GeoEngineers

Appendix D

Results of Geophysical Evaluation

Golder Associates Inc.

18300 NE Union Hill Road, Suite 200
Redmond, WA USA 98052-3333
Telephone (425) 883-0777
Fax (425) 882-5498
www.golder.com

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Our ref: 063-1240.000

I-405 Project Team
600 108th Avenue NE
Bellevue, Washington 98004

Attention: Mr. Anthony Stirbys

RE: FINAL REPORT OF THE GEOPHYSICAL INVESTIGATION AT THE PROPOSED INTERSTATE 405/STATE ROUTE 515 INTERCHANGE RENTON, WASHINGTON

Dear Mr. Stirbys:

In July 2006 Golder Associates Inc. (Golder) conducted a geophysical investigation at the site of the proposed Interstate 405/State Route 515 Interchange in Renton, Washington. This work was conducted under our Consultant Agreement Y-9448, Task Order No. AA. The investigation consisted of two tasks with each task having a different objective and requiring different geophysical methods.

Task 1: Map the depth and topography of the bedrock surface along a section of a proposed retaining wall.

Task 2: Attempt to locate an historic coal mine tunnel beneath the existing I-405.

A combination of seismic refraction and electrical resistivity imaging (ERI) was used to attempt to map bedrock depth and topography (Task 1). Ground penetrating radar (GPR) was used to attempt to locate the historic mine tunnel in the upper 10 feet of the subsurface (Task 2). Figure 1 is a map of the site showing the locations of the geophysical transects.

This report describes the methodology and instrumentation, field procedures, and presents the results of our investigation.

We appreciate the opportunity to work with you on this project. If you have any questions regarding this investigation, please contact either myself or Dick Sylwester.

Sincerely,

GOLDER ASSOCIATES INC.

Matthew A. Benson
Senior Geophysicist

Richard E. Sylwester, L.G., L.E.G.
Senior Geophysicist

MAB/RES/ngs

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1. SITE DESCRIPTION

The geology in the survey area is described as alluvium overlying friable sandstone bedrock (see borehole logs in appendix). The depth to bedrock was reported to range between 5 and 30 feet below ground surface. It was also reported that the overburden materials possible contained waste rock from the mine. A known coal mine in the vicinity ceased operations in the early 1900's.

Construction records indicated that a historic coal mine tunnel was intersected during construction of the traffic lanes for I-405. Historic photographs suggest the tunnel, which may be as much as 25 feet in diameter, could be relatively shallow, with less than 10 feet of overburden to the crown.

2. METHODOLOGY AND INSTRUMENTATION

2.1 Seismic Refraction

Seismic refraction, a traditional method for mapping the thickness of alluvium and depth to bedrock, uses a controlled energy source (hammer, blank shotgun shells, and chemical explosives) to generate a seismic signal. The seismic signals are received by a series of geophones (24, for example) connected to a seismic cable laid on the ground in a linear manner. The geophones are implanted several inches into the ground and spaced approximately 5 to15 feet apart along the geophone cable. The seismic energy source is discharged at several places along the array and off both ends.

The seismic wavelets travel through the earth to the geophones. Geophones convert the acoustic energy in the ground to an electric signal in the geophone cable. The seismograph detects the arriving electric signals with respect to time and stores the records for future data processing. The seismic data is processed to determine the seismic velocity of the earth material through which the energy has traveled and to model the subsurface geology. This geophysical model depicts the earth in cross-section showing the velocity and thickness of the subsurface layers below the seismic line.

The refraction data were acquired with a Geometrics 24 channel GEODE refraction system and 30 Hz geophones. The refraction data was QA/QC'ed in the field using Geometrics SeisImager software. This software was used also used to pick the seismic arrivals. FIRSTPIX and GREMIX software were used to process the refraction data. These software programs are based on the Generalized Reciprocal Method for analyzing seismic arrivals.

2.2 Electrical Resistivity Imaging

The ERI method maps differences in the electrical resistivity of geologic materials including soils and rock. Most soils and rock minerals are electrical insulators or highly resistive. The flow of current in these materials is primarily conducted through the moisture filled pore spaces. Therefore, the resistivity of soils and rock is primarily controlled by the porosity and permeability of the medium, the amount of pore water (degree of saturation) and the concentration of dissolved solids (ionic solutions) in the poor water.

The method involves transmitting an electric current into the ground between two current electrodes and measuring the voltage between two separate potential electrodes. The measured point is called a sounding, which represents the apparent resistance of the area beneath the electrodes. A combination of different electrode arrangements is used to collect enough soundings to produce a resistivity cross section below the ERI transect. The resistivity cross section is presented as a color contoured cross section that highlights stratigraphic features or other information (alluvium, bedrock, etc.) representing variations in subsurface resistivity.

The resistivity data were obtained with an IRIS Syscal R1 Plus system. This system is capable of controlling up to 72 electrodes. Data were collected using a Wenner array and a dipole-dipole array and processed using RES2DINV software.

2.3 Ground Penetrating Radar (GPR)

The GPR method uses electromagnetic (radar) pulses that are directed into the ground from an antenna. Reflections of these pulses from subsurface features are produced where there is a contrast between the electrical properties of subsurface materials, or discrete objects such as tunnels, buried cables, boulders etc., and the surrounding soil.

The reflected electromagnetic pulses are received by the antenna, converted into an electric signal, and recorded by the GPR unit. The GPR unit compiles these pulses to produce a cross section or profile image of the subsurface beneath the path of the antenna.

The depth penetration of a GPR signal is a function of the antenna frequency and the resistivity of the subsurface material. As the frequency of the GPR antenna increases, the resolution (ability to detect small objects) increases, but the depth of subsurface penetration decreases. A lower frequency antenna is capable of greater subsurface penetration, but with reduced resolution. Materials that have low resistivity, or are electrically conductive, such as saturated clay silt attenuate the GPR signal, resulting in poor subsurface penetration.

A Geophysical Survey Systems Inc (GSSI) SIR 2000 GPR system configured with 100 and 200 MHz antennas was used to attempt to locate the historic mine tunnel. A SIR 2000 GPR system configured with a 40 MHz antenna was also used for Task 1 in an attempt to map the bedrock surface. A Sensors & Software Pulse EKKO 1000 GPR system configured with 50 and 100-MHz antennas was used in an attempt to map the depth to bedrock along the proposed retaining wall. GPR data were processed using REFLEX-W software.

3. FIELD PROCEDURES

3.1 Seismic Refraction

The seismic refraction data were recorded using a Geometrics StrataView 24 channel digital engineering seismograph. A 16 lb. sledgehammer was used as the seismic source. The receiver array (spread) was constructed using 24 Mark Products 30-Hz vertical geophones spaced at a 5 foot interval.

A seismic refraction test was conducted using a 55 foot spread (Figure 1). The spread was set up with geophone 1 located to the west and geophone 24 to the east. The seismograph was placed in the center of the spread between geophones 12 and 13. Two shot points were recorded as a test to confirm set up parameters and that acceptable signals could be recorded at this site. One shot point was at the west end and one was at the middle of the spread. Multiple hammer strikes were summed together at each shot point location to increase signal strength in an attempt to overcome background noise. The data were downloaded at the end of test shots and a temporary back up copy was made on removable storage media. Preliminary analysis of the data was done with FIRSTPIX software.

3.2 Electrical Resistivity Imaging (ERI)

ERI data were collected by placing steel electrodes in the ground at a 5 foot spacing along the survey transect. The electrodes are used to transmit electrical current into the ground and measure the voltage potential that develops as a result of current flow through the soil. Over 600 measurements were recorded for each segment of the transect. Resistivity measurements were made using the standard Wenner array (west line) and the dipole-dipole array (east line). Each set of measurements were recorded automatically by the ERI console. At the end of each set of measurements, the data were downloaded from the console in order to perform quality control inspections of the field data and develop preliminary profiles.

The 5 foot electrode spacing produced an ERI spread 355 feet in length. To cover the entire profile length, one full ERI spread and one "roll-along" spread was collected on each of the two lines (Figure 1). The roll-along spread was one half of the full spread which resulted in a 535 foot subsurface profile.

3.3 Ground Penetrating Radar (GPR)

The GPR was used first to meet the Task 2 objective of attempting to locate the historic mine tunnel. Data were collected using the GSSI SIR 2000 system with shielded 100 MHz and 200 MHz antennas. The data were collected by pulling the antenna along the ground at a normal walking pace recording measurements at a rate of 32 scans per second. This pace produced a nominal measurement spacing of 6-8 centimeters. The data were acquired along the outside shoulder of the northbound lanes of Interstate 405 both on the pavement and on the soil adjacent to the pavement. Positioning was accomplished using fiducial markers spaced every 20 feet.

Approximately 500 feet of Interstate 405 was surveyed for anomalies potentially representing voids/tunnels. During the survey WSDOT provided logistical support for traffic control.

The GPR systems were then used to address the Task 1 objective of mapping the bedrock surface. The GSSI system was configured with an unshielded 40 MHz antenna, and the Pulse EKKO 1000 was configured with a 50 MHz unshielded antennas.

4. RESULTS

The interpreted results of the geophysical investigation are presented in Figures 3 through 5. Figures 3 and 4 present the ERI data recorded during Task 1 and Figure 5 presents the GPR data recorded for Task 2. The geophysical data were calibrated using field logs from the geotechnical borings provided by WSDOT. These borings were completed just prior to the geophysical investigation and the field logs were provided to the geophysical crew at the on-set of data collection. Draft copies of the logs are provided in the Appendix.

4.1 TASK 1

4.1.1 Seismic Refraction

Getting sufficient signal into the ground proved to be challenging at this site. According to the borehole logs, the overburden material is "very loose and poorly consolidated debris. This is an extremely poor medium for efficiently coupling seismic energy into the subsurface. This situation was not predicted as the geotechnical borings were completed the day prior to beginning the geophysical investigation.

Figure 2 presents an example of the raw field record from the refraction test. This record represents the best setup for obtaining quality data as the seismic source is located in the middle of the geophone array. Unfortunately very little coherent seismic energy, representing refracted seismic arrivals, is present in this record. In fact, refracted energy is only observed at a distance of approximately 20 feet from the source. At distances greater than this the background noise had higher amplitude than the seismic signal. This limited the usefulness of the seismic refraction method since refracted arrivals from the bedrock interface could not be detected. Therefore, no additional data were acquired using the seismic refraction method.

4.1.2 Electrical Resistivity Imaging

Figure 3 presents the east line resistivity profile collected along the face of the proposed retaining wall and Figure 4 presents the west line resistivity profile. On these figures the low electrical resistivity values (100 to 1200 ohm-meters) are represented by blue and green colors and the relatively high electrical resistivity values (1500 to 22,000 ohm-meters) are represented by yellow through red colors.

The interpreted resistivity profile of the east line is an earth model based on data collected using the dipole-dipole array (Figure 3). The unprocessed resistivity measurements and the modeled earth resistivity values are over 15,000 ohm-meters. The interpreted resistivity profile of the west line is an earth model based on data collected using the Wenner array (Figure 3). Data collected using a Wenner array results in shallower penetration due to the geometry of the electrode spacing. The soil and subsurface resistivity on this profile is also over 15,000 ohm-meters.

Borehole 515-6-06 provides the best information on the surficial and subsurface soil conditions for interpreting the resistivity data. Based on the borehole data the relatively high resistivity values are interpreted to be due to the loose, dry soil present at the ground surface and the loose, porous, and low saturated soils at depth.

The boring logs report bedrock to be at a depth of approximately 35 to 40 feet below ground surface and that the change from soil, to weathered rock to bedrock is transitional. The resistivity profiles, extending to a depth of 35 feet, do not indicate a significant increase or decrease in values that might suggest a change from soil to bedrock.

In areas north of the boreholes where more noticeable variations exist, there is no electrical response indicative of a bedrock contact. It appears that there is little or no contrast in the resistivity values of the near surface soils and the loose soil at depth and the bedrock.

4.2 TASK 2

4.2.1 Ground Penetrating Radar

Figure 5 presents the GPR section collected along the northbound shoulder of I-405. This data was collected using the 100 MHz antenna. The ground penetrating radar was able to map the subsurface to a depth of 25 feet. There are a few small anomalies likely caused by buried cables, joints in the concrete, change from soil to sandstone bedrock. However, there was no evidence on the GPR data consistent with the anomaly expected from a tunnel 25 feet in diameter. The presence of a large tunnel could go undetected by GPR if the tunnel was back-filled with material similar to the surrounding soil and sandstone.

5. CONCLUSIONS AND RECOMMENDATIONS

Two geophysical methods were used to attempt to meet the objectives of Task 1. These methods were unable to achieve the stated objectives for two reasons. The loose, dry nature of the unconsolidated soils, together with vehicle noise, prevented the seismic refraction method from being suitable to map the depth and topography of sandstone bedrock. Furthermore, there was not sufficient contrast in electrical properties between the overburden and bedrock for mapping the bedrock surface with the electrical resistivity method.

GPR proved to be a viable method to map the shallow subsurface in support of Task 2. There were no anomalies consistent with the signature expected from a mine tunnel 25 feet in diameter less than 10 feet below the ground surface.

Golder recommends additional borings and test pits along the proposed retaining wall to better characterize subsurface conditions.

6. LIMITATION OF GEOPHYSICAL METHODS

Golder services are conducted in a manner consistent with the level of care and skill ordinarily exercised by other members of the geophysical community currently practicing under similar conditions subject to the time limits and financial and physical constraints applicable to the services. Seismic refraction, electrical resistivity imaging and ground penetrating radar are remote sensing geophysical methods that may not detect all subsurface features of interest, including the bedrock surface or voids. Furthermore, site specific sources of cultural interference may limit the usefulness of geophysical methods, possibly producing anomalies indistinguishable from subsurface targets.

FIGURES

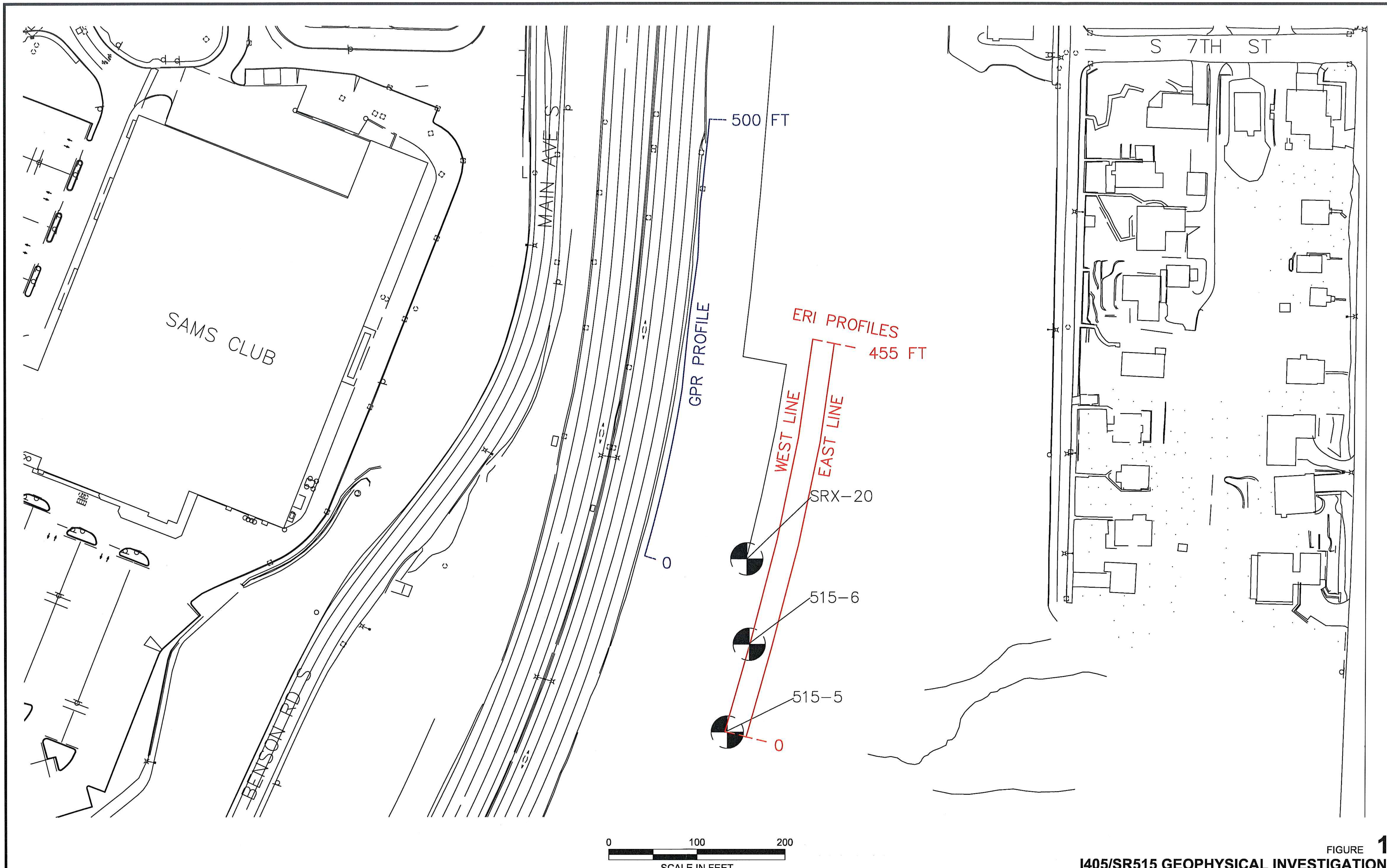


FIGURE **1**

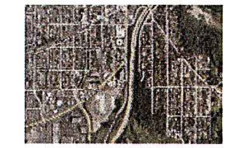
I405/SR515 GEOPHYSICAL INVESTIGATION

LINE LOCATION MAP

4ex100sc_geo_exhib_v1.dwg | Layout: Layout1 | Modified: 10/05/2006, 09:24 | Plotted: 10/05/2006, 09:36

Golder Associates

Site Map

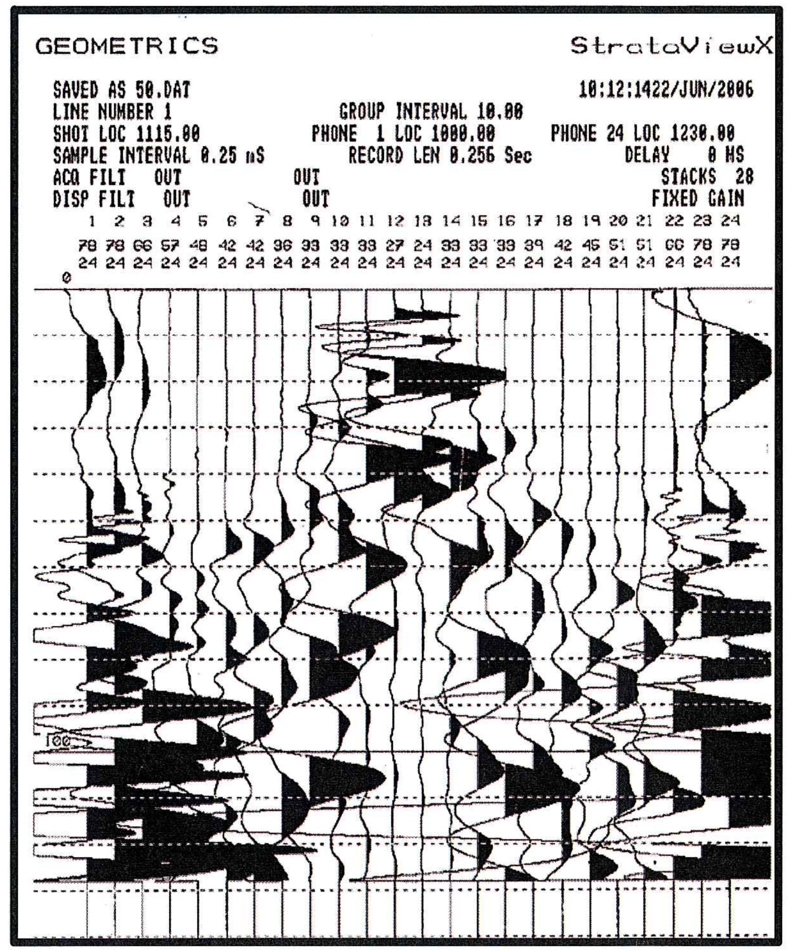


Site Map: Renton, Washington

Instrumentation

GSSI Sir 2000 Ground Penetrating Radar

Legend



Datum

Horizontal: Site spacific (feet)
Vertical: Depth below surface (feet)

Prepared by:

Golder Associates

Golder Associates Inc.
18300 NE Union Hill Rd, Suite 200
Redmond, WA 98052
(425) 883-0777

Prepared for:

WS-DOT I-405 Project Team
600 - 108th Ave. NE
Bellevue, WA 98004

Figure 2

Sample Seismic Refraction Field Record

063-1240.000 / Figure 2.srf

Site Map; Renton, Washington

Instrumentation

IRIS Electircal Resitivity Imaging System

Legend

BH 515-5-06 ⊕ Borehole Location

Contours (ohm-meters)

Datum: NA

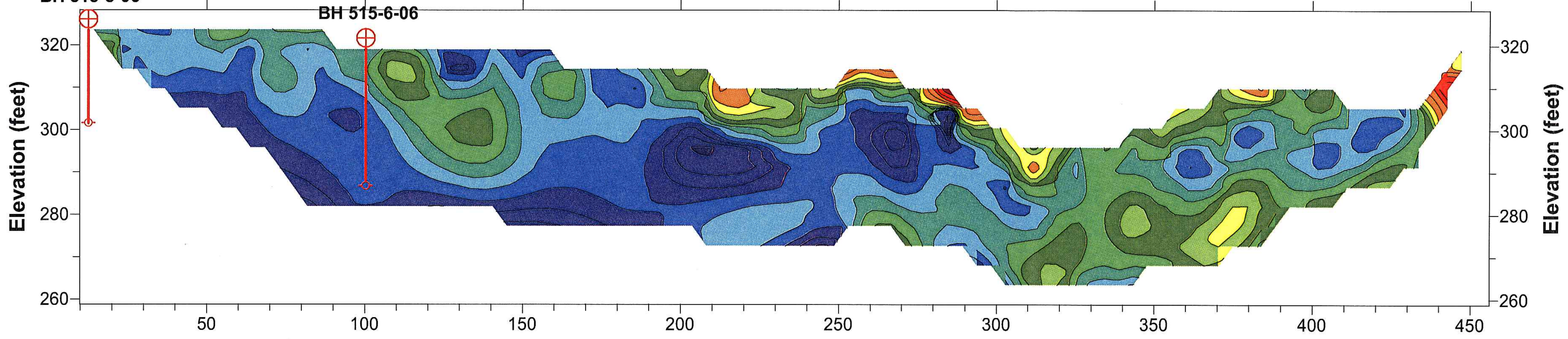
Prepared by

Golder Associates
Golder Associates Inc.
18300 NE Union Hill Rd, Suite 200
Redmond, WA 98052
(425) 883-0777

Prepared for

WS-DOT I-405 Project Team
600 - 108th Ave. NE
Bellevue, WA 98004

EAST LINE



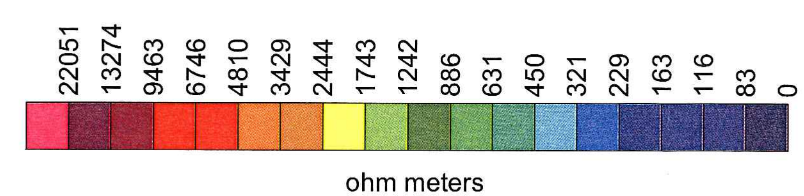


Figure 3

Contoured Electrical Resitivity Imaging Profiles With Borehole Locations