INDUCED POLARIZATION WITH ELECTROMAGNETIC COUPLING: 3D SPECTRAL IMAGING THEORY
EMSP PROJECT NO. 73836

TOPICAL/ANNUAL PROGRESS REPORT

for Period September 15, 2001–September 14, 2002

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RESEARCH PROGRESS AND IMPLICATIONS:

This report summarizes the research work completed on the project between December 2001 and September 2002.

1. A model of all Spectral IP capacitive couplings revealed that potential bearing electrodes should be carefully chosen to obviate some of the capacitive coupling problems. This need becomes more important for borehole sampling. Thus, work had been done to design a porous pot electrode that has all the desired characteristics (low input impedance = 100Ω, low noise = 1 μV/√Hz, low temperature sensitivity = 10μV/°C) and that can be implanted in a borehole for up to two years. Further constructional/fabrication details will be given in the final report. The attached pictures are from a sample of the prototype electrode. Four strings, each consisting of 14 electrodes (7 potential electrodes alternated with 7 metallic-copper current electrodes, each electrode 6ft apart), were constructed and are to be deployed into the four boreholes. (They were eventually deployed in Dec. 2002 and measurements acquired in March 2003).

2. The MIT's Earth Resources Laboratory (ERL) performed Spectral Induced Polarization (SIP) and Time Domain Induced Polarization (TDIP) measurements at the A-14 Outfall during the summer of FY01 as a participant in a DOE-sponsored exercise to assess the state-of-the-art in cross-borehole IP technology for delineating subsurface contaminants. To demonstrate the utility of **SIP** to map **DNAPL** contaminants, we inverted cross-borehole SIP data, taken within a very narrow frequency bandwidth of 1/32 to 9/32 Hz. The narrow bandwidth was selected after carefully studying when effects of emc, electrode polarization, etc. begin to set in. The upper frequency is limited by electromagnetic couplings (emc) and strong capacitive behavior observed for the electrodes and the low-frequency limit is set by the time to take measurements. Because below 9/32 Hz, the IP response seems to be greater than emc in all our measurements, the data was considered invertible by our existing 2D/3D complex resistivity codes. The results of this exercise were inconclusive because the ground-truthing phase of the operation failed to detect any concentration of NAPL above a requisite threshold of 40-50μg/g. It is our understanding that this threshold level is based upon analytic chemical partition analysis, which is dependent upon the physicochemical properties of the soil, its pore-fluid, and organic constituents [Cohen and Mercer, 1993], and thus represents a necessary and sufficient condition to confirm the presence of NAPL. Therefore, since the ground-truthing phase never found PCE concentrations in excess of ~3μg/g, there is no

irrefutable evidence of NAPL; hence, the objective of the FY01 exercise could not be completed. Nonetheless, ERL's inversion results (an example is shown in Figure 1) agree well with the ground truth considering the sparseness of the CRS boreholes, low concentrations of `PCE' (< 3μg/g), and despite poor electrodes. Note that the displacement of the center of the SIP phase anomaly from that of the ground truth data might be due to inaccuracies in the SIP inversion (which we are still working on improving) or sampling depth errors during the ground-truthing phase which could cumulatively amount to a meter or more.

3. As a continuation of the FY01 efforts, another set of surface and borehole SIP measurements were planned at another SRS site during FY02, which unlike the FY01 site,had been verified to have substantial DNAPL presence by SRS engineers. The plan to use Phoenix Geophysics SIP equipment could not materialize because Phoenix discontinued its SIP line and planned to introduce a new line in the Spring/Summer of 2003, which will be too late for us. So our planned second fieldwork of FY02 defaults again to Zonge Engineering and Research Organization equipment.

4. Developments on the modeling and inversion of the new complex resistivity code, that will incorporate inductive coupling, stalled to give way to the electrode design, fabrication and testing(s), which were not anticipated earlier.

Reference

Cohen, R., Mercer, J., Mathews, J. (EPA Project Officer), *DNAPL Site Evaluatio*n, C.K. Smoley, 1993

PLANNED ACTIVITIES

The following shows a timetable of activities planned for the remaining time of the project:

October 2002 to March 2003:Completion of the formulation of the forward and inverse algorithms.

October 2002 to March 200: More field work using Zonge Engineering and Research Organization SIP equipment.

March 2003 to May 2003: Testing of the inverse algorithms using both synthetic and field data.

June 2003 to July 2003: More demonstration field work possibly at Savannah River Site A14 outfall.

July 2003 to September 2003: Interpretation of field results and writing of reports.

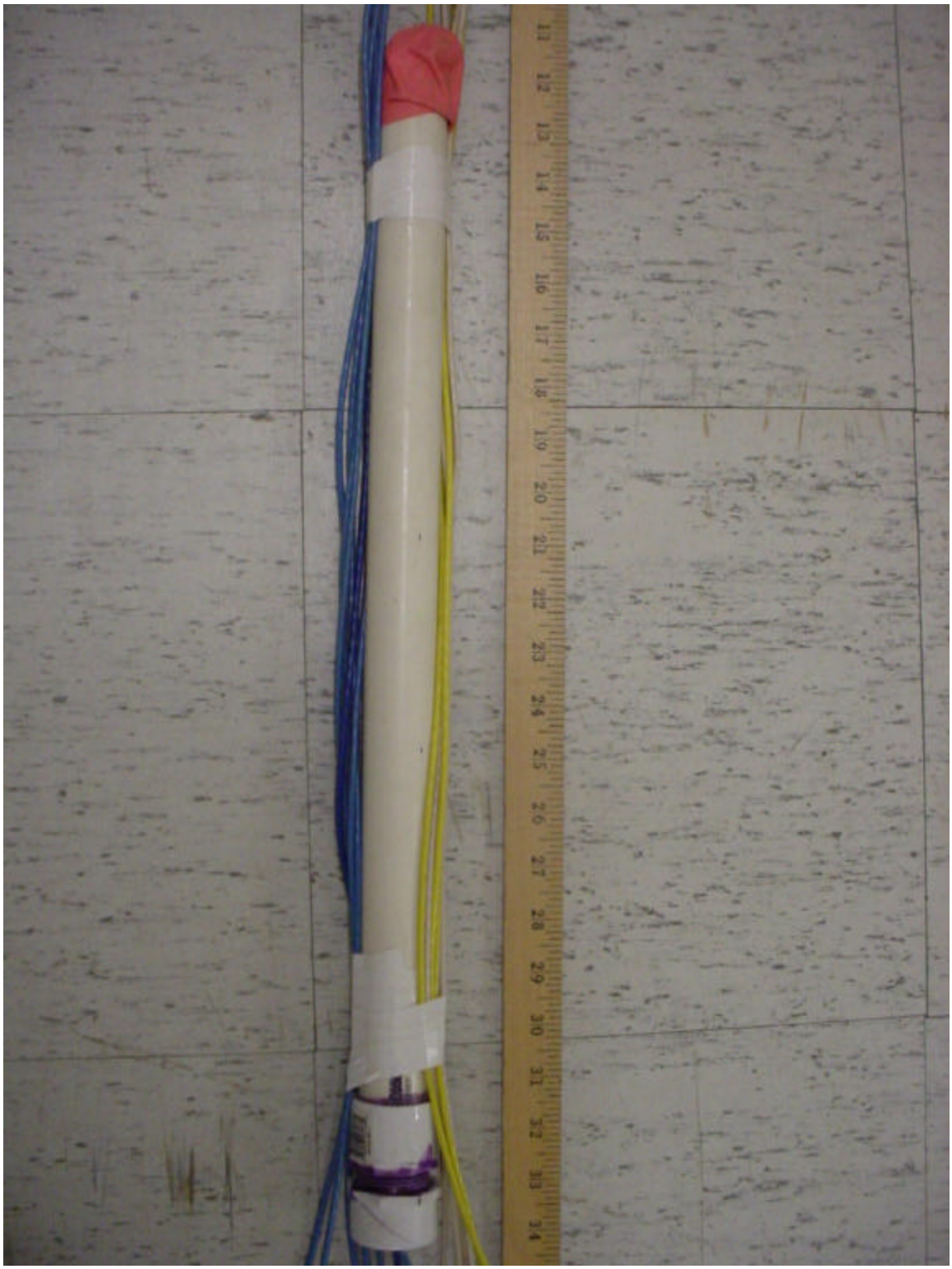

Figure 1 a: Porous pot electrode Potential- shown with protective (red) cover.

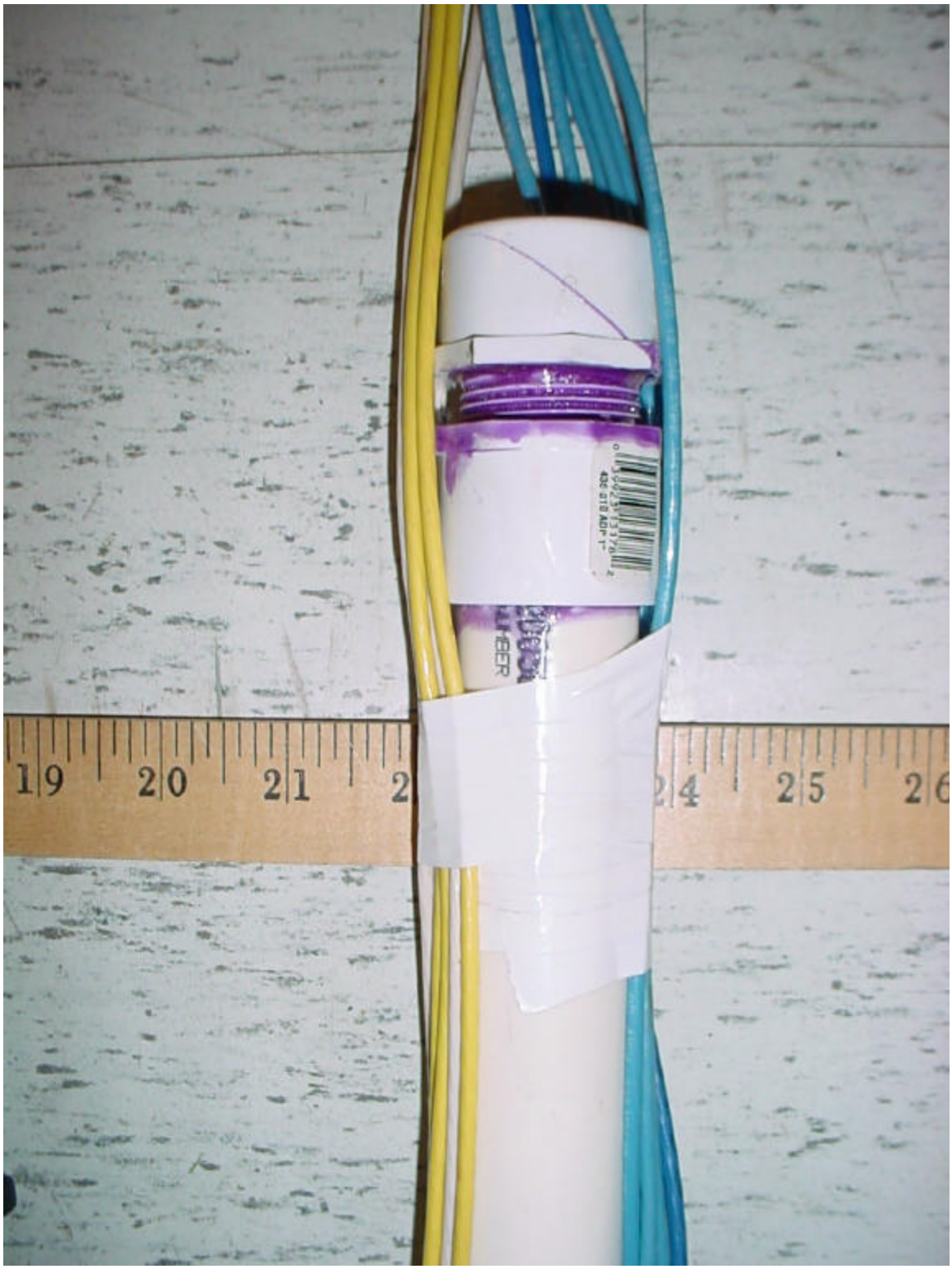

Figure 1 b: Porous pot electrode Potential- width.

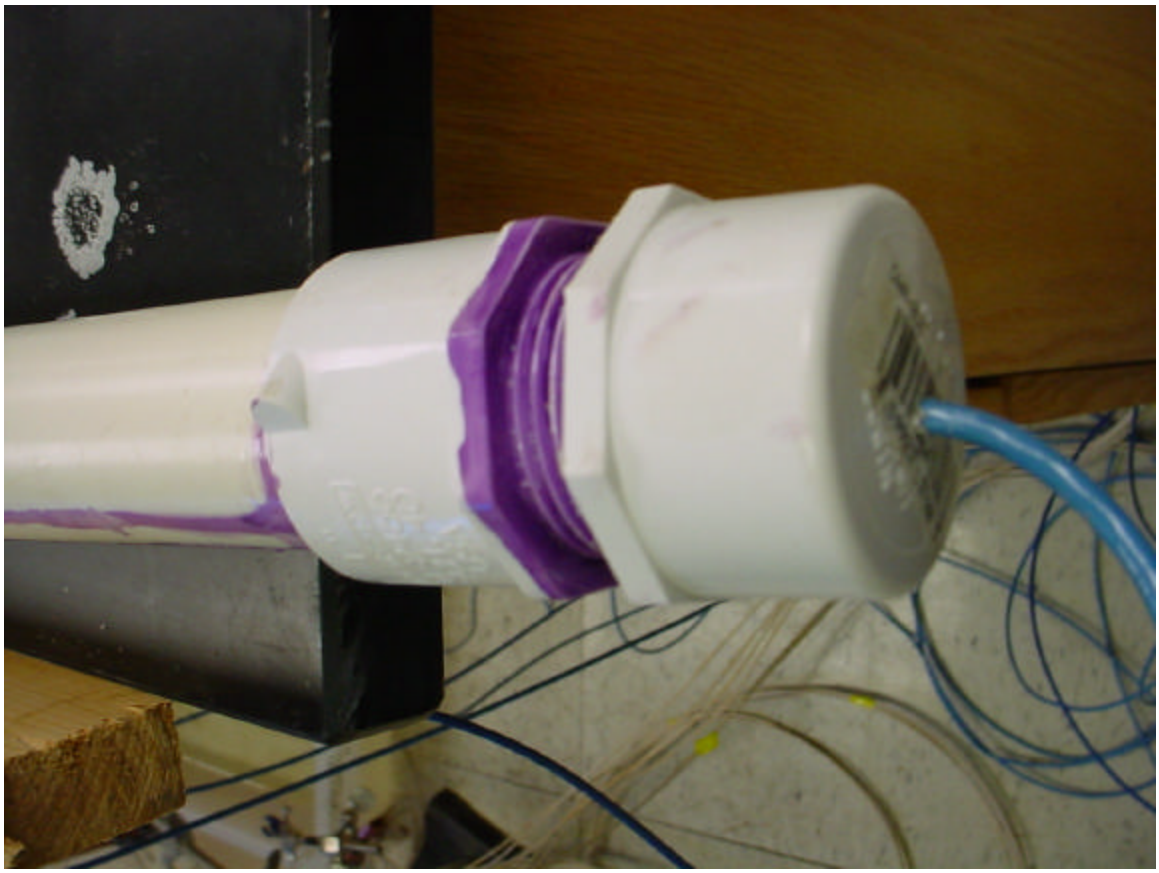

Figure 1 c: Porous pot electrode Potential- showing the cap.

Below is an image that shows the interpolated ground truth concentration of an "unidentified" substance but labeled PCE by SRS ground-truthing team.

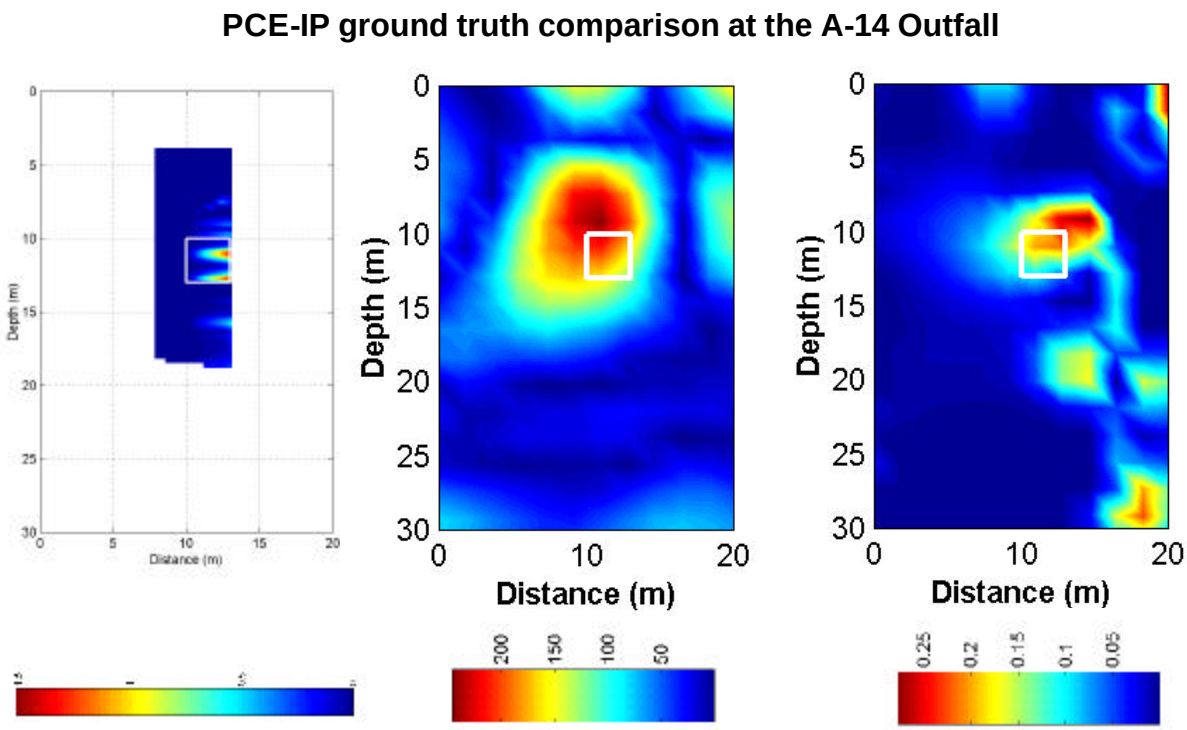

Figure 2 Comparison of the ground-truth PCE anomaly (**a**), the ERL's SIP anomaly (**b**), and the ERL's TDIP anomaly (**c**). Panel **a** has been generated by taking a slice along the MES-2/MES-4 panel from the volumetric PCE concentration (interpolated from the CRS series of boreholes, taken during the FY01 ground-truth exercise). Panels **b** and **c** are the ERL's inversion results along the MES-2/MES-4 panel. MES-4 is located on the right-hand side of all three panels.