The Hutchinson Group, Ltd.
Geophysical and Environmental Services

GEOPHYSICAL INVESTIGATION
of the
SARA LEE KNIT PRODUCTS FACILITY
Winston-Salem, North Carolina

Prepared for:

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1.0 INTRODUCTION

1.1 Background

Delta Environmental contracted with the Hutchinson Group, Ltd. (THG) to image portions of the Sara Lee Knit Products Facility, Winston-Salem, North Carolina (Figure 1). Portions of the approximately 9-acre area buried waste during or before the mid 1970s.

1.2 Work Scope

The work scope consists of imaging the subsurface of the approximately 9-acre tract to provide a footprint to the waste and identify those areas that may contain buried metal.

2.0 GEOPHYSICAL TECHNIQUES

2.1 ELECTROMAGNETIC TERRAIN CONDUCTIVITY SURVEY

2.1.1 Introduction - Electromagnetic terrain conductivity surveys have been employed for landfill investigations for over 20 years (McNeill 1980). Advantages of an electromagnetic terrain conductivity survey include:

1. Excellent resolution in conductivity;
2. No current injection problems;
3. Simple multi-layered earth calculations;
4. Easy, rapid measurements.

Disadvantages of EM for exploratory investigations are few but include:

1. Limited dynamic range;
2. Setting and maintaining the instrument zero;
3. Limited vertical sounding capability.

EM surveys are principally used for landfill boundary detection (Mack and Maus, 1986; McQuown et al., 1991; Rumbaugh et al., 1987; Scaife, 1990; Stenson, 1988) and detection of leachate contaminant plumes (Hall and Pasicznyk, 1987; Mack and Maus, 1986; Russell, 1990; Walther et al., 1986). Several workers have been successful in using EM surveys to identify volatile organic plumes such as gasoline (Fawcett, 1989; Olhoeft, 1986; Olhoeft and King, 1991; Saunders and Cox, 1987). McNeill (1990) contends that "...EM measurements will also undoubtedly be used to assist in locating new sanitary landfills..." (p.209).

While groundwater monitoring wells are aerially limited and are a somewhat expensive sentinel strategy, EM surveys have proven to be inexpensive and effective for establishing compliance (McNeill, 1990; Rumbaugh et al., 1987). EM surveys can also be used to monitor the efficiency of a treatment system (Medlin and Knuth, 1986).

2.1.2 Theory - The terrain conductivity meter is used for the measurement of the electrical conductivity of subsurface soil, rock and ground water. The electrical conductivity (or its inverse, resistivity) is a function of the porosity, permeability and the fluids in the pore spaces (McNeill, 1980). In the landfill setting, the pore fluids dominate the measurement and thus the EM is an excellent tool for delineating buried waste, trench boundaries, drums and other metallic objects. The absolute values of conductivity obtained in a survey are not necessarily diagnostic but the variations in conductivity can be used to identify anomalies (Benson et al., 1988).

The EM method is further useful when integrated with a data logger (Geonics Polycorder Model DL600) and Global Positioning Unit (Trimble ProXRS) that can provide for continuous measurement of the field position and terrain conductivity, thus increasing the survey size and scope while reducing costs over conventional soundings.

The EM tool consists of a transmitter coil that radiates an electromagnetic field. The electromagnetic field induces eddy currents in the earth that generate a secondary electromagnetic field proportional to the magnitude of the current flowing within the coil. Quadrature and in-phase components of the secondary magnetic field are captured by the receiver in the form of an output voltage that is linearly related to subsurface conductivity (McQuown et al., 1991). The quadrature phase component

(terrain conductivity) is measured in milliSiemens/meter (mS/m) and provides a measurement of soil conductivity. The in-phase mode, measured in parts per thousand (ppt), is responsive to highly conductive, buried metallic objects (Geonics Limited, 1994).

The terrain conductivity value is an average conductivity of the effective depth of the survey tool. The effective depth is determined to be about 1.5 times the intercoil spacing (i.e., the distance between the receiving and the transmitting coils). The Geonics EM31-DL terrain conductivity meter, with an intercoil spacing of 13 feet, has an effective penetration depth of 20 feet in the vertical dipole mode (Geonics Limited, 1994). The tool measures the bulk conductivity of the entire skin depth specified by the intercoil spacing. Consequently, the tool averages the response determined through the skin depth such that the response at a depth of 9 feet for the EM31-DL gives maximum contribution to the secondary magnetic field but that at 20 feet there is still a contribution to the bulk conductivity (McNeill, 1980). Near-surface material has a very small contribution to the secondary magnetic field and the orientation of the dipoles in a vertical coplanar fashion is insensitive to near-surface changes in conductivity.

Conductivity values for this sandy soil were estimated to be approximately 40 mS/m (Benson et al. 1988; McNeill 1980; Schutts and Nichols 1991). Fill materials have been observed to have a terrain conductivity of greater than 40 mS/m (McQuown et al., 1991; Hutchinson and Barta, 2000).

2.1.3 Conversion to Decibels - Raw EM data are presented in most of the figures to allow the reader the opportunity to understand how the interpretation was derived. However, one methodology has proven effective for the presentation of EM terrain conductivity data through normalizing the EM data to a background value σ_{app}. The conversion is plotted in decibels (dB) from the following conversion (Greenhouse and Slaine, 1983):

$$L(x, y) = c \log_{10} \frac{\sigma_{app}(x, y)}{\sigma_{arb}}$$

Where, σ_{arb} is the background value for terrain conductivity; $\sigma_{app}(x,y)$ is the measured apparent conductivity and c is a constant. The logarithmic ratio has the advantage of producing whole numbers based on background at the site. Negative numbers indicate sub-background conditions; whereas the positive numbers indicate anomalies above background. Greenhouse et al. (1989) indicate that 6 dB is a factor of 2 above background. The normalized presentation of the surveyed area displays the landfill margins effectively.

2.1.4 Topographic Normalization - Topographic normalization of the terrain conductivity readings was determined to be unnecessary due to low topographic expression. (Monier-Williams et al., 1990). This study was conducted on relatively planar surface and this type of adjustment is not necessary for this type of survey.

2.1.5 Quality Assurance and Quality Control - The interpretation of EM data is not an exact science since the EM response, while shown to have a linear relationship to conductivity, is affected by many phenomena including buried metals, operator error, precipitation, and net changes in ground saturation conditions. Some sources of spurious data can be overcome through a QA/QC program. The quality control program employed with this study included frequent checks and calibration of the EM31-DL unit. The QA/QC program indicates that the EM31-DL unit was functioning as designed during the survey program.

2.2 MODELING PROGRAM

The SURFER (Golden Software, Golden, CO) three-dimensional modeling program was used to smooth and contour the EM data. The kriging method, a statistical technique for spatial interpolation of data, was used to perform the map gridding. Cokriging, a variant of kriging where the value of the derived variable is estimated by weighted linear combination of neighboring samples (Parks and Bentley, 1996), was determined to be unnecessary due to the volume of data and the dramatic difference in conductivity between landfilled material and native soil and rock.

3.0 EM INTERPRETATION

3.1 FREQUENCY-DOMAIN TERRAIN CONDUCTIVITY INTERPRETEATION

EM data represent a response to the electrical conductivity of the skin depth of the tool. Several methodologies exist for presenting EM data including surface mapping and section profiling. Field data acquired for the survey were used to develop a terrain conductivity map for the site from approximately 12,000 readings (Figure 2). Background soil terrain conductivity was measured to be approximately 40 mS/m.

The terrain conductivity map shows the presence of buried metal in the southeastern and western sides of the Metal Shed (Figure 2). The footprint of the buried metal located on the southeastern side of the Metal Shed is approximately 35 feet by 35 feet. The footprint of the inferred buried metal on the western side of the Metal Shed is approximately 15 feet by 25 feet (Figure 3).

3.2 TIME-DOMAIN TERRAIN CONDUCTIVITY INTERPRETATION

A pair of large underground tanks were reported along the entrance road to the facility. The time-domain terrain conductivity mapping of this area shows the inferred locations of the tanks. The tank sizes are estimated to be 12,000 gallons (10' by 20.5').

4.0 CONCLUSION

Terrain conductivity mapping of the Sara Lee Knit Products Facility, Winston-Salem, North Carolina indicated 2 areas of inferred buried metal near the Metal Shed. The time-domain survey identified the location of 2 12,000 gallon tanks.

The findings and conclusions in this report are stated with a reasonable degree of scientific certainty. THG's findings and conclusions are as follows:

- Approximately 9 acres of the eastern portion of the Sara Lee Knit Products Facility, Winston-Salem, North Carolina, were imaged with EM methods June 5, 2007;
- The site is preparing for shut-down;
- The EM analyses show that 2 areas of inferred buried metallic waste were located on the southeastern and western sides of the Metal Shed; and,
- Two 12,000-gallon UST were located on the southern side of the entrance road to the facility.

Geophysical investigations are a non-invasive method of interpreting physical properties of the shallow earth using electrical, electromagnetic, or mechanical energy. This document contains geophysical interpretations of responses to induced or real-world phenomena. As such, the measured phenomenon may be impacted by variables not readily identified in the field that can result in a false-positive or false-negative interpretation. THG makes no representations or warranties as to the accuracy of the interpretations.

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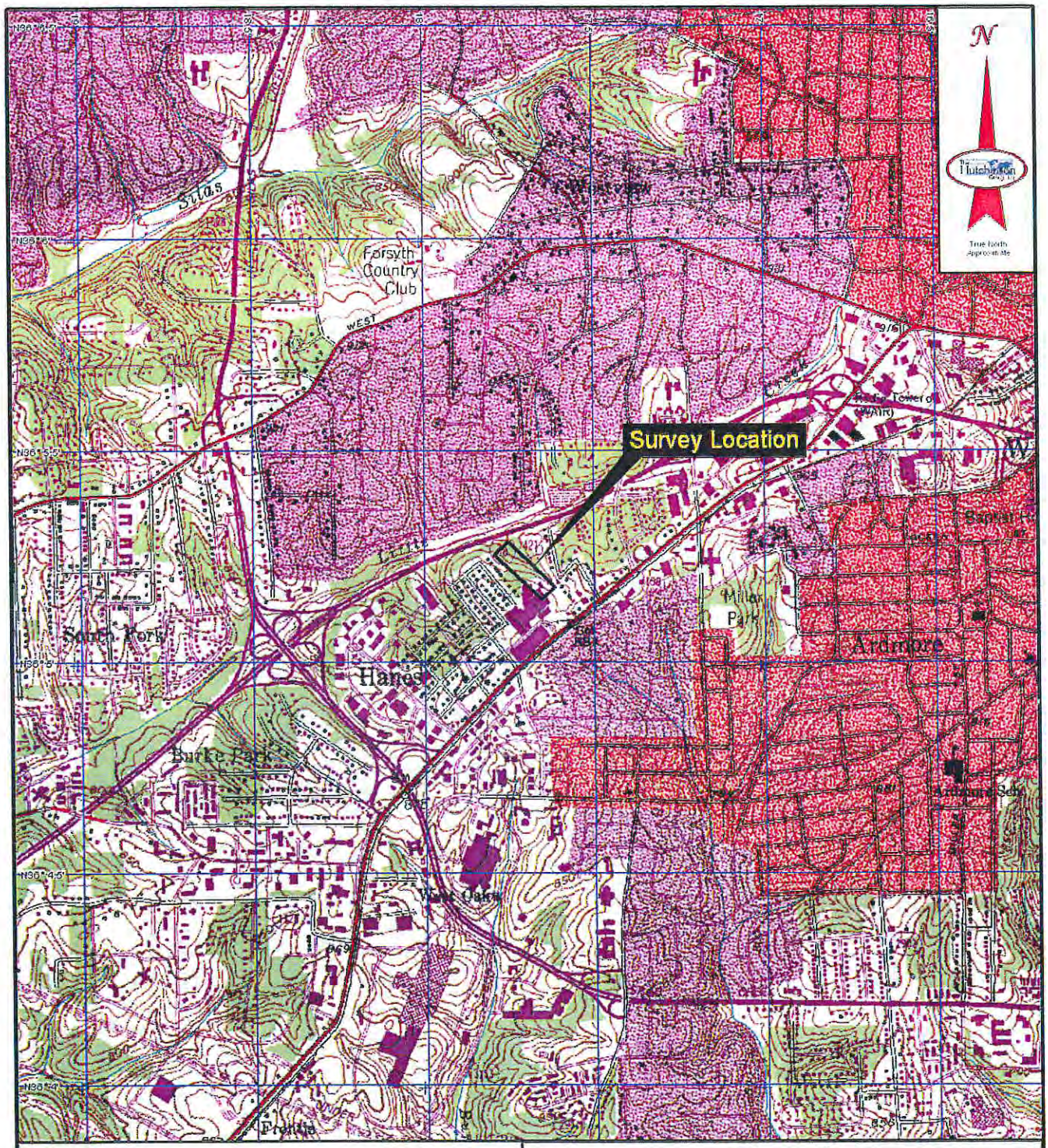

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Contour Interval = 20 feet

0 ft 1000 ft 2000 ft 3000 ft 4000 ft 5000 ft

Figure 1
Site Location Map

Geophysical Investigation
Sara Lee Knit Products Facility
Winston-Salem, North Carolina

SCALE: 1:24,000	PROJECT NO.: 134-3721	DRAWING NO.: DWG3721F1
DATE : 6/7/07		
DRAWN BY: PJH	SOURCE: 1993 Winston-Salem West USGS 7.5 Minute Topographic Quadrangle	
CHECKED BY: PJH		

Legend

160 mS/m
140 mS/m
120 mS/m
100 mS/m
80 mS/m
60 mS/m
40 mS/m
20 mS/m
0 mS/m

Elevated Conductivity and/or Metal

Background

Notes

Geophysical survey conducted June 5, 2007 using Geonics EM-31 terrain conductivity meter.

Real-time positioning of data using fully integrated Trimble ProXRS global positioning system set to NAD 1983 US State Plane (North Carolina) coordinate system in feet.

Locations are approximate.

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DES	PJH	6/7/07
CHK	PJH	6/7/07
REV		
PROJ. MGR.	PJH	6/7/07

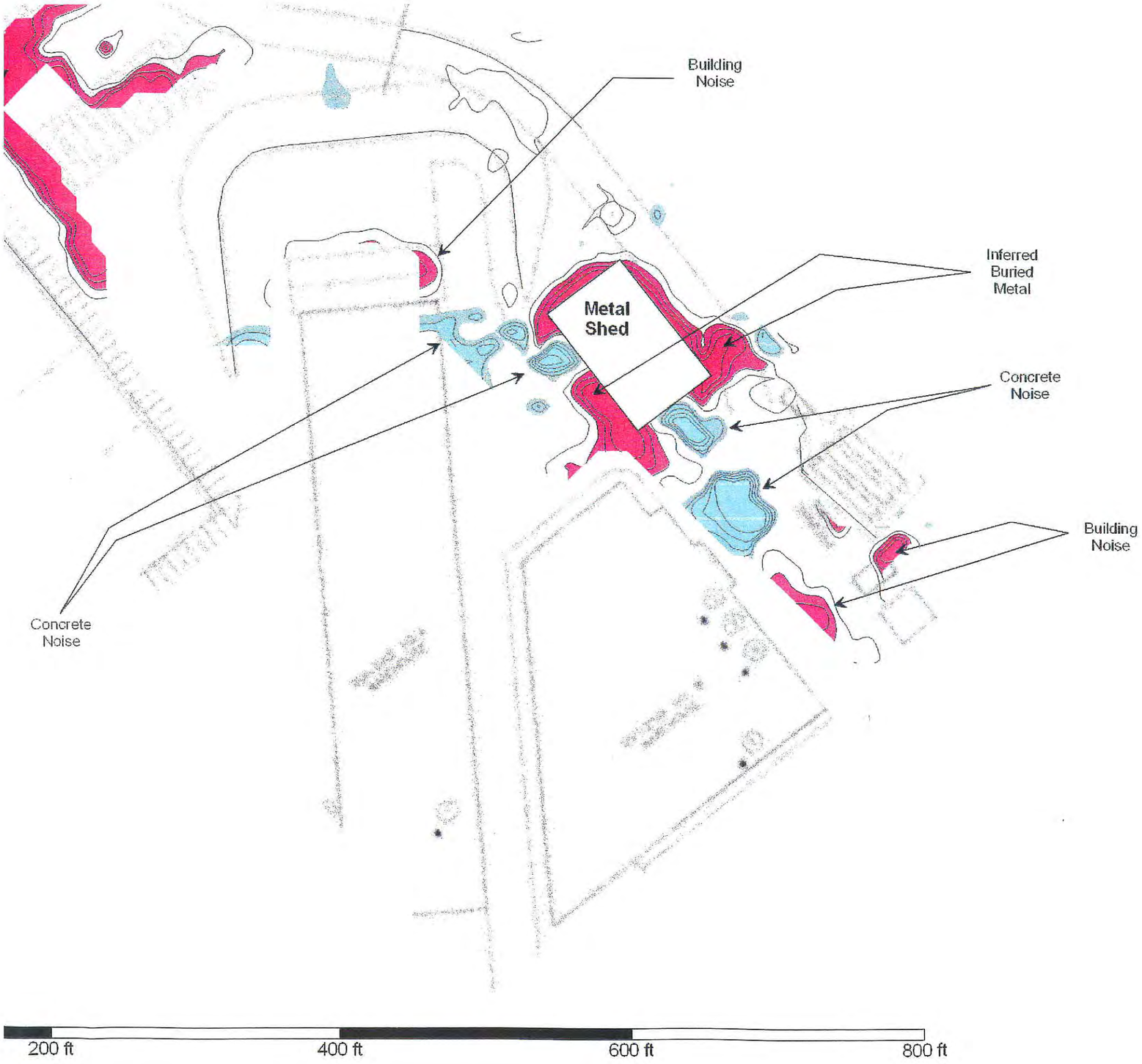
SCALE: 1 in = 75 ft

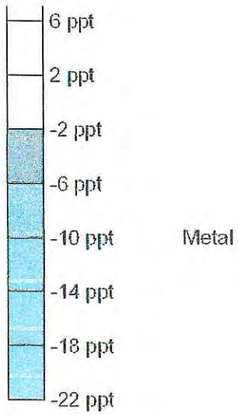
SOURCE: Sara Lee Knit Products, Engineering Div., April 23, 1996

PROJECT:
Geophysical Investigation
Sara Lee Knit Products Facility
Winston-Salem, North Carolina

DRAWING NO.:
Figure 2
Terrain Conductivity Map

Guardrail
Noise
Fence
Noise
Inferred
Buried
Metal
Metal
Shed
Building
Noise
Guardrail
Noise





Notes

Geophysical survey conducted June 5, 2007 using Geonics EM-31 terrain conductivity meter.

Real-time positioning of data using fully integrated Trimble ProXRS global positioning system set to NAD 1983 US State Plane (North Carolina) coordinate system in feet.

Locations are approximate.

Legend

Unknown Utility

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DES	PJH	6/7/07
CHK	PJH	6/7/07
REV		
PROJ. MGR.	PJH	6/7/07

SCALE: 1 in = 75 ft

SOURCE: Sara Lee Knit Products, Engineering Div., April 23, 1996

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PROJECT: Geophysical Investigation
Sara Lee Knit Products Facility
Winston-Salem, North Carolina

DRAWING NO.: **Figure 3**
In-Phase Terrain Conductivity Map (Metals Map)

PROJECT NO.: 134-3721

SHEET TITLE: DWG3721F3

Fence Noise
Truck Noise
Concrete Noise
Building Noise
Metal Shed
Inferred Buried Metal
Concrete Noise
Bu
N
0 ft
200 ft
400 ft
600 ft
800 ft

N

True North
Approximate

Legend

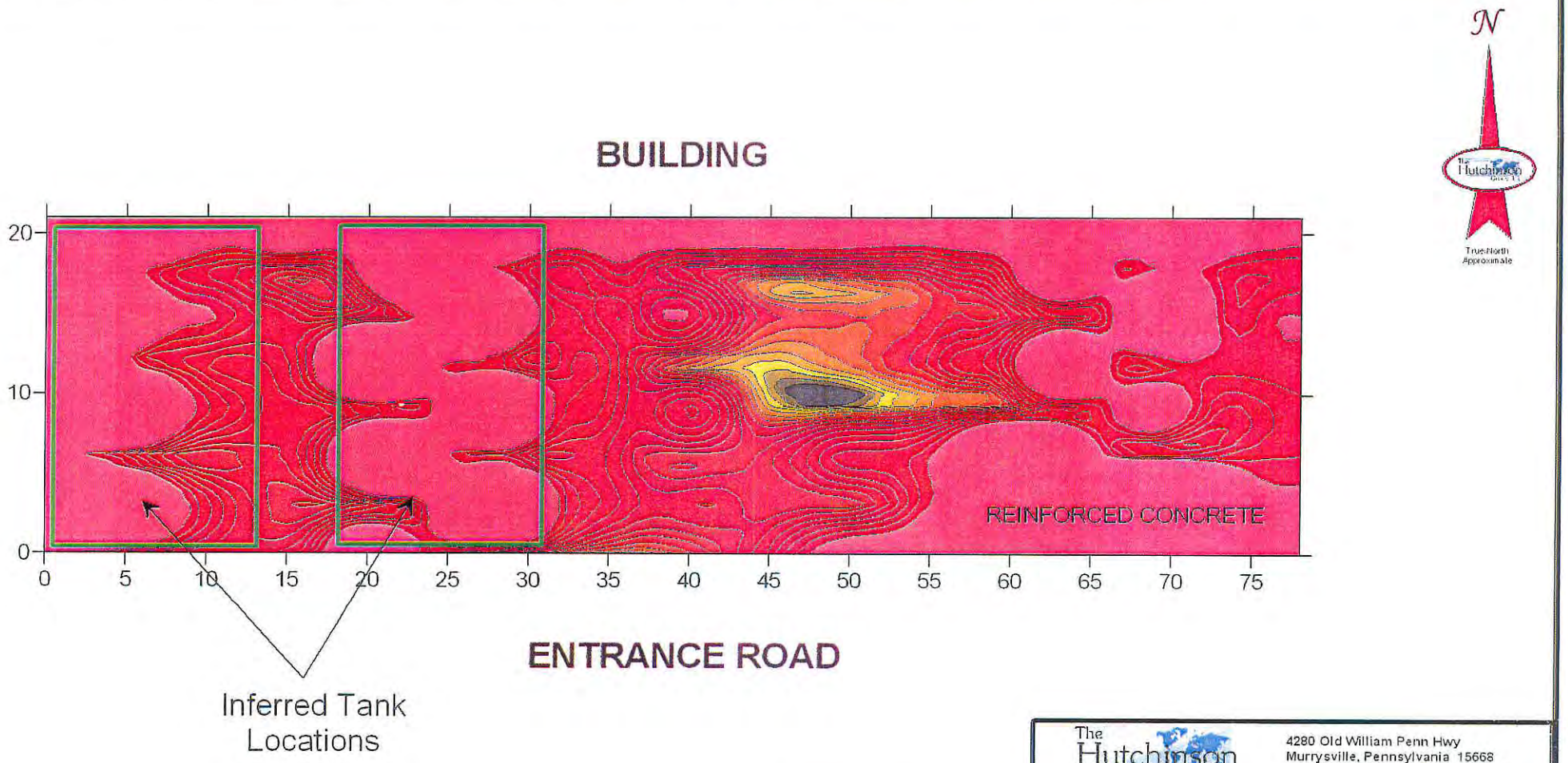
18 ppt	
14 ppt	Metal
10 ppt	
6 ppt	
2 ppt	
-2 ppt	
-6 ppt	
-10 ppt	Metal
-14 ppt	
-18 ppt	
-22 ppt	

Notes

Geophysical survey conducted June 5, 2007 using Geonics EM-31 terrain conductivity meter.

Real-time positioning of data using fully integrated Trimble ProXRS global positioning system set to NAD 1983 US State Plane (North Carolina) coordinate system

Truck
Noise
Fence
Noise
Truck
Noise
Building
Noise
Metal
Shed
Inferred
Buried
Metal
Concrete
Noise
Buildin
Noise
Concrete



Legend

Inferred UST

Notes

Geophysical survey conducted June 5, 2007 using Geonics EM-61 time-domain electromagnetic conductivity meter.

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DES	PJH	3/1/06
CHK	PJH	3/1/06
REV		
PROJ. MGR.	PJH	3/1/06

SCALE: 1 in = 75 ft

SOURCE: Sara Lee Knit Products, Engineering Div., April 23, 1996

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Winston-Salem, North Carolina

DRAWING NO.: **Figure 4**
Peak Differential Response Map

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