ELECTRICAL RESISTIVITY IMAGING
COURT STREET SITE
BINGHAMTON, NEW YORK

Oct 99

HAGER-RICHTER
GEOSCIENCE, INC.

Consultants in Geology & Geophysics

HAGER-RICHTER
GEOSCIENCE, INC

ELECTRICAL RESISTIVITY IMAGING
COURT STREET SITE
BINGHAMTON, NEW YORK

Prepared for:

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File 98G27
October, 1999

Electrical Resistivity Imaging
Court Street Site
Binghamton, New York
October 1999 File 98G27

0. EXECUTIVE SUMMARY

Hager-Richter Geoscience, Inc. conducted a resistivity and inducted polarization (IP) imaging survey at the former MGP site known as the Court Street Site and located in Binghamton, New York for New York State Electric & Gas Corporation (NYSEG) in June and August, 1999. The geophysical survey was performed as part of a research program titled "Innovative Technologies to Characterize MGP Sites."

The Site is a former Manufactured Gas Plant (MGP) located along the Susquehanna River on Court Street in Binghamton, New York. Although this site has been characterized by standard practices including historical review, test pits, soil borings, monitoring wells, and sample analyses to identify and delineate subsurface features and contamination, very little of such information was available to Hager-Richter prior to completing the interpretation of the survey data

The objective of this project was to show that resistivity imaging can provide data that are useful for certain aspects of site characterization and that the method is cost effective. This project was a joint effort by Hager-Richter and The Massachusetts Institute of Technology's Earth Resources Laboratory (ERL).

The resistivity imaging survey consisted of 13 survey lines for a total of 1600 feet. The inversion results detect and locate in three dimensions two large volumes of material in an area known informally as the Direct Push Technology area. The resistivity of one of the materials is high, and, on the basis of a single measurement in the laboratory of the resistivity of a coal tar sample from the site, we infer that the material of high resistivity is soil containing coal tar. The resistivity of the other material is low, and, in the absence of ground truth, the cause of the low resistivity is not identified.

The location and total length of the IP lines are identical to those of the resistivity lines. The inversion results for the Direct Push area show several IP anomalies. However, with some exceptions, they do not correlate closely with the resistivity anomalies. Ground truth is required for identification of the materials that have been imaged with the IP survey.

Spontaneous potential (SP) data were acquired on a 15 X 30 ft grid in the same area of the Direct Push area that was included in the resistivity/IP survey. The values range from near 0

mV to more than 700 mV, with the lower values occurring in the north end of the survey area, near the railroad. The values increase toward the south. Comparison of the SP data with the resistivity results shows a general lack of correlation of SP with resistivity.

On the basis of these results, and in the absence of ground truth, we conclude that resistivity imaging is the most promising of the three techniques for the imaging of coal tar. However, the evaluation of the IP technique must await the availability of ground truth. SP does not appear to be useful for imaging coal tar.

For the cost analysis of this project, we have assumed ideal conditions; namely, that (a) the weather cooperates by providing warm sunny days for the field work, (b) no equipment problems occur, and (c) no time is lost due to such site conditions as the presence of a concrete slab under asphalt that must be drilled in order to insert electrodes into the soil. With these assumptions, this project "cost," exclusive of mobilization, equipment, and computation costs, is as follows:

- 12 hrs of Principal's time
- 8 hrs of Project Manager's time
- 222 hrs of time for a geophysicist with MS degree and 2 yrs of experience conducting such projects
- 52 hrs of time for a field assistant with BS degree and 1 yr of experience conducting such projects
- 10 hrs of time for a CAD person with an Associates degree and 1 yr of CAD experience with geophysical projects

These costs can be reduced significantly for commercial applications, particularly if the IP survey is excluded. The exclusion of the IP portion would reduce the field work by about 40% and the data preparation and processing by 50%. The software is still undergoing changes that are intended to improve the results, and not necessarily reduce the time required for computation and data preparation. For commercial application, the code should be reworked to improve computation time and the effort required to prepare the raw data for input.

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1. INTRODUCTION

Hager-Richter Geoscience, Inc. conducted a resistivity imaging survey at the former MGP site known as the Court Street Site and located in Binghamton, New York for New York State Electric & Gas Corporation (NYSEG) in June and August, 1999. The geophysical survey was performed as part of a research program titled "Innovative Technologies to Characterize MGP Sites," and was conducted in conformance with our proposal dated July 20, 1998.

The Site is a former Manufactured Gas Plant (MGP) located along the Susquehanna River on Court Street in Binghamton, New York. The location is shown in Figure 1. The Site is level, open, and clear of structures with the exception of a small building located in the southern corner of the site. Figure 2 is a site plan. According to information in the Request for Proposal (RFP) to participate in the program, this site has been characterized by standard practices including historical review, test pits, soil borings, monitoring wells, and sample analyses to identify and delineate subsurface features and contamination. However, only the information contained in the RFP was available to Hager-Richter prior to submitting this report.

The objective of this project was to show that resistivity imaging can provide data that are useful for certain aspects of site characterization and that the method is cost effective.

The present geophysical work used three techniques: resistivity imaging, induced polarization (IP) imaging, and spontaneous potential (SP). The locations of the geophysical survey lines and SP data stations are shown in Figure 2.

This project was a joint effort by Hager-Richter and The Massachusetts Institute of Technology's Earth Resources Laboratory (ERL). Personnel from both organizations conducted the field work to acquire data, and were on-site for a few days in June, 1999. However, heavy rains prevented the acquisition of resistivity and IP data. Field work was completed in August, 1999. ERL processed the data. Both organizations participated in the interpretation and report preparation. Original data and field notes will be retained in the Hager-Richter files for a minimum of three years.

2. EQUIPMENT AND PROCEDURES

2.1 ELECTRICAL RESISTIVITY

The general equipment and procedures for electrical resistivity surveys as conducted by Hager-Richter in conjunction with the Earth Resources Laboratory of the Massachusetts Institute of Technology are described in this section. Details specific to this site are given below in section 2.4, Site Specific.

The electrical resistivity of soil *in situ* commonly depends mainly on the resistivity of groundwater and, secondarily on the mineral composition and porosity, respectively of the soil. The details of the dependence are discussed in most textbooks that treat electrical methods of geophysical investigation — for example: Keller and Frischknecht (1966) and Telford et al. (1990). The resistivity of the groundwater depends on composition, and, especially on the concentration and resistivity of any contaminants that may be present.

The resistivity of the subsurface can be measured using four electrodes inserted in the ground. (The mathematics is simpler if the electrodes are arranged in a straight line.) A common arrangement is to use the two outer electrodes to inject current I and the two inner electrodes to measure the potential V. The *apparent* resistivity ρ_a is given in texts for commonly used electrode spacings, and for equal spacing between adjacent pairs of electrodes $\rho_a = 2\pi a \Delta V/I$ where a is the electrode spacing. For small values of a, the resistivity of only shallow soils affects ρ_a. By taking measurements for several successively larger values of a, the resistivities of successively deeper soils can be investigated. Intuitively, the resistivity of the subsurface can be investigated by measuring ρ_a as a function of a, and in fact, the mathematics for such is given in texts for various ways of presenting the results.

The electrical resistivity survey was conducted using IRIS Instruments equipment which consisted of the Elrec-T, Remote Control Multiplexer (RCM), 250 Watt DC-DC converter, twenty intelligent nodes, twenty electrodes, twenty cables, and a 12V car battery. The arrangement of electrodes is shown in Figure 3. The Elrec-T is the resistivity meter which houses the main control unit where currents are generated and potentials measured. The Elrec-T also includes all the memory of the system and the interface with a PC. The RCM is a sophisticated communication interface between the Elrec-T and the network of intelligent nodes, where each intelligent node is connected to an electrode and another node. The RCM with intelligent nodes adds great versatility to the data acquisition by allowing the user to program any pair of electrodes to inject current and any other pair of electrodes to measure potential.

The electrode spacing determines the spatial resolution of the technique as well as the maximum depth of investigation. Data were acquired for segments of resistivity lines using the

Resistivity Array Imaging (RAI) method which was developed at the Earth Resources Laboratory to improve upon traditional data acquisition. RAI is made up of over 750 combinations of pairs of current injection and potential measuring electrodes. RAI includes arrays which sweep current through the subsurface in a manner that provides enhanced imaging, especially on the edges of survey lines.

The data are inverted using a proprietary resistivity code developed at the Earth Resources Laboratory in which all of the data for a twenty electrode segment are inverted simultaneously. The resulting resistivity values for all segments of a resistivity line are then contoured together using Surfer®, a commercial contouring software package.

There are many ways to display the results of the resistivity inversions, and the choice depends on what needs to be emphasized for a particular project. The display options for the data are either resistivity, conductivity or both resistivity and conductivity (resistivity is the reciprocal of conductivity). The choice of scales affects the appearance of the plots, and further emphasizes particular parts of the results, and the choice is most commonly between linear and logarithmic scales although many others could be made. Furthermore, an image can be made to highlight either local detail or regional information.

2.2 INDUCED POLARIZATION

Induced polarization (IP) is the electrical polarization due to the accumulation of charge at various interfaces in the earth. The effect of such polarization on electrical current flow in the earth can be illustrated with the resistivity array. If the current in a dc resistivity measuring array is suddenly switched off, the voltage does not decrease immediately to zero, but decays slowly. The decay time is commonly seconds, but may be as much as several minutes (or even hours in some cases), and is due to induced polarization. The cause of the finite decay time — that is, the source of the IP effects — may be metallic, membrane, and/or mineral. Metallic IP is caused by the build-up of excess charge at the metal/pore fluid interface due to a change in the electric charge carriers at the interface — ions in the groundwater, electrons in the metal. Membrane IP is caused by build-up of excess charge on the surface of certain clay minerals. Mineral IP is developed by an inducing electric field which polarizes the excess positive surface charge in solution, and most mineral surfaces are negatively charge when in contact with pore liquids. The magnitude of the mineral IP effect depends on the level of adsorbed ions. Contaminants are likely to create IP signatures dominated by mineral IP. Most contaminants, including coal tar, when present in sufficient concentrations are expected to display high chargeabilities (greater than 0.1 mV/V). More extensive discussions are given by Ward (1990), Telford et al. (1990), and Keller and Frischknecht (1966).

The parameter that is measured in an IP survey is the change in voltage over a small time interval after the current is switched off, and, when normalized to the voltage before the current was switched off, it is called "chargeability." The unit of chargeability is millivolts per volt.

The equipment is the same equipment that is used for resistivity imaging. Normally, the IP data acquisition either precedes or follows the data acquisition for resistivity imaging, and uses the same exact equipment and physical setup.

The interpretation of IP data in environmental and engineering applications is based on pattern recognition and experience. Ground truth is commonly required for definitive interpretation.

2.3 SPONTANEOUS POTENTIAL

Potential differences in the earth, called spontaneous potentials or self potentials (SP), are caused by flows of fluid, heat, and ions. They typically range in size from a few millivolts to several tens of millivolts — and values as large as 1000 mV have been observed in volcanic and geothermal areas. Such potentials are easily measured, and may be interpreted in terms of their source. Examples of field investigations, including groundwater flow, flow in a landslide body, seepage flow in dams, and geothermally driven fluid flow, are discussed by Sharma (1997).

The equipment needed for an SP survey is the following: electrodes, electrical wire, voltmeter. Hager-Richter uses two silver-silver chloride electrodes mounted in porous clay pots. One electrode, the reference electrode, is set in the earth in an area outside the survey area and the other, called a roving electrode, is positioned at various locations within the survey area. The voltage difference between the reference and roving electrodes is measured with a handheld digital voltmeter. The potential is presented as a contour plot, and the contours may reveal the location(s) of the major sources of the potential. A more extensive discussion of the equipment and techniques is given by Corwin (1990).

2.4 LIMITATIONS OF THE METHODS

2.4.1 Electrical Resistivity. As with any of the electrical geophysical methods, resistivity data are subject to certain limitations, including site surface and subsurface conditions and structures, electrical and "geological" noise, and target depth and size. Interference from such cultural features as buildings, fencing, and underground and overhead power lines is common at many sites, and particularly at active industrial sites. Thus, for certain applications, the use of the resistivity method in urban settings might be inappropriate.

The subsurface is three dimensional in character, and although the resistivity data are acquired along a line, the data are affected by resistivity changes off-line. Therefore, unless there are parallel survey lines that are spaced appropriately, resistivity changes off-line may be interpreted as changes below the survey line where the data are acquired. This limitation is particularly significant for single survey lines.

The target depth, size, and, of course, resistivity contrast may pose limitations. These three parameters, generally characterized as large or small[1], are important in the survey design, and extreme values and some combinations of values can limit the usefulness of the resistivity method. For example: A small target, say a granite boulder 2 ft in diameter, at large depth, say 20 ft or more, even with very high resistivity contrast, say 10^5 Ohm-m in a medium of 0.2 Ohm-m, cannot be detected. A target of reasonable size, say a granite boulder 2 ft in diameter, at shallow depth, say 6 ft or less, may not be detectable where the resistivity contrast is low, say 10^5 Ohm-m in a medium of 10^4 Ohm-m.

A further limitation of the resistivity method arises from lack of data at the edges of a survey line where it becomes more difficult to image the subsurface and anomalies appear shallower than their true depth. The ERL has developed Resistivity Array Imaging (RAI) which makes improvements in data acquisition that greatly enhance the method's capability to image the edges of a survey by sweeping current throughout the subsurface. Whereas standard dipole-dipole or pseudo-section arrays only provide data in a V shape, RAI images an area similar to a 'bowl.' Although the lateral position of anomalies at the very edge of an array is determined correctly by RAI, the depths of the anomalies are shallower than the depths of the causative bodies.

2.4.2 Induced Polarization. Because part of the current flows through any ***grounded*** cultural structure, spurious IP anomalies can result from such structures as fences, power lines, and pipelines.

Geologic noise (which could be the signal in other IP surveys) can arise from the presence of distributed clay minerals in the soils and sulfide mineral concentrations.

2.4.3 Spontaneous Potential. There are several sources of noise for SP surveys, including the following:

- Variations in topography, which are often associated with ground water flow
- Pipelines and other cultural objects using cathodic protection
- Large DC systems or apparatus (such as subways)
- Sulfide materials — chiefly pyrite

[1] The parameters depth and size scale to the electrode spacing. A "large depth" is any depth greater than 10 times the electrode spacing. A "small depth" is any depth less than 3 times the electrode spacing. Depths less than 10, and greater than 3, times the electrode spacing are termed "intermediate depths." A "large size" is any size greater than 2½ times the electrode spacing. A "small size" is any size less than 1 times the electrode spacing. Sizes less than 2½, and greater than 1, times the electrode spacing are termed "intermediate sizes." Resistivity contrast refers to the ratio of the resistivity of one material to that of a second material. A large resistivity contrast is any such ratio of at least 100. A small resistivity contrast is any such ratio no greater than 0.5. Ratios less than 100, and greater than 0.5, are termed "intermediate ratios."

2.5 SITE SPECIFIC

The locations of the survey lines are shown in Figure 2. The locations of Lines A, B, and C were selected by NYSEG so that the results of all the techniques used in the Program could be compared by NYSEG. The area of the other lines was selected on the basis that previous work had demonstrated that coal tar was present in that area and our project was designed to detect coal tar. The lines other than A, B, and C are identified on the basis of coordinates; for example, Line 20S is located on the 20S coordinate.

The resistivity/IP survey consisted of the three lines designated A, B, and C plus seven east-west lines and three north-south lines located in an area known informally as the "Direct Push Technology" area. An electrode spacing of 8.0 feet was used for the lines identified by coordinate, and spacings of 5, 9, and 3 ft were used for Lines A, B, and C. The locations of the survey lines were tied to local landmarks that were recognizable in the field and also on the site plans.

3. RESULTS AND DISCUSSION

3.1 ELECTRICAL RESISTIVITY SURVEY

The locations of all lines are shown in Figure 2. The resistivity imaging survey consisted of 13 survey lines for a total of 1600 feet. The inversion results are shown in profile form in the Appendix for all lines and in three dimensional perspective views for the Direct Push area in Figures 4 and 5. Figures 4 and 5 depict the material of high and low resistivity, respectively, as solid bodies.

A small sample of the coal tar was provided by NYSEG for measurement in the laboratory of its resistivity. We were able to determine that the resistivity of the one sample exceeds 6.5×10^5 ohm-ft (20×10^6 ohm-m).

The resistivity data for the Court Street Site can be separated into three groups: high, low, and intermediate resistivity. Inasuch as our measurement in the laboratory of the coal tar resistivity showed the value to exceed 6.5×10^5 ohm-ft, we infer that the high resistivities in the inversions represent high concentrations of coal tar in the soil (Figure 4). The intermediate values represent background materials without coal tar or other contaminants, and is in the approximate range of 10 to 30 ohm-ft. The low values represent a mixture of one or more unidentified conductive liquids with groundwater and soil or, possibly, conductive soil such as clay. As discussed previously, ground truth is required for identification of the material with low resistivity.

Figure 6 shows the resistivity at depths of 10 to 60 ft in a three dimensional perspective view. Figure 7 shows the resistivity at a depth of 20 ft in plan view. These figures provide additional views of the distribution of the interpreted coal tar and the unidentified "low resistivity material."

The resistivity images for Lines A, B, and C are shown in the Appendix. For each of those lines, the survey successfully imaged regions that are more resistive and others that are less resistive than the soils. Although the regions have been detected, their identification will require ground truth.

3.2 INDUCED POLARIZATION SURVEY

Inasmuch as the IP data are acquired immediately after acquiring the resistivity data and using the same equipment and array, the IP lines are identical to the resistivity lines. Their locations are shown in Figure 2. The IP imaging survey consisted of 13 survey lines for a total of 1600 feet. The inversion results are shown in profile form in the Appendix for five lines and in three dimensional perspective view for the Direct Push area in Figure 8. We have selected an intermediate value to plot as a solid body in Figure 8 because we do not have laboratory data for the chargeability of coal tar. Figure 9 shows chargeability at depths of 10 to 60 ft in a three dimensional perspective view, providing additional views of that parameter.

There are several IP anomalies shown in the figures. However, with some exceptions, they do not correlate closely with the resistivity anomalies. Ground truth is required for identification of the materials that have been imaged with the IP survey.

3.3 SPONTANEOUS POTENTIAL SURVEY

Spontaneous potential (SP) data were acquired on a 15 X 30 ft grid in the Direct Push area. The location of data stations are shown in Figure 2. The values are shown in contour form in Figure 10, and range from near 0 mV to more than 700 mV. The lower values occur in the north end of the survey area, near the railroad and the values increase toward the south. Comparison of Figure 10 with any of the figures for resistivity shows a general lack of correlation of SP with resistivity.

4. CONCLUSIONS

The following surveys were conducted in 1999 at the Court Street Site:

- A resistivity imaging survey consisting of 13 survey lines for a total of 1600 feet. Ten lines were located in the Direct Push Technology area. The locations of three lines (A, B, C) were selected by NYSEG to permit comparison with the results of other technologies.
- An induced polarization (IP) survey using the same lines as the resistivity imaging survey.
- A spontaneous potential (SP) survey on a 15 x 30 ft grid located in the survey area of the Direct Push Technology area.

On the basis of the results of those surveys, we conclude that:

- The resistivity imaging survey in the Direct Push Technology area detected regions of highly resistive material that we infer consist of high concentrations of coal tar.
- The resistivity imaging survey in the Direct Push Technology area also detected regions of low resistivity (conductive) material, and ground truth is required for the identification of such material(s)
- The resistivity imaging survey of lines A, B, and C successfully imaged regions that are more resistive and others that are less resistive than the soils, but their identification requires ground truth.
- The IP survey in the Direct Push Technology area detected regions of anomalous chargeability. However, the regions do not correlate with the regions detected in the resistivity imaging survey. Ground truth is required for the identification of the material(s).
- The SP results do not correlate with the results of either the resistivity imaging survey or the IP survey.

On the basis of these results, and in the absence of ground truth, it appears that resistivity imaging is the most promising of the three techniques for the imaging of coal tar. However, the evaluation of the IP technique must await the availability of ground truth. SP does not appear to be useful for imaging coal tar.

5. COST ANALYSIS

For the cost analysis of this project, we have assumed ideal conditions; namely, that (a) the weather cooperates by providing warm sunny days for the field work, (b) no equipment problems occur, and (c) no time is lost due to such site conditions as the presence of a concrete slab under asphalt that must be drilled in order to insert electrodes into the soil.

Table 1 breaks out the various tasks and assigns man-hours of individuals with specified minimum qualifications to each of the tasks. However, we do not report pay rates for the individuals.

We also do not report costs for mobilization/demobilization, equipment, or computation inasmuch as these costs can vary significantly with site location, a company's field equipment resources, and the computational resources available. We note explicitly, however, that the data processing is computationally intensive.

With the above assumptions, this project "cost," exclusive of the "other costs," is as follows:

- 12 hrs of Principal's time
- 8 hrs of Project Manager's time
- 222 hrs of time for a geophysicist with MS degree and 2 yrs of experience conducting such projects
- 52 hrs of time for a field assistant with BS degree and 1 yr of experience conducting such projects
- 10 hrs of time for a CAD person with an Associates degree and 1 yr of CAD experience with geophysical projects

These costs can be reduced significantly for commercial applications, particularly if the IP survey is excluded. The exclusion of the IP portion would reduce the field work by about 40% and the data preparation and processing by 50%.

The software is still undergoing changes that are intended to improve the results, and not necessarily reduce the time required for computation and data preparation. For commercial application, the code should be reworked to improve computation time and the effort required to prepare the raw data for input.

6. REFERENCES

Corwin RF, 1990, The Self-Potential Method for Environmental and Engineering Applications, *in* SH Ward, editor, **Geotechnical and Environmental Geophysics**, vol 1, p 127-144, publ by Society of Exploration Geophysicists. Discusses several applications and includes extensive bibliography and references to larger bibliographies.

Keller GV, Frischknecht FC, 1966, **Electrical Methods in Geophysical Prospecting**, Pergamon Press.

Sharma PV, 1997, **Environmental and Engineering Geophysics**, Cambridge University Press. Describes several field examples, including groundwater flow, flow in a landslide body, seepage

Telford WM, Geldart LP, Sheriff RE, 1990, **Applied Geophysics Second Edition**, Cambridge University Press.

Ward SH, 1990, Resistivity and Induced Polarization Methods, *in* SH Ward, editor, **Geotechnical and Environmental Geophysics**, vol 1, p 147-189, publ by Society of Exploration Geophysicists. Includes extensive bibliography.

7 LIMITATIONS

This report was prepared for the exclusive use of New York State Electric & Gas Corporation. (Client). No party other than NYSEG shall be entitled to rely on this Report or any information, documents, records, data, interpretations, advice or opinions given to Client by Hager-Richter Geoscience, Inc. (H-R) in the performance of its work. The Report relates solely to the specific project for which H-R has been retained and shall not be used or relied upon by Client or any third party for any variation or extension of this project, any other project or any other purpose without the express written permission of H-R. Any unpermitted use by Client or any third party shall be at Client's or such third party's own risk and without any liability to H-R.

H-R has used reasonable care, skill, competence and judgment in the preparation of this Report consistent with professional standards for those providing similar services at the same time, in the same locale, and under like circumstances. Unless otherwise stated, the work performed by H-R should be understood to be exploratory and interpretational in character and any results or findings contained in this Report or resulting from the work proposed may include decisions which are judgmental in nature and not necessarily based solely on pure science or engineering. It should be noted that our conclusions might be modified if subsurface conditions were better delineated with additional subsurface exploration including, but not limited to, test pits, soil borings with collection of soil and water samples, and laboratory testing.

Except as expressly provided in this limitations section, H-R makes no other representation or warranty of any kind whatsoever, oral or written, expressed or implied; and all implied warranties of merchantability and fitness for a particular purpose, are hereby disclaimed.

TABLE 1. COST ANALYSIS

TASK	DEGREE & EXPERIENCE				
	MS 2 YRS	BS 1 YR	ASSOC 1 YR	PROJECT MGR	PRINCI-PAL
	(Hrs)	(Hrs)	(Hrs)	(Hrs)	(Hrs)
Field Work - RES	25	25			
Field Work - IP	25	25			
Field Work - SP		2			
Data Preparation & Processing - RES	75				
Data Preparation & Processing - IP	75				
Data Preparation & Processing - SP	1				
Interpretation - RES	3				
Interpretation - IP	2				
Interpretation - SP	1				
CAD - RES			5		
CAD - IP			4		
CAD - SP			1		
Report Preparation	15				
TOTALS:	222	52	10	8	12

TABLE 2. OTHER COSTS

Mobilization/Demobilization	
Equipment Rental/Cost	
Computation Cost	

LOCATION

SCALE (feet)

0 2000 4000

Figure 1
General Site Location
New York State Electric & Gas Corp.
Court Street Site
Binghamton, New York

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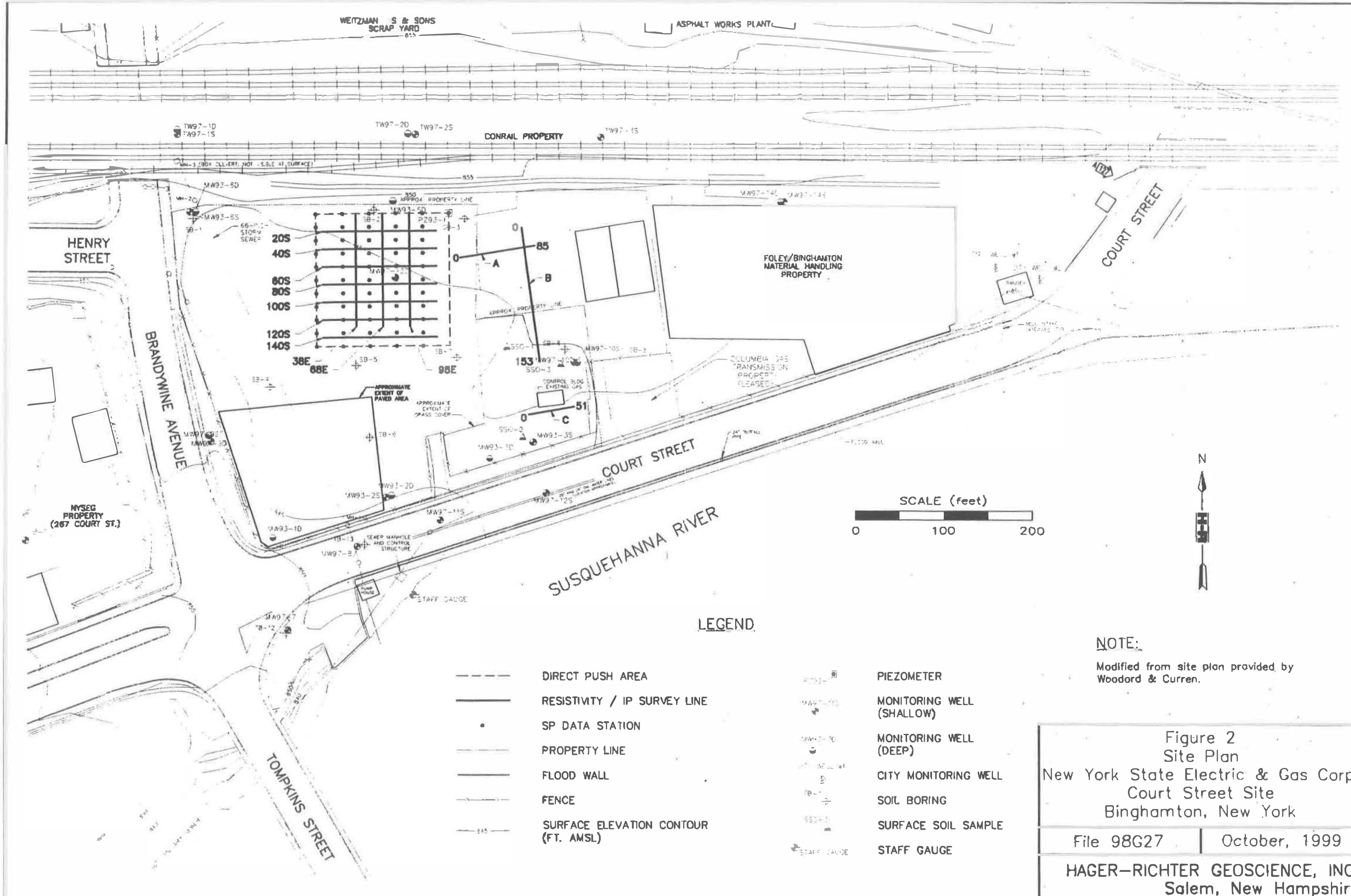
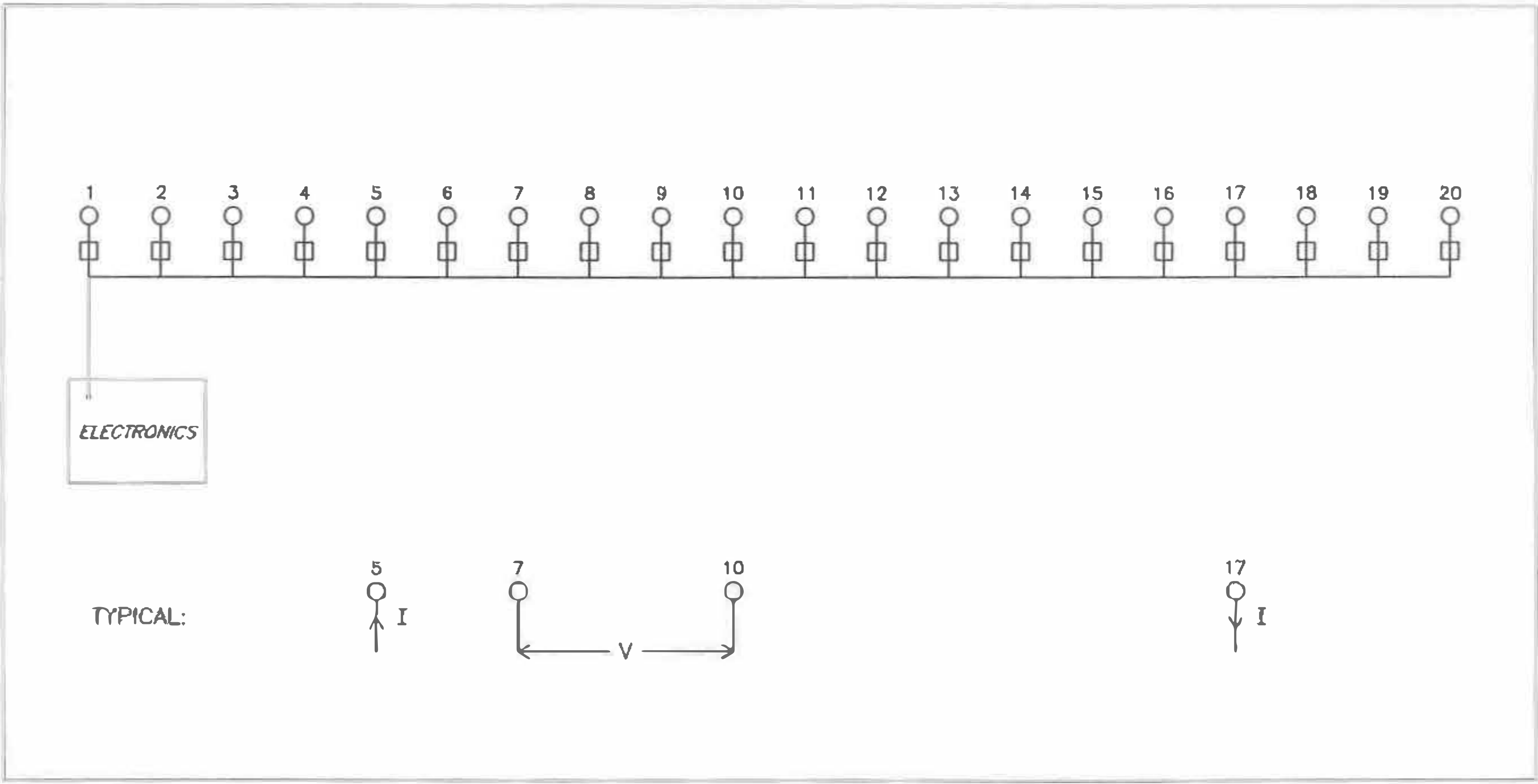
Salem, New Hampshire


WEITZMAN S & SONS SCRAP YARD
ASPHALT WORKS PLANT
CONRAIL PROPERTY
TW97-1D
TW97-1S
TW97-2D
TW97-2S
TW97-3S
HENRY STREET
BRANDYWINE AVENUE
COURT STREET
SUSQUEHANNA RIVER
TOMPKINS STREET
FOLEY/BINGHAMTON MATERIAL HANDLING PROPERTY
NYSEG PROPERTY (267 COURT ST.)
APPROXIMATE EXTENT OF PAVED AREA
APPROX. PROPERTY LINE
STAFF GAUGE
20S
40S
60S
80S
100S
120S
140S
38E
68E
98E
A
B
C
0
85
153
51
SCALE (feet)
0
100
200
N
LEGEND
DIRECT PUSH AREA
RESISTIVITY / IP SURVEY LINE
SP DATA STATION
PROPERTY LINE
FLOOD WALL
FENCE
SURFACE ELEVATION CONTOUR (FT. AMSL)
PIEZOMETER
MONITORING WELL (SHALLOW)
MONITORING WELL (DEEP)
CITY MONITORING WELL
SOIL BORING
SURFACE SOIL SAMPLE
STAFF GAUGE
NOTE:
Modified from site plan provided by Woodord & Curren.
Figure 2
Site Plan
New York State Electric & Gas Corp.
Court Street Site
Binghamton, New York
File 98G27
October, 1999
HAGER-RICHTER GEOSCIENCE, INC.
Salem, New Hampshire



NOTE:

The electrodes, number 1 through 20, are connected to an "intelligent node" which is connected to the electronics by an electrical cable. The intelligent node provides the capability of addressing each of the electrodes from the electronics which contain a microprocessor. Any pair of electrodes can be used via the software program as the current electrodes and any other pair can be selected as the potential measuring electrodes. More than 150 combinations can be accessed, providing a redundant data set for inversion.

Figure 3
Resistivity Array
New York State Electric & Gas Corp.
Court Street Site
Binghamton, New York

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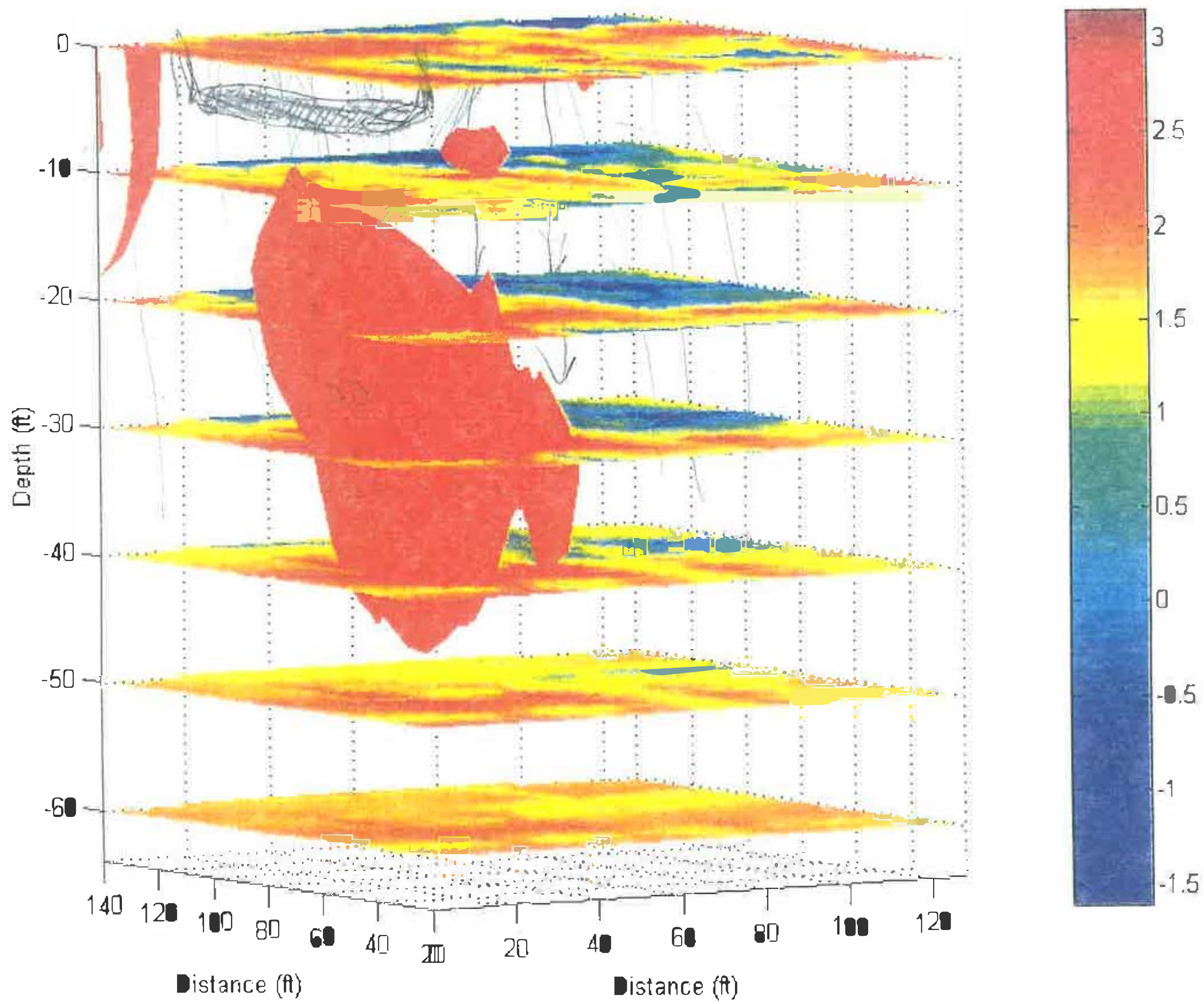
Salem, New Hampshire



Note: The color scale is logarithmic. The numbers on the color bar are exponents. For example, -2 represents 10^{-2} ohm-ft (0.01 ohm-ft) and 1 represents 10^{1} ohm-ft (10 ohm-ft).

Figure 4 Volume of Highly Resistive Material New York State Electric & Gas Corp. Court Street Site Binghamton, New York

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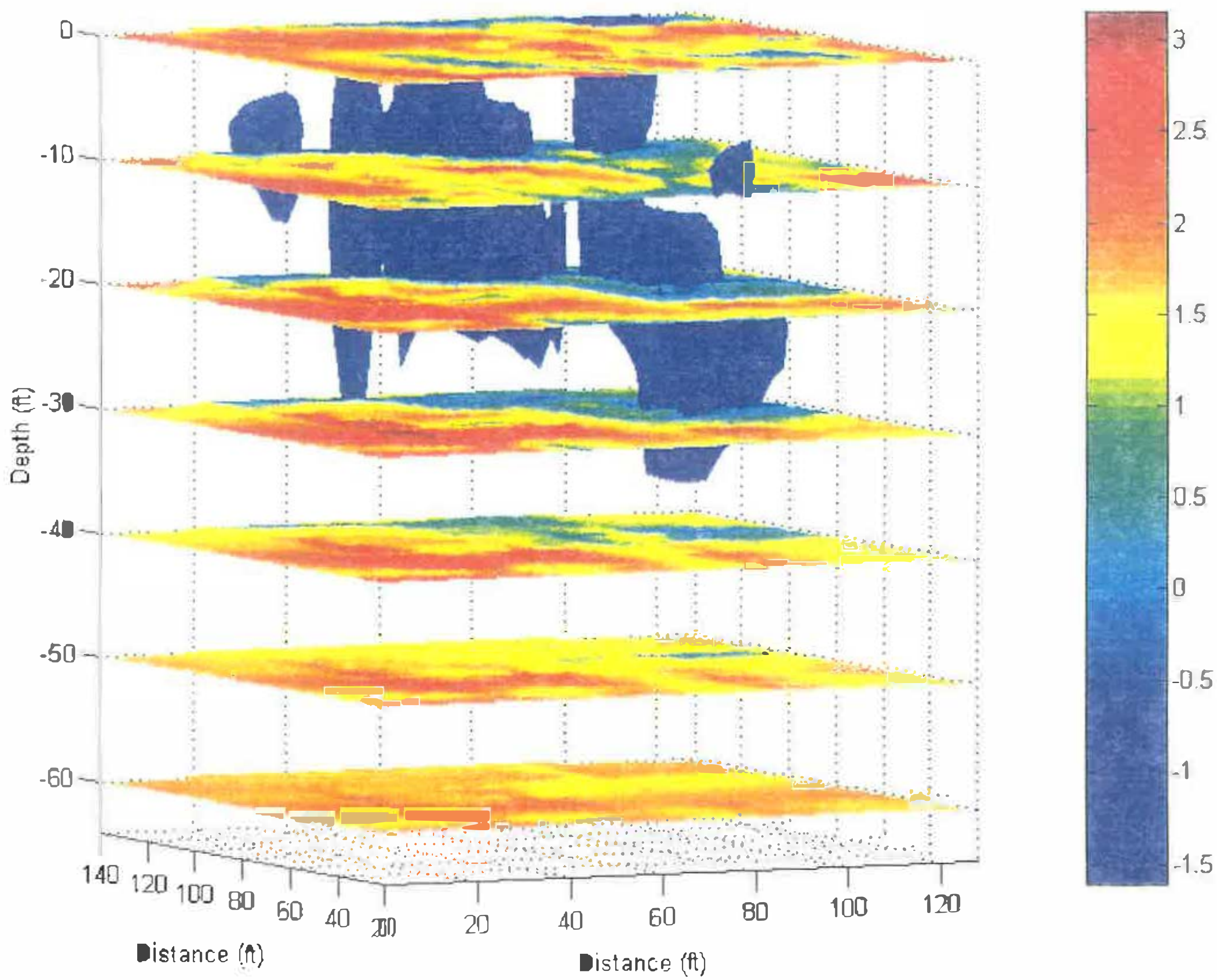
Salem, New Hampshire



Note: The color scale is logarithmic. The numbers on the color bar are exponents. For example, -2 represents 10^{-2} ohm-ft (0.01 ohm-ft) and 1 represents 10^{1} ohm-ft (10 ohm-ft).

Figure 5
Volume of Highly Conductive Material
New York State Electric & Gas Corp.
Court Street Site
Binghamton, New York

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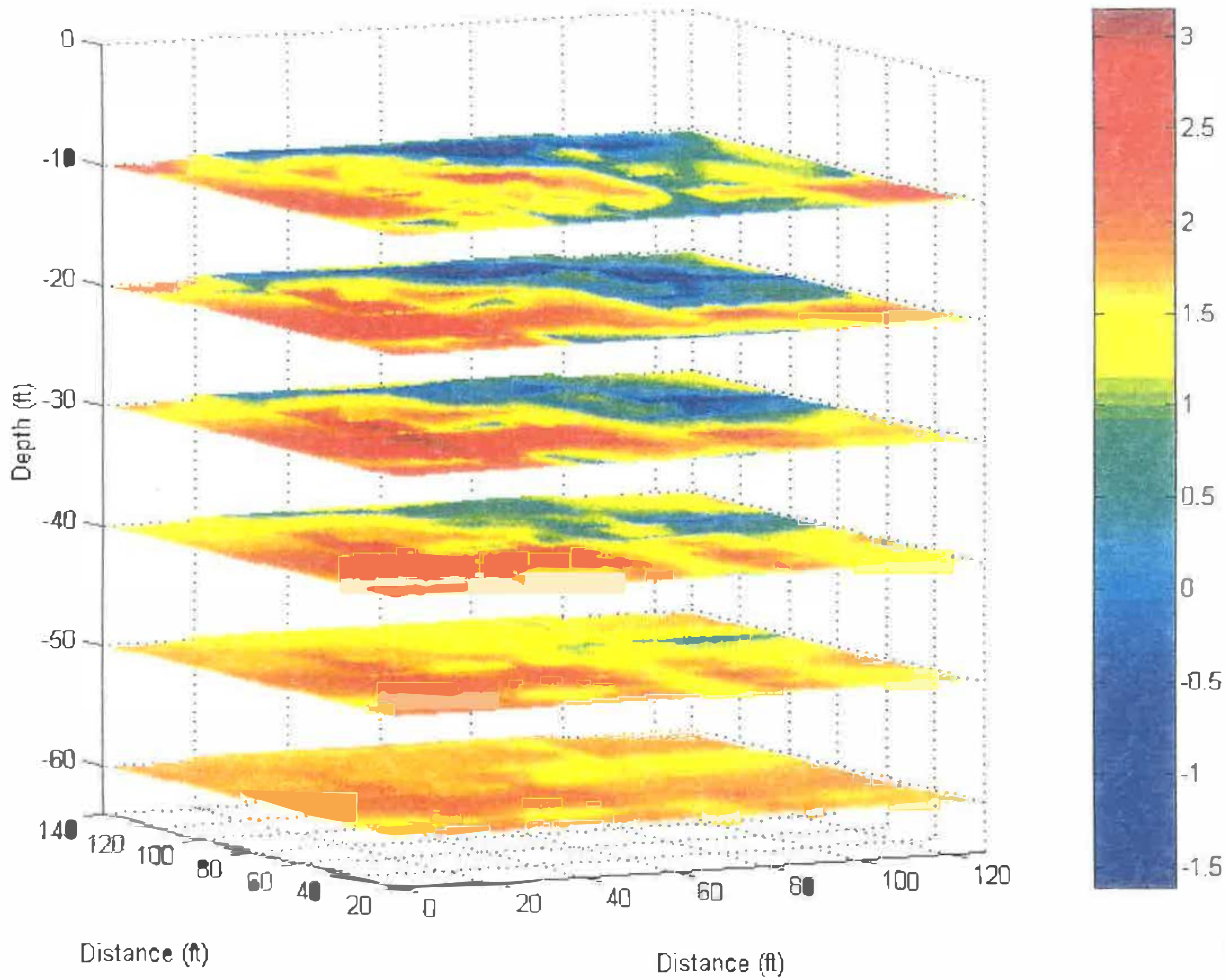
Salem, New Hampshire

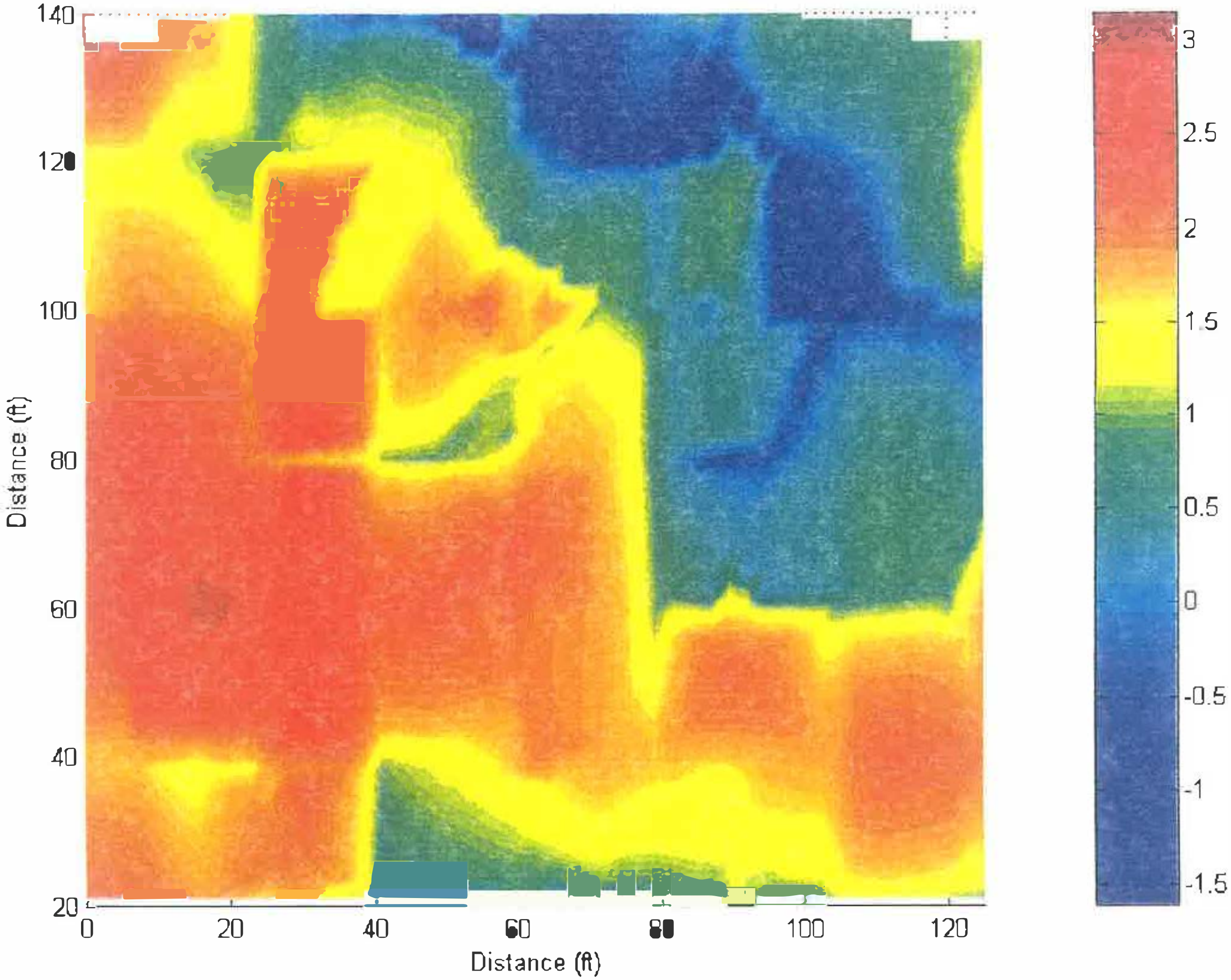


Note: The color scale is logarithmic. The numbers on the color bar are exponents. For example, -2 represents 10^{2} ohm-ft (0.01 ohm-ft) and 1 represents 10^{1} ohm-ft (10 ohm-ft).

Figure 6
Three Dimensional Resistivity
New York State Electric & Gas Corp.
Court Street Site
Binghamton, New York

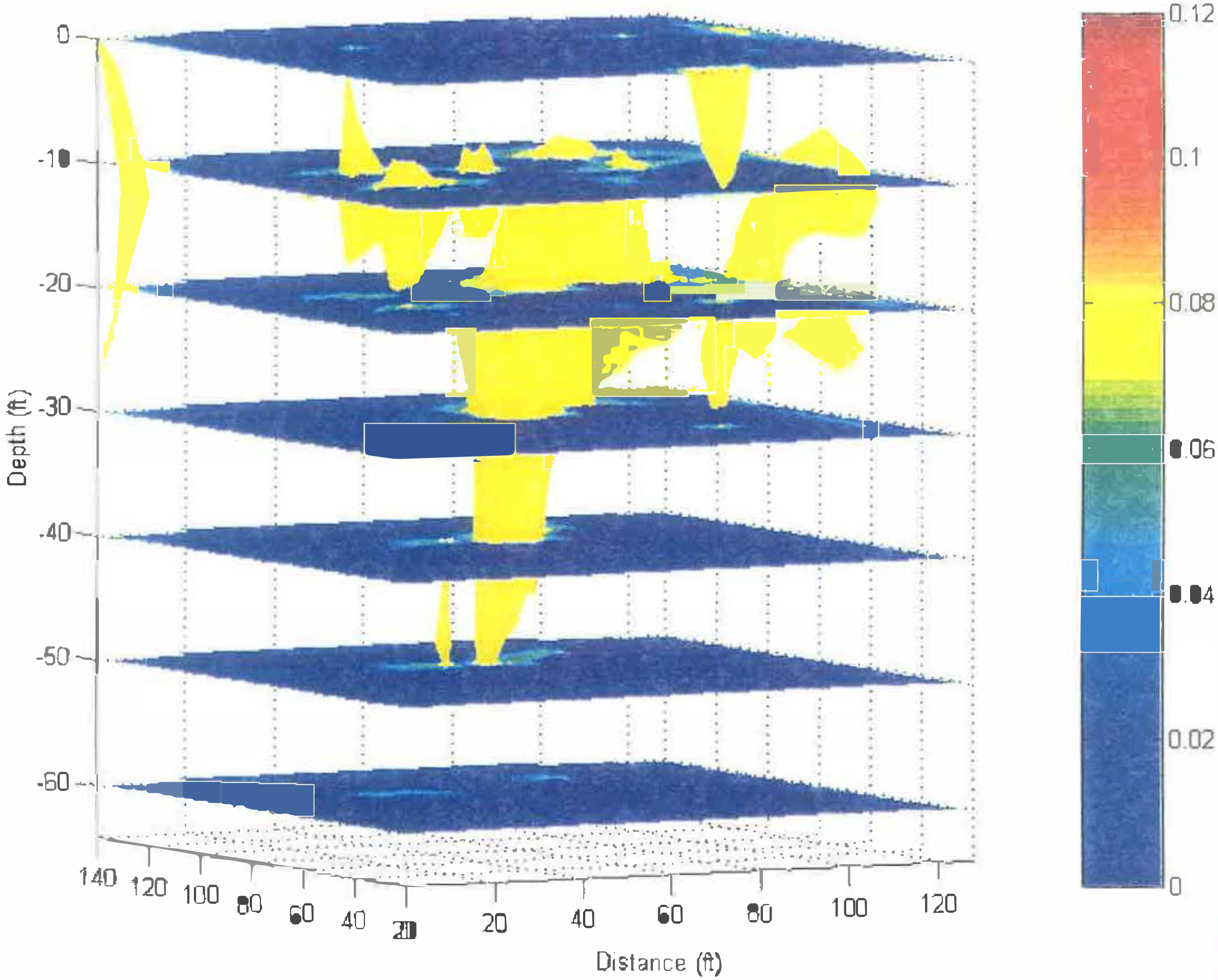
File 98G27	**October, 1999**

HAGER-RICHTER GEOSCIENCE, INC.
Salem, New Hampshire



Note: The color scale is logarithmic. The numbers on the color bar are exponents. For example, -2 represents 10^{-2} ohm-ft (0.01 ohm-ft) and 1 represents 10^{1} ohm-ft (10 ohm-ft).

Figure 7 Resistivity at 20 Feet Depth New York State Electric & Gas Corp. Court Street Site Binghamton, New York	
File 98G27	October, 1999
HAGERRICHTER GEOSCIENCE, INC. Salem, New Hampshire	



Note: The color scale is linear. The units are mV / V.

Figure 8
IP/Chargeability
New York State Electric & Gas Corp.
Court Street Site
Binghamton, New York

File 98G27	October, 1999

HAGER-RICHTER GEOSCIENCE, INC.
Salem, New Hampshire

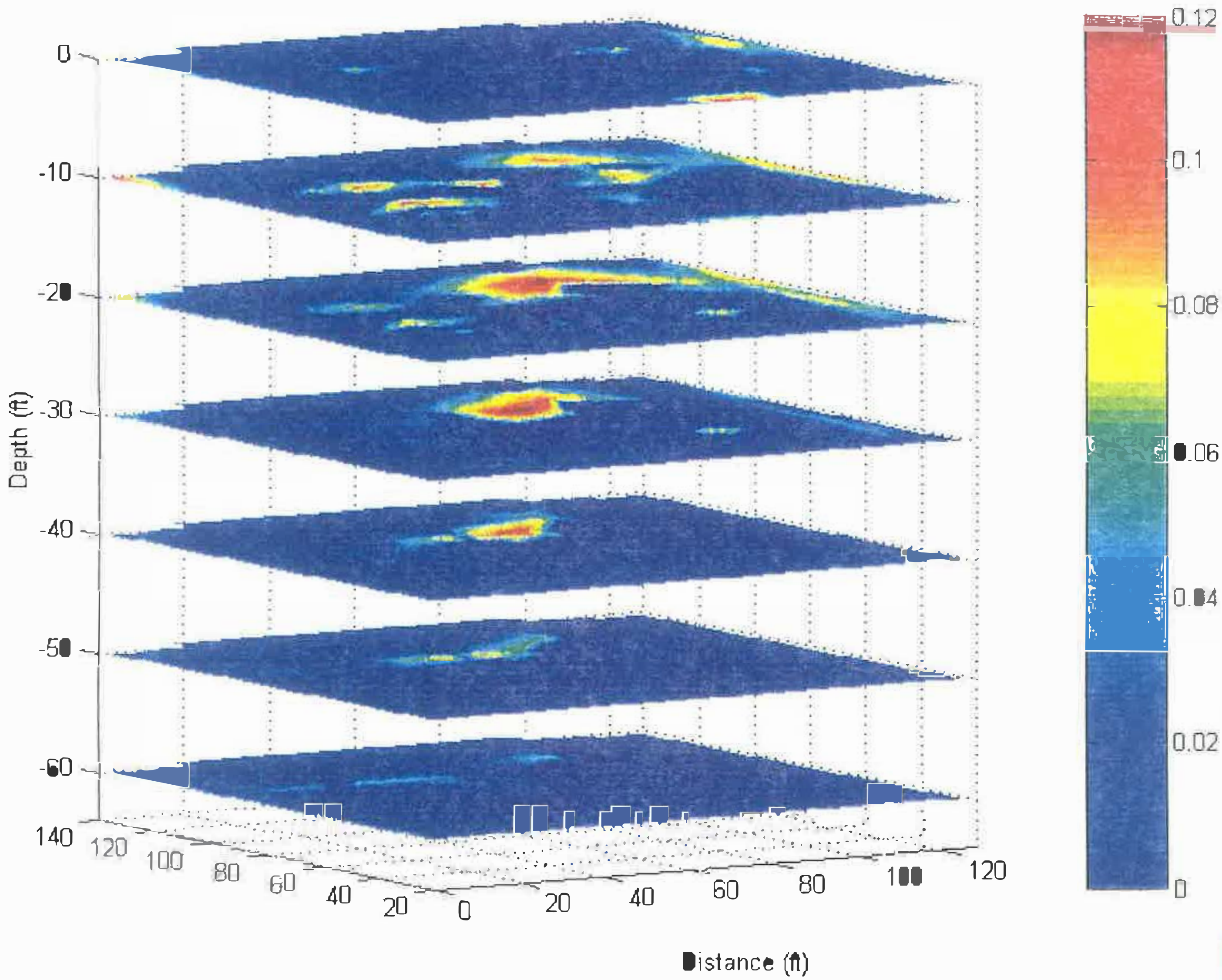
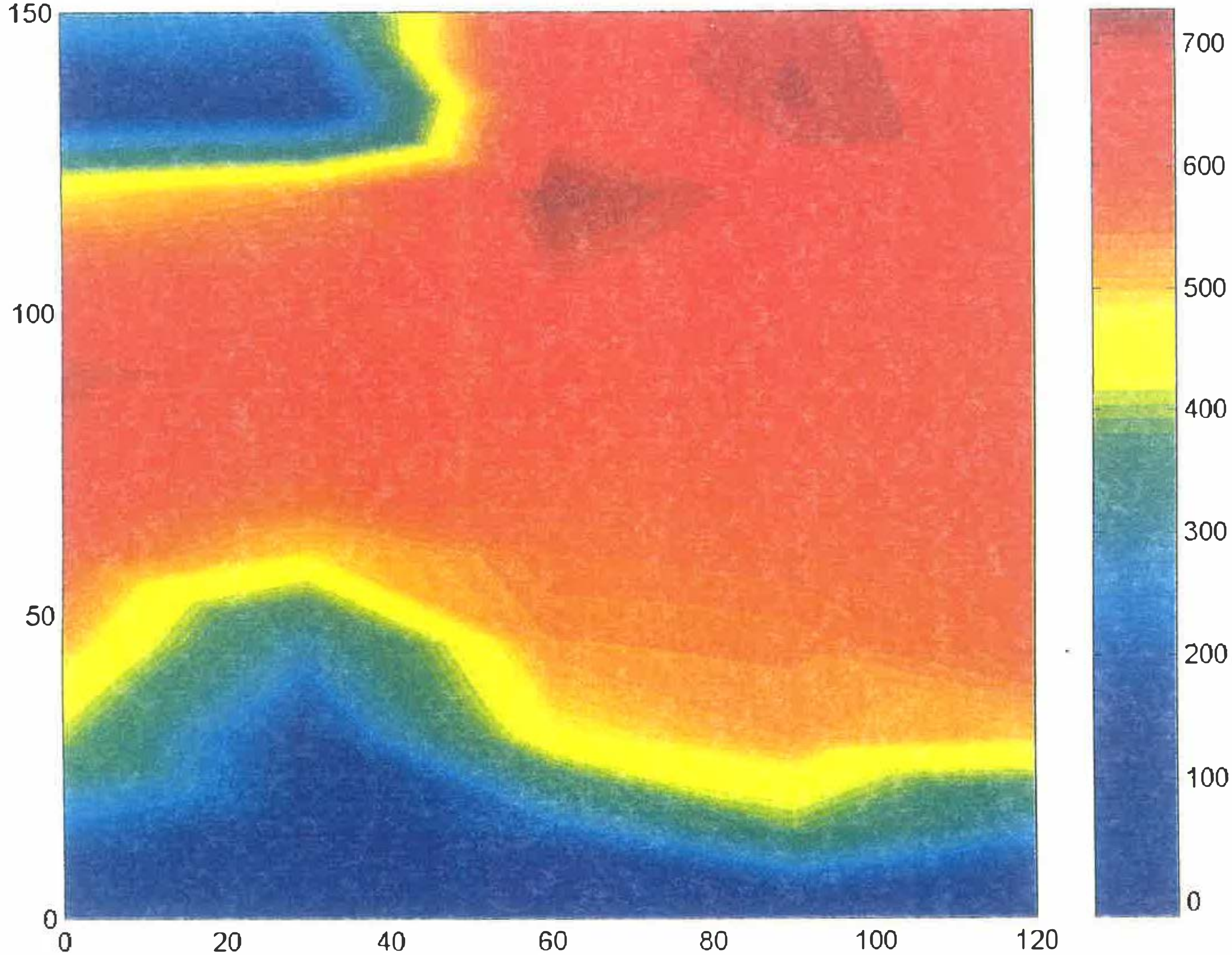


Figure 9
Three Dimensional IP
New York State Electric & Gas Corp.
Court Street Site
Binghamton, New York

File 98G27	October, 1999

HAGER-RICHTER GEOSCIENCE, INC.
Salem, New Hampshire

Note: The color scale is linear. The units are mV / V.



Note: The color scale is linear. The units are mV.

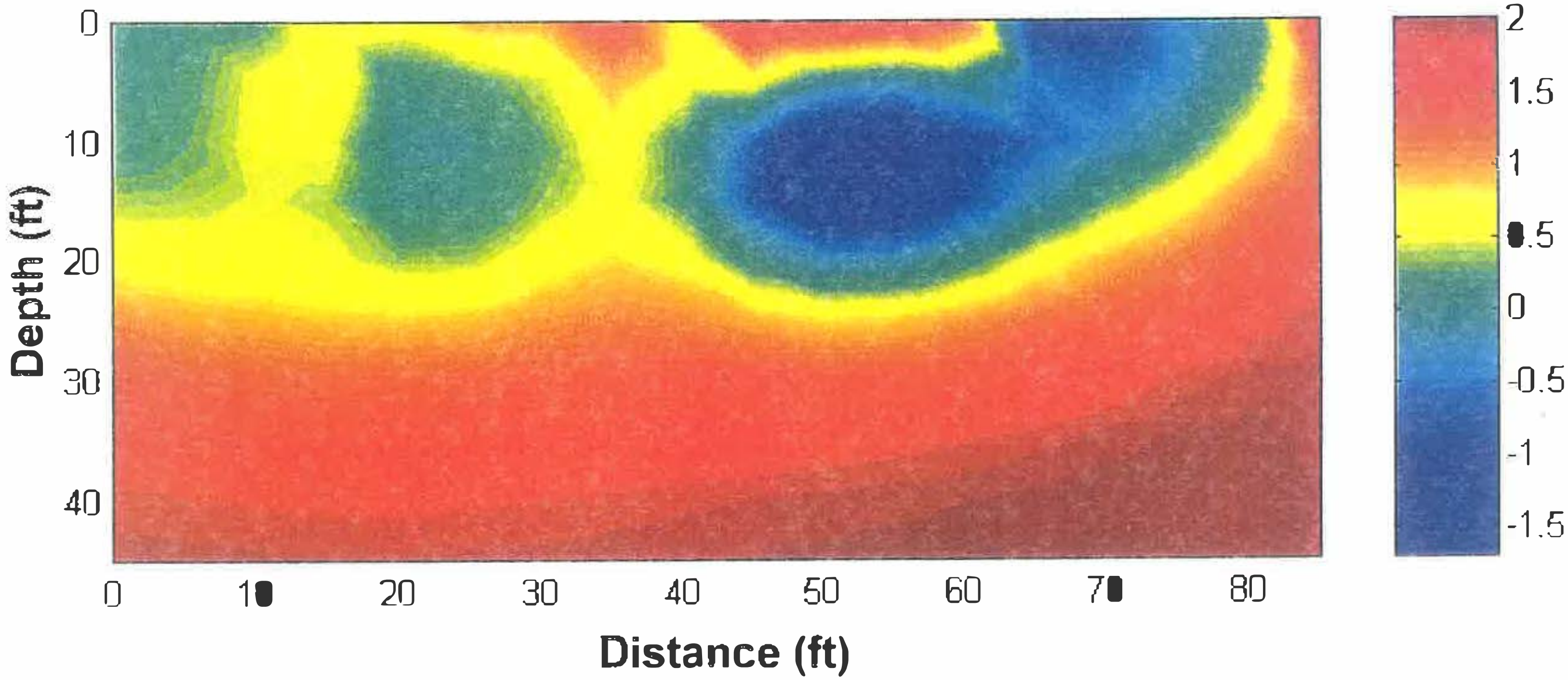
Figure 10
SP
New York State Electric & Gas Corp.
Court Street Site
Binghamton, New York

File 98G27	October, 1999

HAGER-RICHTER GEOSCIENCE, INC.
Salem, New Hampshire

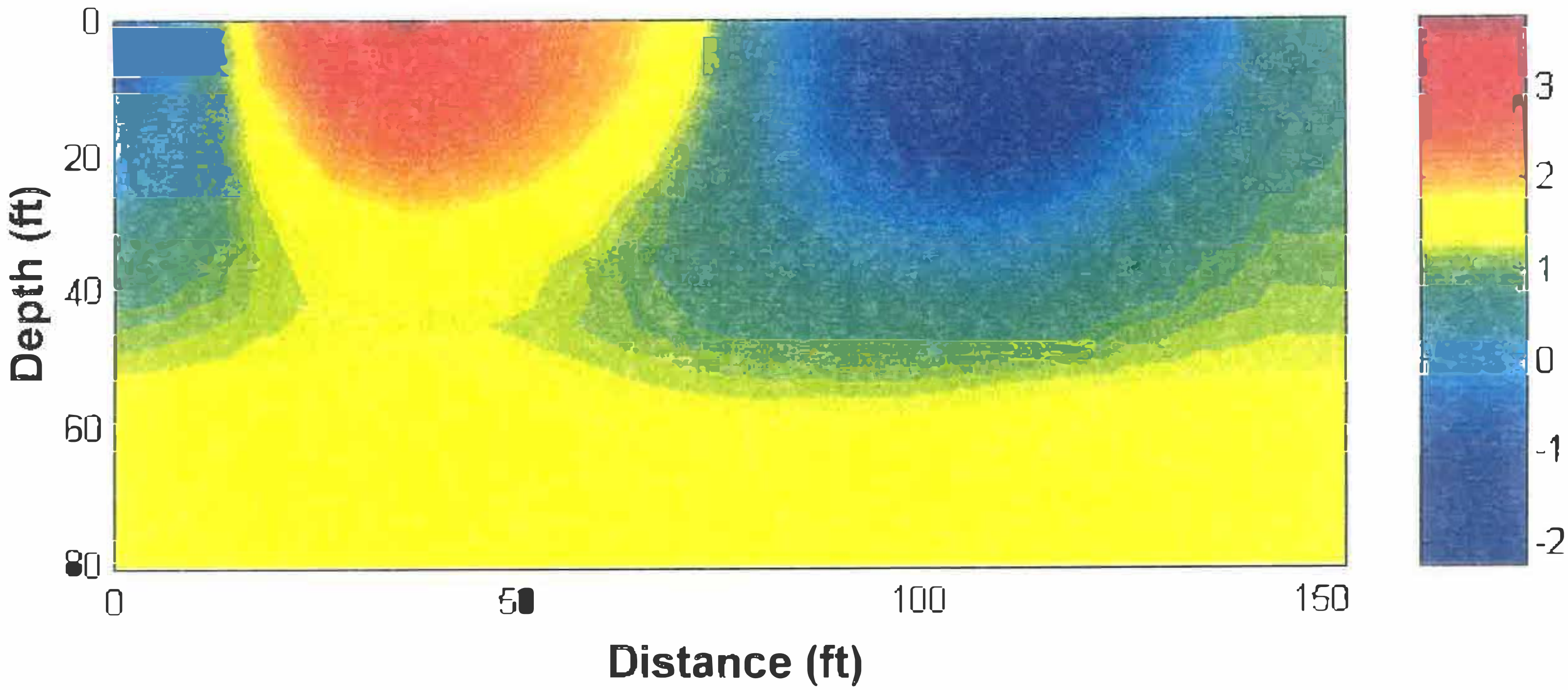
APPENDIX

Resistivity Tomograms
Induced Polarization Tomograms



Note: The color scale is logarithmic. The numbers on the color bar are exponents. For example, -2 represents 10^{-2} ohm-ft (0.01 ohm-ft) and 1 represents 10^{1} ohm-ft (10 ohm-ft).

Line A - Resistivity New York State Electric & Gas Corp. Court Street Site Bing hamton, New York	
File 98G27	October, 1999
HAGER-RICHTER GEOSCIENCE, INC. Salem, New Hampshire	

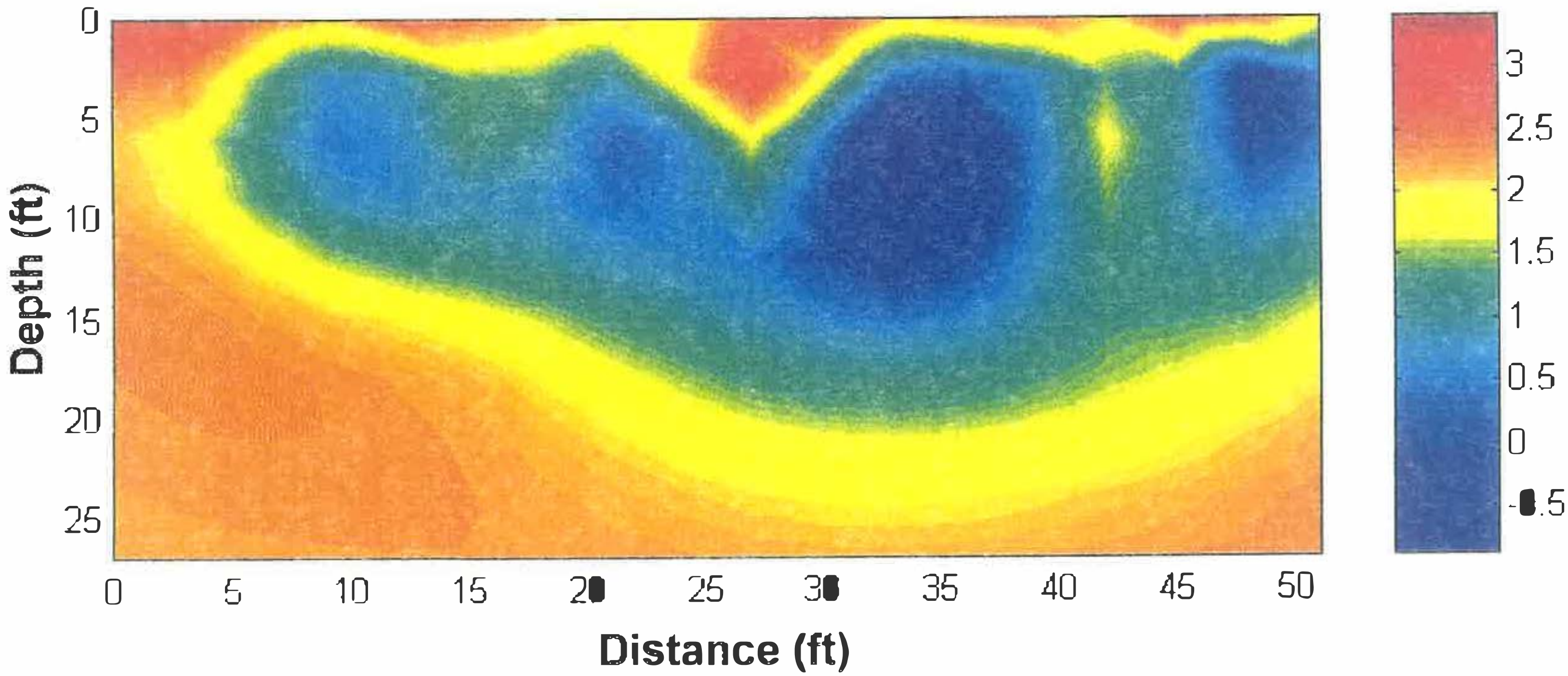


Note: The color scale is logarithmic. The numbers on the color bar are exponents. For example, -2 represents 10^{-2} ohm-ft (0.01 ohm-ft) and 1 represents 10^{1} ohm-ft (10 ohm-ft).

Line B - Resistivity New York State Electric & Gas Corp. Court Street Site Binghamton, New York

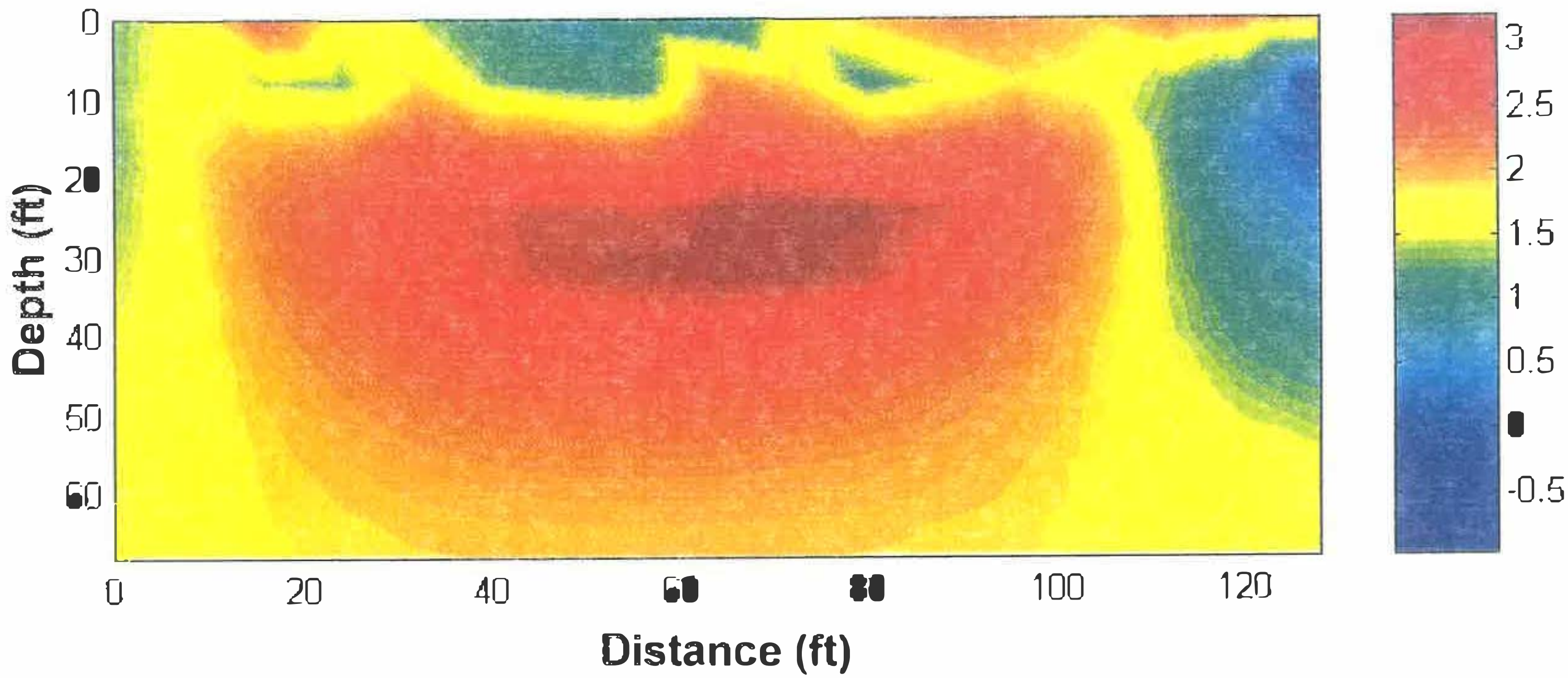
File 98G27	October, 1999

HAGER-RICHTER GEOSCIENCE, INC.
Salem, New Hampshire



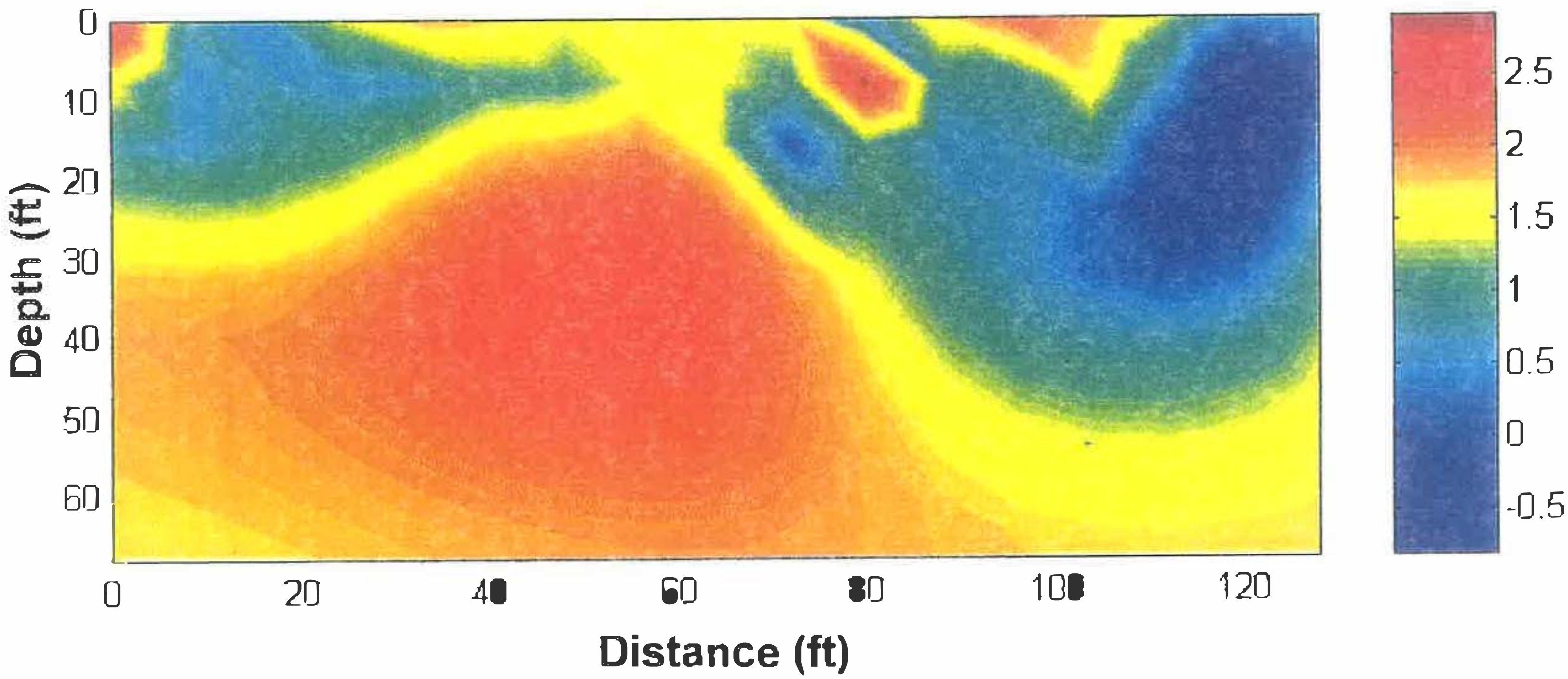
Note: The color scale is logarithmic. The numbers on the color bar are exponents. For example, -2 represents 10^{-2} ohm-ft (0.01 ohm-ft) and 1 represents 10^{1} ohm-ft (10 ohm-ft).

Line C - Resistivity New York State Electric & Gas Corp. Court Street Site Binghamton, New York	
File 98G27	October, 1999
HAGER-RICHTER GEOSCIENCE, INC. Salem, New Hampshire	



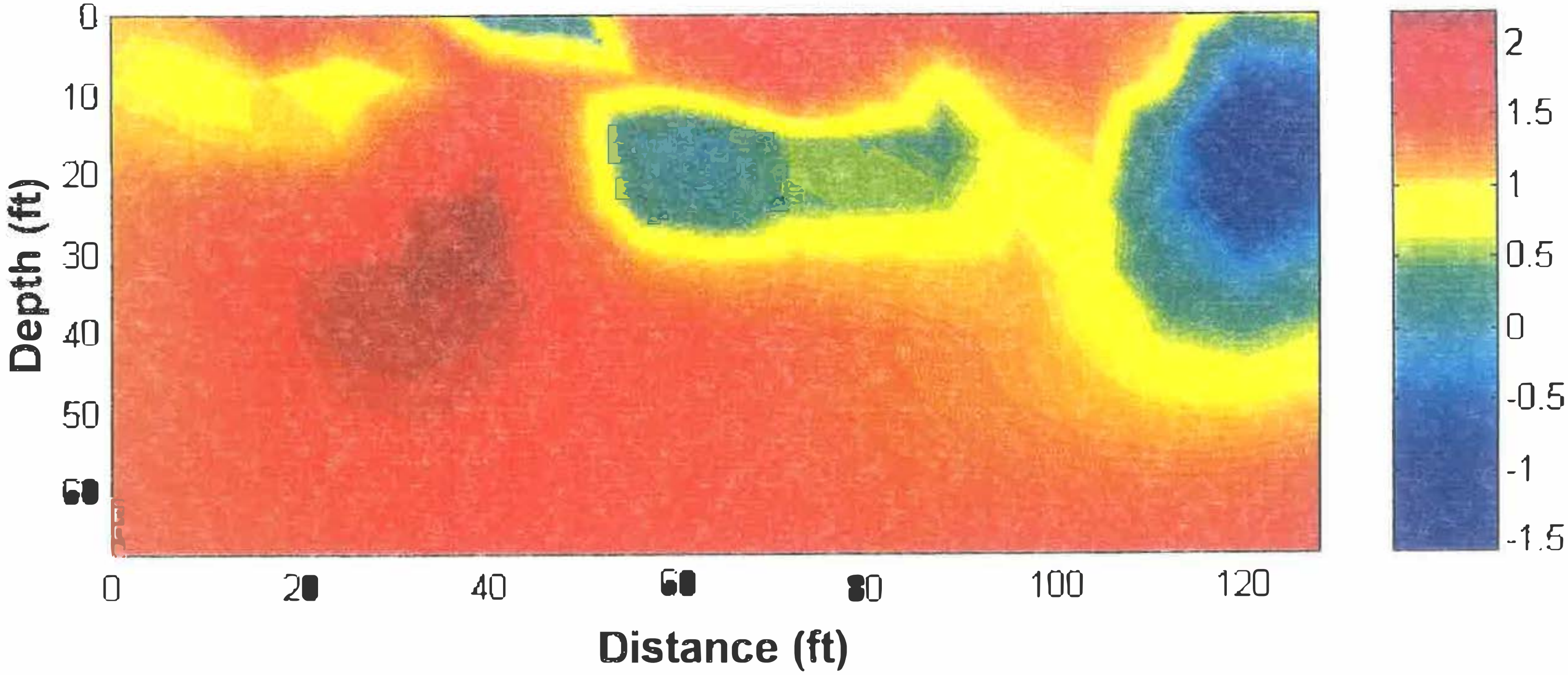
Note: The color scale is logarithmic. The numbers on the color bar are exponents. For example, -2 represents 10^{-2} ohm-ft (0.01 ohm-ft) and 1 represents 10^{1} ohm-ft (10 ohm-ft).

Line 38 E - Resistivity New York State Electric & Gas Corp. Court Street Site Binghamton, New York	
File 98G27	October, 1999
HAGER-RICHTER GEOSCIENCE, INC. Salem, New Hampshire	



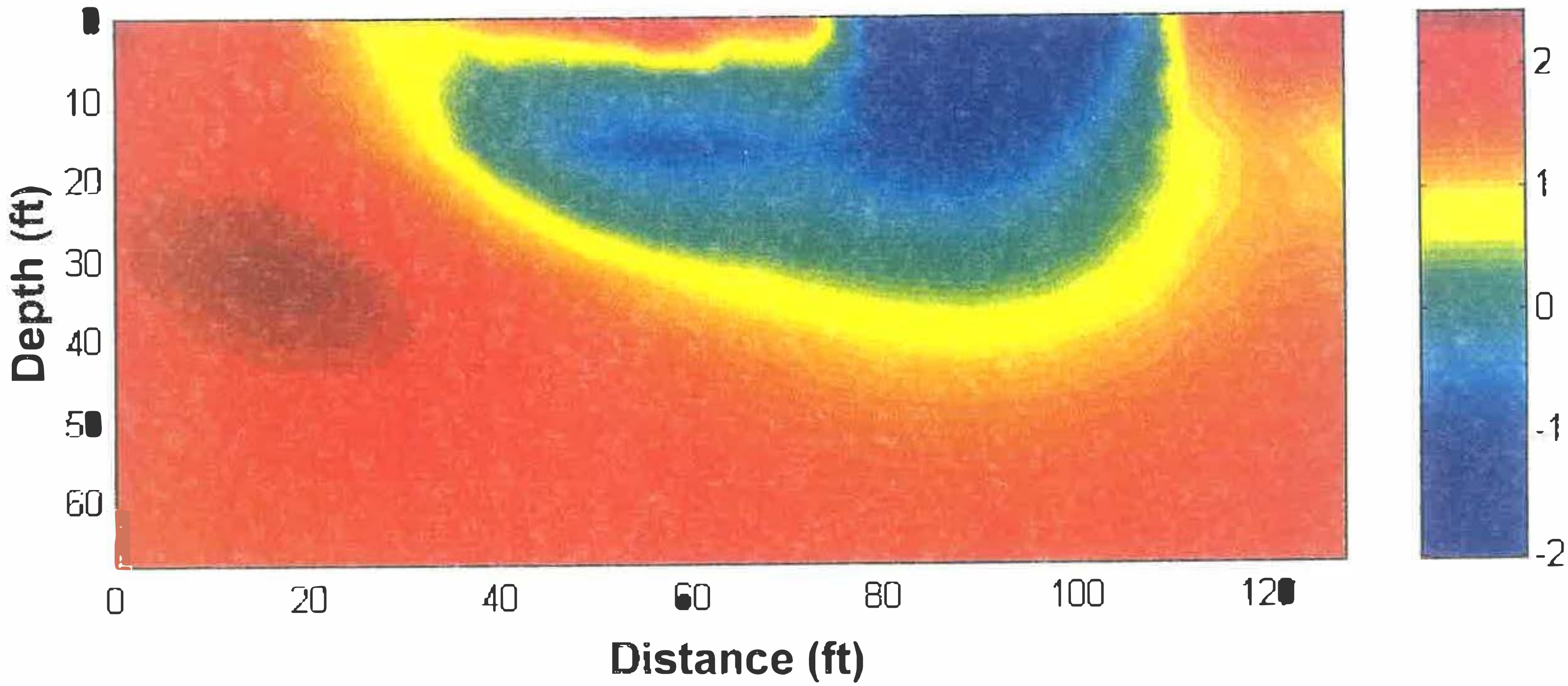
Note: The color scale is logarithmic. The numbers on the color bar are exponents. For example, -2 represents 10^{-2} ohm-ft (0.01 ohm-ft) and 1 represents 10^{1} ohm-ft (10 ohm-ft).

Line 68 E - Resistivity New York State Electric & Gas Corp. Court Street Site Binghamton, New York
File 98G27 — October, 1999
HAGER-RICHTER GEOSCIENCE, INC. Salem, New Hampshire



Note: The color scale is logarithmic. The numbers on the color bar are exponents. For example, -2 represents 10^{-2} ohm-ft (0.01 ohm-ft) and 1 represents 10^{1} ohm-ft (10 ohm-ft).

Line 98 E - Resistivity **New York State Electric & Gas Corp.** **Court Street Site** **Binghamton, New York**
File 98G27 | **October, 1999**
HAGER-RICHTER GEOSCIENCE, INC. **Salem, New Hampshire**

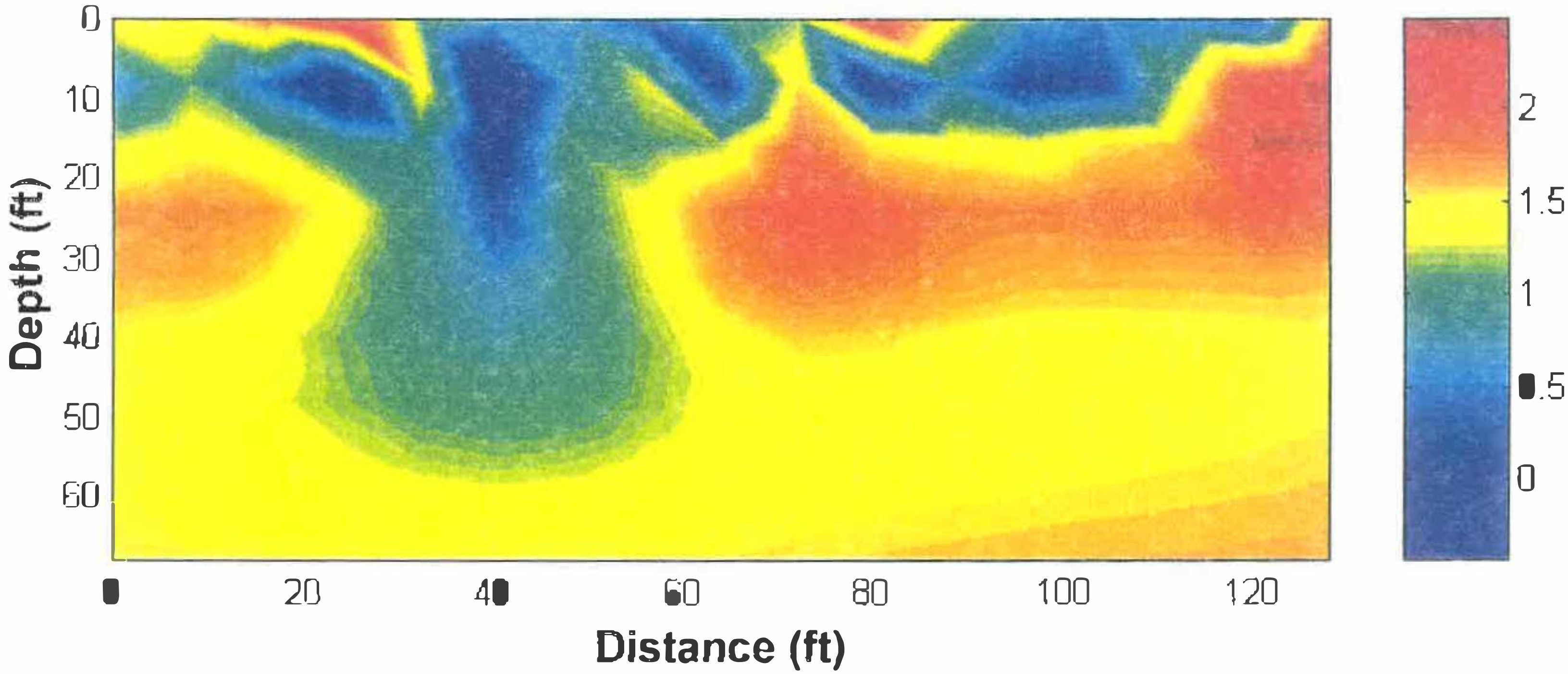


Note: The color scale is logarithmic. The numbers on the color bar are exponents. For example, -2 represents 10^{-2} ohm-ft (0.01 ohm-ft) and 1 represents 10^{1} ohm-ft (10 ohm-ft).

Line 20 S - Resistivity **New York State Electric & Gas Corp.** **Court Street Site** **Binghamton, New York**

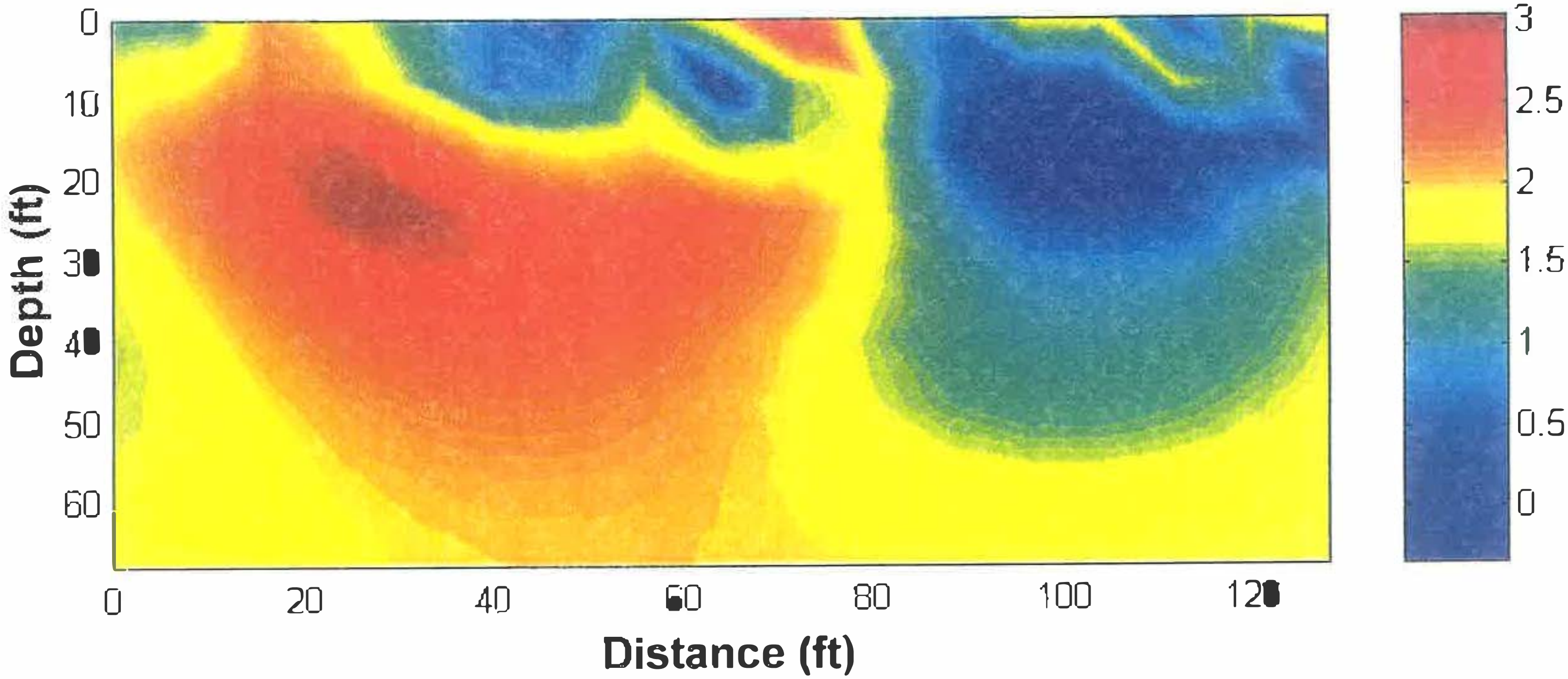
File 98G27	**October, 1999**

HAGER-RICHTER GEOSCIENCE, INC.
Salem, New Hampshire



Note: The color scale is logarithmic. The numbers on the color bar are exponents. For example, -2 represents 10^{-2} ohm-ft (0.01 ohm-ft) and 1 represents 10^{1} ohm-ft (10 ohm-ft).

Line 40 S - Resistivity New York State Electric & Gas Corp. Court Street Site Binghamton, New York	
File 98G27	October, 1999
HAGER-RICHTER GEOSCIENCE, INC. Salem, New Hampshire	

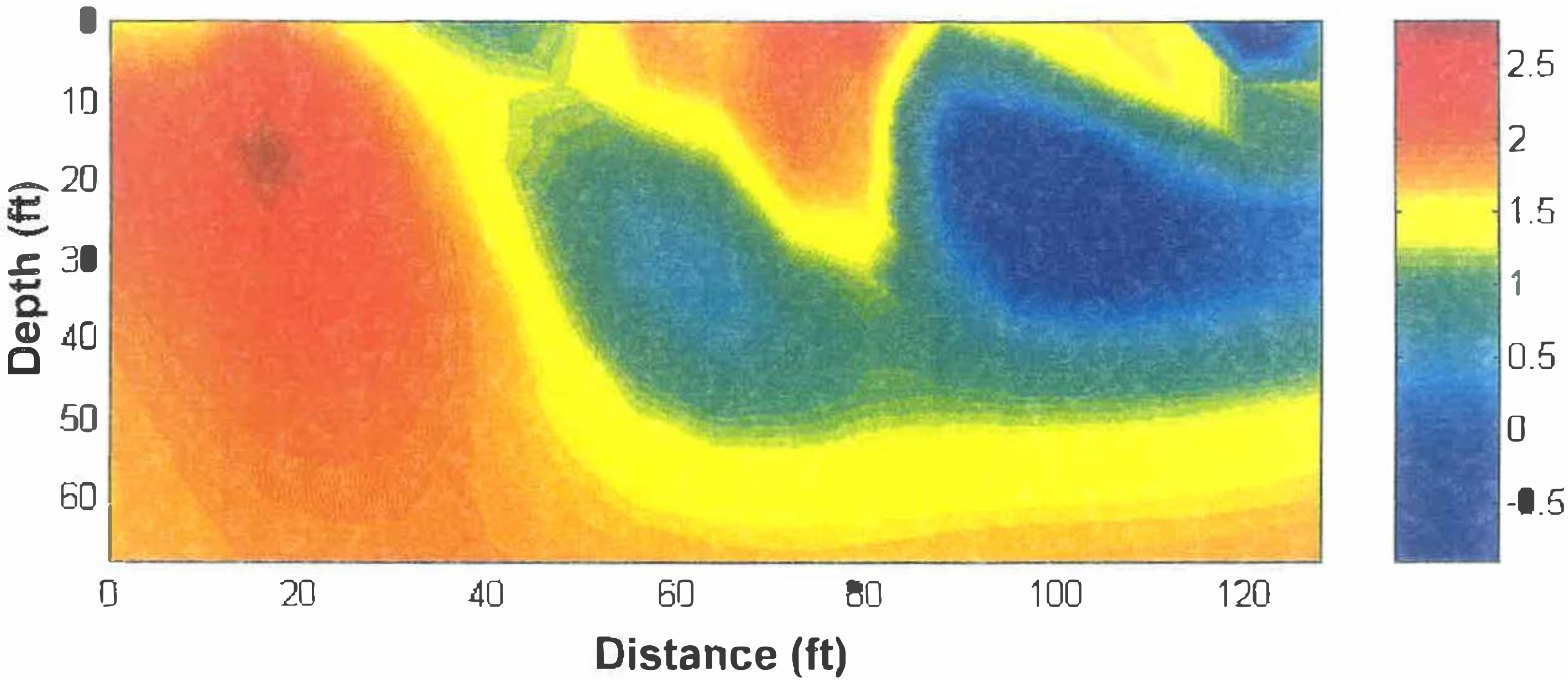


Note: The color scale is logarithmic. The numbers on the color bar are exponents. For example, -2 represents 10^{-2} ohm-ft (0.01 ohm-ft) and 1 represents 10^{1} ohm-ft (10 ohm-ft).

Line 60 S - Resistivity New York State Electric & Gas Corp. Court Street Site Binghamton, New York

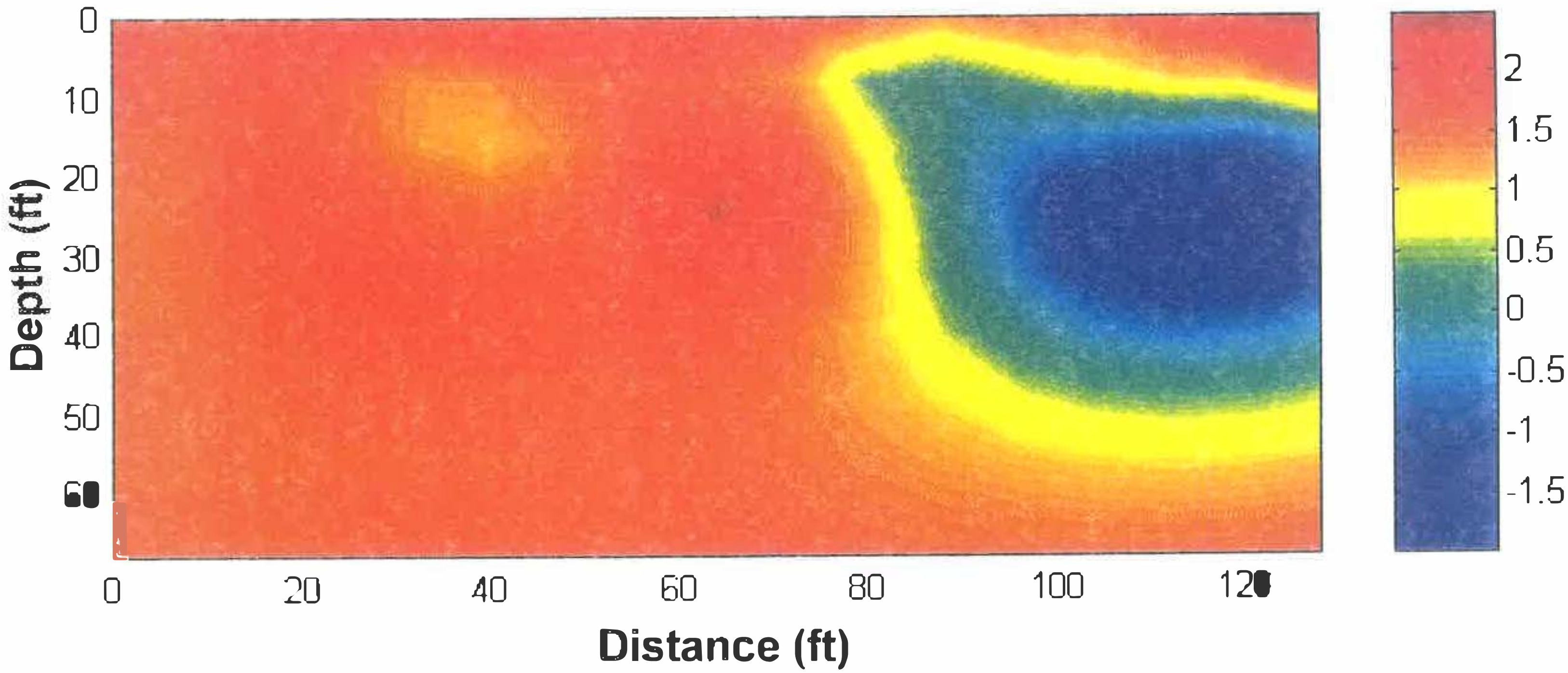
File 98G27	October, 1999

HAGER-RICHTER GEOSCIENCE, INC.
Salem, New Hampshire



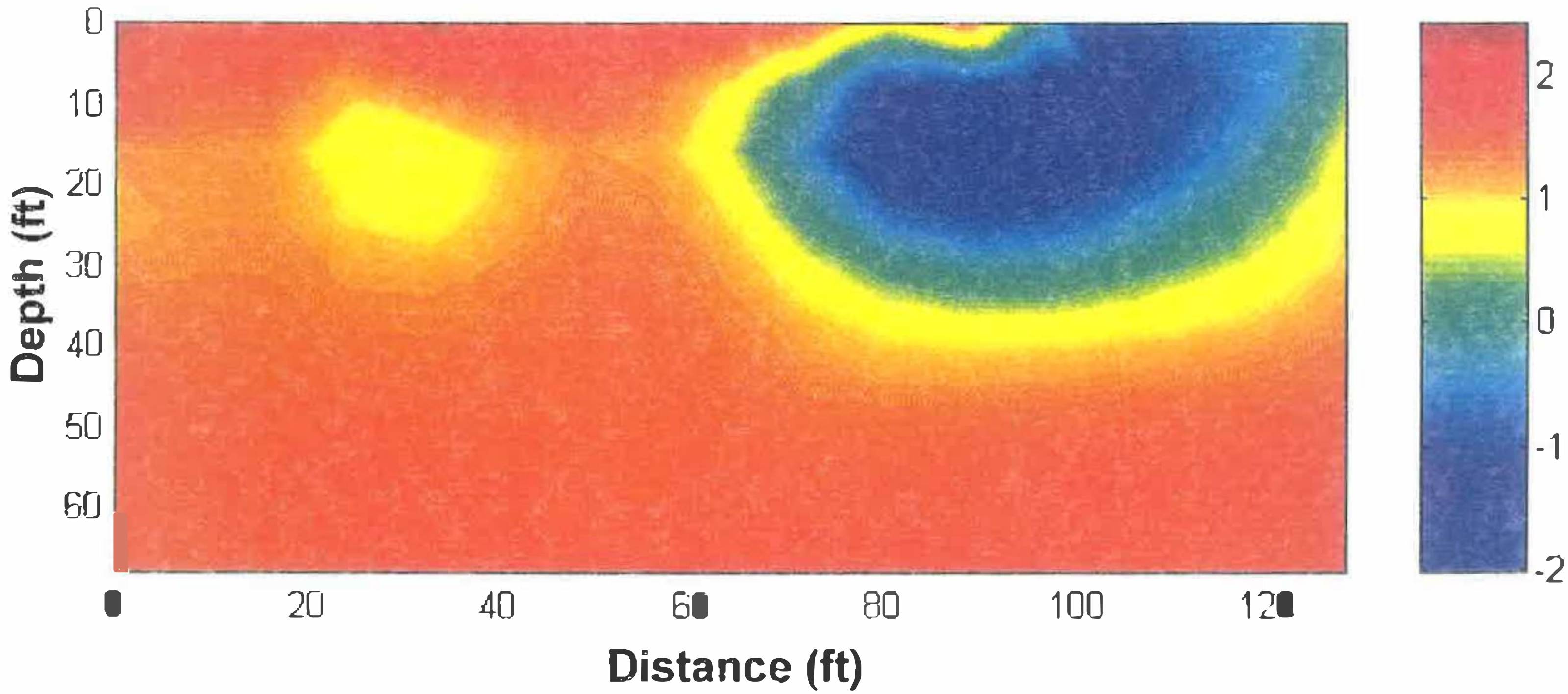
Note: The color scale is logarithmic. The numbers on the color bar are exponents. For example, -2 represents 10^{-2} ohm-ft (0.01 ohm-ft) and 1 represents 10^{1} ohm-ft (10 ohm-ft).

Line 80 S - Resistivity New York State Electric & Gas Corp. Court Street Site Binghamton, New York	
File 98G27	October, 1999
HAGER-RICHTER GEOSCIENCE, INC. Salem, New Hampshire	



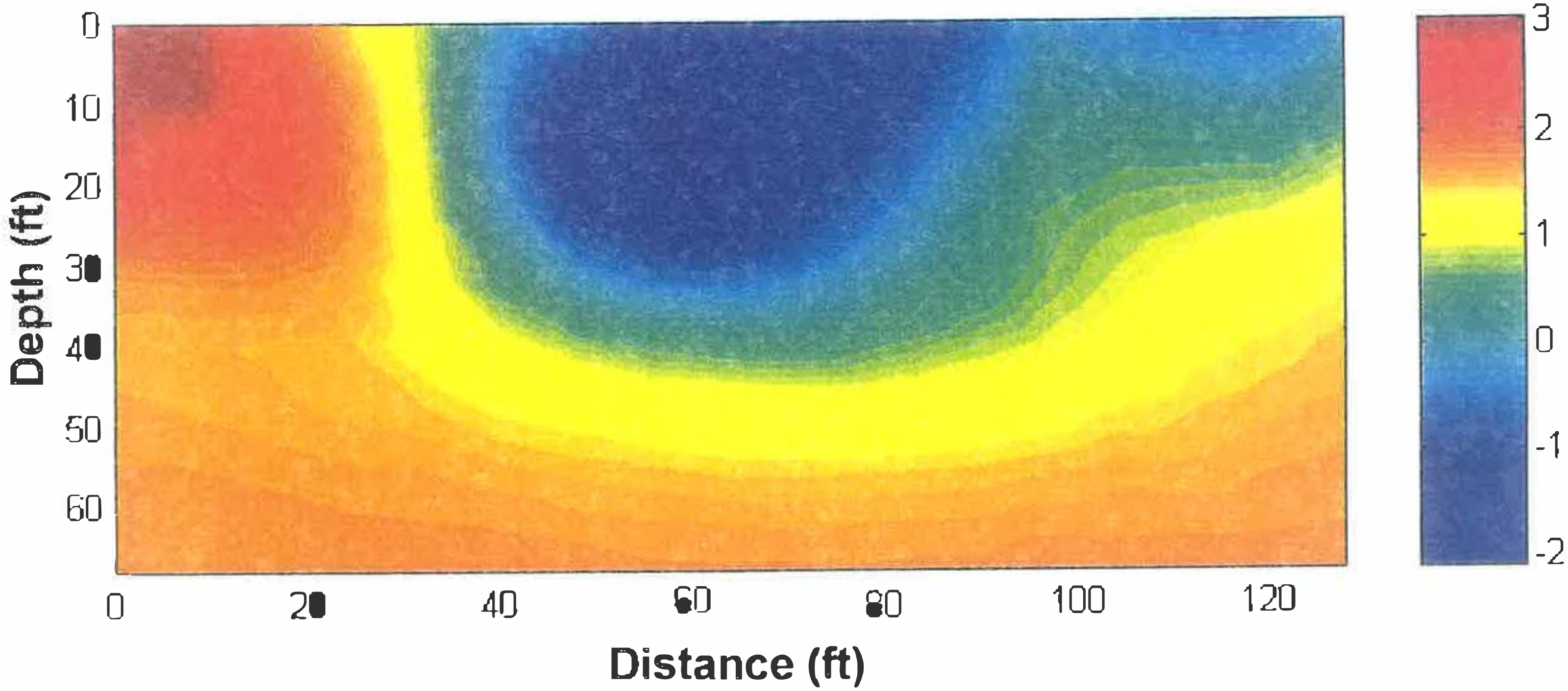
Note: The color scale is logarithmic. The numbers on the color bar are exponents. For example, -2 represents 10^{-2} ohm-ft (0.01 ohm-ft) and 1 represents 10^{1} ohm-ft (10 ohm-ft).

Line 100 S - Resistivity New York State Electric & Gas Corp. Court Street Site Binghamton, New York	
File 98G27	October, 1999
HAGER-RICHTER GEOSCIENCE, INC. Salem, New Hampshire	



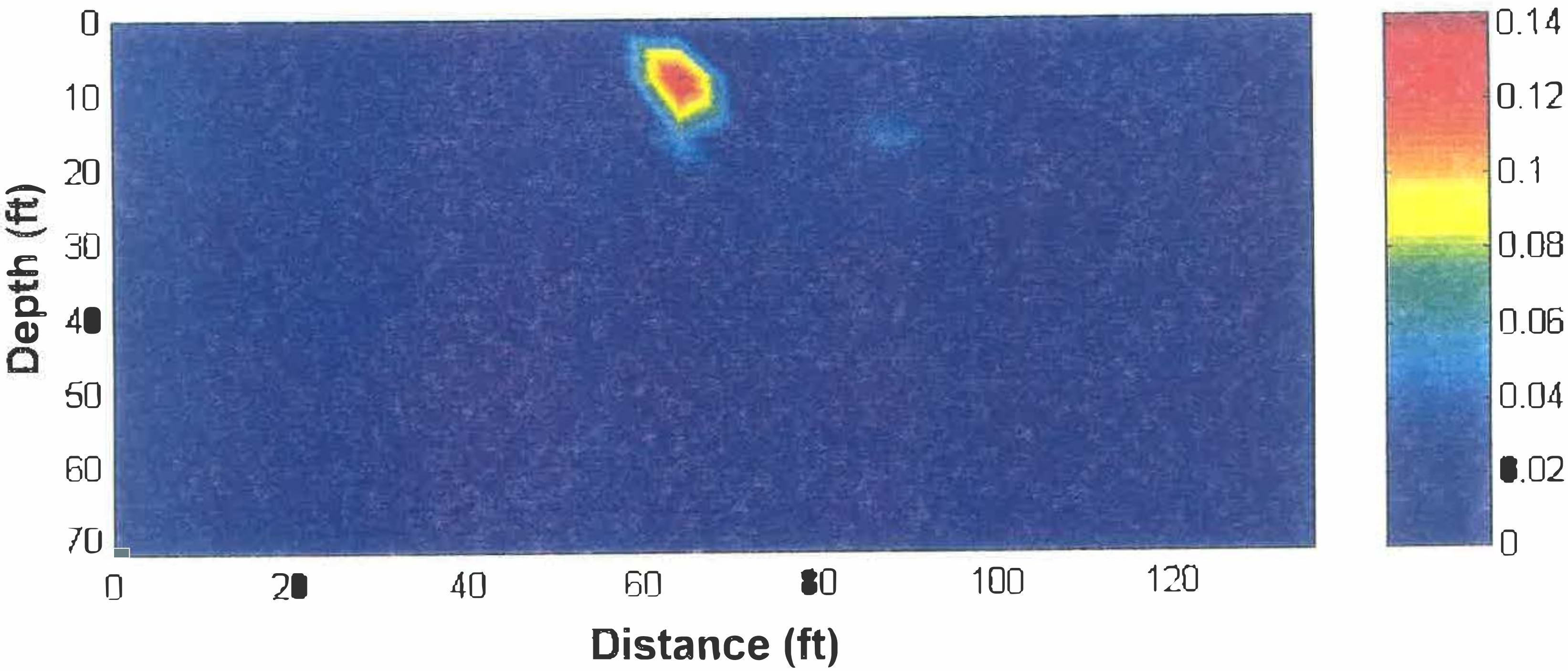
Note: The color scale is logarithmic. The numbers on the color bar are exponents. For example, -2 represents 10^{-2} ohm-ft (0.01 ohm-ft) and 1 represents 10^{1} ohm-ft (10 ohm-ft).

Line 120 S - Resistivity New York State Electric & Gas Corp. Court Street Site Binghamton, New York	
File 98G27	October, 1999
HAGER-RICHTER GEOSCIENCE, INC. Salem, New Hampshire	



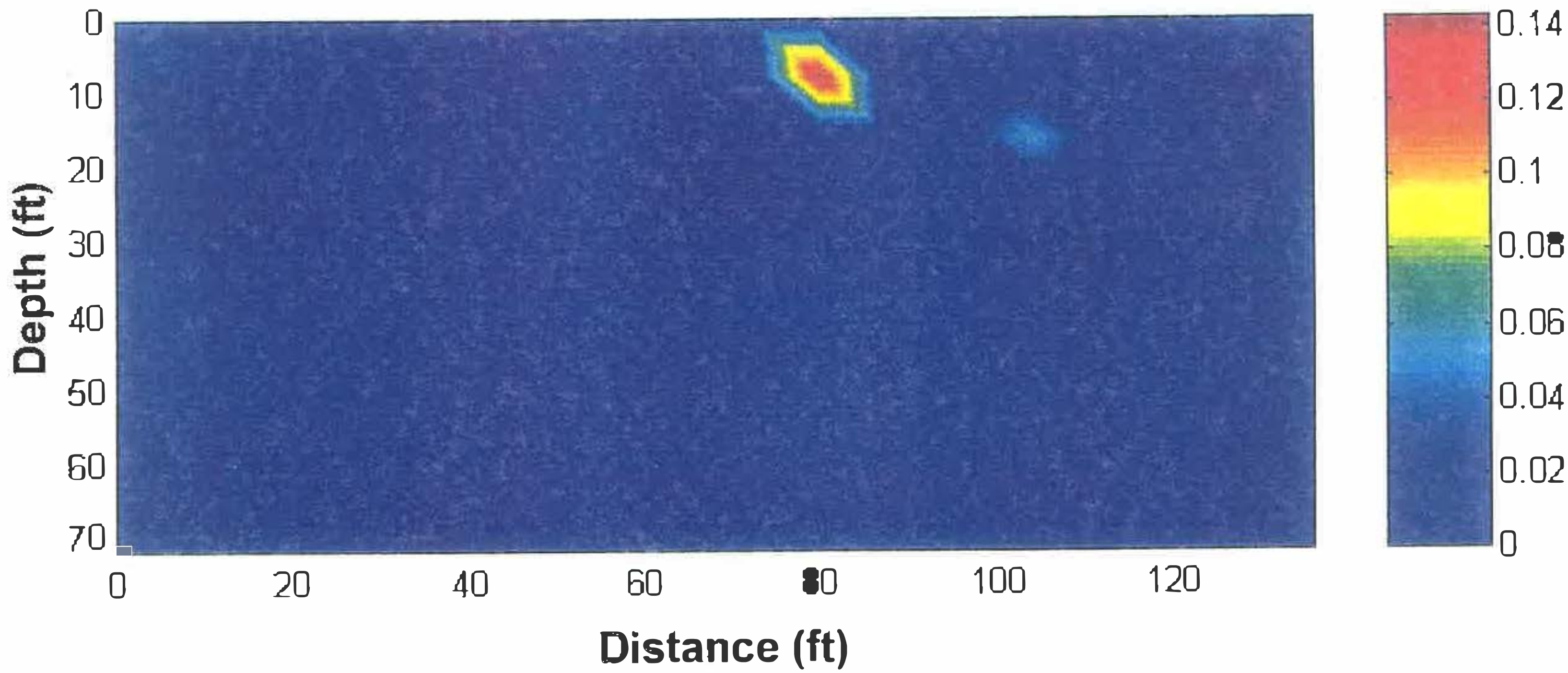
Note: The color scale is logarithmic. The numbers on the color bar are exponents. For example, -2 represents 10^{-2} ohm-ft (0.01 ohm-ft) and 1 represents 10^{1} ohm-ft (10 ohm-ft).

Line 140 S - Resistivity New York State Electric & Gas Corp. Court Street Site Binghamton, New York	
File 98G27	October, 1999
HAGER-RICHTER GEOSCIENCE, INC. Salem, New Hampshire	



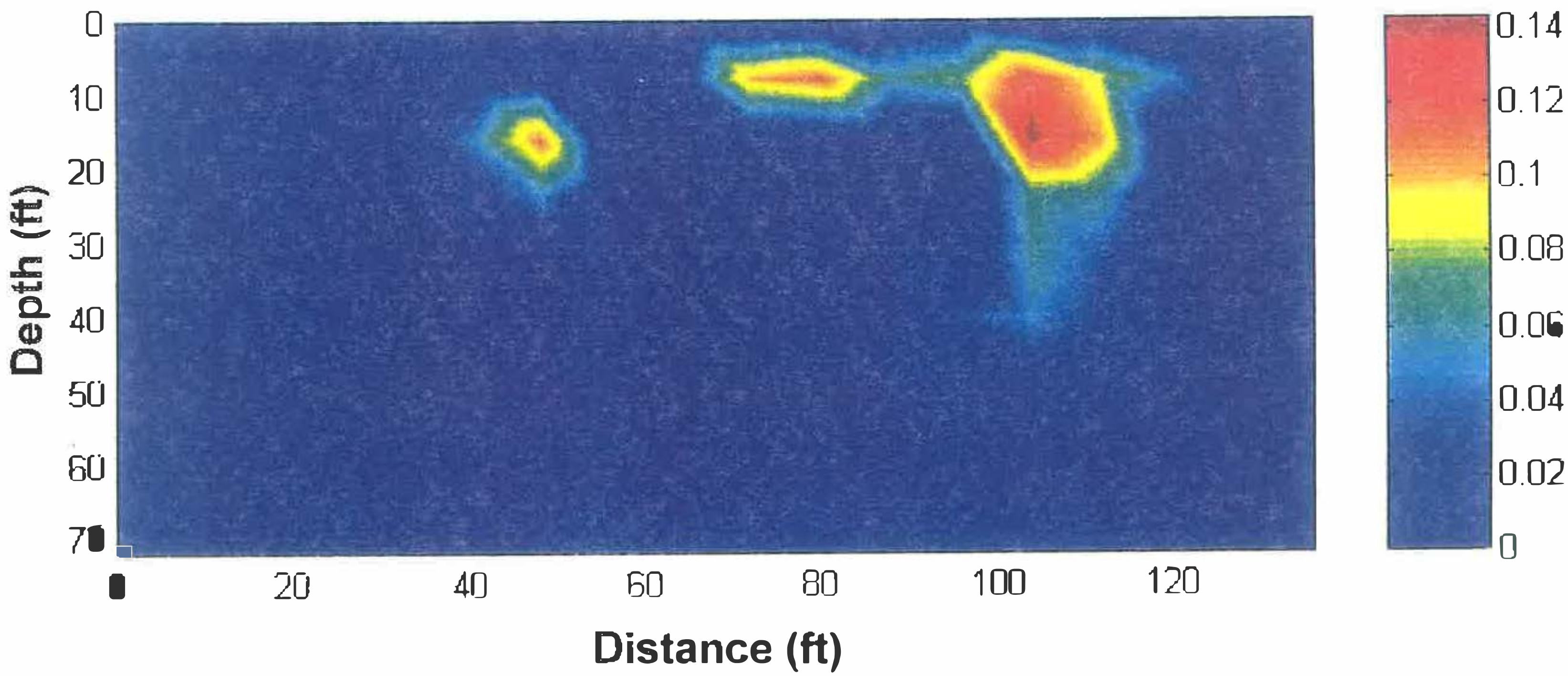
Note: The color scale is linear. The units are mV / V.

Line 38 E - IP New York State Electric & Gas Corp. Court Street Site Binghamton, New York	
File 98G27	October, 1999
HAGER-RICHTER GEOSCIENCE, INC. Salem, New Hampshire	



Note: The color scale is linear. The units are mV / V.

Line 68 E - IP New York State Electric & Gas Corp. Court Street Site Binghamton, New York	
File 98G27	October, 1999
HAGER-RICHTER GEOSCIENCE, INC. Salem, New Hampshire	

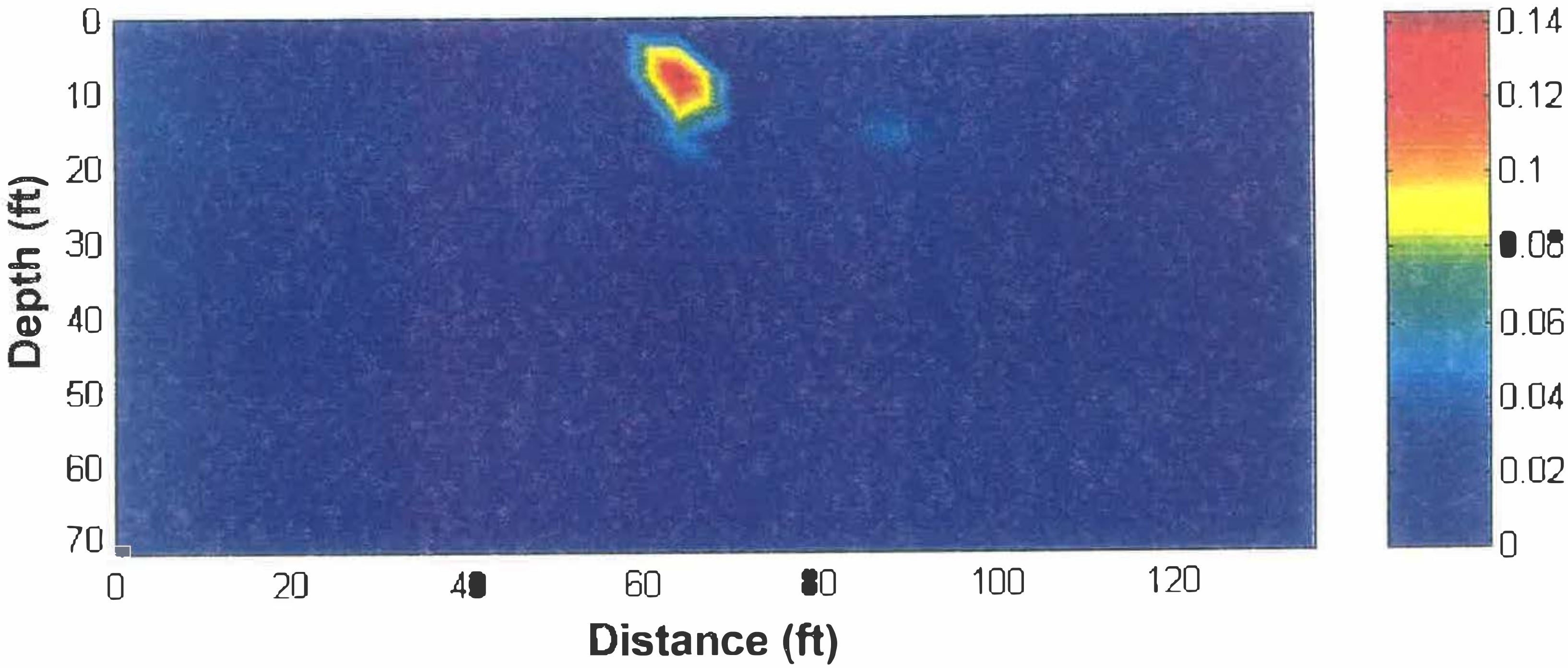


Note: The color scale is linear. The units are mV / V.

Line 98 E - IP
New York State Electric & Gas Corp.
Court Street Site
Binghamton, New York

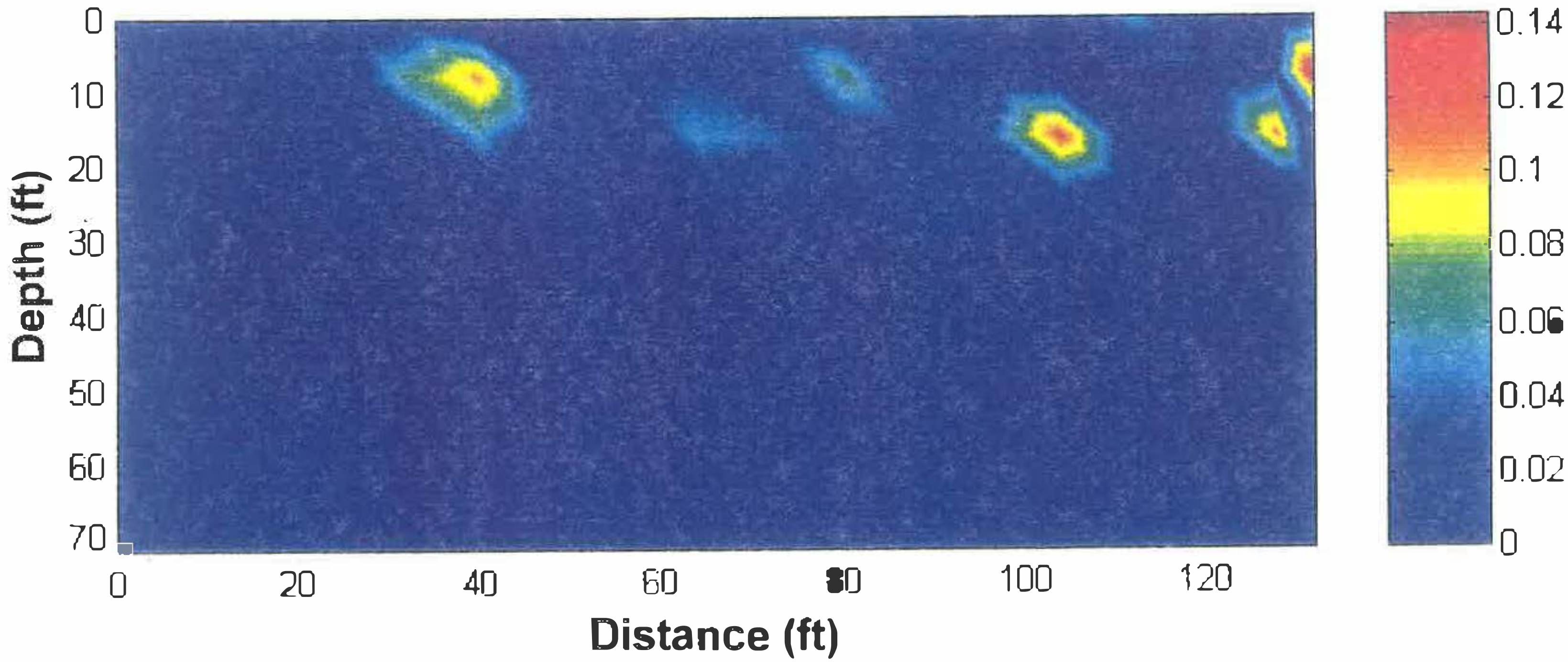
File 98G27	October, 1999

HAGER-RICHTER GEOSCIENCE, INC.
Salem, New Hampshire



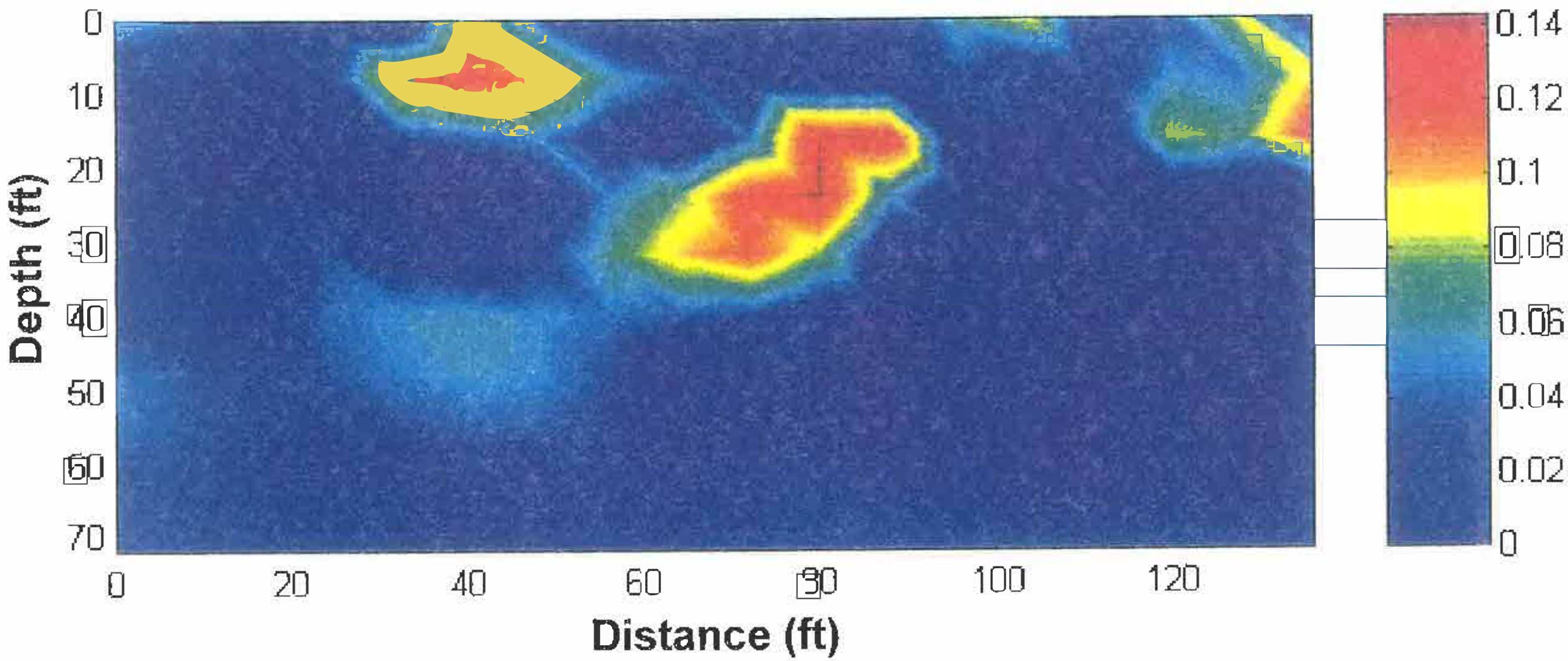
Note: The color scale is linear. The units are mV / V.

Line 20 S - IP New York State Electric & Gas Corp. Court Street Site Binghamton, New York	
File 98G27	October, 1999
HAGER-RICHTER GEOSCIENCE, INC. Salem, New Hampshire	



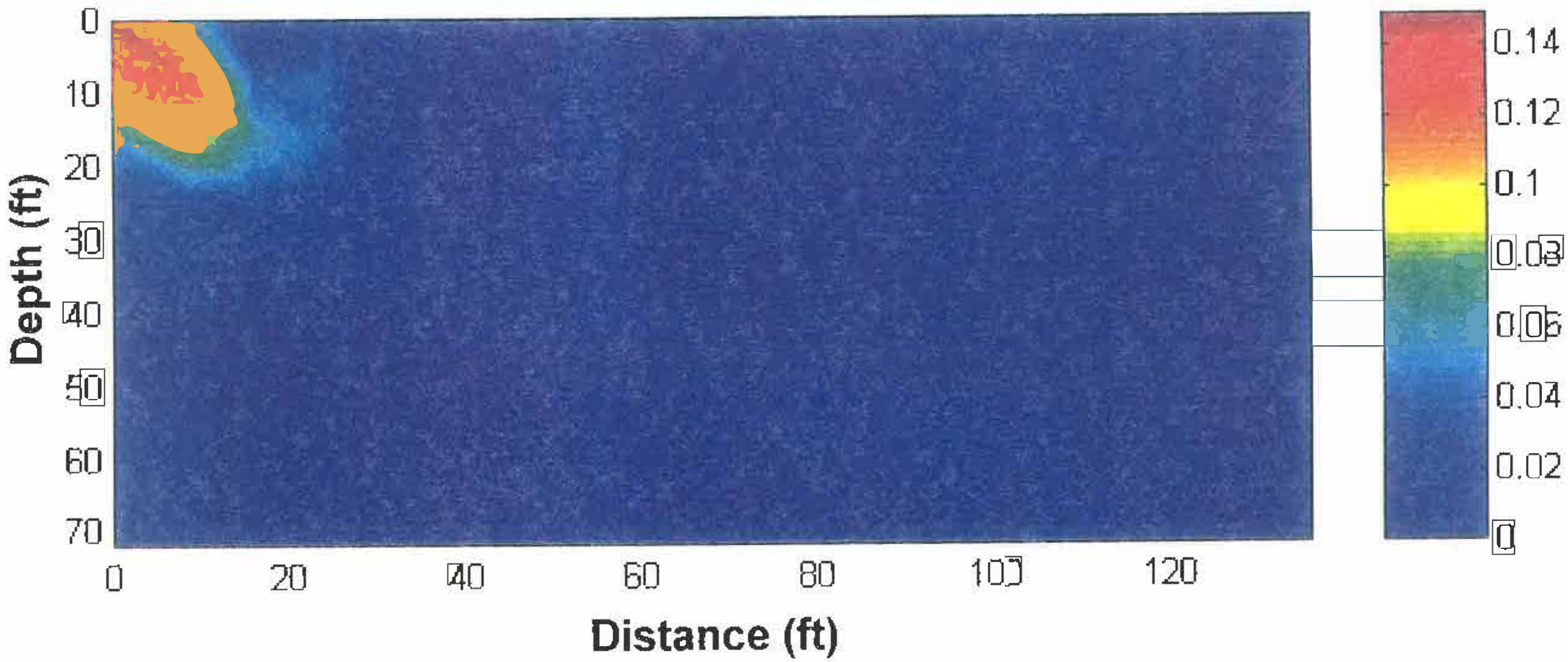
Note: The color scale is linear. The units are mV / V.

Line 60 S - IP New York State Electric & Gas Corp. Court Street Site Binghamton, New York	
File 98G27	October, 1999
HAGER-RICHTER GEOSCIENCE, INC. Salem, New Hampshire	



Note: The color scale is linear. The units are mV / V.

Line 100 S - IP New York State Electric & Gas Corp. Court Street Site Binghamton, New York
File 98G27 — October, 1999
HAGER-RICHTER GEOSCIENCE, INC. Salem, New Hampshire



Note: The color scale is linear. The units are mV / V.

Line 140 S - IP
New York State Electric & Gas Corp.
Court Street Site
Binghamton, New York

File 98G27	October, 1999

HAGER-RICHTER GEOSCIENCE, INC.
Salem, New Hampshire