GEOPHYSICAL METHODS EVALUATION
FORT CALHOUN POWER STATION
BLAIR, NEBRASKA

Prepared for:

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Geotechnology, Inc. Project No. J019386.02

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GEOTECHNOLOGY INC

FROM THE GROUND UP

VIA EMAIL: Patrick.poepsel@hdrinc.com

September 2, 2011 J019386.02

Mr. Patrick Poepsel, P.E.
HDR Engineering, Inc.
8404 Indian Hills Drive
Omaha, Nebraska 68114-4049

Re: Geophysical Methods Evaluation
Fort Calhoun Power Station
Blair, Nebraska

Dear Mr. Poepsel:

Presented herein are the results of the geophysical surveys for the above referenced site. This work was conducted in general accordance with the Geo Subcontractor Services Agreement dated August 22, 2011. Geotechnology tested ground penetrating radar (GPR), electromagnetic terrain conductivity, self potential resistivity, and resistivity profiling methods at the referenced site to evaluate the effectiveness of each method to identify voids in the subsurface. This report includes a description of the geophysical method and survey results.

After careful consideration, we recommend the 3D GPR surveys for near surface and/or sub-pavement void evaluation. We believe the GPR is useful in identifying anomalous zones that can be further evaluated with a limited number of exploratory cores/drill holes. The remaining methods provided less useful information for resolving shallow or deeper voids at the subject site. We recommend considering a different and more labor intensive method, seismic refraction tomography for attempting to resolver deeper voids.

It is a pleasure to be of service to you on this project. If you have any questions or comments, please contact the undersigned at (314) 997-7440.

Very truly yours,
GEOTECHNOLOGY, INC.

Douglas W. Lambert
Senior Project Manager - Geophysics

Glen L. Adams
Senior Geophysicist

GLA, DWL:gla
Copies Submitted:(2)

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1.0 INTRODUCTION

1.1 Site Description. The site consists of approximately 100 acres within the Missouri River flood plain, including main plant buildings, switch yards, and auxiliary office and training buildings. A site location map is presented on Plate 1. Voids are suspected to have developed beneath concrete slabs within the facility due to recent flooding around the site. The goal of our geophysical testing was to evaluate the effectiveness of Ground Penetrating Radar (GPR), electromagnetic (EM) terrain conductivity, self potential (SP), and resistivity profiling for imaging subsurface voids. The evaluation of the geophysical methods was focused over a distressed support column inside the maintenance building, near manhole number 5, and along the main plant access road outside the containment area.

1.2 Scope of Work. The scope of work included mobilizing a GPR unit, EM terrain conductivity meter, SP equipment, and multichannel resistivity profiling system and personnel to the site. Surface conditions and available space to collect data limited the methods that were tested at each of the locations. Test data were processed, interpreted and reported herein.

2.0 GEOPHYSICAL METHODOLOGY

GPR is a geophysical technique in which a broadband electromagnetic (EM) signal is transmitted into the ground. The EM signal travels through underlying materials and is reflected by subsurface features. The magnitudes of the reflections are based on contrasts in dielectric permittivity and conductivity of the subsurface features. Features located below concrete often exhibit distinguishable high-amplitude reflections due to the large dielectric contrast between the concrete and underlying materials including voids, some sub grade materials, and utilities. The reflected signal is recorded with respect to the time required for the signal to travel down and back (two-way travel time in nanoseconds). Data are collected along survey lines and the results are presented in profiles representing reflected radar signal from beneath the survey line. Three dimensional GPR datasets are generated from parallel 2D profiles.

Electromagnetic (EM) surveying is often performed using a terrain conductivity unit such as a Geonics EM31. This induction-type instrument measures terrain conductivity without direct soil contact. This technique operates on the principle that secondary electric and magnetic currents can be induced in conductive bodies when an electric field is applied. This instrument measures the secondary magnetic field strength relative to the primary magnetic field and converts it directly into a conductivity value, measured in milliSiemens per meter (MS/m). Data are recorded for two phases: the quadrature phase (terrain conductivity) and in-phase component. The terrain conductivity is responsive to variations in conductivity regardless of material content, whereas the in-phase component responds primarily to metallic objects. Voids are expected to exhibit a lower conductivity than the natural soils surrounding the void space. The EM31 has an effective depth of penetration of approximately 20 feet. EM31 surveys are subject to cultural interference from power lines and surface metal objects such as building, fences, etc. and from buried conductive features such as metallic utilities. The EM31 data is typically acquired with a real-time differential global positioning system (dGPS) to provide positioning information.

Spontaneous potential (SP) surveying for seepage involves measuring the naturally occurring electrical potential difference that occurs when water moves through a porous medium (also called streaming potential). The SP survey is performed using two porous pot electrodes. The "base" electrode is placed at a fixed location remote from the survey area and the "survey" electrode is placed at successive locations along a line or series of parallel lines away from the base electrode within the survey area. The potential between the two electrodes is measured using a voltmeter at each location occupied by the survey electrode. The potential difference between the two electrodes are plotted along each survey line. Seepage areas will exhibit low or high voltage spike within the general straight line trend of the data.

Resistivity profiling is a surface geophysical technique where the apparent resistivity of the subsurface is determined by inducing current into the subsurface with two current electrodes and measuring the resulting ground voltage using two potential electrodes. The dipole-dipole resistivity profiling method involves using a current dipole positioned a certain distance away from a potential dipole. The voltage is measured at the potential dipole at varying distances from the current dipole. Depth of penetration depends on length of the cable. The dipole-dipole resistivity method is appropriate for resolving lateral variations. Targets such as water filled voids exhibit low resistivity values within more resistive soils. Clay rich soils and water saturated zones exhibit lower resistivity values compared to dry sandy and silt rich soils.

3.0 DATA ACQUISITION AND PROCESSING

Geotechnology performed geophysical surveys at Fort Calhoun Power Station on August 24^{th} through the 26^{th}, 2011, using a GSSI SIR 3000 GPR system and 400 MHz antenna, a Geonics EM31, SP system, and an AGI Super Sting (R8) resistivity profiling system. The surveys were performed within reasonably accessible areas as shown on Plates 2 and 3. GPR data were collected along lines spaced approximately one foot apart extending generally in the north-south and/or east-west directions. Based on site observations, EM and resistivity were not performed near Manhole 5 due to the presence of reinforced concrete and utilities. Of the methods evaluated, GPR is likely the only feasible method for surveying within buildings for voids.

The GPR data were processed using Radan Version 6.6. Data processing included gain equalization, surface normalization, horizontal filtering, and 3D integration of profiles. EM data were contoured with Surfer 9.0. SP data were plotted to show changes in voltage with distance. The resistivity profiles were produced with Earth Imager modeling software produced by AGI. Apparent resistivity inversions were produced by removing data spikes, and inputting relative surface elevation corrections.

A grid of 3D GPR data (Grid 1) was collected over the intersection of the "Power Lane" and the service drive for the Training Center building, near a damaged fire hydrant. Pavement in this area was observed heaving from the weight of shuttle bus traffic while onsite. A resistivity profile and SP survey were conducted on the north side of the road due to over head electric and suspected buried utilities would have greatly hindered resistivity or SP surveying on the south side of the road near GPR Grid 1. The resistivity and SP tests were also offset to the west to prevent access road closure during surveying. A depth slice of the 3D GPR Grid 1 data is shown on Plate 4, and the corresponding EM grid data near this area is shown on Plate 5. Field notes and site sketches are presented in Appendix A.

3D GPR Grid 2 was collected within the Maintenance Building near a column that exhibits settlement. An example GPR depth slice of the 3D data is presented on Plate 6.

3D GPR Grid 3 and SP Line 2 were conducted near Manhole 5 to evaluate these methods within areas of known underground utilties. Voided areas surrounding utility lines were suspected as well as zones of high ground water flow into the manhole. GPR and SP survey locations area shown on Plate 3, and an example GPR data slice is shown on Plate 7.

4.0 RESULTS

The first test for the GPR was to evaluate the depth of penetration. The expected high moisture content of the soil due to the flooding did not appear to inhibit the depth of penetration as expected. The depth of penetration was estimated at approximately 5 to 7 feet within the test areas. High amplitude anomalies were selected as possible voids, but may also be related to changes in subsurface fill or soil content. Within GPR Grid 1 two core locations were performed, one within an anomalous zone (high amplitude reflection) and one out side the zone. The anomalous zone was found to have approximately one foot of soft wet clay directly below the concrete pavement. The core outside the anomalous area had a rocky fill material below the concrete. Although a void space was not found at the anomalous area, the wet clay may have been in-filled into a void space, or placed during construction. Further more we have much experience where we have used the GPR successfully to identify voids beneath concrete. We recommend 3D GPR over critical areas to help identify possible voided areas in the near surface (upper 5-7 feet). GPR interpretations are shown for each grid in Appendix B on the field sketches.

The EM method is sensitive to surface metals, and underground utilities, therefore the area near the Training Center Building was selected due to less surface and presumed subsurface structures. The EM data presented on Plate 5, show some anomalous areas that trend with expected utilities and surface features. The area of the EM and GPR Grid 1 overlap shows how the EM is affected by the reinforcing in the concrete, which mask the anomalies found with the GPR. After viewing the site layout and reviewing the utility drawings, the expected usefulness of the EM is low.

The SP resistivity test was conducted in both a congested and an open area (with respect to surface structures and expected subsurface utilities). The SP was tested to evaluate its usefulness in identifying fluid transport pathways in the subsurface that could be related to voids. The area tested near GPR Grid 3 shown on Plate 3 was over utilities and presents stray electrical current most likely related to cathodic protection. This data is plotted on Plate 8 and shows how the data may not be reliable and in some cases non-measureable. The SP collected near the Training Center Building at the same location as the EM and Resistivity survey did, however, show some potential fluid movement zones. However, the subtle nature and proximity of the survey line to the receding flood waters suggest these zones are most likely zones of higher water infiltration through the soil and not void related. Based on the effect of the utilities and the expected areas to be surveyed, we are not considering the SP as an effective method for void detection on this site.

The resistivity profiling was the final method evaluated. This method requires long open surface areas for data collection. The resistivity survey performed near the Training Center Building exhibited good quality data to a depth of approximately 65 feet below ground surface. This method could be used as part of a parameter survey, for larger/deeper voids that may be below the site. However, within the containment area this would include drilling holes to penetrate the concrete pavement, in addition this method is known to have interference with buried utilities. After evaluating the utility drawings and the surface conditions, we would recommend refraction seismic tomography surveying rather than resistivity surveying with the containment area. The seismic method is typically a 3 to 4 person crew and requires greater effort for data processing and interpretation.