APPLICATIONS FOR CAPACITIVELY COUPLED RESISTIVITY SUVREYS IN FLORIDA

K. Michael Garman and Scott F. Purcell, Subsurface Evaluations, Inc.

Abstract

The use of capacitively coupled resistivity (CCR) as a geophysical method has historically been of limited use in Florida due to the shallow water table and the time necessary to make multiple passes to collect resistivity data at depth. The induced current used by CCR instruments is stronger and can penetrate to greater depth if the surface materials are resistive, because the voltage measured at the receiver equals the current in the transmitter multiplied by the resistivity of the earth materials. The presence of shallow groundwater increases conductivity thereby reducing the CCR signal strength. The availability of a multi-channel CCR instrument, the Ohm-Mapper by Geometrics, Inc. has eliminated the need for multiple passes for a study. Subsurface Evaluations, Inc. has investigated two applications for multi-channel CCR surveys in Florida:

1. CCR has been successfully used to delineate buried depressions in sandy upland areas producing results remarkably similar to ground penetrating radar (GPR) data but easier to interpret; and
2. CCR has been successfully tested on road projects for identifying shallow deleterious soil conditions such as clay and peat lenses that might be missed by a standard drilling program and that are not readily detectable by GPR.

Introduction

In Florida, geophysical surveys for geotechnical engineering applications are usually performed by ground penetrating radar (GPR). Such surveys are typically limited to a maximum depth of about 4.5 to 9 meters (15 to 30 feet) due to attenuation of the signal by the shallow water table common in most of Florida. Despite the limited depth of penetration, GPR is widely used because:

- The profiles generally show enough subsurface structure to identify buried depressions and other possible karst erosion features;
- GPR surveys can be performed quickly (1.6 to 4.8 kilometers per hour or 1 to 3 miles per hour) and economically; and
- The GPR profiles can be read and analyzed in real time by an experienced operator without processing.

In addition to the limited depth of penetration, GPR surveys do not provide information on the densities or compositions of the subsurface materials. Conventional multi-electrode resistivity (MER) surveys generally have depths of penetration of 30 to 61 meters (100 to 200 feet) and provide information on subsurface material composition based upon the calculated true resistivity values; but the data must be processed to produce a geologic cross section for interpretation. The data collection using MER is much slower at 30 to 152 meters per hour (100 to 500 feet per hour) and more costly compared to GPR.

Historically capacitively coupled resistivity (CCR) has been of limited use in Florida due to the shallow water table and the time necessary to make multiple passes to collect resistivity data at depth. However, the availability of a multi-channel CCR instrument, the Ohm-Mapper manufactured by Geometrics, Inc., represents an effective compromise between the relative high speed and low cost of GPR with information on material composition provided by resistivity surveys. The multi-channel CCR survey can be performed at a speed of 1.6 to 4.8 kilometers per hour (1 to 3 miles per hour) comparable to GPR. Although the data must be processed to create a geologic cross section, the cross section provides information on the materials present based upon resistivity. Like GPR, the presence of shallow ground water and conductive materials limits the depth of signal penetration.

Subsurface Evaluations, Inc. (SEI) recently tested multi-channel CCR for the following applications in Florida:

1. To delineate buried depressions in sandy upland areas producing results remarkably similar to ground penetrating radar (GPR) data but easier to interpret; and
2. To identify shallow deleterious soil conditions such as clay and peat lenses along proposed road projects.

Methods and Equipment

CCR is a geophysical method of obtaining a virtual cross-section of subsurface soil and rock layers. It consists of two separate steps: 1) measuring the apparent (weighted average) electrical resistivity of the ground over numerous stations using a towed array; and 2) computerized processing of apparent resistivity data to obtain a virtual cross-section of estimated true resistivity values.

In the field, an AC current is coupled into the earth by a transmitter and measured by receivers that are positioned one behind the other in a towed array (Figure 1). Up to four receivers may be used in the array to collect data from four different dipole spacings simultaneously (Figure 2). Geometrics, Inc., of San Jose, California, manufactures the Ohm-Mapper unit, which was used in this study.

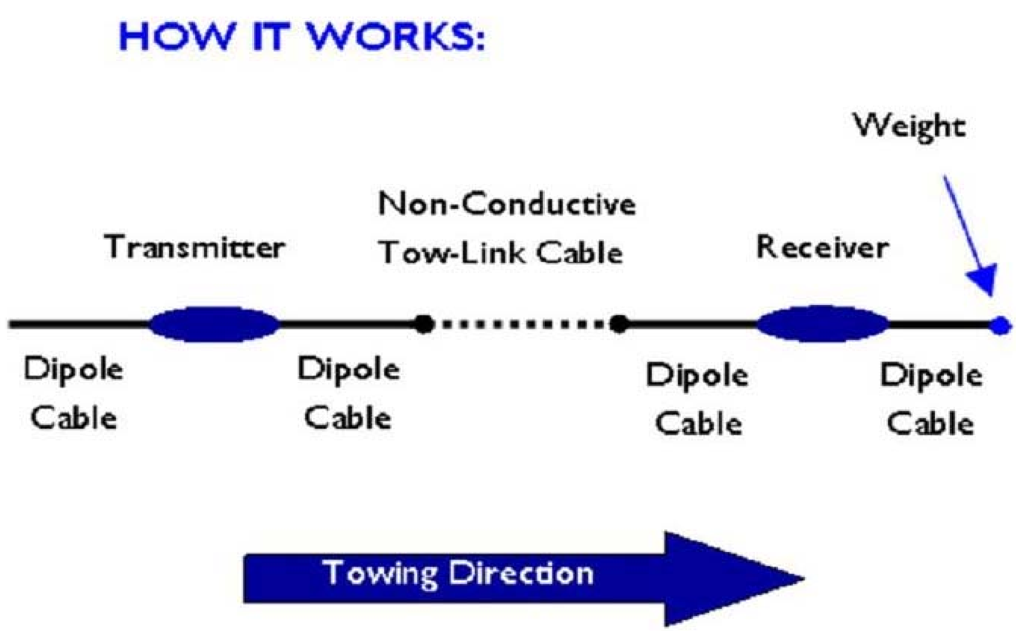

Figure 1.: Schematic of Ohm-Mapper System

Figure 2.: Survey along a roadway using a four-channel Ohm-Mapper.

The induced current used by the Ohm-Mapper is stronger and can penetrate to greater depth if the surface materials are resistive as the voltage (V), which is measured at the receiver, equals the current in the transmitter (I) multiplied by the resistivity of the earth materials (R) between the transmitter and receiver, V = IR. Therefore, for a given transmitter current (I), if the resistivity (R) is low, the voltage (V) will be low. If the voltage is too low, it cannot be distinguished from background noise and no data will be collected.

Array Type

The Ohm-Mapper collects data using a dipole-dipole array, which provides high lateral resolution. The distance between the dipoles and the lengths of the diploes are adjusted to collect apparent resistivity readings from different depths. The longer the dipole and spacing configuration, the greater the depth of the survey as the depth from which data is collected is equal to about 15 percent of the total dipole and spacing length.

Surveys

University of South Florida

The University of South Florida is located northeast of Tampa in the Gulf Coastal Lowlands physiographic area. The University of South Florida campus is an area of active sinkhole development with 112 new sinkholes reported within the 2 square mile campus since 1964. Therefore, geophysical surveys are performed to identify potential buried karst features prior to new construction. The relatively thick surficial sands (about 9 meters or 30 feet) and relatively deep water table (3.6 to 5 meters or 12 to 16 feet) represent good conditions for GPR and CCR surveys.

In order to test the potential effectiveness of CCR at this site, SEI performed GPR and CCR surveys over the same transect. The GPR survey was performed as part of a predevelopment site evaluation. A GPR transect with several distinct potential karst features was selected to be re-surveyed using CCR. The two profiles were remarkably similar as shown on Figure 3.

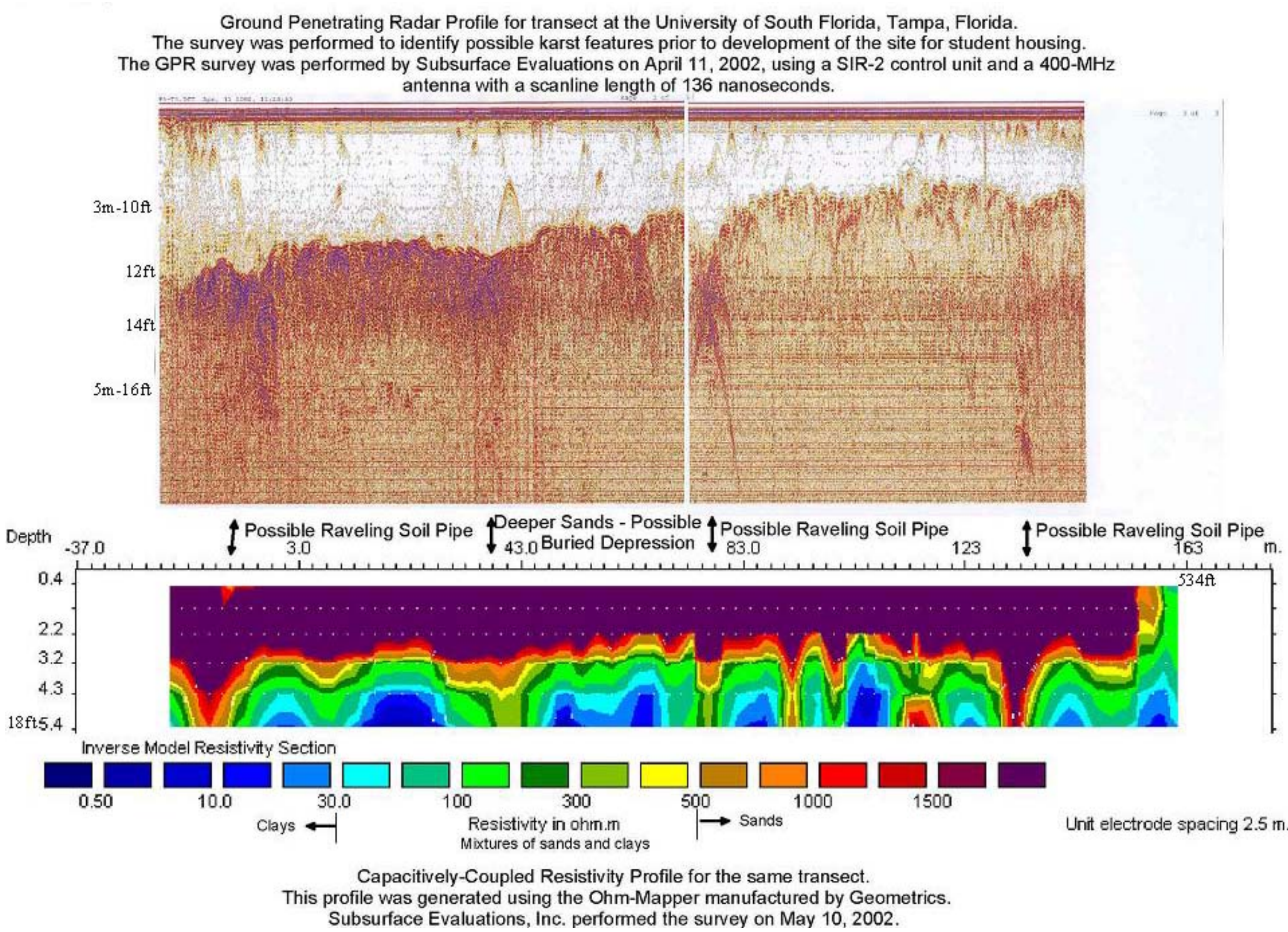

Figure 3.: Comparison of GPR and CCR profiles from University of South Florida, Tampa, Florida.

South Florida

Along the Caloosahatchee River in South Florida, SEI performed 27 miles of MER survey to evaluate the continuity of clay layers to evaluate the site for use as a reservoir. The MER survey was very successful and resolved features to depths in excess of 61 meters (200 feet). Test scanning with GPR showed that no geologically useful results were obtained in the area, which was very conductive from long term usage as an orange grove. Test lines performed with CCR were able to resolve profiles to a depth of about 6.7 meters (22 feet) (Figure 4). The CCR was able to model the top of a clayey conductive layer and provide some information about the continuity of the layer. However, CCR could not discern the thickness of the conductive layer because the depth of penetration was limited by the high conductivity.

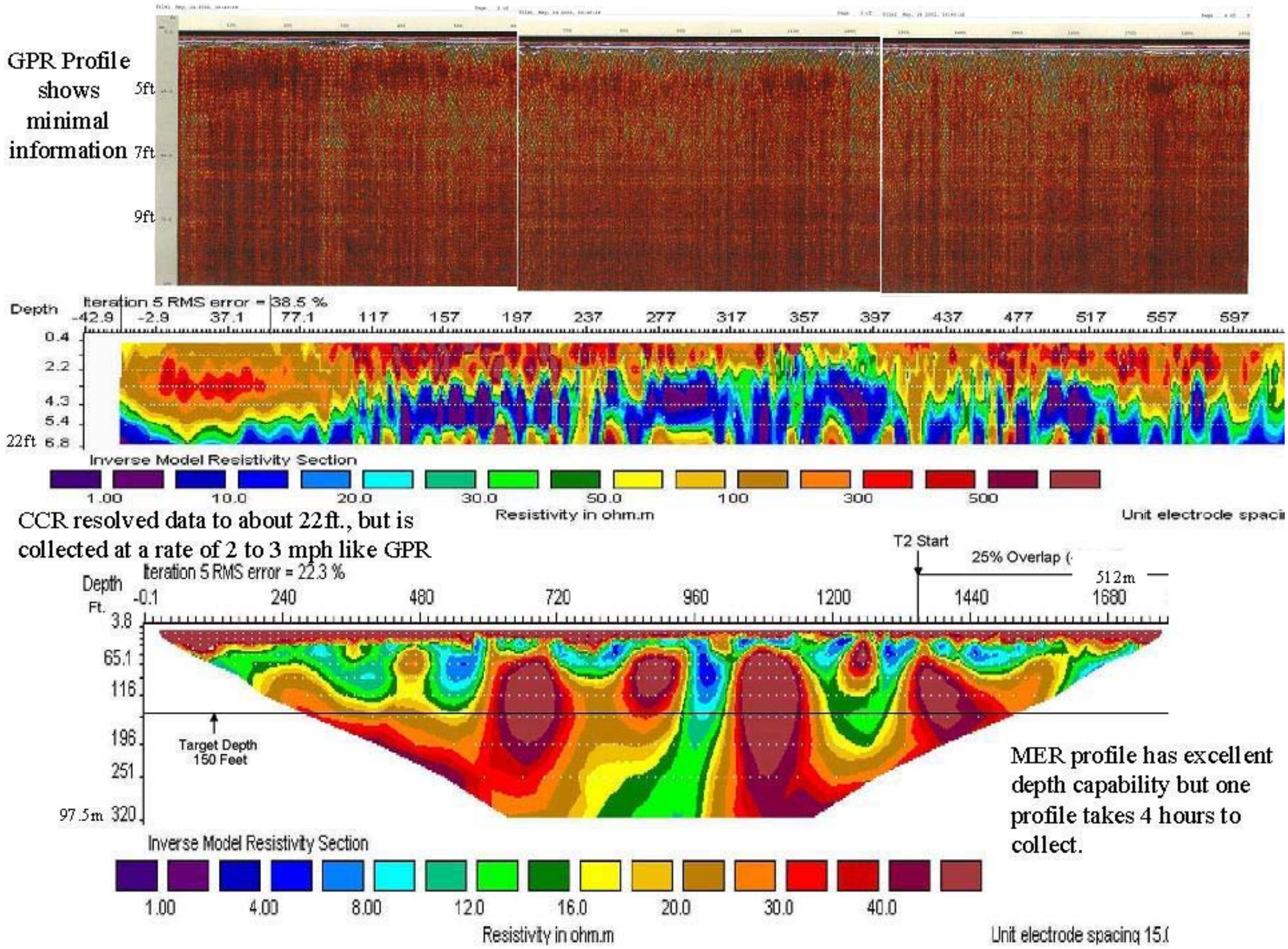

Figure 4.: Comparison of GPR, CCR, and MER profiles from South Florida.

Tampa Area

The CCR method was evaluated as a method to identify and map shallow peat and clay deposits that might adversely affect road projects. This project was ideally suited to the capabilities of the CCR method as it involved material identification based on resistivity and the depth of interest was between the ground surface and a depth of about 6 meters (20 feet). In this application, the CCR was able to identify conductive materials consistent with clay deposits and abrupt changes in resistivities consistent with possible peat deposits and karst features (Figures 5 and 6).

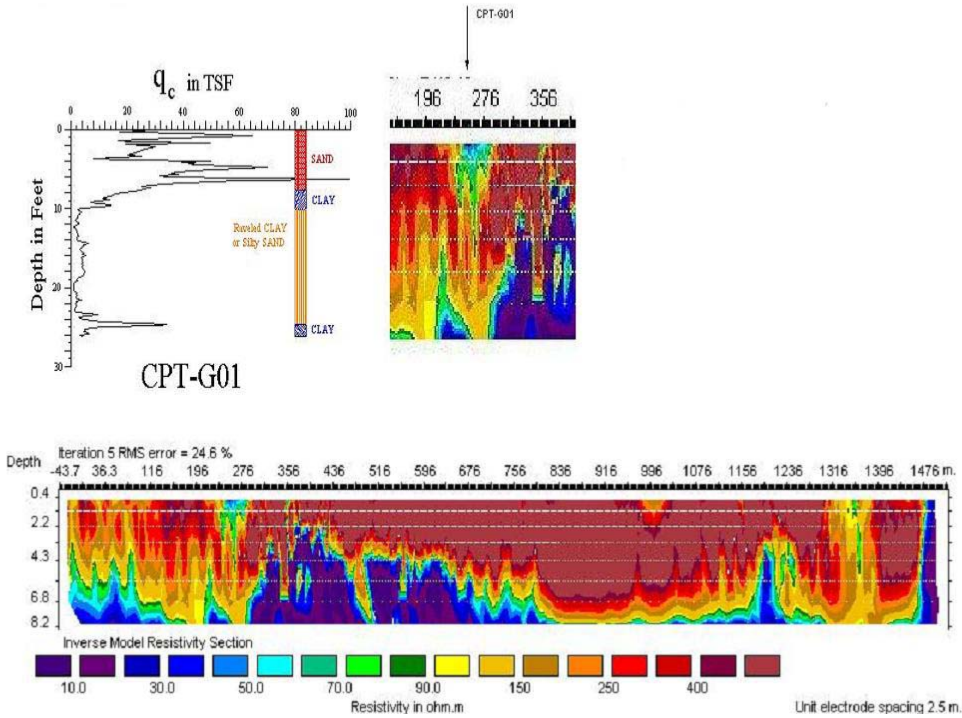

Figure 5.: CCR profiles along road with settlement problems showing piezocone results from an anomalous location.

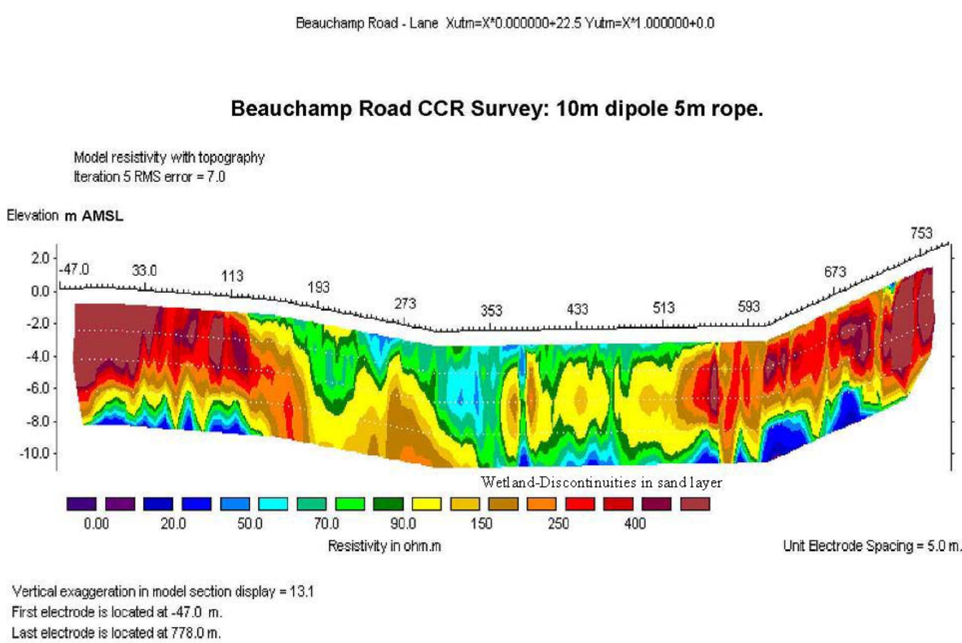

Figure 6.: CCR profile showing changes in subsurface resistivity values across a wetland.

Summary and Conclusions

In Florida in areas with relatively thick surficial sands, the CCR method is very effective for identifying and delineating buried karst features. The CCR profiles are very similar to GPR profiles. Although the CCR profiles must be processed before they can be interpreted, the CCR profiles are easier to interpret. The two surveys proceed at the same speed; but the long straight lines required for CCR make it less useful on small sites.

In low lying and wetland areas, the CCR method has proven to be very effective for identifying shallow clays and peat deposits. In this respect, CCR was far superior to GPR. The CCR is ideal for road projects where the depth of geotechnical investigation is limited to about 20 feet. CCR is also applicable to borrow sites at which shallow clays are needed to construct dams or dikes. For these surveys, the ability of the method to identify clayey materials based on resistivity make it more useful than GPR and the speed makes it more economical than MER. However, if the thickness of a highly conductive layer needs to be evaluated, CCR may not be able to obtain these data if the conductive layer is over 9 meters (30 feet) deep and/or is greater than 3 meters (10 feet) thick.