CHAPTER 7 – CASE STUDY – NATCHEZ TRACE PARKWAY

7.1 INTRODUCTION

Blackhawk performed a production surface geophysical survey using the Frequency Domain EMI method from March 9 through March 12, 2004. The geophysical survey was conducted from MP8 to MP20 and from MP37 to MP59 along the Natchez Trace Parkway in Mississippi resulting in a total of 54.7 km (34 mi) of roadway surveyed (figure 8). Apparent conductivity maps were produced for the surveyed area. These maps were used by Eastern Federal Lands and Highway Division (EFLHD) to aid in the soil-boring program for locating clay-rich zones in the subgrade of the road that is planned for rehabilitation.

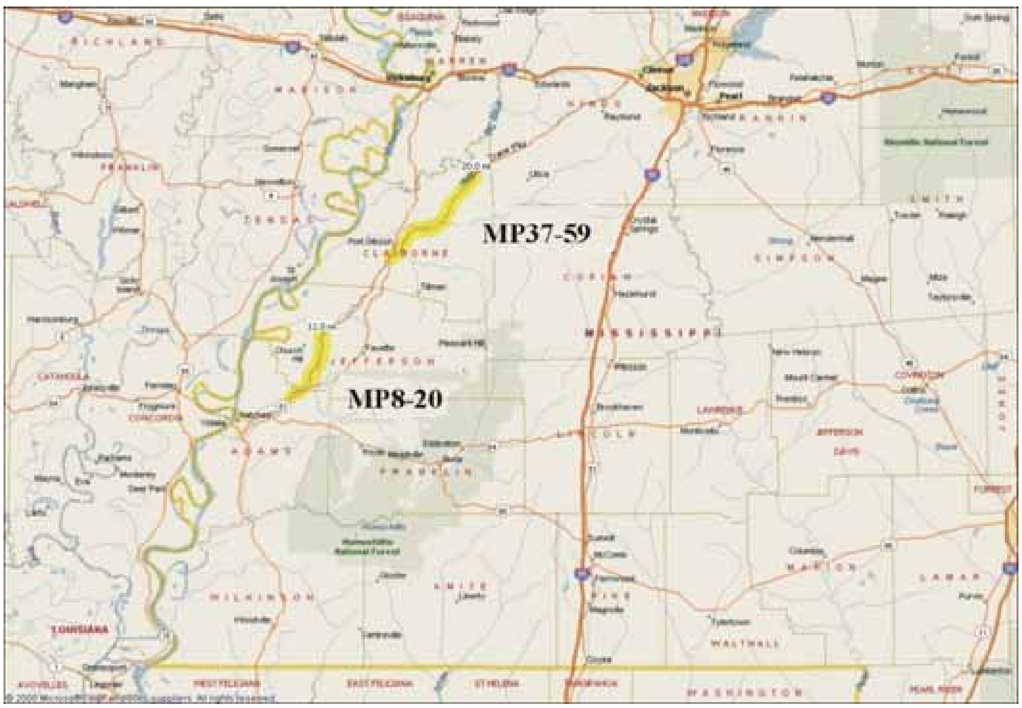

Figure 8. Map. Natchez Trace Parkway Site Map.

7.2 GEOPHYSICAL METHODOLOGY AND INSTRUMENTATION

The surface geophysical survey was performed using a state-of-the-practice instrument, the Geonics Limited EM31-3, a frequency domain electromagnetic induction data acquisition system. This instrument is an upgrade from the standard EM31 MK2. The EM31-3 has a transmitter coil in vertical dipole mode (with the plane of the coils parallel to the ground surface) operating at a frequency of 9.8 kHz. In addition to the standard EM31 MK2 single 3.66 m (12 ft) receiver coil spacing, the EM31-3 has two additional vertical dipole receiver coils spaced 1 m (3.28 ft) and 2 m (6.56 ft) from the transmitter coil. This allows for the acquisition of three separate data sets simultaneously, each measuring the apparent conductivity to a different effective depth below grade. The EM31-3 was mounted onto a specially built tow cart that was constructed with a minimal amount of conductive materials and no ferrous metal materials, thus minimizing its influence on the data. A GPS receiver was mounted above the midpoint between the transmitter coil and the 1 m (3.28 ft) receiver coil. The array is towed using a diesel powered Kawasaki Mule ATV. The EM31-3 mounted on the tow array attached to the ATV is shown in figure 9.

Figure 9. Photo. EM31-3 and ATV on Natchez Trace Parkway.

7.3 DATA ACQUISITION

Data from the EM31-3 and GPS were logged on a Juniper Systems Allegro data logger running the Multi31 acquisition software developed by GeoMar Software Inc. The array was towed at a nominal speed of 16 km/h (10 mph). The data logger recorded the EM31-3 data at 5 Hz and the GPS data at 1 Hz. This provided a nominal EMI data density of about 1 m (3.28 ft) and a nominal GPS data point spacing of about 4.5 m (14.8 ft). Two passes were recorded for each mile of road surveyed with one pass in each traffic lane in the same direction as the flow of traffic.

Data acquisition coverage averaged about 13.7 km (8.5 mi) of roadway per day (27.4 km (17 mi) of linear profile per day) and required four field days to complete the 54.7 km (34 mi) of roadway. At the end of each field day, the data were edited and uploaded to Blackhawk's FTP site along with the transcribed field notes for subsequent processing in the Golden, Colorado office. This was done to decrease the turnaround time necessary to produce preliminary draft maps to aid EFLHD's drilling program. The data was used to determine drilling locations. A small number of soil samples were obtained by EFLHD and the clay content of these samples compared well with the conductivity data.

7.4 DATA PROCESSING

The proprietary Multi-Sensor Towed Array Detection System Data Analysis Software (MTADS DAS) was modified to accept the EM31-3 data. This program has better capabilities than the standard processing programs (Oasis montaj) for editing and correcting GPS problems. After position corrections were applied, the data were exported as a file containing the conductivity data and associated spatial coordinates (XYZ grid file) and uploaded into Oasis montaj written by Geosoft Inc., to grid and display the data, and overlay the mapped cultural features (i.e. MPs and bridges). The data were then exported from Oasis montaj and imported in AutoCAD where the geophysical maps were integrated with the basemaps provided by EFLHD.

No interval conductance modeling was performed on the data.

7.5 GROUND TRUTH

To provide ground truth information, 41 locations (15 between MP8 and MP20 and 26 between MP37 and MP59) were selected from the geophysical data for soil boring sampling and analysis. An EFLHD geotechnical crew collected the soil borings. Laboratory tests, including gradation analysis, Atterberg limits, natural moisture content, and soil classification were performed on representative soil samples.

7.6 RESULTS

7.6.1 Analysis of Geophysical Results

Color contoured plan views of the apparent conductivity for all three coil separations were overlain on the roadway alignment maps provided by EFLHD. An example of this is shown in figure 10. The color-coded scale of the apparent conductivity, ranging from ≤ 20 milliSiemens/meter (mS/m) to ≥ 80 mS/m, is used to show the potential presence of clay zones under the road. For example, the apparent conductivity of 20 mS/m (in dark blue) is indicative of less clay potential, and the apparent conductivity of 80 mS/m (in pink) is indicative of greater clay potential.

The figure is divided into three plan views, one for each receiver coil separation. Coil 1 data are for the 1 m (3.28 ft) receiver-transmitter coil spacing. This spacing has an effective depth of investigation of approximately 1 m (3.28 ft) below ground surface in the configuration used in this survey. The plan view map for coil 1 represents a volumetric measure of the apparent conductivity of the material from 0 to 1 m (0 to 3.28 ft) below ground surface. Coil 2 data are for the 2 m (6.56 ft) receiver-transmitter coil spacing. This spacing has an effective depth of investigation of approximately 2.5 m (8.40 ft) below ground surface. The plan view map for coil 2 represents a volumetric measure of the apparent conductivity of the material from 0 to 2.5 m (0 to 6.56 ft) below ground surface. Coil 3 data are for the 3.66 m (12 ft) receiver-transmitter coil spacing. This spacing has an effective depth of investigation of approximately 5 m (16.4 ft) below ground surface. The plan view map for coil 3 represents a volumetric measure of the apparent conductivity of the material from 0 to 5 m (0 to 16.4 ft) below ground surface.

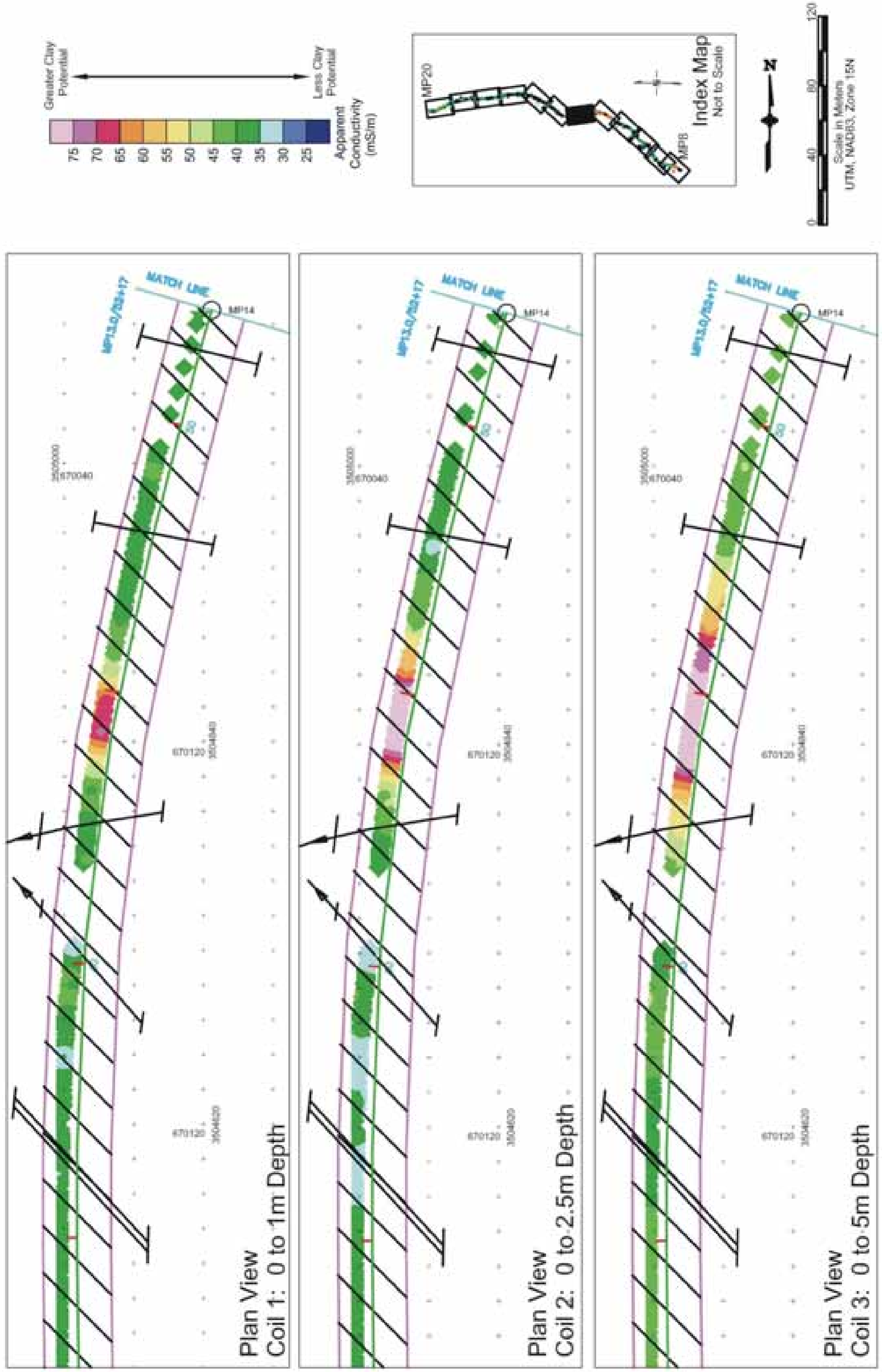

Figure 10. Plan View Map. EM31-3 EMI Apparent Conductivity Map from Natchez, Mississippi.

By comparing the apparent conductivity values for all three-coil spacings at a specific location, a rough estimate can be made on the vertical extent of the clay. For example, if the apparent conductivity for Coil 1< Coil 2< Coil 3, then it is likely that the clay extends from the near surface to the maximum depth of 5 m (16.4 ft) below ground surface. Conversely, if the apparent conductivity for Coil 1> Coil 2> Coil 3, then it is likely that the vertical extent of the clay is confined to the upper 1 m (3.28 ft) below the ground surface. Figure 10, between station 40 and station 50, displays a good example where the apparent conductivity increases with depth. This was the typical case for high-conductivity zones at this site.

7.6.2 Correlation of Geophysical and Atterberg Limits of Soils Properties Data

Table 9 lists the location of the boreholes and the EMI properties at the borehole locations. Table 10 lists the Atterberg Limits of Soils properties derived from samples from the boreholes. Appendix D contains plots comparing the EMI data results and the geotechnical results.

The correlation plots in appendix D show the comparison of bulk conductivity values for the 2 m (6.56 ft) and 3.66 m (12 ft) coil separation EMI data and the liquid limit, plastic limit, plasticity index, moisture content and liquidity index. The bulk soil conductivity does not appear to directly correlate with any of the soil properties data listed above. However, the variation in the values of the soil data is small which leads to a poor comparison.

The distribution of the soil data values for the Natchez data set falls within a narrow range. Table 11 lists the minimum, maximum, standard deviation and average values for each of the Atterberg Limits of Soils property.

In the correlation plots, this leads to a cloud of data points falling within a narrow range of values and may not include a sufficiently broad range of values to adequately determine if a correlation exists.

7.7 CONCLUSIONS

The field survey demonstrated the efficiency of EMI mapping by completing 54.7 km (34 mi) of roadway in four field days. The EMI survey is a fast, efficient, and cost effective geophysical method useful in the preliminary roadway surveys to plan and design road rehabilitation projects where clays in the road base materials are of concern. A soil-boring program, guided by EMI results, can greatly reduce the potential for missing areas of subgrade with potential construction problems in the design phase. Problem areas that are not detected prior to the construction phase can cause significant budget overruns during construction. Currently, this method is most effective as a reconnaissance tool to guide the soil-boring program. Further refinement in the application and data processing of this EMI method will also help realize further cost savings in performing the EMI survey and reduced turnaround time for the results.

Table 9. EMI Properties at Borehole Locations in Natchez, Mississippi.

Boring ID	Nad 83, UTM 15N		Bulk Conductivity (mS/m)		
	Easting (m)	Northing (m)	1 m Coil Separation	2 m Coil Separation	3.66 m Coil Separation
RW-01	665153.04	3498976.86	37.42	29.62	40.06
RW-03	665580.22	3499396.24	38.91	33.05	44.74
RW-04	665721.39	3499709.22	41.06	32.36	34.92
RW-05	666045.10	3500129.31	34.81	24.28	34.18
RW-09	667935.05	3500982.00	31.34	19.34	23.87
RW-10	668744.71	3501498.23	59.6	80.47	90.75
RW-15	670092.40	3503941.52	30.58	21.69	24.94
RW-17	670055.50	3504776.52	39.58	38.91	46.5
RW-18	670194.49	3505267.42	46.09	37.02	42.79
RW-21	671583.57	3506550.84	43.1	33.8	38.76
RW-26	672516.46	3508948.54	41.48	24.27	26.3
RW-27	672522.08	3509183.47	48.38	34.01	34.41
RW-28	672565.29	3509834.20	40.04	24.27	30.08
RW-30	672761.99	3510870.73	41.96	29.3	33.38
RW-33	672853.18	3512338.89	44.31	34.32	44.83
RT-01	689042.69	3534006.14	42.95	51.63	60.34
RT-02	689363.69	3534332.05	33.46	25.4	32.16
RT-06	691177.16	3535130.26	32.64	28.7	36.44
RT-07	691612.99	3535543.67	35.81	30.81	37.71
RT-09	692283.14	3536406.96	23.09	11.67	20.87
RT-10	692530.48	3536929.07	22.69	4.78	12.08
RT-12	692893.51	3538245.99	34.78	30.51	41.53
RT-15	693730.80	3539483.83	33.93	25.63	34.11
RT-19	694879.12	3541054.36	33.57	20.96	27.99
RT-21	695687.17	3541753.37	34.4	24.87	32.96
RT-22	696591.41	3541819.30	25.61	8.6	15.2
RT-23	696050.09	3541855.23	27.75	12.72	19.85
RT-32	701335.13	3542452.84	24.96	6.31	13.7
RT-33	701699.26	3542690.15	23.01	4.12	12.63
RT-36	703145.77	3544457.45	37.22	25.61	33.61
RT-38	703848.34	3545301.70	38.54	29.22	41.65
RT-43	704637.93	3547737.58	46.58	46.98	52.74
RT-44	704832.63	3548305.28	49.99	56.62	70.92
RT-46	705293.14	3549280.82	42.4	44.3	41.58
RT-48	706247.54	3550145.92	46.64	56.63	75.55
RT-50	706819.13	3550710.40	34.75	29.7	39.8
RT-55	708478.82	3552627.55	65.67	84.04	94.26
RT-56	708964.79	3553112.72	37.47	28.73	37.56
RT-60	710293.52	3554780.97	46.02	47.03	59.15
RT-62	710971.48	3555896.22	31.45	20.12	31.13
RT-63	711122.91	3556037.21	29.29	14.74	22.42

Table 10. Atterberg Limits of Soil Properties from Boreholes in Natchez, Mississippi.

Boring ID	Moisture Content (%) (MC)	Liquid Limit (LL)	Plastic Limit (PL)	Plasticity Index (PI)	Liquidity Index (LI)
RW-01	19	30	17	13	0.15
RW-03	14.9	28	21	7	-0.87
RW-04	18.2	28	19	9	-0.09
RW-05	16.9	24	18	6	-0.18
RW-09	21.2	30	16	14	0.37
RW-10	11.1	29	12	17	-0.05
RW-15	19.6	26	16	10	0.36
RW-17	23.9	25	20	5	0.78
RW-18	14.6	25	14	11	0.05
RW-21	16	26	16	10	0.00
RW-26	18.2	28	18	10	0.02
RW-27	15.3	25	20	5	-0.94
RW-28	17.7	32	17	15	0.05
RW-30	18.7	25	19	6	-0.05
RW-33	15.6	25	19	6	-0.57
RT-01	11.7	27	27	na	na
RT-02	12.8	18	9	9	0.42
RT-06	12.7	19	13	6	-0.05
RT-07	18.6	22	10	12	0.72
RT-09	11.6	16	15	na	-3.40
RT-10	8.1	13	12	na	-3.90
RT-12	15	14	14	na	na
RT-15	14.5	19	11	8	0.44
RT-19	17.8	18	13	5	0.96
RT-21	12.1	14	11	3	0.37
RT-22	18.7	29	18	11	0.06
RT-23	13.2	16	12	4	0.30
RT-32	8.3	na	na	na	na
RT-33	5.9	na	na	na	na
RT-36	11.1	24	15	9	-0.43
RT-38	10.2	18	13	5	-0.56
RT-43	9.2	15	12	3	-0.93
RT-44	10.1	20	8	12	0.18
RT-46	8.2	20	9	11	-0.07
RT-48	7.4	14	13		-5.60
RT-50	16.6	29	17	12	-0.03
RT-55	18.1	30	15	15	0.21
RT-56	20	31	19	12	0.08
RT-60	16.4	29	15	14	0.10
RT-62	13.8	24	15	9	-0.13
RT-63	13.9	21	13	8	0.11

Note: not analyzed = na.

Table 11. Statistical Analysis of the Atterberg Limits of Soils Results from Natchez, Mississippi.

	Moisture Content (%)	Liquid Limit	Plastic Limit	Plasticity Index	Liquidity Index
Minimum	5.9	13	8	3	-5.6
Maximum	23.9	32	27	17	1
Standard Deviation	4.2	5.6	3.9	3.7	1.3
Average	14.6	23.2	15.2	9.2	-0.3

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