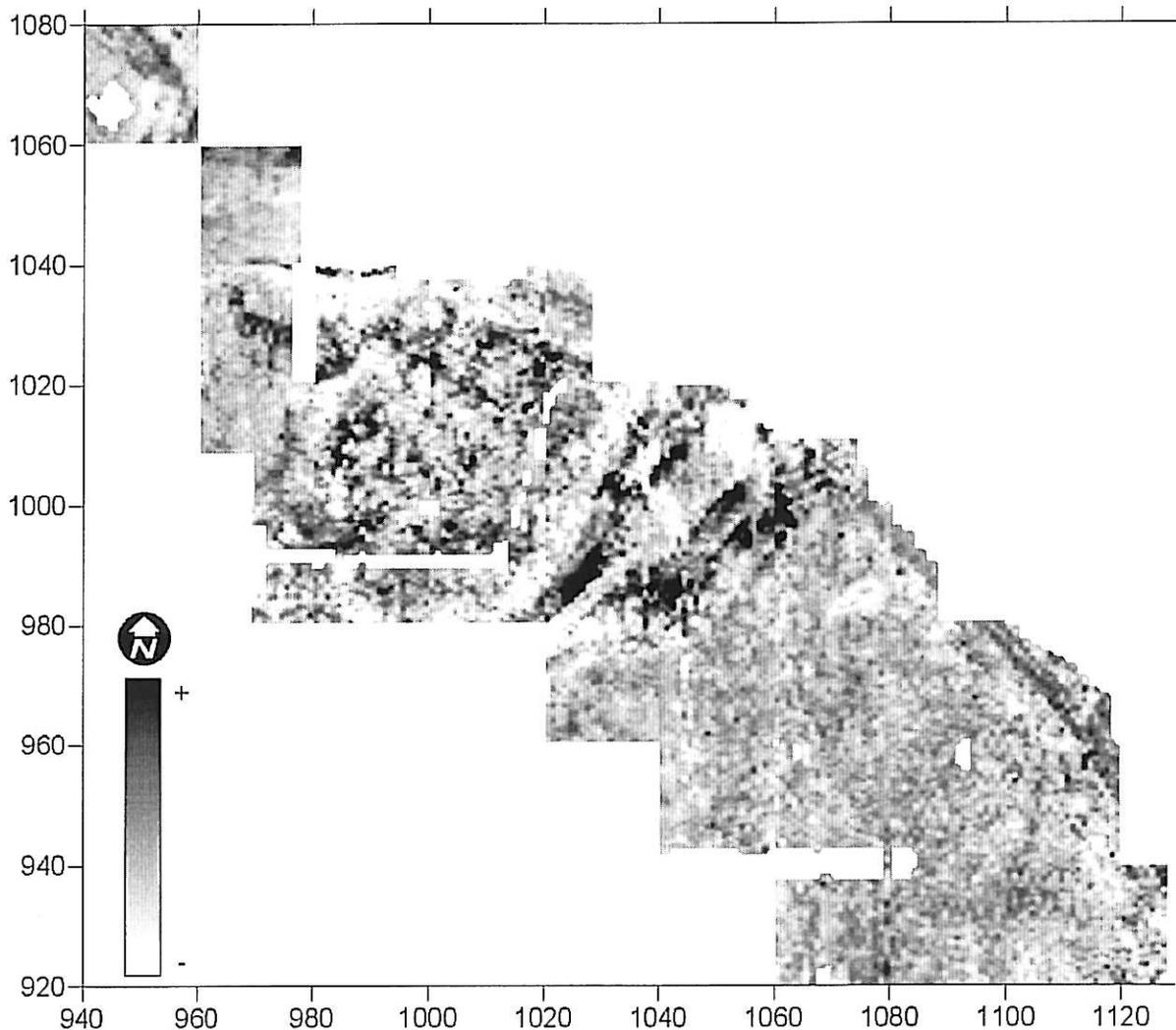


Figure 8. GPR time slice 3 (3.3-7.3 ns, 13.2-29.2 cm). Massive zone of reflectance at center of survey area corresponds to the DuPont road turn-around and buried effluent pipeline. Dark linear anomalies in northern survey area may be significant (from Haley and Johnson 2005:17).

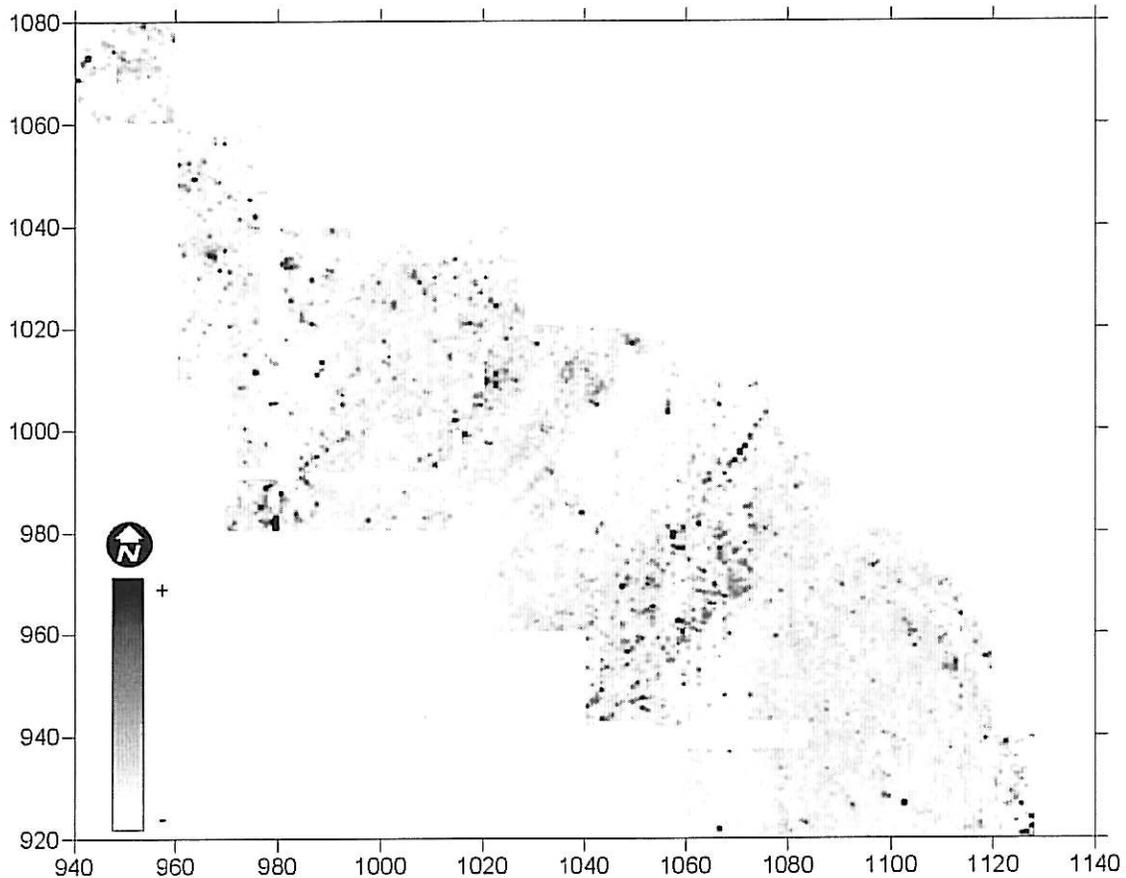


Figure 9. GPR time slice 7 (9.9-13.9 ns, 39.6-55.6 cm). Two dark linear anomalies, east and west of the central DuPont road turn-around (at center), may be significant (from Haley and Johnson 2005:19).

The five geophysical survey methods employed at Old Mobile in 2001-2002 and 2004 revealed many interesting and potentially significant anomalies. These are displayed in a single graphic and have been assigned numbers for discussion purposes (Figure 10). Whether any of the geophysical anomalies relate to archaeological remains of Fort Louis, the principal structure in the French colonial town known as Old Mobile, was not immediately apparent at the completion of fieldwork. Nevertheless, all of the geophysical team leaders expressed optimism that at least some of the anomalies might represent French colonial subsurface features. For instance, R. Berle Clay thought two large anomalies (#26 and #29; Figure 10)—each a hollow conductivity “high” surrounding a “low” rectangle—could be remnants of structures with unburned clay walls, while hastening to add that further evaluation through excavation would be necessary to determine their true identity (Clay 2002:17, 21). Similarly, Robert Melia and Jill-Karen Yakubik thought “the various angle-shaped anomalies evident from the ground survey were suggestive of a fortification,” and the subsequent “View of the area from the air provided a more complete view of anomalies likely associated with the fortification” (Melia and Yakubik 2002). Most recently, Bryan Haley and Jay Johnson pointed out the similarity of low resistance linear features (#20, #21, #24, #25; Figure 10) to the outlines of Fort Louis (Haley and Johnson 2005:14, 20). What did Fort Louis look like, and what kind of subsurface features might survive of that early colonial structure?

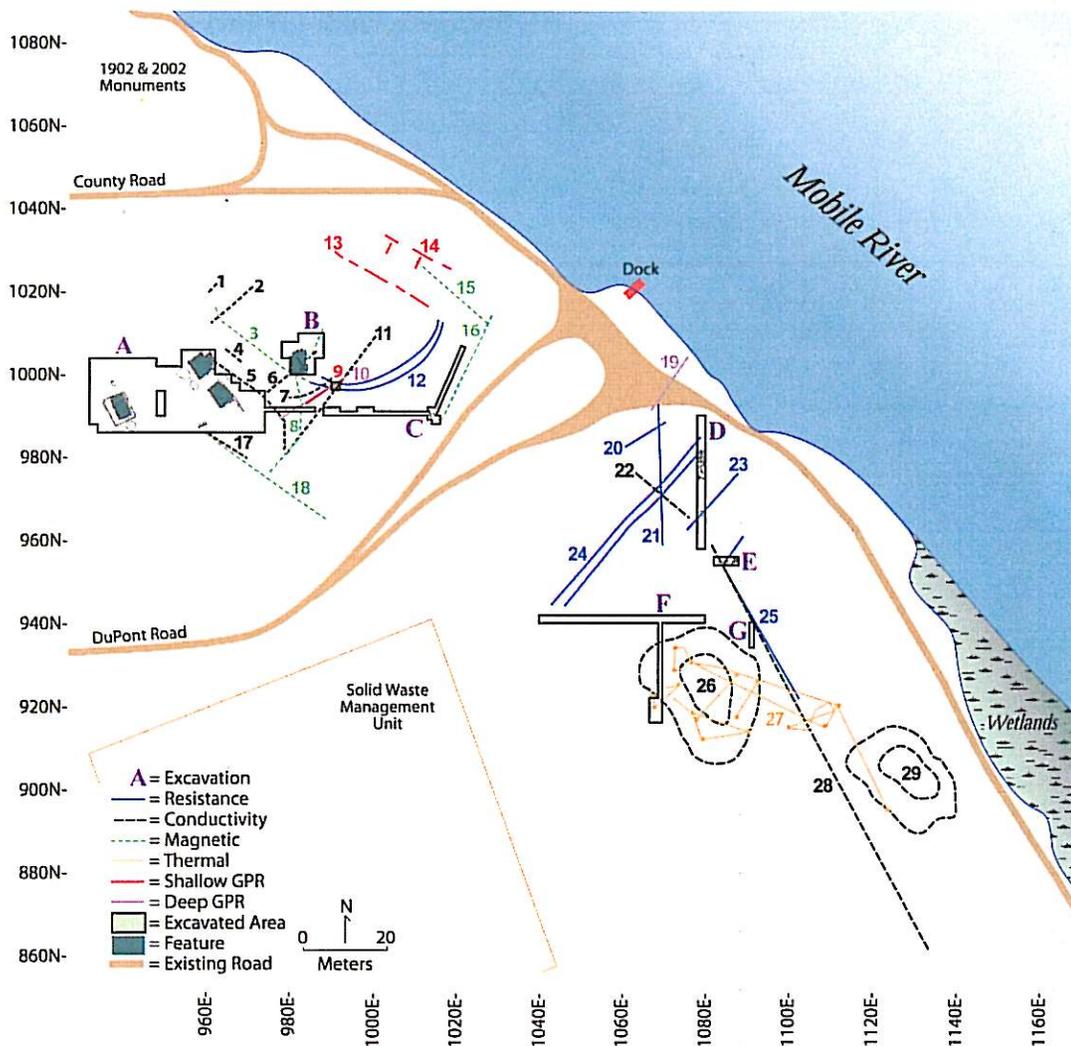


Figure 10. Composite graphic of all recognized anomalies from geophysical survey at the Old Mobile site, except for the aerial thermal imaging feature, which was identified roughly from the vicinity of the ground-level thermal anomalies (#27) north to the Mobile River.

Discussion: Fort Louis

The fort built in 1702 to defend the new French colonial settlement of Mobile is known to us chiefly through two period sketches—drawn in 1702 and 1705—and brief descriptions of its construction, appearance, and repair prior to abandonment in 1711. Thanks to these sources—especially the perspective drawing pasted onto the 1705 map of the settlement—we have more information on the fort than for any other unexcavated structure at Old Mobile. However, a considerable amount of this information is ambiguous or, in some cases, downright contradictory.

On March 3, 1702, Governor Iberville reported to the colonial minister in France that fort construction, which began in January, was proceeding satisfactorily under the direction of Major Charles Levasseur, with four *pièce-sur-pièce* bastions nearing completion. *Pièce-sur-pièce* construction involved the use of squared timbers placed directly on the ground and laid one upon another to form horizontal log walls. Log ends were either dove-tailed and

slipped into slots on upright timbers or interlocked with other horizontal logs by means of dove-tailed corner joints, as was evidently the case with the Fort Louis bastions (McWilliams 1981:167). The resulting walls were extremely strong, capable of repelling cannon fire and able to support great weight. Consequently, this method of construction was often used for bastions, which supported platforms for mounted cannons. We know from a detailed drawing of Fort Maurepas, Fort Louis' predecessor, that the earlier fort had two *pièce-sur-pièce* bastions with wooden decking for cannon, beneath which were located officers' quarters and a chapel. Fort Louis's bastions seem to have functioned solely as cannon platforms, probably supported by soil in-fill. The 1702 map indicates the presence of centrally-placed gates in the east and west curtains, and an entrance is shown in the middle of the east wall on the 1705 sketch (Figure 11-12).

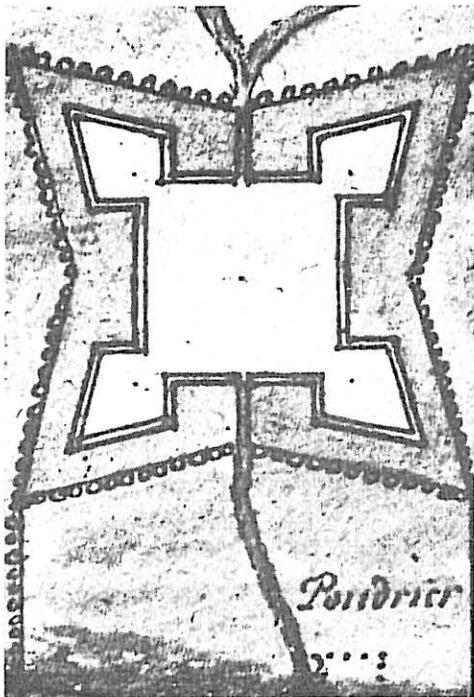


Figure 11. Fort Louis de la Mobile, 1702 (from Higginbotham 1977; *Dépôt de fortifications des colonies, Louisiane, III 6 PFA 119*, Centre de Archives d'Outre-Mer, Aix-en-Provence, France).

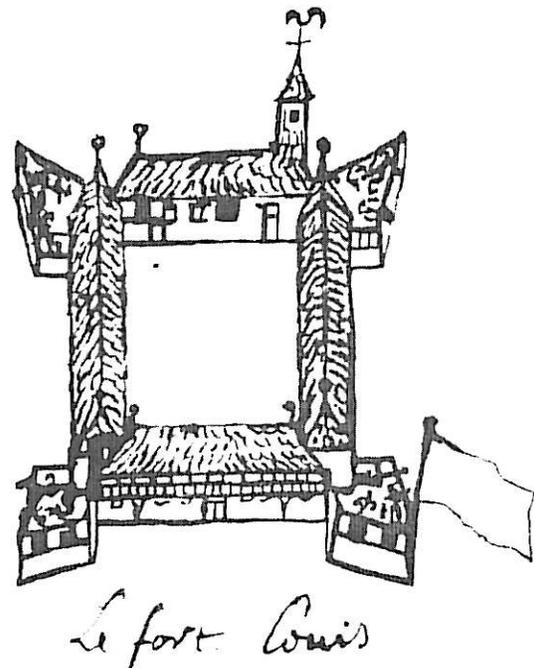


Figure 12. Fort Louis de la Mobile, 1705 (detail from *Dépôt de fortifications des colonies, Louisiane, III 6 PFB 120*, Centre de Archives d'Outre-Mer, Aix-en-Provence, France); both views oriented with west at top.

Levasseur's 1702 map (which is thought to be the original settlement plan forwarded to Governor Iberville in January of that year and sent on to France for royal approval) shows a stockade of upright posts surrounding the bastions and forming an equal-sided star, with the points of the stockade about 56 meters apart. (A later account by Andre Pénigault put the fort's dimensions at "sixty *toises* square," an impossible 117 meters on a side; McWilliams 1988:59). Additional stockade walls are shown extending from the easternmost bastions to the riverbank, some 23 meters away. The 1705 map, on the other hand, does not show a stockade at all; the fort is depicted as more rectangular than square, and in a slightly different location (perhaps because the fort had been sketched separately, cut out, and pasted somewhat inaccurately on a town map). Despite some unreliability in each depiction, both

maps suggest the fort was the town's largest feature, traces of which should still be present close to the riverbank, near the center of Old Mobile.

Fort Louis underwent considerable modification before its abandonment in March 1711. In September 1706, Commandant Bienville reported the fort "almost all rotten," adding that "the garrison ... is outside of the fort which is too small to give lodgings to the soldiers." In October 1708, he explained to the colonial minister how he had ordered the fort "enlarged and remade like a new fort with four bastions" to accommodate the town's entire population in the event of attack by the English and their Creek allies, a threat that seemed imminent. The following April, Ensign Mandeville wrote, "The fort has been rebuilt anew with piles driven in on end with four bastions and cannons on them The fort being completed, they were going to rebuild the King's warehouses that were in the said fort which also made a curtain for it that had been carried away by a squall in the month of May 1708, which made it necessary to use the church of the fort as a warehouse" (Bénard de La Harpe 1971:58; Rowland and Sanders 1929:38, 48, 1932:33, 37, 128, 130).

Historical references contain few hints about the type of curtain walls that connected the Fort Louis bastions. At Fort Maurepas, these had been vertical stake palisades. The 1705 drawing of Fort Louis seems to depict the fort interior structures forming the curtain walls, which is partially confirmed in the 1708 account (cited above) of the outer wall of the King's warehouse comprising the southern curtain. The chronicler Pénigault, once again out-of-step with other eyewitnesses, described four "buildings fifteen feet back from the curtains behind them" (McWilliams 1988:59).

Sources do agree on the functions of the four buildings inside the fort. A town census taken on August 31, 1704 by Nicolas de La Salle, the royal commissary, describes these interior buildings in some detail. The first floor of one—the commandant's quarters on the east—was constructed in the *pièce-sur-pièce* style, with the upper story described as *charpente*, a well-built type of frame, half-timber construction. The King's warehouse, on the south, may have been *pièce-sur-pièce*, as well (although that is not explicitly stated), with a *charpente* roof covered with wooden shingles, as were all of the other fort roofs. On the west was the town's church, and a guardhouse completed the square on the north side, both *charpente*, almost certainly in the *poteaux sur sole* technique employed for substantial houses found during excavations elsewhere at Old Mobile (Waselkov 1999:16). In the center of Fort Louis was an open parade ground, the *place d'armes*.

La Salle's census provides dimensions for these four buildings. The church measured 20.1 x 5.2 meters and included La Salle's living quarters. (Some of the colony's elite who died during the occupation of Old Mobile may be buried under or near the altar of this church.) Across the central parade ground stood the even larger (at 22.0 x 5.2 meters) two-story structure with cantilevered balcony and quarters for Commandant Bienville and other officers. Bienville's kitchen occupied the south end of that building, and his servants were said in 1707 to have helped themselves to the King's goods in the adjacent royal stores. The King's warehouse (*magasin*) measured 13.0 x 5.2 meters and stood opposite the guardhouse (*corps de garde*), a building of identical dimensions, used for storage of arms and ammunition, as on-duty quarters for a sergeant's guard, and as a brig for miscreants (Rowland and Sanders 1929:18-19, 1932:70; AN, AC, C13A, 1:468-470). One note of caution is warranted. La Salle's precise building dimensions indicate the eastern and western buildings were longer than the other pair, which contrasts with the 1705 sketch showing longer northern and southern interior fort buildings.

Apart from a few principal officers, the garrison resided elsewhere, with the lowest ranks occupying small, crudely built structures erected nearby. Pénigault, of whom we should be wary, states that “Barracks for the soldiers and the Canadians were built outside the fort, to the left, one hundred and fifty steps away, on the bank of the Rivière de la Mobile” (McWilliams 1988:59). Bienville informed the colonial minister in 1706, “As there is no place suitable for lodging the soldiers of the garrison of Louisiana he has obliged them to make barracks for themselves in groups of six” (Rowland and Sanders 1929:28).

When the Old Mobile Archaeology Project began in 1989, I assembled these documentary sources and planned to search for the remains of Fort Louis. One of the first steps was to extend the archaeological survey grid to cover the entire town site, 70 acres between the Mobile River on the east and a swamp that bounded the town on the west. By 1993, staff from the Center for Archaeological Studies had thoroughly and systematically collected data from that entire area by means of shovel testing—digging 35-cm diameter holes at 4-meter intervals, for a total of 15,025 shovel tests. The soil from each shovel test was screened through ¼-inch mesh, and the artifacts were plotted on the archaeological site map. That method enabled identification of at least 55 French colonial structures within the town site, identifiable on the basis of clustered French structural artifacts—principally handwrought iron spikes and nails, roof tiles, and a few brick fragments. Unfortunately, the area of the site adjacent to the Mobile River had been plowed during the late nineteenth and early twentieth centuries. Architectural artifacts, which formed discrete clusters representing French structures in unplowed parts of the site, formed a nearly continuous debris field in the plowed section. The entire east-central portion of the site, from the 1902 commemorative monument south to a swamp along the Mobile River, consisted of one enormous, undifferentiated cluster of French nails, roof tiles, and other colonial-period artifacts. If this was the location of Fort Louis, as seemed likely from the cartographic evidence, then it would have to be identified by some other archaeological means.

Based on the available historical descriptions of Fort Louis and knowledge gained from excavations of other structural sites at Old Mobile, I suspected that several kinds of subsurface evidence of the fort might still remain in the ground. The stockade, in particular, seemed a likely survivor of the plowing. The field in this part of the McGowan plantation was last plowed in the 1940s; excavations showed the plowzone to be about 0.35 m (around 1 foot) deep. So any French colonial disturbance of the ground below that point should have left visible “features,” organic stains containing artifacts of the period. We had already discovered footing trenches around French structures elsewhere at Old Mobile, so a substantial fort stockade ought to leave an easily recognizable archaeological residue. But one should recall that the 1705 map did not portray a stockade around Fort Louis, and none is mentioned in any written account. The *pièce-sur-pièce* bastions probably would not leave behind much of a trace, since the squared timbers were said to be dove-tailed at the corners, rather than interlocked with upright posts set deep in the ground. However, Ensign Mandeville’s intriguing 1709 account did mention how the fort had been “rebuilt anew with piles driven in on end,” which suggests that at least the cannon platforms (and perhaps other elements of the fort) might be recognizable as clusters of very large postmolds. Finally, substantial pits have been found adjacent to most of the charpente-style buildings excavated at Old Mobile, where they initially functioned as sources of dirt for *bousillage*, a mixture of mud and other material used to daub house walls, and for raised earthen floors. Once a building was finished, these open daub pits served as refuse pits, into which the colonists

tossed much of their garbage. The interior structures in Fort Louis would have required large quantities daub to construct and maintain, and the bastions may have been filled with dirt to help support the cannon platforms, so one would expect several (perhaps many) large pits associated with the fort. While we might also imagine that a well should be expected inside the fort (and would leave a substantial archaeological footprint), no mention of one appears in any historical account of Fort Louis.

Without belaboring every step taken in the pursuit of Fort Louis, I will simply note that our search initially took the form of a trench (the east-west portion of Excavation Area F on Figure 10) excavated on the DuPont property in 1990 with the hope of crossing remnants of the stockade shown encompassing the fort on the 1702 town map. When that approach failed to uncover any French features at all, I turned once again to the historic maps for clues to the fort's location. Several topographic clues are provided by the 1702 map. Above the town plat, with its tiny depiction of a pallisaded fort, is another drawing (Figure 13) on which Levasseur sketched a box with the notation, "Lieu propre a faire d'un Citadelle" ("Suitable place to make a Citadel"), above two odd converging hatched lines.

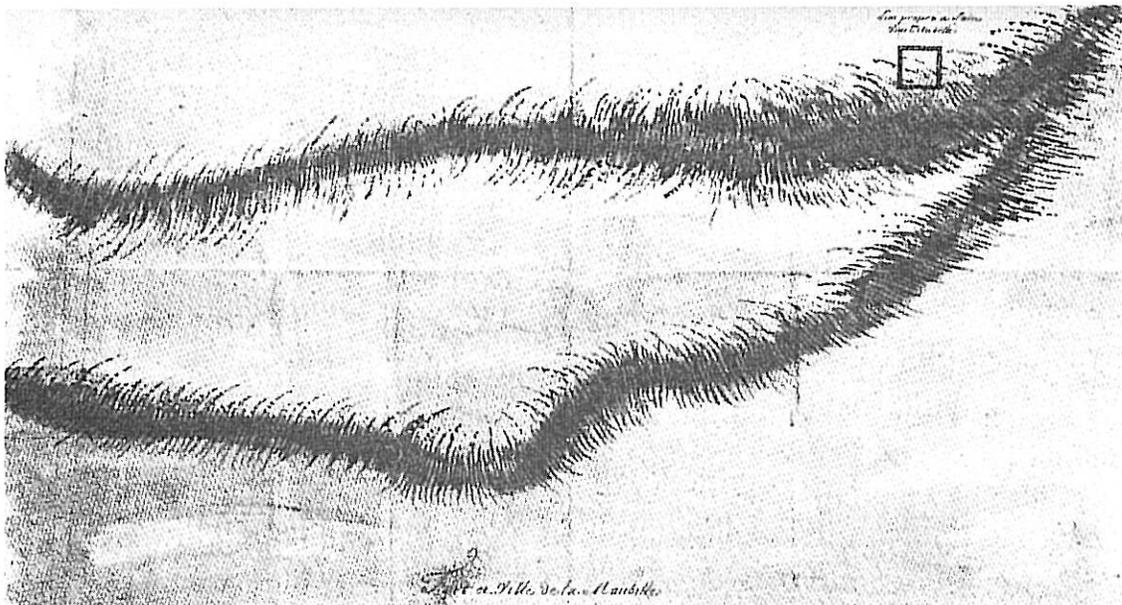


Figure 13. Upper half of 1702 map, showing topography in the vicinity of the location chosen for Fort Louis. The hatched lines seem to depict the outline of a bottomland swamp that exists today below the town site. (From Higginbotham 1977; Plan de la ville et du Fort de La Mobile, 1702, probably by Charles Levasseur, Dépôt de fortifications des colonies, Louisiane, III 6 PFA 119, Centre de Archives d'Outre-Mer, Aix-en-Provence, France).

Everyone familiar with the Old Mobile site recognizes this drawing as a depiction of the bottomland swamp (situated below the bluff) that extends south for 2½ miles, on the west bank of the Mobile River. A fort placed at the north end of this extensive swamp would have effectively controlled traffic up the Mobile River. Today, the northern limit of this bottomland swamp is located on DuPont property, about 80 meters southeast of the turn-around on the DuPont road. However, the riverbank from that point north for several hundred meters is actively eroding today, as it did throughout the twentieth century and probably for much longer than that. So Levasseur's "Suitable place to make a Citadel" probably lay no further south than the current northern limit of the bottomland swamp.

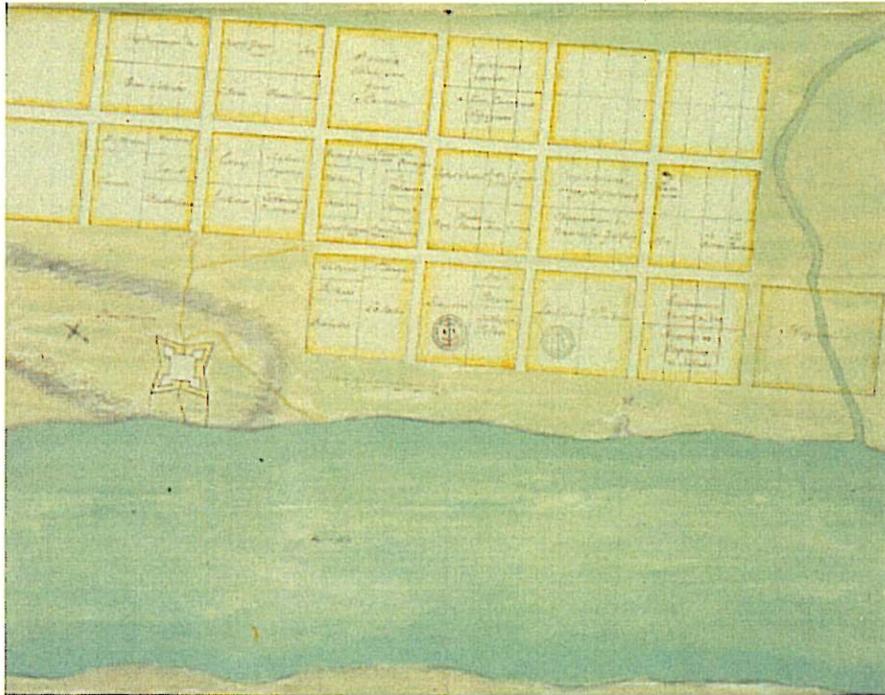


Figure 14. Lower half of Levasseur's 1702 map, showing several important topographic features: a stream north of town (at right); hatching around the fort, possibly indicating higher elevation; and apparently a profile view of the Mobile River's west bank (along the bottom edge). The northern tip of the modern swamp below the town site may be represented at far middle left. (Plan de la ville et du Fort de La Mobile, 1702, probably by Charles Levasseur, Dépôt de fortifications des colonies, Louisiane, III 6 PFA 119, Centre de Archives d'Outre-Mer, Aix-en-Provence, France).

The more familiar portion of Levasseur's map (Figure 14) shows his conception of the fort and town in more detail. Many aspects of this map indicate it was an initial plan for the settlement, not a depiction of the town and fort as actually built. Without going into great detail about the presumed purpose of this drawing, we can focus here on the fort in relation to several topographic features. In this view (and unlike Figure 13) Levasseur has surrounded the fort with hatched lines. Once again based on familiarity with the landforms at Old Mobile, this suggests the high bluff at the riverbank on DuPont property. The high ground near the river falls away steeply to the west, which is conveyed fairly well by the upper hatched line. The little triangle of green between the Mobile River and the lower hatched line corresponds well with the northern limit of the bottomland swamp. One element of the map is most puzzling—the narrow bit of land drawn along the lower map edge. Most observers have assumed this represents the east bank of the Mobile River. However, that interpretation is most unlikely. The river forms a broad bend at Old Mobile. On the inside of that bend, the river has formed a very old, gently curved levee bordering a massive bottomland swamp. The riverside border of that levee is quite uniform, and does not resemble at all the bumpy line drawn by Levasseur. I interpret his sketch as yet another view of the terrain of the new town, drawn for the benefit of Governor Iberville and colonial officials in France who would have been concerned about the location of their fragile toehold on the Gulf coast, and in particular with the situation of the fort. The landform at the bottom edge of Levasseur's map seems to represent the bluff at Old Mobile as viewed from

the river, a horizontal profile of the bluff, with a conspicuously high spot selected for the construction of Fort Louis.

One other important discovery bears on the fort location problem. From 1995 to the present, large-scale excavation (in Area A on Figure 10) has gradually revealed the floor plans of three small structures immediately west of the fort search area. All three are *pieux en terre* structures (literally, pole-in-ground construction), the simplest and least costly method of building employed by French colonists at Old Mobile. Analysis of artifacts from these structures strongly suggests they served as residential quarters for soldiers in the garrison. They may be the barracks “for six” described in Bienville’s 1706 report to the colonial minister (Gums 2002; Dormaier 2005). Although not on the riverbank, as Pénigault maintained, the presence of barracks does suggest that the fort could not have been far away.

This brief review of evidence for the location of Fort Louis skips over other map evidence, such as the relationship of the town plans to two small stream drainages at the north edge of town. Suffice it to say that overlays of the 1702 and 1705 historic maps place the fort in the general vicinity between the 1902 monument and the bottomland swamp, but do not provide a definitive fort location. An additional east-west trench (Excavation Area C on Figure 10) north of the DuPont road, hand excavated between 1998 and 2001 did not encounter any fort-associated features. Excavating the two long east-west trenches had not been entirely futile. They documented considerable areas devoid of French colonial architectural features. Since structures have been routinely found elsewhere at Old Mobile, their absence near the river bluff was a significant discovery that supported the notion that the fort must be in this vicinity. Both of the historic maps, from 1702 and 1705, show open ground surrounding the fort, an area normally cleared of obstructions that could give cover to an attacking enemy. Despite this progress, trenching is a slow, laborious, and inefficient search method. At this point, the first geophysical survey was planned and carried out, with support and encouragement of NCPTT and the Friends of Old Mobile, Inc. When limited hand excavations at selected anomalies identified during that survey also failed to reveal any evidence of Fort Louis, additional geophysical survey was carried out in 2004, with much more intensive follow-up ground-truthing excavations in the spring of 2005, all part of the current NCPTT-funded project.

Discussion: Ground Truthing the Geophysical Anomalies

Effective ground-truthing is necessary to maximize the value of a geophysical survey. Surprisingly, the archaeological literature concerned with geophysics offers little discussion of the merits of alternative approaches to ground-truthing excavation. In the United States, geophysics is often treated as a separate component of the work rather than as an integrated technique (Hargrave et al. 2002:99).

All of the geophysicists involved with the search for Fort Louis have recognized the critical role played by ground truthing in the interpretation of geophysical survey results. Geophysical survey of archaeological sites is intended to locate anomalies of presumed cultural origins. Once located, anomalies must be examined by excavation, coring, metal detecting or some other invasive procedure for evaluation and identification. Unfortunately, when geophysical survey is conducted under contract, the ground truthing often occurs well

after the survey is completed and usually by different personnel, so the opportunity for refinement of survey and ground truthing techniques can be lost or diminished for lack of feedback. One goal of this project has been to evaluate critically the application of five different survey methods and to consider the effectiveness of each in the particular site conditions found at Old Mobile.

One important consideration in the implementation of ground truthing of the Old Mobile geophysical survey results was to insure the preservation of archaeological resources at this important site. The central portion of Old Mobile—the part most likely to contain remains of Fort Louis—is owned and controlled by three entities. Mobile County owns a large tract, containing most of the site’s identified archaeological remains of French colonial structures. Adjoining the county’s property, from the DuPont road southward, is a tract owned by DuPont and protected by a preservation easement given by DuPont to The Archaeological Conservancy (TAC), a national preservation organization. All three parties agreed to allow ground truthing through excavation, but everyone involved (particularly the officers and members of the Friends of Old Mobile, Inc., and the staff at the Center for Archaeological Studies) understood that excavations should be limited in extent and should adhere to high professional standards. Consequently, all excavations followed protocols implemented in the early 1990s at Old Mobile. Since the area to be tested had been plowed, the upper layer of plow-disturbed soil (the plowzone) was excavated with shovels, with all soils processed at a waterscreen using $\frac{1}{16}$ -inch mesh. Excavated units were then trowelled, mapped, photographed, and backfilled.

Many years experience with French colonial features at the Old Mobile site has repeatedly demonstrated that small, narrow dispersed test units will not provide definitive identifications of the anomalies detected by geophysical survey. Since this portion of the site was plowed repeatedly during the late nineteenth and early twentieth centuries, the only colonial features likely to exist, the lowest remnants of trenches and pits dug by the French into the subsoil, will be found beneath the plowzone. Specifically, these could include trenches from fences and structure walls, palisade trenches possibly associated with the fort, and pits used to obtain soil for infill and for daub or *bousillage* structural walls. As shown repeatedly by excavation, three centuries of leaching has so depleted the organic content of sub-plowzone colonial features that they can be hard to detect visually, especially in a small test unit. Therefore, we excavated 2-meter wide units, generally arranged in trenches. In some instances, previously excavated trenches (see Excavation Areas C, F, and G; Figure 10) were reexamined when geophysical anomalies were found to intersect them. Three new trenches (see Excavation Areas B, D, and E, and an isolated unit near B; Figure 10) were excavated to intersect other linear anomalies. Excavation Area B was enlarged to a block excavation to reveal a large pit feature discovered unexpectedly, where geophysical testing had indicated the presence of three intersecting linear anomalies. Other evidence was gathered (visually and with metal detectors) to evaluate anomalies in other locations. In addition, soil samples were collected systematically across several anomalies for soil particle size analysis, to investigate the possibility that some anomalies may indicate the presence of “melted” buildings made of clay or silt.

For ease of reference, the composite view (Figure 10) of all geophysical anomalies considered potentially attributable to historical features, along with the archaeological units excavated in the vicinity, is repeated here as Figure 15. Each geophysical method will be discussed in turn.

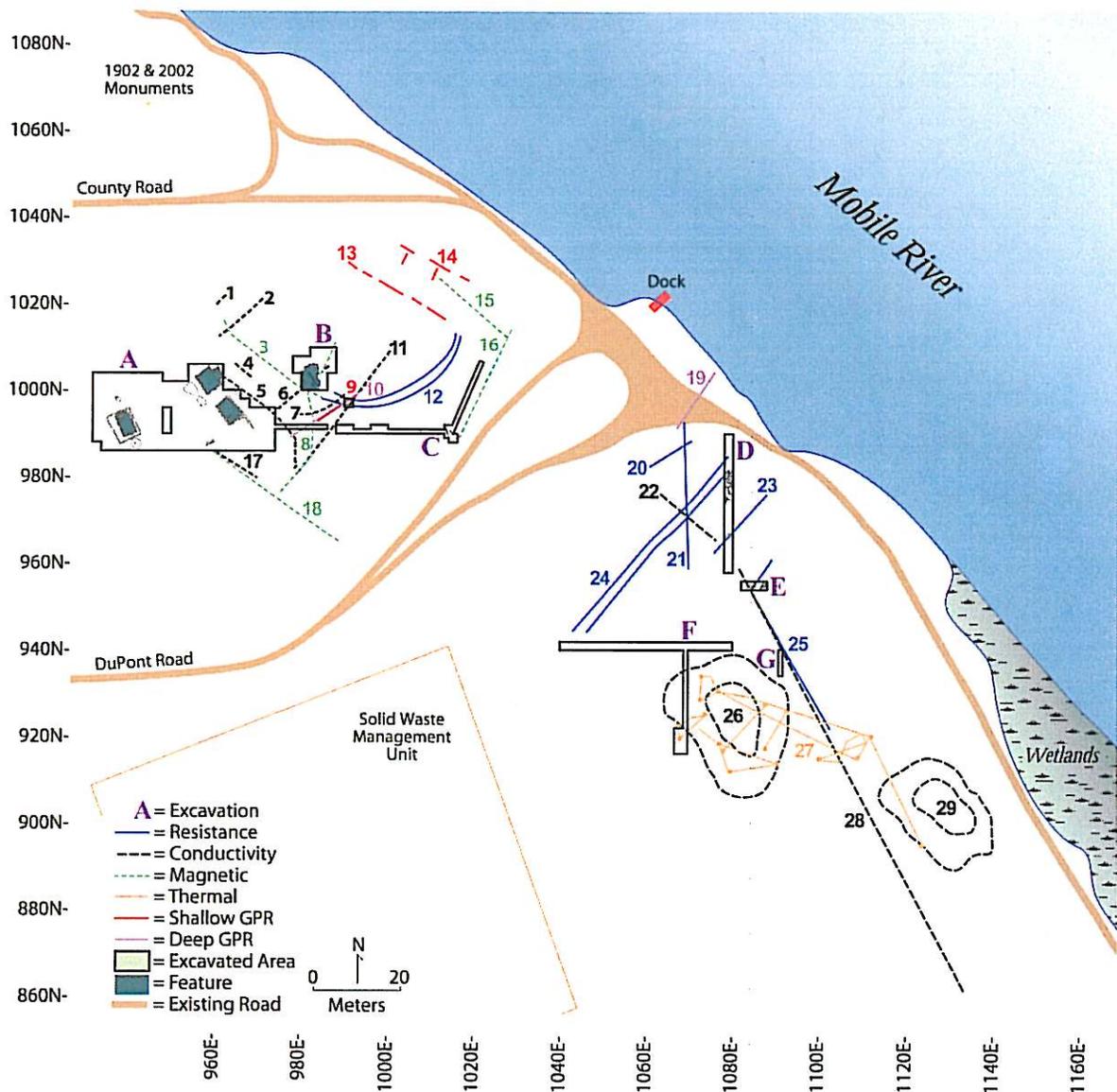


Figure 15. Composite graphic of all recognized anomalies from geophysical survey at the Old Mobile site, except for the aerial thermal imaging feature, which was identified roughly from the vicinity of the ground-level thermal anomalies (#27) north to the Mobile River.

Magnetic survey was plagued by the presence of much modern iron that obscured any historic patterns that might exist. As mentioned above, iron pin flags (used in 1990 to denote 4-meter grid points during the original shovel-testing survey) had been inadvertently mowed south of the DuPont Road prior to the geophysical survey. Since flag stems remained in the ground were readily detected by the gradiometer, a strong, systematic pattern of targets swamped any other magnetic anomalies that might exist in that area of the site. Other large modern targets were found beneath the DuPont Road, caused by a buried effluent pipeline and other industrial features. The only magnetic anomalies of possible archaeological interest were found north of the DuPont Road (where iron pin flags were removed before the geophysical survey). These consisted of five linear features in the magnetic data (see Anomalies 3, 8, 15, 16, and 18, on Figure 15). A close visual inspection

of the area revealed that anomalies 15, 16, and 18 coincide with wire fences of twentieth-century origin, associated with either the McGowan farm or the industrial plants that took possession of the property in the 1950s and 1960s. Several decayed cedar fence post remnants were found along these magnetic alignments, as were some strands of plain (unbarbed) fence wire still attached to trees. Where magnetic anomalies 3 and 8 cross Excavation Units A and B, no subsurface cultural features were found that could explain those anomalies.

Excavations at Old Mobile have recovered large numbers of heavily corroded iron artifacts dating to the eighteenth-century French colonial occupation. Indeed, many iron spikes and nails were found in Excavation Unit B during this ground-truthing exercise. Nevertheless, the patterning in modern iron on the site evidently dominates the magnetometer survey results.

Conductivity revealed numerous linear anomalies (1, 2, 4, 5, 6, 7, 11, 17, 22, and 28) and two very large doughnut-shaped anomalies (26 and 29). Considering the linear anomalies first, two (11 and 17) correlate with magnetic targets, and one (28) coincides with a resistance anomaly. The correlation of some conductivity and magnetic anomalies suggested to Berle Clay that buried modern metal piping could be responsible for both (Clay 2002:12). However, excavations in both of those locations did not uncover metal pipes. Another explanation appeared in the course of ground-truthing excavations—that some (perhaps even all) of the linear conductivity anomalies are ground disturbances caused by logging trucks. This portion of the Old Mobile site has been intensively harvested for timber many times, most recently in 1989, just as the first archaeological investigation of the site began. Throughout the twentieth century, the standard method of logging this sort of upland terrain (as opposed to the swamps in the Mobile-Tensaw Delta east of the site) was to use mechanical loaders to place long logs on trucks driven into the woods. Many temporary logging roads are visible today at Old Mobile, identifiable by the rutted ground surface and lack of large trees in their paths. Several others are no longer recognizable above ground, but have been found during excavations (crossing Structures 5 and 32). Ground-truthing excavations for this project found several more, in the 2x2-meter unit southeast of Excavation Unit B, at the north ends of Excavation Units D and G, and crossing Excavation Unit E. Based on visual inspection of the terrain and vegetation, and on test excavation results, linear conductivity anomalies 7, 11, and 28 correspond with logging roads. In the case of conductivity anomalies 11 and 17 that correlate with magnetic linear anomalies, it is suspected that near-surface iron artifacts (modern or archaeological) may have accumulated through erosion in logging truck ruts.

The two large, doughnut-shaped anomalies—26 and 29, detected by conductivity near the south end of the survey area—were suspected at the time of their discovery to be remnants of burned daub or bousillage structures (Clay 2002). Each consists of a hollow conductivity “high” surrounding a “low” oval or rectangle. They resemble anomalies found at several late prehistoric sites in the Southeast where structures with unburned clay walls decayed, producing a halo of higher conductivity around a floor. Trenching (as the north-south portion of Excavation Area F) across the western edge of anomaly 26 revealed no sub-plowzone features, but that trench did not cross the center of the anomaly. To further test the structural hypothesis, a series of paired soil samples were collected across this anomaly (see Figure 16 for soil sample locations). Five pairs of samples were collected (#21-22, 23-24, 25-26, 27-28, 29-30), with the first of each pair drawn from the plowzone and the second

from the subsoil at the same spot. Samples were analyzed for particle size using the hygrometer method, and the gross results are presented in Table 2.

Particle size analysis suggests another explanation. Although most of the Old Mobile site consists of silty sands and sandy silts, those surface soils vary in thickness and are underlain by clays and sandy clays, which approach the ground surface at many places. Excavations frequently uncover small areas (typically a meter or two across) of clay subsoil at the base of the plowzone. At anomalies 26 and 28, two very large areas of near-surface clays and sandy clays have evidently been truncated and scattered by plowing, which explains the presence of clay in subsoil sample #28. Conductivity detected subsurface soil anomalies in these locations, but they appear to be natural, rather than cultural, formations.

Table 2. Particle size analysis of soil samples from the Old Mobile site.

Sample #	Soil Description	USCS Classification
1	Strong brown fine SANDY SILT	ML
2	Strong brown fine SANDY SILT	ML
3	Strong brown fine SANDY SILT	ML
4	Light olive brown fine SANDY SILT	ML
5	Brown fine SANDY SILT	ML
6	Strong brown fine SANDY SILT, with CLAY pockets	ML
7	Yellowish brown fine SANDY SILT	ML
8	Light olive brown fine SANDY SILT, with SHELLS	ML
9	Brown fine SANDY SILT	ML
10	Brown fine SANDY SILT	ML
11	Grayish brown fine SANDY SILT	ML
12	Brown fine SANDY SILT	ML
13	Strong brown fine SANDY SILT	ML
14	Brown fine SANDY SILT	ML
15	Brown fine SANDY SILT	ML
16	Reddish brown fine SANDY SILT	ML
17	Strong brown fine SANDY SILT	ML
18	Brown fine SANDY SILT	ML
19	Yellowish brown fine SANDY SILT	ML
20	Reddish brown fine SANDY CLAY	CL
21	Dark brown SILTY fine SAND	SM
22	Brown SILTY fine SAND	SM
23	Dark brown SILTY fine SAND	SM
24	Dark brown fine SANDY SILT	ML
25	Dark brown fine SANDY SILT	ML
26	Brown fine SANDY SILT	ML
27	Dark brown fine SANDY SILT	ML
28	Dark red CLAY	CL
29	Dark brown fine SANDY SILT	ML
30	Strong brown fine SANDY SILT	ML

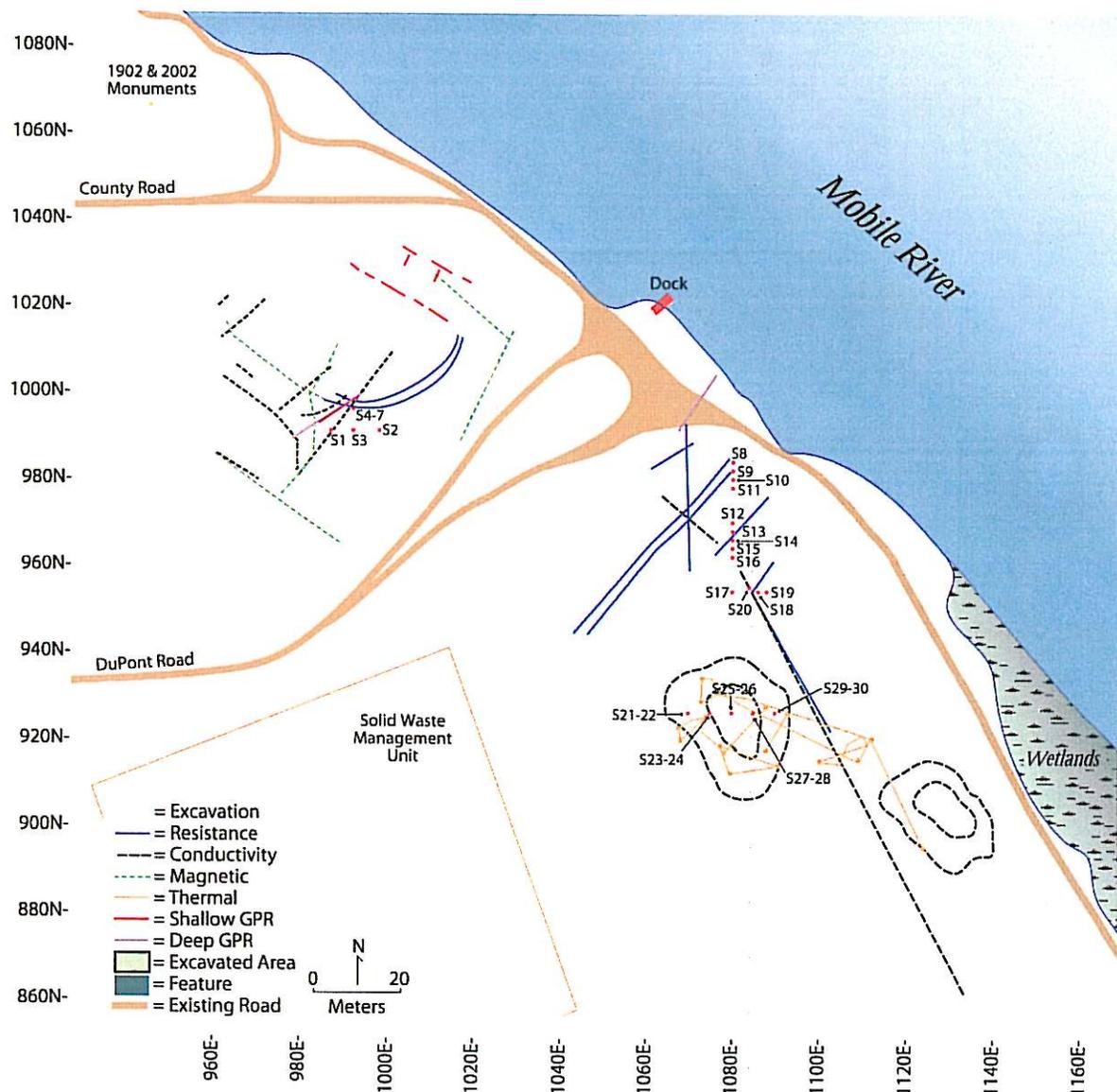


Figure 16. Soil samples in relation to recognized geophysical anomalies at the Old Mobile site (see Figure 15 for geophysical anomaly key).

Resistance anomalies (12, 20, 21, 23, 24, 25) have an equally close correspondence with logging roads. Anomaly 25 partially coincided with conductivity anomaly 28. Excavation Unit E, placed at a point of divergence of those two anomalies, revealed sub-plowzone ruts (filled in places with water-sorted sands) that are the typical subsurface signature of temporary roads created by heavily laden logging trucks. Comparable subsurface features were also discovered crossing the northeast corner of Excavation Unit G, and diagonally crossing Excavation Unit D at the location of resistance anomaly 23. Wider versions of the same type of feature were encountered in the small test unit southeast of Excavation Unit B (anomaly 12) and at the north end of Excavation Unit D (anomaly 24), where double linear anomalies were detected by resistance. Anomaly 24 coincides with a long, slightly raised ridge that may have been a bed for a spur railroad, such as were employed in logging early in the twentieth century in this region. These various road

anomalies are the source of the only other unusual soil samples. Samples #6, 8, and 20 correspond to resistance anomalies 12, 24, and 25. One sample (24) contained shell, which was used to consolidate road beds in this stone-poor region of the country, strengthening the identification of that resistance anomaly as a prepared truck road or railroad bed. The others contained clay, probably brought to the surface by truck wheels deeply rutting the ground. All of the identified resistance anomalies are attributable to the modern era.

Identifying the sources of thermal anomalies at Old Mobile proved most difficult. Some western segments of anomaly 27, which was delineated by a hand-held infrared sensor at ground level, were immediately seen to correspond with the positions of decayed logs that had been removed during ground clearance just prior to the geophysical survey. Some decayed wood was still present at those locations and presumably retained heat. Other segments of that complex anomaly could not be so readily explained. Likewise, the rectangular anomaly seen from the helicopter at an elevation of 1,000 feet over the site, and roughly filling the space from anomaly 27 north to the Mobile River, was not confirmed by ground truthing. Excavation Areas D, E, F, and G were opened to search for subsurface features in this vicinity. However, only modern features were found and these were all identified as modern road features, corresponding to the conductivity and resistance anomalies already discussed. Furthermore, very few French colonial artifacts were recovered from these excavations, despite fine-screening all excavated soils. While artifacts might not be abundant from the site of Fort Louis (because the garrison occupied barracks outside the fort), there were some full-time occupants of the fort, including members of the governor's, the priest's, the commissary's and several officers' households, who would have generated substantial refuse. And presumably the structural debris from this large complex of wooden buildings would also be considerable, judging from excavated French colonial structure sites at Old Mobile, each of which has yielded hundreds of handwrought nails. Extensive ground truthing in this part of the Old Mobile site rules out this spot as the location of Fort Louis. No source for the large aerial thermal anomaly has been found.

The final geophysical survey method employed at Old Mobile, ground-penetrating radar, uncovered very few subsurface anomalies. A near-surface time slice, corresponding approximately to a zone 13.2 to 29.2 cm from the surface, reveals a good deal of disturbance near the ground surface in the northern part of the survey area. Linear radar anomalies 13 and 14 have not been ground truthed by excavation, but they probably lay north of the limits of the farm field plowed by the McGowan family from the late nineteenth to early twentieth centuries. These anomalies may relate to industrial use of the nearby road on Mobile County property, which was part of a rayon-making facility from 1952 until 2002. On the other hand, these untested anomalies may be near-surface colonial features of a type that would have been erased by even the shallow plowing that occurred immediately to the south. Their northwest-southeast bearing corresponds very roughly (and perhaps significantly) to the bearing and alignment of small *pieux en terre* French colonial structures excavated in Area A immediately to the southwest. These GPR anomalies should be subjected to ground truthing in the near future.

Another shallow GPR anomaly (9) partially coincides with a deeper GPR reflection (10) from a zone approximately 39.6 to 55.6 cm in depth. This location—a point of intersection of radar, conductivity, and resistance anomalies—was most heavily disturbed by a wide logging truck road. No explanation for the deep radar anomaly was found in the test unit excavated at that spot. Another deep GPR linear anomaly (19) was found crossing the

DuPont river access road, adjacent to the Mobile River. Since this area was heavily disturbed when the DuPont road was constructed in the 1960s, anomaly 19 is probably a reflection of a modern industrial feature. The rest of the survey area, south of the DuPont road and north of the county road, is remarkably free of ground-penetrating radar anomalies.

Conclusions: The Significance of Ground-Truthing the Geophysical Survey Results at Old Mobile

Ground-truthing has been absolutely critical for assessing the five methods of geophysical survey employed in the search for Fort Louis at Old Mobile. Results from magnetometry, conductivity, thermal imaging, ground-penetrating radar, and resistivity should be thought of as largely complementary. In only a few instances were anomalies detected by one method that could be matched precisely with anomalies from another. In this case study, all of the identified anomalies have been attributed to modern disturbances. None of the tested anomalies correspond to the locations of colonial-era subsurface features. Conversely, the single large colonial feature uncovered by test excavation in the survey area, a very large pit found in Excavation Area B, was not identified by any of the geophysical survey methods employed at Old Mobile. Its discovery is attributable entirely to serendipity, having been found in a group of test units excavated to ground truth linear magnetic and conductivity anomalies in this location.

Given the lack of French colonial features discovered during this survey, one might consider this geophysical experiment a failure. On the contrary, though, there are several reasons to think otherwise, and several important lessons to be drawn from this project.

Old Mobile poses some challenges for geophysical survey. The site was occupied for less than 10 years; occupation sites are widely scattered, with little midden accumulation and little rebuilding; and there are very few surface indications of structures, apart from earthen floors visible at two structure locations. The site is shallow, with virtually all features within 50 cm of the surface, except for the occasional large pits that extend to depths of 1 to 2 meters. Furthermore, the site consists mainly of silty soil sitting atop clay, with a near-surface water table ranging from 1 to 4 meters below the surface. And finally, the site is heavily wooded, which makes geophysical survey difficult without an immense investment in labor to clear the ground surface. On the other hand, many of these characteristics apply to a large number of sites in the north-central Gulf coastal plain, so techniques suitable here will be usefully applied to large areas of Alabama, Georgia, Mississippi, and Louisiana.

The Old Mobile site posed few physical impediments to survey by these five technologies, with the exception of the forest vegetation. A great deal of time and energy were devoted to removal of small trees, underbrush, and accumulated leaf litter from the survey area prior to both survey episodes. The area south of the DuPont road has fewer trees, but those remaining may have contributed to an apparent rectangular anomaly on the aerial thermal images near the Mobile River. And, north of the DuPont road, the more closely-spaced trees and numerous decayed stump cavities created many non-patterned anomalies in the ground-penetrating radar results.

One difficulty in evaluating the relative effectiveness of the five geophysical search technologies at Old Mobile is the scarcity of French colonial archaeological features revealed by the ground-truth test excavations. The only feature discovered in the various test

excavations that is definitely attributable to the French colonial occupation is a very large pit found in Excavation Area B. Since this feature's presence was not detected by any of the remote sensing technologies, they all failed that test. GPR, in particular, might have been expected to locate a pit feature that intruded into silty clay subsoil, but it did not. On the other hand, this array of five geophysical search technologies can not be faulted very much for failing to find French colonial features in an area that contains so few features of that sort. If we broaden the task to detecting all subsurface cultural features in the survey tract, then at least three technologies—resistance, conductivity, and magnetometry—performed successfully. Resistance proved most effective at locating the heavily rutted paths of logging trucks (and one possible spur railroad bed) created by timber harvesters during the twentieth century. Magnetometry detected several abandoned fence lines, again of modern origin. Conductivity yielded more complex results, including one anomaly corresponding to a magnetic fence location and another corresponding to a resistance road anomaly. The two largest conductivity anomalies, the large doughnut-shaped patterns in the south end of the survey tract, seem to be attributable to natural soil disconformities truncated and dispersed by plowing. All three methods found meaningful features, just not of the type that addressed the archaeological research design. One should also note that ground truthing did not test every geophysical anomaly, particularly in the area north of the DuPont road, where additional excavation may yet reveal that conductivity and shallow ground-penetrating radar did, in fact, detect important French colonial features.

This multi-method application of geophysical technologies suggests two important lessons of general applicability to archaeological site surveys in any setting. First, geophysical surveys must deploy complementary technologies. Overlap in feature recognition by these five technologies was minimal (three instances of partial overlap out of 30 anomalies). Each technology has its own strengths, which should be anticipated and correlated to the kinds of subsurface archaeological features sought. Secondly, the kinds of archaeological features anticipated at any given site should not be permitted to overly influence pattern recognition and interpretation of geophysical results. This is a very hard lesson to learn and apply. Everyone involved in this survey—geophysical and archaeological team members alike—had similar, limited preconceptions about the sorts of archaeological features that might be found in the search tract. Most of those preconceptions derived from exposure to the two historical sketches of Fort Louis, found on the 1702 and 1705 maps of Old Mobile. The 1702 sketch, in particular, suggested that a star-shaped palisade trench might be discovered by the geophysicists. Only when ground-truth test excavations revealed no such palisade trenches in the search area did the archaeological team reconsider the historical evidence, which turned out to contain no subsequent mention of a palisade post-dating the 1702 map. Geophysical survey is especially susceptible to *ad hoc* interpretation, which makes intensive ground truthing by excavation so absolutely critical to its successful application. Geophysical teams might consider instituting an extra layer of blind data interpretation by staff members who have not been told what sort of archaeological results to expect. Of course, data collection is less amenable to blind procedures since most of the equipment selected for a specific survey will be chosen for maximally effective detection of features of a certain depth and size. The goal should be to achieve an informed understanding of the range of features likely to be encountered. A geophysical survey must strike a fine balance between an inefficiently broad application of survey techniques and settings and too limited a range of anticipated results.

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