Results from the Geophysical Surveys to improve understanding of the Sand Lake Groundwater Environment, Anchorage, Alaska

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I. Introduction

Recent and ongoing studies in the Sand Lake area of Anchorage, Alaska, have shown data gaps to understanding the regional and local hydrogeology of the groundwater resource. Because of the geologic complexity of the aquifer system in this area and the limited amount of information gained from domestic wells, details of the hydro-stratigraphy are not well understood. Studies by Combellick et al. (2001), Munk et al. (2004) and Kane et al. (2008) have emphasized these complexities and the challenges with determining local groundwater flow paths. However, recent advances in the conceptual geologic model of the aquifer system by the UAA team have improved our understanding of the connectivity of the aquifers. The regional groundwater flow path indicated by Patrick et al. (1989) shows a flow direction in the area of the Sand Lake community to be from the NE to SW. The Kane et al. (2008) study also indicates this general flow path direction for the shallow aquifer; however this is based on measuring non-synoptic water levels. While recent advances by the UAA team have improved our understanding of the groundwater flow direction, the Brailey (2014) report suggests the groundwater flow direction may still not be clearly known.

Electrical Resistivity Tomography (ERT) geophysics was chosen to map out the variations in resistivity of the aquifer system to further elucidate the heterogeneous nature of the stratigraphy, and saturation levels. This method allows a more detailed investigation of the subsurface at a finer scale than correlation from well logs. Together with the geologic information from drillers' well logs and the conceptual geologic model developed by the UAA team, the ERT allows an improved interpretation in the data gaps between well logs. The net gain from implementing this geophysical technique is two-fold: 1) more evidence of the complex hydro-stratigraphic nature of the aquifer system, 2) improved understanding of areas for future monitoring well installations, 3) provide additional data to help understand groundwater flow directions.

II. Methods

We employed ERT to map variations in the electrical resistivity along three north-south transects in the Sand Lake area with focus on the Hidden Hills and Seaveiw Heights neighborhoods (see Fig. 3). Originally developed for mineral exploration, ERT methods have been extensively used in ground water investigations (for a very partial listing see *Gagliano et. al,* [2009]; *Goldman and Neubauer*, [1994]; and *Seaton and Burbey*, [2000]).

The ERT method consists of injecting a known current through the subsurface, typically employing two electrodes, and measuring the resulting potential across two different electrodes. A number of electrode configurations can be employed; however the common aim is to generate a 2-dimentional electrical resistivity cross section, consistent with the measured data. (A more complete description of various electrode configurations is given in *Telford and Geldart* [1990]). A number of commonly used configurations are shown in Figure 1, and include from top to bottom, 1) dipole-dipole, 2) dipole-pole, 3) pole-pole and 4) the Schlumberger array. The commonly used Wenner array, is a special case of the Schlumberger array when electrodes are evenly spaced.

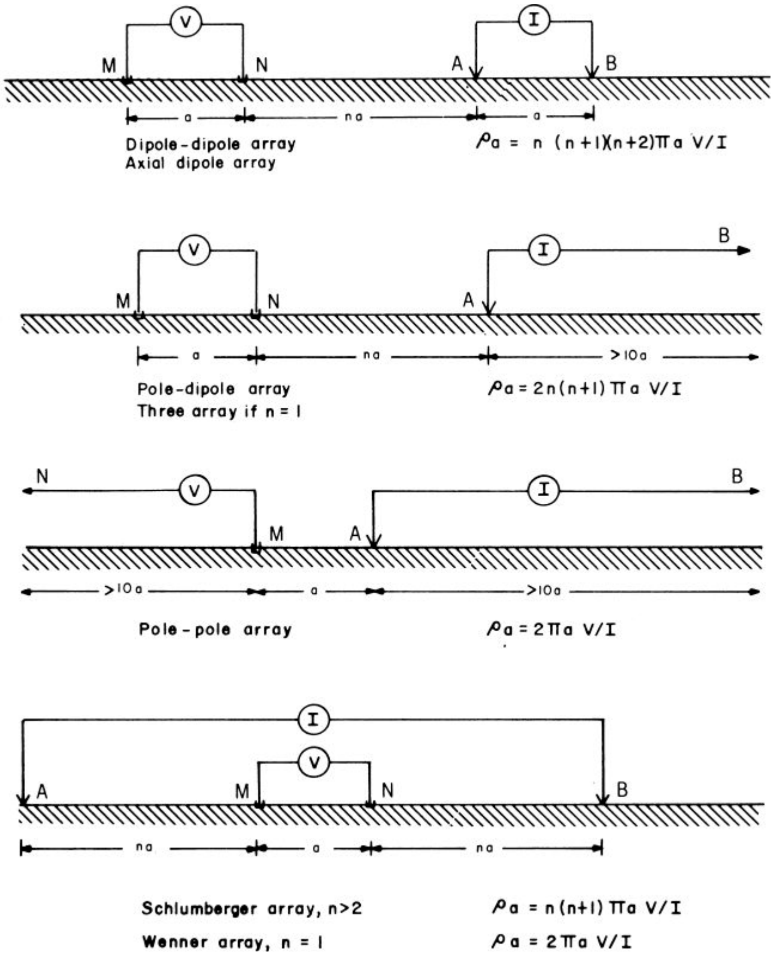


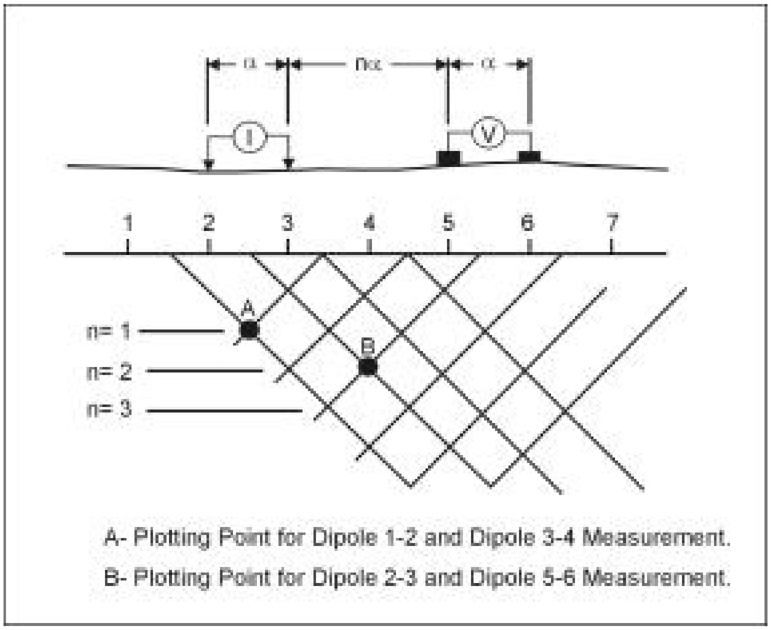
Figure 1: Resistivity array configurations showing from top to bottom, 1) dipole-dipole, 2) dipole-pole, 3) pole-pole, and 4) Schlumberger.

For the current study we utilized dipole-dipole array configuration, wherein current I is injected through two electrodes separated by a distance a, with the resulting voltage ΔV measured across two electrodes, also with a spacing a. The distance between the current and voltage electrodes is $n*a$, where n is an integer (see Figure 1), with the depth of investigation increased for larger values of n, a, or both.

For a homogeneous ground the resistivity can be calculated directly from the known current I, and measured voltage ΔV, along with an array factor p, which takes into account the type of array being used along with the electrode spacing. The same calculation can be used for an inhomogeneous ground, in which case we refer to the calculated value as the "apparent resistivity". For an inhomogeneous ground the apparent resistivities change for each electrode combination and represent our data. For the dipole-dipole the apparent resistivity is given by,

$$\rho_a = (n+1)(n+2)\pi a \Delta V/I,$$

where ΔV and I are the measured voltage, and injected current, respectively, with a and n as previously defined. The data are then displayed as a "pseudo resistivity" cross-section. Figure 2 illustrates how these data are arranged to generate a pseudo resistivity cross-section.



A- Plotting Point for Dipole 1-2 and Dipole 3-4 Measurement.

B- Plotting Point for Dipole 2-3 and Dipole 5-6 Measurement.

Figure 2: Location of apparent resistivity data points for a dipole-dipole array used in generating a pseudo resistivity cross-section.

Data were collected along four transects, as shown in Figure 3, using a dipole-dipole array configuration utilizing an 84 electrode AGI Super-Sting Ohm-mapper with cables having an electrode spacing of 5 meters. The first three transects span approximately 415 m, giving a combined distance of just over 1.0 km. The fourth transect, spanning 835 m, utilized 4 "roll-alongs", in addition to the original array, which spanned 415 m. The roll-along option entails moving the first of 4 sections of cable to the location of the original last section of cable, so that the length of the transect can be extended. The total length of the array however, remains unchanged at 415 m.

The location of each transect was determined using GPS along with the corresponding elevations which were obtained from a DEM. The elevation information is necessary for an accurate inversion of the data since elevation variations over short distances will affect the measured apparent resistivity. The topography along most of the first three transects was relatively constant but in some locations changed by up to approximately 8 m in undulating areas. Along transect 4 there is a dip of approximately 20 m as it runs along South Pond.

To generate the resistivity cross sections shown in Figure 4 and 5 a two-dimensional model is generated such that the resulting apparent resistivity is as close as possible to our measured data. This is accomplished using the inversion software RES2DINV (*Loke and Barker* [1995]). The final solution is obtained through an iterative process, which ceases once changes in the Root Mean Square (RMS) difference between the measured and calculated pseudo-sections meets some specified value. For this investigation iterations were stopped if the successive change in RMS was less than 1%.

III. Results

Figure 4 illustrates the final results and models of the three cross sections from phase 1 of the geophysics study. A fourth transect, shown in Figure 5, spans approximately 835 m in length and runs approximately parallel to Westpark Drive. To ensure consistency in our interpretation; the transects shown in Figures 4 and 5 utilize the same resistivity scale. Variations in resistivity, shown in Figures 4 and 5, result from differences in 1) the type of underlying material (grain size and texture), and 2) the water content. The general correlation is that low electrical resistivity is associated with fine-grained material (e.g. saturated silt and clay) and a high groundwater content. The Sand Lake aquifer system consists of sedimentary deposits of glaciofluvial origin and some glaciomarine origin. The result is a complex system of interbedded and interfingering lithologies of mixed grain size and sorting.

The transects shown in Figure 4 include the locations of wells on or near the cross-section lines. The first transect (shown as the blue line in Figure 3, and the upper panel in Figure 4), shows the location of two monitoring wells, denoted ASG2 and ASG3 (Brailey, [2014]). The low resistivity along this transect, shown as blue, are consist with the water depths indicated in the well logs. This transect confirms the physical water level measurements from the nearby monitoring wells indicating that in this region the ERT can effectively be used to denote the location of the shallow saturated zone (water table aquifer).

Transect 2 illustrates two shallow regions of low resistivity (blues) on the north and south ends. These correspond locally with shallow saturated regions that are probably underlain by thin lenses of saturated clay. Another low resistivity region occurs deeper (~30-40 m below land surface) near the mid to south end of transect 2. This pattern is consistent with the low resistivity regions seen in transect 1 and likely indicates saturated sediments. The locations of monitoring wells SL-3/SL-4D are also shown along this transect, however, because the ERT transect goes through this area on the edge the data are not as deep as the bottom of the monitoring wells.

Transect 3 illustrates a general shift from the lower electrical resistivity in transects 1 and 2 around the 30-40 m depth zone to higher average electrical resistivity (purple) in the most southern part of the study area. This trend could be due to shallow unsaturated course-grained (sand and gravel) deposits at this depth. Additionally there is a trend towards lower resistivity with depth below the purple regions indicating a shift to materials that are saturated. This is consistent with the water levels measured in this area which define the potentiometric surface from the wells that penetrate the deeper confined parts of the aquifer system.

Transect 4, shown in Figure 5, spans 830 meters in length and is located east of transects 1-3 along the east side of the south pond and west of Westpark Drive. The most prominent features along this transect are distinguished by a sharp contrast in resistivity at about 0 masl elevation that extends north-south along the transect. This contrast degrades in the vicinity of the south pond. Above the 0 masl elevation there are consistent north-south trending high resistivity materials which have similar resistivity at the same depth along transect 3 located to the west. This could be indicative of similar unsaturated geologic materials. Below the 0 masl elevation there is a low resistivity unit up to approximately 60 m in thickness as indicated by the green/blue colors. This area consists of saturated geologic materials and is very prominent in its lateral extent. To the south of the south pond above the 0 masl elevation there is a thick unsaturated zone which may be a “hydrologic drain” into the lower saturated zone, this can also be seen on the north side of the south pond as well. Note that in the area of the south pond the shallow low resistive units are missing at the 20-40 masl elevation. This material was likely removed during excavation from gravel mining in the past. It appears that the level of the pond my in fact be the exposed shallow groundwater table as all of the material below it is saturated.

IV. Conceptual Model and Conclusions

The ERT surveys for the Sand Lake area support the geologic and hydrogeologic framework developed by the UAA team and others. Primarily, the complex patterns of heterogeneity laterally and with depth are evident in the geophysical surveys. This work shows that where there are large data gaps due to the lack of wells we now have a basis for developing correlations in the geology and the hydrogeology to improve the conceptual model for the aquifer system. This work indicates that the ERT surveys can be used in the planning of locations of future monitoring wells because they give a general sense of the occurrence of saturated vs. unsaturated portions of the aquifer system, and information pertinent to the general stratigraphy.

V. Acknowledgements

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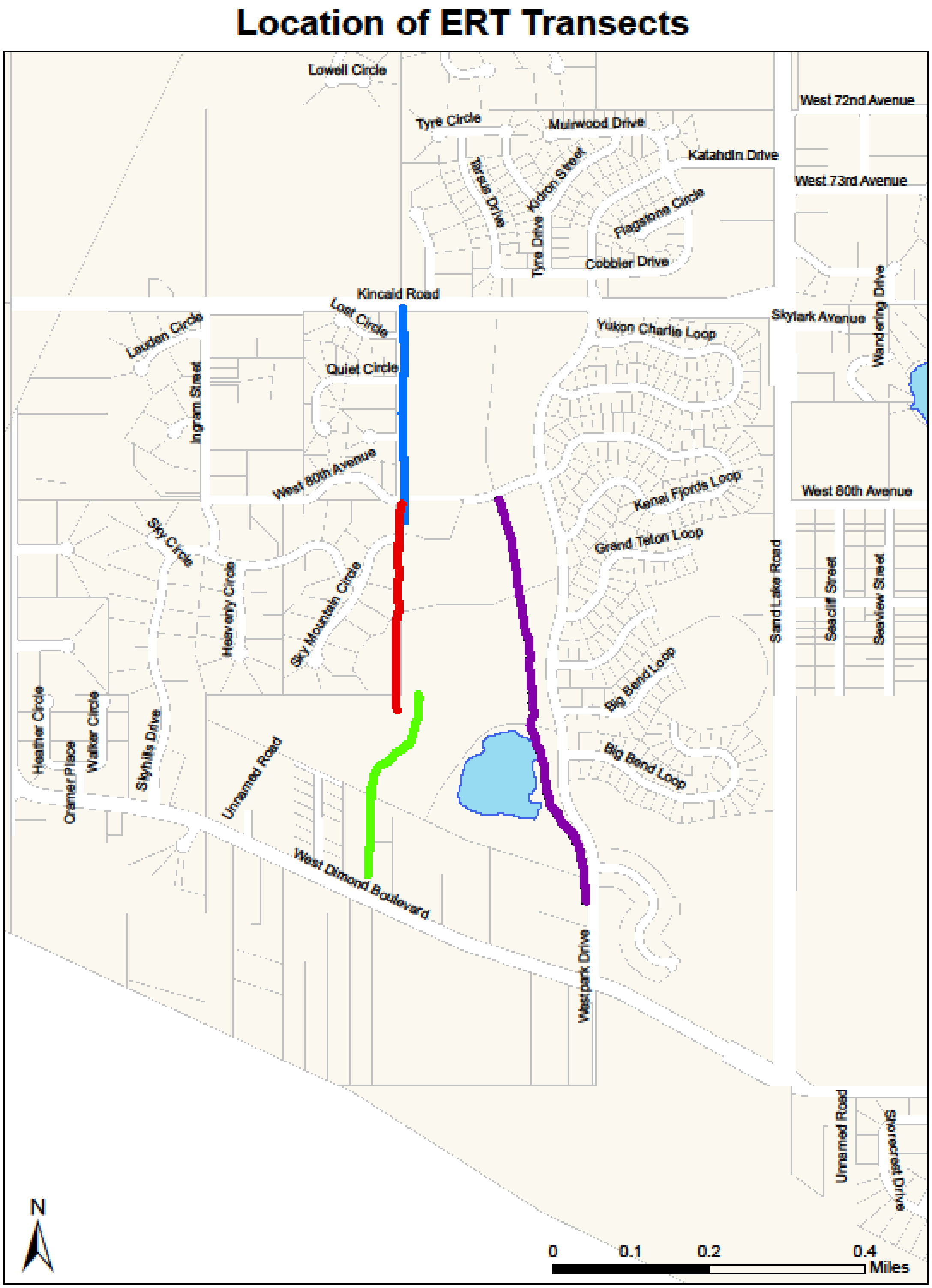


Figure 3: Sand Lake Map showing the location of transects 1through 4, shown in blue, red, green, and purple respectively.

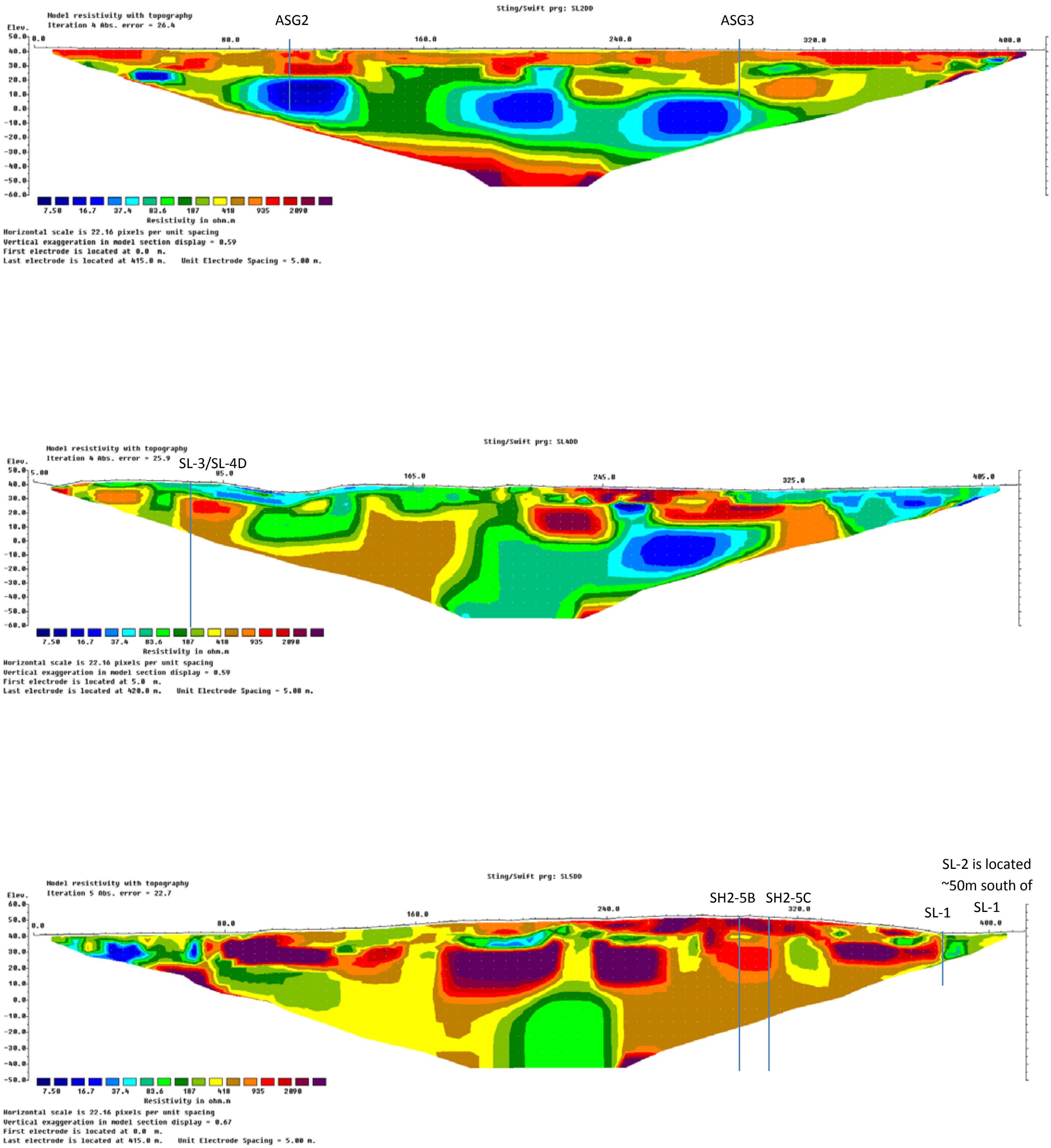
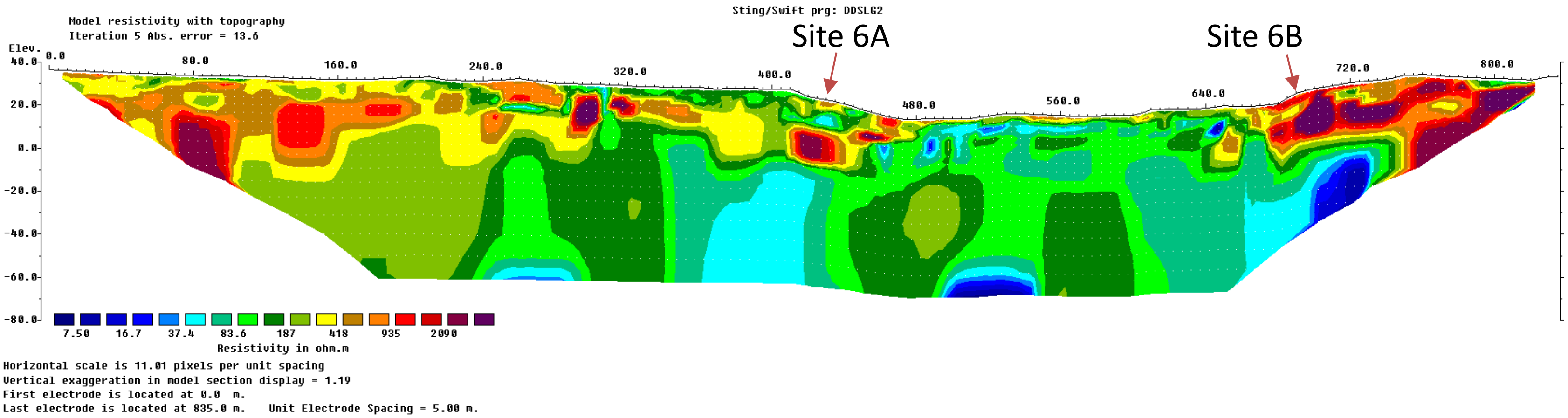


Figure 4: Resistivity cross sections along transects 1 through 3 (from top to bottom). Data were obtained using a dipole-dipole array configuration.



Horizontal scale is 11.01 pixels per unit spacing
Vertical exaggeration in model section display = 1.19
First electrode is located at 0.0 m.
Last electrode is located at 835.0 m. Unit Electrode Spacing = 5.00 m.

Figure 5: Resistivity cross sections along transect 4. Data were obtained using a dipole-dipole array configuration. The south pond is located at approximately 450 to 550 m on the horizontal scale. Proposed drill sited 6A and 6B are located along the transect.

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