Case Study Abstract

Marshalltown Former Manufactured Gas Plant (FMGP) Site
Marshalltown, IA

Site Name and Location: Marshalltown FMGP	**Geophysical Technologies:** Electrical conductivity	**CERCLIS #** Not Applicable
Period of Site Operation: 1870's to 1946–gas manufacturing and electric generation **Operable Unit:** Not Applicable		**Current Site Activities:** Currently 100 employees still work on-site. Groundwater monitoring is being performed.
Point of Contact: Albert Bevolo Ph.D. Ames Laboratory Iowa State University 125 Spedding Hall Ames, IA 50011 (515) 294-5414	**Geological Setting:** Pleistocene glacial till, glaciolacustrine deposits, fluvial deposits, and loess lie unconformably over discontinuous layers of limestone and dolomite.	**Technology Demonstrator:** Geoprobe Systems Corporate Headquarters 601 N. Broadway Salina, KS 67401 1-800-GEOPROBE

Purpose of Investigation:
The geophysical investigation was undertaken as part of a demonstration under the Department of Energy's Expedited Site Characterization program. The goal of the demonstration was to compare the capability of electrical conductivity surveys with more traditional methods for characterizing subsurface stratigraphy, such as borehole geophysical logging and cone penetrometer testing (CPT).

Goals related to the soil conductivity probe (SCP) were to confirm and further refine the site geologic and contamination conceptual models as defined through Phase I activities. Another goal was to define the topography of the lower cohesive unit (LCU) in order to find low-points where dense non-aqueous phase liquids (DNAPLs) might collect.

Number of Images/Profiles Generated During Investigation:
27 conductivity profiles produced from 700 feet of log in 27 holes

Results:
SCP provided high vertical resolution data from which transitions between high conductivity clay and low conductivity sands could be readily identified. Calibration with soil borings and CPT showed that the main stratigraphic units were readily distinguishable. The SCPs provided clear information on stratigraphic transition depths which were readily integrated with data from CPT and boring logs.

A secondary and unexpected result was the apparent response of the SCPs to DNAPL-saturated soils by distinct decreases in conductivities.

EXECUTIVE SUMMARY

The Marshalltown Former Manufactured Gas Plant (FMGP) site is located in an old industrial area in Marshalltown, Iowa. Gasification by-products of the manufacturing process, including coal tar, coke, and other materials, were stored on-site in unlined pits. A site investigation found polycyclic aromatic hydrocarbons (PAHs) in soil samples at levels substantially above background levels. Another investigation, conducted during an underground storage tank (UST) removal, showed the presence of petroleum hydrocarbons in excess of applicable action levels in soil and groundwater.

The site is situated on the edge of the flood plain of Linn Creek where the ground surface is flat to gently sloping. Near surface soils consist of a wide range of fill materials of low plasticity and varying in thickness from 0.5 to 14 feet. This is underlain by fine-grained cohesive soils consisting of low plasticity silty clay with interbedded sandy and gravelly clays, ranging in thickness from 6 to 14 feet. Limestone bedrock is approximately 50 feet below the ground surface. A steep ridge in the bedrock surface, with about 25 feet of relief, trends northwest-southeast across the site.

The Marshalltown site was used a demonstration site for the comparison of various technologies used in the site characterization process. The focus of this case study is an assessment of the performance of a soil conductivity probe (SCP) used to delineate soil stratigraphy and its utility in the Expedited Site Characterization Process. The information in this report was derived from the interpretive report of the geophysical investigation. A site-specific goal for the SCP was to define the topography of the lower cohesive unit (LCU) to identify low-points where dense non-aqueous phase liquids (DNAPLs) might accumulate. The probe determines soil conductivity by measuring the electric potential across electrodes in direct contact with the soil.

Results of the investigation revealed that the SCP provided very useful and reliable stratigraphic data. The upper cohesive unit (UCU) and the LCU contact was inferred by a distinct rise in the conductivity values. Both of these contacts could easily be identified on most of the soil conductivity logs. A secondary and unexpected result was the apparent response of the SCP to DNAPL-saturated soils, measured by decreases in conductivities.

Since this was a demonstration of the SCP when the product was first developed, no direct costs were associated with this investigation. However, based on current models of equipment and prices associated with them an estimated cost of $7,875 can be associated with an investigation of this type.

The capabilities of the SCP were proven. The probe was very versatile in that it could maneuver into small spaces and could penetrate most soil subsurface materials. The SCP was not able to clearly identify weathered bedrock and probes would break when unexpected bedrock or larger sized gravel and cobbles were encountered. The probe was also operationally efficient and could be operated by a single person if necessary. The information collected by the probe can also be used to enhance the site contamination model. The probe has the ability to provide much more detailed stratigraphic information than conventional auger borings. This is very important when considering the fate and transport of contaminants. The SCP detected DNAPL-saturated soil as a distinct decrease in conductivity.

SITE INFORMATION

Identifying Information

Marshalltown FMGP Site
Marshalltown, Iowa 50158
Operable Unit: --N/A
CERCLIS #: --N/A

Background [1]

Physical Description: The Marshalltown Former Manufactured Gas Plant (FMGP) is located in in an old industrial area of Marshalltown, Iowa (Figure 1). The site contains several buildings from the FMGP and former electric plant and is approximately 2.5 acres in size (Figure 2). The nearest residential properties are located several hundred feet to the north. The site is located on the edge of the floodplain of Linn Creek which flows west to east approximately 800 feet south of the site and discharges into the Iowa River roughly 2.5 miles northeast of the site. Site topography is flat to gently sloping, with approximately 10 feet of relief across the site.

Site Use: A manufactured gas plant operated at the site from the 1870's until 1946. When the site first opened in the 1870's, under the name of Marshalltown Gas Light Company, gas manufacturing was accomplished by coal carbonization. Electrical generation began at the site between 1888 and 1892. In 1892 the Marshalltown Gas Company, the Marshalltown Electric Company, and the Marshalltown Street Railway Company consolidated and became the Marshalltown Light, Power, and Railway Company, which brought the electrical and gas operations under common ownership. Between 1910 and 1921, the gas manufacturing process was converted from coal carbonization to carbureted water gas and the ownership was transferred to the Iowa Railway and Light Corporation. Plant operations continued until 1946.

The FMGP site is currently used as the service and materials distribution center for Alliant Utilities gas and electric operations. The site is currently owned by IES Utilities who merged with other mid-western power generation/distribution companies and is now known as Alliant Utilities. There are 100 employees that work on-site, and the plant is scheduled to close within the next two years so remediation can begin [2].

Figure 1: Site Location

SITE INFORMATION

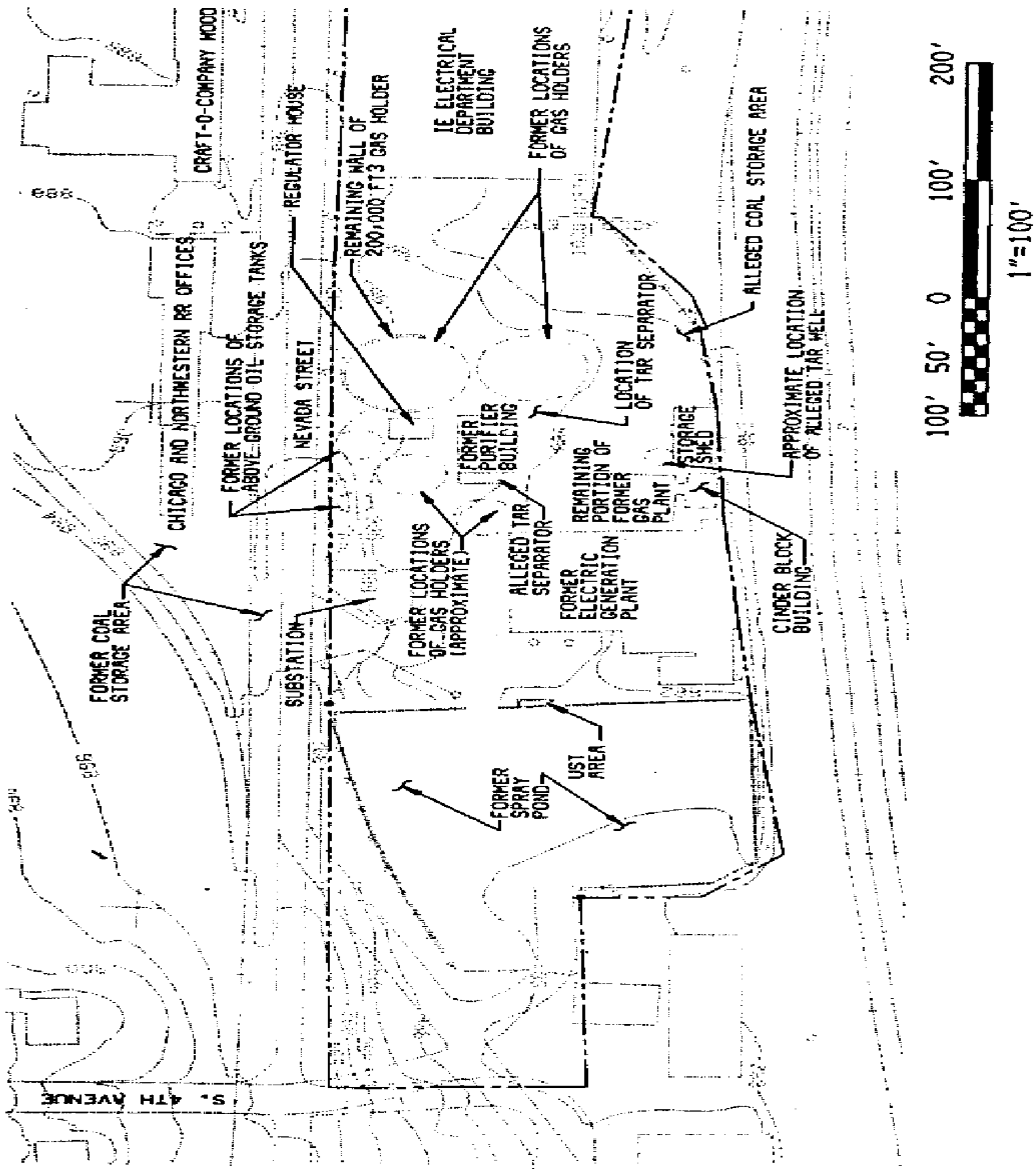

Figure 2: Site Map of Marshalltown FMGP [1] [Poor Quality Original]

SITE INFORMATION

Release/Investigation History: Major by-products of the gas manufacturing process are coke, tar, ash, and spent purifiers. The final disposition of these by-products on the site is unknown, but a substantial portion of the tar may have been disposed on site. The investigation of waste product disposal at the site began with a preliminary study conducted in 1986. In 1987, soil samples collected in a follow-up site investigation revealed the presence of polycyclic aromatic hydrocarbons (PAHs) compounds at levels substantially above background levels. In November, 1988, an underground storage tank (UST) was removed from an area near the west end of the east wall of the former spray pond (Figure 2). Petroleum hydrocarbons in excess of applicable action levels were detected during this removal action. In 1990, a detailed remedial investigation was begun to address requirements under a 1989 Consent Order between the Iowa Department of Natural Resources (IDNR) and Alliant Utilities. The investigation identified a tar pit, two different tar separators, and a tar well as potential contaminant sources. A comprehensive soil and groundwater sampling program was included as part of this investigation. Visible coal tar or fuel contamination was found in the soil sampled from several borings at the site. The site activities that are the focus of this case study include the second phase of the site investigation process and the evaluation of remedial alternatives.

Regulatory Context: The IDNR is the lead agency coordinating all the activities of the Marshalltown FMGP site. The site is being addressed as a result of a 1989 Consent Order entered into between the IDNR and Alliant Utilities. The IDNR is utilizing CERCLA requirements and guidances [3].

Site Logistics/Contacts

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MEDIA AND CONTAMINANTS

Matrix Identification [1]

Type of Matrix Sampled and Analyzed: Subsurface soil and occasional weathered rock

Site Geology/Stratigraphy [1]

The overall stratigraphy of the glacial drift in the area of the site consists of loess over Kansan till, which overlies Mississippian-age limestone and Pennsylvanian shale bedrock. Near-surface soils include a wide range of fill materials (clay, gravel, sand, cinder, and other debris) of low plasticity ranging in thickness from 0.5 to 14 feet. This is underlain by fine-grained cohesive soils consisting of low plasticity silty clay with interbedded sandy and gravelly clays, ranging in thickness from 6 to 14 feet. This layer is also known as the upper cohesive unit (UCU). This is followed by a granular unit comprised mostly of various types of sand. A layer of low plasticity clayey lacustrine soil and low to high plasticity glacial till separates the granular unit from bedrock in most areas of the site. This layer is commonly referred to as the lower cohesive unit (LCU). Depth to bedrock ranges from 20 feet below the ground surface (bgs) in the northern part of the site to 40 feet bgs in the southwestern portion. According to drilling information, a steep ridge in the bedrock surface with about 25 feet of relief trends northwest-southeast across the site. Depth to groundwater at the site averages between 18 to 20 feet bgs. Hydraulic conductivity measurements indicate values that range from 0.0029 to 0.00076 cm/sec for the granular soils. Groundwater in the alluvial sediments tends to flow in a southern direction toward Linn Creek. Bedrock groundwater flow characteristics are not well established and appear to be strongly influenced by the activity of production wells in the area that tap the Mississippian aquifer. The limestone bedrock is part of the Mississippian Burlington and Gilmore City Formations and are part of the regional Mississippian aquifer.

Contaminant Characterization [1]

Primary Contaminant Groups: The primary contaminants of concern at the site include the following: benzene, toluene, ethylbenzene, xylene, phenols, and PAHs, such as naphthalene and phenanthrene. Some contaminants are known to be present as dense non-aqueous phase liquids (DNAPLs).

Matrix Characteristics Affecting Characterization Cost or Performance [1, 4]

Due to surface obstructions encountered on-site, such as buildings, sheds, etc., explorations could not be conducted at some locations. Unexpected cobbles, larger sized rocks, boulders, or bedrock were encountered and posed a problem for the probes. Several probes were broken when these units were encountered.

Factors such as non-uniform infiltration of highly saline solutions from winter road salting operations, poor ground-to-probe contacts at shallow depths, and the diverse nature of the surficial fill contributed to the erratic conductivity data gathered within the top six feet from the surface.

Irregularity in the conductivity trace can also be attributed to thinly interbedded seams of silts, sands, clays, and gravels up to depths of approximately 15 feet bgs. Weathered rock did not have a distinct conductivity signature, and could not be distinguished from soils on the basis of its conductivity.

GEOPHYSICAL INVESTIGATION PROCESS

Investigation Goals [1, 4]

The geophysical investigation was undertaken as part of a demonstration under the Department of Energy's Expedited Site Characterization program. The goal of the demonstration was to compare the capability of electrical conductivity surveys with more traditional methods for characterizing subsurface stratigraphy, such as borehole geophysical logging and cone penetrometer testing (CPT).

Goals related to the soil conductivity probe (SCP) were to confirm and further refine the site geologic and contamination conceptual models as defined through Phase I activities. Another goal was to define the topography of the LCU in order to find low points where DNAPLs might collect.

Geophysical Methods [1, 5, 6]

The focus of this case study is an assessment of the performance of the Geoprobe® SC100 conductivity probe (SCP) in delineating soil stratigraphy. The determines soil conductivity by measuring the electric potential across electrodes, which are in direct contact with the soil. Electrical conductivity varies with soil type, with clays exhibiting higher conductivities than silts, and sands and gravels having the lowest conductivity. The probe has a vertical resolution of 0.05 feet with a data rate of 20 samples per second, and a maximum depth range of 80 feet bgs. The SCP system is small and very maneuverable.

The conductivity probe, shown in Figure 3, consists of a steel shaft running through the center of four stainless steel contact rings. An engineering grade plastic electrically isolates the rings and the shaft from each other. The probe was operated in the Wenner array configuration which reacts linearly to variations in formation conductivity and yields good vertical resolution by using all four electrodes. The probe is approximately eight inches long and has a diameter that tapers from 1-1/8 inch at the top to 1 inch at the point. The taper assures a firm ground-to-probe contact. The probe assembly threads directly to standard Geoprobe® probe rods. A signal cable is threaded through the inside of the rod string and into a PC-based data acquisition system housed in a ruggedized case. Depth

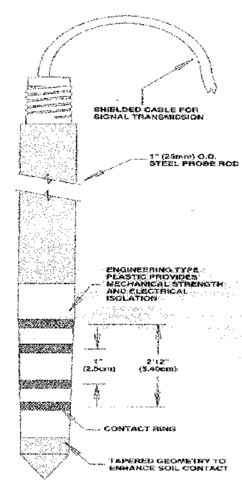

Figure 3: Conductivity Probe [3]

GEOPHYSICAL INVESTIGATION PROCESS

measurements are obtained by a stringpot system configured to measure the distance from the driving mechanism to the ground surface. The stringpot signal is used both to determine probe depth and speed at which the probe is advancing.

Technology Justification

The reasons that soil conductivity was selected for the investigation at the Marshalltown site were not site-specific, but were related to the investigation as a demonstration for the expedited site characterization process. However, due to the many cultural interferences at the site such as chain-link fences, stacks of steel piping, steel storage sheds, and vehicle traffic, other geophysical methods such as ground penetrating radar and electromagnetic offset logging could not provide useful results [4].

GEOPHYSICAL FINDINGS

Technology Calibration [1]

In order to calibrate the SCP with local soils at the site, 123 sample soil cores (which resulted in 127 soil samples) were collected from 27 geoprobe locations at specific depths for standard core logging and visual soil classification (Figure 4). These core samples were two feet long and were collected from six subsurface zones at specified depths using another Geoprobe® system. The units of measurement for conductivity are milliSeimens per meter (mS/m). The Seimen is the inverse of the Ohm, the standard measure for electrical resistivity. Direct calibration of the SCP with soils collected from the site revealed the following comparisons in conductivity values: Clayey soils: 60 - 140 mS/m; sandy soils: 30 - 40 mS/m; gravels: 20 - 35 mS/m (Table 1 and Table 2).

The SCP was advanced adjacent to two existing borings for calibration: MW-3A and B-8. Distances between the borings and probes were 16 and 13 feet respectively. The SCP was also calibrated against CPTs. CPT is a reliable direct-push geotechnical method of characterizing soils on the basis of its physical resistance to penetration. The conductivity profiles were compared directly to the stratigraphic logs for these borings and with the CPT results.

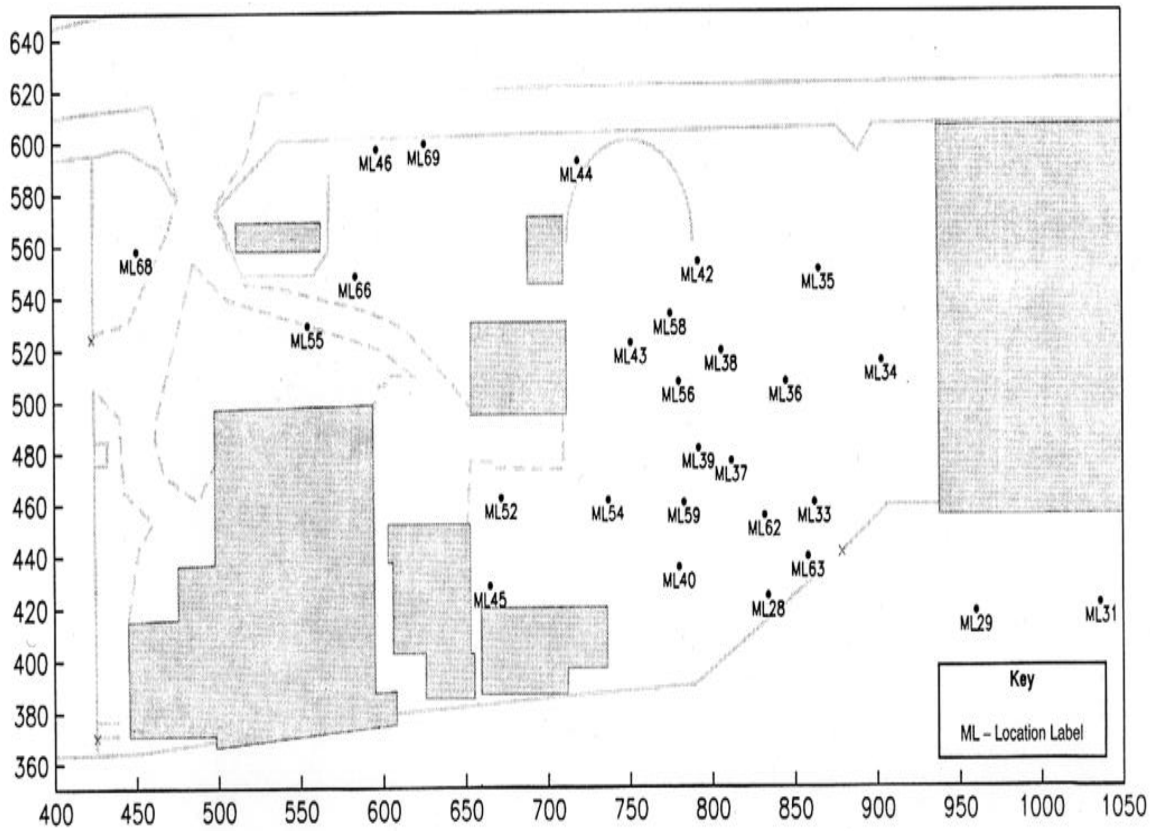

Figure 4: Soil Conductivity Probe Push Locations [1]

Investigation Results [1, 4]

In the Spring of 1994, Geoprobe obtained 27 logs at the Marshalltown FMGP site, using the Geoprobe® 4200 to push the SC100 conductivity probe into the subsurface. Each push was halted upon a confident identification of the lower cohesive unit (i.e., rapid rise in soil conductivity), in locations where the lower cohesive unit was absent, or upon probe refusal. Push depths ranged from 14 feet bgs to 40 feet bgs. The logs were then used to determine the confining bed of clay where contaminants might be found. These logs were merged into 3D models and used to determine soil sampling depths and locations.

The conductivity logging system produced 700 feet of log in 27 holes over a period of 5 working days. The system was operated by a two-man crew. Operation by a one-man crew is possible, although productivity would be significantly lower. The data required minimal post-processing (deletion of negative or repeat values). Digital conductivity and probing speed data and field printouts were provided at the end of each work day for integration into the existing site model.

Twenty-seven SCP penetrations were combined with data from soil borings, Geoprobe® core samples, and CPT penetrations. Locations of the various penetrations are shown in Figure 4. In most conductivity logs, readings from three to five feet bgs exhibited erratic conductivity values. Explanations offered for this phenomenon included infiltration of extremely saline solutions resulting from salting of roads during winter weather and poor ground-to-probe contact at shallow depths. The UCU interface and the LCU interface were easily identified in most locations of the site. The UCU contact with the granular unit could be inferred by the distinct drop in soil conductivity between 14 and 17 feet bgs. The LCU contact with the granular unit above it was identified by an increase in soil conductivity between 30 and 32 feet bgs. Figure 5 shows cross section A-A` showing SCP conductivity profiles and stratigraphic zones as determined by soil boring logs and CPT data. The conductivities of the units and conductivity changes across the transitions in ML-28 and ML-45 are shown in Table 1 and Table 2.

A secondary and unexpected result was the apparent response of the SCP to DNAPL-saturated soils by decreases in conductivities. At the base of the granular unit above the LCU in ML-45, soil conductivity shows a 20 mS/m drop from about 50 mS/m to about 30 mS/m. When depths are adjusted for small stratigraphic variations between sites, the depth of conductivity decrease corresponds closely to a known zone of DNAPL, as seen in the boring logs for B-8.

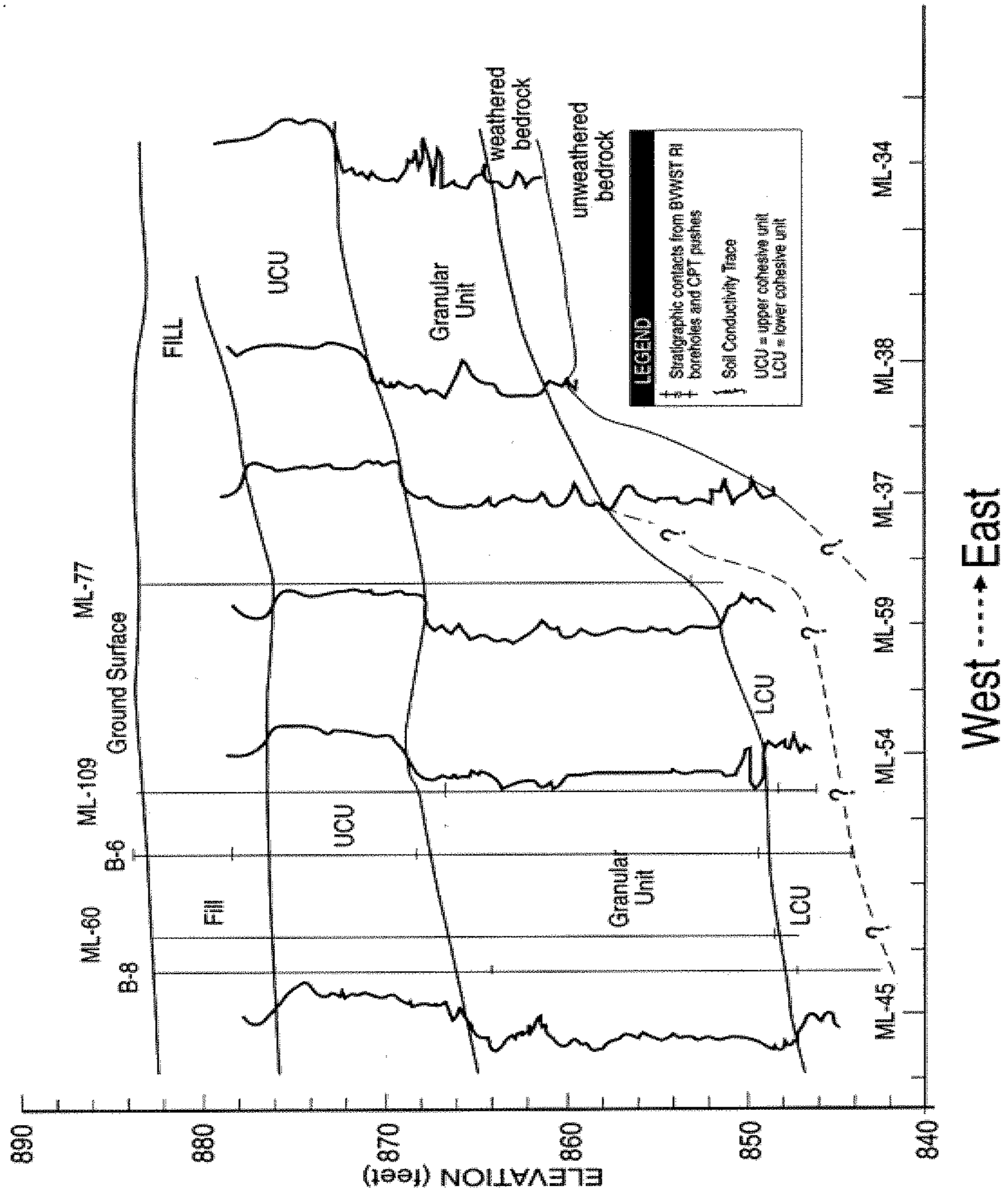

Figure 5: Stratigraphic Cross Section AA` [1]

Results Validation [1, 2]

In addition to comparison with the calibration boring logs and to the discrete soil sample cores, the SCP was also compared to laser-induced fluorescence (LIF) logs that were run in conjunction with the CPT logs. LIF is an innovative method of near-continuous screening for contaminants, in this case PAHs.

The 20 mS/m drop in conductivity at the base of the granular unit above LCU in ML-45 corresponds closely with a high LIF reading indicative of the presence of DNAPLs. There is also a good correlation between high LIF and low conductivities at the contact between the UCU and the top of the granular unit at around 20 feet bgs. The conductivity shows a decrease of about 20 mS/m compared to the more stable value of about 50 mS/m through the relatively uncontaminated section of the granular unit.

Conductivity dips recorded within the granular zone of all profiles at the site were compared with the Geoprobe® soil core logs, with LIF profiles, and with boring logs. The results of this analysis showed that conductivity dips within the granular zone could be attributed to DNAPL contamination 75 percent of the time and to uncontaminated gravel 25 percent of the time.

The SCP filled in absent stratigraphic information between two locations with known stratigraphic profiles. The major stratigraphic unit contacts were very noticeable on the soil conductivity logs and the data was used to generate a database for a three-dimensional site stratigraphic model. When sections from this model were compared to the nearby soil boring logs, a correlation of stratigraphic units within one to two feet was revealed. This was attributed to the difference in stratigraphy over the relative distance between the SCP locations and the soil boring locations, and to the use of different sampling technologies. The investigators believed that the SCP depths were more reliable for sampling because it involved same technology, i.e. Geoprobe direct push depth indicators. Another demonstration at this site used a more invasive Geoprobe® unit to collect large bore soil samples at the identified locations and also confirmed the information in the SCP conductivity logs.

The CPT and conductivity soil profiles show significantly more detail than the boring logs and reveal that the CPT and conductivity soil profiles were in close agreement with the boring logs (Table 1 and Table 2). Depths to stratigraphic contacts between ML-28 CPT and ML-28 SCP are similar, but differ from the soil boring log MW-3A by about two feet (possibly due to differences in stratigraphy as a result of distance between locations). The ML-45 SCP corresponds well with the CPT and soil boring log. Overall, the side-by-side comparisons of the SCPs and the soil boring logs indicated stratigraphic correspondence of the unit contacts to within about one to two feet.

Table 1: Comparison of Soil Stratigraphy Results for ML-28 SCP and CPT, and MW-3A

Stratigraphy	Conductivity mS/m	ML-28 SCP Depth (Feet bgs)	ML-28 CPT Depth (Feet bgs)	MW-3A Log Depth (Feet bgs)
UCU	130-190			
Transition depth for UCU	140->70	16-17	17	17
Granular Unit	20-80			
Transition depth for Granular Unit	50->90	30	29-30	32

Source: [1]

Table 2: Comparison of Soil Stratigraphy Results for ML-45, ML-60, and B-8

Stratigraphy	Conductivity mS/m	ML-45 SCP Depth (Feet bgs)	ML-60 CPT Depth (Feet bgs)	B-8 Log Depth (Feet bgs)
UCU	90-140			
Transition depth for UCU	90->30	17-18	nd	19
Granular Unit	20-80			
Transition depth for Granular Unit	25->85	35-36	34	36
LCU	70-90			

nd=no data
Source: [1]

LESSONS LEARNED

Lessons learned for the Marshalltown site include the following:

- Geophysical survey techniques are an important part of the expedited site characterization process, however not all techniques are appropriate for all sites. Marshalltown had complex stratigraphic conditions that led to significant error and uncertainty in the some of the geophysical survey results. Therefore, potential limitations of each geophysical method must be carefully considered on a site specific basis.

- The stratigraphic correlations between the push technologies (SCP and CPT) and the borehole log data demonstrated that the contacts between soil units can generally be interpreted from the CPT and soil conductivity logs with confidence. Correlations were generally within one to two feet, but this variance was attributed to the distance between SCP locations and the soil boring locations.

- The SCP was more maneuverable and more versatile than the CPT and could penetrate most soil subsurface materials. The probe was also operationally much more efficient than the CPT and could be operated by a single person if necessary. SCP provides reliable high-resolution demarcation between high conductivity clays and silts and low conductivity sands and gravels. With proper calibration from soil borings, the SCP can provide reliable infill information between boring logs and can be used to enhance the site conceptual model. The probe provides more detailed stratigraphic information than conventional auger borings.

- The SCP appears to respond to DNAPL-saturated soil by exhibiting a distinct conductivity dip. Since other factors, most notably sand or gravel lenses, can cause conductivity dips, the SCP cannot by itself detect DNAPLs. However, dips in conductivity in generally low conductivity (sandy permeable) layers immediately above high-conductivity (clayey low-permeability) zones would certainly be a target to investigate pooling of DNAPLs. This would be especially true if the stratigraphic transition occurred at lower elevations compared to surrounding logs. Close inspection of SCP results can provide a good screening tool for the location of accumulated DNAPLs.

- Twenty-seven SCP penetrations were combined with data from soil borings, Geoprobe® core samples, and CPT penetrations. Locations of the various penetrations are shown in Figure 4. The SCP provided high vertical resolution data from which transitions between high conductivity clay and low conductivity sands could be readily identified. Comparison with soil borings and CPT logs showed that the main stratigraphic units were readily distinguishable and that the transition depths agreed among the three methods.

- The SCP was not able to clearly identify weathered bedrock. The probes would break when unexpected bedrock or large gravel/cobbles were encountered. This could be remedied by using more indestructible equipment at developed sites where heterogeneous fill layers would be expected or are already known to exist.

REFERENCES

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6. Personal Communications with Albert Bevolo, Ames Laboratory. August 24, 1998.

7. Fax Communication with Geoprobe Systems. September 15, 1998.