Characterization of an old diesel fuel spill? Results of a multi-receiver OhmMapper survey

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Summary

Geoelectric data were acquired with the OhmMapper TR4 (OM-TR4) over a former tank farm at the Camp Parks Reserve Forces Training Area (RFTA) to map the near subsurface resistivity and possible association with a 30 to 40 year old hydrocarbon plume and locate any additional pipelines and subsurface infrastructure. The OM TR4 is a towed capacitively coupled resistivity system that comprised of one transmitter and four receivers in the dipole-dipole array configuration. Densely sampled data were acquired on both north-south and east-west profile lines. Apparent resistivity maps and two-dimensional inverse models were used in an attempt to correlate geophysical signatures with soil samples analyzed for hydrocarbons. We found some correspondence between conductive zones in the lower vadose zone-shallow saturated zone to concentrations of petroleum hydrocarbons in the diesel range (TPH-d) of 140 ppm at a depth of 2.4 m and 470-17000 ppm at 3.6 m. At a depth of 1 m concentrations of less than 100 ppm were detected and corresponding resistivity values were relatively high.

Site and Survey Description

Established in 1942, the Camp Parks RFTA is a military training facility situated in the southeastern San Francisco Bay Area, California, USA. A former tank farm located on the CPRFTA has a long history of use as a fuel storage and dispensing facility. Diesel and gasoline storage tanks existed both above and below ground. Prior to soil sampling it was believed that diesel was the sole contaminant. New information indicates that potential contaminants include heavy metals from fuel additives and fuel-related organic compounds. The contamination was discovered during installation of a sewer line when workers noticed a fuel odor during excavation.

Clays, which are gray to brownish-gray, of low permeability and conductive, characterize soils on the roughly 10000 m^2 site. The soil is dry most of the year, and moisture does not penetrate deeper than the top meter in a typical water year. The survey was performed in January 2003, after some light rain, while the topsoil was moist. During this period, the ground was covered with green grass and weeds. Groundwater at the tank farm is about 3.3 m below ground surface (BGS).

The capacitively-coupled OM TR4 data were acquired using 4 receivers with a transmitter receiver separation of 5.0, 7.5, 10.0 and 12.5 m, as shown in the photograph of Figure 1and schematically in Figure 2. The transmitter and receivers are ungrounded 5m dipoles operating at 16.5 kHz. This sensor array was pulled with a small vehicle. Survey data were located with a Trimble Differential Global Positioning System (DGPS) system; the data stream from the GPS receiver was fed into the OM data logger as resistivity data we acquired. The offset between the vehicle-mounted GPS coordinates and the actual plotting point of a receiver is accounted for in the processing program. Data were acquired on 2.5 m line spacing on both a north-south and east-west grid. Spatial data density along a profile line is roughly a point per 2 m.

Figure 1. Photo of the 4-receiver OhmMapper in operation at Camp Parks' former tank farm.

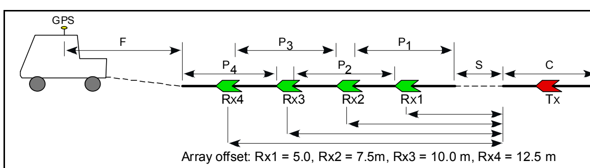

Figure 2. Schematic of the OhmMapper with 4 receivers (Rx) and transmitter (Tx) being pulled by a small vehicle. The potential dipoles (P) and current dipole (C) are both 5 m. The separation (S) is 2.5 m, and the distance (F) between the GPS and the array is 4.2 m.

Previously, OhmMapper surveys required the profiles lines be traversed separately for each Tx-Rx separation. With the TR4 all separations are collected simultaneously resulting in a significant reduction in acquisition time. The traverse lines, shown in Figure 3, were collected in two half-day sessions. After establishing the grid and testing the instrument, the east-west profile lines were acquired in an afternoon with a crew of three. The majority of the work was in turning the array when starting a new profile line. The north-south profile data were collected the following morning.

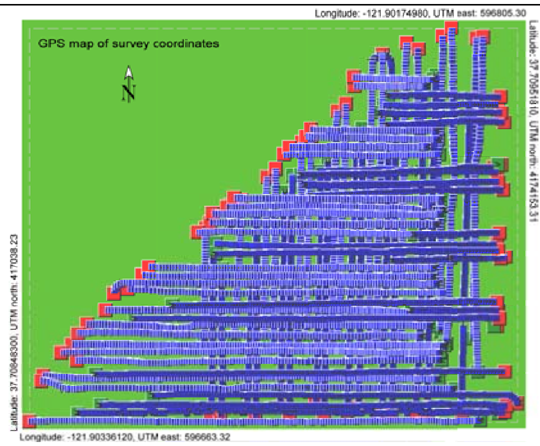

Figure 3. GPS map of the profiles line from the Camp Parks survey.

Survey Results

Data were reduced and processed using the DataMap software (Geometrics, 2001) and the two-dimensional (2-D) inversion software of Loke and Barker (1996). After transferring binary data from the data logger to the PC, it is converted to ASCII format for plotting and editing. Filtering techniques were employed to delete outliers and smooth the data with a 3 pt running average.

Data compiled from both transverse directions are presented as apparent resistivity plan view maps for 2 transmitter-receiver separations – 7.5 m and Rx4 at 12.5 m – in Figure 4 and Figure 5, respectively. Although values did exceed 25 ohm-m, the apparent resistivity was scaled between 2.5 to 25 ohm-m because the subsurface is quite conductive. The conductive subsurface resulted in a shallow depth of investigation. The yellow areas in Figure 5 indicate that the survey area is most conductive in the lower vadose zone and upper saturated zone. The dark blue region to the east in Figure 4 indicates that the least conductive soil is shallow.

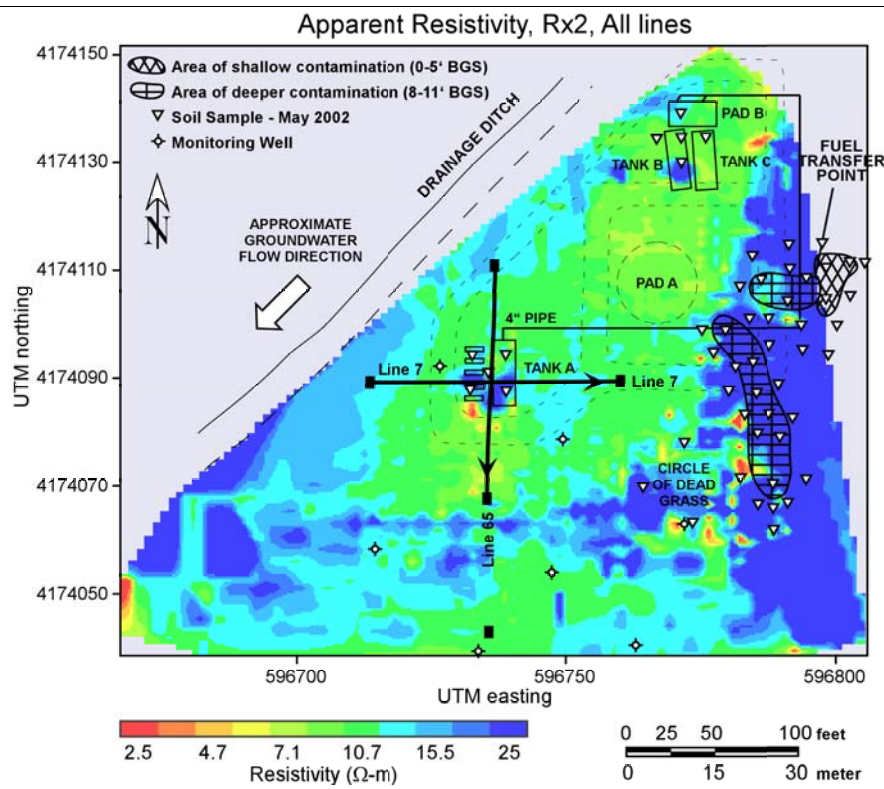

Figure 4. Apparent resistivity plan view map for the all line direction for the 7.5 m transmitter-receiver separation.

OhmMapper survey over a fuel spill

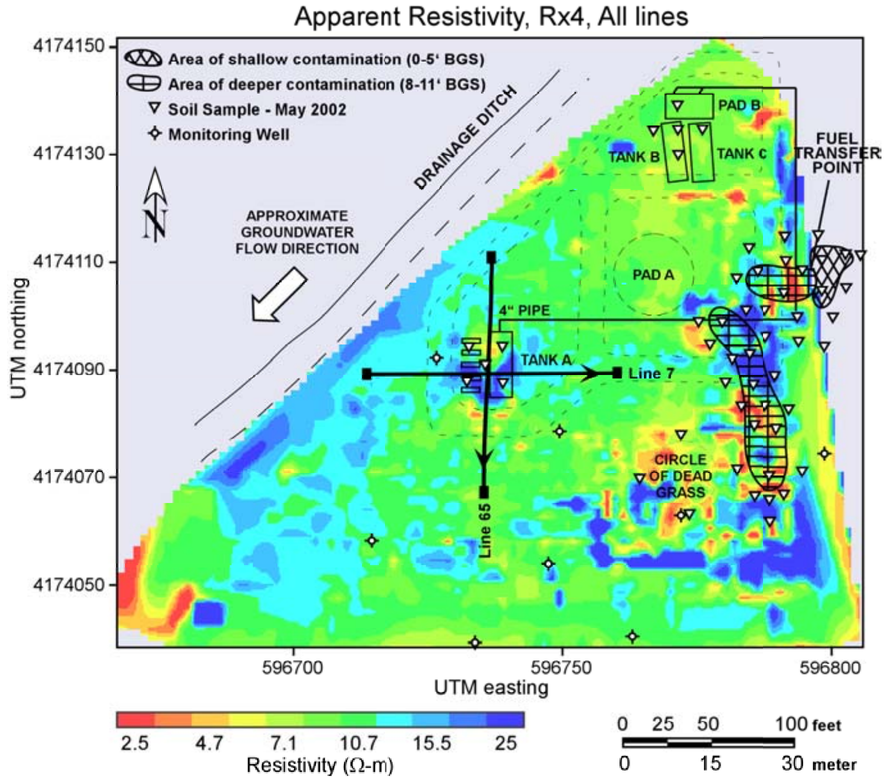

Figure 5. Apparent resistivity plan view map for the all line direction for the 12.5 m transmitter-receiver separation.

Data along Lines 7 and 65 were inverted using the 2-D code of Loke and Barker (1996). A portion of each line, centered over the 'Tank A' anomaly is shown in Figure 6 and Figure 7, respectively. The models indicated a depth of exploration greater than 3 m. Although not apparent in the composite apparent resistivity maps, the 2-D model illustrates the importance of having data in two directions. On east-west trending Line 7, a simple more resistive anomaly is present in both the pseudo-section and model. In contrast, the same structure has a dipolar anomaly in the pseudo-section for the north-south trending Line 65 and is conductive in the model. Thus the mode in which the array is north-south excites the conductive portion of the tank in the top 2 m, whereas the array oriented east-west does not.

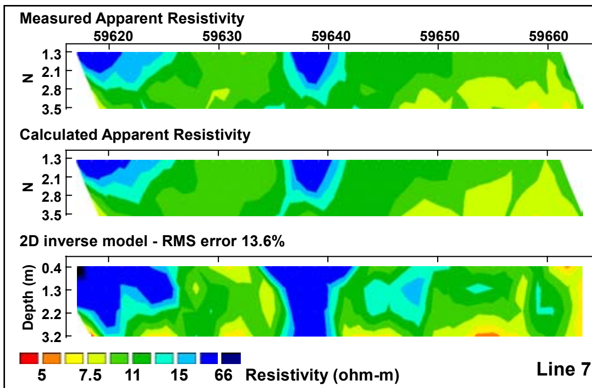

Figure 6. Pseudo-section of data and model response, and the inverted 2-D model for a portion of Line 7.

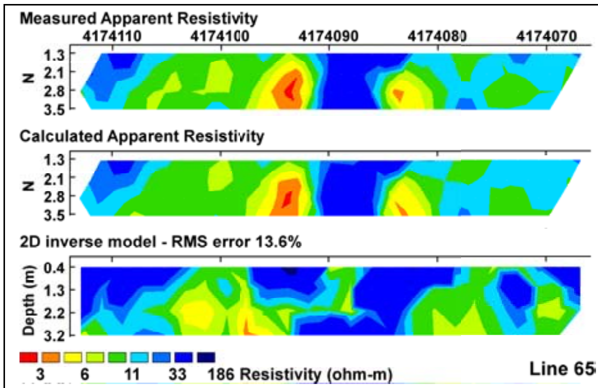

Figure 7. Pseudo-section of data and model response, and the inverted 2-D model for a portion of Line 65.

Discussion

Contrary to notion that hydrocarbons are resistive, studies have shown that hydrocarbon contamination zones older than 30 to 40 years are conductive, particularly in the lower vadose zone and upper saturated zones (Sauk et al., 1998). A goal of the OM survey was to determine if a geophysical signature could be associated with such areas of contamination. Locations of soil samples, denoted as white triangle, are overlaid on the apparent resistivity maps. Analysis for TPH-d showed two depth levels of high-level contamination, which are contoured as hatched areas. Concentrations of TPH-d of 140 ppm were found at a depth of 2.4 m and 470-17000 ppm at 3.6 m. At 1 m, concentrations of less than 100 ppm were detected (USACHPPM, 2002). The results of this study indicate that there is a good correlation between zones of higher contamination and zones of greater electrical conductivity.

Apparent resistivity maps are convenient for a quick evaluation and an overview of survey results, but do not provide accurate depth estimates. Two-dimensional modeling is practical for examining geoelectric structure along a profile line, but of limited use for revealing mode-sensitive structures. For a problem such as this, maps of integrated depth section over various intervals of interests are needed. Although two-dimensional inversion is possible, integrated sections built from one-dimensional inversion results are probably sufficient. A modification of the Laterally Constrained Inversion of Auken et al. (2000) where inverse models between profile lines could be constrained would be most advantageous.

References

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