Appendix E – Geophysical Survey and Downhole Logging Report
Final Report
Borehole Geophysical Logging Program
Two Wells – MW-14C and MW-15C
Emerson Power Transmission Facility
Ithaca, NY
MAG Reference Number 021143

Prepared For: WSP Environmental & Energy
Prepared By: Mid-Atlantic Geosciences
April 6, 2011
April 6, 2011

Mr. Robert Wallace
WSP Environmental & Energy
11190 Sunrise Valley Drive
Suite 300
Reston, VA 20191

RE: Borehole Geophysical Logging Program
Two Wells – MW-14C and MW-15C
Emerson Power Transmission Facility
Ithaca, NY
MAG Reference Number 021143

Dear Mr. Wallace:

Pursuant to our proposal dated February 28, 2011, Mid-Atlantic Geosciences (MAG – the borehole logging division of Enviroscan, Inc.) completed the above-referenced survey on March 24, 2011. The objective of the survey was to locate and characterize fractures and potential water-bearing zones intersecting the wells. To accomplish these objectives, MAG conducted Optical Televviewer, Acoustic Televviewer, 3-Arm Caliper, Fluid Temperature, Fluid Conductivity, and Natural Gamma logging in the wells.

Logging Equipment

Mid-Atlantic Geosciences conducts borehole geophysics, televviewer, and video logging using a Robertson Geologging, Ltd. Micrologger II and/or a Mount Sopris Matrix. These units record digital data for on-site log playback, reproduction, and field interpretation, as well as post-processing and report presentation. The systems are driven by field PCs running software supplied by the manufacturer for data acquisition, log replay, probe control, probe calibration, and logging environment compensation. Video data (if collected) are recorded in real time to the hard drive of a DVD player/recorder, and can be burned in the field to a DVD that is left with the client’s on-site representative.

All of the logging instruments are permanently mounted in a dedicated Ford F350 or Dodge RAM2500 enclosed-bed truck, each with a self-contained power supply, and support and decontamination equipment. The downhole probes or sondes are connected to either a Robertson Geologging Smartwinch with approximately 600 feet of 0.375-inch coaxial cable, or a Robertson 2000m winch with approximately 3000 feet of 0.25-inch coaxial cable – depending on the depth of the wells logged.
Logging Parameters and Methodology

Geophysical well logging in general involves lowering sondes in a borehole and recording parameters that are related to the properties of the adjacent soil or rock, the fluids in the borehole or formation, and/or construction details of the well. There are many tools and techniques that have been developed to provide specific information in different environments and constructions of drilled holes. The data collected can define the nature and extent of geologic formations and formation fluids, and can be used to provide correlation between holes.

The sondes used for this survey are described below. Note that before any of these tools are put into service for a particular job, MAG personnel test them for proper function and recalibrate as necessary. This is essential to the proper acquisition of downhole data and the ability to relate the data from one borehole to another.

**Optical Televiewer**

The borehole optical televiewer (OPTV) or Optical Borehole Imager (OBI) provides a high-resolution digital optical scan of the interior of a borehole using visible wavelength light. From the accurately-scaled, continuous image it is possible to identify the depth and character of features such as fractures, bedding planes, veins, solution openings, etc. In particular, it is possible to calculate the strike, dip, and aperture of planar features. The OPTV operates by using a high-resolution color downhole camera which views a reflection of the borehole walls in a hyperbolic correction mirror. At successive depth increments of 0.5 mm, rings of pixels corresponding to circular scans of the borehole wall are acquired from the probe and stacked into a continuous image. The image is rectangular – representing the interior of a cylinder that has been sliced open and rolled-out flat. The image is oriented to north based on data from three magnetometers and accelerometers in the sonde. Note that the use of magnetometers for orientation leads to image distortion in steel-cased holes, and within several feet of the base of steel casing in open holes. All OPTV sondes require an open borehole, or one filled with a clear fluid.
Mr. Wallace
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Planar features intersecting a cylindrical borehole appear sinusoidal on the flattened cylindrical image. The azimuth of the peak/trough of the sinusoid, and the amplitude of the sinusoid can be measured and used to calculate the strike and dip (see Appendix A) of such features. Based on their visual character, planar features on the optical televiewer (and HRAT – see below) logs have been categorized on the log sheets as various types of geologic interface (fractures, bedding planes, veins, etc.). The features observed on the OPTV log can also be characterized based on the Paillet Ranking System developed by the US Geological Survey, Water Resources Division, Borehole Geophysics Research Project. This system is a semi-subjective evaluation of transmissivity potential. The ranking system assigns a number value between zero and five to observed features. A rank of zero indicates a feature that appears sealed – with no water likely passing through it. Note that the geologic classification of features (e.g. bedding plane, lithologic contact, joint, fracture, foliation, etc.) is not specified in the Paillet System since only water-bearing potential is considered. A rank of five corresponds to a grossly porous zone with large openings (e.g. a major fracture, fault or solution cavity). The ranking system, with examples, is provided in Appendix B.

Tables listing the depth, aperture, strike, dip and type of feature are included in this report, for each well, as Appendix C. Feature apertures are listed in tenths of an inch. An aperture of zero for an open fracture simply means that while it appears to be a continuous open feature, the opening is smaller than the line thickness on the log (~0.015 inches). Note that because of the subjectivity involved in Paillet ranking, MAG has listed fractures in Appendix C only as either open or sealed. Specific Paillet rankings can be assigned by the client, if desired, by comparing the standard pictures in Appendix B to the OPTV log.

Note also that it has been the experience of MAG that the aperture or Paillet rank of a feature is not always a strong indicator of its water-producing potential. Thin, discrete features sometimes produce as much or more water (as evidence by flowmeter logging – see below) than wide, open fractures or fracture zones.

**Acoustic Televiewer**

The high-resolution acoustic televiewer (HRAT) provides a scan or image of the interior of the borehole that is created not by reflected visible wavelength light, but by reflected ultrasound. Since ultrasonic pulses are used, it is possible to record both the amplitude and travel time of each pulse, and construct two separate images. The amplitude log is analogous to a visual scan, while the travel time data are affected primarily by the local diameter of the borehole (i.e. the larger the bore, the later the arrival of the reflected pulse), and therefore can supplement or replace a caliper log. The main advantage of the HRAT probe is that it can be used in larger boreholes than optical tools, and in holes with turbid or particle-loaded fluids that would be opaque to optical methods.
The HRAT operates by using a fixed acoustic transducer and a rotating acoustic mirror capable of focusing on the borehole wall at any distance from the probe diameter upwards. The acoustic transducer is focused based on the borehole diameter and impedance-matched to the borehole fluid to provide optimum image resolution and reflected amplitude. Mirror rotation speed (i.e. circumferential resolution), sampling rate (i.e. depth resolution), signal gain (i.e. amplitude image contrast), and recording time gate (i.e. travel time image contrast) are all variable and under operator control to provide the best image possible under borehole-specific conditions.

HRAT logs are presented as accurately-scaled and accurately-oriented cylindrical images that are sliced open and laid flat. Therefore, planar dipping features appear as sinusoids from which the strike and dip of the feature can be calculated (see Appendix A). Selected and representative televiewer features are listed in Appendix C and on the log sheet. Based on their visual character, planar features have been categorized as various types of geologic interface (fractures, bedding planes, veins, etc.). Feature apertures are listed in tenths of an inch. An aperture of zero for an open fracture simply means that while it appears to be a continuous open feature, the opening is smaller than the line thickness on the log (~0.015 inches). Note that it has been the experience of MAG that the aperture or Paillet rank of a feature is not always a strong indicator of its water-producing potential. Thin, discrete features sometimes produce as much or more water (as evidence by flow meter logging or packer testing) than wide, open fractures or fracture zones.

Caliper

Caliper measurements represent the average diameter of the borehole or well at a given depth. The caliper tool collects and transmits the data from three spring-loaded arms as the tool is lifted upwards through the borehole. The caliper tool is used to locate solution openings or fractures (where the borehole is typically enlarged due either to the presence of natural openings, or to plucking of broken rock by the drill bit), and to determine the length of casing intervals (as evident from small changes in casing diameter, or the small enlargements at threaded junctions, or narrowing due to the bead at welded junctions).

Caliper logs are collected by calibrating the downhole tool with a measuring template, lowering the tool to the base of the well, remotely opening the arms, and then logging the open borehole and casing diameter in an upward direction. Caliper logs are acquired with a logging speed of no more than 12 feet per minute.
Fluid Temperature

Fluid temperature logs provide the temperature of the air or fluid in a borehole as a function of depth. Temperature logs can indicate where water is entering or leaving a borehole – and thereby disturbing the normal geothermal gradient. Deviations, offsets, or changes in the slope of the temperature log can be used to locate zones of water movement within the borehole. Temperature logs must be run in wells that have been allowed to fully equilibrate to the local geothermal gradient following any prior drilling, construction, pumping or sampling. During a temperature survey, data accuracy is ensured by maintaining a downward logging speed of approximately 10 feet per minute (fpm). This provides an adequate time buffer to allow sensors to respond to minor temperature changes.

Fluid Conductivity

Fluid conductivity logs provide a continuous measurement of the electrical conductivity of the borehole fluid – i.e. zero in air or hydrocarbons, greater than zero in water. In water, electrical conductivity is mostly a function of electrolytic content. Water with very low dissolved solid concentrations will yield low fluid conductivity, while water containing a high level of dissolved solids will be proportionally more conductive. Fluid conductivity logs often deflect where water-producing features are transmitting water into or out of the well (since the well water may have a differing electrolytic chemistry than the formation water). The fluid conductivity log is usually collected simultaneously with the temperature log – since for both, data from a fully equilibrated water column is required.

Natural Gamma

Gamma logs are one of the most widely used geophysical logs in groundwater applications. They are used primarily to identify changes in lithology – specifically the relative amounts of clay in various sedimentary units.

A gamma log provides a record of the total natural gamma radiation detected within a given energy range. In water-bearing rocks and sediments that are not contaminated by artificial radioisotopes, the most significant naturally-occurring, gamma-emitting radioisotopes are potassium-40 and the daughter products of the uranium and thorium decay series. If gamma-emitting artificial radioisotopes have been introduced by humans into the groundwater system, they will also produce part of the radiation measured.
The amplitude of gamma-log deflections is affected by any borehole condition that alters the density of the material through which gamma photons must pass or the length of the travel path. The bedding of a gamma-emitting formation must be thick to obtain a quantitative value since the detector will be affected by the radiation from the formation as the tool approaches and passes the bed. Although increases in borehole diameter or the presence of steel casing will decrease the recorded gamma count, it is possible to collect usable information in both cased and open portions of the borehole using the gamma sonde. The presence of potassium-rich (and therefore gamma-emitting) bentonite clay commonly used in well construction will generally produce high gamma count peaks on a natural gamma log. MAG has natural gamma detectors on many sondes, and comparison of the multiple gamma logs collected for any given well logging program are used to ensure that the depths of differing logs are not erroneously shifted. Therefore, the gamma log presented for any well may have been collected simultaneously with any of the other logs from the same well.

**Logging Results**

The wells were logged on March 24, 2011. The logging results for the wells are presented on the enclosed digital logs and tables, and briefly summarized below.

*Note that since analysis of borehole geophysical logs can be quite subjective, and the level of detail is dependent upon the specific goals of the geologist, the analysis by MAG below covers the major features of each log, as well as some possibly minor features to serve as examples or guides for further interpretation by geologists familiar with the site, local geology, and/or project goals. In general, logs may display deviations (i.e. “spikes” where the parameter deviates from, and then returns to, “background” level), offsets (changes in background level), or slope changes. Any of these could be considered significant in certain situations, or when compared to correlating features at the same depth on other logs. If there are any questions about the features discussed (or not discussed) below, please do not hesitate to contact MAG.*
MW-14C

**Noted Features**

- The total depth (TD) of the well was logged at approximately 44.8 feet below ground surface (BGS).

- The depth to water (DTW) was measured at 21.8 feet BGS at the time of the survey.

- The diameter of the casing at the surface was measured to be four inches, and the bottom of the casing (BOC) was located at approximately 24.9 feet BGS.

- The caliper (borehole diameter) log reveals no significant enlargements.

- The fluid temperature log shows no significant deviations, offsets, or changes in slope except at the top of the water column.

- The fluid conductivity log shows no significant deviations, offsets, or changes in slope except at the top of the water column.

- Few planar features were recognizable on the televIEWER logs. The depth, strike, dip, aperture, and feature type are listed on the log, as well as on the accompanying table in Appendix C.

- The natural gamma log shows generally smooth variations that are probably related primarily to the clay content of the formation.
Mr. Wallace  
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MW-15C

**Noted Features**

- The total depth (TD) of the well was logged at approximately 44.6 feet below ground surface (BGS).

- The depth to water (DTW) was measured at 42.8 feet BGS at the time of the survey. Note that since the borehole needed to be filled with potable water from an on-site source, the DTW in the acoustic travel time and amplitude logs are much higher than what was originally recorded.

- The diameter of the casing at the surface was measured to be four inches, and the bottom of the casing (BOC) was located at approximately 24.9 feet BGS.

- The caliper (borehole diameter) log reveals no significant enlargements.

- The fluid temperature log shows no significant deviations, offsets, or changes in slope except at the top of the water column.

- The fluid conductivity log shows no significant deviations, offsets, or changes in slope except at the top of the water column.

- Few planar features were recognizable on the teviewer logs. The depth, strike, dip, aperture, and feature type are listed on the log, as well as on the accompanying table in Appendix C.

- The natural gamma log shows generally smooth variations that are probably related primarily to the clay content of the formation.
Limitations

In making verbal or written interpretation of logs, MAG personnel give the client the benefit of their best professional judgment. However, since all interpretations are based on inference from electrical, magnetic, or other indirect measurements, MAG does not, and cannot, guarantee the accuracy or the correctness of any such interpretations. MAG shall not be liable for any loss, damages, or expenses resulting from reliance on such interpretations. MAG does not warrant the accuracy of log data transmitted by any electronic process and will not be responsible for intentional interpretation of log data by others. MAG makes no warranties – neither explicit nor implied. Under no circumstances shall MAG, its parent company Enviroscan, Inc., or their personnel be liable for consequential damages.

We appreciate this opportunity to have worked with you again. If you have any questions, please do not hesitate to contact me.

Sincerely,
Mid-Atlantic Geosciences

Duro Rajkovic
Project Geophysicist

Technical Review By:
Mid-Atlantic Geosciences

Felicia Kegel Bechtel, M.Sc., P.G.
President

enc.: MW-14C: Televiewer and Geophysical Logs
       MW-15C: Televiewer and Geophysical Logs
       Appendix A: Planar Feature Orientation Parameters
       Appendix B: Paillet Ranking System
       Appendix C: Planar Feature Characterizations Table
Appendix A

Planar Feature Orientation Parameters
Planar Feature Orientation Parameters

Dip = angle of inclination of the plane, downwards from the horizontal
Dip azimuth = azimuth of the line of maximum dip in the plane, clockwise from North
Strike direction = azimuth of a horizontal line in the plane (= dip azimuth + 90°)
  e.g. dip and dip azimuth = 60° N041° or strike and dip = N311° 60°

  e.g. Stratigraphic dip
  or 'bedding'

Other planar geologic features include joints/fractures/veins
faults
cleavage/schistosity
Appendix B

Paillet Ranking System
## Paillet Ranking System

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<th>Example OPTV Feature</th>
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<td><img src="image" alt="Major fracture zone or breakout" /></td>
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<td>Major fracture zone or breakout</td>
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Appendix C

Planar Feature Characterizations Tables
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<th>Depth</th>
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<th>Strike (deg.)</th>
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<td>Feature</td>
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Final Report
Geophysical Survey – Emerson Power Transmission Facility
Electrical Resistivity/Cross-Hole Tomography
Ithaca, PA
Enviroscan Project Number 061037a

Prepared for: WSP Environmental Strategies
Prepared By: Enviroscan, Inc.
September 16, 2010
September 16, 2010

Mr. Scott Haitz

WSP Environmental Strategies
11190 Sunrise Valley Drive
Suite 300
Reston, VA 20191

RE: Geophysical Survey – Emerson Power Transmission Facility
    Electrical Resistivity/Cross-Hole Tomography
    Ithaca, PA
    Enviroscan Project Number 061037a

Dear Mr. Haitz:

Pursuant to our proposal dated June 23, 2010, Enviroscan, Inc. (Enviroscan) has completed a geophysical investigation at the above-referenced site. The purpose of the survey was to identify the location(s) of possible preferential groundwater flow pathways in bedrock. Fieldwork for the survey was completed on August 23-25, 2010.

Site Description

The site is the Emerson Transmission Facility located on a hillside south of downtown Ithaca at the end of South Cayuga Street in Ithaca, NY. The site encompassed relatively steep slopes that fall to the river below the facility.

According to the Geologic Map of New York (http://tin.er.usgs.gov/geology/state/), the site is underlain by the Genesee Group, which is Upper Devonian in age. This group consists of the West River Shale, Genundewa Limestone, Penn Yan and Geneseo Shales, and the North Evans Limestone. The dominant lithology is shale with a secondary rock type of limestone and tertiary rock types of siltstone and black shale (Ibid.).

For this study, the client designated the location of two electrical imaging profiles. One cross-hole tomography profile (CH-01) between wells EXB-01 and EXB-02; and one surface-to-borehole profile (SB-01) utilizing well EXB-02. Refer to Figure 1 for the locations of these profiles and identified utilities that crossed SB-01.
Survey Methods

Surface resistivity measurements involve driving an electrical current in the ground using two current electrodes at the ground surface. The apparent resistivity of the subsurface (essentially the mathematical inverse of terrain conductivity) is determined by measuring the potential difference or voltage between two potential electrodes with a known separation and position/orientation relative to the current electrodes. The depth and volume of the subsurface zone represented by the measured apparent resistivity is a function of the geometry of the current and potential electrodes located at the surface. The principles of electrical imaging are described in the accompanying Introduction to Electrical Imaging (Appendix A). Where suitable boreholes are available, electrodes can also be set at intervals in the holes and used alone (cross-hole measurements), or in conjunction with the surface electrodes (up-hole measurements).

Using an AGI Super Sting R8/IP resistivity meter, and Swift automated electrode switching system, apparent resistivity readings were collected along the two profiles (see Figure 1). Along each profile, electrodes were spaced at the ground surface at 1-meter intervals. To collect electrical imaging data, a dipole-dipole array (which is particularly sensitive to steeply-dipping tabular features) was used (Figure 2). The measured apparent resistivities (ρa’s) were plotted nightly (after each field day) as resistivity pseudo-sections depicting the apparent resistivity versus nominal survey depth for each profile in order to confirm data quality.

In post-field processing, the apparent resistivity pseudo-sections were mathematically inverted using EarthImager 2D by Advanced Geosciences, Inc., to provide color-contoured electrical images of true resistivity versus true depth along each profile as depicted in Figure 2. On these images, low resistivity (high conductivity) material is depicted in shades of blue, with high resistivity (low conductivity) material in shades of red to orange and moderately resistive/conductive materials in shades of green. Note that clay-rich and/or wet materials are typically represented by local resistivity lows (conductivity highs – shades of blue), while competent rock, and dry sands, gravels or other porous materials are typically represented by areas of resistivity highs (low conductivity – red to orange).
Survey Results

In Figure 2, the two inverted resistivity cross sections are presented for Profiles CH-01 and SB-01. These represent a cross-hole tomography profile and an up-hole profile respectively.

Profile CH-01 was a cross-hole resistivity tomography profile collected between wells EXB-01 and -02. These two wells were situated 58 feet apart and were installed approximately 82 feet deep. Both wells were constructed with approximately 20 feet of steel casing set into bedrock with the rest of the well being open hole. In order to ensure that the steel casing did not produce erroneous results, the top-most electrodes in both wells were lowered to a depth of 30 feet below ground surface (bgs), well below the casing, and based on the rule of thumb, that electrodes should be at least two electrode spacings below an interference source. Note that no data were collected between the ground surface and 30 feet bgs (hachured area in Figure 2). At the client’s request, the modeling interpolation in that zone was not blanked. Enviroscan will not support any interpretations or assumptions made from the inspection of this interpolation into an area with no data coverage.

Results for Profile CH-01 indicate three distinct conductive (low resistivity) anomalies (A, B, C, in Figure 2). Anomaly A is located at approximately 40 feet bgs and is approximately 30 feet wide. Anomaly B ranges from approximately 55 – 75 feet bgs and is approximately 48 feet wide. Anomaly C is a small conductive anomaly at approximately 55 feet bgs and is about 10 feet wide. All three of these anomalies are indicative of water-bearing fractures in bedrock.

Profile SB-01 was a surface-to-borehole resistivity profile that was collected instead of a standard surface resistivity profile due to the presence of numerous metallic utilities that both paralleled and bisected the resistivity profile. Due to the presence of a double layer of concrete in the vicinity of EXB-02, the first surface electrode was placed approximately 45 feet away from the borehole – hence the reason for the hachured zone from 0 – 45 feet from the borehole along the profile. Again, this hachured zone has not been blanked at the request of the client and Enviroscan will not support any interpretations or assumptions made from the inspection of this interpolation (Figure 2). Note the large hachured area at the bottom right corner of Profile SB-01. This was also hachured due to the likelihood that little data were collected in this zone due to the length of the profile versus the depth and the presence of metallic utilities, which create large amounts of noise in the data. Therefore, little resistivity variation is seen in this portion of the profile because there is very little data to model. In the hachured zone, the model is an interpolation from good quality data at the shallower depths above this zone. Enviroscan will not support any interpretations or assumptions made from the inspection of this interpolation.
Results from Profile SB-01 indicate a very noisy shallow subsurface, due presumably to the presence of numerous utilities. The red resistive features in the shallow depths below the surface electrodes (from 75 to 190 feet along-profile) could be the result of either resistive rock or dry resistive fractures. Anomalies D, E, F, and G are all conductive anomalies that are indicative of water-bearing fractures. The bottoms of these anomalous zones were not fully defined due the limited depth of penetration of the survey. This could not be avoided due to the weaker signal-to-noise ratio caused by the utilities.

Limitations

The geophysical survey described above was completed using standard and/or routinely accepted practices of the geophysical industry and equipment representing the best available technology. Enviroscan does not accept responsibility for survey limitations due to inherent technological limitations or unforeseen site-specific conditions. However, we make every effort to identify and notify the client of such limitations or conditions.
Mr. Haitz  
September 16, 2010  
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We have enjoyed and appreciated the opportunity to work with you. If you have any questions, please do not hesitate to contact the undersigned.

Sincerely,  
Enviroscan, Inc.  

Craig Ulrich, M.Sc.,  
Geophysics Project Manager  

Technical Review By:  
Enviroscan, Inc.  

Felicia Kegel Bechtel, M.Sc., P.G.  
President  

enc.: Figure 1: Resistivity Profile Location Map  
Figure 2: ERT Resistivity Survey Results  
Appendix A: Introduction to Electrical Imaging
Electrical resistivity data collected at 1m electrode spacings with an AGI SuperSting R8 Resistivity/IP Meter.

Two tomographies were collected:
1) borehole-to-borehole and
2) surface-to-borehole.

Borehole-to-borehole collected between EXB-02 and EXB-01 starting at 30 feet below ground surface (bgs) down to 81 feet bgs.
Appendix A

Introduction to Electrical Imaging
Introduction to Electrical Imaging

by

Timothy D. Bechtel, Ph.D., P.G.

Energy

Electrical currents injected into the subsurface between electrodes pushed into the ground surface or non-intrusive, protected capacitors.

Sensitivity

Detects changes in electrical resistivity (the inverse of conductivity).

Basic Equipment

Either (traditional “steel spike electrode” method):

Steel spike electrodes (called current electrodes) connected by wires to a current source (to inject current), and steel spike electrodes (called voltage electrodes) connected to a microvolt meter (to measure the surficial distribution of electrical potentials). Note that current and voltage electrodes differ only by that to which they are connected (i.e. current source or microvolt meter, respectively.) Modern systems use arrays of electrodes (connected to multi-channel cables and an automated electrode-switching/recording system) to take measurements from electrodes at different locations and spacings (which adjusts the survey depth and resolution). Electrodes are hand-pushed into the ground surface along desired survey profiles.

Or (innovative “capacitively-coupled electrode” method):

Straight-wire capacitors which are capable of driving subsurface electrical currents and measuring surface potentials. The wire lengths and the distance between wires can be varied to adjust the survey depth and resolution. Capacitors are encased in torpedo-like protectors between the wire lengths, and the entire array (similar to a swimming rope with flotation buoys) is hand- or vehicle-towed along desired survey profiles.
Common Applications

Electrical imaging produces color-contour cross sections (commonly called electrical images) of subsurface electrical resistivity variations. These images can depict a target that has a different electrical resistivity from its surroundings, such as: buried wastes (pits, trenches, etc.); conductive groundwater plumes; resistive hydrocarbon plumes; foundation elements; water-bearing or mineralized faults or fractures; clay seams in bedrock; soil moisture anomalies; soil voids; clay layers bounded by sand or sand lenses bounded by clay; the top of competent (non-water-bearing) rock.

Principles

Electrical imaging can be performed by driving a harmless, very low amperage (e.g. 1 milliamp) DC electrical current in the ground between two steel spike electrodes. The depth to which the current flows is dictated by the separation of the two electrodes, and by the resistivity of subsurface materials. The flow of electrical current is mapped by measuring the electrical potential at various points of the ground surface using a very high impedance microvolt meter. Data suitable for determining a cross-sectional electrical image can be collected by taking many voltage readings with differing current electrode separations (i.e. different effective measurement depths) using different current electrode positions and voltage electrode positions (i.e. different locations along a profile). A two-dimensional image or cross-section is produced by employing electrodes in a linear array. Three-dimensional images (or color-contoured blocks of data) can be calculated using multiple linear arrays or grids of electrodes. The field-measured voltages, together with associated electrode positions, are mathematically inverted to provide the statistically best-fitting model of the subsurface resistivity distribution.

Electrical imaging can also be performed using straight-wire capacitors to drive currents and measure voltages. In this case, the length of the transmitter wire and the separation between the transmitter and receiver wires dictate the effective survey depth. Two- or three-dimensional data is collected by varying the lengths and separations of the transmitter and receiver capacitor wires for a given survey profile (i.e. the same profile is traversed several times using different wire lengths and separations).
Capabilities

Electrical imaging can detect and delineate a target that has a different electrical resistivity from its surroundings. Particularly good targets for electrical imaging include: electrically conductive clay seams, and water-bearing or mineralized faults or fractures in resistive bedrock; electrically resistive hydrocarbon plumes in moist electrically conductive soils; highly conductive electrolytic groundwater plumes (e.g. leachate or saltwater intrusion); highly conductive or resistive wastes buried in “normal” soils; soil moisture anomalies (e.g. dam seepage or incipient sinkholes).

Where site conditions allow, capacitively-coupled electrode systems can collect greater quantities of data in a given time (or at a given cost) than the traditional steel spike systems. The capacitive systems can also be used on asphalt pavement (where steel spike systems would require drilling many electrode holes).

Limitations

Electrical resistivities of differing materials have wide and overlapping ranges, making it impossible to positively identify a subsurface material based on its resistivity alone. For instance, profiling of the top-of-rock can be done by electrical imaging, but it is often difficult to specify exactly what resistivity contour corresponds with the top of rock (particularly where there is a weathering or saprolite zone). Since electrical resistivity (unlike seismic velocity) does not correlate with rippability or density, it is not typically the method of choice for rock profiling.

Based largely on a single well-publicized incident, electrical imaging has been promoted (by others) as a method for detecting bedrock cavities. However, since an air-filled cavity and competent rock are both electrical resistors, many cavities are not detectable using electrical methods (in this case, gravity would be the method of choice since air and competent rock have very different densities).

Electrical imaging data is susceptible to interference from underground utilities that capture and channel the subsurface current flow. This can be minimized in two-dimensional surveys by orienting the trace of an image perpendicular to any existing utilities.

Capacitively-coupled electrode systems suffer loss of signal penetration depth in highly conductive terranes. In addition, they are difficult to use in rugged or brushy terrain.

Survey depths using steel spike electrode systems can be limited by high contact resistances between the spikes and highly resistive surficial material.
Final Report
Borehole Geophysical Logging Program
One Well – (MW-540)
Emerson Power Transmission Facility
Ithaca, NY
MAG Reference Number 061037a

Prepared For: WSP Environmental Strategies
Prepared By: Mid-Atlantic Geosciences
September 17, 2010
September 17, 2010

Mr. Scott Haitz
WSP Environmental & Energy
11190 Sunrise Valley Drive
Suite 300
Reston, VA 20191

RE:  Borehole Geophysical Logging Program
     One Well – (MW-540)
     Emerson Power Transmission Facility
     Ithaca, NY
     MAG Reference Number 061037a

Dear Mr. Haitz:

Pursuant to our proposal dated July 8, 2010, Mid-Atlantic Geosciences (MAG – the borehole logging division of Enviroscan, Inc.) completed the above-referenced survey on August 25, 2010. The objective of the survey was to locate and characterize fractures and potential water-bearing zones intersecting the well. To accomplish these objectives, MAG conducted Optical Televiewer, 3-Arm Caliper, Fluid Temperature, Fluid Conductivity, and Natural Gamma, logging in the well.

Logging Equipment

Mid-Atlantic Geosciences conducts borehole geophysics, televiewer, and video logging using a Robertson Geologging, Ltd. Micrologger II and/or a Mount Sopris Matrix. These units record digital data for on-site log playback, reproduction, and field interpretation, as well as post-processing and report presentation. The systems are driven by field PCs running software supplied by the manufacturer for data acquisition, log replay, probe control, probe calibration, and logging environment compensation. Video data (if collected) are recorded in real time to the hard drive of a DVD player/recorder, and can be burned in the field to a DVD that is left with the client’s on-site representative.

All of the logging instruments are permanently mounted in a dedicated Ford F350 or Dodge RAM2500 enclosed-bed truck, each with a self-contained power supply, and support and decontamination equipment. The downhole probes or sondes are connected to either a Robertson Geologging Smartwinch with approximately 600 feet of 0.375-inch coaxial cable, or a Robertson 2000m winch with approximately 3000 feet of 0.25-inch coaxial cable – depending on the depth of the wells logged.
Logging Parameters and Methodology

Geophysical well logging in general involves lowering sondes in a borehole and recording parameters that are related to the properties of the adjacent soil or rock, the fluids in the borehole or formation, and/or construction details of the well. There are many tools and techniques that have been developed to provide specific information in different environments and constructions of drilled holes. The data collected can define the nature and extent of geologic formations and formation fluids, and can be used to provide correlation between holes.

The sondes used for this survey are described below. Note that before any of these tools are put into service for a particular job, MAG personnel test them for proper function and recalibrate as necessary. This is essential to the proper acquisition of downhole data and the ability to relate the data from one borehole to another.

Optical Televiewer

The borehole optical televiewer (OPTV) or Optical Borehole Imager (OBI) provides a high-resolution digital optical scan of the interior of a borehole using visible wavelength light. From the accurately-scaled, continuous image it is possible to identify the depth and character of features such as fractures, bedding planes, veins, solution openings, etc. In particular, it is possible to calculate the strike, dip, and aperture of planar features. The OPTV operates by using a high-resolution color downhole camera which views a reflection of the borehole walls in a hyperbolic correction mirror. At successive depth increments of 0.5 mm, rings of pixels corresponding to circular scans of the borehole wall are acquired from the probe and stacked into a continuous image. The image is rectangular – representing the interior of a cylinder that has been sliced open and rolled-out flat. The image is oriented to north based on data from three magnetometers and accelerometers in the sonde. Note that the use of magnetometers for orientation leads to image distortion in steel-cased holes, and within several feet of the base of steel casing in open holes. All OPTV sondes require an open borehole, or one filled with a clear fluid.
Planar features intersecting a cylindrical borehole appear sinusoidal on the flattened cylindrical image. The azimuth of the peak/trough of the sinusoid, and the amplitude of the sinusoid can be measured and used to calculate the strike and dip (see Appendix A) of such features. Based on their visual character, planar features on the optical televiewer (and HRAT – see below) logs have been categorized on the log sheets as various types of geologic interface (fractures, bedding planes, veins, etc.). The features observed on the OPTV log can also be characterized based on the Paillet Ranking System developed by the US Geological Survey, Water Resources Division, Borehole Geophysics Research Project. This system is a semi-subjective evaluation of transmissivity potential. The ranking system assigns a number value between zero and five to observed features. A rank of zero indicates a feature that appears sealed – with no water likely passing through it. Note that the geologic classification of features (e.g. bedding plane, lithologic contact, joint, fracture, foliation, etc.) is not specified in the Paillet System since only water-bearing potential is considered. A rank of five corresponds to a grossly porous zone with large openings (e.g. a major fracture, fault or solution cavity). The ranking system, with examples, is provided in Appendix B.

Tables listing the depth, aperture, strike, dip and type of feature are included in this report, for each well, as Appendix C. Feature apertures are listed in tenths of an inch. An aperture of zero for an open fracture simply means that while it appears to be a continuous open feature, the opening is smaller than the line thickness on the log (~0.015 inches). Note that because of the subjectivity involved in Paillet ranking, MAG has listed fractures in Appendix C only as either open or sealed. Specific Paillet rankings can be assigned by the client, if desired, by comparing the standard pictures in Appendix B to the OPTV log.

Note also that it has been the experience of MAG that the aperture or Paillet rank of a feature is not always a strong indicator of its water-producing potential. Thin, discrete features sometimes produce as much or more water (as evidence by flowmeter logging – see below) than wide, open fractures or fracture zones.

**Caliper**

Caliper measurements represent the average diameter of the borehole or well at a given depth. The caliper tool collects and transmits the data from three spring-loaded arms as the tool is lifted upwards through the borehole. The caliper tool is used to locate solution openings or fractures (where the borehole is typically enlarged due either to the presence of natural openings, or to plucking of broken rock by the drill bit), and to determine the length of casing intervals (as evident from small changes in casing diameter, or the small enlargements at threaded junctions, or narrowing due to the bead at welded junctions).

Caliper logs are collected by calibrating the downhole tool with a measuring template, lowering the tool to the base of the well, remotely opening the arms, and then logging the open borehole and casing diameter in an upward direction. Caliper logs are acquired with a logging speed of no more than 12 feet per minute.
**Fluid Temperature**

Fluid temperature logs provide the temperature of the air or fluid in a borehole as a function of depth. Temperature logs can indicate where water is entering or leaving a borehole – and thereby disturbing the normal geothermal gradient. Deviations, offsets, or changes in the slope of the temperature log can be used to locate zones of water movement within the borehole. Temperature logs must be run in wells that have been allowed to fully equilibrate to the local geothermal gradient following any prior drilling, construction, pumping or sampling. During a temperature survey, data accuracy is ensured by maintaining a downward logging speed of approximately 10 feet per minute (fpm). This provides an adequate time buffer to allow sensors to respond to minor temperature changes.

**Fluid Conductivity**

Fluid conductivity logs provide a continuous measurement of the electrical conductivity of the borehole fluid – i.e. zero in air or hydrocarbons, greater than zero in water. In water, electrical conductivity is mostly a function of electrolytic content. Water with very low dissolved solid concentrations will yield low fluid conductivity, while water containing a high level of dissolved solids will be proportionally more conductive. Fluid conductivity logs often deflect where water-producing features are transmitting water into or out of the well (since the well water may have a differing electrolytic chemistry than the formation water). The fluid conductivity log is usually collected simultaneously with the temperature log – since for both, data from a fully equilibrated water column is required.

**Natural Gamma**

Gamma logs are one of the most widely used geophysical logs in groundwater applications. They are used primarily to identify changes in lithology – specifically the relative amounts of clay in various sedimentary units.

A gamma log provides a record of the total natural gamma radiation detected within a given energy range. In water-bearing rocks and sediments that are not contaminated by artificial radioisotopes, the most significant naturally-occurring, gamma-emitting radioisotopes are potassium-40 and the daughter products of the uranium and thorium decay series. If gamma-emitting artificial radioisotopes have been introduced by humans into the groundwater system, they will also produce part of the radiation measured.
The amplitude of gamma-log deflections is affected by any borehole condition that alters the density of the material through which gamma photons must pass or the length of the travel path. The bedding of a gamma-emitting formation must be thick to obtain a quantitative value since the detector will be affected by the radiation from the formation as the tool approaches and passes the bed. Although increases in borehole diameter or the presence of steel casing will decrease the recorded gamma count, it is possible to collect usable information in both cased and open portions of the borehole using the gamma sonde. The presence of potassium-rich (and therefore gamma-emitting) bentonite clay commonly used in well construction will generally produce high gamma count peaks on a natural gamma log. MAG has natural gamma detectors on many sondes, and comparison of the multiple gamma logs collected for any given well logging program are used to ensure that the depths of differing logs are not erroneously shifted. Therefore, the gamma log presented for any well may have been collected simultaneously with any of the other logs from the same well.

Logging Results

The well was logged August 25, 2010. The logging results for the well are presented on the enclosed digital logs and tables, and briefly summarized below.

Note that since analysis of borehole geophysical logs can be quite subjective, and the level of detail is dependent upon the specific goals of the geologist, the analysis by MAG below covers the major features of each log, as well as some possibly minor features to serve as examples or guides for further interpretation by geologists familiar with the site, local geology, and/or project goals. In general, logs may display deviations (i.e. “spikes” where the parameter deviates from, and then returns to, “background” level), offsets (changes in background level), or slope changes. Any of these could be considered significant in certain situations, or when compared to correlating features at the same depth on other logs. If there are any questions about the features discussed (or not discussed) below, please do not hesitate to contact MAG.
MW-540

Noted Features

- The total depth (TD) of the well was logged at approximately 39.4 feet below ground surface (BGS).
- The depth to water (DTW) was measured at 30 feet BGS at the time of the survey.
- The diameter of the casing at the surface was measured to be four inches, and the bottom of the casing (BOC) was located at approximately 17.6 feet BGS.
- The caliper (borehole diameter) log reveals a few variable zones, but no distinct major enlargements.
- The fluid temperature log shows no significant deviations, offsets, or changes in slope except at the top of the water column.
- The fluid conductivity log shows no significant deviations, offsets, or changes in slope except at the top of the water column.
- A few planar features were recognizable on the televiewer logs. The depth, strike, dip, aperture, and feature type are listed on the log, as well as on the accompanying table in Appendix C.
- The natural gamma logs show generally smooth variations that are probably related primarily to the clay content of the formation.
Limitations

In making verbal or written interpretation of logs, MAG personnel give the client the benefit of their best professional judgment. However, since all interpretations are based on inference from electrical, magnetic, or other indirect measurements, MAG does not, and cannot, guarantee the accuracy or the correctness of any such interpretations. MAG shall not be liable for any loss, damages, or expenses resulting from reliance on such interpretations. MAG does not warrant the accuracy of log data transmitted by any electronic process and will not be responsible for intentional interpretation of log data by others. MAG makes no warranties – neither explicit nor implied. Under no circumstances shall MAG, its parent company Enviroscan, Inc., or their personnel be liable for consequential damages.

We appreciate this opportunity to have worked with you again. If you have any questions, please do not hesitate to contact me.

Sincerely,
Mid-Atlantic Geosciences

Duro Rajkovic
Project Geophysicist

Technical Review By:
Mid-Atlantic Geosciences

Felicia Kegel Bechtel, M.Sc., P.G.
President

enc.: MW-540: Televiewer and Geophysical Logs
Appendix A: Planar Feature Orientation Parameters
Appendix B: Paillet Ranking System
Appendix C: Planar Feature Characterizations Table
Appendix A

Planar Feature Orientation Parameters
Planar Feature Orientation Parameters

Dip = angle of inclination of the plane, downwards from the horizontal
Dip azimuth = azimuth of the line of maximum dip in the plane, clockwise from North
Strike direction = azimuth of a horizontal line in the plane (= dip azimuth − 90°)

e.g., dip and dip azimuth = 60° N041° or strike and dip = N311° 60°

e.g., Stratigraphic dip or 'bedding'

Other planar geologic features include joints/fractures/veins faults cleavage/schistosity
Appendix B

Paillet Ranking System
<table>
<thead>
<tr>
<th>Example OPTV Feature</th>
<th>Paillet Rank</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>[Image]</td>
<td>0</td>
<td>Sealed feature – no flow</td>
</tr>
<tr>
<td>[Image]</td>
<td>1</td>
<td>Partial open fracture</td>
</tr>
<tr>
<td>[Image]</td>
<td>2</td>
<td>Continuous open fracture</td>
</tr>
<tr>
<td>[Image]</td>
<td>3</td>
<td>Wide open fracture or fractures</td>
</tr>
<tr>
<td>[Image]</td>
<td>4</td>
<td>Very wide fracture or multiple interconnected fractures</td>
</tr>
<tr>
<td>[Image]</td>
<td>5</td>
<td>Major fracture zone or breakout</td>
</tr>
</tbody>
</table>
Appendix C

Planar Feature Characterizations Tables
## Planar Feature Characterizations

<table>
<thead>
<tr>
<th>Depth (in.)</th>
<th>Aperture (in.)</th>
<th>Dip Azimuth (deg.)</th>
<th>Strike (deg.)</th>
<th>Dip (deg.)</th>
<th>Feature Type</th>
</tr>
</thead>
<tbody>
<tr>
<td>18.7</td>
<td>0.0</td>
<td>243</td>
<td>N27W</td>
<td>82W</td>
<td>Sealed Fracture</td>
</tr>
<tr>
<td>20.6</td>
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<td>153</td>
<td>S63W</td>
<td>73E</td>
<td>Sealed Fracture</td>
</tr>
<tr>
<td>38.5</td>
<td>0.8</td>
<td>359</td>
<td>N89E</td>
<td>7W</td>
<td>Sealed Fracture</td>
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