

BOREHOLE GEOPHYSICAL REPORT

**MONITOR WELLS MW-33, MW-34, MW-35 AND MW-36
VASHON ISLAND LANDFILL
VASHON ISLAND, WASHINGTON**

FOR

**ASPECT CONSULTING, LLC
SEATTLE, WASHINGTON**

MAY 2015

**PHILIP H. DUOOS
GEOPHYSICAL CONSULTANT**

May 7, 2015

Our Ref: 1133b-15

Mr. Bob Hanford
Aspect Consulting, LLC
401 Second Ave. S., Suite 201
Seattle, WA 98104

REPORT: Borehole Geophysical Logging
Monitor Wells MW-33, MW-34, MW-35 and MW-36
Vashon Island Landfill, Washington

Dear Mr. Hanford:

Attached are the plots of the geophysical well logging data for the four monitoring wells that I logged on April 20, 2015. The depths indicated on the logs are referenced to the tops of the PVC well casing. A page with details of the well construction is attached. EM conductivity and ground penetrating radar data were recorded in each hole.

EM Conductivity Logs

Conductivity data were obtained using a Mount Sopris MGX II Digital Console and EMP-2493 downhole probe. The earlier survey included obtaining Natural Gamma logs, but the natural gamma tool was not effective in this geologic environment (overburden materials) and the bentonite grout used in the construction of the wells also affected the natural gamma data.

EM conductivity measurements are similar to the resistivity tool but use EM induction and provides more meaningful data in shallow holes and can be run in PVC casing. EM data is used to measure changes in formation resistivity and porosity, water saturation, and fluid resistivity. Magnetic Susceptibility (Mag. Sus.) is also measured, and is useful in delineating ferrous mineralization. The EM response is zero near the borehole (to a radius of about 4 inches). The peak response is at a radius of about 11 inches, with significant response to a radius of about 36 inches. The conductivity and magnetic susceptibility logs are shown for each well. All of the logs were recorded while coming up the holes at speeds ranging from 16 to 18 feet per minute.

The EM conductivity response seems to respond well to the stratigraphy observed in the geologic logs. The shallower materials consisting of primarily sands and gravels are lower in conductivity. The deeper silt layers correlate to generally higher conductivities, with some silt layers showing much higher conductivity values. The fat clays observed in the geologic logs correlate very well to the higher conductivity values.

The EM response is adversely affected by the presence of the steel centralizers used for construction of some of the wells near the bottom of the wells, and is indicated by the high-magnitude and erratic response (MW-34, 35 and 36). However, the response is limited to a fairly narrow band at the centralizers. The EM logs also respond erratically to the debris layer encountered in MW-33 above 30 feet deep. In MW-34 a narrow anomaly is observed at about 180 feet deep and may be related to naturally occurring iron in the geologic materials.

Ground Penetrating Radar Logs

Ground penetrating radar (GPR) data were also recorded in each of the four borings using a MALA ProEx System with the 250 MHz borehole GPR antenna. The antenna is 1.9 inches in diameter and 9.8 feet long and comprised of two sections, each about 5 feet long. The lower section houses the transmitting antenna, and the upper section the receiver.

The transmitter antenna outputs a pulse of electromagnetic energy to the ground. The energy pulse is reflected by geologic layers or objects near the borehole (in a 360 degree direction) back to the receiver. The presence of finer-grained materials such as silts and clays will severely limit the penetration of the GPR signal, while coarser-grained materials such as sands and gravels allow for greater penetration.

The GPR scans are shown with depth down the hole (below the top of the PVC casing) along the right, and the two-way arrival time for the GPR signal across the top. The GPR logs of the various wells show reasonable correlation with the geologic logs, although the change in the GPR signal will not precisely match the geologic logs depths due to the design of the antenna. The depth of the GPR signal is plotted at the midpoint of the two antennas. However, as soon as either antenna is in an area with silts or clays the signal will begin to degrade, so it is difficult to obtain a precise depth on the interface.

For example, at MW-34 the GPR reflective layer is very weak between the top of the hole and about 35 feet deep. The geologic log indicates sandy, silty till to a depth of about 28 feet. The 10-foot long antenna system also has limitations in detecting or resolving thin layers.

The moderate GPR reflective layer between about 35 feet to 105 feet deep correlates well with the sand layer noted in the geologic log. The absence of any noticeable GPR reflections below 105 feet deep correlates with the finer-grained materials noted in the geologic log. The high amplitude reflection in the GPR log between about 165 feet and 183 feet correlates fairly well with the sand layer noted in the geologic log. The higher amplitude reflection may also be related to the loss of materials during drilling in this zone.

The GPR system was first run in MW-34. Upon completion of the data recording, while bringing the GPR antenna up the hole, the gears on the depth encoder for the GPR system were damaged. Temporary field repairs were made, but the accuracy of the GPR depths for the remaining three holes was compromised. In MW-33 and MW-35 the total GPR depth to the bottom of the hole was shallower than the actual depth by 5 feet and 4 feet, respectively. In MW-36 the GPR depth to the bottom of the hole was deeper than the actual by 2 feet. No corrections were made to the GPR logs for this depth error.

LOG CORRECTIONS AND CALIBRATION

The EM tool was calibrated upon completion of logging each well using a calibration ring with known values. The EM tool is sensitive to temperature, so the tool is calibrated quickly upon completion of each hole after it has stabilized to the well fluid temperature. The tool is placed in the air resting on wooden tripods away from the ground and any metal objects. A minimum reading is taken, and a maximum reading is also recorded to provide a reference between wells. The minimum values (should be zero) ranged from -2.43 to 8.84 mS/m. The maximum values ranged from 452.9 to 461.2. The minimum value is within the margin of error taking into account the variation due to temperature, and no corrections to the EM data were made.

The GPR system has no calibration. The settings (primarily gains and length of record) are based on visual inspection of the record.

Please note that while tool checks and calibrations can help correlate the logs between wells, other conditions such as the variations in the volume of bentonite in the annulus (due to wash outs, drilling methods, etc.) and variations in well construction can also affect the logs.

The logs within this report are printed at a scale to fit on one page and scanned to make one PDF file. PDF images of the EM logs and the GPR logs are also provided as separate files, which allow a clearer image that can be expanded for viewing. In this report I have pointed out some of the major features of the geophysical logs and related them to possible geologic features in a general sense to help you in the interpretation of the logs. However, these geophysical logs should be viewed primarily as just another set of data to assist you in your geologic interpretation of the conditions at the site.

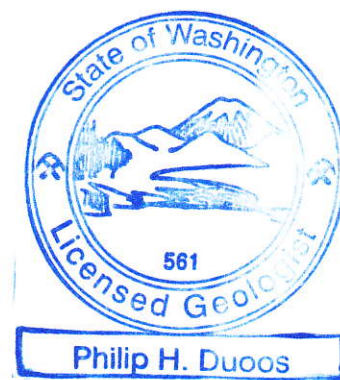
Please feel free to contact me with any questions or comments regarding this information. It was a pleasure to have worked with you on this interesting project.

Sincerely,



Philip H. Duos
Geophysical Consultant

Attachments



Well Construction Measurements

Geophysical Logging Depths are Referenced to Top of PVC Casing
Elevations based on drill log notes.
Depth error in GPR logs are noted as discussed in report.

MW-33

Top of PVC Casing Elev: 359.3'
Ground Surface Elevation: 357.07'
Total Depth (below Top PVC): 139.1'
Measured GPR depth: 134.3'

MW-34

Top of PVC Casing Elev: 385.9'
Ground Surface Elevation: 383.26'
Total Depth (below Top PVC): 247.6'
Measured GPR depth: 247.3'

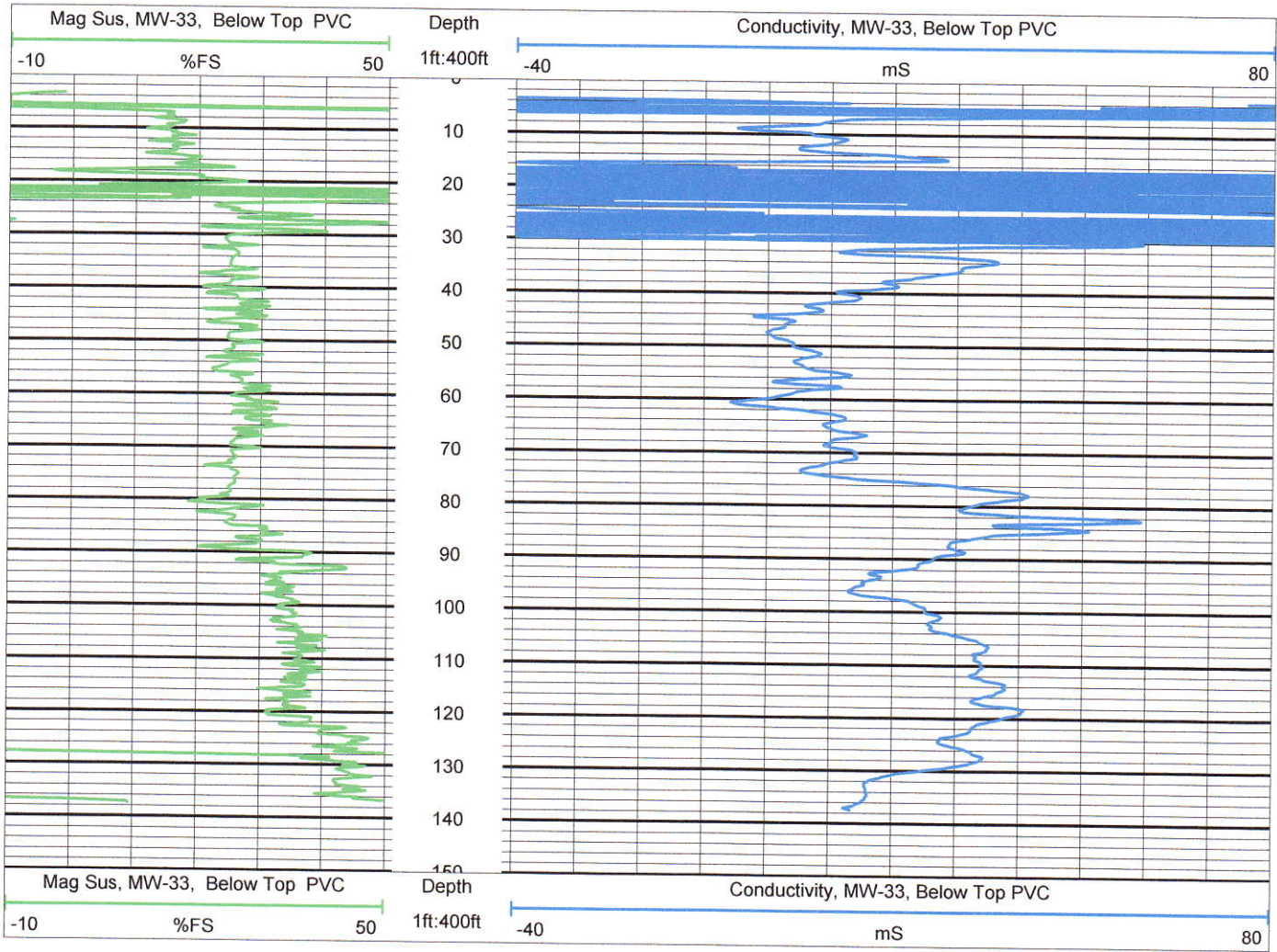
MW-35

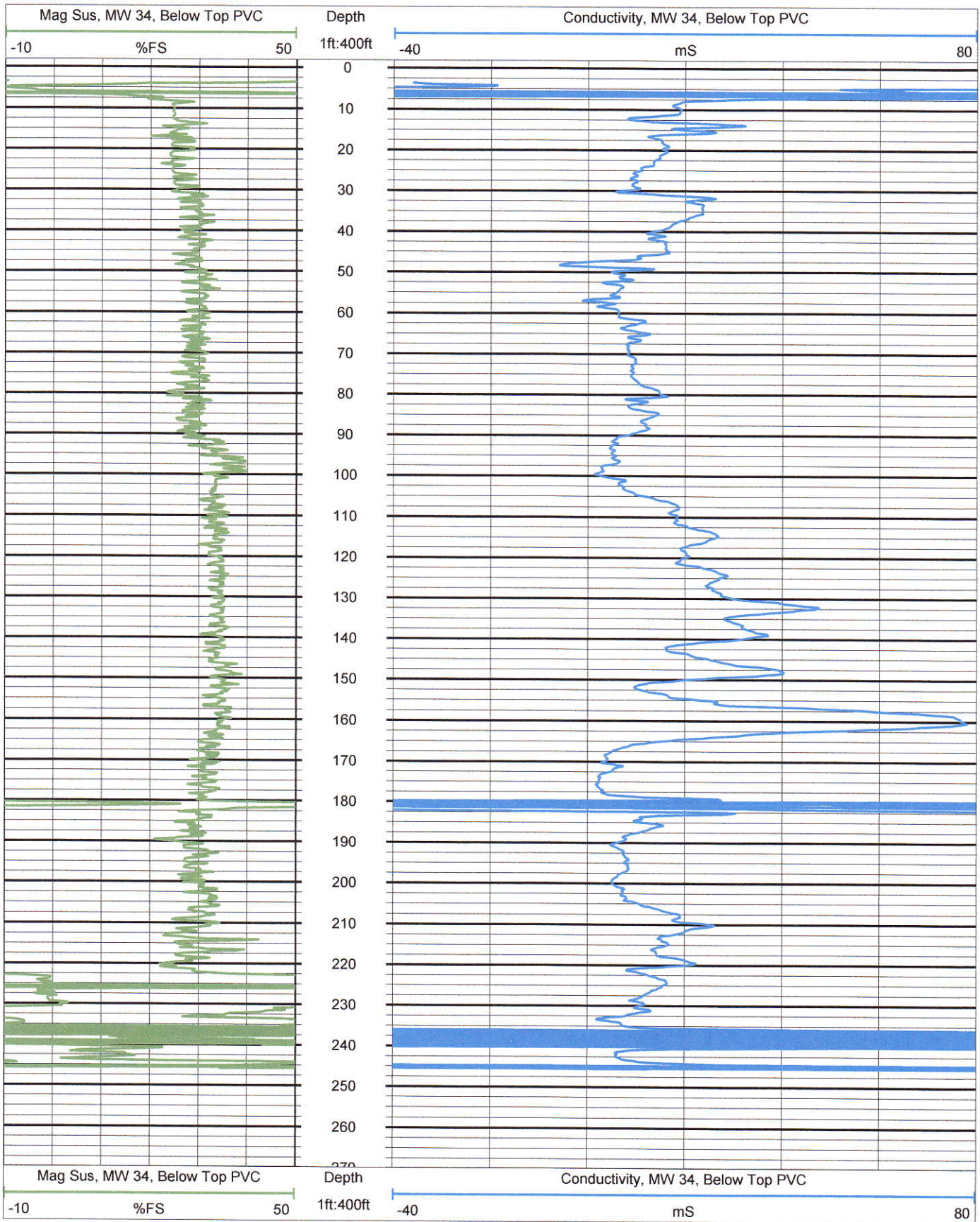
Top of PVC Casing Elev: 361.4'
Ground Surface Elevation: 358.75'
Total Depth (below Top PVC): 127.1'
Measured GPR depth: 122.8'

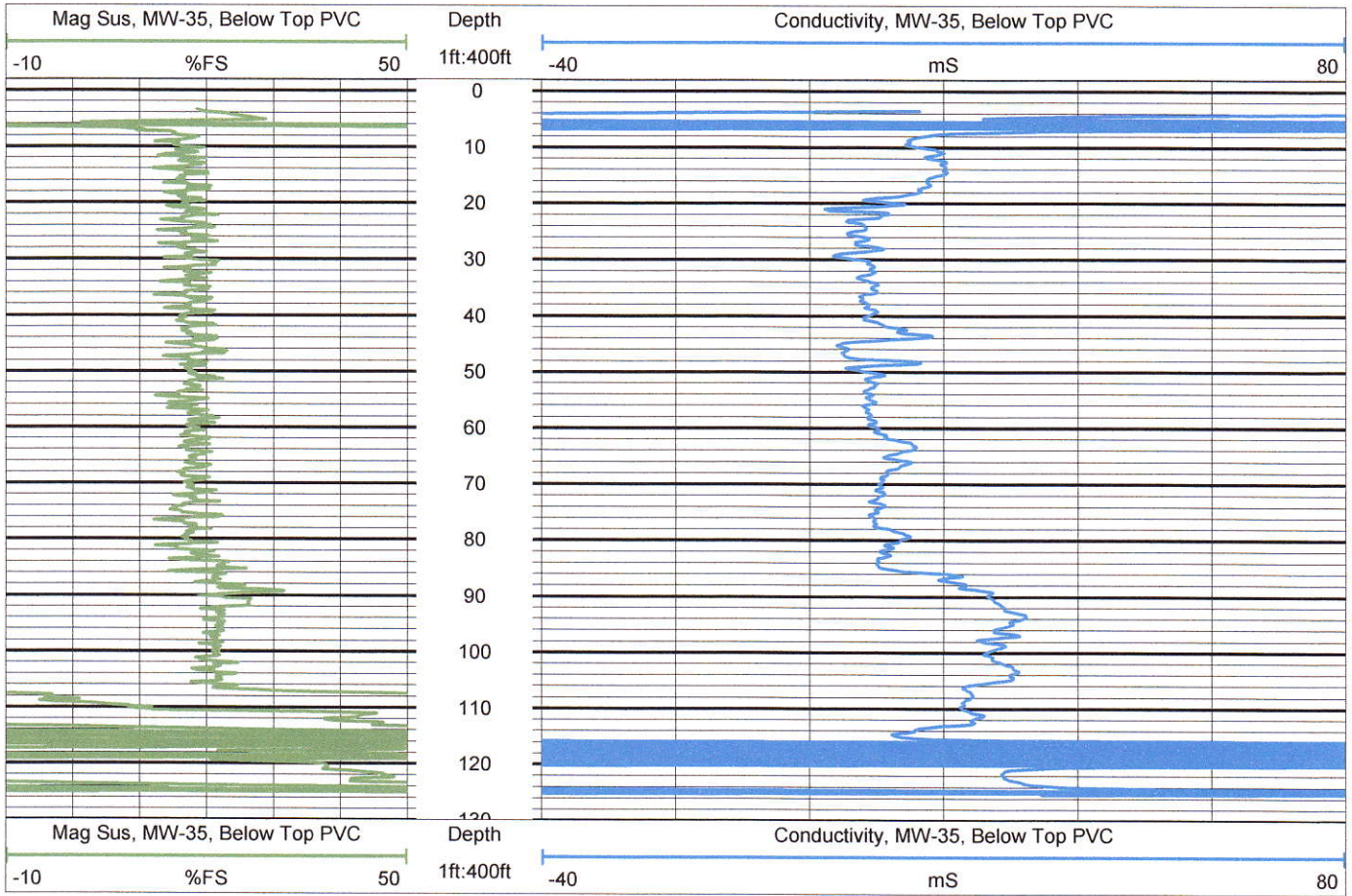
MW-36

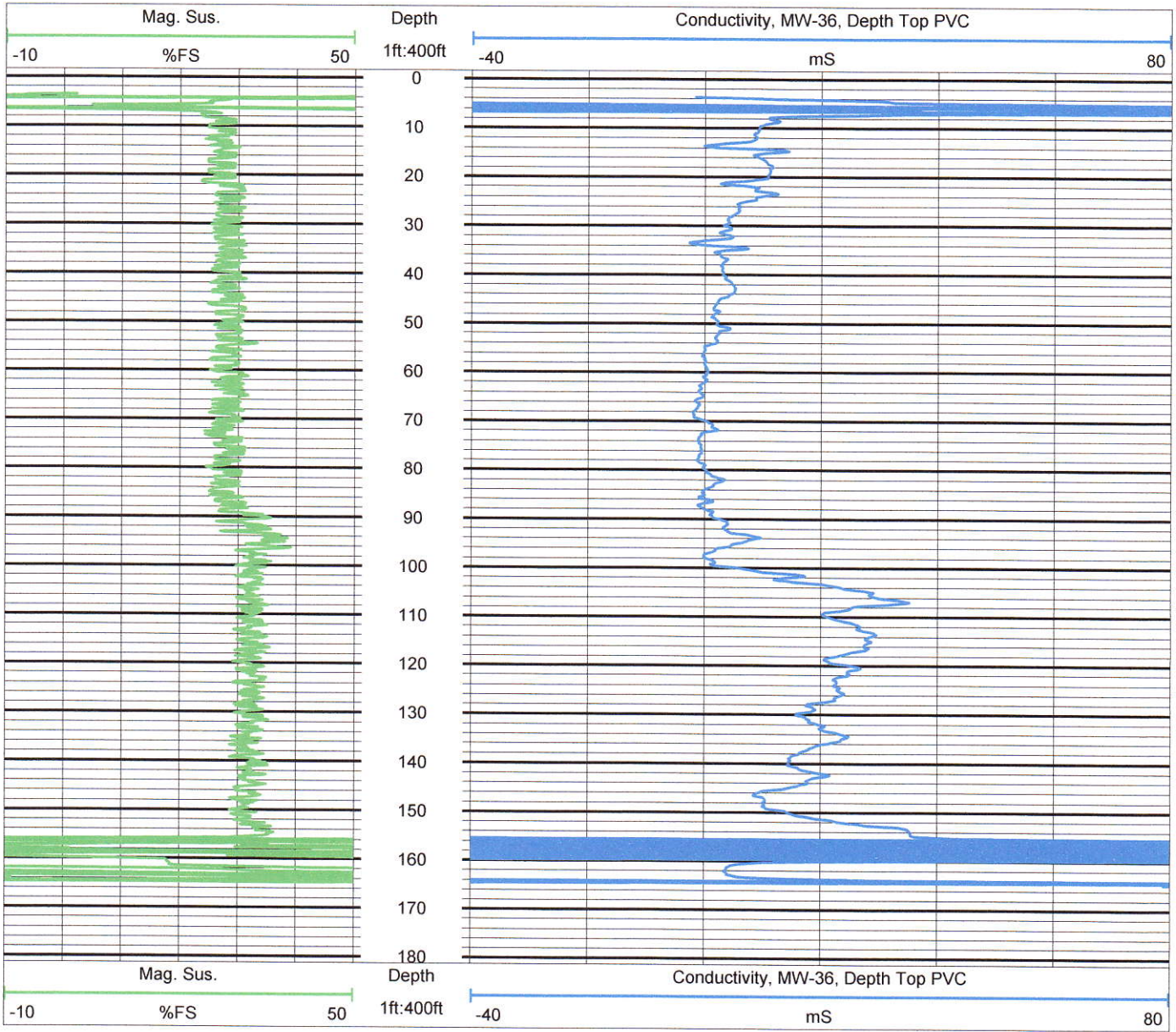
Top of PVC Casing Elev: 378.0'
Ground Surface Elevation: 375.25'
Total Depth (below Top PVC): 166.8'
Measured GPR depth: 169.3'

EM CONDUCTIVITY LOGS
(Magnetic Susceptibility and Conductivity)





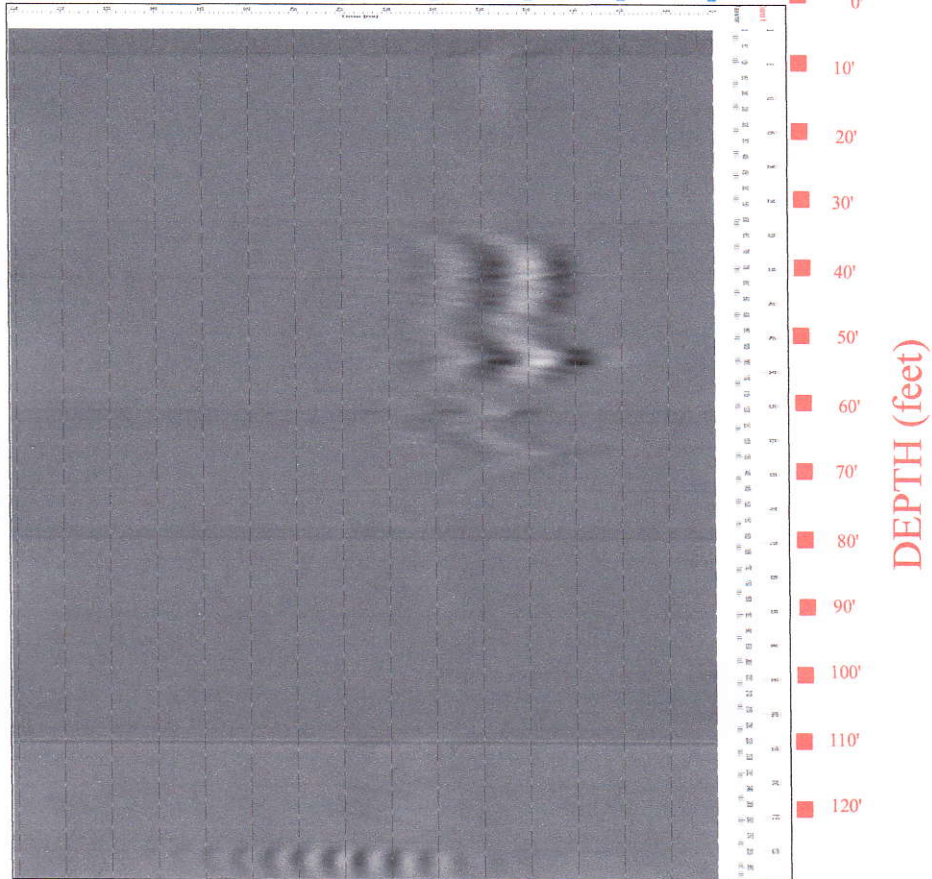




GROUND PENETRATING RADAR LOGS

TIME (nanoseconds)

40 30 20 10 0



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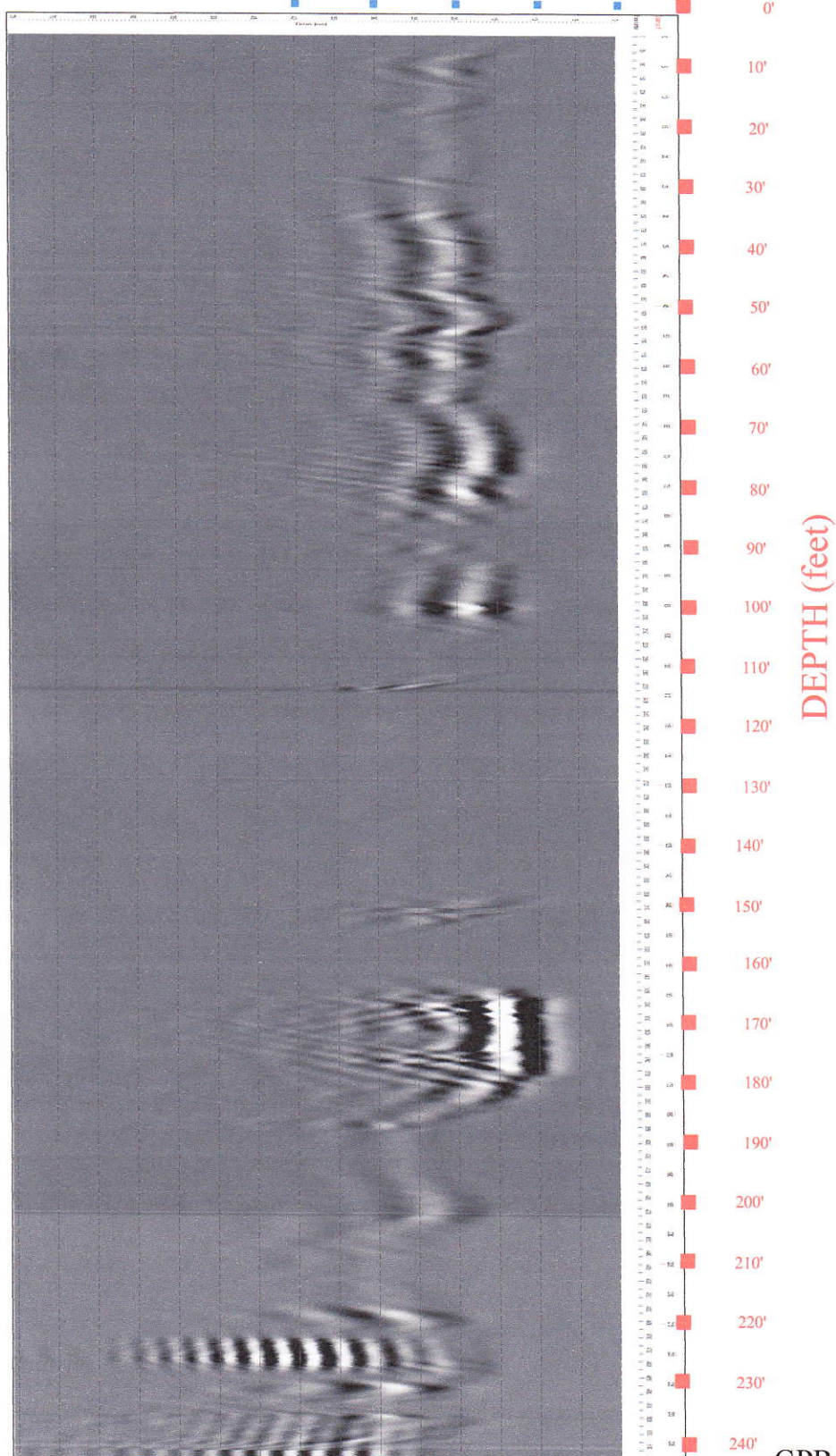
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GPR LOG
VASHON ISLAND LANDFILL
VASHON, WASHINGTON

MW-33

TIME (nanoseconds)

40 30 20 10 0



GPR LOG

VASHON ISLAND LANDFILL
VASHON, WASHINGTON

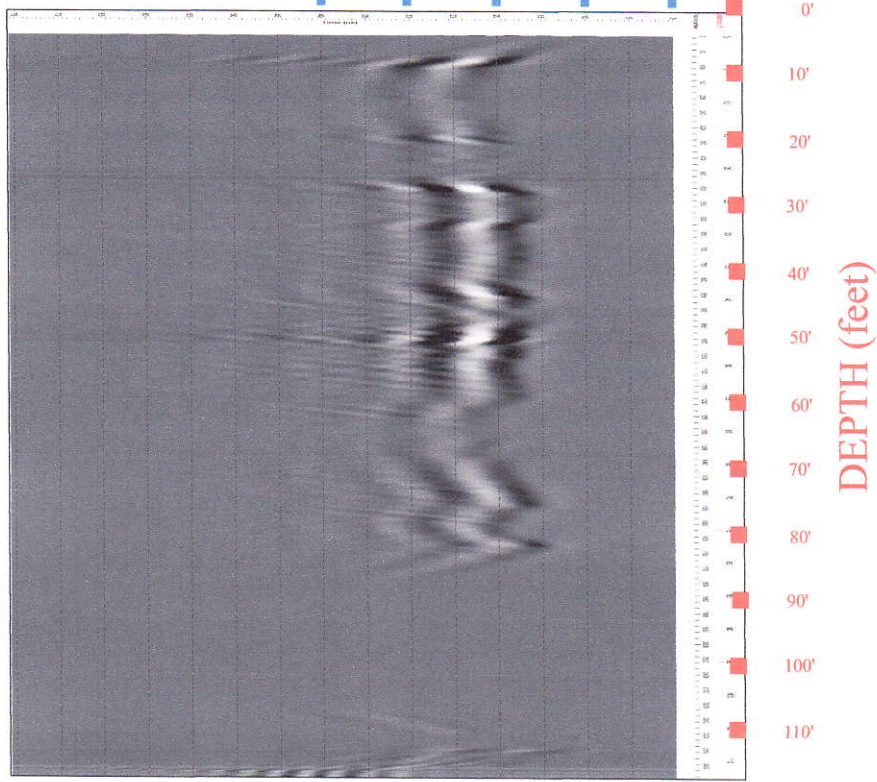
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MW-34

TIME (nanoseconds)

40 30 20 10 0



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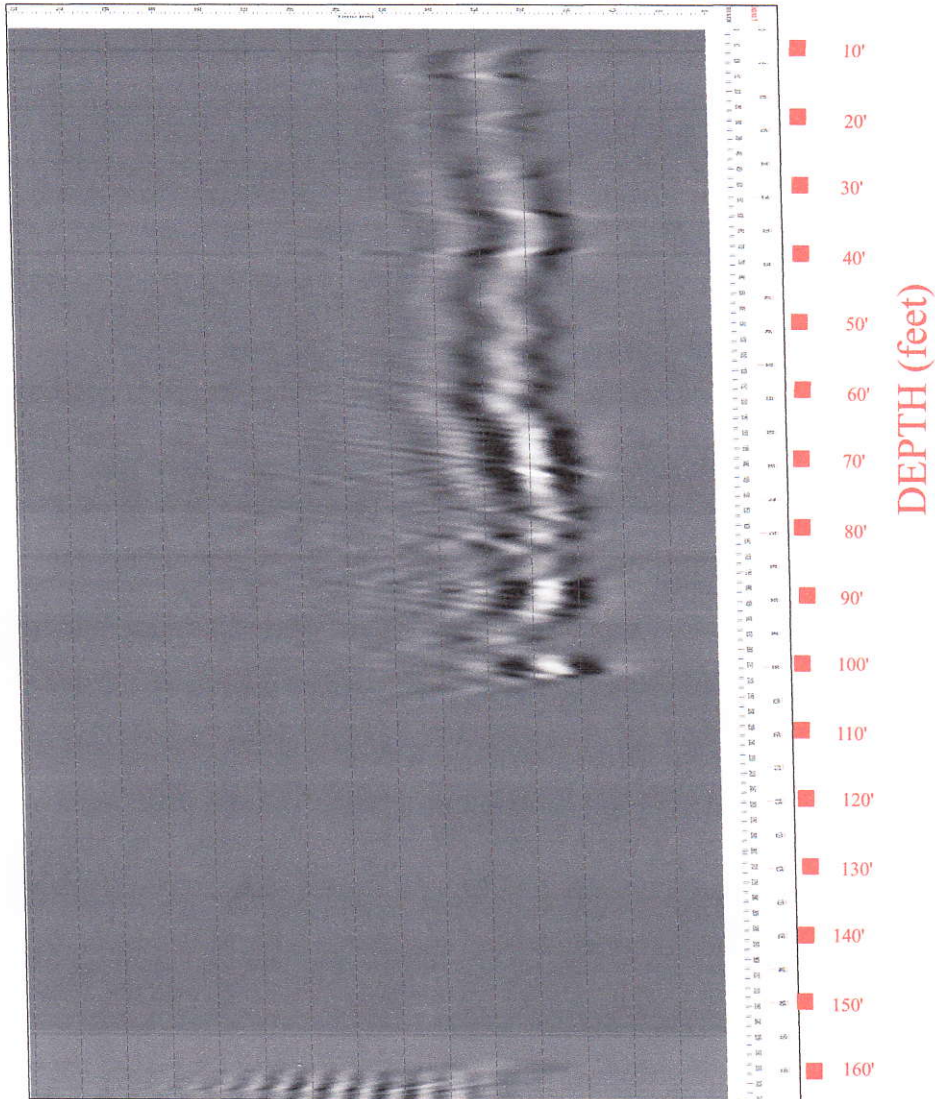
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GPR LOG
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MW-35

TIME (nanoseconds)

40 30 20 10 0



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GPR LOG
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MW-36