APPENDIX C – Downhole Geophysical Test Logging Report

No Change for Rev. 4

DOCUMENTATION OF TECHNICAL REVIEW
SUBCONTRACTOR WORK PRODUCT

Project Name: Clinch River SMR Project

Project Number: 6468-13-1072

Project Manager: Steve Criscenzo

Project Technical Leads: Al Tice, Carl Tockstein

The report described below has been prepared by the named subcontractor retained in accordance with the AMEC QAPD. The report has been reviewed by an AMEC technically qualified person. Comments from the technical review have been appropriately incorporated by the subcontractor. The report is accepted for use on the Clinch River SMR Project.

MATERIAL : Clinch River SMR Project, Borehole Geophysics, GeoVision report 13161-01, Rev. 0 dated January 11, 2014

SUBCONTRACTOR: GEOVision Geophysical Services

DATE OF REVIEW AND ACCEPTANCE : January 13, 2014

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CLINCH RIVER SMR PROJECT
BOREHOLE GEOPHYSICS

GEOVision Report 13161-01 rev 0

January 11, 2014

CLINCH RIVER SMR PROJECT
BOREHOLE GEOPHYSICS

GEOVision Report 13161-01 rev 0

January 11, 2014

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Report 13161-01 REVISION HISTORY

DATE	REVISION NUMBER	REASON FOR CHANGE
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CERTIFICATIONS

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INTRODUCTION

Borehole geophysical measurements were collected in thirty (30) borings at the Tennessee Valley Authority's Clinch River SMR (Small Modular Reactor) Project Site located near Oak Ridge, Tennessee. Geophysical data acquisition was performed between June 20th, 2013 and October 9th, 2013 by Charles Carter and Victor Gonzalez of **GEO***Vision*. Data analysis was performed by Charles Carter, Emily Feldman and Victor Gonzalez and reviewed by Robert Steller and John Diehl of **GEO***Vision*. Report preparation was performed by Emily Feldman and reviewed by Robert Steller and John Diehl of **GEO***Vision* under AMEC Work Instruction WI-076, received on 11/26/2013. The work was performed under subcontract with AMEC Environment & Infrastructure, Inc. (AMEC) for their client Bechtel, with Steve Criscenzo serving as the Project Manager for AMEC.

This report describes the field measurements, data analysis, and results of this work.

SCOPE OF WORK

This report presents the results of borehole geophysical measurements collected in twenty seven uncased and three cased borings, as detailed in Table 1. The purpose of these studies was to supplement stratigraphic information obtained during AMEC's rock coring program and to acquire shear wave (S) velocities and compressional wave (P) velocities as a function of depth, as a component of the Clinch River SMR Project. This work was performed in accordance with the AMEC Geotechnical Work Plan Rev. 0 and the Bechtel Specification 25665-000-3PS-CY00-0001 Rev. 004. Analysis software and hardware was approved for use on the project by AMEC.

The OYO Suspension PS Logging System (Suspension System) was used to obtain in-situ measurements of vertically propagating horizontally polarized shear (S_H) and compressional (P) wave velocities at 1.64 foot intervals. The acquired data was analyzed and profiles of velocity versus depth were produced for both compressional and horizontally polarized shear waves.

A detailed reference for the suspension PS velocity measurement techniques used in this study is:

> Guidelines for Determining Design Basis Ground Motions, Report TR-102293, Electric Power Research Institute, Palo Alto, California, November 1993, Sections 7 and 8.

A Robertson Geologging Dual Induction probe (DUIN) was used to collect long and short conductivity and natural gamma data at 0.05 foot intervals.

A Robertson 3ACS mechanical caliper probe (CAL) was used to collect boring diameter and natural gamma data at 0.05 foot intervals to aid in identification of stratigraphic transitions.

The Robertson Geologging Fluid Temperature Conductivity (FTC / TCDS) probe was used to collect fluid temperature, fluid conductivity and natural gamma data at 0.05 foot intervals in designated boreholes.

The acquired data was combined and a profile of the preceding parameters versus depth was produced.

A Robertson High Resolution Acoustic Televiewer (HIRAT) was used to collect borehole deviation data on at least 0.04 foot intervals and acoustic televiewer images of the rock at 0.004 foot intervals. The acquired data was analyzed and a profile of borehole deviation versus depth was produced for each boring in both downward and upward logging directions. The boring images were analyzed and features such as bedding planes and fractures were identified with calculated feature dip and azimuth.

INSTRUMENTATION

Suspension Velocity Instrumentation

Suspension velocity measurements were performed using the Suspension PS logging system (S/N 160024), manufactured by OYO Corporation, and their subsidiary, Robertson Geologging. This system directly determines the average velocity of a 3.3-foot high segment of the soil/rock column surrounding the boring of interest by measuring the elapsed time between arrivals of a wave propagating upward through the soil/rock column. The receivers that detect the wave, and the source that generates the wave, are moved as a unit in the boring producing relatively constant amplitude signals at all depths.

The suspension system probe consists of a combined reversible polarity solenoid horizontal shear-wave source (S_H) and compressional-wave source (P), joined to two biaxial receivers by a flexible isolation cylinder, as shown in Figure 1. The separation of the two receivers is 3.28 feet, allowing average wave velocity in the region between the receivers to be determined by inversion of the wave travel time between the two receivers. The total length of the probe as used in these surveys is 21 feet, with the center point of the receiver pair 12.5 feet above the bottom end of the probe.

The probe receives control signals from, and sends the digitized receiver signals to, instrumentation on the surface via an armored multi-conductor cable. The cable is wound onto the drum of a winch and is used to support the probe. Cable travel is measured to provide probe depth data, using a sheave of known circumference fitted with a digital rotary encoder.

The entire probe is suspended in the boring by the cable, therefore, source motion is not coupled directly to the boring walls; rather, the source motion creates a horizontally propagating impulsive pressure wave in the fluid filling the boring and surrounding the source. This pressure wave is converted to P and S_H-waves in the surrounding soil/rock. These waves propagate through the soil/rock surrounding the boring, in turn causing a pressure wave to be generated in

the fluid surrounding the receivers as the soil/rock waves pass their locations. Direct arrival of the original pressure pulse in the fluid is not detected at the receivers because the wavelength of the pressure pulse in fluid is significantly greater than the dimension of the fluid annulus surrounding the probe (foot versus inch scale), preventing significant energy transmission through the fluid medium. Separation of the P and S_H-waves observed at the receivers occurs due to the following factors:

1. Orientation of the horizontal receivers is maintained parallel to the axis of the source, maximizing the amplitude of the recorded S_H-wave signals relative to the P-wave signals.
2. At each depth, S_H-wave signals are recorded with the source actuated in opposite directions, producing S_H-wave signals of opposite polarity, providing a characteristic S_H-wave signature distinct from the P-wave signal.
3. The 6.3 foot separation of source and receiver 1 permits the P-wave signal to pass and damp significantly before the slower S_H-wave signal arrives at the receiver. In faster soils or rock, the isolation cylinder may be extended to allow greater separation of the P- and S_H-wave signals.
4. In saturated soils, the received P-wave signal is typically of much higher frequency than the received S_H-wave signal, permitting additional separation of the two signals by low pass filtering.
5. Direct arrival of the original pressure pulse in the fluid is not detected at the receivers because the wavelength of the pressure pulse in fluid is significantly greater than the dimension of the fluid annulus surrounding the probe (feet versus inches scale), preventing significant energy transmission through the fluid medium.

In operation, a distinct, repeatable pattern of impulses is generated at each depth as follows:

1. The source is fired in one direction producing dominantly horizontal shear energy with some vertical compression energy, and the signals from the horizontal receivers situated parallel to the axis of motion of the source are recorded.
2. The source is fired again in the opposite direction and the horizontal receiver signals are recorded.
3. The source is fired again and the vertical receiver signals are recorded. The repeated source pattern facilitates the picking of the P and S_H-wave arrivals as reversal of the source changes the polarity of the S_H-wave pattern but not the P-wave pattern.

The data from each receiver during each source activation is recorded as a different channel on the recording system. The Suspension PS system has six channels (two simultaneous recording channels), each with a 1024 sample record length. The recorded data are displayed as six channels with a common time scale. Data are stored on disk for further processing. Up to 8 sampling sequences can be summed to improve the signal to noise ratio of the signals.

Review of the displayed data on the recorder or computer screen allows the operator to set the gains, delay time, pulse length (energy), sample rate, and summing number to optimize the quality of the data before recording. Verification of the calibration of the Suspension PS digital recorder is performed every twelve months, or more frequently, using a NIST traceable frequency source and counter, using **GEO***Vision* Suspension PS Seismic Logger/Recorder Calibration Procedure revision 2.1. This procedure was supplied and approved in advance of the work and incorporated into the AMEC Geotechnical Work Plan Rev. 0, and is reproduced with pre- and post-project calibration records in the separate Support Document package 13161-03 delivered to AMEC.

Induction / Natural Gamma Instrumentation

Formation conductivity and natural gamma data were collected using a DUIN model dual induction probe, S/N 6691, manufactured by Robertson Geologging, Ltd. The probe is 7.5 feet long, and 1.5 inches in diameter.

This probe is useful in the following studies:

- Bed boundary identification
- Strata correlation between borings
- Strata geometry and type (shale indication)

The probe receives control signals from, and sends the digitized measurement values to, a Robertson Micrologger II on the surface via an armored 4 conductor cable. The cable is wound onto the drum of a winch and is used to support the probe. Cable travel is measured to provide probe depth data, using a sheave of known circumference fitted with a digital rotary encoder. The probe and depth data are transmitted by USB link from the Micrologger unit to a laptop computer where it is displayed and stored on hard disk.

An Electro-Magnetic (EM) induction probe consists of transmitter and receiver coils. An alternating current is applied to the transmitter coil, causing the coil to radiate a primary EM field. This primary EM field generates eddy currents in subsurface materials, which give rise to a secondary EM field. The secondary EM field is measured as an alternating current in the receiver coils, which is proportional to formation conductivity. The probe coil spacing is optimized to achieve high vertical resolution, minimal borehole influence and large radius of investigation. The Robertson focused dual induction probe has effective coil spacings of 1.6 and 2.6 feet, operates at a frequency of 39 kHz, has 1 millisiemens/meter resolution, and operates over a 5 to 3000 millisiemens/meter conductivity range.

Natural gamma measurements rely upon small quantities of radioactive material contained in soil and rocks to emit gamma radiation as they decay. Trace amounts of uranium and thorium are present in a few minerals, where potassium-bearing minerals such as feldspar, mica and clays will include traces of a radioactive isotope of potassium. These emit gamma radiation as they decay with an extremely long half-life. This radiation is detected by scintillation - the production of a tiny flash of light when gamma rays strike a crystal of sodium iodide. The light is converted into an electrical pulse by a photomultiplier tube. Pulses above a threshold value of 60 KeV are counted by the probe's microprocessor. The measurement is useful because the radioactive elements are concentrated in certain soil and rock types e.g. clay or shale, and depleted in others e.g. sandstone or coal.

Caliper / Natural Gamma Instrumentation

Caliper and natural gamma data were collected using a Model 3ACS 3-leg caliper probe, serial number 5368, manufactured by Robertson Geologging, Ltd. With the short arm configuration used in these surveys, the probe permitted measurement of boring diameters between 1.6 and 12 inches. With this tool, caliper measurements were collected concurrent with measurement of natural gamma emission from the boring walls. The probe is 6.82 feet long, and 1.5 inches in diameter.

This probe is useful in the following studies:

- Measurement of boring diameter and volume
- Location of hard and soft formations
- Location of fissures, caving, pinching and casing damage
- Bed boundary identification
- Strata correlation between borings

The probe receives control signals from, and sends the digitized measurement values to, a Robertson Micrologger II on the surface via an armored 4 conductor cable. The cable is wound onto the drum of a winch and is used to support the probe. Cable travel is measured to provide probe depth data, using a 1.31 foot circumference sheave fitted with a digital rotary encoder. The probe and depth data are transmitted by USB link from the Micrologger unit to a laptop computer where it is displayed and stored on hard disk.

The caliper consists of three arms, each with a toothed quadrant at their base, pivoted in the lower probe body. A toothed rack engages with each quadrant, thus constraining the arms to move together. Linear movement of the rack is coupled to opening and closing of the arms. Springs hold the arms open in the operating position. A motor drive is provided to retract the arms, allowing the probe to be lowered into the boring. The rack is coupled to a potentiometer which converts movement into a voltage sensed by the probe's microprocessor.

Natural gamma measurements rely upon small quantities of radioactive material contained in soil and rocks to emit gamma radiation as they decay. Trace amounts of uranium and thorium are present in a few minerals, where potassium-bearing minerals such as feldspar, mica and clays will include traces of a radioactive isotope of potassium. These emit gamma radiation as they decay with an extremely long half-life. This radiation is detected by scintillation - the production of a tiny flash of light when gamma rays strike a crystal of sodium iodide. The light is converted into an electrical pulse by a photomultiplier tube. Pulses above a threshold value of 60 KeV are counted by the probe's microprocessor. The measurement is useful because the radioactive elements are concentrated in certain rock types e.g. clay or shale, and depleted in others e.g. sandstone or coal.

Fluid Temperature / Fluid Conductivity / Natural Gamma Instrumentation

Fluid temperature, fluid conductivity (FTC) and natural gamma data were collected using a Model TCGS temperature / conductivity / gamma probe, serial number 2823, manufactured by Robertson Geologging, Ltd. With this tool, fluid temperature and conductivity measurements were collected concurrent with measurement of natural gamma emission from the boring walls. The probe is 5.35 feet long and 1.5 inches in diameter.

This probe is useful in the following studies:

- Bed boundary identification
- Strata correlation between borings
- Strata geometry and type (shale indication)
- Salt water intrusion
- Ground water flow between aquifers

The probe receives control signals from, and sends the digitized measurement values to, a Robertson Micrologger II on the surface via an armored 4 conductor cable. The cable is wound onto the drum of a winch and is used to support the probe. Cable travel is measured to provide probe depth data, using a sheave of known circumference fitted with a digital rotary encoder. The probe and depth data are transmitted by USB link from the Micrologger unit to a laptop computer where it is displayed and stored on hard disk.

The temperature probe and conductivity electrodes are located in an insulated cavity at the bottom of probe body, with a fluid inlet opening at the tip and exit openings on the side of the probe approximately 100 millimeters above the tip. This tool is designed to collect data as it is lowered into the boring, so that the boring fluid moves through the cavity and passes over the sensors with a minimum of mixing or disturbance of the fluid by the passage of the probe. For the same reason, this is generally the first probe deployed in a suite of boring geophysical measurements.

Pre- and post-project calibrations of the temperature and conductivity functions of the probe were performed by others as procured by AMEC, and these records are presented in the separate Support Document package 13161-03 delivered to AMEC.

Natural gamma measurements rely upon small quantities of radioactive material contained in soil and rocks to emit gamma radiation as they decay. Trace amounts of Uranium and Thorium are present in a few minerals, where potassium-bearing minerals such as feldspar, mica and clays will include traces of a radioactive isotope of Potassium. These emit gamma radiation as they decay with an extremely long half-life. This radiation is detected by scintillation - the production of a tiny flash of light when gamma rays strike a crystal of sodium iodide. The light is converted into an electrical pulse by a photomultiplier tube. Pulses above a threshold value of 60 thousand electron Volts (KeV) are counted by the probe's microprocessor. The measurement is useful because the radioactive elements are concentrated in certain soil and rock types e.g. clay or shale, and depleted in others e.g. sandstone, limestone or coal.

Acoustic Televiewer / Boring Deviation Instrumentation

Boring deviation data and acoustic images of the walls of the borings were collected using a HiRAT model High Resolution Acoustic Televiewer probe (HIRAT), serial number 6641, manufactured by Robertson Geologging, Ltd. The probe is 5.32 feet long and 1.65 inches in diameter. A concept illustration of the HIRAT probe is shown in Figure 4.

In this application, this probe is useful in the following studies:

- Measurement of boring inclination and deviation from vertical
- Determination of need to correct soil and geophysical log depths to true vertical depths
- Acoustic imaging of the boring wall to identify fractures, dikes, and weathered zones, and determine dip and azimuth of these features

The probe receives control signals from, and sends the digitized measurement values to, a Robertson Micrologger II on the surface via an armored 4 conductor cable. The cable is wound onto the drum of a winch and is used to support the probe. Cable travel is measured to provide probe depth data, using a sheave of known circumference fitted with a digital rotary encoder. The probe and depth data are transmitted by USB link from the Micrologger unit to a laptop computer where it is displayed and stored on hard disk.

This system produces images of the boring wall based upon the amplitude and travel time of an ultrasonic beam reflected from the formation wall. The ultrasonic energy is generated by a piezoelectric transducer at a frequency of 1.4 MHz. A periodic acoustic energy wave is emitted by the transducer and travels through the acoustic head and boring fluid until it reaches the interface between the boring fluid and the boring wall. Here a portion of the energy is reflected back to the transducer, the remainder continuing into the formation. By careful time sequencing, the piezoelectric transducer acts as both the transmitter of the ultrasonic pulse and receiver of the reflected wave. The travel time of the energy wave is the period between transmission of the source energy pulse and the return of the reflected wave measured at the point of maximum wave amplitude. The magnitude of the energy wave is measured in dB, a unitless ratio of the detected echo wave amplitude divided by the amplitude of the transmitted wave. The strength of

the reflected signal depends primarily upon the impedance contrast of the boring fluid and the boring wall formation.

The acoustic wave propagates along the axis of the probe and then is reflected perpendicular to this axis by a reflector that focuses the beam to a 0.08 inch diameter spot about 2 inches from the central axis of the probe. This reflector is mounted on the shaft of a stepper motor enabling the position of the measurement to be rotated through 360°. Sampling rates of 90, 180 and 360 measured points per revolution are available. During these surveys, data were collected at 360 samples per revolution. It should be noted that during logging the probe is moving in the boring, so that the measured points describe a very fine pitch spiral.

The probe contains a fluxgate magnetometer to monitor magnetic north, and all raw televiewer data are referenced to magnetic north. The processed data are referenced to true north, using a declination of 5.17 to 5.19 degrees west for this site location and logging dates, obtained from the NOAA declination web site (http://www.ngdc.noaa.gov/geomag-web/#declination). Also, a three-axis accelerometer is enclosed in the probe, and boring deviation data are recorded during the logging runs, to permit correction of structure dip angle from apparent dip, referenced to boring axis, to true dip (referenced to a vertical axis) in non-vertical borings.

The data are presented on a computer screen for operator review during the logging run, and stored on hard disk for later processing.

MEASUREMENT PROCEDURES

Suspension Velocity Measurement Procedures

Measurements followed **GEO***Vision* Procedure for P-S Suspension Seismic Velocity Logging, revision 1.5. This procedure was supplied and approved in advance of the work, incorporated into the AMEC Geotechnical Work Plan Rev. 0 and the Bechtel Specification 25665-000-3PS-CY00-0001 Rev. 004 and is reproduced in the separate Support Document package 13161-03 delivered to AMEC. All borings were filled with water during logging. Prior to each logging run, the probe was positioned with the top of the probe at the top of the surface casing, and the electronic depth counter was set to the distance between the mid-point of the receiver and the top of the probe, minus the height of any casing stick-up, as verified with a tape measure, and recorded on the field logs. The probe was lowered to the bottom of the boring, stopping at 1.64 foot (0.5 m) intervals to collect data, as summarized in Table 2.

At each measurement depth the measurement sequence of two opposite horizontal records and one vertical record was performed, and the gains were adjusted as required. The data from each depth were viewed on the computer display, checked to verify acceptable signal levels, and recorded on disk before moving to the next depth.

Upon completion of the measurements, the probe zero depth indication at the depth reference point was verified prior to removal from the boring, and the after survey depth error (ASDE) was calculated and recorded on the field logs, as summarized in Table 3. Field data were backed up to USB drive upon completion of data acquisition.

Induction / Natural Gamma Measurement Procedures

Measurement procedures, incorporated into Bechtel Specification 25665-000-3PS-CY00-0001 Rev. 004, followed these ASTM standards:

- ASTM D5753-05 (Re-approved 2010), "Planning and Conducting Boring Geophysical Logging"
- ASTM D6274-10, "Conducting Boring Geophysical Logging – Gamma"
- ASTM D6726-01 (Re-approved 2007), "Conducting Boring Geophysical Logging – Electromagnetic Induction"

All borings were filled with water during logging. Prior to the logging run, the measurement depths were referenced to ground level. This was done by placing the top of the probe at grade, and the electronic depth counter was set to the probe length. These calculations are recorded on the field logs. Offset distances between probe tip and measurement points are corrected for in the data acquisition software. The probe was lowered to the bottom of the boring where data acquisition was begun, and the probe was returned to the surface at approximately 10 feet/minute, collecting data continuously at 0.05-foot spacing, as summarized in Table 2.

This probe was not calibrated in the field, as it is used to provide qualitative measurements, not quantitative values, and is used only to assist in picking transitions between stratigraphic units, as described in ASTM D5753-05 (Reapproved 2010), "Planning and Conducting Borehole Geophysical Logging". A functional test was performed prior to the logging run by placing a coil with an effective conductivity value over the probe, and recording the resultant output of the system. The results are recorded on the field logs, as reproduced in the separate Support Document package 13161-03 delivered to AMEC. These functional checks are also presented in LAS 2.0 format in the boring specific sub-directories on the data disks labeled Report 13161-02 that accompany this report.

Natural gamma was not calibrated in the field, as it is a qualitative measurement, not a quantitative value, and is used only to assist in picking transitions between stratigraphic units, as described in ASTM D6274-10, "Conducting Borehole Geophysical Logging – Gamma".

Upon completion of the measurements, the probe zero depth indication at the depth reference point was verified prior to removal from the boring.

Caliper / Natural Gamma Measurement Procedures

Measurement procedures followed these ASTM standards:

- ASTM D5753-05 (Reapproved 2010), "Planning and Conducting Borehole Geophysical Logging"
- ASTM D6167-11, "Conducting Borehole Geophysical Logging – Mechanical - Caliper"
- ASTM D6274-10, "Conducting Borehole Geophysical Logging – Gamma"

All borings were filled with water or drilling mud during logging. This probe was not calibrated in the field, as it is used to provide qualitative measurements, not quantitative values, and is used only to assist in picking transitions between stratigraphic units, as described in ASTM D5753-05

Prior to and following the logging run(s) in each borehole, the caliper tool was verified using AMEC-approved PVC ring ID GV-101 and **GEO***Vision* verification plate S/N 203. Plate S/N 203 is a circular aluminum plate with a series of four machined annular slots in the top surface into which the tips of the caliper arms fit. The slots have outside diameters from 2.1 to 8.0 inches. The verification plate is placed on the probe with its nose section passing through the plates' central hole. The caliper probe arms are opened under program control, and a log is recorded as the tips of the arms are placed in the slots on the plate. The measured dimensions, as displayed on the recording computer screen, were recorded on the field log sheet, as well as in the digital files, and compared with the verification jig dimensions. These functional checks are presented in LAS 2.0 format in the sub-directories of the data directories and disks labeled Report 13161-02 that accompany this report.

If the verification records did not fall within +/- 0.05 inches of the verification jig values, the caliper tool was re-adjusted using the four point verification jig and the verification log repeated. As with the verification, the tips of the caliper arms are placed in the holes marked with the required diameter. During re-adjustment, the value of the current point, as stamped on the jig, is entered via the control computer. The system counts for 15 seconds to make an average of the response. The procedure is repeated for the remaining openings.

The computation and generation of the adjustment file is entirely automatic. The adjustment file is simply the set of coefficients of a quadratic curve which fits the three data points.

Natural gamma was not calibrated in the field, as it is a qualitative measurement, not a quantitative value, and is used only to assist in picking transitions between stratigraphic units, as described in ASTM D6274-10, "Conducting Borehole Geophysical Logging – Gamma".

Prior to each logging run, the sensor positions were referenced to ground level. This was done by placing the top of the probe at grade, and the electronic depth counter was set to the probe length. These calculations are recorded on the field logs. Offset distances between probe tip and Induction and natural gamma sensors are corrected for in the data acquisition software. The probe was lowered to the bottom of the boring, where data collection was begun. The probe was then returned to the surface at approximately 10 feet/minute, collecting data continuously at 0.050 foot spacing, as summarized in Table 2.

Upon completion of the measurements, the probe zero depth indication at the depth reference point was verified prior to removal from the boring, and the after survey depth error (ASDE) was calculated, as summarized in Table 3. Field data were backed up to USB drive each day upon completion of data acquisition.

Fluid Temperature / Fluid Conductivity / Natural Gamma Measurement Procedures

Measurements of temperature and conductivity were made in accordance with AMEC Project Procedure CRP-4 Temperature/Conductivity Logging in Boreholes, Rev 2. Field validation of the temperature conductivity probe during the work was done using **GEO***Vision* Fluid Temperature Conductivity Probe Test and Validation Procedure Revision 0, supplied to and approved by AMEC prior to the field work. Those procedures are reproduced in the separate Support Document package 13161-03 delivered to AMEC. In addition, measurement procedures followed these ASTM standards:

- ASTM D5753-05 (Reapproved 2010), "Planning and Conducting Borehole Geophysical Surveys"
- ASTM D6274-10, "Conducting Borehole Geophysical Logging – Gamma"

Natural gamma was not calibrated in the field, as it is a qualitative measurement, not a quantitative value, and is used only to assist in picking transitions between stratigraphic units, as described in ASTM D6274-10, "Conducting Borehole Geophysical Logging – Gamma".

In each boring, the probe was positioned with the top of the probe at the top of the surface casing, and the electronic depth counter was set to the specified length of the probe, minus the stick-up of the casing, as verified with a tape measure, and recorded on the field logs. The probe was lowered to the bottom of the boring at approximately 10 feet/minute, collecting data continuously at 0.050 foot spacing, as summarized in Table 2.

Upon completion of the measurements, the probe zero depth indication at the depth reference point was verified prior to removal from the boring, and the after survey depth error (ASDE) was calculated, as summarized in Table 3. Field data were backed up to USB drive each day upon completion of data acquisition.

Acoustic Televiewer / Boring Deviation Measurement Procedures

All borings were filled with water during logging. Measurement procedures followed **GEO***Vision* HI-RAT procedure revision 2.0, approved prior to work and incorporated into the AMEC Geotechnical Work Plan Rev. 0 and the Bechtel Specification 25665-000-3PS-CY00-0001 Rev. 004, and are reproduced in the separate Support Document package 13161-03 delivered to AMEC. In addition, the measurement procedures conform to the following ASTM standard:

- ASTM D5753-05 (Re-approved 2010), "Planning and Conducting Borehole Geophysical Logging"

Prior to use, the probe tiltmeter and compass functions were checked by comparison with a Brunton surveyors' compass, and the results recorded on the field logs, as reproduced in the separate Support Document package 13161-03 delivered to AMEC.

Prior to the logging run, the imaging window was referenced to ground level. This was done by placing the top of the probe at grade, and the electronic depth counter was set to the probe length. These calculations are recorded on the field logs. Offset distances between probe tip and imaging window are corrected for in the data acquisition software. The probe was lowered to the bottom of the boring at approximately 10 feet/minute while acquiring a downward deviation data set. The probe was then returned to the surface at approximately 2.5 feet/minute, with an acquisition rate of 250 samples/foot. This provides a vertical resolution of 0.004 feet or nominal pixel height of 0.05 inches.

Upon completion of the measurements, the probe zero depth indication at the depth reference point was verified prior to removal from the boring, and the after survey depth error (ASDE) was calculated, as summarized in Table 3. The log was reviewed in the field, and all data were backed up to USB drive each day upon completion of data acquisition.

DATA ANALYSIS

Suspension Velocity Analysis

Using the proprietary OYO program PSLOG.EXE version 1.0, included in the data disks (DVD-R) labeled Report 13161-02 that accompany this report, the recorded digital waveforms were analyzed to locate the most prominent first minima, first maxima, or first break on the vertical axis records, indicating the arrival of P-wave energy.

The difference in travel time between receiver 1 and receiver 2 (R1-R2) arrivals was used to calculate the P-wave velocity for that 3.28 feet segment of the soil/rock column. When observable, P-wave arrivals on the horizontal axis records were used to verify the velocities determined from the vertical axis data. The time picks were transferred into a Microsoft Excel® template (version 2003 SP2) to complete the velocity calculations based upon the arrival time picks made in PSLOG and actual R1-R2 separation. The PSLOG pick files and the Microsoft Excel® analysis files are included in the boring specific sub-directories on the data disks labeled Report 13161-02 that accompany this report.

The P-wave velocity over the 6.3 foot interval from source to receiver 1 (S-R1) was also picked using PSLOG, and calculated and plotted in Microsoft Excel®, for verification of the velocity derived from the travel time between receivers. In this analysis, the depth values as recorded were increased by 4.79 feet to correspond to the mid-point of the 6.3 foot S-R1 interval. Travel times were obtained by picking the first break of the P-wave signal at receiver 1 and subtracting the calculated and experimentally verified delay from source trigger pulse (beginning of record) to source impact. This delay corresponds to the duration of acceleration of the solenoid before impact.

As with the P-wave records, the recorded digital waveforms were analyzed to locate clear S_H-wave pulses, as indicated by the presence of opposite polarity pulses on each pair of horizontal records. Ideally, the S_H-wave signals from the 'normal' and 'reverse' source pulses are very

nearly inverted images of each other. During processing, zero phase-shift digital Fast Fourier Transform – Inverse Fast Fourier Transform (FFT – IFFT) lowpass filtering was occasionally used to remove the higher frequency P-wave signal from the S_H-wave signal in the soil sections of some borings. Different filter cutoffs were used to separate P- and S_H-waves at different depths, ranging from 600 Hz in the slowest zones to 4000 Hz in the regions of higher velocity. At each depth, the filter frequency was selected to be at least twice the fundamental frequency of the S_H-wave signal being filtered. No filtering was necessary in the hard rock sections of the borings. No filtering other than anti-aliasing filters was applied during data acquisition.

Generally, the first maxima were picked for the 'normal' signals and the first minima for the 'reverse' signals, although other points on the waveform were used if the first pulse was distorted. The absolute arrival time of the 'normal' and 'reverse' signals may vary by +/- 0.2 milliseconds, due to differences in the actuation time of the solenoid source caused by constant mechanical bias in the source or by boring inclination. This variation does not affect the R1-R2 velocity determinations, as the differential time is measured between arrivals of waves created by the same source actuation. The final velocity value is the average of the values obtained from the 'normal' and 'reverse' source actuations.

As with the P-wave data, S_H-wave velocity calculated from the travel time over the 6.3 foot interval from source to receiver 1 was calculated and plotted for verification of the velocity derived from the travel time between receivers. In this analysis, the depth values were increased by 4.79 feet to correspond to the mid-point of the 6.3 foot S-R1 interval. Travel times were obtained by picking the first break of the S_H-wave signal at R1 and subtracting the calculated and experimentally verified delay from the beginning of the record at the source trigger pulse to source impact.

Poisson's Ratio, **ν**, is calculated by the Microsoft Excel® template using the following formula:

$$\nu = \frac{\left(\frac{V_s}{V_p}\right)^2 - 0.5}{\left(\frac{V_s}{V_p}\right)^2 - 1.0}$$

Figure 2 shows an example of R1 - R2 measurements on a sample filtered suspension record. In Figure 2, the time difference over the 3.28 foot interval of 1.88 milliseconds for the horizontal signals is equivalent to an S_H-wave velocity of 1745 feet/second. Whenever possible, time differences were determined from several phase points on the S_H-waveform records to verify the data obtained from the first arrival of the S_H-wave pulse. Figure 3 displays the same record before filtering of the S_H-waveform record with a 1400 Hz FFT - IFFT digital lowpass filter, illustrating the presence of higher frequency P-wave energy at the beginning of the record, and distortion of the lower frequency S_H-wave by residual P-wave signal.

Induction / Natural Gamma Analysis

No analysis is required with the induction and natural gamma data; however depths to identifiable boring log features, such as distinct natural gamma transitions, were compared to verify consistent depth readings on all logs. Using WellCAD™ software version 4.3, these data were combined with the caliper and FTC logs, and converted to LAS 2.0 and PDF formats for transmittal to the client.

Caliper / Natural Gamma Analysis

No analysis is required with the caliper or natural gamma data; however depths to identifiable boring log features, such as distinct natural gamma transitions, were compared to verify consistent depth readings on all logs. Using ALT WellCAD™ software version 4.3, these data were combined with the induction and FTC logs, and converted to LAS 2.0 and PDF formats for transmittal to the client.

Fluid Temperature / Fluid Conductivity / Natural Gamma Analysis

No analysis is required with the fluid temperature, fluid conductivity or natural gamma data; however depths to identifiable boring log features, such as distinct natural gamma transitions, were compared to verify consistent depth readings on all logs. Using ALT WellCAD™ software version 4.3, these data were combined with the Caliper and DUIN logs, and converted to LAS 2.0 and PDF formats for transmittal to the client.

Acoustic Televiewer / Boring Deviation Analysis

The acoustic televiewer data were processed using Robertson Geologging RGLDIP™ software, version 6.2. Sinusoidal projections of planar and semi-planar features in the boring walls were interactively picked on the un-wrapped televiewer image, and are presented on the logs as sinusoids superimposed over the televiewer image, as presented in Appendix B. Green corresponds to bedding features and blue indicates fractures. Bedding features at this site are very numerous, and adjacent features are generally of similar dip and azimuth. Representative bedding features were selected at a frequency of about 1 per foot, as possible, as picking every feature would create an overly complex presentation. The sinusoidal projections were processed to calculate apparent dip angle using the nominal borehole diameter for each boring. True dip was calculated, correcting for the inclination of the borings using the recorded data from the accelerometers located in the probe, and presented in arrow format, with true dip indicated by the arrow position across the plot. Azimuth of dip (not strike), is indicated by the direction of the arrow tail, with true north being "up". These values are presented with the comments to the right of the arrow plots, as dip azimuth followed by dip angle.

The televiewer images were also processed to create a simulated core image of the borings. It must be noted that the simulated core image represents a core that would have the full diameter of the boring, not the diameter of the cores removed during drilling, so that direct comparison between the two is not possible. Also, the unwrapped image is viewed from the perspective of an observer in the center of the boring looking outward. The simulated core image is viewed from the "outside" of the boring looking inward, so there is a reversal of the position of east and west relative to north between the two images.

The televiewer data were also processed to extract the deviation data and produce an ASCII file and three-dimensional plots for both the up and down logs of borehole deviation.

RESULTS

Suspension Velocity Results

Suspension velocity data were collected in twenty seven uncased boreholes at the site; MP-101, MP-102, MP-111, MP-111PS, MP-112, MP-113, MP-120, MP-122PSA, MP-122PSB, MP-201, MP-202, MP-212, MP-213, MP-219A, MP-401, MP-409, MP-412, MP-415, MP-416, MP-417, MP-418A, MP-419, MP-420, MP-421, MP-422, MP-423, MP-425 and MP-426. Suspension R1-R2 P- and S_H-wave velocities for these borings are plotted in Figures 5, 9, 13, 17, 19, 23, 27, 31, 33, 35, 39, 43, 47, 51, 55, 59, 63, 67, 71, 75, 79, 83, 87, 91, 95, 99, 103 and 107, respectively. The suspension velocity data presented in these figures are presented in Tables 5, 7, 9, 11, 12, 14, 16, 18, 19, 20, 22, 24, 26, 28, 30, 32, 34, 36, 38, 40, 42, 44, 46, 48, 50, 52, 54 and 56, respectively. Depths on all figures and tables are referenced to ground surface. Depths for inclined boreholes are along the borehole axis. The PSLOG and Microsoft Excel® analysis files for each boring are included in the boring specific directories on the data disks labeled Report 13161-02 that accompany this report, along with the raw and filtered waveforms.

P- and S_H-wave velocity data from R1-R2 analysis and quality assurance analysis of S-R1 data are plotted together in Appendix A (as Figures A-1 through A-28) to aid in visual comparison. It should be noted that R1-R2 data are an average velocity over a 3.28 feet segment of the soil/rock column; S-R1 data are an average over 6.3 feet, creating a significant smoothing relative to the R1-R2 plots. S-R1 velocity data are also presented in tabular format in Appendix A (in Tables A-1 through A-28), and included in the Microsoft Excel® analysis files in the boring-specific sub-directories on the data disks labeled Report 13161-02 that accompany this report. The Microsoft Excel® analysis files include Poisson's Ratio calculations, tabulated data and plots.

Calibration procedures and records for the suspension PS measurement system, **GEO***Vision* standard field procedures and **GEO***Vision* project-specific field log sheets as approved prior to field work and incorporated into the AMEC Geotechnical Work Plan Rev. 0 are reproduced the separate Support Document package 13161-03 delivered to AMEC.

Induction / Natural Gamma Results

Induction and natural gamma data for borings MP-101, MP-102, MP-111, MP-112, MP-113, MP-120, MP-201, MP-202, MP-212, MP-213, MP-219A, MP-401, MP-409, MP-412, MP-415, MP-416, MP-417, MP-418A, MP-419, MP-420, MP-421, MP-422, MP-423, MP-425, MP-426, MP-428 and MP-429 are presented in single page log plots combined with caliper and caliper based natural gamma data, and Fluid Temperature/Conductivity data when available, in Figures 6, 10, 14, 20, 24, 28, 36, 40, 44, 48, 52, 56, 60, 64, 68, 72, 76, 80, 84, 88, 92, 96, 100, 104, 108, 111 and 114, as well as in scaled (1:10) multi-page log plots in Appendix C. Depths on all figures and tables are referenced to ground surface. Depths for inclined boreholes are along the borehole axis. LAS 2.0 data and Acrobat files of the plots for each boring are included in the boring specific sub-directories on the data disks labeled Report 13161-02 that accompany this report.

Caliper / Natural Gamma Results

Three arm caliper and natural gamma data for borings MP-101, MP-102, MP-111, MP-112, MP-113, MP-120, MP-201, MP-202, MP-212, MP-213, MP-219A, MP-401, MP-409, MP-412, MP-415, MP-416, MP-417, MP-418A, MP-419, MP-420, MP-421, MP-422, MP-423, MP-425, MP-426, MP-428 and MP-429 are presented in single page log plots combined log plots with induction and induction based natural gamma data, and Fluid Temperature/Conductivity data when available, in Figures 6, 10, 14, 20, 24, 28, 36, 40, 44, 48, 52, 56, 60, 64, 68, 72, 76, 80, 84, 88, 92, 96, 100, 104, 108, 111 and 114, as well as in scaled (1:10) multi-page log plots in Appendix C. Mechanical caliper data collected in the six inclined borings at the site, MP-112, MP-113, MP-212, MP-213, MP-425 and MP-426, is not considered reliable as the weight of the probe prevented the opening of the caliper arms against the borehole wall. Depths on all figures and tables are referenced to ground surface. Depths for inclined boreholes are along the borehole axis. LAS 2.0 data and Acrobat files are included on the data disks labeled Report 13161-02 that accompany this report.

Fluid Temperature / Fluid Conductivity/ Natural Gamma Results

Fluid temperature, fluid conductivity and natural gamma data collected in fifteen boreholes – MP-101, MP-202, MP-401, MP-409, MP-415, MP-416, MP-417, MP-418A, MP-419, MP-420, MP-421, MP-422, MP-423, MP-428 and MP-429 – are presented in the single-page combined log plots along with formation conductivity, caliper and induction data in Figures 6, 40, 56, 60, 68, 72, 76, 80, 84, 88, 92, 96, 100, 111 and 114, respectively, as well as in multi-page scaled (1:10) log plots in Appendix C.

LAS 2.0 data and Acrobat files of the plots for each boring are included in the boring specific sub-directories in the data directory on the data disks labeled Report 13161-02 that accompany this report.

Acoustic Televiewer / Boring Deviation Results

Acoustic televiewer data and boring deviation data were collected in all thirty boreholes; however, the logs from the cased boreholes, MP-111PS, MP-122PSA and MP-122PSB, were processed only to extract the deviation data. Acoustic televiewer feature depth, dip and azimuth of dip data are provided on the multi-page acoustic televiewer feature log sheets in Appendix B, and in Tables 6, 8, 10, 13, 15, 17, 21, 23, 25, 27, 29, 31, 33, 35, 37, 39, 41, 43, 45, 47, 49, 51, 53, 55, 57, 58 and 59, as well as in Microsoft Excel® format in the boring specific sub-directories of the data disks labeled Report 13161-02 that accompany this report. Depths on all figures and tables are referenced to ground surface. Depths for inclined boreholes are along the borehole axis.

Rose diagrams are presented in Figures 7, 11, 15, 21, 25, 29, 37, 41, 45, 49, 53, 57, 61, 65, 69, 73, 77, 81, 85, 89, 93, 97, 101, 105, 109, 112 and 115. All are available in .PDF format on the data disks labeled Report 13161-02 that accompany this report.

Upward logged boring deviation data for all thirty boreholes are presented graphically in Figures 8, 12, 16, 18, 22, 26, 30, 32, 34, 38, 42, 46, 50, 54, 58, 62, 66, 70, 74, 78, 82, 86, 90, 94, 98, 102, 106, 110, 113 and 116, and are summarized in Table 4, along with downward logged deviation data for comparison. Deviation data logged at 1.0 foot stations in both directions are presented in text and graphic format on the data disks labeled Report 13161-02 that accompany this report.

SUMMARY

Discussion of Suspension Velocity Results

Suspension PS velocity data are ideally collected in an uncased fluid filled boring, drilled with rotary mud (rotary wash) methods. The borings at this site were generally ideally suited for collection of suspension PS velocity data in the rock. The overburden above rock contact was often disturbed by the placement of surface casing. In some cases, boring wall collapse degraded the quality of the data in the soil portion of the boring and in some instances it was not possible to maintain fluid to the ground surface, so suspension PS data could not be collected to the ground surface.

Suspension PS velocity data quality is judged based upon 5 criteria:

1. Consistent data between receiver to receiver (R1 – R2) and source to receiver (S – R1) data.
2. Consistent relationship between P-wave and S_H -wave (excluding transition to saturated soils)
3. Consistency between data from adjacent depth intervals.
4. Clarity of P-wave and S_H-wave onset, as well as damping of later oscillations.
5. Consistency of profile between adjacent borings, if available.

All of these data show excellent correlation between R1 – R2 and S – R1 data, as well as very good correlation between P-wave and S_H-wave velocities. S_H-wave onsets are clear, and later oscillations are well damped. P-wave arrivals are of very low amplitude as the source frequency is not optimal for this high velocity material. Very small differences in the picked arrival time will result in more scatter than in the S_H-wave data.

Discussion of Induction / Natural Gamma Results

Long and short conductivity profiles provide delineation of the interbeds, showing changes in conductivity that correspond with changes in natural gamma and velocity data. These natural gamma data agree well with the natural gamma data collected with the caliper and FTC probes. The comparison between the data sets provides an almost exact match, verifying the performance of the natural gamma measuring systems.

Discussion of Caliper / Natural Gamma Results

The caliper logs for all borings shows very consistent gauge below the rock surface, with some fractures at shallow depths and a few thin clay layers which are eroded to larger than nominal diameter. Many of these borings had soil or fill overburden above rock surface which was cased during rock coring and geophysical data collection in the rock. Following completion of the work in the rock, the casing was removed to permit data collection in the overburden. This typically produced a significant increase in boring diameter, as well as significant changes in the natural gamma data due to the change in material.

Caliper and natural gamma plots show transitions at the same depths, and correspond well with changes in velocity. The natural gamma data collected with the caliper probe matches the natural gamma data collected with the induction and FTC probes very well, verifying the performance of the natural gamma measuring systems.

Due to compression of the mechanical caliper arms by side loading in the six inclined borings, mechanical caliper data is not reliable for borings MP-112, MP-113, MP-212, MP-213, MP-425 and MP-426.

Discussion of Fluid Temperature / Fluid Conductivity / Natural Gamma Results

Fluid temperature and fluid conductivity data were collected in fifteen of the uncased boreholes, MP-101, MP-202, MP-401, MP-409, MP-415, MP-416, MP-417, MP-418A, MP-419, MP-420, MP-421, MP-422, MP-423, MP-428 and MP-429. Fluid temperature and conductivity changes appear to correspond with fractures identified by the acoustic televiewer in some boreholes, but this relationship is not consistent between boreholes, or even within a given borehole. Natural gamma data were collected with this tool as well, and the comparison with the DUIN and Caliper probes natural gamma data set provides an almost exact match, verifying the performance of the natural gamma measuring systems.

Discussion of Acoustic Televiewer / Boring Deviation Results

Acoustic televiewer data and/or borehole deviation data were collected in all thirty of the boreholes, MP-101, MP-202, MP-401, MP-409, MP-415, MP-416, MP-417, MP-418A, MP-419, MP-420, MP-421, MP-422, MP-423, MP-428 and MP-429. Other than directional borings MP-112, MP-113, MP-212, MP-213, MP-425, MP-426 and MP-427, which were drilled at a nominal inclination of 28 degrees, all borings were inclined at a dip of 3 degrees or less from vertical (with a mean dip of 1.3 degrees), and the greatest error in depth value due to this dip was 0.08 feet in 58 vertical feet (0.14% of depth), as presented in Table 4. This error is less than depth errors from other sources, and, for reference, is substantially less than the 0.4% error from after survey depth error (ASDE) permitted under ASTM D6167-11 "Conducting Borehole Geophysical Logging – Mechanical Caliper" Section 9.15.4. No adjustment of log depths is indicated.

Quality Assurance

These boring geophysical measurements were performed using industry-standard or better methods for measurements and analyses. All work was performed under the AMEC Nuclear Quality Assurance Program (NQAP) and its procedures, which include:

- Use of NIST-traceable calibrations, where applicable, for field and laboratory instrumentation
- Use of approved field data logs
- Use of independent verification of velocity data by comparison of receiver-to-receiver and source-to-receiver velocities
- Independent review of calculations and results by a registered professional engineer, geologist, or geophysicist.
- Field surveillance by AMEC, Bechtel and TVA QA staff.

Suspension Velocity Data Reliability

P- and S_H-wave velocity measurement using the Suspension Method gives average velocities over a 3.28 feet interval of depth. This high resolution results in the scatter of values shown in the graphs. Individual R1-R2 measurements have an estimated precision of +/- 5%. Standardized field procedures and quality assurance checks contribute to the reliability of these data.

Table 1. Boring locations and logging dates

BORING DESIGNATION	DATES LOGGED	COORDINATES [(1)] TENNESSEE STATE PLANE COORDINATES NAD 1983		GROUND ELEVATION [(1)] NAVD88 (FEET)
		NORTHING	EASTING	
MP-101	6/22, 6/23/2013	570249.6	2448355.2	800.5
MP-102	7/16, 7/17/2013	570097.9	2448404.3	797.9
MP-111	7/31, 8/1/2013	570328.7	2448345.0	801.1
MP-111PS	9/17/2013	570345.7	2448334.2	801.6
MP-112	7/9, 7/10/2013	570261.9	2448472.1	799.2
MP-113	7/2, 7/3/2013	570184.9	2448486.5	797.5
MP-120	7/23, 7/24/2013	570319.1	2448584.2	800.1
MP-122PSA	9/17/2013	570140.5	2448638.2	796.7
MP-122PSB	9/17/2013	570117.8	2448648.1	796.6
MP-201	7/30, 7/31/2013	571083.7	2447980.8	790.9
MP-202	6/27, 7/3/2013	570922.1	2448050.0	811.8
MP-212	8/4/2013	571093.5	2448107.3	810.7
MP-213	8/3/2013	571009.3	2448148.5	813.0
MP-219A	8/2/2013	571254.2	2448184.6	808.6
MP-401	7/8, 7/9/2013	571954.2	2447605.1	817.7
MP-409	8/16, 8/17/2013	570584.3	2448158.9	807.0
MP-412	7/21, 7/22, 2013	571424.0	2447850.6	823.7
MP-415	6/20, 6/21, 7/7/2013	569577.1	2448164.8	784.3
MP-416	7/7, 7/8/2013	569978.3	2447520.0	809.6
MP-417	6/26/2013	569915.4	2446630.3	772.7
MP-418A	7/5, 8/1/2013	570514.7	2447049.6	811.1
MP-419	6/23, 6/24/2013	571269.8	2446700.6	799.6
MP-420	7/11, 7/16/2013	572033.0	2446918.3	803.1
MP-421	7/18, 7/19/2013	570532.3	2446439.6	803.6
MP-422	6/24, 6/25/2013	570423.7	2448732.0	799.9
MP-423	7/24, 7/25/2013	571470.3	2448276.4	799.0
MP-425	7/22, 7/23/2013	570814.6	2448199.5	811.9
MP-426	8/19/2013	571764.5	2447811.0	842.2
MP-428	10/8/2013	570755.5	2448681.6	803.8
MP-429	10/9/2013	569975.5	2448591.1	796.0

[(1)] Source: AMEC E&I electronic transmittal CRP-1043.0 dated 12/19/2013,
Horizontal Datum Tennessee State Plane Coordinates NAD 1983, Vertical Datum NAVD 1988

Table 2. Logging dates and depth ranges

BORING NUMBER	TOOL AND RUN NUMBER	DEPTH [1] RANGE (FEET)	OPEN HOLE (FEET)	SAMPLE INTERVAL (FEET)	DATE LOGGED
MP-101	FTC DOWN01	0 – 540.2	540	0.05	6/22/2013
MP-101	SUSPENSION DOWN01	19.69 - 526.57	540	1.6	6/22/2013
MP-101	HIRAT DOWN01	4.2 – 539.5	540	0.04	6/22/2013
MP-101	HIRAT UP01	539.4 - 16.8	540	0.004	6/22/2013
MP-101	DUIN/GAMMA UP01	539.75 - 16.2	540	0.05	6/23/2013
MP-101	DUIN/GAMMA UP02	100.45 – 69.0	540	0.05	6/23/2013
MP-101	CALIPER/GAMMA UP01	536.7 - 11.35	540	0.05	6/23/2013
MP-102	DUIN/GAMMA UP01	349.8 – 5.45	350.6	0.05	7/16/2013
MP-102	DUIN/GAMMA UP02	132.95 – 109.65	350.6	0.05	7/16/2013
MP-102	HIRAT DOWN01	4.4 – 346.5	350.6	0.04	7/16/2013
MP-102	HIRAT UP01	346.5 – 10.8	350.6	0.004	7/16/2013
MP-102	HIRAT UP02	13.6 – 5.6	350.6	0.004	7/16/2013
MP-102	SUSPENSION DOWN01	8.20 – 131.23	350.6	1.6	7/16/2013
MP-102	SUSPENSION DOWN02	132.87 – 334.65	350.6	1.6	7/17/2013
MP-102	CALIPER/GAMMA UP01	345.8 – 2.9	350.6	0.05	7/17/2013
MP-111	DUIN/GAMMA UP01	173.5 – 33.5	173.9	0.05	7/31/2013
MP-111	SUSPENSION DOWN01	34.45 – 160.76	173.9	1.6	7/31/2013
MP-111	CALIPER/GAMMA UP01	173.25 – 5.82	173.9	0.05	7/31/2013
MP-111	HIRAT DOWN01	34 – 173.2	173.9	0.04	8/1/2013
MP-111	HIRAT UP01	173 – 32.5	173.9	0.004	8/1/2013
MP-111	HIRAT UP02	60 – 32.5	173.9	0.004	8/1/2013
MP-111PS	SUSPENSION DOWN01	6.56 – 44.29	59.5	1.6	9/17/2013
MP-111PS	HIRAT DOWN01	2.5 – 58.2	59.5	0.04	9/17/2013
MP-111PS	HIRAT UP01	58.2 – 1.8	59.5	0.004	9/17/2013
MP-112*	DUIN/GAMMA UP01	177.0-25.0	177.5	0.05	7/9/2013
MP-112*	CALIPER/GAMMA UP01	176.7-3.5	177.5	0.05	7/9/2013
MP-112*	HIRAT DOWN01	25 – 52.1	177.5	0.04	7/10/2013
MP-112*	HIRAT DOWN02	52.1 – 109.68	177.5	0.04	7/10/2013
MP-112*	HIRAT DOWN03	109.68 – 176.51	177.5	0.04	7/10/2013
MP-112*	HIRAT UP01	176.4-24.0	177.5	0.004	7/10/2013
MP-112*	SUSPENSION DOWN01	36.1-164.0	177.5	1.6	7/10/2013

(1) ALL DEPTHS REFERENCED TO GROUND SURFACE ELEVATION

(2) * - INCLINED BORING, DEPTHS ALONG BOREHOLE AXIS

Table 2, continued. Logging dates and depth ranges

BORING NUMBER	TOOL AND RUN NUMBER	DEPTH [1] RANGE (FEET)	OPEN HOLE (FEET)	SAMPLE INTERVAL (FEET)	DATE LOGGED
MP-113*	DUIN/GAMMA DOWN01	27.0 – 177.6	178	0.05	7/2/2013
MP-113*	DUIN/GAMMA UP01	177.5 - 25.0	178	0.05	7/2/2013
MP-113*	SUSPENSION DOWN01	26.2 - 164.0	178	1.6	7/2/2013
MP-113*	CALIPER/GAMMA UP01	177.2 - 3.0	178	0.05	7/2/2013
MP-113*	HIRAT DOWN01	26.5 – 177.28	178	0.04	7/3/2013
MP-113*	HIRAT UP01	177.2 - 24.9	178	0.004	7/3/2013
MP-120	DUIN/GAMMA UP01	349.05 – 20.65	350	0.05	7/23/2013
MP-120	DUIN/GAMMA UP02	58.35 – 33.45	350	0.05	7/23/2013
MP-120	SUSPENSION DOWN01	27.89 – 336.29	350	1.6	7/23/2013
MP-120	HIRAT DOWN01	3.9 – 348.2	350	0.04	7/24/2013
MP-120	HIRAT UP01	348.2 – 22.0	350	0.004	7/24/2013
MP-120	CALIPER/GAMMA UP01	348.1 – 1.7	350	0.05	7/24/2013
MP-122PSA	SUSPENSION DOWN01	6.56 – 24.61	38.7	1.6	9/17/2013
MP-122PSA	HIRAT DOWN01	2.8 – 37.6	38.7	0.04	9/17/2013
MP-122PSA	HIRAT UP01	37.6 – 2.2	38.7	0.004	9/17/2013
MP-122PSB	SUSPENSION DOWN01	6.56 – 37.73	51.0	1.6	9/17/2013
MP-122PSB	HIRAT DOWN01	2.7 – 50.1	51.0	0.04	9/17/2013
MP-122PSB	HIRAT UP01	50.0 – 0.3	51.0	0.004	9/17/2013
MP-201	DUIN/GAMMA UP01	420 – 37	420.6	0.05	7/30/2013
MP-201	SUSPENSION DOWN01	39.37 – 406.82	420.6	1.6	7/30/2013
MP-201	CALIPER/GAMMA UP01	420 – 4.75	420.6	0.05	7/30/2013
MP-201	HIRAT DOWN01	38 – 419.6	420.6	0.04	7/31/2013
MP-201	HIRAT UP01	419.6 – 36.5	420.6	0.004	7/31/2013
MP-201	HIRAT UP02	60 – 36.5	420.6	0.004	7/31/2013
MP-201	DUIN/GAMMA UP02	58.5 – 19	420.6	0.05	7/31/2013
MP-201	SUSPENSION DOWN02	19.69 – 49.21	420.6	1.6	7/31/2013
MP-201	CALIPER/GAMMA UP02	58 – 4.92	420.6	0.05	7/31/2013
MP-201	HIRAT UP03	55 – 19.5	420.6	0.004	7/31/2013

(1) ALL DEPTHS REFERENCED TO GROUND SURFACE ELEVATION

(2) * - INCLINED BORING, DEPTHS ALONG BOREHOLE AXIS