Effectiveness of Electrical Resistivity in Delineating a Leachate Plume at the Former Shelby County Landfill in Memphis, Tennessee

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Abstract

Ground-water contamination from waste stored in landfills and other waste sites is a global threat to fresh water supplies. The Shelby County landfill at Shelby Farms in Memphis, Tennessee, lies in the flood plain of the Wolf River and is known to be the source of low-level contamination in the underlying alluvial and Memphis aquifers. The unlined municipal and industrial waste landfill was in operation from the early 1960s to 1988. Prior to closure, discovery of a hydrogeologic "window" in the upper Claiborne confining unit overlying the Memphis aquifer 0.2 km north of the landfill led to several ground-water investigations by the U.S. Geological Survey to evaluate the threat posed to the Memphis aquifer, the regional source for municipal water supplies.

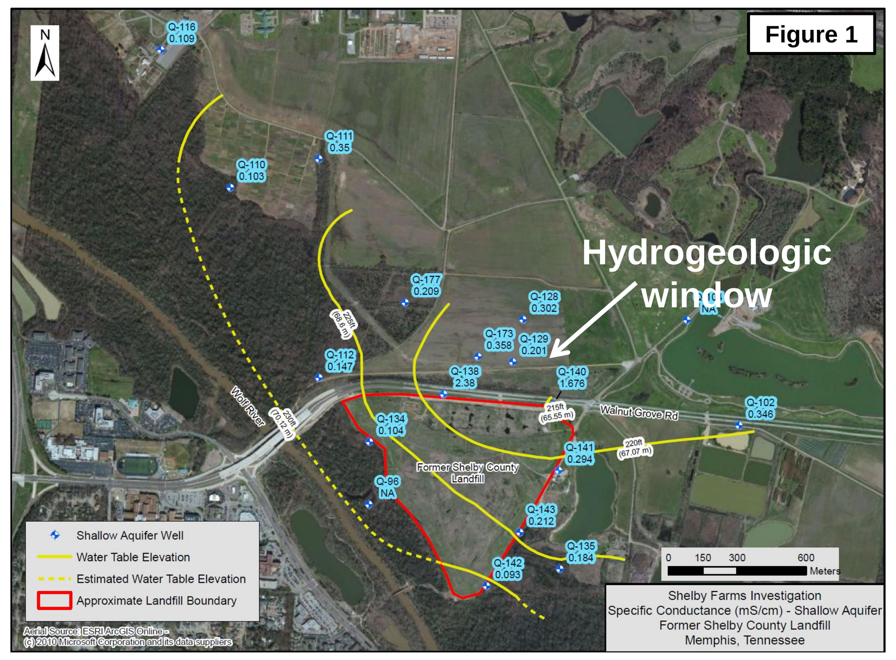
Identification of ground-water contamination is commonly achieved by chemical analysis of water sampled from monitoring wells; however, the distribution of monitoring wells does not always satisfactorily reflect the extent of ground-water contamination. This pilot study gauged the effectiveness of an electrical resistivity survey to identify the extent of contamination in a shallow aquifer beneath a landfill. Seven resistivity lines were completed north of the landfill using a SuperSting© R8/IP with an array of 28 electrodes at 10 meter spacing. Historical geochemical data and geologic logs were used to constrain resistivity data collected and produce a two-dimension cross-section of the subsurface. Preliminary results of the resistivity survey indicate impacted ground water in the shallow aquifer immediately north of the landfill, which is consistent with elevated specific conductance values and poor water quality observed in monitoring wells in the same vicinity during the July 2011 ground-water sampling event. Application of a full-scale resistivity survey may also improve the definition of the window orientation and lithology.

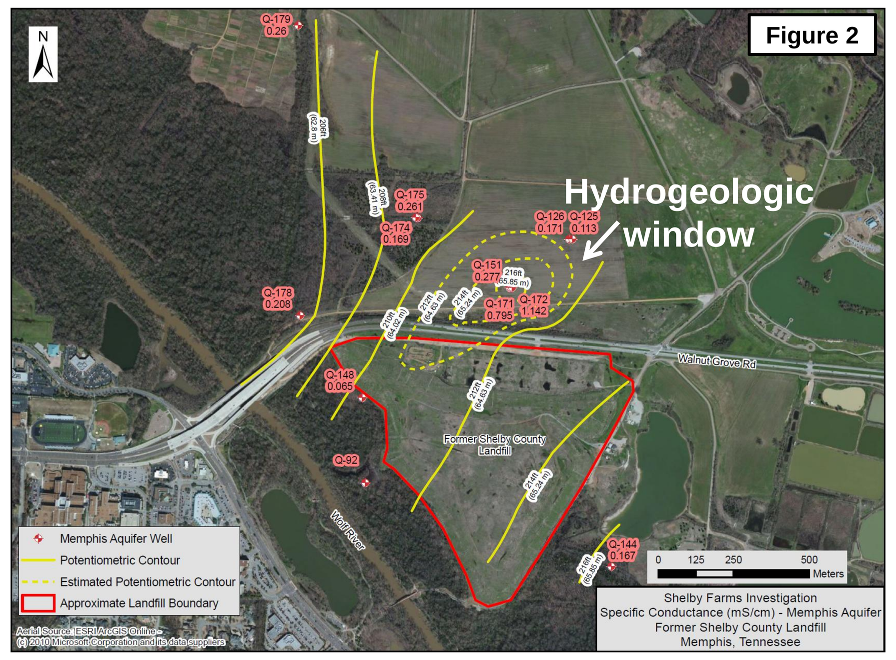
Purpose

The overall goal of the study is to assess the hydrologic integrity of the Shelby County landfill (SCL) by assessing changes in ground water quality in monitoring wells near the landfill and applying geophysical methods to map the distribution of landfill leachate in the subsurface.

Ground Water Sampling Event – July 2011

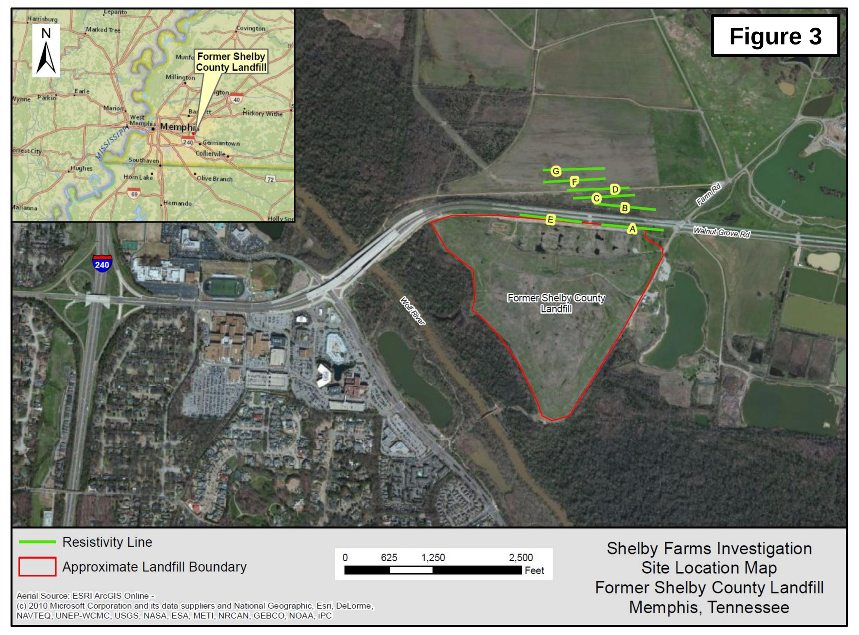
- Twenty-seven monitoring well locations were sampled for field parameters (pH, dissolved oxygen, specific conductance, oxidation-reduction potential, and turbidity) and common anions, ammonia nitrogen, total dissolved solids (TDS), metals, volatile organic compounds (VOCs), and alkalinity.
- VOCs were detected in impacted wells within both aquifers; however, all at concentrations below MCLs. VOCs detected in the shallow and Memphis aquifers are attributed to the landfill since none are detected in background wells and no other known sources are in the vicinity of the landfill.
- Historically, wells Q-138 and Q-140 in the shallow aquifer and wells Q-171 and Q-172 in the Memphis aquifer show either stable values or significant increases in constituents attributed to leachate impacted waters. These trends indicate that leachate, at low concentrations, is gradually being produced in the SCL and entering the shallow aquifer. The leachate-impacted water in the shallow aquifer migrates down the hydrologic gradient into the Memphis aquifer at the hydrologic window (at unconfined cluster) between these two aquifers north of the SCL. The leachate influence is illustrated by elevated specific conductance values in Figures 1 and 2.





Resistivity Pilot Study – May 2012

- Seven resistivity lines (A through G) were completed north of the landfill using a SuperSting© R8/IP with an array of 28 electrodes at 10 meter spacing. **Lines A and E** were located on grassy areas on the northern edge of the landfill. **Lines B, C, D, F, and G** were located north of Walnut Grove Road in either grassy areas or tilled soil. See Figure 3.
- Resistivity data were collected using Dipole-Dipole, Schlumberger, and Wenner arrays with induced polarization (IP) data collected contemporaneously with Dipole-Dipole resistivity data. Multiple arrays were used to ensure quality of data collected and comparison of inversion results between arrays. Advanced Geosciences, Inc. EarthImager 2D was used to invert the observed data.



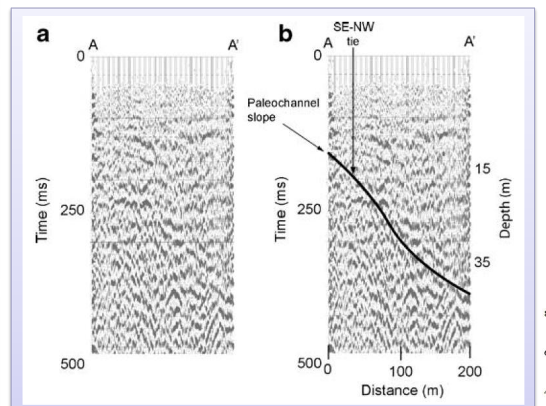
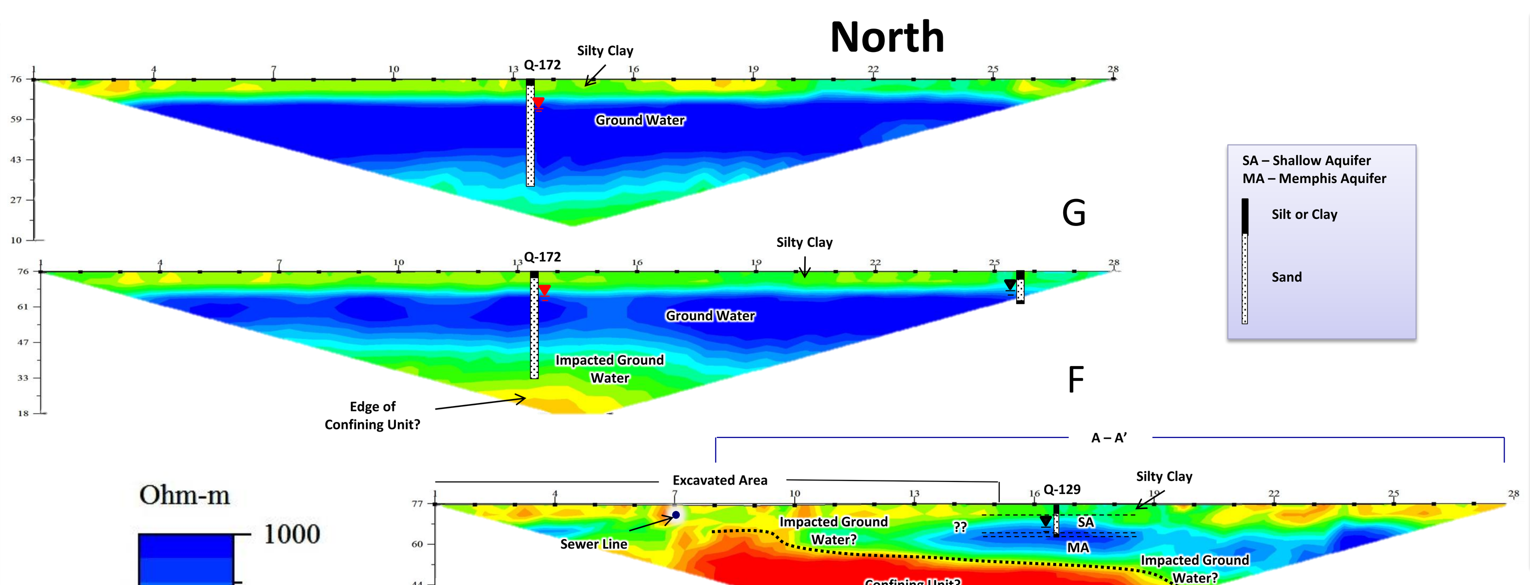
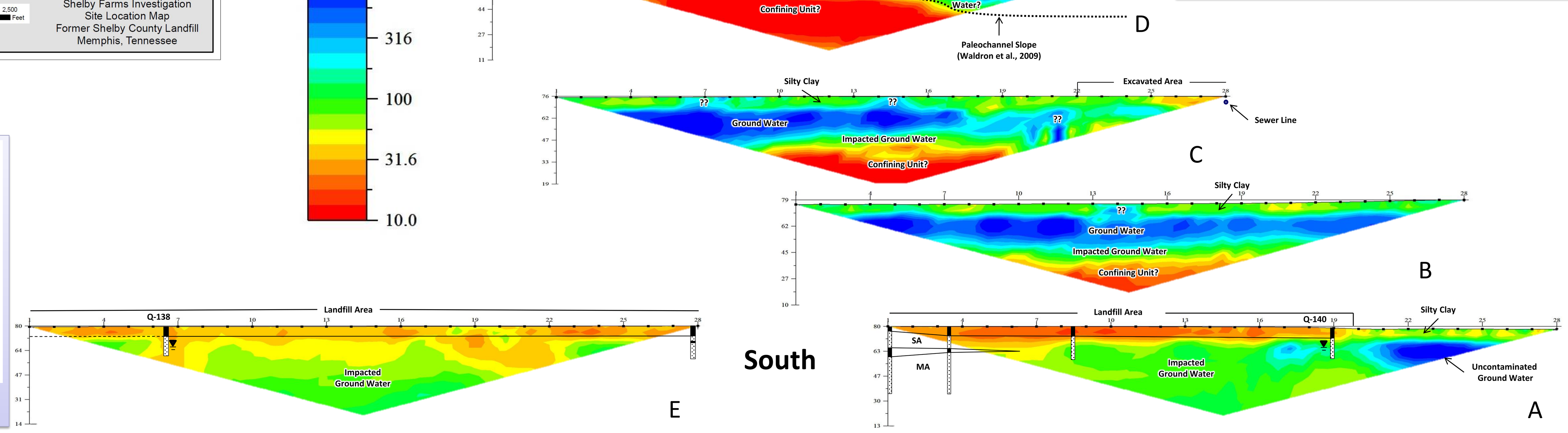
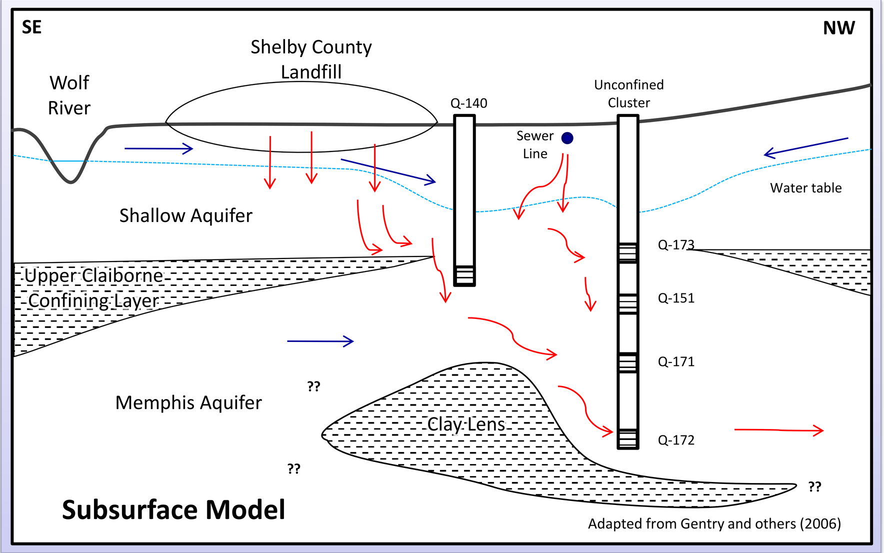


Figure 4
Seismic Section A – A' from Waldron and others (2009)





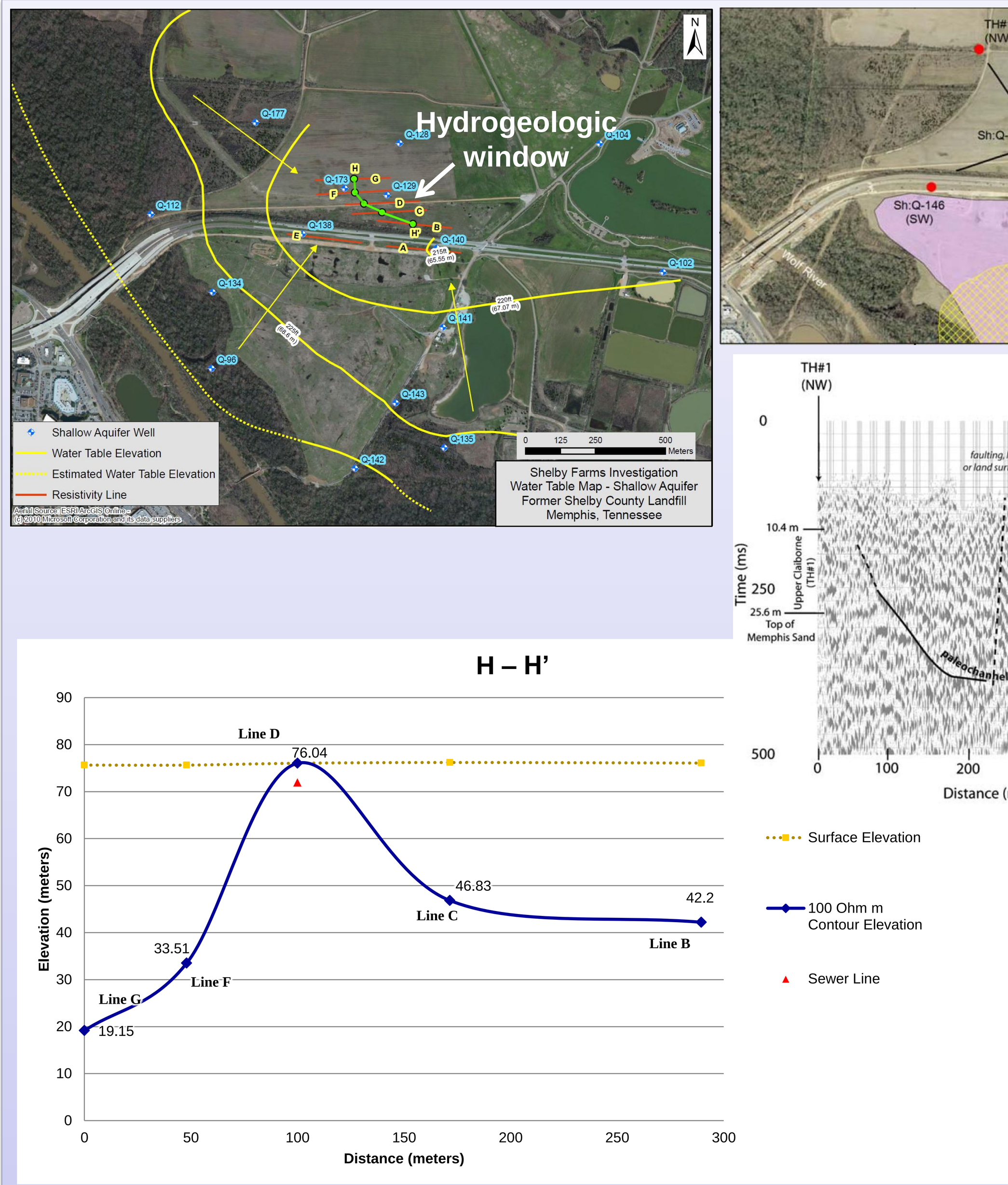


Dipole-Dipole Resistivity Interpretation

- **Line D** shows probable confining unit at depth, impacted ground water, and the effect of excavation and emplacement of the 1.8 meter diameter sewer line in the upper 5 m.
- **Line F** is adjacent south of the unconfined cluster where specific conductance increases with depth, which is interpreted to reflect impacted ground water. The line also shows probable confining unit at depth.
- **Line G** represents background for the overlying silty clay (low resistivity) and uncontaminated water in the shallow aquifer (high resistivity). The confining unit is known to be present from 12 – 21 m below surface approximately 115 m north of **Line G** and absent at that range approximately 45 meters south of **Line G** at **Line F.**
- **Line C** shows probable confining unit at depth, impacted and uncontaminated ground water and similar effects of the sewer line as **Line D.**
- **Line B** shows probable confining unit at depth, impacted ground water, and overlying higher resistivity "uncontaminated" water in the shallow aquifer.
- **Lines E and A** have lower resistivity values near the surface attributed to the former landfill and generally low resistivity values in the subsurface attributed to impacted groundwater. Higher resistivity in the shallow aquifer east of the landfill area is attributed to uncontaminated groundwater in the shallow aquifer.

Discussion

- Gentry and others (2006) introduced a model of the subsurface indicating several hydraulic windows north of the landfill trending to the southeast to northwest.
- Previous water table maps of the area indicate ground water flow to the unconfined cluster with a downward vertical gradient (Q-151, -171, -172, and -173) and Q-140 with a similar southeast to northwest trend (Bradley, 1991; Parks and Mirecki, 1992; Gentry et al., 2006; Larsen et al., 2012).
- Leachate impacts both the shallow and Memphis aquifer at **Line A and E** and **Line F** in the Memphis aquifer, as supported by previous ground water studies mentioned above.
- The low resistivity area (red and yellow) in **Lines B, C, D, F, and G** indicate a clay lens at depth (confining unit). The "green" layer could represent impacted ground water flowing along the edges of the clay lens.
- The depth and slope of the clay lens in **Line D** matches a paleochannel slope identified in a previous seismic investigation (Waldron et al., 2009 – see Figure 4). The paleochannel has a southeast to northwest orientation and may act as a conduit for impacted ground water to flow towards the unconfined cluster. H – H' shows the elevation change of the "green" layer (100 Ohm-m) in Figure 5. The elevation change in **Lines D, F, and G** are similar to the paleochannel interpreted in the southeast to northwest seismic line from Waldron and others (2009) (Figure 5).



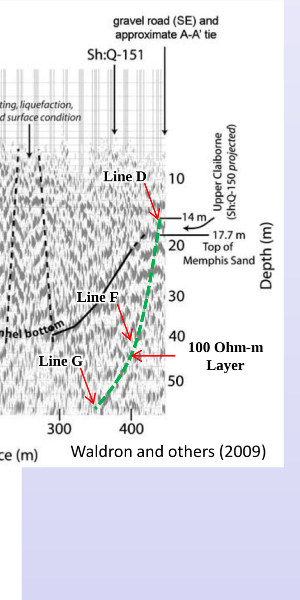


Figure 5
Relationship between NW-SE seismic line (Waldron et al., 2009) and H-H'.

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