Aerial Transient Electromagnetic Surveys of Alluvial Aquifers in Rural Watersheds of Arizona, United States

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INTRODUCTION

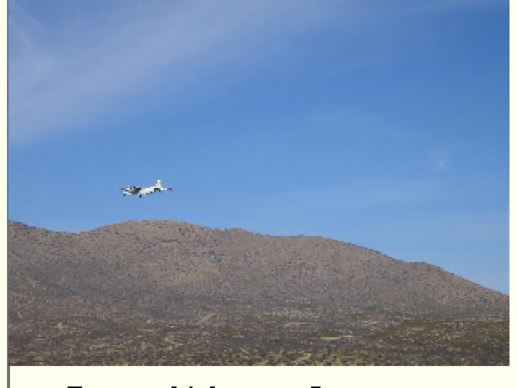
Several rural areas of Arizona are expected to experience increased development and water needs in the near future. Water supplies are poorly defined in these areas because of a lack of information available to describe the primary aquifer, which typically are alluvial basin deposits of varying lithology. A geophysical reconnaissance survey was initiated by the Arizona Department of Water Resources in cooperation with the USGS Arizona Water Science Center to help define the alluvial aquifer extent and lithology.

GEOTEM (Fugro Airborne Surveys) methods were chosen for the surveys because of greater depth of investigation in comparison to other methods and previous successful results in the Upper San Pedro Basin of southeast Arizona (Wynn and others, 1999). GEOTEM is a 30 Hz airborne time-domain electromagnetic (TEM) method (Fig 1). The fixed-wing system is capable of detecting major variations in electrical to depths a few hundred meters, which normally includes the productive portion of alluvial basin aquifers.

Surveys included about 2900 km of data along flight lines flown in the spring of 2006 (Fig. 1). Survey areas included the Willcox and Middle San Pedro Basins in southeast Arizona and the Detrital, Sacramento, and Hualapai Basins in northwest Arizona. Data were processed by Fugro to produce Conductivity Depth Transforms (CDT) along each flight line. CDT's approximate the subsurface distribution of electrical conductivity.

Additional modeling of the data was needed to better calibrate the depths and properties of electrical layers. The transient decay curves were modeled using EMIGMA software (PetRos Eikon, Inc) and subsurface control derived from drill logs, geophysical logs, water-levels in wells, and ground-based TEM surveys. Comparison of airborne and ground-based decay curves indicate that adjustment of signal amplitudes is required for some of the GEOTEM data. An example of the modeling is present here. The modeling process is currently incomplete, however, because the best way to treat the adjustment is yet to be determined.

Preliminary results indicate that the surveys delineated electrical layers within the alluvial aquifers including thick intervals of silt and clay (10 ohm-m) within less conductive sand and gravel intervals (10-100 ohm-m). Electrically resistive bedrock was detected below and adjacent to the aquifer in many areas.



Fugro Airborne Surveys GEOTEM system and CASA 212 aircraft

WAVE FORM and DATA SYSTEM

Briefly describe GEOTEM waveform and data collection system

figure showing waveform and data channels

figure showing example of data channels

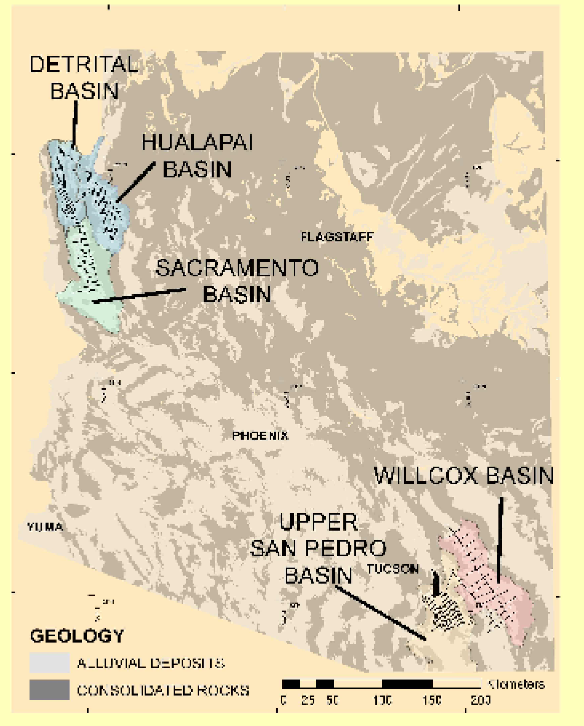


FIGURE 1. GEOTEM SURVEYS IN ARIZONA 2006.

PRELIMINARY RESULTS

Preliminary CDT results (FIG. 3) indicate that the surveys delineated electrical layers within the alluvial aquifers including thick intervals of silt and clay (about 10 ohm-m) within less conductive sand and gravel intervals (10-100 ohm-m). Electrically resistive bedrock was detected below and adjacent to the aquifer in many areas. The most conductive regions (1-10 ohm) are associated with the occurrence of evaporites (gypsum and halite) and poor quality water in parts of the Willcox, Detrital, and Hualapai Basins.

Examples of CDT's from two basins, **Middle San Pedro and Detrital**, display a representative range of conditions found among the surveyed areas. The greatest flight line density was flown in the Middle San Pedro Basin. A lower density of lines was flown in Detrital Basin to acquire reconnaissance information across a large area.

The CDT's in the **Middle San Pedro Basin** show the spatial extent of the electrically conductive alluvial aquifer (yellow to red) within the bounding regions of electrically resistive crystalline rocks and Paleozoic limestone (green and blue). Subsurface data from drill logs corroborate the general distribution of electrical resistivity. The distribution of electrical properties is primarily caused by variations in the electrical properties of the rocks because water in the basin is of generally good quality. Regions of thin alluvial aquifer are indicated by shallow depths to electrically resistive rock in the southern and northern parts of the survey area. An extensive region of electrically conductive silt and clay (red to violet) occurs in the central and northern part of the survey area.

The distribution of electrical properties in the **Detrital Basin** is more complex than in the Middle San Pedro Basin because, in addition to alluvial aquifer, electrically conductive regions (yellow to red) include older sediments and volcanic rocks and poor quality water associated with evaporites. Electrically resistive granitic and metamorphic rocks occur in places on the basin margins. Extensive electrically conductive regions (red) occur both in the alluvial basin and in areas of volcanic rock along the basin margin. Highly electrically conductive regions (violet) occur in the northern part of the basin and greatly limit the depth of investigation. Exploration holes verify the occurrence of evaporites and poor quality water in these highly electrically conductive regions.

MIDDLE SAN PEDRO BASIN

DETRITAL BASIN

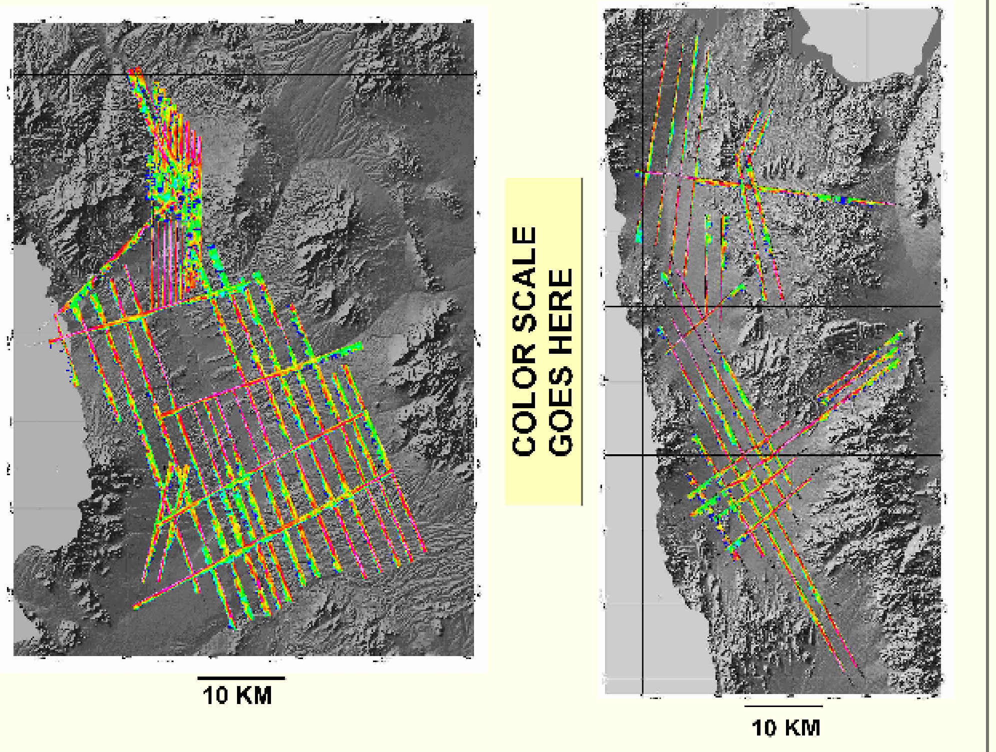


FIGURE 2. CDT maps of the Middle San Pedro and Detrital Basins.

1-D MODELS OF GROUND AND AIRBORNE DATA

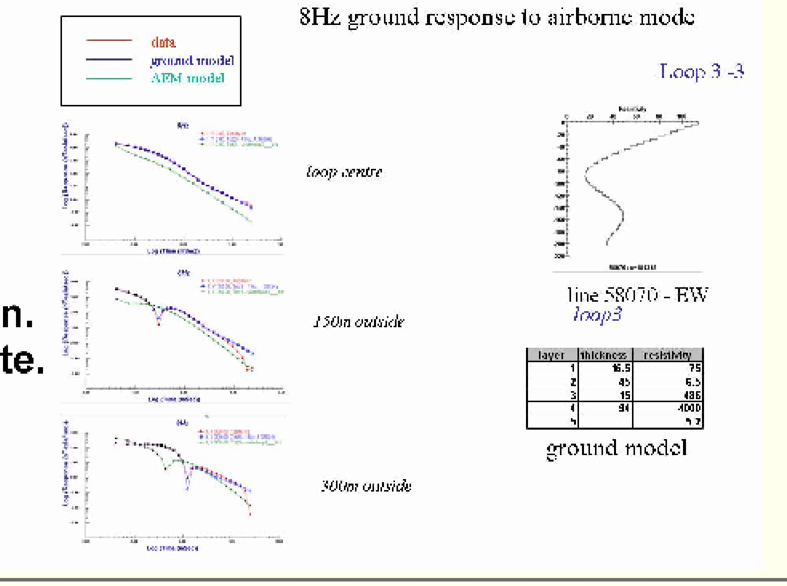
Co-located ground and airborne data offers an excellent opportunity to compare the structural resistivity interpretation from ground and airborne data. The ground data was collected at 9 stations using a square loop transmitter with a size 150m on an edge at a base frequency of 8Hz with 28 data channels. Ground measurements were made at 9 stations – one at the centre of the loop and 4 at 150m from the centre of the loops towards each cardinal direction and 4 at 300m from the centre of the loop again in each cardinal direction. Collection of the ground data in 4 directions and at 3 different offsets from the loop center would indicate to what extent the ground was one-dimensional.

The approach to determining resistivity-depth structure was to use several one-dimensional inversion strategies. Provided the structure is reasonably one-dimensional, stacking (averaging) the data for a given offset will reduce both geological and system noise. The intent is to derive one model that fits the stacked data at all offsets. A model which fits only the in-loop measurement is not adequate as the wider offset data provides more depth resolution for the model.

GEOTEM data includes 2 data components – the vertical, Hz and the horizontal Hx data. The first 5 channels are collected during the primary field transmission and not suitable for simulation purposes. Only the last 15 channels are used.

**Ross- I have very generally outlined this section.
Feel free to insert whatever you think appropriate.
Do you have a better ground/GEOTEM site
that compared better ?
Sites in south San Pedro area ??**

Briefly describe 1-d models of ground and GEOTEM data at a representative site.



layer	thickness	resistivity
1	16.5	75
2	45	6.5
3	15	486
4	94	4000
5		[illegible]

Briefly describe 1-d model of representative GEOTEM profile