CHAPTER 1 – INTRODUCTION

1.1 PROBLEM DESCRIPTION

The presence of swelling clay beneath roadways poses a significant problem to road rehabilitation design and construction. Clays may occur in various geological settings including dipping seams and within flat alluvium seams. Roads constructed over areas of clay are generally subjected to potential differential settlement due to volume changes caused by swell/shrink and low shear strength of the clay resulting from high moisture content. Current practice methods for locating clay seams and sampling typically involve the use of intrusive soil boring through the road pavement, and in some instances involve test pits. Although direct soil sampling provides the best information in terms of soil type and Atterberg Limits of Soils, it is limited. This limitation is that the analysis of the soil sample is only valid for that particular boring location. Due to the great distance between boring locations (typically at 0.8 or 0.4 km (0.5 or 0.25 mi intervals)), interpolation of the geology between borings may not be representative of actual subsurface conditions. More importantly, the potential is great for missing expanses of clay that may be present between borehole locations.

Thus, there is a need to map clays beneath roadways in order that accommodation may be made during the planning stage. The frequency domain EMI geophysical method may have economic potential to rapidly and accurately locate clay seams in various geologic settings. If the deployment of this method proves successful, then it can be used to fill the gaps between the soil sampling locations, and assist in focusing the soil sampling program in areas with the greatest risk for clay problems.

1.2 OBJECTIVES

The main purpose of this multi-phase program was to demonstrate the effectiveness of the EMI method as a state-of-practice geophysical imaging tool for mapping the presence of clay seams beneath roadways. Specifically, the purpose of Phase III was to acquire geophysical and geotechnical data along a 13-km (8-mi) stretch of SR537, Rio Arriba County near Dulce, New Mexico. The results obtained form the multi-phase demonstrations lead to a full scale deployment of the EMI method for mapping clay-rich zones along 55 km (34 mi) stretches of roadway at Natchez Trace Parkway, Mississippi. The overall objectives of this program were to:

- Evaluate the performance of various EMI instruments in locating and defining the presence of high plasticity clay seams by measuring the bulk electrical conductivity of the subsurface.
- Demonstrate the effectiveness of the EMI instruments in providing: a) continuous data collection; and b) complete coverage of the surveyed road area.
- Applying the geophysical data to traditional FHWA geotechnical exploration practices to facilitate the reduction of drilling and sampling locations.
- Evaluate empirical relationships between measured geophysical parameters (e.g., bulk conductivity) and Atterberg Limits of Soils (e.g., plasticity index).

- Demonstrate the usefulness of EMI method as an exploration tool to provide continuous plan and profile (P & P) images over the entire length of surveyed roadway.
- Demonstrate the engineering benefits of the EMI method as a production tool to rapidly and accurately identify and locate clay seams beneath long stretches of roadway.

1.3 GEOPHYSICAL PROGRAM OVERVIEW

Blackhawk, a division of Zapata Engineering, in coordination with the FHWA-CFLHD conducted multi-phase surface geophysical investigations using various EMI instruments on SR537, Rio Arriba County, near Dulce, New Mexico. Phases I and II of the subsurface imaging program, using EMI techniques measuring the bulk electrical conductivity of the subsurface, were completed under separate contracts in 2001 and 2002, respectively. Reconnaissance-level surveys along a 16-km (10-mi) stretch of SR537 comprised the Phase I investigation (figure 1). Phase I was performed between milepost (MP) 45 and 55. A more detailed set of geophysical data was acquired under Phase II from MP 47 to 50. Additionally, under Phase II, geotechnical data were obtained from CFLHD and correlated with the geophysical results. Phase III presents the deployment of the new Geonics EM31-3 instruments, field and analysis methods, and geotechnical correlation and presentation of the geophysical data in the P & P format.

The following sections provide a summary of the geophysical surveys, and the most significant results and conclusions obtained from Phases I and II using various EMI instruments and techniques. This report details Phase III and provides a summary of the full-scale production survey conducted over Natchez Trace Parkway in Mississippi.

1.3.1 Summary of Phase I

Phase I surveys were conducted between September 26 and 30, 2001. The Phase I geophysical survey covered a length of road of about 16 km (10 mi). Survey measurements were obtained on both north- and south-bound lanes from approximately mile marker MP 45.5 north to the intersection with U.S. 64, just north of MP 55 (figure 1).

Phase I survey results were presented in a Blackhawk GeoSciences report, dated November 2, 2001. Summarizing the Phase I investigation, the survey provided the following general results and conclusions:

- A rapid electrical resistivity profiling method using the Geometrics Ohm-mapper was not successful for mapping clay in the roadbase because of the generally conductive soils at this site and the type of capacitive electrode coupling this system employs.
- Field techniques were developed with existing EMI survey instruments to acquire data tied to GPS surveying using a towed array system. EMI terrain conductivity meters showed good resolution of the lateral variations in soil conductivity, which was relatively correlated to the presence of clay in the road base. Field activities must be coordinated with local construction activities to avoid dangerous traffic conditions and maintain crew safety.

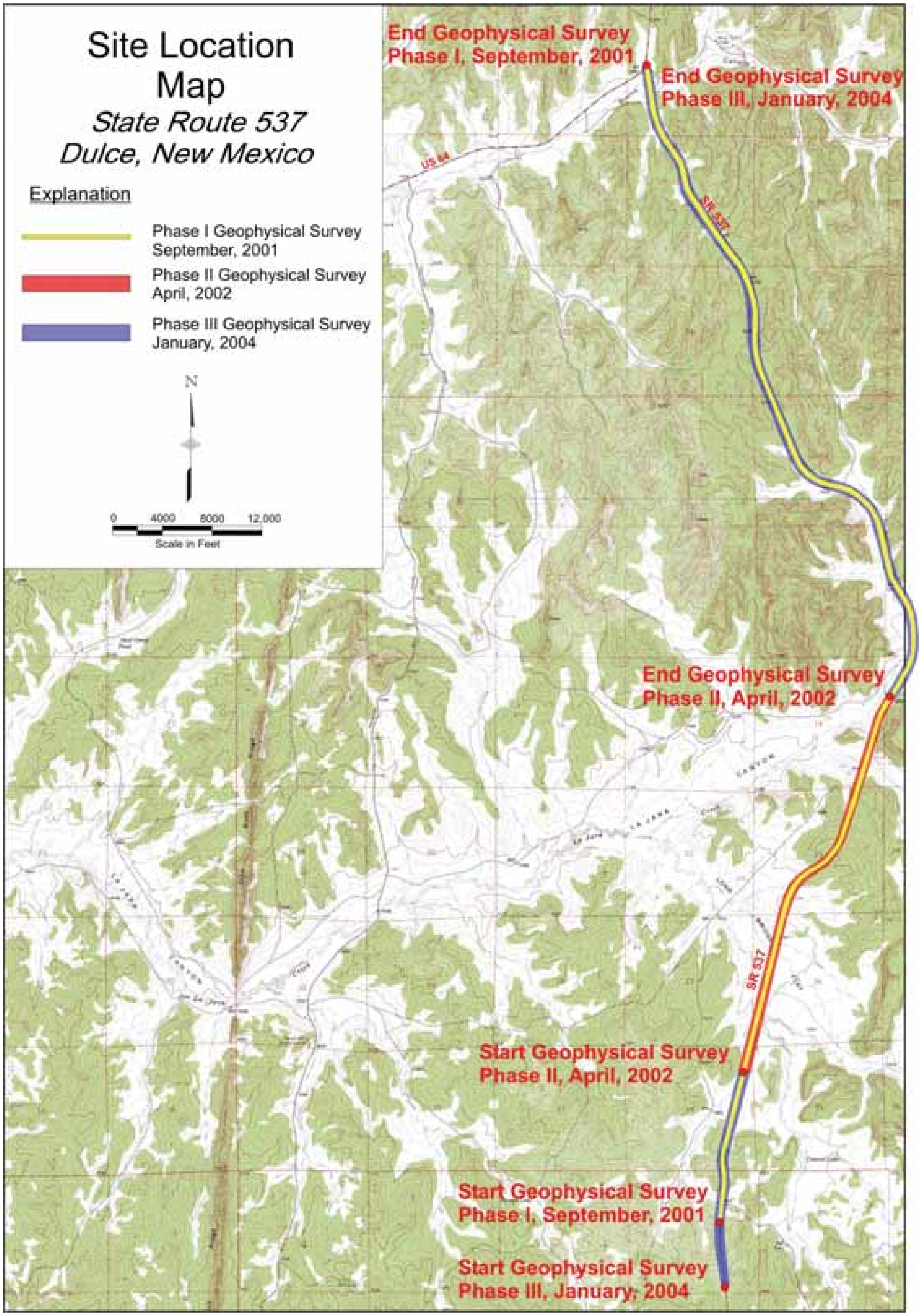

Figure 1. Map. Site Location Map.

- Close cooperation between the geotechnical engineers and our geophysicists is required to determine if any correlation exists between geophysical data and soil properties needed for highway design.
- Limited success was achieved to resolve the vertical section (profile) below the roadbase because of insufficient sampling directly caused by logistical problems and time constraints.

It was concluded from the Phase I investigation that frequency-domain EMI profiling would be the only cost-effective, rapid method capable of mapping, in sufficient detail, the lateral extent of conductive soils in the road base over the 16 km (10 mi) of survey area. Additionally, the conductive soils as defined by the EMI data were generally correlated spatially with the limited number of samples available from a 1989 geotechnical investigation along this 16-km (10-mi) stretch of roadway. However, defining the vertical profile of the upper 2 to 3 m (6.6 to 10 ft) of roadbase proved to be too difficult without additional terrain conductivity data from additional dipole (coil) orientations and coil heights and spacings above the road. The findings from Phase I clearly indicated what additional data would be required to resolve clay materials beneath the road, in plan as well as in profile; thus, a follow-up Phase II investigation was proposed.

1.3.2 Summary of Phase II

Phase II surveys were conducted between April 21 and April 23, 2002. The survey was purposely confined to a short section of SR537 between MP 47 and 50 (figure 1). This 5-km (3 mi) stretch was currently under design by FHWA-CFLHD; therefore the geophysical data were acquired to potentially assist with design. Also, if the objectives of the study could be met, it would provide support to the existing set of geotechnical data.

A well-defined set of objectives was established for Phase II.

- Acquire sufficient EMI geophysical data to provide more resolution in plan and section.
- Recommend geotechnical lab testing on specific samples, and potentially recommend areas where additional sampling should be conducted.
- Procure any and all surficial soil and geologic data (e.g., soil conservation service and USGS, respectively) that can be superimposed on the area of investigation.
- Establish empirical correlations between the EMI induction data and the Atterberg Limits of soils laboratory results – if practical.
- Create a manner to prioritize areas of interpreted clay-rich soils of concern for design and/or construction based on correlation of all the data.
- Produce the geophysical/geological results in P & P format.

Phase II demonstrated that a useful geo-electric section could be acquired and integrated into the P & P engineering drawings. Additionally, Phase II demonstrated evidence of a correlation between EMI measured conductivity and Atterberg Limits of soils laboratory results, such as PI. This correlation should provide an effective means of prioritizing areas of concern for clay-rich soils.