Electromagnetic and Magnetic Surveys of a Former Manufactured Gas Plant

Binghamton, NY

New York State Electric and Gas Corporation
Contract Number 99-008
Geophex Job Number 928

submitted to:

New York State Electric and Gas Corporation
P. O. Box 5224
Corporation Drive, Kirkwood Industrial Park
Binghamton, NY 13902

Headquarters

Geophex, Ltd.
605 Mercury Street
Raleigh, NC 27603-2343

Tel: (919) 839-8515
Fax: (919) 839-8528
Website: www.geophex.com
Email: geophex@geophex.com

Other Locations:

Boston, MA
Tel: (508) 393-4600
Fax: (508) 393-7674

Macon, GA
Tel: (912) 929-2827
Fax: (912) 929-2479

Atlanta, GA
Tel: (404) 888-0123
Fax: (404) 888-0121

Arlington, VA
Tel: (703) 548-5300
Fax: (703) 548-5350

July 1998

Geophex, Ltd.
terram et mare exploramus

Geophex, Ltd.
605 Mercury Street
Raleigh, NC 27603-2343
Tel: (919) 839-8515
Fax: (919) 839-8528

July 13, 1999

Ms. Chris Hebdon
New York State Electric and Gas Corporation
P. O. Box 5224
Corporation Drive, Kirkwood Industrial Park
Binghamton, NY 13902

Phone (607) 762-8877
Fax (607) 762-8407

Reference: Contract Number 99-008
Geophex Job Number 928

Subject: Electromagnetic and magnetic surveys of a former manufactured gas plant in Binghamton, NY.

Dear Ms. Hebdon:

Enclosed is our Final Report for the subject project. Thank you for selecting Geophex to conduct the geophysical investigation. We are open to suggestions for improving and, if necessary, revising the report.

We look forward to continuing our working relationship with NYSEG.

Sincerely,

Craig Murray
Project Manager

Electromagnetic and magnetic surveys of a former manufactured gas plant in Binghamton, NY.

Executive Summary

New York State Electric and Gas Corporation (NYSEG) contracted Geophex, Ltd. to demonstrate innovative geophysical technologies for the site characterization of a former manufactured gas plant in Binghamton, NY. Geophex conducted electromagnetic (EM) and magnetic surveys over the Binghamton site from May 11 to May 13, 1999 in accordance with the Technology Capability Evaluation Plan dated April 29, 1999.

The objective of the geophysical investigation was to identify and delineate subsurface features associated with the former manufactured gas plant. Geophex used the EM and magnetic techniques to locate old foundations, utilities, pipes, fill areas, concrete pads, and other buried objects that might be connected to the manufactured gas plant operations.

Both the EM and magnetic surveys located several subsurface objects that appear to be connected to the manufactured gas plant facility. Figures 3 to 8 present the EM data and Figure 9 presents the magnetic data. Four gas holders, five concrete pads, several utilities, and multiple point anomalies of unknown origin were located using the geophysical data. Figure 10 shows Geophex's interpretation of the locations of these items.

Table of Contents

List of Figures

List of Appendixes

1.0 Introduction

On May 11 through 13, 1999 Geophex, Ltd. conducted a geophysical survey of a former manufactured gas facility at the corner of Court Street and NY Highway 7 in Binghamton, NY. A map showing the surveyed area, the property line and other visible site features is presented in Figure 1.

The objective of the geophysical investigation was to identify and delineate subsurface features associated with the former manufactured gas plant. Geophex used the EM and magnetic techniques to locate old foundations, utilities, pipes, fill areas, concrete pads, and other buried objects that might be associated with the manufactured gas plant operations.

2.0 Geophysical Survey Methods

Geophex utilized electromagnetic (EM), and magnetic geophysical methods to characterize the material beneath the site. Both methods were directed at identifying anomalies that might be caused by subsurface structures.

Geophex acquired electromagnetic data using the GEM-2 and GEM-2H sensor. The GEM-2 and the larger GEM-2H are hand-held, digital, broadband EM sensors that were developed at Geophex (Figure 2a). The sensors exploit the relationship between electric fields, magnetic fields, and electrical current to detect changes in subsurface conductivity. Electrical conductivity is an inherent property of a material to conduct electrical current and can be used to characterize near-surface geological material efficiently.

For this survey the GEM sensors recorded the two components (in-phase and quadrature) of each of three frequencies (1,050 Hz, 7,290 Hz and 18,270 Hz) resulting in six datasets. In general, the in-phase component responds to metallic objects while the quadrature component responds to non-metallic or geologic targets. Appendix A presents additional information on the EM method.

Geophex acquired magnetic data using a cesium-vapor magnetometer, Model G-858, which is manufactured by Geometrics (Figure 2). The G-858 magnetometer has a resolution of 0.1 nano-tesla (nT). Magnetic surveys identify local deviations in the Earth's magnetic field. These local deviations result from targets that possess high magnetic susceptibilities, such as steel or other iron-bearing materials. Appendix B contains additional information on the magnetic method.

3.0 Data Acquisition, Processing and Presentation

Both the GEM-2 and the GEM-2H sensors were used over the designated geophysical test area in several coil orientations to determine which instrument was more applicable to this site characterization. The GEM-2H is capable of deeper penetration, but sacrifices lateral resolution. After comparing the results from each instrument in the field, the GEM-2 was selected to cover the entire site with horizontal transmitter and receiver coils (Figure 2a; Appendix D).

Geophex personnel created an orthogonal survey grid with edges parallel to the western boundary of the geophysical test area (Figure 1). Geophex collected EM and total field magnetic data by traversing the survey area along parallel tracklines spaced two and a half feet apart. Three test profile lines were also collected as described in the Technology Capability Evaluation Plan and are included as Appendix C.

Following each survey, we downloaded the data to a laptop computer in the field for immediate processing. We assigned spatial (i.e., x,y) coordinates to each sensor reading using standard dead-reckoning procedures. The data was originally located in a local coordinate system, then converted into NY state planar coordinates based on GPS data collected at several locations on the site. We imported the data into Surfer© (Version 6.0) to produce color contour plots of each data set. Figures 3 through 8 present color-contour maps for EM data. Figure 9 presents a map of the total field magnetic data.

4.0 Survey Results and Conclusions

The EM and magnetic surveys covered all accessible portions of the site. The white areas in Figure 1 were inaccessible due to surface obstacles such as the three PVC pipes storage areas in the southwest and the two roll-off boxes in the northern and eastern parts of the site. Smaller above ground metal objects (e.g. wells) caused EM and magnetic anomalies, but these effects were very localized and can easily be differentiated from the geophysical anomalies caused by subsurface objects.

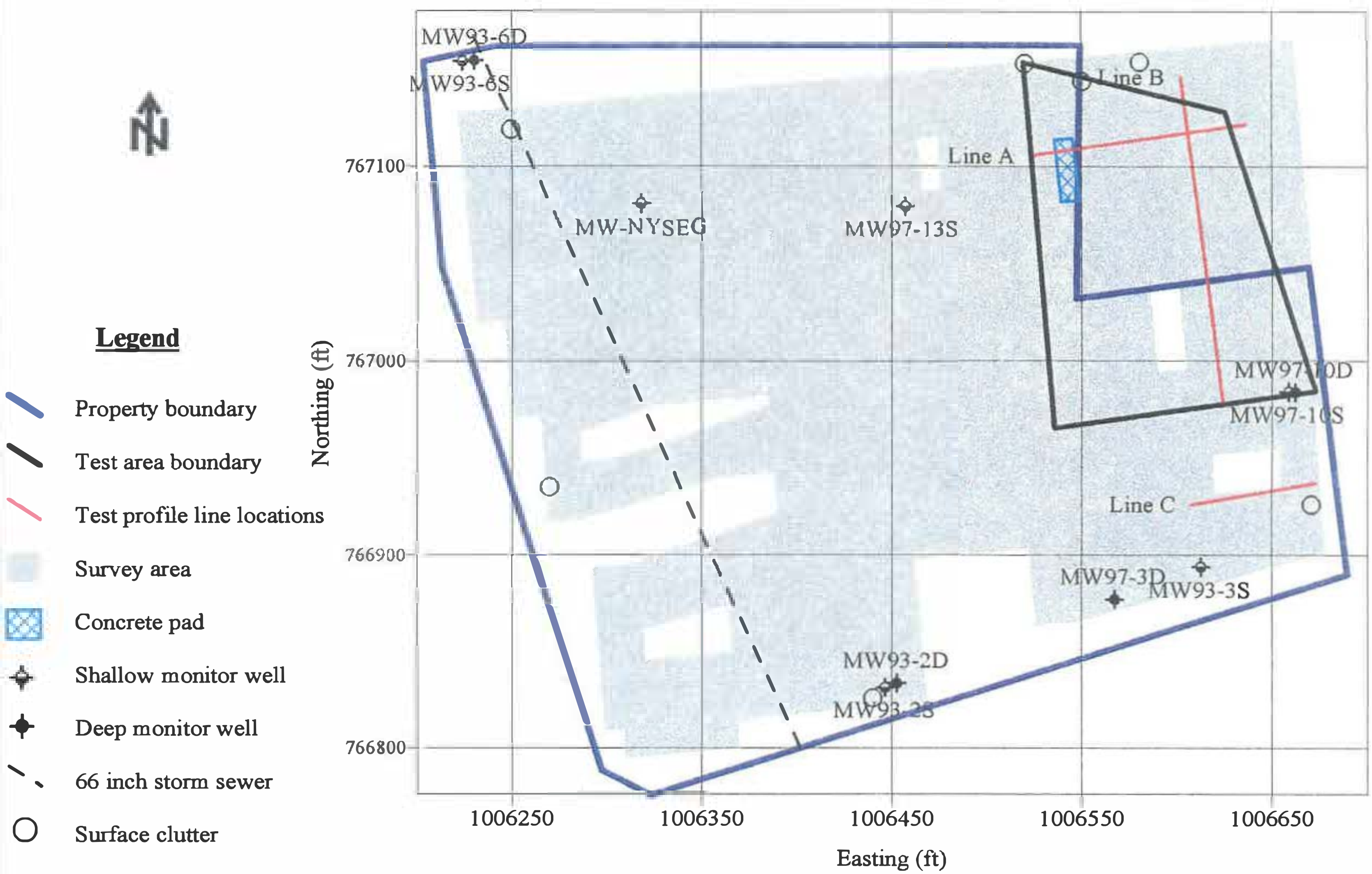
Several linear anomalies are visible in the GEM-2 1,050 Hz in-phase data (Figure 3). In the western part of the site, a northwest-southeast magnetic anomaly corresponds to the known location of a 66-inch sewer line, while the EM anomaly caused by the sewer line is displaced 10 to 15 feet to the east. We believe that the sewer line is actually located beneath the EM anomaly and that the magnetic anomaly is offset because of the inclination of the earth's magnetic field. Gas lines connected to the gas control building are most likely the cause of several linear conductivity highs in the southeastern part of the site. The additional linear anomalies north of the gas control building are probably either utilities serving the Columbia Gas building east of the site, or older pipes remaining from the manufactured gas plant. All of these linear anomalies are shown as light blue lines in Figure 10.

Many small point geophysical anomalies are present over the site. Metal objects on the surface cause many of these anomalies, but several appear to be isolated, subsurface, metallic objects, shown as red crosses in Figure 10. Five rectangular negative anomalies are visible in purple in all of the in-phase maps. Two of these are in the same location as reinforced concrete pads visible on the surface, and the other three are likely due to similar steel reinforcing in shallow buried concrete pads.

One of the major goals of the geophysical survey was to locate any foundations remaining from the former manufactured gas plant. Figure 11 is a transparency of the historic site map supplied by NYSEG at the same scale as the maps in Figures 3 to 10. Anomalies appearing to be caused by the foundations of the four circular gas-holders on the historical map can be seen in the EM and magnetic data.

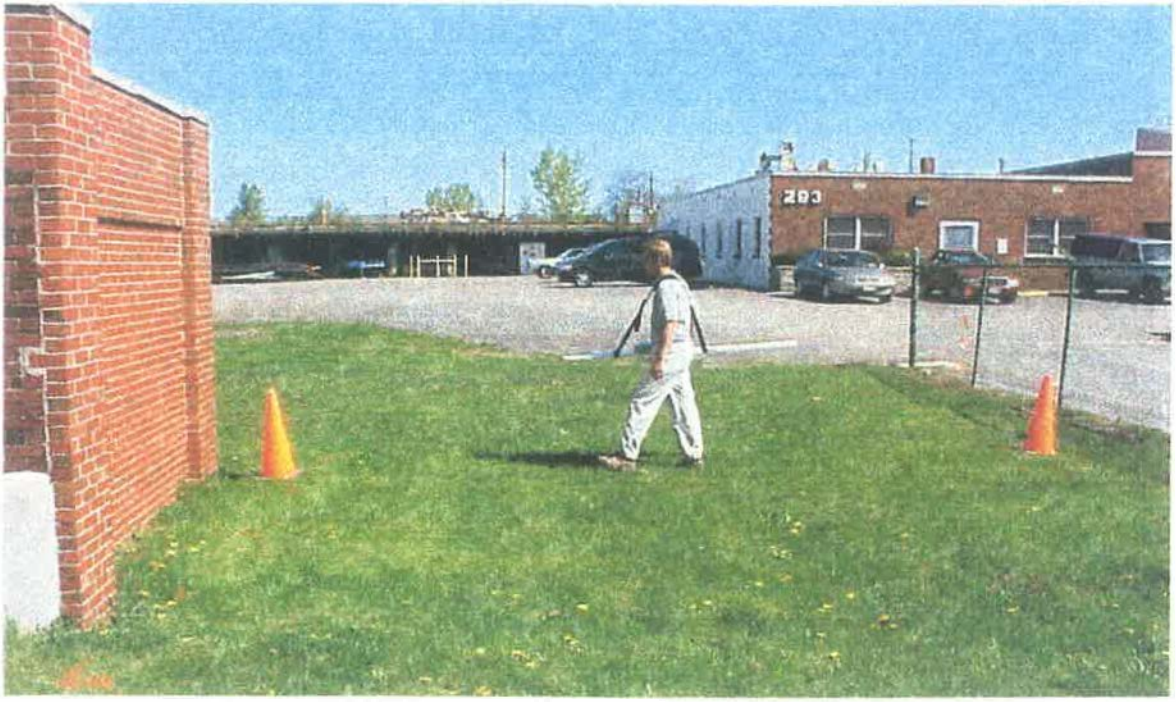
The four gas holders appear in different EM data sets. The eastern holder (Number 1) is best defined in the 1,050 Hz in-phase map (Figure 3), while the western holder (Number 4) is most evident in the 18,270 Hz quadrature map (Figure 8). This suggests that the remaining foundation of holder 1 is ferrous (e. g. steel), while a non-metallic (e. g. concrete) ring of material is present under the previous location of holder 4's walls. Holders 2 and 3 are also evident in the 18,270 Hz quadrature data set as low conductivity zones, possibly caused by compaction beneath the weight of the buildings or a less conductive fill material used beneath the previous locations of the buildings. In Figure 9, the magnetic field map, a metallic foundation component appears to remain at each of the holders' locations. The metallic foundation components are present throughout holder 1, in the southern third of holder 2, at the center of holder 3, and scattered around the edge of holder 4.

A diffuse high conductivity anomaly dominates the 7,290 Hz and 18,270 Hz quadrature maps on the east side of the sewer line (Figures 6 and 8). This feature is also present, but less pervasive, in the 1,050 Hz quadrature map, centered at coordinate (1006515, 766980). This anomalous high conductivity zone is most likely caused by higher conductivity gravel used as fill, higher soil moisture content, changes in soil stratigraphy, or a difference in groundwater chemistry.



Geophex

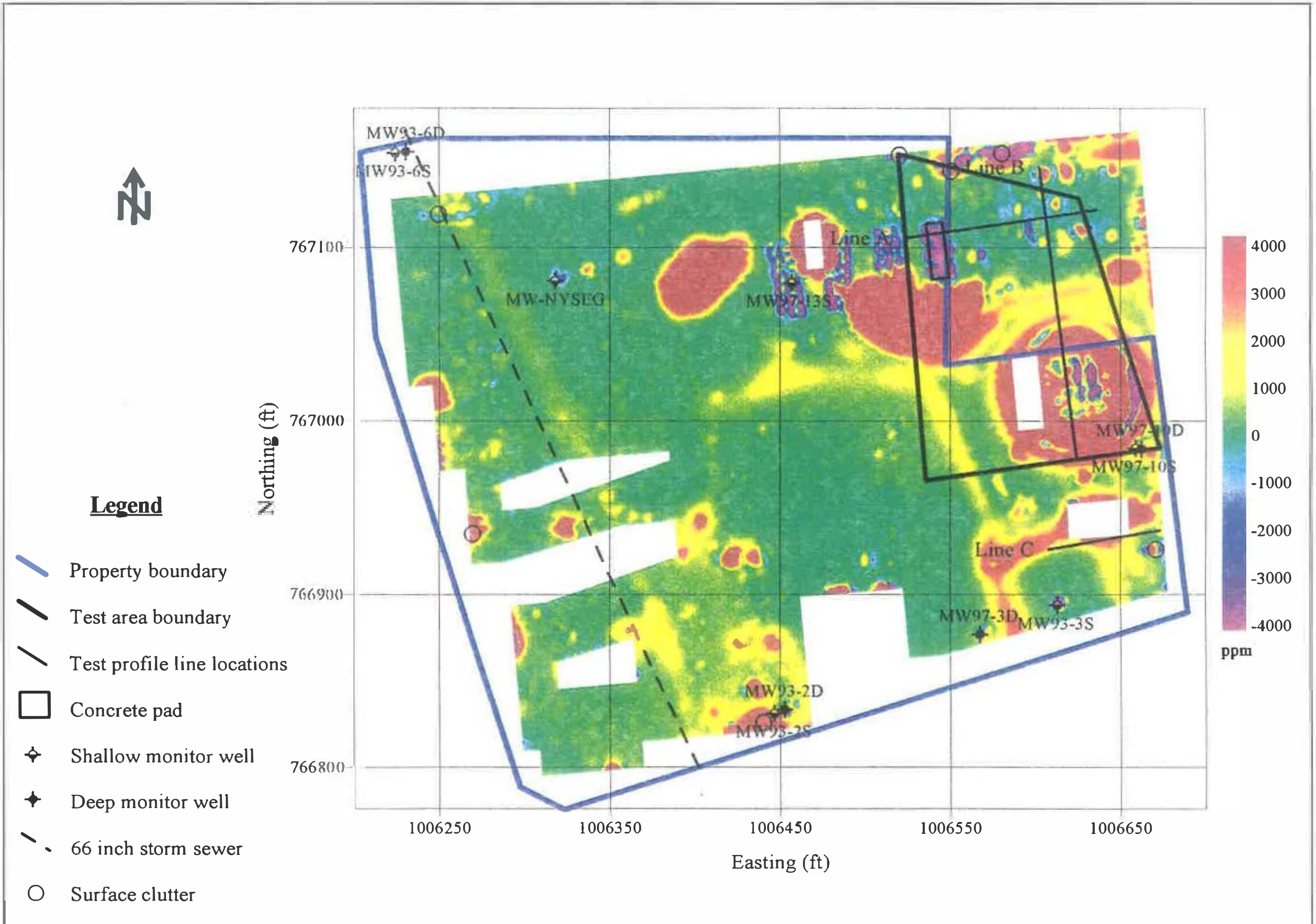
Figure 1. Survey Location and Surface Features



a) GEM-2 multi-frequency electromagnetic sensor.

b) G-858 magnetic sensor.

Figure 2. Photographs of geophysical equipment used for the site characterization.

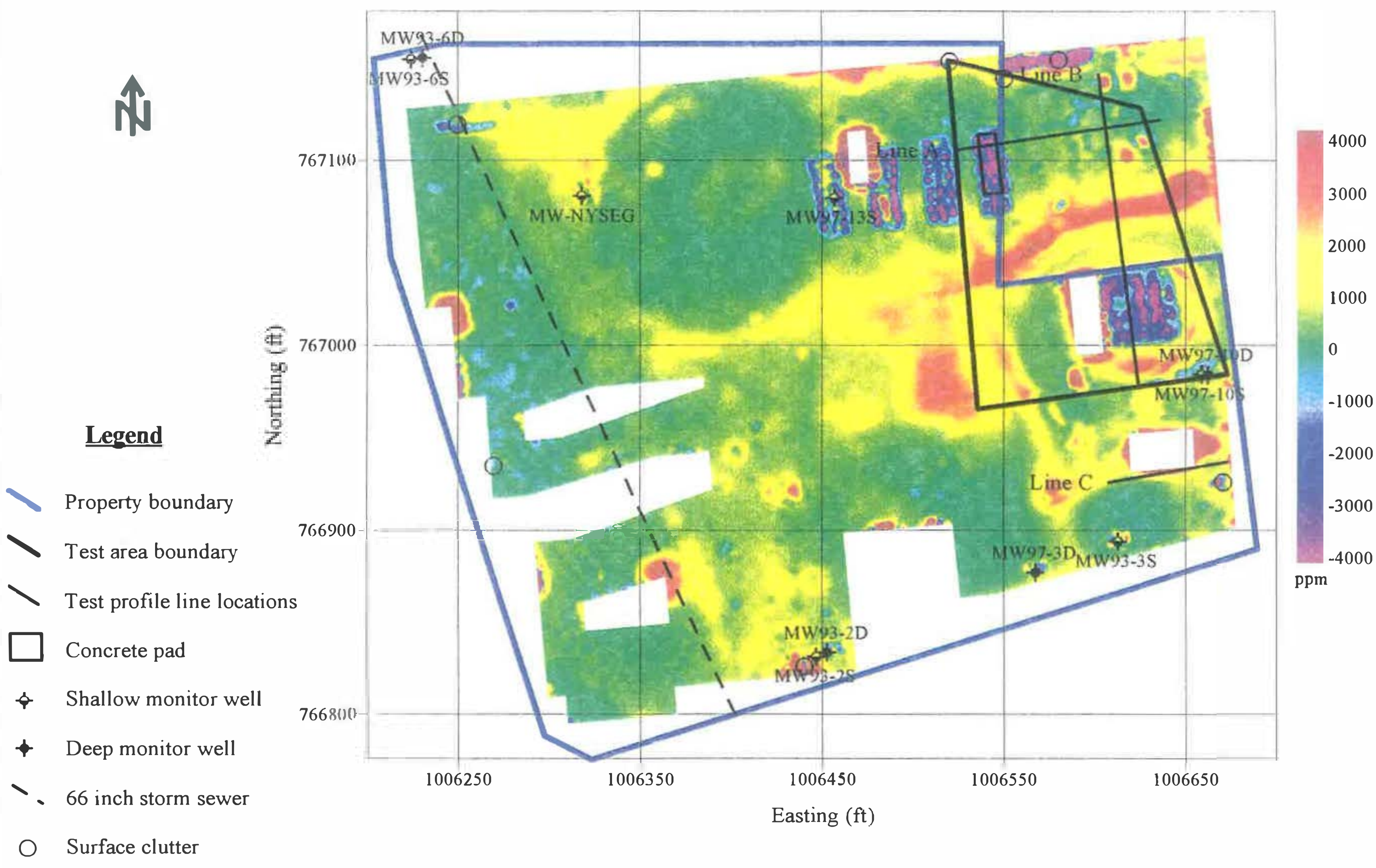


Geophex

Figure 3. GEM2 -1,050 Hz Inphase.

EM and Magnetic Survey, Binghampton NY
NYSEG (July 1999)

Geophex, Ltd.

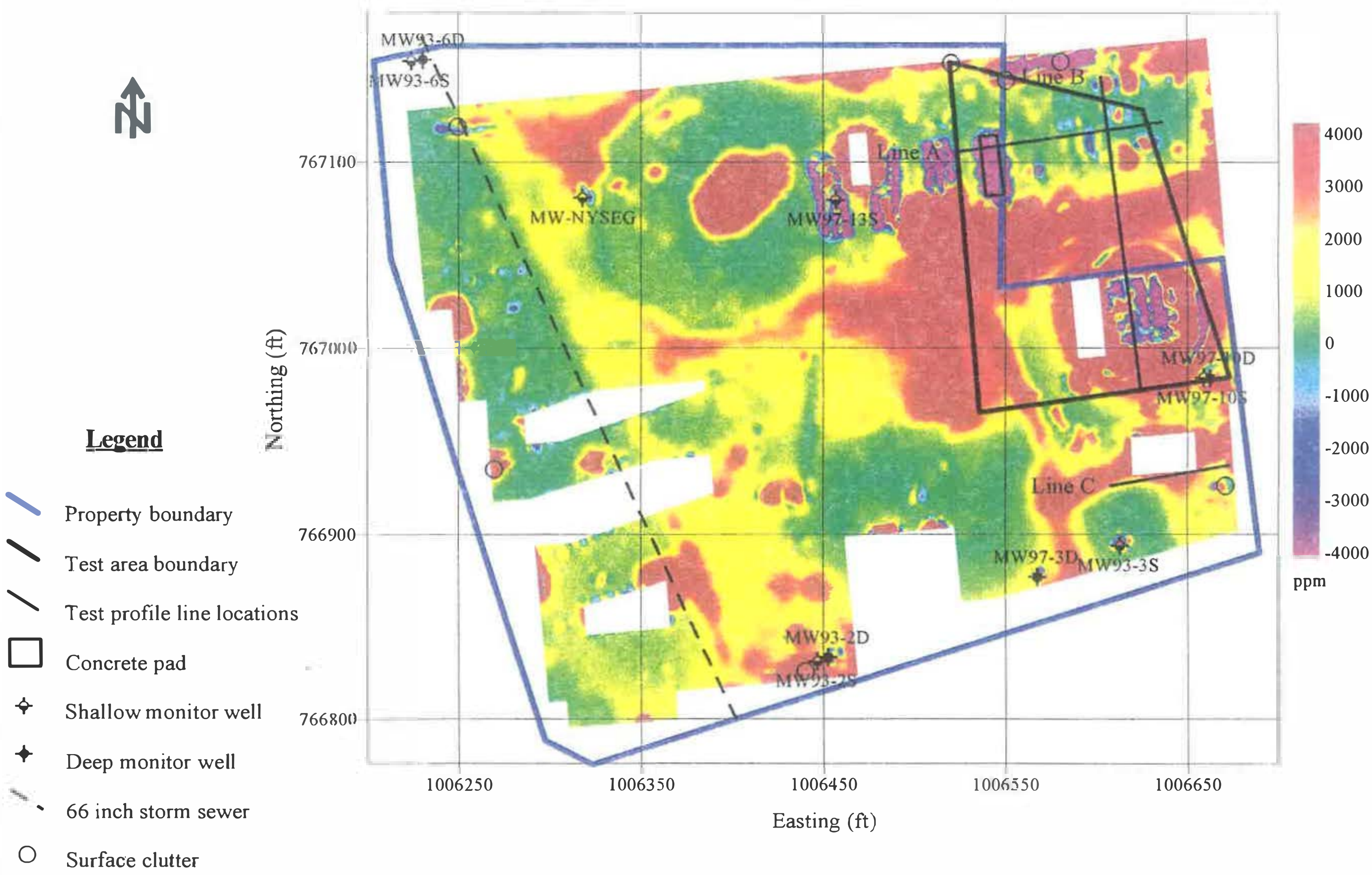


Geophex

Figure 4. GEM2 -1,050 Hz Quadrature.

EM and Magnetic Survey, Binghampton NY
NYSEG (July 1999)

Geophex, Ltd.

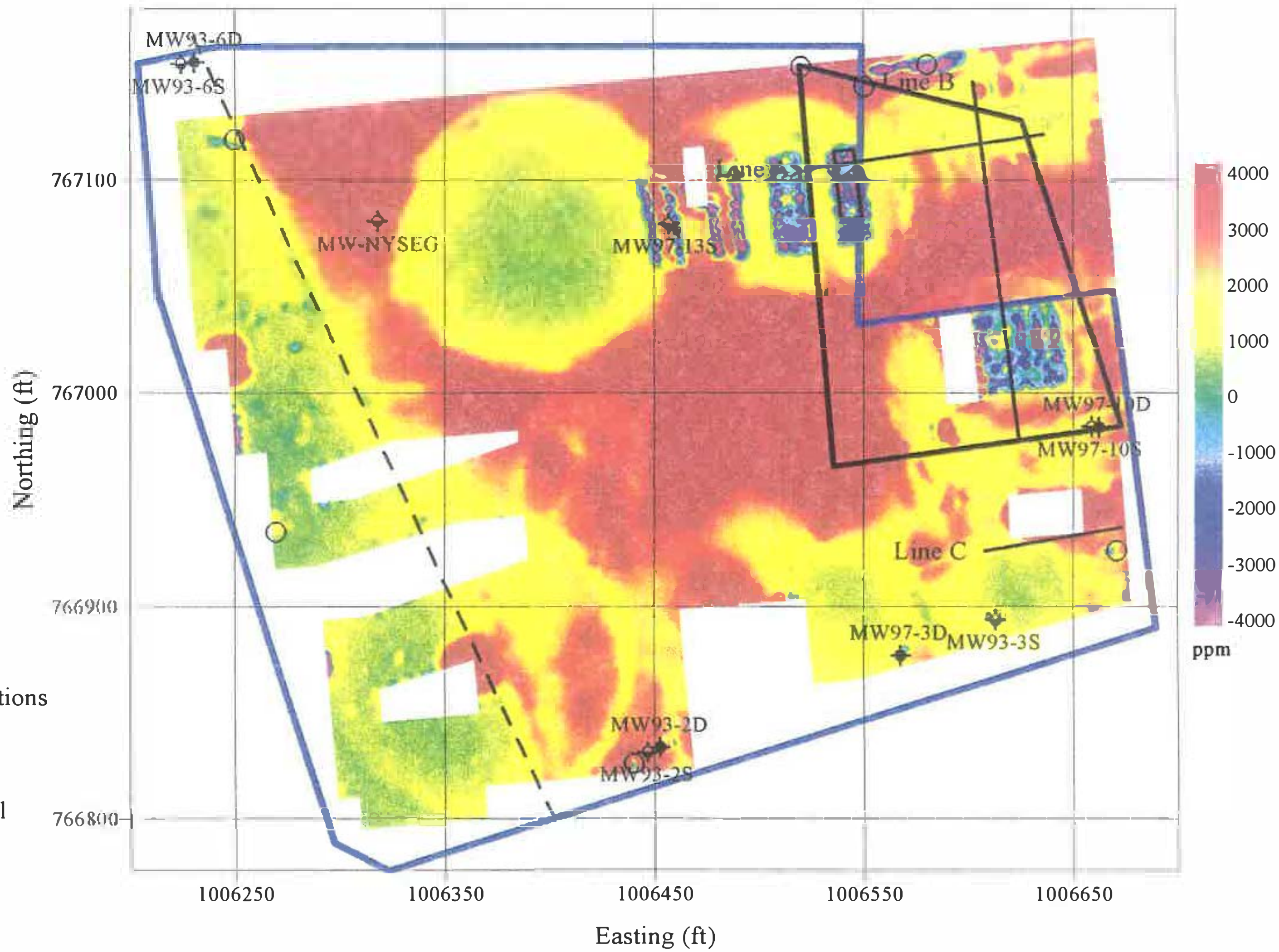


Geophex

Figure 5. GEM2 -7,290 Hz Inphase.

Geophex, Ltd.

EM and Magnetic Survey, Binghampton NY
NYSEG (July 1999)



Legend

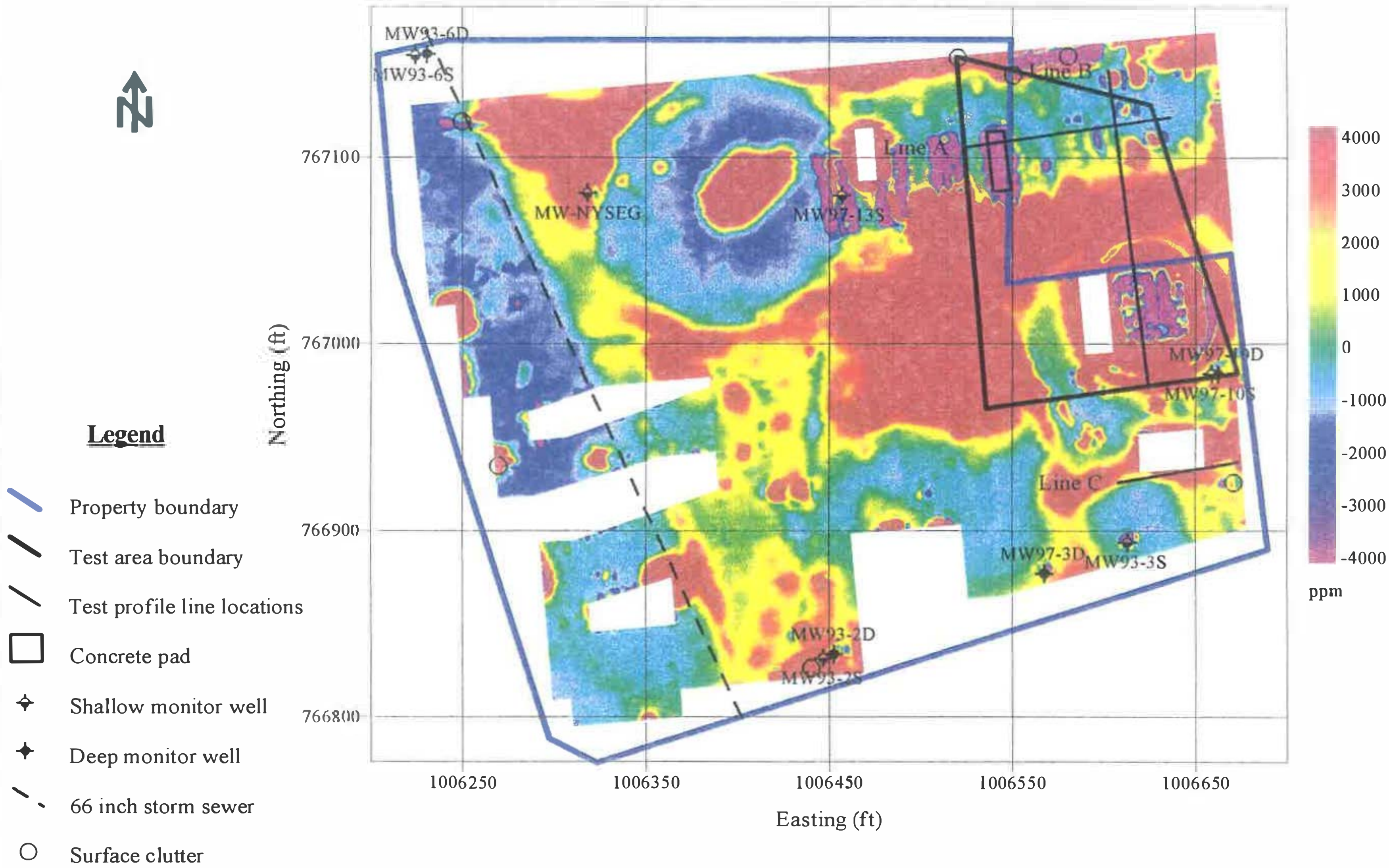
Property boundary
Test area boundary
Test profile line locations
Concrete pad
Shallow monitor well
Deep monitor well
66 inch storm sewer
Surface clutter

EM and Magnetic Survey, Binghampton NY
NYSEG (July 1999)

Geophex, Ltd.

Geophex

Figure 6. GEM2 -7,290 Hz Quadrature

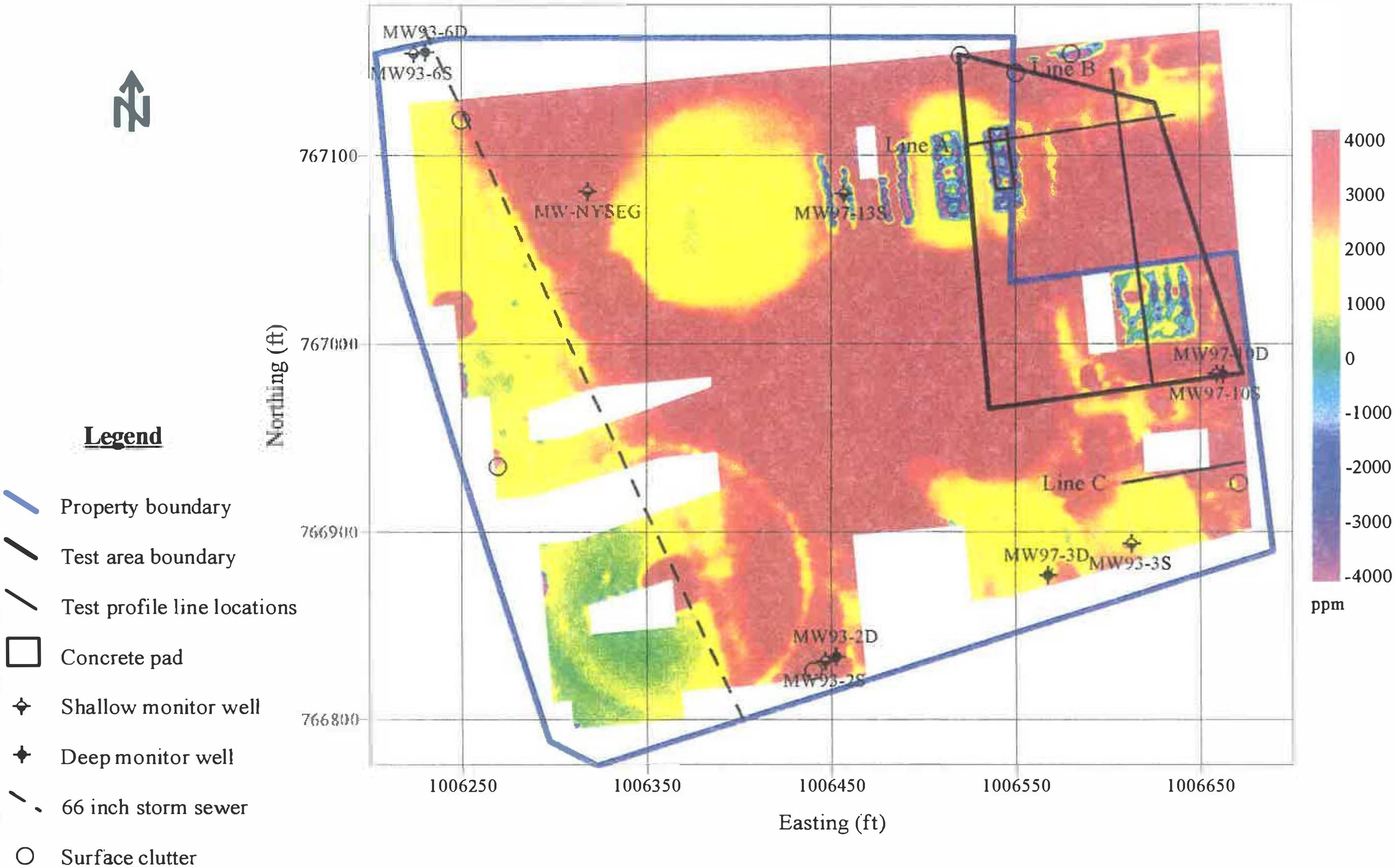


Geophex

Figure 7. GEM2 -18,270 Hz Inphase.

EM and Magnetic Survey, Binghampton NY
NYSEG (July 1999)

Geophex, Ltd.

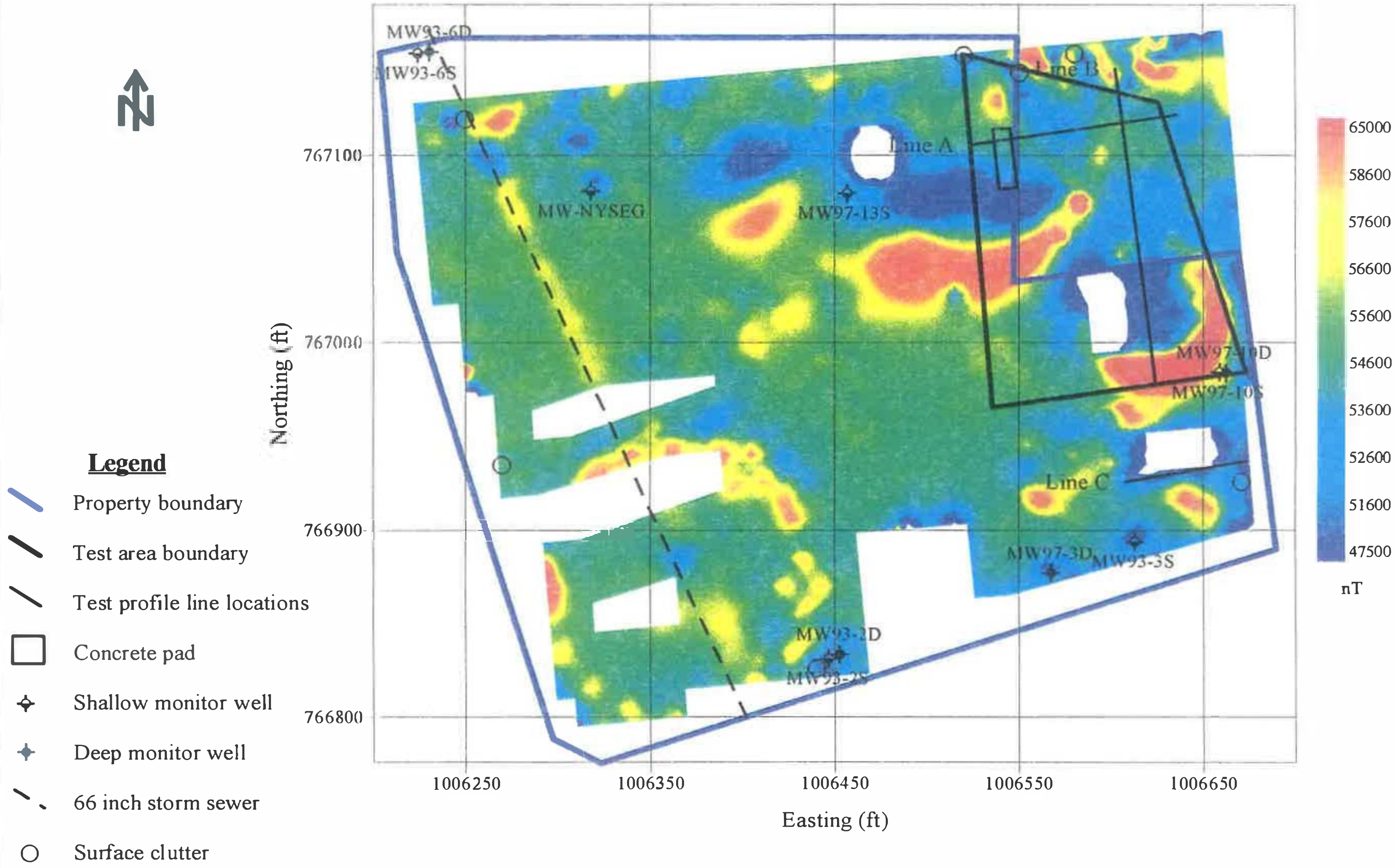


Geophex

Figure 8. GEM2 - 18,270 Hz Quadrature.

Geophex, Ltd.

EM and Magnetic Survey, Binghampton NY
NYSEG (July 1999)

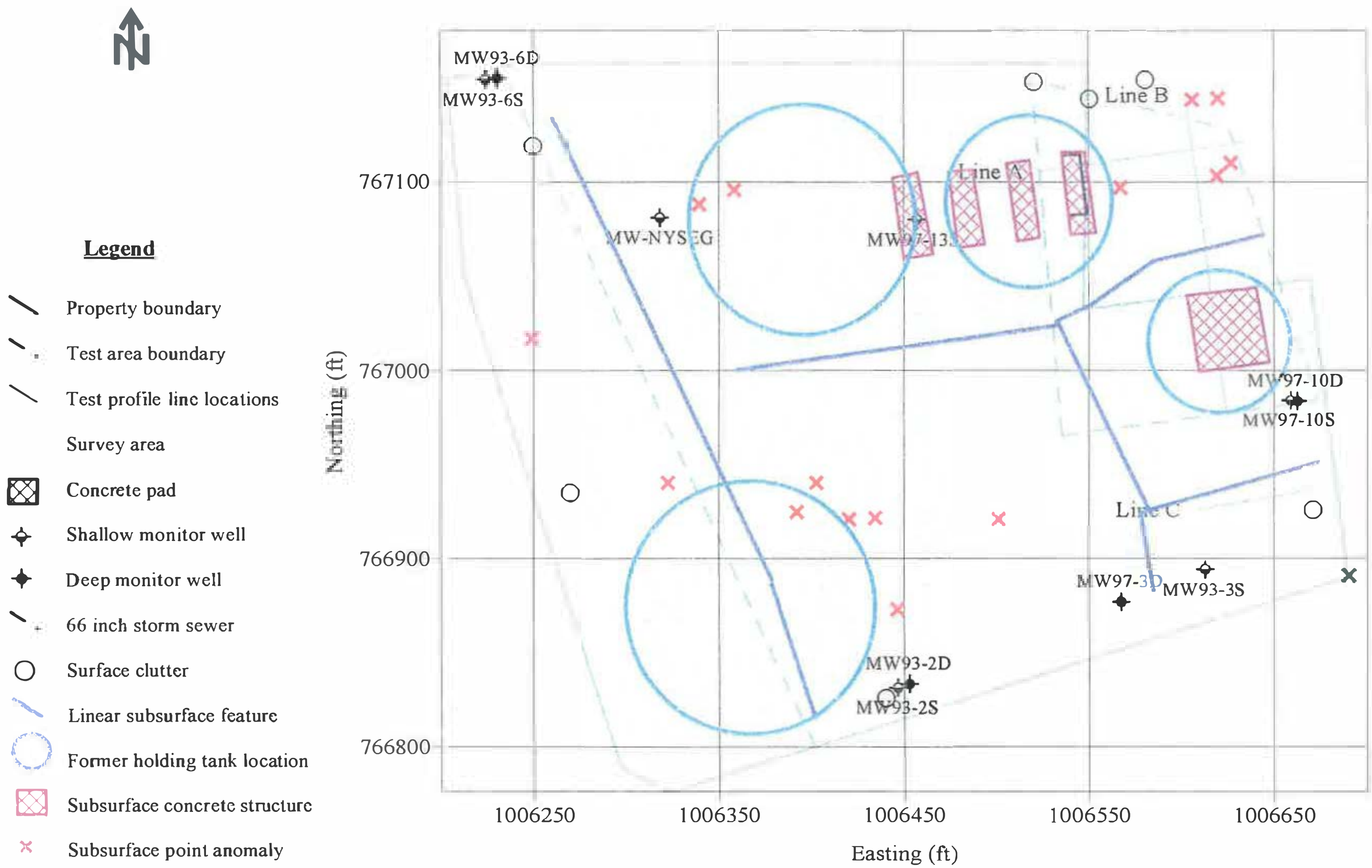


Geophex

Figure 9. Total Magnetic Field

Geophex, Ltd

EM and Magnetic Survey, Binghampton NY
NYSEG (July 1999)



Geophex

Figure 10. Subsurface features based on Magnetic and EM data.

EM and Magnetic Survey, Binghampton NY
NYSEG (July 1999)

Geophex, Ltd.

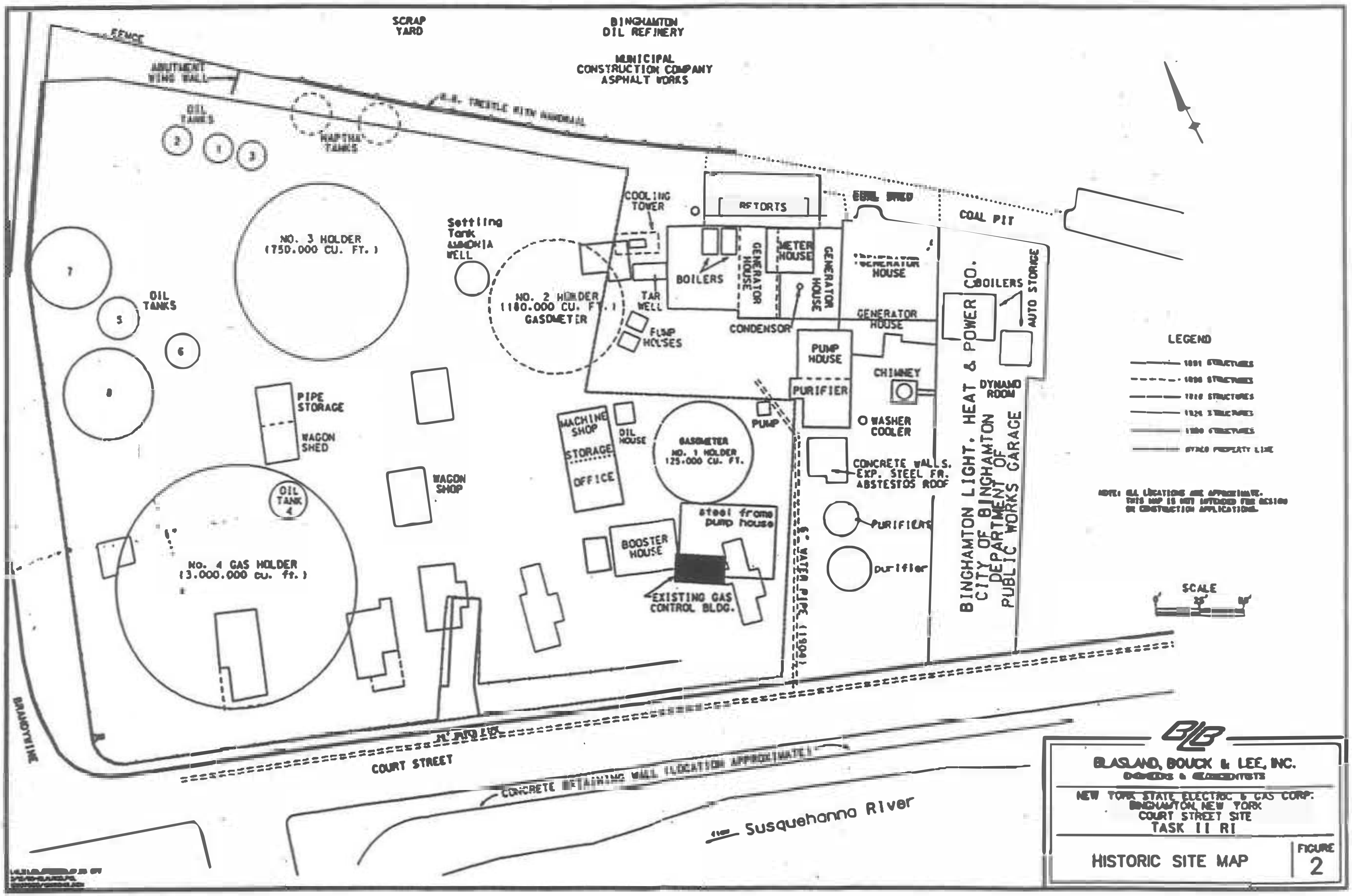


Figure 11. Historical site map.

Appendix A
Electromagnetic Method

Appendix A
Electromagnetic Method

The electromagnetic (EM) induction method, which is founded upon Maxwell's Equations (the relationship between electric fields, magnetic fields and electric current), characterizes the electrical conductivity of the subsurface and can be used to characterize shallow geological conditions. Electrical conductivity is an inherent property of a material to conduct electrical current. Variations in shallow earth conductivity can result from changes in soil moisture content, groundwater constituents (contamination), and lithological properties, as well as buried man-made materials. The primary application of EM surveys in site assessments are for:

- Searching for waste pits and trenches,
- Determining boundaries of landfills and other burial sites,
- Delineating leachate plumes,
- Locating buried drums, USTs, and other isolated metallic objects, and
- Detecting buried unexploded ordnance (UXO).

The EM method involves exciting the ground material with a primary, time-varying, electromagnetic field of one or more frequencies, and recording perturbations of the normal field that result from secondary eddy currents induced in conducting bodies at or beneath the surface. The primary field is typically established, in practice, by passing an alternating current through a small coil (i.e., the transmitter coils). The intensity of the induced eddy currents in the subsurface is a function of the ground conductivity and is measured by the receiver coil. The receiver generally consists of one or more coils, suitably arranged and connected to a data logger. Field efficient EM instruments, such as the Geophex Electromagnetic (GEM) sensor (Figure A-1; Won et al., 1996), combine the transmitter, receiver, and processing electronics (data logger) into a single, lightweight, man-portable instrument.

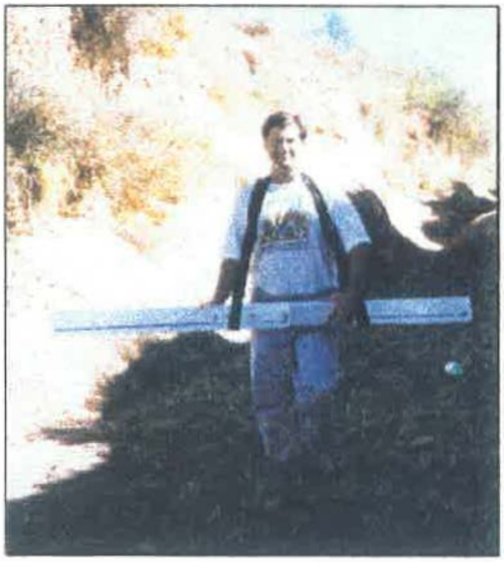


Figure A-1. Photograph of the Geophex Electromagnetic (GEM-2) instrument during a site characterization study.

The primary advantage of electromagnetic induction sensors for detection of shallow man-made targets is that these sensors are sensitive to either ferrous or nonferrous (e.g., aluminum, copper, iron, steel) metals. The electromagnetic induction sensor can be used in conjunction with magnetic surveys for enhanced detection.

Figure A-2, adapted from Won (1980), shows ranges of conductivity for typical earth materials and the relationship between transmitter frequency and the skin depth (i.e., the maximum depth of exploration). In general, sediments and sedimentary rocks have higher conductivity than igneous or metamorphic rocks. Clay, owing to its electrolytic interaction with water, exhibits high conductivity, while typical sand shows relatively low conductivity.

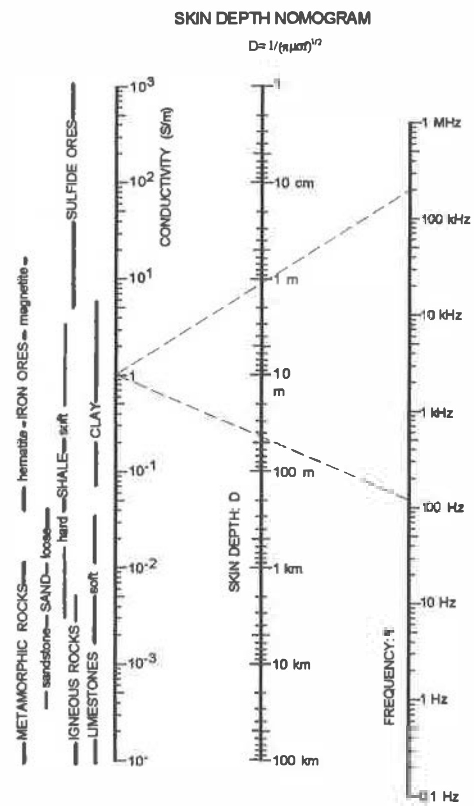


Figure A-2. Nomogram showing the relationship between transmitter frequency, ground conductivity, and depth of penetration. Magnetic permeability, μ, is assumed to be that of the free space. (From Won, 1980. Courtesy: Society of Exploration Geophysicists.)

The electromagnetic induction method can be used to target different depths of interest. The effective depth of exploration can be varied by changing either: 1) the spacing between transmitter and receiver coils, or 2) the frequency of the transmitted field (Patra and Mallick, 1980). The first method is known as *geometrical sounding* and involves recording data using several transmitter-receiver coil spacings at a fixed location; the depth of exploration increases with the coil spacing. The two coils systems (e.g., EM-24 by Geonics), although typically connected by an umbilical cord, are physically separate and thus require two field operators.

The second method is known as *frequency sounding* and involves changing the transmitter frequency, but keeping the transmitter-receiver coil constant (Figure A-3). The depth of exploration is inversely proportional to the square root of the frequency: a low frequency signal travels far through a conductive earth and, thus, sees deep structures, while a high frequency signal can travel only a short distance and, thus, sees only shallow structures. Therefore, broadband parametric sounding is analogous to depth sounding and can be used to create a pseudo 3-D subsurface image (Won, 1983).

Frequency sounding possesses inherent advantages over geometric sounding for depth imaging because: 1) signal attenuation does not allow a signal of fixed frequency to penetrate much deeper than several skin depths, and 2) geometrical sounding averages laterally and thus decreases the resolution. Theoretical and practical discussions on these methods may be found in Grant and West (1965), Keller and Frischkneckt (1966), Kaufman and Keller (1983), and Nabighian (1988).

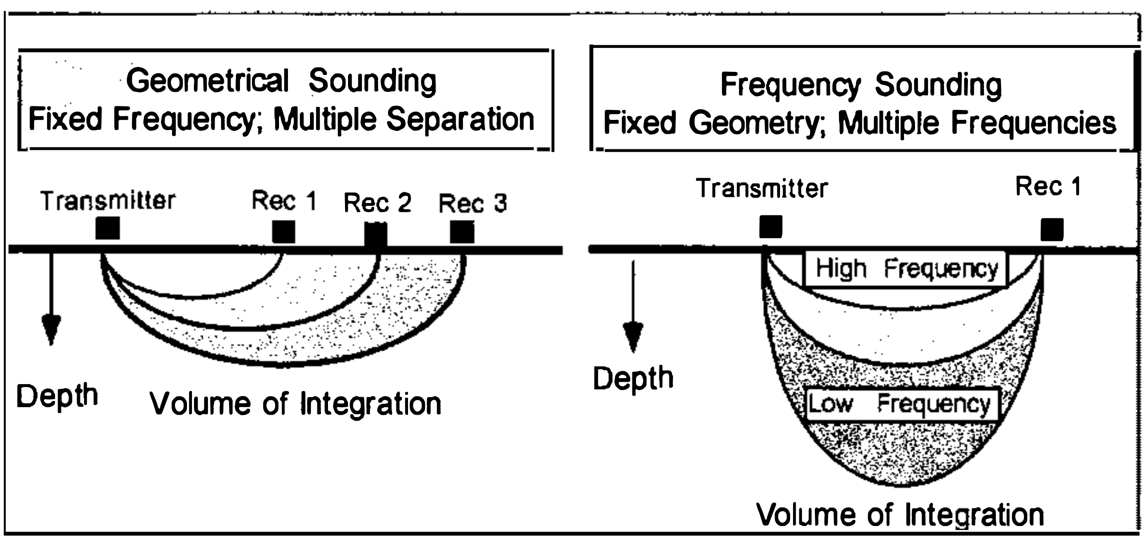


Figure A-3. Electromagnetic methods for depth sounding.

References

Grant, F. S., and West, G. F., 1965, *Interpretation Theory in Applied Geophysics*, McGraw-Hill, New York, 584 p.

Kaufman, A. A., and Keller, G. V., 1983, *Frequency and Transient Soundings*, Elsevier Publishing, Amsterdam, 685 p.

Keller, G. V., and Frischkneckt, F. C., 1966, *Electrical Methods in Geophysical Prospecting*, Pergamon Press, New York, 571 p.

Patra, H. P., and Mallick, K., 1980, *Geosounding Principles 2*, Elsevier Scientific Publishing Company, New York, 419 p.

Won, I. J., 1980, A wide-band electromagnetic exploration method; some theoretical and experimental results: *Geophysics*, v. 45, n. 5, p. 928-940.

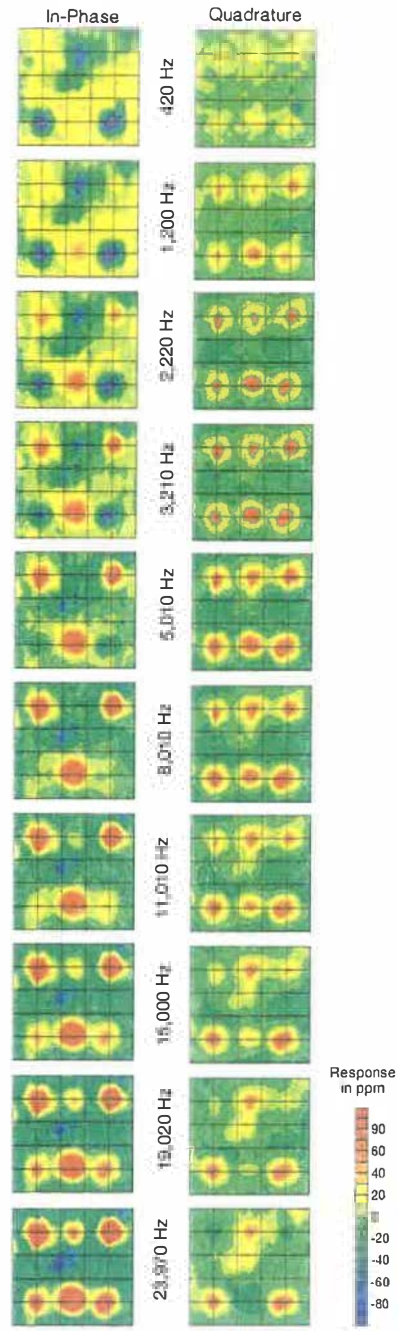
Won, I. J., 1983, A sweep-frequency electromagnetic exploration method, Chapter 2, in *Development of Geophysical Exploration Methods-4*, Editor; A. A. Fitch, Elsevier Applied Science Publishers, Ltd., London, p. 39-64.

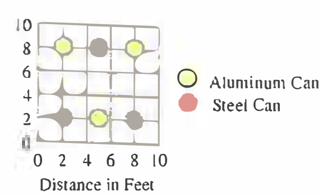
Won, I. J., Keiswetter, D., Fields, G., and Sutton, L., 1996, GEM-2: A new multifrequency electromagnetic sensor, Journal of Environmental and Engineering Geophysics, v. 1, n. 2, p. 129-137.

Electromagnetic Induction Spectroscopy (EMIS)

When an electrically conductive and/or magnetically permeable object is placed in a time-varying electromagnetic field, a system of induced current flows through the object. By observing small secondary magnetic fields emanating from the induced current, we attempt to detect the object - this is the foundation of the time-proven electromagnetic induction (EMI) method. By measuring an object's EMI response over a broad bandwidth, we can detect and ***characterize*** an objects geometry and material composition. This far reaching new technology is called ***Electromagnetic Induction Spectroscopy (EMIS).***

The data to the right illustrate the EMIS technology. EMI data were acquired using Geophex's proprietary electromagnetic induction sensor (GEM-3), at ten frequencies over a 10-ft by 10-ft test site where six small cans were buried on their sides at an eight-inch depth in clay soil. Three are aluminum soda cans and the other three are steel cans having similar size. The measured in-phase response shows an opposite polarity between the aluminum cans and steel cans at low frequencies, but becomes the same polarity at high frequencies. Although the quadrature response is always positive, the response is definitely frequency dependant. Thus, we can readily discriminate aluminum versus steel objects. This example clearly demonstrates the significant advantages of EMIS over existing methods to identify and characterize buried metal objects. This technology has been developed at Geophex and is not commercially available.





Appendix B
Magnetic Method

Appendix B
Magnetic Method

Magnetic methods provide a fast, efficient, and cost-effective technique to identify and characterize local high magnetic susceptibility targets that produce deviations in the Earth's magnetic field. Magnetic susceptibility is a basic material property and represents the degree of magnetization of a material placed in an external magnetic field. Magnetic susceptibility of a geologic material is proportional to its content of iron-bearing minerals, principally magnetite, the most abundant magnetic mineral in the Earth. The principal applications of magnetic surveys in site assessments are for:

- Locating buried drums, USTs, and pipes;
- Delineating pits and trenches containing ferrous materials;
- Delineating boundaries of landfills with ferromagnetic debris; and
- Mapping subsurface geology.

The signals measured in a magnetic survey are influenced by the ambient magnetic field of the Earth. The Earth's magnetic field resembles that of a single dipole whose axis deviates about 10 degrees from geographic north. The strength of the Earth's magnetic field is about 60,000 gammas near the north pole where it is directed vertically into the Earth, and about 30,000 gammas near the equator where it is parallel to the Earth's surface.

Buried steel objects cause local perturbations in the Earth's magnetic field (Figure B-1). The Earth's magnetic field magnetizes ferrous material (either man-made or natural) in parallel with and proportional to the local Earth's magnetic field. Therefore, the intensity and shape of perturbations caused by a buried drum, for example, is a function of latitude (Figure B-2). The total magnetic field measured is the vector sum of the ambient Earth's magnetic field and the local perturbation.

Two types of magnetic surveys are commonly conducted: 1) measurement of the total field, or 2) measurement of the vertical gradient. Although the field procedures are very similar for the two surveys, the measured data and interpretation methods can sometimes be quite different. The vertical gradient, measured by recording the magnetic field at two, vertically separated sensors and calculating the difference, is to detect and locate small and shallow-buried objects, such as drums. Because vertical gradient anomalies decay inversely proportional to distance from the object raised to the fourth power, as opposed to the third power for the total field anomaly, vertical gradient anomalies are more sharply defined in the immediate area of the ferrous object. In contrast, the total field anomaly of a small shallow ferrous object will be broad, and hence, possibly unidentified during an actual survey. Commercially available magnetic instruments (e.g., the G-858 Magnetometer from Geometrics) allow the simultaneous recording of the total field and the vertical gradient.

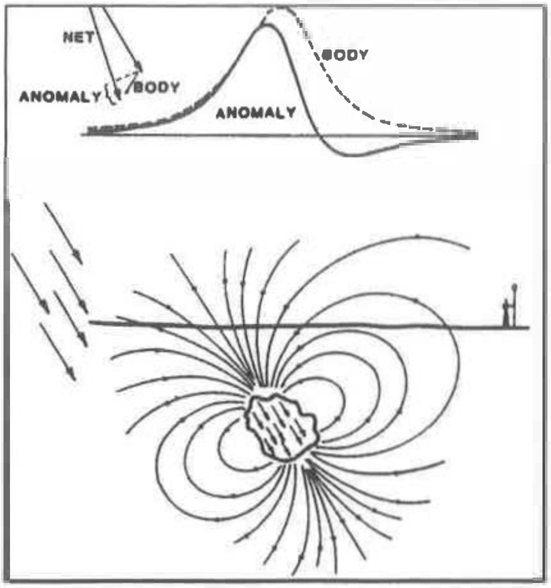


Figure B-1. The Earth's magnetic field induces a magnetic moment in buried ferromagnetic materials (bottom). This induced field, in turn, causes local perturbations (anomaly) in the measured total magnetic field (top).

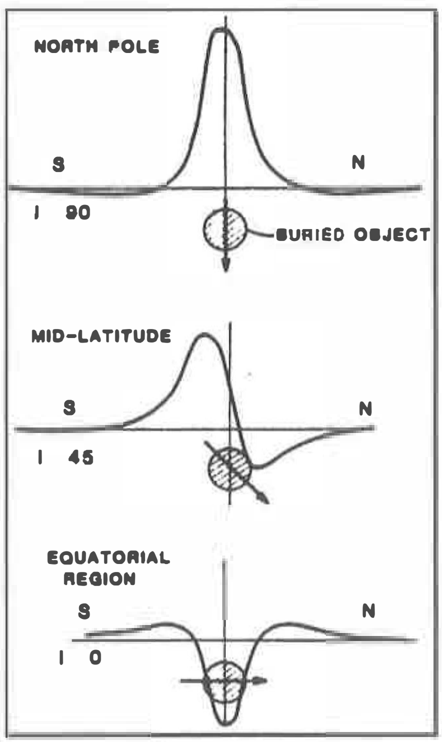
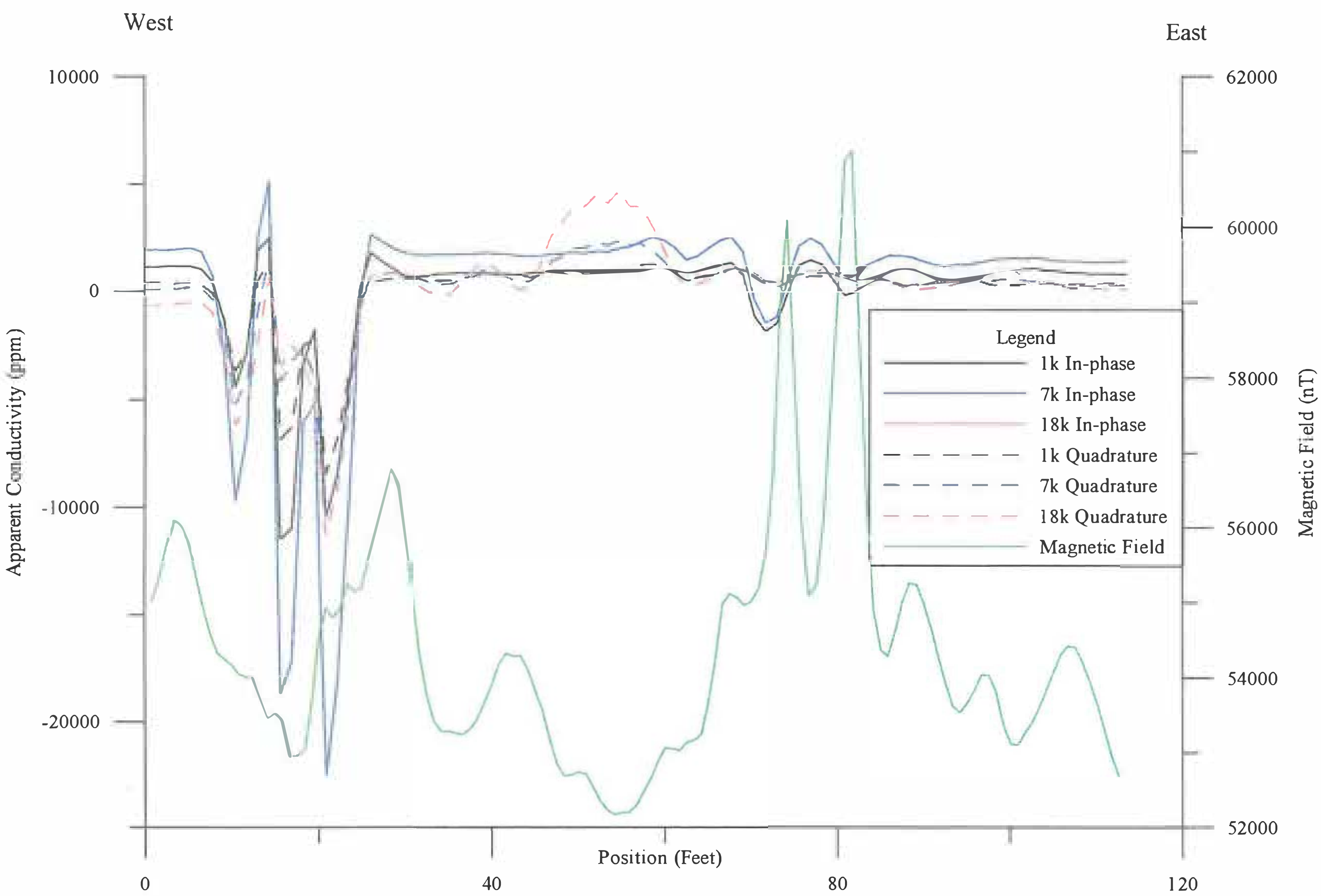


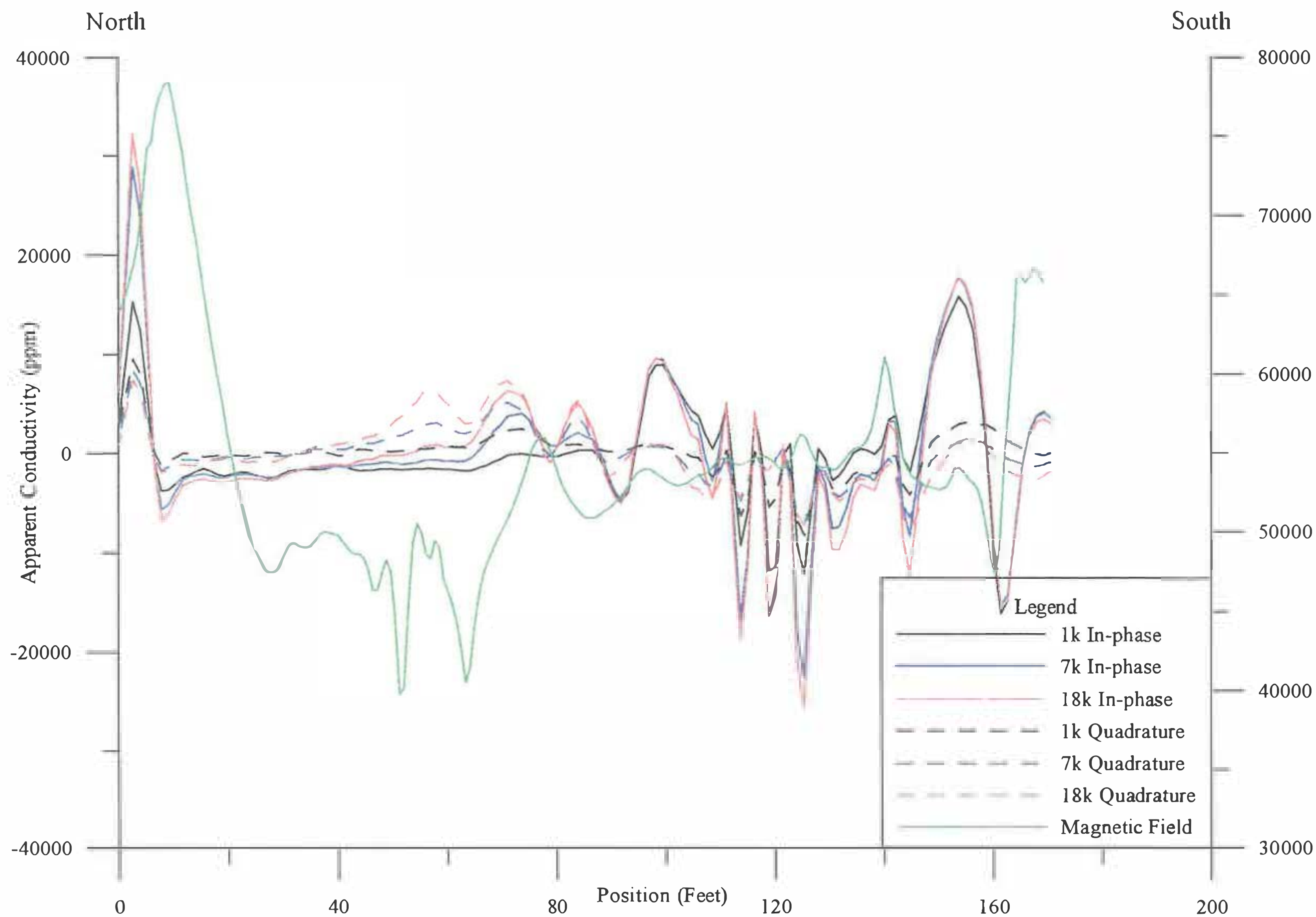
Figure B-2. Schematic illustration of the shape of magnetic anomalies (local perturbations) as a function of latitude.

Appendix C
Geophysical Profile Data



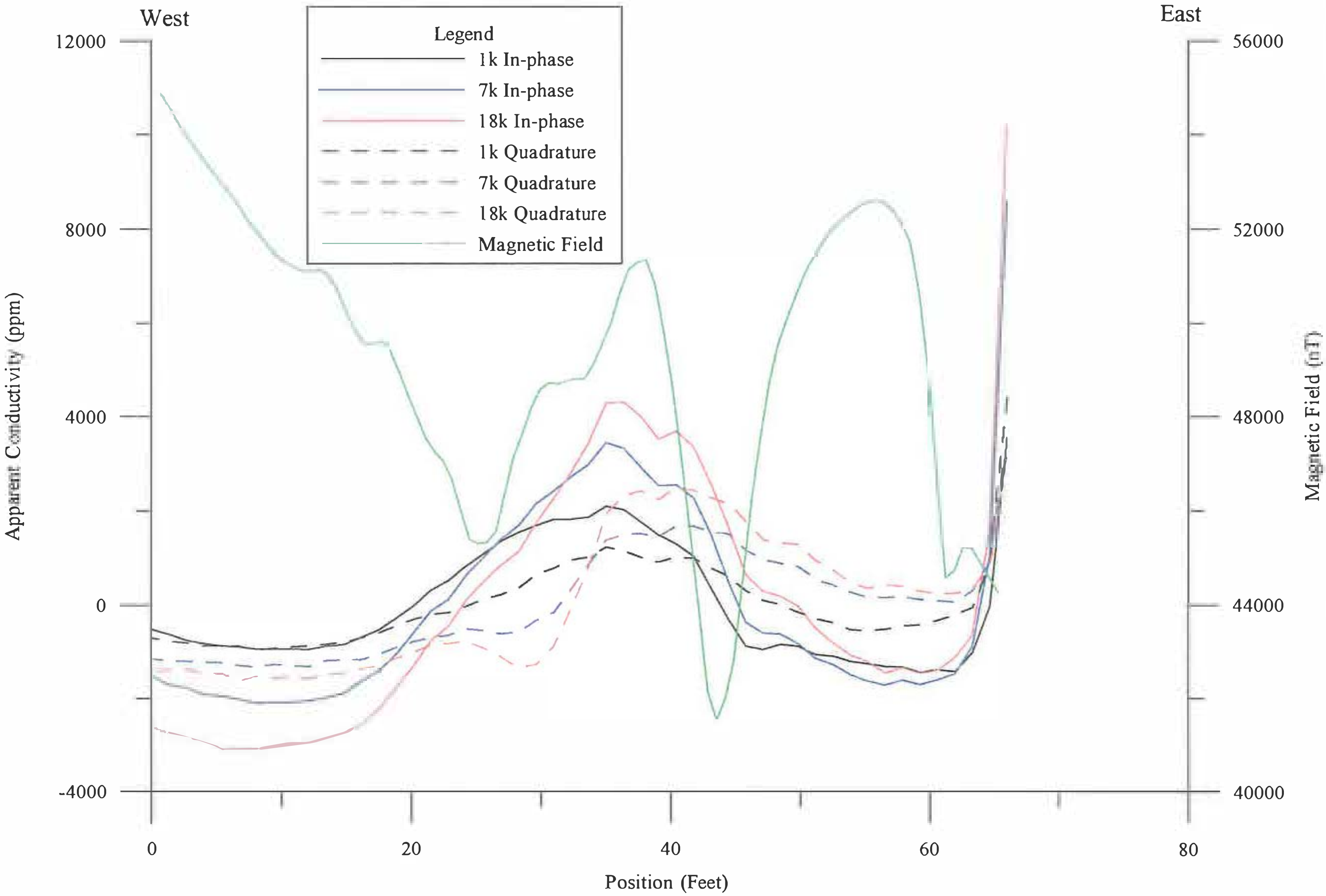
Geophex

Figure C-1. GEM-2 and magnetic data for profile line A.



Geophex

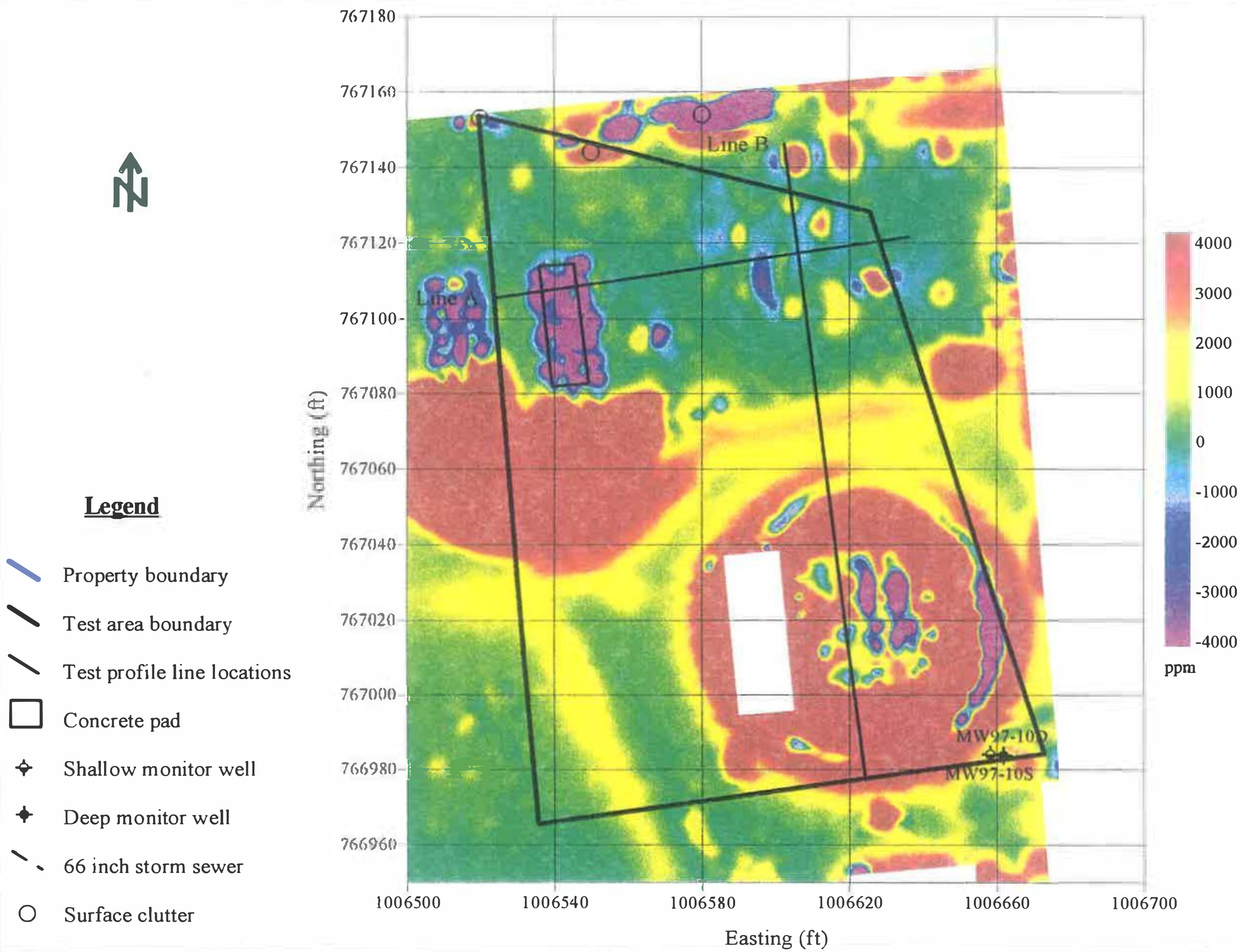
Figure C-2. GEM-2 and magnetic data for profile line B.



Geophex

Figure C-3. GEM-2 and magnetic data for profile line C.

Appendix D
Electromagnetic and Magnetic Data in the Geophysical Test Area

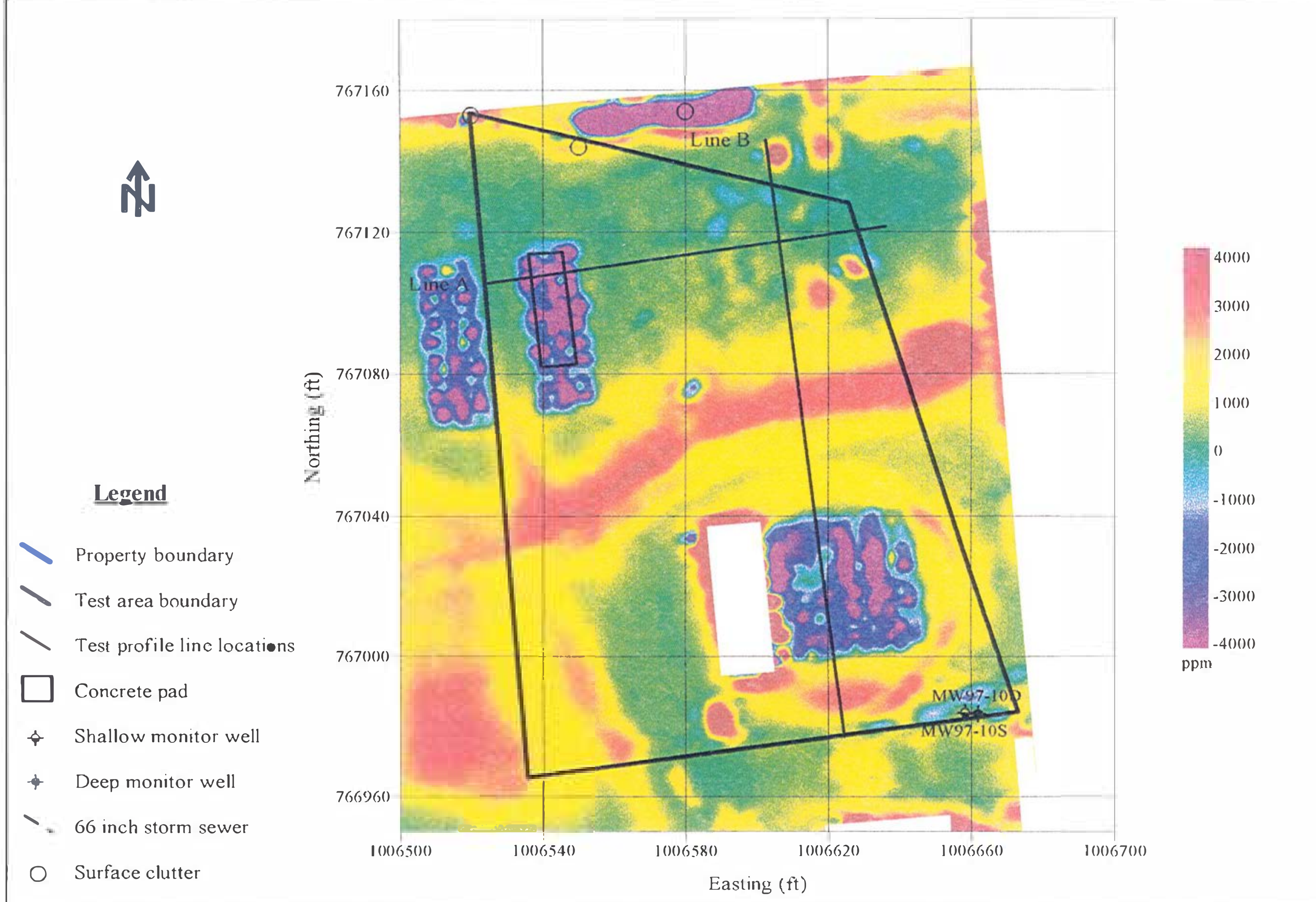


Geophex

Figure D-1. Test Area; GEM2 Data; 1,050 Hz Inphase.

Geophex, Ltd.

EM and Magnetic Survey, Binghampton NY
NYSEG (July 1999)

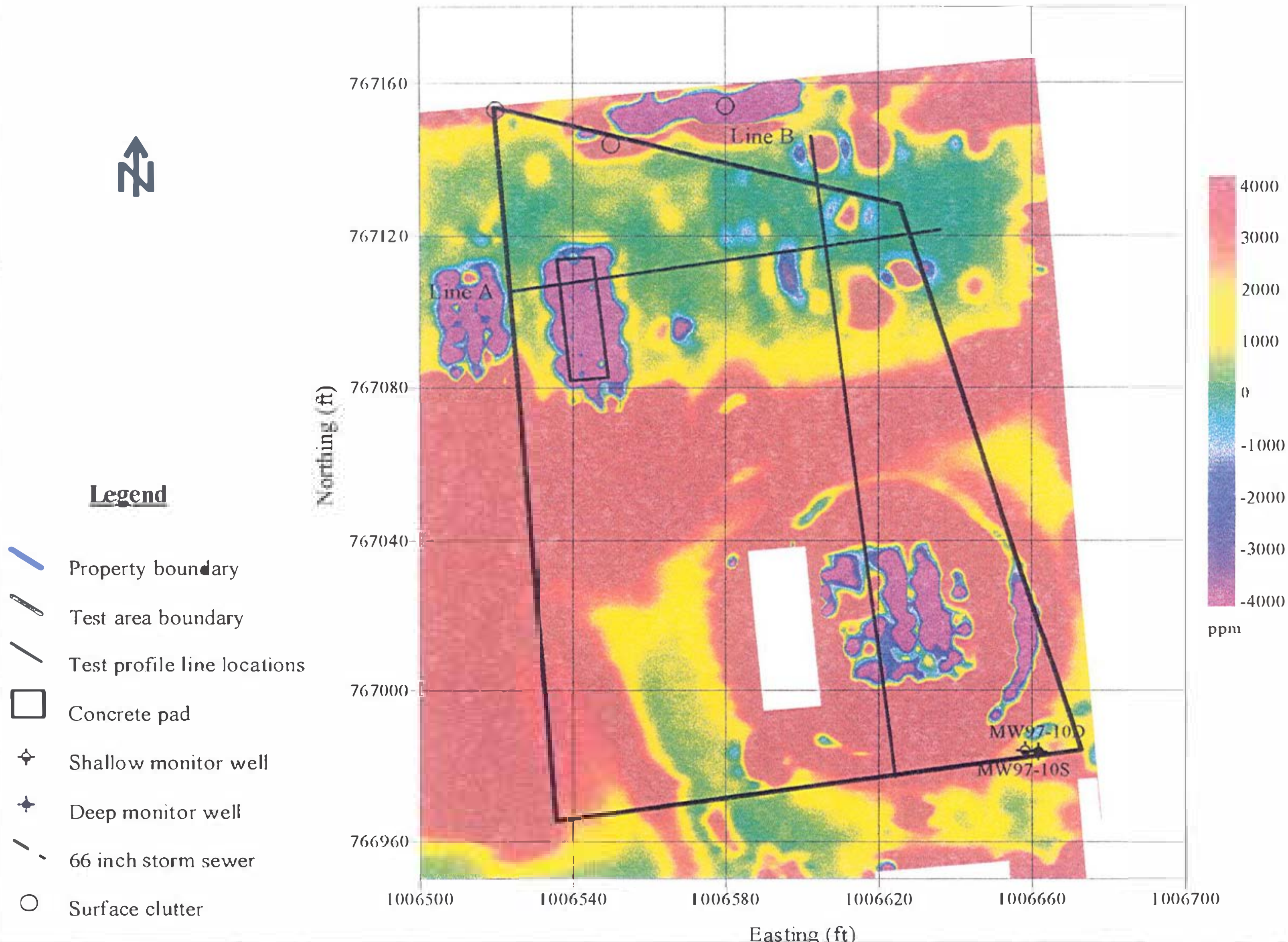


Geophex

Figure D-2. Test Area; GEM2 Data; 1,050 Hz Quadrature.

EM and Magnetic Survey, Binghampton NY
NYSEG (July 1999)

Geophex, Ltd.

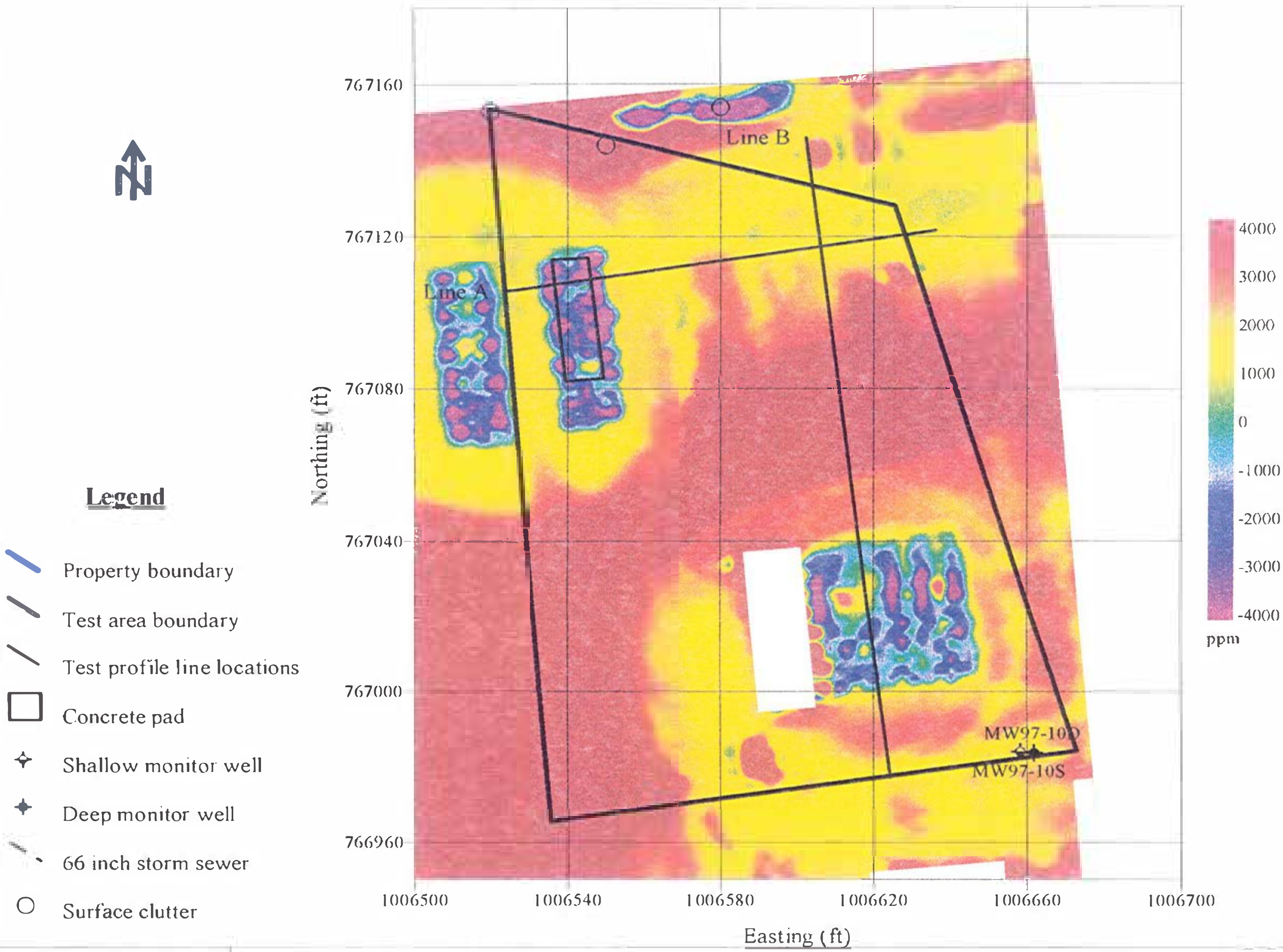


Geophex

Figure D-3. Test Area; GEM2 Data; 7,290 Hz Inphase.

EM and Magnetic Survey, Binghampton NY
NYSEG (July 1999)

Geophex, Ltd.

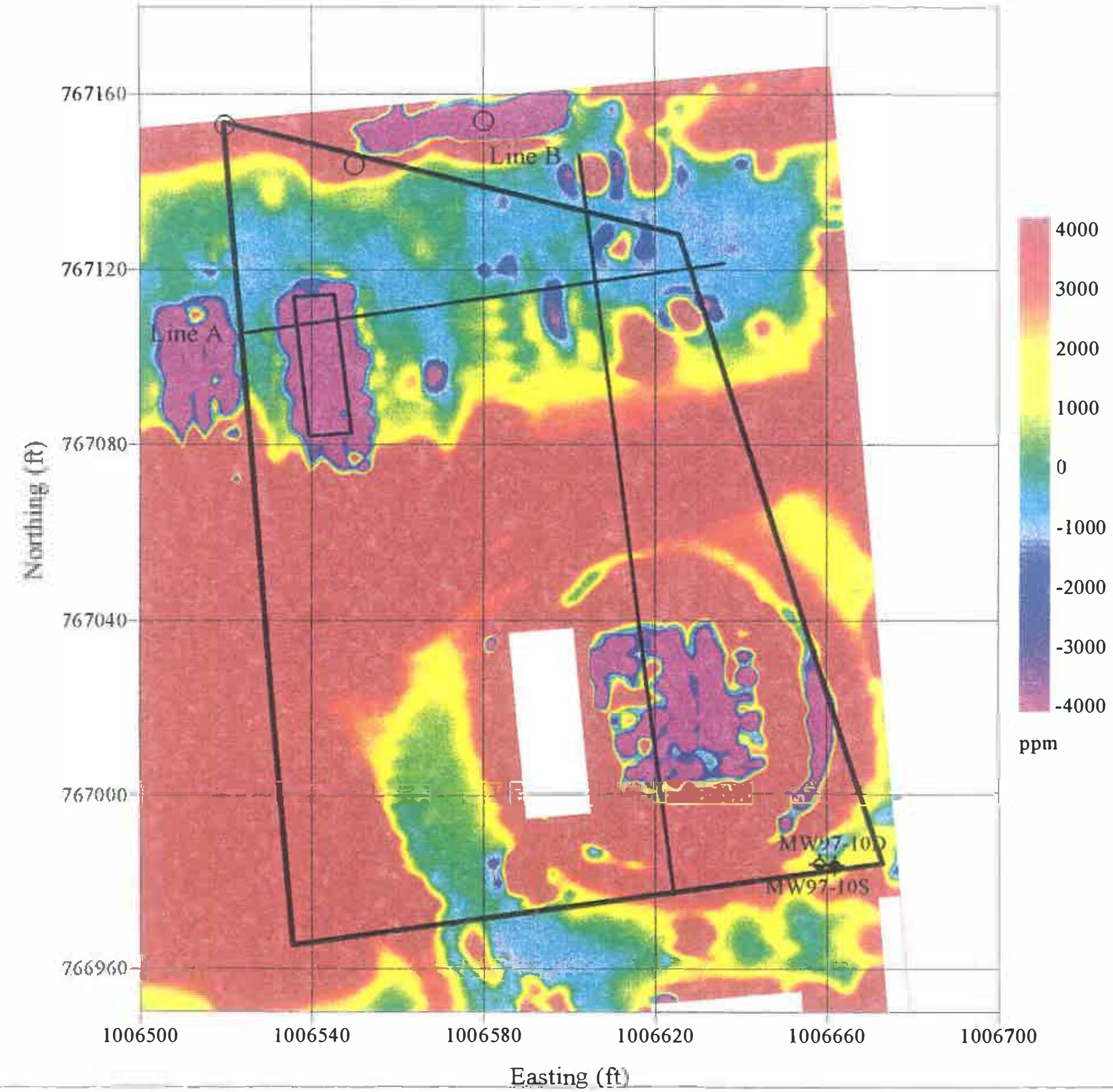


Geophex

Figure D-4. Test Area; GEM2 Data; 7,290 Hz Quadrature.

Geophex, Ltd.

EM and Magnetic Survey, Binghampton NY
NYSEG (July 1999)



Legend

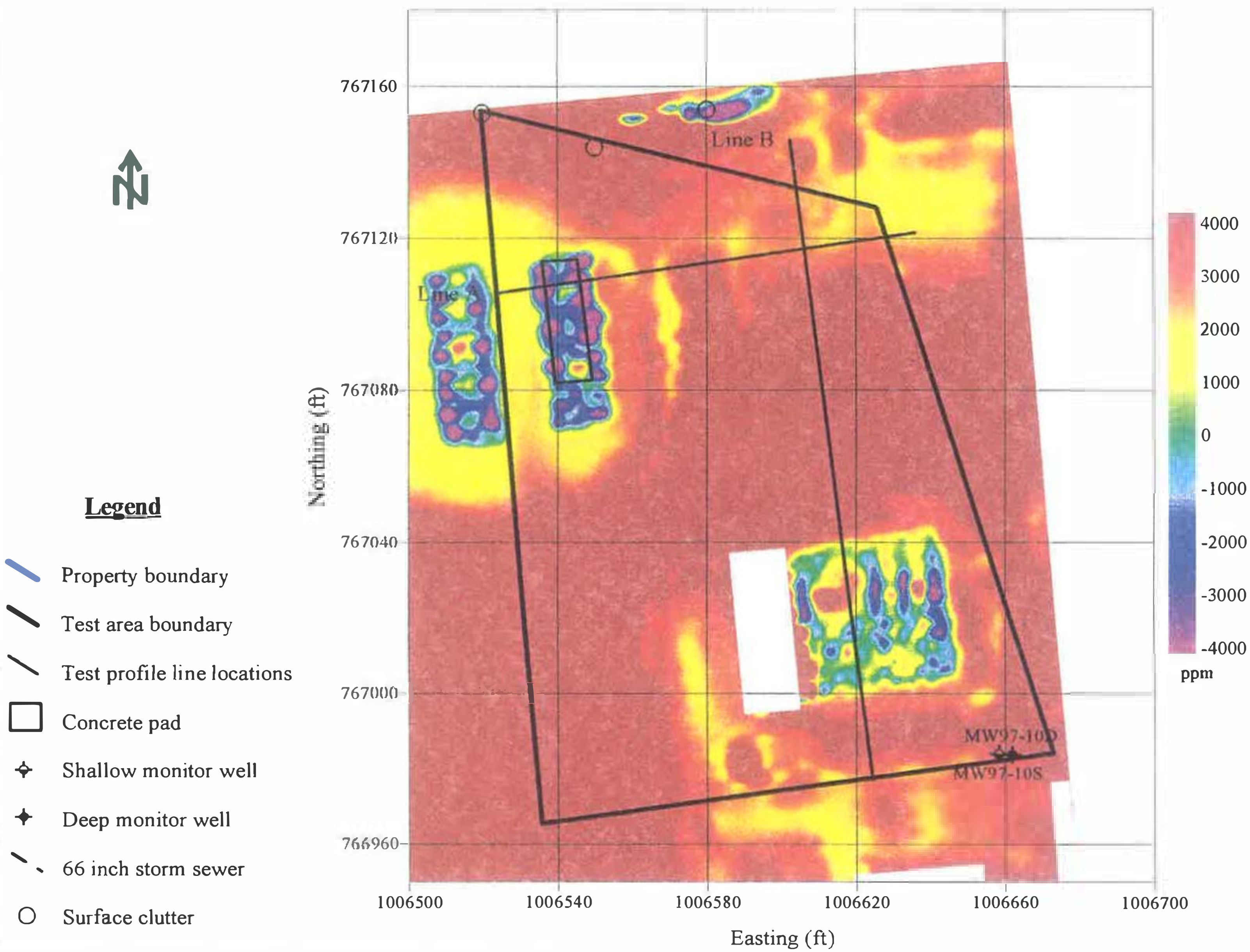
- Property boundary
- Test area boundary
- Test profile line locations
- Concrete pad
- Shallow monitor well
- Deep monitor well
- 66 inch storm sewer
- Surface clutter

Geophex

Figure D-5. Test Area; GEM2 Data; 18,270 Hz Inphase.

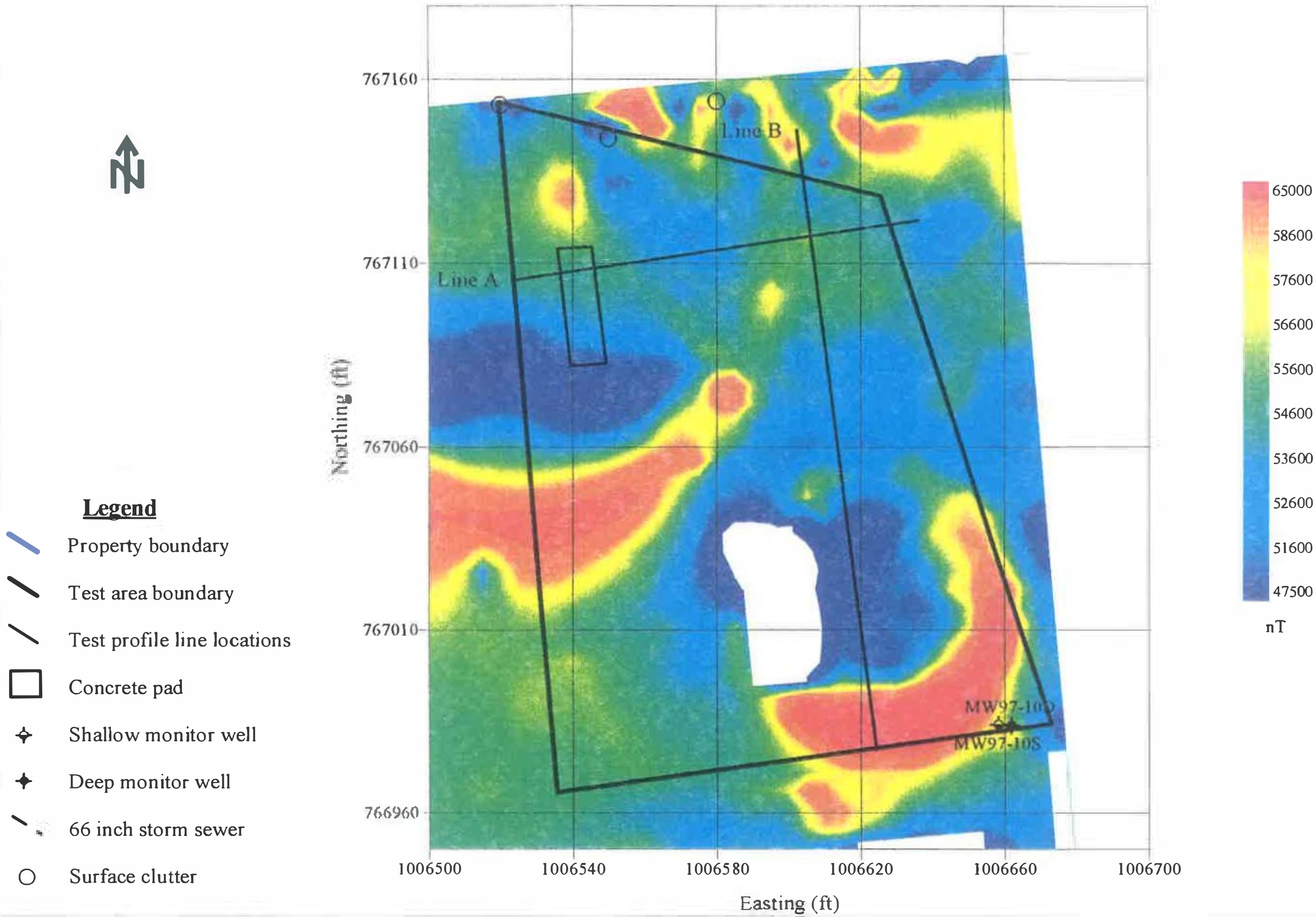
EM and Magnetic Survey, Binghampton NY
NYSEG (July 1999)

Geophex, Ltd.



Geophex

Figure D-6. Test Area; GEM2 Data; 18,270 Hz Quadrature.



Geophex

Figure D-7. Test Area; Total Magnetic Field Data.

Geophex, Ltd.

EM and Magnetic Survey, Binghampton NY
NYSEG (July 1999)