CRREL REPORT 97-4

# Geophysical Investigations at a Buried Disposal Site on Fort Richardson, Alaska

Allan J. Delaney, Jeffrey C. Strasser, Daniel E. Lawson, Steven A. Arcone, and Edward B. Evenson

September 1997

**Abstract:** The Poleline Road Disposal Area, located on Fort Richardson, Alaska, was a U.S. Army dump in the early 1950s. In 1990 it was identified as an area potentially contaminated with volatile organic compounds. CRREL conducted extensive geophysical investigations that delineated anomalous responses in many areas of burial within glacial outwash deposits. Ground penetrating radar and electromagnetic induction surveys were used prior and subsequent to excavation. Geophysical data collected on a 5-m grid defined locations for several anomalous areas containing both dispersed and large, discrete targets. Radar defined anomalous areas by the concentration of strong diffractions. The induction survey differentiated metallic from nonmetallic contaminations. The interpreted maximum depth of debris was 4 m. Uncontaminated areas were generally defined by continuous, horizontal radar reflections, suggesting undisturbed or compacted soil horizons. The anomaly maps produced from these surveys guided an excavation that removed hazardous material. The removed material included munitions, mustard gas cylinders, medical waste, steel drums, and other trash. The radar and electromagnetic surveys were repeated using a more closely spaced grid to verify that the excavated areas were clean and to define more precisely anomalies in the areas not excavated. That survey shows many targets of potential or present contamination that should be removed.

**Cover:** Electromagnetic metal detector (inset) and high-frequency radar in action.

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September 1997

Prepared for
U.S. ARMY ALASKA
DIRECTORATE OF PUBLIC WORKS

## PREFACE

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## INTRODUCTION

The Poleline Road Disposal Area (PRDA) is an abandoned site containing buried hazardous materials and volatile organic compounds in proximity to multiple groundwater horizons. Extensive environmental investigations and remedial activities have followed their discovery. The PRDA, on Fort Richardson near Anchorage, Alaska (Fig. 1), is located in a low-lying wooded area, near the origin of Fossil Creek. The site is bounded on the west by two small hills of glacial deposits, on the south by a marsh, and on the north and east by hummocky terrain. Some earth material has been removed from the south-facing hill slope and may have been used as fill in the disposal area. A gravel road extending from Poleline Road crosses the center of the 300- × 500-ft (90- × 150-m) disturbed area.

In 1990 PRDA was identified by former military personnel, and information on materials and chemicals that may have been buried there was also provided. The list of probable buried items included solvents, smoke canisters, World War II vintage munitions, and kits for personnel identification of mustard gas. Some of the munitions were reportedly destroyed in trenches, while others may have been buried directly. A 1954 Army Post map also identified the area as a potential dump.

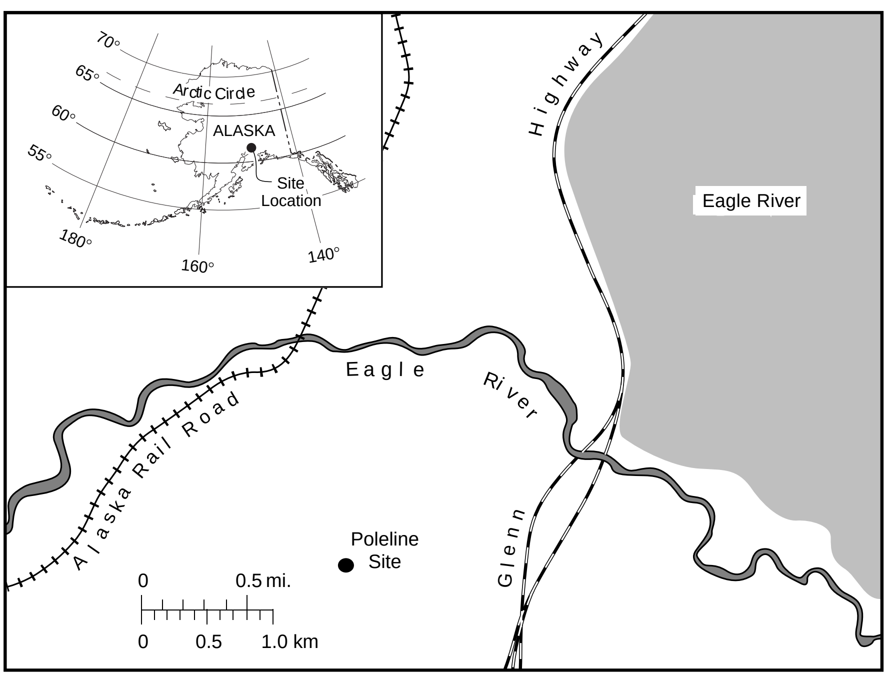



*Figure 1. Poleline Road Disposal Area located on Fort Richardson near the town of Eagle River, Alaska. The site is approximately 1.3 km west of the Glenn Highway.*

In 1990 the U.S. Army Toxic and Hazardous Materials Agency (USATHAMA, now the Army Environmental Center, AEC) contracted Environmental Science and Engineering, Inc. (ESE, Seattle, Washington) to conduct a preliminary site investigation, which included a surface geophysical survey (using electromagnetic conductivity, magnetic techniques, and ground-penetrating radar), installation of five wells to monitor groundwater contamination, and 10 shallow soil borings. The results indicated the presence of volatile organic compounds in the subsurface. A subsequent expanded site investigation, which included more soil borings, was undertaken to determine the extent of contamination (ESE 1991). A remedial plan was developed from the preliminary site investigation. In 1993 OHM Remedial Services excavated two trenches, unearthing mustard gas cylinders in an area where only mustard gas test kits were anticipated. Excavation was immediately halted and a more rigorous exploration effort begun.

In 1994, CRREL conducted Ground-Penetrating Radar (GPR) and ElectroMagnetic Induction (EMI) surveys of the primary area. The adjacent marsh, considered a potential disposal site, was also surveyed. That geophysical investigation identified four areas of distinct anomalies (Lawson et al. 1994). A map of the suspicious areas was created and the anomalies were interpreted as large excavations or multiple, closely spaced trenches. At some locations the GPR records showed evidence of a buried soil horizon, suggesting that these areas may have been covered by fill without significant prior excavation.

A 100-MHz GPR survey of the ice-covered marsh revealed only one area containing suspicious anomalies. These appeared to coincide with the water bottom at a depth of about 3 m. EMI found no significant conductive anomalies in the marsh area. Using the CRREL geophysical results, the Alaska District Survey Section produced a site map containing topography, the location of all survey line end-points, and detected anomalies.

In response to the 1994 CRREL survey results, the Directorate of Public Works at Fort Richardson requested that the U.S. Army Engineer District, Alaska, excavate some of the geophysical anomalies to remove buried debris from the PRDA. That request was further directed by the Rapid Response Section, U.S. Army Engineer District, Omaha, to OHM Remedial Services.

Following the excavation, CRREL returned to the PRDA. The primary objective was to check that the excavated areas were free of significant buried refuse. The secondary objective was to map, in greater detail, the anomalies that were not excavated. The preliminary geophysical investigations at PRDA have been discussed in contract reports (Lawson et al. 1994, Strasser et al. 1995) prepared directly for the Alaska District.

In this report, we compare the geophysical data with the record of hazardous material excavated from the mapped anomalies. We also discuss the data collected during the 1995 survey of the anomalies east of the baseline. The EMI survey of the main disposal area revealed multiple anomalies that directly correlated with the GPR results. The EMI survey aided interpretation of the GPR survey by confirming the general shape of the anomalous areas. Further, the metallic discrimination capability of the EMI aided the GPR in areas where multiple reflections from near-surface debris cluttered the GPR records.

## GEOLOGY

The surficial deposits at the Poleline Road Disposal Area are glacial sediments and tills of Quaternary age that have been reworked by flowing water. Rapid vertical and lateral facies changes attest to a complex, dynamic depositional environment, where groundwater horizons are not well defined (Schmoll and Dobrovolny 1972). The site lies within the Elmendorf Moraine complex and contains materials deposited by a large piedmont glacier that extended down the Knik Arm of Cook Inlet during the last major glaciation episode. The moraines are composed of a variety of marginal and proximal ice deposits, ranging from well-sorted gravels and sands to tills. Soil horizons often dip steeply and are laterally discontinuous. The uppermost 25 m consists of well sorted to silty or clayey gravels (Strasser et al. 1995). Sand lenses are typically several meters thick. Clay and silt lenses are more common at depth (ESE 1991). The monitor-well-drilling records confirmed the primarily poorly graded to clayey gravel that is characteristic in the upper 5 m. A shallow intermittent aquifer exists in the glacial deposits at a depth of between 5.5 and 10 m, while a deeper, more substantial aquifer is at the bedrock interface at a depth of approximately 35 to 40 m (ESE 1991).

## METHODS

### Ground-Penetrating Radar (GPR)

The GPR system used in the CRREL surveys consisted of the digital control unit (GSSI system 10+) and transducer (Fig. 2). This system is manufactured by Geophysical Survey Systems Incorporated (GSSI) of North Salem, New Hampshire. The radar control unit triggers pulses at a selected repetition rate (50 kHz for these investigations). The received radar signals are sampled in progressive time steps and converted to audio frequency scans for display and storage at a rate of 32 per second. The scans were stacked to improve signal quality and to reduce the amount of stored information. Each recorded scan can be displayed using an operator selected time-range to suppress the higher amplitude early returns (especially from the direct transducer coupling). This technique allows enhancement of the lower amplitude later signals that reflect at layer interfaces and material transitions. The technique is well known and is used extensively for shallow subsurface exploration (Morey 1974).

*Figure 2. GSSI ground-penetrating radar system, video display, 400-MHz transducer and cables.*

The radar antennas discussed in this report were 100- and 400-MHz shielded dipole pairs, which radiate pulses with 20- and 5-ns duration respectively. The antenna terminals connect directly to the transmitter and receiver electronics and an entire unit is called a transducer. When using the 400-MHz transducer, the signals were recorded for a time range of 100 ns. To search for deeper horizons, profiles were recorded with the 100-MHz transducer at a time range of 400 ns. The transducers were towed along the ground surface by hand or tracked vehicle (Fig. 3). Survey speed was approximately 1 m/s. This speed provided a profile data density of about 16 scans for each meter of transducer travel. The bottom of the transducer was maintained in close contact with the ground or snow surface to maximize signal transmission through the air/ground interface. The profile data were later filtered to remove noise and horizontally scaled between event markers to compensate for uneven towing speed.

GPR events within a profile consist of bands of reflections from continuous horizons and discrete hyperbolic diffractions that originate from individual targets and abrupt material transitions. The depth to a target is calculated from the apex of each hyperbola when the material dielectric permittivity, which determines the in-situ velocity, is known. Clusters of diffractions often point to a target of interest. However, this is not a foolproof interpretation because diffractions can originate from natural inclusions, such as large buried rocks. In addition, strong reflections can originate from continuous fine-grained soil layers that can contain more water than the surrounding materials. Also, horizontal scale compression can cause sloping subsurface horizons to appear artificially steep and this may be misinterpreted.

*Figure 3. 100-MHz radar antenna set in tow behind a tracked vehicle.*

All GPR profiles presented in this report show distance along the transect as the horizontal axis and the two-way travel time $t$, increasing with depth down the vertical axis. Travel time may be converted to depth $d$ according to

$$d = ct/2\sqrt{\varepsilon}$$

where $c$ = 30 cm/ns, the speed of radio waves in a vacuum, and $\varepsilon$ is the relative dielectric permittivity of the soil. The factor of 2 accounts for the round trip propagation of the pulse, to and from the reflecting surface.

The dielectric permittivity of soils within the PRDA was determined from the time–distance slope of hyperbolic diffraction asymptotes. Several permittivity determinations were made in March 1994 when the soils were frozen. Additional permittivity determinations were made in June 1995 when frost was absent and a layer of silty backfill covered the site. The mean frozen soil permittivity was 4.4. Five determinations of $\varepsilon$ in June 1995 gave a range of 5.4 to 7.4, with a mean of 6.8. All of these values are reasonable for both frozen and unfrozen silty sand and gravel of low moisture content (Arcone and Delaney 1985). With use of the mean $\varepsilon$ of 6.8, the time range settings for 100- and 400-MHz transducers provided an approximate depth range of 20.0 and 5.2 m, respectively, in these materials. The in-situ signal wavelengths are about 30 cm at 400 MHz and 1.2 m at 100 MHz. Accurate depth calibration of the radar records is difficult, however, owing to the local variability within these glacial deposits.

### Electromagnetic Induction (EMI) Technique

To complement the radar data and remove some of the ambiguity in interpretation, we used an EM61 electromagnetic unit manufactured by Geonics LTD, Mississauga, Ontario (Fig. 4). It is a time-domain metal detector that can operate in highly conductive settings where radar techniques fail. The unit consists of a backpack-mounted transmitter and coaxial coil antennas. The closely spaced antennas (vertical magnetic dipoles) are mounted on wheels and towed by the operator. In operation the primary magnetic field induces secondary currents in nearby metal objects, which in turn induce a secondary magnetic field that is sensed at the receiver. After pulsing the transmitter (the repetition rate is 75 Hz), the response from the ground generally decays in about 200 µs. The responses from metal may persist for 400–500 µs. These longer duration responses are detected in time and measured in millivolts (mV) of induced coupling. This high-sensitivity receiver can detect a drum-sized metal object at a depth of over 3 m beneath the antenna. Digital data for up to 10,000 stations are recorded on a hand-held datalogger.

EMI data recordings were controlled by the carriage survey wheel, resulting in approximately four readings per meter. Each data point was subsequently assigned an $X,Y$ location and the data were contoured for comparison with the radar profiles. The amplitude of the secondary field response can vary with the size, depth, and lateral proximity of the buried metal. The off-line responses can complicate interpretation and careful survey techniques are required. Readings between 100 and 1000 mV were considered moderate to strong anomalies, while readings greater that 1000 mV were considered very strong anomalies. Readings from nearby locations without disturbance gave background noise levels of approximately 10 mV. For these investigations, readings greater than 100 mV are considered potential targets, but any persistent deviation from background levels must be considered to signify the presence of metal.

*Figure 4. Geonics EM61 electromagnetic induction unit during a survey. The operator tows the antenna, while the backpack unit generates signals. Data are recorded on the hand-held datalogger.*

## MEASUREMENTS

The entire PRDA was surveyed using both GPR and EMI techniques in the late winter of 1994, when the site was covered by 30 to 50 cm of snow. The GPR transducers were towed behind a tracked vehicle and the EMI antenna was towed by hand along the same transect. Data were collected along transects 2.5 and 5 m apart in an east–west and north–south grid pattern. A CRREL baseline (Fig. 5) was arbitrarily established, extending south–southeast from a birch tree adjacent to the site access road, through monitoring well MW-5. Each transect end point was staked. Event markers on the radar profile correspond with the 5-m marks along each transect. The profiles were offset approximately 1.5 m north or east of the grid lines to avoid driving over stations marks. Most of the GPR surveys used the shorter pulse 400-MHz transducer because it provided greater vertical resolution than the 100-MHz transducer.

Upon completion of the 1994 field work, a level survey of the entire area was performed and all transect endpoints, intercepts, and additional marked stations were located. During the late summer of 1994, the mapped anomalies west of the CRREL baseline were excavated by OHM Remediation Services and all of the removed material was cataloged (OHM 1995).

Following those excavations, the entire PRDA was covered with a silty gravel fill and subsequently graded to a relatively smooth surface. This smooth surface facilitated acquiring geophysical data and improved transducer signal coupling into the ground in later surveys. However, in some locations, fill thickness exceeded 60 cm. Signal loss within this additional fill and reflection at its bottom interface resulted in lower pulse amplitudes reflected from deeper targets.

In June 1995, CRREL returned to acquire a second data set. During this survey, the transducers were towed by hand along this smoothed ground surface. The objectives of this second effort were to verify that all hazardous buried material west of the CRREL baseline had been removed and to refine the survey east of the baseline with a more closely spaced grid. The adjacent marsh south of the main study area was surveyed only in 1994, and as no significant anomalies were discovered (Lawson et al. 1994), there is no additional discussion provided.

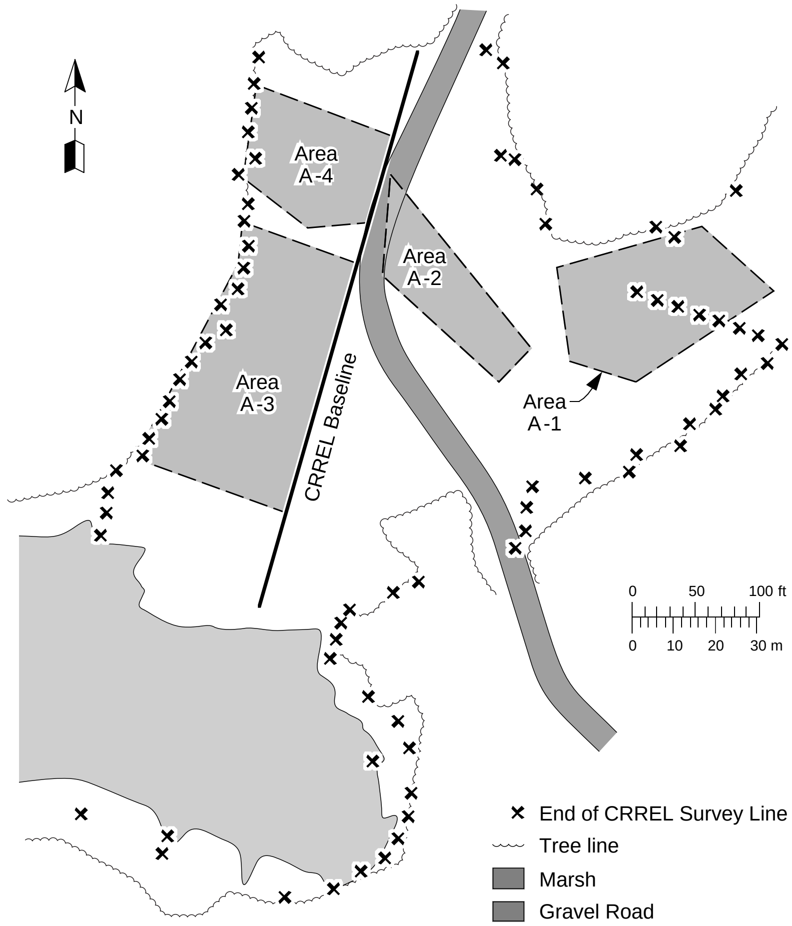



*Figure 5. Entire Poleline Road Disposal Area showing the CRREL baseline and the end points of CRREL transects (x's). The dashed lines define the extent of GPR anomalies identified from the 1994 investigations. (After Lawson et al. 1994.)*

## RESULTS

Each GPR profile in the disposal area was examined to define horizontal layering and the location of subsurface diffractions, which might indicate disturbance or the presence of buried objects, or both. These hyperbolic diffractions are important in attempting to identify areas in which larger metallic objects, such as cylindrical containers, may be buried. This analysis was done independently of the EMI data analysis.

### West of the baseline

The pre-excavation GPR profiles recorded along transects west of the baseline defined two large anomalous areas, A-3 and A-4. Those areas are delineated by the dashed lines on Figure 5. Profiles within these areas are characterized by multiple, strong hyperbolic diffractions and sloping

| Zone | Items |
|---|---|
| 1 | none |
| 1 | radiation dosimeter kit |
| | 1-glass vial with stopper |
| 1 | 1-empty CAIS unit |
| | large carbon filter canisters |
| | misc. scrap metal |
| 1 | 3-empty CAIS units, |
| | 2-full CAIS units |
| 2 | rusted drums |
| | wood DANC crate parts |
| 2/3 | none |
| 3/4/5 | 1-rusted drum |
| | 1-drum lid |
| 6 | large quantities of scrap metal and intact rusted drums |
| 6 | white phosphorus smoke grenade |
| 7 | 2-CAIS units, 1-full, 1-empty |
| | 1-lecture bottle |
| 7 | 1-8"×3" diameter amber bottle with 2 inches clear liquid |
| | large amounts of wood/debris inc. several rusted drums |
| | 2-rusted drums partially full with unknown molasses-type material |
| 3/7 | extremely large amounts of wood debris |
| 6/7 | 1-full, unopened case of HC smoke canisters several small vials of "Eye Decon Solution" |
| 7 | 9-full or partially full amber bottles labeled HD Toxic Gas Set M-1, and 5-empty unmarked clear bottles |
| | 1-larger 24-oz. amber bottle with small amount of clear liquid |
| | 2-artillery round fuses |
| 7 | 1-white phosphorus smoke grenade |
| | 100's of small medicine vials containing aureomycin, rabies serum, and gangrene serum |
| | 1-1 gallon size HC smoke pot |
| | large amounts of wood from smoke grenade crates |
| 7 | 300–400 medical vials |
| | 1-HC smoke grenade |
| 7 | 2-CAIS kits empty by X-ray |
| | 6-lecture bottles |
| 7 | large amounts of wood and crate parts |
| 7 | large amounts of wood and crate parts |

| Zone | Items |
|---|---|
| 9 | oily soil, oily pails, funnels, kits labeled "lewisite eye ointment" |
| 9/10 | oily cans and debris |
| | unbroken, sealed glass ampoule containing yellowish liquid 5/8 full |
| | flame thrower canisters and parts |
| | atropine injection kits |
| 9 | 1-bakelite CS grenade, empty |
| | 1-warhead from a bazooka rocket |
| | 1-artillery round fuse |
| 10 | 3-empty drums |
| | 4-smoke grenade fuses |
| | 2-HC smoke grenades |
| 10 | 9-M51 type artillery round fuses |
| | 1-small bottle marked CN |
| | 1-76 mm artillery round warhead |
| 10 | 1-smoke grenade 4-M51 fuses |
| | 3-nose fuses, 1-HC smoke pot |
| | 8-intact rifle grenades |
| | 2-empty 105 mm casings |
| | 16-rifle grenade tail booms |
| | 27-aluminum grenade bodies |
| | 1-fire starter, 2-empty 75 mm casings |
| | 4-flame thrower canisters |
| 10 | 22-M51 fuses |
| | 85-rifle smoke grenades |
| | 1-HC smoke grenade |
| 10 | 1-HC smoke pot, 8-M51 type fuses |
| | 1-M18 smoke grenades, 1-rifle grenade fuse |
| | 2-105 MM artillery rounds with HE |
| | 1-nose fuse |
| | several-CN Id set bottles |
| 10 | scrap metal, rusted buckets and cans |
| 10 | scrap metal |
| | 3-emtpy 105 mm casings |
| 10 | 1-1/2 gallon intact amber jar |
| | 5-flame thrower canisters |
| | 2-lecture bottles |
| | 5-empty 55 gallon drums |
| | misc. metal debris |
| 10 | 6-flame thrower canisters |
| | 2-lecture bottles |
| | 5-cubic yards of scrap metal |
| | 1-small white jar with unknown white powder |
| 10 | 2-HC smoke grenades |
| | 1-empty 105 mm round |
| | 1-empty 75 mm round |
| | 1-8 oz. small jar with unknown white material |

| Zone | Items |
|---|---|
| 4 | 1-5 gallon pail with water-reactive granular solid that reacts with moisture in air |
| 2 (hill-side) | 2-M60 machine gun belts with unfired blanks |
| | scrap metal and respirator cartridges |
| | 2-tail fins for 250 or 500 lb bombs |
| | 1-broken glass jar with poison markings |
| | 1-white phosphorus grenade |
| | 24-small bottles marked HCL |
| | 1-wood crate marked "hydride charge" |
| | 1000's of old mustard and lewisite detector kit tubes, predecessors to the M-18 kit |

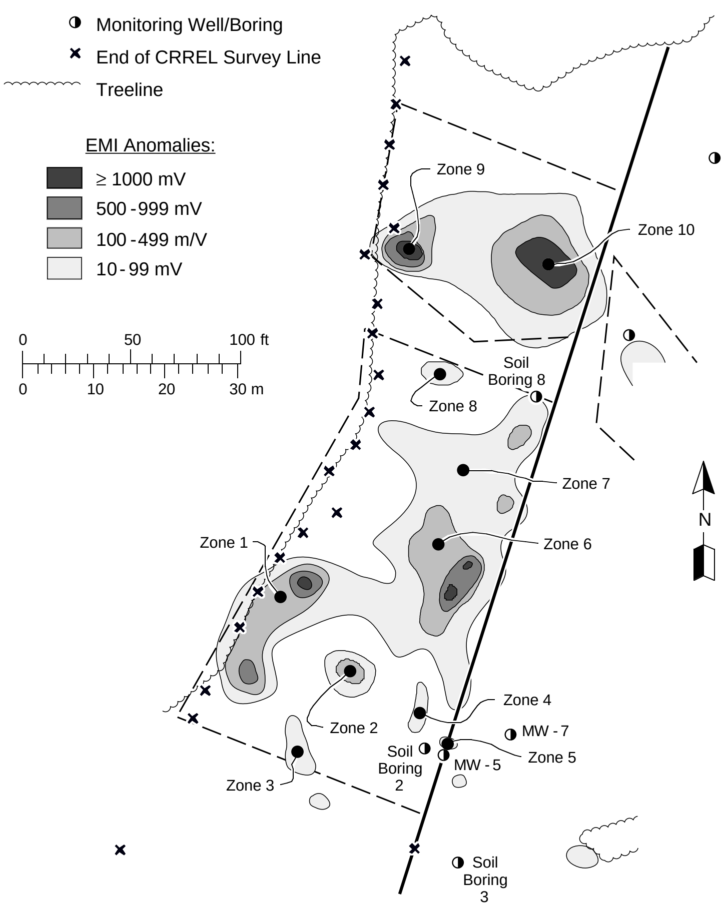



*Figure 6. EMI and GPR anomalies west of the CRREL baseline (areas A-3 and A-4) and a complete catalog of excavated material removed from those sites during the 1994 excavations. CRREL survey lines run from northwest to southeast. (After OHM 1995.)*

horizons that ranged from 1 to over 4 m depth. The difference in depth, shape, and intensity of the hyperbolic returns suggested that different types of materials were buried in different parts of and at different depths in this excavation (Lawson et al. 1994). Zones of intense and uniform hyperbolic diffractions were interpreted as individually stacked and horizontally positioned cylindrical objects, particularly when these diffractions appeared on parallel transects. The reflections from scattered targets were more difficult to interpret and could originate from large boulders or other buried debris. We interpreted the linear trends (in diffractions) as trenches with multiple buried objects.

The EMI data were recorded along each transect to verify the location of metallic targets. These data were then contoured according to the strength of the readings relative to the general level of the background noise. Contours of 100, 500 and 1000 mV correspond with and refine the interpretation of the radar data (Fig. 6).

The excavation of anomalous areas (A-3 and A-4) resulted in the removal and cataloging of a huge volume of material (Fig. 6). Items recovered, which were presumably buried during the 1950s, included: 55-gal. (208-L) drums, miscellaneous metal containers, wooden crates, scrap metal, glass vials and bottles, exploded and unexploded ordnance, chemical agent test kits, and steel cylinders containing chemical agents. The record of excavation and careful cataloging of debris allows comparison of our pre-excavation survey interpretation with the actual targets. The post-excavation survey was conducted to verify the performance of the excavation contractor.

The geophysical data recorded along two transects (before and after excavation) are shown in Figures 7 and 8, which compare records of GPR reflectors and diffractions with the plotted EMI response.

Figure 7 shows GPR and EMI data recorded along transect 02. The pre-excavation profiles (top and middle) show two large areas of disturbance starting at about 1–2 m depth. Many hyperbolic diffractions extend both to the surface and to a sloping subsurface horizon. These events are interpreted as metallic, because of their relatively high amplitude, the presence of diffractions, and the polarity of the reflections, which indicate a high dielectric permittivity (which can also be associated with high conductivity). The pre-excavation EMI profile con-

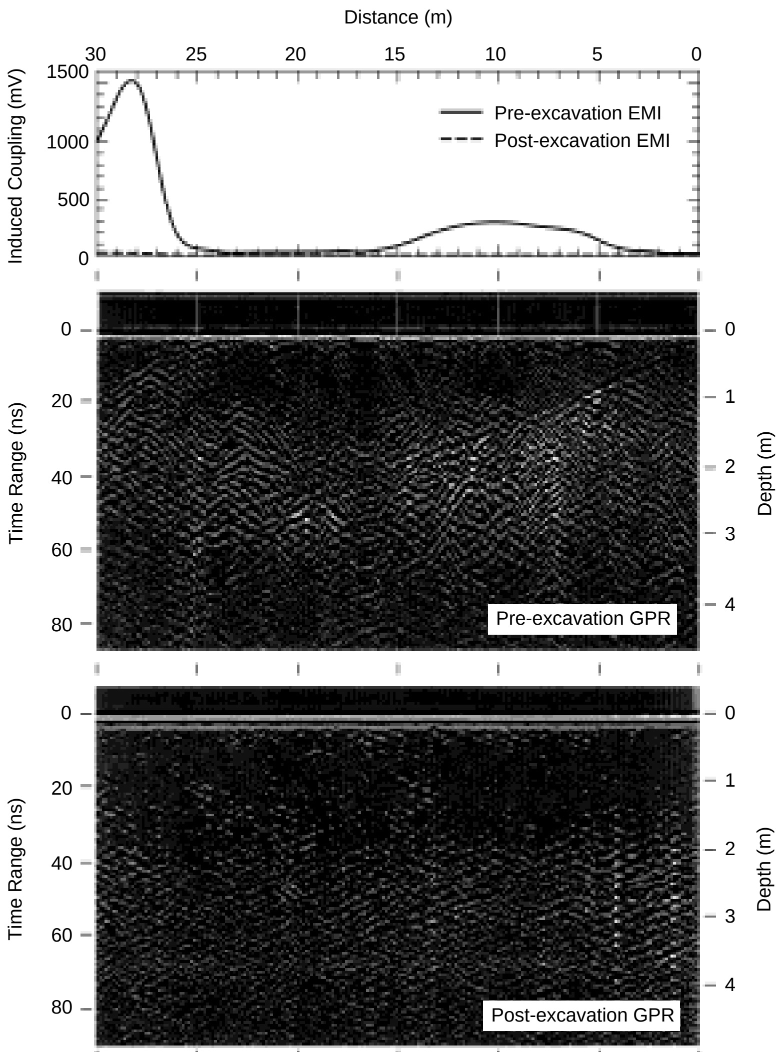



*Figure 7. Profiles recorded along transect 02 (area A-4) with GPR and EMI. The data were recorded before (1994) and after (1995) excavation. The excavation, based on the 1994 survey results, revealed 5 yd$^3$ ($3\frac{1}{2}$ m$^3$) of scrap metal and other debris near the broad, low amplitude anomaly. Several 5-gal. (19-L) pails, funnels, and oil-contaminated soil areas were revealed near the sharp anomaly at station 28 m.*

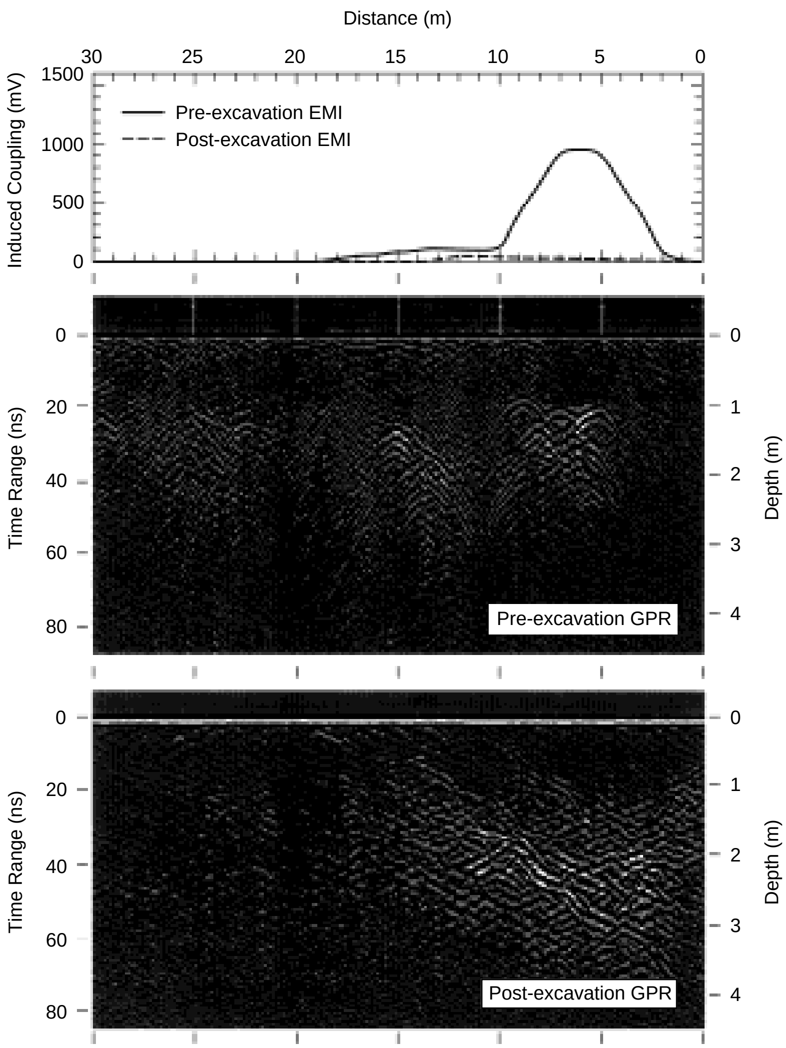



*Figure 8. Profiles recorded along transect 11 (area A-3) with GPR and EMI. The excavation revealed fifty 55-gal. (208-L) steel barrels in the area distinguished by the broad EMI anomaly and the distinct GPR hyperbolic reflections.*

firms this interpretation, showing a narrow high-amplitude anomaly and a broad, low-amplitude anomaly. The narrow anomaly denotes shallow burial of metallic items, while the broad anomaly evidences a more substantial target that is buried deeper. The excavation resulted in removal of more than 5 yd$^3$ ($3\frac{1}{2}$ m$^3$) of scrap metal, 55-gal. (208-L) drums, and other debris from the zone beneath the broad anomaly. Material recovered from the zone beneath the narrow anomaly included 5-gal. (19-L) pails, metal funnels, and contaminated soil. The GPR profile recorded after excavation and backfill is also shown in Figure 7. The lack of any sustained reflections in this profile means that all debris was removed. The post-excavation EMI plot (top, Fig. 7) confirms this.

Figure 8 shows GPR and EMI data recorded along transect 11. The pre-excavation profiles (top and middle) show a highly disturbed area that includes intense diffractions with nearly symmetrical hyperbolas. These diffractions were interpreted as metallic, cylindrical objects because of the strong secondary diffractions generated beneath them (Lawson et al. 1994). Secondary diffractions are characteristic responses from the intersection between closely spaced cylinders. Similar diffractions occur on several adjacent profiles, indicating the presence of substantial amounts of buried metal. The pre-excavation EMI plot of a broad, high-amplitude anomaly confirms the presence of metallic objects along a 15-m segment of this transect. More than fifty 55-gal. steel barrels were removed from this zone. Many of the barrels were intact, which probably contributed to the symmetrical GPR anomalies. The post-excavation GPR profile (bottom) still shows some artifacts where the hyperbolas were previously located. This could point to some small amount of metal remaining off-line; however, the post-excavation EMI survey revealed no substantial anomaly. The sloping GPR horizon seen on the post-excavation profile may be a soil horizon compacted by the excavation process or it may be an old soil horizon previously obscured by the diffractions from the drums.

The results of the post-excavation GPR profiles are summarized in Figure 9. The contoured area corresponds to anomalies at a depth of 1 to 4 m. Profiles recorded on transects 000 through 03 showed no detectable horizons. Most of the area within these transects was excavated in 1994, and we attribute the lack of strong returns in the GPR data to signal attenuation in the silty gravels used as backfill. The remainder of the profiles (04–21) showed a zone with few or no signal returns near the top of the record, which also probably resulted from signal attenuation in the silty fill

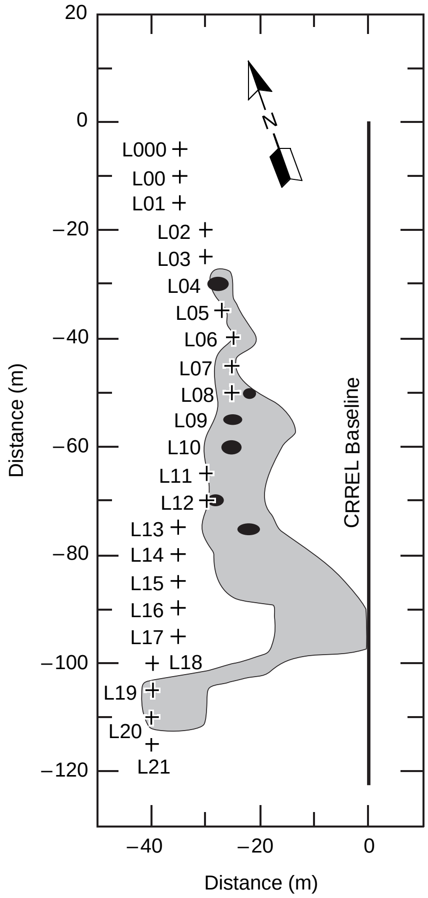



*Figure 9. Anomalous zones west of the CRREL baseline as interpreted from the June 1995 survey. It is likely that this zone represents reflections from large boulders within the sands and gravels (transects are numbered L000 to L21).*

material. Several of the profiles show dramatically the interruption of horizons and scattered returns resulting from the 1994 excavations and backfilling (Fig. 10). Profiles from transects 09–13 also lack returns to 5 m depth in an area that extended from the baseline to about 15 m west of it. West of 15–17 m, each one of these profiles exhibits sloping horizons and diffractions at depths of from 1 to 3.5 m.

Several of the EMI anomalies mapped prior to excavation (Fig. 6) exceeded 1000 mV in amplitude. After excavation, the 1995 EMI survey revealed no significant anomalies in this area and amplitudes at all stations were less than 100 mV. Levels between 40 and 90 mV, at the east end of transects 14 and 15, probably resulted from the steel casing around monitoring well MW-5. This anomaly graded into a broad, low amplitude response several meters towards the west, which we interpret to be a relatively small amount of refuse buried adjacent to the monitoring well. Two broad, low-amplitude anomalies on transects 16 and 17, between approximately 20 and 25 m west of the baseline, suggest buried material. The remaining low-amplitude, narrow anomalies scattered across the area probably originate from small surface or near-surface trash (e.g., bolts and scraps of steel banding). Since the amplitude of the EMI anomalies is low and their positions do not coincide with the GPR anomalies, it is likely that the remaining GPR anomalies result from inhomogeneous geological materials (e.g., large boulders within gravels and sands, typical of such glacial deposits).

**East of the baseline**

Our objective in the 1995 investigation was to define more precisely the location, extent, and depth to targets east of the baseline, which were not excavated. During the 1994 investigations, GPR and EMI data were collected on a 5-m grid while the site was snow covered. The 1995 data were recorded on a 2.5-m grid and we focused on two suspect areas delineated by previous investigations. The transects retain the numbering used during the 1994 survey, and those with an “A” extension were located between existing transects. The EMI and GPR data gathered in 1995 are considered superior in quality and accuracy to those gathered in 1994; therefore, only the 1995 results are discussed.

The results of the EMI survey are shown in contour maps in Figure 11. The two maps are derived from the same data set but are contoured at different intervals. The bottom map in Figure 11 locates low-amplitude EMI anomalies while the top map locates higher amplitude ones. Areas of intense EMI anomalies (more than 200 mV) compare favorably with the 1994 data, although the amplitude of the 1995 readings is lower because of the addition of 0.5 to 1.0 m of silty fill. Two specific areas of intense EMI anomalies, identified as T-1 and T-2, were marked in the field for location by a survey crew.

GPR data were collected using both the 100- and 400-MHz transducers. The 400-MHz data were recorded on every transect within the defined areas of interest, and the 100-MHz data were recorded on selected transects. Additionally, 400-MHz profiles were recorded on three transects parallel to the long north–east axis of area T-1,

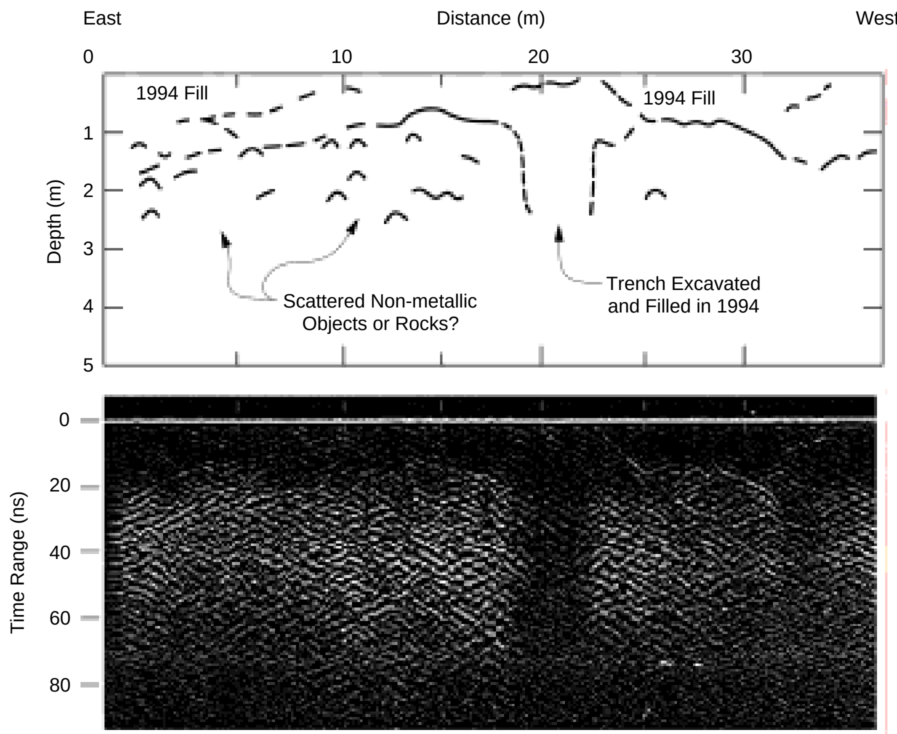



*Figure 10. 400-MHz GPR profile recorded along transect 16 in June of 1995. A reflection from the original ground surface (before fill) is clearly visible from stations 24 to 35 m. Signal attenuation resulting from trench excavation and fill is apparent near station 20 m.*

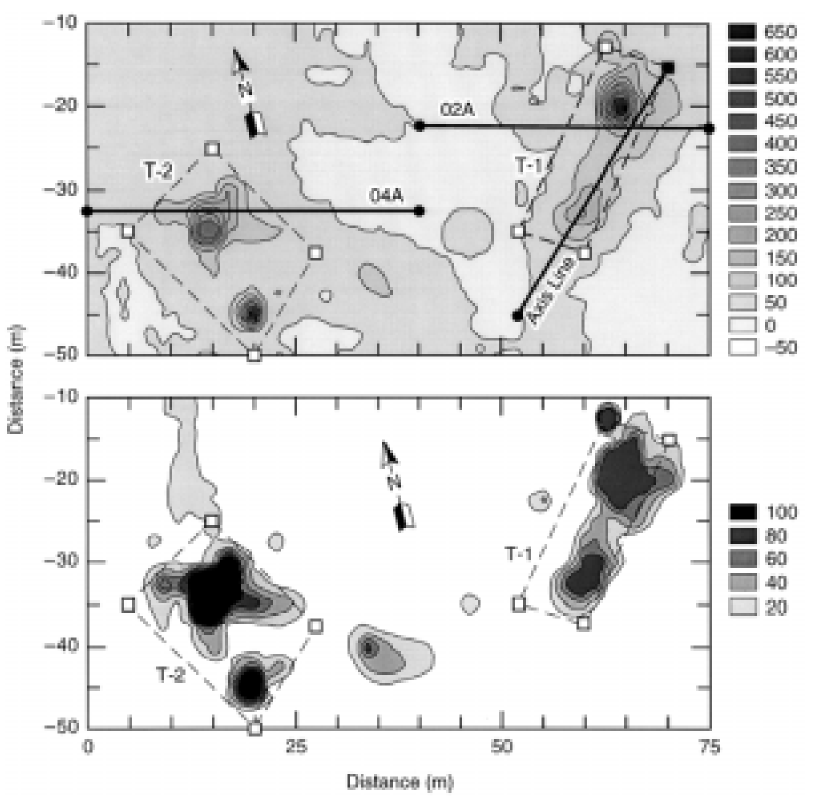


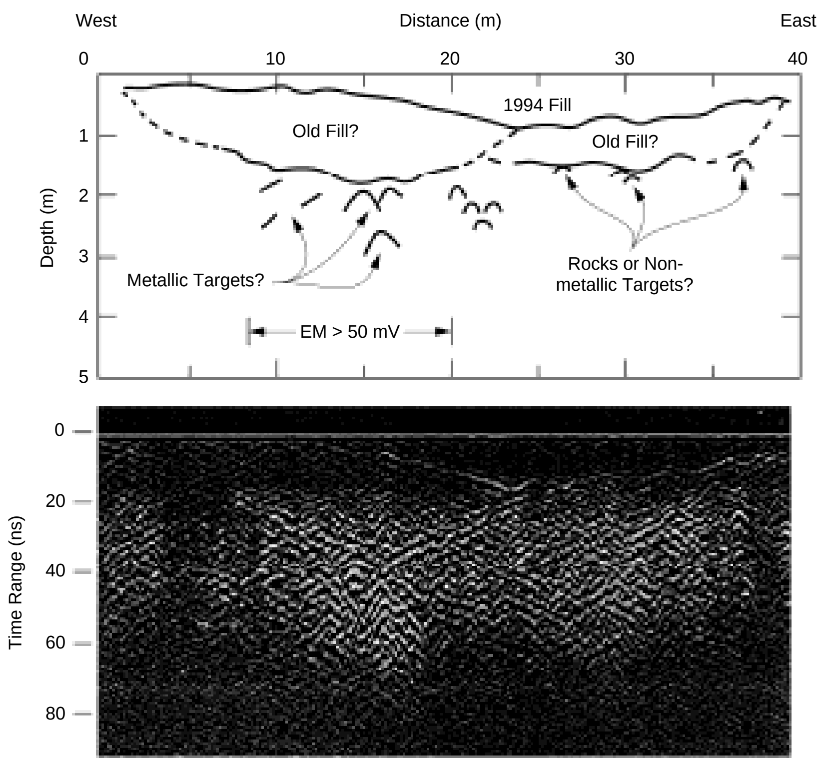

*Figure 11. Contoured maps of the EMI anomalies in the area of T-1 and T-2 east of the CRREL baseline. The heavy black lines show the locations of GPR profiles and interpretative cross-sections. Top—0–700 mV (contour interval = 50 mV); bottom—20–120 mV (contour interval =20 mV).*

and one additional profile extended into wooded terrain on both sides of the cleared area.

Two 400-MHz GPR profiles and interpretive cross-sections, representative of most of the data, are presented in Figure 12. Many of the GPR profiles from the areas east of the baseline exhibit one or two irregular horizons. The uppermost horizon represents the land surface prior to filling and grading in 1994. A second, deeper horizon exists on some profiles and may be either a buried soil horizon that existed before burial activities in the 1950s or the base of former excavations. Zones of intense (high-amplitude) diffractions are present within areas T-1 and T-2 where EMI anomalies are mapped. The areal extent of the radar anomalies exceeds the mapped EMI features, suggesting burial of nonmetallic debris or small metal items that are too deep for detection with the EM-61.

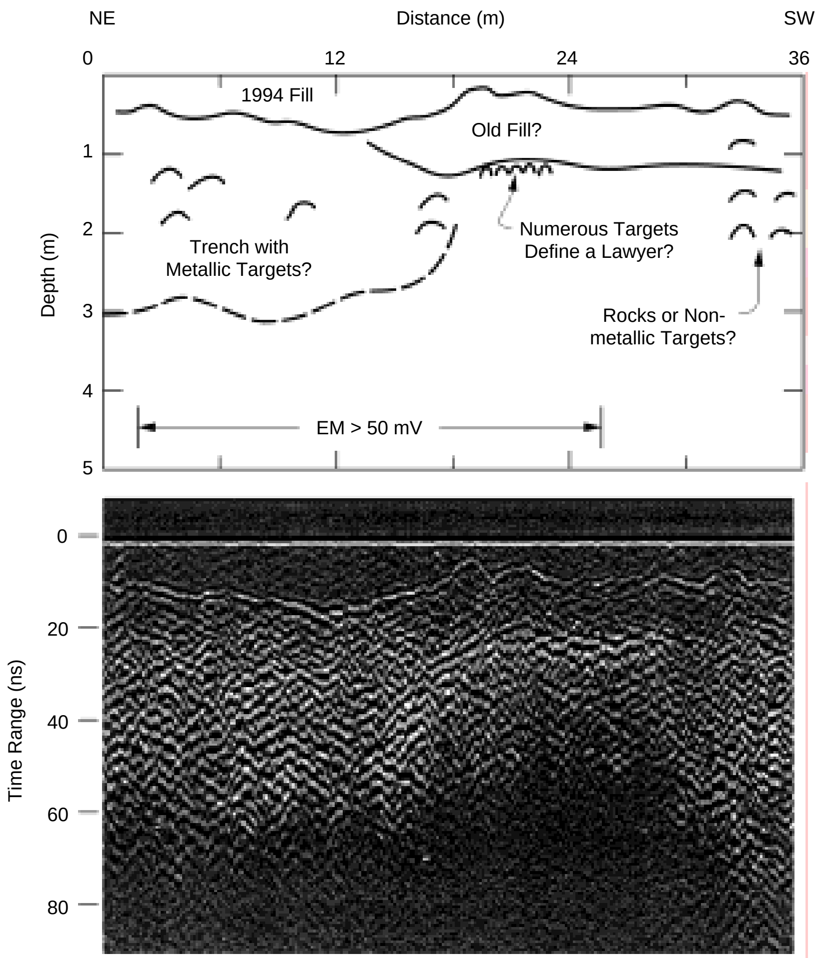
The profile in Figure 12a was recorded along transect 04A and crosses area T-2, extending east from the CRREL baseline for 40 m (Fig. 11). The uppermost subsurface horizon, between the depths of 0.25 and 1.0 m, represents the ground surface prior to backfilling in 1994. Reflections below this horizon, from 0.25- to 2.0-m depths, may be an older buried fill or a former ground surface. Numerous hyperbolic returns below this second surface likely represent large objects that are from 1.5 to 3.0 m deep. The portion along this transect where EMI anomalies exceed 50 mV is shown in the schematic section and GPR diffractions within this zone are consequently labeled as originating from metal objects; other diffractions presumably result from rocks or nonmetallic objects.

The profile in Figure 12b was recorded along a transect traversing northeast–southweast along the axis of area T-1 (Fig. 11). Event marks along the horizontal axis correspond to line intercepts and are thus spaced approximately 6 m apart. Numerous diffractions appear between 0 and 18 m distance below the horizon, representing the 1994 ground surface. The lower limit of these returns lies at approximately 3 m depth. A zone of near-horizontal reflections at approximately 1.2 m depth between 18 and 36 m distance may represent a layer of buried debris, or possibly an abrupt increase in water content (associated with an horizon of fine grain soil). Small diffractions below this horizon are visible to about 2.5 m depth. The portion along this transect where EMI anoma-




*a. Transect 4A recorded in June 1995.*

*Figure 12. 400-MHz GPR profile and interpretative depth sections.*




*b. Recorded along the axis of a suspected trench in area T-1.*

*Figure 12 (cont'd). 400-MHz GPR profile and interpretative depth sections.*

lies exceed 50 mV is shown in the schematic, and GPR diffractions within this zone are thought to originate from metal objects.

Nearly all of the 400-MHz GPR profile data recorded in area T-1 show evidence of a second, deeper subsurface horizon. In many instances this reflection can be followed to intercept with the base of the 1994 fill section. This horizon may represent a former ground surface that was excavated for burial of refuse and then subsequently filled (labeled on Fig. 12 as "old fill"). The EMI anomalies typically fall within the areal limits of the deeper, older horizon. This suggests that refuse was buried in wide, tapered depressions that might allow easy access. Nonmetallic GPR anomalies adjacent to the prominent induction (metallic) anomalies might represent miscellaneous fill material with little metallic content (crates, building materials, concrete, etc.). Alternatively, the nonmetallic GPR anomalies may result from the complex geology, in which case the metallic refuse is indeed confined to narrow trenches.

The areal extent of significant GPR anomalies is presented in Figure 13. Also plotted on this figure are estimated depths to specific targets as determined from the high-amplitude hyperbolic diffractions on the GPR profiles. These targets represent significant items, particularly the ones that lie within the limits of the strong EMI anomalies. All targets are interpreted to be less than 2.6 m deep.

Some additional isolated EMI anomalies exist at the site, most of which are minor (less than 100 mV) and probably result from small pieces of metal near the surface. At the time of this writing, none of the anomalous areas east of the baseline have been excavated.

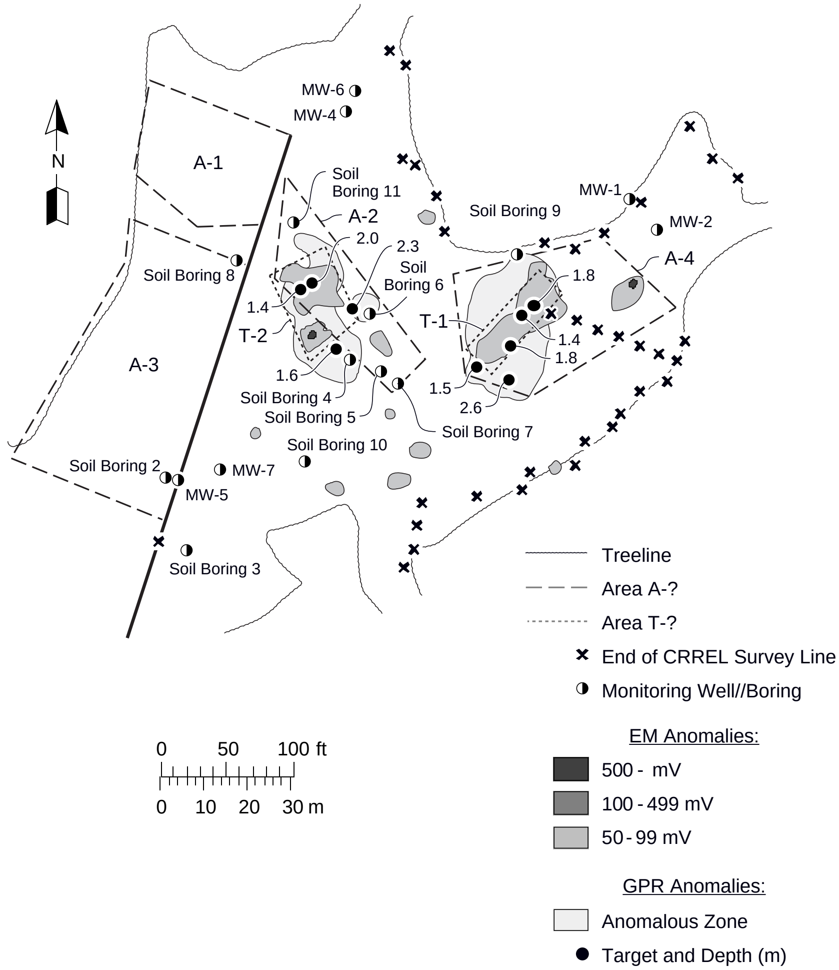



*Figure 13. EMI and GPR anomalies east of the CRREL baseline as compiled from data recorded in June 1995. Interpreted depths to targets are in meters below the existing ground surface. CRREL survey lines run from northwest to southeast.*

## CONCLUSIONS

The 1994 investigations showed that the PRDA contains four large areas within which geophysical methods clearly point to the presence of metallic objects and other buried debris. The variability in their intensity, depth, and location, and the clustering of these anomalies, suggested that both trenches (areas A-3 and A-4) and single or closely spaced excavations (areas A-2 and A-1) were used for burial. Anomalous horizons in each area begin at a depth estimated at 1 to 1.5 m below the surface and extend to a depth of over 4 m. A linear concentration of strong hyperbolic diffractions within area A-3 suggested a trench of about 50 m in length containing stacked cylindrical objects. Excavation of the A-3 area confirmed this interpretation. Prior to backfill and leveling of the entire PRDA, areas A-1 and A-2 both had raised surfaces, which indicated that each was filled above the original ground surface.

GPR and EMI investigations in June 1995 show that the 1994 excavations by OHM successfully removed all major metallic objects. The few scattered, minor EMI anomalies that remained are most likely attributable to the presence of small near-surface metallic debris. The remaining, small GPR anomalies and suspicious zones not correlated with the EMI targets probably reflect the complex geology. The fill material used subsequent to the 1994 excavations is easily delineated with GPR because it contrasts markedly with the original ground surface.

Comparisons between the 1994 and 1995 GPR records show that all major anomalies previously identified are absent in the 1995 data. This means that all foreign material has most likely been removed. The lack of significant EMI anomalies corroborates this conclusion.

The 1995 investigations east of the baseline further define the depth to and extent of the anomalous areas T-1 and T-2. Both areas contain high-amplitude EMI anomalies that we interpret to be significant concentrations of metallic debris. In addition, the EMI survey indicates scattered, small, near-surface objects across the entire site. The GPR profiles tell us that targets lie approximately 1.5 to 3.0 m below the surface and that some of these targets are presumably large (e.g., the size of a 55-gal. drum). A broad GPR horizon, present on most profiles, may represent a former ground surface, buried after debris disposal. This surface may have been the floor of broad pits within which metallic materials were concentrated. Alternatively, this surface may have been the natural ground surface onto which material was dumped and covered. An intense and continuous GPR horizon in the T-1 area suggests trench burial techniques. There are no current plans for further removal of this buried debris from PRDA**.**

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13. ABSTRACT (*Maximum 200 words*)

The Poleline Road Disposal Area, located on Fort Richardson, Alaska, was a U.S. Army dump in the early 1950s. In 1990 it was identified as an area potentially contaminated with volatile organic compounds. CRREL conducted extensive geophysical investigations that delineated anomalous responses in many areas of burial within glacial outwash deposits. Ground penetrating radar and electromagnetic induction surveys were used prior and subsequent to excavation. Geophysical data collected on a 5-m grid defined locations for several anomalous areas containing both dispersed and large, discrete targets. Radar defined anomalous areas by the concentration of strong diffractions. The induction survey differentiated metallic from nonmetallic contaminations. The interpreted maximum depth of debris was 4 m. Uncontaminated areas were generally defined by continuous, horizontal radar reflections, suggesting undisturbed or compacted soil horizons. The anomaly maps produced from these surveys guided an excavation that removed hazardous material. The removed material included munitions, mustard gas cylinders, medical waste, steel drums, and other trash. The radar and electromagnetic surveys were repeated using a more closely spaced grid to verify that the excavated areas were clean and to define more precisely anomalies in the areas not excavated. That survey shows many targets of potential or present contamination that should be removed.

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