

GEOPHYSICAL REMOTE SENSING OF SPANISH-COLONIAL ARCHAEOLOGICAL REMAINS: PRESIDIO DE SAN FRANCISCO

Guy Cross
Golder Associates
University of British Columbia
500 - 4260 Still Creek Drive
Burnaby, British Columbia, Canada V5C 6C6

Barb Voss
Woodward-Clyde Consultants
500 12th Street Suite 100
Oakland CA 94607

ABSTRACT

Archaeological field investigations undertaken in 1993 and 1994 resulted in the discovery of stone wall-foundations representing the main quadrangle of the Spanish-Colonial Presidio de San Francisco. However, the wall-foundations discovered to date indicated that the main quadrangle was significantly larger, to the north and east, than was previously indicated by the historical record. Pavement restricts the use of traditional ground-disturbing archaeological excavations in establishing the presence or absence of archaeological remains over most of the site. Consequently, ground-based remote sensing survey techniques, including ground penetrating radar and electromagnetic conductivity, have been employed in an effort to locate archaeological features in paved locations. Research demonstrates the effectiveness of combined geophysical survey for detection and mapping of potential archaeological remains in urban environments.

Introduction

Since May 1993, archaeological excavations have located extant remains of eastern, northern, and western fronts of the Presidio de San Francisco main quadrangle, a Spanish-colonial/Mexican period fortification. Although the orientation and general location of the exposed wall-foundations conform with predictions based on historic plans and documents, excavated wall-foundation remains are nearly twice as long as those indicated by a 1792 plan of the Presidio by Comandante Hermengildo Sal (Figure 1). Additionally, Sal's plan depicts a three-sided quadrangle, open on the east, while archaeological investigations indicate that the Presidio was closed on the eastern side. It appears that the quadrangle may have been enlarged after additional troops were dispatched to the Presidio in 1796, after the Sal plan was drawn. The relationship between wall-foundation remains exposed by archaeological excavation and the Sal plan have been the focus of recent research at the site.

The Role of Geophysical Remote Sensing

While further archaeological investigation of the historic Presidio is essential for long-term conservation and management of the site, paved roads, walkways and parking lots extend over much of the site, restricting the use of traditional archaeological excavations. It was recognized that, in connection with limited archaeological excavations, geophysical reconnaissance might establish the continuity or absence of wall-foundation remains remotely, thereby expediting archaeological assessment and management processes in a cost-effective man-

ner. Although archaeologists have widely acknowledged the utility of geophysical techniques for remote detection and assessment of archaeological features, the effectiveness of these techniques in urban environments can be significantly restricted by interference from above-ground and subsurface infrastructure. In particular, the Presidio de San Francisco is underlain by a complex network of subsurface utilities, including water, fuel oil, sewage and sprinkler lines. Consequently, in addition to site-specific archaeological objectives, the Presidio project presents an ideal opportunity to evaluate the potential of near-surface geophysical investigations for archaeological research in urbanized environments.

Geophysical Methods

Electromagnetic Soil Conductivity

Apparent soil conductivity measurements were acquired using a Geonics EM-38 conductivity meter. In simple terms, an alternating current is fed through a wire transmitter coil, producing a time-varying magnetic field that penetrates the ground and induces secondary electrical currents within subsurface materials in accordance with Faraday's law of electromagnetic induction. As indicated in Figure 2, these so-called eddy currents, in turn, give rise to a secondary magnetic field that is sensed together with the primary field by the receiver coil.

Under ordinary conditions, induced current flow and, consequently, the strength of the secondary magnetic field are approximately proportional to subsurface conductivity which is

controlled principally by soil compaction-consolidation, moisture content, and ion concentration. Finally, the presence of metallic materials, including pipes and other utilities, produces a characteristic negative-valued reading flanked by anomalously high apparent conductivities.

Ground Penetrating Radar

Ground penetrating radar operates on the simple principle that electromagnetic waves emitted into the ground by a transmitter (Tx) antenna are partially reflected at subsurface interfaces and subsequently detected by a coincident receiver (Rx) antenna. Radar velocity, reflectivity and maximum subsurface penetration depend on the electrical properties of subsurface materials. Reflections arise due to contrasts in subsurface electrical properties. Figure 3 illustrates a conceptual application of the radar being used in the reflection profiling mode on soil over bedrock. Historical and archaeological features are imaged by delineating contrasts between the electrical properties of cultural deposits and those of the host matrix.

The radar system incorporates precise timing electronics to measure the reflection transit-time from transmitter to receiver, which depends on reflector range and radar velocity. Given an estimate of measured radar velocity, corresponding reflector depths may be determined. A radar profile is acquired by moving transmitter and receiver antennas and, concurrently, recording a series of soundings at equal intervals along a traverse. Resulting data are displayed as a series of oscilloscope-like traces having amplitude proportional to reflection strength. While GPR effectively delineates continuous reflecting interfaces, localized anomalous zones produce a characteristic diffraction pattern (Figure 4).

Field Investigations Methods

Electromagnetic soil conductivity mapping was employed in conjunction with ground penetrating radar measurements in an attempt to discriminate between GPR anomalies associated with archaeological remains and similar events arising from subsurface utilities. Utilizing the capacity of electromagnetic conductivity measurements to readily identify the presence of both ferrous and non-ferrous metals, high density EM-38 measurements were used to produce plan-view maps showing the locations and alignments of subsurface utility lines in a given survey area. Subsequent correlation of these maps with coincident GPR profiles allowed the interpreter to identify GPR anomalies associated with subsurface utilities. Remaining GPR anomalies were mapped in relation to the predicted location of archaeological (wall-foundation) remains. Figure 5 depicts the locations of the EM-38 mapping and GPR transects.

Findings

Although ground penetrating radar measurements failed to unequivocally delineate remains of the Presidio de San Francisco, results demonstrate the effectiveness of combined electromagnetic soil conductivity and ground penetrating radar measurements to identify and map potential archaeological features in the presence of substantial cultural interference due to subsurface utilities. Figures 6, 7, 8, and 9 illustrate combined EM-38 and GPR data acquired at Quarters 11 and Pershing Square.

Additionally, the study yielded valuable information. The investigation appears to confirm the presence and alignment of the northern front, extending west from remains exposed by archaeological excavations at the rear of Quarters 11 (NNW-1, -2, -3, -6, -7, -8 and -9) (see Figure 5). In contrast, a lack of significant findings along the northern alignment predicted by the 1792 Sal plan (ONW-1 through ONW-11) suggests that extant remains of this wall are not present, may never have existed, or may have been dismantled in connection with later expansion of the Presidio. Finally, geophysical data acquired in Pershing Square (PS-2 through PS-13) confirm the general location and alignment of the western front of the Presidio quadrangle and further suggest that the western front may have included a third, outer wall in some locations.

Conclusions

Combined electromagnetic soil conductivity and ground penetrating radar measurements appear to distinguish GPR anomalies associated with an extensive network of subsurface services, including utility lines and lawn sprinkler systems, from other more subtle features that may be attributable to archaeological remains. The locations of these features, identified by geophysical investigation, define alignments that generally conform with current models of the Spanish-colonial Presidio and suggest new hypotheses. By nature, interpretations based on geophysical findings are both speculative and subjective and, consequently, require confirmation through direct archaeological investigation. Further field research, scheduled for May 1995, will utilize traditional archaeological excavation to explore the veracity of remotely sensed information. The results of this study will be applicable to resource identification and conservation efforts at other present or formerly used defense installations, and by other land management agencies and urban archaeologists as well.

Notes

This research was conducted as a Partners in Preservation project sponsored by the Army Corps of Engineers and the National Park Service.

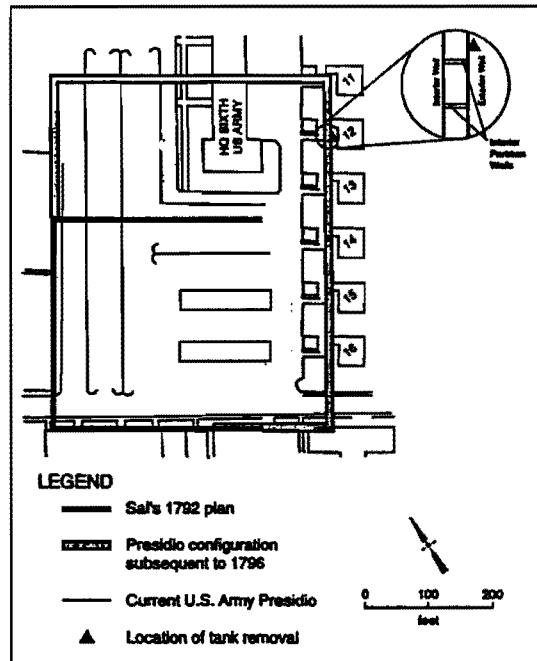


Figure 1. Comparison of 1792 Sal Plan and Archaeological Findings

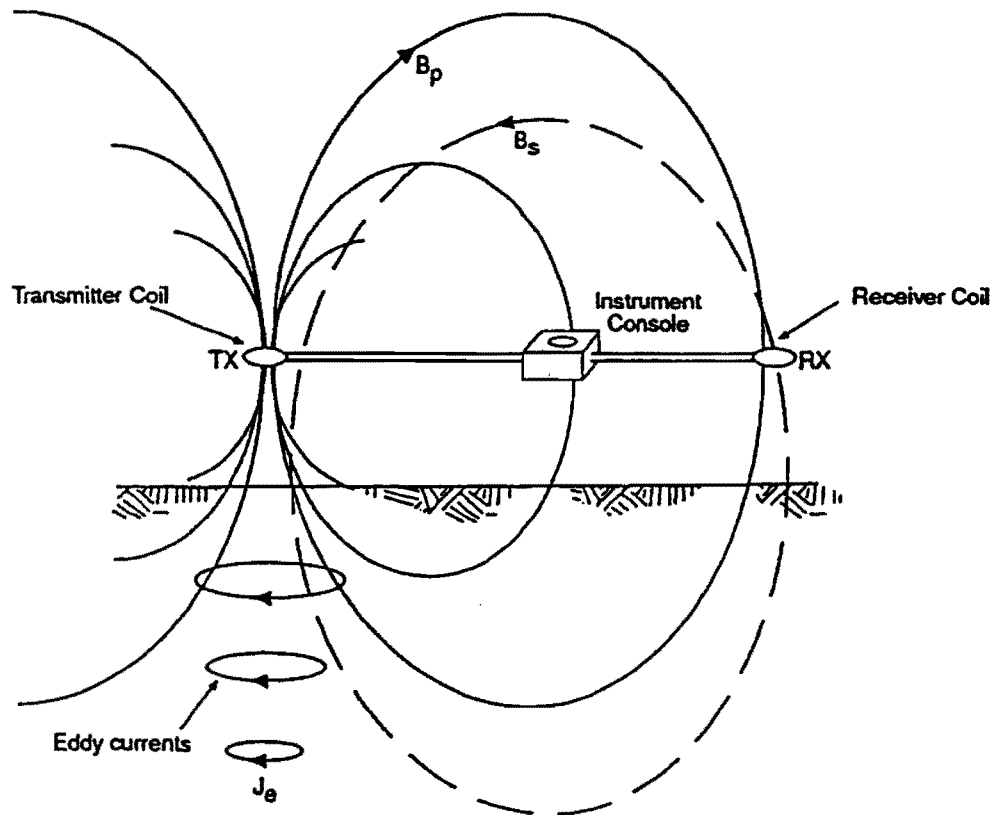


Figure 2. Conceptual Illustration of Electromagnetic Soil Conductivity Mapping

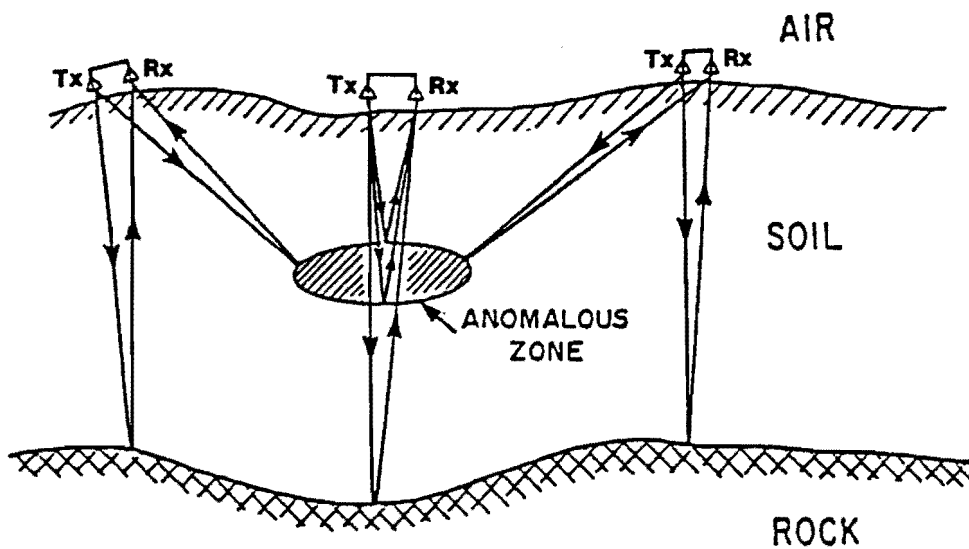


Figure 3. Conceptual Illustration of Radar Being Used in the Reflection Profiling Mode on Soil over Bedrock

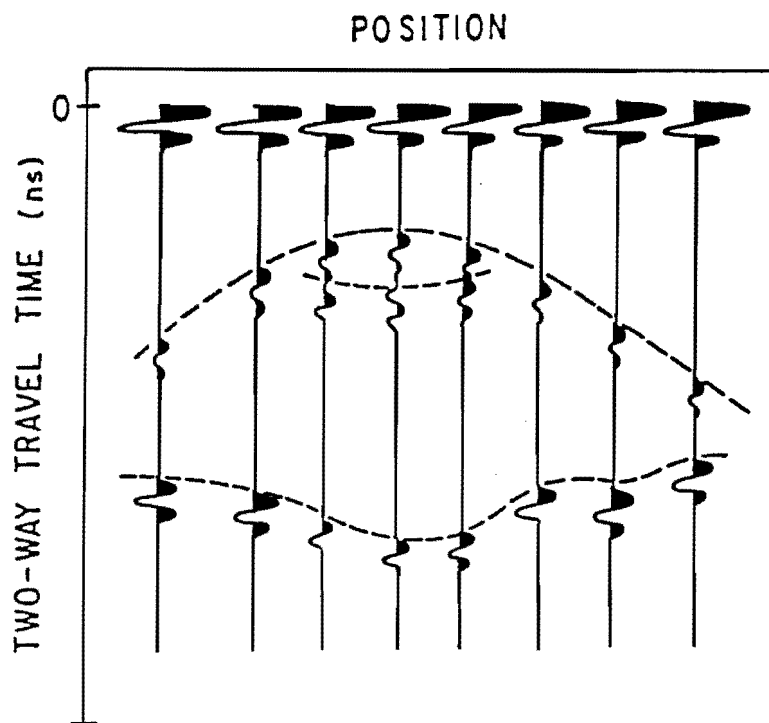


Figure 4. Resulting Radar Record Obtained

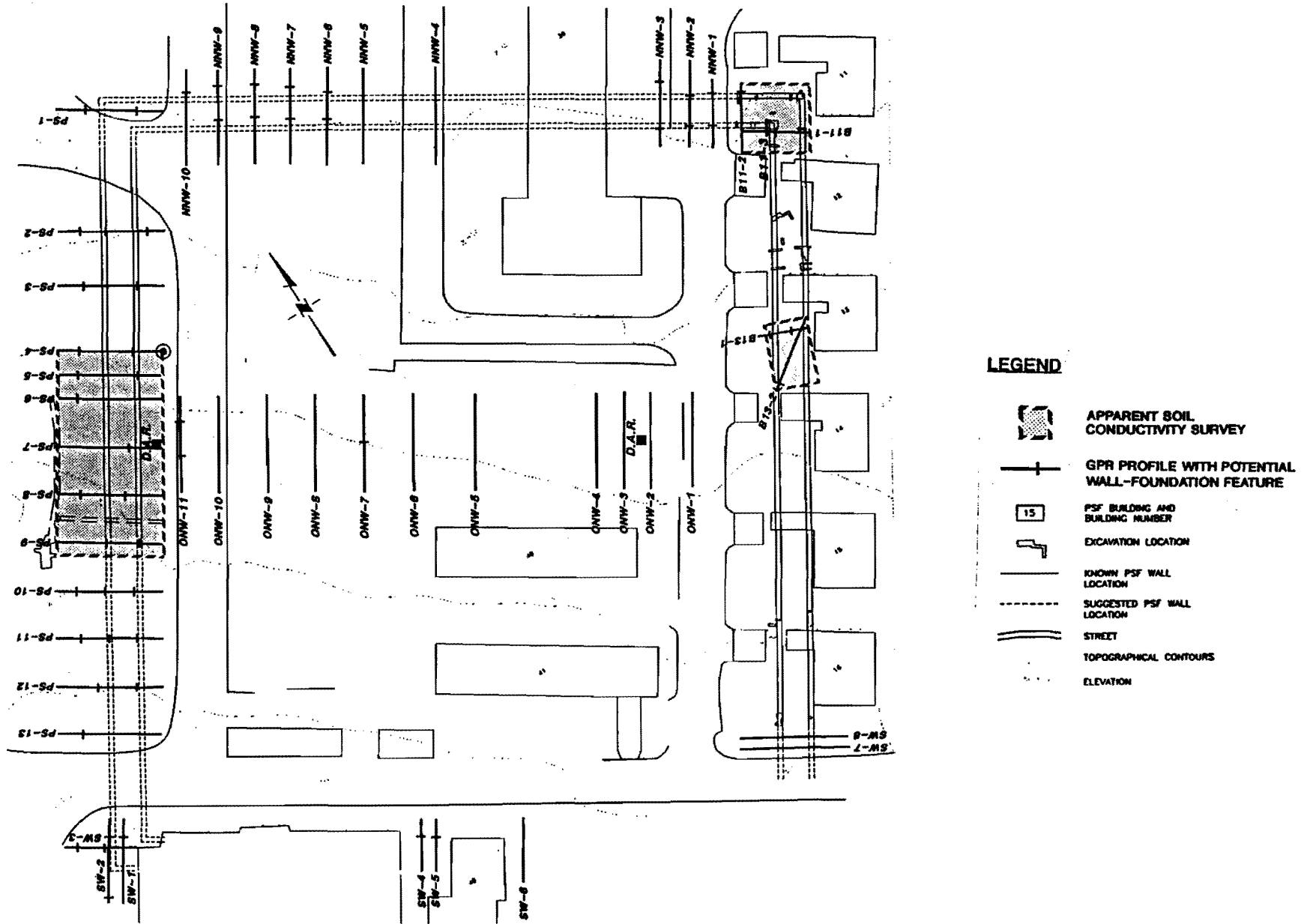


Figure 5. Location of Ground Penetrating Radar Soundings and Electromagnetic Soil Conductivity Mapping

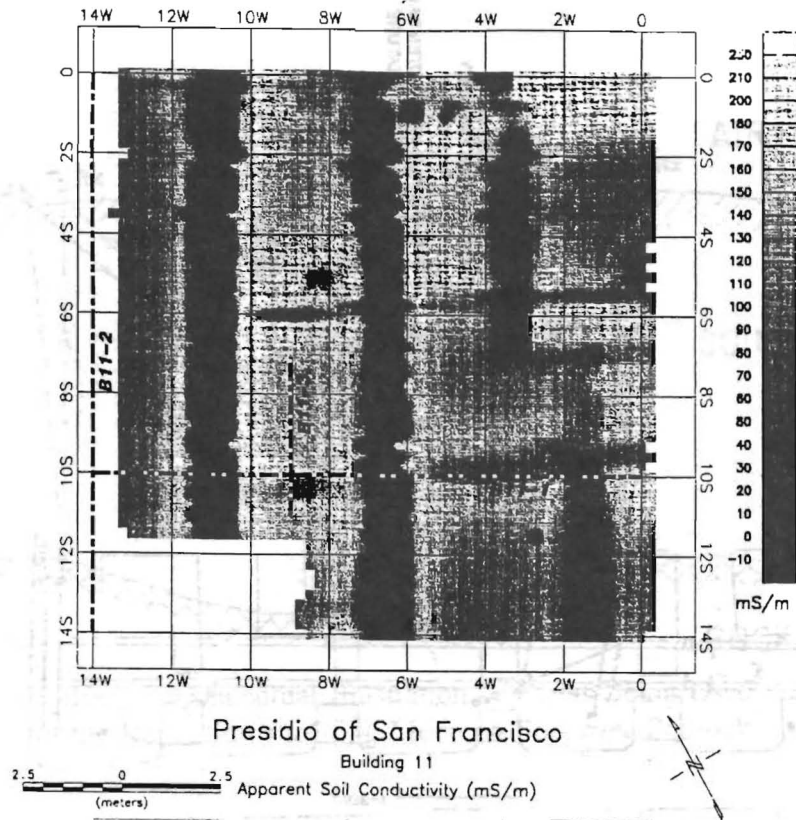


Figure 6. Building 11 Apparent Soil Conductivity

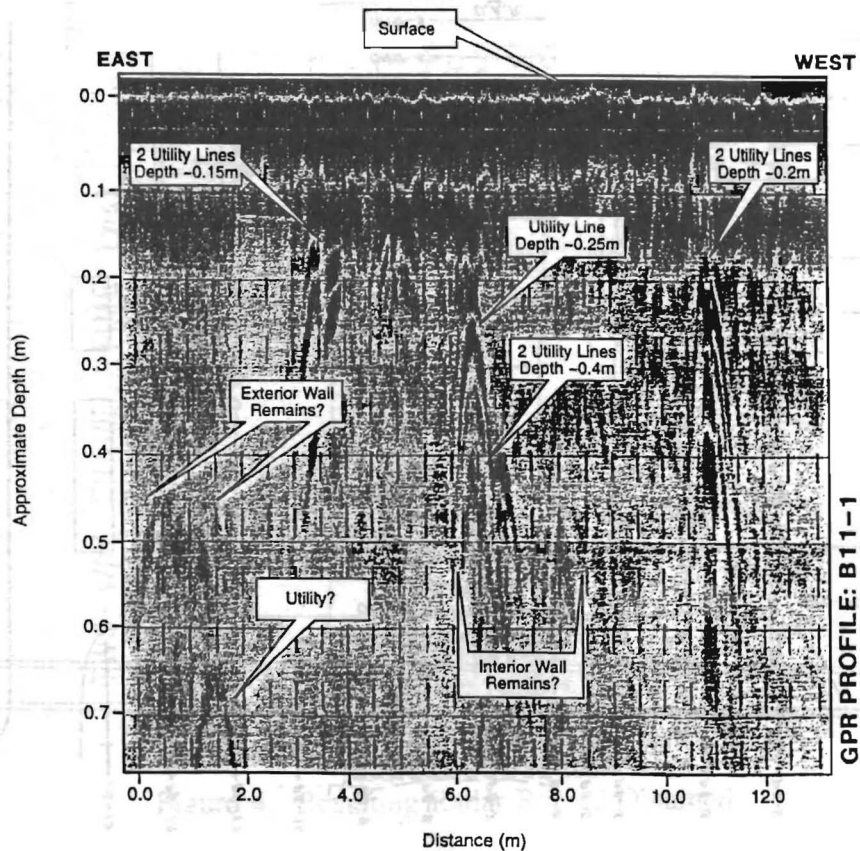


Figure 7. Building 11 Ground Penetrating Radar Sounding, Transect B11-1

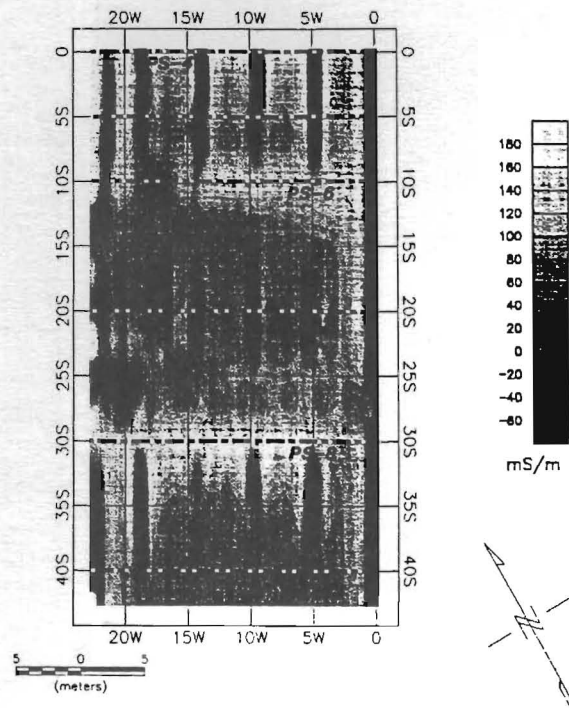


Figure 8. Pershing Square Apparent Soil Conductivity

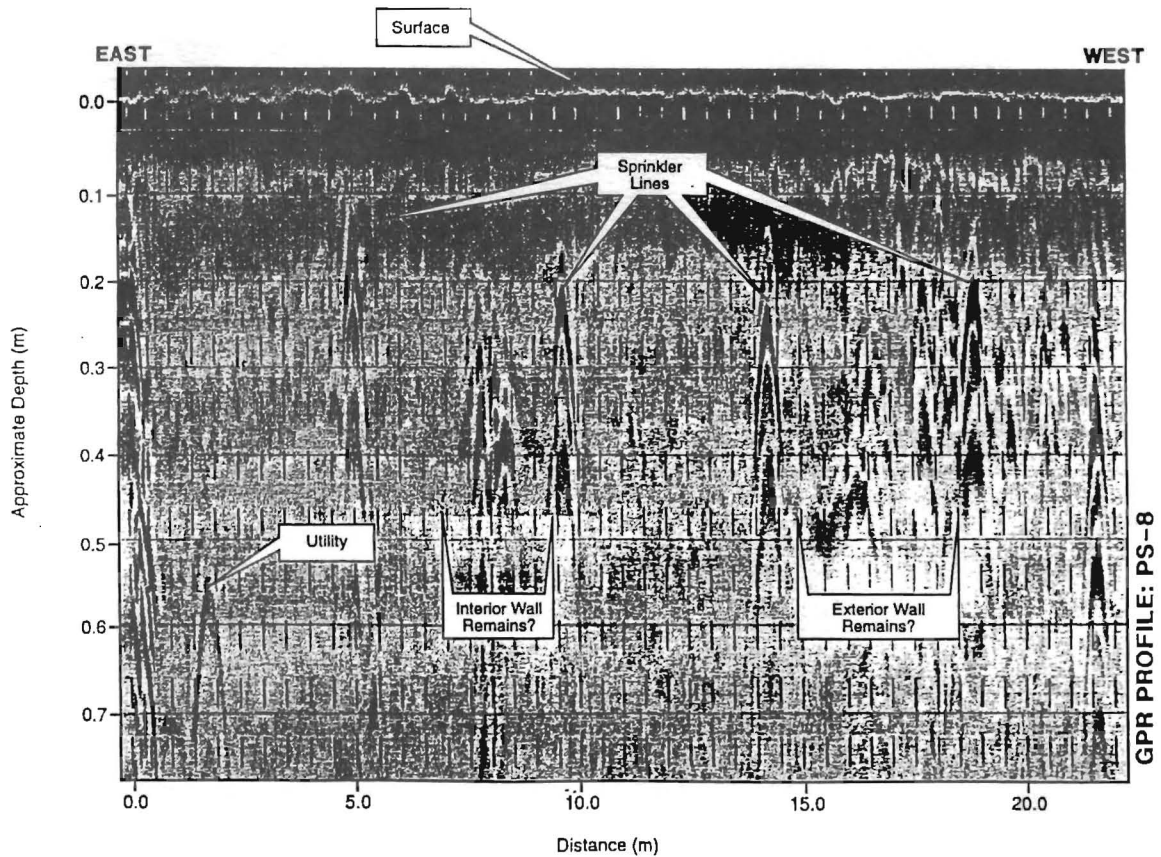


Figure 9. Pershing Square Ground Penetrating Radar Transect, Transect PS-8