ENVIRONMENTAL STRATEGIES CONSULTING LLC
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October 31, 2005

Mr. James E. Burke, P.E.
Environmental Engineer
New York State Department of Environmental Conservation
Region 7
615 Erie Boulevard West
Syracuse, NY 13204-2400

Re: Geophysical Survey Investigation Report
Emerson Power Transmission, Ithaca, New York

Dear Mr. Burke:

On behalf of Emerson Electric Co., Environmental Strategies Consulting LLC is submitting three copies of the *Geophysical Survey Investigation Report* for the Emerson Power Transmission facility site in Ithaca, New York. The report details the results of two phases of geophysical survey work completed by Environmental Strategies.

We are available to discuss this matter at your convenience.

Sincerely yours,

James P. Bulman
Executive Partner

JPB:sph:lpf
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Enclosure

cc\encl: Mr. Derek Chase, Emerson
Henriette Hamel, NYSDOH

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GEOPHYSICAL SURVEY INVESTIGATION REPORT
EMERSON POWER TRANSMISSION FACILITY
ITHACA, NEW YORK

PREPARED

BY

ENVIRONMENTAL STRATEGIES CONSULTING LLC

OCTOBER 31, 2005

A QUANTA TECHNICAL SERVICES COMPANY

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Acronym List

bgs	below ground surface
EPA	Environmental Protection Agency
EPT	Emerson Power Transmission
ER	electrical resistivity
FES	Forrest Environmental Services, Inc.
NYSDEC	New York State Department of Environmental Conservation
R&D	research and development
RMS	root mean square
TCE	trichloroethene

1.0 Introduction

Environmental Strategies Consulting LLC, on behalf of Emerson, conducted a geophysical survey at the Emerson Power Transmission (EPT) facility in Ithaca, New York. The survey, which used electrical resistivity (ER) to remotely image the subsurface, was conducted using large-scale (up to 1,400 feet long), widely spaced transect lines along the EPT property lines and in the neighborhoods adjacent to the facility to produce a picture of the subsurface over a large geographical area. The objective was to identify potential water-bearing zones in the bedrock and provide an overall understanding of how groundwater is migrating through the bedrock and to provide a geologic context for evaluating the results of other investigation activities (e.g., the soil vapor and groundwater sampling activities). The work was conducted in accordance the Geophysical Survey and Supplemental Groundwater Investigation Work Plan approved by the New York State Department of Environmental Conservation (NYSDEC) on July 18, 2005. The work plan was submitted to NYSDEC in fulfillment of requirements outlined in the July 13, 1987, Consent Order entered into by the NYSDEC and Emerson. This report presents a brief site description and history, a description of the scope of work, and the results of the geophysical survey.

2.0 Site Background

The EPT facility is located at 620 South Aurora Street in Ithaca, New York (Figure 1). The site consists of three main buildings along the northeast and southwest edge of South Hill, one of many relatively steep hills that overlook the city of Ithaca (Figure 1). The majority of the floor space is in the main plant building, which stretches more than 1,600 feet along the eastern edge of the 110-acre site. The main building is flanked by a number of smaller buildings to the west and a series of access roads and parking lots that terrace the hillside above the plant. Further uphill and to the east are South Aurora Street and the campus of Ithaca College. Undeveloped woodland borders the site to the southwest along the steep embankments of the hill. West Spencer Street, which runs parallel to the EPT property, marks the western edge of the wooded section and the base of South Hill. Beyond Spencer Street to the west and in areas along the steep northern approach to South Hill and the EPT property are residential areas. These neighborhoods are bordered by Six Mile Creek, which flows north along the base of South Hill and eventually empties into Cayuga Lake approximately 2 miles northwest of the site.

2.1 Site History

The EPT site was first developed in 1906 by the Morse Industrial Corporation, which manufactured steel roller chain for the automobile industry. In 1928, the facility switched from chain production to the manufacture of automotive components and power transmission equipment. Borg-Warner operated the Morse facility until 1983, when it was acquired by Emerson. Emerson, under the new facility name of EPT, continues to manufacture automotive components and bearings, including roller chain and clutches.

During Borg-Warner's plant ownership, Borg-Warner used a number of chlorinated solvents in manufacturing operations. The solvent trichloroethene (TCE), which is widely used in the industry, was reportedly used to clean metal parts in degreasers including one located on the ground floor of the Main Plant building. TCE was discovered in a firewater reservoir that lies beneath one of the outbuildings directly across from the former vapor degreaser area in the main building (Figure 1). Subsequent investigations conducted by Emerson beginning in 1987 revealed TCE-contaminated groundwater in the area directly downhill from the reservoir. Emerson reported these findings to the NYSDEC in 1987. Additional investigation in the late

1980s and early 1990s led to the installation of the groundwater remediation system directly downgradient of the firewater reservoir and a groundwater investigation program that included a number of wells in the neighborhoods adjacent to the EPT facility.

2.2 Site Geology

The site is located on the northern edge of the Appalachian Plateau Physiographic Province, which is characterized in central New York by deeply dissected hilly uplands and glacially gouged stream valleys. The EPT facility occupies the edge of one of the dissected hills and overlooks the Cayuga Lake basin, which is formed in a former stream valley eroded and enlarged by the advance of glaciers. Underlying the site is a thin, discontinuous veneer of glacially till and man-made fill. The soil, also known as the A-zone, is typically a silty or clayey gravel and ranges in depth from 2.5 to 33 feet thick, though most of the EPT facility property and the western slope of South Hill is covered by less than 15 feet of soil. Soil depths generally increase with decreasing elevation and eventually merge with glacio-lacustrine silt and clay that lines the bottom of the valley floor below South Hill.

Beneath the overburden lies bedrock of the Ithaca Siltstone, which is a member of the Genesee Formation. The bedrock is typically well-cemented with generally non-fossiliferous beds ranging in thickness from 0.1 inch to 2.5 feet in thickness. Previous interpretations of the site bedrock, based on core logs recovered from borehole drilled for investigation activities, differentiated the rock into three zones based on the frequency of bedding plane fractures: an upper "stress relief zone" (B-zone), a middle "transitional zone" (C-zone), and a lower "lithologically controlled zone" (D-zone). The uppermost B-zone is weathered bedrock and very highly to highly fractured. The B-zone extends to a maximum depth of approximately 22 feet below ground surface (bgs) and has an average thickness of approximately 8 to 10 feet on the west portion of the site where the current remediation system is located (Figure 2).

The transitional zone (C-zone) extends from the base of the B-zone to a maximum depth of approximately 55 feet bgs beneath the site. The lower lithologically controlled zone (D-zone) extends from the bottom of the C-zone to a minimum depth of 145 feet bgs. In this lower zone, fractures are reportedly confined to intervals that are widely spaced, and their occurrence is controlled by lithology. This terminology was developed by Radian Corporation, the previous consultants at the site, and carried forward by Environmental Strategies.

The bedrock is in the Ithaca area is cut by at least three sets of nearly vertical fractures or joints. Limited geologic mapping performed by Radian at 16 outcrop locations on and around the EPT facility found three consistent joint orientations: N13W to N21W (north-northwest); N70E to N89E (east-northeast); and N45E to N55E (northeast). Two of the three strike orientations measured by Radian are in reasonably close agreement with regional joint set measurements of N19W and N7E made at outcrops of the Genesee Group in Tompkins County. All of the joints measured by Radian were within 8 degrees of vertical.

2.3 Site Hydrogeology

Groundwater is present within the overburden and bedrock at the EPT site. Overburden water appears to be restricted to limited areas of the site where the discontinuous cover of soil is thickest. Based on short duration pumping events and slug test performed by Radian, the overburden groundwater in the area surrounding the treatment system is in hydraulic communication with the underlying bedrock of the B-zone. The extent of the communication has not been quantified; however, in the area around the treatment system, the two units appear to act as a single hydraulic entity. Groundwater is also present in the deeper bedrock wells. Limited pumping and slug tests performed by Radian and Environmental Strategies suggest that the deeper wells in the treatment system area are hydraulically isolated from the overlying B-zone.

Groundwater elevation data collected in May 2005 from B-zone wells in and around the treatment area show a northwesterly flow direction. Groundwater flow in the deeper bedrock intervals likely follows the same flow direction towards the Cayuga Lake basin. However, given the vagaries of groundwater in bedrock wells, which is often dictated by the particular fracture or fractures intercepted by the borehole, flow may vary locally.

3.0 Scope of Work

Two phases of geophysical work were conducted at the EPT facility and the surrounding area. Eight transect lines, designated ER-1 through ER-8, covering more than 5,400 linear feet on and around the facility were surveyed during the first phase of work conducted between July 5 and 7, 2005 (Figure 2). Based on a review of the preliminary survey results, a second geophysical survey was conducted between September 27 and September 28, 2005, along an array of five additional survey lines, designated ER-9 through ER-14, covering approximately 3,600 feet. Proposed ER-13, which was to be survey along the north side of the former research and development (R&D) building, could not be completed due to access limitations along the proposed transect line. For the purpose of defining the map direction of specific areas at the EPT facility and surrounding areas, Emerson has divided the site into four directional quadrants (NW, NE, SW, and SE) with the center of the four quadrants being the fire water reservoir. Figure 2 present the four directional quadrants of the site.

Survey line ER-1, which because of its length was broken into two separate components, ER-1N (northwest) and ER-1S (south), was oriented northeast-southwest and located in the parking lots on the southeast and southwest portions of the EPT facility. The locations for ER-1N and ER-1S were selected to provide fracture information upgradient of the facility. The length of ER-1N was approximately 1,100 feet. Survey line ER-1S was slightly shorter at approximately 900 feet long.

Five ER survey lines were surveyed along the northwest, northeast, and southwest portions of the site to provide fracture information on the downgradient edge of the site. Survey lines ER-2, ER-7, ER-12, and ER-14 formed a roughly northeast-southwest oriented line parallel to the western property line (Figure 2). The northeastern line segment, ER-2, was approximately 675 feet long and extended along the edge of the northeast parking lot between the main plant building and the former R&D building. The line was surveyed to provide bedrock information directly downgradient of the fire water reservoir and current remedial system. The line was overlapped and extended by survey line ER-12, which extended approximately 840 feet and provides information along the northeast boundary directly east of the former R&D building. Survey line segment ER-7, which was later supplemented by survey line ER-14, extended from a point just east of the New York State Electric and Gas substation approximately 1,450 feet southwest along the former rail grade. This line provides information on the bedrock quality along the southwest portion of the site. The final onsite survey line, ER-3, was located along the access road to the EPT facility that connects northeast parking areas and the former R&D building with South Cayuga Street. This 400-foot-long survey line was installed to provide additional bedrock data directly downgradient of ER-2.

Six ER transect lines were surveyed in the public right-of-way in the neighborhoods directly northwest and downhill (northeast) of the main plant and former R&D buildings. Survey line ER-8 was located along the eastern side of South Cayuga Street from its terminus at the EPT facility and extended north approximately 400 feet to the intersection of South Hill Terrace (Figure 2). Two lines, ER-4 and its extension line ER-10, were surveyed to provide bedrock quality information along South Hill Terrace. The combined survey lines, which overlap, cover approximately 900 feet of the street. The remaining ER lines (ER-6, ER-9, and ER-10) were surveyed to evaluate the bedrock beneath Hillview Place (ER-6 and ER-10) and Turner Place (ER-9). Survey line ER-4, which was surveyed during the first phase of work, was extended by ER-10 to cover more than 900 feet of Hillview Place from its intersection with South Aurora Street west to its terminus just east of South Cayuga Street. Transect line ER-9, which is roughly the same length, was located along Turner Place from the EPT property line north to its intersection with South Hill Terrace.

The remaining line, ER-5, was located along West Spencer Street to provide subsurface information along the western face of South Hill (Figure 2). Because of the length, the line was split into two segments designated ER-5N (north) and ER-5S (south). The longer of the two lines, ER-5N, was surveyed from a point just southeast of the intersection with South Cayuga Street southeast approximately 1,090 feet to the traffic circle at the intersections of West Spencer, South Albany, and Park Streets. The southern ER line segment, ER-5S, continued along the west side of West Spence Street southeast of the traffic circle.

3.1 Geophysical Survey Equipment and Methods

The geophysical survey was performed by Forrest Environmental Services, Inc. (FES), of Oak Hill, Virginia. An FES geophysical technician performed all of the data processing and provided preliminary analyses of the findings. Environmental Strategies evaluated the ER findings and hydrogeologic information gained from previous investigations in preparing this report. The geophysical cross-sections (profiles) constructed from the data are included in FES's final report (Appendix A) and are presented in figures 3 through 17.

Each ER survey line was evaluated using a Swift-brand automatic electrode system (Swift), which was connected to a Sting R8-brand earth resistivity meter. The electrodes were placed along the designated ER survey line with approximately 13 feet between each dipole. Each electrode was installed to a depth of approximately 18 inches bgs using a steel sledgehammer. Where the electrodes were to pass through concrete, a portable hammer drill was used to core a small hole to allow the electrode to be installed in the subsurface. In areas where bedrock was encountered at depths less than 18 inches, the electrode was advanced until it was in direct contact with the underlying rock. As many as 84 electrodes were installed along a single line yielding a maximum survey line of approximately 1,100 feet. Once the information was collected from the survey line, the electrodes were removed from the ground and the area was restored with material (e.g., concrete/asphalt) to match the surrounding grade.

3.2 Geophysical Interpretation

The ER data collected from each survey line were converted into a resistivity-depth model using a Rapid 2-dimensional resistivity inversion model and the least-squares method (RES2DINV). Soundings from each survey line were modeled to calculate the apparent resistivities and develop pseudosections based on the model predictions. The pseudosections were then contoured in SURFER, a contouring software package developed by Golden Software, of Golden, Colorado, to produce a color-coded cross section or profile for each ER line displaying the distribution of resistivities between the various subsurface materials. The resistivity scale runs from 1 ohm-meter, which represents low resistivities (i.e., high electrical conductivity), to a high of 5,000 ohm-meters, which represents highly resistive materials. Each resistivity measurement was assigned a color from dark blue (1 ohm-meter) to red (5,000 ohm-meters). Bedrock, a typically highly resistive material, generally yields resistivity measurements of 200 to 5,000-ohm meters, which plot as regions of light green, yellow, and red. Regions with resistivities below 200 ohm-meters generally plot as shades of green and light blue. Water-bearing zones, which have dramatically reduced resistivities due to the highly conductive nature of groundwater, typically yield regions of blue or dark blue within the more resistive areas. The focus of the geophysical interpretation was to identify and generally locate the highly conductive water bearing zones within the subsurface.

The modeling is an iterative process which is designed to match the measured, or true, resistivities to the models interpretation. Generally, the higher the number of iterations the closer is the approximation of the model to the actual measurements. The root mean square (RMS) error is a measure of how closely the model is approximating the measured conditions. Low model iterations and relatively high RMS error (e.g., less than 6 iterations and an RMS error greater than 50) are generally undesirable as they often skew the size and location of the buried features. However, in situations where the subsurface contains extremely high resistivity contrasts or the structure of the bedrock is highly variable or exists in patterns that are not expected by the model (e.g., karst) the iterative process can yield unwanted artifacts that do not reflect the subsurface geology. Interpretation of what is a real feature and what is an artifact is a function of the operator's experience level using the software. A number of the profiles generated during the EPT facility survey exhibited similar artifacts at higher iterations of the model (as interpreted by FES) do to the variability in the subsurface. Consequently, several profiles (e.g., ER-7, ER-10, ER-14) were reevaluated at lower model iterations, which resulted in higher RMS errors. The size and position of the mapped features in the resulting profiles may be slightly offset from their actual locations in the subsurface but still represent the overall pattern of bedrock features and, thus, are consistent with the approach of a low resolution survey of the site.

4.0 Results

Thirteen ER survey lines, designated ER-1 through ER-12 and ER-14, were sounded and evaluated at various locations on and around the EPT facility (Figure 2). Six of the survey lines, ER-1 through ER-3, ER-7, ER-12, and ER-14, were located on the EPT property to characterize the subsurface onsite. Six ER survey lines, ER-4, ER-6, ER-8, and ER-9 through ER-11, were located in the residential areas northwest and northeast of the firewater reservoir. Survey ER-5 was located along the residential areas northwest and southwest of the facility near the base of South Hill. Maximum penetration depths, which depended on the length of the line, ranged from approximately 70 feet along survey line ER-5S to 280 feet along survey line ER-1N. Geophysical cross-sections (profiles) were developed based on the interpretation of the ER data. The ER profiles are presented in Appendix A and show the electrode array, the corresponding elevation, and the interpreted water-bearing zones based on the ER data. A summary of the results of each survey line is presented below. The geophysical profiles for each line are presented in figures 3 though 17. A copy of FES's report is included in Appendix A.

4.1 ER-1 North

Four conductive anomalies were detected in the profile designated as ER-1N. Two of the anomalies, 1N-A and 1N-B, were detected near the middle of the survey line and are centered approximately 50 feet bgs (Figure 3). These near-surface anomalies are surrounded by more resistive near surface bedrock features and may represent a weathered bedrock zone. Both zones appear to be highly conductive with resistivities in the 1- to 5-ohm-meter range. Two other anomalies, 1N-C and 1N-D, were identified at depths of approximately 100 feet bgs. 1N-D appears to be more conductive than 1N-C: the resistivity on 1N-D is in the 2- to 5-ohm-meter range versus the 10- to 20-ohm-meter range for 1N-C. The area of blue near the northeast end of the profile was not considered a conductive anomaly because the data set that defines the feature extends off the edge of the profile and, thus, is incomplete. Anomalies of this type are believed to represent artifacts of the modeling process (i.e., an edge effect) rather than an actual conductive anomaly.

4.2 ER-1 South

Three relatively small, shallow anomalies, 1S-A through 1S-C, were identified in the southern third of the survey line (Figure 4). The anomalies are relatively weak with resistivities ranging from approximately 25 to 50 ohm-meters. No other reliable anomalies were noted in the profile. The blue area near the bottom of the profile was not considered to be an anomaly due to its location near the edge of the profile (i.e., the anomaly is an edge effect).

4.3 ER-2/ER-12

Four conductive anomalies, 2-A through 2-D, were identified in the profile of survey line ER-2 at depths ranging from 40 to 60 feet bgs (Figure 5). Anomalies 2-A and 2-D are highly conductive with resistivities ranging as low as 1 ohm-meter. Anomalies 2-B and 2-C exhibited a somewhat lower conductivity with a mapped resistivity of between 5 and 50 ohm-meters. A number of other anomalies were noted along the ground surface, especially between 0 and 200 feet and 320 and 480 feet along the ER-2 survey line. These anomalies likely represent the overburden in the area of ER-2, which was likely installed as part of the former rail grade that follows the ER-2 transect. Both the native and fill materials onsite typically contain high concentrations of clay minerals, which can yield resistivity signatures that are similar to those of water-bearing zones in bedrock. The anomaly between 0 and 160 feet may also have been exaggerated by local infiltration of surface water from the non-contact cooling water drainage sluice that is adjacent to the ER-2 survey line.

No conductive anomalies were identified within the current remediation area downgradient of the fire water reservoir (Figures 2 and 5). The closest conductive anomaly in this area is 2-A, which was identified 120 feet to the northeast.

Two additional conductive anomalies, 12-A and 12-B, were noted in the profile ER-12, which extends transect ER-2 to the northeast (Figure 16). Both anomalies were located at approximately the same depth (centered at approximately 20 feet bgs); however, anomaly 12-A is more conductive with a resistivity of 2 to 5 ohm-meters than 12-B, which has a resistivity between 10 and 40 ohm-meters. Anomaly 12-A is also located within a region of relatively low resistivity that may indicate weathered bedrock or, as in the case with features in ER-2, may be the result of fill installed as part of the former rail grade. In contrast, anomaly 12-B appears to be contained within a region of highly resistive bedrock. The blue region along the southwest edge of the profile beneath 12-B was considered an edge effect and, thus, not a valid anomaly. Likewise, the numerous small, shallow (less than 10 feet) anomalies between 12-A and 12-B were rejected from the classification as likely buried utilities.

4.4 ER-3

No reliable conductive anomalies were noted in this profile (Figure 6). The blue near-surface areas at the eastern and western ends of the profile are likely due to clay in the overburden, which was placed as part of the construction of the access road where survey ER-3 was conducted.

4.5 ER-4/ER-10

Three conductive anomalies, 4-A through 4-C, were identified in ER-4 centered at approximately 30 feet bgs (Figure 7). All three anomalies are highly conductive with resistivities between 2 and 5 ohm-meters. The anomalies are located within a relatively conductive zone extending from just below grade to a depth of approximately 70 feet bgs, which is underlain by highly resistive material. The 70-foot-thick zone is consistent with weathered bedrock.

Three additional anomalies, 10-A through 10-C, were detected in profile ER-10, which overlaps ER-4 (Figures 2 and 14). Anomalies 10-B and 10-C are centered at approximately the same depth as 4-A through 4-C and appear to be within a similar zone of lower resistance consistent with weathered bedrock. Anomaly 10-A is centered at 50 feet bgs and appears to be flanked on both sides by highly resistive bedrock. The extent to which anomaly 10-A extends down is unknown because the data set at the bottom of the profile is not complete and the lower portion of this blue region may represent an edge effect.

4.6 ER-5 North

Only two reliable conductive anomalies, 5N-A and 5N-B, were noted in profile ER-5N (Figure 8). These anomalies were centered approximately 40 and 50 feet bgs, respectively. Several other anomalous areas were noted; however, many were located less than 10 feet below ground surface and can be attributed to the sewer lines, gas lines, or other buried utilities crossed by the ER-5 transect. The large anomaly at the bottom of the profile is not considered reliable based on the fact that the data set is incomplete (i.e., the anomaly may be an edge effect).

4.7 ER-5 South

Four conductive anomalies, 5S-A through 5S-D, were detected in the profile ER-5S (Figure 9). Two of the anomalies, 5S-A and 5S-B, were relatively small and shallow, with depths of approximately 20 and 30 feet respectively. The two larger anomalies, 5S-C and 5S-D, were centered near 60 feet bgs. All four anomalies appear to be highly conductive with resistivity lows between 2 and 5 ohm-meters, and each appears to be located within a zone relatively low resistivity that may be indicative of either unconsolidated material such as sand or silt, or weathered bedrock.

4.8 ER-6/ER-11

Six conductive anomalies were identified in the profile ER-6. Five of the anomalies, 6-A through 6-E, were relatively small and shallow, with depths ranging between 10 and 30 feet bgs (Figure 10). A larger conductive anomaly was detected near the center of the profile centered at a depth of approximately 50 feet bgs. All of the anomalies appear to be highly conductive with resistivity lows between 1 and 5 ohm-meters.

Five additional conductive anomalies (11-A through 11-E) were identified along Hillview Place in profile ER-11, which extends beyond ER-6 (Figures 2 and 15). With the exception of anomalies 11-B and 11-E, each was generally shallow (approximately 20 feet bgs) and located in a region of relatively low (50- to 100-ohm-meter) resistivity overlying more resistive bedrock. These regions of relatively low resistivity are consistent with weathered bedrock. Anomalies 11-B and 11-E were located significantly deeper in the profile (centered at approximately 40 feet bgs) and were surrounded by highly resistive bedrock. All of the anomalies were highly conductive with resistivities ranging as low as 2 ohm-meters.

4.9 ER-7/ER-14

A single conductive anomaly was identified in the profile ER-7. The anomaly (7-A) appears to be highly conductive (2 to 5 ohm-meters) and was centered at approximately 50 feet bgs (Figure 11). The anomaly appears to be surrounded by highly resistive bedrock.

Two similar conductive anomalies, 14-A and 14-B, were identified in the profile ER-14, which extends ER-7 to the south (Figure 17). Both anomalies are equally conductive with resistivities in the 2- to 5-ohm-meter range and both appear to be contained within a zone of relatively low resistivities that is completely encased in more resistive bedrock. These mapped features appear to represent sediment filled voids within the bedrock.

4.10 ER-8

Five conductive anomalies, 8-A through 8-E, were identified in the profile ER-8 (Figure 12). All of the anomalies were highly conductive (1 to 5 ohm-meters), centered at approximately the same depth (40 feet bgs), and are located within an area of relatively low resistivity. This area is consistent with weathered bedrock. The anomaly near the northern end of the profile is considered an artifact.

4.11 ER-9

Nine conductive anomalies, 9-A through 9-I, were identified in the profile ER-9 (Figure 13). The anomalies ranged in size and resistivity (1 to 20 ohm-meters) and all were located within region of relatively low (50 to 100) resistivity between 25 and 75 feet bgs. The relatively low resistivity zone appears to be a weathered bedrock zone that lies between areas of higher resistivity bedrock. Several smaller, near-surface anomalies located less than 10 feet bgs were not considered reliable. These anomalies can be attributed to buried utilities along the ER-9 transect.

4.12 Discussion of Survey Results

The results of the geophysical survey reveal a complex geologic and hydrogeolgic network. Two highly conductive anomalies were identified along the northeast portion of the site in profile ER-2 (2A and 2D) and overlapped profile ER-12 (12A). Three highly conductive anomalies were also observed along the southwestern portion of the site in profile ER-7 (7A) and in ER profile 14 (14A and 14B). No major conductive zones were identified within the current groundwater remediation area downgradient of the fire water reservoir. Although bedrock cores recovered from groundwater monitoring well borings are generally similar (i.e., all are siltstone of the Ithaca Member), wide variations were noted in electrical response. Highly resistive material (i.e., resistivities greater than 250 ohm-meters) was identified both above and below rock with lower resistivities (i.e., resistivities between 50 and 250 ohm-meters). These lower resistivity regions may represent higher fracture concentrations (such as bedding plane partings) that contain greater amounts of pore water than the highly resistive rock (but not as much as the conductive anomalies); areas of rock that have undergone differential chemical weathering resulting in higher conductive clay content (from in-situ rock degradation) or voids; a lithology change, or some combination of the three.

The conductive anomalies, which likely represent saturated conditions, were noted within large areas of apparently weathered bedrock (e.g., ER-4, ER-5 South) and in regions surrounded by apparently highly-resistive bedrock (e.g., ER-1 South, ER-2, ER-5 North, and ER-12). In both cases, the conductive anomalies varied greatly from relatively small (less than 20 feet in mapped diameter), shallow areas with moderate conductivities (e.g., ER-1 South, ER-5 North) to large scale regions of apparent saturation covering over 100 linear feet of the profile (e.g., ER-4, ER-5 South, ER-7). In some cases both features appeared in a single profile (e.g., ER-1 North, ER-9, ER-10). The data clearly demonstrates that the majority of groundwater within the bedrock is contained within these relatively well defined, discrete zones, which suggests that groundwater flow is in the secondary porosity of the rock (i.e., within fractures, joints, and other openings within the rock) and not the rock itself (i.e., primary porosity). This preferential flow through the openings often results in greater groundwater flow velocities (as compared to flow through the rock matrix) and can yield unexpectedly tortuous flow paths depending upon the level of connectivity between the various openings in the rock. The pathways by which the groundwater flows through bedding plane fractures, joints, faults, or all of the above at the EPT facility is not directly addressed by this survey.

5.0 Summary

The geophysical survey results indicate that five major conductive zones are located along the northeast and southwest portion of the EPT site. No major conductive zones were identified in the immediate vicinity of the current remediation area downgradient of the fire water reservoir, which was identified in 1987 as the source of the TCE release.

The results of the geophysical survey also demonstrate that groundwater migration at EPT is controlled by the orientation of bedrock structures, including bedding plane fractures and vertical joint sets. Groundwater flow through the bedrock, as indicated by the conductive anomalies, is confined to relatively well-defined, discrete water-bearing zones that correspond to the secondary porosity of the rock. In the area directly downgradient of the remediation area where affected groundwater is found in wells that are not near any significant water-bearing anomaly, the flow is likely controlled by the amount of horizontal bedding plane fractures and, thus, the terms stress relief, transition, and lithologically controlled zones (i.e., "B," "C," and "D" zones) are useful for discussing the distribution of affected groundwater. However, it is clear from the geophysical results that the partings alone are not controlling the migration of groundwater over other portions of the site and a horizontally zoned conceptual model cannot be used to generalize the hydrogeologic framework of the site.