SGW-52161
Revision 0

Resistivity and Electromagnetic Investigation at the LERF, 200 East Area of the Hanford Site, Richland, Washington

Prepared for the U.S. Department of Energy
Assistant Secretary for Environmental Management

Contractor for the U.S. Department of Energy
under Contract DE-AC06-08RL14788

CH2MHILL
Plateau Remediation Company
P.O. Box 1600
Richland, Washington 99352

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Revision 0

Resistivity and Electromagnetic Investigation at the LERF, 200 East Area of the Hanford Site, Richland, Washington

Program/Project: SGW

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Date Published
April 2012

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CHPRC CONTRACTOR DOCUMENT SUBMITTAL FORM

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11	45104	11	3	02-27-12

(6) CONTRACTOR: Golder Associates Inc.
18300 NE Union Hill Road, Suite 200
Redmond, WA 98052

SIGNATURE Matthew Benson DATE: 02-27-12

(7) TO: PROJECT RECORDS SPECIALIST MSIN: Phone: 509- -

RECEIVED BY E-mail: FAX: 509- -

PROJECT RECORDS SPECIALIST: Charmaine Busler DATE: 02/28/12

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Re-submitting based on comments. Figure 1A is now included. Figure 2 is corrected. Utility data was collected along the full length of Line 2. The trackline path has been updated to reflect this.

(18) REVIEWER DISTRIBUTION (HARD OR ELECTRONIC)

NAME	NAME	NAME
Steve Miller (A) per email 03-01-12	Mike Thompson (A) per email 03/01/12	Bruce Williams (A) per email 03/09/12

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- C Revise and Resubmit

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- B YES-Resubmit. Minor Comments. Approved to proceed; however resubmittal is required.
- C Revise and Resubmit

Busler, Charmaine N

From: Koerber, Jessica [JKoerber@golder.com]
Sent: Monday, March 12, 2012 7:28 AM
To: Busler, Charmaine N; Benson, Matt
Cc: Hanson, Katlin M
Subject: RE: CONTRACT 45104 - SUB 011 V3 Final Report *** STATUS: A ***

Charmaine,

Received.

Thanks!
Jess

From: Busler, Charmaine N [mailto:Charmaine_N_Busler@rl.gov]
Sent: Monday, March 12, 2012 7:05 AM
To: Koerber, Jessica; Benson, Matt
Cc: Hanson, Katlin M
Subject: CONTRACT 45104 - SUB 011 V3 Final Report *** STATUS: A ***

Jessica,

Please acknowledge receipt of the attached submittal:

Due to the size of the document only the first 6 pages are being sent.

CONTRACT 45104 - SUB 011 V3 Final Report

*STATUS: A-Conforms to the Contract Requirements ****

Sincerely,

Charmaine Busler
Project Document Control
200E/MO2229/R4-29
Office: 509-942-3941

Busler, Charmaine N

From: Hanson, Katlin M
Sent: Monday, March 12, 2012 5:42 AM
To: Busler, Charmaine N
Subject: Concur: **REVIEW** CONTRACT: 45104 - SUB 011 V3 - Final Report (RESUBMITTAL)

Busler, Charmaine N

From: Williams, Bruce A
Sent: Friday, March 09, 2012 1:20 PM
To: Busler, Charmaine N
Subject: A-Conforms to the Contract Requirements: **REVIEW** CONTRACT: 45104 - SUB 011 V3 - Final Report (RESUBMITTAL)

Busler, Charmaine N

From: Thompson, Michael D
Sent: Thursday, March 01, 2012 1:15 PM
To: ^Project Document Control; Busler, Charmaine N
Cc: Williams, Bruce A; Miller, Steven F
Subject: A - Conforms: **REVIEW** CONTRACT: 45104 - SUB 011 V3 - Final Report (RESUBMITTAL)

Charmaine,

The report conforms. Golder has addressed our comments…

Busler, Charmaine N

From: Miller, Steven F
Sent: Thursday, March 01, 2012 9:22 AM
To: 'Figgins, Miranda R'; ^Project Document Control; Busler, Charmaine N
Cc: Williams, Bruce A; Thompson, Michael D
Subject: A - Conforms: **REVIEW** CONTRACT: 45104 - SUB 011 V3 - Final Report (RESUBMITTAL)

Charmaine
Golder has addressed our comments and I approve the final report.
Steve

PROCUREMENT / CONTRACT SUBMITTAL

APW X APX

Conforms to the Contract Requirements

Minor Comments - Approved With Exceptions as Corrected

❑ Re-submittal required ❑ Re-submittal not required

Not Approved - Revise and Resubmit

Sign: K. Hanson per email Date: 03/12/12

REPORT

RESISTIVITY AND ELECTROMAGNETIC INVESTIGATION AT THE LERF, 200 EAST AREA OF THE HANFORD SITE, RICHLAND, WASHINGTON

Contract 45104

Submitted To: CH2M Hill Plateau Remediation Company
Accounts Payable Mail Stop H7-32
Richland, WA 99352

Submitted By: Golder Associates Inc.
18300 NE Union Hill Road, Suite 200
Redmond, WA 98052 USA

February 3, 2012

Project No. 113-93039

A world of capabilities delivered locally

Golder Associates

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1.0 INTRODUCTION

CH2M Hill Plateau Remediation Company (CHPRC) is focusing on the safe, environmental cleanup of the Central Plateau of the Department of Energy's (DOE's) Hanford Site. CHPRC is primarily focused on the treatment and disposal of various radioactive waste streams, groundwater, management of spent nuclear fuel, disposal or disposition of nuclear materials, and non-reactor nuclear facilities, and environmental remediation activities currently funded through DOE's Office of Environmental Management. One location where soil and groundwater remediation efforts are focused is the Liquid Effluent Retention Facility (LERF) in the 200 East Area.

Under contract 45104, Golder Associates Inc. (Golder) conducted a geophysical investigation consisting of two-dimensional electrical resistivity profiling (ERI), time-domain electromagnetic (TDEM) soundings, and micro-gravity surveying near LERF to CHPRC's efforts.

The scope of work involved two phases of investigation with Phase I being an initial field demonstration of the resistivity, TDEM and micro-gravity methods along two profiles approximately 1.5 kilometers (km) in length. Phase II was intended to be based on the results of the field demonstration and consisted of an additional 3.5 km of surveying. During Phase I of micro-gravity surveying, the gravimeter failed to pass field operation and quality control requirements. Because a replacement gravimeter with micro-gal precision was not available in time to meet the schedule for Phase I or Phase II surveying, the micro-gravity method was dropped from the Phase II field investigation. ERI and TDEM were the methods selected for Phase II surveying. This report presents the ERI and TDEM results and interpretations of the geology in the vicinity of LERF.

1.1 Project Objective

This geophysical investigation is part of a broader effort using complementary geophysical methods to map the top of basalt surface, character of the upper part of the basalt, stratigraphy within the supra-basalt section, presence or absence of paleochannels, and faults in the 200 East Area.

This geophysical survey was conducted to assist CHPRC with development of conceptual site models of the hydrogeology and to help locate a new monitoring well north of the LERF ponds.

ERI and TDEM surveys were designed to investigate to depths of up to 100 meters (m) with the primary target being the character of the upper 15 m to 30 m of the underlying basalt. The top of basalt ranges from approximately 55 m to 79 m below ground surface (bgs) near the LERF (SGW-43746). Secondary targets include describing the heterogeneity of the overlying Hanford sediments.

1.2 General Geology of Hanford Area

The general geologic setting in the 200 Areas and the Central Plateau includes basalt bedrock between approximately 152 m below ground surface (bgs) in the south and 18 m bgs in the north, with known depth to basalt near LERF ranging from 55 m to 79 m bgs. The upper 3 m to 10 m of the basalt may be highly fractured and/or weathered, and serve as the basal or whole portion of the unconfined aquifer (SGW-43746).

The basalt is overlain by heterogeneous glaciofluvial gravel, cobble, and sand deposits of the Hanford Formation. There is no significant hydro-stratigraphic barrier between the sedimentary units and underlying basalt. The Hanford Formation is generally characterized as three distinct facies, the lower (H1) Cold Creek Unit, a middle (H2) gravel-dominated Pasco Gravels Unit, and an upper (H3) fine-grained facies referred to as the Touchet Beds (Reidel and Fecht 2005). For the purposes of interpretation in this report, the Hanford Formation is referred to as undifferentiated sands and gravels.

Groundwater levels range from 100 m bgs in the south to 61 m bgs in the north and average from 61 m to 64 m bgs in the survey area. Often, groundwater levels are within a few meters of the bedrock surface.

Table 1-1 provides a listing of boreholes that encountered basalt during drilling that are near the ERI line or TDEM soundings and were used for geologic control in the interpretation of the ERI and TDEM results.

Table 1-1: Geologic Control Boreholes

Well Name	NAD-83 St.Pln. East (m)	NAD-83 St.Pln. North (m)	Basalt Elev (m)	Basalt Depth (m)	Line #	Approx. Line Distance (m)
299-E26-10	575589.0	137023.5	121.2	62.3	1	65
299-E26-11	576180.0	137134.6	122.6	60.4	8	222
299-E27-11	574652.9	137062.7	116.4	79.9	6	8
299-E34-1	574642.7	137238.2	120.5	71.6	6	184
299-E34-2	574634.8	137220.7	119.4	73.5	6	168
299-E34-3	575110.3	137301.4	121.9	64.9	3w	5
299-E34-5	574643.8	137743.3	122.7	57.9	6	690
299-E34-7	575274.2	137357.7	121.8	62.5	3w	170
299-E35-1	575459.7	137465.0	122.5	60.0	3w	355
299-E35-2	575576.1	137255.1	122.7	61.0	2	83
699-47-46A	575869.8	137820.7	124.3	53.0	4	400
299-E26-79	575827.9	137051.5	119.3	63.1	1	303
299-E34-13	574640.3	137297.3	121.9	68.9	6	244

2.0 GEOREFERENCING SURVEY DATA

A real time kinematic (RTK) differential global position system was used to determine project coordinates. This system consists of a base unit that was centered on monitoring well 299-E26-10 and a rover unit that was used by the field geophysicists to measured coordinates. Refer to Table 1-1 for the coordinates of monitoring well 299-E26-10 used for the base station. Golder used two RTK GPS systems during field work, a Trimble R7 and a Hemisphere R130.

RTK positions were recorded with the electromagnetics data in the utility locate survey, for the electrodes in the electrical resistivity survey, and the receiver antenna location in the center of the transmitter coil in the time domain electromagnetics survey. T he coordinate system used for all geo-reference data is Washington State Plane South NAD83 meters.

3.0 UTILITY LOCATE SURVEY

A utility locate survey was conducted along proposed ERI lines and nearby TDEM station locations to help ensure data were not collected in areas where cultural interference could potentially overwhelm geophysical measurements, and to help interpret the ERI and TDEM data. This survey was conducted using a Geonics Limited EM61-MK2 and Radiodetection RD400 Electromagnetic Utility Locator (EMUL). The EM61-MK2 data were collected using differential global positioning (dGPS) for positioning. EM61-MK2 values greater than 20 millivolts were interpreted as being associated with underground utilities and unknown metal debris. The EM61-MK2 results were compared against known utility maps of the LERF area. Both known and unknown utilities are presented in Figure 2. The two primary utilities interfering with geophysical results are underground power and steel process pipelines. There are underground utilities beneath or immediately adjacent to all ERI lines except Line 6. There may still be other utilities present in the LERF area that are either non-metallic or deeply buried relative to their size to be detected with the EM61-MK2, but these are expected to be insignificant in respect to their potential negative impact on ERI and TDEM results.

4.0 ELECTRICAL RESISTIVITY PROFILING DATA ACQUISITION AND PROCESSING

ERI is used to map changes in subsurface soil conductivity or resistivity. The resistivity values are used to interpret geologic features such as lithology, structure, fractures, and stratigraphy, as well as anthropogenic features such as buried metal pipes. In an electrical resistivity imaging survey, a direct current at a specified voltage is passed into the ground through a pair of current electrodes. Because of soil resistance the current produces a voltage drop which is measured across a pair of potential electrodes. The current and potential electrode pairs are arranged in various electrode configurations to map subsurface electrical features that can be associated with geologic features. The supplied current and measured voltage change across the potential electrodes are used to compute electrical resistance for each potential/current electrode configuration. Electrical resistance is multiplied by the geometric factor associated with the particular electrode configuration to derive apparent resistivity values that represent bulk average resistivity values for the volume of earth being sampled. In general, apparent resistivities derived from greater spaced electrode pairs sample a deeper portion of the subsurface than from smaller spaced electrodes. An iterative mathematical process termed geophysical inversion is used to convert the measured apparent resistivities into a “bulk” resistivity distribution of the subsurface. Representative resistivity values for various geologic layers are used to interpret the modeled resistivity values. The inverted or modeled resistivity values representing layers of unconsolidated sand and gravel above the water table are expected to be considerable greater than basalt, particularly if the basalt is beneath the water table and fractured and/or weathered to clay.

4.1 Data Acquisition

Figure 1 shows the locations of the eight ERI lines collected for this project. ERI data were collected using a 96-channel IRIS Syscal PRO system with electrodes arranged in a pole-pole electrode configuration. Stainless steel electrodes were driven into the soil between 8 and 10 inches at each electrode station and watered with approximately 0.5 gallons of salt water. Salt water was added to each electrode to get contact resistance values lower than 5,000 ohms.

The remote electrodes required for pole-pole surveying were located approximately 2,200 m from the LERF. Figure 1A shows the locations of the remote electrodes relative to the LERF. Table 4-1 contains the acquisition parameters used to collect data.

Table 4-1: ERI Acquisition Parameters

Parameter	Setting
electrode array	pole-pole
electrode spacing	5 meters
voltage	400 volts
# of readings per measurements	2 to 6
Cycle time	1 sec

The ERI data set consists of eight individual Lines 1, 2, 3, 3W, 4, 6, 8, and 9. In total approximately 4,500 meters of ERI data were acquired during this project. Table 4-2 provides the coordinates of the endpoints of each line as well as the length. Coordinates are in NAD83 WA State Plane South meters.

Table 4-2: Coordinates of ERI Lines

Line	Start	End	Length (m)
1	575526.28 E 137023.82 N	576199.04 E 137034.82 N	1075
2	576166.16 E 137274.37 N	575493.44 E 137265.53 N	675
3	575498.01 E 137356.73 N	576166.32 E 137372.81 N	670
3W	575463.22 E 137351.85 N	575105.39 E 137358.63 N	370
4	575476.83 E 137797.45 N	575953.38 E 137809.64 N	475
6	574647.20 E 137055.15 N	574648.06 E 137736.80	685
8	576213.19 E 137385.09 N	576214.01 E 136904.17 N	480
9	575616.26 E 137211.65 N	575600.00 E 137672.72 N	460

To help ensure high quality ERI data were collected, data collection was completed in accordance with Golder Associates Inc. Technical Procedure 1.1.19 and American Society for Testing and Materials (ASTM) International D 6431-Standard Guide for Using the Direct Current Resistivity Method for Subsurface Investigation. Details on these procedures are found in the Quality Assurance/Quality Control (QA/QC) Plan. Data collection was restricted to times when the active cathodic protection systems associated with the 200E tank farm were shut down.

4.2 Data Processing

Data were downloaded from the Syscal PRO system and pre-processed using ProSys software. This software is commercially available from Iris Instruments. In general, data files were converted from binary Iris format to text files used as input for the inversion software, RES2DINV, commercially available from GeoTomo Software. Below is the general processing flow used to process ERI data.

- Reformat field files from IRIS format to RES2DINV format.
- Edit data file, remove spurious readings.
- Combine field measurements with elevation data.
- Perform inversion:
  - Forward modeling: finest mesh refinement and 4 nodes per grid
  - Inversion: least-squares with robust constraint and standard Guass-Newton optimization.
- Export psuedosections of field measurements (measured apparent resistivity), calculated apparent resistivity, and final earth resistivity models as x, y, z data in American Standard Code for Information Interchange (ASCII) format.
- Plot sections for interpretation.

Table 4-3: ERI Data Inversion Parameters

Line	Number of Iterations	RMS Error of Final Earth Model (%)
1	7	1.94
2	7	2.5
3	7	1.65
3W	7	1.05
4	7	2.1
6	7	2.07
8	7	2.1
9	7	3.71

5.0 TIME-DOMAIN ELECTROMAGNETIC DATA ACQUISITION AND PROCESSING

TDEM soundings are used to measure vertical changes in subsurface electrical properties by recording the decay rate of an induced electromagnetic signal as it propagates through the earth. Changes in the decay rate are used to model the electrical properties of the subsurface. This model is then used to infer the subsurface soil conditions and stratigraphy.

TDEM surveying requires a transmitter, square loop transmitter coil, a receiving unit and receiver coil. The transmitter sends an electrical current through the transmitter coil, which is turned off after a very brief time producing an EM field. This EM field induces eddy currents in the ground, which in turn, produce a secondary magnetic field. As the eddy currents propagate downward and away from the transmitter coil, the secondary magnetic field loses strength (decays) at a rate proportional to the electrical conductivity of the subsurface. A receiver measures the decaying secondary magnetic field at different points in time (record length). One sequence of secondary magnetic field measurements at a particular location is called a sounding. In a homogenous earth, the secondary magnetic field will decay at a predictable rate. Deviations from this decay rate correspond to changes in subsurface electrical properties. The TDEM method takes advantage of these properties by correlating both the magnetic field strength and measurement time with changes in the electrical properties of the subsurface.

During the TDEM sounding, the transmitter and receiver are synchronized via a reference cable. The receiver instructs the transmitter to turn on and off at predetermined measurement intervals (time gates), and then measures the strength of the decaying secondary magnetic field at up to 30 time gates during the transmitter off period. The signal is enhanced by taking multiple sets of readings and averaging them during a user-determined measurement period (from 2 to 64 micro-seconds in length). The total number of measurements available for averaging per measurement period is determined by the repetition frequency, with higher frequencies giving a larger sample set at the expense of a shorter record length.

The depth of penetration of the TDEM signal depends on the subsurface electrical properties and the area (size), and current strength of the transmitter antenna. In general, a larger antennae size and larger transmitter current strength are required to investigate greater depths. For a given antenna size (and current strength), a greater depth of investigation is achieved in areas underlain by relatively resistive material.

5.1 Data Acquisition

Figure 1 shows the locations of the TDEM soundings. TDEM sounding locations were selected as close to the ERI profiles as possible, depending on cultural interference. Data were collected using a Zonge GDP16, a 50-m transmitter loop, and a TEM3 receiver antenna. The geophysical survey was completed in accordance with Golder Associates Technical Procedures and ASTM International Standard Guides for time domain electromagnetics. Details on these procedures are found in the QA/QC Plan. In total, 30 TDEM soundings were acquired during this project. Table 5-1 presents the coordinates of each TDEM sounding. Coordinates are in NAD83, WA State Plane South meters.

Table 5-1: Coordinates of TDEM Soundings

TDEM Sounding	East (m)	North (m)	Elevation (m amsl*)
TDEM1	576517	137120	179
TDEM2	575638	137265	183
TDEM3	575880	137267	182
TDEM4	575641	136983	183
TDEM5	576111	136946	178
A	575565	137603	180
B	575559	137484	182
C	576179	137551	180
D	575752	137266	182
E	575999	137264	181
F	576125	137274	182
G	576282	137235	185
H	576351	137119	182
I	576298	136975	179
J	576220	136972	178
K	576125	137179	183
L	576127	137100	182
M	576526	136992	177
N	575606	138302	186
O	575609	138113	185
P	575582	137885	177
Q	574616	137673	183
R	574613	137550	186
S	574611	137410	188
T	574584	137280	191
U	574623	137180	192
V	574813	136936	198
W	574993	136921	195
X	575184	136985	190
Y	575371	136970	186

* amsl = Above Mean Sea Level

Table 5-2 contains the acquisition parameters used to collect TDEM data.

Table 5-2: TDEM Acquisition Parameters

Parameter	Setting
Transmit loop	20m
Transmit Frequency	32, 16, & 8 Hz
Record length	31.07 micro-seconds to 12.17 milliseconds

5.2 Data Processing

TDEM data were processed using 1X1D inversion software (Interpex Ltd). Below is the basic data processing procedure.

- Download data from GDP-16 console memory, pre-process from Zonge format to Interpext format.
- Use 1X1D software to plot the measured apparent resistivity curve for each sounding.
- Implement a smooth model inversion to produce an initial model of stepped-resistivity depth that consists of a reasonable number of layers for the site.
- Perform inversion within 1X1D to adjust model parameters to achieve a best-fit to the field data.
- If iterative inversion process does not converge on an acceptable solution, edit the initial model and reprocess.
- Perform an equivalence analysis on the final model to determine how well individual layers and resistivity values for those layers are resolved by the observed data.

6.0 RESULTS

6.1 Electrical Resistivity Imaging Results

ERI models are presented in Figures 3, 4, and 5. Figure 3 presents west-to-east profiles in the vicinity of LERF. Figure 4 presents the south-to-north profiles. Figure 5 presents the west-to-east profile, Line 4, located north of the LERF ponds.

Where nearby boreholes that encountered basalt exist, the projected location of those boreholes and basalt contact elevation were plotted on each ERI model. Additionally, TDEM sounding and model results were projected on the ERI model sections and interpretation were added to Figures 3, 4, and 5. Color-contoured pseudo sections of measured apparent resistivity (top panel), calculated apparent resistivity (middle panel), and inversion results (model resistivity; lower panel) are presented in Appendix A, Figures A-1 through A-9.

Based on low root mean square (RMS) (less than 5%) error of the final earth models, ERI data quality is generally very good. Most ERI lines show three distinct layers, a surface layer with resistivity values across the full range of 20 to 3,000 ohm-m, a middle layer with relatively high resistivity values (greater than 1,000 ohm-m), and a lower layer with relatively low resistivity values (less than 1,000 ohm-m). In a few areas, subsurface utilities have a negative impact on the data quality to the extent that the bedrock contact cannot be reliably interpreted. The locations of known and mapped utilities are shown in Figure 1A and, where apparent, ERI anomalies due to subsurface utilities are shown in Figures 3, 4, and 5.

There is generally sufficient contrast in electrical resistivity values to interpret the contact between the sands and gravels of the Hanford Formation and the basalt of the Columbia River Basalt Group (CRBG). Where there appears to be little contrast in electrical properties between these two layers, and assuming that unknown utilities aren't present, auxiliary information from TDEM, seismic, and borehole logs are used to help define the location of the basalt surface. These interpreted geologic contacts are shown in Figures 3, 4, and 5. Typically, resistivity values are greater than 1,000 ohm-m for the Hanford Formation (middle layer) and less than 1,000 ohm-meters for the CRBG (lower layer).

Where the gradient of resistivity values is steep, the top of the basalt is interpreted as competent and massive. Where resistivity values transition more gradually from relatively high values to low values, the first basalt may be a flow top or heavily weathered surface. Within the upper 20 to 30 m of basalt, zones of low resistivity values can be inferred to represent zones that are more heavily fractured.

6.1.1 Electrical Resistivity Imaging Line 1

Line 1 is 1,075 m long and approximately 75 m south of the LERF ponds. South of Line 1 a 42-inch steel pipeline is known to exist and was mapped with the EM-61MK2 during the utility locate task (Figure 2). It is reasonable to expect some interference from this pipeline, and there is an obvious change in the modeled apparent resistivity in the shallow subsurface starting at approximately 660 m line distance extending to the east (where the pipeline is within 20 m of the ERI line). West of line distance 660 m, the upper layer (down to 160 m amsl elevation) generally exhibits a l ow-high-low resistivity pattern with generally higher absolute resistivity values than the layer below (~155 to 170 m amsl elevation). East of line distance 660 m, the upper layer exhibits lower absolute resistivity values than the layer below (~155 to 170 m amsl elevation). To the west of 660 m, the bedrock contact is interpreted to be at an elevation of 120 to 130 m amsl (between 50 and 60 m bgs based on both ERI and TDEM models). The interpreted depth to CRBG shown east of the 660 m line distance along Line 1 is primarily based on TDEM sounding information.

There are two zones on Line 1 where electrical properties within the basalt are noteworthy. The first is between line distances 260 and 440 m. The second is between line distances 660 and 745 m. These two zones show anomalously low resistivity values that can be interpreted as representing zones within the bedrock that are more heavily fractured. It is reasonable to expect that well 299-E26-79 should be capable of producing more water than wells in higher resistivity zones, e.g. 299-E26-10.

6.1.2 Electrical Resistivity Imaging Line 2

Line 2 is 675 m long and located approximately 100 m north of the LERF ponds. The upper layer (down to 170 m amsl elevation) on Line 2, except around 35 m line distance, exhibits variable resistivity values creating bulls-eye type anomalies with generally higher absolute resistivity values than the layer below (~155 to 170 m amsl elevation). T hese anomalies may represent utilities, but there are no obvious impacts to data quality in the middle or lower layers. The middle layer from approximately 120 to 155 m amsl is about 35 m thick and is interpreted as Hanford Formation. The depth to the top of the lower layer is interpreted to be approximately between 55 and 65 m bgs; and is interpreted as CRBG.

There is one zone where electrical properties within the basalt are noteworthy, between line distances 260 and 475 m. This zone is characterized by anomalously low resistivity values that can be interpreted as representing a zone within the bedrock that is more heavily fractured. Wells located in this zone would likely produce water. This zone of anomalously low resistivity is possible related to the low resistivity zone on Line 1 between line distances 260 and 440 m.

6.1.3 Electrical Resistivity Imaging Line 3

Line 3 is 670 m long and located approximately 210 m north of the LERF ponds. The upper layer on Line 3 is similar to other ERI Line 2 with highly variable model resistivity values creating bulls-eye type anomalies. T he anomalies from 10 t o 90 m line distance represent utilities, but there are no obvious impacts to data quality in the middle or lower layers after a line distance of 125 m. The middle layer is between 30 and 40 m thick and is interpreted as a gravel-dominated zone of the Hanford Formation. The depth to the top of the lower layer is approximately 55 m; the lower layer is interpreted as CRBG. The bedrock contact is interpreted to be at an elevation of 125 to 130 m amsl.

There is one zone where electrical properties within the basalt are noteworthy, between line distances 325 and 490 m. This zone show anomalously low resistivity values that can be interpreted as representing a zone within the bedrock that is more heavily fractured. Although Lines 1 and 3 are almost 200 m apart, the anomalously low resistivity zone on Line 3 may correspond to the eastern low resistivity anomaly on Line 1.

6.1.4 Electrical Resistivity Imaging Line 3W

Line 3W is 370 m long and located approximately 210 m of the LERF ponds and west of Canton Avenue. There appears to be interference from a subsurface utility at a line distance of approximately 175 m. Due to access restrictions at the time of the utility survey, a utility scan was not completed along Line 3W. The bedrock contact is only interpreted between distances of 50 and 150 m, and between 200 and 330 m. Interference, presumably from a utility or other unknown subsurface feature has obscured the Hanford Formation-CRBG electrical interface in the central part of the profile.

There is one zone along Line 3W where the electrical resistivity values for the basalt are anomalously high, ranging between approximately 800 to 1,000 ohm-m. This zone is interpreted as representing some of the most competent or otherwise unweathered or non-fractured basalt in the LERF area.

6.1.5 Electrical Resistivity Imaging Line 4

Line 4, presented is 475 m long and located approximately 310 m north of the LERF ponds (Figure 5). From line distance 0 to 310 m, data were collected along a plastic pipeline. The land surface that is free of vegetation. Between line distances 310 and 475 m, Line 4 is in relatively undisturbed desert land. The upper layer has generally lower resistivity along the land surface that is free of vegetation and higher resistivity in the relatively undisturbed desert land. There appears to be interference from subsurface utilities at two locations, line distances 55 to 75 m and 310 m. The middle layer is between 30 and 40 m thick and is interpreted as a gravel-dominated zone of the Hanford Formation. The bedrock contact is only reliably interpreted between distances of 100 and 440 m, and tentatively extended to west.

There are no anomalous electrical resistivity zones observed in the basalt on Line 4. There is a subtle drop in electrical resistivity values near well 699-47-46A. It is not known whether or not this is caused by the effects of the well or represents an actual zone of increased fracturing in the shallow basalt.

6.1.6 Electrical Resistivity Imaging Line 6

Line 6 is 685 m long and located approximately 560 m west of the LERF ponds. The upper layer on Line 6 is similar to ERI Lines 1, 2 and 3 near LERF, with variable resistivity values creating bulls-eye type anomalies and a low-high-low pattern. These anomalies likely represent variable water, clay or mineral content of the shallow subsurface. The middle layer is between 40 and 60 m thick and is interpreted as a gravel-dominated zone of the Hanford Formation. The depth to the top of the lower layer is approximately 65 meters; the lower layer is interpreted as CRBG.

The gap in relatively high resistivity values interpreted as Hanford gravels (line distances 150 to 200 m) is likely due to the presence of wells 299-E34-2 and 299-E34-1. The low resistivity zone in the basalt between line distances 160 and 245 m is likely due to the presence of the wells.

6.1.7 Electrical Resistivity Imaging Line 8

Line 8 is 480 m long and located approximately 100 m east of the LERF ponds. The upper layer is similar to that on the other ERI lines. However, the middle layer is significantly different, with resistivity values that are much lower, and are essentially indistinguishable from those of the lower layer. There is not an obvious explanation for the relatively low resistivity values of the middle layer. Because it is unlikely that the unconsolidated Hanford Formation is anomalously clay-rich in this area, nor is it likely that groundwater is present near the surface; it is likely that the exterior LERF fenceline or some unidentified pipeline parallel to Line 8 are causing anomalies in the EM data. On the middle panel of Figure 4, the bedrock (CRBG) contact is interpreted based on TDEM sounding results and nearby well information.

Between line distances 60 and 190 m, the electrical resistivity values for the basalt are anomalously low, likely representing basalt that this partially weather or fractured. It is possible that the overlying utilities are creating artificially low resistivity values down through the whole model. If this were the case, the basalt in the area is likely similar to the basalt between lines distances 220 and 350 m.

6.1.8 Electrical Resistivity Imaging Line 9

Line 9 is 460 m long and located approximately 70 m west of the LERF ponds. The upper layer on Line 9 does not have as pronounced a difference in resistivity values as exhibited on other ERI lines. There are areas with variable resistivity values creating bulls-eye type anomalies in the upper portion of the resistivity model due to utilities but there are no obvious impacts to data quality in the lower layer. The middle layer is between 35 and 50 m thick and is interpreted as Hanford Formation. The depth to the top of the lower layer is approximately 65 m; the lower layer is interpreted as CRBG. South of line distance 150 m, the transition in resistivity values is gradual between the middle and lower layers, suggesting the possible presence of a flow top or a zone of weathered basalt. This area is consistent with a similar zone on the west end of Line 2.

There is one large relatively low resistivity anomaly in the basalt, beginning at line distance 150 m and continuing north across the remaining model. These values likely represent weather or fractured basalt.

If there is a northwest-southeast trend of fractured basalt, this zone would coincide with the low resistivity zones in the basalt on Lines 2 and 3.

6.2 Time Domain Electromagnetics Results

TDEM soundings were interpreted using a model with four layers fit to the field measurements. The results of the TDEM survey are presented in Figures 3, 4 and 5. Where there are ERI lines, the TDEM soundings are plotted as a cross section, along with the ERI data. Appendix B presents the results of the TDEM survey. Figures B-1 through B-5 (Appendix B) present field data and a graphical display of the model for each of the 30 soundings. Tables B-1 through B-30 present the corresponding tabular model results.

Typically, the upper one or two layers, depending on the location of the TDEM sounding, are interpreted as representing the unconsolidated, dry Hanford Formation. The lower two or three layers, in general, represent the basalt bedrock of the CRBG. Interpreted resistivity values for the Hanford Formation are typically greater than 1,000 ohm-m and can be as high as 45,100 ohm-m. Interpreted resistivity values for the CRBG are typically less than 1,000 ohm-m and at times are less than 10 ohm-m.

The electrical resistivity values of the CRBG determined using TDEM (10 – 1,000 ohm-m) are very similar to the electrical resistivity values of the basalts determined using ERI. Additionally, where the ERI models show relatively low resistivity values, the TDEM models also show similarly low resistivity values.

7.0 SUMMARY

Lateral variations in electrical resistivity within the basalt bedrock may correlate well with lateral variations in the degree of weathering or fracturing within the shallow basalt. It appears that both ERI and TDEM are suitable to map lateral variations within the unconsolidated sediment and the shallow basalt.

In general, ERI was used to help interpret the contact between the base of the Hanford Formation and the top of the CRBG. ERI data help delineate variations within the upper part of the basalt; however, additional geotechnical data regarding the elevation of the top of the CRBG are required to help guide ERI interpretations. This top of basalt is interpreted to be between 55 and 70 m bgs. This contact may not always coincide with the lithologic depth to the contact interpreted in nearby boreholes due to variations in weathering and presence of fractured flow tops. Even though ERI data can be significantly impacted by subsurface utilities and active cathodic protection systems, this method is suitable to map the contact in most places. No paleochannels were interpreted on the ERI lines. It is uncertain if no paleochannels exist beneath LERF, or if they exist but are too small to be detected from the ground surface with ERI.

TDEM was also used successfully to help interpret the depth to the top of basalt. The depth to bedrock is often interpreted to be at depths between 55 and 70 meters. It's difficult to determine whether or not the top of bedrock is a fractured flow top from just a one-dimensional sounding curve. No interpretation is made on individual soundings with regard to whether or not the basalt is massive or fractured. The major limitation of this method is that it requires a large area of ground surface and shallow subsurface to be free of anthropogenic metallic objects, e.g. utilities and fences.

Figure 6 is a bedrock elevation map based on the results and interpretations of the ERI profiles and the TDEM soundings. Bedrock elevation is highest in the southwest corner of the site, near the west end of Line 1W and the south end of Line 6. Bedrock elevations in this area are interpreted to be approximately 130 m amsl. There are two areas where the interpreted bedrock elevation is lowest, at the east end of Line 1 and the north end of Line 6. Bedrock elevations in both of these areas are interpreted to be approximately 105 m to 110 m amsl.

8.0 LIMITATIONS

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. Electromagnetics and electrical resistivity imaging are remote sensing geophysical methods that may not detect all changes in subsurface conditions. F urthermore, it is possible that anomalies in the geophysical data that are interpreted as utilities or stratigraphic horizons, may upon intrusive sampling, prove to be misinterpreted.

9.0 BIBLIOGRAPHY AND REFERENCE LIST

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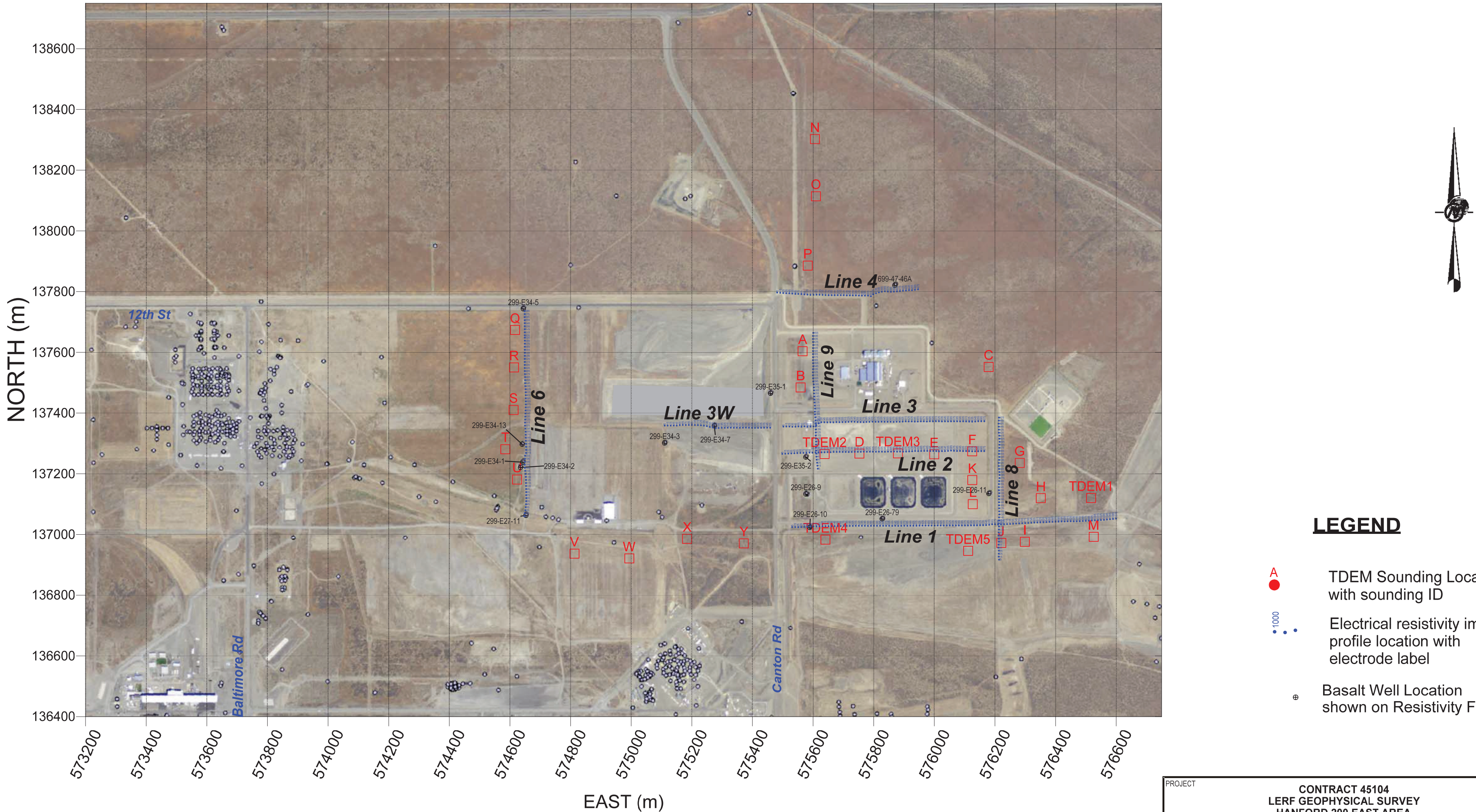
FIGURES



LEGEND

A ● TDEM Sounding Location with sounding ID

1000 • • • Electrical resistivity imaging profile location with electrode label

⊕ Basalt Well Location shown on Resistivity Figures

NOTES:
1. Seismic reflection and refraction data collected June -August 2011.
2. Seismic data collected using 72 channel Geometrics GEODE system.
3. Seismic data processed using SeisImager Pro and SPW software.
4. Base Map provided by CHPRC,
5. Horizontal dataum is WA State Plane South meters, NAD83.
6. Survey objective is to map help map the top of basaslt bedrock.

PROJECT
CONTRACT 45104
LERF GEOPHYSICAL SURVEY
HANFORD 200 EAST AREA

TITLE
200 EAST - LERF GEOPHYSICAL SURVEY ELECTRICAL RESISTIVITY IMAGING AND TDEM SOUNDINGS LOCATIONS

Golder Associates

PROJECT No.		113-93040.200	FILE No. ---
DESIGN	MB	9/21/11	SCALE AS SHOWN REV.
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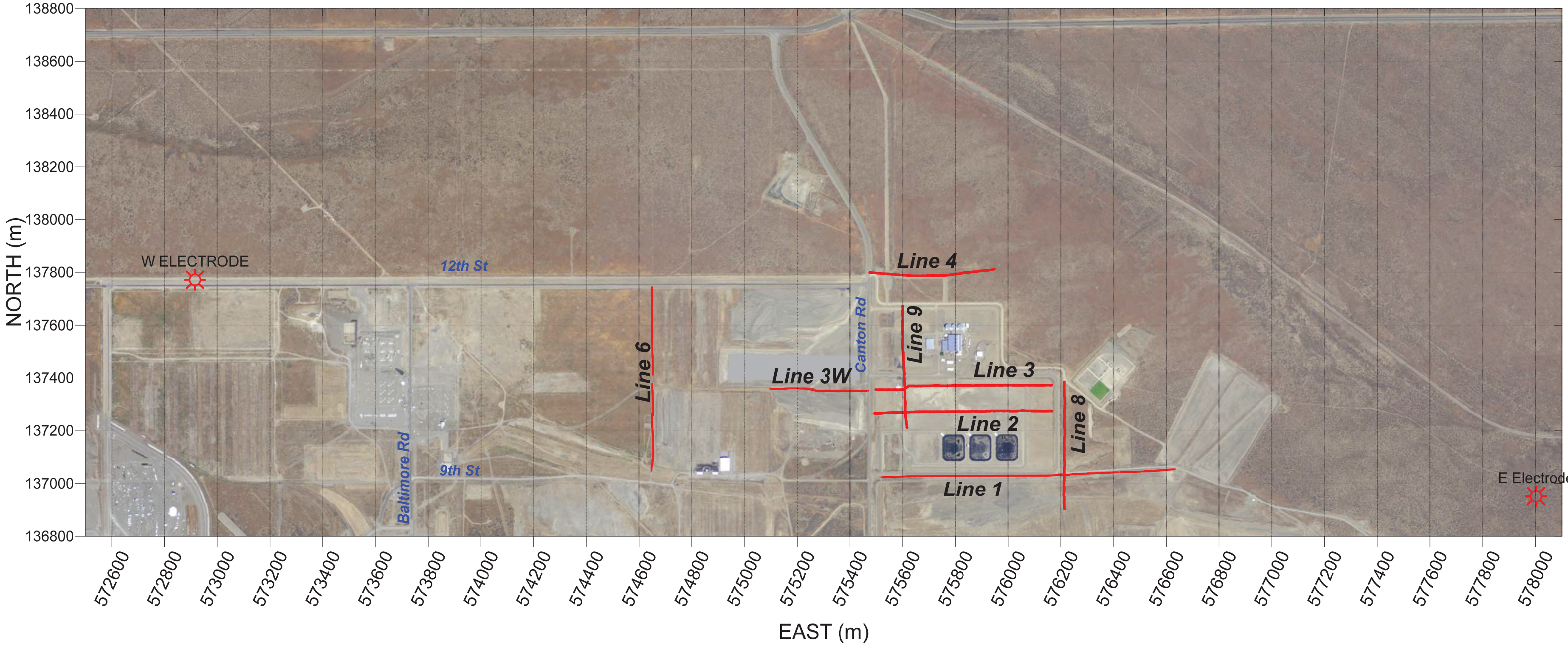
CHECK	ML	9/21/11	**FIGURE 1**
REVIEW	ML	9/21/11	



LEGEND

Remote Electrode Location

Electrical resistivity imaging profile location

NOTES:
1. Resistivity collected July-August 2011.
2. Base Map provided by CHPRC.
3. Horizontal dataum is WA State Plane South meters, NAD83.
4. Survey objective is to map help map the top of basaslt bedrock.

PROJECT	CONTRACT 45104 LERF GEOPHYSICAL SURVEY HANFORD 200 EAST AREA			
TITLE	200 EAST - LERF GEOPHYSICAL SURVEY ELECTRICAL RESISTIVITY IMAGING REMOTE ELECTRODE LOCATIONS			
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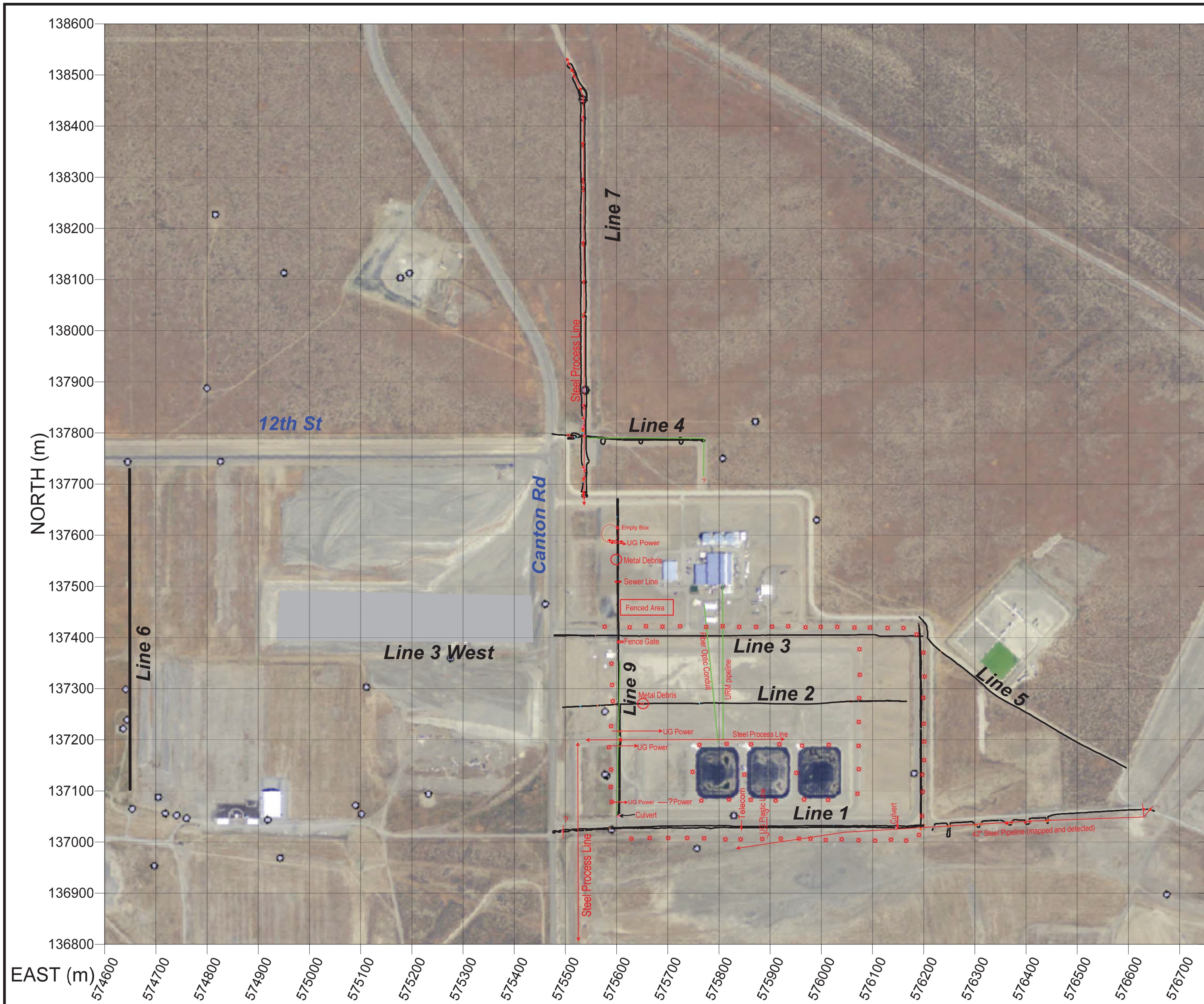

LEGEND

- * Above Ground Power/ Light Post
- UG Power —— Detected Utility Underground / feature
- —— Utility Mapped on "As Built" Drawings
- —— Geonics EM61MKII trackline (colored points indicate values <20mV)

NOTES:
1. Base Map provided by CHPRC.
2. Horizontal dataum is WA State Plane South meters, NAD83.
3. Electromagnetic Utility Locator & Geonics EM61MKII used to map metallic utilities.
4. Additional utilities exist but not mapped.

PROJECT
CONTRACT 45104
LERF GEOPHYSICAL SURVEY
HANFORD 200 EAST AREA

TITLE
200 EAST - LERF GEOPHYSICAL SURVEY
UTILITY LOCATION MAP

Golder Associates

PROJECT No.	113-93040.200	FILE No. Fig 2_LERF Utility Locations.srf	
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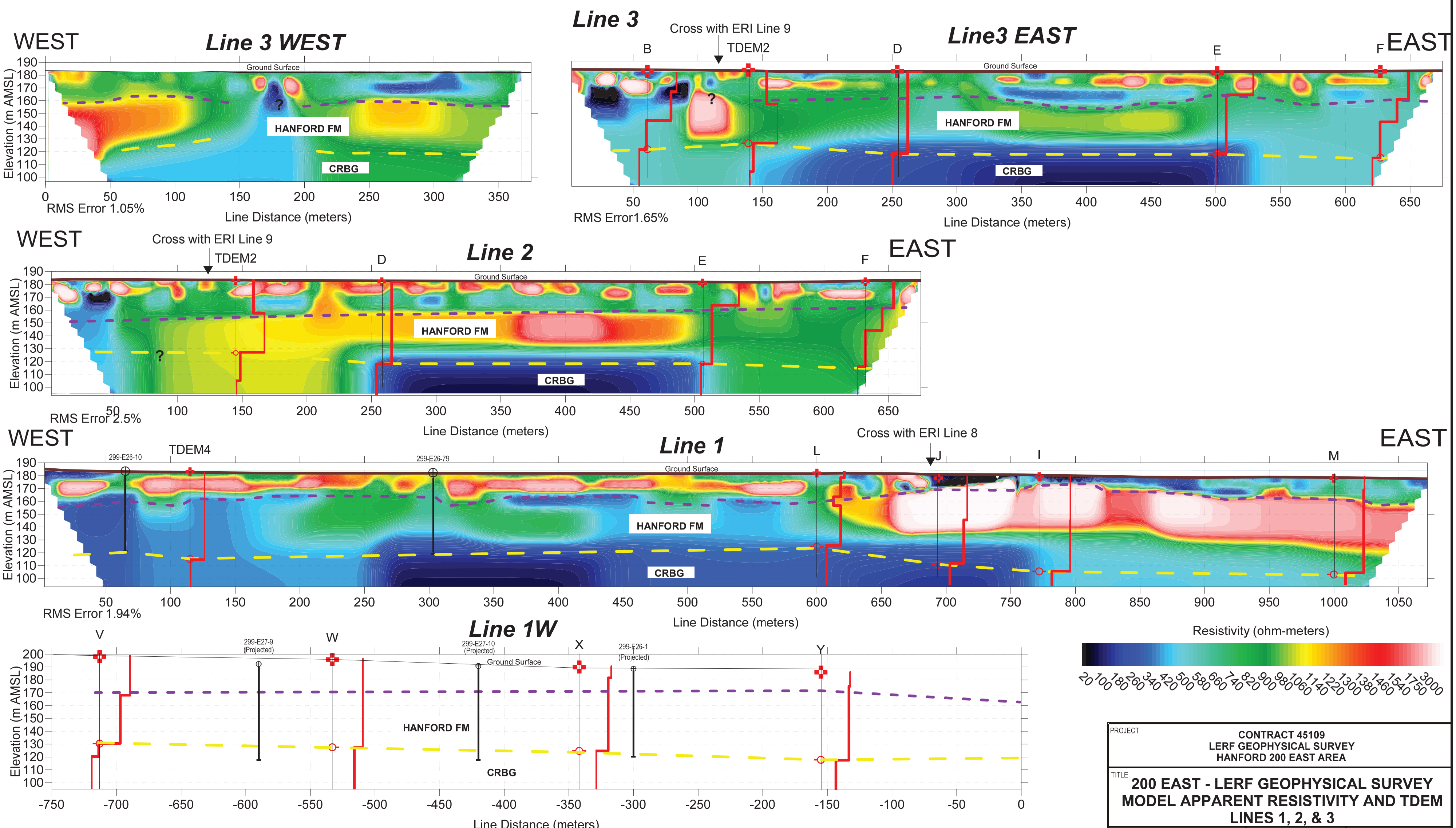
REVIEW	ML	9/28/11	



Hanford formation - upper (silty) and lower (gravel) facies

Columbia River Basalt

NOTES:
NORTHINGS AND EASTINGS IN WA SP SOUTH METERS, NAD83 DATUM
LOCATION INFORMATION COLLECTED WITH HEMISPHERE R130 RTK-DGPS

PROJECT
CONTRACT 45109
LERF GEOPHYSICAL SURVEY
HANFORD 200 EAST AREA

TITLE
200 EAST - LERF GEOPHYSICAL SURVEY
MODEL APPARENT RESISTIVITY AND TDEM
LINES 1, 2, & 3

Golder Associates

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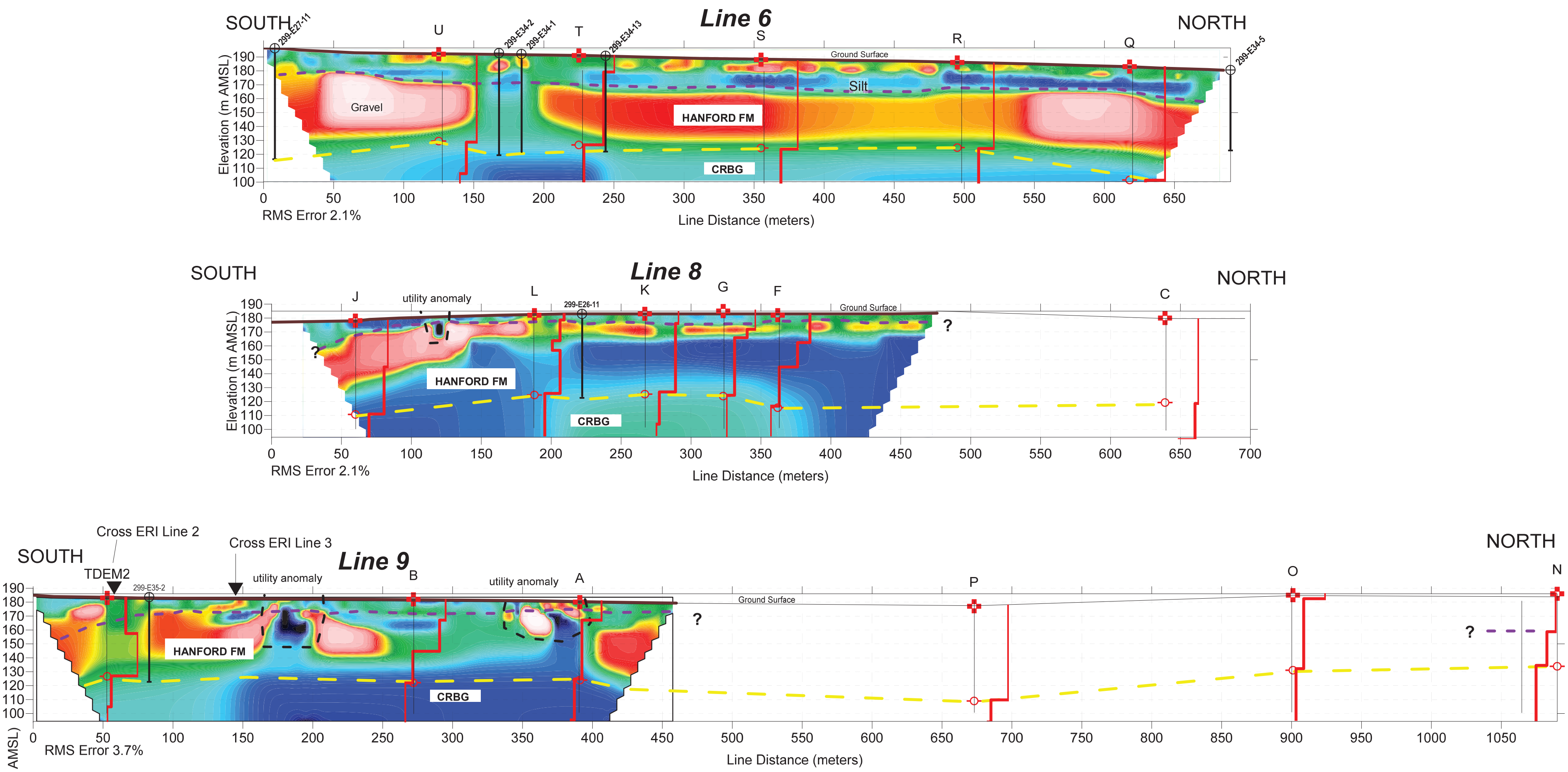
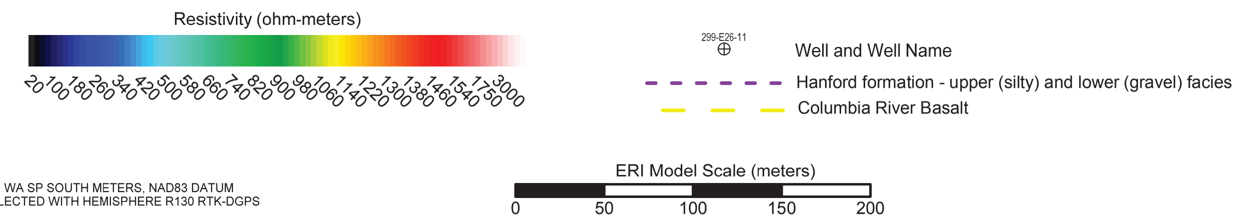
REVIEW	ML	1/31/12	





NOTES:
NORTHINGS AND EASTINGS IN WA SP SOUTH METERS, NAD83 DATUM
LOCATION INFORMATION COLLECTED WITH HEMISPHERE R130 RTK-DGPS

PROJECT
CONTRACT 45104
LERF GEOPHYSICAL SURVEY
HANFORD 200 EAST AREA

TITLE
200 EAST - LERF GEOPHYSICAL SURVEY
MODEL RESISTIVITY AND TDEM
LINES 6, 8, & 9

Golder Associates

PROJECT No.		113-93039.200	FILE No.	ERI_Line6-8-9.srf
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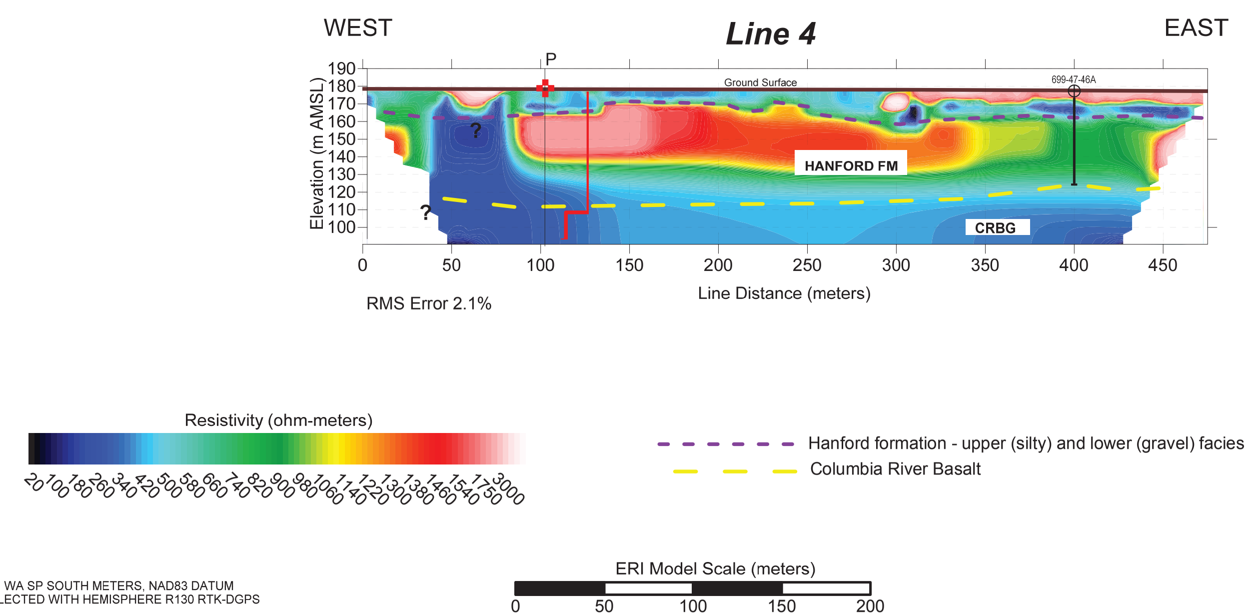
FIGURE 4



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NORTHINGS AND EASTINGS IN WA SP SOUTH METERS, NAD83 DATUM
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PROJECT
CONTRACT 45104
LERF GEOPHYSICAL SURVEY
HANFORD 200 EAST AREA

TITLE
200 EAST - LERF GEOPHYSICAL SURVEY
MODEL RESISTIVITY AND TDEM
LINE 4

Golder Associates

PROJECT No.		113-93039.200	FILE No.	ERI_Line4.srf
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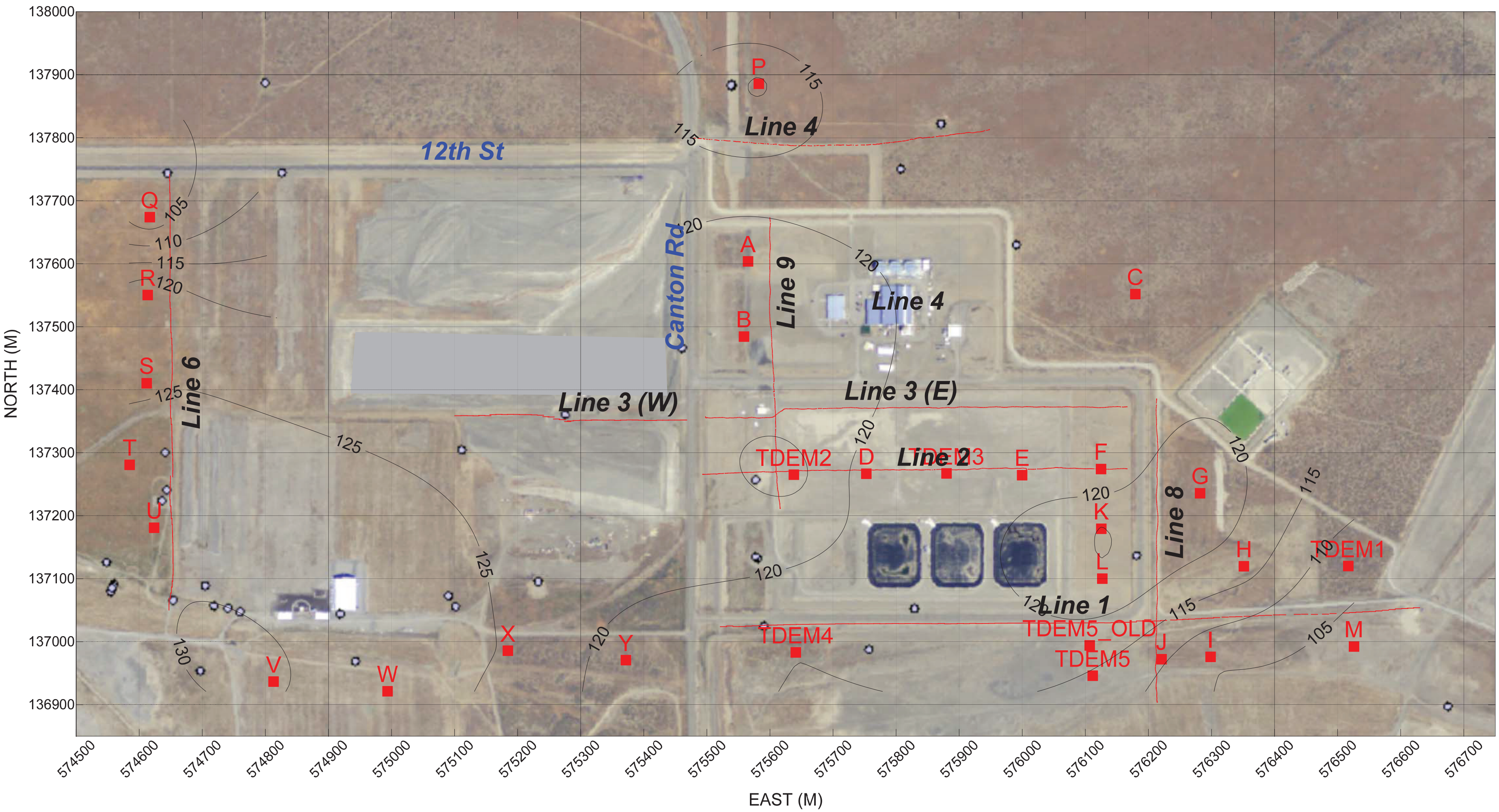
FIGURE 5



TDEM sounding location

TDEM sounding location

ERI Line location

Scale (meters)

0 m 100 m 200 m 300 m 400 m 500 m

NOTES:
1. NORTHINGS AND EASTINGS IN WA STATE PLANE SOUTH METERS, NAD83 DATUM
2. LOCATION INFORMATION COLLECTED WITH HEMISPHERE R130 RTK-DGPS

PROJECT

CONTRACT 45104
LERF GEOPHYSICAL SURVEY
HANFORD 200 EAST AREA

TITLE

200 EAST - LERF GEOPHYSICAL SURVEY ELECTRICAL RESISTIVITY IMAGING (ERI) LINES AND TDEM SOUNDING LOCATIONS

Golder Associates

PROJECT No.		113-93039.200	FILE No. LERF_ERI_locs.srf
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CADD	PEF	8/26/11	
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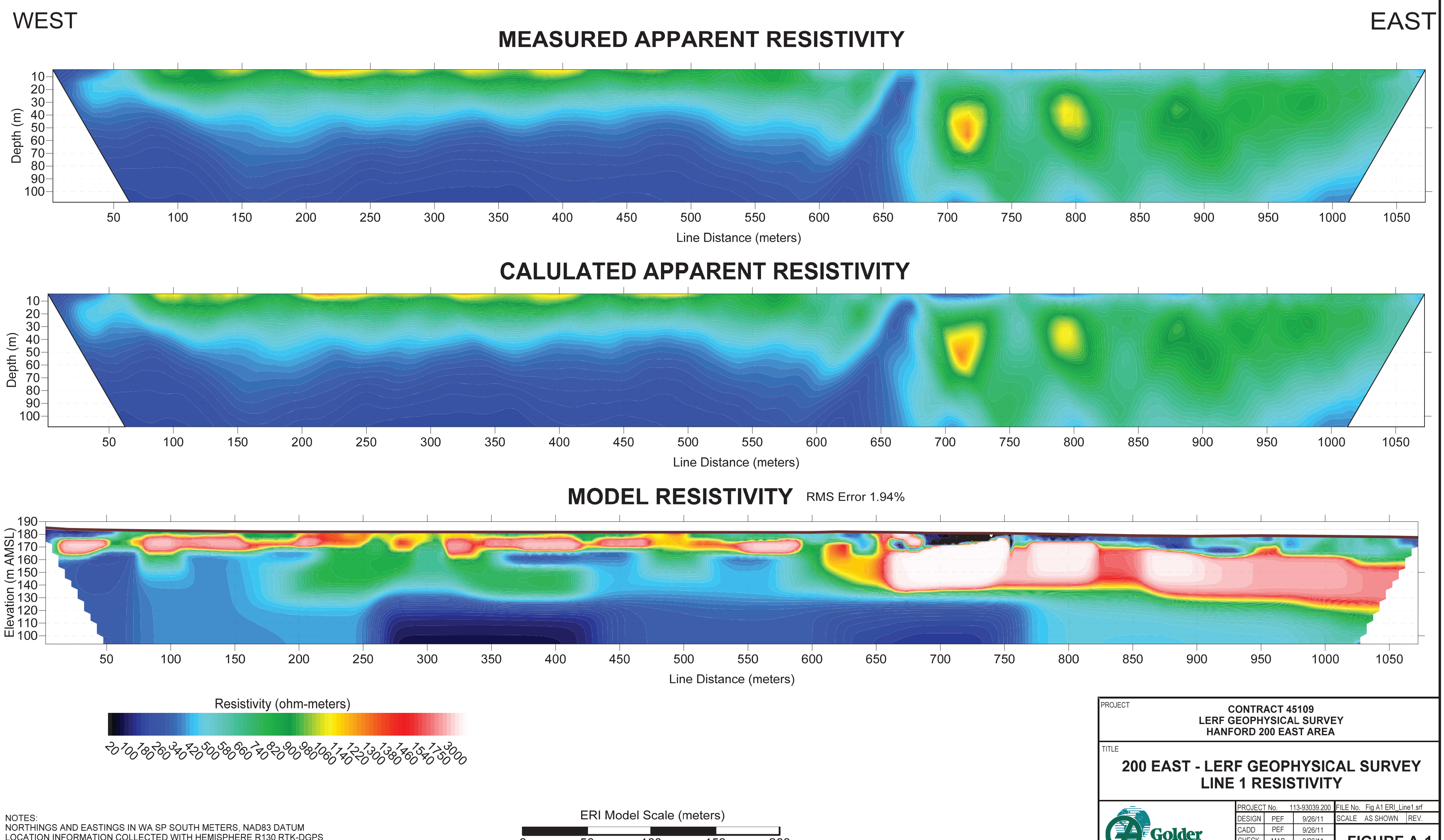
APPENDIX A
ELECTRICAL RESISTIVITY IMAGING LINES



NOTES:
NORTHINGS AND EASTINGS IN WA SP SOUTH METERS, NAD83 DATUM
LOCATION INFORMATION COLLECTED WITH HEMISPHERE R130 RTK-DGPS

PROJECT
CONTRACT 45109
LERF GEOPHYSICAL SURVEY
HANFORD 200 EAST AREA

TITLE
200 EAST - LERF GEOPHYSICAL SURVEY
LINE 1 RESISTIVITY

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PROJECT No.	113-93039.200		FILE No.	Fig A1 ERI_Line1.srf
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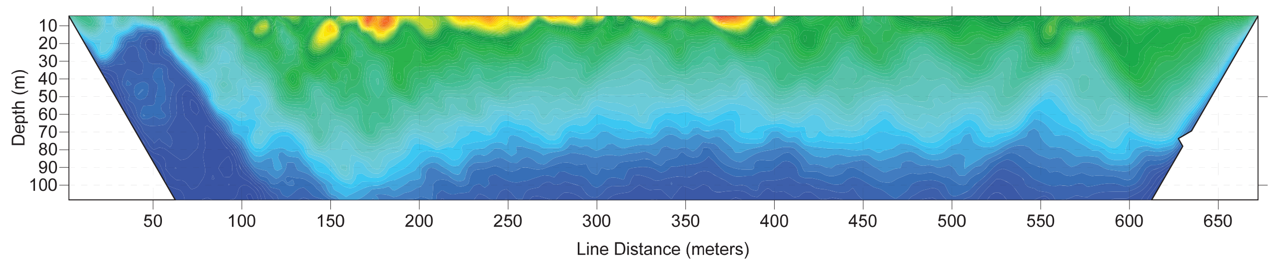
REVIEW	ML	9/26/11		

FIGURE A-1

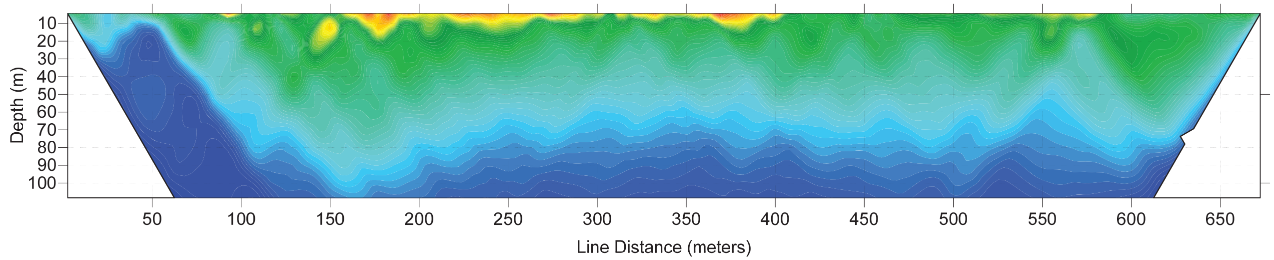
WEST

EAST

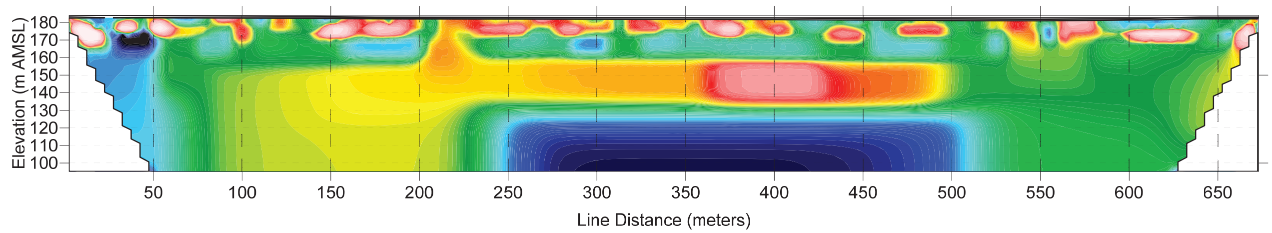
MEASURED APPARENT RESISTIVITY

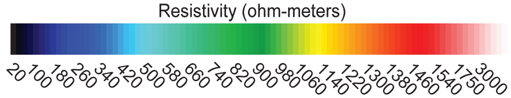


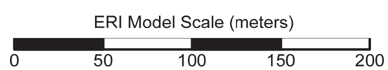
CALULATED APPARENT RESISTIVITY



MODEL RESISTIVITY RMS Error 2.5%







NOTES:
NORTHINGS AND EASTINGS IN WA SP SOUTH METERS, NAD83 DATUM
LOCATION INFORMATION COLLECTED WITH HEMISPHERE R130 RTK-DGPS

PROJECT
CONTRACT 45109
LERF GEOPHYSICAL SURVEY
HANFORD 200 EAST AREA

TITLE
200 EAST - LERF GEOPHYSICAL SURVEY
LINE 2 RESISTIVITY

Golder Associates

PROJECT No.		113-93039.200	FILE No.	Fig A2 ERI_Line2.srf
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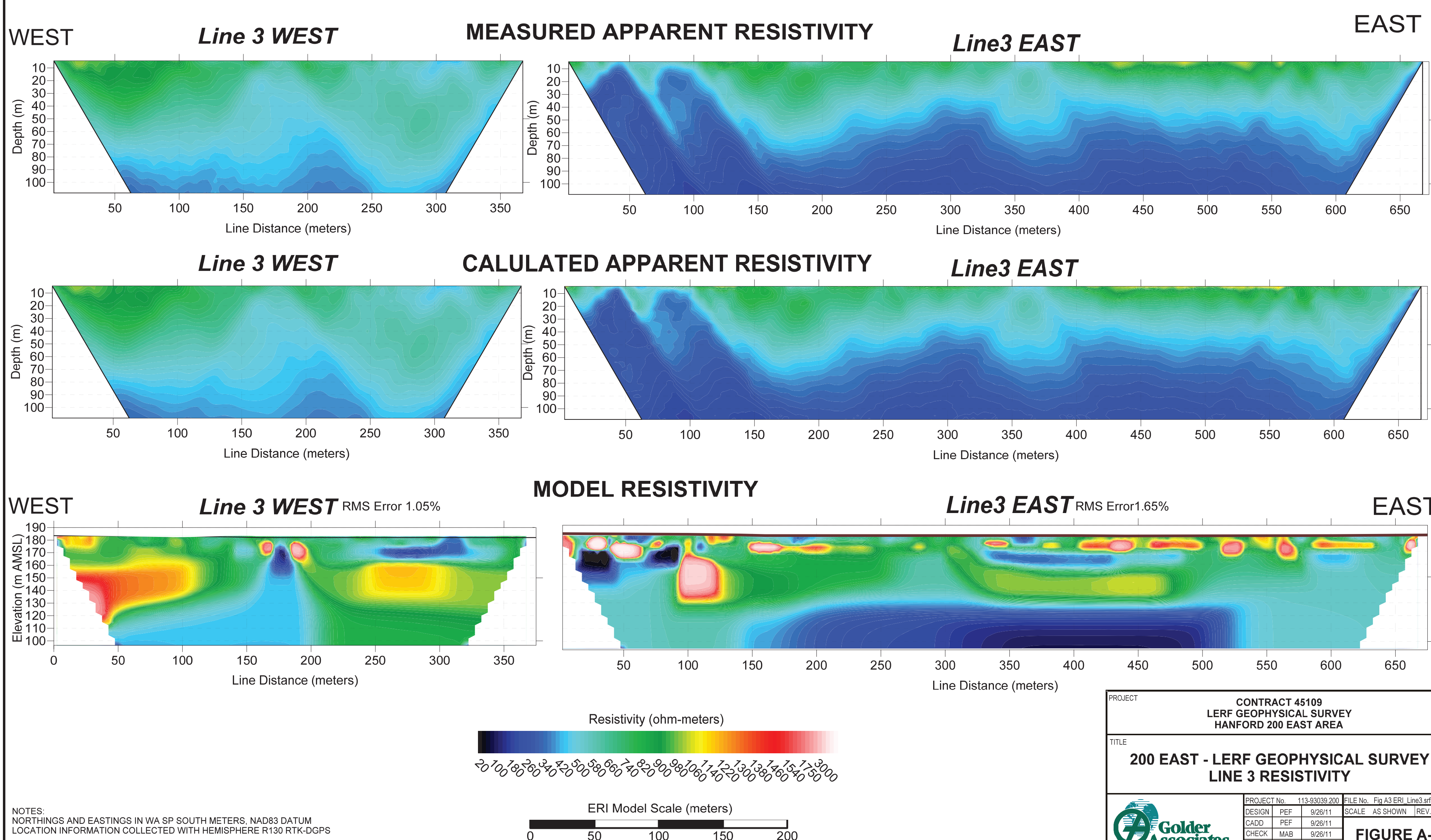

NOTES:
NORTHINGS AND EASTINGS IN WA SP SOUTH METERS, NAD83 DATUM
LOCATION INFORMATION COLLECTED WITH HEMISPHERE R130 RTK-DGPS

PROJECT
CONTRACT 45109
LERF GEOPHYSICAL SURVEY
HANFORD 200 EAST AREA

TITLE
200 EAST - LERF GEOPHYSICAL SURVEY
LINE 3 RESISTIVITY

Golder Associates

PROJECT No.		113-93039.200	FILE No.	Fig A3 ERI_Line3.srf
DESIGN	PEF	9/26/11	SCALE AS SHOWN	REV.
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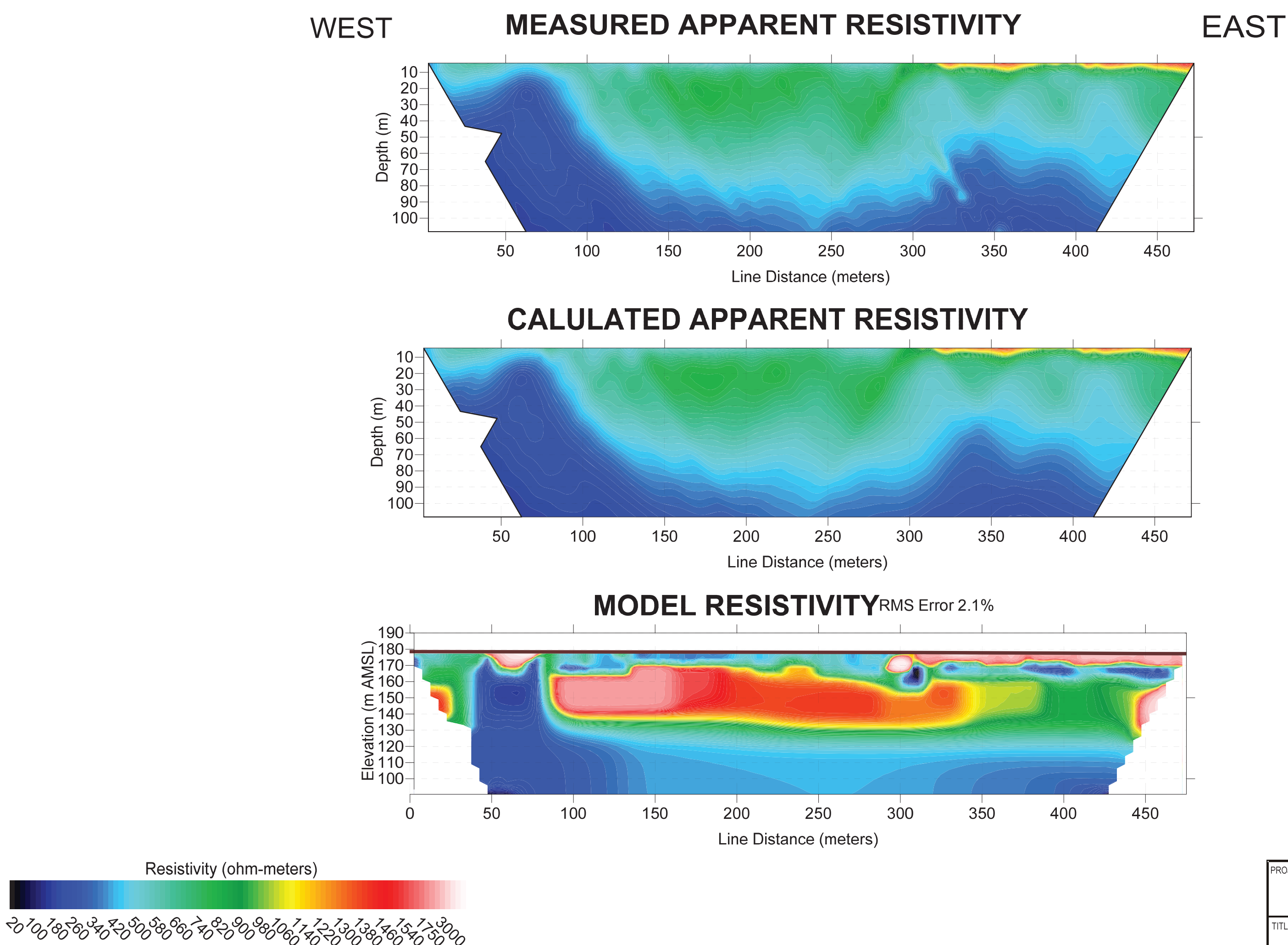
REVIEW	ML	9/26/11		



ERI Model Scale (meters)
0 50 100 150 200

NOTES:
NORTHINGS AND EASTINGS IN WA SP SOUTH METERS, NAD83 DATUM
LOCATION INFORMATION COLLECTED WITH HEMISPHERE R130 RTK-DGPS

PROJECT
CONTRACT 45109
LERF GEOPHYSICAL SURVEY
HANFORD 200 EAST AREA

TITLE
200 EAST - LERF GEOPHYSICAL SURVEY
LINE 4 RESISTIVITY

Golder Associates

PROJECT No.		113-93039.200	FILE No.	Fig A4 ERI_Line4.srf
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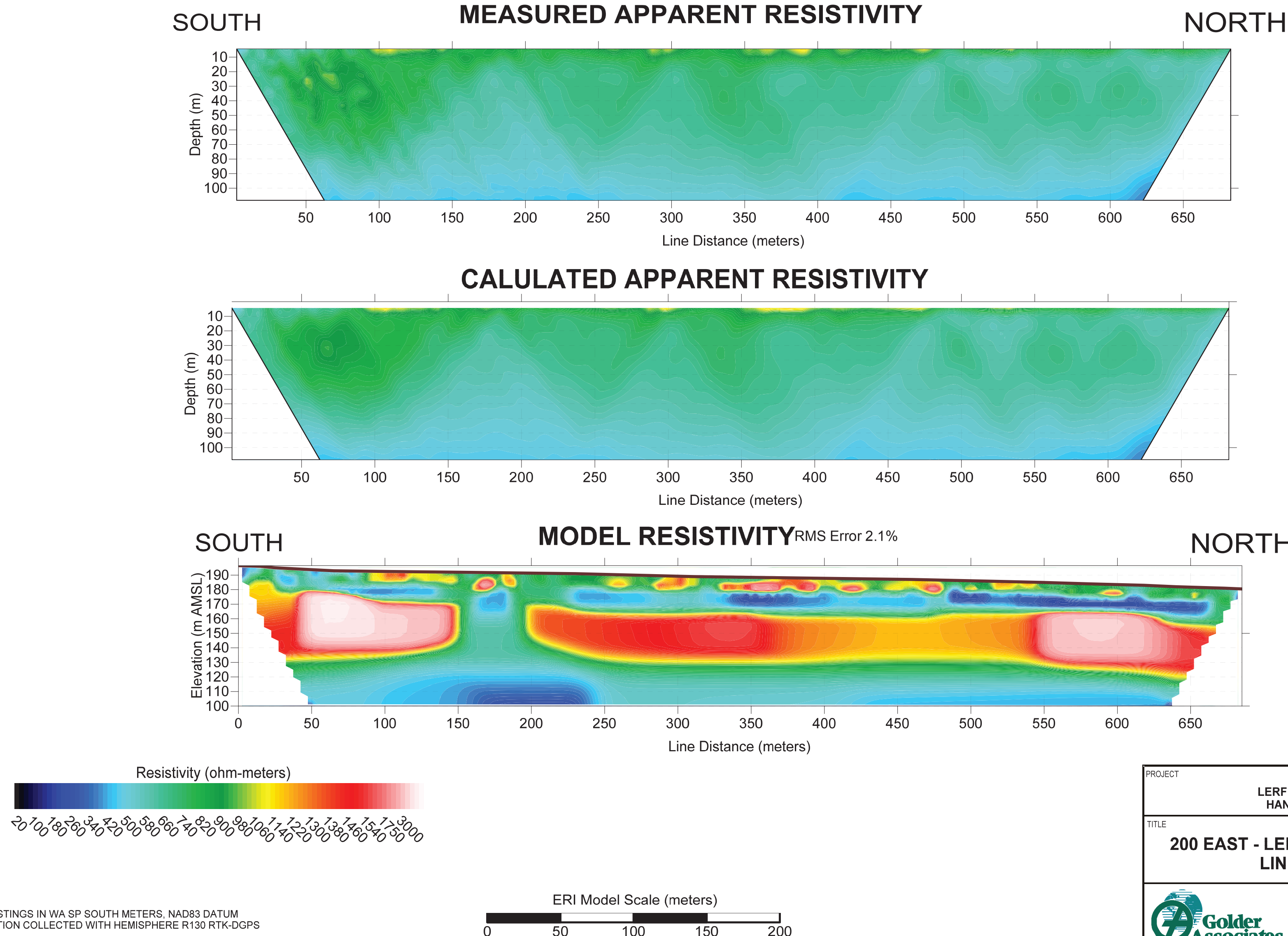
FIGURE A-4



NOTES:
NORTHINGS AND EASTINGS IN WA SP SOUTH METERS, NAD83 DATUM
LOCATION INFORMATION COLLECTED WITH HEMISPHERE R130 RTK-DGPS

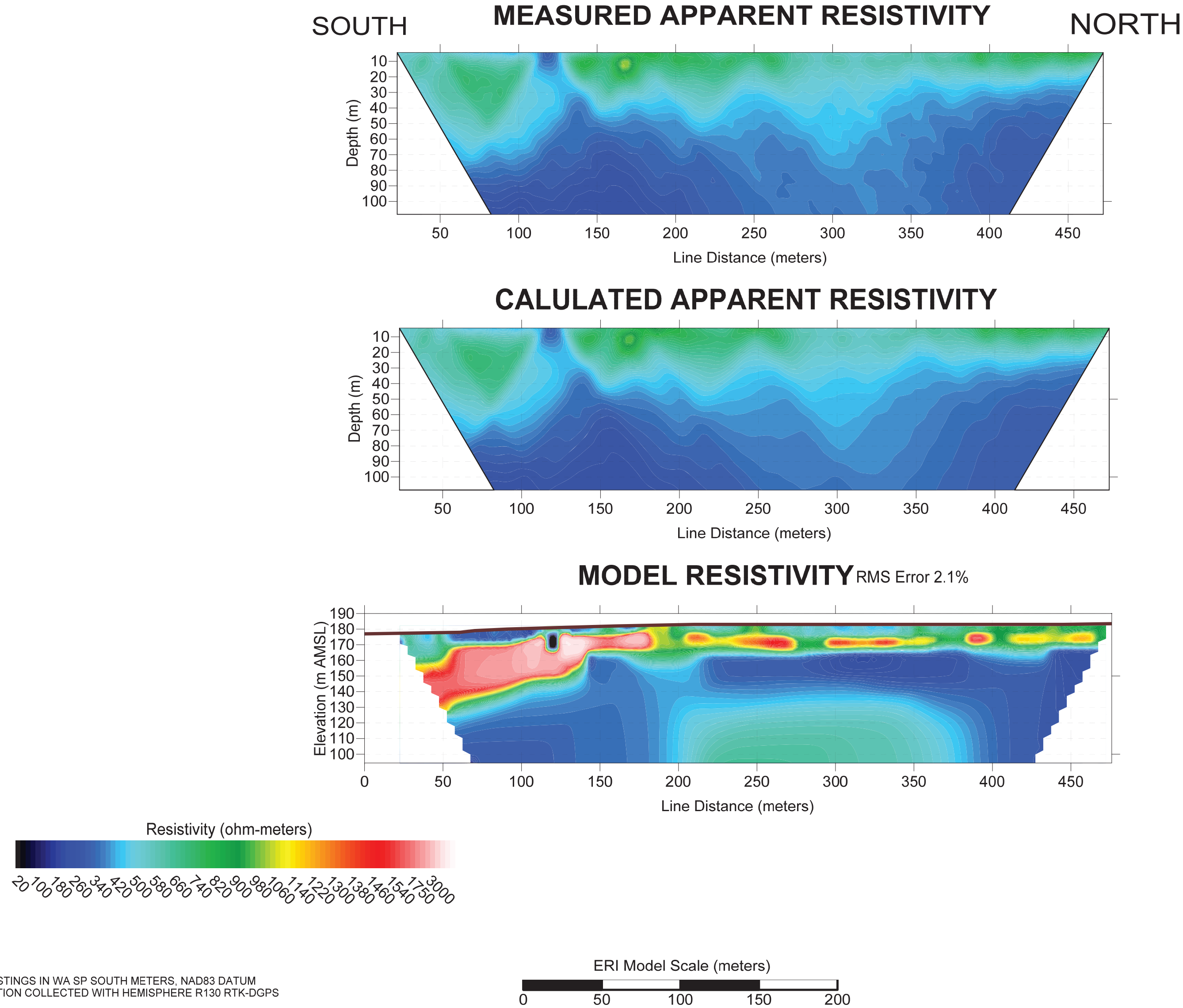
PROJECT
CONTRACT 45109
LERF GEOPHYSICAL SURVEY
HANFORD 200 EAST AREA

TITLE
200 EAST - LERF GEOPHYSICAL SURVEY
LINE 6 RESISTIVITY

Golder Associates

PROJECT No.		113-93039.200	FILE No.	Fig A6 ERI_Line6.srf
DESIGN	PEF	9/26/11	SCALE	AS SHOWN REV.
CADD	PEF	9/26/11		
CHECK	MAB	9/26/11		
REVIEW	ML	9/26/11		

FIGURE A-5



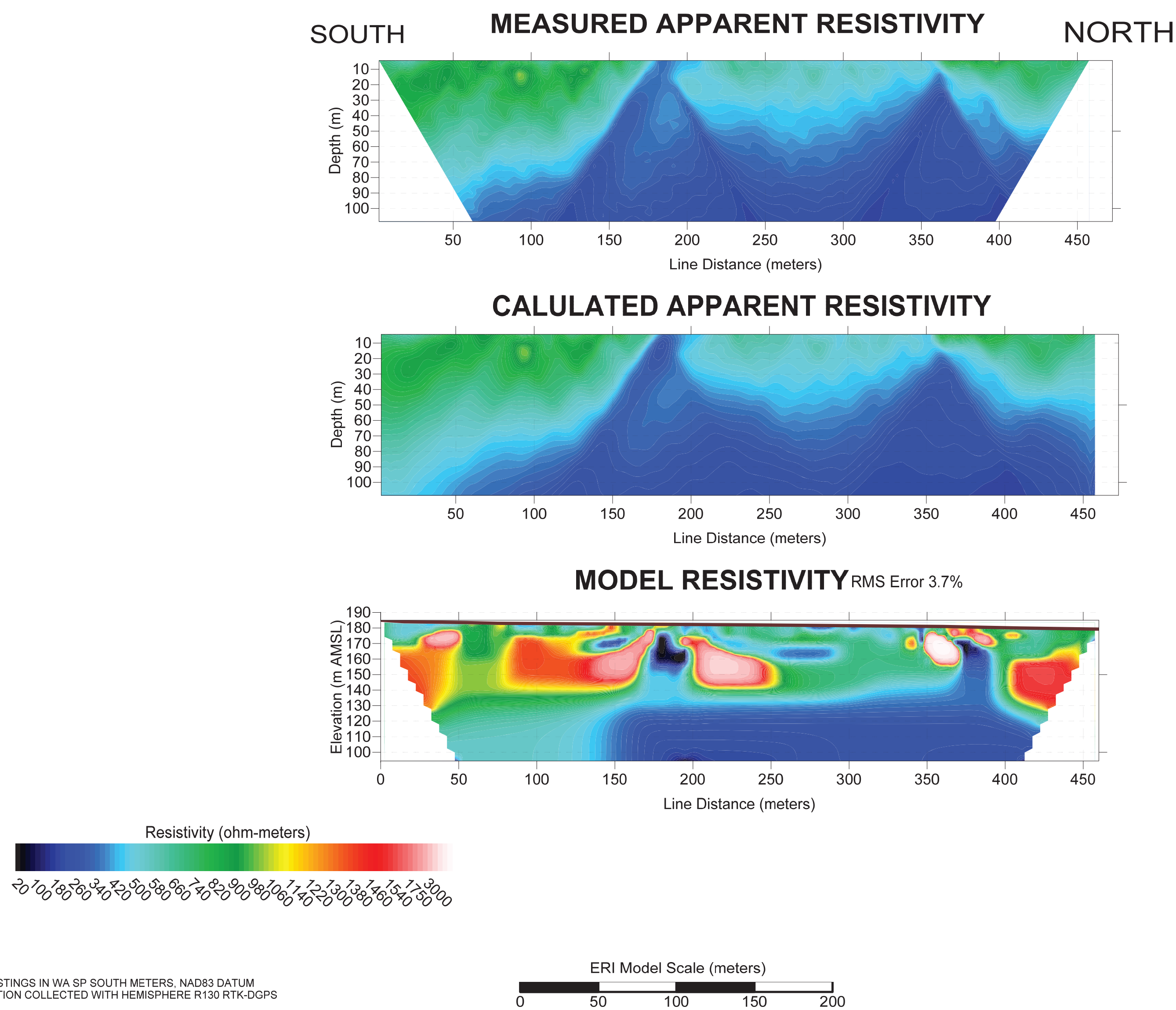
NOTES:
NORTHINGS AND EASTINGS IN WA SP SOUTH METERS, NAD83 DATUM
LOCATION INFORMATION COLLECTED WITH HEMISPHERE R130 RTK-DGPS

PROJECT
CONTRACT 45109
LERF GEOPHYSICAL SURVEY
HANFORD 200 EAST AREA

TITLE
200 EAST - LERF GEOPHYSICAL SURVEY
LINE 8 RESISTIVITY

Golder Associates

PROJECT No.		113-93039.200	FILE No.	Fig A6 ERI_Line8.srf
DESIGN	PEF	9/26/11	SCALE AS SHOWN	REV.
CADD	PEF	9/26/11		
CHECK	MAB	9/26/11	**FIGURE A-6**	
REVIEW	ML	9/26/11		



NOTES:
NORTHINGS AND EASTINGS IN WA SP SOUTH METERS, NAD83 DATUM
LOCATION INFORMATION COLLECTED WITH HEMISPHERE R130 RTK-DGPS

PROJECT
CONTRACT 45109
LERF GEOPHYSICAL SURVEY
HANFORD 200 EAST AREA

TITLE
200 EAST - LERF GEOPHYSICAL SURVEY
LINE 9 RESISTIVITY

Golder Associates

PROJECT No.	113-93039.200		FILE No.	Fig A7 ERI_Line9.srf
DESIGN	PEF	9/26/11	SCALE AS SHOWN	REV.
CADD	PEF	9/26/11		
CHECK	MAB	9/26/11		
REVIEW	ML	9/26/11		

FIGURE A-7

APPENDIX B
TIME DOMAIN ELECTROMAGNETICS SOUNDINGS

Table B-1: TDEM Model Results for Location A.

Layer	Resistivity (Ω-m)	Thickness (m)	Depth (m)
1	353	13.9	13.9
2	2	42.1	56.0
3	0.3	29.3	85.3
4	0.1	--	--

Table B-2: TDEM Model Results for Location B.

Layer	Resistivity (Ω-m)	Thickness (m)	Depth (m)
1	4,041	15.0	15.0
2	744	22.3	37.3
3	0.8	22.6	59.9
4	0.1	--	--

Table B-3: TDEM Model Results for Location C.

Layer	Resistivity (Ω-m)	Thickness (m)	Depth (m)
1	4,486	60.7	60.7
2	1,665	25.9	86.6
3	22	91.0	177.6
4	8	--	--

Table B-4: TDEM Model Results for Location D.

Layer	Resistivity (Ω-m)	Thickness (m)	Depth (m)
1	608	0.2	0.2
2	481	0.2	0.5
3	13	63.4	63.9
4	0.2	--	--

Table B-5: TDEM Model Results for Location E.

Layer	Resistivity (Ω-m)	Thickness (m)	Depth (m)
1	2,2426	17.0	17.0
2	11	45.5	62.5
3	0.5	--	--
4	--	--	--

Table B-6: TDEM Model Results for Location F.

Layer	Resistivity (Ω-m)	Thickness (m)	Depth (m)
1	2,536	21.0	21.0
2	108	17.3	38.4
3	1	28.0	66.4
4	0.1	--	--

Table B-7: TDEM Model Results for Location G.

Layer	Resistivity (Ω-m)	Thickness (m)	Depth (m)
1	3,549	13.9	13.9
2	367	6.0	19.9
3	15	41.1	61.1
4	1.7	--	--

Table B-8: TDEM Model Results for Location H.

Layer	Resistivity (Ω-m)	Thickness (m)	Depth (m)
1	4,681	3.2	3.2
2	258	42.8	46.0
3	4	18.7	64.7
4	2	--	--

Table B-9: TDEM Model Results for Location I.

Layer	Resistivity (Ω-m)	Thickness (m)	Depth (m)
1	5,228	34.4	34.4
2	4,650	73.7	108.1
3	26	114.4	222.5
4	14	--	--

Table B-10: TDEM Model Results for Location J.

Layer	Resistivity (Ω-m)	Thickness (m)	Depth (m)
1	4,333	33.7	33.7
2	1,405	33.7	67.4
3	30	31.5	99.0
4	12	--	--

Table B-11: TDEM Model Results for Location K.

Layer	Resistivity (Ω-m)	Thickness (m)	Depth (m)
1	5,911	8.7	8.7
2	2,279	49.0	57.7
3	37	23.0	80.7
4	15	--	--

Table B-12: TDEM Model Results for Location L.

Layer	Resistivity (Ω-m)	Thickness (m)	Depth (m)
1	2,249	4.8	4.8
2	798	14.7	19.6
3	112	7	26.5
4	817	30.7	57.3
5	16	--	--

Table B-13: TDEM Model Results for Location M.

Layer	Resistivity (Ω-m)	Thickness (m)	Depth (m)
1	4,762	10.6	10.6
2	3,120	64.2	74.8
3	21	40.1	114.9
4	9	--	--

Table B-14: TDEM Model Results for Location N.

Layer	Resistivity (Ω-m)	Thickness (m)	Depth (m)
1	6,600	28.0	28.0
2	620	24.1	52.1
3	39	96.9	148.9
4	7	--	--

Table B-15: TDEM Model Results for Location O.

Layer	Resistivity (Ω-m)	Thickness (m)	Depth (m)
1	5,869	3.9	3.9
2	21	50.0	53.9
3	3	43.4	97.3
4	1	--	--

Table B-16: TDEM Model Results for Location P.

Layer	Resistivity (Ω-m)	Thickness (m)	Depth (m)
1	6,539	68	68.0
2	69	15.8	83.8
3	26	80	163.8
4	11	--	--

Table B-17: TDEM Model Results for Location Q.

Layer	Resistivity (Ω-m)	Thickness (m)	Depth (m)
1	4,079	12.8	12.8
2	4,502	68.7	81.5
3	27	20.0	101.5
4	15	--	--

Table B-18: TDEM Model Results for Location R.

Layer	Resistivity (Ω-m)	Thickness (m)	Depth (m)
1	4,486	61.2	61.2
2	77	46.8	107.9
3	17	112	219.9
4	2	--	--

Table B-19: TDEM Model Results for Location S.

Layer	Resistivity (Ω-m)	Thickness (m)	Depth (m)
1	6,381	63.5	63.5
2	74	41.5	105.1
3	21	73.0	178.1
4	5	--	--

Table B-20: TDEM Model Results for Location T.

Layer	Resistivity (Ω-m)	Thickness (m)	Depth (m)
1	4,062	12.2	12.2
2	219	52.1	64.3
3	1.4	30.2	94.5
4	0.8	--	--

Table B-21: TDEM Model Results for Location U.

Layer	Resistivity (Ω-m)	Thickness (m)	Depth (m)
1	7,544	62.5	62.5
2	459	22.5	85.0
3	75	77.3	162.3
4	13	--	--

Table B-22: TDEM Model Results for Location V.

Layer	Resistivity (Ω-m)	Thickness (m)	Depth (m)
1	4,981	30.3	30.3
2	307	37.4	67.6
3	0.8	10.3	77.9
4	0.1	--	--

Table B-23: TDEM Model Results for Location W.

Layer	Resistivity (Ω-m)	Thickness (m)	Depth (m)
1	5,659	68.3	68.3
2	459	54.7	123.3
3	85	14.4	137.4
4	17	--	--

Table B-24: TDEM Model Results for Location X.

Layer	Resistivity (Ω-m)	Thickness (m)	Depth (m)
1	6,684	8.7	8.7
2	2,492	56.6	65.30
3	76	156.6	156.6
4	0.31	--	--

Table B-25: TDEM Model Results for Location Y.

Layer	Resistivity (Ω-m)	Thickness (m)	Depth (m)
1	3,415	10.8	10.8
2	2,149.	57.4	68.2
3	58	37.9	106.0
4	16	--	--

Table B-26: TDEM Model Results for Location 1.

Layer	Resistivity (Ω-m)	Thickness (m)	Depth (m)
1	45100	2.9	2.9
2	12879	3.1	5.9
3	3815	53.2	59.2
4	5879	26	85.2
5	23774	--	--

Table B-27: TDEM Model Results for Location 2.

Layer	Resistivity (Ω-m)	Thickness (m)	Depth (m)
1	2205	24.1	24.1
2	5550	43.2	67.4
3	20	142.1	209.5
4	4	--	--

Table B-28: TDEM Model Results for Location 3.

Layer	Resistivity (Ω-m)	Thickness (m)	Depth (m)
1	7012	6.1	6.1
2	331	63.2	69.3
3	1097	24.1	93.3
4	10	84.2	177.6
5	1	--	--

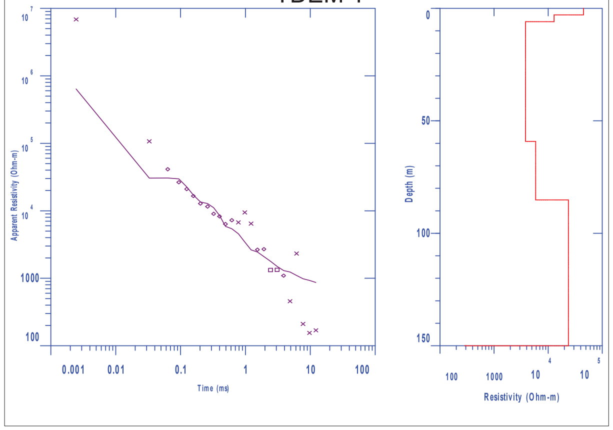
Table B-29: TDEM Model Results for Location 4.

Layer	Resistivity (Ω-m)	Thickness (m)	Depth (m)
1	3156	7.4	7.4
2	7542	17.2	24.6
3	6254	17.5	42.1
4	3556	25.4	67.5
5	5	--	--

Table B-30: TDEM Model Results for Location 5.

Layer	Resistivity (Ω-m)	Thickness (m)	Depth (m)
1	5824	5.5	5.5
2	6736	14.9	20.5
3	5869	59.9	80.4
4	18016	32	112.4
5	154446	--	--

TDEM 1



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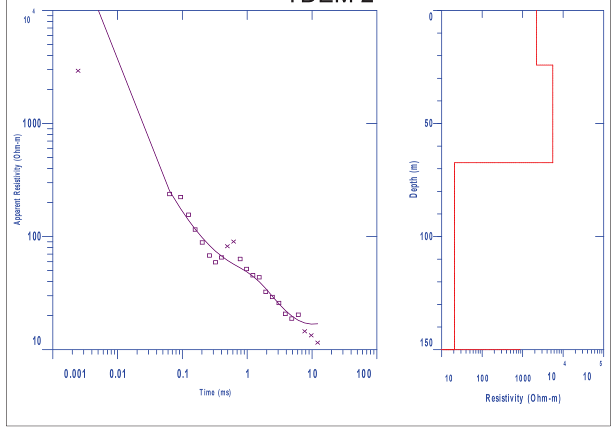

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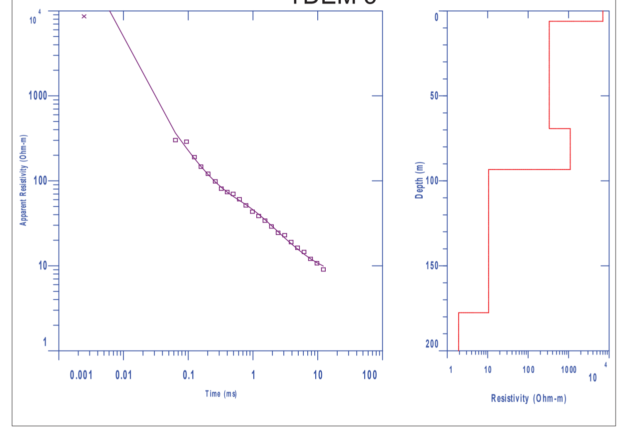

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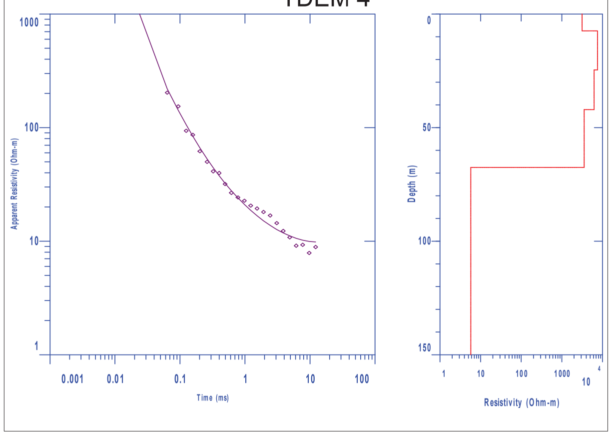

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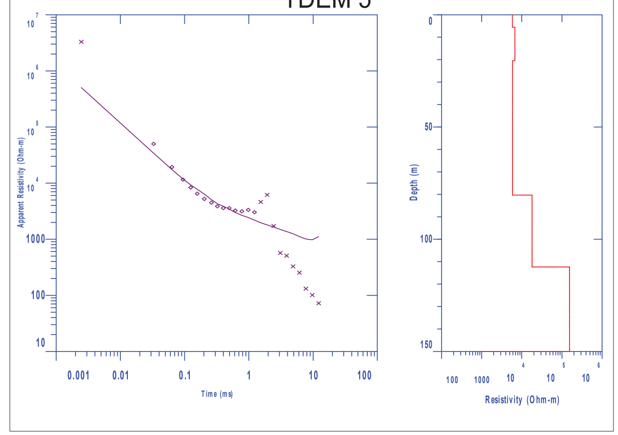


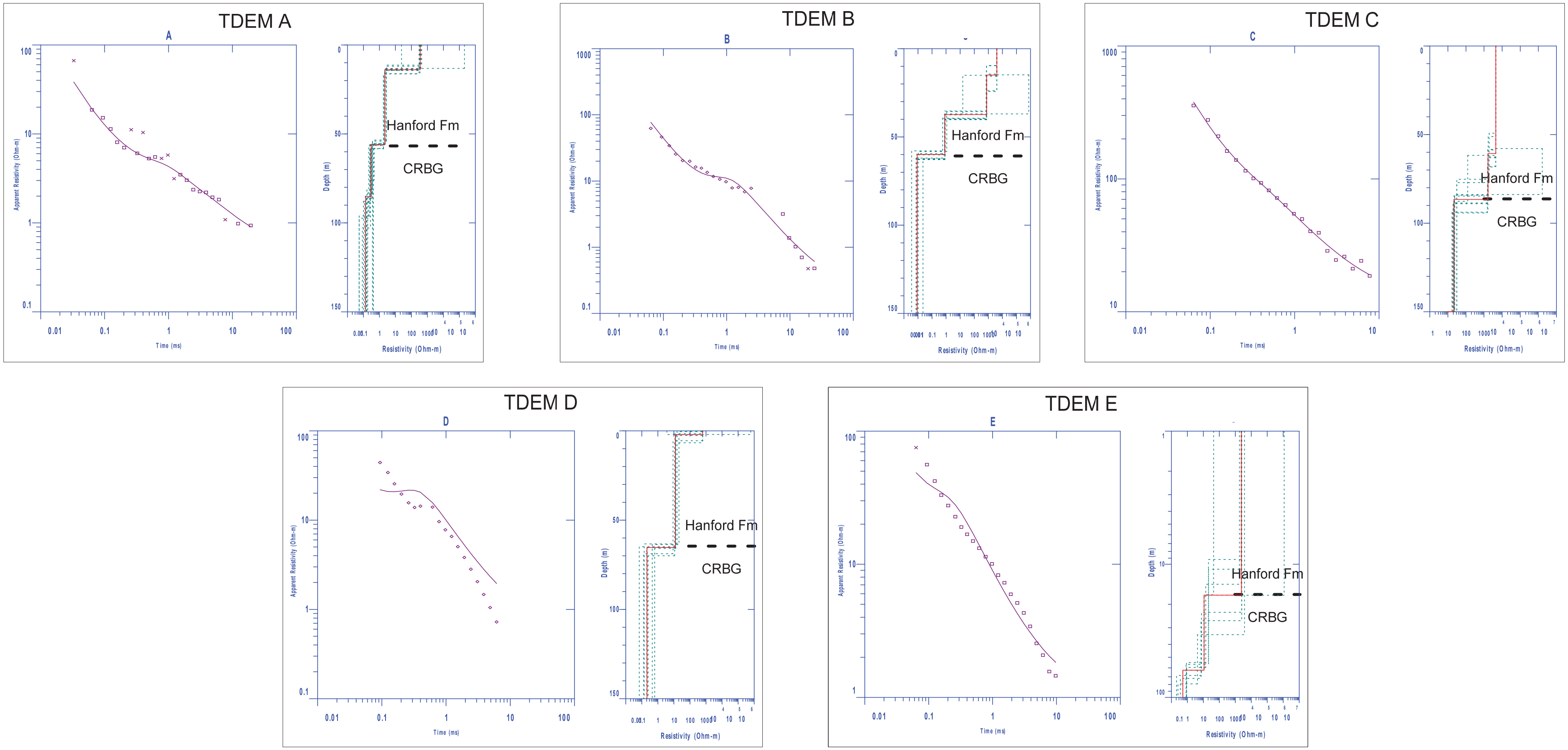
NOTES:
1. TDEM data collected July 2011.
2. TDEM data collected using Zonge GDP 16 50m Tx loop, TEM3 Rx.
3. TDEM data processed using 1X1D TEM from Interprex Ltd.
4. Gravity data collected using L & R G Aliod 100 gravimeter.
5. ERI data collection scheduled to begin late July 2011.
5. Base map and survey locatons provided by CHPRC.
6. Survey objective is to map help map the top of basaslt bedrock.

PROJECT
CONTRACT 45109
LERF GEOPHYSICAL SURVEY
HANFORD 200 EAST AREA

TITLE **200 EAST - LERF GEOPHYSICAL SURVEY PHASE 1 TDEM RSULTS**

Golder Associates

PROJECT No.	113-93040.200		FILE No. ---
DESIGN	MB	7/16/11	SCALE AS SHOWN REV.
CADD	MB	7/16/11	
CHECK	ML	7/16/11	**FIGURE B-1**
REVIEW	ML	7/16/11	



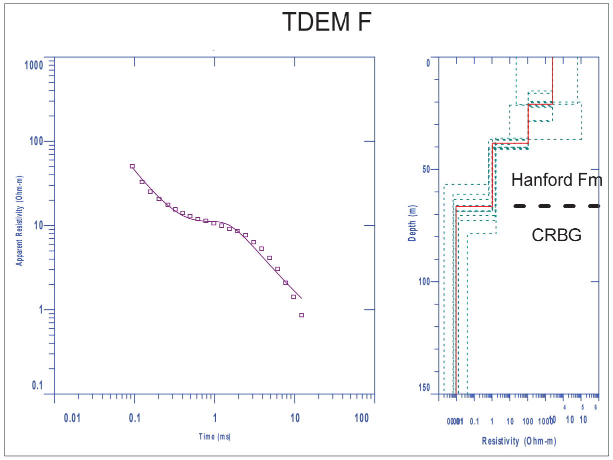
NOTES:
1. TDEM data collected July 2011.
2. TDEM data collected using Zonge GDP 16 50m Tx loop, TEM3 Rx.
3. TDEM data processed using 1X1D TEM from Interprex Ltd.
4. Survey objective is to help map the top of basaslt bedrock.

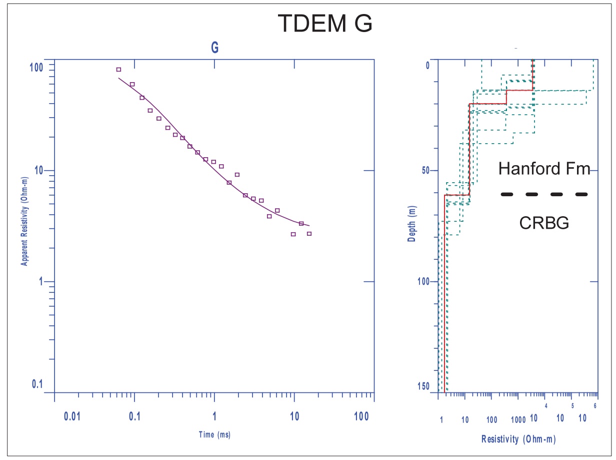
PROJECT
CONTRACT 45104
LERF GEOPHYSICAL SURVEY
HANFORD 200 EAST AREA

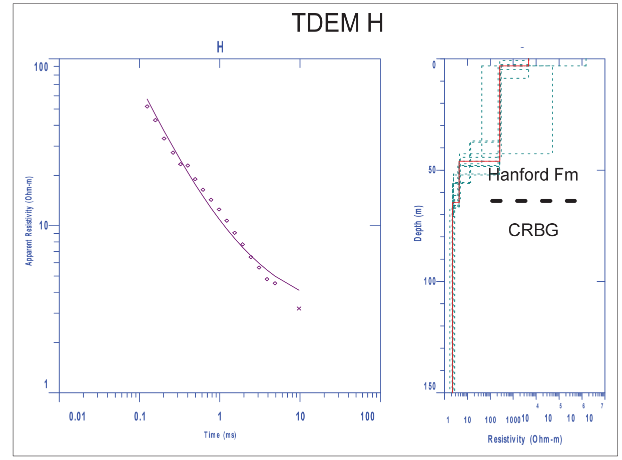
TITLE
200 EAST - LERF GEOPHYSICAL SURVEY
PHASE 2 TDEM RESULTS

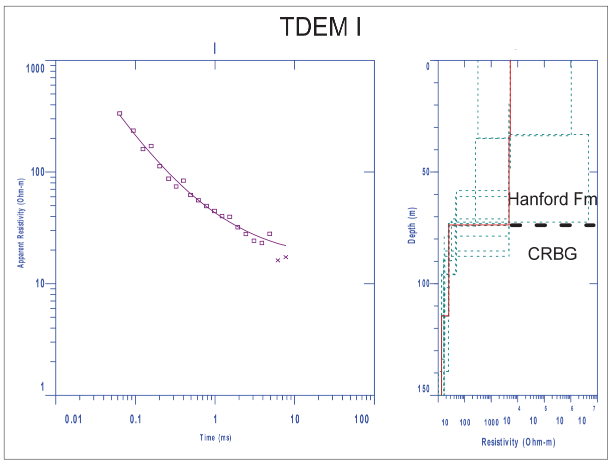
Golder Associates

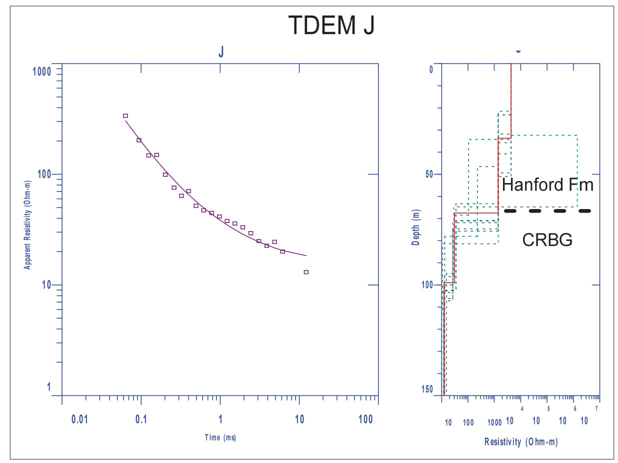
PROJECT No.		113-93040.200	FILE No.	---
DESIGN	MB	9/12/11	SCALE	AS SHOWN REV.
CADD	MB	9/12/11		
CHECK	ML	9/12/11	**FIGURE B-2**	
REVIEW	ML	9/12/11		











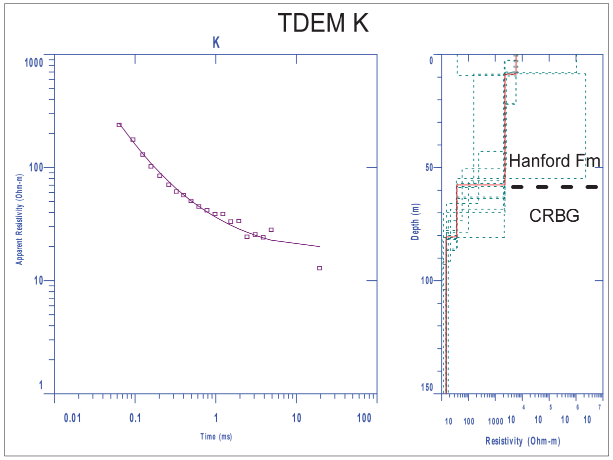
NOTES:
1. TDEM data collected July 2011.
2. TDEM data collected using Zonge GDP 16 50m Tx loop, TEM3 Rx.
3. TDEM data processed using 1X1D TEM from Interprex Ltd.
4. Survey objective is to help map the top of basaslt bedrock.

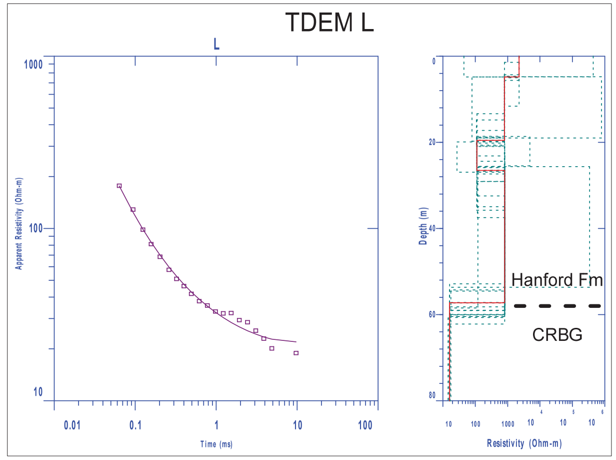
PROJECT
CONTRACT 45104
LERF GEOPHYSICAL SURVEY
HANFORD 200 EAST AREA

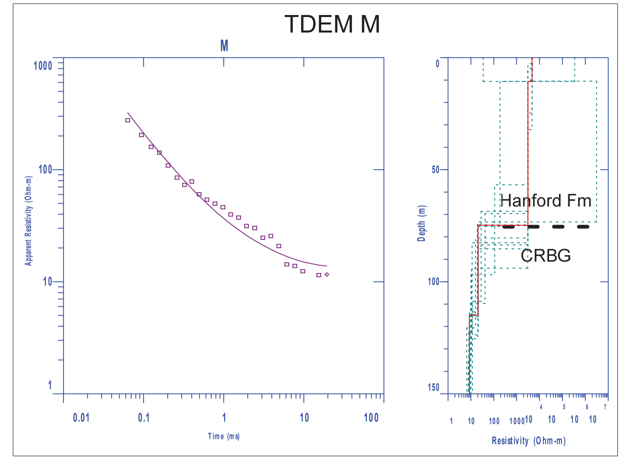
TITLE
200 EAST - LERF GEOPHYSICAL SURVEY
PHASE 2 TDEM RESULTS

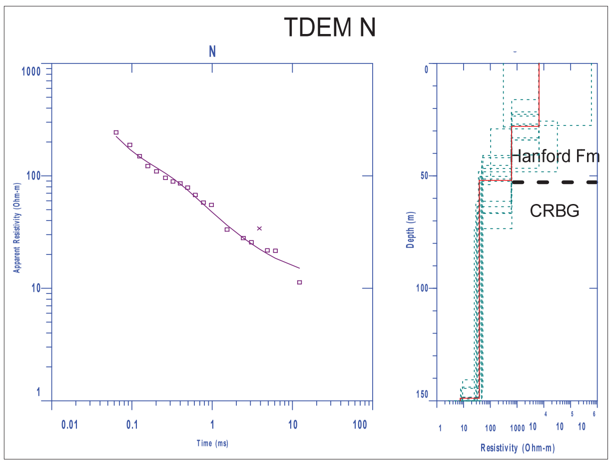
Golder Associates

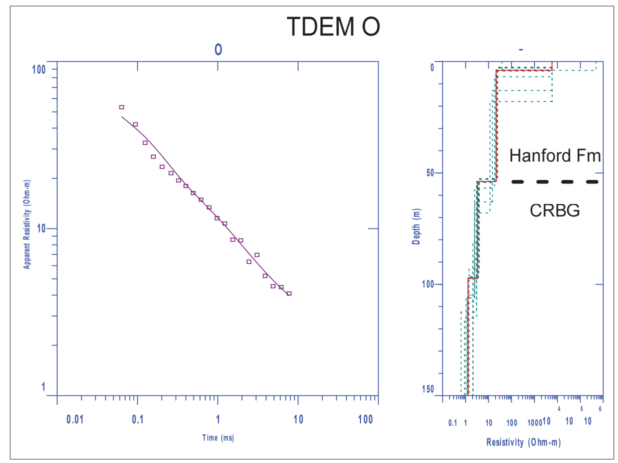
PROJECT No.		113-93040.200	FILE No.	---
DESIGN	MB	9/12/11	SCALE AS SHOWN	REV.
CADD	MB	9/12/11	**FIGURE B-3**	
CHECK	ML	9/12/11		
REVIEW	ML	9/12/11		











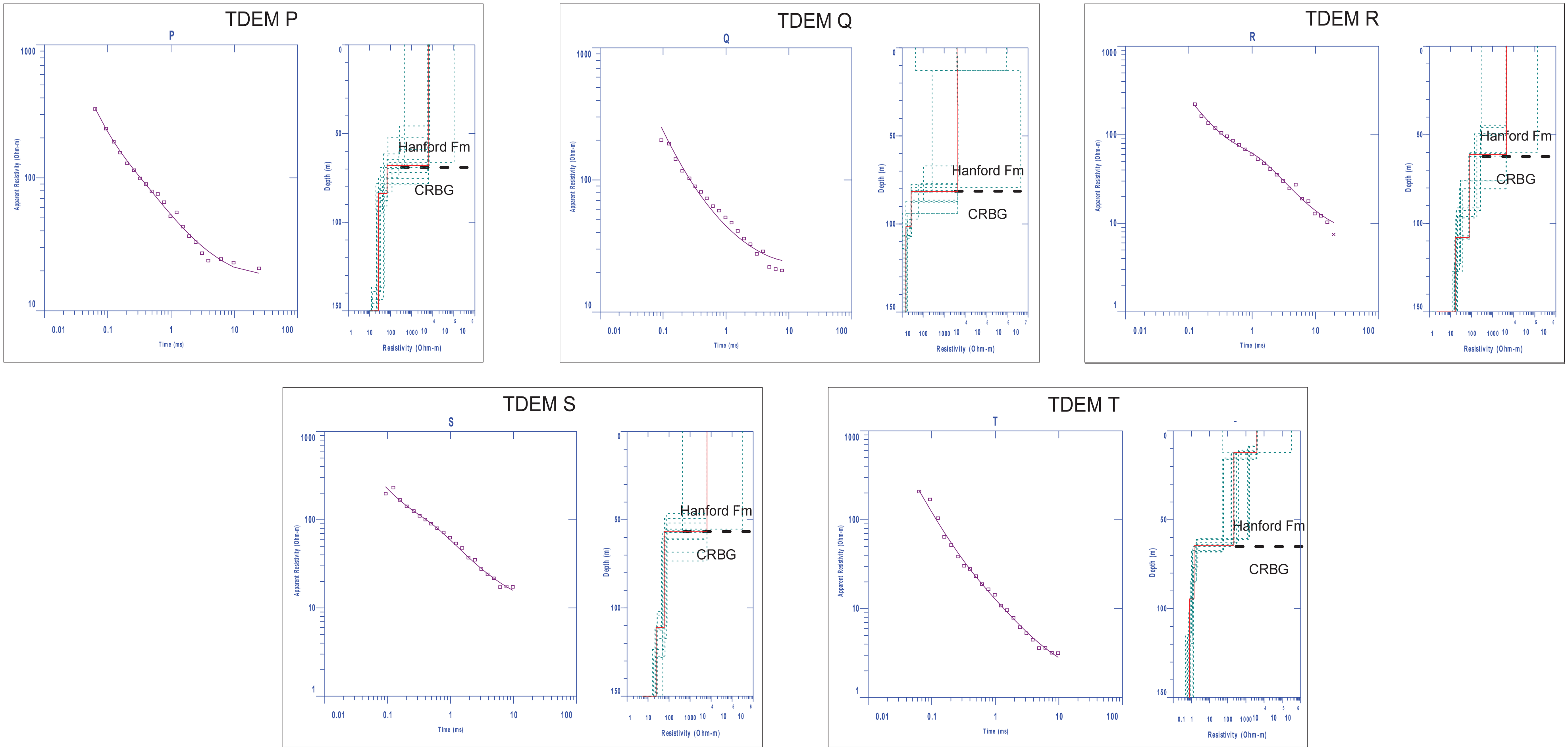
NOTES:
1. TDEM data collected July 2011.
2. TDEM data collected using Zonge GDP 16 50m Tx loop, TEM3 Rx.
3. TDEM data processed using 1X1D TEM from Interprex Ltd.
4. Survey objective is to help map the top of basaslt bedrock.

PROJECT
CONTRACT 45104
LERF GEOPHYSICAL SURVEY
HANFORD 200 EAST AREA

TITLE
200 EAST - LERF GEOPHYSICAL SURVEY
PHASE 2 TDEM RESULTS

Golder Associates

PROJECT No.		113-93040.200	FILE No. ---
DESIGN	MB	9/12/11	SCALE AS SHOWN REV.
CADD	MB	9/12/11	
CHECK	ML	9/12/11	**FIGURE B-4**
REVIEW	ML	9/12/11	



NOTES:
1. TDEM data collected July 2011.
2. TDEM data collected using Zonge GDP 16 50m Tx loop, TEM3 Rx.
3. TDEM data processed using 1X1D TEM from Interprex Ltd.
4. Survey objective is to help map the top of basasIt bedrock.

PROJECT	CONTRACT 45104 LERF GEOPHYSICAL SURVEY HANFORD 200 EAST AREA			
TITLE	200 EAST - LERF GEOPHYSICAL SURVEY PHASE 2 TDEM RESULTS			
Golder Associates	PROJECT No.		113-93040.200	FILE No. ---
	DESIGN	MB	9/12/11	SCALE AS SHOWN REV.
	CADD	MB	9/12/11	FIGURE B-5
	CHECK	ML	9/12/11	
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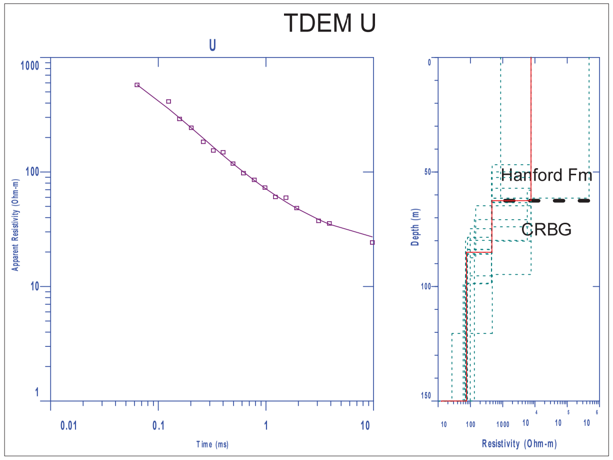

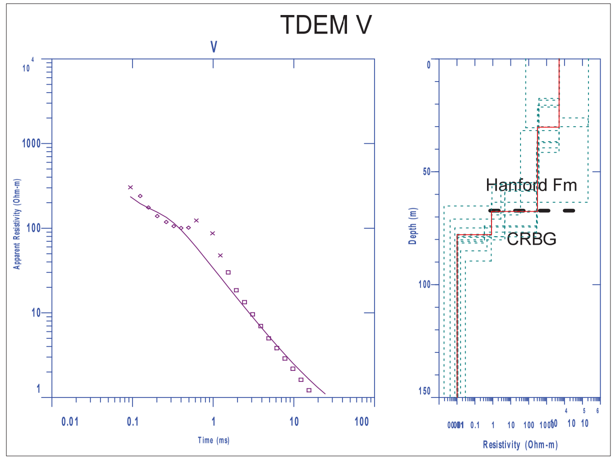

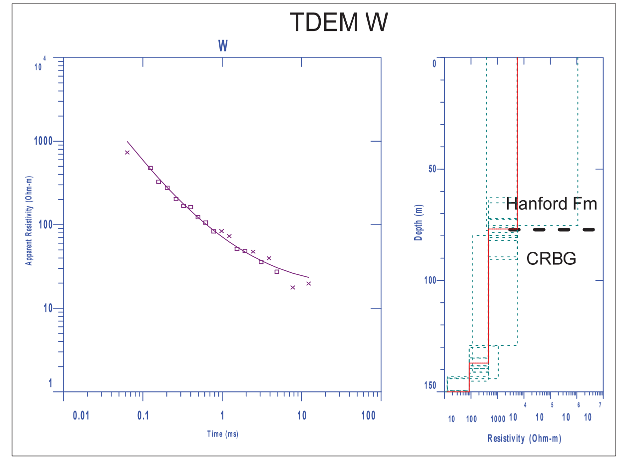

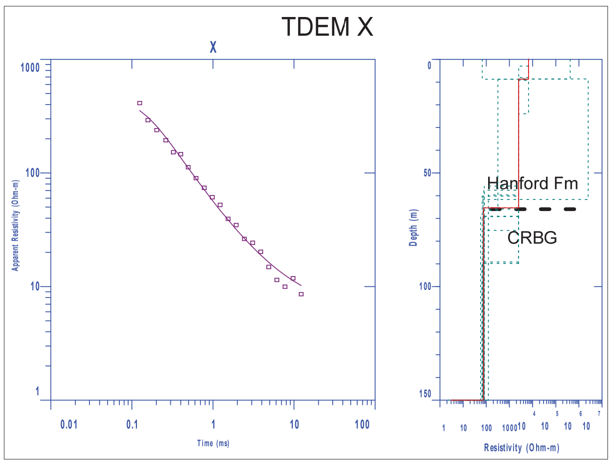

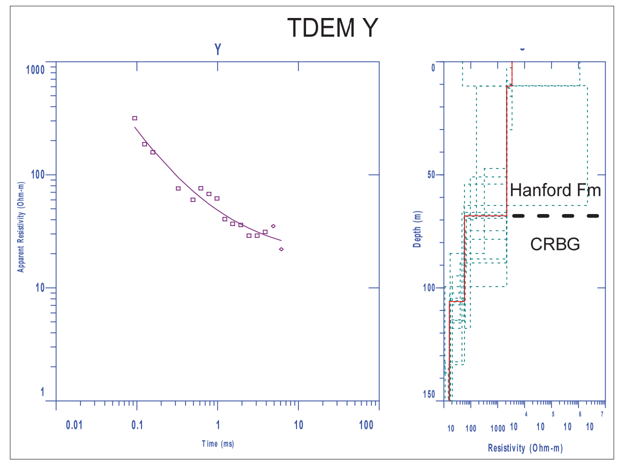

NOTES:
1. TDEM data collected July 2011.
2. TDEM data collected using Zonge GDP 16 50m Tx loop, TEM3 Rx.
3. TDEM data processed using 1X1D TEM from Interprex Ltd.
4. Survey objective is to help map the top of basaslt bedrock.

PROJECT
CONTRACT 45104
LERF GEOPHYSICAL SURVEY
HANFORD 200 EAST AREA

TITLE
200 EAST - LERF GEOPHYSICAL SURVEY
PHASE 2 TDEM RESULTS

Golder Associates

PROJECT No.		113-93040.200	FILE No. ---
DESIGN	MB	9/12/11	SCALE AS SHOWN REV.
CADD	MB	9/12/11	
CHECK	ML	9/12/11	**FIGURE B-6**
REVIEW	ML	9/12/11	

At Golder Associates we strive to be the most respected global group of companies specializing in ground engineering and environmental services. Employee owned since our formation in 1960, we have created a unique culture with pride in ownership, resulting in long-term organizational stability. Golder professionals take the time to build an understanding of client needs and of the specific environments in which they operate. We continue to expand our technical capabilities and have experienced steady growth with employees now operating from offices located throughout Africa, Asia, Australasia, Europe, North America and South America.

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South America	+ 55 21 3095 9500

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