

**Geophysical Surveys of the Perimeter Fortification System  
at the Site of the Second Fort Smith,  
Fort Smith National Historic Site,  
Fort Smith, Arkansas**



**National Park Service - Midwest Archeological Center**

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Fort Smith National Historic Site, Fort Smith, Arkansas**

By  
Robert K. Nickel  
and  
William J. Hunt, Jr.

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## **Abstract**

In a two-week period in September 1999, a team from the Midwest Archeological Center conducted geophysical surveys of the perimeter fortification system at the location of the Second Fort Smith. The work included magnetic surveying, soil resistance surveying, and the application of ground-penetrating radar. Electrical resistance and ground-penetrating radar data revealed several sections of the perimeter wall and portions of three bastions. In addition, a number of other features that may represent historic structures were documented. The urban setting of Fort Smith limits the applicability of magnetic surveying. Although presenting different views of the archeological features, the soil resistance measurements and ground-penetrating radar reflections are both well suited to mapping buried archeological features at Fort Smith National Historic Site.



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## Introduction

From September 13th through September 23rd, 1999, a team of archeologists from the Midwest Archeological Center undertook geophysical mapping of portions of the fortification system of the Second Fort Smith at Fort Smith National Historic Site. The first Fort Smith was established in 1817 on a point of land that lies about a hundred meters (330 ft) west of the later fort and closer to the Arkansas and Poteau Rivers than the later fort. In 1838, the Federal Government purchased the land adjacent to the first fort and began construction of the Second Fort Smith in 1839 (Figure 1). The objective of the geophysical study was to locate intact segments of the footings for the second fort's perimeter walls and bastions and to mark these locations on the ground for use in the park's interpretive program (Figure 2). Historic plans, standing structures, and prior archeological trenching provided a basis for planning the layout of the geophysical grids. The work included magnetic and electrical resistance surveying and the use of ground-penetrating radar, or GPR (Figure 3). Radar provided a means to rapidly scan areas and was particularly effective for mapping the wall segments, while the soil resistance meter was most effective at illustrating the more complex remains of the bastions.

### *Environmental Setting*

Fort Smith National Historic Site is located near the confluence of the Poteau and Arkansas Rivers. The national historic site contains the remains of two early military posts situated on a much-modified point of land overlooking the rivers. The area was originally forested with an oak-elm-hickory woodland (Coleman 1987). The soils found across the present national historic site have been affected by construction of the forts, especially the second, and by early-20th-century railroad and commercial construction. Coleman (1987:9–14) documents the extent of the cutting and filling that occurred in the immediate area of the Second Fort Smith. Figure 4 is a copy of his third figure and indicates the amounts of soil cut from and deposited on the original building site of the second fort (Coleman 1987:14). Figure 5 illustrates the recent condition of the area in and around the second fort. It also illustrates some of the buildings and streets that were built over the features of the former fort.

Prior to the various episodes of land leveling, infrastructure trenching, and basement excavation and refilling, a typical soil column consisted of ca. 50 cm of silt loam soil that graded into about 1.5 m of silty clay, which in turn was underlain by several meters of sand (Coleman 1987:3, 4). This would probably result in the uppermost layer offering resistance of ca. 100–200 ohm/m, an intermediate layer with values in the range of 50–80 ohm/m, and a base layer with values around 1,000 ohm/m (Bevan 1998:8). The electrical resistance of stone building material should equal or exceed the resistance of the lowest sand layers and would result in considerable contrast with both of the upper soil layers. For GPR, the upper soils at Fort Smith are likely to have moderate values of relative dielectric permittivity, while the stone building materials should be low, resulting in a favorable contrast (Conyers and Goodman 1997:23–35).

### *Background for the Geophysical Survey*

A variety of geophysical instruments have been used since the mid-1950s to locate major archeological features. The bulk of the early work was concentrated in England and elsewhere in Europe (Aitken 1974; Scollar et al. 1990; Clark 1996; Hesse 2000), but some archeological geophysics was attempted in North America (Bevan 2000; De Terra 1947). Following work by Johnston and Black (Johnston 1964) and work by Elizabeth Ralph, Bruce Bevan, and their colleagues at the University of Pennsylvania there was a slow but steady increase in the application of geophysics to North American archeology. These techniques, which were originally designed for applications in geology, engineering, and military defense, have been adopted and, in some cases, adapted for use on archeological sites. All of them detect differences in some magnetic or electrical property of the target feature in contrast to the soil matrix in which the feature is buried. In some manner all these techniques provide the benefits of allowing one to “see beneath the soil” (Clark 1996). This subterranean view, even if less than perfect, allows historic features to be studied while the historic fabric and its matrix are left undisturbed.

## ***Instrument Properties***

The soil resistance meter used at Fort Smith was a Geoscan RM 15, selected because its measurements are little affected by proximity to buildings and utilities, and because it can often detect brick or stone footings buried in soil. The RM 15 depends upon measuring changes in electrical current flow when its metal probes are placed on the ground surface. The unit is controlled by a microprocessor and can be set up to record data from grids with a variety of line spacing and reading intervals. The data are transferred to a personal computer at the end of a day or surveying session. Based on earlier work by Coleman and recent construction monitoring by Hunt, the buried fort footings were expected to be shallow, and the matrix was expected to include soils with significant clay content. Thus, masonry footings that should have high resistance were expected to contrast significantly with soils that would produce low electrical resistance.

At Fort Smith, the resistance meter was used in the “twin array” mode, in which only two of the four probes need to be moved about over the survey area. In the twin configuration, the second pair of probes is placed some distance outside the actual survey area, and they remain fixed during data collection for a given grid or group of grids. The instrument and the pair of mobile probes are connected by a long cable to the remote fixed-position probes. The values recorded by the RM 15 in this mode are relative resistance rather than a strict measure of resistance per unit of volume or cross-sectional area. When the remote stationary probes are moved to a new survey area, the values recorded could change. While there are ways to adjust the instrument and probes to reduce this effect, we did not make any effort to achieve this. Each of our groups of grids was intended to document an isolated portion of the fortification system. Also, substantial cutting and filling had occurred and the background values were expected to fluctuate substantially. Our goals were met by detecting subtle local changes associated with the fortification elements in each area and did not require that absolute values from one side of the fort be compared with those on the other side.

The GPR unit employed at Fort Smith was a Noggin 250 that operated with a center frequency of 250 MHz, and was controlled by a dedicated computerized data logger. This unit is mounted on a small cart, much like a lawn mower in size and shape, and uses an odometer wheel to control the amount of data recorded during a traverse and to place fiducial marks on the radar profiles at regular intervals. This helps to ensure that recorded radar profiles of lines of equal length are themselves of equal length, and to ensure that fiducial marks along the radar lines are not inadvertently omitted by the operator. These “tick marks” applied to the radar profiles allow one to more easily associate reflections observed in the radar data with known or expected archeological features.

The choice of frequency in GPR studies always involves a trade-off between depth of penetration and degree of resolution. A higher-frequency radar unit resolves smaller targets but penetrates soils only to a shallow depth. By selecting a lower-frequency antenna, one can get useful radar reflections from a greater depth, but the radar unit will not necessarily resolve small objects or soil discontinuities. The 250 MHz unit that we selected was expected to provide good resolution and depth penetration of a meter or more, even in soil with a fairly high clay content. Soil moisture can also limit the depth of radar penetration, but luckily the period of work at Fort Smith was uniformly warm and dry. GPR has the additional advantage that it can be used to examine areas covered with concrete or asphalt paving.

The magnetometer used at Fort Smith was a Geoscan FM36 Fluxgate Gradiometer. Magnetometers are typically affected greatly by large amounts of iron and by the fluctuating magnetic fields surrounding AC electrical lines. It was expected that the iron and electrical lines associated with standing and demolished buildings, as well as steel fencing, motor vehicles, and other sources of magnetic noise, would greatly limit the utility of the magnetometer. As the survey developed, it became apparent that the radar and resistance data were quite clear while the magnetic data were, as expected, dominated by very strong gradients and seemed primarily useful for documenting major disturbances such as cellars filled with demolition debris. The magnetic data helped explain why the other instruments did not detect the existence of more in situ historic fabric around Bastion 1 (the Commissary).

## Geophysical Survey Areas

The geophysical survey in 1999 was designed to cover all portions of the fortification system that had not already been determined to have been destroyed. Much of the fort area had received enough 19th-century impact that fort-era features were destroyed (Figure 5). The labeling system for the bastions, wall segments, and gates follows that used by Coleman (1990:11) and is shown in Figure 1. Locations of the 1999 geophysical survey blocks are shown on Figure 6. The 1999 work began in Blocks 1–3, which were adjacent 20-m-square blocks covering the area south, southeast, and southwest of Bastion 1. This standing historic building was modified and eventually used as a commissary, but it still contains intact portions of the original bastion. Based on prior archeological testing, short segments of bases of the two curtain wall segments, i.e., 1 and 10, have been reconstructed.

The geophysical work continued with two long narrow grids that were established to examine Wall Segments 8 and 9 of the fort's perimeter wall and their intersection at Bastion 9. Block 4 consisted of a 60-m-long by 10-m-wide grid placed over the area of Wall Segment 9. Block 5 was a 40-m-long by 10-m-wide grid placed over the presumed alignment of Wall Segment 8. After the initial inspection of the data, another 20-m-square grid (Block 12) was created to cover all of Bastion 9.

A 40-m-square grid (Block 6) was established adjacent to the north sidewall of the park's headquarters and maintenance building. It covered virtually all of the landscaped lawn between the building and Rogers Avenue and between Third Street and the alley and trolley line. It was situated to cover the area of Bastion 4 and portions of Wall Segments 7 and 6.

A 20-m by 40-m grid (Block 7) was established in the lawn southwest of Rogers Avenue and southwest of Bastion 1 to examine the portion of Wall Segment 1 near the first gate. Block 8 was a 20-m by 40-m grid on the swale between the railroad lines containing portions of Bastion 2 and Wall Segments 2 and 3. The last portion of the fortification was examined with two adjacent 20-m-square grids (Block 9) placed over what should have been Wall Segments 3 and 4 and the second gate. When the fortification system had been covered, a small area was examined (Block 10) in an attempt to better understand a non-fortification feature revealed during archeological monitoring of geothermal well excavations earlier in the year (Hunt 1999). Block 11 was a 10-m-square unit attached to the southwest side of Block 9 (Figure 6). No anomalies were observed in this area, and Block 11 will not be discussed further.

### ***Blocks 1, 2, and 3***

Three 20-m-square grids adjacent to Bastion 1 were first examined with GPR. Radar transects were recorded first with the antenna moved from south to north along lines spaced every meter from west to east. When all three grids had been examined in this fashion, the radar was used to cover the same grids at the same intervals with the antenna moved east to west starting with the southernmost line. These three grids were examined in detail because they were the first radar profiles we collected and would serve to plan the balance of the radar work. Also, one curtain wall segment was expected to be oriented east-west in our grid and the other was expected to be oriented north-south. Linear features such as the footing for the fort's walls are most clearly seen in radar profiles that cross the target at a right angle. The three grids around Bastion 1 were then examined with the soil resistance meter with readings taken every 0.5 m along lines that were 0.5 m apart. Finally, the three grids were surveyed with the fluxgate magnetometer. The fluxgate data were collected at a rate of 8 samples per meter along lines spaced 0.5 m apart. The lines were walked from south to north, starting with the western traverse. The magnetometer is sensitive to direction and the data at Fort Smith were all collected with the instrument carried in the same direction. Although the resistance meter is not particularly orientation-sensitive, the resistance data were collected in same pattern as the magnetic data but at a lower density.

Figure 7 presents the magnetic data from the three blocks around Bastion 1. The areas of high magnetic field strength are shown as black, and areas of low magnetic field strength are shown as white. Gray tones indicate intermediate values. The patterns in the map all appear to relate to recent developments.

The concentrations of high and low values in the rectangular area along the right side of the figure can be attributed to metal in the rubble that fills the basement of a former commercial building. The group of strong anomalies in the region above 35 m north result from iron debris associated with a former rail line and recent park improvements, such as a water line. The group of linear anomalies that forms a cross-hatch near the southeast corner of the building results from trenches for security and fire alarm systems. The isolated high anomaly at 5 m east and 10 m north is probably iron associated with an interpretive sign in a masonry monument.

Overall, the magnetic data identify post-military changes to the area around Bastion 1. The large complex of anomalies along the east portion of the grid crosses the area where Wall Segment 10 existed and documents a basement excavation that undoubtedly destroyed a good portion of this part of the fortification system. It is not surprising that other surviving remnants of the fortification system are not perceptible in the magnetic data. Stone footings of rather limited dimensions are not likely to yield strongly positive magnetic anomalies unless they had been exposed to extremely high temperatures such as those produced by building fires. It is unlikely that these stone footings were burned since there is no record of substantial wooden structures along the fort's walls, and the surviving portions of the walls would have been below ground even in the early 19th century. In the absence of an episode of substantial heating, it is likely that the sandstone used in the wall footings differs little from the surrounding soil in magnetic properties. Detecting a weak magnetic anomaly in the environment around Bastion 1 would be very difficult unless the numerous sources of magnetic noise were removed.

Figure 8 presents the soil resistance data from the three 20-m grids around Bastion 1. As in the maps of magnetic data, dark areas reflect high values and light areas represent low values. There are a few basic differences in the coverage from that of the magnetometer. The low reconstructions of short segments of the fortification walls attached to the building cannot be measured with a soil resistance meter. Also, a modern walkway is paved in the area close to the southeast corner of the building, and this area was also impossible to measure since the probes must make contact with the ground to produce a measurement. These areas for which no resistivity data were obtained show as white extensions of the quadrant that contains the standing structure.

Like the magnetometer, the resistance meter also recorded a significant change in the area of the filled basement of the commercial building. There is a prominent decrease in soil resistance at about 32 to 33 m east. Stone footings from Wall Segments 1 and 10 of the perimeter wall are shown as very dark values at 11 m east / 14 m north and at 27 m east / 25 m north. These dark values extend beyond the white regions that delimit the reconstructed wall portions.

Portions of the footings of a small building were also evident in the area of the remnants of Wall Segment 10. The building apparently postdates the fort since the footings appear to cross Wall Segment 10. The south wall of the building is delimited by a line of high values from 23 east / 23 north to 32 east / 23 north. The west wall is seen as high values from 23 east / 23 north to 25 east / 33 north. The north wall is indicated by a line of high values from 25 east / 33 north to 32 east / 32 north. The east wall of the building appears to have been removed by the excavation of the basement that occupies much of the eastern portion of Blocks 2 and 3.

A few modern features can be seen in the resistance data. A gravel path extends from the paved walk at the southeast corner of the building southeast to a point near 40 east / 5 north. It can be seen as a line of weak low resistance values. A recent trench for a communication wire can be seen as a narrow line of high resistance values extending east-west at 22 north. The resistance survey near Bastion 1 indicates that some buried original stone footings still exist from both Wall Segment 1 and Wall Segment 10. The resistance data confirm the destruction of much of Wall Segment 10.

Radar data from Blocks 1, 2, and 3 add to the information revealed by the magnetic and soil resistance surveys. Figure 9 presents north-south radar profiles of the first 15 m of Lines 32 east and 36 east in Block 2. The radar profile from Line 32 east illustrates the area outside the filled basement and the profile from Line 36 illustrates the effects of the rubble fill in the basement excavation. A prominent point-source

reflection can be seen in both profiles at about the 12- or 13-m mark. One of the park's security or communication wires is the probable source for this distinct but shallow anomaly. The two profiles contrast noticeably in the first 10 m. The radar profile for Line 32 east presents a coherent pattern of reflections in the first 10 m, while the pattern on Line 36 east is chaotic. No fort-era architectural features are thought to be located in this block, but the radar data from this unit help to understand the post-military modifications to the area around Bastion 1.

Figure 10 presents two north-south radar profiles from the third block. The top profile illustrates reflections recorded along Line 29 east and the lower profile shows Line 32 east. Both lines begin at 20 m north on the geophysical grid and extend north for 20 m. These lines cross the location of Wall Segment 10 a few meters east of Bastion 1. The two profiles are consistent in recording four features. A sharp point reflection is present at about 2.5 m into each profile. This is the location of a buried communications wire. At 5 m into the profiles, reflections from the base of Wall Segment 10 can be seen. Reflections from a buried stone or brick wall base can be seen 12 m into each profile, and the response from a recent water line is recorded at 14 m. All of these features are marked on the radar profiles by small vertical dashed lines. The radar reflections at 12 m into the traverses correspond with the east wall of the small building discussed above in the section on resistance data.

Radar data were also collected on lines that extended from east to west. The objective was to better record linear features that ran north-south. Figure 11 shows three east-west radar profiles from block one. The top profile shows Line 7 north, the middle profile shows Line 10 north, and the bottom profile shows Line 13 north. These three lines cross the probable line of Wall Segment 1. The route of Wall Segment 1 should cross these profiles at about the 8-m mark. A distinct reflection can be seen on all three radar profiles near the 8-m mark suggesting the presence of some remnants of the footing for this wall segment. Figure 12 illustrates three east-west oriented radar profiles from block three. From top to bottom they were recorded on Lines 26 north, 29 north, and 39 north. The top profile is short because it was recorded directly along the alignment of Wall Segment 10 and ended when the radar antenna reached the eastern limit of the reconstructed wall. Reflections from the still-buried footing of the wall are shown from about the 7-m mark to the end of the profile.

The many reflections at the beginning of the profile represent the basement fill of the large commercial building that occupied the eastern portion of geophysical Blocks 2 and 3. The initial portion of the middle profile shows the same filled basement. However, it also shows the reflection (at the 15-m mark) from the buried base of the west wall of the small building that was situated near Bastion 1. The bottom radar profile in Figure 12 was recorded along a former rail line and it contains numerous small reflectors. No known historic features were crossed by this profile, but the distinct signature of a modern man-hole cover can be seen at about 16 m into the profile.

### ***Blocks 4, 5, and 12***

Three geophysical survey units were established to record Wall Segments 9 and 8 and Bastion 5. Figure 13 shows electrical resistance data recorded in Block 4. This block was 60 m long (east-west) and 10 m wide (north-south). It is bounded on the north by an alley and on the west by Second Street. The resistance survey documented two high-resistance features. At the west end of the survey unit the very high resistance values dominate a region of about 5 m east-west and perhaps 7 m north-south. The feature is centered at 5 m east into the grid. The pattern does not correspond to the narrow signature for the wall footings recorded near Bastion 1. It appears to be a "floor" surfaced with stone, concrete, or brick. Wall lines are not distinct, and it is not clear whether the floor was actually within a building. The floor feature may have supported the walls of a modest building or the footings, if any, may be too close to the floor and constructed of material with similar electrical properties. It is not possible to clearly discriminate between a small feature from the fort era and one made in the 19th century with similar material.

Radar profiles were recorded from south to north along every second meter line across Block 4. In addition, profiles were recorded from west to east along the north and south boundaries of the grid. Figure 14 shows the first (western) 15 m of each of these west to east radar profiles. The top profile was recorded

along the northern limit of the grid (adjacent to the alley). The lower profile was recorded along the southern limit of the grid (inside the probable location of the fort wall). The reflection from the buried floor feature can be seen clearly in the lower radar profile. The signature is about 5 m wide and is centered on the point 5 m east. No similar reflection caused by a floor feature is detectable in the upper profile from the northern edge of the grid. This is consistent with the resistance map, which shows the feature ending short of the northern edge of the grid. Figure 15 shows two south-north radar profiles from this portion of the block. The upper profile was recorded along the line located at 3 m east into the grid, and the lower profile shows the radar data from the line located at 5 m east into the grid. On both profiles the reflections from the floor feature are clear in the first 6 m of the profile, while the last 2 to 3 m show a pattern similar to that visible in the top profile in Figure 14. It is likely that the strong reflection at about 7.5 m along the profile for the 5-m-east line is a response from some modern utility.

At the east end of Block 4 a partial radar signature for the pentagonal Bastion 5 can be seen. The bastion occupies the area from about 47 m east to end of the grid. The gorge of the bastion is at about 51 m east and 2 m north. Figures 16, 17, and 18 present south-north radar profiles from Lines 47, 49, 51, 53, 55, and 59 east. All six profiles cross one or more of the major wall elements of Bastion 5 or the adjacent Wall Segment 9. The top profile in Figure 16 crosses Wall Segment 9 just west of the left flank of Bastion 5. The reflection from the base of the wall segment was recorded at 4 m north along the profile. Adjacent profiles farther west did not record any other clear indications of this segment of the fort's perimeter wall. The lower profile in Figure 16 shows the effect of the radar antenna running down the length of a section of the left flank of Bastion 5. The radar reflection is quite uniform from about 3 to 8 m into the profile.

The upper profile in Figure 17 shows the reflection from the base of the wall at the left side of the gorge of Bastion 5 between 2 and 3 m into the traverse. The lower profile in Figure 17 crosses the gap in the gorge. Disturbance to this portion of the footing was reported by Coleman (1990:33) and may be represented by low resistance values and by the radar anomaly seen between 1 and 2 m into the profile. The upper radar profile in Figure 18 presents radar data from along Line 55 east. It shows a reflection from the base of wall at the right of the gorge (at 1 m north) and reflections from an interior feature (at 6 to 8 m north) that may correspond with the "footing for the parados" that Coleman (1990:33) mentions. The lower profile in Figure 18 shows the data from the 59-m-east line. It shows two well-defined reflections (3–4 m north and 7.5 m north) that correspond with the right flank and the right face of Bastion 5.

Block 5 consisted of a 40-m-long (north-south) by 10-m-wide (east-west) survey unit. It was first surveyed by Hunt with the Noggin GPR and then by Nickel with the Geoscan resistance meter. The resistance data are presented in Figure 19. Portions of the right side of Bastion 5 are included in the extreme northwest corner of the block. The footing for Wall Segment 8 extend from the bastion southeast across most of the 40 m length of the survey area. A high-resistance anomaly that probably postdates the fort exists just outside the fortification in the area of 10 to 20 m north. This probably relates to a former commercial building that fronted Third Street. By the time the resistance data were collected, the alignment and extent of Wall Segment 8 was well documented by the radar. The radar data were collected from east to west across the block resulting in the inversion of the east-west scale on the radar profiles when compared with the resistance map. Consequently, 0 m on the radar profile is 10 m east on the plan map and 10 m on the radar profile is 0 m east on the plan map.

Figures 20, 21, and 22 present a sequence of radar profiles that cross the grid along Lines 5, 17, 21, 31, 35, and 39 m east. The selected profiles each show a radar reflection from the foundation for the fort's perimeter Wall Segment 8. These, and the numerous other radar profiles, confirm the seemingly continuous nature of the stonework. In the profile shown in the top of Figure 20 the wall can be seen at the center of the grid (5-m mark), while in the bottom profile the wall is slightly west of the center of the grid (6-m mark). In Figure 21 the westward trend continues with the wall shown at the 6.5-m mark and at the 7-m mark in the lower profile. By the time the radar crossed the wall on the lines shown in Figure 22 the wall segment was located near the 8-m mark. The depth of the footings appears to vary somewhat from just below the surface to as much as 50 cm below the ground.

Because neither of the two narrow grids situated to record Wall Segments 9 and 10 had covered all of Bastion 5, a 20-m grid (Block 12) was established with the goal of encompassing the structure within a single grid. Figure 23 presents the soil resistance data from Block 12. As the survey neared completion it was decided to add a few lines along the north side to ensure complete coverage of the building. The north edge of the final grid extended slightly into the alley where the surface became too compact for the resistance meter to be useful and data collection was stopped. On the plan view (Figure 23) the large blank area in the upper left corner represents “missing data” because this area was covered with a large pile of fill dirt. In fact, the park’s maintenance division had to move a portion of the dirt to allow the full bastion to be surveyed. The juncture of Wall Segment 8 and the right flank of the bastion is located at 10 m north and 12 m east. The very high resistance in the area of the right flank and right side of the gorge suggests that more stone is in place and that it is closer to the surface. Only a very small remnant of Wall Segment 9 projects from the left flank. The trench for a utility line that Coleman (1990:33) describes probably accounts for the narrow band of low values that runs from the salient angle through the center of the gorge. The vertical band of high resistance values near 25 north / 15–20 east results from the modern development of the alley and is not related to the historic structure.

### ***Block 6***

A 40-m-square survey unit (Block 6) was established adjacent to the north wall of the maintenance building and east of Third Street. It was designed to cover the probable location of Bastion 4 and the adjacent Wall Segments 7 and 8. The area was surveyed with the resistance meter and the GPR unit. Figure 24 presents a plan view of the resistance data. A complex of low-resistance linear features that might suggest a rectangular structure actually originate from multiple sources. A band of low values extends north from about 2 m north / 4 m east toward 30 m north. This corresponds with a communications wire trench. A band of low values that intersects the band of low values above it near 30 m north and which extends east to about 30 m north / 25 m east is the result of a depression associated with a filled basement of a commercial building(s) that once abutted Third Street and Rogers Avenue. The very high resistance areas in the southwest quadrant of the map correspond with stone debris that may be associated with the salvage of stone from Wall Segment 6 (Coleman 1990:24). The only portion of the walls or bastion that appeared in the resistance data are shown as the angular region of moderately high resistance values located at 25–30 north / 20–25 east. This appears to be a short segment of Wall Segment 7 and a small portion of the left flank of Bastion 4.

The radar data from Block 6 are interesting but no more encouraging than the resistance data with respect to elements of the fortification system. Figure 25 presents three radar profiles from 6, 10, and 12 m north into the block. The top profile shows Line 12 north from 0 to 15 m east. The middle profile shows Line 10 north from 0 to 15 m east. Both of these profiles show the modern communications wire trench marked by a dashed line at the 4-m mark. Both also show a large radar anomaly centered about 12 m east. This is probably the large deposit of stone debris previously discovered by trenching. The bottom profile in Figure 25 shows the first 15 m of Line 6 north. It also contains the reflection of a trench with the wire at the 4-m mark, but the anomaly centered on 12 east is much reduced.

Figure 26 illustrates radar data from three lines that cross the probable remnants of the bastion and adjacent wall segment. The top profile shows a narrow but well-defined anomaly at the 5 m-mark on the profile. This anomaly is located at the point 25 m east and 25 m north on the resistance map. The center profile is a portion of Line 27 north and shows a weak anomaly at the 4-m mark. The bottom profile shows Line 29 north. It has well-defined anomalies at the 2-m and 6-m mark. These correspond to the resistance anomalies at 20–26 m east and 29 m north on the resistance map. The northernmost radar anomalies are comparable to those recorded over Wall Segment 8 and probably represent a small segment of the intersection of Wall Segment 7 and Bastion 4.

### ***Block 7***

A unit measuring 20 m east-west by 40 m north-south unit was created south of Rogers Avenue and just east of the railroad tracks. This unit, Block 7, was intended to cover any surviving portion of Wall Segment 1. The resistance data for Block 7 are presented in Figure 27. A linear array of high-resistance anomalies extending southwest from 5 east / 40 north probably represents the fort's wall. Unfortunately, this area was the site of a beverage bottling plant, and a substantial amount of disturbance occurred near the surface. Where the probable wall line of the fort meets the west edge of the grid it becomes combined with the signature of a visible concrete curb. The curb, however, remains along the top of the bank by the railroad tracks. The origin of other expansive high-resistance anomalies is unknown. They may relate to the Officers Quarters located just east and southeast of Block 7, or they may relate to the bottling plant.

Because the western limit of the grid was placed at the very edge of the embankment by the railroad, the radar traverses were recorded from east to west. Figure 28 presents three radar profiles from Block 7. The top profile shows the reflections along Line 27 north. The anomaly at the 17-m mark corresponds to the resistance anomaly at 3 m east and 27 m north. In the middle radar profile the probable fort wall can be seen at the 16-m mark on the profile. This corresponds with the resistance anomaly at 4 m east and 34 m north. The bottom profile shows Line 39 north and the wall reflection is located at about the 14-m mark. This corresponds to the resistance anomaly at 5 east and 39 north.

### ***Block 8***

Block 8 was created on the swale between the sets of railroad tracks. It is known to be the location of Bastion 2 (Coleman 1990:23). A survey unit 20 m east-west by 40 m north-south was created. Because of vegetation and the encroaching railroad cut, only the eastern three-quarters of the grid was fully surveyed. The resistance data for Block 8 are shown in Figure 29. This building, like Bastion 1, had been modified from its original form to make it more rectangular. The resistance data clearly show both the right and left flanks, segments of the adjoining walls, and portions of the right and left faces. The footing in the area of the gorge appears to show some of the modification to make the final building less pentagonal. As with Bastion 5, there appear to be several high-resistance features within the bastion. There also appear to be remnants of a stone-footed addition to the exterior of the right flank wall.

The clarity of the resistance data from Block 8 lessened the need for GPR surveys at this building site. We collected a limited number of transects to facilitate the recognition of fort features in other grids and to refine the geophysical signatures that one would expect to see. Figure 30 presents two radar profiles that show nearly parallel transects through the interior of the building parallel to the left flank. The top radar profile began at grid point 20 north / 18 east and ran southwest to 0 north / 6 east. It crossed the edge of the floor in the gorge at the 3-m mark, the "open" interior of the bastion at the 10-m mark, and crossed the left face of the bastion at the 18-m mark. All of these transitions produce clearly identifiable changes in the reflected radar data. The bottom profile in Figure 30 shows the data from a transect that began farther west and ended at the same point. This transect began at 20 north / 16 east and ended at 0 north / 6 east. It also crossed the floor in the enlarged gorge area, one of the interior high-resistance anomalies (at 14 north / 14 east) and crossed the left face of the bastion. These features produce radar reflections centered on the 5-m mark, the 11-m mark, and the 17-m mark.

Figure 31 illustrates three short profiles that crossed the perimeter wall or the wall of the bastion. The top profile crossed the left flank of the bastion just outside its junction with the perimeter Wall Segment 3. The stone footing of the bastion shows clearly at the 5-m mark on the profile. The lower profiles show two runs across Wall Segment 3 near the bastion and near the edge of the cutbank near point 20 east / 9 north on the resistance map. The signature of the wall footings is clear in both profiles and is marked with the short-dashed lines.

## ***Block 9***

Block 9 was established to look for evidence of Wall Segment 4. Considerable trenching had been done over the years around the probable location of Bastion 3. All indications are that fort-era features in this area had been destroyed by road building and other construction work. We placed Block 9 over the anticipated alignment of the fourth wall segment. Block 9 was 20 m north-south by 40 m east-west. It included a portion of the shallow slope adjacent to the railroad on the west and an area with new walks and recent landscaping near the visitor parking lots. The resistance data are shown in Figure 32. There are several prominent anomalies but none of them are aligned with the known orientation of Wall Segment 4. An intermittent line of high-resistance anomalies extends north-south through the grid near the 20-m-east line. This and the parallel thin line of low resistance readings at 15 m east probably relate to the 19th-century commercial development of the area. The diagonal band of high and low values in the upper left corner of the map is the railroad cut and track bed. The resistance meter could not record values on the new concrete walks, and these show as completely white areas forming an inverted 'Y' pattern.

The radar data from two lines in Block 9 are presented in Figure 33. The top profile illustrates the data from Line 28 east. The prominent radar reflection just beyond the 5-m mark is from the modern concrete walk. Adjacent to it is a sharp reflection typical of point sources such as a piece of wire or pipe. The reflection from the walk can be seen to originate very near the surface (top of profile) and in this regard it is quite different from the signatures of the buried stone-wall footings. The lower profile shows the radar data from Line 36 east and contains reflection signatures from two segments of the concrete walk. Otherwise, the relatively homogenous nature of the radar reflections from the upper portion of the deposit suggests that it is all rather clean fill and probably recently applied.

## ***Block 10***

Block 10 was located inside the fortification, adjacent to the existing railroad cut and south of the southern Officers Quarters. It was a 20-m by 20-m grid placed to help evaluate some small segments of stone footing observed by Hunt during a recent construction-monitoring project. The resistivity data from the block are shown in Figure 34. The pattern in the resistivity data is intriguing but not entirely clear. The locations marked by Hunt are not clearly associated with a recognizable pattern of high-resistance anomalies. The diagonal line of moderate to low values in the lower right corner corresponds with the recent oval walkway through the center of the fort's grounds. The line of very low values paralleling the left side of the map associates with a small concrete curb or the top of a retaining wall. While concrete would typically be a high-resistance material, this feature had considerable steel reinforcing rods exposed at ground level and may have acted as a low-resistance path for the electrical current. A rectangular region of low resistance is located in the upper right quadrant of the grid and it is bounded by narrow bands of moderate and high resistance readings. This feature suggests a building without a cellar but with stone or brick footings. Its dimensions would be approximately 8 m by 8 m and it aligns, more or less, with the front of the pair of known Officers Quarters.

The GPR unit was used to examine the areas where the stone footing had been observed during construction. Two of the radar profiles from Block 10 are shown in Figure 35. The top profile illustrates the data from Line 4.5 m north. The radar data were recorded from east to west along this line. A moderate radar reflection occurs near one of the segments of stone marked by Hunt. This location is indicated by the short-dashed line on the top profile. The anomaly is located at 4.5 m north and 13 m east on the resistance map. The lower profile on Figure 35 shows the radar data from Line 11 north. The vicinity of another segment of stone work is indicated by the short-dashed line at the 7.5-m mark on the profile. The second dashed line on this profile marks one of trenches and is not known to contain historic construction material. The presence of stone work at the two locations observed and recorded by the radar might indicate an extension of the "front" (east) wall line of the structure that may be represented by the rectangular array of resistance anomalies.



## Conclusion

The 1999 geophysical survey at Fort Smith National Historic Site was intended to cover all areas where portions of the perimeter fortification system of the Second Fort Smith might exist. All areas were surveyed except those where existing buildings, railroad cuts, or excavated streets made the existence of historic fabric either unlikely or impossible to evaluate. The survey identified a number of structural features related to Fort Smith and the post-military eras (Figure 36).

The work around Bastion 1 provided evidence of some additional footings for portions of the adjacent wall segments (1 and 10). Near Bastion 5, a very small portion of Wall Segment 9 and a substantial length of Wall Segment 8 were mapped with both GPR and soil resistance data. The soil resistance map of Bastion 5 is quite detailed, corroborates the conclusions drawn from archeological trenching, and provides a good basis for locating the interpretive reconstruction. The results of both GPR and soil resistance mapping in the vicinity of Bastion 4 indicate, as did prior trenching, that little of the bastion remains and almost none of the adjacent wall segments can be identified. There was also evidence for a small post-fort-era structure just outside Block 5 fronting Third Street.

Soil resistance measurements were quite successful at delimiting the remaining footings for Bastion 2. The geophysical data show some of the modifications to the original pentagonal building that resulted in a more rectangular structure. Although excavations for the railroad tracks resulted in the destruction of large portions of Wall Segments 2 and 3, small segments survive on the swale between the tracks, and these features were clearly recorded by both radar and soil resistance measurements. Other geophysical survey grids documented some additional portions of Wall Segment 1 (Block 7), the absence of surviving material for Wall Segment 4 (Block 9), a potential historic structure near the Officers Quarters (Block 10), and a small stone floor or surface near Gate 5 (Block 4).

The historic-period features at Fort Smith are mostly amenable to detection by modern geophysical instruments. Soil resistance data, although somewhat slow to collect, provide an excellent rendering of buildings and fortification elements. Ground-penetrating radar is also quite effective at detecting the historic features and can be collected rapidly. The disadvantage to radar as applied at Fort Smith in 1999 is that the profile rendering of the data also presents many reflections from modern features. This aspect may make the GPR data useful for other management purposes, but it can slow or confuse the interpretation of the historic features. The use of radar suitable for plan-view presentations of time-slices would simplify the interpretation of radar reflections.



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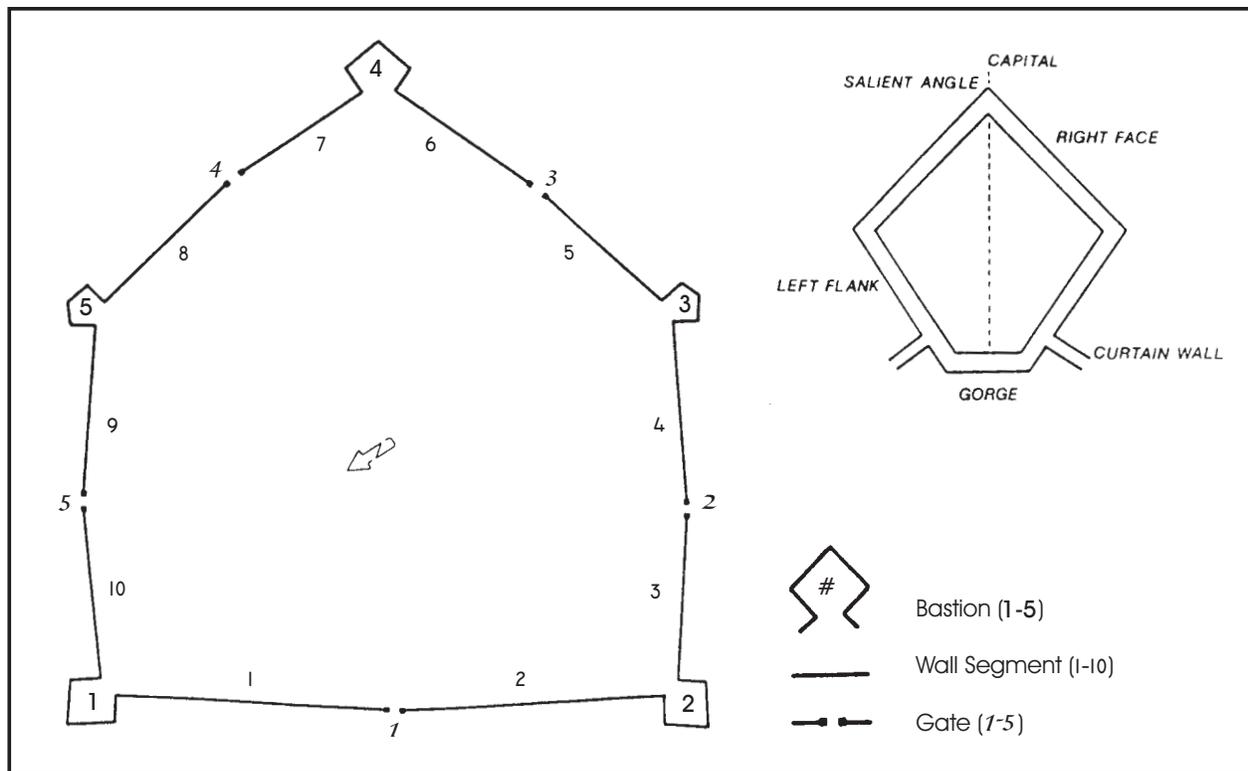


Figure 1. Plan view of the Second Fort Smith, ca. 1840, from Coleman 1990. This report uses the numbered designations and terminology shown here.



Figure 2. The reconstructed wall shape of Bastion 5. View to the south. Compare with Figure 23.



Figure 3. Ground-penetrating radar unit being prepared for use near Bastion 1.

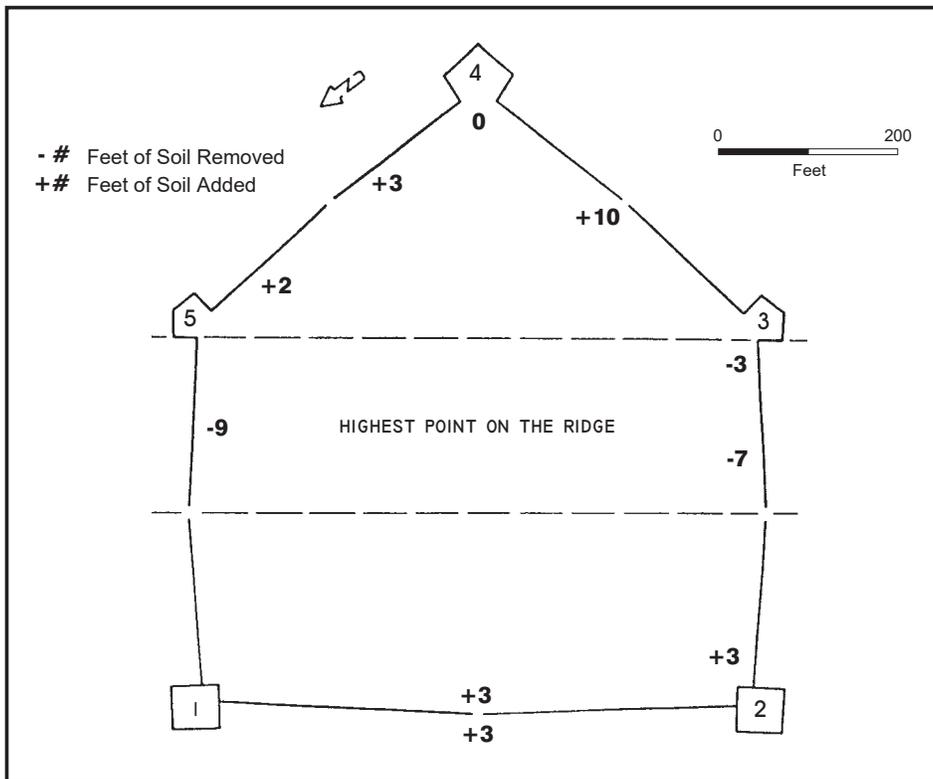


Figure 4. Plan view of the Second Fort Smith indicating where soil was removed and where soil was added during initial construction; based on Coleman 1987.

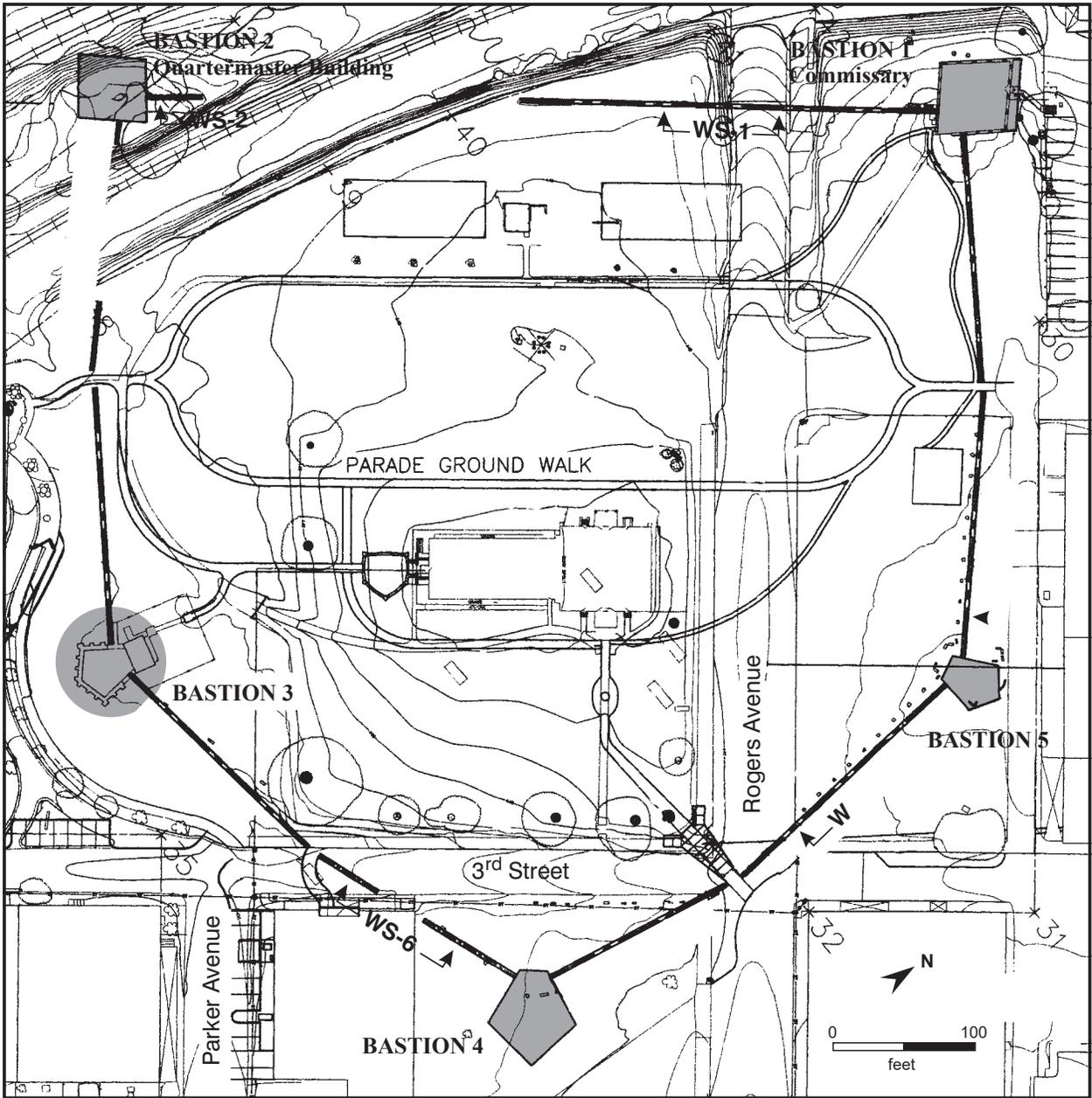


Figure 5. The locations of selected streets, paths, and structures built on the site of the Second Fort Smith. Positions of the Second Fort Smith perimeter walls and bastions have been approximated by the Denver Service Center from historic maps.

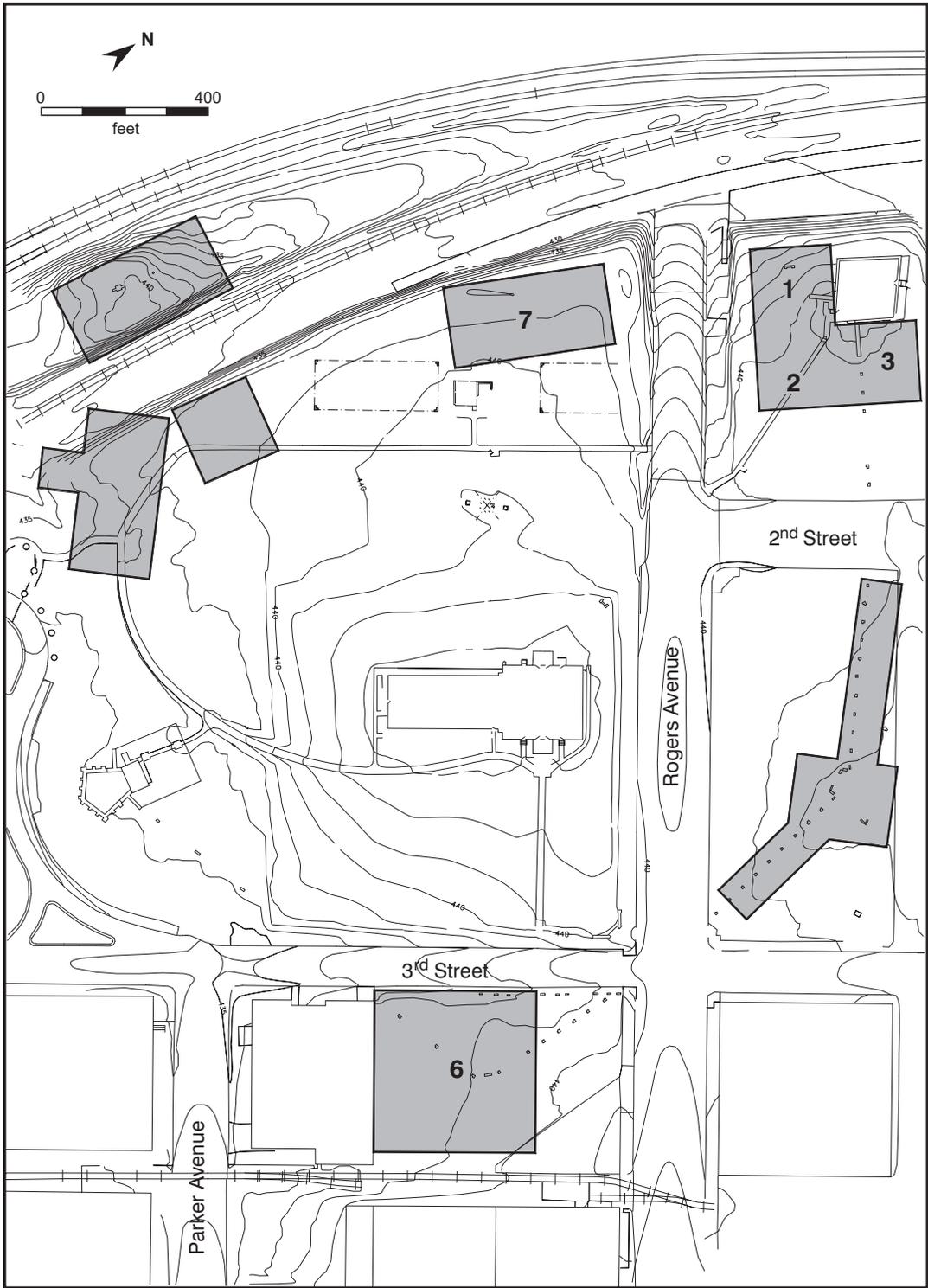


Figure 6. Locations of the twelve 1999 geophysical survey blocks at the Second Fort Smith.

Site : fosm		Gradiometer Survey		Scale	1:369
Comp. : mag1c				Block	Off
Shade Plot (Clip)		Size x 2			
Minimum	-2	Grey Levels	17		
Maximum	2	Palette	Positive		
Contrast	2			Black	Positive
Units	Std.Dev.			White	Negative

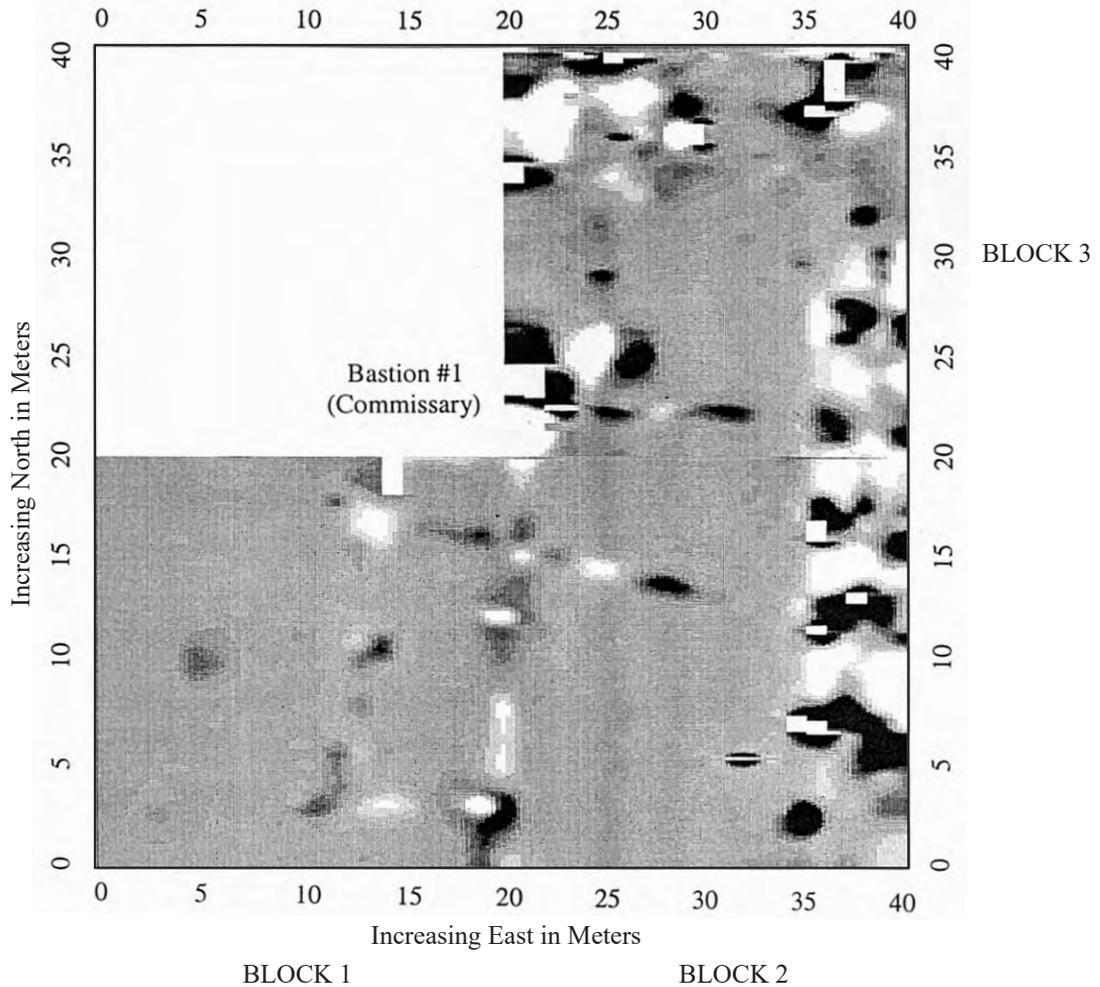


Figure 7. Map of magnetic values in Blocks 1, 2, and 3 to the east and south of Bastion 1, which is a standing historic structure. High magnetic values are shown as darker shades, and low magnetic values are lighter shades. The long, narrow lines of anomalies running parallel from Bastion 1 indicate the locations of modern utility trenches.

Site : fosm		Resistivity Survey		Scale	1:369	
Comp. : fosm1						
Shade Plot (Clip)			Size x 2		Block	Off
Minimum	-2	Grey Levels	17			
Maximum	2	Palette	Positive			
Contrast	.9			Black	High	
Units	Std.Dev.			White	Low	

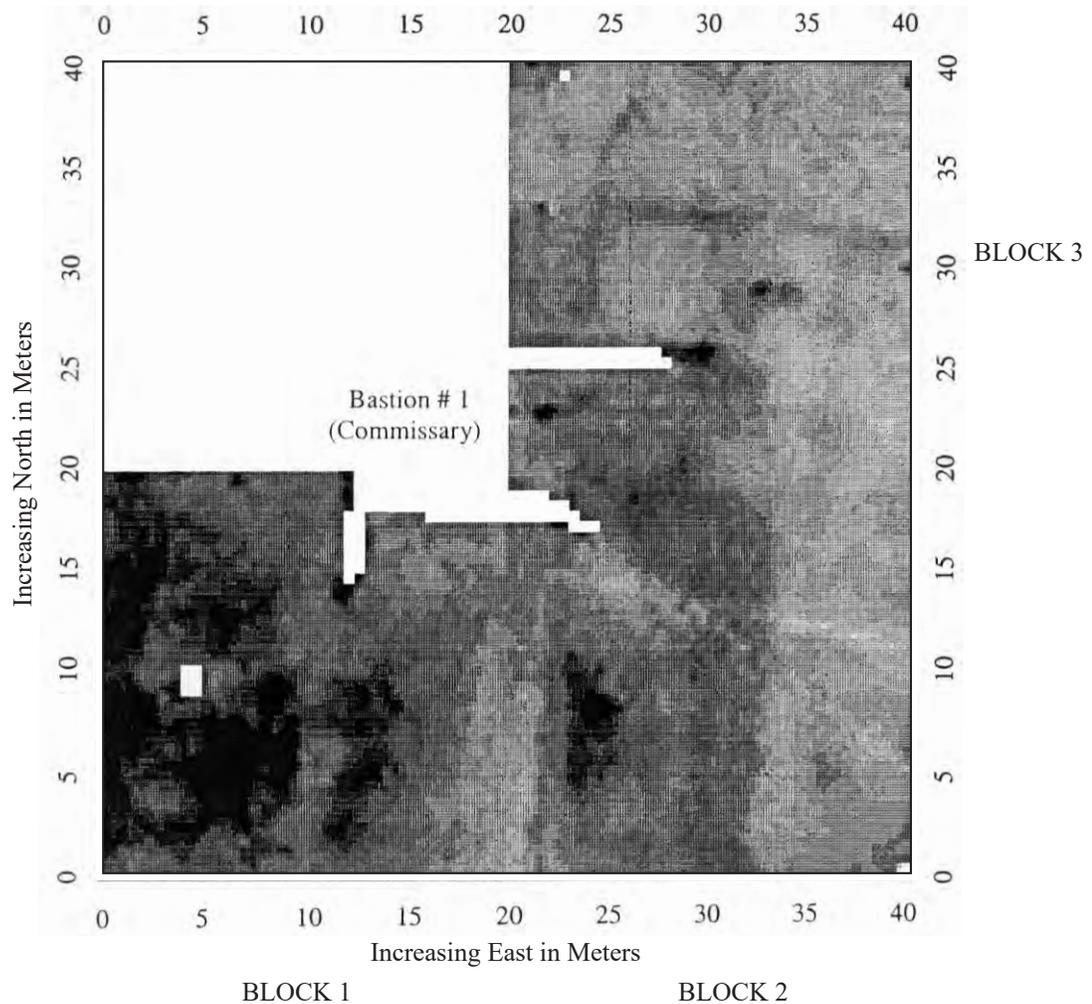


Figure 8. Map of resistivity values in Blocks 1, 2, and 3 to the east and south of Bastion 1, which is a standing historic structure. The white extensions from the bastion walls into the grid are wall reconstructions. The white extension off the lower corner of the bastion is a modern sidewalk. The small white square at 5 m east and 10 m north in the grid is a masonry monument with an interpretive sign. The darker shades indicate areas of higher resistivity and lighter shades indicate areas of lower resistivity.

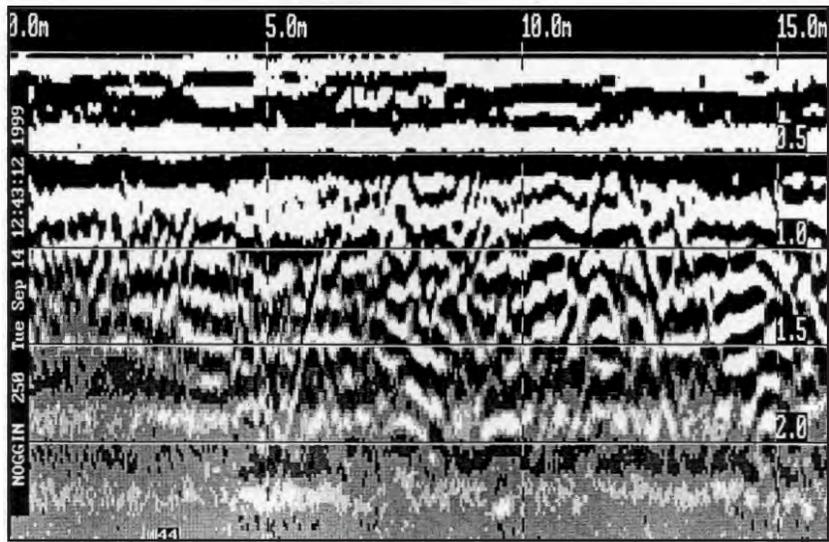
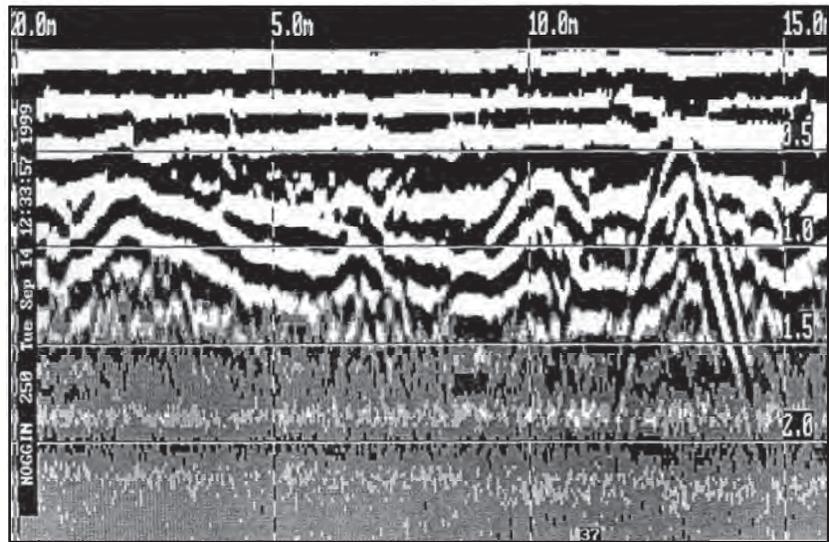


Figure 9. Radar profiles in Block 2 near Bastion 1. Top radar profile shows Line 32 east, 0.5 m north. Bottom radar profile shows Line 36 east, 0.5 m north. Line 32 does not cross the basement area of a razed commercial building and has a fairly coherent pattern of radar reflections. Line 36 crosses the former basement area and its radar reflections are far more jumbled and chaotic because of debris.

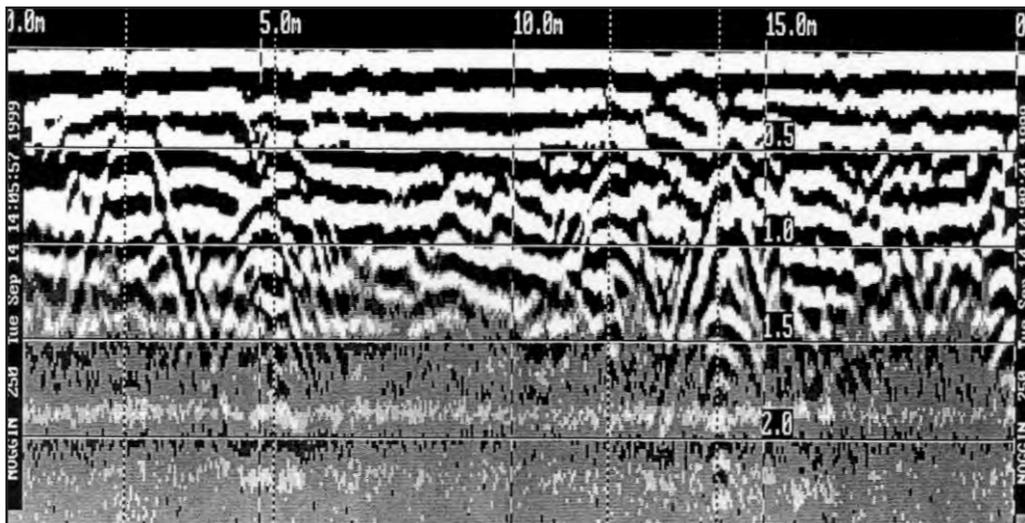
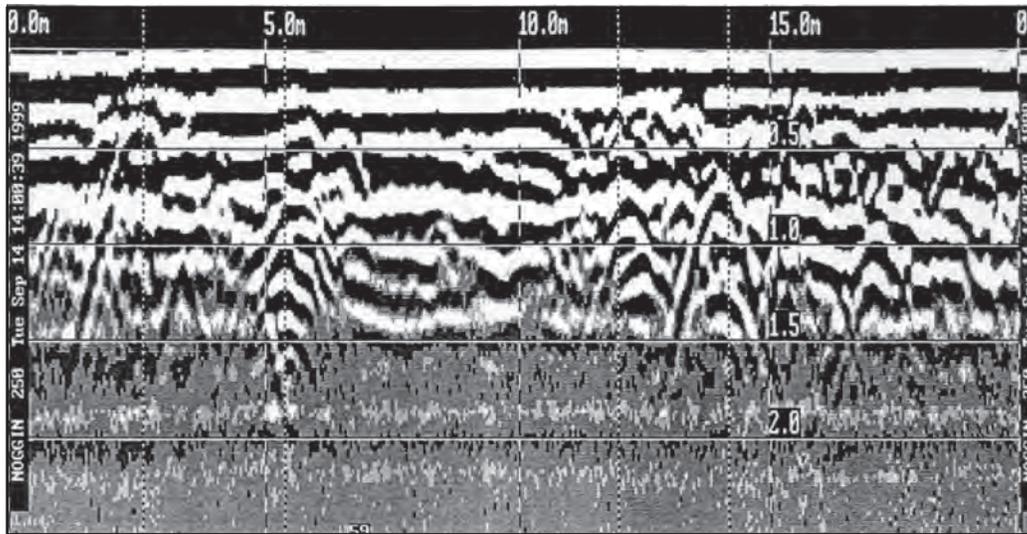


Figure 10. Radar profiles in Block 3 near Bastion 1. Top radar profile shows Line 29 east, 2000 m north. Bottom profile shows Line 32 east, 2000 m north. A buried wire and a utility trench are perceptible at approximately 2 m north. Reflections from the footings for Wall Segment 10 are seen at 5 m north, as are reflections from a buried stone wall at 12 m north and an underground water line at 14 m north.

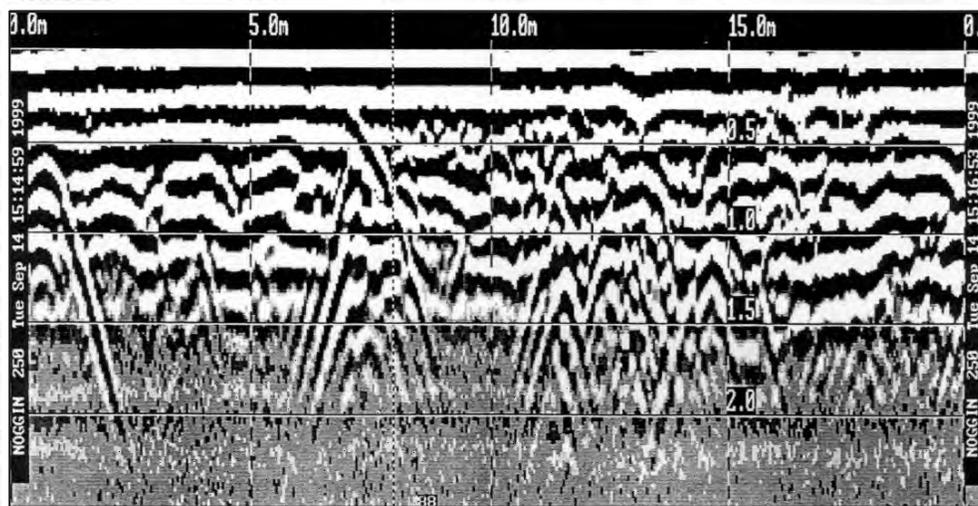
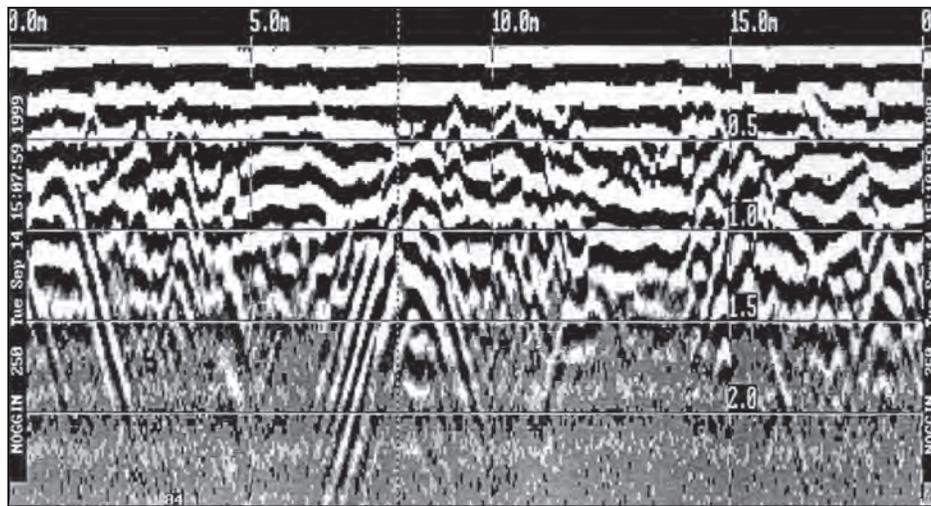
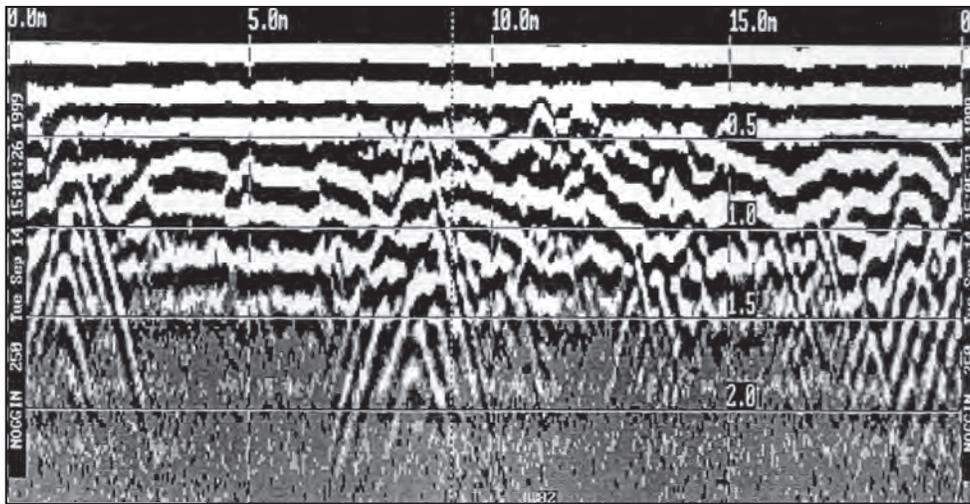


Figure 11. Radar profiles of Lines 7, 10, and 13 north in Block 1 near Bastion 1, recorded from east to west, 2000 m east. Radar reflections from Wall Segment 1 are visible at the 8-m mark on all three traverses.

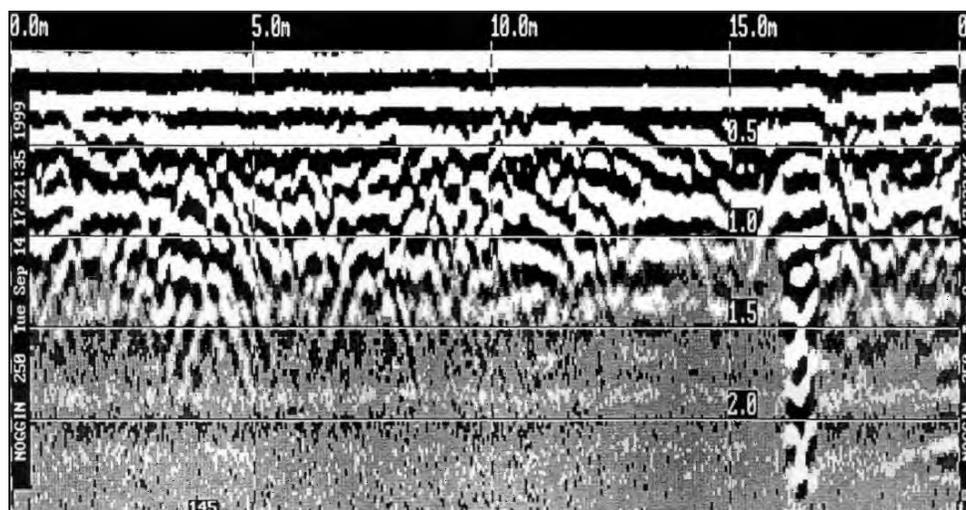
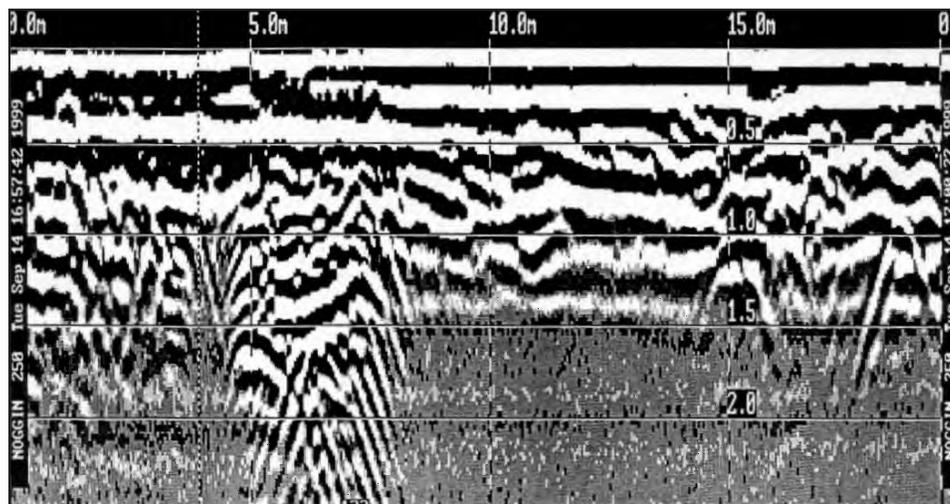
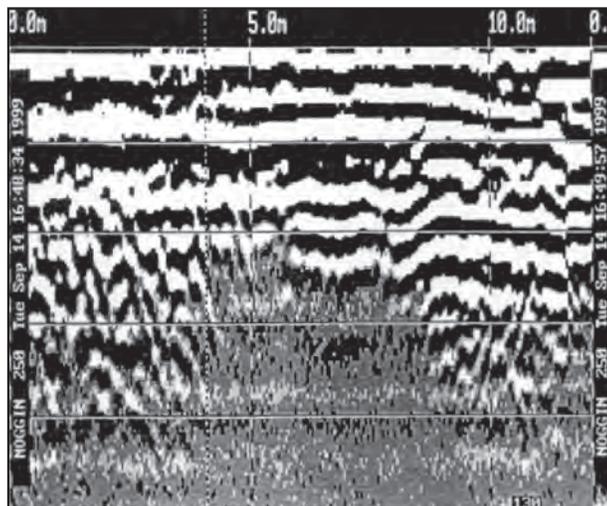


Figure 12. Radar profiles from Lines 26, 29, and 39 north in Block 3 near Bastion 1, recorded from east to west. Profiles illustrate areas of disturbance and historic stone footings from the fort wall and from post-fort buildings.

Site : fosm Comp. : r10alla		Resistivity Survey		Scale	1:369
Shade Plot (Clip)		Size x 2		Block	Off
Minimum	-2	Grey Levels	17	Black	High
Maximum	2	Palette	Positive		
Contrast	1			White	Low
Units	Std.Dev.				

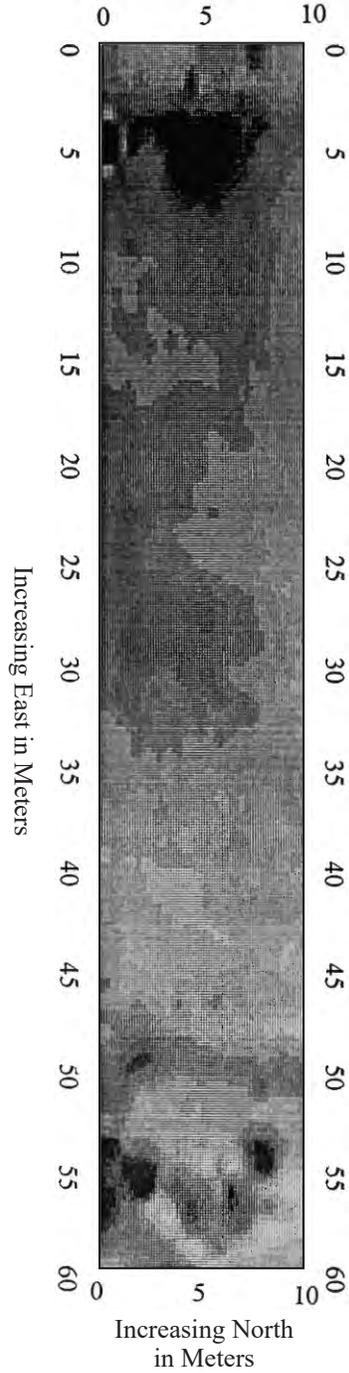


Figure 13. Soil resistance map of Block 4 showing a stone floor near Gate 5 at the top, and portions of Bastion 5 near the bottom.

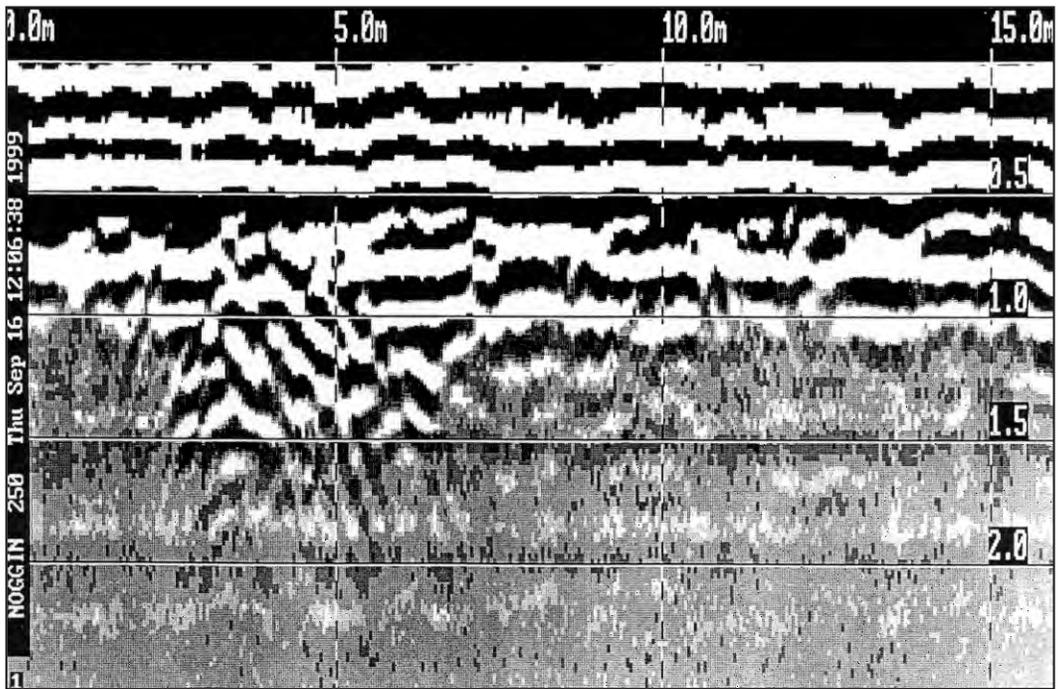
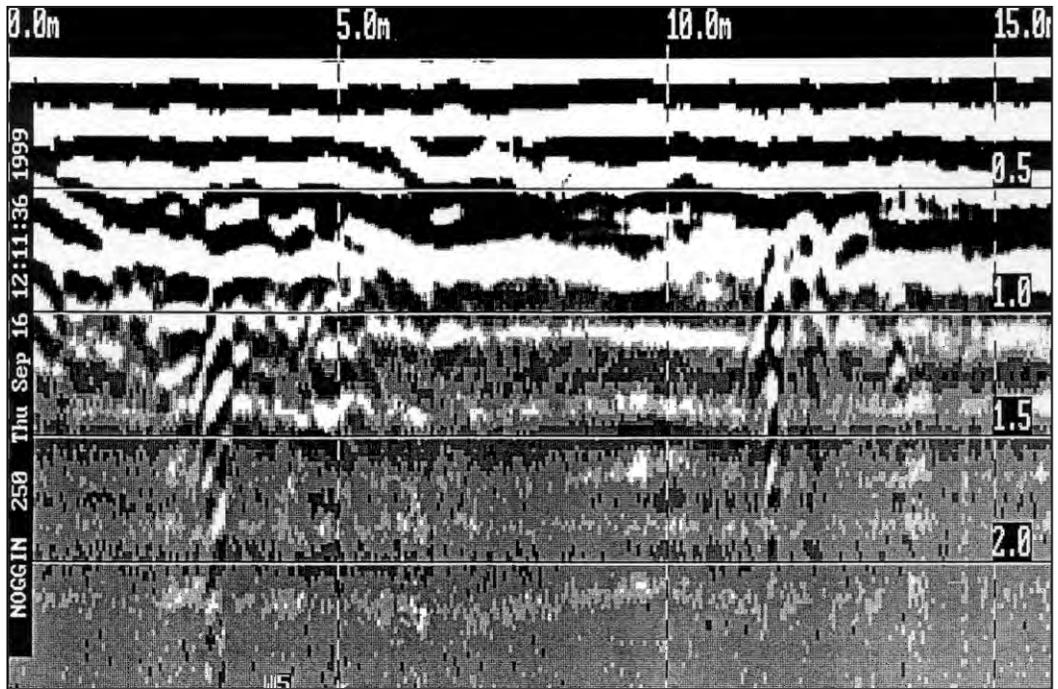


Figure 14. Radar profiles recorded from west to east in Block 4 across the area of the stone floor near Gate 5.

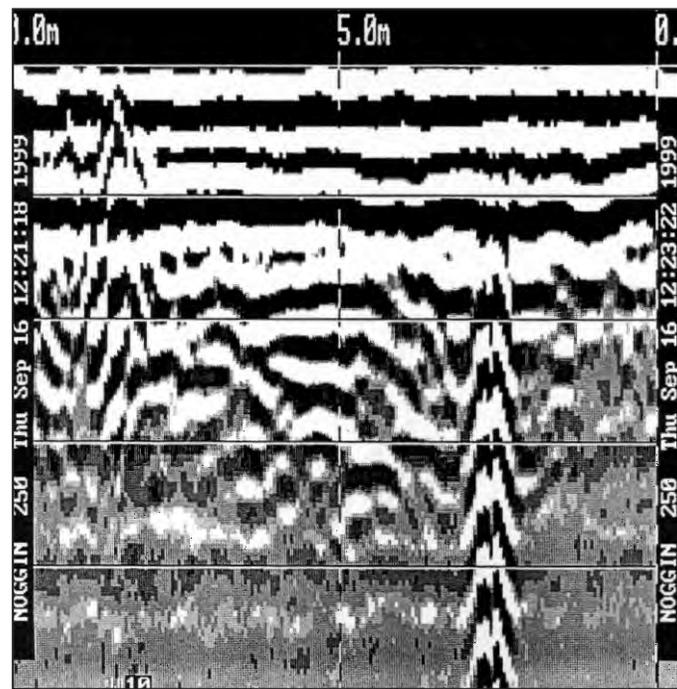
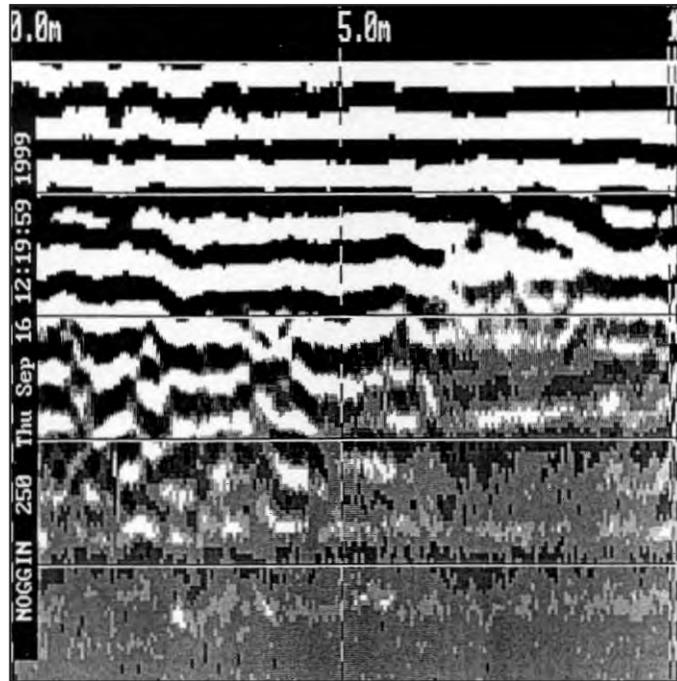


Figure 15. Radar profiles recorded from south to north in Block 4 across the area of the stone floor near Gate 5. The top profile shows the line at 3 east and the bottom profile illustrates the line at 5 east.

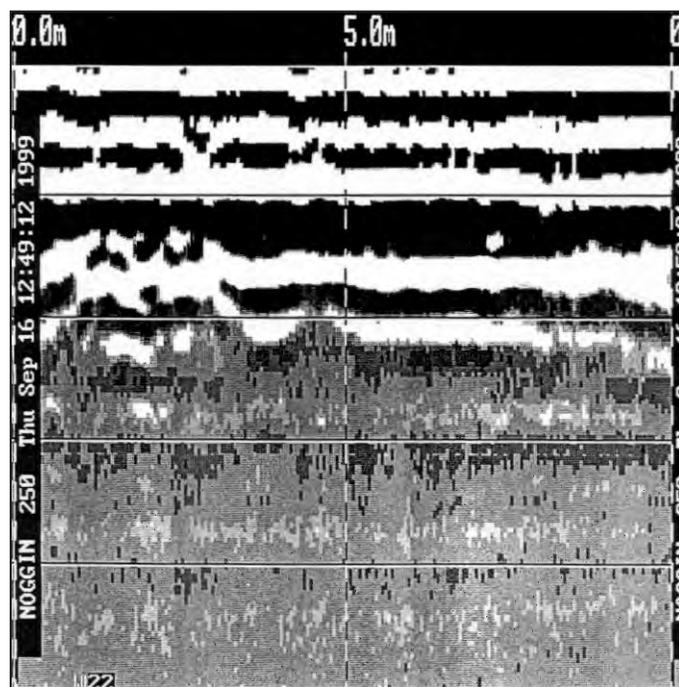
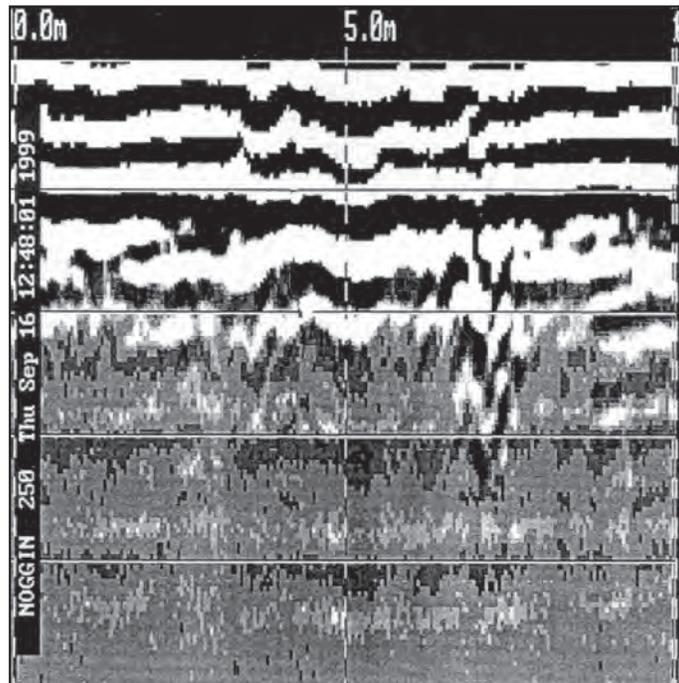


Figure 16. Radar profiles recorded from south to north on Lines 47 east (top) and 49 east (bottom) in Block 4. Line 47 crosses Wall Segment 9 at the 4-m mark. Line 49 traverses the length of left flank of Bastion 5.

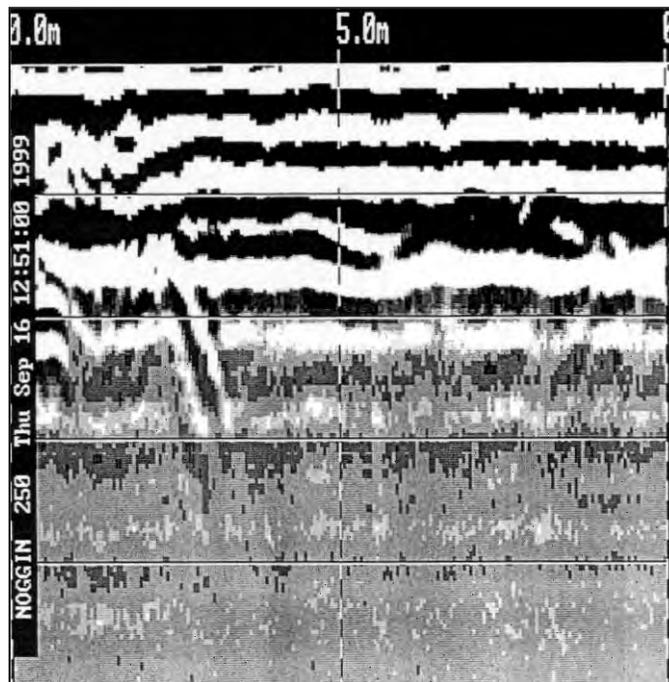
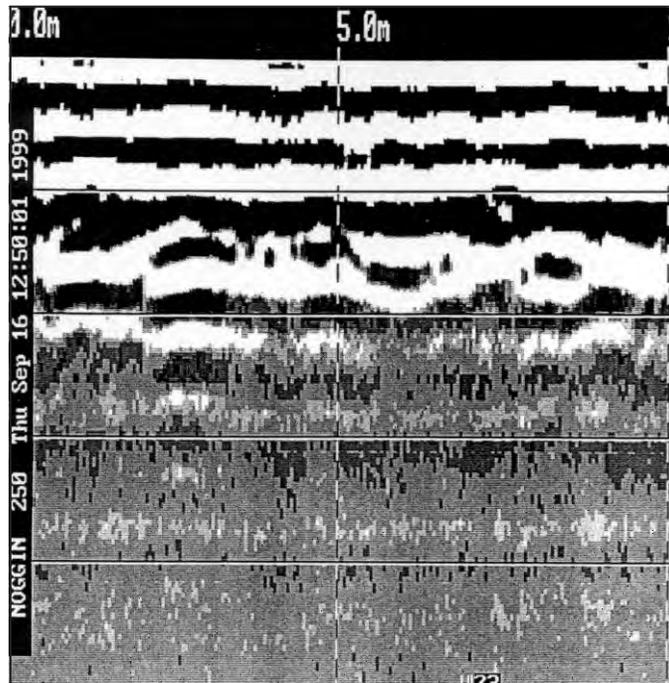


Figure 17. Radar profiles recorded from south to north on Lines 51 east and 53 east in Block 4. Line 51 crosses the gorge of Bastion 5 at 3 m. Line 53 records the disturbance, seen as a gap, in the gorge of Bastion 5.

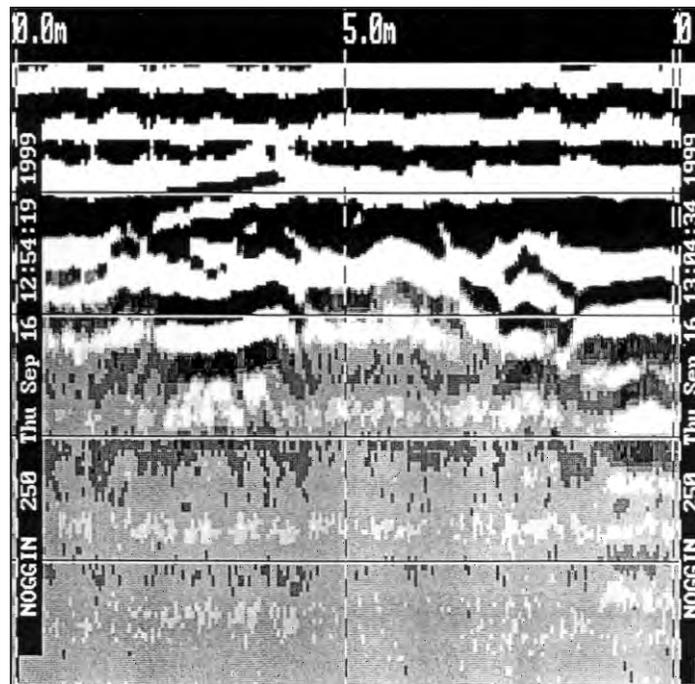
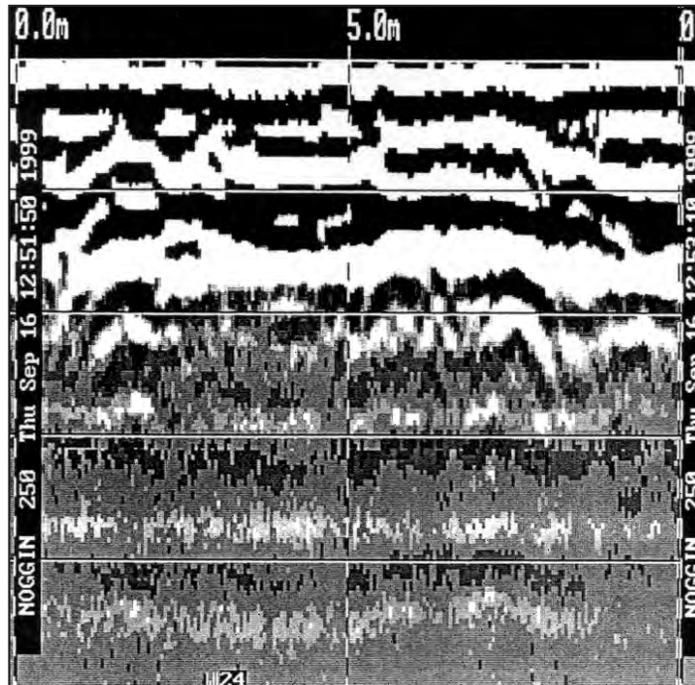


Figure 18. Radar profiles recorded from south to north on Lines 55 east and 59 east in Block 4. Line 55 crosses the gorge of Bastion 5 at 1 m and the footing for the parados at 7 m. Line 59 crosses the right flank of Bastion 5 at 3 m and the right face of Bastion 5 at 7 m.

Site : f0sm Comp. : bl5ma	Resistivity Survey		Scale	1:369
Shade Plot (Clip)		Size x 2	Block	Off
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Maximum	2	Palette	White	Low
Contrast	1			
Units	Std.Dev.	17		
		Positive		

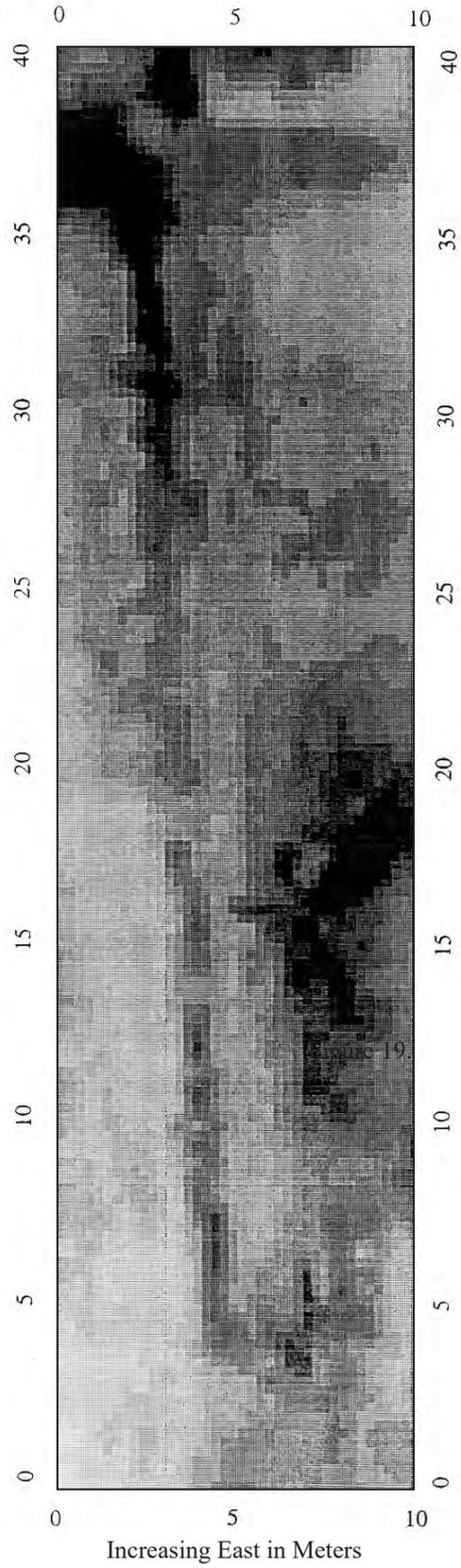


Figure 19. Resistance data from Block 5 showing Wall Segment 8

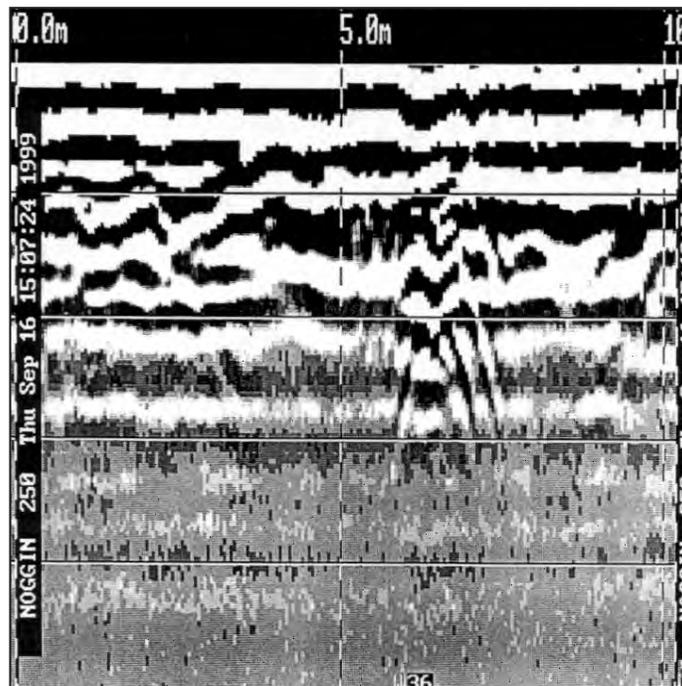
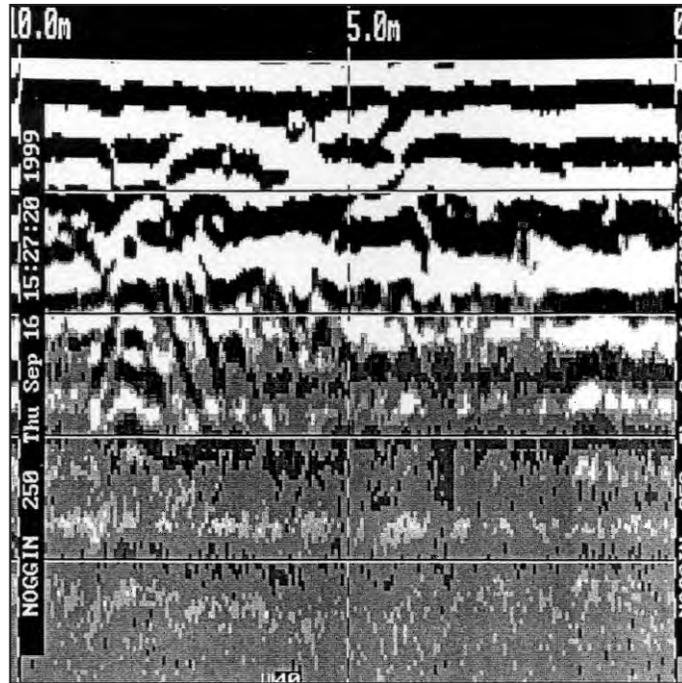


Figure 20. Radar profiles recorded from east to west across Block 5, Lines 5 north (top) and 17 north (bottom). Radar reflections from Wall Segment 8 are recorded at the 5-m mark on Line 5 and at the 6-m mark on Line 17.

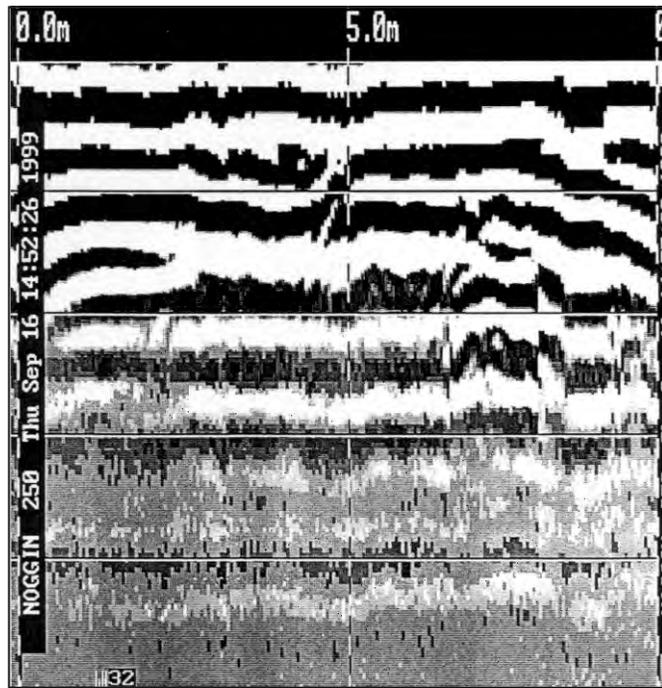
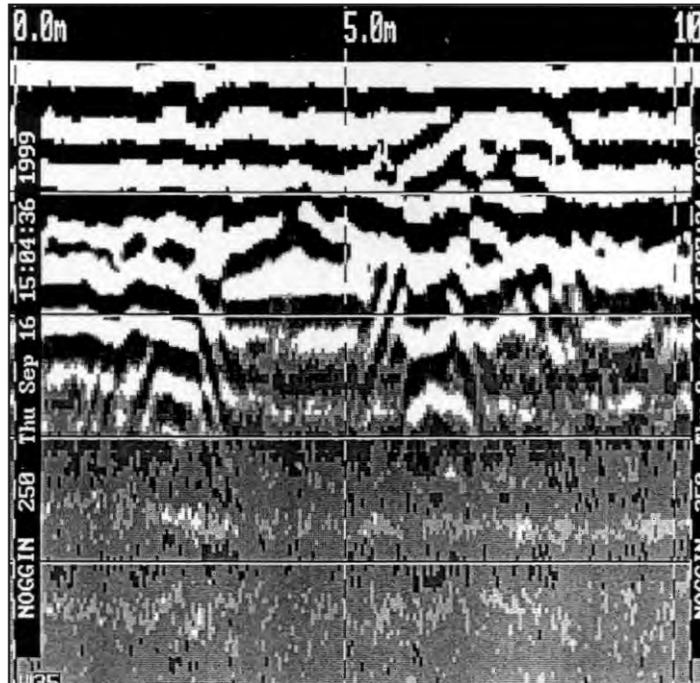


Figure 21. Radar profiles recorded from east to west across Block 5, Lines 21 north (top) and 31 north (bottom). Radar reflections from Wall Segment 8 are recorded at the 6.5-m mark on Line 21 and at the 7-m mark on Line 31.

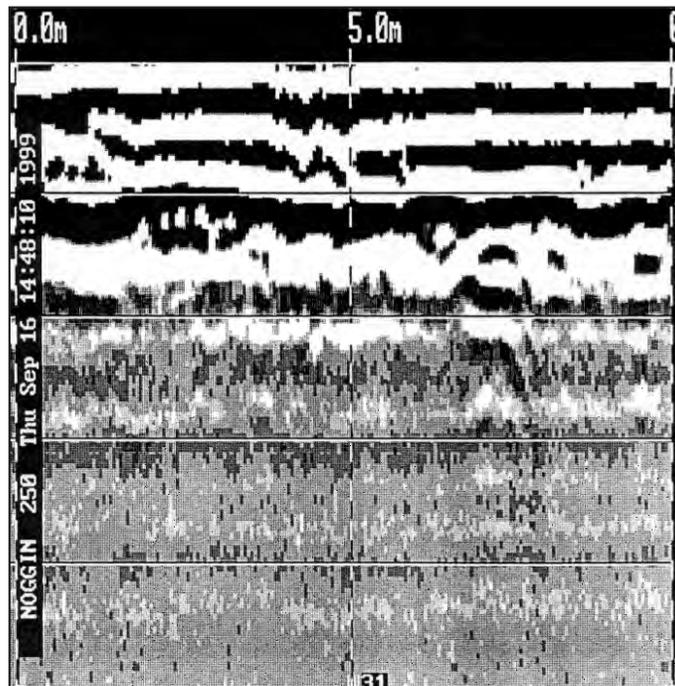
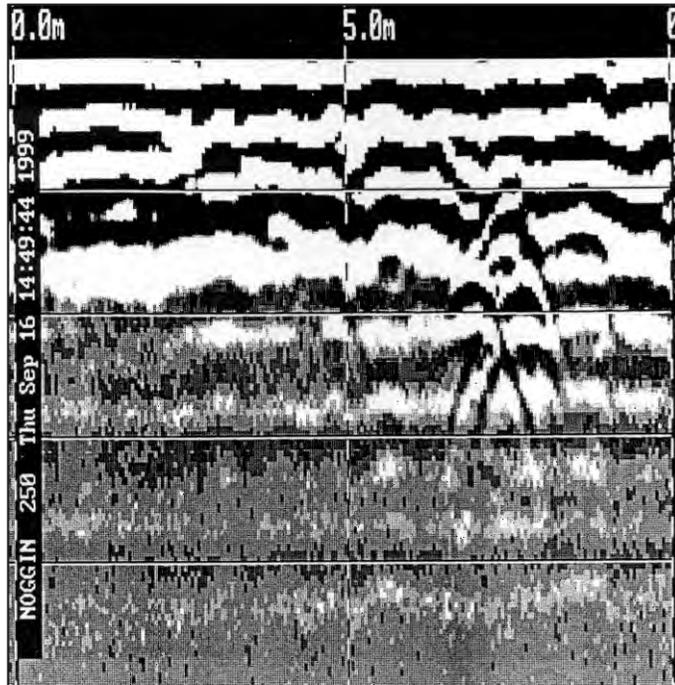


Figure 22. Radar profiles recorded from east to west across Block 5, Lines 35 north (top) and 39 north (bottom). Radar reflections from Wall Segment 8 are recorded at the 8-m mark on both lines.

Site : fosh Comp. : bl12		Resistivity Survey		Scale	1:185	
Shade Plot (Clip)			Size x 4		Block	Off
Minimum	-1	Grey Levels	17	Black	High	
Maximum	1	Palette	Positive	White	Low	
Contrast	1					
Units	Std.Dev.					

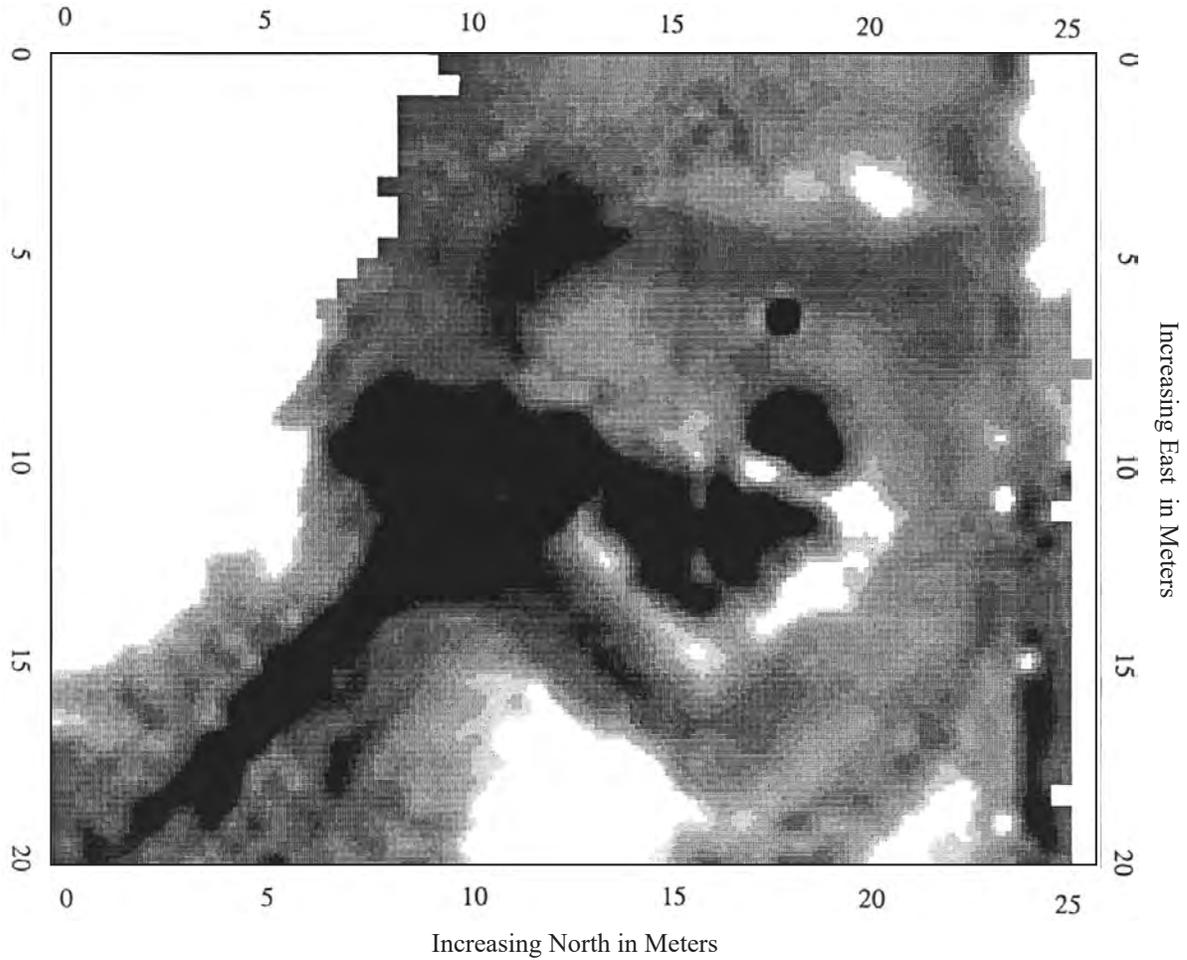


Figure 23. Soil resistance map showing Bastion 5 and the adjacent portion of Wall Segment 8 in Block 12.

Site : fosm Comp. : bl6xa		Resistivity Survey		Scale	1:369
Shade Plot (Clip)			Size x 2	Block	Off
Minimum	-2	Grey Levels	17	Black	High
Maximum	2	Palette	Positive	White	Low
Contrast	2				
Units	Std.Dev.				

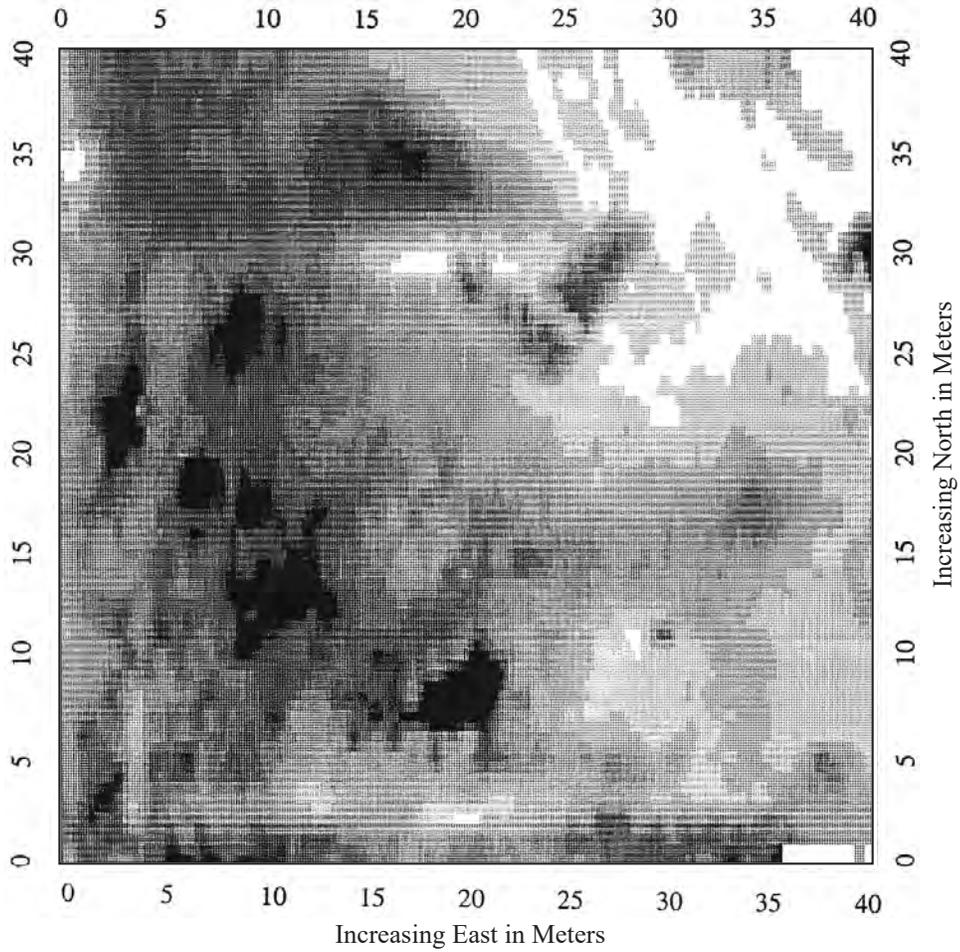


Figure 24. Soil resistance map of Bastion 4 and the adjacent portion of Wall Segment 7 in Block 6.

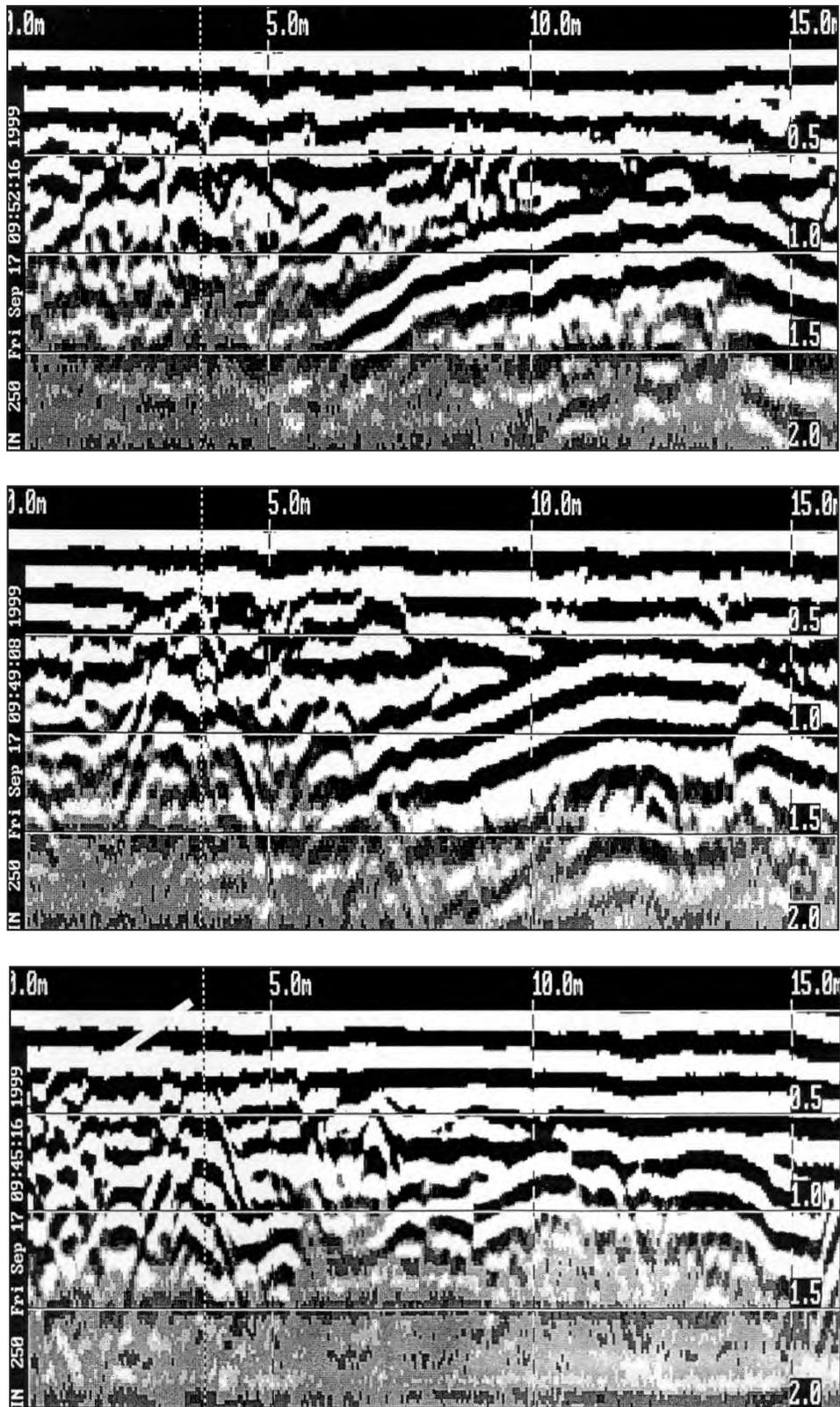


Figure 25. Radar profiles recorded from west to east on Lines 6 (bottom), 10 (middle), and 12 (top) north in Block 6. Radar reflections from rock rubble are apparent on Lines 10 and 12 from 6m east but not as apparent on Line 6. A utility trench is visible on all three lines at 4 m east.

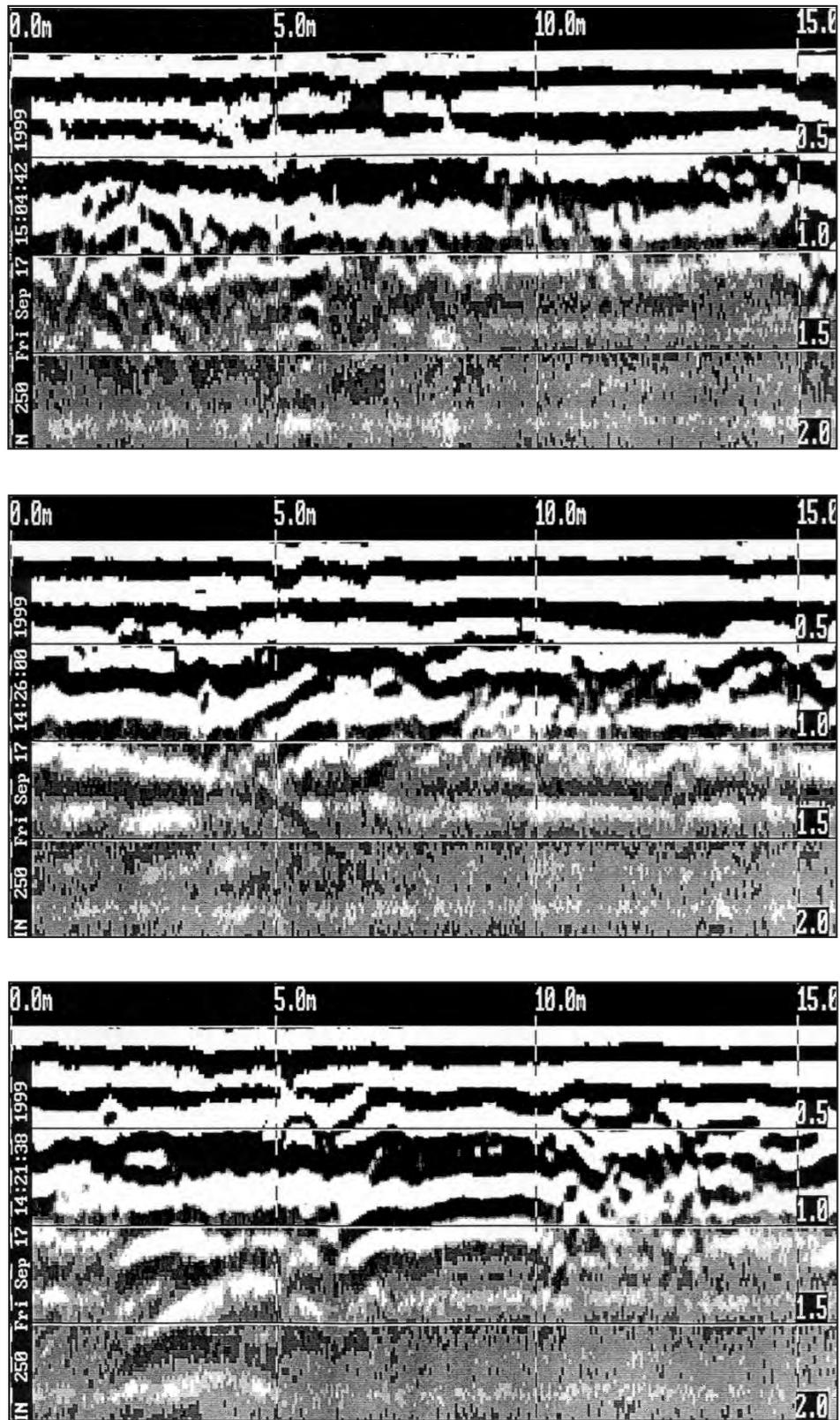


Figure 26. Radar profiles recorded from west to east on Lines 25 (top), 27 (middle), and 29 (bottom) north in Block 6. These profiles record reflections from Wall Segment 7 and the left flank of Bastion 4.

Site : fosm Comp. : bl7a		Resistivity Survey		Scale	1:369
Shade Plot (Clip)		Size x 2		Block	Off
Minimum	-1.5	Grey Levels	17	Black	High
Maximum	1.5	Palette	Positive	White	Low
Contrast	.9				
Units	Std.Dev.				

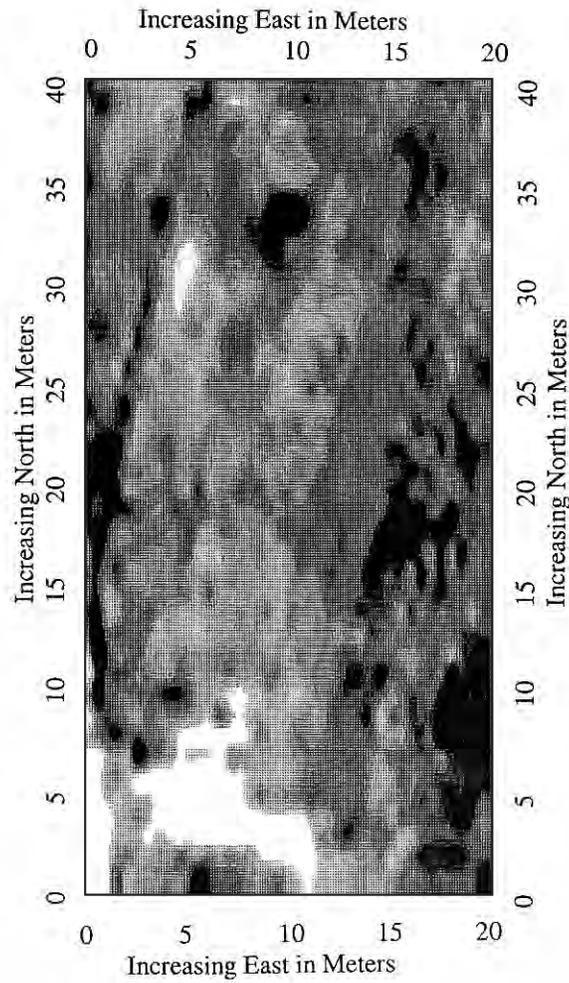


Figure 27. Soil resistance map of Block 7 showing a portion of Wall Segment 1.

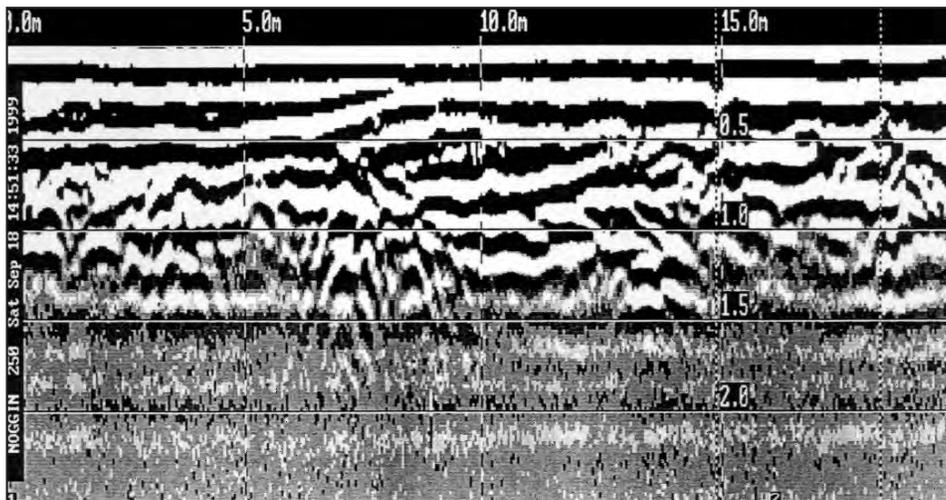
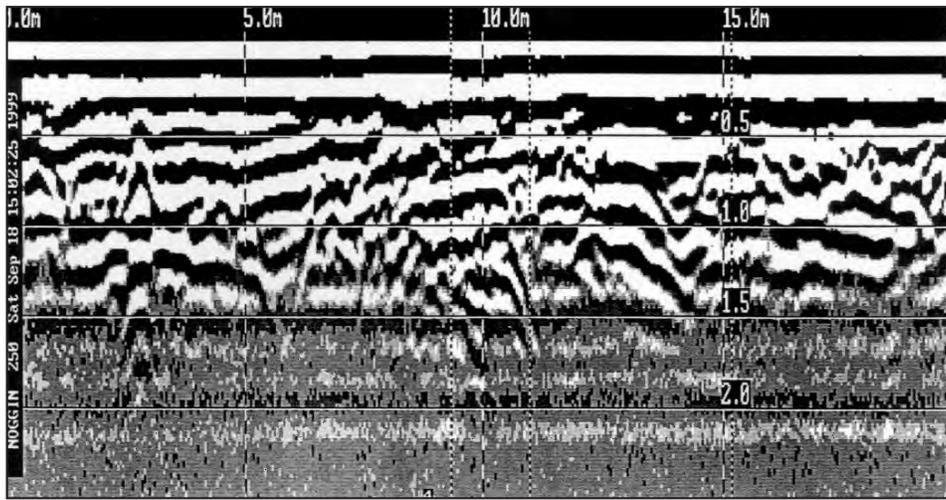
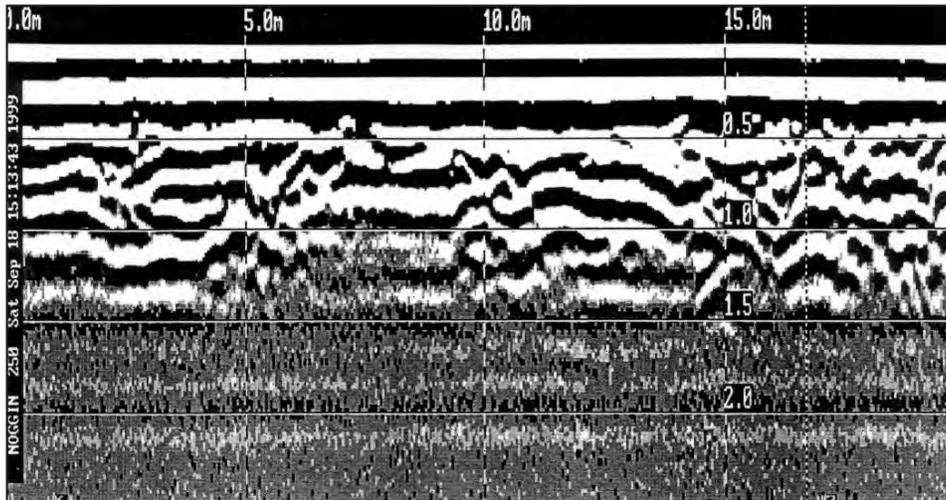


Figure 28. Radar profiles from Block 7 recorded from east to west on Lines 27 (top), 34 (middle), and 39 (bottom) north. Radar reflections from Wall Segment 1 are recorded at 17 m north, 16 m north, and 15 m north on Lines 27, 34, and 39 respectively.



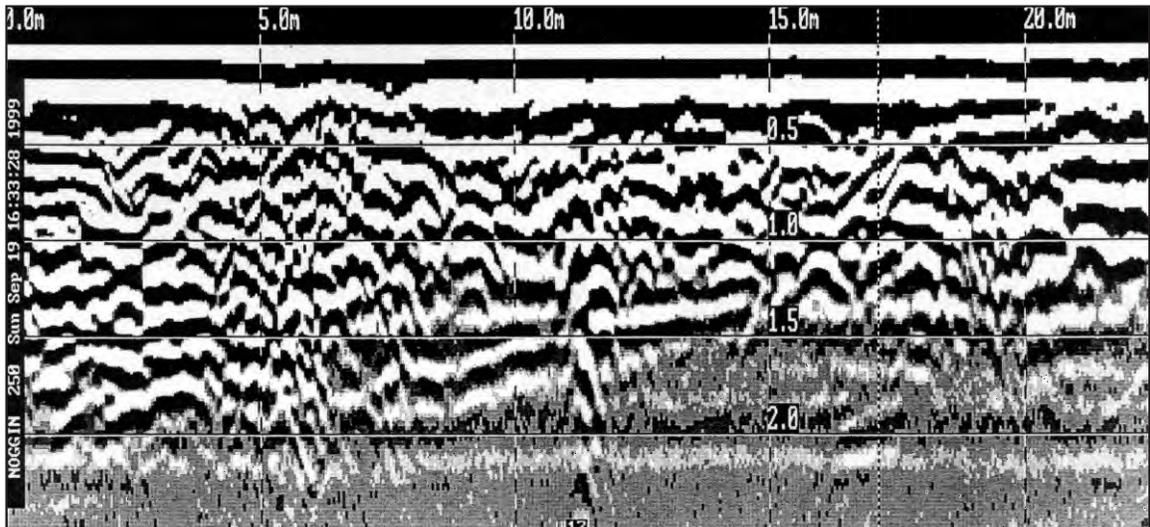
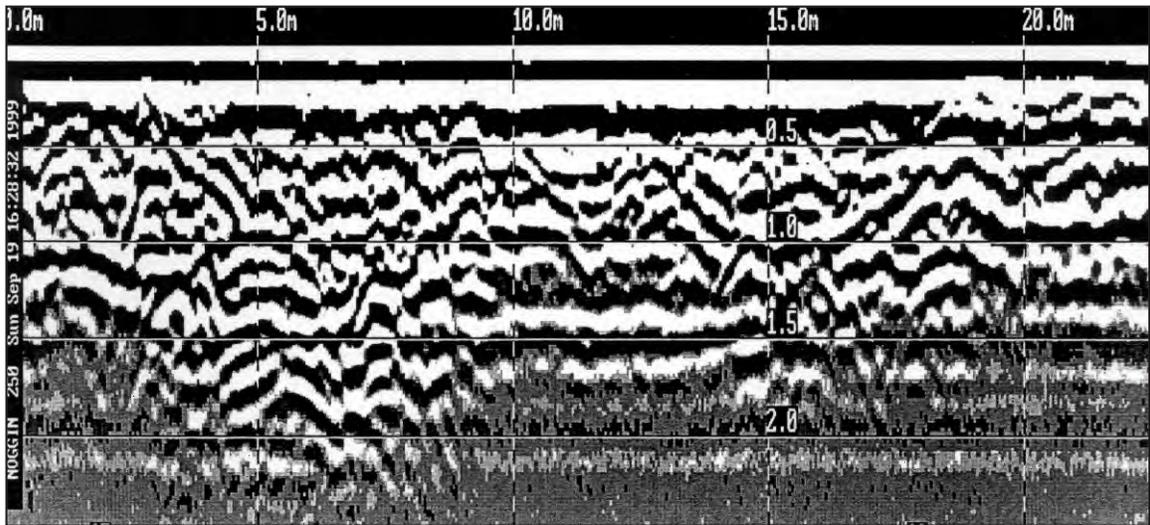


Figure 30. Radar profiles from Block 8 showing wall and floor elements of Bastion 2.

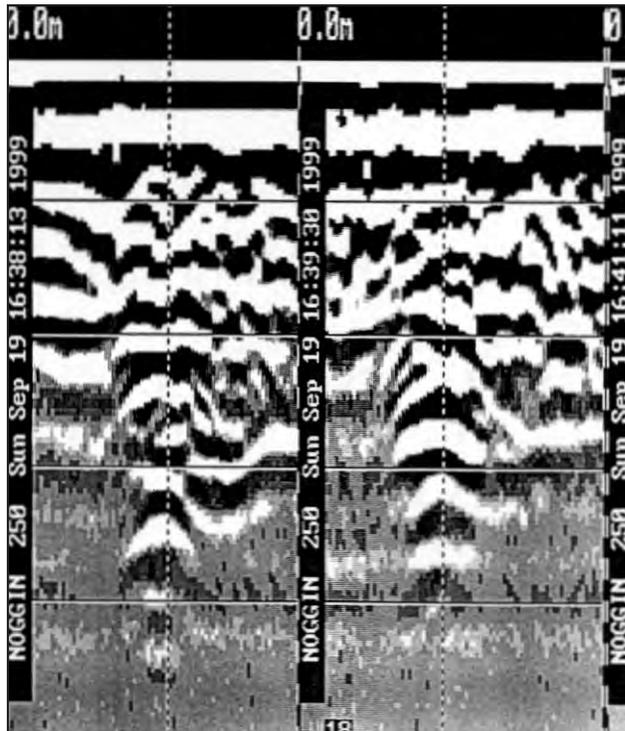
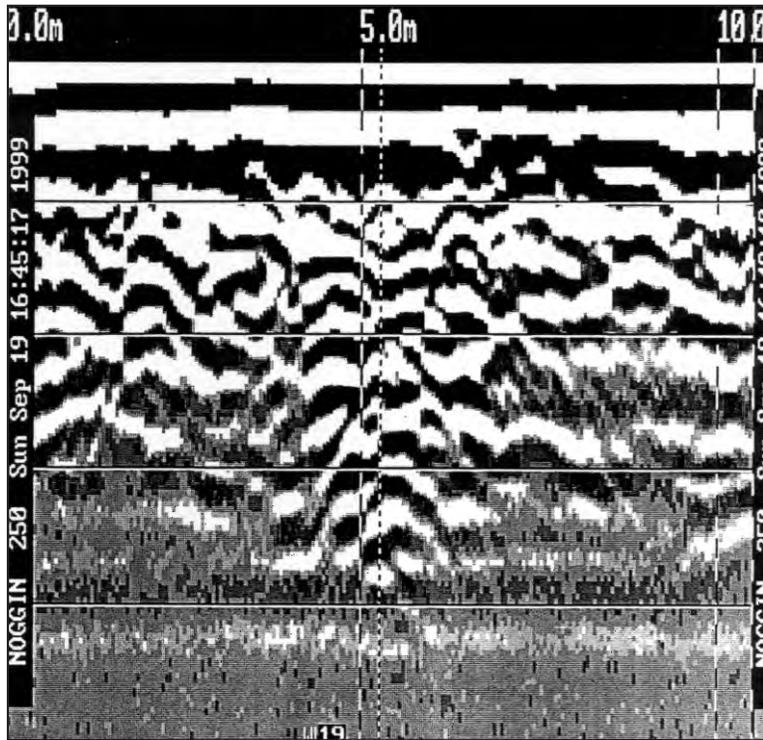


Figure 31. Radar profiles from Block 8 showing the left flank of Bastion 2 (top) and Wall Segment 3 (bottom).

Site : fosm Comp. : bl9a		Resistivity Survey		Scale	1:369
Shade Plot (Clip)		Size x 2		Block	Off
Minimum	-2	Grey Levels	17	Black	High
Maximum	2	Palette	Positive		
Contrast	1			White	Low
Units	Std.Dev.				

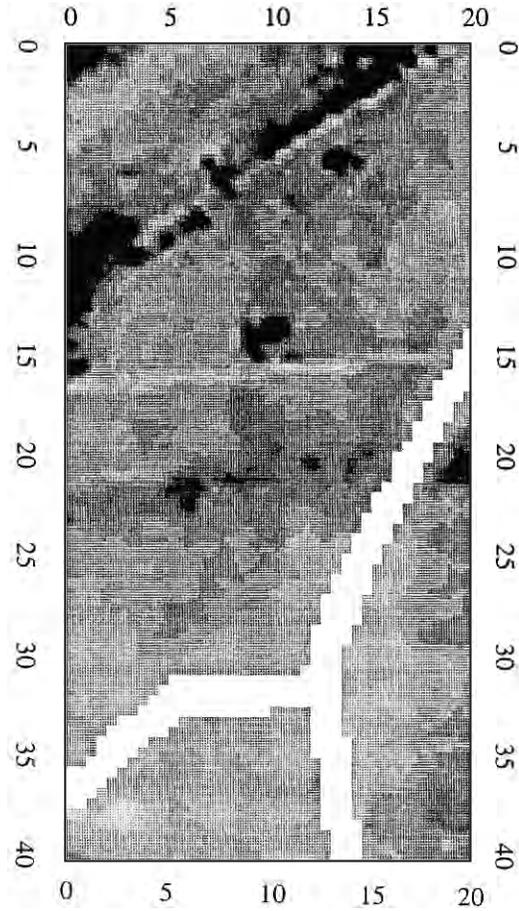


Figure 32. Soil resistance map of Block 9 showing a railroad cut in the upper left corner and modern walkways in the lower right.

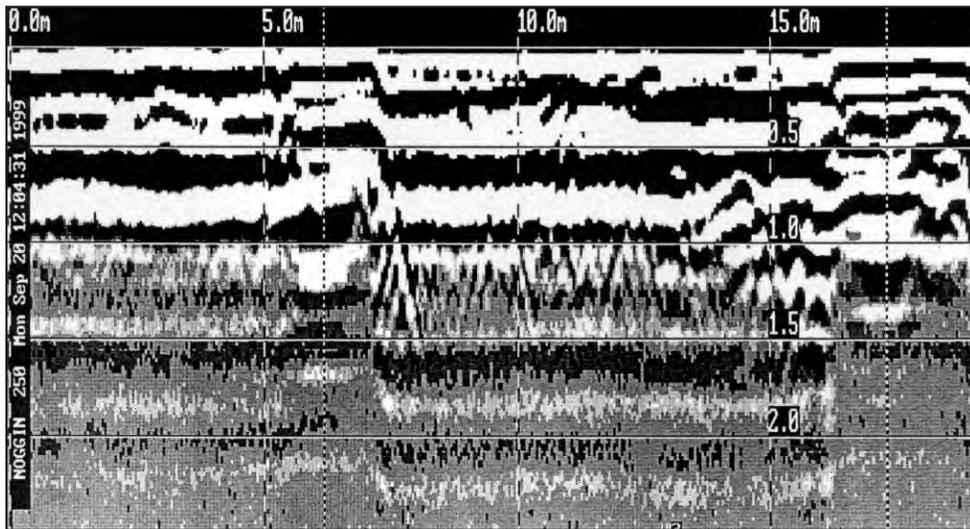
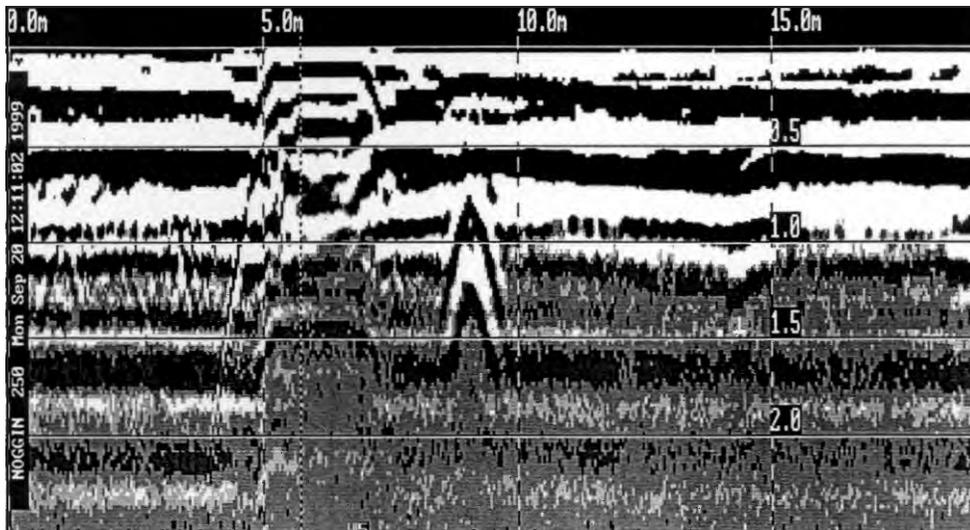


Figure 33. Radar profiles from Block 9 recorded from south to north on Lines 28 (top) and 36 (bottom) east. Radar reflections from modern walks are recorded at 5 m north on Lines 28 and 36 and at 17 m north on Line 36.

Site : fosm Comp. : bl10a		Resistivity Survey		Scale	1:185
Shade Plot (Clip)		Size x 4		Block	Off
Minimum	-2	Grey Levels	17	Black White	High Low
Maximum	2	Palette	Positive		
Contrast	1				
Units	Std.Dev.				

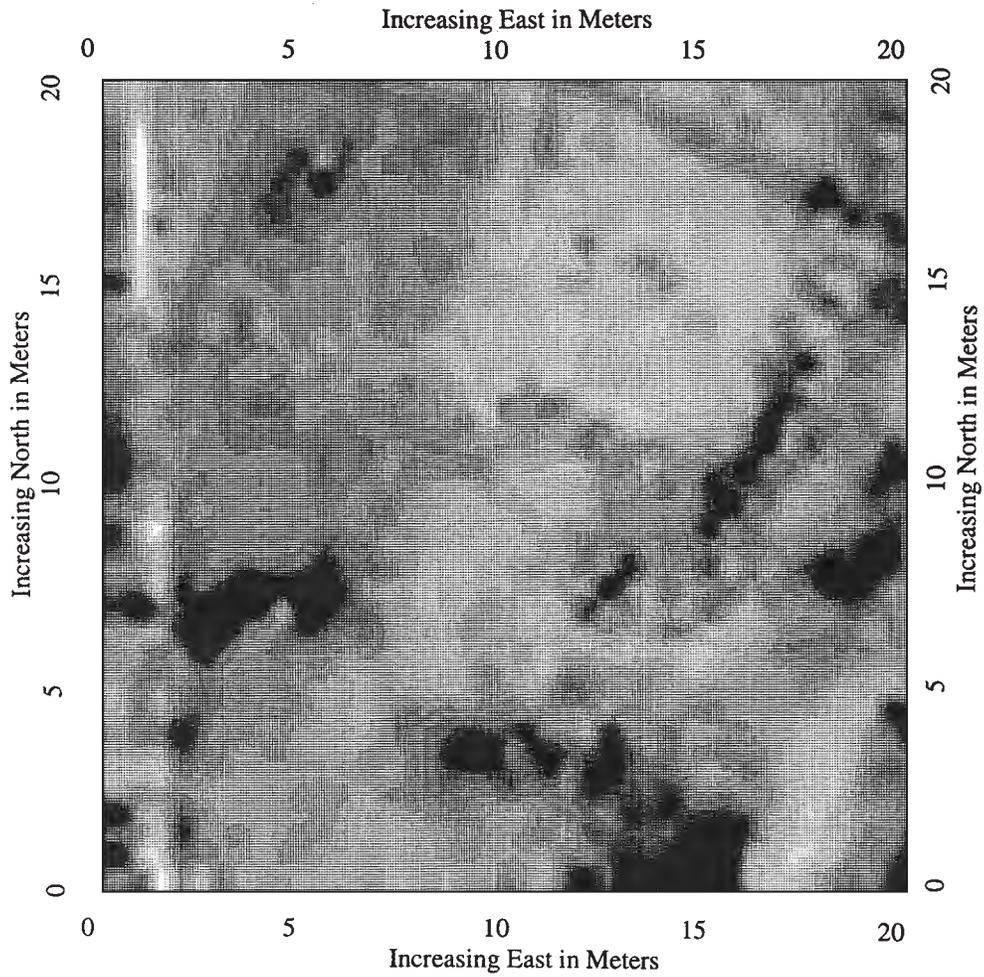


Figure 34. Soil resistance map of Block 10 showing modern development features and a possible historic structure location in the upper right quadrant.

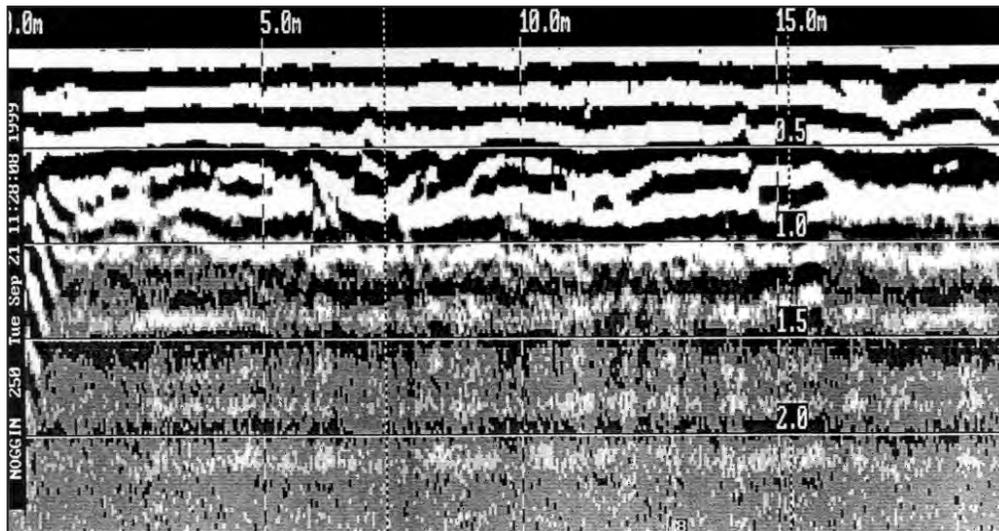
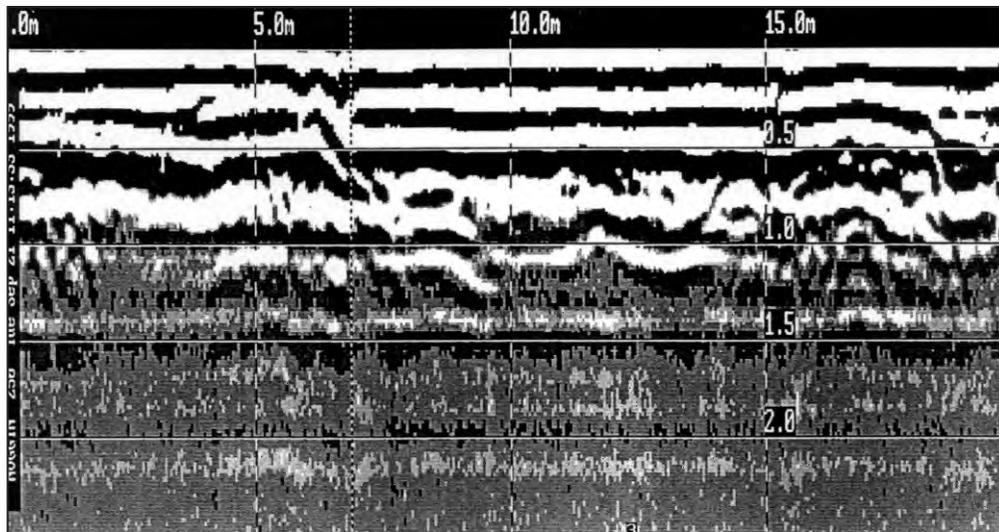


Figure 35. Radar profiles from Block 10 recorded from east to west on Lines 4.5 (top) and 11 (bottom) north. Radar reflections from a possible building wall are recorded at the 6-m mark on both lines and at the 15-m mark on Line 11.

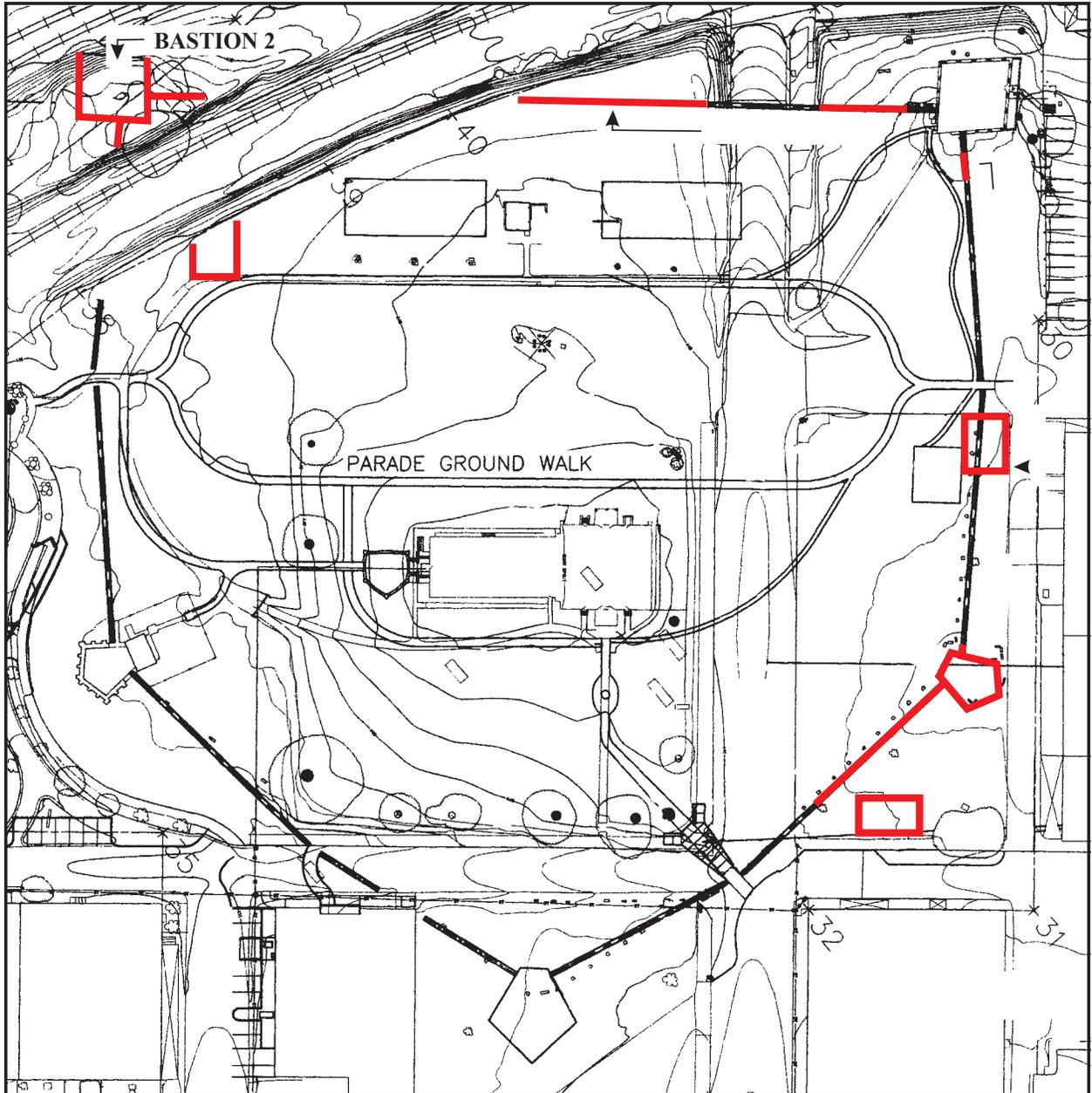


Figure 36. Approximate locations of buried structural remnants identified during this geophysical survey.