FINAL SUBMITTAL

GEOPHYSICAL SITE INVESTIGATION FAMILY HOUSING REPLACEMENT TAKU SITES (FTW251 & FTW283)

FORT WAINWRIGHT, ALASKA

CONTRACT NO. DACA85-02-D-0010
DELIVERY ORDER NO. 0018

Prepared For:

U.S. ARMY ENGINEER DISTRICT, ALASKA
P.O. Box 6898
Elmendorf AFB, Alaska 99506-6898

July, 2004

R&M CONSULTANTS, INC.

R&M CONSULTANTS, INC.
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July 30, 2004

R&M No. 041466

Mr. Chuck Wilson, CEPOA-EN-ES-SG
U.S. Army Engineer District, Alaska
P.O. Box 6898
Elmendorf AFB, AK 99506-0898

RE: Geophysical Site Investigation
Family Housing Replacement
Taku Sites (FTW251 & FTW283)
Fort Wainwright, Alaska
Contract No. DACA85-02-D-0010, Task Order No. 0018

Dear Mr. Wilson:

Enclosed please find our final geophysical site investigation report performed for the above referenced project. This work has been completed in accordance with Contract No. DACA85-02-D-0010, Task Order No. 0018.

We have enjoyed the opportunity to participate with you on this project. Should you have any questions or desire additional information, please do not hesitate to call.

Very truly yours,

R&M CONSULTANTS, INC.

Charles H. Riddle, C.P.G.
Vice President

CHR:slv

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Prepared For:

U.S. ARMY ENGINEER DISTRICT, ALASKA
P.O. Box 6898
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Attention:
Mr. Chuck Wilson
CEPOA-EN-ES-SG

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July, 2004

GEOPHYSICAL SITE INVESTIGATION FAMILY HOUSING REPLACEMENT TAKU SITES (FTW251 & FTW283)

FORT WAINWRIGHT, ALASKA

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GEOPHYSICAL SITE INVESTIGATION
FAMILY HOUSING REPLACEMENT
TAKU SITES (FTW251 & FTW283)

FORT WAINWRIGHT, ALASKA

1.0 INTRODUCTION

R&M Consultants, Inc. (R&M) and Northwest Geophysical Associates, Inc. (NGA) conducted a geophysical site investigation for the Family Housing Replacement, Taku Sites (FTW251 and FTW283) project at Fort Wainwright, Alaska. Figure 1 shows the location of the site on Fort Wainwright, immediately east of Fairbanks, Alaska.

As set forth in the Scope-of-Work:

> "During the drilling program, metal items were encountered in (boring) AP-8980, at a depth of 2.50 meters and other debris was reported to be present in the site. Metal debris was also discovered in recent clearing work at the northeast portion of the project site. The purpose of the geophysical survey is to locate and identify to the extent possible the presence of subsurface anomalies indicating buried materials."

Hence, the geophysical survey was designed to detect buried debris or construction waste which may remain on the site from former activities.

The geophysical investigation included both an electromagnetic (EM) survey utilizing the Geonics EM31 terrain conductivity meter and a magnetic (MAG) survey utilizing a Geometrics G858G magnetometer/gradiometer. Basic principles of these techniques are described in Appendix B, Geophysical Detection of Buried Objects.

A detailed site map is presented as Figure 2. Interpreted results are discussed in Section 4 and presented as a Geophysical Interpretation Summary map on Figure 3.

2.0 FIELD SURVEY

Geophysical field work was carried out between May 22 and 27, 2004, by a senior geophysicist from NGA, a field technician from R&M Consultants, and a field assistant from the Alaska District, U.S. Army Corps of Engineers (USACE). The 29-hectare (71-acre) site is generally flat (Figure 2). The site had been cleared and graded prior to the geophysical field work. Trees and brush removed from the site had been piled in windrows on the east and south perimeters of the site using a D-8 Caterpillar tractor. There was also an east-west log windrow down the center of the site. The center windrow, or wood pile, was actively being removed and only about 150 meters remained by the time the geophysical field work was complete.

Data acquisition and data processing procedures used for this investigation were similar to those used on four other sites during the October, 2003 field program. Those sites are the Whole Barracks Renewal, Phase 5 (FTW271), Pallet Processing Project (FTW259), Family Housing (FTW251), and the Allen Field Runway (FTG123) at Fort Greely.

Unlike those surveys, most of the present survey utilized a staked grid which was established and used for position information. That grid was mapped to the Corps site coordinates (Alaska State Plane) using grid coordinates of known features and using sub-meter differential GPS mapping.

For portions of the site around the perimeter, and around the central windrow, a differential global positioning system (DGPS) was used to acquire positioning information. Those position data were recorded simultaneously with the EM and MAG data into the same data files.

Other changes from previous surveys include adjustments in EM data processing to minimize the effect of microwave transmissions from a tower south of the site, and the use of a magnetic base station.

2.1 GPS Mapping Control

A staked grid was established with an E-W baseline (1580N) along the east-west power line 120 meters (m) south of the northern project limit. A north-south tie line was established (800E) at the junction of the north-south power line spur using a right angle prism. The grid was staked at 10m intervals on the north-south lines spaced 50m apart. Geophysical data were acquired on E-W lines spaced 5m apart. The staked grid was used to provide "fiducials" for station spacing and to keep the operator "on-line" and assure uniform coverage.

This "staked grid" system was used because the planned differential GPS equipment was not delivered on schedule due to problems with our equipment supplier. When the GPS equipment became available the last two days of the survey, the system was integrated with the geophysical data acquisition systems. GPS data were recorded concurrently, into the same data file with the geophysical data, and were used for positioning the data points.

Differential GPS was also used to provide position information for the mapping of the site. For the DGPS operation, a local base station was established using a Trimble 5700 GPS system with a real time radio link to the rover unit. The rover unit was also a Trimble 5700 GPS system. A differential GPS mapping base station was established at USACE bench mark “W-4.” Data were corrected in post processing to provide a best fit to the known locations of bench marks and other identifiable site features. The equipment and procedures employed provide “sub-meter” accuracy for the geophysical mapping.

2.2 Magnetic Data Acquisition

The MAG survey was conducted using a Geometrics G858G cesium magnetometer/gradiometer. This instrument was run in the “continuous” sampling mode, recording the magnetic field at 0.2 second intervals (approximately 0.3 meters). Two magnetic sensors spaced 0.5 meters apart, one above the other, were used to obtain the vertical magnetic gradient. Line spacing for the MAG survey was 5 meters. Magnetic survey lines are shown on Figure 3 and the magnetometer data plots included in Appendix A, Figures A1 through A3.

Because this survey ran over several days, a local magnetic base station was used to monitor the diurnal changes in the earth’s ambient magnetic field. The base station was established about 50m north of the site in a clearing away from all vehicular traffic, and in an area of low magnetic gradient. A Geometrics G856 magnetometer was used for the base station, sampling continuously at a 15 second interval.

2.3 EM Data Acquisition

EM data were acquired using a Geonics EM-31 terrain conductivity meter. Both quadrature-phase (apparent conductivity) and in-phase data were recorded. Data were recorded at a 0.2 second interval, corresponding to a distance of approximately 0.3 meters. Data were recorded on an Allegro handheld ruggedized field computer (Windows CE/DOS) running NAV31 software from Geomar of Mississauga, Ontario. EM data points are shown on Figure 3 and the EM data plots included in Appendix A, Figures A4 and A5.

The EM data were strongly affected by the microwave transmissions from a communications tower a few hundred meters south of the power substation. The microwave signal overpowers the EM electronics and introduces considerable low frequency (periods of 1 to 5 seconds) noise into the data. Hence, the useful range of the EM was greatly diminished and only the larger anomalies can be identified with any certainty. Nonetheless, we feel this did not reduce the effectiveness of the survey, as the major anomalies can easily be identified. Resolving individual anomalies within the areas of scattered debris is beyond the scope of this survey.

3.0 DATA PROCESSING

Magnetic (MAG) and Electromagnetic (EM) data were gridded and contoured using the Geosoft Data Processing and Analysis software system. Color contour data plots are included in Appendix A. As with the data acquisition, data processing was essentially the same as other geophysical surveys in the October, 2003 program as well as previous geophysical surveys for the Alaska District (July, 2003 and November, 2002).

3.1 Magnetic Field Data

Magnetic data are displayed on three figures, one plot of the analytic signal (Figure A1), the total magnetic signal (Figure A2), and the vertical magnetic gradient (Figure A3). The analytic signal is our preferred presentation as it provides a simplified signature and better resolution of the anomalous areas than unprocessed field data. A high in the analytic signal occurs directly over the magnetic "source." The analytic signal is discussed in the following section (Section 3.2).

All magnetic data were corrected for the diurnal changes in the magnetic field to relate them to a common datum. On May 22 and 27, diurnal variations approached a maximum of 150 nanotesla (nT) during the time of the survey. On other days it was less than 50 nT.

The total magnetic field plot shows the data from the bottom sensor of the G858, which was also used to calculate the analytic signal. The vertical gradient is obtained by taking the difference in the magnetic field as measured by two sensors spaced 0.5 meters apart, one above the other. Anomalies will have both high and low values associated with them.

3.2 Analytic Signal

The analytic signal is derived from the total magnetic field data. It is presented here as a more concise display of that data set. On the color contour plot (Figure A1) values of the analytic signal below a threshold value are not colored (i.e., are white) and represent areas where little or no metallic material may be present. Higher amplitude anomalies generally indicate "stronger" source objects. A "stronger" source object may be more magnetic (generally a larger mass of steel), or it may be closer to the surface, or both. The amplitudes of the anomalies also depend upon the orientation of the source objects in the earth's magnetic field. This is especially true for elongate bodies such as pipes and cables.

The analytic signal is defined as the amplitude of the gradient vector of the total magnetic field data. The gradient (rate of change) of the total magnetic field is a vector field. The analytic signal is the magnitude of that vector, or the rate of change in the direction of maximum rate of change. The color contour plot shows the amplitude of the gradient.

Mathematically, the analytic signal can be expressed as:

$$A = \left[\left[\frac{\partial M}{\partial x}\right]^2 + \left[\frac{\partial M}{\partial y}\right]^2 + \left[\frac{\partial M}{\partial z}\right]^2\right]^{\frac{1}{2}}$$

where:

A	is the analytic signal,
M	is the observed total magnetic field, and
∂	is the partial derivative operator.

Derivatives are calculated in the frequency domain, from the gridded total field data.

Further discussion of the concept of the analytic signal can be found in the following publication:

> Roest, W.R., Verhoef, J., and Pilkington, M., 1992, "Magnetic interpretation using the 3-D analytic signal", Geophysics, Vol. 57(1); p.116-125.

3.3 Electromagnetic Data

Both quadrature phase (apparent conductivity) and in-phase EM data were recorded in the field. Appendix B includes a discussion of these two measured parameters of the EM response. Plots of both data sets are included in Appendix A.

In-phase data were "leveled" to remove drift in the in-phase data. The microwave interference in the field made it impossible to properly zero the in-phase compensation in the field. Hence, this additional step in data processing was required to reference readings to one datum.

There is still some "banding" in the data, particularly on the southern edge of the site. There appears to be a "heading error" which is difficult to explain with any geologic cause. The high readings on the east and south do correspond with the radiation patterns of the two dish antennas on the tower.

Data were also filtered with a 5-second low pass filter to diminish the effect of the microwave interference. This translates to a special frequency of about 5m. Hence, small amplitude anomalies less than 5m across would not be resolved in the processed data set.

4.0 RESULTS AND INTERPRETATION

EM and magnetic data plots are included in Appendix A. The interpretation of those data in terms of possible locations of buried objects, foundations, and utilities, is summarized in Figure 3 and discussed below. The anomaly designations (A through U) in the following sections refer to anomalies identified on Figure 3, *Geophysical Interpretation Summary.*

The site is characterized by general scattered debris with a few large disposal areas with extensive metallic debris. We have highlighted these "anomalous" areas in Figure 3. Anomalies A1 through A12 are not associated with any features we have identified, and hence classified as "unknown anomalies." Anomaly F1 is associated with a fence. Anomalies S1 through S3 are associated with surface or near-surface debris or objects. Anomaly U1 is associated with known or suspected utilities. These are discussed below.

4.1 Anomaly A1 – Former Disposal Area

Anomalous area "A1" is centered around two excavations at the northern perimeter of the site. The excavations were dug during the current site preparations when large metallic debris was discovered on the surface during grading operations. Large (car sized) objects as well as several truck loads of miscellaneous debris were reportedly removed from the excavation. This evidence indicates that this area was formerly a debris disposal area.

The MAG and EM indicate that the disposal area is approximately 150 meters east-west by 75 meters north-south, although it may extend past the survey area to the north. Several MAG lines were extended to the area north of the anomaly, and appeared to reach the northern extent. However, vegetation in the area to the north precluded extending the survey to resolve a definitive boundary.

4.2 Anomaly A2 – Possible Disposal Area

Anomaly A2 is very similar to Anomaly A1 and covers a large area, 200 meters E-W by 75 to 100 meters N-S. The anomaly is on the eastern portion of the site, roughly midway between the north and south limits of the project area. While no test excavations have sampled this area, its geophysical response is very similar to that of A1, and hence we expect the causative materials to be similar.

4.3 Anomaly A3 – Possible Disposal Area

Anomaly A3 is a smaller anomalous area, 50m by 50m, at the southwest corner of the fenced school yard to the north of the site. Parts of this anomalous area are linear features typical of utilities. Other parts of the anomaly are more chaotic and indicative of buried metallic debris.

4.4 Anomalies A4, A5, A6, and A7 – Possible Utilities

Anomalies A4, A5, A6, and A7 are linear features with anomalous EM and MAG responses. These are typical of steel pipes or utility conduits. No surface expression of these utilities was noted and they appear discontinuous, indicating that they may be abandoned utility lines.

Anomaly A5 has a strong MAG response, indicative of a large diameter pipe or possibly an abandoned utilidor. Anomalies A4 and A6 have locally strong, but discontinuous MAG responses, possibly indicating a large steel pipe, with the joints having large MAG signatures. Anomaly A7 has a much weaker geophysical response, indicating a smaller utility.

4.5 Anomaly A8 – Unidentified Anomaly

Anomaly A8 is a strong MAG anomaly at the northeast corner of the community garden area. This is a strong MAG dipole anomaly typical for a steel culvert or similar sized steel object. No culvert was noted during the geophysical survey, but no effort was made to locate a culvert or other possible cause of the anomaly.

4.6 Anomalies A9 and A10 – Unidentified Anomalies

Anomalies A9 and A10 represent larger anomalies within the northeastern area of scattered debris, S2. These anomalies may represent larger buried objects within that area.

4.7 Anomaly A11 – Unidentified Anomaly

The area east of the eastern wood windrow, along the dirt road between the windrow and the trees and brush at the eastern limit of the site, contains numerous scattered anomalies. Anomaly A11, at approximately 1600N, is a somewhat larger anomaly and may be indicative of a larger buried object or debris.

4.8 Anomaly A12 – Unidentified Anomaly

Anomaly A12 is a MAG anomaly in the southeast corner of the site. At the time of the survey it was south of a windrow of trees and brush. Due to that windrow, this anomaly could not be well delineated. While the MAG response in this area is probably affected by the substation 30m to the south, the "chaotic" nature of the anomaly leads us to believe there may be other materials buried in this area.

4.9 Anomaly S1 – Former Community Gardens

This area, formerly used as community gardens, contains numerous small scattered surface or near surface objects or debris. Visible on the surface were two or more sections of 18 mm or 25 mm cast iron pipe (presumably used for irrigation) which were 75 to 100 meters in length. Also visible were several steel fence posts and other garden material.

The MAG and EM response observed over this area is consistent with this type of scattered near-surface debris, and we do not suspect any large collection or buried debris in this area. The exception would be Anomaly A8 discussed above.

4.10 Anomaly S2 – Scattered Surface Debris

Anomaly S2 is an area with numerous small scattered MAG anomalies. This area covers the northeast quarter of the site. Most if not all of these anomalies represent objects of 5 kg (10 pounds) or less. Few of the anomalies are observed on more than one survey line.

4.11 Anomaly S3 – Scattered Surface Debris

Anomaly S3 covers an area approximately 100m by 100m in the northwest corner of the site. There are fewer small anomalies in this area than in either S1 or S2 and some of the anomalies appear to follow linear trends, suggestive of pipes or shallow utilities.

4.12 Anomaly F1 – Fence

Anomaly F1 is due to the 1.8-meter cyclone fence surrounding the school yard to the north.

4.13 Anomaly U1 – Underground Communications Line

Anomaly U1 is a long linear EM anomaly extending E-W across the site beneath the power lines at 1580N. There is a communications junction box near the western edge of the site, and a communication line identified on the DOWL Engineers site drawing.

The EM data suggest that there may be two utility lines spaced 8 to 12 meters apart. However, with the east-west survey line orientation we could not clearly resolve two separate anomalies. There was no associated MAG anomaly indicating the lack of steel piping or conduit.

5.0 CLOSURE

Geophysical surveys performed as part of this survey may or may not successfully detect or delineate any or all subsurface objects or features present. Locations, depths and scale of buried objects or subsurface features mapped as a result of this survey are a result of geophysical interpretation only, and should be considered as confirmed, actual, or accurate only where recovered by excavation or drilling.

R&M Consultants, Inc. and Northwest Geophysical Associates, Inc. performed this work in a manner consistent with the level of skill ordinarily exercised by members of the profession currently practicing under similar conditions. No warranty, express or implied, beyond exercise of reasonable care and professional diligence, is made. This report is intended for use only in accordance with the purposes of the study described within.

Very truly yours,
R&M Consultants, Inc.

Charles H. Riddle, C.P.G.
Vice President

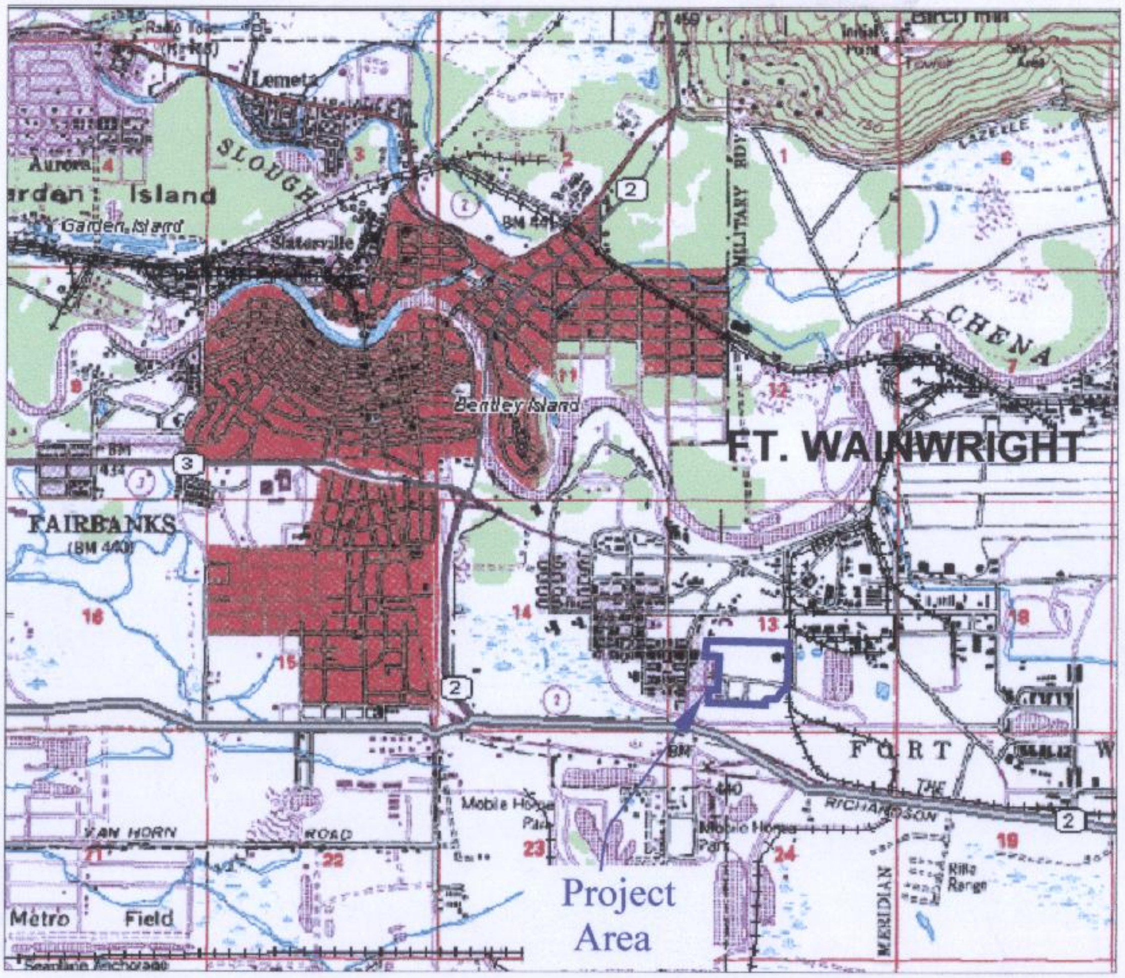
Northwest Geophysical Associates, Inc.

For

Rowland B. French, R.G.
Vice President

CHR:RBF*slv

NGA Project #: 554   FILE: FTW283_FAMILY_LOCATION.DWG   DATE: MAY_2004   REVISION: B-06-JUL-04



from: FAIRBANKS (D-2) NE 1:25,000 USGS Quadrangle

0 1.0 2.0
SCALE (km)

N

FIGURE 1

SITE LOCATION MAP

Geophysical Site Investigation
Family Housing Replacement
Taku Sites (FTW283 & FTW251)
Fort Wainwright, Alaska

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Prepared for:
ALASKA DISTRICT
CORPS OF ENGINEERS
ANCHORAGE, ALASKA
CONTRACT # DACA85-02-D-0010 (D.O.# 0018)

NGA PROJECT #: 569 FILE: NGA_TAKU_Site.dwg [site_3k] DATE: MAY 2004 REVISION: A-06-JUL-04

LEGEND

- 1300 N / 900 E — NGA STAKED GRID (meters)
- WINDROW — WOOD DEBRIS WINDROW
- POWER POLE
- POWER POLE WITH GUY LINE
- DUMPSTER
- SURVEY MONUMENT
- PROJECT AREA
- ELEVATION CONTOURS MAJOR INTERVAL 2.5m MINOR INTERVAL 0.5m

0 50 100
SCALE (meters)

BASEMAP FROM USACE "partial topo.dwg", REF.# GFM-2, 11/19/03
with modifications from DOWL survey drawing, "ARMY FAMILY HIOUSING TOPOGRAPHY"
REF# 15-04-609, 2/23/04

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ANCHORAGE, ALASKA

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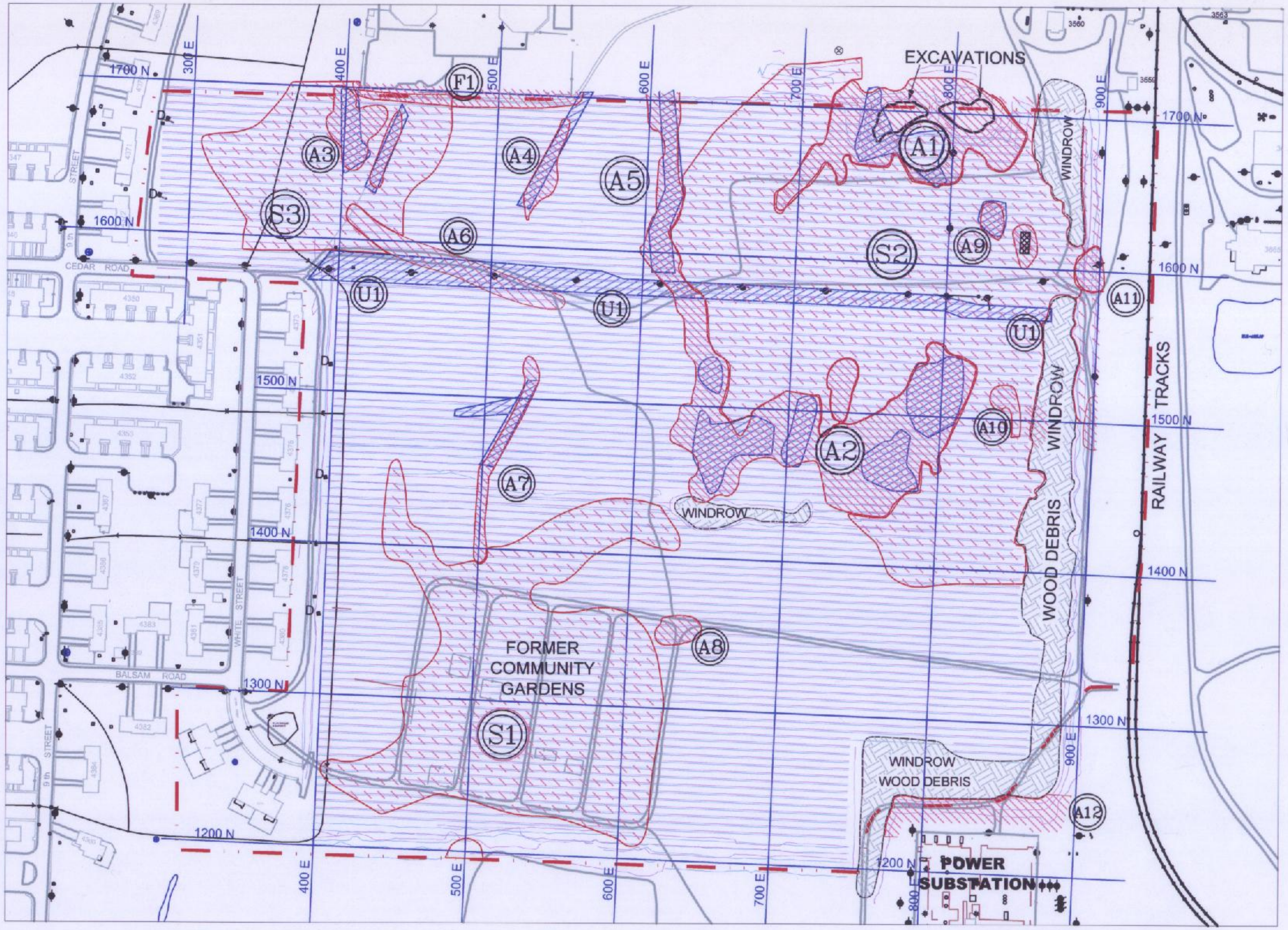
FIGURE 2

SITE PLAN

Geophysical Site Investigation
Family Housing Replacement
Taku Sites (FTW251 & FTW283)
Fort Wainsright, Alaska

NGA PROJECT #: 569 FILE: NGA_TAKU_Site.dwg [Interp_3k] DATE: MAY 2004 REVISION: A-06-JUL-04



LEGEND

GEOPHYSICAL SURVEY LINES MAG (magenta) EM (lt. blue)

A1 ANOMALIOUS AREA DISCUSSED IN TEXT

MAG ANOMALIES

EM ANOMALIES

"SCATTERED DEBRIS" NUMEROUS SMALL MAG & EM ANOMALIES

0 50 100 SCALE (meters)

BASEMAP FROM USACE "partial topo.dwg", REF.# GFM-2, 11/19/03 with modifications from DOWL survey drawing, "ARMY FAMILY HIOUSING TOPOGRAPHY" REF# 15-04-609, 2/23/04

FIGURE 3

GEOPHYSICAL INTERPRETATION SUMMARY

Geophysical Site Investigation
Family Housing Replacement
Taku Sites (FTW251 & FTW283)
Fort Wainsright, Alaska

Prepared by:
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P.O. Box 1063, Corvallis, Oregon 97339

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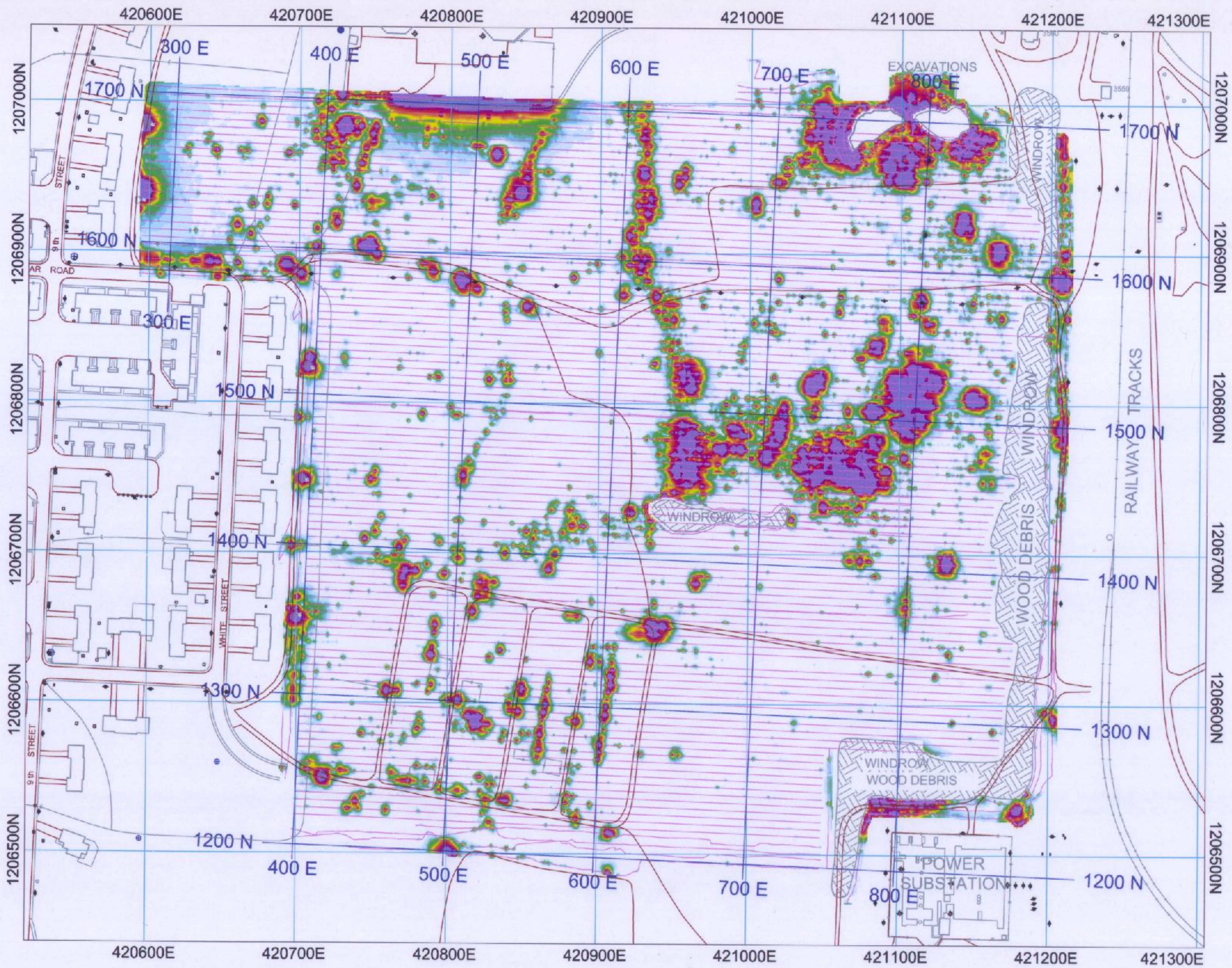
APPENDIX A

GEOPHYSICAL DATA PLOTS

Magnetic Analytic Signal .... Figure A1
Total Magnetic Field .... Figure A2
Vertical Magnetic Gradient .... Figure A3
EM31 Apparent Conductivity .... Figure A4
EM31 In-Phase Response .... Figure A5



REVISION: D-06-JUL-04
DATE: MAY 2004
FILENAME: AKFTW283_Ansig.map
NGA PROJECT #: 589

750
700
650
600
550
500
480
460
440
420
400
380
360
340
320
300
280
260
240
220
200
190
180
170
160
150
140
130
120
110
100
90
80
70
60
50
40
30
20

MAGNETIC ANALYTIC SIGNAL (nT/M)

LEGEND

MAGNETIC DATA LINES
(for detailed legend see Figure 2)

Scale 1:3000
25 0 25 50 75 100 125 150
metres
NAD83 / Transverse Mercator

FIGURE A1

MAGNETIC ANALYTIC SIGNAL
Geophysical Site Investigation
Family Housing Replacement
Taku Sites (FTW251 & FTW283)
Fort Wainwright, Alaska

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ANCHORAGE, ALASKA
CONTRACT #DACA85-99-D-0009 (D.O.# 0018)

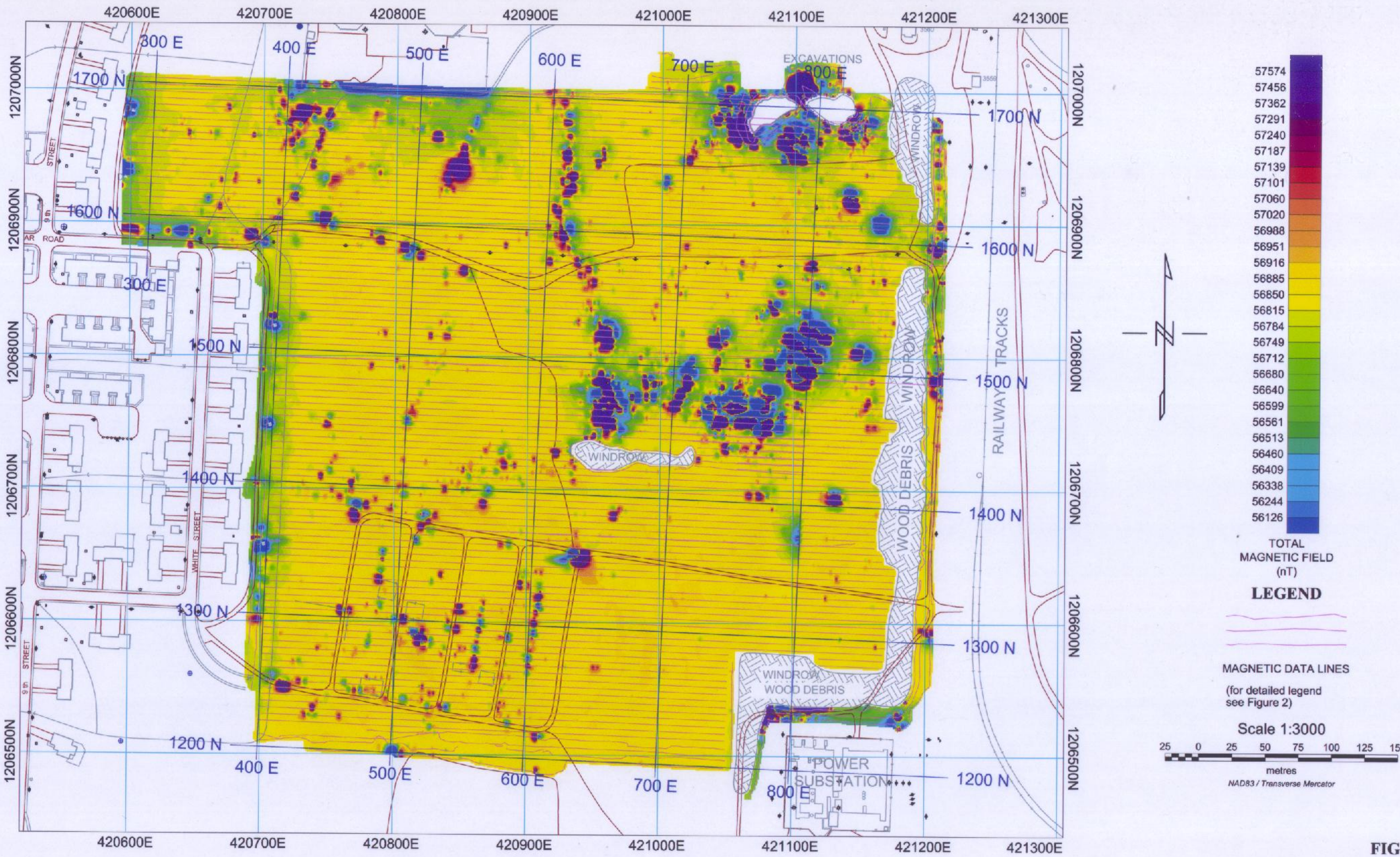

FIGURE A2

TOTAL MAGNETIC FIELD
Geophysical Site Investigation
Family Housing Replacement
Taku Sites (FTW251 & FTW283)
Fort Wainwright, Alaska

Prepared By: Northwest Geophysical Associates, Inc.

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Prepared For: ALASKA DISTRICT CORPS OF ENGINEERS ANCHORAGE, ALASKA
CONTRACT #DACA85-99-D-0009 (D.O.# 0018)

NGA PROJECT #: 589
FILENAME: AKFTW283_Vgrad.map
DATE: MAY 2004
REVISION: D-06-JUL-04

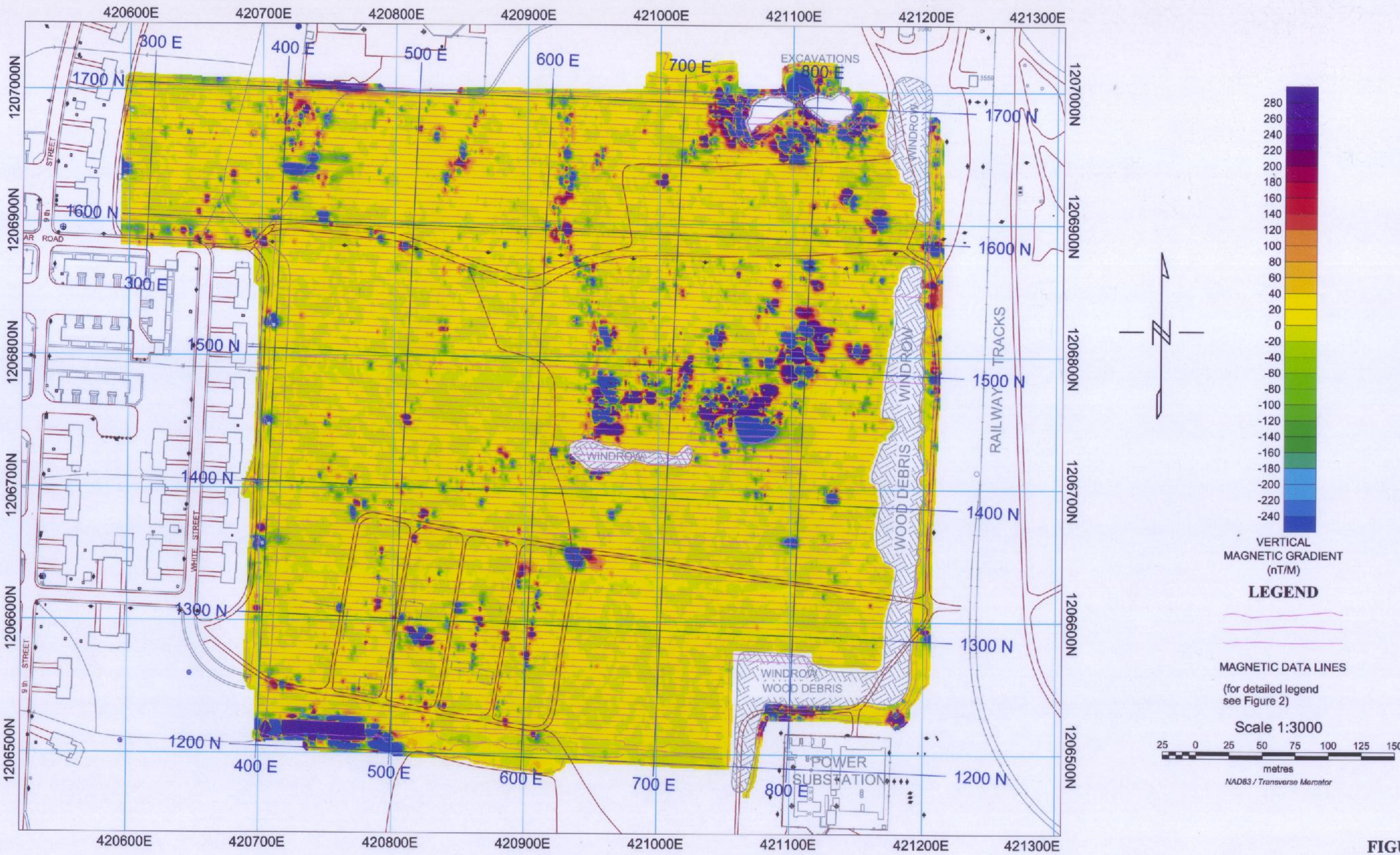

FIGURE A3

VERTICAL MAGNETIC GRADIENT
Geophysical Site Investigation
Family Housing Replacement
Taku Sites (FTW251 & FTW283)
Fort Wainwright, Alaska

Prepared By:
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CORPS OF ENGINEERS
ANCHORAGE, ALASKA
CONTRACT #DACA85-99-D-0009 (D.O.# 0018)

REVISION: D-06-JUL-04
DATE: MAY 2004
FILENAME: AKFTW283_Emq.map
NGA PROJECT #: 569

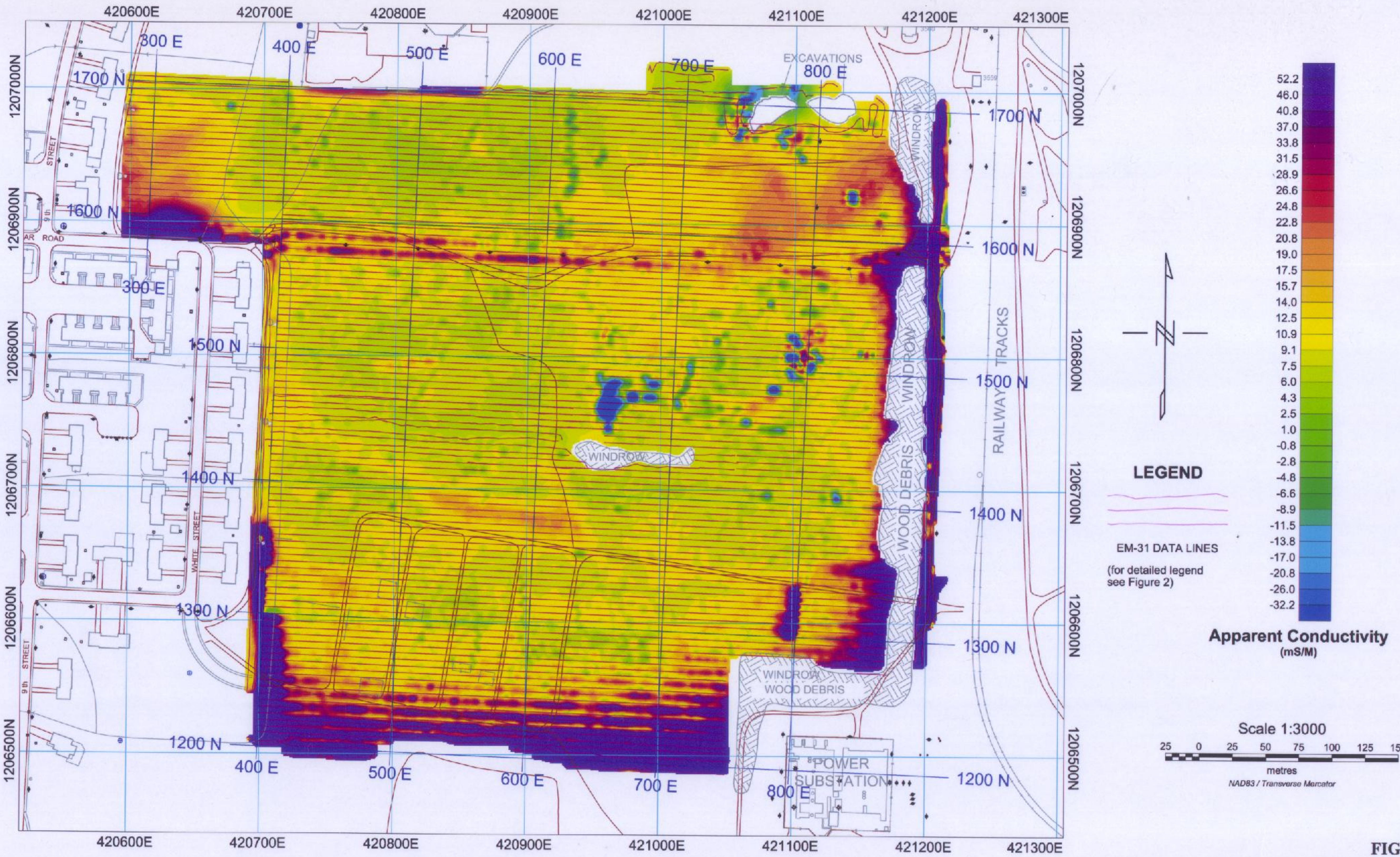

FIGURE A4

EM-31 APPARENT CONDUCTIVITY
(Quadrature Phase Response)

Geophysical Site Investigation
Family Housing Replacement
Taku Sites (FTW251 & FTW283)
Fort Wainwright, Alaska

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ANCHORAGE, ALASKA
CONTRACT #DACA85-99-D-0009 (D.O.# 0018)

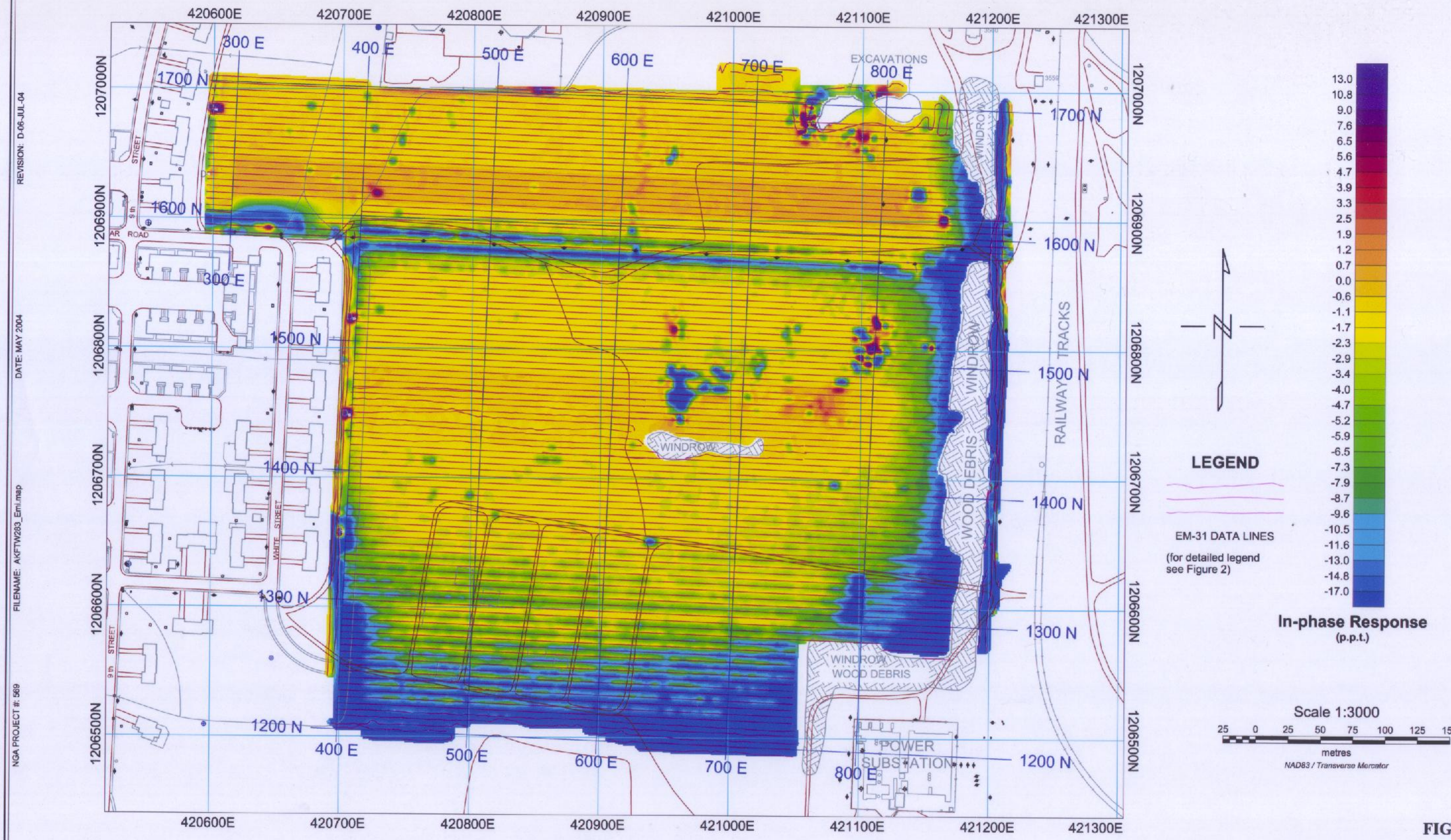

FIGURE A5

EM-31 IN-PHASE RESPONSE
Geophysical Site Investigation
Family Housing Replacement
Taku Sites (FTW251 & FTW283)
Fort Wainwright, Alaska

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Prepared For:
ALASKA DISTRICT
CORPS OF ENGINEERS
ANCHORAGE, ALASKA
CONTRACT #DACA85-99-D-0009 (D.O.# 0018)

APPENDIX B

TECHNICAL NOTE:

Geophysical Detection of Buried Objects

Ground Penetrating Radar

Geophysical Detection of Buried Objects

Electromagnetics - *EM31*

Magnetics

COVER v.7.31.01

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GEOPHYSICAL DETECTION

OF BURIED OBJECTS

Various geophysical techniques are used for locating buried objects such as underground storage tanks, pipes, utilities, drums and other debris. These techniques are now used routinely, and are often recommended or required by the EPA, on sites where underground burial of steel drums or other debris may have occurred or where underground storage tanks are suspected. Geophysics is generally used in the early reconnaissance phase of these investigations as a guide to sampling, excavation and/or placement of monitoring wells.

UTILITY OF GEOPHYSICS:

First, a few words about "geophysics" as used for environmental and geotechnical engineering applications. Surface geophysical techniques probe subsurface materials (soils and rock) using surface instruments. This is done by measuring physical signals which have interacted with the earth materials. These signals may be electrical, magnetic, acoustic (seismic) or electromagnetic.

Surface geophysics offers several advantages over other exploration techniques:

1) Surface geophysical methods are *"non-intrusive"* in that they do not disturb the ground surface, or stir up any contaminants which might be in the soil.

Geophysical methods *measure earth properties over a large volume.* Whereas drilling only samples the earth at the point of the borehole, the measured geophysical response is affected by earth materials several feet, or tens of feet, away from the instrument sensor. This allows broad areas to be effectively "screened" with a series of surface measurements.

3) Most geophysical equipment used in environmental and geotechnical applications *can be hand carried.* Geophysical surveys do not require vehicular access, but only a walking path, clear of brush and obstacles.

4) Geophysical surveys are relatively *inexpensive* and can be performed quickly.

TYPICAL OBJECTIVES:

Geophysics may be used in either the reconnaissance mode, or in a detailed survey mode. In the reconnaissance mode, geophysics is used to "screen" large areas to determine the presence or absence of buried objects. In more detailed surveys, the location and extent of the object is mapped in greater detail. This facilitates the efficient excavation of tanks or debris, aids the effective placement of monitoring wells, or improves the design of a sampling program.

The techniques discussed here are also useful for objectives other than identifying buried objects. Electromagnetic induction (EM) is especially useful in mapping changes in soil (e.g. sand or gravel channels), mapping clay aquitards and mapping contaminant leachate plumes in groundwater. GPR can be used to map shallow stratigraphy or to map zones of disturbed soils.

GEOPHYSICAL METHODS:

Three geophysical methods are commonly used in the search for buried objects: 1) electromagnetic induction (EM), 2) magnetic techniques, and 3) ground penetrating radar (GPR). EM and magnetics are complementary methods, most effective in the reconnaissance mode but also useful for more detailed work. GPR is most effective for detailed work, but may also be used in reconnaissance surveys.

Electromagnetic Methods:

The electromagnetic induction (EM) technique measures the electrical conductivity of the earth by inducing an alternating electric current in the earth. This technique was developed to measure natural soil conductivity to aid in identifying soil types and to measure rock conductivity in order to identify zones of conductive mineralization.

Man-made metallic objects are generally orders of magnitude more conductive than natural soils. Thus, the electric currents induced in the ground by EM instruments will be dramatically affected by the presence of any man-made metallic object. Examples include pipes, tanks, cables, concrete reinforcing steel, or steel drums. By looking for anomalous signals which cannot be attributed to natural soils, buried metallic objects can readily be identified.

The Geonics EM-31 is the most common EM instrument used for buried object detection. The upper left photo on the cover shows the EM-31 in a field situation. A transmitter coil is in one end of the boom and a receiver coil in the other end. Depth of investigation is generally 10-15 feet, but the EM-31 may detect large metal objects at a somewhat greater distance. The instrument can quickly cover a wide area, mapping anomalous areas (metallic object locations) as well as changes in the soil character.

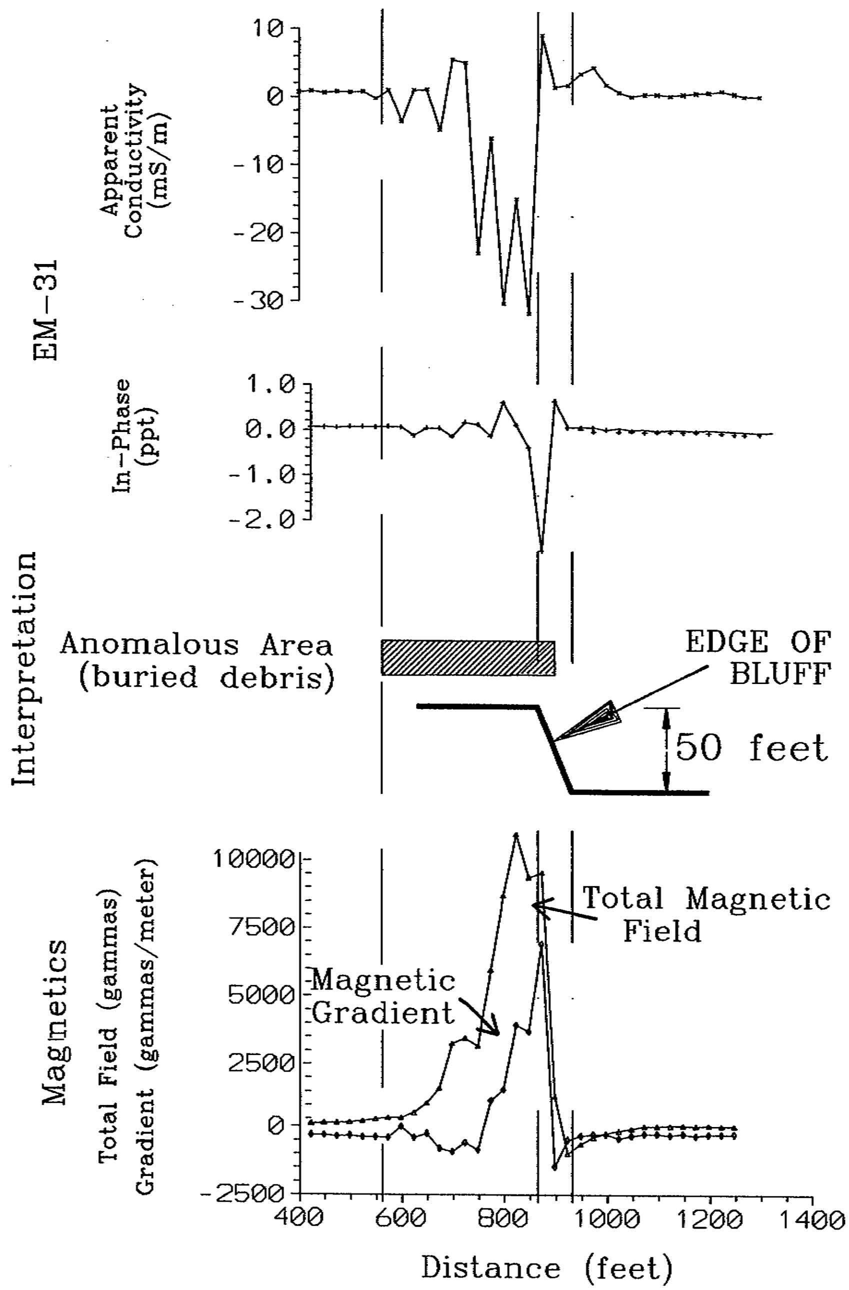
Figure 1 shows some sample data over a disposal site where 55 gallon steel drums had been dumped on the edge of a bluff and then covered with soil, extending the bluff for tens of feet (cross hatched block in Figure 1). The noisy and/or negative "apparent" conductivity is a clear indicator of metallic objects. The EM-31 also records an "in-phase response" which aids in identifying metallic conductors. Data in Figure 1 indicate the zone of burial extends from 560 feet to 940 feet along the line of the profile.

Magnetic Methods:

Magnetic methods measure disturbances in the earth's natural magnetic field. These disturbances are caused by magnetic materials, either magnetic rocks, or man made objects containing iron or steel. Most soils have negligible magnetization (both induced and remanent). Thus, most magnetic disturbances from shallow sources can be attributed to iron or steel objects which have been placed there by man's activities.

FIGURE 1

SAMPLE EM & MAGNETIC PROFILES



LINE 831S, King Salmon, AK

Magnetometers used for buried object detection usually measure the gradient of the magnetic field. This is done by measuring the difference between the magnetic field at two sensors separated vertically by two or three feet. This configuration is more sensitive to nearby disturbances, and is less effected by disturbances caused by distant objects or shallow bedrock.

The upper right photo on the cover shows a magnetometer/gradiometer. This instrument can also cover wide areas quickly, providing complementary data to the EM. Figure 1 includes total magnetic field data and gradiometer data over the barrel disposal area. The large deviations in both total field and gradient are indicative of steel objects in close proximity.

Ground Penetrating Radar:

Ground penetrating radar (GPR), like other radar techniques, sends out an electromagnetic pulse (radio wave or microwave) which is reflected off a "target" and returns to the receiver. GPR operates at lower frequencies (80-500 MHz) than other radar to obtain better penetration in the earth materials. The antenna is pulled slowly along the ground surface to produce a continuous subsurface profile.

The lower photo on the cover shows a GPR unit in operation. The 500 MHz antenna shown is being pulled along the sidewalk. The control and recording unit, on the tailgate of the truck, is powered by a 12 volt automobile battery.

Figure 2 is an example GPR profile over a shallow pipe. The vertical scale is a time scale, giving the time for the radar pulse to travel down to the reflector and return to the receiver. Knowing the pulse velocity in the soils, we can convert this to depth. The horizontal scale corresponds to distance along the surface. Fiducial time marks on the record are placed at ten foot intervals. The pipe reflector shown appears as a hyperbola on the record. The pipe produces a strong reflection with a characteristic ringing of the electronics, which appears as a dark band below the first arrival from the pipe.

GPR is a tool for looking at selected areas in detail. Its continuous subsurface profiles give a graphic portrayal of subsurface conditions, and often provide an excellent means of accurately locating pipes and tanks. However, the GPR depth of exploration is strongly dependent on soil conductivity and subsurface conditions. In dry, sandy soils useful data may be obtained from depths down to 15 feet, whereas in conductive clay soils, investigation depth is often limited to two or three feet.

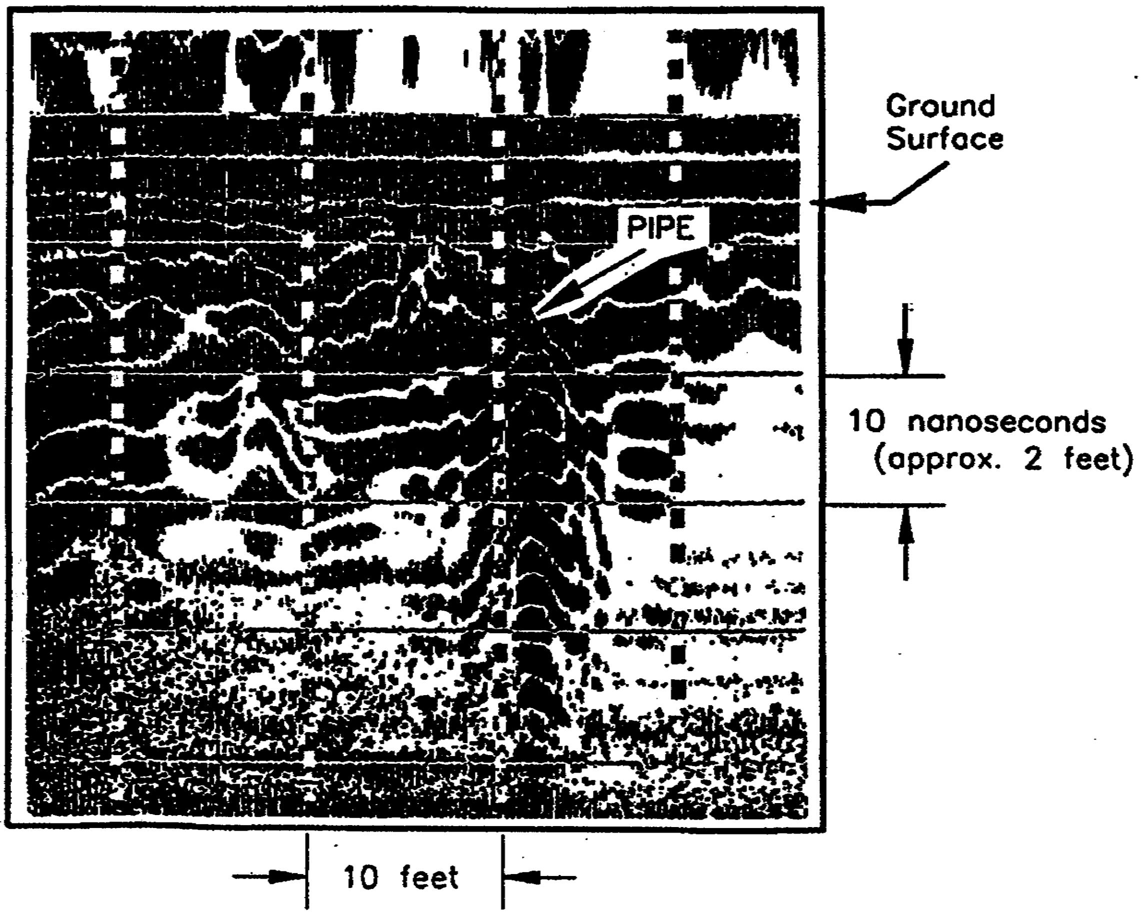
DISCUSSION:

As we have stressed, EM and magnetics are effective in screening large areas quickly to identify areas where buried objects may be present. Often these techniques can provide a rough estimate of the size and depth of the object causing the anomalous readings.

The major limitation of these two techniques is their sensitivity to "cultural noise". Buildings, fences, metallic surface debris, and vehicles all create cultural noise. The EM and magnetic instruments respond

FIGURE 2

SAMPLE GPR PROFILE



to any metallic objects, whether buried or in plain view above ground. Thus, areas within 20 to 40 feet of buildings, vehicles or pipelines will be masked by the strong response from those objects. EM and magnetics will not be able to definitively identify other buried objects within that masked zone.

GPR on the other hand is fairly immune to those forms of cultural noise. The radar signal is confined to a broad beam, spreading at roughly a 45° angle, beneath the antenna. Most antennas are well shielded with little upward propagation of the pulse. Thus GPR can be run next to buildings, fences and parked vehicles. GPR may be run inside buildings and even over reinforced concrete.

Because the GPR beam is directional, it does not have the same utility as a reconnaissance tool as the EM and magnetics. Whereas the latter techniques would readily detect a large tank 10 or 20 feet off the survey line, GPR would not detect the tank unless the survey line passed directly over the tank.

No geophysical technique should be used without some form of "ground truth" by drilling, excavation, or some other form of sampling. The geophysical signature of an underground storage tank may be very similar to that of a buried automobile. However, geophysics can eliminate random drilling or extensive excavation when searching for underground tank or other materials.

To conclude, EM, magnetic and GPR techniques are effective, complimentary techniques used in the detection and delineation of subsurface metallic objects. The choice of technique or techniques depends very much on both site conditions and the survey objective.

FURTHER READING:

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DISCUSSION OF GEOPHYSICAL TECHNIQUES

GEOPHYSICAL DETECTION OF BURIED OBJECTS

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